US contributions to the AMMA field campaign during 2006

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1. Introduction and overview of the international AMMA field campaign

The African Monsoon Multidisciplinary Analysis (AMMA) is an international project to improve 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. Over the past 50 years the West African change from wet conditions to much drier conditions is among the strongest inter-decadal signals of the past century. This drying trend coupled with marked interannual variations has had devastating environmental and socioeconomic consequences. Unfortunately, fundamental gaps in our observation, understanding, and modeling of this complex system have limited prediction skill. To bridge these gaps, AMMA adopts a multidisciplinary approach, involving substantial international collaboration that links observation, data analysis and modeling on a wide range of space and time scales. One of the primary objectives of AMMA is to address the land surface role on monsoon intensity, variability and predictability, making soil moisture observation and modeling a central goal.

The AMMA field program builds on the CATCH hydrological experiment, and provides enhancements to the current sustained observing system in West Africa. The Sahelian region has one of the strongest soil moisture – precipitation feedbacks in the world (Koster et al., 2004), indicating that improved soil moisture knowledge is likely to yield improved prediction. 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 program. 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. AMMA is a multi-year project with 3 nested observation periods, a long-term observing period (LOP), an enhanced observing period (EOP: 2005-2007) and a special observing period (SOP) in 2006; each was previously described in GEWEX News by Lebel et al (2003). 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, the SOP will support detailed studies of key processes, which are impractical to study in a multi-year framework. These are focused on enhancing the observations along the climate transect through provision of additional ground-based instruments (e.g. radars, lidars, sodars, high frequency rawinsoundings, etc), research aircraft and other platforms (e.g. driftsonde, tethered ballons, etc). Here we briefly describe the four sub-periods within the SOP.

- ***SOP-0: Dry Season (January - February 2006)***

  The SOP-0 measurements will concentrate on in-situ and remote sensing measurements of aerosols and their effects on solar and terrestrial radiation. These special observations will be used to validate (i) satellite retrievals of intrinsic aerosol properties that have recently been developed for atmospheric columns over land surfaces, (ii) aerosol modules that have been developed for inclusion in climate and numerical weather prediction models, and (iii) surface based retrievals of aerosol properties. In addition, concurrent aircraft, surface based and satellite observations of the radiation budget will allow synergistic assessment of radiation in the atmospheric column.

- ***SOP-1: Monsoon Onset (15 May – 30 June)***

  The focus of SOP-1 is on providing the necessary observations required to support analysis and understanding of the seasonal evolution of the low-level thermodynamic contrasts along the climate transect (including the Gulf of Guinea), their relationship with regional circulations (e.g. jets and direct circulations), and atmospheric and continental water budgets (at local to regional scale). Surface energy budgets over land and ocean are required to support this analysis including how these are impacted by evolution of the land surface (vegetation, soil moisture) and the upper ocean (mixed layer). Special observations will be made to support this analysis in addition to those provided by the EOP: (i) atmospheric boundary layer thermodynamic variables and winds over land and ocean will be measured by aircraft and boundary layer drifting balloons observations (in addition to rawinsoundings and surface flux measurements provided by the EOP), (ii) high resolution observations of the ocean mixed layer and atmospheric boundary layer will be made from a ship cruising in the Gulf of Guinea and (iii) additional moored buoys and drifters will be deployed to provide extra ocean surface observations extending the coverage provided by the ships.

- ***SOP-2: Peak Monsoon (1 July – 14 August)***

  A major objective of SOP-2 is to provide the observations needed to support mass, momentum and water budgets at the mesoscale (~100km). The SOP-2 is also the key period to focus on the multiple scale interactions between the surface conditions, synoptic environment, and propagating MCSs including the role played by microphysics on convection and how this is impacted by aerosols. The overall AMMA observing strategy over the continent during SOP-2 consists of an enhancement of the surface and atmospheric observations along the climate transect, including enhanced soil moisture, vegetation, and precipitation observations. This will be supported by observations from at least 4 aircraft, driftsondes (with dropsondes), and remotely sensed data from Doppler and microwave radars, sodars, and satellites. Through such enhancements the CATCH hydrology experiment will be developed into a 3D multi-scale observing system to support the analysis of the seasonal evolution of the coupled West African Monsoon (WAM) system, the diurnal cycle, African easterly waves (AEWS), embedded convective and mesoscale precipitation systems, and water, heat, and momentum budgets.

- ***SOP-3: Late Monsoon (15 August – 30 September)***

  The seasonally evolving surface conditions, low-level thermodynamic contrasts and associated regional circulations will continue to be observed during SOP-3 as the monsoon retreats equatorwards, although greater emphasis in SOP-3 will be given to the eastern tropical Atlantic just downstream of West Africa. The SOP-3 is also focused on how the WAM impacts the downstream tropical Atlantic both through providing the "seedlings" for tropical cyclones and through the export of trace gases and aerosols and their subsequent contribution to the global oxidizing capacity and radiative forcing on a global scale. The nature of the synoptic and mesoscale systems downstream of the continent will be observed through a combination of research aircraft operating out of Dakar, Cape Verde, and the Caribbean, and dropsondes from the driftsonde system (see 2.2(c) below) and two surface moorings deployed during SOP-1 (see 2.2(a) below).

More detailed information regarding the different field phases, including those provided by the LOP/EOP and this year's SOP, is available in the International Science Plan and in the AMMA Implementation Plan (see http://www.amma-international.org). We now describe the major US-facilities that will contribute to the SOP during 2006. US contacts for these facilities are provided at the end of this article.

2. Major US facilities

2.1 Enhancements to the Niamey mesosite, Niger

The US will support two major platforms in Niamey: (a) the ARM Mobile Facility and (b) the MIT C-band radar. A brief description of these deployments is provided here.

(a) ARM Mobile Facility

The ARM Mobile Facility (AMF) includes a comprehensive suite of instruments, including surface radiometers for both broadband and spectrally resolved fields, standard surface meteorological measurements, and active instruments for probing the vertical structure of the troposphere including a 95 GHz cloud radar, a Micropulse Lidar, and Radar wind profiler. The AMF has been making measurements at the Niamey airport and at an ancillary rural site 60km east since the beginning of January 2006 and will remain deployed there for 1 year. It is a key facility of the "Radiative Atmospheric Divergence using ARM Mobile Facility, GERB data and AMMA Stations" project (known as RADAGAST). RADAGAST will combine measurements made by the suite of instruments available from the AMF with measurements from research aircraft, the Geostationary Earth Radiation Budget (GERB) sensors, and the other enhancements made through AMMA to examine the radiation budget of the atmospheric column. Particular emphasis will focus on the effects of the high dust loadings during the dry season, and the abundant water vapor during the summer monsoon season.

(b) MIT C-band radar Doppler radar

Understanding the variability of the water cycle and associated rain-bearing systems in the two contrasting mesosites in Niamey and Oueme (Benin) along the climate transect (Fig. 1) is essential to improve our knowledge of the WAM. Both sites are supported by a unique array of hydrological and atmospheric measurements, and have precipitation measurements from the NASA TRMM satellite. Europeans are providing two radars in the Oueme region (RONSARD and an X-band). Europeans and Africans have also supported the establishment of two quadrilaterals of rawinsounding stations (akin to the intensive flux arrays in TOGA-COARE) centred on Niamey and Oueme (See Fig. 1), that will provide high frequency sonde launches to support the analysis of water, heat and momentum budgets. NASA has recently agreed to support the deployment of the MIT C-band radar in Niamey providing an essential but otherwise missing component to this observing strategy.

The MIT C-band Doppler radar will be deployed in Niamey for a minimum of 75 days starting in June 2006. The radar will provide reflectivity and radial Doppler velocity in full volume scans at 10 minute intervals on a continuous basis. Efforts are ongoing to deploy it for an additional year to sample two consecutive summers. The radar in Niamey will support analysis of (i) convection including intense MCSs in this region, key for a better understanding of the water cycle as well as the weather systems themselves; and (ii) hydrology and land-surface interactions (known to be particularly strong in this region, c.f. Koster et al (2004)). The analysis of the intense and electrically active MCSs will also be supported by the ZEUS lightning detection network that is now operating in the West African region (Chronis and Anagnostou (2006)).

(c) A Future Workshop

Given the NASA support for the MIT radar in Niamey and the substantial contribution from DOE-ARM for the AMF deployment, efforts are underway to organize a workshop to discuss, and coordinate where appropriate, the scientific efforts taking place in the US that are relevant to these deployments and the AMMA field program in general. The workshop would focus on land surface, water cycle, aerosol and radiation budget issues. Both DOE and NASA have indicated an intent to support this workshop. More information will be made available on the AMMA-US website during February (http://www.joss.ucar.edu/amma).

2.2 Downstream observations

Two major planned US activities downstream of the main AMMA continental region are: (a) NOAA R/V Ronald H. Brown and related observations during SOP-1 and SOP-2, and (b) Aircraft and ground-based observations during SOP-3.

(a) NOAA R/V RONALD H. BROWN and related observations

The NOAA *R/V RONALD H. BROWN* will perform two transects during the 2006 AMMA field campaign. The first leg (28 May – 22 June, SOP-1) will be along 23^{o}W from ~5^{o}S-15^{o}N ending with a 3 day stop in Recife (Brazil). One main objective of this first leg will be to service a French TAO Mooring currently deployed at the equator and to deploy two additional TAO Moorings along the transect (~5^{o}N and ~12.5^{o}N). In addition, oceanic (e.g. surface and subsurface temperature, salinity and current observations) and atmospheric (e.g. rawinsondes and in situ thermodynamics) measurements will be made along this initial leg to support regional analysis of the West African monsoon. The second leg (25 June – 21 July, SOP-2) will also be along 23^{o}W from 5^{o}S to 20^{o}N collecting ocean and atmospheric observations similar to those obtained during the first leg. These observations will support the regional analysis of the coupled West African monsoon system as well as the environment where African weather systems pass after leaving the West African coast (see below). In particular, they will support the study of mechanisms that influence the tropical Atlantic upper layer heat content (including SST) and the Saharan Aerosol Layer, both known to be important for summer monsoon rainfall and tropical cyclone development.

(b) Aircraft and ground-based observations during SOP3

NASA and NOAA aircraft will be coordinated to study the downstream evolution of precipitating convective systems, largely as this evolution pertains to tropical cyclogenesis. The NASA-AMMA (NAMMA-06) component will leverage off one or more airborne science platforms, satellite remote sensors (particularly the Tropical Rainfall Measurement Mission [TRMM] satellite), and ground-based instrumentation.

NASA anticipates that the DC-8 high altitude research aircraft will serve as the primary research tool for NAMMA-06 investigations. The DC-8 will likely base from the Cape Verde Islands and may be flown in coordination with one or more NOAA Hurricane Research Division aircraft operating in the central and eastern Atlantic basin. Approximately 120 flight hours will be available on the DC-8 for a four week period commencing September 1, 2006. NASA also anticipates conducting a ground-based scientific component with its polarimetric weather research radar (NPOL) and C-band Doppler weather radar (TOGA radar). NPOL will likely be based in Dakar, Senegal, along with the Senegalese S-band radar. Together these radars will provide an understanding of the transition of convective systems from continental to marine environments and the linkage to tropical cyclogenesis. Further, NASA is seeking to establish the TOGA radar on the Cape Verde Islands. One or more Aerosonde unmanned aerospace vehicles (UAVs) may be available for continuous monitoring of the oceanic planetary boundary layer and lower half of the Saharan Air Layer (SAL). The suite of ground based measurements in Cape Verde and Senegal, such as enhanced upper air soundings, lidar, flux tower and microwave radiometers will support the aircraft objectives on a continuous basis. These measurements will provide valuable experiments for African scientists/students and US graduate students (especially those from traditionally under-represented group- African and Hispanic Americans) in addition to contributing to SOP3 mission objectives

As part of the Saharan Air Layer Experiment (SALEX) investigations begun during the 2005 hurricane season, the NOAA HRD anticipates deploying the G-IV high altitude research aircraft and a single WP-3D Orion from Barbados in the Caribbean. Approximately 120 research hours will be available on the G-IV and 125 on the WP-3D during the period 1 July - 30 September, 2006. The G-IV and WP-3D will be used to provide in situ thermodynamic and kinematic profiles in and around developed AEWs, tropical cyclones, and the SAL using GPS dropsondes.

These downstream activities will also be coordinated with the driftsonde deployment (see below) and other European aircraft (e.g. French Falcon, British BAe 146).

2.3 Driftsonde

The driftsonde was developed by NCAR primarily in response to needs of the World Meteorological Organization THORPEX (The Observing System Research and Predictability Experiment) program (e.g., Shapiro and Thorpe 2004) The effort is a technical collaboration between CNES providing the ballooning expertise and NCAR providing the sounding (including deployment) expertise. The driftsonde operations during the AMMA SOP will be based in N'dajamena, Chad with daily launches during periods of interest. This location is well-suited to cover the West African region and also regions of hurricane genesis in the tropical Atlantic. Currently the driftsonde is funded for 8 missions carrying 40 sondes each. This AMMA-THORPEX collaboration will be the first driftsonde research deployment and will be useful for several AMMA and THORPEX research and forecast topics including: (i) characterization of the SAL and the ability of models to represent its evolution, (ii) numerical and observational studies of the impact of dry air on convection and tropical cyclogenesis, (iii) investigation into the interactions between convection and African easterly waves, (iv) studies of tropical cyclone genesis and efforts aimed to extend the accurate prediction of tropical cyclones in the medium range, and (iv) studies of the impact of targeted observations on weather system prediction.

3. Final Remarks

There are a number of other important US-contributions to this effort that we do not have space to describe in detail. For example, NCEP is collaborating with European NWP centers and with African forecasters to provide forecasts and training to support operations and in-the-field decision-making. Also, there are several other contributions to the field campaign that will be described on the AMMA-US website shortly (http://www.joss.ucar.edu/amma).

We believe that there is a great opportunity for researchers to contribute to the AMMA program. The planned workshop will be an opportunity to discuss these opportunities in more detail and we look forward to announcing something very soon.

US Contacts for Major Facilities:

ARM mobile facility:	Mark Miller (miller@bnl.gov)
	Peter Lamb (plamb@ou.edu)
MIT Radar:	Earle Williams (earle@ll.mit.edu)
Ronald H Brown:	Bob Molinari (Bob.Molinari@noaa.gov)
SOP3 Downstream:	Jeff Halverson (Halverson@agnes.gsfc.nasa.gov)
	Greg Jenkins (gjenkins@howard.edu)
	Jason Dunion (Jason.Dunion@noaa.gov)
Driftsonde:	David Parsons (parsons@ucar.edu)

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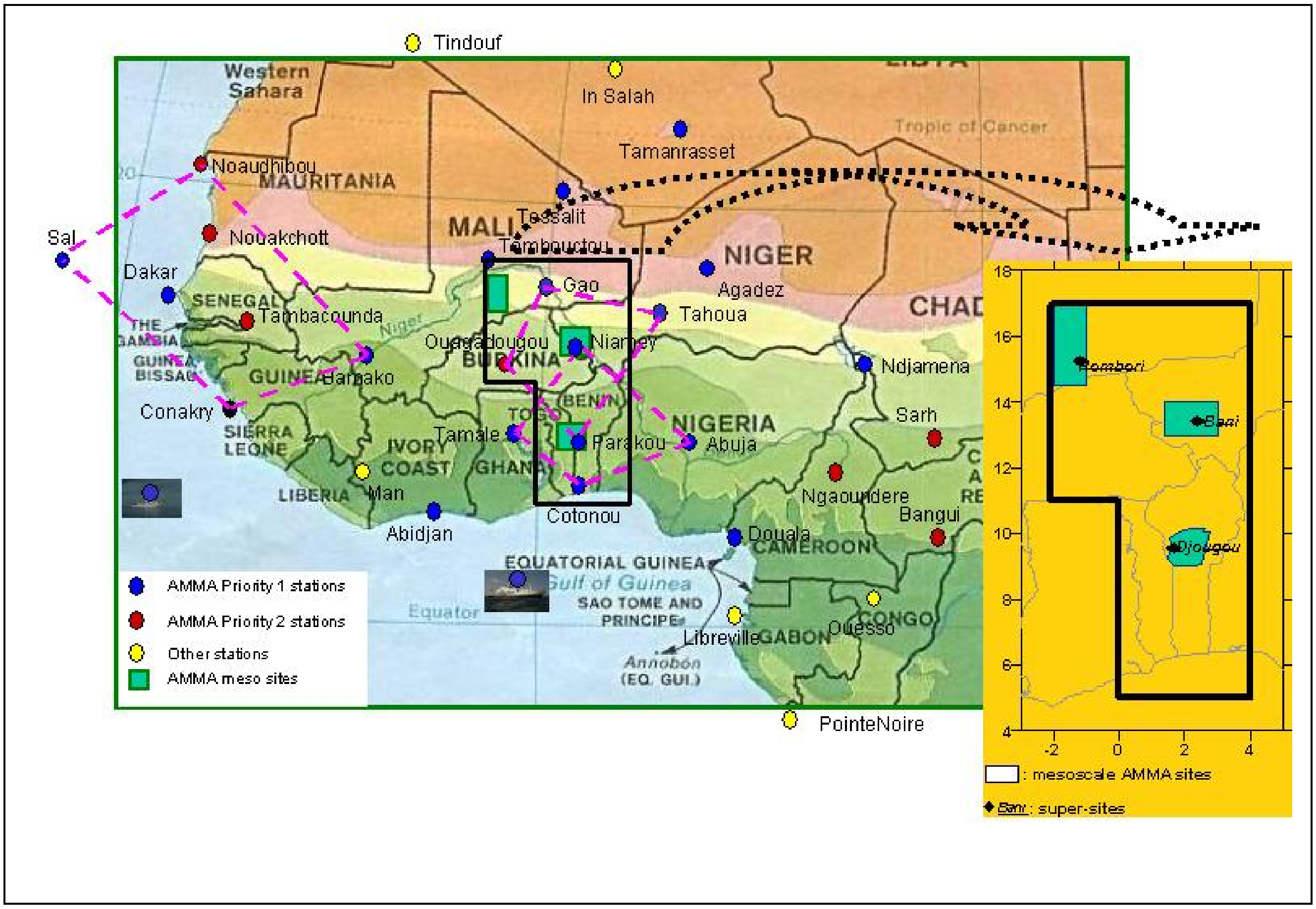

Figure 1 Field implementation of AMMA observations based on nested networks. Circles indicated the atmospheric sounding network activated during the SOP. A more detailed description of the radiosounding network is available on the AMMA International Coordination and Implementation Group webpages reached via the AMMA International website (http://www.amma-international.org)