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Unravelling Antarctic plate tectonics from ice loading effects using GPS measurements and glacial isostatic adjustment modelling

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Department of Geography, Durham University
In partnership with School of Civil Engineering and Geosciences, Newcastle University; NERC British Antarctic Survey

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Overview

This project focuses on understanding the ongoing deformation of the Antarctic Plate. To date, spatially sparse Global Positioning System (GPS) measurements of crustal velocity suggest that there is presently no internal deformation within continental Antarctica. However, this conclusion is at odds with observations of intraplate earthquakes, which indicate significant stresses in the oceanic sectors of the Antarctic plate, and it is limited by the measurement noise, which is up to 0.5-1.0 mm/yr, and the low spatial density of measurements.

Although no part of the global plate boundary network lies close to continental Antarctica, slow deformation may be associated with volcanic processes and a relatively warm upper mantle in some parts of West Antarctica. Furthermore, any tectonic signal is to some extent masked by deformation due to glacial isostatic adjustment (GIA), related to ice mass loss since the Last Glacial Maximum, and by elastic rebound (ER), related to present-day ice mass loss. One cannot interpret the tectonic signal without considering GIA and ER, and to date studies of the horizontal deformation field have not considered either effect.

In part this is due to GIA models not considering three-dimensional Earth structure (that is, lateral variations in lithospheric thickness and mantle viscosity); all widely used models at present assume only radially-varying Earth structure, which leads to the potential for seriously misrepresenting the horizontal velocity field. In terms of ER, our knowledge is limited by a lack of understanding of the magnitude and spatial patterns of present-day ice mass change. Both of these are being addressed through new observational and modelling efforts, including substantial new datasets from Newcastle University and modelling efforts in a large research project at Durham University.

This project will focus on the exploitation of these datasets and model improvements to separate the GIA and ER signal from observed GPS velocities to provide the first robust estimate of the stability of the Antarctic Plate.

Methodology

The project will develop an ensemble of Antarctic GIA models, using software available at Durham, which will then be augmented to account for elastic and viscoelastic deformation due to present-day and recent (decade to century scale) surface mass balance. These models will then be tested against new and existing GPS velocity data. The residual velocities will be used to test rigid-plate and deforming-plate hypotheses for the Antarctic, which can be compared with other geological and geophysical evidence.

Timeline

Year 1 will involve training in GIA modelling, leading to the production of a suite of plausible models of present-day GIA-related deformation in Antarctica based on published ice histories (e.g. ICE-5G/6G) and variations on these provided by Whitehouse. Forward modelling of elastic deformation in response to present-day surface mass balance will occupy the early part of Year 2, followed by consideration of decadal viscoelastic deformation in areas where variations in mass balance may have a significant effect. The combined work of Years 1 and 2 should lead to a published output.

In Year 3, GPS/GNSS data from existing sites and those to be deployed in other projects by Newcastle/Durham and collaborators during the early part of this project will be collated and processed to provide an experimental velocity field against which the forward models of GIA and ER can be tested – a key advance in the understanding of Antarctic solid Earth deformation in general and GIA in particular. Residual velocities to these models will then be used to generate and test rigid-plate models, with and without plate boundary zones, leading to a robust estimate of the rigidity of the Antarctic plate and of the confidence limits of this estimate in the presence of GIA and ER. This will form a second publication. The final part of the studentship will be occupied with combining these two papers and associated material into the PhD thesis.

Training & Skills

In addition to generic training provided by the Department, Faculty and IAPETUS, the student will need training in the modelling of GIA and the processing of GPS data. The relevant international communities regularly hold graduate summer schools in these techniques, and an important part of the student's training (and embedding in the international community) will be attendance at these (one in GIA, one in GPS). Further training will be provided through attendance at the British Geophysical Association's annual postgraduate meeting, the annual IAPETUS student meeting, and a major international conference (EGU, AGU, IAG/IUGG or similar).

The student will gain valuable skills including geophysical modelling, management of large geo-datasets, GNSS geodesy, and time series analysis, and they will have opportunities to work with other partners in the UK and internationally. There will be opportunity to travel to national and international scientific meetings to present results, and we aim to see all students publish 2-3 papers in leading scientific journals during their PhD. Upon completion, the student will be well equipped for a career in academia or in a range of industries.

References & Further Reading

Bromwich & Nicholas (2010). Ice-sheet uncertainty. *Nature Geoscience*, **3**(9), 596-597.

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Further Information

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