Hybrid gravimetry and water storage changes In the critical zone

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Outline

- Introduction to hybrid gravimetry

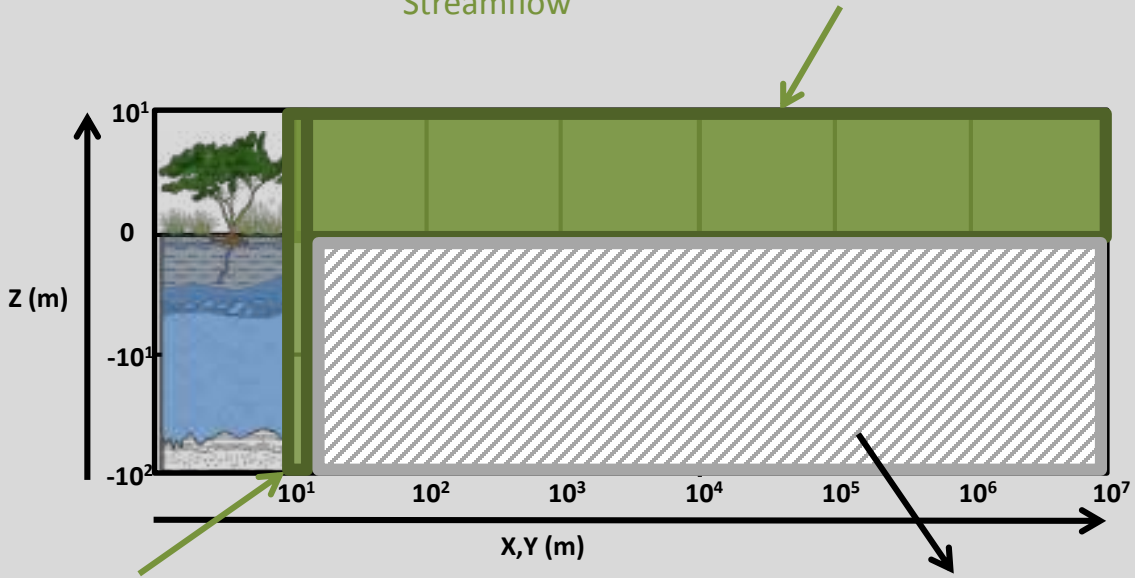
- An example of application in hydrology:
  the Ara catchment in Benin

- Ongoing projects within CRITEX:
  the Strengbach catchment (Vosges)
  the Fontaine du Vaucluse karst system

Spatial scales of the Critical Zone

Measurement scales

Remote sensing (+ inversion methods)
Streamflow

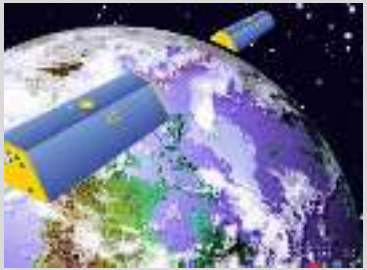


Point measurements

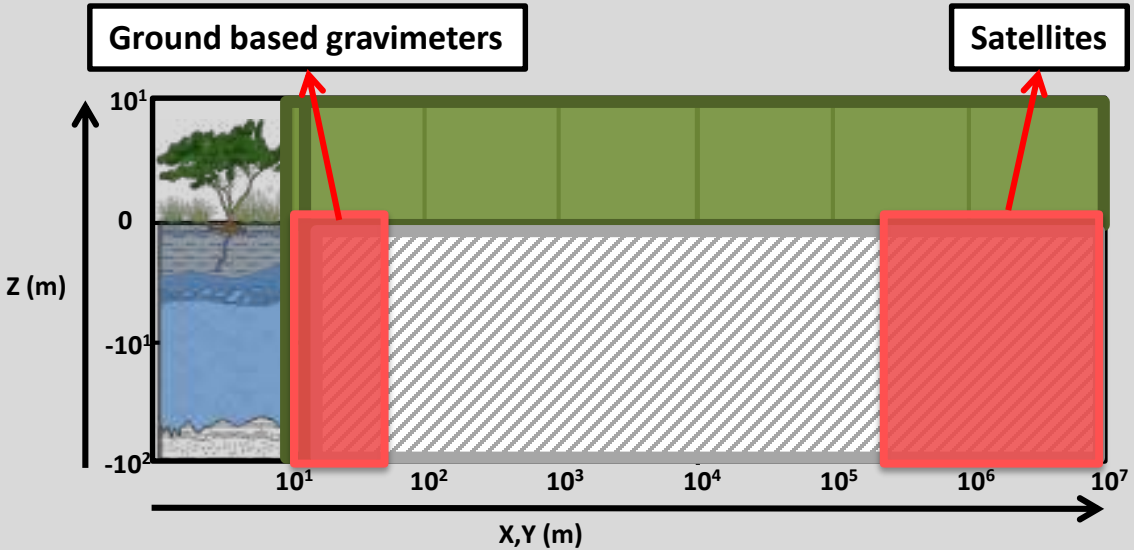
Models

FG5 absolute gravimeter

SG: superconducting gravimeter



GRACE



Gravimetry

Ground

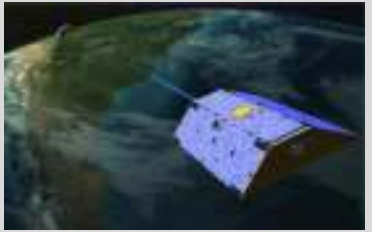
Satellite

absolute

relative

spring

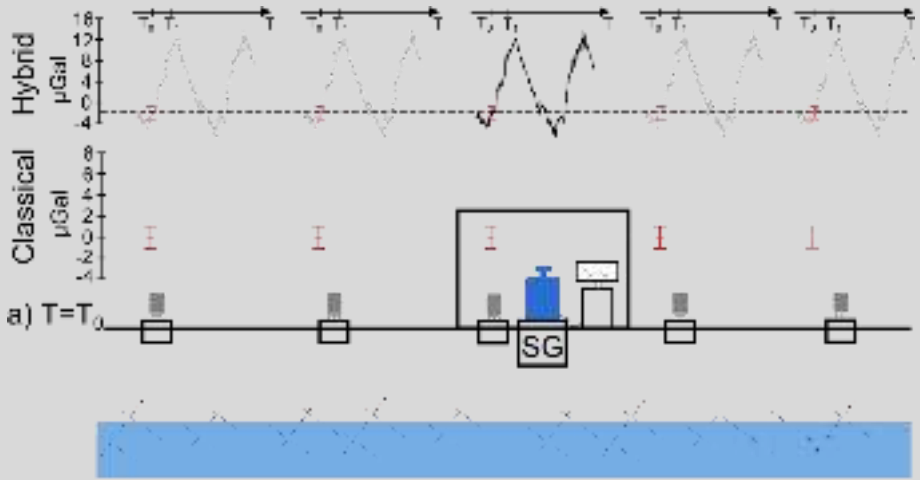
superconducting



FG5	CG5	OSG	GRACE
2 µgal 5 cm H_20	***precision*** 2 µgal 5 cm H_20	0.1 µgal 2.5 mm H_20	2 µgal 5 cm H_20
No drift /transportable	***advantage*** **Easy to move**	**High precision continuous**/low drift	**Spatial coverage**
Maintenance (laser, superspring)	***disadvantage*** Precision/drift	Maintenance (cryogenics)	Low sampling

What is hybrid gravimetry?

Principles of hybrid gravimetry (SG + microgravimeter)

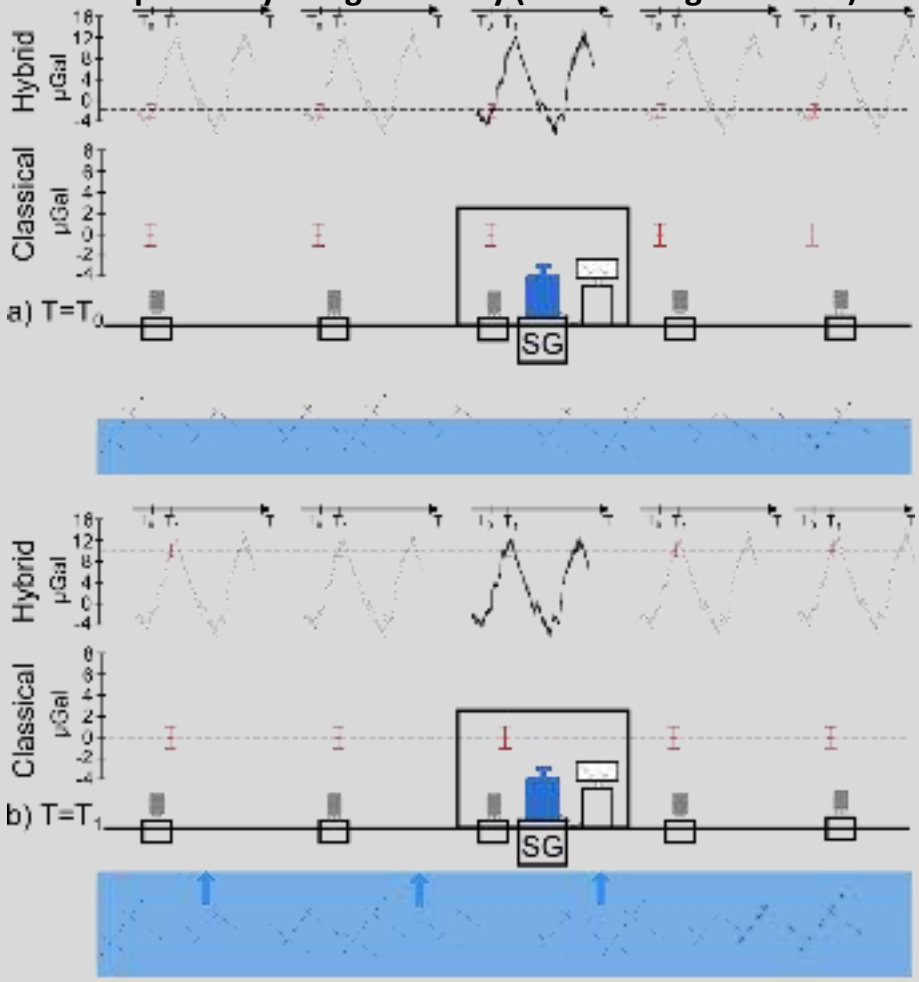


a) Time T_0

- SG : gravity changes at a base station
- CG5 microgravimeter: gravity differences btw each station and base station

$\Rightarrow$ SG + CG5: gravity changes at all stations

Principles of hybrid gravimetry (SG + microgravimeter)



a) Time T_0

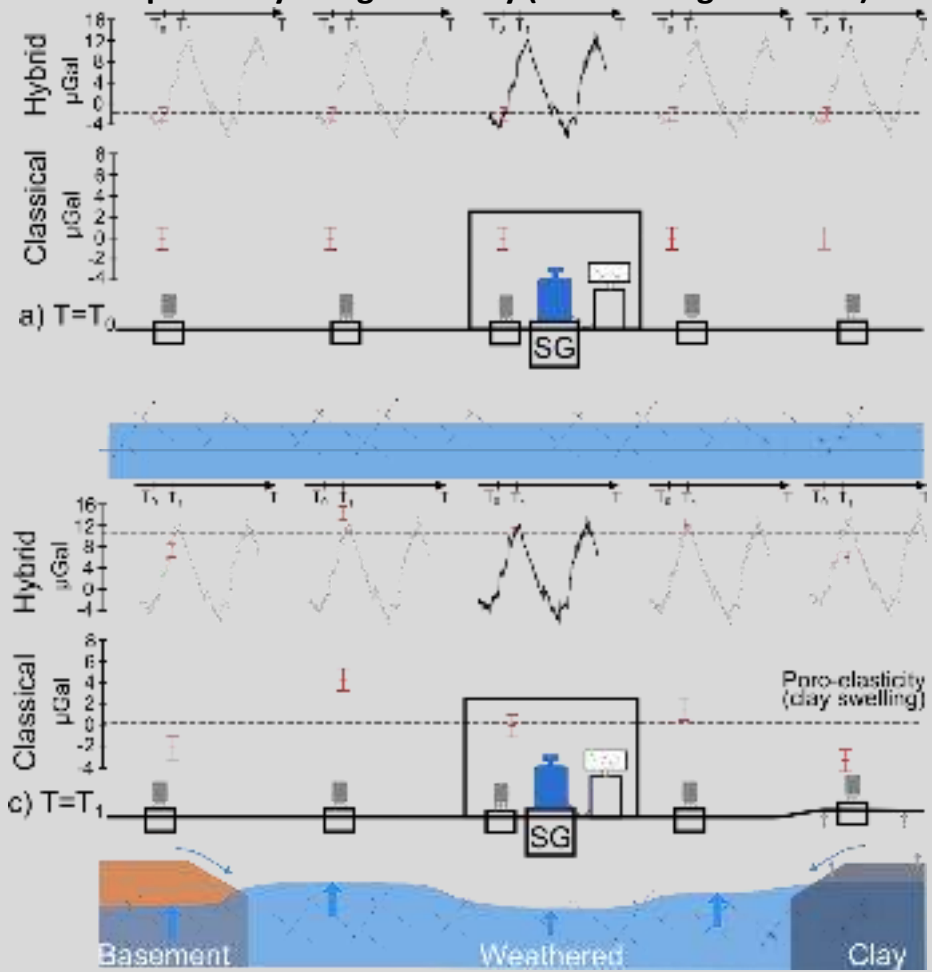
b) Time T_1

Homogeneous case

CG5 -> 0
(no spatial variations)

Gravity changes are SG changes

Principles of hybrid gravimetry (SG + microgravimeter)



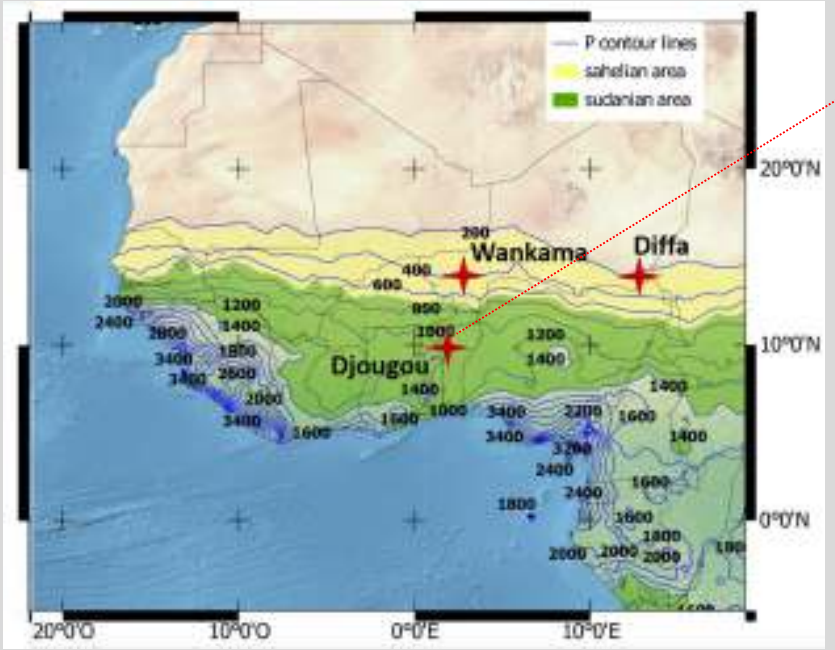
a) Time T_0

b) Time T_1

Heterogeneous case

Gravity changes are SG changes + CG5 changes

One example from GHYRAF (Gravity and Hydrology in Africa) ANR project



Strong north-south climatic gradient

❑ Djougou Benin (West Africa)

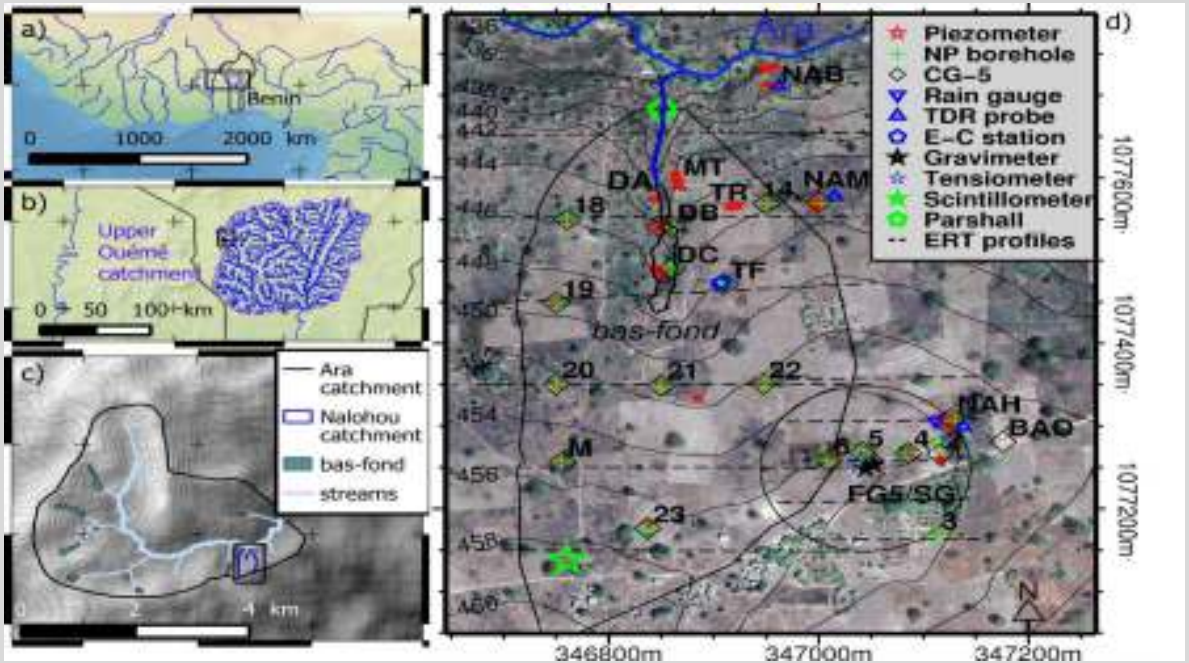
Hybrid gravimetry: AG + RG + SG + GRACE

Precise positionning: GPS

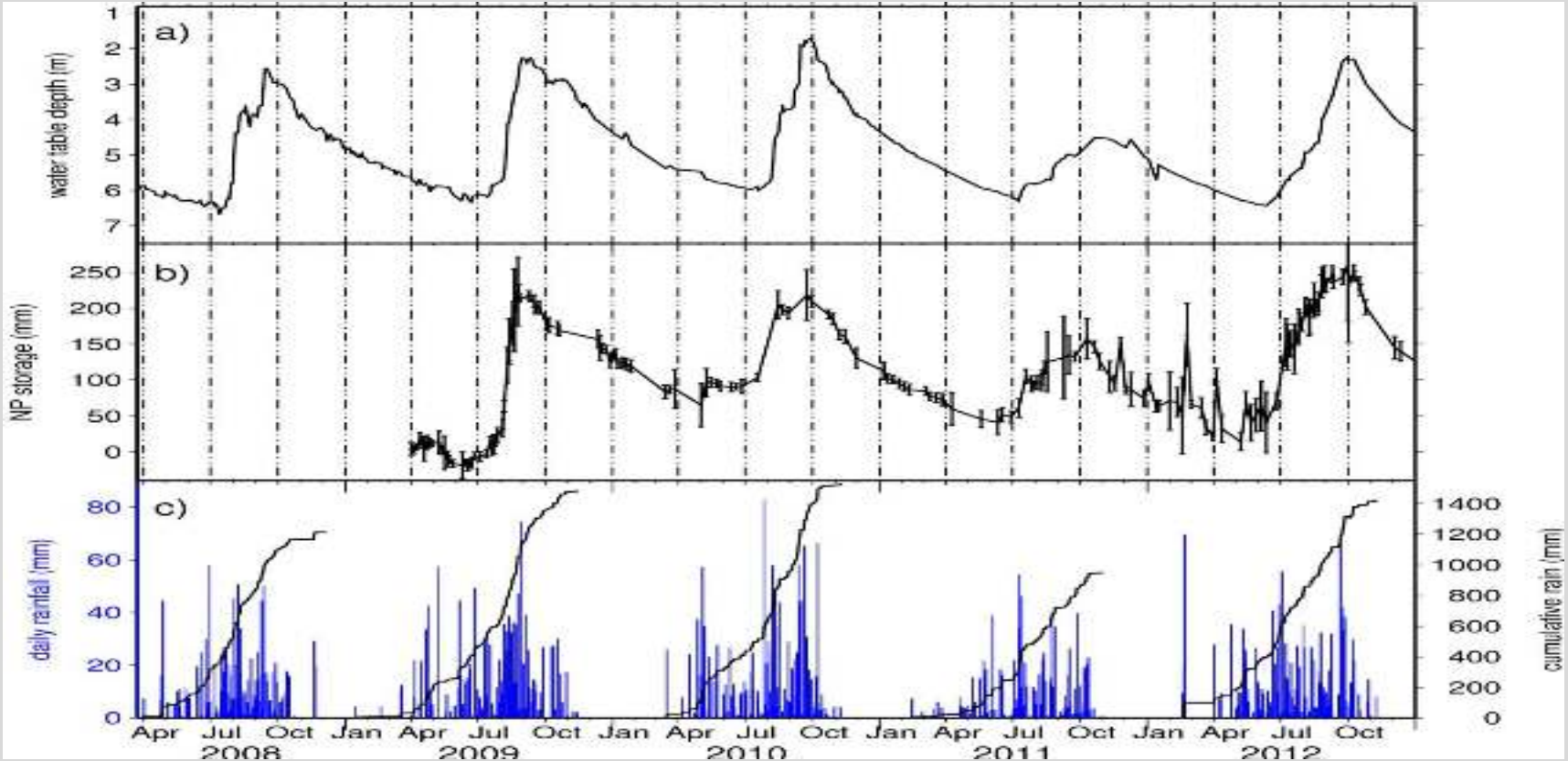
Hydrological sensors: neutron probes, piezometers, soil humidity

Hinderer et al. JoG 2009, PAGEOPH 2011; Hector et al. GJI 2013, JoG 2014, WRR 2015

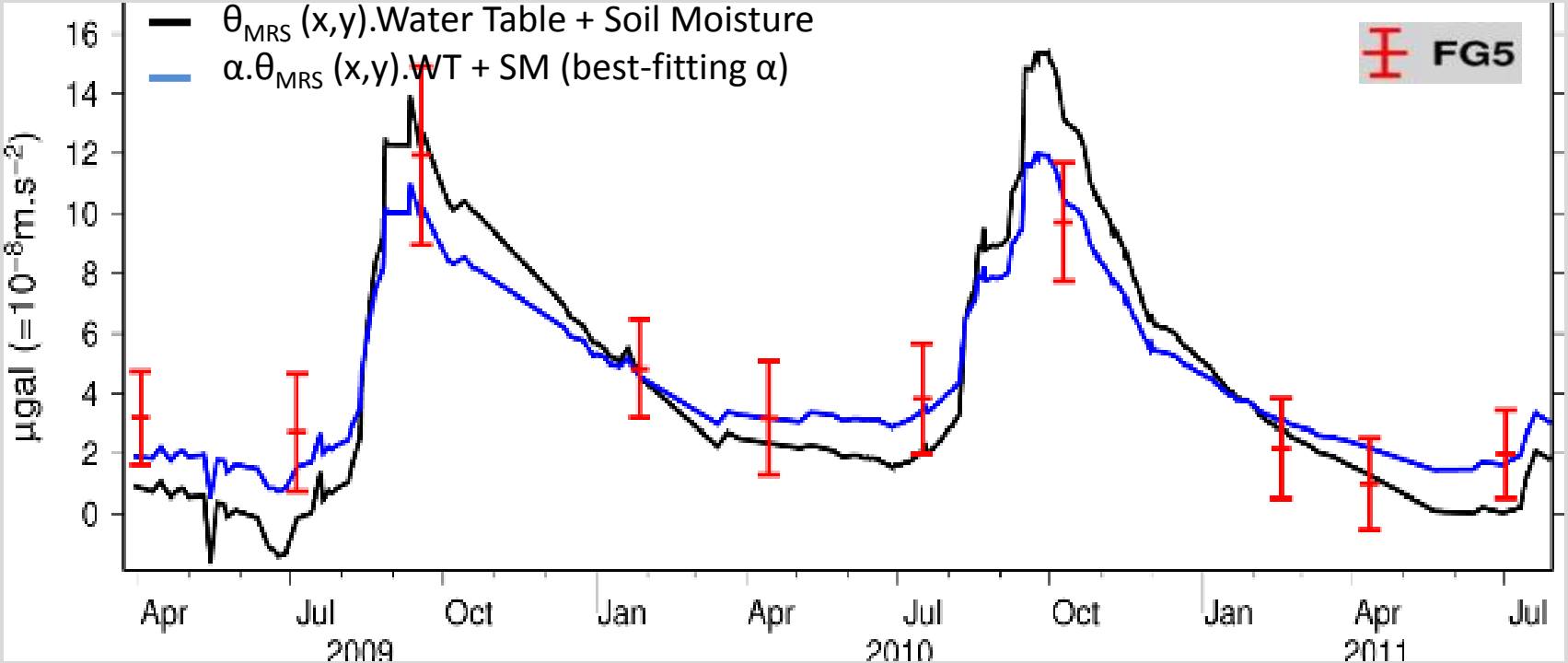
Djougou Bénin
AMMA- CATCH



Water table level, NP storage and rain



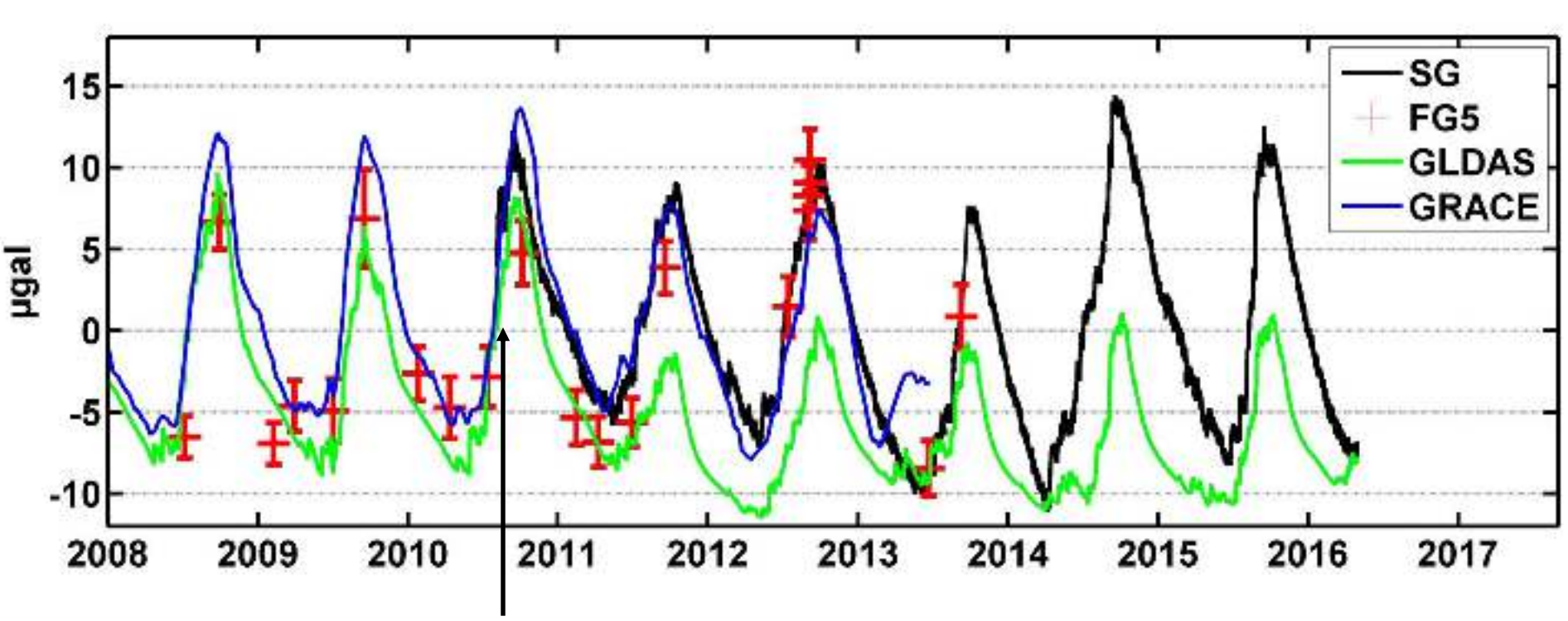
Gravity changes: observations versus local hydrological model



black and blue curves: gravity modeling of hydrological effect with different soil humidity and water table changes (use of resistivity mapping and MRS soundings)

only with AG

Ground (SG + AG)and space (GRACE) gravity versus hydrological model

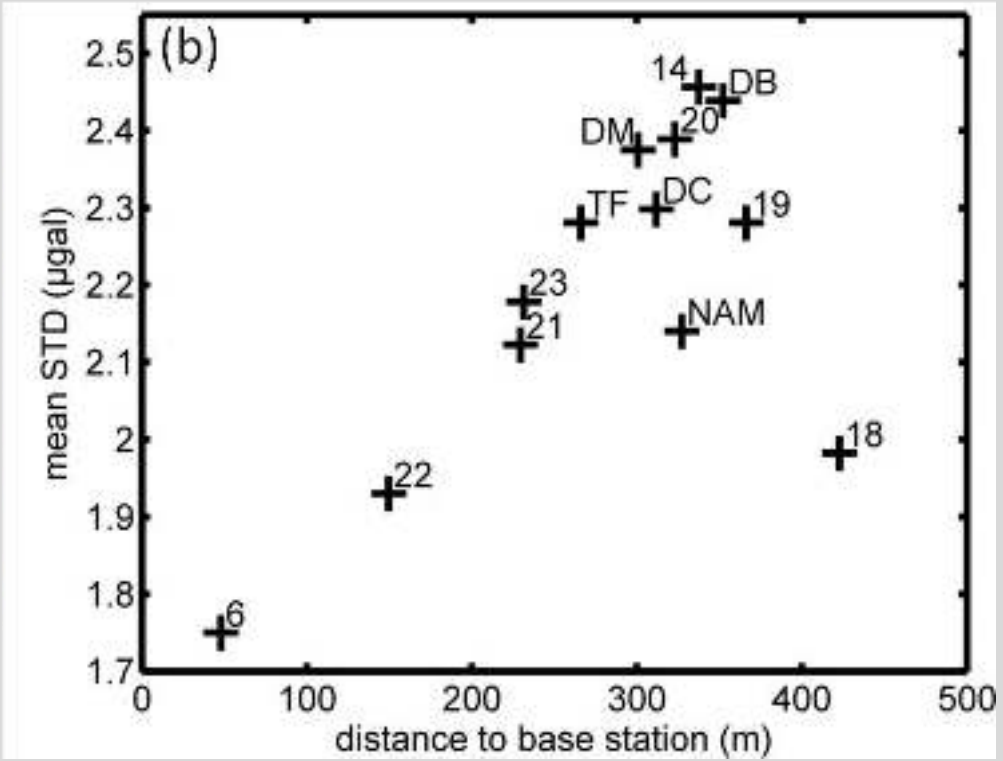


with SG and AG

Micro-gravity surveys

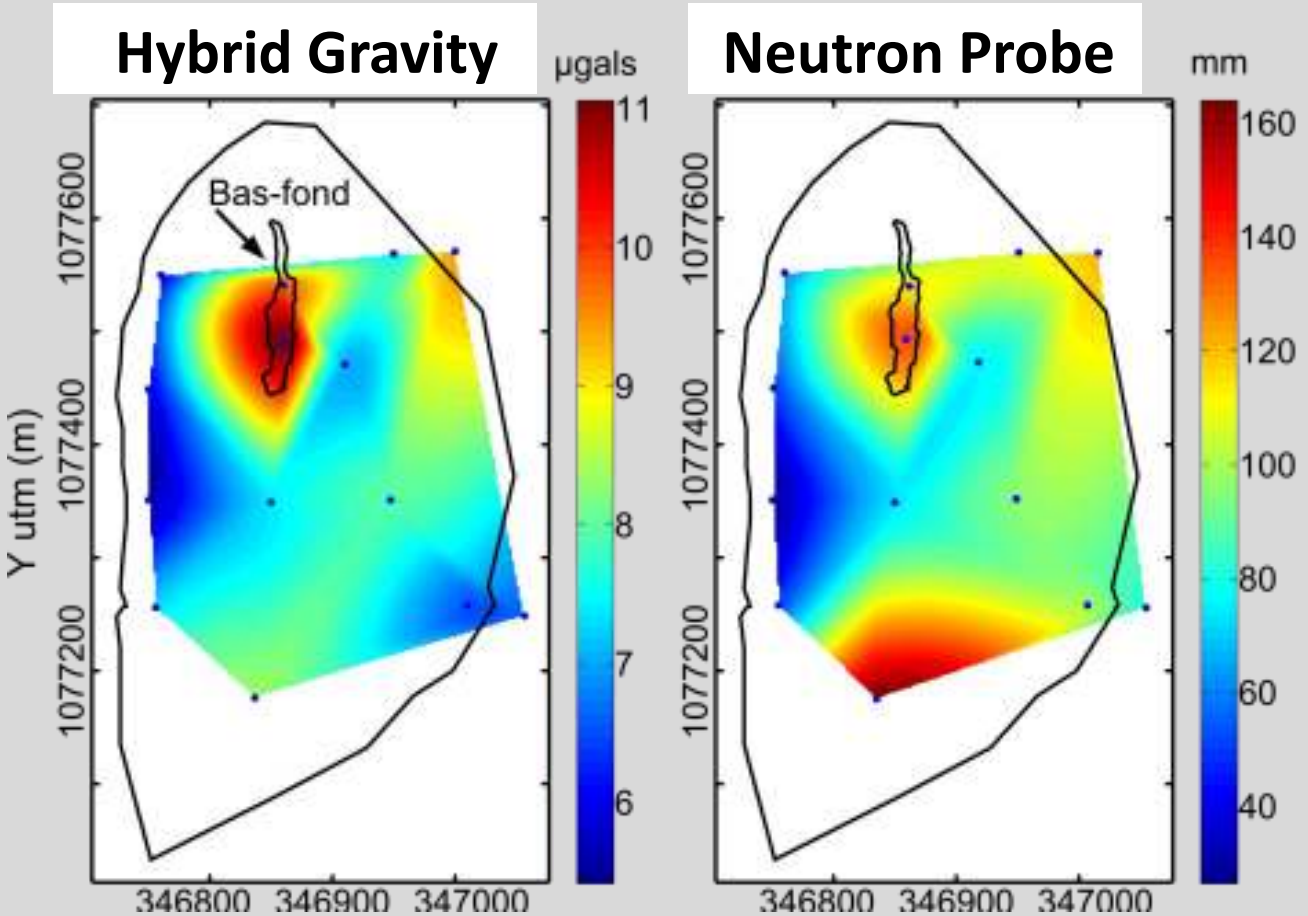
(a)

70 surveys with Scintrex CG5 RG of a network of 15 stations covering contrasted years



low uncertainties (< 2.5 µgal) on station gravity determinations

Seasonal amplitude of water storage changes



Hector et al., *Water Resour. Res.*, 2015

Hybrid: with SG, AG and RG

On-going CRITEX projects in hydro-gravimetry

- Available equipments:

✓ 3 superconducting gravimeters GWR iGrav

✓ 1 relative gravimeter Scintrex CG5

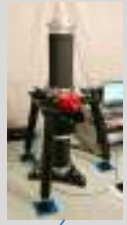
- Validation of iGravs at Strasbourg Observatory since installation in July 2016 see poster Portier et al.

- First iGrav installation planned in may-june 2017 at Strengbach watershed

- Second iGrav installation planned in fall 2017 at Fontaine de Vaucluse karst system

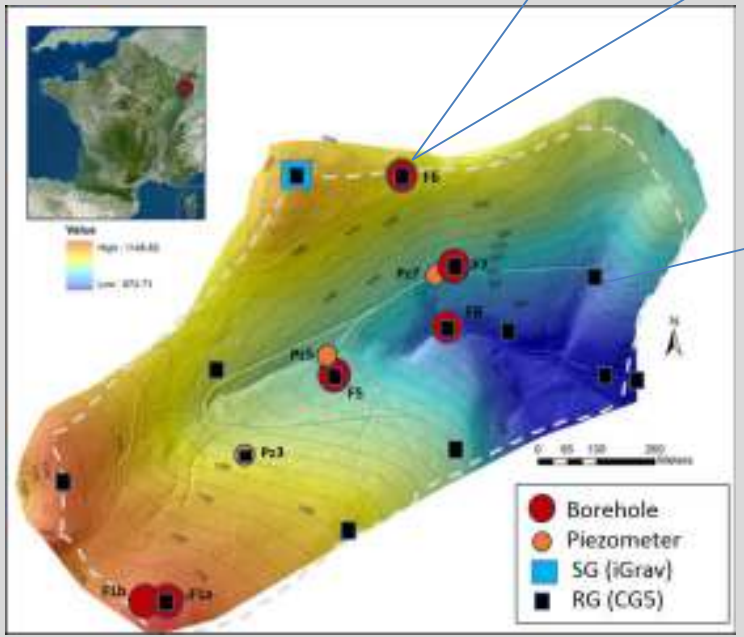
- Third iGrav to be used in a pumping test experiment in Brittany (spring 2018)

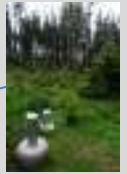
Our strategy for studying the water storage changes in the Strengbach catchment (Vosges mountains)



Use of hybrid gravimetry to investigate WSC:

- Continuous monitoring with SG (iGrav) at summital base station
- Regular measurements at base station with AG (FG5)
- Repetition of micro-gravity network with RG (Scintrex CG5) on 17 stations within the catchment including 6 boreholes/piezometers





Complemented by:

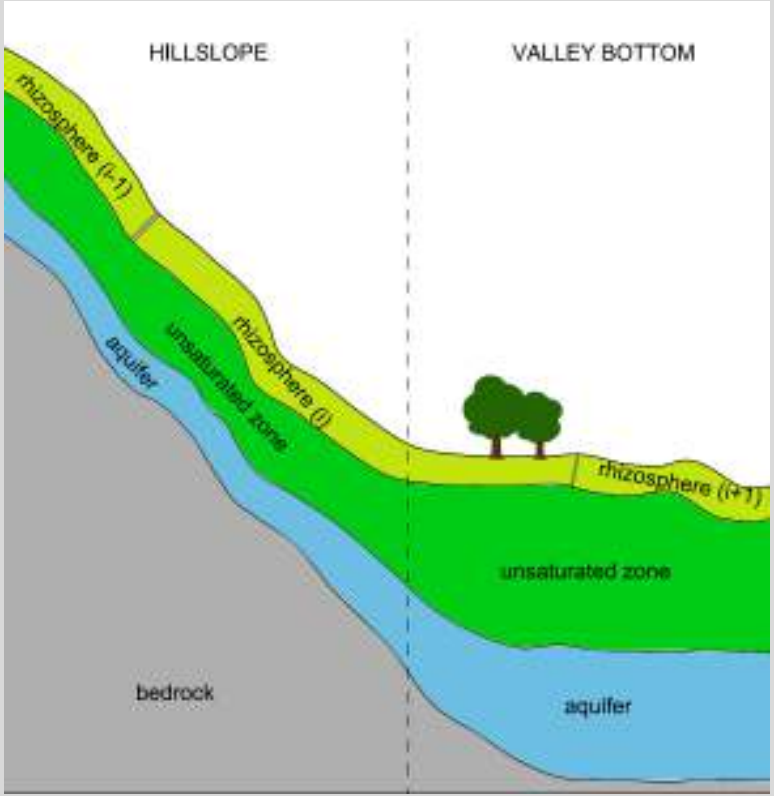
- Monitoring of water level in several boreholes and piezometers
- Monitoring of soil water content with different probes (TDR, optical fiber, etc..)

more in Pierret et al. talk + poster by Chaffaut et al.

- To improve the conceptual model of a topographically complex mountain catchment

- To reach better constraints in the hydrological inversion procedure

- To reduce uncertainty in water storage dynamics with respect to the classical case (using only streamflow data)

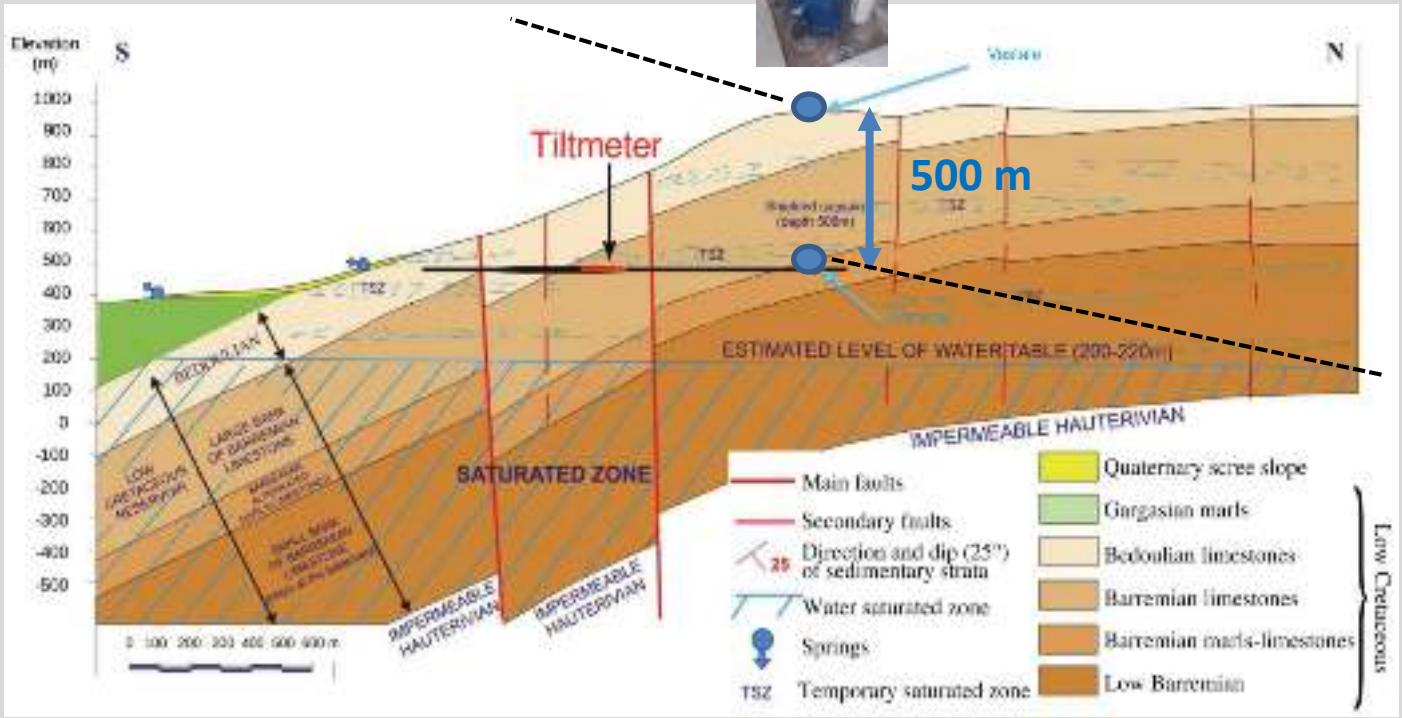


Simplified schematic representation of the hydrological model (Piccolroaz et al. 2015)

+ fractures with enhanced fluid circulation …

Fontaine de Vaucluse: a new CRITEX experiment based on differential gravity

Future location (Vestale)
of CRITEX iGrav



Present location (Rameau)
of MIGA iOSG4

Summary:

- ❑ hybrid gravimetry (AG + SG + RG) leads to valuable information on water storage changes in time and space

- ❑ combined with other geophysical and hydrological observations helps to understand the hydrological behaviour of a catchment

- ❑ after successful validation tests in Strasbourg the CRITEX superconducting gravimeters will be deployed soon on two selected sites (Strengbach and LSBB) in a fully hybrid gravimetry approach

Thank you for your attention!