P1.50 SIMULATED RAINFALL DIURNAL CYCLE OF AFRICAN MONSOON: A SENSITIVITY STUDY TO MODEL RESOLUTION AND SEA SURFACE TEMPERATURE FORCING.

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1. INTRODUCTION

The rainfall diurnal cycle of the African Monsoon is one of the most intriguing physical features of tropical convection along with its “phase – locked” occurrence. Global models do not reproduce its spatial and temporal characteristics, while the rainfall cycle is clearly identified by satellite-based precipitation patterns. In order to provide additional information to the dynamical description of monsoon mechanisms during the warm rainy season and a better comprehension of the convection “coherence”, a regional reanalysis strategy has been developed based on Regional Atmospheric Modelling System (RAMS), forced by NCEP/DOE Reanalysis (R-2) dataset. A sensitivity study has been performed with several model configurations in order to analyze the different contributions of principal forcing mechanisms acting on the phase – locked rainfall diurnal cycle. Five (2004-2008) extended boreal summer seasons, from April to November, have been simulated, testing two model grid spacing resolutions (i.e., at 30km and 60km), and two different sea surface temperature datasets (i.e., HADSST at 1°x1° of horizontal resolution and the 8 days MODIS SST at 36km x 36km of horizontal resolution). The proposed regional modeling strategy has been evaluated analyzing atmospheric fields with respect to NCEP/DOE Reanalysis and precipitation fields, using a classical statistical skill scores analysis, with respect to the CMORPH/NOAA rainfall estimates (Joyce et al., 2004).

2. RAMS MODEL SETTINGS

Since the NCEP/NCAR Reanalysis Project released the atmospheric global datasets a new avenue to increase our understanding of the atmospheric dynamics has become accessible (Kalnay et al., 1996; Kanamitsu et al., 2002). However, a space-time dynamical scale gap still remains and should be filled in order to catch the details of the regional atmospheric circulation. Low-cost parallel computing power is now a reality and, thus, dynamic downscaling using regional models is an opportunity at hands (e.g., Soderman et al., 2003; Miguez-Macho et al., 2005; Castro et al., 2005). Low-resolution dataset produced by global models cannot resolve many dynamical characteristics of atmospheric physical mechanisms acting, at regional scale, in the tropics. In particular the interaction between the large scale easterly flow with both the Ethiopian high plains and the sub – Sahelian mountains ridges are not fully represented at such resolution. The topographic uplift mechanism, acting as convective triggering, is, in general, underestimated due to the smoothed topography used by global models. Furthermore, at those large spatial scale, the complex interaction between soil moisture and the convective boundary layer couldn't be satisfactory represented reducing the possibility of reproducing the strong coupling acting between soil and atmosphere as revealed by observed data analysis (Kohler et al., 2009, Taylor and Ellis, 2006, Taylor et al., 2007) and numerical model experiments (Mathon et al., 2002, Alonge et al., 2006, Gantner and Kalthoff, 2009, Vivoni et al., 2009). Thus, in order to catch local interactions and increasing the quality of the description of the atmospheric evolution it is important to define a "downscaling technique" using a regional modelling approach. In recent years several modelling experiments have been proposed in order to describe the behaviour of West African Monsoon (Sijikumar et al., 2006; Cook and Vizy, 2006; Druyan et al., 2006; 2007; Xue et al. 2010).

Following those approaches the modelling study presented in this paper is based on the RAMS model. It is a regional model constructed around the full set of non-hydrostatic, compressible equations that describe the atmospheric dynamics and thermodynamics, plus the conservation equations for scalar quantities and a large selection of parameterizations such as for turbulent diffusion, solar and terrestrial radiation, moist processes, cumulus convection, and energy exchange between the atmosphere and the surface through vegetation (Avissar and Schmidt, 1998; Chen and Avissar, 1994; Golaz, 2001; Pielke, 2001). In synthesis, the physical package of the model is formed by a number of sub-packages that describe various atmospheric effects: (i) an isoentropic analysis package (ISAN) for data analysis for the initial and boundary conditions (Pielke et al., 1992), (ii) an atmospheric turbulent Mellor-Yamada diffusion scheme (Mellor and Yamada, 1982), (iii) a cloud microphysics parameterization scheme (Walko et al., 1995; Meyers et al., 1997), (iv) the a Kuo type cumulus parameterization scheme (Kuo, 1974), (v) the Harrington radiative transfer parameterization scheme (both for short and long wave radiation) (Walko et al., 1995), and (vi) the Land Ecosystem Atmosphere Feedback scheme (LEAF-3) for the energy and moisture exchanges between soil, vegetation, and atmosphere (Walko et al., 2000).

The proposed dynamic downscaling strategy is based on nesting the RAMS model into the NCEP/DOE AMIP-II Reanalysis atmospheric fields (Kanamitsu et al., 2002, hereafter ReaII) used as initial and boundary atmospheric conditions every 6 hours throughout the simulation period through a weak lateral nudging setting, acting on a frame 10° wide.

RAMS is then forced by sea surface skin temperature from PODAAC–MODIS SST fields (http://podaac.jpl.nasa.gov, MODIS Terra Global Level 3 Mapped Thermal IR SST), with a 8 days of temporal resolution and linearly interpolated between two subsequent date and following the WAMME initiative SST and sea ice data from HadISST dataset (Rayner et al., 2003). More details in the official website: http://wamme.geog.ucla.edu/initiative.html. Ocean variability is described only through a sea surface temperature one – way forcing from the ocean to the atmosphere. For each simulated year a single long run is started on April up to October from 2004 to 2008, covering the full five-years satellite climatology period. A single domain is used, characterized as follows (see Fig. 1 and Fig.2): 30 km and 60 km of grid spacing, covering a portion of the northern hemisphere ranging in latitude from 10°S to 33°N and in longitude from 35°W to 75°E, 36 vertical levels. The spatial resolution and the coverage of the RAMS domain is far larger than the study area in order to feed the reanalysis dataset at the boundary over flat and ocean areas in the east – west boundary, achieving a stable representation of the atmospheric forcing at the larger scale. The boundary layer has been described in the model with a high level of accuracy, as one of the acting physical mechanisms in this tropical area is the interaction of the easterly flow with the topography along with the surface energy exchanges between soil and atmosphere. The vertical layers were defined based on a stretched vertical coordinate algorithm and resulted to be more dense at lower elevations (the vertical spacing ranges form 300 m near the surface to 1200 m in the free troposphere). This vertical layers set-up was driven as balanced choice between a suitable representation of the atmosphere and the numerical stability of the simulation itself (Pasqui et al., 2005). Satellite rainfall estimates were used in the set up phase of the model as reference precipitation fields to properly represent the simulated large and local scale atmospheric behavior and the resulting precipitation distribution and cycles.

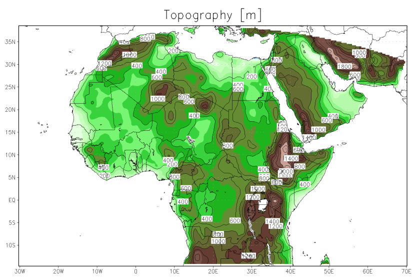

Fig.1 RAMS – HighRes domain with a 30km of grid spacing and topography.

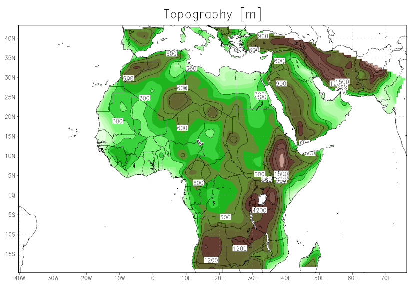

Fig.2 RAMS – LowRes domain with a 60km of grid spacing and topography.

5. DISCUSSION AND CONCLUSIONS

Footprint of RAMS convection diurnal cycle has been compared with one computed by MSG satellite – based precipitation patterns as in Melani et al., 2010.

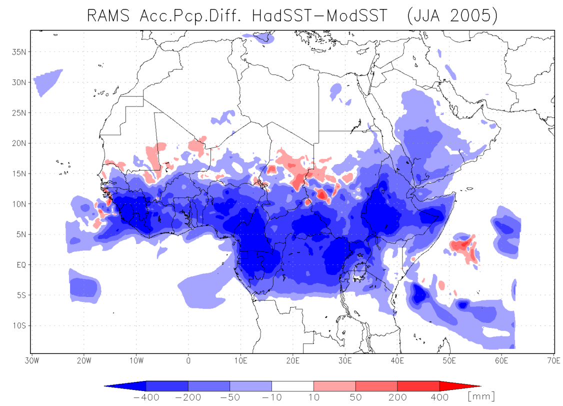

Fig.3 High resolution RAMS simulation precipitation difference.

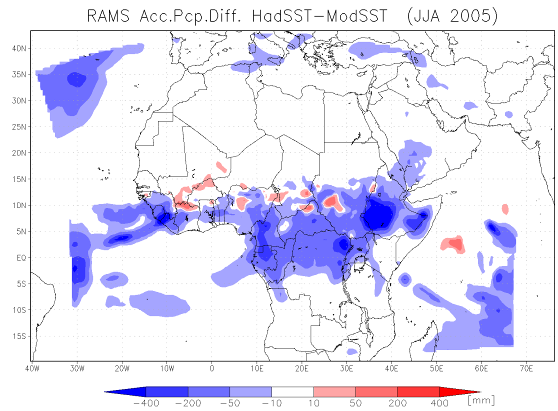

Fig.4 Low resolution RAMS simulation precipitation difference.

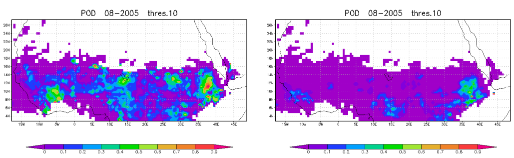

Fig.5 HighRes (left) and LowRes (right) probability of detection skill scores example for August 2005, with a daily precipitation threshold of 10mm.

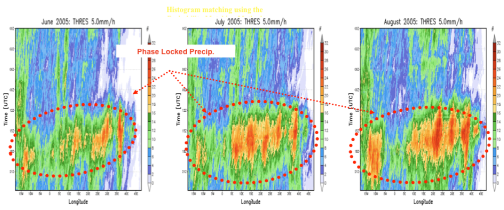

Fig.6 Precipitation diurnal cycle (as in Melani et al., 2010) computed with satellite MSG rainfall estimates.

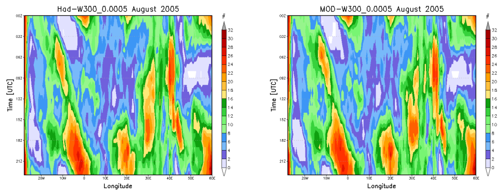

Fig.7 Precipitation diurnal cycle computed using RAMS LowRes vertical velocity field at 300hPa as footprint of deep convection; ModisSST forcing (right) and HadSST forcing (right).

In general, the persistency of the precipitation systems decreases toward the west, while the signal due to the diurnal variations is generally evident across all longitudes between 0° and 40°E but becomes less evident westward. The convection in the eastern part of the domain shows a daily oscillation across the African continent (maxima near 1500-1600 UTC) and mainly initiates in the lee of steep topography (maxima in correspondence to the Ethiopian highlands, the Darfur mountains, the Jos Plateau and the mountains of Cameroon) and it is consistent with the thermal heating due to the terrain elevation and the results in literature (Tetzlaff and Peters 1988; Laing and Fritsch 1993, Laing et al. 2008, Melani et al., 2010). Farther west, maxima can be found in correspondence to the late evening or nighttime hours. The westward propagation of precipitation patterns was even more evident in the average diurnal cycle when moving from June to August and signals could travel longest distances. In these diagrams, the coherent rainfall patterns represent a phase-locked occurrence of the precipitation events.

Vertical velocity at 300hPa is a “clear” tracer of convection and it was preferred in the comparison with the precipitation estimations at higher resolution retrieved from satellite observations. Figure 7 shows the mean diurnal cycle of RAMS modeled vertical velocity at 300hPa for the months of August 2005, at a given longitude-UTC coordinate as an example.

A stronger convective activity can be observed for the last two months, with precipitation peaks near 1600-1700 UTC and a maximum amplitude corresponding to the Ethiopian highlands (33°E-38°E). In 2005 a marked convective activity is observed with maximum amplitudes corresponding to the Ethiopian highlands (33°E-38°E) and the Darfur mountains (20°E). Unrealistic precipitation peaks are however visible during morning time in the easterly part of the domain, especially in July and August 2005. Probably this is due to the incorrect representation of the dynamical interactions between the African Easterly Jet (AEJ) and the Ethiopian orography by the regional model, producing a physically unrealistic dynamical signal.

The methodology has correctly detected and followed the evolution of the intense convection dynamics in terms of organized rainfall events with coherent propagation in the longitude-time space, characteristics of those tropical areas (Melani et al., 2010). In this sense, the coherency characteristics allowed to study the intraseasonal variability of the monsoon regime, the diurnal cycle and the zonal component of motion. These results are relevant in the overall understanding of the dynamics of monsoon precipitation genesis and evolution, and their impacts in the long-term forecasting and climatic changes:

- the higher model resolution the better characterization of maxima

of rainfall diurnal cycle, both in time and in space;
- furthermore MODIS – SST dataset greatly improved the overall description of convection features along the season providing .

The reconstruction of the monsoon dynamics with a regional model has shown good capacity in the detection of some phase-locked behaviors, typical of those precipitation patterns, in the perspective of a better comprehension and forecasting of the considered phenomenology. In order to represent the African climate variability at small scales we need regional high-resolution modeling. This is why we have to tune small scale dynamics simulated by the regional models: diurnal cycle analysis can highlight problems arising from the simulations and thus numerical modeling should be able to correctly represent such cycle.

6. ACKNOWLEDGMENTS

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