How the idea of ENIGMA was born

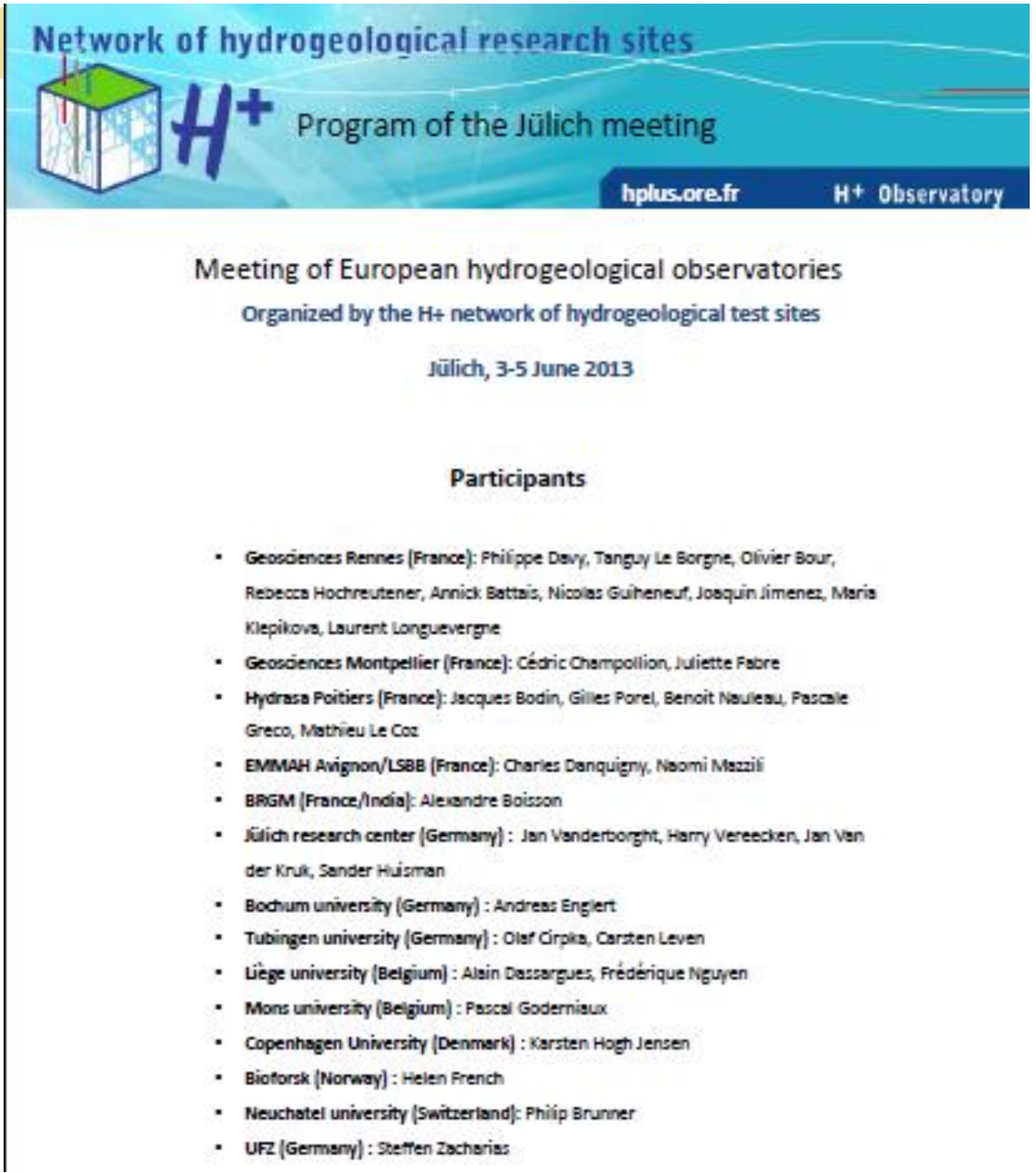
Motivations for the 2013 Julich meeting

High quality field observations are needed for testing concepts and understanding processes

Hydrogeological field sites are **often developed independently** in each country with large investments that should be valorized by opening the infrastructures and sharing data

They often **lack visibility** compared to historical sites (e.g. Cape Cod, MADE, Mirror lake…)

General **lack of structuration** of the hydrological community for field infrastructures in Europe compared to other communities



Network of hydrogeological research sites

Program of the Jülich meeting

hplus.ore.fr H+ Observatory

Meeting of European hydrogeological observatories

Organized by the H+ network of hydrogeological test sites

Jülich, 3-5 June 2013

Participants

- **Geosciences Rennes (France)**: Philippe Davy, Tanguy Le Borgne, Olivier Bour, Rebecca Hochreutener, Annick Battais, Nicolas Guiheneuf, Joaquin Jimenez, Maria Klepikova, Laurent Longuevergne
- **Geosciences Montpellier (France)**: Cédric Champollion, Juliette Fabre
- **Hydrasa Poitiers (France)**: Jacques Bodin, Gilles Porel, Benoit Nauleau, Pascale Greco, Mathieu Le Coz
- **EMMAH Avignon/LSBB (France)**: Charles Danquigny, Naomi Mazzilli
- **BRGM (France/India)**: Alexandre Boisson
- **Jülich research center (Germany)** : Jan Vanderborght, Harry Vereecken, Jan Van der Kruk, Sander Huisman
- **Bochum university (Germany)** : Andreas Englert
- **Tubingen university (Germany)** : Olaf Cirpka, Carsten Leven
- **Liège university (Belgium)** : Alain Dassargues, Frédérique Nguyen
- **Mons university (Belgium)** : Pascal Goderniaux
- **Copenhagen University (Denmark)** : Karsten Hogh Jensen
- **Bioforsk (Norway)** : Helen French
- **Neuchatel university (Switzerland)**: Philip Brunner
- **UFZ (Germany)** : Steffen Zacharias

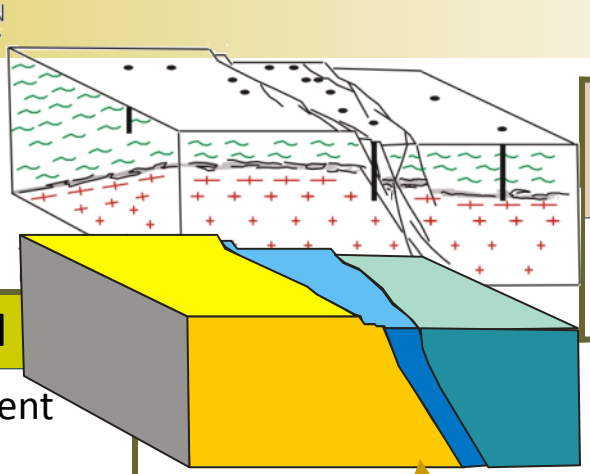
Highly instrumented sites with complementary scientific objectives

PI: O. Bour, co-PIs: T. Le Borgne, C. Champollion

Ploemeur (France)	Poitiers (France)	Mallorca (Spain)	Larzac (France)
L. Longuevergne (Rennes)	G. Porel (Poitiers)	P. Pezard (Montpellier)	C. Champollion (Montpellier)
MONITORING OF A PUMPED FRACTURED AQUIFER	ADAPTED WELL ARRANGEMENT FOR EXPERIMENTS AND MODELLING	MONITORING OF THE FRESHWATER-SALINE WATER INTERFACE	CAPACITIVE BEHAVIOR OF A KARSTIC AQUIFER

LSBB (France)	Hyderabad (India)	Krauthausen (Germany)	Llobregat (Spain)
K Chalikakis (Avignon)	J.C. Maréchal (Montpellier)	H. Vereecken (Jülich)	J. Carrera (Barcelona)
LARGE SCALE TUNNEL FACILITIES IN THE UNSATURATED ZONE	TROPICAL FRACTURED AQUIFER UNDER OVEREXPLOITATION	HYDROGEOPHYSICAL EXPERIMENTAL SITE	MONITORING OF A SEA WATER INTRUSION BARRIER

Coupling data, modelling and prediction



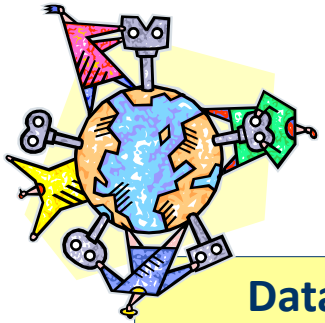
Hydrogeological system:

Media, resource, specific issues

Questions: management, protection, …

Hydrogeological model

Answers: forecasting, management strategies, critical processes/areas



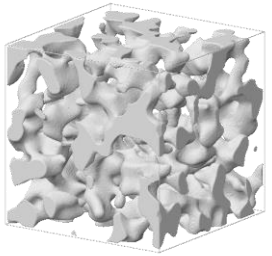
Inverse problem

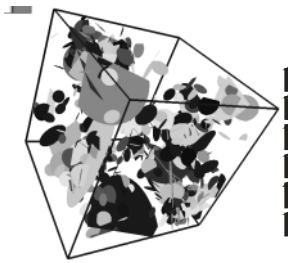
In the context of undersampled systems compared to heterogeneity and variability

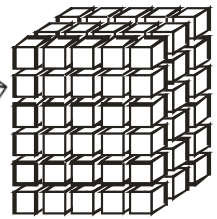
Data and constraints

- **Structure** geology, geophysics, ..
- **Flux**: hydraulic, chemical, ..
- **Properties**: permeability, …
- **Tests**: pumping, tracer…

Conceptual model



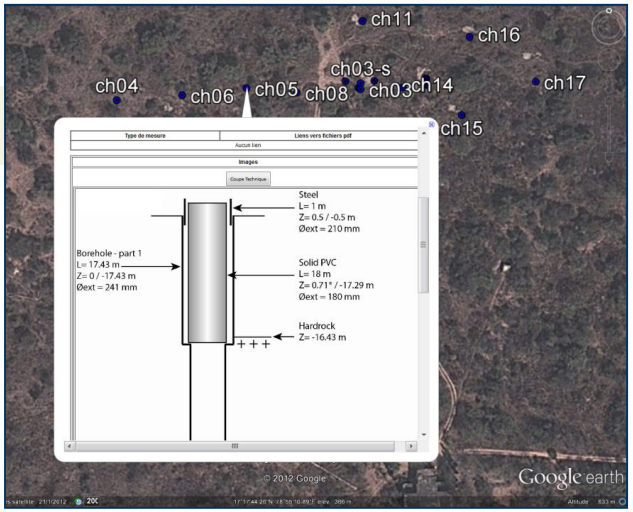




On line database

- Accumulative knowledge
- Availability for the scientific community

website : hplus.ore.fr



Platform-based database

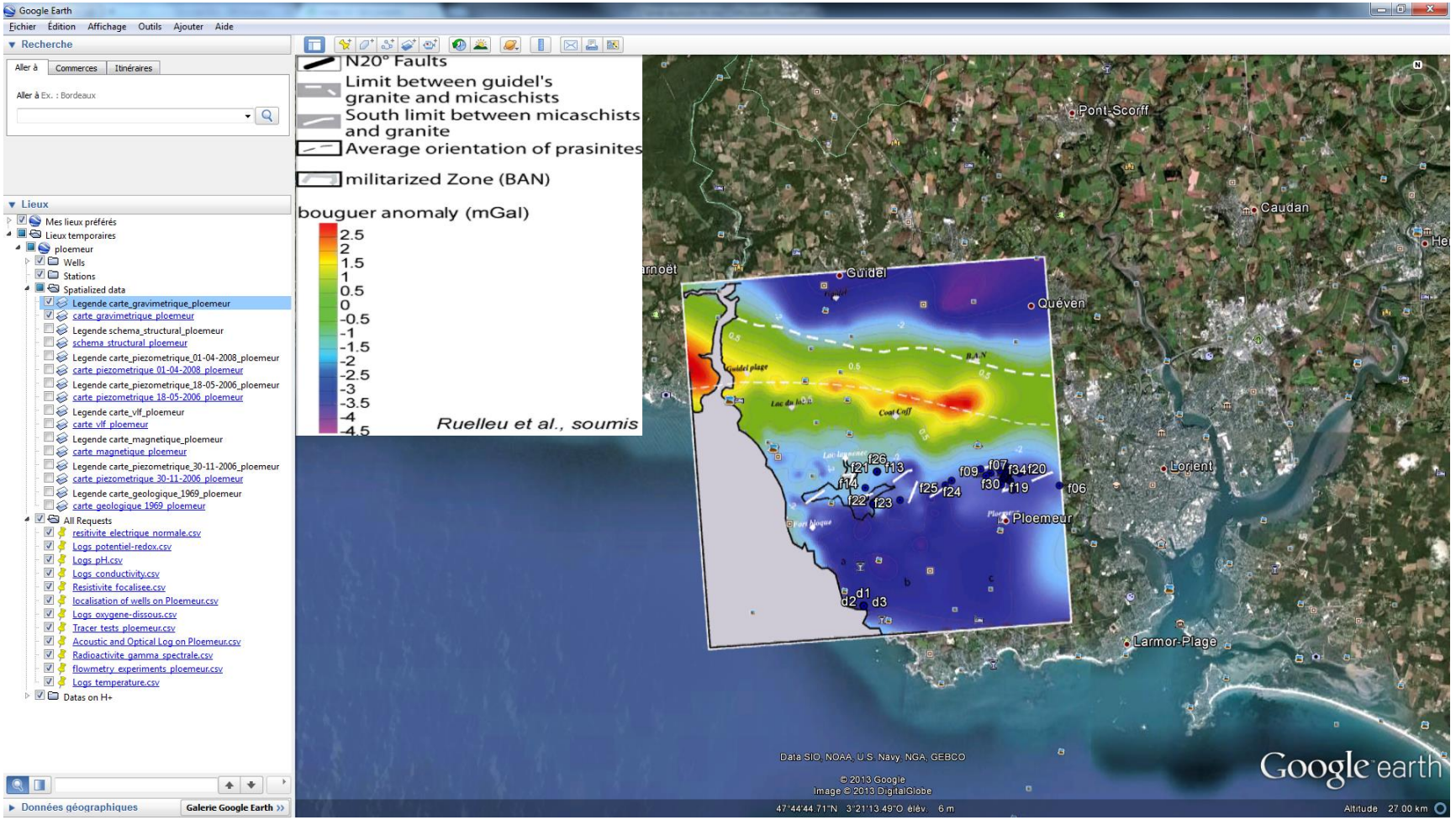
- Well (general characteristics)
- Well logs
- Core / cuttings sampling
- Borehole geophysics
- Borehole flowmetry
- Piezometric survey
- Hydraulic tests
- Chemical analysis
- Tracing tests
- Meteorological data

3D-field (meta)database

- “Geophysical” and geological survey

On line database

- Accumulative knowledge
- Availability for the scientific community **website : hplus.ore.fr**



Link between experimental sites and companies

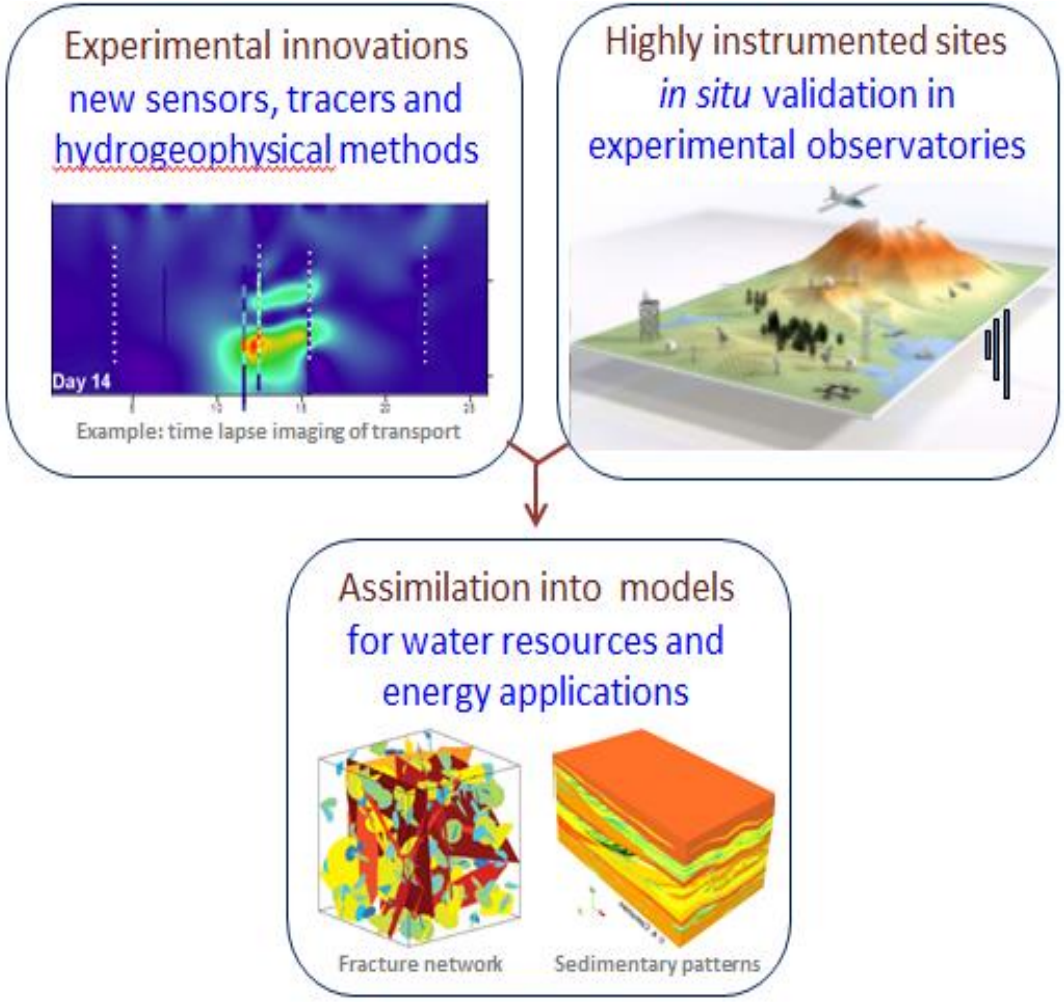
Innovative sensors and models for answering societal issues

Hydrogeophysical tools
Schlumberger
SILIXA
muQuans

Energy resources
ANTEA group
TOTAL

Underground waste storage
ANDRA
SKB

Modelling tools
ITASCA
Amphos21



Field Infrastructures (& H+ Hyderabad)

Field infrastructures	Unique attributes
Krauthausen (FZJ), Hermalle (ULG), Lauswiesen (TU), H+ Poitiers (CNRS)	Hydrogeophysical test sites with high borehole density and large hydrogeophysical databases
H+ Ploemeur (CNRS) H+ Hyderabad (BRGM) Aspo Hard Rock Laboratory (SKB)	Fractured rock observatories for long term monitoring and in situ experiments
TERENO- Selke (UFZ) HOBE obs. (UCPH) Emme (UNINE)	Nested observatories in highly instrumented catchments
Llobregat-Argentona (CSIC) H+ Mallorca (CNRS)	Salt water intrusion monitoring and experimentation
H+ Larzac (UM) H+ Low Noise Lab. (CNRS)	Unsaturated zone observatories for long term monitoring and in situ experiments

Linking hydrogeological infrastructures in Europe

Hydrogeological Sites

Database

Scientific instruments

Experimental sites

Meetings

Scientific projects

Field infrastructures for

- developing research-oriented data acquisition: *means, teams, instruments*
- promoting scientific projects in relation with hydrogeological fundamental knowledge (*structure heterogeneity, processes*) *including modeling*
- providing a learning tool for students and end-users

This network is not

- a collection of “representative” sites
- a long-term monitoring of global phenomena (like climate change)

ENIGMA field infrastructures will bring

- a significant research effort on a few well-characterized and highly instrumented experimental sites
- the possibility to link newly acquired experimental data to long term monitoring data available at the sites
- a collaborative and optimized effort of research bringing together both national institutes, local organizations and companies

15 ESR – PhD positions : Presentation of each PhD (2 slides for 5' including questions) : 14h30-16h

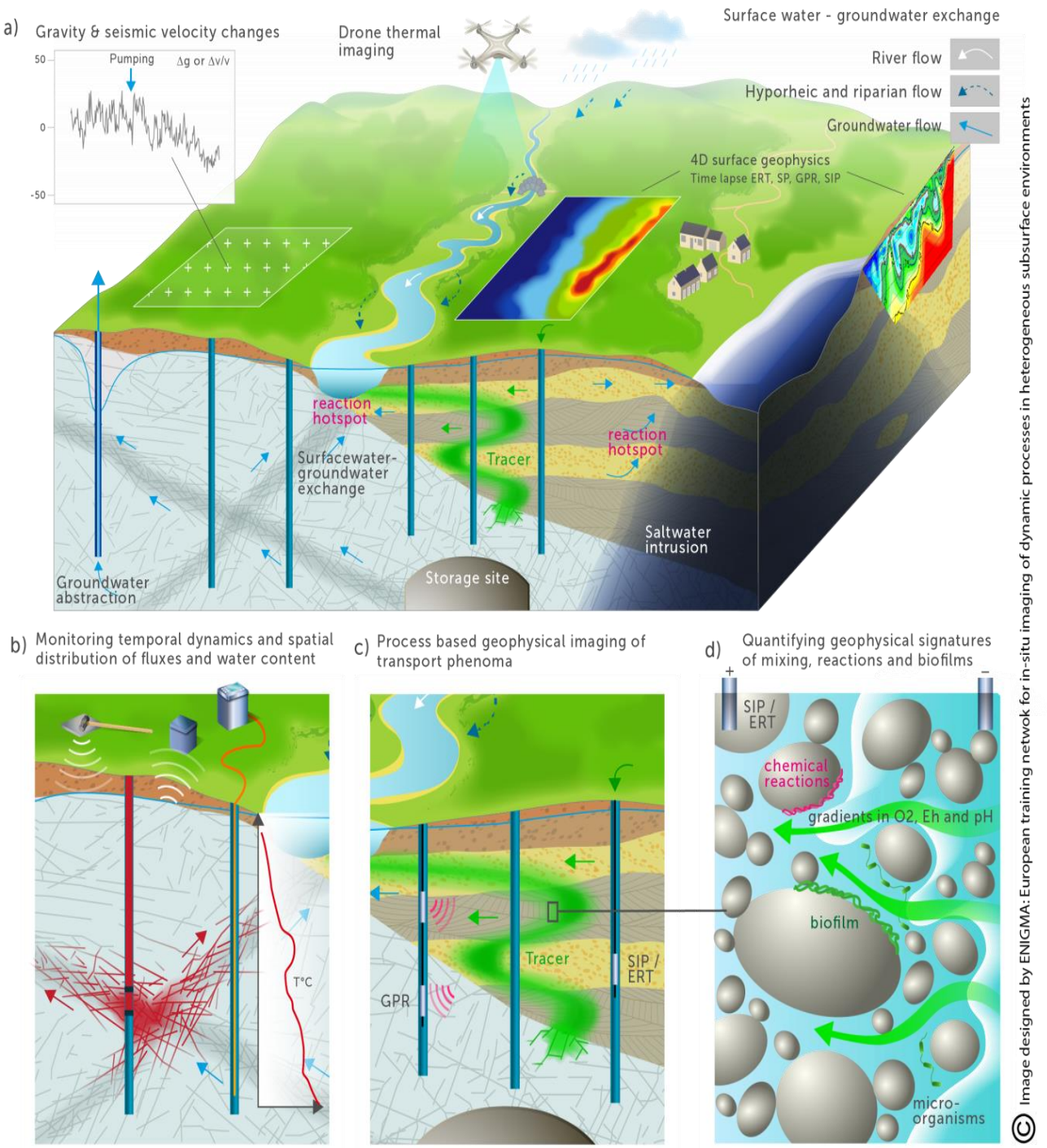
1	CSIC M. Dentz	Mixing and reactions in saline-freshwater systems	**Llobregat-Argentona**: reactive tracer tests in the saline freshwater mixing zone
2	UFZ J. Fleckenstein	Flow and reactions in stream-riparian zone systems	**TERENO Selke**: imaging methods for quantifying flow and reaction in riparian zone **River Emme**: same in a pre-alpine context
3	UNINE P. Brunner	Flow and transport in hyporheic-meander systems	**River Emme** and **TERENO Selke**: application of imaging methods for quantifying flow and reaction in riparian zone
4	ITASCA C. Darcel	Flow and transport in fracture networks	**Äspö hard rock laboratory**: GPR imaging of tracer motion in fracture networks
5	CNRS L. Longuevergne L. Bodet	Passive and active seismic imaging of water content distributions	**H+ Ploemeur**: fractured media flow **Krauthausen** heterogeneous porous media flow **H+ LSBB**: thick unsaturated zone, extreme rainfall
6	CNRS O. Bour	Active fiber-optic DTS for imaging subsurface flow distributions	**H+ Ploemeur**: fractured media flow **Llobregat-Argentona**: saline intrusion flow **TERENO Selke**, **Hermalle**: hyporheic exchange
7	UCPH K. Jensen	Multi-scale thermal imaging of groundwater upwelling	**HOBE**: test and validation of the method **TERENO Selke**, **river Emme**: application in different geomorphological contexts
8	µQS O. Desruelle/ C. Champollion	Absolute gravimeter for monitoring water content distribution	**H+ Larzac, H+ LSBB**: test and validation by comparison with fixed supraconductor gravimeter in karstic aquifers **HOBE**: comparison with soil moisture data

15 ESR – PhD positions -

9	UNIL N. Linde	Geophysical signatures of spreading and mixing	Primarily lab experiments and if possible field testing at the **Llobregat-Argentona site**
10	FZJ J. Van der Kruk	GPR full-waveform inversion for high resolution imaging of transport processes	**Krauthausen**: imaging mixing fronts in tracer tests **H+** Ploemeur: fractured rock imaging **HOBE** : imaging mixing fronts in tracer tests **Lauswiesen**: image structural properties
11	ULG A. Dassargues J. C. Maréchal	Joint heat and solute tracer test inversion for imaging preferential pathways	**Hermalle**: heat and solute tracer tests in alluvial aquifer **H+ Hyderabad**: idem in a fractured aquifer under overexploitation
12	FZJ S. Huisman D. Jougnot	SIP monitoring for quantifying biochemical reactions	Primarily lab experiments and subsequent validation at **H+ Ploemeur** site
13	UT O. Cirpka	Fully coupled hydrogeophysical inversion of 3D tracer tomography	**Lauswiesen**: methodology validation **Krauthausen**, **Hermalle**: alluvial aquifer imaging **TERENO Selke**: stream and groundwater mixing
14	CSIC J. Carrera	Geologically constrained joint inversion of hydraulic, tracer and ERT data for process imaging	**HOBE**: validation of the inversion methodology **Llobregat-Argentona**: application in saline intrusion context
15	ULG F. Nguyen	Integration of dynamical hydrogeophysical data in a multiple-point geostatistical framework	**Hermalle**: validation of the methodology **Llobregat-Argentona**: application in a saline intrusion context **River Emme:** application in a surface-water groundwater exchange context

ITN Enigma

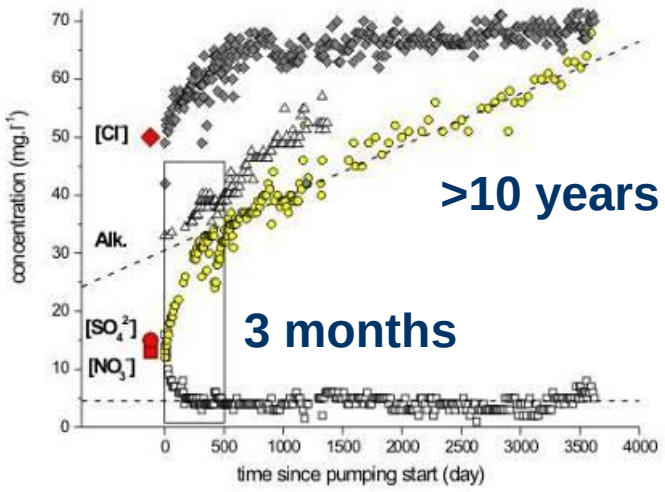
European training **N**etwork for **I**n situ ima**G**ing of dyna**M**ic processes in heterogeneous subsurf**A**ce environments



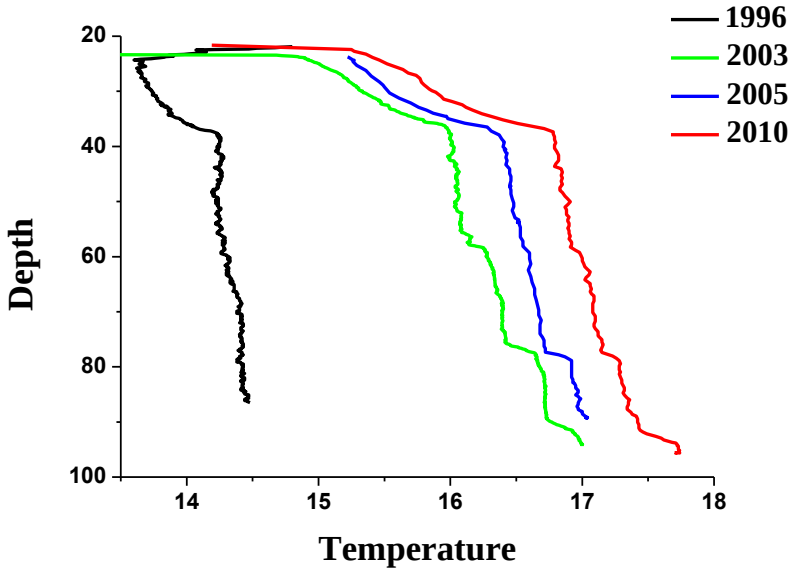
Long term monitoring

Residence times of water and elements

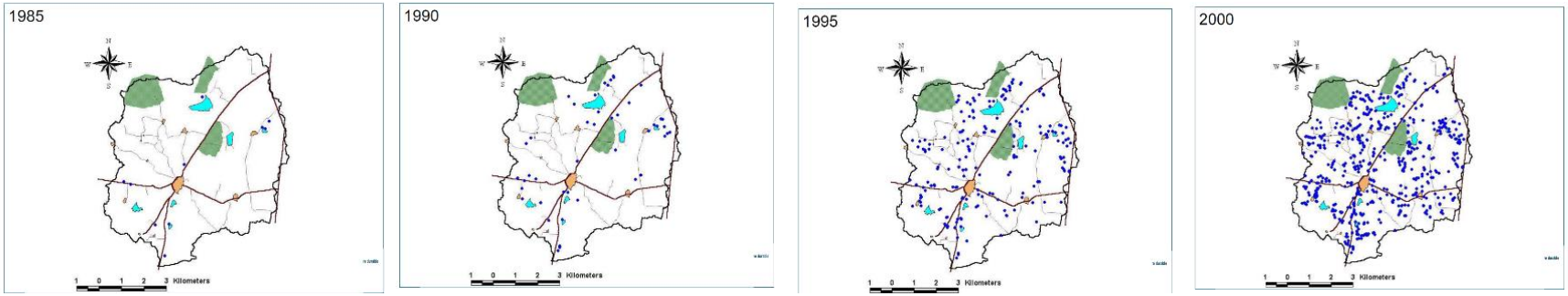
- Chemistry



Groundwater temperature



Changes in groundwater management



Scientific instruments and experimentation

- **Sharing**

  Instruments and savoir-faire

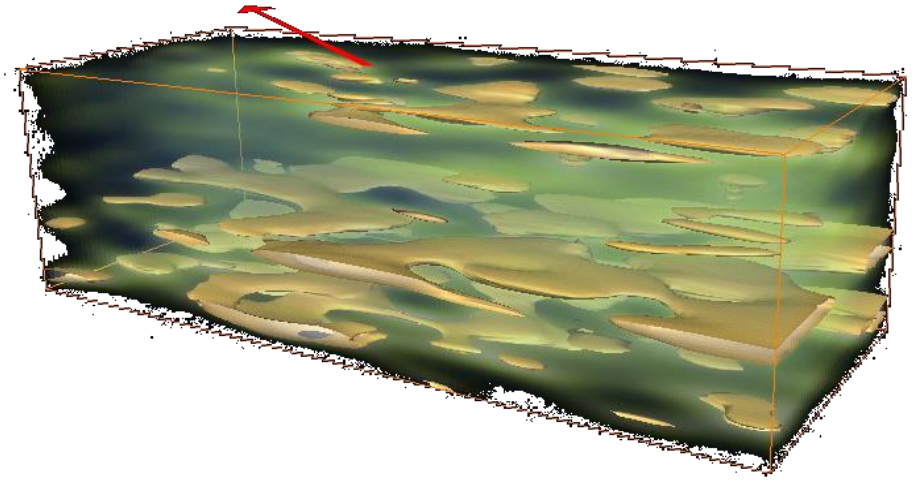
- **Developing**

  Measure new parameters

  Increase the resolution of measurements

  Increase the measure coverage

Imaging flow structures



Performing controlled tracer tests