African Monsoon Multidisciplinary Analysis (AMMA) : An International Research Project and Field Campaign

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1. Introduction to AMMA

African Monsoon Multidisciplinary Analysis (AMMA) is an international project to improve our knowledge and understanding of the West African monsoon (WAM) and its variability with an emphasis on daily-to-interannual timescales. 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. Vulnerability of West African societies to climate variability is likely to increase in the next decades as demands on resources increase in association with one of the World’s most rapidly growing populations. Vulnerability may be further increased in association with the effects of climate change and other factors linked to the fast growing population such as land degradation and water pollution.

Recognising the societal need to develop strategies that reduce the socioeconomic impacts of the variability of the WAM, AMMA will facilitate the multidisciplinary research required to provide improved predictions of the WAM and its impacts. The international AMMA project has three overarching aims:

(1) To improve our understanding of the WAM and its influence on the physical, chemical and biological environment regionally and globally.

(2) To provide the underpinning science that relates variability of the WAM to issues of health, water resources, food security and demography for West African nations and defining and implementing relevant monitoring and prediction strategies.

(3) To ensure that the multidisciplinary research carried out in AMMA is effectively integrated with prediction and decision making activity.
AMMA is endorsed by the World Climate Research Programme (WCRP) and continues to develop in association with CLIVAR and GEWEX\(^1\). AMMA has also been endorsed by two projects within International Geosphere-Biosphere Programme (IGBP): IGAC and ILEAPS. AMMA is working with other international projects and programmes to achieve its aims including GCOS, GOOS and THORPEX.

2. Motivation and Major Issues

The interannual and interdecadal variability of the West African monsoon (WAM) is well documented and has motivated considerable research efforts (e.g. Nicholson, 1981; Lamb, 1983; Folland et al, 1986; Fontaine and Janicot, 1996; Le Barbé et al., 2002). The dramatic change from wet conditions in the 50s and 60s to much drier conditions in the 70s, 80s and 90s over the whole region represents one of the strongest interdecadal signals on the planet in the 20\(^{th}\) century. Superimposed on this, marked interannual variations in recent decades have resulted in extremely dry years with devastating environmental and socio-economic impacts. Such variability has raised important issues related to sustainability, land degradation, and food and water security in the region.

We are currently hindered in providing skillful predictions of WAM variability and its impacts. There are still fundamental gaps in our knowledge of the coupled atmosphere-land-ocean system at least partly arising from lack of appropriate observational datasets but also because of the complex scale interactions between the atmosphere, biosphere and hydrosphere that ultimately determine the nature of the WAM. The monitoring system for the WAM and its variability is inadequate with many gaps in the standard routine

\(^1\) All acronyms referred to in the executive summary are included at the end of the summary
network and lack of routine monitoring of some key variables. While the next generation of satellites will undoubtedly help with routine monitoring and prediction efforts, more research is required to validate and exploit these data streams. Dynamical models used for prediction suffer from large systematic errors in the West African and tropical Atlantic regions (e.g. WCRP, 2000, Davey et al, 2002). Finally, there is a lack of integrative science linking the work on WAM variability with work on food, water and health impacts.

The WAM system provides an ideal framework for considering scale interactions in a monsoon system: it possesses pronounced zonal symmetry with characteristic jets and associated well-defined weather systems. Research on such scale interactions and in particular those linking dynamics and convection with the land surface will be relevant to other monsoon systems and is needed in order to improve coupled atmosphere-ocean-land models used for weather and climate prediction. In order to carry out this research extra observations are needed.

Further motivation for a research project concerned with WAM variability and predictability comes from recognizing the role of Africa on the rest of the world. Latent heat release in deep cumulonimbus clouds in the ITCZ over Africa represents one of the major heat sources on the planet. Its meridional migration and associated regional circulations impact other tropical and midlatitude regions, as is exemplified in the known correlation between West African rainfall and Atlantic hurricane frequency (e.g. Landsea and Gray, 1992). In addition to the large-scale interactions, we know that a majority of
hurricanes that form in the Atlantic originate from weather systems over West Africa (e.g. Avila and Pasch, 1991); however we know little about the processes that influence this and why only a small fraction of these “seedlings” actually become hurricanes. Tropical Africa is also the world’s largest source of atmospheric dust. Both the fire aerosols and dust play a major role in radiative forcing and in cloud microphysics, and thus are an important part of WAM system that requires study.

Finally, West Africa is also an important source region for natural and anthropogenic emissions of precursors to key greenhouse forcing agents (e.g. ozone, aerosols). For example, Africa contributes around 20% of the global biomass burning fires. Long-range transport of trace gases out of West Africa has important implications for the global oxidizing capacity of the atmosphere (which controls the level of many greenhouse gases), global climate change and the transport of key constituents (e.g. water vapour, ozone depleting substances) into the stratosphere.

A review of the present state of knowledge on the West African Monsoon and the related scientific questions to be addressed by AMMA are described in the International Science Plan (ISP). The ISP also includes a description of the strategy proposed to tackle these questions. The ISP is available on the international AMMA website at http://www.amma-international.org/science/docs/AMMA_ISP_May2005.pdf.
3. The AMMA Programme

3.1 A Multiscale Approach

To address the multiple scales that characterize the WAM the AMMA program is structured around 4 interacting spatial scales (see schematic below): (i) **Global scale**; the scale at which the WAM interacts with the rest of the globe; emphasis is given to improving our understanding of the role of global SST patterns on WAM variability; seasonal-to-decadal variability are the main time scales of interest (ii) **Regional scale**; the scale at which we consider monsoon processes and scale interactions; emphasis is given to improving our understanding of the interactions between the atmosphere, land and tropical Atlantic ocean (especially the Gulf of Guinea). It is important to study the role of land surface feedbacks on variability of the WAM at this scale including the key roles of vegetation and soil moisture. The annual cycle and seasonal-to-interannual variability are the main time scales of interest. (iii) **Mesoscale**; the scale of the typical rain-producing weather systems in the WAM. It is central for studying the variability of rainfields at the seasonal scale and the coupling between hydrology and the atmosphere at the catchment scale. (iv) **Local scale or sub-meso scale**. From an atmospheric point of view, this is the convective rain scale; it is central to the hydrology of the Sahel and of small watersheds to the south; it is the main scale of interest for agriculture.

AMMA emphasizes the importance of improved understanding of how these scales interact and combine to characterize the WAM and its variability, including how these interactions impact sources and transport of water vapour, aerosol and key chemical
species (e.g. key greenhouse gases, ozone and aerosol precursors) in the West African region and globally.

3.2 Integrative Science

While it is convenient and appropriate to describe the research plans in terms of the different spatial scales, it is essential, for an improved understanding, to study the scale and process interactions. The implementation of AMMA is designed in this spirit. The AMMA project integrates the scales at which the geophysical and human processes interact. Furthermore the various disciplines involved in the study of the WAM need to be integrated to achieve the three overarching aims. This approach has guided the structuring of the scientific objectives.

From the geophysical perspective, the fundamental science underpinning the AMMA project can be viewed as the various disciplines coming together within broader integrative science topics: i) the interactions between the WAM and global climate from a physical as well as a chemical perspective, ii) the water cycle of the WAM from the regional to the local scale and iii) the coupled atmosphere-land-ocean system and its multiple scales. To feed these integrative topics with sound disciplinary knowledge of the processes and their scale dependence detailed studies of the processes are needed: i) atmospheric processes with a focus on the convective processes which are key to the rainfall production, ii) oceanic processes as they contribute and depend on the WAM, iii) biophysical processes over the continent from the regional to the local scale and iv) aerosol and chemical processes in the atmosphere.
To study the human dimension of the variability and possible trends in the West African Monsoon AMMA aims to address the direct impact of the environmental conditions on three limiting conditions for the African societies: i) Land productivity, ii) water resources and iii) health impacts. This activity will be coordinated to achieve a better understanding of how weather and climate variability impact food security and human processes in the region.

To achieve the AMMA scientific objectives and to master the challenge of multi-scale and multi-disciplinary aspects, a consistent set of tools and methods adapted to the problem of the West African Monsoon will be used: i) models and data assimilation, ii) field campaigns, iii) satellite remote sensing and long-term atmosphere/land/ocean data collection and iv) data base. These activities are key to transferring knowledge from the geophysical community in AMMA to the activities in the human dimension. AMMA will strive to use the above tools and activities to collect and consolidate knowledge, integrate the knowledge and materialize the predictive skill gained with this knowledge.

3.3 The Field Programme

The AMMA field programme will provide enhancements to the current sustained observing system in West Africa and builds on the CATCH hydrological experiment that has been ongoing successfully in the region since 1997. The CATCH observational “window”, indicated in Fig. 1 by solid lines, includes 3 mesosites that sample contrasting environments across the marked north-south gradient in surface conditions. This “climate transect” is at the heart of the AMMA field programme. Extra in situ observations will be
made at the mesosites and along the climate transect within the broad CATCH window to address science issues at local-to-regional scales. In addition, AMMA will provide enhancements to the regional observing system over West Africa and in the Gulf of Guinea to support this analysis at regional scales and to extend the climate transect into the Atlantic, key for understanding the coupled WAM system.

AMMA is planned to be a multi-year project and involves 3 nested observation periods. The enhancement of observations during these periods will provide a unique opportunity to determine future operational monitoring necessary to improve weather and climate forecasts over the West African region. More than this, a high priority for AMMA is to establish this operational network of observations providing a visible legacy for the international AMMA programme.

- **The Long term Observing Period (LOP)** is concerned with observations of two types: (i) historical observations to study interannual-to-decadal variability of the WAM (including currently unarchived observations) and (ii) additional long term observations (2002-2010) to document and analyse the interannual variability of the WAM.

- **The Enhanced Observing Period (EOP)** is designed to serve as a link between the LOP and the SOP (below). Its main objective is to document over a climatic transect the annual cycle of the surface conditions and atmosphere and to study the surface memory effects at the seasonal scale. The EOP will be 2-3 year duration (2005-2007).

- **The Special Observing Period (SOP)** will focus on detailed observations of specific processes and weather systems at various key stages of the rainy season during three periods in the summer of 2006: (i) the dry season (Jan-Feb), (ii) Monsoon onset (15 May-30 June), (iii) Peak monsoon (1 July – 14 August) and (iv) Late monsoon (15 August-15 September).
More detailed information regarding the different field phases, including next year’s SOP, is available in the ISP and in the AMMA Implementation (see AMMA web site). Here we only briefly describe the different periods.

Central to the observing strategy for AMMA is the CATCH hydrology project. CATCH has established enhanced observations in the “CATCH-window” depicted in Fig. 3 to support the long-term monitoring of the surface component of the continental water cycle. It includes 3 mesosites that sample different environments along a climate transect.

The observing strategy for the EOP is to enhance the observations of the atmosphere, land and ocean along the ‘climate transect’ that includes the CATCH hydrology project. These enhancements include: (i) extra radiosoundings, (ii) new surface flux measurements along the climate transect, (iii) ground-based remotely sensed observations (e.g. radars, profilers), (iv) enhanced hydrological observations (underground water fluxes, soil moisture), vegetation, aerosol & trace gas monitoring and (v) ocean observations in the Gulf of Guinea to extend the climate transect into the ocean.

Embedded within the multi-year framework provided by the LOP/EOP is the Special Observing Period (SOP). Detailed studies of key processes, impractical to study in a multi-year framework, will be carried out within the SOP and are focused on enhancing the observations along the climate transect through provision of additional ground-based instruments (e.g. radars, lidars, sodars, high frequency radiosoundings etc), research aircraft and others (e.g. driftsonde, tethered ballons etc).
The special measurements proposed during the SOP, combined with those established through the LOP/EOP will provide the international community with an invaluable set of observations to investigate the multiple-scale interactions and processes that determine the nature of the WAM and its variability.

4. Implementation of AMMA

4.1 National and Pan-national projects (See http://www.amma-international.org/projects/index)

The international AMMA programme benefits from several national and pan-national projects. **AMMA-Africa** brings together scientists from many African nations and coordinates their contribution to AMMA. It is based on proposals made by teams in universities and operational and research centers. Compared to the other components of AMMA the emphasis in AMMA-Africa is more on impact studies. **AMMA-EU** is an Integrated Project funded by the European Union. It federates most of national activities in Europe and brings together the geophysical and socio-economical communities working in Africa. **AMMA-France** who initiated AMMA, is a project supported by all French research organizations involved in environmental sciences and covers most of aspects of AMMA. **AMMA-UK** is the sum of various projects associated with a NERC-funded consortium, bringing together the British AMMA community. **AMMA-US** gathered a number of American scientists to prepare a US proposal for AMMA. While this was not supported as one, DOE, NASA and NOAA are supporting several projects including some sub-projects that arose from this proposal.
4.2 International Coordination

AMMA aims to strengthen the international framework needed to facilitate interactions between researchers working in the different national and pan-national projects and ensure that the field campaigns are well coordinated to optimize the scientific impact of the observations. An international structure has been established to oversee and coordinate these efforts (See Fig. 4 below). The International Scientific Steering Committee (ISSC) will ensure the scientific integrity and coherency of the scientific objectives of AMMA and the fulfillment of the three overarching aims. The ISSC is under the control of the International Governing Board (IGB) to ensure that it fulfills its coordination role for AMMA. Implementation of the multi-year field campaign is the responsibility of the International Implementation and Coordination Group (ICIG). In addition, a permanent Project Office (PO) assists the ISSC & ICIG.

(i) Scientific Working Groups

For the scientific coordination the work of the ISCC is structured by 5 integrative science working groups (WGs) (Fig. 4) which take up 5 topics central to the aims of AMMA. 

WG1: West African Monsoon and Global Climate is concerned with the 2-way interactions between the WAM and the rest of the globe, especially as they relate influence the variability of the WAM and its global impacts. WG2: Water cycle is concerned with the processes involved in the water budget occurring through all scales regional-scale, mesoscale and local scale (See Fig 1). WG3: Land Surface-Atmosphere feedbacks is concerned with providing increased knowledge and understanding of the coupling between atmosphere and continental surfaces at regional and mesoscale. WG4:
Prediction of climate impacts is concerned with the 2\textsuperscript{nd} major aim of AMMA and will provide strong linkages between the work taking place on impacts and that taking place on observed variability and predictability of the WAM in WG1. **WG5: High impact weather prediction and predictability:** is a joint WG with THORPEX and is concerned with improving our knowledge and understanding of high impact weather over the West African continent, and its impacts on the tropical Atlantic and extratropics. Operational activities will be promoted including tailoring of forecast products for users, data impact and targeting studies.

**(ii) Implementation of Field Observations**

The implementation of the field programme is carried out through the establishment of task teams (TT) and support teams (ST). The TTs responsibilities are: i) to design an observational strategy for a given subset of scales/variables of interest, as identified to be needed to reach the scientific objectives of the present ISP; ii) to monitor and have final responsibility for deployment of relevant instrumentation. The TTs are composed of the PIs of the instruments planned to be deployed in the framework of the space/time scale covered by the TT. The ST responsibilities are: i) to act in support of TTs; ii) to look in more detail into operational matters and funding issues related to these “cross-cutting” actions; iii) to propose a scheme of operations to be agreed upon by TT leaders and to be submitted to the ISSC to verify that these schemes satisfy the needs of AMMA.
5. Final Comments

AMMA has been carefully conceived to improve our fundamental understanding of the West African monsoon and its societal impacts and to make sustainable improvements to monitoring and prediction of the West African environment. Our activities are embedded within a ‘Long-term observing period’ (LOP) structure, which will ensure that our intensive activities are directed towards systematic improvements in monitoring and prediction over the coming decades. We will develop and upgrade two important land-based atmospheric monitoring systems (for the upper air and surface fluxes), and over the LOP we will transfer responsibility for these networks to the local African agencies. In addition, ocean monitoring systems surrounding West Africa that have been shown to improve both weather and climate forecasts will continue to provide data to these groups. These networks of observations are of enormous value both to global prediction systems and to local forecasting systems, based in Africa.

Acronyms used in this document

CLIVAR    Climate Variability and Predictability
GEWEX    Global Energy and Water Cycle Experiment
IGAC     International Global Atmospheric Chemistry
IGBP     International Geosphere-Biosphere Programme
ILEAPS   Integrated Land Ecosystem – Atmosphere Processes Study
GCOS     Global Climate Observing System
GOOS     Global Ocean Observing System
THORPEX  The Observing System Research and Predictability Experiment
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References


Figure 1 Simplified schematic of key phenomena together with their associated space and time scales. The arrow is included to highlight the importance of scale interactions and transport processes in the WAM.
Figure 2 Implementation of AMMA: Integrative science for the geophysical (a) and human dimension (b) Integration from this knowledge through various tools and for the exploitation by impact studies (c)
Figure 3 Field implementation of AMMA observations based on nested networks. Circles indicated the atmospheric sounding network activated during the SOP.
Figure 4: International organization of AMMA