3D Numerical modeling of glacial isostatic adjustment with lateral heterogeneities

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Analytical spherically layered models are commonly employed to study the response of the Earth to the melting of the late–Pleistocene ice-sheets in order to predict postglacial deformations and gravity variations. To overcome the limits of analytical approaches, numerical models have been developed to keep into account lateral varying rheological structures that may significantly affect various geophysical quantities related to Glacial Isostatic Adjustment (GIA), and particularly postglacial relative sea level (RSL) variations and horizontal deformations. We develop 3D spherical finite element models with lateral variations of lithospheric thickness and Newtonian upper mantle, and we directly compare the outcomes of these models with RSL data selected from a publically available global data set. This differs from previous investigations, that have mainly focused on extensive sensitivity analysis or have considered a very limited number of RSL observations pertaining to the formerly glaciated regions or to their periphery. In our study the lithospheric thickness is constrained to mimic the global structure of the cratons based on geological evidence, and the upper mantle includes a low–viscosity zone beneath the oceanic lithosphere. We use two distinct global surface loads, based upon the ICE1 and ICE3G deglaciation chronologies, respectively. Our main finding is that using all of the available RSL observations in the last 6000 kyrs it is not possible to discern between homogeneous and heterogeneous GIA models. This finding, that holds for both the ice chronologies employed here, suggests that the cumulative effects of laterally varying structures on the synthetic RSL curves tend to cancel out globally, thus providing signals that do not significantly differ from those based on the traditional radially stratified models. We have also considered specific subsets of the RSL database, selecting sites sharing similar geographical settings and distances from the main centers of deglaciation. In the regions where the disagreement between predictions and observations is particularly evident, further investigations will be needed to improve the geometry of the deep heterogeneous structures and of the surface ice sheets distribution.