Temporal Geoid Variations as Constraint in Global Geodynamics

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Density distributions derived from various seismic tomographies as well as modifications to these models with an upper-mantle slab sinking model and viscosity models of Earth's mantle are investigated in analytical flow models in order to fit the models' predicted observables to the GRACE satellite-mission's gravity and geoid measurements and to observed plate motions while reproducing estimates of dynamic topography as an additional constraint. Advecting successful models' density distributions yields temporal variations of the above observed quantities. We investigate whether identifiers of such mantledynamic processes may be discerned from other sources' signal contributions to the GRACE-measured global temporal geoid variation in order to impose an additional constraint on global geodynamic modeling.

The ongoing 5-yr Grace satellite mission yields estimates of Earth's global gravity field of unprecedented accuracy. A globally improved resolution of the static geoid itself will not affect the constraint on global geodynamic modeling due to the large uncertainties in quantities dominating the modeling process (apparent in the large discrepancies when comparing different global seismic tomography models or geodynamic mantle models based on past slab subduction as well as in the uncertainties involved in the conversion of seismic velocity anomalies to density heterogeneities for flow model calculations) and also due to the limitations when imposing suitable upper boundary conditions in order to reproduce observed plate motions. The temporal sequence of monthly mean gravity field estimates, however, provides a time history of its global variability, which may serve as a surface observable (in addtion to the commonly employed static geoid or gravity field, surface velocity or estimates of dynamic topography) constraining geodynamic flow, provided contributions from mantle flow are discernable from the main signal. Furthermore, the combined data sets of geoid and its temporal variation may be used to infer not only relative, but also absolute global viscosity distributions within the Earth. While viscosity estimates from glacial isostatic adjustment are expected to be biased by continental influences, GRACE data provides an evenly distributed coverage to this end. Also the correlation beween instantaneous geoid and its rate of change possibly contains additional information about the geodynamic processes involved. It is expected to differ for retreating subduction zones, detaching slabs, and developing plumes. Global temporal geoid variations estimated by advecting density heterogeneities from our range of successful models exhibit variing spatial patterns which are, however, small (O(-6) m) in comparison to those due to ocean circulation, redistribution of water and biological masses, PGR or massive volcanic processes, which are of the order of the observed temporal variability itself (O(-3) m).