Convection in planetary mantles

Anne Davaille*[1]

[1]Laboratoire FAST, CNRS / University Paris-Saclay – University Paris-Sud, Laboratoire FAST, CNRS – France

Abstract

Born hot in a cold universe, a planet evolves due to its cooling. Its evolution will therefore be conditioned by heat transfer in its most viscous envelope, the rocky mantle. A planetary mantle is cooled from above, heated from within by radioactive elements and heated from below by the core. As cold rocks are denser than hot rocks, the former can sink under gravity, while the latter will rise: this is the principle of thermal convection, whereby heat and mass transfer are due to buoyancy-powered advection. In the 1930s, Arthur Holmes (Holmes, 1931), among others, proposed that thermal convection in the Earth's mantle provided the necessary force to drive the continental motions suggested by Wegener (1924). Since then, studies of mantle dynamics and thermal convection have been closely intertwined.
According to the classical scenarios of planetary formation, terrestrial bodies were likely partially or totally molten, forming a magma ocean (MO). Given the viscosity and thermal diffusivity of melted rocks, the Prandl number range is Pr _˜ 10ˆ{-1}-10ˆ2 and the Rayleigh number Ra _˜ 10ˆ{23}-10ˆ{32}. This put a MO is the turbulent " Ultimate regime " of convection. During MO solidification, turbulent convective motions are commonly thought to efficiently outgas dissolved volatiles, progressively forming a secondary atmosphere. Through the atmospheric blanketing effect, exsolved volatiles can then significantly slow down the solidification of MO, which can alter the final thermo-chemical state of the mantles and their long-term evolution. Once the rocky mantle is mostly solidified, Pr _˜ 10ˆ{23} and the Rayleigh number Ra _˜ 10ˆ6-10ˆ9, so that inertia is now inexistent, but thermal convection is still in the high Ra-domain. However, as the rheology of rocks strongly depends on temperature and deformation, the patterns of thermal convection are now controlled by this complex rheology. I shall review the recent progress on these topics and what questions it poses to the turbulent convection community.

*Speaker