Science
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Towards the improved understanding of land-surface processes and coupling with the atmosphere over West Africa

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Land-atmosphere feedbacks in the West African Monsoon (WAM) region are of critical importance for numerical weather prediction in Africa. The pioneering work of Charney [1] was among the first studies to show the impact of land surface vegetation and surface soil conditions on regional scale atmospheric circulations, and more recently Koster et al. [2] showed that an ensemble of global climate models (GCMs) predict significant land-atmosphere coupling over this region. The dominant feature of land-atmosphere interactions over West Africa is the large range of characteristic coupled processes at different spatial and temporal scales. At the small scale, these interactions have an impact on convective cells within mesoscale storm systems, while at the regional scale they influence the position of the Intertropical Convergence Zone and the African Easterly Jet through a significant meridional surface flux gradient [3]. A better understanding and prediction of land-atmosphere coupling processes are key scientific foci of the African Monsoon Multidisciplinary Analysis (AMMA) Project.

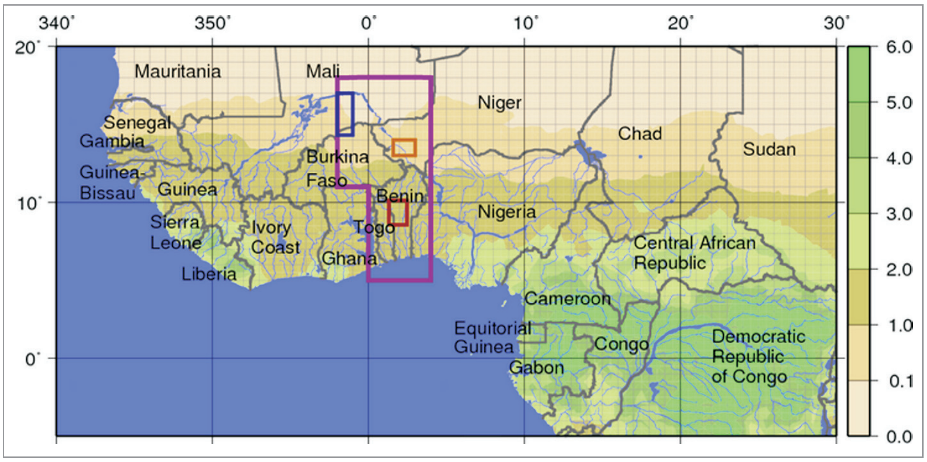

Figure 1. The AMMA regional scale land surface modelling domain. The regional-scale computational grid cells are shown in grey. The CATCH transect or sub-domain (outlined in violet) contains three meso-scale sites: Oueme (red), Niamey (orange) and Gourma (blue). There are 22 local scale soil moisture measurement sites within the transect. Contours correspond to the annually-averaged Leaf Area Index (LAI m^2 m^{-2}).

The land surface modelling strategy of AMMA relies on the following structure: 1) coordinated development and use of various Land Surface Models (LSMs), each focusing on different processes and working at different temporal and spatial scales. These include hydrological models, soil-vegetation-atmosphere transfer schemes, and crop models. 2) Creation of a multiscale low-level atmospheric forcing database over land. These data are essential for a coherent multi-disciplinary modeling approach at various spatio-temporal scales. 3) Development of an African Land Data Assimilation System. The goal is to improve the representation of initial conditions corresponding to the land surface vegetation and surface soil conditions in operational numerical weather prediction (NWP) models, especially in terms of soil moisture which can influence the initiation and development/decay of convective systems fundamental to the monsoon hydrological cycle. The development and improvement of model parameterizations, coupling, and calibration, as well as assimilation methods, are the basis for the modelling studies conducted in AMMA.

Land Surface Models require forcing variables consisting of near-surface atmospheric state variables, downwelling radiative fluxes and rainfall as well as land parameters (land cover, vegetation metrics, soil texture) as input. Precipitation is the most crucial forcing input, and it must be well resolved in terms of intensity, frequency, duration of events, and spatial distribution. At the regional scale, the use of Meteosat Second Generation (MSG) remote sensing products gives a consistent set of atmospheric forcing variables. The precipitation is from the EPSAT (Estimation of Precipitation by SATellite) product available within AMMA-SAT (the AMMA-PRECIPitation sub-group), and the downwelling radiative fluxes are from the Satellite Application Facility projects (LAND-SAF and Oceans and Ice SAF). Model evaluation and/or calibration depend upon observations of surface turbulent fluxes (latent and sensible heat, carbon, net radiation) and model prognostic and diagnostic variables (soil moisture, stream flow, vegetation dynamics, etc.). These requirements are addressed by the comprehensive AMMA field campaign. Instruments have been deployed during the course of AMMA for the Long (LOP: 20022010), Extended (EOP: 20052007), and Special (SOP: 2006) Observation Periods. In particular, SOP measurements provide ancillary information needed to perform specific case studies, for example aircraft based measurements of thermal infrared temperature of the surface and atmospheric humidity along a latitudinal transect where significant spatial heterogeneities of soil moisture are observed [4]. The overall AMMA study domain, the location of the meridional transect, and the three main mesoscale observation sites are shown in Fig. 1.

Coordination of the land surface modelling activities in AMMA is supported by the AMMA LSM Intercomparison Project (ALMIP). It is an international effort conducted along the same lines as previous LSM intercomparison studies, such as the Rhône AGGregation Land Surface Scheme Intercomparison Project (Rhône-AGG [5]), but it focuses on West African land processes. ALMIP has the following main objectives: 1) intercompare results from an ensemble of state-of-the-art models, 2) determine which processes are missing or not adequately modeled by the current generation of LSMs over this region, 3) examine the LSM response to changing spatial scales, 4) develop a multi-model climatology of "realistic" high resolution (multiscale) soil moisture, surface fluxes, as well as water and energy budget diagnostics at the surface that can then be used by other projects within AMMA, 5) evaluate how relatively simple LSMs simulate vegetation response to atmospheric forcing on seasonal and interannual timescales, and 6) examine the impact of satellite-based forcing data compared to data

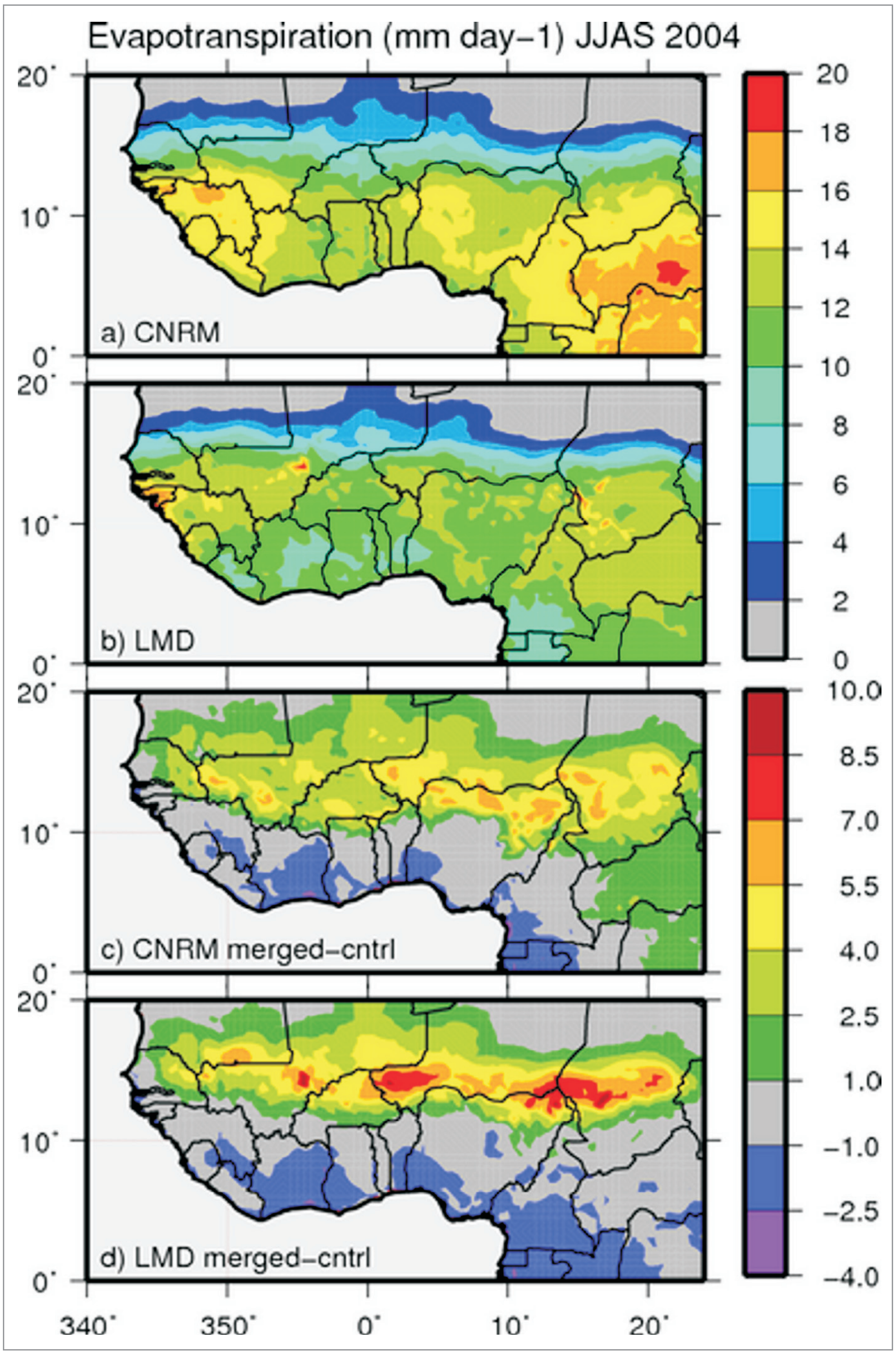

Figure 2. The evapotranspiration (Evap) simulated by two Land Surface Models from the Centre National de Recherches Météorologiques (CNRM) and the Laboratoire de Météorologie Dynamique (LMD) averaged over the monsoon season (June-Sept.) in 2004, using the merged/inferred (satellite-based product combined with numerical weather prediction, NWP, data) atmospheric forcings (panels a and b). The Evap simulated using the merged forcing less Evap produced using the control or pure NWP forcings are shown in panels c-d. The increased Evap in the northern part of the domain is associated with errors in the NWP data (a monsoon displaced too far south compared to satellite-based data).

from NWP models. The average evapotranspiration (*Evap*) simulated by two LSMs averaged over the monsoon season (June - Sept.) in 2004, are shown in Fig. 2a-b. Despite the same input forcings, the *Evap* (the critical link between atmosphere coupling and hydrology) is significantly different. The impact of replacing satellite-inferred precipitation and radiative fluxes with NWP (control) data is shown in Fig. 2c-d. Both LSMs show the displacement of the active precipitation zone to the north when using the inferred data, but the magnitude and spatal distribution of the *Evap* difference is quite different. The high atmospheric *Evap* demand combined with the water-limited precipitation regime should act to enhance LSM differences over the semi-arid portion of the AMMA domain.

In summary, there is a need to better understand land-atmosphere and hydrological processes over western Africa due to their potential feedbacks with the regional monsoon circulation. This is being addressed through a multi-scale modelling approach using an ensemble of LSMs which rely on dedicated satellite-based forcing and land surface parameter products, and data from the AMMA observational field campaigns. The far reaching goal of this effort is to obtain better understanding and prediction of the WAM which then can be used to improve water management and agricultural practices over this region.

Based on a French initiative, AMMA has been established by an international group and is currently funded by a large number of agencies, especially from France, the UK, the US and Africa. It has been the beneficiary of a major financial contribution from the European Community's Sixth Framework Research Programme. Detailed information on scientific coordination and funding is available on the AMMA international web site (https://www.amma-eu.org/).

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