The effect of recent accumulation changes in the Antarctic Peninsula upon Glacial Isostatic Adjustment

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1. Introduction

- The Antarctic Peninsula (AP) is undergoing Glacial Isostatic Adjustment (GIA) in response to ice mass changes since the Last Glacial Maximum.
- Changes in AP ice mass during the last few hundred years have the potential to contribute substantially to the present-day GIA signal.
- Ice cores show significant accumulation increase in recent decades (e.g. *Thomas et al.,* 2008), which may have led to cumulative ice mass increase.
- **Aim:** to model this increase in accumulation and ice mass, and estimate the contribution to present-day GIA in the AP.

2. Recent Accumulation

How do we extrapolate the accumulation seen in ice cores over the whole AP?

1. Take surface mass balance (SMB) output from climate model RACMO2.1/ANT (*Lenaerts et al.,* 2012) between 1989 and 2010 (Figure 1).
2. Estimate empirical orthogonal functions (EOFs) to infer spatial pattern of accumulation (Figure 2).
3. Since Gomez ice core accumulation continues to increase until 2001, we extend each core to 2010 by linear extrapolation using the same rate of increase as between 1930 and the end of the ice core record.
4. Combine EOFs with the ice core data (*Thomas et al.,* 2008; *Mosley-Thompson,* 1992; *Peel,* 1992) (locations shown in Figure 4) to reconstruct the accumulation history between 1855 and 2010, assuming spatial pattern remains constant over the period of the data (Figure 3).

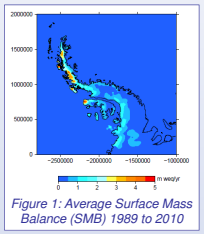


Figure 1: Average Surface Mass Balance (SMB) 1989 to 2010

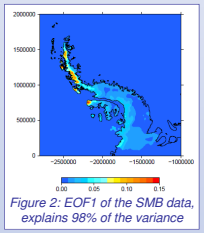


Figure 2: EOF1 of the SMB data, explains 98% of the variance

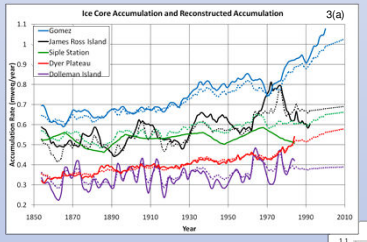


Figure 3: Accumulation in metres water equivalent per year (m_{weq} y^{-1}) derived from ice core records (solid lines) and EOF-reconstructed accumulation time series at each location using (a) data from all ice cores (dotted lines), and (b) data from all ice cores except the one being reconstructed (light coloured lines).

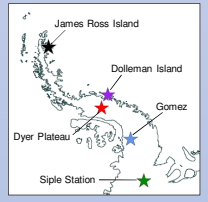
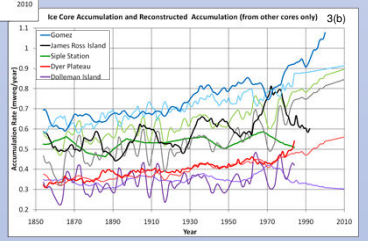


Figure 4: Map of ice core locations



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3. Ice Sheet Modelling

- The accumulation history drives a high resolution (5km) ice-sheet model (the Glimmer community ice-sheet model (*Rutt et al.,* 2009)).
- Ice thickness changes are predicted in response to the reconstructed accumulation rate (Figure 5).
- The model is run for 155 years (1855-2010) from an equilibrium state.
- Total ice thickness is output every 5 years and differenced with the equilibrium ice thickness to obtain the cumulative ice thickness increase due to the reconstructed accumulation history.
- The final ice thickness increase in the northern AP is less than the sum of the reconstructed accumulation history as much of the accumulated ice is quickly lost to the oceans due to high velocity ice flow.

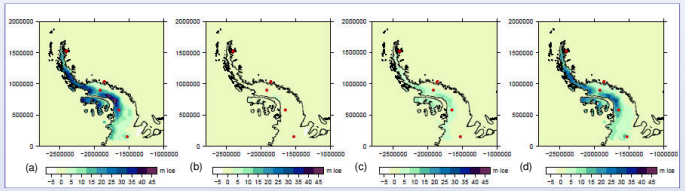

Figure 5: Net accumulation for: (a) 1855 to 2010; and 50 year periods: (b) 1860 to 1910, (c) 1910 to 1960, (d) 1960 to 2010. Ice core locations shown in red.

4. GIA Modelling

- The output of the ice modelling is used to drive a GIA model, which calculates the response of the Earth to changes in ice loading at the surface.
- The maximum spherical harmonic representation of the mass loads is 256.
- The model is run over 155 years with no change in ice thickness in the final few time steps. This eliminates the elastic effects of a changing load from the present-day uplift rate.
- There is a strong sensitivity to the Earth model, particularly upper mantle viscosity.
- Accumulation between 1855 and 2010 contributes around +0.5 to -6.5 mm yr^{-1} to the uplift rate, for realistic Earth Models for the AP, with greatest subsidence predicted in the western AP (Figure 6).

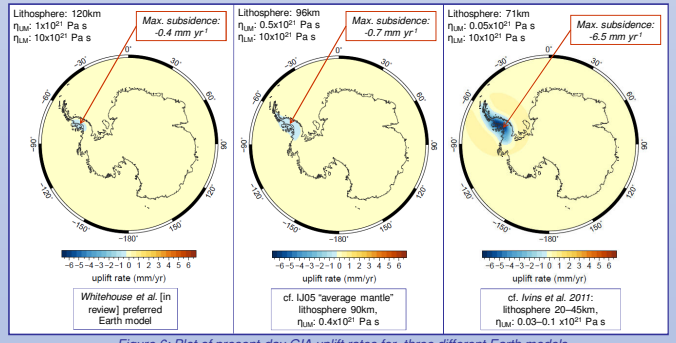

Figure 6: Plot of present-day GIA uplift rates for three different Earth models

5. Discussion

- GPS observations suggest low rates of GIA uplift on the AP (*Thomas et al.,* 2011).
- The addition of an arbitrary, uniform thickness of ice on the AP to an existing deglacial model (*Whitehouse et al.,* 2012) during the last 1000 years can improve the fit between modelled GIA uplift rates and GPS data (*Whitehouse et al.,* in review), but results in predicted subsidence on the eastern AP (Figure 7).
- This study demonstrates that an E-W gradient in accumulation can generate a spatially variable GIA response that may help explain the observed low rates of GPS uplift in the AP.

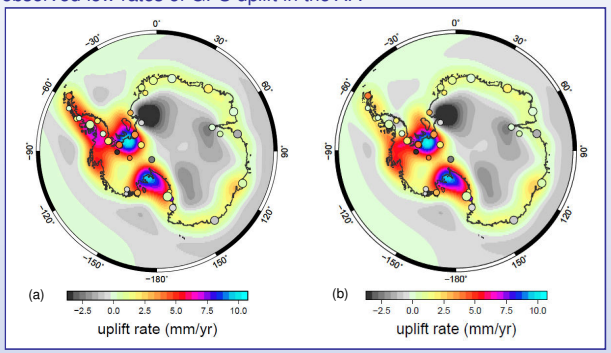

Figure 7: Plot of present-day GIA uplift rates for (a) Whitehouse et al. ice model; (b) ice model in (a) with extra 300m of ice on the AP. Circles are GPS rates from Thomas et al. [2011]. *Figure taken from Whitehouse et al. [in review].*

6. Conclusions

1. Accumulation reconstruction and ice sheet modelling shows up to 45 m of ice accumulation in the AP over 155 years….
2. ….causing a GIA-related uplift signal of +0.5 to -6.5 mm yr^{-1} for realistic Earth models for the AP.
3. GIA model results have strong sensitivity to the upper mantle viscosity.
4. The extra ice loading, if added to an existing ice loading history, may explain the low rates of GIA-related uplift observed in the AP from GPS measurements.

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