Boundary-modulated convection, a new model for mantle dynamics

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The most basic paradox in mantle dynamics would be inconsistency between the seismological structure and the convectional thermal structure. So far revealed 3D structure of seismic velocities is characterized by predominance of heterogeneity with long wave length. Since the heterogeneity in seismic wave velocities can be interpreted as heterogeneous temperature distribution, thermal field in the mantle has also predominance of long wave length structure. On the other hand numerical simulations of the mantle convection show predominance of shorter wave length thermal structure for the estimated Ra of the mantle. Although several models have been proposed to explain this discrepancy such as the role of phase change and temperature dependent rheology, they are not so conclusive yet. Here we propose a new model of mantle dynamics based on laboratory experiment,a boundary modulated convection.

A model convection experiment has been conducted on mixture of viscous fluid and solid particles with slightly heavier density. With 2D cell of basal heating and top cooling we performed Rayleigh Benard type thermal convection experiments. The viscous fluid phase is aqueous solution of syrup and the solid phase is polystyrene beads with a diameter of 1mm. Both the viscosity and the density of the fluid is controlled by changing the mixing ratio of syrup and water and adding salt,respectively. Ra number ranges from.

The initial state is a layered structure,the lower layer is a porous layer composed of styrene particles and the upper layer is a single fluid layer. When thermal convection occurs by heating the bottom boundary, the particles in the lower layer are mobilized depending on the relative difference of the density between styrene particle and the syrup solution. When the difference is small enough the thermal agitation by the convection overcomes the density difference and complete suspension flow appears. When the density difference is large enough porous structure is firmly maintained and the layered convection appears,convection in porous layer and in fluid layer. When the density difference is intermediate interesting features appear. Convection flow mobilizes and transport particles near the interface. Erosion of the particle layer is significant at the upwelling region which results in thinning of the particle layer. At the downwelling region, on the other hand sedimentating particles form thicker layer. The basic control parameters in this system are Ra number, a measure of the strength of thermal convection and Shi, so called Shields parameter, a relative measure of force exerted on sphere by convection over negative buoyancy. In the diagram between Ra and Shi convection styles are clearly separated. At higher Ra and intermediate Shi, the bottom particulate layer is erodible and its boundary conforms to the downwelling and upwelling structure. We call this regime as the boundary modulated convection. Once this harmonized structure is established this is stable for long time. Basic structure of ordinary RB convection at is composed of small sized units and above large scale flows,sometime called as a mean wind,appear but they are usually unstable and time dependent. In this boundary modulated convection large scale flow is stabilized by the soft boundary.

We propose this harmonized action of the soft boundary and convection works to generate long scaled structure of the thermal field of mantle convection.