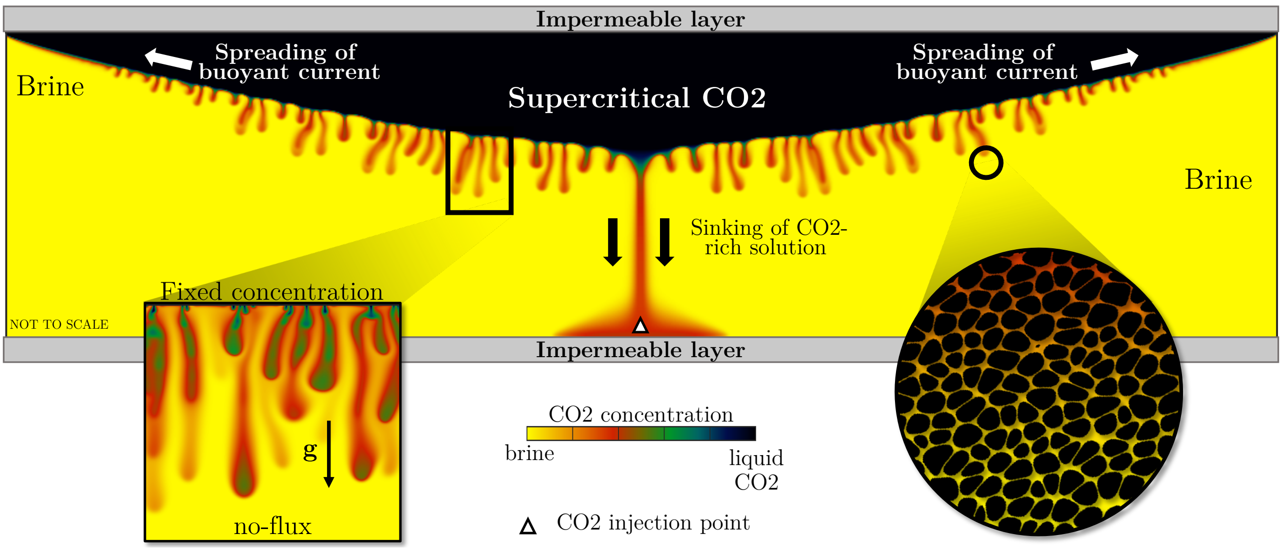
Title: Convection-driven porous media flows: Implications for carbon dioxide sequestration

Abstract: Convection in porous media is crucial in a number of geophysical subsurface flows, such as water contamination, petroleum migration and sea ice formation. We focus here on the Carbon Capture and Storage (CCS) process, which consists of three main phases: Carbon dioxide (CO2) produced from localized sources (e.g., power stations or industrial plants) is captured, pressurized to reach a liquid state, and finally injected in underground geological formations. It is estimated that CCS can operate at least 100 years to stabilize the CO2 emission as a unique storage technology. In this frame, it is important to identify the dissolution rate of CO2 in water, to determine whether a geological formation is suitable to CO2-storage or not. The approach commonly used to tackle this problem consists of two-dimensional numerical simulations. However, experiments revealed that the scaling laws for the dissolution rate predicted numerically overestimate the real dissolution flux. As a result, erroneous estimates of the CO2 migration and dissolution times are obtained. This discrepancy, which is produced by the small-scale properties of the porous matrix, makes the behavior of the flow to deviate from the ideal Darcy law.

We investigated numerically, experimentally and theoretically the process of convective dissolution in porous media. With the aid of 2D and 3D high-resolution numerical simulations, we analyze the influence of domain properties on the dissolution rate. The same configuration is studied experimentally by means of Hele-Shaw cells. We performed measurements of solute concentration and we defined the limits of applicability of the Darcy law. Finally, we develop a large-scale model to investigate the migration of a current of CO2, and we include the physical processes observed at the Darcy-scale and at the pore-scale.



Bio Marco De Paoli received his Bachelor's and Master's degrees in Mechanical Engineering from the University of Udine, under the supervision of Professor Cristian Marchioli. In 2013, he worked at Institute of Fluid Mechanics of Toulouse (Toulouse, France), where he collaborated with Professor Pascal Fede on stochastic modelling for particle tracking in LES flow fields. In 2014, he obtained a doctoral fellowship at the Multiphase Flow Laboratory led by Professor Soldati (University of Udine, Udine, Italy), where he worked on numerical modelling of convective porous media flows. After defending his PhD dissertation in 2017, he became University Assistant at the Vienna University of Technology (Vienna, Austria). His current research interests include dynamics of anisotropic particles in turbulence, optical methods for Hele-Shaw cells, droplets-laden jets, convection-driven porous media flows.