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Reversal of the Direction of Horizontal Velocities induced by GIA as a function of Mantle Viscosity

Wouter van der Wal (1,2), Tim Hermans (3,1), Taco Broerse (4,1), Stephanie Konfal (5), Terry Wilson (5), and Pippa Whitehouse (6)

(1) Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands (w.vanderwal@tudelft.nl), (2) Faculty of Aerospace Engineering, Delft University of Technology, Delft, Netherlands, (3) NIOZ Royal Netherlands Institute for Sea Research, Department of Estuarine & Delta Systems, Yerseke, The Netherlands, (4) Faculty of Geosciences, Utrecht University, Utrecht, Netherlands, (5) School of Earth Sciences, Ohio State University, Columbus, United States, (6) Department of Geography, Durham University, Durham, United Kingdom

Vertical GPS velocities show that due to glacial isostatic adjustment (GIA) regions that were formerly covered with ice sheets are currently uplifting, while surrounding areas subside. Present-day horizontal surface motion is mostly ob-served to point away from the former ice load. However, in some regions horizontal velocities point toward the former ice load, for instance at GPS sites near the Ross Sea Embayment (RSE). These observations could point to the importance of a transition from low to high upper mantle viscosity that is thought to underlie the Transantarctic Mountains. The effect of lateral viscosity transitions on the direction of horizontal motion is difficult to understand, partially because the dependence of horizontal motion on homogeneous mantle viscosity has not been systematically studied.

Here we investigate how the direction of GIA-induced horizontal velocities de-pends on mantle viscosity, using simple loading scenarios applied to Earth models with a homogeneous mantle viscosity. We use the normal mode method and an axisymmetric finite element model to compute internal and surface motion through time, and vary mantle viscosity between 1019 and 1023 Pa s. Subsequently, we use a 3D GIA model with viscosity transition to study horizontal velocities in the RSE.

In contrast with the prevailing idea that GIA-induced horizontal velocities point away from former ice sheets, we find that present-day horizontal velocities can point either away or towards the former ice load, depending on mantle viscosity. This is a result of the opposing motions of mantle flow and the lithosphere flexure. Present-day horizontal velocities point away from the former ice load for mantle viscosities lower than 1020 Pa s and towards it for viscosities higher than 1022 Pa s, with a transition in between. We investigate whether this finding applies in the RSE. Our 3D GIA model predicts horizontal velocities that point away from the former ice load in the region underlain by low viscosity upper mantle in Marie Byrd Land, and towards it near the Transantarctic Mountains where the lateral gradient in earth properties between East and West Antarctica is strongest. This finding agrees with GPS-observed rates of horizontal motion, most notably in the southern Transantarctic Mountains region where GIA models using an Earth model with homogeneous mantle viscosity are unable to reproduce motions towards West Antarctica.