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Thermo-solutal convection in magma oceans

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Because of giant impacts, the history of the Earth's mantle may have begun with a period during wich it is largely molten, the magma ocean era. We should understand the cooling and freezing of such an ocean to obtain information about mantle differentiation and the beginning of plate tectonics.
Current models for magma oceans usually make the hypothesis of a compositionally well mixed isentropic liquid. Indeed the low viscosity of such an ocean and the huge radiative heat flow at the top should lead to vigourous convection. Nevertheless, fractionnal crystallization of liquid at the bottom of the liquid may produce a basal enrichement in FeO of the ocean (making it denser) possibly ending up with the formation of a stably stratified layer. Whether or not this happens depends on the competition between the destabilising thermal buoyancy and the stabilising compositional one. With that question in mind, we have developed a model for direct numerical simulations of rotating thermosolutal convection in a 3D spherical geometry.

We have decided to focus on the consequences of two physical processes –possibly underwent by magma oceans– on the dynamics and on the properties of heat and solute transports. These phaenomena are the fractional crystallization of the liquid inducing basal enrichment in iron oxyde and the radiative equilibrium between the ocean and an atmosphere.

Considering the thermodynamics of crystallization at the bottom, we obtain a linear relationship between the heat and solute fluxes at the bottom, a condition that we implemented in the numerical code. For the top boundary, radiative equilibrium is taken into account by imposing a linear relation between temperature and heat flux (Robin condition).

An exploration of parameter space (mainly Rayleigh, Ekman and Biot numbers) has been conducted. We eventually discuss the possible formation of a chemically stratified layer at the bottom of the magma ocean as well as the influence of the Robin boundary condition on convection.