The role of the D'' layer in the core-mantle thermal coupling

Atsuko Namiki[1], Kei Kurita[2]

[1] Dept. Earth Planet. Sci., Univ. of Tokyo, [2] Dep. Earth & Planet. Phys.,Univ. of Tokyo

We report experiments on thermally driven convection of a high Prandtl number fluid with an inclined upper boundary. For an inclined angle greater than critical, we observed a new convection pattern where migrating convection cells and plumes coexist, and the heat flux has a long wave length variation. The critical angle is determined by comparing the two length scales, the height difference in one convection cell caused by the inclined upper boundary and the thickness of the viscous boundary layer. Recent seismological observations have revealed that the thickness of the D'' layer varies horizontally. Our experimental results indicate that the variety of the D'' layer should modify the heat transfer from the core to the mantle.

Recent seismological observations have revealed the D'' layer is chemically distinct from the overlying mantle. In such a view, the D'' layer seems like a blanket for the core, because a layer which is chemically separated from the overlaying mantle and has smaller thermal conductivity than the core will control the heat transfer from the core to the mantle. Seismological observations also showed that the D''-mantle boundary undulates with an amplitude larger than the mean thickness of the D'' layer (> 300 km) and that the thickness of the D'' layer varies horizontally. Since the thickness of the layer is significantly important factor to the heat transfer, the thickness variety of the D'' layer should modify the heat transfer from the core to the mantle.

We conducted laboratory experiments to explore how the conduction/convection pattern and heat transfer are modified when the thickness of the layer varies horizontally. Here we simulated the varying thickness by the inclined upper boundary layer. A rectangular tank is filled with glycerol solution is heated from below and cooled from above. In this experiment, Rayleigh number varies horizontally. We defined the local Rayleigh number (Ra_l) using the height of the convective layer at each site. The experiments were carried out at 1E2 < Ra_l < 1E8 , and inclined angle < 14 degree. Convection patterns were visualized using the thermotropic liquid crystals. Local heat flux was calculated from the temperature gradient of the thermal boundary layer. Vertical temperature profiles at three different locations were measured using movable thermistor probes.

We observed three regimes, i) conduction (Ra_l < Ra_c), ii) resembles to the leveled case (small Ra_l and small inclined angles), iii) migration of the convection cells (large Ra_l and large inclined angles).

Under the conduction regime and for small Ra_l and small inclined angles, the pattern and heat transfer is not significantly modified by the inclined upper boundary.

For large inclined angles and large Ra_l the convective cells initiate the horizontal migration toward the thinner regions. The migration induce the separation and coalescence of convection cells. When the convection cells separate and coalesce, three-dimensional plumes are observed. Cold plumes from the upper boundary migrate from the thicker region toward the thinner region, hot plumes migrate in the opposite direction. The plumes should transfer the heat horizontally.

We also measured the local heat transfer at three sites of the convection layer. It shows that the heat flux becomes larger (smaller) at the site where convection layer is thick (thin) for the upper boundary, and vice versa for the lower boundary. The inclined upper boundary generates the heat flux heterogeneity with a wave length that exceeds the width of each cell.

The regime of large wave length heat flux heterogeneity corresponds to the regime where the migration of convection cells occurs. We can interpret this result as a consequence of the horizontal transfer of heat and momentum by the plumes. We remark that the phase of the heat flux is reversed between the upper and lower boundaries; i.e., the region where

maximum heat enters at the lower boundary is the region where minimum heat comes out from the upper boundary. The amplitude of the heat flux heterogeneity increases with Ra_l and the inclined angle.

Numerical simulations of geodynamo have shown that the maximum heat flow at CMB occurs at the pole and the equator regions. However, hot spots, the carriers of the heat associated with the core cooling, are mostly distributed at the middle latitude. The thickness of the D'' layer is thin at the pole and the equator regions. This suggests that the thickness variety of the D'' layer reverses the pattern of the heat flux heterogeneity generated by the geodynamo and let the reversed pattern of the heat flux heterogeneity out to the overlying mantle.