An effect of the inner core on bottom-up type critical convective flows in a rotating spherical shell

*Hinami Taniguchi[1], Futoshi Takahashi[1], Shin-ichi Takehiro[2], Hisayoshi Shimizu[3]

1. Kyushu University, 2. Kyoto University, 3. University of Tokyo

The dynamos in the fluid core of the terrestrial bodies is powered and sustained by a certain kind of compositional/thermal buoyancy sources. In the Earth’s core, compositional buoyancy is given by light element ejection into the outer core caused by inner core growth. In other words, the compositional convection occurs as “bottom-up” type with the growing inner core. When a dynamo action associated with the bottom-up type convection substantiated in the Earth’s core, the inner core could be smaller than the present one. Different core geometry could yield a variant convection structure and resultantly generate a different magnetic field. In this study, basic features of the flows driven by the bottom-up type buoyancy are investigated by a linear stability analysis to gain insights into the Earth’s core in the past. This study focuses on the fundamental physical processes at the onset of the bottom-up compositional convection in a rotating spherical shell with a smaller inner core. We consider the Boussinesq fluid contained in a rotating spherical shell, of which radius ratio is 0.2. The linearized governing equations, that is, conservation equations of the momentum and mass, and the transport equation of composition, are solved as an eigenvalue problem. The adopted values of the Ekman number, E_k and the Prandtl number, P_r are 5×10^{-5} and 1, respectively. Boundary conditions are stress-free and impermeable for the velocity field, and fixed flux for the composition. The obtained convective flow at the onset has the columnar structure outside and alongside an inner core tangent cylinder, which is an imaginary cylinder co-axial with the rotation axis touching the inner core at the equator, owing to the effects of rotation. Between the convection columns and the tangent cylinder, the ageostrophic shear layer, of which thickness is $E_k^{1/3}$, develops. Within the shear layer the kinetic energy of the azimuthal velocity increases around the equatorial region, and which is transferred to higher latitudes inside the tangent cylinder by the viscous effects. In other works, there is mass flux in the latitudinal direction around the tangent cylinder. By investigating the distribution of the velocity field, it is found that the cylindrical radially outward flows and the inward flows through the tangent cylinder correspond to those from the anticyclone and the cyclone, respectively. The flows going through the tangent cylinder play a role in enhancing viscous dissipation to keep the total kinetic energy budget in balance. The flow structure and analysis of kinetic energy budget suggest an influence of the inner core on the structure of the critical flows.

Keywords: fluid dynamics, stability, inner core, bottom-up type convection

