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

Program Element II: Research on Earthquake Occurrence and Effects

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Technical Abstract. This project continues work begun under an earlier NEHRP grant to develop postglacial rebound models at subduction zones to explain the past record of vertical crustal motion due to glacial-cycle loading and unloading of the Earth's surface. The main goals are to: 1. Determine whether significant crustal motion due to postglacial rebound may still be continuing that would "contaminate" observations of present-day crustal motion made to assess tectonic processes, 2. Develop better constraints on subduction zone rheology, which can be used as input for other geodynamic models of subduction zone processes, such as the great earthquake cycle. Work proceeded on two fronts and addressed both goals.

1. A preliminary postglacial rebound model was developed for the Alaska Peninsula. A previously published reconstruction of the ice sheet at Last Glacial Maximum, combined with published maps of ice margin retreat, allowed an ice model to be constructed. Predictions of sea-level change were produced and compared to observations of past sea-level change. For reasonable ice load histories, mantle viscosity values above about 2×10^{20} Pa s are too high to agree with the observations. The low values of mantle viscosity found for this portion of the Alaskan margin are smaller than those derived from global models of postglacial rebound. They are, however, generally consistent with values from studies of postseismic relaxation in subduction zone settings and with previous postglacial rebound modelling of the northern Cascadia subduction zone. An important implication of a low value of mantle viscosity is that present-day vertical motions due to ice mass changes in the late Pleistocene are expected to be of the magnitude of ~1 mm/yr, and possibly only tenths of a millimeter per year. However, if ice mass changes have continued into the Holocene and up to the present, as is the case for some parts of the Alaskan margin, vertical crustal motion due to more recent ice mass changes can be substantial with these smaller values of mantle viscosity.
2. The preliminary postglacial rebound modelling at the northern Cascadia subduction zone begun under a previous NEHRP grant 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 NEHRP-funded 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.