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Anelastic convection model in rotating spherical shells for stars, gas and icy giant planets.

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The problem of convection in rotating spherical shells has been studied vigorously as a fundamental model of global convection presumably emerging in celestial bodies, such as stars, gas and icy giant planets, and terrestrial planetary interiors. Recently, according to development of numerical computational abilities, fundamental aspects and characteristics of convection have been revealed and knowledge about this issue is increased under the assumption of Boussinesq approximation, which ignores compressibility of the fluid. However, compressible convection in rotating spherical shells has not yet understood compared with Boussinesq convection, although some studies performed so far use the anelastic approximation in order to deal with compressibility. Compressibility is an important element for discussing deep convection of stars, gas and icy planets, since thickness of their convection layers is several times larger than the scale height. Not only for these celestial bodies but also for extra-solar gas giant planets, which have been so many discovered with recent sophisticated technologies of astronomical observations, compressibility could not be ignored for considering fluid motion in their interiors. Investigation into effects of compressibility on convection in rotating spherical shells is expected to contribute to the basic knowledge for considering fluid motions in the interiors of these many celestial bodies.

In the present study, we develop a numerical model of an anelastic fluid in rotating spherical shells in order to assess effects of compressibility on convective motions. The governing equations are anelastic equations with polytrope basic state. We already developed numerical model of Boussinesq convection in rotating spherical shells as a member of Hierarchical Spectral Models for Geophysical Fluid Dynamics "SPMODEL". On the development of the anelastic model, we extended our numerical model of Boussinesq convection in rotating spherical shells accomplished so far to the anelastic system.

In all calculations, the ratio of inner and outer radii, the Prandtl number, the Ekman number are fixed to 0.35, 1, 10^{-3}, respectively. The Rayleigh number is also fixed 1.2 times the critical Rayleigh number. The inverse density scale height, N, is varied from 10^{-5}, 1, 2, 3, and 5. For each combination of parameters, time integration is carried out until quasi-steady state is established. When the case of N is 10^{-5}, columnar convection along the rotation axis emerged near the inner boundary. This feature is similar the Boussinesq case. On the other hand, the location of convection column becomes close to the outer boundary, and the convective motion occurs are near the outer boundary as the value of N is increased.

Keywords: Convection in rotating spherical shells, Compressible convection, Anelastic equation