Calving and Rifting on the McMurdo Ice Shelf, Antarctica

Alison Banwell1*, Ian Willis1, Doug MacAyeal2, Becky Goodsell3, Grant Macdonald1, David Mayer2,4 & Anthony Powell1

1) Scott Polar Research Institute, University of Cambridge, UK; 2) Department of the Geophysical Sciences, University of Chicago, IL, USA; 3) Antarctica New Zealand, Christchurch, NZ; 4) US Geological Survey, Astrogeology Science Center, AZ, USA. *ab39@cam.ac.uk

1. Introduction
- Ice shelf brittle behaviour, leading to fracture, iceberg calving & disintegration, is challenging to study because events are often: i) not noticed until after they occur; ii) hidden from view; iii) difficult to anticipate; iv) hard to monitor with sensors operating periodically.
- Previous studies of rifting/calving typically used one observational system (e.g. satellite remote-sensing), making it hard to determine exact timing & potential cause(s).
- Here, we report on a calving and rifting event on the McMurdo (Mcm) Ice Shelf that fortuitously happened when multiple genres of observations were available to assess its cause.
- A better understanding of ice-shelf changes caused by brittle behaviour is required to more accurately predict future ice-shelf calving & breakup.

2. Field Area

3. Data
- Satellite imagery (Worldview-1 & 2, Landsat 8) to determine spatial geometries of rifting/calving.
- Ground-based camera imagery (real time & time-lapse) to constrain calving from the NZ Scott Base ‘SBA’ Station (1 Hz ~0.2 m wide & where it was not snow-filled, the rift side freeboard was ~11 m wide & snow-filled (Fig. 1, loc. A). (b) 1.5 km W of a), the rift was ~2 m (consistent with Fig 3. The rift extension on 10 Nov. 2016 (~8 months after it opened). (a) Here the rift was ~11 m wide & snow-filled (Fig. 1, loc. A). (b) 1.5 km W of a), the rift was ~3 m wide & where it was not snow-filled, the rift side freeboard was ~2 m (consistent with ~20 m ice thickness) & showed little lateral displacement (Fig. 1, loc. B). Icicles draping the rift sides may indicate a breached active sub-surface water system during rifting. (c) 500 m NW of b), the rift was only ~0.2 m wide & ~0.4 m deep (Fig. 1, loc. C).

4. Chronology of Events
- Jan/Feb 2016: Fast ice in Mcm Sound began breaking up & drifted northwards; the largest change in sea-ice conditions prior to main calving/rifting event (2 Mar).
- 1 Mar 2016: Small area of fast ice in narrow bight near Cape Armitage broke-out (yellow area, Fig. 1).
- 2 Mar 2016: Tabular icebergs calved from the Mcm Ice Sheet (blue areas, Fig. 1) & an ice-front parallel rift that had been static for ~4 years, widened and lengthened westward by ~3 km (dotted red line, Fig. 1). This rift extension narrows to a point of un-refracted ice. ~1 km from the ice front, preventing the complete detachment of a 14 km2 iceberg.

5. Analysis: Satellite Imagery:

6. Proposed Cause of Calving/Rifting
- Of all the environmental conditions documented prior to the calving/rifting event, the one that shows the greatest change around the time of the event is the high sea swell recorded by the SBA seismometer & ground-based cameras near Scott Base. The alternatives (presence or absence of fast ice, melting at the ice shelf’s surface or base, glaciological stresses, wind conditions) do not show extraordinary change or development over the days leading up to, and during, the calving/rifting event on 2 March 2016.
- Therefore, we suggest that the 4 day period of high amplitude (short/medium- & long-period) sea swell in Mcm Sound first caused the remnant sea ice to breakout on 1 March, which removed any stabilizing effect to the ice front from the sea ice. And second, it introduced elastic flexure to the ice shelf itself, fatigue & weakening it, which ultimately caused the calving of tabular icebergs & rifting on 2 March.

Acknowledgements: We (the 1-19F field team) are extremely grateful to the NSF for funding this project (PLR-1443126). We also thank everyone at McMurdo Station and Scott Base who helped to make our project a success, & we are grateful to the Polar Geospatial Center for supporting our aquisition of satellite imagery. AB also acknowledges the support of a Leverhulme Early Career Fellowship and GM acknowledges support from a NASA Earth and Space Science PhD Fellowship.