Project 8 (WP3): Modeling climate change in Western Africa

Project lead: Sophie Bastin
Post-doctoral researcher: Marco Gaetani
Project Start/End: October 2014 – September 2016

Position offer: The laboratory of excellence L-IPSL of the Institut Pierre-Simon Laplace offers a 2-year post-doctoral position to work on climate change modeling over West Africa.

Context: The Sahel has undergone a severe (large scale and long-lasting) drought in the 1970s-1980s. West Africa has also undergone a strong paleo variability, with evidence for a "green Sahara" about 6000-7000 years ago. The recent Sahelian drought was probably in large part driven by the decadal variations of the sea surface temperature. For people of that region who crucially rely on the monsoon rainfall, anticipating the possible future variations of the African monsoon system is of great importance. However, coupled ocean-atmosphere climate model still show a rather poor skill in simulating the African monsoon, and there is still a large spread of climate projections on that region. The downscaling experiments performed under the Cordex program (which did prioritize the African continent), are at least as dispersed and biased as those from the global models. Despite the important dispersion, CMIP5 models suggest a general tendency to a reinforcement of rainfall in central Sahel, with a slight drying on the Senegal/Guinea coast. This signal may be related to some robust features found in idealized simulation that show that CO2 increase produce a rapid reinforcement of ascending motions in the tropics. This effect could be reinforced by a regional water vapor positive feedback: increased convergence over the Saharan heat low brings more water which in turns strengthens regionally the greenhouse effect. This mechanism share similarities with the response of monsoon to enhanced Northern hemisphere seasonal insulation that prevail during the "green Sahara" period. The general purpose of the work would be twofold: 1) identify the elements of robustness in climate simulations (paleo, historical reconstructions and climate change projections), analyzing the contribution of for instance change in large scale circulation and SSTs, direct CO2 forcing or regional water feedback, and 2) question the strategies for downscaling experiments over West Africa as to their ability to account for the identified critical mechanisms.

Description of work: The work will be based in part on the multi-model analysis of CMIP5 simulations (in order to identify robust mechanisms and features), benefiting from the fact that the same model has been used for past climate, historical simulations and climate change projections. A particular focus will be put on the analysis of the radiative forcing (CO2 and aerosols) and feedback (water vapor) over the Saharan heat low. To test physical hypotheses about the role of these forcings and feedbacks on climate change over West Africa, the analysis of existing simulations will be complemented by dedicated simulations with the LMDZ atmospheric general circulation model, which is the atmospheric component of the IPSL Coupled Model (involved in CMIP5). The model can be run either in global mode or zoomed over a particular region of the globe. It can be run either in climatic mode or "nudged" toward the large scale dynamics of the reanalysis or the results of another simulation. The LMDZ physical package has also been coupled to the dynamics of the WRF regional model, which will allow to test the use of limited area model without modifying the physics. This suite of configuration will be used 1) to separate local feedbacks from large scale couplings (using nudging or not at the boundary of the domain, or imposing idealized diabatic heating like albedo patches over a region, or more or less interactions with surface), and 2) to perform big-brother experiments to compare and assess the strengths and limitations of different downscaling approaches: a reference simulation run with a fine global regular grid is used as a reference (or model truth) for various approaches (zoom with or without nudging, limited area versions).

Supervision team: The work will be conducted under the main supervision of Frédéric Hourdin from LMD and Sophie Bastin from LATMOS together with colleagues from the two teams (Cyrille Flamant, Sandrine Bony, Jean-Louis Dufresne....). The work will be performed in alternance between the two labs with a schedule to be discussed, and followed jointly by a larger Labex team who will also involve P. Braconnot (LSCE).

Experience: The applicant will have experience with numerical modeling of the Earth system based on global or regional model. He/she also have experience with handling large datasets. The applicant publication record should show a majority of papers published in English in top ranking journals.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a CV, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Cyrille Flamant (cyrille.flamant@latmos.ipsl.fr) before 15 March 2014.

Preliminary results

West African Monsoon dynamics and precipitation: the competition between global SST warming and CO2 increase in CMIP5 idealized simulations

In this study, the July-to-September West African Monsoon (WAM) variability in the period 1979-2008 is studied in climate simulations driven by observed SST, extracted from the CMIP5 dataset. The individual roles of global SST warming and CO2 atmospheric concentration increase are investigated through idealized experiments simulating a 4K warmer SST and a 4x CO2 concentration, respectively. Results show a dry response in Sahel to SST warming, with dryer conditions over western Sahel. Conversely, wet conditions are observed when CO2 is increased, with the strongest response over central-eastern Sahel. The precipitation changes are associated with modifications in the regional atmospheric circulation. The analysis of the dynamics associated to the observed modifications reveals that the SST warming affects the Sahelian precipitation through changes in the global tropical atmospheric circulation, reducing the importance of the regional drivers, while the CO2 increase reinforces the coupling between precipitation and regional dynamics. In the perspective of skilful simulations of Sahel precipitation, the importance of the comprehension of the competitive actions of SST warming and CO2 increase on Sahelian precipitation, and the sensitivity of climate models to this competition, is finally highlighted.

Understanding the mechanisms behind the West African Monsoon strength in the Mid-Holocene

The objective of this study is to improve the reconstruction of the WAM in the Mid-Holocene (MH), through the understanding of the role of land cover and dust atmospheric concentration in modifying the precipitation pattern, and to relate the precipitation changes to the modification in the regional atmospheric dynamics. To this aim, a fully coupled climate model is used to simulate the MH climate in presence of a "Green Sahara" and the consequent reduced dust concentration, and the precipitation and dynamics fields are analysed. Sensitivity experiments show a significant northward migration of the rainbelt across the continent and reaching 30°N. The associated atmospheric circulation over North Africa coherently responds to the regional forcing ("green Sahara" and reduced dust concentration), showing a sizable rearrangement in the thermal anomalies at the surface, and in the zonal flow in the low, mid and high troposphere. Our results show excellent agreement with available proxy data, only when both the greening of the Sahara and dust reduction are taken into account. The analysis presented in this paper is particularly relevant in the perspective of possible future scenarios for West Africa, which depict a positive trend in line with the last 30 years recovery in precipitation, and consequent possible land greening and dust reduction.

Analogies of CMIP5 mid-Holocene and sstClim simulations of WAM and implications for future

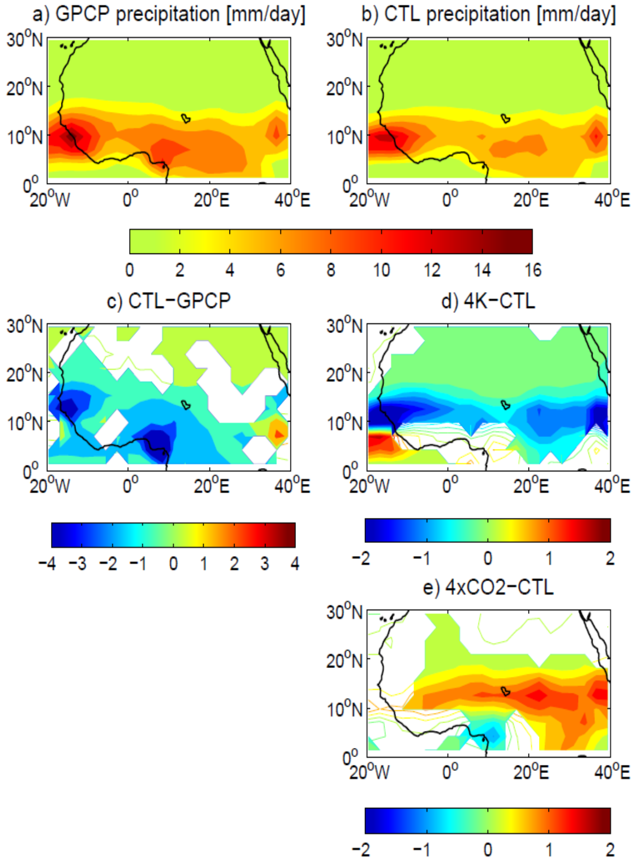

Figure 1: JAS mean of precipitation [mm/day] for the period 1979-2008: (a) GPCP data, (b) control simulation and (c) difference with observations. Modifications in (d) 4K and (e) 4xCO2 sensitivity experiments.

In this study, precipitation and atmospheric dynamics over West Africa from CMIP5 MH simulations are compared with present-day simulations forced with idealized CO2 forcing (namely abrupt4xCO2 and sstClim4xCO2). The aim is to find analogies useful for the comprehension of the past climate variability and possible future scenarios. Results show interesting analogies between the modifications of the precipitation patterns and regimes in the MH and the ones observed in the idealized 4xCO2 simulations, even though, the amplitude of the signal in the MH precipitation cannot be completely explained by these analogies.

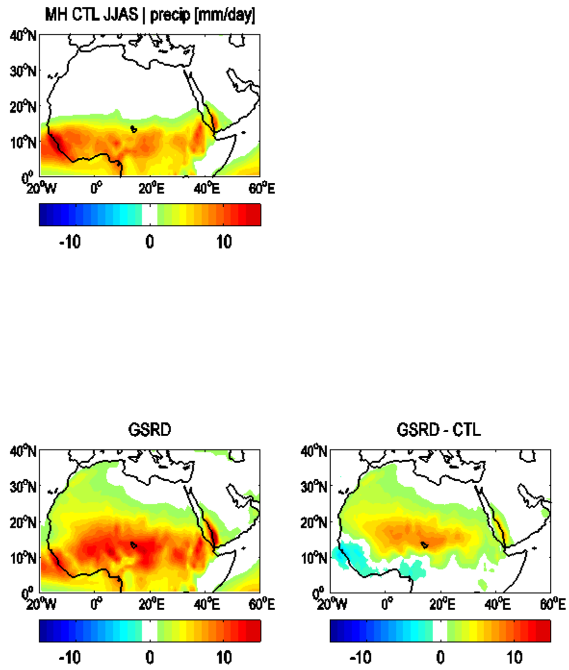

Figure 2: JJAS precipitation ensemble means [mm/day]: (top) MH control simulations, (bottom) "green Sahara-reduced dust" sensitivity experiment (left) mean and (right) difference with control.

Papers under review and in preparation

Gaetani, M., C. Flamant, S. Bastin, S. Janicot, C. Lavaysse, F. Hourdin, P. Braconnot, S. Bony, 2015: West African Monsoon dynamics and precipitation: the competition between global SST warming and CO2 increase in CMIP5 idealized simulations. Climate Dynamics, CLDY-S-15-00501

Gaetani, M., G. Messori, Q. Zhang, C. Flamant, F.S.R. Pausata, 2015: Understanding the mechanisms behind the West African Monsoon strength in the Mid-Holocene. In preparation

Zheng, W., P. Braconnot, K. Izumi, M. Gaetani, 2015: Analogy of WAM between mid-Holocene and sstClim simulations and its implication for future, in preparation