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The impact of lateral variations in lithospheric thickness on glacial isostatic adjustment in West Antarctica

Grace Nield (1), Pippa Whitehouse (1), Wouter van der Wal (2), Bas Blank (2), John Paul O'Donnell (3), and Graham Stuart (3)

(1) Durham University, Department of Geography, Durham, United Kingdom (g.a.nield@outlook.com), (2) Faculty of Aerospace Engineering, Delft University of Technology, Delft, NL, (3) School of Earth and Environment, University of Leeds, Leeds, UK

Differences in predictions of Glacial Isostatic Adjustment (GIA) for Antarctica persist due to uncertainties in deglacial history and Earth rheology. The Earth models adopted in many GIA studies are defined by parameters that vary in the radial direction only and represent a global average Earth structure (referred to as a 1D Earth model). Over-simplifying actual Earth structure leads to bias in model predictions in regions where Earth parameters differ significantly from the global average, such as West Antarctica.

We investigate the impact of lateral variations in lithospheric thickness on GIA in Antarctica using two rheological models of the lithosphere. The first experiment defines an effectively elastic lithosphere with spatial variations in thickness inferred from seismic studies. We compare the results from this 3D model to a 1D Earth model that has a uniform lithospheric thickness defined as the average of the 3D lithospheric thickness. Irrespective of ice model and sub-lithospheric mantle viscosity, we find higher gradients of present-day uplift rates (i.e. higher amplitude and shorter wavelength) in West Antarctica from the 3D models, due to the thinner-than-average lithosphere prevalent in this region. The second experiment uses seismically-inferred temperature as input to a power-law rheology thereby allowing the lithosphere to have a viscosity structure. Modelling the lithosphere with a power-law rheology has the effect of reducing the local effective elastic thickness and results in higher amplitude and shorter wavelength deformation compared to defining the lithosphere as elastic.

We conclude that using a 1D Antarctic-wide average lithospheric thickness in GIA models will result in peak uplift and subsidence that is biased low in West Antarctica. This has important implications for ice sheet modelling studies as steeper gradients of uplift predicted from the more realistic 3D model may promote stability in marine grounded regions of West Antarctica. Including lateral variations in lithospheric thickness, at least to the level of considering West and East Antarctica separately, is important for capturing short wavelength deformation in this region and has the potential to provide a better fit to GPS observations and an improved GIA correction for GRACE data in the future.