MICAS
Modelling and Intensive Computation for Aquifer Simulations

ANR-CIS Project

Kick-off meeting

INRIA Rennes

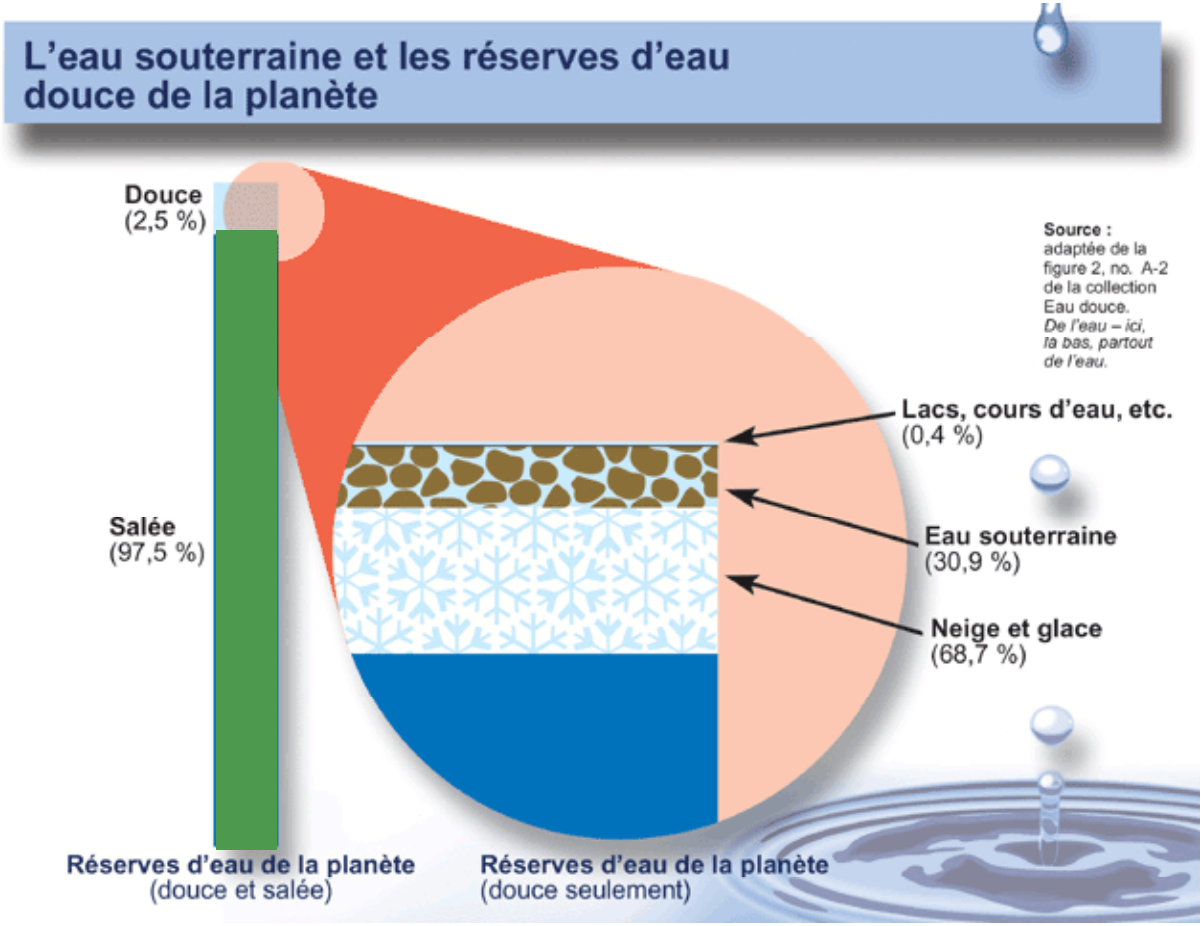
January 30th – February 1st

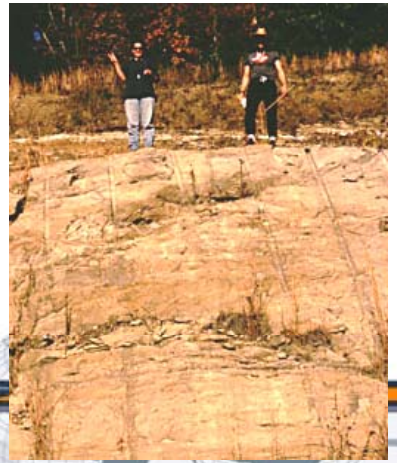
Jocelyne Erhel

Surface water and groundwater

©Yves Chaux

L'eau souterraine et les réserves d'eau douce de la planète





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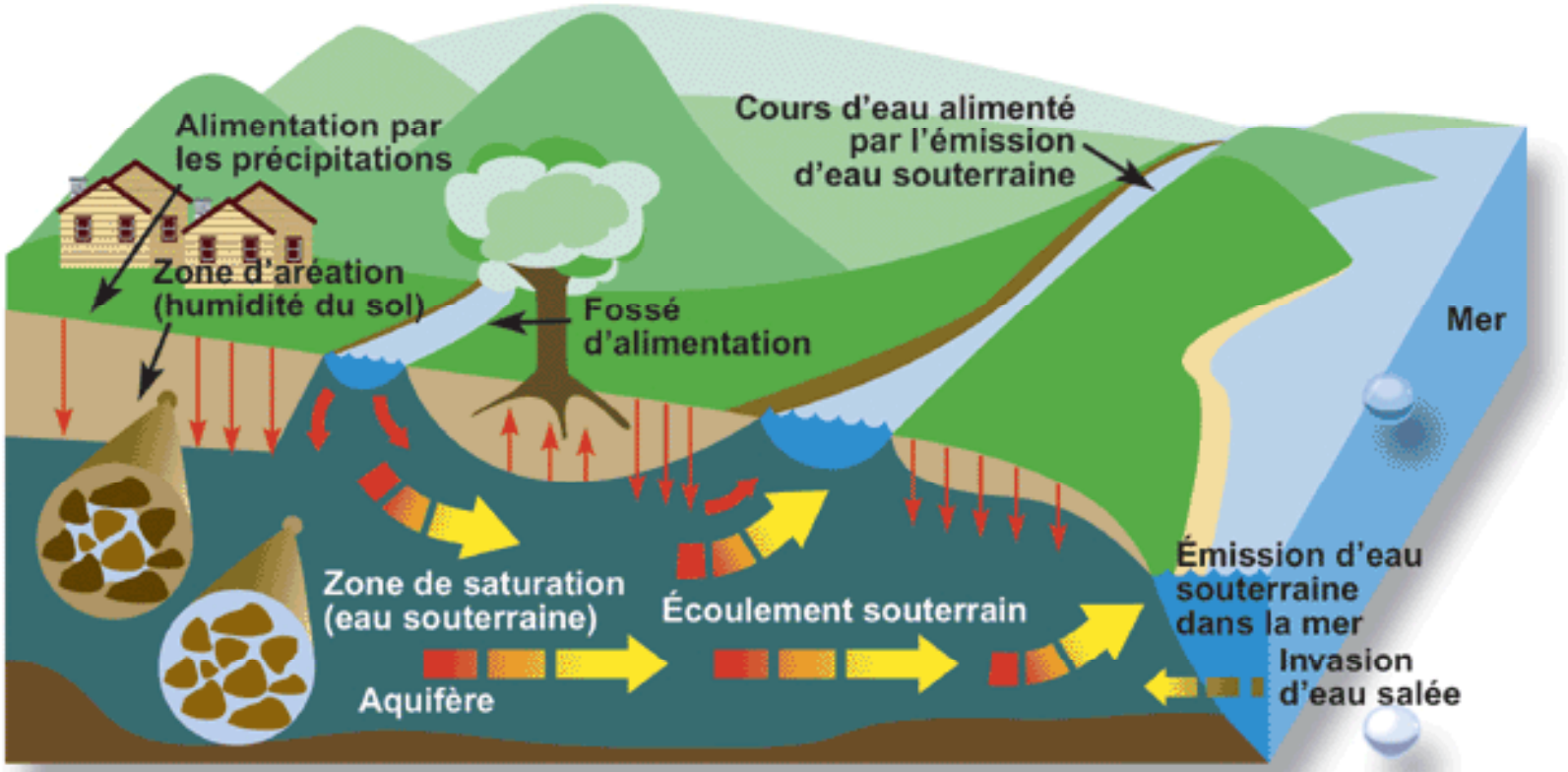
Écoulement de l'eau souterraine



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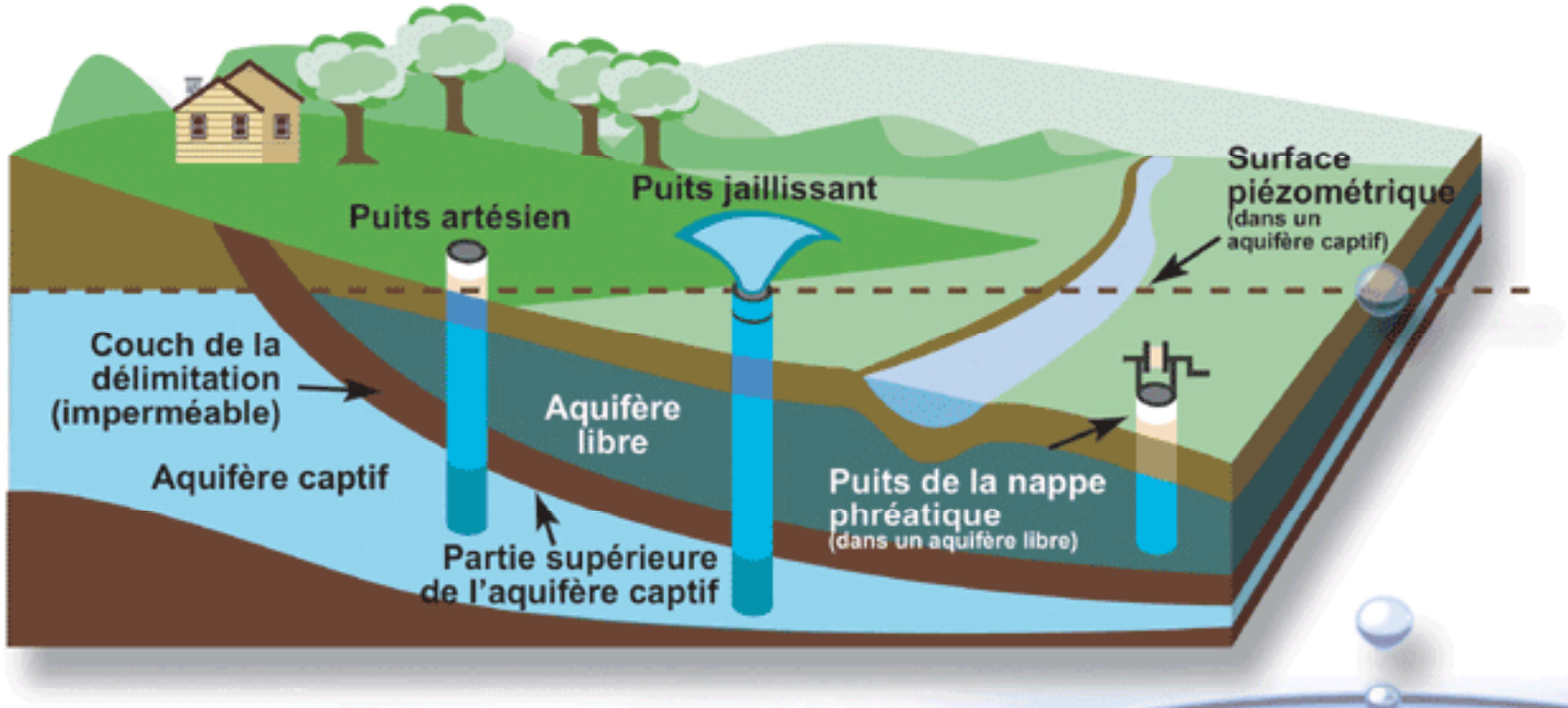
Aquifères et puits



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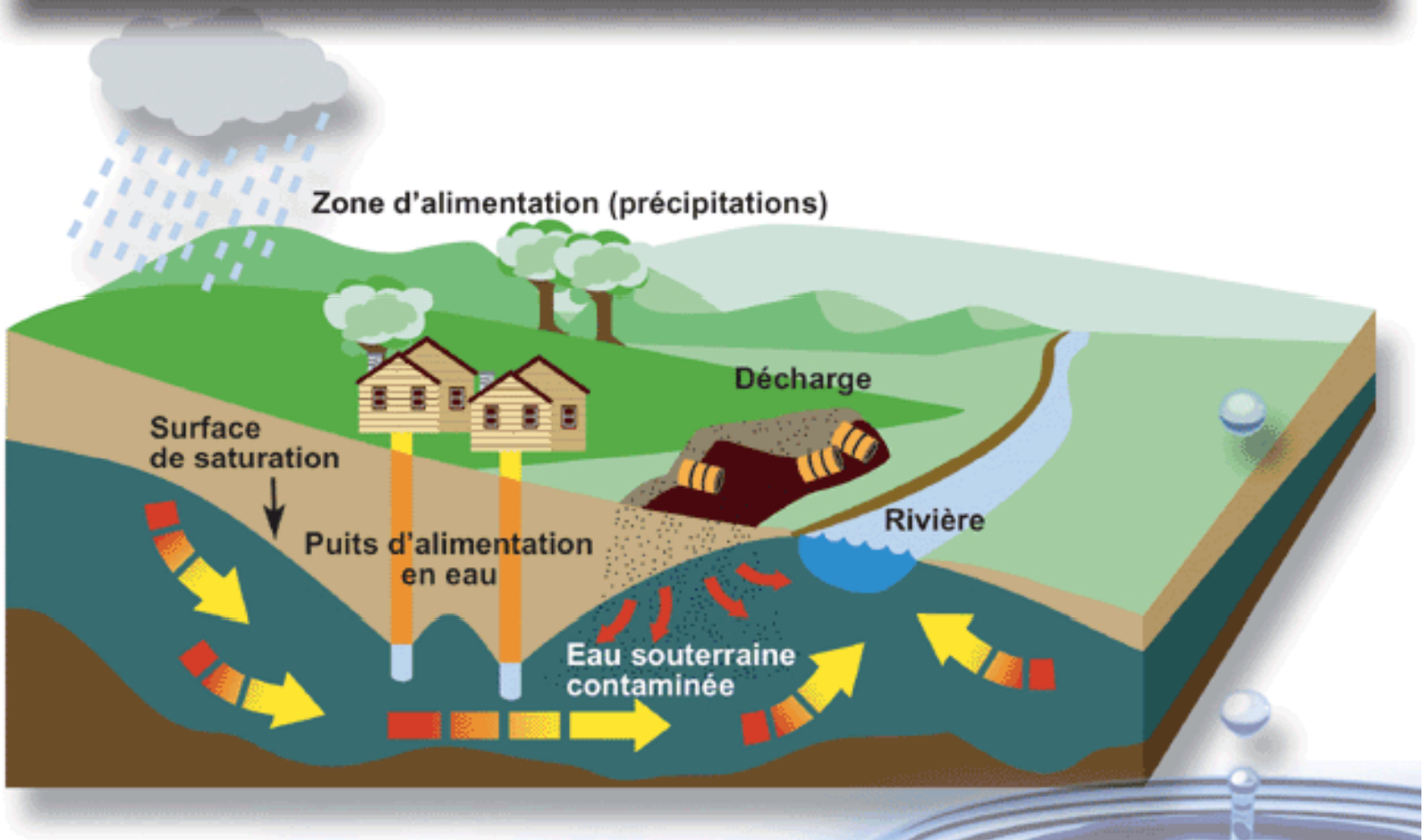
Contamination des eaux souterraines par un décharge



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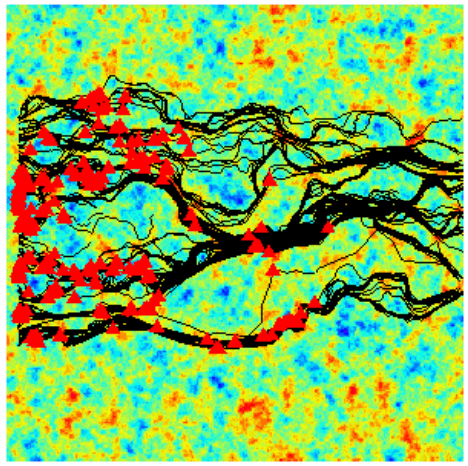
Groundwater numerical models

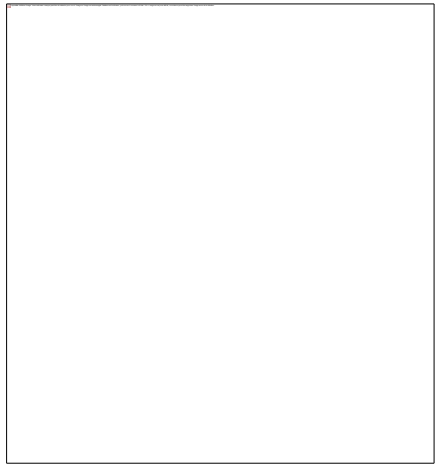
- **Understand physical phenomena**
- **Manage water resources**
- **Prevent risks of pollution**
- **Help in remediation**

MICAS project: summary

Understand physical phenomena

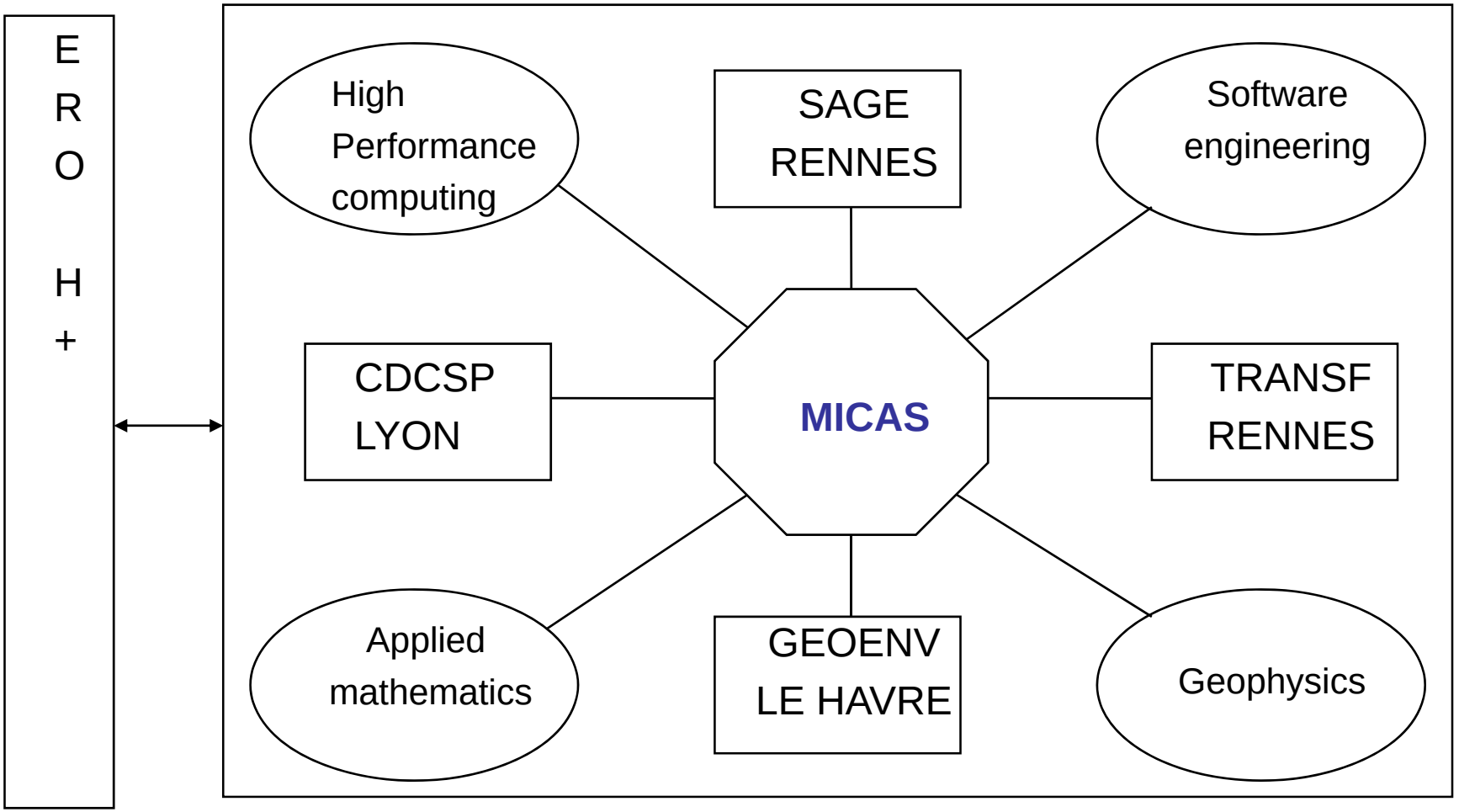
Heterogeneity and lack of data





- 7 great challenges in hydrogeology
- A scientific software platform

MICAS project: partners

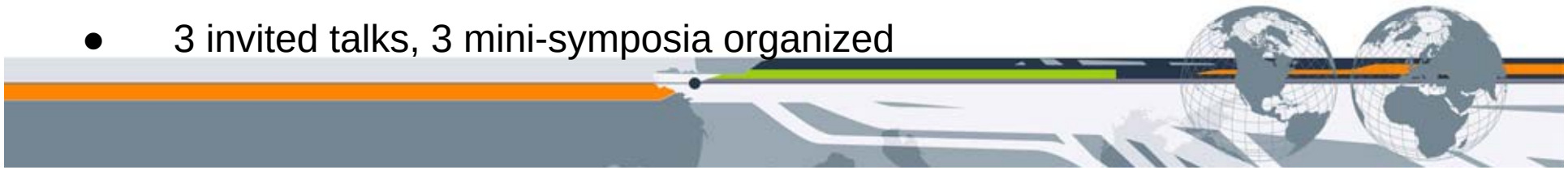


MICAS project: history

- Ph-D of J-R. de Dreuzy, 1999
- Ph-D of H. Mustapha, 2005
- Post-doc of A. Beaudoin, september 2004 to august 2005
- Secondment of D. Tromeur-Dervout, september 2005 to august 2006
- Junior engineer E. Bresciani, october 2006 to january 2008

- Grants from ACI GRID: Hydrogrid, 2002-2005 ; Grid'5000, 2004-2007
- Grant BQR from U. of Rennes 1: Geolog, 2006
- Grant from ANR CIS: Micas, 2008-2011

- Co-authored publications 2003-2007 :
- 3 papers in journals, 7 proceedings of conferences,
- 3 invited talks, 3 mini-symposia organized



MICAS project: tasks

1. Macro-dispersion in 3D heterogeneous porous media
2. Steady flow in 3D Discrete Fracture Networks (DFN)
3. Well test interpretation in 2D and 3D heterogeneous porous media and in DFN
4. Flow in 2D and 3D fractured porous media
5. Large scale multilevel sparse linear solvers
6. Stochastic models and algorithms for dealing with lack of observation
7. Deployment of multi-parametric simulations on a computational grid
8. Development of a scientific software platform
9. Flow solvers for 3D fractured porous media
10. Parametrization and inverse problems

Micas project: management (1/2)

T1. Macro-dispersion in 3D heterogeneous porous media

Post-doc, 18 months, at Geoenv

T2. Steady flow in 3D Discrete Fracture Networks (DFN)

Post-doc, 18 months, MICAS, at Transf, Géraldine Pichot

T3. Well test interpretation in 2D and 3D heterogeneous porous media and in DFN

Post-doc, 18 months, INRIA, at Sage

T4. Flow in 2D and 3D fractured porous media

Thesis, 36 months, at Geosciences, Delphine Roubinet

T5. Large scale multilevel sparse linear solvers

Thesis, 36 months, at CDCSP

T6. Stochastic models and algorithms

Thesis, 36 months, at Sage, with ENS-Cachan/Ker Lann

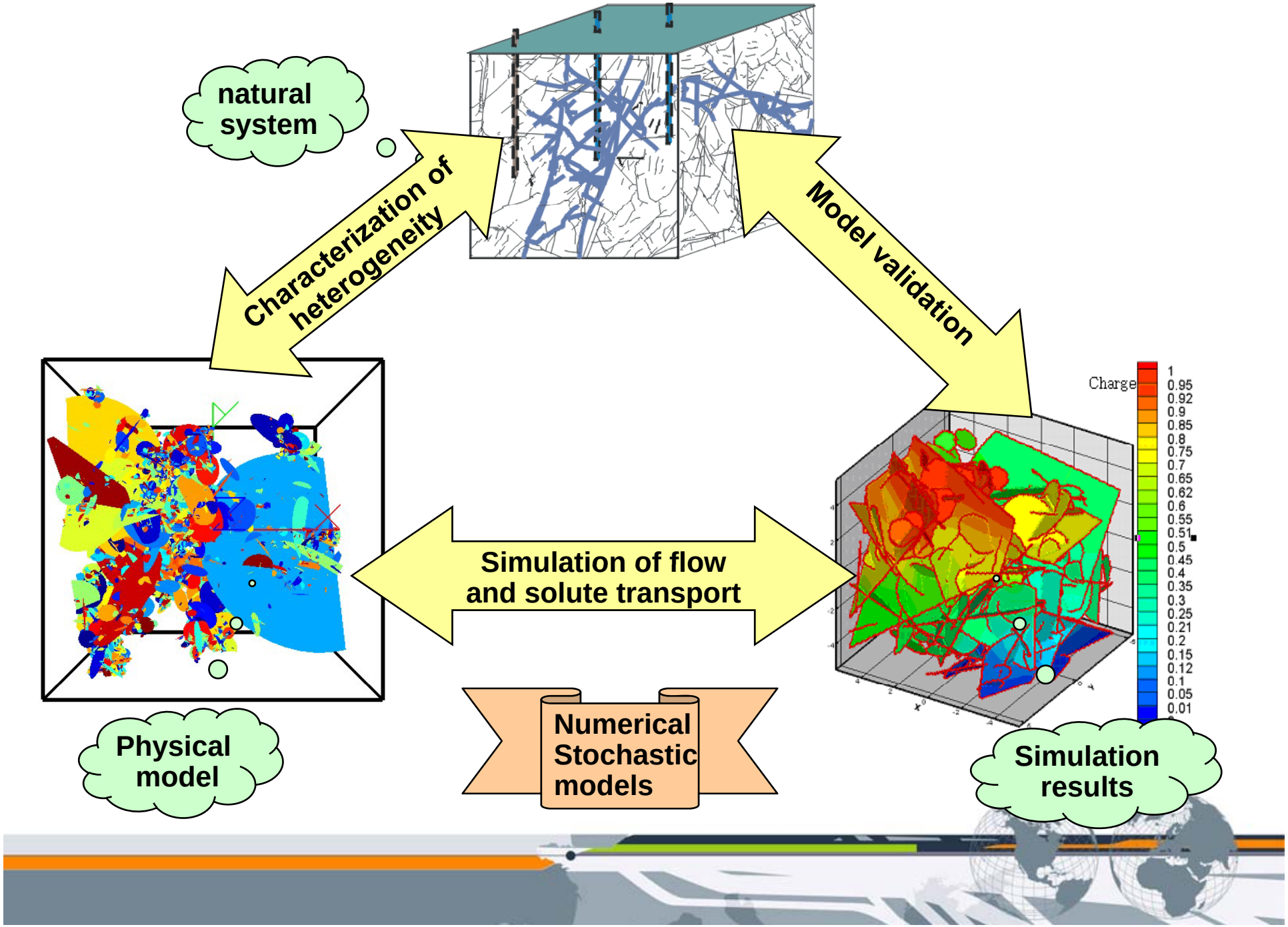
MICAS project : management (2/2)

T7. Deployment of multi-parametric simulations on a computational grid
Engineer, 5 months, INRIA, at Sage, 09/2007-01/2008, Etienne Bresciani
T8. Development of a scientific software platform
Engineer, 12 months, INRIA, at Sage, Etienne Bresciani
Engineer, 36 months, at Sage

T9. Flow solvers for 3D fractured porous media
Thesis, 36 months, MESR, at Sage, Baptiste Poirriez
T10. Parametrization and inverse problems
Thesis, 36 months, CNRS, at Transf, Romain Le Goc

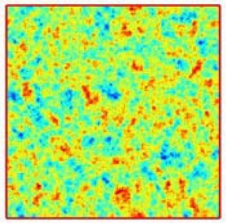
MICAS project : planning

Task	TO	TO+6	TO+12	TO+18	TO+24	TO+30	TO+36	TO+42
T1								
T2								
T3								
T4								
T5								
T6								
T7								
T8								
T9								
T10								

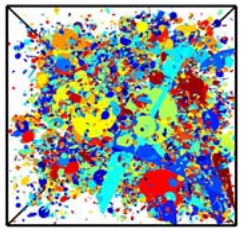

natural system
Characterization of heterogeneity
Model validation
Simulation of flow and solute transport
Physical model
Numerical Stochastic models
Simulation results
Charge
1
0.95
0.92
0.9
0.85
0.8
0.75
0.7
0.65
0.62
0.6
0.55
0.51
0.5
0.45
0.4
0.35
0.3
0.25
0.21
0.2
0.15
0.12
0.1
0.05
0.01

Physical models

Porous Media



Fracture Networks



Physical equations

- Steady-state or transient flow $\epsilon V = -K\nabla h, \nabla . V = 0$
- Advection-diffusion $\frac{\partial(\epsilon c)}{\partial t} + \nabla.(\epsilon c V) - \nabla.(\epsilon d \nabla c) = 0$

Numerical models

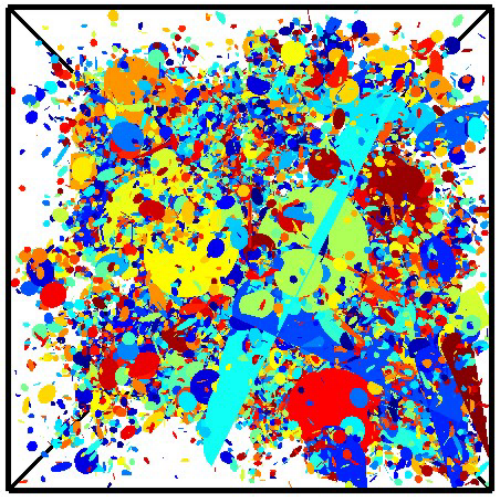
Porous geological media
fractured geological media

Spatial heterogeneity

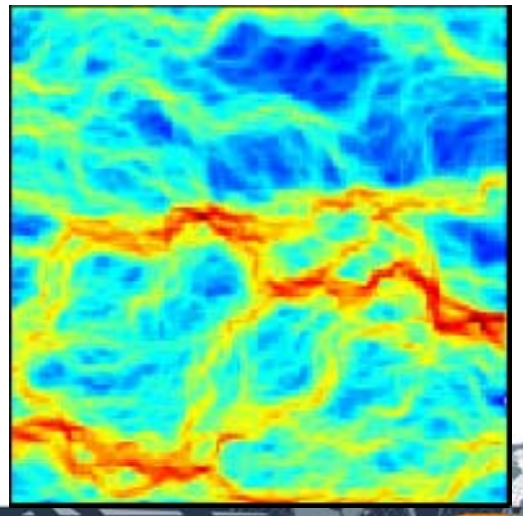
Lack of observations

Stochastic models of flow and solute transport

-random velocity field
-random solute transfer time and dispersivity

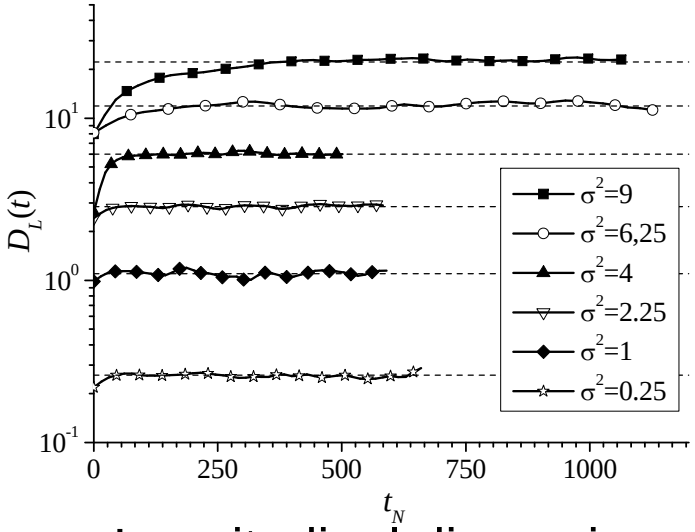


3D Discrete Fracture Network

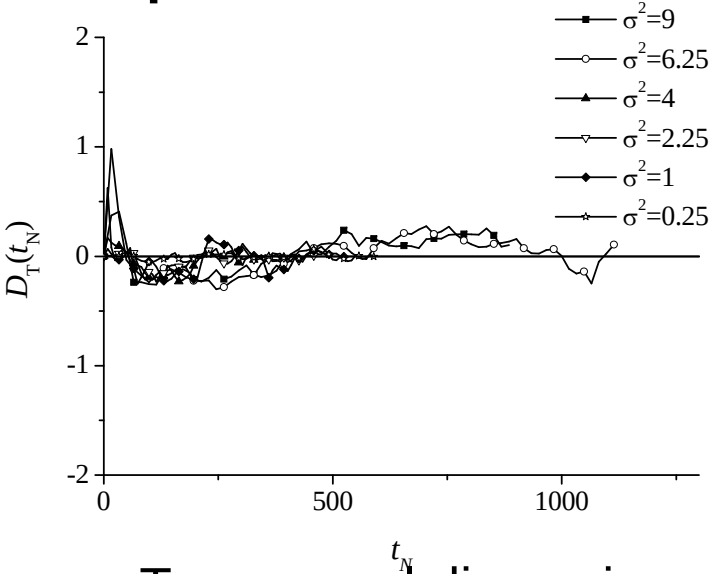


Flow in highly heterogeneous porous medium

T1: Macro-dispersion in 3D porous media



Longitudinal dispersion



Transversal dispersion

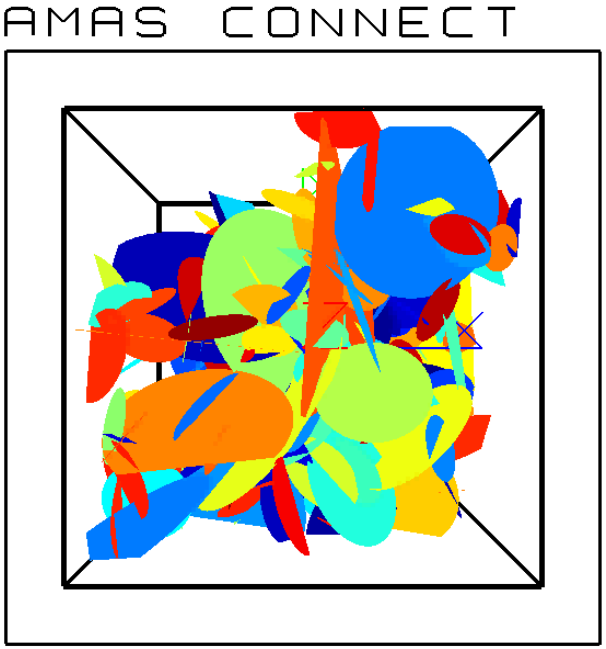
Each curve represents 100 simulations
on domains with 67.1 millions of unknowns
high performance computing is required

Challenge: switch from 2D to 3D

T2: Flow in 3D Discrete Fracture Networks

For $j=1,\ldots,N_s$

generate random discrete fracture network and permeability field

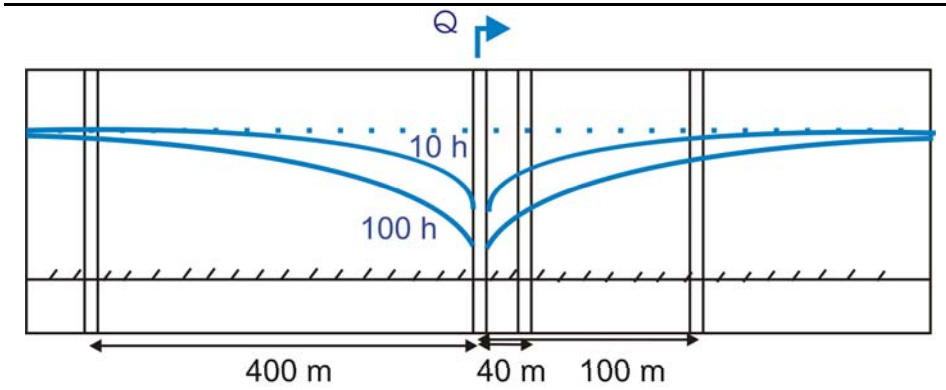


Compute $V(\omega_j,x)$ using A mixed finite element method

End For

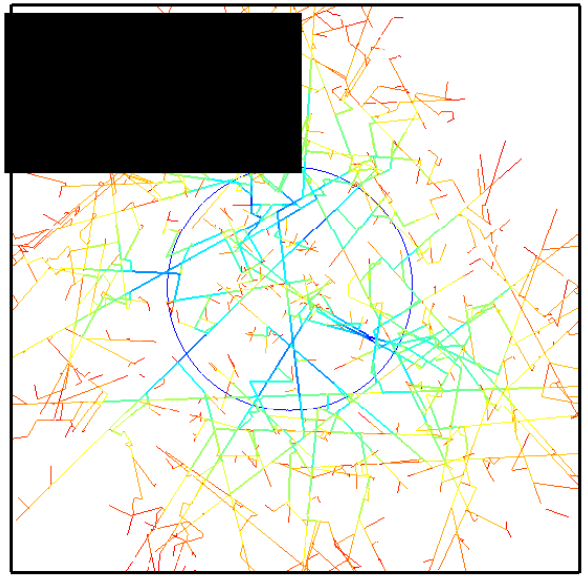
Challenge: non conformal intersections

T3: Well test interpretation



Generalized flux equation

$$S\frac{\partial h}{\partial t} = \frac{T}{r^{D-1}}\frac{\partial}{\partial r}\left(r^{D-1-(d_w-2)}\frac{\partial h}{\partial r}\right)$$



Challenge: relation between drawdown and physical model

Challenge: large scale transient simulations

T4: Porous Fractured media

Challenge: coupling porous and fractured models

T5: multilevel methods

Clusters at Irisa

Grid'5000

project

Numerical model

Funded by ACI GRID

and Brittany council

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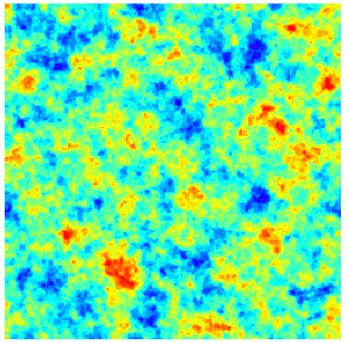
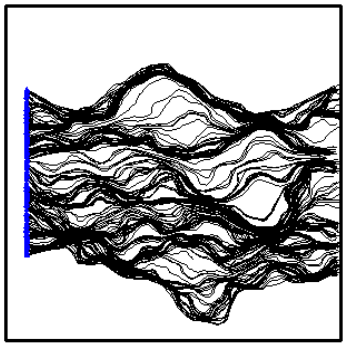
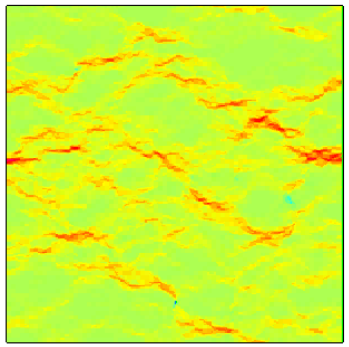


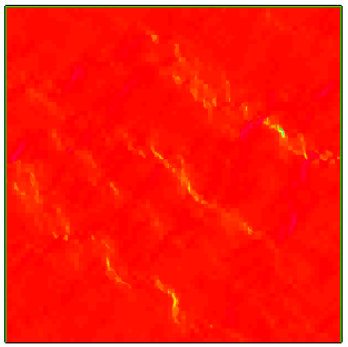


16,8 millions of unknowns

in 100 seconds

with 16 processors





Challenge: 16 billions of unknowns

T6: Uncertainty Quantification methods

Challenge: non intrusive methods for random data and random domains

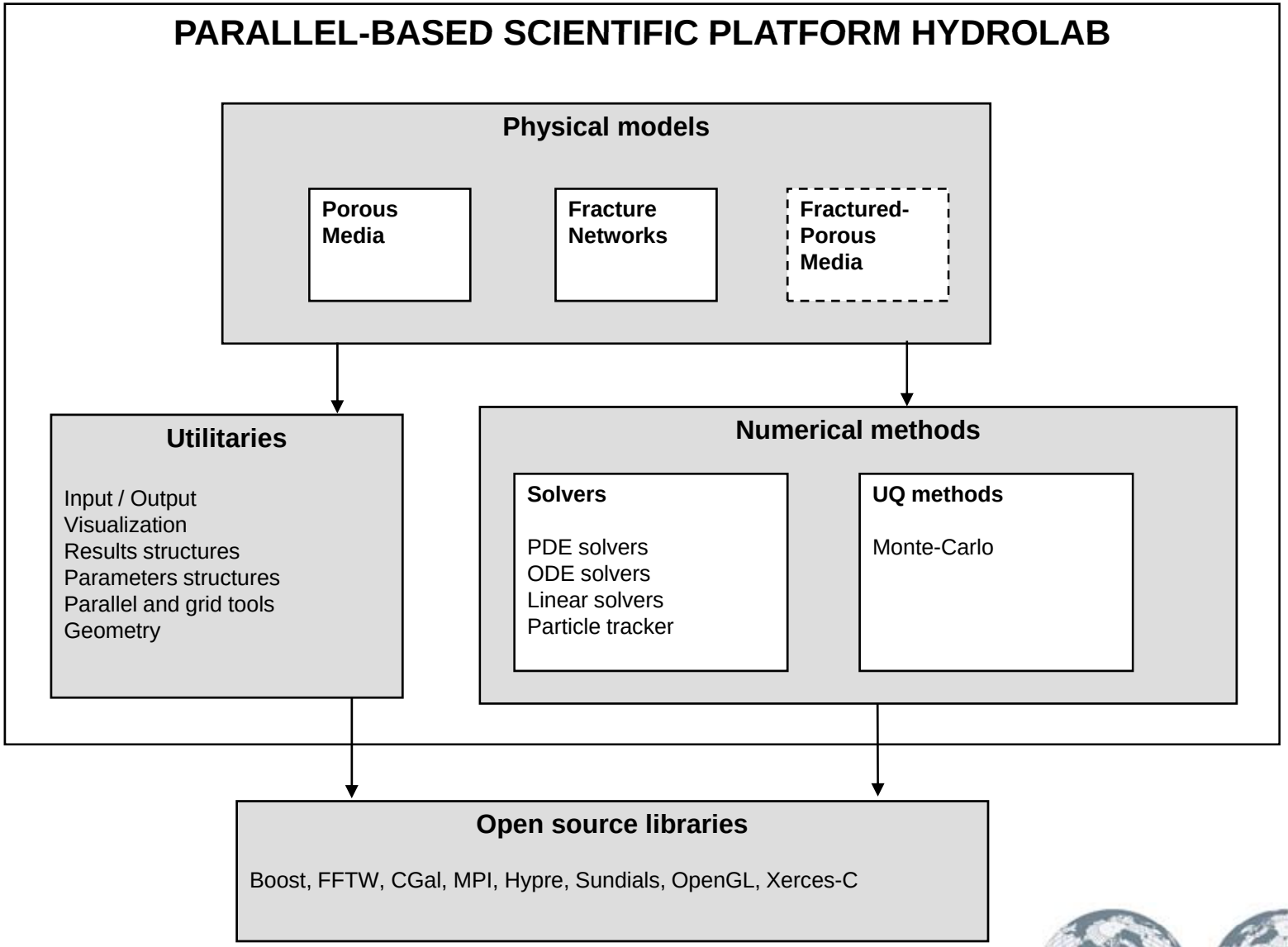
T7: Multiparametric simulations on grids

Efficient tools for parametric studies

- Automatic generation of parametric studies
  - Parameters files
  - Running batch
- Automatic crossing of several executions
  - Results files

Challenge: using several clusters in a grid

T8: scientific platform Hydrolab



T8: scientific platform Hydrolab

- Object-oriented and modular with C++
- Parallel algorithms with MPI
- Efficient numerical libraries

Objective: management of the software
Objective: web portal Hydroweb and database Hydrodata

Excepted results

- Publications in top journals and proceedings
- Breakthroughs in hydrogeology
- Achievements in high performance computing
- Original numerical methods
- Generic software platform