ALMIP2: Whitepaper

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1 Introduction

The African Monsoon Multidisciplinary Analysis (AMMA) project was organized in recent years with the main goal of obtaining a better understanding of the intra-seasonal and inter-annual variability of the West-African monsoon (WAM). In particular, land-atmosphere coupling is theorized to be significant in this region. The magnitude of the north-south gradient of surface fluxes (related to soil moisture and vegetation) has an influence on the position of the tropical front and the strength of the monsoon. Using a combination of modeling and observational data, transient soil moisture patterns have been found to induce dynamic and thermodynamic responses in the PBL on length scales of ten to several thousand kilometers, and they have been shown to influence the dynamics of the overall monsoon circulation through the associated convective feedbacks (e.g. Taylor *et al*., 2011). Over longer timescales, there is evidence that observed extreme rainfall variability over West Africa is influenced by the land surface through a soil moisture memory mechanism (e.g., Nicholson 2000; Philippon *et al*. 2005). In addition, complex feedbacks between surface and sub-surface hydrology and land surface processes are at work in the Sahelian and Sudanian regions (Séguis et al., 2011), but there is still a lack of understanding of how this feeds back into the monsoon system (Peugeot et al., 2011). Finally, the links between land surface processes and the WAM have also been demonstrated in numerous numerical studies using global climate models (GCMs) and regional scale atmospheric climate models (RCMs) over the last several decades (see Xue *et al*., 2012, for a review). However, interpretation of the results, from any one of such studies, must be tempered by the fact that there are substantial discrepancies in African land-atmosphere coupling strength among current state-of the-art GCMs (Koster *et al*., 2002).

The deficiencies with respect to modeling the African monsoon arise from both the paucity of observations at sufficient space-time resolutions, and because of the complex interactions of the relevant processes at various temporal and spatial scales between the biosphere, atmosphere and hydrosphere over this region. A high priority of AMMA is to better understand and model the influence of the spatial and temporal variability of surface processes on the atmospheric circulation patterns and the regional scale water and energy cycles. This is being addressed through a multi-scale modeling approach using an ensemble of land surface models which rely on dedicated satellite-based forcing and land surface parameter products, and data from the AMMA observational field campaigns (Redelsperger *et al*., 2006; Lebel *et al*., 2009).

2 AMMA Land surface Modeling Initiative: ALMIP

The coordination of the land surface modeling activities in AMMA is supported by the AMMA Land surface Model Intercomparison Project (ALMIP). It is being conducted along the same lines as previous GEWEX-supported LSM intercomparison studies, such as the Global Soil Wetness Project (GSWP; Dirmeyer *et al.* 2006), and the Project for the Intercomparison of Land-Surface Parameterization Schemes (PILPS, Henderson-Sellers *et al.,* 1995). It will explore scaling issues as in the Rhone-AGG LSM model intercomparison experiment (Boone *et al*., 2004), but with a larger local-scale evaluation component. In such projects, an ensemble of LSMs is forced in “offline” mode (i.e. decoupled from a host atmospheric model) by a mixture of data from numerical weather analysis and prediction, satellite products and surface observations. In this sense, the simulations comprise the equivalent of a multi-model reanalysis product.

The recently completed ALMIP Phase I dealt with the regional scale (Boone *et al.*, 2009a). A dozen different groups from the international community performed multi-year offline simulations (2002-2007) over West Africa using multiple forcing input forcing datasets. In terms of evaluation, the LSMs were able to produce spatial and temporal surface soil moisture patterns consistent with remotely sensed brightness temperature (deRosnay *et al.*, 2009). Using aggregated fluxes from local scale observational sites from the Mali supersite (Timouk *et al.*, 2009), grid scale ALMIP surface sensible heat flux estimates were found to have the same basic response (amplitude and phase) to the wet season over a period of several years. Finally, ALMIP simulated continental water storage changes have been shown to compare well with estimates from GRACE, especially in terms of representing the inter-annual variability (Grippa et al., 2010). The resulting LSM simulations have been used extensively for hydrological modeling, regional scale water budget estimates (Meynadier *et al.*, 2010; Bock et al., 2011) and mesosale water budget studies (Peugeot et al., 2010), mesoscale atmospheric case studies (Guichard *et al.*, 2009), regional dust (Tulet *et al.*, 2008) and atmospheric chemistry modeling (Delon *et al.*, 2010), land-atmosphere coupling (Taylor et al., 2011) and to examine the influence of initial soil moisture states on numerical weather prediction (Agusti-Panareda *et al.,* 2010). In addition, the results have been used for the evaluation of regional scale atmospheric model (RCM) surface physics improvements (e.g. Steiner *et al.*, 2009), and for evaluating both RCMs and global climate models (GCMs) within two Intercomparison efforts (Ruti *et al.*, 2011); the AMMA atmospheric Model Intercomparison Project (AMMA-MIP: Hourdin *et al.*, 2010) and the GEWEX-sponsored West African Monsoon Modeling Evaluation project (WAMME: Xue *et al.*, 2010; Boone *et al.* 2009b). However, at the spatial and temporal resolutions of ALMIP Phase 1 (0.5 degrees), the comparison with in-situ data is quite difficult without the use of some sort of upscaling methodology, and this can only be done in relatively data dense areas (such as over the AMMA supersites). This in turn makes it more difficult to understand inter-model differences and model deficiencies.

3 ALMIP Phase 2: Focus on land surface and hydrological processes

In the next ALMIP Phase (2), LSMs will be evaluated using observational data from the AMMA-CATCH observing system (Lebel *et al.*, 2009) which covers a north-south transect encompassing a large eco-climatic gradient. ALMIP2 will focus on the three heavily instrumented super site “squares” in Mali, Niger and Benin (Fig. 1). In addition to evaluating LSMs using field data, LSM simulations of hydrological processes will also be compared to results from both conceptual and distributed hydrological models. The goal is to facilitate the scientific exchange with the hydrological modeling community for a common site, potentially leading to the improvement of the representation of hydrological processes with land surface models and of the production functions (surface runoff, evaporation) in hydrological models. Such a convergence should help improve the understanding of the coupling of the land surface and hydrological-hydrodynamic processes for West African watersheds, and potentially lead to model improvements. In addition, land surface models with the capability of simulating the temporal evolution of the vegetation will be evaluated using satellite and local scale data, and compared to detailed vegetation process models which have already been extensively validated over this region (e.g. Saux-Picart *et al.,* 2009; Tracol *et al.*, 2006). Finally, the results will be used in conjunction with those from ALMIP1 in an effort to evaluate the effect of scale change on the representation of the most important processes from the local to the meso then to the regional scale, which is an important step for improving the process representation in RCMs or GCMs.

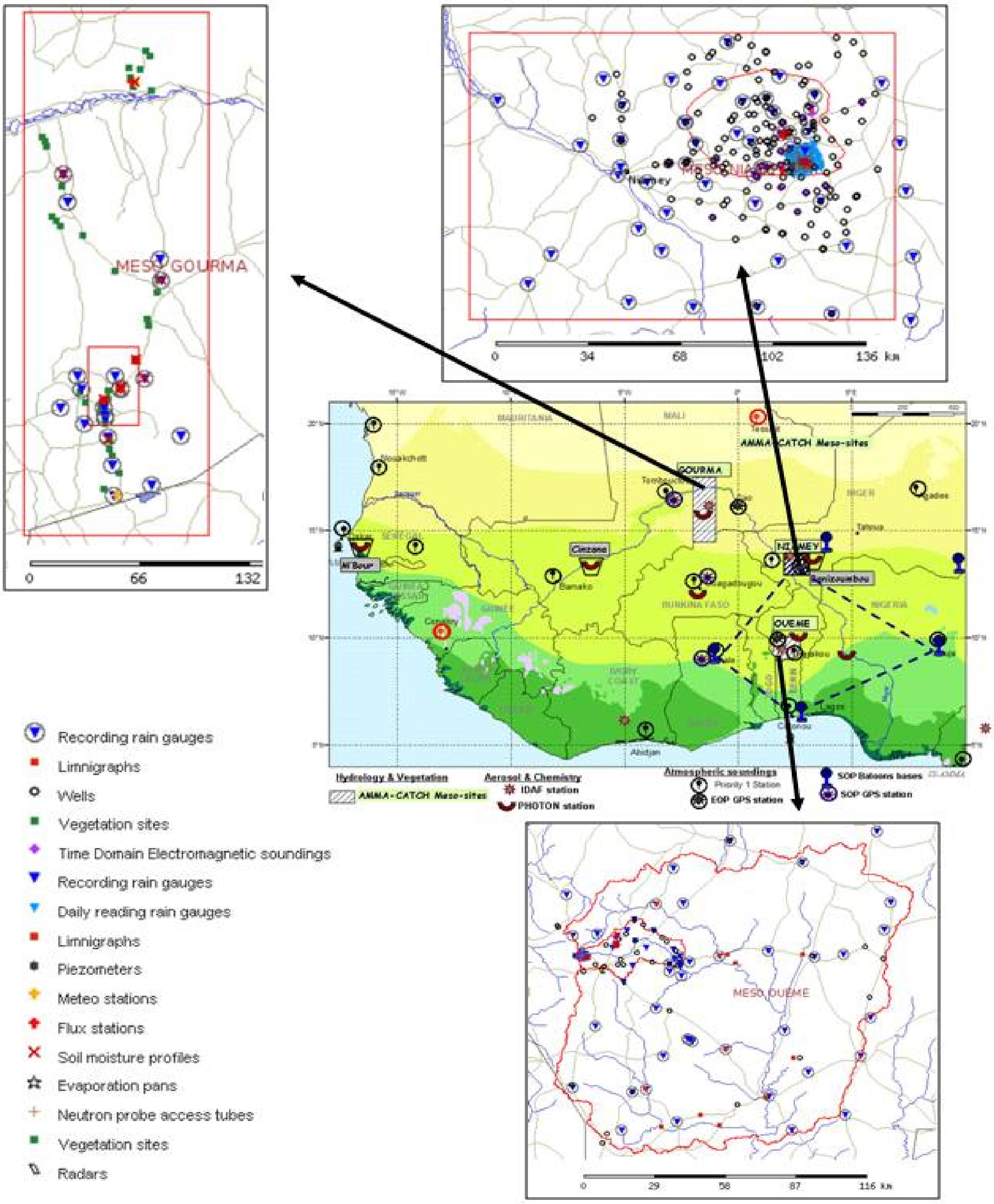

Fig. 1: The three mesoscale domains are shown with the locations of observation sites indicated using symbols defined in the figure at the lower left. The AMMA-CATCH region consists in a north-south transect encompassing the three meso-sites. Finally, the Ouémé catchment is shown in the lower right, with the Donga sub-basin in the northwestern part of the domain.

3a AMMA-CATCH Sites

A coordinated set of model experiments over the three AMMA-Catch (http://www.amma-catch.org) sites will provide a good idea of the contrasting characteristics and processes in the Sahel and Sudano-Guinean regions. The location of the three sites is shown in Fig. 1. Each site observing system provides both forcing (i.e. micro-meteorological description and soil and vegetation properties) and validation data (surface fluxes, soil moisture, water table and runoff). Detailed documentation of the different sites is available on the ALMIP2 ftp server (ftp.bddamma.ipsl.polytechnique.fr) which is a part of the AMMA-DataBase (AMMA-DB: http://database.amma-international.org/). In addition, remote sensing images have been processed in order to infer land surface properties at the mesoscale, such as land cover, leaf area index maps, land surface temperature, albedo and superficial soil moisture. A comprehensive special issue in the Journal of Hydrology (Lebel *et al.*, 2009) gives a comprehensive overview of the different sites and modeling activities. A brief description of the three AMMA-Catch supersites is given below.

The Gourma-Mali site is located in the northern Sahel (14.8ºN–17.3ºN). It is a typical rangeland region, covered with semi-arid natural vegetation. LSM simulations will be focused on the Hombori super site, a 50x50 km area which extends over the central Sahel where most of the in situ instrumentation is concentrated (Mougin *et al.,* 2009). The rainy season is quite short, lasting from late June to mid September, with an average annual precipitation recorded at Hombori over 1950-2007 of 370 mm. The site is characterized by three soil types over which two different hydrological system operate. Vegetation comprises an herbaceous layer almost exclusively composed of annual plants, among which grasses dominate, and scattered bushes, shrubs and low trees.

The South-West Niger site (13ºN–14ºN) is typical of the central Sahel conditions with average annual rainfall decreasing from 570 mm in the south to 470 mm in the north (1990–2007 average). The mesoscale site is located near Niamey, generating heavy demographic pressure, including intensive agricultural usage and wood cutting for fuel. The area is now essentially composed of millet fields, fallows and tiger bush and bare soil (Cappelaere *et al.,* 2009). Simulations will be performed for a one-degree square (2-3°E; 13-14°N) characterized by a typical semi-arid tropical climate, with a long dry season (from October to May) followed by a single wet season of 4-5 months.

The third site is the Ouémé-Benin site (Guyot *et al*., 2009; Séguis *et al*., 2011a) (9°N–10.2°N), where annual rainfall averages 1,200–1,300 mm. The natural vegetation is wooded savanna typical of Sudano-Guinean formations, with interspersed crops including maize, yam, cassava, groundnut and “niébé" (black-eyed pea). Simulations will focus on the upper Ouémé watershed (14,600 km²). The rainy season lasts from April to October. Contrary to the two other Sahelian sites, river runoff is structured by an arborescent drainage network, and sustained by the drainage of superficial water-tables. The vegetation cover is patchier than on the other sites, with forest clumps scattered in mixed fields and fallow landscape.

The typical endorheic (internal drainage basin) nature of the surface hydrology of the two Sahelian sites (Mali and Niger), for which catchments are limited to scales on the order of a few tens of km^2, include both highly runoff-prone and infiltration-prone surfaces (Séguis *et al*., 2011b). This is in contrast to the nested hydrological catchments over the Benin site which range in size from 600 to 10 000 km² and nearly cover the entire Ouémé mesoscale domain. The smallest sub catchment, the Donga, is located in the north-western part of the catchment, and it is covered by a very dense observational network (Fig 1). For this reason, the focus of the hydrological modeling will be for the Benin mesoscale square.

3b ALMIP2 Science Questions

The standard justification for performing experiments using multiple LSMs is that it is difficult to make general conclusions for the research community using a single model only. So by inter-comparing an ensemble of state-of-the-art models, ALMIP2 seeks to address the following science questions:

1. Which processes are missing or not adequately modeled by the current generation of LSMs which are critical in this region?
2. Can relatively simple LSMs simulate the vegetation response to the atmospheric forcing on seasonal and inter-annual time scales for West-African vegetation?
3. How can LSM simulate mesoscale hydrology given their relatively simple representation of such processes (compared to more detailed hydrological models)? And, are the production functions of hydrological models or the timescale (typically daily time step) adequate compared to the more explicit LSM approaches?
4. How do the various LSM processes respond to changing the spatial scale (three scales will be analyzed: the local, meso and regional scales)?
5. What are the impacts of uncertainties of the precipitation forcing on the surface fluxes and hydrological responses of the LSM models? Can progress be made in terms of developing adequate sub-grid and possibly temporal disaggregation precipitation parameterizations for LSMs?

In terms of processes (1), it has been recognized since HAPEX-Sahel (Goutorbe *et al*., 1997) and highlighted once again in by AMMA (Lebel et al., 2009) that certain land surface processes are quite specific to this region (e.g.s hydrophobic effect on infiltration over crusted soils, vegetation with deep water extraction...) and are currently not taken into account in a physically-based manner in most current state-of-the-art LSMs, especially those used in GCM or RCM simulations. Such dry season processes have also been shown to cause difference in the seasonality of total water storage (Grippa *et al.,* 2011).

The general trend in the climate modeling community (such as for CMIP activities) is to include dynamic vegetation models and improved representations of photosynthesis in their fully coupled systems to, in principle, model the feedbacks between the Carbon in the atmosphere and the land surface by simulating gross primary production and ecosystem respiration (2). Such processes are now even being employed in LSMs coupled to operational forecast models (Boussetta *et al*., 2012). Some LSMs have been extensively evaluated for mid-latitude vegetation (for example, where the spatial distribution of FLUXNET stations is largest), and might need adaptations to better model the unique combination of plant types and climate over West Africa where needed measurements are more sparse. Also, the vegetation inter-annual variability can be quite large in West Africa, especially over the Sahel owing to the possibility of significant atmosphere-vegetation feedbacks. Vegetation has adapted to prolonged dry spells (rapid growth cycles in semi-arid regions, and roots extending over 10 m deep for example), and such features are generally not explicitly accounted for in current LSMs. In order to address questions concerning the effect of future climate change in this region, a robust representation of the vegetation dynamics (and associated Carbon fluxes and stores) is urgently needed.

All of the aforementioned processes are coupled either explicitly or implicitly to the representation of hydrology in LSMs (3). Most current LSMs are essentially vertical in nature (lateral flow and surface runoff processes are highly parameterized, if at all). In order to be able use fully coupled GCMs to make inferences about the impact of future climate change on water resources in such regions (where human activities and demographic growth induce direct or indirect pressure on water resources), such models must be able to better quantify the different water budget components. In ALMIP2, processes that are important for water resource management which will be examined are: (i) water table recharge, ii) river flow and freshwater fluxes to the ocean, iii) runoff generation, iv) endorheic processes and v) sub-surface flow to the river network.

In addition to improving the representation of the above processes, there is a need to understand how the local scale processes can be scaled properly (4) for application in large scale coupled model applications, and the link between the mesoscale and regional scales will be examined using ALMIP Phase 1 and 2 results, while the links between local and mesoscales will be examined using the ALMIP2 experiments. In addition, exploring the uncertainties in the forcing data (especially the precipitation) is of critical importance (5). This will be addressed by using multiple precipitation products based both on gage (using different interpolation techniques) and radar-based data. The hydrological and surface flux responses to the different precipitation inputs will be examined.

Finally, it is emphasized that another offshoot of this experiment is that the simulation results will contribute to the effort to provide a multi-model climatology of ``realistic'' high resolution (multi-scale) soil moisture, surface fluxes, water and energy budget diagnostics at the surface. This data can then be used by other research groups or projects for mesoscale atmospheric model, water budget, and hydrological studies.

4 Overview of Experiments

Two main experiments will be performed, and they are differentiated by the spatial scale. The first experiment will be at the mesoscale using a grid resolution of 0.05°, and covering several years during and after the Enhanced Observation Period (EOP: 2005-2008) and encompassing the Special Observation Period (SOP: 2006). Participants will be requested to run their models for the prescribed time period (which is a function of the site: see Table 1) for the three mesoscale squares using two (three for the Donga domain) different atmospheric forcing input datasets (which only differ in terms of the rainfall for the control experiments). Hydrological models will perform this experiment for the Benin domain only (Ouémé and the Donga sub-basin) where extensive hydrological measurements have been taken. The second set of experiments will be performed at the local scale during the same time period for several representative sites within each of the mesoscale "squares". The addition of more **optional** experiments is possible if the time to do the runs and the required input data stay reasonable. Please refer to section 5a for a complete list of runs to be done (and which are mandatory or optional).

4a Mesoscale LSM (Mandatory)

The control mesoscale simulations will be performed over a multi-year time frame for each «meso-square». The control mesoscale experiment is summarized in Table 1. Each domain is on the order of 10^4 km^2 and uses a grid with a 0.05 degree spatial resolution and a forcing time step of 30 minutes. These simulations are mandatory.

The forcing precipitation fields are derived from rain gage data over the observational network using a i) Thiessen (sometimes called nearest neighbor or proximal) interpolation, or ii) a Lagrangian-kriging interpolation method (Vischel *et al.*, 2012): i.e. when Lagrangian estimates can't be used (owing to data gaps or intermittent precipitation events), the usual kriging method is used. For the Donga sub-basin, radar-based rain fields are also available. The goal of using multiple precipitation datasets as input is to explore the impact of uncertainties and errors in the rainfall on both the simulated surface fluxes and states, and the hydrological response of the models.

For the Niger, Benin (Ouémé) and Mali mesoscale domains, the downwelling longwave and shortwave radiative fluxes are from the LAND-SAF project (Geiger *et al*., 2008). Fluxes began to be produced operationally in July, 2005, and they continue to be computed and archived. They have been interpolated to the ALMIP2 grids by IPSL (Institut Pierre Simon Laplace, Paris, France). Meteorological state variables have been derived from ECMWF deterministic forecasts using the same data as in ALMIP1. Although the spatial and temporal resolutions of such fields is rather coarse by comparison (0.5 degree and 3 hours), the meteorological fields are consistent with the local scale observations. At any rate, there are too few local scale observations for a robust spatial interpolation of the meteorological state variables, so the NWP data is used except for the Donga sub-basin (see next paragraph for details).

As an example, from Table 1 it can be seen that a LSM performing the **mandatory** control mesoscale runs will produce **24** year long output time series total (e.g. for the Niger site, this corresponds to 4 years X 2 atmospheric (rainfall) forcing inputs = 8 yearly output data files (the same is true for the Benin-Oueme site); for the Mali site, this corresponds to 3 years for one atmospheric forcing input and 1 year for an additional atmospheric forcing input X 2 soil databases = 8 yearly output data files). For the Donga domain (optional runs), the meteorological forcings are derived from a combination of local scale observations and the Benin mesoscale forcing using a method which best preserves the spatial variability of the variable under consideration (determined by the observations).

Meso-Square	**Domain**	**Rain Forcing (dt) & Soil Data**	**Time Period**
Niger	1.55°E to 3.15°E 12.85°N to 14.15°N (32x26: *d*=0.05°)	• *T, L (30 min)* • *ECOCLIMAP*	2005-2008 (*T, L*) [8 years of forcing]
Benin-Ouémé	1.45°E to 2.85°E 8.95°N to 10.20°N (28x25: *d*=0.05°)	• *T, L (30 min)* • *ECOCLIMAP*	2005-2008 (*T, L*) [8 years of forcing]
Mali	-1.90°E to -1.20°E 15.0°N to 15.7°N (14x14 *d*=0.05°)	• *T, L (30 min)* • *ECOCLIMAP, ECO(veg) +Satellite -local (soil)*	2006-2008 (*T*) 2008 (L) [4 years of forcing, 2 soil dataset inputs]
Benin-Donga	-1.56°E to -1.97°E 9.65°N to 9.91°N (41x26 *d*=0.01°)	• *T, L, R (10 min)* • *Local-based (veg and soil)*	2005-2008 (*T, L*) 2006-2007 (R) [10 years of forcing]

Table 1: The CONTROL mesoscale experiment summary. For rain forcing, *T, L* and *R* represent Thiessen, Lagrangian-krigged and radar-based, respectively. The default soil and vegetation parameters are from ECOCLMAP-II for the Niger, Benin-Ouémé and Mali, while a local-based dataset is used for Benin-Donga. Note that for the Mali site, 2 different soil databases are provided. The domain coordinates correspond to the domain limits (with a horizontal spatial resolution, *d*, and the number of grid points indicated). The total number of year-long simulations to be reported from the above total is 8 for the Niger, 8 for Benin-Ouémé and 12 for Mali and 10 for Benin-Donga.

The input soil and vegetation parameters are from the ECOCLIMAP-II-Africa database (Kaptué *et al.,* 2010).The soil data is based on FAO (10 km spatial resolution), and includes sand and clay fractions, along with soil depth. ECOCLIMAP2 includes inter-annual variability of the vegetation parameters over West Africa (ECOCLIMAP1 from Masson *et al*., 2002, uses a single annual cycle for all years). Note that for the Mali site, sub-grid soil texture and depth information are also available. Each grid of 0.05° is characterized by the percentage of 12 soil classes derived by the supervised classification of LANDSAT remote sensing images. Each of these soil classes is characterized by a given soil texture (coarse and fine fraction, the latter separated into clay, loam and sand) and soil depth. Soil classes also include soils that are seasonally flooded. For the latter, dates of flood beginning and end each year, estimated using MODIS data combined with in-situ measurements at the Kelma local site, are also provided. The goal of this experiment is to explore the impact of soil data on the simulations (a widely used off-the-shelf dataset from the FAO, verses a locally-derived high resolution dataset).

Finally, if a particular model *must* use *their* “native” input soil-vegetation parameters, then the parameters must be reported to ALMIP (for analysis/interpretation purposes). But, we strongly encourage participants to use the provided soil-vegetation parameters, or at least, attempt to “map” them into their own parameter sets. Participants are welcome to provide an additional set of runs with their native parameter datasets.

4ai Mesoscale-Hydrological Simulations (Mandatory)

Hydrology models will be invited to perform the mesoscale simulations for the Ouémé and Donga basins within the Benin square. Such models can use their native grid/hydrological unit methodology with the provided gridded multi-year forcing (the modelers can then aggregate/interpolate the forcing to adapt to their model architecture). However, it is required that the model results be delivered for the same time increments on the same grid as the forcing fields. A set of GIS layers describing the DTM, river network, catchment masks will be provided. Additionally, time series of Potential EvapoTranspiration (PET) will be provided for the whole period, for those models using this type of forcing data.

A total of 12 sub-basins (out of 19 monitored) have been selected for the hydrological experiment (Table 2 and Fig. 2). For the hydrological models which must be calibrated, hourly observed discharge data will be provided for two contrasting years (for 2005, a dry year, and 2008, a relatively wet year) for the two main Ouémé sub-basins : Beterou and Cote 238. Model evaluations will be performed for 2006 (dry) and 2007 (wet) for the aforementioned sub-basins, and for the entire four-year period for the remaining 10 sub-basins.

Sub-basin	Area (km²)		Sub-basin	Area (km²)
AFFON-PONT (1)	1 165		**Cote 238 (9)**	**3 133**
AGUIMO (2)	402		DONGA-PONT (10)	586
AVAL-SANI (4)	3 283		IGBOMAKORO (13)	2 334
BORI (5)	1 607		SARMANGA (17)	1 378
BETEROU (6)	**10 326**		TEBOU (18)	515
BAREROU (8)	2 162		WEWE (19)	293

Table 2. Sub-basin list for the hydrological experiment. Discharge stations and corresponding basins are numbered in accordance with Fig. 2.The 2 sub-basins proposed for calibration are outlined in bold letters.

ECOCLIMAP parameters may also be aggregated accordingly. Model performance will be evaluated using observed discharge and piezometric measurements (where available). In addition, the results will be compared to LSM derived discharge and water budget components.

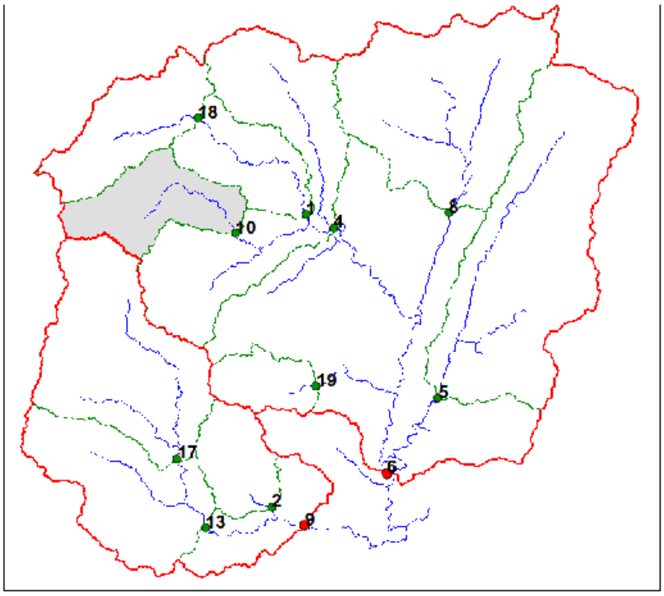

Fig. 2. Map of the two main sub-basins proposed for calibration (red) and the remaining 10 sub-basins (green). The numbers refer to basin identification as in table 2. The major river network is figured in blue, as well as the limits of the ALMIP domain (black rectangle). The greyed area is the Dong basin selected for the sub-meso scale experiment (see next section).

Finally, note that LSM runoff components (Section 4a) will be fed into a post-processing river routing scheme (see Section 5cii for further details), and the resulting discharge and water table recharge will be compared to observations and those quantities simulated by hydrological models.

4aii Sub-Mesoscale Hydrological Simulations (Optional)

The Donga basin (586 km2) is a so-called intermediate scale basin which is located within the Benin meso-square. The spatial resolution of the model grid is 5x larger than for the other three mesoscale simulations and the temporal resolution is increased by a factor of 3 (see Table 1, bottommost row). The spatial density of the observations is also considerably larger, justifying the increased spatial resolution (see Fig. 1). There are two objectives for this set of simulations:

1. Evaluate the added value of using radar-based rain fields as opposed to those based on the spatial interpolation of rain gages

2. Evaluate the water at a higher spatial scale (again, owing to the larger number of observations). This addresses the scale question mentioned in the science questions

The radar-based rain fields reveal a significant spatial heterogeneity in contrast to the gage-based spatially interpolated precipitation. In order to evaluate the impact of the radar data, a composite radar-gage rainfall forcing has been prepared in addition to the other two rain forcings. When radar data is not available, the precipitation is gap-filled using the Lagrangian-krigged precipitation (described in section 4a). The radar rain forcing is available for the year 2006-2007.

As previously, for the hydrological models which must be calibrated, hourly observed discharge data will be provided for year 2005, for the Donga basin. Model evaluations will be performed for 2006 (dry) and 2007 (wet) for Donga and two sub-basins : Ara (12 km² and Kolo (104 km²), see fig. 3. PET time series will be provided.

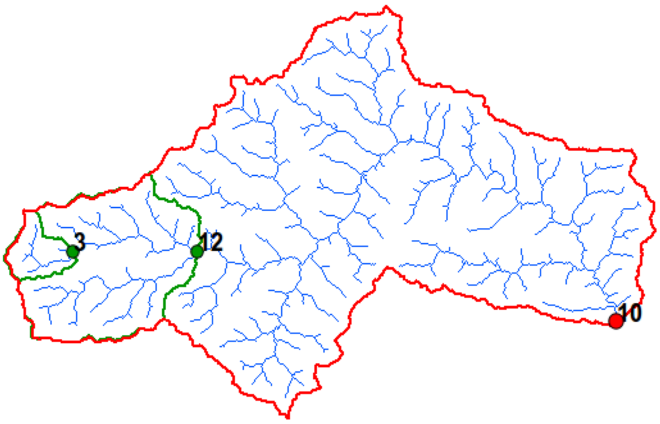

Fig. 3. Same legends as in fig. 2. Donga basin (10) with calibratin data, and Ara (3) and Kolo (12) sub-basins

4aiii Mesoscale Dynamic vegetation mesoscale sub-experiment (Optional)

The models which have the capability to simulate the temporal evolution of the vegetation will be requested to repeat the control experiment (see Table 1) with their option to simulate the evolution of the vegetation activated. The resulting fluxes and land surface states will be compared to the control simulations, and vegetation variables (notably the LAI) will be evaluated using MODIS and in situ vegetation data. This will permit an evaluation of the impact of the vegetation simulation on the simulated water and energy budgets, an evaluation of the model's ability to simulate the "real" vegetation and it will allow an investigation of the impact of using different precipitation datasets on the vegetation growth and development. We will also examine the impact of interactive vegetation on the hydrological processes within the Benin domain (evaluation using observations and comparison with the control simulations of river flow, etc.). This experiment will only be possible for a sub-set of models, but we will strongly encourage modelers (who can) to do this experiment.

4b Mesoscale Sensitivity Tests

4bi Mesoscale Alternate land mesoscale parameter databases (optional)

Alternate (to ECOCLIMAP) databases can also be used in an additional set of mesoscale experiments (using the same precipitation as in the control experiment). In addition, special dedicated detailed high resolution land use maps have been derived for some regions within the CATCH domain, and modelers can be requested to rerun the Control experiment setup for certain sites using alternate land (vegetation and soil) parameters. More information will be provided to participants during the project if such data becomes available. These simulations will be **optional**.

In addition, there will possibly be additional experiments proposed using alternate atmospheric forcing data input. Recent work has been done showing that aerosol (dust) effects on the downwelling longwave and shortwave radiances must be considered (e.g. Ramier *et al*., 2010). Work is ongoing to develop a methodology to correct the SAF fluxes using aerosol optical depths from ECMWF. If the data is ready in time for ALMIP2, participants will be informed. Again, these simulations will be **optional**.

4bii Mesoscale Parameterization tests (optional)

Modelers who wish to submit runs using (several) different physics options may repeat the control mesoscale simulations and submit their runs (for example, for different runoff parameterizations, soil hydrological or thermal conductivity formulations, soil grid resolutions, photosynthesis options etc.). But because of the potential large data volume, current we would like to restrict this to **three** separate sets (of 24) of runs maximum. If a modeler has strong arguments to submit more results, they should contact the ALMIP2 team.

4c Local Scale Experiments (Strongly Recommended)

The main goal of the local scale experiments is to evaluate the processes simulated by the LSMs. The local scale experiments will be run in single-grid point mode for the models. Initial data will be provided based on the observations (soil temperature, soil moisture etc...). The atmospheric state variables, radiative forcing and precipitation inputs have been derived using local scale data. The gap filling techniques are described in detail in documents on the ALMIP2 ftp server. In terms of model evaluation, gaps in the time series data are possible, but sites with the most complete time records or those which cover certain key periods of interest (e.g. monsoon onset) will be used. As much as possible, sites for which an estimate of energy budget and/or water closure have been selected. A description of the soil and vegetation parameters will also be provided to modelers (see Table 4, next page). A summary of the local scale sites to be used is given in Table 3 below.

Local Site	Location	Type of Surface	Time Period (Forcing)	Evaluation Data
Niger – Wankama Crop	13.6444N – 2.6298E	Millet	06/2005-12/2007	*Rn, G, H, LE, CO2* *Tg Wg* : (10,50,100, 150, 200, 250 cm)
Niger – Wankama Fallow	13.6475N - 2.6337E	Fallow	06/2005-12/2007	*Rn, G, H, LE, CO2* *Tg Wg* : (10,50,100, 150, 200, 250
Mali - Agoufou	15.34N, -1.48E	Herbaceous savanna on sandy dunes	01/2006-12/2008	*Rn, G, H, LE, CO2, sap flow* *Tg, Wg (5, 10, 40, 120, 220 cm),*
Mali - Kelma	15.22 N, -1.57E	seasonally flooded acacia forest	01/2006-12/2008	*Rn, G, H, LE, CO2, sap flow* *Tg, Wg (5, 20, 80, 100*

				cm),
Mali - Eguérit	15.50N, -1.39E	bare soil	01/2005-12/2005	*Rn, H, LE Tg, Wg (10, 50)*
Benin – Bira	9.82670N, 1.71670E	Fallow/shrub savannah	01/2006-12/2009	*Rn, G, H ; Tg Wg* (5, 10, 20, 40, 60, 100 cm*)*
Benin - Béléfoungou	9.79120N, 1.71800E	Dry Forest	01/2006-12/2009	*Rn, G, H, LE, CO2 Tg Wg* : *(5, 10, 20, 40, 60, 100 cm)*
Benin - Nalohou	9.74480N, 1.60460E	Early stage fallow/grass	01/2006-12/2009	*Rn, G, H, LE, CO2 Tg Wg* : *(5, 10, 20, 40, 60, 100 cm)*

Table 2: The **local scale experiment** summary. Atmospheric forcing data consist in: air temperature, specific humidity and wind speed (at some effective height between 2 and 10m), surface pressure, rain rate and downwelling shortwave and longwave radiative fluxes.

Parameter	Mali Agoufou	Mali Kelma	Mali Eguerit	Benin Nalohou (young fallow/grass	Benin Bira (fallow)	Benin Bellefoungou (forest)	Niger Wankama Millet (crop)	Niger Wankama grass/shrub	Time Dependence	Depth Dependence
Albedo (soil) NIR and VIS	X	X	X	Y	Y	Y	X	X	X	
Alebdo (veg) NIR and VIS	X	X	X	Y	Y	Y	X	X	X	
Emissivity (soil)	Y	Y	Y	Y	Y	Y	Y	Y	X	
Emissivity (veg)	Y	Y	Y	Y	Y	Y	Y	Y	X	
Surface roughness (soil)	Y	Y	Y	Y	Y	Y	Y	Y		
Surface roughness (veg)	Y	Y	Y	Y	Y	Y	Y	Y	X	
Vegetation cover fraction	X	X	X	Y	Y	Y			X	
Vegetation Height	X	X	X	Y	Y	Y	X	X	X	
Sand content	X	X	X	X	X	X	X	X		X
Clay content	X	X	X	X	X	X	X	X		X
Soil type (USDA)	X	X	X	X	X	X	X	X		
Soil depth	X	X	X	X	X	X	X	X		
Soil Organic content	X	X	X				X	X		X
Root Fraction	X	X	X							X
Total soil depth	X	X	X	X	X	X	X	X		
Topography/Topographic indexes	X	X	X				X	X		
LAI	X	X	X	X	X	X	X	X	X	
Vegetation type	X	X	X				X	X		
Soil hydrodynamic properties	Y	Y	Y	X	X	X	X	X		
Saturated hydraulic conductivity (m.s-1)	Y	Y	Y	X	X	X	X	X		
Soil density (-)	X	X	X	X	X	X	X	X		
saturated soil water content (cm3.cm-3)	Y	Y	Y	X	X	X	X	X		
residual soil water content (cm3.cm-3)	Y	Y	Y	X	X	X	X	X		
Soil porosity (cm3.cm-3)	Y	Y	Y	X	X	X	X	X		
Irrigation/flood	X	X	X							

Table 4. Soil and vegetation parameters needed by LSM models. Note that some models combine the soil and the vegetation, so for such models (for example) only a single effective surface roughness is required. Time dependence depends on the measure, but at least monthly is used. Hydrological and thermodynamic parameters are assumed to be derived from the given sand, clay and soil organic contents. However, directly measured quantities can also be used (for porosity, hydraulic conductivity at saturation, etc…) if measurements exist for a given site. Finally, note that a depth dependence (last column on the right) is possible, but not required.

The local scale experiments will be performed in two steps. First, soil and vegetation data will be provided to participants along with the atmospheric forcing data. Results will then be reported to ALMIP2. We will then make a preliminary analysis (of output surface fluxes, soil moisture, etc.) and send a summary to all participants. This comprises the control local scale runs. In a second step, modelers will be able to adjust their models or model parameters (based on the analysis) and make an additional submission of local scale results. This second step is optional, however, we strongly encourage participants perform step 2 (see Section 4d).

4ci Local scale dynamic vegetation experiments (optional)

As described in Section 4aiii for the mesoscale, this experiment is for those models which can simulate the LAI or biomass of the vegetation. The methodology is simple: the LSM is to repeat the experiment outlined above with the option to simulate the vegetation activated. The simulations will be inter-compared and evaluated in the same manner as in the control experiment. CO2 fluxes will be used to asses photosynthesis, and observed vegetation metrics will also be used for evaluation. The two-step process described in the previous section will also be adopted here.

4d Optional: Local scale reruns (optional)

All modelers will have the opportunity to rerun the local scale simulations after they have seen the first analysis. Note that the first set of results will be retained and both sets will be treated as separate runs in the analysis. This is the same basic approach as was used in the Rhône-AGGregation experiment for example (Boone *et al.*, 2006). Modelers are encouraged to do this second step since at the local scale, tuning or modification of parameters or even parameterizations are often necessary to obtain good results (and can elucidate certain model problems or important processes).

4e Optional: Local scale parameterization tests

As described in Section 4bii for the mesoscale, modelers who wish to submit runs using (several) different physics options may repeat the control local scale experiments and submit their runs (for steps 1 and/or step 2, as described in Section 4c).

5 Simulations, Inter-comparison and Evaluation

5a Procedure

A summary of the overall procedure is as follows:

Step 1) Simulations:
Participants will be notified when the data to download is ready on the ALMIP2 web server hosted by IPSL (AMMA-DB). They will have a few months to perform the requested MANDATORY runs (see the **Calender** in section 6):

- a) **Mandatory** Mesoscale CONTROL: Run the 24 yearly control mesoscale simulations (see section 4a) using the model standard parameterizations and configurations (options). Note that additional runs can also be done using alternate model options and/or parameters here also

- b) **Mandatory** Local scale CONTROL: Run the model for the 8 local scale sites. As for the mescale runs (step 1.a), additional runs can also be done using alternate model options and/or parameters.

- c) **Optional** additional Forcing: if additional forcing datasets are available during this stage, they will be provided to the participants via the ALMIP2 server. These runs will be optional.

Step 2) Evaluation:
Different ALMIP2 groups will perform the analysis (a group by site):

- a) Mesoscale simulations will be evaluated using a set of available mesoscale data (remote sensing products, river discharge for the Benin meso-site...)

- b) Mesoscale simulations will be evaluated using local scale data for the corresponding grid points

- c) Local scale simulations will be evaluated using local scale data

- d) Note that during this stage, a first analysis will be done to check for energy and water budget errors, problems, etc. If we find behavior which seems to be anomalous, we will contact the corresponding participants and give them the opportunity to rerun/bugfix.

Step 3) Re-runs:
At this point, we will submit a preliminary analysis to all model participant groups. Groups will have the **option** to rerun the simulations**.** In theory, we will not release any observational data at this point. Modelers can make changes based on the analysis and rerun if they like: therefore this is not a calibration .

- a) **Optional** Adjust models (parameters, physical parameterizations...) at the local and mesoscale and rerun. Note that this step is important in particular for the local scale runs, as it will afford the chance to obtain a better understanding of the processes at the local scale.

- b) Resubmit results. Note that both the initial and re-run results will appear in the analysis. The only exception to this is results which were determined to have bugs (step 2d): there results will not be used in any analysis.

The goal of the three different steps is to best determine the different factors which affect the performance of the LSMs and the hydrological models: in terms of different atmospheric forcings on the mesoscale simulations, the impact of the different physical parameterizations, differences owing to scale (local versus meso at the corresponding points). Also, after the local scale reruns (Step 3.b), possible improvements at the local scale might translate to improvements at the mesoscale.

5b Common Analysis For all 3 Sites

At the local scale, surface fluxes, soil moisture and soil temperature, and various vegetation measurements will be used to evaluate the LSM models at various local scale sites: see Table 4 (above) for a listing of local scale data at each site. We will inter-compare the various terms of the water and energy budgets between the models. Note that for some sites, the observations do not cover the entire annual cycle, however, sites have been selected such that variables during the main seasons (wet, dry etc..) have been sampled. See Table 5 for details (below).

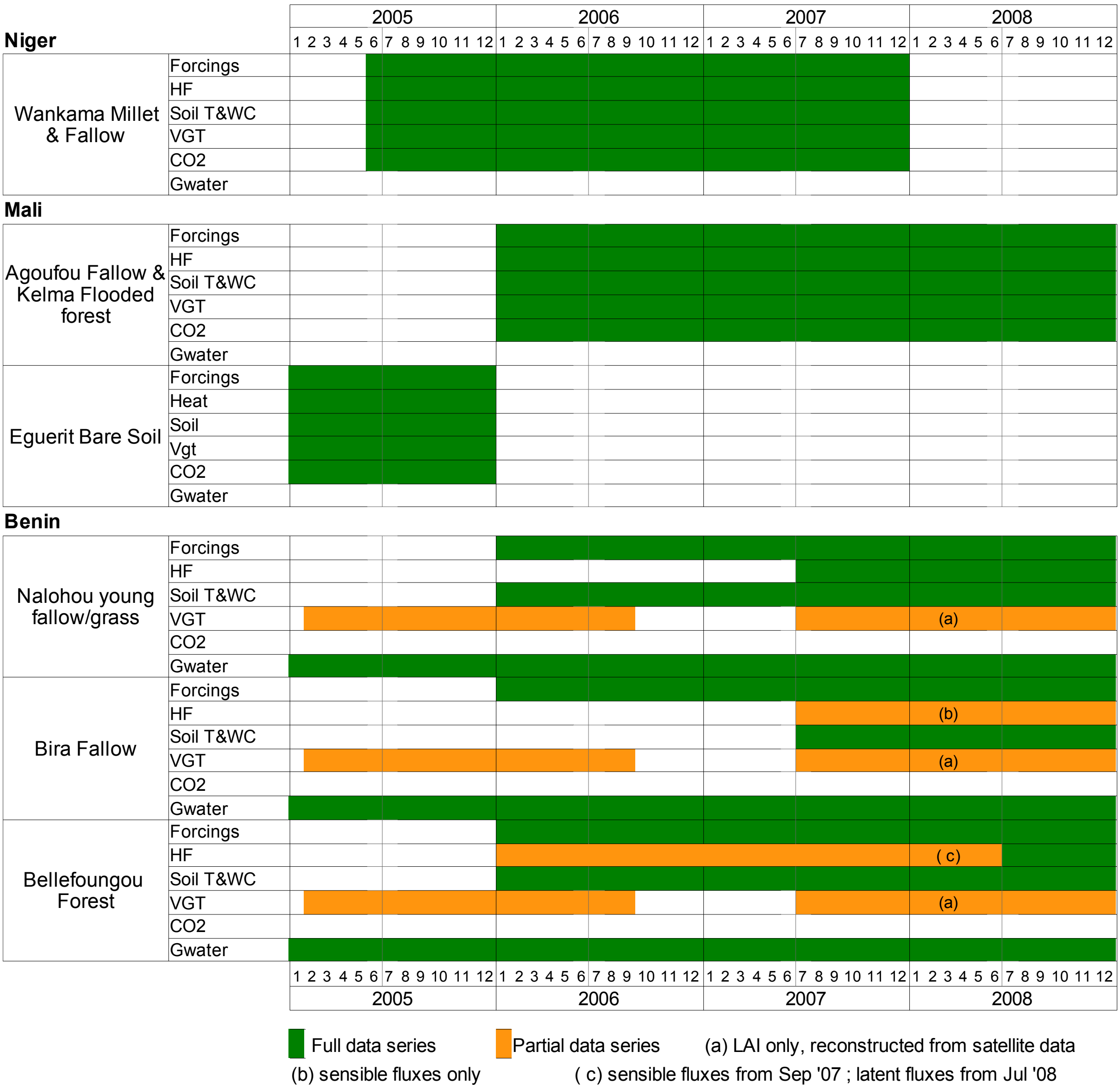

Table 5. Graphical view of the time periods where local-scale data are available. Forcing fields and evaluation data : sensible, latent and ground heat fluxes (HF), Soil temperature and water content profiles (Soil T&WC), LAI, biomass, fAPAR (VGT), CO_2 fluxes (CO_2) and local groundwater level (Gwater). Most of these data series are complete (less than 10 % gaps with a 30 min resolution, *green*), but a few of them are more discontinuous in time (more than 10% gaps) or partial as to one or more variable (*orange*).

At the mesocale, the LSMs will be both inter-compared and evaluated using several different satellite-based products. In terms of the surface fluxes, the ALEXI evapotranspiration product (http://www.soils.wisc.edu/alexi/alexi.html) (Anderson *et al.* 2007; Anderson et al., 2011) will be used as the reference evapotranspiration. For the ALMIP2 project, ALEXI is being calibrated using the local scale flux data over the 3 sites. If possible, comparisons with other available evapotranspiration products, such as MODIS, could be also performed. Concerning land surface temperature, the product derived of SEVIRI/MSG sensor will be used (http://landsaf.meteo.pt/). The last product will be at least available for 2007-2008, at a 5 km resolution and 15 minute time increment. The procedure will consist to post process surface, soil and/or vegetation temperatures simulated by each LSM, using a radiative transfer model to estimate the surface temperature for each LSM in the observed spectral domain and viewing configuration of MSG sensor.

In addition, several other products will be also used at mesoscale, especially MODIS products which are available over the three sites at a moderate spatial and temporal resolutions. For instance, comparisons will be carried out on albedo, LAI/fAPAR, GPP and 16-day MODIS albedo. Soil temperature and moisture profiles will be used in combination with upscaling relationships to upscale from the local to the scale of 0.05 degrees, will be employed to evaluate mesoscale simulations at the correspondent grid cells.

Dynamic vegetation models will be evaluated using LAI et fAPAR derived by hemispheric photographs as well as biomass, vegetation height and phenology measurements available at the local sites. Biomass and CO2 fluxes and sap flow measurements are also available at Kelma and Agoufou sites. Vegetation in-situ measurements (fcover, biomass, height and NPP) are also available at other 8 locations within the mesoscale site and they will be used for evaluation of the mesoscale simulations at the correspondent individual grid cells. These measurements will also provide mean values for the whole mesoscale site that will be used for global evaluation of the meso results.

5c Site Specific Analysis

5ci Mali site

For the evaluation of hydrology at the meso Mali site, a specific routing scheme will be used which is based on an available map of the elementary water basins with ponds as outlets (Fig 4, next page). For the Agoufou et Bangui Mallam watersheds, measurements of water volume in the ponds are available and can be used to validate, at least qualitatively, runoff output from models. All runoff generated in a grid within the Agoufou and Bangui Mallam watersheds will multiplied by the fraction of the grid belonging to the watershed, according to an existing 20 m resolution map. Then, on a weekly base, the runoff will be transferred into the pond (at the weekly time scale we can consider that the transfer as immediate) and compared to the pond's volume data. This is derived from the pond surface inferred from remote sensing data (Gardelle *et al.*, 2010) and the pond profile measured in situ.

5cii Niger

For this site, the mesoscale water budget analyses are constrained by the endorheic nature of the catchments: at the resolution of the experiment, water outflow from any grid cell is actually zero or near zero, runoff being trapped inside the grid cell where it is re-distributed into aquifer recharge and evaporation. A specific post-processing has been developed to compare models to the observational groundwater data. These water budget analyses will be limited to time scales from monthly to yearly, to allow neglecting the transfer processes.

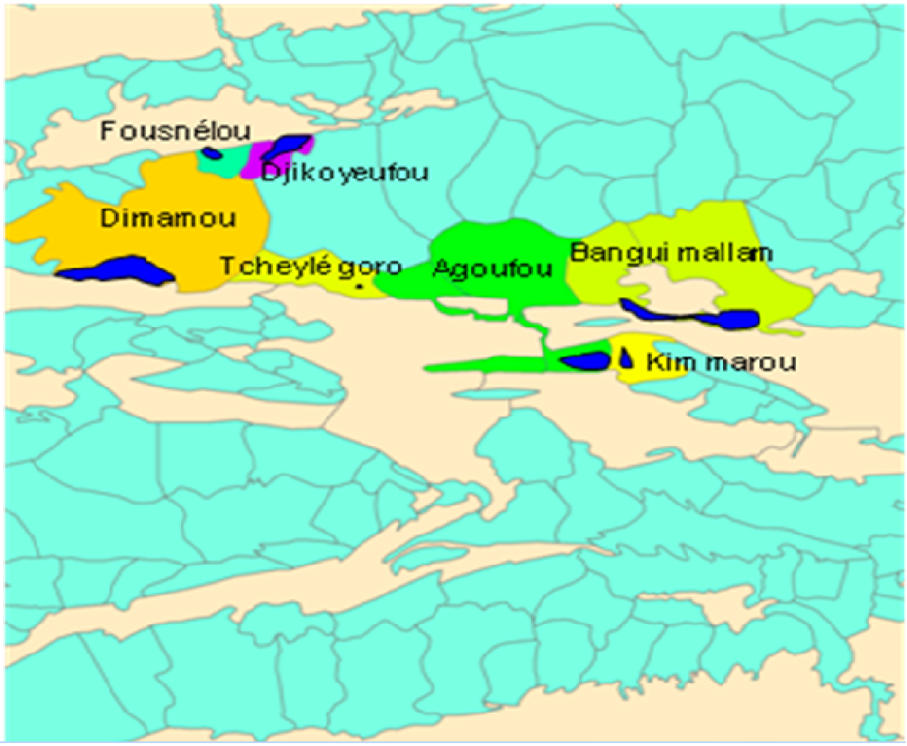

Fig 4. Elementary watersheds and main ponds within the Gourma, Mali meso site. Pink shaded areas are endorheic.

5ciii Benin

Water budget analyses will first be done at the inter-annual, annual or monthly timescale which enables us to neglect the river routing processes. LSM results will have to be post-processed to comply with the dominant sub-surface horizontal transfers coupled with the recharge/discharge of the underlying aquifer, for which observational data are available. At finer timescales (1- to 10-day), when transfer can not be neglected, a routing method will be used (see below).

In addition to the hydrological analysis mentioned in Section 5ai (analysis for all sites), hydrological model computed and LSM-routed water fluxes will be compared to observed discharge for this meso-site. This analysis is limited to the Benin site since this is the only meso-domain which contains a structured hydrological network. Discharge data are available for 10 sub-basins. The LSM model runoff will be transferred to the river using linear reservoirs and routed within the river network using a Muskingum-Cunge approach (described in Getirana *et al.,* 2012). The flow routing scheme is based on the non-linear version of the Muskingum-Cunge (MC) method coupled with linear reservoirs representing the residence times of both surface water (runoff) and groundwater (baseflow) before reaching the river network (shown in Fig. 5). The main advantage of the MC method is that model parameters are physically-based (e.g. river length, width and slope) and can be easily derived from satellite imagery and/or in situ observations. The Manning coefficient n is known for most channel conditions but can be calibrated for a specific case. The residence time of surface water is determined by the Kirpich's formula. For the baseflow, the residence time of groundwater is parametrized. A third reservoir can also be used to represent local aquifers: a fraction of the baseflow is sent to the aquifers at each time step. This fraction is parametrized according to the groundwater regime of the study area, thus the aquifer recharge can be estimated. Note that for LSMs there are no additional mesoscale hydrology runs since the control results will be used for this experiment.

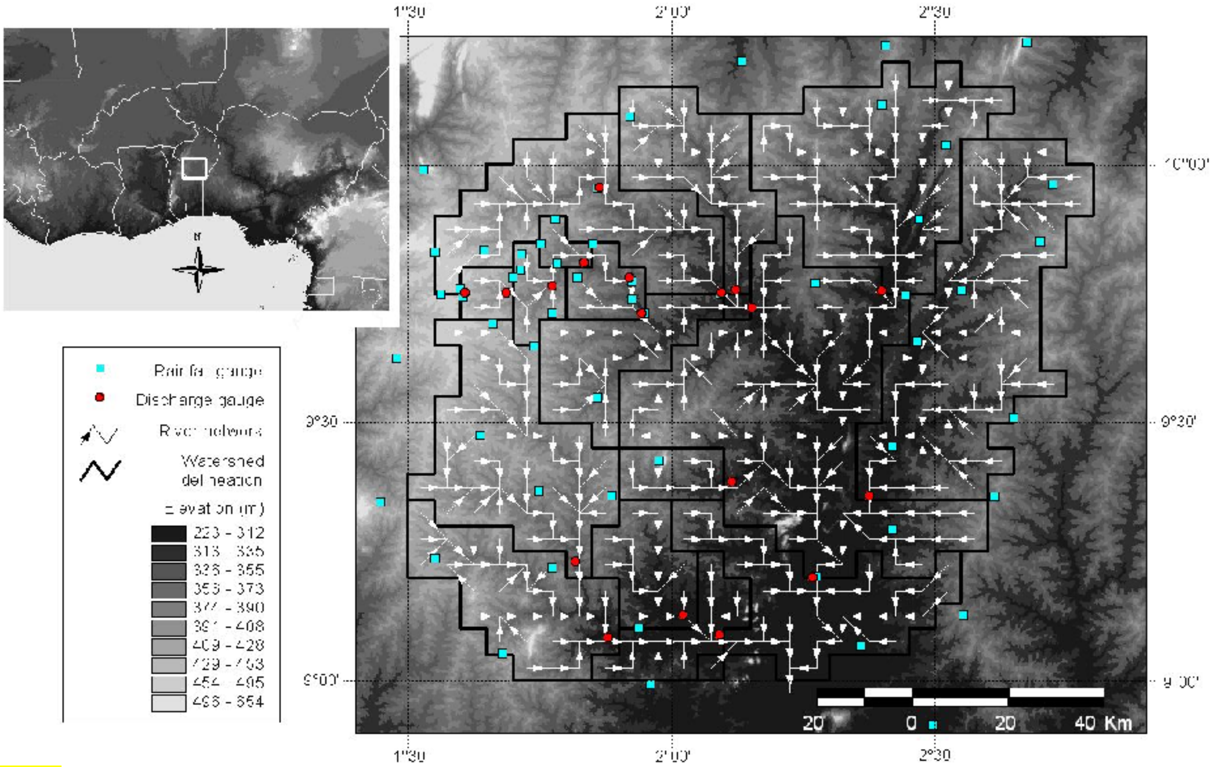

Fig. 5 The river network used to rout LSM runoff for the Benin meso domain.

6 Calendar

- February 1st, 2012: Start of International Project: Sever access open for data download/upload
- March 1st, 2012: Final Versions of all observational data finalized (for ALMIP2 analysis teams)
- April 2012: Official Start (call to participation)
- July 31, 2012: Deadline for model results
- September 30, 2012: First feedbacks of model evaluations to participants
- November 15, 2012 : Rerun deadline
- Workshop in Toulouse (France) : 3 days, between Dec 2012 and Feb 2013 (*to be determined*)
- Publication of a Special Issue 2013-2014

7 Data Exchange (upload, download, general information)

Maintenance and development of an ALMIP-2 web site at CNRM-GAME, Météo-France (http://www.cnrm.meteo.fr/amma-moana/amma_surf/almip2/index.html). Correspondence with participants, bug reports/fixes, data problems, address scientific issues which might arise (with questions and responses) will be posted online (pending the approval of the authors of the email exchanges). General information about the project is provided on this web site.

The ALMIP model input data and additional documents are located on the ALMIP2 server at IPSL (Paris, France) which is a part of the AMMA-Data base (AMMA-DB). Model results will also be uploaded to this site. Separate logins and passwords are required, and will be provided to model participants. At the end of ALMIP2, model results will be made available to all people accessing the AMMA-DB (it is free to access: one needs to simply make a request and then a login and password is provided). Different groups performing analysis can access the data from all of the models. All input and data will be formatted/output in NetCDF following the AMMA-DB and ALMA conventions (see
http://web.lmd.jussieu.fr/~polcher/ALMA/ or the examples from ALMIP1
http://www.cnrm.meteo.fr/amma-moana/amma_surf/almip/input.html
The only difference with the aforementioned ALMIP1 format is that for ALMIP2, the grids will be 2D, not 1D (to facilitate processing using NCL, GrADS, Ferret, MatLab and other software packages which can directly read NetCDF data). The NetCDF header information is available on the ALMIP2 web site (menu item - *Input Data*).

The groups will then be given a date for which to submit results. During this time, the initial analysis software and methodologies will be developed. First, to check results (sign conventions, units, errors in outputs, etc....). Participants should be able to download a set of results to the ALMIP2 server to be quickly checked by ALMIP2 for errors/consistency, and then feedback can be given to the participant(s). This has proven to be of value in the past: experience has shown that iterations with groups are usually necessary (before all issues are resolved). This can be done if the modeling groups respect the ALMA conventions and the requested file formats (as has been done in nearly all of the inter-comparison projects cited in section 1). ALMIP2 can check for water and energy budget errors, and send a report back to the modelers. If the modelers accept the report, then their results are final. If they see a problem, they will be given a short time frame to redo their runs. This was also done in ALMIP1.

As a final note, model spin-up results for the mesoscale simulations are **not** to be reported. The number of spin-up years, initialization method and convergence criteria are up to the participants. As a basic guideline, participants should repeat the first annual cycle for each of the four mesoscale domains until adequate convergence is obtained. For example, we suggest that total soil moisture at all pixels within a domain changes by less than 1% or 0.1% of the precipitation (whichever is larger) between Jan. 1 and Dec. 31 of the spin-up year.

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