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Using postglacial sealevel, crustal velocities and gravity-rate-of-change to constrain the influence of thermal effects on mantle lateral heterogeneities

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Lateral heterogeneities in the mantle can be caused by thermal, chemical and non-isotropic pre-stress effects. Here, we used observations of the glacial isostatic adjustment (GIA) process to constrain the thermal contribution to lateral variations in mantle viscosity. In particular, global historic relative sea level data, GPS in Laurentide and Fennoscandia, radar altimetry over land, altimetry together with tide-gauge data in the Great Lakes area, and GRACE data in Laurentide and Fennoscandia are used. The lateral viscosity perturbations are inferred from the seismic tomography model S20A or Steve Grand's model by inserting the scaling factor β to determine the contribution of thermal effects versus compositional heterogeneity and non-isotropic pre-stress effects on lateral heterogeneity in mantle viscosity. When β = 1, lateral velocity variations are caused by thermal effects alone. With $\beta < 1$, the contribution of thermal effect decreases, so that for β = 0, there is no lateral viscosity variation and the earth is laterally homogeneous. These lateral viscosity variations are superposed on four different reference models which differ significantly in the lower mantle. The Coupled Laplace-Finite Element method is used to predict the GIA response on a spherical, self-gravitating, compressible, viscoelastic earth with self-gravitating oceans, induced by the ICE-4G and ICE-5G deglaciation models.

Results show that the effect of β values on uplift rates and gravity rate-of-change is

not simple and involves the trade off between the contribution of lateral viscosity variations in the transition zone and in the lower mantle. Models with a small viscosity contrast in the lower mantle cannot explain the observed uplift rates in Laurentide and Fennoscandia. However, the RF3S20 model with a reference viscosity profile simplified from Peltier's VM2 with the value of β around 0.2 to 0.4 is found to explain most of the global RSL data, the uplift rates in Larentide and Fennoscandia and the BIFROST horizontal velocity data. In addition, the changes in GIA signals caused by changes in the value of β are large enough to be detected by the data, although uncertainty in other parameters in the GIA models still exists. This may encourage us to further utilize GIA observations to constrain the thermal effect on mantle lateral heterogeneity as seismic tomography and geodetic and satellite gravity measurements are improved.