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An assessment of forward and inverse GIA solutions for Antarctica

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GIA has, until recently, been estimated using forward models that attempt to determine how the solid Earth responds to changes in ice-ocean loading through time. These models require knowledge of spatially-varying Earth rheology, including mantle viscosity, and ice load history, both of which have large uncertainties for Antarctica. Recent advances in GIA models include consideration of three-dimensional variations in Earth rheology and power-law rheologies. Such GIA models predict remarkably different patterns of uplift over Antarctica when compared to those using one-dimensional Earth models, such as a shift in the uplift maximum from the Ross to the Wedell Sea (van der Wal et al., 2015). However, large uncertainties still remain in the ice loading history models (A. et al 2014 and van der Wal et al., 2015) and substantial regional differences are found between Antarctic reconstructions. An alternative approach is to use observations of crustal motion from GPS, combined with mass trends from GRACE to invert for GIA. However, this is an undetermined problem which requires assumptions on the density profile of the ice column for which numerical models have been commonly used (Gunter el al., 2014).

Here we present a novel solution to the inverse problem using state-of-the-art methods in statistical modelling of spatio-temporal processes. Specifically, we combine observational data, including satellite radar and laser altimetry, GRACE, GPS and InSAR, with prior information on the spatial and temporal smoothness of the underlying process to solve, simultaneously, for ice mass trends and GIA. This is achieved via a spatio-temporal Bayesian hierarchical model and the resulting solution is only dependent on length and smoothness properties obtained from numerical models, but is otherwise entirely data-driven.

We compare the most recent forward and inverse GIA solutions for Antarctica with a set of 68 observed vertical velocities over the period 2009 – 2014 from the GPS network POLENET. The misfits between observed and modelled GIA rates display some common features in all solutions. For instance, the region with the largest WRMS across all solutions is the Amundsen Sea Embayment where none of the analysed GIA solutions predict the high uplift rates obtained from the GPS observations. The observations at the GPS sites located over the western edge of the Trasantarctic Mountains also seem to be systematically underestimated by the GIA models. Modelled uplift rates for the South Antarctic Peninsula are over-estimated by many of the solutions. For the complete set of POLENET GPS observations, our solution (known as RATES) improves the overall fit to the available GPS observations over Antarctica providing the smallest WRMS