# Projects in environmental fluid mechanics

Are you fascinated by physics and interested in conducting experiments and simulations to better understand how fluids shape environmental systems? We are looking for students to carry out research on flows in porous media.

In many environmental and industrial systems involving fluids in porous media, local flow conditions may induce changes to the pores structure. Likewise, the flow is controlled by the geometry of the porous matrix. This is the case of snow: when ice crystals melt, water infiltrates through the interstitial space, melting neighbouring crystals or refreezing around them. A similar scenario occurs when carbon dioxide is injected in the subsurface with the aim of permanent storage: $CO_2$ reacts with the rocks, which may dissolve posing a risk on the structural integrity of the formation (see Fig. 1). The formation of sea ice is also a process of flow within a porous (mushy) layer that evolves in response to oceanic and atmospheric conditions. Predicting the dynamics of these systems is challenging due to the multiway coupling, multiscale nature and feedback mechanisms.

We use controlled laboratory experiments and high-resolution numerical simulations to develop physical models to design, predict and control these flows.

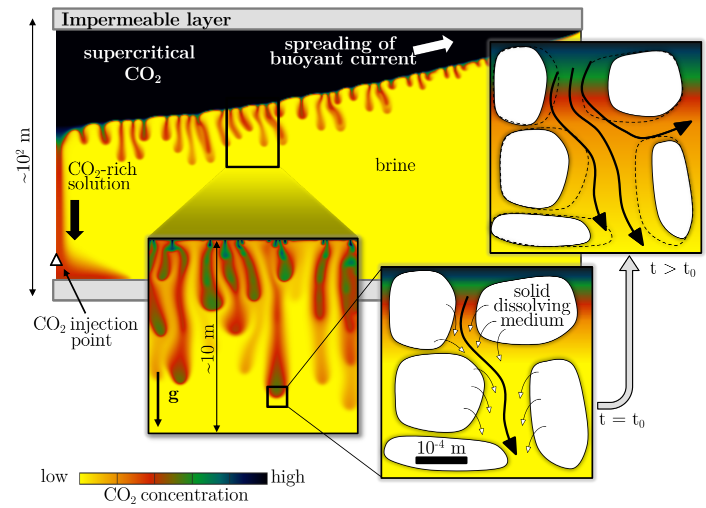


Figure 1: Schematic representation of the mixing process of $CO_2$ in the subsurface (see De Paoli, EPJ-E 46.12 (2023):129), with the rocks experiencing morphology variations due to dissolution.

## Details

- Group: Research group of Environmental Fluid Mechanics, Institute of Fluid Mechanics and Heat Transfer, TU Wien (Vienna, Austria).
- Supervisors:
  - Numerical projects: Daniele Rossi, Marco De Paoli.
  - Experimental projects: Vlad Giurgiu, Marco De Paoli.
- Locations:
  - Numerical projects: Institute (BA 07, Getreidemarkt 9, 1060, Wien).
  - Experimental projects: Laboratory (OZ 02, Franzgrillstrasse 9, 1030 Wien).

## Projects description

1. **Simulation of mixing in porous media.** Analyse the effects of the fluid properties on mixing in porous media via numerical simulations. Fluid with a non-monotonic density-concentration curve will be considered, and the efficiency of the mixing process analyzed. The objective is to derive physical models exploiting a large database available from previous simulations.

2. **Measure concentration gradients in porous media.** Quantify measurement uncertainties involved in measuring concentration gradients in a transparent 2D convection cell using a 12-bit camera. Develop and optimize the methodology required for these measurements. Perform novel experiments, apply your methodology, and compute quantities related to the concentration gradients.

3. **Test facility for porous media.** Design, build and operate an experimental facility to characterise the properties of a porous medium by measuring the pressure drop over a porous medium sample (glass beads and 3D-printed matrix) and compute its permeability. You will design a test facility to determine porous media properties.

4. **Design and 3D-print porous media.** Porous rocks have a wide range of shapes and morphologies, which makes hard to perform repeatable and reproducible experiments. To overcome this issue, 3D-printed media are needed to investigate the flow evolution in reproducible experiments. 3D printed media will be designed, produced in the laboratory and tested to determine their properties (permeability, porosity, tortuosity).

5. **Develop a method to produce snow.** Snow is among the largest freshwater resources available on Earth, and determining its response to climate variations is key to effectively address climate adaptation strategies. A rigorous method to produce snow with desired properties is required to study melting of snowpacks. Based on previous studies, a protocol to produce icy porous media will be developed.

6. **Calibration system for advanced optical measurements.** Build a calibration cell for Laser Induced Florescence (LIF) containing a fluid and a dye and kept at a defined constant temperature. A laser sheet is introduced in the cell and imaged with a camera to build a calibration curve between light intensity and temperature.

7. **Measurement of temperature and velocity fields in porous media convection.** Advanced optical measurements will be employed to measure temperature and velocity in water. In particular, for the temperature field Laser Induced Florescence (LIF) will be employed, while for the velocity field Particle-Image-Velocimetry (PIV) in quasi-2D and 3D convection cells will be used. The same techniques will be used when the facility is filled with hydrogel spheres and water.

8. **Characterise heat losses in convection cell.** Study and quantify the heat losses in a 3D facility filled with water and a porous matrix using theoretical predictions, numerical simulations, and measurements.

If you are interested in one of these projects, please write to marco.de.paoli@tuwien.ac.at including your CV, time commitment (possible start/end dates, and how many hours/week you expect to work on the project) and indicating the desired project.

Updated on May 1, 2026.