4. Tools and Methods

4.1 Models and Assimilation

4.1.1 Data assimilation and forecasting systems

Laboratories: CNRM, CETP, LGIT, IGN, LOA, SA
Coordinator: JP Lafore

General objectives

This sWP is aimed at producing state-of-the-art analyses of the atmosphere. Furthermore, the sWP aims at providing users throughout the IP with support, documentation and guidance regarding the methodologies and data involved in the generation of these analyses, so that they can be used for research purposes by scientists in this and other WPs. The impact of these analyses on the forecasts will be evaluated. The priority will be given to the humidity field that is crucial in tropical regions as it strongly impacts the occurrence/suppression of the convection. Such analyses will be extensively used in other WPs for processes studies and to improve the water budget (WP1.2). Two scales will be considered: the global scale and the mesoscale using 4D-Var and 3D-Var variational techniques of assimilation respectively. We identify 2 specific objectives.
O4.1.1.1 Data assimilation in the atmosphere at global scale using 4D-Var
O4.1.1.2 Data assimilation in the atmosphere at fine scale using 3D-Var

Foreseen deliverables

Improved and finer atmospheric analysis to be used by other WPs.

Observations needed from the field campaigns

Radiosounding network data
Routine surface station data (SYNOPs)
Surface raingauge data and cloud observations
METEOSAT and MSG radiances and derived cloud classifications
AMSU-B, microwave (SSMI, AMSR) and Near Infra Red (PARASOL/MODIS/MERIS) measurements

Data required (observations & modeling)

WP	Input to WP4.1.1	Output from WP4.1.1
1.2		Humidity analyses for the water cycle study
2.1		Improved analysis integrating the maximum of field observations and satellite data. - To initialise and evaluate mesoscale and CRM simulations, - to allow process studies
4.1.3		Model validation
4.2	Observational data to be assimilated	
4.3 **On GTS**	Satellite products All real time data necessary for operational purposes (Numerical Weather Prediction)	

4.1.1 Data assimilation in the atmosphere at global scale

4.1.1.a 5 year Plan

Objectives

The scope is to define and develop methods for analyzing atmospheric humidity observations in order to provide tri-dimensional fields at finer resolution and including more observations than current operational meteorological analyses. These methods are based on optimal estimation to extract information consistently from different instruments (space-based, ground-based, in-situ). The aim is to include as much observations as possible with modular configuration depending on their availability (day/night, cloudy/clear, ...).

Work content

This project will coordinate the following approaches:

- Statistical inversion of AMSU-B over land, independently or in conjunction with SSM/I.
- 1DVAR inversion of microwave (SSMI, AMSR) and Near Infra Red (PARASOL/MODIS/MERIS) measurements above land. Possibility of including GPS as an additional constraint on total column water vapor is also considered.
- Running and testing of assimilation experiments with Meteo-France ARPEGE forecasting system by implementing developments made in 1DVAR.
- Direct 4D-Var assimilation of AMSU-B to improve the humidity field within the ARPEGE forecast system. Evaluation of its impact on forecasts over Africa.
- Comparison and evaluation of the different analyses.

In conjunction with this project, a water vapor campaign (VAPIC) was settled up by SIRTA at spring 2004. This will provide a dedicated data set of in-situ, ground-based and spatial remote sensing (passive and active) measurements which will be analyzed to prepare methodology before AMMA extensive measurement periods.

4.1.1.b Report on research conducted in year 2004

CETP:

The thesis of Fatima Karbou (October 2004) at CETP allowed to elaborate a climatology of AMSU surface emissivities over continents and to retrieve atmospheric temperature and humidity profiles over land from AMSU-A and AMSU-B data. It has been shown that the estimation of surface emissivities at different angles of observation improves the retrieval of atmospheric temperature and humidity profiles using a neuronal method. This work opens new perspectives to better use the AMSU-A and AMSU-B data at low frequencies in operational assimilation systems to improve temperature and humidity fields, especially in tropical regions such as over Africa where the soundings network is sparse.

CNRM:

Several works have been performed at CNRM to assimilate new datasets within the operational ARPEGE 4D-Var analysis. It concerns the QuikSCAT data whose impact is currently tested in a new operational forecast chain and the AMSU-B data.

AMMA-VAP:

A French work group named AMMAVAP has been formed in 2003 for studying questions about the availability, accuracy, and combination of water vapor observations mainly from space-borne platforms but also from ground-based instruments (e.g. GPS), in the framework of AMMA. The main action in 2004, was the preparation and conduction a one-month experiment, VAPIC, 15

May-15 June 2004, at SIRTA. The experiment consisted in collecting data from routinely operated instruments and special instruments focusing mainly at water vapor observations. A number of 17 Intensive Observing Periods (IOPs) of 6hr each have been conducted in clear air periods (mainly because some of the verifying instruments, such as lidars, operate only in clear air). IOPs time slots were chosen to match overpass of 6 platforms (Terra, Aqua, Envisat, NOAA 16 and 17 and DMSP satellites). Nearly half of the IOPs were conducted during daytime (09-15 UTC), and the other half during nighttime (21-03 UTC).
Level 1 and 2 products from the following space-borne instruments are also archived for the experiment period:

(a) Integrated water vapor (IWV), level 2, products : MODIS/Terra+Aqua, MERIS/Envisat, SSMI/DMSP, Meteosat-MSG: WV chanel
(b) Level 1 data from microwave and IR profilers : AMSU-B/NOAA, HSB + AIRS/Aqua.
(c) Level 2 water vapour profiles: will be retrieved when available (e.g. MODIS, AIRS)

4.1.1.c 1–year Plan

Work content

The 2005-year will be dedicated to

4D-Var assimilation of AMSU-A and AMSU-B data over continents within the ARPEGE system (CNES Post-Doc of F. Karbou at CNRM). The key task will be to implement an operational method to estimate surface emissivities in real time starting from the results from the Karbou's thesis. The impact of this assimilation will be evaluated for the WAM region.

4D-Var assimilation of MSG clear air radiances within ARPEGE after the work done in 2004 with the Aladin 3D-Var system.

Testing the 4D-Var assimilation of SSM/I

Developing of the 4D-Var assimilation of GPS surface data.

4D-Var assimilation of satellite wind provided by MSG.

The exploitation of in-situ, ground-based and spatial remote sensing measurements acquired during the VAPIC 2004 campaign. This will include

- intercomparisons of different retrievals (GPS IWV / lidar Raman / soundings, ground based microwave radiometers, satellite based retrievals) to ARPEGE operational analyses.
- improving satellite retrieval techniques: This work will be mainly done on SSMI using a 1Dvar retrieval technique combining both microwave observations from SSMI and IR observations from POLDER and MODIS. The objective is to retrieve IWV over land, assessing the problem of surface emissivity with the help of IR data. The test period therefore is august 2003 and the scale is from the AMMA region to global scale.
- testing the sensitivity of SSM/I 1DVAR algorithm to initial conditions of humidity, temperature and surface a priori information and introduce operators for other data (Near-Infra Red, GPS total column content).

Foreseen deliverables

4D-Var assimilation of AMSU-B data within ARPEGE system.

4.1.2 : Data assimilation at fine scale

Laboratories: CNRM, CETP

4.1.2.a 5-year Plan

Objectives

The goal is to provide fine scale analyses integrating a maximum of data collected at small scales during the SOP. Emphasis will be put on all data (satellites, GPS, lidar…) that are expected to improve the quality of humidity fields, a key parameter for the water budget and for convective events forecasting. Two complementary approaches will be used in parallel:

- The variational technique MANDOPAS developed at CETP, well suited to assimilate all types of observations collected at small scale. This method can be applied without any guess field and thus can provide independent analyses.
- The 3D-Var technique of the next high resolution (~3 km) forecast operational system project AROME currently developed at Météo-France (CNRM). It is better suited to provide initial fields to initialize Cloud Resolving Models (CRMs) such as Méso-NH to be used in WP2.1.

The extensive use of these analyses by other WPs, in particular to estimate the water cycle budget (WP2.1) will constitute a stringent test of their quality. It will allow us to evaluate the improvements gained by the assimilation of new types of data and of the AMMA supplementary data.

Work content

- The application of the 3D-Var AROME over Africa needs the development of methods to estimate the "covariance matrix of background errors" corresponding to the WAM area and to CRMs.
- The impact of these improvements on CRMs will be tested in close collaboration with WP2.1, and will allow us to explore the predictability of convection in the WAM.
- Evolution of MANDOPAS method to include satellite and in-situ observations, namely ground-based GPS data, and take into account time of measurement (4D-Var configuration).

4.1.1.b Report on research conducted in year 2004

CNRM:

A new forecast error cost function formulation (J_b) has been computed for data assimilation purposes using the spectral mesoscale limited area model ALADIN at 10km resolution (Montmerle et al 2004). The so-called "lagged NMC" method has been applied using sets of forecast differences performed during the summer over the West Africa. The resulting auto and cross-correlations display very different features than thoses obtained for Western Europe and reflect the uncertainty of forecasting the main meteorological behaviours of the WAM.

Assimilation of METEOSAT radiances (IR and WV channels*)* together with humidity profiles inferred from a EUMETSAT cloud classification has been performed with the 3D-Var ALADIN analysis (AROME). The contribution of each data source has been studied by performing numerical simulations with Méso-NH model at meso-β (10km, convection parameterised) and meso-γ (5km, explicit convection) scales. The case study is taken from the JET2000 campaign. Results of the simulation show that the impact depends upon resolution. The strongest and positive impact of METEOSAT data is found at fine (5km) scale, and lasts 4 to 10 hours (Nuret et al. 2004).

CETP:

This year, we have used a MESO-NH simulation (HAPEX case) provided by CNRM as a reference. Different source of measurements, which correspond to the observations that are foreseen to be available during AMMA SOP have then been simulated from the MESO-NH outputs in order to provide additional constraints in MANDOPAS. The impact of these different constraints has finally

been worked out individually. These tests have first been done with the 3D-VAR version of MANDOPAS (no temporal evolution included), and in parallel a 4D-VAR version of MANDOPAS has been built and validated this year. When all the constraints are developed, this approach will be used next to evaluate different observational strategies (optimal location of the GPS receivers, of the additional soundings, etc ...).

The development of the 3D-VAR MANDOPAS technique and sensitivity tests

The wind field : the retrieval of the 3D wind field was initially relying on the conventional wind data (radiosoundings, essentially) and the airmass continuity equation. A constraint including the Meteosat winds at three levels has been added this year. These winds have a strong impact in the wind retrieval by MANDOPAS, especially over the ocean where there is no other wind data to assimilate.

The water vapour : The retrieval of water vapour relies on constraints on simulated water vapour profiles at the operational sounding locations, integrated water vapour contents from a simulated GPS network and the following satellite observations of water vapour : MERIS, MODIS on the AQUA and TERRA platforms, and the AIRS, AMSU, and IASI water vapour profiles. This year we have also added the continuity equation for water vapour, the condensation/evaporation source term being provided for this test by MESO-NH, but during AMMA will be provided by the satellite observations (AMSR-E, SSM/I).

In terms of observational strategy, it has also been shown that a single radiosounding in the Saharian area (north of the selected West African domain) would greatly improve the retrieval of the basic atmospheric 3D fields over West Africa.

Accounting for non simultaneous measurements

The 4D-Var approach within MANDOPAS for wind fields has been developed and validated this year using the MESO-NH simulation as a reference. Regarding the wind field retrieval, a physical constraint on the temporal evolution of vertical vorticity has been added, as well as the constraints described previously in the 3D-VAR configuration. The accuracy of the retrieved wind field is found to be consistent with the foreseen scientific applications (validation of operational analyses, initialization of a CRM, water budget computations).

A similar approach to process water vapour fields with accounting for a physical constraint has been developed. This constraint is deduced from the continuity equation of the water vapour content . This additional constraint provided a 3D water vapour field which fits at best the conventional measurements (RS, GPS), the satellite measurements of water vapour and the satellite estimate of latent heat relaxation given by the algorithm of precipitation estimation. However, this 4D-VAR approach suffers from a relatively poor temporal sampling by the different instruments (especially the satellite observations). The quantitative impact of this poor temporal resolution on the water budget computation still has to be estimated in a near future.

4.1.2.c 1-year Plan

Laboratories: CETP, CNRM

Work content

- The comparison of the J_b with its midlatitude counterpart indicating opposite behaviors of the dynamics between the two regions (Europe – AMMA) will be published this year.
- Also the study impact of the 3D-Var assimilation of Meteosat data on the Méso-NH simulation of a JET2000 case study will be published.
- Application of the 3D-Var analysis AROME to a second case but for the summer 2004 to test the impact of MSG-1 data (more channels assimilated (8 instead of 2), finer spectral

resolution). The impact of an assimilation cycle (succession of analysis) will be studied. Sensitivity to input data will be done.

- Comparison of the MANDOPAS and 3D-Var ALADIN assimilations on a same case study.
- pursue the development and validation of the 3D-Var and 4D-Var MANDOPAS analyses at high resolution for the AMMA domain, using a grid-nested MesoNH simulation.
- Provide recommendations for the observational SOP strategy from MANDOPAS results.

2004 Publication List of WP4.1.1

Papers (submitted)

S. Bastin, C. Champollion, O. Bock, P. Drobinski, F. Masson: On the use of GPS tomography to investigate water vapor variability during a Mistral/sea breeze event in southeastern France,. Submitted to Geophys. Res. Let.

Guidard, V., Fischer, C. and M. Nuret, 2004: Evaluation of the ALADIN 3D-VAR with observations of the MAP campaign. Submitted to MAP.

Nuret M., J. P. Lafore, V. Gouget and V. Ducrocq, 2004: Mesoscale analysis and impact on the simulation of the IOP14 of the MAP experiment. Submitted to *Q. J. Roy. Meteorol. Soc.*

Montmerle T., J.P. Lafore, L. Berre and C. Fisher, 2004: Limited area model error statistics over Western Africa: comparisons with mid-latitude results. To be submitted to *Q. J. Roy. Meteorol. Soc.*

Karbou, F., F. Aires, C. Prigent, and L. Eymard, 2004, Potential of AMSU measurements for temperature and humidity sounding over land, *J. Geophys. Res*, 2004JD005318. Submitted.

Karbou, F., 2004, A new microwave land emissivity parameterization, IEEE Trans on *Geoscience and Remote sensing*, TGRS-00430. Submitted.

Papers (sous presse)

C. Champollion, F. Masson, M.-N. Bouin, A. Walpersdorf, E. Doerflinger, O. Bock, J. Van Baelen, GPS Water Vapour Tomography: First results from the ESCOMPTE Field Experiment, Atmos. Res., 2004, in press.

O. Bock, E. Doerflinger, F. Masson, A. Walpersdorf, J. Van-Baelen, J. Tarniewicz, M. Troller, A. Somieski, A. Geiger, B. Bürki, " GPS Water Vapor Project associated to the ESCOMPTE Programme: Description and first results of the field experiment," Phys. Chem. Earth, 29, 149-157, 2004.

Karbou, F., C. Prigent, L. Eymard, and J. Pardo, 2004: Microwave land emissivity calculations using AMSU-A and AMSU-B measurements, IEEE Trans on *Geoscience and Remote sensing*, TGRS-00185, 2004, A paraître.

Thesis

Fatima Karbou:Inversion des mesures radiométriques haute fréquence au-dessus des surfaces continentales. Paris VI. Octobre 2004

International Conferences

M.Nuret et al. : Variational assimilation of METEOSAT data for JET2000, Joint SRNWP/Met Office/HIRLAM Workshop on variational assimilation. 15th-17th November 2004, Exeter, UK.

O. Bock, J. Tarniewicz, J. Pelon, C. Thom, Retrieval of water vapor profiles and integrated contents with Raman lidar and GPS, 22nd International Laser Radar Conference, Matera, Italy, 2004.

O. Bock, C. Champollion, Ch. Thom, J. Pelon,, F. Masson, Validation of GPS slant path water vapor retrievals with a pointed Raman lidar, EGU General Assembly, Nice, France, 2004.

O. Bock, C. Flamant, E. Richard, C. Keil, M.N. Bouin, Validation of precipitable water from ECMWF model with GPS data during the MAP SOP, 11th conference on mountain meteorology, 21–25 June 2004, Bartlett, NH.

H. Brogniez, R. Roca, L. Picon, Interannual and intraseasonal variability of Free Tropospheric Humidity using METEOSAT water vapor data, Proceedings of the 2004 Meteorological satellite conference, Prague, Czech Rep., 31 May- 4 June 2004, in press.

Karbou, F., F. Aires, C. Prigent, L. Eymard et J. Pardo, Atmospheric temperature and humidity profiles over land from AMSU-A and AMSU-B data, Microrad04, February 2004, Roma, Italy.

Karbou, F., L. Eymard, C. Prigent et J. Pardo, Retreival of AMSU surface emissivities, Microrad04, February 2004, Roma, Italy.

National Conferences

Utilisation de METEOSAT pour valider des simulations Méso-NH par M.Nuret et al Ateliers de Modélisation de l'atmosphère, 2004

Stages and Internal Reports