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Global changes impacts on water fluxes of the critical zone for the sudanian area in West-Africa

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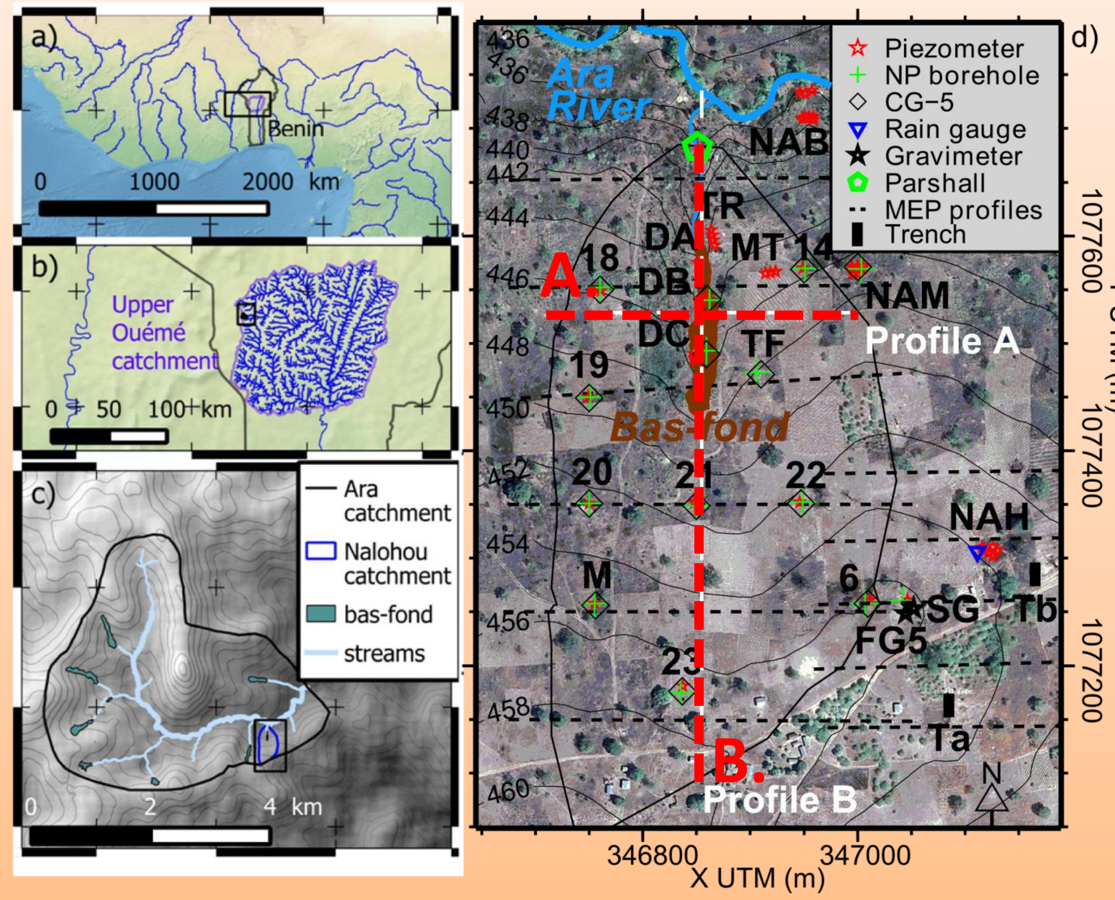
Abstract n°2321

1.



Study area: a 16ha catchment around a seasonally water-logged bas-fond in basement area.

Introduction and context

While in the endoreic Sahel, seasonal streamflow has increased despite the 70'-80' drought and because of simultaneous land-use change, the more humid Sudanian area **(1)** underwent a **severe streamflow decrease (2)**.

Prevailing processes responsible for such relationships are not fully understood in this area, mostly because **streamflow is dominated by baseflow (3)**, a complex flow component which links all compartment of the critical zone (from bedrock to the top of canopy).

In anticipation of **possible extreme precipitation increase** in the future, as well as **expected land-use and land-cover changes**, precipitation-discharge relationships need to be understood **within a critical zone perspective**.

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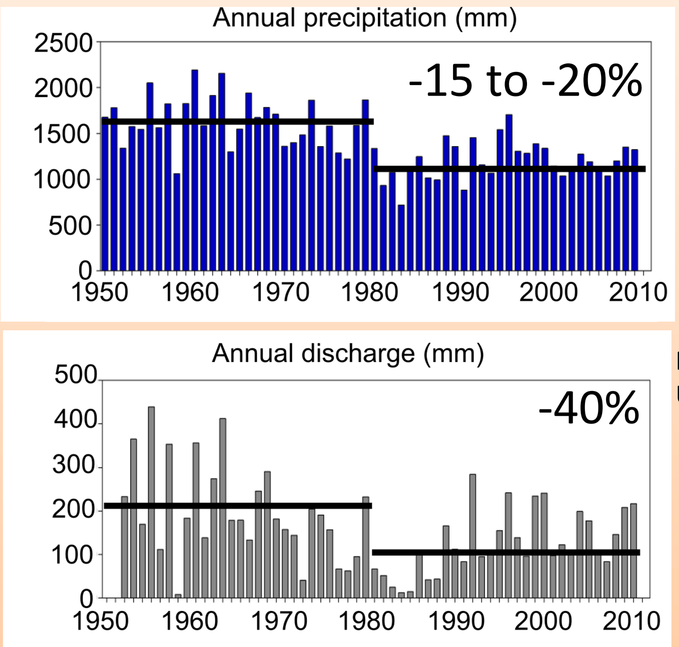
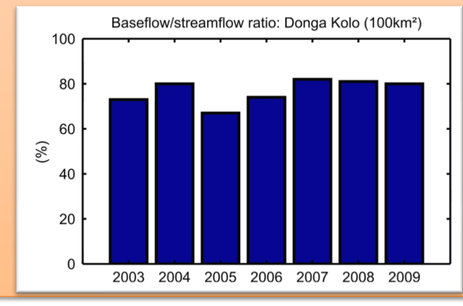


Precipitation and discharge in the Upper Ouémé valley (14300km²)

3.



Baseflow/streamflow decomposition from filter analysis and geochemical tracers in the Donga Kolo catchment

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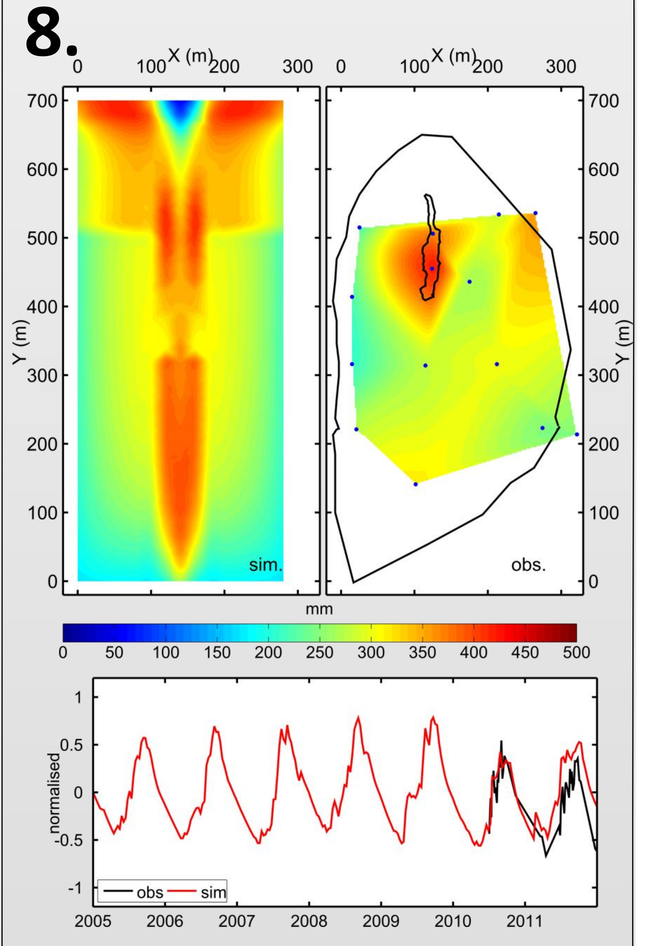


Simulated (left) and observed (right) seasonal storage amplitude

A. Material & Method

In this study, we aim to:

- present our **conceptual model of a headwater catchment** (16ha), built based on many local observations **(1)**
- present the **physically-based critical zone model** we use to simulate the hydrological functioning
- Validate a reference **simulation of a simplified V-shaped catchment** with in-situ observations
- test **the sensitivity of the model to land cover**.
- apply the model to the **upper Oueme catchment (14300km²)**, the meso-scale site of the AMMA-CATCH observatory

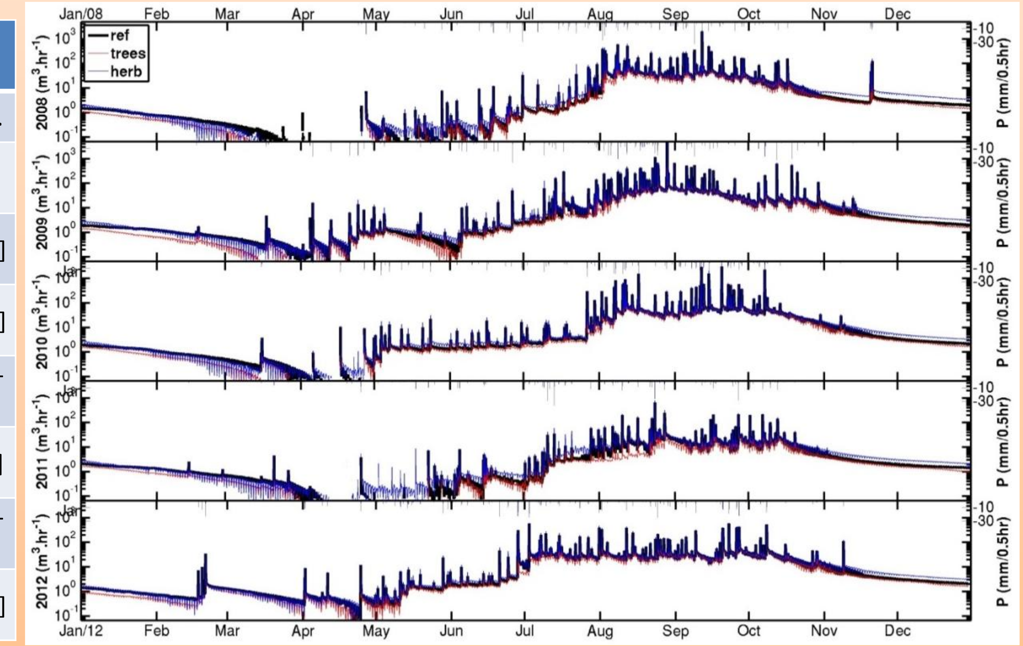
E. Virtual experiment

- We test two extreme cases: 1) a fully tree-covered catchment and 2) an herbaceous-covered catchment.
- **ET differences** between the two cases vary **between 6 and 13% of yearly Precipitation**.
- **30% less streamflow with tree covers than with herbaceous covers (11)**.

Year	P(mm) [(%)]	ET (mm) [(%)]			Q (mm) [(%)]			S (mm) [(%)]		
		Ref.	trees	Herb.	Ref.	trees	Herb.	Ref.	trees	Herb.
2006	913 [100]	762 [83]	897 [98]	700 [77]	174 [19]	121 [13]	206 [23]	-24 [-3]	-101 [-11]	6 [1]
2007	1214 [100]	828 [68]	914 [75]	788 [65]	362 [30]	281 [23]	405 [33]	22 [2]	14 [1]	20 [2]
2008	1211 [100]	789 [65]	900 [74]	738 [61]	392 [32]	305 [25]	442 [37]	33 [3]	11 [1]	34 [3]
2009	1496 [100]	957 [64]	1038 [69]	919 [61]	565 [38]	459 [31]	613 [41]	-5 [0]	9 [1]	-12 [-1]
2010	1572 [100]	892 [58]	963 [63]	861 [56]	644 [42]	564 [37]	683 [45]	6 [0]	18 [1]	-1 [0]
2011	934 [100]	769 [82]	893 [96]	714 [76]	216 [23]	141 [15]	255 [27]	-49 [-5]	- 90 [-10]	-35 [-4]
2012	1422 [100]	862 [61]	929 [65]	834 [59]	512 [36]	419 [29]	551 [39]	48 [3]	70 [5]	37 [3]

Water budget (ET = Evapotranspiration, Q = streamflow, S = Storage) for each year in mm and % of yearly Precipitation

11.

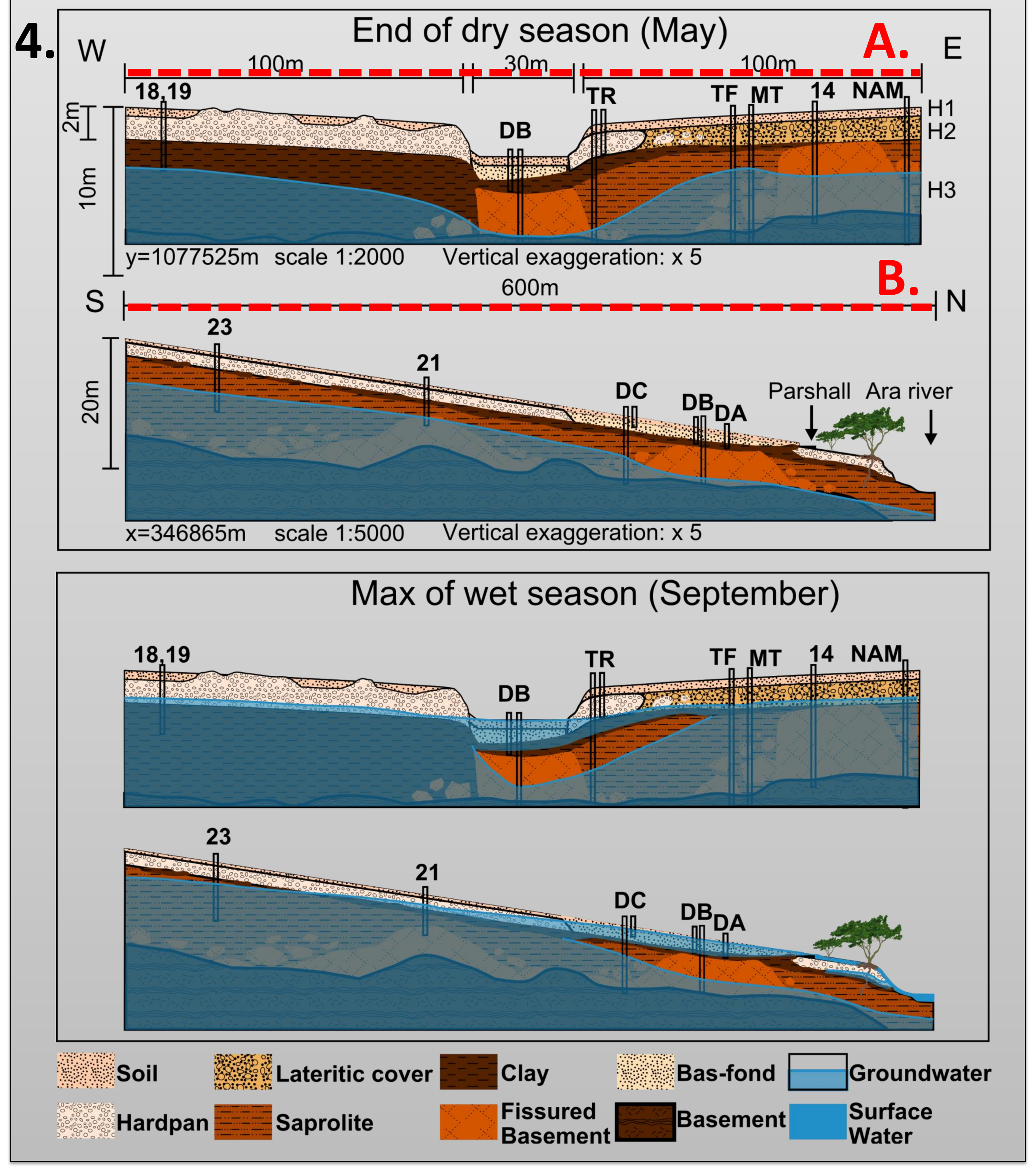


Streamflow as semilog plot for the three tested cases

B. Conceptual model

The conceptual model is built based on all observations. It is composed by **a fast system which feeds the baseflow through lateral connections** of perched water table and permanent water table in upstream areas; and **a slower system characterized by the seasonal oscillation of the permanent groundwater**. Permanent groundwater may not be connected to the river in the downstream areas, and is expected to discharge mostly into tree-driven evapotranspiration.

4.



C. Critical zone model

Parflow is a saturated/unsaturated flow model with an overland flow scheme. It is coupled to a SVAT model: CLM, and allows to reproduce complex critical zone interactions within the terrestrial hydrological cycle for large scales and high resolutions (Maxwell & Miller, 2005).

It is applied to a simplified **(5)** lithological model of the Nalohou catchment **(1)**, from 2005 to 2012 with 30mn/20m resolution, forced with observed meteorological variables.

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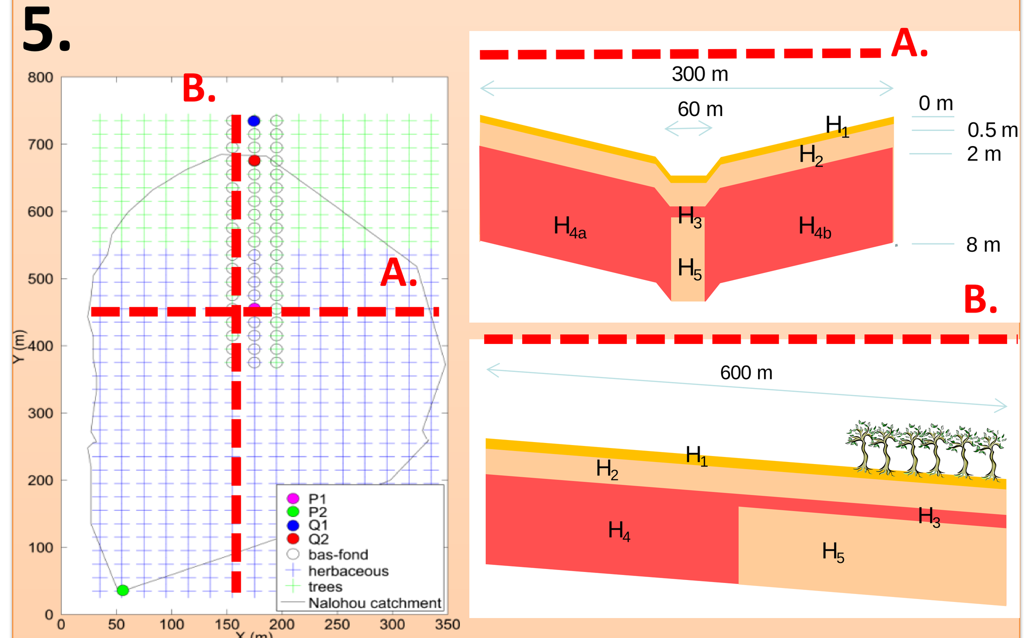
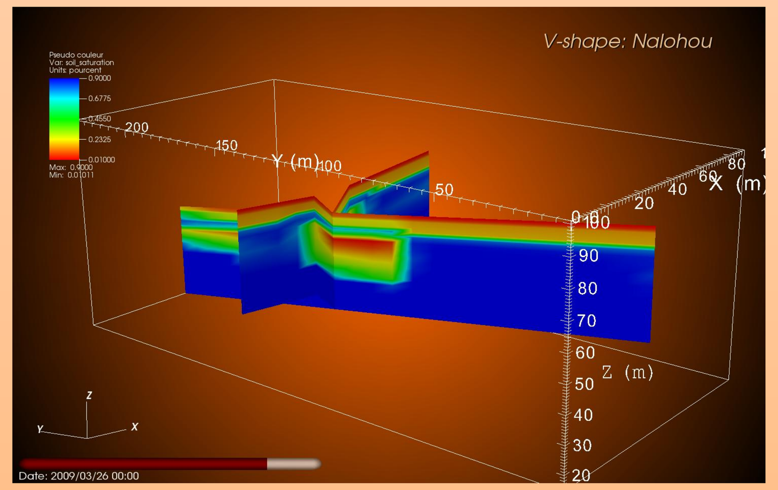


Left: catchment mesh. Blue cross = herb. Green cross = trees. Circles = Bas-fond.
Right: Cross sections and lithological/pedological units

6.



Perspective view of the saturation for a single time step

D. Model validation

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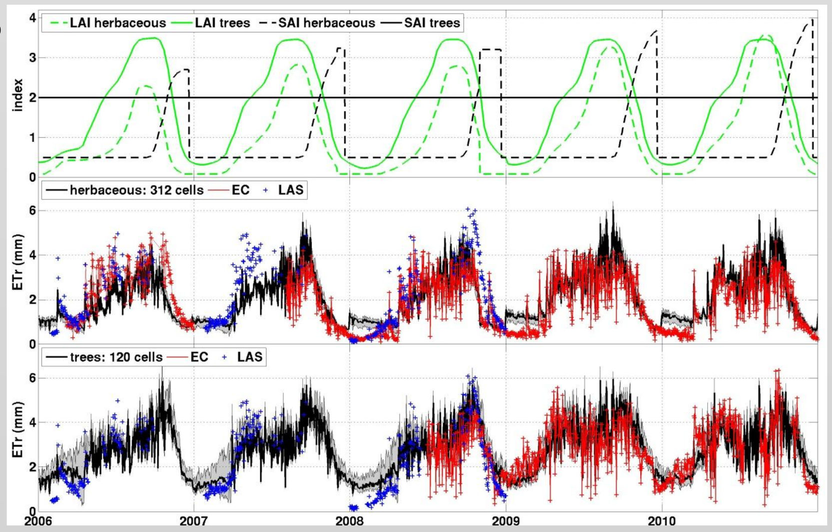
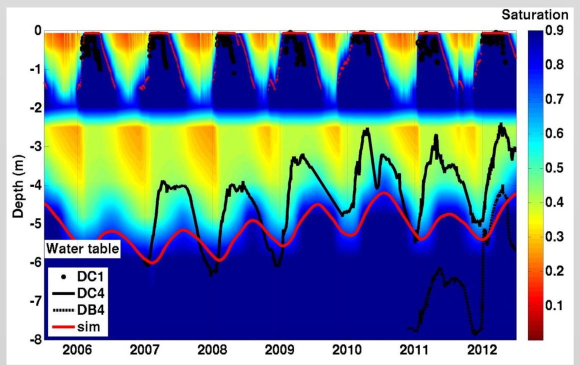


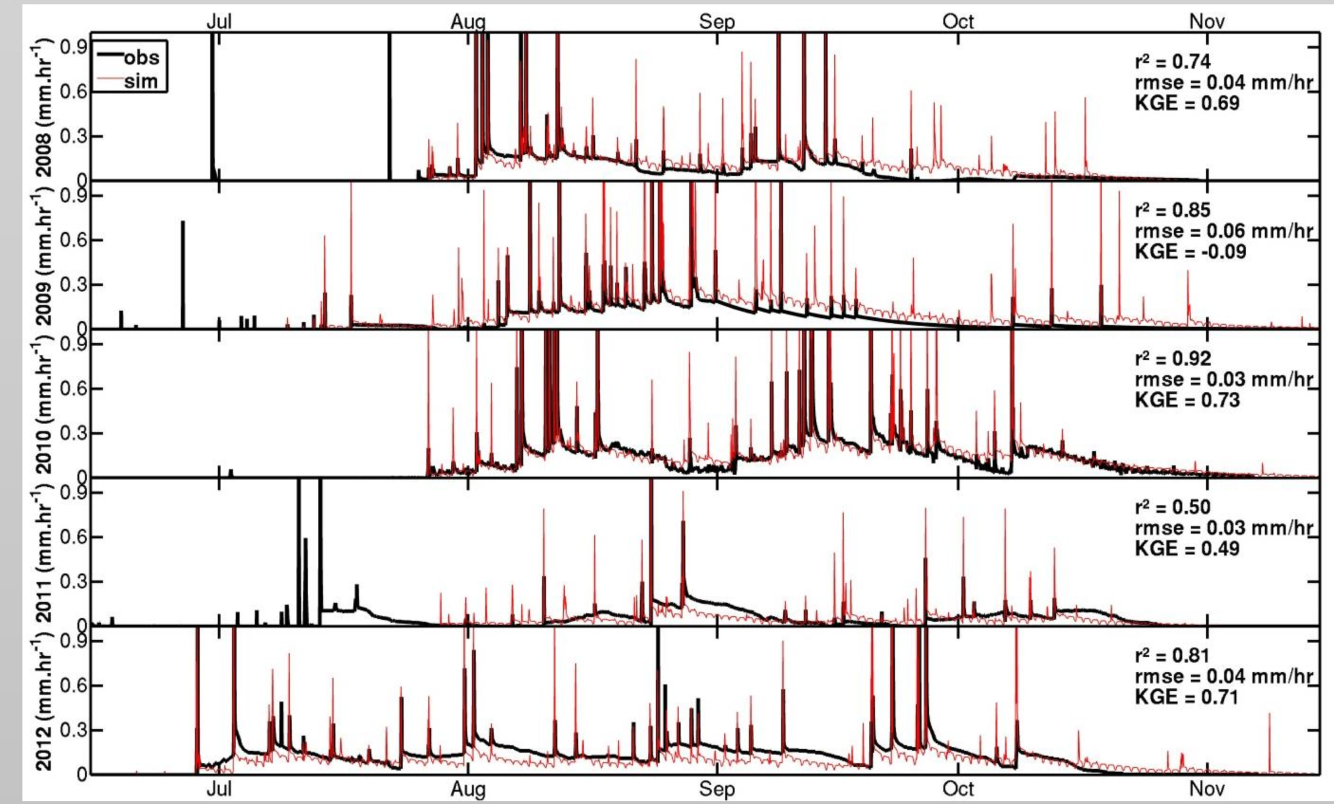
Vegetation forcings (upper) and simulated and observed ET over herbaceous (center) and tree (lower panel) covers

9.



Simulated saturation at P1 and simulated and observed water table

10.



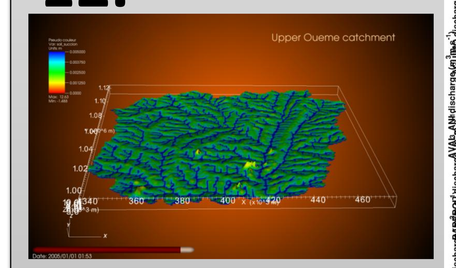
Yearly simulated and observed streamflow

- Good match for ET, except for too high simulated evaporation in the dry season **(7)**. ET for trees is higher in the dry season and early wet season.
- The bas-fond shows the highest/left bank shows the lowest seasonal storage amplitude, both in simulation and gravity observation **(8)**
- Good match for streamflow onset and baseflow amplitude **(10)**. High flow peaks do not affect much the budget because baseflow dominates largely (around 80%)

F. Meso-scale simulation

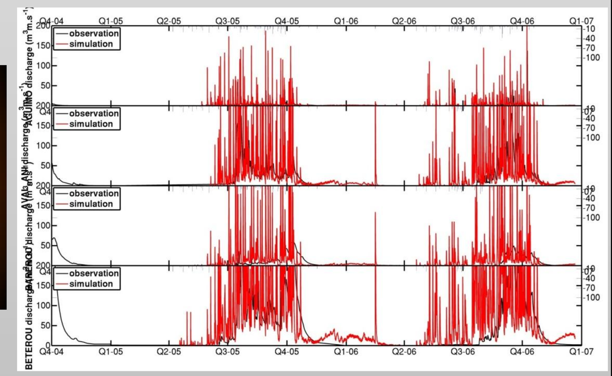
- The model is applied on the Upper-Oueme catchment (14300km²) with a 1km resolution **(12)**
- Large discrepancies with observation exist **(13)**, but remain a satisfactory first step for a non-calibrated experiment

12.



The Upper Ouémé catchment model

13.



Observed ans simulated streamflow

Conclusions

- A physically-based critical zone model is able to simulate states and fluxes satisfyingly even in highly heterogeneous hard-rock basement with intermittent hydrology.
- Such explicit representation of the critical zone allows to conduct virtual experiments.
- In the Sudanian context, replacing trees by human-induced herbaceous cover may decrease the evapotranspiration of as much as 13% of yearly precipitation and increase streamflow significantly.
- The major streamflow decrease since the 80' is due to the precipitation decrease, but the impact of the concomitant deforestation is not clear yet.
- The impact of such global changes at meso-scale basins will be investigated.

References

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Hector, B., Séguis, L., Hinderer, J., Cohard, J.-M., Wubda, M., Descloitres, M., Benarrosh, N., and Boy, J.-P., 2015, Water storage changes as a marker for base flow generation processes in a tropical humid basement catchment (Benin): Insights from hybrid gravimetry: Water Resources Research, doi: 10.1002/2014WR015773.
Hector, B., Cohard, J.-M., Maxwell, R.-M., Séguis, L., Galle, S.: Hydrological functioning of West-African inland valleys explored with a critical zone model. *Hydrol. Earth Syst. Sci.* In prep.