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Convective models in young terrestrial planets with semi permeable surface

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Young terrestrial planets have warm interiors due to accretion and radioactive heating. An intense volcanic activity might take place. The proportion of heat carried towards the surface during magmatic processes should not be neglected in the thermal balance. Most models of interior dynamics have impermeable boundary conditions imposed at the top surface leading to the development of a thermal boundary layer under it. Thus, heat is carried through the top surface by diffusion only.
We developed a new set of semi permeable boundary conditions in order to take into account of heat advection and diffusion through the top surface. We incorporated them in a 3-D cartesian model of infinite Prandtl number thermal convection in the Boussinesq approximation. Boundary conditions for the velocity field and the temperature are required in such models. We imposed a no shear stress boundary condition on the top surface. The vertical velocity is not set to zero but generates a topography that obeys a diffusion equation in order to model processes such as magma spreading or erosion. We impose a temperature set to zero for downwelling currents, and no vertical gradients for upwellings.
We have run experiments with either internal heating or bottom heating. The variation of the diffusivity coefficient of the topography allows the models to go continuously from thermal convection with permeable surface boundary to thermal convection with impermeable one. The pattern of convection is characteristic of the permeable boundary conditions when the diffusion of topography mimicking all the erosional processes is efficient and the topography negligible. Whereas small diffusivity coefficients of the topography lead to patterns of convection characteristic of the usual impermeable boundary conditions. We have run cooling models in order to compare the cooling rate associated with the different boundary conditions. We show that the permeable boundary conditions are more efficient to cool down a young terrestrial planet than an impermeable ones.
Finally, we discuss the implication of this new set of boundary conditions in the thermal evolution of young terrestrial planets.