Numerical studies on the classification of flow regimes of the 3-D thermal convection of rotating fluids

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In this study we made a series of statistical analysis for a thermal convection in a three-dimensional Cartesian box rotating about a vertical axis, aiming at obtaining clues to readily understand the flow regimes of rotating convection. First we conducted numerical calculations of 20 cases where the values of Rayleigh number (Ra), Ekman number (Ek) and Prandtl number are systematically varied in the range of earlier studies. We confirmed that, based on the efficiency of convecting heat transfer, the flow patterns of these cases are classified into three regimes mainly depending on Ra and Ek: (i) no-rotating convection, (ii) the regime with strong effect of rotation, and (iii) that with moderate effect of rotation. In particular, we found that the change between the regimes with strong and moderate effect of rotation is associated with the change in the pattern and occurrence of Ekman pumping near the top and bottom boundaries, which can be clearly seen from the correlation between the vertical components of velocity and vorticity there. In the regime with strong effect of rotation, a strong correlation is observed in the vertical flows both away from and toward the horizontal boundaries. In the regime with moderate effect of rotation, in contrast, it is observed only in the flows departing from the boundaries. Our findings suggest that, from the viewpoint of rotating convection, the flow regime the Earth's outer core can be well identified from the observation of the correlation between the radial components of velocity and vorticity.

Keywords: thermal convection of rotating fluids, 3-D numerical experiments, Ekman pumping

