ALMIP AMMA Land Surface Model Intercomparison Project

The ALMIP Experience: Implications for land-atmosphere coupled systems

Photo by Laurent **Kergoat,** CNRS

GLASS Workshop, ECMWF, Reading, UK, Nov. 9-12, 2009

METEO FRANCE Toujours un temps d'avance

ALMIP AMMA Land Surface Model Intercomparison Project

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AND Special thanks to:

S. Cloché

K. Ramage

R. Lacaze (Medias)

Jean-Louis Roujean

GLASS Workshop, ECMWF, Reading, UK, Nov. 9-12, 2009

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African Monsoon Multi-disciplinary Analysis

<u>**One of Main Goals**</u>: to improve our understanding of the West African Monsoon and its influence on the physical, chemical and biological environment, regionally and globally

<u>ALMIP</u>: 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**

Context: why is the land surface important for the WAM?

- Surface conditions modulate PBL development, convective initiation
- Surface fluxes condition low level meridional gradients of moist static energy
- Surface albedo and meridional gradient influence radiative feedbacks
- Surface humidity and roughness influence flux of aerosols
- Long term surface memory effects from deep soil moisture reserves and vegetation extraction ➔ long term prediction
- Vegetation feedbacks and Carbon fluxes, impacts on hydrological cycle…

Break various components of complex coupled system into managable portions which can then provide insight into various processes: 1st step➔ Force LSMs in *Offline* mode

PILPS

ALMIP Science Questions:

- **What is response of different schemes to scale change (local➔meso➔regional)**
- **What are the impacts of more realistic surface fields on coupled model simulations?**
- **What improvements needed in SVATs to simulate processes particular to African climate and surface/hydrology?**
- **How do simple SVATs simulate the spatial distribution and inter-annual variability of vegetation?**
- **What is impact of satellite-based forcings?**

GSWP

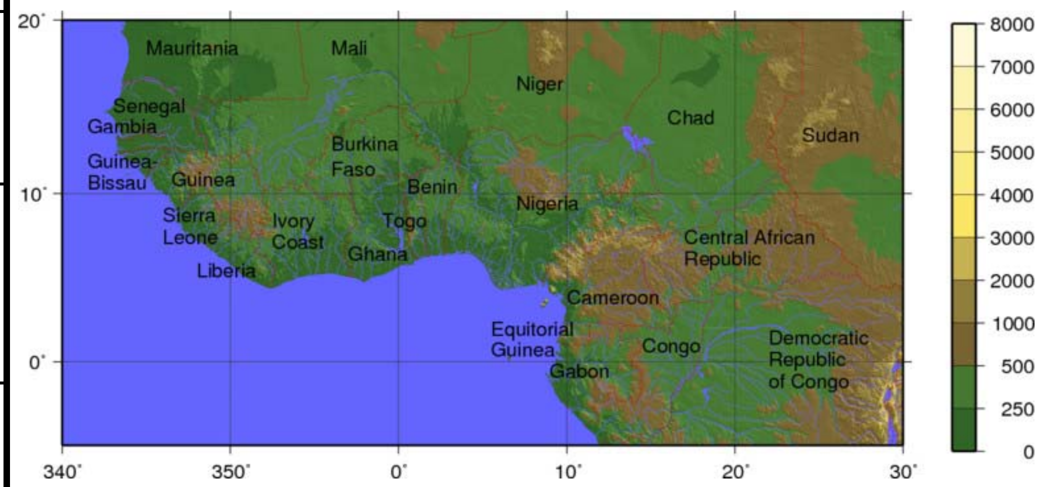
SnowMIP

Rhone-AGG

Experiments:

Exp. Name:	Resolution	Time period
Exp 1: Regional	0.5deg, 3h: NWP (ECMWF forecasts)	2002-2007
Exp 2: Regional Merged	0.5deg, 3h: OSI-LAND **SAF**, **EPSAT-SG**, ECMWF	2004-2006
Exp 3: Regional Merged	0.5deg, 3h: OSI-LAND **SAF**, **TRMM 3B42,** ECMWF	2002-2007
Exp 4: Mesoscale Merged Exp 5: local scale	3 domains (< 0.1 deg, 1h) Multiple sites within each domain	2005-2008

Model Domain (land points only)



*ECOCLIMAP sfc parameters used by 10 of 12 LSMs

Experiments:

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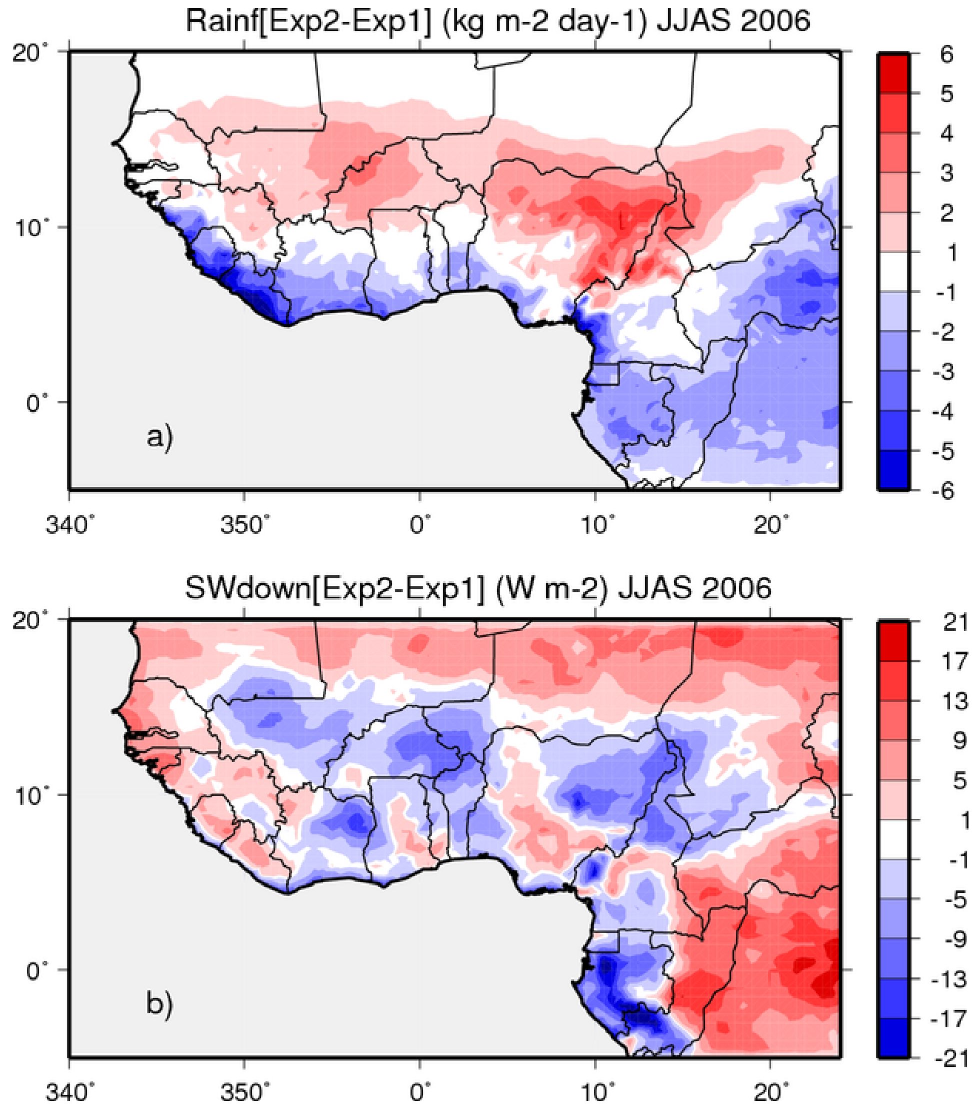
- Use to Correct NWP model bias



Studies using ALMIP results:

Agusti-Panareda, A., G. Balsamo, and A. Beljaars, 2009: Impact of improved soil moisture on the ECMWF precipitation forecast in West Africa. *Geophys. Res. Letters*, (submitted).

Boone, A., P. de Rosnay, G. Basalmo, A. Beljaars, F. Chopin, B. Decharme, C. Delire, A. Ducharne, S. Gascoin, M. Grippa, F. Guichard, Y. Gusev, P. Harris, L. Jarlan, L. Kergoat, E. Mougin, O. Nasonova, A. Norgaard, T. Orgeval, C. Ottlé, I. Poccard-Leclercq, J. Polcher, I. Sandholt, S. Saux-Picart, C. Taylor, and Y. Xue, 2009: The AMMA Land Surface Model Intercomparison Project. *Bull. Amer. Meteor. Soc.,* (in press), doi:10.1175/2009BAMS2786.1

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Studies using ALMIP results:

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de Rosnay P., M. Drusch, A. Boone, G. Balsamo, B. Decharme, P. Harris, Y. Kerr, T. Pellarin, J. Polcher and J.P. Wigneron, 2008: Microwave Land Surface modelling evaluation against AMSR-E data over West Africa. The AMMA Land Surface Model Intercomparison Experiment coupled to the Community Microwave Emission Model (ALMIP-MEM). *J. Geophys. Res*., 114, D05108, doi:10.1029/2008JD010724.

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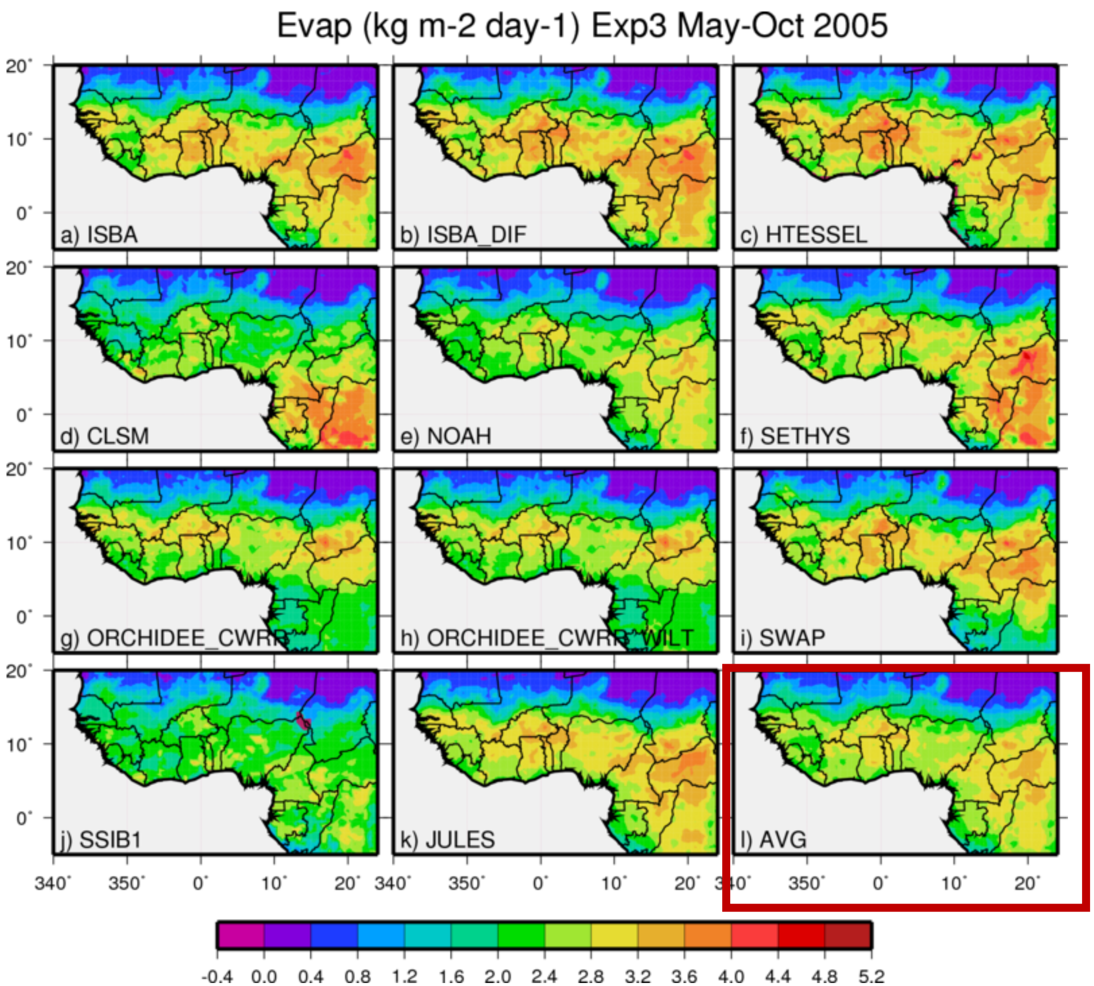
3) Intra-LSM spread

Use for initializing and/or evaluating GCM, NWP simulations



Latent heat flux averaged over JJAS from ALMIP Exp3: for comparison with GCMs compute LSM ensemble mean

Precipitation exerts strongest control in northern part of domain, in southern portion more differences owing to intra-model physics differences

- examine variability, level model agreement, obtain estimates of model spread

3) Intra-LSM spread

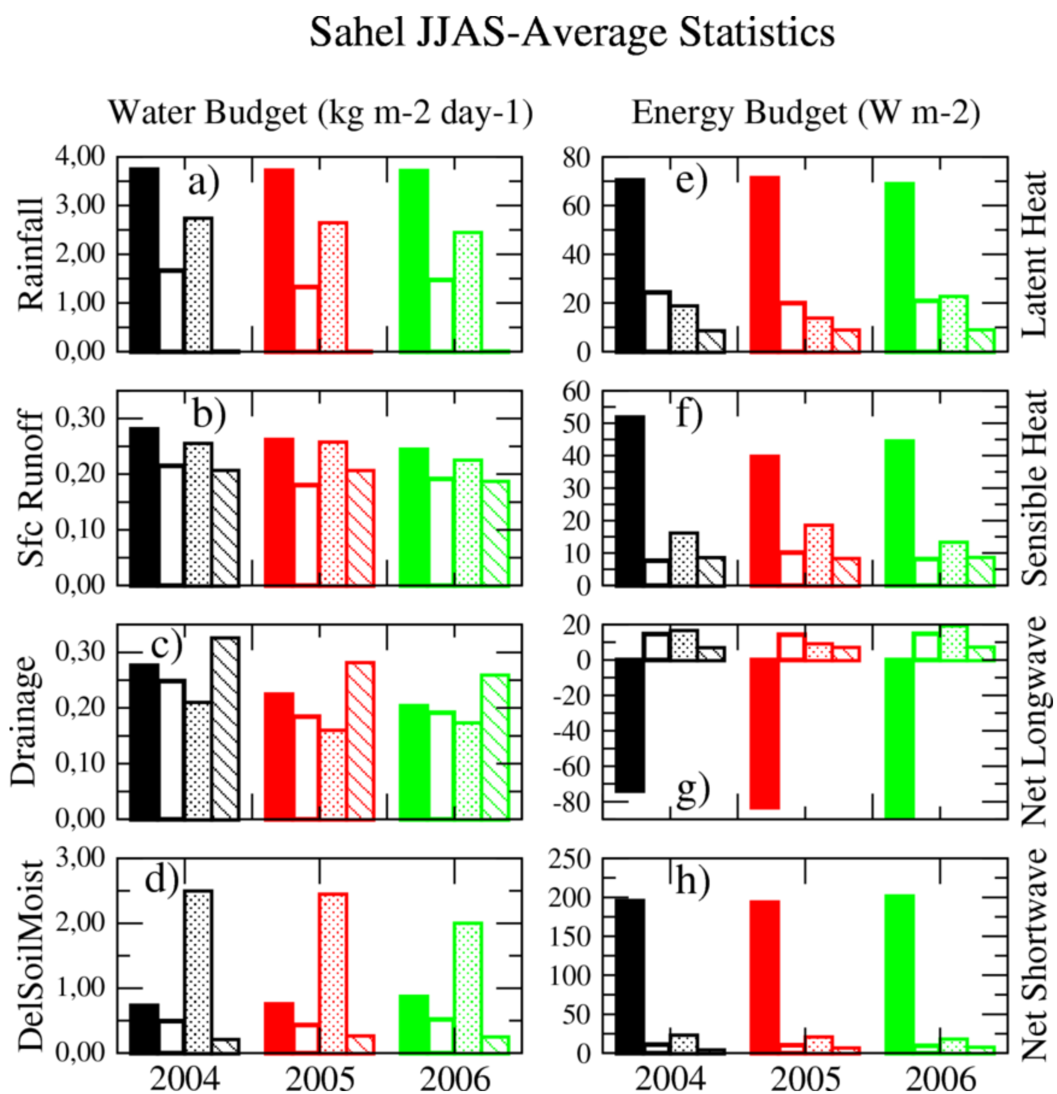
Statistical analysis:
Determine which surface fluxes agree the best among LSMs

Runoff components exhibit the largest intra-LSM var

Turbulent fluxes agree relatively well

High degree of agreement of radiative fluxes (largely imposed)

Soil moisture *change* good agreement, despite largest spatial variability



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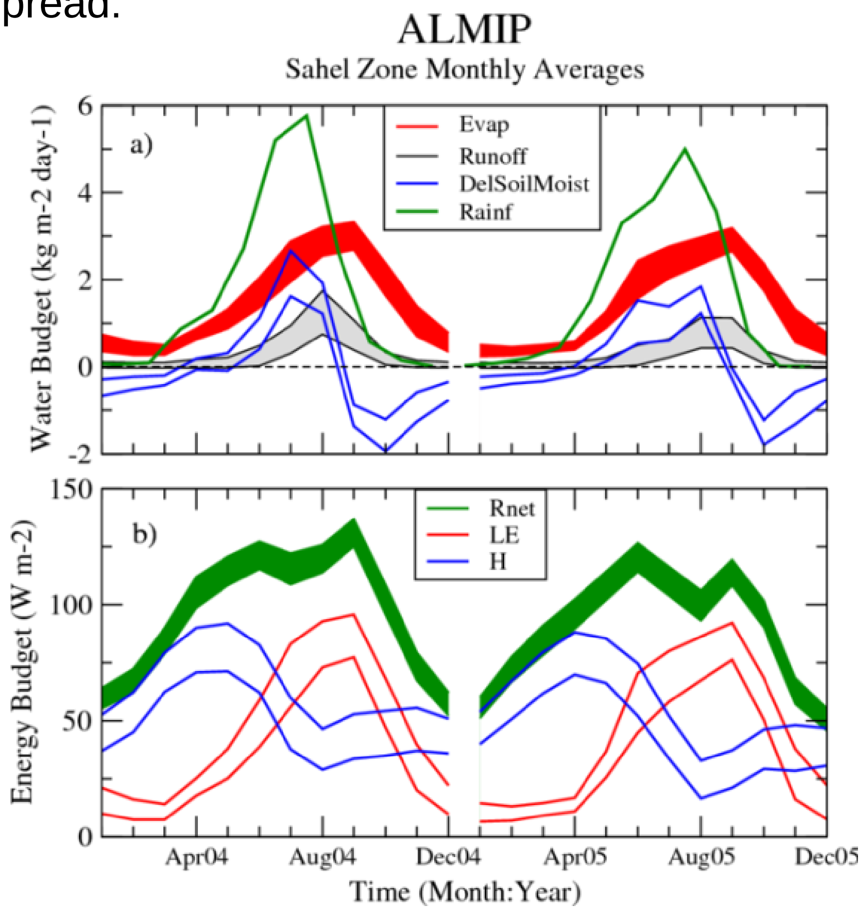
Example of time series of surface energy and water budget components and intra-LSM spread:



2) LSM Evaluation

<u>GRACE</u> Gravity Recovery And Climate Experiment

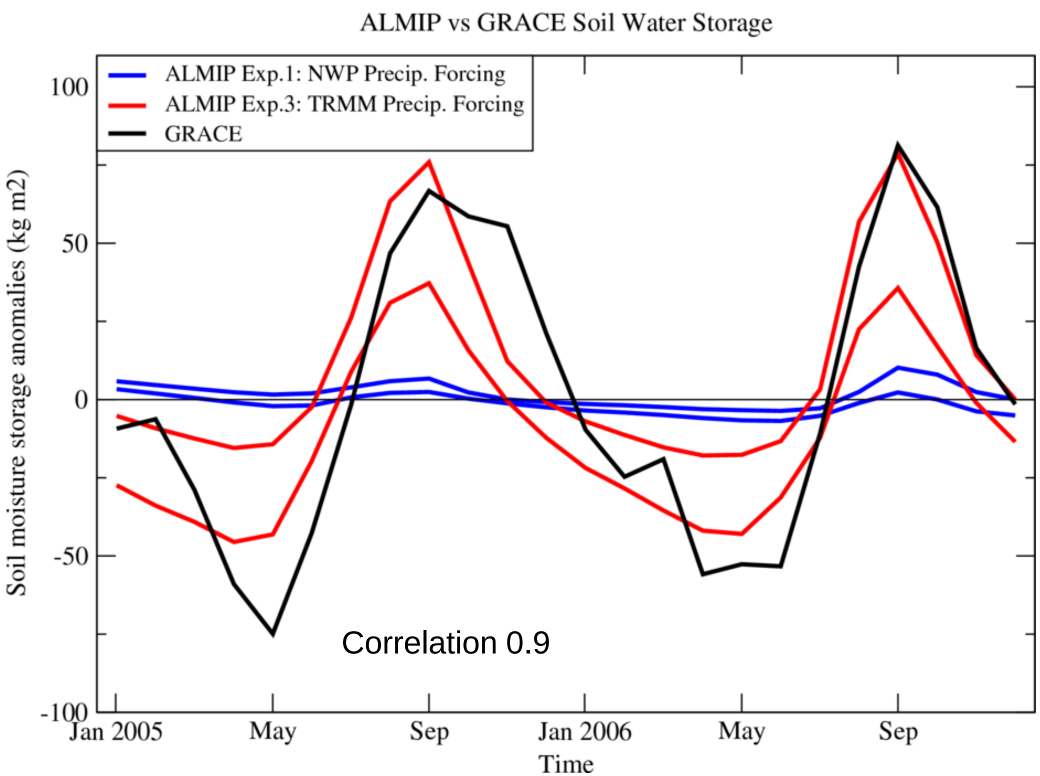
Measures changes in total column vertical water storage

Several GRACE solutions available….

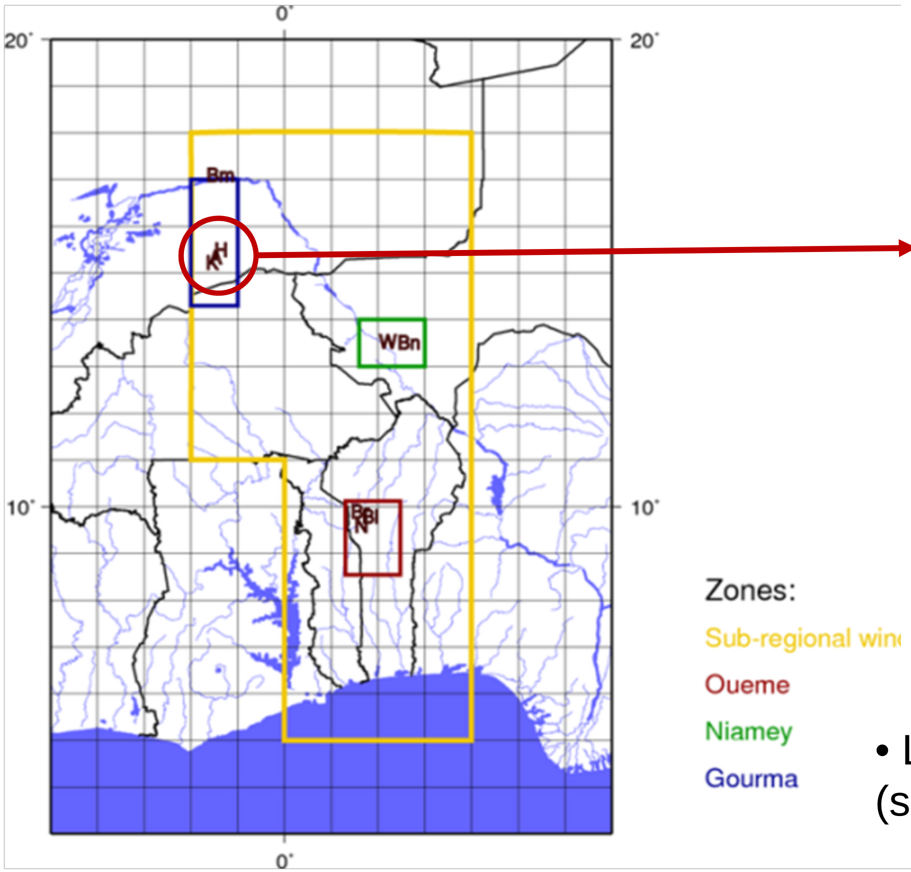
Relatively coarse horizontal and temporal resolutions, but represents 1st direct estimate of continental (scale) water storage

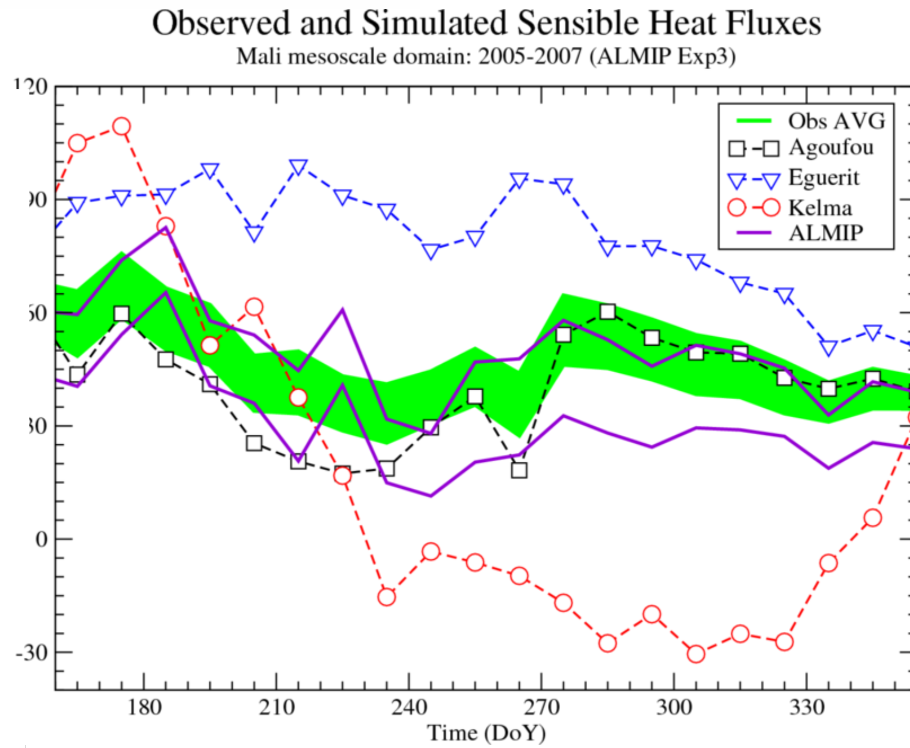
ALMIP model spread together with recent CNES GRACE product for 2 annual cycles over the Sahel

Intra-annual variability very good agreement between GRACE-ALMIP (Grippa *et al*. 2010)



2) LSM Evaluation





- Local scale comparison with model output difficult (scaling, heterogeneity…)
- Aggregated fluxes from the Mail meso-square (Timouk *et al.* 2009)
- Amplitude and seasonal cycle of sensible heat fluxes from ALMIP agrees well

ALMIP-MEM (deRosnay et al., 2009)

AMMA Land Surface Model Intercomparison Project – Microwave Emission Model

Context: SMOS / AMMA (African Monsoon Multidisciplinary Analysis)

ALMIP (**AMMA Land Surface Model Intercomparison Project**, **Boone et al.,, 2009**)

Concept:

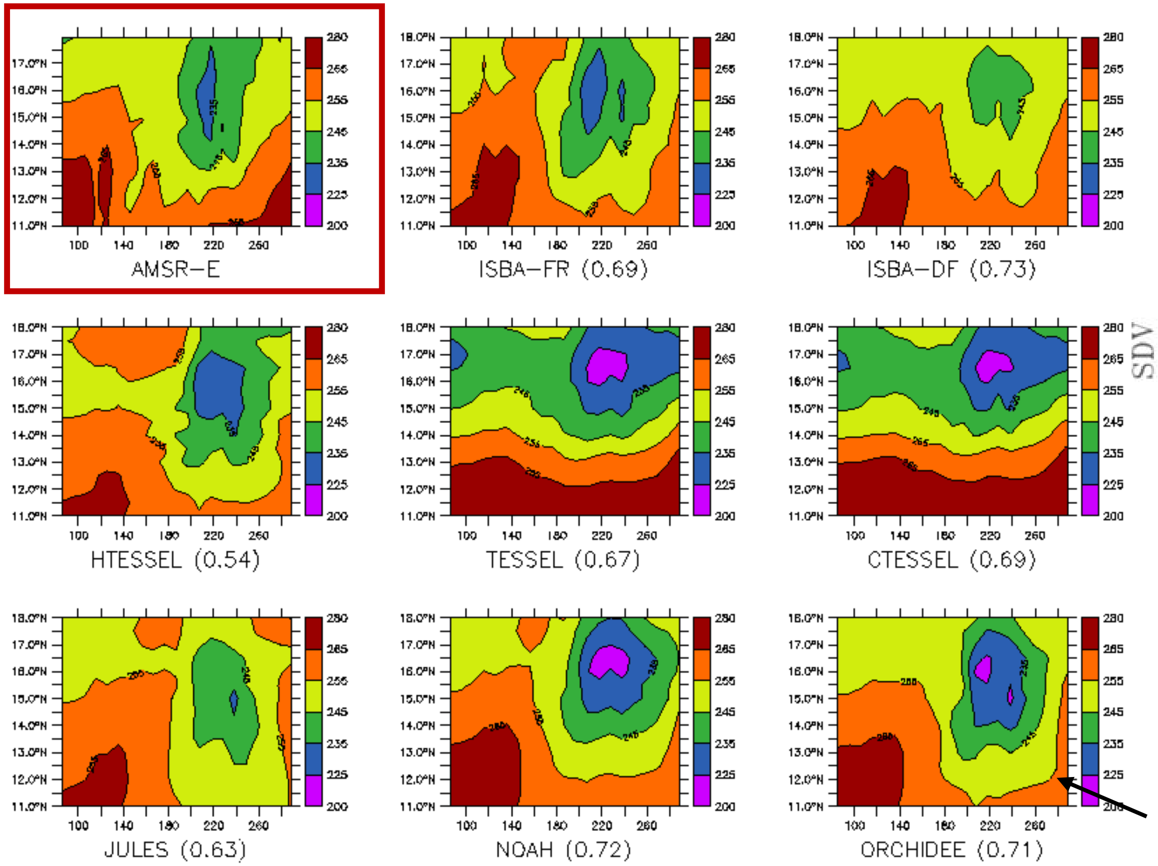
- Combined **8 LSMs and 12 microwave models** inter-comparison
- Based on the modular configuration of the Community Microwave Emission Model (CMEM): http://www.ecmwf.int/research/ESA_projects/SMOS/cmem/cmem_index.html
- Simulation of C-Band Brightness Temperature (TB) for 2006 over West Africa
- Evaluation against C-band AMSR-E data

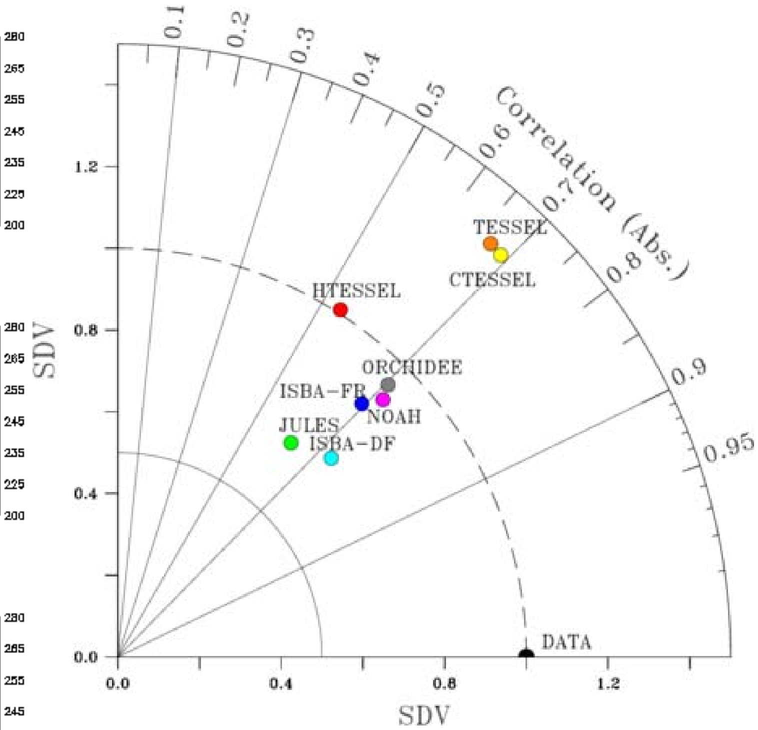
Aim:

- Sensitivity of simulated TB to the LSM and MWM parametrisations
- Identify key parametrisations for the CMEM forward operator

2) LSM Evaluation

Simulated Brightness Temperature





(correlation)

de Rosnay, P., M. Drusch, A. Boone, G. Balsamo, B. Decharme, P. Harris, Y. Kerr, T. Pellarin, J. Polcher, and J.-P. Wigneron (2009), AMMA Land Surface Model Intercomparison Experiment coupled to the Community Microwave Emission Model: ALMIP-MEM, *J. Geophys. Res*.

CMEM and the ALMIP-MEM study

ALMIP-MEM:

- Based on LSM community experience in inter-comparison (PILPS, GSWP2), but focus on West Africa and extended to compare different combinations of LSMs and radiative transfer models
- **1st inter-comparison exercise of land surface MW emission models**
- Coupled LSM-CMEM models capture convective system occurrence in Sahel, as well as latitude-time feature of TB
- **Sensitivity of simulated TB to MW models as important as that to LSMs**
- Robustness of the Kirdyashev opacity model to simulate TB in best agreement with AMSR-E measurements, for any LSM.

Consistence between Skylab (Drusch et al., 2009) and ALMIP-MEM (de Rosnay et al., 2009), although different angle, freq, LSM, scale are considered

High importance of MW modelling approach for SMOS monitoring and assimilation study

WAMME simulations

(Xue and Lau et al.)

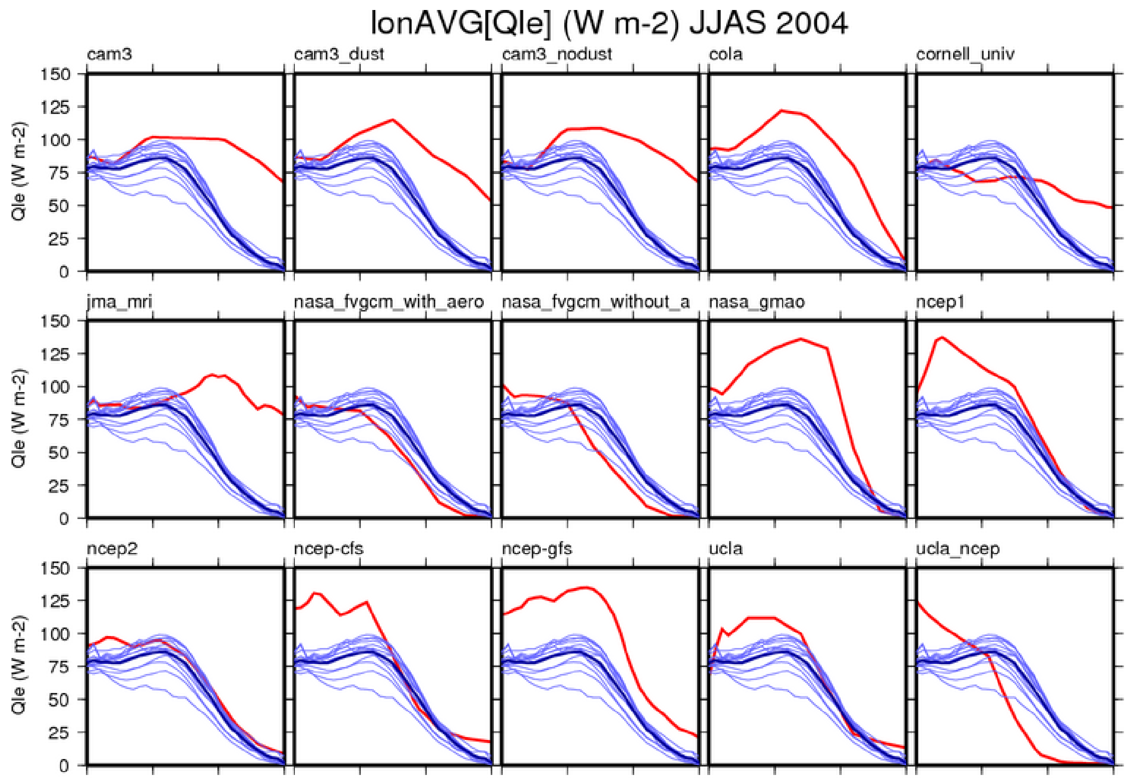
- Longitudinal gradient in surface fluxes (Qle): key for monsoon circulation
- NCEP2 again consistent with ALMIP
- UCLA and NCEP-CFS only models with good slope and position

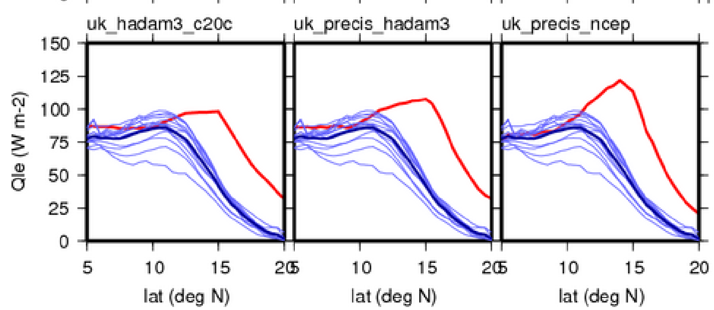
key:

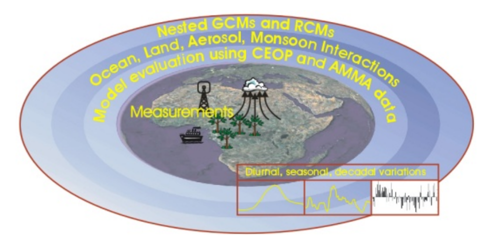
WAMME Models

ALMIP Models

AVG[ALMIP]







High resolution simulation of August 1 AMMA case: impact of soil moisture initial state on the PBL dynamics and comparison with observations.

S. Bastin , C. Taylor , A. Boone

With contributions/help from: D. Bou Karam, D. Parker, N. Asencio, J. Escobar, P. LeMoigne

LATMOS/IPSL (CNRS/UPMC/UVSQ), Paris, France
CEH, Wallingford, UK
CNRM/Meteo-France, Toulouse, France

Questions:

- Which are the vertical and horizontal extents of the effects of surface heterogeneities?
- Is there a threshold (intensity of gradient/U or hPBL) ?
- How long do effects persist?
- Are parameterizations of these effects in models OK, i.e. is a good surface and synoptic forcing enough to reproduce observations?

1 August 2006: First step to answer these questions

4) Applications

MESONH Simulations

- Version MASDEV4_7_2
- 2 domains: 12 et 3 km
- 57 vertical levels
- Initialised at 00Z on 1 August 2006.
- Surface model = ISBA

ECM Simulation

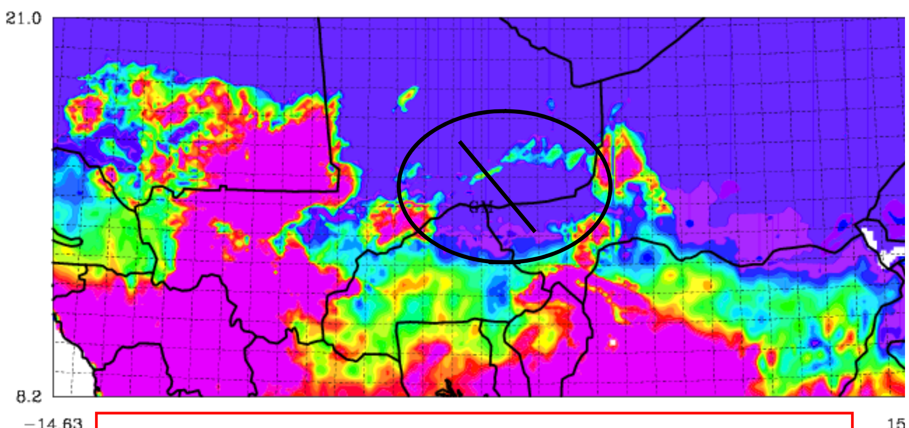
- Atmos. 3D fields: ECMWF (~1°)
- Surface fields: ECMWF (~1°)

SWI Simulation

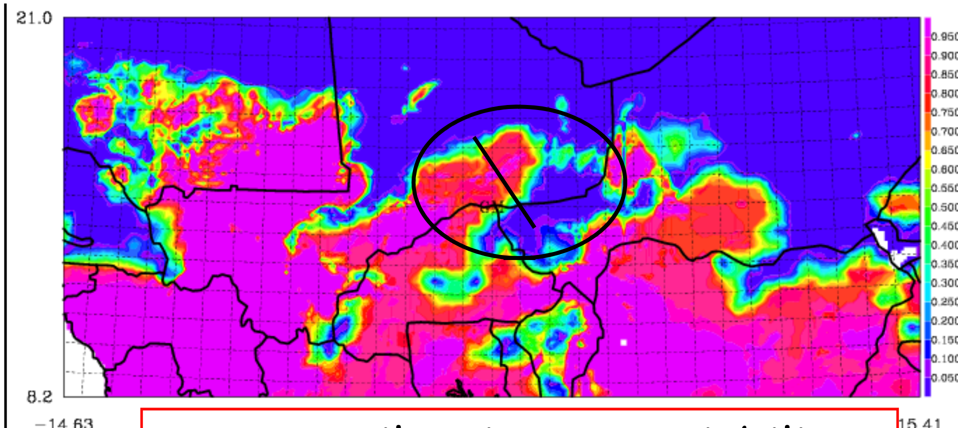
-Atmos. 3D fields: ECMWF (~1°)

-Surface fields: Tsoil and soil moisture from ALMIP simulations (~50 km) (off-line mode of BA)

Soil moisture at 0600 UTC



No soil moisture variability in the area of interest



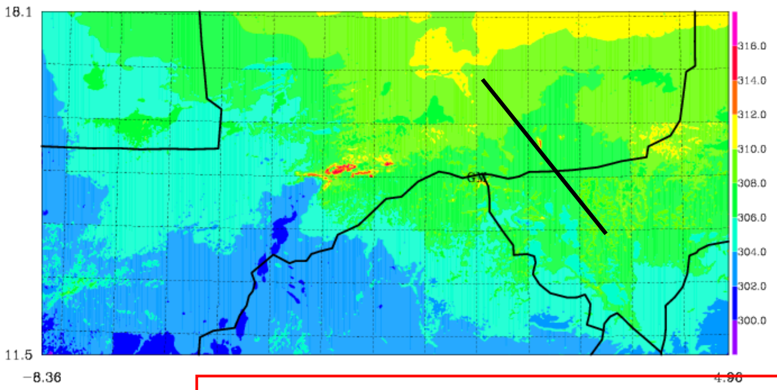
Strong soil moisture variability before sunrise

ALMIP AMMA Land Surface Model Intercomparison Project

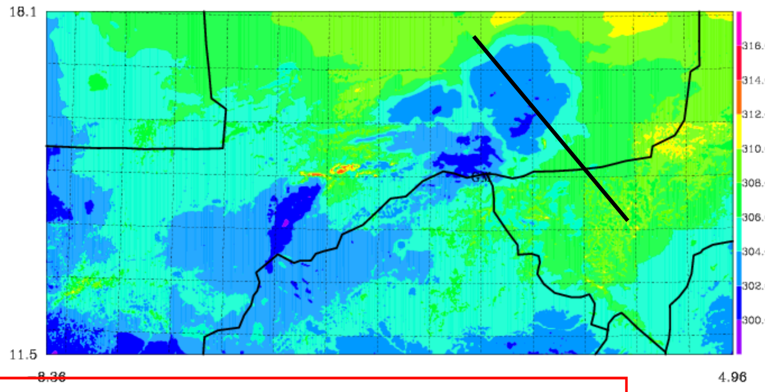
Simulation ECM

Simulation SWI

T2- 1000 UTC

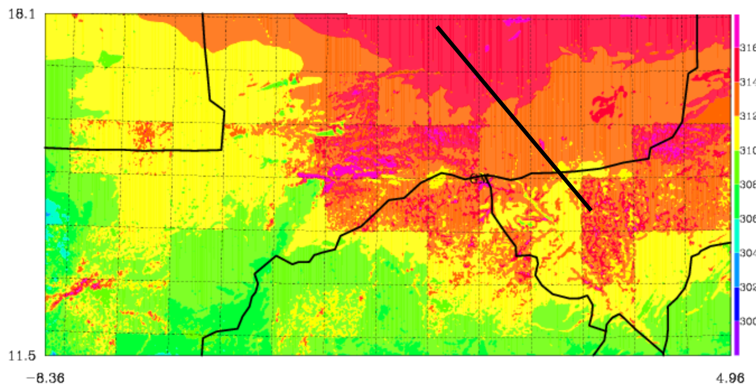


T2- 1000 UTC

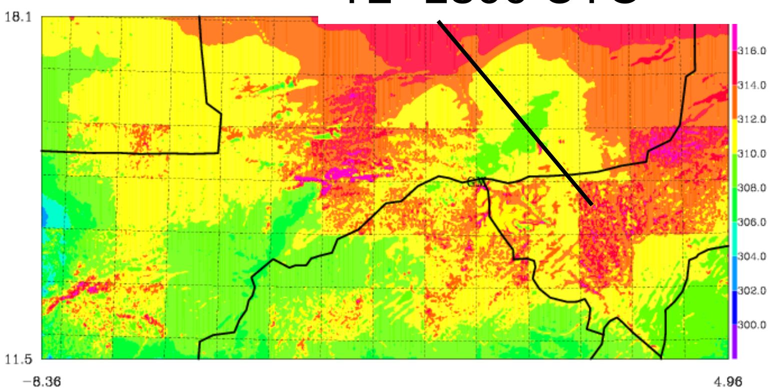


Cold pool persists after soil moisture evaporation in the model

T2- 1300 UTC

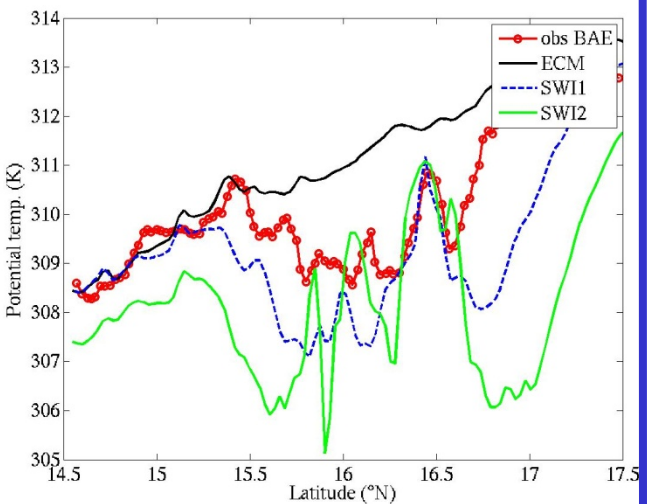


T2- 1300 UTC

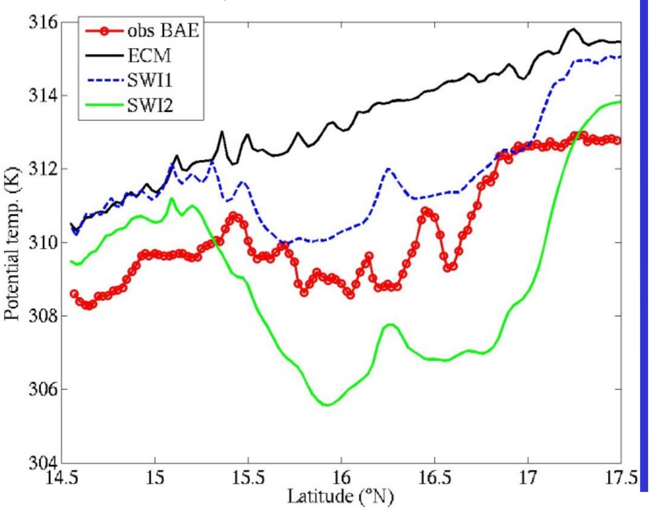


4) Applications

Model outputs at 12Z



Model outputs at 1330 UTC



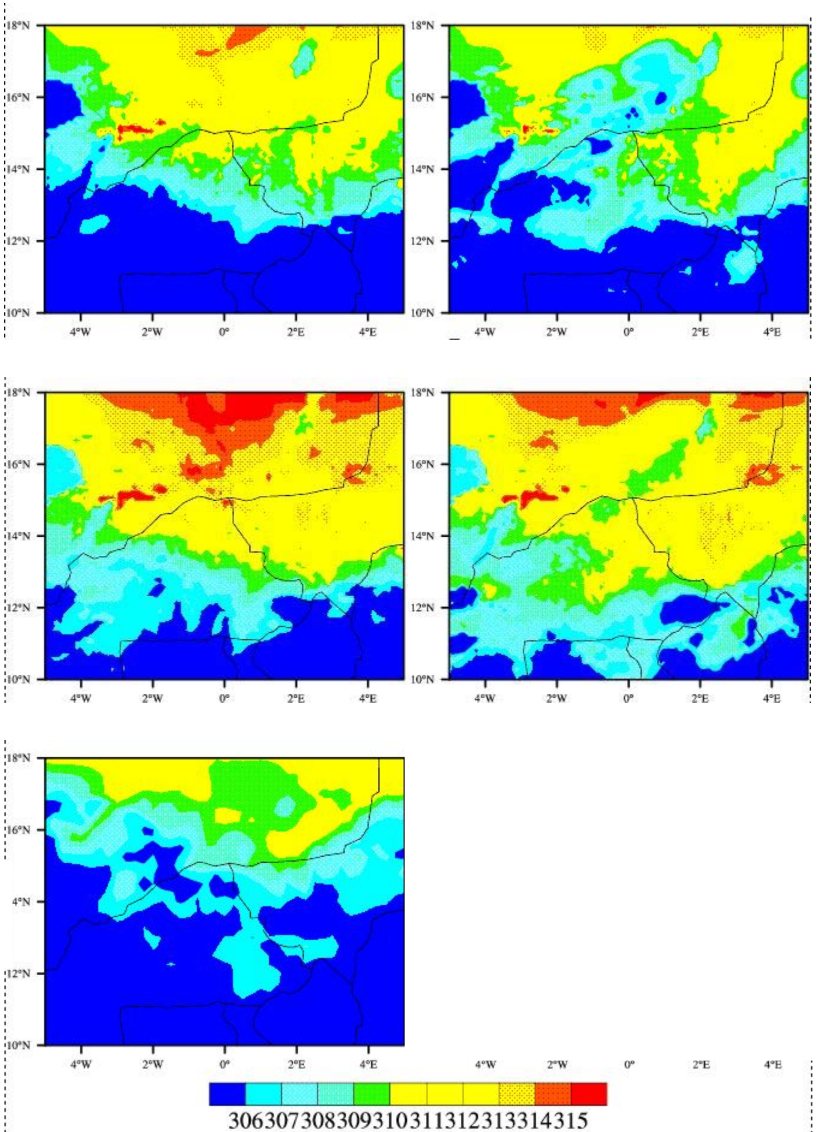
MNH/ECM

MNH/ALMIP

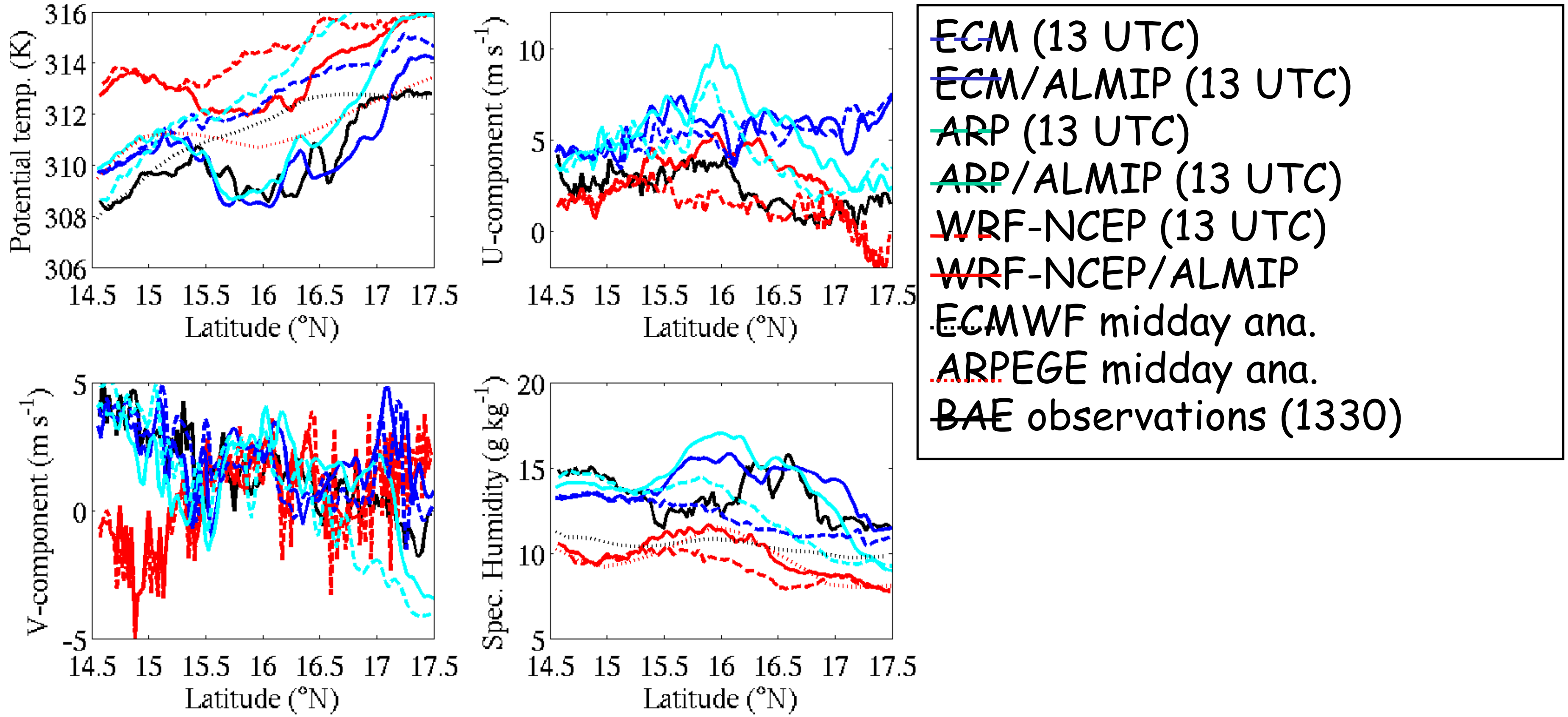
12 UTC

1330 UTC

Midday ECMWF analysis



4) Applications

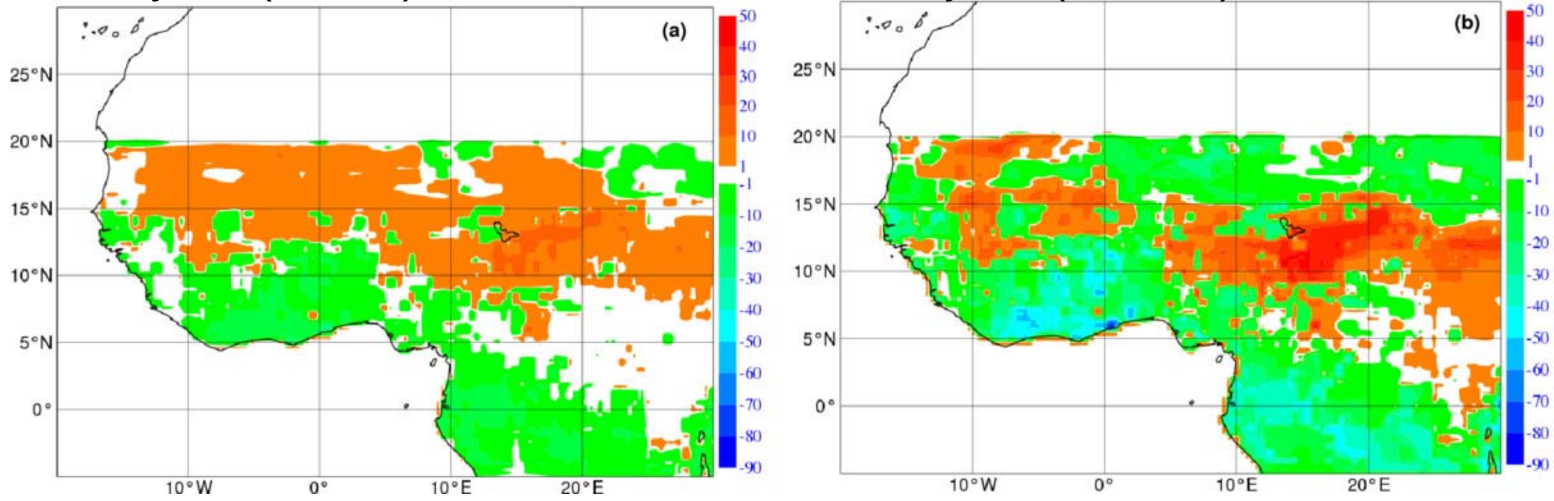


- ALMIP has a strong impact on the PBL thermodynamics in the 3 coupled simulations.
- The impact on the wind can be locally strong: to be analized
- None of the simulations is able to reproduce Q variability.

Impact of improved soil moisture on the ECMWF precipitation forecast in West Africa

A. Agusti-Panareda, G. Balsamo, A. Beljaars

Layer 1 (0-7 cm) Layer 2 (7-28 cm)



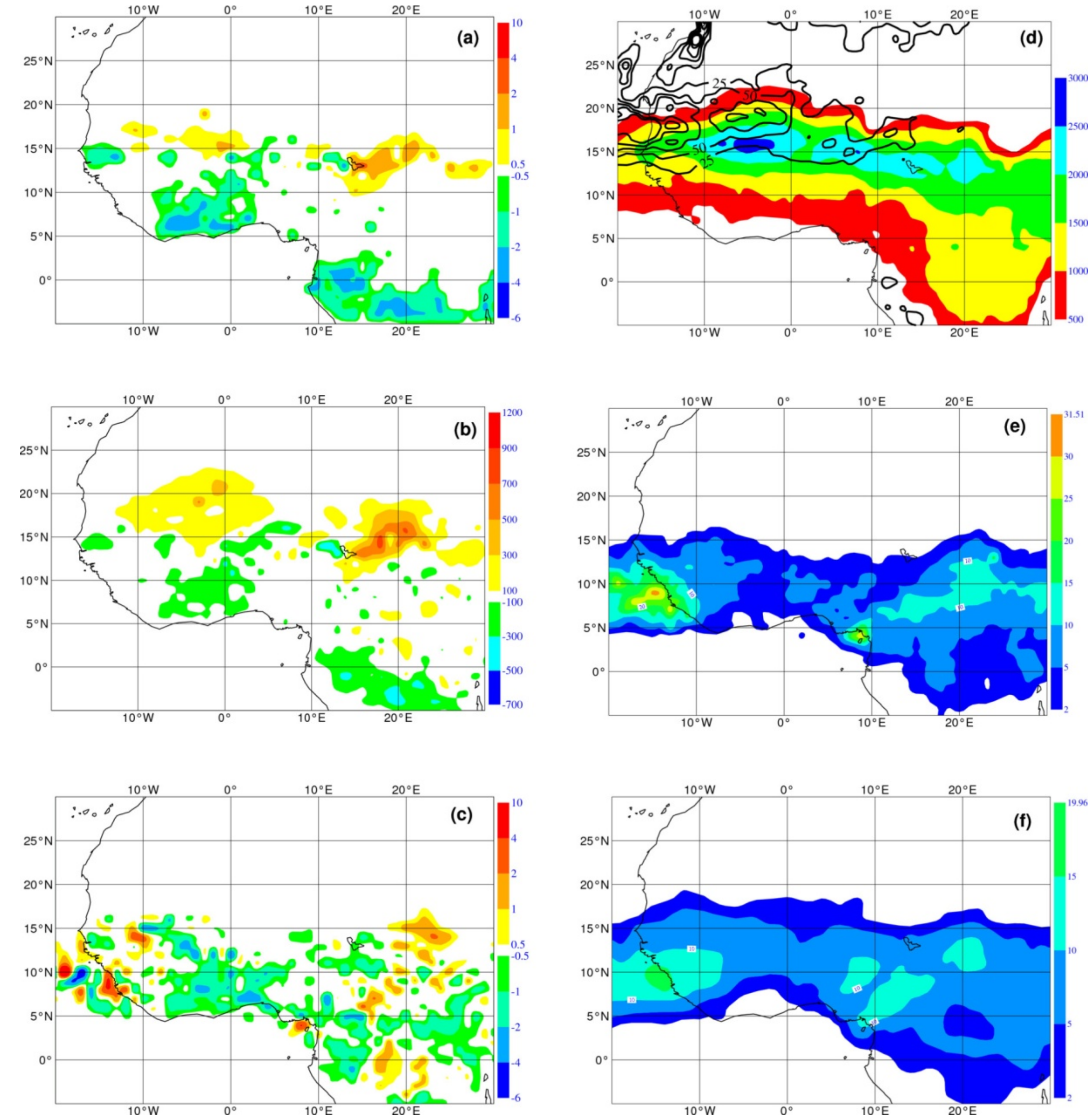
Mean difference in the initial soil moisture between the experiment with ALMIP soil moisture and the control experiment for the period
(mean difference from 1 to 31, August 2006)

4) Applications

<u>Left panels are monthly mean differences</u> between the forecast initialized with ALMIP soil moisture and the control forecast (ALMIP - CONTROL) for:

(a) evaporation [mm/day] from T+24 to T+48
(b) CAPE (J/m2) at T+36
(c) precipitation [mm/day] from T+24 to T+48;

<u>Right panels are mean fields of;</u>
(d) CAPE [J/kg] (in colour) and CIN (contour lines, starting from 25 J/kg with contour interval of 25 J/kg) from the control forecast at T+36
(e) precipitation [mm/day] from T+24 to T+48 from the forecast with ALMIP soil moisture
(f) precipitation [mm/day] from the Global Precipitation Climatology Project (GPCP). The forecasts were initialized daily from 1 to 31 August 2006 at 00 UTC.

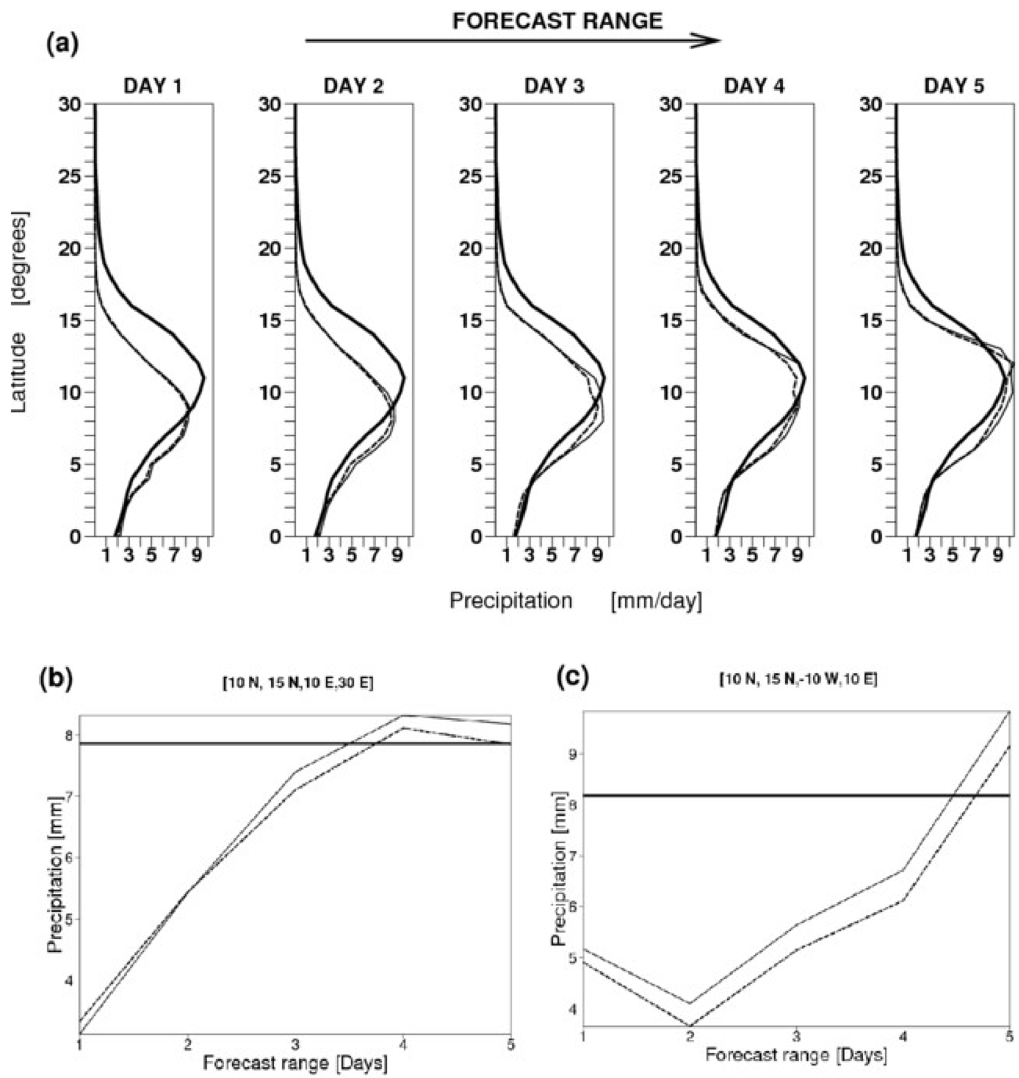


4) Applications

(a) Monthly mean zonally averaged precipitation with respect to latitude (y-axis) within the region 15o W–30o E and 0o –30o N for different forecast ranges.

Bottom panels are monthly mean precipitation with respect to forecast range (x-axis) for the regions of (b) eastern Sahel (10o E–30o E, 10o N–15o N) and (c) central Sahel (10o W–10oE, 10o N–15o N). The lines for all plots correspond to the forecast initialized from ALMIP soil moisture (dash line), the control forecast (thin solid line) and the Global Precipitation Climatology Project (GPCP, thick solid line).

The forecasts were initialized daily from 1 to 31 August 2006 at 00 UTC.



The Atmospheric Water Cycle of the West African monsoon

Anna Agustí-Panareda, Anton Beljaars, Olivier Bock,
Remi Meynadier, Gianpaolo Balsamo

Thanks to
P. de Rosnay, A. Boone, R. Forbes, J.-J.Morcrette, A.Garcia Mendez
M. Nuret, F. Guichard, J.-P. Lafore, A. Fink, D. Parker,J.-B. Ngamini

Assessment of water balance in NWP models

- Hybrid method to obtain a best estimate
- Comparison between NWP models.
- Impact of radiosonde humidity bias correction and enhanced AMMA radiosonde network.

4) Applications

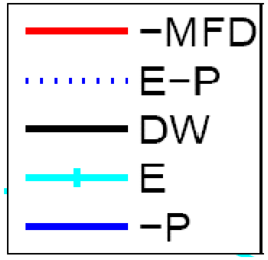
- **PTRMM** satellite-based precipitation TRMM 3B42 V6 (3 hourly, 0.25x0.25)
- **EALMIP** multi-model average evaporation from 10 Land Surface Model simulated within ALMIP exp-3 (3 hourly, 0.5x0.5) forced with TRMM 3B42 V6 rainfall data
- **PWV** precipitable water vapor from ERA INTERIM re-analysis (6 hourly, 0.75x0.75)
- **MFDHybrid** computed as a residual from budget equation

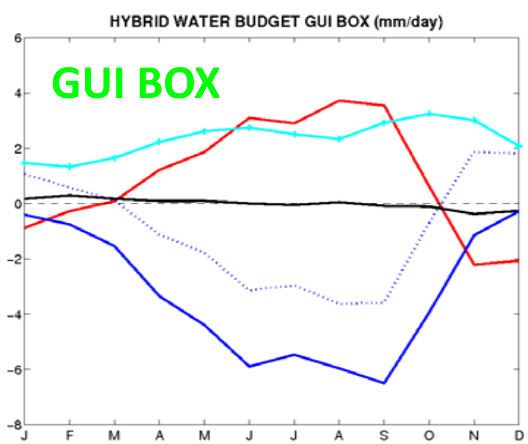
(Meynadier et al,2009)

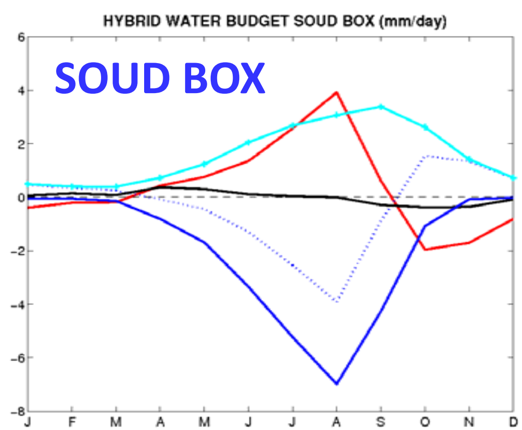
$$\underbrace{\left(\nabla_H \cdot \vec{Q}\right)_{hyb}}_{\text{MFD}} = E_{ALMIP} - P_{TRMM} - \frac{\partial}{\partial t} W_{NWP}$$

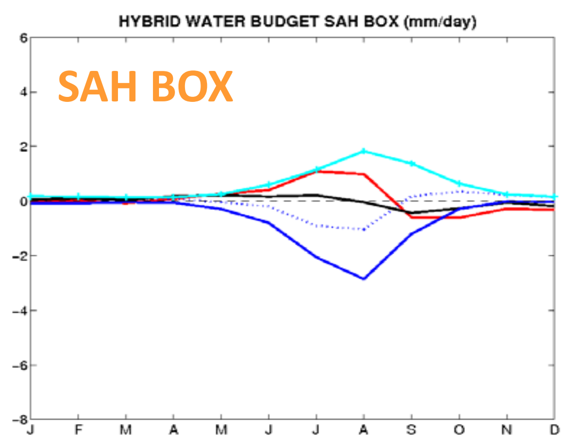
MFD

Moisture Flux Divergence



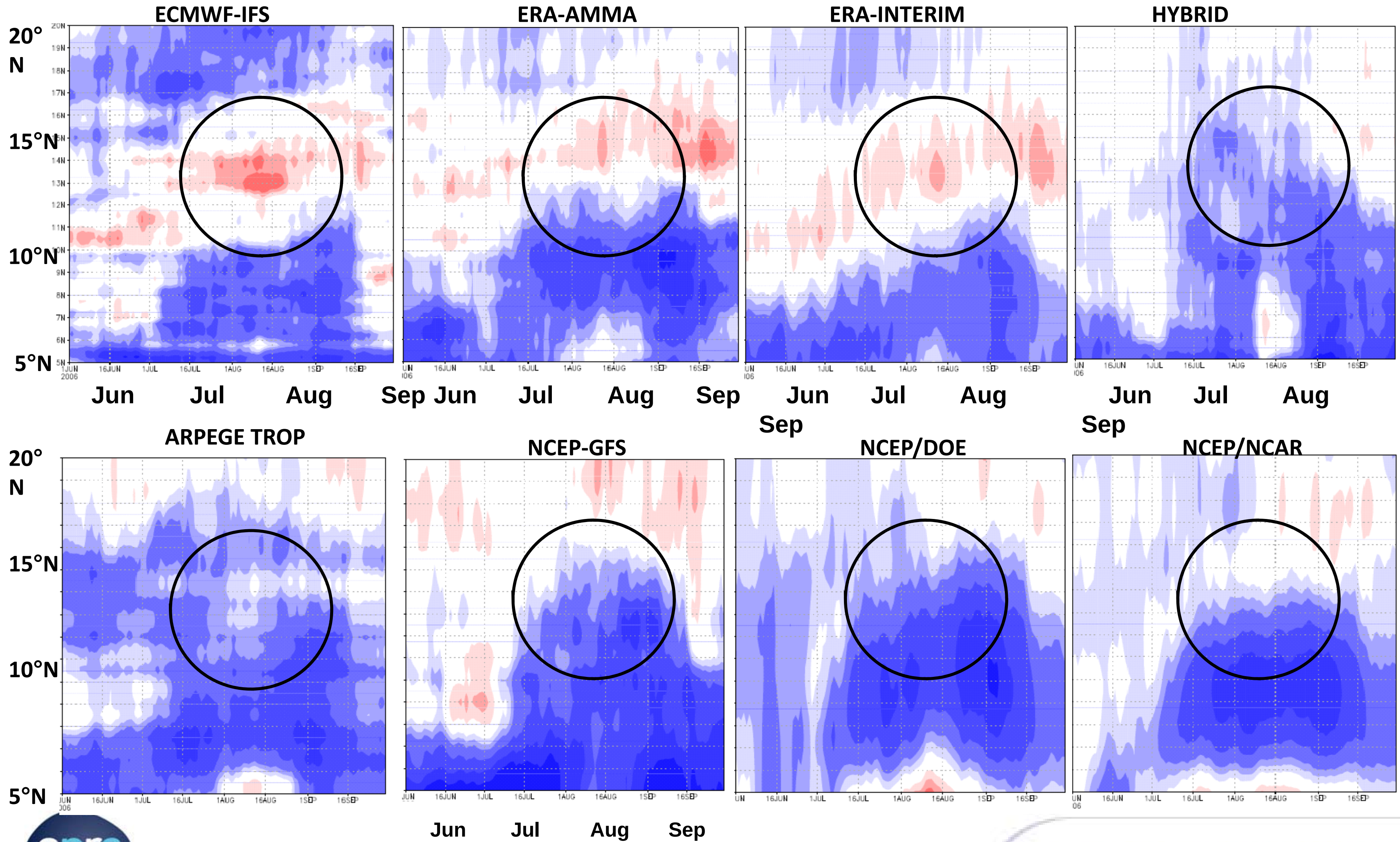






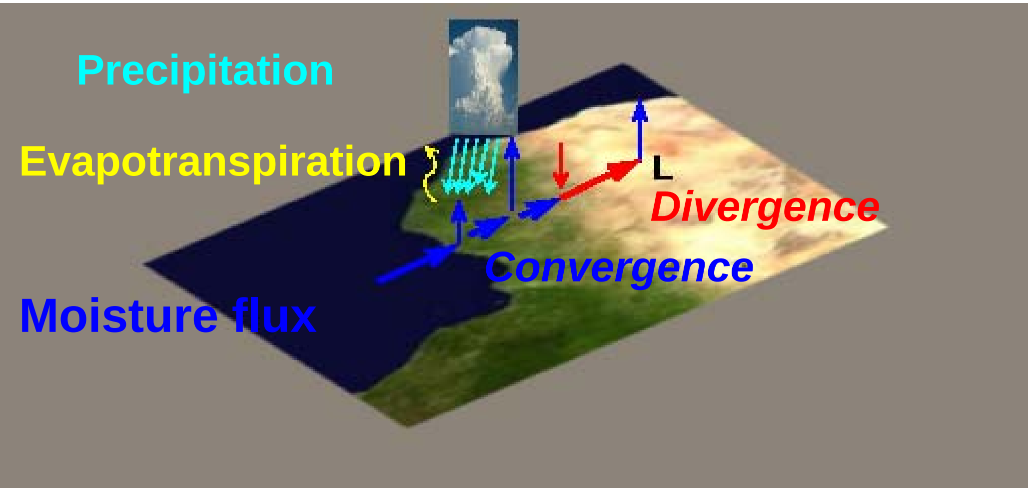
ALMIP AMMA Land Surface Model Intercomparison Project

Assessment of water balance in NWP models: flux divergence (Meynadier and Bock)



METEO FRANCE Toujours un temps d'avance

4) Applications



The atmospheric water budget has been assessed using a **hybrid dataset** which contains the best estimates of the different terms of the water budget. This is a powerful tool which provides a reference to investigate NWP model biases.

All NWP models have problems:

- Too much precipitation over the Guinea coast and too little over Sahel.
- ECMWF AMMA reanalysis with enhanced radiosonde network and a radiosonde humidity bias correction scheme presents improvements over the Soudanian region (~12 N) with respect to the operational model and ERA-Interim.
- ECMWF model has too much divergence and subsidence over Sahel. This could explain the southern shift of the rainbelt.

ALMIP 1: Summary of Project:

•6 years of offline simulated surface states and fluxes (proxy for a reanalysis of surface fields) hydrological variables...Exp3 2002-7 now on AMMA-DB!

•Numerous GCM/RCM intercomparison efforts using or will use ALMIP fields or "functions« (AMMA-MIP, WAMME, ENSEMBLES...), also individual model evaluation

•Fields also being used in numerous modeling studies for initiailization and evaluation: convective initiation and development, aerosols, atmospheric chemistry/Nitrogen budget...

•Water Cycle Work: regional to mesoscale water budget studies, evaporation production functions for hydrological modelling

•Remote Sensing Applications: comparison of radiative temperatures with satellite data, forward modelling of brightness temperature

•Characterisation of the intra-LSM spread of surface variables: hydrology identified as area needing the most work (despite recent strides)

•Examine inter-annual variability of continental water storage (Grippa et al), surface and links with other variables (SST, NDVI...Taylor et al.)

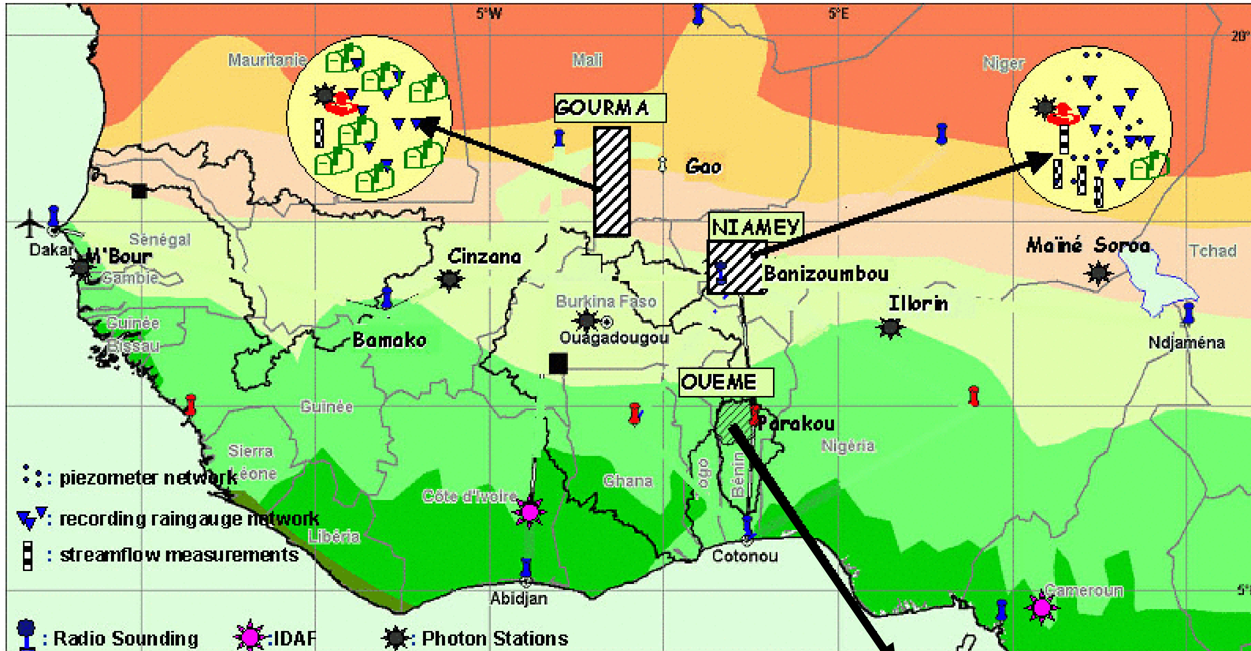
•Sensitivity to forcing, especially the precipitation: but products still far better (and have better agreement) than coupled model estimates

•Coupled model sensitivity tests using ALMIP surface states or functions…

ALMIP Phase II: Local and Mesoscale

(set for 2010)

Focus on key land surface-hydrological processes across a strong eco-climatic gradient



Meso-Super Sites

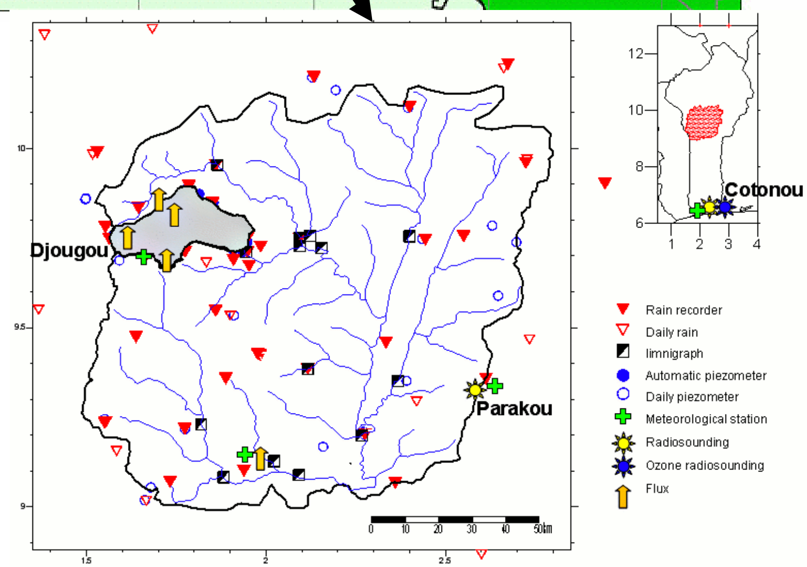
Model evaluation

And Forcing

- Local scale data
- Turbulent fluxes
- Soil moisture, Temp
- Discharge
- Vegetation (LAI…)

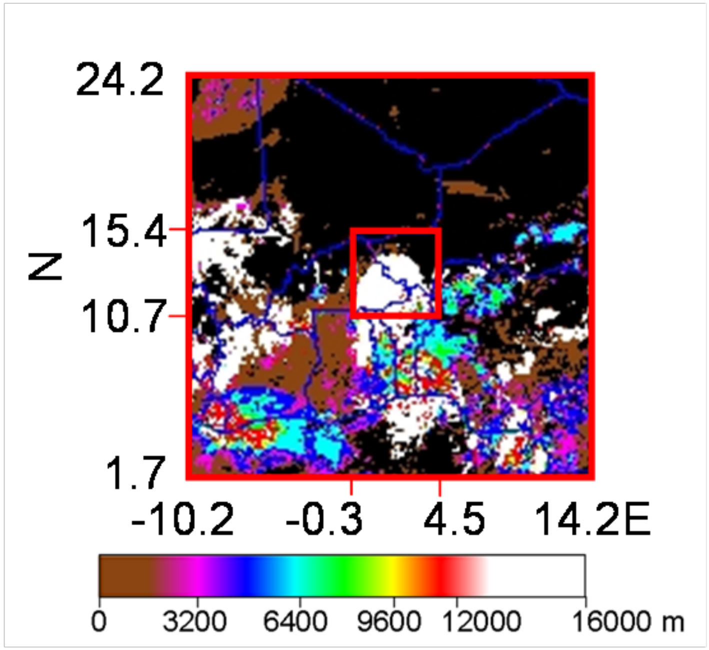
E.g. 2004
- 44 rain gauges
- 19 discharge sites
- 4 flux stations
- etc….

Rainfall forcing Tests: Krigged, Lagrangian, Radar-based, Satellite based (0.05deg, 30min)



EXTRA…

1. Simulated domain

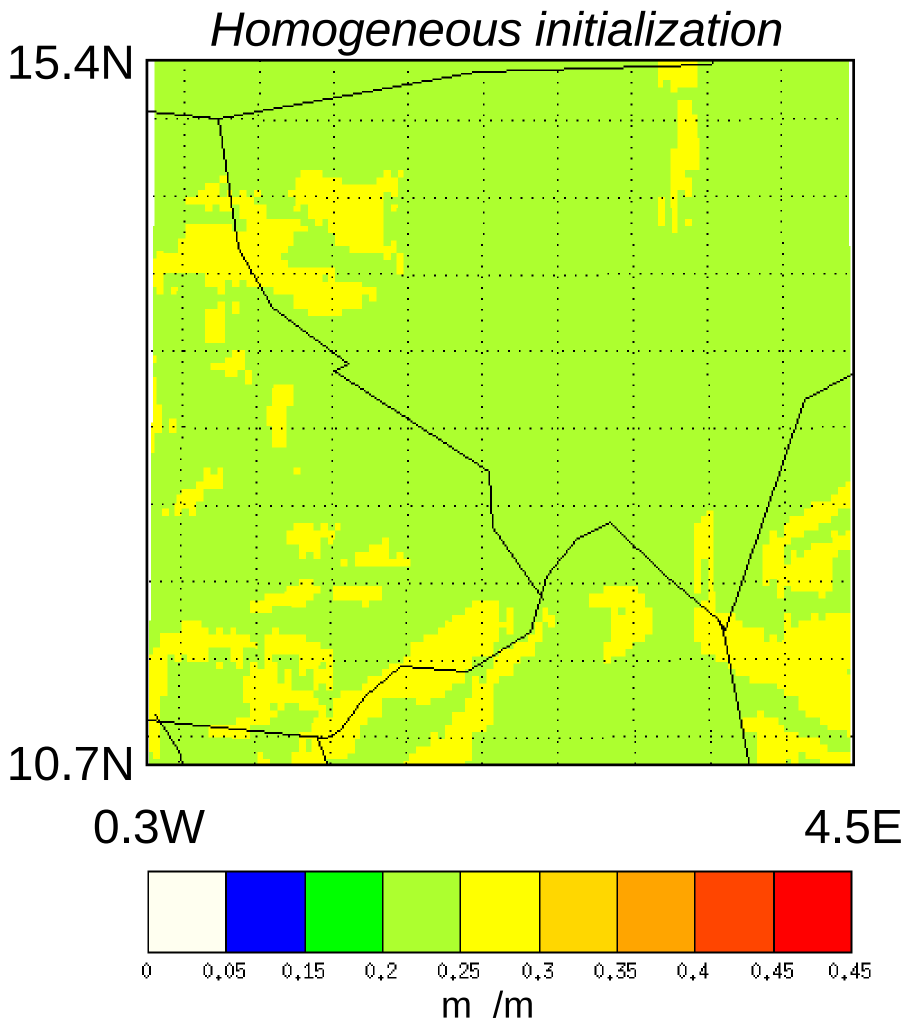


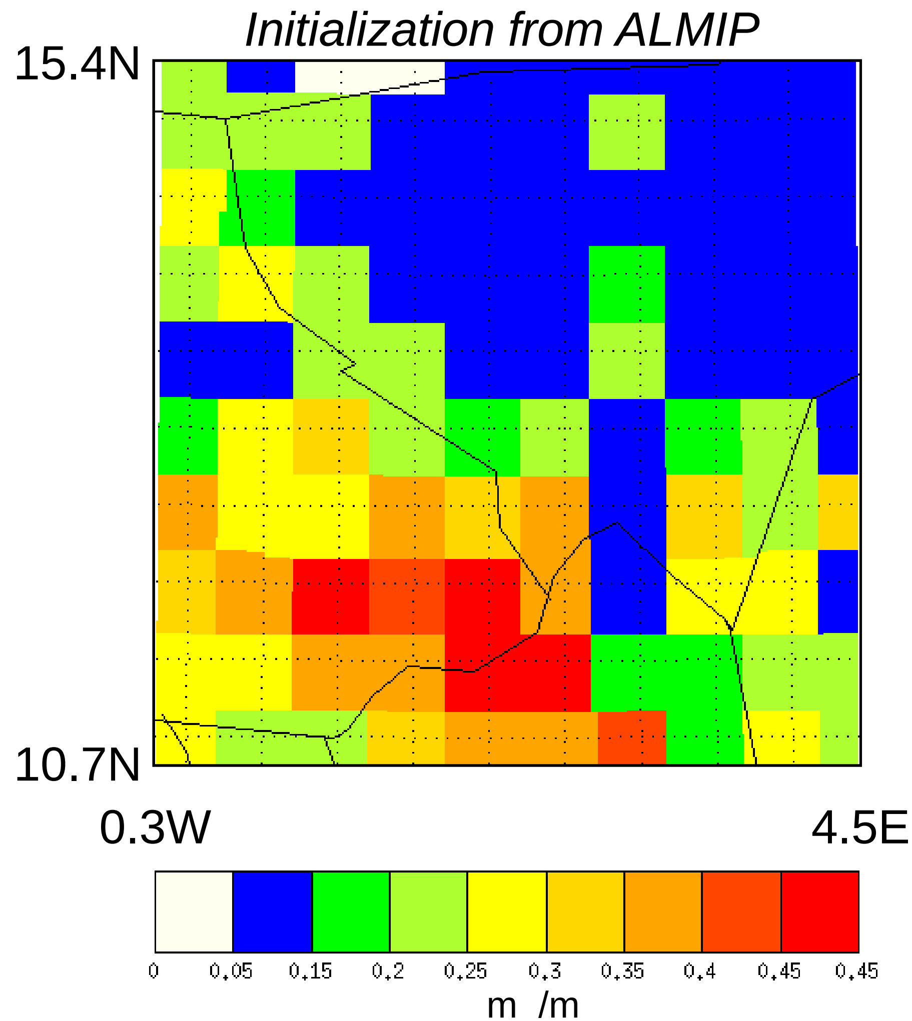
- 2 nested grids (2-way nesting) both centered on Niamey (13N;2E)
- Grid 1 characteristics:
  nx = ny = 101; Dx = Dy = 25 km
- Grid 2 characteristics:
  nx = ny = 102; Dx = Dy = 5 km
- For both grids: nz = 50 levels
  from ground to 22 km agl, with 20 levels in the PBL
- Large scale forcing: ECMWF

2. Simulated period

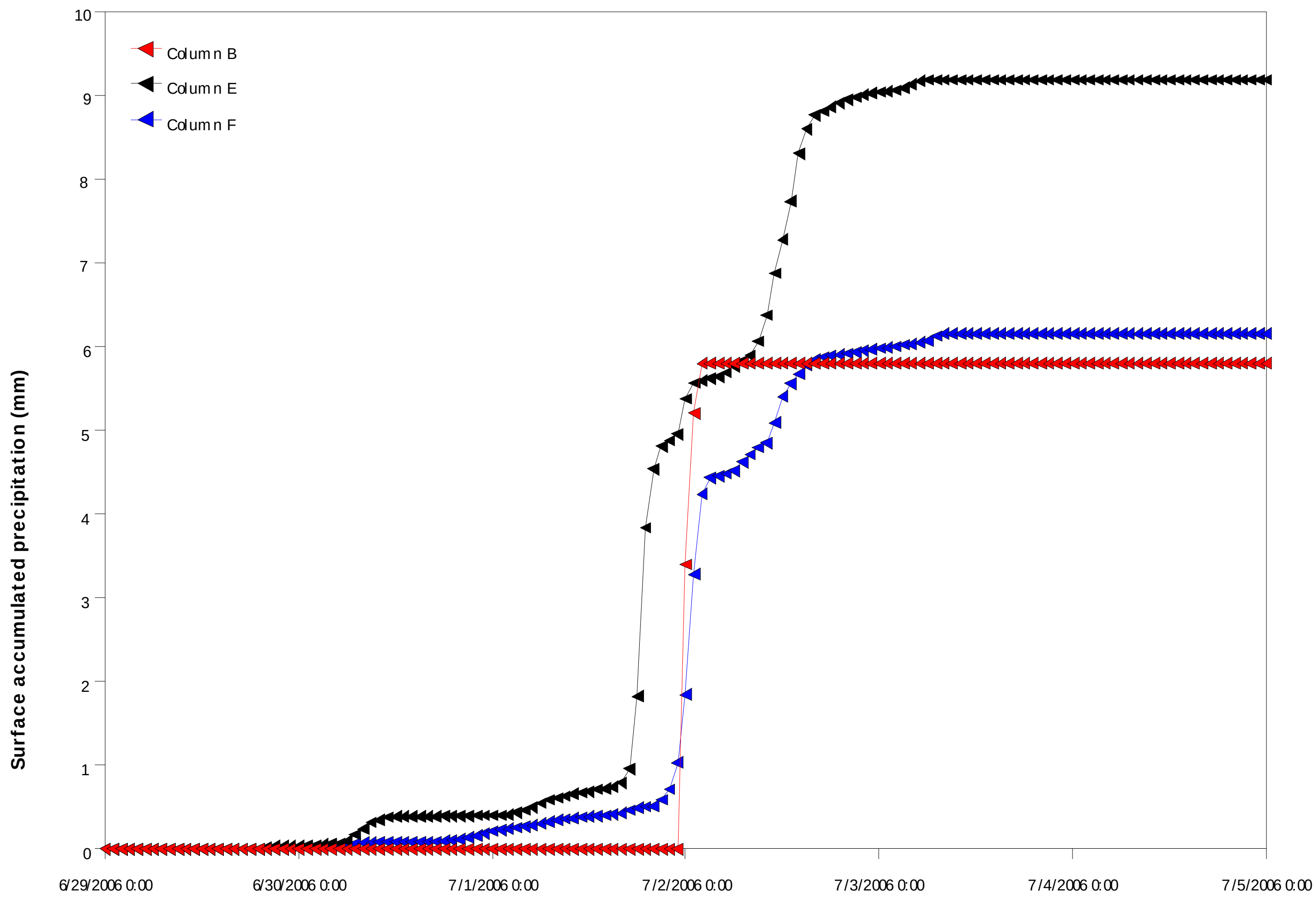
The simulated period starts on 2006 June, 29 at 0UTC and lasts 6 days to ends on July, 5 at 0UTC.

4) Applications



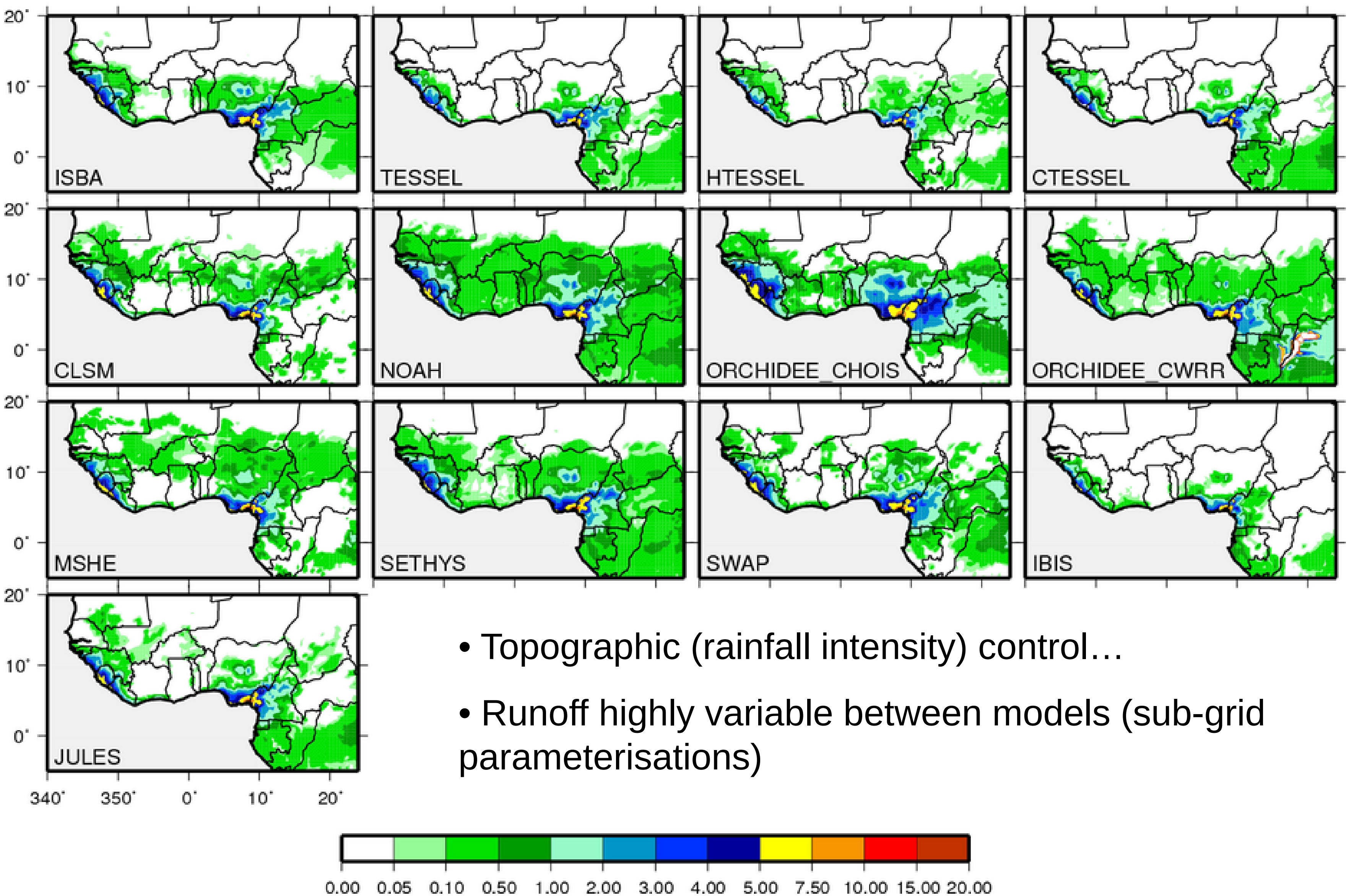


Rainfall temporal evolution – Wankama



Model Results

Runoff (mm day-1) JJAS Exp2 2005

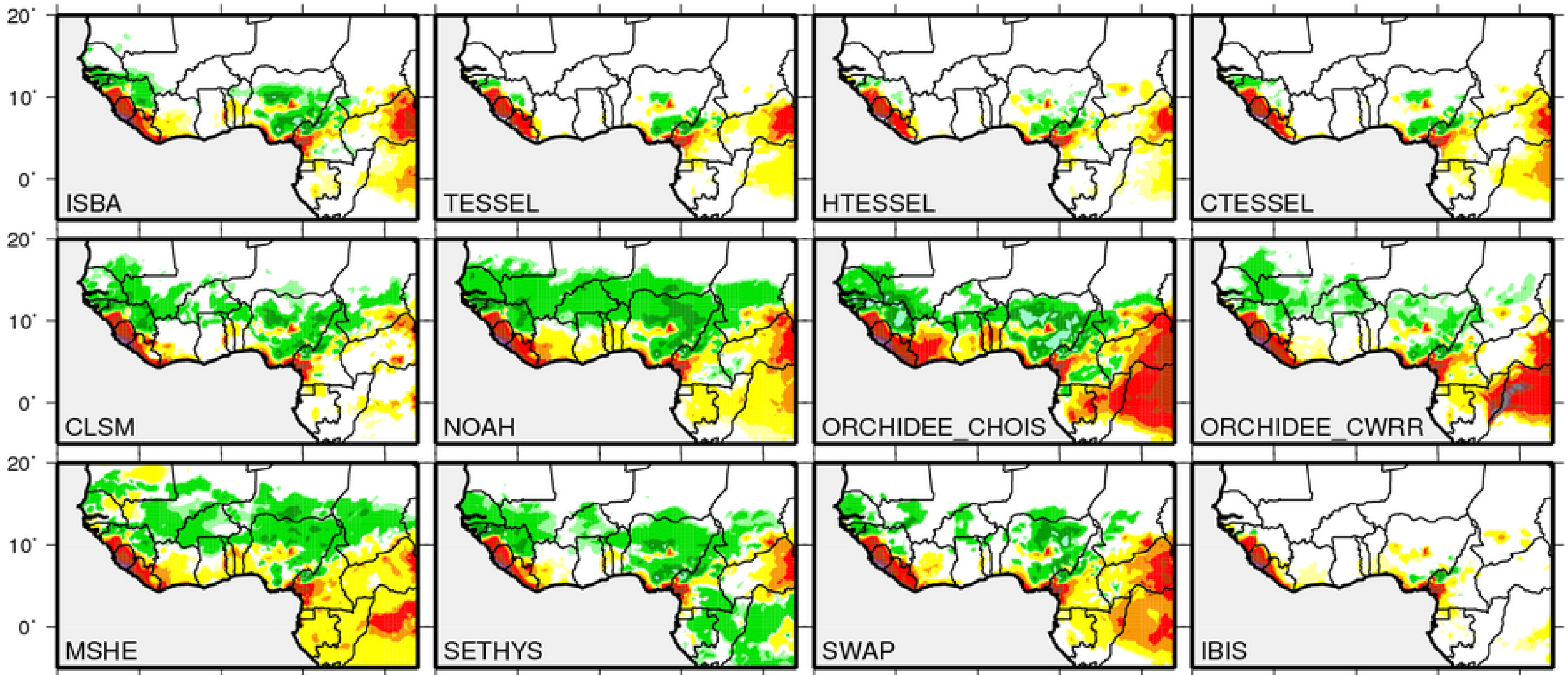


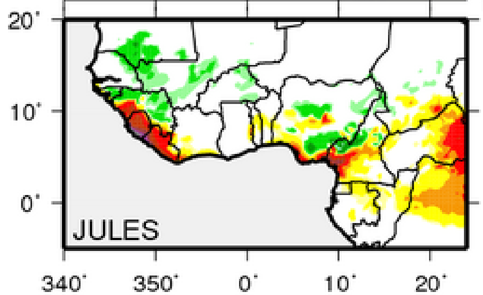
- Topographic (rainfall intensity) control…
- Runoff highly variable between models (sub-grid parameterisations)

AMMA ALMIP AMMA Land Surface Model Intercomparison Project

Model Results

Runoff (mm day-1) JJAS Exp2-1 2005





Runoff Exp2 – Exp1

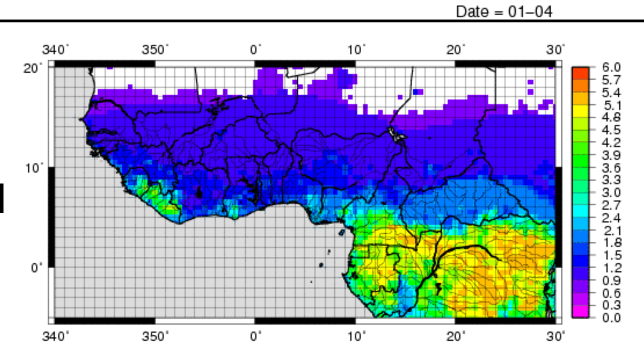
Runoff highly variable between models (sub-grid parameterisations)➔ runoff water is not recycled…

Meso – Input Forcing

Land Surface Model Soil-Vegetation Parameters

- ECOCLIMAP – global 1x1 km2, decadal
- Operatioal NWP, Mesoscale research CNRM/Météo-France
- Single annual cycle ==> **ECOCLIMAP2** (inter-annual var) Kaptué & Roujean (CNRM)

LAI



OSI and LAND-SAF Downwelling radiative flux products

E.g. LAND-SAF Solar Radiation:

- MSG Data: 0.6µm, 0.8µm, 1.6µm
- Land/Sea Mask, Cloud Mask (SAF-NWC software)
- Total Column Water Vapour (ECMWF)
- Ozone Content (Climatology)
- Land Surface Albedo: Static Map, later AL product
- [Visibility -> Aerosol Optical Thickness]
- AMMA-SAT ➔ 0.05 deg., 30 min., July 2005+

(see Geiger et al)

Lagrangian kriged Rainfall

T. Vischel, T. Lebel, M. Gosset (LTHE, LMTG)

- 0.05 degrees, 30 minutes
- 2005-2007 (2008?)
- Multiple realisations: explore parameter uncertainty/errors, impact on LSMs and hydrological Response

Meteorology: ECMWF...obs?

Observational Data Needed: as much as possible of...

Forcing (input)

- Meteorological State: Air T, RH (2 m), surface pressure, Wind speed (10 or 2 m)
- Radiative Fluxes: Downwelling shortwave (SWdown) and longwave (LWdown) fluxes (30min to 3h)
- Precipitation Flux (30min to 3h)
- Soil (texture, hydrological & thermal parameters, albedo)
- Vegetation (cover type, characteristics: LAI, albedo, Rs_{min}, root depth, height...)

Evaluation (output)

- Turbulent fluxes: H (sensible heat), LE (latent heat/evapotranspiration)
- Radiative Fluxes: SWup (or albedo), LWup
- Surface temperature (radiative?)
- Soil temperatures
- Surface ground heat flux G
- Soil Moisture (to rooting depth...or more)
- CO_2 flux
- Vegetation evolution measures (LAI...biomass)
- Hydrology (runoff, discharge, area of flooded zone, river depth (anomaly)

Some data can be satellite based for mesoscale...

Break various components of complex coupled system into managable portions which can then provide insight into various processes: 1st step➔ Force LSMs in *Offline* mode

LSM (or SVAT) ➔ lower BC for atmospheric models, upper BC for hydrological model

ALMIP2 Science Questions:

1. Which processes are missing or not adequately modeled by the current generation of LSMs over this region (infiltration over crusted soils, plants with defensive water strategies, endorheic hydrology...)?

2. How do the various LSM respond to changing the spatial scale (three scales will be analyzed: the local, meso and regional scales)? The relation between meso and regional scales will be made using ALMIP Phase 1 results.

3. Can relatively simple LSMs simulate the vegetation response to the atmospheric forcing on seasonal time scale (for several annual cycles) for the diverse climates/vegetation covers?

4. How can LSM simulate mesoscale hydrology given their relatively simple representation of such processes?

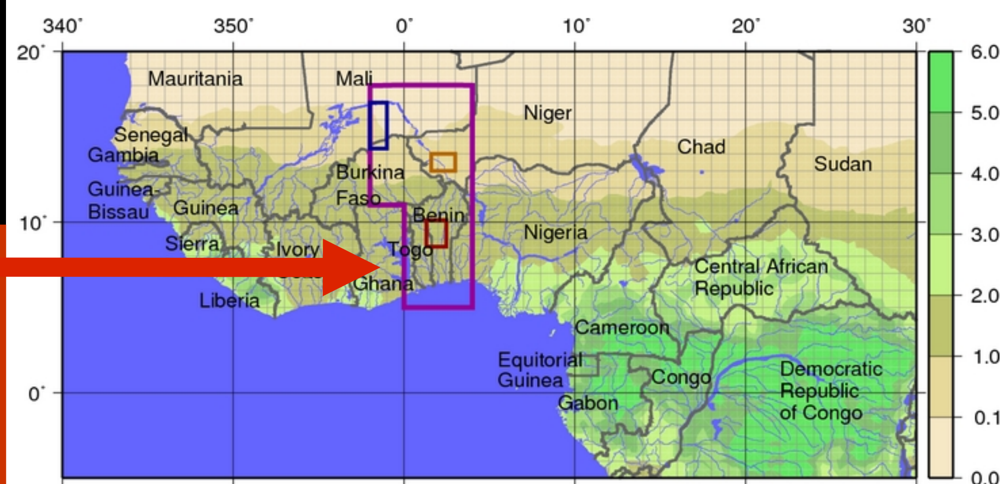
5. What are the impacts of uncertainties in the precipitation on the surface fluxes and hydrological responses of the LSM models?

ALMIP AMMA Land Surface Model Intercomparison Project

Experiments:

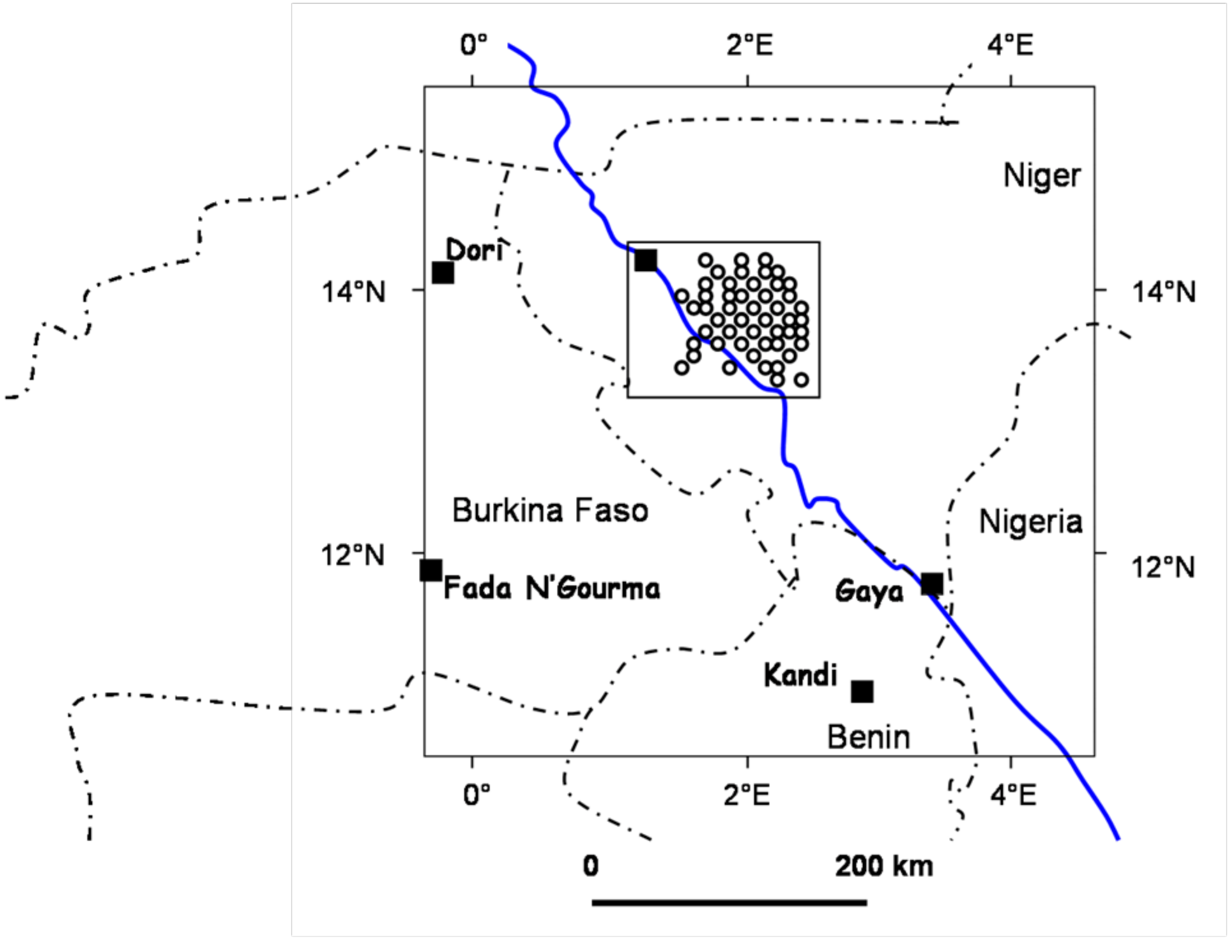
Exp. Name:	Resolution	Time period
Exp 1: Regional NWP	0.5deg, 3h	2002-2007
Exp 2: Regional Merged	0.5deg, 3h:	2004-2007
Exp 3: Mesoscale Merged	0.05 deg, 30min	2005-2007 (2008?)
Exp 4: Local	3 + sites	2005-2007 (2008?)

Model Domain (land points only)



Exp3a: Control experiments for the 3 meso-sites, 2005-2007 (2008?)
Exp3b: Perturbed precipitation inputs (Benin..plus other 2 sites?)
Exp3c: as in 3a and 3b, but simulate the vegetation

Exp4a: Simulate local scale for at least 1 site (more!?) for each meso-square
Exp4b: as in 4a, but simulate the vegetation


0°
2°E
4°E
Niger
Dori
14°N
14°N
Burkina Faso
Nigeria
12°N
12°N
Fada N'Gourma
Gaya
Kandi
Benin
0°
2°E
4°E
0
200 km