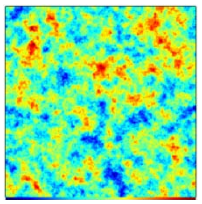
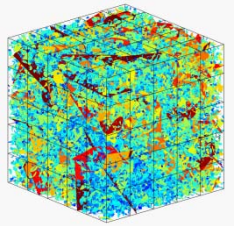


H2OLAB: object-oriented software for heterogeneous hydrogeology



N. Soualem, team SAGE (engineer, 2008, 36 months)

E. Bresciani, team SAGE (engineer, 2008, 3 months)

G. Pichot, team TRANSF (post-doc, 2008, 18 months)

B. Poirriez, team SAGE (Ph-D, 2007)

D. Roubinet, team TRANSF (Ph-D, 2008)

A. Beaudoin, team LMPG

D. Tromeur-Dervout, team CDCSP

T. Le Borgne, team TRANSF

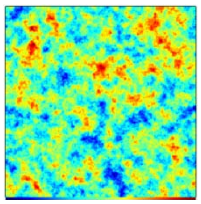
J-R. de Dreuzy, team TRANSF

E. Canot, team SAGE

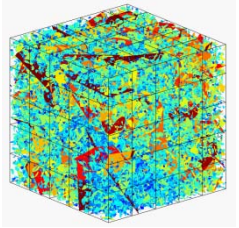
J. Erhel, team SAGE

E. Bresciani, team TRANSF (Ph-D, ANR Mohini, 2008)

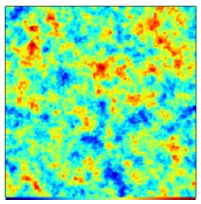
R. Le Goc, team TRANSF (Ph-D, CNRS, 2007)



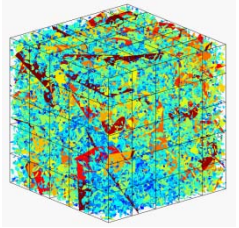
H2OLAB
Other existing platforms



- **FEFLOW** (SWS)
  - Finite elements, complex-coupled physical phenomena
  - Commercial, non modifiable
- **MODFLOW** (USGS)
  - Finite differences, numerous modules (rivers,…)
  - Field simulations
- **TOUGH, TOUGH-REACT, iTOUGH** (LBNL)
  - Field simulations and theoretical studies, parallel
- **IPARS** (Austin U., M. Wheeler, T. Arbogast)
  - Parallel simulation of multiphase flow in porous media
- **UG** (Heidelberg, P. Bastian, G. Wittum)
  - Large complex domains, parallel, PDE
- **CSIC** (Barcelona, J. Carrera)
  - Coupled models and inverse problems in porous media
- **UFZ** (Leipzig, O. Kolditz)
  - Field and theoretical studies, parallel



Originalities of H2OLAB



- Heterogeneous models

3D porous and fractured media

- Stochastic models

Monte-Carlo and non intrusive methods

- High performance computing

Distributed and grid computing

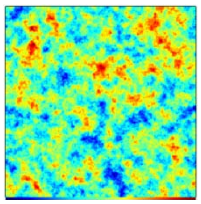
- Numerical methods

Public-domain libraries and specific algorithms

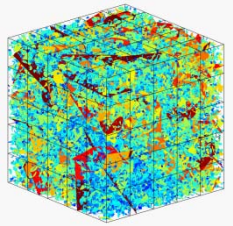
- Software component approach

Encapsulated objects

- Currently, few spatial discretizations
- Currently, few coupled models



Architecture



PARALLEL-BASED SCIENTIFIC PLATFORM H2OLAB

Geological observations and models

Geometrical models and hydraulic properties

- **Porous Media**
- **Fractured-Porous Media**
- **Fracture Networks**

Physical phenomena
Single phase flow, transport

Utilitaries

Input / Output
Visualization
Results structures
Parameters structures
Parallel and grid tools
Geometry

Numerical methods

Solvers

PDE solvers
ODE solvers
Linear solvers

Particle methods

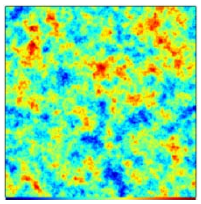
Inert transport
reactive transport

UQ methods

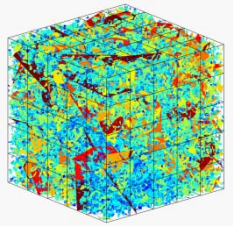
Monte-Carlo

Open source libraries

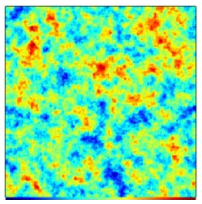
Boost, FFTW, Blas, Lapack, CGal, MPI, OpenGL, Xerces-C
Umfpack, Hypre, Mumps, Sundials



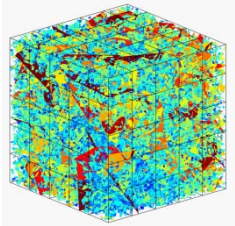
H2OLAB: methodology



- **Optimization and Efficiency**
  - Use of numerical libraries
  - Test and comparison of numerical methods
  - Parallel computation (distributed and grid computing)
- **Genericity**
  - Object-oriented programming (C++)
  - Code factorization (avoid redundancies)
  - Object and interface definition (virtual classes, public methods of classes)
- **Modularity**
  - Encapsulated components with well-identified interfaces
  - Hierarchy of packages
- **Maintenance**
  - Intensive testing
  - Documentation
- **Flexibility**
  - Development of additional components

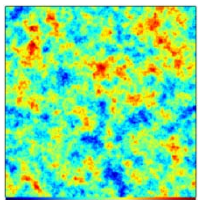


H2OLAB: collaborative development

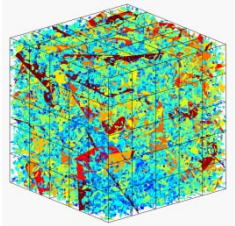


- **Management**
  - Advanced Server (Gforge)
  - Bug tracking (Gforge)
  - Documentation (Doxygen, wiki)
  - Lists and forums (Gforge, sympa)
- **Consistency**
  - Control of versions (SVN)
  - Tests (Ctest)
  - Coding rules
- **Development and portability**
  - Integrated development environments (Visual, Eclipse)
  - Cross-platform software (Cmake)

https://gforge.inria.fr/projects/hydrolab

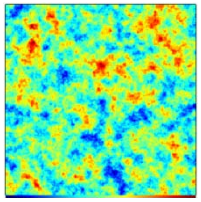


H2OLAB: data and parameters



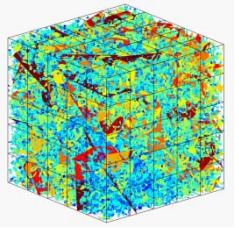
- XML format
- Friendly user interface

name	type	value	default_value	possible_values	description
simulation_general					
simulation_type					
flow_state	short		0	0=steady, 1=transient	choice of the flow simulation : steady or transient
transport	bool		1	1=activated, 0=desactivated	activate or desactivate the simulation of transport (Tracker method)
end simulation_type					

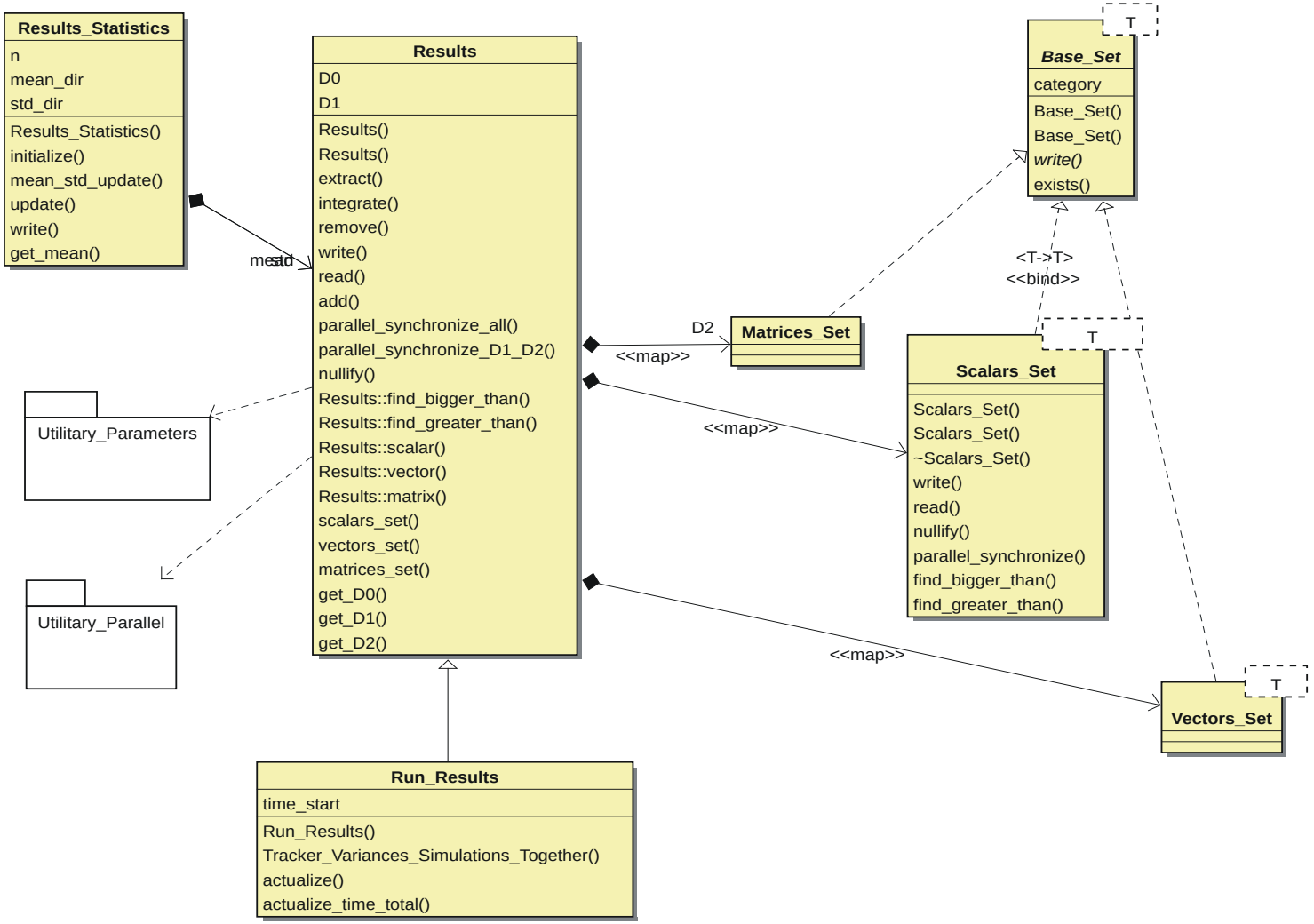


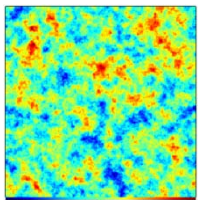
H2OLAB: results

0D, 1D, 2D results

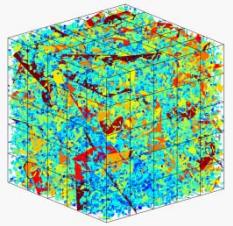


Project: Utilitary_Results

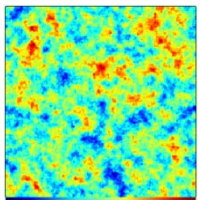




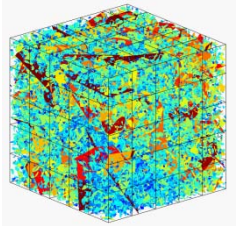
H2OLAB: documentation



- **User guides**
  - How to use the platform
  - Scientific foundations of the numerical methods
- **Technical documentation**
  - Description of the main components (UML modeling)
  - Details of the specific implementations (doxygen)
  - Description of procedures (control of version, testing)
- **Scientific documentation**
  - Articles and reports
  - Presentations



H2OLAB: testing



Objectives

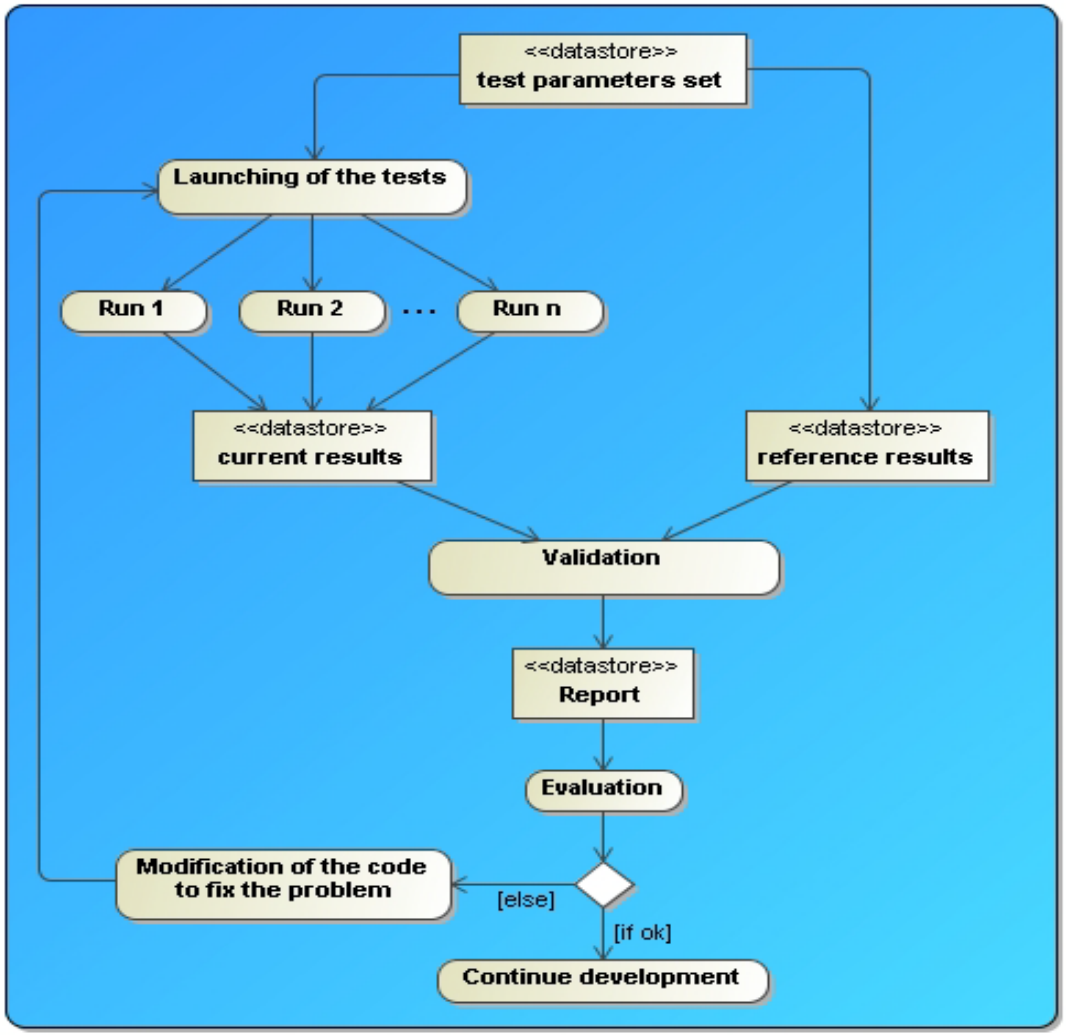
- Frequent testing
- Broadest coverage
- Automatic

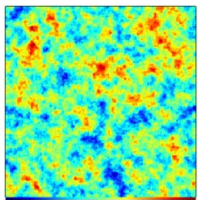
Validation tests

- Analytical solutions
- Statistical laws
- Visual inspection

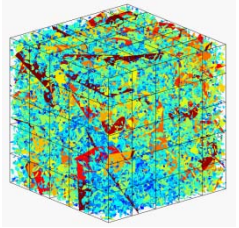
Characteristics

- Daily and automatic (ctest)

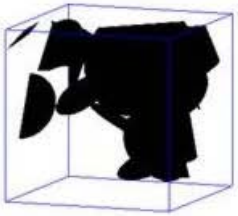
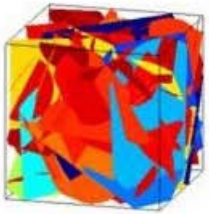
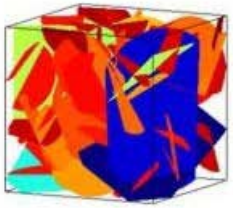
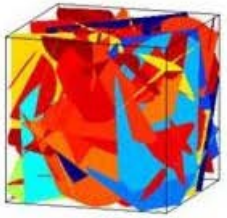
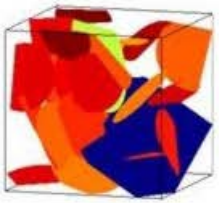
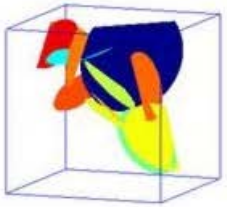
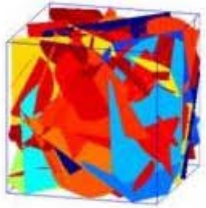
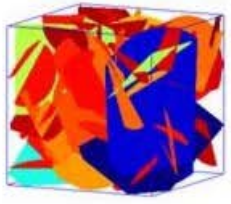
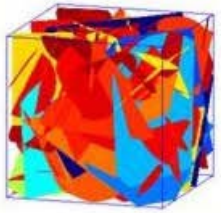


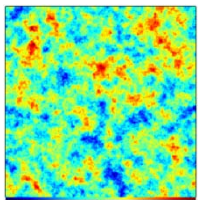


H2OLAB: visual inspection

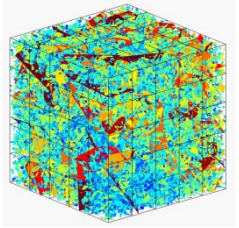


Different definition of fracture densities

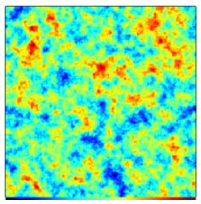
Network					
Infinite Cluster					
Parameter Value	0 (THRESHOLD)	1 (NUMBER=100)	2 (MASS DENSITY = 3)	3 (PERCOLATION P=10)	5 (20% ABOVE THRESHOLD)



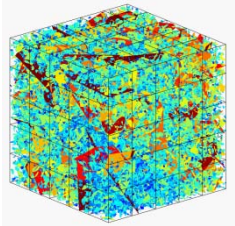
H2OLAB: perspectives



- **Tool for research in hydrogeology**
  - Influence of heterogeneity on hydraulic properties
  - Coupled problems, inverse problems
- **Collaboration with academic partners**
  - Hydromed project (INRIA-Med program): end-users, field cases
  - New project (Barcelona and Leipzig): benchmark, GUI, software components
- **Database and remote execution**
  - Efficient use of simulation results
  - Remote high performance computing
- **Software**
  - Registration of libraries



H2OLAB: Database and Interface



- Ojectives
  - Long term storage of the results
  - Efficient and convenient recovering
- Database
  - Results
  - Execution parameters
  - Metadata
- H2Oweb : database interface
  - Data uploading
  - Results selection by pertinent criteria
  - Display of the results
  - Download of the selected results

H2OLAB: remote execution