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SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

# WP3

# Innovative technologies & computational energy science

Cécile Münch & Thomas Driesner

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In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

# WP3 Innovative Agenda

Develop **technical** and **computational energy** innovations

providing concrete solutions to reach

the **energy strategy 2050** targets

for **Hydroelectricity and Geo-energies**

# Innovative technologies & computational energy science

## Key areas of research for HYDRO

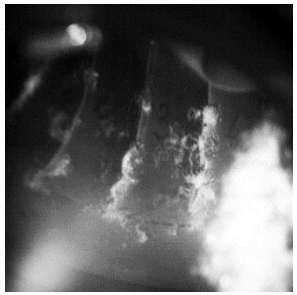
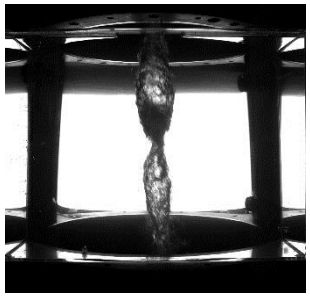
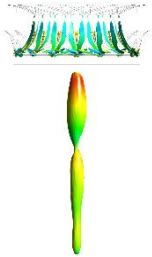
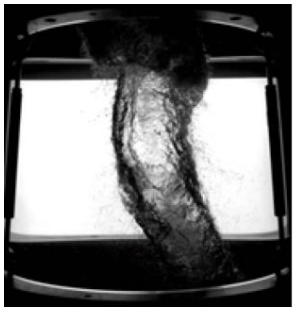
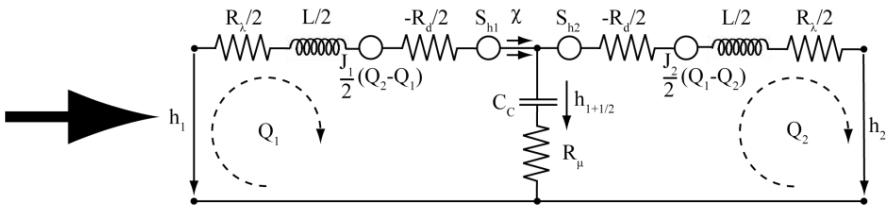
- Enhance hydropower plants flexibility
- Harvest the potential of existing infrastructure
- Modelling of silt erosion & cavitation

# Innovative technologies & computational energy science

## HYDRO

**Enhance hydropower plants flexibility**

### Expanding the operating range of hydraulic turbines and pump-turbines

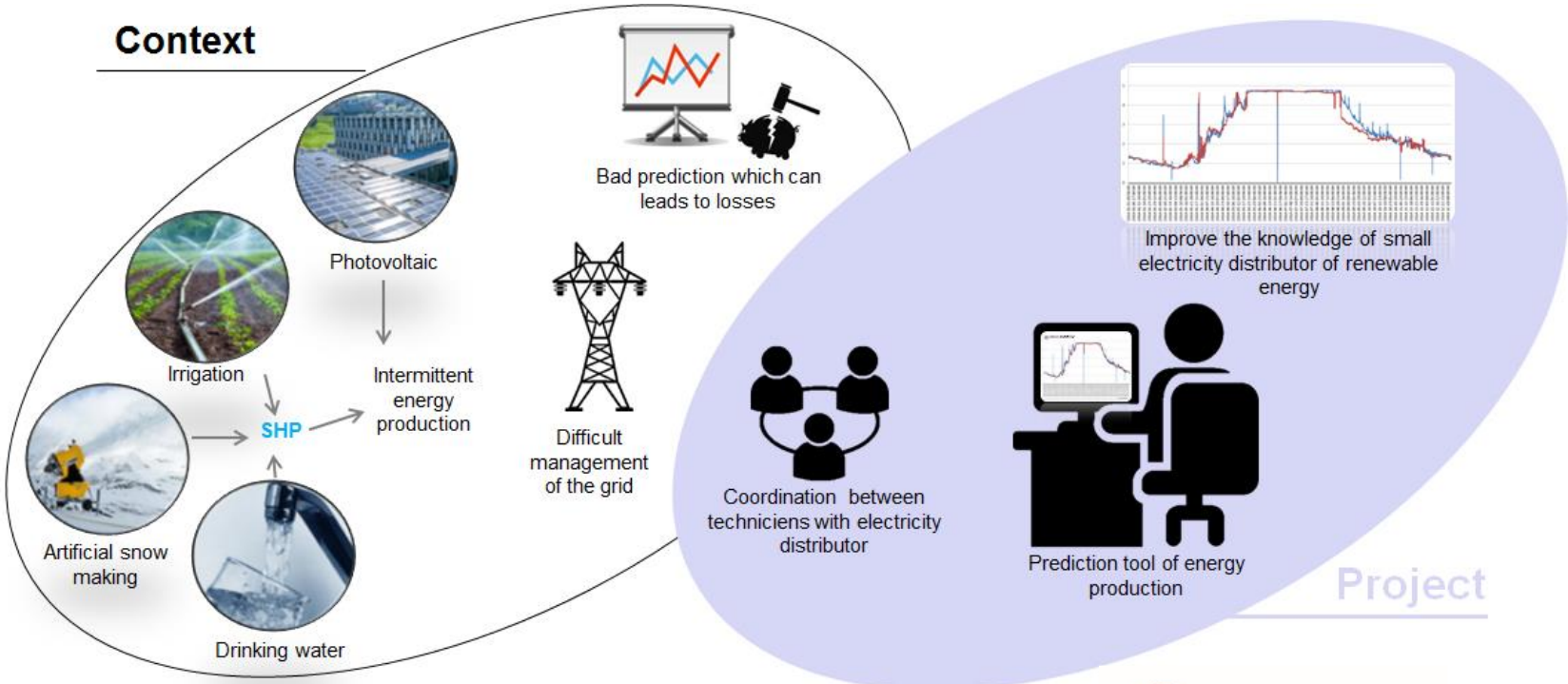

HYPERBOLE

# Innovative technologies & computational energy science

## HYDRO

**Enhance hydropower plants flexibility**

## Control and prediction of a cluster of SHPs production



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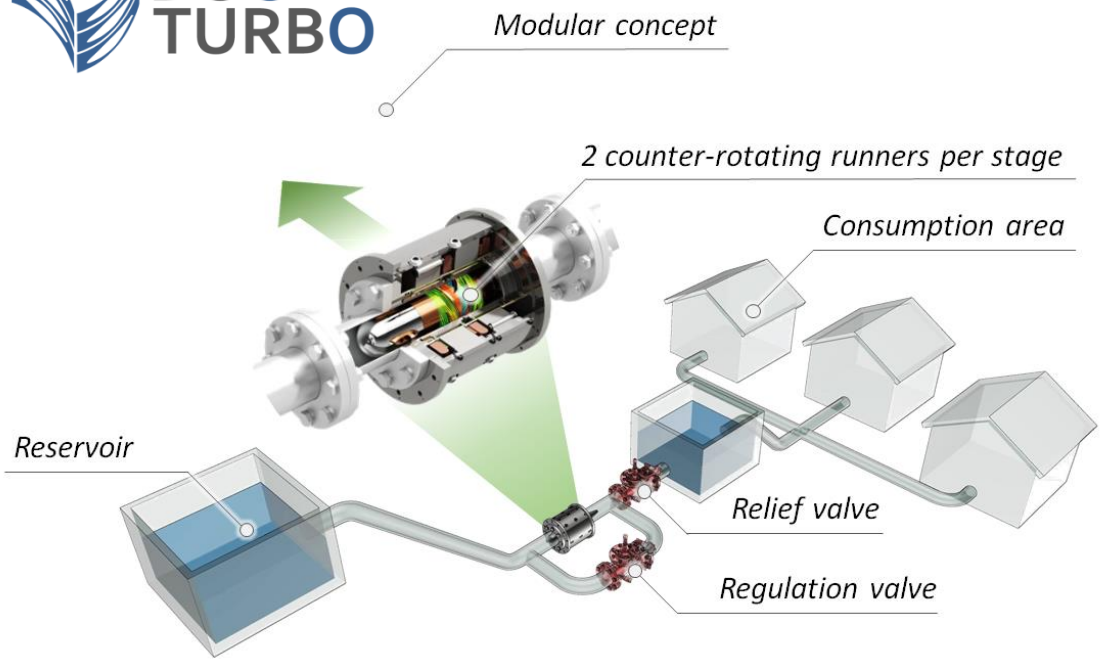
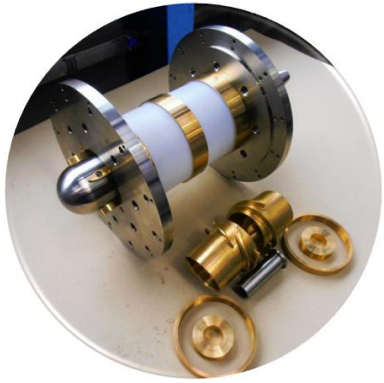
## HYDRO

**Harvest the potential of existing infrastructure**

DUO TURBO

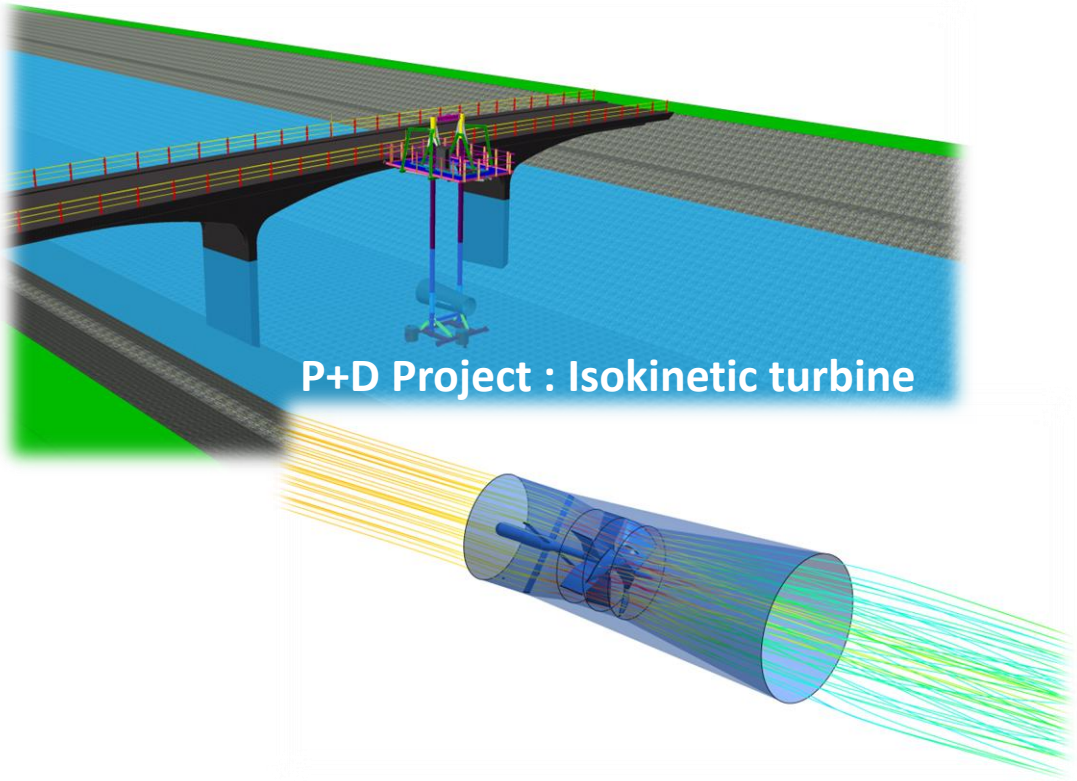


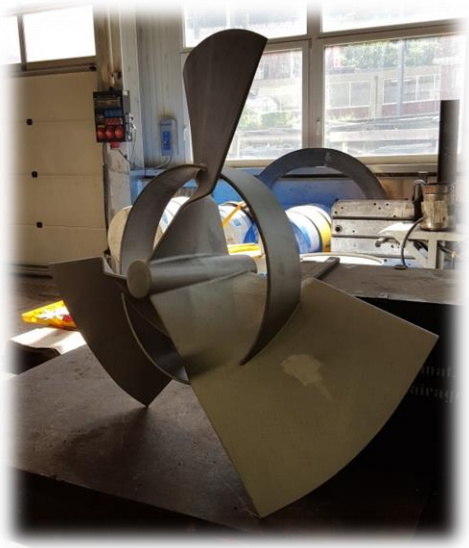



# Innovative technologies & computational energy science

## HYDRO

**Harvest the potential of existing infrastructure**



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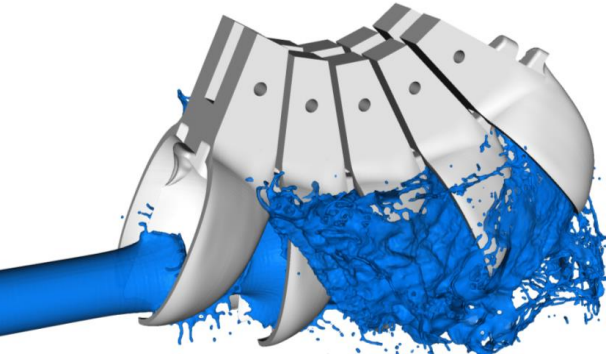
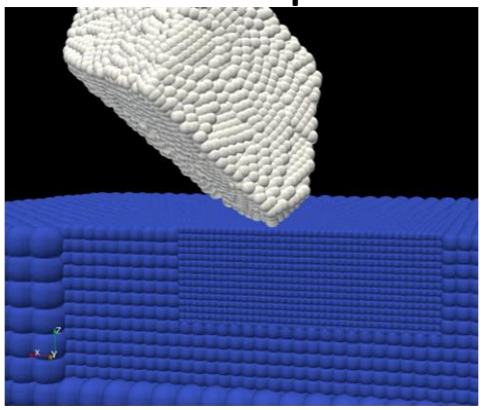
## HYDRO

**Modelling of silt erosion & cavitation**

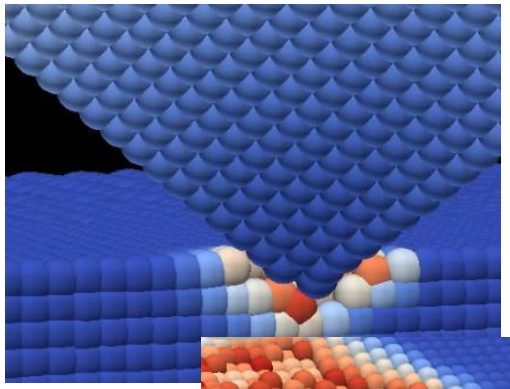
fluid flow in Pelton turbine

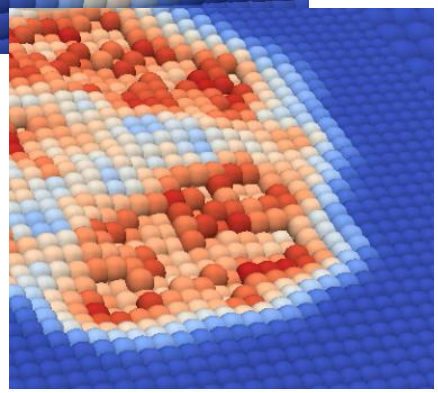


sediment transportation



contact & deformation





damage

## GPU-SPHEROS

**Erosion model includes :**

- ✓Strength and fracture models
- ✓Thermo-plasticity
- ✓Arbitrary-shaped sediments
- ✓Frictional contact

# Innovative technologies & computational energy science

## HYDRO

### Modelling of silt erosion & cavitation

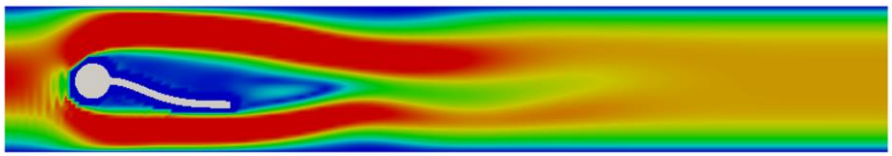
**Boundary-fitted methods**, such as the Arbitrary Lagrange Eulerian approach, can be numerically **unstable and inaccurate for large deformations due to mesh deformations**

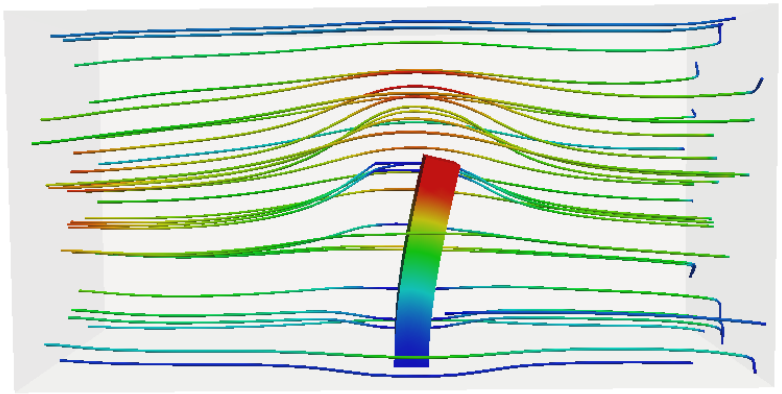
Idea: use **independent meshes** for fluid and solid - **overlapping decomposition**

Parallel **$L^2$ projection to transfer data** from the fluid to the solid mesh and viceversa

**Novel framework** by taking inspiration from **immersed boundary method** and **non-conforming domain decomposition** methods

**Coupling model** between **a Newtonian fluid** and a **Nonlinear Elastic Material**





Modeling Facility

PASC-project *AV-Flow* (Obrist, Krause)

SNF-Project *Geometry-Aware FEM in Computational Mechanics* (Hormann/Krause)

# Innovative technologies & computational energy science

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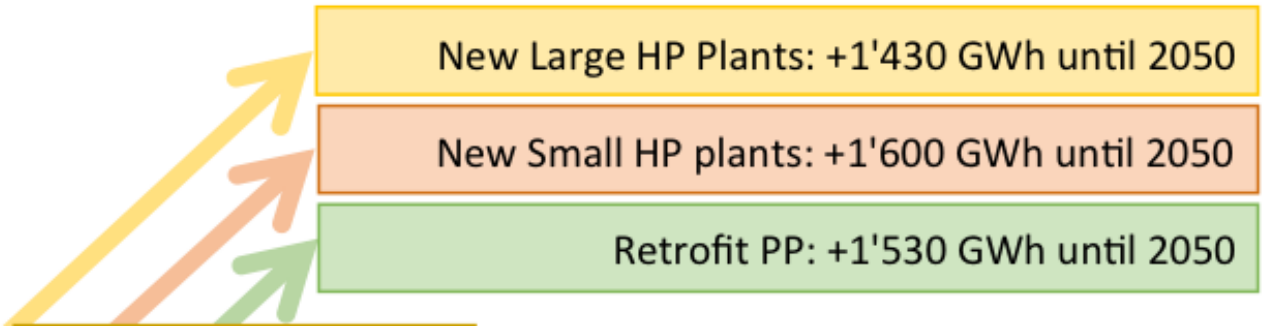
## HYDRO

**Link to the energy strategy 2050 ?**




**Enhance hydropower plants flexibility**

**Harvest the potential of existing infrastructure**

**Modelling of silt erosion & cavitation**

# Innovative technologies & computational energy science

## Key areas of research for GEO-ENERGIES

Quantitative modelling of THM(C)S processes

Control seismic risk

Optimisation of exploration and production

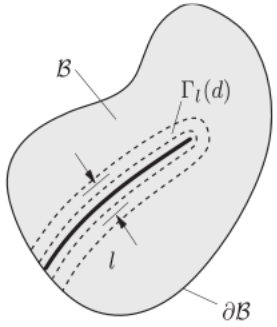
# Innovative technologies & computational energy science

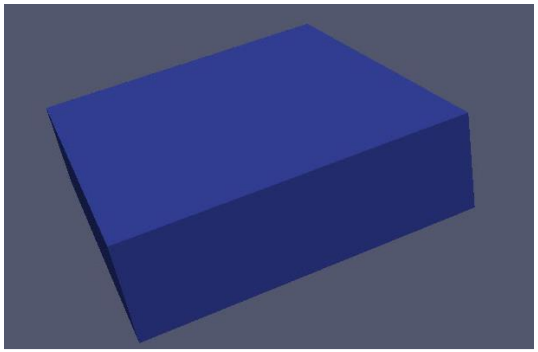
## GEO-ENERGIES

**Quantitative modelling of THM(C)S processes**

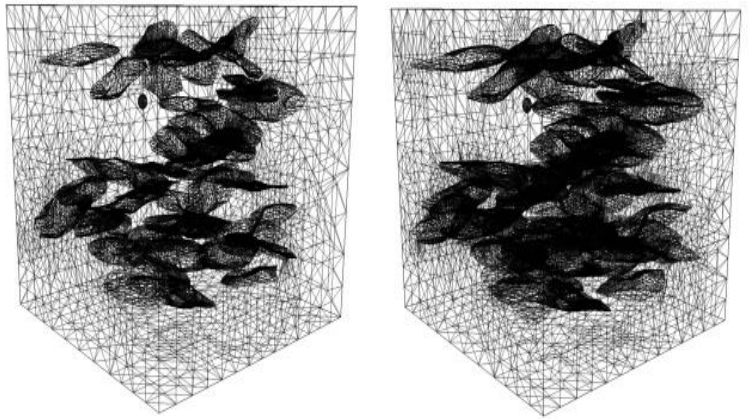
Several parallel efforts on THM(C)S in fractured reservoirs:

- Understand THM(C)S coupling
- Translate experimental results to reservoir conditions
- Evaluate optimal stimulation strategies



R. Müller et al. (USI): Phase Field Approach to Fracture



M. Nejati, ETHZ: Incremental growth of fifty interacting randomly-oriented penny-shaped cracks under uniaxial tension. Finite element.

# Innovative technologies & computational energy science

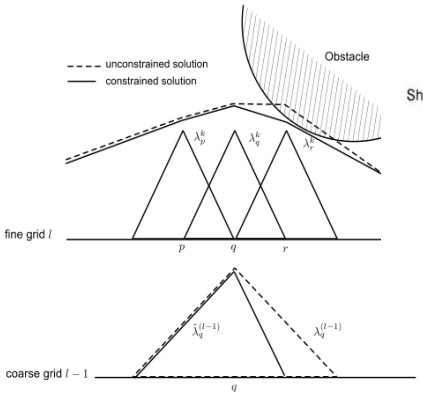
## GEO-ENERGIES

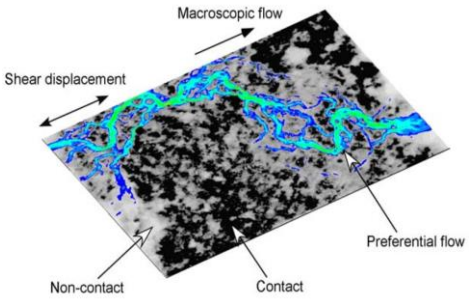
**Quantitative modelling of THM(C)S processes**

### Contact problem in fractured rocks: efficient nonlinear multigrid schemes for detection and handling of contact

C. von Planta, H. Kothari (ICS/USI), R. Krause (ICS/USI)

- Resolve contact locally in the smoother
- Truncated basis functions to deal with global influence of interface effects
- $L^2$-projection for constraints at contact interfaces
- Scalable solution method with optimal complexity

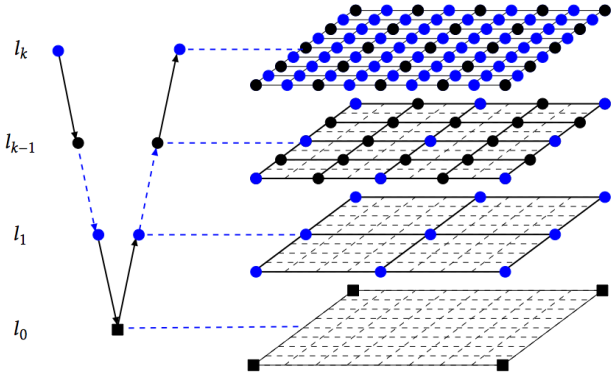



Source: Watanabe 2009

### Semi-geometric multi-grid for complex geometries and fracture

A. Kopanicakova, R. Müller, C. von Planta, R. Krause (USI/ICS)




- Multigrid requires hierarchy of **nested** meshes/approximation spaces
- Hard to obtain for fracture networks or complex geometries
- Remedy: use hierarchy of **non-nested** meshes
- Create MG hierarchy using discrete $L^2$-projection

# Innovative technologies & computational energy science

## GEO-ENERGIES

**Control seismic risk**

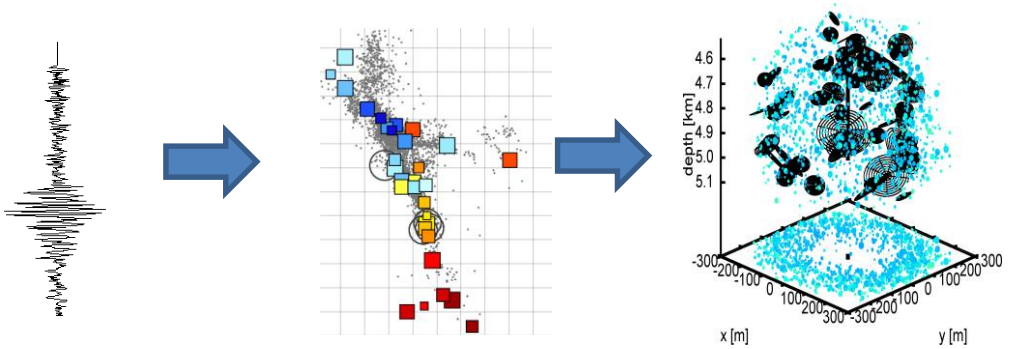
### Real time, data-driven reservoir characterization and risk assessment

SED, ETHZ, GES, …

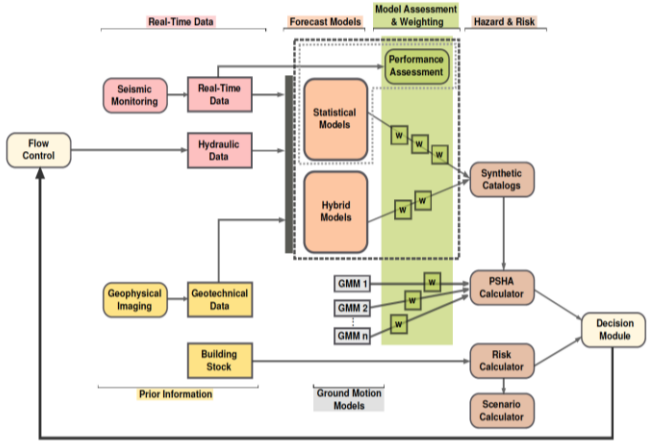
Bringing together the best in observations, modeling and forecasting into a real-time framework for risk and safety assessment and smart decision making.

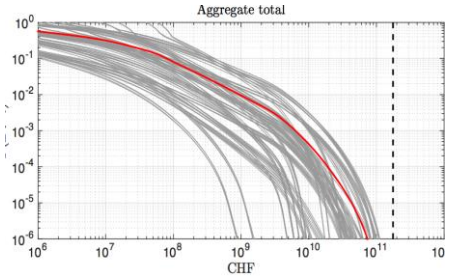
Method development, calibration plus professional grade software development for robust, largely automated forecasting in a 24/7 environment.

Strong link with team 'Risk and safety'. Supported also through GEOBEST-CH (SED), Horizon2020 project DESTRESS (ETH) and CTI project RT-RAMSIS (SED).




Data Analysis Modeling




Hazard and Risk

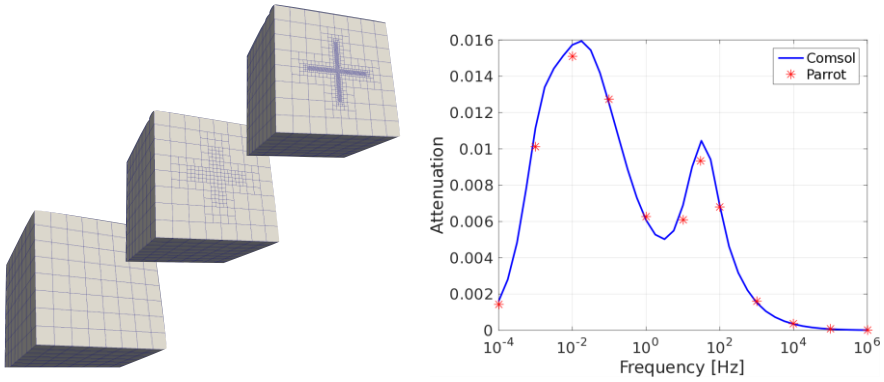
# Innovative technologies & computational energy science

## GEO-ENERGIES

**Optimisation of exploration and production**

### Parrot: a new code for seismic velocity dispersion and attenuation

M. Favino (ICS/USI), J. Hunziker, E. Caspari, B. Quintal, K. Holliger(U Lausanne), R. Krause (ICS/USI)



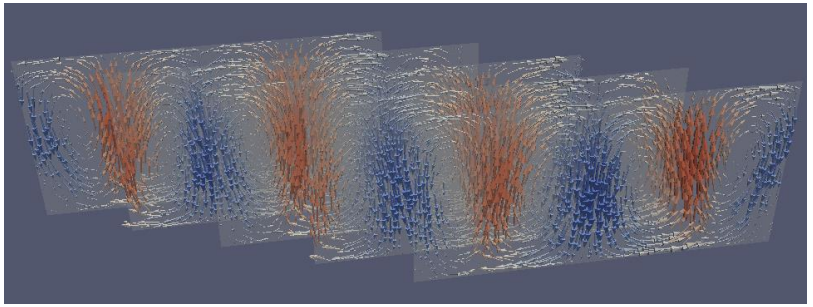

Fractured media requires high resolution meshes:

- Cracks represented only by jumps in parameters
- Randomly generated
- Adaptive mesh refinement at the cracks
- No need of remeshing or human interaction

### Flow and heat transfer in fractured reservoirs

J. Patterson, T. Driesner (ETHZ), UniNE, USI

Goals: (1) predict optimal reservoir operation
(2) evaluate optimal natural sites



- Natural convection leads to heterogenity of temperature in reservoir
- Thermal communication between fractures
- Nominally impermeable rock masses may develop thermal plumes due to fracture flow

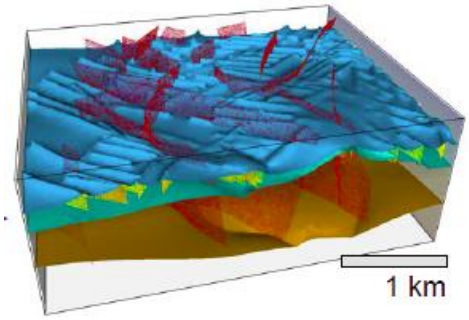
# Innovative technologies & computational energy science

## GEO-ENERGIES

**Optimisation of exploration and production**

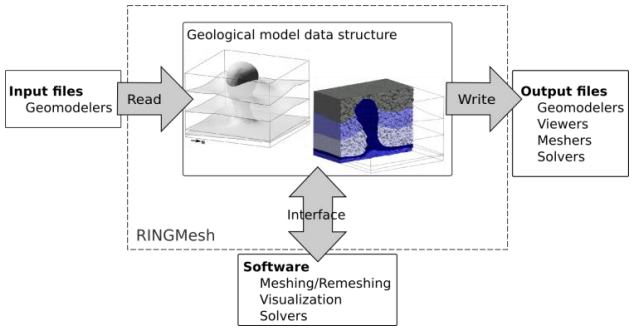
## Integrated workflows with user-friendly interface

- New collaboration with RINGMesh consortium at Uni Nancy (2 PhD students)
- Will interface Geomodelling software (e.g., Gocad/SKUA) and SCCER reservoir process simulators.
- Advantage: direct interfacing of site-specific geometric/geologic models from exploration and characterization phases with cutting edge simulation.

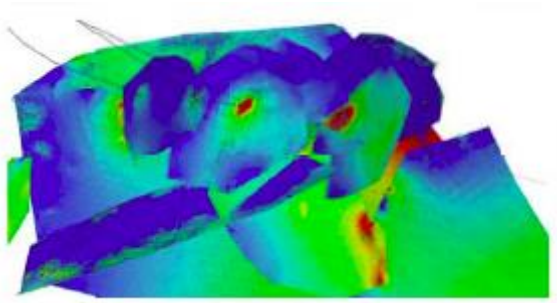



SKUA model of fractured oil reservoir ; courtesy of S.K. Matthai & C. Milliotte

RINGMesh interface (image: RING group)




Fractured reservoir simulation (courtesy of S.K. Matthai)



# Innovative technologies & computational energy science

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## GEO

Link to the energy strategy 2050 ?

Quantitative modelling of THM(C)S processes

Control seismic risk

Optimisation of production

Key technologies to make geothermal power a viable option:
- Ways to economic production
- Seismically safe