1. Integrative Studies

1.1 : West African monsoon and the global climate

Laboratories: CERFACS, CETP, CNRM, CRC, LA, LGMA, LMD, LOA, LODYC, LSCE, LTHE, SA

Coordinators: S. Janicot (LODYC) and K. Law (SA)

General objectives

The aim of this Work-Package (WP) is to better understand and predict the multi-scale variability of the aspects of the global climate linked to the West African Monsoon (WAM). The WAM is a dynamical coupled system in which climate evolution is linked to ocean/land surface forcings and to changes in the atmospheric composition. Due to the structure of the API_AMMA, to address the best possible this issue, coordinated sensitivity experiments involving both oceanic and land surfaces will be defined in workshop joining WP1.1 and WP1.3. In WP1.1, we will address mainly the role of the ocean, but experiments involving land surface processes will also be performed.

'Teleconnection' mechanisms communicate global sea surface temperature (SST) anomaly patterns to the West African region: the different timings of these forcings and the different inertia of the WAM components develop multi-scale interactions, and generate a large spectrum of variability. The variability is dominated by interannual changes, WAM onset variations, intraseasonal monsoon variability, including breaks and surges, and synoptic modulations. All of these modes of variability are critical to prediction methods and decision-making for the region. In this context, we also address the global impacts and regional interactions associated with the WAM emission of chemical oxidants and aerosols on the radiative forcing of the WAM, as well as interactions between photochemical processes and convection.

Inversely the WAM climate and atmospheric dynamics impact on the climate of several remote regions. On the one hand, it has impacts inside its own coupled system by modifying the oceanic surface and sub-surface conditions in the eastern tropical Atlantic, which in turn modify the WAM dynamics, as well as to a lesser extent on the Mediterranean summer climate variability. On the other hand, the WAM, through chemical and aerosol emissions, has a big impact on the long-range transport of trace constituents downwind from West Africa, and then on quasi-global oxidant and aerosol budgets, as well as radiative forcing.

General strategy

In order to achieve our scientific goals, we aim to integrate science by developing collaborations between the French laboratories involved in AMMA. This effort has been started a few years ago through different proposals to French programs. For instance, the PNEDC proposal entitled “Variabilité intra-saisonnière à interannuelle du cycle de l’eau de la mousson d’Afrique de l’Ouest” has been conducted in collaboration with some of the laboratories involved in AMMA. The present WP1.1 enables to involve now a larger community in France. This WP1.1 will be obviously tightly inter-related with the other WPs to help addressing its own scientific questions.

This WP has been initially split into three sub-WPs which have been defined to better organize the research activities. However, a new organization has been proposed after having better defined where priorities must be put in this WP and how to better develop them. WP1.1 is still divided into three defined sub-WPs but scientific issues have been defined differently and sub-divisions have been included.

WP1.1.1: Interannual variability and trends of the African Monsoon : the main objective is to examine the causes and trends of the WAM variability, and to determine how this will evolve in the

years to come by taking into account higher greenhouse gas concentrations and land-use effect. Three sub-divisions have been defined:
sWP1.1.1a: Study of the ocean-atmosphere couplings and their impacts on the WAM dynamics
sWP1.1.1b: Analysis of the African ITCZ
sWP1.1.1c: Interannual/decadal variability and climate scenarios
WP1.1.2 : WAM impacts on atmospheric composition and global climate : the main objective is to determine the impact of the WAM emissions on global oxidant and aerosol budgets, the oxiding capacity and global radiative forcing.
WP1.1.3 : Predictability of WAM from intra-seasonal to multi-seasonal time scales: The main point is to focus on the predictability of the WAM through a continuum from intra-seasonal to inter-seasonal timescales. In this part, we will have to examine specifically the interactions between the large and regional scale flow and the WAM weather systems, so as to better predict key-points of the monsoon, notably its onset and the occurrences of breaks and surges. Predictive schemes coherent from intra- to multi-season scales will be developed.

These sub-WPs are inter-related. Firstly, WP1.1.1 and WP1.1.3 have close links as together they address the WAM dynamics on complementary scales, from global and long-term scales down to synoptic and short-term scales. In particular, we are interested in the potential interactions between interannual and intra-seasonal scale variability. WP1.1.2 is related to the two other sub-WPs by addressing the interactions between atmospheric dynamics and trace gas and aerosol budgets; it will provide information on the impact of WAM emissions on global climate including direct impacts on radiative forcing and possible modification of dynamical systems. WP1.1.2 will use results on the causes of observed and modelled atmospheric variability at different space-time scales which will aid the analysis of the impact of WAM emissions on global scales. Interactivity will be favored also by the use of common tools (in-situ and satellite data, climate models).

This WP needs to be closely linked to integrative WP1.2 and WP1.3. It will also focus on the integration of the processes studied in the WP2.x which are the most relevant for understanding and simulating accurately WAM variability and its impact on climate. It will benefit from improvements which will be provided to the global and regional models (and specifically ocean-atmosphere coupled models) for coordinated simulations, as well as from in-situ and satellite measurements to support diagnostic analyses.

Points relevant to WP1.1.1

Priorities have been defined towards three issues. The first one addresses the ocean-atmosphere coupled character of the WAM. It will be studied by using both diagnostic and modelling analyses, and by focusing on the domain of the eastern tropical Atlantic – West and Central Africa – Mediterranean Sea. Diagnostic analyses will be based on the most recent satellite products like TMI-SST, TRMM rainfall, ISCCP cloud data, QuikSCAT and ERS winds, turbulent fluxes, combined by ERA40 and NCEP2 reanalyses, which will enable us to document the interactions between convection, wind, SST and fluxes at the interface from intra-seasonal to multi-seasonal time scale. This will be complemented by the exploitation of forced atmospheric and oceanic models and analyses of French ocean-atmosphere coupled models simulations. The first work will be to document precisely the different components of the WAM system (monsoon circulation, heat low dynamics, ITCZ convection, water vapour transport, cloud type distribution, fluxes at the interface,..) especially in the coupled models to have a better knowledge of the deficiencies of these models (the WP4.1.3 should provide also specific diagnostics). We will look especially at the seasonal cycle and its intra-seasonal variability, and at the diurnal cycle. Then we will study the sensitivity of WAM to SST anomalies with forced AGCM simulations as well as forced OGCM simulations. Intermediate coupled models (AGCM coupled to an oceanic mixed layer model), relevant to study mechanisms at the intra-seasonal time scale, will also be used. This will enable us to better understand the impact of the different mechanisms (atmospheric forcing, fluxes at the interface, oceanic circulation) on the WAM dynamics and the mixed layer temperature tendencies. This will also offer a large scale context to the interpretation of the EGEE measurements (air-sea fluxes and oceanic measurements especially in the mixed layer), and to analyse different phases of these campaigns once these measurements will be assimilated. Discussions and collaborations with WP2.2 will be developed.

The second issue addresses the variability of the ITCZ convection. It will be studied by analysing the interactions between the ITCZ and the regional scale environment like the role of the heat low transverse circulation and Saharan boundary layer in advecting Saharan air into the ITCZ. Again both diagnostic studies and model simulations will be developed. Available and on-going data bases of mesoscale convective systems (MCS) life cycle will be explored as well as the relationships between MCS and the atmospheric environment (ERA40 and NCEP2 reanalyses). This part is in fact included in WP1.1.3. Modelling studies will be supported by WP4.1.3 and the role of WP1.1.1 will be to test in AGCM the sensitivity of different current or new parametrisations (for instance the implementation of the new density current and convective schemes which should be able to simulate the MCS propagation, the sensitivity to entrainement, the sensitivity to the boundary layer scheme) in the context of the WAM dynamics at the regional scale and focusing especially on the seasonal cycle and its intra-seasonal variability as well as the diurnal cycle. Intermediate models like QTCM will enable to analyse some mechanisms linking the oceanic and land surface conditions with the monsoon dynamics at the regional scale; for instance the concept of the monsoon "jump" will be a priority issue. Collaborations will be developed with WP1.1.2 to study the impact of the aerosols transported by the atmospheric circulation (and especially the heat low) on the radiative budget, the cloud formation and the convection strength in the ITCZ. Some efforts will be put on the role of the orography of North Africa on the heat low dynamics, the dry intrusions and finally the ITCZ variability, in collaboration with WP2.1. Sensitivity to SST anomalies in the eastern tropical Atlantic and the Mediterranean Sea will also be examined (see above) to analyse the water vapour transports and budgets and their impacts on the ITCZ. The model to satellite approach will be developed to take advantage of the new products in the satellite database and to contribute with WP4.1.3 to the definition of new diagnostics. The objective will be also to take advantage of the continuous measurements implemented in AMMA during the EOP (satellite, profiler-winds, GPS integrated water vapour, surface fluxes…) to monitor the time scales from the diurnal cycle to the seasonal cycle, and to use this long-term continuity to integrate these local measurements into the larger scale of the seasonal cycle.

The third issue addresses the mechanisms linked to interannual to decadal and longer-term (climate scenarios of global change / CO2 and sulfate aerosols, scenarios devoted to the land-use effects) variability, and their uncertainties linked to the oceanic and land surface interactions (the analysis of the intra-seasonal to inter-seasonal variability is included in the WP1.1.3). This issue, which focuses on the regional and large scales of the GCM, will be complementary to the approach of the land-atmosphere coupling examined at the scale of the convective system which will be developed in the WP1.3. At the regional scale we will analyse the impact that the interactions between the atmosphere and the vegetation can have on the possible amplification of the oceanic forcing on the WAM. At the global scale, we will examine the impact of tropical teleconnections, especially with the Indian ocean and the Indian-Asian monsoon because some studies showed that these mechanisms could interact with the atmospheric dynamics over the eastern Mediterranean area which is a key-region for the dry intrusions and may be the initiation of MCS. We need to know how this area can be partly controlled by the Indian-Asian convection in particular through the modulation of the westerly subtropical jet. On the longer term, it is necessary to be able to differentiate in the WAM climate variability over the last 50 on-going years the part due to the natural variability from the part due to anthropogenic effects (greenhouse gas and land use). Historical databases will be useful to validate the climate simulations, and time-slice simulations combined with detection/attribution methodologies at the regional scale (zoomed AGCM) will be implemented.

Points relevant to WP1.1.2

Within WP.1.1.2 the aim is to use global models including chemistry and/or aerosols to determine the impacts of WAM emissions on the global composition/budgets, oxidising capacity and eventually radiative forcing. In the initial stages of the project, participating chemistry models will be evaluated using existing data (e.g. MOZAIC) and including satellite data available through WP4.1.3. Existing validations of aerosol models (i.e. AEROCOM), which used global datasets such as AERONET, will also be reviewed with a focus on WAM. Note that model evaluation of parameterisation of the convective transport of tracers and related will take place in 4.1.3. Improved understanding about both chemical and dynamical processes (2.1/2.4) and their impact on regional and global scale chemical/aerosol production and loss, the global scale models will be re-evaluated using SOP data. Global models, run at higher resolution over WAM, will be compared to all relevant SOP data. This will take place in conjunction with work to improve model parameterisation schemes (4.1.3). In WP.1.1.2, a particular focus will be on the analysis of SOP2/3 data collected during continental-scale flights which have the aim of characterising chemical/aerosol composition in air masses transported downwind from the main emission/convective regions. Here, the issue of scaling up from regional to continental and finally global impacts will be addresses.

In terms of links with other WP1.1 activities, global fields of particular radiatively active constituents (e.g. ozone, black carbon) can be provided for use by the climate models for either present-day or possibly future scenarios. The aim is to improve climate prediction by including better representations of GHGs and aerosols, not just CO2. An ultimate goal is the development of fully coupled chemistry-aerosol-climate models. It is envisaged that within the framework of AMMA, that some progress will be made towards this goal. Further discussions will take place in 2005 in order to determine what is feasible in terms of further development of coupled processes taking into account work which is already planned (e.g. coupling aerosol/chemistry and hydrological cycle).

Points relevant to WP1.1.3

This issue addresses the predictability of the WAM through a continuum from intra-seasonal to inter-seasonal timescales. The approach must be supported by detailed analyses of the involved mechanisms. At the intra-seasonal time scale, we will examine specifically the interactions between the large and regional scale flow and the WAM weather systems, so as to better predict key-points of the monsoon, notably its onset and the occurrences of breaks and surges. Different processes are already suspected to modulate the convective activity in the WAM ITCZ at these scales : Kelvin and Rossby equatorial waves, MJO activity, dry intrusions from mid-latitudes, the remote effect of Indian monsoon, as well as local surface-atmosphere interactions. Satellite and ERA40/NCEP2 reanalyses will be used to document this variability and statistical methodology combined with intermediate atmospheric models will be implemented to better identify the main mechanisms. EOP (and SOP) surface measurements (land and ocean conditions, soil moisture content, flux and radiative budget along the meridional transect and in the quadrilateral over Benin, vegetation monitoring) as well as the enhanced radiosonding network, once assimilated in new reanalyses and combined with satellite data will support reliable studies. These data are also necessary for the study of the multi-seasonal memory linked to the rainfall fields of different rainy seasons, as suspected from empirical studies. It is necessary to monitor the mechanisms and the evolutions of the relevant variables from one season to at least the one or two following ones, both in observations and in simulations (global and regional models), to ascertain the scenario being able to explain this memory. The best possible datasets related to the surface conditions must be available (development of LDAS over West Africa, GSWP2, coherency studies between different satellite land characteristic variables like vegetation and estimation of soil moisture), especially over the savanna in Benin. These works will need to be developed in collaboration with WP1.3, WP2.2 and WP2.3, to integrate at the seasonal and regional scales the involved local scale processes. In parallel and downstream of these investigations, predictive schemes coherent from intra- to multi-season scales will be developed. Statistical schemes, as well as statistico-dynamical schemes will be developed at these different time and spatial scales. Some efforts will be put on the DEMETER seasonal forecasts ensembles where statistical and numerical (with mesoscale models) downscaling approaches will be developed in collaboration with WP1.2 to extract the best predictors.

Observations needed from the field campaigns and models

Observations and models needed have been described in the above section (General strategy).

Links to other WPs

WP	**Input to WP1.1**	**Output from WP1.1**
1.2	Impact and variability of the West African monsoon in terms of regional water budget interaction	Water vapour flux (convergence) over WA in reanalyses and model data. Computations of role of the global climate on regional water budget.
1.2	Expertise in tools to address interactions between large scale flow and synoptic weather patterns	Analysis of regional scale atmospheric environment.
1.3	Provide sound assumptions on soil moisture sensitivity experiments with GCMs Understanding of role of land and ocean feedbacks	Impact of large and regional scale environment and teleconnections processes. Understanding of the impact of ocean feedbacks on WAM.
2.1	Impact of small-scale processes including surface heterogeneity on convective events. Process studies related to the heat low and dry intrusions Model calculations of tropical cyclone-mineral dust interaction	Large-scale environment of convective events Integration of the different processes to better understand intra-seasonal variability of WAM
2.2	Analysis of the different oceanic processes involved in the variability of sea surface temperatures.	Impact of large and regional scale atmospheric environment on the variability of sea surface temperatures.
2.3	Provide sound assumptions on vegetation sensitivity experiments with GCMs	Provide a regional and global context associated to the WAM to land surface processes
2.4	Improved models following detailed studies of chemical/ aerosol processes and interactions with WAM dynamics	Impact of WAM emissions on global climate

4.1	Coordination of model experiments/intercomparisons	Intercomparison of existing model skill on the WAM region Evaluation of parametrizations in the context of the WAM variability
4.2	Provide data and observations of the coupled system	Operational planning
4.3	Provide data and observations of the coupled system	
4.4	Archived reanalyses	

1.1.1: Interannual variability and trends in the African Monsoon

Laboratories: CERFACS, CNRM, CRC, LA, LMD, LODYC, LSCE, LTHE
Sub-coordinator : S. Janicot (LODYC)

1.1.1a 5 year plan

Objectives

The general objective of this sub-WP is to examine the causes of variability and long-trends of the WAM, to examine the changes in this variability and to determine how these will evolve in the years to come with higher greenhouse gas concentrations. We will concentrate (1) on the coupled atmosphere-surface character of the West African monsoon and especially on the interactions of the monsoon with the oceanic state, (2) on the analysis of the African ITCZ, (3) on interannual/decadal variability and climate scenarios. Due to the structure of the API_AMMA, to address the best possible this issue, coordinated sensitivity experiments involving both oceanic and land surfaces will be defined in workshop joining WP1.1, WP1.3, WP2.2 and WP.4.1.3.

More precisely (see also general strategy), the specific objectives of this sub-WP are:

- To investigate the ocean-atmosphere coupled character of the West African monsoon system by developing diagnostic studies, performing forced atmospheric and oceanic runs and examining coupled ocean-atmosphere runs in the Africa – Tropical Atlantic - Mediterranean domain. We will also estimate the relative impact of oceanic *vs* continental processes in the WAM variability (linked to WP1.3).
- To study the mechanisms related to the variability of the ITCZ convection in the context of the regional scale by developing diagnostic analyses and performing numerical simulations of sensitivity experiments to different parametrizations. We will focus both on the seasonal cycle and its intra-seasonal variability as well as the diurnal cycle.
- To study in climate scenarios of the future (anthropogenic change in greenhouse gas concentration and in land-use) and compare to the present climate, the changes in the West African monsoon variability (seasonal cycle and interannual variability) and in the teleconnexion mechanisms. We will focus especially on differentiating in the WAM climate variability the part due to the natural variability and the part due to anthropogenic effects. The remote effects of the Indian ocean and Indian-Asian monsoon will be also investigated since they seem to be large over the eastern Mediterranean area.

Work content

These issues will be addressed by combining diagnostic studies and modeling experiments. In particular, a hierarchy of GCM will be used, from coupled surface-atmosphere models, AGCM (including “aqua-terra-planet”) and OGCM, to intermediate models (spectral primitive equation model and Quasi Equilibrium Tropical Circulation Model –QTCM-). The advantage of such intermediate models is that individual physical processes can be isolated and specific basic state climatologies from observations (reanalyses) can be imposed. For instance, it allows to analyze mechanisms linking oceanic and land conditions with the monsoon dynamics at the regional scale like the monsoon "jump". Their computational efficiency means also that wide range of experimental designs can be tested. Moreover observational and diagnostic analyzes will enable to validate the models and to orientate new modelling experiments, while the model simulation results can provide information for observational strategy.

WP1.1.1a

- First, diagnostic studies will be developed based on the best available datasets as long as the new data from AMMA will be provided and assimilated. New reanalyses combined with satellite products (SST, wind, clouds, precipitation, turbulent fluxes) will be used to document the interactions between convection, wind, ocean and air-sea fluxes from intra-seasonal to multi-seasonal time scales ***(CETP, LODYC (Sultan, Lazar, Janicot), LTHE (Diedhiou))***
- Then detailed evaluation of the AGCM over West Africa from intra-seasonal to decadal time scales will be performed; after the field campaigns, similar goals will be addressed by stressing models evaluation owing to the use of EOP, LOP and satellite datasets and paying special attention to the parameterization of deep convection ***(CNRM (Royer, Douville, Chauvin, Joly), LMD (Grandpeix, Lahellec, Hourdin)***
- We can then focus on the influence of SST in diagnostic studies, and in ensembles of AMIP-type runs and sensitivity studies to prescribed SST anomalies and land surface conditions (mainly soil moisture, and possibly vegetation) on the interannual/decadal variability of the West African monsoon using ensembles of seasonal atmospheric simulations (LMDZ low and high resolution and ARPEGE-Climat not stretched and stretched centered over Atlantic ocean forced by observed and simulated SST) and of idealised dynamical models simulations ***(CNRM (Royer, Douville, Chauvin, Joly), LMD (Grandpeix, Lahellec, Hourdin), CERFACS (Caminade), CRC/CEREGE (Moron, Philippon, Fontaine), LTHE (Hall))***
- Conversely, we will analyze the role of WAM forcing on tropical Atlantic SST by analysing and performing specific ORCA2° and 0.5° forced runs in the tropical Atlantic; this action will focus on intra-seasonal to multi-seasonal time scales and will be combined with the diagnostic studies described above, using most recent satellite datasets and reanalyses; it will consider also the interactions with coastal upwellings ***(LODYC (Janicot, Lazar, Sultan), CETP)***
- We will finally analyse in the coupled AOGCMs the nature of the interactions between the WAM and the oceanic circulation; consider the main factors of the WAM climatology both at intra-seasonal/seasonal and diurnal cycle; and we will combine this analysis with experiments on forced atmospheric and oceanic simulations – see points above - ***(CNRM (Royer, Douville, Chauvin, Joly), LMD (Grandpeix, Lahellec, Hourdin), LODYC (Janicot, Lazar, Sultan), LSCE (Braconnot, Yiou))***
- Complementary coordinated simulations will also be defined with other WPs to compare the relative role of the oceanic circulation and of the vegetation changes ***(all the partners of WP1.1.1 and WP1.3)***

WP1.1.1b

- Since we focus on the regional domain of tropical Atlantic – Africa north of the equator – Mediterranean sea, and since preliminary results indicate that North Africa mountains play a role in the WAM dynamics, we will analyze the impact of the North Africa orography on the WAM variability and its main action centers by performing ensemble simulations by modifying the lift and drag associated with this orography in LMDZ and in zoomed ARPEGE; we will look especially at the interaction between the heat low and the ITCZ, as well as the low-level water vapour advection and high-level dry intrusion from the Mediterranean area ***(LMD (Grandpeix, Lahellec, Roca), CERFACS (Lorant), LA (Ramond), LODYC (Janicot, Sultan); collaboration with WP2.1 (LMD/Drobinski))***

- We will also study the interactions between the ITCZ, the heat low and the monsoon flux with LMDZ simulations with convection scheme perturbed in the WAM (analysis of energy and water budget); sensitivity to the boundary layer scheme will also be considered, especially concerning interactions with the Saharan boundary layer; we will focus on the application to the new version of LMDZ (after the implementation of the new density current and convective schemes which should be able to simulate the squall line propagation) in different SST contexts ***(LMD (Grandpeix, Lahellec, Hourdin))***
- In a complementary way, we will combine dynamical and statistical approaches by using the UCLA QTCM intermediate model to simulate variability of mesoscale convective systems distribution in the ITCZ; we will also use inverse modeling approach with constraints based on the relationship between surface theta-e and the strength of the Hadley circulation, conservation of water vapor and moist static energy to better understand the ITCZ variability along its seasonal cycle ***(LTHE (Hall))***

WP1.1.1c

- The analysis of global change scenarios (GHG, aerosols) and idealized CO2 doubling experiments will be carried out to compare dynamical and rainfall variability of the WAM in current and future climate; we will consider specifically the land-use effect.
  - We will analyse several ensembles of time-slice simulations at regional scale using the variable resolution version of ARPEGE for the current and perturbed climate (1950-2000 and 2070-2100), with different aerosol forcings. These simulations will be used for the climate change detection study and also to estimate their impacts upon the West African climate as well as the associated uncertainties; mean variables as well as frequency distribution will be examined ***(CERFACS)***
  - In association with the study of the ITCZ dynamics in the current climate, we will study the sensitivity of the ITCZ position to CO2 concentration in idealized CO2 doubling simulations performed with the IPSL coupled model, and in the zoomed ARPEGE simulations ***(LMD (Grandpeix, Lahellec), LSCE (Braconnot, Yiou), CERFACS (Lorant))***
  - As we suspect that the Indian monsoon has an impact upon the Mediterranean area which represents a key area for the WAM, we will analyze the teleconnection mechanisms between the African and the Indian monsoons, compare to the present climate and discriminate natural variability from anthropogenic effects ***(CERFACS (Caminade), LSCE (Braconnot, Yiou), CRC (Philippon, Fontaine), LODYC (Janicot), LA (Ramond))***
  - Since we need to know how intra-seasonal variability is modified in future climate if we want to have an accurate estimate of the water resources, we will develop adapted statistical analyses to discriminate the changes of variability at different space and time scales ***(LSCE (Yiou), CRC (Philippon, Louvet, Fontaine), LODYC (Sultan), LTHE (Hall))***
  - We will analyze the processes which contribute most to the large spread in predicted rainfall changes and the impact of these uncertainties on the predicted surface processes at the regional scale. We will estimate the scale at which the predicted changes in the continental water cycle are useful. ***(LTHE (Hall), CRC, LODYC (Sultan), CNRM, CERFACS)***
  - The role of the land-use will be also addressed in the context of the climate change detection on WAM since this anthropogenic pressure is high in this area and must be differentiated from natural and greenhouse gas forcings; these effects will be analyzed independently of other forcings ***(LSCE (De Noblet))***
  - Finally we will compare the relative role of changes in the oceanic circulation and of the vegetation changes by performing complementary simulations; analysis of the impact of different

complexity of the vegetation parametrization (from prescribed to interactive) in collaboration with WP1.3. ***(all the partners of WP1.1.1)***

- We will make available most simulations to the AMMA community through the database (see WP4.4).

Foreseen deliverables

- Quantification of the interactions between monsoon dynamics and oceanic-continental conditions at seasonal to decadal timescale
- Estimate of the impact of the orography of North Africa on the WAM
- Detection and attribution of the climate change over West Africa; mechanisms associated with the changes in WAM variability and ITCZ dynamics
- Further insights into processes that determine rainfall variability and the relative importance of remote and local influences of dynamical factors
- Most of the simulations produced in this sub-WP will be archived and made available to the AMMA community through the database (see WP4.4).

1.1.1b Research conducted in year 2004

From a preliminary analysis of short (few years) LMDZ simulations, it appears that this model in its present form may be used for initial WAM studies : the various characteristic features of the WAM are reasonably placed (Heat-Low, ITCZ, FIT) and the bulk structure of the simulated seasonal cycle agrees with the observed one. However, the diurnal cycle of deep convection is very poorly represented, the simulated convection being maximum at noon.

A first analysis of the coupled model IPSL-CM4 idealized simulations (CMIP-like : 1% CO_2 increase per year up to 2.5 times the pre-industrial value) was performed. The first conclusion is that the WAM is very poorly represented in these simulations ; the ITCZ is centred at 6N during summer; moreover, it stays at the same position when CO_2 concentration increases. Obviously, understanding this bad behaviour will be an important objective of 2005. The second conclusion is that the simulated rainfalls over West Africa exhibit an inter-annual variability very similar to El Nino Oscillation. Generally the two oscillations are in phase; however, the correlation is not very strong. The last conclusion is that precipitations over West Africa decrease when CO_2 concentration increases (and so do precipitations over East Equatorial Pacific).

The coupled seasonal forecasting system based on the new version 4 of ARPEGE-Climat and the ORCA ocean circulation model provided by IPSL/LODYC has been implemented on the IBM computer at ECMWF and the production of the first series of seasonal forecasting series has been started.

A coupled simulation with ARPEGE-Climat coupled to the ocean model OPA.8 from IPSL/LODYC has been made over the period 1860-2000, using the anthropogenic forcings from the IPCC/20C3M projects. A forced simulation has been performed with the same version of ARPEGE-Climat using the observed monthly SSTs from HadISST from 1870-2000 provided in the framework of the C20C project. The two simulations will be used to study the interannual variability of the African monsoon

The impact of increased greenhouse gases (GHG) and sulfate aerosols concentrations upon the WAM is investigated for the late 21st century period using the Météo-France ARPEGE-IFS high-resolution atmospheric model. Perturbed (2070-2100) and current (1961-2000) climate are compared using the model in time-slice mode. The model is forced by global SST provided by two transient scenarios performed with low-resolution coupled models and by two GHG evolution scenarios, SRES-A2 and SRES-B2. Comparing to reanalysis and for observed data sets, the model is able to reproduce a realistic seasonal cycle of WAM despite a clear underestimation of the African Easterly Jet (AEJ) during the boreal summer. Mean temperature change indicates a global warming over the continent (stronger over North and South Africa). Simulated precipitation change at the end of the 21st century shows an increase in precipitation over Sudan-Sahel linked to a strong positive feedback of surface evaporation. Along Guinea Gulf coast, rainfall regimes are driven by large-scale advection humidity process. Results show a precipitation decrease (increase) in the most (less) enhanced GHG atmosphere. Modification of the seasonal hydrological cycle consists in a rain increase during the monsoon onset. Enhanced precipitation over Sahel is linked to large-scale circulation changes, namely a weakening of the AEJ and an intensification of the Tropical Easterly Jet.

The development of models of intermediate complexity for identifying mechanisms associated with remote influences and local feedbacks has begun with :

- Adaptation of spectral primitive equation model for community use.
- Preparation of basic states from reanalysis data.
- Preliminary experiments with remote tropical SST anomalies.

In the study of the oceanic surface conditions influence upon interannual to multi-decadal precipitation variability in West Africa, we showed with ARPEGE simulations that :

- At interannual time scale, the main SST mode associated with Sahelian rainfall is ENSO (similar pattern than the global tropical SST mode shown by Trzaska and Janicot, 2001).
- At multi-decadal time scale, a global mode with strong SST anomalies located in the extra-tropics has been characterised (similar pattern than the Global extratropical SST mode (GE) shown by Trzaska and Janicot, 2001).
- The observed rainfall trend in the Sahel contrasting a dry (1950-1970) and a wet (1970-1990) period can be accurately reproduced by simulations forced by oceanic surface conditions, the ensemble mean (DAT) being a good estimator of forced variability. The associated SST mode is the GE mode. This result agrees with previous studies performed by Giannini et al (2003).

At a shorter time scale, the analysis of links between SST in the Guinea Gulf and the WAM has begun by considering the year 1998. The onset and intra-seasonal variability of convection during the WAM has been studied in details and concomitant intra-seasonal time fluctuations in the TMI-SST has been detected in this oceanic basin. This work will be pursued next year.

In the investigation of the impact of the North Africa orography on the WAM, it has been observed that the West African monsoon onset is concomitant with the enhancement of the Saharan heat low. We showed through a combined diagnostic and linear modelling study a possible interaction between northern Africa orography and the deepening of the Saharan heat low at the time of the monsoon onset. The amplification of an anticyclonic circulation above and north of the Hoggar massif leads to an increase and a southeasterly-northeasterly rotation of the wind ahead of the Hoggar which contribute to an increased leeward-trough effect enhancing the Saharan heat low. The Atlas does not play any role during the monsoon onset but contributes to the mean climatological location of the Saharan heat low.

1.1.1c 1 year plan (2005)

Objectives

For 2005, the aim is to begin addressing the performances of the coupled ocean-atmosphere models in details, examining the climate scenarios at the regional scale, analysing the sensitivity of the WAM to SST anomalies in the eastern tropical Atlantic and the Mediterranean basins, and looking on the reverse side at the oceanic response of the WAM forcing. We will consider the role of the northern Africa orography of the WAM dynamics in the regional context of the eastern tropical Atlantic – West Africa – Mediterranean Sea domain.

Work content

- Diagnostic analyses will go on based on the most recent satellite products like TMI-SST, TRMM rainfall, ISCCP cloud data, QuikSCAT and ERS winds, turbulent fluxes, combined by ERA40 and NCEP2 reanalyses, which will enable us to document the interactions between convection, wind, SST and fluxes at the interface from intra-seasonal to multi-seasonal time scale ***(CETP, LODYC (Sultan, Lazar, Janicot), LTHE (Diedhiou))***.
- Large-scale validation of the ARPEGE-Climat AGCM and the ARPEGE-OPA AOGCM over West Africa from the intraseasonal to decadal timescales over the 20-th century will be made with the new forced and coupled simulations using the available observed climatologies (GISST, CRU, Xie & Arkin, etc…) and reanalyses (NCEP, ERA40) to validate the large-scale features of the African monsoon. Beyond the analysis of the annual cycle and of the model climatology, a specific attention will be paid to the interannual variability and the teleconnections, through the use of common statistical techniques like correlations, composites, and EOF analyses, with special emphasis on the African easterly waves activity. ***(CNRM/Royer et al.)***
- Priority will be also given to documenting and analyzing the behavior of the coupled model IPSL-CM4. ***(LMD (Grandpeix, Lahellec, Hourdin), LSCE (Braconnot, Yiou, de Noblet), LODYC (Janicot)):*** 1) Analyze the seasonal cycle of the WAM simulated by IPSL-CM4: (i) determine the meridional extension of the monsoon layer, its humidity and its thickness, the position of the Heat-Low and the position of the ITCZ, the dynamic structures (Hadley cell); (ii) assess surface fluxes and soil water content; (iii) assess SST of Guinea Gulf and Mediterranean sea. 2)Analyze the diurnal cycle of the WAM simulated by IPSL-CM4: assess the diurnal cycle of the Heat Low, the diurnal cycle of deep convection and their interference. 3)Beginning of pre-industrial land-use simulations to study the impact of the vegetation and the role of this coupling of the WAM dynamics.
- We will analyze the sensitivity of the atmospheric GCM (LMDZ) to SST of the Guinea Gulf and to the SST of the Mediterranean sea to estimate the impact of regional oceanic anomalies on WAM. Another objective of this action is to determine what are the reasons of the poor performance of the coupled model. ***(LMD (Grandpeix, Lahellec), LODYC (Janicot))***
- This action will be associated with complementary OGCM ORCA2° simulations forced by atmospheric conditions linked to the WAM onset and specific intra-seasonal variability. The OGCM will be forced 1) by atmospheric fields composited around the onset, 2) in an interannual context where a composite approach around the onset will be applied on the outputs. Sensitivity experiments to the different components of the forcing will be performed to better understand how the atmosphere impacts the oceanic state by analysis of the heat budget in the mixed layer. We will focus on the oceanic response in the eastern tropical Atlantic and specifically on the equatorial and tropical upwellings ***(LODYC (Sultan, Lazar, Janicot), CETP)***
- In association with the modeling simulations described above, the detection of the typical Atlantic and Mediterranean SST anomaly patterns (composite analyses) that influence the monsoon on seasonal-to-interannual time scales will be carried out by diagnostic approaches, and

statistical impacts on atmospheric dynamics and rainfall will be estimated. ***(CRC (Roucou, Louvet, Fontaine))***

- At the more global scale, we will continue to study the impact of global sea surface temperature natural modes on interannual to multi-decadal precipitation variability in West Africa (Sahel). We will focus on the physical process associated at the different time-scales considered, and try to distinguish the influence (or not) between anthropogenic forcing (GHG, aerosols) and natural SST modes (oceanic forcing) on the West African rainfall. ***(CERFACS (Caminade))***
- Initial implementation and testing of QTCM will be performed. Definition of surface interaction studies to be carried out with QTCM will be set-up, making use of knowledge acquired from teleconnection experiments above. ***(LTHE (Hall))***
- We will participate to the definition of a suitable sensitivity experiment to study the influence of SST anomalies in the Gulf of Guinea on the subsequent monsoon development. ***(all the partners of WP1.1.1 in coordination with AMMA_IP)***
- We will begin to study the sensitivity of the simulated WAM to Northern Africa orography.
- This study will proceed by reducing in the AGCM LMDZ the drag and lift due to specific mountains (Zagros mountains, Hoggar, Atlas, Air). Its purpose is to assess the importance of orography parametrization in WAM simulation. ***(LMD (Grandpeix, Lahellec, Hourdin), LA (Ramond)) :*** 1)The high resolution simulations of the current climate produced by Arpege-climat will allow us to study the role of the orography on the intra-seasonal variability (onset, easterly wave) of the AM. ***(CERFACS (Lorant));*** 2) We will continue to collaborate with WP2.1 for simulations with a linear model ***(LMD (Drobinski)).***
- We will look at the response of climate to anthropogenic forcing at a regional scale. Such regional study is made, thought feasible by reducing (hopefully) the signal-to-noise ratio (using an atmospheric model instead of a coupled model), and by increasing the resolution. This study will use Arpege-climat atmospheric model simulations forced with observed changes in GHG gases, sulphate aerosol and sea surface temperature. The most recent version of Arpege-climat will be used (version 4.1), and the method so-called “variable resolution” will be use. Detection and attribution studies of both surface temperature and precipitation response to anthropogenic greenhouse (GHG) gases and aerosol will be considered. The frequency distribution of surface temperature and precipitation will be looked at in order to characterize changes in the frequency and intensity as well as changes in the mean of those variables. ***(CERFACS (Lorant))***
- As part of the validation of the Arpege-climat model over Africa, we will have to compare results of simulations forced by different dataset of aerosol. Such comparison will allow us to document the sensitivity of the simulated WAM climate to the choice of the aerosol forcing. ***(CERFACS (Lorant))***
- The results from the new ARPEGE coupled and forced simulations over the 20-th century will be made available on a DODS server ***(CNRM/Royer et al)***

Tools and data :

- ARPEGE-Climat simulations forced by observed SSTs:

  - *1950-2000 with Reynolds SSTs (SF2)*
  - *1950-2000 with NCEP SSTs (SF4)*
  - *A 1870-2000 simulation with HadISST performed in the framework of the C20C project*

- ARPEGE-Climat - OPA.8 coupled simulation over 1860-2000 using anthropogenic forcing (CT1)

- ARPEGE-Climat stretched-rotated simulations centered over Atlantic Ocean, forced by observed and simulated SSTs :

  - *Reynolds (1960-89) for present climate (DF5)*
  - *Reynolds + SST anomaly (period 2070-99 minus 1960-89) from an A2 scenario (DF6)*

- 2 x 6 atmospheric forced simulations performed with ARPEGE GCM version 4.1 (T63 configuration – regular grid) over the 1900-2003 period:
a) 6 numerical experiments forced by observed monthly SST (ersstv2 reynolds data set), + (GHG + aerosols) constant to their 1900 concentration.
b) 6 numerical experiments forced by observed monthly SST, GHG + aerosols evolving following their observed values.
- Time slice experiments (IPCC scenarios SRES-A2 B2) with ARPEGE GCM version 4.1 (T63 configuration – regular grid).
- Idealized simulations with ARPEGE-GCM and Hall-Simmons model (simple dynamical model). Example: to test the model sensitivity to El Nino SST anomalies, dynamical mechanism studies, etc
- Two 6-members ensemble simulations performed with Arpege_climat_HR (HR stands for high resolution over west Africa) from 1950 to 2000.

- *one ensemble ran with constant pre-industrial GHG and aerosol concentrations.*
- *one ensemble ran with increasing GHG and aerosol concentrations.*

- The two experiments are forced by the same set of Reynolds observed sea surface temperature.
- Different old and new versions of the coupled model IPSL-CM4
- OGCM ORCA2°
- QTCM model
- Historical climatic data sets and ERA40/NCEP2 reanalyses
- Recent satellite data

Foreseen deliverables

- First results on the evaluation of the new versions of available ocean-atmosphere coupled models
- First results on the couple ocean-atmosphere character of the WAM
- Definition of coordinated sensitivity experiments to address the surface-atmosphere coupled character of the WAM
- First results of the climate scenarios for the WAM at the regional scale
- First results on the impact of the northern Africa orography on WAM dynamics
- Definition of an experimental design for the way to combine physical and statistical approaches using intermediate models

1.1.2 - WAM impacts on atmospheric composition & global climate

Laboratories: CNRM, LA, LOA, LSCE, SA
Sub-coordinator: K. Law (SA)

1.1.2a 5-year plan

Objectives

The main objective of this work is to determine the impact of West African emissions on global oxidant and aerosol budgets, the oxidising capacity and global radiative forcing using a combination of global chemistry-aerosol modelling and data analysis (e.g. satellite). A particular focus is on the role of the WAM in the long-range transport of trace constituents downwind from West Africa. Transport of trace gases into the TTL and stratosphere will also be considered. Specific objectives are:

• To quantify the key transport pathways, photochemical reactivity and aerosol properties in air masses downwind from West Africa, particularly in relation to WAM dynamics with the aim of determining the net export of trace gases and aerosols from West Africa relative to other sources.

- To quantify the impact of WAM emissions on global trace gas budgets, oxidising capacity, stratospheric composition and radiative forcing on seasonal and inter-annual time scales.
- To quantify the impact of West Africa on global aerosol radiative forcing on seasonal and inter-annual time scales with a focus on primary and secondary organic aerosols, biomass burning and dust.

The specific strategy/methodology is the following one : Preliminary calculations of the impact of West Africa on global trace gas and aerosol budgets will be used to make a first assessment of global model behaviour over West Africa; a region where very little is known about variability in chemical and aerosol variability. For this purpose, models will first be run for the same annual cycle and compared with available data (MOZAIC, IDAF, satellite). To complement this work more detailed analysis of MOZAIC, ozonesondes and satellite data will focus on the study of transport of trace gases into/out of WA. The overall aim is to build up a picture of pollutant import/export over this region and to pinpoint key model deficiencies in long-range transport and emissions. The work on inter-annual variability in emissions to be used by participating models will also be used to improve this understanding. The work will be closely linked to that in 4.1.3 where detailed evaluation of specific parameterisations is planned using for example single column versions of the global models used in 1.1.2 run with tracers. These results will form the basis of detailed studies into chemical processes, aerosol properties, emissions and regional scale impacts of convection carried out in WP2.4. SOP3 data on long-range transport of pollutants and transport of trace gases into the TTL/stratosphere will also be used specifically by models in 1.1.2, together with EOP data (satellite, ozone sondes) to quantify the export of trace gases and aerosols out of WAM. Thus, following further model evaluation and improved coupling of model processes to physical variations in climate (e.g. lightning emissions to convection) and aerosol interactions with dynamics/radiation (WP2.1, 2.4, 4.1) models with improved predictive capability will be used to quantify WAM impacts on a global scale and to provide improved radiative forcing estimates for climate simulations.

Work content

- Analysis of satellite data (MOPITT, IASI) of global chemical composition (e.g. CO) in conjunction with global modelling to elucidate key transport pathways of trace gases out of West Africa during WAM during SOPs and on inter-annual timescales. Monthly average CO distributions over West Africa will be examined from 2000 to present. Assimilation of MOPITT CO into the MOCAGE and LMDz-INCA models together with updated CO emission inventories will also be used to understand the diverse transport pathways for CO and therefore pollutant transport into and out of West Africa. In this context, the SOPs will be a focus and comparisons between the 2 different models will be made (***SA(Clerbaux), LA(Attie))***.
- Analysis of MOZAIC (O3, CO) and ozone sounding data over West African region and beyond using trajectory models to identify air mass origins and fates and to better quantify the ozone paradox in the southern Atlantic on seasonal and on a case study basis. The Lagrangian model, LAGRANTO will be used to study air mass origins on a seasonal basis and the Meso-NH model will be used for particular case studies ***(LA (Thouret, Cammas)).***
- Analysis of satellite aerosol products (e.g. CALIPSO), ground-based and airborne aerosol measurements collected downwind of West Africa and North/South America to examine transport pathways of aerosol layers across the Atlantic and their radiative impact ***(SA (Pelon, Flamant), LOA(Tanre)).***
- Analysis of aircraft SOP data on chemical composition to examine the photochemical processing of layers during long-range transport downwind from West Africa and sensitivity of results to mixing/dilution with air masses of other origin (e.g. stratospheric) using combination of data-initialised trajectory models and a global model ***(SA (Law)).***

- Global modelling of trace constituent (e.g. H_2O, CH_4) transport into the stratosphere using a global chemical-climate model (LMDz) and offline chemistry model (MIMOSA). Coordination of links with EU SCOUT-O3 and in particular the SCOUT-AMMA balloon programme leading to joint data analysis of TTL/stratospheric composition addressing issues such as quantification of the origin/magnitude of transport of trace constituents into the stratosphere ***(SA (Pommereau, Bekki, Jourdain, Marchand)***.
- Determination of the net impact of WAM emissions (e.g. biogenics, industrial, lightning) on the global ozone budget, including export fluxes and oxidising capacity (OH) over selected annual cycles (inc. 2006) using a global chemistry-aerosol-climate/transport models (1 with zoom over West Africa, 1 with assimilated data). Uncertainties will be assessed based on differences in results ***(SA (Law, CNRM(Peuch)).***
- Integrations over several annual cycles to investigate the impact of inter-annual variations in WAM dynamics on distributions of key constituents. The inter-annual variation in biomass burning emissions will be investigated using an offline model (MOZART). Results of studies using the coupled module for biogenic emissions in ORCHIDEE/LMDz-INCA will also be examined over West Africa ***(SA (Law, Granier), LSCE(Hauglustaine, Lathier)).***
- Determination of net impact of aerosols transported downwind from West Africa on global radiative forcing using global aerosol models on seasonal and inter-annual and in particular, the contributions of dust, biomass burning and primary and secondary organic aerosols ***(LA (Liousse), LOA (Tanre), CNRM (Peuch), LSCE (Schulz, Balkanski)).***
- Analysis of aerosol distributions and budgets from a coupled aerosol chemistry model (LMDz) from existing and new model simulations which have been validated further using new SOP data over West Africa ***(LSCE (Schulz)).***

Foreseen deliverables

- To quantify key pathways transporting oxidants and aerosols out of West Africa associated with the outflow from WAM convective systems**.**
- To determine the photochemical reactivity of air masses transported downwind from West Africa relative to air masses of other origin and the role of dynamical interactions.
- To determine the characteristics of aerosol layers transported downwind from West Africa (e.g. dust, secondary organics).
- To quantify the impact of West African emissions on global oxidant and aerosol budgets, the oxidising capacity, TTL/stratospheric composition and radiative forcing including an assessment of the impact of inter-annual variations in WAM dynamics and assessment of uncertainties.

1.1.2b Research conducted in year 2004

Participants in 1.1.2 took part in several discussions concerned with the planning for the SOPs and contributed to the on-going discussions about which aircraft to deploy, where and with what instrumentation. A particular focus has been the planning for SOP3 and the collection of data on a larger scale than just around convective systems over WA. Collection of data on continental-scales and also downwind from West Africa are important for the validation of global models which will be used to quantify global impacts of WA emissions. The current plan is that there will be chemistry/aerosol flights between Niamey and Dakar (B146/FF20) and also one aircraft based at Dakar (DLR-20). Several discussions were also initiated related to the participation of a high altitude aircraft in AMMA. To this end, discussions were held at various SCOUT-O3/ AMMA meetings. The current situation is that the Geophysica will not fly during AMMA but that the possibility of flying balloons to collect data on TTL composition will be investigated and is a priority within SCOUT-O3. Possibilities for funding a short Geophysica mission in West Africa are also being discussed. Discussions were undertaken at the annual AMMA Atelier to improve the links between 1.1.2 and other research planned in 1.1. It was concluded that further discussions are required particularly concerning the use of improved radiative forcing estimates in climate simulations planned in 1.1.1.

Some limited analysis of chemical model behaviour over West Africa has been undertaken. The MOCAGE model was compared to monthly mean MOZAIC data collected over West Africa. Model results are systematically too high compared to observations, throughout the year. However, this first comparison is quite encouraging because MOCAGE does reproduce the shape of the profiles, in winter at least (strong ozone enhancement in the lower troposphere), and the seasonal cycle throughout the troposphere over Lagos for example (maximum in DJF in the lower troposphere and no clear seasonal variation above). MOZAIC data over WA has also been analysed in terms of air mass origin. The ozone distribution in boreal winter (DJF) in the free troposphere over West Africa is dictated by biomass burning from the entire zonal band 15°W to 40°E transported by the Harmattan and the AEJ. During the summer monsoon period (JJA) the free troposphere over Lagos is either very clean or laden with biomass burning products from the southern burning regions (central Africa) depending on the intensity of the monsoon flow over the coastal areas.

Results from the coupled biogenic emissions module in ORCHIDEE/LMDz-INCA are now available and currently being for analysed over West Africa. Work has continued on analysis of global satellite data products relevant to studies over West Africa (e.g. MOPITT, GOME). Analysis from CO data from MOPITT clearly shows the seasonal movement of the ITCZ. West African CO, mostly emitted by biomass burning, is lifted by Harmattan winds over the monsoon flow and is then transported to South America around the Saint-Helen anticyclone. Results from the AEROCOM project are also now available and includes comparison of the LMDz-INCA and TM4 models with other global models and with existing datasets such as AERONET. Comparison of results over West Africa with IDAF data shows that there are still large problems related to the treatment of deposition of aerosols. Work on reactions of gas uptake on mineral dust has also shown this to be an effective mechanism which could be contributing indirectly to ~20% O3 loss over dust-rich regions (e.g. downwind from the Sahara).

1.1.2c 1 year plan (2005)

Objectives

The work in this sub-WP is closely linked to planning and collection of data (4.2), analysis of processes (2.4/2.1) and improvements to specific model parameterisations (4.1.3). The preliminary assessment of model behaviour on seasonal timescales will continue and focus on a one or two year time period (e.g. 2000/2001) when there is limited data to compare with and specific emission datasets are available (e.g. biomass burning). For aerosols, evaluations made to date will be evaluated and suggestions made for further comparisons. Analysis of existing datasets (e.g. MOZAIC, MOPITT) will focus on identification of air mass origin and trace gas export from West Africa.

Work content

- Coordination of 1.1.2 activities with other research planned in 1.1 on climate simulations, processes (2.4/2.1) and model comparisons/improvements (4.1.3). One topic to be discussed will be the extent to which fully coupled chemistry/aerosol/climate simulations are performed (developed further) within AMMA and how the work planned in 1.1.2 feeds through into 1.1 in terms of improved radiative forcing estimates (***SA (Law), LSCE (Hauglustaine, Schulz), LODYC (Janicot), CNRM (Peuch).***

- Preliminary evaluation of existing and/or new simulations over a specified annual cycle (2000-2001) will be undertaken by comparing with available datasets. In the case of trace gas simulations, model results will be compared with MOZAIC, IDAF and satellite data. In the case of aerosols, global comparisons which have taken place as part of the AEROCOM comparison initiative will be examined over West Africa to examine further particular regions where models are able (or unable) to capture observed behaviour seen in, for example, AERONET, IDAF data. ***(SA (Law, Pham, Granier), LSCE (Hauglustaine, Schulz), CNRM (Peuch), LA (Liousse), LOA (Tanre)).***
- First assessment of the behaviour of the stratospheric version of the LMDz model and/or the offline isentropic model, MIMOSA, in the TTL using data from the HIBISCUS project ***(SA (Bekki, Jourdain, Marchand).***
- Examination of pollutant transport pathways into and out of West Africa using MOZAIC data in conjunction with the LAGRANTO trajectory model and Meso-NH (case studies) and also by further examination of satellite data (MOPITT) ***(LA(Thouret, Attie), SA(Clerbaux, Pelon, Flamant), LOA (Tanre)).***
- Collection of fire count and/or burnt area information over West Africa and globally for years 2000 to 2002 with the aim of producing temporally varying biomass burning emissions ***(SA (Granier); also in collaboration with 2.4.3).***
- Continued work on coupling biogenic emissions to climate model, LMDz-INCA ***(LSCE (Hauglustaine, Lathier).***
- A feasibility study of SCOUT-O3 balloon flights during SOP 2-3 in collaboration with CNES and in close consultation with the AMMA organisational group for operational logistics, aircraft and ground-based observational strategy will be carried with the aim to produce a preliminary planning document in February 2005 and a final campaign planning document in April 2005 ***(SA (Pommereau)).***

Foreseen deliverables

- Preliminary assessment of global model behaviour over West Africa
- Improved understanding about pollutant transport pathways
- Detailed planning for SOP3 and for AMMA-SCOUT activities
- Improved emission datasets on inter-annual timescales

1.1.3 : Predictability of the WAM from intra-seasonal to multi-seasonal times scales

Laboratories: CNRM/GMGEC, CRC, LA, LGMA, LODYC, LTHE
Sub-coordinator: B. Fontaine (CRC)

1.1.3a 5 year plan

Objectives

The main objective is to focus on the predictability of the WAM through a continuum from intra-seasonal to inter-seasonal timescales. Then we will have to examine specifically the interactions between the large and regional scale flow and the WAM weather systems, so as to better predict key-points of the monsoon, notably its onset, the occurrences of breaks and surges during the different rainy seasons, and the total seasonal rainfall amount. This activity is central to many of the aims of AMMA, and it feeds directly into the applications. The ultimate goal of this sub-WP is the development and the implementation of multivariate statistical, statistico-dynamical and dynamic WAM forecast models at these different time scales, for the different rainy seasons over West and Central Africa. We will also use the same hierarchy of general circulation models (GCMs) as in sub-WP1.1.1, including hindcasts with prescribed surface conditions and forecasts with coupled atmosphere-land-ocean models (ie DEMETER integrations) combined with downscaling approaches to assess to which extent the key modes of WAM variability are predictable. Evaluation of sensitivity of DEMETER seasonal forecasts to new parametrizations will be also performed in collaboration with WP4.1.3.

More precisely (see also general strategy), the specific objectives of this sub-WP are:
- To study the multi-seasonal memory linked to the rainfall fields of different rainy seasons, as suspected from empirical studies, by monitoring the mechanisms and the evolutions of the relevant variables from one season to at least the one or two following ones, both in observations and in simulations (global and regional models), to ascertain the scenario being able to explain this memory;
- To investigate intra-seasonal modes of convection of West Africa linked to the different pauses in the seasonal excursion (scale 30-90 days) of the ITCZ and to shorter variability (10-25 days), their coherence with the convective activity in West Africa and in the tropical band (MJO-type signals), and their control by surface-atmosphere interactions;
- To document how the life cycle of the different MCS categories is modulated by the intra-seasonal as well as interannual variability of the WAM;
- To study the factors influencing the African easterly waves activity
- To determine predictors from intra-seasonal to multi-seasonal time scales of WAM seasonal rainfall amounts, WAM onset and WAM intraseasonal variability, including breaks and surges of the monsoon, and develop statistical forecast models at these timescales and at different spatial scales from regional to local.

Work content

- Analysis of the mechanisms (oceanic and land conditions) related to the multi-season memory of the rainfall fields over West Africa combining diagnostic studies with regional models, GCM and idealised models simulations ***(CRC, CNRM (Royer, Douville, Chauvin, Joly), LMD (Polcher), LTHE (Hall))***
- Study the impact of soil moisture and vegetation cover on WAM variability ***(CRC, CNRM (Royer, Douville, Chauvin, Joly), LMD (Polcher), LGMA)***
- Use of statistical analyses of re-analyses and GCM output to infer the role of large-scale intraseasonal variability on WAM onset and break periods, on synoptic weather types, and on the life cycle of mesoscale convective systems; extension to the whole seasonal cycle and the different rainy seasons in West and Central Africa ***(CRC, LMD (Roca), LTHE (Diedhiou), LODYC (Sultan, Mounier, Bella-Medjo, Janicot)***
- Explore the coherence of convective activity in the tropical band at the 10-90-day range variability related to WAM intra-seasonal variability using combined diagnostic studies and idealized model simulations of linear and non-linear wave propagation on varying basic states from a variety of SST-related heat sources ***(CRC, LODYC (Janicot, Sultan, Mounier, Bella-Medjo), LTHE (Hall), LA (Ramond), LMD (Roca))***
- Study the factors influencing African Easterly Waves activity ***(CNRM (Chauvin, Royer), LTHE (Diedhiou))***
- Cross-analyses on observed, reanalyzed and modeled-predicted (DEMETER) atmospheric fields to develop statistical and statistico-dynamical forecast models at the seasonal scale; evaluation of sensitivity of DEMETER seasonal forecasts to improved atmospheric physics and/or an improved land surface initialization ***(CRC, CNRM (Royer, Douville, Chauvin, Piedelièvre, Guérémy), LODYC (Sultan))***

- Use of “field-oriented” methods (as CCA, analogs) and statistico-dynamical approaches to hindcast and forecast weather types associated to monsoon break/surge and fields of 5-day to 3-month cumulative rainfall, and to produce maps of predicted dates of onset and pauses. Implementation of the statistical and statistico-dynamical prediction schemes ***(CRC, LODYC (Sultan, Mounier), LTHE (Hall, Diedhiou))***
- The MM5 model will be used both for numerical downscaling of DEMETER seasonal forecasts and to perform sensitivity studies with varying land/sea surface conditions at different spatial scales. ***(CRC(Sijikumar, Roucou, Fontaine)).***

Foreseen deliverables

- Improved knowledge on the mechanisms related to the multi-season memory of rainfall fields over West Africa;
- Improved knowledge on the relationship between tropical waves and WAM dynamics on the intraseasonal time scale
- Identification of robust weather types describing the monsoon circulation and breaks/surges
- Improved real-time seasonal forecast of WAM
- Set-up of real-time forecast of intraseasonal variability with application to WAM onset and dry sequence occurrences; extension to other rainy seasons over West and Central Africa;
- Implementation of operational predictive schemes
- Creation of a database to make available the simulations to the AMMA community.

1.1.3b Research conducted in year 2004

The preparation of the experimental design and preliminary tests have been started for the production of a 10-yr global soil moisture climatology by driving the ISBA land surface model with the ISLSCP2 atmospheric forcing. An “off-line” version of the ISBA land surface model at a 1° by 1° resolution is forced by the global atmospheric forcing fields of the ISLSCP2 dataset, using the framework of the Global Soil Wetness Projet (GSWP2). The forcing fields available from 1986 to 1995 have been used to validate new developments in the ISBA model over large river basins. The production of a 10-year soil moisture climatology with the ARPEGE version of ISBA (2-layer hydrology without subgrid variability) and with the soil and vegetation parameters used in the ARPEGE boundary conditions is expected to be done by the end of the year

Analysis of AVHRR NDVI and ERS soil moisture estimates fields has begun and detection of some leading signals regarding the Sahel rainy season are been highlighted. The coherency between the two satellite-derived datasets is not so strong, which induces uncertainties in the interpretation.

The interannual variability of African Easterly Waves (AEW) has been assessed with the help of Spatio-Temporal Spectral Analysis (STSA) and Complex Empirical Orthogonal Functions (CEOF) methods applied to the results of 10-member multi-year ensemble simulations with the ARPEGE-Climat GCM. Two sets of experiments have been analysed, one with interactive soil moisture (control), and the other with soil moisture relaxed towards climatological monthly means calculated from the control. Composites of Sahelian AEWs were constructed and associated physical processes and dynamics were studied in the frame of the waves. It is shown that the model is able to simulate realistically some interannual variability in the AEWs, and that this dynamical aspect of the West African climate is potentially predictable (i.e. signal can be extracted from boundary conditions relatively to internal error of the GCM), especially along the moist Guinean coast. Compared with ECMWF 15-year reanalysis (ERA15), the maximum activity of AEWs is located too far to the South and is somewhat too zonal, but the main characteristics of the waves are well represented. The major impact of soil moisture relaxation in the GCM experiments is to reduce the seasonal potential predictability of AEWs over land by enhancing their internal variability. A revised paper describing these results has been submitted to Climate Dynamics.

A method for the detection of the normal dates of surges and breaks in the monsoon including the Guinean pre-onset and the Sahelian onset (period; 1979-2002) has been developed to evaluate their relationship with intraseasonal signals in the atmosphere (jets, MJO)
Water vapour transport from the Atlantic and the Mediterranean sea have been computed and diagnostic estimation has been made of the part of water vapour of atmospheric origin in the precipitation against water vapour from local origin (recycled precipitation) in the West African area. Weather types classifications of West African monsoon circulation have been established.

By using daily gridded NOAA-OLR, in-situ rainfall and NCEP-DOE AMIP-II Reanalysis datasets over the period 1979-2000, it is shown the evidence of two main independent modes of convection at intraseasonal timescale in the West African summer monsoon. One depicts a meridional dipole of convection over West Africa with a modulation of the latitude of the ITCZ; it is associated with a westward propagative signal of the convection over the Sahel, and linked to a modulation of cyclonic vorticity at these latitudes. The other one is characterized by a monopole of convection over West Africa with a modulation of the convective activity in the ITCZ without any significant modulation of its latitudinal location; it is associated with a stationary signal of the convection modulation centred along the Guinean coast, and linked to a modulation of the zonal wind component over the eastern equatorial Atlantic. The dominant periodicity of these two modes is around 15 days. These results imply that it is necessary to take into account the relative parts of these two modes in order to accurately analyze the mechanisms involved in intra-seasonal variability of the African monsoon

1.1.3c 1 year plan (2005)

Objectives

- To investigate the mechanisms related to the multi-season memory of the rainfall fields over West Africa and linked to the oceanic and land surface conditions;
- To better understand the impact of soil moisture and vegetation dynamics on the WAM seasonal cycle;
- To investigate intra-seasonal modes of convection of West and Central Africa linked to the different pauses in the seasonal excursion (scale 30-60 days) of the ITCZ and to shorter variability (10-25 days), their coherence with the convective activity in West Africa and in the tropical band, and their control by surface-atmosphere interactions;
- To study the mechanisms influencing the African easterly waves activity
- To determine atmospheric predictors at the intraseasonal to multi-seasonal time scale of WAM seasonal rainfall amount, WAM onset and WAM intraseasonal variability, including breaks and surges of the monsoon, and evaluate the predictability at these timescales at regional scale;
- To develop statistical & dynamico-statistical predictive schemes at these different time scales

Work content

- To investigate the model capacity in reproducing observed lagged correlations between the precipitation anomalies and soil moisture over the Guinean region and subsequent monsoon season ***(CNRM/Royer et al)***
- To use the surface moisture climatology produced from the GSWP analyses to test the relevance of improved boundary conditions or initial conditions of soil moisture for simulating the African monsoon and its interannual variability. ***(CNRM/Royer et al)***

- To analyze of the vegetation cover evolution at different steps of the WAM by using remote sensing (SPOT, LANDSAT) and geographical information system (GIS), and validation on the three AMMA super-sites ***(LGMA)***
- To evaluate the skill of the DEMETER seasonal forecasts over West Africa: Correlations and economical values will be computed for the summertime precipitation field over West Africa. Composites of the summertime predicted precipitation field will be calculated for the years of the largest observed precipitation anomalies over West Africa. ***(CNRM/Royer et al)***
- To investigate the predictability through analysis of the DEMETER simulations. We will produce hindcasts + predictions using both selected rainfall (Sahel, Sudan, Guinea) and atmospheric indices (AEJ, WAMI). Skill comparison of SST forced AGCMs, statistical models and statistico-dynamical models to discriminate years for which Sahelian rainfall are rather forced by global SST or by local continental conditions. ***(CRC)***
- To validate MM5 use for desagregating the DEMETER ensemble predictions over West Africa ; sensitivity experiments with varying SST, soil moisture and vegetation anomaly patterns using the MAR model in collaboration with Louvain La Neuve (Belgium) to assess the question of inter-season memory effects. ***(CRC)***
- To investigate he mechanism influencing the activity and propagation of African Easterly waves in idealized conditions, by using a version of ARPEGE-Climat with zonally symmetric surface boundary conditions (“aqua-terra planet”) so as to allow a comparison with zonal and simplified models. ***(CNRM/Royer et al)***
- Detailed diagnostic studies of the equatorial Kelvin and Rossby waves role in the intra-seasonal variability of the African ITCZ convection in collaboration with G. Kiladis (Boulder). Study the links between the Rossby waves and dry/wet intrusions above the Mediterranean area for the years 1992, 1998 and 2000 using reanalyses and water vapor transport models; this issue will be also examined in Arpege-Climat. ***(LODYC (Mounier, Janicot), LMD (Roca), LA (Ramond), CERFACS (Lorant))***
- Development of modeling approach for mobile SST anomalies (to simulate influence of MJO). Definition and execution of suite of experiments with varying basic states and sources. Application to the impact of intra-seasonal modes of convection in the tropical domain on the atmospheric circulation and comparison with diagnostic results ***(LTHE (Hall), LODYC (Mounier, Sultan, Janicot))***
- Impact of the intra-seasonal variability of the WAM on the life cycle of the different categories of MCS, on the easterly waves activity by energy cycle computations, and on the high frequency rainfall distribution ***(LTHE (Diedhiou), LODYC (Mounier, Janicot, Sultan))***
- Beginning of the study of intra-seasonal variability over Central Africa along the year ***(LODYC (Bella-Medjo, Janicot))***
- Statistical predictive schemes will be set-up at the intra-seasonal time scale using SSA-ARMEM approach by taking advantage of our knowledge of the intra-seasonal variability of the African ITCZ convection ***(LODYC (Sultan, Mounier, Janicot))***
- Hindscats and forecasts of the main rainy episodes (onset, surges, breaks, end of the rainy season) using linear and non linear statistical models (MLR, LDA, neural networks) to complement the current efforts made at ACMAD and AGRHYMET to implement operational seasonal rainfall forecasting schemes in West Africa. ***(CRC)***

<u>Tools and data (other than in WP1.1.1) :</u>

- Ensembles of seasonal atmospheric simulations driven by observed SST and relaxed toward or initialized with “realistic” soil moisture fields (and possibly interannual vegetation densities)
- Ensembles of seasonal coupled atmosphere-ocean forecasts with an improved version of the ARPEGE AGCM and/or a improved land surface initialization
- Ensemble of DEMETER simulations

- Hall-Simmons model (simple dynamical model)
- "Aqua-terra planet" model

Foreseen deliverables

- Better understanding of the mechanisms related to the multi-season memory of the rainfall fields over West Africa and linked to the oceanic and land surface conditions;
- Identification of robust weather types describing the monsoon circulation and breaks/surges, and the corresponding modulation of the mesoscale convective systems.
- Better understanding of the relationship between tropical waves and the monsoon dynamics at the intraseasonal scale over West and Central Africa
- Preliminary evaluation of the predictability of onset/break episodes of the WAM
- Advances in the development of new seasonal predictive schemes and estimation of their skill

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