Topography and geoid from instantaneous flow calculations in spherical shell: Effects of lateral viscosity variation in the mantle

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We have employed instantaneous flow calculations in the three-dimensional spherical shell to investigate effects of lateral viscosity variation (LVV) in the lithosphere and mantle on the long-wavelength geoid anomaly. The density model is constructed by combining the high-resolution tomography model with the subducted slab model based on the seismicity (Yoshida et al., 2007). The global strain-rate model is used for modeling the weak (low viscosity) plate margins in the lithosphere. The LVV in the lower mantle is compiled by using the reasonable relation between the seismic velocity and the viscosity.

Calculations have been performed by using ConvGS, which is newly developed mantle convection code. For this study, we compute the instantaneous flow field without solving the heat transport equation with the time evolution. The finite volume (FV) method is used for the discretization of basic equations on the staggered grid. Comparing with the finite-difference method, the advantage of the use of the FV method is to ensure the conservation of physical values and relatively stable the calculation of the convection with the variable viscosity. The computational grid is used of the Yin-Yang grid, which is two component longitude-latitude grids covered over the spherical shell. The SIMPLER algorithm is used on the staggered grid to solve the velocity and pressure fields from the continuity and momentum equations. A multi-color relaxation method is used to solve the flow field. Parallel calculations have been performed using one-dimensional domain-decomposition method with MPI.

Our results show that, considering highly viscous slabs in the upper mantle, the observed positive geoid anomaly over the subduction zones is realized only when the viscosity contrast between the reference upper mantle and the lower mantle is around 10^3, and weak plate margins are imposed in the lithosphere. The LVV in the lower mantle has a large influence on the geoid pattern. The geoid anomaly over the subduction zone shows generally positive pattern with quite high amplitude compared with observation, even when low activation enthalpy of perovskite in the lower mantle is considered. The is because the negative buoyancy of the subducting slab is supported by the highly viscous cold materials in the deep mantle. The expected weaker slab in the lower mantle may be supported by recent mineral physics, in which the possibility of grain-size reduction due to the postspinel phase transition is pointed out.