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GIA model with non-linear 3D Earth rheology and viscoplastic ice model for Scandinavia

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Global ice models implicitly assume (linear) Earth rheology and certain viscosity profiles. Thus, inferences on the rheology of the Earth based on such ice models are possibly biased by these assumptions. Here, we use an ice model where the margins are determined by georeferenced geological evidence and the shape is determined by plastic or visco-plastic ice. The resulting ice volume leads to contribution of the Fennoscandian ice cap to sea level of 14 m, which fits well with climate reconstructions. Our aim is to see if a non-linear flow law for mantle rocks in combination with temperatures derived from seismology is compatible with GIA observations in Scandinavia.

The Earth is modeled by a finite element model with self-gravitation and with self-consistent sea-levels included. Elastic parameters for a 6-layer model are derived from PREM and incompressibility is assumed. The flow law is based on diffusion and dislocation creep in olivine. Temperatures for the upper 230 km are taken from published values derived from seismology. Grain sizes are varied from 1, 4 and 10 mm, in agreement with xenoliths findings. Water content is varied between a ‘wet’ and a ‘dry’ rheology. For lower elements we use flow law parameters that are shown to fit well in a global model.

We compare predictions with relative sea level data from 51 sites, present-day uplift rates from GPS and gravity rates from GRACE. The best fit to the sea level data is obtained with wet rheology. However, a dry rheology provides a better fit for late Holocene data (< 6,000 years before present). A dry rheology leads to larger uplift and geoid rates which better fit GRACE and GPS data.