3B.7 AN IDEALIZED APPROACH OF THE WEST AFRICAN MONSOON

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1. INTRODUCTION

Better understanding of the West African Monsoon (WAM) involves to improve our understanding of interactions of scales and processes. As illustrated by the difficulty of GCMs have to simulate the WAM (e.g. AMIP and WAMP results), these interactions are presently difficult to be represented in global models. A complementary approach is to use a model of intermediate complexity in which the main interactions are more easily quantifiable than in a complete GCM (e.g. Chou and Neelin 2001). In the present study, a non-hydrostatic limited area model (Lafore et al. 1998) is used in an idealized configuration. Considering the strong zonal symmetry of the WAM and of the distribution of surface properties (Vegetation, albedo…), a 2D vertical-latitudinal plan is set up to represent the zonal mean circulation between 10°W and 10°E. This framework is chosen to represent the monsoon regime along a simplified manner but not far from reality in term of dynamics and precipitation. The final objectives are i) to quantify the relative importance of various interactions and ii) to investigate the physics and role of its main processes (mainly convection and surface-atmosphere coupling). The latter issue will be reached in using the grid nesting technics with an explicit representation of clouds (future work). Some examples are given here on the usefulness of such a tool in the WAM study in aiming to answer to two basic questions: i) at which extent the WAM can be viewed as a regional response to the latitudinal gradient of surface properties and ii) what is the importance of large scale advections of heat and moisture.

2. MODEL CONFIGURATION

In the present study, the domain of simulation extends from 30°S to 30°N with a 70km horizontal grid mesh and from the surface to 30km height. Neither mass nor energy exchanges are allowed to occur between the inner and the outer of the domain (rigid wall boundary conditions) leading to impose a mean vertical velocity equals to zero over the whole domain. The initial atmosphere is horizontally homogeneous, dry (RH< 10%), at rest (u=v=w=0) and the vertical profile of potential temperature corresponds to the seasonal climatology. Surface properties are initialized with simplified meridional profiles based on the zonal means of July 2000 data from Ecoclimap (Masson et al. 2000) and Reynolds (Reynolds and Smith, 1994) for the soil and SST, respectively. The SST is held constant during the simulation while the continental surface evolves owing the use of a coupled land surface scheme (Noilhan & Planton 1989). The convection is parameterized (Bechtold et al., 2000) and the turbulent scheme is based on a TKE equation (Cuxart et al. 2000). The simulations start the 15 June at 00h UTC and last 30 days. Starting from homogenous atmospheric conditions, a transitory stage of 15 days is necessary to reach a monsoon regime. Results discussed here concern this regime and fields correspond to an average on last 15 days.

3. RESULTS

Starting from the very simple initial conditions given above where only surface conditions are meridionaly varying, the model is able to develop a monsoon circulation including some important features such as westerly winds over the continental surface and a convective zone associated with the Tropical Easterly Jet (TEJ) (Fig.1a c). In comparison to the observed WAM, the simulated monsoon presents nevertheless several differences, among others a too northward extent of monsoon flow, a not well defined African Easterly Jet (AEJ), a lack of the southward Harmattan flow and precipitation over the heat low. Several factors are missing in this simple experiment looking at a regional answer to meridional surface gradients. This simple numerical framework allows to test the importance of external large-scale advections. The ECMWF analyses are used to compute the advections of temperature and humidity along the 3 directions x, y, z:

$A = -U\frac{\partial\alpha}{\partial x} - V\frac{\partial\alpha}{\partial y} - W\frac{\partial\alpha}{\partial z}$, where α stands for the potential temperature or water vapor mixing ratio. This term is calculated at every grid point on the domain [10°S-40°N][10°W-10°E] and every 6 hours. The zonal mean of A and wind components are also computed. If $\overline{\alpha}$ is the zonal mean of α over 10°W-10°E and α' the deviation from $\overline{\alpha}$, the zonal mean of advection can be computed as:

$$\overline{A} = -\overline{V}\,\overline{\frac{\partial\alpha}{\partial y}} - \overline{W}\,\overline{\frac{\partial\alpha}{\partial z}} - \overline{U}\,\overline{\frac{\partial\alpha}{\partial x}} - \overline{U'\frac{\partial\alpha'}{\partial x}} - \overline{V'\frac{\partial\alpha'}{\partial y}} - \overline{W'\frac{\partial\alpha'}{\partial z}}$$

Only the two first advection terms are explicitly represented in a 2D vertical-meridional model. The additional term to be considered in the model (i.e. external large scale forcing) is the sum of the last four terms representing the mean zonal advection and the transports associated to zonal variations of the motion (U',V',W') and of α'. A four months average is calculated to obtain the final external forcing and is shown for temperature on Fig 2.

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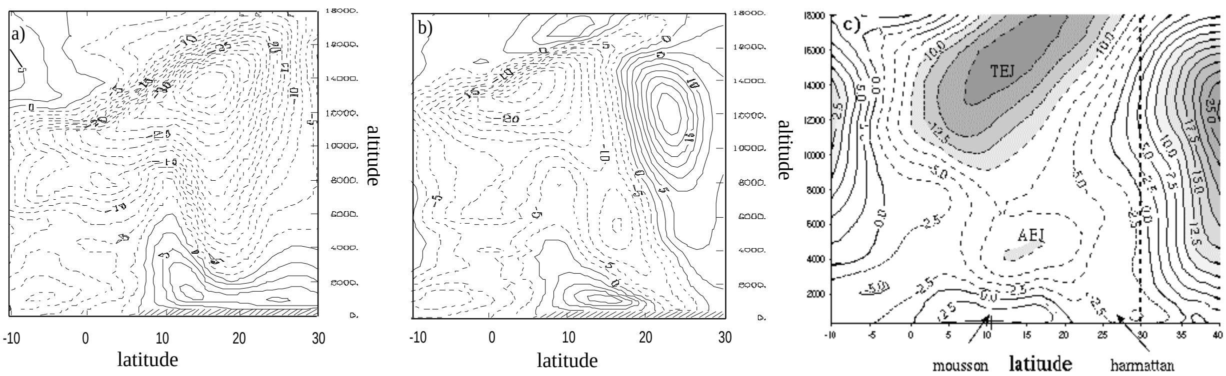

Fig 1: Mean Zonal Wind as simulated (a) without external large scale forcing, (b) with external large scale forcing and (c) from ECMWF analyses for July 2000. The vertical dotted in (c) shows the limit of the domain of simulation (30°N). Isoline every 2.5 m/s, westerly winds

From these diagnoses, a 2D model lacks at low levels in the heat low region a strong cooling (-5K/day) and a humidification (2g/Kg/day). Above 2km height, the 2D model lacks a heating (1K/day) and does not dry enough (-1g/Kg/day).

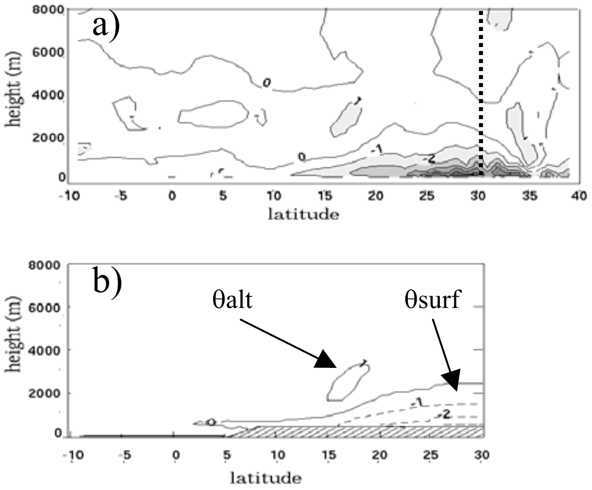

Fig2:Temperature forcing a) to be represented in the 2D model, from ECMWF analyses, b) parameterized in the model. Isoline every K/day.

These forcing (θ and Rv forcing) are included in the model through analytical functions according to the results from the ECMWF analyses. They are held constant during the simulation. The surface and mid level (above 2km) structures are noted with the subscripts surf and alt, respectively. A reference simulation is obtained with θ_{surf} = -3K/day, θ_{alt} =+1K/day for the θ forcing and Rv_{surf}=+1g/Kg/day, Rv_{alt}=-1g/Kg/day for the Rv forcing. The large scales fields appear to be efficient to limit the northward extent of monsoon (Fig1b-c). Moreover they contribute to improve the simulated dynamical structure with a northeasterly Harmattan flux in the heat low region and an AEJ (African Easterly Jet) well located near 17°N. The precipitation field does not exhibit anymore precipitations in the heat low region (not shown). Sensitivity tests to the forcing have been performed in doubling the magnitude or neglecting each forcing term over the last ten-day period of simulation. Results showed a consistent behavior of the WAM simulated regime. A stronger blocking of the monsoon is observed for an increase of the θ_{surf} large-scale term, which reduces the meridional temperature gradient and generates more harmattan flow. At the opposite increasing the Rv_{surf} term favors a stronger convection (corresponding to a greater θ_e in the lower layers), that leads to a more northward extent of monsoon. Thus the heat low region appears to be a key zone to determine the extent of the WAM.

4. SUMMARY

The idealized approach presented here appears to be useful to better understand the WAM system. First results show that large-scale fields are important to represent some important features of the monsoon. The heat low region seems particularly important. Indeed an equilibrium between thermodynamic and energetic feedbacks occurs (through the θ and Rv forcing in the model) which impacts on the intensity and localization of the convective zone. One of next steps will be to perform high-resolution simulations (~2km) to explicitly represent convection. This will allow to study the role of convection in the WAM and further to hopefully improve convection parameterization needed at low resolution in GCMs.

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