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The International Implementation Plan

Version 3.0
May 2006

Coordinated by The International Coordination and Implementation Group (ICIG)

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AMMA International Implementation Plan (IIP)

The IIP is composed out of an Introduction chapter and 10 TT-documents written within different time periods due to project development.

The following versions of the whole document or of TT-documents were subsequently published:

Version 1.0	September 2005
Version 1.1	December 2005
Version 2.0	March 2006
Version 3.0	May 2006

Note: The version indicated at the footnote of each TT-document indicates the version incorporating the latest changes.

CONTENT

1. Overall observing strategy in AMMA
2. EOP Vertical sounding of the atmosphere (TT1)
3. EOP Surface layer measurements (TT2a)
4. EOP/LOP Aerosols Monitoring and radiation (TT2b)
5. EOP Integrative studies on the Gourma meso-scale site (TT3)
6. EOP Integrative studies on the Niamey meso-scale site (TT4)
7. EOP Integrative studies on the Ouémé meso-scale site (TT5)
8. EOP/SOP Oceanic campaigns in open ocean (TT6)
9. Dry season SOP (TT7)
10. Wet season SOP (TT8)
11. Downstream SOP (TT9)

PREAMBLE

This document is a detailed description of the observing strategy and related actions carried out to fulfil the scientific objectives of the AMMA international program, as given in the AMMA International Science Plan.

In 29 countries, more than 140 institutions countries are involved in AMMA, representing a still larger number of laboratories. The number of active scientists is in the order of 400 to 500, contributing to the various components of the program: long term observing program, EOP and SOP field campaigns, diagnostic studies, preliminary modelling work, data base construction. One challenge in AMMA is to build a coherent international program from research proposals funded and evaluated in a national of pan-national framework. This challenge starts at the scientific level by setting priorities in our scientific objectives. It then translates into the observing strategy and associated deployment requirements. Making sure that there is a real coherency and good coordination of all the field work scheduled by each of the various AMMA components is the major task of the International Coordination and Implementation Group (ICIG). This is a difficult but necessary commitment if one wishes to reach the overall ambitious scientific goals of the program, and not only the piece wise goals of each individual project.

To that end, AMMA has been structured in Task Teams (TTs) and Support teams (STs), defined around a coherent ensemble of instruments in term of observing strategy. The task teams are thus cutting across the scientific working groups set up by the International Steering Scientific Committee, as well as across the individual projects composing AMMA. The organisation of the IIP thus follows the way the AMMA implementation is structured. Each TT has produced a TT document which constitutes a chapter of the IIP. Note that each TT document includes information on how the observations are related to satellite monitoring and, when applying, to the modelling strategy.

There does exist a self consistency of each Task Team, but there are also natural links between them. The articulation with the activities of other TTs is thus the object of one section in each TT chapter.

The current version presents the status of the AMMA implementation at the start of the SOP (2006). There are still some lacking elements which will be added as soon as they become available.

As such it is hoped that this Implementation Plan will help AMMA insiders and outsiders to obtain a global vision of the AMMA deployment and will also effectively support the field activities.

Chapter 1

Overall Observing Strategy in AMMA

1 A brief reminder of the AMMA Scientific objectives

The three overarching goals of AMMA, as given in the AMMA International Science Plan (ISP) are:

(1) To improve our understanding of the WAM and its influence on the physical, chemical and biological environment regionally and globally;

(2) To provide the underpinning science that relates climate variability to issues of health, water resources, food security and demography for West African nations and defining relevant monitoring and prediction strategies;

(3) To ensure that the multidisciplinary research is effectively integrated with prediction and decision making activity.

A detailed description of all the interlaced scientific questions deriving from the above overall objectives is given in the ISP. The ambition of the programme is both to improve our understanding of the numerous processes that are the skeleton of the WAM and to gain a new knowledge on how these processes interact to form a climatic system, characterised by a great interannual and decadal variability. The consequences of this variability for the population are huge. Unreliable rainfall, poor predicting capacity, rapid modification of the environment combine to produce harsh agricultural conditions and to threaten the success of development policies.

The AMMA observing program reflects the complexity of its scientific agenda. While individual processes are often spanning a limited range of scales, documenting them all, as well as their interactions, requires a specific observing program covering a broad range of relevant scales, from regional to local. Factors originating outside of the study area have been demonstrated to interfer with the WAM, which draws attention towards the global scale. Impact of the WAM variability on population is felt at the scale of the field plot, which means studying how the regional scale variability is transferred to the local scale.

2 Space and time scales of the AMMA observing program

In order to elaborate a coherent observing strategy and to take into account the multi-scale nature of the various components of the West African monsoon, the observing strategy of AMMA is built around a combination of different study areas and observing periods. These are designed to sample the main space and time scales of interest to AMMA.

2.1 Space scales and study areas

Four main interacting spatial scales are identified, as illustrated in Figure 1.1 above :

(i) ***Global scale***. This is the scale at which the WAM interacts with the rest of the globe; emphasis is given to improving our understanding of the role of global SST patterns on WAM variability; seasonal-to-decadal variability are the main time scales of interest. On this scale we are also concerned with the impacts of chemical and aerosol emissions from the monsoon system on the entire global climate.

(ii) Regional scale. This is the scale at which emphasis is given to improving our understanding of the interactions between the atmosphere, land and tropical Atlantic ocean (especially the Gulf of Guinea). It is important to study the role of surface feedbacks on variability of the WAM at this scale, including the key roles of vegetation and soil moisture over the continent and SSTs in the Gulf of Guinea. African Easterly Waves (AEWs) and other synoptic systems are also studied at this scale. This scale corresponds to a window larger than the one shown in Figure 1.1; it includes a larger portion of the Ocean to the West and to the South, extends North to the Heat Low (sounding stations in Tessalit and Tamanrasset) and East to Soudan (sounding station in Khartoum).

(iii) Mesoscale. This is the scale of the typical rain-producing weather systems in the WAM. It is central for studying the variability of rainfields at the seasonal scale and the coupling between hydrology and the atmosphere at the catchment scale. It is important to study the interactions of the mesoscale weather systems with synoptic scales (e.g. AEWs). In Figure 1.1, this scale is illustrated by the Ouémé catchment (14600 km²).

(iv) Local scale or sub-meso scale. From an atmospheric point of view, this is the convective rain scale, of a few kilometres; it is central to the hydrology of the Sahel and of small watersheds to the south; it is the main scale of interest for agriculture. In Figure 1.1, this scale is illustrated by the Donga catchment (576 km²)

AMMA emphasizes the importance of improved understanding of how these scales interact and combine to characterize the WAM and its variability, including how these interactions impact sources and transport of water vapour, aerosol and key chemical species (e.g. key greenhouse gases, ozone and aerosol precursors) in the West African region and globally.

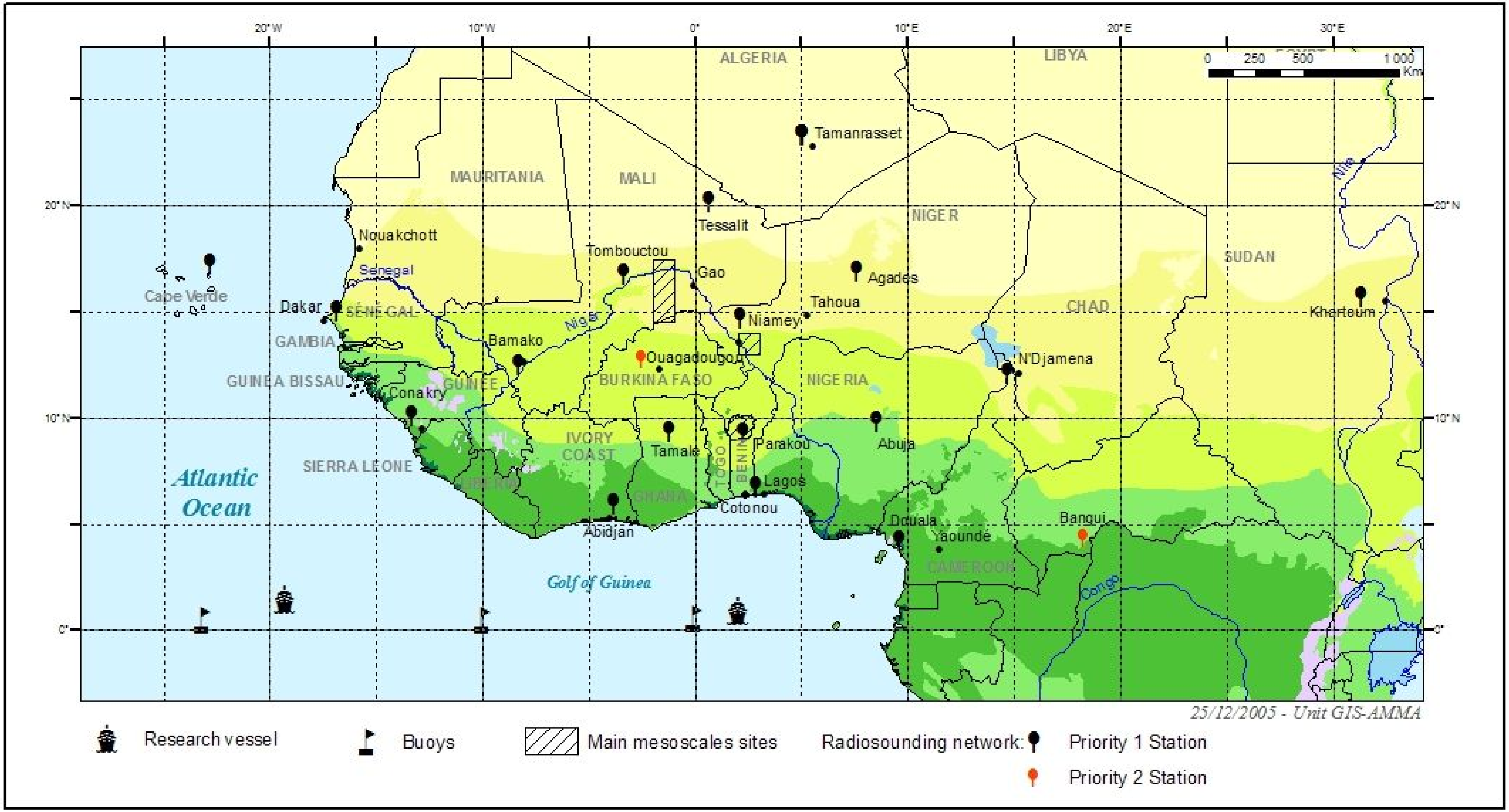

Fig 1.1. The regional scale AMMA study area. The radiosounding stations on the continent and the PIRATA buoys are the primary source of in situ information at that scale, in addition to the observations of the meteorological and hydrological operational networks.

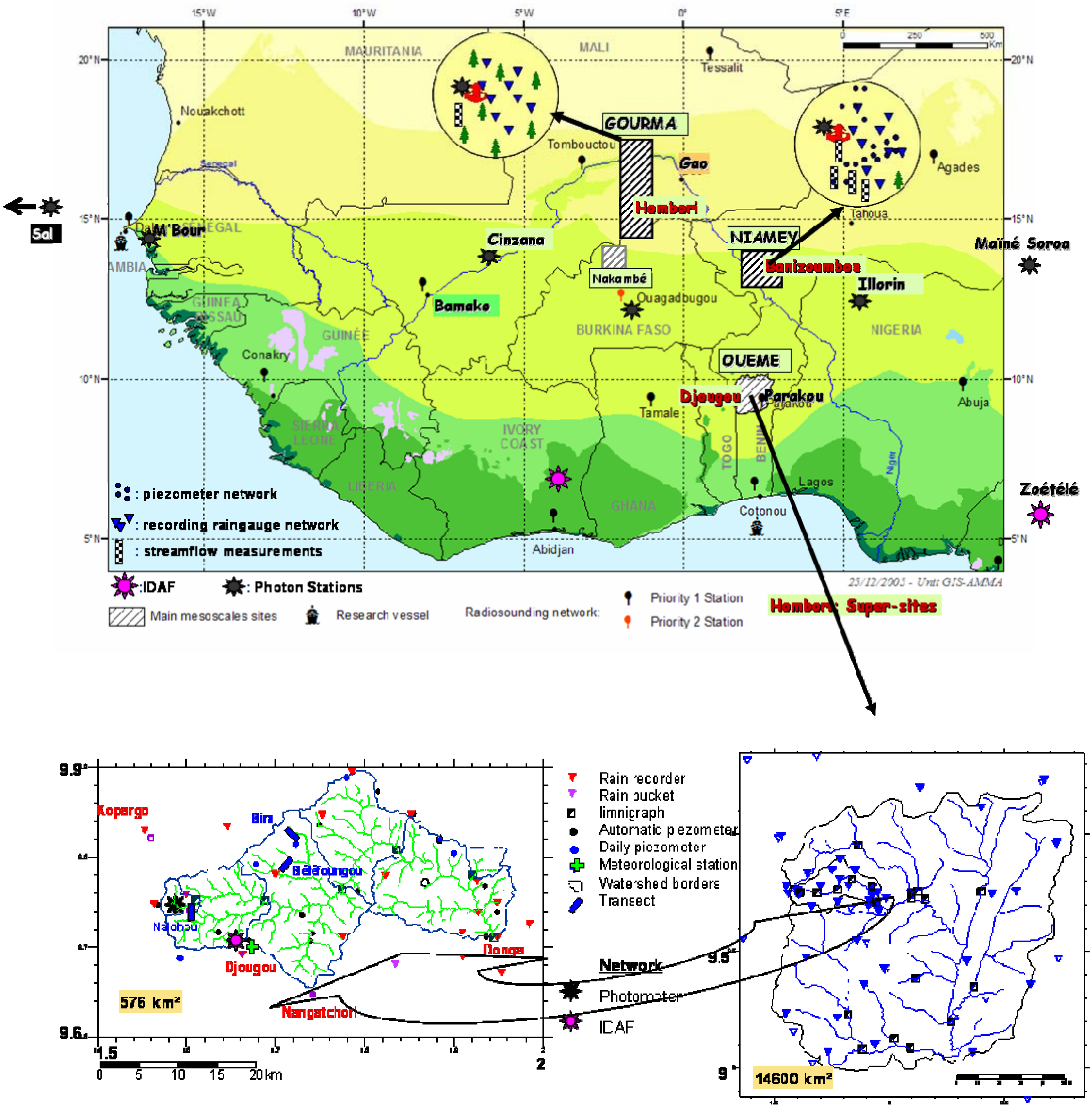

Fig 1.2. The long term AMMA observations on the continent. On the continent, the regional scale is monitored both through operational networks and specific networks (PHOTON, IDAF for aerosols and wet/dry deposits). The three mesoscale areas (Gourma, Niamey, Ouémé) include so-called super-sites and intensive local sites (as shown by the zoom on the Ouémé catchment). Another mesoscale site is the Nakambé catchment in Burkina-Faso.

2.2 Time scales and periods of study

Three periods of study are considered in order to sample the interannual variability and the intraseasonal variability as well as to be able to properly document the mean seasonal cycle, and possible decadal scale trends. These three periods are the Long term Observing Period (LOP: 2001-2010), the Enhanced Observing Period (EOP: 2005-2007) and the Special Observing Period (SOP: 2006).

2.2.1 LOP

Given the great variability of climatic conditions from year to year, observations are needed over several annual cycles in order to gain a proper vision of the diversity of the seasonal cycles, around a mean state which is only a statistical concept, but is never observed as such. The operational networks are precisely intended at this type of monitoring. However, operational networks are not dense enough to sample properly the spatial scales of interest when studying the links between the climate, the water cycle and the vegetation dynamics at the intrasesonal scales. Rainfall for instance has been shown to be extremely variable in space over the Sahel with characteristics scales in the order of 20-30 km, event when considering accumulation over the whole rainy season. It stems from this that the operational networks cannot sample the great variability of the seasonal rainfields and that the global rainfall indices supposed to characterise the rainy season are giving an oversimplified image of what the rainy season is. Since many other climatic and environmental variables are dependent on rainfall, this mere fact underlines how important it is to densify, at least locally, the operational networks. Moreover the operational networks of West-Africa are not in an homogeneous state of maintenance and reliability all over the region. For this decadal scale documentation of the climate and the environment AMMA is thus relying on specific observing systems that do not cover the whole region but provide a sampling of the main eco-climatic conditions encountered in West Africa (Fig 1.2). These systems are part of the *Observatoires de Recherche en Environnement* (ORE) program setup by the French ministry of Research. Five such OREs (2 over the ocean, 3 over the continent) were specifically setup in 2001, building on previous observations, some of which started as far back as the 1980's.

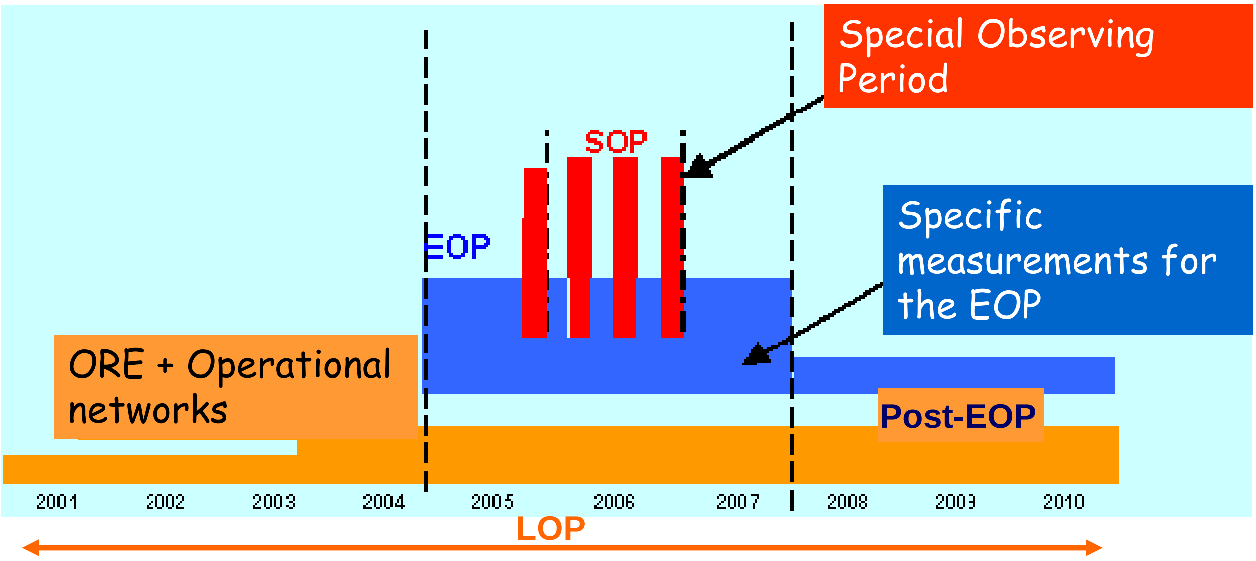

Fig 1.2. The AMMA observing periods.

Table 1.1. Parameters measured by the 5 OREs covering the AMMA region since the early 2000's.

ORE Name	Parameters	Instruments
PIRATA http://www.brest.ird.fr/pirata/	Ocean-atmosphere Fluxes	10 Atlas Buoys
SSS http://www.brest.ird.fr/sss/salinit1.html	Sea Surface Salinity	XBTs and Thermo-Salinographs, since 2003, along commercial routes.
CATCH http://www.lthe.hmg.inpg.fr/catch/	Hydrology, Vegetation	3 mesoscale sites (Gourma, Niamey, Ouémé): observations from the mid-1980's and the 1990's. Increased density of measurements from 2001.
IDAF (DEBITS)	Atmospheric Deposits	5 stations in the AMMA region. First installed in 1993.
PHOTONS (AERONET)	Aerosols	8 stations from 2001, 2 additional from 2005

Oceanic OREs (see also maps in Chapter 8, TT6).

PIRATA (http://www.brest.ird.fr/pirata/piratafr.html), 10 atlas buoys in the Atlantic Ocean; 5 are managed by IRD, located at 23°W-0°N, 10°W-0°N, 0°E-0°N, 10°W-6°S and 10°W -10°S; 5 are managed by Brazil, located at 35°W-0°N, 38°W-4°N, 38°W-8°N, 38°W - 12°N and 38°W-15°N.

SSS (Sea Surface Salinity). Based on data provided by commercial ships, this ORE monitors sea profile temperatures (XBT) and sea surface salinity (http://www.brest.ird.fr/sss/salinit1.html and http://www.brest.ird.fr/xbt/xbtorst.html).

Other oceanic international programs of interest to AMMA include the surface drift buoys (SVP) recording SSTs in the framework of the GOOS Global Drift Programme (http://www.aoml.noaa.gov/phod/dac/gcd.html) and the deep drift buoys (PROVOR) providing every 10 days profiles of temperature and salinity in the framework of the ARGO program and its French component CORIOLIS (http://www.ifremer.fr/coriolis/).

Continental OREs.

CATCH: An ensemble of three sites (see Fig. 1.1) devoted to studying the hydrological cycle from the local to the mesoscale and to its coupling with the vegetation dynamics. The three sites are: ***Gourma*** a 25000 km² area in Mali (2°W-1°W; 14°30'N-17°30'N), ***CATCH-Niamey*** a 16000 km² area in Niger (1°40'E-3°E; 13°N-14°N), ***Ouémé*** a 14600 km² catchment in Bénin (1°30'E-2°45'E; 9°N-10°10'N). On Gourma the emphasis is on the vegetation studies with the aim of regional modelling of its dynamics. The two other sites are densely instrumented in hydrological measurements (detailed maps in chapters 5, 6, 7).

IDAF: A network of 5 stations documenting the atmospheric deposits; 3 are installed on each of the CATCH super-site, and 2 are sampling the forest areas (Zoétélé in Cameroon and Lamto in Ivory Coast).

PHOTONS (http://www-loa.univ-lille1.fr/photons/). A transect of 4 Sahelian stations Sal, M'Bour, Ouagadougou, Illorin, plus a station in Morocco (Dakhla), plus one station on each of the CATCH super-site, that is a total of 8 stations. Note that in 2005, a photometer was installed in Cinzana (Mali) and one in Maine Soroa (East Niger), thus enlarging and densifying the Sahelian transect for the 2005-2010 period. Further details may be found in Chapter 4 (TT2b)

Other long term programs of interest to AMMA over the continent include the German GLOWA projects (GLOWA-Impetus on the Ouémé catchment and GLOWA-Volta on the Volta catchment in Burkina-Faso and Ghana), and the Burkina EIER/INRAB Nakambe catchment.

The LOP also involves atmospheric monitoring on the routine synoptic and upper air networks of the region (sounding stations shown in Figure 1.1). Some stations in the region have long and successful climate records, and must be sustained throughout the period, both for direct climatic analysis and to provide consistency in the atmospheric analyses (e.g. ECMWF reanalyses) in which they are assimilated.

2.2.2 EOP

The Enhanced Observing Period (EOP) is designed for a detailed documentation of the annual cycle of the surface and atmospheric parameters for convective to synoptic scales. As such it builds upon the LOP setup and its mesoscale sites strategy associated with a regional monitoring. The enhancement of observations over the mesoscale sites is done at two levels: i) a spatial densification of existing measurements and ii) the installation of instruments allowing for the measurement of variables not observed during the LOP, because these instruments are too costly to operate over such a long period. The regional coverage is obtained through various actions: i) a restoration and upgrade of the radiosounding network operated by ASECNA and national meteorological services; ii) installation of specific new instruments deployed in networks. Added to this continental deployment are oceanic measurements carried out by a research vessel during two annual cruises: one in June and one in September of each EOP year.

As shown in Figure 1.2, some specific EOP instruments will remain in operation after the end of the EOP, which means that there will be more instruments in operation during the post-EOP LOP than during the preliminary 2001-2004 period.

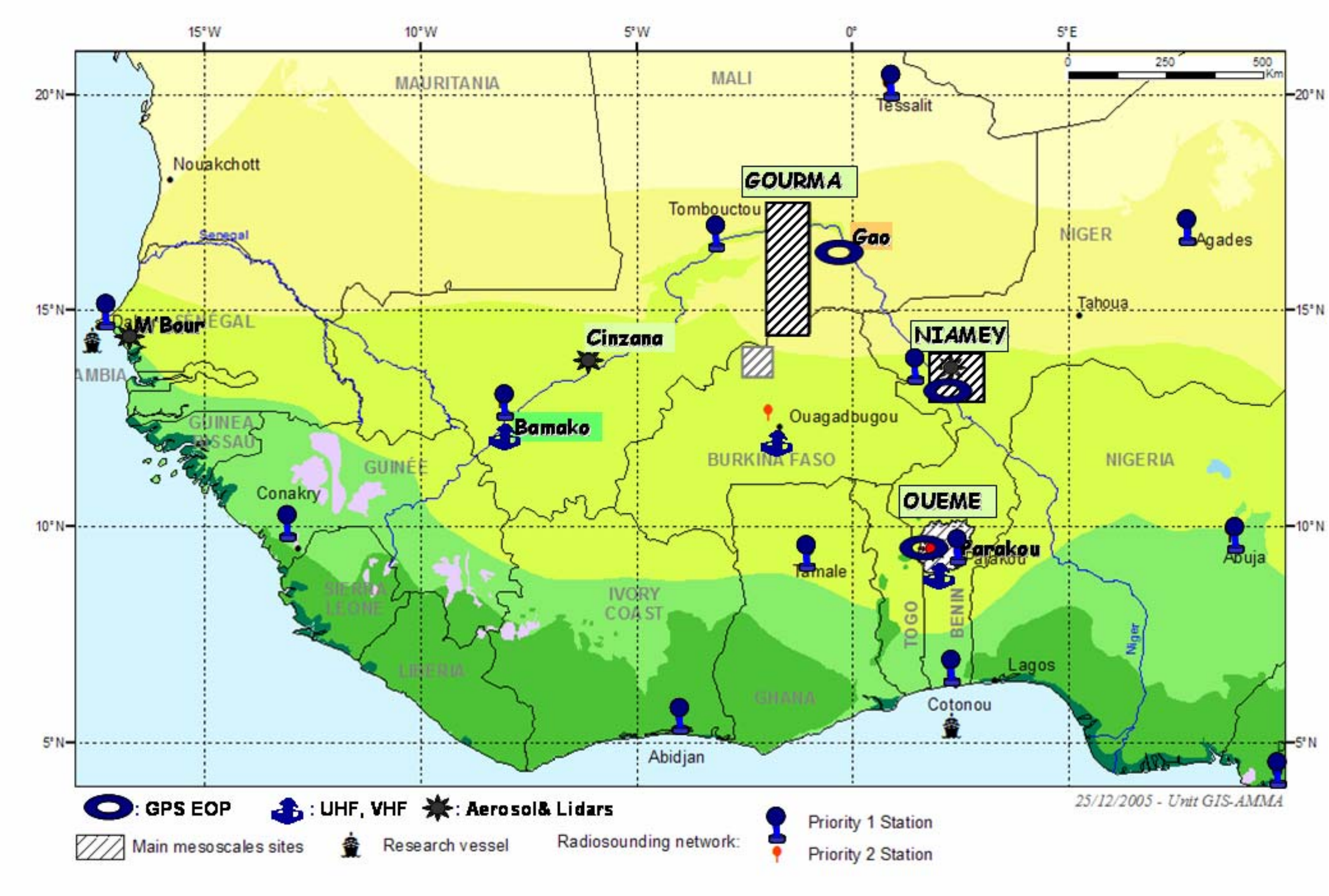

Fig 1.3. The EOP regional observing system on the continent.

2.2.3 SOP

The Special Observing Period, in 2006, focus on the study of processes specific of the main phases of one monsoon cycle, that is: i) the dry phase (phase ***0***) lasting from November to February; ii) the onset phase (phase ***1***) leading to the monsoon jump (end of June); iii) the well developed monsoon (phase ***2***: peak of the rainy season over the Sahel, and little dry season on the coast) from the end of June to mid-September; iv) the period most favourable for the tropical cyclogenesis over the Atlantic, lasting from mid-August to mid-October. This latter period is not a monsoon phase per se and it overlaps phase ***2***. It was identified as a separate period (***3***) because of a specific interest for the Atlantic tropical cyclones that hit the Caribbean and the South-Eastern coast of the USA; phase 3 is also of interest in certain aspects of the aerosol export westwards over the Atlantic. While phases ***0***, ***1*** and ***2*** correspond to well defined regional climatic patterns their exact time frame obviously varies from year to year. Now, the heavy SOP deployment (aircraft and balloons) cannot cover continuously the entire year; thus only a limited part of each phase will be documented by the full SOP setup. These sub-periods are called SOP0, SOP1, SOP2 and SOP3 as shown in Figure 1.4. A number of different platforms and instruments will be deployed in these sub-periods, in different characteristic modes according to their needs and scientific outputs.

Some EOP ground-based networks will be enhanced regionally for a large part of the SOP year – for instance the GPS network and lidar networks will be enhanced in this period. At the same time new ground-based systems will be installed for the SOP year: as an example, the ARM Mobile Facility (AMF) is now installed at Niamey and will operate until 31 December 2006. Other ground-based systems will be installed for sub-periods, according to their scientific priorities (e.g. radars to target precipitation systems in the rainy months of SOP1 and SOP2).

Ships, balloons and aircraft, whose deployments are by necessity relatively short, will be coordinated with the ground-based deployments for specific parts of the SOPs, as illustrated in Fig. 1.5. Within a given SOP, specific aircraft campaigns are defined with a suffix '_a1', '_a2' or '_a3', so that, for example, the second phase of aircraft activity in SOP2, at which we aim to deploy 5 research aircraft in cooperation, is denoted SOP2_a2. The detailed coordination of these instruments is elaborated later in this Implementation Plan.

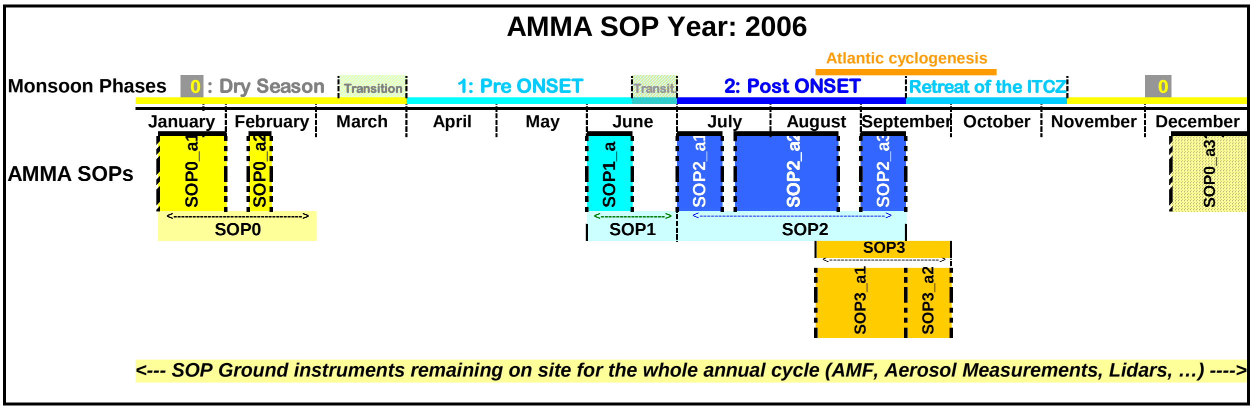

Fig 1.4. The SOP sub-periods

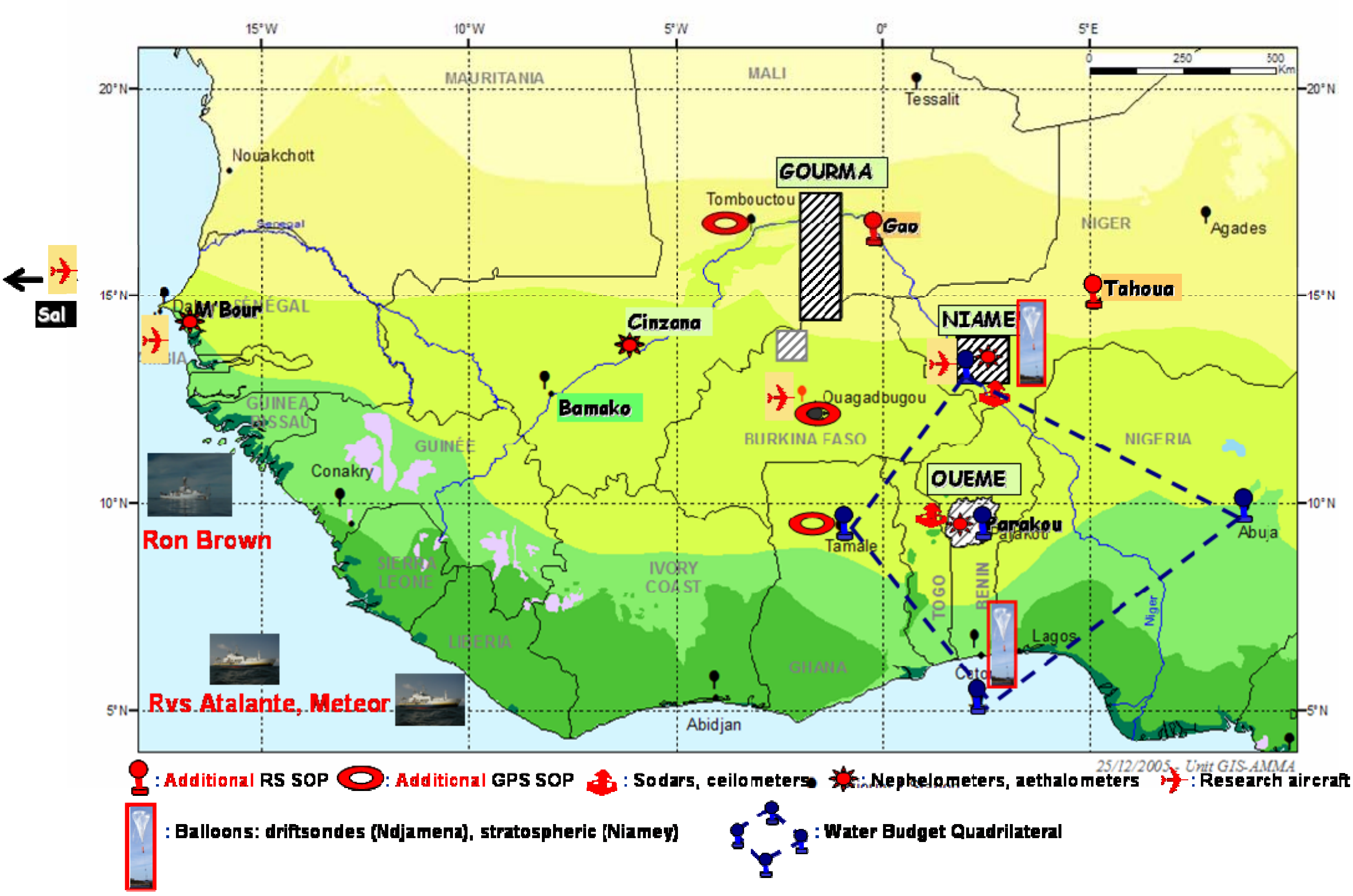

Fig 1.5. The SOP regional observing system. Instruments displayed in red are specifically deployed for the SOP. Note however that not all SOP instruments will be in operation for the whole 2006 year, the deployment of some instruments being limited to a single SOP (see SOP chapters 9 to 11 for details).

3 Presentation of the main AMMA entities

The implementation of the AMMA field programme is coordinated by the International Coordination and Implementation Group (ICIG). This group reports to the ISSC, and is responsible for coordinating the diverse needs of the science teams and instrument teams within AMMA. Given the broad timescales, spatial scales and multidisciplinarity of AMMA, the ICIG has chosen to structure the implementation according to temporal scale, LOP, EOP and SOP as defined above. Following this approach, the implementation is being coordinated by teams whose shared objectives lie in these scales. These teams are termed ‘Task Teams,’ and their remit has been to define coordinated deployment strategies for sets of instruments with shared objectives. There are certain principles which underlie this choice of management structure for the implementation:

- AMMA is a multidimensional and multidisciplinary programme, and it is imperative that communication between Task Teams, and an effective overall vision of the implementation is not lost. It is the role of the ICIG, reporting to the ISSC, to hold this integrative vision of the programme.
- Every instrument is managed by at least one Task Team.
- Some instruments with different modes of activity (e.g. radiosondes) may be managed by more than one Task Team.
- The work of the task teams is a continuous process of refinement of strategy, which will evolve during the months leading to the actual deployment, and which includes ‘responsive’ strategy

during the deployment (for instance, the SOP Task Teams are responsible for flight-planning). However, the work of the Task Teams is time-limited: following the respective periods of deployment, the Task Teams will not be required and the responsibility for coordination of data use will lie with the AMMA Working Groups (WGs), which report to the ISSC.

Table 1.2. The AMMA task teams

TT#	TT Name	Time and Space Scales	Type of sampling
TT1	EOP Sounding of the Atmosphere	EOP; Regional	Homogeneous over the whole sub-continent, plus transects
TT2a	EOP Surface Flux Measurements	EOP; Regional to local scale	Concentration on meso-scale sites, plus station to the South
TT2b	EOP/LOP Aerosols Monitoring and radiation	LOP/EOP; Regional	Sahelian transect & Super-sites
TT3	EOP/LOP integrative studies on the Gourma meso-scale site	LOP/EOP; Mesoscale to local scale	1x1 km² "plots" distributed all over the study area
TT4	EOP/LOP integrative studies on the Niamey meso-scale site	LOP/EOP; Mesoscale to local scale	Homogeneous sampling at the mesoscale with denser networks on a super-site
TT5	EOP/LOP integrative studies on the Ouémé meso-scale site	LOP/EOP; Mesoscale to local scale	As in TT4, except for one additional minor super site
TT6	EOP/SOP Oceanic campaigns & measurements in open ocean	EOP/SOP; Regional (Ocean)	Cruises following "rails".
TT7	Dry season SOP	SOP; Regional to mesoscale	Intensive observations using aircraft & ground instruments
TT8	Wet season SOP	SOP; Regional to mesoscale	Intensive observations using aircraft, balloons & ground.
TT9	Downstream SOP	SOP; Regional/ Downstream	Intensive observations using aircraft, & ground instruments

In addition to the AMMA Task Teams, certain ‘Support Teams’ (STs) have been defined, in areas where an aspect of the implementation crosses the temporal and disciplinary boundaries of the Task Teams (e.g. ST3, the database team).

It should be made clear that support teams do not provide resources for AMMA scientists, but exist as a coordination tool for different groups with similar needs. For example, ST2 (SOP Logistics) exists as a forum between the numerous groups who are coordinating the logistical needs of instruments in Africa, so that resources can be shared and good practice can be disseminated.

Table 1.3. The AMMA support teams

ST#	ST Name	Function
ST1	EOP logistics	Inventories and synthesises the EOP TTs needs and interacts with the AMMA Operation Centre to determine how these needs can be satisfied. Evaluate the associated cost and human resources.
ST2	SOP logistics	Inventories and synthesises the SOP TTs needs and interacts with the AMMA Operation Centre to determine how these needs can be satisfied. Evaluate the associated cost and human resources.
ST3	Data base	Meta data base, data base, data policy.
ST4	Fund raising, capacity building and training	In charge of raising funds for AMMA-Africa, making AMMA known to international funding agencies and program with the aim of attracting funding to the African institutions and scientists involved in AMMA. Organises summer schools, training sessions, field schools, workshops. Centralises opportunities for training in University programs in Europe or USA.

4 Sites and Instruments.

The AMMA field program relies on operational networks and on instruments specifically deployed on various sites for periods of varying duration, as described above. In this section we first provide an overview of the sites (see also maps 1.1, 1.3 and 1.5) and platforms on which instruments are deployed; then two tables summarise the instruments in operation during the three main AMMA periods. More details can be found in the TT chapters and in appendix.

4.1 Sites and Platforms

4.1.1 Ground Sites

Table 1.4. The regional scale windows and transects

Name	Position	Description	Periods of activity
Continental Regional Window	4°N -21°N; 18°W-10°E	The whole continental area of interest. The monitoring is based on the operational networks (Radio-sounding stations, Synoptic stations, Raingauge national networks). IDAF and PHOTONS networks*. Remote sensing plays a major role.	2001-2004 2005-2007 2008-2010
Sub- Regional Window	5°N -18°N; 0-4°E + 11°N -18°N; 2°W-0° 780,000 km²	Includes the three main mesoscale sites, plus the ancillary sites of the Nakambe and Dano in Burkina Faso.	2001-2008
Sahelian Transect	M'Bour, Cinzana, Banizoumbou	Aerosol (3 stations) studies during EOP and post EOP; Convective systems studies (radars during SOP), including their role in dust transport	2005-2007 2008- ? 2006
Water Budget Quadrilateral South	Cotonou, Tamale, Niamey, Abuja	Water budget closure studies during the SOP year	2006

* Note that the IDAF network extends to Zoetele 3°N,11°E (Cameroun) and PHOTONS include one station in Morocco.

Table 1.5. The mesoscale sites

Name	Position	Description	Period of activity
Ouémé Catchment	Bénin; 9°-10°N; 1.5°-3°E 14200 km²	Densely instrumented catchment with denser instrumentation on sub-catchments (Donga, Aguima, Ara). Soudanian climate (different types of rain systems) and Savannah vegetation. Global models; impact of climate variability on water resources.	1997-2007 + post EOP monitoring
Niamey meso-site / Kori de Dantiandou	Niger; 13°-14°N; 1.6°-3°E 16000 km² / Catchment in the North-East of Niamey meso-site 5800 km²	The survey of the "Niamey square degree" started in 1990. Heavy observations in 1992, monitoring from 1994 to 2002, densification starting again in 2003. Sahelian climate with semi-arid vegetation (Millet crops, Tiger bush,…). Long series of high resolution rain data and groundwater levels.	1990-2008 + post EOP monitoring
Gourma	Mali; 14.5°-17.5°N; 2°-1°W 30000 km²	Sahelian to saharo-sahelian climate (between isohyets 400 and 100 mm). Semi-arid natural vegetation composed of annual grasses and a sparse tree layer. Crops only present in the southern part of the area. 16 vegetation sites monitored since 1984. Also satellite products validation sites (vegetation, soil moisture).	1984-2008 + post EOP monitoring
Nakambé	Burkina; 14.1°-10.9°N; 2.5°-0.1°W; 40836 km²	Sahelian climate (between isohyets 400 and 100 mm). Semi-arid natural vegetation. Hydrological monitoring, erosion studies.	2004-2009

Table 1.6. Super sites

Name	Position	Description	Period of activity
Donga Catchment	Bénin; 9.6°-9.9°N; 1.6°-2°E 590 km²	Sub-catchment of the Ouémé catchment with a dense recording raingauge network (14 stations) and 5 streamflow stations. Land surface process studies, hydrological modelling, coupling with the sub-surface and the atmosphere.	2002-2008 + post EOP monitoring
Aguima Catchment	Bénin; 9.10°-9.14°N; 1.9°-2°E, 30 km²	Sub-catchment of the Ouémé catchment, with a dense recording raingauge network (9 stations, some are in neighbouring catchments) and 5 water level recorders, 3 weather stations. Evaporation and soil moisture measurements. Land-surface process and agricultural studies; hydrological modelling.	2001-2008 + post EOP monitoring
Niamey Super- Site	Niger; 2°35'-2°48'; 13°25'-13°45', 600 km²	Kori de Dantiandou and adjacent areas. Dry vegetation cover. Land surface process studies, hydrological modelling, coupling with the sub-surface and the atmosphere. Rainfall vs vegetation spatial relationship, at the local scale	1991-2008 + post EOP monitoring
Titao Catchment	Burkina Faso; 13°40'-14°N, 2°-2°2' W < 50 km²	Sub-catchment located in the north of the Nakambé basin. Hydrological, erosion, bio climatic, environmental, soil physics and vegetation dynamics studies. Water, matters (solid and dissolved) and energy flux. Three different soil surface types (bare soils, cultivated lands and natural vegetation covered surfaces).	2004-2009
Dano	Burkina Faso, 11.15°N, 3.07°W, 20km²	Sudan Savannah, dam at outlet of subcatchment/testsite, micrometeorological system and various devices for C/N/H2O turnover	2005-2007

Table 1.7. AMMA local intensive sites

Name	Position	Description	Period of activity
Ara Catchment	Bénin; 9.9°N; 1.6°E 14 km²	Sub-catchment of the Donga and Ouémé catchments. Geophysical and geochemical studies. Flux measurements. X-Band radar and disdrometer. Emphasis on process studies	2003-2008
Banizoumbou	Niger (13°31'30''N, 2°38'21''E)	Ground based measurement of aerosols properties (physico-chemical, optical) and dust fluxes measurements. Weather station. Local water budget.	1991-2008
Wankama	Niger; 1,8 km²	Flux measurements ; Soil moisture; local recharge	1991-2008
Hombori-Agoufou	Mali; 15.2°N, 1.3°W 1 km²	Sand dune site with a sparse tree cover. Annual rainfall : 370 mm (1920-2003). Vegetation and soil moisture measurements. Automatic Weather Station. Flux measurements. Sun photometer. Validation of satellite products. Vegetation modelling.	2002-2008
Tougou Catchment	Burkina Faso; 13°40'39" N, 2°13'41" W 36 km²	Sub-catchment located in the north of the Nakambé basin. Hydrological, erosion, bio climatic, environmental, soil physics and vegetation dynamics studies. Particle transport (solid and dissolved) and energy flux. Three different soil surface types (bare soils, cultivated lands and natural vegetation covered surfaces).	2004-2009

Table 1.8. Other Local sites of interest to AMMA

Name	Position	Description	Period of activity
Dahra (Ferlo Region)	Sénégal 15° 49' 09.012" N 15° 03' 39.118" W	Sahelian climate (300-450 mm rain) with semi-arid savannah vegetation. Annual grasses with a maximum height of 60 cm. Tree and shrub canopy cover generally < 5 %. Pastoralism is the dominant activity, but rain-dependent cultivation is an important secondary land use. Livestock are present year-round	2005-2008
Lamto	Côte d'Ivoire	Wet and dry atmospheric deposition. Vegetation studies	1991-2008

4.1.2 Aircraft and Balloons

Table 1.9. Aircraft characteristics

	BAe-146 G-LUXE	ATR-42 F-HMTO	Falcon F-GBTM	Falcon D-CMET	Geophysica 55204	DC8 NASA
Weight	44.2 t	16.9 t	14.5 t	13.8 t	24.6 t	
Wingspan	26.34 m	24.57 m	16.32 m	16.32 m	37.46	
Length	31 m	22.67 m	17.15 m	18.75 m w. Noseboom	22,87	
Height	8.61 m	7.59 m	5.32 m	5.37 m	4.83	
Take off field length	1600 m	1200 m	1400 m	1830 m	>2000 m	
Max. Payload	4 t	4.6 t	1.2 t	1.65 t	2.25	
Scientific Payload, normal config.	4 t	2.5 t	1.0 t	1.20 t	1.5 t	
Maximum Endurance	6 hours	5 hours	5 hours	4,6 hours	5.5 hours	
Endurance in AMMA config.	5 hours	3.5 hours	4 hours	4,0 hours	4.5 hours	
Max cruising speed	796 km/h	490 km/h	871 km/h	917 km/h	720 Km/h	
Scientific cruising speed	220-780	250-470		740 km/h	250 – 720	
Max. Range scientif. Config.	3200 km	1200 km	3220 km	2780 km	2800 Km	
Max. Range opt. conditions	3700 km	2000 km	4100 km	3200 km	3300 Km	
Logistics						
Flying Crew/ Equipage en vol	21	11	6	5-6	1	
Ground Crew/ Equipe au sol	6	3	3	3	15	
Fuel Weight (Jet A-1)	2800 l/h	3500 l	4130 kg	4006 kg	7600 kg	
GPU / Unité auxiliaire au sol	60 kva	28 kva	28 kva max 285 A	28 kva max 600A	35 KVA	
Air Control						
Low level flight	250' AGL	150' AGL	**N**	500´ AGL	**N**	
Dropsondes	**Y**: clearance	**N**	**Y**: clearance	**N**	**N**	

Table 1.10. Aircraft deployement in SOP 1 (1st June- 15th June) and SOP2 (1st July- 15th September).

Dates (weeks) / Aircraft	29/5	5/6	12/6	19/6	26/6	3/7	10/7	17/7	24/7	31/7	7/8	14/8	21/8	28/8	4/9	11/9	18/9
Bae 146 (UK)								17Juil. - 21 Aout					22-28/8				
ATR 42 (FR)	1er - 15 Juin					1er-15 Juil.				25 Juil. -25 Aout							
F20 (FR)	1er - 15 Juin					1er-15 Juil.				25 Juil. -25 Aout					1er-15 Sept		
F20 (D)						1er-15 Juil.					31/07 -18/08						
M55(EU)											31/07 -18/08						

- (light green) from Niamey (Niger)
- (orange) from Dakar (Senegal)
- (blue) from Ouagadougou (Burkina Faso)

In addition to the aircraft listed in the table above, there is the possibility of including in the AMMA deployment the Skyvan from Helsinki University of Technology (HUT) equipped with the EMIRAD radiometer, operating from Niamey and/or Gao airport. The Skyvan has short take off and landing capabilities (typically take off distance of 700m at sea level in standard conditions). The funding of this aircraft is not yet secured at that time.

Table 1.11. Balloons requiring flight clearances

	BPCL	Drif-Sondes (SBDS)	Stratospheric balloons
Poids - Weight			
Envergure – Wingspan	2.5 m	12 m	30 m
Hauteur - Height	2.5 ..m	27 m	70 m
Aire de lancement/ Launching Pad	30 x 30 m	100 x 100 m	100 m x 100 m
Endurance	15 days	15/20 days	6 hours
Max. Range envisioned for AMMA			400 km
Measured Parameters/ Paramètres	Coordinates + P, T, RH	Coordinates + P, T, U, RH	Coordinates + P, T, U, RH, chemistry
Logistics			
Ground Crew/ Equipe au sol: Science	2	4	27
Ground Crew/ Equipe au sol: Technic.	4	11	15
Air Control			
Identification	flashlight	Radar transponder, flash-lamp, Radar reflector	Radar transponder, flash-lamp, Radar reflector
Flight –Altitude- de Vol	850-900 hpa	50/60 hpa	15000-30000 m
Dropsondes	**N**	**Y**: clearances	**N**
Deployment / Déploiement			
SOP1 (1 – 15 Juin)	Cotonou (1-30 June)		
SOP2_a1 (1-15 Juillet)			
SOP2_a2 (20 Juillet-20 Août)		N'Djamena; 8 to 10 launchings	Niamey, about 15 launchings
SOP3		SOP2 and SOP3 interest interest launchings	

4.1.3 Research Vessels

Table 1.12. RVs characteristics

Measurements \ cruises	Suroît (EOP)	Atalante (SOP)	Ron Brown (SOP)	RV Météor SOP***	ITAF DEME SOP
Hydrology (CTDO2)	YES	YES	YES	YES	YES*
Currents (S-ADCP and/or L-ADCP)	YES	YES	YES	YES	NO
Continuous SST and SSS (TSG)	YES	YES	YES	YES	NO
Temperature profiles (XBT)	YES	YES	YES	NO	YES*
Salinity profiles (XCTD)	YES	YES	NO	NO	NO
Surface drifters deployment (SST)	YES**	YES**	YES	??	??
Surface drifters deployment (wind & sea level pressure)	YES**	YES**	YES	??	??

Table 1.12 (followed). RVs characteristics

ARGO profilers deployment (T&S profiles)	YES	YES	YES	YES	YES*
Sea water samples for analysis (S, O2, and nutrients)	YES	YES	YES	YES	YES
Ocean microstructures (turbulence)	YES ***	YES ***	??	YES	NO
Helium (air and ocean) for upwelling rate estimate	partly ****	YES ****	NO	YES****	NO
Meteorological measurements (classical station -eg BATOS-)	YES	YES	YES	YES	YES
Atmospheric microstructures & air sea fluxes (turbulence)	NO	YES	NO	NO	NO
Radiosoundings (from vessel)	NO	YES	NO	YES	NO
Sea water samples for analysis (O18, 13C & CO2 parameters)	YES	YES	NO	YES	NO
Aerosol (photometer)	YES	YES	NO	NO	NO
Drifting vertical temperature profiles (MARISONDE)	NO	YES	NO	NO	NO

*: provided and/or funded by (or in the framework of) AMMA-France (API)
**: provided and/or (maybe partly) funded by (or in the framework of) AMMA-US (NOAA)
***: provided and funded in the framework of German CLIVAR-TACE contributions (IFM-GEOMAR)
****: provided and funded in the framework of German SOLAS contribution (University of Bremen)

4.2 Instruments

An AMMA instrument is defined as a sensor or set of sensors allowing for a coherent spatio-temporal sampling of a geophysical variable or of a set of inter-related variables with respect to the study of a given process. Following are a few broad types of instruments:

- Isolated station making point measurements (ex : a meteorological station).
- Network of stations allowing for a coherent spatio-temporal sampling on a super-site or a meso-scale site (typically a raingauge network, soil moisture measurement sites, a set of vegetation plots, an ensemble of similar flux stations), or possibly at the regional scale (Photometres Network, GPS Network, buoys Network).
- Isolated instrument making spatially integrated measurements and/or with a large spatial coverage (typically a radar).
- A set of co-located instruments (aerosol, local water fluxes, aircraft instrumentation).
- Mapping Campaigns (vegetation, geophysics).

A complete list of all the instruments deployed in AMMA is given in appendix. The table below provides a synthetic overview of this deployment. Note that the details of the deployment in the framework of SOP3 are still not fully known, some funding issues being still not decided.

Table 1.13. Summary of EOP and LOP instruments. Many instruments agglomerate several sensors, so the total number of sensors corresponding to the 41 EOP instruments is in the order of a few hundreds.

Type of instruments	Number of inst. Deployed (EOP – LOP)	Scale (or sites)	TT
RS networks, GPS network, Ozone sounding	5 – 0	Regional	1, 5
Met. Radars, UHF, VHF	3 – 0	Djougou (Rad. X, VHF) Bamako, Ouaga (UHF)	1, 5
Flux and Met. Station (isolated or in networks); disdrometers	7 – 7	3 Mesoscale sites, most often on super-sites	2a, 3, 4, 5
Other Flux measurements (Balloon, Scintillometer)	2 – 0	Hombori, Djougou	2a, 3, 5
Aerosols	2 – 1	Sahel Transect + Lamto	2b, 5
Nox	2 – 0	Hombori, Djougou	3, 5
Hydrological and vegetation monitoring networks	4 – 2	Gourma Mesoscale site	3
Hydrological and vegetation monitoring networks	7 – 4	Niamey Mesoscale site	4
Hydrological and vegetation monitoring networks	6 – 6	Ouémé Mesoscale site	5
Buoys (XBT, CTD, ..)	3 – 6	Regional (Ocean)	6
TOTAL	EOP: 41 LOP: 26		

Table 1.14. Summary of SOP ground instruments.

Type of instruments	Number of inst. Deployed	Scale (or sites)	TT
RS & GPS networks, RS on the ocean, Ozone sounding	7	Regional	1,5, 6, 8
Balloons: BVC and Drift	2	Cotonou & N'djamena	8
Radars, Profilers, Sodars	9	Dakar, Niamey, Djougou	8, 9
Other Flux measurements (Balloon, Station)	2	Niamey, Dano	8
Aerosols: Lidars	4	SS + M'Bour + Tamanrasset	2b, 7, 8
Aerosols & Chem.: Nephelo., Aethelometers, TMS, Impactors	4	Super-sites	2b, 7, 8
Collection of Met., Flux, Profile and Radiometric measurements	12	Niamey and Banizoumbou	ARM Mobile Facility
Chemistry	1	Djougou	8
Met. And Fluxes on the Ocean, Buoys (XBT, CTD, ..)	5	Regional (Ocean)	6
Miscellaneous (Lightning, (	1	Djougou	8
TOTAL	**47**		

Chapter 2
Sounding of the Atmosphere
TT1

Andreas Fink, Serge Janicot and Doug Parker

1 Scientific justification and objectives

It is the general goal of the AMMA Radiosonde Group (ARG or TT1 group) to assist in the development and maintenance of a coordinated network of radiosonde, PILOT balloon, VHF/UHF and GPS Total Columnar Water Vapour (TCWV) stations during the AMMA EOP period and beyond to address specific AMMA scientific objectives for atmospheric research and monitoring.

AMMA is planned around three nested timescales that will be referred to in the following text:

- LOP studies are based on long-term observations, including archived data and rescued datasets;
- EOP (Extended Observing Period) studies are to be based around the years 2005 to 2007, during which a coordinated set of observations of the atmosphere, land and ocean systems will be obtained. Multi-season observations are to be made in order to evaluate variability in the system, as well as mechanisms of 'memory' between seasons.
- SOP (Special Observing Period) studies will take place in the summer of 2006. The SOP is aimed at intensive observations of particular processes and is subdivided into four periods according to particular scientific goals:

1) SOP0 Dry season processes: January/February 2006
2) SOP1 Monsoon onset: 1 June – 30 June 2006
3) SOP2 Monsoon maximum: 1 July – 15 September 2006
4) SOP3 Late Monsoon: 15 September – 30 September 2006

The upper air networks of radiosoundings, pilot balloons, UHF/VHF profilers and GPS stations are crucial for the success of AMMA. Good upper air observations are essential for the generation of reliable model analyses, which are in turn necessary for environmental monitoring over the continent and the downstream Atlantic. Upper air data is also needed for quantifying the basic physical processes of the atmosphere. The current operational network consists of some stations that have a good recent record of soundings, and a number which are experiencing problems. AMMA aims at upgrading the existing stations and will also add a few additional stations for the EOP. AMMA strives for the new stations at Tamale, Abuja and Cotonou to be incorporated in the long term operational network.

The most extensive set of upper air measurements over the continent was conducted during the GATE experiment in 1974 (Kuettner and Parker 1976; their Fig 4). These soundings remain a valuable resource for monsoon studies (and are soon to be archived at the British Atmospheric Data Centre (BADC)). ERA-40 reanalyses assimilating the radiosondes from the GATE year are also now available. However, during GATE much of the emphasis, including the majority of the observational subprograms, was focused on weather systems over the Atlantic Ocean; during AMMA we aim to integrate the atmospheric sounding network with observations of both the continental and ocean systems.

The WAMEX project of 1979 also involved increased soundings over the continent. These data are stored as part of the FGGE archive.

Six stations in the region (Dakar, Niamey, Abidjan[1], Tamanrasset, Addis Ababa and Douala), are currently members of the GCOS Upper Air Network (GUAN), and are therefore subject to scrutiny by the GUAN group. One of the objectives of the AMMA radiosonde group will be to arrange similar support and attention to other key stations within the African Monsoon domain.

2 Observing Strategy

2.1 Overall strategy

All suitable operational radiosonde stations in the AMMA region are listed in Table 2. The upgrading of stations and the deployment of radiosondes has been designed around some key arrays of stations.

In order to plan and prioritise the soundings, we have organized the stations into key arrays – identified as "instruments", for the purposes of different scientific programmes within AMMA. Several stations appear in more than on of these arrays, highlighting the importance of these soundings to a number of AMMA objectives. We suggest four groups of arrays (some of which consist of sub-arrays; see also Fig.1)

(i) Monsoon array

Monsoon Inflow Stations: Conakry, Abidjan, Cotonou, Douala, Bangui

Climate array: Cotonou, Tamale, Parakou, Abuja, Niamey

This array is needed for study of the monsoon seasonal cycle, and for understanding of the monsoon and ITCZ dynamics and fluxes throughout the full EOP period. The Monsoon Inflow Stations monitor the profiles along the southern part of the summer monsoon region, in the zone where the low-level monsoon winds are carrying moisture from the humid boundary layer over the Gulf of Guinea and the Congo basin. The Climate Array quadrilateral monitors the seasonal, intra-seasonal, synoptic and diurnal variations in the monsoon, as it penetrates inland, feeding moisture into the continent. For this reason, higher frequency soundings (4 per day or more) are desired during the SOPs.

Note that there is likely to be extension of the climate array with soundings from the Ron Brown research vessel in the Gulf of Guinea during SOP1.

(ii) Zonal (Sahelian) array

This comprises a series of stations lying in the Sahelian zone across the continent, from Sal to Addis Ababa, including Conakry (Fig.1).

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[1] Note however that, despite being a GCOS station, Abidjan has not operated since its gas station exploded in June 2001

This array is needed for the study of synoptic variability in the monsoon, since weather systems are initiated in the east of the continent and propagate towards the west and into the Atlantic (where they are known to initiate a majority of tropical cyclones). Furthermore, it is thought that intraseasonal fluctuations in the rainfall, including the monsoon onset, are manifested as slowly-propagating anomalies moving from the west. This array is also needed for validation of satellite winds and temperatures, and for data assimilation studies. Owing to the northward advance of the monsoon, and the strengthening of the synoptic variability, this array is of highest importance around the period of the summer monsoon, including the onset and retreat phases.

(iii) Northern stations

Agadez, Tombouctou, Tessalit, Tamanrasset

These stations lie in a critical zone on the southern fringes of the Sahara. The soundings are needed for measurements of the northern structure of African easterly Waves (AEW) disturbances, which are known to be of importance in synoptic development further south, and in propagation over the Atlantic (Reed et al. 1977, Pytharoulis and Thorncroft 1999), but have never been observed with comprehensive upper air data. Tombouctou, being further west, is best placed for such study of AEWs, which tend to amplify as they move across the continent.

Tessalit is perfectly placed to observe the monsoon trough and heat low in the summer months, in a zone where the model errors due to aerosol loadings can be large. In this regard, its position is better than that of Tamanrasset, whose climate is somewhat affected by the Hoggar Mountains.

These northern soundings also represent an extension of the meridional Climate Array in the summer period. They are needed for understanding of monsoon dynamics and the role of the diurnal cycle in the zone of strongest thermodynamic gradients, during the monsoon peak. In this context, the data from the Northern Stations will be used in association with surface observations from the northern extensions of the flux station network.

These stations are of primary interest in the summer periods, when the low-level thermodynamic gradients are located in the Northern Sahel.

(iv) SOP Flux networks (quadrilaterals, see Fig. 2)

Southern quadrilateral: Cotonou, Parakou, Niamey, Tamale, Abuja

Northern quadrilateral: Parakou, Tahoua/Birni/tAgadez/Kano, Tombouctou, Ouagadougou, Niamey

Western quadrilateral: Bamako, Dakar, Sal, Conakry, Nouakchott

At the centre of each quadrilateral, a meteorological radar is to be deployed. These quadrilateral arrays are needed in process studies, for estimation of budgets in the water vapour and energetics of each region. Such diagnostics are necessary for studies of cloud systems and hydrology. These methods have been employed in related studies within the GATE, TOGA-COARE and IHOP experiments, for example. A frequency of at least 4 soundings, during the SOPs, is needed for these purposes.

Due to limitations in hydrogen production, such high sounding frequencies may only be possible through the use helium. Therefore, the costs and logistic challenges of distributing helium bottles to the above-mentioned stations must be explored. The price of 9cbm helium in Niger is about $130 per cylinder.

The US ARM programme will secure 4-daily soundings at Niamey throughout the year of 2006. A temporary station, to be deployed during the SOP in a location to the east of Niamey, is required to complete the northern quadrilateral of stations. Possible temporary sites for this station include Birni n'Konni (13.80N, 5.25E) and Tahoua (14.90N, 5.25E). The Tahoua site would be priority. A substitute

MODEM ground station from ASECNA Dakar can be relocated to Tahoua along with a spare DCP for telecommunication purposes. The hydrogen provision problem has to be tackled. If a temporary radiosonde facility is not available, Agadez or Kano are also possibilities to act as a completion of the northern quadrilateral, making additional soundings as the easternmost point in the northern quadrilateral.

Note that we must be sensitive to the errors in budget estimates, which may arise where stations are located close to major topographic features. For instance there may be problems arising from coastal circulations at Dakar and Cotonou.

The anticipated frequencies of soundings on these stations are outlined in Table A1 of Appendix 1. Note that 'responsive' soundings are those which will be deployed flexibly, to support other observational activities (e.g. aircraft and radar) at relatively short notice.

Intensive observing IOPs have been proposed by TT8 for the onset period (around 22 – 26 June suggested) and mature monsoon (probably the main aircraft detachment of SOP2-a2. It is considered that owing to the high demands on staff, particularly in gas generation that these IOPs cannot be sustained for more than 5 days in each case (but see note below regarding helium options).

Ideal sounding capacities, bearing in mind the known facilities and personnel at each site, were suggested for the following stations:

Agadez	4
Abuja	8
Cotonou	8
Niamey	8 (using ARM and ASECNA's two GIP 3 hydrogen generators in parallel)
Ouaga	4
Parakou	8
Tamale	8
Tombouctou	4
Tahoua	2
(Kano	2)

2.1.1 Contributing parties to the AMMA radio-sounding program

The currently available budget (~2,5 M€) comprises three sources: AMMA-EU (~ 2.1 M€), AMMA-France (~0.23 M€) and AMMA-UK (~0.17 M€). The majority of the budget is from AMMA-EU and this will deal with most of the infrastructure needs.

The US ARM programme will fund 4 radiosoundings/day at Niamey during the entire year of 2006. Contact person is Kim Nitschke (nitschke@lanl.gov).

The US GCOS programme is funding a new electrolytic hydrogren generator at Dakar (~80k$). It is planned to be installed in March/April 2006.

The SCOUT balloon program will contribute to some responsive soundings at Niamey during SOP 2006.

Funded ship-based radiosonde programmes

Within the French AMMA/EGEE programme, the funding of 90 (40) Vaisala sondes to be launched during the EGGE 3 (4) cruises in the Golf of Guinea between 25 May and 07 July 2006 and in September 2006 is secured. The sounding data are transmitted to the GTS in real-time.

Within the German AMMA and SOLAS programmes, the funding of twice daily (total 64) and (total 52) Vaisala sondes to be launched during two METEOR cruises in the tropical and subtropical Atlantic Ocean (06 June-08 July 2006 and 11 July-08 August 2006) is secured. The sounding facilities are provided by the German Weather service (DWD) and the data are transmitted to the GTS in real-time.

Details of the sounding programme on the Ron Brown research vessel are presently unknown.

For further details on the AMMA oceanographic component (e.g. cruise tracks), the reader is referred to the TT6 document.

Other:

Dropsondes will be released from the British BAe146 and French Falcon during SOP 0, SOP 1 and SOP 2. The release of driftsondes is also planned for SOPs. It is intended to transmit data from these soundings to the GTS in real time. For details, the reader is referred to the corresponding TT7 and TT8 documents.

Contacts to the European AMDAR programme revealed that it is planned to enhance the daily provision of enroute data and profiles from or to African airports. These data (wind and temperature) are collected and transmitted in real time to the GTS by commercial aircrafts.

Contributed funding:

The project will rely on the large, existing and new operational commitment from ASECNA and other Meteorological organisations (e.g. Nigerian Meteorological Service (NIMET), Ghana Meteorological Agency (GMA), and Algerian Meteorological Service).

2.1.2 Communication and infrastructure improvement needs (radiosondes)

SYNOP surface and TEMP and PILOT upper-air data are transmitted into the GTS via the regional meteorological telecommunication network of WMO Region I (Africa). In short and in principle, the Regional Telecommunication Hubs (RTHs) are Niamey, Brazzaville and Dakar. Niamey collects the data from Ghana, Togo, Benin, Nigeria, Burkina and Niger. Brazzaville collects the data from Cameroon and the Central African Republic and other countries. Dakar collects data from Ivory Coast, Mauritania, Mali, Guinea and other countries. Dakar, Niamey and Brazzaville are transmitting the data to Toulouse. Technically, the data are mainly communicated through the regional aviation safety telecommunication network maintained by ASECNA.

Several stations require new communications systems. More specifically, several ASECNA stations need a radiolink or another fast connection between the observer's buildings and the CAT (Centre Automatique de Télécommunication) building for an automatic transmission of TEMP messages into the GTS. A benchmark system is about to be installed at the new radiosonde station of Cotonou. If successful, other stations will be equipped with this system jointly by ASECNA and AMMA-EU (see list below).

Five SUTRON DCPs (Data Collection Platforms) funded by AMMA-EU are available at Dakar (for training purposes and a spare part), Cameroon (Ngaoundere), Benin (Parakou), Ghana (Tamale) and Abuja (Nigeria). A training of Ghanaian, Nigerian and ASECNA technicians funded by AMMA EU took place at Dakar from 30 Nov. 2005 to 02 Dec. 2005. Currently, TT1 strives for sufficiently long METEOSAT windows for TEMP transmission. Until Meteosat 9 is operational in mid-2006, the availability of time windows is limited due to a communication failure on Meteosat 8.

Where needed we recommend a backup communication system through local mobile phone networks or satellite phones during SOP 2006.

Automatic monitoring of transmission of data from stations in the network is being conducted by the ECMWF and can be viewed online at:

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/amma/

These pages also quantify the assimilation of the data into the ECMWF model. For new stations, close attention will be paid, manually, to the communication of data to the GTS, until the station is regarded to be reliably established.

2.1.3 GPS Total Columnar Water Vapour (TCWV) Measurements

A TCWV network can significantly contribute to improve our knowledge of the atmospheric water cycle in the WAM and to document its variability from the mesoscale to interannual scale. TCWV provides a column-integrated observation of water vapour with a high temporal frequency (15 min – 1 h), which is not the case with the radiosounding network. Such a high frequency can provide useful information on the diurnal cycle. The 3D-Var or 4D-Var assimilation of these water columns, associated with other observation types (the satellite water channels of MSG and others), can provide a much finer analysis of the space-time water vapour field in the WAM. Assimilation of GPS data is planned for the future re-analysis that will be conducted after the field experiment.

Presently 5 permanent GPS stations (IGS network) exist in the domain of interest for AMMA: 25°W-15°E by 5°S-20°N. . At the EOP scale, the objective is to implement 3 stations along a north-south axis (Djougou, Niamey, Gao) to document the seasonal excursion of the WAM as well as shorter fluctuations associated to monsoon surges, heat low dynamics and Inter-Tropical Front (ITF) meridional migrations, and to monitor meridional gradients of integrated moisture associated with the different steps of the WAM and especially the abrupt shift of the monsoon onset. At the SOP scale, the monitoring of the water vapour along a second meridional transect (Tamale, Ouagadougou, Tombouctou) west of the EOP transect will allow to monitor the non-zonal part of the monsoon flow at a much higher temporal resolution and to enhance the assimilation process through a more dense and regular observational network, which contributes to the process studies.

Olivier Bock (bock@aero.jussieu.fr) from the Service d'Aéronomie du CNRS is coordinating the TCWV measurement campaign.

Six GPS TCWV stations are then planned:

- EOP: Djougou (Bénin), Niamey (Niger), and Gao (Mali) within or near the three mesoscale sites. These stations have been installed in summer 2005.
- SOP: Tombouctou (Mali), Ouagadougou (Burkina), and Tamale (Ghana) to enhance the temporal resolution (15 min. – 1 hourly) of RS-based TCWV values. These stations will be installed at the beginning of 2006.

One difficulty in the operation of these GPS stations is with the transfer of raw GPS data from the stations to the analysis centre in Paris. This transfer represents an amount of 500 Kb per day per station. The TCWV atmospheric product is only obtained after these raw data are processed. A two-week delay is required for obtaining precise (climate-quality) products (this delay is related to the availability of precise satellite orbits). Such a processing is planned for the EOP data. A near-real time processing is considered for the SOP. This depends mainly on the telecommunication capability that can be made available by the time of the SOP. Presently, two Inmarsat phones are in operation in Benin and Mali. The communications are very irregular and would not permit near-real time operations. Local cellular phone network solutions are under study for the SOP. If near-real time data transmission will be possible is not yet determined.

2.1.4 UHF/VHF profiler measurements

The expected five UHF/VHF wind profilers define an observational network with a high time and vertical resolution from which the 3D synoptic circulation of the WAM can be retrieved, especially when it is co-located with radio soundings and GPS TCWV measurements. It provides continuous high-frequency time and scale measurements of the atmospheric boundary layer and its interaction with the African easterly waves and the AEJ, the intra-diurnal to seasonal fluctuations of the ITF, the evolution of the low-level nocturnal jet, the fluctuations due to gravity waves with periods from hour up to several days in the energy budget and momentum transport. It allows also to measure flux of energy in lower stratosphere, stratospheric-tropospheric exchanges and studies of the deep and precipitant convection.

Bernard Campistron (camb@aero.obs-mip.fr) for the Laboratoire d'Aérologie of CNRS is coordinating the UHF/VHF measurement campaign. Presently the status for the array is the following one:

- It is planned to implement at Djougou a VHF profiler for an 18-month period beginning in February-March 2006 to participate to the SOP and partly the EOP. This instrument will provide vertical profiles of wind speed and direction, vertical velocity, radar reflectivity, turbulence data, virtual temperature if acoustic sources for RASS are implemented and water vapour mixing ratio (tentative, to be validated). These measurements will be associated with those done at the same location with the radiosoundings, the GPS TCWV, and the XPORT (EOP) and RONSARD radars (SOP). The combination with an UHF profiler on the same site should be possible at least for the SOP but this is still uncertain at the present time due to technical and funding issues.

- A UHF instrument, belonging to ASECNA, is presently doing measurements at the Bamako airport. The objective is to organize the data collection since presently they are stored locally for the last four months only. ASECNA has also planned to implement a similar instrument at Ouagadougou in September 2005. Another one might be implemented at N'Djamena. This instrument is not specifically "AMMA instrument" as it has not be funded by AMMA and its implementation has not been discussed in AMMA. So it is not fully integrated in the observation strategy of TT1 but its data will be very fruitful for some of the AMMA objectives

The US ARM programme is currently looking at having a 1290 MHz UHF profiler at Niamey sometime in May/June 2006. This has not been secured yet.

2.2 List of sites, instruments and relevant maps

The list of instruments whose main attachment is TT1 is given in Table 1a below, while Table 1b lists the instruments attached to another TT but whose deployment is closely related to the TT1 strategy.

Table 1a: TT1 List of instruments (P1: priority 1; P2: priority 2).

#	Code	PI Name	E-Mail Address	Instrument	Platform
EF1	AE.GPS_1	M.-N. Bouin, O. Bock	bock@aero.jussieu.fr; bouin@ensg.ign.fr	3 GPS stations in Djougou, Niamey and Gao	1st Meridional Transect
EE1	AE.RS_1	Andreas Fink	fink@meteo.uni-koeln.de	8 P1 RS stations (Conakry, Abidjan, Cotonou, Douala, Tamale, Parakou, Abuja, Niamey) and 1 P2 (Bangui)	Monsoon Array

Table 1a (followed): TT1 List of instruments (P1: priority 1; P2: priority 2).

EE2	AE.RS_2	Serge Janicot	serge.janicot@lodyc.jussieu.fr	6 P1 RS stations (Sal, Dakar, Bamako, Niamey, N'Djamena, Khartoum) and 1 P2 (Ouagadougou)	Sahelian Array
EE3	AE.RS_3	Doug Parker	doug@env.leeds.ac.uk	4 P1 RS stations in Agadez, Tombouctou, Tessalit and Tamanrasset	Northern Array
EF5x	AE.VHF_O	Bernard Campistron	camb@aero.obs-mip.fr	1 CNRM VHF radar in Djougou	Ouémé Méso site
EA1x	AE.VHF_BO	Bernard Campistron	camb@aero.obs-mip.fr	2 Asecna UHF radars in Bamako and Ouaga	Sahelian Array

Table 1b: List of instruments closely related to TT1.

#	Code	PI Name	E-Mail Address	Instrument	Platform	TT
SF1	AS.GPS_1	M.-N. Bouin, O. Bock	bock@aero.jussieu.fr ; bouin@ensg.ign.fr	3 GPS stations in Tamale, Ouagadougou and Tombouctou	2nd Meridional Transect	8
SE1	AS.RS_1	Andreas Fink	fink@meteo.uni-koeln.de	5 P1 RS stations (Cotonou, Parakou, Niamey, Tamale, Abuja)	SOP Southern Quadrilateral	8
SE2	AS.RS_2	Doug Parker	doug@env.leeds.ac.uk	4 P1_EOP RS stations (Parakou, Agadez, Tombouctou, Niamey), 2 P1_SOP (Tahoua, Ouaga) and 2 P2 (Birni, Kano)	SOP Northern Quadrilateral	8
SE3	AS.RS_3	Tbd	Tbd	4 P1 RS stations in Bamako, Sal, Conakry and Dakar + 1 P2 (Nouakchott)	SOP Western Quadrilateral	8
SE5	AS.RS_D	Nobert Kalthoff	norbert.kalthoff@imk.fzk.de	Radiosonde station at Dano by FZK	Dano	8

Table 2: Radiosonde stations in the AMMA region, and their operational priorities for AMMA EOP.

Country	Station Number	Station Name	Latitude	Longitude	AMMA priority
COTE D'IVOIRE	65578	ABIDJAN	05 15N	03 56W	1
NIGER	61024	AGADEZ	16 58N	07 59E	1
MALI	61291	BAMAKO/SENOU	12 32N	07 57W	1
GUINEA	61832	CONAKRY	09 34N	13 37W	1
BENIN	65344	COTONOU	06 21N	02 23E	1
SENEGAL	61641	DAKAR/YOFF	14 44N	17 30W	1
CAMEROON / CAMEROUN	64910	DOUALA R.S.	04 01N	09 42E	1
SUDAN / SOUDAN	62721	KHARTOUM	15 36N	32 33E	1
NIGERIA	65125	ABUJA	09 15N	07 00 E	1
CHAD / TCHAD	64700	NDJAMENA	12 08N	15 02E	1
NIGER	61052	NIAMEY-AERO	13 29N	02 10E	1
BENIN	65330	PARAKOU	09 21N	02 37E	1
CAPE VERDE / CAP-VERT	8594	SAL	16 44N	22 57W	1
GHANA	65418	TAMALE	09 30N	00 51W	1
ALGERIA / ALGERIE	60680	TAMANRASSET	22 48N	05 26E	1
MALI	61202	TESSALIT	20 12N	00 59E	1
MALI	61223	TOMBOUCTOU	16 43N	03 00W	1

Table 2 (followed): Radiosonde stations in the AMMA region, and their operational priorities for AMMA EOP.

ETHIOPIA / ETHIOPIE	63450	ADDIS ABABA-BOL	09 02N	38 45E	2
NIGERIA	65046	KANO	12 03N	08 32 E	2
CENTRAL AFRICAN REP	64650	BANGUI	04 24N	18 31E	2
CAMEROON / CAMEROUN	64870	NGAOUNDERE	07 21N	13 34E	2
MAURITANIE	61415	NOUADHIBOU	20 56N	15 57W	2
MAURITANIE	61442	NOUAKCHOTT	18 06N	17 02W	2
SENEGAL	61687	TAMBACOUNDA	13 46N	13 41W	2
BURKINA FASO	65503	OUAGADOUGOU	12 21N	01 31W	2
CHAD / TCHAD	64750	SARH	09 09N	18 23E	2
COTE D'IVOIRE	65548	MAN	07 23N	07 31W	
BURKINA FASO		DANO	11 10N	03 05W	
		ASECNA Substitute DKR			
		ASECNA TRAINING NIM			

Figure 1 displays the sites and their priorities within the AMMA international programme during the Enhanced Observing Period (EOP).

Figure 2 displays the sites and their priorities within the AMMA international programme during the Special Observing Period (SOP) in 2006.

As already mentioned, it is considered to temporarily move the substitute MODEM ground stations at ASECNA Dakar to Tahoua during at least the SOP 1/2 June-September period.

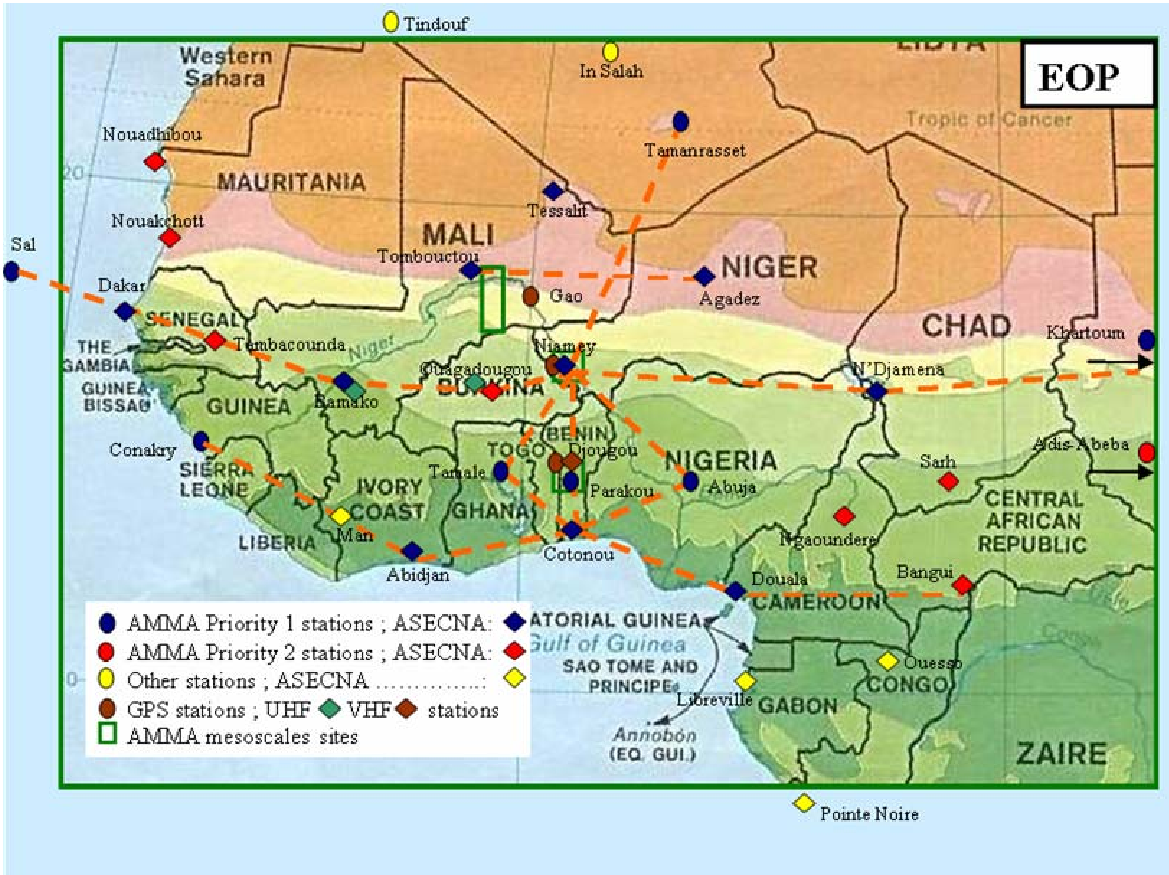

Fig. 1: Locations, priorities, transects (arrays), GPS, UHF/VHF profiler and the mesoscale sites of AMMA international during EOP

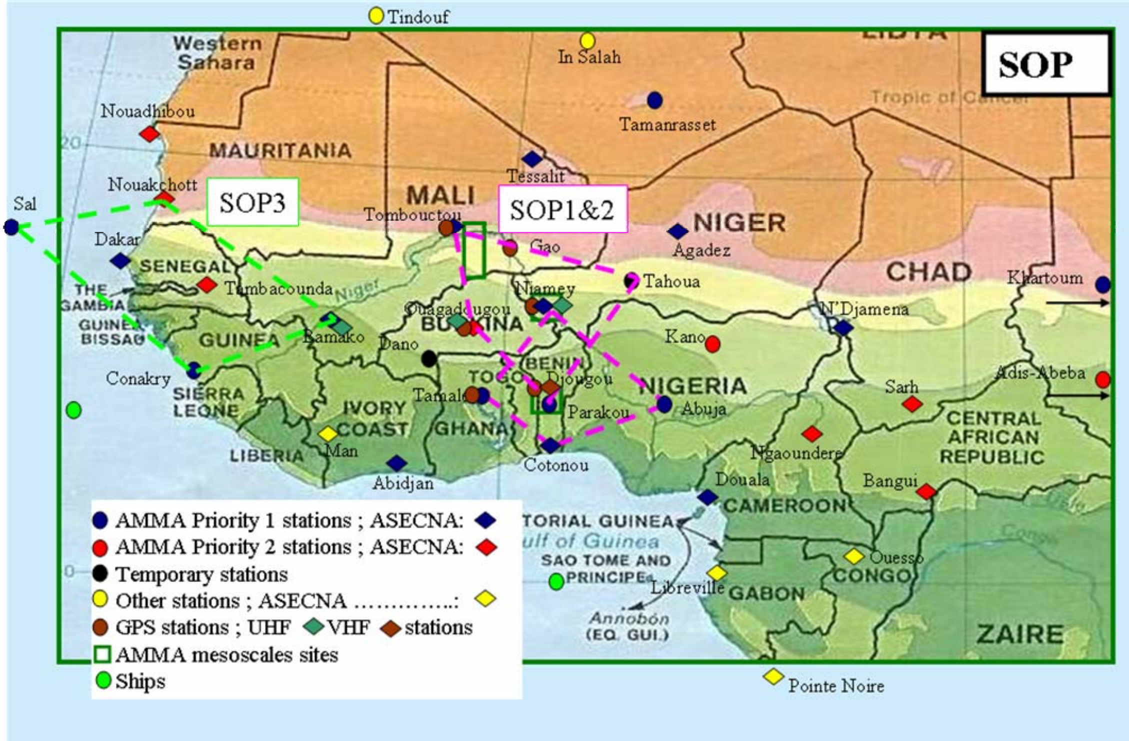

Fig. 2: Locations, priorities, quadrilaterals (flux arrays), GPS, UHF/VHF profiler and the mesoscale sites of AMMA international during SOP 2006

2.3 Priorities (Radiosondes)

Two priorities have been agreed by this TT for the AMMA EOP radiosoundings: priority 1 and 2, where '1' is the highest one. Station priorities are indicated in Fig. 1 and Fig. 2, as well as in Table 2. Seven-teen (17) priority 1 and 9 priority 2 stations have been identified based on scientific justification. A close partnership with ASECNA has been developed (11 out of 17 P1 stations) whose staff will operate the soundings, among which are 11 out of the 17 P1 stations.

No specific priorities have been defined for the SOP. A number of soundings in the SOP will be defined to be 'responsive', that is, deployed in response to the day-to-day requirements of coordination with aircraft and radar.

For the SOP period a GRAW radiosonde system operated by Forschungszentrum Karlsruhe (FZK) as a responsive research sounding stations will be deployed at Dano, Burkina Faso, in conjunction with other ground-based instruments. This system will be deployed with the aim of making downstream observations of systems moving to the west from the intensive mesoscale sites of Niamey and Djougou. Data are transmitted via ftp and the German Weather Service in real-time to the GPS The strategy for the deployment is managed by TT8 and is described in the TT8 document.

Priorities for telecommunication and infrastructure are as follows:

Upgrade priorities (by the end of 2005):

1) Improvement of telecommunication. New Data Collection platforms (DCPs) at Ngaoundere, Parakou, Tamale, and Abuja. Direct links to the GTS at Cotonou, Douala, Nouakchott, Dakar and Ndjamena (by 12/05).
2) Replacement of existing Digicora I stations by refurbished Digicora II stations in the ASECNA network (by 12/05).
3) Upgrade of existing Digicora II stations in the ASECNA network (by 12/05).

4) Replacement of key STAR stations by refurbished Digicora II stations (by 12/05).
5) Operation of 4 new stations (Tamale, Parakou, Cotonou, and Abuja) in early 2006. Cotonou has become operational in June 2005, and is transmitting properly to the GTS since 27 October 2005.
6) Implement training of operators on the VAISALA/MODEM groundstations, on VAISALA (RS92) and MODEM (M2K2) PTU GPS sondes and on DCPs (by 12/05). A MODEM M2K2 training took place in Cotonou in early June 2005 and in Parakou in mid-December 2005.

Finally due to the special scientific requirements of the funded programmes, there is a set of additional constraints on the priorities for the radiosondes. AMMA-EU has defined a priority A and B (with A being higher priority) for its own interests. These priorities take into account both the EOP and SOP needs of AMMA-EU. The differences between the EU priorities A and B, and the international AMMA EOP priorities 1 and 2 are

7) Tessalit is priority A for the EU project. The existence of this station was not apparent at the time of the EOP 1-2 definitions. It is perfectly-placed to sample the monsoon trough and heat low.
8) Ouagadougou is priority A for the EU and priority 2 for EOP. This is because of the station's importance in the SOP, as part of the northern quadrilateral, but its relative unimportance for the EOP, on longer time and space-scales.
9) Abidjan, Conakry, Douala, Khartoum and Sal (priority 1) are lower priority for the EU (priority B). This is because the main focus of activity for the EU project is around the longitudes of Gourma, Niamey and Djougou.
10) AMMA-ACI has placed a special priority on the activation at Cotonou – all of the funds from this French programme will be directed at Cotonou.
11) AMMA-UK has a budget for radiosondes which will be deployed in the northern quadrilateral, to the north of Niamey. The sondes will be deployed during the EOP and SOP, and additional sondes will be specifically deployed in support to the UK Bae146 aircraft operations.

2.4 Other critical issues

There is a clear strategy for the deployment of additional resources should they become available. Our first aim would be to support those EOP Priority 1 stations which are not covered by the existing funded projects (primarily Khartoum and Conakry). However the situation of the two stations is different. AMMA has established links with the met. Service in Guinea, an evaluation of the existing station was made and ASECNA is willing to help in the deployment, should the appropriate funds be available. In Khartoum, links with the Meteorological Service and the evaluation of the station remain to be done.

This Abidjan station has for a long time been a major priority for AMMA. Asecna is in the process of transferring the station to a new location and this has nothing to do with the refurbishing of the old gas station. What we wanted to do is refurbish this old gas station just for AMMA. Asecna is going to start building the new station before the end of the year and might not want to spend money in the old gas station. What is sure is that the new station will not be ready for AMMA.

The radiosonde station of Kano (Nigeria) equipped with a Digicora I has been tested successfully using RS80 GPS sondes. It is considered to activate this station with 00 and 12 UTC soundings for the SOP1 period from 01 June to 15 September 2006.

The Algerian Meteorological Service OMN has confirmed that Tamanrasset can do two additional soundings at 06 and 18 UTC during SOP 1 and 2 provided that the additional helium, balloons and sondes costs are supplied. A cooperation contract is negociated between CNRS and ONM Algeria.

3 Deployment

3.1 Planning

The planning of the deployment of infrastructure is detailed and updated in a station-by-station fashion in the ARGIS document available under http://www.meteo.uni-koeln.de/amma and reproduced here in the Annex. Similarly, the planning of the consumables deployment during EOP/SOP is available from the EXCEL spreadsheet “Consumable_planning.xls” that can be downloaded under the same URL (given here in Table 2).

3.2 Logistical considerations

The consumables and infrastructure for the ASECNA RS stations within the AMMA network will be purchased, installed and launched by ASECNA. Therefore, shipping, handling and customs clearing will be dealt with through ASECNA. Consumables for Ghana and Nigeria will be ordered by ASECNA and shipped by the manufacturer to Accra and Lagos, respectively. Universities of Cologne and Leeds will manage the infrastructure installation and training at the new stations Tamale (Ghana) and Abuja (Nigeria) in close cooperation with the national meteorological services The Ghanaian and Nigerian meteorological services have agreed to assist in customs clearing and transportation.

4 Partnership

Training for stations on the ASECNA network will be conducted through the existing ASECNA facilities at EAMAC (Niamey). The radiosonde manufacturers will travel to Africa to convey the new techniques to the training schools (for engineers and for operators).

MODEM has already performed two trainings at the new Cotonou station at and in Parakou.

There are two important stations that are outside the ASECNA network, in anglophone countries (Tamale and Abuja). After discussions with the operating agencies in these countries, it was agreed that training and installation will be conducted in each country by a Vaisala technician in January 2006.

Within the framework of the US ARM programme, a training on the operations of a Vaisala Digicora III groundstation is conducted at Niamey in early January 2006.

5 Organisation of TT1

5.1 Leaders, core group, membership

The group currently consists of the following members:

- **Andreas Fink (U. Koeln)**
- **Anton Beljaars (ECMWF)**
- **Arona Diedhiou (LTHE-IRD, Niamey)**
- Boubacar Madina Diallo (DMN Guinea)

- Cherif Diop (DMN Senegal)
- **Chris Thorncroft (U. Albany, SUNY)**
- **Doug Parker (U. Leeds)**
- **Francis Dide (DMN, Benin)**
- Frank Roux (Laboratoire d'Aerologie, Toulouse)
- Ismail Fudl El Moula Mohamed (Meteorological Authority, Khartoum)
- **Jean Blaise Ngamini (ASECNA Dakar)**
- Jean-Luc Redelsperger (CNRM, CNRS, Toulouse)
- Mahaman Saloum (DMN, Niger)
- Karim Traoré (DMN, Niger)
- Infeanyi Nnodu (NIMET, Nigeria)
- Mama Konate (DMN, Mali)
- Michael Douglas (National Severe Storms Laboratory/NOAA)
- Mohamed Kadi (DMN, Algeria)
- Olivier Bock (IPSL, France)
- **Serge Janicot (LOCEAN Paris)**
- **Thierry Lebel (LTHE-IRD, Grenoble, Niamey)**
- Lamin Mai Touray (Dept of Water Resources, the Gambia)
- Zinede Minia (Meteorological Department, Ghana)

The group is presently co-chaired by Andreas Fink and Serge Janicot.

Core group members are listed in bold. We have aimed to include representatives of relevant scientific communities, and from the major national and pan-national groups.

Each of the major funding agencies has its own management committee who are also represented in this TT.

5.2 Internal coordination

The internal communication is mainly performed via e-mail exchange and teleconferences among the core group

5.3 External diffusion of the information and reporting

Various reports have been produced and are available under the “Leeds” and “Cologne” web pages. The reporting to the AMMA ISSC is guaranteed by the ISSC membership of Andreas Fink .

Monitoring of the performance of stations in the network, and in the assimilation of data, is being conducted by ECMWF and can be viewed online at:

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/amma/

The RS consumable deployment planning is closely coordinated with the SOP TT leaders (e.g. Jim Haywood and Jacques Pelon for TT7 and Doug Parker and Cyrille Flamant for TT8.

ANNEX 1 : Radio Sounding Frequency at the various stations

Table A1: Anticipated soundings on the EOP and SOP network. Yellow indicates stations operating one sounding per day (usually 1200 UTC), green indicates 2 soundings per day, and the numbers denote the additional soundings needed, above the normal operational levels, to achieve these frequencies. The red cells indicate stations that will do four-times daily soundings during SOP. The additional soundings needed are indicated (last update: Dec. 2005)

Additional AMMA consumables (EOP + SOP)

StationName	Type	2005/1	2005/2	2005/3	2005/4	2006/1	2006/2	2006/3	2006/4	2007/1	2007/2	2007/3	2007/4
ABIDJAN	V	0	0	0	0	0	0	0	0	0	0	0	0
ADDIS ABABA-BOLE		0	0	0	0	0	0	0	0	0	0	0	0
AGADEZ	V	0		61	92	90	151	246	31	0	0	0	0
BAMAKO/SENOU	V	0	0	0	0	0	0	0	0	0	0	0	0
BANGUI	M	0	0	0	0	0	0	0	0	0	0	0	0
CONAKRY	V						30	92					
COTONOU	M	0	22	92	92	181	262	358	123	90	91	92	31
DAKAR/YOFF	V	0	0	0	0	20	0	0	0	0	0	0	0
DANO	G						50	50					
DOUALA R.S.	V	0	0	0	0	0	0	0	0	0	0	0	0
KHARTOUM		0	0	0	0	0	0	0	0	0	0	0	0
MAN													
ABUJA	V	0	0	0	0	121	262	358	123	90	91	92	31
KANO	V	0	0	0	0		60	154		0	0	0	0
NDJAMENA	V	0	0	0	0	91	91	92	31	0	0	0	0
NGAOUNDERE	V	0	0	0	0	0	0	0	0	0	0	0	0
NIAMEY-AERO	V	0	0	0	0	0	182	184	0	0	0	0	0
TAHOUA	M						60	154					
NOUADHIBOU	V	0	0	0	0	0	0	0	0	0	0	0	0
NOUAKCHOTT	V	0	0	0	0	0	0	0	0	0	0	0	0
OUAGADOUGOU	M	0	0	0	0	31	151	246	31	0	0	0	0
PARAKOU	M	0	0	0	31	121	262	358	123	90	91	92	31
SAL		0	0	0	0	0	0	0	0	0	0	0	0
SARH		0	0	0	0	0	0	0	0	0	0	0	0
TAMALE	V	0	0	0	0	121	262	358	123	90	91	92	31
TAMANRASSET	V	0	0	0	0	0	60	154	0	0	0	0	0
TAMBACOUNDA	M	0	0	0	0	0	0	0	0	0	0	0	0
TESSALIT	V	0	0	0	0	0	60	154	0	0	0	0	0
TOMBOUCTOU	V	0	0	0	0	90	151	246	31	0	0	0	0
DDT DKR	V+M	0	0	0	0	0	0	0	0	0	0	0	0
EAMAC NIM	V+M	0	0	0	0	0	0	0	0	0	0	0	0
ASECNA responsive							100	100					
non-ASECNA responsive							30	30					

ANNEX 2: AMMA Radiosonde Task Group: Implementation Strategy, as for 19/12/2005

Immediate priorities:

1) Upgrade of Communications/IT-Equipment on key stations in existing network (by 09/05).
2) Installation of new stations at Cotonou, Parakou, Abuja and Tamale (by 05/05-12/05). Cotonou is active since 05/2005.

Upgrade priorities (by the end of 2005):

3) Replacement of existing Digicora I stations by refurbished Digicora II stations (except Dakar that will be equipped with a new Digicora III MW21) in the ASECNA network (by 12/05).
4) Upgrade of existing Digicora II stations in the ASECNA network (by 12/05).
5) Replacement of key STAR stations by refurbished Digicora II stations (by 12/05).
6) Implement training of operators on the VAISALA/MODEM groundstations, on VAISALA (RS92) and MODEM (M2K2) PTU GPS sondes and on DCPs (by 12/05)

Status of existing stations

Each station name is followed by its code (when it exists), the country, the operator, the AMMA priority (1 or 2), the EU priority (A or B)

Digicora MW11 (I) stations

Addis Ababa (GCOS station), Ethiopia, ASECNA, P2, B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora	None (priority 2)	
Communications/IT-Equipment	??	None	
Gas generation	??	None	
Building	??	None	

Agadez (61024), Niger, ASECNA, P1, A

	Status, July 2005	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora MW11 (1994) with MF12	Upgrade to RS92 (Refurbished Digicora II)	12/05, 27 kE, ASECNA AMMA-EU
Communications/IT-Equipment	VSAT	Cable/Radiolink to VSAT building;	12/05, 4 kE, ASECNA/ AMMA-EU
Gas generation	GIP 3, two old ones	None for twice-daily soundings	
Building	OK, but old (1974)	none	
Power Supply	Less reliable	Power Generator or UPS	ASECNA AMMA-EU

Dakar (61641 GCOS station), Sénégal, ASECNA, P1, A

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora I MW11 (1989) and STAR	New Digicora III MW21	09/05, 52 kE, ASECNA AMMA-EU
Communications/IT-Equipment/	No automatic transmission to CAT,	Automatic transmit to CAT via radiolink	12/05, 4 kE, ASECNA
Gas generation	GIP 3 (Electrolyser unserviceable)	New Electrolyser	US GCOS programme
Building	OK	None	

Douala (64910 GCOS station), Cameroon, ASECNA, P1, B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora MW11 (1986)	Upgrade to RS92, Digicora II	12/05, 13 kE, ASECNA, GCOS support
Communications/IT-Equipment	No automatic transmission to CAT,	Automatic transmit to CAT via radiolink	5 kE, ASECNA
Gas generation	GIP 3	None	
Building	OK	None	

Niamey (61052 GCOS station), Niger, ASECNA, P1, A

	Status, September 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora MW11 (1994) and STAR (with MF12)	Upgrade to RS92, Digicora II	09/05, 27 kE, ASECNA AMMA-EU
Communications/IT-Equipment	No direct connection to CAT	Cable/Radiolink to VSAT building	09/05, 4 kE, ASECNA, AMMA-EU
Gas generation	GIP 3	None	
Building	OK	None	
Power Supply	OK	None	

Khartoum (62721), Sudan, Meteorological Authority, Sudan, P2, B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora	None	
Communications	Unserviceable	None	
Gas generation	??	None	
Building	??	None	

Sarh (65548), Niger, ASECNA, P2,B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora I		
Communications			
Gas generation			
Building			

Tamanrasset, (60680 GCOS station), Algeria, DMN Algeria, P1, A

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora I	None	
Communications/IT-Equipment	??	None	
Gas generation	??	None	
Building	??	None	

Tessalit, (61202), Mali, ASECNA, Abandoned due to logistic problems

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora I	Upgrade to RS92, Digicora II)	12/05, 27 kE, ASECNA AMMA-EU
Communications/IT-Equipment		None	09/05, 7,5 kE, ASECNA AMMA-EU
Gas generation		Two new GIP 3	12/05 12 kE, , ASECNA AMMA-EU
Building	To be determined		

Tombouctou (61223) Mali, ASECNA, P1, A

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora MW11 (1994)	Upgrade to RS92, Digicora II)	12/05, 27 kE, ASECNA AMMA-EU
Communications/IT-Equipment	VSAT	Cable/Radiolink to VSAT building;	12/05, 4 kE, ASECNA/ AMMA-EU
Gas generation	GIP 3	None	
Building	OK	None	

Digicora MW15 (II) stations

Abidjan (65578 GCOS station), Cote d'Ivoire, ASECNA, P1, B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora II	Upgrade to RS92	Asap, NOAA/GCOS
Communications/IT-Equipment	No direct connection to CAT	Install	12/05, 4 kE, ASECNA, AMMA-EU
Gas generation	Electrolyser destroyed by June 2001 accident	GIP 3 needed	12/05 12 kE, ASECNA AMMA-EU
Building	Under construction	Complete construction	ASECNA

Man (65548)Cote d'Ivoire, ASECNA, Status of the station unclear

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora I		
Communications			
Gas generation			
Building			

N'Djamena (64700) Chad, ASECNA, P1/A

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora MW15 (1999)	Upgrade to RS92	12/05, 10 kE, ASECNA AMMA-EU
Communications/IT-Equipment	No automatic transmission to CAT,	Automatic transmit to CAT via radiolink	12/05, 4 kE, ASECNA
Gas generation	GIP 3	None	
Building	OK	None	

Ngaoundere, Cameroon, ASECNA, P2/B

	Status, May 2004	**Proposed actions**	**Date, cost, source**
Groundstation	Digicora II	Upgrade to RS92	12/05, 10 kE, ASECNA
Communications/IT		DCP currently shipped	
Gas generation	GIP 3	None	
Building	OK	None	

Nouakchott (61442), Mauritania, ASECNA, P2, B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	Digicora MW15 (1999)	Upgrade to RS92	12/05, 10.0 kE, ASECNA AMMA EU
Communications/IT-Equipment	No automatic transmission to CAT,	Automatic transmit to CAT via radiolink	12/05, 5 kE, ASECNA
Gas generation	GIP 3	None	
Building	OK	None	

Star stations

Bamako (61291), Mali, ASECNA, P1/A

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	STAR (1994), PC (DOS 6.22)	Replace by a refurbished DIGICORA II	12/05, 27 kE, ASECNA AMMA-EU
Communications/IT-Equipment	No direct connection to CAT	Install	09/05, 5 kE, ASECNA
Gas generation	GIP 3	None	
Building	OK	None	

Bangui (64650), Central African Republic, ASECNA, P2/B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	STAR	Install new groundstation	12/05, 35-60 kE, ASECNA
Communications/IT-Equipment	Automatic transmission to CAT	None	
Gas generation	GIP 3	None	
Building	OK	None	

Nouadhibou (61415) Mauritania, ASECNA, P2, B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	STAR (1994),	Install new groundstation	12/05, 35-60 kE, ASECNA
Communications/IT-Equipment			
Gas generation			
Building			

Ouagadougou (65503) Burkina Faso, ASECNA, P2, B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	STAR	Replace by refurbished DIGICORA II	12/05, 27 kE, AMMA EU
Communications/IT-Equipment	Automatic transmission to CAT	None	
Gas generation	GIP 3	None	
Building	OK	None	

Tambacounda (687) Senegal, ASECNA, P2, B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	STAR	Install new groundstation	12/05, 35-60 kE, ASECNA
Communications/IT-Equipment	???	None	
Gas generation	GIP 3	None	
Building	OK	None	

Others

Sal (08594 GCOS station), Cape Verde, Cape Verde Meteorological Service, P1, B

	Status, May 2004	Proposed actions	Date, cost, source
Groundstation	ATIR US INC (radiotheodolite)	None	
Communications/IT-Equipment	??	None	
Gas generation	??	None	
Building	??	None	

Status of new stations

Abuja (65125), Nigeria, NIMET, P1, A

	Status, December 2005	Proposed actions	Date, cost, source
Groundstation	None	New DIGICORA III MW 21 is in Cotonou	
Communications/IT-Equipment	To be reviewed	DCP is in Lagos	
Gas generation	None	Two new GIP 3 presently in Cotonou	
Building	None	To be finished in early January 2006	NIMET
Power Supply	To be reviewed	To be reviewed	

Cotonou (65344), Benin, ASECNA, P1, A

	Status, December 2005	Proposed actions	Date, cost, source
Groundstation	MODEM SR2K2	None	
Communications/IT-Equipment	Manual transmission working	Automatic transmission to CAT via radiolink	09/05, 4 kE, ASECNA
Gas generation	GIP 3	None	
Building	OK, amendments completed	None	
Power Supply	OK, no outages	None	

Parakou (65330), Benin, DMN Bénin/ASECNA, P1, A

	Status, December 2005	Proposed actions	Date, cost, source
Groundstation	None	MODEM SR2K2 on site	
Communications	None	DCP available	
Gas generation	Gip 3	None	
Building	OK	None	
Power Supply	Reliable, outages infrequent	Supply of an UPS	09/05, AMMA-EU DMN Benin

Tamale (65418), Ghana, Met. Service, Ghana, P1, A

	Status, January 2006	Proposed actions	Date, cost, source
Groundstation	None	DIGICORA III MW 21 currently shipped from Cotonou to Accra	
Communications	VSAT	DCP is in Accra	
Gas generation	None	Two GIP-3 in Accra	
Building	Completed in January 2006		GMA/AMMA-EU
Power Supply	OK	UPS provided by AMMA EU	

Conakry (61832), Guinea, DMN, P1, B

	Status, December 2005	Proposed actions	Date, cost, source
Groundstation	Digicora MW11 (1993)	Upgrade	
Communications/IT-Equipment	VSAT, no automatic link to VSAT building	None	
Gas generation	Electrolytic gas generator, US manufacturer (1994) Type MZ8 / AK029T	Replace some wear parts	
Building	OK	None	
Power Supply	Poor, also problems with water supply	Site survey to be conducted by an ASECNA technician	

Status of ASECNA training sites

Dakar, Senegal, ASECNA, Training/Spare station

	Status, October 2004	Proposed actions	Date, cost, source
Groundstation	Digicora I and Star	Refurbished Digicora II	27 kE, AMMA EU NIMET

Niamey, Niger, ASECNA, Training

	Status, October 2004	Proposed actions	Date, cost, source
Groundstation	Digicora I and Star	Refurbished Digicora II	09/05,ACI/CNRS (France)

15 January 2005

Chapter 3
EOP Surface Flux Measurements
TT2a

Colin Lloyd, Chris Taylor

1 Scientific justification and objectives

An important component of the AMMA project is the monitoring of surface conditions continuously over the course of the Extended Observation Period (EOP). Over West Africa, the seasonal evolution of the atmosphere is accompanied by pronounced changes in surface properties, driven by rainfall. These properties (notably soil moisture and leaf area) control fluxes of heat and moisture into the atmosphere and thus affect characteristics of the coupled system. We have at this time little knowledge of the evolution of these properties and associated fluxes during the annual cycle, and from one year to the next. Furthermore, their poor representation in large scale models affects the overall simulation of the monsoon system. Where we do have observations, these are for a limited period over a relatively small area (e.g. HAPEX-Sahel).

Flux observations are not representative of the areal average fluxes even at the mesoscale, due to strong heterogeneity in factors such as vegetation cover, soil characteristics, and rainfall. At the larger scale, these detailed observations by themselves provide little insight into processes occurring elsewhere on the vegetation gradient between the natural closed canopy forest in southern West Africa and the desert in the north of the region. The primary aim of the EOP surface flux monitoring in AMMA is therefore to make continuous observations from a selection of typical land covers under a broad range of climatic conditions over a minimum of 2 years. The ensemble of instruments (a network of flux stations augmented by other micrometeorological instrumentation e.g. radiation, soil physics) will provide a coherent set of observations with which to understand how the land surface typically evolves at representative points on the gradient. Crucially, the flux stations will provide ground truth to link with earth observation data, and to constrain surface models. This will feed into the land data assimilation scheme, the measurements playing a critical role in attempts to quantify the daily to interannual variability of the land surface at scales from the meso- to the monsoon scale. In addition, the systems will provide flux observations to support field/catchment scale studies.

The provision of surface fluxes, surface meteorological measurements and soil physics measurements during the EOP/SOP is required in various of the Work Packages listed in Table 1.

The location and operation of the flux systems provides, not only the time-series of regional point measurements of sensible and latent heat and carbon dioxide fluxes for the above work packages, but also the relevant long-term data to vegetation, soil moisture, energy balance and aerosol experiments at each of the supersites. There are therefore very strong links between TT2a and TT2b, TT3, TT4 and TT5.

Table 1. Stated measurement requirements by the Work Packages

WP	Rainfall	Soil Moisture	Evaporation	Sensible Heat	CO2	Radiation	Met Data
1.1	√		√	√			
1.2	√	√	√			√	√
1.3	√	√	√	√		√	√
2.1	√		√	√			
2.3	√	√	√	√	√	√	√
2.4	√				√	√	√
3.1	√	√	√		√		√
3.3	√	√					√
3.4	√	√	√				√
4.1	√	√	√	√		√	√
4.3	√	√	√			√	√
4.4	√	√	√	√	√	√	√
5.1			√			√	√
6.1	√	√	√	√	√	√	√

2 Observing strategy

2.1 Overall Strategy

The primary aim above can be met by addressing the different energy balances of the typical vegetation surfaces in the region and so the deployment of the flux stations has attempted within the overall budget constraints to encompass these differences. Of overall concern is the efficient collection of continuous data during the EOP – an effort that would be compromised by attempting a transect approach to the measurements.

The network of new equipment, expressly commissioned for the AMMA project, is enhanced through other surface flux measurement systems, currently operating within other projects but linked to AMMA. These include wide-aperture scintillometer instruments and modified Bowen Ratio systems.

The scientific need informed the design of a multi-site network of simple and robust heat flux stations capable of running with minimum maintenance throughout the EOP. This network comprises four super sites, encompassing the north-south rainfall gradient and the typical vegetation covers found within a super site. The sites are based around existing measurements and experimental infrastructure. The sites are in the Hombori-Gao region of N. Mali (5-300 mm annual rainfall), the Niamey region of Niger (550 mm), the Upper Ouémé catchment in Benin (1200 mm), and another (at present undefined) site in southern Benin (around 1400 mm, during 2 wet seasons within the year).

The success of funding bids to both NERC (UK) and the EU has provided the flexibility to convert several of the heat flux stations to full eddy correlation systems measuring water and carbon fluxes. These conversions are necessary over certain surfaces where the heterogeneity of the vegetation and soil surfaces severely limits the ability of simple heat flux stations in combination with energy balance considerations to provide believable estimates of evaporation. Even the interpretation of sensible heat flux measurements is complicated by the heterogeneity of these surfaces and an independent measure of evaporation allows better quality control of the data. Additional full eddy correlation systems have been funded from other sources (the French API-AMMA and the UK funded CLASSIC programmes).

2.2 Modelling and satellite observations

The surface flux observations will provide an important source of ground truth for land surface modelling and satellite efforts in AMMA. They will provide:

- the means to develop and calibrate land surface schemes at the point scale
- a characterisation of 'typical' land surface functioning across the vegetation gradient for comparison with surface scheme behaviour in NWP and climate models
- observations which can be compared with both remotely-sensed data and land surface schemes forced by remotely-sensed data

In the cases of (2) and (3), the spatial scales do not correspond, the flux observations being sub-grid and sub-pixel scale. On any particular day, direct comparisons might be poor, due for example to spatial variability of rainfall. However, in many cases the behaviour of the surface at the larger scale should resemble that which is observed locally when averaged over longer periods, or when account is taken of spatial variability in vegetation. Given the lack of available ground truth fluxes across the region for developing satellite and surface modelling schemes, use of the flux data will increase confidence in results from these larger scale tools.

The sites have been chosen to capture a broad range of surface conditions found in the monsoon region. The systems will produce standard forcing variables for land surface schemes (summarised in Table 2) as well as the turbulent fluxes for verification. These will be available at 30 minute resolution for the duration of the EOP. From the modelling prespective, it is crucial to have long time series of forcing data, and the more verification (flux) data that is available, the better. However, given the inherent problems of flux measurements, verification datasets will be shorter than the more routinely observed meteorological data. Additional data will be made available describing site – vegetation coverage, soil type etc.

It has been agreed that Quality Controlled data will be available 6 months after the collection from the field sites. Non quality controlled data can be made available upon request as soon as it has been added to the flux database. Quality control, in the first instance, will consist of isolation of physically unrealistic values. While gap-filling strategies based on protocols developed within the CarboEurope programme are available, these are intrinsically models and should not be used to generate "measurements" for inclusion in databases. Gap-filling is pertinent when individuals or groups are preparing period or annual budgets within reported scientific research.

Within the constraints of time (to database submission) and man-power, it will only be possible to identify physically unrealistic data in the meteorological forcing data. This is known as Level 1 quality control (QC). Within the flux data, Level 1 QC can generally be applied to scalar values (e.g. horizontal windspeed, temperature, gas concentration) and most errors will occur during rainstorms. Level 2 QC will generally apply to the fluxes themselves. With fluxes, even apparently unrealistic data (e.g. energy balance mismatch) at the 30 minute scale may be perfectly acceptable. While there are detailed analysis procedures to identify data which does not conform to the basic tenets of surface flux measurements (e.g. stationarity, advection concerns, stability), there is not the necessary critical mass of expertise within the AMMA community to be able to quality control all the flux data to this level. A measure of the daily or period energy closure, and the identification of flux measurements which fail the stability and windspeed criteria (mostly nighttime conditions) may be the best quality control on the flux data that can be achieved with the manpower and time available.

As the Level 1 QC criteria can be specified as a data range for every averaging period, the QC can be automated and performed locally at the supersites where day-to-day appreciation of the local conditions will be invaluable. Level 2 QC requires experience of flux data and a more general appreciation of longer-term and larger scale micrometeorological processes. An appreciation of the latter will be addressed at a workshop to be convened in Cotonou early in 2006.

The main aim of TT2a is to provide surface flux measurements to the AMMA community. To take advantage of this data, it is necessary to identify individuals, or groups of individuals, who have an interest in using the data to augment their other studies (plant physiology, hydrology, aerosols etc.), or are interested in the comparison of the different land covers at each supersite. The comparison of data across the mesoscale sites in terms of land surface function is an additional key area of work. This analysis will be performed in WP1.3 and WP2.3 and will be coordinated from Wallingford, working in close collaboration with the mesoscale groups.

2.3 List of sites, instruments and relevant maps

The TT2a instrument network consists of 14 flux stations and 2 scintillometer stations grouped at the following regional locations. The instrument systems and the parameters measured are described in the tables following the location descriptions.

2.3.1 Mali-Gourma Mesosite

The northernmost main site is in the region of Hombori-Gao, Mali, where a heat flux station (HFS) will be located at a largely unvegetated desert site at Bamba (50 -100mm annual precipitation, >95% sand soil). In the absence of existing AMMA activity in a completely unvegetated area, this should provide relevant ground truth for desert conditions. The area around Hombori (300 mm annual precipitation) is largely either low-intensity grazed savannah grassland or laterite areas with little vegetation. Isolated areas of open acacia forest are also present. An HFS will be established over an extensive laterite pan (common across the region) while complete CO2/evaporation/Heat flux stations (Mk4) will be installed over both a typical area of grassland and an open forest site. Instrumental details for the HFS and Mk4 flux systems are shown in Table 2a and complete instrumentation information is supplied in ANNEX 1.

2.3.2 Wankama-Banizoumbou Mesosite

A Sahelian region main site will be sited around Wankama, to the east of Niamey, Niger where the annual precipitation is around 600 mm. Here the typical surfaces consist of Millet (the local grain crop), heavily grazed fallow bush , degraded fallow bush and laterite pans, mostly covered with poor to good dense vegetation strips known as Tiger Bush. Methodological difficulties with interpreting Tiger Bush energy fluxes identified during HAPEX-Sahel have not been resolved sufficiently in the intervening period for routine data monitoring practice, and the surface will be excluded from the flux station deployment. Some insight will be gained from consideration of the laterite surface at the northern Mali site. An API funded CO2/H2O flux station (see Table 2a and ANNEX.1 for instrument details) will be installed over an area of fallow bush. Another API funded CO2/H2O system will operate over an area of Millet to characterise the heat, evaporation and carbon dioxide fluxes. An HFS system will operate over degraded fallow bush close to the API system mentioned above. This will provide a useful comparison of the energy flux differences that may occur due to climate change or farming practice. An HFS system will be used on a campaign basis alongside the tower measurements of “erosion” flux (TT2b) in an area of

Millet to provide the micrometeorological parameters that define, and help to explain, the turbulent transport of dust and aerosols.

In addition to the above, a heat and water vapour eddy correlation system will be set up at Niamey airport as part of the ARM Mobile Facility from January to December 2006.

BENIN

2.3.3 Djougou Mesosite

A Soudanian region main site will be sited around Djougou in the Ouémé catchment, northern Benin (1200mm annual precipitation). The vegetation surfaces here are typically open scrub forest and croplands with some isolated areas of forest. The small scale homogeneity of the region croplands presents difficulties in evaluating evaporation from a HFS System owing to the point nature of the radiation and soil heat flux measurements compared to the field scale of the sensible heat fluxes. In response to TT5 requests for complete latent heat and CO2 flux measurements, funds will be sought to augment one HFS with a Licor Li7500 H2O/CO2 instrument. This will be installed (augmented or not) in an area of fallow bush. Another HFS system will be deployed over a more homogeneous crop or open scrub grassland site where energy balance considerations can be adequately applied. A Mk4 System will measure CO2/H2O and Sensible Heat fluxes over a typical forest site where the heterogeneity requires direct flux measurements of water vapour and CO2 (see Table 2a and ANNEX.1 for details).

A micrometeorological & flux station, operated and funded by the Laboratoire d'Aerologie, has been installed near the village of Nangantchori, 10km ESE of Djougou (9° 38.820' N, 1° 44.460' E). It consists of the instrumentation shown in Table 2b and ANNEX.1.

A long path large aperture scintillometer system has been installed between the villages of Nalohou I and Nalohou II over the Ara water basin in the Djougou region by LTHE, Grenoble. This instrument will provide long-path averaging of sensible heat flux, (and evapotranspiration from energy budget considerations) over a distance of 2.4 km (Table 2c and ANNEX.1).

Another flux station is operational at 9° 06'160" N, 1° 56'37.6" E in the HVO catchment near Parakou in the east of Benin. This is a modified Bowen Ratio machine operated within the IMPETUS project and run by the University of Cologne. The instrumentation is summarised in Table 2d and more fully detailed in ANNEX.1

2.3.4 Southern Benin

A more southern site at Ejura in Ghana was to have been established alongside the on-going GLOWA project. This is a site of 1300mm annual precipitation but with markedly different seasonality compared to the Ouémé sites. However, the logistical difficulties of operating multiple flux stations across west Africa that became apparent during the Mali installation, and budgetry considerations, demanded a re-appraisal of the location of the allocated Mk4 system. In consequence, a MK4 system will be installed in a similar climatic zone to the previously proposed site at Ejura. Ideally, this would be over tropical forest in an area close to Cotonou. However, the cost of providing a tower for supporting the flux system above the tall forest is prohibitively expensive. It is expected that a MK4 flux system will be installed over a Palm plantation near Cotonou. The instrumentation will be the same as shown in Table 2a and ANNEX.1.

The flux systems to be installed at the above locations consist of the following instruments and measurement parameters shown in the following tables. (See Table 3 for symbol explanation).

Table 2a. Systems composing the main network of 12 flux stations funded by AMMA-UK, AMMA-EU, AMMA-API, and CLASSIC.

Table 2a Flux stations

System	Sensor	Measurements										
API Flux system	Campbell CSAT3 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+Variances
	Licor 7500 IRGA	CO2c	H2Oc	Fc	LE							
	Kipp & Zonen CNR1 Radiation	Sin	Sout	Lin	Lout	al	Rn					
	Vaisala HMP45	Ta	RH									
	Young Propeller Anemometers	Ws	Wd		At 2.5m and 8m heights							
	Rimco 0.5mm Raingauge	Pg	Pd	Pi								
	TDR Soil Moisture Profile	VWC		Profile of 6 sensors								
	Soil Temperature Profile	Tsoil		Profile of 6 sensors								
HFS	Solent R3-50 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+Variances
	Vaisala WTX510 Weather Station	Ta	RH	Pr	Ws	Wd	Pg	Pd	Pi			
	Kipp & Zonen CNR1 Radiation	Sin	Sout	Lin	Lout	al	Rn					
	Campbell CS616 Soil moisture	VWC		at 10 and 50 cm depths								
	Campbell T107 Soil thermistors	Tsoil		at 10 and 50 cm depths								
	Rimco 0.5mm raingauge						Pg	Pd	Pi			
MK4	=HFS system above + following											
	(Embedded IRGA)	CO2c	H2Oc	Fc	LE							

Table 2b Micrometeorological and flux station operated by the Labo. d'Aérologie in the region of Djougou (Ouémé)

Operator	Sensor	Measurements										
L d'A	Solent R1 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+Variances
	Licor 7500 IRGA	CO2c	H2Oc	Fc	LE							
	Kipp & Zonen CNR1 Radiation	Sin	Sout	Lin	Lout	al	Rn					
	Micromet Station	u	RH		Wd	Ta	Pg	Pd	Pi			
	Soil Temperatures	Tsoil										
	Campbell CS616 soil moisture	VWC										

Table 2c Scintillometers operated by LTHE on the Djougou and Wankama mesosites

Operator	Sensor	Measurements										
LTHE		u	v				H	M	u*	z0	z/L	+Variances

Table 2d The modified Bowen Ratio flux system operated by the Univ. of Cologne within the IMPETUS project

IMPETUS	METEK USA-1 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+Variances
	2 Frankerberger psychrometers	Ta	Twb									
	Kipp & Zonen NR-LITE	Rn										
	2 HFP01 Soil Heat flux plates	G										
	Equitensiometer	SWP										
	Raingauge						Pg	Pd	Pi			

2.3.5 Other Instrumentation

Other flux Instrumentation

During the Special Observation Periods (SOP), various sites will be operating flux systems for short periods in combination with other SOP activities.

ALGERIA

A flux site at Tamanrasset (22° 47’ N, 5° 31' E) is being set up for the SOP period associated with the TRESS system operated by IPSL/SA. During this period, a Campbell Scientific CSAT3 sonic anemometer, together with an IPSL-developed Optical Depth Sensor (ODS) and a CIMEL CE 312 CLIMAT radiometer will be operational. These instruments will augment the TReSS system at the same site observing the radiative and structural properties of clouds and aerosol layers, and ABL dynamics. This instrument package includes CIMEL sun photometers, Nephelometers, and an Heitronics IR radiometer. This SOP instrument primarily associated with TT7 and TT8, has measurements of interest to TT2a which are shown in Table 2e.

Table 2e Flux measurements associated with the TRESS system operated by IPSL/SA in Tamanrasset

Operator	Sensor	Measurements										
IPSL/SA	Campbell CSAT3 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+Variances
	CLIMAT radiometer	Lin										
	Heitronics IR Radiometer	Lin										

BURKINA FASO

In Burkina Faso, Forschungszentrum Karlsruhe (FZK) will be operating two flux systems at sites in Bontioli Park near Dano. One will be a Gill Solent/Lyman-α/Licor-7500 flux system with associated energy balance measurements (PI is Norbert Katthoff), and the other a Campbell CSAT3/Licor-7500 flux system, again with associated energy balance measurements (PI is Harald Kunstmann). These SOP systems and their measurements are more fully detailed in TT8 but measurements of interest to TT2a are shown in Table 2f

Table 2f FZK Flux system measurements at Dano and Bontioli Park sites in Burkina Faso

Operator	Sensor	Measurements										
FZK/Dano_1	Gill Solent R3-50	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+variances
	Lyman-α humidity sensor		H2Oc		LE							+variances
	Kipp & Zonen CM14 radiometer	Sin	Sout									
	Vaisala HMP34 humidity sensor	Ta	RH									
	Licor 7500	CO2c	H2Oc	Fc	LE							+variances
	Schulze net radiometer	Rn										
	3 Heat flux plates	G										
	Meteolabor Dew-Point sensor	Td										
FZK/Dano_2	Campbell CSAT3 Sonic Anemometer	u	v	w	Wd	Ts	H	M	u*	z0	z/L	+variances
	Licor 7500	CO2c	H2Oc	Fc	LE							+variances

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The list of instruments as defined in the introduction of the implementation plan is given in the tables of section 3.

Other Instrumentation

Depending on users needs, it may be necessary and useful to increase the measurements by the addition of PAR (Photosynthetically Active Radiation) sensors, NDVI sensors and Diffuse radiation at some of the locations. InfraRed Thermometers to record surface “skin” temperature may also be useful. The current budget does not include the provision of any of these instruments. However, provision of a limited number of these sensors has been built in to the design, construction and operating software of the HFS and Mk4 systems. The UK CLASSIC programme has funded the provision of four NDVI sensors (SKR1800, Skye Instruments, UK) and two Total/Diffuse solar radiation sensors (BF3, Delta-T Devices, UK). The NDVI sensors will be attached to all the Mali flux stations, while the BF3 sensors will be attached to the Grassland Mk4 system and the Bamba HFS system. The Institute of Geography, University of Copenhagen have supplied five SKR1800 dual channel radiometers which correspond to Meteosat Second Generation (MSG) SEVIRI channels and AVHRR channels. These will be installed at the Bira fallow bush site in Benin (AVHRR configuration) and at the Wankama degraded fallow bush site in Niger (SEVIRI configuration).

Table 3 Nomenclature used in Tables 2a-2e.

Legend	Description
u, Ws,	Horizontal wind velocity in the direction of the mean wind
v	Crosswind velocity
w	Vertical velocity
Wd	Wind direction
Ta, Ts, Td	Air temperature (air, speed of sound derived), Dew-point temperature of the air
H	Sensible heat flux
M	Momentum flux
u*	Friction velocity
z0	Roughness length
z/L	Atmospheric Stability parameter
RH	Relative Humudity
Pr	Atmospheric Pressure
Pg, Pd, Pi	Rainfall amount, duration, intensity
Sin, Sout	Shortwave radiation; incoming, reflected
Lin, Lout	Longwave radiation; incoming, outgoing
al	Albedo – derived quantity
Rn	Net radiation from sensor components
VWC	Volumetric Water Content
SWP	Soil Water Potential
Tsoil	Soil temperatures
CO2c, H2Oc	Surface level CO2 and H2O concentrations
Fc, LE	Fluxes of CO2 and Evaporation
G	Soil Heat Flux

2.4 Priorities

The HFS, Mk4 and API flux systems cited in this document have secured funding from NERC, the EU or French API. Priorities with regard to production of such systems is therefore not necessary.

The additional instrumentation that can be attached to the HFS and Mk4 systems, i.e. Diffuse radiation, PAR, NDVI and IRT do not currently have funding within the EU or NERC funding of AMMA. The CLASSIC programme is providing funding for the inclusion of some of these measurements at one or more of the Mali supersite locations.

In the case of extra but limited funding being found, priorities will need to be decided for the above instrumentation.

With regard to risk, the following areas of concern may apply during the operation of the instrumentation in the EOP. Most of this information is particular to the AMMA-EU and AMMA-NERC equipment but many of the risks are pertinent to the operation of sophisticated instruments in west Africa.

Delay in manufacture of HFS and Mk4 systems will ultimately impinge on the deployment date for the systems.

All equipment has allocated funds for airfreight and experience shows that this is the best option for the shipping of delicate items with low risk of damage and/or non-arrival. Equipment will be shipped allowing sufficient time for airfreight and customs release.

The deployment of the systems has taken note of the current political and social stability of the countries within west Africa. Mali, Benin, Niger and Ghana have all been stable for several years and local knowledge has been sought at every opportunity to minimise this risk.

The production of the HFS and Mk4 systems has taken note of the valuable nature of items in the systems, e.g. batteries, solar panels etc to the local economy and has taken precautions to prevent opportunist loss of these items. The deployment has tried to avoid the placement of systems in remote areas so that adequate local guarding of the valuable equipment can be organised. However, the requirements of the AMMA programme with regard to the latitudinal rainfall gradient has inevitably meant that some stations have been located in the north of Mali and southern Algeria. The use of solar powered battery systems for data measurement and collection has avoided some of the problems associated with reliance on mains-power.

The risk of loss of data during the EOP has been addressed through a thorough design process of the instrumentation and logging equipment with regard to the climate, robustness of the sensors, the current general inexperience of the proposed operators and the length of the EOP. Thorough training of operators, provision of a complete spare HFS system and regular maintenance field visits by flux system experts during the EOP will help this situation but this risk cannot be eradicated and some loss of data should be expected from one or more of these continuously running systems during the EOP. The long-term unattended running of multiple eddy correlation flux systems in remote and harsh conditions has not been attempted before anywhere. With visits to field sites often being of the order of every 6 weeks, there is the very real possibility of up to 6 week gaps in the flux data. More frequent field visits will be effected during the periods around each SOP.

In the Djougou area, there are frequent power cuts which will affect all systems running on mains power. The system at Nangantchori is running on mains power with backup APS on line. To further minimise data loss during long power cuts or through thunderstorm damage, a technician will drive from Djougou to site to assess the situation and restart the system. It is expected that data loss will be of the order of a few minutes/hours per day during these events.

3 Deployment

3.1 Instruments and related detailed observation program

3.1.1 Priorities

The HFS, Mk4 and API flux systems cited in this document have secured funding from NERC, the EU or French API. Priorities with regard to production of such systems is therefore not necessary.

The additional instrumentation that can be attached to the HFS and Mk4 systems, i.e. Diffuse radiation, PAR, NDVI and IRT do not currently have funding within the EU or NERC funding of AMMA. The CLASSIC programme is providing funding for the inclusion of some of these measurements at one or more of the Mali supersite locations.

In the case of extra but limited funding being found, priorities will need to be decided for the above instrumentation.

With regard to risk, the following areas of concern may apply during the operation of the instrumentation in the EOP. Most of this information is particular to the AMMA-EU and AMMA-NERC equipment but many of the risks are pertinent to the operation of sophisticated instruments in west Africa.

All equipment has allocated funds for airfreight and experience shows that this is the best option for the shipping of delicate items with low risk of damage and/or non-arrival. Equipment will be shipped allowing sufficient time for airfreight and customs release.

The deployment of the systems has taken note of the current political and social stability of the countries within west Africa. Mali, Benin, Niger and Ghana have all been stable for several years and local knowledge has been sought at every opportunity to minimise this risk.

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3.1.2 Deployment

Planning

Lead times for manufacture and supply of sensors, together with the necessary time to construct and test the equipment, has meant that hardware for 3 Mk4 systems and 2 HFS systems have already been ordered and delivered (1 Feb 2005) from within the AMMA-NERC budget which came on-stream at the beginning of October 2004. This allowed some systems to be installed in Mali in April. OSIL received their funds from AMMA-EU on the 1st June 2005. Construction of the four HFS systems by OSIL commenced at that time. To maintain compatibility within the training, data collection and subsequent analysis, CEH have liased directly with OSIL in the design and production of the AMMA-EU funded flux systems being produced by OSIL. The four systems were completed at the beginning of October 2005.

3.2 Logistical considerations

Installation and maintenance field visits to the flux station locations has to correspond with the presence of local field staff who can organise the transport and accomodation arrangements. It is imperative that the local knowledge of staff is used at all times with regard to local political activity and changing governmental bureauacracy and political situation. West African states have different policies with regard to visas, airfreight and customs control. Sufficient time needs to be allocated for the release of airfreighted equipment from customs control at the airport. The remote site at Bamba, Mali can only be serviced at 6 week periods in contrast to the remaining sites which will be serviced at 3 weekly periods - although operational considerations with regard to the Hombori site may require 6-week visits as well. This has necessitated some change to the data collection hardware and the controlling software. The longer time between servicing has attendant risks for the vulnerability of the equipment and loss of data, but modelled gap filling of lost data is easier at this site than more vegetated sites.

Three of the AMMA-NERC flux systems and the CLASSIC-funded flux system were installed during 9-25 April. Two HFS systems were installed at the Bamba desert site and at a laterite site. The CLASSIC funded Mk4 system was installed at the grassland site and the AMMA-NERC Mk4 over a sparse forest site. The install period also included time for training of local IRD personnel and for field testing of the systems. No local African researcher has yet been found to service the Hombori sites - efforts are continuing. In the meantime, IRD staff and occasionally visiting CEH staff are servicing the systems.

Locations for flux systems at the Wankama, Niger and Djougou, Benin supersites were identified in early May 2005. Subsequently, the two API funded flux systems were installed at the Wankama, Niger field site in June 2005.

The IMPETUS flux system has been operational for some time.

The next install was dependent upon the timing of the completion of manufacture and testing of the systems currently on order. The install timing was also dependent upon the availability of both CEH and OSIL staff to install the systems and local staff to provide both logistical support and to be available for system training. For the HFS systems being constructed under the EU funding programme, 20-24 weeks were required for construction and testing. OSIL did not receive funds from AMMA until the 1st June 2005 This set a likely date for delivery of the HFS systems for field testing as the beginning of October 2005 at the earliest. The systems were delivered on time. As the systems, both in design and structure, are completely new, it would have been beneficial if a period of field testing prior to shipment to their final locations had been done. However, the time required to clear customs in Niger and Benin (3 weeks) and the planned installation in early November 2005, precluded this action and the flux systems were airfreighted to Benin in the second week of October with the other flux systems airfreighted to Niger during the 3rd week of October. The remaining two Mk4 systems constructed under NERC funding were available for installation in June 2005. But other fieldwork operations by CEH staff and budgetry constraints precluded these installations before the major Benin installation in November 2005. It was also decided at the Biarritz meeting in September 2005 that the planned Mk4 installation at Ejura in Ghana would now be redeployed over a suitable site in southern Benin.

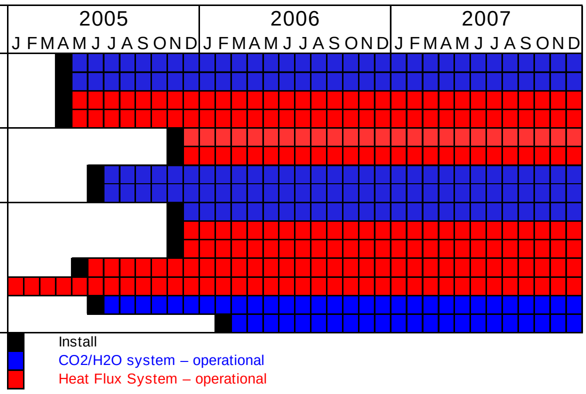
The two AMMA-EU HFS systems and one AMMA-UK Mk4 Hydra system were installed in the Djougou area of Benin between 7-12 November. The remaining two AMMA-EU HFS systems were installed at the Wankama/Banizoumbou sites during 14-17 November. It is currently planned that the last AMMA-UK Mk4 Hydra system will be installed at the southern Benin site in February 2006.

The installation timing and operational periods for the flux systems are shown in table 4 below.

Table 4 The installation timings and operational period for the flux systems.

Location	Location Site	Operator	System	Surface
Mali	AE.H2OFlux_G	CEH/CESBIO	Mk4(C)	Grassland
	AE.H2OFlux_G	CEH/CESBIO	Mk4(N1)	Forest
	AE.SHFlux_G	CEH/CESBIO	HFS(N1)	Laterite
	AE.SHFlux_G	CEH/CESBIO	HFS(N2)	Desert
Niger	AE.SHFlux_Nc	CEH/IRD	HFS(E1)	Degraded Fallow Bush
	AE.SHFlux_Nc	CEH/IRD	HFS(E2)	Millet/Aerosol
	AE.H2OFlux_Ncw	IRD	CSAT3/7500 (API-1)	Fallow Bush
	AE.H2OFlux_Ncw	IRD	CSAT3/7500 (API-2)	Millet
Benin	AE.H2OFlux_Odc	CEH/IRD	Mk4(N2)	Forest
	AE.SHFlux_Odc	CEH/IRD	HFS(E3)	Cropland
	AE.SHFlux_Odc	CEH/IRD	HFS(E4)+7500	Fallow Bush
	AE.Scintil_Od	LTHE	Scintillometer	Mixed Surface
	AE.SHFlux_Od	U.Cologne	Bowen Ratio	Scrub Forest
	AE.H2OFlux_Od	Lab.d'Aerologie	Solent/7500	Composite scrub forest
	AE.H2OFlux_Ve	CEH/IRD	Mk4(N3)	Palm Plantation

N – AMMA-UK
E – AMMA-EU
C- CLASSIC
API – French Funds



The general operation and maintenance of the flux systems and the collection of data will be the responsibility of the locally trained operators under the supervision of the supersite captains or designated AMMA personnel. Regular inspection and maintenance field visits will be conducted by CEH and OSIL staff. The timing of these trips must be flexible in order to respond to instrumental non-operation and the technical capability and knowledge of the local operating staff in dealing with the problem, and with the priority placed upon that system at any particular time of year. A general series of field visits by OSIL and CEH staff prior to the SOPs will help to ensure correct operation during these important periods.

Vehicles

The staff of CEH and OSIL are entirely dependent upon the provision of vehicles by AMMA organisations resident in Mali, Niger, Benin and Ghana. It is necessary therefore to organise installation and maintenance visits to coincide with the field operations of the local staff wherever possible. Installation at each supersite will require carriage of approximately 2000 kg of equipment from the airfreight airport to the general area of deployment. This can generally be done before the installation staff arrive. Subsequent deployment of each system will require use of one 4 x 4 vehicle of LandCruiser size. Each installation trip will therefore need the use of one 4 x 4 vehicle and driver for the duration of the installation trip i.e. of the order of 2 weeks. Subsequent maintenance visits (requiring one 4 x 4 vehicle + driver) will generally be of the order of 1 week.

After installation, the regular 3 week (6 week at Bamba) visit to each flux station to inspect and download the data will require transportation to be arranged locally. The close proximity of the flux stations at each supersite means that all flux stations could be visited in a single day.

Human Resources

The installation of the flux stations will require a minimum of 2 people (for safety reasons) to build each station. Each station will be built consecutively. It would be more efficient if 3 people were involved in the assembly of each flux station.

Regular inspection and downloading of the data from each station can be undertaken by 1 person. That same person will be responsible for the upload of data to supplied computer and subsequent copying of data to CD-ROM for posting to designated people within the AMMA community for quality control and databasing.

Infrastructure

The flux station installation and maintenance personnel will have to liase with and rely upon local staff for provision of invitation documents for visas, collection of airfreight from airport customs authorities, provision of vehicles and accomodation. The flux systems are solar panel battery powered and therefore mains power is not essential. Installation can be done without any specific office facilities but occasional use of a bench or part of an office for the use of laptops and inspection of sensors may be necessary.

Four mains-powered Dell PC's have been purchased for the downloading of data and transfer to CD-ROM. These four PC's will require permanent bench space in an office at each of the supersites in Mali, Niger, Benin and Ghana for the whole of the EOP. There is no operational reason for these PC's to be linked into the local computer network

3.3 List of instruments

Table 5 TT2a List of Instruments

#	Code	PI Names	E-Mail Address	Instrument	Platform
EB1/EF7	AE.H2OFlux_G	F.Timouk C.Lloyd	franck.timouk@ird.fr crl@ceh.ac.uk	2 MK4 systems in Hombori (grassland and open forest sites)	Hombori Super Site
EB2	AE.SHFlux_G	F. Timouk, C.Lloyd	franck.timouk@ird.fr crl@ceh.ac.uk	2 HFS systems in Bamba (very dry) and Hombori (extensive laterite pan)	Gourma Meso Site
EB3/EF9	AE.H2OFlux_Odc	S.Galle C.Lloyd	galle@ird.fr crl@ceh.ac.uk	1 Mk4 system over forest at Belefoungou	Ouémé - Donga Super Site
EB4	AE.H2OFlux_BS	S.Galle C.Lloyd	galle@ird.fr crl@ceh.ac.uk	1 Mk4 system over Palm plantation in southern Benin	Benin
LE2/LF9	AL.SHFlux_Odc	S.Galle S.Holland	galle@ird.fr Stuart.Holland@osil.co.uk	2 HFS (OSIL) systems at Bari (Fallow bush) and Nalohou (Crop)	Ouémé - Donga Super Site
LE1/LF8	AE.SHFlux_Nc	B.Cappelaere S.Holland	Bernard.cappelaere @msem.univ-montp2.fr Stuart.Holland@osil.co.uk	2 HFS (OSIL) systems at Wankama (Degraded fallow) and Banizoumbou (Millet)	Niamey Central super site
EF8	AE.H2OFlux_Ncw	N.Boulain B.Cappelaere	Bernard.cappelaere @msem.univ-montp2.fr	2 CSAT3/Li7500 H2O/CO2 flux systems over Fallow bush and Millet at Wankama	Niamey Central super site
		Andreas Fink	af@meteo.uni-koeln.de	METEK USA1 Heat flux system	Parakou
EF10	AE.Scintil_Od	Jean-Martial Cohard	Jean-Martial.Cohard@ hmg.inpg.fr	Sensible Heat Flux Scintillometer	Donga Super Site
SF14	AS.TRESS_Tam (TRESS)	C.Flamant	cyfl@aero.jussieu.fr	TReSS multi-sensor active/passive remote sensing of radiative and aerosol layers	Tamanrasset, Algeria
EF33	AE_VAN_Od	D.Serça	Serd@aero.obs-mip.fr	Gas/combustion particle analysers+energy flux+NO2 profile	Ouémé - Donga Super Site
EF34	AE_Nox_G	D.Serça	Serd@aero.obs-mip.fr	Chamber measurements of soil NO and CO2	Gourma Meso Site

Table 6 List of instruments related to TT2a

#	Code	PI Name	E-Mail Address	Instrument	Platform	TT
SE04	AS.H2OFlux_D	Norbert	Norbert.kalthoff@imk.fzk.de	Solent/Lyman-α/Licor7500	Bontioli Park	TT8

		Kalthoff		system*		
SU1	AS.smet_S	Anthony Slingo	as@mail.nerc-essc.ac.uk	ARM Mobile Facility	Banizoumbou	ARM

* A CSAT3/Licor7500 system was reported to be run by Harald Kunstmann on the same site; no further info.

Table 7. Location, system designation and surface type for the TT2a flux systems

Country	Site Name	Latitude	Longitude	System	Vegetation
Mali	Bamba	17°05.907' N	1°24.073' W	HFS (NERC)	Desert
	Hedgerit	15°30.171' N	1°23.460' W	HFS (NERC)	None – Gravelly Red Soil
	Agoufou	15°20.595' N	1°28.841' W	Mk4 (CLASSIC)	Grassland
	Kelema	15°13.422' N	1°33.972' W	Mk4 (NERC)	Open Forest
Niger	Wankama	13°38.853' N	2°38.022' E	CSAT3 / Li7500	Fallow Bush
	"	13°38.628' N	2°37.805' E	CSAT3 / Li7500	Millet
	"	13°38.779' N	2°38.581' E	HFS(EU)	Degraded Fallow Bush
	Banizoumbou - Koma Koukou	13°31.294' N	2°37.737' E	HFS (EU)	Spare/ Aerosol/dust Campaign fluxes Millet
Benin	Bari, Djougou	9°49.397' N	1°43.067' N	HFS (EU)	Fallow Bush
	Nalohou, Djougou	9°44.456' N	1°36.335' E	HFS (EU)	Mixed Crops
	Belifoungou,	9°47.279' N	1°43.158' E	Mk4 (NERC)	Forest
	Nangantchori	9°38.820' N	1°44.460' E	Solent/Li7500	Secondary forest/woody Savanna
	Djougou Area			Wide Aperture Scintillometer	Composite
	Parakou	9°06'160" N	1°56'37.6" E	Modified Bowen	Open Forest
s. Benin	??	?° ??'N	?° ??'E	Mk4 (NERC)	Plantation

4 Partnership

4.1 Field observations

It is imperative, in any long-term measurement programme, to have dedicated staff to service the equipment and to collect the data. Each of the Super sites have very experienced staff who have worked in the region for many years. They have built up good relationships with the local people and have experience of the sophisticated equipment comprising the flux systems.

WP 4.2.3 indicated that the "training of African scientists and technicians is a very important component of the activity of European teams involved in LOP-EOP" This is still the required aim; to employ and train local African researchers to operate and maintain the equipment, download and analyse the data and either write scientific papers or contribute to the writing of those papers. However, it has proved difficult to identify suitable local staff to maintain the novel and instrumentally sophisticated HFS, Mk4 and similar flux systems and currently there is no general solution within budget. The priority for CEH and Ocean Scientific International Ltd (OSIL) has been to build and deploy these systems before the first SOP which has left little time to organise structured and comprehensive training before the systems were installed. More effort needs to be applied to find suitable African technicians and to train them sufficiently to be able to routinely run the flux systems

A local technician employed by the Institut d'Economie Rurale (IER) at the Bamba (Mali) site has been recruited. The remoteness of this site and the unavoidable short training programme given to him during the installation of the flux system has meant that currently data is sporadic from this site. The other sites in Mali are being operated by staff of IRD from Bamako (16 hours travel from Hombori) which is expensive and deflects IRD staff from their normal duties.

The situation in Niger and Benin, where field sites are no more than 1 hour from the main supersite centre, will be easier to organise and maintain. The Site Captains at Niamey and Djougou have identified competent researchers to undertake the maintenance and data collection from the flux systems. In Niamey, this is Manon Rabanit (IRD) and at Djougou Simon Alloganvinon (University of Cotonou).

At the Mali Supersite around Hombori, Dr Eric Mougin (Supersite Captain) and the staff of CESBIO will be conducting intensive vegetation surveys throughout the EOP and will provide the staff to service the flux systems at Hombori on a 3 week cycle. Currently, this is being performed by Ing. Franck Timouk (CESBIO, IRD) but it is highly desirable to find an African researcher to take on this responsibility. The northern site at Bamba is being serviced by M. Lamine Touré, chef d'antenne de conservation de la nature de Bamba. This site, due to its remote location, will only be serviced every 6 weeks. A strong linkage to IRD is important for transport and other logistics.

At the Banizoumbou, Niger supersite, Dr Luc Descroix (supersite Captain), Dr Bernard Cappalaere, Dr Jean-Louis Rijot have project interest in the flux data. Mme Manon Rabanit and will be involved with the collection and use of the flux field data.

At the Djougou, Benin supersite, Drs Sylvie Galle and Christophe Peugeot (supersite Captains) will be requested to assume overall responsibility for the supervision of the maintenance of the flux systems and the collection of the data.

4.2 Training programme

Training is an important component of the AMMA programme and OSIL UK and CEH Wallingford will provide suitable training in understanding the design, technical specification and field operation of the flux systems. Of equal importance when operating flux systems is an appreciation of the micrometeorology of the local region around the flux system. A short and concise training package will be created that provides field operatives with the background knowledge to appreciate the operation of the flux systems and the micrometeorology of the flux station site. Training will be given locally on the operation of the measurement systems but funding is being sought to allow a Workshop to be convened in west Africa that will provide a much wider appreciation of the measurement techniques, operation and use of the resultant data. Close collaboration with ST4 on this latter topic will help in identifying suitable candidates, training locations, possible funding and the workshop organisational aspects.

A workshop is being planned for the spring of 2006 in Cotonou, Benin to acquaint AMMA field scientists involved in the collection and analysis of flux data with pertinent aspects of micrometeorological theory and practice that will provide them with further information for the correct appreciation of the strengths and weaknesses of the eddy correlation method in the interpretation of the flux data.

5 Organisation of the TT.

5.1 Leaders, core group, membership

Drs Colin Lloyd and Chris Taylor will jointly lead the TT to provide an amalgam of observation and modelling (Colin Lloyd will spend some length of time in the field).

Surname	First name	email address	Function
TT Leaders			
Lloyd	Colin	crl@ceh.ac.uk	Surface Fluxes
Taylor	Chris	cmt@ceh.ac.uk	Land-Atmosphere Interactions
Core Group Members			
Boone	Aaron	aaron.boone@cnrm.meteo.fr	ALMIP modelling intercomparison
Cappelaere	Bernard	Bernard.Cappelaere@msem.univ-montp2.fr	TT4 Niger & surface interactions
Diedhiou	Arona	diedhiou@ird.ne	AMMA-AFRICA: Meteo-France
Ottlé	Catherine	catherine.ottle@cetp.ipsl.fr	Land surface modelling; Satellite
Serça	Dominique	serd@aero.obs-mip.fr	Benin Flux and Chemistry measurements
Timouk	Franck	Franck.timouk@cesbio.cnes.fr	TT3 Mali Flux measurements & Satel.
Other members			
Beljaars	Anton	Anton.beljaars@ecmwf.int	Numerical Weather Prediction
Boulain	Nicolas	Nicolas.Boulain@msem.univ-montp2.fr	TT4 Niger: API flux measurements
Cohard	Jean-Martial	jean-martial.cohard@hmg.inpg.fr	TT5 Benin Scintillometry
Descroix	Luc	descroix@ird.ne	TT4 Supersite Captain
Fink	Andreas	af@meteo.uni-koeln.de	Benin (Parakou) Flux measurements
Galle	Sylvie	galle@ird.fr	TT5 Benin Supersite Captain
Hanan	Niall	niall@nrel.colostate.edu	Afriflux
Laurent	Jean-Paul	jean-paul.laurent@hmg.inpg.fr	
Marticorena	Béatrice	marticorena@lisa.univ-paris12.fr	TT2b EOP/LOP Aerosols
Morse	Andy	A.P.Morse@liverpool.ac.uk	Disease Vector Modelling
Mougin	Eric	eric.mougin@cesbio.cnes.fr	TT3 Mali Supersite Captain
Norgaard	Anette	an@geogr.ku.dk	Senegal: remote sensing
Parker	Doug	doug@env.leeds.ac.uk	AMMA-UK Leader
Peugeot	Christophe	cpeugeot@ird.fr	TT5 Benin Supersite Captain
Rabanit	Manon	rabanit@ird.ne	Niger Flux measurements
Rajot	Jean-Louis	rajot@ird.ne	Niger: Dust deposition, Aerosols
Sandholt	Inge	is@geogr.ku.dk	Senegal: remote sensing
Slingo	Tony	as@mail.nerc-essc.ac.uk	ARM Facility, Niger
Kounouhéwa	Basile		African Representative, Benin

5.2 Internal coordination

Diffusion of information will be made by email using the member list above. A web-based mailing list has been set up using the UK academic ISP Jiscmail. This mailing list and its archives is visible to the whole AMMA community and items can be posted to the list by registered members. The mailing list can be found at: http://www.jiscmail.ac.uk/lists/AMMA-SURFACE-FLUXES.html

This mailing list has, as one of its functions, to provide for the rest of the AMMA community, up to date information on such items as instrumental deployment, travel plans, site visit reports, data reports, data availability and problems.

5.3 Request handling for new instruments

There is no money in either the AMMA-EU or AMMA-UK budgets to purchase new instruments. Instruments that will be of use at some sites include a PAR (Photosynthetically Active Radiation) sensor, an NDVI (Vegetation Index) sensor, a soil heat flux plate and an Infrared thermometer to measure soil surface "skin" temperature. The ability to plug these instruments in to the Flux Systems is provided. Funds will then need to be sought to purchase these sensors. Any other requested instruments to run concurrently with the Flux Systems will need separate power, logging and data collection facilities which would require negotiation with Site Captains with regard to the training and extra workload placed on researchers currently engaged in servicing the Flux systems.

5.4 External diffusion of the information and reporting

External diffusion of information will be subject to the dissemination rules decided within AMMA. News items and contact information in the first instance will be provided via the AMMA International Implementation Web Page. The TT will report to the appropriate organisational and funding bodies, i.e. ICIG, AMMA-EU and the relevant national programmes.

6 Coordination with other TTs.

Coordination with the other task teams will initially be through diffusion of information via email and the mailing list site described above. In particular, the following strong linkages will be maintained.

TT2b	Coordination with boundary layer radiation measurements
TT3	Coordination with the intensive vegetation, soil moisture and soil respiration studies. Coordinate to provide efficient and cost-effective logistical arrangements
TT4	Coordination with the catchment and sub-catchment hydrological studies. Coordinate to provide efficient and cost-effective logistical arrangements
TT5	Coordination with the ongoing hydrological and vegetation studies. Coordinate to provide efficient and cost-effective logistical arrangements
TT7	Coordination and comparison with the larger scale radiation, sensible and latent heat fluxes.
TT8	Coordination and comparison with the mesoscale modelling aspects of the surface flux regime. Coordination with the experimental aspects of this TT.

15 September 2005, edited 17 January 2006

Chapter 4
EOP/LOP Aerosols Monitoring and radiation
TT2b

Béatrice Marticorena, Francesco Cairo

1 Scientific justification and objectives

1.1 Context

West Africa is the world's largest source of biomass burning aerosols and mineral dust. Satellite sensors consistently indicate that these aerosol plumes are the most widespread, persistent and dense found on Earth. The effect of dust and carbonaceous aerosols on climate change is one of the largest uncertainties in the Earth radiative budget (IPCC, 2001). They directly impact visible and infrared radiation and the microphysics of clouds, and have the potential to be exported over great distances by prevailing winds and atmospheric waves. Mineral dust exported from western Africa over the subtropical Atlantic Ocean also represents a significant nutrient input (mainly ferrous species) for remote marine ecosystems. The seasonal cycle of dust and smoke is directly linked to meteorological processes in the monsoon.

For example, a clear correlation was established between drought occurrences and increase in desert dust load in the atmosphere not only in the Sahel (N'Tchayi et al. 1994) but also far downwind from African sources in the transport zone of Caribbean islands (Prospero and Lamb, 2003). These two simultaneous increases (dust haze in the Sahel, concentration of long range transported dust) have been interpreted as being due to an increase of the local dust emissions in the Sahel during the drought periods. This increase is attributed to the appearance of additional Sahelian sources in regions where lowest rainfall has led to an observed decrease of the vegetation cover rate (Tucker et al., 1991). The contribution of the Sahelian belt to the mineral dust emission from North Africa has been further questioned based on numerical simulations of the mineral dust cycle performed with a global transport model. Tegen and Fung (1995) show that a correct simulation of dust concentrations over the Northern Tropical Atlantic Ocean and of the seasonal pattern of the Saharan plume requires the inclusion of Sahelian sources with a contribution of 30-50 % of the global dust emissions. These Sahelian emissions were attributed to regions affected by climatic changes and/or anthropogenic disturbance. From these results, some authors concluded that the Sahel was the major source of mineral dust in North Africa (Nicholson, 2000).

Similarly, the atmospheric content of biomass burning aerosol is expected to be connected to El Niño events. Indeed during years of regional drought, such as those in southern Africa associated with El Niño events, the area burned decreases by about half (Justice *et al.*, 1996). It is believed that this is caused principally by a decrease in fuel availability. Since gas and aerosol emissions from biomass directly depend on the burned areas, the relationships between the atmospheric content of carbonaceous aerosols atmospheric content and climatic indicators of the intensity of El Niño events are investigated (Liousse et al, forthcoming).

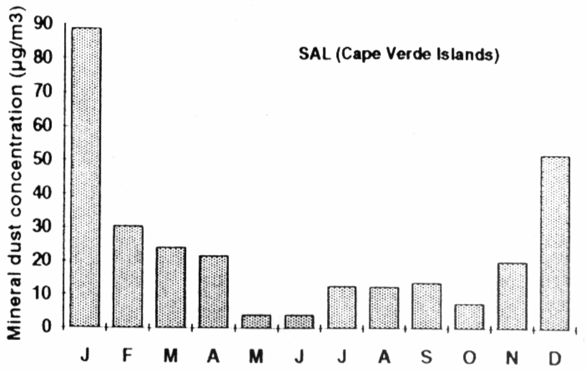
Because the aerosol emissions and transport are controlled by climatic parameters (directly or indirectly through vegetation variations), a long term monitoring of the aerosol atmospheric content at the regional scale is required to elucidate these complex relationships.

In recent decades, remote sensing has offered the opportunity to document on a large spatial and temporal scale the aerosol load over Western Africa. However the retrieval of the aerosol content over land surfaces is much more complex than over ocean so that, to date, the available information is only semi-quantitative (Aerosol Index TOMS; Infrared Different Dust Index). New sensors, such as MODIS, are starting being used to fill this important gap (Remer et al., 2005; Levy et al., 2005). In this respect, ground based monitoring is absolutely essential to (1) document properly the annual and interannual variability of the atmospheric aerosols content over the African continent for improved understanding of the controlling processes and (2) quantify their optical properties in order to better constrain their radiative impact. Such monitoring was initiated in western Africa in the 90's through two networks in particular: PHOTONS/AERONET and IDAF.

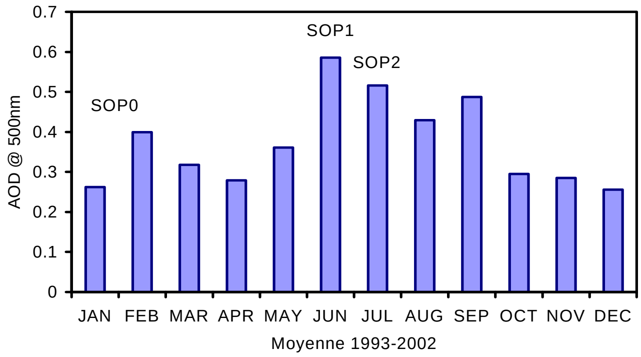
PHOTONS (http://www-loa.univ-lille1.fr/photons/) is a part of the international sunphotometer Aerosol Robotic Network (AERONET), which was developed to provide aerosol information from ground-based measurements all over the world. It provides globally distributed near-real time observations of the aerosol spectral optical thickness and sky radiance as well as derived parameters such as particle size distributions, single-scattering albedo and complex refractive index. The AERONET data have been widely used to establish climatology of aerosol properties (Holben et al., 2001; Dubovik et al., 2000) for the validation of satellite aerosol retrievals and regional-to-global simulations of the aerosol atmospheric content. To date, more than 10 years of worldwide distributed data from the AERONET network of ground-based radiometers are available. They are suited to reliably and continuously derive the detailed aerosol optical properties in key locations. From 1994, 14 stations have been installed in western Africa, with different period and duration of observations. Ten stations are operational today. PHOTONS/AERONET is a French National Observatory for Environmental Research dedicated to aerosol observation supported by the French national agencies for Space Studies (Centre National d'Etudes Spatiales, CNES) and for Earth and Universe studies (Institut National des Sciences de l'Univers, INSU).

The IDAF (IGAC/DEBITS/Africa) network is the African component of the international program DEBITS (International Global Atmospheric Chemistry / Deposition of Important Biogeochemically Trace Species) devoted to the monitoring of the gas and aerosol concentrations in the atmosphere and in wet and dry atmospheric deposition. It was created in 1994 and is, like PHOTONS, a French National Observatory for Environmental Research (ORE). The 5 IDAF ORES stations are located in the 3 main African ecosystems: dry savannah, wet savannah and equatorial forest. The main objectives of the IDAF network are to analyse the evolution trends of the chemical composition of aerosol, precipitations and gas as a function of the main seasonal emission sources. The data are used to identify the physical and chemical processes controlling the wet and dry deposition processes and, finally, to improve the parameterisation of these processes in atmospheric models.

In addition to these pre-existing networks, a "Sahelian Dust Transect" will be equipped in order to document specifically the mineral dust content and its transport toward the North Atlantic Ocean. One of the characteristics of the mineral dust originating from the Sahara and Sahelian regions is that it can be transported at different altitudes. Typically, during summer, mineral dust from the Sahara is transported across the North Atlantic Ocean above the MBL within the Saharan Air Layer (SAL). This is supported by various lidar measurements offshore western Africa (Karyampoudi et al., 1999; Immler and Schrems, 2003) as well as in split-window satellite retrievals of GOES data (Dunion and Velden, 2004), and it becomes evident when looking at the combination of surface concentration and the column-integrated aerosol optical depth of mineral dust measured over the Cap Verde Islands (figure 1). Recently, intensive field campaigns including aircraft measurements (CLAIRE-LBA, PRIDE, AEROSE) showed that long range transport of Saharan dust can also take place within the surface layer (Formenti et al., 2001; Reid et al., 2002; Nalli et al., 2005). The altitude of the dust transport layer, and in particular the position of the dust layers relative to clouds can significantly change the dust radiative impact. Different altitude transport patterns will also induce different deposition patterns and thus impact significantly the regional dust budget. To take into account this variability, three stations have been selected along the main dust transport pathway, for which the surface concentration, the vertically integrated dust amount, the vertical distribution and the wet and dry deposition will be monitored during the EOP period.



Dust surface concentration (*Chiapello , 1995*)



Averaged aerosol optical depth 1993-2002 *(data from the AERONET network)*

Fig 1.1. Monthly averaged mineral dust surface concentration and monthly averaged aerosol optical thickness measured at Sal (Cap-Verde Islands).

1.2 Scientific questions related to AMMA-EU WP

1.2.1 Main related Working Packages.

The main objective of these ground-based stations is to provide observations that will be used to investigate the variability of the regional distribution of aerosol over western Africa, at various time scales, from a few days to a decade. This network of monitoring sites provides additional constraints for the assessment of long range aerosol transport, moisture modification, and radiative impact. Thus, it is of particular importance for the **WP 2.4 “Aerosol and Chemical processes in the Atmosphere”**. The questions raised from this integrative WP that will benefit from the data obtained in this TT are listed below :

WP 2.4.1 Aerosol radiative properties

- What is the regional and vertical distribution of the aerosols over WA, and what is its dependence on
- the seasonal cycle of the monsoon?
- How do the physical-chemical properties of mineral dust depend on source region (Sahara/Sahel)?

- How does the aerosol vertical layering control its radiative impact?

WP 2.4.2 Gas and particle phase chemistry

- How much secondary organic aerosol is produced from anthropogenic and biogenic species in the
- WAM region?
- What is the potential for new particle production in the free troposphere from biogenic and
- anthropogenic gas-phase precursors?

WP 2.4.3 Surface processes

- What is the magnitude of surface emissions of aerosols and trace gases from WA and how do these
- emissions vary at the seasonal and interannual timescales in relation with the variability of the
- monsoon system?
- What are the respective contributions of the climatic and anthropogenic factors in the variability of the
- aerosol (mineral dust and biomass burning aerosols) and trace gas emissions?
- What are the regulating factors of the wet and dry deposition of aerosols?
- Is the Sahelian belt a net source of mineral dust or a deposition area for Saharan dust?

WP 2.4.3 Effect of convection on regional chemical and aerosol budgets

- What is the role of convective physical processes, vertical transport, mixing, and deposition on the
- budget of major oxidants and aerosols in the free troposphere over West Africa?
- \- How do deep convective processes influence the distributions of chemical constituents in the TTL
- compared to other transport processes?
- What is the role of photochemical reactivity and heterogeneous chemistry on air masses transported
- over West Africa from large-scale convective outflow?

1.2.2 Other related WP.

The assessment of aerosol properties and their regional distribution is required to achieve the objectives of several other WP concerned by the impacts of aerosol, and, in particular, the impact of the aerosol radiative effect on dynamic processes at various spatial and time scales. The main questions of the different WP in terms of aerosol impact are listed below:

- determination of the impact of the WAM emissions on global oxidant and aerosol budgets, the
- oxidizing capacity and global radiative forcing **(WP 1.1.2)**
- assessment of the variations in sensible heat flux forced by both atmospheric composition (aerosol
- content) and soil moisture **(WP 1.3.2)**

- quantification of the effect of the radiative forcing due to aerosol and humidity patterns in the clear air; understanding of the interaction between convective and radiative processes interacting with the dynamics of weather systems developing along the the Sahel **(WP 2.1);** and assessment of the role of the Saharan air layer in AEW dynamics over land and in the development and intensity change of tropical cyclones **(WP 2.1.1).**

1.2.3 TT2b-related Objectives from the PIAF.

As listed below, some of the projects from the PIAF could also benefit from the measurements and theoretical studies developed in this TT. It must be noted that some of the responsible of these project are already involved in the experimental deployment of the TT2b stations.

Table 1.1. List of the PIAF projects related to TT2b

Name	Affiliation / country	Research area	Project proposal
AKPO Aristide	Bénin	Aérosols, convection, Physique de l'Atmosphère	Impacts des aérosols désertiques sur la Mousson Africaine
SILVA Ana Maria	Portugal	Atmospheric Physics	The Health effects of aerosols at Cabo Verde
JEANNE Isabelle	CERMES	Conception analyses SIG Télédétection Terrain	Méningites et climat. Paludisme et climat : CLIMPAL-Niger
KOUADIO Georges	Côte d'Ivoire	Dynamique de l'Atmosphère,Mesure des flux et paramétrisation	Quantification et modélisation des émissions d'oxydes d'azote par les agrosystèmes fertilisés et impact sur la chimie de l'air en Afrique de l'Ouest
N'GORAN Yao	Côte d'Ivoire	Rayonnement, Gisement	Etude et exploitation du gisement solaire Ouest Africain à partir de l'imagerie satellitaire(GISOA-SAT)
YOBOUE Véronique	Côte d'Ivoire	Bilan de l'azote	Etude de la pollution atmosphérique dans les capitales africaines en Afrique de l'Ouest et chimie des précipitations en zone de savane humide
SEYDOU SANDA Ibrah	Niger	Aérosols-convection, Variabilité atmosphérique	Aérosols et convection
Zibo Garba	Niger	Aérosols, Ensablement, Paléoclimatique, SIG Télédétection	Mise en place d'un observatoire "proximal" en bordure du Sahara pour la surveillance et l'analyse des processus éoliens et de leurs impacts (Nguigmi, Mainé-Soroa et Gouré au Niger Oriental, Bassin du Lac Tchad)
CAMARA Moctar	Sénégal	Physique de l'Atmosphère	Perturbations atmosphériques en Afrique de l'Ouest et activité cyclonique sur l'Atlantique
GAYE Amadou Thierno	Sénégal	Aérosols-Pollution	Aérosols-chimie-processus radiatifs-pollution

2 Observing strategy

2.1 Main instrumentation

2.1.1 Observation period

Both the AERONET/PHOTON and the IDAF network are operational and will provide measurements for the whole **LOP** period (10 years). The Sahelian dust transect will operate during the **EOP** (3 years) with a possible extension to 5 years, depending on experimental conditions and financial support. The EOP stations are not yet fully equipped but will be operational by the end of 2005.

2.1.2 Deployment.

Despite their long-term operating status and commitment to measurement in given areas, both AERONET/PHOTON and IDAF have adapted their station deployment to meet the needs expressed by the various WPs of AMMA. The Sahelian dust transect has been deployed specifically for the AMMA project. The location of the stations was defined in order to (1) be north of the main biomass burning areas; (2) follow the main summertime transport pattern of mineral dust; (3) be at equal distances between each other; (4) as a function of logistic constrains. Finally, political considerations have been taken into account in the proposed deployment.

Table 1 summarizes the name, location and status of the different stations that are also located on figure 2.

Table 2 : Name and coordinates of the ground based stations involved in TT2b and related networks.

Station	IDAF	AERONET	Dust Transect	SOLAS
Agoufou (15.34N, 1.48W), Mali	x	x		
Banizoumbou (13.54N,2.66E), Niger	x	x	x	
Sal Island (16.73N, 22.93W), Capo Verde		x		x
Dahkla (23.71N,15.95W); Morocco		x		
Dakar (14.39N,16.96W), Senegal		x	x	
Djougou (9.66’N, 1.91E); Benin	x	x		
IER-Cinzana (13.28N,5.93W), Mali		x	x	
Illorin (8.32N, 4.34E), Nigeria		x		
Lamto (6N, 5W)Ivory Coast)	x			
Ouagadougou (12.20N, 1.40W) Burkina Faso		x		
Zoétélé (3.16N,11.96E) Cameroon	x			

As illustrated in figure 2, the AERONET/PHOTONS stations covers two main axes : a longitudinal transect from Niamey to Dakar and an almost latitudinal line from Agoufou to Illorin. During the SOP period these axes will be extended further East toward the Chad frontier (Maine Soroa, Niger) and further North (Tamanrasset, Algeria) and South (shipboard, aircraft operations).

The IDAF stations have been deployed in order to represent the 3 main African ecosystems: Agoufou (Mali) and Banizoumbou (Niger) are located in the dry savannah; Djougou (Benin) and Lamto (Ivory Coast) in the wet savannah; and Zoétélé in the equatorial forest.

The Sahelian dust transect stations have been deployed along the main direction of transport of Saharan and Sahelian dust, i.e the longitudinal AERONET axis from Niamey to Dakar.

Several proposals have been submitted by British, German and American groups to install SOLAS (Surface Ocean - Lower Atmosphere Study) observatories in the Cap Verde Islands and at Barbados, i.e along the same longitudinal axes. In addition, a station fully equipped with meteorological sensors, selected radiometers and a set of aerosols samplers should be set up in the Gulf of Guinea for a 2-year monitoring including the SOPs period (2006-2007) (Rosenstiel School for Marine and Atmospheric Science (RSMAS), University of Miami, USA). These related proposals are briefly described in part 2.2.2.

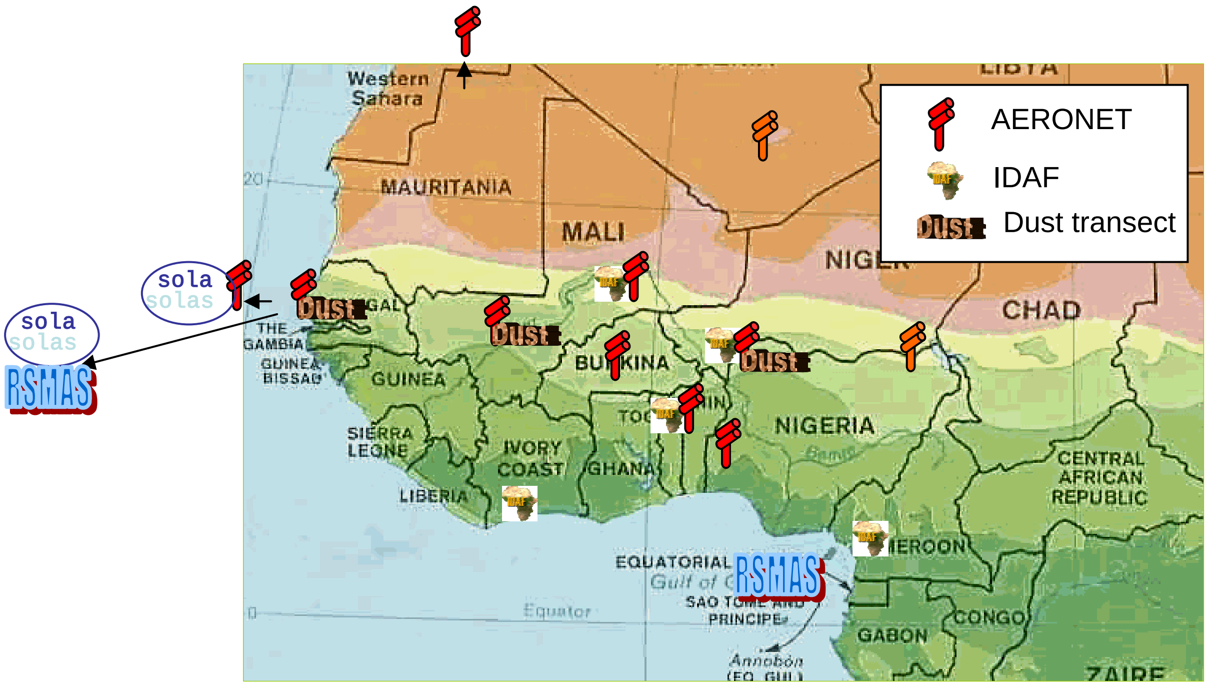


Figure 2 : Location of the ground based TT2b stations; the red AERONET symbols correspond to the EOP period deployment, the orange symbols correspond to instruments that will be deployed during SOP period only. The SOLAS and RSMAS observatories are described in part 2.2.2.

2.1.3 Instrumentation

Tables 3, 4, and 5 summarize the instruments deployed in the different sites and the parameters that will be retrieved from these instruments for each network. A complete description of the instrumentation can be found in the instruments forms (IDAF related froms : LF26/CL.Depot_RW; EF32/AE_Aerosol_Lam; Sahelian dust transect related forms: EF30/AE_DUST_ST).

2.1.3.1 AERONET

The sunphotometer (CIMEL) used in AERONET is an automatic instrument providing direct sun and diffuse radiation measurements under clear sky conditions at a variable frequency throughout the day. Data from all AERONET sites are sent hourly from each fieldsite to the Wallops Receiving Center via transmissions to satellite (GOES, METEOSAT) using VITEL transmitters. These raw data are then transferred hourly from the Wallops receiving station to the Goddard Facility for treatment.

The standardized network procedures (Holben et al., 1998; Smirnov et al., 2000) of instrument maintenance, calibration, cloud screening, and data processing allow for quantitative comparison of the aerosol data obtained in different times and locations. The inversion algorithm (Dubovik and King 2000) provides improved aerosol retrievals by fitting the entire measured field of radiances (sun radiance and the angular distribution of sky radiances at 0.44, 0.67, 0.87, and 1.02 µm) to a radiative transfer model.

The retrieved geophysical parameters and inversion products are available in almost real time on the AERONET web site (http://aeronet.gsfc.nasa.gov/).

Table 3: Measurements and retrieved parameters from the AERONET/PHOTON network.

AERONET/PHOTONS	
Measurement	**Geophysical Parameter**
Sun radiation extinction at several wavelengths	Aerosol Optical Thickness Angström coefficient
Angular distribution of sky radiance	Size distribution Single scattering albedo

2.1.3.2 IDAF

The measurements performed at the IDAF stations are weekly aerosol sampling for particle sizes smaller than 10 µm (PM10) and 2.5 µm (PM2.5) diameter, and wet deposition collected after each rain. Mass weighing and chemical speciation are performed for both aerosol and rain samples. The sampling and analytical procedures respond to the international standards defined by the World Meteorological Organization (WMO) and Global Atmospheric Watch (GAW). Additionally, the black and organic carbon fraction in the PM2.5 is determined. These protocols are described on the IDAF webpage : http://medias.obs-mip.fr.idaf/.

The data are collected and transmitted to this web site and are available to the AMMA program.

Table 4a : Measurements and retrieved parameter from the IDAF network.

IDAF	
Measurement	**Geophysical Parameter**
Aerosol sampling/chemical analyses	- Atmospheric mass concentration at the ground level for PM2.5 and PM10 - Chemical composition (mineral and organic soluble fraction, carbonaceous fraction, trace metal) - Particulate carbon (concentration, Black carbon and organic carbon)
Rain collector	Wet deposition Rain chemical ionic composition, pH, conductivity
Gas phase sampling/analysis	Atmospheric concentration (SO2, NO2, NH3, HNO3, O3)

Additional measurements will be performed in the Djougou station during the EOP period in order to further investigate the aerosol optical properties. Djougou is also an AERONET station; thus, all the microphysical parameters derived from the photometric measurements will also be available.

Table 4b : Additional measurements for the Djougou IDAF station.

DJOUGOU IDAF station	
Measurement	**Geophysical Parameter**
Aerosol physical and optical properties	Particle number concentration, size distribution, absorption and extinction coefficient;
Meteorological parameters	To be described
Gas phase sampling/analysis	Atmospheric concentration (NOx, CO, CO2)

2.1.3.3 Sahelian dust transect

The objective of this Sahelian dust transect is to provide a set of aerosol measurements for the determination of the mineral dust budget at regional scales. It includes measurements of the aerosol concentration at a surface level, the aerosol vertical distribution, the wet and dry deposition flux, and the column-integrated aerosol amount and properties. The three stations are AERONET stations so that all the microphysical parameters derived from the photometric measurements will also be available. Banizoumbou is also an IDAF station and will provide additional information on the chemical composition of rain and aerosols.

The aerosol concentration is measured by an autonomous instrument (TEOM) with a frequency of 15 minutes. Wet deposition is collected for each rain event. For dry deposition the sampling period is conditioned by the minimum total collected mass that can be measured. The objective is a weekly sampling but longer sampling periods are expected during winter and shorter periods during the spring when surface concentrations and dust event frequencies are the highest. Lidar measurements will be performed at selected times throughout the day and/or night (depending on the station). The measurement frequency should be on the order of 4/day but is still being negotiated with attention to maintenance costs and available funding. The data are collected locally and will be made available as part of the AMMA database.

Table 4a : Measurements and retrieved parameter from the Sahelian Dust transect.

Sahelian Dust Transect	
Instrument-Measurement	**Geophysical Parameter**
Aerosol sampling	Atmospheric mass concentration for PM10
Rain collector	Wet deposition
Passive collector	Dry deposition (mass and size distribution)
Microlidar (MPL)/Extinction profile	Aerosol vertical distribution, aerosol identification

Ideally, dust emission fluxes should also be monitored continuously over the EOP period. However, the vertical emission flux measurement and detailed aerosol characterization (composition, optical properties) cannot be routinely measured due to the complexity of the experimental techniques and the cost (in time and money) required by the chemical analysis. Such measurements will be performed during SOPs only at the Banizoumbou super-site (SF-10 instrument). To get information on the variability of the dust emission fluxes, the "erosion" flux (horizontal flux) will be monitored at Banzoumbou over an agricultural field. The site will also be equipped with a heat flux station (TT2a) that will provide information on the local wind shear stress u* (controlling the intensity of the erosion fluxes) and roughness length Z_0 (that strongly influence the erosion threshold). The vegetation cover will also be monitored to determine its influence on the erosion fluxes.

Table 4b : Additional measurements to monitor the erosion fluxes at Banizoumbou.

Sahelian Dust Transect	
Instrument-Measurement	**Geophysical Parameter**
Micro-mast equipped with sand catchers	Vertical profile of eroded mass
Saltiphone	Erosion threshold; erosion periods
Vegetation cover	Surface cover rate, mean height

2.2 Related instrumentation

2.2.1 Related SOP instrumentation

The TT2b stations include the three super-sites for aerosol measurements (Dakar, Banizoumbou, Djougou) and radiative measurements (ARM mobile facility in Niamey airport and field measurements in Banizoumbou; TReSS station in Tamanrasset) that will be deployed for the SOP period. These super-sites are mainly deployed to fully describe the physical-chemical and optical properties of the atmospheric aerosols and to determined experimentally the aerosol radiative effect. The equipment of these stations is described in the TT7 and TT8 strategic planning and related instrumentation form. Compared to these intensive measurements, the TT2b stations will provide fewer measurements but over a larger time period and a regional scale. Obviously, the data obtained from the TT2b stations during the SOP period will be used to establish physical links between the parameters retrieved from the EOP set up and the extensive physico-chemical description obtained with the SOP instrumentation.

2.2.2 Related EOP instrumentation

2.2.2.1 Heat flux and radiative fluxes stations

The TT2b stations include the stations devoted **to EOP Heat flux measurements** (TT2a : Agoufou, Banizoumbou, Djougou). **Radiative flux measurements** will be deployed at these three sites but also in Ghana (TBD). This offers the opportunity to study the influence of the trospospheric aerosols on the surfaces fluxes and in particular the radiative flux over a long-time period.

2.2.2.2 SOLAS proposals

In the framework of the UK DODO proposal, an intensive 6 week experiment at the SOLAS Cape Verde supersite during SOP0, involving measurements of the composition of single particles by the University of Birmingham (UoB). Continuous monitoring of trace gases and aerosols could be extended from 2006 to 2009 within the framework of a SOLAS proposal (UK-SOLAS , led by York, but also with Univ. Leeds and Bristol, and D-SOLAS via MPI-Jena and Univ. of Leipzig).

Complementary to this SOLAS station, studies on aerosol deposition processes (wet and dry) and chemistry will be conducted an Barbados with a major focus on dust Fe (and other trace elements) and related N and P nutrients during 3 years (RSMAS, Miami, USA).

Table 5 : Measurements and retrieved parameter from the SOLAS observatories.

SOLAS Observatory in Cap Verde Island	
Instrument-Measurement	**Geophysical Parameter**
Aerosol sampling	To be defined
Gas phase sampling/analyses	Atmospheric concentration (O3,CO, NO, NO2, NMHCs, OVOCs, DMS, NH3, HNO3, long lived and reactive halocarbon, stable gas)
Meteorological station	To be defined
Radiation measurements	To be defined

2.2.2.3 RSMAS station

RSMAS (E. Key and P. Minnett) propose the deployment of an advanced meteorological, aerosol, and cloud sampling station within the Gulf of Guinea, over the Island of Bioko (3°30N, 8°45E), for two years starting at the beginning of the SOP0. An additional station at this specific location is of great interest to TT2b, since it offers a unique opportunity to get long-term observations in a region where the atmospheric effects of monsoon convection, dust aerosol, and smoke from biomass burning converge. By providing correlative measurements in nearshore and marine environments, the proposed installation complements the development of atmospheric and surface satellite products. Indeed, retrievals from space are complicated in the equatorial sun glint region, where the direct reflection of the sun off the ocean surface saturates the detectors of most visible sensors. It also contributes significantly to the AMMA campaign, in particular by providing aerosol optical properties and radiation measurements in complement to the chemical measurements performed at the IDAF station of Zoélété (Cameroon).

This joint science-commerce proposal is under evaluation.

Table 6 : Measurements and retrieved parameter from the RSMAS Bioko station.

RSMAS Bioki station	
Instrument-Measurement	**Geophysical Parameter**
AEROSOL Total Particle counter (TEOM) Concentration particle counter Aerodynamic Particle Sizer spectrometer Scanning Mobility Particle Sizer Spectrometers Aethelometer Nephelometer Sun photometer (CIMEL)	Aerosol mass concentration Aerosol concentration Dust and large aerosol sizing Biomass burning and fine aerosol sizing Aerosol light absorption Aerosol light scattering Aerosol optical depth
RADIATION Portable Radiation package	 Incident solar and infrared radiation, aerosol optical depth
CLOUDS Sky imager Ceilometer	 Cloud presence, amount, type Cloud presence, base and height
METEOROLOGY Weather Pak meteorological Array Optical rain gauge Radiosonde receiver	 Barometric pressure, air temperature, relative humidity, vector wind Precipitation rate Atmospheric temperature, humidity and wind profiles
GAZ Open Path gas analyzer	 Relative humidity, CO2 concentration

2.2.3 Instrumentation

The tables below summarise the instruments – in the sense defined in the introduction of the implementation plan – attached to TT2b (Table 6a) or attached to another TT but closely related to TT2b, except for the SOP instrumentation that is fully described in the TT7 and TT8 documents.

Table 7a : TT2b List of instruments

#	Code	PI Name	E-Mail Address	Instrument	Platform
EF30	AE.Dust_ST	Jean-Louis Rajot	rajot@ird.ne	3 sites (TEOM, micro-LIDAR,Photometer)	Sahelian transect
EF32	AE.Aerosol_Lam	Cathy Liousse	lioc@aero.obs-mip.fr	Aerosol measurements at Djougou	Djougou
EF33	AE.VAN.Od	Dominique Serça	serd@aero.obs-mip.fr	Labo van	Djougou
LF26	CL.Depot_RW	Corinne Galy-Lacaux	lacc@aero.obs-mip.fr	5 Statons IDAF (4 with Aethalometer)	Regional window

Table 7b : List of instruments related to TT2b

#	Code	PI Name	E-Mail Address	Instrument	Platform	TT
EB1/ EF7	AE.H2O Flux_G	F. Timouk, C. Lloyd	Xx crl@ceh.ac.uk	2 MK4 systems in Hmbori (grassland and open forest sites)	Hombori Super Site	2a
EB2	AE.Flux _G	F. Timouk, C. Lloyd	xx crl@ceh.ac.uk	2 HFS systems in Bamba (very dry) and Hombori (extensive laterite pan)	Gourma Meso Site	2a
SU1	xxx	Kim	xxx	ARM Mobile Facility	Niamey Airport	x

3 Modelling and satellite observations

AERONET measurements have been widely used to test and validate aerosol satellite products and simulations of aerosol models. Additional information on the aerosol surface concentrations, chemical composition and vertical distribution will help to further constrain models and satellite retrievals. The distance between the stations favours the use of the acquired data set for both global and regional simulations. The lidar measurements will be particularly useful for CALIPSO validation. In turn, satellite aerosol products will provide a way to interpolate the local ground based measurements.

These measurements are necessary for the evaluation of 3D aerosol models and their ability to reproduce the long-term variability of the aerosol atmospheric content. This implies that the relationships between aerosol emissions and deposition and the climatic conditions have been understood and correctly described in such simulations. These measurements are particularly suited for testing simulations performed over long periods (CHIMERE-Dust) and simulations of aerosol cycles in climatic models (LMDz; REG-CM…).

4 Partnership

Many the TT2b stations are maintained through collaborations with local representations of the French Institut pour la Recherche et le Développement (IRD), or with local institutions, to ensure continuous monitoring, for manual sampling and chemical testing (i.e., wet and dry deposition collection), and to address equipment failures. Local people involved in the measurements are trained by European scientists either on site or in host European laboratories.

It must also be noted that African partners involved in the deployment of these stations have proposed scientific projects in the PIAF. Further efforts are thus required to develop scientific cooperation with those already involved and to encourage new applications.

Table 8 : List of the local institution involved in the implementation of the TT2b stations

Station	Local Institution
Agoufou, Mali	IRD, Bamako; Department of Physics, National University of Mali, Bamako.
Banizoumbou, Niger	University Abou Moumouni, Niamey.
Capo Verde	National Institut of Meteorology and Geophysics, Esparagos, Sal Island, Cape-Verde.
Dahkla, Morocco	Royal Center for Remote Sensing, Rabat, Morroco
Dakar, Senegal	IRD, M'Bour, Senegal
Djougou; Benin	IRD, Djougou
IER-Cinzana, Mali	IER, Cinzana, Mali
Illorin, Nigeria	Department of Physics, University of Illorin, Illorin, Nigeria.
Lamto, Ivory Coast	University of Abidjan, Abidjan, Ivory Coast
Ouagadougou, Burkina Faso	IRSAT, Ouagadougou, Burkina Faso
Zoétélé, Cameroon	IRD, Yaoundé

5 Organisation of the TT.

5.1 Leaders, core group, membership

Coordinators

Béatrice Marticorena (France), Francesco Cairo (Italy)

Core group

C. Liousse (France), J.L Rajot (France/Niger), P. Gouloub (France), V. Yoboué (Ivory Cost) (TBC).

Representation

Representatives of the TT3, 4 and 5 : F. Lavenu (TBC), JL. Rajot, C. Liousse.

TT2a: C. Lloyd

TT7: Ellie Highwood

TT8: P. Formenti

Other members

UK related proposals : Hugh Coe ; Martin Todd, Richard Washington
SOLAS observatory : Allistair Lewis; Konrad Müller, Martin Heimann.

ARM station : Tony Slingo;

RSMAS Bioko station : Erica Key

Modelling groups : Gé Verver, B. Vogel

Satellite groups : I. Chiapello, J.F Léon

AERONET : B. Chatenet

IDAF : C. Galy-Lacaux + local scientist

Local institutions: to be defined

5.2 Internal coordination

The implementation of the EOP/LOP observations will be coordinated within the existing EU project structure. It will be the work of this TT to ensure that the operations of these groups are synergistic and complementary.

5.3 How are requests for new instruments handled?

Deployments are discussed by the whole TT2b group and approved by Core Group. However, the installation of any additional instrumentation obtained through the national label (ORE) will be discussed with regard to the national objectives.

5.4 External diffusion of the information and reporting

External diffusion of the information will be insured through the AMMA international implementation web page. The TT will report to the ICIG, AMMA-EU and national programs.

6 Coordination with other TTs.

TT2b	Coordination with Heat and radiative fluxes measurements
TT3	Coordinating complementary instruments (radiation, fluxes, vegetation, etc ..); Optimizing logistical efforts.
TT4	Coordinating complementary instruments (radiation, fluxes, vegetation, etc ..); Optimizing logistical efforts.
TT5	Coordinating complementary instruments (radiation, fluxes, vegetation, etc ..); Optimizing logistical efforts.
TT7	Coordination of measurements with SOP, intercomparison of aerosol measurements, possible increase of the sampling frequency.
TT8	Coordination of measurements with SOP, intercomparison of aerosol measurements, possible increase of the sampling frequency.

TT3 - EOP integrative studies on the Gourma meso-scale site (Mali)

Updated May 8, 2005

1. *Scientific justification and objectives :*

The aim of this document is to present the observing strategy in the Gourma meso-scale site in Mali, with respect to the objectives of the AMMA project detailed in the AMMA-IP and AMMA-API proposals. Particularly, this document gives the list of the instruments, presents the schedule of their deployment and addresses the associated logistic issues.

In Mali, EOP focuses on quantification of water, CO2 and energy fluxes that occur between the surface and the atmosphere. Among the surface processes under consideration, emphasis is put on evapotranspiration which is the most important process coupling the physical, biological and hydrological processes occurring at the continental surface. It is also the term of the water budget responsible of the surface retroaction to the atmosphere, since evapotranspired water then enters the regional atmospheric circulation. It is also the most poorly measured and understood term of the water budget. The main scientific objective is therefore to better understand, model and predict temporal and spatial variations of evapotranspiration in a bottom up approach integrating all the physical, biological and hydrological processes involved.

Understanding, modelling and predicting plant phenology (i.e. the seasonal cycle of LAI and biomass) is the key issue to correctly predict the evapotranspiration cycle along the year. Most process studies focus on integrating the numerous ecological processes (carbon assimilation, water uptake and release, vegetation growth and decay, coupled C/H2O/N cycles,…) responsible for the phenological cycle. Moreover, water transpiration is closely linked to CO2 assimilation through the stomatal control by plants. This coupling is simulated in most current SVAT models. The water extraction strategy and the phenological cycle of plants are used to define major plant functional groups.

The question of the long term dynamics of sahelian vegetation is also addressed since the Gourma vegetation sites have been monitoring for about 20 years. The vegetation monitoring sites are part of the *AMMA-CATCH* observing system (*ORE: Observatoire de Recherche sur l'Environnement*) and of the '*GLOBALSAV*' network (http://www.globalsav.org). Furthermore, they are used as validation sites for satellite products including vegetation parameters (LAI, Cover) within the frame of the *VALERI* project (www.avignon.inra.fr/valeri), and soil moisture (http://eopi.esa.int/esa/esa?cmd=aodetail&aoname=smos) within the SMOS activities.

Besides, sahelian ecosystems contribute a significant fraction to global biogeochemical C and N cycling. Biogenic emissions of NOx by soils as well as wet and dry surface deposition control tropospheric ozone, particle formation (aerosols) and gas concentrations. Biogenic emissions are linked to meteorological and surface characteristics such as soil moisture and temperature (NOx), phenology and plant water stress (BVOC) whereas dry deposition fluxes are largely dependant on land use covers. We also have the objectives to provide a better parameterization linking biogenic emissions and surface characteristics at local and meso scale.

The overall methodology is as follows:

- Analysis of the spatio-temporal variability of soil moisture and vegetation in relation with the variability of atmospheric variables (mainly rainfall),
- Analysis of the spatial-temporal variability of water and energy fluxes from local to meso-scales,
- Investigate how biogeochemical cycles are controlled by land surface processes,
- Estimation of meso-scale surface fluxes, vegetation phenology, soil moisture and water budget through the assimilation of remote sensing data into coupled vegetation/SVAT models.

2. *Observing strategy :*

2.a. Overall strategy

The overall strategy is based on the deployment of a variety of instruments, from local- to meso-scales, dedicated to the monitoring and documentation of the major variables characterizing the climate forcing, the spatio-temporal variability of the surface conditions including vegetation cover and soil moisture, wet and dry depositions and surface fluxes. Emphasis is put on the estimation of surface fluxes through observation and modelling to address interactions between land surface and the atmosphere at the meso-scale. Furthermore, emphasis is put on soil moisture monitoring since soil moisture controls soil evaporation, plant transpiration and thus energy fluxes. Process studies focus on integrating the numerous ecological processes (carbon assimilation, water uptake and release, vegetation growth and decay, coupled C/H2O/N cycles, *etc.*) responsible for the phenological cycle.

Up-scaling of surface fluxes that are estimated at a local scale, thanks to the flux stations, to the meso-scale window is performed using land surface models and remote sensing data following an assimilation/spatialisation strategy.

The overall set up provides data sets, forcing variables and functional understanding of land surface to validate large-scale models.

Atmospheric forcing variables :

. *Rainfall* : The variability of rainfall is monitored by the raingauge network deployed within the frame of the AMMA-CATCH 'ORE'. This network consists of 8 automatic raingauges (*CL.Rain_G*) installed since 2004 in the Gourma mesoscale window. This network is complemented by 15 national rainfall stations or manual raingauges that are deployed by CESBIO along a North-South transect within the Gourma window.

. *Meteorological variables* : Two automatic weather stations (*AL.Met_G*), located on the Agoufou local site (15.3°N) and on the Bamba site (17.1°N), provide the necessary forcing variables for local land surface models. The Bamba weather station is also part of the ROSELT (*Réseau d'Observatoires de Surveilance Ecologique à Long Terme*) network. These measured data are complemented by those collected by the AERONET sun photometer installed at the Agoufou site, which gives information about aerosol optical properties and water vapour content.

Atmospheric parameters

. *Atmospheric chemistry*: Chemical composition of rainfall water and dry and wet depositions as well as gaz concentration are provided by the analysis of data collected by the IDAF station at the Agoufou local site. This station is part of a regional IDAF network deployed in West-Africa within the frame of the IDAF Observing System (or 'Observatoire de Recherche sur l'Environnement – ORE-).

. *CO_2*: Concentrations of atmospheric CO_2 along vertical profiles in the nocturnal boundary layer (0-200 m altitude) are measured with a tethered balloon (*CE.BA.CO2_G*). These measurements allow to estimate flows of CO_2 between vegetation and atmosphere at a scale larger than the previous flux measurements collected with the flux stations. They thus contribute to scale up the results at larger scales. Measurements are performed at the Agoufou site during 3 week field campaigns in August.

In addition, the GPS stations (*AE.GPS_1*) of Gao and Tombouctou, the sun photometer of Cinzana (*AE.DUST_ST*) are part of a regional network deployed during EOP. Data collected by the UHF of Bamako (*UHF_BMKO)* under the responsibility of ASECNA is used to characterize the Atmospheric Boundary Layer (ABL). Besides, an acoustic sodar (A*E.RS_T1*) is deployed on the Hombori super-site during SOP1 and SOP2.

Continental water cycle

. *Soil moisture*: Documentation of the spatio temporal variability of soil moisture is performed using local measurements and satellite observations. A network of 8 soil moisture profiles (*CE.SW_G*) is deployed within the Gourma window documenting the spatio-temporal variability of soil moisture. Automatic measurements are complemented by field measurements made on the vegetation monitoring sites along 1km transects. Spatialised data are also used to validate satellite products such those derived from AMSR (*Advanced Microwave Scanning Radiometer*) data.

. *Water and energy fluxes* : 4 flux stations including 2 heat flux and 2 CO2/H2O stations (*AE.Flux_G*) are deployed within the Gourma site. Among them, 3 are installed within the Hombori super-site on representative dominant surfaces, namely a grassland on sand dunes (Agoufou), an open *Acacia* forest on clayey-silt soil, and on a rocky erosion surface sparsely covered by a short grass layer and a few scattered trees. The fourth station is positioned in the northern part of the Gourma window at the Bamba site within the Saharo-sahelian zone. This area is characterized by a very low vegetation cover.

. *Sap flow measurements*: two sap flow stations (*CE.Sap_Gh*) should be installed at the Agoufou on typical trees (evergreen and deciduous) and at the *Acacia* site. These automatic stations give an estimation of the transpiration from trees, providing useful data to interpret the measurements made by the flux stations.

Vegetation

. *Vegetation phenology*: For the Gourma meso-scale site, the monitoring of the vegetation phenology is based on the survey of 43 1km x 1km sites distributed along a North-South transect (*CE.VegSoil_G*). Measurements are made every month during the rainy season for three identified plant functional types namely, annual herbs, perennial herbs and trees. On the Agoufou local site, the temporal variation of LAI, biomass and vegetation cover is monitored every 10 days during the growing season using hemispherical images, destructive methods and PAR interception estimation.

. *PAR measurements*: Automatic measurements of PAR interception by plant canopies (*CE.PAR_Ga*) complement measurements performed along transects and provide useful data for model development and validation. Incident and transmitted through vegetation, are measured using PAR cells deployed above and below the vegetation cover at the Agoufou site (grassland) and at the open *Acacia* forest site.

. *Ecophysiology and Vegetation/Soil chemical analyses*: Field work consists of measuring stomatal conductance, leaf water potential, and gaz exchanges linked to evapotranspiration and photosynthesis as both processes are closely related (*CE.VegSoil_G*). The plant response to their environment (mainly water stress) is monitored with a LICOR 6400 (photosynthesis, stomatal conductance), an AP4 porometer (stomatal conductance), a pressure chamber (leaf and stem water potential) and a delta T press (leaf water potential). Field campaigns are mainly conducted at the Agoufou local site. Laboratory chemical analysis of soil and vegetation samples provide the necessary input parameters for land surface models (i.e. soil texture) and for model parameterization (i.e. minimum stomatal conductance).

2.b. Modelling and satellite observations

The modelling strategy is designed to provide meso-scale estimate and understanding of surface fluxes with coupled vegetation/SVAT/hydrology models (e.g. with the coupled STEP/SETHYS models). Simulations are performed for scales corresponding to integrated measurements: flux stations, scintillometer *(to be defined*), aeroplane transects, CBL studies (UHF, balloon). The focus is on 'meso-scale' models like ORCHIDEE, as well as large-scale models, but detailed models (2D, 3D) can be used to some extent.

Control and spatialisation of the surface models rely on the assimilation of multi-spectral and multi-resolution satellite images. Over the Gourma site, the satellites that are used are as follows:

Sensor:	***Spatial resolution:***
SPOT-HRV	20 m
Landsat TM (multispectral)	30 m
SPOT-VEGETATION	1 km
MODIS	250 - 500 m
ENVISAT/ASAR	30 m - 1 km
QuickScat	25 km
AMSR	50 km

In addition, very high resolution images (1 m) such those delivered by QuickBird are used to derive information about tree density and land use cover for the Hombori supersite. Extension to the meso-scale site is performed using high resolution SPOT/VGT images (2.50m).

2.c. List of sites, instruments and relevant maps:

The Gourma window includes 3 monitoring spatial scales:

1. **The Gourma mesoscale site** (~30,000 km², 14.5°-17.5°N; 2°-1°W). This window is characterized by a sahelian to saharo-sahelian climate (isohyets 400-100 mm). Vegetation is composed of a layer of annual herbs with scattered trees and shrubs. The crops (millet mainly) occur only in the southern part of this area. Data on herbs and woody vegetation are collected on 43 sites among which some are also used for validation of remote sensing products (LAI, Net primary Productivity, soil moisture) derived from SPOT-VGT, MODIS and AMSR.

2. **The Hombori super site** (~2250 km², 15.13 -15.58°N; 1.38 - 1.65°W). Interactions between hydrological and vegetation functioning, and the effects of spatial heterogeneities on fluxes (gaseous exchange, flow of energy, of carbon and water) between continental surface and atmosphere are studied at this scale.

3. **The Agoufou intensive local site** (1 km², 15.3°N - 1.3°W). The mean annual rainfall is 370 mm (over the 1920-2003 period). The site concentrates measurements on vegetation and soil moisture, automatic weather stations, a flux station (energy, water, CO2), a sun photometer (AERONET) and an IDAF station. The data collected on this site are used to parameterize and to test vegetation and SVAT models. Furthermore, the Agoufou local site is the main validation site for remote sensing products (LAI, NPP, soil moisture).

The site maps and the location of LOP/EOP instruments are given in Appendix 1. The list of instruments is given in Appendix 2.

2.d. Priorities:

All the listed instruments are deployed in time apart from two of them which are not presently funded and therefore constitute our first priorities:

- Sap flow stations (*CE.Sap_Gh*)
- PAR cells (*CE.PAR_Ga*)

3. *Deployment*

The deployment of most instruments (particularly raingauges and automatic weather stations) has started in 2002 within the frame of the ORE AMMA-CATCH. All the funded instruments are operating in 2005.

a. Planning

The period of deployment for each instrument is given in Table 1. The associated field missions are given in Tables 2 and 3.

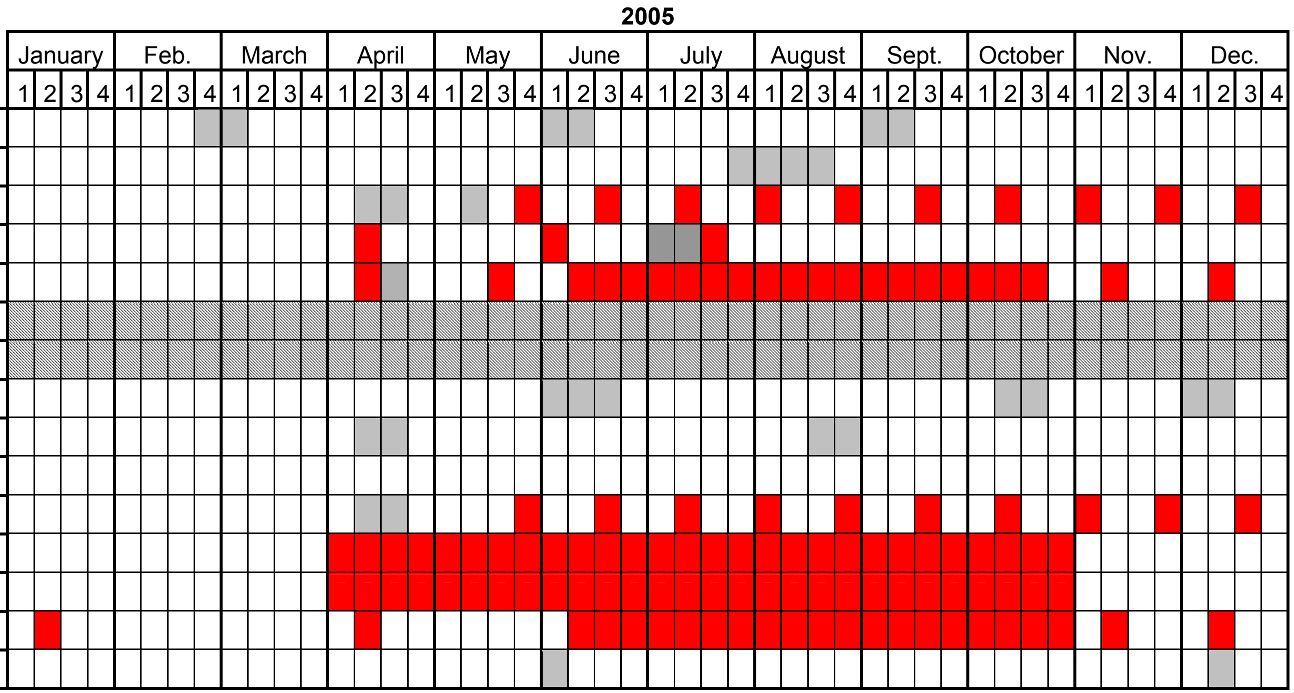
Table 1. Planning of instrument deployment

			2004	2005												2006												2007											
Form #	**Inst. Code**	**Description**	exist	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
EF1	AE.GPS_1	GPS stations																																					
EF6	AE.Ba.CO2_G	Tethered balloon																																					
EF7	AE.Flux_G	Network of 4 flux stations																																					
EF14	CE.SW_G	Network of SW stations																																					
EF15	CE.VegSoil._G	Vegetation studies																																					
EF16	CE.PAR_Ga	PAR interception station																																					
EF17	CE.Sap_Gh	Sap flow stations																																					
EF30	AE.DUST_ST	1 AERONET Photometer																																					
EE9	AE.Flux_G	Network of flux stations																																					
EE?	AE.RS_T1	Acoustic sodar																																					
LF1	AL.Met_G	2 weather stations																																					
LF16	CL.Rain_G	8 recording raingauges																																					
LF26	CL.Depot_RW	1 IDAF station																																					
-	CL.Photometer	1 AERONET Photometer																																					
-	UHF_BMKO	TT1																																					

to be defined

Table 3. Planning of missions 2005

EOP		
EF1	AE.GPS_1	GPS stations
EF6	AE.Ba.CO2_G	Tethered balloon
EF7	AE.Flux_G	Network of 4 flux stations
EF14	CE.SW_G	Network of SW stations
EF15	CE.VegSoil._G	Vegetation studies
EF16	CE.PAR_Ga	PAR interception station
EF17	CE.Sap_Gh	Sap flow stations
EF30	AE.DUST_ST	Cinzana photometer
EE9	AE.Flux_G	Network of flux stations
EE?	AE.RS_T1	Acoustic sodar
LF1	AL.Met_G	Weather stations
LF16	CL.Rain_G	8 recording raingauges
LF26	CL.Depot_RW	1 IDAF station
-	CL.Photometer	1 AERONET Photometer
-	UHF_BMKO	TT1



field mission for people permanently in Bamako

field mission for people in mission in Mali (P: # people)

to be defined

Table 2c. Planning of missions 2006

EOP			2006																																															
			January				Feb.				March				April				May				June				July				August				Sept.				October				Nov.				Dec.			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
EF1	AE.GPS_1	GPS stations																																															
EF6	AE.Ba.CO2_G	Tethered balloon																																															
EF7	AE.Flux_G	Network of 4 flux stations																																															
EF14	CE.SW_G	Network of SW stations																																															
EF15	CE.VegSoil._G	Vegetation studies																																															
EF16	CE.PAR_Ga	PAR interception station																																															
EF17	CE.Sap_Gh	Sap flow stations																																															
EF30	AE.DUST_ST	Cinzana photometer																																															
EE9	AE.Flux_G	Network of flux stations																																															
EE?	AE.RS_T1	Acoustic sodar																																															
LF1	AL.Met_G	Weather stations																																															
LF16	CL.Rain_G	8 recording raingauges																																															
LF26	CL.Depot_RW	1 IDAF station																																															
-	CL.Photometer	1 AERONET Photometer																																															
-	UHF Bamako	TT1																																															

field mission for people permanently in Bamako

field mission for people in mission in Mali (P: # people)

to be defined

b. Logistical considerations

Due to the location of the Gourma site within the sahelian pastoral region, logistical constraints have to be taken into account. This can be done if requests for missions are transmitted to the Task leaders at least 2 months prior the mission. Particularly, the need for vehicles and drivers should be specified as soon as possible because it can be a limiting factor. The Agoufou local site is located at 950 km from Bamako what means that a minimum of a full day journey is necessary to reach the site. The accessibility to the Bamba site cannot be guaranteed due to episodic security problems encountered within this area.

Vehicles

The IRD Centre in Bamako has 5 4-wheel-drive vehicles. Among them, one is dedicated to the AMMA team. A maximum of 3 vehicles can be used by the AMMA teams at the same time. Consequently, in case of extra needs, a possible solution is either to obtain a vehicle from another IRD Centre of West Africa (Ouagadougou for instance) or to hire 4WD vehicles and drivers in an agency in Bamako.

Infrastructures

Office in Bamako

In Bamako, AMMA teams are housed in the IRD Centre which offers usual telecommunications and an internet access.

Housing in Hombori during field missions

Housing for people in mission for field work is possible in an encampement hotel located in the Hombori village which is at about 30 km from the Agoufou local site. "*The hotel is basic but pleasant. Sanitation is good with cold shower, basin and flushing toilet. Food is good but basic. Power is only supplied from a fuel generator*" (Colin Lloyd's comments after his first visiting period in August 2003). Daily cost is 4000 CFA what includes lodging and meals. A participation of 4000 CFA/person/day is asked for covering extra costs (improved meals, mineral water,…).

Human resources

Office in Bamako

The AMMA permanent team in Bamako is 3 people (Josiane Seghieri, François Lavenu and Franck Timouk). F. Lavenu is responsible of the EOP/LOP logistics. The team can provide help and advices for logistical problems. Hotel booking in Bamako can also be done by the IRD Centre.

Technical maintenance in the field

Depending on the need, local 'technicians' and guardians can be contracted, trained, and thus can maintain a series of instruments during the whole operation period.

Communications

Bamako

The IRD Centre is equipped with usual telecommunication facilities and a good internet connection.

Gourma site

The village of Hombori has only one telephone and mobile phones cannot be used within the Gourma site. The nearest facilities are found in Gao at about 230 km from Hombori. A satellite phone can be useful.

4. Partnership

a) Field observations

Partnerships for field observation mainly involve:

- Direction Nationale de la Météorologie : Radio-soundings (Gao and Tombouctou), GPS stations (Gao and Tombouctou), UHF (Bamako), Rainfall station network.
- Institut d'Economie Rurale (IER)/Centre Régional de Recherche Agronomique de Gao (CRRA-Gao) : Vegetation monitoring (Gourma). The *CRRA-Gao* is responsible of the vegetation site network around Bamba.
- Institut Polytechnique Rural (IPR) de Katibougou : Aerosols/Rainfall/Chemistry (Agoufou), vegetation (Gourma).
- Département de Physique, Faculté des Sciences et Techniques (FAST), Université de Bamako : Photometer (Agoufou).
- Ecole Nationale d'Ingénieurs : UHF Radar (Bamako).
- Direction Nationale de l'Hydraulique :

b) Training program

- Students from IPR : 2 engineer students in 2005

5. Organisation of the TT.

a) Leaders, core group, membership

Task Team leaders :

Eric MOUGIN mougin@cesbio.cnes.fr
Josiane SEGHIERI seghieri@ird.fr
Lassine DIARRA lassine.diarra@ier.ml IER / AMMA-Mali

Core Group members :

François LAVENU	lavenu@ird.fr	Logistics, ST2 representative
Franck TIMOUK	timouk@ird.fr	EOP Instrumentation
Aly SOUMARE	crra.gao@ier.ml	Bamba sites/ROSELT
Mohamed KOITE	dnm@afribone.net.ml	Meteorology Representative
Colin Lloyd	crl@ceh.ac.uk	TT2 fluxes representative
Corinne GALY-LACAUX	lacc@aero.obs-mip.fr	IDAF Representative

The full list of TT3 members is given in Appendix 3

b. Internal coordination

Diffusion of information is made by email using the member list given in Appendix 3. Meetings are planned several times a year in Bamako between the Core team and the AMMA-Mali committee.

c. How are handled requests for new instruments?

Requests must be sent to the TT leaders, at least 3 months prior installation, with all the relevant information. Requests for malian partnership if any, as well as for technical assistance must be sent at the same time. Francois Lavenu in Bamako can provide help and advice for logistic problems and custom formalities. Instruments to be installed in Mali must be sent via air freight to Bamako airport.

d. External diffusion of the information and reporting

External diffusion should be based on web page support.

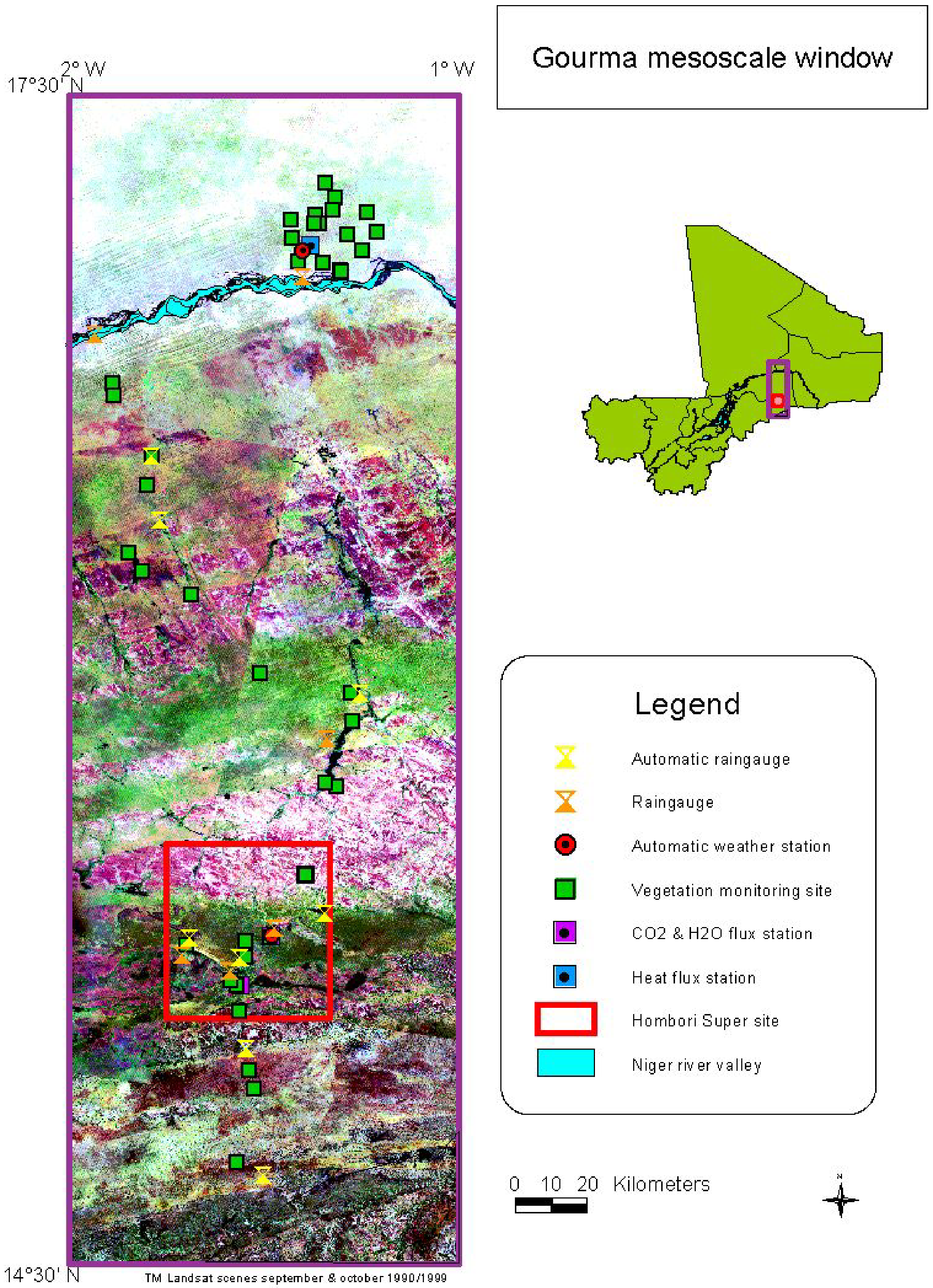
6. Coordination with other TTs

The leaders of TT3 are in close inter-relation with TT2 (Colin Lloyd and Chris Taylor), TT1 (Doug Parker) and with the task teams of the two others meso-scale sites : TT4 (Niger) and TT5 (Benin). Coordination with the CATCH-, IDAF- and AERONET- 'Observatoire de Recherche sur l'Environnement (ORE)' is also effective.

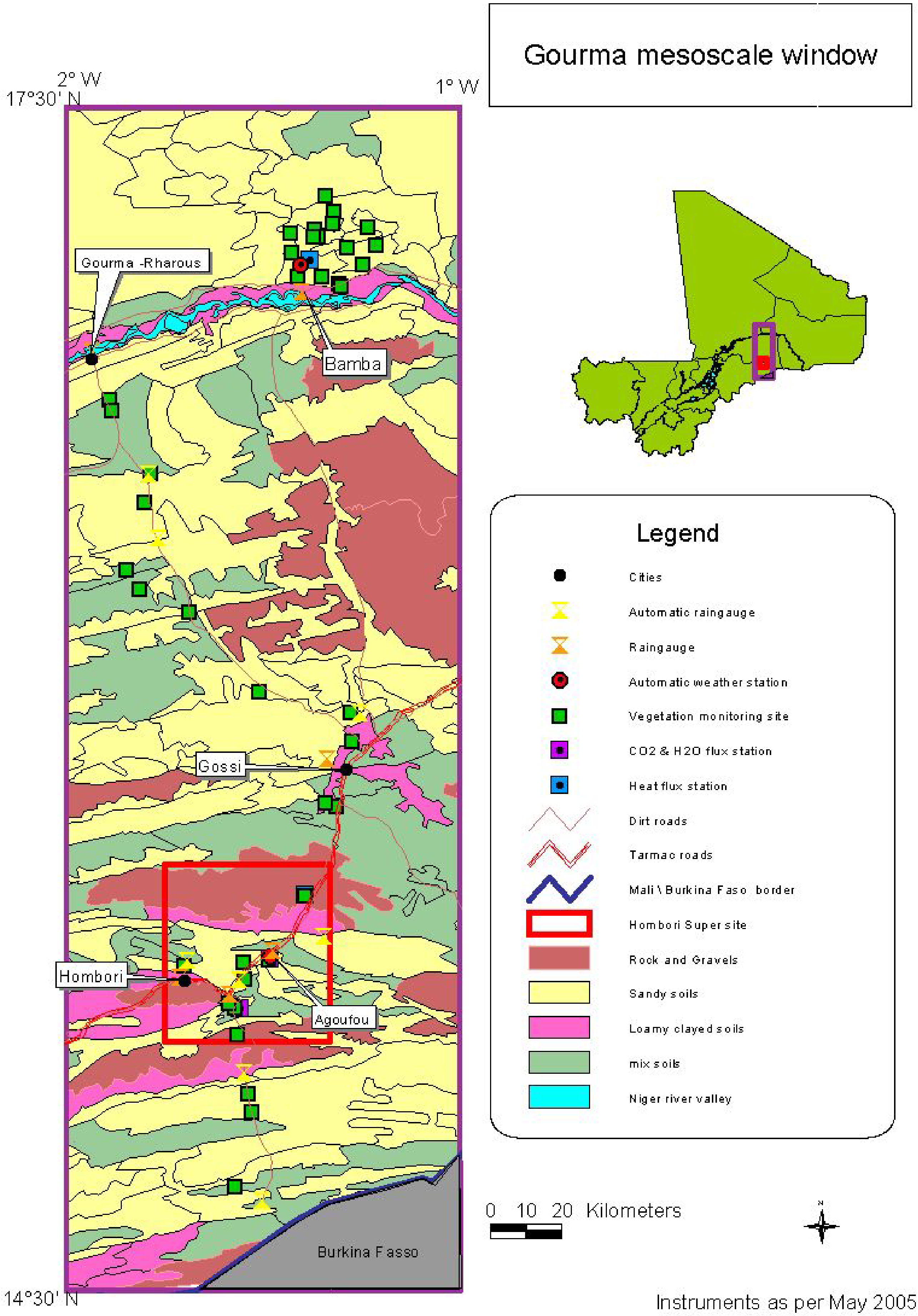
7. Ancillary information, references, logistic forms, site document

Site maps for the different scales are given in the Appendix 1.

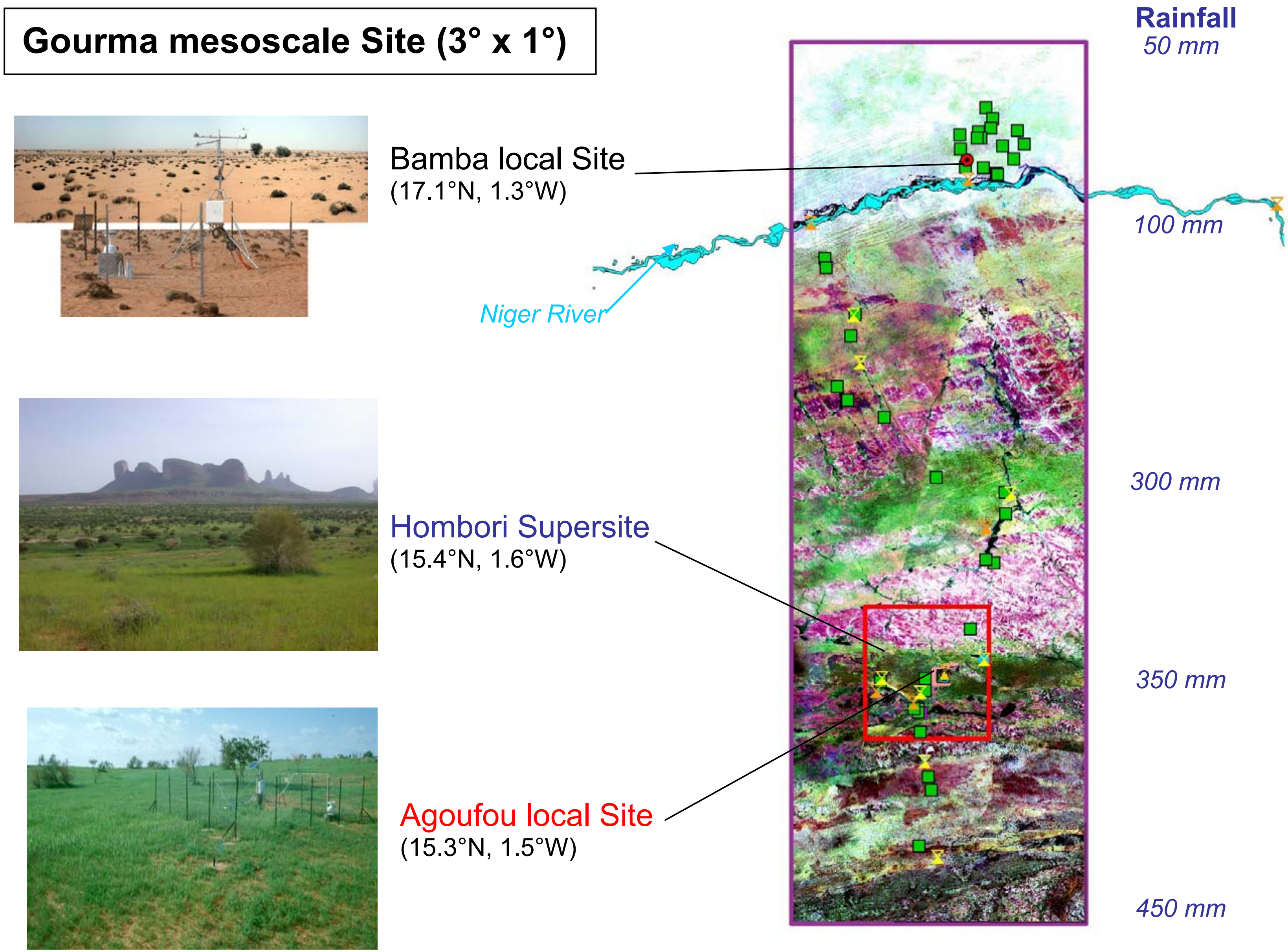
Appendix 1
Site Maps



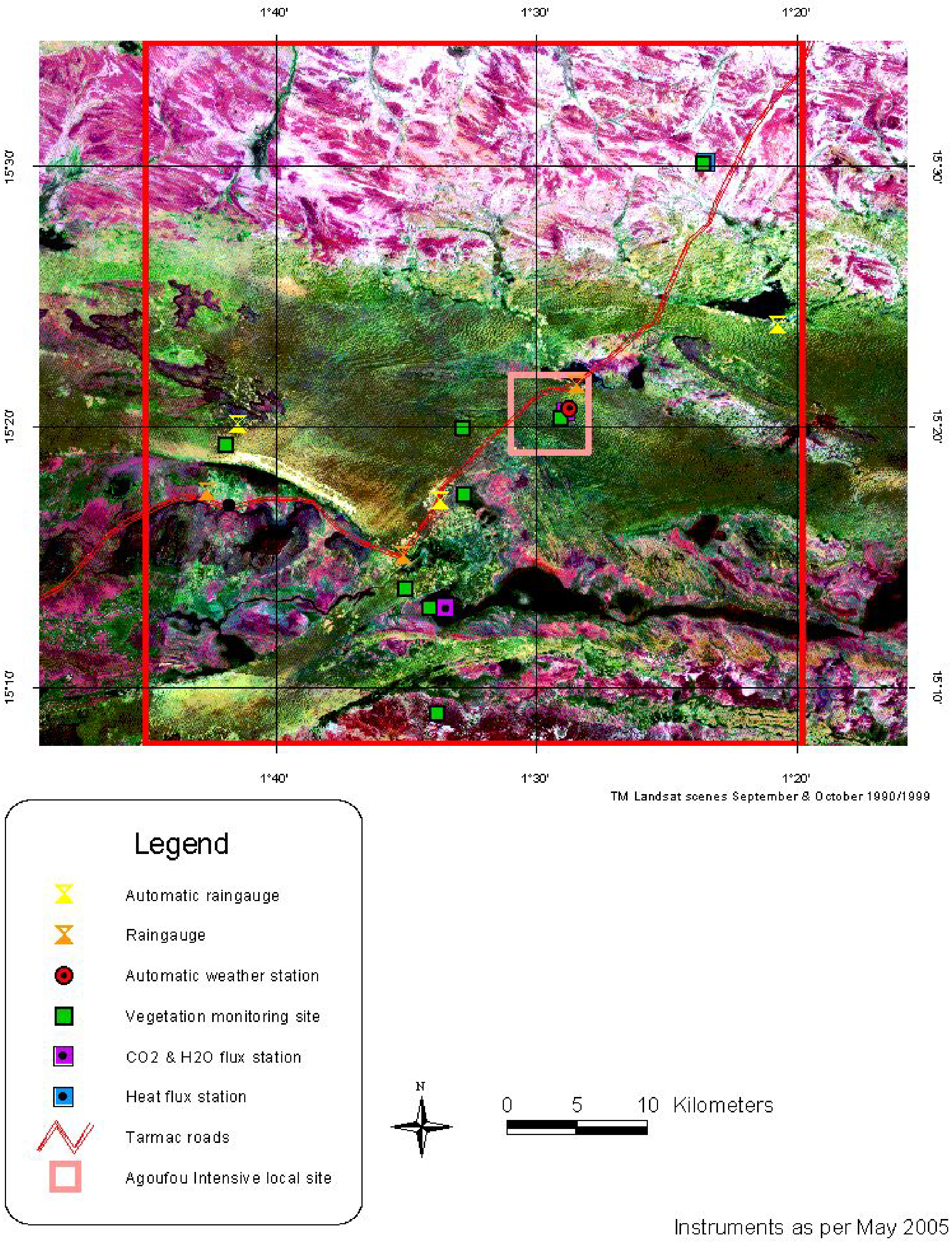
Instruments as per May 2005

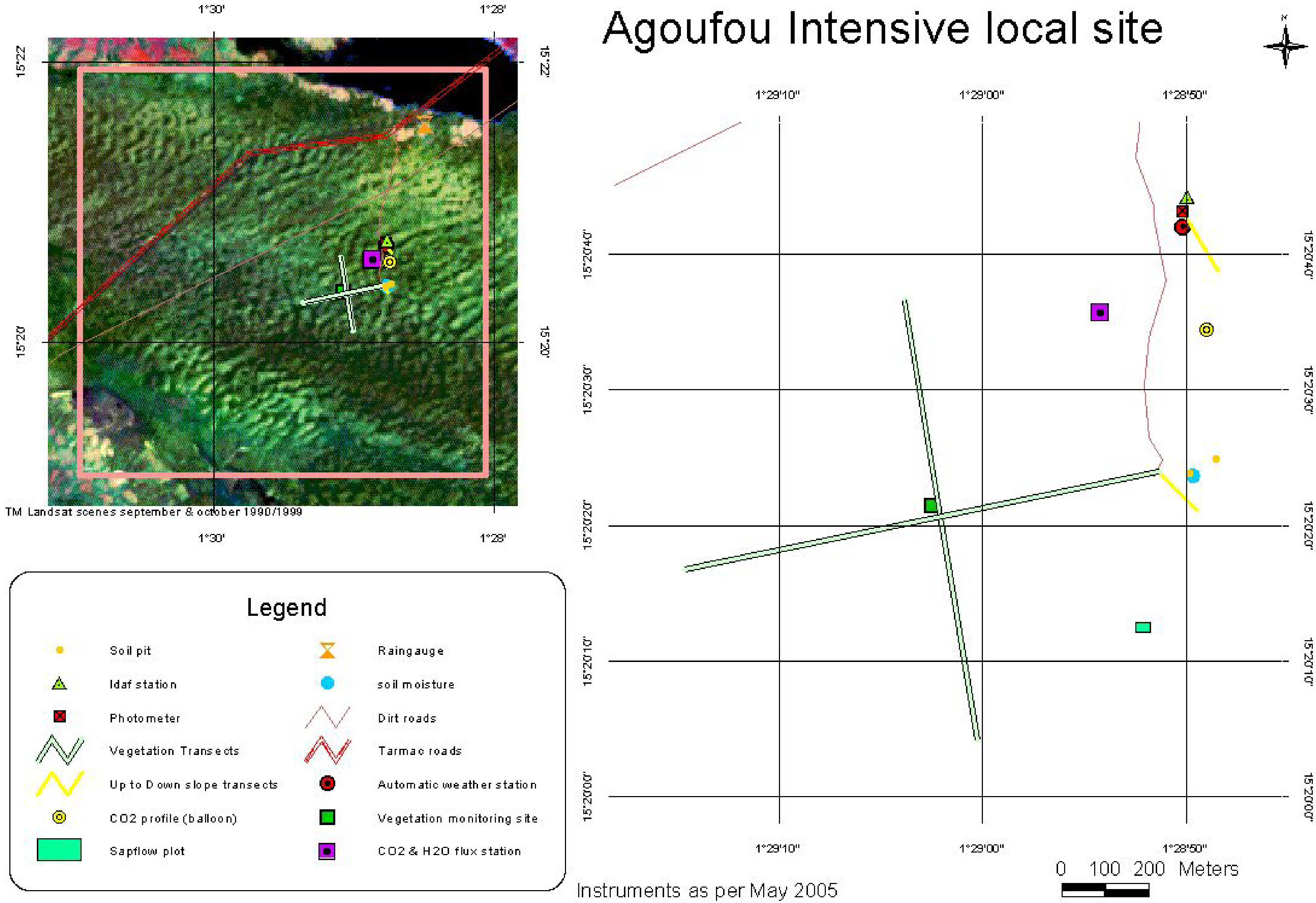

Gourma mesoscale window
2° W
17°30' N
1° W
14°30' N
Gourma -Rharous
Bamba
Gossi
Hombori
Agoufou
Burkina Fasso
Legend
Cities
Automatic raingauge
Raingauge
Automatic weather station
Vegetation monitoring site
CO2 & H2O flux station
Heat flux station
Dirt roads
Tarmac roads
Mali \ Burkina Faso border
Hombori Super site
Rock and Gravels
Sandy soils
Loamy clayed soils
mix soils
Niger river valley
0 10 20 Kilometers
Instruments as per May 2005

Gourma mesoscale Site (3° x 1°)



Hombori super site




Agoufou Intensive local site
TM Landsat scenes september & october 1990/1999
1°30'
1°28'
15°22'
15°20'
1°29'10"
1°29'00"
1°28'50"
15°20'40"
15°20'30"
15°20'20"
15°20'10"
15°20'00"
Legend
Soil pit
Idaf station
Photometer
Vegetation Transects
Up to Down slope transects
CO2 profile (balloon)
Sapflow plot
Raingauge
soil moisture
Dirt roads
Tarmac roads
Automatic weather station
Vegetation monitoring site
CO2 & H2O flux station
0 100 200 Meters
Instruments as per May 2005

Appendix 2

List of TT3 instruments

List of TT3 instruments

Nomenclature:
Form #: XY# with X=L(*LOP*)/E(*EOP*)/S(*SOP*); Y=F(*French*)/E(*European*) instrument
Instrument code XY.name_G(d)(c): X=A(*Atmosphere*)/C(*Continent*)/O(*Ocean*) ; Y=L/E/S, idem form # ; G(h)(a)=G(Gourma site)/(h)(Hombori supersite)/(a)(Agoufou=local)

Period	Form #	Code	PI Name	E-Mail Address	Instrument	Platform
EOP	**EF6**	AE.Ba.CO2_G	L. Kergoat (CESBIO)	laurent.kergoat@cesbio.cnes.fr	Tethered balloon for CO_2 profiles in the nocturnal boundary layer	Agoufou
EOP	**EF7**	AE.Flux_G	F. Timouk (CESBIO)	franck.timouk@cesbio.cnes.fr	Network of 4 flux stations (2 HF and 2 CO2/H2O)	Gourma
EOP	**EF14**	CE.SW_G	P. de Rosnay (CESBIO)	patricia.derosnay@cesbio.cnes.fr	Network of 9 automatic stations for soil moisture measurements.	Gourma
EOP	**EF15**	CE.VegSoil._G	J. Seghieri (CESBIO)	josiane.seghieri@ird.fr	Network of 1 x 1 km² vegetation sites, soil and vegetation chemical analyses, Ecophysiology measurements	Gourma
EOP	**EF16**	CE.PAR_Ga	V. Demarez (CESBIO)	valerie.demarez@cesbio.cnes.fr	Network of automatic PAR cells for grass and tree canopies	Agoufou
EOP	**EF17**	CE.Sap_Gh	V. Le Dantec (CESBIO)	valerie.ledantec@cesbio.cnes.fr	Automatic measurements of sap flow on trees.	Hombori
LOP	**LF1**	AL.Met_G	F. Timouk (CESBIO)	franck.timouk@cesbio.cnes.fr	2 automatic weather stations	Gourma
LOP	**LF16**	CL.Rain_G	F. Lavenu (CESBIO)	françois.lavenu@ird.fr	Network of 8 automatic raingauges	Gourma
LOP	**LF26**	CL.Depot_RW	C. Galy-Lacaux (LA)	lacc@aero.obs-mip.fr	1 IDAF station	Agoufou
LOP	**-**	CL.Photometer	P. Goloub (LOA)	goloub@loa630.univ-lille1.fr	PHOTON/AERONET Photometer	Agoufou

Instruments relevant to other Task Teams

Nomenclature:
Form #: XY# with X=L(*LOP*)/E(*EOP*)/S(*SOP*); Y=F(*French*)/E(*European*) instrument
Instrument code XY.name_G(d)(c): X=A(*Atmosphere*)/C(*Continent*)/O(*Ocean*) ; Y=L/E/S, idem form # ; G(h)(a)=G(Gourma site)/(h)(Hombori supersite)/(a)(Agoufou=local)

Period	Form #	Code	PI Name	E-Mail Address	Instrument	Platform
EOP	**EF1**	AE.GPS_1	M.N. Bouin (IGN) Olivier Bock (SA)	bouin@ensg.ign.fr bock@aero.jussieu.fr	GPS stations	Meridional transect: Gao - Tombouctou
EOP	**EF30**	AE.DUST_ST	Bernadette Chatenet	chatenet@lisa.univ-paris12.fr	PHOTON/AERONET Photometer	Sahelian Transect Cinzana
EOP	**EE9**	AE.Flux_G	C. Lloyd (CEH) C. Taylor (CEH)	crl@ceh.ac.uk taylor@ceh.ac.uk	Flux station network	Benin, Gourma - Mali, Niger
EOP	**EE?**	AE.RS_T1	D. Parker (U. Leeds)	doug@env.leeds.ac	Acoustic sodar	Transect Sahel
EOP	**-**	UHF_BMKO	B. Campistron	camb@aero.obs-mip.fr	UHF Bamako	Bamako

Appendix 3

List of TT3 members

Name	Surname	E-Mail Address	Affiliation	Country	Associated Instrument	Instrument / Position
Bâ	Abdramane	abdramane@yahoo.fr	FAST	Mali	AERONET Sun photometer	CL.Photometer
Bennie	Jon	j.j.bennie@durham.ac.uk	CEH	UK	Vegetation surveys	CLASSIC
Bock	Olivier	bock@aero.jussieu.fr	SA	France	GPS stations	AE.GPS_1, AS.GPS_1
Bouin	Marie-Noëlle	bouin@ensg.ign.fr	IGN/ENSG	France	GPS stations	AE.GPS_1, AS.GPS_1
Campistron	Bernard	camb@aero.obs-mip.fr	LA/UPS	France	UHF Bamako	TT1
Chatenet	Bernadette	chatenet@lisa.univ-paris12.fr	LISA	France	AERONET Sun Potometer	AE.DUST_ST
Damesin	Claire	claire.Damesin@.fr	ESE/Orsay	France	Licor gaz exhange devices	CE.VegSoil._G
Delon	Claire	claire.delon@aero.obs-mip.fr	LA/UPS	France	Soil NOx emissions	ECCO/PNBC
Demarez	Valérie	valerie.demarez@cesbio.cnes.fr	CESBIO	France	PAR cells	CE.PAR_Ga
De Rosnay	Patricia	patricia.derosnay@cesbio.cnes.fr	CESBIO	France	Soil moisture network	CE.SW_G
Diarra	Lassine	lassine.Diarra@ier.ml	IER	Mali	President Malian AMMA Committee, vegetation surveys	AMMA Mali
Diop	Babakar	mbbdiop@yahoo.fr	FAST	Mali	IDAF	CL.Depot_RW
Epron	Daniel	daniel.Epron@oo.fr	EEF/Nancy	France	Licor gaz exhange devices	CE.VegSoil_G
Dembélé	Fadiala	Crra.gao@ier.ml	IPR	Mali	Vegetation surveys	AMMA Mali
Famouké	Traoré	tfamouke@yahoo.fr	ENI	Mali	UHF Bamako	AMMA Mali
Fediere	Gilles	Gilles.fediere@ird.fr	IRD	Mali	Head IRD in Mali	Head IRD in Mali
Fofana	Al Mostapha	dnhe@afribonemali.net	DNH	Mali	Hydrology	AMMA Mali
Frison	Pierre-Louis	frison@umvl.fr	UMVL	France	Satellite validation	Satellite validation
Galy-Lacaux	Corinne	lacc@aero.obs-mip.fr	C. Galy-Lacaux	France	IDAF station	CL.Depot_RW
Guichard	Françoise	francoise.guichard@meteo.fr	CNRM	France	Tethered balloon	AE.Ba.CO2_G
Goloub	Philippe	goloub@loa630.univ-lille1.fr	Uni-Lille/LOA	France	Sun Photometer	CL.Photometer
D'Herbes	Jean-Marc	dherbes@mpl.ird.fr	IRD/Montpellier	France	Vegetation studies	ROSELT
Hiernaux	Pierre	hiernaux@cesbio.cnes.fr	CESBIO	France	Vegetation studies	CE.VegSoil_G
Karambé	Moussa	moussa.karambe@ird.fr	FAST	Mali	Vegetation studies	AMMA Mali
Kergoat	Laurent	laurent.kergoat@cesbio.cnes.fr	CESBIO	France	Tethered balloon	AE.Ba.CO2_G
Koité	Mohamed	dnm@afribone.net.ml	DNM	Mali	Rainfall network	AMMA Mali
Lavenu	François	françois.Lavenu@ird.fr	CESBIO	Mali	Raingauge network , AERONET	CL.Rain_G,CL.Photometer

Le Dantec	Valérie	valerie.ledantec@cesbio.cnes.fr	CESBIO	France	Sap flow stations	CE.Sap_Gh
Lloyd	Colin	crl@ceh.ac.uk	CEH	UK	Flux station network	AE.Flux_G
Mazzega	Pierre	pierre.mazzega@cnes.fr	LEGOS	France	Remote sensing studies	TOSCA
Mercado	Lina	lmme@ceh.ac.uk	CEH	UK	Vegetation surveys	CLASSIC
Mougenot	Bernard	mougenot@cesbio.cnes.fr	CESBIO	France	Soil characterization	CE.VegSoil_G
Mougin	Eric	mougin@cesbio.cnes.fr	CESBIO	France	Vegetation studies	TT Leader, CE.VegSoil_G, CE.SW_Gh, CE.PAR_Ga
Parker	Doug	doug@env.leeds.ac	U. Leeds	UK	Radio sounding network	AE.RS_T1
Saïd	Frédérique	saif@aero.obs-mip.fr	LA/UPS	France	UHF Bamako	TT1
Seghieri	Josiane	seghieri@ird.fr	CESBIO	Mali	Vegetation studies	CE.VegSoil._G
Serça	Dominique	serd@aero.obs-mip.fr	CNRS/LA	France	Soil NOx emissions	ECCO/PNBC
Sissoko	Mamadou	malirep@asecna.org	ASECNA	Mali	UHF Bamako	AMMA Mali
Soumaré	Aly	Crra.gao@ier.ml	IER	Mali	Vegetation surveys	AMMA Mali
Taylor	Chris	chris.taylor@ceh.ac.uk	CEH	UK	Network of flux stations	AE.Flux_G, TT2
Timouk	Franck	franck.timouk@cesbio.cnes.fr	CESBIO	France	Automatic weather stations, flux stations	AL.Met_G, AE.Flux_G

25 March 2005

Chapter 6

EOP integrative studies on the Niger meso-site

Luc Descroix, Bernard Cappelaere, Guillaume Favreau, Thierry Lebel

This chapter introduces the programme of the so-called TT4 Task Team that hosts AMMA field studies of land processes over the Niger mesoscale site over EOP and LOP.

1 Scientific justification and objectives

1.1 Context

The lasting drought of the 1970's and 1980's over West-Africa was one motivation for setting up the AMMA project. This drought was especially severe in the Sahel, remaining unabated until 1997. At the same time the population growth remains strong (and in Niger, the growth rate is increasing), causing a severe land use change and in most parts, a generalized soil degradation.

One consequence of the drought was a significant reduction of the large river discharges: the Senegal river annual runoff decreases by 60% (1971-90 vs 1951-70) and the Niger river's by 55%, to be compared with an average rainfall deficit of 25-30% (Lebel et al., 2003). Dust transport and aeolian erosion also increased significantly. On the other hand, it is now well known that at smaller scales, the water cycle does not necessarily reflect changes witnessed at the regional scale. The number and duration of temporary pools for instance has significantly increased over the past 30 years. Larger runoff leading to this new hydrological state of Sahelian areas is a natural consequence of the degradation of the vegetation. However there is no well established scheme allowing relating this increase in local runoff to the decrease of the large river discharges. The degradation of the vegetation cover has also resulted in a general stage of active erosion involving soil degradation, and a strong silting up of valley bottoms. This causes significant modifications of the through the modification of the hydrological environment: ponds migration, appearance of spreading areas, changes in stream course and location.

In this respect, AMMA is an unique opportunity to address the scale problems inherent to the understanding of the complex relationships between climate, environment and the water cycle. The Niamey area has a rich history of hydrological observations carried out since the Hapex-Sahel experiment established in 1990 and prolonged by the CATCH observing system. Given this long history of observations and scientific results on rainfall distribution (Ali et al., 2003), runoff processes (Cappelaere et al., 2003), aquifer replenishment (Favreau et al., 2002) and coupled hydrological/vegetation modelling (Boulain et al., 2005), the HAPEX-Sahel site has naturally become one of the three meso-scale sites of the AMMA observing system. Located between 13°N and 14°N, this Niger "meso-site" is central between the Ouémé Sudanian site (9.5°N-10.5°N) and the dry-sahelian site of Hombori, in Mali (15°N-17.5°N)..

1.2 Needs for a long term observing system

In the context briefly recalled above, there are several key scientific questions that remain to be investigated in order to better understand and predict the variability of the water cycle in the Sahel in relation with climate variability, vegetation change and the overall dynamics of the coupled soil-vegetation-atmosphere system. The two figures provided below illustrate how useful has been the long term monitoring of the period 1990-2002 as well as some key additional questions raised by analysing the data collected over this period.

While the general pattern of the annual rainfall field averaged over several years is well known to be primarily organised along a dominant North to South positive gradient, the annual rainfield of any given year recorded by the CATCH-Niger rain observing system shows no consistency with this general pattern as can be seen in Figure 6.1. The role played by various factors (large scale atmospheric forcing, mesoscale organisation of the convection, including possible feedbacks from the surface, local factors like small scale pattern of vegetation and humidity) in shaping the annual rainfield pattern needs further investigations. The scale relationship between annual rainfield patterns and average internannual patterns is also a puzzling question related to critical water ressources related issues.

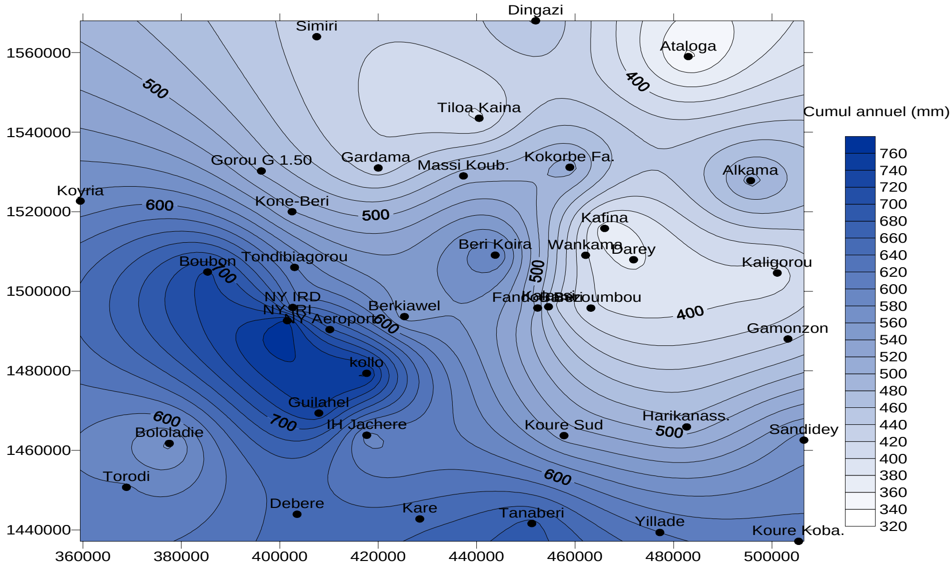


Fig 6.1. The 2005 annual rainfield over the CATCH_Niger area.

In the Niamey area, the unconfined aquifer integrates the changing water balance observed for the past decades. Recent estimates of the groundwater recharge concluded at rates > 20 mm/year, but this figure rely heavily on the poorly known properties of the aquifer (Favreau et al., 2002). While the rise of the water table level is well documented and generalised, the rate of this rising varies significantly from one point to another, as illustrated by Figure 6.2. One question raised by this result is thus whether this is due to changing recharge rates and/or different properties of the unconfined aquifer.

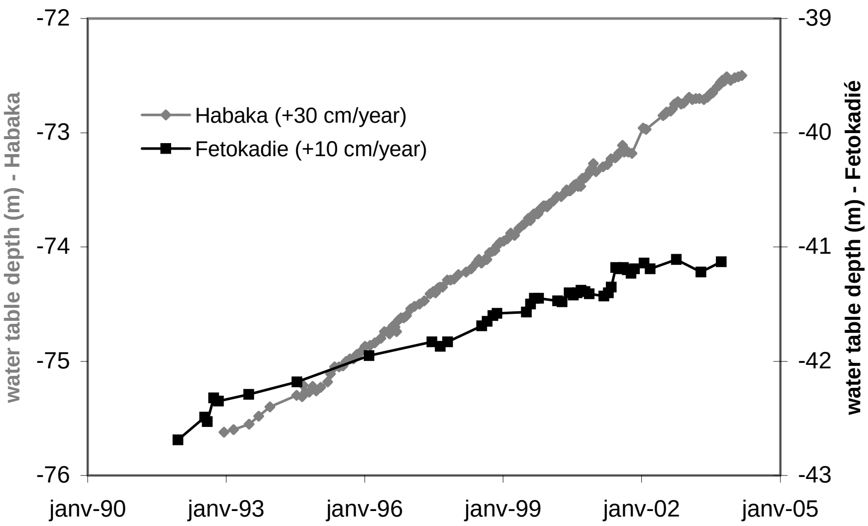


Fig 6.2. Various intensities in water table rises (SW Niger, 1990-2005).

From the two results illustrated above, one may derive several motivations for a continuing monitoring of the Niamey study area, involving of course some adaptation of the observing strategy:

- Observations made over the 1990-2000 period showed the great year to year variability of the rainfall regime with a great impact on the water cycle; this variability combines with the decadal scale signal linked to both anthropogenic activities and large scale climate forcing to generate a great variety of seasonal water balance pattern that needs to be studied over a long period.

- New instruments offer the possibility to gain more insight into the processes conditioning the water cycle in the region; thus the AMMA long term period will not be only a continuation of the pre-existing monitoring but rather a real enhancement focusing on some key processes identified from the past monitoring as being pivotal in the understanding of the water cycle variability of the region. Deep infiltration and recharge of the aquifer, on the one hand, coupling of the hydrology with the vegetation dynamics, on the other hand are among the most essential of these key processes.
- Scale issues are far from being fully understood, despite the work carried out on rainfall scale modelling, which means that an adaptated sampling strategy has to be set up.
- Coupled models remain to be developed, and the specificities of the Sahelian environment (as described in the papers cited in the introduction) have to be taken into account in this development; while climate variability has been drastic over the past 50 years, land use changes play a major role in the surface water increase despite the overall rainfall decrease.
- AMMA provides a unique opportunity to combine a short term strategy of high resolution and density sampling with a long term strategy involving water resources, land use and health issues studies.

1.3 Main scientific objectives

- Refining the computation of the local water balance, in order to better balance the change in runoff with reduction of evapotranspiration on the one hand, reduction in soil water holding capacity, on the other hand.
- How much has the water table recharge increased over the past decades in most of endoreic areas ?
- Has the vegetation harvesting a role in the rainfall reduction ? Is it possible to establish a link between rainfall variability and roughness evolution or albedo increase?
- Obtain a data set that will allow to better address the question of the regionalisation of the water balance.
- Address scale related issues, most notably how the water balance changes from increased runoff at the local scale to diminished streamflow over the large river systems of the region.

References

Ali, A., T. Lebel, A. Amani, 2003: Scale invariance of Sahelian rainfields. *J. of Hydrometeorology*, **4(6)**, 996-1011.

Boulain N, Cappelaere B, Séguis L, Gignoux J, Peugeot *C,* 2005. Hydrologic and land use impacts on vegetation growth and NPP at the watershed scale in a semi-arid environment, *Reg. Environ. Change.*

Cappelaere B., Vieux B., Peugeot C., Maia-Bresson A. and Séguis L., 2003. Hydrologic process simulation of a semiarid, endoreic catchment in Sahelian West Niger. 2. Model calibration and uncertainty characterization. *Journal of Hydrology*, **279,** 244-261

Favreau G., Leduc C., Marlin C., Dray M., Taupin J.D., Massault M., Le Gal La Salle C., Babic M, 2002. Estimate of recharge of a rising water table in semiarid Niger from ^{3}H and ^{14}C modelling. *Ground Water* **40(2)**, 144-151.

Lebel, T., A. Diedhiou, H. Laurent, 2003: Seasonal cycle and interannual variability of the Sahelian rainfall at hydrological scales, *J. Geophys. Res.*, **108(D8),** 8389, doi:10.1029

2 Observing strategy

2.1 Overall Strategy

The overall strategy for the SW-Niger meso-site is devised in accordance with the general observational structure of AMMA's field programme, as defined by the AMMA International Science Plan. The LOP monitoring network was built in 2001 largely as the consolidation of pre-existing sets of ground instruments, most of which had previously contributed to the Hapex-Sahel experiment and to the subsequent CATCH program. The LOP network has now become a part of the EOP programme initiated in 2005, taking advantage of a number of new observational components designed to meet the EOP objectives.

While the LOP emphasis was mostly on documenting the interannual variability of the mesoscale land water cycle, the EOP programme aims at investigating land processes at a broader range of scales both in space (from local to meso) and time (from event to seasonal). In addition to a denser space-time sampling of hydrological variables, the monitoring scope is significantly extended during the EOP to include vegetation dynamics and energy budget parameters, in order to capture the major physical and biological processes that are closely associated with the Sahelian water cycle.

As described below (section 2.2), the EOP setup is designed as a spatially-nested structure of sites covering the area-specific hierarchy of scales, including two meso-scale levels (so-called α and β, resp., see below), a super-site, and a few elemental endoreic units, characteristic of the Sahelian local scale. Both point-specific and small-scale integrative measurements are included in the latter. The need for this spatial structure of sites arises from the area's landscape properties, as they control the organization of land processes and the conditions for water budget closure.

This monitoring also aims at building a multi-scale data set to be used in the investigation of the land surface-atmosphere feedbacks. Following the work of Taylor and Lebel, 1998 which is considered to constitute the only empirical evidence of such feedbacks at convective scale in the Sahel, all modelling studies failed to reproduce the persistency patterns of rainfields as observed by the LOP AMMA monitoring of this site. Two requirements stem out of this matter of fact. One is to improve the rainfall monitoring so as to cover a larger spectrum of scales of variability (in this perspective, linking with some SOP measurements – such as the MIT C-band radar, see Chapter 11 – will be of special interest). The second is to study the pattern of vegetations in order to identify factors possibly affecting the triggering or enhancement of convection at convective scale. Some of these factors (roughness for instance) are not obvious to define, least to compute, and one aim of this Task Team is to contribute some methodological advances in this area.

The Niger meso-site also hosts one station of the mineral dust monitoring transect and one station of the IDAF (chemical species emission and deposits) network, which are attached to the TT2a and TT2b sets of instruments, respectively (see Chapters 3 and 4 of this implementation plan).

Other field studies that need to be led in close association with climate, vegetation and water cycle monitoring are included in the TT4 package: this is essentially the case of the health impact studies, (see 2.1.3).

2.1.1 Strategy for hydrologic studies

Here, the general strategy of AMMA mesoscale sites was adapted to the particular context of the Niger site as enunciated above. South-Western Niger is typical of the central Sahel hydrological environment. The long term monitoring (since 1991) of rainfall and water table recharge in this area has shown a very significant modification of the water balance linked to both the drought and the degradation of the vegetation. The enhancement of observations during the EOP aims at further analyzing the processes that couple the various compartments of the hydrologic cycle, and more specifically the interactions between water and vegetation as well as the spatial distribution of groundwater recharge.

The observations strategy takes into account some specific features of the area, mainly the fact that the surface flow is not organized according to the usual tree-like hydrographic structure but as a mosaic of small (a few km² at most) endoreic catchments feeding into ponds or "humid" valley bottoms. Consequently, the hydrological/ vegetation studies are organized following a hierarchy of scales described below in section 2.2.

Following the research carried out in this area over the past 10 years, one major challenge remains to better understand where the water table recharge occurs. To better document the links between the surface and the aquifers, a few experimental catchments will be studied, for the two main configurations of the region:

- Gullies, because very few measurements were made in the past on these elements;
- ponds, to extend the knowledge acquired during 14 years at the Wankama site.

There is a great need for improving the calibration methods allowing the determination of pond areas (by remote sensing) and its evolution during the rainy season and after during the dry season.

One open question is whether the vegetated strips of the tiger bush may also contribute to the recharge of the aquifers. Whereas it is hardly possible to install hydrometric stations in this context, some clue may be obtained through a soil moisture monitoring program. To determine where, how and how quickly does water infiltrate, and eventually, recharge the aquifer depending on the environment, a soil moisture monitoring program started in 2004 and will be enhanced in 2005:

- infiltrometers (Trims type) tests will be made in order to describe topsoil (0-30 cm) hydrodynamics behavior; this is completed by soil physico-chemical analysis;
- soil moisture monitoring: these devices include 8 tensiometers (watermark) and 7 TDR sensors located from 20 to 300 cm depth; the recorder system allows for a continuous monitoring in time;
- Neutron probe tests enable to control soil moisture down to 10-12 meters in order to record deep infiltration below the root system. A specific monitoring of water infiltration around "acacias albida" will be undertaken in order to better apprehend the role of these trees in the water balance;
- A piezometric network will supplement the monitoring system to allow the control of possible water table seasonal fluctuations near the assumed recharge areas.

A side issue tackled by TT4 is erosion. Working both on small endoreic catchments and on larger exoreic tributaries on the right bank of the Niger River, a monitoring program of sediment loads associated with discharge is carried out.

2.1.2 Vegetation monitoring

Vegetation monitoring is carried out as a combination of local measurements of LAI and PAR, to help in the calibration of the vegetation-hydrology model and of calibration campaigns over the Kori de Dantiandou area for satellite validation purposes.

Aerial and satellite data will be used to study the evolution of the vegetation cover over the study area.

2.1.3 Health studies

The malaria prevalence is known to be linked to some environmental parameters as soil moisture, hygrometry, presence of ponds, vegetation, etc. In order to improve our understanding of these links, the observations of both environmental parameters and malaria prevalence will be enhanced.

To that end, a Health/Hydrology program, supported by NOAA, is developed in collaboration with CERMES (a research centre of the Niger Ministry of Health and a member of the Réseau International des Instituts Pasteur and IRD.

The following measurements will be carried out simultaneously in two villages, under two very different micro-climate:

- a set of environmental and micro-climatic data, including rainfall, temperature inside and outside houses, hygrometry and soil moisture in the immediate neighbouring of village population;
- the prevalence of malaria in this two villages, based on mosquitoes counting, mosquitoes analyses, population infested by malaria at a given moment, etc
- this device is completed by studies of malaria prevalence in 10 other village in the same area.

The two villages are located respectively:

- in a typical sahelian “wet land”, a “bas fond” characterized by a dense vegetation due to permanent high soil moisture and recently by appearance of water table due to its rising in endoreic areas; therefore, permanent ponds arebecoming very common in the Dallol Bosso, surrounding the village of Zindarou;
- in a valley of the plateaux area, a more spread configuration; despite the rise in water table, these areas remain dry areas with ponds increasing in number and in extension due to enhancement of runoff caused by natural vegetation removing. The village of Banizoumbou is typical of this configuration.
- Ten other villages are monitored more slightly with malaria prevalence observation.

2.2 Experimental sites covering the hierarchy of scales

- At the mesoscale α, one site is the support of continued and refined studies on the interannual and intraseasonal variability of rainfall the focus being on the documentation of convective structures. This site is a 16 000 km² rectangle (Niamey meso-site denoted N in the table below), over which the present raingauge network of 34 raingauges will be densified locally to allow for a better documentation of the local rainfall variability. The second site partially overlaps the Niamey meso-site (see map). It is named *Kori de Dantiandou* Basin (Nkd, 5645 km²). In order to control the lateral exchange terms, the boundaries were defined from the geometry of the aquifer (see map). This study area thus exceeds the limits of the original 16 000 km² HAPEX-Sahel rectangle, and forms a consistent hydrological entity allowing for a study of the water balance closure. The *Kori de Dantiandou* Basin is however too large for determining precisely all the terms of the water balance equation, especially since the topography is not accurately known. Hence, a smaller meso-scale area was defined. Runoff, soil water content, infiltration and evapotranspiration must be studied at smaller scale to enable an appropriate modelling.

Name	Location	Description
Niamey meso-site (N)	13°-14°N; 1.6°-3°E 16000 km²	The survey of the wrongly-called “Niamey square degree” (~1.5 squ.°) started in 1990. Heavy observations in 1992, monitoring from 1994 to 2002, densification starting again in 2003. Sahelian climate with semi-arid vegetation (Millet crops, Tiger bush, …). Long series of high resolution rain data and groundwater levels.
Kori de Dantiandou Basin (Nkd)	2°15-2°57E ; 13°15’-14°15’N; 5500 km²	Kori de Dantiandou (KD) and adjacent areas. Dry vegetation cover. Land surface process studies, hydrological modelling, coupling with the sub-surface and the atmosphere. Rainfall vs vegetation spatial relationship, at the local scale.

- At the mesoscale β, a composite of endoreic areas covering 1760 km² (Nc, Niger Central Super Site; that means the Dantiandou Basin Central Area) was chosen to compute a more comprehensive and accurate water budget. This smaller area enables the providing of regular land use maps allowing the modelling of vegetation/hydrology interactions and the evolution of water balance due to land use current changes. On this site denser measurements of the various terms of the water balance will be performed. The computation of water budgets on this super-site requires the estimation of lateral groundwater flows along the site boundaries, which can be obtained through aquifer modelling performed over the Nkd meso-scale site. Hydrology will be coupled with vegetation and its evolution using the abc-rwf model.

Name	Location	Description
Niger Central Super Site (Nc)	2°20'-2°49'E; 13°30'-13°52'N, 1760 km²	Subset of endoreic catchments representing core part of Nkd, with a denser rain gauges network and concentration of pool, runoff, soil moisture and flux measurements. The objective is to obtain a more precise assessment of the water balance and to test the hydrological model using the modeling over Nkd to set the outer boundary condition (aquifer).

- At the local scale, 5 intensive sites – elementary endoreic units or fractions of such units – were selected to study basic processes such as infiltration and evapotranspiration, based on flux stations and runoff plots. These 5 sites are representing the various typical situations in the super-site landscape. The main aims are to validate at this elementary scale a coupled vegetation/hydrology model and to describe the processes of changes in water and sediment budget due to land use evolution, at the plot and at the small basin scales.

-

Name	Location	Description
Wankama endoreic system (Ncw)	2°39'E; 13°39'N; 2 km²	Typical endoreic system, with full plateau -to- kori-bottom toposequence, including largely cultivated catchment, sandy hydrographic network (ravine, mid-catchment spreading zone, alluvial fan), and kori pond. Comprehensive hydrologic and vegetation process analyses: overland runoff, hydrographic network losses, groundwater recharge, soil moisture, evapotranspiration, crop and fallow vegetation dynamics.
Tondi Kiboro small catchment *including* Sofia Bangou	2°42'E; 13°33'N; <1 km² 2°43'E, 13°32'N, 0.1 km²	Upland small catchment, along ravine running down from plateau to spreading zone. Previous hydrometric record (1993-1994) allows for investigation of changes in runoff due to severe land degradation. Analysis of channel losses. Plateau pond and tiger bush
Kafina endoreic system	2°44'E; 13°44'N; ~1 km²	Upland endoreic catchment with pool
Banizoumbou	2°40'E; 13°32'N	Meteo. and aerosol stations + pond. Malaria/Hydrology program WP 3-4
Zindarou	2°55' E; 13°26'N	Malaria /Hydrology program WP 3-4

- At the boundary between meso and local scale, an intensive network of 66 rain gauges is installed near Banizoumbou : 6 lines of 11 raingauges constitute a 10 km X 10 km square slightly faced to E-N-E (N70°) in order to be perpendicular to squall lines. Each day, two observers are reading the information of quantity of rain fault in the past 24 h. This long term study area will be used for the study of vegetation feed back on rainfall.
- A "Long Term Bocage" operation is planned to begin in 2006. Linked to the previous network, it consists in the planting (by the peasants) of vegetal hedges on a significant area (some hundreds of km²) in order to avoid or to reduce water and wind erosion and to constitute a "bocage" able to impact the boundary layer and the convection. Both operations (bocage and raingauges network) are linked, one of the aims of the latter being to monitor rainfall during some decades (20 years at least) to record possible differences in rainfall behaviour according to the surfaceUse of Satellite data in the modelling strategy

2.3 Use of Satellite data in the modelling strategy

Land surface models coupling the dominant vegetation and hydrology processes in this area are being developed and applied at the various levels of the scale hierarchy described above. While at the smaller scales land modeling mainly relies on field-collected inputs, the super-site and meso -scales require remotely sensed data for model operation.

Specifically, the various information layers that need to be produced, essentially from satellite data, are as follows:

- year-by-year land-use/land-cover maps; given the dominant crop/fallow rotating practice in this largely cultivated area, it is necessary to yearly update this essential information layer that controls a large number of land cover -related parameters of the vegetation and hydrologic models;
- seasonal dynamics of vegetation development, essentially through LAI-related indices over each EOP season; this input will be used as the major validation source for the modelled vegetation dynamics; a 2-week time step is considered to be adequate for this purpose;
- seasonal dynamics of accumulated surface waters; if such information can be produced with sufficient reliability and completeness, it can be used as a very effective validation input to the surface hydrology model component; again a 2-week time step appears as being an acceptable compromise between field variability and acquisition costs;
- soil surface moisture maps; distributed soil moisture information can be very valuable for the hydrologic model component, as it can be used to control the runoff/infiltration process over the simulated domain; assimilation procedures ought to be developed to do so, for the various simulation modes that are being operated in the area, ie., from simplest to most complex: anterior precipitation index, simple energy budget, full SVAT model (Sisvat). Expected frequency is similar to that of two previous layers. Remotely-sensed soil moisture data could provide a very convenient means to partly compensate for the lack of high spatial resolution maps of rainfall inputs over the simulation domain, thereby reducing uncertainties in all simulated state variables of the vegetation and hydrology models.

3 Deployment

3.1 Instruments and related detailed observation program

3.1.1 Hydrology:

The hydrological EOP measurements on the SW-Niger mesoscale site mostly constitute a denser sampling in space and time of the water cycle and related processes. It is based on the LOP monitoring carried out since 2001 (and earlier for rainfall, local runoff and aquifer recharge) and described in ST1 (*LOP monitoring*). The emphasis is on the documentation of the seasonal cycle and its variability (in space; inter-annual, and intra-seasonal for some processes). More specifically the objectives in term of process studies and modeling are the following:

- Investigating small scale variability of certain variables: rainfall (instruments CE.Rain_Nc and CL.Rain_N); soil moisture (instruments CE.SW_Nc and CE.SWsan_Nc), runoff (instruments CE.Run_Nc and CE.Pond_Nc), erosion ( ), PE (instruments AE.Flux_Ncw, AE.Flux_Nc, and AL.Met_Nc), aquifer recharge (CE.Gwat_Nc and CL.Gwat_N) and their impact on the water budgets at larger scale.
- Joint modeling of surface hydrology and aquifer recharge at the mesoscale (Kori de Dantiandou, see list of sites) in order to cross-constrain the transient hydrological balance at the observation scale.
- Investigating the surface feedback effects on rainfall will make use of a specific rainfall monitoring network designed to cover scales of variability not well documented by the LOP monitoring network (see Figure 6-3).

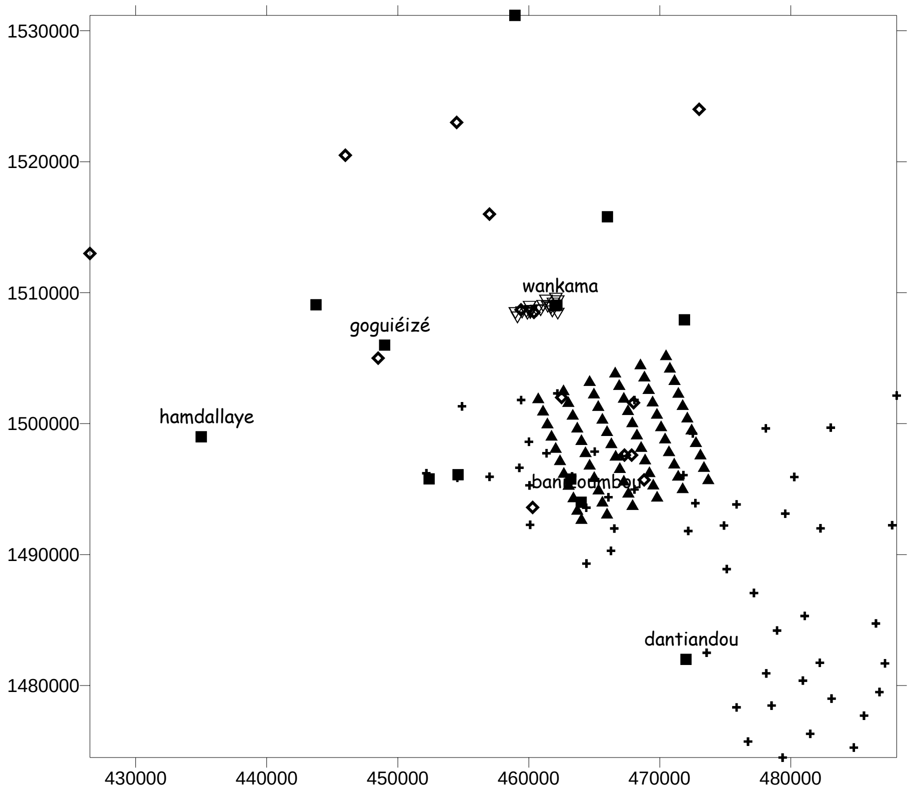


Figure 6-3 : rainfall measurement through embedded networks covering a 50x50 km² area.

- Investigating the role of vegetation in runoff, infiltration, soil moisture and aquifer recharge/discharge. Here the objective will consist in further constraining the hydro(geo)logical balance, combining new methods (mostly geophysics) with the long-term piezometric surveys (Fig. 1). More precisely, for groundwater recharge, the long term chronicles bring information of fundamental importance that will be combined (i) with subsurface geophysics (e.g. RMS sounding) in order to decipher the cause for changing water table rise intensities (equivalent to the apparent annual excess of recharge) and therefore (ii) better constrain the current water table balance, both at the seasonal and decennial scale. At some sites (<1 km²), data and information obtained by various methods (eg groundwater temperature and piezometric monitorings, surface water balance, transient RMS sounding, DC investigations) will be incorporated in a single transient groundwater modelling (1993-present) in order to better constrain the long-term water table balance computed for the whole mesoscale (Favreau et al., 2002).

3.1.2 Vegetation.

The vegetation monitoring consists of:

1) Vegetation will be assessed in all experimental sites as cited in Introduction (Wankama, Tondi Kiboro, Koma koukou): current situation mapping, historical inventory (aerial pictures, IGNN and Corona, satellite files, “Pixy” inventories (Pixy is a small flying device conceived by IRD (Asseline et al., 1998). In all observation season (2005-2006 and 2007), a complete inventory of experimental site will be realized: density of vegetation, evolution intra- and inter-seasonal, on cultivated as well as in natural areas. This will made with the support of colleagues of UAM (Faculty of Biology and Geography). The specific evolution of millet is monitored since 2004 season by the partnership of Cirad and Agrhymet in 11 villages of the square degree, 3 of

them located in the Central Site. This monitoring has been deployed since Dec. 2003 when a first field calibration was realized in order to plan a “land cover mapping” in course (now almost achieved) at CETP laboratory. Another calibration was carried out in October 2005. Methodologies based on optical satellite data classification allow a land cover mapping since 1986 (1986, 1990, 1991, 1992, 1994, 1996, 2003, 2004). This will be continued until the end of EOP and possibly until the end of LOP.

2) At Wankama basin site, a specific study of vegetation is carried out by Nicolas Boulain of HSM-Montpellier. In fallow and millet plots, the parameters for the Treegrass model are measured. It consists in a complete follow-up of phenologic, allometric and photosynthetic characteristics, including vegetation density, biomass and foliar index for shrubs, millet and herbaceous layer throughout the vegetation season. Specifically, parameters measured for all vegetation layers are: density, cover, height, phenology, biomass, foliar area, LAI, photosynthetic parameters, and roots. Crown area and plant diameter are also measured for shrubs and millet, and herbaceous species are identified over time. This is a EOP monitoring, funded from 2004 to 2007.
3) Roselt partners are managing since the beginning of the 1990’s a set of 10 enclosed plots where vegetation is assessed in density and quality 2 times a year (once during rainy season, once during dry season); this will be continued on a long period, with specific funding of the *Observatoire du Sahara et du Sahel* (OSS).
4) ICRISAT team driven by Bruno Gérard (partners of AMMA TT4) is carrying out a heavy GIS on the Fakara (including Banizoumbou area) for twelve years: land use is monitored from the beginning of the 1990’s and previous pictures show the strong evolution of land use land cover in the last half century. This will be continued as a long term monitoring, with specific funding of ICRISAT and Belgian cooperation program.
5) Field measurements of soil moisture are processed since the rainy season 2004 in 5 villages (4 to 6 sites per village, on different land uses); soil water content is measured at each sampling. This inventory is made each time that ENVISAT satellite is acquiring a radar image in the Central site area. Thus, a vegetation calibration could be made in the same time with few additional time and inversion. This will be continued until the end of EOP.
6) On the Wankama basin, 3 *acacia albida* (gaos) sites will be equipped with soil water content sensors, and with tree-growth sensors and neutron probe access tubes: one in a millet field, another is a fallow and the last one near the pond.

A number of image series are available to build an evolving GIS: aerial pictures of 1950, 1975 and 1992 (IGN and IGNN), Corona (USA) pictures of 1965, Landsat and SPOT satellite products since the 1980’s, and since 2002, MODIS data (resolution :5m X 5 m, locally 1m X 1m).

Updating the 1992 vegetation map over the 1°x1° HAPEX square to quantify the vegetation change and its impact on the water cycle is the first priority. A second priority is to produce maps for older periods. These maps are needed to better understand how the vegetation change influenced the hydrology of the region over the past 50-60 years.

Other tasks to achieve are:

- Analysing the seasonal cycle of the vegetation – focusing on millet, fallow trees – in interaction with water constraints.

- Providing a re-parameterisation of the Treegrass model (initially developed for humid tropical eco-systems) and upscaling towards a larger scale model (Tgpix) (instrument CE.Veget_Ncw).
- Investigating the influence of land use changes in water cycle evolution based on farm surveys over the 1°x1° square to validate the SARRA_H crop simulation model for regional yield forecasting and climate change impact studies.
- Determine and analyse the special role of Acacia Albida in the water balance, particularly in the water content of soil and sub soil and the recharge of aquifer;

3.1.3 Health Studies.

Sampling effort will be concentrated on malaria vectors both on aquatic stages and adult mosquitoes. Previous data show good relevance of insecticide house-spraying method rather than classical CDC- light traps. Aquatic stages will be evaluated either by eye-directed rapid sampling or by dipp-in or aquatic net in cases of large breeding sites.

All samples will be recorded in a GIS and all sampling sites will be GPS marked. Environment (temperature, rainfall, humidity of soil and air) will be studied by automatic apparatus for fine steps timing periods. Follow-up of ponds will be made by the Niamey's hydrology team.

Experience in satellite data image analyzing in the CERMES will be used to study environmental spatial factors.

The experiment consists in equipping two very different villages with in each one, the following devices:

- Hydrology : (automatic monitoring system)
  - 4 Atmospheric temperature sensors
  - 4 Soil moisture sensors
- Health :
  - an insect detector
  - an infra red light source

An OFIDIS analysis software would allow to document the mosquitoes population in real time all year long. This is completed by other sampling in 10 more villages, in order to verify significance of the two instrumented ones.

3.1.4 Validation of aircraft and remote sensing measurement.

This mostly consists in a site documentation in preparation of the SOP campaigns (TT8, TT9).

- Satellite validation:

- radar (ASAR ENVISAT): during the rainy season 2004, 8 measurements campaigns were made to validate with this new sensor sensitive to soil moisture; 5 villages, with 6 observations points in each one (in different land use) : 10 measurements (Thetaprobe) and 2 gravimetric water content measures at each point. This operation has been continued during 2005 rainy season with a large number of ASAR acquisitions.
- SPOT/HRV: High resolution optical data are used to monitor land use. Different archived optical data are used to analyze change in land cover in the last decennials. The map is actualized each year since 2003…
- 2005 to 2007: Ground truth validation will continue simultaneously to satellite acquisitions. It concerns soil moisture measurements and annual actualization of land cover map. A large number of optical (SPOT/HRV) and radar ASAR data are programmed during this period.

- a pool mapping methodology is developed, allowing a monitoring of pool number and sizes for different SPOT optical data acquisitions (in 1986, 1990, 1991, 1992, 1994, 1996, 2003, 2004); this needs validation.

3.2 List of instruments

Table 01 TT4 List of Instruments

Code	Name of Instr.	PI Name	Description of the instrument	Status of Deployment	Site
LF17	CL.Rain_N	Thierry Lebel	30 recording raingauge network	Deployed since 1990	N
LF20	CE.Pond_Nc	B. Cappelaere	6 recording level in ponds network	Deployed since 2000	Nc
LF24	CL.Gwat_N	B Cappelaere	Level recorders in wells (aquifer)	Deployed since 1996	N
EF18	CE.Rain_Nc	Luc Descroix	15 recording raingauge network	Deployed in April 2005	Nc
EF19	CE.Run_Nc	Luc Descroix	Network of 6 recording streamgauges	Deployed in April 2004	Nc
EF20	CE.Gwat_Nc	Luc Descroix	Level recorders, 12 drilled boreholes	6 Deployed from 2000 to 2002; 3 installed in 2004; 3 to be installed in 2006	N
EF21	CE.SW_Nc	B. Cappelaere	4 sites Watermark and TDR	1 installed in July 2004; 3 in July 2005	Nc
EF22	CE.SWsan_Nc	Luc Descroix	Soil water neutron probe	34 Holes drilled in Dec 2004; 10 in 2005-06	Nc
EF23	CE.Veget_Ncw	Nicolas Boulain	Leaf index and gaz exchange meas.[t]	Instrument deployed in 2005	Ncw
EF34	CE.VegIso_Ncw	J. Gignoux	Isotopic analize of water[t]	Beginning in June 2005	Ncw
EA27	CE.Ero_Ncw	I. Bouzou	Erosion measure on plots and catchment	1 site in 2004; 2 sites in 2005 and following	Ncwb
LF2	AL.Met_Nc	Luc Descroix	Campbell Met. Station	Deployed in July 2004	Ncb
LA27	CL.Rain_Nc	Luc Descroix	Local scale rain gauges network	33 deployed in 2005, 33 more in 2006	Ncb
LA28	AL.Met_Nc	I.Bouzou	Campbell Met. Station	Deployed in March 2005	Nikoye Torodi

E-Mails addresses of the PIs are given in Appendix (Table xx).

Table 02 List of Instruments related to TT4

Code	Name of Instr.	PI Name	Description of the instrument	Status of Deployment	Site	TT
EF8	AE.Flux_Ncw	B. Cappelaere	2 H2O/CO2 flux stations	Deployed in July 2005	Niamey-Wankama	2a
EE1	AE.Flux_Nc	C. Lloyd / B. Cappelaere	2 HFS flux stations	Deployed in Nov 2005	Niamey SS central	2a
EF30	AE.Dust_ST	Jean-Louis Rajot	Dust monitoring sites	Deployed in June 2005	Banizoumbou and Koma koukou	2b
LF26	CL.Depot_RW	C. Galy-Lacaux	5 stations IDAF (4 avec aethalomètre)	Deployed in 1990	Regional Window	2b
EF1	AE.GPS_1	O. Bock	Niamey GPS station (in a set of 4).	Deployed in March 2005	Niamey airport	1

Table 03 Measurement periodicity

Instrument	**dry season**	**rainy season**
Recording raingauges	Each month	Twice a month
Recording water level in ponds, wells and streams	Each month	Twice a month
Recording soil moisture stations	Each month	Twice a month
Recording meteo station	Each month	Twice a month
Recording flux station	Twice a month	Twice a month
Neutron probe counting	Sept-Jan : Twice a month Jan – May : once a month	after each rainy event and twice a week during one month after the last one
Vegetation density measurement	once at the beginning and once at the end of rainy season	once a month
Health/hydrology devices		mosquitoes sampling once a week in the two experimental villages, once a month in the 10 others

Measurement periodicity

Otherwise, during the rainy event:

- stream flow are regularly sampled in order to document the solid transport.
- Flows are measured in order to calibrate the stream gauge stations

After each rainy event, a series of data are collected:

- rainfall amount in the manual raingauges network
- runoff and solid load transport on plots (10 m²)
- neutron counting is made daily as often as possible.
- Horizontal flux are measured after each event

4 Partnership

List of existing programs:

- Moustapha Amadou (Agrometeorologist at INRAN): influence of vegetation development on aerodynamical roughness ; determination of aquifer recharge areas by neutron probe measurements ;
- Ibrahim Bouzou Moussa (dept of Geography, UAM) and Moustapha Adamou (dept of Agronomy, UAM): characterization and process study (erosion, runoff and infiltration) on the '"bas fonds" areas (valleys bottoms);
- Abdou Guéro and Hassan Adamou (DRE: water resources dept of Niger): geophysical study of the Sama Dey pond area, RMS measurements (subsurface geophysics) for constraining transient groundwater modelling.
- Bruno Gérard (ICRISAT): determination of the contribution of runoff from the plateaux on the degradation of landscape; spatial variability of rainfall;
- Jean Bernard Duchemin (CERMES): (AMMA application project): malaria and hydrology: a case study in 15 villages of the Fakara area.
- Seydou Traore (AGRHYMET). 11 villages identified over the 1°x1° square for the monitoring of the determining factors of millet yield (agricultural practices, phenology, pests, yield components).
- Emmanuèle Gautier, Claude Cosandey and Eric Le Breton (LGP, Paris 1 Univ.): measurement of runoff, erosion and solid transportation at Wankama and Tondi Kiboro sites

A long term partnership is activated with ROSELT (Réseau d'Observation Sahélien de l'Environnement à Long Terme) for the monitoring of the Dantiandou super site and with the DMN (meteorological service of Niger) for rainfall monitoring on the meso-scale site and for upgrading the synoptic network of Niger (12 stations).

b. Training program

The TT4 training program includes:

1) two students from Nigeria are performing their Master, one of both being planed to begin a PhD in September, 2006;
2) two student (one from Nigeria, the other from France) started their PhD in September 2005;
3) two other Nigerian student are planned to start their Master in September 2006;
4) Jean Paul Laurent, from the LTHE, is coming at least once a year in order to enhance capacitation in Neutron probe experimentation and in the Campbell dataloggers functioning;
5) Three local technicians are permanently working in the TT4 team: one of INRAN (Hamissou Alassane) and 2 from the Direction of Ressources en Eau (Boubé and Balkissa Alzouma)

6) Four local students and the TT4 coordinator (LD) will be capacitated in GIS in April 2006 (Arc view) and in may in remote sensing.

5 Organisation of the TT.

5.1 Leaders, core group, membership

	Name	First Name	Institution		Email adress
Task Team lead					
(international	DESCROIX	Luc	IRD/LTHE	Hydrology	Descroix@ird.ne
Coordination)	CAPPELAERE	Bernard	IRD/HSM	Hydrology	cappelaere@msem.univ-montp2.fr
Core Group					
In Niger	RAJOT	Jean Louis	IRD/LISA	Aerosols	rajot@ird.ne
	LEBEL	Thierry	IRD/LTHE	Hydrometeorology	lebel@ird.ne
	BOUZOU MOUSSA	Ibrahim	UAM dep geog	Erosion	ibouzou@uva.ne
	NAZOUMOU	Yahaya	UAM dep geol	Hydrogeology	nazoumou@ird.ne
	MAHAMANE	Ali	UAM dep biol	Biology	mahama@refer.ne
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Members					
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	AMANI	Abou	AGRHYMET	hydrology	amani@sahel.agrhymet.ne
	BAILLEUL	Charlotte	IRD/LTHE/VI	hydrology	bailleul@ird.ne
	RABANIT	Manon	IRD/HSM/VI	flux	rabanit@ird.ne
	ADAMOU	Moustapha	UAM agronomy	hydrology	adamou@refer.ne
	TRAORE	Seydou	AGRHYMET	agronomy	seydou@agrhymet.ne
	ADAMOU	Hassan	DRE	hydrology	dresirba@intnet.ne
	AMBOUTA	JM Karimou	UAM agronomy	geography	pijd@intnet.ne
	FATONDJI	Dougbedji	ICRISAT	Agro-meteorology	d.fatondji@cgiar.org
In France	BARON	Christian	CIRAD	agronomy	christian.baron@cirad.fr
	BOULAIN	Nicolas	IRD/HSM	biology	boulain@msem.univ-montp2.fr
	FAVREAU	Guillaume	IRD/HSM	hydrogeology	guillaume.favreau@msem.univ-montp2
	GIGNOUX	Jacques	ENS Biologie	Biology	gignoux@biologie.ens.fr
	BOUSQUET	Sandie	ENS Biologie	Biology	sbousque@biologie.ens.fr
	MASSUEL	Sylvain	IRD/HSM	Hydrogeology	sylvain.massuel@msem.univ-montp2.f
	ZRIBI	Mehrez	CETP/CNES	Remote sensing	mehrez.zribi@cetp.ipsl.fr
	GAUTIER	Emmanuèle	U Paris 8, CNRS	Fluvial geomorphol	emmanuele.gautier@cnrs-bellevue.fr
	LE BRETON	Eric	U Paris 1	erosion	eric.le-breton@wanadoo.fr
	AMOGU	Okechukwu	IRD/LTHE	Erosion	Okechukwu.Amogu@hmg.inpg.fr
In England	MORSE	Andy	CEH Wallingford	Hydrometeorology	A.P.Morse@LIVERPOOL.AC.UK
In Belgium	GERARD	Bruno	Univ Louvain la N	agrometeorology	b.gerard@cgiar.org

5.2 Internal coordination

A monthly meeting open to all members of TT4 is held in order to plan and monitor the operations related to the field observations and data base issues.

5.3 How are handled requests for new instruments ?

The requests from PIs regarding installation, travels, and all other logistical matters, are now managed by Hachimou Tahirou Bana (tahirou@ird.ne) and Cheikh Kane (citizenkane@ird.ne) at the IRD representation.

5.4 External diffusion of the information and reporting

A report is diffused after each meeting and all information is diffused by e-mail.

http://www.ird.ne/ammanet/ (click on Niger super site !).

6 Coordination with other TTs.

Permanent contact is established with TT3 and TT5, in the framework of the ORE AMMA-CATCH. This includes a permanent collaboration on instruments, data collection and data analysis. One yearly meeting is organized, including a field visit.

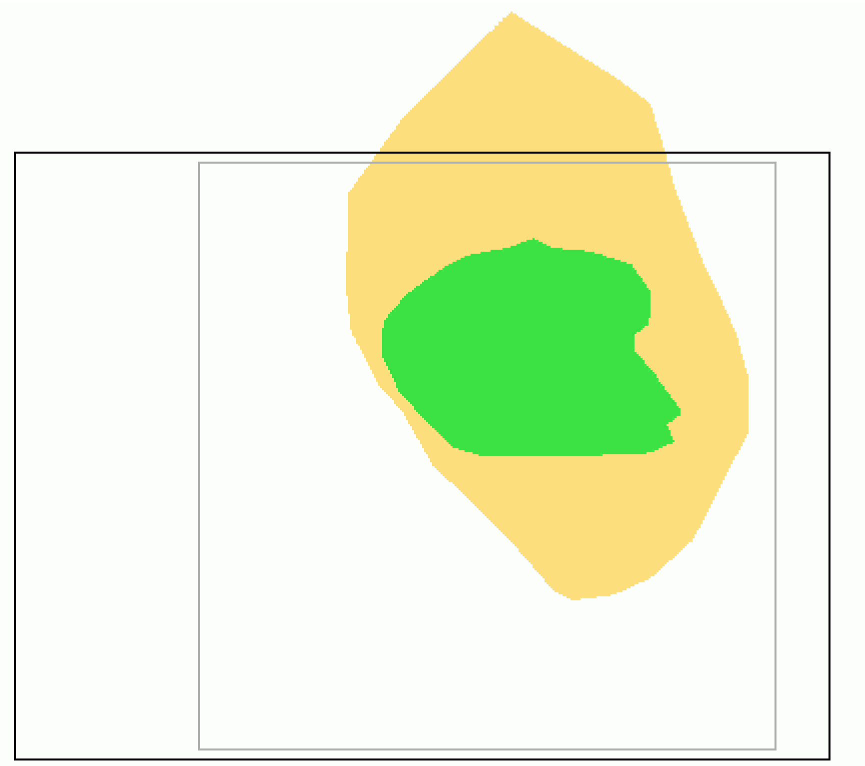
The coordination with TT2a is effective for the installation of instruments and is envisioned for using flux data in hydrological modelling.

Contacts with TT8 are underway to organise ground support for the wet SOP measurements..

Coordination not related to fieldwork will occur through AMMA meetings and workshops.

Appendix1

Maps



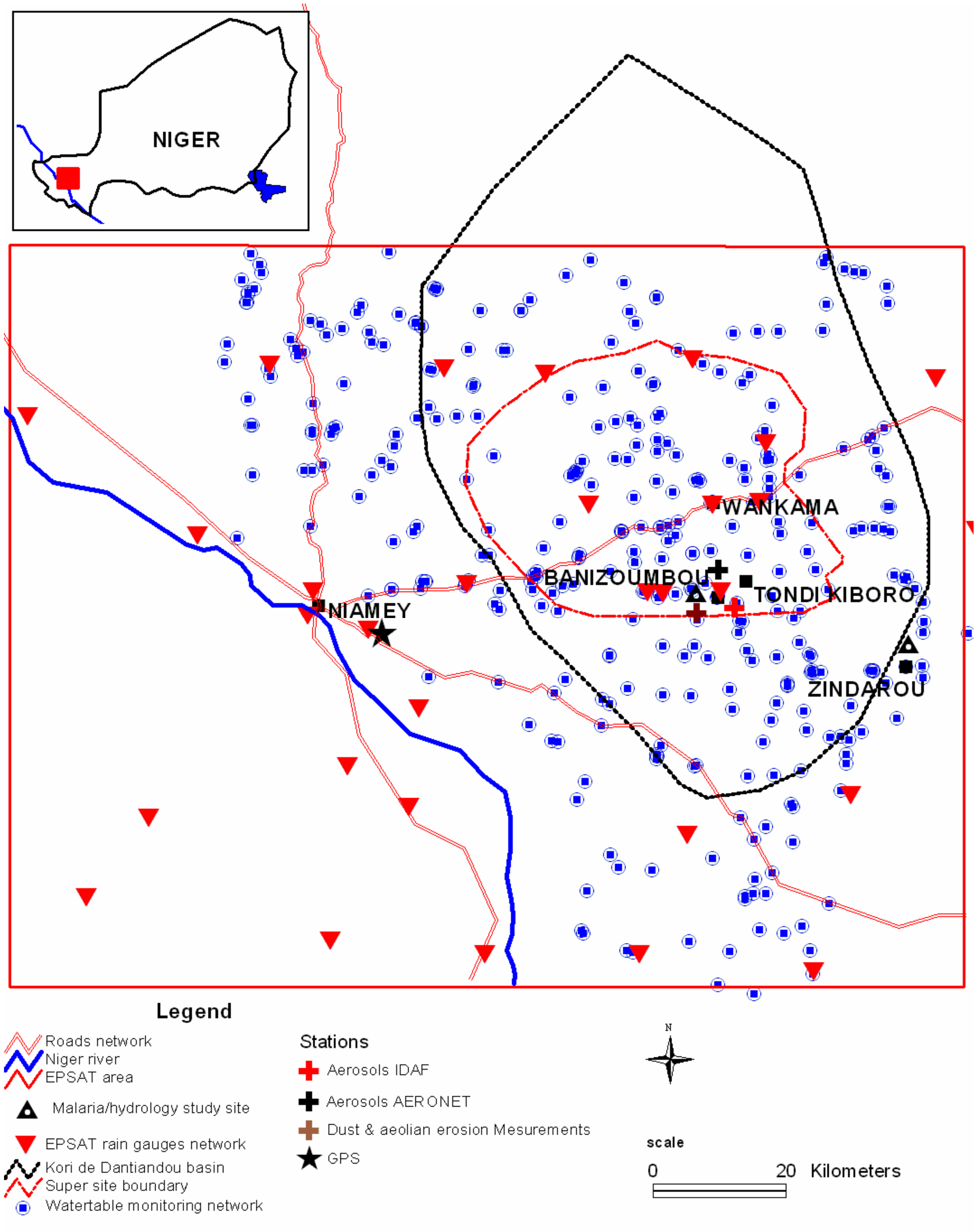
black outer rectangle:
Niamey meso-site (N)

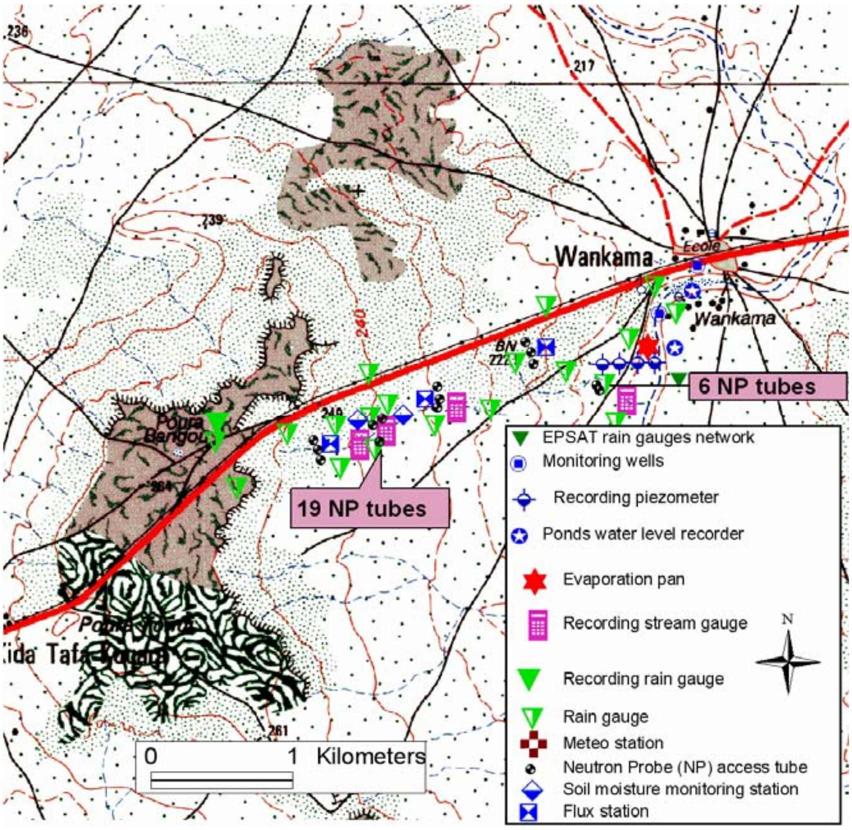
grey square :
Niamey square degree

yellow area : *Kori de Dantiandou* Basin (Nkd)

green area : Niger Central Super Site (Nc)

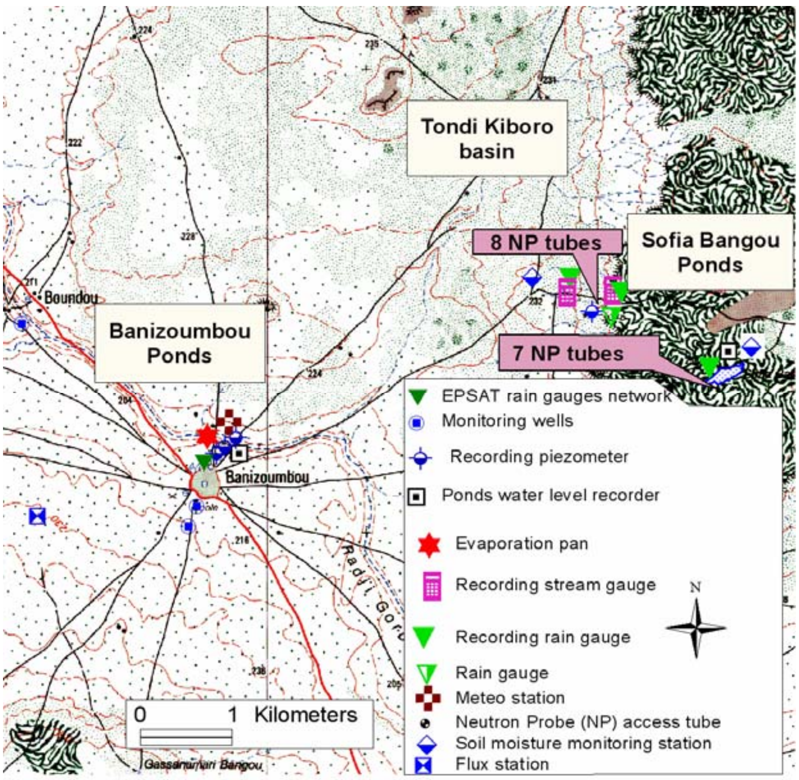
local intensive sites are located within Nc supersite (green)


NIGER
NIAMEY
BANIZOUMBOU
WANKAMA
TONDI KIBORO
ZINDAROU
Legend
Roads network
Niger river
EPSAT area
Malaria/hydrology study site
EPSAT rain gauges network
Kori de Dantiandou basin
Super site boundary
Watertable monitoring network
Stations
Aerosols IDAF
Aerosols AERONET
Dust & aeolian erosion Mesurements
GPS
N
scale
0
20 Kilometers

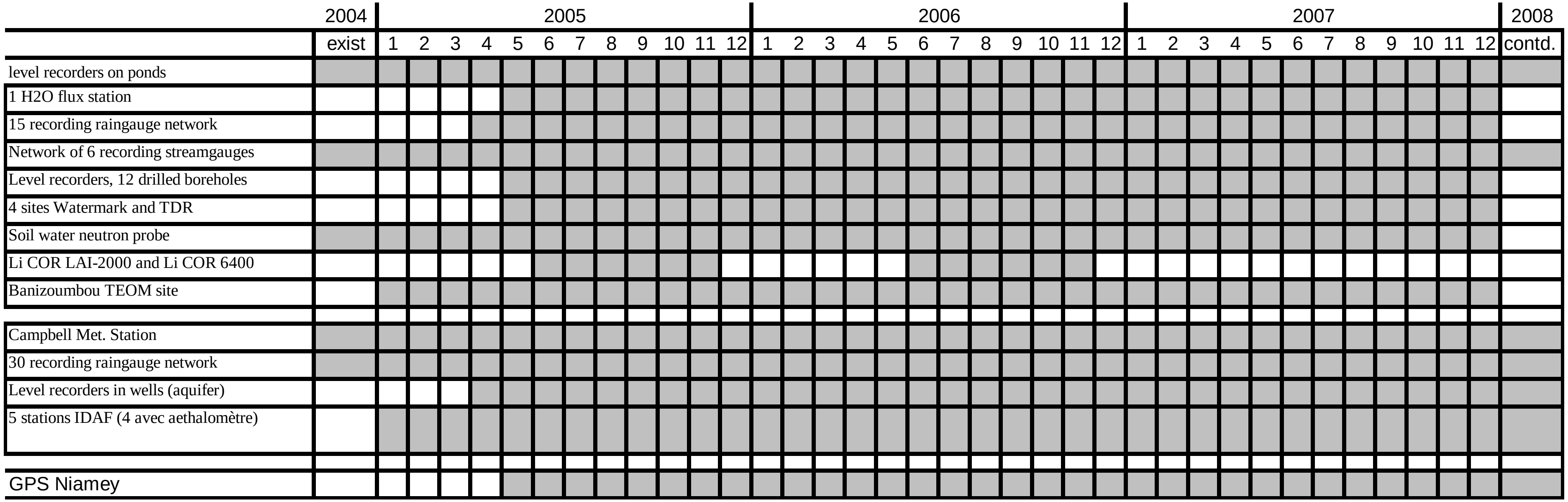


Wankama experimental cathment

Tondi Kiboro experimental catchment



STATUS OF THE FIELD PROGRAM (November 2005)



31 march2006

Chapter 7

EOP integrative studies on the Ouémé meso-scale site

–TT5–

S. Galle, C. Peugeot, A. Borgstedt

1. Scientific justification and objectives

The aim of this document is to present the scientific consistency of the observing strategy on the Ouémé meso-scale site in Benin during the EOP, with respect to the objectives of AMMA detailed on the AMMA-EU and AMMA-API documents, to coordinate instrument deployment and address the associated logistic issues. These aspects are extended to the Cotonou site.

Some aspects are also relevant to Task team 1 (Radio-soundings), 2a (Fluxes), 6 (oceanic campaigns) and 7, 8, 9 (SOP).

Most of the instruments are deployed on the Upper-Ouémé catchment, (14600 km^2, centred on 9,5°N, 2°E), with average yearly rainfall of 1200 mm (one single season).

These instruments document processes in the soudano-sahelian domain of the AMMA experiment.

2. Observing strategy

2.1 Overall strategy

The observing strategy on the Ouémé meso-scale site is based on a multi-scale approach, associating LOP, EOP and some of the SOP instruments. Even if this TT is limited to EOP, some SOP instruments are considered in the observation strategy, when they complement LOP/EOP set-up.

The observing strategy has been conceived for the documentation of:

1) climatic forcing and atmospheric parameters,
2) the continental water cycle, from local to meso scale, and feed backs
3) aerosol and atmospheric chemistry processes.

2.2 Climatic forcing and atmospheric parameters

Spatial and temporal variability of rainfall fields is documented on the long term by a network of 46 automatic raingauges (CL.Rain_O and CL.Rain_Od [1]) operating since 1997 as part of the LOP component of AMMA (labelled as the AMMA-CATCH ORE [2]). In EOP and SOP periods, these data will be of primary importance for most of the instruments, as a quantification of rain inputs to the hydrologic and vegetation systems, and for aerosol deposition and surface emissions.

This network will be improved in EOP and SOP periods with the deployment of two Doppler, polarized meteorological radars: Xport (AE.RadX_O) and RONSARD (AE.Ronsard_Or, SOP). They will provide essential high resolution, 3D description of rainfall events, and contribute to a better estimation of rainfall fields to force hydrological models, as well as to link storm-scale processes to larger dynamical signatures. They are associated with one disdrometer (AE.Dsd_Or), one optical spectro-pluviometer (AE.OSP_Od) and one bi-static receptor (AE.BIST_RADAR). They are completed by a microrain radar (AS_RADK_Od) during SOP. To validate radar rainfall estimations, two raingauge lines (eastwards and north-eastwards), and two high-resolution target made of a series of locally denser raingauges located 12km and 30-km east of Djougou have been designed (see Appendix A1.2).

During EOP two sites bring together a noticeable collection of instruments :

The Djougou site, located downtown, with oil fired power supply bring together atmosphere survey instruments : the Xport Radar, a GPS (AE.GPS_1), a meteorological station (AE.Met_Od), a disdrometer (AE.OSP_Od).

The Nangatchori site will be the SOP supersite for atmospheric column documentation. Located, 10 km SE from Djougou (see Appendix A1.2), it offers a non polluted area with power supply but possible power cut. During the EOP the implemented instruments concerns aerosol, chemistry and flux instrument (AE.Van_O, CL.Depot_RW , see below), a disdrometer (AE.Dsd_Or), the VHF and UHF Profiler (AE.VHF_O). This equipement will be completed during the SOP by a dust impactor (AS.Dust_Od), a lidar-ceilometer (AE.CT25K), a micro-wave temperature and humidity profiler (AE.PROF_T)) a micro-rain radar (AE.RADK_T) to help characterizing the state of the atmospheric column (wind, water vapour profile, integrated water vapour content, cloud bottom height,...) see Appendix A1.2.

The Beninese site contributes, for some instruments, to regional observations systems: the GPS in Djougou is part of a network of two meridian transects: Djougou-Niamey-Gao, operated during the EOP, and Tamale-Ouagadougou-Tombouctou, operated only during the SOP (May-Sept 2006). This network provides continuous (1-hourly) monitoring of total column water vapour in the atmosphere, which is one of the key components of the water cycle.

As well, the Parakou and Cotonou radio-sounding (AE.RS_Q1), in EOP and SOP periods, are part of a West African RS network (see TT 1 “Radiosoundings” document), and complement the documentation of the state of the atmosphere over Ouémé and Benin (Appendix A1.3). Specifically these stations are two of the five RS stations of the quadrilateral window stretching over Nigeria, Benin, Togo, Ghana and Niger, and documenting large scale atmospheric forcing, to help constraining analyses and re-analyses. This quadrilateral is a pilot window, including the upper Ouémé watershed, for integrated surface-atmosphere water budget studies (WP1.2 of AMMA-EU and AMMA-API). Within this network, the combinaison of UHF and VHF in Nangatchori will give an extra point for wind profile .The ozone radio-sounding in

[1] In this section the instrument code is mentioned besides the instrument name for clarity. Refer to Appendix 1 for instrument list and nomenclature.
[2] Observatoire de Recherche en Environnement, French Ministry of Research.

Cotonou (AE.RSO3_O), documents ozone concentration profile up to the troposphere, and contribute to the studies of ozone dynamics in tropical areas.

These instruments and related issues are handled by Task Team 1 (Radio-soundings and GPS).

2.3 Continental water cycle and feed backs

Observation of the continental water cycle is based on a multi-scale (spatial and temporal) approach, associating local sites (transects), super-sites (Donga Watershed) and meso-scale watershed (upper Ouémé basin), and combines long-term (LOP) and enhanced (EOP) observation periods.

Local scale observations are dedicated to elementary processes studies. Detailed measurements of the water cycle components will be performed on three transects (or catena) representative of an increasing part of the woody layer (herbaceous fallow, fallow bush and forest) (see Appendix A1.1). These sites include soil water monitoring stations (*CE.SW_Odc*), piezometers (*CE.GWat_Odc*), runoff on small gullies (*CE.Run_Odc*), vegetation monitoring (*CE.Veg_Odc*) and fluxes stations (*AE.Flux_Odc*).

The three fluxes stations are also part of a regional network documenting the meridian gradient of decreasing rainfall from south Benin (one station), upper Ouéme (four stations), the Niger Site (four stations), and the Gourma site (four stations).

As well, superficial geophysical surveys with electric soundings (*CC.Geophy_Odc)* or Protons Magnetic Resonance (*CC.RMP_Odc*) will document the geometry of the sub-surface reservoir, and the piezometric level fluctuations in relation with the river discharge. Chemical composition of surface, subsurface, and ground water on transects will be analysed (*CE.WChem_Odc*), and compared to chemical composition of water in river to determine water origins, flow paths and transfer time.

A particular effort is made on the observation of the feed-back term of the water cycle (evapo-transpiration), with the deployment of a flux station (*AE.Flux_Odc*) on each transect (one additional is associated to the mobile laboratory) and one infra-red scintillometer (*CC.Scintill_Od*) on the fallow site. The strategy is to locally document the fluxes dynamic in relation with the evolution of vegetation and the hydric resource, and to find spatial integration method on a limited area using the scintillometer. Larger up-scaling of fluxes is foreseen using satellite-derived images, and -if relevant- airborne fluxes measurements during SOP.

The local-scale observation strategy is adapted to the super-site scale (Donga catchment), with the documentation river runoff (*CL.Run_Od*), water table levels (*CL.GWat_Od*) and water chemical composition in wells, boreholes and river (*CL.GWat_Od*) and flux stations (*AE.SHFlux_Odc* and *AE.H2OFlux_Odc*). These data, associated to knowledge and processes captured at local scale, will be used in a hydrologic modelling framework to test and validate water cycle processes, characterize the water cycle compartments and quantify the water balance components, at intra-seasonal to inter-annual time scales.

The Aguima catchment, located south of the upper-Ouémé meso-scale site (see Appendix A1.3), is been intensively surveyed by the German project IMPETUS[3], to document meteorological, hydrologic and environmental processes. Collaborations and data sharing agreements have been developed with this project,

[3] IMPETUS is not formally associated with AMMA, but a few of IMPETUS teams are also involved in the AMMA European Project.

and this site can be considered as a secondary super-site, on a geologically contrasted area, as compared to the Donga basin.

The previous observation strategy is also transposed at the meso-scale, with observations of river flow on 20 stations (*CL.Run_O*), water table levels (*CL.GWat_O*), and chemical composition of water in rivers (*CE.WatChem_O*). As the large basin integrates contributions from various geological areas and spatial variability of rainfall, the chemical signature of water helps understanding the flow paths and transfer time at the meso-scale. Based on processes identified at the super-site scale, meso-scale hydrologic data combined with satellite-derived vegetation maps (land cover, LAI dynamics) will be used in a modelling framework to validate the continental water cycle processes and calculate the water budget components. These efforts contribute to water budget studies (WP 1.2).

2.4 Aerosol and atmospheric chemistry processes

As a component of the aerosol and atmospheric chemistry part of the AMMA experiment, a series of instruments (formerly part of the mobile laboratory of Laboratoire d'Aérologie, Toulouse, France) will be deployed as from march 2005. For convenience they are all included in the unique instrument *AE.Van_Od*. They will be deployed in the Nangatchori site, 10 km SE from Djougou (see Appendix A1.2). The objectives are:

- to gather a precise documentation on biogenic emissions (processes and seasonal variability). This will be done through the development of a methodology allowing for a better quantification of the different types of emissions. Modules of biogenic emissions and deposition of reactive trace gases (NOx, COV, O3) will be developed and validated directly through field experiments. These modules will eventually be integrated in chemistry-climate interaction models focused on the West-African region.

- to build and emission inventories of biogenic sources (NOx, COV), biomass combustions (savannah and domestic fires) and urban sources with a spatial and temporal resolution adapted to the chemistry-climate models

- to link existing networks and observatories with ground-based data obtained in Djougou to study inter-annual and seasonal variations of combustion tracers (BC, CO) and aerosols optical properties. Later, this work will be used to build a 3D data base over two years for assimilation and validation in regional and global models. These models will help to conduct regional studies (like deposition-transport of aerosol impact and processes-Meso-NH-Chimie, and seasonal scale studies-RegCM), as well as large scale studies (TM4, MOCAGE). Models will be used to constrain emission inventories and study the species redistribution influenced by the main dynamical phenomena (convection, transport) associated to the monsoon, and study their impact on the chemistry and climate.

To document dry and wet deposition, as well as aerosol composition, an IDAF station (*CL.Depot_RW*) and dust impactors (*AS.Dust_Od*), will be deployed on the Nangatchori site. Incidentally, chemical analyses of rainfall water produced for IDAF studies will be also used to detect noise in chemical tracing of flow paths (see hydrology section above) due to unexpected atmospheric inputs in river water.

This setup is complemented by a sun photometer (*CL.Photometer*) of the PHOTON-AERONET network, deployed 7 km N from Djougou since January 2003.

Together with AMMA-CATCH, IDAF and PHOTON-AERONET (labelled as OREs) observing systems are part of the LOP component of AMMA.

2.5 Modelling and satellite observations

These instruments provide data for calibration, validation and data assimilation in atmospheric, hydrologic and chemistry models, as well as validation data for satellite products (vegetation cover , fluxes). Refer to AMMA documents for more details.

A particular need concerns the estimation of annual land cover maps, intraseasonal LAI (or NDVI) dynamics of the different land cover of the basin, and the large scale fluxes (evapotranspiration) from local tower and scintillometer measurements, and satellite images, using models.

2.6 List of sites, instruments and relevant maps

Site maps and LOP/EOP instrument location are given in Appendix 1 : Local scale A1.1, super-site A1.2, meso-scale site A1.3. SOP instruments are mentioned for information on the meso-scale map in A1.4.

The full list of instruments is provided in Appendix 2. Some SOP instruments are considered, when they complement the LOP/EOP and campaigns set-up (ex. RONSARD Radar).

The coordinates of the main instruments and/or sites are in Appendix 4.

2.7 Priorities

Most of the instruments cited in this document have secured funding from either French-API or EU (or other sources). There is therefore no need to attribute priorities among them, except in case of competition for funds.

Some instruments, **of significant interest**, are not funded:

- Geophysical Surveys (*CC.Geophy_O*) **Priority 1**
- Magnetic Proton Resonance (*CC.RMP_O*) **Priority 2**

Concerning the risk issue, no particular aspect is to be mentioned, except unexpected delays in material shipping, which may delay field deployment. These risks are normally anticipated by instruments PI's by early shipping.

The political situation in Benin has been very stable for years. Next presidential elections will be held in March 2006. In principle, this political event gives no cause for concern for the course of the experiment.

3 Deployment

Deployment, operation and maintenance of these instruments imply a number of logistical constraints, detailed below.

3.1 Planning

The periods of deployment of the various EOP and LOP instruments is foreseen following the planning given in Table 1a, next page, the related SOP instrument are indicated Table 1.b

The set-up, operation and maintenance of these instruments require regular mission in the field, either for people permanently in Benin (IRD teams and Beninese partners) or people coming in mission for a limited stay. A planning of missions reviewed by instrument PI is presented in Table 2 for 2005 and 2006.

The deployment and operation programs shown in the tables below impose a number of logistical needs: human resources, buildings, vehicles, and communications.

Table 1a. Planning of EOP and LOP instrument deployment

Sheet #	Inst. Code	Description	PI
EF2	AE.RadX_O	Radar Xport	√
EF3	AE.Dsd_ Or	Disdrometer	√
SF02	AS.Ronsard_O	Radar Ronsard	
SE10	AS.BISTat_Od	Bi-static radar	√
LF18	CL.Rain_0	30 recording raingauges	√
LF19	CL.Rain_Od	18 recording raingauges	√
LF21	CL.Run_O	14 recording streamgauge	√
LF22	CL.Run_Od	6 recording streamgauges	√
LF23	CL.ADCP_O	ADCP	√
LF25	CL.Gwat_Od	21 surveyed wells	√
LF26	CL.Depot_RW	1 IDAF station	
LF3	AL.Met_Od	Meteo Station Campbell	√
L-	CL.Photometer	photometer	
EE1	AE.RS_Q1	2 RS Stations	
EB3/EF9	AE.H2OFlux_Od	1 H2O flux stations	
LE2/LF9	AE.SHFlux_Od	2 SH flux stations	√
EB4	AE.H2OFlux_Po	1 H2O flux station	
EF1	AE.GPS_1	1 GPS station in Djougou	
EF10	AE.scintil_Od	Scintillometer	√
EF24	CE.Run_Odc	runoff on 1 transects: Nalohou	√
EF25	CE.WChem_O	surf/ground water chem. Anal.	√
EF26	CE.WChem_Od	surf/ground water chem. Anal.	√
EF27	CE.Gwat_Odc	Network of 27 piezometers	√
EF28	CE.SW_Odc	9 SW stations	√
EF29	CE.Veg_Odc	vegetation surveys	√
EF31	AE.RSO3_Od	Ozone radiosoundings	√
EF33	AE.VAN_Od	Labo Van + aérodynamique	
EF4	AE.OSP_Od	Opt, Spectro Pluviometer	
EF5	AE.VHF_O	Radar ST	√
CF?	CC.RMP_Odc	RMP surveys	
CF1	CC.Geophy_Odc	geophysical surveys	

instrument deployment   not funded   delayed   updated 20/01/06

Table 1b. Related instruments (tentative)

Instruments SOP

			2004	2005												2006												2007												2008	ok P
Sheet #	**Inst. Code**	**Description**	exist	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	contd.	
SE11	AS.lightning_O	lightning detectors																																							
SE12	AS.PROF_O	Microwave Profiler																																							√
SE6	AS.CT25K_Od	Lidar Ceilometer																																							√
SE9	AS.RADK_Od	Micro Rain Radar																																							√
SF12	AS.Dust_Od	Atm. deposition																																							√
S-	AS.GPS_1	1 GPS station in Djougou																																							
S-	AS.BVC_T2	Ballon Volume Constant																																							
SE1	AS.RS_1	5 P1 RS stations (Cotonou, Parakou, Niamey, Tamale, Abuja)																																							
SE2	AS.RS_2	4 P1_EOP RS stations (Parakou, Agadez, Tombouctou, Niamey), 2 P1_SOP (Tahoua, Ouaga) and 2 P2 (Birni, Kano)																																							
SE10	AS.BISTAT_Od	Bistat. Radar (Wind field)																																							
SB3	AS.TMS_O	TMS – tube microsampler: temperature and flow controlled adsorption tube sampling for collection of volatile organic compounds.																																							
SF02	AS.Ronsard_O	C-band Doppler polarimetric radar																																							
SF13	AS.RSO3_Od	Radiosondes (PTU and ozone) from Vaisala																																							
SF18	AS.UHF_O	UHF Windprofiler																																							

instrument deployment | not funded | delayed | updated 20/01/06

Table 2a. Planning of missions 2005

2005

EOP			january				february				march				april				mai				june				july				august				sept.				october				nov.				dec.				PI
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
EF2, EF3	AE.RadX_O, AE.Dsd_Or	Radar Xport											2P																																					
EF4	AE.OSP.O	Spectro-pluvio																																																
-	AS.Ronsard_Og	Radar Ronsard														2P																										2P								
	AS.Bist_radar	bi-statique																																																√
EF5	AE.VHF_O	Radar ST								1P																																2P								√
	AE.RADK_T	Micro Rain Radar																															1P																	√
	AE.CT25K	Lidar Ceilometer																															1P																	√
	AE.PROF_T	Microwave Profiler																															1P																	√
LF18, LF 19	CL.Rain_O, CL.Rain_Od	Raingauge network (*)																																																√
LF21, LF22, LF23, EF24	CL.Run_O, CL.Run_O, CL.Run_Odc,	River runoff network (*)																																																√
LF25, EF27	CL.Gwat_Od, CE.Gwat_Odc	Piezometer network (*)																																																√
EF25, EF26	CE.WChem_O, CE.WChem_Od	surf/ground water chem. Anal.																																																√
LF3	AL.Met_Od	Meteo Station (*)																																																√
EF28	CE.SW_Odc	Soil Water stations (*)																																																√
CF1	C_geophy_Odc	Geophysical surveys																																																√
EF29	CE.Veg_Odc	Veget. surveys on transects																																																√
EF33	AE.VAN_Od	Mobile Lab (**)												2P			1P							1P		P/15D+1P/30																								
LF26	CL.Depot_RW	1 IDAF station (**)																								1P																								
SF12	AS.Dust_O	Atm. Deposition																																																√
-	CL.Photometer	sun photometer (*)																																																
EE9, EF9	AE.Flux_Od, AE.Flux_Odc	Flux stations																	1P/8D																							2P/8D								√
CF2	CC.scintil_Od	Scintillometer						1P											1P/8D																							1P/10D								√
EF31	AE.RSO3_Od	Ozone Radio-sounding		1P																																										1P			√
EF1	AE.GPS_1	1 GPS (Djougou)																			2P													2P																
EE1	AE.RS_Q1	2 RS Stations																																																
-	AS.BVC_T2	Ballon Volume Constant																																																

(*) (**) instruments visited simultaneously

field mission for people permanently in Cotonou

field mission for people in mission in Benin (P: # people ; D # days)

to be detailed

Table 2b. Planning of missions 2006

EOP			january	february	march	april	mai	june	july	august	sept.	october	nov.	dec.	PI
EF2, EF3	AE.RadX_O, AE.Dsd_Or	Radar Xport													√
EF4	AE.OSP_O	Spectro pluvio													
	AS.Bist_radar	bi-statique		1P				1P			1P				√
-	AS.Ronsard_Og	Radar Ronsard				4P	2 teams (2x 2P)/120 D				4P				
EF5	AE.VHF_O	Radar ST													
SE6	AE.CT25K	Lidar ceilometer	3P/8d 1P/7d					1P		1P					√
SE9	AE.RADK_T	micro rain radar													√
SE12	AE.PROF_T	microwave profiler													√
LF18, LF 19	CL.Rain_0, CL.Rain_0d	Raingauge network (*)													√
LF21, LF22, LF23, EF24	CL.Run_O, CL.Run_O, CL.Run_Odc, CL.ADCP_O	River runoff network (*)													√
LF25, EF27	CL.Gwat_Od, CE.Gwat_Odc	Piezometer network (*)													√
EF25, EF26	CE.WChem_O, CE.WChem_Od	surf/ground water chem. Anal.													√
LF3	AL.Met_Od	Meteo Station (*)													√
EF28	CE.SW_Odc	Soil Water stations (*)			2P/7D										√
CF1	C_geophy_Odc	Geophysical surveys													
EF29	CE.Veg_Odc	Vegetation surveys on transects													√
EF33	AE.VAN_Od	Mobile Lab (**)	5P/11d 2P/15d					3P/15d	4P/15d	5P/15d					√
SF12	AS.Dust_Od	Atmosph. deposition													√
LF26	CL.Depot_RW	1 IDAF station (**)													
-	CL.Photometer	sun photometer (*)													
EE9, EF9	AE.Flux_Od, AE.Flux_Odc	Flux stations		4P/5d 1P/5d											√
CF2	CC.scintil_Od	Scintillometer													√
EF31	AE.RSO3_Od	Ozone Radio-sounding	1P												√
EF1	AE.GPS_1	1 GPS station (Djougou)					2P						2P		
EE1	AE.RS_Q1	2 RS Stations													
-	AS.BVC_T2	Ballon Volume Constant						1P							

(*) (**) instruments visited simultaneously

field mission for people permanently in Cotonou

field mission for people in mission in Benin (P: # people ; D # days)

to be detailed

3.2 Human resources

3.2.1 IRD Research Team

Permanent IRD staff working for AMMA in Cotonou in December 2005 is 16 persons (6 researchers, 3 engineers, 3 french technicians, 4 local technicians) and 6 students (4 PhD, 2 masters).

3.2.2 Beninese AMMA Operating Center (BAOC)

The Beninese AMMA Operating Center (BAOC) is in charge of administratif and logistic support for AMMA teams, permanently and temporarily in Benin during the EOP and SOP.

The support the BAOC can provide to AMMA teams is :

- Receipt and processing of requests for participating teams (mail, email, fax, phone calls, in French and English)
- Planning of instrument deployment operations
- Support for foreign missions (hotel, travel, vehicles booking)
- Support for field missions
- Air or sea freight operations, custom procedures
- Support for site preparation
- Secretary support for AMMA teams in Benin
- Relationships with beninese authorities, including regulation issues (authorization requests, …)
- Information and communications
- Updating of the implementation web page
- Support to events organisations (seminars, workshops…)

The Benin AOC works in collaboration with and under the responsibility of the Benin AMMA site coordinators : Drs. Christophe Peugeot and Sylvie Galle. It has no authority nor possibility to make scientific choices or perform instrument implementation or fixing.

The tasks of the Benin AOC (BAOC) are taken in charge by a team of three persons :

- 1 coordinator, also responsible for administrative aspects (Dr Ariane Borgstedt)
- 1 Engineer (IRD agent), responsible for technical aspects (Jean-Michel Bouchez),
- 1 administrative secretary

The coordinator and the secretary are contracted in the framework of the AMMA-EU.

The BAOC is expected to be maintained from October 2005 to March 2007

3.2.3 Technical maintenance in the field

A number of teams have not planed to have permanent staff in the field to watch their instrument(s). Considering that breakdowns or incidents are very likely events, due to the particular context (frequent electric power cuts, fuel penuries, lightning…), the Task Team coordination strongly suggest that one or two technician(s) could be locally contracted, trained, and then stay on the site and permanently watch and maintain a series of instruments during the whole operation period (vehicles such as motorcycles should be provided). They could warn teams in Cotonou in case of incident with cellular phones.

Decisions on this point must be taken by instruments PI's (EOP and SOP), with the support of TT5 coordination.

Rough costs estimates: Gross annual salary 5000€; motorcycle 3000 €

3.3 Infrastructures

3.4.1 Offices in Cotonou

AMMA teams are housed in three location in Cotonou

- Direction de la Météorologie Nationale, near the airport (radar and atmospheric chemistry teams)
- Direction Générale de l'Hydraulique (hydrology teams), in a neighbourhood of 5 km.
- AMMA building, near IRD headquarter provide extra housing capacities for the BAOC office, permanent (hydrology) and temporary AMMA teams, one meeting room; one secured storage area; one office for teams in mission and one office for the Benin AMMA National Committee, all equiped with usual telecommunication facilities including full internet. This house renting is funded by AMMA-EU.

3.4.2 Housing in Djougou during field missions

Housing in Djougou for people in mission in the field is possible in the existing IRD house (basic facilities), depending on availabilities, or in hotels. Housing in remote sites (Copargo, RONSARD Radar) has not been considered here, and must be addressed specifically. The Task Team coordination can provide help in that concern.

See also logistics thumbnail of the web site : http://www.lthe.hmg.inpg.fr/AMMA_International/

3.4 Vehicles

IRD in Cotonou dispose of a pool of 7 4-wheel-drive vehicles, including two bought in 2004; 2 new cars are available since mid-2005, and 2 additional "urban" cars, amongst which one is dedicated to people in mission. The 4WD vehicles are primarily dedicated to IRD teams in Benin (50% involved in AMMA), but also to AMMA teams depending on availability. In case of extra needs, renting solutions are possible, with a reliable institution in Cotonou offering good conditions.

3.5 Internet Communications

3.5.1 Cotonou sites

All the buildings where AMMA people will stay in Cotonou, are equipped with a full-internet connection (satellite connection), with a remote administration by Direction des Systèmes d'Information (DSI) at IRD-Montpellier (France). Internet equipment for the DMN has been achieved in February 2006.

3.5.2 Field sites

Internet Communication needs in the fields concerns the sites of Djougou (Xport Radar, GPS), Copargo (Ronsard Radar), Nangantchori (atmospheric chemistry and aerosols, VHF-UHF, lidar), and Kolokondé (BiStatic). It is essential for coordination of aircraft flight (aircraft base and main operation center –OC- in Niamey) that near-real-time quick-looks of RONSARD data (image) be available for the Niamey OC. As well, transmission of Xport images to Cotonou is essential for near-real-time analyses. The other instruments settled next to Xport will also benefit from the link for data transmission.

Other communication need is identified for the Parakou RS station, and a solution using classical telephone network and modem will be implemented (RS task Team).

The Task Team core group has made an inventory of all the possible technical solutions available in Benin, with a rough cost estimate (see appendix 5). The final choice has to be made when the precise technical requirements will be established, and the funding issue solved. This has to be done in strong coordination with SOP Task Teams and Principal Operation Centre coordination.

A list of available technical solutions, with rough costs estimates, is given in Appendix 5.

4 Partnership

4.1 Field observations

Partnerships for field observation mainly involve:

- Direction Générale de l'Hydraulique/Service de l'Hydrologie : meso-scale runoff-data on the Ouémé and Donga basin
- Direction de la Météorologie Nationale : Radio-soundings (Cotonou and Parakou), RS Ozone (Cotonou), Xport Radar (test phase in Cotonou)
- Département de Physique, Faculté des Sciences et Techniques (FAST), Université d'Abomey Calavi (UAC): Radars, atmospheric physics, fluxes, Maths Dept.
- Institut National des Recherches Agricoles du Bénin (INRAB) : fluxes
- Centre de Recherches Hydrographiques et Océanographiques Béninois (CRHOB) : oceanographic campaigns. EGEE cruises and in charge of an autonomous thermometer in the Cotonou port, at their disposal in the scope of EGEE.
- IMPETUS, German integrated project with shared field activities on water cycle observations (monitoring of the Aguima watershed, included in the upper-Oueme basin).

4.2 Training program

Students from UAC (FAST, Faculté des Sciences Agronomiques : 2 master, 1PhD in 2005), technicians from DMN :RS and RS-ozone training, and radar acquisitions. Flux Worshop devoted to field measurement and data first analysis.

5 Organisation of the TT.

5.1 Leaders, core group

5.1.1 Task team leaders are :

Christophe PEUGEOT	christophe.peugeot@ird.fr
Sylvie GALLE	sylvie.galle@ird.fr

5.1.2 The Core Group members are :

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Bernard BOURLES	bourles@ird.fr	TT oceanographic. Campaigns
Frédéric CAZENAVE	cazenave@ird.fr	Telecommunication resources
Marielle GOSSET	marielle.gosset@hmg.inpg.fr	radar representative
Serge JANICOT	jslod@lodyc.jussieu.fr	TT Radiosoundings representative
Cathy LIOUSSE	lioc@aero.obs-mip.fr	aerosols/chemistry representative
Colin LLOYD	crl@ceh.ac.uk	TT2a Fluxes representative
Alain PROTAT	protat@cetp.ipsl.fr	TT9 Representative
Luc SEGUIS	luc.seguis@ird.fr	Donga coordination
Dominique SERÇA	serd@aero.obs-mip.fr	Aerosols/chemistry representative

The full list of TT member is given in Appendix 3

5.2 Internal coordination

5.2.1 Scientific information

Diffusion of information is made by email using the member list in appendix 3.

5.2.21 Mission prepration

To help local organization of missions in Benin, the scientific request must be addressed to the TT5 leaders (C. Peugeot and S. Galle), while the logistical informations must be sent to the Benin AOC coordinator (A. Borgstedt).

In any case

- 3 months prior mission, preliminary information (period, duration, field trip, ..) must be provided **to BAOC coordinator AND TT coordinators**.

- detailed information on mission must be transmitted **to BAOC** 1 month prior arrival (dates, housing, specific needs...)

5.3 How are handled requests for new instruments ?

All requests are received by the TT coordinator, and are transmitted to the relevant TT members and BAOC.

Request for new instruments must be transmitted at least 6 month prior installation, with detailed information on instrument relevance to AMMA scientific objectives, integration in the existing implementation plan, local partnership, technical characteristics, logistic needs, technical supports. **Instrument and logistic sheets** must be provided.

Then the information procedure proposed for missions (previous section) must be applied

5.4 External diffusion of the information and reporting

External diffusion of the information and reporting should follow a procedure common to all the task teams. This procedure, to be defined,should involve mailing lists and web pages support.

6 Coordination with other TTs

Coordination with other task teams is foreseen through diffusion of information (email), and meetings of leaders outside IP or API meetings (no marginal travel costs).

The leaders of the TT in inter-relation with TT5 are part of the core group, namely B. Bourles (oceano. campaigns), S. Janicot (RS), C. Lloyd (Fluxes). Coordination with SOP TT must be clarified, one the one hand for aircraft operation (flight plan coordination), and on the other hand for Ground-SOP activities, to avoid overlapping (RONSARD relevant to SOP TT and this one, RS relevant to EOP and SOP TT depending on RS frequencies...).

Coordination with LOP Support Team remains unclear. For TT 5, IDAF and PHOTON PIs are members of the TT, as well LOP/Ouémé coordinators.

7 Status of the field program (Décember 2005)

7.1 AOC-Bénin setup

The **AOC- Benin** (**A**MMA **O**peration **C**entre in Benin) has started working in October 2005. The AMMA-house is rented since the same date. AOC-Benin is a secondary operational centre, working in coordination with the principal AOC based in Niamey

Their first task is the administrative and logistic support for AMMA teams, permanently and temporarily in Benin during the EOP and SOP. Their next task will be to prospect and organise installation of satellite communication during SOP.

7.2 Communication

7.2.1 Official presentation of AMMA in Cotonou

On September 2nd, 2005 a seminar was organised in Cotonou by Dr M.T. Lamizana representative of IRD in Benin and AMMA team, to widely present AMMA and its objectives to the ministries, the interested institutions, the public and to the press.

Apart from the IRD-crew, all the national scientific and technical partners were present as well as resource persons of various implied ministries, and representative of foreign embassies, gathering a hundred of participants.
A short speech of the Principal Private Secretary of the Minister of Education closed the ceremony. He exhorted the Beninese young scientists to seize the opportunity that AMMA offers through doctoral education, summer school and training in the field. He also promised unconditional assistance of him and his ministry to help AMMA to carry out their activities. The seminar was completed by a diner cocktail.

The event have been reported in national and local press (17 papers), as well as on radio and TVs broadcasts.

7.2.2 Presentation of AMMA to local authorities in Djougou

As a follow-up of the presentation of AMMA in Cotonou in September, a presentation of the programme and its experimental activities on Upper Ouémé valley was organized by the Benin-AOC (J.-M. Bouchez, IRD) on the site of the XPort Radar, in Djougou, on the 8th November 2005.

In the presence of the administrative (1st assistant of Djougou's Mayor) and traditional (king of Djougou) authorities, this presentation brought together representatives of Beninese and European teams involved in the programme, members of the Benin-AMMA operational centre (AOC) and members of the AMMA-Benin committee. Regional delegates of the Ministry of Public Building and of the Ministry of Hydraulics were present, as well as a representative of the European Commission, the director of electricity and water supply in Djougou. The local observers and the major of the main villages involved in AMMA were also invited

The local press and a local radio broadcast reported the event.

7.3 Action carried out in 2005

At the end of 2005, the majority of the instruments to be deployed in Benin are currently in operation (see table 1a).

EOP

Some instruments still remain to install.

- automatic water conductivity probes on 10 stations (upper-Ouémé meso-scale site). *Scheduled April 06.*

- southern site flux station (CO2/H20). *Scheduled Feb. 06*
- VHF/UHF profiler. *To be shipped to Benin within 2 months. Site preparation under way.*

SOP

Instruments not yet installed:

- RONSARD radar. *To be shipped to Benin within 2 months. Site preparation under way.*
- Bistatic receptor, associated to RONSARD (PI : M. Hagen, DLR) *Reconnaissance planed in feb-march 06.*
- Lightning detector network (PI H. Hoeller, DLR) ; *reconnaissance done*
- Optical spectro-pluviometer (PI. L. Barthès, CETP). *Installation in April 06, as scheduled.*

Burning issues:

- The geophysics campaigns (EOP), necessary to document the underground structure, with consequences on water storage, are still not funded.

- Data backup problem for the IR scintillometer (EOP) associated with the flux station on the filed-fallow site (Donga super-site)

- Constant volume balloon (SOP, PI P. Drobinski, SA). *No reconnaissance neither installation scheduled.*

- Flux station were installed beginning of november but the two HFS are not working because of software mismatch. The problem should be corrected within 2 months. The gaz analyser of the H2O/CO2 flux is not working : not flux data will be available for 2005 on the Donga supersite.

Appendix1

Maps

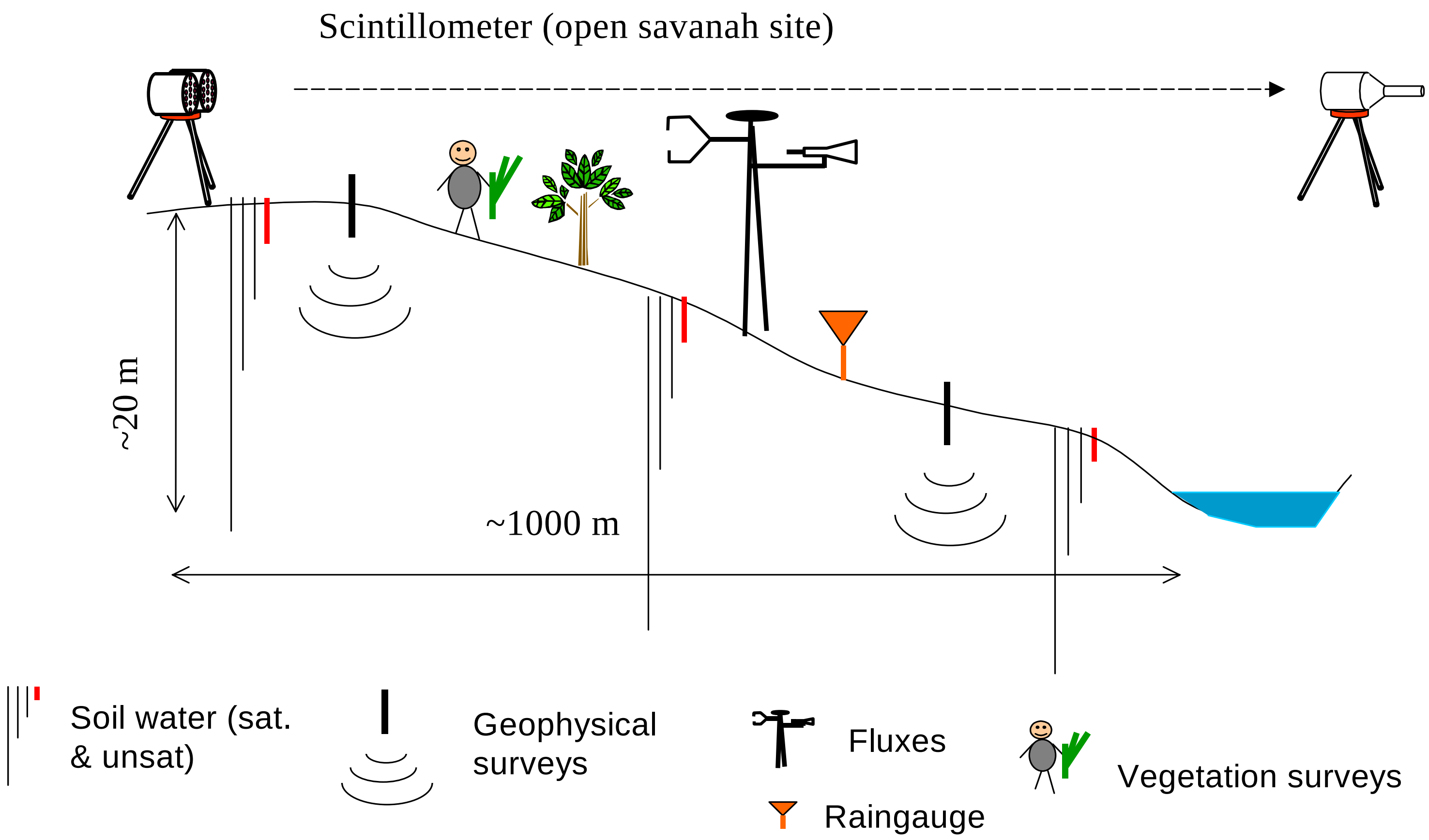
A1.1 Local scale (transect) EOP equipment

A1.2 Donga super site LOP/EOP equipment

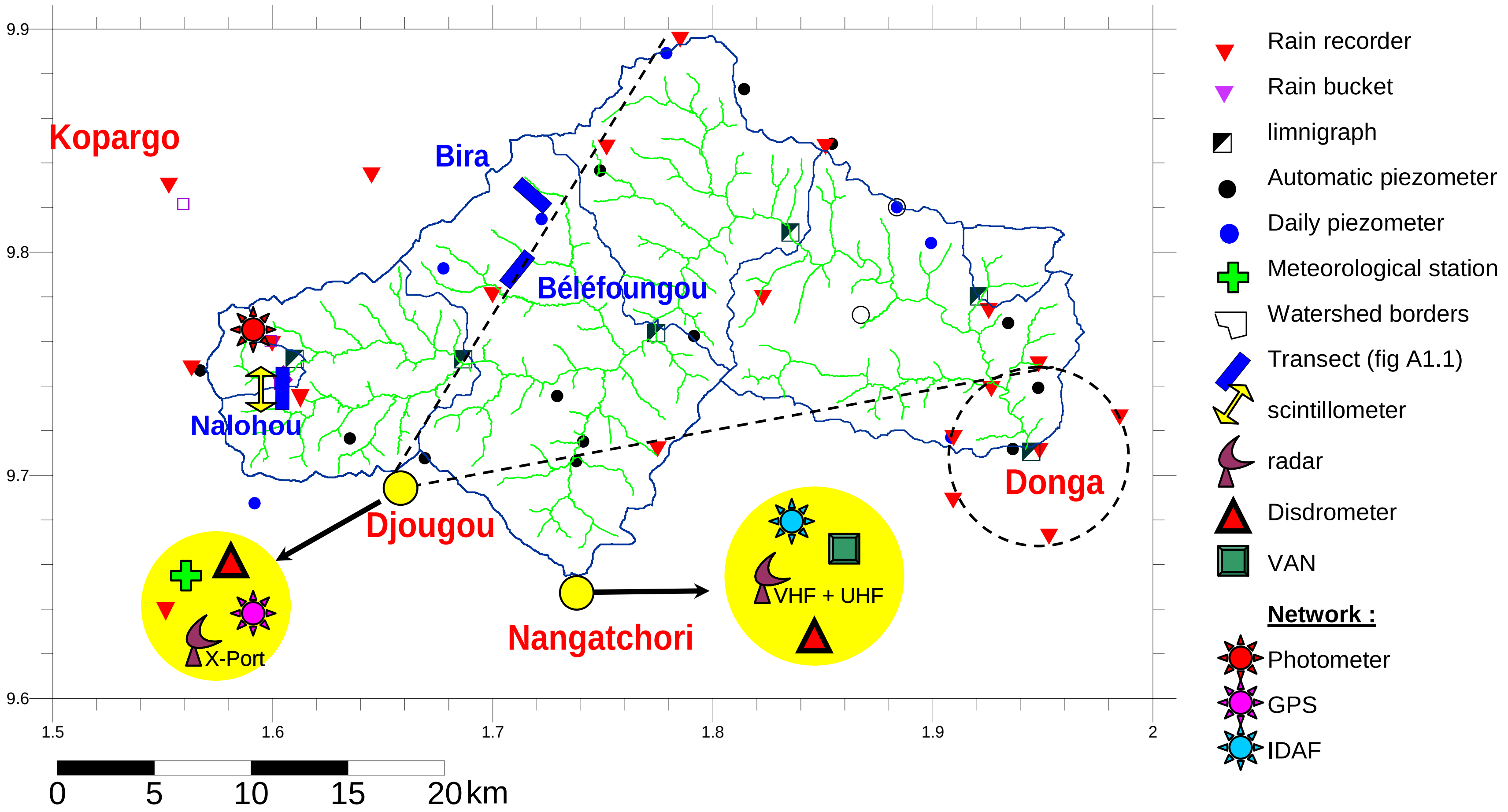
A1.3 Mesoscale Ouémé site LOP/EOP equipment

A1.4 Mesoscale Ouémé site SOP equipment

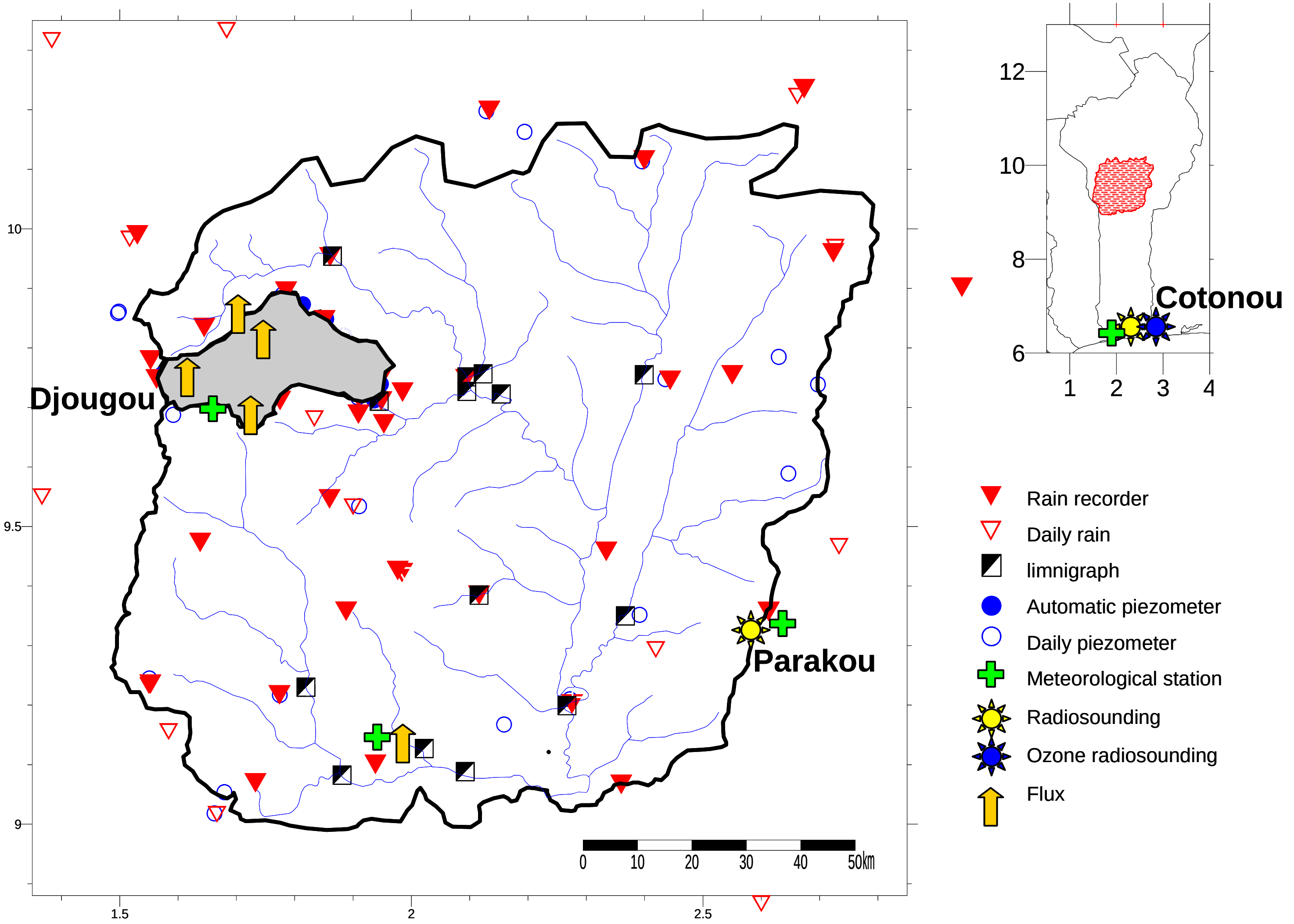
A1.1 Local scale (transects) EOP equipment



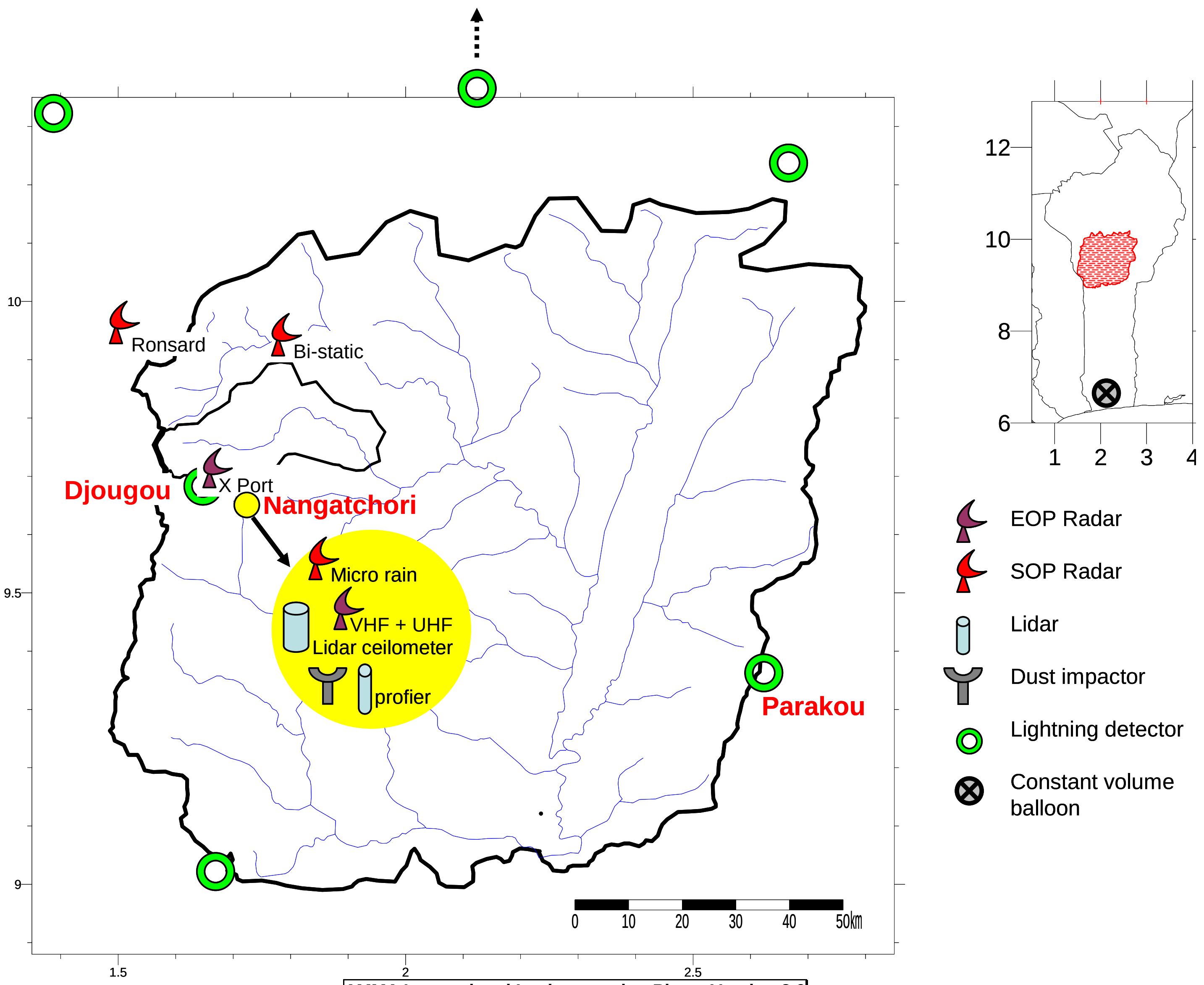
A1.2 Donga super site LOP/EOP equipment



A1.3 Mesoscale Ouémé site LOP/EOP equipment



A1.4 Mesoscale Ouémé site SOP equipment



Appendix2

List of TT5 and related instruments

Nomenclature:
Form #: XY# with X=L(*LOP*)/E(*EOP*)/S(*SOP*)/C(*Campaign*) ; Y=F(*French*)/E(*European*) instrument
Instrument code XY.name_O(d)(c): X=A(*Atmosphere*)/C(*Continent*)/O(*Ocean*) ; Y=L/E/S/C, idem form # ; O(d)(c)=O(Ouémé site)/(d)(Donga supersite)/(c)(catena=local)

Instruments EOP

#	Code	PI Name	E-Mail Address	Instrument	Platform	TT
EF2	AE.RadX_O	Marielle Gosset	Marielle.Gosset@hmg.inpg.fr	X Band Hydromet. Radar	Djougou	5
EF3	AE.Dsd_ Or	Marielle Gosset	Marielle.Gosset@hmg.inpg.fr	Disdromètre Parsival	Nangatchori	5
EF4	AE.OSP_Od	Laurent Barthès	barthes@cetp.ipsl.fr	Optical Spectro Pluviometer	Dakar puis Djougou	5
EF24	CE.Run_Odc	Luc Seguis	seguis@ird.fr	1 seuil jaugeur on 1 transects: Nalohou	Donga, transects	5
EF25	CE.WChem_O	Christophe Peugeot	peugeot@ird.fr	Chemical Analysis: surf/ground water	Ouémé	5
EF26	CE.WChem_Od	Luc Seguis	seguis@ird.fr	Chemical Analysis: surf/ground water	Ouémé-Donga	5
EF27	CE.Gwat_Odc	Luc Seguis	seguis@ird.fr	Network of 27 piezo in drilled wells	Donga, transects	5
EF28	CE.SW_Odc	Sylvie Galle	galle@ird.fr	3 soil moisture stations on 3 transects: 9 in total	Donga, transects	5
EF29	CE.Veg_Odc	Josiane Seghieri	seghieri@ird.fr	Vegetation survey	Ouémé-Donga	5
EF31	AE.RSO3_Od	Valérie Thouret	thov@aero.obs-mip.fr	Ozone Radio-sounding	Cotonou	5
EF33	AE.VAN_Od	Dominique Serça	serd@aero.obs-mip.fr	NOx measurements + 1 flux station	Nangatchori	5
EF5	AE.VHF_O	Bernard Campistron	camb@aero.obs-mip.fr	CNRM VHF: l = 6.7 m ; m = 45 MHz	Nangatchori	1
EB3/ EF9	AE.H2OFlux_Odc	Colin Lloyd	crl@ceh.ac.uk	1 Water Vapor and CO2 Flux stations	Ouémé-Donga	2a
EB4	AE.H2OFlux_Po	Colin Lloyd	crl@ceh.ac.uk	1 WV/CO2 flux station in a Southern Benin (Pobè)	South Benin	2a
LE2/LF9	AE.SHFlux_Odc	Sylvie Galle	sylvie.galle@ird.fr	2 Sensible Heat Flux stations (OSIL)	Ouémé-Donga	2a
EF10	AE.Scintil_Od	Jean-Martial COHARD	Jean-martial.cohard@hmg.inpg.fr	Scintillometer for Sensible Heat Flux measurement on a 1km transect	Ouémé-Donga-Ara	2a
EE1	AE.RS_1	Andreas Fink	fink@meteo.uni-koeln.de	8 P1 RS stations (Conakry, Abidjan, Cotonou, Douala, Tamale, Parakou, Abuja, *Niamey* ,) and 1 P2 (Bangui)	Monsoon Array	1
CF1	CC.geophy_Odc	JM Descloitre?		Geophysics with SYSCAL Pro and R2	Donga, transects	5
CF?	CC.RMP_Odc	JM Descloitre?		Geophysics with RMP	Donga, transects	5
EF1	AE.GPS_1	Marie-Noëlle Bouin, Olivier Bock	bock@aero.jussieu.fr bouin@ensg.ign.fr	4 GPS stations	regional window including Djougou	1

Instruments LOP

#	Code	PI Name	E-Mail Address	Instrument	Platform	TT
LF3	AL.Met_Od	Sylvie Galle	galle@ird.fr	Campbell Met. Station	Djougou (Ouémé)	5
LF18	CL.Rain_0	Luc Le Barbé	Luc.Le-Barbe@ird.fr	30 recording raingauge network	Ouémé meso site	5
LF19	CL.Rain_Od	Luc Le Barbé	Luc.Le-Barbe@ird.fr	Network of 18 recording raingauges	Ouémé-Donga	5
LF21	CL.Run_O	Christophe Peugeot	peugeot@ird.fr	14 recording streamgauge network	Ouémé meso site	5
LF22	CL.Run_Od	Luc Seguis	seguis@ird.fr	Network of 6 recording streamgauges	Ouémé-Donga	5
LF23	CL.ADCP_O	Christophe Peugeot	peugeot@ird.fr	Accoustic Doppler Current Profiler	Ouémé	5
LF25	CL.Gwat_Od	Luc Seguis	seguis@ird.fr	21 village sites (11 recorders)	Ouémé-Donga	5
LF26	CL.Depot_RW	C. Galy-Lacaux	lacc@aero.obs-mip.fr	5 stations IDAF (4 avec aethalomètre)	Regional Window	5
	CL.Photometer	Philippe Goloub	goloub@loa630.univ-lille1.fr	ORE PHOTON (aérosols)	Regional Window	

Instruments relevant to other Task teams (p.m.)

p.m. Technical stop of oceanographic ship for EGGE EOP campaigns in Cotonou Port

Appendix3

List of TT5 members

Name	Surname	E-Mail Address	Affiliation	Country	Function	Instrument / position
Afouda	Simon	Simon.afouda@ird.fr	IRD	Benin	Technical support, networks	CL.Rain_O CL.Rain_Od, CE.GWat_Odc,CL.GWat_Od, CL.GWat_O, CE.Run_Od, CL.Run_O
Afouda	Abel	afoudabel@yahoo.fr	UAC/FAST	Benin	Hydrological studies	AMMA Benin
Agbossou	Euloge	agbossou2001@yahoo.fr	UAC/FSA	Benin	President Benin AMMA committee	AMMA Benin
Akpo	Aristide	akpoarist@yahoo.fr	UAC/FAST	Bénin	Ozone Radiosounding	AE.RSO3_Od
Alloganvinon	Simon	salloganvinon@yahoo.com	IRD	Bénin	Technical support fluxes	AE.Flux_Odc, CE.SW_Odc, AL.Met_Od, CC.scintil_Od
Arjounin	Marc	arjounin@ird.fr	IRD/LTHE	Benin	Rainfall data monitoring and processing	CL.Rain_O,CL.Rain_Od
Adisso	Pierre	padis.lmedh@intnet.bj	DGH	Benin	Head of Hydrology Service	AMMA Benin
Azonsi	Félix	felixazonsi@gmail.com	DGH	Bénin	Head of Water Resources	AMMA Bénin
Barthès	Laurent	barthes@cetp.ipsl.fr	CNRS/CETP	France	Optical Spectro Pluviometer	AE.OSP_Od
Blarel	Luc	blarel@loa.univ-lille1.fr	Uni-Lille/LOA	France	Sun Photometer	CL.Photometer
Bock	Olivier	bock@aero.jussieu.fr	CNRS/SA	France	GPS stations	AE.GPS_1, AS.GPS_1
Borgstedt	Ariane	Ariane.Borgstedt@ird.fr	PACE consult.	Bénin	BAOC Coordinator	
Bouchez	Jean-Michel	jean-michel.bouchez@ird.fr	IRD/LTHE	Benin	EOP Logistics Rainfall and runoff ,network supervision	CE.Run_Od, CE.Rain_Od, CL.Run_O, CL.Run_Od,
Bouin	Marie-Noëlle.	bouin@ensg.ign.fr	IGN/ENSG	France	GPS stations	AE.GPS_1, AS.GPS_1
Bourles	Bernard	bourles@ird.fr	IRD/LEGOS	France	Coord oceanographic campaigns	Coord TT6
Campistron	Bernard	camb@aero.obs-mip.fr	CNRS/LA	France	VHF profiler	AE.VHF_O, AS.UHF_O
Cazenave	Frédéric	cazenave@ird.fr	IRD/LTHE	Benin	Engineer, X Band Hydrometeo. Radar,	AE.RadX_O
Cohard	Jean-Martial	Jean-Martial.Cohard@hmg.inpg.fr	UJF/LTHE	France	Scintillomètre flux de chaleur sensible	CC.scintil_Od

Name	Surname	E-Mail Address	Affiliation	Country	Function	Instrument / position
Crewell	Suzanne	crewell@meteo.physik.uni-muenchen.de	Uni-Muenchen /meteo	Germany	Ground SOP coord AMMA-IP Instr. PI	AS.CT25K_Od, AE.RADK_Od, AE.PROF_O
Depraetere	Christian	Christian.Depraetere@inpg.fr	IRD/LTHE	France	Meso-scale raingauge network, rainfall data analysis	CL.Rain_O
Dide	Francis	dide_fral@yahoo.com	DMN	Benin	Secretary Benin AMMA committee	AMMA Benin
Drobinski	Philippe	drobinski@aerov.jussieu.fr	CNRS/SA	France	Constant Volume Baloon	AS.BVC_T2
Durbe	Roger	roger.durbe@meteo.fr	Meteo-France	France	VHF profiler	AE.VHF_O
Faroux	Jacques	jacques.faroux@cetp.ipsl.fr	CNRS/CETP	France	Radar Ronsard	AS.Ronsard_Og
Galle	Sylvie	sylvie.galle@ird.fr	IRD/LTHE	Benin	H2O flux station, soil moisture stations, Meteo station	TT co-leader AE.Flux_Odc, AE.H2OFlux_Po, AE.SHFlux_Odc , CE.SW_Odc, AL.Met_Od
Galy-Lacaux	Corinne	lacc@aero.obs-mip.fr	LA	France	IDAF station	CL.Depot_RW
Gignoux	Karine	ginoux@dr5.cnrs.fr	CNRS/IPSL	France	AMMA Project Office	PO
Goloub	Philippe	goloub@loa630.univ-lille1.fr	Uni-Lille/LOA	France	Sun Photometer	CL.Photometer
Gosset	Marielle	Marielle.Gosset@hmg.inpg.fr	IRD/LTHE	Benin	X Band Hydrometeo.. Radar, Disdro Parsival	AE.RadX_O, AE.Dsd_ Or
Hagen	Martin	martin.hagen@dlr.de	DLR	Germany	Bi-static receptor	AS.Bist_Radar
Hoeller	Hartmut	hartmut.hoeller@dlr.de	DLR	Germany	Coord. Deployment WP 4.23 Lightning detector	AS.lightning_Od
Hottier	Jack	hottier@aero.jussieu.fr	CNRS/SA	France	Radar Ronsard - Logistics	AS.Ronsard_Og
Houngninou	Etienne	houngnb@yahoo.fr	UAC/FAST	Benin	Atmospheric Physics	AE.VHF_O, AS.UHF_O, AS.Ronsard_Og, AS.PROF_O, AS.lightning_Od, AE.RadX_O
Janicot	Serge	jslod@lodyc.jussieu.fr	IRD/LOCEAN	France	RS Stations	AE.RS_Q1
Kane	Cheikh	citizenkane@ird.ne	IRD	France	AMMA Project Office	PO
Kounouhewa	Basile	kbbasile@yahoo.fr	UAC/FAST	Bénin	Flux stations	AE.Flux_Odc, AE.H2OFlux_Po, AE.SHFlux_Odc
Kuntzman	Harald	harald.kunstmann@imk.fzk.de	IMK-IFU	Germany	Coord. Deployment WP 4.23	Coord
Lamizana T.	Moumouni	lamizana@ird.fr	IRD	Benin	Head IRD in Benin	Coord
Lebel	Thierry	lebel@ird.ne	IRD/LTHE	France	Coord deployment French API, ISSC member	Coord
Lloyd	Colin	crl@ceh.ac.uk	CEH/Wallingford	UK	2 SH and 2 H2O flux stations TT2a leader	AE.Flux_Odc, AE.H2OFlux_Po, AE.SHFlux_Odc
Luc Le Barbé	Luc	Luc.Le-Barbe@ird.fr	IRD/LTHE	Benin	Super-site scale, rainfall data analysis	CL.Rain_Od

Name	Surname	E-Mail Address	Affiliation	Country	Function	Instrument / position
Malinur	Fred	malinur@ird.fr	IRD/LTHE	Benin	Groundwater data monitoring and processing	CE.GWat_Odc, CL.GWat_Od, CL.GWat_O
Mariscal	Armand	mariscal@ird.fr	UPS-IRD/LA	Benin	Mobile Laboratory operations, Ozone Radiosoundings Op. Sun photometer maintenance	AE.VAN_Od, AE.RSO3_Od CL.Photometer
Ney	Richard	Richard.Ney@cetp.ipsl.fr	CNRS/CETP	France	Radar Ronsard	AS.Ronsard_Og
Nodichao	Leifi	nleifi@yahoo.fr	INRAB	Bénin	Physiologie palmier à huile Station de flux de Pobè	AE.H2OFlux_Po
Ouani	Théodore	Theodore.ouani@ird.fr	IRD	Benin	Technical support, networks	CL.Rain_O CL.Rain_Od, CE.GWat_Odc,CL.GWat_Od, CL.GWat_O, CE.Run_Od, CL.Run_O
Peugeot	Christophe	Christophe.peugeot@ird.fr	IRD/HSM	Benin	Meso-scale Chemical Analysis: surf/ground water, streamgauge network, Acoustic Doppler Current Profiler	TT Leader CE.WChem_O, CL.Run_O, CL.ADCP_O
Pont	Valérie	ponv@aero.obs-mip.fr	CNRS/LA	France	Impacteur, CCN, HTDMA, VTDMA	AS.Dust_Od
Pospichal	Bernhard	bernhard@meteo.physik.uni-muenchen.de	Uni-Muenchen /meteo	Germany	Atmospheric column	AS.CT25K_Od, AE.RADK_Od, AE.PROF_O
Protat	Alain	protat@cetp.ipsl.fr	CNRS/CETP	France	Ground SOP French AMMA-API coord.	Coord
Robain	Henri	Henri.Robain@bondy.ird.fr	IRD/Geovast	France	Résistivimètres SYSCAL Pro et R2	CC.geophy_Odc
Scialom	Georges	scialom@cetp.ipsl.fr	CNRS/CETP	France	Radar Ronsard	AS.Ronsard_Og
Seghieri	Josiane	Josiane.Seghieri@ird.fr	IRD/CESBIO	Mali	Vegetation surveys (biomass, phenology, LAI)	CE.Veg_Odc
Seguis	Luc	Luc.seguis@ird.fr	IRD/HSM	Benin	Local and Super-site scale : water chemical analyses, ground water networks, streamgauge networks, Meso-scale groundwater monitoring	CE.Run_Odc, CL.Run_Od, CE.WChem_Od,CE.Gwat_Odc, CL.Gwat_Od CL.Gwat_O
Serça	Dominique	serd@aero.obs-mip.fr	CNRS/LA	France	Atmo. Chemistry and aerosols Mobile Laboratory	AE.VAN_Od
Soula	Serge	sous@aero.obs-mip.fr	CNRS/LA	France	5 field mills	AS.Field_Mills_O
Thouret	Valérie	thov@aero.obs-mip.fr	CNRS/LA	France	Ozone Radio-sounding	AE.RSO3_Od
van den Akker	Elisabeth	Elisabeth.vandenAkker@ipsl.jussieu.fr	CNRS/IPSL	France	AMMA Project Office	PO
Vouillamoz	Jean-Michel	Jean-Michel.Vouillamoz@hmg.inpg.fr	IRD/LTHE	France	Protons Magnetic Resonance	CC.RMP_Od

Name	Surname	E-Mail Address	Affiliation	Country	Function	Instrument / position
Zannou	Arnaud	Arnaud.zannou@ird.fr	DGH	Bénin	Hydrological studies AMMA-DGH focal point	CE.WChem_O, CL.Run_O, CL.ADCP_O, CL.Rain_O

Appendix 4

Location of sites and instruments

Site	UTM-Est	UTM-Nord	long E	lat N	long E	lat N	confirmed by PI
Djougou-TP	353158	1071649	1° 39' 41.4"	9° 41' 31.2"	1.66150	9.69200	yes
Spectro-photometer	346336	1079217	1° 35' 56.6"	9° 45' 36.5"	1.59905	9.76019	yes
Ronsard			1° 33' 34"	9° 49' 17"	1, 55944	9, 82139	yes
Bistatic	366117	1093400	9°53'20.89"	1° 46' 44.01"	1.77889	9.88914	Yes
Scintilllo-emetteur	345648	1079248					yes
Scintilllo-récepteur	346763	1077103	1° 36' 11.9"	9° 44' 27.8"	1.6033	9.74109	yes
Nangatchori	361879	1066676	1° 44' 28.1"	9° 38' 50.4"	1.74114	9.64733	yes
Catena_Nalohou (center)	347016	1077575	1° 36' 19.1"	9° 44' 43.3"	1.60531	9.74536	yes
Catena_Béléfoungou (center)	359017	1083023	1° 42' 52.2"	9° 47' 42.1"	1.71451	9.79506	yes
Catena_Bira (center)	359297	1086533	1° 43' 01."	9° 49' 36.5"	1.71694	9.82681	yes

Djougou-TP : Météo, Xport, GPS

Nangatchori : VAN, UHF+VHF, disdrometer, microrain radar, lidar ceilometer, microwave profiler, dust impactor, IDAF

Catena : Raingauge, Soil water probes, Piezometers, Flux station, Vegetation surve

Appendix 5

Telecommunication solutions
Djougou, Kopargo and Nangatchori

Data transmission needs

Site	Duration	Type of data	Quantity
NANGATCHORI			
UHF radar	SOP 1,2	Daily transmission of a quick-look (250Kb/day) + archiving of data every week on DVD, the DVD is sent to France by post mail.	2 MB/day
VHF radar	18 months : Mar. 2006 - Aug. 2007	UHF+VHF : hourly transmission of 2 MB minimum	48 MB/day
MW profiler	1 year : Jan.- Dec. 2006	If high-speed connection is not available, then data transferred from on-board PC to laptop every month (20 MB / day). If possible some of the products (about 100 kB) should be transmitted to LMU via internet daily.	100 kB/day
Ceilometer	1 year : Jan.- Dec. 2006	Data transferred from laptop every month (230 kbytes a day) to CD and mailing to LMU (out of SOP period) by operator	
Micro rain radar	1 year : Jan.- Dec. 2006	Data transferred from laptop every month (approx. 300 MB in one month in rainy season) to CD and mailing to LMU (by operator out of SOP period, someone there during SOP)	
Cimel Lidar	1 year : Jan.- Dec. 2006	an average lidar vertical profile every half an hour (100 Kb/hour) + Data transferred from laptop every week to CD and mailing to SA by operator	20MB/day
		TOTAL NANGATCHORI	**70MB/day**
DJOUGOU			
X-Port	EOP (Mai 2005 -		
GPS station	EOP instrument (2 years 2005-2006)	300-500 KB/day to be transferred daily to the analysis center in Paris	Existing Satellite connection
Optical Spectro-pluviometer 1	SOP1,2 and 2007.	transferred daily to CETP, Vélizy. Instrument status is checked remotely using VNC (so a permanent connection is required).	1 MB/day
		TOTAL DJOUGOU	**1 MB/day**
KOPARGO			
RONSARD	15 June – 15 Sept. 2006	200 kO every 15 minutes, but only when there's convection → 800 kB/hour→ 20 MB/day	20 MB/day (average 10MB/day)
Optical Spectro-pluviometer 2	SOP 1, 2	Taken care of by the Ronsard technicians	
		TOTAL KOPARGO	**10 MB/day**
KOLOKONDE			

bistatic receiver	Id Ronsard	stored on the computer, regular archiving	BLR to Ronsard

Data Transmission solutions

AOC Benin opted for independent communication facilities via satellite for the sites of Nangatchori and Kopargo. For satellite connection, there are three options: communication via satellite modem (e.g. BGAN) via a mini satellite antenna, or via Satellite antenna GEOLINK (antenna exists in Cotonou). BAOC studies costs and facilities.

Nangatchori

As can be seen above, the biggest communication need is in Nangatchori. Note also that the need extend to august 2007 for UHF-VHF.

Kopargo

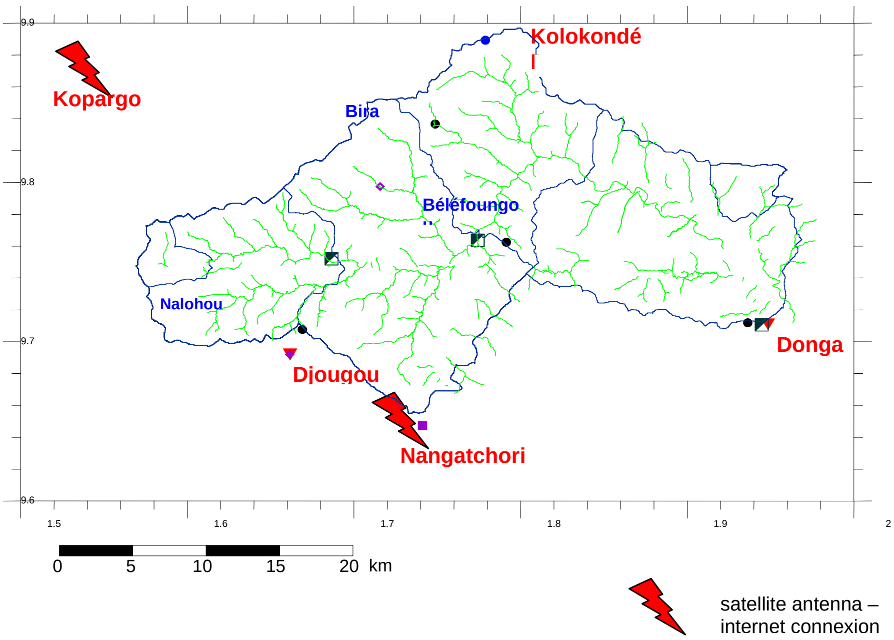
The transmission of the RONSARD data is of main interest for SOP. It is funded by the AOC. It stops at the end of september 2006.

Djougou

The GPS allready has its own inmarsat connection. Marginal other data may be transmitted through this connection. Djougou won't have a satellite connection as other data can be transmitted via the existing "internet café"-connection.

Kolokondé

Local need covered by BLR.



Djougou Data Tansmission scheme

Voice communication

Existing GSM telephone network

- Djougou → GSM is working (telecel + areeba), telephone network, internet connection with modem, no DSL available, research site is not connected to the telephone network
- Nangatchori → GSM is working (telecel + areeba), no existing telephone network
- Kopargo → limit of GSM covering, no telephone network
- Kolokondé → no GSM, no telephone network

The GSM-Net Telecel and BeninCell are covering Djougou and Nangatchori. Kopargo is at the limit of the GSM covering. The network of fixed telephones just exists in Djougou.

Satellite telephone

As GSM communication may be weak or overbooked, some additional satellite telephones will secure permanent communication for internal coordination during SOP and EOP.

The different available satellite telephones in Benin are Thuraya, Inmarsat or Iridium.

IMPETUS can lend 2 INMARSAT telephones. There's the possibility to connect a fax without additional costs.

Chapter 8

Oceanic campaigns and measurements from open Ocean (EOP and SOP)

Bernard Bourlès, Robert L. Molinari, Peter Brandt

1 Scientific justification and objectives

The oceanographic observations of AMMA will support the land and atmospheric measurements during the three observing periods; Long term Observing Period (LOP), Enhanced Observing Period (EOP), and Special Observing Period (SOP). Detailed scientific rationale for these data is given in both international and national AMMA documents (e.g., French API, EU, US). Specifically, the TT6 aims to provide needed measurements for:

- the study of processes that determine seasonal to interannual variability of observed sea surface temperature (SST), sea surface salinity (SSS), mixed layer depth and heat content, in the Tropical Atlantic and in the Gulf of Guinea, and their linkage with West African land surface conditions;
- the study of processes that determine the seasonal evolution of the cold tongue - Inter Tropical Convergence Zone (ITCZ) - West African Monsoon (WAM) system.
- the study of both ocean and atmosphere boundary layers and air-sea exchanges;
- the validation of models, satellite data and products.

2 Observing strategy

2.1 Overall Strategy

The overall strategy is mainly based on (1) the acquisition of in situ measurements in the eastern Tropical Atlantic and the Gulf of Guinea (GG) and (2) the integration of these data to characterize the air-land-sea monsoon system during the three observing periods of AMMA (and thereby resolving different timescales ranging from annual to interannual):

For the LOP and EOP observations, the measurements will be principally collected through existing sustained observing networks and acquisition programs (e.g., PIRATA ATLAS buoy network, the Voluntary Observatory Ship (VOS) expendable bathythermograph (XBT) networks, surface drifters of the Global Drifter Program, and the ARGO and CORIOLIS operational programs). LOP/EOP measurements will also be acquired through oceanographic research vessels, coastal stations, tide gauges and the meteorological station at São Tome Island (Eq-6°E). These measurements will be enhanced by additional observations directed at specific monsoon questions. For the SOP WAM process studies, a large number of additional oceanic and meteorological measurements will be collected as presented in details below.

The different types of measurements (lagrangian, eurelian, synoptic, surface and subsurface, high frequency acquisition etc…) and the different measured parameters (currents, hydrology and even tracers) should allow obtaining the most complete necessary data sets for the process studies.

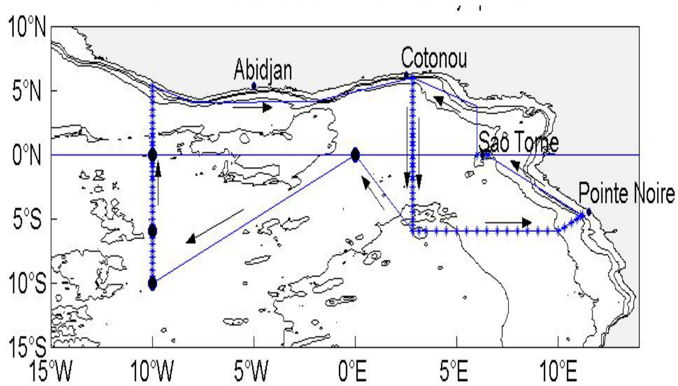
Maps and list of measurements

The oceanic measurements will be described using the framework of the AMMA Observing Periods (i.e., the EOP, LOP and SOP). We first present the oceanographic cruises planned in the framework (or closely linked to) of AMMA in France, US, Germany and Senegal, before mentioning a few cruises that are of large interest for AMMA and for which collaborations are underway. Then, other international programs or instruments already deployed in the tropical Atlantic are briefly presented

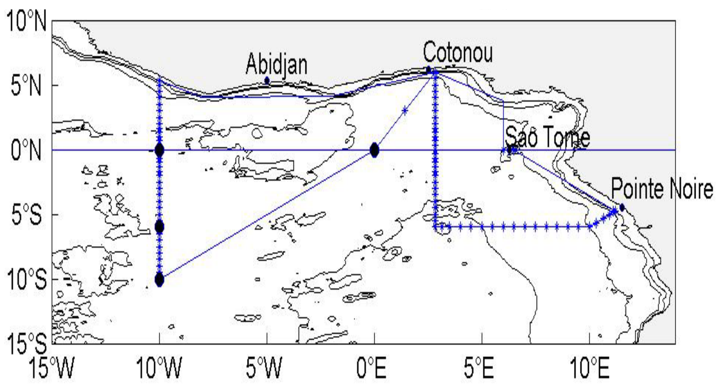
2.2 The Cruises

2.2.1 EOP/SOP French cruises: Observation period

French EOP and SOP 3 EGEE cruises:



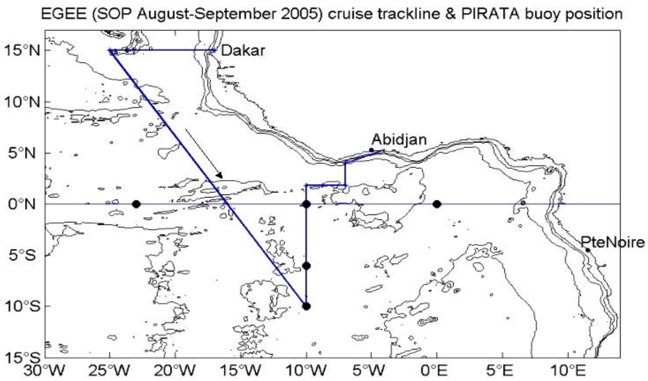
French SOP 1 EGEE cruise:



In order to assess interannual and seasonal variability, six EGEE cruises in the Gulf of Guinea are planed in the framework of AMMA-France, with two cruises per year scheduled during the three EOP AMMA years (2005-2007). In order to sample the GG during contrasting climatic situations, the cruises will be carried out in boreal spring-summer (monsoon setting, in phase with the equatorial upwelling onset, i.e. around end of May to July), and boreal fall (late monsoon, end of equatorial upwelling, the ITCZ going back to its southernmost position, i.e. around September-October). The repetition of the cruises during these two opposite seasons during all three years will allow assessment of seasonal and interannual variability. To achieve this objective, the same tracklines will be repeated with particular attention directed at the 10°W meridional section, which has been occupied several times during previous PIRATA and EQUALANT cruises.

Presently (March 2005), the three first EGEE cruises are funded and scheduled. EGEE 1 and EGEE 2 will be carried out with the R/V LE SUROIT in June (June 6 - July 4) and September (September 3 – October 1) 2005 respectively, and the EGEE 3 cruise, during the first phase of the SOP, will be carried out in June (May 25 - July 7) 2006 with the R/V L'ATALANTE. Maintenance (or replacement) of the PIRATA ATLAS moorings located in the Gulf of Guinea (see black dots on the maps above) will also be conducted during these cruises. The section located south of Benin will complete the SOP terrestrial radio-soundings line planned from Benin and Niger, at 2°50'E. During EGEE 3 (SOP 1 campaign), this section will be occupied in coordination (and simultaneously) with measurements from aircrafts (see also TT8 for more information). This cruise will document the pre-onset and onset of the monsoon offshore, with particular attention directed at surface fluxes, oceanic turbulence and advection of humidity. Atmospheric turbulence measurements will be collected using a turbulent flux measurements system. These atmospheric measurements of radiative and turbulent fluxes will provide observations similar to those obtained with the instrumented mast, positioned in the front of the R/V, during the EQUALANT 1999 cruise. This system will provide oceanic flux measurements for comparison with observations obtained from different methods (i.e., inertio-dissipative, correlation and bulk). Radio-soundings will also be launched from the vessel.

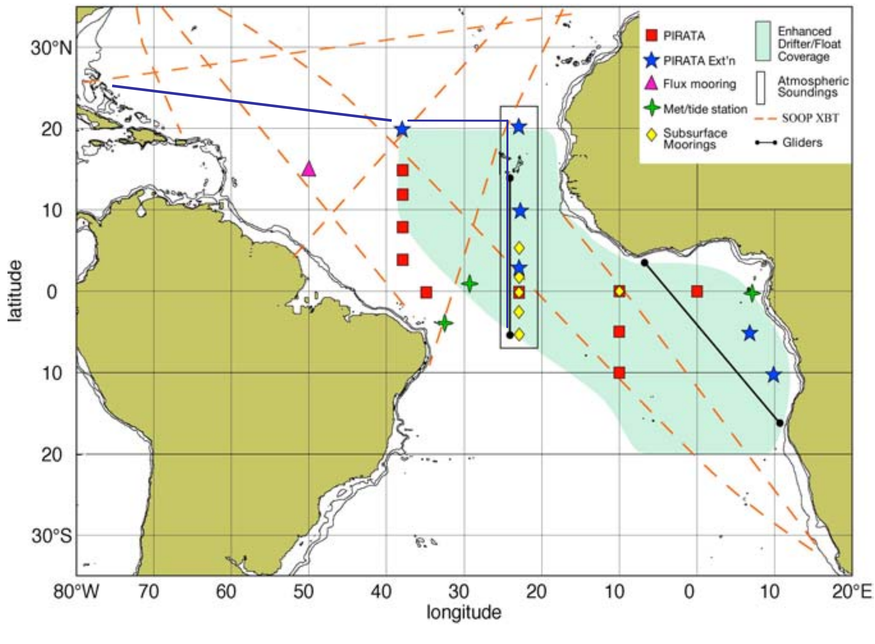
In addition to classical current (SADCP and LADCP) and hydrological (T,S,O2) measurements, surface drifters (coll. NOAA/AOML) and ARGO/CORIOLIS profilers will be deployed during each cruise. PIRATA ATLAS buoys will also be maintained during the cruises. Turbulence measurements, by IFM-GEOMAR colleagues and Helium measurements, for upwelling rate estimates by colleagues from the University of Bremen will also taken during some of the cruises.



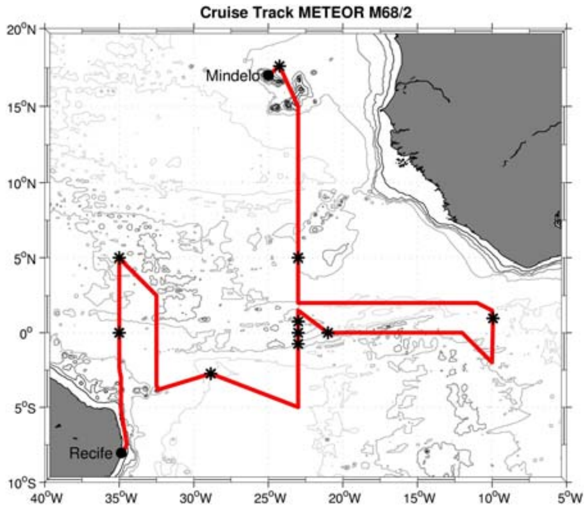
During the SOP 3 EGEE 4 cruise, occupations of both a Dakar-Cape Verde section and a Guinea Dome cross-section (right) was an option. The realization of short cruises from the Senegalese R/V ITAF DEME, if funded, could provide part of needed information needed in this area (see below).

2.2.2 SOP I U.S. Cruise (with implications for EOP and LOP cruises)

This cruise is scheduled for May-June 2006. During this cruise, in addition to classical current and hydrological measurements in the upper ocean layers, 2 ATLAS buoys will be deployed at positions along 23°W to be determined but in the vicinity of the blue stars in the figure at right. In addition, surface drifters (all equipped with SST sensors and some with wind and atmospheric pressure sensors) and ARGO profilers will be deployed in the green shaded area to the right. Support will also be requested for two other ATLAS moorings to be deployed in 2007 (i.e., implying yearly cruises to the region to maintain the ATLAS buoys). These ATLAS buoys along with the ones located along 10°E will collect data in both the ocean and atmosphere boundary layers and the variability on both sides of the ITCZ during all the phases of the WAM.

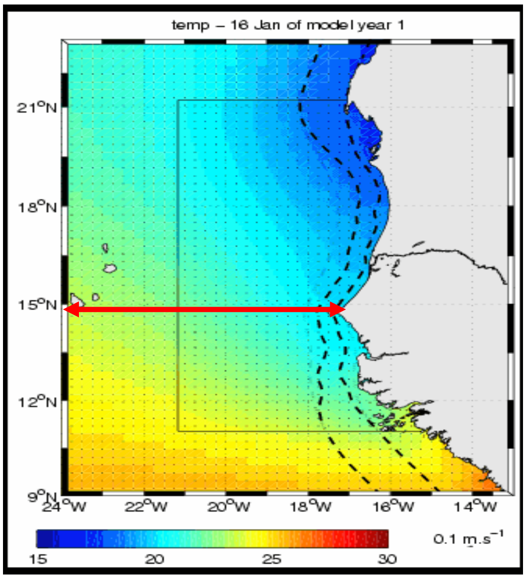


2.2.3 SOP-I German Cruise:



A German cruise by IFM-GEOMAR with R/V METEOR is funded and scheduled from June 6 – July 9 2006, in the framework of a German CLIVAR-TACE contribution. Main part of this cruise will be the deployment of a current meter mooring array consisting of 5 moorings near 23°W at the equator as well as intensive microstructure measurements in the equatorial region. The observations will provide estimates of transport and water mass variability of the flow toward the eastern upwelling regions (cold tongue) and to document intraseasonal, seasonal and interannual variability in the central equatorial Atlantic. During the cruise twice-daily radio-soundings will be performed. The cruise will also be used to deploy ARGO profilers from the German ARGO program

2.2.4 SOP Senegalese cruises:



Several 5-day cruises are proposed in the framework of the oceanographic component of the AMMA-Senegal project. These cruises could be conducted using the R/V ITAF-DEME of CRODT/ISRA, in collaboration with the French AMMA/EGEE program. The French program would partly found the vessel chartering. Three cruises are planed at about one month interval from Dakar to Cap-Vert to survey the ocean boundary layer with CTD and XBT profiles, and could be also opportunities for surface drifter and profiler deployments.

The AMMA dedicated or linked oceanographic cruises are summarized in the following table:

CRUISE NAME	STATUS	COUNTRY / VESSEL	DATE	AREA
EGEE 1	Funded / Scheduled	FRANCE / LE SUROIT	June 2005	Gulf of Guinea
EGEE 2	Funded / Scheduled	FRANCE / LE SUROIT	September 2005	Gulf of Guinea
EGEE 3	Funded / Scheduled	FRANCE / L'ATALANTE	May-July 2006	Gulf of Guinea
METEOR 68/2	Funded / Scheduled	GERMANY / METEOR	June-July 2006	Equatorial Atlantic
US AMMA	Funded / Scheduled	USA / RON BROWN	May-June 2006	North East Tropical Atl.
EGEE 4	Funded / Proposed	FRANCE / ANTEA	September 2006	Gulf of Guinea
SENEGAL AMMA 1	Proposed	SENEGAL / ITAF DEME	May 2006	North East Tropical Atl.
SENEGAL AMMA 2	Proposed	SENEGAL / ITAF DEME	July 2006	North East Tropical Atl.

SENEGAL AMMA 3	Proposed	SENEGAL / ITAF DEME	September 2006	North East Tropical Atl.
EGEE 5	Proposed	FRANCE / ANTEA	June 2007	Gulf of Guinea
EGEE 6	Proposed	FRANCE / ANTEA	September 2007	Gulf of Guinea

The list of instruments and associated measurements obtained during the field campaigns is summarized in the following table:

Measurements \ cruises	EGEE EOP	EGEE SOP	US SOP	German SOP***	Senegalese SOP
Hydrology (CTDO2)	YES	YES	YES	YES	YES*
Currents (S-ADCP and/or L-ADCP)	YES	YES	YES	YES	NO
Continuous SST and SSS (TSG)	YES	YES	YES	YES	NO
Temperature profiles (XBT)	YES	YES	YES	NO	YES*
Salinity profiles (XCTD)	YES	YES	NO	NO	NO
Surface drifters deployment (SST)	YES**	YES**	YES	??	??
Surface drifters deployment (wind & sea level pressure)	YES**	YES**	YES	??	??
ARGO profilers deployment (T&S profiles)	YES	YES	YES	YES	YES*
Sea water samples for analysis (S, O2, and nutrients)	YES	YES	YES	YES	YES
Ocean microstructures (turbulence)	YES ***	YES ***	??	YES	NO
Helium (air and ocean) for upwelling rate estimate	YES (partly) ****	YES ****	NO	YES****	NO
Meteorological measurements (classical station -eg BATOS-)	YES	YES	YES	YES	YES
Atmospheric microstructures & air sea fluxes (turbulence)	NO	YES	NO	NO	NO
Radiosoundings (from vessel)	NO	YES	NO	YES	NO
Sea water samples for analysis (O18, 13C & CO2 parameters)	YES	YES	NO	YES	NO
Aerosol (photometer)	YES	YES	NO	NO	NO
Drifting vertical temperature profiles (MARISONDE)	NO	YES	NO	NO	NO

*: provided and/or funded by (or in the framework of) AMMA-France (API)
**: provided and/or (maybe partly) funded by (or in the framework of) AMMA-US (NOAA)
***: provided and funded in the framework of German CLIVAR-TACE contributions (IFM-GEOMAR)
****: provided and funded in the framework of German SOLAS contribution (University of Bremen)

NOTE relative to the French API Instruments list:

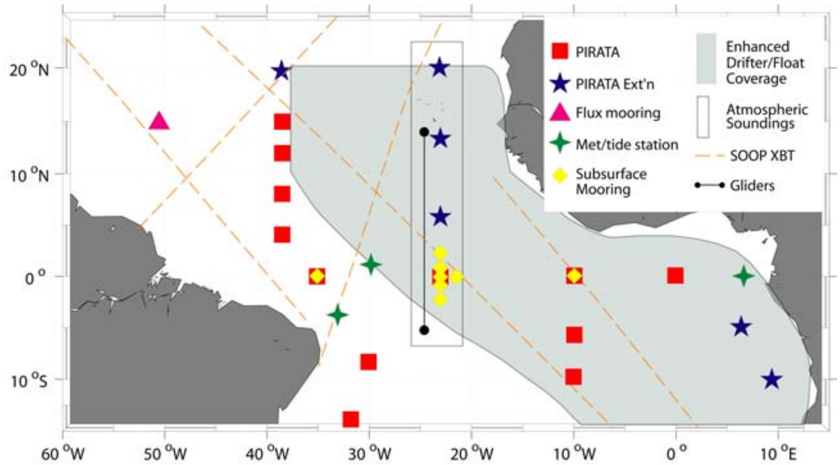
- The measurements referenced as “Hydrology” is referred in the Instruments List “OE_CTD”.
- The measurements referenced as “Currents”, “Continuous SST and SSS”, “Sea water samples for analysis”, “Ocean microstructures”, “Helium (air and ocean)” and “Meteorological measurements “ are related to the Instruments List “OE_Navire”.
- The measurements referenced as “Temperature profiles XBT” and “Salinity profiles XCTD” are referred in the Instruments List “OE_XBT”.
- The measurements referenced as “Surface drifters deployment “ are referred in the Instruments List “OL_Drift”.
- The measurements referenced as “ARGO profilers deployment “ are referred in the Instruments List “OL_Prov”.

- The measurements referenced as "Radiosoundings " are referred in the Instruments List "OS.RadioSondages".
- The measurements referenced as "Atmospheric microstructures " are referred in the Instruments List "OS. MatInstrumente".
- The measurements referenced as "Drifting vertical temperature profiles " are referred in the Instruments List "OS. Marisondes".

2.3 Other LOP/EOP Observations

2.3.1 Observations in the Ocean

PIRATA ATLAS buoys:



In the framework of the PIRATA program 13 buoys are deployed to perform oceanic and atmospheric measurements. 10 buoys have been deployed in 1997, another 3 buoys as southwestern extension in 2005. Their locations are shown by red squares. Four additional buoys will be deployed in 2006 and 2007 by US-NOAA (blue stars) as discussed above. A southeastern extension, that should be endorsed by PIRATA in 2006, is also planed with two buoys (blue stars). One of these buoys could be deployed in 2006 during an EGEE cruise around 6°S-8°E (funded by the regional Benguela Current Large Marine Ecosystem -BCLME- program).

PIRATA surface current mooring:

A PIRATA mooring was deployed at 23°W-Equator from December 2001 to December 2002 then from early 2004, close to an ATLAS buoy. The mooring is equipped with an LADCP measuring the current within the upper 100m. In 2004, IFM-GEOMAR added a downward looking ADCP as part of their CLIVAR program. We can thus expect to have a good current survey for the upper 700 m of the water column. Deep current meters and one acoustic source are also installed on this mooring as components of the French "Equatorial Deep Jets" and German CLIVAR-TACE programs, respectively.

XBT and TSgraph VOS lines:

VOS (Volunteer Observing Ships) provide long time series of subsurface temperature and surface salinity data along regular lines, shown as dashed red lines. These lines have been maintained by NOAA and IRD in the framework of WOCE and CLIVAR. They will continue to be occupied through the EOP and LOP of AMMA.

ARGO Profilers:

From 2000, the ARGO International project (A global array of profiling floats) and its French component CORIOLIS plan to deploy a network of 3000 autonomous floats that provide temperature and salinity vertical profiles to depths between 1000 m and 2000 m. Each profiler provides data every 10 days and the data are available in real-time through the Global Telecommunications System. The 3000 float array will provide coverage on an average 3° of latitude by 3° of longitude grid. The design life-time of the floats is 4 years. Profilers will be deployed in the tropical Atlantic during AMMA cruises. During the 2005 EGEE cruises, 20 PROVOR (French ARGO profilers) will be launched in the Gulf of Guinea, and at least 10 per year in 2006 and 2007. US and German cruises will also deploy a large number of these profilers in 2006.

Current meter mooring array at 23°W-Equator:

Additionally to the present PIRATA mooring at 23°W at the equator, IFM-GEOMAR will install in June 2006 a current meter mooring array in the framework of a German CLIVAR-TACE contribution. The mooring array will consist of 4 current meter/hydrographic moorings around this location including ADCPs for the near surface flow (including the PIRATA ADCP), as well as deep current meters and CTD sensors at different depths down to a depth of about 1000m. The mooring array would require cruises for recovery/redeployment that could be used for repetitions of the 23°W section from Cape Verde to the equator.

Glider:

A Glider section along 23°W from Cape Verde toward the equator is proposed within the German CLIVAR-TACE program. The Glider will measure temperature, salinity and oxygen in the upper 800m of the water column. However the mission depends on availability and technical ability of a Glider-system.

2.3.2 Coastal Observations

Meteorological station:

During October 2003, a meteorological station was installed at São Tomé Island (6°E-0°N) as a component of the French EGEE/AMMA program. This station failed in December 2003 and was repaired in August 2004. The ATLAS suites of atmospheric observations are collected at this station thus extending the PIRATA measurements eastward along the equator. Data are transmitted daily by ARGOS.

In the framework of the Senegalese oceanographic project, if endorsed by Senegal and funded, a meteorological station could be installed at the westernmost point in Dakar (Pointe des Amadies) in 2006.

Tide gauges:

A tide gauge has been maintained by IRD at São Tomé for many years. This tide gauge was positioned by GPS in 2002. Data are transmitted daily by ARGOS, and accessible through internet at the PIRATA web site. Unfortunately, no other gauges are operational along the GG coast. A few tide gauge stations should be installed in Senegal and the GG in 2005 and 2006 in the framework of ODINAFRICA and GOOS Africa projects (personal communication by Angora AMAN, LAPA-Abidjan/RCI). It should be noted that a few older tide gauges maybe available at NOAA that could also be deployed at to be determined locations.

Coastal stations:

A few coastal stations are maintained in some West Africa countries. In the framework of EGEE/AMMA, an evaluation of these stations began and some efforts will be carried out in order to qualify and standardize the SST measurements using “ONSET” temperature sensors. Contacts have already been done in Ivory Coast, Benin and Togo for these deployments. CRO/ISRA may maintain 7 coastal stations in Senegal. It has to be noticed that three autonomous “ONSET” temperature sensors were already installed in Ivory Coast in December 2002 and January 2003 (at 10m, 20 and 40m depth off Abidjan), but due to internal problems and political events in this country, measurements have been interrupted in mid-2004 (one sensor has been lost). Onset sensors have been bought and are planed to be installed in Benin, Togo, Nigeria and Ghana, and reinstalled in Ivory Coast when possible.

2.4 Satellite observations

Remote sensing of SST, sea surface height anomalies, surface wind and ocean color are needed to provide increased spatial and temporal resolution of the eastern tropical Atlantic. Products already exist that combine these data to obtain an integrated look at oceanic surface conditions and these products should be furthered tailored to characterize SOP, LOP and EOP conditions.

2.5 Link with modelling studies

2.5.1 Process studies

The cruise data will be used for many numerical experiments that will be conducted by the countries involved (e.g., US, France, Germany) as well as other AMMA investigators. Data will be used for model validation (in France: MERCATOR, ROMS), model improvements (e.g. mixing parameters) and/or assimilation schemes validation. Data will also be used for satellite data validation (SST, SLP, sea surface color, SSS) or satellite sensor calibration (SSS).

2.5.2 Operational use

During the EGEE cruises, most of the temperature and salinity profiles (XBT & CDT) will be transmitted in quasi-real time by satellite (ARGOS) to the CORIOLIS Data Center in France for assimilation processes (MERCATOR). All the drifter, Argo and VOS XBT meteorological and oceanic data are transmitted in real-time without cost through the GTS for use by weather and climate forecast centers.

2.5.3 Data synthesis by models

To obtain a truly four-dimensional view of the oceanic component of the WAM, assimilative models will be used to combine the in situ and remote observations.

On weather time-scales, numerical weather prediction models run at operational centers will combine the ocean and land observations to generate weather forecasts.

On climate time-scales, operational forecast centers will use the oceanic data to generate SST forecasts that are needed for longer time-scale predictions (e.g., seasonal to interannual).

3 Deployment:

3.1 Planning

- during EOP&SOP AMMA cruises :

	2005												2006												2007											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
CTD																																				
XBT (and a few XCTD)																																				
Currents																																				
Surface drifters																																				
ARGO profilers																																				
Sea water samplings																																				
Ocean turbulence																																				
Air Sea fluxes																																				
Radiosoundings																																				
Drifting T(z)																																				
Helium																																				
Tracers analysis																																				

- Additional measurements:

Most of these measurements are obtained thanks to international networks maintained in the framework of CLIVAR, GOOS, etc (eg VOS networks, PIRATA…), and the meteorological station at São Tomé has been installed in October 2003 in the framework of EGEE/AMMA.

x: additional measurements and/or deployments during cruises.

	2004	2005												2006												2007							
	1-12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
São Tomé meteorological station																																	
XBT VOS network							x			x							x	x	x			x									x		
SSS VOS network							x			x							x	x	x			x									x		
ARGO profilers	Only a few						x			x								x	x			x									x		
São Tomé tide gauge																																	
PIRATA ATLAS buoys	-> 5 in GG						x	h	o	p	e	f	u	l	l	y		x		h	o	p	e	f	u	l	l	y		h	o	p	e
Coastal stations (SST)																																	

3.2 Required enhancements to the LOP/EOP network

Surface drifters equipped with thermister chains and meteorological sensors:

The PIRATA array is limited spatially. Satellite tracked surface drifters can be equipped with thermister chains and meteorological sensors (e.g., sea level pressure and wind). The existing 5° by 5° global drifter array and 3° by 3° Argo array in the eastern tropical Atlantic should be enhanced to include these types of drifters. Specific objectives include increased resolution to determine the adequacy of satellite SST observations in this area of atmospheric aerosol occurrences; characterize the temporal development of the monsoon over the eastern tropical Atlantic; determine the oceanic processes that control the evolution of the SST field in the region; and characterize the temporal evolution of the cooling in the equatorial and coastal upwelling regions with respect to the ITCZ and WAM.

Improved meteorological packages on VOS:

The VOS lines described above collect rudimentary meteorological observations. Placing IMET packages on these vessels would greatly improve the quantity and quality of surface meteorological data, which can be used for both weather forecasts and long-term climate studies.

Improved meteorological packages on research vessels:

The vessels that service the Atlantic ATLAS moorings should be equipped with radiosounding systems to obtain characterizations of the atmospheric boundary layer.

The instruments and associated parameters obtained during the field campaigns are summarized in the following table:

Instrument	**Oceanic Parameters**							**Atmospheric parameters**			
	Surface			**Profiles**							
	Tempe rature	Sali nity	Curren	Tempe rature	Salinity	tracers	Current	Wind	T	P	Fluxes
PIRATA ATLAS r	Yes	Yes		Yes	Yes			Yes	Yes	Yes	Yes
PIRATA current m			Yes				Yes				
CTD	Yes	Yes		Yes	Yes						
XBT	Yes			Yes							
XCTD	Yes	Yes		Yes	Yes						
Surface drifters SS	Yes		Yes								
Surface drifters wi pressure	Yes		Yes					Yes		Yes	
VM-ADCP			Yes				Yes				
L-ADCP			Yes				Yes				
Tsgraph	Yes	Yes									
ARGO profilers				Yes	Yes						
MARISONDE	Yes			Yes				Yes		Yes	
ST Meteo Station								Yes	Yes	Yes	Yes
Coastal stations	Yes	Yes						Yes		Yes	
Atmospheric micro air sea fluxes	Yes							Yes	Yes	Yes	Yes

3.3 Logistical considerations

The cruises and deployment of instruments impose a few constraints that are generally common to every oceanographic cruise and which Task Team members have experience. Most of the problems concern the transportation of equipment to ports used by the research vessels and the need for custom clearances. Efforts to resolve any potential problems should begin now.

One constraint for the EGEE cruises will be storing instruments at Cotonou (Benin) between the two June and September 2005 cruises. This issue can be resolved (for 2005) through communications between TT5 (C.Peugeot/IRD) participants, the Cotonou CRHOB (coll. R.Djiman), and local shipping agents, which have begun.

During the SOP 1 EGEE 3 cruise, the communication between the ATALANTE and the aircraft that will simultaneous survey the Benin section will not be a problem.

The logistics for the German glider using in the Gulf of Guinea and along 23°W, as planed in the framework of TACE by IFM-GEOMAR (see below), have to be established in collaboration with French cruises.

3.4 Priorities and potential problems

3.4.1 Priorities

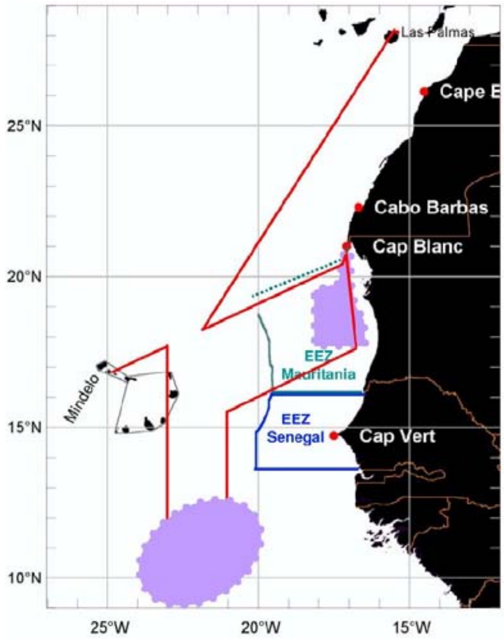
Most of the basic networks are funded (e.g., Argo, surface drifters, two ATLAS moorings, VOS XBT lines, etc.) and are of equal importance for the planned process studies, calibration/validation of satellite measurements and numerical model validations. A general priority however is to enhance these networks for improving spatial and temporal resolution of both the atmospheric and oceanic boundary layers. Ensuring the maintenance of the ATLAS buoys (and potential extensions) during all three observing periods specifically for air-sea fluxes studies should also be considered as a priority task. We can also consider that during the SOP 1 French EGGE 3 cruise, ocean and atmosphere boundary layers measurements, turbulence (microstructure) measurements in the upwelling areas and the simultaneous survey from aircraft of the Benin section are of top priority.

3.4.2 Potential problems

1) - Vessel time: Several EOP cruises are presently not supported (e.g., EGEE 4, SOP 3 late period during boreal fall 2006 and both EGEE cruises planned in 2007).
2) - Senegal cruises: The Senegalese (CRODT/ISRA) contribution is also presently not funded.
3) - ATLAS buoys: ATLAS buoy have failed due to vandalism typically associated with fishing activities in the GG (e.g., 2004). The PIRATA project will continue through 2006. An evaluation of the utility of the buoys for operational agencies and research studies will be conducted in 2005 to determine the form of the post-2006 array. For instance, the equatorial buoys at 10°W and 0°E could be displaced farther south or in the center of the tropical Atlantic basin to reduce potential vandalism problems.
4) - Countries clearance: Cruises trajectories are subject to authorization by countries which control the EEZ in which measurements are planned. Thus, the EGEE cruises track lines may be modified if one of several of the following countries do not provide the requested authorization: Liberia, Ivory Coast, Ghana, Togo, Benin, Equatorial Guinea, Congo, Gabon, São Tomé and Principe, Nigeria, Senegal.
5) - Observers: Due to the large number of clearance countries for EGEE cruises and the fact that these countries may impose one (or even two) observers onboard, the number of scientists could be reduced.

4 Partnership

4.1 Field observations



1) German (IFM-GEOMAR) biogeochemical program: This R/V METEOR cruise is planed in July 2006 in the Guinea Dome and Mauritania upwelling region. Contacts for collaboration are in progress. Twice-daily radio-soundings, as well as ocean microstructure (turbulence) measurements are planned. It would be a potential opportunity for profiler and surface drifter deployments.

2) French PIRATA cruises: These cruises are dedicated to the maintenance of the PIRATA ATLAS buoys network at 23°W-Equator. The four buoys located in the Gulf of Guinea will be maintained during the EGEE cruises from 2005 to 2007. IFM or NOAA could also maintain the 23° W-Eq moorings. These cruises can be opportunities to provide temperature profiles (XBT) and to deploy drifting buoys and ARGO profilers

3) CLIVAR-Atlantic TACE program: The CLIVAR Atlantic TACE program includes the global observing networks described previously. Other TACE activities represent potential opportunities to deploy additional measurement systems (e.g., gliders along 23°W and in the GG by IFM-GEOMAR.

4.2 Training program

- French PIRATA and EGEE cruises will provide opportunities to embark African students or scientists. For example:
- A student from LPA/UCAD-Dakar (Sénégal) would embark during the next PIRATA cruise in May 2005. He will obtain experience in sea water sampling, CTD acquisition, profiler deployments and XBT launches that will be necessary during the potential SOP Senegalese ITAF-DEME cruises.
- - EGEE/AMMA collaborators of LAPA (Univ./Cocody/RCI) are supposed to contribute to the cruises and to send onboard some students (one per cruise).
- Scientists in Togo and Bénin involved with EGEE/AMMA could also participate on cruises.
- Scientists of the solicited EEZ countries will participate as observers but can also be trained in data acquisition and initial processing.
- ARGO data Center: In the framework of ARGO, two data centers exist: one in US (NOAA/AOML-Miami) for the South Atlantic (20°N south) and one in France (IFREMER-Brest) for the North Atlantic (20°S north). Training courses will be organized during which African scientists will be trained in oceanographic data treatment. A meeting was held in Cape Town during May, 2005 about this issue and information is available on the AOMLl website www.aoml.noaa.gov (search for SAARDAC).
- Theses carried out in the framework of AMMA are already in progress in France (1 from LPA/UCAD-Dakar; 2 from University of Cocody/Abidjan).
- Project: In France, African partners will be trained to use MERCATOR results. Simulations stored on CD/DVD can be provided to countries without web connections.

5 Organisation of the TT.

5.1 Leaders and core group, membership:

	Name	Surname	Organism	Function	Email adress
Task Team lead					
International coord.	BOURLES	Bernard	IRD/LEGOS	French cruises	bernard.bourles@ird.fr
	MOLINARI	Robert	NOAA/AOML	US cruises	molinari@aoml.noaa.gov
	BRANDT	Peter	IFM-GEOMAR	German cruises	pbrandt@ifm-geomar.de
Core Group					
In France	CANIAUX	Guy	Météo-France	Air-Sea fluxes in the G during French SOP 1 c	guy.caniaux@meteo.fr
	GOURIOU	Yves	IRD/US025	French cruises material currents	yves.gouriou@ird.fr
	MARIN	Frédéric	IRD/LEGOS	Hydrology, currents	frederic.marin@ird.fr
	ELDIN	Gérard	IRD/LEGOS	Currents	gerard.eldin@ird.fr
	DUPENHOAT	Yves	IRD/LEGOS	Hydrology, currents	
	GIORDANI	Hervé	Météo-France	Air-Sea fluxes	herve.giordani@meteo.fr
In USA	GARZOLI	Silvia	NOAA/AOML	ATLAS buoys	garzoli@aoml.noaa.gov
	LUMPKIN	Rick	NOAA/AOML	Drifters	rick.lumpkin@noaa.gov
	SCHMID	Claudia	NOAA/AOML	Hydrology, currents	Claudia.Schmid@noaa.gov
In Germany	DENGLER	Marcus	IFM-GEOMAR	Microstructures	mdengler@ifm-geomar.de
	RHEIN	Monika	Univ. Bremen	Helium	mrhein@physik.uni-bremen.d

5.2 External diffusion of the information and reporting:

All information concerning this Task Team have to be shared and let available to all national groups, the national AMMA SCs & international AMMA SCs (EU & ISSC), in particular all other international Task Teams. Cruise and data reports will be accessible through AMMA data Center and AMMA web sites.

6 Coordination with other TTs.

Coordination with other related task teams, i.e. mainly TT7, TT8 and TT9 will, occur during field operations through email, phone and fax. Coordination not related to fieldwork will occur through meetings and workshops.

7 Status of the field program (April 2006)

7.1 About the coordination between the cruises

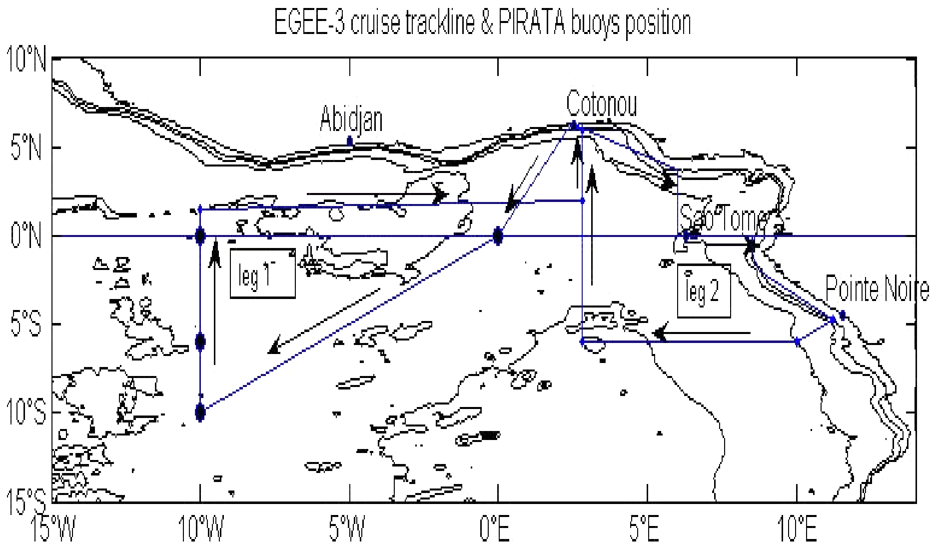
Many points have been clarified from August, mostly during the PIRATA, TACE and CLIVAR Atlantic Panel meetings (Toulouse, 12-14, Venice, 17-19 and 20-21, 2005). During the 2006 SOP, three oceanic cruises will be carried between May and July 2006 as a common and quasi-simultaneous effort from US, Germany and France. Additional short cruises were also planed from Senegal, in order to assess the oceanic upper layer during the different phases of the WAM and to deploy ARGO profilers between Senegal and Cape Verde. These cruises are proposed in the Senegal national AMMA program and elaborated in close collaboration with EGEE, and would be mostly funded by AMMA-France (EGEE). Unfortunately, for many different reasons, these cruises will not be feasible before late 2006 or 2007, and thus no data will be carried out in this area during the SOP. However, and thanks to a close collaboration between the partners and an efficient communication, the ARGO profilers, provided by NOAA/AOML, planed to be deployed during the first Senegalese cruise, initially scheduled in May 2006, will be deployed between Cape Verde and Mauritania in July during an IFM-GEOMAR cruise (Meteor 68/3) especially dedicated to geochemical measurements (resp. A.Körtzinger).

It has to be noticed that during these three French, German and US quasi-simultaneous cruises, radio-soundings, XBT and reduced CTD profiles data will be transmitted in quasi-real time from the three research vessels for Coriolis/Argo and Mercator/Godae projects.

Tracklines of the cruises and measurements that will be carried out during these cruises are explained in detail in the following.

1) The EGEE 3 cruise: From Cotonou to Cotonou (Benin), May 24 to July 6, 2006 onboard the R/V L'ATALANTE, by IRD, Meteo-France & CNRS (France).

Interactions between TT6 and TT8 led to discuss the coordination of Ocean soundings and aircraft flights. The cruise trackline (direction; see map below) and schedule have been adapted in order to ensure the simultaneousness with equipped airplane flights scheduled along the Cotonou line (2°50'E) in mid-June and July (see details below), and also in order to ensure the replacement of the PIRATA ATLAS buoys (black dots on the map above) at the very beginning of the SOP measurements.



During this cruise, many experiments and measurements will be carried out that will be done by teams from the three countries involved in the AMMA TT6 (France, Germany & US).One of the main priorities during the cruise is air-sea fluxes measurements. Different operations are the followings:

a) Flux measurements:

Turbulent fluxes will be estimated by different methods: inertial dissipation, correlation and bulk. Complementary measurements will include radiation, solar and infrared, specific measurements concerning precipitation and precipitation temperature. Collaboration with RSMAS/USA will provide skin sea surface temperature measurements along with solar radiation and aerosol measurements. Turbulent fluxes will be measured during 6 long duration stations (24h to 48h) located close to the PIRATA ATLAS buoys and south of the Sao Tome Island, a few miles off the meteorological station.

Radio-soundings will be performed twice a day, and other at the passage of satellite in the area (*i.e.* a total amount of about 150 atmospheric profiles), with real-time data transmission by GTS.

Ocean mixed layer will be thoroughly documented thanks to thermistance drifting chains (12 “Marisonde” drifters) and a few Surface Velocity Profilers equipped with thermistance chains down to 70m depth.

b) Hydrology and currents:

About 100 profiles (from the surface down to 1000m, maybe 2000m within the equatorial band) will be done during hydrological stations (every ½° along the 10°W, 2°50’E, 6°E and 6°S sections). During these stations, temperature, salinity and dissolved oxygen profiles are acquired continuously along with both horizontal components of the current velocity, and sea water samplings are done for different parameters analysis (salinity, dissolved oxygen, nutrients, Helium, and for a few stations at depths CO2, O18, C13 and CFCs, along with for biogeochemical analysis). Ocean microstructure measurements (vertical mixing) will be done after most of the CTD profiles (coll. IFM-GEOMAR/Germany).

All along the cruise trackline, meteorological parameters, upper layer currents, sea surface temperature and salinity will be continuously measured, and surface sea water samplings will be done for salinity, CO2 parameters and nutrients analysis.

Ten Surface Velocity Profilers (SVP) will be deployed, that measure sea surface temperature (SST) and transmit daily their position and SST measurements. ARGO profilers will also be deployed. These profilers provide every 10 days temperature and salinity profiles from the surface down to 2000m depth. 22 profilers have already been deployed in 2005 during the two first EGEE cruises. About 120 temperature profiles will be carried out (every ¼°) with expendable probes (XBT).

c) Simultaneous airplane measurements:

Two aircrafts will survey twice the 2°50’E meridional section (“Benin” section) from the African coast to 2°N, at low and high atmosphere levels, in order to measure representative parameters of the atmospheric boundary layer conditions (see also TT8 document). During the EGEE 3 cruise, the research vessel will be at the same date at some location of this section, and the same parameters at the air-sea interface, along with parameters within the oceanic boundary layer, will be measured. The two surveys are scheduled on June 15 and July 4, *i.e.* hopefully before and after the WAM monsoon latitudinal drop.

d) Other operations:

The four ATLAS meteo-oceanic buoys of the PIRATA array located in the Gulf of Guinea will be replaced at 10°W-10°S, 10°W-6°S, 10°W-0°N, and 0°E-0N. Actually, two of them disappeared from their last servicing probably due to vandalism (10°W-6°S and 10°W-0°N, respectively in September 2005 and February 2006). But a commitment of the PIRATA committees ensures to maintain the actual network configuration at least until early 2008. Furthermore, an additional buoy will be deployed during the cruise at 6°S-8°E in the framework of the PIRATA-Southeast extension funded by BCLME and proposed by South-Africa.

The meteorological station implemented in Sao Tome in October 2003 will be serviced, before a long duration station (24-48h) that will be done just offshore in order to check if its measurements are representative of the surrounding oceanic conditions.

Furthermore, as IFM-GEOMAR will take care about the PIRATA currentmeter mooring at 23°W-Equator (see below), the deployment of an additional currentmeters mooring at 10°W-Equator, funded by IRD in the framework of PIRATA-France and EGEE, could be feasible during their cruise (see below) in order to assess the surface equatorial currents during the whole SOP period at this particular longitude.

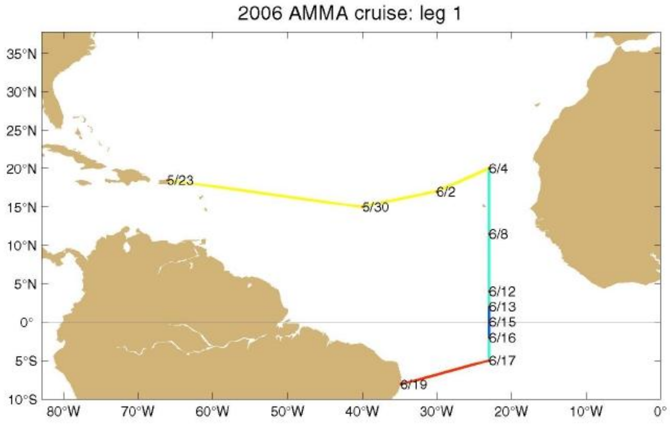
Finally, two radio sounding moorings of IFM-GEOMAR, installed in the framework of CLIVAR in January 2004 during the French PIRATA-FR12 cruise, will be recovered at 10°W-6°S and 10°W-1°N.

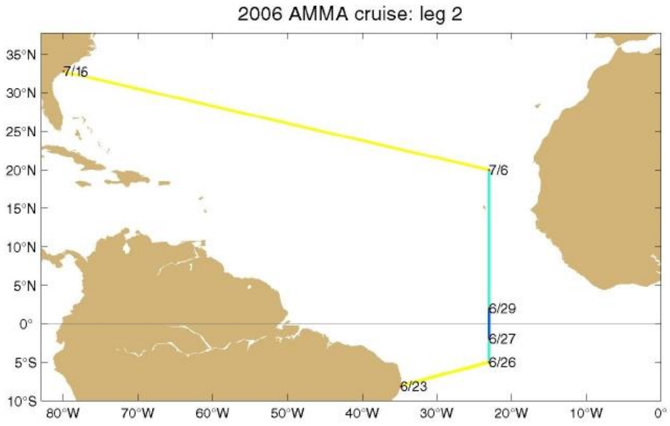
To summarize, coordinated actions by US and German teams during the EGEE 3 cruise include:

- Ocean microstructure measurements (vertical mixing), with IFM-GEOMAR, Kiel (Germany)
- Skin sea surface temperature measurements & aerosols with RSMAS (USA).
- Surface Velocity and temperature profilers (SVP) with AOML/NOAA (USA)
- Helium sampling (vertical upwelling rate) with the University of Bremen (Germany)
- Biogeochemical, radiance, particulate and dissolved absorption with LAMONT (USA)
- Two radio soundings mooring recovering, for IFM-GEOMAR, Kiel (Germany)

Finally, colleagues from several African laboratories (Nigeria, Benin, Togo, maybe Ghana, Ivory Coast, Congo and Senegal) will participate to the EGEE 3 cruise, in order to contribute to the data acquisition and for training and also as observers for the concerned Exclusive Economic Zone (EEZ) of their country.

2) The R/V RON-BROWN cruise: From San Juan (Porto Rico) to Recife (Brazil), and from Recife to Charleston (USA), May 23-July 16, 2006 by AOML/NOAA (USA)





This cruise will be carried out in the Tropical Eastern Atlantic Ocean, principally along the 23°W longitude (meridional section carried out twice at the few weeks interval, see maps for the two legs of the cruise).

During this cruise, many kinds of measurements will also been carried out, in the framework of AMMA and also PIRATA, as two additional ATLAS mooring along 23°W will be deployed in the framework of the PIRATA-North-Eastern extension, proposed and supported by NOAA (USA). These buoys will allow getting atmospheric measurements off Africa during the whole AMMA SOP period.

Different operations are the followings:

a) Flux measurements:

Atmospheric data will be collected to characterize the vertical structure of the Saharan air layer (SAAL), including mineral dust aerosol over the Atlantic Ocean. Skin sea surface temperature, solar radiation and aerosol measurements will be carried out all along the cruise. Atmospheric data will also be collected to investigate the linkages between the vertical distributions of tropospheric ozone with Saharan dust outbreaks. In addition, a suite of trace gas and aerosol ambient measurements, ozonesondes and aerosol sampling will be taken to quantify the microphysical and chemical evolution of the Saharan dust, to analyze the biological and chemical content of size –fractionated aerosol samples and to characterize the density and mass concentrations of aerosols within the SAL.

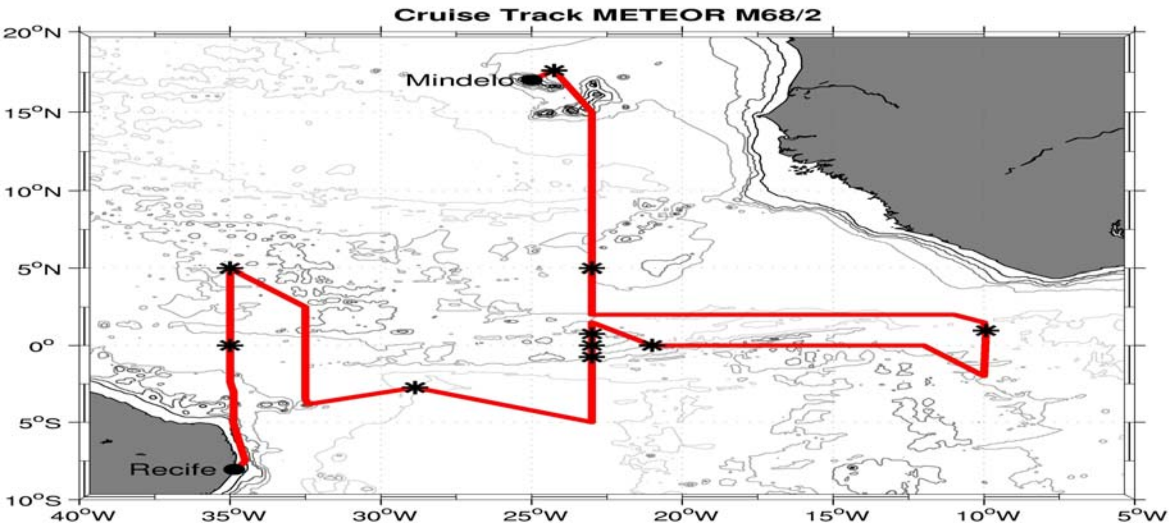
Radio-soundings (86) and ozonesondes (20-30) will also be launched twice a day during this cruise, with real-time data transmission by GTS.

b) Hydrology and currents: Shipboard current measurements and sea surface temperature and salinity will be continuously measured, as well as on-station CTD and current profiling from the surface down to 1500m depth will be carried out along 23°W (about 60 CTD profiles during each leg). Sea water samplings will be done for salinity and oxygen analysis. About 100 temperature profiles will be carried out with expendable probes (XBT).

c) Other operations:

Two ATLAS moorings will be deployed along 23°W (at 4°N and 11.5°N) in the framework of the PIRATA-Northeastern extension, to provide time series of the surface atmospheric parameters, upper ocean temperature, salinity and current structure.

3) The R/V METEOR 68/2 cruise: From Recife (Brazil) to Mindelo (Cape Verde), June 6–July 7, 2006 by IFM-GEOMAR (Germany)



This cruise will allow getting measurements about the ocean circulation in the west (35°W) and center (23°W) of the basin almost simultaneously to the two other cruises and also along the 10°W section near the Equator at a few days interval after EGEE 3.

a) Atmospheric measurements: Radio-soundings will be launched twice a day during this cruise with real-time data transmission by GTS.

b) Hydrology and currents: Shipboard current measurements and sea surface temperature and salinity will be continuously measured, as well as on-station CTDO2 and current profiling (L-ADCP) will be carried out. Sea water samplings will be done for different parameters analysis (salinity, oxygen, nutrients, Helium, and CFCs). Ocean microstructure measurements (vertical mixing) will be done, mostly along the equator, along with Helium sampling. ARGO profilers deployment will be done notably along the equator between 23°W and 10°W.

c) Other operations:

At 23°W between 0.75°N and 0.75°S as well as at 21.5°W-0°N, currentmeters moorings will be deployed and the PIRATA ADCP mooring deployed in May 2004 will be replaced at 23°W-0°N (also equipped with other deep currentmeters in the framework of the German-CLIVAR program). Additional CTD/O2 moorings at 23°W, 5°N and near Cape Verde will be deployed.

If the PIRATA ADCP apparatus correctly works at 23°W-0°N, an additional ADCP mooring will be deployed at 10°W-0°N for the French EGEE/AMMA and PIRATA programs. Equipped with an ADCP around 100m depth, this mooring will allow us to assess the surface equatorial currents during the whole SOP period at this particular longitude.

Finally, AGO profilers provided by USA will be deployed between the Cape Verde Islands and the Mauritanian coasts during a following cruise (the Meteor 68/3 cruise) in July 2006 dedicated to geochemical measurements.

4) ITAF-DEME cruises: From Dakar to Cap-Verde, July to September, 2006 onboard the R/V ITAF-DEME, by Senegal.

In spite of the proposition made by API-AMMA (France) to partly fund these cruises, no clear answer were given by AMMA-Senegal about the organization of these cruises, mostly due to a lack of interest/involvement from the CRODT-Dakar. That point has been discussed in December 2005 during the AMMA conference in Dakar with the coordinator of AMMA-Senegal (Amadou Gaye) and the PI of the ocean project in Senegal (Bamol Ali Sow), who provided an answer regarding the possible participation of R/V ITAF-DEME rather in March 2005 only. In spite of some material preparation at the CRODT, the possibility to send in Dakar XBTs and other material from France and ARGO profilers from US, and the participation of an experimented engineer from IRD, such a late answer and the absence of a clear estimate of the vessel time cost are the main reasons why the first Senegalese cruise initially planed in May 2006 had to be delayed. Anyway, works continue to be done in order to organize cruises from Senegal with the R/V ITAF-DEME in late 2006 or 2007.

7.2 About the R/V ANTEA of IRD and next EGEE cruises.

The next EGEE cruises (*i.e.* EGEE 4 planed in fall 2006 and EGEE 5 & 6 planed in spring and fall 2007) will be carried out from the R/V ANTEA of IRD. There is clear commitment by IRD to repair the R/V ANTEA by spring-summer 2006, in order to be able to do EGEE 4 cruise in fall 2006. This cruise will be a 'test' for the vessel. At now, we know that motors will be changed soon (by June 2006), and scientific material partly replaced and renewed during 2006. Anyway, to provide precise schedules for the EGEE 4 cruise is still impossible at now.

7.3 About the ongoing GOOS observations in the eastern Atlantic

The eastern Atlantic is somewhat arbitrarily defined here as the area between 20°S and 20°N and east of 30°W.

a) Argo floats: As of the middle of October 2005, approximately 75 Argo floats were located in the eastern Atlantic. Additional information is available at http://w3.jcommops.org/website/ArgoMapp

b) Surface drifters: As of the beginning of December there were approximately 35 surface drifters located in the eastern Atlantic. Additional information is available at http://www.aoml.noaa.gov/phod.

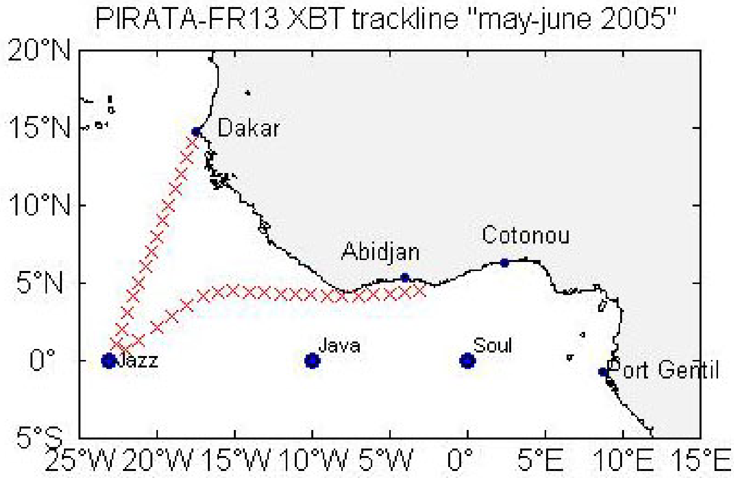
c) High density XBT line AX8: AX8 which runs from Capetown to New York was occupied 3 times during 2005 with another occupation planned before the end of the year. Additional information is available at http://www.aoml.noaa.gov/phod.

d) About the XBT and thermosalinograph VOS lines AX11, AX15 and AX20 under IRD responsibility : AX11 run operationally with high frequency profiles (XBT and XCTD) during two transects carried out in the framework of the ARAMIS project (resp. S.Arnault, IRD/LOCEAN); XBT along AX15 were interrupted during one year from November 2004 to November 2005, and thermosalinograph from February 2005 to November 2005; three transects were achieved along the AX20 line.

7.4 Actions Carried Out In 2005

7.4.1 PIRATA FR 13 cruise:

This cruise has been scheduled in order to replace the ATLAS buoy and currentmeter mooring of PIRATA at 23°W-Equator, in charge of France. It has been possible thanks to the chartering of the R/V LE SUROIT by IRD, which paid 70k€ for that! (cost of the 7 additional days to go to 23°W-Equator from Dakar and to do the field works, the vessel being normally in transit to go directly from France to the Gulf of Guinea for the EGEE 1 cruise).



Two scientists of the IFM-GEOMAR (Kiel) have participated to the cruise in order to do some works in the framework of their German-CLIVAR program and in close collaboration with AMMA-EGEE and PIRATA programs.

During this cruise, the following works (list limited to AMMA-EGEE, PIRATA & ARGO activities) have been carried out:

- Replacing of the ATLAS PIRATA buoy at 23°W-Equator
- Replacing of the currentmeter (surface ADCP) mooring of PIRATA at 23°W-Equator
- 37 XBT launches (see map). Data sent in quasi-real time in the framework of CORIOLIS.
- ARGO profilers have been deployed (1 French PROVOR, 6 German RAFOS -4 deep and 2 shallow-, 6 German APEX and 2 German NEMO)
- 6 Surface Velocity Profilers (SVP, surface drifters) has been deployed (provided by NOAA/AOML)
- 1 CTD-O2 profile has been done at 23°W-Equator
- Sea surface water samplings have been done for salinity and nutrients analysis (every degree).

7.4.2 EGEE 1 and EGEE 2 cruises:

These cruises have been carried out with the R/V Le SUROIT from Cotonou (Benin) from June 7 to July 5, 2005 and from September 3 to September 29, 2005 respectively (see maps below).

These cruises allowed carrying out:

- About 60 hydrological profiles (CTD-O2) and current profiles (L-ADCP) per cruise, along with 11 sea water samplings along the water column (surface to 500m or 1000m) for salinity, dissolved oxygen and nutrients analysis;

- More than 110 temperature profiles per cruise (XBT);

- Change of the 4 ATLAS buoys of the PIRATA program located in the Gulf of Guinea (black dots on the EGEE 1 map above);

- The deployment of 24 ARGO profilers (18 French PROVOR and 6 US SOLO that provide temperature and salinity profiles from the surface down to 2000m depth every 10 days) ;

- About 30 sea surface samplings per cruise for salinity, nutrients, CO2 parameters, C13 and O18 analysis;

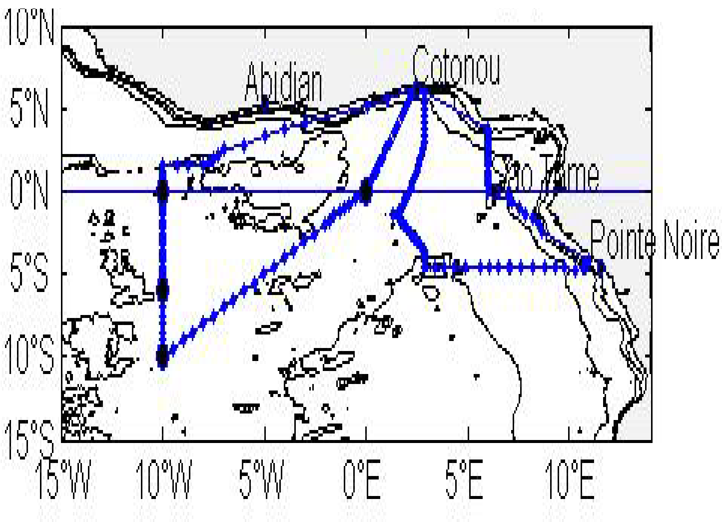
- The deployment of 16 surface drifters (SVP) that provide daily sea surface temperature and surface current drift measurements (coll. NOAA/AOML -Miami-USA).

- Upper layer current measurements all along the trackline (surface to 200m depth), along with meteorological measurements, sea surface temperature and salinity (thermosalinograph);

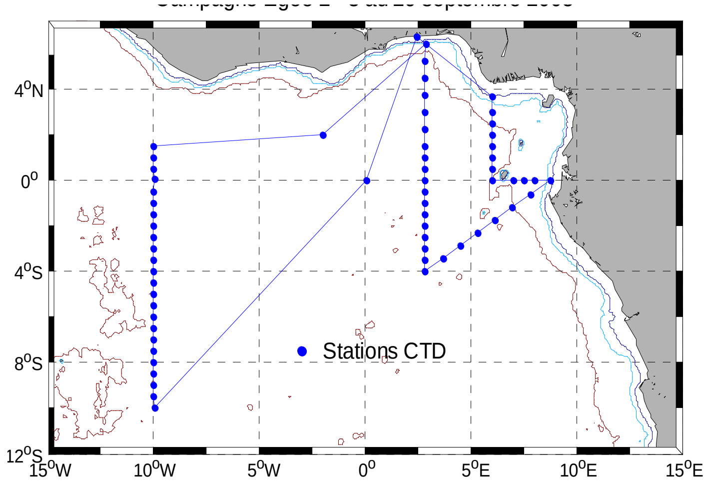
- 12 microstructure profiles along 10°W during EGEE 2 (that allow an estimate of vertical mixing; coll. IFM-GEOMAR / Kiel, Germany)

- About 60 sea water sampling along the vertical during hydrological profiles along 10°W and 3°E during EGEE 2 for Helium (that allow an estimate of vertical upwelling rate; coll. University of Bremen, Germany).

Trackline of the EGEE 1 cruise
(dots correspond to temperature profiles)



Trackline of the EGEE 2 cruise
(dots correspond to temperature/salinity profiles)



Due tot the reduced vessel speed, the planed tracklines have been modified in the eastern part and about 80% of the initial objectives have been achieved during these two cruises. However, the adapted trackline during EGEE 2 east of São Tome allowed us to have fitted measurements in order to study the Equatorial UnderCurrent termination.

7.4.3 Coastal stations:

In the framework of EGEE/AMMA, an autonomous “ONSET” temperature sensor has been installed in the port of Cotonou (Benin) in July 2005. The data will be compared with the usual coastal measurements carried out in a traditional way (twice or three times per week).

7.4.4 Training:

- A total of 8 scientists from African countries have participated to the three French cruises carried out in 2005. Details are given in the following. Actually, it is systematically asked to the competent authorities of the solicited countries for working clearances in their Economic Exclusive Zones (EEZ) to favour the participation of scientists in place of official observer when possible.
- One Senegalese young scientist, Mr Malik Wade, from the Laboratoire de Physique de l’Atmosphère (LPA, University of Dakar) has been invited to participate to the PIRATA FR 13 cruise. This

scientist is actually doing a Master in physical oceanography in France (Université de Bretagne Occidentale / Brest) from Oct. 2005.

- Three scientists of Benin, Dr.Roger Djiman (chief of the Centre de Recherche Hydrologique et Océanographique du Benin: CRHOB), Georges Degbé & Zacharie Sohou, both working to CRHOB, have been invited to both EGEE 1 and EGEE 2 cruises (one people per leg).
- One scientist of Ivory Coast, Dr.Yves Kouadio, working to the Laboratoire de Physique de l'Atmosphère (LAPA; University of Cocody) has been invited to participate to the EGEE 1 cruise (1st leg; no scientist had time availability to participate to EGEE 2, for which one scientist of LAPA were also invited).
- One scientist of Nigeria, Mr Lekan Adekanmbi working with Mme Regina FOLORUNSHO to the Nigerian Institute for Oceanography and Marine Research (NIOMR), has been invited to participate to the EGEE 2 cruise (2nd leg), in place of an usual official observer from the Nigerian Navy (as done during EGEE 1).
- One scientist of Togo, Mr Damien Gatogo working with Pr A.B. BLIVI to University of Lomé (Dept of Geomorphology), has been invited to participate to the EGEE 2 cruise (1st leg).
- One scientist of Congo, Mr Auguste Locko, working to the IRD Center of Pointe Noire, has been invited to both EGEE 1 and EGEE 2 cruises (2nd legs)

Chapter 9

Characterisation of aerosols during the dry season and analysis of their radiative impact

TT7

Jim Haywood, Jacques Pelon

Karine Desboeufs, Paola Formenti, Ellie Highwood, Béatrice Marticorena

1 Scientific justification and objectives

The African continent is the largest global source of both mineral dust aerosols and biomass burning aerosols. These aerosols are known to significantly affect the solar and terrestrial radiation of the African region thereby modifying the planetary albedo and the outgoing longwave radiation and reducing the radiation flux available to the ocean. In addition to attenuation by scattering, these aerosols absorb a significant proportion of both solar and terrestrial radiation in the atmospheric column and therefore modify the heating rates of the atmosphere. They also significantly influence the surface radiation balance with subsequent effects on the sensible and latent heat fluxes over land surface which may affect the atmospheric dynamics and hydrology of the region. Additionally, the aerosol produced during the dry season may play a role in the interannual variability through the modulation of the radiation energy stored in the ocean in the Benin Gulf. On the reverse, rainfall and the development of the vegetation, linked to the penetration of West African Monsoon, indirectly controls dust emission and biomass burning emissions during the dry season. Deposition of west African dust to the Atlantic ocean provides ocean nutrients, including iron and subsequent changes in ocean productivity affects the global carbon cycle.

The importance of the radiative forcing of aerosols and potential impact on dynamics has been shown at different scales. The lack of inclusion of mineral dust aerosol has recently been highlighted as a major model deficiency in numerical weather prediction models (Haywood et al., 2005). On the other hand, aerosols are now included in climate models to predict how they affect long-term climate changes acting directly on radiative budget or indirectly through the modification of cloud life cycle. To address these issues, the Met Office Unified model has been developed to include mineral dust generation, transport and deposition in both the global and CAM (crisis area model) versions. However interaction processes still need to be better understood and parameterised.

Until now, dust and biomass aerosol properties and radiative impact have been characterized in regions where they have been studied independently. Dust uptake from the surface to the atmosphere has extensively been analysed and parameterisations have been developed for modelling (Marticorena and Bergametti, 1995). Source regions for dust and biomass burning particles as well as horizontal transport processes near sources can be identified by radiometry from satellite, but one of the main difficulties remains to precisely identify the vertical extension of the transported particles, which is critical for further dispersion and to the radiative impact due to their significant absorption. Far from the sources, dust or biomass burning aerosols can be frequently observed in elevated layers (Ansmann et al., 2005). Karyampudi et al. (1999) have first used lidar observations from LITE to analyse the dispersion of dust particles over the Atlantic ocean. Combination of in situ, passive and active remote sensing during the SHADE campaign (Tanré et al., 2003) have more recently allowed a better characterization of their radiative impact (Haywood et al., 2003a). Biomass burning aerosols have been extensively characterized during the SAFARI campaign (Haywood et al., 2003b). Although their radiative forcing is negative over low reflectance surfaces, the observations made during the SAFARI campaign have first evidenced a positive radiative forcing due to elevated biomass particle layers over water clouds (Keil and Haywood, 2003).

Dust and biomass burning aerosol particles have different microphysical and radiative properties (size, shape, absorption) and their mixing is leading to complex modifications (Gaudichet et al., 1995; Ruellan et al., 1999; Formenti et al., 2003a; Formenti et al., 2003b). Mixing and, further on, aging, sedimentation and cloud processing occurring over land and ocean will then result in a variable forcing which needs to be better understood. This is the purpose of the AMMA SOP0 field experiment.

The SOLAS observational programme Dust Outflow and Deposition in the Ocean (DODO) will be conducted in collaboration with AMMA and will extend observations of dust outbreaks further west towards Cape Verde and the Atlantic Ocean. It will be complemented by dust modelling, laboratory studies and remote sensing products, to produce a quantitative climatology of dust deposition to the Atlantic Ocean, including extensive analysis of iron content. In situ measurements of aerosol chemical and microphysical properties will be made using the FAAM aircraft and associated instrument suite during dust outflow events.

To summarize, the primary objectives of the AMMA SOP0 are:

- To perform high quality in situ and remote sensing measurements of the optical and physical properties of mineral dust aerosols, anthropogenic biomass burning aerosols, and combinations of the two from sub-Sahelian West Africa.
- To provide high quality spectral measurements of the solar and terrestrial radiative effects of both mineral dust and biomass burning aerosols.
- To determine the consistency between in situ measurements/satellite and surface based remote sensing methods of the effects on the radiation budget of the Earth of the composite biomass and mineral dust aerosols.
- To measure and model the effect of the presence of aerosols on the radiation budget at the top of the atmosphere, throughout the atmospheric column, and at the surface of the Earth over land and ocean.
- To contribute to new satellite validation and allow data to be further used in the analysis at the regional and global scale.
- To improve and validate numerical models (global and regional) to better understand the impact of aerosols on the radiation budget, hence the climate.
- To better determine the winter-time source regions, source strengths and emission factors of mineral dust and biomass burning aerosols.
- To better determine the winter-time outflow and deposition of mineral dust aerosols.

References

Ansmann A., J. Bösenberg, A. Chaikovsky, A. Comeron, S. Eckhardt, R. Eixman, V. Freudenthaler, P. Ginoux, L. Komguem, H. Linné, M.A. Lopez Marquez, V. Matthis, I. Matthis, V. Mitev, D. Müller, S. Music, S. Nickovic, J. Pelon, L. Sauvage, P. Sobolewsky, M. Srivastava and M. Wiegner, 2003 : Long range transport of Saharan dust to northern Europe : The 11-16 October 2001 ourtbreak observed with EARLINET, J. Geophys. Res., 108, D24, 4783, doi:101029/2003JD003757.

Formenti, P., W. Elbert, W. Maenhaut, J. Haywood, S. Osborne, and M. O. Andreae, Inorganic and carbonaceous aerosols during the Southern African Regional Science Initiative (SAFARI 2000) experiment: Chemical characteristics, physical properties, and emission data for smoke from African biomass burning, J. Geophys. Res., 108 (D13), 8488, doi:10.1029/2002JD002408, 2003a.

Formenti, P., W. Elbert, W. Maenhaut, J. Haywood, M. O. Andreae, Chemical composition of mineral dust aerosol during the Saharan Dust Experiment (SHADE) airborne campaign in the Cape Verde region, September 2000, J. Geophys. Res., 108 (D18), 8576, doi:10.1029/2002JD002648, 2003b.

Haywood, J. M, Allan, R. P., Culverwell I., Slingo, A., Milton, S., Edwards. J. M., and Clerbaux, N., Can desert dust explain the outgoing longwave radiation anomaly over the Sahara during July 2003? *J. Geophys. Res*., 110, D05105, doi:10.1029/2004JD005232, 2005.

Haywood, J.M., Francis, P., Osborne, S.R., Glew, M., Loeb, N., Highwood, E., Tanré, D., Myhre, G., Formenti, P., and Hirst, E., Radiative properties and direct radiative effect of Saharan dust measured by the C-130 aircraft during SHADE: 1. Solar spectrum, *J. Geophys. Res.*, 108(D18), 8577, doi:10.1029/2002JD002687, 2003a.

Haywood, J. M., Osborne, S. R. Francis, P. N., Keil, A., Formenti, P., Andreae, M.O., and Kaye, P.H., The mean physical and optical properties of regional haze dominated by biomass burning aerosol measured from the C-130 aircraft during SAFARI 2000, *J. Geophys. Res.*, 108(D13), 8473, doi:10.1029/2002JD002226, 2003b.

Karyampudi, V. M., et al., Validation of the Saharan dust plume conceptual model using lidar, Meteosat, and ECMWF data, Bull. Am. Meteorol. Soc., 80, 1045– 1075, 1999.

Keil, A., and Haywood, J. M., Solar radiative forcing by biomass aerosol particles over marine clouds during SAFARI-2000. *J. Geophys. Res.*, 8467, 108(D13), doi:10.1029/2002JD002315, 2003.

Marticorena, B. and G. Bergametti, 1995, Modelling the atmospheric dust cycle: 1. Design of a soil-derived dust emission scheme: J. Geophys. Res., v. 100, no. D8, p. 16,415-16,430.

Ruellan, S., H. Cachier, A. Gaudichet, P. Masclet, and J. P. Lacaux, Airborne aerosols over central Africa during the Experiment for Regional Sources and Sinks of Oxidants (EXPRESSO), J. Geophys. Res., 104, 30,673– 30,690, 1999.

Tanré, D., Haywood, J.M., Pelon, J., Léon, J.F., Chatenet, B., Formenti, P., Francis, P., Goloub, P., Highwood, E.J., Myhre, G., Measurement and modeling of the Saharan dust radiative impact: overview of the SaHAran Dust Experiment (SHADE), *J. Geophys. Res.*, 8574, 108(D13), doi:10.1029/2002JD003273, 2003.

2 Observing Strategy

2.1 Overall strategy

2.1.1 Period of investigation

The period of investigation has been chosen to maximise the contribution to the atmospheric aerosol burden from both biomass burning and Saharan dust aerosol particles. Figure 1 shows a MODIS image of mineral dust and biomass burning aerosols interacting in January 2005.

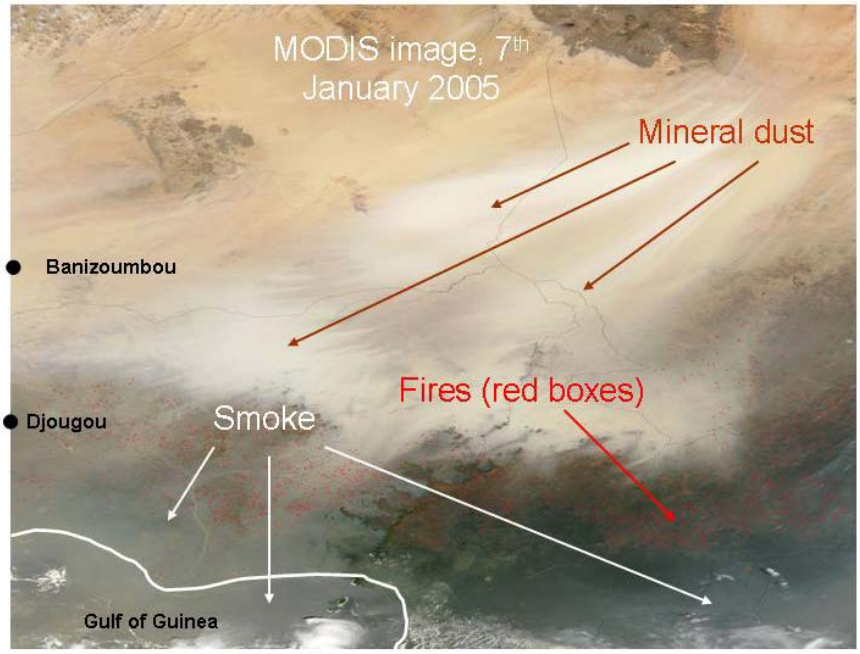


Figure 1. MODIS image from 5th January 2005 showing the presence of significant mineral dust and biomass burning aerosol over Nigeria/Benin/Burkina Fassau.

Mineral dust and biomass burning aerosols may be seen as distinct aerosol areas, but their interaction can clearly be identified close to the River Niger in the MODIS image.

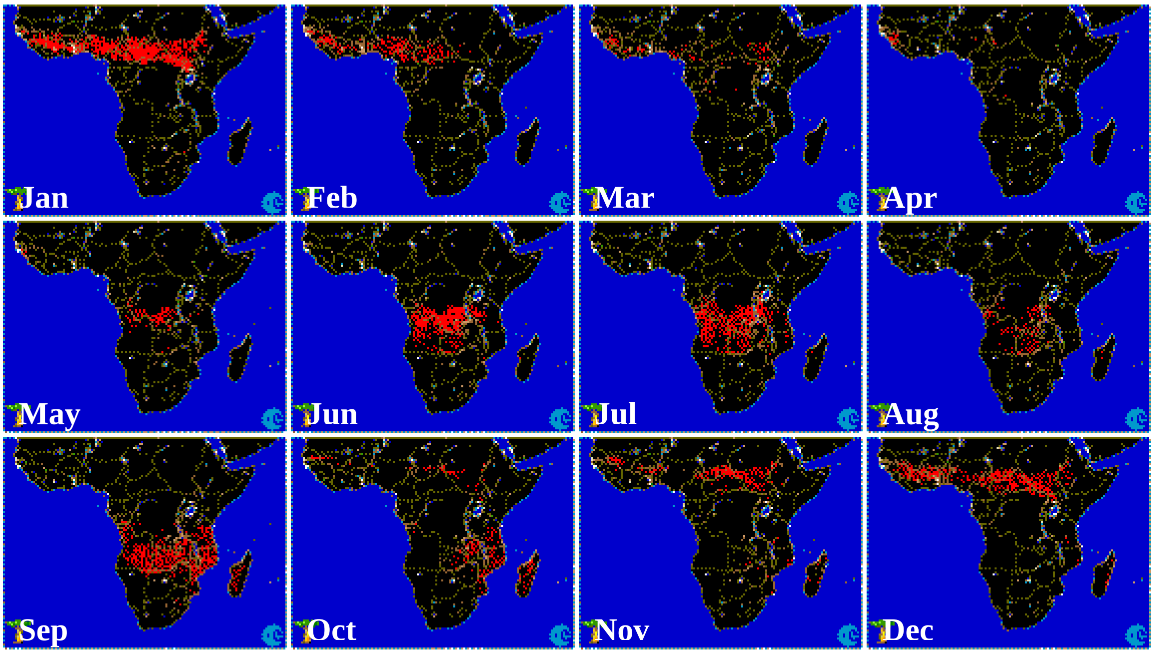


Figure 2. ATSR satellite retrievals of the number of fires during 2000 as a function of the month (starting from January top left image).

Figure 2 shows the annual variability in the number of fires in the region for the year 2000. It can be seen that the greatest number of biomass burning events occur in the sub-Saharan Sahelian region during the December-January-February period, subsequent to which the area of intense biomass burning moves further south reaching its southernmost extent in September.

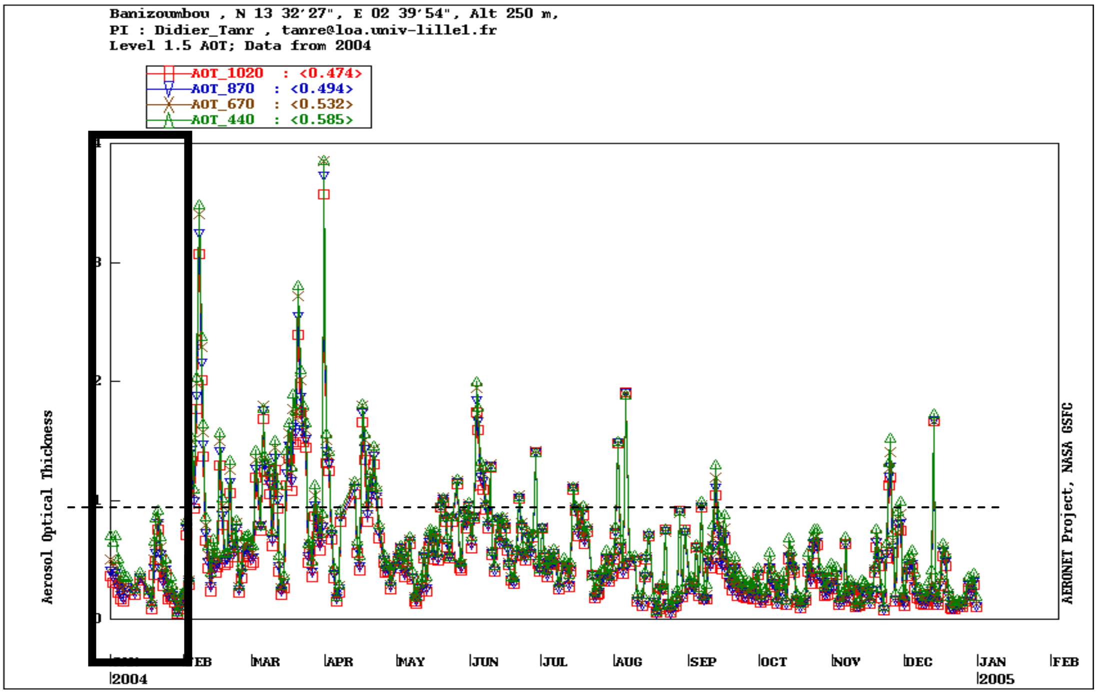


Figure 3. Aerosol optical depth measured by the AERONET sunphotometer at Banizoumbou during 2004. The bold frame delimits the selected period of observations.

Further qualitative analysis of the aerosol loading over the operating region may be performed by analysing the aerosol optical depth measurements from the AERONET site at Banizoumbou (13°32N, 2°40E) (Figure 3).

Table 1. Number of days when dust aerosol optical depth measured by sunphotometer is larger than a given threshold at Banizoumbou.

Banizoumbou	**2001**				**2002**				**2003**			
Period	Jan	Feb	Nov	Dec	Jan	Feb	Nov	Dec	Jan**	Feb	Nov	Dec
AOD > 0.5	5	7	6	2	3	5	4	3	3	6	6	5
AOD > 1	0	1	2	0	2	0	0	0	2	0	2	1
AOD > 2	0	0	0	0	0	0	0	0	1	0	1	0

Banizoumbou	**2004**				**2005**	
Period	Jan	Feb	Nov	Dec	Jan	Feb
AOD > 0.5	4	9	10	6	5	14
AOD > 1	1	7	3	1	1	6
AOD > 2	0	4	0	0	0	1

* Level 1.5 data ** some missing data

Five days of high aerosol load (corresponding to major dust/biomass burning events with optical depth larger than 1) have been observed in 2004 during the January/February operating period shown by the box in Figure 3. Multi-year statistics of the aerosol optical depth at Banizoumbou are presented in Table 1 using threshold AODs of 0.05, 1.0, and 2.0. In general a larger number of dust episodes is seen on statistical basis during the period of February. Over the five year period from 2001-2005, the return period for AODs > 0.5 is 2.5 days, for AODS > 1.0 is 8 days, and for AODS > 2.0 is 26 days.

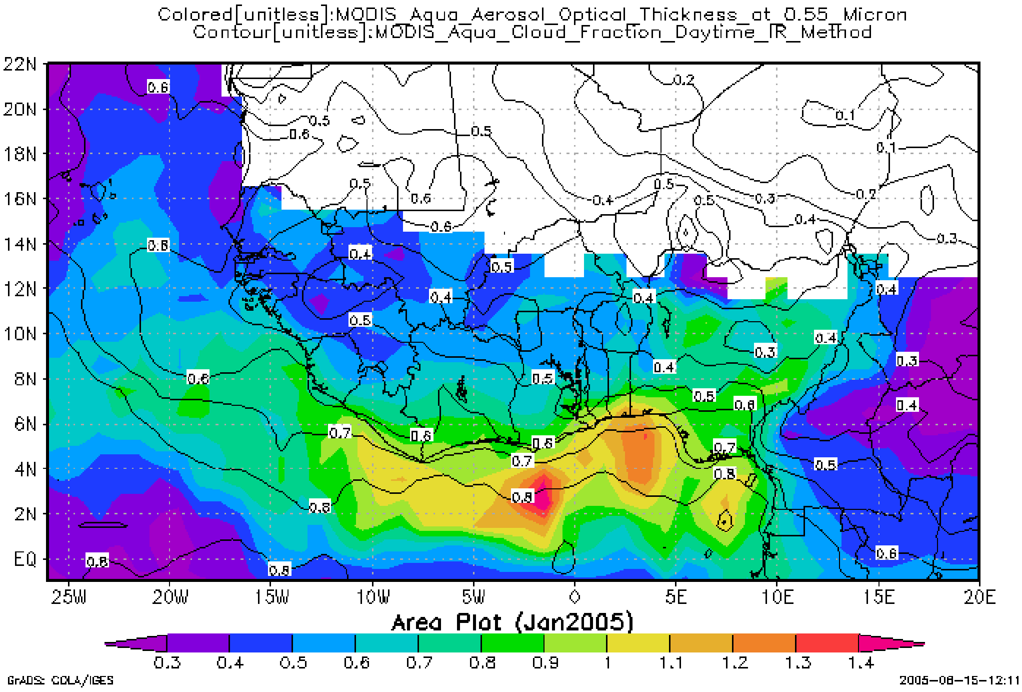


Figure 4. Average aerosol optical depth for January 2005 as observed with MODIS/AQUA, and cloud fraction contours (NASA Goddard Earth Science).

The interannual variability for AODS > 1.0 suggests that return periods of between 4 and 30 days are possible. This analysis suggests that the period of aircraft observations should not to be too short otherwise dust events with AODs > 1 might be missed altogether.

Finally, Figure 4 shows the aerosol optical depth determined by the MODIS instrument together with the cloud fraction. It can clearly be seen that the cloud fraction is relatively low over the northern regions of the AMMA operating region. Thus conditions of high aerosol optical depth and low cloud amount are prevalent during over the operating region during December–February.

In conclusion, December to February is the most suited period for investigating mixing of dust and biomass burning aerosols over western Africa. Although logistical reasons have initially led to target January and February 2006 for the SOP0 field experiment, November–December 2006 is considered as a valid alternative (SOP0-A'), should the situation arise that the earlier deployment of ground stations/aircraft would not be possible or would not allow to meet all objectives.

2.1.2 A multi-platform observational approach

In order to achieve the scientific objectives presented in section 1, a synergy of observations from three research aircraft (ATR-42, FR F-20, UK BAe146), various ground-based stations and space-borne instruments has originally been designed (Figure 5) to be operational in January–February 2006.

Several facts justify the choice of a multi-platform observational approach.

First, the area of interest, including source regions and areas where mixing occurs (Figure 1), cannot be covered by a single ground-based station or aircraft. This imposes to recur to various ground-based stations cleverly located in representative areas, and various aircraft making the link amongst them. Satellite sensors would of course allow overcoming this difficulty, but satellite are often blind over bright surfaces or their signal and retrieval algorithms are still prone to large errors over land.

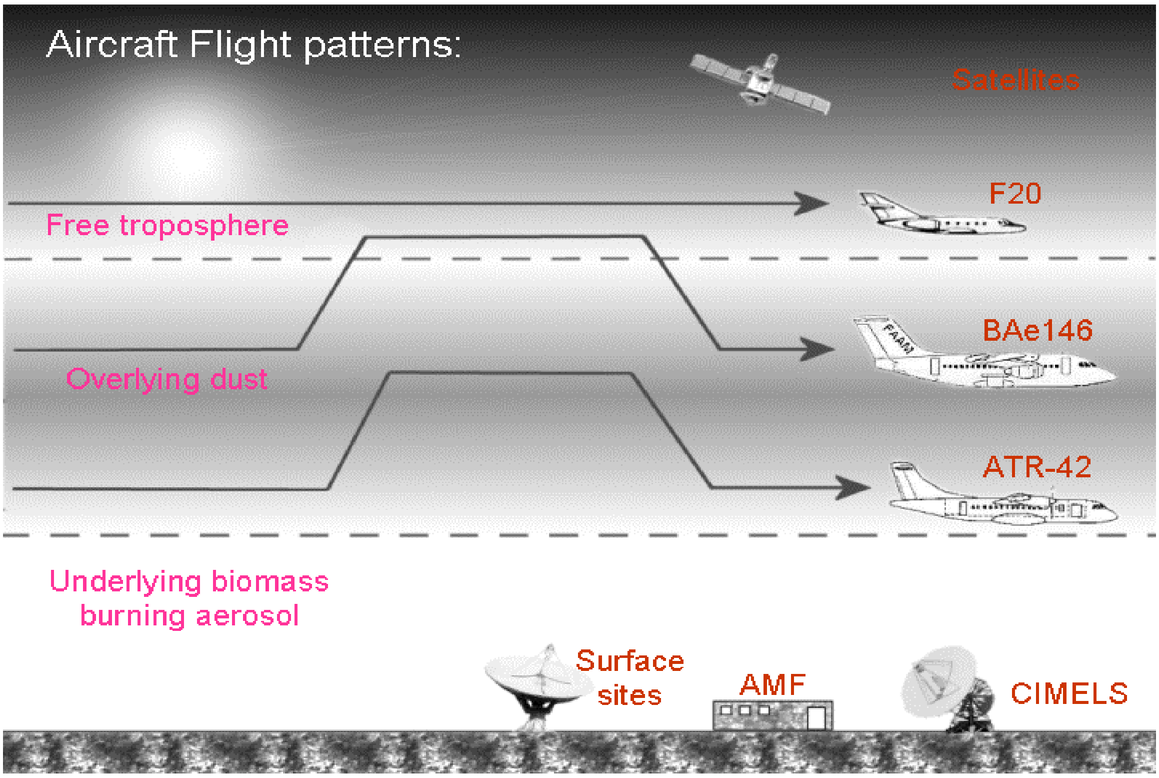


Figure 5. Schematic diagram of the aircraft, ground-based and satellite operations as in the original SOP0 plan (three aircraft operating together)

Second, the aerosol vertical distribution depends on source type, season, and residence time after emission. While pollution aerosols are generally constrained within the boundary layer, mineral dust and biomass burning aerosols are generally found in the free troposphere, where stratified layers of distinct origin and properties can be observed (Formenti et al., 2003a; Haywood et al., 2003a; Osborne and Haywood, 2004). As a consequence, aircraft and lidar systems are crucial to the SOP0 observational plan.

Third, mineral dust and biomass burning aerosols have complex and distinct physico-chemical characteristics, and in turn optical and radiative properties. Dust aerosols in particular have a size distribution encompassing various orders of magnitude (from fractions to tenths of microns), which cannot be simply documented by a single instrument, but requires a combination of counters/sizers. In turn, the experimental determination of size distributions suffers of artefacts depending on the composition and shape of the aerosols. Several authors (e.g., Reid et al., 2003) have shown that the number size distribution of dust aerosols can be severely miss-sized, particularly in the coarse fraction. In particular, airborne optical sizers such as the PCASP and FSSP are calibrated assuming non-absorbing spherical particles, whilst dust aerosols are not spherical but irregular in shape, and can be absorb radiation, both in the shortwave and in the longwave spectral regions (Lafon, 2004). Potential miss-sizing has little impact on the determination of optical properties in the mid-visible, but can cause large errors when computing optical properties at longer wavelengths (Reid et al., 2003; Osborne et al., 2004). As a consequence, it is necessary to have access to the largest possible number of redundant observations, in order to be able to identify and correct artefacts. It is also important that observations of the physical-chemical characteristics (number size distribution, mass size distribution, chemical composition, shape) of the aerosols are made under controlled and comparable conditions, so that these parameters can be combined with minimum ambiguity.

To summarize, the combination of ground-based, airborne and space-borne datasets would provide with the opportunity of performing:

1) internal consistency checks by means of signal-to-signal comparisons (examples: comparison of lidar signals; comparison of number size distributions measured by inlet- and wing-mounted probes)
2) closure tests and empirical parameterisations (examples: comparison of measured spectral scattering/absorption coefficients to those calculated from measured physical-chemical properties; comparison of measured CCN/CN ratios to those expected from measured physical-chemical properties)
3) radiative closure (example: comparison of measured radiative fields to those based on experimental validated optical properties)
4) remote-sensing product validation (examples: signal-to-signal validation between space-borne measurements and their aircraft simulators; retrieval of micro-physical parameters combining in situ and remote sensing observations).

as a prerequisite to combining all information to meet the objectives identified in section 1.

In the original SOP0 plan, three aircraft are involved, namely the FR ATR-42, the FR F-20 and the UK BAe146. The three aircraft need to perform various independent or co-ordinated flight patterns as deemed necessary to meet the scientific objectives detailed in section 1. The FR ATR-42 is predominantly concentrating on in situ sampling of aerosol physico-chemical and optical properties, vertical profiles and aerosol optical depth, the FR F-20 focusing on vertical structure and optical properties from remote sensing measurements, and the UK BAe146 aiming at performing a combination of in situ and remote sensing measurements of aerosol properties and radiation fields.

2.2 Observational strategy for each type of mission

2.2.1 Radiative closure

Flight patterns will be defined over ground-based sites in three regions of interest (Banizoumbou in the proximity of dust sources, Djougou in the fire region, and M'Bour for mixed aerosols; overflying of Tamanrasset is not planned because of security restriction or limited endurance of the aircraft). This will allow comparing

- column measurements by the AERONET sunphotometers with similar measurements which may be performed by a stacked profile ascent/descent flying into/down sun by the UK BAe146
- column aerosol optical depth measurements by the AERONET sunphotometers with the vertical-resolved aerosol optical depth measured by the PLASMA sunphotometer onboard the FR ATR-42.
- lidar measurements by the ground-based lidar systems (Univ. of Munich, ISAC-CNR, LOA/SA) with lidar measurements onboard the FR F-20 and FR ATR-42.
- in situ number size distribution and optical properties (scattering and absorption) measured at the ground-based stations with those measured onboard the UK BAe146 and the FR ATR-42.

In addition, aircraft intercomparison[1] will be performed in order to allow the results from one measurement platform to be used with confidence in conjunction with those from another platform. Comparison will be possible for both in situ aerosol measurements (e.g. aerosol size distributions, aerosol scattering etc.) and radiation measurements (e.g. SW, LW irradiances). For in situ measurements,

[1] The possible intercomparisons will of course depend on the simultaneous availability of the different aircraft. See below in section 4 for a discussion on this issue.

intercomparison between the UK BAe146 and the FR ATR-42 will be performed for heavy biomass burning pollution and heavy dust conditions as ~ 20 minute wing-tip–to–wing-tip straight and levelled run (SLR) measurement leg. For radiation measurements, intercomparison between the UK BAe146 and the FR F-20 will be performed as ~ 10 minute wing-tip–to–wing-tip straight and levelled run (SLR) measurement leg.

Being the endurance of the FR ATR-42 limited to 3.5h, two FR ATR-42 flights will be necessary to perform in situ sampling and radiative closure above the super-site of Djougou. No endurance problems to reach Banizoumbou, which is 50 km east of Niamey. On a first flight, the FR ATR-42 will climb at maximum altitude to sound the aerosol vertical distribution, and then it will transit within the aerosol layer southwards towards Djougou. Once over Djougou, the FR ATR-42 will perform a series of stacked levelled runs for in situ sampling. It will then land in Parakou or in Niamtougou (Togo). The second flight mirrors the first, the stacked levelled runs being now being performed over the ground-based site of Banizoumbou. The lidar onboard the FR ATR-42 will be pointing upward or downward depending on flight altitude. When the FR F-20 is above, the FR ATR-42 lidar will be pointed upward to allow for signal-to-signal comparison and inversion.

2.2.2 Aerosol characterisation at the regional scale

Two observational plans are dedicated to the characterisation of the aerosol load at the regional scale.

- North-to-south flights towards the Bay of Benin to document mixing between dust and biomass burning aerosols, and outflow. Here the UK Bae146/ FR ATR-42 climbs up to maximum altitude to obtain a vertical profile of the interesting aerosol parameters, then transits towards Djougou at altitudes based on the aerosol vertical structure. At least two altitudes will be sounded, to obtain an indication of the vertical distribution as a function of the expected north-to-south gradient in the aerosol dominant type. FR F20 will fly a high level leg making radiation and lidar measurements. Due to the limited endurance, it will not be possible for the FR ATR-42 to reach Djougou on this single flight pattern.
- West-to-east flights from Niamey towards the lake Chad (one of the largest dust source regions) to document the chemical-physical and optical properties of undisturbed mineral dust. Here the UK Bae146 / FR ATR-42 climbs up to maximum altitude to obtain a vertical profile of the interesting aerosol parameters, then transits eastwards at altitudes based on the aerosol vertical structure. At least two altitudes will be sounded, to obtain an indication of the vertical distribution as a function of the expected north-to-south gradient in the aerosol dominant type. FR F20 will fly a high level leg making radiation and lidar measurements, aiming at reaching the AERONET site of Maine Soroa. Due to the limited endurance, it will not be possible for the FR ATR-42 to reach this AERONET site on this single flight pattern.

2.2.3 Biomass burning particle aging

By performing flight legs progressively downwind of local biomass burning sources at different altitude levels, the aging of biomass burning aerosol will be assessed by the UK BAe146 in terms of evolution of the aerosol size distribution, optical properties, hygroscopic nature and mixing with mineral dust. Overflights of the FR F20 – if available – would allow making a 2D cross-sectional analysis of evolution of the plume at the same time.

2.2.4 Dust outflow and deposition

In order to follow dust transport towards the Atlantic, during DODO the UK BAe146 will fly from Dakar towards the Cape Verde Islands, and further downwind. Overflight of ground/ship based measurements and cross plume transects will be performed whenever possible.

2.2.5 Satellite validation

AURA satellite has been launched in July 2004, and AMMA SOP 0 offers a unique opportunity of validation of aerosol measurements from OMI. CALIPSO is to be launched in 2006 and may benefit from extended SOP0 (SOP0_a3) observations.

2.3 Satellite instruments

MODIS and MISR retrievals of aerosol properties have recently been developed over land surfaces but these retrievals still have a high degree of uncertainty owing to a reduction in the signal-to-noise ratio over bright land surfaces. Aircraft flights will be performed in conjunction with the TERRA and AQUA satellites where logistically possible thereby providing suitable data for testing the retrieval algorithms.

An important information provided by Modis observations is the location of fires. This is obtained in quasi real time (http://rapidfire.sci.gsfc.nasa.gov/subsets/mosaic.php?).

Onboard AURA, which is part of the AQUA-Train, the OMI (Ozone Monitoring Instrument) will also bring important information. OMI allows multi-spectral measurements, namely in the UV and gives results comparable to TOMS. Desert dust and biomass burning aerosols are very absorbing in the UV, so that they can be easily detected using OMI. An example of OMI observations for the dry season are given in Figure 10. Images can be obtained at the address ftp://toms.gsfc.nasa.gov/pub/omi/images/aerosol/

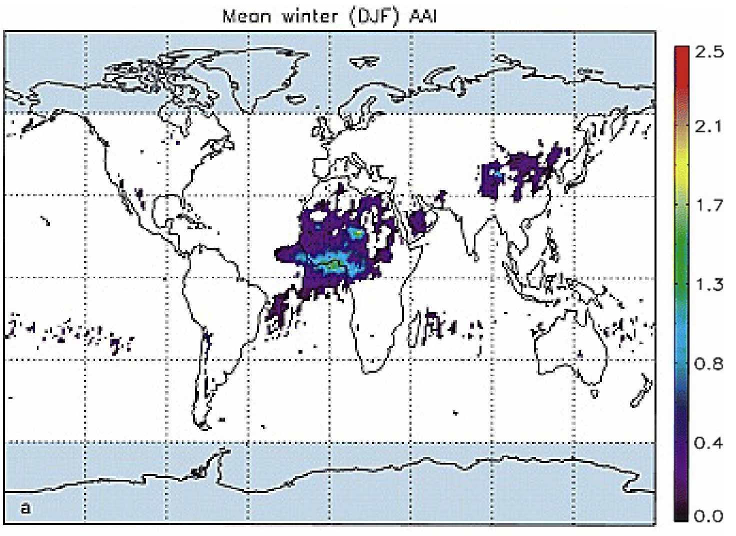


Figure 10 : Aerosol Absorption Index obtained from OMI for December-January-February showing the regional extent of desert and biomass aerosols during the dry season (de Graaf et al., 2005)**.**

One can see on Figure 10, and this is comparable to MODIS observations (see Figure 4), that aerosols during the dry season are transported south of the african coasts, which leads to a strong decrease in available solar flux at the surface of the ocean. It is to be noticed that the LAUVA lidar measurements will be made at the same UV wavelengths and will help analysing OMI observations.

Another component of the AQUA-Train is the CALIPSO satellite, which is now planned to be launched at the beginning of 2006. Validation of its measurements (Lidar, wide field camera and 3 wavelength IR imager) will take place until 2007 (level 2 products). As part of the AQUA-Train, its orbit is sun-synchronous with overpasses at 13:30 UTC. The orbits accumulated over 16 days (repeat cycle) are shown in Figure 11. The different colors allow to identify the day of observation. Overpasses close o Niamey correspond to days 1, 8, 15 (and nigttime overpasses nights 16, 9 and 2). As overpass 1 can be identified as January 21st from present day AQUA orbit, this corresponds during SOP A to January 19, 21, 28 (daytime) and January 20, 22, 29 (nights) over the Niamey-Djougou area. The Dakar area is observed near day 5 which would correspond to 10 February during the second phase of SOP0 (SOP0_a2).

Aerosol retrievals will allow analysis of the dynamical evolution of dust and biomass burning plumes at a resolution of a few km. These measurements will be validated using aircraft measurements and will in turn allow verification of the transport models.

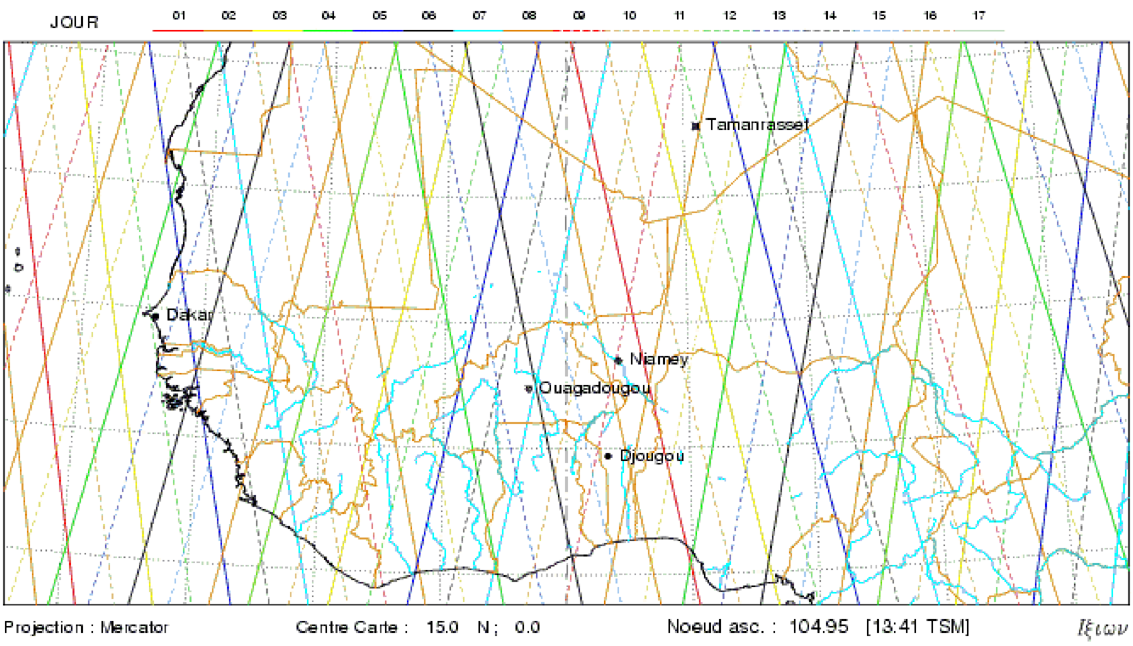


Figure 11. CALIPSO tracks over a 16 days period (Ixion, M. Capderou, IPSL/LMD)

In addition to the polar orbiting satellites of the AQUA-Train a particular attention will be paid to the contribution of the GERB and SEVIRI sensors mounted on the Meteosat-8 geostationary satellite (Radagast proposal). These sensors provide top of the atmosphere radiances/irradiances at unprecedented temporal resolution. GERB data will be obtained with a very short time delay and compared to the UKMO forecast model output (Sinergee project).

A specific dust product has been elaborated by EUMETSAT and can be visualised on their site for western Africa (http://oiswww.eumetsat.int/IDDS-cgi/listImages.pl?m=prod,a=0,sa=8,pr=RGB,f=1,c=DUST,se=5,n=6,d=1,v=400,pp=0,t=200512141700#controls).

2.4 Modelling

Modelling activities for SOP0 (SOP0-A/SOP0-A') will be of two kinds. Various models will be initialised and run period to forecast the occurrence of favourable aerosol (e.g., dust outbreaks and/or fire plumes). This includes emission/transport and trajectory models. Post-field comparison of model outputs against in situ, aircraft and satellite measurements will allow assessing of the model performance.

2.4.1 UK Met Office

The Unified model Crisis Area Mesoscale Model (CAMM), has been set up over western Africa. This model is high resolution (25 km at a latitude of 15oN) and includes dust generation, transport and deposition. In addition, the global NAME chemical transport model will be initialised. These models will be used to predict dust outbreaks and also the transport of biomass burning aerosol across the region of interest. An example of output from the NAME model is given in Figure 12.

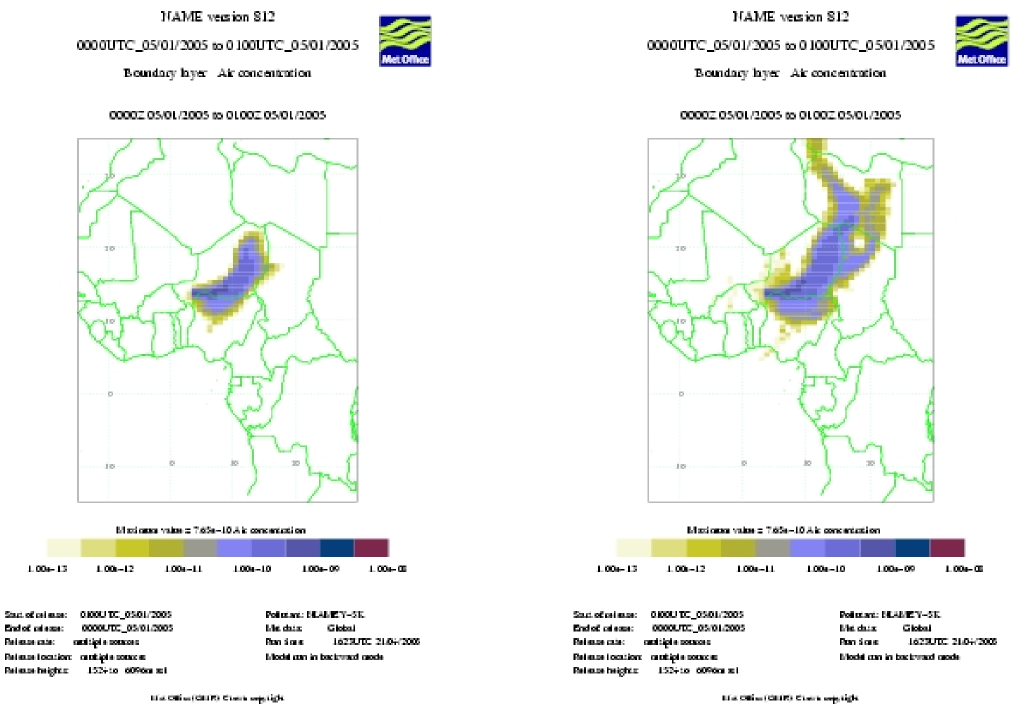


Figure 12. Showing the source areas of particles over Niamey from a) two days, b) 4 days from the NAME model.

Name forecasts are available at http://metresearch.net/DABEX/forecasts/

2.4.2 LMDZ-INCA

Forecasts of aerosol dust events and transport are available from the general circulation model LMDz-INCA developed at IPSL/LSCE (M. Schulz, S. Szopa and co-workers). Images can be obtained at the address http://www-lsceinca.cea.fr/cgi-bin/lsce/inca_work_annualrs.pl

CHIMERE

Chimere is a transport model operating with MM5 and NCEP analyses developed by IPSL/LMD and LISA (R. Vautard, L. Menut, M. Beekmann and co-workers). It can be used to give forecast information over 3 days on dust uptake and transport. Forecasts calculated for AERONET stations are available as well as other charts. The address is the following :

http://euler.lmd.polytechnique.fr/menut/chimeredust/dust-fcst.html

2.4.3 Trajectory Analysis

FLEXPART

Use of Flexpart (developed by A. Stohl and coworkers, http://zardoz.nilu.no/~andreas/flextra+flexpart.html) will allow to perform backward and forward trajectories from sources. A specific development to characterise aerosol properties (biomass burning aerosols and dust) using ECMWF analyses has been undertaken at LA (C. Mari and co-workers).

HYSPLIT

The HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory, http://www.arl.noaa.gov/ready/hysplit4.html) model results of a joint effort between NOAA and Australia's Bureau of Meteorology. New features include improved advection algorithms, updated stability and dispersion equations. It now allows to define a sampler that moves through the model simulation domain in space and time with its velocity (aircraft) or transported by the winds (ballon).

2.4.4 Radiative models

Such models will use field data to estimate the aerosol optical properties and radiative effects. Careful screening of field data will be done to discriminate case studies of the optical response of non-spherical particles.

3 Deployment

3.1 Timing

The BAe is a fully certified aircraft with funding from both the Met Office Dust and Biomass burning Experiment (DABEX) and the Dust Outflow and Deposition to Ocean (DODO) project, and has firmly committed to operating during January–February 2006.

At contrary, significant certification issues in 2005 have precluded the deployment of the FR ATR-42 and FR F-20 in January - February 2006.

To take into account the fact that these aircraft cannot be involved in the January campaign, the TT7 group has formulated two complementary observational plans.

Plan SOP0_a1 (January 2006 in Niamey) and SOP0_a2 (February 2006 in Dakar)

- Deployment of UK BAe146 aircraft.
- Complementary observations using an ultra-light.
- Ground-based sites operated in temporal and spatial coincidence with aircraft deployment

Actual observational plans and details of deployments (dates, locations, payload) are discussed in the following sections.

Under Plan SOP0_a1/a2, the UK BAe146 will concentrate on in situ and remote-sensing measurements. In the framework of the international coordination, two French scientists (P. Formenti and K. Desboeufs) will be in charge of the aerosol sampling onboard the UK BAe146. Analysis of filters for biomass burning particles will be done both by English/Belgian and French (K. Liousse and co-workers) groups. This collaboration has been approved by AMMA-France (API2006). The Ultra-light will concentrate on complementary remote sensing measurements, combined with in situ extinction measurement (see section 4).

The scientific outcomes of this campaign will be evaluated during a dedicated AMMA SOP workshop to be held in March/April 2006. As previously discussed, the characterisation of the number size distribution and mineralogy of mineral dust aerosols over the largest possible size spectrum is of particular concern.

As detailed in section 4, the BAe146 will carry three optical counters able to size particles up to ~ 40 µm (FSSP, SID and GRIMM OPC, the first two being wind-mounted, the last sampling from the newly mounted LTI (Low Turbulence Inlet).

The mineralogical/chemical characterisation will rely on (i) an aerosol mass spectrometer measuring major ions for submicron aerosols with a time resolution of seconds; (ii) filter sampling for the analysis of the elemental and composition and carbon fraction for submicron aerosols with a time resolution of 10 to 30 minutes (depending on aerosol load); (iii) impactor sampling and analysis of individual particle shape and mineralogy for sub and supermicron aerosols with an expected time resolution of tenths of minutes (depending on aerosol load). Impactor sampling will be done from the LTI and it will be implemented in the following months. This sampling technique will thus be used for the first time onboard the UK BAe146 during the SOP0_a1. So, the post-field meeting of March/April 2006 will tell whether the impactor data will be useful to characterise the mineralogy of the coarse fraction of mineral dust, so estimate the aerosol refractive index to be used in optical and radiative forcing calculation at long wavelengths. Also, this is needed to correct the number size distributions measured by the optical counters. The mass size distribution obtained from the impactor could also serve to constrain the number size distribution. Note also that the in situ scattering and absorption coefficients are measured from submicron inlets, therefore cannot really be used to constraint the aerosol refractive index of coarse particles. However, this can be done using radiation field measurements in the IR (such as ARIES).

If the available observations were not sufficient to meet the scientific objectives of the relevant WPs (AMMA-EU 2.4.1, AMMA-France WP2.4, AMMA-UK), an additional observational phase (SOP0_a3) including the FR ATR-42 and FR F20 is requested.

Plan SOP0_a3:

- Deployment of the FR F-20 aircraft in December 2006.
- Deployment of FR ATR-42 aircraft in December 2006.
- Ground-based sites operated in temporal and spatial coincidence with aircraft deployment

The FR ATR-42 will carry an instrumental ensemble specifically thought to perform optical closure experiments on coarse particles by sampling from a single particle inlet under identical collection conditions. Unfortunately, the passing efficiency of the inlet and of the entire instrumental system is to date still not characterised. The inlet passing efficiency is currently being looked at by modelling, and should be further explored during the pre-SOP test flights. Measurements include filter sampling, impactor sampling, optical sizing, and measurements of spectral in situ scattering and absorption.

The FR F20 has been received in November and is being equipped.

Actual observational plans and details of deployments (dates, locations, payload) are discussed in the following sections.

Depending on the scientific outcomes of the SOP0_a1 campaign, as evaluated during a dedicated AMMA SOP 0 workshop to be held in March/April 2006, a new deployment will be planned for the end of the year to achieve all the initial objectives.

In December 2006, the FR ATR-42 will concentrate on in situ sampling and the FR F-20 will concentrate on remote sensing measurements. To ensure comparability of results, the UK BAe146, the FR ATR-42 and the FR F-20 would fly an intercomparison flight over sea (likely the British Channel) in November 2006.

Funding for SOP0_a3 (and the intercomparison flight) is not presently secured. Should the decision from the spring meeting be positive, a detailed budget and funding request is to be examined by the AMMA-France API committee. A deployment of UK BAe 146 aircraft during SOP0_a3 may be then discussed end of spring, depending on the evolution of status of presently planned campaign in which the BAe is to be involved end of 2006.

3.2 Aircraft specification and instrumental fits

The main characteristics of the three aircraft are summarised in the Table 2. Note that the endurance refers to the specific payload carried during SOP0 (i.e. might differ from SOP1 and SOP2).

Each of these aircraft will be comprehensively equipped for specific purposes:

- FR F-20: remote sensing, radiation measurements.
- FR ATR-42: in situ measurements of aerosol chemical, physical, and optical properties; radiation measurements to determine the effect of aerosols on atmospheric radiative fluxes.
- UK BAe146: in situ measurements of aerosol chemical, physical, and optical properties; radiation measurements to determine the effect of aerosols on atmospheric radiative fluxes and radiances in both the solar and terrestrial regions of the spectrum.

In addition to these research aircraft, an Ultra-light is being equipped on the French side for SOP_a1. It has the capability to operate at an altitude from 30 ft to 15000 ft, embarking payload of 100 kg at a range of 300 km. Instruments will be set on by the pilot for a flight duration of about 3h.

Table 2. Main characteristics of the three deployed aircraft

Aircraft	FR F-20	FR ATR-42	UK BAe146
Operating altitude	500ft-42000ft	500ft-25000ft	50ft-35000ft
Payload	1200kg	2500kg	4000kg
Range	3200km	3000km	3700km
Staffing	3 crew, 2 scientists	3 crew, 7 scientists	3 crew, 18 scientists
Duration	4.5 hours	3.5 hours	5.5 hours

3.2.1 FR F-20

The FR F-20 will be equipped with a wide range of thermodynamic sensors. In addition, the FR F-20 aircraft will perform remote sensing and radiation measurements

Aerosol profiles (lidar LEANDRE New generation (LNG) operating at 0.35; 0.53 and 1.06 µm).

Aerosol optical thickness, size distribution (POLDER and MINIMIR+MICROPOL, polarization and directionality of earth reflectances from 440 to 2200 nm)

Brightness temperatures (CLIMAT Multichannel thermal infrared radiometer)

Broadband radiometers (visible and IR irradiance, up and down)

Basic thermodynamics

Dropsondes

The fit of the aircraft is shown in Figure 6.

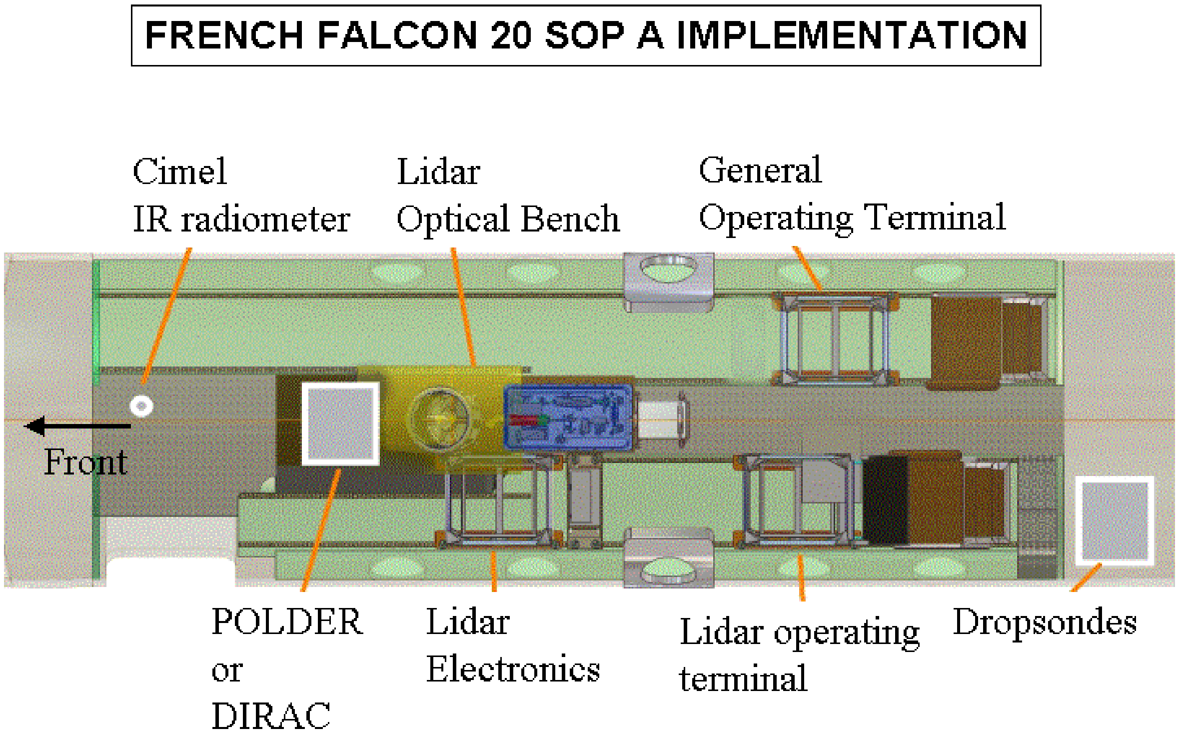


Figure 6. The layout of the Falcon 20 aircraft during SOP0'.

3.2.2 FR ATR-42

The ATR-42 aircraft will be dedicated to in situ aerosol measurements. The scientific payload will allow measurements of

- size distribution (wing-mounted PCASP, FSSP, X-PROBE; inlet-mounted GRIMM, DMPS, PCASP
- aerosol chemistry (filter sampling, impactor sampling)
- spectral aerosol scattering and back-scattering (3 channel TSI nephelometer)
- spectral aerosol absorption (7 channel Magee aethalometer)
- UV aerosol backscattering profile (1 channel lidar)
- spectral aerosol optical depth (PLASMA sun photometer)
- total aerosol number (CNC)
- cloud condensation nuclei counter (CCN)
- solar irradiances (upper and lower Eppley BBRs 0.3-3.0 m).
- UV irradiances (upper and lower Eppley BBRs 0.29–0.3 m).
- terrestrial irradiance (upper and lower pyrgeometers 4.0–45 m).
- j(NO2) fluxes (upper and lower METEO CONSULT)
- Ozone concentrations (UV THERMOELECTRON 49PS)
- CO concentrations (UV THERMOELECTRON 48CS)

The fit of the aircraft is shown in Figure 7.

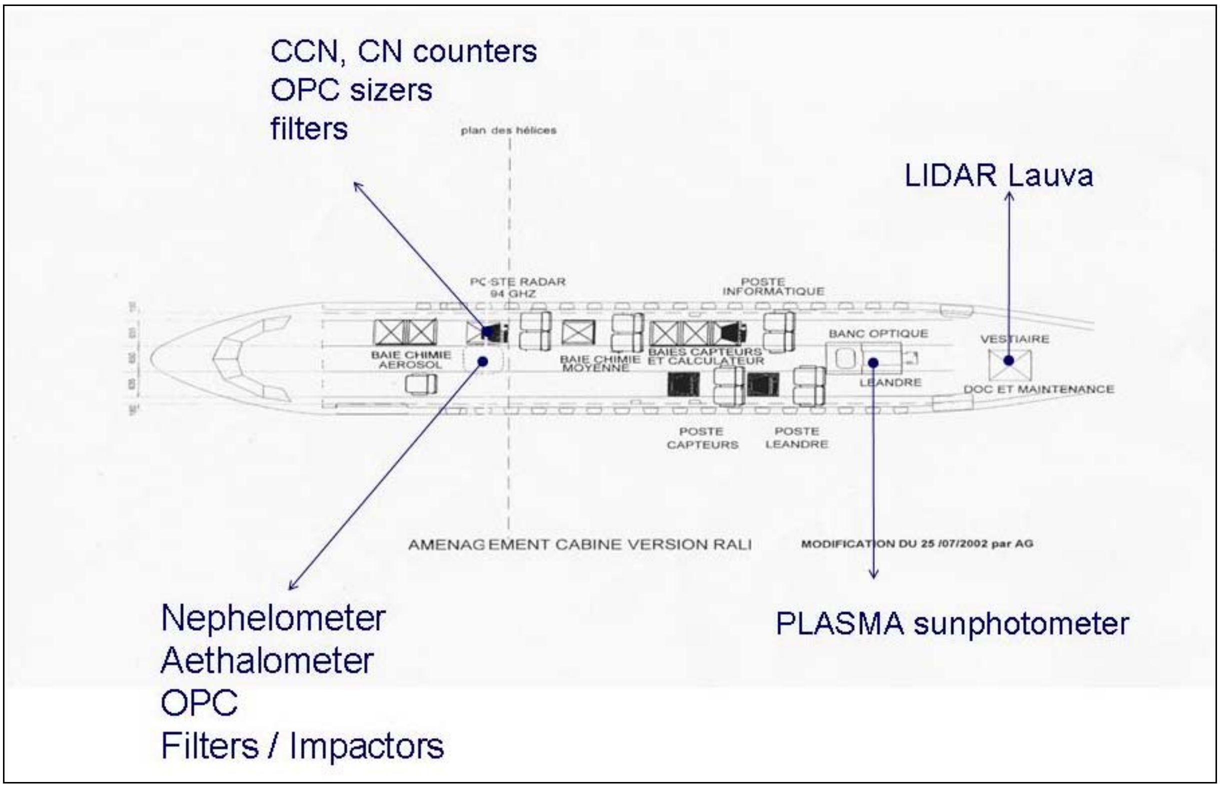


Figure 7. The layout of the ATR 42 aircraft during SOP0'

3.2.3 UK BAe146

The UK BAe146 aircraft will be equipped with in situ aerosol measurement instrumentation, and a complementary set of radiation equipment. Briefly the following specific equipment directly relevant to the study of aerosols and their direct radiative effects will be carried

- size distribution (wing-mounted PCASP, FSSP, SID; CVI PCASP, VACC, PCASP)
- aerosol chemistry (Aerodyne mass spectrometer, VACC, filter sampling)
- spectral aerosol scattering and back-scattering (3 channel TSI nephelometer)
- aerosol absorption (PSAP)
- hygroscopic growth (3 channel RH controlled TSI nephelometer)
- total aerosol number (CNC)
- cloud condensation nuclei counter (CCN)
- Aerosol ice nucleation counter (INC)
- solar irradiances (upper and lower Eppley BBRs 0.3-0.7   m, 0.3-3.0   m).
- terrestrial irradiance (upper and lower pyrgeometers 3.0-30   m).
- solar radiances (SWS instrument)
- terrestrial radiances (ARIES spectral interferometer)
- Dropsonde system for measurements of temperature and humidity.
- Gaseous measurements of ozone, NOx, CO, CO2.
- Whole air sampling for full laboratory analysis.

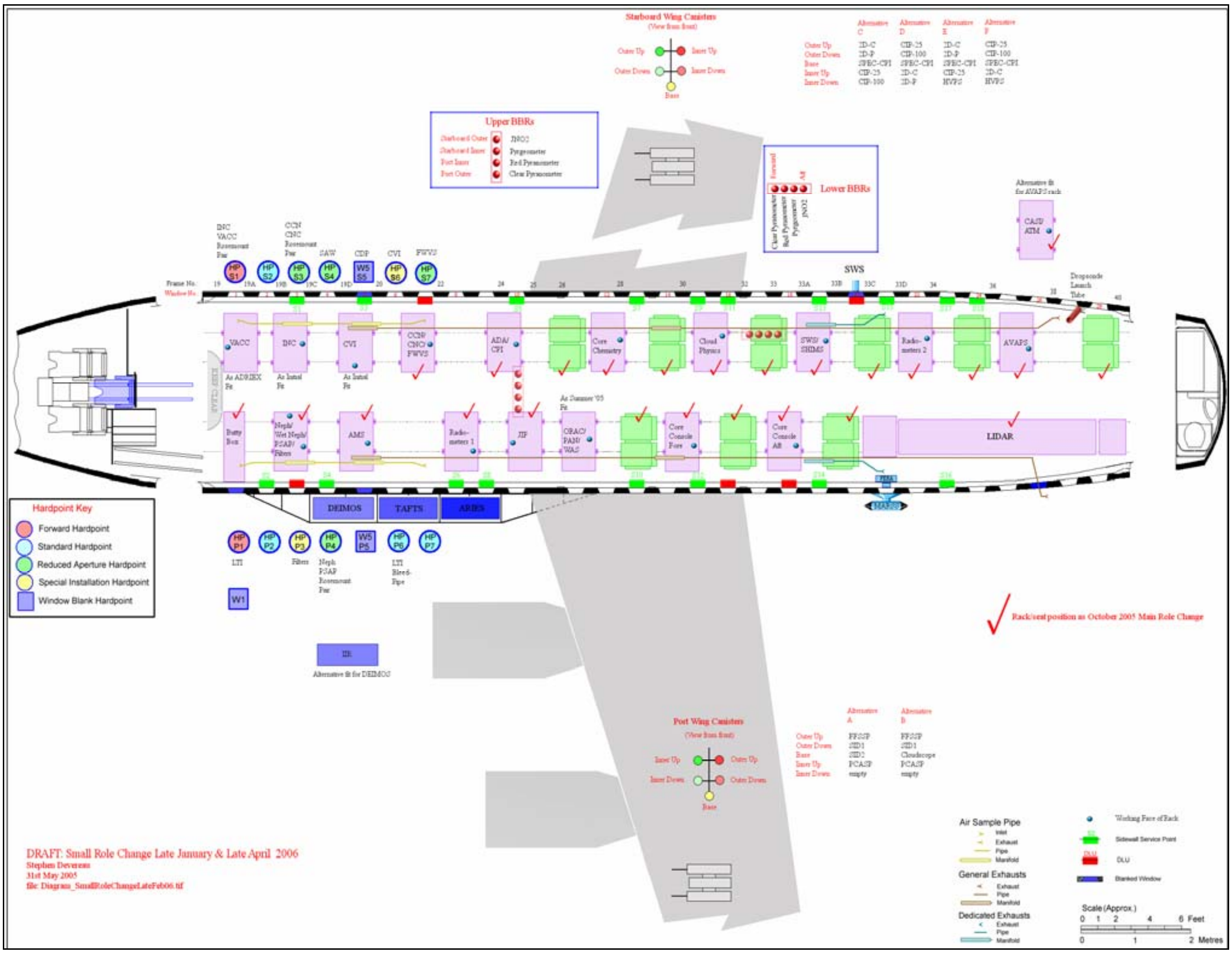


Figure 8. The layout of the UK BAe146 aircraft during SOP0.

3.2.4 Ultra-light

The payload will be composed of remote sensing and a few in situ measurements :

- the backscatter lidar LAUVA (355 nm) developed at IPSL/LSCE
- a PTU sonde,
- a GPS,
- a wide-band nephelometer operating at 880 nm,

3.3 Ground-based stations

The ground-based stations will provide in situ sampling of aerosol chemical, physical and optical properties, aerosol vertical distribution, column retrievals of aerosol microphysical and optical properties, and weather measurements for the central operations centre at Niamey airport (I am not sure I understand this last bit of sentence).

The overall distribution of ground-based stations of interest for the TT7 observational plan is shown in Figure 9.

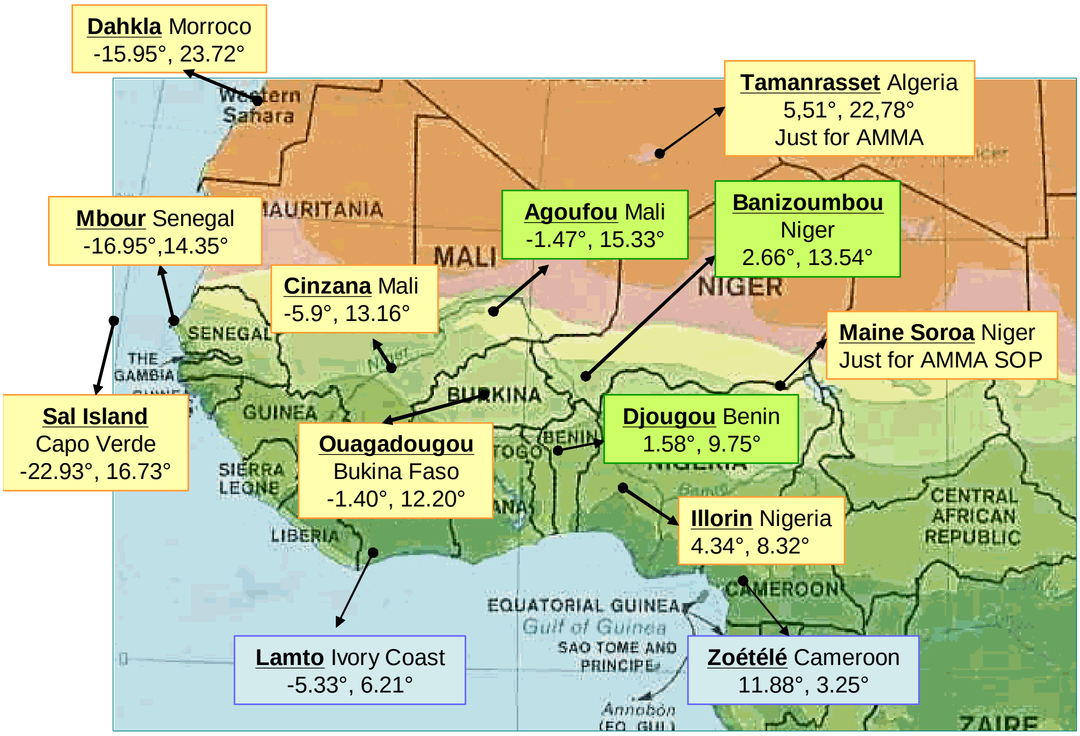


Figure 9. AERONET (yellow), IDAF (blue) and both AERONET/IDAF (green) ground-based stations.

There are two characteristic modes of operation for ground-based instruments:

- Intensive monitoring. This mode includes 4 fully equipped ground-based stations (super-sites): Banizoumbou (Niger), Djougou (Benin), M'Bour (Senegal) and Tamanrasset (Algeria), all coinciding with AERONET/PHOTON stations, providing high-quality and high-frequency aerosol and radiation measurements specific to the TT7 observational strategy. Measurements are a complete set of physico-chemical and optical measurements, including size-segregated sampling for chemical and mineralogical analysis, measurements of number size distributions, spectral scattering and absorption coefficients, aerosol vertical profiles, column-integrated content and properties, as well as spectral and/or broadband radiation fluxes. Operations are secured for SOP0_a1 and SOP0_a2, whilst operations during SOP0_a3 are still at the proposal stage, depending on funding availability. Additional measurements of the composition of single particles will be made in the framework of SOLAS. During the DODO part of SOP0 (SOP0_a2), the single particle measurements will be based on a ship (German Poseidon) which will cruise under the UK BAe146 aircraft and makes some other ocean and deposition measurements too. These measurements will then be continued at the SOLAS Cape Verde supersite, which will be installed as soon as possible during 2006.
- Continuous monitoring. This mode is typical of instruments belonging to networked stations, i.e. AERONET/PHOTON, IDAF, local Met Offices, EOP-type instruments (radiosounding, Sahelian Dust Transect) and the ARM mobile facility (AMF). These are described in detail in the TT2b working document. To facilitate reading this document, some details are given in the following sections.

3.3.1 Intensive monitoring

The location of the four stations has been chosen to be representative of the physico-chemical and radiative properties of mineral dust (Banizoumbou, Tamanrasset) and mixed biomass-burning and pollution aerosols (Djougou, M'Bour). Details of the deployed instruments and their temporal resolution by site are summarized in Table 3.

The instrumentation and mode of operation of the ground-based stations have been chosen to fully integrate the observational strategy. Besides providing the temporal and regional coverage lacking to aircraft operations, the ground-based stations should provide with the boundary layer aerosol characteristics to be compared/contrasted to those measured in the elevated layers by the aircrafts. Therefore, the sampling strategy and protocol of the ground-based measurements has been designed to match as closely as possible the one of the aircrafts. Dedicated flights over some of the ground-based sites are also planned for radiative closure purposes. These are described in the following sections.

Finally, ground-based measurements such as lidar profiles and real-time aerosol optical depth from the sunphotometers, will be used as a flight planning elements. It is therefore important that communication between the airport and the ground-based sites is ensured.

In order to insure the comparability of results amongst the different stations, which is delicate particularly for the chemical composition data, an intercomparison of analytical methods used by the implied laboratories for the determination of elemental tracers of mineral dust and elemental/organic carbon will be conducted during autumn 2005 prior to measurements in the field under the supervision of the LISA group (PI K. Desboeufs). In addition to sampling specific to the site location, collection of the PM10 aerosol fraction will be conducted at each site and used as a control parameter.

In addition to the super-site measurements, measurements of the composition of single particles will be made onboard the German Poseidon research vessel and at the SOLAS Cape Verde site. These measurements will provide data on the dust chemical composition (mixing state of the particles, and the extent to which inorganic salts and organic species are present on the dust surfaces). The sampling procedure and the analysis of aerosols will be in accordance with AMMA practice and hence, the provided physico-chemical data could be used to respond with SOP0 objectives.

A control of the calibration of radiation instruments should be performed under the supervision of the LOA group (PI J.-F. Léon).

The analysis of the in situ optical measurements will be based on state-of-the art protocols, as described in Anderson and Ogren (1998), Bond et al. (1999), Haywood and Osborne (2000), Alfaro et al., (2004).

References

Anderson,T.L., and Ogren, J.A., "Determining aerosol radiative properties using the TSI 3563 Integrating Nephelometer," *Aerosol Science and Technology*, 29, 57-69, 1998.

Bond, T.C., T.L. Anderson, and D. Campbell, Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols, Aerosol Sci. Technol., 30, 582-600, 1999.

Haywood, J. M., and S. R. Osborne, Corrections to be applied to the PSAP and nephelometer for accurate determination of the absorption coefficient, scattering coefficient and single scattering albedo, MRF Tech. Note 31, 2000 (Available from Met Office, Bracknell, UK).

Alfaro S. C., S. Lafon, J. L. Rajot, P. Formenti, A. Gaudichet, M. Maillé (2004), Iron oxides and light absorption by pure desert dust: An experimental study, J. Geophys. Res., 109, D08208, doi:10.1029/2003JD004374.

3.3.2 Continuous monitoring

3.3.2.1 AERONET/PHOTON sunphotometers

The understanding of the mixing state of aerosols and their radiative properties will rely on ground-based sun photometer measurements in the framework of the AERONET network. For the sites operational during the AMMA experiment (Figure 9), data (level-0) are available at near-real time and they will be used as an element of flight planning.

New retrieval algorithms using measurements of sky radiance have been developed for determining the physical and optical properties of aerosol from sunphotometers (e.g. Dubovik et al, 2000). The consistency of these retrievals will be assessed from aircraft measurements during closure experiments.

3.3.2.2 IGAC-DEBITS-Africa (IDAF)

IDAF-Africa is part of the global network DEBITS providing chemical measurements of wet and dry deposition for various African regional ecosystems (http://medias.obs-mip.fr/idaf/program/index.en.php). It provides data on chemical composition of aerosol water-soluble and rainfall and gas concentrations. The IDAF stations are presented in the Figure 9. See the TT2b document for further details.

3.3.2.3 Mobile ARM site

The Atmospheric Radiation Measurement (ARM) mobile facility (AMF) will be situated in Niamey from December 2005 through Jan 2007. The deployment period encompasses all the SOP0 sub-periods. This site will provide comprehensive high quality surface radiation budget data such as spectrally resolved fluxes, broadband fluxes, sky radiances, micro-pulse lidar observations of aerosol etc. The RADAGAST proposal (http://www.metre.uk/radagast) will ensure that the measurements from GERB and SEVIRI instruments on board the Meteosat-8 platform will be archived during this period enabling a detailed post-campaign analysis of the consistency of radiative transfer models and observations when the detailed measured physical properties of aerosols are excluded and included in radiative transfer calculations. In addition to the standard instrumentation (http://www.arm.gov/sites/amf/instruments.stm) a CIMEL sunphotometer will also be deployed in Niamey. A subset of the ARM instruments will be deployed at the Banizoumbou super-site (see list below and Chapter 12 of the IIP).

Table 3. Subset of ARM ground-based instruments deployed at Banizoumbou

Measurement	Manufacturer	Instrument
Broadband infrared irradiance	Eppley Labs	PIR
Broadband solar irradiance	Eppley Labs	PSP
Multiband global/diffuse solar irradiance	Yankee Environmental Systems	MFRSR
Wind Speed/Wind Direction	RM Young	05103-L
Barometric pressure	Vaissala	PTB220
Temperature/Relative humidity	Vaissala	HMP-45C
Rain rate	Optical Scientific Instruments	ORG-815

EOP blue / SOP black / IDAF-AERONET red	Djougou		Banizoumbou		Mbour		Tamanrasset	
Deliverables	Instruments	Frequence	Instruments	Frequence	Instruments	Frequence	Instruments	frequence
Aerosol Physico- chemistry								
Number concentration	1 CPC (0.01-3µm)	continuous			1 CPC (0.01-1 µm)	continuous		
					1 Laser Part. Cntr (0.3 -5.0 µm)	continuous		
Mass concentration			1 TEOM (PM10, PIP)	continuous	1 TEOM (PM10)	continuous		
			1 TEOM (PM10)	continuous				
Size distribution	1 optical analyzer	continuous	2 optical analyzers (PIP)	continuous	1 Laser Part. Cntr (0.3 -5.0 µm)	continuous	1 optical analyzers (0.1-0.5 µm)	continuous
	1 SMPS (3-300nm)	continuous					1 optical analyzers (0.3-5 µm)	continuous
Mass Size concentration and composition	2 cascad impactors (13 stages)	3/day	2 cascad impactors (4 & 13 stages)	2/day	1 cascad impactor (3 stages+back up)	1/day + event		
Size resolved C concentration	1 cascad impactor	3/day	1 cascad impactor + 1PM10	2/day				
Chemical composition (minerals + C)	PM 2.5/10 filtration lines	/week	bulk filtration lines (PIP) + 1 PM10	2/day	bulk filtration lines (PIP/PM10)	2/day - event	PM 20; PM 10; PM 2.5; PM 1	1/day
Mineralogy	PM 2.5/10 filtration lines	/week	bulk filtration lines (PIP)	2/day	dry deposition sampler			
Individual characteristics			bulk filtration lines (PIP)	2/day	1 cascad impactor (3 stages+back up)	1/day + event		
Free iron oxides			bulk filtration lines (PIP)	2/day	bulk filtration lines (PIP)	2/day - event ?		
WSF, Fe speciation	PM 2.5/10 filtration lines	/week	bulk filtration lines (PIP)	2/day	bulk filtration lines (PIP)	2/day - event ?		
CCN ability (if foundings)	CCN counter	continuous						
WSF Chemical composition	PM 2.5/10 filtration lines	/week	PM 2.5/10 filtration lines	/day	bulk filtration line (PM10)	2/day - event		
Isotopic iron composition					bulk filtration line (PIP)	1 per event		
Aerosol optical properties								
Aerosol column profile	1 lidar	continuous	1 lidar (Depolarisation/N2 Raman)	continuous	1 lidar	continuous	channels backscatter) (TReSS)	continuous
	1 Lidar Ceilometer	continuous	1 micro-lidar (day/night)	continuous	1 micro-lidar (night)	continuous		
Aerosol column optical properties (AOT)	1 sunphotometer AERONET	continuous	1 sunphotometer AERONET	continuous	1 sunphotometer AERONET	continuous	1 sunphotometer (TReSS)	continuous
Diffusion coefficient	1 nephelometer (1l)	continuous	1 spectral (4l) nephelometer (PIP)	continuous	1 nephelometer (635nm)	continuous	1 nephelometer (550nm)	continuous
	2 nephelometers	continuous						
Spectral Absorption coeff & BC concentrations	1 aethalometer (7l)	continuous	1 spectral (7l) aethalometer (PIP)	continuous	1 aethalometer (7l)	continuous		
			1 aethalometer	continuous				
Cloud / rain properties								
Cloud emissivity & equivalent black body T°							1 IR radiometer	continuous
Horizontal structure and motion of clouds							camera (TReSS)	continuous
LWC profile, rain rate..	1 Micro Rain Radar	continuous						
T, HR, LWP	1 microwave radiometer	continuous						
Radiation:								
Global, diffuse and direct			Shadow-band (7l) radiometer	continuous	1 pyranometer (0.3 – 2.8 µm)	continuous	1 pyranometer short-wave (TReSS)	continuous
							4 pyranometers	continuous
							3 pyrheliometers	continuous
							Shadow-band assembly	continuous
IR, VIS	4 components radiometer	continuous			1 pyranometer (0.7 – 2.8 µm)	continuous	1 UVb-pyranometer	continuous
Sensible heat fluxes	1 sonic anemometer	continuous					1 sonic anemometer	continuous
PAR: photosynthetically active radiation	Licor Quantum	continuous						
NO2 photolysis constant	J(NO2) Filter Radiometer Metcon	continuous						
Gas Chemistry:								
O3	active sampler (real time monitoring)	continuous	Analyzer in real-time monitoring	continuous			1 Dobson	continuous
CO	active sampler (real time monitoring)	continuous	Analyzer in real-time monitoring	continuous				
SO2	active sampler (real time monitoring)	continuous						
NOx	active sampler (real time monitoring)	continuous	Analyzer in real-time monitoring	continuous				
COV	active sampler (real time monitoring)	continuous						
SO2, HNO3, NH3, NO2, O3 (monthly average)	passive samplers	/month	passive samplers	/month				
fluxes of CO2 and H2O	LICOR 7500	continuous						
fluxes of isoprene	fast isoprene sensor	continuous						
fluxes of NOx	dynamic chambers	continuous						
Deposition:								
Total Deposition fluxes			Total deposition samplers	/week	Total deposition samplers	/week		
Wet deposition fluxes			Wet deposition samplers	/event	Wet deposition samplers	/event		
Dissolved rainfall composition	Automatic precipitation collector	/event	Sequential rain sampler	/event				
			Automatic precipitation collector	/event				
Meteorology:								
Wind speed, T°, HR, 5-levels profiles	lab-made weather station	continuous	weather mast	continuous	weather station	continuous	weather station	continuous
Wind direction								
Pluviometry			rain gauge	/week	rain gauge	/week		
soil temperature profile	lab-made sensor	continuous						
soil humidity	TDR CS 616 CAMPBELL	continuous						

Table 4. Summary of super-site instrumentations

3.3.2.4 Sahelian Dust Transect

The Sahelian Dust Transect (SDT) has been developed for the EOP in order to study of role of easterly waves and Mesoscale Convective Systems (MCS) on dust emission, transport and deposition. It includes three fully equipped stations along the E/W transect at 13°N, namely Banizoumbou (Niger), Cinzana (Mali) and M'bour (Senegal) (Figure 9). At each of these sites, the following parameters will be monitored by the instrument indicated into brackets:

- dust concentration (PM10) at the ground level (TEOM)
- total, wet and dry dust deposition (automated passive collector)
- column-integrated aerosol content and properties (AERONET/PHOTONS photometer)
- vertically-resolved aerosol distribution (micro-LIDAR, ISAC-CNR).

Further details are available on the TT2b document.

3.3.2.5 Lidar systems

From 2005 on, Banizoumbou, Djougou, M'Bour will be equipped with lidar systems from various institutions (University of Munich, ISAC/CNR, LOA/CNRS, SA/CNRS, MPL/NASA). Acquisition protocols and data treatment are coordinated under WP2.4.1 of AMMA-EU. Further details are given in the TT2b document.

3.3.2.6 Radiosonde ascents

An upgraded radiosounding network is operational during EOP and SOP field experiments. During the period of intensive observation by the aircraft, radiosonde ascents will be launched twice/day by the radiosonde stations close to and within the operational area of the aircraft (Table 5). This data will augment the aircraft data by providing temperature and humidity measurements above the maximum altitude of the aircraft and ensure that the numerical weather prediction models have data for assimilation purposes.

Table 5. RS station within the operational area of the aircraft

Country	RS Sites	Lat	long
Algeria	Tamanrasset	22 48N	05 26E
Benin	Cotonou	06 21N	02 23E
Benin	Parakou	09 21N	02 37E
Burkina Faso	Ouagadougou	12 21N	01 31W
Cameroon	Douala	04 01N	09 42E
Cape Verde	Sal	16 44N	22 57W
Chad	N'Djamena	12 08N	15 02E
Gabon	Libreville	00 27N	09 25E
Mali	Bamako	12 32N	07 57W
Mali	Tombouctou	16 43N	03 00W
Niger	Agadez	16 58N	07 59E
Niger	Niamey (airport)	13 29N	02 10E
Senegal	Dakar	14 44N	17 30W
Senegal	Tambacounda	13 46N	13 41W

3.3.2.7 Synoptic visibility measurements

Local Met centres will be asked to report local synoptic visibility so that large biomass burning events and/or mineral dust conditions will be reported to the central operations centre at Niamey airport.

4 Details of the aircraft operations

Under the original plan SOP0, aircraft observation was to be conducted simultaneously by the UK BAe146, the FR ATR-42 and the FR F-20 aircrafts during January 2006 in Niamey and by the UK BAe146 based alone in a second phase in Dakar (DODO) for a period of approximately 2 weeks (beginning of February).

Although this approach has been modified, the main scientific and experimental objectives given in Section 2.2 remain unchanged.

4.1 SOP0_a1 and SOP0_a2 (BAe aircraft and UL)

SOP0_a1 (11 January – 3 February), aircraft observation will be conducted by the UK BAe146 aircraft and the FR Ultra-Light (UL). The UK BAe146 will be based in Niamey (DABEX), along with the UL. Its flights will be coordinated with those of the UK BAe 146 as a function of selected objectives. In a second phase (SOP0_a2, 6 February – 16 February) the UK BAe146 will be in Dakar (DODO) for operational flying for a period of approximately 2 weeks. Dates of aircraft deployment and number of flight hours on task are detailed in the following table.

The super-sites of Banizoumbou, Djougou and Tamanrasset will be operated during SOP0_a1, to encompass the aircraft observation based from Niamey. Conversely, it is suggested that the M'Bour station is operated during SOP0_a2, in conjunction with the BAe observations out of Dakar. The concerned PIs are Isabelle Chiapello (LOA) and Pascal Flament (ELICO).

Date (2006)	Event BAe
10 January	Cranfield -> Niamey (non-science transit)
11–12 January	Set-up
13 Jan–1 Feb	**Operational flying (50h=10flights)**
2 February	Pack-up
3 February	**Niamey -> Dakar (science flight)**
4–5 Feb	Set-up
6-15 Feb	**Operational flying (30h=6 flights)**
16 February	Pack-up
17 February	Dakar -> Cranfield (non-science transit)

Various types of observations have been proposed in accordance to the scientific objectives of the participants. In any case, flight plans have been checked or for feasibility with SAFIRE and FAAM, and the aircraft pilots. Operational flights towards the Bay of Benin will be planned in careful consideration of the political situation of the area.

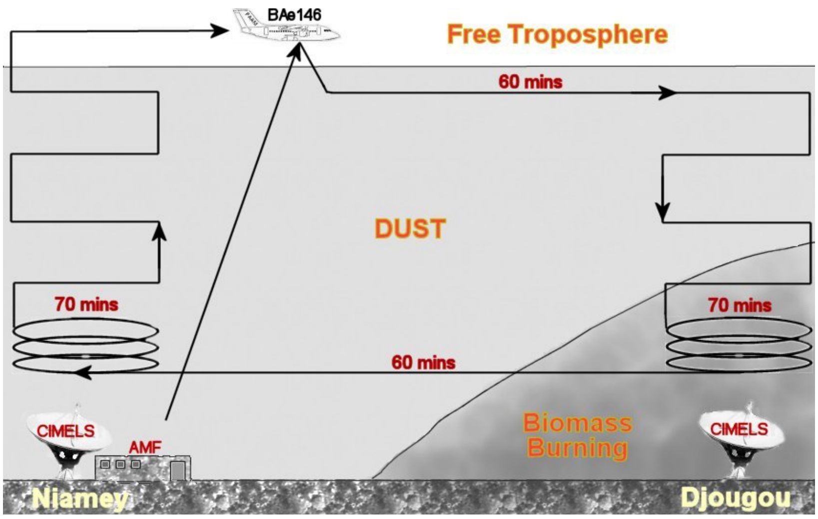
4.1.1 Radiative closure

Flight patterns will be defined over ground-based sites in three regions of interest (Banizoumbou in the proximity of dust sources, Djougou in the fire region, and M'Bour for mixed aerosols). This will allow comparing:

- column measurements by the AERONET sunphotometers with similar measurements which may be performed by a stacked profile ascent/descent flying into/down sun by the UK BAe146.
- lidar measurements by the ground-based lidar systems (Univ. of Munich, ISAC-CNR, LOA/SA) with lidar measurements onboard the FR UL.

- in situ number size distribution and optical properties (scattering and absorption) measured at the ground-based stations with those measured onboard the UK BAe146.

Flight patterns will be defined over ground-based sites in three regions of interest (Banizoumbou in the proximity of dust sources, Djougou in the fire region, and M'Bour for mixed aerosols). This will allow comparing column measurements by the AERONET sunphotometers with similar measurements which may be performed by a stacked profile ascent/ descent flying into/down sun by the UK BAe146.



The FR UL will simultaneously perform predefined pattern in the Banizoumbou and Djougou areas at high level to make lidar profiles and monitor the evolution with time. Besides airborne observations, comparisons will be aimed at in Niamey (Banizoumbou) and Djougou areas from the ground to compare with visible lidar measurements to assess wavelength impact on the aerosol property analysis for the two aerosol types aimed at.

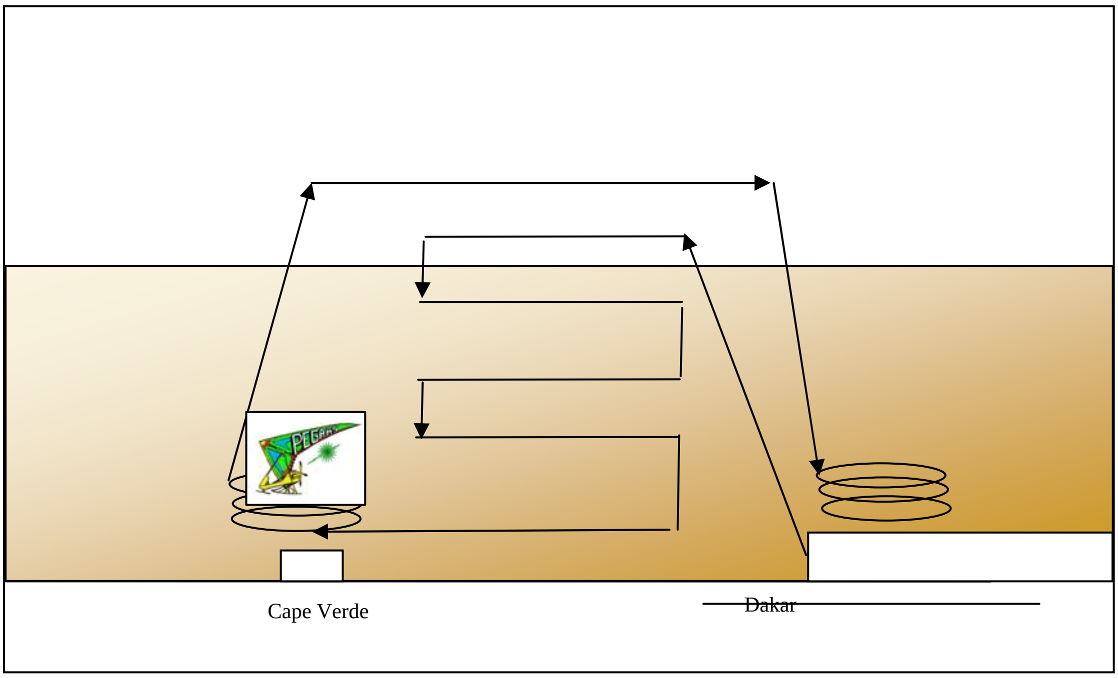
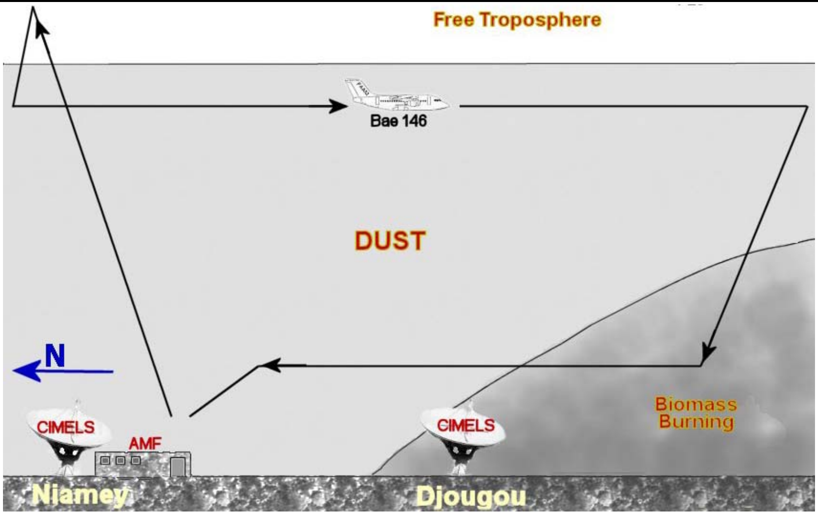


Figure 10 : Flight pattern for radiative closure during SOP0_a2

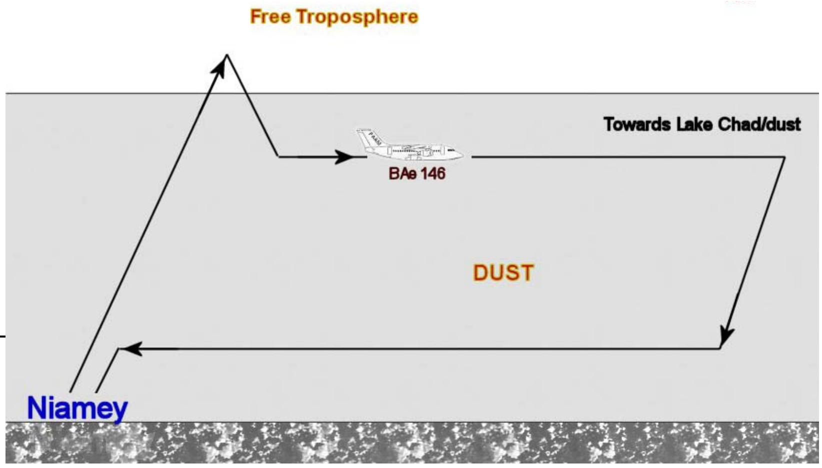
4.1.2 Aerosol characterisation at the regional scale

Two observational plans are dedicated to the characterisation of the physico-chemical and optical properties of the aerosols at the regional scale.

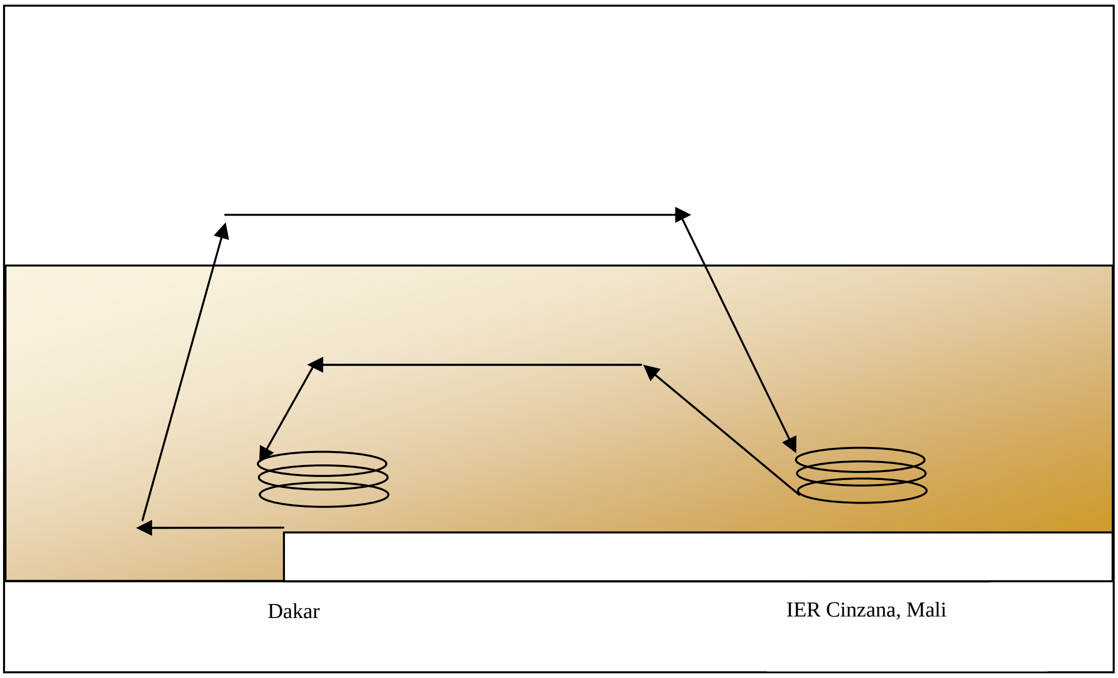
1- North-to-south flights towards the Bay of Benin to document mixing between dust and biomass burning aerosols, and outflow. The planned aircraft flight pattern for the BAe 146 is shown below. The FR ULA will be involved in this analysis to characterize the N-S evolution. This will be coupled with the radiative closure flights.



2- West-to-east flights from Niamey towards the lake Chad (one of the largest dust source regions) to document the chemical-physical and optical properties of undisturbed mineral dust. The planned flight patter is shown on the right.

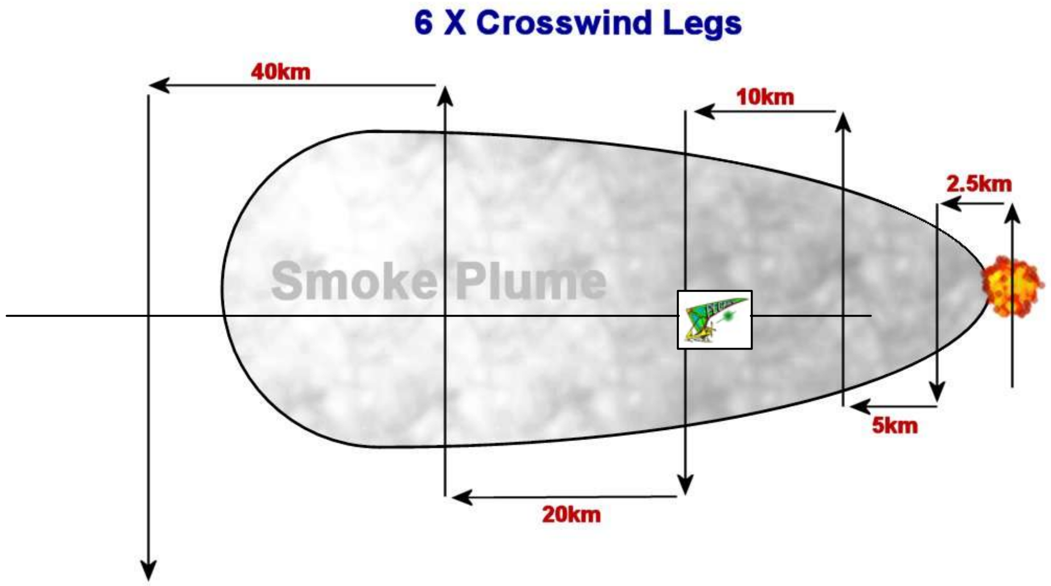


3- East–to–west flight to document dust transport across Western Africa. This objective will be pursued by the UK BAe146 only, in two ways: (i) during the transit flight from Niamey towards Dakar; (ii) during dedicated flights inland during SOP0_a2 (UK BAe146 based in Dakar). This latter one-aircraft flight pattern is shown below. In both cases, the UK BAe146 will overfly the IER Cinzana EOP station in Mali (one of the EOP Sahelian Dust Transect stations).



4.1.3 Biomass burning particle aging

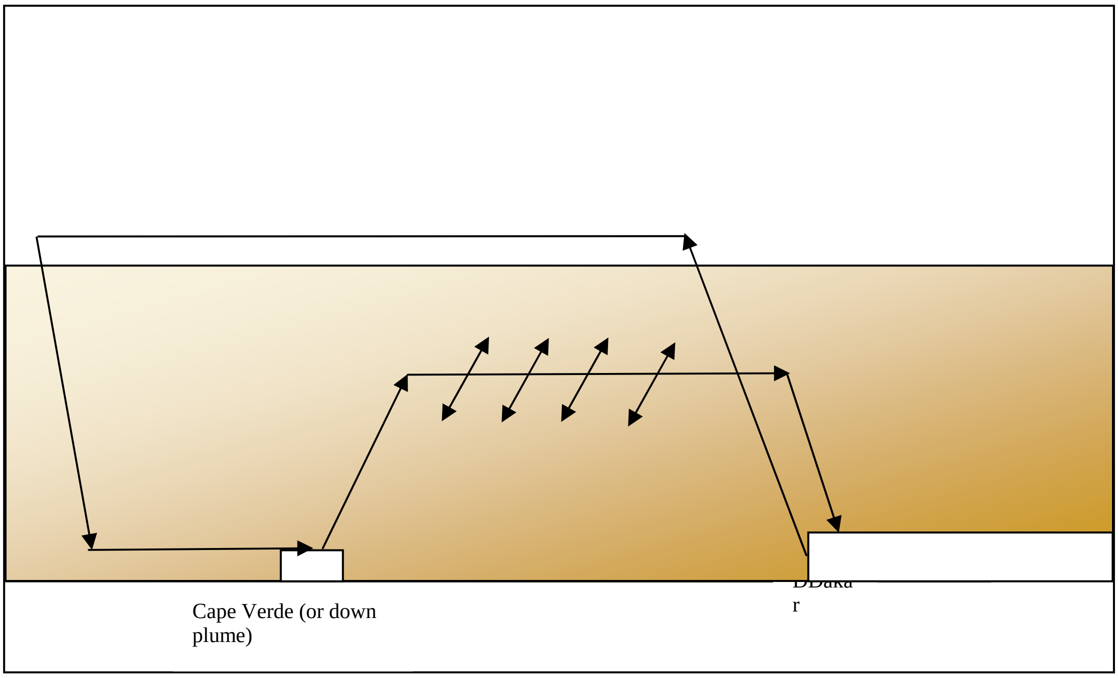
By performing flight legs progressively downwind of local biomass burning sources at different altitude levels, the aging of biomass burning aerosol will be assessed in terms of evolution of the aerosol size distribution, optical properties, hygroscopic nature and mixing with mineral dust.



Overflights of the FR UL will be done to obtaine a 2D crossectional analysis of evolution of the plume at the same time.

4.1.4 Dust outflow and deposition

In order to follow dust transport towards the Atlantic, during DODO the UK BAe146 will fly from Dakar towards the Cape Verde Islands, and further downwind. Overflight of ground/ship based measurements and cross plume transects will be performed whenever possible.



4.1.5 Satellite observations

As mentioned earlier, several polar orbiting and geo-stationary satellites will simultaneously observe this area and will be used to analyse aerosol properties at the regional scale. Besides MODIS on Terra and AQUA, which will also be used to detect fires during the field experiment and analyse aerosol optical depth after the campaign, OMI will bring complementary characterisation in the UV, SEVIRI and GERB observations on Meteosat Second Generation (MSG) will be of prime importance to the analysis of aerosol impact.

Overall, the clear-sky ocean flights above the Bay of Benin planned for the UK BAe146 during SOP 0-A will be done in coordination with the AQUA and TERRA satellite overpasses (at 13:30 and 10:30 UTC, respectively).

4.2 SOP0_a3 (two aircraft in December 2006)

Aircraft observation will be conducted by the FR ATR-42 and the FR F-20 aircraft end of 2006, from Niamey. This would allow a full deployment of the experimental set-up , a better characterisation of aerosol mixing and transport processes, a better characterisation of observed radiative impact at the regional scale after validation of CALIPSO observations. An intercomparison flight in Europe during November 2006 would also be performed including all three aircraft so that the consistency of the measurements can be assessed.

Another motivation for SOP0_a3 is that the AQUA-Train is planned to be formed with the launch of CALIPSO and CloudSat satellites during spring of 2006, allowing for lidar profiling of dry season aerosol properties at the end of 2006. At the moment of writing the AMMA International Implementation Plan the funding of SOP0_a3 is not yet decided.

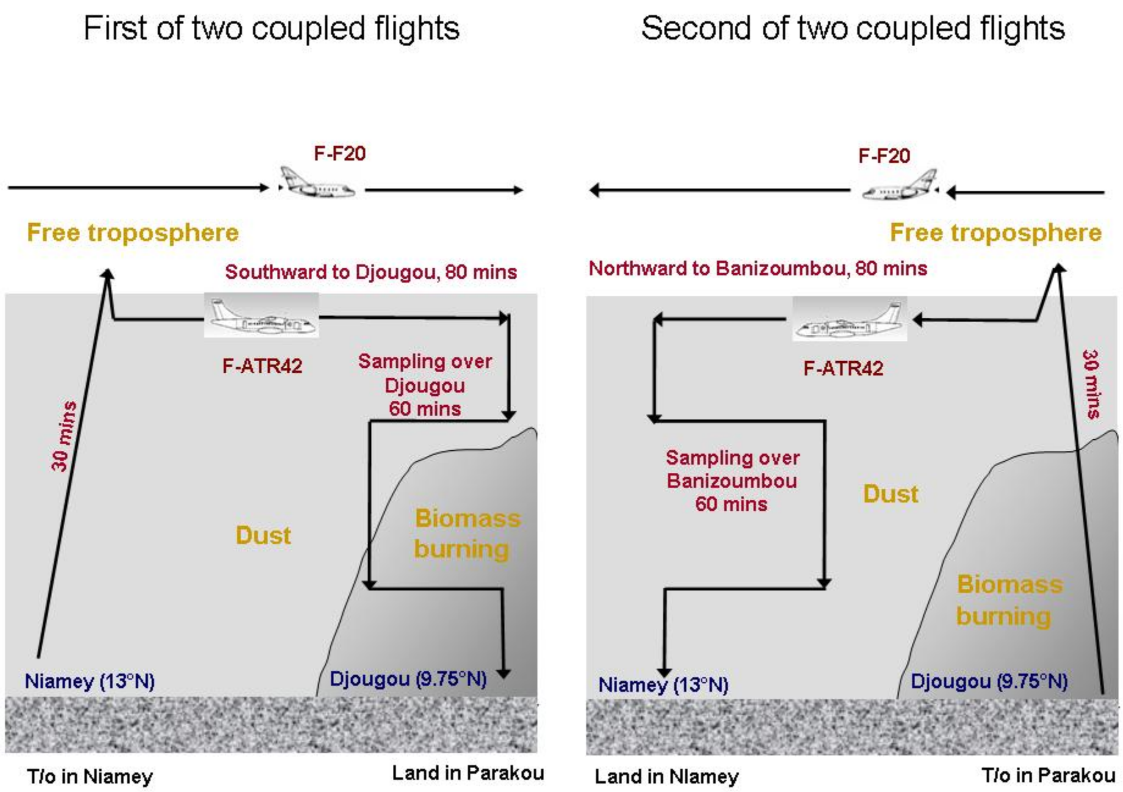
Dates of aircraft deployment and number of flight hours on task are detailed in the following table.

November	Co-ordinated calibration flight with FR ATR-42 and FR F-20		
23–24 Nov		**Creil -> Niamey**	**Francazal -> Niamey**
25–26 Nov		Set-up	Set-up
27 Nov–16 Dec		**Operational flying (40h = 9 flights)**	**Operational flying (31h = 9 flights)**
17 Dec		Pack-up	Pack-up
18–19 Dec		**Niamey -> Creil**	**Niamey -> Francazal**

4.2.1 Radiative closure

Two main fllight patterns will be defined over ground-based stations, with the aim of comparing:

- in situ number and mass size distribution, mineralogy, optical properties (scattering and absorption) and CCN/CN ratio measured at the ground-based stations with those measured onboard the FR ATR-42.
- lidar measurements by the ground-based lidar systems (Univ. of Munich, ISAC-CNR, LOA/SA) with lidar measurements onboard the FR F-20 and FR ATR-42.
- column aerosol optical depth measurements by the AERONET sunphotometers with the vertical-resolved aerosol optical depth measured by the PLASMA sunphotometer onboard the FR ATR-42.
- radiation field measured onboard the FR ATR-42 and the FR F-20 to those measured by the AMF station.

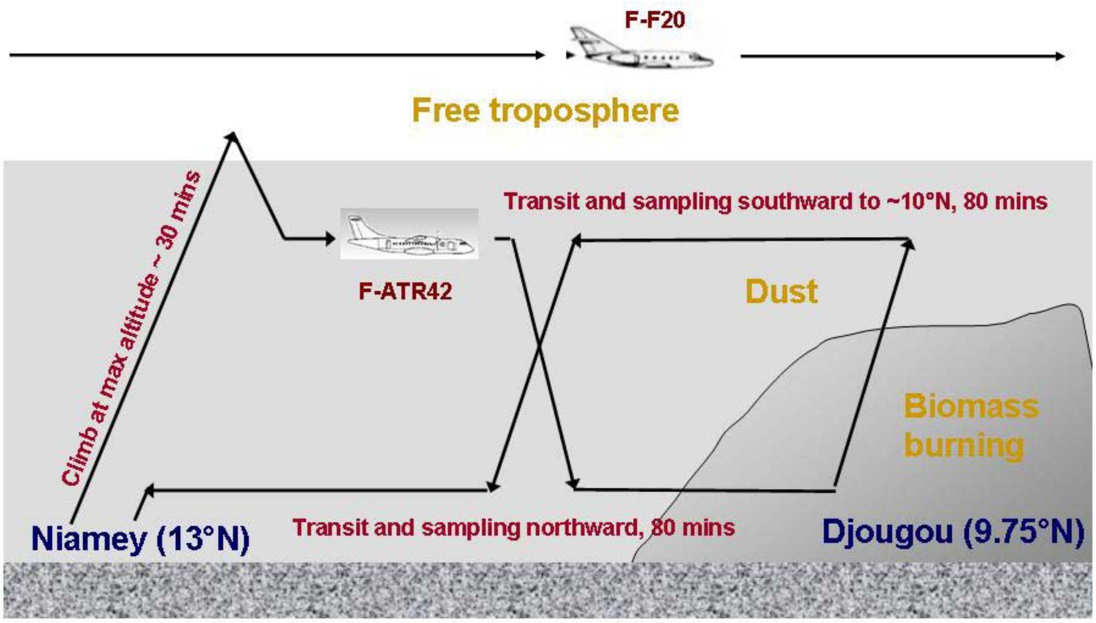


Being the endurance of the FR ATR-42 limited to 3.5h, two flights will be necessary to perform in situ sampling and radiative closure above the two super-sites of Banizoumbou and Djougou. On the first flight, the FR ATR-42 will climb at maximum altitude to sound the aerosol vertical distribution, and then it will transit within the aerosol layer southwards towards Djougou. Once over Djougou, the FR ATR-42 will perform a series of stacked levelled runs for in situ sampling. It will then land in Parakou. The second flight mirrors the first, the stacked levelled runs being now being performed over the ground-based site of Banizoumbou. The FR F-20 will simultaneously perform circles at high level with a constant radius will make lidar profiles, flux measurements and monitor the aerosol evolution with time. The lidar onboard the FR ATR-42 will be pointing upward or downward depending on flight altitude. When the FR F-20 is above, the FR ATR-42 lidar will be pointed upward to allow for signal-to-signal comparison.

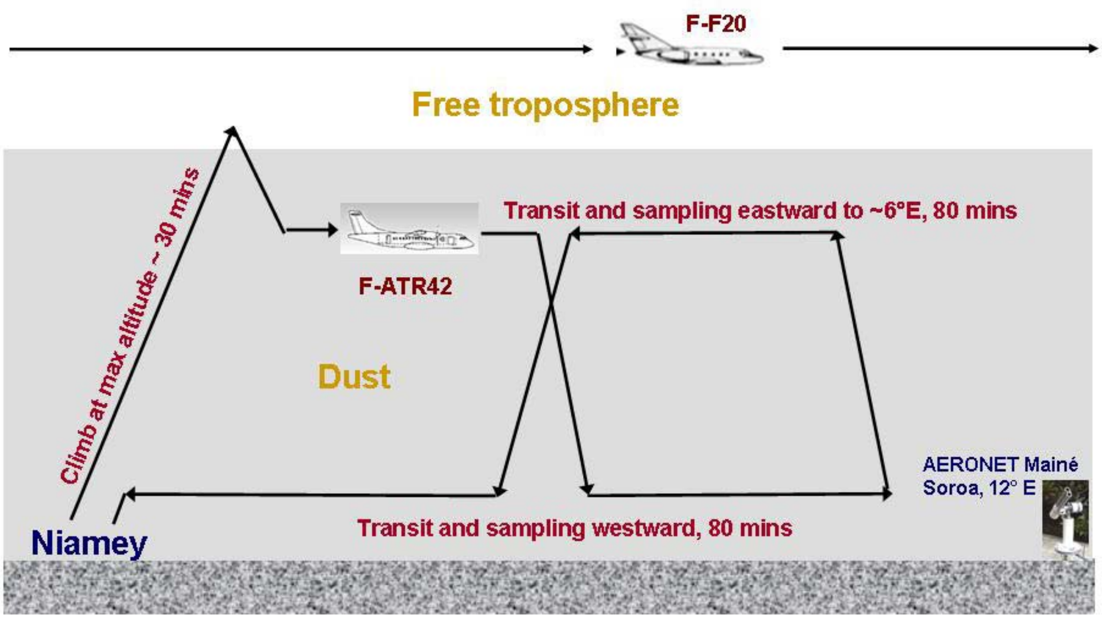
4.2.2 Aerosol characterisation at the regional scale

Two observational plans are dedicated to the characterisation of the aerosol load at the regional scale.

North-to-south flights towards the Bay of Benin to document mixing between dust and biomass burning aerosols, and outflow. Here the FR ATR-42 climbs up to maximum altitude to obtain a vertical profile of the interesting aerosol parameters, then transits towards Djougou at altitudes based on the aerosol vertical structure. At least two altitudes will be sounded, to obtain an indication of the vertical distribution as a function of the expected north-to-south gradient in the aerosol dominant type. Due to the limited endurance, it will not be possible for the FR ATR-42 to reach Djougou on this single flight.



West-to-east flights from Niamey towards the lake Chad (one of the largest dust source regions) to document the chemical-physical and optical properties of undisturbed mineral dust. Here the FR ATR-42 climbs up to maximum altitude to obtain a vertical profile of the interesting aerosol parameters, then transits eastwards at altitudes based on the aerosol vertical structure. At least two altitudes will be sounded, to obtain an indication of the vertical distribution as a function of the expected north-to-south gradient in the aerosol dominant type. Due to the limited endurance, it will not be possible for the FR ATR-42 to reach the AERONET site of Maine Soroa on this single flight.



4.2.3 Biomass burning particle aging

The FR ATR-42 and FR F-20 will not fly this type of flight during SOP0_a3.

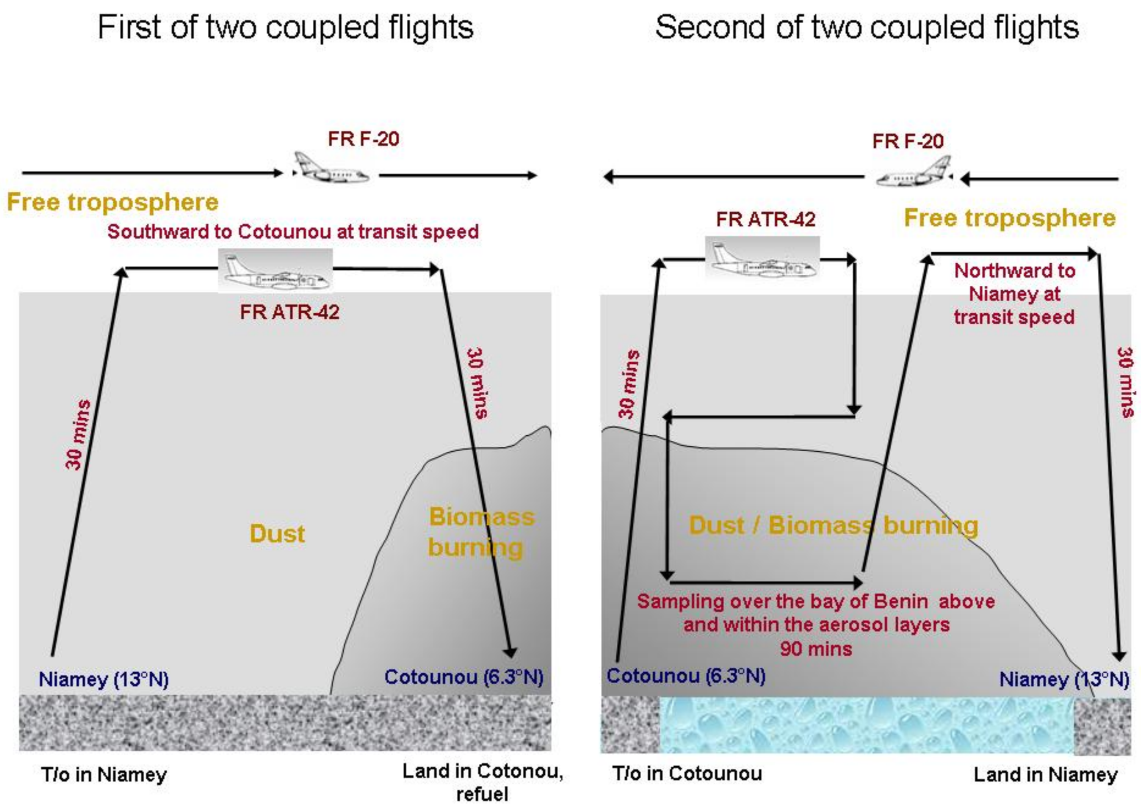
4.2.4 Dust outflow and deposition

The FR ATR-42 and FR F-20 will not fly this type of flight during SOP0_a3.

4.2.5 Satellite validation

Overall, we will try and time all flights in order to allow coordination with the AQUA and TERRA satellite overpasses (at 13:30 and 10:30 UTC, respectively). In addition, one or two clear-sky ocean flights above the Bay of Benin are planned for both the FR ATR-42 and the FR F-20 to allow for satellite validation. As previously stated, by "satellite validation" we mean (i) signal-to-signal comparison; and (ii) validation of retrieved-products, such as aerosol optical depth, size distribution, single scattering albedo, etc.

A generic strategy to reach these objectives is described below. Adaptation to the specific satellite characteristics might be needed. In particular, flying under the CALIPSO trace is demanding as its swift width is of the order of 1 km.



Due to its limited endurance, two coupled flights will be necessary to the FR ATR-42 to reach this objective. A first flight will consist on a climb to maximum altitude at science speed, transiting out to Cotonou at transit speed, and landing after a profile descent at science speed. After refuelling, the FR ATR-42 will climb at maximum altitude (possibly above the aerosol layer) at science speed while transiting over ocean on a completely cloud-free area. There the aircraft will perform a series of stacked and levelled runs above and within the aerosol layers. Levels will be chosen based on the aerosol vertical distribution observed during the profile ascent. The lowest one should be at the aircraft minimum altitude to allow for comparison of aircraft and satellite sensors for the whole aerosol column. The aircraft will then profile up at maximum altitude, transit towards Niamey at transit speed for landing.

The FR F-20 will overfly the area above the aerosol layer in close coordination with the ATR-42.

5 Patnership and Training

Where ever possible, local African meteorologists/scientists will be actively engaged in the flight planning thereby providing training in the decision making processes.

6 Organisation of TT7

6.1 Internal coordination

The Task team leaders are:

Jim Haywood (jmhaywood@metoffice.com) and **Jacques Pelon** (jacques.pelon@aero.jussieu.fr)

The core group members are:

- Karine Desboeufs (desboeufs@lisa.univ-paris12.fr)
- Paola Formenti (formenti@lisa.univ-paris12.fr); also TT8 core group, TT2b enlarged group, AMMA-EU WP2.4.1 coordinator
- Ellie Highwood (e.j.highwood@reading.ac.uk)
- Béatrice Marticorena (marticorena@lisa.univ-paris12.fr); also TT2b leader, AMMA-EU WP2.4.3 coordinator, AMMA-France 2.4 co-leader

Enlarged group members are:

Stéphane Alfaro, Francesco Cairo (TT2b co-leader), Isabelle Chiappello, Patrick Chazette, Hugh Coe (DODO), Juan Cuesta, François Dulac, Philippe Goloub (AERONET), Laurent Gomes, Federico Fierli (AMMA-EU WP1.2), Cyrille Flamant (AMMA-France SOP leader, Tamanrasset station leader, TT8), Pascal Flament, Birgit Heese, Michel Legrand, Jean-François Léon, Cathy Liousse, Céline Mari (TT8 core group AMMA-France, SOP2 and WP2.4, AMMA-EU WP2.4.2 coordinator), Laurent Menut, Sean Milton, Vincent-Henri Peuch, Veronique Pont, Jean-Louis Rajot (TT5), Philippe Ricaud, Tony Slingo (AMF/RADAGAST), Michael Schulz, Sophie Szopa, Didier Tanré.

The implementation of the SOP observations will be coordinated within the existing EU project structure, with separate **Aircraft (part of WP4.2.1)** and **Ground-based (part of WP4.2.2)** coordination groups. The leaders of the aircraft group will be Jim Haywood, Ellie Highwood, Jacques Pelon and Paola Formenti; the leader of the ground-based group will be Karine Desboeufs. It will be the work of this TT to ensure that the operations of these groups are complementary.

6.2 Handling of requests for new instruments

These are discussed by the whole TT7 group and approved by the Core Group. Financial implications will also be considered, and discussed with the ICIG where necessary.

We also need to handle requests for new objectives with the old instruments! This will be undertaken by the same groups.

6.3 External diffusion of the information and reporting

This TT will consist of members representing all the interest-groups relevant to SOP-Dry season. This TT will also include representatives of the ICIG, ISSC and CSAM. These individuals will be tasked with reporting information out of the TT.

7 Coordination with other TTs

TT1	High frequency radiosondes will be required, perhaps at short notice and in support of flights.	
TT2	Soil moisture and surface flux analyses, aerosol measurements from ground sites and remote sensing, may be needed for planning of flights.	
TT3	Gourma	Installation of SOP-related ground instrumentation. Overflights and data comparisons. Quick analyses for flight planning.
TT4	Niamey	
TT5	Oueme	
TT6	Close cooperation regarding flights over the ocean and radiative impact of aerosol on available solar flux	
TT8	Cooperation in logistical arrangements especially for aircraft.	
TT9	Coordinated studies of system lifecycles; trajectories/long-range transport; …	
TC1	We can benefit from past (LOP) case-studies in our operational planning, as outlined in the EU project in WP2.1	
TC2	This link with the Operational Centres is vital! We need to communicate our requirements in data communication and operational planning.	
TC3	Data format; archive resolution; … a major task!	
TC4	We need to seek funding for African participation in the operational planning in Niamey.	

8 Ancillary information: reference, logistic forms, site document

France / SAFIRE / FA-20 F-GBTM

S.LA_FFR F-20	Dew point	SAFIRE-FA20	Water Vapour H2O	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.GPS_FFR F-20	INS, GPS	SAFIRE-FA20	Position, winds, u,v,w	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.5PTP_FFR F-20	5-port turbulence probe	SAFIRE-FA20	Turbulence	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.PRT_FFR F-20	Rosemount PRT	SAFIRE-FA20	Temperature T	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.Drop_FFR F-20	AVAPS dropsondes	SAFIRE-FA20	Vertical profiles of dynamical variables	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.HUR_FFR F-20	Aerodata humidity sensor	SAFIRE-FA20	Relative Humidity	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.BBR_FFR F-20	Pygreometers and Pyranometers (up/down)	SAFIRE-FA20	Upwelling/Downwelling, Vis/IR Broadband radiation	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.JNO2_FFR F-20	Photometer	SAFIRE-FA20	NO2 photolysis j(NO2)	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.PMS_FFR F-20	Size particle / rain drop distribution	SAFIRE-FA20	300 to 3 000 nm PCASP PMS: 1DC-OAPX, 1DP-OAPY, 2DC	SAFIRE	M. Pontaud (marc.pontaud@meteo.fr)	2006
S.LEANDRE_FFR F-20	Aerosol profiles	SAFIRE-FA20	Lidar	IPSL	J. Pelon (Jacques.Pelon@aero.jussieu.fr)	2006
S.Dirac_FFR F-20	Brightness temperatures	SAFIRE-FA20	IR radiometer	IPSL	J. Pelon (Jacques.Pelon@aero.jussieu.fr)	2006
OSIRIS_FFR F-20	Polarization and directionality of earth reflectances from 440 to 2200nm	SAFIRE-FA20	Aerosol optical thickness, size Distribution	LOA	J. F. Léon (leon@loa630.univ-lille1.fr)	2006
MINIMIR+MICROPOL	Polarization and directionality of earth reflectances from 440 to 2200nm	SAFIRE-FA20	Aerosol Optical thickness, Size Distribution	LOA	J. F. Léon (leon@loa630.univ-lille1.fr)	2006
CLIMAT	Multichannel thermal infrared radiometer.	SAFIRE-FA20	Brightness temperatures	LOA	G. Brogniez (brogniez@loa630.univ-lille1.fr)	2006

France / SAFIRE / FR ATR-42 H-MTO

S.SPR_ATR-42	Rosemount,Thales Avionic	SAFIRE-ATR-42	Static pressure	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PRT_ATR-42	Rosemount PRT	SAFIRE-ATR-42	Temperature T	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.DP_ATR-42	Buck Research dew point sensor	SAFIRE-ATR-42	Dew point	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LA_ATR-42	AIR	SAFIRE-ATR-42	Water Vapour H2O	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.LWC_ATR-42	King Probe, Gerber Probe, JW	SAFIRE-ATR-42	Liquid water content	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.GPS_ATR-42	INS, GPS	SAFIRE-ATR-42	Position, winds, u,v,w	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.5PTP_ATR-42	5-port turbulence nose	SAFIRE-ATR-42	Turbulence	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.HEIGHT_ATR-42	Thales Avionic radioaltimetre	SAFIRE-ATR-42	Height above ground	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.NOx_ATR-42	Chimiluminescence NOx instrument	SAFIRE-ATR-42	NO, NO2 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.CO_ATR-42	IR-CO instrument	SAFIRE-ATR-42	CO in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.O3_ATR-42	UV-O3 instrument	SAFIRE-ATR-42	O3 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.JNO2_ATR-42	Photometer	SAFIRE-ATR-42	NO2 photolysis j(NO2)	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PCASP_ATR-42	Externally sampling PCASP	SAFIRE-ATR-42	Size distribution (0.2-30 um)	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.BBR_ATR-42	Pygreometers and Pyranometers (Up/down)	SAFIRE-ATR-42	Upwelling/Downwelling, Vis/IR Broadband radiation	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.PMS_ATR-42	Size particle / rain drop distribution	SAFIRE-ATR-42	PMS: 1DC-OAPX, 1DP-OAPY, 2DC, FSSP	SAFIRE	M. Pontaud marc.pontaud@meteo.fr	2006
S.AVIRAD_ATR-42	AVIRAD particle inlet	SAFIRE-ATR-42	Coarse particle inlet (AVIRAD)	LISA/LSCE	P. Formenti formenti@lisa.univ-paris12.fr	2006
S.AVIRAD.GRIMM_ATR-42	Optical sizer GRIMM	SAFIRE-ATR-42	Size distribution (0.3-20 µm)	LISA	P. Formenti formenti@lisa.univ-paris12.fr	2006
S.AVIRAD.AETH_ATR-42	7- aethalometer	SAFIRE-ATR-42	Particle soot, black carbon	LISA	P. Formenti formenti@lisa.univ-paris12.fr	2006
S.AVIRAD.NEPH_ATR-42	3- Nephelometer	SAFIRE-ATR-42	Spectral Scattering and backscattering coefficients	LISA	P. Formenti formenti@lisa.univ-paris12.fr	2006
S.AVIRAD.Filt_ATR-42	filters for individual	SAFIRE-	Particle shape and composition	LISA	P. Formenti	2006

	particle analysis	ATR-42			formenti@lisa.univ-paris12.fr	
S.AVIRAD.DKT_ATR-42	4-stage impactors	SAFIRE-ATR-42	Aerosol composition and mass distribution	LISA	P. Formenti formenti@lisa.univ-paris12.fr	2006
S.VC_ATR-42	Particle inlet	SAFIRE-ATR-42	Aerosol Particle inlet ("Veine communautaire")	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.VC.FIL_ATR-42	filters for sub and supermicron particle collection	SAFIRE-ATR-42	Ions, trace, BC/OC	LA	V. Pont ponv@aero.obs-mip.fr	2006
S.VC.UCPC_ATR-42	Ultrafine CPC	SAFIRE-ATR-42	Particle number concentration > 3nm	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.VC.CCN_ATR-42	CCN counter	SAFIRE-ATR-42	CCN	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.VC.CPC_ATR-42	Multi-channel CPCs	SAFIRE-ATR-42	Size distribution > 10nm	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.VC.DMA_ATR-42	DMPS	SAFIRE-ATR-42	Size distribution of Aitken and accumulation mode particles (20-1000 nm)	LaMP	P. Laj P.Laj@opgc.univ-bpclermont.fr	2006
S.VC.PCASP_ATR-42	PCASPX	SAFIRE-ATR-42	Size distribution 0.3-10 µm	LaMP	P. Laj P.Laj@opgc.univ-bpclermont.fr	2006
S.VC.THERMO_ATR-42	Thermodenuder	SAFIRE-ATR-42	Volatility analysis of particles	LaMP	P. Laj P.Laj@opgc.univ-bpclermont.fr	2006
S.XPRO_ATR-42	X-Probe	SAFIRE-ATR-42	Aerosol and droplet size distribution (0.5-50 µm)	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.FFSSP_ATR-42	Fast FSSP	SAFIRE-ATR-42	Cloud droplet spectrum	CNRM	L. Gomes Laurent.gomes@meteo.fr	2006
S.LAUVA_ATR-42	UV lidar	SAFIRE-ATR-42	Aerosol vertical profile	LSCE	P. Chazette pch@lsce.saclay.cea.fr	2006

Version 3 May 2006

Chapter 10

SOP Monsoon: Strategic planning document

–TT8–

Coordinators:
Doug Parker & Cyrille Flamant

Core group:
Francesco Cairo, Suzanne Crewell, Arona Diedhiou, Cyrille Flamant, Paola Formenti, Anne Garnier, Hartmut Hoeller, Norbert Kalthoff, Katherine Law, Céline Mari, Doug Parker, Jean-Pierre Pommereau, Alain Protat, Claire Reeves, Hans Schlager, Chris Thorncroft, Garba Zibo

Providing input to this document:

- Members of TT8 should send comments directly to the TT8 coordinators
- Partners in the AMMA-EU consortium should channel their feedback through workpackage representatives (section 5.1 below) where possible.
- Members of other national consortia should provide their feedback through these groups.
- Specific comments on the Aircraft and Ground-based parts of the document can be sent to Cyrille Flamant and Claire Reeves (Aircraft) or Susanne Crewell and Alain Protat (Ground-based).
- If in doubt, general comments on the overall strategy can be sent to Doug Parker in the first instance.

1. Scientific justification and objectives

Key questions to be addressed by AMMA are listed in the International Science Plan.

A number of SOP-Monsoon objectives are also defined by the funded and proposed parts of AMMA. TT8 will organise these objectives into complementary activities, and this is described in subsequent sections of this document. Appendix E lists the objectives and subprojects which are concerned with TT8.

2. Observing strategy

2.1 Overall strategy

2.1.1 Aircraft and ground-based measurements

A detailed overview of the SOP-Monsoon strategy is included in section 3 of the AMMA International Science Plan (ISP – http://amma.mediasfrance.org/international/documents/index).

In order to achieve the scientific objectives related to the onset and mature monsoon phases decribed in the AMMA ISP, a synergy of observations from up to five research aircraft (F/ATR-42, F/F-20, UK/BAe146, D/F20 and EEIG/Geophysica), various ground-based stations and space-borne instruments has been designed to be operational in June–September 2006.

The overall strategy for the SOP observations is a multidisciplinary, multi-instrument approach. ***Research aircraft*** will be used to gain high temporal and spatial resolution measurements while ***ground-based systems*** will provide continuity in time. The aircraft will also be used for a 'Lagrangian' approach (for instance following weather systems through more than one phase of their evolution), with the ground-based systems giving an Eulerian (fixed location) view.

There are two important modes of instrument operation:

1. **Intensive observing periods (IOPs)** of 1-4 days will be used to focus attention on specific events in the monsoon: notably the effects of convective rainfall events on the various environmental systems. Central to these IOPs will be the deployment of ***research aircraft.*** Prescribed IOP patterns are numbered I1, I2, …
2. **Intensive monitoring** will be conducted throughout the SOP period using ground-based instruments. The activity of some of the EOP monitoring systems (such as the radiosonde network) will be enhanced in this period. This enhancement of monitoring systems will also involve the deployment of ***SOP ground instrumentation.***

Table 2.1 below lists the deployment dates of various instruments.

Week	29/5	5/6	12/6	19/6	26/6	3/7	10/7	17/7	24/7	31/7	7/8	14/8	21/8	28/8	4/9	11/9
SOP #	**SOP1**					**SOP2**										
Dates	1 June – 30 June					1 July – 15 Sept										
Aircraft	**SOP 1-a**				**SOP 2-a1**			**SOP 2-a2**						**SOP 2-a3**		
Dates	1 – 15 June				1 – 15 July			17 July – 25 August						1 – 15 Sept		
BAe146								17 July – 21 August						22 – 28/8		
ATR	1 – 15 June				1 – 15 July				27 July – 20 August							
F-F20	1 – 15 June				1 – 15 July				27 July – 20 August					1 – 15 Sept		
D-F20					1 – 15 July					31 July – 18 August						
Geoph.										31 July – 18 August						
Ground																
Dano fluxes	1-15 June								23 July – 20 August							
Dano r'sondes	1-15 June								23 July – 20 August							
Driftsondes												15 August – 15 September (Diffa or Zinder)				
Ocean soundings	25 May – 7 July (R/V Atalante)															
Oceanic mast	25 May – 7 July (R/V Atalante)															
Constant vol. balloons			15 June – 15 July													
Tethered balloon								17 July – 21 August								
Sodar network	1 June – 21 August															
MIT C-band radar	1 June – 15 August															
SCOUT Balloons									24 July – 29 August							
Ronsard radar			15 June – 15 September													
Bistatic radar receivers			15 June – 15 September													
Micro rain radar	January-December															
Lidar network	M'bour, Niamey (ARM Mobile Facility), Banizoumbou, Djougou, Tamanrasset (TReSS)															
Lidar ceilometer	Niamey (ARM Mobile Facility), Djougou															
Deposition fluxes	M'Bour, Cinzana, Banizoumbou															
Aerosol characterisation	M'Bour, Cinzana, Banizoumbou, Tamanrasset, Djougou															
Chem. instruments					SOP 2a1 & 2a2											
Lightning network	SOP 1 & SOP 2															
Microwave radiometer	January-December															
UHF radar	April-September															
GPS network	Tombouctou, Ouagadougou and Tamale															
RS network	SOP southern, northern and western quadrilaterals															
ARM Mobile Facility	January-December															
Soil moisture radar	June-September															
Ozone soundings	Cotonou															

Table 2.1: SOP dates and periods of instrument deployment. Red = Niamey; Blue = Dakar; Yellow = Ouagadougou; Green = Dano; Orange = Djougou; Pink = 'other'. The SOP-Monsoon periods have been sub-divided into periods of coordinated aircraft deployment labelled SOP1-a, SOP2-a1, SOP2-a2 and SOP2-a3. Details of instruments are contained in Appendix B of this document.

2.1.2 Modelling and satellite observations

Model and satellite products will be used for planning of IOPs and aircraft operations (coordinated through the AMMA Operations Centre - AOC). Need for these products, according to IOP, is detailed in the forecasting requirements for SOPs (Table 3.1 below). It should be noted that a number of products will be required for SOP planning, which are beyond the usual remit of operational weather prediction, as per example the dust and biomass burning plume trajectories.

Data assimilation with certain datasets from the SOP (radiosondes, dropsondes, driftsondes in particular) is a major priority.

Targetted observations using dropsondes, radiosondes and driftsondes could be supported (see I5 plan in section 2.4).

Coordination with satellite overpasses needs to be discussed.

Representatives of the modelling and satellite communities are members of TT8.

2.2 Surface-based deployment strategy

2.2.1 Overview

In the SOP observing startegy, the objective of the surface-based deployment is two-fold: (i) obtain continuous monitoring of processes and their evolution during the different phases of the monsoon (i.e. pre-onset, onset, and mature) and (ii) provide complete and mutidisciplinary datasets for numerical modeling validation as well as satellite products validation.

The surface-based deployment will be implemented in five ways essentially:

- ***Enhancement of EOP measurements*** as for example balloon soundings networks around the Niger and Benin mesoscale sites, and ozone soundings in Cotonou, Benin;
- ***Addition of new instruments on existing supersites*** as for example in the Donga basin (Benin) or around Niamey;
- ***Networking of instruments along transects according to the coherence of the related measurements*** as for example the enhancement of the EOP east-west “aerosol sahelian” transect with lidars and in situ aerosol sampling devices or the installation of a north-south GPS transect west of the EOP GPS transect;
- ***Activation of isolated stations/supersites in remote locations or locations not included in the transects*** as for example the supersites of Tamanrasset (Algeria) and Dano (Burkina-Faso), or the balloon releasing sites of Cotonou (Constant volume balloon) and N’Djamena (Driftsondes);
- ***Seaborne operations*** in the Gulf of Guinea in the framework of the EGEE-3 cruises envolving the R/V Atalante (balloon soundings, air-sea exchanges characterization) and other R/V in the Equatorial and Tropical Atlantic.

The list of ground-based instruments proposed for the SOP is included as Appendix B. There are two characteristic modes of operation for ground-based instruments:

1. ***‘Continuous’ monitoring (M).*** This mode is typical of instruments measuring vertical profiles or scalar parameters, such as sodars, wind profilers, automatic weather stations, surface energy balance stations. Such stations may need periodic maintenance, in some cases daily. Some of these instruments may be EOP instruments which operate in an enhanced mode during the SOP,
2. ***‘Responsive’ operations (R).*** In such cases, instrument operation depends critically on the prevailing conditions, and on the particular scientific objectives in question. This mode is characteristic of radar, balloon-borne soundings, and tethered balloon systems. In such cases, the instruments will be linked to the IOP patterns listed in section 2.4 (I1, I2, …). In addition, there may be IOP patterns which involve ground-based instruments alone.

2.2.1.1 Enhancement of EOP measurements

2.2.1.1.a SOP radiosonde network

The RS network is being upgraded and coordinated for the EOP period by TT1. Priorities defined by TT1 are largely for EOP monitoring. For the radiosondes, the additional SOP monitoring is defined on the networks provided for the EOP, particularly the 'quadrilaterals', and the 'monsoon transect', which are now briefly described.

(i) SOP Flux networks (quadrilaterals, see Fig. 2.2.1)
Southern quadrilateral: Cotonou, Parakou, Niamey, Tamale, Abuja
Northern quadrilateral: Parakou, Tahoua/Birni/tAgadez/Kano, Tombouctou, Ouagadougou, Niamey

At the centre of each quadrilateral, a meteorological radar is to be deployed. These quadrilateral arrays are needed in process studies, for estimation of budgets in the water vapour and energetics of each region. Such diagnostics are necessary for studies of cloud systems and hydrology. A frequency of at least 4 soundings per day, during the SOPs, is needed for these purposes.

Concerning the northern quadrilateral, due to the orographic influences on the local meteorology of Agadez, there is a strong motivation to replace this station. A temporary station, to be deployed during the SOP in a location to the east of Niamey, is required to complete the northern quadrilateral of stations. Possible temporary sites for this station include Birni n'Konni (13.80°N, 5.25°E) and Tahoua (14.90°N, 5.25°E). The Tahoua site would be priority. A further option for this station might be Kano, in northern Nigeria.

(ii) Northern stations (see Fig. 2.2.1)
Agadez, Tombouctou, Tessalit, Tamanrasset

These stations lie in a critical zone on the southern fringes of the Sahara. Tessalit is perfectly placed to observe the monsoon trough and heat low in the summer months, in a zone where the model errors due to aerosol loadings can be large. In this regard, its position is better than that of Tamanrasset, whose climate is somewhat affected by the Hoggar Mountains.

These northern soundings also represent an extension of the meridional Climate Array in the summer period. They are needed for understanding of monsoon dynamics and the role of the diurnal cycle in the zone of strongest thermodynamic gradients, during the monsoon peak. In this context, the data from the Northern Stations will be used in association with surface observations from the northern extensions of the flux station network. These stations are of primary interest in the summer periods, when the low-level thermodynamic gradients are located in the Northern Sahel.

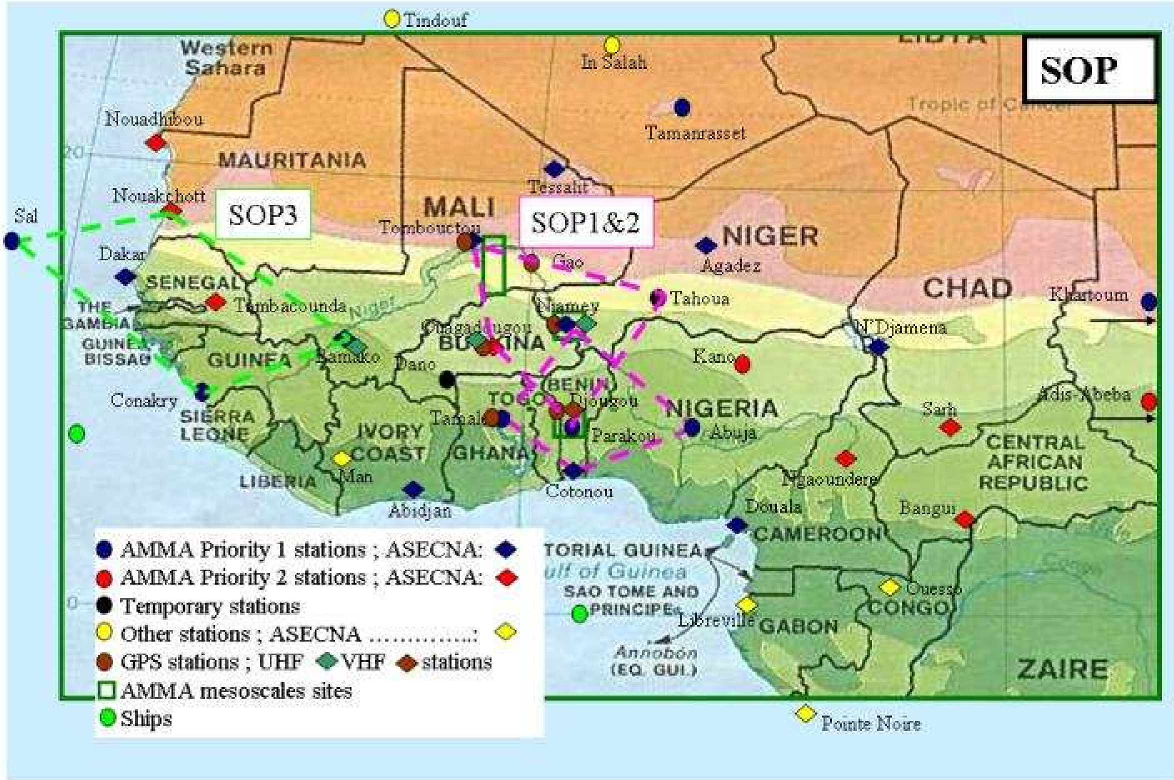


Figure 2.2.1: Radiosonde stations for AMMA, marking the northern, southern and western quadrilaterals.

The majority of the stations relevant to TT8 are operated by ASECNA, who are a full partner in the AMMA-EU programme, and funded directly through AMMA-EU to deliver the soundings needed. Enhanced soundings from the very effective Algerian station at Tamanrasset are also planned.

The SOP sounding programme will also be enhanced by the provision of soundings by the ARM Mobile Facility (AMF), who will launch 4 soundings per day from Niamey. At the Dano site **(1-15 June 2006 for SOP 1 and 23 July – 20 August 2006 for SOP 2a2)**, there will be an additional radiosonde station operated by FZK for the SOP. There will be ship-launched soundings from the R/V Atalante during the EGEE-3 cruise in the Gulf of Guinea **(25 May – 7 July 2006)**.

It is noteworthy that all these atmospheric profiles will be complemented by numerous dropsonde launches from aircraft operations during IOPs.

2.2.1.1.b Ozone soundings in Cotonou

The objective is to sample the vertical distribution of ozone in the troposphere and in the stratosphere in the vicinity of Cotonou to characterise its seasonal (and possibly interannual) variability over equatorial Africa,and to assess the transport pathways from the different source regions. Moreover, these soundings aim at complementing the SHADOZ network which provides no ozone data over continental equatorial Africa except in Nairobi (Kenya). The measurement frequency is of one sounding per week for the EOP period (December 2004 – November 2006) at a fixed day and time. During the SOP (June-Augut 2006), the frequency will be increased to three times a week.

2.2.1.2 Addition of new instruments on existing supersites

2.2.1.2.a The Donga basin site in the Ouémé region

In the framework of the EOP, this region has been instrumented mainly for hydrological applications (X-Port radar, rain gauges, etc..). During the SOP, additional instruments will be located in three sites (Figure 2.2.2): **Kopargo** which will be equipped with the Doppler polarimetric C-band radar RONSARD and **Kolokonde** which will be equipped with the DLR bistatic radar receivers. This radar network together with the X-Port in **Djougou** will define a Doppler radar area within which the dynamical and microphysical processes associated with organized MCSs and non-organized convection will be documented. RONSARD will operate from 15 June to 15 September. Its maximum range is either 200 or 100 km, with range gates of 100 or 200 m. The sampling achieved by RONSARD will also be carefully coordinated with that of X-Port in order to access the 3D wind field. RONSARD also has clear-air capabilities which could eventually be very useful for the characterization of low-level clear-air dynamics ahead of MCSs, where low-level chemical flights will occur in SOP2a2.

Within this radar array, a third site, **Nangatchori**, will be dedicated to the in-situ and vertical stratification of chemistry, aerosol, precipitation, dynamics and energy budget during the monsoon season, by means of in situ (sampling of chemical compounds and aerosols, optical spectropluviometer for rain rate and fall speed of hydrometeors, etc..), active remote sensing (lidar, UHF/VHF radars, micro-rain radar, lidar ceilometer) and passive remote sensing (profiling microwave radiometer) measurements. A lightning detection network will also be installed in the Donga Basin region by DLR.

The UHF and VHF will run unattended onder the control of a technical staff for Benin. The data will be transfered to CNRM in Toulouse for quality control and data processing. Quicklooks and possibly data will then be transfered to the AOC in Niamey.

The primary aim of the Univ. Of York field work at the ground site in Benin is to determine the dominant C10 and larger biogenic species, (particularly terpenoids and carbonyl compounds), present in surface layer above this region of West Africa. The data will be used to determine biogenic influence on both local and regional ozone processes and potential organic aerosol formation. A small number of filter samples of ambient aerosols will also be collected and the organic content (both volatile and macromolecular) determined by subsequent laboratory analysis. Surface measurements carried out at Djougou will provide a ground constraint to complement similar measurements made on the BAE 146 during SOP2 and measurements of species such as isoprene / ozone made concurrently by CNRS.

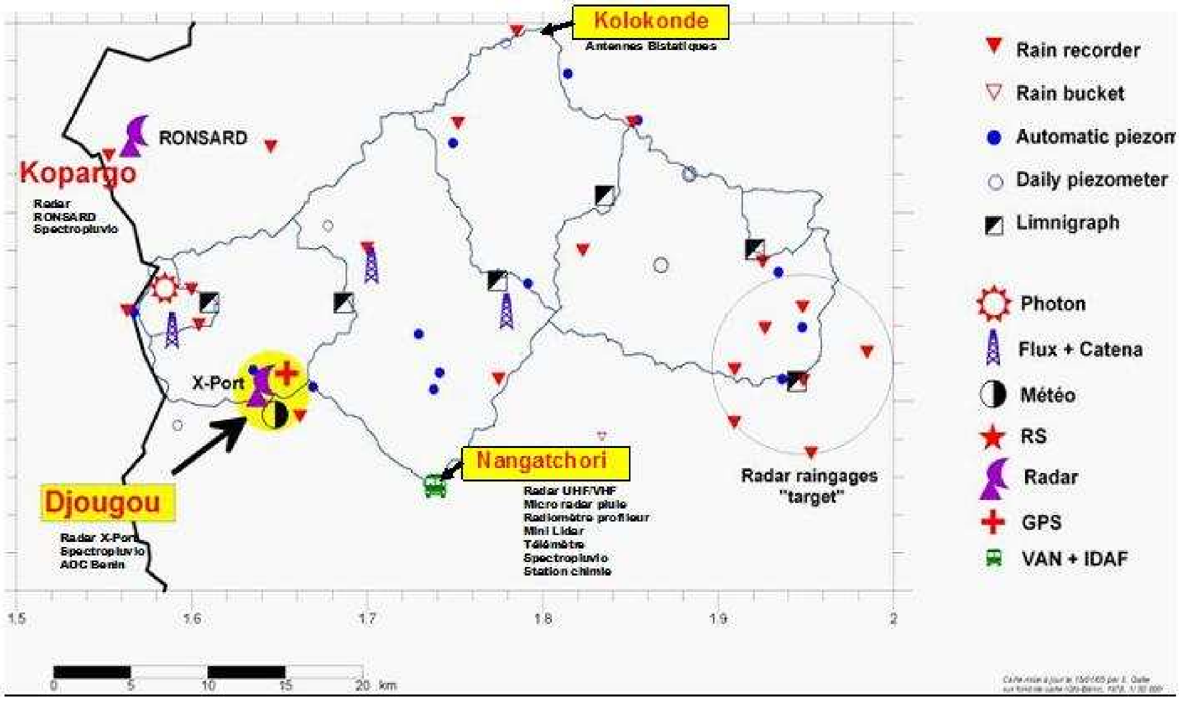


Figure 2.2.2: SOP instrumentation in the Donga basin area.

2.2.1.2.b The Niamey-Banizoumbou supersite

During the SOP, a station dedicated to measuring wind erosion fluxes and dust physical-chemical characteristics as well as aerosol vertical distribution will be implemented in **Banizoumbou** (east of Niamey) to measure dust fluxes in the Sahel related to soil uses and climate variations, and to characterize dust radiative impact related to dust sources and to dust physical and chemical properties.

An ensemble of instrumental platforms will also be implemented at the Niamey airport to provide high spatio-temporal resolution observations relevant to AMMA objectives: the **Massachussets Institute of Technology (MIT) Doppler C-band radar** (operational from June 1 to August 15) for the documentation MCS-related dynamics and precipitation processes as well as hydrology and land-surface interactions, the **ARM Mobile Facility** (operation for the whole of 2006) equipped with a backscatter lidar and a cloud radar, among many other instruments) for the monitoring of the radiative budget and of the optical, dynamical, and microphysical properties of cirrus clouds and anvil clouds, and the so-called **SCOUT balloons** equipped to document the thermodynamics and the chemistry in the upper troposphere and lower stratosphere (collaboration with EU SCOUT project). The

SCOUT sondes and balloon measurements are planned between July 17 and August 30, 2006.

Finally, an array of 4 sodar stations (3 from Univ. of Leeds, 1 from FZK) is planned for deployment in SOP1 and SOP2 (1 June – 21 August 2006). The sodars measure winds continuously up to a level of about 500 m, at time resolution of around 10 to 30 minutes and vertical resolution of 10 m or greater ('Monitoring' mode). In association with the sodar array, a tethered balloon system (Univ. of Leeds) will be deployed during SOP2-a2 (17 July – 21 August 2006), from which wind profiles, thermodynamic profiles and turbulent fluxes profiles can be made over periods of many hours (in 'responsive' mode). The combination of these instruments will be used to measure: local circulations due to surface heterogeneity (vegetation and soil moisture), the diurnal cycle of the low level monsoon flow, the vertical structure of the low level monsoon flow,'sea-breeze'-type flows forced by the land surface, and low level wind structure of MCS events. The deployment of the sodars is planned as a "Y" pattern, of scale around 100 km, 'tuned' to the typical scales of soil moisture variability resulting from MCS events.

2.2.1.3 Networking of instruments along transects according to the coherence of the related measurements

2.2.1.3.a Sahelien aerosol transect

In the framework of the SOP, three stations of the EOP "Sahelien aerosol transect" (see TT2b), dedicated to study of the evolution of dust properties during their transport towards the Atlantic Ocean and the role of easterly waves and Mesoscale Convective Systems (MCS) on dust emission, transport and deposition, will be equipped with a suite of instruments enabling detailed documentation of the radiative, optical and hygroscopic properties of dust: M'Bour (Senegal), Cinzana (Mali), and Banizoumbou (Niger, see section ***2.2.1.2.b*** above). At each of these sites, the following parameters will be monitored by the instrument indicated into brackets:

- Ø dust concentration (PM10) at the ground level (TEOM)
- Ø total, wet and dry dust deposition (automated passive collector)
- Ø column-integrated aerosol content and properties (AERONET/PHOTONS photometer)
- Ø vertically-resolved aerosol distribution (micro-LIDAR, ISAC-CNR).

2.2.1.3.b GPS meridien transect

GPS-derived total columnar water vapour (TCWV) measurements along meridien transects can significantly contribute to improve our knowledge of the atmospheric water cycle in the WAM and to document its variability from the mesoscale to interannual scale. TCWV provides a column-integrated observation of water vapour with a high temporal frequency (15 min – 1 h), which is not the case with the radiosounding network. In the framework of the EOP 3 stations have been implemented along a north-south axis (Djougou, Niamey, Gao) to document the seasonal excursion of the WAM as well as shorter fluctuations associated to monsoon surges, heat low dynamics and Inter-Tropical Front (ITF) meridional migrations, and to monitor meridional gradients of integrated moisture associated with the different steps of the WAM and especially the abrupt shift of the monsoon onset. For the SOP, the monitoring of the water vapour along a second meridional transect (Tamale, Ouagadougou, Tombouctou) west of the EOP transect will allow to monitor the non-zonal part of the monsoon flow at a much higher temporal resolution. These stations will provide an additional north-south transect to the west of the EOP GPS transect. The provision of two north-south arrays for the SOP will reduce the dependence of analyses on the longitude of Niamey, which experience particular climatology due to the upwind topography.

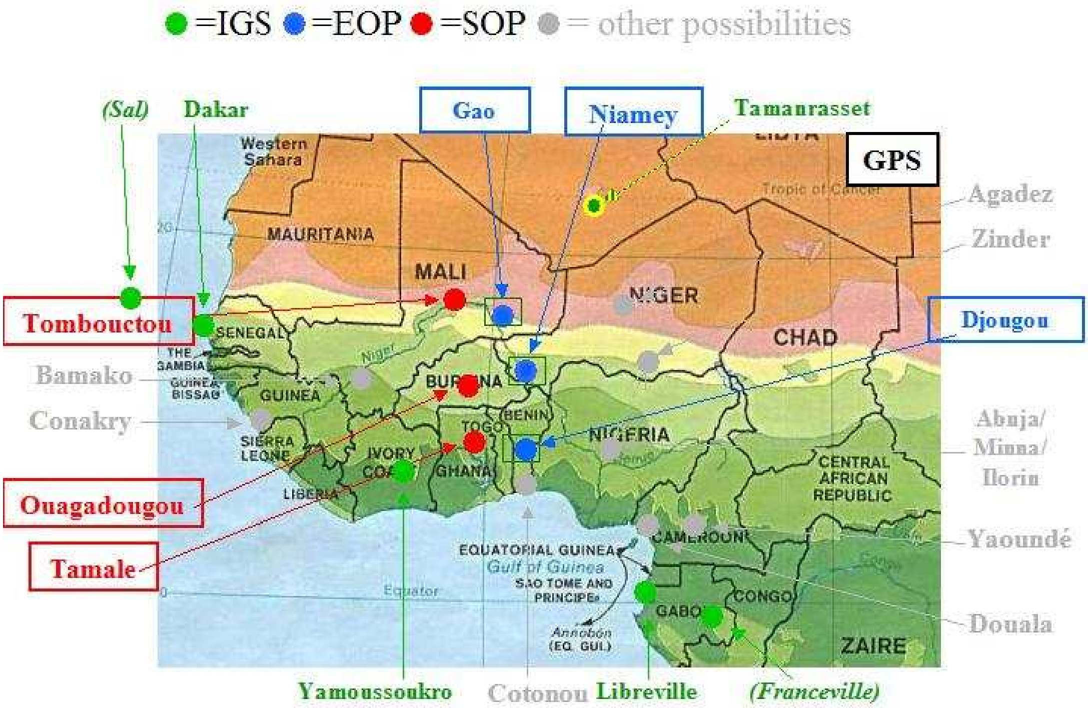


Fig. 2.2.3: Locations of GPS stations for EOP and SOP.

2.2.1.4 Activation of isolated stations/supersites in remote locations or locations not included in the transects

2.2.1.4.a Tamanrasset supersite

In the framework of the SOP, the Transportable Remote Sensing Station (TReSS) will be operated from 15 January to 15 September 2006 in Tamanrasset, under the auspicies of the ONM. TReSS is an autonomous and high-performance system designed to observe radiative and structural properties of clouds and aerosol layers, as well as atmospheric boudary layer dynamics. **The overarching objective is to improve the knowledge of heat low dynamics variability (and its impact on the monsoon) through detailed seasonal characterisation of above variables**, and in combination with airborne and space-borne measurements. The standard payload is made of the following instruments: 1) a multi-wavelength elastic and Raman channels backscatter Mini-Lidar operating at 532, 1064 and 607 nm (with diverse polarization capability at 532 nm), 2) a sun-photometer, 3) an IR radiometer and 4) a full sky visible channel web-type camera. For the AMMA SOP period, the platform capability will be enhanced with an Optical Depth Sensor (ODS for daytime and nighttime measurements), a CLIMAT radiometer and a sonic anemometer. During SOP 0, near-surface extinction and size distribution measurements will also be performed. The above instrumentation will also be enhanced by the measurements conducted routinely by the OMN.

2.2.1.4.b Dano supersite

The site of Dano (Burkina Faso) is located west of the Benin and Niger mesoscale sites and will be operated during 2 SOPs: from 1 to 15 June 2006 for SOP 1a and from 23 July to 20 August 2006 for SOP 2a2. The measurements in Dano will contribute to enable the tracking of the MCSs, and the survey of their modification and evolution on their path from Eastern Africa to the Atlantic Ocean. High frequency balloon sounding (3 hourly) will be performed, which will deliver information about the longitudinal variation of the dynamical and thermodynamic properties of the monsoon layer. Energy balance measurements are also to be performed for different land use classes (cultivated area and natural vegetation). Measurements at different latitudes and with different land use are necessary to cover the whole variety of energy transformation which exists in the AMMA domain. Finally, soil moisture measurements are to be performed in different depths and on a grid size of about 1 km^2 to investigate the spatial distribution of soil moisture. The data provide information about the spatial heterogeneity of soil moisture. Such data are important input data for mesoscale models. This combined set of soil moisture, energy balance and tropospheric data can be used to calculate of the heat and moisture budget of the monsoon wind layer, the influence of surface conditions on convection and for the validation of model simulations.

2.2.1.4.c Boundary layer pressurised balloons in Cotonou

The boundary layer pressurised balloons (BLPB) will be launched from **Cotonou** (Benin) in the monsoon layer (~850 hPa) between **mid-June and mid-July 2006**. The balloons fly at constant density, and are expected to follow the monsoon winds towards the north-east. The BLPB will be deployed during SOPs 1 and 2 (monsoon onset) and will allow to address several scientific issues :

- lagrangian trajectory and humidification of the monsoon (diurnal cycle),
- modulation of the monsoon by the african easterly waves (maximum of perturbation at 700 hPa),
- estimation of the monsoon penetration over the continent and determination of the monsoon onset,
- quantification of the performances of NWP on the meteorological fields (wind speed and direction, pressure, temperature and moisture) in the AMMA region,
- validation of research models for the understanding of the dynamical processes associated with the monsoon onset.

2.2.4.1.d Driftsondes in Diffa or Zinder (Niger)

Regular dropsonde launches from high-altitude ballons using the driftsonde technology will enhance in a significant manner the spatial radiosounding coverage of West Africa. This specific deployment would mostly allow to describe features of the monsoon climate system not fully covered by the enhanced radiosounding operations to be documented : the heat-low region, the west coast of Africa, continental and oceanic easterly waves. This tool fills the gap between radiosoundings at synoptic scale (except around AMMA supersites) and dropsondes launched from aircraft at mesoscale. Driftsondes will most likely be launched from **Diffa or Zinder (Niger)** between **mid-August to mid-September (and maybe extended to end of September in support of TT9 activities)**. This deployment will allow to address several scientific issues :

- Ø complement the radiosounding network in regions void of measurements
- Ø impact of the assimilation of the dropsonde data
- Ø quantification of the performances of NWP (NCEP, ECMWF, …) on the meteorological fields (wind speed and direction, pressure, temperature and moisture) in the AMMA region.
- Ø validation of research models for the understanding of the dynamical processes associated with convection and cyclogenesis.

2.2.1.5 Oceanic measurements

The EGEE-3 cruise with the R/V *L'Atalante* is funded for the period 25 May – 7 July 2006. This cruise will deploy a meteorological instrumented mast and radiosondes, to complement the 'monsoon transect' of soundings on land (Cotonou, Parakou, Niamey and 'Northern stations'). During SOP1a and 2a1, these radiosoundings will allow to document the monsoon flow, its evolution until the monsoon onset and the ocean-land gradient of static energy. Two north-south transects extending this radiosonde array are planned, to the south of Cotonou that will coincide with aircraft deployment during SOP 1a and SOP 2a1. The first transect is scheduled around 15 June 2006, i.e. at the end of SOP 1a, after the western cruise is completed 26 May - 15 June). The second cruise is scheduled around 7 July, i.e. during Sop 2a1, after the eastern cruise is completed (18 June - 7 July). These transects are to be ccordinated with aircrfat operations during I1.3 IOPs (see Section 2.4 for details). During these cruises, 15 drifting MARISONDE buoys equipped to measure near surface winds and atmospheric pressure as well as oceanic temperatures at different depths. The objective is to document surface and subsurface variables in the Gulf of Guinea along the trajectories of the buoys to observe mixed layer depths and their evolutions. Depending on availability, X-probes could also be released to document the hydrological structure in the upper layers of the Equatorial Atlantic and more especially in the Gulf of Guinea, and to survey the oceanic mixed layer and sea surface temperature.

The NOAA R/V *Ronald H. Brown* will conduct underway atmospheric surveys between the eastern US seaboard and the African coast during SOP1. Interferometric, meteorological, radiative, and flux measurements will be collected in the SAL outflow region and along a 23°W line in an area of maximum tropical

Atlantic variability. TAO-like moorings will be deployed and refurbished along this line, which is part of the larger PIRATA array. Sea surface skin and bulk temperature measurements will also be collected over the length of the cruise for satellite validation and algorithm development.

A German cruise with the R/V *Meteor* is scheduled for 6 June – 8 July 2006 – much of this cruise will operate along 23°W although operations along 10 W are also planned. The cruise will involve meteorological measurements, including fluxes and radiosoundings.

Funding is currently being sought to reactivate the meteorological station at the island of São Tomé (6° E, 0 °N).

2.2.2 Networking

Networking is key to the SOP observing startegy as in many instances, similar instruments are deployed on several of the AMMA supersites. Furthermore, in some instance, the SOP instruments will enhance existing networks. For instruments operating in a 'responsive' mode, acquisition protocols and data processing will carefully be coordinated.

2.2.2.1 Balloon sounding network

2.2.2.1.a Radiosondes

The SOP sounding programme will be enhanced by the provision of soundings by the ARM Mobile Facility (AMF), who will launch 4 soundings per day from Niamey. At the Dano site **(1-15 June 2006 and 23 July – 20 August 2006)**, there will be an additional radiosonde station operated by FZK for the SOP. There will be ship-launched soundings from the R/V Atalante during the EGEE-3 cruise in the Gulf of Guinea **(25 May – 7 July 2006)**.

It is planned that the deployment of SOP soundings will be conducted in three modes:

1. Enhanced monitoring at key stations, with 4 soundings per day on the southern quadrilateral and the northern stations of Agadez and Tamanrasset.
2. Two periods of intensive soundings on the southern quadrilateral and at Agadez, at a frequency of 8 soundings per day (or more if possible). Each period would deploy 20 additional soundings per day on this array. One such period will be timed for the onset time of the monsoon (20 – 29 June 2006) and one period for the peak monsoon, to coincide also with the period of maximum aircraft observational activity (1-15 August 2006). These periods are to be described as Intensive Observing Periods (see I5 below).
3. A reserve of sondes exists to support IOPs with high frequency soundings at key stations, in a short-term responsive mode. These sondes will be coordinated with the responsive sondes at the Dano site.

Bearing in mind the known facilities and personnel at each site, likely sounding capacities were determined/proposed for the following stations by TT1: Agadez (4, or 8 with assistance), Abuja (8), Cotonou (8), Niamey (8), Ouaga (4), Parakou (8), Tamale (8), Tombouctou (4), Tahoua (2) and Kano (2).

2.2.2.1.b Dropsondes from aircraft

The F/F20 and D/F20 as well as the UK/BAe146 are equipped with AVAPS dropsonde systems. It is schedule that approximately 350 and 135 dropsondes be released by the F/F20 and the UK/BAe146 during SOPs 1 and 2. Concerning the F/F20, the approximate partition between the SOPs is : 200 for SOP 1a and SOP 2a1, 130 for SOP 2a2 and 20 for SOP 2a3. It is also proposed to release dropsondes during the ferry from Europe in and out of Niamey to enhance observations in the Sahara region (see detailed in Section 2.6). It is not anticipated that the D/F20 will dropsondes during the SOPs 1 and 2.

2.2.2.1.c Boundary layer pressurised balloons

The BLPB will be launched from Cotonou (Benin) in the monsoon layer (~850 hPa) between mid-June and mid-July 2006. The balloons fly at constant density, and are expected to follow the monsoon winds towards the north-east. The number of balloons is about 20. Since one can not expect more than 2-3 balloons to prepared every other day, the sampling strategy will consist in releasing a balloon every other day, with enhanced activity during IOPs (i.e. the launching of a maximum of 2-3 balloons).

2.2.2.1.d Driftsondes

Driftsondes will most likely be launched from **Diffa or Zinder** between **mid-August and mid-September**. Eight gondolas, possibly ten will be available, each gondola carrying 40 dropsondes (possibly 50). The gondolas will be launched upstream (to the east) of the main AMMA study areas, and will drift towards the west in the lower stratosphere (100 or 50 hPa). The gondolas will release the dropsondes, either at regular times or on demand. The current plan is to have dropsonde releases at synoptic hours (0000 and 1200 UTC), in addition to droping on demand based on targeting needs for hurricanes, developing tropical cyclones and AMMA convective systems. The lifetime of the gondolas being on the order of 15 days, typical operations will imply that approximately 30 dropsondes will be released for twice daily soundings and approximately 20 will be available for ‘responsive’ launches.

2.2.2.1.e SCOUT balloons

The SCOUT-03 sondes and balloon activities are planned in Niamey between **July 26 and August 29, 2006**. The SCOUT-O3 balloons are part of the tropical activity of the SCOUT-O3 EU funded programme. The objective of the SCOUT-O3 balloon campaign during AMMA is to further study the convective vertical transport, water vapour, cirrus clouds and chemistry in the Tropical Tropopause Layer (TTL) between 14 and 20 km and their possible impact on the lower stratosphere above MCS. Of particular importance are measurements above cumulo-nimbus cloud turrets during their development phase in late afternoon and early evening. They could contribute significantly to the AMMA objectives, particularly those of the SOP 2_a2 aircraft (including M55 Geophysica), by carrying daytime and also nighttime observations close and above MCS in the TTL during their maximum phase of development, difficult to perform otherwise. Balloon trajectory simulations will be performed for the final flights decision, e.g. before or after the pass of the MCS, and coordination with aircraft.

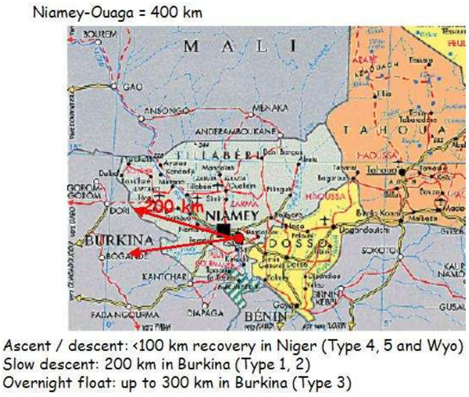
The experiment involves:

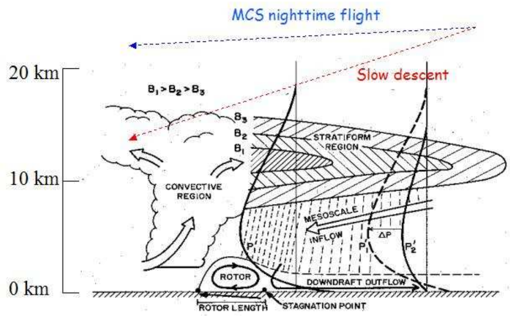
- 15 sondes on Raven 1500 m^3 ballons carrying up to 8-10 kg,
- 20 ECC ozonesondes,
- 10-11 small balloons carrying several payloads of 10- 50 kg up to 23-25 km and then descending slowly through the TTL,
- one 4000 m3 Raven balloon (ascending to 33 km and then descending slowly).

The sondes include Vaisala RS92 soundings which could be used as “responsive” sondes to study the diurnal variation of temperature and humidity in the TTL as a complement to the 4 sondes / per day planned in TT1; Flash-B Lyman-α hygrometers for sensitive measurements in the UTLS; backscatter sondes for detecting cirrus and ice particles; and ozonesondes. The sondes will be operated by Danish Meteorological Institute with the Russian Central Aerological Observatory and CNRS-SA.

The measurements onboard small balloons include tracers of various life time by GC (micro-DIRAC of UCAM), air samplings (mini sampler of the University of Frankfurt) further analysed in the laboratory for tracers, water vapour isotopes and a number of organic species, water vapour and methane by tuneable diode laser (micro-SDLA of the university of Reims), clouds, aerosol and ice particles by in situ backscatter laser diode (LABS of CNR-ISAC) and optical counter (OPC of UMIST and the University of Wyoming) as well as remote by micro-lidar (MULID of ENEA), NO2 and BrO by solar occultation UV-Vis spectrometry (SAOZ of CNRS-SA), IR and UV-Vis radiometry (NILUCUBE of NILU, IR radiometer of CNRS-SA), and finally an electric field probe (AIRS of CNRS-CETP). Several instruments combinations are being defined depending on the objective to be addressed. They could be prepared in parallel on the field for an optimum flight according to the meteorological conditions. The current combinations include i) in situ water vapour, saturation ratio, fast uplift above storms; ii) in situ ice and aerosol redistribution and uplift of chemical species in the upper TTL and LS above and next to storms; iii) remote anvils, thin cirrus water vapour and electric field above convective storms; iv) remote / in situ chemistry: BrO/NO2/O3, short lived organic bromine, photolysis rates; v) in situ average transport in convective area.

The payload of the 4000 m^3 Raven balloon operated by Univ. Wyoming consists of 2 OPC (Optical Particle Counter) instruments and an ozonesonde (total weight of about 45 kg). The primary scientific goal is to obtain an in situ measurement of the size distribution of stratospheric aerosol, with some special interest in the UTLS if there was other evidence of larger particle/cirrus.





According to the wind climatology available in Niamey area where SCOUT-O3 balloon launches are planned in the summer convective period, the balloons will drift westward from Niamey. The maximum measurement range, defined by the telemetry system, is of about 300 km.

Details on the flights can be found in Appendix H.

2.2.2.2 Surface flux network

Measurements from the EOP surface flux network (described in TT2a) will be enhanced during the SOP with stations at **Dano (1-15 June 2006 and 23 July – 20 August 2006), Tamanrasset (15 January – 15 September 2006),** and **ship-borne** instrumentation for intermittent periods in the SOP **(25 May – 7 July 2006)**. There is strong motivation to attempt to deploy some limited surface flux sensors in the heat low zone, perhaps at the synoptic station at Tessalit (see section 2.6.2 below).

2.2.2.3 Lidar network

The EOP lidar network, which involves an east-west array of nighttime operating lidars (2 profiles per night during the entire EOP period) in M'Bour, Cinzana and Banizoumbou (coordinated by TT2b) will be enhanced by:

- A east-west array of lidar systems able to operate during the day- and nighttime with a temporal resolution of the order of 5 minutes in a 'responsive' mode: The LOA CIMEL min-lidar in M'Bour and the ARM Mobile Facility micropulse lidar in Niamey,
- a north-south transect of day- and nighttime operating systems a temporal resolution of the order of 5 minutes in a 'responsive' mode: the IPSL Mini-Lidar from the TReSS platform in **Tamanrasset**, as well as the IPSL CIMEL lidar and the Univ. Of Bonn lidar ceilometer CT25K in **Nangatchori** in the Donga basin (near Djougou).

The IPSL CIMEL lidars will run unattended (10 min. acquisition sequences every 30 min.). It will be under the scientific responsability of the aerosol station PIs of Djougou. In M'Bour, the aerosol station and the LOA CIMEL lidar will also run unattended (the LOA CIMEL lidar acquisition sequences being the same as the one in Djougou). It will be under the responsibility of an IRD technical staff already in charge the sunphotometer and other EOP-related instruments.

2.2.2.4 GPS network

See details in Section 2.2.1.3.b above.

2.2.2.5 Sodar network and tethered balloons

An array of 4 sodar stations (3 from Univ. of Leeds, 1 from FZK) is planned for deployment in SOP1 and SOP2 (1 June – 21 August 2006). The sodars measure winds continuously up to a level of about 500 m, at time resolution of around 10 to 30 minutes and vertical resolution of 10 m or greater (‘Monitoring’ mode). In association with the sodar array, a tethered balloon system (Univ. of Leeds) will be deployed during SOP2-a2 (17 July – 21 August 2006), from which wind profiles, thermodynamic profiles and turbulent fluxes profiles can be made over periods of many hours (in ‘responsive’ mode). The balloon can in principle be flown to an altitude of 2 km, in practice this may be restricted by Air Traffic Control. It is possible that another tethered balloon system will be deployed in the Gourma region by the CESBIO team.

The deployment of the sodars is planned as a “Y” pattern, ‘tuned’ to the typical scales of soil moisture variability resulting from MCS events (see Figure 2.2.4). The Univ. Leeds tethered balloon will be collocated with the sodar at Banizoumbou (Koma Koukou site), at the centre of the “Y”.

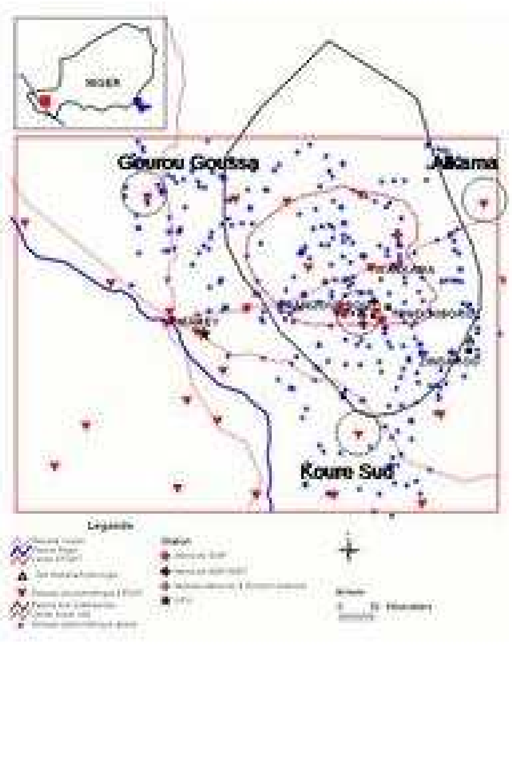


Figure 2.2.4: The proposed arrangement of the sodar network – the 4 sites are indicated by open circles at Gourou Goussa, Alkama, Banizoumbou and Koure Sud.

The AMMA-Niger group is interested in improving the understanding of the processes leading to MCS breakup in the region of Dosso and Dogondoutchi, east of Niamey. This interest is compatible with the planned sodar network of Fig. 2.2.4.

Deployment will take place in the following modes:

1. ***Land-atmosphere IOPs (I1.1 – I1.7 all possible).*** The balloon will be deployed on days when the BAe146 or ATR42 are making boundary-layer flights over the mesoscale region in which the balloon is deployed.
2. ***Nocturnal transition observations.*** These measurements would be considered on days when no aircraft operations were planned over the balloon region. The balloon will be deployed from 1500 to 1100 (20 hours) to observe the development and erosion of nocturnal circulations. In order for these measurements to be made, good recent estimates of the regional scale (10-100km) soil moisture distributions would need to be available (see I1.4 description).

The system will not be deployed during cumulonimbus events, due to risk of lightning damage

2.2.2.5 Radar network

Radar operations are planned for the central locations of the northern and southern radiosonde quadrilaterals (Niamey and Djougou respectively). The detailed documentation of MCS-related dynamics, microphysics and precipitation processes provided by the MIT Doppler C-band radar and the IPSL RONSARD Doppler C-band in Niamey and Djougou during the SOP will nicely be complemented by measurements made with the Burkinabe radar based in Ouagadougou, as well as by the Senegalese radars (Dakar and Linguere) further downstream.

On the Donga basin site, the sampling achieved by RONSARD will be carefully coordinated with that of X-Port and the DLR bistatic radar receivers. A strength of the dual-Doppler and bistatic networks is that they can provide a temporally continuous record of MCS structure throughout the experimental period. A broad description of convection, associated precipitation, and associated mesoscale 3D dynamics and microphysics will be achieved in a large area 400 km in diameter (or 200 km depending on the mode of operation) by the Ronsard radar data only, using single—Doppler retrieval methods. Then, more detailed dynamics, precipitation patterns, and microphysical and dynamics processes will be attainable at convective-scale in a relatively smaller domain (around 40 x 40 km^2) using the X-Port and bistatic radar receiver data.

2.2.2.5.a RONSARD radar

The Ronsard will operate from 15 June to 15 September from Kopargo, 20 km north of Djougou, Benin. The Ronsard radar is operating at C-band, Doppler, and has dual polarization capabilities. Scanning speed is 30 seconds per PPI. Its maximum range is either 200 or 100 km, with range gates of 100 or 200 m. The sampling achieved by Ronsard will also be carefully coordinated with that of X-Port in order to access the 3D wind field.

The radar will be used to target MCS events, non-organised rainfall (congestus and other types of cumulonimbus) and also has clear-air capabilities, which could eventually be very useful for the characterization of low-level clear-air dynamics ahead of MCSs, where low-level chemical flights will occur in SOP2a2.

Whenever an MCS is approaching (as seen from MSG images) the radar at 200 km range, a surveillance PPI mode will be activated (3 to 4 successive elevations at relatively low elevation angles from 0.5° to 8°, with the 200 km range). These surveillance PPIs will allow provision of structural information about the approaching convective system (maximum height of leading convective part, convection intensity, horizontal extent, apparent propagation speed). This information will be sent to the AOC and to the pilots of the aircraft in real-time during SOP 1a, SOP 2a2 and SOP 2a3 to refine the I2, I3 and I4 flight plans (see below, section 2.4). When the leading edge of convection arrives at 80-100 km range from the radar, the volumetric scanning mode will be activated, with a 100 km maximum range and the 100 m range gates (best resolution).

The volumetric scanning mode details are still under discussion but it should include:

- two interleaved sets of 12 elevations (including a vertical pointing, and the same value of the lowest elevation in the two interleaved sets, for rainfall estimation at sufficient temporal resolution), and
- 2 RHIs (elevation scanning at fixed azimuth) for the microphysical classification of hydrometeors.

The total duration of this would be around 12 minutes (for 3D wind retrieval), with a repetition of the lowest elevation every 6 minutes, which is compatible with the temporal scales required for rainfall estimation, and a new classification of hydrometeors every 6 minutes. This radar sequence will start with the antenna at 0° elevation, then will make the first RHI at a given azimuthal direction. Then the first set of interleaved elevations will be performed, down to the lowest elevation (0.5°, probably). A second RHI will then be performed with an azimuth shifted with respect to the first one in order to describe the variability of the microphysical classification perpendicular to the propagation direction of the MCS. Then the radar sequence will end with the second set of 12 elevations, with a vertical pointing to start and the same lowest elevation as in the first set of interleaved elevations.

In addition to providing information valuable to *nowcasting of convective storms*, for balloon launches and other ground-based activities and for coordinated MCS flights in the vicinity of Djougou, RONSARD will provide two products: rainfall estmaites and 2D/3D winds.

A- Rainfall estimation

Rainfall estimation is used in soil moisture evaluation and moisture budget computations (supported by fluxes, satellite and radiosonde networks). These issues are simply fundamental to AMMA – related toWG2 (water cycle) and WG4 (land-atmosphere), with important input to WG1 (WAM and climate) and WG5 (impacts).

The rainfall estimated using the radar will be used to refine the spaceborne retrievals of instantaneous rainfall using microwave radiometry over land (there are methods presently developed for this, see WP4.3), and the more statistical rainfall retrievals using geostationary satellites (MSG, see also WP4.3).

The radar rainfall data are particularly necessary for the evaluation of scale interactions (EU WP1.4) – matching the cloud-scale rainfall structures with the regional-scale distributions. In the northern Sahel, around and north of Niamey, where vegetation is sparse, the surface state is particularly sensitive to rainfall, so the distributions which are resolved in the rainfall and resulting soil moisture fields impact very strongly on the distributions of surface fluxes on scales from a few km up to the range of the radar. In particular, these scale interactions are critical to:

- local microclimates and social impacts (mosquito environments; agriculture) (WG5; WP3.x, WP5.x)
- monsoon and cloud dynamics (WG2; WP1.3, WP2.1)
- water cycle (WG2; WP1.2)
- If the radar has dual-polarization capabilities, it can be used in the study of the interaction between microphysical and dynamical processes (WG2; WP2.1).
- distributions of surface fluxes, and associated model evaluation (WG3; WP2.2, WP4.1)
- distributions of chemical emissions (WP1.1, WP2.4): in the northern Sahel where soil emissions are particularly important, patterns of rainfall influence the spatial distributions of chemical and aerosol fluxes from the surface. The radar will be used to analyse these patterns, in association with aircraft missions in the boundary layer.

In terms of the third major goal of AMMA, prediction of the amounts and spatial distributions of rainfall is the primary need of decision-making for West Africa. Radar is an important part of improving our scientific understanding of the rainfall processes.

B- *Wind data* for mesoscale analysis of MCS events.

These data are important in the understanding of the dynamics of MCSs and their interactions both with the larger-scale monsoon (as in 1(b) above) and the land surface. For instance, from HAPEX-Sahel results it is thought that soil moisture patterns may persist through an intensification of convective cells over patches of wet soil (Taylor and Lebel 1998), and the radar will be used to evaluate the mechanisms of this effect.

Analysis of the wind fields in MCS systems will also be needed for the analysis of lightning occurrence, with its consequences for NOx production.

2.2.2.5.b MIT C-band radar

The MIT C-band radar will start to deploy at the Niamey airport on May 15, 2006, and the radar will be operational from June 1 to August 15 2006. The useful range of the MIT C-band radar is given at 150 km with a range for reliable rainfall estimates at 100 km. These numbers are compatible with a deployment at the Niamey airport for a quantitative monitoring over the Kori de Dantiandou catchment. MIT's transportable C-band Doppler radar has been deployed in a wide variety of meteorological environments around the world. The current operating characteristics of this radar are included below:

Operating frequency	5590 MHz
Antenna diameter	8 ft
Antenna 3dB beamwidth	1.2 deg
Peak transmitter power	500 kW
Total power consumption	~10 kW

The observing strategy is based on full volume radar scans at 10 minute intervals, with occasional RHI scans. The measured parameters include: radar reflectivity, cloud top height, mean, Doppler velocity derived parameter: rainfall rate, Doppler spectral width.

The deployment of the MIT C-band radar in the Niamey region will enhance AMMA related science in three major topics:

A- *Application to hydrology and land-surface interactions*

The value of radar measurements of rainfall over catchments is widely recognized. In the presence of scattered convective scale rainfall of the kind anticipated in the premonsoon season around Niamey, the radar will provide superior resolution to the gage network in defining the areal distribution of rainfall. Soil moisture is a quantity of key interest in AMMA and the radar will document the rainfall with a sub-kilometer resolution matched to this interest. The proposed 24/7 radar operation for a 75-day period during SOPs 1 and 2 will also allow for the exploration of antecedent conditions in catchment response to a rainfall event, key for analysis of land-surface-atmosphere interactions. Accurate radar calibration is essential for this application, and MIT has experience with this aspect. The radar measurements will be combined with numerous aircraft missions over the Niamey region, as well as intensive satellite analyses and vertical profiling from the ARM Mobile Facility.

The availability of NASA TRMM satellite observations in the time frame of this field program will enable the validation of rainfall measurements from space in one of the most continental tropical regions.

B- *Three-dimensional characterization of convection*

Previous field programs in the tropics at other longitudes (Maritime Continent and the Amazon basin) have clearly demonstrated the distinctions in the vertical development of the convection in different meteorological regimes, including the regimes targeted in the various SOPs in AMMA). The three dimensional characterization of precipitation with radar volume scanning is well suited to expose this vertical development and the sensitive role of the updraft in modulating ice microphysics and the convective ice factory. This key information is lacking in both surface observations and in satellite observations of opaque clouds, and is uniquely provided by radar. The strength of the updraft is dependent on subtleties of the thermodynamics of surface air, which will be well documented in AMMA. The information on the vertical structure of precipitation is valuable in interpreting the lower level radar reflectivity for quantitative rainfall. The proposed radar location is well suited for comparisons of the 3D precipitation and wind field with the planned AMMA meridional transects by aircraft at this longitude.

C- *Mesoscale convective systems in the context of the AEWs*

It is widely recognized that mesoscale convective systems are key components of the AEWs at the synoptic scale. Yet previous studies of the AEWs are primarily based on satellite imagery that does not resolve the MCSs in any quantitative detail. In contrast, radar is well suited to investigating the three dimensional structure of deep, vigorous convection and the accompanying stratiform precipitation with extensive radar bright band that characterizes MCSs. The availability of multiple radars in Africa during AMMA, at different locations along the AEW ‘pipeline’, will provide for a new avenue to explore the mesoscale component of AEWs. The use of Doppler capability at full radar range may even provide some capability to monitor the circulations in the large vortices that make up the AEW, some of which evolve into tropical cyclones and ultimately hurricanes in the western Atlantic Ocean.

Note that the planned deployment ends on 15 August which is during the 5-aircraft period of SOP2-a2. It would be scientifically desirable to extend the deployment to 15 September 2006; the end of SOP2-a3.

2.2.2.5.c DLR bistatic radar receivers

A bistatic Doppler radar network consists of a transmitting Doppler radar and at least one remote Doppler receiver. Since a Doppler radar can only measure the radial component of the 3-dimensional wind vector, measurements of the Doppler velocity from different locations are necessary to retrieve the 3-dimensional wind vector. A bistatic Doppler radar network is a less expensive solution compared to operating two Doppler radars. The remote receiver consist of a fixed passive radar antenna (2m x 30 cm), a GPS receiver for time and frequency synchronization. The remote Doppler radar receiver is based on a standard PC with additional cards. Electrical power is required, a possible operation with solar panels is under investigation. A communication link to RONSARD is mandatory. Measurements from RONSARD, bistatic radar receivers, and the X-Port radar at Djougou will be used to retrieve the full 3 dimensional flow field in the Djougou area.

2.2.2.6 Ligntning detection network LINET

LINET[1] (Lightning Detection Network) is a particularly sensitive network working at VLF/LF range with 3D capability. Thus intra-cloud (IC) as well as cloud-to-ground flashes can be detected. The efficiency of the system allows for unprecedented low-amplitude detection power. Since abundant IC events are located an effective discrimination against CG is performed. Preferentially, the TOA (time of arrival) method is used for locating the horizontal and vertical position of lightning strikes. The system can measure the time, the horizontal and vertical location of VLF-sources as well as the amplitude and the polarity of these events.

Each station of the LINET (6 station DLR network) consists of:

- a crossed loop antenna for measuring the magnetic field,
- a GPS antenna for measuring the precise time reference and
- a PC for data aquisition.

The deployment of LINET is planned in co-ordination with the radar network in Benin consisting of the French Ronsard polarimetric Doppler radar, the X-Port and the DLR bistatic receiver. Thus it is possible to observe thunderstorm properties as complete as possible on the same scale. The deployment and operation is planned to be performed in cooperation with African partners from UAC - University Abomey Calavi (Prof. Etienne Houngninou) and the Benin DMN (Francic Dide). The University of Munich (Prof. Betz) has build the system and cooperates with data analysis and scientific evaluation.

[1] http://www.pa.op.dlr.de/linet/Overview/overview.html

Figure 2.2.5: Left: Envisaged sensor locations fro the DLR lightning detection network LINET around Djougou, Benin during the AMMA SOP. Right: The LINET antenna consiting of two perpendicularly oriented metal rings measuring the magnetic field emitted from lightning.

2.3 Aircraft deployment strategy

Up to five aircraft will be envolved during SOP 1 and 2: the UK FAAM BAe146[2], the french SAFIRE Falcon 20 and ATR-42[3], the DLR Falson 20[4], and the EEIG M55/Geophysica[5]. Details on the aircraft payloads can be found in Appendix A of this document.

Aircraft	FR F-20	FR ATR-42	UK BAe146	D F-20	Geophysica
Operating altitude	500ft-42000ft	500ft-25000ft	50ft-35000ft	500ft-41000ft	1000ft-68000ft
Payload	1200kg	2500kg	4000kg	1500kg	1500 kg
Range	3200km	3000km	3700km	3500km	3500 kg
Staffing	3 crew, 2 scientists	3 crew, 7 scientists	3 crew, 18 scientists	3 crew, 3 scientists	1 crew
Duration	4 hours	4 hours	5.5 hours	3.5-4.5 hours	4 - 5 hours
Ground speed	170-200 m/s	95 m/s	110 m/s	170-220 m/s	200 m/s

Table 2.3.1: Main characteristics of the three deployed aircraft

The UK/BAe146, the F/ Falcon 20, the D/Falcon 20 and the F/ATR-42 will operate out of Niamey, Niger. For logistical constraints of operating the M55/Geophysica in West Africa the M55 and D/F20 will be based in Ouagadougou during SOP 2a2, Burkina Faso. Most importantly a sufficiently large hangar has been identified which can house the M55 (pending permission from the Burkinabe military). Ouagadougou is also close enough to Niamey (approx. 400 km) to perform joint missions with the AMMA aircraft deployed from Niamey, to make coordinated flights with the SCOUT-AMMA balloons and to make flights near to the super-site at Djougou with its lightning detection network, radar and lidar systems.

The aircraft deployment strategy is based around standard IOP patterns which are detailed in Section 2.4. It also aims to:

- link with ground-based networks,
- assess the coherence of the datasets via thourough instrument and data intercomparison,
- transmit data to GTS in real time.

2.3.1 Instrument and data intercomparison

Intercomparison of data from different sensors must be planned in advance of the SOP periods. A detailed strategy for intercomparisons will be developed early in 2006 and refined at the TT8 planning meeting early in April. Key instruments which must consider a commitment to intercomparison are:

[2] http://www.faam.ac.uk/
[3] http://www.cnrm.meteo.fr/safire/ or http://www.dt.insu.cnrs.fr/avions/avions.php
[4] http://www.dlr.de/fb/en/desktopdefault.aspx/tabid-527/
[5] http://www.geophysica-eeig.cnr.it/index.php

- Aircraft platforms,
- Turbulence and flux stations,
- Surface-based chemical and aerosol instruments,
- Radiosondes and dropsondes (also Vaisala/Modem systems).

2.3.2 Transmission of dropsonde data on the GTS in real or near-real time

In addition to radiosondes, dropsondes can also provide valuable information to be assimilated into numerical weather prediction (NWP) models. It is scheduled that approximately 350 and 135 dropsondes be released by the F/F20 and the UK/BAe146 during SOPs 1 and 2. Transmission of data from dropsondes to the GTS for assimilation into NWP models is considered very important. Particular efforts must be made by TT8 co-chairs to inform NWP centres of this process and to ensure that the dropsonde data is assimilated.

2.3.3 Integration of in-situ measurements from low-level flights with ground-based measurements over the meso-sites

At the Seignosse ‘Process Studies’ meeting in September 2005 we started a debate among the physical and chemical communities within AMMA, regarding the integration of aircraft-derived and ground-based measurements, including atmospheric fluxes. This has been followed with open email discussion among TT8. Arguments from these discussions are summarised in Apendix F.

2.4 IOP strategy

The strategy for deployment of responsive instruments in IOPs is based around some standard 'IOP patterns' (labelled I1.1 to I5) described in this section. Funding sources are listed in Table 2.5.1 (Section 2.5) and scientific stakeholders for these IOP patterns are listed in Table C1 and C2 of Appendix C.

I1.1 Surface-atmosphere-aerosol: Inter-tropical front and heat low surveys (SOP1-a, SOP2-a1 – Flamant)

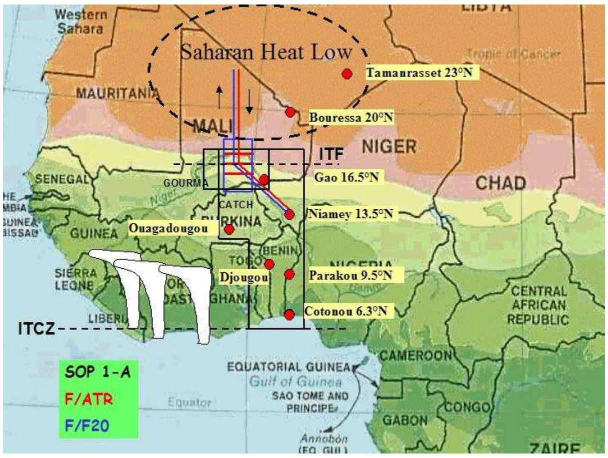
The Saharan heat low (SHL) region is key to understanding the monsoon dynamics and the thermodynamic budget of the thermal low over the Sahara desert is an important element of the climate of the West African region. Despite its central role, the very little is known on the dynamics of SHL as well as the diurnal and seasonal evolution of its main characteristics (position, horizontal extent, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (Saharan aerosol layer -SAL, inter-tropical front -ITF). Furthermore, this region is affected by an important horizontal variability of its main characteristics and features at the regional scale.

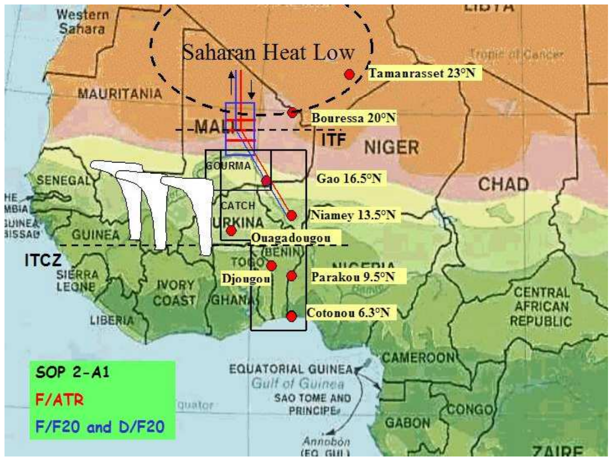
Within AMMA, we propose to characterize the SHL main characteristics (including radiative properties) and features at the daily, seasonal and inter-annual scales. This will be done by two means:

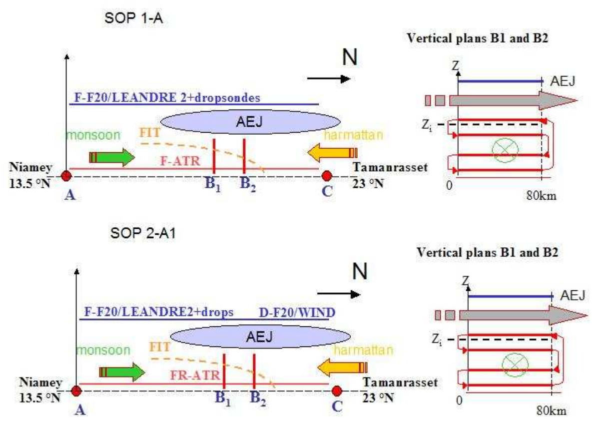
- Carrying coordinated aircraft operations in the IFT region to analyse the dynamical and radiative processes associated with the IFT structure and the Harmattan-Monsoon-African easterly jet (AEJ) interactions during the SOP1-a and SOP2-a1 of AMMA. The role of the surface (soil moisture in particular) will also be investigated. Aircraft measurements will be enhanced by surface measurements made at the Banizoumbou (Niger), Gourma (Mali) and Tamanrasset (Algeria) supersites. Improved knowledge of the above mentioned processes will be obtained by coupling numerical dynamical simulations with airborne and ground-based measurements of atmospheric thermodynamics, surface characteristics and aerosol radiative and optical properties. This strategy is relevant to TT8 and will be described hereafter,
- Characterizing the SAL and IFT structural parameters and radiative properties at the seasonal and interannual time scales in the Sahel and the Sahara using continuous *in situ* (e.g. mass concentration, size distribution) and remote sensing (e.g. lidar and sunphotometer derived aerosol optical depth) measurements at the two Sahelian Dust Transect stations of Banizoumbou (Niger) and IER-Cinzana (Mali) as well as in Niamey (Niger) and Tamanrasset (Algeria). This strategy is described in the TT2b implementation plan.

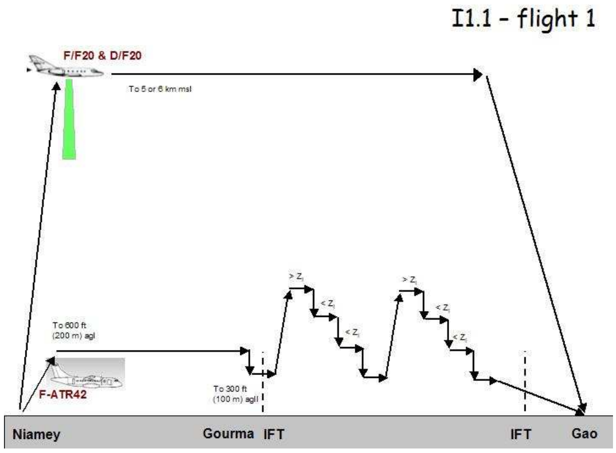
During SOP1a, the exploration of the inter-tropical front (ITF), which is assumed to be north of Niamey at the time of SOP1-a, will be made using 2 aircraft: the F/ATR in the PBL and the F/F20 flying above the PBL (with the nadir looking LEANDRE 2 lidar) at a level around 500 hPa to enable the documentation of the atmospheric reflectivity and moisture fields in the lower troposphere. The F/F20 will also release dropsondes, as it is highly desirable to document temperature and wind (with a 0.5° or 1° resolution). High horizontal resolution is not necessarily an issue for temperature, as opposed to moisture which will be provided by LEANDRE 2. In addition to measuring mean and turbulent variables, the F/ATR will also be equipped with the AVIRAD and HYGRO aerosol packages for measuring aerosol optical and radiative properties in the PBL.

Combining the in situ aerosol meaurements and laser remote sensing measurements will enable to retrieve two-dimensional fields of aerosol extinction at high horizontal and vertical resolution.









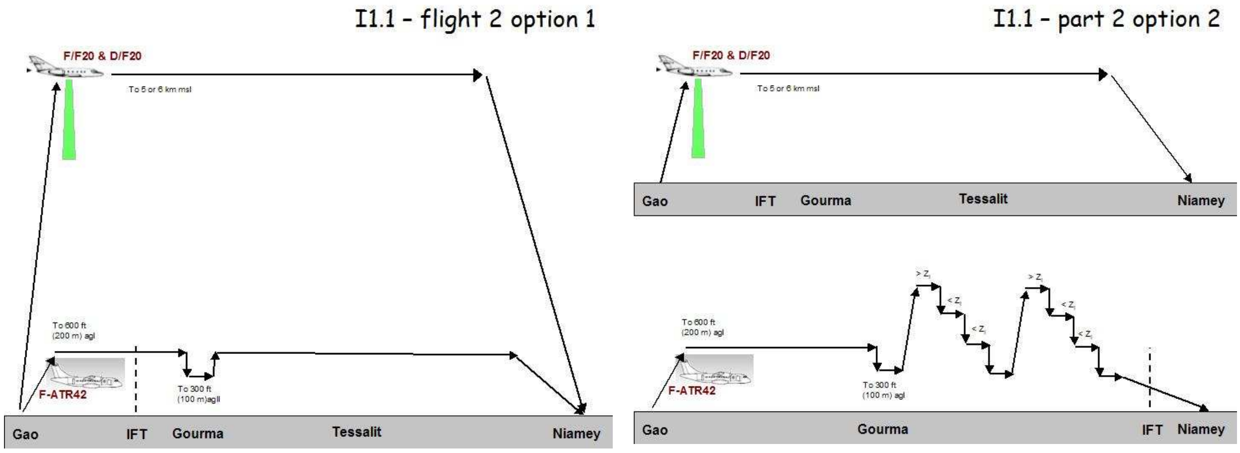


Figure 2.4.1: proposed aircraft operations designed to investigate the structure of the IFT and the SAL during SOP 1-a and SOP 2-a1.

Main highlights for the mission are:

1. take off from Niamey and ascend to 6 km msl and 300 m msl for the F/F20 and F/ATR respectively, heading for the Gourma site,
2. exploration of the ITF over the Gourma site. Upon reaching the ITF, the F/F20 will explore the vertical structure of the atmosphere (3 levels) to the south of the position of the ITF at the surface (as forecasted by ACDMAD and determined in the fields from lidar measurements). Two series of vertically stacked flight levels will be performed, separated by at least 50 km. The vertical exploration will last 2h. In the mean time, the F/F20 will describe a square pattern around the position of the IFT at the surface to try to grasp some spatial and/temporal evolution in the coupled monsoon-harmattan-AEJ system,
3. landing in Gao for refuelling (1h to 2h expected),
4. take-off from Gao, ascend to 6 km msl and 300 m msl for the F/F20 and F/ATR respectively. Depending on the position of the IFT, the F/ATR will either fly north with the F/F20 (Option 1), or sample the IFT again, while the F/F20 heads north (Option 2),
5. exploration of the SHL region by the F/F20, heading for Tessalit. Turn around in Tessalit and fly back towards Gao to sample the atmosphere in the vicinity of the IFT. Option 1: the F/ATR also explores the SHL before returning to Gao. Option 2: the F/ATR heads back to Gao after sampling the IFT,
6. ferry back to Niamey and landing.

All missions are scheduled to start early, around 0700 UTC, to enable a landing in the daytime. The overall length of the mission will be on the order of 8 or 9 hours, depending on the time needed for refuelling in Gao.

During SOP 2a1, the same basic pattern is proposed. D/F20 (equipped with the nadir looking Doppler lidar WIND) flights will be coordinated with the French aircraft flights. The F/F20 will also release dropsondes, as it is highly desirable to document temperature (with a 0.5° or 1° resolution) in addition to the remotely sensed wind and water vapour fields. Nevertheless, the D/F20 may not be able to participate to the

SHL exploration, due to possible overheating problems to be expected during the refuelling stop in Gao as the heat might be difficult to withstand for WIND. In this case, the D/F20 will contribute to the IFT exploration and head back to Niamey.

Link with the modelling strategy:

The proposed flight plans will provide three-dimensional (3D) observations of the IFT structure in the region of the Gourma. The thermodynamical structure of the monsoon flow and overlying harmattan will be constructed from dropsonde and lidar measurements in the lower troposhere (below 6 km msl). These measurements will be compared with the IFT structure obtained from high resolution simulations. Combining the in situ aerosol meaurements and laser remote sensing measurements will enable to retrieve two-dimensional (2D) fields of aerosol extinction at high horizontal and vertical resolution to the north and to the south of the IFT. These fields will also be compared with high resolution numerical simulation, to assess the possible impact of saharan aerosol on the IFT structure and propagation. Sensitivity analyses will also be conducted to assess the impact of soil moisture in the region of the IFT.

Ground-based cooperation:

- Coordination with the radiosonding network: additional soundings to be requested in the northern quadrilateral (Ouagadougou, Tombouctou, Agadez, Niamey Tamanrasset) – at least 4 balloons per day,
- Coordination with ground sites along the flight pattern in the Gourma site, including the tethered balloon in Hombori,
- Coordination with the Tamanrasset Supersite,
- Coordination with the tethered balloon in Niamey.

Forecasting requirements

- Cloud cover: clear-air conditions are needs for optimal use of active and passive remote sensing instruments,
- MCS activity: to be avoid during these missions,
- Position of the IFT: the success of the mission relies strongly on the prediction of IFT position, even though adjustement can be made in real time during the operations. It is particularly important that the position of the IFT is accurately forcasted as optimal conditions sought for these missions are met when the IFT (at the surface) is located just north of Gao (Mali),
- Position of the SHL core: this information is crucial for the SHL survey part of the mission (i.e. after refuelling in Gao) as the aircraft will head directly for that region to experience the strongest gradients in thermodynamical variables and possibly aerosol properties,
- African easterly jet: the position (latitude) and altitude of the core of the African will be important for pining down the flight levels for the F/F20 and D/F20,
- Soil moisture distribution in the Gourma region.

Satellite data

Flights will be planned on the basis of satellite observations of the cloud cover north of Niamey. Satellite observations of the aerosol load and soil moisture to the north of Niamey will also be of great interest for mission planning.

Recommendations for enhancement:

- An airborne soil moisture instrument will enhance significantly the analyses of the land-atmosphere interactions to be achieved in the Gourma region,
- The exploration of the SHL will be significantly enhanced if the D/F20 was to participate to the coordinated F/20 and F/ATR effort.

I1.2: Surface-atmosphere-aerosol: Squall-line related aerosol emissions surveys (SOP1-a – Formenti)

We propose to quantify the "net" mineral dust emissions in the Sahelian part of north western Africa at various time scales: daily, seasonal and inter-annual. This will be done by two means:

- Estimating the mineral dust budget and properties of dust during squall line events in the Monsoon period by coupling numerical dynamical simulations with local measurements of erosion and deposition fluxes, and vertically-resolved dust concentration, size distribution and mineralogy. Measurements at the ground station of Banizoumbou and onboard aircrafts (F/ATR-42 and F/F-20) will be conducted during the SOP1-a period of AMMA. This strategy is relevant to TT8 and will be described hereafter.
- Estimating the mineral dust emissions at the seasonal and interannual time scales in the Sahel using a physical model of dust emission including specific parameterisation for semi-arid areas and continuous measurements of mass concentration, deposition, size distribution and vertical profile at the three Sahelian Dust Transect (SDT) stations of Banizoumbou (Niger), IER-Cinzana (Mali), and M'Bour (Senegal). This strategy is relevant to TT2b and is described in the TT2b implementation plan.

Choice of observation period

Observations during SOP1-a are preferred because local dust emissions in the Sahel occur prevalently at the beginning of the monsoon season. Indeed the growing vegetation rapidly inhibits local dust emissions. Moreover, non-precipitating convective systems can occur at the very beginning of the monsoon season. Such non-precipitating squall lines should be the most efficient vector for the injection of locally emitted dust to altitude favourable to long-range transport. The occurrence of precipitation prevents the type of operations to be conducted during SOP 2.

Based on the surface observations of the occurrence of squall lines conducted by Rajot (2001) at Banizoumbou between 1995 and 1998 (May through July), the observation period can be further narrowed down. Indeed, the most favourable period for such a study is June (see table below), when a squall line event can be expected every 2 to 4 days.

Period	Occurrence of squall line events		
	Mean	Min	Max
01–15 May	1	0	2
16–31 May	3	1	4
01–15 June	4.25	2	7
16–30 June	5.5	5	7
01–15 July	3.75	2	5
15–31 July	2.5	1	4

Finally, logistical constraints of aircraft availability within AMMA led to target the period 1–15 June (SOP1-a) as the dedicated airborne observation period of I1.2. Ground-based measurements will continue until 15 July, thus encompassing the entire SOP1-a – SOP2-a1 field phases.

Description of observational strategy

The I1.2 type missions are designed to estimate, at the relevant time-scale, the quantity of dust mobilized as well as deposited by the squall lines, in order to determine the net quantity of dust that remains in the atmosphere after the passage of a squall line and therefore that can be long-range transported. Simultaneously, the physico-chemical and optical properties of the emitted dust across its size spectrum should be determined so to able to estimate its impact on the solar and terrestrial radiation.

To do so, we propose an experimental approach based on measurements of emission and deposition fluxes, total column content, vertical distribution and properties of mineral dust. Measurements should be made under background conditions and under conditions perturbed by the passage of a squall line. By their difference, it should be possible to establish the net emission budget at the local scale for selected squall line events, to be compared to the numerical simulation of vertically-resolved dust concentration using a transport model (RAMS) coupled to the physical dust emission model of the LISA.

To have access at these measurements over the entire atmospheric column for a maximum number of events, ground-based and aircraft measurements are needed. Ground-based measurements will be performed in Niger at Banizoumbou (13°N, 2°E), close to Niamey. Measurements made at the site are relevant to the scientific objectives of other TTs, namely TT2a, TT2b, TT5 and TT7. Amongst the various measurements, the following are relevant to TT8: (1) dust emission (horizontal and vertical mass fluxes by size classes) and dry/wet deposition; (2) dust vertical profile by a daytime two-wavelength lidar; (3) column aerosol optical depth and microphysical and optical properties by AERONET sun-photometer; (4) dust mineralogical composition and mass distribution by filter/impactor sampling; (5) dust number distribution for particles between 0.3 and 20 µm optical diameter by optical counting; (6) spectral scattering and absorption coefficients by nephelometer and aethalometer. The Banizoumbou station will be operational from 1 June to 15 July 2006, thus encompassing the entire SOP1a period.

The F/ATR-42 will be equipped for in situ sampling and characterisation of physico-chemical and optical properties of coarse dust particles. The F/ F20 will be eqquipped with the water vapor lidar LEANDRE 2 and will provide with aerosol and water vapour distribution up to ~12 km msl. RAMS simulations indeed show that squall lines are able to mobilise then redistribute dust up to the tropopause, which is approximately at 16 km over the Sahel.

Finally, intensive I1.2 type measurements during SOP1a will be associated to long-term measurements of aerosol concentration and composition, wet and dry deposition fluxes, as well as vertically-integrated and vertically-resolved aerosol load performed on the pathway of dust transport, that is, beside Banizoumbou in Niger, at

IER-Cinzana in Mali and at M'Bour in Senegal. This should allow estimating the regional budget at the seasonal time scale. Spatial integration will require the modelling of all events over a complete seasonal cycle. The reader is referred to the TT2b document for a full description and motivation of these stations.

Coupled ground-based and aircraft observations can provide the emission and deposition fluxes and vertical redistribution of dust aerosols related to the passage of a squall line over a disturbed field. Emission fluxes (as a function of particle size) and wet/dry deposition are measured at the ground. The vertical resolved concentrations and properties are obtained by ground-based lidar and in situ and remote sensing aircraft measurements. Combining lidar backscatter measurements on the F/F20 and at the ground with *in situ* measurements made on board the F/ATR-42 will enable aerosol extinction coefficient 2D fields to be derived. From the difference in the vertically-integrated concentration before and after the squall line, we should assess locally the net emissions. From the difference in the vertically-resolved concentrations we may also assess the differences in the horizontally exported fluxes. Comparison between the total mass sampled on flight and the ground-based vertically-integrated and/or resolved measurements (optical depth, backscatter profiles) will provide an estimation of the dust mass exported at altitudes higher than the flight altitude. In addition, the 2D moisture field measured with LEANDRE 2 will also enable to assess how water vapor vertical is redistributed in the vertical by the passage of squall lines.

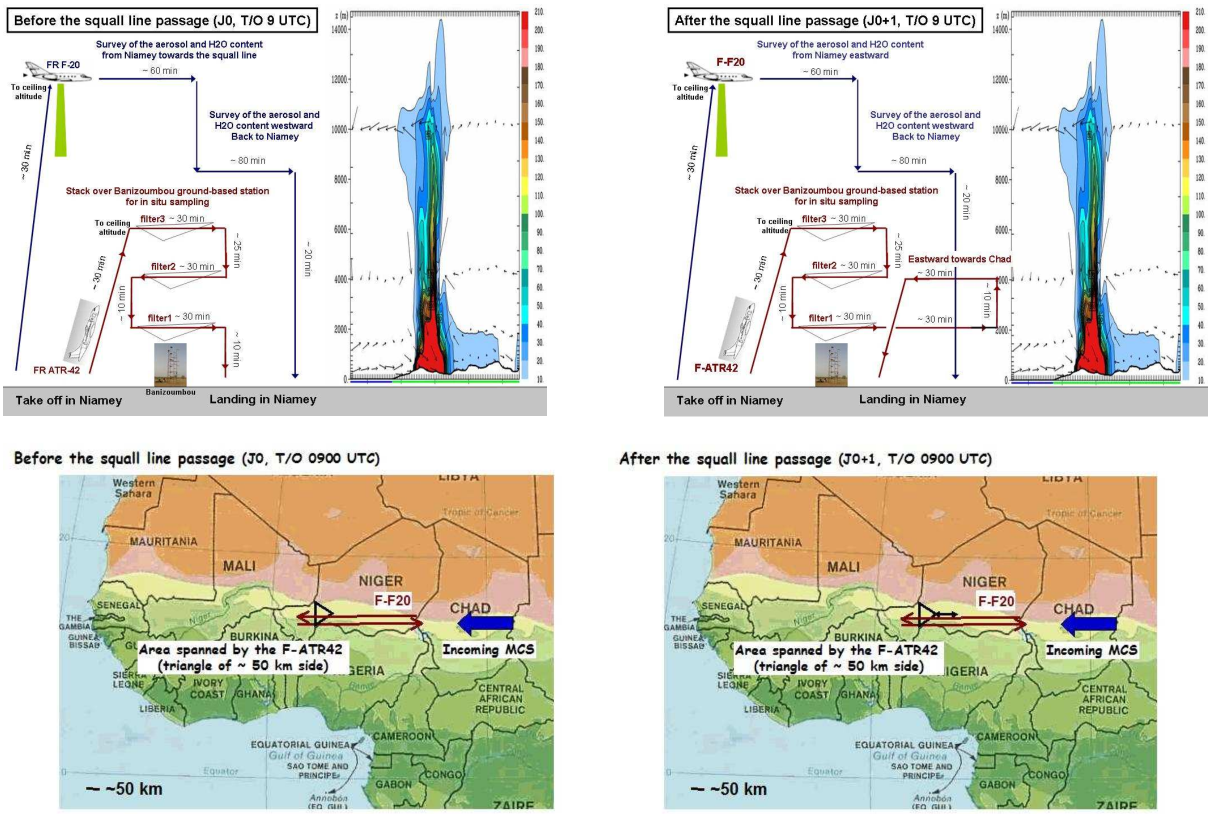


Figure 2.4.2: Proposed coupled sorties for investigating dust emissions by squall lines during SOP1a: left, before the squall line passage; right, after the squall line

passage.

The aircraft missions will be composed of two flights, one before and one after the passage of a squall line. Around 13°N, squall lines generally develop in the late afternoon. The flight before the squall line event should be a morning or early afternoon sortie, while that after the squall line event should be a next morning flight. Take off time at 0900 UTC seems appropriate. A morning warning of the approaching squall line is necessary in order to ensure maximum security. From the instrumental point of view, one hour should be sufficient for two people to prepare the filters and impactors to be exposed during the flight.

On the flight before the squall line (left panel in Fig. 2.4.2), the F/ATR-42 mission articulates in the following elements:

(a) a profile ascent to maximum altitude from Niamey airport towards the ground-based site of Banizoumbou to identify the aerosol layers (~ 30 min);

(b) a series of two–three stack levelled runs (SLR) at altitudes determined prior de flight but adjusted in real time by the mission scientist based on the aerosol vertical distribution observed during the profile ascent, as well as by lidar measurements in Banizoumbou and with the airborne lidar LEANDRE 2 flying ahead of the F/ATR-42. At least 30 minutes at constant altitude should be allowed for collecting sufficient mass on the impactor for subsequent post-field chemical analysis. This length will be determined by the mission scientist during the flight depending on the vertical aerosol distribution (on-line measurements on particle number and scattering) observed during the first vertical profile. SLR will be flown above the ground-based site of Banizoumbou in a closed geometry in order to minimise the covered area, therefore the horizontal variability of the measurements. A triangular path oriented with respect to the wind-blowing direction (to avoid sampling aircraft exhausts) seems adapted as it would also allow minimising dead time due to manoeuvres;

(c) a series of two–three profile descents (number depending on SLR) to allow passing from one sampling level to the other, and land at Niamey; we do estimate those to last 30–40 minutes. Land in Niamey.

The F/ F20 will take off in Niamey at the same time of the F/ATR-42, it will climb at ceiling altitude (12 km msl). It will then transit eastward to document the aerosol layering ahead of the squall line as well as the moisture distribution, the PBL structure and the surface state using the onboard downward looking remote sensing instruments (lidar and radiometers). Upon reaching the squall-line (say 50 km to the west of the squall-line), the aircraft will turn around and head back to Niamey flying at 8 km msl on its way back to the airport. During the flight, the F/ F20 will drop sondes to document the atmospheric structure (particularly temperature and winds).

The next morning flight (right panel in Fig. 2.4.1) articulates in the following elements:

(a) a profile ascent to maximum altitude from Niamey airport towards the ground-based site of Banizoumbou to identify the aerosol layers (~ 30 min);

(b) a series of two–three stack levelled runs (SLR) at altitudes determined prior de flight but adjusted in real time by the mission scientist based on the aerosol vertical distribution observed during the profile ascent, as well as by lidar measurements in Banizoumbou and with the airborne lidar LEANDRE 2 flying ahead of the F/ATR-42. At least 30 minutes at constant altitude should be allowed for collecting sufficient mass on the impactor for subsequent post-field chemical analysis. This length will be determined by the mission scientist during the flight depending on the vertical aerosol distribution (on-line measurements on particle number and scattering) observed during the first vertical profile. SLR will be flown above the ground-based site of Banizoumbou in a closed geometry in order to minimise the covered area, therefore the horizontal variability of the measurements. A triangular path oriented with respect to the wind-blowing direction (to avoid sampling aircraft exhausts) seems adapted as it would also allow minimising dead time due to manoeuvres;

(c) a couple of eastward straight levelled runs at fixed altitude with the SAL and the monsoon layers towards and from lake Chad to measure the regional aerosol load. This should last about 1 hour each;

(d) a series of two–three profile descents to allow passing from one sampling level to the other, and land at Niamey; we do estimate those to last 40 minutes to 1 hour overall.

The F/ F20 will take off in Niamey at the same time of the F/ATR-42, it will climb at ceiling altitude (12 km msl). It will then transit eastward to document the aerosol layering ahead of the squall line as well as the moisture distribution, the PBL structure and the surface state using the onboard downward looking remote sensing instruments (lidar and radiometers). Two hours into the flight, the aircraft will turn around and head back to Niamey flying at 8 km msl on its way back to the airport. During the flight, the F/ F20 will drop sondes to document the atmospheric structure (particularly temperature and winds).

Link with the modelling strategy:

The proposed flight plans will provide 2D observations of the squall-line environment. The thermodynamical structure of the atmosphere will be constructed from dropsonde and lidar measurements in the lower troposhere (below 6 km msl). Combining the in situ aerosol meaurements and laser remote sensing measurements will enable to retrieve two-dimensional 2D fields of aerosol extinction at high horizontal and vertical resolution prior to and after the passage of a dry line. These measurements will be compared with simulated squall-line propagation. Flights performed before the squall-line passage will be used as initial conditions in the simulations made with high resolution and mesoscale models. Flights performed after the MCS passage will be used to assess the perturbed environment, relevant to model validation. Some key variables will be given particular attention in the making: (i) water vapor and aerosol vertical distribution, (ii) PBL structure and surface-PBL interactions, and (iii) emission fluxes.

Ground-based cooperation:

- Coordination with the radiosonding network: additional soundings to be requested in the northern quadrilateral (Ouagadougou,Tombouctou, Agadez, Niamey, Tamanrasset) – at least 4 balloons per day,

- Coordination with ground sites along the SDT,
- Coordination with the Tamanrasset Supersite,
- Coordination with the tethered balloon in Niamey.

Forecasting requirements

- MSC: activity: The success of the mission relies strongly on the prediction of squall line triggering east of Niamey and on the squall-line tracking and development within the target zone,
- Soil moisture distribution east of Niamey.

Satellite data

Flights will be planned on the basis of satellite observations of the MCSs east of Niamey. Satellite observations of the aerosol load and soil moisture to the north of Niamey will also be of great interest for mission planning.

Recommendations for enhancement:

- Radar operation needed in Niamey to document the 3D dynamical structure and evolution of the sampled squall-line. It is essential to have information on the dynamics of the MCSs to understand the redistribution and aging of aerosols and precursors,
- An airborne soil moisture instrument will enhance significantly the analyses of the land-atmosphere interactions prior and after the squall-line passage.

I1.3 Surface-atmosphere: North-South ‘land-ocean-atmosphere interactions’ surveys (SOP1-a, SOP2-a2 Flamant, Parker)

Understanding the role of the continental surface and of the ocean on the monsoon onset is key to predicting the monsoon inter-seasonal variability. Within AMMA, we propose to characterize simultaneaously the structure of the monsoon layer, the continental and oceanic surface state at the daily, seasonal and inter-annual. This will be done by to means:

- Carrying coordinated aircraft operations in the CATCH window to analyse the thermodynamical processes and surface-atmosphere interactions during the monsoon onset period, i.e. the SOP1-a of AMMA. Aircraft measurements will be enhanced by surface measurements made along the flight track, including the Djougou supersite. Improved knowledge of the above mentioned processes will also be obtained by coupling numerical dynamical simulations with airborne and ground-based measurements of atmospheric thermodynamics as well as continental and oceanic surface characteristics. This strategy is relevant to TT8 and will be described hereafter,
- Characterizing the monsoon layer structural parameters at the seasonal and interannual time scales in the CATCH window using continuous in situ and remote sensing measurements of atmospheric thermodynamics as well as continental and oceanic surface characteristics. This strategy is described in the TT2a, TT4, TT5 and TT6 implementation plan.

During SOP1-a, the exploration of the monsoon flux south of Niamey (and over the CATCH window), will be made using 2 aircraft: the F/ATR in the PBL and the F/F20 flying above the PBL (with the nadir looking LEANDRE 2 lidar) at a level around 500 hPa to enable the documentation of the moisture field in the monsoon flow as it penetrates over the continent. Exploration of the monsoon flow structure as well as surface turbulent flux over the ocean are also highly desirable. Dropsondes released from the FR/F20 will provide wind and temperature fields with a 0.5° or 1° resolution. Coordination will be sought with constant level ballons being released from Cotonou as well as the numerous ground sites along the flight pattern. Coordination will also be sought with the EGGE 3 cruise, in particular with so called “Benin radial”, a north-south transect due south of Cotonou, wich will take place 17 and 21 June 2006. In addition to measuring mean and turbulent variables, the F/ATR will also be equipped with the AVIRAD and HYGRO aerosol packages for measuring aerosol optical and radiative properties in the PBL.

Main highlights for the mission:

1. take-off in Niamey and ascent to 6 km msl and 300 m msl for the F/F20 and F/ATR respectively, heading north;
2. exploration of the ITF north of Niamey for approximately 45 min., including fly back towards Niamey;
3. overpass of the CATCH window between Niamey and Cotonou (Benin) and exploration of the vertical structure of the atmosphere and surface characteristics;
4. landing and refueling in Cotonou;

5. take-off from Cotonou, ascend to 6 km msl and 50 m msl for the F/F20 and F/ATR respectively, over the Gulf of Guinea;
6. exploration of the vertical structure of the atmosphere and oceanic surface characteristics for approximately 45 min., including fly back towards Cotonou;
7. F/ATR-42 climbs to 300 m msl. Overpass of the CATCH area sites on the way back to Niamey.

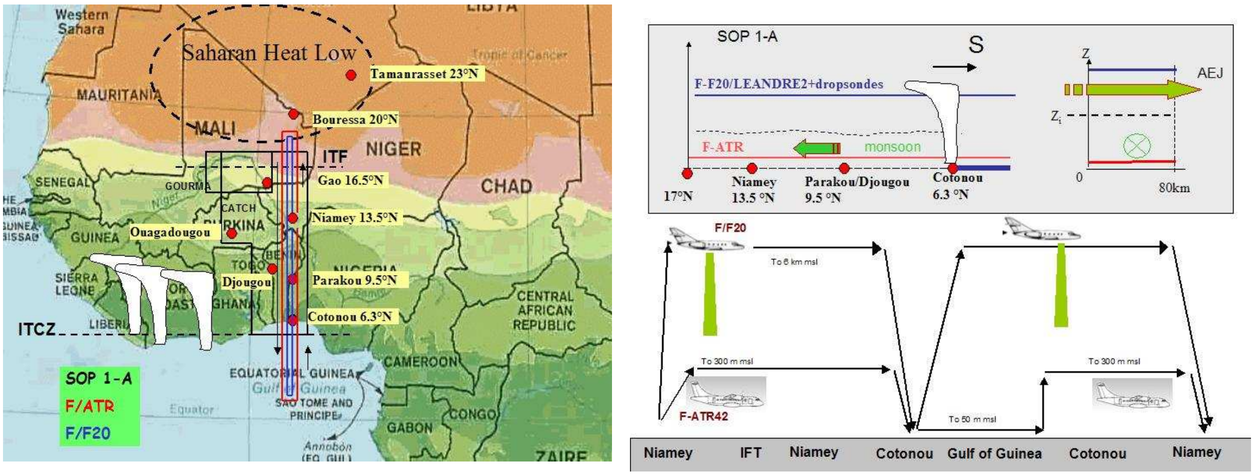


Figure 2.4.3: proposed aircraft operations designed to investigate the structure of the monsoon and the surface-atmopshere-ocean interactions during SOP1-a.

All missions are scheduled to start early 0800 or 0900 UTC to enable a landing back in Niamey in the day time. The overall length of the mission will be on the order of 8 or 9 hours, depending on the time needed for refuelling in Cotonou.

Link with the modelling strategy:

The proposed flight plans will provide 2D observations of the monsoon structure between the IFT and the Gulf of Guinea. The thermodynamical structure of the monsoon flow will be constructed from dropsonde and lidar measurements in the lower troposhere (below 6 km msl). Airborne surface turbulent heat fluxes will also be measuremed onboard the F/ATR-42. These measurements will be compared with the monsoon layer structure obtained from high resolution mesoscale simulations. Sensitivity analyses will also be conducted to assess the impact of soil moisture in the region of the CATCH window as well as the role of the ocean, and the sea surface temperature in particular.

Ground-based cooperation:

- Coordination with the radiosonding network: additional soundings to be requested in the northern and southern quadrilaterals – at least 4 balloons per day,
- Coordination with the boundary layer pressurised balloons (BLPB) which will be launched from Cotonou in the planetary boundary layer (PBL) in June and July,

- Coordination with ground sites along the flight pattern in the CATCH window in Benin,
- Coordination with the Tamanrasset Supersite,
- Coordination with the tethered balloon and sodars in Niamey.

Forecasting requirements

- Cloud cover: clear-air conditions are needs for optimal use of active and passive remote sensing instruments,
- MCS activity: to be avoid during these missions,
- Position of the IFT: accurate forecasting of the position of the IFT will be important for mission planning.

Satellite data

Flights will be planned on the basis of satellite observations of the cloud cover south of Niamey and over the Gulf of Guinea. Satellite observations of the aerosol load and soil moisture to the north of Niamey will also be of great interest for mission planning.

Recommendations for enhancement:

An airborne soil moisture instruments will enhance significantly the analyses of the land-atmosphere interactions north of Niamey.

Repeat of the I1.3 flights by the BAe146 aircraft during SOP 2a2 would enable seasonal variations in the system to be explored more fully.

It is desirable to sample marine boundary layer air to provide the upwind composition of the monsoon layer. A long N-S run to Cotonou and out over the Gulf of Guinea will provide information on compositional gradients over a long latitudinal transect. This IOP will involve 2 flights with refueling at Cotonou. One flight should be mostly at low level in the boundary layer (500 ft) to examine emissions between Niamey and the coast. This should be in the afternoon when the boundary layer is well developed and reasonably constant in height. The other flight should include the runs in the MBL off the coast and a high level run at 20kft for dropsondes between the ocean and Niamey. Thus take off could be at 12:00, a 4 hour flight to Cotonou in the BL. Two hours for refuelling. Take off at 18:00, runs in the MBL and return at altitude, landing at 22:00. With 3 hours preflight this gives 13 hour flight crew duty. This IOP will need planning from a flight crew duty perspective, because we may need permission to fly in an area outside the standard NOTAM area (550nm radius from Niamey) and for refuelling arrangements in Cotonou. These flights could also be coordinated with an ozone sonde launch from Cotonou.

I1.4 Surface-atmosphere: Land-atmosphere interactions (SOP2-a2 – Parker)

During SOP 2a2, horizontal flight legs from the lowest possible levels in the CBL to the aircraft ceiling will be performed with the **UK BAe-146** aircraft. These legs will observe the land surface state using onboard radiometry; the CBL (mixed layer and shallow cumulus) fields; the transiently-mixed monsoon layer; the SAL; and the troposphere above this. The flights will focus on the impacts of spatial variability at the land surface on the physical and chemical properties of the overlying atmosphere.

Two kinds of land-surface variability will be targeted for these missions: (i) soil moisture variability in the northern Sahel and (ii) vegetation and land surface variability in the southern Sahel.

(i) Soil moisture variability

Flights targeting soil moisture anomalies will typically take place in the region of the northern quadrilateral of AMMA. Here the vegetation is sparse, resulting in a strong sensitivity of surface energy fluxes to recent rainfall. In addition, compared to further south, reduced cloud cover permits the acquisition of near-real-time high resolution land surface temperature data which can be used as a proxy for surface soil moisture. Flights will be performed over strong gradients in soil moisture, and do not require ground-based measurements. However, flights over the Niamey and Gourma sites are preferred when soil moisture and cloud conditions are favourable.

Flights will be planned on the basis of rainfall events, and will be executed in the 2 to 3 days following such events, over which time soil moisture patterns are equilibrating. Rainfall may be from large MCS events, or from more 'patchy' rainfall. Flights in advance of rainfall events would be desirable if they can be forecast sufficiently well.

A good case for conducting these flights would be following recent rain after a dry spell of 3 or more days. The impact of soil moisture on the atmosphere has strong length scale dependencies. It is therefore important to sample wet surfaces of length scales from 10 km upwards, and preferably under different synoptic conditions. Large scale east-west variability (upwards of several 100 km) should be sampled in the region of Niamey, though flights associated with such a pattern would focus on the transition region. It is also crucial that the SOP provides at least one case where moist convection develops in the vicinity of the flight to assess the role of spatial variability in soil moisture on the early stages of convective systems.

(ii) Vegetation and land surface variability

Flights targeting vegetation patterns and their associated physical and chemical fluxes may be conducted further south, over the southern quadrilateral and the Oueme mesoscale intensive site. Flight patterns can be designed on the basis of vegetation patterns, as well as the location of ground-based monitoring sites, and therefore will be determined in advance of the detachment, in consultation with the TT5 team coordinating observations in the Oueme region.

A possibility is 1 or 2 east-west flights around the Parc W region to the south of Niamey. This area exhibits sharp contrasts in land use and tree cover. Flights in this zone would permit an assessment of the impact of land use on the physical and chemical properties of the boundary layer, with strong gradients in the emission of trace gases anticipated. East-west flights would minimise the impact of larger scale gradients on the observations. If undertaken when it hadn't rained in the region for at least 2 days, the impact of transient spatial variability in soil moisture would be reduced. Clear sky satellite data would not be essential for such a flight as the surface features can be inferred from existing vegetation maps.

Flights over different vegetation patterns will also be covered in IOP1.5. IOP1.4 is likely to focus more on the flights in the northern region where variations due to rainfall are likely to be greater.

Timing of flights and legs within flights will be scheduled to observe the developed CBL and later in the evening the nocturnal decoupled layers. Flights will typically take 3 or 4 hours. Proposed schedules of flights are summarised in the tables below.

Sequence 1

J-1	J0		J+1
Precipitation	1300	1900	DOWN
	1700	2200	DAY

Sequence 2

J-1	J0		J+1		J+2
Precipitation	1300		1300	1900	DOWN
	1700		1700	2200	DAY

Sequence 3

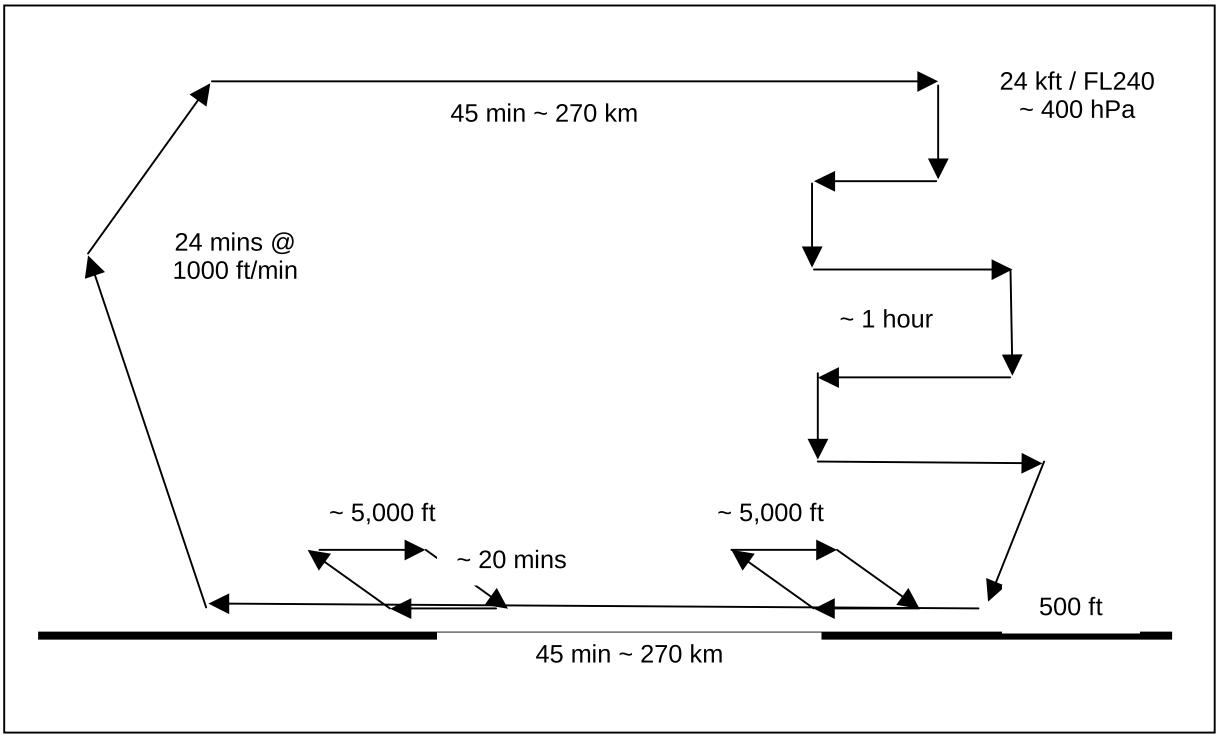
J-1	J0		J+1		J+2		J+2
Precipitation	1300		1300		1300		DOWN
	1700		1700		1700		DAY

Table 2.4.1: Sets of proposed take-off (row 2) and landing times (row 3) for I1.4 flights over soil moisture patterns and vegetation patterns ((i) and (ii)), beginning on day J0. UTC assumed.

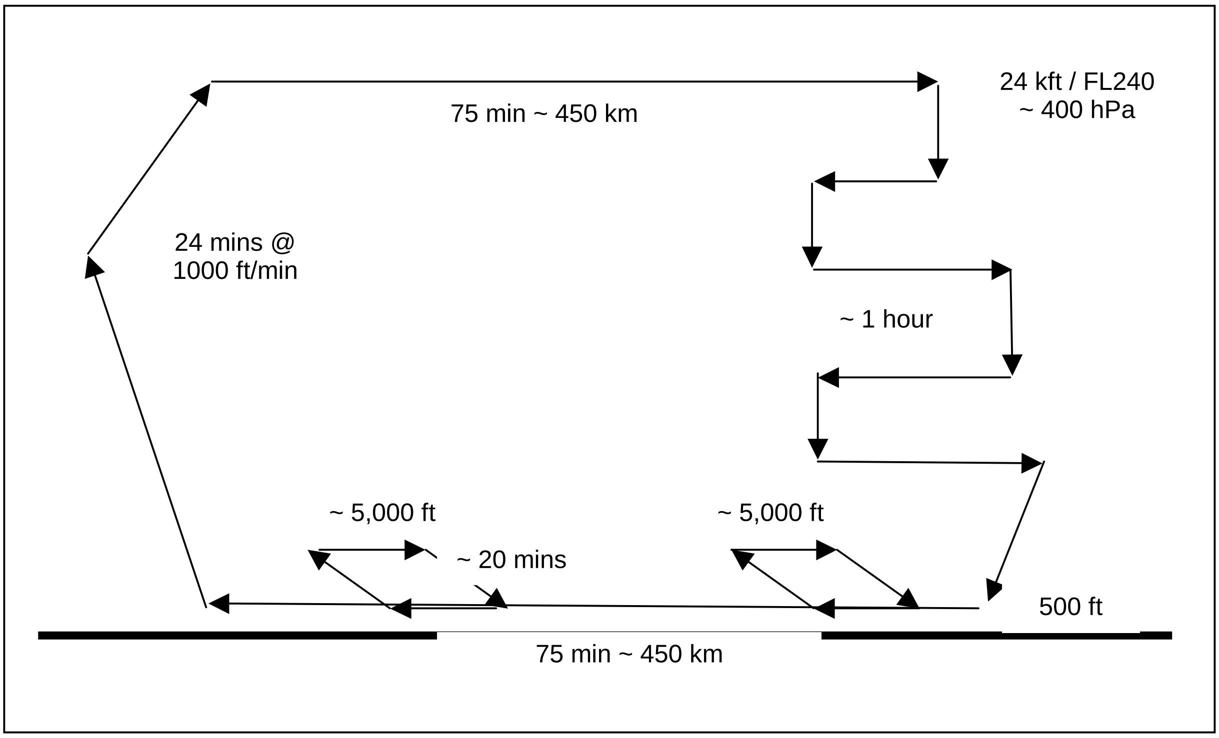
Any of these 3 sequences in Table 2.4.1 may be curtailed by
- adverse weather on day J+1 or J+2;
- outcomes of data collection on J0 and/or J+1;
- lessons learned from previous events during the campaign.

For instance after performing Sequence 2 early in the campaign it may be decided that flights on day J+2 of Sequence 3 will never be required. At this stage, before the campaign, we prefer to leave the option open if possible.

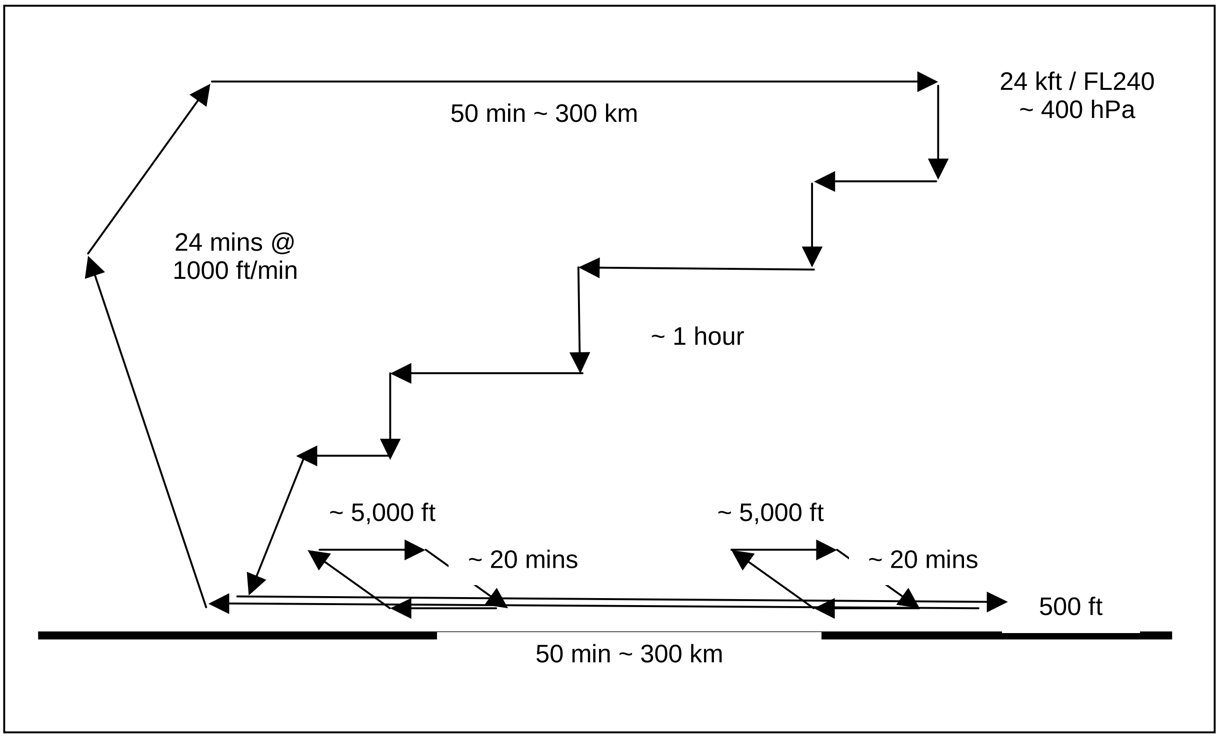
A final decision to conduct any of these sequences (GO/NOGO) will be made by TakeOff-3 hours; typically 1000UTC on day J0, based on the early morning satellite images.



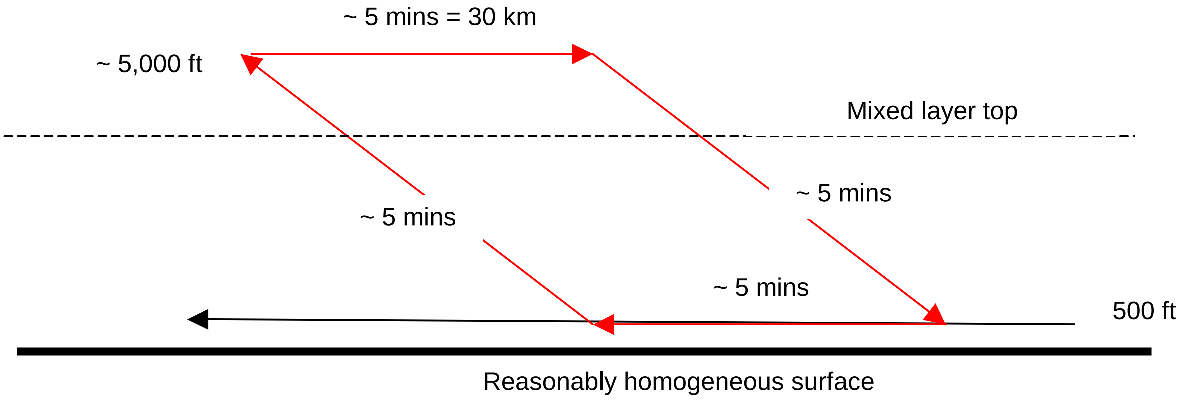
Flight duration excluding transits: 3h 34mins



Flight duration excluding transits: 4h 34mins



Flight duration excluding transits: 4h 34mins



Detail of mixed-layer / troposphere sampling
for mixed layer depth < 5,000 ft

Figure 2.4.4: Proposed flight patterns for I1.4, for different operational durations and different horizontal extents. Dropsondes will be released on the higher altitude section of each pattern at 0.5 or 1 degree resolution.

It would be useful from a chemical point of view to interrupt the low level legs with short profiles up out of the boundary layer with a 5 minute run above. A profile will be needed over each different type of land surface (e.g. wet soil, dry soil, different vegetation type). The profile down back into the BL could be on a reciprocal heading to minimise discontinuities in the sampling over the land surface.

The orientation of the stacked legs should be aligned along air mass layers as seen in the dropsonde data and forecast by trajectories.

Radiosonde coordination:

In association with these flights, high frequency radiosoundings (4 per day, or possibly more during flying days) may be requested. These soundings will be used to provide a temporal perspective on the evolution of the lower troposphere in response to the surface variability. If costs allow, additional sondes will be requested on all stations in the local quadrilateral; otherwise, additional sondes on a subset of radiosondes will be requested.

Links with ground-based monitoring:

Where possible, flights will be designed to over-fly the surface flux networks and chemical monitoring sites of the mesoscale EOP networks. Flights targeting soil moisture anomalies outside the domains of the northern and southern quadrilaterals are possible, for instance over the Gourma site, if the soil moisture patterns indicate that this is worthwhile. However, the usefulness of many of the chemical measurements will be very much enhanced by the availability of surface data beneath the flights.

Radar schedule and patterns:

Regular PPI scans throughout the period of the flights are desirable – for instance at 15 minute resolution – in order to describe the rainfall generating soil moisture patterns and, where relevant, the subsequent rainfall patterns over the given soil moisture distributions.

Tethered balloon flights:

At (Hombori and) Niamey the tethered balloons will, where possible, be deployed to coordinate with the flights, as outlined in **section 2.2.** If soil moisture patterns are suitable, with a transition between dry and moist soil being situated at the tethered balloon location, then **tethered balloon flights in the absence of the aircraft can be made.**

Modelling:

Data from the flights will be used to evaluate models of:

- Soil moisture
- Boundary layer response (dynamics and composition) to surface properties
- Mesoscale dynamics, thermodynamics and transport through shallow convection and horizontal advection

Dropsonde profiles will be made at high horizontal resolution (0.5 to 1 degree) in order to initialise and drive models. Aircraft profile data will also be used, as well as high frequency local radiosonde data, to provide temporal evolution of the thermodynamic and wind profiles.

Satellite data:

Flights will be planned on the basis of satellite analyses of soil moisture distributions, tropospheric composition of biogenic chemicals, and rainfall distributions.

Flight data will be used to evaluate and calibrate satellite analyses of soil moisture distributions and tropospheric composition of biogenic chemicals.

Forecasting needs:

- Mature MCS activity: to be avoided.
- Development of moist convection in region of flight during early evening desirable on at least one flight
- Soil moisture distributions in case (i): good cases will involve distinct zones of soil moisture anomalies, on scales of up to 100 km. In cases of large soil moisture anomalies, flights may target the transition zones between dry and moist surface. On the morning of the first flight of this IOP there must be clear skies to allow the moisture patterns to be visible in the satellite images.

Opportunities for enhancement:

- If airborne soil moisture instruments can be flown, then far better analyses of the land-atmosphere interactions can be achieved.
- Boundary layer flights with additional aircraft on the same track and the same day will give far better information about the PBL response to the surface (dynamical and chemical, where compatible chemistry is possible).

I1.5: Vegetation and soil emission surveys (SOP2-a2 – Reeves, Parker)

Many of the objectives relating the composition observed in the boundary layer to the land surface and vegetation characteristics will be met by I1.4. I1.4 will provide surveys of the **UK BAe-146** in the BL, repeated over a couple of days, over various land surface types and I1.3 (flight to Cotonou and the Gulf of Guinea) will provide a long N-S transect in the BL of the **UK BAe-146** across a whole range of vegetation types. However, the range of the aircraft will not allow detailed sampling in the BL over the Djougou or Gourma sites along with the runs required by I1.4 and I1.3. Therefore I1.5 has been devised to address this specifically.

It will be aimed at sampling the BL above the Gourma, Niamey and Oueme mesoscale sites, providing data over 3 different and well defined vegetation/land surface types in a N-S transect across W. Africa. The range of the aircraft and the size of the Gourma and Oueme sites means that sampling will be focussed over limited areas (e.g. Hombori and Donga supersites) the rather than across the whole of these mesoscale sites. The plan will be to fly the **UK BAe-146** in a rectangular type patterns, orientated along the vegetation belts (E-W) or across wind if the air flow is significant. For Niamey, we should avoid samples being impacted by anthropogenic emissions from the city, which should be considered by I1.6 (urban sources). The Figure below illustrates some of the areas that might be covered by flights in I1.5.

The surveying over the sites should be in the afternoon when the BL is well developed and the entrainment from above is not too great. It will also be necessary to sample air above the BL to evaluate the impact of entrainment.

Ideally the transits should be in the BL, returning along a reciprocal to sample over the same areas at a different time of day to observe the diurnal variability of the emissions and boundary layer state. These N-S transit legs will be made across contrasting vegetation regimes and will put the the measurements made above the ground sites in a wider context and will also enable an assessment of the synoptic-scale variability in the boundary layer thermodynamic state. However, the range of the aircraft may mean that transits to Gourma and Oueme might have to be at higher altitude to maximise the time available for surveying over the sites. Additional N-S runs in the BL could be added to the Niamey site flights, which along with some BL runs made during I1.4 flights could help fill in the gap in the N-S transect.

Where possible, flights will be coordinated with the I1.7 patterns planned for the F-ATR42 aircraft.

Links with ground-based programme

Radar estimates of precipitation in the preceding 24 hours will be useful to plan flights. Flights will be planned where possible to over-fly ground-based monitoring sites, particularly those at Djougou and Banizoumbou.

Figure 2.4.5: Proposed flight patterns for the UK Bae 146 for I1.5.

Forecasting requirements

I1.5 operations can be committed relatively easily, as they are not sensitive to the details of the prevailing situation.
Flights should take place in the absence of cumulonimbus activity.
Estimates of CBL depth, soil moisture (see I1.4), soil temperatures (see I1.4), and emissions will be useful for planning the flight locations.

Links with modelling

Model products will be used in an attempt to forecast / analyse areas of significant emissions (and emissions gradients). Such models will also be evaluated with the flight data. Satellite, radar and onboard radiometry will be used to analyse the cloud fields along the flight track, and to estimate the surface radiative fluxes for input to retrospective modelling studies. Attempts will be made to evaluate turbulent fluxes of those species which can be measured at high time-resolution (including water vapour) and these fluxes will be related to estimates obtained from research and operational models. Composition and emissions estimates will be used to refine and evaluate models of global atmospheric composition.

Links to NOx surface flux model simulations.

Satellite requirements

If requested, these flights can be scheduled to coincide with the times of satellite overpasses.

Recommendations for enhancement

Measurements of chemical composition or fluxes at the ground-based sites would be useful.

I1.6: Urban surveys (SOP2-a2 – Parker, Lewis)

Short surveys of large urban regions – e.g. box flights around Lagos may be performed with the UK BAe 146. The objectives of these flights will be to sample the effects of these large and growing urban regions on air quality.

These flights would take place as opportunity flights, capitalising on the aircraft being in the vicinity, and have a duration of 2 hours or less. (i.e. Combining two flights (with a refuel at Lagos), to meet objectives of I1.4 and I1.5, similar to I1.3). Flights would take place in the boundary layer and sample both the upstream and downstream conditions to make a first-order assessment of the urban impact on atmospheric composition.

Proposed flight patterns will depend on ATC and the flight hours available. Typical flights might involve 2 stacked legs (one in and one above the boundary layer) on transects upstream and downstream of the city, or along-wind legs over and downstream of the city.

Figure 2.4.6: Proposed flight patterns for the UK Bae 146 for I1.6.

Ground-based coordination

Data from ground-based aerosol and chemical monitoring stations would be valuable in data analysis.

Forecasting needs

Profiles of wind direction and strength. Absence of cumulonimbus.

I1.7: Aerosol mixing and hygroscopicity (SOP2-a2 – Mari)

These flight plans are devoted to the study of aerosol mixing and hygroscopicity (WP2.4.1). The main objective of this sub-WP is to provide the basic scientific understanding of the physico-chemical characteristics, hygroscopic, optical and radiative properties and regional and vertical distributions of the main aerosol types in the WAM region. Depending on locations, aerosols over West Africa result from a mixing of mineral dust, biomass burning, biogenic emissions or sulphates coming from industrial regions along the Gulf of Guinea. The modification of the aerosol properties along their transport has a direct radiative effect but may also have an indirect and semi-direct impact on cloud properties. For this IOP, the main question addressed will be how do mixing and in-cloud processes change the surface, hygroscopic, and therefore optical properties of dust and biomass aerosols?

For that, 4 F-ATR42 flights will be devoted to this study by using a combination of the CVI and HYGRO configurations (based on CVI and SAFIRE aerosol inlets). The main objective is to characterise the north-south gradient of hygroscopic particles (soluble and/or insoluble) near and within shallow to moderately deep clouds. The CVI measurements focus on cloud particle and interstitial aerosol characterization in cloud layers. The main objective is to understand microphysical, radiative as well as physico-chemical properties of boundary layer convective clouds, e.g. stratocumulus clouds downstream the MCS. This contribution will allow us to complete the aerosol measurements made in cloudless situations (or out of cloud measurements) with the CVI mounted on the ATR-42, which will provide a characterization of all forms of stratiform clouds in the WAM region that the aircraft ATR-42 might encounter. Complementary measurements on the aircraft ATR-42 of particle properties will be performed in cloud and cloudless conditions by a similar set of instrumentation downstream the aerosol inlet (e.g. SAFIRE inlet) with its HYGRO configuration and the CVI. Thus, while passing through partly cloudy regions the aerosol inlet and CVI inlet will complement each other and commutate to deliver a complete data set of aerosol particle properties without gaps.

Thus, during cloud presence, The F-ATR42 will perform:

- 3 flights including: (i) 1 latitudinal transect from Niamey to Cotonou with ascents and descents from under cloud base to cloud summit (in case of extended stratiform layers) at altitudes determined by the mission scientist before the flight and in coordination with ground-based measurements in Djougou. Transects at constant altitude will allow to collect enough matter on filters for subsequent chemical analyses (about 15-30 min); (ii) 1 passage over the Gulf of Guinea; flight length and altitude levels will be determined by the mission scientist just before the flight depending on the vertical aerosol and cloud distributions; and (iii) 1 latitudinal transect from Cotonou to Niamey with ascents and descents from under the cloud base to the cloud summit (in case of extended stratiform layers) and in coordination with ground-based measurements in Djougou (same flight plan as latidunal transect from Niamey to Cotonou). The flight patterns need to be coordinated with the latitudinal transects performed by the UK-Bae-146 in I1.5.

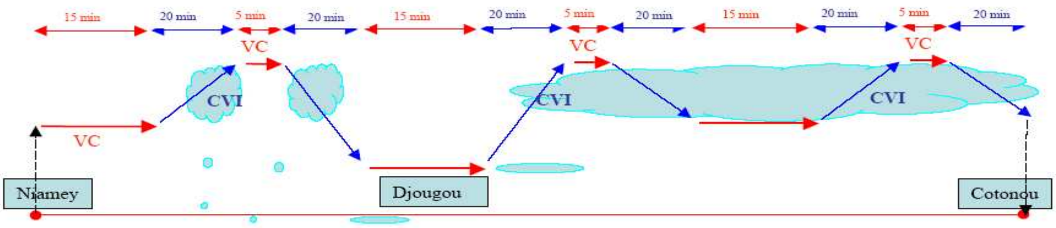
- 1 flight dedicated to the characterization of the vertical and regional gradient of hygroscopic particles (soluble and/or insoluble) near and within shallow to moderately deep clouds between Niamey and the Gourma site. It will include vertical profiles from under the cloud base to the cloud summit (in case of extended stratiform layers) and stays at constant altitude allowing to collect enough matter on filters for subsequent chemical analyses (about 15-30 min).

Flights will be conducted upon alert (minimum time 1h) according to model forecasting giving aerosol and cloud horizontal and vertical distributions (MESO N-H for example). As far as possible, coordination will be made with other aircrafts flying at higher altitude and with ground-based measurements (aerosol, radar, etc.) in order to combine aircraft and surface measurements. The cloud in-situ instrumentation will detail obtained radar observations (onboard aircraft as well as routine ground-based radar network over land), as the planned flight-level measurements will sample properties of interstitial and in-cloud aerosol e.g. in the MCS vicinity.

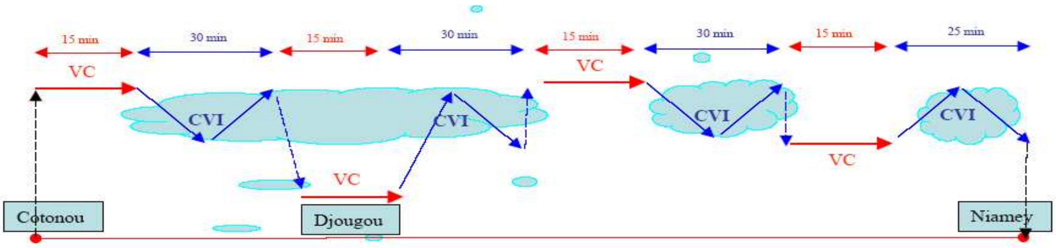
Link with the modelling strategy
Measurements of CN and CCN below the cloud base provide initial conditions for cloud droplet activation models. The latitudinal transect will serve to test the sensitivity of the cloud droplet nucleation to the emissions of gaseous precursors and water vapour humidity gradient.

Ground-based cooperation
Coordination with CN, CCN and aerosol precursor measurements in Djougou (Benin)

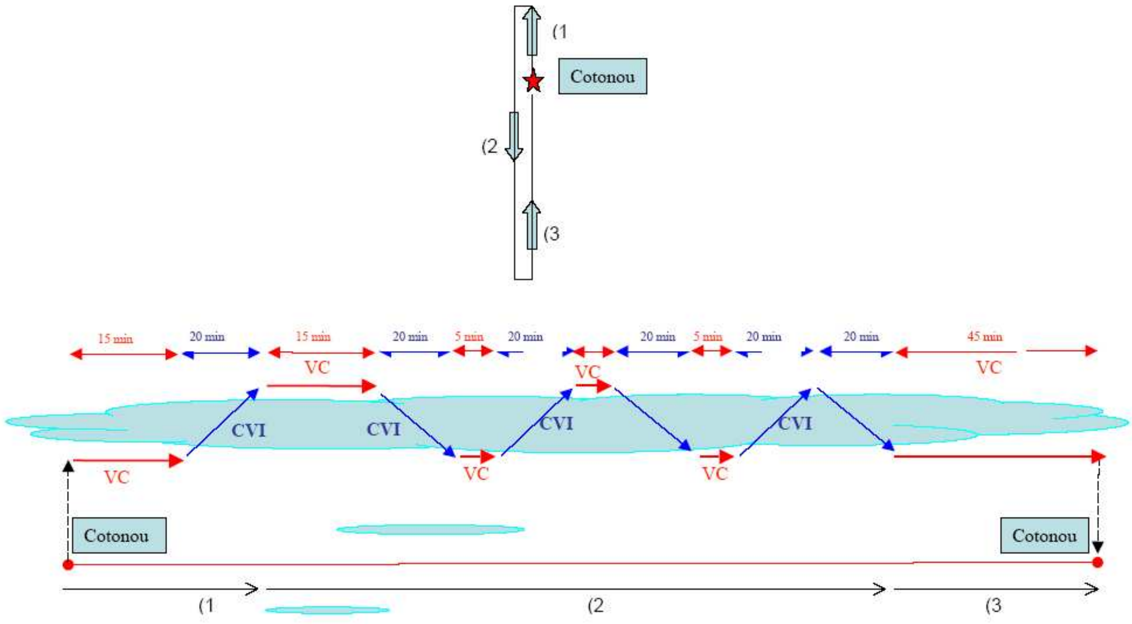
Forecasting requirements
Preference for non-precipitating clouds. Forecast of the cloud base altitude needed. Vertical distribution of aerosols and cloud layer needed.



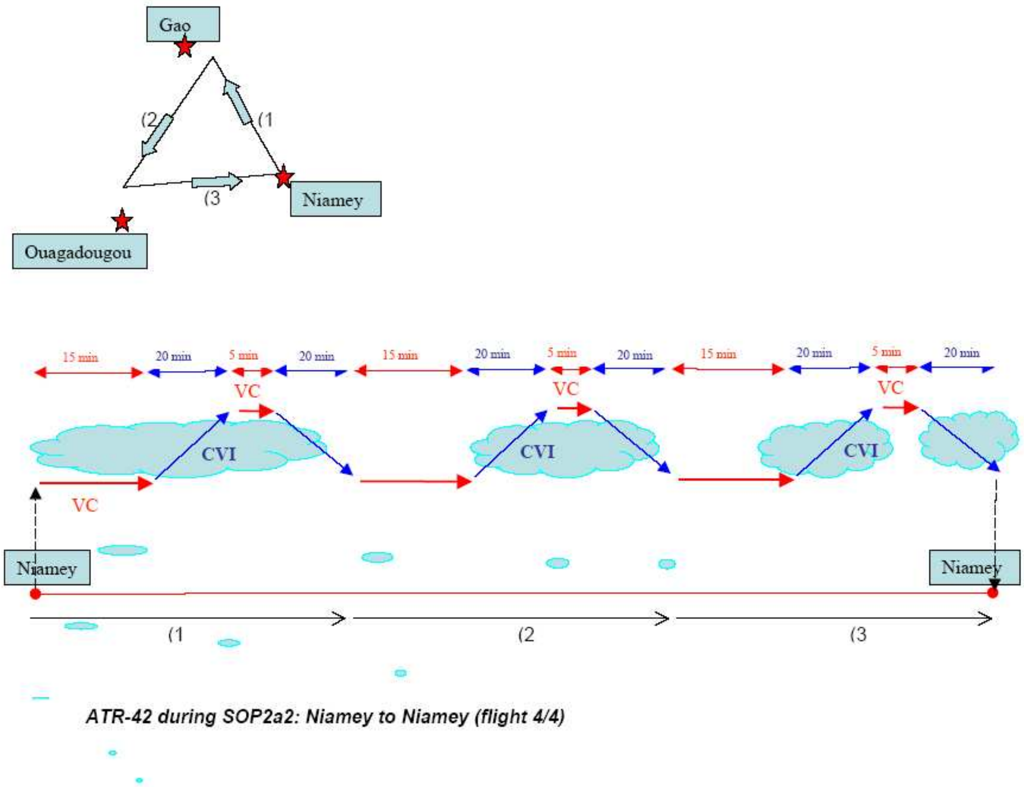
ATR-42 North–South Transect during SOP2a2: Niamey to Cotonou (flight 1/4)



ATR-42 North–South Transect during SOP2a2: Cotonou to Niamey (flight 3/4)



ATR-42 during SOP2a2: Cotonou to Cotonou (flight 2/4)



ATR-42 during SOP2a2: Niamey to Niamey (flight 4/4)

I2: Dynamics and chemistry of MCSs (SOP 2a1, SOP 2a2 – Mari, Flamant, Reeves, Hoeller)

MCSs-related IOPs will be conducted in a region delimited by a circle of approximately 800 km in radius and centered on Niamey (the red circle in Fig. 2.4.8). Three priority zones have been identified:

1. **zone E (11.85 – 17.85 N , 2.00 – 7.85 E) :** Convective initiation and MCS formation "upstream"; Main cities : Tahoua, Maradi (Niger), Sokoto (Nigeria),
2. **zone W (11.85 – 17.85 N , 3.85 W – 2.00 E) :** Mature MCS "downstream"; Main cities : Tilabéri (Niger), Ouagadougou, Kaya, Boussé (Burkina), Gao, Tombouctou, Bandiagara (Mali)
3. **zone S (7.75 – 11.85 N , 1.50 W – 5.50 E) :** Joint observations with the ground-based network of Djougou-Parakou; Main cities: Bolgatanga, Tamale (Ghana), Kandi, Natitingou, Parakou (Bénin), Ogbomoso, Ilorin, Wawa (Nigeria).

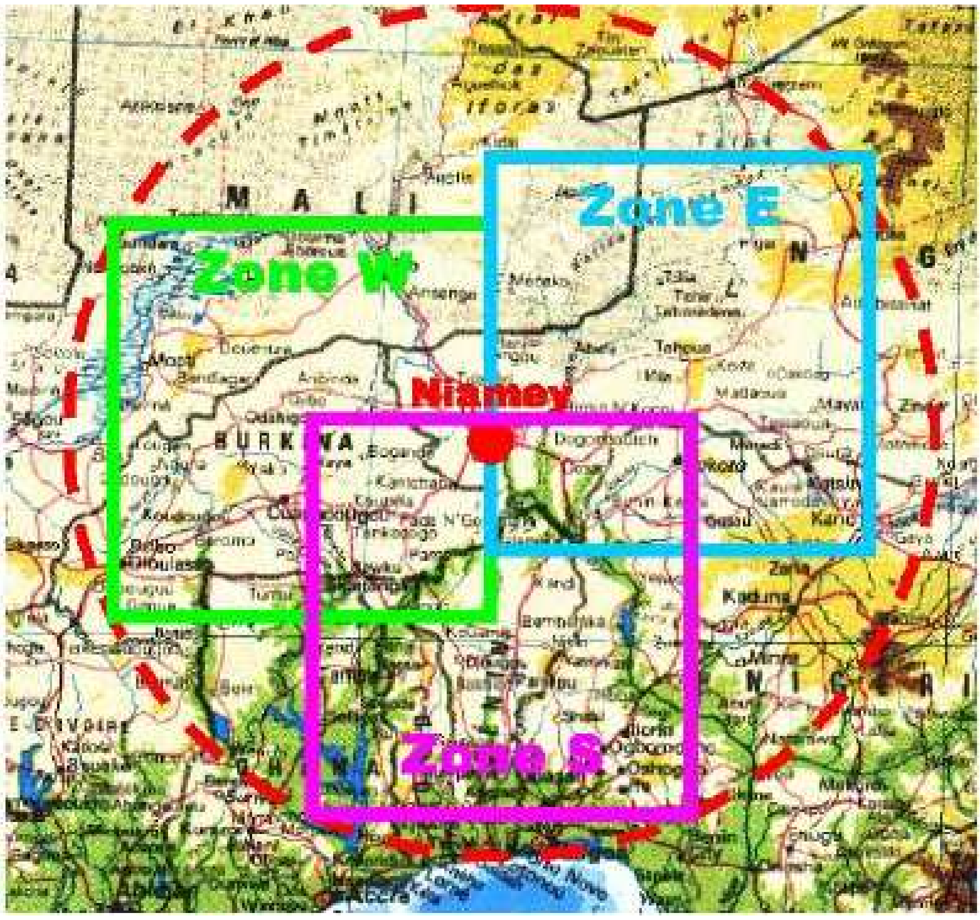


Figure 2.4.8: Target zone during SOP 2a1 and SOP 2a2

Flight patterns for SOP2-a1 (1-15 July)

During this period, the exploration of the mesoscale dynamics of MCSs and their environment will be made with 3 aircraft: the ATR42 in the PBL, the F/F20 as well as the D/F20. The two last aircraft will sample the environmental conditions around a

MCS by means of dropsondes and lidar 2D fields (water vapour and wind) along with flight level measurements.

During SOP-B2 we propose to conduct operations for 2 or 3 MCS cases. Operations shall not be tied either to the Niamey, but should be conducted within the area delimited by the northern radiosonde quadrilateral. The “generic” MCS plan is shown in Fig. I2-1. The following conditions must be met:

i) ferry time from Niamey to initial point (1) - and from end point (16) to Niamey - must be less than 30 min, i.e. about 300 km range. This is also the time necessary to reach an altitude of 40 kft (12 km) ;
ii) to optimize the flight strategy with respect to the MCS propagation (10-20 m/s or 35-70 km/h, toward NW to S), it is preferable to conduct airborne observations when the MCS is east of Niamey ;
iii) the way points are along an *« outer octogon »* (fixed diameter of 500 km) and an *« inner hexagon »* (variable diameter of ≈200-300km, depending on the size of the considered MCS) ;
iv) optimum flight level is 40 kft, but it could be lowered to 35 or 30 kft, to avoid commercial traffic or to fly below cloud cover (for LEANDRE-2 and WIND operations during SOP-B2) ;
v) dropsondes must be released at each way point. With a fall speed of about 8 m/s, it takes about 25 min to reach the ground. During this period, the aircraft flying at 220 m/s covers a distance of about 330 km, during which a maximum of 4 dropsondes will be released due to the limitations of the 4-channel receiver ;
vi) the initial point can be (4) instead of (1), depending on the MCS location with respect to Niamey (instead of 1-2-3-4-5-6-7-8, the aircraft would then fly 4-3-2-1-8-7-6-5) ;
vii) the first leg (1-2-3-4) is to sample the upstream environment at about 150 km in front of the MCS, followed by a closer sampling (5-6-7-8) at 10-20 km (depending on flight safety) fom the MCS leading convective line ;
viii) at way point (8) a « GO / NOGO » decision must be taken concerning flight continuation : depending on MCS development - as seen on radar (if available) and satellite images - and flight safety from pilot's opinion, the aircraft should either fly around the southern edge of the MCS through way point (9) if safe, or return to Niamey if unsafe. In the later situation, the downstream part should be conducted during a following flight with (13) or (16) as initial point, most probably when the MCS has propagated west of Niamey ;
ix) leg (9-10-11-12) should be flown near the edge of the trailing stratiform anvil of the MCS . If possible, way point (11) should be within the stratiform cloud ;
x) leg (12-13-14-15-16) is a remote leg to sample the downstream environment at about 150 km behind the MCS ;
xi) coordinated flights with several aircraft would include :
    1. during SOP2-a1 and 2-A2, the F/ATR will make in situ measurements in the low levels (1 to 5 kft) : first flight will be upstream, along way points (1-2-3-6-7-8), second flight after refueling in Niamey will be downstream along way points (10-11-12-13-14-15) ;

2. during SOP2-a1, the D/F20 equiped with WIND Doppler lidar should fly at same altitude and close distance from the French FA-20. Lidar measurements are not possible within cloudy air, so the upstream (1-2-3-4-5-6-7-8) and the far downstream (13-14-15-16) parts of the flight must be in clear air.

The combination of LEANDRE 2 and WIND measurements around the MCSs will enable detailed, high spatio-temporal resolution analysis of the moisture inflow into MCSs for the first time.

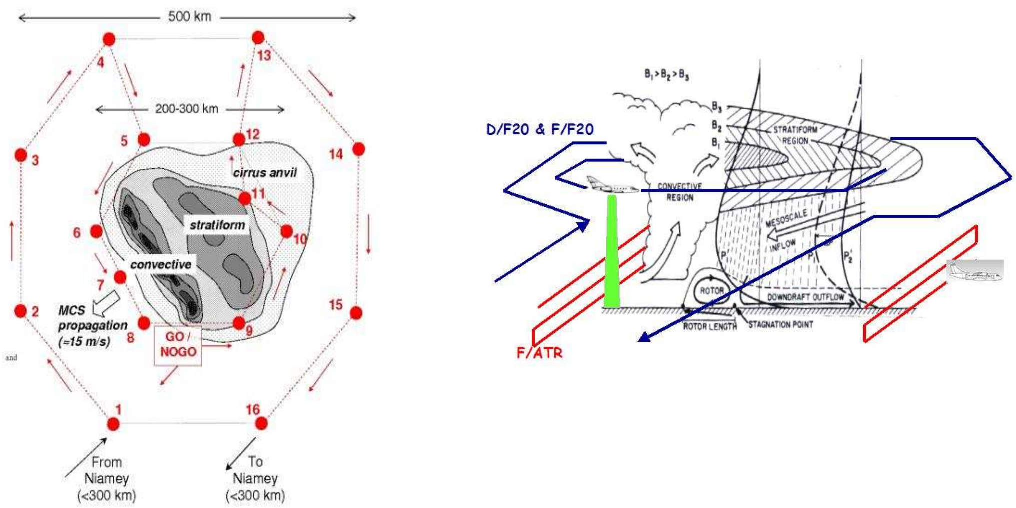


Figure 2.4.9: Left: Proposed generic aircraft operations designed to investigate MSCs environment during SOP 2. Right: Proposed operations during SOP 2a1.

Flight patterns for SOP2-a2 (17 July – 21 August 2006)

Up to five aircraft (UK-BAe146, F-F20, D-F20, F-ATR42 and Geophysica) will be deployed. Three « small » MCSs (size less than 1-2°) and three large MCSs will be sampled above different emission environments (two above the Sahel region north or close to Niamey in Niger, two above of the forest region close to Djougou in Benin). A possible target could be MCSs initiated over the Aïr mountains. Two (potentially four) MCSs will studied in coordination between the chemistry and the dynamics with simultaneous measurements of airmass chemical composition and environmental conditions with dropsondes (about 20 dropsondes/flights for the F-F20 and the UK-BAe-146). The F-ATR42 and the UK-BAe-146 have instrumentation for making aerosol measurements and turbulent air motion measurements. Because of these payloads and operational characteristics, the F-ATR42 flights will emphasize process-oriented studies associated with aerosol properties and ozone photochemistry and include boundary layer investigations and the UK-BAe146 will explore the meteorological, aerosol and chemical characteristics of the boundary layer and lower-tropospheric air that feeds the MCSs; the mid-tropospheric dry air which feeds convective and stratiform downdraughts; and the midtropospheric detrainment layer, all between the surface and 7 km.

Two (potentially four) MCSs will be sampled with the UK-BAe146 depending on the MCS development (one flight around if safe, two flights east and west if unsafe). The flights of the BAe-146 proposed for the large MCSs in I2 are similarly to those of I1.4 where stacked profiles are flown following a rainfall event. We will attempt to combine the BAe-146 flights in I2 with I1.4 such that I2 will provide an additional pre-rainfall flight. Flights ahead of forecast MCS will be valuable if flown in range of the Niamey radar.

The F-F20 will characterize the ozone photochemical precursors and dynamics in the upper troposphere, near the MCSs. Adaptative flight plans are proposed depending on the MCS development and security recommendations. The F-F20 should either fly around the MCS or return to Niamey during day 1 (GO/NOGO decision). In case, the F-F20 returns to Niamey, measurements in the downstream part will be conducted on the morning of day 2 once the MCS has propagated west of Niamey or Djougou. Ideally, the Geophysica high altitude aircraft, based in Ouagadougou, will make measurements above cumulonimbus cloud turrets during their development phase in late afternoon and early evening. The number of flight hours for the Geophysica is not yet secured.

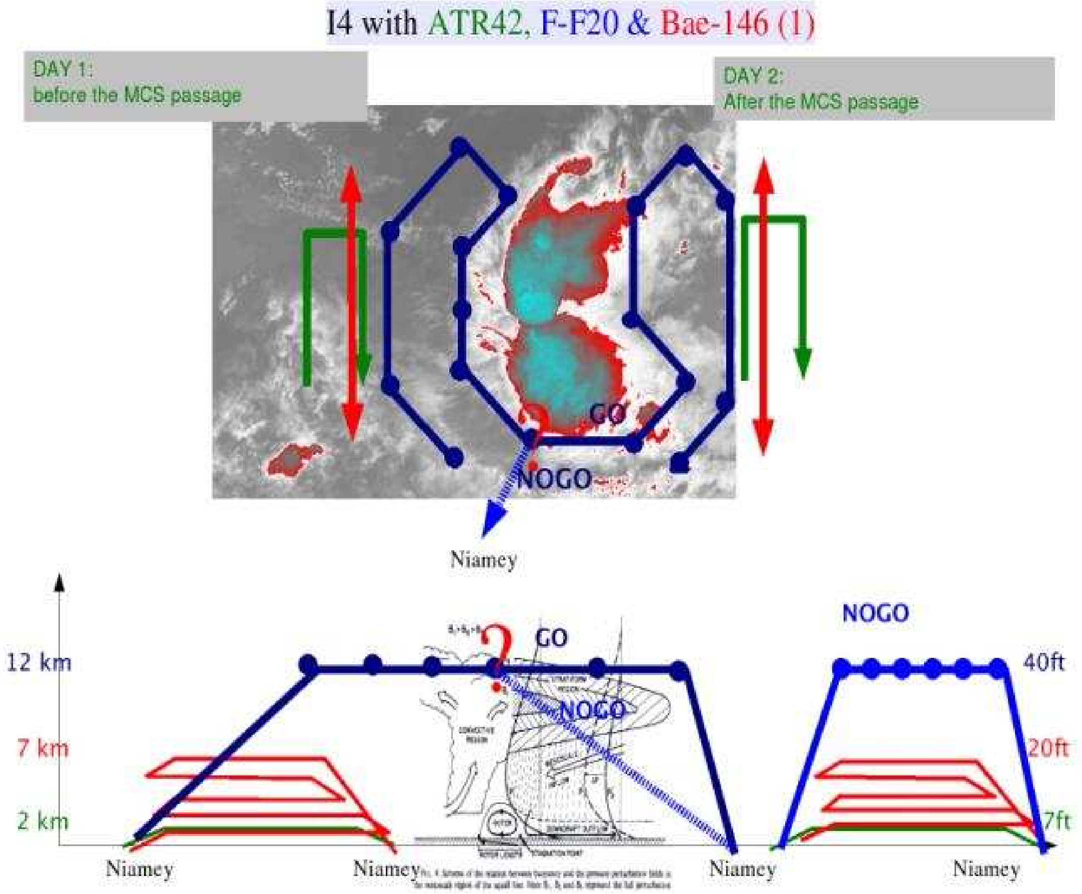


Figure 2.4.10: Proposed generic aircraft operations designed to investigate MSCs environment during SOP 2a2.

Link with the modelling strategy

The proposed flight plans will provide 3D observations of the MCS environment. Vertical distributions of dynamical and chemical parameters will be constructed from measurements in the boundary layer inflow, in the mid-tropospheric dry layer and in the upper tropospheric outflow regions. Dropsondes will provide the main structure of the flows close to and downstream of the MCSs. These measurements will be compared with simulated MCS developments and impacts at the local, regional and global scale. Flights performed before the MCS passage measure the dynamical and chemical conditions to initialize the high resolution and mesoscale models. Flights performed after the MCS passage measure the perturbed environment to compare with model outputs. Additional measurements in the TTL above the MCSs will be available from the SCOUT balloons during the night and the Geophysica aircraft during daytime, for comparison with trajectory or Eulerien models.

Ground-based cooperation

- Coordination with driftsondes being released from N'Djamena (targeting experiments of MCSs and their environment).
- Coordination with ground sites along the flight pattern at Djougou (Benin) and Banizoumbou (Niger). These two sites will operate in the EOP mode for the aerosol and chemistry measurements (see recommendations for enhancement). The radar and lightning networks will contribute measurements of MCS structures. The IOP will also benefit from the ozonesondes in Niamey (SCOUT EU program) and Cotonou (French and EU projects)
- Coordination with the radiosonding network – additional soundings to be requested in the northern or southern quadrilateral as permitted by logistical constraints – up to 8 per day.
- Coordination with the SCOUT balloon campaign to further study the convective vertical transport, the water vapor budget, cirrus clouds and chemical composition of the TTL region in the vicinity of MCS events. Small balloons will be deployed during SOP2-a1 and SOP2-a3 including measurements of water vapor, ice and aerosols distribution, remote and in-situ chemistry (BrO/NO2/O3), short lived organic bromine. The balloons will be released as soon after the MCS event as is practically possible and will be timed to descend slowly through the TTL region in the following hours, sampling the outflow of a system whose upstream and downstream tropospheric environment is to be observed with the BAe146. The impact of these balloons will be enhanced by the provision of high frequency radiosondes within the flight region.

Forecasting requirements

The success of the mission relies strongly on the prediction of MCS triggering east of Niamey and on the MCSs tracking and development within the target zone. Forecast of aerosol and gases venting plumes and trajectories will discriminate between emissions by the vegetation and low emissions over sahelian regions. The decision-making for TTL small balloons mostly relies on near-real time forecasting based on radar (cloud/no cloud) and radiosoundings (surface wind speed, humidity profiles).

Recommendations for enhancement:

- Radar operation needed in Niamey to document the 3D dynamical structure and evolution of the sampled MCSs. It is essential to have information on the dynamics of the MCSs to understand the redistribution and aging of aerosols and precursors
- Ground-based measurements in the SOP intensive mode during SOP2-a2.
- Additional flight hours for the Geophysica (see Section 2.6).

I3: Long range transport surveys (SOP2-a2 – Reeves, Mari, Schlager)

The aim is to characterize trace gas and aerosol evolution in air masses transported downwind from convective regions and large-scale impact of WAM emissions by coordinated flights. Two flight patterns have been devised to address the scientific objectives related to trace gases and cirrus firstly on the local scale looking at outflow near to MCS and secondly on the larger continental scale to investigate the larger-scale impact of deep convection on trace gas, aerosol and cirrus cloud distributions.

I3.1: Impact of Mesoscale Convective Systems on TTL composition (MCS-TTL)

A major aim of the MCS-TTL flights is to make flights using the M55, DE-F20 and other aircraft based in Niamey around an MCS passing over the US radar in Niamey or alternatively that of Djougou. The aircraft (B146, F/F20) based in Niamey would be used to characterise trace gas and aerosol distributions before the arrival of the MCS. The DE/F20 and M55 would then make flights together with the other aircraft in inflow and outflow regions of the MCS. In particular, the M55 can make measurements in the region above the MCS from the anvils at 14 km, through the cold point near 18 km, up to the top of the TTL at 20 km. An important feature of the M55 aircraft, not always exploited in the past, is its capacity for vertical exploration of the TTL layer and not only to fly at its highest possible altitude. The aim is to collect data on trace gas/aerosol distributions at several different levels in order to characterise their variability in this region (see Fig. 2.4.11). It is also an aim to coordinate these flights with launches of the SCOUT-AMMA balloons from Niamey. They will be launched upwind of a system and then descend westward enabling sampling of convective outflow in the TTL. Another objective is also to make flights of the M55 and DE/F20 around MCS near the radar and lightning detection network at Djougou with the aim of investigating the distribution and impacts of lightning NOx emissions.

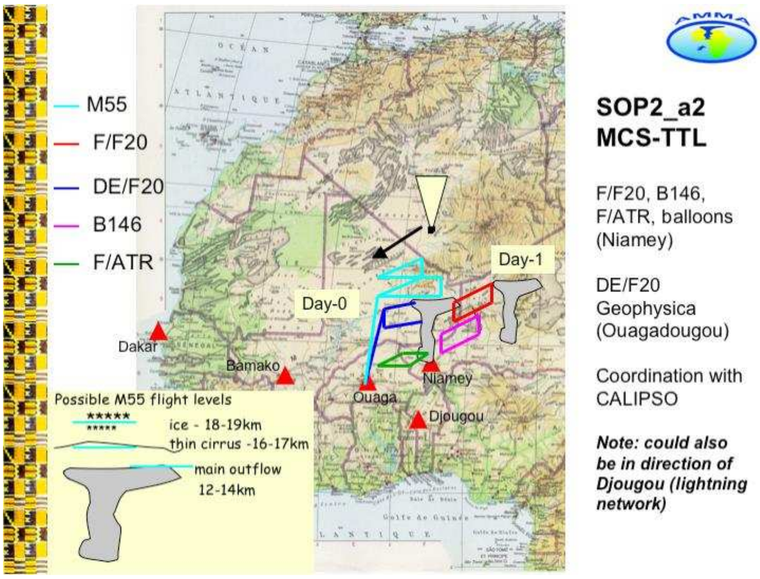


Figure 2.4.11: Schematic of flight pattern MCS-TTL

Two flights are currently being funded. Additional funds are being sought for an additional flight (see Section 2.6)

We can use I1.4 type flights of the BAe-146 aircraft to characterise trace gas and aerosol distributions before the arrival of the MCS.

I3.2: Large-scale impacts of deep convection – long-range transport (LRT-TTL)

The M55 will be flown together with the DE/F20 and possibly also in coordination with the B146 and F/F20 between the passage of significant MCS activity in order to characterise the chemical and aerosol characteristics of the UT and TTL in background quiescent regions which have not been recently perturbed by convection thereby providing a reference for the comparison with MCS perturbed regions. The transfer flights to and from Europe will also be used for this purpose since if there a rapid succession of MCS (every 1-2 days) it is likely that the chemical composition will be perturbed over large regions of the UT/TTL in West Africa. In this case, flights will be designed to cut across this general outflow. In fact, Ouagadougou is in a very favourable location for this kind of study (see Fig. 2.4.12).

These flights can also be coordinated with the balloon flights from Niamey which will collect data in the LS as well as in the TTL (see Fig. 2.4.13). Flights will be made along N-S transects (or E-W transects) at several different altitudes in the TTL. This kind of flight and also the transits to/from Europe will also provide which is useful for CALIPSO validation. Two flights are currently being funded.

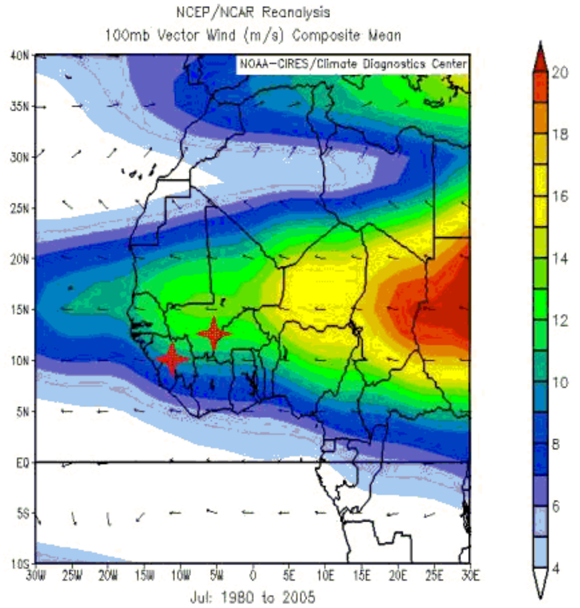


Figure 2.4.12: Wind speed and direction over West-Africa at 100 hPa for the month July from NCEP reanalysis 1980-2005 (courtesy U. Schumann) and locations of AMMA aircraft operation centres in Niamey and Ouagadougou.

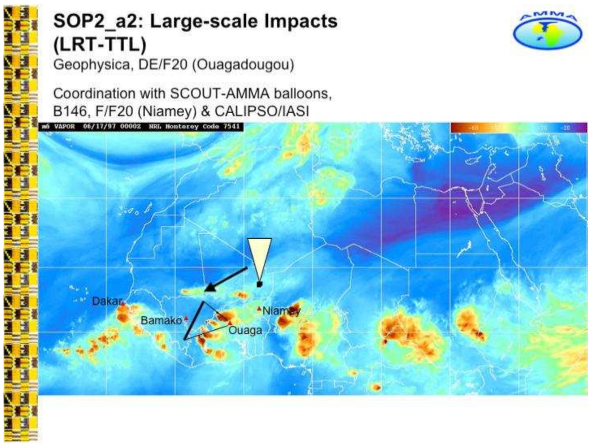


Figure 2.4.13: Schematic of flight pattern LTR-TTL.

Whilst the BAe-146 can be used to help other higher altitude aircraft characterise the transport to the TTL of the deep MCSs, the BAe-146 itself will focus on the mid-tropospheric level long range transport (i.e. the AEJ). This may be related to MCSs, but also to cumulus congestus lifting BL air to around 500 hPa, which is subsequently transported in the AEJ. Since the mixing from the BL air in to the AEJ occurs on a diurnal cycle the BAe-146 will be used to sample the AEJ at 3 times of day:

1. in the late afternoon following the daytime mixing with BL air (as in I1.4)
2. in the evening, after sunset, to examine the impact of night-time chemistry on the decoupled layers (as in I1.4)
3. in the late morning to examine day-time chemistry before substantial mixing with the BL

This will involve runs along and across the AEJ.

Link with the modelling strategy

Tracking of MCSs over a 2-3 days periods will allow to document the ozone and aerosols aging at the continental scale. This experiment extends the temporal and spatial windows of the MCSs exploration proposed in I2 and will be used mainly for global modelling of WAM impacts on aerosols and chemistry. *The synergy between the proposed flights and the global modelling community needs to be refined. In particular, it may be needed to have more extended latitudinal and longitudinal transects at high altitude for comparison with the global models outputs.*

Ground-based cooperation

Flights will be coordinated with the lightning detection network over Djougou and balloon launches near Niamey.

Forecasting requirements

The same products than those listed for I2 have to be available at the secondary AOC in Ouagadougou. In particular, the MCSs tracking forecast is of prime importance for the I3.1 experiment.
Trajectories (including chemical tracers) will be used to forecast the position of the AEJ.

Recommendations for enhancement:

Additional flight hours for the Geophysica (see Section 2.6).
Additional soundings along the zonal transect (N'Djamena, Niamey, Bamako, Dakar, Sal if possible) and possibly the northern stations at Agadez and Tombouctou; up to 4 per day.

I4: Microphysical and dynamical properties of stratiform and cirriform clouds and their interaction with the West-African Monsoon system. (SOP2-a3 – Bouniol, Protat)

Deep convection is the ultimate source of tropical upper tropospheric extended clouds, i.e. tropical anvils. The anvil lifetime, typically 6-12 hours, exceeds the duration of deep convection by many hours. Far from the active centre of the convective core the anvil structure becomes optically thinner but still has a significant radiative impact. The day after strong convective episodes large residual cirriform clouds persist for several hours. The microphysics of ice crystals within this type of clouds systems is an important parameter impacting radiation budget, the amount of water stored in ice phase within the troposphere and chemical concentrations for soluble species and species that adsorb onto ice. Regarding more specifically the African Monsoon mechanisms, the convective anvils, through their modification of the atmospheric dynamics on a large area, is expected to play a significant role of modulation of some of the monsoon components (e.g., modulation of the subtropical jet, warming of the upper troposphere, modification of the radiative budget, dynamical feedbacks with the convective part of the squall lines, moistening of the environment of the convective anvils, modification of the precipitation efficiency, and of the reevaporation after the passage of an MCS…). The magnitude of this modulation is completely unknown, and is a major objective of this project. Two types of flight plans are proposed to address these scientific objectives, which are described in the following.

I4.1: Horizontal microphysical variability of MCS anvils

The “mesoscale structure flight” will be performed with a single aircraft, the F/F20, equipped both with RALI (combination of a 5-beam 94 GHz Doppler cloud radar with a 3-λ (355, 532, 1064 nm) high-spectral resolution lidar) and a set of standard in-situ microphysical sensors (FSSP / 2D-C / 2D-P). The main objective of this flight pattern is to obtain a three dimensional description of the internal dynamical (3 wind components), thermodynamical (pressure and temperature perturbations) and microphysical/radiative (ice water content, effective radius, optical extinction and depth) structure of the MCS anvil and thus to derive physical properties at the scale of the anvil.

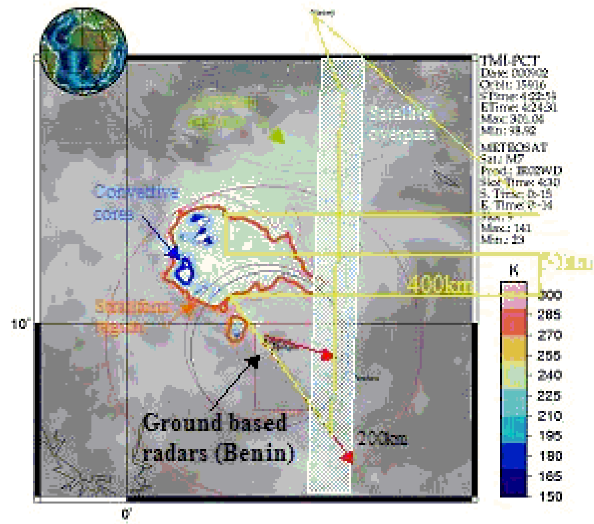
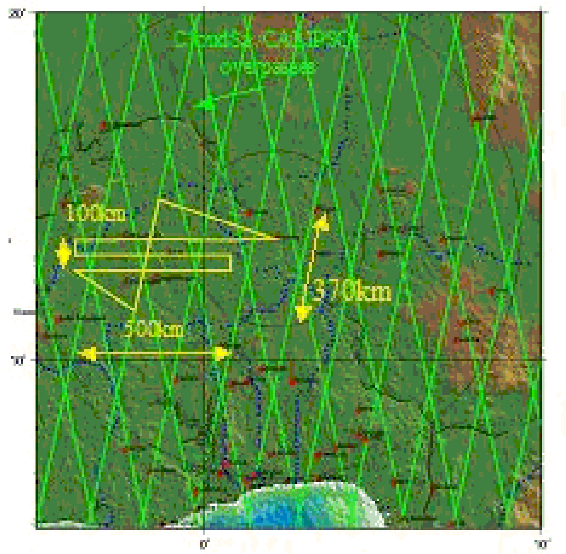
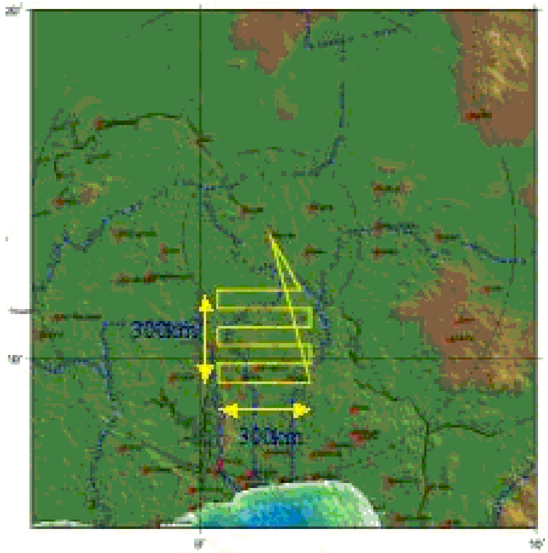


Figure 2.4.14a (left): General concept for proposed aircraft operations for IOP I4.1.

Figure 2.4.14b & 2.4.14c (below): Possible adaptations of the "Mesoscale structure flight"





The general concept of "mesoscale structure flight is presented in Fig. 2.4.14a: it consists in three legs (400 to 500 km in length, that is, 45 minutes assuming the F-F20 ground speed is 200 ms^{-1}) aligned with the propagation direction of the MCS at the same altitude (as high as possible : about 11-12 km for the F20), separated horizontally by about 50 km, sampling the stratiform and cirriform region of the MCS. Overpasses of ground based facilities of ground based facilities (MIT C-band radar & ARM Mobile facility, Ronsard or Xport for instance) will be achieved for purposes of validation of the classification of hydrometeors and combined analysis for the description of the 3D dynamics. The remaining time of the mission will be used for taxi to the airport, The aim of such a flight plan is also to document the transverse variability of the MCS anvils in terms of microphysical, radiative and dynamical properties since three parallel vertical cross-sections will be sampled. This will be particularly useful for the processing of the spaceborne observations. The spaceborne active remote sensing instrumentation that will be launched in 2006 is on a polar orbit (CloudSat / CALIPSO). It is then expected that this sampling strategy will provide a transverse documentation for the 2D documentation from space, that can be used to extrapolate the active remote sensing retrievals to the case of the passive spaceborne instrumentation of the A-Train (much larger swath).

Then by using data assimilation tools developed in the framework of WP3.1.1 (MANDOPAS) the use of these three legs and of the dropwindsondes information (possibly ground-based Doppler radars as well for flights performed in the radar coverage area) will give access to the 3D documentation of the MCS at mesoscale. This 3D documentation will then be used to access diagnostic parameters and the different terms of the water budgets related to ice phase (input to WP1.2). This 3D docuemntation can also be interpreted as a quasi-instantaneous image of the system (as can be obtained from a model output). Thus by degrading this image at different model scales (CRM or GCM for instance) the sub-grid scale variability of microphysical, radiative and dynamical parameters can be computed and compared with those held in models (input to WP 2.1).

The *"mesoscale structure flight"* concept is given in Fig. 2.4.14a for an ideal situation where a well organised system is passing over the region of interest and in coincidence with a satellite overpass. The probability that such a situation occurs is not very large given the 12 days of SOP2a3 period. This flight plan will therefore be adapted to field situations in order to match as well as possible the scientific objectives. Several constraints have to be taken into account : distance of the system to Niamey (where the F-F20 will be based), size of the system, degree of organisation, satellite overpass... Two main adaptations are proposed and illustrated in Fig.2.4.14b ("priority to satellite overpass") and in Fig.2.4.14c ("priority to 3D documentation"). In all cases these adaptations fit the 4.5h time mission devoted to the F-F20 scientific flights.

The first one (Fig.2.4.14b) will give priority to the A-Train overpass (as shown by the green line). It will be particularly suitable for clouds resulting from convection of the day before and persisting for several hours. First the three legs will be performed in order to document the organisation of the MCS anvil perpendicular to the A-Train track and then the aircraft will fly below the satellite track in coincidence with the satellite schedule. In this case the priority will not be given to ground stations overflown. In the second case (Fig.2.4.14c) the legs in the main propagation direction of the MCS anvil are shortened but multiplied in order to cover a 300 x 300 km^2 domain. This adaptation is particularly suitable for obtaining a 3D documentation of the system using the MANDOPAS tool.

I4.2: Vertical microphysical variability of MCS anvils

The "mesoscale structure flight" will be performed with a single aircraft, the F/F20, equipped both with RALI and a set of standard in-situ microphysical sensors (FSSP/2D-C/2D-P). The main goal is to document the vertical layering of microphysical properties.

This flight plan consists in three legs of about 540km (45' minutes assuming the F20 speed is 200 ms^{-1}) aligned with the propagation direction of the MCS at three different altitude (7,9 and 11 km for instance, but in all cases well above the melting layer in order to avoid aircraft freezing problems), sampling the stratiform and cirriform region of the MCS. These legs must overpass the ground based facility performing polarimetric measurements (Ronsard or Xport for instance) which will provide ice hydrometeor classifications. The remaining time of the mission will be used for taxi to the airport and ascending and descending trajectories in order to build vertical profiles of detailed microphysics properties with in-situ probes.

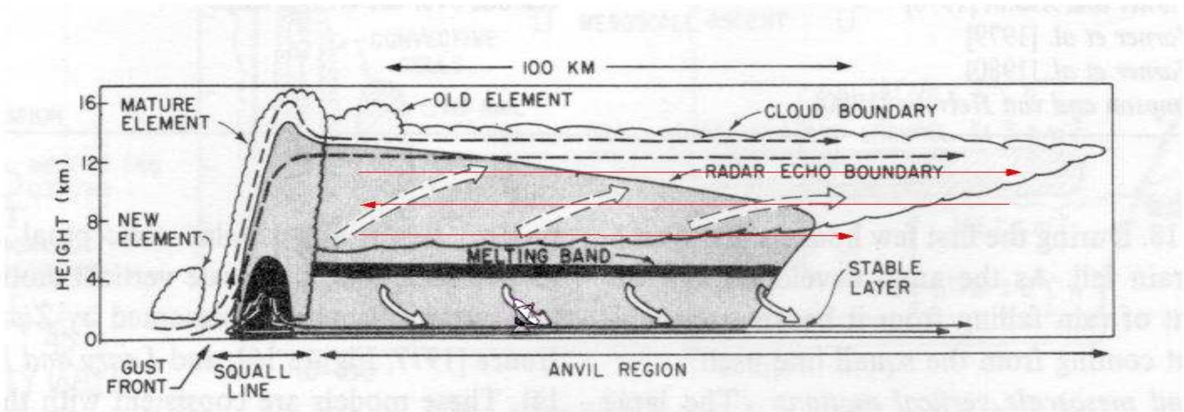


Figure 2.4.15: Proposed aircraft operations for IOP I4.2.

This kind of flight plan will be particularly dedicated to the detailed vertical microphysics documentation, since the aircraft will sample three different altitudes where different ice particle habits are expected. This documentation is of particular interest for the improvement of rain products obtained from spaceborne microwave radiometers and for validation of hydrometeor classification obtained from ground-based polarimetric meausrements (see WP2.1) Therefore the priority will be given to it in case of a well organised MCSs passing over one of the ground stations where polarimetric radars are installed.

Such a flight plan will also give access to the temporal variability of microphysical, radiative and dynamical properties since the same vertical cross-section will be described three times. It is thus of particular interest for comparison with CRM simulations that will be performed with a detailed ice microphysics parametrisation in the framework of WP2.1.

I5: Intensive regional observations

It has been proposed to make an intensive set of regional observations over two 10-day periods during SOP 1 and SOP2. These observations are for the evaluation of flux budgets, in particular through assimilation in global and regional numerical weather prediction (NWP models). Such measurements are important to data impact evaluation, or in association with prediction of high-impact weather (the theme of AMMA Working Group 5) such as hurricanes, or possibly of dry spells in the Sahel.

Observations which could be included in such intensive studies would be:

- Radiosondes;
- Targetted dropsondes – released in data-sparse areas or in areas identified through objective targeting techniques, such as singular vector computations;
- Driftsondes;
- GPS water vapour systems;
- UHF and VHF wind profilers.

Two I5 periods are planned:

I5.1 Monsoon onset (20 – 29 June 2006).
I5.2 Monsoon peak (1 – 15 August 2006).

In each period, we propose to make 8-per-day radiosoundings on the southern radiosonde quadrilateral, and at Agadez. This is a tough demand at these stations, particularly in gas production, and the stations will need to be supplied with additional staff. We will also make every effort to ensure that other stations in the network are operating at their best capacity in each period.

I6: Intercomparison flights

If the data from the different aircraft is to be combined either in a single experiment around an MCS or across the whole campaign it is essential that can quantify any differences between comparable measurements. This requires wing-tip to wing-tip comparisons between the aircraft for which flight hours must be set aside. To minimise the number of comparison flights required a change of comparisons could be set up that would link all aircraft. The instrument suite on each aircraft should be considered to ensure that all similar instruments can be linked.

Since it is usually a requirement that pilots meet before a comparison flight it will be easier for aircraft at the same base to perform such flights. During SOP2-a2 the DE/F20 and the M55 will be at Ouagadougou and the F/F20, F/ATR42 and UK/BAe-146 will be at Niamey. The UK/BAe-146 could perform comparison runs with both the F/F20 and F/ATR42 during this period. It is suggested that the DE/F20 and the M55 perform a comparison flight. The link between the two sets of aircraft might be the F/F20 and DE/F20 (If required it might be possible for the pilots to meet during SOP2-a1 when both aircraft will be in Niamey. It may also be necessary to compare instrumentation flown during SOP2-a1). The comparisons should involve level runs of around 15 minutes in clear sky at 2 to 3 altitudes to cover a range of meterological and chemical conditions.

2.5 Flight hours provision during the SOP

The funding sources for different IOP patterns are presented in Table 2.51.

	I1							I2	I3		I4	
	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2.1	I3.1	I3.2	I4.1	I4.2
BAe146				NERC	NERC EU	NERC		NERC	EU			
ATR	API	API	API				API	API	API			
F-F20	API	API	API					API	API		API	API
D-F20	EU							EU	EU			
M55									EEIG INSU CNES EU			

Table 2.5.1: Funding sources for different IOP patterns and aircraft.

The number of flight hours for each aircraft are summarized in Table 2.5.2. The proposed partition between IOPs is also detailed. The figures given in the Table are for secured flight hours. The numbers given between parentheses indicate the number of flight hours for which additional funding is sought.

F/ATR and F/F20: The cost for the SAFIRE aircraft are covered by the AMMA-API (contributions for many French Agencies). A minimal number of flight hours has been secured to ensure the meaningful scientific assessement. Additional flight hours have also been requested to enhance this assessement.

D/F20: The costs for the D/F20 deployment are covered by AMMA-EU (50%) and DLR. AMMA-EU finances a total of 4 weeks (2 weeks WIND + 2 weeks in situ aerosol/chemistry) with 4 local flights in each 2-week-period. Additional Falcon flights and an extension of one week are being sought from German funding sources.

M55/Geophyisca: The costs for the Geophysica are covered by contributions from various agencies – namely the EEIG, INSU, CNES, AMMA-EU and SCOUT-O3 giving a total of 600 k€ plus 305 k€ from M55 instrument PIs and associated groups who are paying for their participation in the campaign. A proposal has been submitted to INSU & CNES to request for additional flights of the M55, in particular in convective outflow regions of mesoscale convective systems. The priority request is for 2 additional flights (Option 1) - one additional flight in MCS outflow with focus on trace gases (Option 1a) and one additional flight in MCS outflow dedicated cirrus and CALIPSO validation (Option 1b). Further options have also been proposed: Option 2 (3 additional MCS flights - 2 cirrus + 1 trace gas) and Option 3 (4 additional MCS flights - 2 cirrus + 2 trace gas).

ATR42

Flight plan	I1.1	I1.2		I1.3	I1.4	I1.5	I1.6	I1.7		I2.1 and I2.2	I3	I4.1	I4.2
								I1.7.1	I1.7.2				
Description of FP	ITF and Heat Low	Aerosol emissions/ squall passage		N/S Land/Atmos/Ocean interaction	Land/Atmos interact	Veget. emission	Urban Survey	Aerosol mixing. Hygroscopicity		Dyn and Chem of MCS	Long range transport	Mesoscale structure	Vertical structure
		Before squall line	After squall line					Niamey-cotonou +guinee gulf	Niamey-Hombori				
FH/flight	4	4	4	4				4	4	4			
nb of flights	8	2	2	4				3	1	16			
Total FH	32	8	8	16				12	4	64			
Typical time of flights	0700 - 1600 LT	Variable	variable	0700 - 1600 LT				Variable	Variable	Variable			
Total													**144**

F-F20

Flight plan	I1.1	I1.2		I1.3	I1.4	I1.5	I1.6	I1.7		I2.1 and I2.2	I3	I4.1	I4.2
								I1.7.1	I1.7.2				
Description of FP	ITF and Heat Low	Aerosol emissions/ squall passage		N/S Land/Atmos/Ocean interact	Land/Atmos interact	Veget. emission	Urban Survey	Aerosol mixing. Hygroscopicity		Dyn and Chem of MCS	Long range transport	Mesoscale structure	Vertical structure
		Before squall line	After squall line					Niamey-cotonou +guinee gulf	Niamey-Hombori				
FH/flight	4	4	4	4						4	4	4	4
nb of flights	8	2	2	4						11	3	3	3
Total FH	32	8	8	16						44	12	12	12
typical time of flights	0700 - 1600 LT	Variable	variable	0700 - 1600 LT						Variable	Variable	Variable	Variable
Total													**144**

D-F20

Flight plan	I1.1	I1.2		I1.3	I1.4	I1.5	I1.6	I1.7		I2.1 and I2.2	I3	I4.1	I4.2
								I1.7.1	I1.7.2				
Description of FP	ITF and Heat Low	Aerosol emissions/ squall passage		N/S Land/Atmos/Ocean interact	Land/Atmos interact	Veget. emission	Urban Survey	Aerosol mixing. Hygroscopicity		Dyn and Chem of MCS	Long range transport	Mesoscale structure	Vertical structure
		Before squall line	After squall line					Niamey-cotonou +guinee gulf	Niamey-Hombori				
FH/flight	3.5									4	4		
nb of flights	2									2	4 (+1)		
Total FH	7									8	16 (+4)		
typical time of flights	10:30-15:00 LT									variable	variable		
Total													31 (+4)

BAe146

Flight plan	I1.1	I1.2		I1.3	I1.4	I1.5	I1.6	I1.7		I2.1 and I2.2	I3	I4.1	I4.2
								I1.7.1	I1.7.2				
Description of FP	ITF and Heat Low	Aerosol emissions/ squall passage		N/S Land/Atmos/Ocean interact	Land/Atmos interact	Veget. emission	Urban Survey	Aerosol mixing. Hygroscopicity		Dyn and Chem of MCS	Long range transport	Mesoscale structure	Vertical structure
		Before squall line	After squall line					Niamey-cotonou +guinee gulf	Niamey-Hombori				
FH/flight					4	4	2			4	4		
nb of flights				2 flights, with I1.5	12	5	2			4	3		
Total FH					48	20	4			16	12		
typical time of flights					1400-1800, 2000-2300	1200-1600, 1400-1800	any			variable	variable		
Total													100

Geophysica													
Flight plan	**I1.1**	**I1.2**		**I1.3**	**I1.4**	**I1.5**	**I1.6**	**I1.7**		**I2.1 and I2.2**	**I3**	**I4.1**	**I4.2**
								I1.7.1	I1.7.2				
Description of FP	ITF and Heat Low	Aerosol emissions/ squall passage		N/S Land/Atmos/Ocean interact	Land/Atmos interact	Veget. emission	Urban Survey	Aerosol mixing. Hygroscopicity		Dyn and Chem of MCS	Long range transport	Mesoscale structure	Vertical structure
		Before squall line	After squall line					Niamey-cotonou +guinee gulf	Niamey-Hombori				
FH/flight											5.5		
nb of flights											4 (+1)		
Total FH											22 (+5.5)		
typical time of flights											variable		
Total													**22 (+5.5)**

Table 2.5.2: Partition of flight hours between the IOPs during SOPs 1 and 2 for the F/ATR, F/F20, D/F20, UK/Bae146 and Geophysica.

IOP pattern	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2	I3	I4.1	I4.2

Aircraft	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2	I3	I4.1	I4.2
ATR-42	2	4	2								
F-F20	2	4	2								
D-F20											
BAe146											
Geophysica											

Table 2.5.3: Partition of numbers of flights according to IOP pattern and aircraft in SOP1-a

IOP pattern	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2	I3	I4.1	I4.2
Aircraft											
ATR-42	2	4	2					4			
F-F20	2	4	2					2			
D-F20	2							2			
BAe146											
Geophysica											

Table 2.5.4: Partition of numbers of flights according to IOP pattern and aircraft in SOP2-a1

IOP pattern	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2	I3	I4.1	I4.2
Aircraft											
ATR-42							4	12			
F-F20								9	3		
D-F20								4 (+1)			
BAe146			part of I1.5	12	5	2		4	3		
Geophysica								4 (+1)			

Table 2.5.5: Partition of numbers of flights according to IOP pattern and aircraft in SOP2-a2

IOP pattern	I1.1	I1.2	I1.3	I1.4	I1.5	I1.6	I1.7	I2	I3	I4.1	I4.2

Aircraft		
ATR-42		
F-F20	3	3
D-F20		
BAe146		
Geophysica		

Table 2.5.6: Partition of numbers of flights according to IOP pattern and aircraft in SOP2-a3

2.6 <u>Priorities for enhancement of the SOP activities</u>

2.6.1 C-band radar at Niamey (Protat)

The provision of radar at Niamey has been identified as a major priority for the SOP-Monsoon programme. Every efforts has been made to obtain and to fund a C-band radar at Niamey. A 75-day deploymen of the MIT C-band radar has been funded by NASA through a proposal submitted by Earle Williams. The current deployment is planned for the 1 June – 15 August 2006 period. **It is highly desirable to extend this period to at least the end of SOP 2a3 (i.e. 15 September 2006).**

The involvement of African scientists in the operation of the radar is being sought to offer some training and possibly extend the deployment over a longer time span by reducing the daily costs.

2.6.2 Scientific exploitation of the transit flights from Europe to Africa (Flamant)

Flight patterns

In the framework of the AMMA SOP, transit flights are scheduled between Europe and Africa, associated with the different deployment phases (Table 1). Because the air traffic routes cover a large part of the northern African continent, north of the AMMA domain, where data are sparce, the transit flights have been identified as potentially very valuable to enhance understanding of meteorological and radiative processes in the ‘heart’ of the Saharan heat low (SHL) region.

On 17 July 2006, the UK Bae146 aircraft is scheduled to fly Agadir – Niamey. This flight could, if space on the aircraft allows, conduct dropsonde and basic aircraft ‘core’ instrment measurements, at cruising altitude, which will be dedicated to the study of the ‘heart’ of the SHL and the inter-tropical front (ITF). We would aim to release dropsondes at 0.5 to 1 degree resolution (50 – 100 km) or possibly higher resolution over critical surface features. The dropsonde strategy for this flight will be developed in the context of high resolution model results and the data obtained from I1.1 flights in SOP1_a1.

Link with the modelling strategy

Measurements acquired on these transects will provide a high-quality set of observations for improving the representation the heat low dynamics and the impact of aerosol radiative forcing in numerical simulations and meteorological analyses, in a region where observations are scarce.

Link with satellite observations

Real-time tracking of mesoscale convective systems (MCSs) as aircraft should stay away from them.

Ground-based cooperation

Coordination with radiosondes from Tessalit will be strongly recommended.

Forecasting requirements

Position of the SHL and of the ITF.
Dry intrusions.
Position and height of the african easterly jet.
Tropospheric aerosol distributions.

2.6.3 Surface flux measurements in the heat low region (Parker)

The Saharan heat low (SHL) region is key to understanding the monsoon dynamics. The SHL is roughly defined as the region 20°-30°N, 15°W - 10°E. The SHL can be characterized as a region of high surface albedo, overlain by strong synoptic subsidence, where dry convection dominates. Mineral dust in the atmosphere when heated by shortwave solar radiation absorption presents a secondary heat source in the Saharan planetary boundary layer, also sometimes refered to as the Saharan aerosol layer (SAL). The presence of the dust layer combined with the high soil temperature which is controlled by the earth's surface heat balance, constitute a unique destabilization factor for the Saharan desert mixed layer. The thermodynamic budget of the thermal low over the Saharan desert is an important element of the climate of the West African region. It has recently been argued that the temperatures and pressures in this zone are critical to driving the whole monsoon system (Thorncroft and Blackburn). Indeed, Parker et al. (2005) show a good correlation between monsoonal winds at Niamey and the surface temperatures at 21.5N. Thus, the intensity of southerly/southwesterly monsoon flow (including the sudden surge associated with the so called "jump" or onset) is partly controlled by the intensity of the SHL. Variability in the fluxes in this region is strongly related to aerosol loading (e.g. Tompkins et al 2005) and shows (from satellite measurements) intraseasonal variability. Therefore, observations of actual fluxes and thermodynamic properties of this zone are required, in order to test and develop global and theoretical models.

Due to the logistical constraints of working in the heat low zone, a full EOP flux station in this zone was not feasible. Within AMMA, instrumentation to the north of the EOP surface flux networks is focussed on the Tamanrasset 'Supersite' (22°47'N, 05°31'E). Instrumentation here includes broadband radiometers, sun photometer and the Transportable Remote Sensing Station (TreSS) for observations of vertical profiles of the boundary layer, clouds and aerosols. However, this station is influenced by nearby topography and is rather north and east of the peak heat low. We therefore wish to make efforts to deploy broad-band radiometers in the heat low zone, perhaps at the synoptic station of Tessalit (Mali).

2.6.4 Airborne soil moisture measurements (de Rosnay)

Soil moisture remote sensing is a key component of AMMA project. It provides spatially integrated information on soil moisture at a scale relevant for atmospheric processes. METOP/ASCAT will provide soil moisture estimates for 2005-2007 from active measurements. AMSR microwave passive measurements has been providing soil moisture products since 2002. SMOS measurements for 2007-2010 period is extremely relevant to AMMA project to enhance the quality of soil moisture products over West Africa. In turn, West Africa is a hot spot region where SMOS is expected to have a major scientific feedback and crucial innovative applications for seasonal forecast, water resources management. AMMA project is selected as a validation site for the future SMOS satellite for the period 2007-2010. AMMA is a unique opportunity for SMOS project to validate soil moisture products and inversion algorithms at different spatial scales along a strong climatic gradient and for several annual cycles. The aim of validation studies over AMMA is to use both ground measurements and land surface modelling approaches to compare and validate SMOS products over West Africa in the framework of AMMA project (SMOS cal-val AO ESA de Rosnay et al. 2005).

The SOP (Special Observing Period) of AMMA in 2006 occurs before the SMOS launch, so that satellite based measurements of soil moisture with SMOS sensor will be not available for the SOP. However SMOS measurements during the SOP of AMMA is of great interest for both SMOS and AMMA projects. From the SMOS point of view, the main interest of possible L-band aircraft measurements during the SOP period of AMMA relies on the fact that:

i) the ground based measurements network is very important, including 24 soil moisture stations (profiles from 0 to 3m), complete meteorological station, 12 flux stations, vegetation measurements which are critical for SMOS algorithm validation. This network allows to consider a strong N-S climatic gradient including various vegetation cover and soil moisture conditions. The density of the measurements ensure to provide a complete data base particularly suitable to develop, to test and to validate direct and inverse approaches of microwave modelling,

ii) both the soil moisture and vegetation water content dynamics are very strong in July-August. This is critical too for the SMOS algorithms validation.

Conversely, SMOS is relevant for AMMA because soil moisture over Sahel is a key variable of the forecast systems (Koster et al 2004), soil moisture is involved in many disciplines related to WAM (plant phenology, chemical processes, convection, aerosol...). During the SOP, aircraft measurements of soil moisture with an L-band radiometer would provide information on soil moisture dynamic with a very high level of accuracy. Soil moisture is a critical boundary condition of the atmosphere. Its remote sensing estimation from L-band measurements in 2006 would allow to follow the soil moisture dynamic according to the convective systems developments and dynamic. Last, soil moisture is a critical variable in chemical processes studies which are characterised by high instrumental deployment during the SOP. Information on soil moisture from aircraft measurements is the basis of a better understanding of these processes.

Airborne soil moisture measurements are planed to be carried out during AMMA project in summer 2006. The flight plans will be established according to atmospheric flights devoted to atmospheric processes studies and accounting for local ground soil moisture measurements for validation objectives.

Soil moisture aircraft measurements are highly relevant for various SOP experiments:

- I1.1: heat low and InterTropical Front analysis during SOP1-2. However in June soil moisture variation remains limited in Sahelian area and the post-onset period is preferred.
- I.4 : atmospheric dynamic and aerosol, during SOP 2
- I.5 : vegetation survey

Each of this SOP campaigns presents specific interests in being coordinated with SMOS campaign. In order to identify priorities and define soil moisture flights calendar, a specific SMOS aircraft campaign meeting will be held in Biarritz meeting in September.

2.6.5 Additional Geophysica flights (Mari, Schlager)

The deployment of the M55-Geophysica in West Africa during AMMA is a unique opportunity to study these processes in a region of continental convection. The M55 will operate between 14 and 20 km, an altitude region not accessible by other AMMA aircraft. Note that there have been no previous measurements in the TTL over West Africa and more generally almost none over continental convective regions where MCS are thought to penetrate deeply into the stratosphere. Data collected in this region will also provide a contrasting picture to that from the SCOUT campaign in Darwin (Nov 2005); a region dominated by maritime convection. The proposed synergy between AMMA-funded aircraft measurements covering the boundary layer up to the TTL, SCOUT funded balloon measurements and satellite (CALIPSO) data validation and analysis will make a significant contribution towards addressing these issues at French and international levels. Joint analysis of data collected in this project as part of AMMA and elsewhere within SCOUT will lead to improved understanding about tropical upper troposphere.

A proposal has been submitted to INSU & CNES to request for additional flights of the M55, in particular in convective outflow regions of mesoscale convective systems. Due to the heterogeneity in emissions from different sources (vegetation, soils, urban areas, lightning NOx), we expect to see different signatures in trace gas and aerosol distributions in outflow regions in the UT/TTL. This is also an ideal region to study cirrus clouds and their properties. At present, only 4 local flights are funded – 2 dedicated to flights in the near-field outflow of convective (MCS) and 2 aimed at characterising the composition on larger continental scales. No flights are currently dedicated specifically to CALIPSO validation.

The priority request is for 2 additional flights (Option 1) - one additional flight in MCS outflow with focus on trace gases (Option 1a) and one additional flight in MCS outflow dedicated cirrus and CALIPSO validation (Option 1b). Further options have also been proposed: Option 2 (3 additional MCS flights - 2 cirrus + 1 trace gas) and Option 3 (4 additional MCS flights - 2 cirrus + 2 trace gas).

2.6.6 Convective initiation and break-up over Niger (Parker, Flamant)

During the Dakar conference, a number of suggestions have been made the TT8-chairs by the AMMA-Niger group:

- Ø AMMA-Niger is interested to improve understanding of CI in the vicinity of the Aïr Mountain (northern Niger, region of Agadez). Initiation over the Aïr is one of the 3 major MCS sources impacting Niamey. The CI processes are not entirely known as in some instances CI is forecasted in August, when the IFT is north of the Aïr) and does not occur. Prefered period is August. TT8 chairs are in charge of proposing ways in which existing flight hours might be used to explore the initiation of convection over the Aïr. AMMA-Niger is in charge of sending a more detailed rationale to TT8 chairs. It can be noted that the region of interest here corresponds to zone E of the I2 IOP pattern, I1.2, and an option for I1.4, and therefore may be consistent with existing options for flights.
- Ø AMMA-Niger is also interested in understanding the processes by which organized MCSs become disorganized upon reaching the region of Dongodoutchi and/or Dosso approximately 150 and 100 km, respectively, east of Niamey. Aircraft operations are adequate for this type of obsectives. Possible ground-based deployment has also been discussed (see below). Prefered period is August. TT8 chairs are in charge of proposing an adequate flight plan. AMMA-Niger is in charge of sending a more detailed rationale to TT8 chairs.

The sodar and tethered balloon team welcomes scientific partners from Niamey. Three UK scientists will work with the instruments during SOP2 (approximately 10 July - 31 August), and the addition of one or two local scientists to this activity (making a team of 5 in total) would be very helpful.

2.6.7 Instrument and data intercomparison

Intercomparison of data from different sensors on aircraft platforms is needed to ensure the coherence of the collected datasets and the relevance of the expected scientific results. Aircraft to aircraft intercomparison are extremely difficult to perform before the SOPs. Hence an effort should be made to coordinate such flights during the SOP. These flight should be regarded as priority by the funding agencies.

2.6.8 Participation of African PIs

Every effort needs to be made to support the costs of African scientists to take part in the operational planning and procedures during SOP1 and SOP2, particularly in the primary and secondary operational centres.

3. Operations Coordination

This part details the operational responsibilities and schedules of AMMA SOP1 and SOP2. The plan is needed as guidance for the logistical teams, notably those of the AMMA Operational Centre (AOC), in order for them to plan their activities. ***It is still being discussed amongst the TT8 participants***.

The objectives of the SOP coordination are:

- To manage, and to maintain information on the operational status of instruments, on the current environmental situation, the records of previous and ongoing activity, and the planned activities of PIs;
- To implement decisions on the commencement and termination of IOPs, based on the current and predicted environmental conditions, and the status of operational facilities;
- To review and select the most promising scientific activities for the coming days, based on environmental analyses and predictions, as well as on previous activity and the level of 'opportunity' represented by a forecast;
- To select the most suitable operational modes and timings of 'responsive' ground-based instruments and aircraft;
- To communicate decisions to all of the necessary teams and personnel;
- To liaise between scientists and operational centres such as ATC.

It must be stressed that the degree of coordination needed for operations is not anticipated to be the same. For instance only one aircraft will be deployed during SOP 2a3, while five aircraft (based on 2 international airports in different countries) will be deployed during SOP 2a2. Coordination in the latter case is further complicated by the meteorological features being targetted (MCSs for example). Fortunately, difficulties will increase crescendo during the SOP, starting with the deployment of two aircraft (SOP 1a), then three (SOP 2a1) enabling TT8 members and SOP leaders to build sufficient expertise before the much dreaded SOP 2a2.

Finally, the Operations Coordination Plan defined here **will be revised** following the SOP0 activities of January – February 2006. In particular, greater precision will be given to the timings of the daily meetings, and to the processes of liaison with ATC.

3.1 Coordination structure

3.1.1 Named responsibilities

In the following we detail a number of identified responsibilities to be filled in the course of the SOP. Note that this is a general framework, which can be applied to all aircraft SOPs. Nevertheless, in some cases, some of the responsibilities may not be required, as per example during the SOP 2a3 which only involves one aircraft.

<u>Scientific Coordinator:</u>
The Scientific Coordinator should be a named senior scientific PI, from the ISSC Executive Committee, designated on a weekly rota and preferably not an identified

instrument/platform PI. For each week, there will be named deputies, who will provide for rest days, continuity from week-to-week, and cover in case of sickness.

Possible candidates:
ISSC-EC: CD Thorncroft (CDT), JL Redelsperger (JLR), T Lebel (TL), J Polcher (JP), A Diedhiou (AD), DJ Parker (DJP).

Identified tasks:
- acts as chair of the IOP Selection Team
- liaises with local authorities where necessary
- in charge of producing the IOP overview summary
- ensure the balance between the different objectives of the SOP
- takes a final decision on the type of IOP to be run, in case of ambiguous forecasts, i.e. which cannot provide clear guidance for a particular type of IOP, and in case of dispute between PIs of the IOP Selection Team.

<table>
<tr><th>SOP</th><th>SOP 1-a</th><th></th><th>SOP 2-a1</th><th colspan="4">SOP 2-a2</th><th>SOP 2-a3</th></tr>
<tr><td>Dates</td><td>1 – 15 June</td><td></td><td>1 – 15 July</td><td colspan="4">17 July – 25 August</td><td>1 – 15 Sept</td></tr>
<tr><td>Scientific Coordinator</td><td>1 – 15 June
Lebel</td><td>16–30 Jun
Diedhiou</td><td>1-16 July
Lebel</td><td colspan="2">17–30 July
Thorncroft</td><td>31 Jul– 3 Aug
Redelsperger</td><td>14–25 Aug
Polcher</td><td>26 Aug – 15 Sept
Lebel</td></tr>
<tr><td>Deputy</td><td>AD</td><td>TL</td><td>AD</td><td>-25
DJP</td><td>26-
JLR</td><td>TL</td><td>Tl / AD</td><td>AD</td></tr>
<tr><td>Others available at AOC</td><td>CF</td><td></td><td>CF</td><td></td><td>TL, AD, DJP</td><td>AD, DJP, JP</td><td>DJP</td><td></td></tr>
</table>

Table 3.1.1: Suggested schedule for Scientific Coordinators. Initials are CD Thorncroft (CDT), JL Redelsperger (JLR), T Lebel (TL), J Polcher (JP), A Diedhiou (AD), DJ Parker (DJP), C Flamant (CF). These details are provided also in Appendix D, Table D3, along with other 'Named Responsibilities'.

<u>Scientific secretary:</u>
The Scientific Secretary should be a scientist, on a weekly rota (with a named alternate), preferably not an identified instrument/platform PI. The Scientific Secretary shall be familiar with West African Meteorology as well as with the AMMA project. The Scientific Secretary will be a member of the IOP Selection Team.

Identified tasks:
- liases with forecasters and instrument PIs where necessary
- in charge of collecting all forecasts, and making the information available on the relevant web pages
- in charge of writing the minutes of each small group or plenary meetings, and making these minutes available on the relevant web page
- in charge of keeping records of general weather situation, and making the information available on the relevant web pages
- in charge of collecting the IOP overview summaries, and making them available on the relevant web pages
- in charge of collecting instruments/platforms mission summaries written by PIs, and making them available on the relevant web pages

<u>Facility Coordinator</u>

The Facility Coordinator monitors and maintains records of instrument, personnel and facility status, and maintains communications between facilities, in terms of the evening briefings and the necessary input to the IST. This person need not be a senior PI, but should have some familiarity with instrument operations, and is to be designated on a weekly rota (with a named alternate). Suitable post-docs and PhD students may undertake this job.

Identified tasks:

- in charge of the information flow between the primary AOC and the secondary AOCs as well as the isolated sites (Tamanrasset, Dano, R/V Atalante, etc..)
- in charge summarizing the status of each instrument/platform everyday, passing this information on to the IOP Selection Team and the IOP Planing Group and making this information available on the relevant web pages
- in charge of preparing, with the Scientific Coordinator, the summary of operations for the day, and making it available to all interested parties as well as putting it on the relevant web pages

<u>Facility Representatives</u>
Each facility or instrument must nominate a single representative (possibly with a deputy) for each period in which the instrument will be deployed. Each facility representative will liaise with the Facility Coordinator on a regular basis.

- keep records of status of facility
- contact point with Facility Coordinator for routine daily communications.

<u>Principal investigators (PIs)</u>
Each science team will declare which of their scientists is to be designated a PI. Certain roles and responsibilities are expected of PIs; notably the ability and authority to make decisions regarding instrument deployment, and a scientific stake in the outcomes of the programme.

3.1.2 Planning sub-groups

3.1.2.1 IOP Selection Team (IST)

IOPs will be selected by an IST. It is important that the IST does not become too large to function effectively, in its meetings and its decision-making capacity. A nominal maximum membership is suggested to be 12 people on any given day.The composition of this group will be as follows (and to be reviewed by the Scientific Coordinator).

- The management group for each key platform or instrument will nominate its own PI for a given day, who will have final responsibility for the activities of that platform or instrument in the IST. It may be necessary for a given platform to nominate 2 or 3 PIs where there may be conflicting interests on the use of that platform, or if it is likely that decisions for the following day’s activities may have to be made in the absence of PIs who are currently flying.
- The IST will also comprise other PIs of AMMA who are not members of the management teams of particular instruments, and including African scientists.
- The IST will be chaired by the Scientific Coordinator.

3.1.2.2 IOP Planning Group (IPG)

Following the discussions of the **IST**, a small **IOP Planning Group** will work on detailed flight plans (to be activated the following day), and will, where necessary, choose between IOP options, and abort when necessary. The IOP planning group will comprise the following personnel:

- PIs of instruments involved in the IOP in question; in particular the Mission Scientists scheduled to fly on each aircraft;
- Other PIs with a direct scientific interest in the IOP, as approved by the IST;
- One operational forecaster according to a pre-arranged roster.

It is possible that more than one IOP planning group may be nominated for a given day J0, for instance if separate IOPs in different parts of the region are planned. In such cases, the operational forecaster will divide his responsibilities between the different groups as required.

The IPG will begin its work at the downtown Operational Centre, following which it will move to the airport for submission of any necessary flight plans on day J-1. Suitable transport will be required to convey the IPG members to the airport on day J-1, and for flight planning on day J0.

The activities of each IPG will be scheduled to meet the needs of the given IOP. For instance, the IPG will need to prepare details of flight plans in the hours leading up to a given take-off time.

3.1.2.3 Operational forecast team

The operational forecast team will comprise local forecasters working at ACMAD. An ideal mode of activity will be for the operational forecasters will work in a combination of daily shifts and 'responsive' activity during IOPs. A suggested schedule for 4 forecasters would be the following:

Day:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
F1	D	D/I	I	X	D	D/I	I	X	D	D/I	I	X	D	D/I	I	X
F2	X	D	D/I	I	X	D	D/I	I	X	D	D/I	I	X	D	D/I	I
F3	D/I	X	D	D/I	I	X	D	D/I	I	X	D	D/I	I	X	D	D/I
F4	D	D/I	X	D	D/I	I	X	D	D/I	I	X	D	D/I	I	X	D

Table: Possible roster for forecasters F1 to F4. D=daily briefing; D/I=daily briefing followed by IPG support; I=IPG support; X = rest day.

3.1.2.4 Driftsonde decision-making

1. Driftsonde launch and dropsonde deployment decision points are to be located in Toulouse.

2. Operations begin 15 August 2006 and if necessary run to 15 Sept

3. Decision team includes:

a) For 15 Aug to 1 Sept
One science staff representing AMMA SOP 2 (Drobinski)
One science staff representing NCAR driftsonde (Parsons)
CNES ballooning representative
Air traffic control interface
NCAR software specialist

b) For 1 Sept to 15 Sept
One science staff from downstream AMMA (To Be Determined)
One science staff from NCAR driftsonde (Parsons)
CNES ballooning rep
Air traffic control interface
NCAR software specialist (if necessary)

c) Decisions for operations are to be made after consultation with Niamey (AMMA prospective) and relevant forecast centers (THORPEX prospective).

3.2 Decision-making cycle

The decision-making cycle for IOPs is structured according to the requirements of aircraft operations, as these are the instruments requiring the most coordination (with Air Traffic Control in particular).

3.2.1 Schedule

The basic schedule of strategic planning for an aircraft-based IOP will be (for an operation on day J2):

- ***Day J0*** – identification of possible IOPs, based on available instruments and overall strategy
- ***Day J1*** – use of forecasts for identification of realistic IOP possibilities. Submission of a set of provisional flight plans, perhaps with a contingency option. The exact time at which these need to be submitted is yet to be resolved. NOTAM.
- ***Day J2*** – development of detailed flight plans, to be submitted at least 2 hours before take-off.

Two time scales have been utilized: one for meeting (UTC) and one for aicraft-related operations (time scaled with TO –Take off) and L (Landing) time stamps in red).

Nota: NOTAMs need to be submitted 24 h in advance for aircraft flying over 15000 ft (exact ceiling remains to be agreed) (F20s and M55/Geophysica). For aircraft below 15000 ft (to be agreed; ATR and BAe146), NOTAMs can be submitted for the entire SOP periods at the begining of the experiment.

Meeting schedule (UTC):

0500 – 0700 Preparation of daily forecast (ACMAD)
The forecast will be prepared according to criteria developed in consultation with the AMMA Forecasting Group, by 2 local forecasters working at ACMAD. One of these forecasters will subsequently be assigned to work with the IOP Planning Group.
This activity will create a record of the wider meteorological situation in the SOP periods, beyond the relatively narrow requirements of flight-planning.

Summary briefing to be put on the AOC web page to be available for other AOCs

0700 – 0730 Forecast briefing (Operational Centre)
Tailored to prepare next day's NOTAM to be submitted at 0900 UTC (1000 LT Niamey) where necessary.

Forecasters will present an outlook of the conditions for Days J0, J1 and J2.

According to the SOP, forecasters will the present a comprehensive forecast of the meteorological features of interest to the PIs (i.e. the IFT, AEJ, AEW, MCSs, etc..). This aspect of the forecast will be crucial for the subsequent discussions and will likely facilitate appropriate proposals by PIs at the Niamey and Ougadougou AOCs. The meeting will consists of:

i. Presentation of the forecast for the coming 48 hours and outlook (Forecast Office),
ii. Presentation of special products relevant to IOPs (PIs).

0745 Deadline for receipt of status reports from all platforms and isolated sites
The Facility Supervisor will ensure that the reports are available on the web and investigate in case of missing reports

0800 Deadline for indications of likely operations for Days J1, J2 and J3
The Facility Supervisor will collect proposals (Table of IOP patterns) and make sure them available on the web. A simple summary of such proposals is suggested in Table 3.0.

Facility	J1	J2	J3
ATR	I1.7	I2 or I1.7	I2
BAe 146	I1.5 or I1.4	I2 or I1.4	I1.4 or Downday
F-F20		I2	
D-F20	Downday	I2	
M55		I2	

Table 3.0: Typical summary of proposals for coming days, as received from aircraft teams by Facility Supervisor.

0815 – 0830 Morning IST meeting (Operational Centre)
Teleconference – Discussion amongst the IST (IST members may be scientists associated with secondary AOCs). The meeting will consits of:

i. IOP priorities for Day J1, Day J2 and Day J3,
ii. **Nomination of the IOP Planning Group for Day J1 and Day J2, including contingency plans.**

List of responsibilities for the IOP Planning Group:

i. Definition and preparation of the flight plans, including T.O. time,
ii. Prepare notification of all involved secondary AOCs, isolated sites and associated platforms/instruments (web & telephone) with Scientific Secretary and Facility Coordinator,
iii. Nomination of Day J1 Early Bird meeting at ACMAD (in case of newly selected IOP by the IST)
iv. Nomination of Day J1 Flight Monitoring Group (in case of newly selected IOP by the IST)
v. Nomination of Day J2 Early Bird meeting at ACMAD,
vi. Nomination of Day J2 Flight Monitoring Group,
vii. Consultation with pilots and preparation of NOTAM.

0830 – 1430 Documentation of meteorological forecast (ACMAD)
The objective of the afternoon monitoring is prepare the **IOP Selection Team meeting** and the **Evening briefing** (see below).

1600 – 1615 IOP Selection Team meeting (Operational Centre)

Teleconference – Discussion amongst the IST (IST members may be scientists associated with secondary AOCs). The meeting will consits of:

i. Weather update (Forecast Office) as well as presentation of special products relevant to IOPs (PIs)
ii. Reassessment of priorities

1700 – 1800 Evening open TT8 meeting (Operational Centre) to be led by the Science Coordinator
The discussion will be an open meeting, to which all members of TT8 will be able to contribute. This daily meeting will consist of:

i. Review of Day J0 IOP (on days when an IOP was conducted, including wheather and data quicklooks)
ii. Review of IOP plans for Day J1 and Day J2.

<u>Operation schedule on IOP days envolving aircraft (in addition to the above):</u>

T.O.-5h – T.O.-4h Early birds meeting (ACMAD or Operational Centre)
The PIs designated by the IOP Planning Group for that day and the Forecasters on duty meet to review the latest weather update for the coming day. The best place for this meeting to be held is left at the discretion of the PIs. **This meeting will include consultation with all relevant AOCs and facilities.** For PIs not so familiar with forecasting in West Africa, such meeting could take place at ACMAD to faciliate inetractions with forecasters and ensure quick decision-making. For PIs familiar with forecasting issues over West Africa, this meeting could take place at the Operational centre, PIs then being able to communicate with Forecasters by phone or e-mail. The objective of the meeting is two-fold:

- Make final decision on wether the IOP should be conducted with the aircraft (GO/NOGO decision),
- Prepare a modified set of flight plans if needed, according to the weather update.

This group of PIs will decide to alert/inform aircraft teams.

T.O.-4.5h – T.O.-2h Transfer to Airport
Transfer of aircraft operation, technical and scientific crews from Hotels to Airport. Each platform works on its own schedule (BAe 146 powered 4 h before T.O. / SAFIRE aircraft powered 2 h before T. O.)

T.O. – L. Monitoring of flight planning (Operational Center and/or airport)
Monitor weather conditions, especially in the case of MCS related IOP (I1.2, I2, I3 or I4). A group nominated by the IPG will work in close interaction with ATC, pilots and aircraft scientists. **Includes nowcasting and MCS tracking when needed.**

L. – L.+0h30 Post IOP aircraft debriefing (Airport or downtown – at the discretion of each facility)
A short debriefing after the flight is possible for a quick shakedown of operations as well as prepare the IOP report for the open TT8 evening briefing. Alternatively this meeting can be held downtown in association with briefings for the following day.

Once an IOP is called, the IOP Planning Group will begin work on detailed flight plans and schedules. This activity will commence at the downtown operations centre. On the day of the flight, the IPG will continue working solely on this IOP, while the IST activities continue in parallel for consideration of subsequent days. This implies that sufficient mission scientists are available at the operational centres to work on current and future IOP planning. Note that the IST activities follow a fixed schedule each day, whereas the IPG activities must adapt to the particular timing of that IOP plan.

IOP pattern	I1.1: ITF and Heat Low Surveys	I1.2: Dry Squall Line Passage	I1.3: N-S Land-Ocean-Atmosphere Interactions	I1.4: Land-atmosphere	I1.5: Vegetation Emission Surveys	I1.6: Urban Surveys	I1.7: Aerosol Mixing and Hygroscopicity	I2: Dynamics and Chemistry of MCSs	I3: Long Range Transport	I4: MCSs Mesoscale & vertical Structure
Key Phenomena/ Lead time	24 hours	24 hours or less	1-4 days	1-4 days	24 hours	12 hours	1-4 days	24 hours	1-3 days	24 hours or less
Intraseasonal regime	Flights before and after monsoon onset	Pre-onset	Monsoon onset.	Presence of wet or dry period; likelihood of subsequent rain	Presence of wet or dry period	N/A	N/A	Presence of a wet or dry period	Needs to be defined.	Presence of a wet period
Heat Low	Intensity of heat low	N/A	Intensity of heat low	Intensity of heat low	N/A	N/A	N/A	N/A	N/A	N/A
ITCZ/ITF	Location of ITF affects flight patterns	N/A	Location of ITCZ affects flight pattern	May influence latitude of flights	May influence latitude of flights	N/A	Location of ITCZ affects flight pattern	Influences convective regime.	N/A	N/A
Jets (AEJ, TEJ, STJ)	Consider AEJ position and strength	N/A	N/A	May influence latitude of flights	Affect latitude of flights	N/A	N/A	Influences convective regime.	Jet strengths influence outflow	Influences convection regime
AEWs and vortices	Consider AEW activity and phase.	N/A	Consider AEW activity and phase.	May influence location of flights	Location and intensity of trough/ridge patterns and vortices	N/A	N/A	Location and intensity of trough/ridge patterns and vortices	Consider AEW activity and phase.	N/A
Dry intrusions	N/A	N/A	N/A	N/A	May be relevant to AEW patterns	N/A	N/A	Location and depth of dry air	Strong SAL intrusions wil be of interest	N/A
MCSs and convection	Avoid Cb	Dry squall events.	Seek land surface responses to Cb. Avoid Cb during flights.	Seek land surface responses to Cb. Avoid Cb during flights	Avoid Cb	Avoid Cb	Avoid Cb	MCSs over the mesoscale ground sites	May follow MCS events from east to west	MCS over the radar ground sites or within the swath of the A-Train
Non-precipitating convection	N/A	N/A	N/A	May Influence flight pattern	Northward extent may affect latitude of flights	N/A	May Influence flight pattern	N/A	Northward extent may affect latitude of flights	N/A
Land surface	Flights before and after monsoon onset	Dust emission & deposition	N/A	Soil moisture will guide flight planning	Strong E-W soil moisture variability	N/A	N/A	Rainfall on dry surface could be attractive.	Probably N/A – needs to be clarified	N/A

Special products	N/A	Satellite aerosol products.	N/A	Soil moisture patterns from satellite	Chemical trajectories. Soil moisture patterns from satellite		N/A	Soil moisture patterns from satellite	Chemical trajectories	Ground based radar products

Table 3.1: Table of IOP forecast criteria (to be refined and coordinated with AOC). The elements in this table define factors which should be taken into account for each type of IOP. Those shaded yellow are critical for the decision to conduct that kind of IOP. Other criteria may affect the desirability of an IOP, or the details of its conduct (e.g. exact timings). Also, data from the mesoscale instrumented sites, and from recent aircraft observations, will be used in the planning process.

3.2.2 Conduct of an active IOP

The conduct of an active IOP will include the following considerations:

- The IPG will prepare detailed plans and timings for the proposed IOP immediately following the IST meeting. This work will be conducted at the Operational Centre in Niamey. Note that if we are able to anticipate an IOP on day J-2, members of the IPG may have been preparing IOP plans prior to the IST meeting on day J-1.
- All facilities will be notified by the IPG, through the Facility Scientists.
- A Flight Notification will be developed in consultation with pilots, and submitted to ATC after 1200 local time.
- The forecast will be monitored overnight, as necessary, by PIs from the IPG (or nominees).
- Detailed flight planning will commence around 4 hours before take-off, with the IPG working Operational Centre.
- A decision to abort the IOP and/or associated flights will be taken where necessary.
- During flights, the IPG will communicate with Mission Scientists on the aircraft. Mission scientists will pass requests to pilots directly. Pilots will work directly with ATC. There will be no direct formal communication between the IPG and ATC.

3.3 Planning

Personnel tables are included as Appendix G.

Personnel roles and availability during the SOP1-2 periods need to be established. As of today, the Scientific Coordinator, Scientific secretary, and Facility coordinators' rosters have not been finalised. Concerning the Instruments and platforms Pis, this task is being conducted by the **Aircraft** and **Ground-based** coordination groups. For the ground-based supersites, one or more coordinator needs to be identified beforehand in order to smooth communication between the primary and secondary AOCs.

4. Communications

During the SOP, some IOP patterns require a sophisticated level of communication between the secondary and primary AOCs, as well as between the primary AOC and the aircraft to ensure smooth running. At the same time, it is crucial that all secondary AOCs and isolated sites be informed of the progress in the campaign and the decisions that have been taken. In the case of isolated sites (e.g. Tamanrasset, Dano, N'Djamena), the type of support for such information shall be telephone : we propose that a message be recorded on a dedicated answering machine for all PIs to consult. This is believed to be the most reliable way of informing people. For those PIs who have access to internet, a message will also be posted on the daily operation web page.

As detailed in Section 2, information will be sought by the IST at the primary AOC from the different supersites involved in the IOPs, prior to or during the IOPs:

- Niamey/Banizoubou,
- Djougou/Oueme basin,
- Ouagadougou,
- Gourma,
- Dano,
- Tamanrasset,
- Cotonou,
- N'Djamena,
- The R/V Atalante.

As for the coordination, it must be stressed that the degree of communication needed for operations is not anticipated to be the same for the different SOPs. For instance only two aircraft will be deployed during SOP 2a1, while five aircraft (based on 2 international airports in different countries) will be deployed during SOP 2a2. Communication in the latter case is further complicated by the meteorological features being targetted (MCSs for example).

4.1 SOP 1a

On the days of operation, information from a number of given sites, most often in the general area of airborne operations, will be need for fine tuning of the flight plans as per example:

- Ø IOP I1.1: Need status report and information from Tamanrasset, Gourma and Niamey/Banizoumbou supersites,
- Ø IOP I1.2: Need status report and information from Niamey/Banizoumbou and Tamanrasset supersites,
- Ø IOP I1.3: Need status report & information from Tamanrasset, Niamey/Banizoumbou and Djougou supersites.

No specific meteorological conditions are not required for I1.1 and I1.3 operations. I1.2 type operations will strongly depend on the MSC forecast to give ample time for pre-MCS operations. As IOP I1.2 patterns need not be flown in the vicinity of MCSs, aircrfat guidance for the MIT C-band radar will not be requested. Satellite tracking of MCSs using MSG data will be sufficient.

4.2 SOP 2a1

As during SOP 1a, information from a number of given sites, most often in the general area of airborne operations, will be need for fine tuning of the flight plans as per example:

- Ø IOP I1.1: Need status report and information from Tamanrasset, Gourma and Niamey/Banizoumbou supersites,
- Ø IOP I1.3: Need status report & information from Tamanrasset, Niamey/Banizoumbou and Djougou supersites,
- Ø I2: Need status report and information Niamey/Banizoumbou and/or Dano and Djougou super sites – key data will be provided by the C-band radars.

IOP I2 aircraft PIs believe that it is very important to have the RONSARD and MIT C-band radar scientists involved in the aircraft operations. Note that even though aircraft do not intend to fly inside MCSs, it would be important to know which one are developing or decaying. Moreover the lightning network PIs are aiming to provide real time data (possibly overlain with RONSARD) through Djougou for aircraft guidance.

4.3 SOP 2a2

Information from a number of given sites, most often in the general area of airborne operations, will be need for fine tuning of the flight plans as per example:

- Ø I1.4: Need status report and information Tamanrasset, Niamey/Banizoumbou and Gourma supersites,
- Ø I1.5 & I1.7: Need status report and information Niamey/Banizoumbou and Djougou super sites,
- Ø I1.6: Need status report and information Niamey/Banizoumbou super site,
- Ø I2 & I3: Need status report and information Niamey/Banizoumbou and/or Dano and Djougou super sites – key data will be provided by the C-band radars.

The successful deployment of the Geophysica together with the D/F20 aircraft during SOP2_a2 in Ouagadougou requires close coordination and good communication with other aircraft and SCOUT-AMMA balloons based in Niamey during the same period, the lightning detection network at Djougou and water vapour/ozonesonde launch sites.

For optimum guidance of the airborne operations it seems important that real time radar (and similar) data (selected quicklook products) are available via internet for flight planning and guidance. A communication capability by phone between the radar operator and the flight planning groups, and possibly the mission scientist onboard, is also identified. This should include both the RONSARD and the MIT radars.

The real time information is not only important for aircraft operations within clouds but also for those aircraft trying to avoid clouds. Also last minute decisions on go or no-go for a specific IOP flight pattern needs real time information. Moreover balloon launches are relying on real time radar (esp. the MIT C-band radar).

The quicklooks to be transmitted via internet should include PPIs at selected levels every 10 min or so and ideally some information on cloud top height. If the latter is not feasible this should be communicated by the radar operator via phone as is also desirable for special scans like RHIs through area of most active convection. Once the radar quicklooks are available on the internet they will be accessible from anywhere not just at the AOCs.

Concerning the real Ouaga operations a certain degree of authonomy will be necessary. An overall coordination is absolutely necessary but the final decisions have always to be taken locally as there are many things coming up last minute and also the flight planning can only be done locally by the aircraft operator. So the comms between aircraft and ground staff will be done primarily with the respective airbase, thus requiring a strong secondary AOC in Ouaga. But these issues have to be discussed in more detail with the respective aircraft teams.

4.4 SOP 2a3

Two meteorological targets are chased in this SOP2a3 : (i) well-organised MCSs with fully-developed stratiform part, and (ii) widespread cirriform anvils persisting the day after the passage of a large MCS. The requirements for communication is much more demanding for the first target (well-developed MCS), while for the second target the description of the convective activity of the previous day and MSG images in real-time at Niamey are enough. For the well-developed MCSs, information from a number of given sites, most often in the general area of airborne operations, will be needed for fine tuning of the flight plans as per example:

- I4.1 & I4.2: Need status report and information from Niamey/Banizoumbou and/or Dano and Djougou super sites status – key data will be provided by the C-band radars.

Close coordination with the RONSARD and MIT C-band radars as well as lidars in Niamey (ARM Mobile Facility) and Djougou/Nangatchori (IPSL lidar) is the key to scientific achievement in this case. The success of the flight will essentially depend on the location of the aircraft inside the MCS anvil and cirriform areas. The most convective cells should completely avoided.

For optimum guidance of the airborne operations it is very important that real time radar quicklook be available via internet for flight planning. A communication capability by phone between the radar operator and the flight planning groups, and possibly the mission scientist onboard, is also identified. This should include both the RONSARD and the MIT radars. Also last minute decisions on go or no-go during an IOP flight needs real time information. The quicklooks to be transmitted via internet should include PPIs or CAPPIs at selected levels every 10 min or so and ideally some information on cloud top height. If the latter is not feasible this should be communicated by the radar operator via phone as is also desirable for special scans like RHIs through area of most active convection. Once the radar quicklooks are available on the internet they will be accessible from anywhere not just at the AOCs.

4.5 Summary of communication needs

Aircraft: Communication between the aircraft and the promary AOC is crucial for some IOPs. The UK/BAe146 is equipped with a satellite telecommunication, enabling the scientists to talk directly to the AOC without going through the pilots. The F/F20 and F/ATR will be equipped with satellite phones for SOP 2 (voice and possibly data transfers). D/F20 is equipped with satellite telecommunication (IRIDIUM). **The EEIG/Geophysica telecom equipment is tbd.**

Niamey/aiport: instruments deployed in the Niamey airport will be connected onto the primary AOC via a local loop.

Banizoumbou: Phone connection only is being provided using the Thuraya phones from the University of Oxford.

Djougou: we request that the radiolink between the RONSARD and Djougou is provided so that the Quicklooks can be available in real time at the Niamey AOC, for I2 and I4 IOP patterns in particular. We also request that a phone connection be available at the RONSARD site.

The Benin AOC has been working on realistic possibilities of communication between the different sites in the Oueme basin:

- Radio connection of Kopargo – Djougou and Nangatchori – Djougou and internet connection at Djougou,
- Direct satellite internet connection of Kopargo and Nangatchori.

For the moment, the budget of the AOC finances only the transmission of data sent by the RONSARD, all other communications should be beard by the different teams.

Ouagadougou: This secondary AOC may also support locally based AMMA activities in Burkina Faso. It will be managed by the logistical coordination group of EIGG (Stefano Balestri), EIER (Harouna Karambiri) and DLR (Heinz Finkenzeller) for the M55 and D/F20 mission. Certain improvements to the infrastructure at the airport are required before the campaign takes place. These include refurbishment of offices, the hangar and installation of high-speed internet (50-60 persons) and telephone lines.

Gourma: Phone connection only (?)

Dano: Phone connection only (?)

Tamanrasset: The TReSS platform is being hosted at the ONM in downtown Tamanrasset. The internet connection there will most likely not enable data or information exchanges in a satisfactory responsive mode. Internet cafés exists in Tamanrasset, but this is not very convienient. A telephone link with occasional

exchange of images by fax and/or internet will be the basic operation mode. This will be tested during SOP 0 starting mid-January, and revised if needed.
Telephone:+213-29-34-4673
Facsimile:+213-29-34-4673
Contact person E-mail: m_mimouni_dz@yahoo.fr

Cotonou: Phone connection only (?)

N'Djamena: Phone connection only (?)

R/V Atalante: Internet connection and cell phones. Daily bulletins will be provided by R/V Atalante PIs to the primary AOC (and vice-versa) during the 2 legs: B. Bourlès and G. Caniaux (leg 1) and B. Bourlès and L. Eymard (leg 2). The PIs e-mail addresses onboard the Atalante are:
bernard.bourles@atalante.ifremer.fr (24 May – 6 July)
guy.caniaux@atalante.ifremer.fr (24 May – 18 June)
laurence.eymard@atalante.ifremer.fr (1 June - 6 July)

4.6 Other issues

Apart from the communications needs for the AOC, the following are priorities for communication during the SOP:

- Links between the AOC and the responsive instruments for operation of the IOPs,
- Transmission of data from radiosondes and dropsondes to the GTS for assimilation into numerical weather prediction (NWP) models,
- Rapid release of aircraft data to PIs for post-flight analysis, and planning of subsequent flights.

5. Partnership

5.1 Field observations

A decision-making protocol for separately-owned instruments is outlined in section 3 above.

5.2 Training program

All partners will be included in the daily operational discussions, as members of TT8.

Efforts will be made by operators of the larger aircraft (BAe146, ATR42 …) to obtain permission for partners to fly on IOP missions. This process requires considerable forward planning and applications should be made **immediately** to Doug Parker, Claire Reeves or Cyrille Flamant. Information on this procedure will be sent to ST4.

We will make every effort to take account of the unfunded projects identified in the PIAF in our operational objectives.

5.3 Collaboration

The AMMA International conference in Dakar will be used to exchange scientific ideas among members of TT8.

6. Organisation of TT8

6.1 Leaders, core group, membership

Coordinators:
Cyrille Flamant (cyf@aero.jussieu.fr), Doug Parker (doug@env.leeds.ac.uk)

Core group:
Francesco Cairo, Suzanne Crewell, Arona Diedhiou, Cyrille Flamant, Paola Formenti, Anne Garnier, Hartmut Hoeller, Norbert Kalthoff, Katherine Law, Céline Mari, Doug Parker, Jean-Pierre Pommereau, Alain Protat, Claire Reeves, Hans Schlager, Chris Thorncroft, Garba Zibo.

Enlarged group:
The enlarged group is composed about **165 researchers** from **Europe** (about 100), **Africa** (about 55) and the **USA** (about 10). A detailed list of the enlarged group participants can be obtained from Doug Parker.

Representation:
- All of WP4.2 (management) in the EU project
- Instruments (a representative (PI) for each aircraft, and each ground instrument)
    - D-F20
    - F-F20
    - ATR42
    - BAe146
    - Geophysica
    - Radar (Protat, Williams and Jenkins)
    - Aerosonde
- Science areas (selected EU work packages):
    - WP1.1 WAM/global climate (Fink, Law)
    - WP1.2 Water cycle (Roux)
    - WP1.3 Land-atmosphere (Parker)
    - WP1.4 Scaling issues (Hall)
    - WP2.1 Dynamics and convection (Parker)
    - WP2.2 Oceanic (Brandt)
    - WP2.3 Physical / biological processes over land (Kunstmann)
    - WP2.4 Aerosol/chemical processes (Mari, Formenti, Reeves)
    - WP3.1 Land productivity
    - WP3.2 Human processes
    - WP3.3 Water resources
    - WP3.4 Health (Morse)
    - WP4.1 Modelling (Lafore)
    - WP4.3 Satellite (Desbois)
    - WP4.4 Database (Eymard, Hoepffner)
    - WP5.1 Weather Prediction (Kamga, Beljaars)
- National and international groups: e.g. Benin, EU, France, Germany, Mali, Niger, UK, USA, CSAM (Diedhiou, Gaye), …
- The NASA funded N-Pol activity

- AMMA-Weather
- ARM / RADAGAST
- International agencies: ACMAD, ASECNA, AGRHYMET, …
- PIs of PIAF proposals
- Representatives of linked TTs
    - TT1 Radiosondes (Fink, Parker)
    - TT2 Fluxes (Taylor)
    - TT3 EOP meso Gourma
    - TT4 EOP meso Niamey
    - TT5 EOP meso Oueme
    - TT6 Ocean (Brand, Bourles)
    - TT7 SOP-0 (Coe)
    - TT9 SOP-Downstream (Roux, Halverson, Protat, Bouniol)
    - ST1 EOP
    - ST2 Operations Centres (Diedhiou)
    - ST3 Database
    - ST4 Training and capacity building (Diedhiou, Parker)

We can conduct our business by email and telephone conference. We need a major international planning meeting, which has been proposed for 4-6 July 2005, to be held at the University of Leeds.

6.2 Internal coordination

The implementation of the SOP observations will be coordinated within the existing EU project structure, with separate **Aircraft (part of WP4.2.1)** and **Ground-based (part of WP4.2.2)** coordination groups. The leaders of the aircraft group will be Cyrille Flamant and Claire Reeves; the leader of the ground-based group will be Susanne Crewell and Alain Protat. It will be the work of this TT to ensure that the operations of these groups are complementary.

6.3 How are requests for new instruments handled?

These are discussed by the whole TT8 group and approved by the Core Group. Financial implications will also be considered, and discussed with the ICIG where necessary.

We also need to handle requests for new objectives with the existing instruments! This will be undertaken by the same groups.

6.4 External diffusion of the information and reporting

This TT will consist of members representing all the interest-groups relevant to SOP-Monsoon. This TT will also include representatives of the ICIG, ISSC and CSAM. These individuals will be tasked with reporting information out of the TT.

7. Coordination with other TTs

Team	Role	Refer to section	Summary
TT1	Upper air	2.2.1.1	High frequency radiosondes will be required, perhaps at short notice and in support of flights.
TT2a	Surface fluxes	2.2.1.7	Soil moisture and surface flux analyses, from ground sites and remote sensing, may be needed for planning of flights.
TT2b	Aerosol / rad'n		
TT3	EOP Gourma	2.2.2.2	1. Installation of SOP-related ground instrumentation. 2. Overflights and data comparisons. 3. Quick analyses for flight planning.
TT4	EOP Niamey		
TT5	EOP Oueme		
TT6	Ocean	2.2.2.3	Close cooperation regarding flights over the ocean.
TT7	SOP0 (Dry season)		Cooperation in logistical arrangements especially for aircraft. Joint meeting planned 3-7 April 2006.
TT9	SOP3 (Downstream)		Coordinated studies of system lifecycles; trajectories / long-range transport; …
ST1	EOP/LOP		We can benefit from past (LOP) case-studies in our operational planning, as outlined in the EU project in WP2.1
ST2	SOP AMMA Operational Centre	3.1	This link with the Operational Centres is vital! We need to communicate our requirements in data communication and operational planning.
ST3	Database		Data format; archive resolution; … a major task!
ST4	Training and capacity bldg.	4.1, 4.2, 4.3	We need to seek funding for African participation in the operational planning in Niamey.

Table 6.1: Summary of links with other AMMA Teams.

8. Ancillary information: reference, logistic forms, site document.

See appendices.

Appendix A: Aircraft payloads

F/F20 payload

Table A1 – Measurements common to all SOPs

General Eastern dew point sensor 1011B	Dew point	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
INS, GPS	Position, winds, u,v,w	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
5-port turbulence probe	Turbulence	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Rosemount	Temperature T	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Aerodata humidity sensor	Relative Humidity	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
UV-O3 and IR-CO instrument	O3 and CO in situ	SAFIRE	Stephane Letourneur letourneur@dt.insu.cnrs.fr

Table A2 – Measurements required for the SOP2-a1

AVAPS dropsondes	Vertical profiles of dynamical variables	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Pygreometers and Pyranometers (Up/down)	Upwelling/Downwelling, Vis/IR Broadband radiation	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Multichannel thermal infrared radiometer (CLIMAT)	Brightness temperature	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Differential absorption lidar LEANDRE 2	2D water vapor field (below the a/c)	IPSL	C. Flamant cyf@aero.jussieu.fr

Table A3 – Measurements required for the SOP2-a2

Pygreometers and Pyranometers (Up/down)	Upwelling/Downwelling, Vis/IR Broadband radiation	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Photometer	NO2 photolysis j(NO2)	SAFIRE	Mar Pontaud Marc.pontaud@meteo.fr
AVAPS dropsondes	Vertical profiles of dynamical variables	SAFIRE	Mar Pontaud Marc.pontaud@meteo.fr
Nitrogen oxides analyser	NO, NO2 and NOy in situ	LISA	P. Perros perros@lisa.univ-paris12.fr
Mircroadsorbent tubes and ground analysis with CG--MS	COV	LISA	P. Perros perros@lisa-univ-paris12.fr
Oxygenated VOC sampling and ground analysis CG--MS	Oxygenated COV	LISA	P. Perros perros@lisa.univ-paris12.fr
HCHO	Formaldehyde	LISA	P. Perros perros@lisa.univ-paris12.fr
H2O2	Hydrogen peroide	LISA	P. Perros perros@lisa.univ-paris12.fr

Table A4 – Measurements required for the SOP2-a3

RALI	Cloud optical properties dynamics and microphysics	INSU IPSL	N. Grand grand@dt.insu.cnrs.fr
Size particle/rain drop distribution	2 DC - 2 DP – FSSP	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
AVAPS dropsondes	Vertical profiles of dynamical variables	SAFIRE	Mar Pontaud Marc.pontaud@meteo.fr

F/ATR-42 payload

Table A5 – Measurements common to all SOPs

Rosemount, Thales Avionic	Static and dynamic pressure	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Rosemount PRT	Temperature T	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Buck Research dew point sensor	Dew point	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
AIR Lyman Alpha	Water Vapour H_2O	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
INS, GPS	Position, winds, u,v,w	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
5-port turbulence nose	Turbulence	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
radioaltimetre Thales Avionic	Height above ground	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
IR-CO instrument	CO in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
UV-O3 instrument	O3 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Externally sampling PCASP	Size distribution (0.1 to 3 µm)	SAFIRE	M. Pontaud Marc.pootaud@meteo.fr
Pyrgreometers and Pyranometers	Upwelling/Downwelling, Vis/IR Broadband radiation	SAFIRE	M. Pontaud Marc.pontaud@meteo.fr

Table A6 – Measurements required for the SOP2-a1

Chimiluminescence NOx instrument (METAIR)	NO, NO2 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Photometer	NO_2 photolysis $j(NO_2)$	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Size particle / rain drop distribution	FSSP	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
AVIRAD particle inlet	Coarse particle inlet (AVIRAD)°	LISA/LSCE	formenti@lisa.univ-paris12.fr
Optical sizer GRIMM	Size distribution (0.3-20 um)	LISA	formenti@lisa.univ-paris12.fr
7-λ aethalometer	Particle soot, black carbon	LISA	formenti@lisa.univ-paris12.fr
3-λ Nephelometer	Spectral Scattering and backscattering coefficients	LISA	formenti@lisa.univ-paris12.fr
filters for individual particle analysis	Particle shape and composition	LISA	formenti@lisa.univ-paris12.fr
4-stage impactors	Aerosol composition and mass distribution	LISA	formenti@lisa.univ-paris12.fr
Particle inlet	Aerosol Particle inlet ("Veine communautaire")	CNRM	L. Gomes Laurent.gomes@meteo.fr
filters for sub and supermicron particle collection	Ions, trace, BC/OC	LA	V. Pont ponv@aero.obs-mip.fr
Ultrafine CPC	Particle number concentration > 3nm	CNRM	L. Gomes Laurent.gomes@meteo.fr
CCN counter	CCN	CNRM	L. Gomes Laurent.gomes@meteo.fr
Multi-channel CPCs	Size distribution > 10nm	CNRM	L. Gomes Laurent.gomes@meteo.fr
DMPS	Size distribution of Aitken and accumulation mode particles (20-1000 nm)	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
PCASPX	Size distribution 0.3-10 µm	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
Thermodenuder	Volatility analysis of particles	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
X-Probe	Aerosol and droplet size distribution (0.5-50 µm)	CNRM	L. Gomes Laurent.gomes@meteo.fr
Fast FSSP	Cloud droplet spectrum	CNRM	L. Gomes Laurent.gomes@meteo.fr

Table A7 – Measurements required for the SOP2-a2

Gerber Probe, King Probe	Liquid water content	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Chimiluminescence NOx instrument (METAIR)	NO, NO2 in situ	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Photometer	NO_2 photolysis $j(NO_2)$	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Size particle / rain drop distribution	FSSP	SAFIRE	M. Pontaud marc.pontaud@meteo.fr
Spectres dimensionnels		LaMP	Alfons Schwarzenboeck a.schwarzenboeck@opgc.univ-bpclermont.fr
Particle inlet	Aerosol Particle inlet ("Veine communautaire")	CNRM	L. Gomes Laurent.gomes@meteo.fr
filters for sub and supermicron particle collection	Ions, trace, BC/OC	LA	V. Pont ponv@aero.obs-mip.fr
Ultrafine CPC	Particle number concentration > 3nm	CNRM	L. Gomes Laurent.gomes@meteo.fr
CCN counter	CCN	CNRM	L. Gomes Laurent.gomes@meteo.fr
Multi-channel CPCs	Size distribution > 10nm	CNRM	L. Gomes Laurent.gomes@meteo.fr
DMPS	Size distribution of Aitken and accumulation mode particles (20-1000 nm)	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
PCASPX	Size distribution 0.3-10 µm	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
Thermodenuder	Volatility analysis of particles	LaMP	P. Lal P.Laj@opgc.univ-bpclermont.fr
X-Probe	Aerosol and droplet size distribution (0.5-50 µm)	CNRM	L. Gomes Laurent.gomes@meteo.fr
Fast FSSP	Cloud droplet spectrum	CNRM	L. Gomes Laurent.gomes@meteo.fr
Microadsorbent tubes and ground analysis with GC--MS	COV	LISA	P. Perros Perros@lisa.univ-paris12.fr
Oxygenated VOC sampling and ground analysis with GC--MS	Oxygenated COV	LISA	P. Perros Perros@lisa.univ-paris12.fr
PAN-GC	Peroxyactylnitrate	LISA	P. Perros Perros@lisa.univ-paris12.fr
HNO3	Nitric acid	LISA	P. Perros perrons@lisa.univ-paris12.fr

D/F20 payload

Table A8 – Measurements required for SOP 2a1

Rosemount temp probes	Temperature	DLR-FB	Andreas Giez Andreas.giez@dlr.de
INS, GPS	Position, wind	DLR-FB	Andreas Giez
Lyman-alpha	Relative humidity	DLR-FB	Andreas Giez
WIND lidar	Vertical profiles of the wind vector below the a/c along the flight track	DLR-IPA	Oliver Reitebuch Oliver.reitebuch@dlr.de

Table A9 – Measurements required for SOP 2a2

UV photometer	O3	DLR-IPA	Hans Schlager Hans.schlager@dlr.de
VUV fluorescence	CO	DLR-IPA	Hans Schlager
IR	CO2	DLR-IPA	Hans Schlager
CL	NO	DLR-IPA	Hans Schlager
CL + Au converter	NOy	DLR-IPA	Hans Schlager
Filterradiometer	j(NO2)	DLR-IPA	Hans Schlager
IT-CIMS	HNO3	MPI-K / DLR-IPA	Frank Arnold / Hans Schlager
IT-CIMS	SO2	MPI-K / DLR-IPA	Frank Arnold / Hans Schlager
PERCA	RO2	Uni Bremen	Lola Hernandez lola@iup.physik.uni-bremen.de
CPSA (Multi-channel condensation particle counter)	Nucleation mode aerosol size distribution	DLR-IPA	Andreas Minikin andreas.minikin@dlr.de
Airborne-DMA	Aitken mode aerosol size distribution	DLR-IPA	Andreas Minikin
PCASP-100X	Accuumulation mode aerosol size distribution	DLR-IPA	Andreas Minikin
FSSP-300, FSSP-100	Coarse mode aerosol and cloud element size distribution	DLR-IPA	Andreas Minikin
Thermodenuder + condensation particle counters	Aitken mode aerosol : volatile and non-volatile particle fractions	DLR.IPA	Andreas Minikin
PSAP absorption photometer	Aerosol absorption coefficient	DLR-IPA	Andreas Minikin
Impactor sampler	Single particle analysis	DLR-IPA	Andreas Minikin
Rosemount temp probes	Temperature	DLR-FB	Andreas Giez Andreas.giez@dlr.de
INS, GPS	Position, wind	DLR-FB	Andreas Giez
Lyman-alpha	Relative humidity	DLR-FB	Andreas Giez

UK/BAe146 payload

Table A10 – Measurements required for SOP 2a2

Rosemount Thermometers	Non-deiced/deiced temperatures	FAAM	Stephen Devereau stde@faam.ac.uk
General eastern	Dew point	FAAM	Stephen Devereau stde@faam.ac.uk
FWVS Lyman-α fluorescence	Water vapour	UKMO	Jim Haywwod jim.haywood@metoffice.gov.uk
INS, GPS, wind vanes	Position, winds, u,v,w	FAAM	Stephen Devereau stde@faam.ac.uk
Cruciform GPS	Position	UFAM/Camb	Stephen Devereau stde@faam.ac.uk
Video cameras	Forward, rearward, upward, downward	FAAM	Stephen Devereau stde@faam.ac.uk
Radar altimeter	Altitude	FAAM	Stephen Devereau stde@faam.ac.uk
Radar	Rainfall	UFAM/Camb	Stephen Devereau stde@faam.ac.uk
5-port turbulence probe	Turbulence	UFAM/Camb	Stephen Devereau stde@faam.ac.uk
Heimann IR thermometer	SST	FAAM	Stephen Devereau stde@faam.ac.uk
SWS	Short wave radiation	UKMO	Jim Haywwod jim.haywood@metoffice.gov.uk
AVAPS dropsondes	Vertical profiles of dynamical variables	FAAM	Stephen Devereau stde@faam.ac.uk
Pygreometers and Pyranometers	Broadband radiation	FAAM	Stephen Devereau stde@faam.ac.uk
Photometer	NO_2 photolysis j(NO_2)	Leicester	Paul Monks psm7@le.ac.uk
Fixed bandwidth radiometry,	O_3 photolysis j(O^1D)	Leicester	Paul Monks psm7@le.ac.uk
UV	Ozone in situ	FAAM	Stephen Devereau stde@faam.ac.uk
VUV fluorescence	Carbon monoxide CO	FAAM	Stephen Devereau stde@faam.ac.uk
PTR-MS	Real-time Oxygenates	UEA	David Oram d.e.oram@uea.ac.uk
Whole air samples (WAS) and ground analysis with dual channel GC	>100 VOCs inc NMHCs, alcohols, ketones, aldehydes, ethers	York	Ally Lewis acl5@york.ac.uk
WAS and ground analysis with 2DGC	Semivolatile VOCs	York	Ally Lewis acl5@york.ac.uk
Microadsorbent tubes and ground analysis with GC-TOF-MS	VOCs	York	Ally Lewis acl5@york.ac.uk
WAS and ground analysis with GC-MS	>40 halocarbons	UEA	David Oram d.e.oram@uea.ac.uk
Gold convertor + chemiluminescence	NO_Y, NO, NO_2, HNO_3	UEA	David Stewart d.stewart@uea.ac.uk
TECO	NO_X	FAAM	Stephen Devereau stde@faam.ac.uk

Gas chromatography (GC)	Peroxyacetylnitrate	UFAM/York	Jim Hopkins jh61@york.ac.uk
Fluorometric	Speciated peroxides (inorg/organic)	UEA	Brian Bandy b.bandy@uea.ac.uk
Fluorometric	Formaldehyde	UEA	Graham Mills g.mills@uea.ac.uk
Chemical amplifier – PERCA	Peroxy radicals (RO_2 + HO_2)	Leicester/ UEA	Paul Monks psm7@le.ac.uk
FAGE (laser induced fluorescence at low pressure)	OH, HO_2	Leeds/UFAM	Dwayne Heard d.e.heard@leeds.ac.uk
Aerosol mass spectrometer AMS	Aerosol size and composition	UNIMAN/ UFAM	Hugh Coe hugh.coe@manchester.ac.uk
TSI condensation particle counters	Particle number concentration > 3nm	FAAM/ UNIMAN	Hugh Coe hugh.coe@manchester.ac.uk
internally and externally sampling (OPCs) PCASP	Size distribution (0.2-30 um)	FAAM	Stephen Devereau stde@faam.ac.uk
internally and externally sampling (OPCs) GRIMM	Size distribution (0.2-30 um)	UNIMAN	Hugh Coe hugh.coe@manchester.ac.uk
filters for sub and supermicron particle collection and ionic analysis	Ions	FAAM/ UNIMAN	Hugh Coe hugh.coe@manchester.ac.uk
Fast FSSP	Drop size spectrum	FAAM	Stephen Devereau stde@faam.ac.uk
CCN spectrometer	CCN	UKMO	Jim Haywwod jim.haywood@metoffice.gov.uk
PSAP	Particle soot, black carbon	FAAM	Stephen Devereau stde@faam.ac.uk
Nephelometer (TSI),	Scattering	FAAM	Stephen Devereau stde@faam.ac.uk
SID1	Particle sizes, non-sphericity	Herts/UKMO	Jim Haywwod jim.haywood@metoffice.gov.uk

Geophysica/M55 payload

Table A11 – Measurements required for SOP 2a2

FOZAN Dye chemiluminescensce + ECC	O_3	CNR	Fabrizio Ravegnani
FOX UV absorption	O_3	DLR	Hans Schlager
FISH Lyman-α photo-fragment flourescence	H_2O (total)	FZJ	Cornelius Schiller
FLASH Lyman-α	H_2O (gas phase)	CAO	Vladimir Yushkov
ACH mirror hygrometer with digital feedback	H2O frost-point -> H2O (gas phase)	CAO	Vladimir Yushkov
SIOUX Chemi-luminescence, + Au-converter + Subisokinetic inlet	NO NOy Particle NOy	DLR	Hans Schlager
HALOX Chemical-conversion resonance fluorescence + thermal dissociation	ClO BrO, $ClONO_2$	FZJ	Fred Stroh
HAGAR GC/ECD GC/ECD GC/ECD GC/ECD GC/ECD IR absorption	N_2O, CFC 12, CFC11 Halon 1211 SF_6 CH_4 CO CO_2	Uni Frankfurt	C. Michael Volk
ALTO TDL	N_2O, CH_4 CO	INOA	Piero Mazzinghi
CO-TDL		INOA	Piero Mazzinghi
COPAS 4 channels 2-channel CN counter, one inlet heated	Condensation nuclei (CN-total , CN-non-volatile)	Uni Mainz	Stephan Borrmann
FSSP3000 or FSSP100 Laser-particle pectrometer	Size speciated aerosols (0.4-40µm)	Uni Mainz	Stephan Borrmann
Particle Imager		Uni Mainz	Stephan Borrmann
MAS Multi-wavelength Scattering	Aerosol optical properties	CNR	Francesco Cairo
MAL 1 &2 Microjoule-lidar	Remote Aerosol Profile (2km from aircraft altitude)	Obs. Neuchatel	Valentin Mitev
WAS Whole air sampler	Trace gas isotopes Water vapour isotopes	MPI-Heidelberg	Thomas Röckmann
TDC Rosemount probe	Temperature	CAO	G. Shur
PT100, 5-hole probe	horizontal wind	CAO	G. Shur
MTP Microwave passive sensor	vertical profile of temperature and potential temperature	JPL	MJ Mahoney
SMOKE	Vertical velocity Diffusivity	AWI	Markus Rex

Appendix B: Surface-based instrumentation

An updated list of the SOP instruments as well as instrument forms are available at:
http://www.lthe.hmg.inpg.fr/AMMA_International/instruments/List_SOPInstruments_Total.html

Table B1: Ground-based instrumentation

Instrument	Period	Code	Instit'n	PI	Location	Deployment Period	Mode	Sampling
SOP southern quad	EOP-SOP	AS.RS_1	U Koeln	Fink	5 P1 RS stations	EOP	R	
SOP northern quad	EOP-SOP	AS.RS_2	U Leeds	Parker	4 P1_EOP RS & 2 P1_SOP RS stations	EOP	R	
SOP western quad	EOP-SOP	AS.RS_3	IPS	Janicot	4 P1 RS & 1 P2 RS stations	EOP	R	
Flux station Dano	SOP	AS.Flux_D	FZK	Kalthoff	Dano	1 June - end July	M	30 min
Radiosounding Dano	SOP	AS.Rs_D	FZK	Kalthoff	Dano	1 June - end July	R	3-6 hrs
Lidar Ceilometer CT25K	SOP	AE.CT25K_Od	U Bonn	Crewell	Djougou	January-December	M	15 sec
Micro Rain Radar	SOP	AE_RADK_Od	U Bonn	Crewell	Djougou	January-December	M	10 sec
Bistat. Radar receiver	SOP	AS_BISTAT_Od	DLR	Hagen	Djougou	15 Jun-15 Sep	M	Continuous
Lightning detection network	SOP	AS.Lightning_Od	DLR	Höller	Djougou	SOP1 & 2	M	Continuous
Sodar network	SOP	AS.SODAR_N	U Leeds/FZK	Kalthoff / Parker	Niamey	1 June - 21 Aug	M	
Tethered balloon	SOP	AS.Tethersonde_N	U Leeds	Parker	Niamey	15 July - 21 Aug	R	to be arranged
Microwave Radiometer	SOP	AS.PROF_O	U Bonn	Crewell	Djougou	January-December	M	1 min
COV measurements	SOP	AS.TMS_O	U. York	Lewis	Djougou	SOP 2a2	M	30 min
GPS humidity	SOP	AS.GPS_1	CNRS	Bock	Tamale, Ouaga, Tombouctou	May-September	M	30 min
C-Band Radar Ronsard	SOP	AS.Ronsard_O	CNRS	Scialom	Djougou	15 Jun-15 Sep	R	
Oceanic soundings	SOP	OS.RS_SAG	CNRM	Caniaux	Atalante/EGGE	25 May – 7 July	R	
Oceanic instrumented mast (mean variables)	SOP	OS.Mat_SAG	CNRM	Caniaux	Atalante/EGGE	25 May – 7 July	M	
Oceanic instrumented mast (turbulence)	SOP	OS.Flux_SAG	CNRM	Caniaux	Atalante/EGGE	25 May – 7 July	M	
Marisonde buoys	SOP	OS.Mari_SAG	CNRM	Rolland	Gulf of Guinea	June Ł	M	10 min

Expendable probes	SOP	OS.XBT_GG	LEGOS	Bourles	Gulf of Guinea	25 May – 7 July	M	
XCTDs and XTBs	SOP	OS.ITAF_Sn	LEGOS	Bourles	Tropical Atlantic	July-September	M	
Constant volume balloon	SOP	AS.BVC_T2	CNES	Drobinski	Cotonou	15 June - 15 July	R	
Driftsondes	SOP	AS.Drift_T1	CNES/NCAR	Drobinski / Parsons	Diffa or Zinder	15 Aug.-30 Sep.	R	
Wet and dry deposition fluxes, etc..	SOP	AS.Dust.ST_flux	UP12	Desboeuf	Niamey	June-August	M	continuous
Chemical instrumentation	SOP	AS.Dust_Od	UPS	Pont	Djougou	SOP 2a1	M	
Ozone soundings	EOP-SOP	AS.RSO3_Od	LA	Thouret	Cotonou	June-August	M	
Lidar	SOP	AS.TRESS_Tam	IPSL	Flamant	Tamanrasset	June – September	M	
Lidar	SOP	AS.lidar_Mbour	LOA	Tanré	M'Bour	June –August	M	
Aerosol characterisation	SOP	AS.Aeros_MBour	LOA	Chiapello	M'Bour	SOP 2	M	
Soil moisture radar	SOP	AS.RAD4.3_Bani	LTHE	Cohard	Banizoumbou	June-September	M	
UHF radar	SOP	AS.UHF_O	LA	Campistron	Djougou			
X-Band pol. Radar	EOP-SOP	AS.RADX_O	IRD	Gosset	Djougou	EOP	R	
Surface station	SOP	AS.met_S	U Reading	Slingo	Banizoumbou	January-December	M	1 min
IR and VIS radiative fluxes	SOP	AS.skyrad_S	U Reading	Slingo	Banizoumbou	January-December	M	1 min
Radiosounding	SOP	AS.sonde_S	U Reading	Slingo	Niamey	January-December	M	4 per day
VHF wind profiler & 915 nm Doppler radar	SOP	AS.rwp_S	U Reading	Slingo	Niamey	January-December	M	6 min
W-Band cloud radar	SOP	AS.wacr_S	U Reading	Slingo	Niamey	January-December	M	2 sec
Microwave radiometer	SOP	AS_mwr_S	U Reading	Slingo	Niamey	January-December	M	25 sec
Lidar ceilometer CT25K	SOP	AS.vceil_S	U Reading	Slingo	Niamey	January-December	M	15 sec
Lidar	SOP	AS.mpl_S	U Reading	Slingo	Niamey	January-December	M	1 min
Sky imager	SOP	AS.tsi_S	U Reading	Slingo	Niamey	January-December	M	30 sec
Downwelling radiance at 869 nm	SOP	AS.nfov_S	U Reading	Slingo	Niamey	January-December	M	1 sec

Digital camera	SOP	AS.twrcam_S	U Reading	Slingo	Niamey	January-December	M	1 hour
MIT C-band Doppler radar polarized	SOP	AS.MITRadC_N	U Reading	Slingo	Niamey	January-December	M	

Appendix C: Scientific stakeholders for the IOPs

Table C1: Scientific stakeholders for different IOP patterns

	IOP pattern	I1. 1	I1.2 :	I1. 3	I1. 4	I1. 5	I1. 6	I1. 7	I2	I3	I4. 1	I4. 2	I5. 1	I5. 2
AMMA-EU	1.1.1													
	1.1.2													
	1.1.3									■				
	1.3.1													
	1.3.2	■	■	■	■	■			■	■			■	■
	1.3.3	■	■	■	■	■			■	■			■	■
	2.1.1	■	■	■	■	■			■	■	■	■	■	■
	2.1.2	■	■	■	■	■			■	■	■	■	■	■
	2.1.3	■	■	■	■	■	■		■	■	■	■	■	■
	2.4.1	■	■	■	■	■	■	■	■	■				
	2.4.2		■			■	■		■	■				
	2.4.3		■			■	■							
	2.4.4		■						■	■				
AMMA-UK	1.3	■		■	■	■							■	■
	1.4	■		■	■	■							■	■
	2.1	■		■	■	■							■	■
	2.2	■		■	■	■							■	■
	3.1	■		■	■	■							■	■
	3.2	■		■	■	■			■				■	■
	3.3	■		■	■	■	■		■	■			■	■
	3.4	■		■	■	■			■	■			■	■
	3.5	■		■	■	■			■	■			■	■
	4.1	■		■	■	■	■			■			■	■
	4.2	■		■	■	■	■			■			■	■
	4.3			■	■	■			■	■			■	■
	4.4			■					■	■				
	5.1			■					■	■				
AMMA-France	1.1.1													
	1.1.2													
	1.1.3								■					
	1.3.1													
	1.3.2	■	■	■	■	■	■		■	■			■	■
	1.3.3	■	■	■	■	■	■		■	■			■	■
	2.1.1	■	■	■	■	■	■		■	■			■	■
	2.1.2	■											■	■
	2.1.3		■	■	■	■	■		■	■	■	■	■	■
	2.1.4			■							■	■	■	■
	2.1.5			■										
	2.1.6			■										
	2.4.1	■	■	■	■	■		■	■	■				
	2.4.2		■			■	■		■	■				
	2.4.3		■			■	■							
	2.4.4		■				■		■	■				

I1.1: IFT and heat low surveys

I1.2: Squall-line related aerosol emissions

I1.3: North-south land-ocean-atmosphere interactions

I1.4: land-ocean-atmosphere interactions

I1.5: Vegetation emission surveys

I1.6: Urban surveys

I1.7: Aerosol mixing and hygroscopicity

I2: Dynamics an chemistry of MCSs

I3: Lang-range transport

I4.1: Horizontal variability of MCS anvils

I4.2: Vertical microphysical properties of MCS anvils

I5.1 Intensive regional observations: Monsoon onset

I5.2: Intensive regional observations: Monsoon peak

Table C2: Scientific stakeholders for different SOP ground-based instruments

Instrument	Code	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
SOP Southern, Northern & Western quadrilaterals	AS.RS_1 AS.RS_2 AS.RS_3	X	X			X		X	X					X		X	X
Flux station Dano	AS.Flux_D			X		X								X			X
Radiosounding Dano	AS.Rs_D	X	X			X		X	X					X		X	X
Lidar Ceilometer CT25K	AE.CT25K			X		X			X								X
Micro Rain Radar	AE_RADK_T		X			X								X		X	X
Bistat. Radar (Wind field)	AS_BISTAT_Od		X			X			X					X			X
Lightning detection network	AS.Lightning_Od					X			X					X			X
Sodar network	AS.SODAR_N					X								X			X
Tethered balloon	AS.Tethersonde_N					X											X
Microwave Radiometer	AS.PROF_O		X	X		X								X		X	X
COV measurements	AS.TMS_O			X				X	X					X			X
GPS humidity	AS.GPS_1		X			X								X		X	X
C-Band Radar Ronsard	AS.Ronsard_O		X			X			X					X		X	X
Oceanic soundings	OS.RS_SAG	X		X		X	X										X
Oceanic instrumented mast (mean variables)	OS.Mat_SAG			X		X	X							X		X	X
Oceanic instrumented mast (turbulence)	OS.Flux_SAG			X		X	X							X		X	X
Marisonde buoys	OS.Mari_SAG	X					X							X			X
Expendables probes	OS.XTB_GG	X					X							X			X
XCTDs and XTBs	OS.ITAF_Sn	X					X							X			X
Constant volume balloon	AS.BVC_T2	X	X	X		X								X			X

Driftsondes	AS.Drift_T1	X	X			X											X
Wet and dry deposition fluxes, etc..	AS.Dust.ST_flux	X							X					X		X	X
Chemical instrumentation	AS.DUST_Od								X								X
Ozone soundings	AS.RSO3_Od								X								X
Lidar	AS.TRESS_Tam	X		X		X			X					X			X
Lidar	AS.lidar_Mbour	X		X					X								X
Aerosol characterisation		X							X					X		X	X
Soil moisture radar	AS.RAD4.3_Bani	X	X	X		X								X		X	X
UHF radar	AS.UHF_O	X				X								X			X
X-Band pol. Radar	AS_RADX_O		X			X			X					X		X	X
MIT C-band Doppler radar polarized	AS.MITRadC_N		X			X			X					X		X	X
ARM Mobile Facility	AS.met_S AS.skyrad_S AS.sonde_S AS.rwp_S AS.wacr_S AS.mwr_S AS.vceil_S AS.mpl_S AS.tsi_S AS.nfov_S AS.twrcam_S	X	X			X			X					X		X	X

Appendix D: Provisional planning of PIs during SOP 1 & 2

		29/5	5/6	12/6	19/6	26/6	3/7	10/7	17/7	24/7	31/7	7/8	14/8	21/8	28/8	4/9	11/9	18/9
BAe146	Coe								■	■	■	■	■	■				
	Evans								■	■	■	■	■	■				
	Highwood												■	■	■	■		
	Lewis								■	■	■	■	■	■				
	Matthews							■	■	■	■							
	McQuaid								■	■	■	■	■	■				
	Messager									■	■	■						
	Methven											■	■	■				
	Monks								■	■								
	Murphy								■	■	■	■	■	■				
	Oram							■	■	■	■	■	■					
	Parker								■	■	■	■	■	■				
	Reeves							■	■	■	■	■	■	■				
	Stewart							■	■	■	■	■	■	■				
	Taylor								■	■	■	■	■					
ATR42	Said	■	■	■		■	■	■	■									
	Lothon	■	■	■		■	■	■	■									
	Formenti	■	■	■		■	■	■	■									
	Durand									■	■	■						
	Lohou											■	■	■				
	Gomes	■	■	■		■	■	■	■									
	Schwarz.									■	■	■	■	■				
	Jambert								■	■	■	■						
F-F20	Flamant	■	■	■		■	■	■	■			■	■	■				■
	Cammas	■	■	■														
	Chong					■	■	■	■									
	Roux									■	■	■	■					■
	Perros									■	■	■	■	■				
	Borbon								■	■	■	■	■	■				
	Bouniol														■	■	■	
	Pelon														■	■	■	
D-F20	Reitebugh					■	■	■	■									
	Dabas					■	■	■	■									
	Schlager										■	■	■					
	Minikin										■	■	■					
M55	Cairo										■	■	■					
	Law										■	■	■					
	Schlager										■	■	■					

Table D1: Aircraft PIs planning during SOP 1 and 2 (provisional)

			29/5	5/6	12/6	19/6	26/6	3/7	10/7	17/7	24/7	31/7	7/8	14/8	21/8	28/8	4/9	11/9	18/9
Tamanrasset	TReSS	Cuesta																	
		Edouart																	
		Marnas																	
		Lapouge																	
		Gibert																	
Niamey/ Banizoumbo u	Dust station	Chatenet																	
		Marticorena																	
		Caquineau																	
	MIT C-band radar	Williams																	
	Tethersonde	Brooks																	
		Hobby																	
		Lavender																	
		Bain																	
	Soil moisture Radar	Cohard																	
	ARM Mobile Facility																		
	GPS	Bock																	
Djougou	RONSARD	Scialom																	
		Protat																	
	X-PORT	Gosset																	
		Cazenave																	
	Bisitatic radar	Hagen																	
		RONSARD PI																	
	Lightning Network	Hoeller																	
		Houngninou																	
	Dust Incl. LIDAR	Galy-Lacaux																	
		Delon																	
		Lewis																	
	Ceilometer Radiometer	Crewell																	
		Pospichal																	

	Rain radar																		
	UHF radar	NO PIs ONSITE																	
Dano	Radiosonde	Kalthoff																	
		Kohler																	
	Flux	Kalthoff																	
		Kohler																	
R/V Atalante	Radiosonde	Caniaux																	
		Eymard																	
	Mast	Caniaux																	
		Eymard																	
	Air-sea int. Buoys	Caniaux																	
		Eymard																	
	SVP, ARGO, PIRATA buoys	Bourles																	
	Hydrology/ Salinity	Bourles																	
		Gouriou																	
Cotonou	Ozone Sounding	Thouret																	
	PCVB	Basdevant																	
	Dust station Incl. LIDAR	NO PIs ONSITE																	
Diffa / Zinder	Driftsondes	Drobinski																	
		Redelsperger																	

Table D2: Ground-based instruments PIs planning during SOP 1 and 2 (provisional)

		01-Jun		15-Jun		01-Jul		15-Jul	17-Jul	25-Jul			22-Aug	25-Aug	01-Sep		15-Sep
		start SOP 1a		end SOP 1a		start SOP 2a1		end SOP 2a1	start SOP 2a2					end SOP 2a2	start SOP 2a3		end SOP 2a3
		arrival F20 & ATR		departure F20 & ATR		arrival F20 & ATR		departure F20	arrival BAe14	arrival F20 & ATR SAFIRE			departure	departure	arrival F20		departure F20
							& DLR F20	& ATR					F20	BAe146			
								& DLR F20					& ATR				
No SOP aircraft activity		SOP 1a 1-15 June				SOP 2a1 1-15 july			SOP 2a2 17 july - 25 august						SOP 2a3 1-15 sept		
No SOP ground-based activity				SOP 1g 15-30 June													
Week	22/05/06 – 28/06/06	29/05/06 – 04/06/06	05/06/06 – 11/06/06	12/06/06 – 18/06/06	19/06/06 – 25/06/06	26/06/06 – 02/07/06	03/07/06 – 09/07/06	10/07/06 – 16/07/06	17/07/06 – 23/07/06	24/07/06 – 30/07/06	31/07/06 – 06/08/06	07/08/06 – 13/08/06	14/08/06 – 20/08/06	21/08/06 – 27/08/06	28/08/06 – 03/09/06	04/09/06 – 10/09/06	11/09/06 – 17/09/06
AOC Niamey																	
Science coordination																	
ISSC-EC																	
T. Lebel		1/6/06		15/6/06		1/7/06		15/7/06							1/9/06		15/9/06
				16/6/06		30/6/06					1/8/06		18/8/06				
J.L. Redelsperger											1/8/06	13/8/06					
										25/7/06	31/7/06						
A. Diedhiou				16/6/06		30/6/06											
		1/6/06		15/6/06		1/7/06		15/7/06		26/7/06		7/8/06	19/8/06	25/8/06	1/9/06		15/9/06
C. Thorncroft									17/7/06		31/7/06						
J. Polcher													14/8/06	25/8/06			
												08-13/08/06					
D. Parker									17/7/06	25/7/06							
C. Flamant		1/6/06		15/6/06		1/7/06		15/7/06									

Table D3 – Roster for Scientific Coordinators and Deputies

		01-Jun		15-Jun		01-Jul		15-Jul	17-Jul	25-Jul			22-Aug	25-Aug	01-Sep		15-Sep
		start SOP 1a		end SOP 1a		start SOP 2a1		end SOP 2a1	start SOP 2a2					end SOP 2a2	start SOP 2a3		end SOP 2a3
		arrival F20 & ATR		departure F20 & ATR		arrival F20 & ATR		departure F20	arrival BAe146	arrival F20 & ATR SAFIRE			departure	departure	arrival F20		departure F20
							& DLR F20	& ATR					F20	BAe146			
								& DLR F20					& ATR				
No SOP aircraft activity			SOP 1a 1-15 June				SOP 2a1 1-15 july					SOP 2a2 17 july - 25 august				SOP 2a3 1-15 sept	
No SOP ground-based activity					SOP 1g 15-30 June												
Week	22/05/06 – 28/06/06	29/05/06 – 04/06/06	05/06/06 – 11/06/06	12/06/06 – 18/06/06	19/06/06 – 25/06/06	26/06/06 – 02/07/06	03/07/06 – 09/07/06	10/07/06 – 16/07/06	17/07/06 – 23/07/06	24/07/06 – 30/07/06	31/07/06 – 06/08/06	07/08/06 – 13/08/06	14/08/06 – 20/08/06	21/08/06 – 27/08/06	28/08/06 – 03/09/06	04/09/06 – 10/09/06	11/09/06 – 17/09/06
Forecast Group																	
J.-P. Lafore	19/5/06			13/6/06					21/7/06			11/8/06					
Vidal	19/5/06	2/6/06															
Chapelon	19/5/06		6/6/06					11/7/06		28/7/06							
Forecast Support Group																	
F. Couvreux (CNRM)		2/6/06				30/6/06											
N. Asencio (CNRM)						27/6/06				25/7/06							
J. Yu (IPSL)											4/8/06			25/8/06			
M. Nuret (CNRM)														25/8/06			15/9/06
IPSL, CNRM & LA "non instrument-PIs" Scientists																	
Could act as Scientific Secretary or deputy																	
Could act as Facility Supervisor																	
F. Aires (IPSL)		30/5/06		16/6/06													
M.-P. Lefèvre (IPSL)	26/5/06			13/6/06													
B. Sultan (IPSL)						30/6/06			21/7/06								
S. Janicot (IPSL)						27/6/06			18/7/06								
C. Mari (LA)						30/6/06	7/7/06										
A. Deme (IPSL)									18/7/06			8/8/06					
F. Guichard (CNRM)									20/7/06		5/8/06						
P. Peyrillé (CNRM)										28/7/06		11/8/06					
J.-Y. Grandpeix (IPSL)												8/8/06			29/8/06		
G. Gastineau (IPSL)												11/8/06			1/9/06		
F. Cheruy (IPSL)															29/8/06		15/9/06

Table D4: Commitment of scientists to other 'Named responsibilities' at Niamey AOC for the SOP periods.

		01-Jun		15-Jun		01-Jul		15-Jul	17-Jul	25-Jul			22-Aug	25-Aug	01-Sep		15-Sep
		start SOP 1a		end SOP 1a		start SOP 2a1		end SOP 2a1	start SOP 2a2					end SOP 2a2	start SOP 2a3		end SOP 2a3
		arrival F20 & ATR		departure F20 & ATR		arrival F20 & ATR		departure F20	arrival BAe14	arrival F20 & ATR SAFIRE			departure	departure	arrival F20		departure F20
							& DLR F20	& ATR					F20	BAe146			
								& DLR F20					& ATR				
No SOP aircraft activity		SOP 1a 1-15 June				SOP 2a1 1-15 july			SOP 2a2 17 july - 25 august						SOP 2a3 1-15 sept		
No SOP ground-based activity				SOP 1g 15-30 June													
Week	22/05/06 – 28/06/06	29/05/06 – 04/06/06	05/06/06 – 11/06/06	12/06/06 – 18/06/06	19/06/06 – 25/06/06	26/06/06 – 02/07/06	03/07/06 – 09/07/06	10/07/06 – 16/07/06	17/07/06 – 23/07/06	24/07/06 – 30/07/06	31/07/06 – 06/08/06	07/08/06 – 13/08/06	14/08/06 – 20/08/06	21/08/06 – 27/08/06	28/08/06 – 03/09/06	04/09/06 – 10/09/06	11/09/06 – 17/09/06
									arrival DLR F20 & Geophysica					departure DLR F20 & Geophysica			
AOC Ouaga																	
I. Bouara										28/7/06			18/8/06				
B. Cadet										28/7/06			18/8/06				
MSC specialist (CNRM?)																	
J. Polcher																	
AOC Djougou																	
C. Rio									20/7/06				20/8/06				

Table D5: Commitment of scientists to ‘Named responsibilities’ at Ouagadougou AOC for the SOP periods.

Appendix E: Objectives of (inter)national AMMA groups

1. AMMA-EU sub-workpackages with specific interest in this SOP

WP1.1 WAM and the global climate
- 1.1.1 Interannual variability and trends of the WAM
  - 1.1.1.a: study of the ocean-atmosphere couplings and their impacts on WAM dynamics
  - 1.1.1.b: analysis of the African ITCZ
- 1.1.2 WAM impacts on atmospheric composition and global climate (impact of WAM emissions on global oxidant and aerosol budgets, the oxidising capacity and global radiative forcing)

WP1.2 Water cycle

WP1.3 Land surface-atmosphere feedbacks
- 1.3.1 Land surface processes and atmospheric forcings
- 1.3.2 Atmospheric responses to land surface processes
- 1.3.3 Coupling studies

WP1.4 Scale interactions

WP2.1 Atmospheric dynamics and convection
- 2.1.1 Regional to synoptic scale
- 2.1.2 Synoptic to mesoscale
- 2.1.3 Mesoscale to cloud scale

WP2.4 Aerosols and chemical processes in the atmosphere
- 2.4.1 Aerosol radiative properties and hygroscopicity
- 2.4.2 Gas and particle phase chemistry
- 2.4.3 Surface processes
- 2.4.4 Effect of convection of chemical and aerosol budgets

2. AMMA-UK Objectives relevant to TT8 / SOP-Monsoon

Objectives of relevance to TT8 are:

WP1.3 To implement a high resolution land surface-only version of the Met Office Unified Model (UM) over the tropical North African region, forced by observations, to generate daily analyses of land surface properties and fluxes. The use of MSG data to nudge soil moisture towards observed cloud-screened brightness temperature patterns will produce analyses of greatly improved quality, reducing the sensitivity of the output to poorly observed precipitation data. This technique can be applied where cloud cover permits - from experience at least one in three days in the southern Sahel and more often further north. Coupled with radiation estimates from MSG, this will provide the dominant atmospheric forcing at scales down to 2.5 km. Vegetation and topography data exists at even high resolution, thus permitting the production of high resolution soil moisture and leaf area data.
WP1.4 To provide daily surface fields of soil moisture, soil temperature and leaf area for initialisation and validation of Unified Model simulations from micro to synoptic

scales, exploring soil-canopy-atmosphere interactions. This work package will also make use of ground data from the CATCH, IMPETUS and other networks provided by the international AMMA consortium, ECMWF atmospheric analyses, rainfall analyses from GPCP, and satellite datasets (MSG and MODIS).

WP2.1 To make sub-canopy observations alongside the flux station array, and thereby to quantify the microclimates of the region, in relation to spatial patterns inferred by satellite and aircraft data.
WP2.2 To use mesoscale model simulations (on spatial resolutions of 1km or smaller) to attempt to simulate the control of the microclimate by spatial inhomogeneities of surface properties (as provided by WP1). This modelling will be in the form of case studies and idealised simulations.
WP3.1 To develop validated model case studies of the diurnal cycle of convection in the continental WAM, and over anomalies of soil moisture.
WP3.2 To use case studies to quantify the response of the WAM dynamics to MCSs.
WP3.3 To quantify the transport properties of dry and moist convective circulations, on the mesoscale and the continental scale, through model case studies and through use of chemical tracers that act as markers of source regions and of air mass ages. Within this, to model mixing in the monsoon layer and its implication for the monsoon fluxes.
WP3.4 To develop synoptic cases studies of AEW structure both north and south of the AEJ, and explore the interaction of these AEWs with soil moisture patterns.
WP3.5 To describe the evolution of the SAL on synoptic and diurnal timescales.

WP4.1 To make, for the first time, comprehensive observations of the atmospheric composition within the WAM, and thereby to characterise the composition (trace gases and particles) of the different zones within the WAM system.
WP4.2 Relate the composition observed in the boundary layer to land surface and vegetation characteristics, as derived from satellite and ground-based observations, and make a first attempt to derive airborne vertical fluxes of biogenic VOCs within the WAM region.
WP4.3 Use the improved understanding of the dynamics to evaluate the role of the monsoon circulation in transporting chemical constituents within the WAM region (e.g. boundary layer to mid-troposphere).
WP4.4 Use the observational dataset to provide improved constraints on our understanding of how natural emissions (VOC and NO_X) impact the chemistry (e.g. O_3 and HO_X budgets, secondary organic aerosol) of the WAM region, and the production of constituents that may be transported both into the TTL and over regional and continental scales. This objective will relate the chemical control of the particulate material to its ability to act as cloud condensation nuclei and to affect the radiative properties of the particulates.
WP5.1 To use observations of the convective outflows in the TTL region to analyse the chemical and dynamical processes occurring in such outflows.

3. AMMA-France Objectives for TT8 / SOP Monsoon

The management structure for AMMA-France is identical to that of the AMMA-EU programme (section 1.1 above).

1. SOP-Monsoon-related Objectives from the PIAF

The following projects have been proposed as part of the PIAF (African involvement plan – http://www.ird.ne/ammanet/).
The full project descriptions can be found by contacting the proposers of each project, or by consulting members of the African coordination committee (CSAM – see http://www.ird.ne/ammanet/).

Name	Affiliation / country	Research area	Project proposal
EL MAJDOUB Ali	ACMAD	Prévision Numérique	Evaluation de l'impact de AMMA sur la PNT, cas du modèle Aladin NORAF
FOAMOUHOUE Kamga	ACMAD	Recherches Développement des Applications	Validation des modèles climatiques pour l'exploitation et formation
MUMBA Zilore	ACMAD	Météorologie	Inter-Annual and Intra-seasonal Variability of the West African Monsoon System
B, TRAORE Seydou	AGRHYMET	Agrométéorologie, unité Méthodes et applications	Analyse de la variabilité des rendements agricoles en Afrique de l'Ouest en fonction des facteurs climatiques liés à la mousson
ABOU Amani	AGRHYMET	Hydrologie	1. Evaluation régionale de l'impact du changement climatique sur les ressources en eau en Afrique de l'Ouest; 2. Amélioration de la prévision saisonnière des écoulements en Afrique de l'Ouest
ABOU Amani	AGRHYMET	Hydrologie	Evaluation des techniques de downscaling en Afrique de l'Ouest
ONIBON Hubert	Bénin	Modélisation stochastique	Analyse des problèmes d'échelles liés à l'étude d'impact de la variabilité climatique sur les ressources en eau
AKPO Aristide	Bénin	Aérosols, convection, Physique de l'Atmosphère	Impacts des aérosols désertiques sur la Mousson Africaine
DIDE Francis	Bénin	Météorologie	Dynamique de la Mousson - Spécialités de la région du Golfe du Bénin à la Donga

YACOUBA Hamma	Burkina Faso	Erosion, physique du sol	Impact du changement climatique sur les processus de dégradation de l'environnement au Burkina Faso: Application à l'identification des zones à risque majeur d'érosion et de perte de fertilité dans le bassin supérieur du Nakambé
LENOUO André	Cameroun	Physique de l'Atmosphère	Impact de la stabilité et de l'humidité sur les Ondes d'Est Africaines
MONKAM David	Cameroun	Physique de l'atmosphère	Monsoon rainfall behaviour in recent times and impact assessment of El NIÑO and LA NIÑA episodes on local/regional scale in the Northern Africa
CORTE-REAL Joao	Portugal (Cap Vert)	Atmospheric Sciences	African Easterly Waves and its interactions with the West African Monsoon System
SILVA Ana Maria	Portugal (Cap Vert)	Atmospheric Physics	The Health effects of aerosols at Cabo Verde
JEANNE Isabelle	CERMES	Conception analyses SIG Télédétection Terrain	Méningites et climat. Paludisme et climat : CLIMPAL-Niger
ASSAMOI Paul	Côte d'Ivoire	Dynamique de l'Atmosphère	Interconnexion des Phénomènes Océaniques et Continentaux dans la Circulation de la Mousson Ouest-Africaine
KOUADIO Georges	Côte d'Ivoire	Dynamique de l'Atmosphère, Mesure des flux et paramétrisation	Quantification et modélisation des émissions d'oxydes d'azote par les agrosystèmes fertilisés et impact sur la chimie de l'air en Afrique de l'Ouest
KOUAME Brou	Côte d'Ivoire	Agriculture	Analyses fréquentielles de la pluviométrie : détermination des calendriers culturaux de plantes annuelles
MAHAN N'DJEANGNONMOU Claude	Côte d'Ivoire	Océanographie, upwelling Côtier	Upwelling Ivoiro-Ghanéen : fluctuations halieutiques et variabilité climatique
N'GORAN Yao	Côte d'Ivoire	Rayonnement, Gisement	Etude et exploitation du gisement solaire Ouest Africain à partir de l'imagerie satellitaire(GISOA-SAT)
YAPI Ahoua	Côte d'Ivoire	Santé, Coordination	Impact de la variabilité climatique sur l'étiologie de la maladie asthmatique

YAPI YAPI Grégoire	Côte d'Ivoire	Climat, santé	Impact de la variabilité climatique sur la transmission du paludisme et des bilharzioses en zone forestière et pré-forestière de Côte d'Ivoire
YOBOUE Véronique	Côte d'Ivoire	Bilan de l'azote	Etude de la pollution atmosphérique dans les capitales africaines en Afrique de l'Ouest et chimie des précipitations en zone de savane humide
ADAMOU Garba	EAMAC	Dynamique des systèmes convectifs	Etude de la dynamique des systèmes convectifs et leurs impacts sur les changements climatiques au Sahel
KONATE Daouda	EAMAC	Météorologie	Etude de l'interconnexion entre l'occurrence et l'intensité des pluies de mousson et les systèmes de temps dans la méditerranée
DIAKITE Cheick Hamala	Mali	Géographie	1. Relations entre Méningite et climat pour la mise en place d'un système d'alerte précoce : le cas du Mali. 2. L'eau, Système de prévision de l'inondation du Delta Central du Niger et développement régional
FOFANA Almoustapha	Mali	Hydrologie, hydrochimie	Etude hydrologique et hydrochimique des mares du Gourma
MARIKO Adama	Mali	Hydrologie, Télédétection	Analyse d'impacts et stratégies d'adaptation au changement climatique en zone soudano-sahélienne : cas du Delta intérieur du Niger au Mali
KAMAYE Maâzou	Niger	Dynamique de l'Atmosphère, Aérosols	Etude statistique de la Variabilité du flux de Mousson et régimes de précipitation en Afrique de l'Ouest
SEYDOU SANDA Ibrah	Niger	Aérosols-convection, Variabilité atmosphérique	Aérosols et convection
Zibo Garba	Niger	Aérosols, Ensablement, Paléoclimatique, SIG Télédétection	Mise en place d'un observatoire "proximal" en bordure du Sahara pour la surveillance et l'analyse des processus éoliens et de leurs impacts (Nguigmi, Mainé-Soroa et Gouré au Niger Oriental, Bassin du Lac Tchad)

AMMA-Niger	Niger	Atmospheric dynamics and Convection	Improved understanding of convective initiation over the Aïr mountain. Improved understanding of the processes leading to MCS breakup in the region of Dosso and Dogondoutchi, east of Niamey
Prof OMOTOSO Bayo, OYEBANDE Lekan	Nigeria	Meteorology	Modelling of mesoscale convective systems over West Africa
CAMARA Moctar	Sénégal	Physique de l'Atmosphère	Perturbations atmosphériques en Afirque de l'Ouest et activité cyclonique sur l'Atlantique
DIOP Mariane Kane	Sénégal	Dynamique des systèmes convectifs	Dynamique des systèmes convectifs de méso-échelle (MCS)
DIOP Mbaye	Sénégal	Agro-climatologie	Impact de la mousson africaine sur les cultures au Sénégal
GAYE Amadou Thierno	Sénégal	Aérosols-Pollution	Aérosols-chimie-processus radiatifs-pollution
KEBE Cheikh Mohamed Fadel	Sénégal	Estimation des pluies, Télédétection	Estimation des pluies par radar et satellite
LECLERC Grégoire	Sénégal	Pastoralisme	Impact de la mousson sur le pastoralisme
NDIAYE Aminata	Sénégal	Climat-Socio Economie	Evaluation socio-économique des impacts de la mousson
NDIONE Jacques André	Sénégal	Environnement-Santé	Impacts de la mousson sur la santé
SAMBOU Soussou	Sénégal	Hydrologie et Hydrogéologie	Processus hydrologiques liés à la mousson
SOW Bamol Ali	Sénégal	Océanographie physique	Réponse de l'océan au forçage de petite échelle dans le système d'upwelling sénégalais
WATT Mamadou	Sénégal	Amélioration du réseau	Réseau d'observation du Sénégal
Dr BLIVI Adoté	Togo	Dynamique des Surfaces	Evoulution Climato-Hydrologique Récente et Conséquence sur l'Environnement/l'Exemple du Bassin Versant du Fleuve Mono (Togo-Bénin)

Appendix F: Integration of in-situ measurements from low-level flights with ground-based measurements over the meso-sites

1. Problems with intercomparing ground- and aircraft-derived fluxes

Over the heterogeneous terrain of the area, fluxes are highly variable in space. A ground-based measurement is only really relevant to its 'local' domain (perhaps the area of a few tens or hundreds of metres over which the vegetation is homogeneous?). An aircraft-based measurement, which requires averaging over flight legs of perhaps 30-50 km, naturally averages out much of this 'local' variability, although is should capture mesoscale structure. Also, the aircraft have a minimum altitude of 500 ft (~ 170 m), somewhat outside the 'constant flux layer' (about 50m). For these reasons, we do not expect that exact matching of aircraft-derived and ground-based measurements will be useful.

2. Different capabilities of each kind of measurement.

A 'surface flux' is a complex, derived quantity. Despite the difficulties and ambiguities in evaluating this from measurements, the fluxes are extremely important for modelling, and therefore for prediction. The aircraft and ground-derived fluxes are 2 ways of exploring the same quantity. The ground-based measurements give a long and consistent time-series, from which we can learn about seasonal and more rapid variability, response to rainfall, response to vegetation (from a network of sites) and so on. The aircraft data, in contrast, give a nearly instantaneous view of the fluxes, with the important advantage that they can sample spatial variability over the heterogeneous surface (albeit at mesoscale resolution). So the aircraft should at least attempt to measure the surface fraction that is seen by the surface station, and then a larger area to document the corresponding area averaged flux.

It is possible that the heterogeneity of the vegetation over the Gourma site is lower than over the other sites, so this would be the best chance of directly comparing aircraft- and ground-derived fluxes.

There is a motivation to combine ground- and aircraft-derived fluxes over the mesoscale sites, in that these may be combined to give a spatial and temporal view of fluxes. For example, over the Gourma site, we may fly aircraft following a rain event, and evaluate the spatial patterns in fluxes in response to this event. The ground-based data will then provide a ground-truth evaluation of the temporal response of the fluxes to this rain event, and a number of other rain events.

Aircraft transit times to the Gourma site from Niamey make it more expensive to operate there. However, during the wet season we can't see the Niamey region very often with visible/thermal satellite data, in which case high resolution mapping of rainfall relies on other sources (for which Niamey is well-equipped, but which may not get assimilated into surface analyses. For these reasons, flights over the Gourma region measuring surface fluxes from the lowest possible altitude are desirable.

3. Other data for intercomparison

From the JET2000 project we learned alot about spatial heterogeneity and surface-atmosphere coupling by evaluation of lower-order diagnostics, which do not require the same, long averaging times as aircraft fluxes. For instance, TKE, and simply water vapour, showed significant response to the local surface during the day (Taylor *et al,* 2003, *QJRMS*). These lower-order diagnostics may provide a greater incentive to over-fly the ground sites. ***Mid afternoon*** is a good time to use the aircraft to sample for lower order diagnostics, especially with an aircraft which cannot fly very low.

4. Chemical fluxes

We will attempt to evaluate fluxes of trace gases from some of the flights, but it is accepted that the errors in these estimates are likely to be large. In this case, overflying surface sites may provide some useful limits on the error bars.

Regarding these chemical fluxes, there are different scientific issues related to the Djougou, Niamey and Gourma sites, with the southern region interesting for biogenic emissions from vegetation, and the northern, especially Gourma, sites interesting for emissions from bare soil.

5. Summary

In summary, we can regard the attempt to evaluate fluxes with flights over the mesoscale sites as important, but only when aimed at ***phenomena*** which are relevant to spatial heterogeneity (e.g. recent rainfall, soil type, vegetation type, topography ...). It should be accepted that overflying the surface flux sites is unlikely to yield interesting comparisons except (a) over the Gourma where the surface may be more homogeneous, or (b) in regard to fluxes of trace gases, for which the aircraft-derived error-bars may be very large.

6. Existing plans

IOP patterns I1.1 (Gourma), I1.3 (Djougou), I1.4 (various), I1.5 (various), all propose to overfly the mesoscale sites, with the capacity to make measurements of use in flux calculation. I2 (MCS sampling) and I3 (long-range transport) also could involve low level flights for the purposes of flux evaluation.

We hope to deploy a tethered balloon near Banizoumbou, with the capacity to evaluate fluxes up to 1km in altitude. We can discuss whether particular flight legs and / or balloon operations need to be recommended.

Appendix G: Tables of personnel with particular responsibilities

3.3.1 SOP 1a

			Expertise				
			Atlmospheric dynamcis	Chemistry	Aerosols	Surface-atmosphere interactions	Water cycle
Aircraft	F/F20	Flamant (Leandre 2)	x		X	x	
		Cammas (dropsondes)	x				
	F/ATR	Formenti (AVIRAD)	x		X		
		Said (Turbulence)	x			x	
		Gomes (HYGRO+)			X		

Table G1: List of aircraft PIs for SOP 1a.

		Site coordinator	**Instrument PIs**
Site	Tamanrasset	Cuesta/Edouart	Cuesta/Edouart (TReSS)
	Niamey/ Banizoumbou		? (MIT C-band radar)
			Marticorena (aerosol station)
			? (sodar)
			? (soil moisture radar)
			? (ARM Mobile Facility)
	Djougou (Kolokondé, Kopargo, Nangatchori)		? (RONSARD)
			? (X-PORT)
			Hagen (bistatic radar receiver)
			Hougninou & Hoeller (lightning)
			Galy-Lacaux (aerosol station)
			? (Micro-rain radar, ceilometer, radiometer)
			? (UHF)
			? (lidar)
	Dano		Kalthoff (radiosonde, flux)
	R/V Atalante		? (buoys)
			? (soundings)
			? (instrumented mast)
	Cotonou		? (constant level balloons)
			? (Ozone soundings)
	M'Bour		? (lidar)
			? (aerosol station)

Table G2: List of ground-based PIs for SOP 1a.

3.3.2 SOP 2a1

			Expertise				
			Atlmospheric dynamcis	Chemistry	Aerosols	Surface-atmosphere interactions	Water cycle
Aircraft	F/F20	Flamant (Leandre 2)	x		X	x	
		Chong (dropsondes)	x				
	F/ATR	Formenti (AVIRAD)	x		X		
		Said/Lothon (Turbulence)	x			x	
		Gomes (HYGRO+)			x		
	D/F20	Reitebuch/Dabas (WIND)	x				

Table G3: List of aircraft PIs for SOP 2a1.

		Site coordinator	Instrument PIs
Site	Tamanrasset	Cuesta	Cuesta (TReSS)
	Niamey/ Banizoumbou		? (MIT C-band radar)
			Caquineau (aerosol station)
			? (sodar)
			? (soil moisture radar)
			? (ARM Mobile Facility)
	Djougou (Kolokondé, Kopargo, Nangatchori)		? (RONSARD)
			? (X-PORT)
			RONSARD PI & Hagen (bistatic radar receiver)
			Hougninou & Hoeller (lightning)
			Delon (aerosol station)
			? (Micro-rain radar, ceilometer, radiometer)
			? (UHF)
			? (lidar)
			? (chemistry)
	R/V Atalante		? (buoys)
			? (soundings)
			? (instrumented mast)
	Cotonou		Basdevant (constant level balloons)
			? (Ozone soundings)
	M'Bour		? (lidar)
			? (aerosol station)
	Diffa or Zinder		? (driftsondes)

Table G4: List of ground-based PIs for SOP 2a1.

3.3.2 SOP 2a2

			Expertise				
			Atmospheric dynamcis	Chemistry	Aerosols	Surface-atmosphere interactions	Water cycle
Aircraft	F/F20	Perros/Borbon(chemistry)		X			
		Roux (dropsondes)	X			X	X
	F/ATR	Jambert (chemistry)		X			
		Durand/Said (Turbulence)	X			X	
		Gomes/Schwarzenboeck (HYGRO & CVI)			X		
	D/F20	Schlager (chemistry)	X	X			
		Minikin (aerosol)			X		
	M55	Schlager (chemistry)	X	X			
		Law (chemistry)	X	X			
		Cairo (aerosol)			X		
	UK/ Bae146	Coe		X	X		
		Evans		X			
		Lewis		X	X		
		Matthews	X				
		McQuaid		X	X		
		Messager	X			X	
		Methven	X	X	X		
		Monks		X			
		Murphy		X			
		Oram		X			
		Parker	X			X	
		Reeves		X	X		
		Stewart		X			
		Taylor	X			X	

Table G5: List of aircraft PIs for SOP 2a2.

		Site coordinator	Instrument PIs
Site	Tamanrasset	Marnas/Lapouge/Gibert	Marnas/Lapouge/Gibert (TReSS)
	Niamey/ Banizoumbou		? (MIT C-band radar)
			? (aerosol station)
			Brooks (sodar & tethered balloon)
			? (soil moisture radar)
			? (ARM Mobile Facility)
	Djougou (Kolokondé, Kopargo, Nangatchori)		? (RONSARD)
			? (X-PORT)
			RONSARD PI & Hagen (bistatic radar receiver)
			Hoeller & Hougninou (lightning)
			Pont/Lewis (aerosol station)
			? (Micro-rain radar, ceilometer, radiometer)
			? (UHF)
			? (lidar)
			? (chemistry)

	Dano		Kohler (radiosonde, flux)
	Cotonou		Basdevant (constant level balloons)
			? (Ozone soundings)
	M'Bour		? (lidar)
			? (aerosol station)
	Diffa or Zinder		? (driftsondes)

Table G6: List of ground-based PIs for SOP 2a2.

3.3.2 SOP 2a3

			Expertise				
			Atlmospheric dynamcis	Chemistry	Aerosols	Surface-atmosphere interactions	Water cycle
Aircraft	F/F20	Bouniol (RALI)	x				X
		Pelon (LNG)	x		x		
		Duroure (PMS probes)	X		X		X
		? (dropsondes)	X				X

Table 3.8: List of aircraft PIs for SOP 2a3.

		Site coordinator	Instrument PIs
Site	Tamanrasset	Cuesta	Cuesta (TReSS)
	Niamey/ Banizoumbou		? (MIT C-band radar)
			? (aerosol station)
			? (soil moisture radar)
			? (ARM Mobile Facility)
	Djougou (Kolokondé, Kopargo, Nangatchori)		? (RONSARD)
			? (X-PORT)
			Hagen (bistatic radar receiver)
			Hougninou & Hoeller (lightning)
			? (Micro-rain radar, ceilometer, radiometer)
			? (UHF)
			? (lidar)
			? (Ozone soundings)
	M'Bour		? (lidar)
			? (aerosol station)

Table 3.9: List of ground-based PIs for SOP 2a3.

Appendix H: SCOUT-03 balloon flights in AMMA

Type of FlightsType 1: Water vapour (in situ)µSDLA (H2O, CH4), LABS (BKS, depolar), µDirac (tracers, VSLS)
12 SF balloon, ascent in the afternoon to 25 km, slow nighttime descent 2m/s down to 13.5 km + large parachute
3 Flights: nighttime, 2 MCS, 1 non convective as referenceType 2: Ice and aerosols (in situ)OPC (size distribution), LABS (BKS, depolar), µDirac (tracers)
5 SF balloon, launch at anytime, ascent to 23 km, slow descent 2 m/s down to 13.5 km,
2 Flights: anytime, next to MCS Type 3: Anvils and Cirrus (remote)µlidar (cirrus, anvil), IR Radiometer (brightness temp), SAOZ (H2O, cirrus, O3, NO2 et sunset), AIRS (electric field, lightning and blue-jet flashes)
3 SF balloon, ascent in the afternoon to 22-24 km, overnight flight as long as possible
3 Flights: nighttime MCSType 4: ChemistrySAOZ-N (O3, NO2), SAOZ-UV (BrO), µDirac (Tracers and VSLS organic), NILUCUBE (Photolysis rates)
10 ZL balloon, afternoon launch, ascent to 30 km, end after sunsetdown
2 Flights: daytime, MCS outflow Type 5: Chemistry and transport (in situ)Minisampler: tracers, age of air, H2O isotopes, organic coumpounds
Post flight analysis of samplings in the laboratory in Europe
12 SF balloon, ascent to 25 km, descent
1 Flight: anytime
Instrument under devt, to be confirmed
UWyo (NSF funded flight, operated by Uwyo + help CNES)
Double OPC + ozone sonde
4000 m3 Raven balloon, ascent / descent 33 km
1 Flight: anytime

Campaign planning17-24 July: installation
24-29 July: Ice and aerosol 1, Water vapour 1, UWyo
31-July-5 Aug: Chemistry 1, Anvil and cirrus 1
7-12 Aug: Water vapour 2, Ice and aerosol 2
14-19 Aug: Anvil and cirrus 2, Chemistry 2, Chemistry/transport TBC)
21-26 Aug: Water vapour 3, Anvil and cirrus 3

Chapter 11

AMMA Downstream (SOP-3)

–TT9–

DRAFT

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1. SCIENTIFIC JUSTIFICATION & OBJECTIVES

Variability in West African weather and climate impacts the tropical Atlantic. We know that a majority of tropical cyclones that form in the Atlantic originate from weather systems over West Africa; however we know little about the processes that influence this. At daily-to-weekly timescales there is a particular need to improve intensity forecasts including genesis.

The West African Monsoon (WAM) controls the synoptic environment (jets and wind shear, divergence and vorticity centers, temperature and humidity profiles) and the evolution of convective clusters, some of which become cyclone “seedlings”. Tropical Africa is also the source of the dry and aerosol-laden air in the Saharan Air Layer which strongly interacts with cloud systems and frequently inhibits or delays further cyclonic development.

Dust plays a major role in radiative forcing and in cloud microphysics, and thus is an important part of WAM system. A key priority is to determine the transport of dust from the surface to the upper atmospheric layers and the subsequent transport by the WAM, in particular into the tropical Atlantic.

The African, European and US interests and scientific objectives related to AMMA-downstream are now briefly described.

1.1 US objectives

Tropical cyclonic storms pose a serious, imminent, and ongoing hazard to citizens of the United States. In recent years, U.S. scientific agencies (National Aeronautics and Space Administration [NASA]; National Oceanographic and Atmospheric Administration [NOAA]) have investigated tropical cyclones using a combination of satellite-based sensors, in situ airborne platforms and numerical modeling studies. The NASA Convection and Moisture Experiments (CAMEX-3, 1998; CAMEX-4, 2001; Tropical Cloud Systems and Processes [TCSP], 2005) have used the high altitude ER-2 and DC-8 research aircraft to investigate tropical cyclone intensity change, genesis, rainfall and methods to improve numerical parameterizations and model data assimilation strategies.

Every year, the NOAA Hurricane Research Division (HRD) research aircraft (P-3 Orions, Gulfstream IV) investigate tropical cyclones in the Atlantic, Caribbean, Gulf of Mexico and Eastern Pacific to better understand the physical processes governing tropical cyclone intensity change, air-sea interaction and collection of datasets to improve parameterizations used in the high resolution HWRF (Hurricane Weather Research and Forecasting) model. In 2005, the NOAA research aircraft were flown in support of the NOAA Intensity Forecast Experiment (IFEX), Genesis Experiment and Saharan Air Layer Experiment (SALEX). As part of the 2005 IFEX, the NOAA P-3 Orions flew joint missions with the NASA ER-2, based out of Costa Rica, in support of the NASA TCSP goal of better understanding the genesis and intensification of western Atlantic and Eastern Pacific tropical cyclones.

Proposed research is herein described in support of a downstream component to the African Monsoon Multidisciplinary Activities (AMMA) experiment, to be conducted during the Special Observation Period (SOP-3) of September 2006. NASA - and NOAA - supported research during AMMA will be to study the downstream or oceanic evolution of precipitating convective systems, largely as this evolution pertains to tropical cyclogenesis. The NASA-AMMA (NAMMA-06) component will leverage off one or more airborne science platforms, satellite remote sensors (particularly the Tropical Rainfall Measurement Mission [TRMM] satellite), and ground-based instrumentation. The NOAA HRD-based SALEX seeks to better understand the role of fugitive aerosols shed from the Sahara on tropical cyclogenesis and intensity change, by examining the SAL properties of dry air, shear and aerosol abundance as they are entrained into embryonic tropical cyclones. As in past NASA field programs investigating hurricanes (i.e. CAMEX), NASA and NOAA foresee partnering to conduct joint missions, when and where feasible, in order to maximize high altitude investigations of African Easterly Waves (AEWs) undergoing transition to tropical depressions, and spin-up into tropical cyclones.

The downstream activities will also be coordinated with the driftsonde deployment which was developed by NCAR primarily in response to the World Meteorological Organization THORPEX (The Observing System Research and Predictability Experiment) program (Shapiro and Thorpe 2004). The motivation behind the driftsonde development was to obtain accurate, all-weather profiles of the troposphere and lower stratosphere in regions currently devoid of in-situ measurements at a far lower cost than could be obtained by convention aircraft dropsonde operations. Driftsonde consists of a stratospheric balloon carrying a gondola containing dropsondes and a disposible processing-control system capable of deploying dropsondes on command and relaying the data back in near real-time. These soundings could be utilized to i) study their potential improvement of hurricane genesis forecasts in current operational and research models, ii) calibrate and validate a variety of satellite measurements, iii) investigate model performance in the ability to replicate the observed complex thermodynamic structure in the genesis environment including the treatment of the Saharan Air Layer, iv) advance knowledge of physical and dynamic processes associated with hurricane genesis. A proposal is in preparation to increase the number of sondes and balloons to lock in the time period to coincide with NASA operations.

The following three key science topics broadly address the core objectives of the AMMA U.S. Downstream Component:

- Characterize precipitation processes in the West African region and adjacent eastern Atlantic, with specific focus on the transition of convective systems from a continental to maritime regime;
- Investigate tropical cyclogenesis in the eastern and central Atlantic, particularly the manner in which AEWs evolve into strong (category 3, 4, and 5) hurricanes that impact the United States east coast;
- Ascertain the composition and vertical structure of the Saharan Air Layer. The Saharan Air Layer will be investigated with regard to the manner in which aerosols impact the efficiency of cloud precipitation processes and also its hypothesized influences (e.g. sheared mid-level easterly jet, dry air and thermodynamic stability) on cyclone development.

Central to these science topics will be investigations of hypotheses governing tropical easterly wave-to-depression transition, incipient cyclogenesis, and processes contributing to tropical cyclone intensification.

More specific scientific objectives will seek to:

- Improve our understanding of the processes that influence the relationship between African easterly waves and convection;

- Include the moisture information from GPS dropwindsondes (launched during AMMA-related missions) in operational parallel runs of the NOAA GFS model and assess the impact of this data on the GFS initial/forecast humidity fields and its forecasts of TC track and intensity;
- Collect dynamic and thermodynamic data in the western, central and possibly eastern North Atlantic that can be used to verify global models (e.g. GFS and NOGAPS) and the Hurricane WRF model that is currently under development;
- Determine how low-level vortices associated with organized mesoscale convective systems are produced;
- Determine the dynamical linkage between synoptic-scale forcing and processes that lead to spin-up of the low-level mesoscale vortex;
- Determine how pre-existing mid- and low-level mesoscale vortices interact during genesis;
- Determine how effectively large-scale models predict TC genesis. Assess how well these models capture large-scale dynamics, AEWs, the Saharan Air Layer (dry air and an enhanced low to mid-level jet), and MCSs in their initial and forecast fields;
- Ascertain the manner in which the TC warm core develops in relation to vortex dynamics, convective bursts and the background thermodynamic fields;
- Collect observations of the atmosphere and ocean in and around the storm scale circulation that can be used to develop an evaluation and validation package for the high resolution HWRF;
- Collect observations in a variety of atmospheric/oceanic conditions (e.g. atmospheric shear and humidity environments, oceanic warm core eddies) to assess the influence of these features on observed and modeled TC intensity and structure changes

1.2 French objectives

The French objectives concern the evolution of disturbances (MCSs and AEWs) leaving the West African continent and arriving over the warm eastern Atlantic ocean. The goal is to collect wind, temperature and humidity profiles from dropsonde data, in-situ microphysic measurements, and radar/lidar observations within West-African disturbances arriving over the tropical eastern Atlantic during two or, if possible, three successive days. Following the climatological occurrence of AEWs, MCSs and tropical cyclogenesis in this region (e.g. Thorncroft and Hodges 2001 : JClim 14 1166-1177), only a limited number of West African disturbances might evolve into a tropical storm during the considered period. The collected data will have the potential of revealing the physical processes and interactions which control the oceanic evolution of continental disturbances. Developing and non-developing cases are equally important to identify the main factors of this evolution.

Kinematic and thermodynamic sampling will provide information on the synoptic environment and mesoscale structure of continental, coastal and oceanic cloud clusters. Special attention will be given to the position and intensity of low level southwesterly flow of warm and moist air, mid level African Easterly Jet and associated wind shear, divergence and vorticity centers in relation with African Easterly Waves and other synoptic features, temperature and humidity fields. We will seek continuity in dropsonde sampling in order to analyze the evolution of vorticity in the low and mid-levels in relation with convective activity and large-scale forcing.

Another major objective of this AMMA “downstream phase” or SOP-3 is the validation of satellite products at different locations in West Africa. Thus, these flights will be performed as regulary as possible (given the occurrence of MCSs in this region) within the swath of the active

(TRMM/PR, CLOUDSAT, CALIPSO) and passive (TRMM/TMI, AQUA, MODIS, DMSP...) satellites passes in order to collect the wider data base as possible of « quasi » coincident measurements. Since such colocated measurements of satellite and airborne instrumentation are rather difficult to collect due to the difficulty of having coincidence between MCS occurrence, satellite overpass and flight capability, an alternate strategy of validation will also be considered. It will consist in a more statistical evaluation of satellite products over the different regions (continental vs. oceanic) and for different MCS categories (developing vs. non-developing, organized vs. non-organised, ...). Such a « climatological » data base will allow to statistically validate satellite products for different MCS type and environment.

1.3. AMMA-Africa objectives

Beside the necessary development of applications to cope with the varying climate, the region has some interest to build early warning systems for safety of the people and infrastructures. The overall goal is here to document the atmosphere-ocean-land system (atmosphere, biosphere, ocean, hydrological cycle, …) and its relation with the social and economic system during the monsoon season. Special emphasis will be given to coastal and marine regions. It is known that the impacts are not limited to those regions and contributes significantly to theglobal climate system., For example it is now known that the frequency of cyclones in the Atlantic which can impact the United States is linked to the West African monsoon system (rainfall, easterly waves; aerosols, dust, etc..). One aim is that international effort will lead to predictability of Atlantic hurricanes and concurrentlybenefit the predictability and knowledge of the WAM at various scales (day to season).

Specific goals are the following:

- Improvement of predictive capabilities (meteorological, hydrological and marine forecasts) at various scales;
- Evaluation of the impact on socio-economic sectors (agriculture, health, water resources, fisheries, pastoralism, …);
- Capacity building and training for operations and research on climate and its impacts; (link with ST4);
- Integration of multidisciplinary research to decision making by development of tools (models, new accurate satellite products);

To achieve these objectives a series of scientific tasks (research and operational) has been developed:

- Study of seasonal to interannual variations of WAM in its various components (atmosphere, biosphere, ocean, hydrological cycle, …) at various spatial and temporal scales;
- Study processes that determine seasonal to interannual variability of observed sea surface temperature (SST), sea surface salinity (SSS), mixed layer depth and heat content, in the Tropical Atlantic and in the Gulf of Guinea, and their linkage with West African land surface conditions; (link with TT6);
- Development of Limited Area Models (LAMs) for the region (atmosphere, ocean, coupled);
- Reinforcement and improvement of the observation and measurement network; LOP measurements are targeted to insure environmental monitoring of the marine and terrestrial ecosystems.
- Validation of models, satellite data and products;
- Stimulate a strong international collaboration with the region.

1.4 UK objectives

A NERC SOLAS (Surface Ocean – Lower Atmosphere System) funded project DODO (Dust Outflow and Deposition to the Ocean) will deploy the BAe146 FAAM aircraft from Dakar for the period 20-29 August 2006. Flights will be performed mainly over the ocean between Dakar and Sal, concentrating on measuring aerosol characteristics such as size distribution and chemical composition, as well as their radiative impact. Approximately 4 4.5 hour flights from Dakar will be performed during this period.

DODO objectives are :

1) To deliver case study based predictions of dust deposition to the northern hemisphere Atlantic Ocean constrained by in situ aircraft measurements.
2) To describe how chemical and physical changes in the dust affect its transport over the ocean, and are themselves affected by the transport
3) To assess the size distributed iron loading in the dust, and characterise the chemical form of the iron
4) To fingerprint dust sources using single particle characterisation and assess their main composition, including iron content
5) To assess the climatological representativity of the case studies and therefore predict the seasonal footprint of dust deposition and its associated iron to the north Atlantic Ocean

Additionally we aim:

6) To Assess the radiative impact of the dust over the Atlantic Ocean and its effect on sea surface temperatures.

This observation period at the end of SOP3 will build on a longer campaign in Dakar in January and February 2006 (SOP-0) in association with the UK Met Office DABEX campaign. Other activities in DODO include ship based measurements of dust flux during SOP-0, and the development of modelling of dust outbreaks.

In addition to DODO, some flights from the UK funded AMMA programme (P.I. Claire Reeves) will also look at aspects of longer range transport of chemical constituents across continental Africa.

2. OBSERVING STRATEGY

2.1 Overall strategy

There are many complementary aspects in the different national goals concerning the SOP-3 of AMMA. The western part of the African continent is a place where specific phenomena occur with importance consequences downstream. Though there are many relations between these phenomena, 5 main scientific objectives can be identified :

A. West-African dust plume and Saharan Air Layer to characterize the chemical and physical characteristics of aerosol content in the easterly flow, its impact on radiative fluxes, and evolution during transport over the Atlantic ocean.

B. MCS structure and evolution in the transition region between the continent and the ocean, associated changes in convective/stratiform organization, generation processes, mesoscale vorticity, impact on the boundary layer and tropospheric fields of wind, pressure and humidity.

C. Microphysical characteristics of continental and oceanic clouds with emphasis on supercooled regions, evolution of the ice phase and electrification, properties of ice nucleating aerosols, especially in relation to the presence of Saharan Air Layer.

D. Role of synoptic environment in cloud cluster evolution with the presence of specific tropospheric flows (low-level southwesterly jet, African easterly jet, SAL, Tropical easterly eet, Subtropical westerly jet), tropical disturbances (African easterly waves, cyclonic wake of coastal mountains, ...) and upper level features (upper tropospheric low and high pressure zones).

E. Tropical cyclogenesis as a result of further evolution of convective perturbations, TC genesis and intensity change over the Atlantic with the development of a cyclonic warm core in relation with mesoscale dynamics, convective outbursts, environmental thermodynamic fields, and the presence of Saharan Air Layer.

2.2 Aircraft deployment strategy

As detailed below, the involved aircraft will make measurements relative to the different scientific objectives :

A. West-African dust plume and Saharan Air Layer : UK BAe-146 (in situ measurements), NASA DC-8, (in situ state variables, vertical structure of temperature, water vapour and aerosol), NOAA G-IV (in situ state variables and dropsondes), FR FA-20 (in situ state variables, dropsondes, lidar)

B. MCS structure and evolution : NASA DC-8 (MW radiometer, Doppler radar), FR FA-20 (94 GHz radar + lidar)

C. Microphysical characteristics of continental and oceanic clouds : NASA DC-8 (microphysical probes, Electric field, MW radiometer, Doppler radar), FR FA-20 (microphysical probes, 94 GHz radar + lidar)

D. Role of synoptic environment in cloud cluster evolution : NASA DC-8 (in situ state variables, dropsondes), FR FA-20 (in situ state variables, dropsondes), NOAA G-IV (in situ state variables, dropsondes), NOAA P3 (in situ state variables, dropsondes), Aerosondes (in situ state variables)

E. Tropical cyclogenesis : NASA DC-8 (Doppler radar), NOAA G-IV (in situ state variables, dropsondes), NOAA P3 (in situ state variables, dropsondes, Lower Fuselage and Tail Doppler radars)

These objectives are of course not independent and, as far as possible, coordinated approaches with the diffferent aircraft will be followed to sample the different aspects. Ground-based equipments, radiosoundings supplemented with driftsondes and satellite measurements will also provide complementary information.

2.2.1 US Aircraft Deployment Stratefy

NASA anticipates that the DC-8 high altitude research aircraft will serve as the primary research tool for NAMMA-06 investigations. The DC-8 will likely base from the Cape Verde Islands and may be flown in coordination with one or more NOAA Hurricane Research Division aircraft operating in the central and eastern Atlantic basin. Approximately 120 flight hours will be available on the DC-8 for a four week period commencing September 1, 2006. Sortie duration from a cruising altitude of 13 km is typically on the order of 8 hours.

The following general types of payloads will provide crucial in situ and remotely sensed profiling information during NAMMA-06:

- observations of cloud and hydrometeor microphysics;
- precision observations of the *in situ* and vertical structure of water vapor and aerosols;
- passive microwave observations of cloud ice;
- vertical radar structure of precipitation;
- *in situ* meteorological state variables (temperature, humidity, pressure, winds);
- remotely sensed profiles of temperature;
- cloud electrical fields;
- airborne observations of soil moisture in the L-band (passive, active or both preferred).
- GPS dropsonde measurements

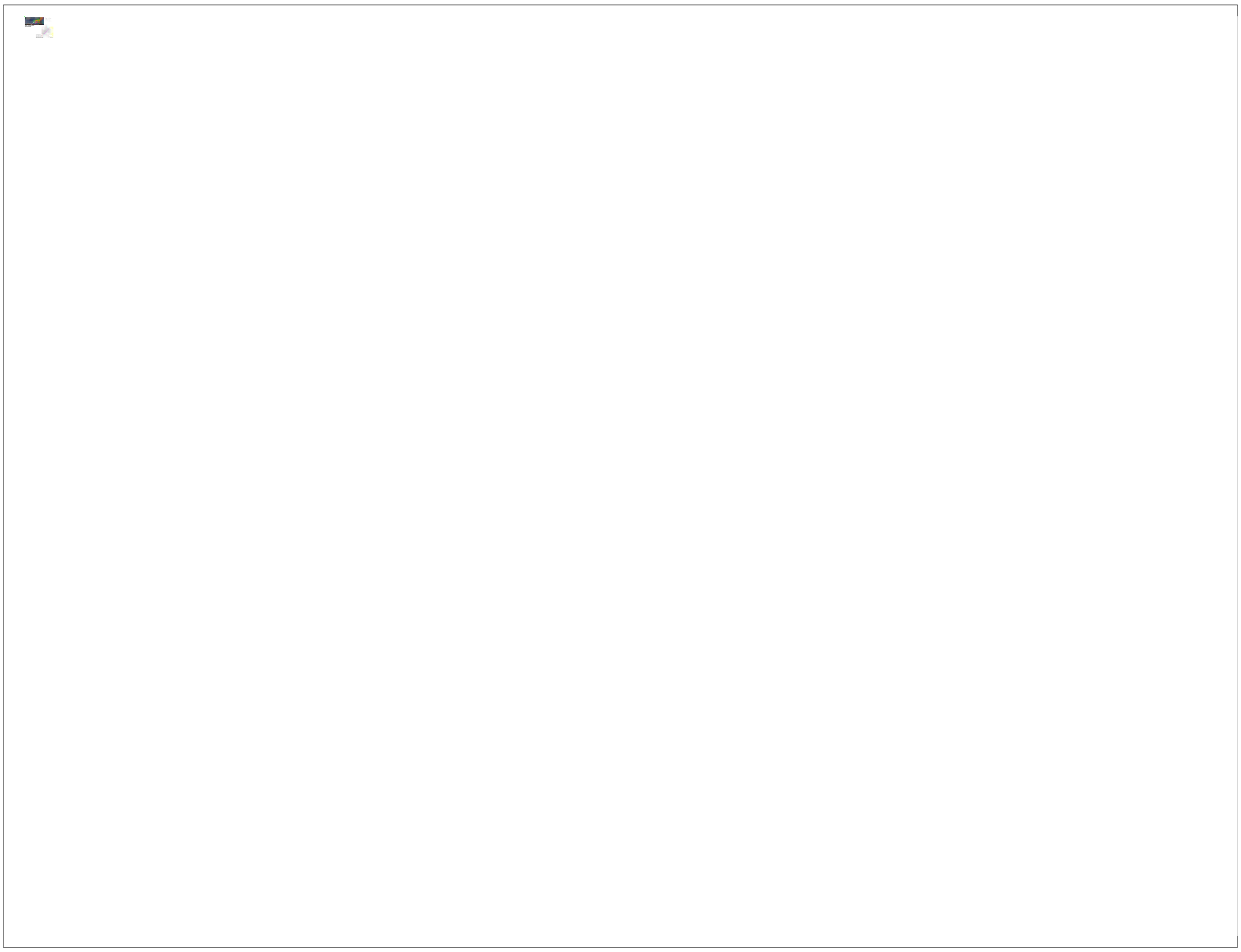


Figure 1 : *Schematic illustrating one possible scenario of how the NASA DC-8, NOAA G-IV and Aerosondes will be meshed to conduct joint missions in a hypothetical tropical depression evolving from an AEW with SAL entrainment.*

The NASA DC-8 will fly west from Cape Verde and operate a saw-tooth, survey type pattern back and forth across the wave axis. The goal of the DC-8 will be to sample not only the vertical shear structure along the wave axis, but also provide in situ microphysical information on stratiform and weak convective elements contained within MCSs. Dropsondes will be used to map the structure of a mid-level mesovortex center (or multiple mid- and low-level centers) which may or may not be present at this stage in the wave evolution. In addition, vertical incidence passive microwave radiometry and Doppler radar sampling will provide information on precipitation intensity, ice composition and vertical structure of embedded MCSs. A combination of flight level meteorological measurements and dropsonde information may be able to identify temperature anomalies associated with the nascent warm core.

As part of the SALEX investigations begun during the 2005 hurricane season, the NOAA HRD anticipates deploying the G-IV high altitude research aircraft from Barbados in the Caribbean. Approximately 120 research hours will be available during the period 1 July - 30 September, 2006. The G-IV will be used to provide in situ thermodynamic and kinematic profiles in and around developed AEWs, tropical cyclones and the SAL using GPS dropsondes. The G-IV has an endurance of approximately 7-8 hours and cruise altitude is 13 km.

The NOAA G-IV and P3 aircraft will likely operate out of Barbados during SOP 3. The G-IV GPS dropwindsonde drop points will be selected using real-time GOES SAL tracking imagery from UW-CIMSS and mosaics of SSM/I total precipitable water from the Naval Research Laboratory. Specific effort will be made to gather atmospheric information within the Saharan Air Layer as well as regions of high moisture gradients across its boundaries. Specific attention will be focused on capturing the high moisture gradient regions associated with the SAL (Fig. 1, A & B) and the low to mid-level inflow of dry, dusty SAL air that typically entrains into the northwest and southwest quadrants of the developing TC (Fig. 1, C). The 700 hPa African easterly jet will also be targeted to assess how it is affecting the magnitude of the vertical wind shear in the storm environment (Fig. 1, B). The P3 aircraft will cover the western part and the fringes of the central North Atlantic. It will provide information on TC life cycle and on the concentration /particle size distribution in relation with the vertical extent of dry air, mineral dust and easterly winds.

One or more Aerosonde uninhabited air vehicles (perhaps embarking from Conakry, Guinea) may be available for continuous monitoring of the oceanic planetary boundary layer and lower half of the Saharan Air Layer. They may be used in the mode of providing continuous, long-endurance low-mid tropospheric transits within the SAL layer - with particular emphasis on measuring thermodynamic (atmospheric stability, relative humidity) and vertical shear properties through the core of the dust plume.

Characteristics and payloads of NASA / DC-8 and NOAA / G-IV can be found in Appendices 2 and 3, respectively.

2.2.2 French Aircraft Deployment Strategy

During the last two weeks of September 2006, the French Falcon-20 (FR / FA-20) aircraft will be based in Dakar, Senegal (14.73 N, 17.50 W) to investigate the evolution of AEWs and MCSs propagating westward from the West African continent, to the warm waters of the nearby tropical eastern Atlantic ocean. Characteristics and payloads of FR / FA-20 can be found in Appendix 4.

Six missions – each of 4.5 h duration with 16 dropsondes – would be necessary to sample 2-3 potentially active perturbations at different stages of their development over the continent and, more specifically, over the nearby ocean. The performances of the FR / FA-20 (cruising speed : 220 m/s , flight level : 40 kft – 12 km, flight duration : 4.5 h including ferry time) make it possible to sample a domain of about 500 km x 500 km with 16 more or less regularly spaced dropwindsondes (e.g. at 100-150 km from each other, see below) anywhere within a range of about 800 km from Dakar.

The objective is to collect kinematic and thermodynamic data to characterize the structure of convective cloud clusters and the synoptic forcing during the evolution from continental to oceanic environment, with the associated changes in mesocale cyclonic vorticity.

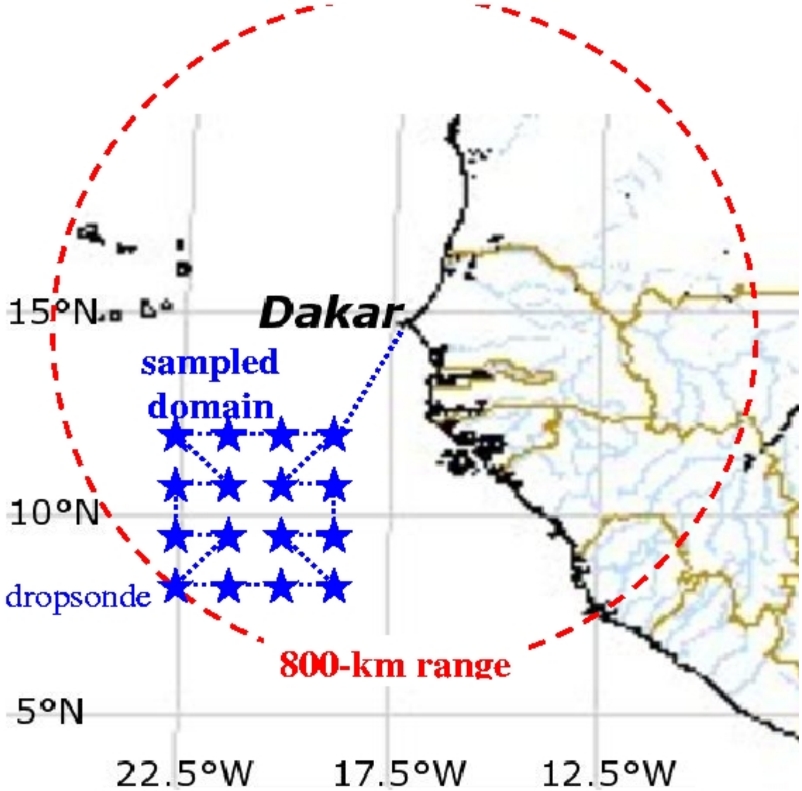


Figure 2 : *Example of a 4h30 dropwindsonde sampling mission dedicated to a developing tropical disturbance with the FR / FA-20 based in Dakar (Senegal)*

Six other missions – each of 4.5 h duration – will be needed to sample the microphysical characteristics of 2-3 potentially active perturbations. Two flight strategies will be used on different MCS types in order to evaluate the differences in microphysical properties and their evolutions as the MCS propagate over the ocean.

The first flight strategy will be devoted to a documentation of the vertical structure (3 IOPs) of microphysical properties by performing vertical/Lagrangian ascent within clouds (stratiform and cirriform regions) over land and ocean. The second flight strategy will be devoted to the study of the horizontal variability (3 IOPs) of microphysical and dynamical properties in order to obtain a 3D-documentation. Six missions (3 vertical structure flights and 3 horizontal structure flights) – each of 4.5 h duration – would be necessary to sample vertical and horizontal varibility of several types of cloud systems, to obtain a documentation of their diffences over land and ocean in coordination with satellite overpasses.

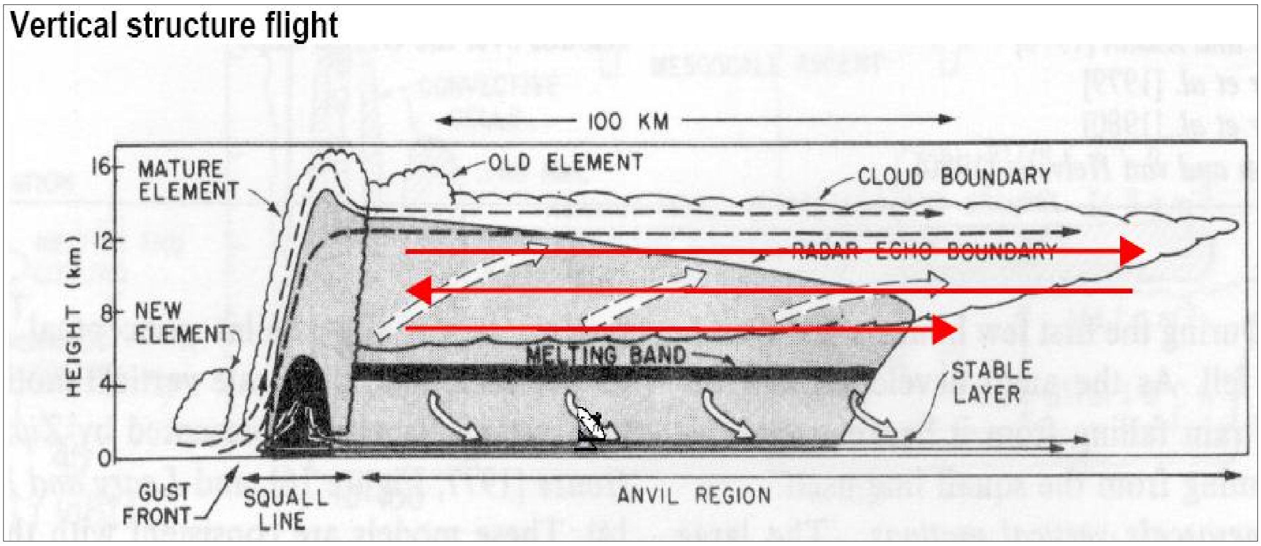


Figure 3 : *Microphysical sampling mission in a continental or oceanic MCS with the FR / FA-20 based in Dakar*

Coordination between FR / FA-20 and NASA / DC-8 should help to improve spatial coverage owing to the longer flight duration of DC-8 allowing combined dropsonde and in situ sampling of meso- and synoptic scale thermodynamic and kinematic fields. FR / FA-20 will be limited to a region of about 800 km around Dakar, while the NASA DC-8 based in Sal (Cape-Verde) will be able to make observations westward, over the central tropical Atlantic, and to provide a more complete view of tropical cyclogenesis. Likewise, coordinated FR / FA-20 and NASA / DC-8 microphysical measurements combined with airborne remote sensing observations at different levels, locations and phases of cloud clusters will provide a more complete coverage and complementary observations for the validation of satellite observations.

<u>Note on the deployment of the French FALCON-20</u> :

The proposed timing is to have the Falcon on 15-30 September 2006 in Dakar for SOP-3a2, after being used from Niamey (Niger) for SOP-2a3 on 1-14 September 2006 for "microphysical" flight over the radars in Djougou (Benin) (this is <u>option A</u>).

Other options need to be considered in case technical, logistical or administrative constraints would cause unexpected delays.

- <u>Option B</u> considers a shorter duration of SOP-2a3 (4-15 September 2006) and a very short delay of the beginning of SOP-3a2 (16-30 September 2006);

- Option C would result from longer delays in the previous planning, with SOP-2a3 from 7 till 18 September 2006, and SOP-3a2 from 19 till 30 September 2006.

Note also that one or two days of recovery might be necessary after ther transit from Niamey to Dakar for the Falcon-20 to be fully operational for dropsonde and/or microphysical flights.

2.2.3 British Aircraft Deployment Strategy – DODO

The UK BAe146 will be deployed for 9-days out of Dakar from 20-29 August 2006. Measurements will be targeted at dust plumes, will overfly AERONET sites at Dakar and Sal (Cape Verde) and will co-incide wherever possible with satellite overpasses, in particular MODIS on both Terra and Aqua. Dropsondes will also be used to measure the atmospheric variables. Immediately prior to this deployment, the BAe146 will be based in Niamey (TT8 – SOP-D) performing measurements funded by AMMA UK and AMMA –EU. Characteristics and payload of UK BAe146 can be found in Appendix 5.

Around 4 missions of 4.5 hours duration will be flown during this deployment. Illustrative flight patterns are shown in Figure.

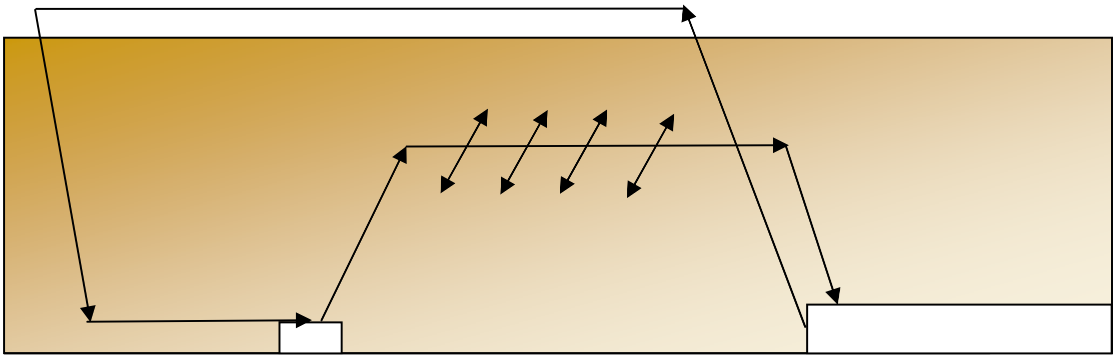


Figure 4 : *Illustrative ... ght pattern for in-situ and radiometric sampling between Dakar and Cape Verde.*

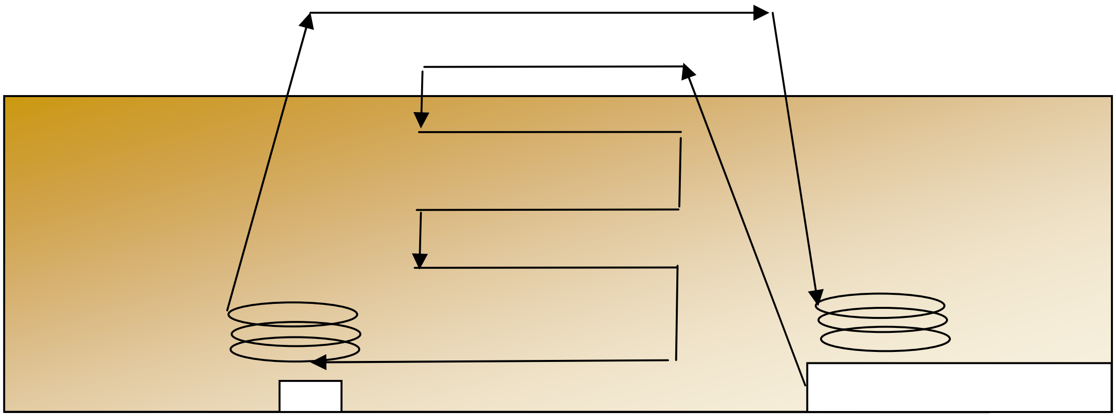


Figure 5 : *Illustrative B... pattern2, for in-situ sampli... dust plume evolution measurements. Double flight with land and refuel at Sal.*

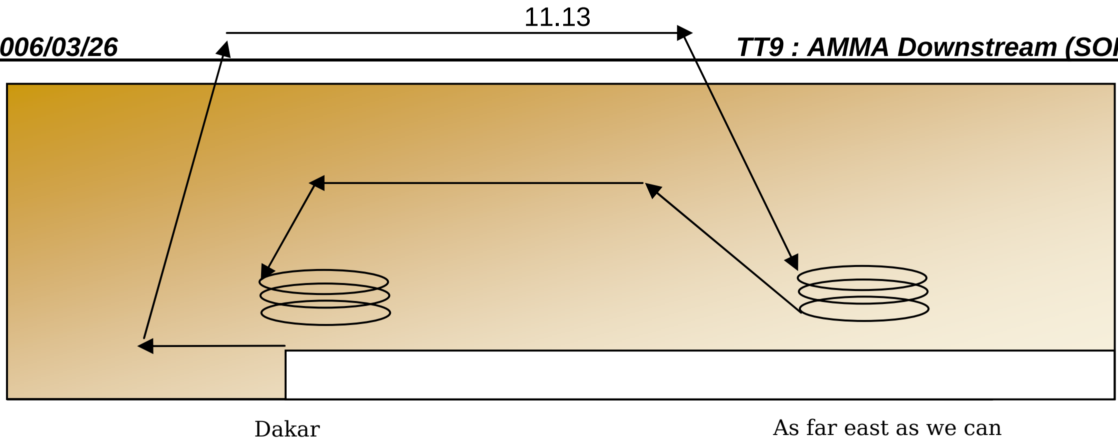


Figure 6 : *Illustrative BAe-146 flight pattern 3, for land surface characterisation, in-situ and radiative measurements over land.*

2.2.4 Driftsonde

Driftsonde consists of a stratospheric balloon carrying a gondola containing dropsondes and a disposible processing-control system capable of deploying dropsondes on command and relaying the data back in near real-time. The progress to date includes five driftsonde flights and the development of a low-cost, light-weight dropsonde for driftsonde called MIST (Miniature In-situ Sounding technology). The early driftsonde plans were to conduct missions over the Pacific Ocean during winter on a balloon designed to last a 3 to 5-day crossing times. The driftsonde for AMMA will be in a lighter wind environment so that the crossing the Atlantic will take of order ~15 days. The French Space Agency (CNES) has developed and tested a balloon system for AMMA to carry the drifsonde gondola,

The driftsonde operations during the 3rd AMMA SOP will be flown out of N'Djamena, Chad with daily launches during periods of interest. This location is well-suited to cover the regions of hurricane genesis. The driftsonde trajectories (Fig. 1- need figure) show that these systems will provide large-scale, continuous sounding coverage over the subtropical Atlantic to support the more localized episodic aircraft missions (Fig. 2- need figure). These soundings could be utilized to i) study their potential improvement of hurricane genesis forecasts in current operational and research models, ii) calibrate and validate a variety of satellite measurements, iii) investigate model performance in the ability to replicate the observed complex thermodynamic structure in the genesis environment including the treatment of the Saharan Air Layer, iv) advance knowledge of physical and dynamic processes associated with hurricane genesis. Currently the driftsonde is funded for 8 missions carrying 40 sondes each.

2.3 Ground-based deployment

In order to achieve the primary objectives measurements (characterization of precipitation processes from continental to marine environments, tropical cyclo-genesis, the Saharan Air Layer) ground based measurements will support aircraft and satellite measurements during the August-September of 2006. The ground-based instruments includes surface based radars, disdrometers, radiosondes, flux towers, a tethered balloon system, IR/solar radiometers and Lidar measurements. The measurements will take place in Cape Verde and Senegal and will be supported by Met services, University researchers and other research institutions in these countries. There will be two characteristic modes of operation for ground-based instruments: Continuous monitoring and targeted operations. Tables showing the ground-based instruments and the associacted PI are in Appendix 1.

The relations with the scientific objectives are :

A. West-African dust plume and Saharan Air Layer : lidars, radiometers

B. MCS structure and evolution : radars, raingauges, surface and boundary layer measurements

C. Microphysical characteristics of continental and oceanic clouds : radars, raingauges, disdrometers

D. Role of synoptic environment in cloud cluster evolution : radiosoundings

NASA anticipates conducting a ground-based scientific component with its polarimetric weather research radar (NPOL) and C-band Doppler weather radar (TOGA). NPOL will likely be based in Dakar, Senegal, along with the Senegalese S-band radar. NASA is seeking to establish the TOGA on the Cape Verde Islands. Upper atmospheric soundings will be routinely collected from both Dakar and Cape Verde. NASA may support operation of a micropulse, 532 nm lidar profiling system to continuously monitor water vapor and aerosol vertical structure at both Dakar and Cape Verde.

The aerosol forcing from the SAL will be investigated from Cape Verde and Senegal. These measurements will provide validation of satellite measurements (MODIS, Calipso) DC-8 and FF-20 Lidar Measurements during September. We currently expect 2-3 Lidars in Senegal during the SOP3 and 1 lidar in Cape Verde. The lidars are expected to be situated near the AERONET sites (Sal, Cape Verde, Mbour, Senegal) during the SOP3. These instruments will provide AOD (Aerosol Optical Depth) values which will be available to researchers in near real time. Solar and IR surface flux measurements in Cape Verde and Senegal are expected to provide some estimates of the aerosol surface forcing during SAL outbreaks. The Lidar instruments are expected to be deployed in late 2005 and early 2006 for the AMMA SOP/EOP deployments. IR/Solar radiation measurements are expected primarily during SOP3 and may be extended beyond the SOP in Senegal and maintained by scientists at the university (LPASF).

Microwave Radiometer (MWR) measurements in Senegal and Cape Verde are being proposed for the continuous measurements of cloud properties (cloud effective radius, liquid cloud water) during the SOP3. These ground based measurements will complement DC-8 and FF-20 aircraft measurements. They will also be compared to all CLOUDSAT overpasses. The combination of the MWR the radar measurements will allow us to directly link cloud properties to precipitation for a variety of precipitating systems (non-MCS and MCS) during the SOP3. Further, they allow us to examine the spatial variability between marine (Cape Verde), coastline (Senegal) and continental (Niger). The exact locations of these measurements will be determined before the spring of 2006.

2.3.1 Surface-based radar network

Ground based radars will provide to provide continuous monitoring for the depiction of precipitation properties as convective systems (organized and disorganized) propagate from continental to coastline and purely marine environments during August and September of 2006. The NASA Polarimetric and Senegalese S-band radars will provide coverage for continental and coastline observations and the NASA TOGA C-band radar will provide coverage for marine observations. The radar measurements will be coordinated by teams of scientists in the US and Senegal.

The ground radar measurements in Senegal will also serve to validate for TRMM validation in a coastline environment. In particular derived rain rates and characteristics from TRMM PR will be compared to ground radar values. All of the observed convective systems associated with TRMM overpasses will be compared to ground radar measurements. The comparison will allow for errors in the TRMM overpasses associated with spatial/temporal under-sampling of convective systems. The ground radar measurements will also be compared to TRMM 3B42RT 3 hour rain estimates in this transition zone.

Scanning Strategies

Two different scanning strategies that will be implemented based on the type of operation (high resolution volume scan/rain mapping and aircraft vectoring). We plan to operate NPOL in a coordinated (e.g. start of the hour) 10 min temporal sampling resolution unless NPOL is being utilized for aircraft vectoring (e.g. DC8 or the French Falcon-20) in which case NPOL will be operated in a 5-6 min repeat cycle.

Nominally, we plan to scan in a 10-min repeat sequence. The scanning sequence will include a combination of long-range surveillance scans, rain-mapping scans, and full volume scans. A long range (max range ~300 km) surveillance scan, at a elevation angle of 0.5° elevation will start at every repeat cycle. Following the surveillance scan, a three elevation rain map scan (max range ~150 km) will start immediately after the surveillance scan. The rain map scan will be followed by a 16-19 tilt volume scan (max range ~150 km) to complete the 10 min sequence. We plan to implement two types of volume scans based on the storm properties. For storms up to 15 km height and at a 30-150 km in range, a “FAR SCAN” will be employed. The vertical resolution is 2/2.5/3.0 km below 5, 10, and 15 km respectively. For deep convection near the radar (< 30 km) a second volume scan (NEAR SCAN) will be deployed. The NEAR SCAN sacrifices vertical resolution to provide coverage of the storm top to obtain more complete vertical structure information. There will also be the option to schedule RHI scans in place of the surveillance scan if there is an interesting feature within a mesoscale convective system.

When NPOL is being used in support of aircraft operations, the scanning sequence will be modified to a 4-6 min repeat cycle. In this case, the surveillance and rain map scan may not be implemented and the number of tilts maybe reduced to fit into the higher resolution time window. Also, there is an option to operate in a sector scan mode to provide high temporal measurements over the region being sampled by the aircraft.

The proposed scanning strategies are illustrated in Figure 3. Scanning sequence (A) consists of a surveillance scan, three-tilt rain mapping scan followed by full-tilt volume scan. Scanning sequence (B) will be available for rapid updates when during aircraft operations. The radar can be operated at a reduced tilt volume scan or full-tilt sector scan sampling the region of the storm of interest. A rain mapping scan is scheduled at the beginning of the sequence to provide adequate spatiotemporal resolution for rainfall products. Sequence (C) will be scheduled when it is desirable to sample the rapid evolution of newly forming convection during aircraft operations.

A. Surveillance /Rainmap/ Volume Scan Mode

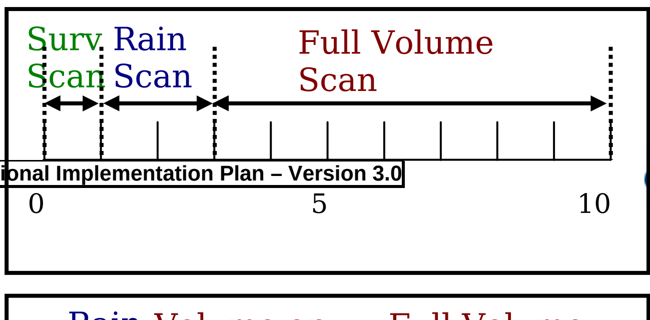


Figure 7*. Proposed scanning strategies for NPOL during AMMA.*

2.3.2. Rain gauge / disdrometer network

Continuous rain measurements and drop size distributions during SOP3 is expected in Cape Verde and Senegal. This rain-gauge network will allow us to derive basic information on the precipitation yields from the principal mesoscale convective systems as they traverse from continental to marine environments. Disdrometers will be co-located with rain gauges to study the raindrop size distribution for the mesoscale convective systems.

In Senegal, a network of 40-50 tipping bucket rain gauges (Qualrimetrics and Hydrological Systems) will be deployed over coverage area of NPOL. A subset of the rain gauges (~20 gauges) will be placed in a dense rain gauge network to capture the small-scale rainfall variability of the region and provide error estimates for the NPOL radar. The first set of rain gauges were deployed during the summer of 2005 and the rain gauges for the dense rain gauge network was sited. All rain gauges will undergo calibration tests prior during installation and after every wet season. On site calibration checks will be performed periodically during monthly data download and service visits. The coarse grid rain gauge measurements in concert with the existing rain gauge network in Senegal will be compared directly to TRMM rain rates. The rain gauge network in Senegal will be left in place for longer term measurements that will be available for students and researchers in Senegal/US.

In Cape Verde, the network is expected to be comprised of existing and supplemental rain gauge measurements during SOP3. The rain gauges are expected to be distributed amongsts the various islands with several expected near the TOGA radar. At least one disdrometer is expected for Cape Verde for drop size distributions that will be compared to upstream (Senegal and CATCH basin) DSDs. An assessment of the rain gauge network in Cape Verde will be conducted during Jan./Feb. of 2006.

2.3.3. Thermodynamic and dynamic measurements

Surface-atmosphere interactions govern the transports of water vapor from the lower atmosphere to the deep atmosphere. Also, these processes control the onset of atmospheric convection and timing of precipitation. To achieve a quantitative understanding of these surface controls, we propose to develop a field program in which we will integrate surface-based water vapor transports with both thermodynamic and dynamic characteristics of the deeper atmosphere. Surface flux towers, a tethered balloon and radiosonde launches are expected to provide insights on these processes. We expect a 10 m surface flux tower in Senegal and Cape Verde, the tethered Balloon near the NPOL radar and radiosonde launches in Cape Verde (Sal) and Senegal (Dakar and Tambacounda).

2.3.4. Flux Tower Measurements

These tower measurements will also provide critical information to quantify the temporal variability in the vertical water vapor transports. Air temperature (5 levels), wind speed/direction, relative humidity (2 levels) and soil temperature (5 depths), and soil heat flux will be recorded continuously.

2.3.5. Tethered Balloon Measurements

We will use a tethered sonde system to define the thermodynamic and dynamic features of the atmospheric layer from the surface to 1.5 km. We will fly a 76 m^3 (2500 ft^3) tethered balloon to lift a single sonde to a maximum altitude of 1500 m. The sonde will provide measurements of temperature, humidity, pressure, and wind speed and wind direction. The sonde will be lifted at a constant rate-of-rise/descent of 1 m s^{-1}. All variables will be recorded every 2 s giving a maximum vertical resolution of 2 m. We will fly the tethered system every three to six hours. The times will coincide with the releases of the rawinsondes in Dakar.

2.3.6. Radiosonde Measurements

Radio sounding measurements will be important for identifying important large scale features such as the African Easterly Jet and African Easterly Waves. The soundings will also provide important information about the low level flow regimes in Senegal which can be continental or marine. These sounding will provide important information about the thermodynamic state of the atmosphere and its potential for convection. Because Cape Verde and Senegal are under the influence of the SAL, the radio sounding will provide valuable information on how the moisture, dynamic and thermal structure of the atmosphere is altered in the presence of the SAL. Currently, Cape Verde does one radiosounding per day, Dakar Senegal launches 2 per day and Tambacounda launches 1 per day. We hope to supplement these stations for a minimum of 2 sounding per day.

Figure 8 : *Western Quadrilateral of radiosounding for AMMA SOP 3..*

NOTE :
Need more on the « Western Quadrilateral » which TT9 is responsible for: we would like these to be launching at least once per day and ideally twice a day.

Dakar
Conakry
Sal
Tamdacounda
Nouakchott
+ Bamako ?

Needs urgent action and identification of key personnel to liase with and work with ASECNA and other relevent people running stations.

2.3.7. Aerosol and Cloud Microphysical properties

Continuous and extended observations from surface sensors (Lidar, microwave radiometers) will complement the in situ measurements and moreover provide information on the temporal variability of the SAL and cloud properties and its impact on the surface that can not be achieved through aircraft flights.

2.4 Ocean based deployment

The NOAA *R/V Ron Brown* will perform two transects during the 2006 AMMA field campaign. The first leg (28 May – 22 June) will be along 23^{o}W from ~5^{o}S-15^{o}N with a 3 day stop in Dakar, Senegal or Tenerife, Canary Islands. The main objectives of this first leg will be to service a French Tao Mooring currently deployed at the equator and to deploy two additional Tao Moorings along the transect (~5^{o}N and ~12.5^{o}N). Oceanic (e.g. SSTs and surface drifters) and atmospheric (e.g. rawinsondes and in situ thermodynamics) measurements will be made along this initial leg. The second leg (25 June – 21 July) will also be along 23^{o}W from ~15^{o}N-5^{o}S and will focus more specifically on oceanic and atmospheric measurements. If the Canary Islands are selected as the port of call, additional measurements could be made along both legs between 15^{o}N and Tenerife (~28^{o}N).

2.5 Modelling studies

Modeling studies will consist of three fundamental parts, with overlap between each: Numerical Weather Prediction, Cloud Resolving Modeling and Idealized Modeling. These are all linked together by the use of special AMMA observations for verification of the weather systems.

More information on the French non-hydrostatic multi-nested Méso-NH model can be found at URL http://www.aero.obs-mip.fr/mesonh

More on what models will be used:
Meso-NH
WRF
Other?

During the SOP3 period, the Weather Research and Forecasting (WRF) model will be used operationally (http://wrf-model.org). The wrf model has two cores the Advanced Research WRF (ARW) and Non-hydrostatic Mesoscale Model (NMM). The NMM has been optimized for operational forecasts and has a faster turn-around time for forecasts. During AMMA SOP3, we expect to run the NMM operationally at 000 and 1200 UTC over a large domain which covers land and ocean areas. The model is expected to be run at 12 km for the parent domain and a four km nest , with a focal area between the western Sahel and to the west of Cape Verde. Based on the WRF model simulations for August 22nd-September 2005 (AMMA “Dry Run”), we have found that the model has skill in forecasting large/synoptic scale (TEJ, AEJ, AEW) , westward propagating MCSs (squall lines) and locally forced convection using a 12km/4km configuration. We have also found that the model has shown skill in forecasting tropical cyclone development (Figure xx).

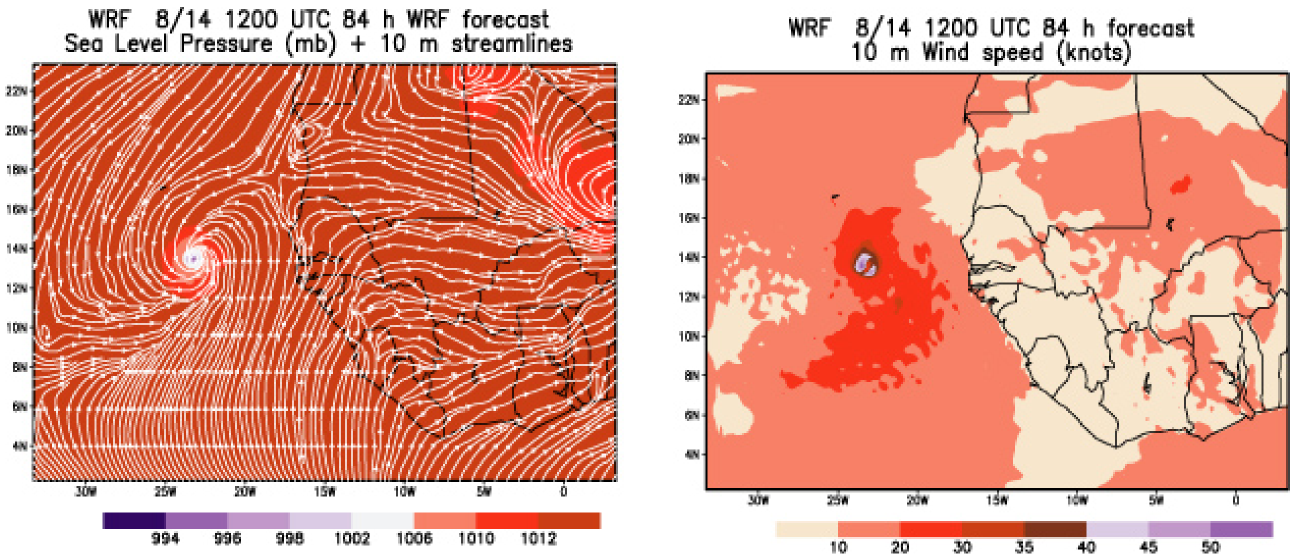


Figure 9: *WRF 84 hour forecasts of (a) Sea Level Pressure and (b) 10-m wind speeds associated with Tropical Storm Danielle, August 14, 2004.*

2.5.1 Operational forecasting

Forecasts and analyses from operational centers will be critical for several aspects of AMMA and its modeling component, including in-the-field decision making for conducting intensive observation periods, large-scale diagnostic studies and initial and boundary conditions for limited area modeling studies. The enhanced observations available in SOP3 will provide an opportunity to evaluate the ability of operational NWP forecasts and analyses to represent the evolution of weather systems over West Africa and the tropical Atlantic, their convective characteristics and interactions with the large-scale environment. Global models employing convective parameterizations will be critical to understanding the key scale interactions. The sounding networks will provide a foundation for validating the parameterization schemes via budget studies and via direct detailed observation of the convection.

There will be four targeted forecast areas during SOP3 which extend from the CATCH basin to the Western Atlantic (Figure xx). The anticipated forecast area will allow us to track large-scale features such as AEWs for approximately 100° of longitude. Forecast products from Global and Mesoscale models and satellite observations (VIS/IR/water vapor/microwave/TRMM PR) will serve as primary guidance for operations. Analysis maps of large scale features (AEJ, TEJ, AEW axis, AEW, precipitation features, and SAL outbreaks will be displayed. Forecasted variables for zones 1-4 at 0-24h, 0-48h, 3-5 days will made available.

FORECASTED VARIABLES FOR ZONES 1-4

Precipitation

Class A	Class B
Organized	Local

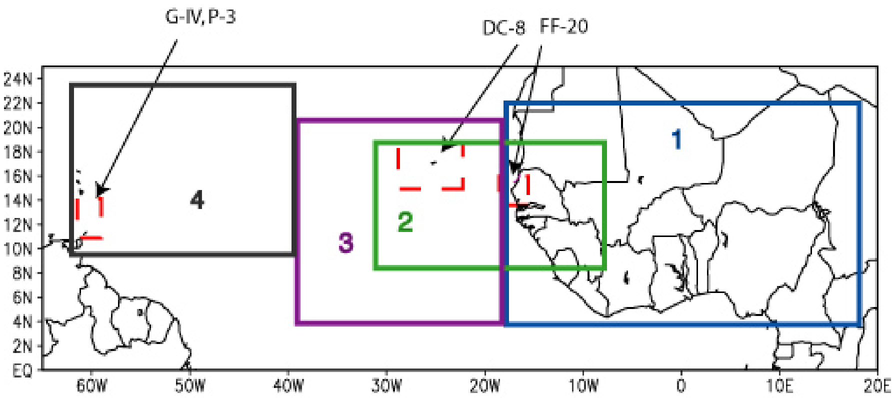
Intensity
Duration
Area Coverage
Type (squall lines. MCCs)
Time of initiation

Intensity
Duration
Area Coverage

Dynamic field linked to Precipitation
Surface Winds and direction
African Easterly Jet Position and Magnitude
Tropical Easterly Jet Position and Magnitude
African Easterly Wave position
Relative Vorticity (850 hPa and 700 hPa)
Mid-lower Tropospheric Shear (900-600 hPa)
Upper-lower tropospheric shear (200-850 hPa)
Vertical Velocity at 700 or 500 hPa
Low level convergence (850 hPa)
Upper level divergence (200 hPa)
GENESIS parameters

Thermodynamic/stability field linked to Precipitation
Surface Temperature
Theta/Theta-e
CAPE/CIN
Model Soundings
Depth of the Monsoon Trough
PBL height
Latent/surface fluxes

Proposed Forecast Zones in association with
Downstream aircraft operations during SOP 3 (2006)



Zone 1 - AMMA international (continent)
Zone 2 - AMMA transition (continent to ocean + Guinea Highland)
Zone 3 - AMMA E. Atlantic (18W-40W)
Zone 4 - AMMA C. Atlantic (40 W- 65W)

Figure 10 *: Forecast Zones during AMMA SOP3.*

In addition to these modeling efforts products will also made available through the THORPEX project TIGGE. Several NWP centers will make available ensemble forecasts. NCEP has agreed to provide products specifically for AMMA.

More on forecasting :
MSG receving station in Dakar (Weather service, ASECNA) ?
Internet link to get the AOC products from Toulouse
Where will the operation center be located ? (ASECNA ? who can be contacted ?)
Include NCEP/GFS, USN/NOGAPS & UKMO TCgenesis products
Include SAL products (from Meteosat & GOES)

2.5.2 Case Studies

High-resolution regional simulations will be used to investigate the multi-scale aspects of the weather systems on timescales of days and less, building on earlier simulations performed with either global models or regional climate models. Because of the versatility of regional models, questions about sensitivity to grid spacing and physical parameterization can be addressed in a straightforward way as well as an investigation of process studies. Regional models will also be used for experimental data assimilation.

2.6 Satellite observations

The relations with the scientific objectives are :

A. West-African dust plume and Saharan Air Layer : MODIS, …

B. MCS structure and evolution: MSG, GOES, A-Train, TRMM, DMSP, …

C. Microphysical characteristics of continental and oceanic clouds: A-Train

D. Role of synoptic environment in cloud cluster evolution : NOAA, METOP, MSG, GOES

E. TC genesis : NOAA, METOP, MSG, GOES

In addition to the existing geostationary (MSG) and polar-orbiting satellites (NOAA, DMSP, A-Train, possibly TRMM...), this project will also gain by the foreseeable presence of ESA / METOP satellite, Europe's first polar-orbiting satellite dedicated to operational meteorology. METOP will carry a new generation of instruments with improved remote sensing capability permitting accurate measurements of temperature and humidity profiles (IASI, AMSU, HIRS, MHS, GRAS), wind speed and wind direction over the ocean (ASCAT). The Afternoon or "A-Train" satellite constellation which will consist of six satellites flying in formation around the globe (Aqua, Aura, OCO, PARASOL, CALIPSO and CloudSat) will also provide unique measurement capabilities of aerosol, cloud microphysics**,** temperature, relative humidity, and radiative fluxes.

Dropsonde measurements will characterize the temperature and humidity profiles with much higher vertical resolution than available from the METOP instruments. Provided that spatial and temporal coincidence is adequate, this will help to validate the satellite-derived profiles in a tropical oceanic region where humidity content is large, and vertical structure can be complicated by the sporadic and possibly simultaneous presence of stable, dry and dusty layer associated with SAL, and saturated layer associated with MCS outflow. In the tropical upper troposphere (12-18 km) above the aircraft flight level and satellite-derived temperature and humidity profiles will be unique sources of information on the vertical exchanges across the tropopause associated with deep convection. Scatterometer and cloud-motion winds will also help to identify the evolution of the mesoscale vortex. Visible and infrared MSG images at high spatial and temporal resolutions; in coordination with less frequent but more penetrating microwave images from DMSP, TRMM and AQUA, will help to identify the successive convective developments.

Since the environment of the system in terms of wind, temperature and humidity will be sampled by dropsondes, a documentation of the internal structure of the tropical anvils (dynamic and microphysical properties) has to be achieved on several cases of observations. Progress in remote sensing measurements and in data analysis can now provide an accurate microphysical and dynamical documentation. Since in-situ microphysical data have never been collected in West Africa, it has first to be checked that the range of application of the retrieval algorithms fits within the microphysical characteristics measured in this region. Once this step is completed, the three dimensional microphysical description can be built in conjunction with dynamics. The airborne active instruments (cloud radar and lidar) will allow a 3D documentation of the cloud properties at the mesoscale for a limited amount of cases. Spaceborne instrumentation will then be used to extrapolate the cloud properties from a few airborne studies to a more systematic survey.

However, the spaceborne active measurements (TRMM / PR, CALIPSO, CLOUDSAT) alone are not sufficient to work at the scale of an African monsoon season. The passive remote sensing measurements from space (e.g. Aqua/MODIS, Aqua/AIRS, TRMM/TMI...) have much larger swaths, but represent vertically integrated values. It is therefore necessary to constrain the retrieval methods from passive instruments with the active measurements during AMMA, and then to extrapolate the active remote sensing documentation of the cloud properties to the swath of the passive instruments. Once constrained and validated during the AMMA-SOP the satellite products could be exploited for other monsoon seasons the A-train and other satellites will document.

At this stage it has to be noticed that AMMA / SOP-3 is planned to take place in the Dakar region after the AMMA / SOP-2a3 in the Niamey (Niger, first two weeks of September 2006) region where the same kind of instrumentation (ground-based and airborne) will be deployed. SOP-3 will then complement SOP-2a3, with measurements taken in different environmental conditions in terms of aerosol species and environmental conditions (continental versus oceanic). Indeed the aerosol layer in the Niamey region is expected to be strongly influenced by biomass burning whereas the aerosol layer in the Dakar region is more influenced by dust originated from the Sahara region that could be modified by the oceanic environment. From a geographical point of view the Niamey region is a fully continental area while the Dakar region is on the west coast of Africa. The two experimental field phases will allow to work out potential differences in the microphysical characteristics and the same differences will be seeked in the A-Train products.

A good understanding of the ice phase topology within the different regions of the system is critical to improve any retrieval from satellite data. This requires to document the processes taking place in the cloud part (stratiform and cirriform) of MCCs to explain both the vertical and horizontal habits of ice phase, understand the processes of condensation and evaporation, the transports and sedimentation of the main species according to their characteristics in terms of density and size, and document the interaction between microphysical and dynamical processes leading in some cases to tropical cyclogenesis.

This project will also represent an opportunity to evaluate how does the assimilation of satellite-derived temperature and humidity profiles and surface winds impact the ability of Global Circulation Models (GCMs) to correctly forecast tropical disturbances, regions favourable to cyclogenesis, and the fate of "hurricane seedlings".

2.7 Other relevant observations

2.7.1 Upstream Observations

The relations with the scientific objectives are :
D. Role of synoptic environment in cloud cluster evolution

The improved radiosounding network established by TT1 and TT8 (Fig X below) whose data will be transmitted and assimilated into operational GCMs, will certainly lead to more reliable and precise analyses of the synoptic conditions prevailing over West-Africa during the monsoon season. In addition driftsondes launched from N'Djamena (Chad) will further improve the upstream synoptic analyses.

At the core of the AMMA observing strategy over the continent are the three mesosites located along the “climate transect” (TT3, TT4, TT5). Enhanced observations of the surface and atmosphere including two radars in the Oueme catchment will provide us with a detailed analysis of the synoptic easterly waves and embedded MCSs before they reach the coast. A C-band radar will also be present in Niamey from June until mid-August but not during SOP3 (accurate at time of writing).

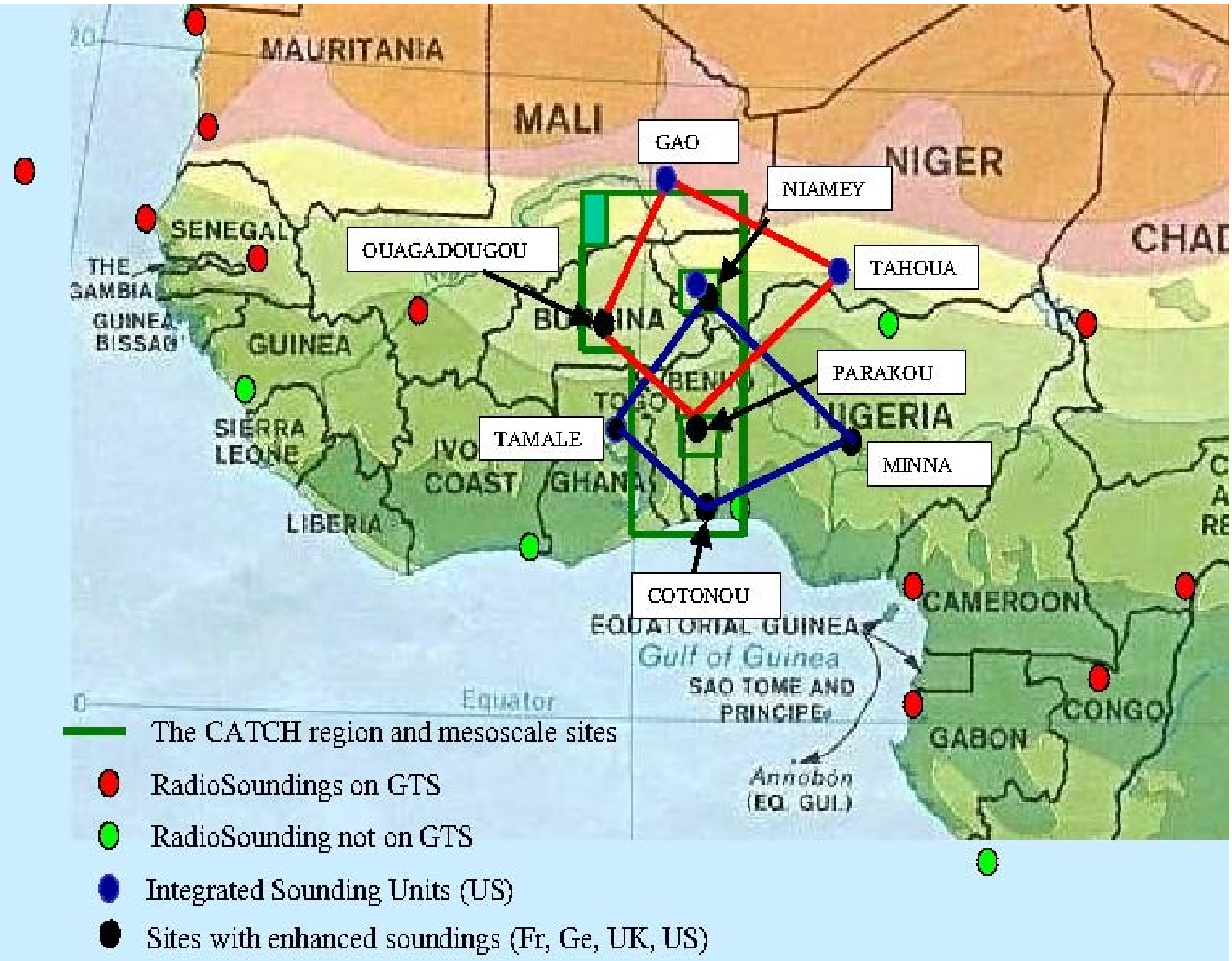


Figure 11 : *Radiosonde stations for AMMA, marking the northern, southern and western quadrilaterals.*

2.7.2 SOLAS

The relations with the scientific objectives are :

A. West-African dust plume and Saharan Air Layer

An atmospheric laboratory is being established by UK SOLAS on Cape Verde. The UK SOLAS observatory development being coordinated by DIAC (the NERC Distributed Institute for Atmospheric Chemistry), and will be implemented in partnership with Cape Verde National Institute of Meteorology and Geophysics (INMG), the Cape Verde National Institute of Fisheries and the Sea (INDP) and international SOLAS.

UK SOLAS will focus on atmospheric measurements, as summarised in the table below:

Measurement	Method or Instrument
CO	Aerolasser 3001
Greenhouse gases	Flask sampling
O_3 and NOx	ANNOXA
NMHCs	

CH_4	Dual channel automated
OVOC's	GC-FID
DMS	
BrO, IO	MAX-DOAS

2.9. Observational priorities and decision-making (Frank/Jeff et al)

Priorities for flights :

(i) Targetting seedlings leaving West Africa
(ii) Targetting environmental conditions (SAL, shear, convergence…)
(iii) Targetting predicted genesis locations

Forecasting needs : AEW over the continent and the ocean, SAL location and evolution, upper tropospheric troughs, MCS over Senegal and tropical eastern Atlantic, convective development within long-lived cloud clusters, mesoscale and synoptic scale cyclonic centers in the ow and mid-levels, …

3. OPERATIONS

3.1. Decision making protocol (!!!! DRAFT !!!!)

The decision-making cycle for IOPs is structured according to the requirements of aircraft operations, as these are the instruments requiring the most coordination (with Air Traffic Control ATC in particular).

From Niamey ATC (I do not know whether this is also true for Dakar ATC) :
NOTAMs need to be submitted 24 h in advance for aircraft flying over 15000 ft (e.g. FR/FA-20 and NASA/DC-8). This does not allow flight plans to be proposed for the next day. Hence, there will be a lack of reactivity for the MCSs flights envolving high-flying aircraft, which could be problematic.

General Schedule

The basic schedule of strategic planning for an aircraft-based IOP will be (for an operation on day D) :

- ***Day D-2*** **–** identification of possible IOPs, based on available aircraft, instruments and overall strategy
- ***Day D-1*** **–** use of forecasts for identification or realistic IOP possibilities. Submission of a set of provisional flight plans, perhaps with a contingency option. The exact time at which these need to be submitted is yet to be resolved with ATC.
- ***Day D*** **–** development of detailed flight plans, to be submitted at least 2 hours before take-off.

Meeting schedule (Local Time):

0600 - 0800 : Preparation of daily forecast (Dakar : ? LAPA / DMN / ASECNA ?, Sal : ?)

The forecast will be prepared with the input from Web server of the AMMA Operational Center (AOC) in Toulouse, France (see http://aoc.amma-international.org/ need to ask for the inclusion of Tropical Cyclogenesis products from NCEP, UKMO, ... + ? Howard U / MM5 forecast ?), by local forecasters working in Dakar at LAPA / DMN / ASECNA ? + Sal ? + MM5 ? according to criteria developed in consultation with the AMMA Forecasting Group ;

One of these forecasters will subsequently be assigned to work with the IOP Planning Group.

0800 - 0830 : **Weather briefing (Dakar : ? LAPA / DMN / ASECNA ? ; Sal : ?)**

Forecasters will present an outlook of the conditions for Days D, D+1 and D+2, with a focus on the meteorological features of interest to the PIs (i.e. IFT, AEJ, AEW, MCSs, SAL, Tropical Cyclogenesis parameters, ...).

0830 - 0845 : Status and IOP briefing (Dakar : ? LAPA / DMN / ASECNA ? ; Sal : ?)

The Facility Supervisor (? who ?) will report on the daily status of platforms and instruments (airborne and ground-based).

Review of operations already planned for Day D and D+1.

0845 - 0930 PI discussions

Local discussions + teleconference(s) between Dakar – Sal (Cape Verde) – ? Bridgetown (Barbados) / NOAA ?

0930 - 1000 Proposal from PIs (Dakar : ? LAPA / DMN / ASECNA ; Sal : ?)
PIs from Dakar, Sal & Brigetown make coordinated proposals for D+1 and D+2.

1000 - 1100 : IOP Planning
Prepare notification of isolated sites and associates instruments ?
Consultation with pilots and preparation of NOTAM
Nomination of a Flight Monitoring Group

1800 - 1830 : Weather update (when an IOP is planned for D+1) (Dakar : ? LAPA / DMN / ASECNA ; Sal : ?)
Forecasters will present an outlook of the conditions for Day D+1.
If necessary, teleconference(s) between Dakar – Sal (Cape Verde) – ? Bridgetown (Barbados) / NOAA ?

<u>Operation schedule on IOP days envolving aircraft (in addition to the above):</u>

T.O.-4h – T.O.-3h
The PIs and the Forecasters on duty meet to review the latest weather update for the coming day. The objective of the meeting is two-fold:

- Make final decision on whether the IOP should be conducted with the aircraft (GO/NOGO decision),
- Prepare a modified set of flight plans if needed, according to the weather update.

If necessary, teleconference(s) between Dakar – Sal (Cape Verde) – ? Bridgetown (Barbados) / NOAA ?
This group of PIs will decide to alert/inform aircraft teams.

T.O.-3h – T.O.-2h NOTAM meeting (Operational Centre)
Consultation with pilots and preparation of modified NOTAM (if needed). Submission of modified flight plans and NOTAM.

T.O.-2h – T.O.-1h Transfer to Airport
Transfer of aircraft operation, technical and scientific crews from Hotels to Airport.

T.O. – L. Monitoring of flight planning (Operational Center and/or airport)
Monitor weather conditions, especially in the case of MCS related IOP. A group will work in close interaction with ATC, pilots and aircraft scientists.

L. – L.+0h30 Post IOP aircraft debriefing (Airport)
A short debriefing after the flight is intended for a quick survey of operations, as well as to prepare the IOP report.

Need to coordinate aircraft and driftsonde (launches and dropsondes) ; also high frequency soundings.

3.1.1 How do we choose IOPs?

Links to analyses and forecasts ;
Need an operation center in Dakar in ASECNA ?
Communication between US PIs in Sal and French+Senegalese PIs in Dakar

3.2. Planning

Should highlight the timetable for planning the SOP-3 experiment – meetings ? confcalls ?
8 am local : weather briefing
9 am local : conf call between Sal and Dakar
10 am local : PIs proposal
11 am : IOP decision (starting 2 pm – if already in alert - until next day)
6 pm local : weather update
+ any necessary meeting (weather, PIs, pilots, ATC) when
Site surveys ?

3.3 Logistical Considerations

This TT will collect the logistical requirements of the ground-based instruments. The logistics associated with aircraft will be coordinated by ????.

We need to coordinate basic facilities in the centres of operational activity (Dakar ? Cape Verde ?).

We need to document:

- operational requirements for each IOP pattern
    a. Air Traffic Control and restrictions;
    b. operational lead times for aircraft and for notification of ground instruments;
    c. instrument requirements;
- operational requirements for ground-based instruments
- personnel requirements (city transit; accommodation etc).

A site visit to each of the three mesoscale sites must be coordinated by the 'Ground-based' sub-group, in close consultation with the AOC.

3.3.1 Communications

(a) Links between Dakar and AOC in Toulouse to get the "forecasting package";
(b) Communications between Dakar and Sal for IOP planning ;
(c) Communications between operational center (in Dakar and/or in Sal) and the aircraft to provide real-time meteorological guidance;
(b) Transmission of data from radiosondes and dropsondes to the GTS for assimilation into numerical weather prediction (NWP) models. Particular efforts must be made (??) to inform NWP centres of this process and to ensure that the dropsonde data is assimilated;
(d) Rapid release of aircraft data to PIs for post-flight analysis, and planning of subsequent flights.

4. PARTNERSHIP

4.1. Field observations

Partnership with African PIs to be identified ; the AMMA philosophy is that each instrument should have an African PI . We need to discuss this.

4.2. Training program

What efforts can be made for capacity building efforts –

- African partners included in daily briefings : in Dakar : ASECNA, Senegalese Weather Service, LPASF, others … in Sal : ?
- African PIs able to fly ? (no seat available in FR / FA-20 …)
- More ?

4.3 AMMA-Forecasting (Greg)

Linkages with AOC in Toulouse and in Niamey

5. ORGANIZATION OF TT-9

5.1. Internal coordination

To be discussed : TT8 has a core group and a wider group of PIs – this is essential since TT8 is so large – I would propose that given the smaller group involved in TT9 that we have just one group. That way – communication is more efficient -
Need to agree leadership : 2 or 3 people (to be discussed)

5.2. Coordination with other TTs

The three key TTs that TT9 should coordinate with are :
TT1 Radiosoundes (Fink/Janicot) : For establishing the enhancements to the soundingnetwork
TT6 Ocean (Brand/Bourles) : For coordinating ocean observations and soundings
TT8 SOP-Monsoon (Parker/Flamant) : For coordinating with upstream observations of AEWs and MCSs

Appendix 1 : Ground-based instruments and relevant maps

Instrument	Code	Lead institution	PI	Location	Deployment
NPOL-Radar		NASA - Howard University	Gerlach Joseph	Kawsara, Senegal	15 Aug.-30 Sep.
Senegal S-Band		DMN-Senegal		Linguere, Senegal	15 Aug.-30 Sep.
Rain Gauges Network		UND - Howard University	Kucera	Senegal	15 Aug.-30 Sep
Tethered Balloon		UVA - Howard University	Fuentes Joseph	Kawsara, Senegal	15 Aug.-30 Sep
Flux Towers		UVA - Howard University	Fuentes Joseph	Kawsara, Senegal	15 Aug.-30 Sep
Lidar		NASA	Welton	Mbour?	Continuous
Broadband IR/Solar		Howard University	Joseph	Kawsara, Senegal	15 Aug.-30 Sep.
Disdrometer		NASA - UND	Gerlach Kucera		15 Aug.-30 Sep.
Radiosounding		ASCENA	Fink	Dakar, Senegal	Continuous
Radiosounding		ASCENA	Fink	Tambacounda, Senegal	Continuous
Radiosounding		Howard Unviersity	Joseph Jenkins	Kawsara, Senegal	15 Aug.-30 Sep

Table 1 : *Ground instrument deployment in Senegal during AMMA SOP 2006.*

Instrument	Code	Lead institution	PI	Location	Deployment
TOGA-Radar		NASA	Gerlach	Cape Verde	1 Sept- 30 Sept.
Lidar		NASA		Cape Verde	15 Jun-15 Sep
Broadband IR/Solar		NASA			15 July - 21 Aug
Microwave Radiometer		NASA			
Radiosounding				Sal Cape Verde	1 Sept.-30 Sept.
Disdrometer		NASA		Cape Verde	1 Sept.-30 Sept

Table 2 : *Proposed Ground instrument deployment in Sal (Cape-Verde) during AMMA SOP 2006.*

- Radiosounding Sites
-Radar sites (NPOL, Senegalese S-Band)
- High Density rain gauge network
- NASA MPL, aeronet site, radiation measurements

Figure 8 : *AMMA SOP3 Ground Observation sites.*

Appendix 2 : NASA / DC-8 CHARACTERISTICS & PAYLOAD

Appendix 3 : NOAA G-IV CHARACTERISTICS & PAYLOAD

Appendix 4 : FR / FA-20 CHARACTERISTICS & PAYLOAD

Dassaut Falcon 20GF F-GBTM

Technical Specification

General Description:

Dimensions:
Length: 17.15 m
Height: 5.32 m
Wingspan: 16.32 m
Cabin:
Length: 7.26 m; Width: 1.79 m; Height: 1.70 m
Apertures: Main door: 1.5 m * 0.8 m;
Engines:
Honeywell/Allied Signal ATF3-6A-4C (2*5200 lbs)

Flying performance:

Max. take-off weight: 14515 kg
Empty weight 8520 kg
Max. payload: 1200 kg
Max. cruising speed: 871 km/h
Ceiling: 42000 ft
Max. range: 4100 km
Max. endurance: 5 h
Conditions for max. range: FL400 at max fuel. Speed=414 KTAS
IFR,VFR,Weather conditions,icing: VFR (2 pilots); IFR (2 pilots)
Initial climbing altitude: 39000 ft
Take-off runway length: 1414 m
Total electrical power: 28 V / max 285 A conversion to 220V / 50 Hz
Cabin pressurisation: Cabin pressurised
Avionics: Universal EFIS and Flight Management Systems

Information for scientific users-

Specialized informations:

- Scientific payload in normal operation:1000 kg
- Range(s):
  At maximum fuel: 3220 km
- Practical ceiling:
  Practical ceiling: 42000 ft
  description of limitations: tbd
- Min. altitude :
  Above sea: 150 m
  Above ground: 150 m
- Speed :
  Max. speed: 254 m/s
  Min. speed: 82 m/s
- Seat available for users :
  From 2 to 4 depending on missions
- Electrical power available for users :
  6 kW (28V)
- Specific limitations :

-

Modifications:

Nose boom: length 1.8 m carrying measuring probe (e.g. five holes probe for turbulence measurements)

Windows: 2 coverable photo windows in the bottom (diameter 520 mm each) and 2 on top of the fuselage (diameter 320 mm each)

Openings: 4 openings (diameter 80 mm each) on top of the fuselage, and 1 opening (diameter 200 mm) in the bottom of the fuselage.

Hard points: 4 hardpoint stations (2 under each wing) to carry loads up to 500 kg each (using standard 14" NATO attachment system) but has to stay within the maximum payload limitation.

Inlets: tbd

Additionnal systems:

Pyranometer – radiometer
Pyrgeometer – surface temperature
Dropsonde launching system (Vaisala AVAPS GPS system for RD93 dropsondes)

Component	Technique
Cloud physical properties S.RALI_FF20	95 GHz radar / aerosol Lidar
O3 and CO in situ S.Mozart_FF20	UV-O3 and IR-CO instrument
Water Vapour H_2O S.LA_FF20	Lyman-α fluorescence and dew point
Position, winds, u,v,w S.GPS_FF20	INS, GPS
Turbulence S.5PTP_FF20	5-port turbulence probe
Temperature T S.PRT_FF20	Rosemount PRT
Vertical profiles of dynamical variables S.Drop_FF20	AVAPS dropsondes
Relative Humidity S.HUR_FF20	Aerodata humidity sensor
Broadband radiation S.BBR_FF20	Pygreometers and Pyranometers
NO_2 photolysis $j(NO_2)$ S.JNO2_FF20	Photometer
300 to 3 000 nm PCASP PMS: 1DC-OAPX, 1DP-OAPY, 2DC, S.PMS_FF20	Size particle / rain drop distribution

Appendix 5 : UK BAe 146 CHARACTERISTICS & PAYLOAD

UK Bae 146	Wingspan: 26.34 m Length: 31 m Height: 8.61 Weight: 44.2 t Take off distance: 1600 m Typical operating speed 220	Flying crew: 21 Ground Crew: 2-3 Fuel load: 12000 kg Consumption: ?? l/h GPU: 60 kva Other:	4.5 hours	E. Highwood C. Reeves