# Present-day regional climate simulation of the North American and West African monsoons: A comparative study

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## 1. Background

Monsoon circulation systems are a major component of the summertime hydrologic cycle in the subtropics. Both the southwestern USA and West Africa are subject to such systems in June-September (JJAS), respectively the North American Monsoon system (i.e. NAM, also referred as northwestern Mexico or Arizona monsoon) and the West African Monsoon system (WAM).

These two monsoon systems, which develop in response to seasonal changes in the thermal contrast between the continent and adjacent oceanic regions, exhibit many of the feature of their Asian counterpart (e.g. an intense low-level inflow of moisture to the continent). However, predicting reliable future changes in the monsoon regions remains a challenge for regional climate models (RCMs).

The aim of this study is to quantify and intercompare the systematic errors of an RCM in simulating the present-day climate associated with the NAM and WAM systems. The idea is to discern whether the deficiencies arise from the model formulation or the quality of the large-scale driving conditions in different monsoon regions.

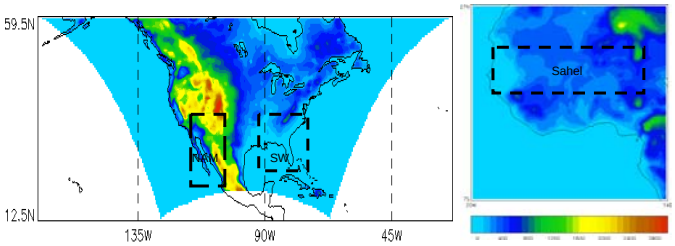


Figure 1: internal domain (without the relaxation zone) used for the simulation over North America and West Africa. The boxes with dashed outlines indicate areas used in the analysis, namely the area influenced by the North American Monsoon (NAM:115-105ºW, 20-37ºN), Southwestern US (93-80 W, 25-37N), and Sahel (15W-10E, 10-20N). The colour contour indicates the orography in metres.

## 2. Methodology

**Regional climate model**

The model used here is the Hadley Centre regional climate model HadRM3P. This model is part of the regional climate modeling system "Providing Regional Climates for Impact Studies (PRECIS)" , for which an extensive description is given by Jones et al., 2004.

**Experimental configuration**

A pair of 22-yr continuous integration of hadRM3P is performed at 0.44° latitude x 0.44° longitude horizontal resolution (~50 km) for the period 1979-2001, separately over two different model domains. The first domain cover the entire West Africa, so as to permit a realistic representation of the WAM climate and the Sahel region (Fig. 1a). The second domain covers entirely the United States of America (USA) and North of Mexico (Fig. 1b).

The initial conditions (ICs) and time-varying lateral boundary conditions (LBCs) are taken from the National Centers for Environmental Prediction NCEP-R2 reanalysis.

**Verification datasets**

The following four datasets are used to assess the realism of HadRM3P and its consistency at large-scale with large-scale driving atmospheric conditions:

- Surface temperature and precipitations from the CRU gridded monthly data at 0.5x0.5 degree horizontal resolution, available just over the continent;
- Oceanic precipitation from the CPC merged Analysis of Precipitation (CMAP) at 2.5x2.5 degree horizontal resolution;
- Atmospheric circulations from both ERA40 and NCEP-R2 reanalysis, respectively with 1.125x1.125 and 2.5x2.5 degree horizontal resolution.

## 3. Results

**How realistic are the simulated mean low-level monsoon circulation and precipitation?**

The comparison of HadRM3P mean JJAS (1981-2001) horizontal wind at 925 hPa with NCEP-R2 and ERA40 indicates a large-scale consistency with the driving conditions (Fig 2). The space wind correlation with NCEP-R2 is 0.79 over West Africa and 0.83 over North America. Despite a slight overestimation of wind magnitude, HadRM3P reproduces the West African cross-equatorial monsoon flow and Great Plains low-level jet.

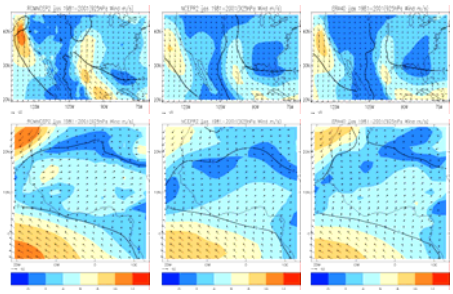

Fig. 2: Climatology of averaged JJAS (1981-2001) horizontal wind at 925 hPa for HadRM3P (left), NCEP-R2 (centre), ERA40 (right) on a 2.5x2.5 grid. The solid black line is the zero zonal wind and colour contour indicates the wind magnitude in m/s.

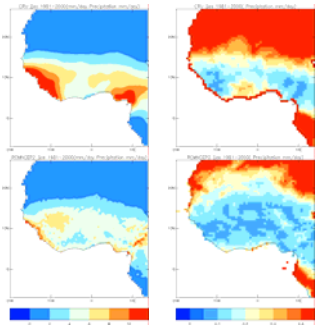

Fig. 3: Mean JJAS (1981-2000) precipitation in mm/day (left) and coefficient of variation CV (right). The CV is standard deviation divided by the mean and represents the year-to-year spatial variability. The panel compare CRU data (top) with HadRM3P (bottom).

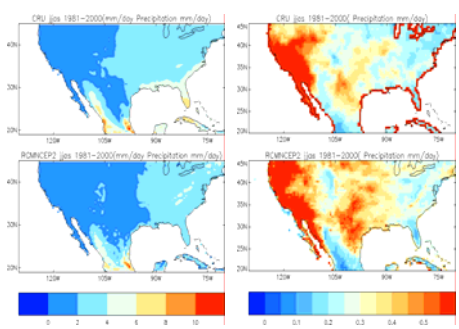

Fig. 4: Same as Fig. 3 but for the North American domain.

**Figures 3 and 4** compare the mean JJAS spatial distribution and the coefficient of variation for simulated and observed rainfall over the two monsoon regions. HadRM3P simulates reasonably the pattern of precipitation but underestimates their maxima, particularly over the mountainous areas of West Africa. The RCM produces standard deviations of similar magnitude to observed, but underestimates the variability over the Sahel region.

**Figure 5** shows JJAS rainfall anomalies, expressed as a regionally averaged departure from the long-term mean and divided by the standard deviation. This figure compares observed and simulated rainfall fluctuations in 1980-2000 over Sahel and NAM regions. HadRM3P tends to better simulates the interannual variability of the North American monsoon precipitation.

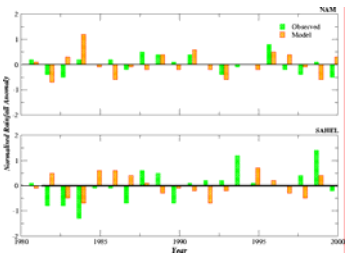


Fig. 5: JJAS rainfall anomalies, expressed as a regionally averaged and normalized anomaly ( departure from the long-term mean divided by the standard deviation).

**Conclusions and future plans**

HadRM3P RCM when driven by the reanalysis NCEP-R2 captures reasonably the basic feature of the climate over the NAM and WAM regions, including the intense low-level inflow of moisture to the continent and associated rainfall changes. The RCM shows better skills over the North American Monsoon region. In the future, further work is needed to understand the differences in simulating the NAM and WAM with HadRM3P. A series of RCM simulations With ERA-40 LBCs are planned to assess the influence of large-scale conditions.

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References:
Jones, R.G., Noguer, M., Hassell, D.C., Hudson, D., Wilson, S.S., Jenkins, G.J., Mitchell, J.F.B.: 2004, Generating high resolution climate change scenarios using PRECIS, Met Office Hadley Centre, Exeter, UK/UNDP, New York, USA: 35pp.