

Groundwater monitoring in a karst system using geodetic techniques

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Overview

- Karst systems and water storage changes
- Why use hydro-geodesy?
- The Durzon karst system
- Gravity changes and water storage changes
 - absolute measurements
 - relative measurements
- Tilt deformation and water storage
- Conclusions and perspectives

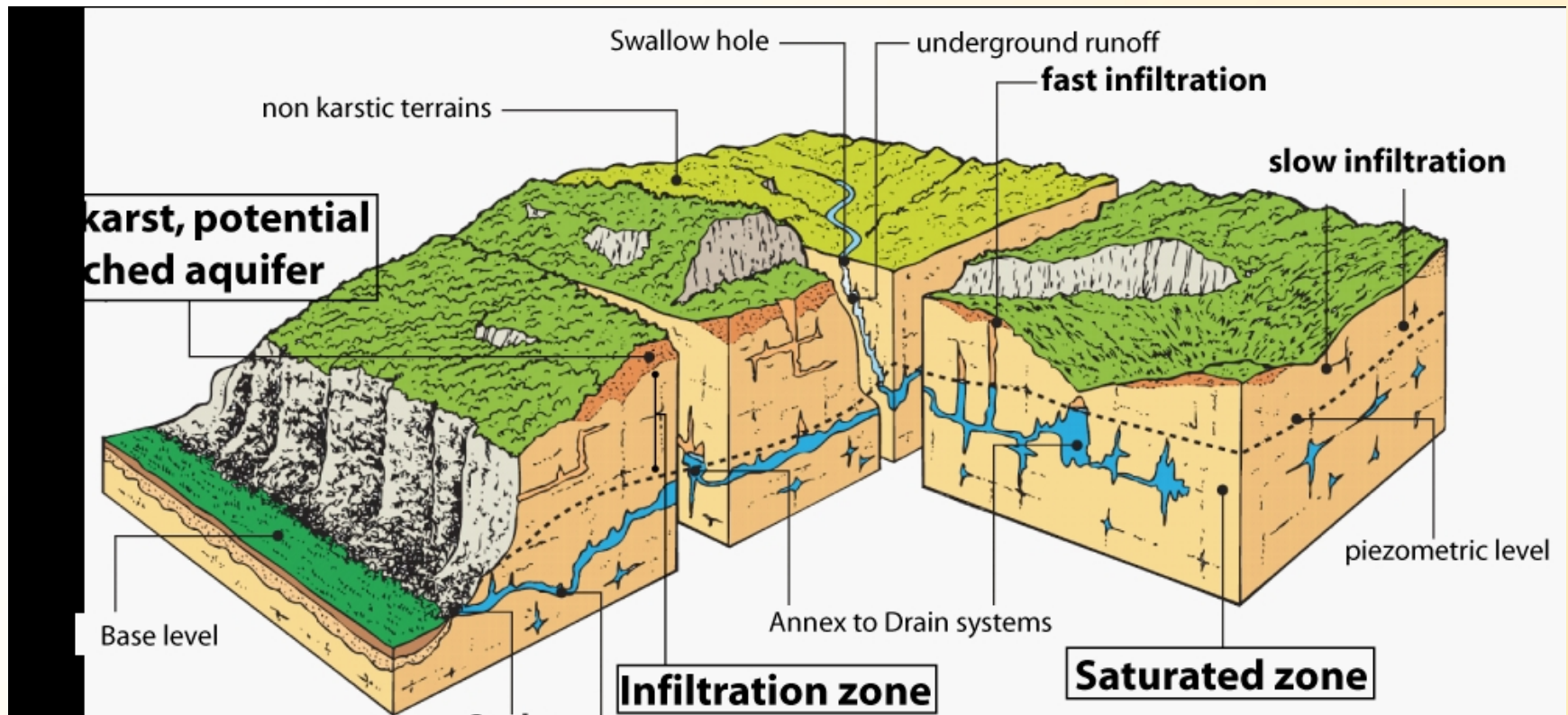
Karst systems

Karstification:

- hydraulic gradient
- Dissolution

→ Flow organisation

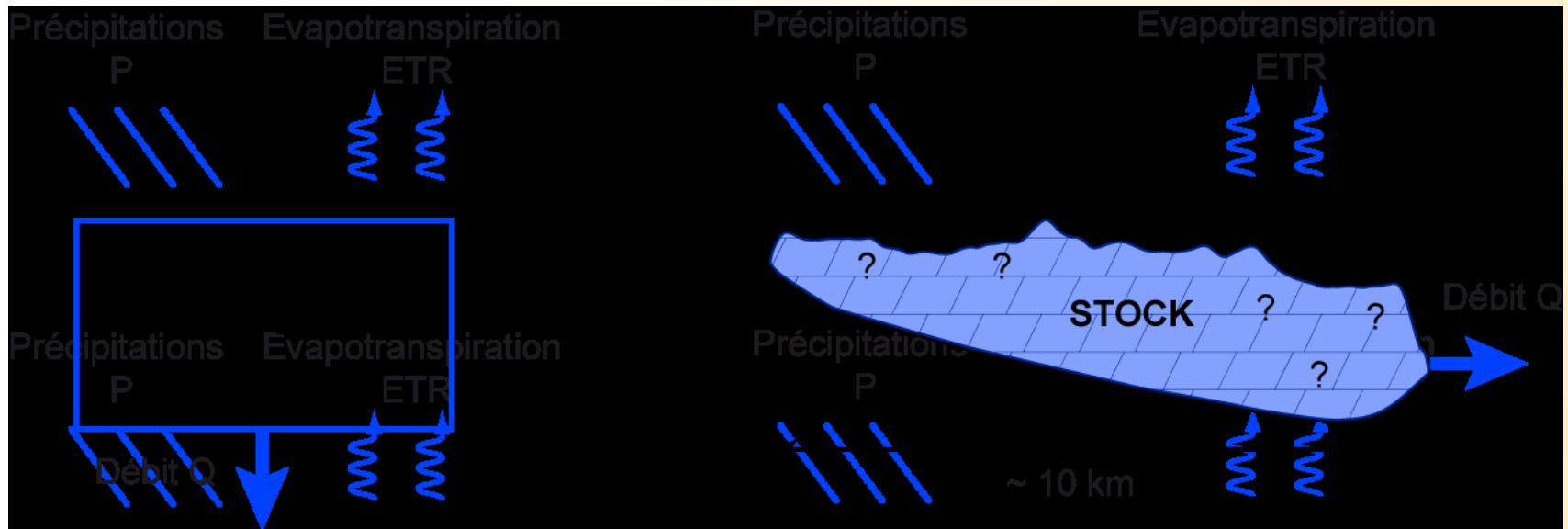
→ little surface flow



Where do water storage changes occur?

How does the transfer take place?

Advantages of hydro-geodesy



Rainfall-Runoff models → flux data: P, Q.

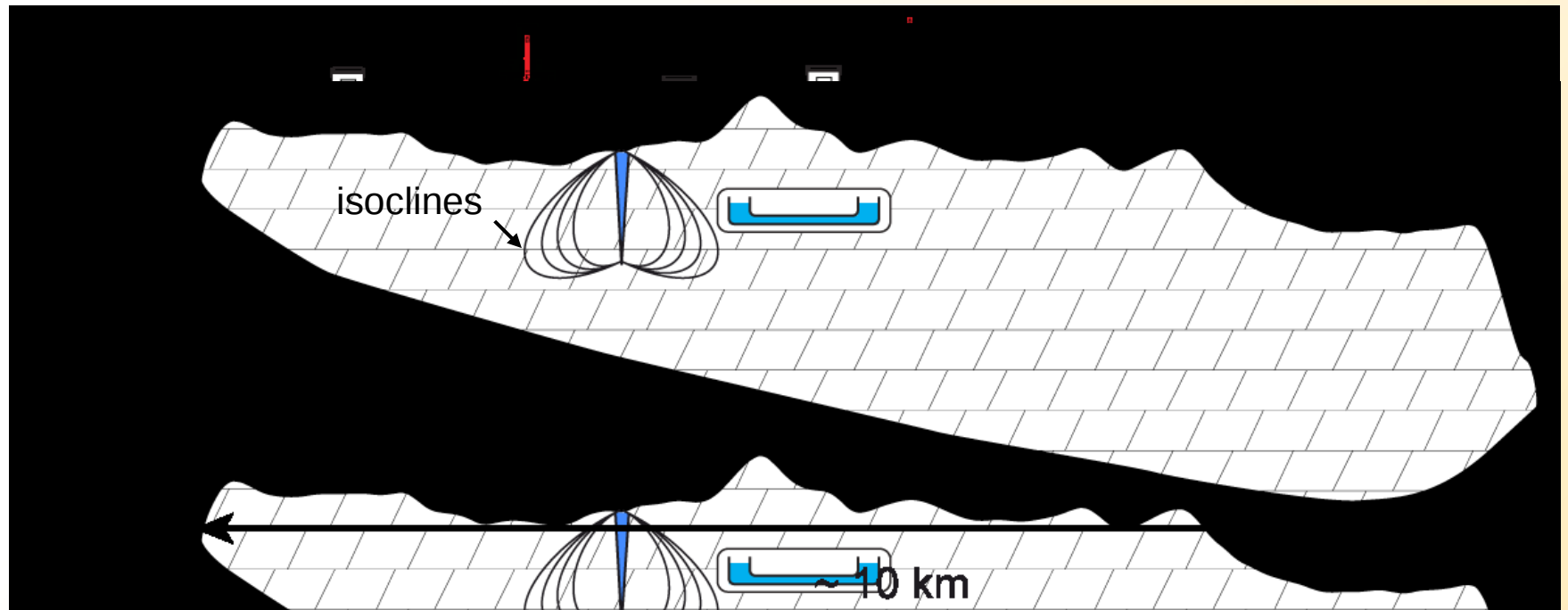
RET unconstrained → storage changes unconstrained

Storage can not be spatialized

Gravimetry → 'direct' measurement of storage changes

Tilt → 'indirect' measurement of storage changes

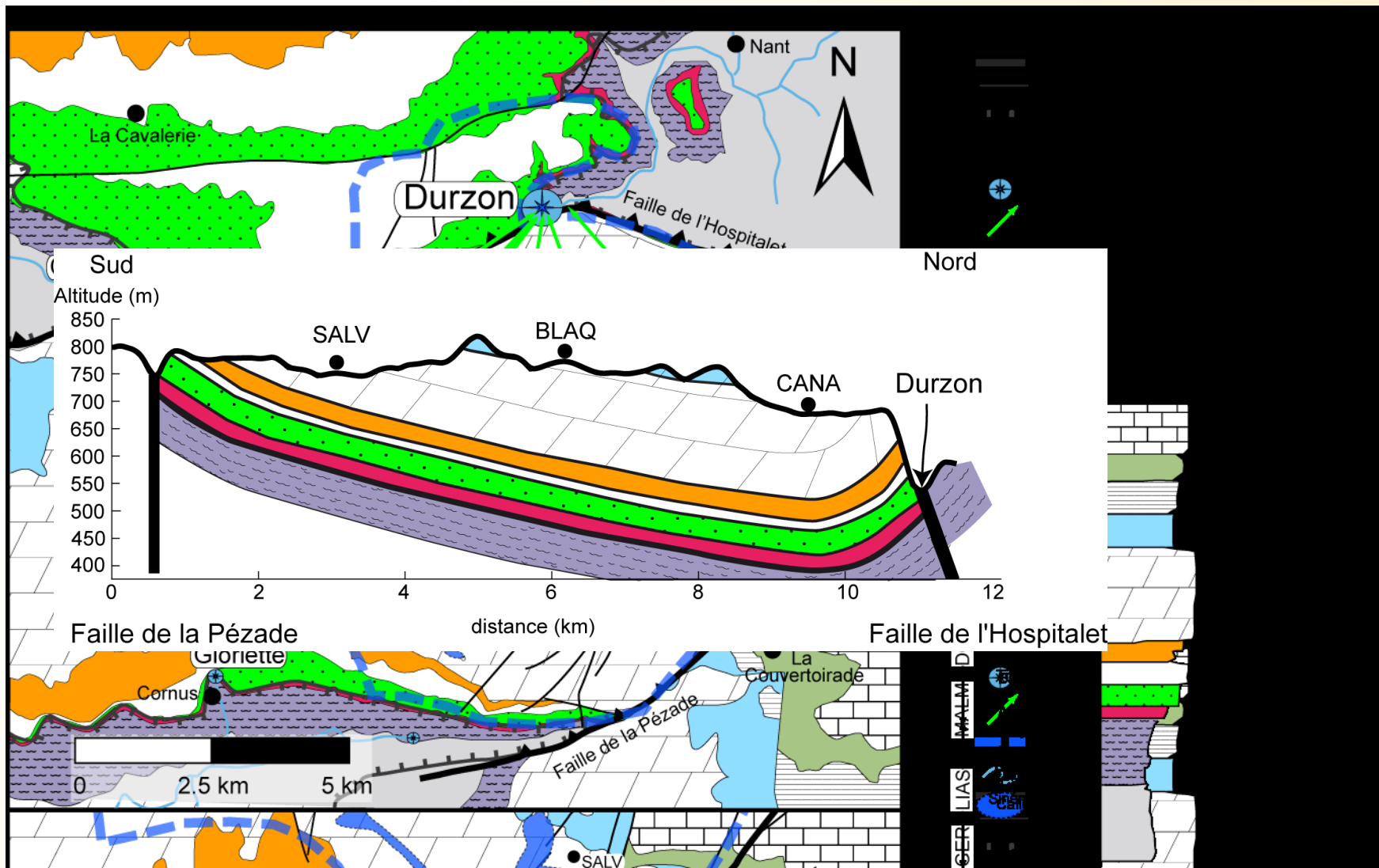
Investigation methodology

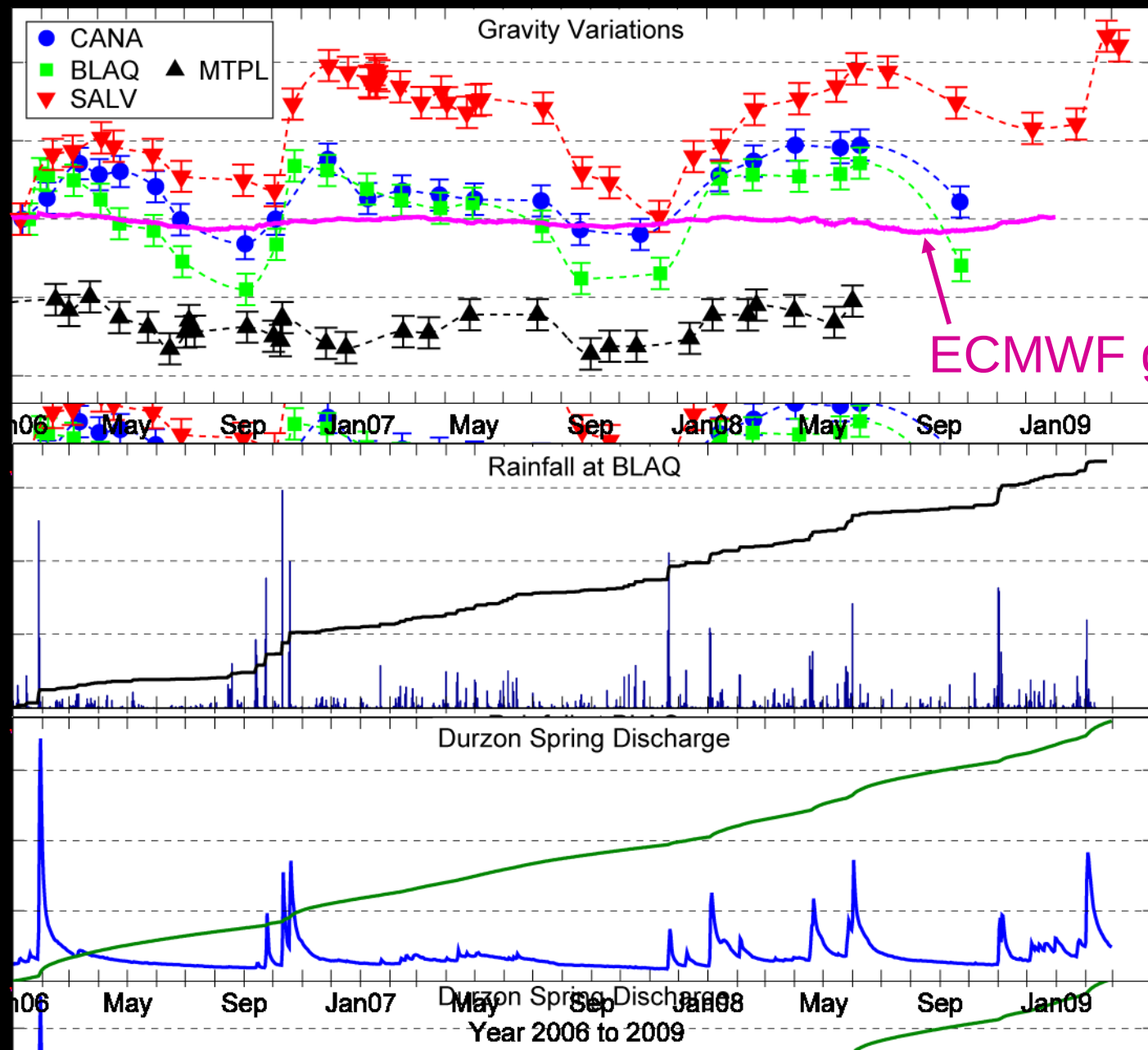


Gravimetry: - absolute | Time lapse measurements
- relative

Tilt: continuous measurements

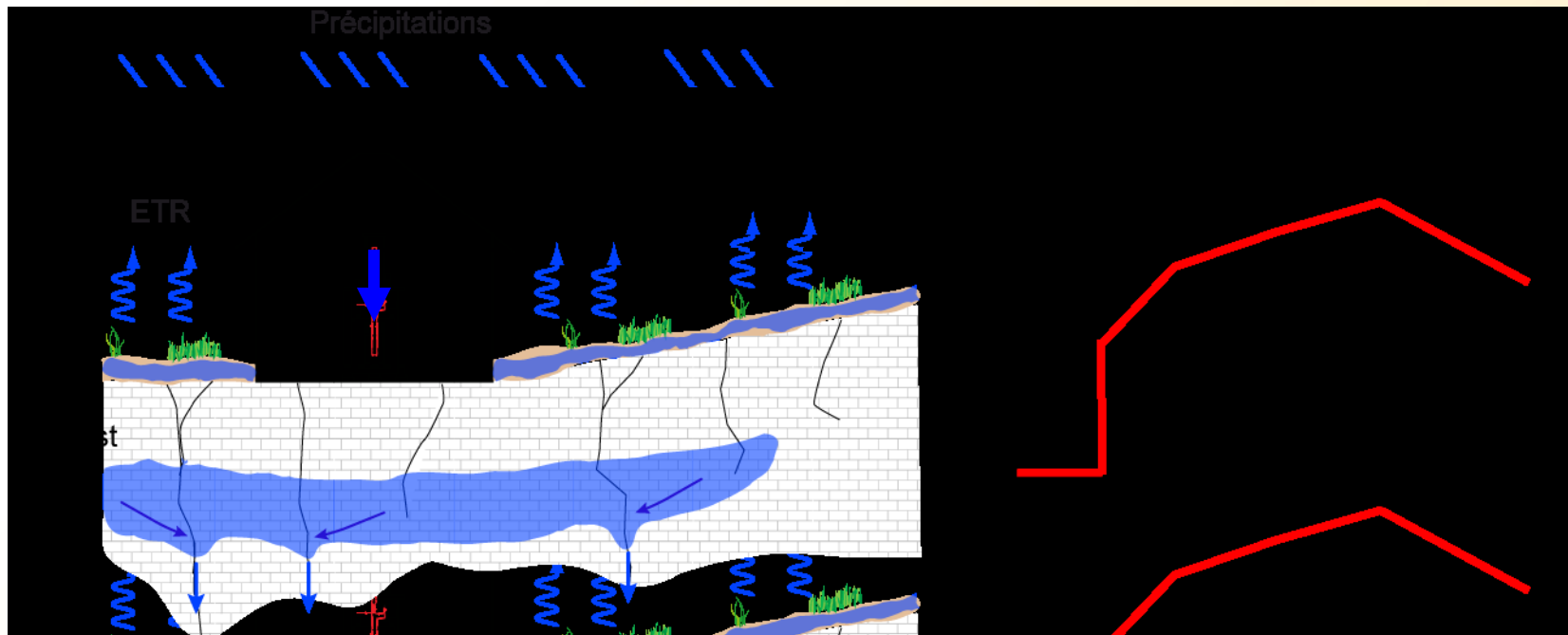
The Durzon Karst





Gravity changes in the field

At a given site:

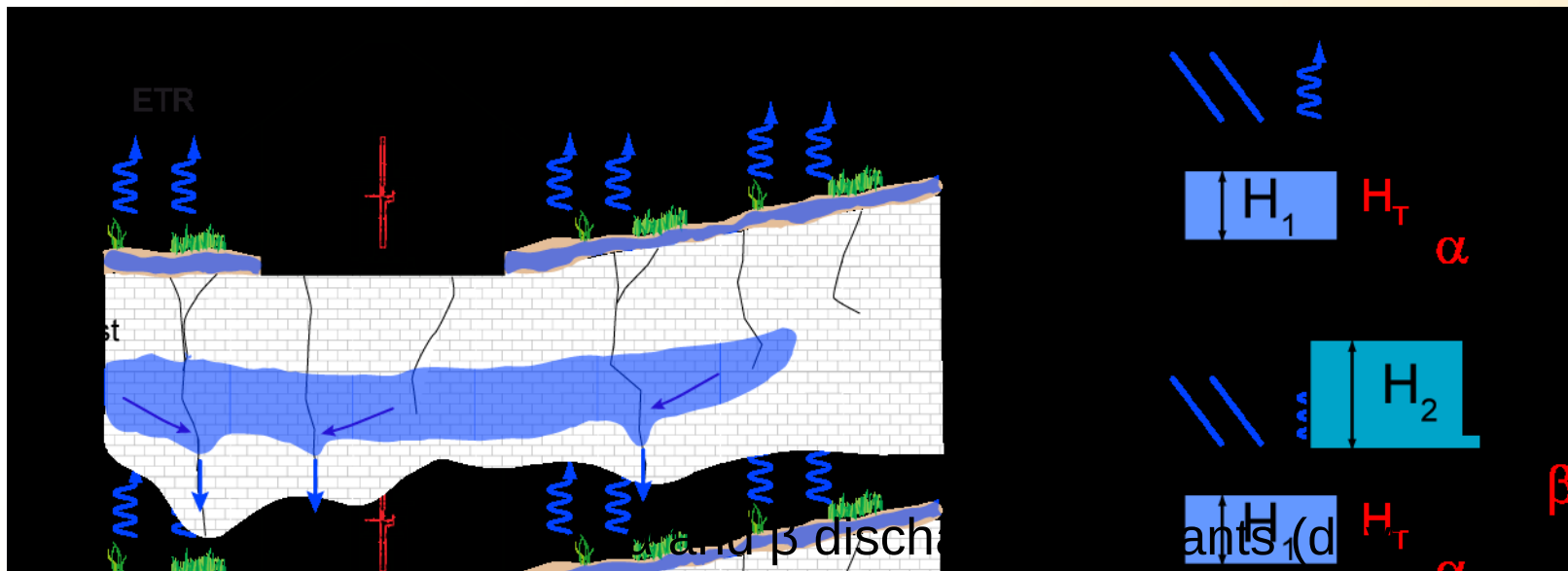


Slab hypothesis is invalid:

→ building 'mask'

→ topography

Reservoir modeling: a simplification



H_T = threshold (mm)

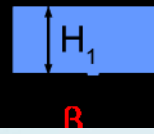
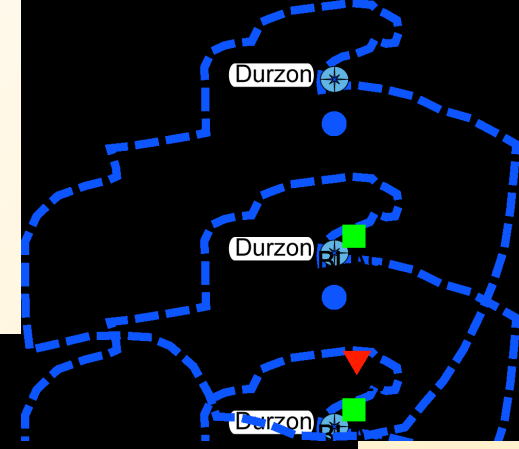
$$g_{model} = X_1 \cdot \gamma_{\sigma\alpha\beta}(H_1) + X_2 \cdot \gamma_{\sigma\alpha\beta}(H_2)$$

-If slab hypothesis valid $\rightarrow C_1=1$ and $C_2=1$
otherwise $C_1 < 1$ and $C_2 < 1$

Absolute time series \rightarrow used to fit growing complexity models

Results for BLAQ

Little 'mask' effect



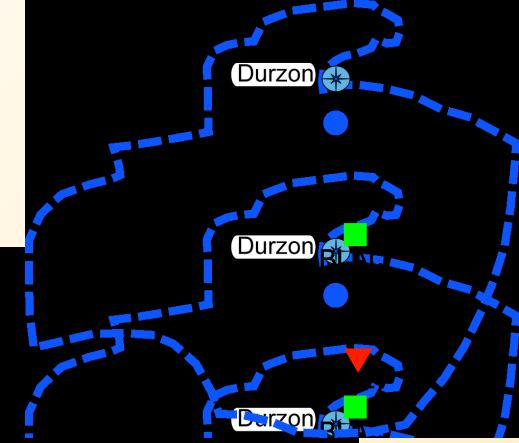
H_T
 α

$$\beta^{-1} = 217 \text{ j}$$

$$H_T = 430 \text{ mm}$$



Results for SALV



Strong
effect

$$H_1 \quad H_T \quad \alpha$$

$$H_2(t)$$

$$\alpha^{-1} = 29 \text{ j}$$

$$\beta^{-1} = 400 \text{ j}$$

$$H_T = 73 \text{ mm}$$

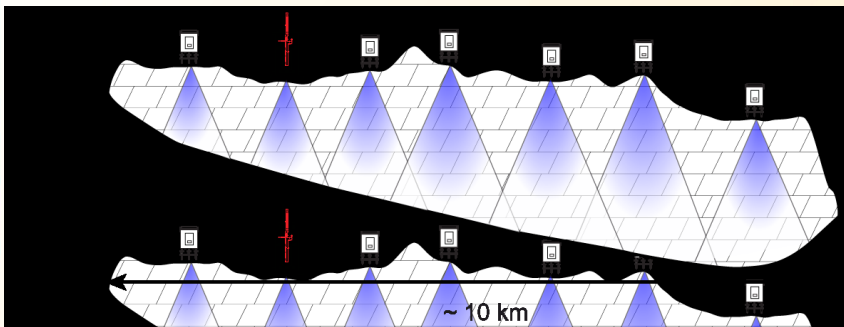
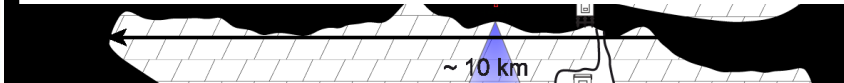
$$C = 0.41$$



Relative gravimetry (Scintrex CG5) and localization of water storage changes

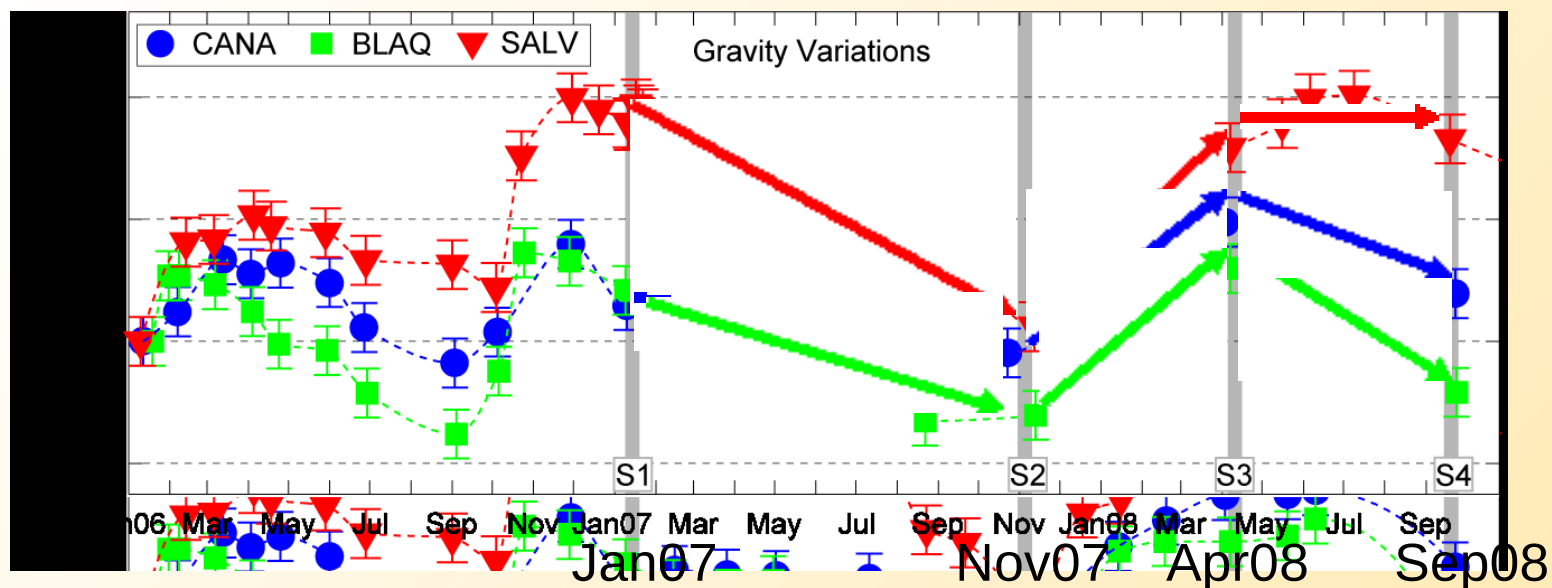
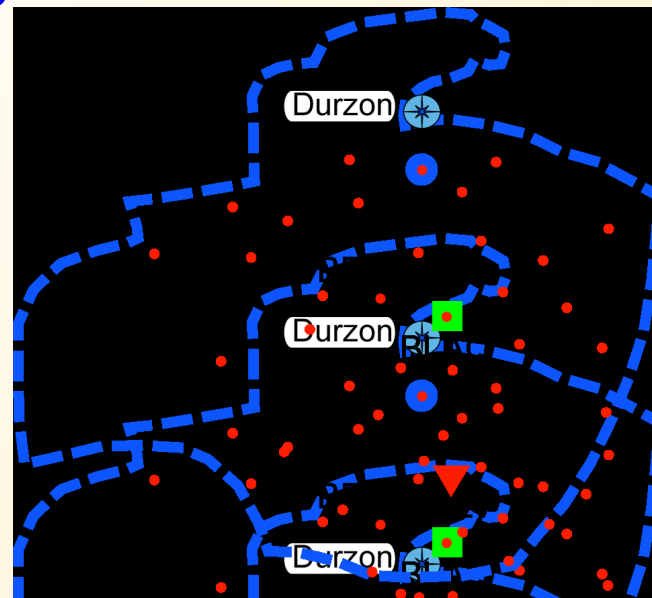


- Where do water storage changes occur?
- What happens on the rest on the recharge area?



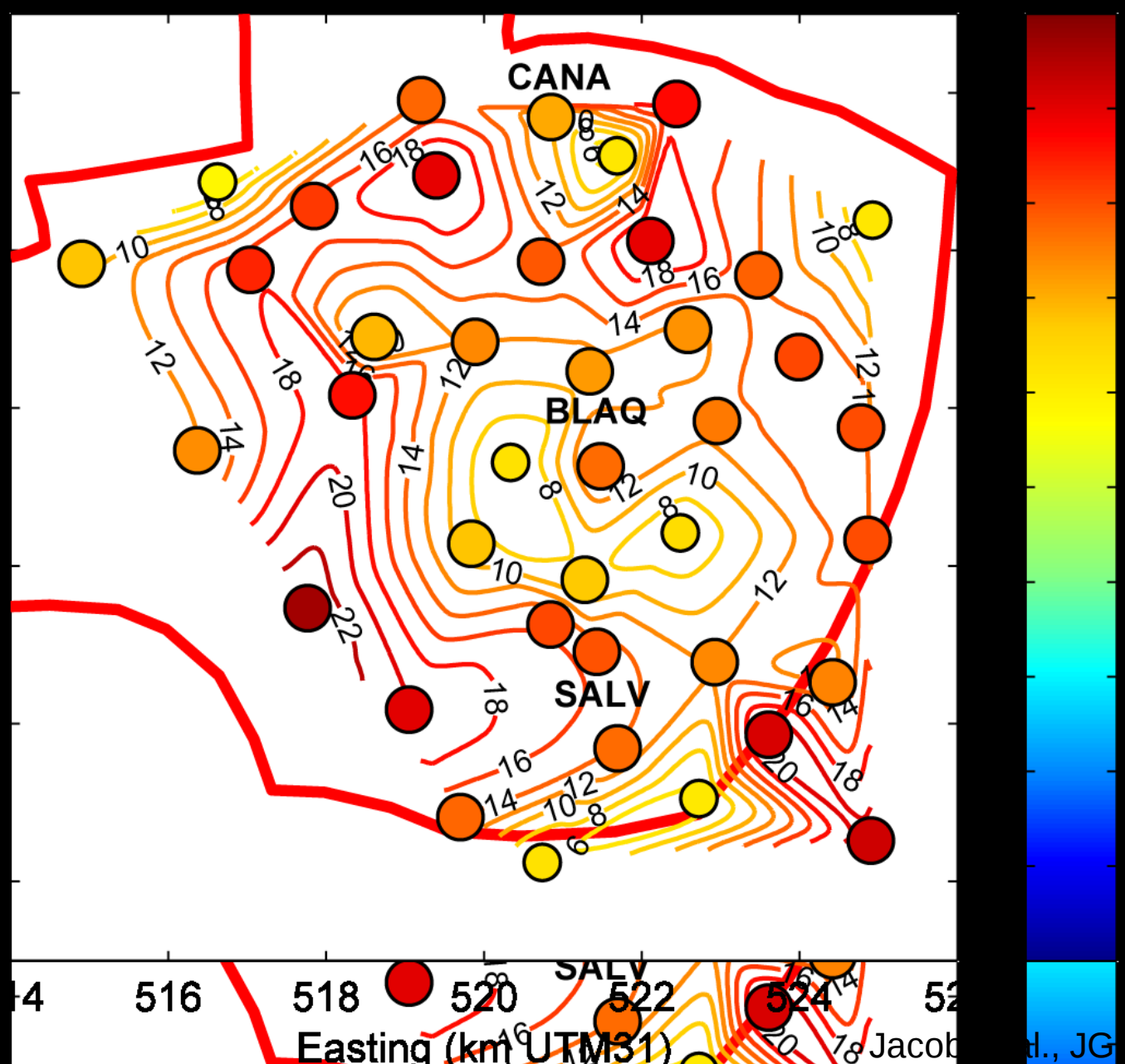
Microgravity surveying

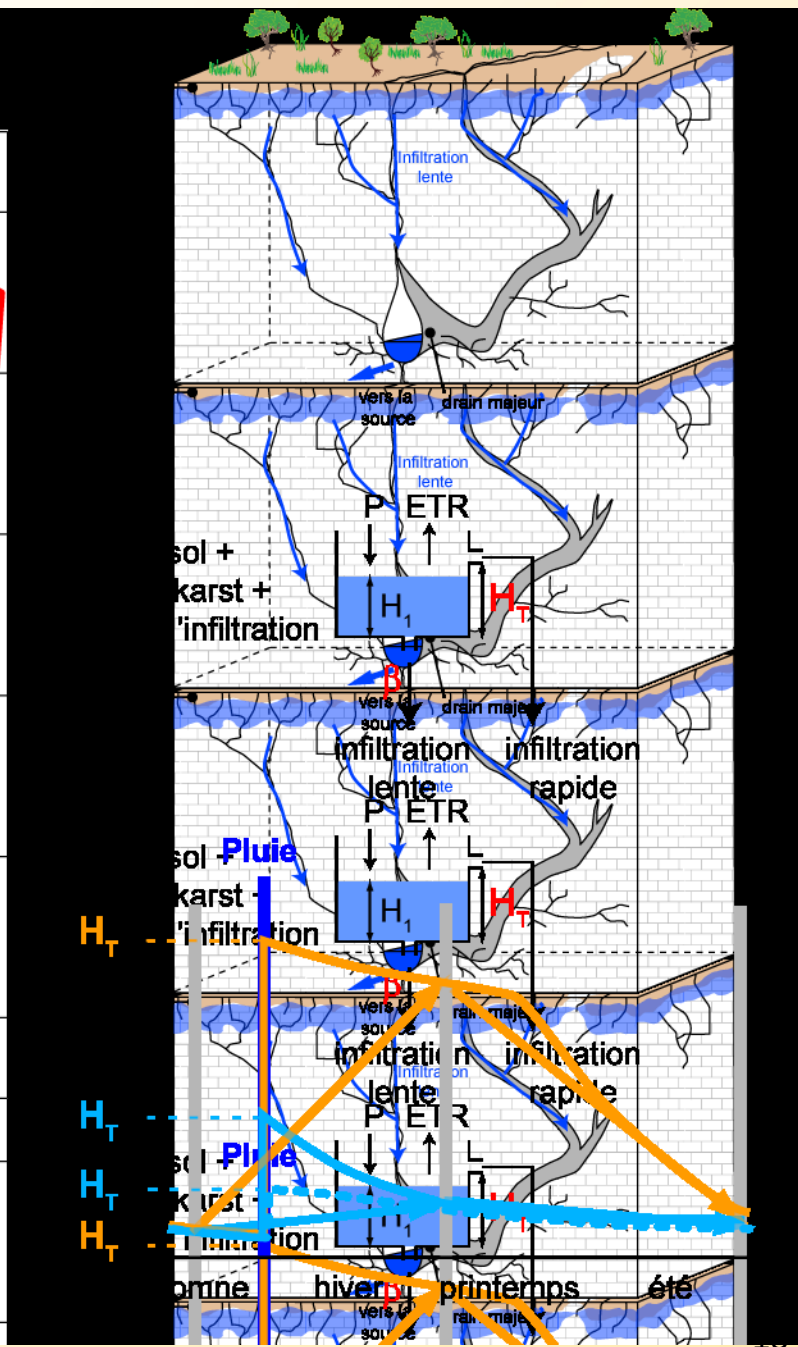
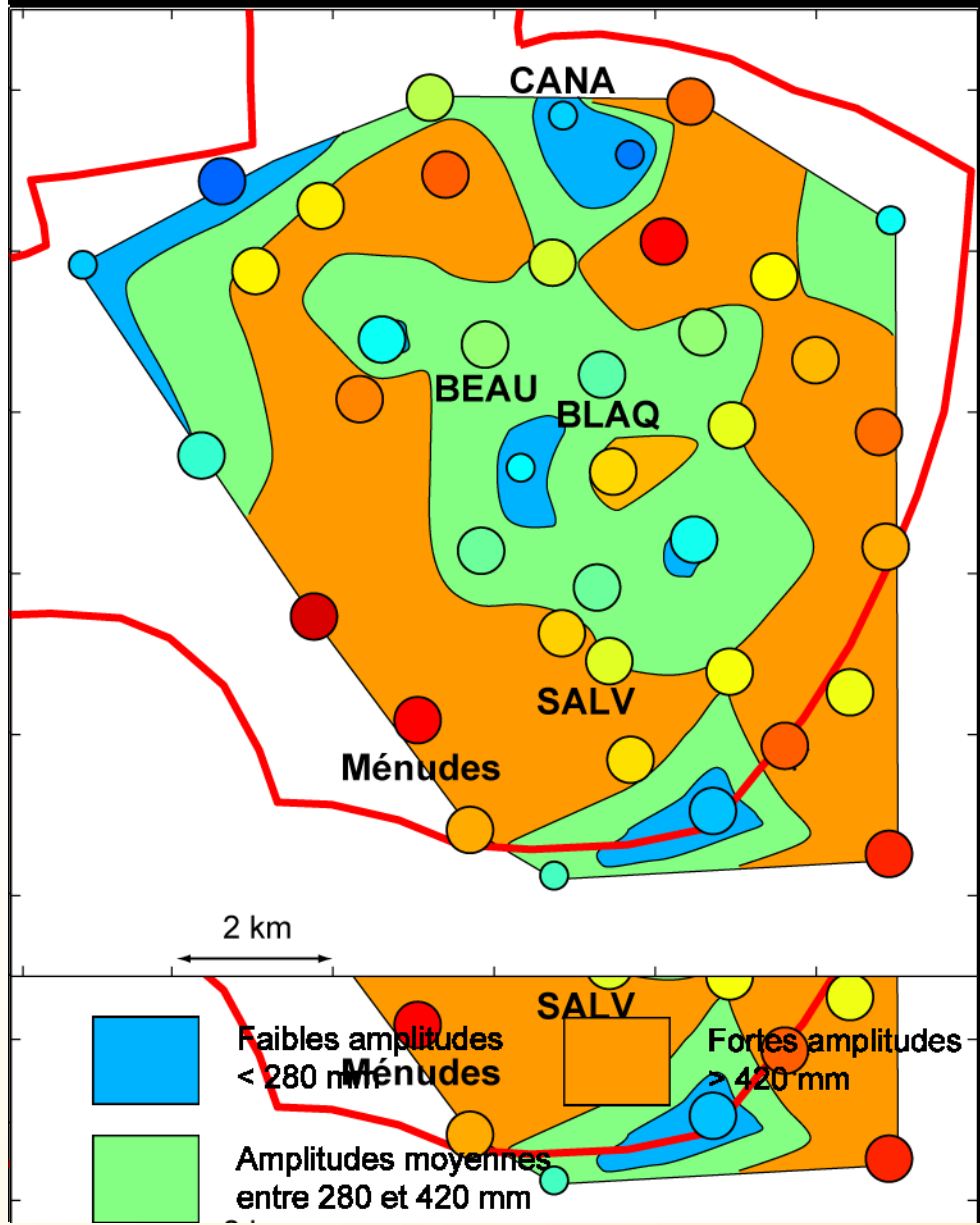
- 40 sites on the recharge area
- 4 surveys during wet and dry periods

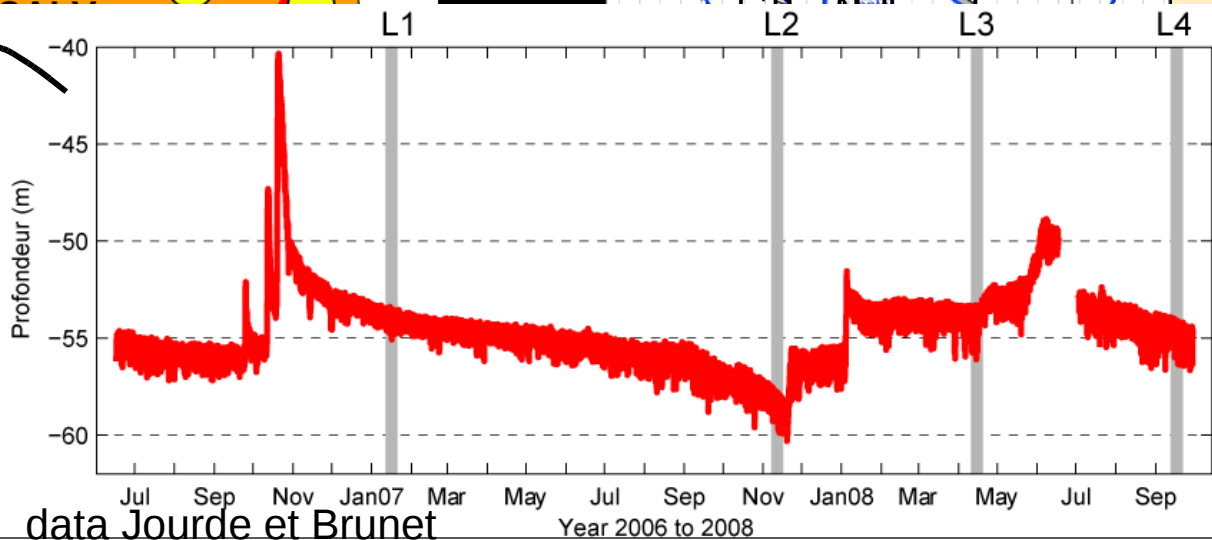
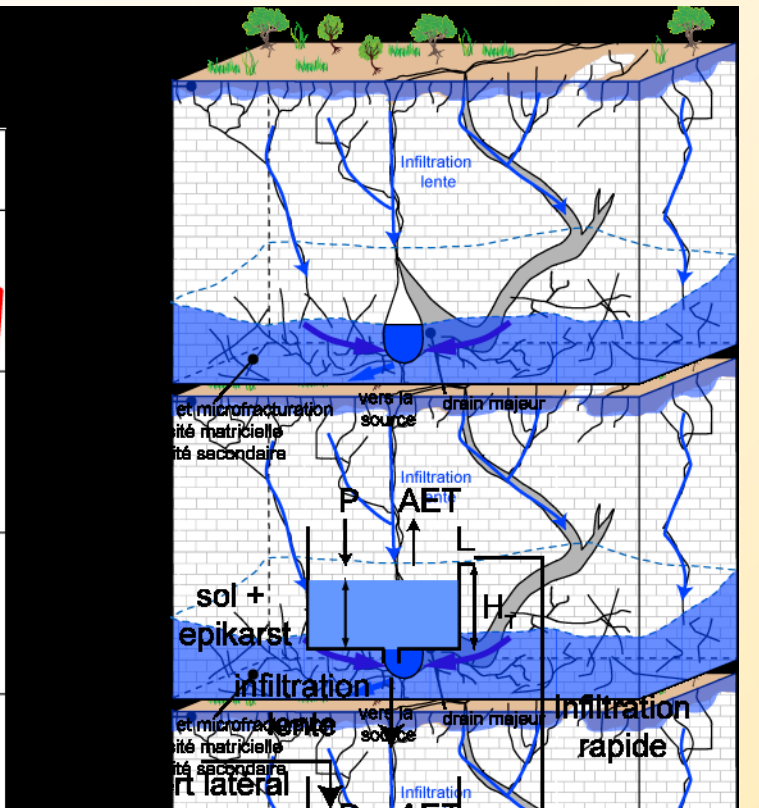
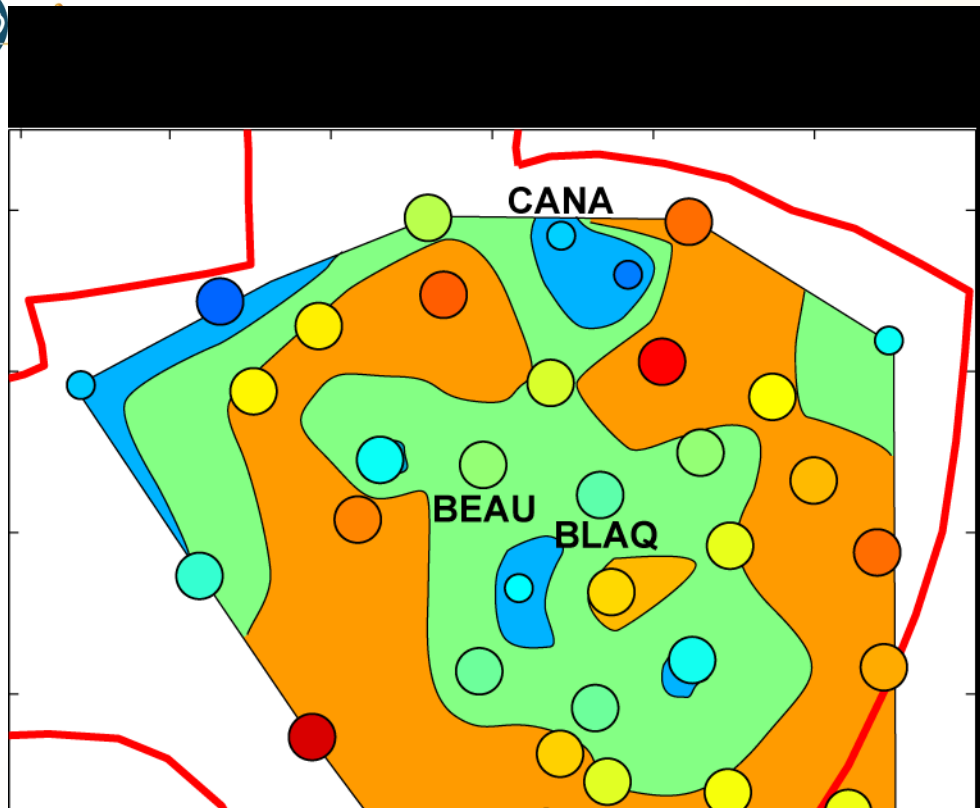


- Large scale storage changes between these periods

November 07 - April 08: recharge period

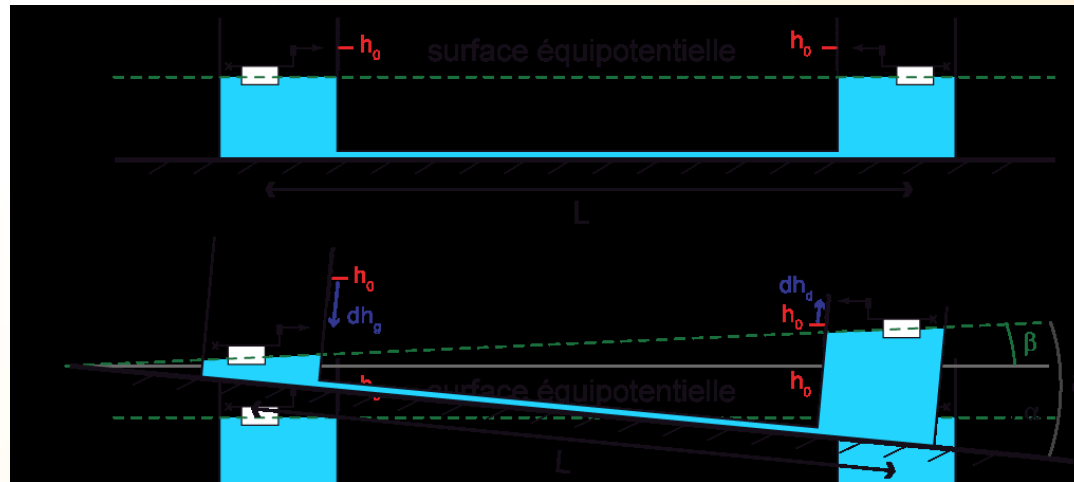






Long base tiltmeter monitoring

Principle:

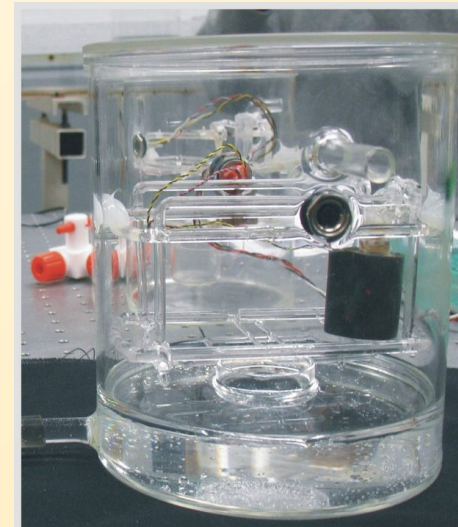


Water storage
change

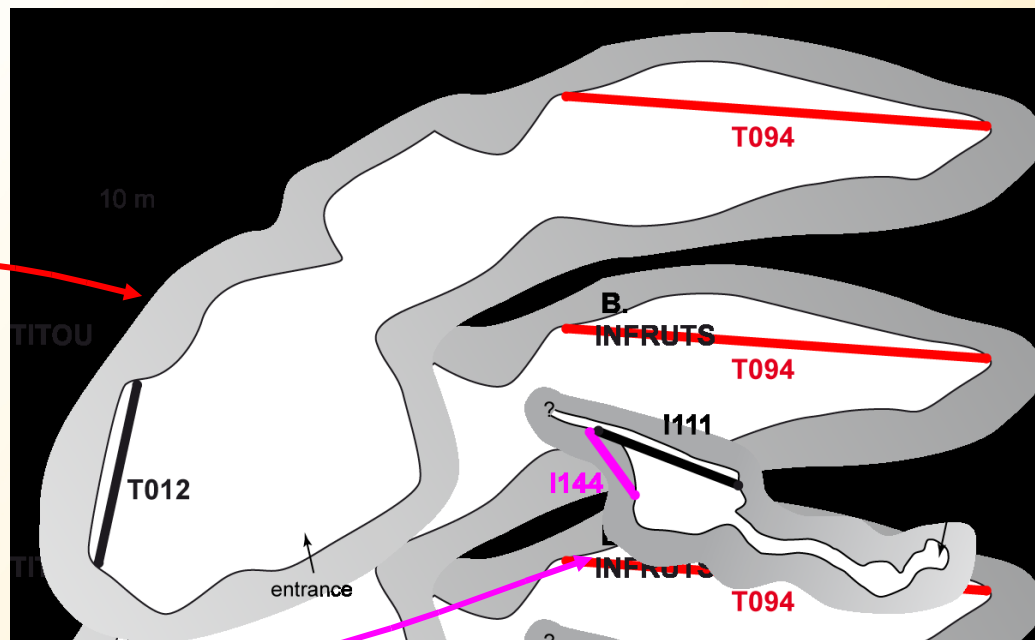
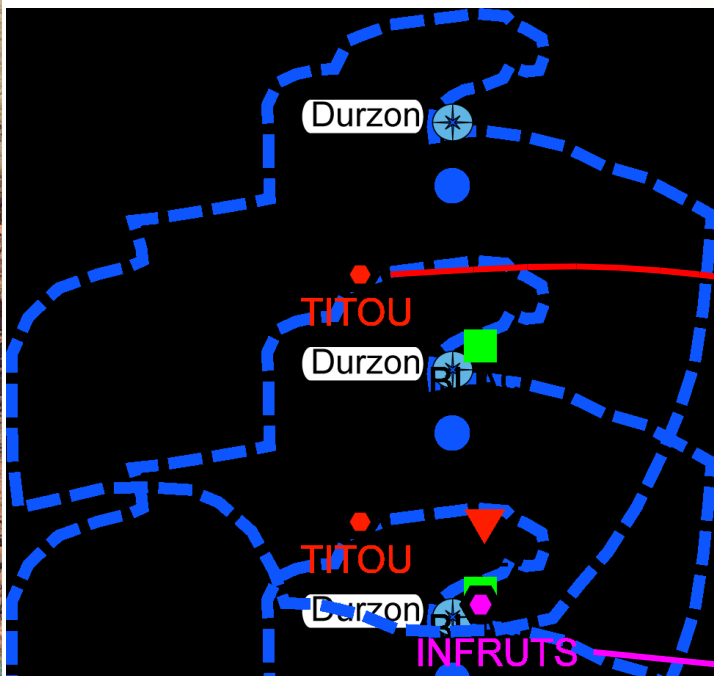
Strain

Equipotential surface

- stability better than 10^{-8} rad per month
- continuous measurement
- base from 5 to 100 m

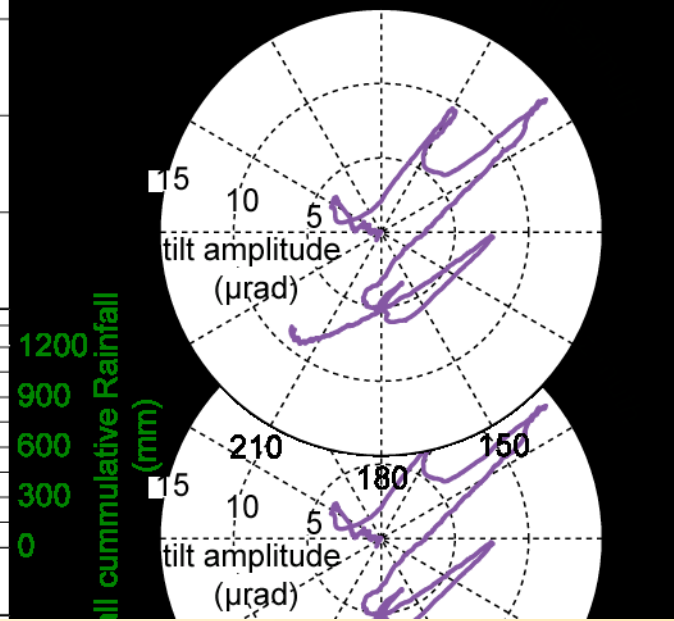
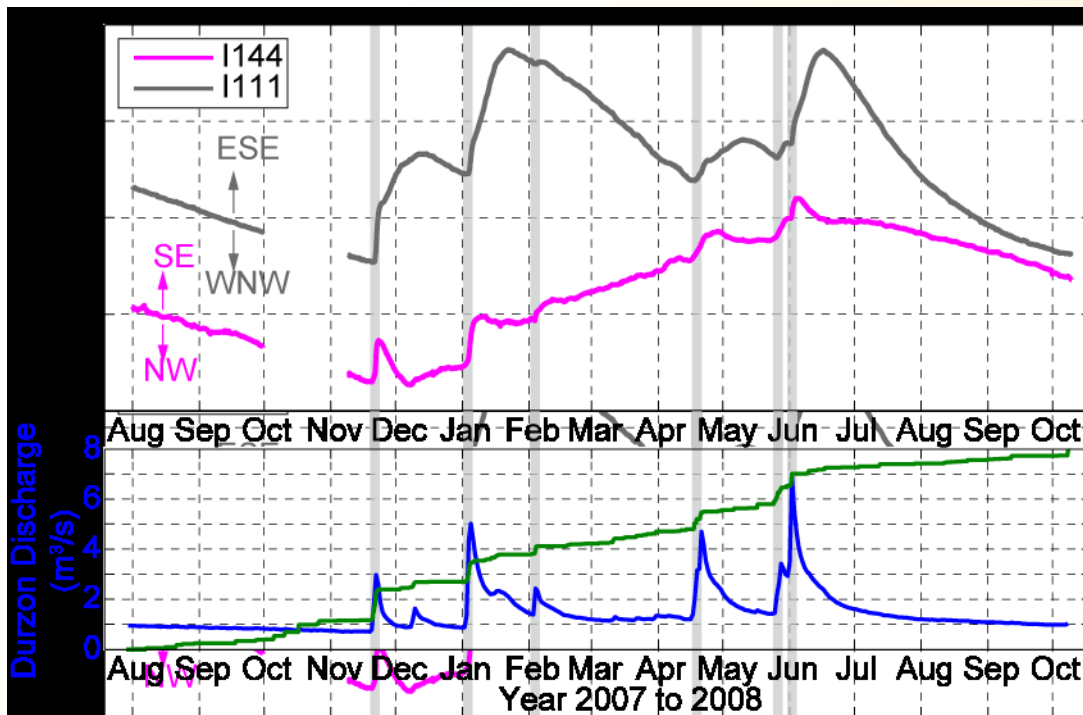
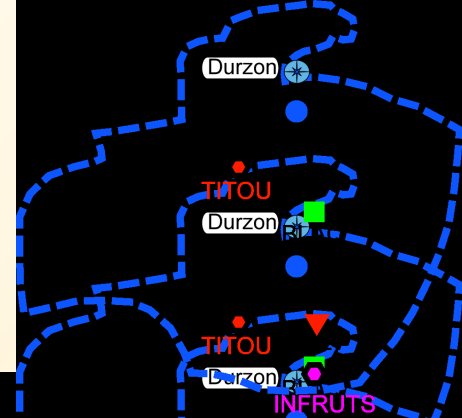


Sites and installations



<i>Site</i>	<i>depth (m)</i>	<i>azimuth (°)</i>	<i>length (m)</i>	<i>name</i>
TITOU	- 50	12	10.8	T012
		94	24.9	T094
INFRUTS	- 16	111	8.9	I111
		144	4.7	I144

Infruts sites

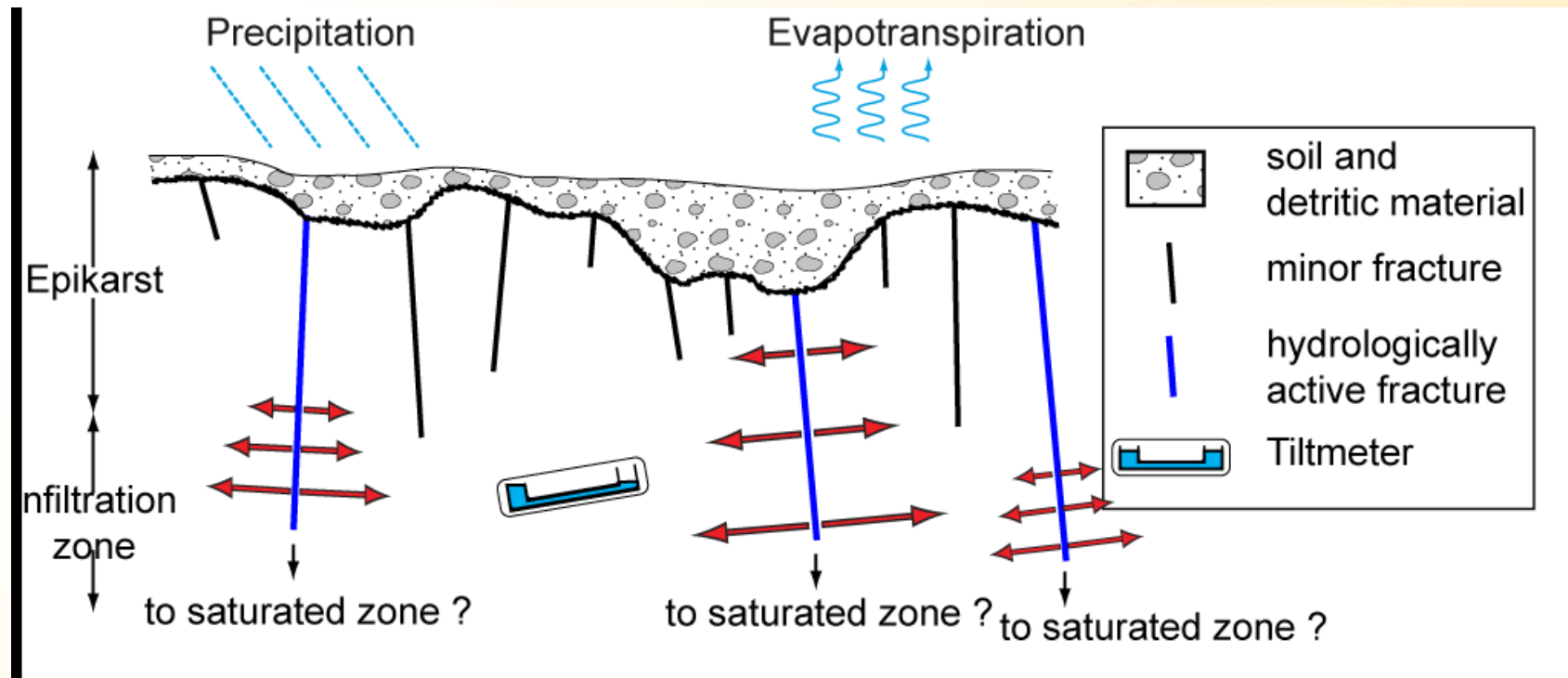


Jacob et al., WRR, 2010

~ 1-10 μrad response, several time responses

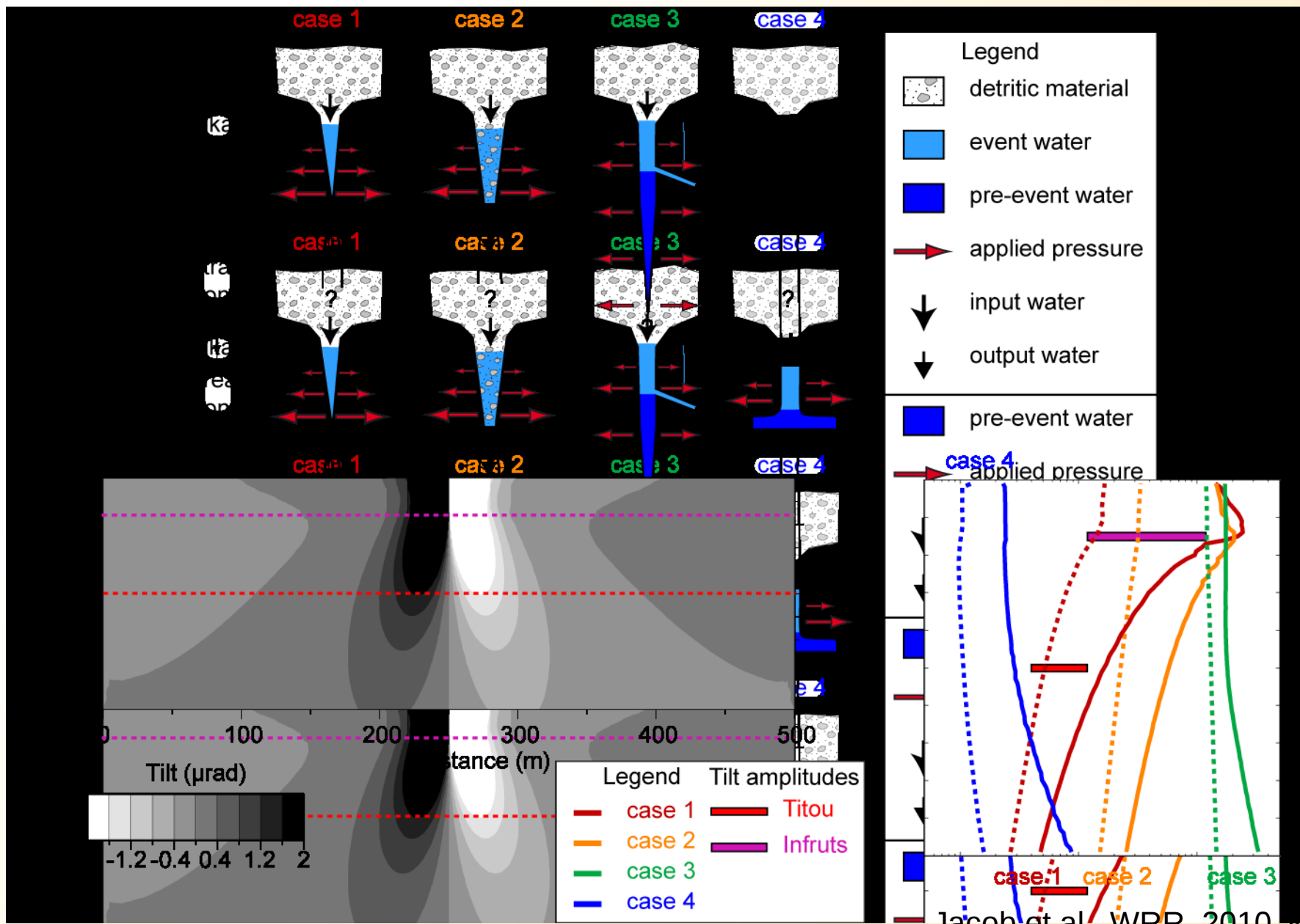
Lag between maximum discharge and maximum tilt

Which mechanism is responsible for tilt ?

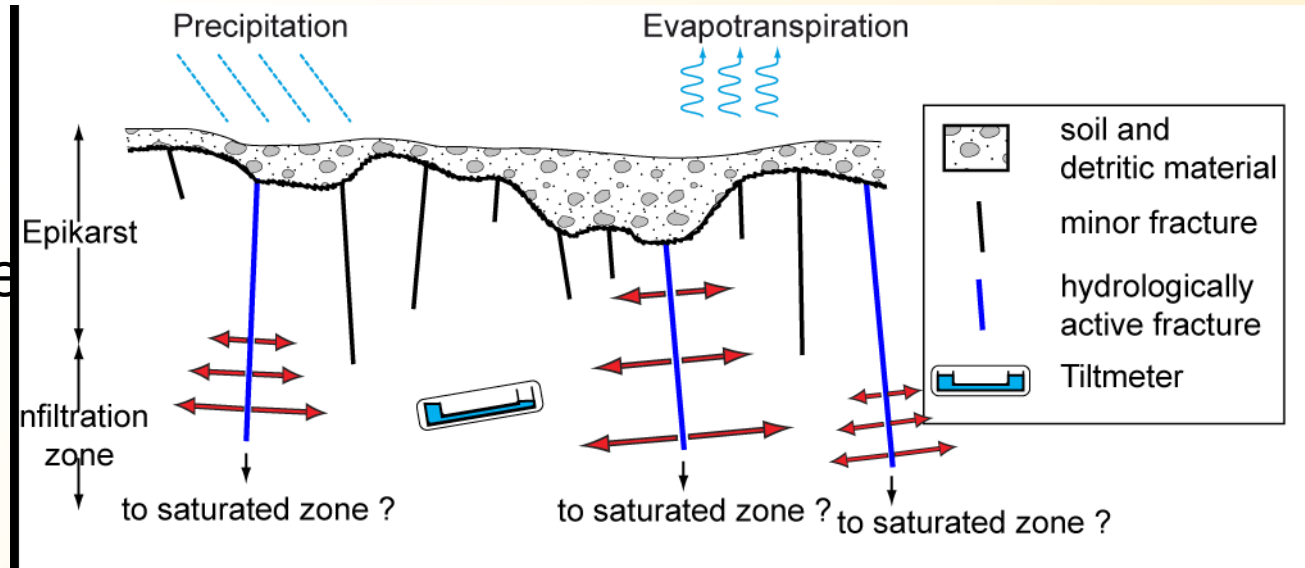


→ Elastic medium

Fracture pressure loading



Plausible situation:
more than one fracture

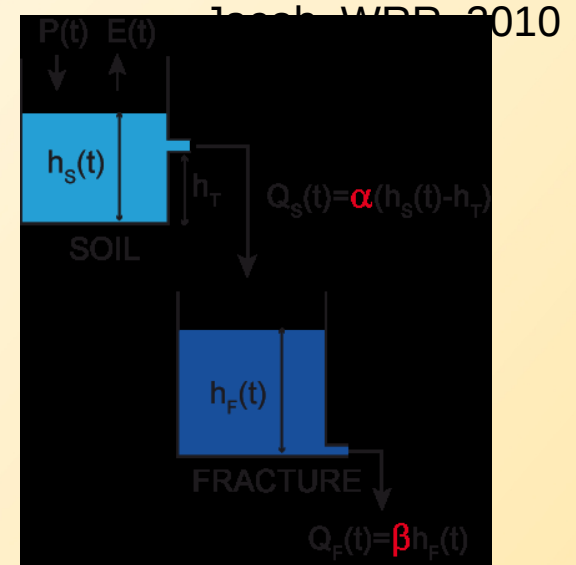


For a single fracture:
elementary model

$$\text{Tilt} = K h_F^n$$

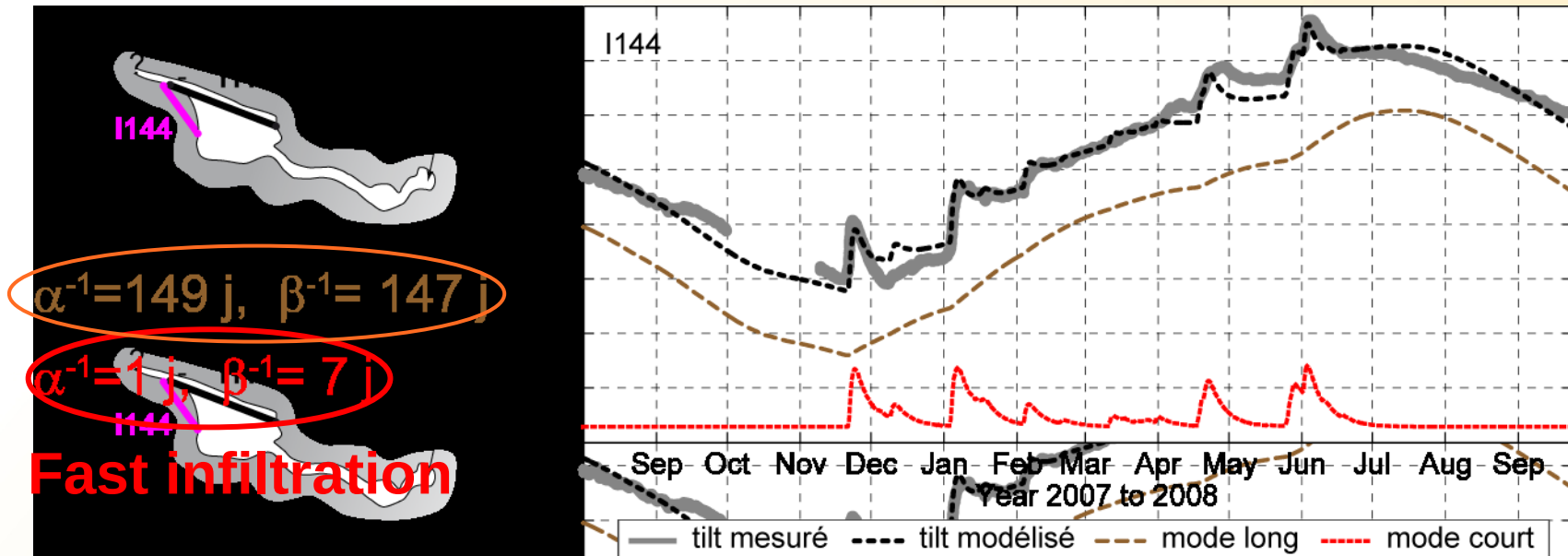
$$\text{Tilt} = \sum_{i=1}^N K_i h_{Fi}^n$$

For N fractures:



→ N=2 suffices

Slow infiltration



Jacob, WRR, 2010

Simple reservoir modelling: → discharge constants



- **water storage changes** and its heterogeneity
- role of the **epikarst**
- Long term monitoring of ‘slow’ phenomena

Tilt

- Plausibly fracture pressure influenced
- ‘Fast’ and ‘slow’ phenomena

The Future: iGrav SG

Observatoire de la Jasse

