Signature of large-scale models along a meridian transect over West Africa : AMMA-CROSS

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I. CONTEXT

West Africa is characterized by well defined strong meridian surface gradients (illustrated in Fig. 1), coupled to specific atmospheric circulations, such as the African easterly jet (AEJ) which develops during the monsoon season. The location of the AEJ itself is strongly constrained by meridian surface temperature and moisture gradients *(Thorncroft & Blackburn QJRMS 1999)*. In particular, inter-annual variability of the West African monsoon (WAM) is accompanied by changes in these basic structures. Synoptic variability in turn is dominated by African easterly waves which are dynamically linked to the AEJ. The structure and variability of these basic large-scale features involve complex interactions with soil, surface, turbulent and convective processes occurring on different scales. Finally, the WAM exhibits specific seasonal variations, with an abrupt monsoon onset to be compared to a more progressive latitudinal retreat (*Sultan & Janicot J. Climate 2003*).

While current numerical weather prediction (NWP) analyses seem able to reasonably capture these large-scale atmospheric features, the extent to which large-scale models are able to properly reproduce these observations remains unclear, and likely sensitive to changes in the physical parametrizations.

The objective of this starting study is therefore to get a more precise view concerning the ability of the large-scale models involved in the AMMA project to simulate these fundamental features of the WAM. Beyond, we also want to explore and compare the mechanisms and feedbacks involved in the WAMs as depicted by these models.

To do so, we follow an approach proposed by *Siebesma et al. (QJRMS 2004)*, and apply it to the Western African region: we define a North-South cross-section, over which we compare model behaviours with analyses and observational products, with the help of dedicated diagnostics.

This poster successively presents the case study together with the defined model outputs (II), GCM-related information (III), preliminary results (IV) and perspectives (V).

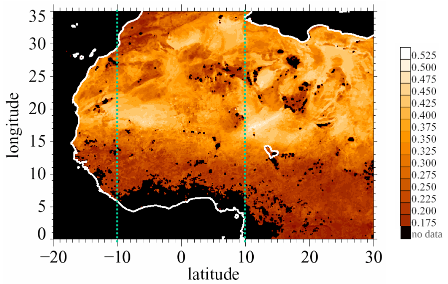

Figure 1: *Shortwave albedo for the 1st decade of June 1997 (POLDER-1, POSTEL, AMMASAT).*

II. CASE-STUDY AND SPECIFICATIONS FOR SIMULATIONS AND OUTPUTS

The meridian cross section spans 10W to 10E (Fig. 1), and extends from 20S to 40N. Two recent contrasted years : **2000** (year of the JET2000 experiment) and **2003** (MOZAIC data available for chemistry) have been chosen. They present distinct northern migration of the monsoon, with significantly more (less) rainfall North (South) of 8N in 2003 (Fig. 2). This is accompanied by typical changes in the dynamical structures such as seen on the August average zonal wind (Fig. 3): for instance, in 2003, the monsoon flow is thicker, the AEJ weaker and locater further north, while the TEJ is stronger, when compared to the same monthly mean for 2000. Note however that in 2003 the Eastern Atlantic sea surface temperatures (SST) anomaly was positive towards the Equator and South of it, i.e. the 2003 WAM does not fall in the category of wet years previously identified, that are characterized by similar rainfall patterns, but by an opposite correlation with SST anomalies. Fig. 2 also underlines the significant differences existing between available rainfall datasets (here TAMSAT and GPCP products, GPCP overestimates rainfall rates compared to TAMSAT).

Simulations presented below were performed with **prescribed time-varying SST** (files & information available from http://amma-mip.lmd.jussieu.fr).

A **list of model outputs** has been defined: it consists in time-latitude-height and time-latitude series of daily-mean fields averaged between 10W and 10E. These include atmospheric fields (winds, temperature, humidity, convective heating...), surface and top of the atmosphere (TOA) variables and quantities such as heat, water and radiative fluxes.

Reanalyses and **data products** (to be extended) over [10W,10E] are available as figures at http://www.cnrm.meteo.fr/amma-moana/transect/index.html (for pw: email florence.favot@meteo.fr)

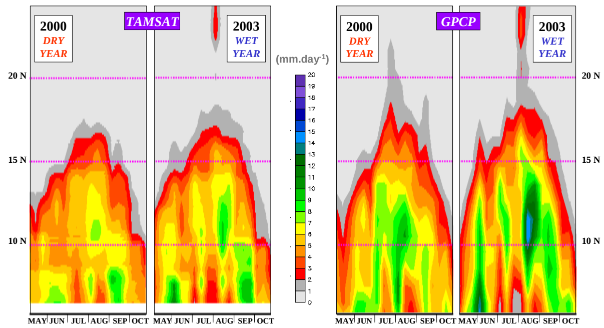

Figure 2: *Seasonal variation of rainfall as given by TAMSAT and GPCP products for the two selected years: time-latitude series of [10W-10E] decadal values.* TAMSAT : Tropical Applications of Meteorology using SATellite and other data; GPCP: Global Precipitation Climatology project

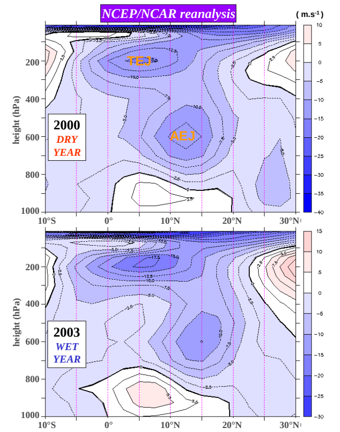

Figure 3: *2000 and 2003 August-mean [10W,10E] average zonal wind, from NCEP/NCAR reanalysis. ERA-40 provides close results.*

III. INFORMATION ABOUT MODELS AND SIMULATIONS

A very brief summary of the three general circulation models (GCMs) ARPEGE-Climat, ECHAM4 & LMDZ4, and of the simulations performed with them is given in the table below.

name of model	ARPEGE-Climat	ECHAM4	LMDZ4
horizontal resolution	T63 (~2.8°x 2.8°)	T30 (~3.75°x3.75°)	3.75° x 2.5°
numb. vertical levels	31	19 or 42	19
radiation	from ECMWF	from ECMWF	from ECMWF
surface	ISBA	Roeckner & Arpe 1995	ORCHIDEE
turbulence	Mellor-Yamada	diffusion	diffusion
convection	Bougeault	Tiedtke	Emanuel or Tiedtke
microphysics	diagnostic	prognostic	prognostic
year 2000 simulation	last year of a Jan 1999 to Dec 2000 run	year 2000 of a Jan 1999 to Dec 2003 run	year 2000 of a Jan 1985 (or 86/87/88/89) to Dec 2003 run
year 2003 simulation	last year of a Jan 2002 to Dec 2002 run	year 2000 of a Jan 1999 to Dec 2003 run	year 2003 of a Jan 1985 (or 86/87/88/89) to Dec 2003 run

These simulations differ in many respects, even for radiation for instance, as the treatment of aerosols is model dependent (which may affect the heat low properties and AEJ, *Tompkins et al. GRL 2005*). Soil initialization methods and the associated spin-up duration also vary according to the land-surface scheme that is used. Beyond these first simulations, we are planning to perform additional simulations, with increased resolution and/or updated parametrizations.

IV. PRELIMINARY RESULTS

All the simulations reasonably depict the broad seasonal migration of rainfall (Fig. 4). The differences among them concern in particular: the range of the northern monsoonal extension of rainfall, the rainfall retreat phase, the magnitude of intraseasonal variability.

Differences appear in the comparison between GPCP and the reanalyses and among reanalyses. During the monsoon season, GPCP rainfall rate is overall higher than predicted by the three climate GCMs.

In LMDZ4, as well as in the two reanalysis products, rainfall does not reach the northern areas indicated by data products. ARPEGE-Climat and ECHAM4 are not affected by this bias while at the same time, their zonal wind departs somewhat more from the analyses (AEJ located too far North and low level westerly extending too far North in ECHAM4, low level westerly too strong in ARPEGE-Climat) than it does in LMDZ4 – cf Fig. 5.

These distinct behaviours of models are quite robust along the monsoon season. Difference among simulations are not restricted to the monsoon season though.

In addition, these results are found to be quite sensitive to the convection scheme (LMDZ4) and to the vertical resolution (ECHAM4). For LMDZ4, differences among runs performed with different convection schemes (Tiedtke versus Emanuel) are larger than among ensemble runs all performed with the same convection scheme.

Finally, the contrasted rainfall regimes between 2000 and 2003 seem to be captured by ARPEGE-Climat.

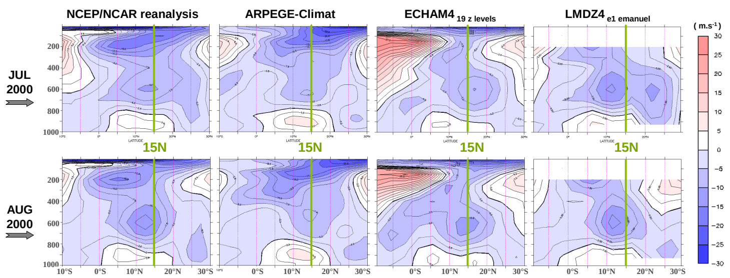

Figure 5: *July 2000 and August 2000 [10W,10E] average zonal wind from NCEP/NCAR reanalyses, ARPEGE-Climat, ECHAM4 (simulation with 19 vertical levels) and LMDZ4 (first simulation of the ensemble, using Emanuel convection scheme).*

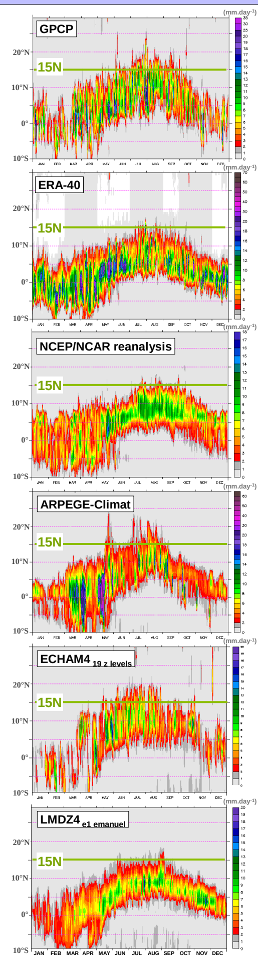

Figure 4: *[10W,10E] average daily mean rainfall for 2000, from GPCP, reanalysis products and GCM runs.*

V. PERSPECTIVES

Further work will involve in particular the analysis of surface and TOA variables, heat, water and radiative fluxes, and how they are related to convective activity and cloud cover. (Fig. 6 shows the seasonal variation of some of them as depicted by the NCEP/NCAR reanalysis).

The surface flux climatology database developed within AMMA should be particularly helpful for this study as well as AMMA-SAT and ISCCP products.

Links with the chemistry-transport modelling studies should also be strengthened through our choice of years (simulations available).

Finally, a complementary and coupled study **AMMA-2DMAP** will allow to assess how representative this cross-section analysis is and to relate it to the synoptic and intra-seasonal variability simulated by models versus observed over West Africa. (see http://amma-mip.lmd.jussieu.fr for further information.)

Figure 6: *from NCEP/NCAR reanalysis, year 2000 seasonal latitudinal variation of [10W,10E] average daily-mean potential temperature θ and equivalent temperature θ_e close to the surface (model level 0.995sigma), and surface sensible and latent heat fluxes.*
As for rainfall, preliminary comparison indicates less agreement among reanalysis-products for these fields than for analysed dynamical fields.