APPENDIX A: *AMMA-International*

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.

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.

At this time scientists from more than 20 countries, representing more than 40 national and pan-national agencies are involved in AMMA. AMMA is endorsed by the World Climate Research Programme (WCRP) and continues to develop in association with CLIVAR and GEWEX. AMMA has also been endorsed by two projects within the International Geosphere-Biosphere Programme (IGBP): IGAC and ILEAPS. AMMA is also working with THORPEX to achieve shared goals concerned with high impact weather prediction and predictability. AMMA is working with other international projects and programmes to achieve its aims including GCOS and GOOS.

To achieve the aims of AMMA, substantial international collaboration and coordination are required. AMMA International aims to strengthen the international framework needed to facilitate interactions working in the different national and pan-national projects and to optimize the scientific impact of the observations. An international structure has been established to oversee and coordinate these efforts:

- The International Governing Board (IGB) is in charge of the institutional governance of AMMA.
- The International Scientific Steering Committee (ISSC) coordinates the AMMA Science.
- The International Implementation and Coordination Group (ICIG) is in charge of managing the instrumental deployment of AMMA.

IGB

The IGB carries the final responsibility of the AMMA program. It is responsible for approving the structure and implementation of AMMA. Members include representatives from the main funding agencies and stakeholders in AMMA.

ISSC

Recognising the societal need to develop strategies that reduce the socioeconomic impacts of the variability of the WAM, AMMA facilitates the multidisciplinary research required to provide improved predictions of the WAM and its impacts. The **ISSC** coordinates this through 5 international working groups (WGs). ***WG1: West African Monsoon and Global Climate*** is concerned with the 2-way interactions between the WAM and the rest of the globe, ***WG2: Water cycle*** is concerned with the processes involved in the water budget occurring through all scales *regional-scale*, *mesoscale* and *local scale*. ***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*** 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.

ICIG

The implementation of the multi-year field campaign is the responsibility of the ICIG under the control of the ISSC to ensure that it meets the scientific needs of the program. The implementation is carried out through the establishment of 10 task teams (TTs) and 4 support teams (STs). The TTs responsibilities are (i) to design the observing strategy, and (ii) to monitor and have final responsibility for deployment of relevant instrumentation. The STs responsibilities are (i) to act in support of TTs, (ii) to look in more detail into operational matters, and (iii) to propose a scheme of operations in collaboration with TT leaders.

More information about AMMA-International the IGB, ISSC and ICIG, past and future meetings, the international science plan and the international implementation plan can be found at http://www.amma-international.org. This website also provides links to the various national and pan-national projects that contribute to AMMA.

APPENDIX B: Breakout Summaries (and additional text on ocean-surface feedbacks)

Introduction to breakout sessions

Reports are provided from the breakout sessions in the order that they were presented at the workshop.

B.1 Water cycle: Paul Houser

The advection of atmospheric humidity, its transformation into precipitation, and the abundance of rain water over land is one of the defining measures of the West African monsoon. The role played by humidity advection, latent heat release and the associated energy transports and exchanges is of central importance for monsoon dynamics and its variability. A better understanding of the water cycle in the coupled oceanic, atmospheric and continental system, with the associated benefits for forecasting, is thus a major issue for AMMA.

During the EOP and the SOP, AMMA will provide detailed measurements of key parameters concerning the water cycle. From these observations, it will be possible to evaluate the different terms of the water budget for different aspects of the monsoon for the ocean, the land surface and the atmosphere. Integrated analyses with routine observations, satellite remote sensing measurements and numerical modeling should help to generalize the local results to the regional scale.

The substantial enhancements to the observing system along the AMMA "climate transect" (during the SOP in 2006) including key contributions from NASA (MIT Radar) and DOE (ARM mobile facility), and the expertise and interest of US PIs working on water cycle issues has motivated the coordination of AMMA-US contributions to optimize these contributions. The aims of this coordination are to identify key water cycle science issue foci, identify coordinated actions regarding the US contributions to address these science issues, and identify pathways to support the coordinated research.

The AMMA-US working group for the water cycle identified several research foci that would be well suited to their community, and would help fill critical gaps in the AMMA research program. The identified AMMA-US water cycle research foci are:

- Determine and predict the interactions between mesoscale, synoptic and monsoon systems, by identifying scaling structures and process connections (e.g., PV advection, adiabatic ascent, synoptic advection of temperature and humidity, surface processes, etc.).
- Routinely monitor and predict local-scale hydrologic connections and interactions with mesoscale and monsoon processes in order to improve resource allocation and outcomes in climate sensitive sectors.

The AMMA-US working group identified a number of areas that AMMA research agenda will need to be strengthened to address these research foci, as follows:

AMMA-US water cycle observation needs:

- Land surface moisture observations, including soil moisture, recharge, etc.
- Access to operational radars, raingage networks (NCEP may be able to establish access to these).
- Integrated atmospheric profiles from satellites (NASA A-Train, TRMM, CloudSat, etc.).
- Combined rain-radar mosaic, including raingauge correction, model and satellite data.

AMMA-US major water cycle science needs:

- Mid-term (weeks to months) forecast skill improvement focus (for decision support).
- Inclusion of energy & radiation in water cycle studies
- Coordination of downscaling efforts (consider non-linear feedbacks and uncertainty, and consider scale tradeoffs on water cycle processes).
- Improved coastal water cycle observations.
- Use lightning (using direct relationship with convection) to bridge between satellite observations and models.
- Enable better atmospheric prediction and local impacts, such as hydrological processes (rainfall spatial/temporal variability).
- Improved estimation of land moisture conditions (soil moisture, streamflow, groundwater) to establish land-atmosphere feedbacks, and to improve general water cycle understanding.

The AMMA-US working group identified a number of resources that it could specifically strengthened to address its research foci, as follows:

- Develop a AMMA Water Cycle data integration activity:
    - Include remote sensing, in-situ observations, and model predictions
    - Leverage on existing programs that integrate data: CEOP
    - Common formats, quality control, easy access interfaces, error assessment and combined data products, “one-stop data shop”, estimate all elements of water budget (HAPEX-SAHEL good example).
    - “Optimal” or “best” data will need to be assessed as each time/space scale and application.
- Tools exist and can be readily applied to study interactions between mesoscale, synoptic and monsoon systems (i.e. cloud resolving models, mesoscale models, and appropriate observations).
- Combined deterministic and stochastic approach could help to address local-scale hydrologic connections & impacts with mesoscale and monsoon systems.
- Establish crosscutting working groups, perhaps based on scale interactions, to enable links between water cycle and other important processes (such as carbon cycle or land-surface hydrology).
- Recommend a international AMMA water cycle workshop.
- Establish a AMMA-US water cycle team coordination on establishing support and funding.

Finally, the AMMA-US working group identified some potential funding sources for the ideas above. Generally, since there is no official U.S. program for funding the research above, it is thought that the working group will need to propose compelling AMMA science to existing (non-AMMA) programs. Some working group success has been realized with various NSF proposals, and it is expected that NOAA may be willing to support some AMMA research. NCAR has a small water cycle, university focused effort that may be leveraged. Finally, it was suggested that we contact international programs (USAID, State Dept., etc.).

B.2 Radiation-aerosol: Peter Lamb and Mark Miller

B.2.1 Funded Research Contributing to AMMA

There are several funded projects that directly or indirectly address AMMA objectives funded by the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA). The projects funded by DOE are all associated with the deployment of the Atmospheric Radiation Measurement Program's Mobile Facility (AMF) in Niamey, Niger, Africa during 2006. The AMF Site Scientist (Dr. Mark Miller) is currently engaged in research associated with the impact of dust on radiation and cloud microphysics. A post-doctoral associate (Dr. Kirstie Stramler) has been funded by the AMF Site Scientist to engage in specific research associated with the AMMA-related deployment in Africa. In addition, Dr. Tom Ackerman of the Pacific Northwest National Laboratory is funding work to compute a broadband heating rate profile in collaboration with the University of Reading, England (Dr. Anthony Slingo) using unallocated ARM Chief Scientist funding. This leftover funding expires at the end of the current fiscal year. The University of Reading will continue this work by employing a doctoral student and research associate using funds from the Geostationary Earth Radition Budget (GERB) and SERVI (Visible, IR and Water Vapor Imager) Science Teams. The NOAA Environmental Research Laboratory (ERL) is currently mentoring the AMF Aerosol Observing System and will be submitting a proposal to examine data from multiple AMF deployment locations, including Niger.

There is a substantial effort by NASA to fund AMMA-related projects in the area and radiation and aerosols. NASA Radiation and Dynamics funded five of ten submitted proposals during the last open call. The funded proposals include a project to transport a mobile radiation site to Cape Verde for the NASA-AMMA (NAMMA) project and place a Micropulse Lidar (MPL) in Senegal. Another of the funded proposals enables the NASA airborne cloud radar to be deployed on the DC-8 during NAMMA. Dr. Mian Chen will be simulating the NAMMA period with an aerosol transport model and Dr. Christine Chu will work with satellite data in a project to detect aerosol over land. Dr. Wei Kuo Tau will perform regional simulations in support of NAMMA. The NASA MAP-05 and MAP-06 projects will also contribute to AMMA. The MAP-05 project (Dr. Bill Lapenta) was designed to forecast hurricanes using a one-quarter by one-quarter degree grid. This year, the MAP-06 project will be modified such that the emphasis is expanded to include new science, rather than exclusive emphasis on operations. NASA funds Dr. Rachael Pinker to examine large-scale radiation budgets. She is studying the radiation budget of West Africa and operates a radiation site in Nigeria, southwest of Niamey, Niger, where the AMF is deployed. Her primary focus is the poor treatment of aerosols in global scale models.

There is research into atmosphere-ocean coupling is being conducted by the University of Miami (Dr. Erica Key). While this research is not AMMA-specific, measurements with relevance to the AMMA project are being made by NOAA funded investigators aboard the RV Ronald H. Brown. The thrust of this research is on the role of Sea Surface Temperatures (SST) in the atmosphere-ocean interaction process. These offshore measurements and the various on-shore measurements should present a relatively comprehensive view of the entire monsoon circulation (Niger to the tropical Atlantic). Most of the funding for these efforts is derived from satellite validation projects.

B.2.2 Scientific Interests

The Radiation and Aerosol Working Group maintains a diverse scientific interest with respect to AMMA.   A list of specific scientific questions as communicated during our breakout session is:

a. What are the respective roles of local biomass burning and transport of plumes from other parts of the region in modulating the radiation budget?
b. How much aerosol experiences wet deposition and what is the chemical composition of the rainwater?
c. What are the respective roles of dust and biomass burning in modulating the radiation heating rate profile in West Africa?

B.2.3 Unmet Measurement Needs

The Radiation and Aerosol Working Group identified a number of desired measurements that currently missing from the AMMA, NAMMA, and AMF projects. This list includes the following:

a. Spectral measurements of surface reflectance
b. Separate measurements of the scattering and absorption properties of biomass burning and dust components
c. Discrimination of locally generated and advected aerosol
d. Spectral scattering properties of the dust
e. Ice Nuclei
f. Soil Moisture Measurements (we are unclear about the distribution)
g. UV Measurements at the ARM Mobile Facility (UV radiation has been suggested as is link to disease in West Africa)
h. Oxidation of Ozone (are the characteristics different in extreme heat)
i. Rainwater samples from Niamey

B.2.4 Programmatic Considerations

There is a fundamental lack of coordination between the modeling and observational efforts in the US-AMMA program. While this type of interaction is difficult in most circumstances, lack of a solid funding base for the US-AMMA program makes it particularly acute in the current situation. At minimum, we need a master list of measurement and modeling efforts on a web site with contact information.

We identified several scientific gaps that need to be addressed. There is gap between the Radiation and Dynamics communities. We need to understand the links between clouds and large-scale dynamics and aerosols and the monsoon circulation. There is also a link between aerosols and the water cycle that bears further investigation.

Aerosols, clouds, and the accompanying radiative heating rate profile are at the core of the links with larger scale dynamics and the water cycle. Toward this end, our group recommends that this group should be dispersed into the other groups so as to improve the implied scientific links.

B.3 AMMA downstream (tropical cyclogenesis): Jason Dunion and Greg Jenkins

The downstream component of AMMA will include a number of aircraft, ground-based, and satellite assets from NASA, NOAA, the United Kingdom, and France. Coordination between these various research efforts is considered an important element of the downstream component of AMMA. The following describes these key research activities and how they will contribute to the overarching goals of downstream AMMA:

1. AIRCRAFT

a. North Dakota DC-8

- **Deployment Strategy**: The DC-8 will be based in Sal, Cape Verde from 15 August to 15 September and will be mission ready from 18 August to 13 September. A total of 8-12 research missions are anticipated during this period. The decisions regarding whether or not to fly over the African continent and whether or not the launching of dropsondes will be permitted over the land are still being discussed.
- **Science Objectives**: The main objectives of the DC-8 will be to investigate 1) the evolution of AEWs, 2) precipitation processes, especially comparative observations in continental vs. maritime regimes, and/or in clean vs. dusty environments, 3) composition and vertical structure of the Saharan Air Layer, 4) under-flights of the NASA A-Train satellites
- **Onboard Instrumentation**: Diode laser hygrometer (DLH); High Altitude MMIC Sounding Radiometer (HAMSR); LASE Differential Absorption Lidar (aerosol and water vapor profiles); Diode Laser Hygrometer (High Resolution H2O, RHw, RHi); In Situ Aerosol Sensors (Dry Size, Optical Properties, Number Density, Volatility);
- **Aircraft Specifics:** Missions will likely be flown at levels between 0.3 km (1000 ft) and 12 km (41,000 ft) and flight durations will be ~5-8 hours, depending on the science objectives for each mission. Dual aircraft coordination is possible with the BAe146 (when possible) in the eastern North Atlantic and possibly over the African continent.

Coordination with downstream aircraft operating in the western and central North Atlantic (NOAA G-IV and P-3 Orion) is also planned, though these missions will not be conducted in the same airspace.

b. NOAA G-IV

- **Deployment Strategy**: The NOAA G-IV will deploy to Barbados and possibly St. Croix or Bermuda on a case-by-case basis. Two to three deployments are anticipated, with two flights per deployment.
- **Science Objectives**: The G-IV will conduct NOAA/HRD's Saharan Air Layer Experiment. The primary objectives of this experiment are to 1) better understand how the SAL's dry air, mid-level easterly jet, and suspended mineral dust affect Atlantic TC intensity change and 2) include the moisture information from the GPS dropsondes in operational parallel runs of the NOAA Global Forecast System (GFS) model. The impact of this data on the GFS initial/forecast humidity fields and its forecasts of TC track and intensity will be assessed.
- **Onboard Instrumentation**: GPS dropsondes; flight-level thermodynamic and kinematic data
- **Aircraft Specifics**: Missions will be flown at ~12-14 km (~41,000-45,000 ft) and flight durations will be ~6-8 hours. Approximately 25 dropsondes will be launched during each flight. Dual aircraft coordination is planned with the P-3 (when possible) and downstream coordination is planned with the DC-8, UK BAe146, and French Falcon-20 that will be operating in the eastern North Atlantic and over the African continent.

c. NOAA P-3 Orion

- **Deployment Strategy**: One NOAA P-3 Orion will deploy to Barbados and possibly St. Croix or Bermuda on a case-by-case basis. One to two deployments are anticipated, with two flights per deployment.
- **Science Objectives**: The P-3 Orion will conduct NOAA/HRD's Saharan Air Layer Experiment and Tropical Cyclogenesis Experiments on a case-by-case basis. The primary objectives of these experiments are to 1) better understand how the SAL's dry air, mid-level easterly jet, and suspended mineral dust affect Atlantic TC intensity change 2) test prevailing hypotheses relating to top-down vs. bottom-up development of TCs, and 3) document aspects of the mesoscale and synoptic-scale environments of incipient disturbances to identify characteristics necessary in TC genesis.
- **Onboard Instrumentation:** GPS dropsondes; Aircraft Expendable Bathythermographs (AXBTs); Stepped Frequency Microwave Radiometer (SFMR); C-Band lower fusalage (LF radar); X-Band Tail Doppler Radar; Flight-level thermodynamic and kinematic data
- **Aircraft Specifics**: Missions will be flown at ~3-6 km (~10,000-20,000 ft) and flight durations will be ~8-10 hours. Approximately 25 dropsondes will be launched during each flight. Dual aircraft coordination is planned with the G-IV (when possible) and downstream coordination is planned with the DC-8, UK BAe146, and French Falcon-20 that will be operating in the eastern North Atlantic.

d. UK BAe146

- **Deployment Strategy:** The UK BAe146 will be based in Dakar from 21-28 August.
- **Science Objectives**: The UK BAe146 will be conducting the Dust Outflow and Deposition to the Ocean (DODO) Experiment. The primary objectives of this experiment will include investigating aerosol microphysics, aerosol radiative impacts, air chemistry, and aerosol deposition rates.
- **Onboard Instrumentation:**

- **Aircraft Specifics**: Missions will be limited to below 6 km (20,000 ft) altitude with durations of 4-4.5 hours. A limited number of GPS dropsondes (1-2) will be launched per flight and missions are planned for both over the ocean and the African continent. Coordination between the BAe146 and DC-8 aircraft is anticipated.

e. French Falcon-20

- **Deployment Strategy:** The French Falcon-20 will be based in Niamey from 01-15 September and subsequently based in Dakar from 16-30 September.
- **Science Objectives**: The main objectives of these research missions will include investigating MCSs: their microphysical and dynamic properties, their interaction with the large-scale environment, and their role in tropical cyclogenesis.
- **Onboard Instrumentation:**
- **Aircraft Specifics**: The FF-20 will operate at flight altitudes of up to 11 km (35,000 ft) with flight durations of 3.5 hr (~800 km range). Plans include launching ~6 dropsondes during microphysics focused missions and ~16 dropsondes during flights focused on MCSs. Coordination with downstream aircraft operating in the western and central North Atlantic (NOAA G-IV and P-3 Orion) is also possible, though these missions will not be conducted in the same airspace.

2. Ground Based Observations

a. Driftsondes

- **Deployment Strategy:** Driftsonde operations will likely be based in Niger with operations commencing on 15 September. The driftsonde and dropsonde control centers will be located in Toulouse, France and plans include deploying sondes twice per day (at standard times, 00 and 12 UTC) plus on command to meet specific scientific needs.
- **Science Objectives**: The main research and forecast objectives of the driftsonde deployments include (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.
- **Instrument Specifics**: Currently the driftsonde is funded for 8 missions carrying 40 sondes each. The balloons will fly at ~50 hPA and take of order 8 to 15 days to go from Africa to the Caribbean, spreading out to cover latitudes between ~5 N to ~25 N. Plans do not include overflying the Caribbean or the American continent so the balloons will be brought down prior to reaching these areas.

b. MIT Radar

- **Deployment Strategy:** MIT radar operations will be based in Niamey and will begin in June and continue for at least 75 days.
- **Science Objectives**: The MIT radar will support analysis of 1) convection including intense MCSs in this region, key for a better understanding of the water cycle as well as the weather systems themselves; and 2) hydrology and land-surface interactions (known to be particularly strong in this region).
- **Instrument Specifics**: The MIT radar will provide reflectivity and radial Doppler velocity in full volume scans at 10 minute intervals on a continuous basis.

c. N-Pol Radar

- **Deployment Strategy:** N-Pol radar operations will be based in Dakar, Senegal and will

- **Science Objectives**: (i) investigate precipitation systems (e.g. MCSs) and antecedent conditions in the transition region (over Senegal) between land and ocean, and the connection to tropical cyclogenesis; (ii) Provide support for aircraft and radar operations (DC-8, FF-20) over Senegal and the adjacent Atlantic and define uncertainties associated with TRMM precipitation estimates.
- **Instrument Specifics**:

d. TOGA radar

- **Deployment Strategy:** TOGA radar operations will be in Praia, São Tiago in the Cape Verdes from August 15-September 15, 2006
- **Science Objectives**: Characterize the mesoscale circulation and accompanying precipitation and thermodynamic structures of convective systems associated with easterly waves, especially those embodying organized cyclonic flow features.
- **Instrument Specifics**: Coordinated DC-8 in situ (thermodynamic & microphysical) and dropsonde data are critical to place TOGA radar observations in context and to better understand the evolution of these systems. Optimal sampling will be within 100 km of the radar site. Support for coordinated DC–8 operations could perhaps be extend to ~200 km

The following PIs have been funded under NAMMA:

1. Bruce Anderson; NASA Langley Research Center; Water Vapor and Aerosols (DC-8)
2. Edward Browell; NASA Langley Research Center; Water Vapor and Aerosols from the LASE LIDAR (DC-8)
3. Paul Bui; NASA Ames Research Center; In situ meteorological and turbulent measurements (DC-8)
4. D. Allen Chu; JCET/UMBC; Effects of dust radiative and microphysical properties on precipitation and energy budgets (A-Train, modeling)
5. Robert Cifelli; Colorado State University; radar-based studies of convection, AEWs, and TCs (TOGA, N-pol, and MIT radars)
6. Kerry Cook; Cornell University; modeling TC genesis (MM5, WRF, QuikSCAT, TRMM, AMSR-E, DC-8, surface-based onservations)
7. Michael Douglas; NOAA/NSSL; Evolution of AEWs to TCs (DC-8, satellites)
8. Leonard Druyan; Columbia University; Mesoscale analysis of AEW and TC structure from climate model simulations and NAMMA observations (TRMM, QuikSCAT, Aqua, Terra, and SSM/I satellites, NCEP and ECMWFF global analyses, RM3, GCMs)
9. Jason Dunion; University of Miami; Effects of the SAL on TC intensity change/model forecasts of TC track and intensity (G-IV, P-3 Orion, and DC-8; GOES, Metesosat-8, and Aqua, Terra, and SSM/I satellites; GFS, GFDL, and WRF models)
10. Michael Goodman; NASA MSFC; Data and information system to support project coordination/decision support and collection/archiving/dissemination of data to support NAMMA
11. Andrew Heymsfield; UCAR; microphysical measurements and analysis to characterize the microphysical and cloud-active aerosol properties of AEWs/MCSs (DC-8)
12. Eastwood Im; JPL; Dual Frequency Airborne Precipitation Radar (APR-2) for studying processes/microphysics/and dynamics of precipitating convective systems (DC-8)
13. Jack Ji; UMCP; GSFC SMART and COMMIT facility for studying the MBL, SAL structure/radiative effects, radiation budgets, and cloud/dust aerosol/trace gas/precipitation interactions

14. Everette Joseph; Howard University; Precipitation processes and TC genesis using data from the N-Pol radar and surface-based networks (RAOBS, N-Pol, rain gauges, flux sites), and TRMM
15. Tiruvalam Krishnamurti; FSU; Modeling of TC genesis from AEWs (DC-8, TRMM, Aqua, Terra, SSM/I, WRF model)
16. Bjorn Lambrigsten; JPL; Investigating TCs using HAMSR (High Altitude MMIC Sounding Radiometer, vertical profiles of temperature/water vapor/liquid water and precipitation estimates (DC-8)
17. William Lau; NASA GSFC; Studies of the AEJ, SAL and TC genesis (GEOS-5 model, NAMMA observations, satellite observations)
18. Paul Lawson; SPEC Incorporated; impacts of aerosols cloud microphysics, transition of convective systems from the continental to maritime (DC-8: cloud particle imager (CPI) and 2D-S stereo probe)
19. Francis Schmidlin; NASA GSFC/Wallops Flight Facility; upper air measurements to study AEWs and convective storms (enhanced rawinsonde network in the Cape Verdes)
20. David Starr; NASA GSFC; development of MCSs, MCVs in AEWs (DC-8, sounding data, satellites)
21. Earle Williams; MIT; transition of AEWs from continent to ocean (VLF lightning detection networks and Doppler radars)
22. Liguang Wu; NASA GSFC; influence of the SAL on TC genesis (NAMMA data, A-Train/TRMM, WRF/MM5 models)
23. Edward Zipser; University of Utah; properties of convective clouds (TRMM, data assimilation, global model analyses)

Ramesh Kakar is the NASA program manager for NAMMA, Ed Zipser is the lead mission scientists for NAMMA. Robbie Hood, Jeff Halverson, Dave Starr and Gerry Heymsfield are mission scientists for NAMMA. Mike Gaunce will be project manager in Sal during NAMMA. Gregory Jenkins is helping to coordinate NAMMA with other AMMA activities.

B.4 Climate variability and change: Allesandra Giannini and Bob Molinari

B.4.1 Funded research that will contribute to AMMA, including source of funding:

PIs /Affiliation	Project Title/ Description	Calendar Years	Funding Agency
i) R. L. Molinari R. Lumpkin C. Schmid NOAA/AOML	Deployment of 4 Atlas moorings as a component of PIRATA and data collection during buoy servicing cruises along 23°W	2005 –ongoing	NOAA
ii) R.L. Molinari R. Lumpkin S. Garzoli M. Baringer	Maintenance of surface drifter, Argo float and high density XBT networks	Ongoing	NOAA

G. Goni C. Schmid NOAA/AOML			
iii) Chris Thorncroft Anantha Aiyyer University of Albany	Role of the WAM on Atlantic Tropical Cyclone Variability	ends 2006	NOAA
iv) Chris Thorncroft Philippe Peyrille University of Albany Chidong Zhang University of Miami	Shallow meridional circulations and Saharan Heat Low: their roles in the tropical Atlantic variability	2005-2008	NOAA
v) Chris Thorncroft Gareth Berry Susanna Hopsch Ademe Mehonnen University of Albany George Kiladis NOAA/ESRL Nick Hall IRD/Grenoble	Multiscale analysis of African easterly waves	2005-2008	NSF
vi) Chris Fairall NOAA/ESRL	Role of surface fluxes and cloud/ precipitation in eastern tropical Atlantic		NOAA
vii) Edward Vizy Kerry Cook Cornell University	Regional Modeling of AWD and Tropical Cyclogenesis	2007-2008	NASA
viii) Gregory Jenkins	International Research Experiences for Students during the AMMA 2006 field experiment.	2006-2009	NSF

B.4.2 Scientific priorities of interested PIs and how they address gaps:
Priorities were not established but descriptions of both funded and non-funded AMMA related projects were given and are summarized below. Current gaps are given here and in the 'required coordination section'.

(i) Monsoon processes
Role of SST on evolution of the WAM

Role of stratus deck on evolution of the WAM
Scale interactions – weather/jet interactions and impacts on WAM and
Evaluation of heating profiles (from radiosonde observations) and their impact on the WAM circulations

(ii) Variability and predictability of the WAM
Mechanisms that force SST variability….
Variability of weather systems (mesoscale and synoptic)
Proxies for rainfall to extend the numerical record (including tree rings)

(iii) Global impacts of the WAM
Impacts on tropical cyclone variability via changes in the environment (e.g. shear, SAL, weather systems)

B.4.3 Define the required coordination among U.S. AMMA investigators that will increase knowledge and understanding.

Two types of coordination were discussed, scientific/technical and operational/administrative, both of which will enhance the ability of U.S. PIs to meet their AMMA objectives.

(i) Scientific/technical coordination required:
Integrate land-sea-atmosphere studies to develop an integrated characterization of the WAM and the systems that propagate downstream into the eastern Atlantic from the WAM.
Develop heating profiles for through coordination with international community
Coordinate integration of model-observations comparison studies.
Coordinate calibration/validation studies of satellite products (e.g., wind data, SST data, aerosol data, etc.).
Coordinate estimates of surface flux fields.
Coordinate generation of time series of aerosol distributions.

(ii) Operational/administrative coordination required:
Reduce duplication between U.S. and non-U.S. PIs in such areas as satellite calibration, model-data comparisons, etc.
Generate list of funded projects.
Develop U.S. AMMA data base (underway).
Generate list of U.S. AMMA publications.
Promote integration of individual projects, both funded and to be proposed.

B.5 Land-surface-atmosphere feedbacks: Fatih Eltahir and Eric Wood
A group of about 10 US, European, and African scientists, with common interest in land-atmosphere feedbacks and processes, met during the breakout session to discuss coordination of research efforts in this area under the US-AMMA umbrella. Professor Elfatih Eltahir (MIT) has volunteered to co-ordinate the activities of this group.

As a background information, we recognize that none in the group had any AMMA-specific funding, only one researcher has an active project working in the AMMA region, however a majority of the attendees could apply their current research to the AMMA region.

The following potential contributions by U.S. scientists were identified and discussed:

B.5.1 Remote sensing retrieval algorithms and products for use and for comparison to European products:

(a) Radiation, short wave/longwave.
(b) Surface temperature (MODIS LST)
(c) Precipitation. (CMORPH, TRMM-3B42, etc.)
(d) Atmospheric soundings (NOAA and NASA sounders)
(e) Soil moisture(TRMM/TMI and AMSR-E microwave brightness, Total soil water column from GRACE)
(f) Ground-based RADAR precipitation. A gridded, gauge-Radar precipitation product based on all available radars in the AMMA domain is needed. This requires calibration of the radars and integration of the radars.

Aerosols (products consistent with the above radiation, atmospheric and land surface products)

B.5.2 Modeling of coupled Land-atmosphere system

Strong US community, is recognized in this area, however they somehow need a funding opportunity to collaborate in AMMA. It was also agreed that European research tends to be hydrologic/BL process-oriented (smaller space-time scales), while US research tends to look at more integrated, large scale factors. Therefore collaboration between the two groups offers broader insights, especially the up-scaling from process scales to synoptic scales. There is a need for in-depth analysis of process-scale observations and modeling studies and the relations from these analyses to similar analyses from large-scale models (Both through inter-comparison studies and diagnostic studies.) For these activities, the access to AMMA data is critical. The suite of models used should include both research and operational models.

B.5.3 Dynamic soil moisture and Dynamic vegetation studies

AMMA scientific plans include studies on satellite-based vegetation and land cover classification. There is extensive expertise in the U.S. in this area. An important scientific issue is the accurate simulation of the seasonal cycle of the atmosphere, vegetation and their coupling. AMMA plans for a two-year modeling study, but there is expressed interest to look at a century scale modeling study of dynamic vegetation and its impact on climate variability. Inter-comparison studies of vegetation dynamics (seasonal and inter-annual) are emphasized.

B.5.4 Data assimilation of remote sensing, and in-situ observations.

Strong US community is recognized in this area and is encouraged to collaborate with AMMA European scientists. Both communities are rather small, so collaboration is critical. AMMA needs a coherent description of the water, energy and vegetation system that can only be provided through remote sensing, and integrated with in-situ observations and models through a data assimilation activity. A U.S. effort is needed to develop this integrated system in collaboration with AMMA.

B.5.5 Value added products for impact studies and societal needs.

An underlying scientific issue is the role of land states (vegetation, soil moisture) on the west African monsoon and its predictability. This would include the predictability of related hydrologic variables like soil moisture, stream-flow, crop production, water pools, and human health impacts.

B.6. Ocean-surface atmosphere feedbacks (text provided by Erica Key)

The air-sea flux component of AMMA-US builds upon almost a decade of mooring data and underway measurements conducted in the equatorial Atlantic. The PIRATA (Pilot Research Moored Array in the Tropical Atlantic) buoys, deployed on the equator and 3 meridional spurs (38W, 23W, and 10W), have collected surface meteorology, radiation, and bulk oceanic temperature as far back as 1997. Data are transmitted via ARGOS and are available in near-real time. The buoys are maintained by a combination of US, French, and Brazilian science teams, with yearly cruises to service and redeploy each mooring as necessary. Each of these 20+ research cruises includes underway air-sea flux measurements, as well as hydrographic, biophysical, and upper air observations for complete characterization of the atmospheric boundary and oceanic mixed layers.

During the AMMA timeframe, a cruise of the NOAA R/V Ronald H. Brown will deploy two new moorings along the 23W spur at 4.5N and 11N. An eddy flux correlation system funded and operated by NOAA (Chris Fairall, ESRL) will measure air temperature, humidity, pressure, wind speed and direction in the tropical Atlantic. Additional NOAA-funded sensors deployed to support these flux measurements include a ceilometer, microwave radiometer, 915 MhZ wind profiler, PMS Lasair-II for fine-mode aerosol spectra, and a C-band radar for precipitation characterization.

These measurements are supported by significant instrumental contributions from the University of Miami, Howard University, and the University of California at Santa Barbara. The UM group (P. Minnett, B. Albrecht, K. Voss) provide:

- radiometrically-derived sea surface skin and surface air temperatures from the Marine-Atmospheric Emitted Radiance Interferometer
- surface meteorology from a Coastal Environmental Systems' Weatherpack
- incident radiation from an Eppley pyrgeometer and pyranometer
- 2-channel Radiometrics microwave radiometer retrievals of cloud liquid water
- aerosol optical thickness, direct, diffuse, and narrow-band radiances from the Portable Radiation Package

- hemispheric sky imagery for determination of cloud type, level, and amount
- bulk sea surface temperature measurements
- aerosol and cloud backscatter from a MicroPulse Lidar
- MOUDI aerosol size and chemical fractionation
- aerosol number concentration from an Aerodynamic Particle Sizer
- X-band radar for cloud profiling
- up/downwelling radiation profiles of the upper mixed layer.

Howard University contributes additional atmospheric characterization through measurements of the Saharan Air Layer and cross-equatorial ozone advection:

- Microtops sun photometer
- Vaisala ozonesondes
- Cascade impactors
- RAAS high volume aerosol sampler
- Laser particle counter
- A multi-frequency rotating shadowband radiometer
- Trace gas samplers
- CCN counter.

Both NOAA and NASA-funded radiosondes will be launched along the cruisetrack to maximize coverage during Saharan dust outbreaks, passage through the ITCZ and over upwelling zones, and in the presence of aerosol-convective cloud interaction. These radiosondes will be incorporated into the GTS and made available to NCEP and ECMWF. Discussions have been held with both modeling entities to perform parallel data denial runs in which the shipboard radiosondes will be removed from the analysis to determine the impact of the increased atmospheric sampling on forecast accuracy.

Much of the UM data collection effort is funded by NASA; so, the data will be used in validation exercises of MODIS, AVHRR, AMSR-E, AIRS, and, with links to ESA, AATSR. The primary concern is sea surface temperature validation, which is a necessary component of air-sea flux determination. Additional validation of satellite atmospheric retrievals of temperature and moisture over the AMMA region from AIRS will be conducted using M-AERI derived products, radiosondes, and output from the data denial NWP runs. Proposals to several US funding agencies have also been made to test and analyze M-AERI-based retrieval products of aerosol and cloud microphysical parameters with data collected aboard the *Ron Brown* as well as with a M-AERI on the French vessel *L'Atalante* (EGEE-3) and a land-based AERI in Niamey. These and other active measurements of cloud and aerosol made during the cruise could provide a comprehensive tropical dataset for validation of the newly-launched CALIPSO and CloudSat NASA A-Train sensors.

Links to other oceanographic cruises being conducted by French (EGEE) and German (METEOR) AMMA teams during SOP-1 and SOP-2, as well as historical and future cruises within the 2-year AMMA EOP, lend a seasonal and interannual context to the flux and boundary layer measurements. A long-term NOAA commitment to the

PIRATA buoys at 23W provide continued opportunities to sample fluxes in the tropical Atlantic beyond the AMMA timeframe. However, the collaboration with French, Brazilian, and German partners in sampling the tropical Atlantic gives even broader access to flux measurements made by international teams on other vessels during both the monsoon onset and dry season when US vessels may not be available for buoy maintenance. Within the context of those international oceanographic networks is a close relation with African universities and scientists that fulfills AMMA nation-building and information exchange requirements with host countries. On board the *L'Atalante*, for example, NASA-funded US collaboration with researchers from Cote d'Ivoire, Ghana, Togo, Benin, and Nigeria allowed for information and expertise exchange, leading to the verification and future publication of sensible and latent heat fluxes in the Gulf of Guinea.

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Appendix D: NCEP contributions to AMMA

NOAA's National Centers for Environmental Prediction (NCEP) has committed computing and infrastructure resources to support the AMMA field program activities. The Climate Prediction Center (CPC) at NCEP will provide real-time monitoring and forecast support to AMMA using the NCEP Operational Global Data Assimilation System (GDAS), the Global Forecast System (GFS) at approximately 37.5 km resolution, and the Coupled Forecast System (CFS). Products will be focused over Africa and downstream over the tropical Atlantic basin and distributed via a web page. The CPC's African Desk will coordinate with the CPC Development Branch to implement this as a real-time monitoring web page. The Africa Desk will host visiting scientists from West African nations prior to, during and after the AMMA field campaign. These experienced meteorologists from West Africa will help interpret products and provide support to the AMMA Forecast Operations Center for the SOP, EOP and LOP programs. The CPC's Africa Desk also plans to participate in real time forecast briefings who gets the briefings and for what purposes should be given here in collaboration with the Niger's Direction de la Meteorologie Nationale, the African Centre of Meteorological Applications for Development (ACMAD), Meteo France, the UK Met Office, and other African and non African institutions. The CPC's Africa Desk is working with The Observing System Research and Predictability Experiment (THORPEX) through the NCEP's Environmental Modeling Center (EMC) to define the scope and range of products needed in short and medium range weather/climate monitoring and predictions for West Africa. For further information, please contact: Dr. Wassila Thiaw at wassila.thiaw@noaa.gov or visit the CPC web page at www.cpc.ncep.noaa.gov and click on Africa.