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Numerical modeling of fluid migration in subduction zones

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It is well known that fluids play a crucial role in subduction evolution. For example, excess mechanical weakening along tectonic interfaces, due to excess fluid pressure, may enable oceanic subduction. Hence, the fluid content seems to be a critical parameter for subduction initiation. Studies have also shown a correlation between the location of slab dehydration and intermediate seismic activity. Furthermore, expelled fluids from the subduction slab affect the melting temperature, consequently, contributing to partial melting in the wedge above the down-going plate, and resulting in chemical changes in earth interior and extensive volcanism. In summary, fluids have a great impact on tectonic processes and therefore should be incorporated into geodynamic numerical models. Here we use existing approaches to couple and solve fluid flow equations in the SLIM-3D thermo-mechanical code.

SLIM-3D is a three-dimensional thermo-mechanical code capable of simulating lithospheric deformation with elasto-visco-plastic rheology. It incorporates an arbitrary Lagrangian Eulerian formulation, free surface, and changes in density and viscosity, due to endothermic and exothermic phase transitions. It has been successfully applied to model geodynamic processes at different tectonic settings, including subduction zones. However, although SLIM-3D already includes many features, fluid migration has not been incorporated into the model yet. To this end, we coupled solid and fluid flow assuming that fluids flow through a porous and deformable solid. Thereby, we introduce a two-phase flow into the model, in which the Stokes flow is coupled with the Darcy law for fluid flow. This system of equations becomes, however, nonlinear, because the rheology and permeability are depended on the porosity (fluid fraction of the matrix). Ultimately, the evolution of porosity is governed by the compaction pressure and the advection of the porous solid.

We show the details of our implementation of the fluid flow into the existing thermo-mechanical finite element code and present first results of benchmarks (e.g. solitary wave) and experiments. We are especially interested in the coupling of subduction processes and the evolution of the magmatic arc. Thereby, we focus on the key factors controlling magma emplacement and its influence on subduction processes.