Experimental study of convection cell transition induced by internal heat source in a shallow layer

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The dynamics in mantle convection of the earth is strongly affected by its heat generation which is brought by radioactive decay. This internal heat generation induces a distinctive thermal convection.

Convection cell induced by internal heat sources in a shallow layer is hexagonal shape with descending flow at the center of the cell and behaves characteristically with respect of internal Rayleigh number (R_I, $R_I = gbHL^5/(2lkn)$; b, H, l, k, and n are respectively bulk modulus, heating rate, thermal conductivity, thermal diffusivity and kinematic viscosity). For example, horizontal scale of the cell increases dramatically in proportion to R_I and at higher R_I, the shape of descending flow region is modified into a spoke-like shape (Spoke-like structure) or another cell structure is formed; an additional cell appears in the cell (Double cell). These transitions of the cell structure haven't been investigated well experimentally although it doesn't correspond with theoretical analysis and numerical simulation in an ideal condition even though its system is so simple.

We attempt to determine the flow structure in a cell by Particle Image Velocimetry (PIV) to investigate these transition mechanisms. The fluid layer has 210 times 210 mm of the cross section and is 7 mm in the height. Simultaneous multi-layer measurement is performed by using color-striped light sheet. Internal heat generation is realized by applying electric current to the fluid layer. Transitional and steady state of convection cell is observed by this method. Vertical velocity component is also obtained and we investigate how cell behaves with respect of R_I quantitatively. R_I/R_{Ic} was changed from 4 up to 25, where R_{Ic} corresponds to the critical Rayleigh number at the onset of the convection.

We confirmed cell transition is strongly related with the development of descending flow at the center of a cell. Cell dilatation process is described as a consequence that descending flow develops and strongly expands at the bottom of the fluid layer. We suggest that spoke-like structure is a stable solution in this system usually and double cell structure is formed if there are some kinds of uncertainties in the system, e.g. finite lateral boundaries or the imperfection of uniform heating.