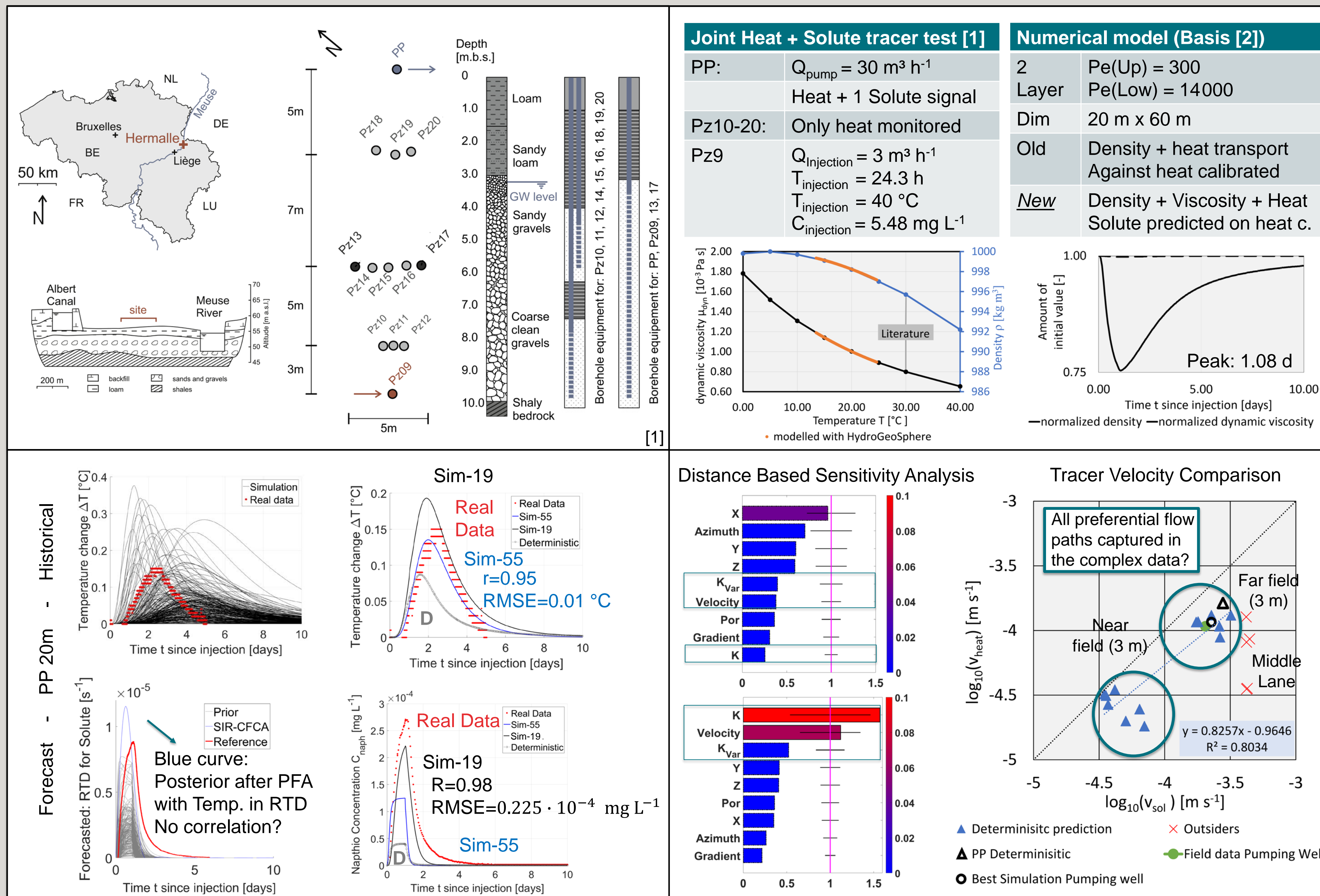


## Motivation for using complementary tracer behavior and performing joint modelling/inversion

1. Characterize preferential flow paths using innovative heat, solute and dissolved gas tracer for advanced subsurface process imaging + multiple scale transport.
  - Compare multiple tracer injection tests in heterogeneous media like alluvial sediments (A: Hermalle (H+)) and fractured rocks (B: Chalk).
2. Assess the impact of preferential flow paths and quantify + reduce the associated uncertainty in model predictions using HydroGeoSphere for transport modelling.
  - Perform e.g. Bayesian Evidential Learning for porous media (A) and using a dual-domain modelling approach for a double porosity Chalk (B).

### Part A - Porous media – 20 m - Hermalle-sous-Argenteau, Liege (BE)



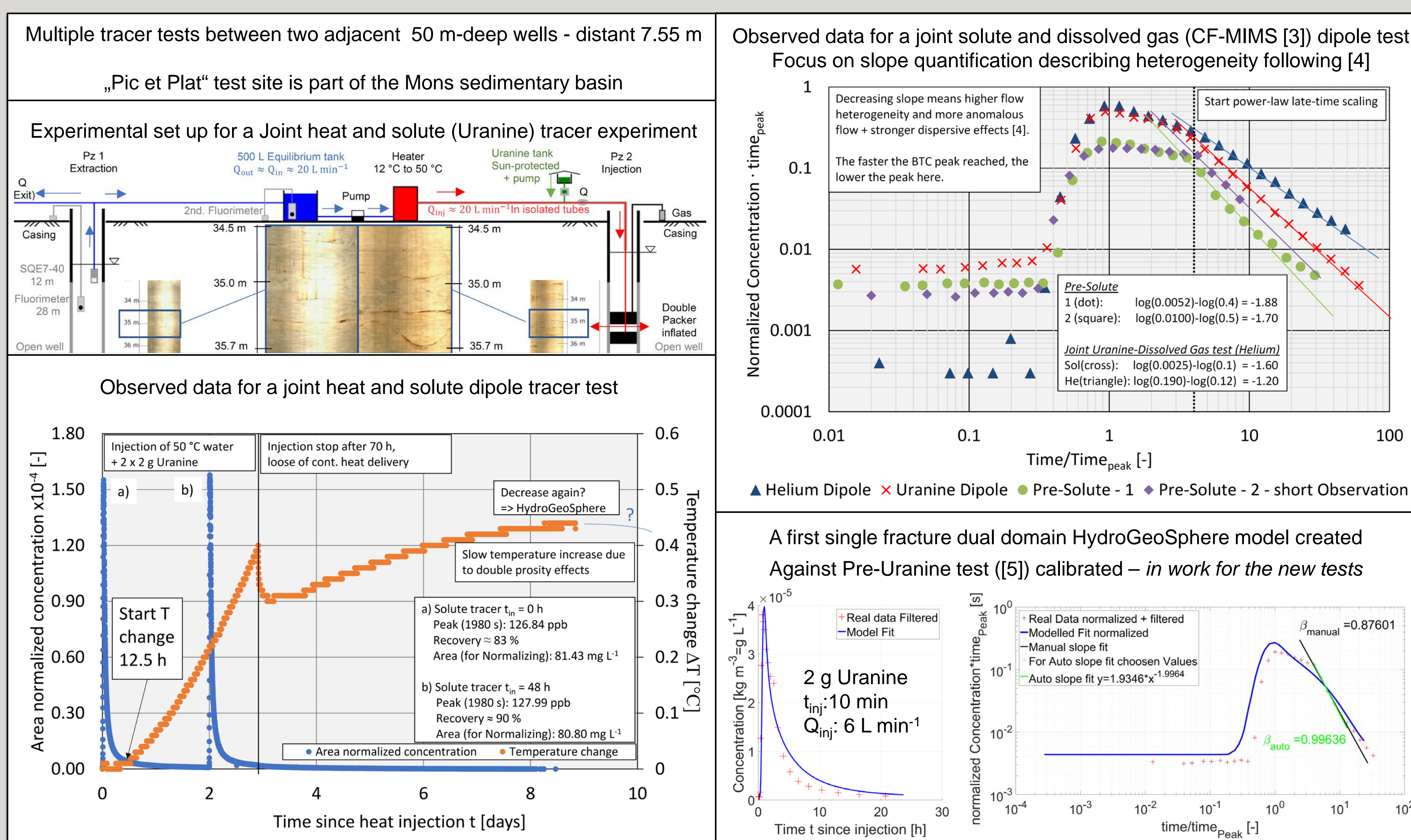
### A - Key-Results

- A1** Solutes are, as expected for porous media systems with high advection, sensitive to hydraulic parameters.
- A2** On the contrary, heat is less sensitive to a spatial variation of hydraulic conductivity as expected.
- A3** So far there is no "one" best porous medium model allowing to fit both individual tracer behaviour... but individual best solutions exist.

### A - Discussion

- Solute needs an accurate quantification of the flow preferential pathways caused by heterogeneity, while heat needs an accurate conduction parametrization acting as a "wave front movement".
- Models dominated by advection neglect too much the heat conduction
- Stacked overlaps of many simulations respecting the best simulation for each observation point by an individual weight, seems to be a possible integration of the different behavior with reduced uncertainty.

### Part B - Single fracture in double porosity Chalk – 7.55 m – Mons (BE)



### B - Key-Results

- B1** Heat in chalk is far more delayed compared to solute tracer and its distribution is more isotropic around the injection well.
- B2** When heat injection is stopped, a fast temperature decrease is followed by a slow rebound.
- B3** "Heterogeneity factors" [4] are derived for Uranine (0.7) and for Helium (0.2), for a possible higher heterogeneity in chalk with increasing diffusivity.

### B - Discussion

- Unlike solute tracer, heat is influenced by conduction in the chalk matrix and shows a temperature rebound cause by the release of heat from the matrix to the colder water drawn from the surroundings by pumping in Pz1.
- Helium prefers more "anomalous flow" than other solutes and is less influenced by double porosity effects than heat.

## Over all conclusion + Outlook

- Heat + solute tracers brings: complementary behaviors and added information on matrix properties
- Joint tracer tests have a high potential for advanced heterogeneity characterization + Uncertainty reduction
- 1<sup>st</sup> Secondment: Push-Pull tests at H+ Site Hyderabad (India) (BRGM: A. Selles + J.C. Maréchal, End 2018)
- 2<sup>nd</sup> Secondment: GPR Training for parallel tracer imaging (FZ Jülich: J. van der Kruk, End 2019)

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