DESCRIPTION MODELES UTILISES DANS WP 4.2.3

MAR - Regional Climate Model

Participation

- MAR is generally used for integrative studies in tropical and polar regions.
- In the frame of AMMA, MAR is validated for the simulation of the West African Monsoon (climatology and variability).
- Validation of a coupled architecture composed by a regional climate model (here MAR), a SVAT model and hydrologic models.
- Improvement of physical parametrizations of convection/clouds/boundary layer processes.

Atmosphere

- General: MAR is a regional climate model just initialized once and nudged on the sides for the remainder of the MAR. MAR is nudged in large scale by meteorological fields (ERA-15, ERA-40, LMDZ) [Marbaix et al., 2003]. MAR is a hydrostatic primitive equation model in which the vertical coordinate is normalized pressure.
- Dynamics: Grid point model based on primitive equations of meteorology.
- Physical parametrizations : The warm part of the cloud microphysics is based on a bulk representation associated with the work of Kessler [1969], Ntezimana [1994] and Gallée [1995]. The ice and snow part is described according to Lin et al. [1983], Levkov et al. [1992] and Cassano et al. [2001]. Detailed solar and infrared radiation schemes are taken respectively from Fouquart and Bonnel [1980], and Morcrette [1984] or Morcrette[2000]. MAR is adapted to tropical regions by including the convective adjustment scheme of Bechtold et al. [2001].

Chemistry and aerosols

- General: Generic chemistry model
- Aerosol: Terrigeneous aerosols (blown snow: validated; dust: must be validated)

Ocean

- General: forced SSTs (in time and space).

Land Surface Processes

- Atmospheric part of MAR is coupled to the Surface Vegetation Atmosphere Transfer model of De Ridder and Gallée [1998]. The SVAT contains one vegetation layer and 7 unevenly spaced soil layers, with a finer resolution near the surface.
- Soil hydrology: contained in the SVAT or treated by using a coupling architecture which permits the use of high resolution hydrological models adapted to the relevant processes of identified catchments.

Model configurations for AMMA :

- Pluriannual climatic simulations with forced SSTs and a regular grid with a 40km spatial resolution.
- Coupled simulations with high resolution of the surface over hydrological catchments (1 to 5km).

Key persons :

- Christophe Messager (christophe.messager@hmg.inpg.fr)
- Hubert Gallée (hubert.gallee@lgge.obs.ujf-grenoble.fr)

References :

- Gallée H, Moufouma-Okia W, Betcthold P, Brasseur O, Dupays I, Marbaix P, Messager C, Ramel R (2004) A high resolution simulation of a West African rainy season using a regional climate model. Journal of Geophysical Research. 109: D5.
- Messager C, Gallée H, Brasseur O (2004) Precipitation sensitivity to regional SST in a regional climate simulation during the West African monsoon for two dry years. Climate Dynamics. 22: 249-266.
- Marbaix P, Gallée H, Brasseur O, Van Ypersele JP (2003) Lateral boundary conditions in regional climate models : a detailed study of the relaxation procedure. Accepted for publication in Monthly Weather Review.
- Brasseur O, Tricot C, Ntezimana V, Gallée H, Schayes G (1998) Importance of the convective adjustment scheme in the simulation of the diurnal cycle of convective activity in Africa. Proceedings of the International Conference. "Tropical climatology, meteorology and hydrology" Demarée G., J. Alexandre and M. De Dapper (Eds), 299-312.
- De Ridder K, Gallée H (1998) Land Surface-induced regional climate change in Southern Israel. Journal of Applied Meteorology 37: 1470-1485.
- De Ridder K, Schayes G (1997) The IAGL land surface model. J. Appl. Meteorol., 36: 167-182.
- De Ridder K (1997) Land surface processes and the potential for convective precipitation. J. Geophys. Res. 102: 30085-30090.
- Gallée H (1995) Simulation of the Mesocyclonic Activity in the Ross Sea. Antarctica. Mon. Wea. Rev. 123: 2051-2069.
- Gallée H, Schayes G (1994) Development of a Three-Dimensional Meso Gamma Primitive Equations Model. Katabatic Winds Simulation in the area of Terra Nova Bay. Antarctica. Mon. Wea. Rev. 122: 671-685.

The Méso-NH Atmospheric Simulation System

Participation

- Used for process studies (WP2).
- Explicit simulations of convection cases observed during the SOP in order to study its interaction with the large scale dynamics (jets, waves, intrusions…), with the surface (WP2.1), its role in the processing of the ozone and aerosols (WP2.4).
- Study of the water cycle at fine scales with the support of the SOP observations (WP1.2).
- Use of the Méso-NH simulations in CRM (Cloud resolving Model) or eventually in LES (Large Eddy Simulation) modes to evaluate and improve the physical parameterizations convection/clouds/boundary layer processes (WP4.1.2), lightning, indirect effect of aerosols and cloud processing of aerosols (WP4.1.3).
- Idealized modelling in 2D of the West African Monsoon to study the scales interactions, the two-way coupling of the atmosphere with the continental surface and with the oceanic mixing layer in order to better understand the WAM system and its intraseasonal variability (WP2.1 and WP2.2).

Atmosphere

- **General :** Méso-NH is the non-hydrostatic anelastic mesoscale atmospheric model of the French research community (Lafore et al. 1998). It is intended to be applicable to all scales ranging from large (synoptic) scales to small (large eddy) scales and it is coupled with an on-line atmospheric chemistry module.
- **Dynamics :** Grid point limited area model. Choice of the cartesian coordinate system or of a conformal projection (Lambert, Polar Stereographic or Mercator). On the vertical, use of the Gal-Chen and Sommerville coordinate (1975). Positive advective schemes for scalars. Choice of different types of lateral boundaries conditions (open, periodic or wall), two-way interactive gridnesting.
- **Physical parameterizations :** A complete physical package to run at different resolutions including;
    - 1D or 3D turbulence scheme (Cuxart et al. 2000) based on diagnostic second-order moments and a turbulent kinetic energy prognostic equation,
    - a bulk scheme for the microphysics combining a three-class ice parameterization with a Kessler scheme for warm processes including a sub-grid condensation scheme,
    - a deep and shallow convection scheme (Bechtold et al 2001) adapted from Kain and Fritch,
    - The Morcrette (1989) and Fouquart (1980) radiation scheme of the ECMWF.
- **Initialization :** a complete procedure to initialize fields for idealized flows or for real cases from the ECMWF and ARPEGE analysis. Chemical components are initialized using data available from the CTM MOCAGE.
- **Diagnostics:** a complete set of diagnostic tools including;
    - In-line budget of all model prognostic variables and a set of post-processing facilities to compute budget of different derived variables.

- Eulerian passive tracers variables (Gheusi and J. Stein 2002) associated with a Lagrangian analysis tool of airflows.

- **Documentation :** http://www.aero.obs-mip.fr/mesonh/

Land Surface Processes

- The Interaction Soil-Biosphere-Atmosphere (ISBA) soil scheme of Noilhan and Planton (1989). Cf Belair et al. (1998) for further details.
- The Town Energy Balance (TEB) scheme (Masson et al. 2003).
- A complete procedure to initialize land surface parameters from physiographic data including the ECOCLIMAP high resolution database (Masson et al. 2003).

Chemistry and aerosols

The version used for AMMA treats gas phase chemistry, bulk cloud chemistry, tri-modal and spectral aerosol dynamics and chemistry.

- **Chemical processes**

The chemical processes are calculated using operator splitting manner. The choice of the chemical scheme is kept flexible. The chemistry model for AMMA will consider 37 chemical species using 17 photolytic reactions and 128 chemical reactions (ReLacs, Crassier et al., 1998). Several chemical solvers are presently available: SIS, LinSSA, Cranck-Nicholson, EXQSSA (QSSA with extrapolation), SVODE (Gear-type). Photodissociation rate are obtained on-line with a radiative transfer model (TUV). A parameterisation is used to correct the clear-sky photolysis rates for cloud cover. Dry deposition velocities are calculated interactively at each time step following the resistance-in-series approach [Wesely et al, 1989]

- **Gas and aerosols emissions**
    - Anthropogenic emissions for gases and aerosols (industry, fossil fuel, and industrial biofuel) representative of the year 1995 are based on the EDGAR v3.2 emission database.
    - Biomass burning emissions for CO are based on monthly fields from Duncan et al (2003). Emissions for species other than CO are derived from the emission factor ratios given by Andreae and Merlet (2001)
    - Soil emissions of NO are based on Yienger and Levy (1995) and natural emissions of volatile organic compounds are based on GEIA database.
    - Lightning-produced NOx: explicit lightning scheme for process level or parameterized scheme coupled with the convection scheme.
- **Aerosol size distribution and microphysical processes**
    - ORISAM is a size bin scheme with a flexible number of bins geometrically spaced. Typically, we use 12-20 size classes between 1 nm and a few micrometres.
    - ORILAM is a interactive lognormal scheme with three modes (for aitken, accumulation and dust mode).
    - The models treats the coagulation, condensation, absorption, nucleation, dry deposition and sedimentation processes.
- **Aerosols chemical composition**

  The aerosol model accounts both for inorganic (NO_3^-, SO_4^{2-}, NH_4^+) and organic species of primary or secondary origin. Secondary organic aerosols from biogenic and anthropogenic gas precursors are partitioned into gas and particulate phases through a temperature dependent partition coefficient.

- **Cloud processes**
    - A explicit simple cloud chemistry based on cloud liquid water content and grid point concentrations of gaseous species is included.
    - A implicit wet deposition scheme is coupled with the convection scheme.

Model configurations for AMMA :

- The Méso-NH atmospheric system is very open, so that a wide range of configurations is possible in term of resolution, of number of nested models, of combination of parameterizations…
- For real cases in AMMA, a typical configuration will be 2 or 3 nested models at 10, 5 and 2.5 km resolution covering the West Africa down to the convective system scale respectively. The outer domain is forced by ECMWF, ARPEGE or MOCAGE analysis. Such simulations (see Diongue et al. 2002) can be run several days during the SOP.
- Idealized 2D simulations of the WAM in a meridian vertical slab from 30°S to 40°N at ~60 km resolution over the entire cycle of the monsoon. High resolution runs (2-3 km) to detail the convective processes and their impact on the monsoon system and on the diurnal cycle.
- Semi-idealized 3D simulations of a convective system using observed radiosoundings for the meteorological forcings, the explicit lightning scheme and aqueous chemistry. High resolution runs to detail the convective processes and their impact of LNOx and scavenging on the ozone budget.

Key persons :

- Jean Philippe Lafore (jean-philippe.lafore@meteo.fr)
- Céline Mari (marc@aero.obs-mip.fr)

References :

- Bechtold, P., E. Bazile, F. Guichard, P. Mascart, and E. Richard, A mass-flux convection scheme for regional and global models, *Quart. J. Roy. Meteor. Soc.*, *127*, 869-886, 2001.
- Bélair, S., P. Lacarrère, J. Noilhan, V. Masson, and J. Stein, High-resolution simulation of surface and turbulent fluxes during HAPEX-MOBILHY, *Mon. Weather Rev.*, *126*, 2234-2253, 1998.
- Cuxart, J., P. Bougeault, and J.-L. Redelsperger, A turbulence scheme allowing for mesoscale and large-eddy simulations, *Quart. J. Roy. Meteor. Soc.*, *126*, 1-30, 2000a.
- Diongue, A., J.-P. Lafore, J.-L. Redelsperger, and R. Roca, Numerical study of a Sahelian synoptic weather system: Initiation and mature stages of convection and its interactions with the large-scale dynamics, *Quart. J. Roy. Meteor. Soc.*, *128*, 1899-1927, 2002.
- Morcrette, J-J. Description of the radiation scheme in the ECMWF model. ECMWF Technical Memorandum 165, 1989.
- Gheusi, F., and J. Stein, Lagrangian description of airflows using Eulerian passive tracers, *Quart. J. Roy. Meteor. Soc.*, *128*, 337-360, 2002.

- Lafore, J.-P., J. Stein, N. Asencio, P. Bougeault, V. Ducrocq, J. Duron, C. Fischer, P. Héreil, P. Mascart, V. Masson, J.-P. Pinty, J.-L. Redelsperger, E. Richard, and J. Vilà-Guerau de Arellano, The Meso-NH Atmospheric Simulation System. Part I: adiabatic formulation and control simulations. Scientific objectives and experimental design, *Ann. Geophys.*, *16*, 90-109, 1998.
- Mari C, Jacob DJ, Bechtold P, Transport and scavenging of soluble gases in a deep convective cloud, *J. Geophys Res.*, *105* (D17): 22255-22267 SEP 16 2000.
- Masson, V., J.-L. Champeaux, C. Chauvin, C. Meriguet, and R. Lacaze, A global database of land surface parameters at 1 km resolution for use in meteorological and climate models, *J. Climate*, *16*, 1261-1282, 2003.
- Masson, V., C. S. B. Grimmond, and T. R. Oke, Evaluation of the Town Energy Balance (TEB) scheme with direct measurements from dry districts in two cities, *J. Appl. Meteorol.*, *41*, 1011-1026, 2002.
- Stein, J., E. Richard, J.-P. Lafore, J.-P. Pinty, N. Asencio, and S. Cosma, High-resolution non-hydrostatic simulations of flash-flood episodes with grid-nesting and ice-phase parameterization, *Meteorol. Atmos. Phys.*, *72*, 203-221, 2000.
- Suhre K, Crassier V, Mari C, Rosset R, Johnson DW, Osborne S, Wood R, Andreae MO, Bandy B, Bates TS, Businger S, Gerbig C, Raes F, Rudolph J, Chemistry and aerosols in the marine boundary layer: 1-D modelling of the three ACE-2 Lagrangian experiments, *Atm. Env*., 34 (29-30): 5079-5094, 2000
- Tulet P, Suhre K, Mari C, Solmon F, Rosset R, Mixing of boundary layer and upper tropospheric ozone during a deep convective event over Western Europe, *Atm. Env*. 36 (28): 4491-4501 SEP 2002

Météo-France « ARPEGE » climate model

Participation

- WP1.1 / Validation of the ARPEGE-Climat AGCM and the ARPEGE-OPA AOGCM over West Africa.
- WP1.1 / Link between African Easterly Waves and cyclogenesis in the tropical Atlantic.
- WP1.1 / Influence of SST and land surface on the interannual variability of the West African monsoon.
- WP1.1 / Seasonal forecasting of West African monsoon rainfall.
- WP4.1.3 / Improvement of physical parametrizations: change the diagnostic into prognostic versions for the microphysics and the boundary layer schemes ; test new versions for cloud and convection schemes (shallow + deep).

Atmosphere

- General: ARPEGE-Climate is a General Circulation Model based on the NWP version, but with several modifications in the physic package (Courtier et al, 1991 ; Déqué et al., 1994 ; Gibelin and Déqué, 2003). There is an optional capability of zooming, by using stretched grid and tilted pole versions, to arrive at a global variable resolution model (Courtier and Geleyn, 1988 ; Déqué and Piedelievre, 1995 ; Déqué et al. 1998 ; Gibelin and Déqué, 2003). Arpege uses a hybrid sigma-p coordinate on the vertical (pure sigma near the ground, pure p close to the top), from Simmons and Burridge (1981). There is an optional capability in nudging the model toward meteorological analysis. The version 3 has been delivered in 1999 and the version 4 in 2003.
- Dynamics: It is a spectral global model, based on triangular truncation and with primitive equations (Courtier et al, 1991). A semi-implicit, two time-level semi-lagrangian 3D advection scheme is used (almost the same as in Arpege-NWP and in close connection with the IFS counterpart).
- Physical parametrizations: The radiation scheme is from Fouquart and Morcrette (1989, 1990), including the basic aerosols and the variable sulphate aerosol. The turbulent diffusion in the Boundary layer is from Ricard and Royer (1993). It is made of a diagnostic 2.0 order TKE scheme (Mellor-Yamada, 1982) and a statistical, diagnostic scheme for condensed water (Bougeault, 1982), associated with Kessler (1969) and Smith (1990) schemes used to describe the large-scale precipitation, condensation and evaporation processes. The older scheme of Louis (1979) and Louis et al. (1982) is still used for the surface layer, with a thermal roughness length equal to 1/10 of the dynamic one (Mascart et al., 1995). The mass flux scheme used for describing the deep moist convection is from Bougeault (1985). The lift and mountain blocking effects are included in the gravity wave drag scheme (Lott and Miller, 1997 ; Lott, 1999).
- Documentations: http://www.cnrm.meteo.fr/hiretycs/div/arp4ca.pdf (in French) or http://www.cnrm.meteo.fr/hiretycs/div/arp4cae.pdf (in English)

Chemistry and aerosols

- General : A linear prognostic model is used to represent an interactive ozone chemistry. The sources terms are obtained from Cariolle and Déqué (1986).

Ocean

- General : forced SSTs or OPA general circulation model.

Land Surface Processes

- Soil thermodynamics : a 4-layer heat diffusion scheme, without relaxation toward any prescribed temperature.
- Soil hydrology : 4 reservoirs (canopy interception, snow, shallow surface, root layer) with a bottom runoff by gravitational drainage described in Mahfouf et al. (1995). The root reservoir includes a liquid and a solid reservoir.
- The ISBA soil-vegetation scheme is from Noihlan and Planton (1989). More recent improvements are described in Mahfouf et al. (1995) and Douville et al. (2000). There are 4 vegetation classes (sea, ice, high and low vegetation) determined from the ECOCLIMAP data base (0.5 x 0.5 degrees). The rainfall interception by the canopy is limited for high convective rates. A more elaborated snow parameterization is described in Douville et al. (1995). Two prognostic values are managed for the density and the albedo of snow. The roughness length and the emissivity are, in turns, modified by the fraction of snow.

Model configurations for AMMA :

- Pluriannual climatic simulations in T63 with forced SSTs and a regular grid based on 128x64 in longitude/latitude
- Shorter zoomed simulations (up to 80 km resolution over the monsoon domain).
- Coupled simulations (T63 and 128x64 in longitude/latitude).
- Simulations with a zoom (60 to 50 km resolution) over the Atlantic for cyclone simulations.

Key persons :

- Main contact: Pascal Marquet (pascal.marquet@meteo.fr) ; also: jean-francois.royer@meteo.fr ; jean-francois.gueremy@meteo.fr ; herve.douville@meteo.fr ; michel.deque@meteo.fr.

References :

- Bougeault, Ph., 1982: Cloud ensemble relations based on the gamma probability distribution for higher-order models of the planetary boundary layer. *J. Atmos. Sci.*, **39**, 2691-2700.
- Bougeault, Ph., 1985: A simple parameterization of the large-scale effects of cumulus convection. *Mon. Wea. rev.*, **113**, 2108-2121.
- Courtier, Ph. and Geleyn, J., F., 1988: A global numerical weather prediction model with variable resolution: application to the shallow water equations. *Q. J. R. Meteor. Soc.*, **114**, 1321-1346.

- Courtier, Ph., Freydier, C., Geleyn, J., F., Rabier, F., Rochas, M., 1991, The Arpege project at Météo-France. In Proc. ECMWF Workshop on Numerical Methods in Atmospheric Modelling, 9-13 Sept 1991, vol 2, p. 193-231.
- Cariolle, D. and Déqué, M, 1986: Southern hemisphere medium-scale waves and total ozone disturbances in a spectral general circulation model. *J. Geophys. Res.*, **91**, 10,825-10,846.
- Déqué, M., Dreveton, C., Braun, A., Cariolle, D., 1994: The Arpege/IFS atmosphere model: a contribution to the French community modelling. *Clim. Dyn.*, **10**, 249-266.
- Déqué, M. and Piedelievre, J., Ph., 1995: High resolution climate simulation over Europe. *Clim. Dyn.*, **11**, 321-339.
- Déqué, M. and Marquet, P., Jones, R., G., 1998: Simulation of Climate change over Europe using a global variable resolution general circulation model. *Clim. Dyn.*, **14**, 173-189.
- Douville, H., Royer, J., F., Mahfouf, J., F., 1995: A new snow parameterization for the Météo-France climate model. Part I: validation and stand alone experiment. *Clim. Dyn.*, **12**, 21-35. Part II: Validation in a 3-D GCM experiment. *Clim. Dyn.*, **12**, 36-52.
- Douville, H., Planton, S., Royer, J., F., Stephenson, D., B., Tyteca, S., Kergoat, L., Lafont, S., Betts, R., A., 2000: The importance of vegetation feedbacks in doubled-CO2 time-slice experiments. *J. Geophys. Res.*, **105**, 14,841-14,861.
- Gibelin, A., L., Déqué, M., Dreveton, 2003: Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. *Clim. Dyn.*, **20**, 327-339.
- Kessler, E., 1969: On distribution and continuity of water substance in atmospheric circulations. *Met. Mon.*, **10**, n°32, *American Met. Soc.*, Boston, 84 pp.
- Lott, F. and Miller, M., J., 1997: A new subgrid-scale orographic drag parameterization: its formulation and testing. *Q. J. R. Meteor. Soc.*, **123**, 101-127.
- Lott, F., 1999: Alleviation of stationary biases in a GCM through a mountain drag parameterization scheme and a simple representation of mountain lift forces. *Mon. Wea. Rev.*, **125**, 788-801.
- Louis, J.F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Bound. Layer Meteor.*, **17**, 187-202.
- Louis, J.F., Tiedtke, M., Geleyn, J., F., 1982: A short history of the operational PBL parameterization at ECMWF. 25-27 Nov. 1981. 59-60.
- Mahfouf, J., F., Manzi, A., O., Noihlan, J., Giordani, H., Déqué, M., 1995: The land surface scheme ISBA within the Météo-France climate model ARPEGE. Part I: implementation and preliminary results. *J. Clim.*, **8**, 2039-2057.
- Mascart, P., Noihlan, J., Giordani, H., 1995: A modified parameterization of the surface layer flux-profile relationships using different roughness length values for heat and momentum. *Boundar- Layer Meteorol.*, **72**, 331-344.
- Mellor, G. and Yamada, T., 1982: Development of a turbulence closure model for geophysical fluid problems. *Reviews of Geophysical Physics and Space Physics*, **20**, 851-875.
- Morcrette, J., J., 1989: Description of the radiation scheme in the ECMWF model. *ECMWF Technical Memorandum.*, **165**.
- Morcrette, J., J., 1990: Impact of changes to the radiation transfer parameterizations plus cloud optical properties in the ECMWF model. *Mon. Wea. Rev.*, **118**, 847-873.
- Noihlan, J. and Planton, S., 1989: A simple parameterization of land surface processes for meteorological models. *Mon. Wea. rev.*, **117**, 536-549.
- Ricard, J.,J. and Royer, J., F., 1993: A statistical cloud scheme for use in an AGCM. *Ann. Geophysicae*, **11**, 1095-1115.
- Smith, R., N., B., 1990: A scheme for predicting layer clouds and their water content in a general circulation model. *Q. J. R. Meteor. Soc.*, **116**, 435-460.
- Simmons, A., J. and Burridge, D., M., 1981: An energy and angular momentum conserving vertical difference scheme and hybrid coordinates. *Mon. Wea. rev.*, **109**, 758-766.

IPSL climate model

Participation

- Used for integrative studies.
- Validation of the simulation of the African Monsoon (mean climatology and variability).
- Validation of the IPSL coupled model used for IPCC scenarios.
- Improvement of physical parametrizations of convection/clouds/boundary layer processes.
- Real time simulations with nudging during the campaign.

Atmosphere

- General : LMDZ General circulation model with optional nudging by meteorological analysis. Longitude-latitude grid with zooming capability. Hybrid sigma-p coordinate on the vertical.
- Dynamics : Grid point global model based on primitive equations of meteorology (Sadourny et Laval 1981).
- Physical parametrizations : Morcrette 1984 and Fouquart 1980 radiation scheme. Turbulent diffusion in the Boundary layer with Louis formulas for the surface layer. Mass flux schemes (Tiedtke or Emanuel) for moist convection. Wake parametrization to be included. Prognostic clouds. Lott and Miller gravity wave drag.
- Documentation : http://www.lmd.jussieu.fr/~lmdz

Chemistry and aerosols

- General : No chemistry

Ocean

- General : forced SSTs or ORCALIM general circulation model.
- Dynamics and grid :
- Physics : …

Land Surface Processes

- Soil thermodynamics : determined by a 7-layer heat transfer model Cf. Polcher (1994) for further details.
- Soil hydrology : 2-layer land surface scheme SECHIBA (Schématisation des Echanges Hydriques à l' Interface entre la Biosphère et l'Atmosphère). 7 prescribed vegetation classes. Cf Ducoudré et al. (1993) for further details.

Model configurations for AMMA :

- Pluriannual climatic simulations with forced SSTs and a regular grid based on 96x71 or 144x96 in longitude/latitude
- Shorter zoomed simulations (50 km resolution over west Africa).
- Coupled simulations (96x71).
- Real time simulations with the zoomed version and nudging during AMMA OPs.
- Simulations with a zoom (40 km) over the Atlantic for cyclone simulations.

Key persons :

- Frédéric Hourdin (hourdin@lmd.jussieur.fr)
- Ionela Musat (musat@lmd.jussieu.fr)

References :

- Ducoudre, N., K. Laval, A. Perrier, 1993: SECHIBA, a new set of parameterizations of the hydrologic exchanges at the land/atmosphere interface within the LMD atmospheric general circulation model. *J. Climate*, **6**, 248-273.
- Louis, J.F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Bound. Layer Meteor*., **17**, 187-202.
- Polcher, J., 1994: Etude de la sensibilité du climat tropical a la deforestation. Ph.D. dissertation, Université Pierre et Marie Curie, Paris, France.

LISA/IPSL Chimere-dust model

Participation

- Used for regional climatology over western Africa
- Improvement of dust surface emissions, wet and dry deposition and scavenging parameterizations (sensitivity tests)
- Simulations in forecast mode during the campaign (focused on mineral dust transport)

Atmosphere

- Cartesian longitude-latitude grid with zooming capability. Meteorological forcing ensures by ECMWF of NCEP at largest scale, and MM5/WRF at the regional scale
- Physical parametrizations : Only turbulent diagnostic parameterizations. Dry convection using convective plumes [Hourdin et al 2001], [Louis, 1979] parameterization for surface layer parameters (Kz, u*friction velocity and Q0 surface sensible heat flux), [Tiedke] scheme for moist convection.
- Documentation : http://www.lisa.univ-paris12.fr/mod/chimeredust/chimdust.html

Chemistry and aerosols

Possibility to use a coupled version chimere-dust and chimere (gas and aerosols) with the same meteorological forcing (see http://euler.lmd.polytechnique.fr/chimere/ for details)

Ocean

Use of ECMWF and/or MM5-WRF forcing for the lower atmosphere over ocean. No ocean parameterization used.

Land Surface Processes

Mineral dust emissions: saltation proposed by [Marticorena and Bergametti, 1995], sandblasting by [Alfaro and Gomes, 2001], calculation of friction velocity threshold by [Iversen and White, 1982]

Model configurations for AMMA :

- Spatial: Regional nested domains. (1) 1 degree resolution over north atlantic. (2) a few kilometers resolution on a domain to be define. Vertically, 20 levels from surface up to 200hPa.
- Temporal: one hour resolution for raw simulations. Calculation of diagnostized parameters (monthly AOT, deposition fluxes budget etc.)

Key persons :

- Laurent MENUT (menut@lisa.univ-paris12.fr)
- Catherine SCHMECHTIG (schmechtig@lisa.univ-paris12.fr)

References :

Schmechtig C., L.Menut, B. Marticorena and B.Chatenet, Preliminary validation of the mineral dust transport model CHIMERE-DUST, ENVISAT conference, Salzburg, Austria, Septembre 2004

MOCAGE

Participation

- Chemistry and transport process studies in the PBL, free troposphere, TTL and lower stratosphere ; study of the scale dependency of parameterisations (transport and scavenging by convective processes).
- Validation of the chemical simulations in Tropical Africa (climatology, variability and specific episodes).
- Provide large-scale chemical forcings for limited-area models.
- Provide assimilated fields of observed chemical constituents.
- Provide Real-Time forecasts during SOPs.

Dynamics and Physics

- MOCAGE is a grid-point multiscale Chemistry and Transport Model (CTM). For an overview of model characteristics and applications, see (Peuch, 1999) ; see also (Dufour et al., 2004).
- Dynamics and physics rely on external meteorological analyses or forecasts : temperature, horizontal winds, pressure, humidity and surface energy budget. Two options will be used for the forcings : ARPEGE (Météo-France global spectral NWPM, with an equivalent horizontal resolution of 2° ; 4 assimilation daily with a short cut-off) and IFS (ECMWF global spectral NWPM, with an equivalent horizontal resolution of 0.4° ; 2 assimilation daily with a long cut-off).
- Resolved-scale transport : semi-lagrangian scheme adapted from (Williamson and Rasch, 1988).
- Turbulent diffusion : (Louis, 1979)
- Transport and mixing by convective processes : two versions of (Tiedtke, 1989) (one simplified, one corresponding to the current version in IFS) ; (Bechtold, 2001), including recent modifications by P. Bechtold. See (Josse et al., 2004).
- Scavenging : in-cloud and below-cloud for convective rainfall (Mari,2000) ; in-cloud and below-cloud for large-scale rainfall based upon (Giorgi et Chameides, 1986). See (Josse, 2004).

Chemistry and aerosols

- Over ten optional chemical schemes, merging detailed tropospheric and stratospheric chemistry : the reference chemical schemes merges RACM (Stockwell et al., 1997) and REPROBUS (Lefevre et al., 1994) and includes heterogeneous chemistry on Polar Stratospheric Clouds.
- Comprehensive representation of aerosol (size bins approach), including the dust and black carbon components. The ORISAM/ORILAM module (Liousse at al. ; Tulet et al.) will also be introduced shortly.

Surface Processes

- Dry deposition : detailed scheme based upon (Wesely, 1989) “big-leaf” approach and ISBA land-suface parameterization (Noilhan and Mahfouf, 1996). See (Michou and Peuch, 2002), (Michou et al., 2004) for gazes and (Nho et al., 2004) for aerosols.
- Gazeous emissions : several options including for the global scale GEIA and EDGAR V2.0 inventories. Some work is on-going for time-dependent biomass burning emissions.
- Aerosol emissions : dusts (Marticorena and Bergametti, 1995) ; black-carbon from GEIA.

Model configurations for AMMA :

- MOCAGE will be used in two configurations : configuration A (global domain at 2° horizontal resolution) ; configuration B (global domain at 2° horizontal resolution ; continental domain covering Africa and East Atlantic at 0.4° horizontal resolution).

Chemical data assimilation :

- Several chemical data assimilation techniques are possible within MOCAGE : sequential assimilation scheme in equivalent latitude (Cathala et al., 2003) ; NCAR Kalman-Bucy filter (Pradier et al., 2004) ; PALM multi-method software (http://www.cerfacs.fr/~palm).

Key persons :

- Vincent-Henri Peuch (Vincent-Henri.Peuch@meteo.fr)
- Béatrice Josse (Beatrice.Josse@meteo.fr)

MOCAGE References :

- Cathala, M.-L., J. Pailleux and V.-H. Peuch, 2003 : Improving global chemical simulations of the upper tropospher-lower stratosphere with sequential assimilation of MOZAIC data, *Tellus*, 55B, 1-10.
- Dufour, A., M. Amodei, G. Ancellet and V.-H. Peuch, 2004 : Observed and modelled "chemical weather" during ESCOMPTE, *Atmos. Res.*, ESCOMPTE special issue, in press.
- Josse, B., P. Simon and V-H., Peuch, 2004 : Radon global simulations with the multiscale chemistry and transport model MOCAGE, *Tellus*, 56B, 339-356.
- Josse, B., 2004 : Représentation des processus de transport et de lessivage pour la modélisation de la composition chimique de l’atmosphère à l’échelle planétaire, PhD, Université Paul Sabatier, Toulouse.
- Michou, M. and V.-H. Peuch, 2002 : Surface exchanges in the MOCAGE multiscale chemistry and transport model, *Rev. Sci. Eau,* surface exchanges special issue, 173-203.
- Michou M., P. Laville, D. Serça, A. Fotiadi, P. Bouchou and V.-H. Peuch, 2004 : Measured and modeled dry deposition velocities over the ESCOMPTE area, *Atmos. Res.*, ESCOMPTE special issue, in press.
- Nho-Kim, E.-Y., M. Michou and V.-H. Peuch, 2004 : Parameterization of size dependent particle dry deposition velocities for global modeling, *Atmos. Env.*, vol. 38, n.13, 1933-1942.
- Peuch, V.-H., Amodei, M., Barthet, T., Cathala, M.-L., Josse, B., Michou, M. and Simon, P., 1999 : MOCAGE, Modèle de Chimie Atmosphérique à Grande Echelle, *Actes des Ateliers de Modélisation de l’Atmosphère*, Météo-France, 33-36.
- Pradier, S., J.-L. Attié, M. Chong , J. Escobar, V.-H. Peuch, J.-F. Lamarque, B. Khattatov and D. Edwards, 2004 : Evaluation of 2001 springtime CO transport over West Africa using MOPITT CO measurements assimilated in a global chemistry transport model, *J. Geophys. Res.*, en révision.

Other References :

- Bechtold, P., E. Bazile, F. Guichard, P. Mascart and E. Richard. A mass flux convection scheme for regional and global models, *Q. J. R. Meteorol. Soc,* **127**, 869-886.
- Giorgi, F. and W.L. Chameides. Rainout lifetimes of highly soluble aerosols and gases as inferred from simulations with a general circulation model. *J. Geophys. Res.*, **91**, (D13), 14,367-14,376.
- Lefèvre, F., G.P. Brasseur, I. Folkins, A.K. Smith, and P. Simon. Chemistry of the 1991-1992 stratospheric winter: three-dimensional model simulations. *J. Geophys. Res.*, **99**, (D4), 8183,8195.
- Louis, J.-F., 1979. A parametric model of vertical eddy fluxes in the atmosphere. *Bound.-Layer Meteor*., **17**, 187-202.
- Mari, C., D. J. Jacob and P. Bechtold. Transport and scavenging of soluble gases in a deep convective cloud. *J. Geophys. Res*., **105**, (D17), 22,255-22,267.
- Marticorena, B. and G. Bergametti. Modeling the atmospheric dust cycle: 1-Design of a soil derived dust production scheme. *J. Geophys. Res*., **100**, 16415-16430, 1995.
- Tiedtke, M.: A comprehensive mass flux scheme for cumulus parameterization in large-scale models. *Mon. Wea. Rev.* , **117**, 1779-1800.
- Wesely, M. L., Parameterization of surface resistances to gaseous dry deposition in regional-scale numerical models. *Atmos. Environ*., **23**, 6, 1293--1304, 1989.
- Williamson, D. L. and P. J. Rasch. Two-dimensional semi-lagrangian transport with shape-preserving interpolation, *Mon. Wea. Rev.*, **117**, 102-129,1989.

Hall / Hoskins-Simmons Dynamical Model

Participation

- Used for studies of large scale atmospheric dynamics.
- Perturbation studies – linear or nonlinear – time dependent or time independent - to changes in forcing / initial conditions.
- Normal mode studies – isolate linear dynamical structure with fastest exponential growth rates.
- Simple GCM configuration – empirical forcing replaces physical parameterisations to give a model that can be used for long integrations with explicit simulation of transient eddies.

Atmosphere

- General: Hoskins Simmons code used in numerous studies of midlatitude and tropical dynamics and tropical / extratropical interactions.
- Dynamics : Spectral model of primitive equations in terms of vort, div, temp, ln(p*). Sigma coordinates in vertical. Currently used at T31l10. Semi-implicit time step. (Hoskins and Simmons, 1975).
- Physical parametrizations : Can be used with linear damping and empirical forcing. (equicalent to relaxation forcing). (Hall, 2000).
- Data: Basic states and eddy flux information from ECMWF and NCEP data.
- Documentation : Provided with model package.

Land Surface Processes: *None*

Model configurations for AMMA :

Currently used in normal mode and forcing perturbation configurations to study easterly waves and response over Africa to convective heating anomalies. Fixed basic state. T31L10.

Key persons : Nick Hall (Nick.Hall@hmg.inpg.fr)

References :

Hoskins, B.J. and A.J. Simmons, 1975: A multi-layer spectral model and the semi-implicit method. *Quart. J. Roy. Meteorol. Soc.* **101,** 637-665.

Hall, N.M.J., 2000: A simple GCM based on dry dynamics and constant forcing. *J. Atmos. Sci.* **57,** 1557-1572.

LMDZ-INCA

Participation

- Used for integrative studies.
- Model valiation on seasonal and annual timescales.
- Model validation with the zoom version during the SOP.
- Evaluation of convective transport with tracers such as CO and importance of convection for O3 and other oxidants.
- Role of volatile organic compounds and peroxides on the budget of radicals and ozone photochemical production in the upper troposphere
- Mixing with air masses of other origins.
- Evaluation of the net impact of the WAM emissions on the global ozone budget, oxidising capacity and radiative forcing.
- Impact of biogenic emissions of precursors on ozone
- Evaluation of lightning NO_x emissions
- Evaluation of the removal of the aerosol in tropical climates
- Revision of the source of dust and organic aerosols in the Sahel zone and tropical African regions
- Impact of the aerosol radiative effect on the WAM
- Intercomparison of different aerosol and chemistry models simulating the WAM region

Atmosphere

- General : LMDZ General circulation model with optional nudging by meteorological analysis. Longitude-latitude grid with zooming capability. Hybrid sigma-p coordinate on the vertical.
- Dynamics : Grid point global model based on primitive equations of meteorology (Sadourny et Laval 1984). Advection of water with a finite volume scheme (Van Leer, 1977, Hourdin et Armengaud, 1999).
- Physical parametrizations : Morcrette 1991 and Fouquart and Bonnel 1980 radiation scheme. Turbulent diffusion in the Boundary layer with Louis formulas for the surface layer. Mass flux schemes (Tiedtke, 1989 or Emanuel, 1991) for moist convection. Prognostic clouds predicted through a probability distribution function of the subgrid-scale total water, coupled to convection (Bony and Emanuel, 2001). Wake parametrization to be included. Prognostic clouds. Lott and Miller (1997) gravity wave drag.
- Documentation : http://www.lmd.jussieu.fr/~lmdz

Chemistry and aerosols

- INCA (INteractive Chemistry and Aerosols) model calculates interactively emissions, dry and wet depositions, ozone photochemistry in the troposphere, aerosol dynamics and sedimentation.
- Gas phase chemistry including non-methane hydrocarbons. Over 300 chemical reactions and 85 tracers (Hauglustaine et al., 2004).

- Lightning NO_x emissions based on Jourdain et al. (2001).
- Multi-modal aerosol scheme including major components (25 tracers), including heterogenous chemistry (Bauer et al. 2004)
- Interactive dust and sea salt sources (Schulz et al. 2004, Balkanski et al. 2004), organic aerosol emission inventory corrected for interannual variability of biomass burning (Generoso et al 2004)
- Documentation of the model and aerosol model performance: http://www.ipsl.jussieu.fr/~dhaer/inca http://nansen.ipsl.jussieu.fr/AEROCOM/DATA/aerocom.html

Ocean

- General : forced SSTs.

Land Surface Processes

- Soil thermodynamics : determined by a 7-layer heat transfer model Cf. Polcher (1994) for further details.
- Soil hydrology : 2-layer land surface scheme SECHIBA (Schématisation des Echanges Hydriques à l' Interface entre la Biosphère et l'Atmosphère). 7 prescribed vegetation classes. Cf Ducoudré et al. (1993) for further details.
- Interactive biogenic NMHC emissions and NO soil emissions (Lathière, 2005).
- Impact of vegetation dynamics (ORCHIDEE) on dust sources in the Sahel zone (in work).

Model configurations for AMMA :

- Pluriannual climatic simulations with forced SSTs and a regular grid based on 96x71 or 144x96 in longitude/latitude
- Shorter zoomed simulations (50 km resolution over west Africa).
- Real time simulations with the zoomed version and nudging during AMMA OPs.

Key persons :

- Didier Hauglustaine (hauglustaine@cea.fr) and Juliette Lathière (lathière@lsce.saclay.cea.fr)
- Michael Schulz (Schulz@lsce.saclay.cea.fr) and Yves Balkanski (balkanski@lsce.saclay.cea.fr)
- Kathy Law (kathy.law@aero.jussieu.fr)

References :

- Bony, S., and K. A. Emmanuel, 2001: A parameterization of the cloudiness associated with cumulus convection; evaluation using TOGA COARE data, J. Atmos. Sci., 58, 3158-3183.
- Balkanski Y., Schulz M., Claquin T., Moulin C., Ginoux P., 2004. Global emissions of mineral aerosol: formulation and validation using satellite imagery. Emissions of atmospheric trace compounds, Granier C., Artaxo P., Reeves C.E. (Eds), Kluwer, 239-267 .
- Bauer, S.E. , Y. Balkanski, M. Schulz, D. Hauglustaine, and F. Dentener, Global Modelling of Heterogeneous Chemistry on Mineral Aerosol Surfaces: The Influence on Tropospheric Ozone

Chemistry and Comparison to Observations, J. Geophys. Res., 109, D02304, doi:10.1029.2003JD003868, 2004.

- Ducoudre, N., K. Laval, A. Perrier, 1993: SECHIBA, a new set of parameterizations of the hydrologic exchanges at the land/atmosphere interface within the LMD atmospheric general circulation model. *J. Climate*, **6**, 248-273.
- Emanuel, K. A., 1991: A scheme for representing cumulus convection in large-scale models, J. Atmos. Sci., 48, 2313-2335.
- Forget, F., F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, M. Collins, S. R. Lewis, P. L. Read, and J.-P. Huot., 1999: Improved general circulation models of the Martian atmosphere from the surface to above 80 km, J. Geophys. Res., 104, 24,155-24,176.
- Fouquart, Y., and B. Bonnel, 1980: Computations of solar heating of the Earth's atmosphere: A new parametrization, Contrib. Atmos. Phys., 53, 35-62.
- Generoso, S. , Bréon, F. , Balkanski, Y. , Boucher, O. and Schulz, M., Improving the seasonal cycle and interannual variations of biomass burning aerosol sources, Atmospheric Chemistry and Physics, Vol. 3, pp 1211-1222, 22-8-2003
- Hauglustaine, D. A., F. Hourdin, S. Walters, L. Jourdain, M.-A. Filiberti, J.-F. Larmarque, et E. A. Holland, Interactive chemistry in the Laboratoire de Météorologie Dynamique general circulation model : description and background tropospheric chemistry evaluation, J. Geophys. Res., 109, D04314, doi:10.1029/2003JD003957, 2004.
- Hourdin, F., and A. Armengaud, 1999: Test of a hierarchy of finite-volume schemes for transport of trace species in an atmospheric general circulation model, Mon. Wea. Rev., 127, 822-837.
- Hourdin, F., and J.-P. Issartel, 2000: Sub-surface nuclear tests monitoring through the CTBT xenon network, Geophys. Res. Lett., 27, 2245-2248.
- Hourdin, F., P. Le Van, F. Forget, and O. Talagrand, 1993: Meteorological variability and the annual surface pressure cycle on Mars, J. Atmos. Sci., 50, 3625-3640.
- Hourdin, F., O. Talagrand, R. Sadourny, C. Régis, D. Gautier, and C. P. McKay, 1995: General circulation of the atmosphere of Titan, Icarus, 117, 358-374.
- Krinner, G., C. Genthon, Z. Li, and P. Le Van, 1997: Studies of the Antarctic climate with a stretched-grid general circulation model, J. Geophys. Res., 102, 13731-13746.
- Jourdain, L. and D. A. Hauglustaine, The global distribution of lightning NOx simulated on-line in a general circulation model, Phys. Chem. Earth (C), 26, 585-591, 2001.
- Li, Z., 1999: Ensemble Atmospheric GCM Simulation of Climate Interannual Variability from 1979 to 1994., Journal of Climate, 12, 986-1001.
- Lott, F., and M. Miller, 1997: A new sub-grid scale orographic drag parametrization: its formu lation and testing., Q. J. R. Meteorol. Soc., 123, 101-128.
- Louis, J.F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Bound. Layer Meteor.*, **17**, 187-202
- Morcrette, J., 1991: Radiation and cloud radiative properties in the European Centre for Medium Range Weather Forecasts forecasting system, J. Geophys. Res., 96, 9121-9132.
- Polcher, J., 1994: Etude de la sensibilité du climat tropical a la deforestation. Ph.D. dissertation, Université Pierre et Marie Curie, Paris, France.
- Sadourny, R., and K. Laval, January and July performance of the LMD general circulation model, in New perspectives in Climate Modeling, edited by A. Berger and C. Nicolis, Elsevier, 173-197, Amsterdam, 1984.
- Schulz M., de Leeuw G., Balkanski Y., 2004. Sea-salt aerosol source functions and emissions. Emissions of atmospheric trace compounds, Granier C., Artaxo P., Reeves C.E. (Eds), Kluwer, 333-359.
- Tiedtke, M., 1989: A comprehensive mass flux scheme for cumulus parameterization in large-scale models, Mon. Wea. Rev., 117, 1179-1800.
- Van Leer, B., 1977: Towards the ultimate conservative difference scheme : IV. a new approach to numerical convection, J. Computational Phys., 23, 276-299.

LaMP M2C2 model: Model of Multiphase Cloud Chemistry

Participation

- M2C2 model is used for process studies; it is an air parcel model coupling gaseous and aqueous phase chemistry with cloud and aerosols microphysics.
- M2C2 will be used for AMMA with trajectory computed by RAMS model to study interactions between aerosols, cloud and chemistry. These simulations will provide the partitioning of chemical species between gas, cloud, rain, ice for various species such as HOx, organic peroxides as already done for CIME campaign (Leriche et al., 2003).

Atmosphere

- Air parcel dynamic framework
- Microphysics: two moment scheme considering cloud and rain represented by log-normal spectrum. Nucleation of new droplets, condensation/evaporation, collision/coalescence processes and sedimentation of rain are considered. Ice implementation is in progress.

Chemistry and aerosols

- Gas phase chemistry from Madronich and Calvert (1990), explicit mechanism adaptable for any environment.
- The exchange of chemical species between the gas phase and the aqueous phase is parameterized with the mass transfer kinetic formulation developed by Schwartz (1986).
- Aqueous phase chemistry: detailed chemistry of HO_x, chlorine, carbonates, NO_y and sulfur, the oxidation of organic volatile compounds (VOCs) with one carbon atom, the transition metal ions chemistry for iron, manganese and copper and the chemistry of oxalic acid (Leriche et al., 2003; Deguillaume et al., 2004).
- Photolysis frequencies are calculated using the Tropospheric Ultraviolet-Visible Model (TUV version 4.1) developed by Madronich and Flocke (1998), which has been extended to include calculations of photolysis frequencies, in cloud droplets.
- Aerosols are represented as the sum of three dimensional log-normal distributions which evolve as a function of time by nucleation as a net sink for aerosol particles. Interactions of aerosols with chemistry are considered by the dissolution of chemical soluble species when aerosols are activated to form new droplets.

Model configurations for AMMA:

- For AMMA, M2C2 will use trajectories computed by RAMS model in order to follow the main paths in the convective towers.

Key persons:

- Maud Leriche (M.Leriche@opgc.univ-bpclermont.fr)
- Nadine Chaumerliac (N.Chaumerliac@opgc.univ-bpclermont.fr)

References:

Deguillaume, L., Leriche, M., Monod, A., Chaumerliac, N., 2004, "The role of transition metal ions on HO_x radicals in clouds: a numerical evaluation of its impact on multiphase chemistry", Atmos. Chem. Phys., vol. 4, pp. 95-110.

Madronich, S., Calvert, J.G., 1990, "The NCAR Master Mechanism of the gas phase chemsitry", NCAR technical Note, TN-333+SRT, Boulder Colorado.

Madronich, S., Flocke, S., 1998, "The role of solar radiation in atmospheric chemistry", In: Handbook of Environmental Chemistry, Boule, P., ed., Springer-Verlag, Heidelberg, pp. 1-26.

Leriche, M., Deguillaume, L., Chaumerliac, N., 2003, "Modeling study of strong acids formation and partitioning in a polluted cloud during wintertime", J. Geophys. Res., vol. 108, no. D14, 4433, doi:10.1029/2002JD002950.

Schwartz, S.E., 1986, "Mass-transport considerations pertinent to aqueous phase reactions of gases in liquid water clouds", In: Chemistry of Multiphase Atmospheric Systems, Jaeschke, W., ed., NATO ASI Series, G6, Spinger-Verlag, pp. 415-471.

LaMP RAMS-Chimie-Aérosols

Participation

- RAMS (Regional Atmopheric Modeling System, Cotton et al., 2003) is used to study atmospheric system at meso-scale (from 1 km to 2000 km).
- In the frame of AMMA, RAMS is validated for the simulation of the zonal ITCZ shift (EXPRESSO campaign using data assimilation) and for the simulation of tropical deep convection (INDOEX campaign).
- Radical, peroxide and NO_x chemistry in the troposphere near the convective towers: impact on the oxidizing capacity and role of biogenic VOCs and NOx from lightning.
- Impact of biogenic emissions from various vegetal covers (forest, savanna) such as isoprene and NO.
- Squall lines interactions with desert dust budget: raise, dry and wet depositions, vertical distribution, presence of dust in the anvil (IN role). At the local scale, estimation of the influence of large convective systems such as squall lines on the mineral dust budget. At the regional scale, investigation of the long-term trends of variation of the mineral dust cycle and their relations with the Monsoon intensity and the changes in land use.
- In dry season, mixing of biomass burning plumes with ambient dust aerosol particles: heterogeneous chemistry.
- Dry season desert dust cycle with emphasis on radiative effect (direct; interaction with marine Sc; Pradelle et al, 2002a; Pradelle and Cautenet, 2002b).
- Modeling of atmospheric chemistry and aerosols into WAM. Study of interaction with dynamics and of the intraseasonal variability. Satellite data assimilations will be involved.

Atmosphere

- **General:** Cartesian grid and modified sigma-p coordinate on the vertical, used of multiple nested grids available (two-way interactive grid nesting). Meteorological nudging ensured by ECMWF or by outputs from global models such as ARPEGE. 4D assimilation available from observations.
- **Dynamics:** non-hydrostatic, anaelastic.
- **Physical parameterisations** : Microphysics: single or two moments parameterisation including cloud, rain and five ice categories with gamma distribution representation (Walko et al., 1995; Meyers et al., 1997). Convection: Kuo's scheme modified by Tremback (1990). Radiation scheme: Harrington (1997) long/shortwave model with two stream scheme interacts with liquid and ice hydrometeor size spectra, Morcrette (1989) and Fouquart (1980) radiation scheme of the ECMWF adapted to mineral aerosols (Cautenet et al., 2000). Turbulent mixing parameterization: Deformation-K closure scheme from Smagorinsky et al. (1963), Ensemble, averaged TKE (Mellor and Yamada, 1982), LES (Kosovic, 1997)

Chemistry and aerosols

- **Chemistry:** Gas and aqueous phase chemistry (MOCA2.2, Aumont et al., 1996; Audiffren et al, 2004) online adapted for simulation of biomass burning (Poulet et al., 2004) and for urban area (Taghavi et al., 2004a; 2004b). Recently, RACM scheme was implemented.
- **Aerosol**:
  - Dust : spectral bin aerosol scheme, with 20 intervals from 0.1 to 15 μm (Cautenet et al, 2000; Minvielle et al, 2004a and 2004b).
  - Biogenic and anthropogenic aerosols: coupling with ISORROPIA code in progress.
- **Emissions code:**
  - Anthropogenic emissions for gases and aerosols (industry, fossil fuel, and industrial biofuel) representative of the year 1995 are based on the EDGAR v3.2 emission database.
  - Biogenic emissions from various vegetal covers (forest, savanna) such as isoprene and NO are adapted to African cover (Poulet et al, 2004)
  - NOx emissions from lighting (Pickering et al, 1998)
  - Biomass burning emissions from burnt areas derived from satellite pictures (Cautenet et al, 1999).
  - Dust mass source derived from soil properties (Marticorena and Bergametti, 1997)
- **Initialization:** Chemical components are initialized using data available from a CTM (MOCAGE for example).
- **Deposition:** Dry deposition velocities are calculated interactively at each time step following the resistance-in-series approach (Wesely et al, 1989). Explicit wet deposition from cloud microphysics.
- **Photolysis rates:** On-line photolysis rates calculation (FASTJ, Wild et al, 2000)

Ocean

- General: prescribed SST (in time and space: 1 km) derived from MODIS database.

Land Surface Processes

- Soil/vegetation - LEAF-2 model (Walko et al., 2000). Subgrid parameterization based upon the "patches" scheme.

Model configurations for AMMA:

- Nested domains: (100 km to 1km horizontal resolution up to 8 nesting grids).
- Interpretation of observations: configurations will involve 2 to 4 grids. Budgets of either mineral dust or chemical species will be performed at two scales: either at "tower" scale (1 km in the horizontal), or at the convective system scale (hundreds of km).
- Sensitivity runs will be run for the same configuration than above, in view to study a large set of phenomena, such as the impact of lightning, the variability of biogenic emissions, radiative interactions with aerosols, …

Key persons :

- Sylvie Cautenet (S.Cautenet@opgc.univ-bpclermont.fr)
- Guy Cautenet (G.Cautenet@opgc.univ-bpclermont.fr)
- Maud Leriche (M.Leriche@opgc.univ-bpclermont.fr)

References :

Audiffren, N. ; Buisson, E. ; Cautenet, S. ; Chaumerliac, N. Photolytic impact of a stratocumulus cloud layer upon the chemistry of an offshore advected plume of pollutants during the NARE 1993 intensive experiment: a numerical study. Atmos. Res. Vol. 70, No. 2, 89-108, 2004.

Aumont B.,A. Jaeker-Voirol, M. Martin and G. Toupance, Tests of some reduction hypotheses made in photochemical mechanisms. *Atmos. Environ.,* 30, 2061-2077, 1996.

Cautenet S., D. Poulet, C. Delon, R.A. Delmas, J. M. Gregoire, J.M. Pereira, S. Cherchali, O. Amram and G. Flouzat, Simulation of carbon monoxide redistribution over central Africa during biomass burning events (EXPRESSO experiment) J. Geophys.Res., 104 (D23), 30641-30658, 1999.

Cautenet, G. ; Guillard, F. ; Marticorena, B. ; Bergametti, G. ; Dulac, F. ; Edy, J. Modelling of the Saharan dust event Meteor. Zeit. Vol. 9, No. 4, 221-230, 2000.

Cotton, W.R., R.A. Pielke Sr., R.L. Walko, G.E. Liston, C.J. Tremback, H. Jiang, R.L. McAnelly, J.Y. Harrington, M.E. Nicholls, G.G. Carrio and J.P. McFadden: RAMS 2001: Current status and future directions, Meteorol. Atmos. Phys., 82, 5-29, 2003.

Marticorena, B., and G. Bergametti, Modeling the atmospheric dust cycle : 1 – Design of a soil-derived dust emission scheme, *J . Geophys. Res.*, *100*, 16,415-16,430, 1995.

Meyers, M.P., R.L. Walko, J.Y. Harrington, and W.R. Cotton: New RAMS cloud microphysics parameterization. Part III. The two-moment scheme, Atmos. Res., 45, 3-39, 1997.

Minvielle, F. ; Cautenet, G. ; Andreae, M.O. ; Lasserre, F. ; Foret, G. ; Cautenet, S. ; Léon, J.-F. ; Mayol-Bracero, O.L. ; Gabriel, R. ; Chazette, P. ; Roca, R. Modelling the transport of aerosols during INDOEX 1999 and comparison with experimental data. Part 1:Carbonaceous aerosol distribution Atmos. Environ. Vol. 38, No. 12, p. 1811-1822, 2004.

Minvielle, F., G. Cautenet, Lasserre, F. ; Foret, G. ; Cautenet, S. ; Léon, J.F. ; Andreae, M.O.; Mayol-Bracero, O.L. ; Gabriel, R. ; Chazette, P. ; Roca, R. Modelling the transport of aerosols during INDOEX 1999 and comparison with experimental data. Part 2: Continental aerosols and their optical depth Atmos. Environ. Vol. 38, No. 12, p. 1823-1837, 2004.

Morcrette, J-J. Description of the radiation scheme in the ECMWF model. ECMWF Technical Memorandum 165, 1989.

Poulet D., S.Cautenet , B. Aumont and G. Foret, Simulation of the chemical impact of the bush fires emissions, in Central Africa, during the EXPRESSO campaign., en révision au J. Geophys. Res, 2004.

Pradelle, F., Cautenet, G., Jankowiak, I., Radiative and microphysical interactions between marine stratocumulus clouds and Saharan dust 1. Remote sensing observations, J. Geophys. Res., Vol. 107 , No. D19 , 4412, 2002a.

Pradelle, F. and Cautenet, G. Radiative and microphysical interactions between marine stratocumulus clouds and Saharan dust 2. Modeling, J. Geophys. Res., Vol. 107, No.D19, 4413, 2002b.

Smagorinsky, J.: General circulation experiments with the primitive equations. Part I, the basic experiment, Mon. Wea. Rev., 91, 99-164, 1963.

Taghavi, M., S.Cautenet, G. Foret, Simulation of ozone production in a complex circulation region using nested grids, Atmos. Chem. Phys. Vol. 4, No. 3 , 825-838, 2004a.

Taghavi M., S. Cautenet and J. Arteta, Impact of a high detailed emission inventory on modeling accuracy, accepted to Atmos. Res., (Special issue ESCOMPTE), 2004b.

Tremback, C.J.: Numerical simulation of a mesoscale convective complex: Model development and numerical results, Ph-D, Colorado State University, 247 p., 1990.

Walko, R.L., W.R. Cotton, M.P. Meyers, and J.Y. Harrington: New RAMS cloud microphysics parameterization. Part I: the single-moment scheme, Atmos. Res., 38, 29-62, 1995.

Walko, R.L., L.E. Band, J. Baron, T.G.F. Kittel, R. Lammers, T.J. Lee, D. Ojima, R.A. Pielke, C. Taylor, C. Tague, C.J. Tremback, and P.L. Vidale: Coupled atmosphere-biosphere-hydrology models for environmental modelling, J. Appl. Meteor., 39, 931-944, 2000.

Wild, O., Xin Zhu M.J., Prathier M. J., Fast-J: Accurate simulation of in- and below-cloud photolysis in tropospheric chemical models. J. Atmos. Chem., 37, n°3, 245-282, 2000.