Report on AMMA activities for CLIVAR

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AMMA achievements over the last 10 years

AMMA was launched in February 2002 in Niamey (Niger), and has represented the largest coordinated research effort into African weather, climate and environment ever attempted. Following its first phase (2002-2009), which was dominated by a large integrated field programme, AMMA is continuing with a further decade of research more strongly focused on the integration of weather and climate science with decision-making for the West African region. AMMA strives to improve our knowledge and understanding of the coupled West African monsoon (WAM) system and its variability and continues to emphasize daily-to-decadal timescales including climate change. Supported by WCRP, IGBP and WWRP, AMMA is motivated by an interest in fundamental scientific issues and by the societal need for improved prediction of the WAM and its impacts on West African nations. Substantial progress has been made during this past decade through strong international coordination of African, European and US scientists : (i) the deployment of long-term observation systems since 2001, and more far-reaching field campaigns between 2005 and 2007, with several periods of intense observation; (ii) an unprecedented multi-scale multidisciplinary database used across the world and mirrored in Africa; (iii) more than 600 papers in quality peer-reviewed publications, including 10 special issues; (iv) the organisation of international conferences (Dakar 2005, Karlsruhe 2007, Ouagadougou 2009, and more recently Toulouse 2012) bringing together an average of 400 researchers, and several summer schools. A more thorough review of this progress together with the plan for 2010-2020 is included in AMMA's 2nd International Science Plan, available on the AMMA website (http://www.amma-international.org). In terms of achievements for CLIVAR, AMMA highlights of particular note include :

Intraseasonal Variability: The intraseasonal time scale is critical in planning for agriculture, health and water-resources in West Africa, where resources are highly rainfall dependent. Two main timescales of variability have been identified in the WAM; around 15 days and around 40 days. The related modes have a regional scale and can strongly influence precipitation and convective activity. Their initiation and propagation are partly controlled by atmospheric dynamics, including teleconnections from the Indian monsoon (Fig 1; Mohino et al. 2011) and from the Mediterranean, and show some interactions with the land-surface over West Africa on these timescales. AMMA has begun developing monitoring of these modes in collaboration with African meteorological services, which offers a substantial opportunity to improve intraseasonal prediction in the future.

Monsoon Onset: The WAM has a distinctive annual cycle in rainfall that remains a challenge to understand and predict. AMMA researchers highlighted a rapid poleward shift in peak rainfall between the coastal region and the Sahel at the end of June, marking the monsoon onset there. Though inertial instability has been invoked to explain this shift, emphasis has also been given to a thermodynamic explanation of monsoon onset (Fig 2; Thorncroft et al. 2011) involving the seasonally varying surface conditions over the ocean (specifically the establishment of the cold tongue) and over the land (including the evolving heat low). AMMA continues to emphasize and implement observations in the Equatorial Atlantic and over the continent to support research on the monsoon including its onset.

Multi-annual Variability (interannual, decadal, climate change): The multi-annual timescale remains extremely important for West African societies. Research concerned with variability and predictability of the WAM at interannual timescales, multi-decadal timescales (i.e. the next 10 to 30 years) and in association with climate change scenarios (up to 2100 for example) remains crucial for AMMA. AMMA has remained focused on increasing our knowledge and understanding of key feedbacks in the coupled WAM system that control variability of the WAM on these timescales. There is a growing interest in analysing the CMIP5 datasets for the WAM region to carry out work concerned with decadal predictability and climate change. First CMIP5 analysis shows that a strong SST bias persists in the eastern tropical Atlantic, affecting the ability to predict interannual to decadal tropical Atlantic variability as well as climate change (Fig.3; Roehrig et al. 2013). The comprehensive set of observational data now available allows an in-depth evaluation of the WAM, especially through the use of high-frequency outputs provided by some CMIP5 models at selected sites along the AMMA transect. Most models capture many features of the WAM with varying degrees of accuracy. In particular, the simulation of the top-of-atmosphere and surface energy balances, in relation with the cloud cover, and the intermittence and diurnal cycle of precipitation demand further work to achieve a reasonable realism.

Land-Atmospheric Coupling: Research in AMMA has highlighted the atmospheric impact of soil moisture on space scales of 5 km upwards, and time scales of several days. Observational and modelling studies have shown how antecedent rainfall patterns affect new storms in the Sahel. The land feedback operates through various mechanisms, including a direct link to afternoon storm initiation from surface-induced mesoscale circulations (Fig 4; Taylor et al. 2011), and indirectly via a large-scale moisture transport in the nocturnal monsoon. The results suggest potential for significant improvements in weather forecasting through assimilation of satellite data. Intraseasonal variability in soil moisture and vegetation has also been observed, and seems to be coupled to propagating atmospheric modes discussed above. Monitoring of the surface conditions may therefore also contribute to improved intraseasonal prediction in the future.

References

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Future plans and issues in the coming 5 years

The 2nd International Science Plan has recently been launched and efforts must be made to build on the knowledge learned in the first phase in order to tackle the key scientific and societal problems that remain. Together with end-users and decision-makers, AMMA aims at developing and improving tailored tools and products to cope with hydro-meteorological and climate hazards, and on enhancing capacity building and training efforts in the context of climate and environmental change. Together with geophysical research, the research on the human dimension is key to drive adaptation and mitigation efforts, quantify the local and regional impact of human activities, and evaluate the contributions and limits of climate information in front of needs and livelihood strategies. For Phase 2 (2010-2020) AMMA hinges on 3 key interacting research themes: (i) interactions between society, environment and climate, which necessitates the second theme: (ii) study of predictability and improvement of meteorological, seasonal and climate forecasting, which itself requires the third theme: (iii) continued effort to enrich our knowledge of the monsoon system. From the perspective of CLIVAR, AMMA will address as priority areas :

Monsoon system: Improving dynamical models for weather and climate prediction requires continued improvements and refinements in our knowledge and understanding of WAM variability and predictability. The second phase of AMMA is focused on the essential feedback loops at three key scales: weather, intra-seasonal and multi-annual. In parallel, AMMA must work towards better understanding of the nature and causes of human induced climate change, particularly in regard to the disagreement between projections for the 21st century presented in the successive IPCC reports. Crossing these scale-based studies, AMMA also aims to extend the understanding of energy and water cycles of the WAM system, in particular through the second phase of ALMIP (AMMA Land surface Model Inter-comparison Project) activities.

Weather, seasonal and climate predictability and forecasting: The AMMA program will work towards improving our ability to make weather and climate forecasts, and increasing our confidence in climate change projections. The knowledge acquired from Phase 1 must be "pulled-through" to improve dynamical models used for weather and climate prediction and reduce some of their robust biases, in terms of weather (e.g. mesoscale convective storms, easterly waves and Kelvin waves, tropical cyclogenesis) and climate (intra-seasonal, seasonal and inter-annual to decadal) forecasting, including understanding and forecast of extreme events evolution, as well as climate change scenarios. One of the essential aspects of integrating the knowledge acquired into improvement of forecasting models is the reinforcement of links between the AMMA scientists and operational centres, represented by people working on model improvement and data assimilation. This will enable AMMA to provide contribution to climate services implementation in West Africa.

AMMA will continue to develop and implement its strategy for observations in order to support the whole range of these studies, with as the backbone the maintenance of environmental monitoring systems over the long term. Moreover, AMMA supports the implementation of new experimental campaigns for studying the key processes which were not sufficiently dealt with in the first phase, including especially those that relate to evolution of the Atlantic cold tongue (EU FP7 PREFACE project 2013-2017), the Saharan heat low (FENNEC on-going project), or the dynamics-aerosol-chemistry-cloud interactions in West Africa (EU FP7 DACCIWA project 2014-2018).

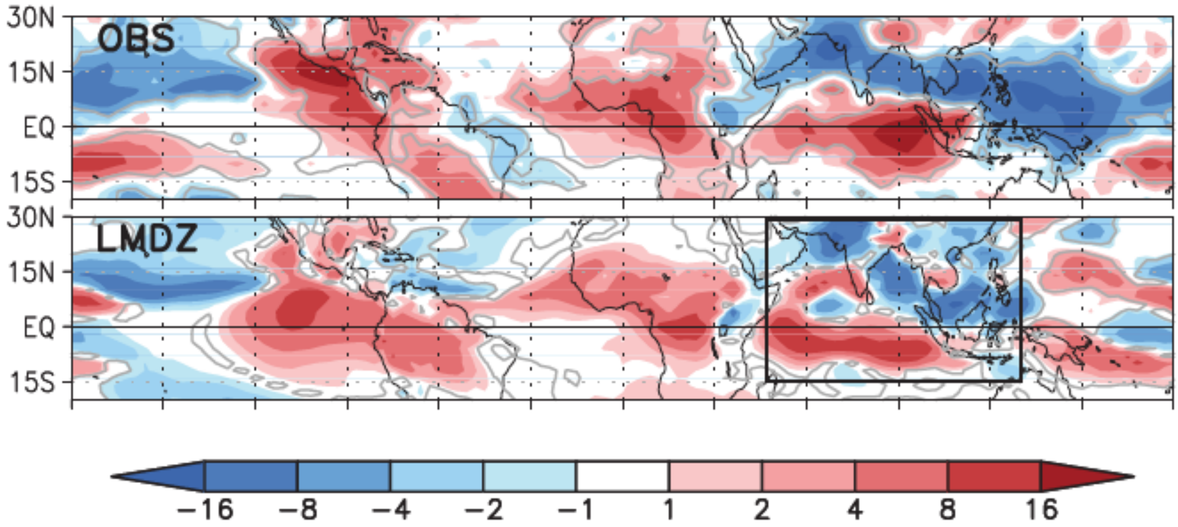

Figure 1: OLR anomalies present in observation and simulation, showing that the Indian monsoon intraseasonal variability has a significant impact on African monsoon convective activity.

Top panel : 1979-2008 summer composites of observed deseasonalized anomalies of OLR (Wm^{-2}) according to the active phase of the MJO signal over India (phase "8"). Grey contours mark 95% significant regions (according to a one sample t test).

Bottom panel : Same as bottom but for OLR simulated by the LMDZ atmospheric model relaxed toward reanalyses in the box domain.

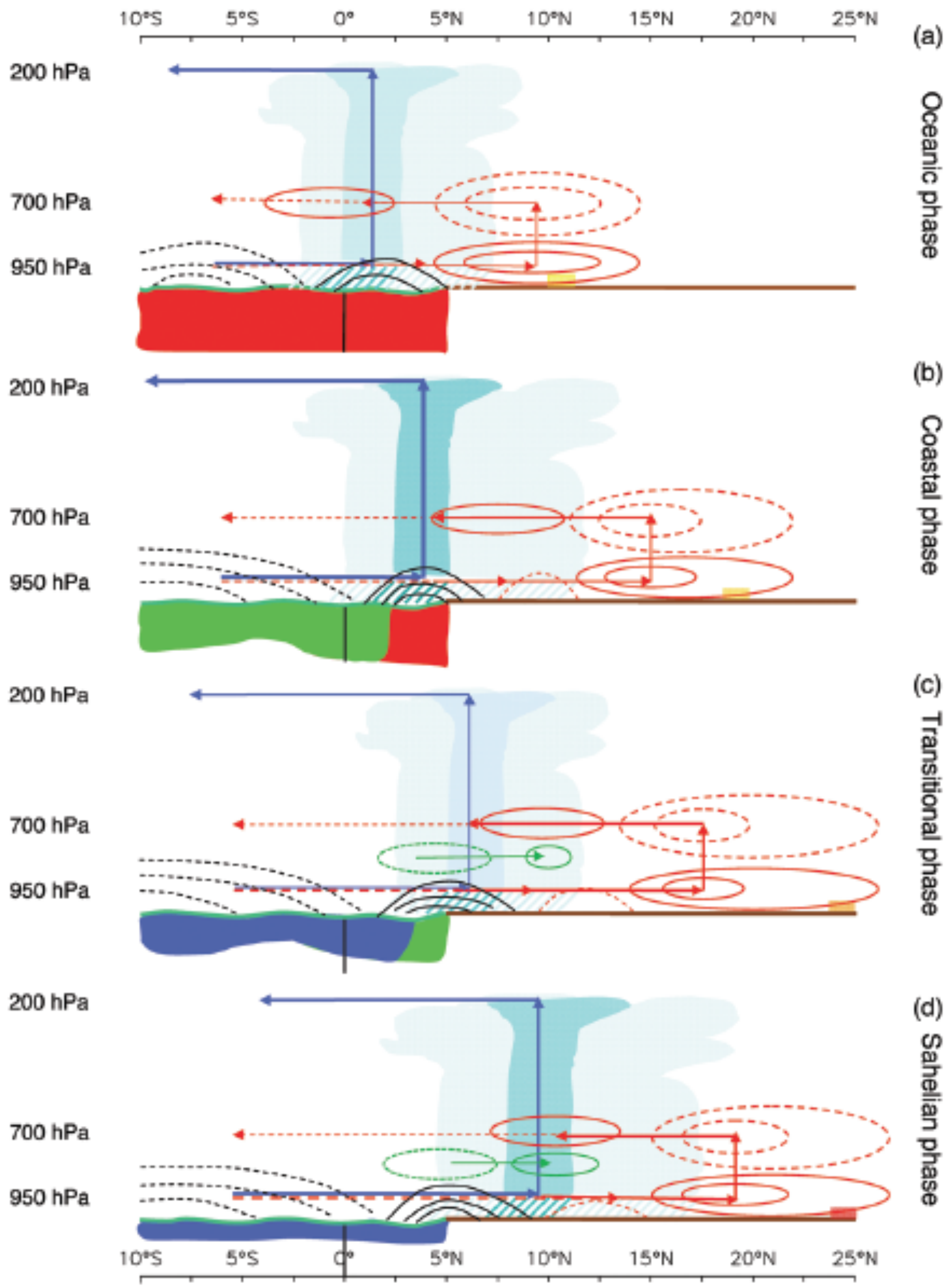

Figure 2: Schematic showing the four key phases of the annual cycle of the West African monsoon. Included for each phase are the following: the location of the main rain band (indicated by clouds and rainfall with peak values highlighted by darker shaded clouds and rainfall), the location of the Saharan heat-low (indicated by yellow, orange and red shading at the surface poleward of the rain band, with increased redness indicating increased intensity). Atlantic ocean temperature and associated mixed-layer depth (with decreased temperatures indicated by the red-to-green-to-blue transition). Moisture flux convergence maxima and minima (solid contours indicate moisture flux convergence and dashed contours indicate moisture flux divergence), and the deep and shallow meridional circulations (blue and red lines with arrows).

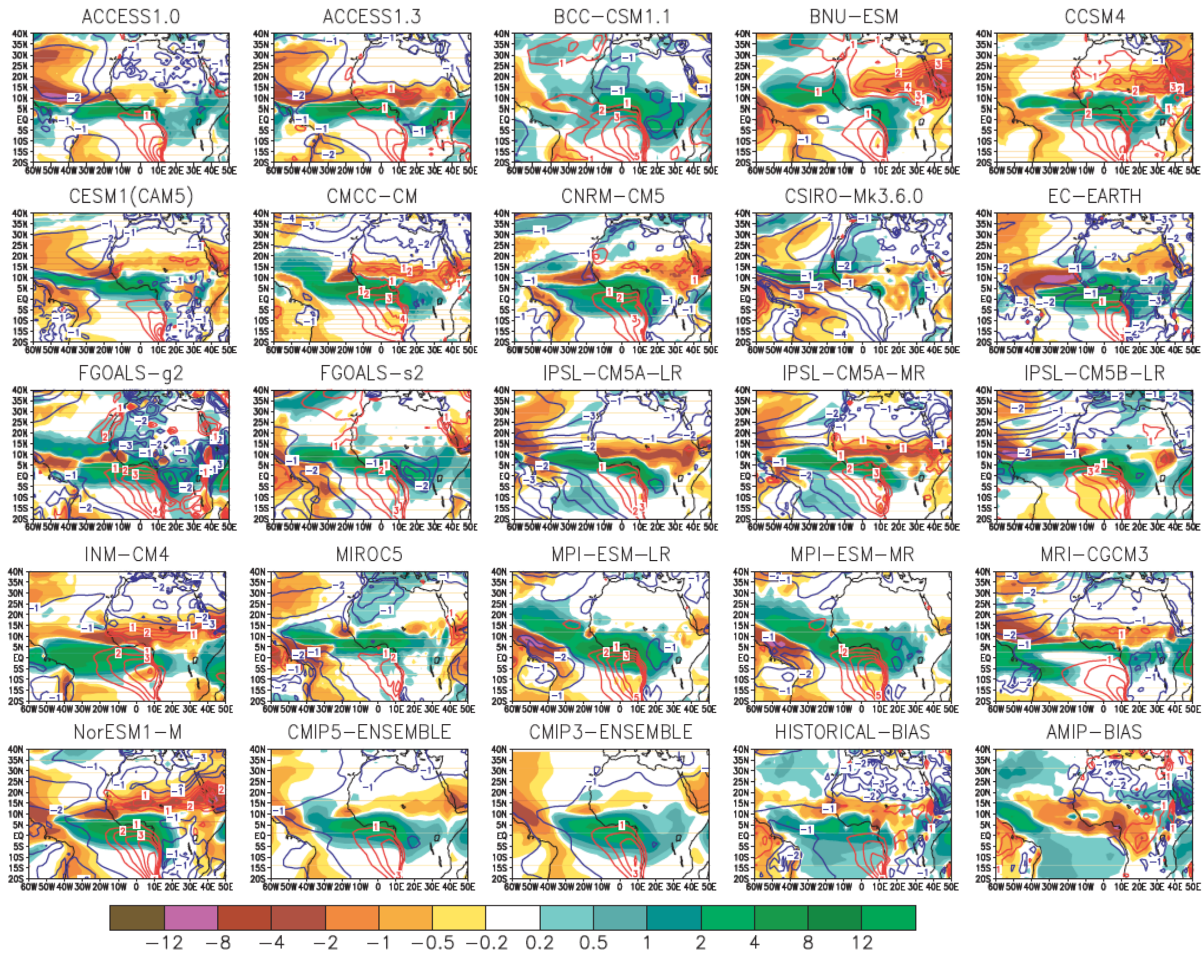

Figure 3: Difference between historical and AMIP simulations for precipitation (shaded, mm.day^{-1}) and 2-m temperature (contours every 1K with the 0 contour omitted) averaged over the JAS seasons of the 1979–2008 period. The CMIP3 and CMIP5 ensemble means are shown in the bottom row, as well as the CMIP5 ensemble mean biases of historical and AMIP simulations against the GPCP dataset for precipitation and the ERA-Interim dataset for the 2-m temperature.

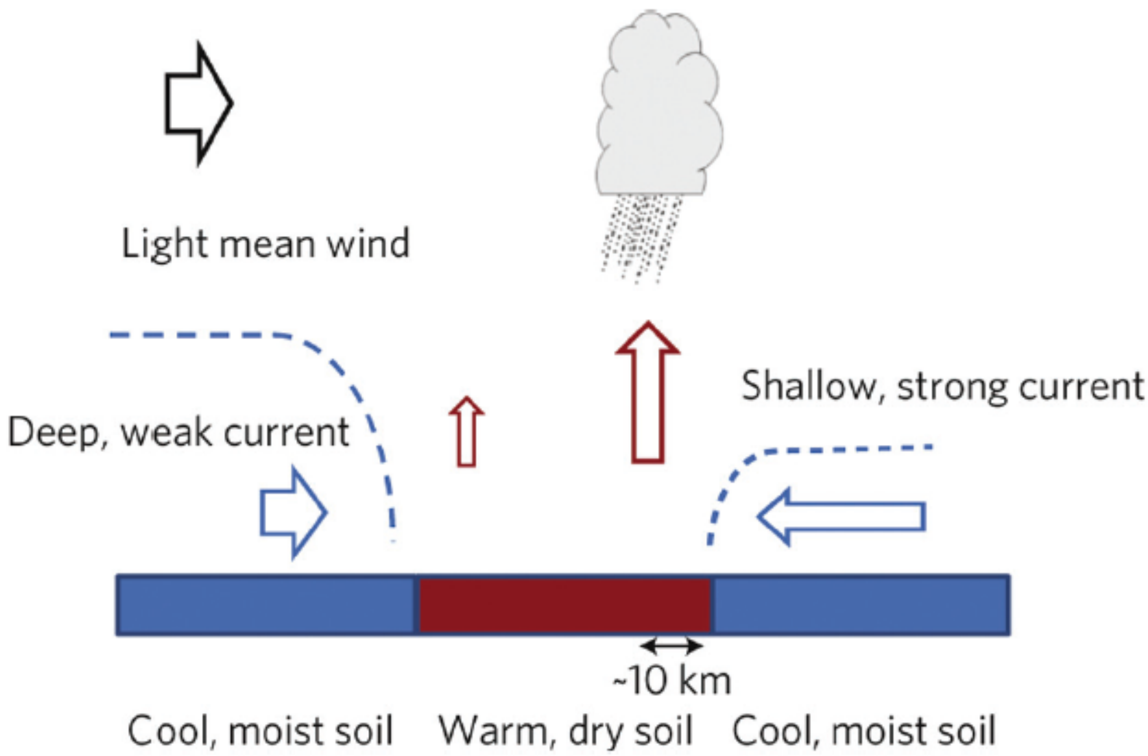

Figure 4: Schematic depicting the impact of soil-moisture heterogeneity on convective initiation.