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Effect of strong lateral viscosity variations on the global mantle flow

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Reconstruction of the mantle flows within the mantle is essential for understanding of the Earth evolution. Up to now the most of the real Earth models based on the observed geoid, seismic tomography and surface plate velocities have been calculated employing the mantle flow theory with only depth-dependent viscosity. It is therefore important to analyze the effects caused by lateral viscosity variations (LVV) related to temperature and composition anomalies in the mantle. We analyze 2- and 3-D mantle flow models with strong LVV (up to 9 orders of magnitude) to investigate this effect. For 2-D models we employ the generalized Moresi-Solomatov method. The 3-D models are calculated with the CITCOM code. It is generally accepted that in the anomalous zone velocities are inversely proportional to viscosity changes. Zhang and Christensen suggested scaling velocity variables by relative viscosities, which might help to stabilize the solution in the case of large-scale viscosity variations. However, numerical tests have shown that in the case of whole mantle LVV on the scale up to the 20th degree this transformation may cause significant problems. For instance, it is well known that large-scale up- and downwelling flows are of nearly the same magnitude, despite the viscosity is remarkably different. Our calculations have confirmed that the effect principally depends on the size and type of lateral viscosity anomalies. The velocities are approximately inverse-proportional to LVV only in the case when the anomaly is big and fixed in space. By contrast, velocities within a relatively narrow and unbound viscosity anomaly become identical and equal to the velocity of the surrounding mantle. The modifications of large-scale vertical flows are also much less than it would be expected from the inverse-proportion relationship.