Postglacial Rebound Analysis for Better Determination of Earthquake-Related Deformation and Rheology at Subduction Zones

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Investigations Undertaken

1. Develop a preliminary postglacial rebound model for a portion of the Alaskan margin.
2. Refine a postglacial rebound model for the southern Cordilleran ice sheet (British Columbia and northern Washington State).

Results

1. A postglacial rebound model was developed for the Alaska Peninsula. It is based on a published reconstruction of the Alaska Peninsula ice sheet at Last Glacial Maximum (Figure 1) and maps of ice margin retreat. The ice load is described on a 40 km x 40 km grid (Figure 2) to accommodate the spatial detail provided by the source maps. Relative sea-level curves were generated for a broad range of possible values of mantle viscosity and lithospheric thickness, and compared to available sea-level observations. The comparison shows that mantle viscosity values above about 2 x

10^{20} Pa s are too large to explain the observations. These values of mantle viscosity are small compared to mantle viscosities inferred from global models of postglacial reound. The low viscosity required by the observations is consistent with mantle viscosity values inferred from postseismic relaxation studies at subduction zones. It is also similar to the low value found for the northern Cascadia subduction zone, based on earlier postglacial rebound modelling. The small mantle viscosities found for these subduction zones may reflect the mobile nature of a subduction zone, in which fluids flux through the mantle wedge. At greater depths the subduction zones are underlain by oceanic mantle, which may be relatively more fluid than the mantle underlying continents. An important implication of low mantle viscosity is that present-day postglacial rebound crustal uplift rates are expected to be ~1 mm/yr or less. This prediction is corroborated by early Holocene relict lake shorelines in the study region which have experienced very little post-formation tilting compared to proglacial lake shorelines in Puget Sound.

2. Preliminary postglacial rebound modelling at the northern Cascadia subduction zone was extended to consider the implications of layered (non-uniform) mantle viscosity. The main result is that deeper portions of the mantle can have large values of mantle viscosity, provided regions shallower than 440 km depth retain the low viscosity values previously found. The chief implication of this is that the very low predictions of crustal uplift (<0.1 mm/yr) previously made are upwardly revised to ~1 mm/yr. These rates are larger than previously reported, but still smaller than predictions from global models of postglacial rebound featuring larger viscosity values at shallow depths. Confirmation of a low value of mantle viscosity at shallow depths is also important because a study of interseismic deformation at the Cascadia subduction zone, using three-dimensional viscoelastic models, adopted a low value of mantle viscosity from our preliminary study.

Non-Technical Summary

In some earthquake regions the surface of the Earth is moving because of ice sheet and glacier changes that occurred in the past and that exerted a changing weight, or load, on the Earth. This motion is called postglacial rebound. In analyzing observations of crustal movements, it is important to separate geological effects from postglacial rebound effects. Models of postglacial rebound were developed to explain observations of past sea-level change for western Alaska and southern British Columbia/northern Washington State. They show that present-day postglacial rebound uplift rates are quite small, indicating that observations of present-day crustal motion should be mainly due to geological, or tectonic, processes. The models also indicate that the interior of the Earth below these regions is relatively fluid. This information is used to better understand the active geological processes causing earthquakes.

Reports Published

Clague, J. J., and T. S. James, History and isostatic effects of the last ice sheet in southern British Columbia, *Quaternary Science Reviews*, **21**,71-87, 2002.

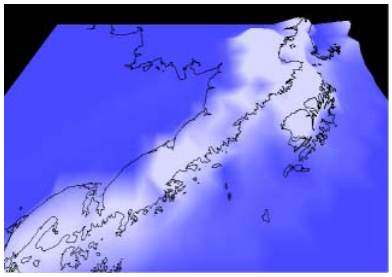

Figure 1. Oblique view of Alaska Peninsula with LGM ice surface represented with paler shades.

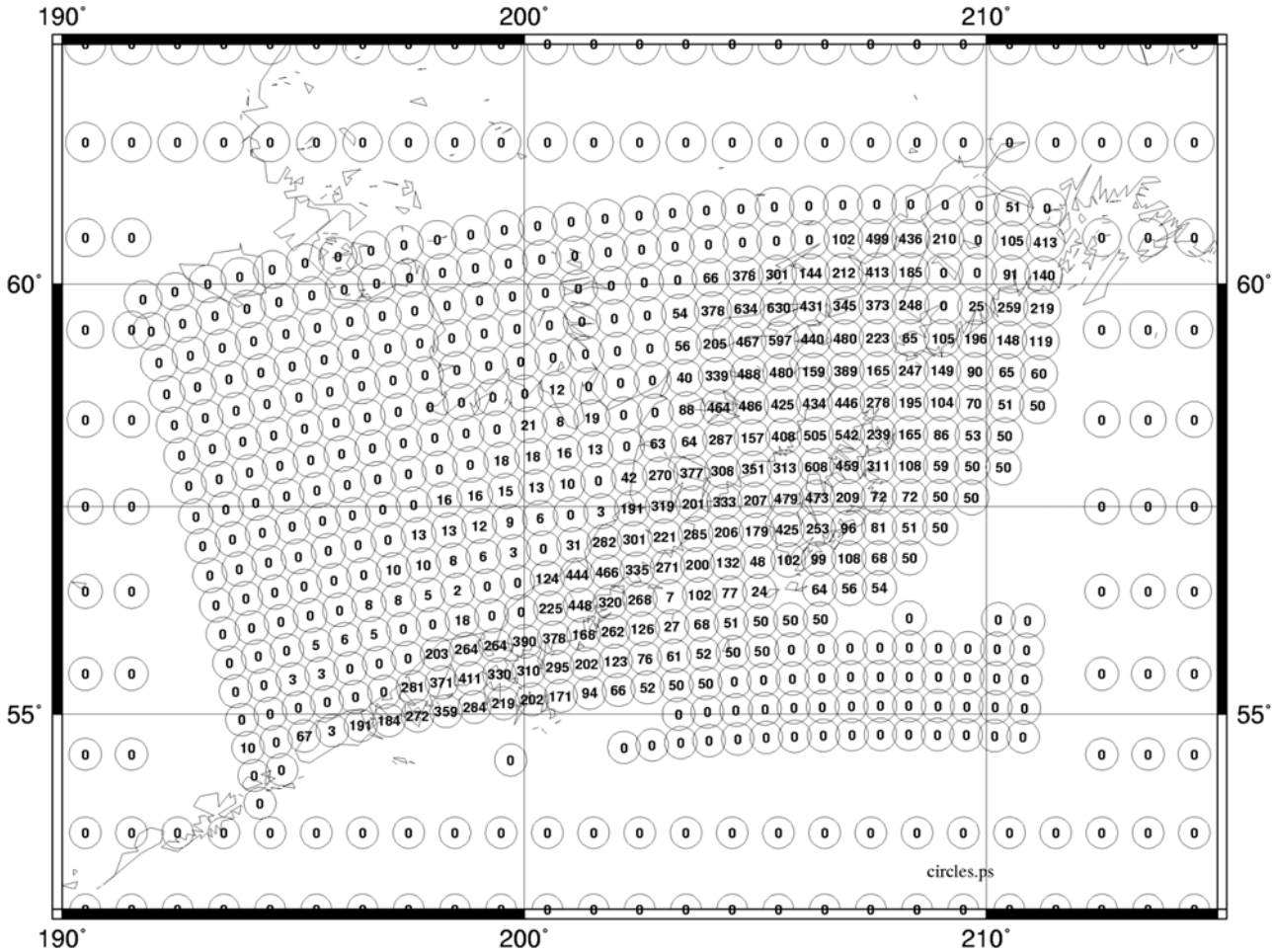

Fig. 2: The ice load model at 16,000 ^{14}C years ago. The dense grid is the Alaska Peninsula model developed in this study, the surrounding sparser grid is derived from a previously published global model. The numbers are the ice thicknesses in meters.