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Thermal convection in fractured porous media of water with variable physical properties.

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Natural convection through permeable formations is an important phenomenon which may govern fluid flows and heat transfer in geothermal aquifers.
Our main objective is to study the influence of natural convection on the transport of a passive tracer in porous media which can be fractured.
Flow is governed by the mass conservation equation for slightly compressible fluid supplemented by Darcy's law. Temperature is solution of an energy equation; local thermal equilibrium is assumed to hold, i.e. in an elementary volume element, liquid and solid temperatures are equal. These two first equations are coupled. Mass transfer is governed by a convection-diffusion equation; since the solute concentration does not affect the fluid density, this last equation uses the velocity field, but does not influence it. The fluid viscosity and the thermal expansion coefficient may vary with temperature. Variations of fluid properties are described by experimental correlations for water; the temperature difference between the top and the bottom of the system is as large as 100°C. The governing equations are discretized by the finite volume technique and solved by conjugate gradient methods. Numerical dispersion in the convection-diffusion equation is reduced by a flux-limiting scheme. Although the effect of thermal expansion coefficient and viscosity temperature-dependent on the onset of convective flow was examined in the literature, the actual flow patterns that result from the convection of water with real properties did not attract much attention in the past.
Results are compared to the thermal convection of a Boussinesq fluid, where the density variations are approximated by a linear function of temperature.
Results reveal that Nusselt numbers (and fluid velocities) are dramatically increased, up to one order of magnitude; time-dependent solutions appear at even moderate Rayleigh numbers. During the transient states, the flow pattern sometimes bifurcates from one pattern
to another, and this has a large influence on the output mass flux; sometimes, this change is fast enough to break the solutal plumes and interrupt the release of matter at the surface.
Application to fractured porous media is in progress. Fractures are inserted as two-dimensional convex polygons, where the fluid is assumed to satisfy a 2D form of Darcy's law. A particular attention is paid to the exchanges between the fractures and the surrounding porous medium. Preliminary results show that the temperature dependency of the fluid properties is even more crucial when fractures are inserted in the porous medium.