WAIS sensitivity to sub-ice-shelf bathymetry during the last glacial cycle: model-data convergence in the Ross Sea

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Abstract

Sub-ice bathymetry has been shown to influence ice-sheet stability at a continental scale (e.g. Gasson et al., 2015; Bart et al., 2016) down to the scale of an individual ice stream (e.g. Favier et al., 2014; Huybers et al., 2017). Here we investigate post-LGM ice-sheet sensitivity to bed elevation underneath the modern Ross Ice Shelf. Bed elevations have significant uncertainty in this region, despite playing an important role in Last Glacial Maximum (LGM) ice retreat. We conservatively estimate a sub-ice-shelf vertical uncertainty of about 200 meters (Lythe et al., 2001; Timmerman et al., 2010; Fretwell et al., 2013). Model simulations were run over altered bed configurations to assess ice-sheet response to bed uncertainty: seafloor elevations were raised or lowered across the sub-ice-shelf region, using Bedmap2 as the default configuration. This sensitivity analysis brackets the possible range of dynamic ice-sheet behavior and ice volume changes throughout the last glacial cycle.

If bed elevations underneath the modern Ross Ice Shelf are indeed lower than represented in Bedmap2, we find that this amendment does not significantly affect modeled ice-sheet behavior or ice volume loss compared to the default model run. Sub-ice-shelf bed elevations higher than Bedmap2, however, influence the behavior of individual ice streams and even the stability of the West Antarctic Ice Sheet (WAIS). In this scenario, Ice Stream D (Bindschadler Ice Stream, feeding Whales Deep trough) does not fully develop, and the resultant large grounding-line embayment facilitates Ross Sea deglaciation. Increased activity of Siple Coast ice streams leads to thinning in the interior WAIS, with greater post-LGM ice volume loss predicted.

Geologic observations can be used to constrain the observed model variability. Based on analysis of Ross Sea geomorphology, Halberstadt et al. (2016) reconstruct post-LGM retreat characterized by the formation of an embayment over Whales Deep trough. This feature drew down the ice profile and directed ice flow into the embayment. Modeled ice-sheet behavior replicates this pattern of retreat when sub-ice-shelf elevations are higher than presented by the Bedmap2 dataset.

Independent model-data convergence reproducing this distinct retreat event implies that Bedmap2 elevations under the modern Ross Ice Shelf may under-predict bed elevation, at least in the Marie Byrd Land sector directly upstream of Whales Deep trough. This reconstruction of ice-sheet retreat behavior provides crucial context for establishing a detailed Ross Sea deglacial history and interpreting radiocarbon dates in the Whales Deep trough (e.g. McGlannan, 2017). These observations can also be scaled up to build a better understanding of the impact of poorly known sub-ice shelf bathymetry on deglacial ice-sheet stability.

Keywords: bathymetry, Ross Sea, LGM deglaciation, ice-sheet stability, model sensitivity

References

Bart, P. J., Mullally, D., and Golledge, N. R., 2016. The influence of continental shelf bathymetry on Antarctic Ice Sheet response to climate forcing. *Global and Planetary Change*, 142, 87-95.

Favier, L., Durand, G., Cornford, S.L., Gudmundsson, G.H., Gagliardini, O., Gillet-Chaulet, F., Zwinger, T., Payne, A.J. and Le Brocq, A.M., 2014. Retreat of Pine Island Glacier controlled by marine ice-sheet instability. *Nature Climate Change*, 4(2), 117-121.

Fretwell, P., Pritchard, H.D., Vaughan, D.G., Bamber, J.L., Barrand, N.E., Bell, R., Bianchi, C., Bingham, R.G., Blankenship, D.D., Casassa, G. and Catania, G., 2013. Bedmap2: improved ice bed, surface and thickness datasets for Antarctica. *The Cryosphere*, 7(1).

Gasson, E., DeConto, R., and Pollard, D., 2015. Antarctic bedrock topography uncertainty and ice sheet stability. *Geophysical Research Letters*, 42(13), 5372-5377.

Halberstadt, A. R. W., Simkins, L. M., Greenwood, S. L., and Anderson, J. B., 2016. Past ice-sheet behaviour: Retreat scenarios and changing controls in the Ross Sea, Antarctica. *The Cryosphere*, 10(3), 1003–1020.

Huybers, K., Roe, G., and Conway, H., 2017. Basal topographic controls on the stability of the West Antarctic ice sheet: lessons from Foundation Ice Stream. *Annals of Glaciology*, 1–6.

Lythe, M.B. and Vaughan, D.G., 2001. BEDMAP: A new ice thickness and subglacial topographic model of Antarctica. *Journal of Geophysical Research: Solid Earth*, 106(B6), 11335-11351.

McGlannan, A.J., 2017. Post-LGM grounding line and calving front translations of the West Antarctic Ice Sheet in the Whales Deep paleo-ice-stream trough, eastern Ross Sea, Antarctica. Master's Thesis, Louisiana State University, Baton Rouge, Louisiana.

Timmermann, R., Le Brocq, A., Deen, T., Domack, E., Dutrieux, P., Galton-Fenzi, B., Hellmer, H., Humbert, A., Jansen, D., Jenkins, A. and Lambrecht, A., 2010. A consistent data set of Antarctic ice sheet topography, cavity geometry, and global bathymetry. *Earth System Science Data*, 2(2), 261-273.