Potential for non-linear response of Antarctic outlet glaciers; insights from David Glacier, Antarctica

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Abstract

Interactions between ice sheets, outlet glaciers and the ocean, where ice shelf collapse and unstable grounding-line migration may cause centennial to millennial-scale ice-sheet retreat represents a significant uncertainty for projecting future ice sheet behaviour (DeConto and Pollard 2016; Golledge et al. 2015). These marine-ice processes have been observed by satellites for less than 50 years yet geological evidence can extend this record over centuries to millennia, providing transformative insights into the processes that drive marine-ice retreat (Jones et al. 2015; Mackintosh et al. 2011; Stone et al. 2003). Associated ice-sheet modelling, evaluated against geological data, will ultimately lead to more realistic predictions of ice sheets and sea level.

Sampling ice transported rock clasts for cosmogenic nuclide exposure age dating will provide critical insights into marine-glacier processes by constraining the recent ice-elevation history of David Glacier, the largest outlet glacier in Northern Victoria Land. Using satellite imagery, aerial and ground photos, modern ice surface velocity and flow stripe mapping we have identified eleven appropriate ice-free areas along the length of David Glacier suitable for reconstructing its recent geological history. By building on the site selection and sampling methods successfully applied at Mackay Glacier (Jones et al. 2015), clasts will be sampled over elevational transects adjacent to the glacier. Strategic sampling, particularly near the present-day grounding line, will allow us to reconstruct a high resolution ice-elevation history of this glacier from the Last Glacial Maximum to present day. This field programme is timely as we plan close collaboration with a team from the Korean Antarctic Programme who plan similar work on nearby glaciers during the 2018/19 austral summer. Together, we will link transects at David Glacier to broader glacier and ice sheet changes in the Terra Nova Bay region, including the Drygalski Trough where the David Glacier evolved into an ice stream, coalescing with grounded ice in the Ross Sea.

A new thinning history for David Glacier will provide constraints for numerical modelling experiments using a model specifically designed for marine terminating outlet glaciers by considering key processes related to ice shelf buttressing, basal and lateral drag and dynamic grounding line behaviour (Jamieson et al. 2012). These processes are appropriate considering the modern David Glacier has a ~70 km long ice shelf, multiple over-deepened basins along its length, a narrow fiord (relative to a less confined marine trough) and marine subglacial geomorphic features indicative of grounded ice. Constrained by geological data and geomorphic mapping, this modelling is designed to pinpoint the external (climate, sea level) and internal (feedbacks between ice and bedrock topography) controls of marine ice retreat.

Keywords: Outlet glacier modelling, Cosmogenic exposure dating, Glacial geomorphology

References

DeConto, Robert M., and David Pollard. 2016. "Contribution of Antarctica to Past and Future Sea-Level Rise." Nature 531 (7596)

Golledge, N. R., D. E. Kowalewski, T. R. Naish, R. H. Levy, C. J. Fogwill, and E. G. W. Gasson. 2015. "The Multi-Millennial Antarctic Commitment to Future Sea-Level Rise." Nature 526 (7573).

Jamieson, Stewart S R, Andreas Vieli, Stephen J Livingstone, Colm Ó Cofaigh, Chris Stokes, Claus-Dieter Hillenbrand, and Julian A Dowdeswell. 2012. "Ice-Stream Stability on a Reverse Bed Slope." Nature Geoscience 5: 799–802.

Jones, R S, A N Mackintosh, K P Norton, N R Golledge, C J Fogwill, P W Kubik, M Christl, and S L Greenwood. 2015. "Rapid Holocene Thinning of an East Antarctic Outlet Glacier Driven by Marine Ice Sheet Instability." Nature Communications 6

Mackintosh, Andrew, Nicholas Golledge, Eugene Domack, Robert Dunbar, Amy Leventer, Duanne White, David Pollard, et al. 2011. "Retreat of the East Antarctic Ice Sheet during the Last Glacial Termination." Nature Geoscience 4 (3). Nature Research: 195–202

Stone, John O, Gregory A Balco, David E Sugden, Marc W Caffee, Louis C Sass, Seth G Cowdery, Christine Siddoway, et al. 2003. "Holocene Deglaciation of Marie Byrd Land, West Antarctica." Science *(New York, N.Y.)* 299 (5603)