

The water resource in mountainous environment.

How the combination of multiple CRITEX instruments allow to better understand and characterized this resource. The Strengbach watershed case (Vosges Mountain).



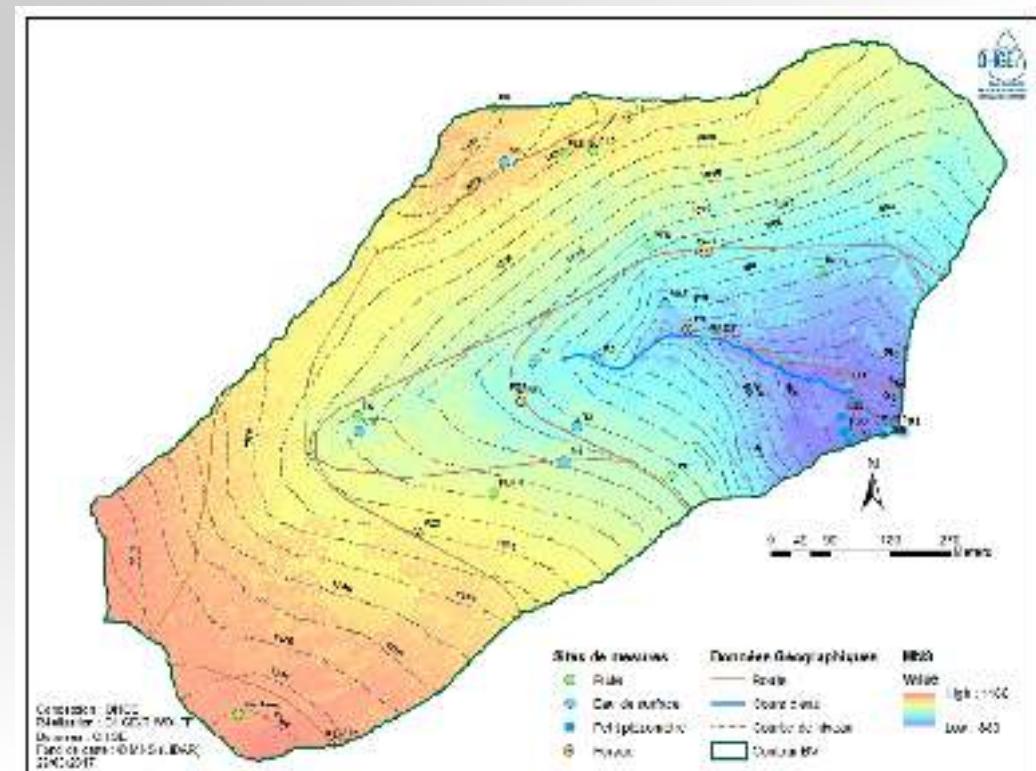
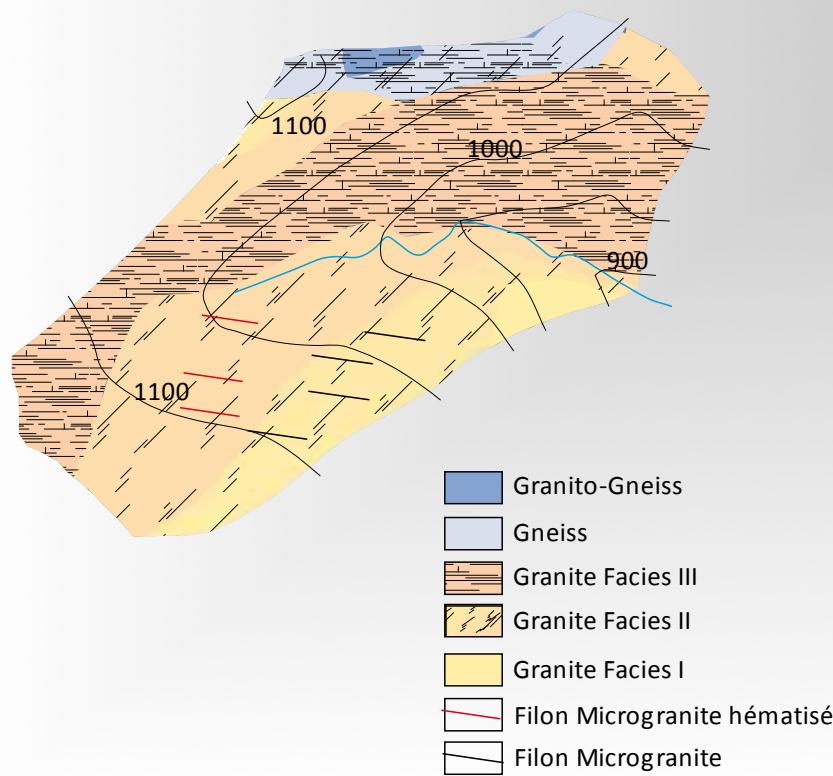
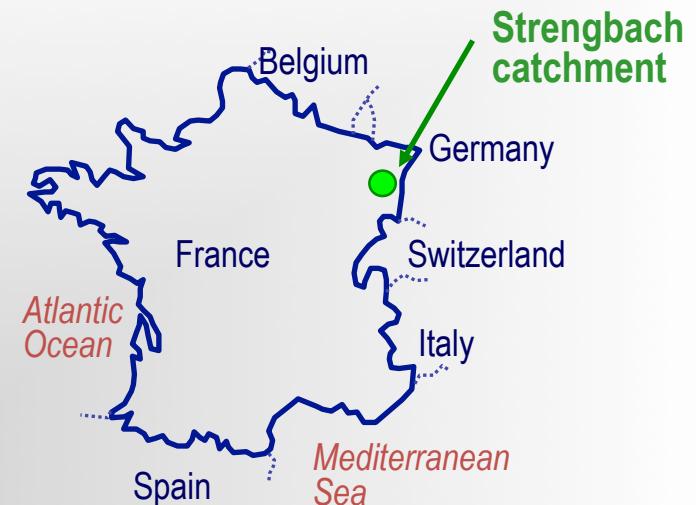
Observatoire Hydro-Géochimique de l'Environnement OHGE

Pierret M.C.¹, Bernard, J.D.², Cotel S.¹, Chabaux, Gance, J.⁴, Girard J.F.², Henry G.⁵, Hinderer J.², Lajaunie M.², Larnier H.², Legtchenko A.⁶, Malet J.P.², Masson F.², Pezard P.⁵, Sailhac P.³, Viville D.¹, Gangloff S.¹

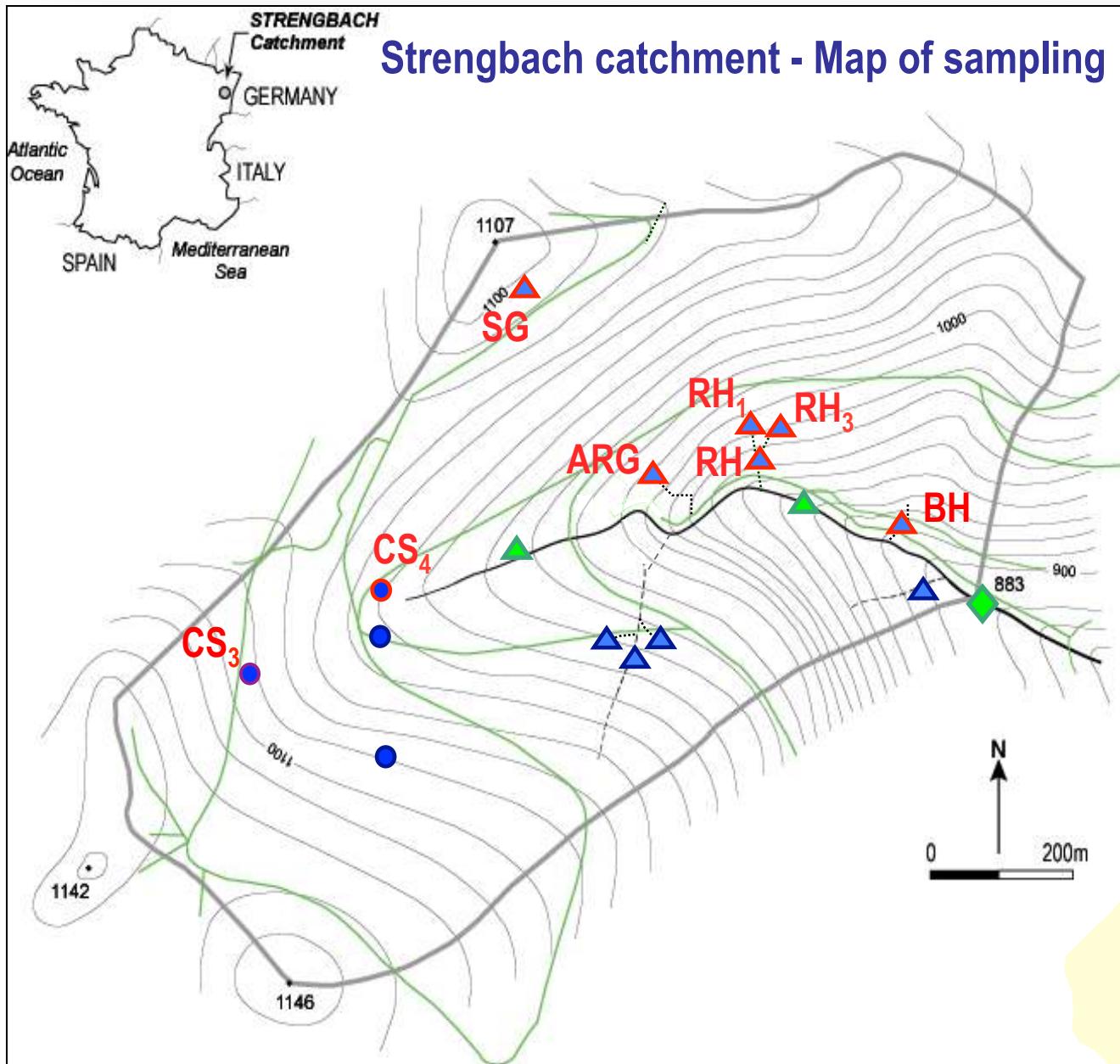


- Vosges Massif (880-1150 m) - 80 ha
- Hercynian base poor granite
- **Monitored since 1986**
- 90 % forest : beeches (20%) + spruces (80%)
- Discharge : 3-500 l/s
- Rainfall : 1400 mm /yr
- Runoff : 800 mm/yr – pH ≈ 6.5
- **S atmospheric input : 8 t → 0,8 t / yr**
- Weathering flux : 2-3 T km⁻¹yr⁻¹

characteristics



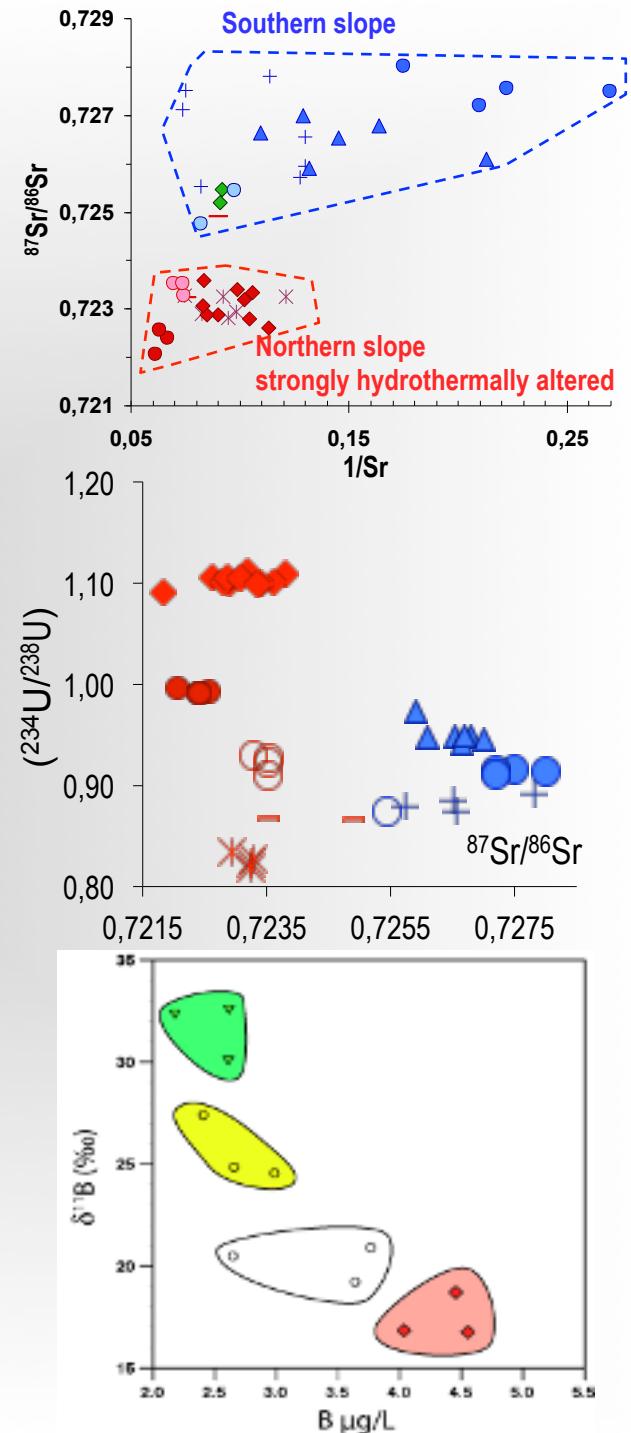
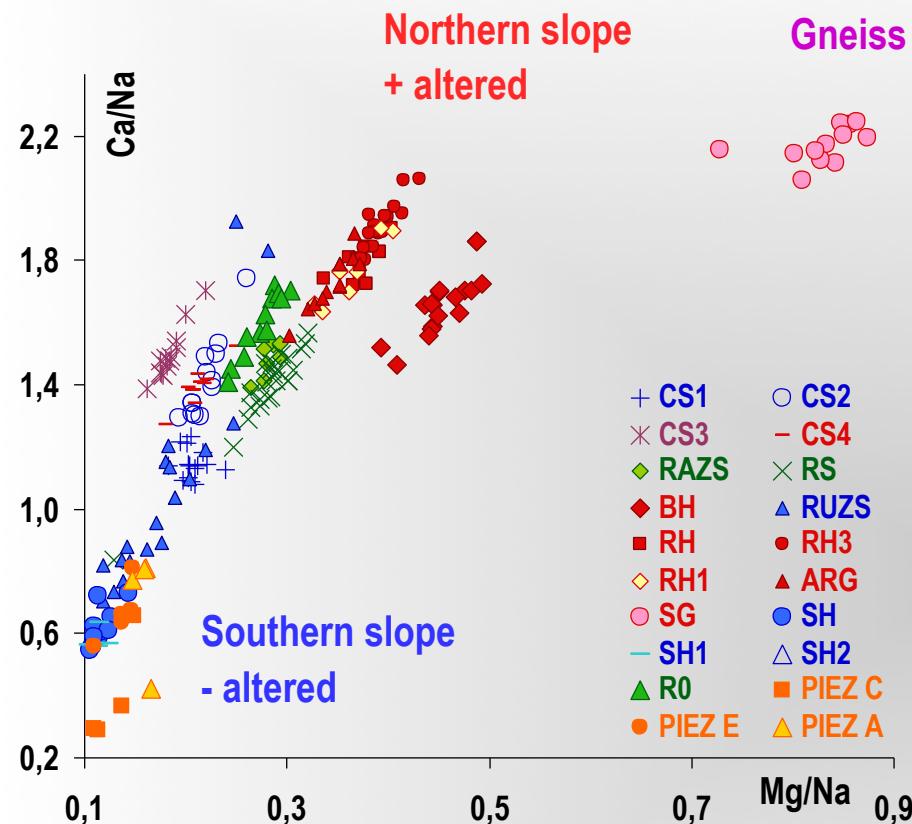
Presentation of sampling



Springs from the Northern slope: SG, CS₄, ARG, RH, RH₁, RH₃, BH

Strongly hydrothermally altered

Some geochemical results



Chemical and isotopic signatures

- Large heterogeneity even at a small watershed scale (temporal + spatial)
- Individual water pathways
- Along complex fracture networks

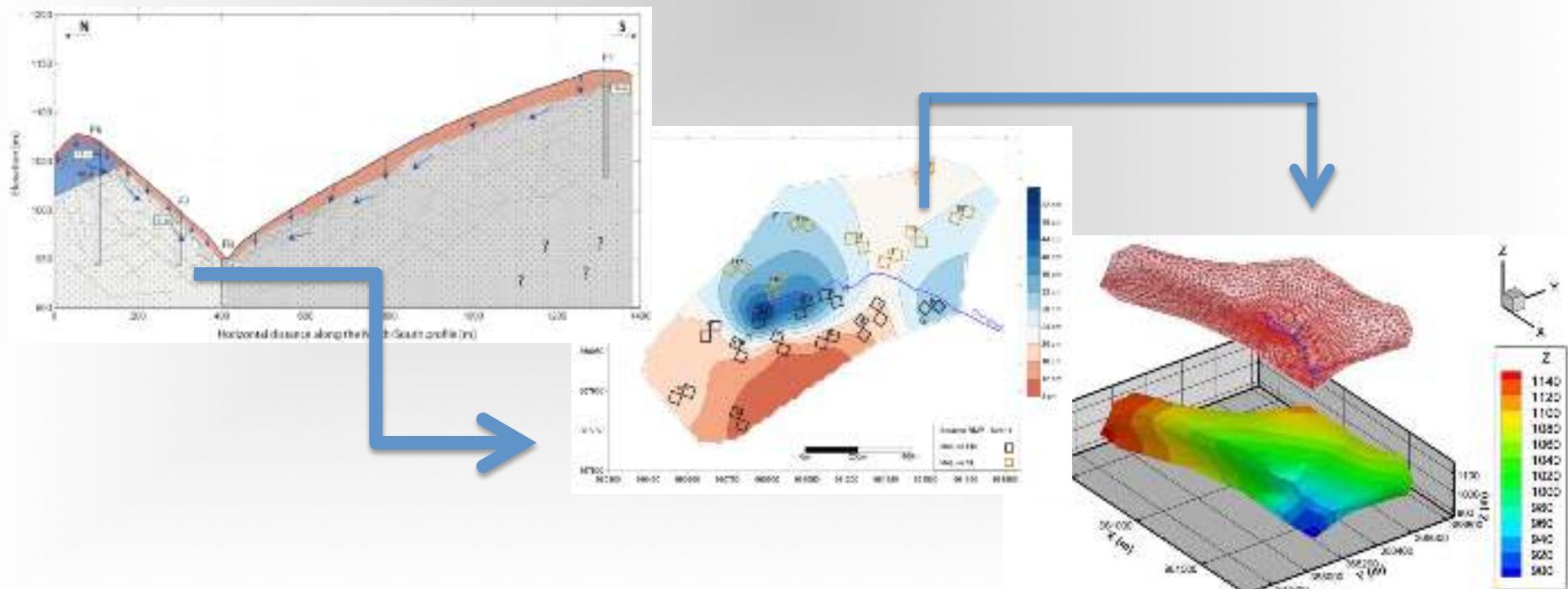
Cividini et al., 2010; Prunier, 2010, Pierret et al., 2014

QUESTIONS

- better understand the geochemical signature of water / water pathways
- Identification of the zone of water storage / recharge area / Hydrological functioning
- Evolution in response to perturbations (climatic, forestry, pollution....)

REQUIREMENTS

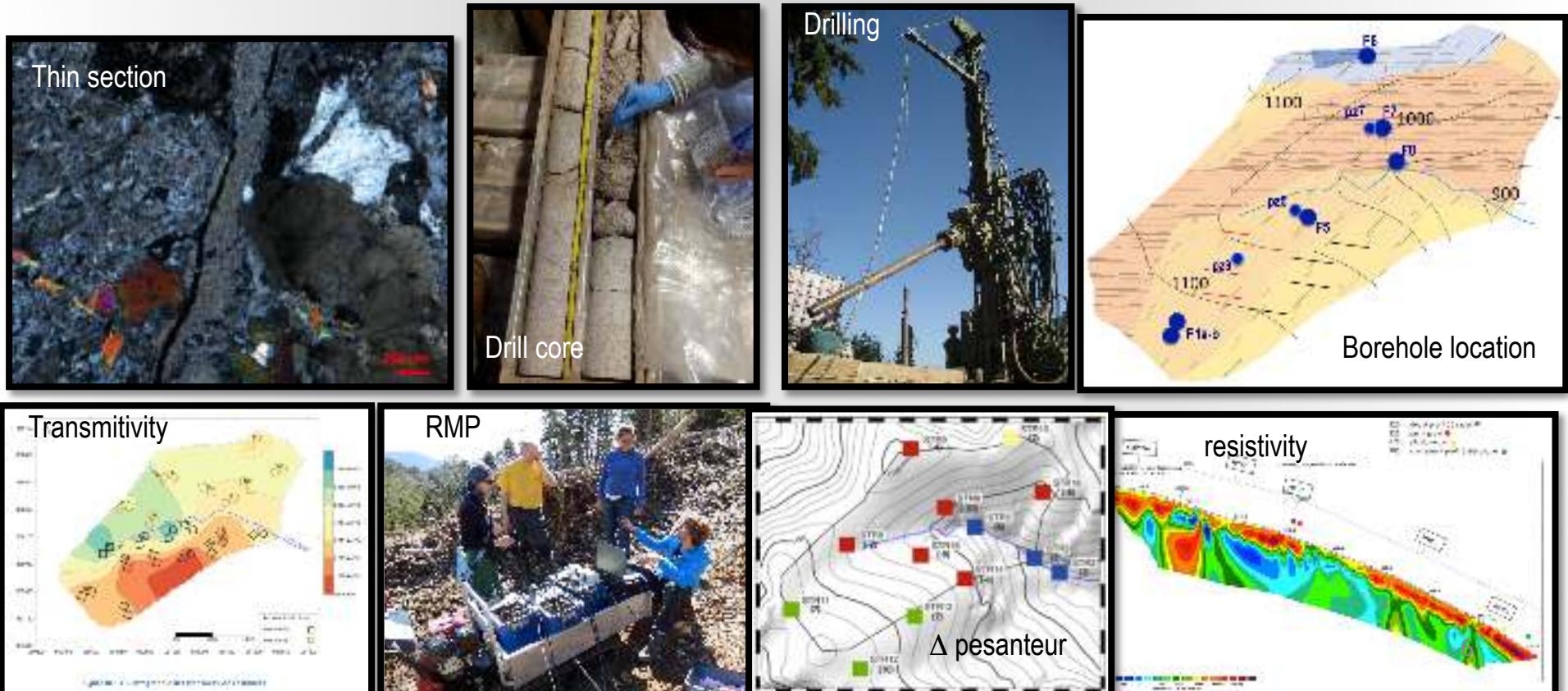
- 3D structure (surface + deep)
- Parameters (water content, porosity, permeability...)
- Spatial and temporal evolution (dynamics of groundwater storage)
- Models



TOOLS → surface and deep explorations / With support of CRITEX



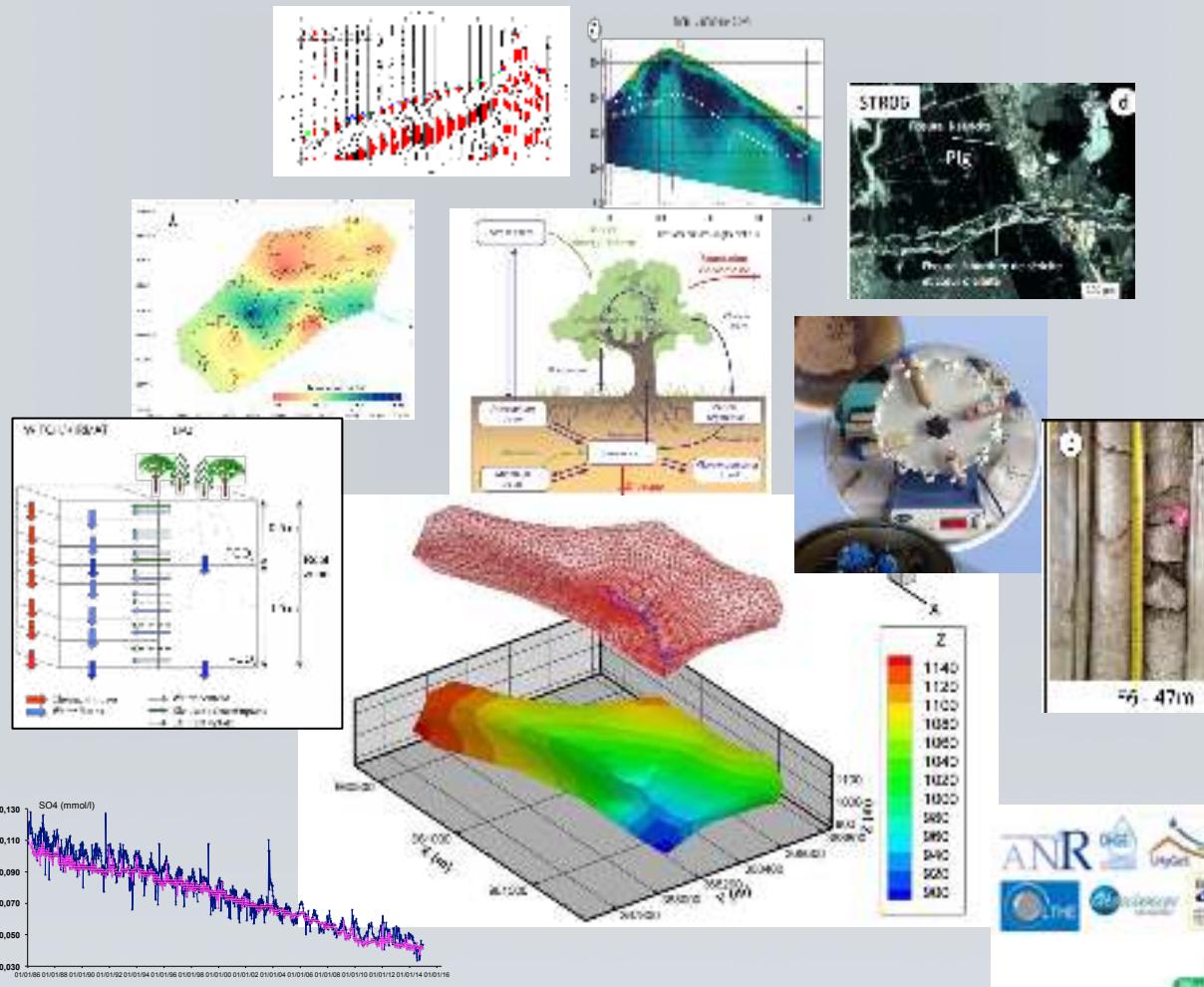
- 6 boreholes (\rightarrow 120m deep) + 3 piezometers
- Combining different geophysical methods (resistivity, CSAMT, seismic, radar) / boreholes and surface survey \rightarrow 3D structures
- Study of water storage dynamics (well logging, MRS and gravimetry time-lapse)
- Characterization of parameters (water content, porosity, permeability...) MRS + direct measurements on surface and deep samples



CRITEX was a catalyst for the HYDROCRIZSTO project founded by ANR (2016/2020)



Combination of geophysical, geochemical and hydrological investigations to better understand and model past, present and future watershed functioning.
<http://hydrocrizsto.unistra.fr>



Hydrogravimetry on the Strengbach catchment (Vosges mountains)

Use of hybrid gravimetry to investigate
Water Storage Changes:

- Repetition of micro-gravity network with RG (Scintrex CG5) on 17 stations within the catchment including 6 boreholes and 3 piezometers

started in june 2014

- Regular measurements at base station with AG (FG5)

started in 2016

- Continuous monitoring with SG (iGrav) at summital base station

planned in June 2017

SG

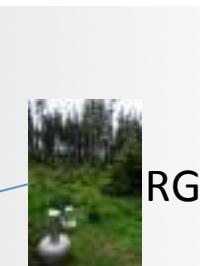
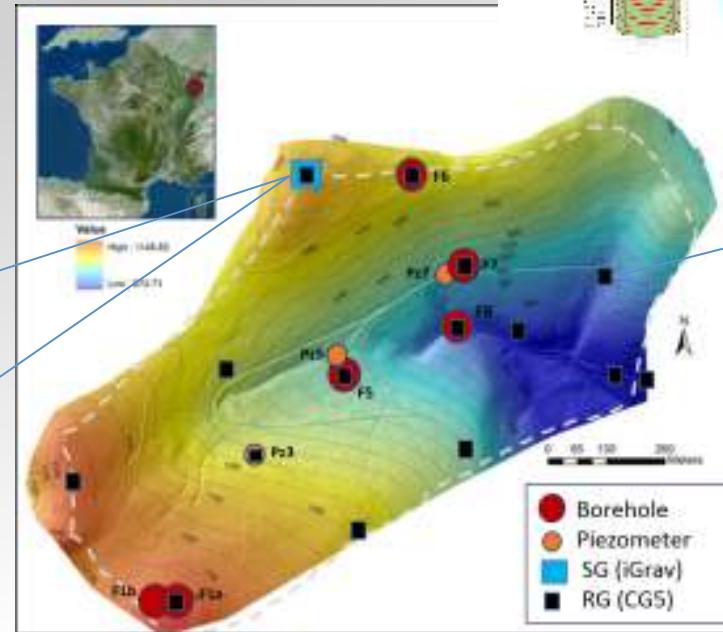
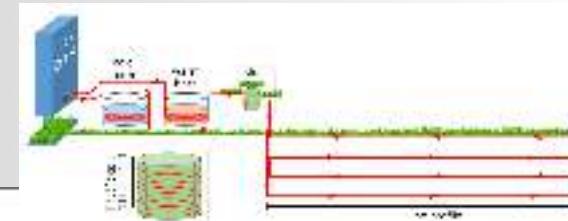


AG



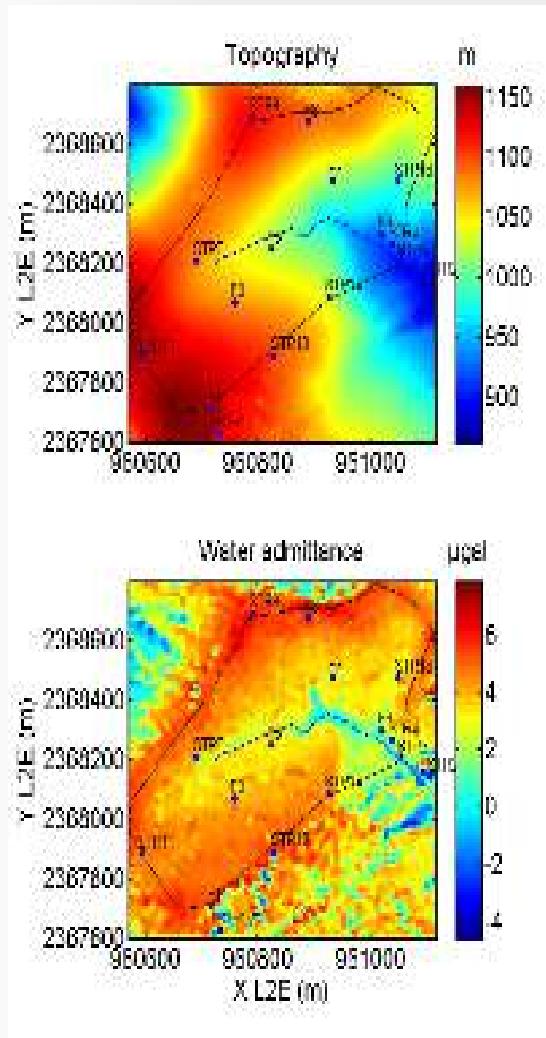
Complemented by:

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

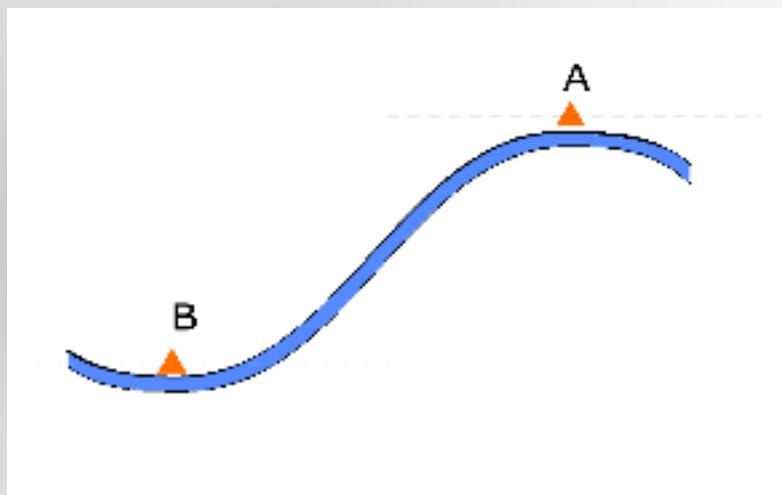


RG

Topographic influence on gravity admittance in case of a mountain catchment



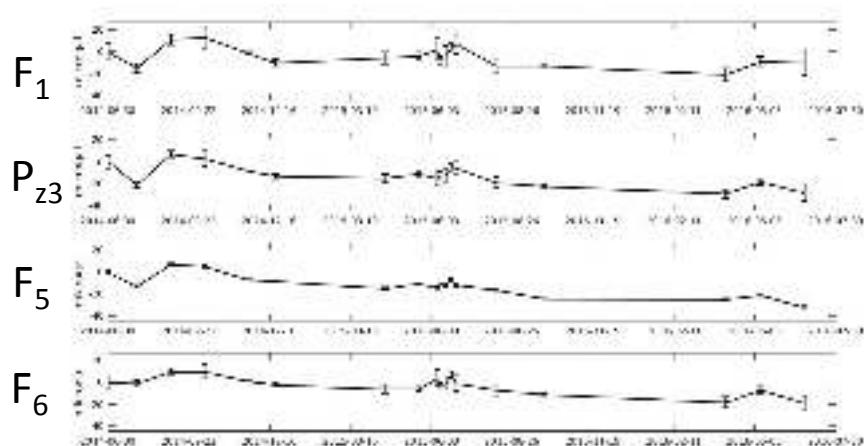
Bouguer plate (without topography):
4.2 μGal gravity change /10 cm of water



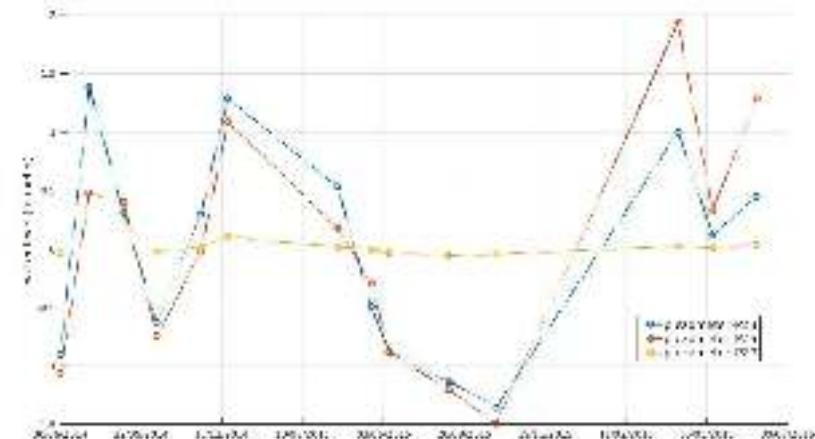
Higher values on crest
Lower values in valley

Even in the simplistic case of a uniform infiltrated water layer gravity changes will be \neq according to altitude

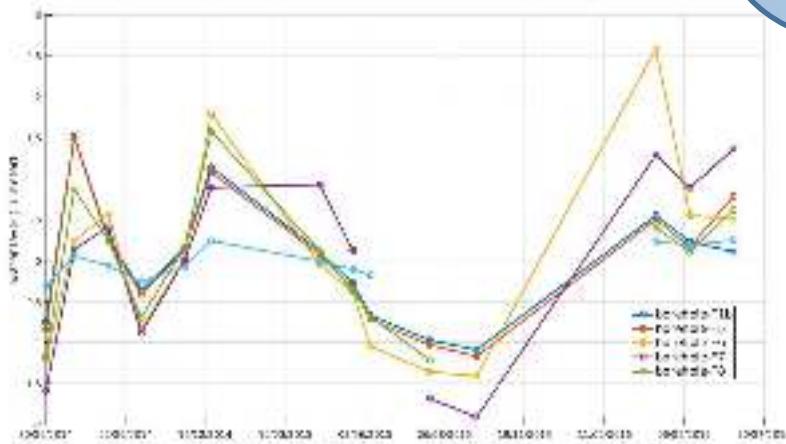
Gravity changes (06/14-06/16)



Water level changes in piezometers

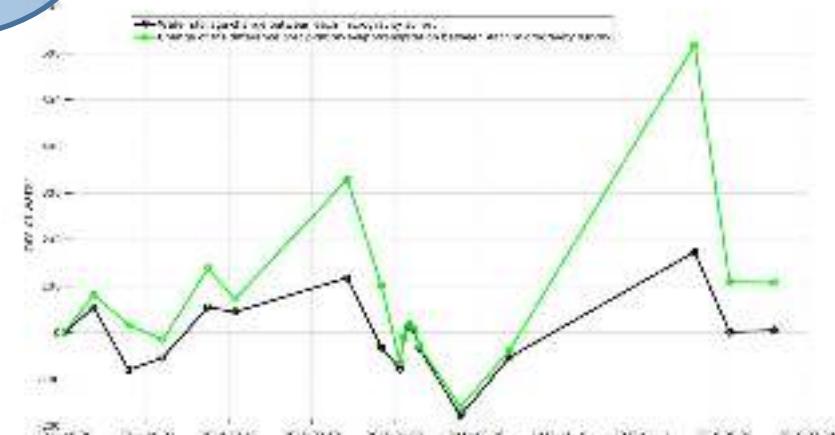


Water level changes in boreholes



LINK?

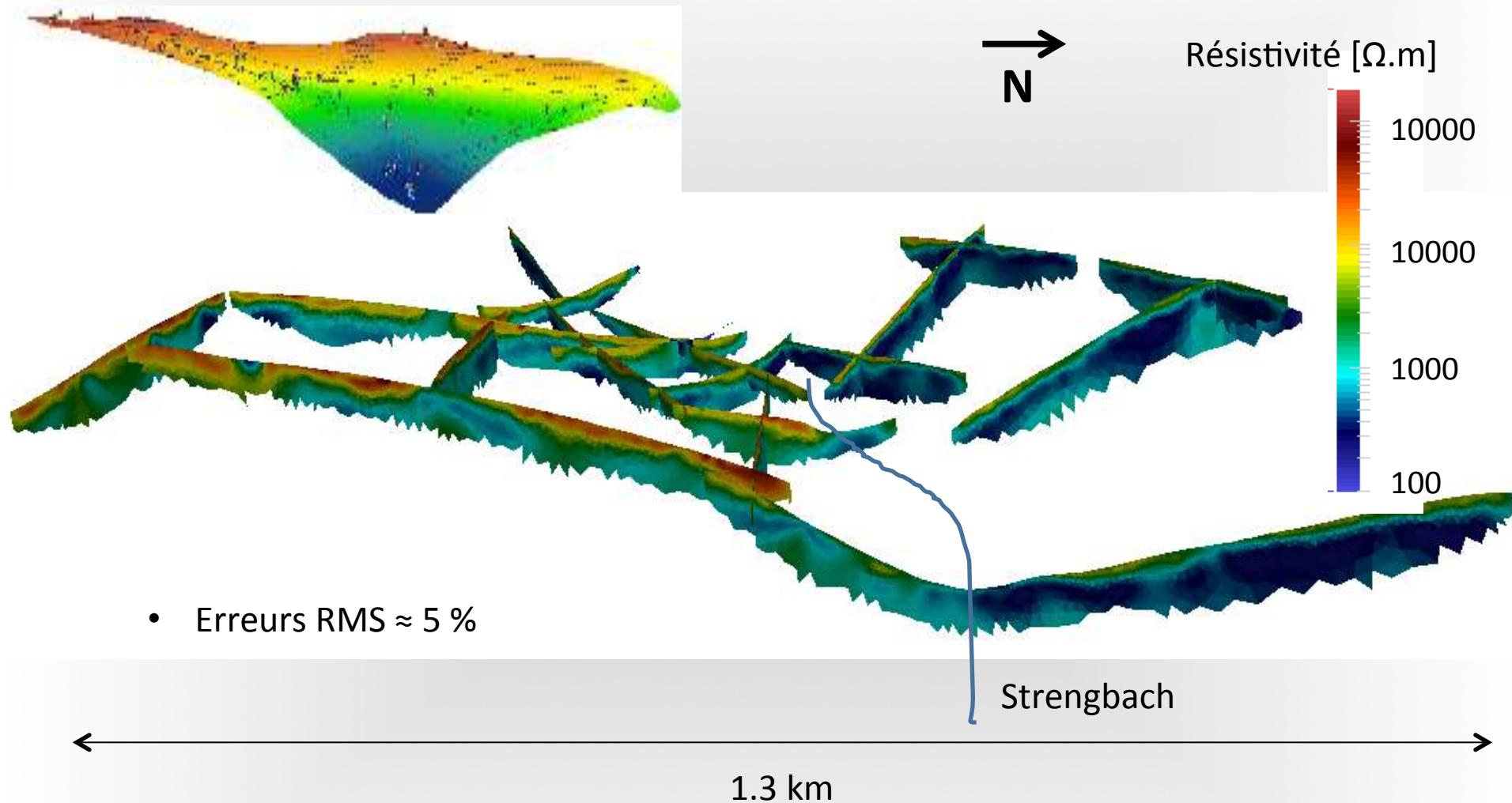
Water storage budget



First space/time decomposition with EOF
Empirical Orthogonal Functions)

See poster by Chaffaut et al.

ERT method to image the electrical resistivity at the Strengbach catchment (Gance et al.)



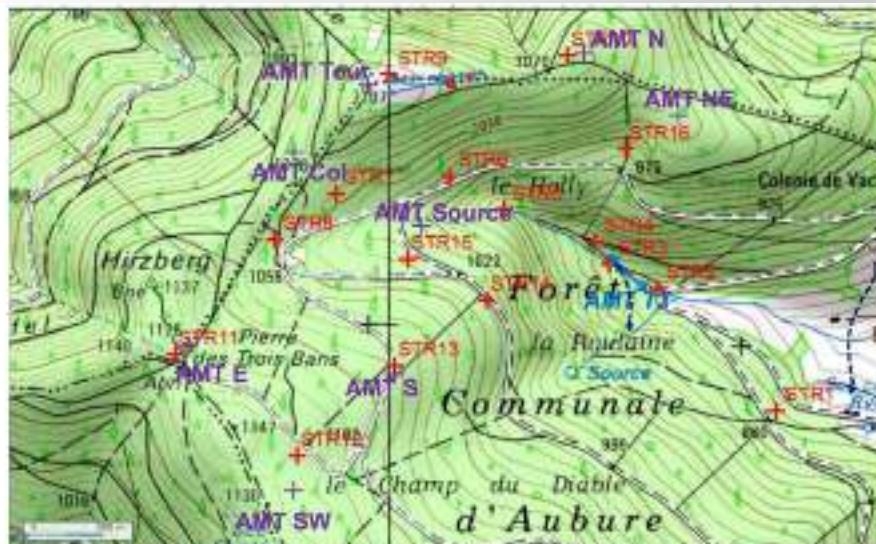
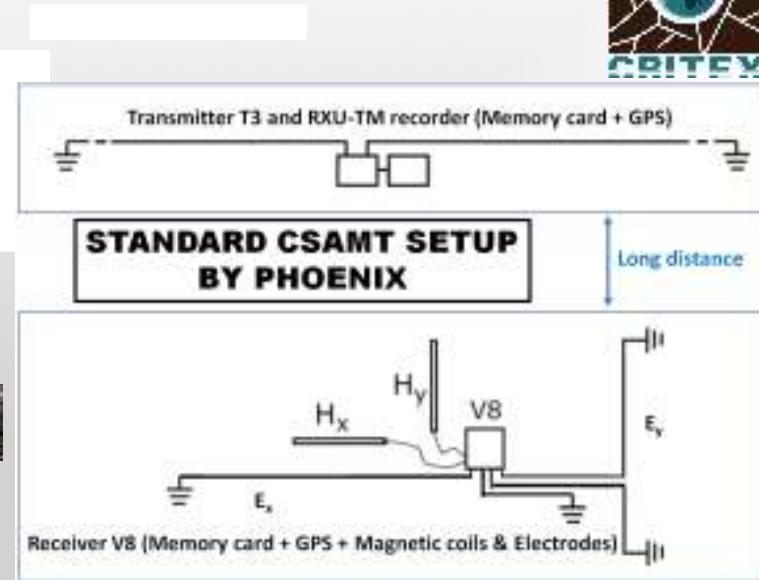
- Strong contrast between the two slopes
- Depth of investigation : 10/15 m
- What about deeper ?

CSAMT & AMT experiments and processing to image the electrical Resistivity deeper than ERT method (Sailhac et al. / CRITEX WP6.5)

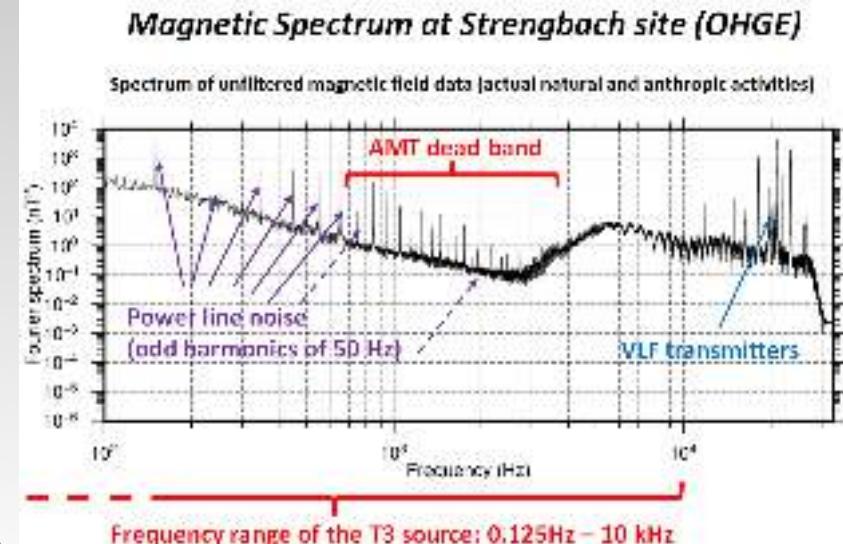
WP 6.5



CRITEX T3 transmitter for CSAMT, set up at the Strengbach



Location of AMT/CSAMT and Gravity sites at the Strengbach



PhD Myriam Lajeunie (Poster)

CSAMT & AMT experiments at the Strengbach catchment (OHGE) CRITEX and HYDROCRIZSTO works



Use of AMT & CSAMT to investigate underground water behaviour:

- ERT 3D modelling and first AMT soundings
started in 2014 / Julien Gance PostDoc
- CSAMT soundings
started in 2015 / Zoe Terniesen M1 Internship
- AMT new processing
started in 2016 / Hugo Larnier PhD
- Repetition of AMT & CSAMT soundings
started in 2017 / Myriam Lajaunie PhD

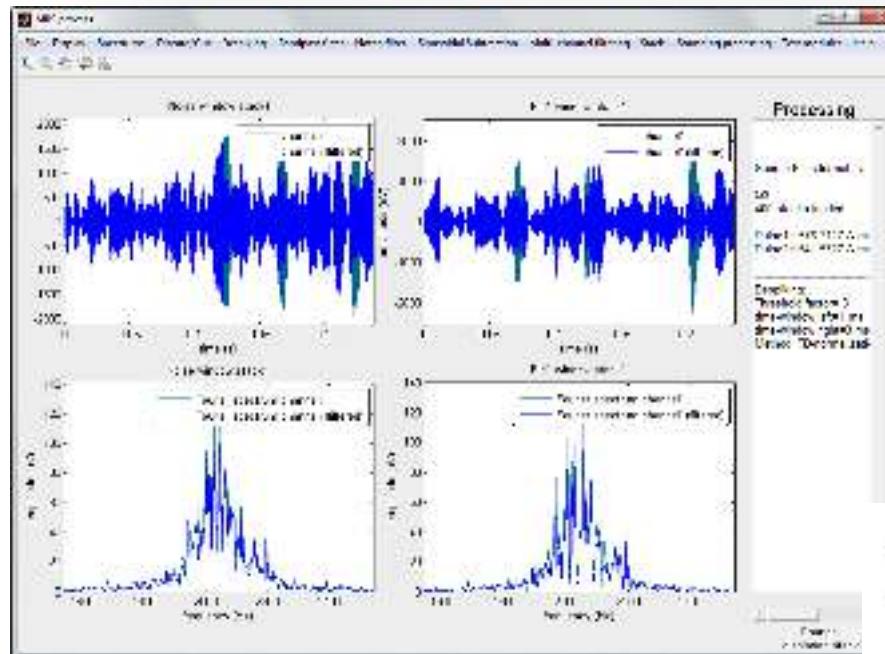


Sailhac et al. (Thursday)
Guillemoteau & Sailhac (Wednesday)

Complementary CRITEX & HYDROCRIZSTO works:

- Time-lapse and monitoring of water level and water electrical conductivity in boreholes (Montpellier / P. Pezard)
- SLINGRAM
- SIP experiments
- Gravity monitoring
- Hydrogeological/chemical modelling

RMP: improvement in signal processing

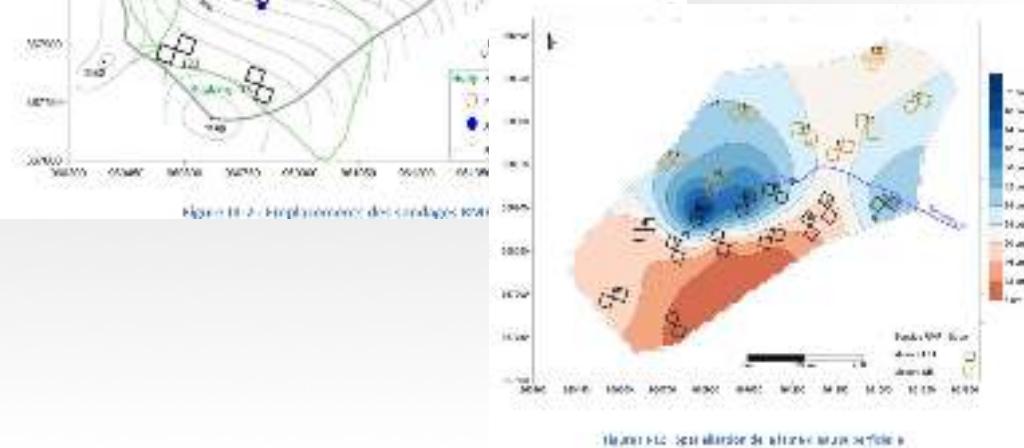
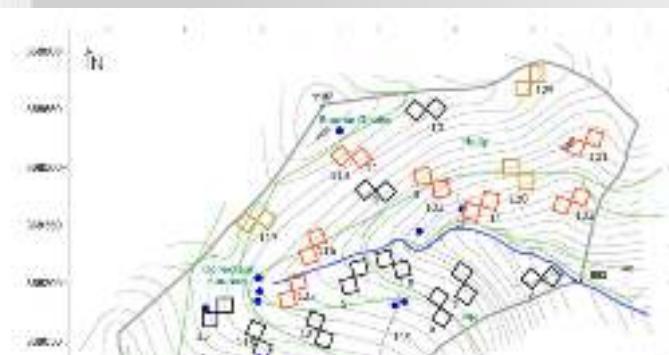


Matlab software
MRS process
developed by
S. Penz (BRGM)
JF Girard (IPGS)
Benchmarked with
Legchenko software
(Samovar): mostly
equivalent..

- Handle various type of data (Numis^{plus}, Numis^{poly}), mono and multi-channel



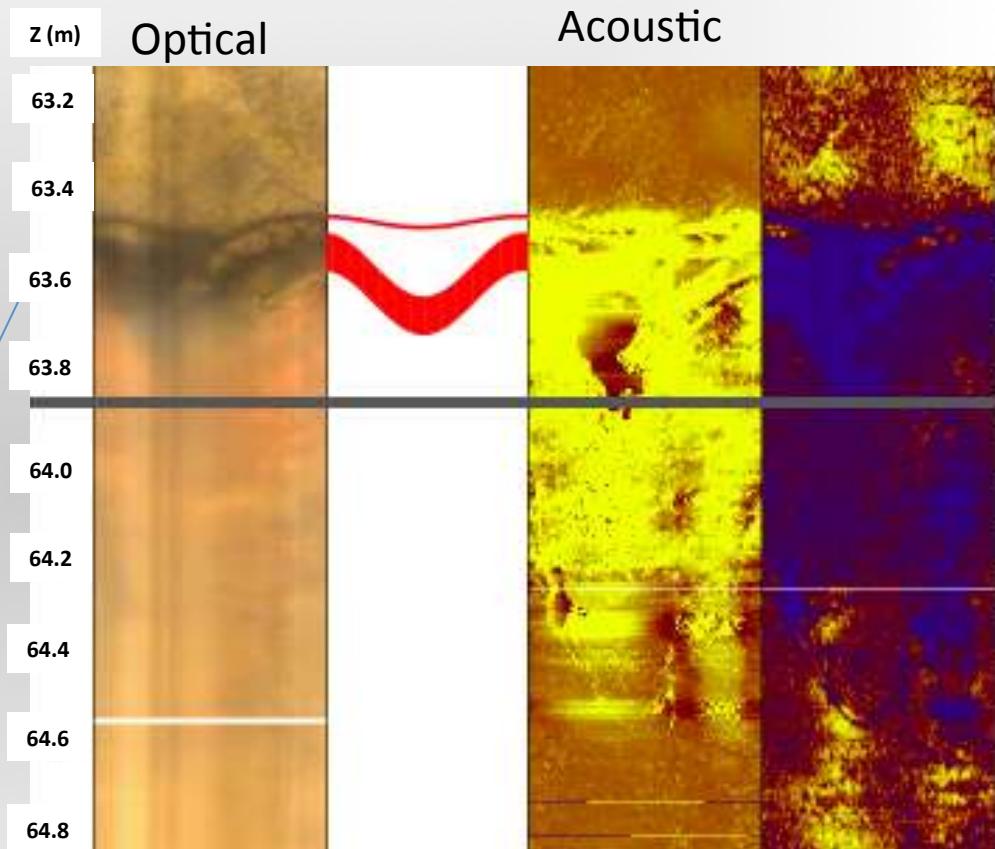
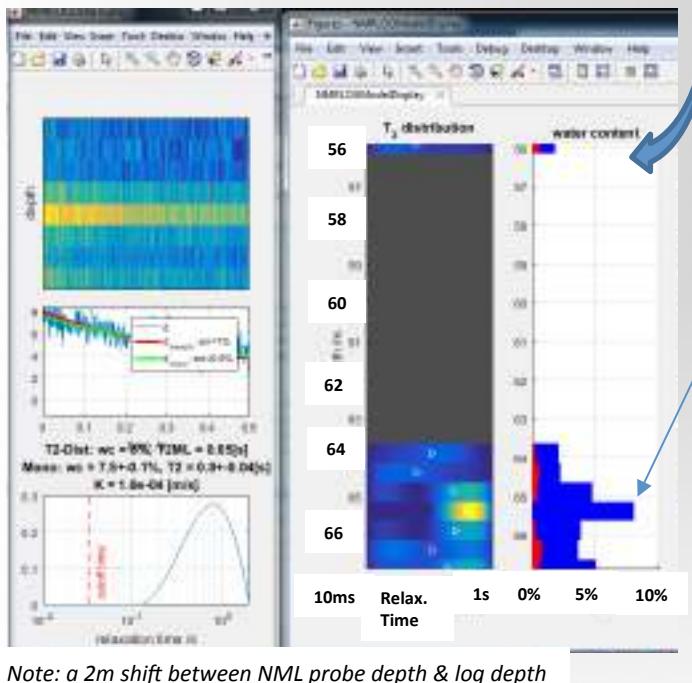
Multi-channel system has not yet been used at Strengbach. Efficiency to be tested... (Post-doc Clara Jodry, Idex Unistra) -> use of square large loop instead of « figure-of-eight »



Contact:
c.jodry@unistra.fr

NML results at borehole F6 confirms water content estimate from MRS

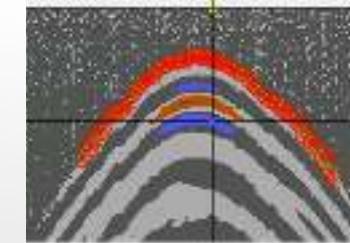
significant NMR Signal ~1-2 vol % with T2 of 100-200ms.
MRS response confirmed



water content increases up to 4 vol% with long relaxation times (~0.8s) indicating free water

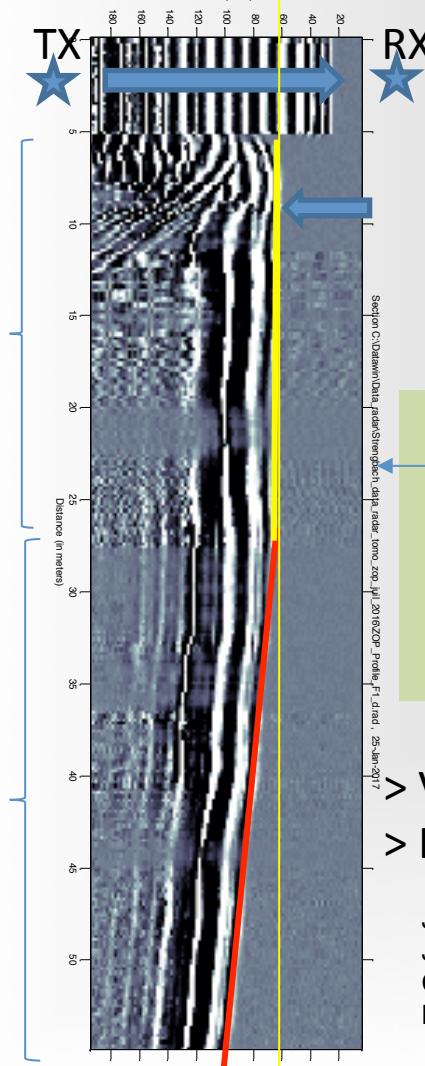
Cross Borehole Radar tomography

Boreholes F1a & F1b

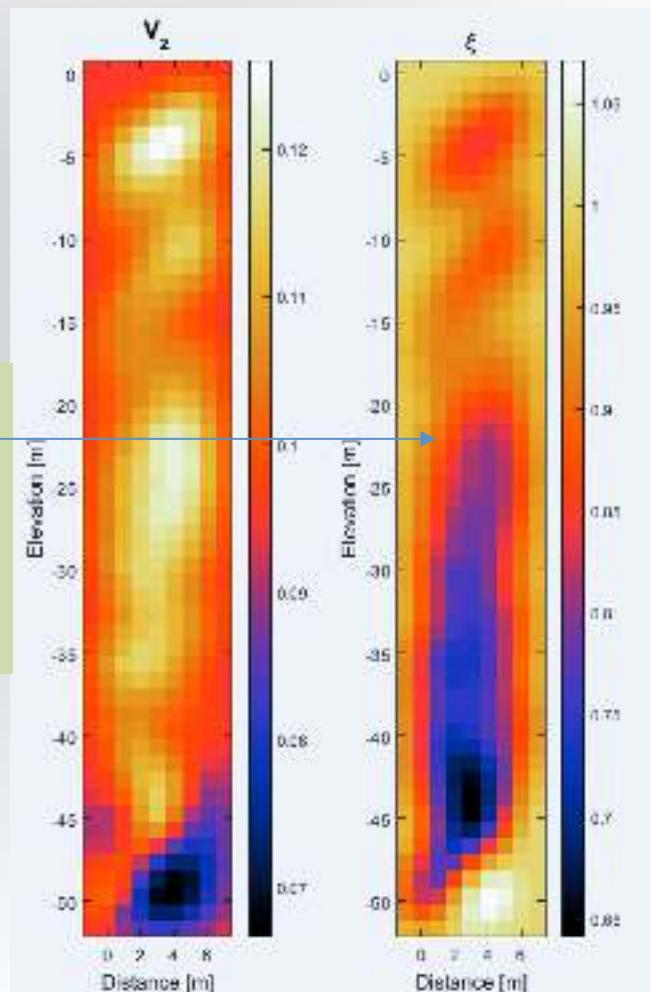


Ramac
100 MHz

Zero offset profile



Multiple Offset Profile



Jean-Rémi Dujardin: j.r.dujardin@unistra.fr
 Jean-François Girard IPGS - EOST
 Collaboration with Bernard Giroux (BHTOMO)
 NRS (Quebec) www.ete.inrs.ca www.liamg.ca

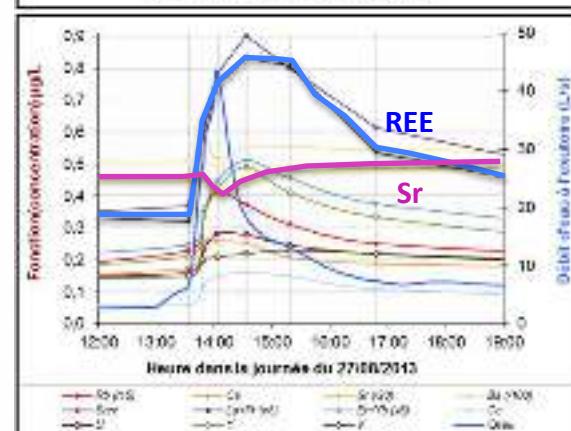
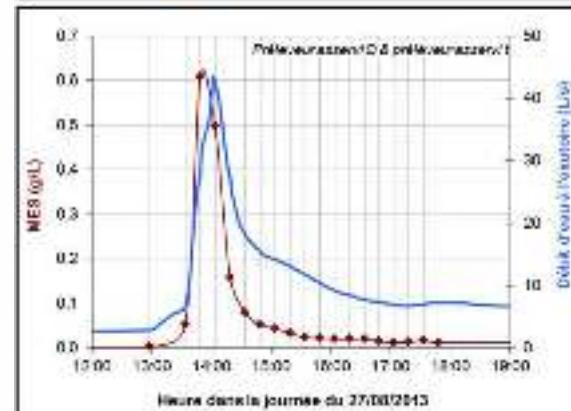
Very near future CRITEX action :

High frequency approach

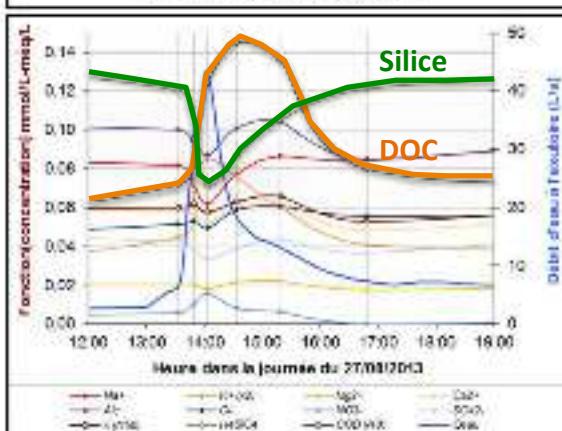
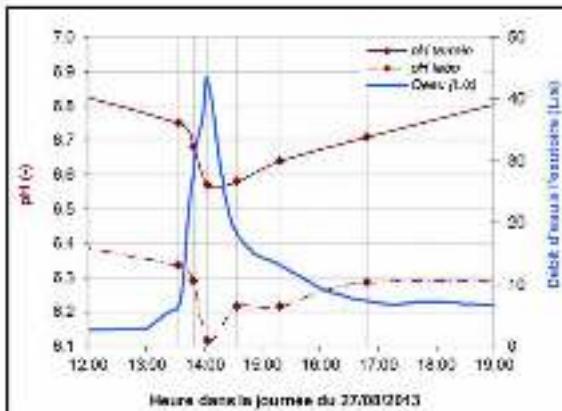
Installation of a RIVER LAB in June 2017

→ Periodicity/seasonality (d/n; m; yr...)

→ Extreme event hydrodynamic behavior



Storm event – 08/2013



CONCLUSIONS

Real multidisciplinarity

Connection between geophysics / geochemistry / hydrology / modeling

New collaborations

Catalysis project founding (ANR....)

Still in progress

Announcement :

The Strengbach watershed site is
open to (and will welcome) other
technical development or
methodology

