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Accuracy and sensitivity of GIA data in the study of the role of thermal effect on seismic anomalies in the mantle

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Studies of Glacial Isostatic Adjustment (GIA) are very useful in understanding the rheologic structure of the Earth (and thus mantle dynamics) and past ice sheet histories (thus past and present climate change). To better constrain GIA models, new GIA observations are needed. In order to determine the optimal location of new data, we need to know the accuracy level of the measurements such as GPS, absolute gravity or the Gravity Recovery and Climate Experiment (GRACE) and whether the sensitivity of the data to the rheology or ice history of a certain region of interest is above the accuracy level (Wu et al. 2010, GJI). The sensitivity kernel of GIA is also useful in the inversion of mantle rheology. We demonstrate, for example, that beside degree 2 data (e.g. rotational motion), only geodetic (e.g. GPS, gravity-rate-of-change etc.) and relative sea-level data near the center of rebound in Laurentia are able to resolve the deep lower mantle viscosity. This has important implications in the inversion of mantle rheology from sea-level and geodetic data.

We also illustrate this with a 3D rheologic model that studies the role of thermal effect on seismic anomalies in the mantle, which are revealed in seismic tomography. An outstanding issue is the role of thermal versus non-thermal (e.g. compositional, partial melting) contribution to seismic velocity anomalies. The observations from the GRACE satellite mission and GPS crustal uplift rates show that thermal effect increases from about 65% in the upper mantle to 80% in the shallow part of the lower mantle and to about 100% in the deep lower mantle above the D" layer. This is consistent with temperature excess in the lower mantle from high core heating. However, the uncertainty increases from < 1% in the upper mantle to 20% in the shallow lower mantle and is less well constrained in the deep lower mantle. The implication of large thermal contribution is that hot buoyant plumes can cause large viscosity reduction in an otherwise high viscosity lower mantle that impedes motion.