Multiscale hydrogeological and hydrogeophysical approach to monitor vadose zone hydrodynamics of a karst system

A. Watlet*[,1,2], A. Poulain[3], O. Francis[4], V. Hallet[3], O. Kaufmann[1], Y. Quinif[1], G. Rochez[3], A. Triantafyllou[1,5], M. Van Camp[2]

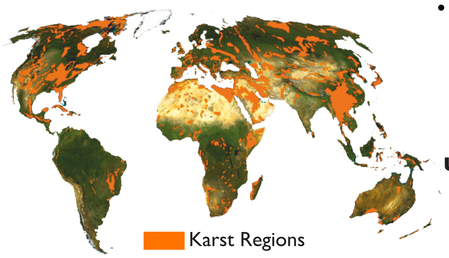
[1] University of Mons [2] Royal Observatory of Belgium [3] University of Namur
[4] University of Luxembourg [5] University of Nantes




The authors

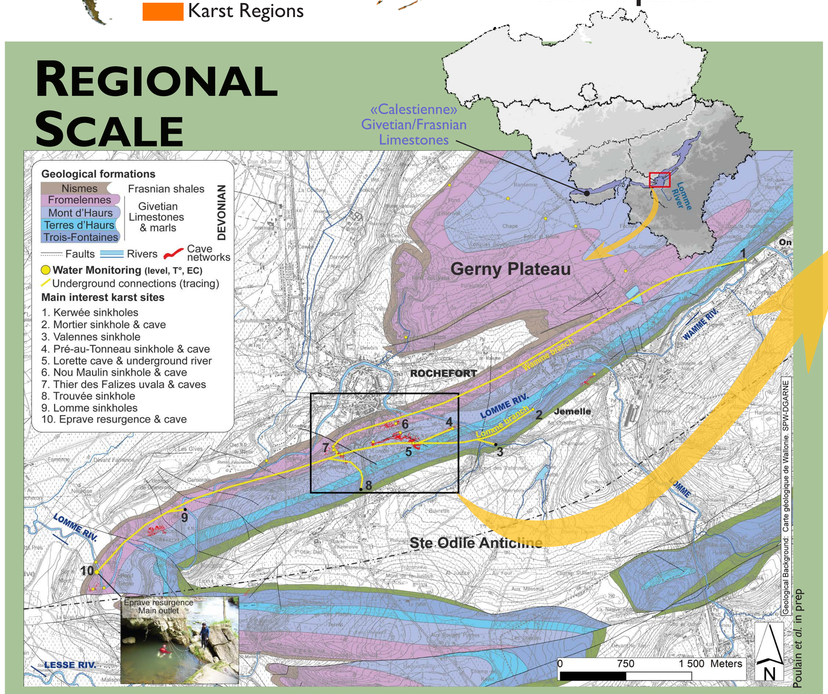
Goals & Challenges

- Karst provides drinking water to 25% of world population
- Management of karst water resources is crucial in a changing world
- The complex structural heterogeneities and non-linear dynamic are challenging



This multidisciplinary and multiscale study aims at understanding groundwater recharge and storage in karst aquifers

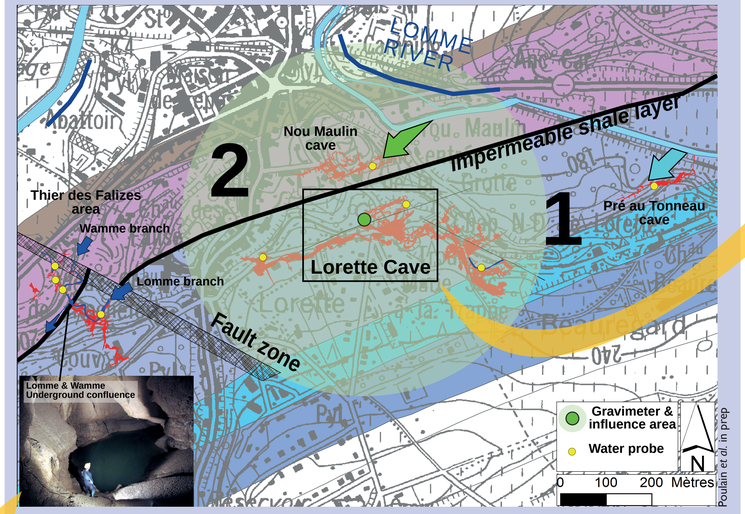
Regional Scale



- 10 dye tracing in 2013-2015 highlight the groundwater organisation
- Identification of 2 underground branches : the underground Wamme river and the underground Lomme river that meet in the Thier des Falizes faulted zone
- Surface and groundwater monitoring precise the seasonal and floods dynamics

Local Scale

Caves around Rochefort



Saturated Zone Dynamics

Monitoring & tracing highlight two compartments with different behaviors separated by an impermeable layer (shales).

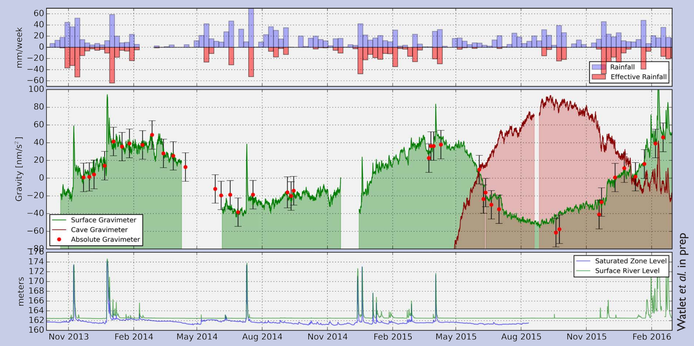
Compartment 1 is flooded when the Lomme river reaches 15m³/sec and overflows the Pré au Tonneau.

Compartments 1+2 are flooded when the Lomme river reaches 20-25m³/sec and overflows the Nou Maulin cave.

A major fault zone in the Thier des Falizes area enables hydrogeological connexion.

Gravimetric Monitoring

Gravity measurments integrate all the Lorette Cave area. Bouguer anomaly links gravity changes to karst water content: $\Delta g = 2.\pi.\rho.G.H$
with G, gravitational constant; ρ, density of water and H, variation of water



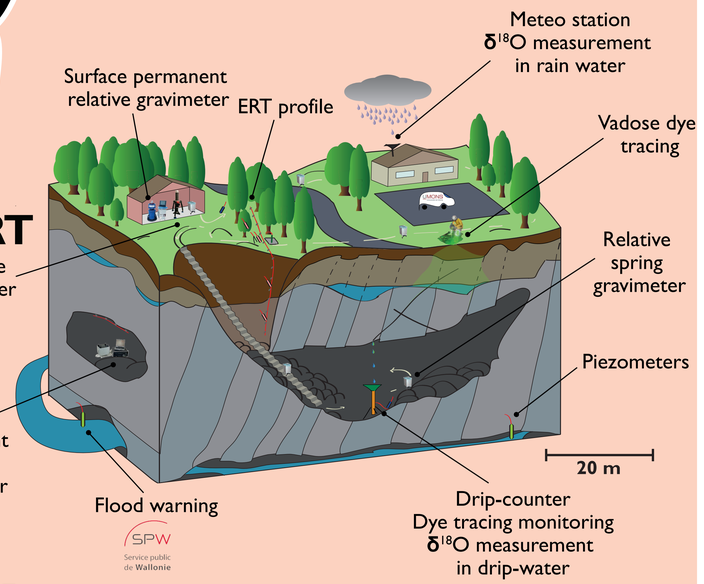
Flash flood variations:

- Gravimeter is only sensible to floods that occur simultaneously in both compartments 1 and 2 :
  - Floods in compartment 1 are much smaller
  - Average porosity of compartment 1 has to be smaller
  - Increase in gravity is lower than what water level sensors suggest: floods overestimated by direct measurements

Seasonal variations:

- No correlation with saturated zone levels except for flash flood events
- Variation related to water content changes in the vadose zone
- Anti-correlation with gravity monitored in the cave means that most of changes occur above the cave

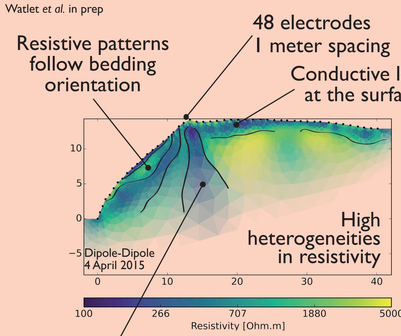
Rochefort Cave Lab Site Scale



ERT Monitoring

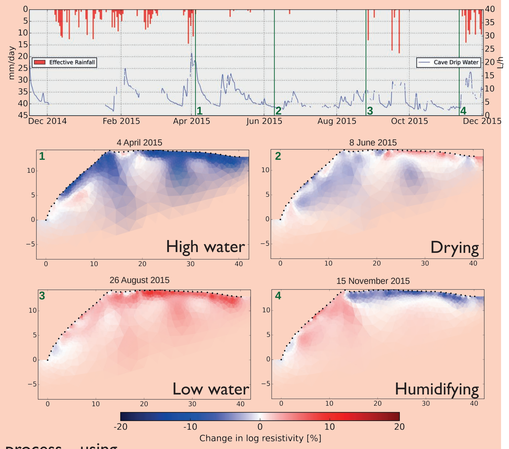
Permanent Profile at the Surface

Watlet *et al.* in prep



Conductive area next to the sinkhole may be related to:

- Clayish layers between limestone beds
- Infiltration pathways

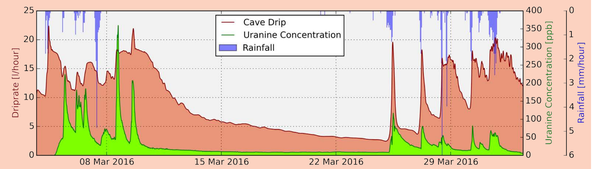


Inversion process using BERT (Günther & Rücker 2006)
Data converged to chi² 1-5 (error model well fitted)
Rms 5-10%

- Time-lapse with a reference model
- Temperature corrected
- Vizualisations compared to mean model

Dye Tracing In the Vadose Zone

Dripping rate reacts quicly to rainfall events, highlighting a high transmissivity in the limestone massif. However, uranine concentrations shows that groundwater has also a high residence time in the vadose zone (>1 month).



Conclusions

- **Hydrogeological monitoring & dye tracing are essential to understand the karst system dynamic at a regional scale**
- **Combining geophysics (gravimetry & ERT) is applicable to validate and interpret hydrogeological data**
- **Drip counter & vadose dye tracing provide valuable data to precise the local dynamic of the epikarst and aquifer recharge**

www.karag.be

References

Günther, T., Rücker, C., Spitzer, K. (2006) Three-dimensional modelling and inversion of dc resistivity data incorporating topography - II. Inversion. Geophysical Journal International. 166(2).

Poulain, A., Rochez, G., Bonniver, I., Hallet, V. (2015) Stalactite drip-water monitoring and tracer tests approach to assess hydrogeologic behavior of karst vadose zone: case study of Han-sur-Lesse. Env. Earth Sci., 74 (12), 7685-7697

Barchy, L., Dejonghe, L., Marion, JM. (under press) Rochefort-Nassogne 59/3-4. Carte géologique de Wallonie. SPW-DGARNE

Acknowledments

This research is part of the KARAG project funded by the Belgium National Fund for Scientific Research (FNRS)
We are particularely thankful to C. Barcella, C. Bastin, A. Triantafyllou, P. Meus, L. Funcken, T. Lecocq, the Royal Meteorological Institute, M. Vandiepenbeeck, The British Geological Survey Tomography Team, P.Vuylsteke, G. De Sadelaer, M. Legros, J-L. Nandancé, S. Gailliez, all the Lorette Cave staff and local cavers who helps during field work.