AMMA Water Cycle Work Group (WG2)

Case study of moving precipitating systems: Associated water atmospheric and hydrological budgets

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(1) Context

A privileged scale where most of disciplines and models can be integrated in AMMA is the meso-scale (10^3 - 10^5 km²) (ISP, 2005). This scale complies with both hydrologic and atmospheric model capabilities. It is also the scale of MCS & many surface-atmosphere interactions governing the transports of water vapour from the lower atmosphere to the deep atmosphere and controlling the timing of convection and precipitation. This scale is also where benefits from enhanced observations (EOP/SOP) are the most directly expected (high frequency soundings, surface flux network, radar observations, …) .

In the framework of the meso-scale part of AMMA Water Cycle Work Group (WG2) setup by ISSC (International Scientific Steering Committee), a first case study is proposed to compare atmospheric and hydrologic simulations at the meso-scale between them and with observations. It constitutes a first step in « science integration » and will prepare further studies based on SOP observations (tools and methods testing).
The main motivation comes from the need to validate model outputs and to ensure that outputs of atmospheric models comply with forcing of hydrologic models, and vice-versa. This is illustrated in fig1.

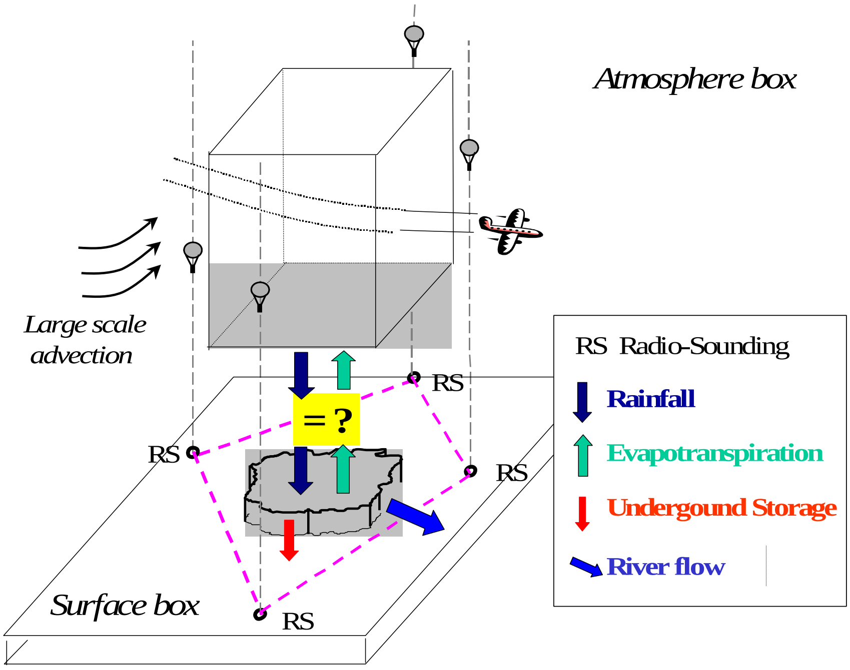


Figure 1. Schematic view of the meso-scale surface atmosphere modelling challenges.

This exercise also aims at structuring the AMMA meso-scale community with an actual case. It is part of the 2006 working plans for the components of the AMMA project working on the "Water Cycle" issues, namely Work Group 2 (AMMA International), Work Packages 1.2 and 1.4 (AMMA-EU) and Work Package 1.2 (AMMA-France).

(2) Methodology

The important objective is to run on a same case study, meso-scale atmospheric models (MSAM) with explicitly represented convection, and meso-scale hydrologic models (MSHM). The comparison of the two approaches between them and with observations is a necessary challenge to tackle the questions related to meso-scale water cycle as raised in the AMMA International Science Plan (ISP, 2005).
This case will be also an excellent way to evaluate representation of water cycle in global and regional models. In particular this case is part of the "dry run" of AOC (AMMA Operation Center) forecast. Many Numerical Weather Prediction (NWP) models participate to this exercise (Lafore et al. 2005) showing difficulties to represent the observed precipitating convective system.
If results on the present case study are enough good quality, the case could be proposed as a case study as well for Atmospheric Single Column Models (ASCM) coupled with a surface representation.

The proposed exercise will include two steps

2.a Step 1

The purpose is to run independently MSAM and MSHM on the case study.

MSAM runs:

Atmospheric fields to initialize MSAM will be derived from NWP analysis, as well as lateral boundary conditions. For this purpose, different analyses can be used. To simplify the

MSAM intercomparison, it was decided to use the ECMWF analysis for reference simulations (ECMWF analysis appeared to be the only common choice for participating models). At the same time, comparisons of analyses from different NWP centers will be made between them and with available observations in order to assess their quality. That includes comparison of important atmospheric parameters but also soil moisture. As NWP analyses may differ, it is very likely that tests will be necessary to assess the impact of using different analyses on MSAM results (apart from the intercomparison).
The final objective here is to provide the more realistic MSAM precipitation field to force MSHM.

MSHM runs

Forcing fields for hydrologic runs will be derived from observations :
- rainfields computed from statistical interpolation of point-observations (raingages) : krigging with a variogram derived from observations.
- Potential Evapotranspiration (ETo) from meteorological stations (FAO formulation)

These forcing fields will be common to all participating models. The space-time resolution of these fields will be defined commonly by model PI's.

MSHM initialization concerns the moisture state of the system (soil and groundwater). In the simulation domains, the hydrologic systems are reset to the driest moisture status at the end of each dry season. Hydrologic model initiation is simply made by assigning the reservoirs to their dry status, then the whole season is simulated, and the time-period of the case-study is extracted.
None of the participating models are configured to be forced during time integration by other fields than rainfall and ETo. It is proposed to run the models for the whole season with "default" parameter set, and if needed to calibrate the model on the 2005 year, and then compare the results.

The objective is to simulate the hydrologic impact of the precipitating system, as observed on the 3 mesoscale sites, by computing the resulting runoff production, groundwater refilling, soil moistening, and evaporation and transpiration in the period following the rainstorm. One has to notice that due to transfer processes, the hydrologic impact can be apparent only 12 to 48 hours after the system has passed over the domain.

MSAM and MSHM evaluations

The simuations have first to be evaluated to assess how well the case is simulated, with a focus on key relevant variables assessing the model simulations in their geophysical domain. Comparisons will be made using reference datasets commonly defined

- MSAM : analysis of timing, propagation, intensity and smaller scale structures (e.g. cell statistical properties) of the simulated precipitating system. Regarding specific hydrological needs, this translates into rainfall statistics (intensity, space-time distribution) and impact on the low levels of atmosphere (wind, temperature, moisture, cloud cover) including changes in surface evaporation and the surface energy budget. Reference dataset à valider : integrated water vapour from GPS ; MCS motion ; point and areal rainfall from ground observations ; meteorological data from ground stations (or other sources ?) ; surface energy budget components from ground stations if available (or other sources ?). soil moisture ?

Pour la pluie, fait-on des comparaison avec les produits opérationnels (GPCP), ou produits AMMA-Sat ?

- MSHM : comparison of the simulated components of the continental water cycle fto observed dataset, focusing on the following key variables : river runoff at basin and/or at sub-catchements outlet ; groundwater level ; evapotranspiration (point observations from flux stations if available, autres observations disponibles ?) ; soils moisture (satellite or ground observations).

MSAM/MSHM intercomparison

This intercomparison will focus on variables simulated by both types of model, viewed as “interface” variables between the surface and the atmosphere : evapo-transpiration (MSHM) vs latent heat flux (MSAM) ; Soil moisture. These comparisons would require to use up/downscaling techniques.

Practical aspects

This will be done through a web interface, where the participants could get reference dataset and post their simulation results. The specifications of reference and simulated fields have to be detailed for each variable (time-space resolution, format) in dedicated sub-groups.

With these specifications each team take in charge all the tests and comparisons, and post synthetic results on the web site

Il faut definir les formats et resolutions des varioables de reference et champs de forcages et produire ces champs de forçage, puis definir les formats et resolution des champs simulés
je verrai bien 2 coord (à designer) pour cela : un hydro et un atmo qui travaillent ensemble pour harmoniser les résolutions des variables pour l’intercomparaison

2.b Step 2

If the step 1 is considered successful, the second step will consist to run MSHM as forced with the rainfall fields simulated by MSAM. These numerical experiments will require rainfall downscaling techniques.

(3) Description of the case study

A MCS named “A” formed over central Africa (Southern Sudan/Chad) the 27th Aug around noon. The MCS moved first northwards over the Chad and then westwards (Nigeria) centred along the 10 North latitude during the night. The 28th Aug in the morning, a new MCS “B” was initiated over the north part of Jos Plateau (North Nigeria) near MCS “A” (northwest from its leading edge). The case-study will focus on this second MCS “B” (see Fig.2a), rapidly growing, propagating westward, and passing over Benin between 16:00 and 21:00 UTC, and then over Ghana where it dissipates. A new convective element (named C) was initiated on the north part of MCS “B” at 16:00UTC along Nigeria and southern Niger limit (see Fig.2b). It moved across Niger during the night and developed in moving westward over Burkina Faso.

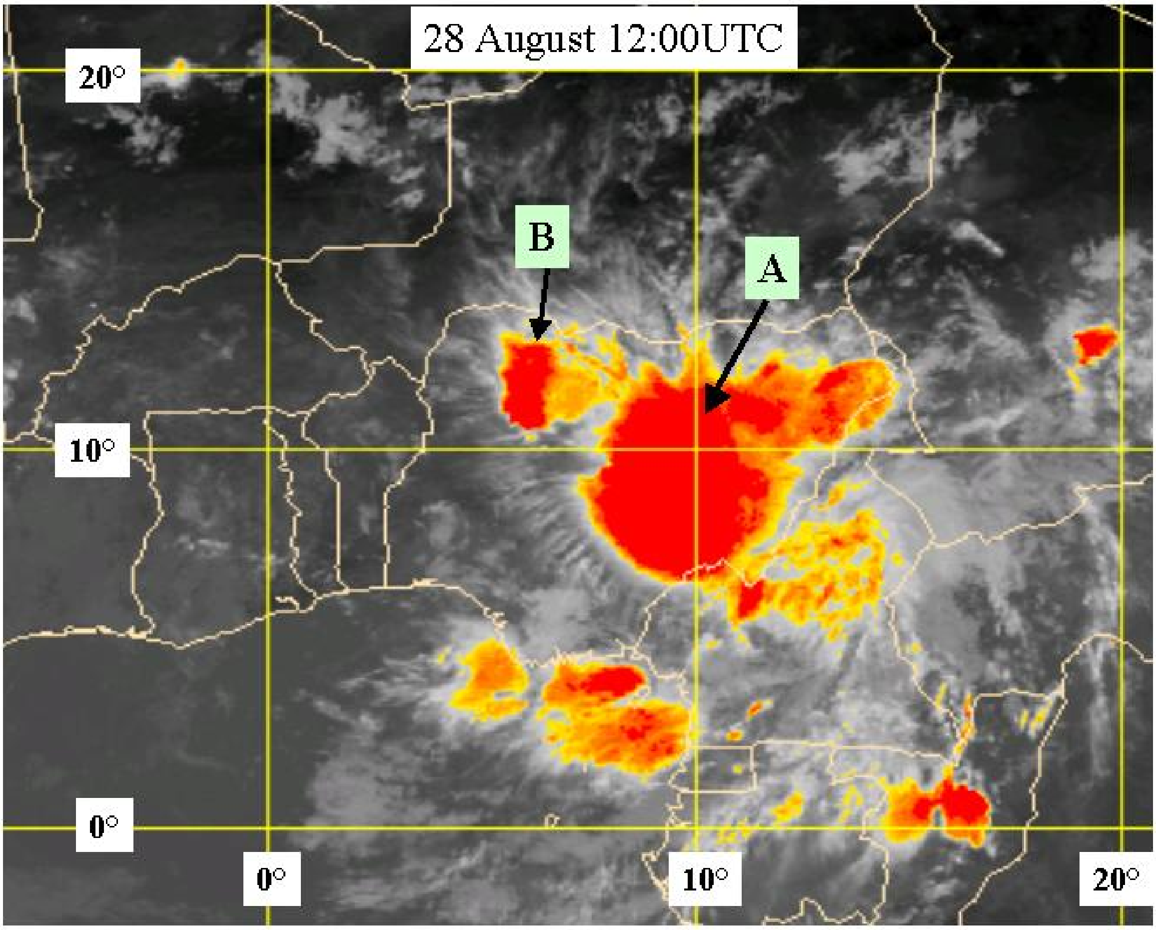


Fig 2a: Infrared image from MSG (T=-40C)

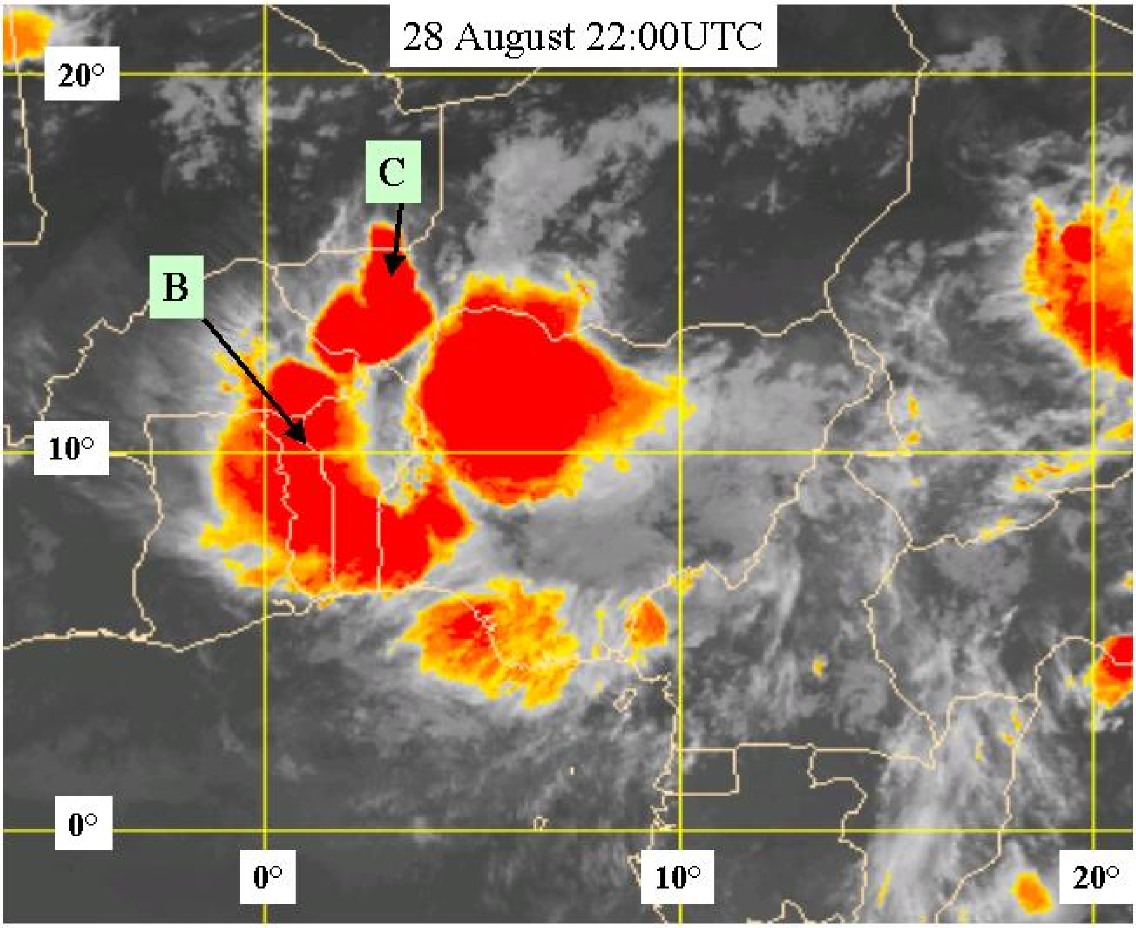


Fig 2b: Infrared image from MSG (T=-40C)

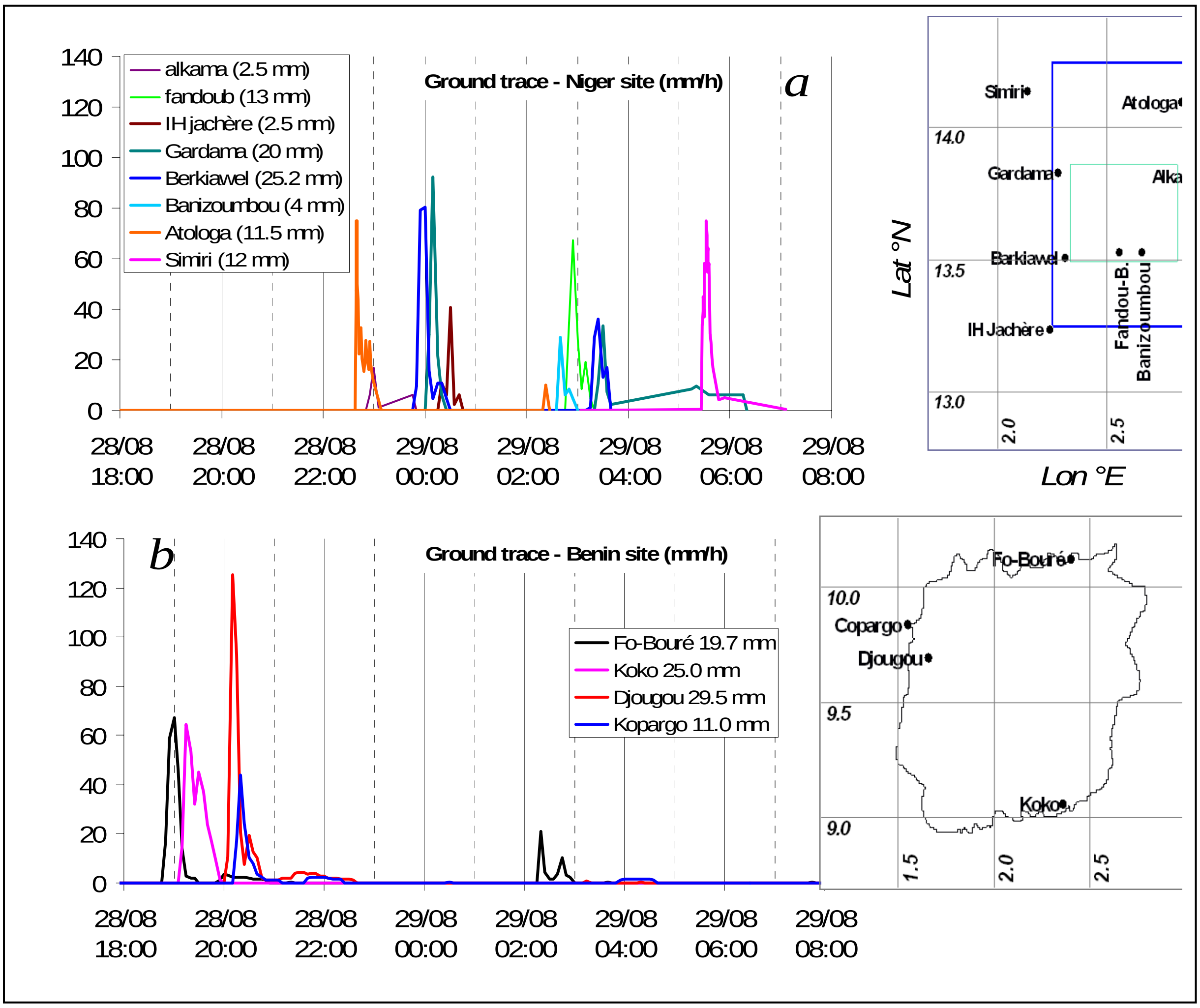
All the 15-minute figures of the MCS tracking are available on the "dry run "web site
http://www.cnrm.meteo.fr/amma-moana/dryrun2005/ (password available …)

Ground networks (rainfall, runoff) have recorded the hydrologic impact of the MCS "B" and "C". Fig 3 shows the rainfall impact on the Niger and Benin meso-scale sites. That confirms that the MCS B first rained over the Benin site, then the MCS C few hours later over the Niger site.

As shown by the figure, the rainfall recorded by the raingage networks for this event suggests it has had a moderate hydrological impact on the surface**,** with rain depths in the order of 15-20 mm and peak intensities around 60 mm/h in Bénin (120mm/h in Djougou), and more variable depths (3 to 25 mm) in Niger, with peak intensities around 60-80 mm/h

CP: tbi Sirba rainfall
OK : tjs à faire

Fig 3. Rainfall hyetographs recorded on Aug 28th on the Niger (a) and Benin (b) sites. The Kori de Dantiandou (a, dark blue), the central super-site (a, light blue) and the upper Ouémé basin (b, black) are the limits of the domains for hydrological simulations.



(4) Numerical setup

The domain of interest for the WG2 objectives must include AMMA meso-scale sites where ground data are available and where meso-scale hydrological models have been set-up and tested. The coordinates of the smallest window complying with these constraints are (fig4):

1.5°W-3°E x 8.5-14.5°N

It is on this domain where WG2 will focus in term of water cycle. The computation domain for atmospheric models would be larger to be able to represent features necessary to successfully simulate the MCS events.

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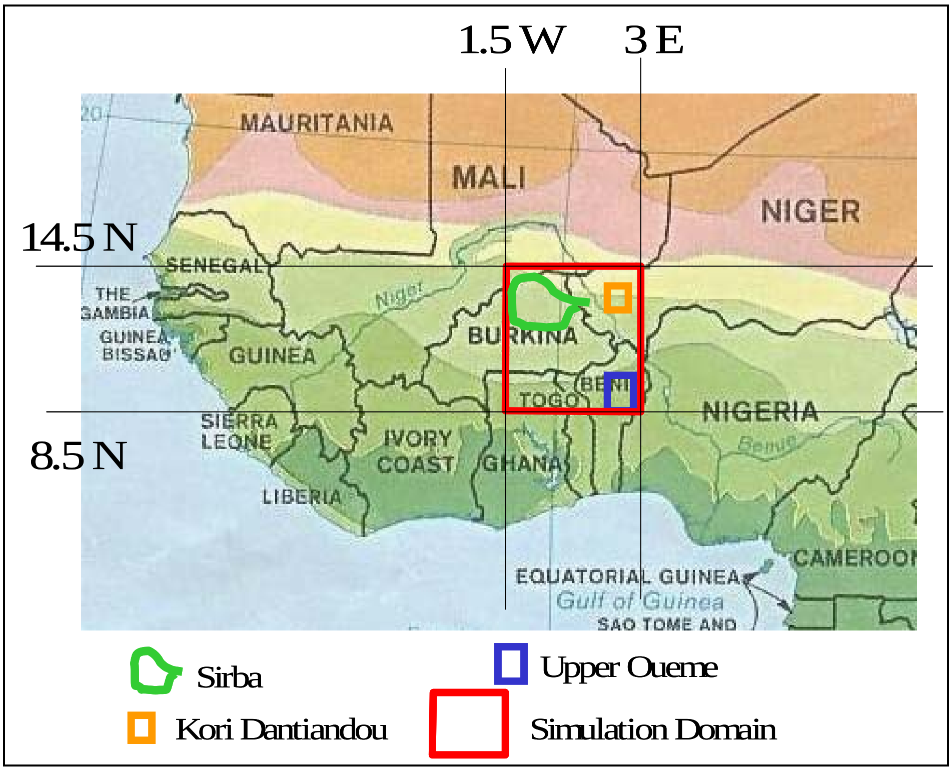

Fig 4. Domains of interest

The following table summarizes the characteristics as recommended.

Dates	Start : 27 Aug 2005 00TU End: 29-30 Aug for atmospheric runs; 2-3 Sep for hydrologic runs: (accounts for delayed impacts e.g. evaporation or transpiration)	Precipitating events having travelled across the AMMA central region See Fig 2
Final domain of interest	1.5°W-3°E x 8.5-14.5°N	See Fig 4
Basins	Upper Ouémé basin Kori de Dantiandou Sirba	Outlet at Koko, Bénin, 14 600 km2 Niger, 5 500 km2 Garbe Kourou, Niger, 139 000 km2, over Burkina and Niger
Atm. Models Grid	Coarse 10 to 30 km Fine 4x4km (or better)	Finest grid over the hydrological basins nested in the coarse grid

Either atmospheric and hydrologic simulations will be checked for consistency with adapted validation or verification data before beginning the intercomparison phase, i.e. comparison of outputs for the same geophysical variable produces by the two types of model. The table below summarizes the variables involved in this cross-evaluation, as well as indicative space and time resolution at which comparisons would be made. These comparisons will be made for step 1 (forcing of hydrological model with observed rainfall) and step 2 (forcing of hydrological model with simulated rainfall).

(please validate the table)

Outputs from atm. Models	Outputs from hydrol. models	Space resolution	Time resolutio n	Unit	Comments
Rainfall accumulation		1-4 km	hour, day	[L]	Evaluation of atm. model simulation of accumulated rainfall with respect to observed data
Rainfall intensity (point time-series)		Point	5 min	$[LT^{-1}]$	Evaluation of simulated rainfall intensities with respect to observed data (major forcing factor for hydrologic models); preparation of experiment 2 (one-way coupling).
Integrated water vapour fluxes at the bottom of the vertical domain	Evapo-transpiration	4 km	hour, day	$[LT^{-1}]$	Feed back term. Requires up/downscaling to fit spatial resolution of atm. and hydrol. simulations. (Experiment 1 and 2)
Soil moisture from surface scheme	Soil moisture	1-4 km and Point	hour, day	$[kg.kg^{-1}]$ or $[L^3.L^{-3}]$ or [-]	Time series and maps to compare the dynamics of soil moisture produced by atm. and hydrol. models.

(5) Calendar

The proposed exercise will last the whole 2006 year, with the following expected schedule.

a. First version of case study paper (C. Peugeot & JL Redelsperger): March 2006
b. Initialisation, forcing and validation data-base building, including data cross-check: Mid-april 2006)

    Actions :

    - To gather all available atmospheric data (O. Bock, SA/IPSL)
    - To gather all surface (including radar images) and hydrological data (rainfall, soil moisture, heat and water vapour fluxes, wind, temperature, humidity, radiative budget) for the period (L. Descroix, S. Galle, C. Peugeot, IRD ; A. Amani, AGRHYMET). N'identifier qu'un coordinateur : action CP
    - Build fields to force hydrological models : Identifier un coordinateur : action CP. Travail en cours pour pluies.
    - To gather satellite data (F. Fierli, ISAC) : all available data concerning atmospheric water cycle (cloud top, tracking, water vapor, …) from the AMMASAT database.
    - To gather surface moisture information: ALMAS and Satellite estimates will be gathered (A. Boone CNRM)

c. Simulations

    First atmospheric simulations are available since mid-march 2006. Due to the implication of hydrologists in the SOP campaign (may-oct 06), hydrological simulations are expected not earlier than September 2006.

d. Analysis of simulation results

    A common format to share and process simulated data needs to be used. The NetCDF format is proposed for field-variables, and simple vector (text format) for time series of point-variable (e.g. runoff at a given location). A valider.

    Analysis of simulation data (atmospheric and hydrologic models) and comparisons with other data (simulated or observed) is expected to be discussed during the SOP workshop in November 2006.

    - Qui fait les comparaisons ? definit les formats les variables : cf § 2

(6) Participants

This exercise is opened to the whole AMMA-community.

The participants identified to date are listed in the table below. **A few teams participating to AMMA have not yet confirmed their interest.**
Toujours pas de retour : je relance un nieme fois.

Institution/Team	PIs	Contribution	Comment/Model (*)
LTHE, Grenoble/Cotonou	M. Gosset	Production of rainfall fields from radar images and raingauges (Benin site)	Assessment/validation of simulated rainfall fields
LTHE, Grenoble/Niamey	L. Descroix	Production of surface data (Niger site)	Supply the case-study data-base
SA, Paris, (France)	O. Bock	Gathering of Amospheric data	Forcing/validation data Building-up of the case-study data-base
CNRM, Toulouse, (France)	F. Guichard, N. Asencio, M. Nuret, J.-L. Redelsperger	Atm. model	Meso-NH

Contd…

Institution/Team	PIs	Contribution	Comment/Model (*)
ISAC, Bologne, (Italy)	F. Fierli, M. Zampieri	Atm. model	BOLAM
NCAR, Boulder, (USA)	B. Lamtey	Atm. model	WRF
LTHE, Grenoble/Cotonou & HSM, Montpellier/Cotonou (France)	S. Galle, C. Peugeot, R. Haverkamp, L. Séguis	Hydrol. Model	TOP-MODEL (Oueme) GR4J (Oueme) POWER (Donga)
AGRHYMET, Niamey, (Niger)	A. Amani, M. Hamattan	Hydrol. Model	GeoStreamFlow (Sirba basin) confirm model name ; provide a description

Other teams contacted ; participation to be confirmed

HSM, Montpellier, France	B. Cappelaere, S. Massuel	Hydrol. Model	Rwf-abc model (K. Dantiandou)
LTHE, Grenoble, France	C. Messager	Coupled atm/hydrol model	Coupled MAR/abc model (Sirba and KDantiandou basins)
Univ. Köln, Germany	H. Paeth, A. Fink	Atm. model	ECHAM4 ?
……others …			

(*) refer to annex for details on models.

References

ISP, 2005. AMMA International Science Plan. Downloadable at: http://www.amma-international.org/science/docs/AMMA_ISP_May2005.pdf

Lafore, J.-P. et al., 2005. The Dry-run forecasting activities in Summer 05 for AMMA: Elaboration and test of the Forecasting tools, methods and procedures. First AMMA international conference, 28 nov-2 dec. 2005, Dakar, Senegal. (http://www.amma-international.org/meetings/internationalConferences/dakar2005/programme/docs/WG5_Lafore.pdf)

ANNEX

List and short description of models

Atmospheric models
MAR - Regional Climate Model (participation tbc)
The Méso-NH Atmospheric Simulation System

Hydrological models
ABC and abc-rwf (participation tbc)
POWER
TOP MODEL (description missing)
GR4 l
Geostreamflow (confirm name, description missing)

MAR - Regional Climate Model

Atmosphere

- General: MAR is a regional climate model just initialized once and nudged on the sides for the remainder of the MAR. MAR is nudged in large scale by meteorological fields (ERA-15, ERA-40, LMDZ) [Marbaix et al., 2003]. MAR is a hydrostatic primitive equation model in which the vertical coordinate is normalized pressure.
- Dynamics: Grid point model based on primitive equations of meteorology.
- Physical parametrizations : The warm part of the cloud microphysics is based on a bulk representation associated with the work of Kessler [1969], Ntezimana [1994] and Gallée [1995]. The ice and snow part is described according to Lin et al. [1983], Levkov et al. [1992] and Cassano et al. [2001]. Detailed solar and infrared radiation schemes are taken respectively from Fouquart and Bonnel [1980], and Morcrette [1984] or Morcrette[2000]. MAR is adapted to tropical regions by including the convective adjustment scheme of Bechtold et al. [2001].

Land Surface Processes

- Atmospheric part of MAR is coupled to the Surface Vegetation Atmosphere Transfer model of De Ridder and Gallée [1998]. The SVAT contains one vegetation layer and 7 unevenly spaced soil layers, with a finer resolution near the surface.
- Soil hydrology: contained in the SVAT or treated by using a coupling architecture which permits the use of high resolution hydrological models adapted to the relevant processes of identified catchments.

References :

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- Marbaix P, Gallée H, Brasseur O, Van Ypersele JP (2003) Lateral boundary conditions in regional climate models : a detailed study of the relaxation procedure. Accepted for publication in Monthly Weather Review.

- Brasseur O, Tricot C, Ntezimana V, Gallée H, Schayes G (1998) Importance of the convective adjustment scheme in the simulation of the diurnal cycle of convective activity in Africa. Proceedings of the International Conference. "Tropical climatology, meteorology and hydrology" Demarée G., J. Alexandre and M. De Dapper (Eds), 299312.

- De Ridder K, Schayes G (1997) The IAGL land surface model. J. Appl. Meteorol., 36: 167-182.

Meso-NH Atmospheric Simulation System

Atmosphere

• Meso-NH is the non-hydrostatic anelastic mesoscale atmospheric model of the French research community (Lafore et al. 1998). It is intended to be applicable to all scales ranging from large (synoptic) scales to small (large eddy) scales

• Dynamics : Grid point limited area model. Cartesian coordinate system or of a conformal projection (Lambert, Polar Stereographic or Mercator). On the vertical, Gal-Chen and Sommerville coordinate (1975). Positive advective schemes for scalars. Various possibilities for lateral boundaries conditions (open, periodic or wall), two-way interactive gridnesting.

• Physical parameterizations : A complete physical package to run at different resolutions including:

- 1D or 3D turbulence scheme (Cuxart et al. 2000) based on diagnostic 2^{nd}-order moments and a turbulent kinetic energy prognostic equation,
- A bulk scheme for the microphysics combining a three-class ice parameterization with a Kessler scheme for warm processes including a subgrid condensation and precip scheme,
- A deep and shallow convection scheme (Bechtold et al 2001) adapted from Kain and Fritch, (for resolution larger than 10km)
- ECMWF radiation scheme

• Initialization from the ECMWF and ARPEGE analysis.

• Documentation : http://www.aero.obs-mip.fr/mesonh/

Land Surface Processes

•The Interaction Soil-Biosphere-Atmosphere (ISBA) soil scheme of Noilhan and Planton (1989).

•A complete procedure to initialize land surface parameters from physiographic data including the ECOCLIMAP high resolution database (Masson et al. 2003).

References :

•Bechtold, P., E. Bazile, F. Guichard, P. Mascart, and E. Richard, A mass-flux convection scheme for regional and global models, Quart. J. Roy. Meteor. Soc., 127, 869-886, 2001.

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•Masson, V., J.-L. Champeaux, C. Chauvin, C. Meriguet, and R. Lacaze, A global database of land surface parameters at 1 km resolution for use in meteorological and climate models, J. Climate, 16, 1261-1282, 2003.

ABC and abc-rwf hydrological models

General features
- Hydrological catchment models abc-rwf and ABC
- Physically based and spatially distributed
- Model forcing: precipitation at fine temporal resolution
- Parameterization from satellite and aircraft images and local field reconnaissance
- calibration (model and error estimates algorithm)
- validation from hydrological observations (pools, soils, ground water)

Domains of applicability
- Domains: km² to10^4 km² with, from individual decennal rainfall events to a few decades
- Resolutions : 10m to km, seconds to minute (during rainfall event)

Coupling with other models
- Coupling without feedback with the ground water flow model (Modflow)
- Interactive coupling with vegetation models (TreeGrass & Tgpix)

References

• Cappelaere B., Vieux B., et al. (2003). Hydrologic process simulation of a semiarid, endoreic catchment in Sahelian West Niger. 2. Model calibration and uncertainty chatacterization. J of Hydrology 279, 244-261

• Peugeot C., Cappelaere B., et al. (2003). Hydrologic process simulation of a semiarid, endoreic catchment in Sahelian West Niger. 1. Model-aided data analysis and screening. J of Hydrology 279, 224-243

POWER Hydrological model

General features

- Hydrological model at the basin scale
- Spatially distributed and physically based
- Calculation are performed on irregular meshes, relevant for hydrology (basin, subbasin, field scale)
- Several embedded levels of discretizations: 1)sub-catchment REW –Representative Elementary Watershed- scale 2) field scale REC – Representative Elementary Column-scale 3) layers in the soil, etc.. with discretization adapted to each flow process.
- The model is run using series of rainfall and potential evapotranspiration (which can be distributed at the REW or REC scale)
- Spatially distributed information on soil hydraulic properties, land-use and vegetation characteristics is required (vegetation evolution must be prescribed)
- River and groundwater flow are modelled at the catchment or sub-catchment scale using mass and momentum conservation equations
- Flow in the non-saturated zone is modelled using a robust, rapid numerical solution of the Richards equation (vertically and laterally) including a sink term for root extraction by plants. Heterogeneous soils can be taken into account
- Surface runoff includes both Horton and overland flow

Domains of applicability

- Spatial and temporal domains: a few km^2 to 10^4 km and from the event to a few years
- Spatial resolution: REW: 1 to 100 km^2, REC: a few ha to a few km^2
- Temporal resolution: depends on the objectives and the data available: forcing from hours to daily, calculation time step: minutes to hours

Coupling with other models

- Not implemented to date (but the code is already a coupling between different models for the different flow processes)

References

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GR4 hydrological model

General features

- Hydrological model at basin scale
- Conceptual (bucket model) and global.
- 4 tuning parameters
- Daily time-step
- Model forcing: precipitation and PET
- Calibration with observed data (river flow)
- Evaluation from hydrological observations (river flow)

Domains of applicability

- Domains: km² to10^4 km² with daily forcing
- Resolutions : same than “domain” (global model)

Coupling with other models

- Not implemented to date

References

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