液体金属による熱対流のパターンと水平スケール

Horizontal scale of patterns in liquid metal convection

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Convection occurring in a liquid metal is an essential process for understanding dynamics of the Earth and planetary cores. The characteristics of flow pattern in liquid metal convection are, however, less understood as flows in ordinary fluids because of the opaqueness of it. Recently, ultrasound techniques are widely applicable for the study of flow in opaque fluids. We performed laboratory experiments on Rayleigh-Benard convection with a liquid metal in a square geometry having an aspect ratio five. Horizontal velocity profiles of convective flow were measured at several lines by using ultrasonic velocity profiling. By combining the information from profiles, we can reconstruct organized flow structures with turbulent fluctuations. Systematic variation of the structure was detected with increasing the Rayleigh number (Ra) up to 10^5, in which a quasi-two-dimensional roll changes to a cell having a relatively larger horizontal scale. In addition, we found that the organized large-scale structure, whether it is roll or cell, show quasi-periodic oscillation whose representative period is approximately same as the circulation time of the large-scale flow. We also performed numerical simulations of convection with the same geometry as our experiments by setting a small Prandtl number (Pr = 0.025) like a liquid metal. Quantitative comparison on the velocity profiles between experiments and simulations provided quite satisfactory agreement, and we analyzed the whole structure of the flow and the style of oscillation in detail based on the result of simulation. By integrating results from experiments and simulations, we propose a scaling low on the Ra dependence of horizontal size of large-scale flow structure, and estimate an enlarged value of effective momentum diffusivity by turbulence in a liquid metal convection.

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