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Reconstructions of the Weichselian ice sheet, a comparative study of a thermo-mechanical approach to GIA driven models.

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Observations of glacial isostatic adjustment (GIA) have been used both to study the mechanical properties of the Earth and to invert for Northern Hemisphere palaeo-ice-sheets. This is typically done by solving the sea-level equation using simplified scaling laws to control ice-sheet thickness. However, past ice-sheets can also be reconstructed based on thermo-mechanical modelling driven by palaeo-climate data, invoking simple analytical models to account for the Earth's response. Commonly, both approaches use dated geological markers to constrain the ice-sheet margin location. Irrespective of the approach, the resulting ice-sheet reconstruction depends on the earth response, although the interdependence between the ice model and the earth model differs and therefore the two types of reconstructions could provide complementary information on Earth properties.

We compare a thermo-mechanical reconstruction of the Weichselian ice-sheet using the UMISM model (Näslund, 2010) to two GIA driven reconstructions, ANU (Lambeck et al., 2010) and ICE-5G (Peltier & Fairbanks, 2006), commonly used in GIA modelling. We evaluate the three reconstructions both in terms of ice-sheet configurations and predicted Fennoscandian surface deformation

ICE-5G comprise the largest reconstructed ice-sheet whereas ANU and UMISM are more similar in volume and areal extent. Significant differences still exists between ANU and UMISM, especially during the final deglaciation phase. Prior to the final retreat of the ice-sheet, ICE-5G is displays a massive and more or less constant ice-sheet configuration, while both ANU and UMISM fluctuates with at times almost ice-free conditions, such as during MIS3. This results in ICE-5G being close to isostatic equilibrium at LGM, whereas ANU and UMISM are not. Hence, the pre-LGM evolution of the Weichselian ice-sheet needs to be considered in GIA studies. For example, perturbing the ANU or UMISM reconstructions we find that changes more recent than 36 kyr BP may change the predicted uplift velocities by more than 0.1 mm/yr, while changes more recent than 55 kyr BP may change the predicted uplift 10 kyr ago by more than 5 m.

Despite their differences we find that all three reconstructions can equally well fit observations of the present day uplift in Fennoscandia, as well as the observed sea-level curve along the Ångerman river, Sweden, albeit with different optimal earth models. However, only for ANU can a single optimal earth model be determined as a bifurcation in the optimal viscosity arises from the generally faster present day rebound rates in ICE-5G and UMISM, resulting in a range of well-fitting earth models for the latter reconstructions.

Studying models with a reasonable fit to observed present day uplift velocities we find general trends of over- and under-prediction, indicating that all three ice-sheet reconstructions need improvement. In general, all three reconstructions tend to over-predict the uplift rates in southwestern Fennoscandia, whereas over Finland ICE-5G generally over-predicts and ANU generally under-predicts the uplift rates. UMISM tend to under-predict the velocities over central to northern Sweden and similar trends can also be seen in ANU and ICE-5G.