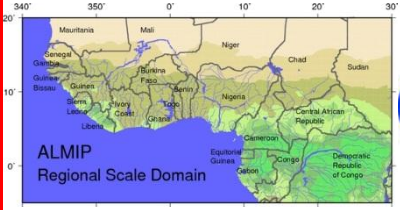

ALMIP AMMA Land surface Model Intercomparison Project Phase 2

A meso-scale river routing scheme for the AMMA Land Model Intercomparison Project – Phase 2

Augusto Getirana (1*)

in collaboration with Aaron Boone (1), Christophe Peugeot (2)

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1 Météo-France/CNRM
2 Hydrosciences Montpellier
* Current affiliation: NASA Goddard Space Flight Center

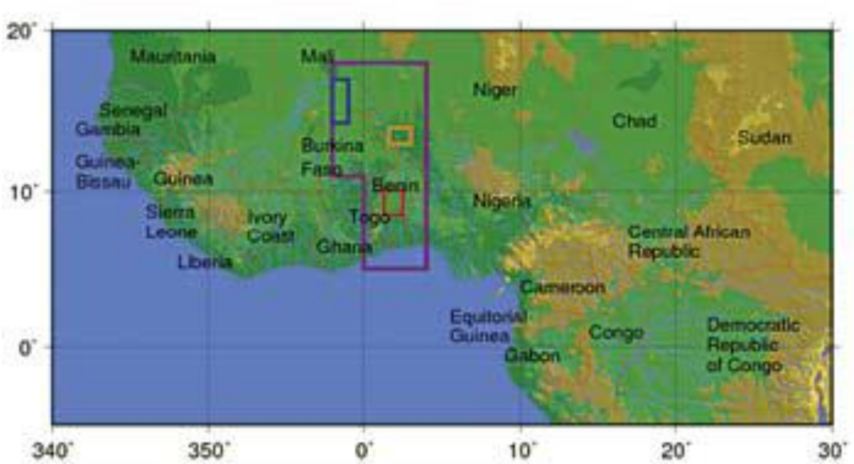
Motivation

ALMIP-2 Science Questions

- **1. Complexity of hydrological processes: How can LSM simulate meso-scale hydrology?**

- **2. Unknown processes: Which processes are missing or not adequately modeled by the current generation of LSMs over the West Africa (e.g. endorheic hydrology...)?**

- **3. Precipitation uncertainty: What are the impacts of precipitation uncertainties on the surface fluxes and hydrological responses of LSMs?**

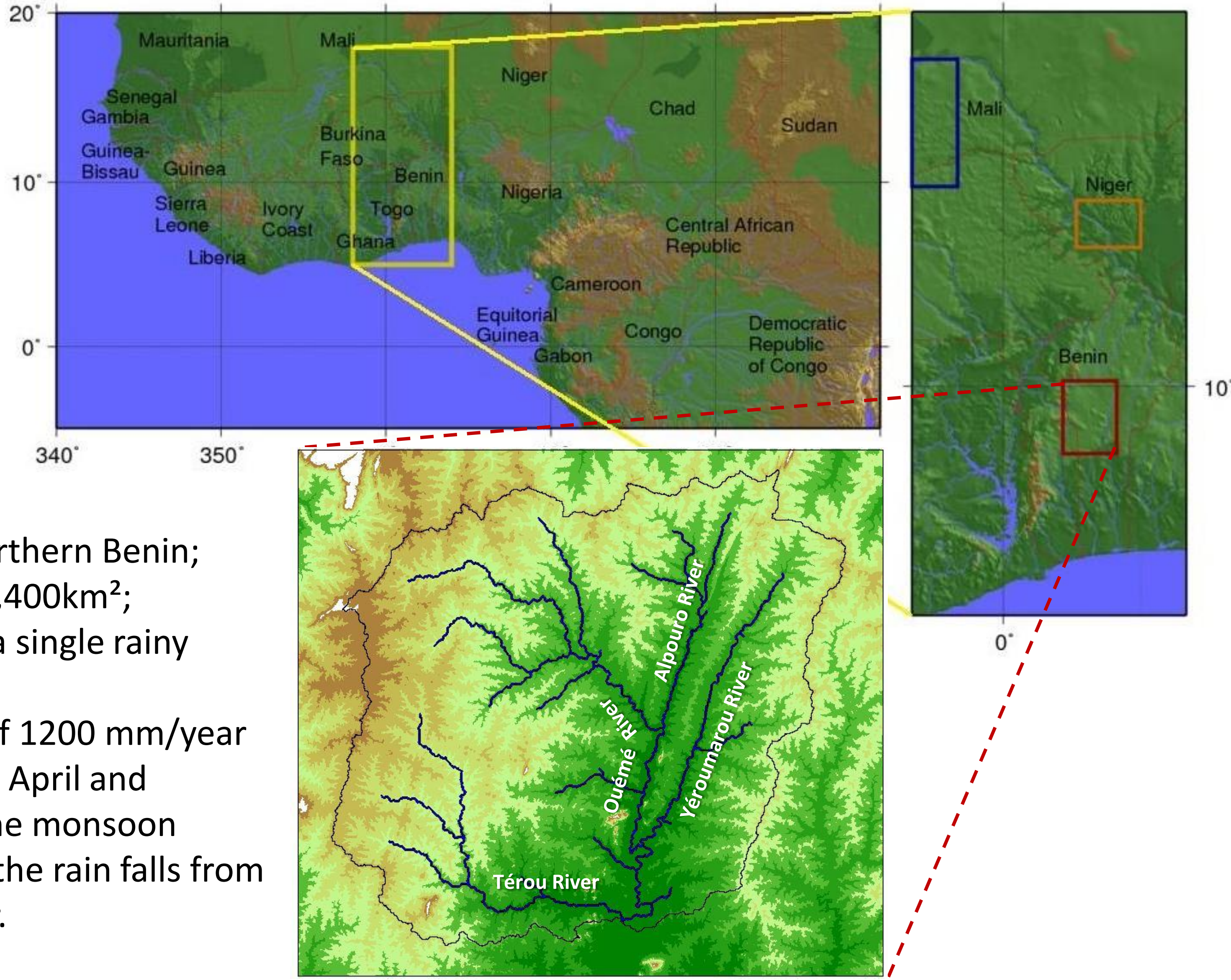


Boone et al. (2011)

Objectives

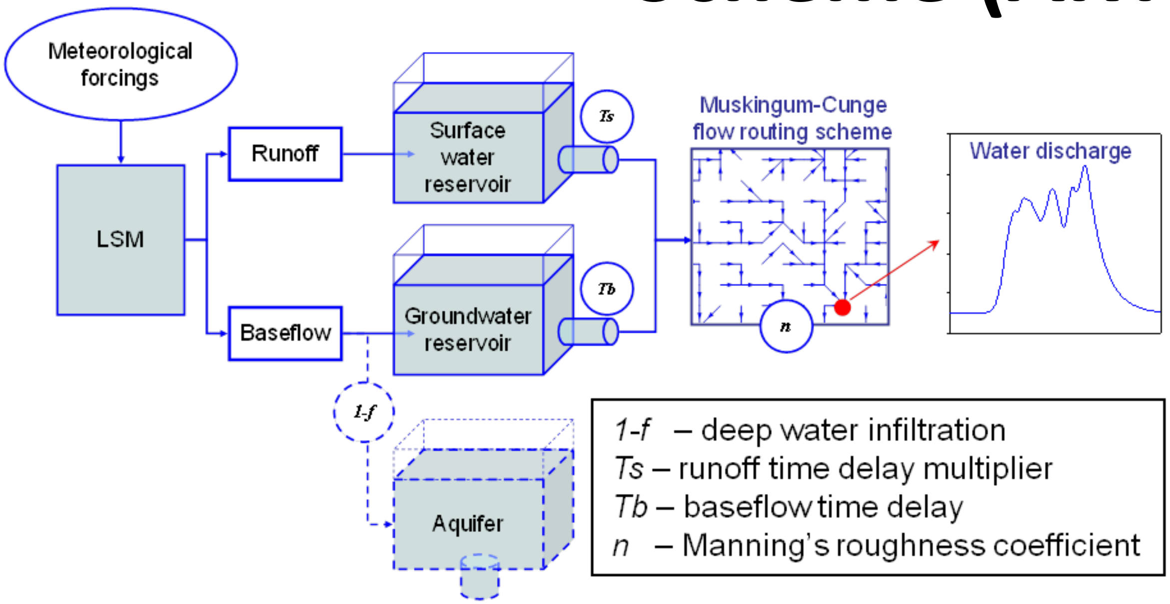
- Describe the river routing scheme for the evaluation of ALMIP-2 models;
- Perform the calibration of parameters using outputs from a single LSM;
- Give the first insights for a better understanding of the water budget in the upper Ouémé River basin:
    - Deep water infiltration ;
    - Baseflow time delay.

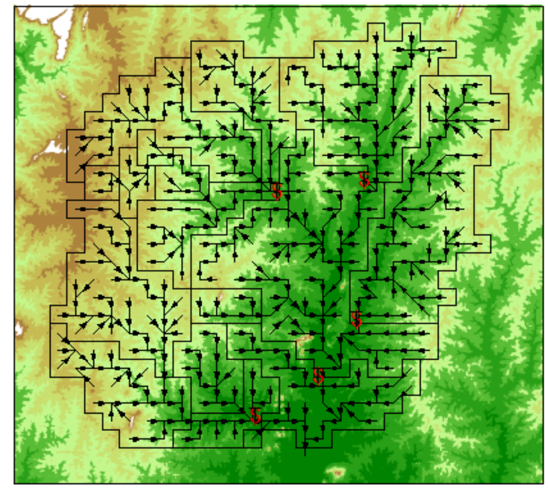
The upper Oueme River basin



- Located in the Northern Benin;
- Drainage area: 14,400km²;
- Characterized by a single rainy season;
- Average rainfall of 1200 mm/year occuring between April and October, during the monsoon periods (~60% of the rain falls from July to September.

The ALMIP-2 river RouTing Scheme (ARTS)





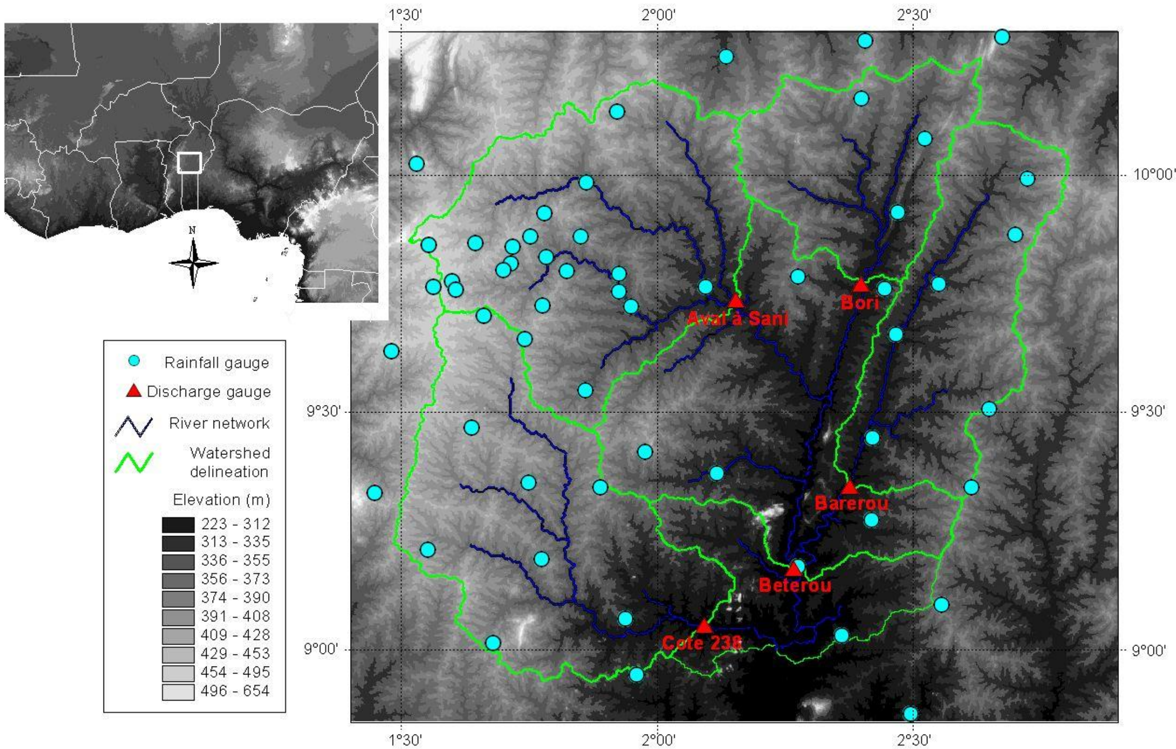
The watershed was discretized in 473 squared grid cells sizing 0.05 degrees

- Non-linear Muskingum-Cunge (MC) method coupled with three reservoirs;
- Two linear reservoirs represent the time delay of both (1) runoff and (2) baseflow before reaching the river network and a third reservoir is used to represent aquifers;
- The Manning's roughness coefficient *n* has been defined as homogeneous and equal to 0.03;
- The runoff time delay is determined by the Kirpich's formula and multiplied by a correcting factor (*Ts*);
- The baseflow time delay (*Tb*) is parameterized.
- At each time step, a fraction *f* of the baseflow remains in the river network while 1-*f* leaves the system to an aquifer representing deep water infiltration (endorheic hydrology). The fraction *f* is parameterized in order to fit observed and simulated water volumes.

Available Dataset

LSM forcings

- ✓ ECOCLIMAP2 database (Kaptué et al., 2011).
- ✓ Mesoscale downwelling radiative fluxes form the LANDSAF project.
- ✓ Precipitation is derived from a combined krigged-LaGrangean methodology based on dense rain gauge networks (Vichel et al., 2011).
- ✓ Meteorological variables are from ECMWF operational forecast data.

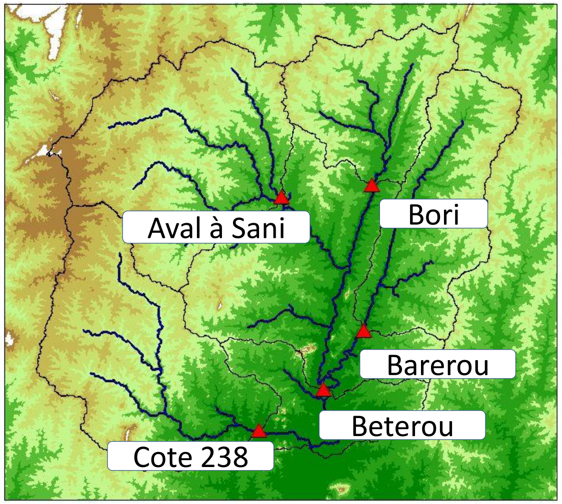


Five gauging stations used to calibrate the model (Peugeot et al., 2012)

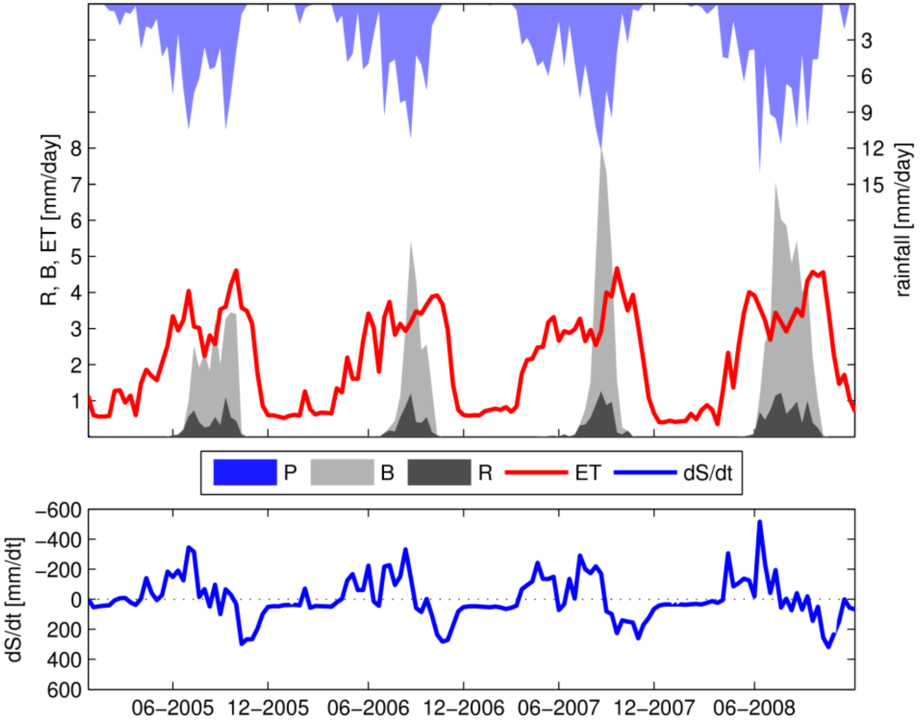
Station	Area (km^2)	Q (m^3/s)	Rainfall (mm/year)	Runoff (mm/year)	Runoff/rainfall rate
Bori	1630	4.86	1135	95	0.08
Barerou	2141	8.03	1110	117	0.11
Cote 238	3152	17.61	1073	175	0.16
Aval à Sani	3307	17.54	1080	168	0.15
Beterou	10140	43.13	1157	135	0.12

Daily observations from 2005 to 2008;
River length and slope derived from SRTM;
River width at 12 stations.

Water budget in the upper Oueme basin from ISBA



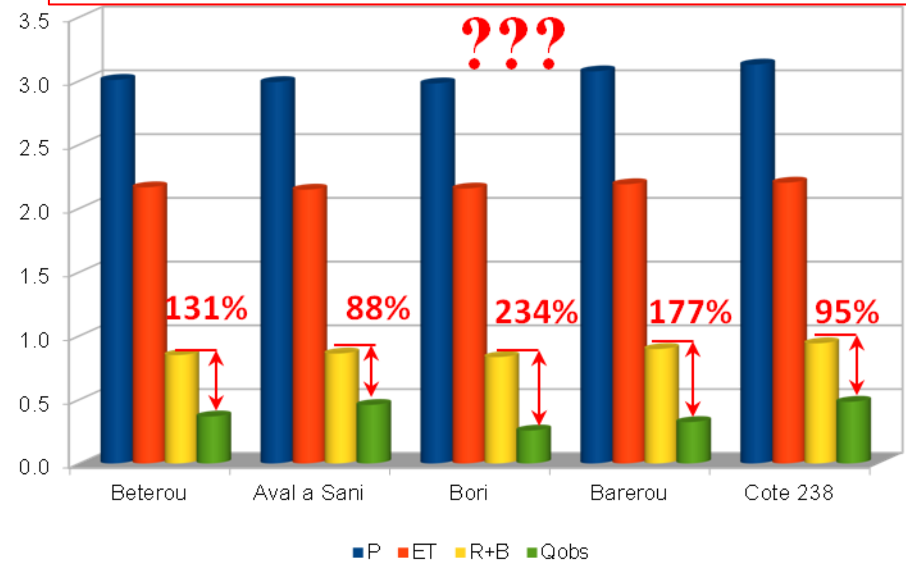
Averaged hydrological variables for the upper Oueme River basin



Mean values for the 2005-2008 period (mm/d)

P	ET	R	B
3.00	2.15	0.17	0.68

Large difference between observed discharge and simulated runoff+baseflow



Experimental design

1. The model is run at the daily time step from 2005 to 2008 (the first year is run twice for spin up);

2. Three parameters were calibrated (*Ts*, *Tb* and *f*):

3. After a manual calibration, parameters were automatically calibrated using the MOCOM-UA (Yapo et al., 1998) multi-criteria optimization algorithm;

4. 200 points were used in the search for optimal parameter sets;

5. Three calibration experiments were performed:

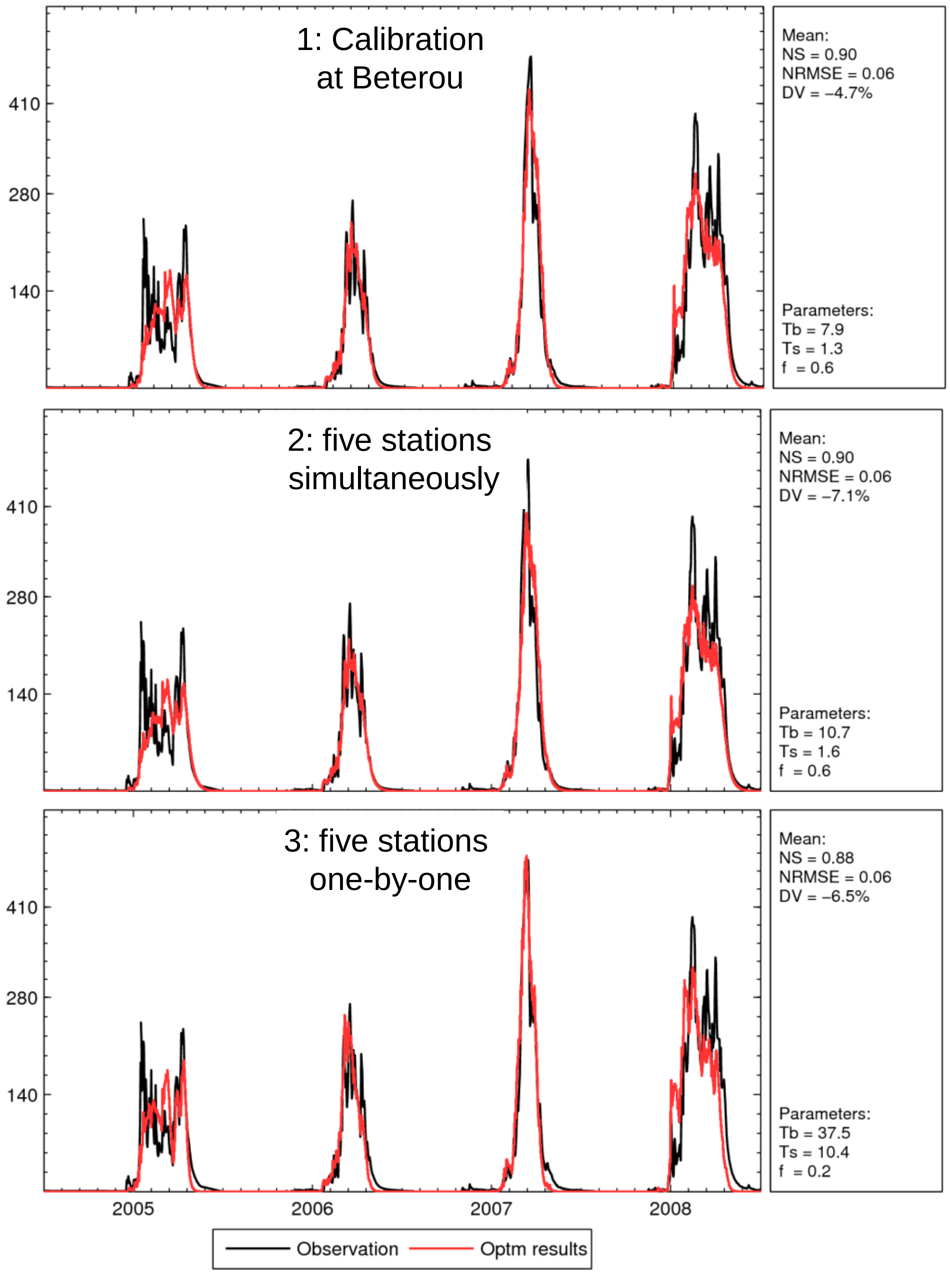
   a. using observed discharge at a single station (Beterou);

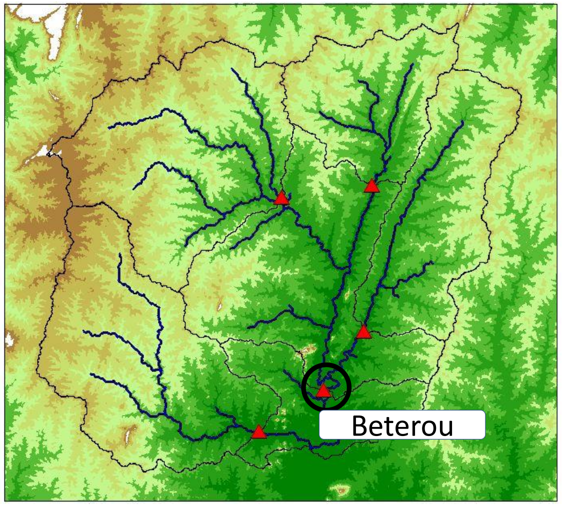
   b. using observed discharge at five stations simultaneously; and

   c. using observed discharge at five stations one-by-one.

6. The optimization is based on the simultaneous maximization of the Nash-Sutcliffe (NS) coefficient and the normalized RMS error (NRMSE).

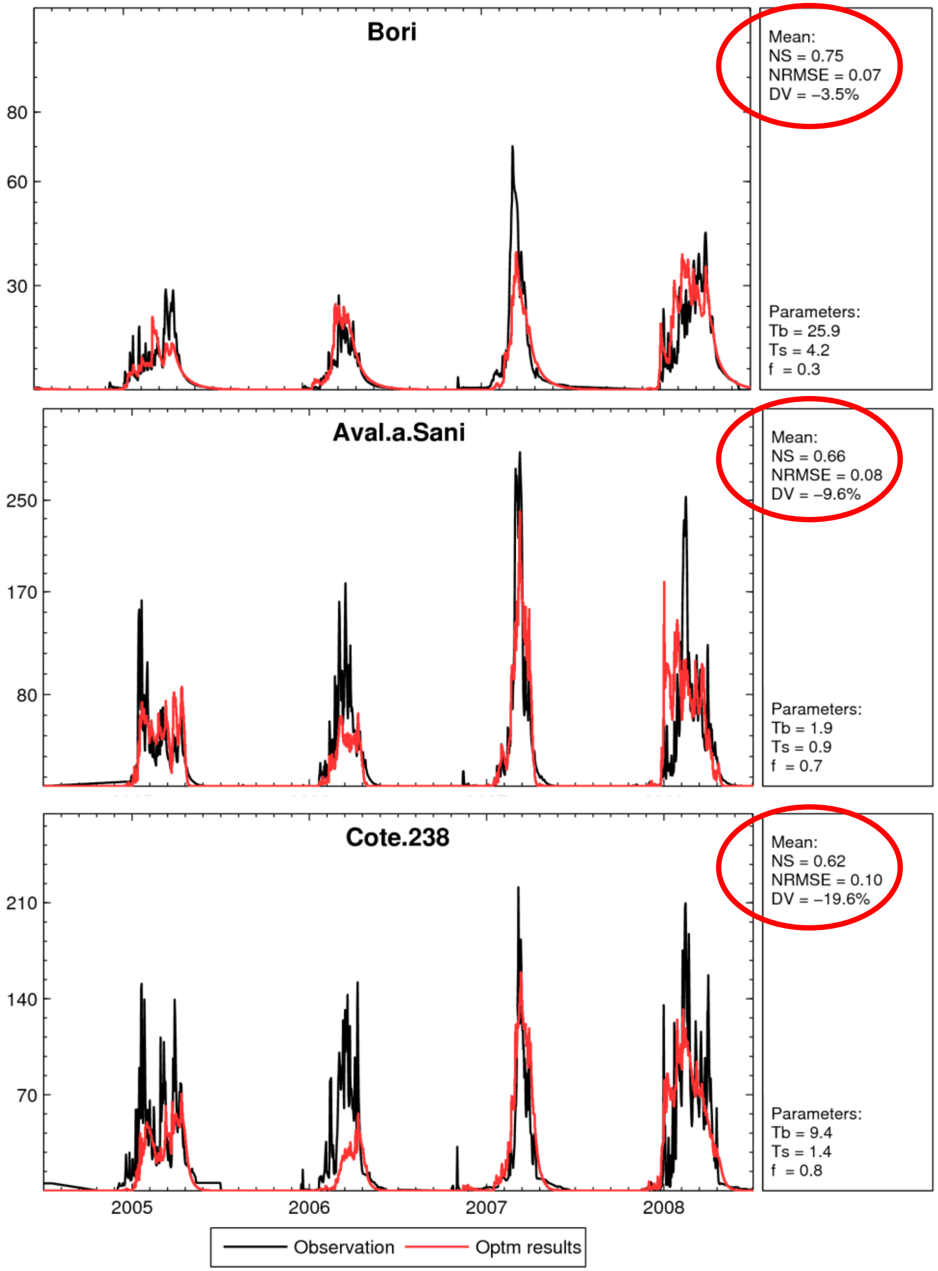
Calibration results at the Beterou station

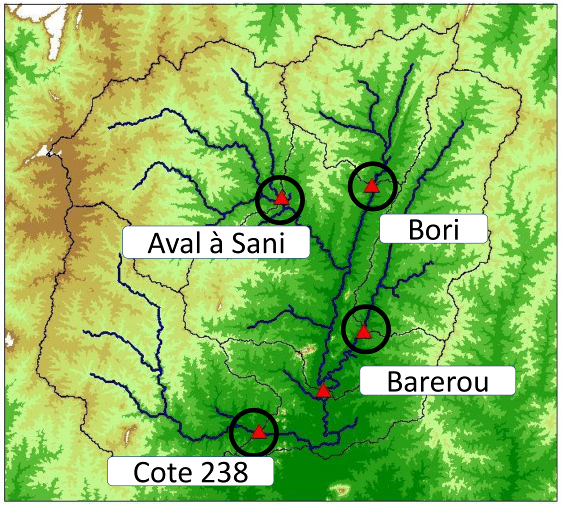




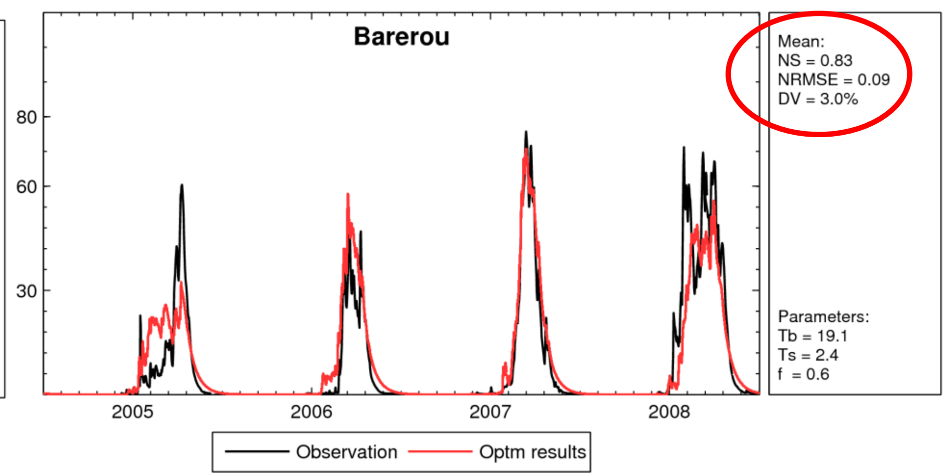
Best NS values: 0.88 to 0.90 ;
Best volume errors (DV): -6.6% to -4.7%;
Experiment (1) is the best for this station:
- Water losses are 40% of baseflow (f=0.6);
- Mean baseflow time delay Tb varies from 8 to 37 days.

Calibration results: Five stations one-by-one

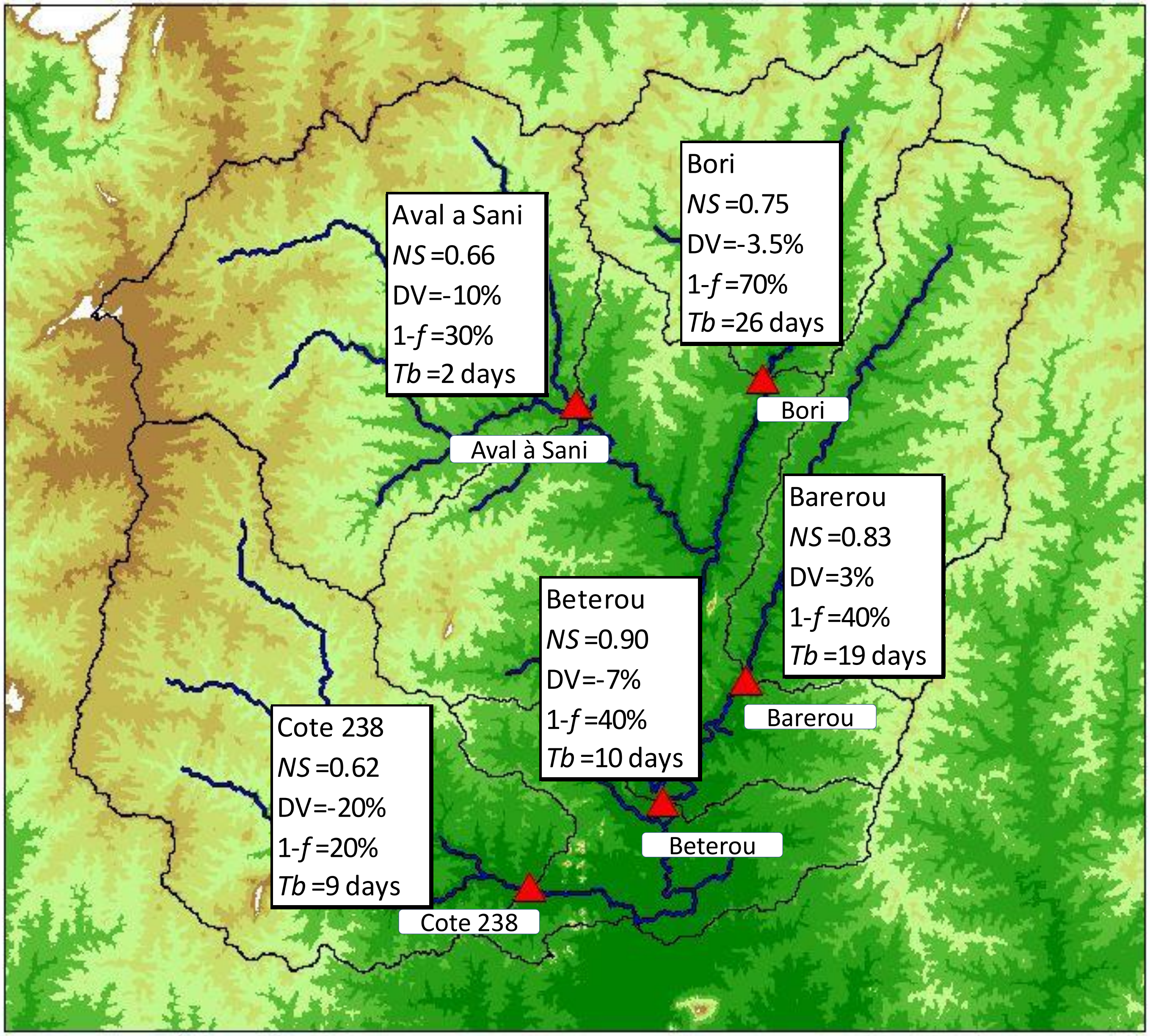




Best NS values: 0.62 to 0.83;
Best DV values: -19.7% to 3%;
Water losses vary from 20% to 70% (f=0.3 to 0.8);
Baseflow time delay Tb varies from 2 to 26 days.



Calibration results: Overview



Conclusions

1. The model was able to well represent daily discharges at the meso-scale, with NS values varying from 0.62 (Cote 238 station) up to 0.90 (Beterou station);
2. Objective functions based on NS and NRMSE coefficients are appropriate to calibrate the model in this particular region
3. Evidence of deep water infiltration varying from 20% to 80% of the baseflow, depending on the catchment;
4. But the validation of simulated evapotranspiration must be performed prior to a final conclusion;
5. The reservoir approach used to represent the deep water infiltration is quite simple; the implementation of more complex solutions in LSMs considering seasonality, soil type and depth is recommended for future studies.

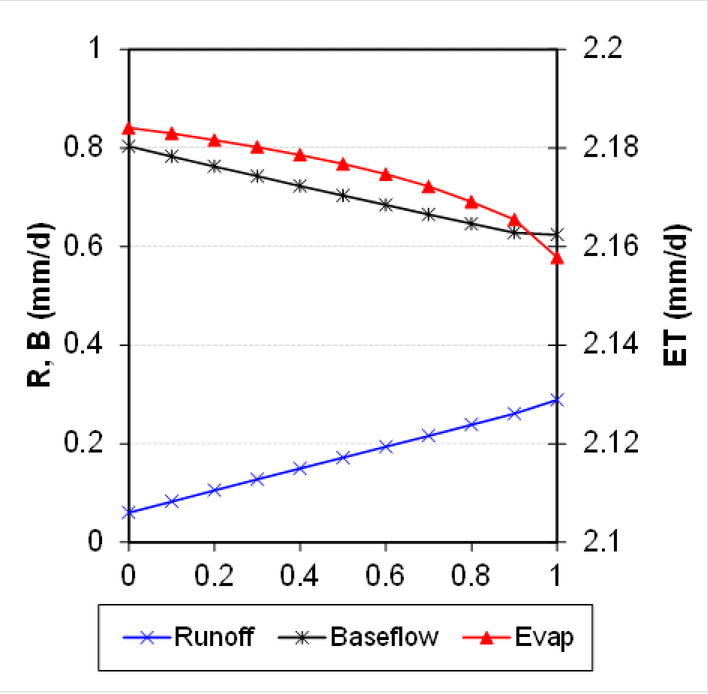
Thank you for your attention!

Augusto Getirana
augusto.getirana@nasa.gov

The Interactions between the Soil-Biosphere-Atmosphere (ISBA) model

ISBA (Noilhan and Mahfouf, 1996) is a state-of-the-art LSM which is currently used for operational **numerical weather prediction** (Giard and Bazile, 2000), **global climate model** simulations (e.g. Douville, 2004), operational **hydrological forecasting** over France (Habets et al., 2008), offline **land data assimilation** applications (e.g. Mahfouf et al., 2009) and in mesoscale **atmospheric research modeling** (e.g. Noilhan et al., 2010).

The parameter w, which is the volumetric water content corresponding to when the near surface soil moisture is sufficiently humid to generate surface runoff, was set as 50% of the wilting point value (by default, w has been set somewhat arbitrarily to the wilting point value for large scale or global modeling applications).



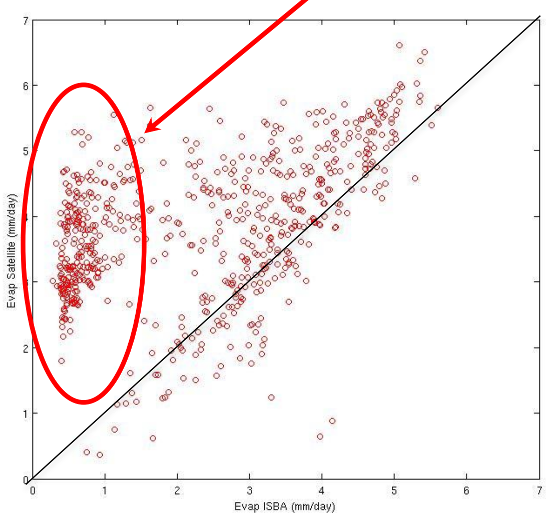
Evolution of mean runoff, baseflow and Evap (2005-2008) when the wilting point multiplier, w, varies from zero to 1 (1 is the default value). Mean precipitation is 3.04mm/d.

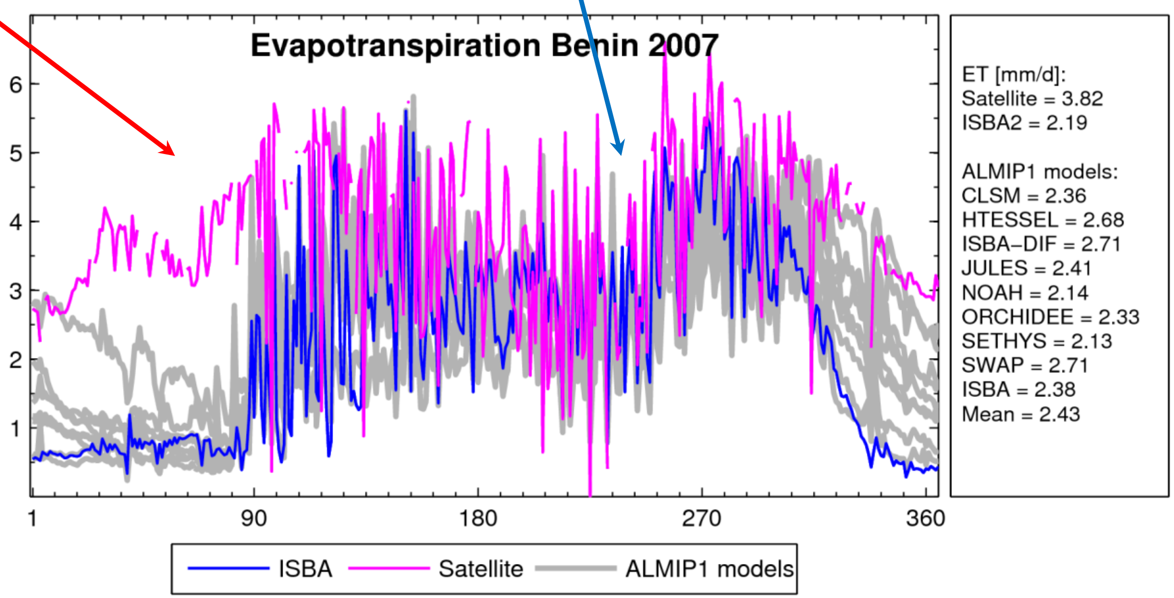
Water budget in the upper Oueme basin

Simulated ET compared against satellite-based estimates (Anderson et al., 2011)

Sat-based ET is particularly high during dry seasons

ET estimates generally agree during the monsoons

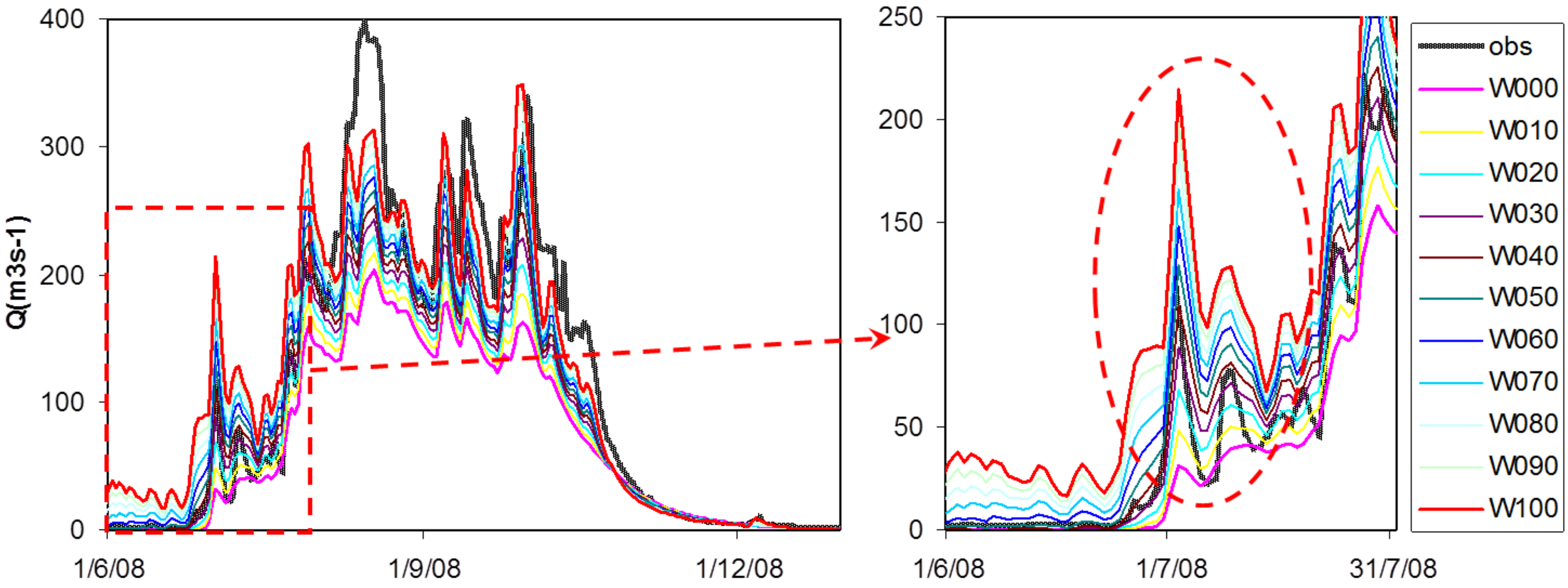




Daily evapotranspiration averaged to the Oueme basin

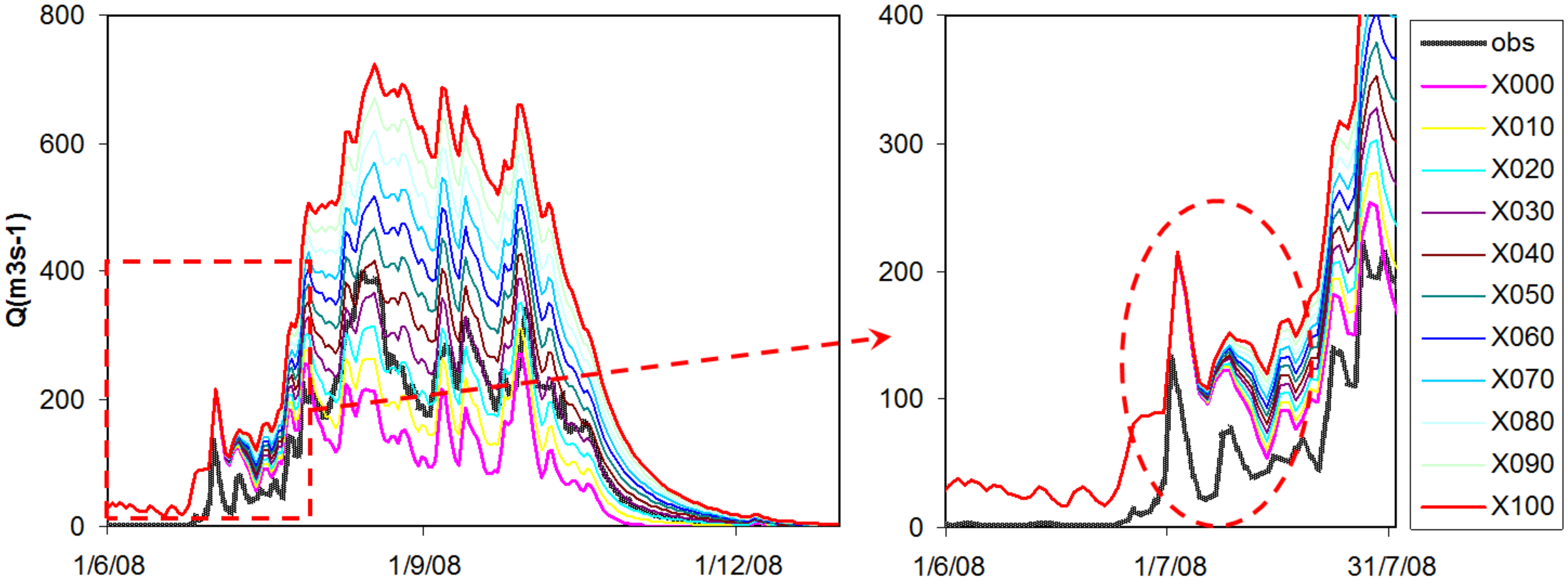
Sensitivity analisis of ISBA parameter w

Daily water discharge during the monsoon of 2008 with default ISBA parameterization, except for w multiplier varying from zero to 1 (Ts=70, Tb=400, n=0.03 and f=0.8).

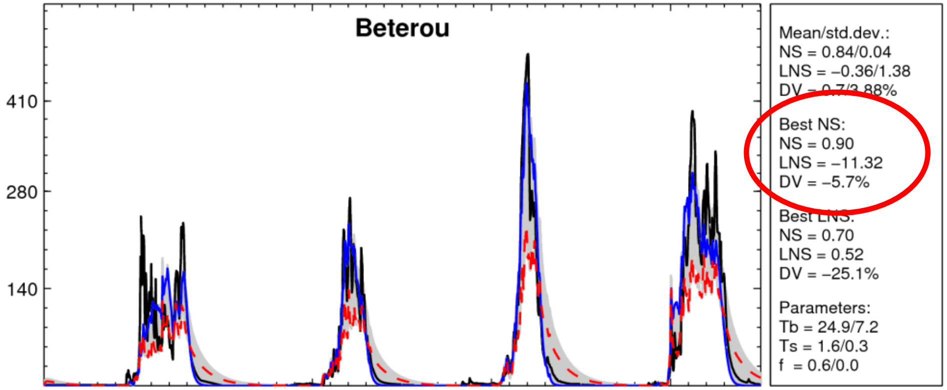


Sensitivity analisis of parameter *f*

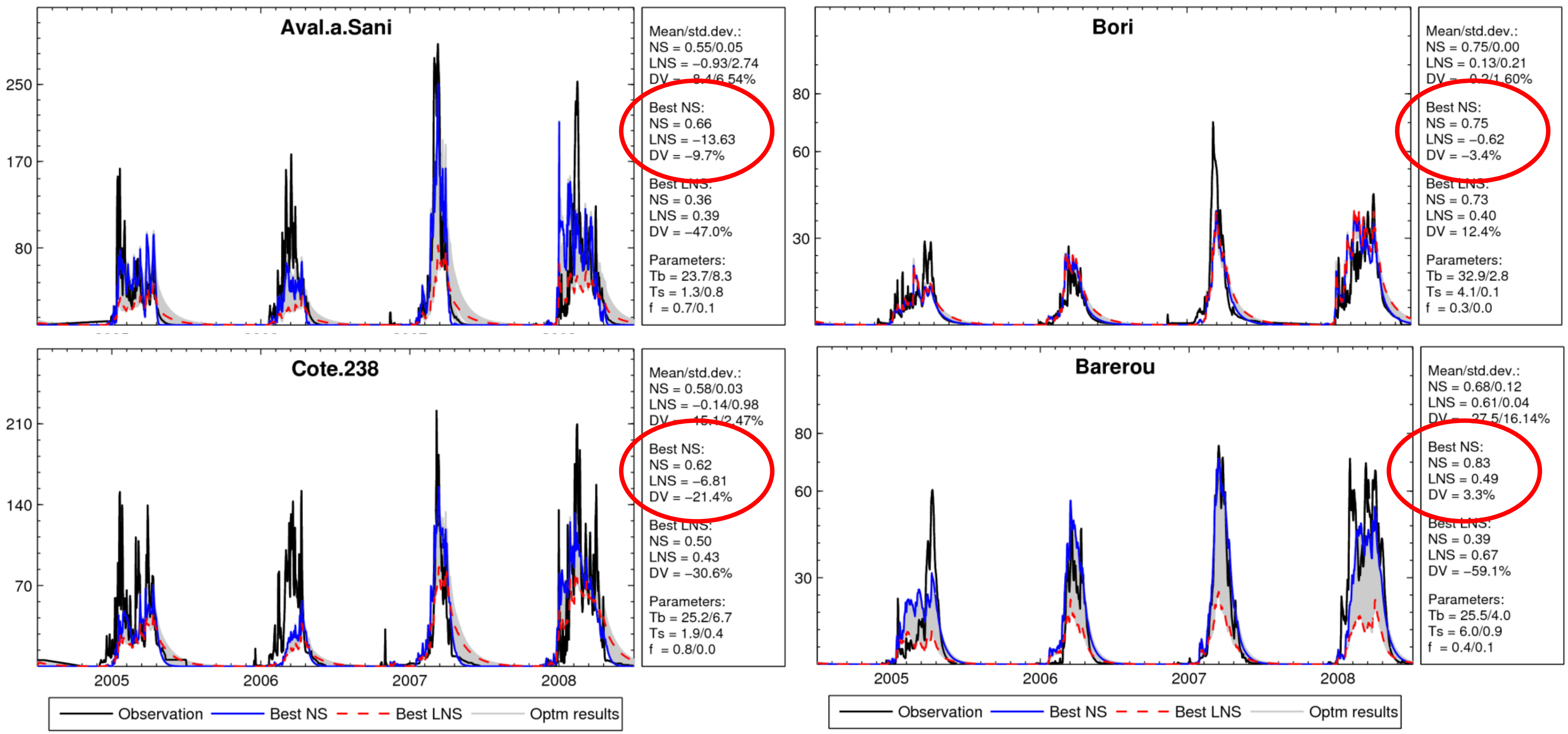
Daily water discharge during the monsoon of 2008 with default ISBA parameterization (Ts=70, Tb=400, n=0.03 and fvarying from zero to 1).



Calibration results using NS and LNS



Best NS results are similar to the NSxNRMSE experiments, but a larger uncertainty is evidenced when using LNS;



Calibration results at the Beterou station