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Inversion for mantle viscosity from post-glacial rebound and the influence of 3D variations

A. Paulson, S. Zhong, J. Wahr

University of Colorado, Boulder, CO, USA (archie.paulson@colorado.edu)

Observations of post-glacial rebound (PGR) can provide important constraints on mantle viscosity structure. In this study, we investigate how well PGR observations are able to constrain the spherically symmetric (1D) viscosity structure of the earth. We generate synthetic PGR data by calculating the response of an earth model with realistic 3D viscosity. The viscosity model is constructed starting from seismic tomography models. Computation of the earth's response includes realistic glacial loading, gravitationally self-consistent ocean loading via the sea level equation, and the effects of polar wander. The computation is performed with the spherical finite element code CitcomSVE [Zhong et al., 2003]. We also develop a fast spectral technique to solve for PGR, including the sea level equation and polar wander effects, for earth models with 1D (spherically symmetric) viscosity structures. For each forward model, we measure the following PGR observables: relative sea level (RSL) change at various locations in North America, $\dot{J}_2$, polar wander, and the rate of change of higher order gravity Stokes coefficients (anticipated GRACE data). We consider the constraints on the inferred viscosity model that each of these measurements provides, and their sensitivity to the complications of (a) lateral viscosity variations in the earth, (b) uncertainties in the glacial model, and (c) noise in the PGR data. We find that measurements of the decay times of RSL curves near Hudson Bay tend to remain robust despite these complications and that GRACE data must be summed regionally (rather than using the raw Stokes coefficients) to remain useful, while raw RSL curves (which must be employed for those curves that are not approximately exponential) can be too sensitive to these complications (a, b, and c) to provide useful constraints on mantle viscosity. We also perform a Monte Carlo inversion for 1D viscosity based on minimizing misfit to these synthetic data. We find that when we attempt to invert for more than about three parameters in the 1D model (for example, a several-layer viscosity model), there exist

many 1D models, each with low misfit to the PGR of the 3D earth, whose viscosities may differ widely among each other.