2. Process studies

2.1 Convection and atmospheric dynamics

Coordinators: JP Lafore, C. Flamant
Laboratories : CNRM, CETP, ELICO, LA, LaMP, LODYC, LMD, LOA, LTHE, SA

General objectives

This WP is devoted to the study of the processes in the atmosphere which control the West African Monsoon and its downstream environment. We know that due to the strong solar forcing in this region, the dynamics of the atmosphere are dominated by the patterns of dry and moist convection. However, we also need to understand and quantify other effects in order to describe the monsoon, including the stable nocturnal boundary layer and the radiative forcing due to aerosols, humidity patterns in the clear air and widespread anvils. Ultimately we aim to understand how these convective and radiative processes interact with the dynamics of weather systems developing along the strong thermodynamic gradients of the Sahel.
In this highly-coupled system we take as inputs the forcings from the inhomogeneous lower boundary and its variable patterns of fluxes. We also consider control by global-scale forcing, such as incoming upper level features. In turn, we aim to understand the way in which the atmospheric processes (winds, fluxes, rainfall and so on) create patterns of forcing which will act as inputs for work packages concerned with the land surface and ocean.

In order to achieve our scientific goals, we aim to integrate science first by developing collaborations between the different French laboratories involved in AMMA. This effort started a few years ago through the PNEDC, PATOM and PNTS programs. Nevertheless the present WP2.1 provides the opportunity to enlarge our goals with a special attention given this year to the preparation of the field experiment to be started in 2006. WP2.1 is part of the French contribution to the European project AMMA-IP. Due to its wide spectrum of activities the French contribution will be crucial to achieve the scientific goals of WP2.1. Thus a second mission of this group will be to organize and represent the French participation in the European project. We also aim to achieve the integration of data from diverse instruments and models currently being developed across Europe.

New organization

We have decided to change the WP organization, as the previous separation in 3 sub-WPs according to the physical scales of interest appears to limit multi-scales studies. WP2.1 is now subdivided into 6 sub-WPs according to key WAM components and a management structure composed of the 6 sub-WP leaders.
sWP2.1.1 deals with the PBL dynamics and its response to surface forcing and to entrainment at the PBL top.
sWP2.1.2 focuses on the Heat Low dynamics which is believed to play a major role in the monsoon dynamics.
sWP2.1.3 is concerned with the details of convective systems, for which the synoptic environment is an imposed forcing.
sWP2.1.4 deals with widespread anvils and non-precipitating clouds strongly modulating the radiative budget.
sWP2.1.5 explores the origin and dynamics of dry intrusions and their potential modulating effect on the development, organization and intensity of convection.
sWP2.1.6 addresses the interactions between the different components of the dynamical system to understand its intraseasonal variability. This group uses a set of idealized models of intermediate complexity to bridge the gap between observations, simulations of real cases and climatologies.

In the following presentation of the 5-year and 2005 plans for each sub-WP, we decided to add a "Scientific motivations" section for sWP2.1.2 and sWP2.1.4. Indeed the key roles played by the Heat Low, anvils and non-precipitating clouds within the WAM system were to weakly considered in the White Book written in 2002. We felt important to correct this weakness to better explain our priorities and our observation strategy. Nevertheless this "update" of the White book lengthen the presentation of the corresponding sWPs.

Work content

We will coordinate the attainment of targets and deliverables in WP2.1 and the activities of the sub-work-packages working in WP2.1. In particular, we will coordinate the input of scientific objectives of this WP into operational planning during the SOPs, and ensure compatibility between the selection of SOP case studies for post-analysis.
We will organize meetings of the sub-WPs and meetings of the whole WP. We will also undertake coordination of key publications.
We will ensure the coordination of the activities of this WP with the rest of the project, in particular through the presentation of progress on the AMMA website.
We will represent the French contribution to the European project AMMA-IP.
We will coordinate the communication of operational plans and observational needs from WP2.1 to WP4.2.

Actions in 2004

- Involvement in the definition of the observation strategy for the SOP
- 2-day WP2.1 workshop (7-8 nov. 2004) in Toulouse (~20 persons)

Foreseen deliverables

- Coordination of key WP publications: case studies, climatologies and model intercomparisons
- Compilation of progress reports on the WP.

Observations needed from the field campaigns

Scale	Observations	SubWP
Regional to synoptic scale	Oceanographic observations with air-sea flux measurements and radiosounding capability	1, 3, 6
	Radiosounding network data, including high temporal resolution (3 hourly) radiosonde data	1 – 6
	Radiative fluxes and aerosol optical/microphysical properties as well as vertical distribution during SOPs from lidar, radar, sun photometer, and in situ samplers, in particular in the region of the Saharan heat low	1, 2, 4, 5
	METEOSAT surface temperature and free tropospheric humidity estimates, as well as METEOSAT and SEVIRI cloud cover classification	1 – 5
	CALIPSO, CLOUDSAT, PARASOL boundary-layer, aerosol and cloud products	1 – 4

Synoptic to mesoscale	Aircraft (flight level measurements, remote sensing measurements – wind, water vapour mixing ratio and cloud microphysics and dynamics- and dropsondes): coordinated free troposphere (remote sensing) and boundary layer flights in the ITF zone at different times during the diurnal cycle, plus targeted dropsondes	1 – 4, 6
	Driftsondes to document synoptic patterns during SOPs	1 – 4, 6
	UFH + VHF wind profilers at Parakou (Benin) and Niamey (Niger)	1 - 3, 6
	Continuous planetary boundary layer (PBL) observations of humidity, temperature and winds during SOPs from sodar, microwave radiometric profiles, sun photometers and GPS stations.	1 – 3, 6
	Constant level balloons from Cotonou (Benin) to document the monsoon flow	1, 3
Mesoscale to cloud scale	Aircraft (flight level measurements, remote sensing measurements – water vapour mixing ratio and cloud microphysics and dynamics- and dropsondes): around MCS, plus targeted dropsondes	1, 3, 4
	RALI (Radar Lidar) plateform on the Falcon during the SOP3 to document convective anvils associated with MCSs	3, 4
	C- and S- band, polarimetric Doppler radar (SOP)	1, 3, 4
	X-Band (during the EOP) plus C-band (SOP) polarimetric Doppler radars near Djougou	1, 3, 4
	Surface rain gauge data and disdrometer and cloud observations	3
	Surface heat flux measurements and soil properties	1, 2, 3
	Lightning detection network	3

To fully achieve our scientific goals we will also need climatologies of all structures and systems of the WAM (MCSs, anvils, intrusions, jets, monsoon flux, waves, heat low…) over the whole EOP and LOP periods and over the historical period. It will allow to assess the representativity of the case studies documented during the SOPs and to assess the WAM variability. The elaboration of most of those climatologies will be made in the WP4.3 and will feed the data base (WP4.4).

Links to other WPs

WP	Input to WP2.1	Output from WP2.1
1.1	Large-scale environment of convective events in 2006 [3 – 6] Large-scale advections from Mediterranean [2]	1, 3, 4: Impact of small-scale processes including surface heterogeneity on convective events in 2006 1, 2, 3, 6: Observations and model analyses of monsoon onset in 2006 1, 2, 6: Impact of SAL in AEW dynamics over land 4: MCS anvils impact on monsoon circulation
1.2		1: Observations and model analyses of atmospheric humidity fluxes 3: Space-time convective rainfall structures 4: MCS anvils related water storage in the upper troposphere
1.3	Surface flux and land use distributions [1 – 3]	3: Space-time convective rainfall structures 1, 2: PBL observations and analyses
1.4		3: Space-time convective rainfall analyses
1.5		3: Space-time convective rainfall analyses
2.2	Sea surface forcings [1, 3]	1, 3: PBL analyses
2.3	Continental surface patterns and forcings [1- 3]	1 – 3: PBL analyses
2.4	Observed aerosol structures for radiative forcing [2]	1, 2, 3: Analyses of thermodynamics, winds and turbulence for transport and process studies related to chemical species and aerosols 3: Role of Sharan dust on the occurence of lightning 4: MCS anvils impact on soluble chemical species and chemical species that adsorb onto ice
3.1 – 3.3		1, 3: Space-time convective rainfall and PBL analyses
4.1	Coupled model results [1 – 3]	1 –6: Process studies; Model validation through case studies
4.2	Observational data [1 – 6]	1 – 6: Operational planning
4.3	Satellite products and derived climatologies: FTH, cloud classification, low level winds, MCS tracking and climatology [1 – 5]	4: Ice microphysics parametrization for deriving rain products from satellite microwave data

2.1.1 Planetary Boundary Layer

2.1.1.a 5 year Plan

Coordinator: P. Drobinski
Laboratories: CNRM, SA

Scientific context

In western Africa, the PBL dynamics is substantially modulated by the nature of the surface which varies from south (ocean then forest) to north (savanna then desert), by soil moisture. The surface properties affect the dry and moist static energy (and thus the location of the ITCZ and the ITF), the PBL depth, the stratification and generate thermal winds (sea-breeze and inland breeze) which redistribute water vapour and matter (aerosols and chemical species). The PBL dynamics is also driven by entrainment at PBL top. It is a key aspect since the moist monsoon layer lies below dry air layer, with strong wind shear at the interface between the two layers. Finally, the diurnal cycle modifies the PBL thermodynamical properties, modulate the heat low and monsoon circulations.

In this sub-workpackage 2.1.1., we distinguish the "one-way" response of PBL dynamics to surface forcing. The two-way feedbacks are investigated in workpackage WP1.3, so the time dedicated to the surface/atmosphere interactions is shared between the two workpackages.

Strategy

At mesoscale: In terms of observations at meso-scale, the instrumental set-up for SOP-1 has been re-discussed according to the key issues to be addressed. The aircrafts will fly meridional transects from the coast to north of Niamey. The transect was determined so that the aircrafts will fly over the instrumented sites.
The data provided by the ATR are the meteorological variables, the turbulent fluxes and some chemistry. The French Falcon 20 with the water vapour lidar LEANDRE-2 provides the reflectivity and water vapour fields and consequently the PBL depth. The German Falcon 20 with the Doppler lidar WIND provides the reflectivity and wind fields and consequently the PBL depth.
The aircraft measurements will thus allow us to calculate the gradient of wind and moisture at the PBL top, and to document the entrainment zone and quantify the entrainment at the PBL top. The aircraft data will be correlated to the surface energy budget derived from the surface measurements (meteorology and fluxes). This instrumental set-up is thus suited to address the scientific objectives in terms of water vapour variability and convection (entrainment and skewness at the PBL top), and surface/atmosphere interactions.
The numerical tools used to address this issue are large-eddy simulations (LES) and limited area models (LAM) such as Méso-NH, MM5 or RAMS. The data will allow model initialization, forcing and validation whereas the numerical models will provide the 4D meteorological environment necessary to understand the processes. The use of these models will also serve to improve or develop new parametrisations, in interaction with workpackage WP1.1 and WP1.3.
At synoptic scale: The use of satellites to derive PBL structure (CALIPSO) and surface properties (land use, LAI, soil moisture,…) will be a novel approach to address surface/atmosphere interactions. Indeed, the large-scale structure of the PBL from the Gulf of Guinea to the Sahara will be correlated with the large-scale variation of surface properties. These data will be a source for the validation of mesoscale models and GCMs. This approach links the workpackages WP2.1 with WP1.3 and WP1.1.

Work content

The work content can be divided into several aspects related to the **role of the PBL** in:

- **the horizontal transport, vertical exchanges and redistribution** of concentration of water vapor, aerosols and chemical species (the PBL being the major emission source);

- **moist convection initiation** by driving the water vapour variability;
- **the monsoon intensity** through the PBL static and dry energy budget;
- **the monsoon onset** (through the evolution of PBL static and dry energy budget as a function of time, and the activation of convection over the continent);
- **the convection feedback** on the PBL (energy loss) and return to PBL equilibrium after convective perturbation.

Foreseen deliverables

- A description of changes in PBL characteristics, moist convection and regional-scale circulations associated with the monsoon onset.
- To relate pre-monsoon and monsoonal rainfall events to their environment and upper level (surface forcing and entrainment at the top of the PBL between the moist monsson flow and the dry upper air). This will completed by a systematic analysis of these parameters for the SOP period.
- An observational and dynamical description of the SAL and ITF variability in association with regional and synoptic scale variability in surface energy budget and convection.

2.1.1.b Report on research conducted in year 2004

Roles of key factors (entrainment and soil moisture) controlling the variability of the moisture field in the PBL and their impact on moisture fluxes and cumulus initiation - Bastin, Flamant, Drobinski (IPSL/SA), Chen (NCAR), Couvreux (CNRM):

Moisture fluctuations associated with a growing convective boundary layer over land have been investigated by means of large eddy simulations and IHOP 2002 observations. LES provide a realistic picture of the PBL growth and variability. A salient result concerns the intense negative skewness of the water vapour due the entrainment of dry air at the PBL top deeply into the boundary layer (work conducted at CNRM in cooperation with IPSL/SA).
Impact of surface heterogeneity (land use, vegetation, soil moisture and temperature) on PBL dynamics and water vapour variability has been investigated using the non-hydrostatic NCAR-PSU MM5 model and the IHOP_2002 database. The study evidenced the role of soil moisture in enhancing surface heat flux gradients and generating inland thermal breezes which redistribute water vapour in the PBL. This study is in progress and should lead to the writing of an article by the end of the year. This study is in close connection with WP1.3 for which sensitivity studies on surface properties to PBL dynamics, water vapour variability and convection initiation will be conducted (work conducted at IPSL/SA in cooperation with NCAR).

GPS water vapour retrieval to investigate water vapour variability and PBL diurnal cycle - Bastin, Bock, Drobinski (IPSL/SA), Champollion, Masson (LDL):

GPS integrated water vapor and tomography analyses of water vapor in the lower troposphere, complemented by high resolution numerical simulations have been used to investigate sea breeze in the region of Marseille during ESCOMPTE. This is the first time GPS tomography is used to validate the three-dimensional water vapor concentration from a numerical simulation, and to analyze a small-scale meteorological event. The high spatial and temporal resolution of GPS analyses provide a unique insight into the evolution of the vertical and horizontal distribution of water vapor. Such very promising results are an encouragement to the use of the GPS network during AMMA, where water vapor plays a key role in monsoon dynamics (Bastin et al., submitted).

PBL diagnostics to identify error sources in PBL cloud forecast - (IPSL/SA):
In this study (Mathieu et al., submitted), ARPEGE and ECMWF outputs were compared to observations available on the SIRTA stations since March 2003. Observations of dry and cloudy PBL over SIRTA were compared to model forecast by ECMWF and ARPEGE. A diagnostic

approach was used to estimate the contribution from meso-scale movement to the vertical structure of the PBL and to the development of clouds. Using the diagnostic approach, error sources in planetary boundary layer cloud forecast could be identified. This was a way to "isolate" physical processes linked to the PBL and evaluate their importance by comparing with observations. The use of such diagnostics to evaluate numerical models is a key issue during AMMA and is closely linked to WP1.1.

2.1.1.c 1-year Plan

Objectives

This WP will ensure that the tools necessary for achieving the scientific objectives of WP2.1 (i.e. determine the regional and synoptic-scale changes in patterns of convection and atmospherics dynamics associated with the regional-scale monsoon and its variability) will be ready and available at the beginning of the SOP in 2006. This comprises:

- process studies using already existing databases relevant for the preparation of AMMA (e.g. IHOP_2002, ESCOMPTE, HAPEX_Sahel, SIRTA,…);
- analysis of novel types of data like GPS to be used to investigate PBL dynamics, water vapour and diurnal cycle;
- providing the underpinning models results, pre-SOP case studies and theoretical ideas with which to plan atmospheric observations in WP4.2;
- performing idealized 2D modelling of the WAM to study the scales interactions and couplings involved;
- defining the PBL diagnostics to be to monitor the key large scale structures of the WAM and their evolution.

These objectives will be addressed by using relevant datasets collected during relevant field campaigns (ESCOMPTE, IHOP_2002) or from dedicated instrumented site (SIRTA at Palaiseau). Most of these projects are funded by the national programs such as PATOM, PNCA, PNTS.

Work content

Behaviour of PBL for a WAM case - Asencio, Peyrillé, Diviné (CNRM)
The behaviour of the PBL in CRM simulations will be analyzed for a WAM case study, as a function of the soil moisture and of the dryness of the air capping the PBL. The effort will first be devoted to adjusting the proper diagnostics (budgets).
The PBL will be also analyzed in the idealized 2D WAM simulations owing to budget tools. The main goal will be to characterize its dependency on the latitude due to different surface conditions and large-scale forcings.
A similar analysis will be attempted with the idealized “aqua-terra-planet” model. Nevertheless at this point the effort will be first oriented on the development of the required diagnostics, and the goal will be more to test the PBL representation by parameterizations of ARPEGE-Climat. Such work partly takes place in the WP4.1.3.

Roles of key factors (entrainment and soil moisture) controlling the variability of the PBL moisture field and cumulus initiation - Bastin, Flamant, Drobinski (IPSL/SA), Chen, Weckwerth (NCAR), Protat, Bouchard (IPSL/CETP), Couvreux, Guichard (CNRM)
This work includes the analysis of the very fine scale processes (i.e. entrainment, using LES simulations) and meso-scale dynamics (role of the surface heterogeneity on convection initiation, using MM5 mesoscale modelling at SA and NCAR) of a IHOP_2002 convection initiation case (12 juin 2002).
The mesoscale numerical experiment of the IHOP_2002 case will be extended to the impact of mesoscale assimilation using MANDOPAS on water vapour representation and convection initiation in the MM5 model.

In 2005 the main work specific to AMMA will consist in analysing Méso-NH simulations already performed at CNRM on a HAPEX-Sahel PBL case. The goal is to find a typical case study appropriated to elaborate an idealized Sahelian PBL LES case. This will probably involves to gather all available data for that case in collaboration with F. Saïd and M. Lothon (LA).
All the above studies are in close relation with WP1.3.

GPS water vapour retrieval to investigate water vapour variability and PBL diurnal cycle - Bastin, Bock, Drobinski (IPSL/SA), Champollion, Masson (LDL):
The GPS related research effort is now focused on the analysis of the diurnal cycle with GPS integrated water vapour and tomography analyses, and the classification of different types of flow (thermally induced, dynamically induced) as a function of water vapour content and variability. This study will make use of the ESCOMPTE-GPS database.

2.1.2 Saharan thermal low (or heat low)

2.1.2.a 5 year Plan

Coordinator: C. Flamant
Laboratories: CNRM, LMD, LOA, SA

Context and objectives

The Saharan heat low (SHL) region is key to understanding the monsoon dynamics. The SHL is generally (and very roughly) defined as a region bounded latitudinally by 20°N and 30°N, and longitudinally by 15°W and 10°E. The SHL can be characterized as a region of high surface albedo (Fig. 2.1.1), overlain by strong synoptic subsidence, where dry convection is an important heating process (and moist convection is not). In addition, the omnipresence of a sand layer heated by shortwave solar radiation absorption presents a secondary heat source in the Saharan planetary boundary layer, also sometimes referred to as the Saharan aerosol layer (SAL). The presence of the dust layer combined with the high soil temperature, which is controlled by the earth's surface heat balance, constitutes a unique destabilization factor for the Saharan desert mixed layer.

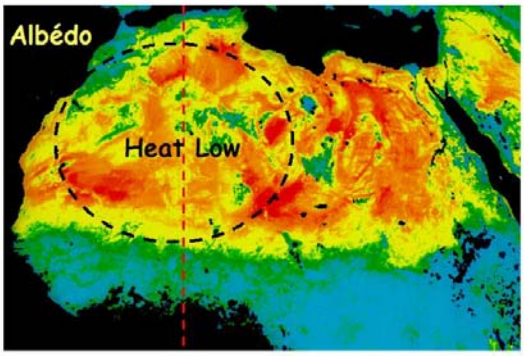

Fig. 2.1.1: Polder derived surface albedo over northern Africa for Jun 97. High (low) albedo values are in red (blue). A tentative position of the SHL is superimposed (black dotted line). The red dotted line materializes the location of the meridan cross-section shown in Fig. 2. (Courtesy from R. Lacaze)

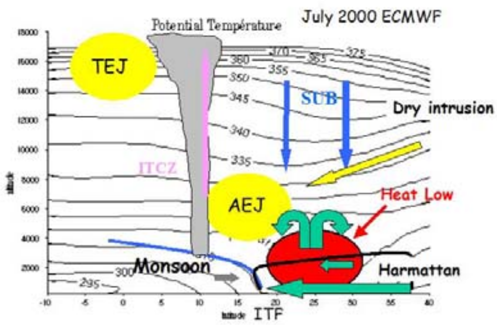

Fig. 2.12: schematic of the monsoon system dynamics along a meridian cross-section such as the one shown in Fig. 1. Salient features such as the inter-tropical front (ITF), the african easterly jet (AEJ) and strong subsidence above the SHL region (SUB) are shown. (Courtesy from P. Peyrillé)

The thermodynamic budget of the thermal low over the Sahara desert is an important element of the climate of the West African region. Also, there is now evidence that the intensity of southerly/southwesterly monsoon flow (including the sudden surge associated with the so called "jump" or onset) is partly controlled by the intensity of the SHL.

Despite its central role, the very little is known on the dynamics of SHL as well as the **diurnal** and **seasonal** evolution of its main characteristics (position, horizontal extent, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (SAL, inter-tropical front -ITF). Furthermore, this region is affected by an important **horizontal variability** of its main characteristics and features at the **regional scale**.

The objectives of this sWP are to determine the regional and synoptic-scale changes in patterns of convection and atmospheric dynamics associated with the regional-scale SHL and its variability. This involves determining the relationship between the distribution of dry convection and

• surface fluxes and albedo patterns [WP1.3 and WP2.3],
• the variability of dust uptake and related radiative forcing [WP2.4],

• the large-scale low level advection of air coming from the Mediterranean and the Atlantic Ocean,
• the changes in large-scale flow splitting induced by orography (the Atlas and the Hoggar, in particular) related to changes in large scale circulation patterns,
• the changes in moist convection patterns further to the south (in connection with the african easterly waves –AEWs) [sWP2.1.6].

We also aim to assess the role of the Saharan Air Layer (SAL) in AEW dynamics over land.

At the heart of this work, we aim to make the first comprehensive observations of these processes over the continent and the adjacent sea surface, and to do this we need to integrate data from a variety of instruments and platforms, operated by various partners. Within this sWP, we aim to use these data to describe the basic state balances of the monsoon, as well as their variability down to synoptic scales. Using these observations made at key times in the seasonal cycle, notably the monsoon onset period, we aim to test the model representations of the dynamics responsible for monsoon variability, and to identify key atmospheric processes which are critical to correct model behaviour.

Strategy

Since the diurnal cycle is very marked in this region and the mesoscale variability is important (both in terms of SAL structural parameters and dust emissions), the experimental strategy calls for a complementary ground-based/airborne/spaceborne observational approach to address these key issues. The objective of the ground-based (resp. airborne and spaceborne) component of the experimental strategy is to document the diurnal cycle (resp. mesoscale variability) of relevant variables (structural, thermodynamics, radiative, etc..) in the SHL region. This will partly be achieved during the SOP via airborne explorations north of the ITF and the implementation of the Tamanrasset "Supersite" [WP4.2]. It is also of great importance that these measurements be compared with those acquired outside of the SHL region. This will partly be achieved during the SOP via airborne explorations south of the ITF and the implementation of the Niamey, Banizoumbou and Cinzana "Supersites" [WP4.2]. The seasonal variability needs to be recorded on the basis of long time series (satellite, sounding, radiative measurements archives) [WP4.3 and WP4.4].

Furthermore, observations (by essence limited in time and space) need to be put in the perspective of numerical modelling [WP4.1]. Besides bridging a gap between ground-based, airborne and space-borne observations, numerical modelling also allows us to conduct sensitivity studies, both aspect being crucial for the identification and assessment of processes key to understanding the role of the SHL in the monsoon system.

In the years prior to the SOP (2004 and 2005), the focus of this sWP will be on climatologies (analysis of long observational time series and simulations of the seasonal cycle of the monsoon system), as well as detailed case studies (using both observations and simulations) and sensitivity experiments (conducted with idealized and real case simulations).

Work content

Model analyses, satellite land surface and cloud data will be used to study historical monsoon onset processes. These studies will be fed into WP4.2 and used as guidance for the SOP planning.

Boundary layer data (from surface-based data and aircraft), lidar measurements (backscatter, water vapour and wind), radiosondes, dropsondes, land surface data (WP1.3 and WP2.3), aerosol data (WP2.4), satellite data (WP4.3) and model analyses (WP4.1), will be used to describe the the SHL characteristics (position, horizontal extent, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (SAL, inter-tropical front -ITF). In particular the results will be used in the northern Sahel to characterise the thermodynamic structure of the Inter-tropical Front

(ITF) and its associated circulations, and to characterise the convective and dynamical changes associated with monsoon onset (linking with WP1.2 and WP 2.3).

Representation of these processes in model analyses and forecasts will be assessed. Results will be documented and feed back into sWP4.1.1.

Radiosonde data (at high temporal frequency) and radar data will be used in association with the aircraft flights as well as airborne lidar data (water vapour and wind) to quantify advective fluxes on both sides of the ITF for use in WP1.2.

The interaction of heat low patterns in the northern Sahel with African Easterly Waves (AEW) dynamics will be explored through model analyses and idealised models (combining WP1.3, WP2.1, WP2.2, WP2.4) on regional to synoptic scales.

An idealised 2D model representing the main features of the West African monsoon -WAM- system (including the SHL) will be used to study the seasonal and diurnal cycles of the SHL characteristics, as well as the sensitivity of the SHL to a number of key processes (low-level advections, vertical distribution of aerosols, surface forcing, subsidence aloft, intensity of deep convection).

Multi-nested 3D aerosol models will be used to assess the sensitivity of the SHL over land to aerosol processes (historical cases).

Foreseen deliverables

- A climatology of the **diurnal** and **seasonal** evolution of the SHL characteristics (position, horizontal extent, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (SAL, inter-tropical front -ITF).
- A description of changes in SHL characteristics and features associated with the monsoon onset.
- An observational and dynamical description of the SAL and ITF variability in association with regional and synoptic scale variability in convection.
- An analysis of periodicity and seasonality of African dust occurrence (using the TOMS archive).
- Improved knowledge of SHL dynamics sensitivity to aerosol processes.
- To describe the links between regional (Saharan) and synoptic (AEW) variability in the northern Sahel and diabatic processes at the surface and in the clear air.
- An idealised 2D model representing the seasonal cycle of the SHL (among other main features of the WAM system) available to study the role of the SHL on the monsoon onset.
- Design of diagnostics to identify the SHL and low-level advections from the Mediterranean in a variety of numerical modelling tools (2D and 3D idealized models, 3D mesoscale models and general circulation models –GCMs) and analyses.
- Design of diagnostics to identify the SHL in satellite imagery (Meteosat, PARASOL).

2.1.2.b 2004 Activity report

In 2004, the focus of the work conducted in this sWP has been on the analysis of satellite data (18-year archive of african dust occurrence and 10-day archive of cloud cover in the SHL region) as well as numerical simulations (idealized 2D simulations of the seasonal cycle of the monsoon system, WAM representation in GCMs, case studies using 3D mesoscale models, analyses and linear models).

Numerical simulations and model analyses

SHL seasonal cycle using idealized 2D simulations - P. Peyrillé, J.-P. Lafore (CNRM):
The simulation of the WAM seasonal cycle with the idealized 2D model, stressed the importance of the heat low and allowed to note a sudden change of the SHL at the monsoon onset. This tool is particularly well suited to analyze the evolution of the heat budget in the region of the SHL. Sensitivity analyses have been conducted to analyze the impact of low-level advections and aerosol vertical distribution on the development of the SHL.

Impact of aerosol radiative forcing on regional scale dynamics using 3D RAMS simulations - F. Minvielle, C. Flamant, J. Pelon (IPSL):
A multi-nested 3D aerosol simulation of a major dust event which occured in September 2000 (in the framework of the Saharan Dust Experiment –SHADE) has been designed using the Regional Atmospheric Modelling System (RAMS) model to asses the impact of aerosol radiative forcing on the regional scale dynamics in the region of the SHL. In the simulation, we use state-of-the-art dust generation and radiative modules, namely the Dust Production Model and the radiative EC3 code. The simulation covered the period from 15 to 28 September 2000. The simulation on 25 and 26 September was validated using satellite products (aerosol optical depths from MODIS) and airborne measurements (lidar measurements of the vertical structure of the dust plume and aerosol size distributions made onboard the UK Met C-130). A preliminary analysis shows that in the dust plume region, aerosol radiative effect induce a significant change of temperature (ranging from 1°C to 3°C) in the surface layer (20 m agl) and impact the dynamics of the flow in the regions of important dust uptake.

Role of orography on SHL deepening at the time of the onset - P. Drobinski, B. Sultan, S. Janicot (IPSL):
Combining NCEP/NCAR analyses and a linear model, Drobinski et al. (2004) have evidenced a possible interaction between northern Africa orography and the deepening of the SHL 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 SHL. The Atlas does not play any role during the monsoon onset but contributes to the mean climatological location of the SHL.

Satellite datasets

Periodicity and seasonality of African dust occurrence using the TOMS archive – I. Chiapello (LOA):
A climatology of mineral dust has been achieved based on TOMS (Total Ozone Mapping Spectrometer) and Meteosat observations. We used 18 years of daily Absorbing Aerosol Index (AAI) images from the TOMS/Nimbus-7 (1979-1992) and TOMS/Earth-probe (1997-2000) sensors to compute Dust Optical Thickness (DOT) over North Africa and north tropical Atlantic. Our analysis has shown a large impact of meteorological factors on African dust year-to-year variability. The North Atlantic Oscillation affects mainly the variability of winter export of dust over the northern part of the Athantic (Chiapello and Moulin, 2002), whereas the Sahel drought has been shown to have a large impact on year-to-year variability of both winter and summer dust export (Moulin and Chiapello, 2004).

Diurnal cycle of cloud cover characteristics over the SHL region during JET2000 using Meteosat data - G. Sèze (IPSL):
For the JET 2000 ten day period, cloud types present over the heat low region have been analysed using Meteosat cloud DCM (Dynamical Clustering Method) classifications. In this preliminary study performed between 1130 GMT and 1600 GMT, the cloud cover in the northern part of the

region is characterized by a strong diurnal cycle. Cloud cover forms at the end of the morning and develops in the afternoon. In spite of its strong and quick development up to the middle part of the atmosphere (600-300hPa), cloud cover does not reach the high levels of the atmosphere (above 300 hPa).

2.1.2.c 1-year Plan

Objectives

This sWP will ensure that the tools necessary for achieving SHL-related scientific objectives (i.e. to determine the regional and synoptic-scale changes in patterns of convection and atmospheric dynamics associated with the SHL variability) will be ready and available at the beginning of the SOP in 2006. This comprises:

- developing the model tools for effective use of the observations collected during the EOP and the SOP,
- defining the diagnostics and forecast tools to be used during the SOP to monitor the SHL characteristics and features as well as low-level advections from the Mediterranean, and their evolution,
- designing the diagnostics to identify the SHL in satellite imagery (Meteosat, TOMS),
- assessing the diurnal and seasonal evolution of the SHL characteristics (position, horizontal extent, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (SAL, inter-tropical front -ITF) through climatologies (model, satellite, sounding, radiative measurements archives
- providing the underpinning model results, pre-SOP case studies and theoretical ideas with which to plan atmospheric observations in WP4.2.

Work content

Satellite and climatological datasets

Periodicity and seasonality of African dust occurrence using the TOMS archive - I. Chiapello (LOA), C. Flamant (IPSL):
Using the TOMS/Earth-Probe archive we will analyze the periodicity and seasonal cycle of mineral dust over the Sahara region in order to investigate the possible link with the SHL intensity. This archive will also be used to determine cases for which massive dust uptake occured in the region of the SHL. From these cases, a couple of cases shall be selected to be simulated with RAMS.

Historical Tamanrasset and Assekrem dataset - C. Flamant, J. Cuesta, P. Flamant (IPSL):
Analysis of the climatological data (soundings as well as radiative and aerosol measurements) acquired over the last decade (possibly the last two decades) by the Météo Algérienne in Tamanrasset and Assekrem will be conducted to assess the diurnal and seasonnal variability of the SAL structural characteristics, surface energy budget and thermodynamic variables as well as aerosol size distribution.

Diurnal and seasonal cloud cover characteristics over the SHL region using SEVIRI and Meteosat data - G. Sèze (IPSL):
Cloud cover over the SHL region will be analysed for the 2004 summer by applying the DCM cloud classification scheme to the SEVIRI data, as well as the cloud type and cloud pressure SEVIRI SAFNWC product. The whole diurnal cycle will be included in the analysis. When SEVIRI data will be available for summer 2005, the analysis of the cloud cover and of its diurnal cycle in the SHL region will continue on this period. To improve the description of the cloud cover, in particular the cloud top altitude, the new instruments CALIPSO and PARASOL which will be

available at that time, will also be used. The comparison of the cloud properties observed from SEVIRI under the track of CALIPSO and the cloud layers observed with CALIPSO, will allow to evaluate the precision of the cloud classification and cloud top pressure obtained from SEVIRI. Using the 1983-2001 DX Meteosat data set (30 km resolution, every 3h hours), seasonal and inter-annual variability of the cloud cover in the SHL region will also be studied.

Numerical simulations and model analyses

<u>*SHL and low-level advection diagnostic in numerical simulations and model analyses*</u> *- P. Peyrillé, B. Diviné, J.-P. Lafore (CNRM), J.-Y. Grandpeix, C. Flamant, F. Minvielle, B. Sultan (IPSL) :*
Design of diagnostics to identify the SHL and low-level advections from the Mediterranean in a variety of numerical modelling tools (2D and 3D idealized models, 3D mesoscale simulations using Meso-NH and RAMS and global simulations using LMDZ) as well as NCEP/NCAR and ECMWF analyses. There are many ways to define the SHL, for example using the surface pressure field, the surface temperature field, the convergence of the wind field or the vertical thermal structure of the lower troposphere. Furthermore, hourly, daily or weekly averaged fields may be used. Finally, we aim to assess what is the impact of model resolution on the diagnostics.

SHL diurnal and seasonal cycle using a hierarchy of models (idealized 2D, idealized 3D, GCM) - P. Peyrillé, B. Diviné (CNRM), J.-Y. Grandpeix (IPSL):
Sensitivity tests and budgets analysis will be performed with idealized 2D simulations to study the structure of the SHL and its role in the WAM in particular at the onset. The first task will be to study its diurnal cycle and to propose parameters to characterize its intensity, size and position that could be computed for different analysis and simulations.
A similar and complementary study will be conducted with the idealized “aqua-terra-planet” model, to examine the SHL behaviour in a more realistic 3D configuration. In particular the intraseasonal variability of the SHL will be examined in relation with the waves generated in a 3D framework.
Finally, the diurnal and seasonal cycles of the SHL, as well as its stability and its persistence shall be analysed in a global and realistic GCM framework using LMDZCorrelations will be sought between the Heat Low position and the ITCZ position.

<u>*Impact of aerosol radiative forcing on regional scale dynamics using 3D RAMS simulations*</u> *- F. Minvielle, C. Flamant, J. Pelon (IPSL):*
Analysis of the SHL dynamics sensitivity to aerosols processes using multi-nested 3D RAMS simulation for historical cases of massive dust uptake occuring in the region of the SHL. Such cases will be identified from the TOMS archive. Sensitivity analyses will be conducted to assess whether dust induced heating in the SHL region can trigger AEW, in connection with the work conducted by N. Hall in the framework of sWP2.1.6.

<u>*Role of orography on SHL deepening at the time of the onset*</u> *- P. Drobinski, B. Sultan, S. Janicot (IPSL):*
Further investigations of the role of orography on the deepening of the SHL at the time of the monsoon onset will be conducted (a) on the strength of the wind direction shift at the monsson onset on a year-to-year basis (instead of a composite approach). The objective is to quantify the respective contribution of potential causes at the monsson onset (change of stratification on the windward side of the massifs, enhanced surface temperature, role of SST over Mediterranean and Gulf of Guinea); and (b) on the causes of wind direction shift on the windward side of the massifs**.**

<u>Deliverables</u>

- Report on the needs of observations and priorities for the atmospheric components of WP4.2.
- SHL sensitivity to aerosols processes historical case

- A climatology of the **diurnal** and **seasonal** evolution of the SHL characteristics (position, horizontal extend, subsidence aloft, thermodynamic budget, radiative budget, cloud cover) and features (SAL, inter-tropical front -ITF).
- An analysis of periodicity and seasonality of African dust occurrence (using the TOMS archive).
- Design of diagnostics to identify the SHL and low-level advections from the Mediterranean in a variety of numerical modelling tools (2D and 3D idealized models, 3D mesoscale models and general circulation models –GCMs) and analyses.

2.1.3 Convection

2.1.3.a 5 year Plan

Coordinator: JP. Lafore
Laboratories: CETP, CNRM, LA, LMD, LTHE

Objectives

The key aims of this sWP are to determine the processes which control the various aspects of the life-cycle of Mesoscale Convective Systems (MCSs) (triggering, growth, decay, propagation and diurnal cycle) and to study their impact at the larger scale (heat, vapour, momentum and vorticity). In particular we aim to determine the relative roles of the synoptic environment and surface conditions in controlling the behaviour of organised convection, its rainfall efficiency and its hydrological impact. In regard to surface conditions we aim to assess the influence of land surface heterogeneity on the characteristics of convective clouds (including congestus and MCSs). This involves studying the initiation, evolution and sub-structure (with WP1.3, WP2.3) of cumulonimbus, as an input to WPs on the distribution of rainfall and interaction with the land surface. With regard to the large scale forcing we aim to explain the role of the synoptic environment (Saharan Air Layer (SAL) intrusions, dry intrusions, monsoon layer depth, African Easterly Jet (AEJ) shear, Tropical Easterly Jet (TEJ) anomalies) on convective initiation and organisation. A first goal will be to document the characteristics of precipitating systems and their seasonal and interannual variability. This will be performed on the basis of the climatology of West African MCSs developed and produced by WP4.3 resulting from the use of MCS tracking algorithms from IR Météosat imagery.
In addition, we also aim to collaborate with WP2.3 to better understand, quantify and represent the vertical transport of chemical species and aerosols due to convection.
We also aim to explain the role of Saharan dust aerosols in the occurrence of lightning, and furthermore to explain why tropical Africa is so lightning active. To do this, we aim to assess the spatial and temporal distribution of lightning in African storms.

Work content

The three-dimensional structure and evolution of wind and precipitation will be analysed in association with surface rainfall within precipitating systems passing or developing over the region near Djougou (Benin), using two Doppler radars, the dense rain gauge network and hydrological measurements.

Concerning the characterisation of precipitating systems in the Sudanese region the following tasks will be performed at LTHE in link with WP1.2:

- Provide a detailed catalogue of rain events and a relevant classification of events, with respect to their pluviometric impact.
- Gather an exhaustive catalogue of the rain events observed at the ground and document the characteristics at all scales from a combination of sensors (from disdrometer, to radar and satellite derived information).

- Analyse the links between the various observed characteristics of rain events : 3D structure, rainfall amounts, efficiency, trajectory.
- Compare the characteristics for the Sudanese region (from observations over the Oueme mesoscale and Donga local scale site) and the Sahelian region.
- Analyse the seasonal and interannual variations of rain event characteristics.
- Analyse the diurnal cycle of precipitation over Benin, using historical data.
- Assess the representivity of the SOP events according to EOP derived statistics.

Surface-based, remote-sensed and aircraft observations will be used to characterise the structure, evolution and sub-structure of shallow cumulus, congestus and MCSs (for output to WP2.3, 1.2, 1.3, 3.1).

The three dimensional structure and evolution of wind and precipitation in MCSs will be analysed as they propagate over West Africa, leave the West African continent and propagate over the eastern tropical Atlantic.

PBL changes resulting from MCSs (with WP1.3, WP2.3 and sWP2.1.2) will be assessed in aircraft and ground-based microwave data. Characteristics of the ocean-atmosphere interaction in association with MCSs will also be investigated, in association with WP2.2.

The SOP case studies for MCS events will be documented and used as the basis for process studies. Careful numerical model intercomparisons and evaluation with observations are necessary, to ensure that the models accurately reflect the observed features, before more sophisticated diagnostics are extracted from them. These studies will be used to evaluate the sensitivity of the genesis and lifecycles of the systems to synoptic environment, and to the pre-storm boundary layer state (and, through sWP1.3.3, the land surface state).

The case studies will be employed to evaluate the large scale forcings (heat, moisture and momentum) due to the organised convection. CRM intercomparisons will test the sensitivity to topographic control, the synoptic state and the diurnal cycle. From such models, idealised studies of AEW forcing by convection will be performed.

CRM simulations will be a key tool to integrate SOP observations, to analyze processes and interactions within convective systems, their impact on PBL and on their environment. During the pre-SOP years the main effort will be put into the preparation of these tools and their improvement, including diagnostics. The impact of the assimilation of new observations (satellite, GPS, aircrafts…) developed in WP4.1.1 and WP4.1.2 for the atmosphere and surface respectively, will be evaluated.

Idealised modelling of characteristic convective environments will be used to test theoretical ideas of convective equilibrium (and disequilibrium), from the shallow cumulus through to organised MCSs, for input to WP4.1.

The three-dimensional distribution of liquid and ice hydrometeors will be analysed from polarimetric measurements with the two radars operating at different wavelengths. This will be related to lightning activity, which will in turn be related to convective vertical velocity measurements. A mesoscale model incorporating lightning processes will be applied to the SOP case studies in order to explain lightning occurrence. This work will link closely with sWP2.4.4 where NOx production by lightning will be analysed from airborne measurements.

Foreseen deliverables

- Comprehensive observational case studies of MCS events, including pre- and post-storm boundary layer state.
- To explain the relationships between convective system behaviour and synoptic environment, including boundary layer variability.
- Model intercomparisons based on the observational case studies.
- Use of models for the evaluation of sensitivity to synoptic environment and land boundary layer heterogeneity.
- Observations of lightning structure within MCSs in relation to microphysical properties.
- Cloud-lightning model evaluation.
- Evaluation of ice cloud microphysical schemes and parameterisations.

2.1.3.b Report on research conducted in year 2004

LA: *Stage DEA OAB UPS A.-C. Bennis :* A numerical study has been performed to analyse the impact of different environments representative of the WAM on the propagation of squall lines. Three types of environment have been selected to initialize 2D (zonal-vertical) Méso-NH simulations and corresponding to (i) continental, (ii) transition between continent and ocean and (iii) oceanic environment with presence of dry Saharan air aloft. Soundings from Korhogo (Ivory Coast on 810623), Dakar (Senegal, mean August 2000) and Sal (Cape Verde, mean August 2000) have been used respectively. The main results are :
- the wind shear between the monsoon layer and the AEJ inhibits isolated convection , but favours formation and extent of the trailing stratiform region;
- dry mid-levels (presence of Saharan air?) allows the development of the trailing stratiform region if the monsoon layer is humid enough ;
- in both situations, MCSs can propagate even though isolated convection cannot develop;
- changes in the TEJ have limited impact, surface changes (when a MCS passes from the continent to the ocean) require long integration time (>10 h) to induce sensible effects, if the atmospheric environment does not change.

LTHE: *Contribution to climatological studies*

- Characterization of precipitating systems according to the time space structure of the precipitation field.
- 5 years of precipitation data observed on the ground with the network of rain gages installed in the Ouémé region (a homogeneous network of 35 gages over a 10 000 km x km area).
- A robust method based on the analysis of a composite hyetogram has been developed and run this year. This allows us to derive the propagation speed and direction of rain events as observed from the ground.
- A basic classification of these systems according to the appearance of the composite hyetogram (either a squall line type structure -with a well defined convective range followed by an extended region of stratiform precipitation - or a less defined structure)
- This preliminary work shows that the systems observed in the Ouémé region exhibit a lot of variety compared to what is observed in the sahelian region.

CNRM:

Climatology of West African MCSs (Piriou)

This work has been mainly performed within the satellite WP4.3 in close collaboration with K. Ramage, to compare 2 MCS tracking algorithms (ISIS at MF and LMD-LTHE one) from IR Météosat imagery. It allowed verifying that although the 2 algorithms produce slightly different climatology, the physical conclusions that may be drawn are close. Based on an 8-year MCS climatology CNRM developed a classification in 5 types of MCS depending on their life cycle duration (less and more than 9hr) and on their zonal propagation speed (low-moving, moderate and fast-moving MCS separated by the 7 and 13 m/s westward speeds). This classification allows separating different types of convection regimes that dominate in some regions and periods of the season. It also allows to better characterizing the internal variability.

CRM simulations of real cases:
The goal is to improve the skill of Méso-NH to simulate WAM weather systems and their interactions with the synoptic environment. It is performed on some case studies from the HAPEX-Sahel and JET2000 experiments. SOP case studies will later be simulated with Méso-NH in order to exploit the observations and to interpret these cases. In 2004 the following task has been accomplished:

- The 3D turbulence scheme has been modified (Tomasini) to account for the strong lateral mixing occurring on the edges of growing convective cells. This leads to improvements in the simulation of the maximum vertical velocity in convective regions. The impact on the simulation of African weather systems is currently being tested (precipitation, water budget, morphology…) on the HAPEX-Sahel case.
- A JET2000 case has been simulated. It corresponds to the diurnal development of a MCS over the lake Chad (Regimbeau 2004). It confirms that the CRM model (5 and 2.5 km resolution) dramatically improves the quality of the simulation compared with lower resolution runs (10 km) using a convective scheme. In the latter case too much precipitation is formed in the Sahel region and the convection dissipates too early in the evening. This case study has been used to test the positive impact of the assimilation of satellite data using the 3D-Var AROME system (see WP4.1.1).

Idealized 2D WAM Model:
The diurnal cycle of convection has been studied in the 2D WAM model (Peyrillé et al 2004) when a convective parameterization is used. In GCMs the maximum of convection occurs at midday whereas the observed maximum is during the night. Also the convection tends to occur too far north of the ITF. Such typical faults in convection schemes in terms of the location and timing of convection need to be understood by using high resolutions runs as planed for the next year.

2.1.3.c 1-year Plan

Objectives

In 2005, this sWP will ensure that the tools necessary for achieving the scientific objectives of WP2.1.1 will be ready and available at the beginning of the SOP in 2006. This comprises:

- Developing the modelling tools (CRM) for effective use of the observations collected during the EOP and the SOP.
- Providing the underpinning models results, pre-SOP case studies and theoretical ideas with which to plan atmospheric observations in WP4.2.
- Developing comprehensive climatologies of West African precipitating systems based on both satellite and precipitation observations.

Work content

CRM simulations of real cases (CNRM)

- Evaluate the impact of some modifications concerning the in-cloud turbulence treatment and the representation of the ice in non-precipitating clouds proposed by WP2.1.4 (Giraud).
- Treatment of another case study of the 2004 season to evaluate the impact of the 3D-Var assimilation of MSG data (collaboration with Nuret in WP4.1.1).
- Definition and organization of a first version of the database for CRM simulations that will be made available to the AMMA community.
- Initialisation of the soil moisture for a case study CRM simulation. A first analysis will be performed of the impact on the convection development and implementation of the suitable

diagnostics (budgets…) will be started. This will be performed in collaboration with the WP4.1.2 providing soil moisture fields, and will contribute to WP2.1.1, WP1.2 and WP1.3.

Generation of a Mesoscale Convective Vortex (MCV) in the trailing stratiform region of MCS (LA - master or 1st year thesis of an Ivorian student: to be confirmed)
The following questions will be studied: influence of thermodynamic and the wind profile on the MCV, evolution of its intensity and of the radial and vertical wind distribution, relation with temperature perturbations and thermal wind balance, analysis of PV structure and generation through latent heat release, relation between MCV and MCS propagation and evolution, role of the environmental characteristics (humidity, jets, waves, ...). This work will be conducted using MésoNH (3D simulations, idealized and/or real cases and comparisons with METEOSAT satellite observations).

Climatological studies of West African precipitating systems (LTHE, CNRM)
One of the central objectives of AMMA is the link between climate and water resources provided by precipitating systems. A key parameter to analyze is the precipitation efficiency of these systems. It is important to analyze the link between characteristics of the rain field observed at the ground and the dynamics and structure of the systems, as observed from satellite or described by reanalysis. It will help to assess how well we can predict the hydrological impact of a system from its large scale features and may be give a hint about which process are at stake.
Systems in the Sahelian region have been well documented thanks to the observations made during HAPEX/Epsat Campaigns. The systems crossing over the Sudanese area have been much less documented so far. Thanks to the network of gages which has been operated since 1999 over the Ouémé Basin (an area of about 1 by 1°, centered at 9.5° N, 2°E) it is now possible to analyse the characteristics of the rain events at that latitude too. The preliminary analysis of this data set shows that the systems observed in the Sudanese region have different characteristics from the ones in the Sahelian zone and show more variety and complexity.
The main objective for 2005 is to compare the characteristics of the systems as observed at ground level (LTHE) and the classification already established using the satellite data at CNRM (WP4.3).
A climatology of events has been established at CNRM using the ISIS tracking algorithm from the Meteosat IR imagery. A catalogue and a climatology of the events which have touched the Oueme mesoscale site will be provided to LTHE.
LTHE will compare/validate the speed and direction derived from the composite hyetogram method over the guage network. The work will start with the year 2003.
The correlation between the characteristics observed at the ground over the Oueme site (rainfall amount, intensities, spatial and temporal structure and variability...) and those derived from the satellite tracking (speed, overall duration, spatial extension...) will be analysed.
Comparisons will be made with similar results for the Sahelian region.

Idealized WAM Modelling (CNRM)

- Using the gridnesting technique offered by Méso-NH, high-resolution runs will be performed with the 2D WAM model in order to explicitly resolve the convection. This will allow the study of the impact of explicitly sumulated convection (as compared to parameterization) on the whole WAM system and on its diurnal cycle.
- 2D-3D: The wall type lateral boundaries used in the 2D WAM model will be replaced by a relaxation towards the mean state simulated at mid latitudes by the 3D WAM model. It will allow a comparison of the two approaches in terms of: diurnal cycle, link between waves and convection, precipitation patterns and intensity.

Deliverables

- Improved version of the 2D WAM model
- First version of the 3D “aqua-terra-planet” configuration of ARPEGE-Climat for the WAM.
- First version of the database of CRM simulations.

- Catalogue and classification of the precipitating systems seen at ground level with a dense network of rain gages and as detected by the tracking algorithm from satellite IR imagery.

2.1.4 Anvils and non-precipitating clouds

Context

Deep convection is the ultimate source of tropical upper tropospheric extended clouds, i.e. tropical anvils (Webster and Stephens, 1980). The anvil lifetime, typically 6-12 hours (Ackerman et al, 1988; Leary and Houze, 1980), exceeds the duration of deep convection by many hours (Houze, 1989). Far from the active centre of the convective core the anvil structure becomes optically thinner but still has significant radiative and chemical impacts. The microphysics of crystals in this type of clouds is an important parameter impacting radiation budget, the amount of water stored in ice phase within the troposphere and chemical concentrations for soluble species and species that adsorb onto ice.

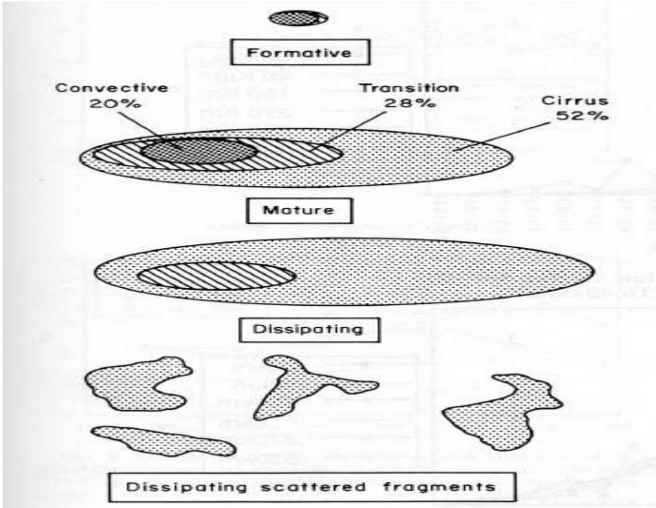

FIG. 5. Schematic cloud structure in an average tropical convective system in its formative, mature, and dissipating stages, illustrating terminology used in text.

Machado and Rossow (1993) used ISCCP data to examine the properties of tropical convective cloud systems observed in the whole tropics (between 25°S to 25°N). In each cluster, they separated deep convective clouds and the surrounding cloud cluster. They then divided the remaining cluster into "transition anvil cloud" (optical depth between 9 and 23) and "cirrus anvil cloud" (optical depth less than 9). Figure 1 (from Machado and Rossow) is a schematic of the life cycle of a convective system that is consistent with their results and previous studies of convective systems (Leary and Houze 1980, Fu et al. 1990). During the formative stage (~1% of the observed systems), convective cloud largely dominates the system. During the mature stage (~75% of the observed systems), they found that the average tropical convective system consists of 20 percent deep convective clouds, 28 percent transition anvil cloud, and 52 percent cirrus anvil cloud. During the dissipating stages (~24% of the observed systems), first the deep convective clouds disappear, then the transition anvil clouds, leaving only scattered fragments of cirrus anvil clouds. The occurrence frequency of the scattered fragments of cirrus anvil clouds has not been determined because they are in many cases undetectable from ISCCP data. They can be observed decoupled from the convective cores, as they maintain after the convection decay or due to reactivation process.

The locale radiative effects of these cloud components have been investigated. It is shown that the meso-scale clouds (transition + cirrus anvils) reinforces the diabatic heating of the atmosphere by convection and may help sustain these systems at night. The evaluation of radiative forcing shows the dominant role of anvils in determining the diabatic heating (Houze 1982), which itself drives the atmospheric circulation at regional and global scales. For instance Slingo and Slingo (1988) showed that tropical anvils not only warms the tropical upper troposphere, but also accelerates the subtropical jets.

Leary and Houze (1980) and Gamache and Houze (1983) estimated the water budget components of tropical convective systems: they found that roughly 60-75% of anvil condensate was detrained from deep convective updrafts. The remainder, roughly 25-40% of anvil mass, is generated by circulations outside the deep convective core i.e. in the anvil itself. Roughly 40% of Mesoscale Convective Systems (MCSs) precipitation comes from the stratiform region (Zender and Kiehl, 1997). The quantitative estimate of precipitation from the convective part and stratiform anvil of MCSs at mesoscale from dual-polarization radars and at global scale from spaceborne active and passive sensors is a key issue to several objectives of AMMA. Although the liquid phase of MCSs is now well understood, a more accurate estimate of precipitation at mesoscale and global scale still requires a thorough documentation of the ice microphysics at different scales.

During the COPT 81 experiment devoted to the dynamics of squall lines, no effort was devoted to the microphysics. The ground-based radar will be able to provide us with a description of the dynamics and the thermodynamics of the meso-scale structure of the observed systems. New polarimetric capabilities from Ronsard will also allow to build a three-dimensional field of particle types. This will give us a quite complete set of observation to understand the relationship between the MCS and its ice microphysics. In return, this ice microphysics is known to have a critical feedback impact on the system structure and life cycle.

If ground based polarimetric radar are a unique tool to describe the meso- to small-scale of the monsoon rain system, satellites allow to document their meso- to large-scale. If infrared observation can provide reliable monthly rain estimates, only passive microwave radiometers can give access to instantaneous rainfall. These instruments are nevertheless affected by a strong drawback: above continental surfaces, only the signal arising from ice scattering can be used. Hence, a good understanding of the ice phase topology within the rain system is critical to improve any retrieval of surface rain from satellite data. This requires to document the processes taking place in the stratiform anvil to explain both the vertical and horizontal habits of ice phase, understand the processes of condensation and evaporation, the transports and sedimentation of the main species according to their characteristics in terms of density and size.

The mesoscale nature of these anvil features has hindered their representation in most general circulation models (GCMs) moist convection schemes (Donner, 1993). For large scale circulation model issues, spatio-temporal scale mismatch between convective and stratiform processes and GCM resolution makes anvil parameterization difficult. GCMs currently employ two common methods to represent these processes. The first one diagnoses anvil clouds from column relative humidity, while the second one prognoses anvil clouds by assuming an anvil detrainment efficiency which acts on the convective mass flux predicted by the moist convection scheme. The first method shows some difficulty to represent the radiative influence of detached anvils. The second one does not explicitly account for the anvil mass formed by secondary circulations outside the deep convective core (Donner, 1993).

Cloud Resolving Models (CRMs) have been extensively developed and used during the last twenty years to study deep convection. Such studies have mainly focused on fast moving squall lines organised perpendicular to a moderate to strong wind shear (Tao and Simpson 1989, Caniaux et al. 1994), because these cloud systems exhibit a relatively well defined spatial structure. A decomposition of their total impact has highlighted the significant contribution of both the convective and stratiform parts of squall lines, in general in good agreement with observations (Johnson 1984, Chong and Hauser 1990). Nevertheless these studies only consider the mature quasi-permanent stage of such systems. The initial and dissipating stages are not simulated and analysed, whereas their impact at larger scales cannot be neglected.

The anvil cloud properties are strongly variable in space and time, and this is the main reason why the impact of such clouds on climate and the global circulation is still so poorly known despite some important effort already done for studying mid-latitude ice clouds. Indeed, within the last fifteen years almost 10 intensive field experiments have been carried out to document mid-latitude ice clouds in USA and Europe, and very few in the tropics (CEPEX, SUCCESS, CRYSTAL-FACE) because of technical difficulties to reach high altitude clouds at those latitudes.

2.1.4a 5 year plan

Coordinator: V. Giraud
Laboratories: CETP, LMD, LaMP, SA, LOA, ELICO

Objectives

Past studies on tropical MCS anvils and their impact on large scale clearly highlights the impact that these anvils most likely have on the African monsoon climatic system (see the above scientific motivations). The convective anvils, through their modification of the atmospheric dynamics on a large area is expected to play a significant role of modulation of some of the monsoon components (e.g., modulation of the subtropical jet, warming of the upper troposphere, modification of the radiative budget, dynamical feedbacks with the convective part of the squall lines, moistening of the environment of the convective anvils, modification of the precipitation efficiency…). The magnitude of this modulation of African monsoon components by the tropical anvils is completely unknown. Its quantification is a major objective of the present project.

In order to address these broad scientific objectives, a documentation of the internal structure of the tropical anvils (macrophysical, microphysical and dynamical properties) has to be achieved on several cases of observations. Progress in remote sensing measurements (especially active) and in algorithms make now this documentation realizable with the deployment of adequate simultaneous ground-based and airborne instrumentations.

The results of these subWP will impact other WPs of AMMA :

- MCS anvils impact monsoon circulation by their interaction with radiation. It is a key issue for WP 1.1 objectives.
- MCS anvils store water in the upper troposphere. This water may be redistributed far from the convective clouds. Large amounts of precipitating hydrometeors are also generated through microphysical processes at mid-troposphere. Finally anvil clouds modify the radiative budget, which modifies in turn the surface fluxes that govern the reevaporation of precipitation that reaches the ground (WP 1.2 objectives).
- MCS anvils may impact soluble chemical species and chemical species that adsorb onto ice (WP 2.4)
- Ice microphysics parametrization will be used by WP4.3 for deriving rain products from satellite microwave data (SSMI, AMSR, ...).
- MCS anvils may directly interact with other process that are studied in this WP (Jets and waves)

Work content

It is proposed to deploy a specific observation strategy benefiting from satellite observations planned at the horizon of 2005 (active and passive remote sensing, vertical sounding …) and perform closure analyses on water and radiation budgets through a comprehensive observation to modelling approach.

The proposed strategy relies on an upscaling of the MCS anvil properties from the in-situ documentation inside the anvil to the documentation of the cloud properties at the scale of the West-African monsoon system. Remote sensing measurements from ground-based (ARM Mobile Facility, and radar/lidar/radiometer set of observations with for instance Ronsard, Xport and bistatic antennas), airborne (RALI, IR radiometers) and satellite (A-Train: CALIPSO/CloudSat/Aqua, DMSP, and may be TRMM) platforms are new tools which will help us understand how anvils impact regional and global radiation and water budget.

From ground based active instruments that will provide a mesoscale description of the dynamics and thermodynamics of the system with some complement on microphysics of the precipitation and the airborne active instruments (cloud radar and lidar) that will allow a 3D documentation of the vertical stratification of the cloud properties for a limited amount of cases, we should be able to document a rather complete water and energy budget. The ground-based observations will provide statistically-representative documentation of this vertical stratification of anvil properties at high temporal resolution and on a longer time scale than the airborne observations. The spaceborne instrumentation will then be used to extrapolate the cloud properties from local scale / long time series (ground-based) and mesoscale / case studies (airborne) to regional (West-Africa) and global scales. The simultaneous system documentation by ground-based and airborne facilities will allow us to assess the representativeness of the 3D airborne representation of a limited number of cases within the climatology that can be built from the ground observations. Conversely, the airborne documentation will serve as a validation for the space-time conversion of ground-based observations. Furthermore, the set of "rain" radars will give a description of the dynamics within the precipitating part of the anvil that will allow to make the connection with thermodynamics and microphysics.

These ground-based and airborne documentations will be evaluated using in-situ microphysical sensors onboard the same aircraft. Then, the spaceborne retrievals of the ice species properties from the active and passive sensors will be validated using the ground-based facility on a statistical basis. However, these spaceborne active measurements alone are not sufficient to work at the scale of the African monsoon system. The passive remote sensing measurements from space (e.g. Aqua/MODIS, Aqua/AIRS, Aqua/AMSR-E, DMSP/SSMI, TRMM/TMI...) benefit from a much larger swath but are integrated measurements in the vertical. The clue here is therefore to constrain the retrieval methods from passive instruments with the active measurements during AMMA (RALI/ ARM Mobile Facility, Ronsard, Xport, Bistatic antennas), and then to extrapolate the active remote sensing documentation of the cloud properties to the swath of the passive instruments. Once constrained during the AMMA SOP the satellite products could be exploited for other monsoon seasons the A-Train and other satellites will document. The second way to explore for accessing a sufficient coverage of the African Monsoon system is to use the ground-based / airborne / spaceborne radar, microwave and lidar measurements as constraints and/or elements of validation to mesoscale and regional scale modelling. Then, once the model parameterisations and satellite retrievals are satisfactorily validated or tuned, models and satellite data can be used to access the cloud properties for a longer period and therefore to analyse the impact of the life cycle of the anvils on the African Monsoon system.

A single aircraft must be deployed in the field during AMMA SOP (Special Observing Period) to perform this upscaling strategy. This aircraft should be equipped both with RALI and a set of in-situ microphysical sensors. Different flight plans are proposed in WP4.2.1.

The flight strategy need to include ground-based site overpasses. These flights must also be coordinated with overpasses of the A-train (CALIPSO/CloudSat/Aqua) or passive and active precipitation instruments (TRMM/PR and TMI, DMSP/SSMI) in order to compare the physical products deduced from the different satellite sensor combinations (CloudSat/CALIPSO, Aqua, PARASOL) with in-situ and active ground-based and airborne measurements. At the same time, different models (from spectral microphysics model, such as EXMIX developed at LaMP, to bulk microphysical parameterizations used in high resolution meso-scale models such as MESO-NH or RAMS) will be used to reproduce the observed anvils. These simulations will also be compared to the high-resolution observations performed during the field experiment and to the satellite products. The comparison with satellite observations can be extended to the life cycle of the anvils thanks to the repetitive nature of these measurements. Once the simulations match the observations, they can be used to (1) build up budgets at the different steps of the life cycle of these anvils, (2) investigate the impact of anvils on the atmosphere stability and atmospheric component redistribution, and (3) simulate chemical species evolution using a coupling chemical model. An other interest is to use the diversity of the models (bin to bulk microphysics scheme) to derived physical parameterisations suitable for GCMs. We propose to test the impact of parameterisations in a simplified dynamical model (cylindrical model) developed at Lamp. Simulations with the meso-scale model may also serve to establish a statistical description of variability on the GCM's sub-grid scale. We will use this possibility to evaluate an existing GCM parameterization for the sub-grid scale variability of total water content [Tompkins, JAS 2002] and to investigate the possible introduction of an additional parameterization for sub-grid scale variability of the temperature. Evaluation using measurements of satellites and ground-based remote sensing data will enable us to investigate impacts of new model developments and to improve the representation of the high-level clouds. The statistical properties of the cloud parameters derived from the 1-year ground-based observations will also serve as a constrain dataset for climate model performances over West Africa.

Foreseen deliverables

- Documentation of the internal structure of the tropical anvils and their evolution:
    - Macrophysical properties : cloud overlap, horizontal and vertical heterogeneity
    - Microphysical properties : vertical distribution of particle habit, crystal size, terminal fall velocity, and crystal density.
    - Dynamical properties : 2D/3D wind, PV (Potential Vorticity), horizontal and vertical transports, variation of wind intensity within the different parts of the tropical anvil (convective, transition anvil, cirrus anvil)

- Documentation of physical processes involved in the anvil life cycle:
    - microphysical processes: aggregation, evaporation, condensation, sedimentation...
    - dynamical processes: transports, PV diagnostics
    - radiative processes: implication on the diurnal cycle and surface fluxes that govern the re-evaporation of precipitation.
- Documentation of the contribution of the tropical anvils to the water budget.

2.1.4.b 2004 Report on research conducted in year 2004

For the specific ice anvil part of this proposition, the majority of the researchers implied takes part and/or took part in a federator project support by the PATOM since 2002. This project: MONUMEEP-CIRRUS (Modélisations et Observation des NUages à Multi-Echelles pour l'Etude de Processus, applied to Cirrus clouds) brings together French researchers (13 full times in 2002, 20 in 2003 and 15 in 2004, distributed in 10 laboratories) implied in the observation (in situ and remote sensing from ground or space, active or passive) and/or the simulation (on various scales and resolutions) of the cirri. It was born from the will to join together complementary competences and to support exchanges and interactions in the objective to include/understand and parameterize microphysical, radiative and dynamic processes, and their interactions, which govern the life cycle (from formation to dissipation) of the cirri. A part of the participants in this project are invested now in the study of the anvils caused by the development of MCSs. Even if the formation and the microphysical properties of these clouds are relatively different from those of the cirri hitherto studied within the framework of MONUMEEP, similar tools and models can be used within the framework of AMMA.

For the part more specifically related to ice phase precipitations, works are complementary to the activities supported by PATOM. They concern the restitution of the profiles of release of latent heat in the tropical cyclones by satellites. Indeed in oceanic or continental precipitant tropical systems, feedbacks between ice phase processes and the system life cycle are fundamental and yet poorly documented. Experience gained with TRMM, it appears in addition that regional and temporal variability can be important. The project set up here, within the framework of AMMA, will make it possible to fill an important gap on the African continent.

2.1.4.c 1-year Plan

Objectives

The Pre-SOP activities will be to test on MCS anvil studies tools and methodologies that have been developed for cirrus and stratiform precipitation studies in the MONUMEEP group and others. This includes:

- Satellite retrievals to assess the variability of MCS anvil structures in West Africa

- Test the ability of a GCM to represent high-level ice clouds at regional scale over West Africa during the monsoon period.
- A key inter-comparison models on anvils simulations,
- Produce synthetic observations from cloud resolving model to help analysis of similar observations performed from different plate-forme (airborne, ground and space),
- Test the airborne configuration (microphysics and RALI) and flight plans to improve the SOP sampling strategy.

Work content

1. MCS satellite data analysis

Different satellite retrievals will be applied to document the different parts of the MCS. It is complementary with the climatology of West African MCSs carried out in WP4.3. The 2004 monsoon season will be study in priority. It is also planned to analyse other past seasons.

- (Seze and col.) The spatial structures of MSC will be analysed using the cloud type SEVIRI SAFNWC product, the cloud type classification obtained with the DCM method and the SEVIRI radiances. The high convective cloud systems will be divided in several parts. The fifteen-minute time resolution of the SEVIRI data will allow a good documentation of the life cycle of the various parts of the systems.
- (Viltard and col.) Systematic retrieval of precipitation from TRMM instruments during the 1998-2004 period will be done for each monsoon season. We will try to identify possible inter-annual to changes in terms of structure or meso-to-large scale properties.
- (Stubenrauch and col.) The TOVS Path-B dataset (Scott et al., 1999), processed at LMD, covers at present the time period from 1987 to 1995. It provides global atmospheric temperature and water vapor profiles as well as cloud and surface properties at a spatial resolution of 1° latitude x 1° longitude. The good spectral resolution in the IR of the TOVS instruments makes them a very useful tool to analyse cirrus clouds (Stubenrauch et al. 1999). Recently, this dataset (for NOAA10 observations from 1987 to 1991) has been extended for cirrus by the following variables: mean effective ice crystal diameter (Rädel et al., 2003) and ice water path (Stubenrauch et al., 2004), as well as the horizontal extent and upper tropospheric relative humidity. We propose first to determine the properties of the anvil cirrus and their convective parts as well as their interannual variability over the AMMA region and second to study correlations between microphysical cirrus properties and horizontal extent of the anvil as well as distance to the convective center distinguishing different dynamical situations. Horizontal extent and microphysical properties of these anvil cirrus could also be related to surrounding upper tropospheric relative humidity.
- From preceding points, cloud structures of typical MCSs will be derived. Mean cloud radiative forcing and water budgets of the different parts of the MCSs will then be evaluated.

2. Model to satellite comparisons

- (Stubenrauch, Seze, Quaas and col.) For the LMDZ GCM, a detailed bulk microphysical scheme has been developed, which includes both liquid and ice phase microphysical processes..
  With this new scheme, new and more realistic evaluation strategies become possible. We developed a method to evaluate the cloud scheme using microphysical data derived from the TIROS-N Operational Vertical Sounder (TOVS) measurements, as well as with a lidar in space, the Geoscience Laser Altimeter System (GLAS) instrument.
  In contrast to other instruments, the TOVS and GLAS measurements are reliable also over highly reflective land surfaces. Thus, these data are well suited to be used also for the region of interest here above North-West Africa. Focusing on this region, the GCM cloud microphysical scheme shall be evaluated, and a number of different parameters will be tested. We will adopt the "model-to-satellite" approach in the case of the lidar instrument to simulate

directly the backscatter signal and the depolarization ratio measured by the lidar.
Parameters to be investigated include the assumed width of the subgrid scale total water distribution [Le Treut and Li, 1991], the assumptions on particle shape, and assumptions in the parameterizations of precipitation formation.
With improvements of these representations in the GCM, the model will better be able to simulate cloud horizontal and vertical distributions, as well as rainfall patterns and extreme events.

- (Viltard and col.) Radiative transfer model simulation will be performed on the PR data to simulate TMI brightness temperatures similarly to Viltard et al (2001). This approach is equivalent to model-to-satellite but with real rain fields deduced from the radar and real brightness temperature measured simultaneously to validate the simulation. This is a very powerful tool to check that the ice microphysics parametrization is properly set in the radiative transfer model and thus in the mesoscale models.

3. Inter-comparison of CRM simulations (Giraud and col.)

To evaluate the sensitivity of the simulated anvil to model schemes, we propose to conduct some specific initial model comparisons based on well-known observed case (collaboration with Asencio in WP2.1.3). These are intended to identify the major causes of discrepancies between models, their sensitivities to physical parameters for the ice phase process parameterizations whose values are uncertain and to identify an appropriate framework for the future conduct of observationally based case studies during the SOP.

The life cycle of a Sahelian squall line observed during the HAPEX-Sahel experiment remains the favoured candidate due to the extensive analysis that has been already done at CNRM. Simulations will be performed with two models: Meso-nh and RAMS. For Meso-nh simulations, two different pristine ice microphysical schemes have to be evaluated. The first one is the based model version with some hypothesis on auto conversion threshold to transform non-precipitable ice into precipitable ice. The second one has been developed to be more representative of cirrus cloud process. Specific budget analysis will be developed to compare lifespan, horizontal extension and water and radiative budgets of the anvil part of the system.

4. Synthetic observations calculated from CRM (Thesis of Sophie Prud'homme)

Jointly to the development of an improved microphysical scheme for pristine ice in Meso-nh, radiative tools to simulate lidar profiles (backscattering and depolarization), cloud radar profiles (reflectivity and Doppler signal) and passive visible and infrared observations have been constructed (MONUMEEP and Thouron PhD Thesis). From the simulations of the life cycle of a Sahelian squall line described in previous point, we propose to calculate synthetic observations that should be obtained simultaneously from a fixed ground based station equipped with lidar and radar, from space ships (Calipso, Cloudsat and AQUA) and from Falcon 20 (RALI) along test flight plans. This observational configuration is closed to the one proposed to document anvil clouds during the SOP.

5. Demonstration-dedicated campaign (Gayet, Bouniol, Protat and col.)

- A field campaign is planned in September 2005 with the Falcon equipped with RALI and part (or full) in-situ instruments. This campaign carried out from Creil will perform flights over the SIRTA site to combine ground based remote observations and in situ data.

The financial support for this demonstration campaign will be requested from the CNES.

<u>Deliverables</u>

1. MCS satellite data analysis

- Estimation of anvil radiative forcing,
- Estimation of ice water stocked and transport in cloud anvils
- Give elements to chose what type of MCS have to be document in priority during the SOPs,

- Give elements to evaluate the representativeness of the few cases that will be intensively observed during the SOPs.

2. Model to satellite comparisons

- Investigated parameters include the assumed width of the subgrid scale total water distribution [Le Treut and Li, 1991], the assumptions on particle shape, and assumptions in the parameterizations of precipitation formation.
- Check that the ice microphysics parametrization is properly set in the radiative transfer model and thus in the mesoscale models.

3. Inter-comparison of CRM simulations

- Identify the major causes of discrepancies between cloud resolving models and their sensitivities to physical parameters for the ice phase process parameterizations whose values are uncertain,
- Recommend an appropriate framework for the future conduct of observationally based case studies during the SOP.

4. Synthetic observations calculated from CRM

From the set of synthetic observations and their sensibility to the model ice microphysical parameterizations, we planned to:

- Optimise flight plans to constrain accurately the model and highlight the complementarities of the different observations (this action will contribute to the WP4.2.1)
- Test retrieval algorithms to derive 3D structures of MCS by synergism of active and passive observations (this action will contribute to the WP4.3).

5. Demonstration-dedicated campaign

- Test and validate all the instrument chains on the new Falcon aircraft;
- Define flight plans in order to optimize the combination of remote sensing measurements and in situ measurements performed in a same cloud.

2.1.5 Dry intrusions and convective systems in the WAM

2.1.5.a 5 year Plan

Coordinator: R. Roca
Laboratories: CNRM, LA, LMD

Objectives

The amount of moisture in the free troposphere in the convective regions is one of the important factors that determines deep convective activity hence rainfall. In particular, the role of dry air in the troposphere appears complex and ambivalent: inhibiting convection in certain cases and favouring the occurrence of organized mesoscale convective systems in other cases. The main objective of this subWP is to assess to which extent dry air from the extra-tropics that reaches Sahel

modulates rainfall variability in the WAM and consequently to provide the forecast basis of such events.
By nature such a topic spans many scales, regions and processes. In the present WP, we perform physical process analysis at fine scale as well as dynamical process analysis. The integration of the scales at play is also performed in the present framework. Establishing the relative role of dry intrusions with respect to other forcing agents of African rainfall is performed in close collaboration with WP2.1.6 and WP1.1.3 for both synoptic and intra-seasonal scale. The fine scale analysis relies on the realistic CRM simulations (including tracers) constructed in WP2.1.3. Some of the large-scale aspects of the dynamics of intrusions are also further analyzed in WP1.1. Some of the tools are developed there as well as in WP1.1 and supporting satellite products are obtained from WP4.3. Outreach towards the chemistry WPs are mentioned but only concerns a marginal effort.

Work content

- **Dynamics and predictability of the polar jet instability yielding to dry air outbreaks.** theoritical and case study analysis to identify the mechanism of the blocking that favors dry and cold air outbreak from the midlatitudes towards the equator. Predictability studies. Relies on ECMWF analysis.
- **Climatology of the full Sahelian mid-tropospheric dry intrusions events and squall lines occurrence.** Build and analyse the climatology of the dry intrusions, couple it with the squall line climatology and analyse the link at the interannual scale. Relies on satellite derived MCS climatology.
- **Water vapor dynamics of the squall line / large scale environment interactions.** Pathway of dry air within the squall line at mesoscale and process of interaction of water vapor between the squall line and the large scale environment. Relies on mesoscale simulations and results from the SOP.
- **Role of dry intrusions in the rainfall variability in complement to the others identified forcings** intraseasonal modulation of the AEWs sensitivity of convection to dry intrusions depending on the other local forcing (land surface conditions, SAL and Harmathan winds). Analysis of the SOP cases and the climatology.

Foreseen deliverables

- Enhanced understanding of the rainfall forcing over the WAM.
- Predictability indices of the dry air structures over the region and forecast of dry intrusions

2.1.5.b Report on research conducted in year 2004

A number of activities have been undertaken within this WP during 2004. Some are very central to it some concerns some more general developments that are nevertheless reported here.
One of the main efforts has been to finalize the publication of the paper on the dry intrusions (Roca et al., 2004) that has been finally accepted this summer. Recall that this study showed that some very dry extratropical air (RH < 5%) reaches the near environment of a well formed squall line at 500 hPa (~ 5km). The case study extension to the whole 1992 season confirmed the strong correlation between squall line occurrence and dry air occurrence. A fine scale scenario (to be further tested in 2005) has been proposed to explain this correlation. It was proposed that theses intrusions could modulate the rainfall variability through its interaction with organized convection.
The other 2004 outreach is the dynamical analysis of the extra-tropical conditions that yield to dry air outbreak over the African mid-troposphere. This work (see Montoux, 2004) confirms the strong difference between the Hadley/Walker cells theory and the dry intrusions process. The instabilities of the polar jet have been identified as the key factor producing the favorable conditions for this extra-tropical air to be deflected towards the Equator by the dynamical barrier of subtropical jet. This confirmation opens up a forecast window through the forecast of these instabilities, which will be developed in 2005.

Two related although less central works have also been achieved during the year. First the feasibility of using the LMDz and its nudging options to simulate accurately the water vapor distribution in monsoon regions has been confirmed thanks to the work of Tombette (2004) in collaboration with the LMDz GCM team. This tool allows further investigation of the WV transport and then the depth and physics of the dry air intrusions in an Eulerian framework that completes the back trajectory technique already used in this WP. This tool will serve next year's effort to document the large scale vertical distribution of environmental air in Sahel. A second work concerns the analysis and use of the METEOSAT FTH dataset produced by LMD for the analysis of the key eastern Mediterranean region water vapor distribution and associated dynamics. This effort reveals the original mixing between tropical and extra-tropical air taking place in this subsidence area that yields the lowest moisture content of the whole tropical troposphere over this region (Brogniez et al., 2004). This supports importance of this region, as highlighted by the previous study on the large scale dynamics of the region, and extends it to the moisture distribution.

We expect the end of the year 2004 (till December) will see the finalization of the publication work proposed in 2004 concerning both the 1998 year case study and the dynamical origin of the outbreak analysis. Note that a number of things that were done within the 2.1 framework (mainly the code developments) are now exported to other WPs to gain in science integration capability and do not appear in the 2005 proposal.

2.1.5.c 1-year Plan

Objectives

In the next year, we will put our effort into the "dry intrusions forecast" milestone of the 5-year plan in support of SOP activities. We will try to provide an index-of-dry-intrusions forecast to support the AOC actions. We don't expect to be fully ready for the 2005 tests although are willing to participate to the exercice "à la volée". The fine scale analysis will start this year but it is not anticipated that it will be finished by the end of the 2005. We also aim to finish on-going work presented last year, actually 5 months ago.

Work content

While cruising towards such endeavour, we will focus our effort around two main objectives:

- The fine scale relationship between dry air and organized convection will be investigated with the help of the Meso-NH tracers capabilities. The 1992 case study will be a starting point that will allow us to characterize the pathways of air around and in the squall line and should allow us to highlight the relative role of the large scale environmental dry air ahead and/or behind the squall line in forming the evaporative layer. A by product of such analysis will be the more precise location of the altitude of the inflow of dry air (mid-troposphere and extra-tropical, low-to-mid troposphere and Sahelian origins). This question is also investigated at larger scale in WP1.1.3 where the phasing between the extra-tropical and Sahelian advections is analyzed at the intra-seasonal scale.
- Dynamical diagnostic study of extra years: 1998 and 2000 in order to achieve a deeper understanding of the process at play using the ECMWF reanalysis. Both Eulerian and Lagrangian techniques will be set up to characterize these two years and should favour interactions with others WPs. In refining the scenario for the dry air outbreaks, a predictability index and a criterion for characterizing both the polar jet instability, as well as the Rossby wave activity, will be assessed. Similar work will be performed on forecast rather than analysis to bracket the forecast lead we can expect for these large scale disturbances of the tropical African mid-tropospheric moisture.

Besides these new items, the actions already engaged concerning the production of the Sahelian dry intrusions climatology will be finalized. Another although smaller new aspect of the work concerns the link with the chemistry work package for which we propose a large scale dynamics support (dry intrusions might as well be dirty) as well as more concrete analysis in particular around the use of the Tamanrasset soundings of ozone and relative humidity acquired in LISA.

Deliverables

- Preliminary assessment of some forecast indices of the large scale dry intrusions structures
- Climatology of Sahelian dry intrusions
- Finalized conceptual model of the mid-latitudes dry air out-breaks.
- Contribution to the AOC 2005 test

2.1.6 Jets structures, waves and intraseasonal variability

2.1.6.a 5 year Plan

Coordinator: N. Hall
Laboratories: CNRM, LTHE, LODYC

Objectives

In this sub work package we aim to characterise the structures and mechanisms associated with the WAM including the large scale jet flow, the local Hadley cell, waves and instabilities, the monsoon onset and the interaction with associated precipitation systems, both in terms of their control by the larger scale dynamical environment and their feedback on the development of that environment over the seasonal cycle. A mixed approach of observational analysis and modelling will be used. The observational effort will be centred on characterisation and monitoring of the WAM, and in particular the analysis of SOP and EOP data as it becomes available. The work done on this theme has some common ground with the work done in WP1.1, but here we will put the emphasis on physical mechanisms, with a view to reinforcing the link between observations and some mechanistic modelling of the WAM. The modelling effort will draw on a variety of modelling tools, each of which is focussed either on a particular mechanism or a particular geometry. These will range from idealised models with either prescribed basic states or limited geometry, to fully explicit convection resolving models. A two way interaction between the results of these modelling activities and the observations is envisaged, whereby the observations are used to validate the models and inspire further idealised experimentation, but equally the results of models may be used to guide observational strategy.
This group also has a wider role as an assembly point for theory and mechanisms, and as a conduit for increased international visibility of the french AMMA project, including several international collaborations which are already underway.

Work content

Due to the degree of overlap between some of the subjects treated in this sub WP and those treated in WP1.1 (especially 1.1.3) some coordination will be required between the two. Common meetings and sharing of tasks will easily be facilitated as several people are working in both groups. The work content for 2.1.6 can be divided into three categories.

Characterisation of the jet, the ITCZ and the ITF, and its intraseasonal variability
Here we draw on the SOP data, using analysis techniques already defined by the analysis of the WAM in 1998 to analyse and document the following phenomena:

- Seasonal evolution (including the rapid monsoon onset)
- Intraseasonal variability (with particular attention to the climatology if MCSs)
- Using the methods of Sultan and Janicot (2003) and Roca et al (2003) monsoon monitoring will take place for direct interaction with the planning of SOP and EOP observations (Sultan et al).
- Short term prediction techniques will be used to anticipate the arrival of active/break sequences in the monsoon.

Mechanisms for the maintenance of the jets and meridional circulations.
The basic mechanisms of the WAM will be elucidated here using a hierarchy of models.

2D simulations of the WAM will be carried out using an idealised model. This model will be used specifically for:

- testing the impact of convection and PBL parameterisations (close link with WP4.1.3).

- analysis of the interaction between the heat low and the Hadley cell/ITCZ/ITF, especially during the onset.
- coupling with continental surface, also impact of aerosols (one way study).
- coupling with ocean (collaboration with WP2.2 H. Giordani).

3D simulations will also be carried out using the ARPEGE model in aqua-terra-planet configuration corresponding to the WAM. This model will be a useful test bed for isolating the influence of local phenomena from external influences. Specifically we aim to explore

- The relationship between the local ITCZ and the jet structure
- The influence of idealised land/ocean configurations corresponding to a zonal strip of continent (5°N to~35°N).
- Role of waves on the mean meridional structure, in particular through meridional transport of heat, momentum and humidity, as compared with the 2D idealized WAM model

Waves and instabilities

African easterly waves (AEWs) are a much studied phenomenon, but their link with the large scale flow on the one hand and the variability of precipitation on the other hand in still not fully understood. In this sub WP we will focus on observed properties and dynamics of AEWs using composite data analysis and idealised dynamical modelling.

- Composite studies of filtered OLR will give information on the link with convection. This work will also be related to the tracking analysis of MCS (WP4.3) and scaling properties of the WAM (WP1.2.4).
- A primitive equation model has been developed which is used to isolate dynamical modes associated with 3-d climatological basic states of the WAM. Fundamental work on the stability of these modes, their relationship with the large scale flow and their excitation by transient forcing is ongoing.
- The above mentioned 3-d ARPEGE aqua-terra-planet model will also be analysed for its wave activity. This work will complement the idealised modal analysis taking the position of intermediate complexity in a model hierarchy between academic studies and full GCM analysis. The link between theory and observations will thus be clarified.
- Link between waves and convection for the specific configuration of the WAM, characterized by opposite meridional gradients of temperature and moisture. Link with the convection scheme studied in collaboration with WP4.1.3

Foreseen deliverables

- A spectrum of idealized models to study the basic physics and interaction within the WAM system (*inputs to WP4.1.3 and WP1.1)*.
- A mechanistic analysis of SOP and EOP data with relevance to jet structures and regional scale circulation features.
- A short term prediction system for intreaseasonal active/break variations in the WAM.
- A thorough documentation of the seasonal cycle for the SOP/EOP period backed up by modelling analysis of the same period.
- A model based deconstruction of the essential mechanistic elements of the WAM.

2.1.6.b 2004 Activity report

CNRM/IPSL

The joint effort of LODYC, LMD and CNRM, provided an analysis of the variability during the 1998 season by mixing different sources of data: NCEP and ECMWF reanalysis, WV and IR Meteosat channels, trajectories to retrieve humidity fields, MCS tracking, Meteosat low level winds provided by LMD (Tzantai and Desalmand), and by considering different points of view and methods: composite analysis, dry intrusions analysis, crossing between waves, intrusions, flow in the monsoon layer and the convective activity and organisation. In all approaches a strong intraseasonal variability is found in the range of 10-15 days periods. Similar analyses will be applied during the EOP. The current effort is to complete a publication (Sultan el al.) by the end of the year.

An idealized 2D model of West African Monsoon (WAM) has been developed over the last few years to study the interactions between the surface processes, the convection and the large-scale flow associated with the Hadley circulation. It consists of a vertical meridional slab from 30°S to 40°N. Starting from a homogeneous mean tropical atmosphere and simply prescribing the oceanic and continental surface conditions a typical WAM circulation is obtained after ~10 days of simulations. The main progress and results for the 2004-year are:

- Improvement of the realism of the model by including a parameterization of meridional fluxes of heat and momentum associated with the baroclinic and batropic waves, and of the Mediterranean sea (Peyrillé et al 2004).
- The first simulation of a full seasonal cycle of the WAM including realistic features such as the monsoon onset (Faroux 2004)

LTHE

A primitive equation model has been developed for dynamical easterly wave studies. It works in conjunction with an observed three dimensional time-mean basic state to deduce modal structures that can respond to the jet entrance/exit structure in longitude. The resulting 3-d modes are compared with observed time filtered composites. An new theory for the generation of Easterly waves has been explored in which, with a reasonable amount of surface friction, the system is stable. The waves consist of linear decaying modes, which are initiated by some external event, such as convective heating. An analysis of the modal structure shows remarkable agreement with observed composites, including upstream baroclinic/downstream barotropic structure. Two publications are near to completion in collaboration with George Kiladis (NOAA) and Chris Thorncroft (SUNY).

IPSL

Statistical analyses have been performed to document intraseasonal variability of convection over West Africa. Two main independent modes of convection are highlighted. One is associated with a westward propagative signal of the convection over the Sahel and the other is characterized by a stationary uniform modulation of convection over the whole West African domain. The dominant periodicity of these two modes is around 15 days. This study has just been published in Geophys. Res. Letters.

Work has also been done on the interaction of dry intrusions with the Hadley/Walker cell as reported in 2.1.5, and which could have implications for modelling activities proposed in this section. A new tool for water vapour transport analysis has also been developed in which the LMDz GCM is constrained by reanalysis data.

2.1.6.c 1-year Plan

Objectives

In the one year time frame the objectives are principally the preparation for the SOP, including the refinement of analysis procedures and producing more detailed recommendations for the field campaigns, the publication of work already completed and the transfer of techniques from historical data to projected field campaign data.

Work content

The work planned over the next year is to a large extent a continuation of work done in 2004 across several groups, finalising publications and moving forward to joint efforts. The work already achieved is highly complimentary and the differing strengths of the groups involved will be brought together over the next year into a more closely coordinated collaboration.

CNRM/IPSL

Monitoring of intraseasonal variability

The first task is to finalize the publication (Sultan el al.) on the intraseasonal variability in 1998.On this basis we will propose a set of diagnostics to analyse the monitoring of intraseasonal variability during the EOP and SOP. Such tools should be developed and made available to the AOC during the SOP. It will be necessary to collaborate with WP1.1 to interact with the group in charge of the AOC implementation. This effort should involve the 6 subgroups of WP2.1 (PBL, Heat Low, Convection, non precipitating clouds and intrusions, jets and waves) in order to characterise and diagnose the different structures and atmospheric components of the WAM. This material will then be synthesized under subWP2.1.6 to provide an overview of the intraseasonal variability.

Analysis of scale interactions occurring in gridnesting simulations of WAM case studies

A spectral approach is currently being developed (Luijing, Guichard, Yano) to analyse the scale interactions simulated by way of two-way interactive gridnesting, available with Méso-NH. Simulations of WAM case studies (Hapex-Sahel, JET2000), will be used in 2005 to study these interactions between the convection, its mesoscale organisation and the jets and waves surrounding the studied weather system.

WAP 2D Model (Thesis of Ph. Peyrillé)

Following the development of the WAP 2D model, it is now proposed to use it to study the basic behaviour of the WAM and some involved interactions between scales and processes. The following actions which concern several subgroups of WP2.1, are planed for 2005:

- Finish 2 publications in preparation for the validation the 2D WAM model and the presentation some salient results concerning the diurnal cycle, the impact of the SST, the role played by aerosols and ventilation on the balance of the WAM through budget analysis.
- Detailed analysis of the WAM seasonal cycle for a third publication.

This tool will be widely used in WP2.1.6 to study the behaviour of the WAM and its variability. It will also be used in WP2.1.3 using the gridnesting technique offered by Méso-NH to allow a comparison of explicit versus parameterised convection and the effect on the WAM system and its diurnal cycle. In parallel it will be also used in WP4.1.3 to study the interactions between the different parameterizations involved in WAM models and to improve them.

In strong collaboration with WP2.2 (H. Giordani) a simple model (bulk and 1D) of the oceanic mixed layer will be implemented in the 2D WAM model to study the possible role played by this coupling during the WAM onset.

This tool will also be used to develop conceptual models which will help to define the optimal observation strategy during the SOP to test these ideas.

WAP3D Model(Thesis of B. Diviné)

The above approach is strongly limited by the 2D assumption. To overcome it we have recently started a new work to develop an idealized “aqua-terra planet” using of the ARPEGE-Climat model. It corresponds to an extension to the third direction (zonal) of the idealized 2D WAM model. It will allow us to study the basic physics of the WAM by removing all the complexity of our planet, in particular the interactions with the other continents (such Indian Monsoon). It will be ideal to analyse interactions between jets, waves and convection. For 2005 the main objectives will be:

- Develop the WAM “aqua-terra planet” configuration of ARPEGE-Climat.
- As a first step, compare the results with the 2D WAM model, after having modified the latter to have comparable on the north and south sides.
- Explore the potential of this tool to understand the WAM and its simulation by ARPEGE-Climat. This will consist of sensitivity experiments to detect key parameters, parameterizations and conditions (surface, aerosols…) for the WAM equilibrium and its

seasonal cycle. This it will also contribute to WP4.1.3 by helping in the assessment of the most useful schemes to simulate the whole WAM system, their strengths and weaknesses.

From this study it will be decided which crucial points will be further studied and the best methodology to be developed. Suitable diagnostics will be then implemented.

LTHE

Two publications on the dynamics of AEWs are currently in preparation and these must be seen to completion. The first is on composite studies and the second on modal structures. A third is envisaged on initiation of events, and work on this important subject will occupy most the time available to the PI (N. Hall) during 2005. Development work towards the inclusion of the representation of convection in the dynamical model will be an active area of discussion within the WP2.1 (not only WP2.1.6) for longer term plans including the comparison with more sophisticated model results and SOP/EOP data if appropriate.

IPSL

In the next year, in support of SOP activities, the main goal is to study the predicability of the 15-day modulation of convection. Short time lead forecasts will be provided to support the AOC actions using statistical analyses. The skill of this forecast will be computed on the 2000 to 2004 years in readiness for the 2005 AOC tests.

In preparation for diagnostics from the EOP and SOP, dynamical diagnostic studies of the years 1998 and 2000 will be carried out in order to achieve a deeper understanding of the process at play using the ECMWF reanalysis, as reported in section 2.1.5.

Deliverables

MOANA/CNRM

- An aqua-terra-planet configuration of the ARPEGE model corresponding to the WAM case, to study the basic physics and interactions within the WAM system.
- Two publications in AMS journals on the idealized 2D WAM model.
- A third publication on the simulation of the seasonal cycle.

LTHE

- Two publications in AMS journals on the dynamics of easterly waves.
- A third publication underway.

IPSL

- A short time lead prediction of 15-day fluctuations of convection.
- A publication on the forecast method and skill.
- A joint publication (MOANA/CNRM, LMD,LODYC) on the intraseasonal variability in 1998.

-2004 Publication related to WP2.1

Papers (submitted)

Impact of the assimilation of AERI temperature and moisture data on simulated precipitation: a case study F. Couvreux, T.M. Weckwerth, J.O. Pinto, submitted to J. Appl Meteorol.

Assessment of water vapour variability within a convective boundary layer over land using Large Eddy Simulations and IHOP observations F. Couvreux, F. Guichard, J.-L. Redelsperger, C. Flamant, V. Masson, C. Kiemle, J.-P. Lafore. To be submitted

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