AMMA Working Group 2: Water cycle

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6 Sept 2005: Revised version (ISSC feedbacks, Synthesis for sections 3 and 4, Membership)

1. Introduction

Understanding the global water cycle and the rate at which it may be changing due to natural or human induced factors is critically important to advancing global change research.
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 availability of water is indeed one of the most limiting parameters for life, agriculture and economic development in the Sahel. 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.

A complete view of the water cycle is, however, a difficult task since it would require the availability of data concerning a very large number of processes at a great variety of spatial and temporal scales. Many of these processes are physical, but there is also a significant influence from biological and chemical phenomena. Most importantly, coupling between many of these processes induces complex feedbacks, which can either amplify or reduce the impact of oceanic, atmospheric or continental perturbations on water availability.

The lack of field experiments on the African continent has weakened our ability to understand the underlying processes associated with water cycle. During the EOP and the SOP, AMMA will provide detailed measurements of key parameters concerning the water cycle. An exhaustive documentation of all phenomena occurring at different scales during the West African monsoon is clearly out of reach, but special observations during AMMA will concentrate on the sampling of statistically representative events at specific locations. From these data, 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.

2. Key questions from the ISP relevant to WG2

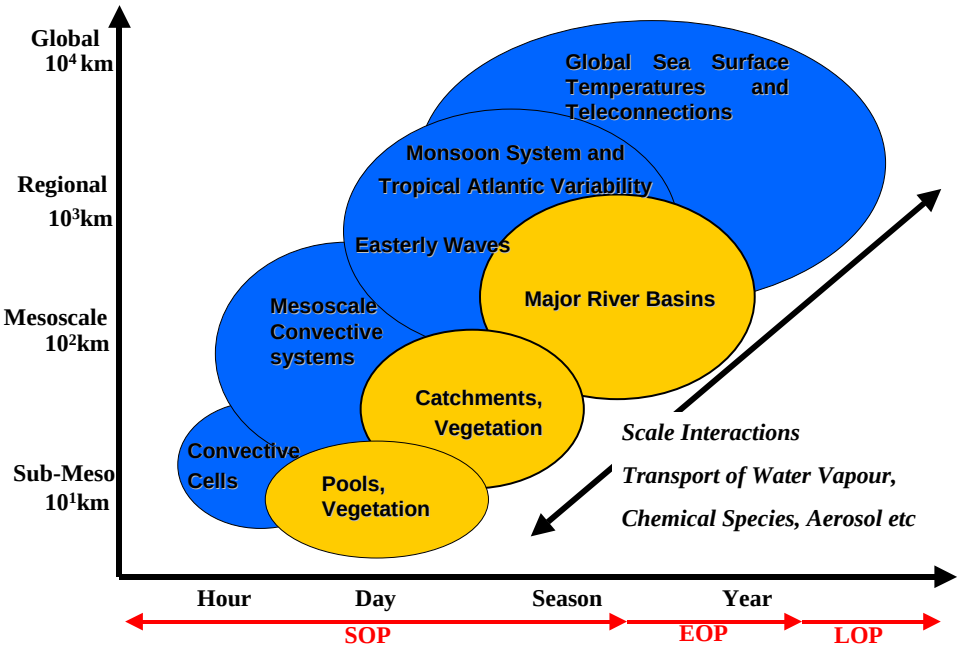

Figure from ISP: Simplified schematic of key phenomena together with their associated space and time scales. The arrow is included to highlight the importance of scale interactions and transport processes in the WAM.

Regional scale

- What are the atmospheric and surface factors that determine the spatial pattern of rainfall deficits or excess over West Africa
- What are the key scales of rainfall variability over the region? How do these scales vary on seasonal-to-decadal timescales and to what extent are they predictable?
- What are the sources and sinks of water vapour in the region and how does the water vapour distribution impact convection and its variability? How much is transported into the region and how much is recycled?
- What is the variability of surface water and energy budget? How important is this variability to understand the water cycle? How does this variability impact the variability of low-level gradients of dry and wet static energy in the boundary layer?
- What are the relevant physical processes that determine the coherent diurnal cycle of the heat low circulation and its impact on the continental water budget?

Mesoscale

----MCS----

- How does the MCS structure determine the pattern of rainfields at the ground ?
- What is the typical rain rate associated with MCSs in West Africa, specially the Sahel?
- What are the effects of MCSs on the synoptic circulation in terms of heat, moisture and momentum? What are the environmental conditions, including the state of the PBL, prior, during and after the passage of MCSs? How does the degree of organization modulate these effects ? How do the differences between stratiform and convective regions evolve between initial, mature and decay stages of MCS? What are the differences between systems north and south of the AEJ?
- What fraction of the rain is stratiform versus convective and what is the duration/intensity of the types of precipitation?
- How does the space-time variability of rainfall associated with convective systems impact the variability of the surface water budget ?

----Other clouds----

- Need to consider also other important clouds for water cycle (shallow convection, upper level outflows). Not presently in the ISP

----budget/balance----

- With which accuracy can we determine the various components of the continental water budget and what are the errors involved in closing the 3D water balance?
- At which time scale and with which degree of accuracy is it possible to estimate the evapotranspiration at the mesoscale?
- Is there a significant feedback of the continental surface on the dynamics of the convective system and can this in turn create persistent patterns in rain fields and impacts on vegetation, soil moisture and texture spatial distributions?
- To what precision is it possible to close the surface water balance depending on the size of a catchment?

Local scale

----hydrology----

- How does vegetation degradation act to enhance or reduce the runoff coefficients and can thus mitigate the impact of rainfall deficit?
- How does the geology contribute to the various components of the water budget and to the partition between fast and delayed responses of the rivers ?
- To what extent can we evaluate the deep infiltration and evaporation terms at the local scale so as to be able to close the water balance of small watersheds ?

Downscaling & Upscaling (Link with WG4)

- Is it possible to identify scaling properties in the field of variables that display the strongest spatial variability (i.e. convective structures, rainfall, soil moisture, …) ?
- How can these scaling structures, when they exist, be used in desegregation or aggregation algorithms?
- To what extent can a field available at a given resolution be used at a higher spatial resolution, either directly or through desegregation techniques ?

- How can the errors inherent to coarse resolution fields produced by large scale models or remote sensing be taken into account when used as inputs to higher resolution models (either directly or through desegregation techniques) ?

3. Needs of WG2

Water cycle needs to be approached through the estimation of the water budget components, which raise methodological problems:

A) Some components can be estimated directly from measurements (e.g. river outflow, rainfall), but most often not => use of models

*Water budget from models are generally closed by construction but the relative weight of each term in the balance may be false !!

*Accuracy of water balance closure is not necessarily the same at all scales (e.g. atmospheric water balance from (re)analyses *versus* balance from ground-station fluxes measurements).

Needs:

*To introduce external constraints to improve water budgets (e.g. for atmospheric budgets: new/better satellite-derived rainfall fields, evapo-transpiration fields from hydrological models).
*To asses the accuracy of each terms of water budget at various scales
*To asses compatibility between independent estimates of water budget coming from different but connected sub-domains (e.g. rain events and watershed, oceanic surface and monsoon flow, …) and to verify closure of the associated water budgets
*To perform regular reviews of these assessments during AMMA (in regard to improved observations at different scales, improved understanding of processes and their coupling relevant to the water cycle and improved models and associated assimilation of observations, …)

B) Different components of the water budget display large spatial and temporal heterogeneities and scale interactions.

Needs: Methods of upscaling and downscaling need to be developed to transfer information between scales.
(e.g. precipitation is heterogeneous on all scales down to the scale of the individual rain event; hydrological systems are very sensitive to changes not only to the amount of precipitation, but also to its distribution both in space and time; the water balance components and associated errors may vary across temporal or spatial scales).(Link also with WG4)

*Information at larger scales needs to be disaggregated following rules derived from field observations or models (linkages between different variables)

*Aggregation, or upscaling of precipitation and fluxes also necessary to evaluate the large scale water budget and to feed into work on parameterization of the land surface and associated feedbacks.

4. Overall approach

Facing to large uncertainties of the water cycle components specially at regional scale, the chosen approach is based on nested spatial domains with scales relevant to the important physical processes occurring in the water cycle. It is proposed that the WG2 is organized along 4 research activities:

(a) Regional/Large scale (>10^6 km²) water cycle.

To determine water budgets and their interannual variability at this scale and for spatial and temporal resolutions of few hundred kms and 10-day to month, respectively.
(major objective of AMMA)

Studies in 2003 and 2004: large uncertainties exist to these scales and with these resolutions.

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*Improvement of knowledge of external constraints (e.g. precip & surface fluxes) and decrease of uncertainties in representation of processes thanks to studies at mesoscale during AMMA project

*Improved soundings network (EOP/SOP) should improve the quality of the regional analyses made by NWP centres thus improving the confidence at this scale.

*Beyond EOP and SOP: necessity to adequately monitor the water budget

- Need to evaluate satellite products used in water budget analysis (AMMA-data).
- Need to evaluate/improve assimilation of remote sensing products such as soil moisture, surface temperature, LAI, in land surface models (AMMA data).

(b) Mesoscale water cycle (10^3 - 10^5 km²).

Preferred scale for atmosphere and surface integration:

*Scales complies with both hydrologic and atmospheric model capabilities
*Scale of MCS & many surface-atmosphere interactions governing the transports of water vapor from the lower atmosphere to the deep atmosphere and controlling the timing of convection and precipitation
*Benefit the most directly from enhanced observations (EOP/SOP) (high frequency soundings, surface flux network, radar observations, …)

Case studies (Pre-SOP, SOP)
EOP studies

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*Decrease of uncertainties at mesoscale also expected from studies at local scale
*Improved mesoscale budgets will be used to better assess uncertainties at large scales.

(c) Local scale water budget (1-10 km²).

*Improved local scale water budget will be used to improve and assess mesoscale models and water budget
*Better water cycle parameterizations evaluated using high resolution data on super-sites of AMMA field experiment.

(d) Downscaling and upscaling

*Disaggregation of rainfall or other variables affecting water balance
*Upscaling problems (mainly for fluxes or soil wetness)

Do we want to compare statistical and dynamical downscaling methods? This is a link to WG4 and is linked to the 2nd major challenge on the ISP.

4. Proposed Activities

a) Coordination of 4 research activities described in previous section
(based on AMMA-EU, AMMA-France, GEWEX community and past experience, ….)
That includes to identify gaps in activities, to entrain more people in AMMA, to push "process people" to work more along an integrated view on water cycle.

b) Organization of AMMA sessions:

*Plenary, parallel and poster sessions of Dakar Conf

*AMMA sessions to GEWEX conferences/meetings (links with AMMA representatives to GEWEX committees, link with WG3)

*AMMA sessions to other conferences

c) Writing with WG) AMMA-International reports to GEWEX; to try to promote AMMA studies in various GEWEX branchs (e.g. intercomparison of water cycle from GCMs output , case studies), to promote short articles on AMMA results in GEWEX newsletter

d) Participate and report to other WGs (see above links with WGs)

5. Proposed Membership

VERY PRELIMINARY: TO BE COMPLETED DURING DAKAR CONFERENCE

*Need to make sure that the 4 research activities are well represented and that include PIs of relevant projects

Very draft table

Name	Main interests	Large	Meso	Local	Scaling	Role
A. Gaye	Rain systems		+++	+		Leader water cycle in AMMA-Africa Co-chair WG2
L. Sigha						
A. Amani	Impact on hydrology				++	Co-chair WG4
F. Fierli						Leader Water cycle AMMA-EU
M. Desbois	Satellite Rain systems	++	+++			Leader Satellite AMMA-EU & AMMA-France
JL Redelsperger	Water budget Surface interactions	++	+++			Co-chair WG2

C. Peugeot			++	+++		Leader Water cycle AMMA-France
F. Guichard	Water budget	++	+++			
P. Roucou	Water budget	+++				
A. Protat						
H. Karambiri						
D. Parker						Chair TT8/SOP Chair of AMMA-UK
R. Kershaw??						
P. Houser						Co-chair WG2
P. Lamb						Co-chair WG1
J. Polcher						Co-chair WG3
!!!!To be completed!!!						

Way to proceed: Request names from different coordinators of projects
=>Ensure that some people can link with other WG

*Need to find/nominate leaders for each 4 activities

*Core group: leaders of WG2 and leaders of each 4 activity