Earth rheology from glacial rebound analysis

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The knowledge of the Earths mantle viscosity remains unsatisfactory despite the many laboratory and field studies that have been conducted. Is the viscosity depth dependent and does it vary laterally? Is it linear or is it non-linear? The rebound of the crust to the past ice loads has often been described as Natures own experiment in estimating the viscosity but, as is often the case with elegant experiments, reality is more complex and the viscosity estimates that have been inferred from rebound analyses are usually only as good as the assumptions made about the surface loading history of the ice sheets and analyses of rebound have to consider both the rheology and the ice history as imperfectly known functions. Thus strategies for the inversion of rebound data have to be developed that separate out earth- and ice-model parameters and that enable depth- spatial- and time- dependencies of the effective viscosity function to be determined.

Iterative solutions for earth-response and ice-load parameters have yielded some separation of parameters through focussing on (i) regional inversions of rebound data rather than global solutions, (ii) using differential methods to separate eustatic change from the rebound signal, (iii) using the responses observed on different time scales (e.g. geodetic versus geological), (iv) observing the response at different wavelengths, and (v) observing both radial and horizontal rebound responses. The results confirm that simple linear models for the viscosity function can provide an accurate response of the mantle to surface loading on time scales from decades to millennia. Depth dependence of the viscosity is important, with a marked increase from the average upper mantle to the average lower mantle, as well as increases within the upper mantle that correspond to the seismic transition zone. Lateral variability is also significant, with the viscosity variation following the seismic evidence for lateral variation in mantle shear-wave velocity and attenuation. Finally, there is evidence for a time dependence of the effective viscosity, with analyses based on observations of the recent response leading to higher upper mantle viscosity estimates than analyses based on geological data for past millennia.