Tides in the Amery Ice Shelf / Prydz Bay Region, East Antarctica

A Bathymetry Map

Ben Galton-Fenzi[1,2,3]
Email: bkgalton@utas.edu.au
Address: c/- ACE CRC, Private bag 80, Hobart, 7001, Tasmania, Australia

Claire Maraldi [4,5]
John Hunter [1,3]
Richard Coleman [1,2,3]
Benoit Legresy [5]
Laurent Testut [5]

Overview

Ocean circulation beneath ice shelves and associated rates of melting and freezing are influenced strongly by water column thickness and depth. The shape of the cavity beneath the Amery Ice Shelf (see Fig. 1 for location) is important for our understanding of ice shelf stability and freshwater input to the ocean and their dependence on climate. Much of the cavity shape beneath the Amery Ice Shelf is unknown, particularly in the South (see Fig. 2).

Surface elevation and ice thickness has been measured over much of the Amery Ice Shelf using satellite radar altimeter and radio-echo sounding (see Fig. 3). These data are used to provide ice draft estimates along the grounding zone and are incorporated into the kriging interpolation method that is used to create the bathymetry maps. A vertical section of the cavity, following the dashed line in Fig.2, is shown in Fig.4.

The sensitivity of the tides to the different water column thickness of the Amery Ice Shelf cavity was tested using TUGO, a 2-D (vertically averaged) high resolution model (Fig. 5). The tidal simulations were compared with GPS observations (see Fig. 2). The 'best' water column thickness corresponds to the smallest error, which is the complex sum of the difference between observed and simulated harmonics for the 4 main tidal constituents (K1, O1, S2, M2). Fig. 6 shows that the complex error is smallest for scenarios that have a mean water column thickness between 360 m and 390 m.

Conclusions

A map of the bathymetry with 150 m contour intervals is shown in Fig. 7. The new geometry will be used in climate modeling studies of the Amery Ice Shelf cavity (see Fig. 8).

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References

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A. Ruddell. Antarctic Co-operative Research Centre, Unpublished ice-draft and bed elevation data for the Amery Ice Shelf.

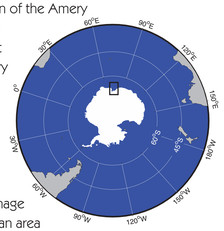


Figure 1: The location of the Amery Ice Shelf (black box) and Prydz Bay in East Antarctica. The Amery Ice Shelf is the third largest embayed ice shelf in Antarctica, and drains the grounded ice from the interior of the Lambert Glacier drainage basin, which covers an area of 16% of the East Antarctic ice sheet.

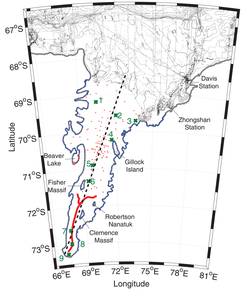


Figure 2: Location of bathymetry and GPS data used in the analysis. Red points are seismic derived bathymetry, collated by Ruddell (unpublished) and during the 2001/02 and 2005/06 field seasons. Blue points represent the ice draft at the grounding line. Green crosses show the locations of the GPS data. The dashed line is the location of the vertical section and the thick red line shows the prescribed channel centerline (see Fig. 4). The black points in Prydz Bay are a subsample of ship tracks and GEBCO bathymetry.

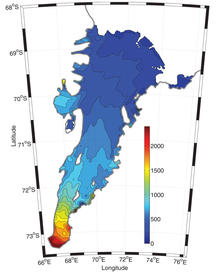


Figure 3: Ice draft showing 150 m contour intervals (after Fricker et al., 2000).

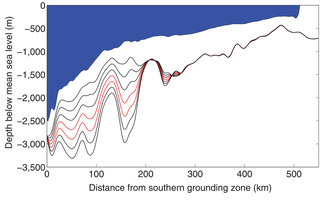


Figure 4: A vertical profile showing the change at the Southern part of the Amery Ice Shelf for each of the 7 scenarios. Each scenario was created by varying the thickness of the water column below the ice shelf along the thick red line shown in Fig. 2. The linear kriging interpolation was done using a 2 x 2 km grid in WGS84 coordinated that extends from roughly 66E to 81E and -73.6S to -66S. The best estimate, shown in Fig. 7, is between the two red lines.

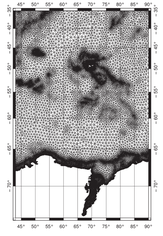
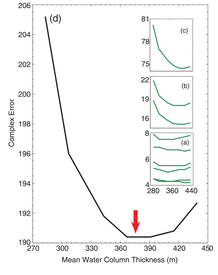


Figure 5: The finite element mesh of TUGO-m/MOG2D, a 2D gravity wave model, adapted from Lynch and Gray (1979). The ocean boundary conditions are forced using the global ocean tidal solution, FES2004. The water column thickness required for the model was found by subtracting the ice draft from each bathymetry scenario. The bottom friction coefficient is doubled beneath the ice to account for the ice/water interface.

Figure 6: The sum of the complex errors for the 4 major tides are compared with each bathymetry for:
(a) GPS sites 1 to 6,
(b) GPS sites 7 and 8,
(c) GPS sites 9 and
(d) The sum over all these GPS sites.
Note that site 9 lies within the ice shelf flexure zone which acts to damp the tidal amplitude, thereby increasing the complex error.



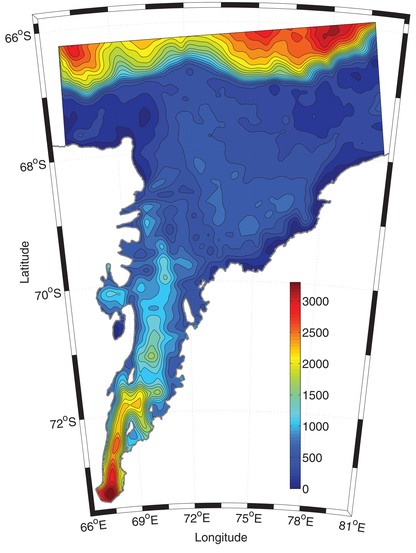


Figure 7: The resulting bathymetry map with a mean water column thickness of about 375 m showing 150 m contour intervals.

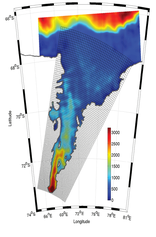


Figure 8: The polar grid that is used in the Regional Ocean Modeling System (ROMS) overlying the new bathymetry data product. ROMS is a 3-D hydrodynamic ocean model with ice/ocean thermodynamics. Results will lead to estimates of the response of the ice-shelf cavity to climate change.

1. Centre for Marine Science, University of Tasmania (CMS)
2. Commonwealth Scientific and Industrial Research Organisation, Marine and Atmospheric Research (CMAR)
3. Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC)
4. University Paul Sabatier, Toulouse
5. Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)

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