

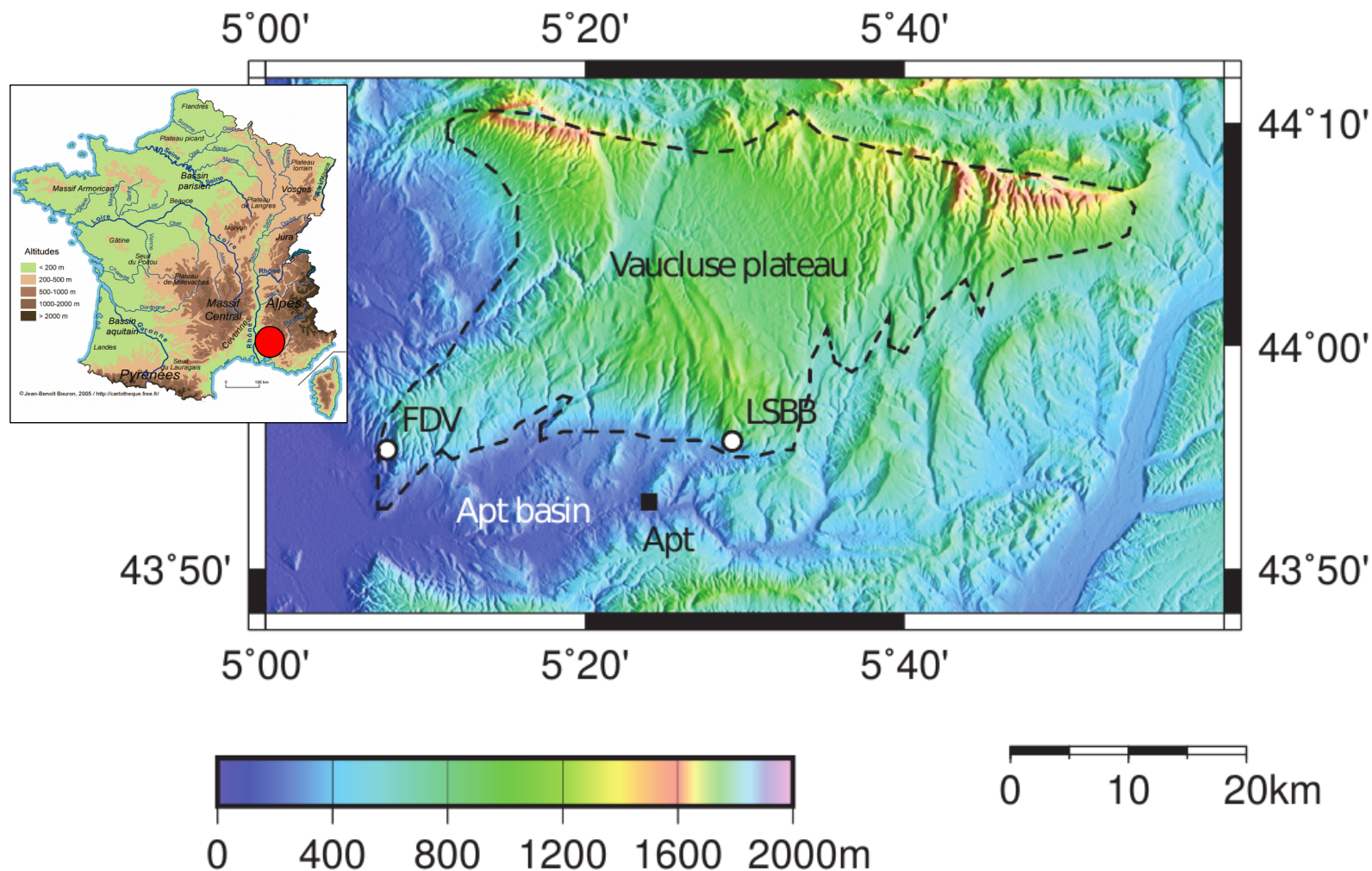
# Observatories of the karst :

- Larzac H+ observatory, France
- LSBB H+ observatory, France

Champollion C., Le Moigne N., Chéry, C., Doerflinger, E., Fores B. (PhD)  
K. Chalikakis, N. Mazzilli

# LSBB geological context

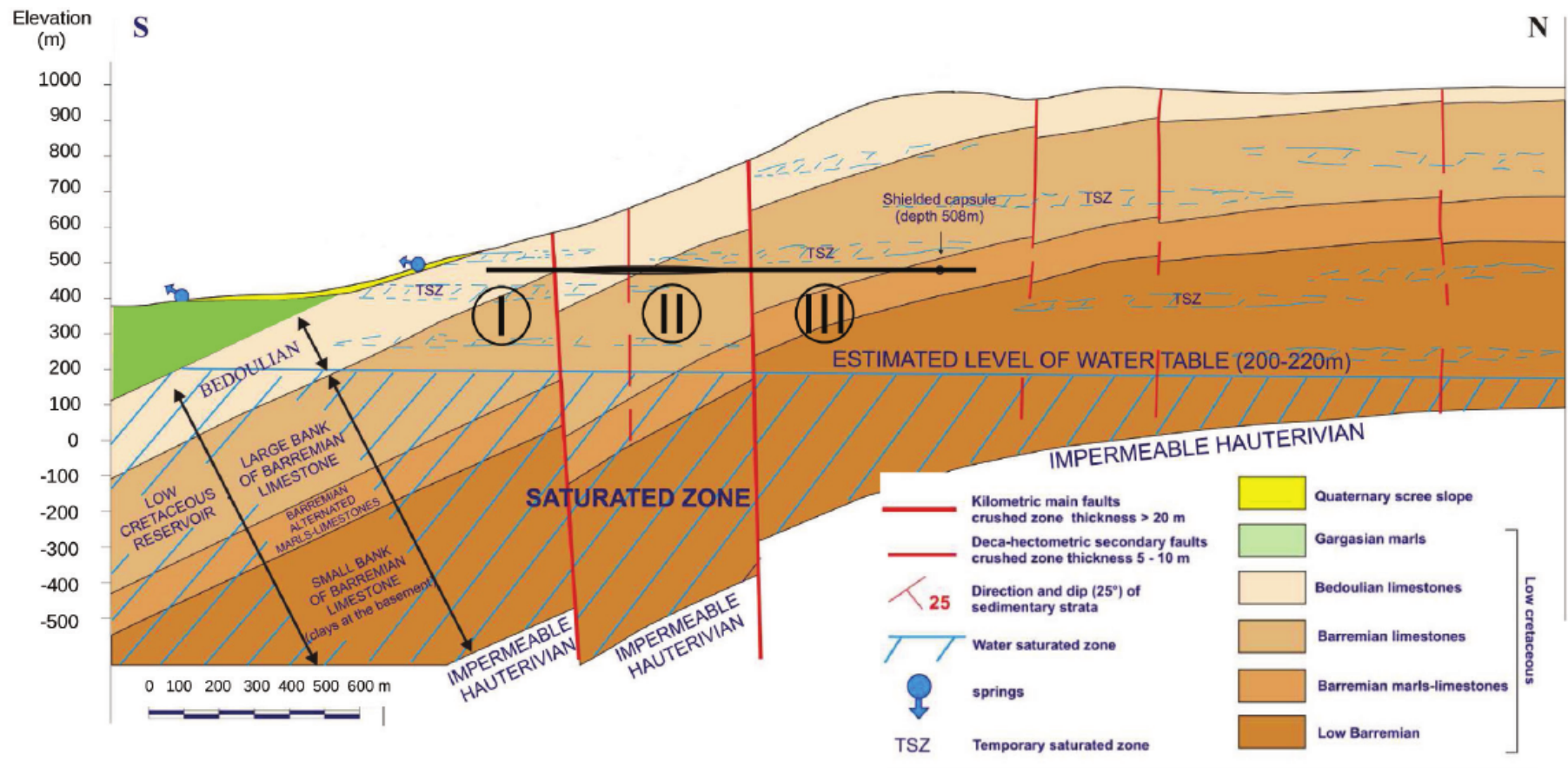
- Fontaine de Vaucluse (FDV) catchment area  $\sim 1130 \text{ km}^2$ .
- Opportunity to instrument the underground laboratory of LSBB (Laboratoire Souterrain à Bas Bruit).



(Fleury et al., 2007; Chawah, et al., 2015.)

# LSBB geological context

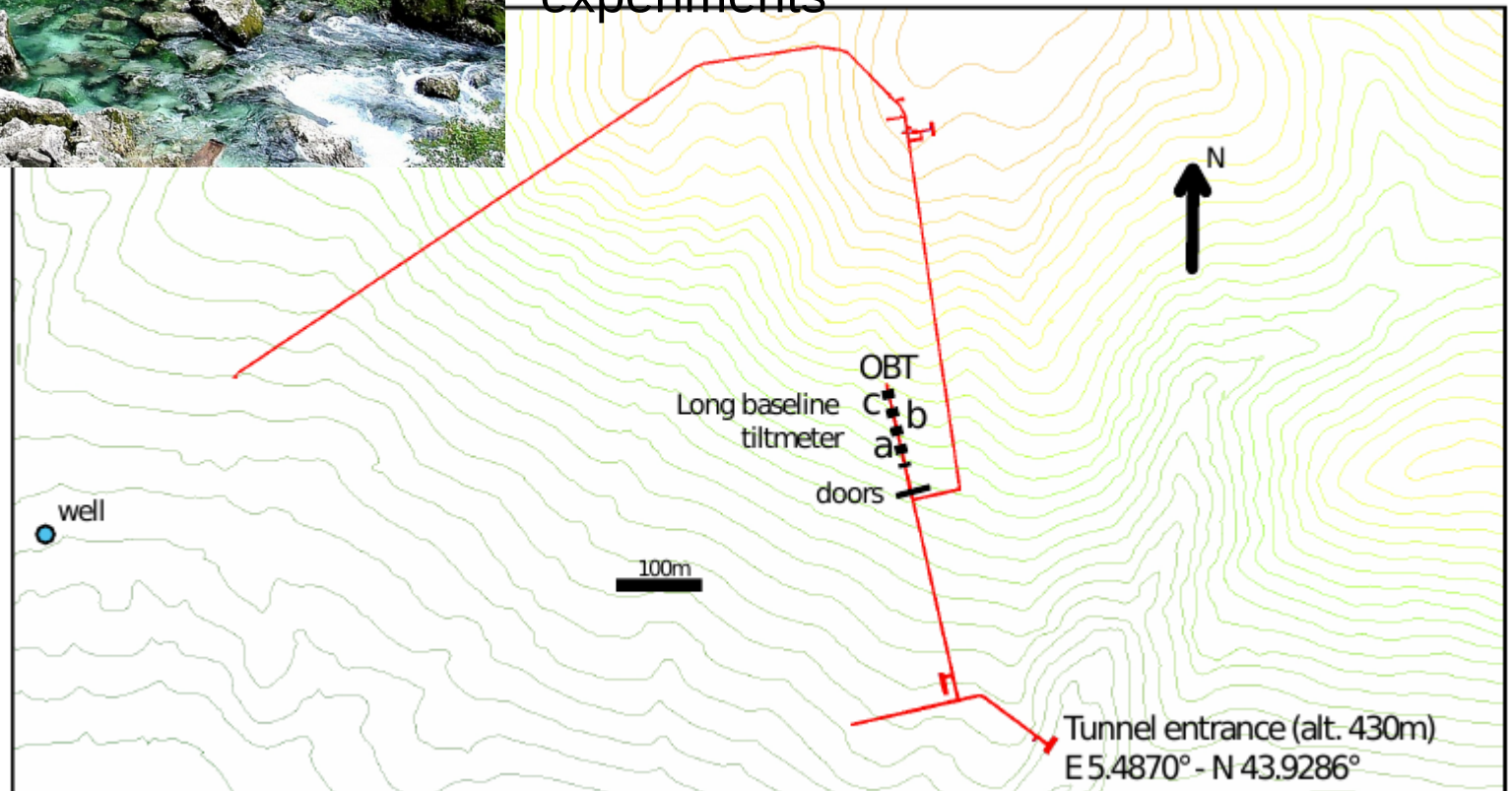
- Karstified limestones outcrop throughout the Vaucluse plateau.
- Limestones layer thickness  $> 1$  km.
- On the southern side  $\rightarrow$  impermeable marls.





# LSBB facilities

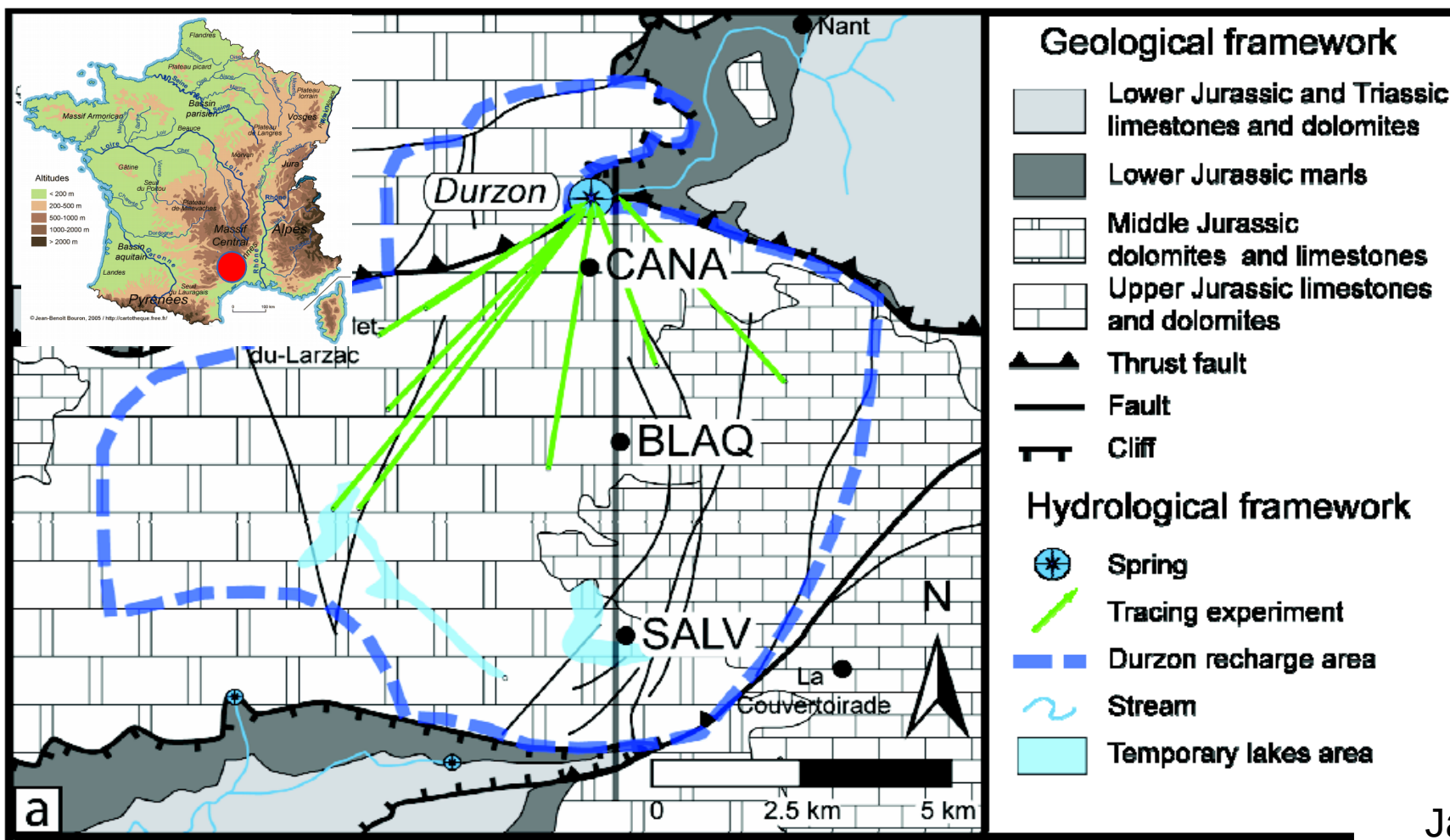
- Continuous **gravity** measurements
- Continuous **deformation** measurements (probably some of the most accurate)
- Numerous groundwater **drip flow** monitoring
- Numerous **MRS**, **ERT** and **GPR** experiments





# Larzac geological context

- **Mediterranean Karst:** Low altitude (500m) / ~ flat topography / Mainly dolomite / 120m ZNS / 100 km<sup>2</sup>



# Larzac Karst observatory

- **Permanent continuous** and experimental instrumentation from boreholes to gravimetry, ERT, fluxes, GPS, sismometer

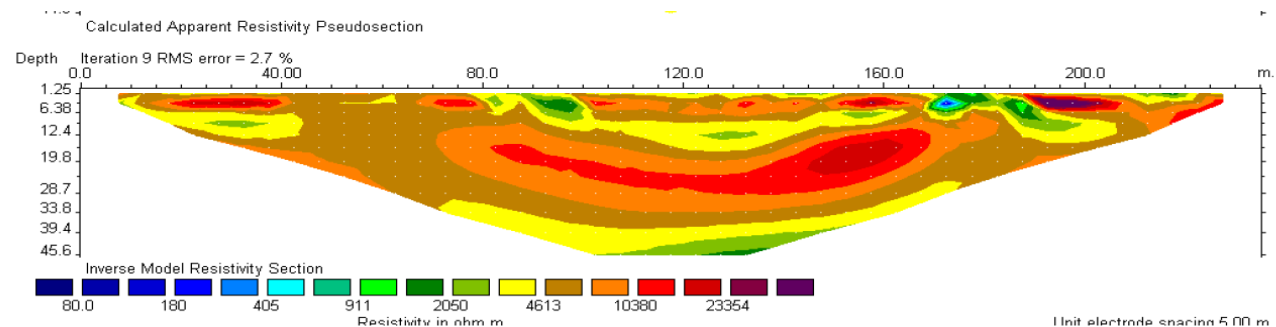


Figure 14 : Modèle de résistivité « Dipole-dipole »



# ***In-cave experiments***



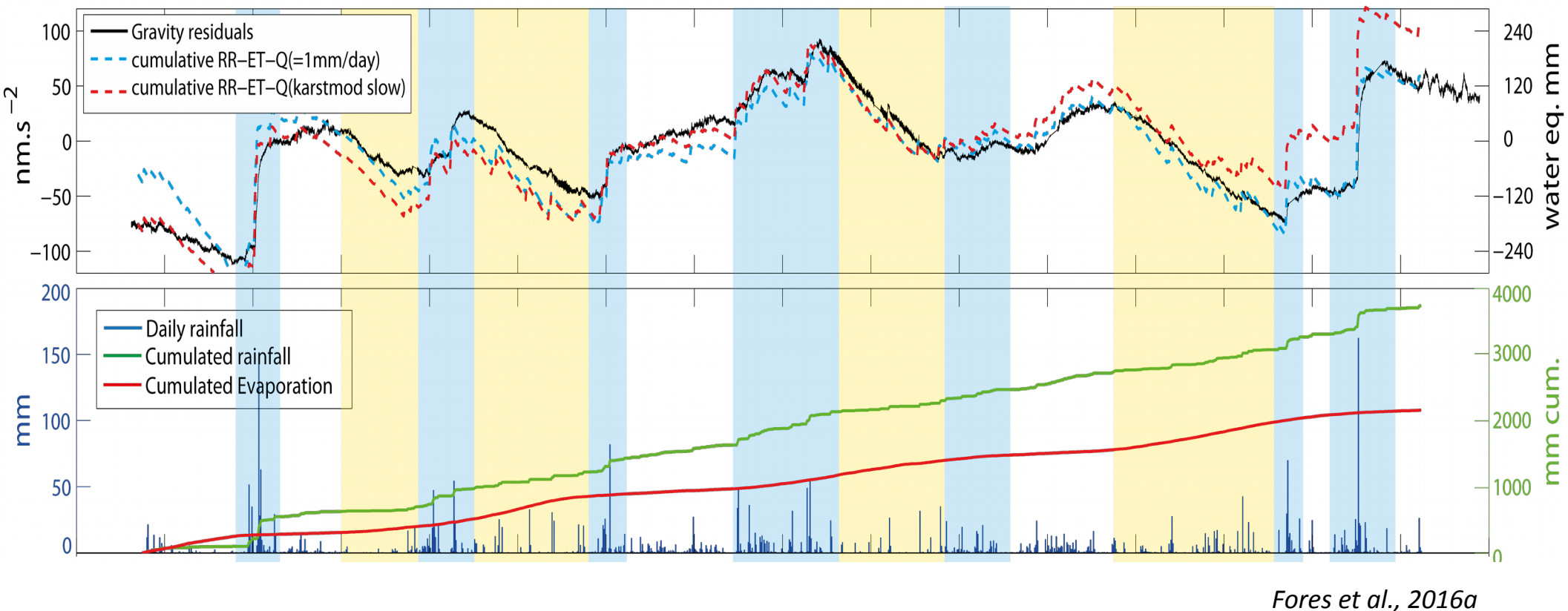


# Larzac observatory : Main Objectives

- **Water stock** variations and **water transfer** at different time – and space – scales from observations
- **Numerical models** of water transfer at local scale constrained from data (Ex.: constrained Hydrus with gravity and seismic data PhD B. Fores)
- Instrumental and methodological **\*developments**

\* The **Larzac** GEK Observatory is an **open** place for hydrology, karstology, ecology and geophysics !

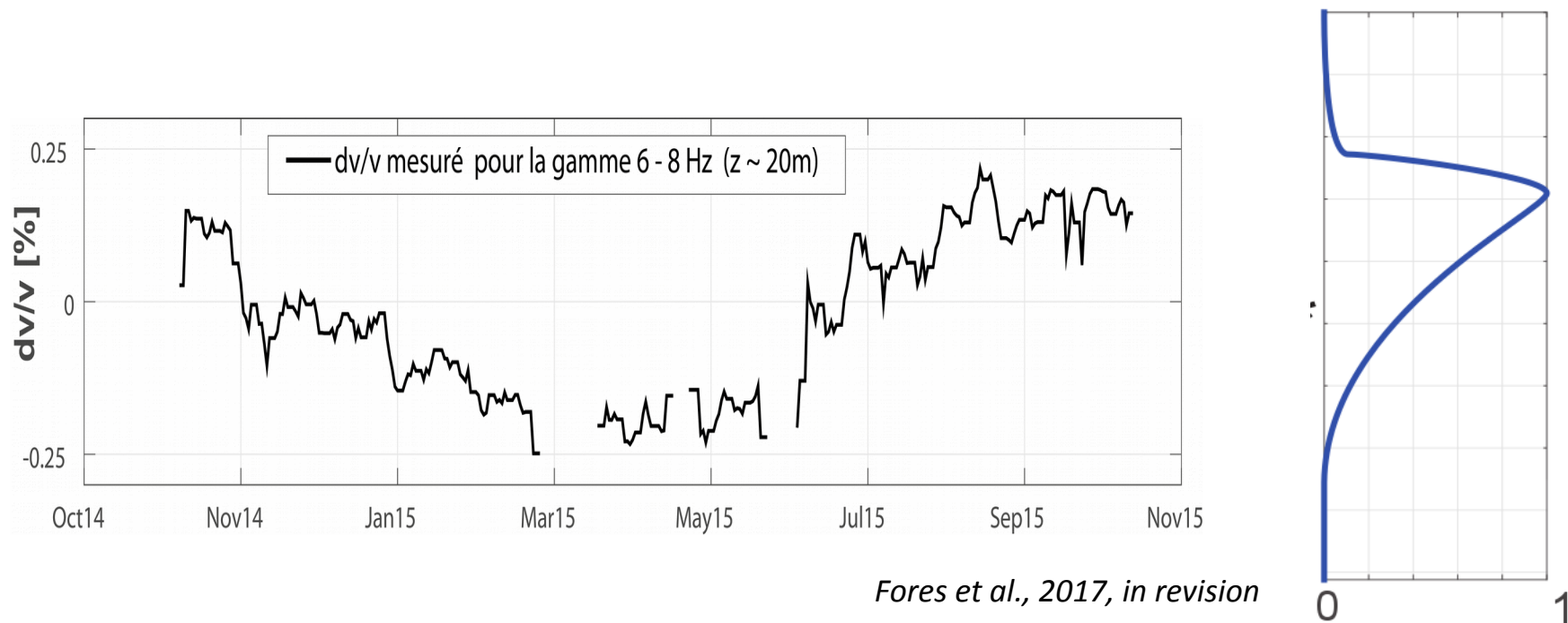
# Groundwater gravity monitoring at local scale (observatory)



**But ... no vertical resolution**

# Passive seismic noise

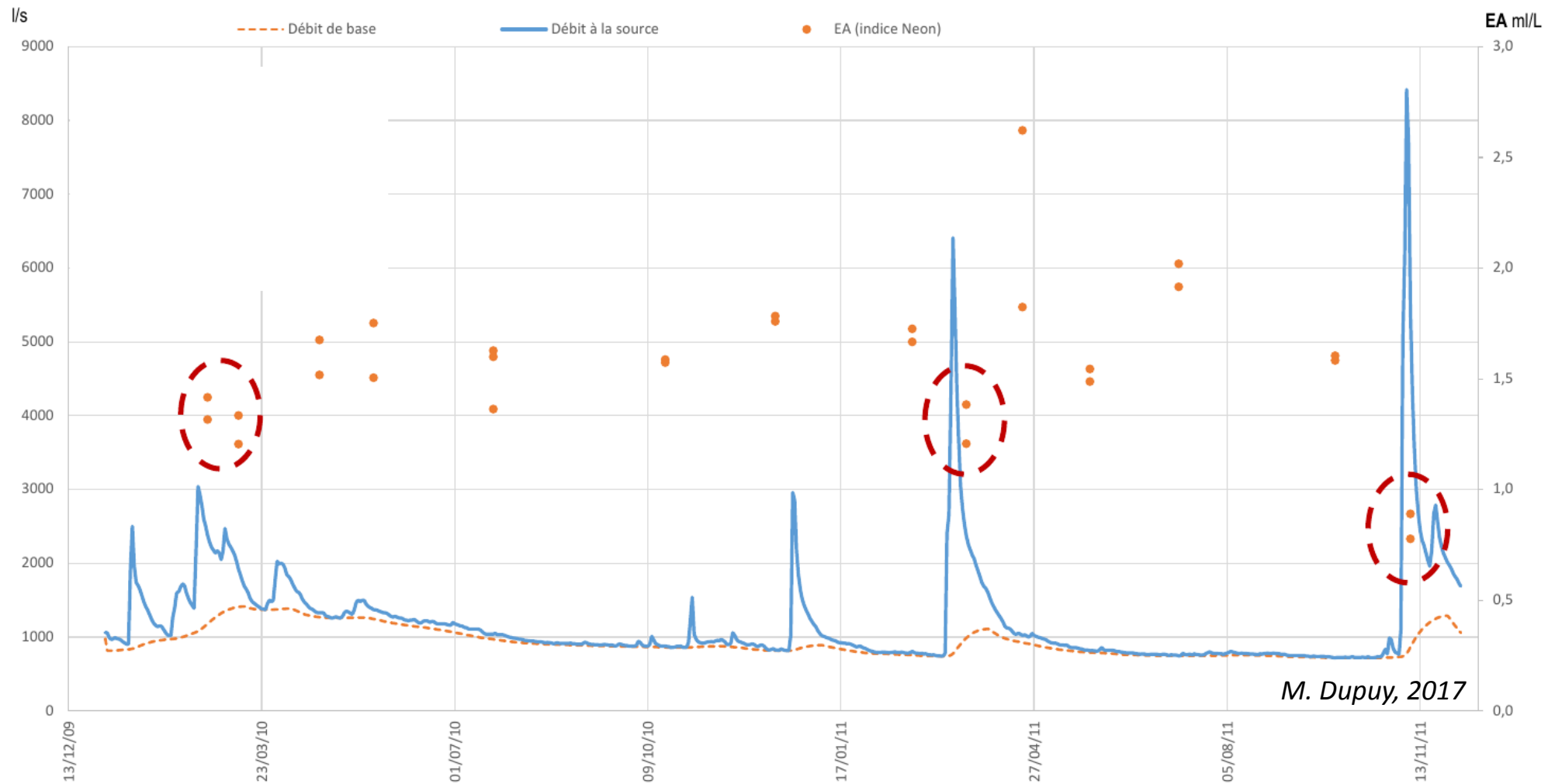
- Continuous monitoring with a depth sensitivity



→ Integration in physical models (HYDRUS) in progress

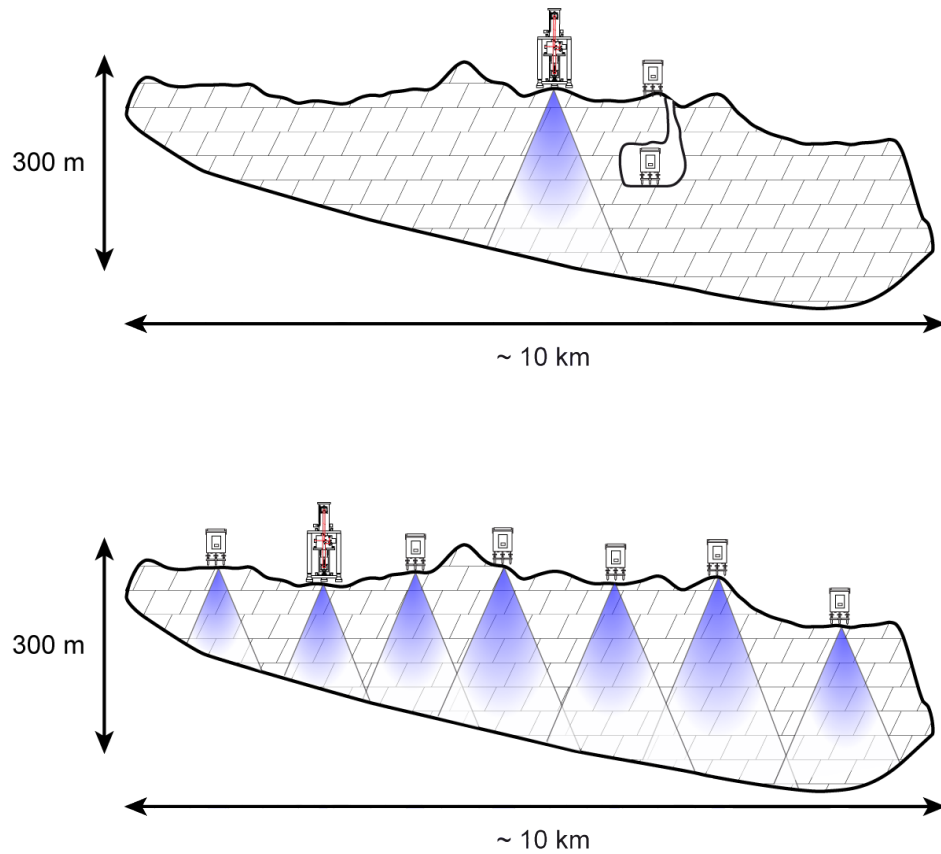


# Chemistry monitoring (Dissolved gas, Air Excess)



**Process of recharge and transient water storage**

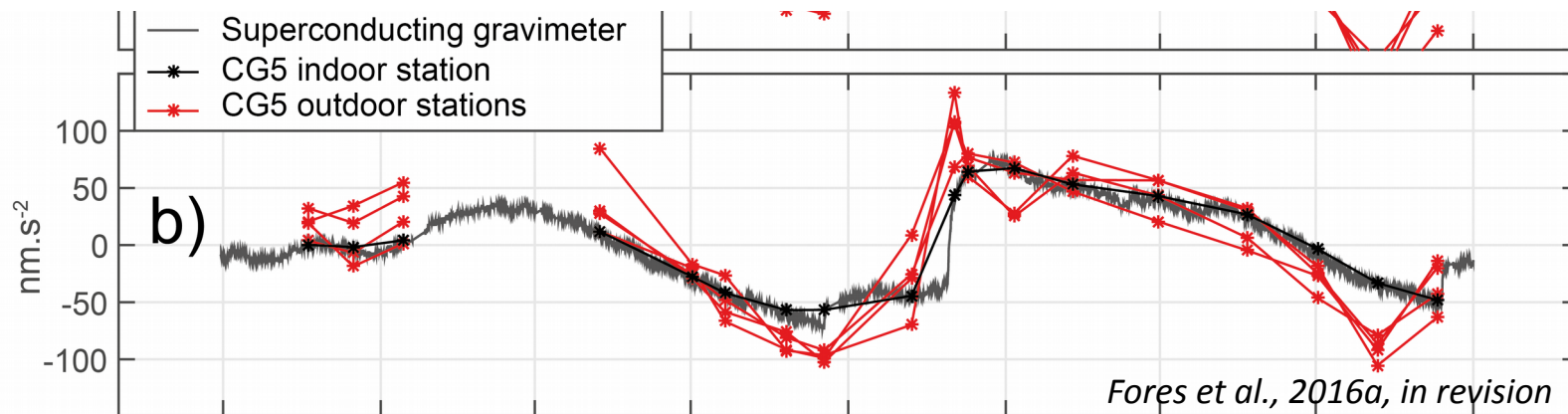
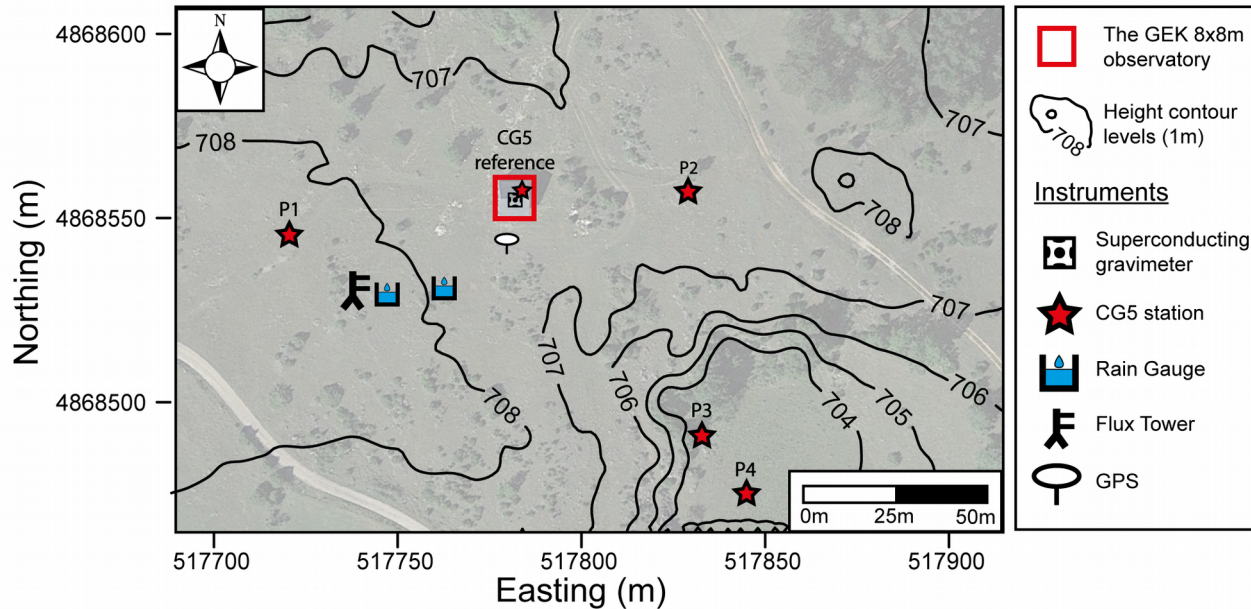
# Groundwater storage spatial variability



*Modified from T. Jacob*



# At the field scale (100m)

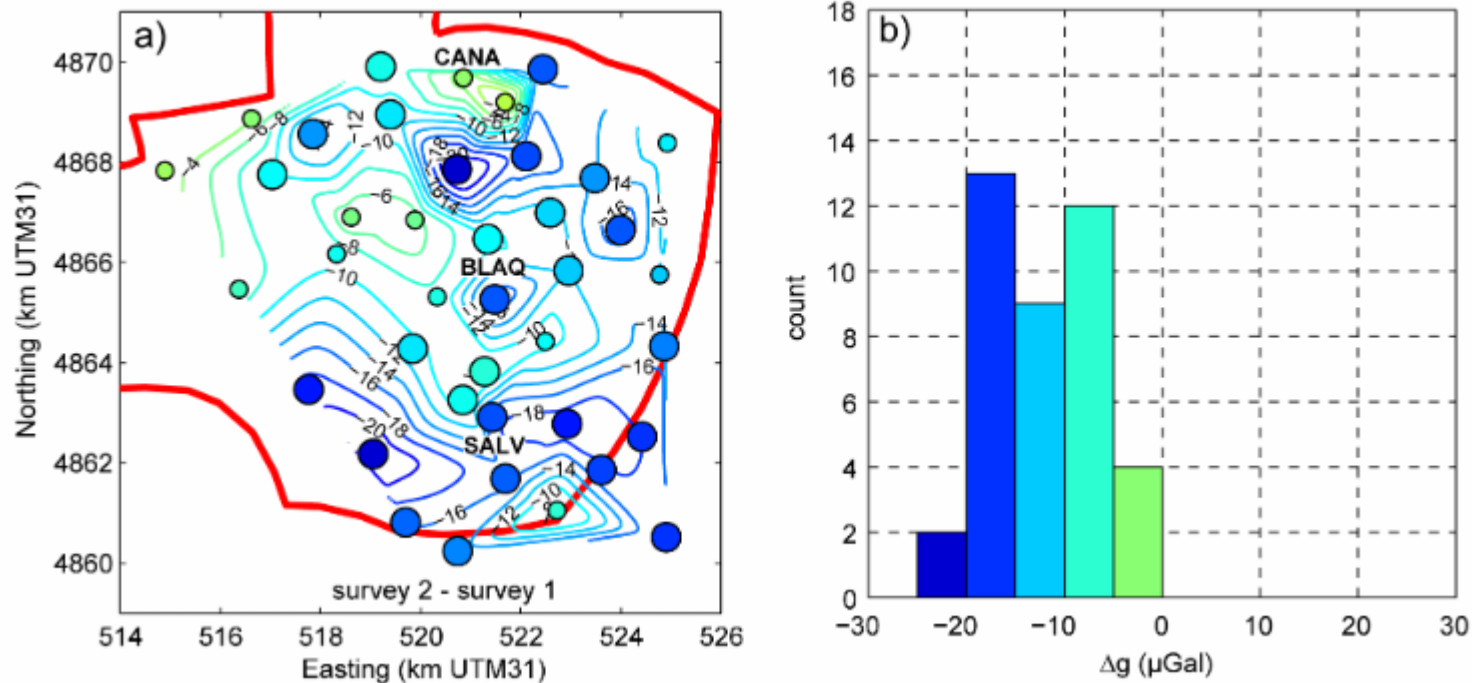


→ No significant variability of groundwater storage around the observatory



# At the basin scale (km)

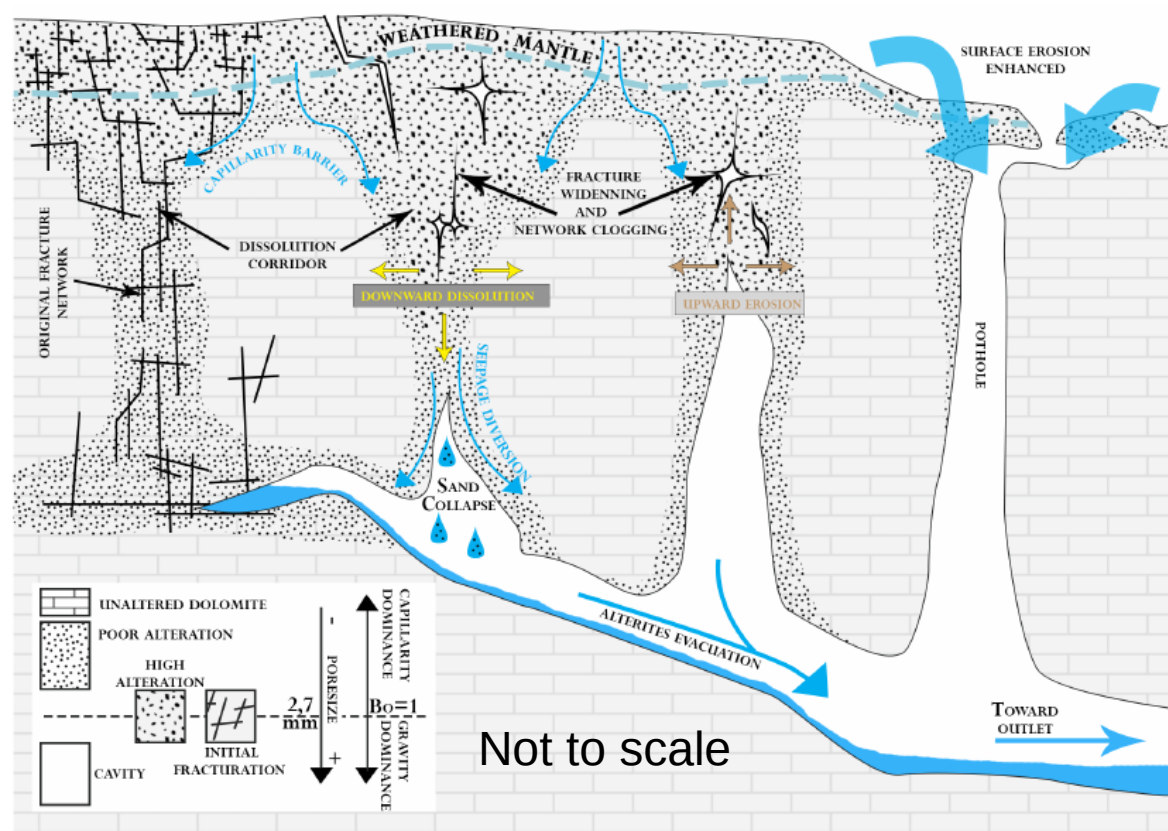
Differences between wet and dry season



*Modified from Jacob et al., 2010*

**Clear spatial variability of groundwater storage**

# (new) geophysical experiments



→ Dense gravity network (PhD 8)

→ Impact of anisotropy on Vp/Vs monitoring (PhD 5) ?

→ Infiltration monitoring by IR imaging or cosmic rays (PhD 7) at high resolution ?

Fig. 5. Interpretative schema of the different erosional steps in the Durzon karst. The left corresponds to the South part of the Durzon catchment area and the right to the North. Close to the surface, the weathering mantle depth depends of lithological, tectonic, vegetal and underground network development. The original fracture network organises the dissolution corridor distribution.

# List of continuous measurements

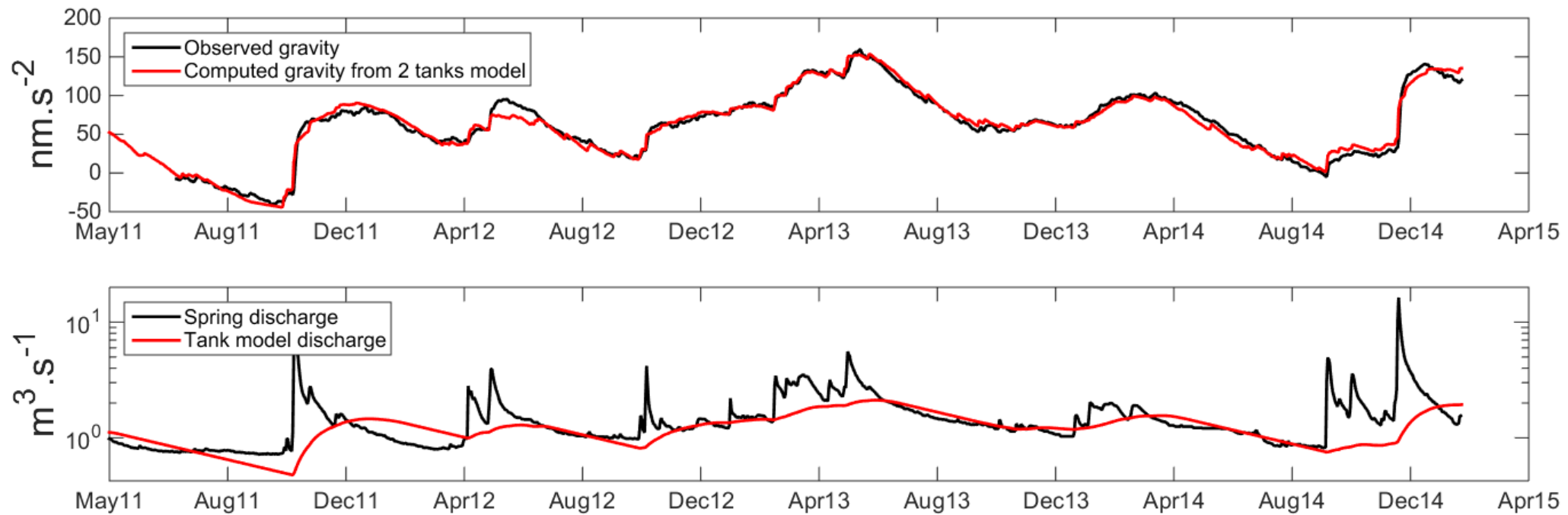
- Gravity
- GPS
- Seismometer
- Water level, Temp and Cond in three boreholes
- Eddy-covariance Evapo-transpiration
- Electrical Resistivity Tomography
- Tiltmeters (in natural caves)
- Underground drip and river flow (4 in natural caves)
- Pluviometers (3)

**Thanks for your attention**

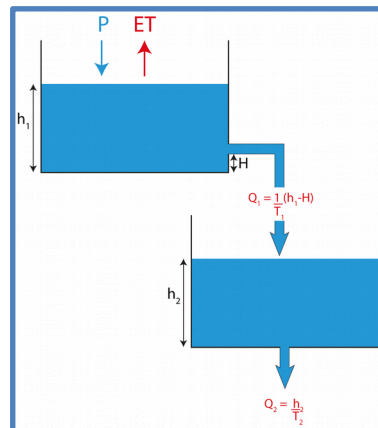




# Is a gravimeter a (very) expensive pluviometer ?



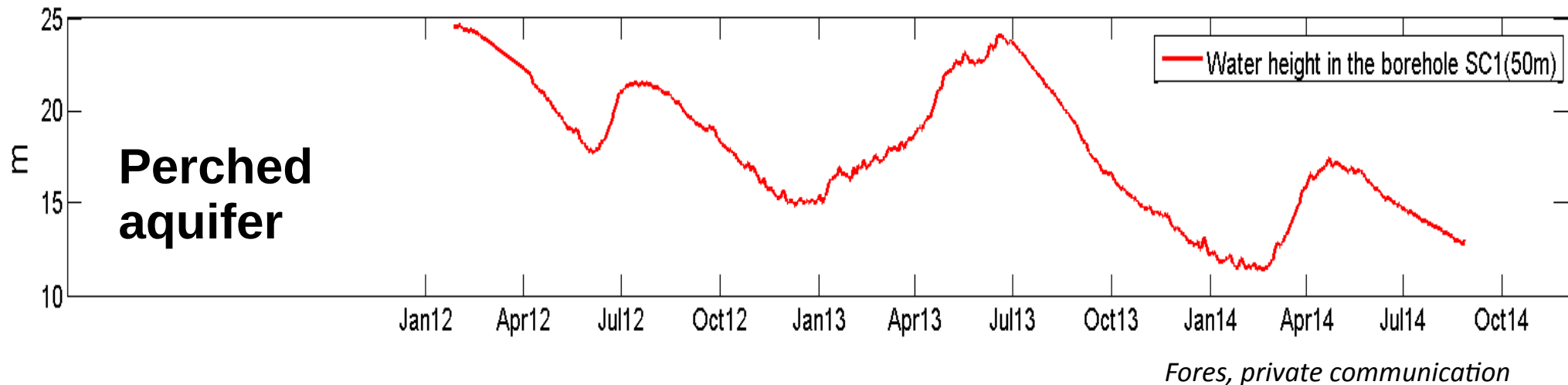
*Fores et al., 2016a, in revision*



*A gravimeter ~ a large scale flowmeter*

# We need a timer

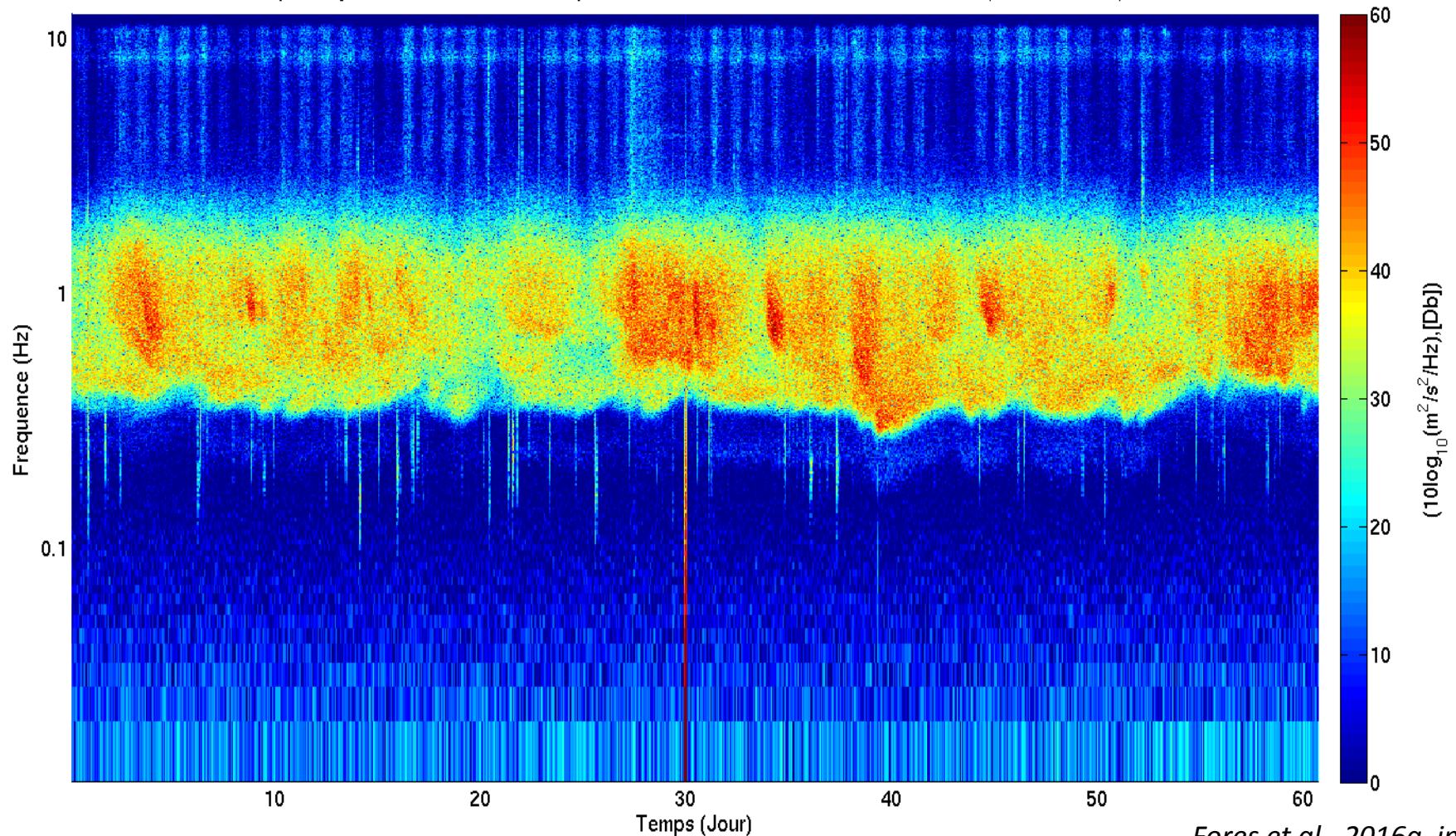
- First natural choice : a piezometer



→ Not coherent with gravity dataset (1D vs 2D, scales, depth boundary condition)

# We need a geophysical timer at the measurement scale

Spectrogramme station STN01 composante verticale du 2014/11/01 au 2014/12/31 (décimé 10 fois)

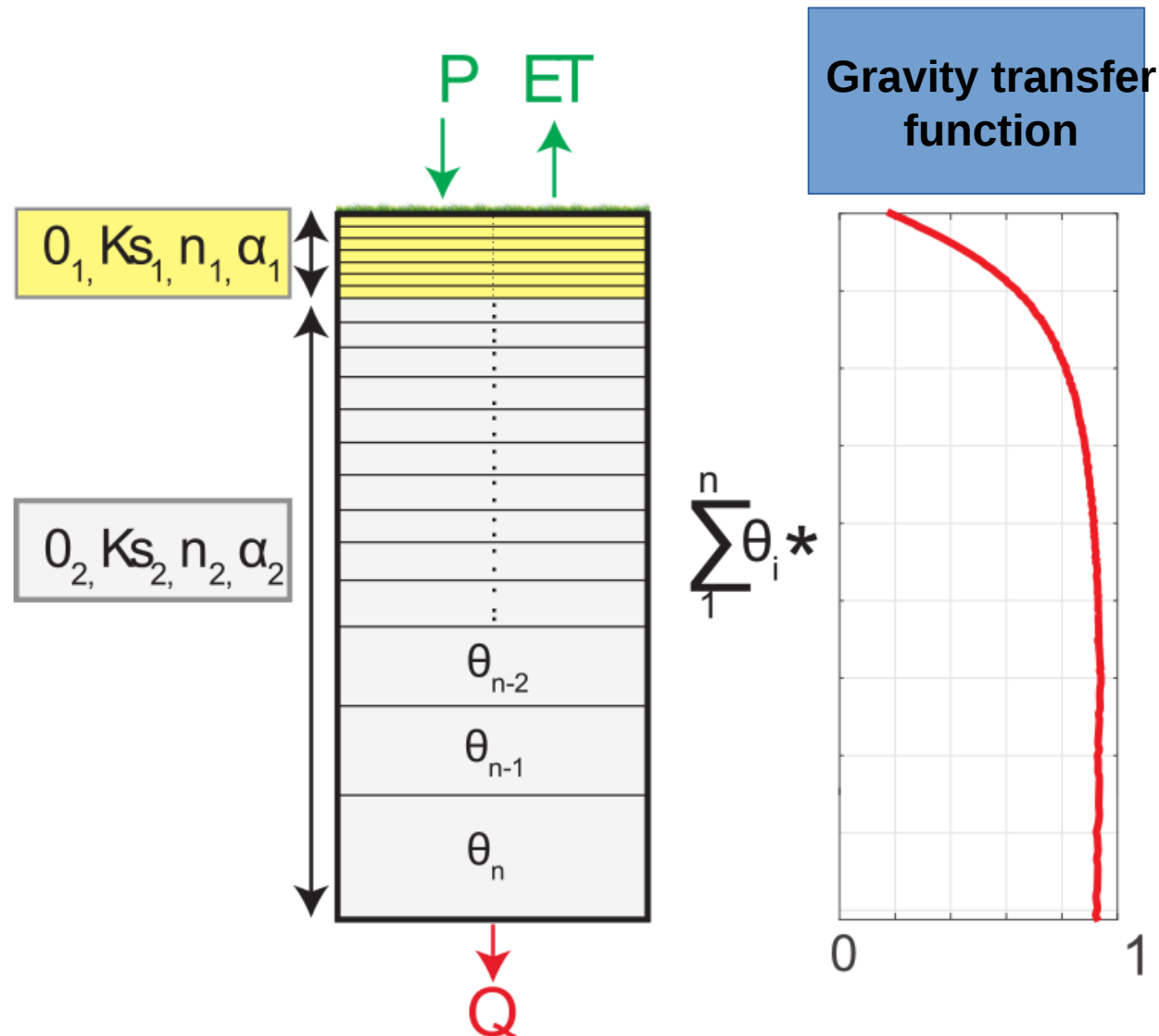


*Fores et al., 2016a, in revision*

→ Ambient seismic noise correlation

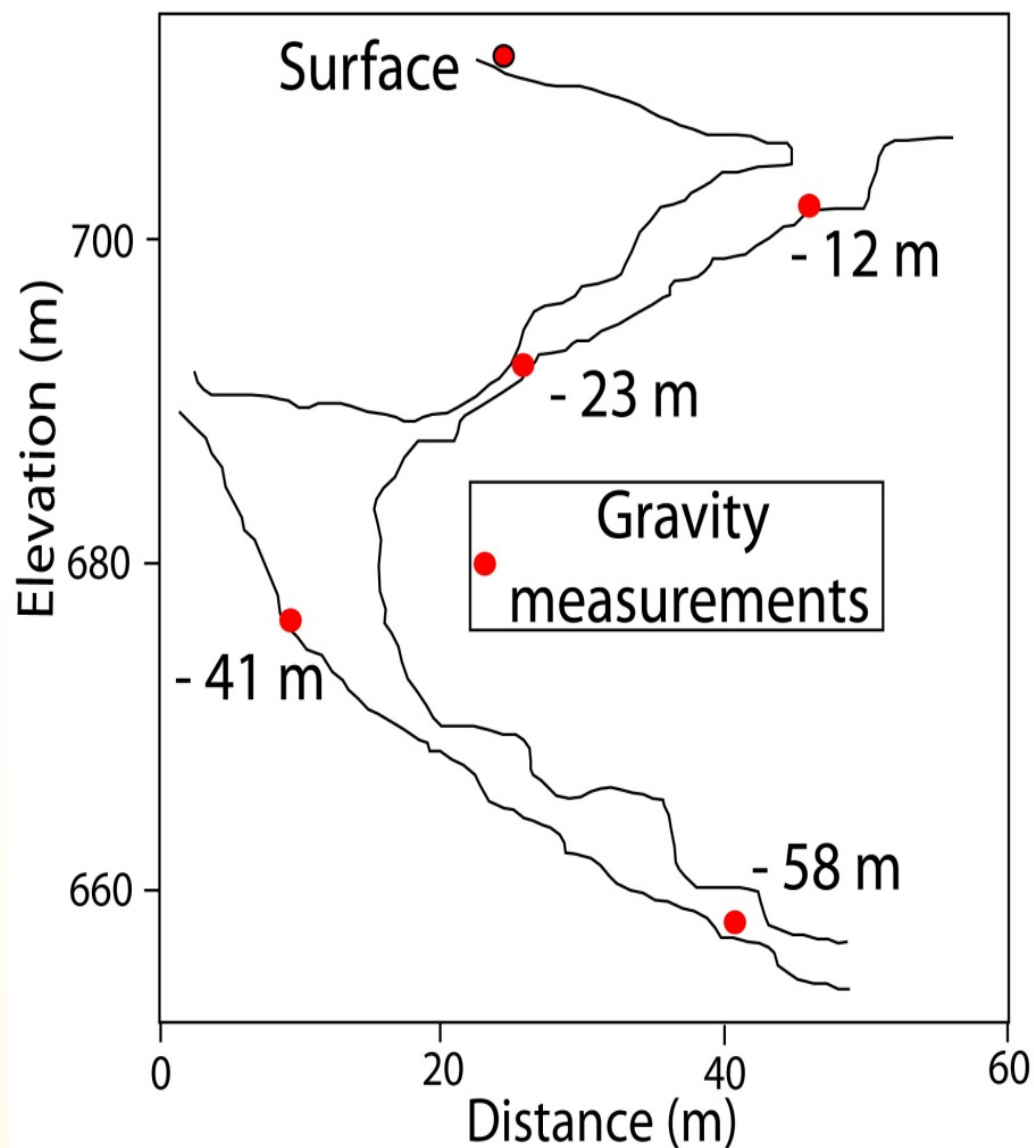


# Integration of gravity data in simple physical models (Richards / Van Genuchten / Hydrus 1D)



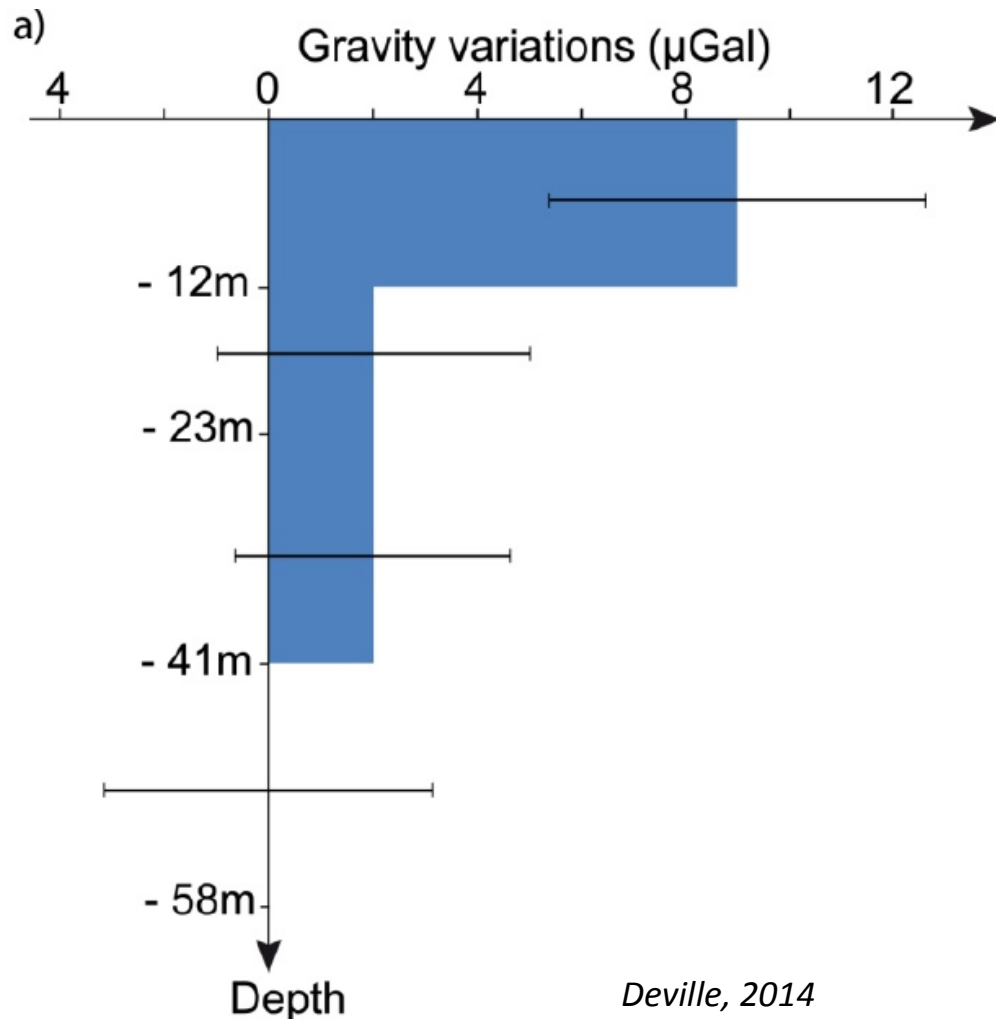
→ Low impact of gravity data alone

# Inside the karst

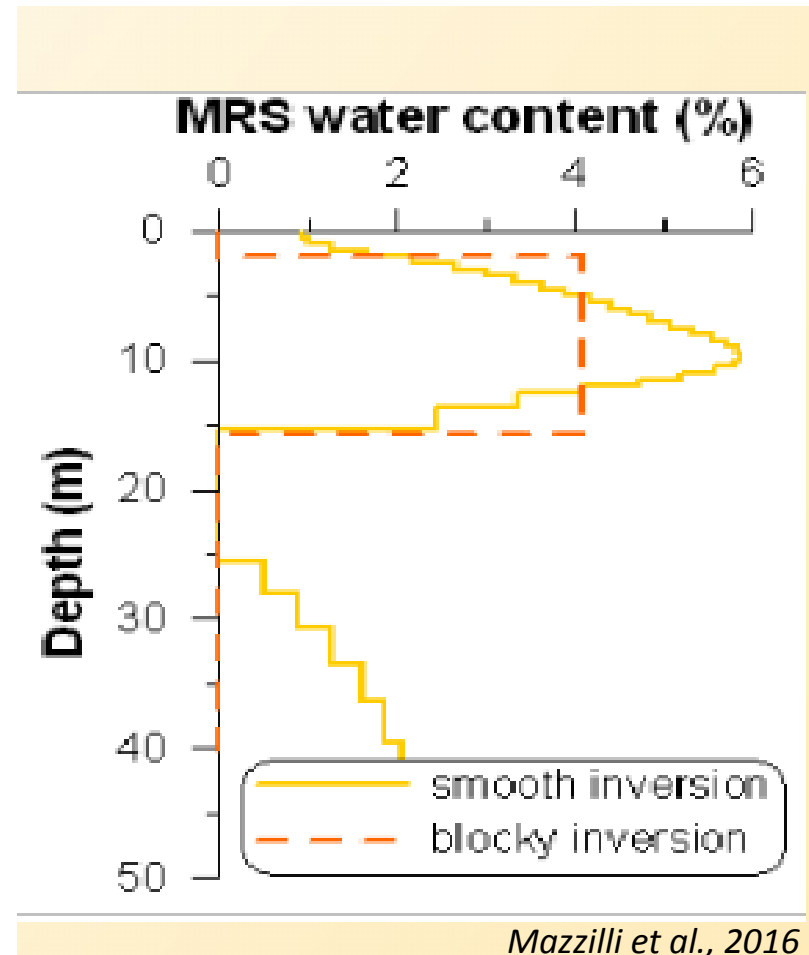


*Deville, 2014*

# Surface to depth gravity



*Deville, 2014*



*Figure 6.5 : S2D gravity difference function of in 2010; b) and discharge period in 2011.*



# Observatory site overview

