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Effects of Lateral Viscosity Variations in the Lithosphere on the Surface Tectonics

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Numerical simulation of an instantaneous Newtonian viscous flow in a spherical shell driven by the negative buoyancy forces due to the subducting slabs has been conducted to understand the effects of lateral lithospheric viscosity variations i.e., strong plate interiors and weak plate margins, on the surface motion. The density heterogeneity models used are those inferred from the seismic slabs (SS) or the subduction history (SH). Weak plate margins make each plate mobilize. We found that the reasonable plate velocity relative to that of the Pacific plate can be obtained for the model without the lower mantle density anomalies (SS model), while, the reasonable directions of the plate motions can be obtained from the models with the lower mantle density anomalies (SH model).

A preliminary numerical simulation of an instantaneous Newtonian viscous flow in a 3-D spherical shell driven by the negative buoyancy forces due to the subducting slabs has been conducted to understand the effects of lateral lithospheric viscosity variations, i.e., strong plate interiors and weak plate margins, on the surface motion, the topography, the geoid and the intraplate stress. The density heterogeneity models used are those inferred from the seismicity related to the subducting slabs (SS model), the subduction history (SH model) and the combination of these two models(SSH model). The radial distribution of the viscosity except weak margins is 3-layered: the lithosphere (0 km to 100 km), the upper mantle (100 km to 670 km) and the lower mantle (670 km to 2900 km). The ratio of the viscosity at weak margins to that of the lithosphere is changed from 1 (i.e., no weak margin) to 0.0001. Weak plate margins make each plate mobilize. For SS model, the Pacific and the Australian plates have large absolute motions and the Antarctic and the North American plate have small absolute motions, which resembles to the observable features. For SS or SSH model which have density loads in the lower mantle, the direction of the Nazca and Pacific plates becomes similar to the observations. However, in these models, the plates with small observed velocities, such as the Eurasian plate, become mobilized. We found that the reasonable plate velocity relative to that of the Pacific plate can be obtained for the model without the lower mantle density anomalies (SS model), while, the reasonable directions of the plate motions can be obtained from the models with the lower mantle density anomalies (SH or SSH models). The effect of the decrease of plate margin viscosity mainly influences the high degree components of the geoid. The stress magnitude (deviatoric stress) near the plate margins reaches the order of 100 MPa for the model with the 1.0 x 10^20 Pas of the upper mantle and plate margin viscosity. The stress within each plate shows generally an extension along the directions of the plate motion. This may imply that the other forces like those related to the ridge push may be necessary to explain the actual intraplate stress field.