Geophysical Research Abstracts
Vol. 16, EGU2014-11022, 2014
EGU General Assembly 2014

Numerical and laboratory experiment of volumetrically heated fluid: implications of boundary conditions on planetary evolution.

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In the last decade numerical simulations of mantle convection have included an increasing number of physical processes (e.g., phase transitions, compositional heterogeneities, depth dependent properties), to gain a better understanding of the Earth's thermal evolution. This increasing complexity has led to a more precise description of the convective behavior of the Earth's mantle, but may have render its deciphering somewhat more difficult and sometimes ambiguous. Coupled experimental and numerical studies are then useful to interpret the results of the modeling. Here we present numerical simulations of a simple system, which is only cooled from above and internally heated, coupled with innovative laboratory experiments. Three-dimensional simulations are conducted with the code Stag3D [Tackley 1993], and the laboratory experiments used a newtonian fluid whose viscosity and thermal expansion are both temperature dependent. The experimental approach, presented in detail in a companion abstract by Limare at al. (EGU2014-6207), is very challenging and it was first important to validate numerically the experimentally measured temperature and velocity fields. We then used the combined approach to quantify the effect of boundary conditions (i.e., rigid, as in the laboratory experiments, or free slip) on the internal thermal structure of the convective fluid. In particular, we calculate the horizontally and time-averaged temperature across the top thermal boundary layer for a large range of Rayleigh number (10^5<Ra<10^9). We show that boundary conditions have an important effect (more than 20%) on the spatially averaged temperature, and that different scaling laws can be defined for different boundary conditions. The obtained scaling laws can be used to model the thermal evolution of planetary mantles with stagnant or mobile lid.

Tackley, P.J., Effects of strongly temperature-dependent viscosity on time-dependent, three-dimensional models of mantle convection, Geophys. Res. Lett., 20 (20), 2187-2190, 1993