Viscosity structure of Earth's mantle inferred from glacial isostatic adjustment

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Observations of glacial isostatic adjustment (GIA) contain important information about the Earth's deformation. Here we examine four GIA data sets in inferring mantle viscosity structure: secular variations in zonal harmonics of Earth's geopotential Jn-dot ($2 \leq n \leq 6$), relative sea level (RSL) changes for the Last Glacial Maximum (~21 kyr BP) at Barbados and Bonaparte Gulf in Australia, RSL changes at 6 kyr BP in the Australian region and postglacial RSL changes in the intermediate region of the North American ice sheet. These observations are largely dependent on gross melting history of the polar ice sheets, and sensitive to the upper and lower mantle viscosities. The geodetically derived Jn-dot is highly sensitive to the GIA-based Earth's response and also affected by recent melting of glaciers and Greenland Antarctic ice sheets. We therefore evaluate the GIA-induced Jn-dot using the geopotential zonal secular rates and recent melting taken from the IPCC 2013 Report. Inference of the mantle viscosity from these observations is based on the three viscosity models, (i) simple three-layer viscosity model characterized by lithospheric thickness and upper and lower mantle viscosities, (ii) two-layer lower mantle viscosity model defined by viscosities for 670-D km depth and D-2891 km depth with D-values of 1191 and 1691 km, and (iii) viscosity model with an exponential profile described by temperature (T) and pressure (P) distributions and constant activation energy (E_{um} for the upper mantle and E_{lm} for the lower mantle) and volume (V_{um} and V_{lm}). Our preferred viscosity structure through the analyses of these RSL changes based on these viscosity models is as follows: laterally heterogeneous upper mantle viscosity of (1-10) $\times 10^{20}$ Pa s, ~10^{22} Pa s at 670 km depth (significant viscosity jump at 670 km depth), and smooth depth variation in the lower mantle viscosity (an order of gradual increase) following $\exp[(E_{lm}+P(z)V_{lm})/RT(z)]$ with constant E_{lm} and V_{lm}.

Keywords: Glacial isostatic adjustment, Mantle viscosity