B31 – a giant iceberg in the Southern Ocean

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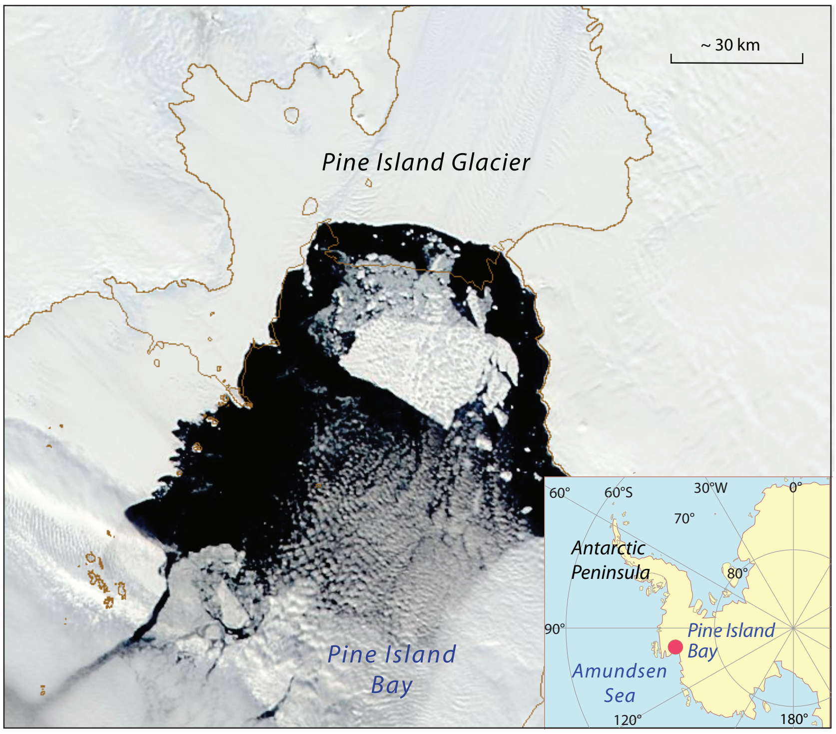
During July–November 2013 a giant iceberg calved from the Pine Island Glacier in Ellsworth Land, West Antarctica, into the Amundsen Sea. The iceberg was initially ~ 720 km^2 in area – roughly the size of the island of Singapore (Figure 1). The calving of this iceberg had been anticipated for more than two years, after a long crack was seen in the glacier in October 2011 during flights for Operation IceBridge, NASA's 6-year study of polar ice. The rift gradually widened until, in June 2013, it extended across the entire glacier. However, it wasn't until austral summer began to approach that the iceberg actually calved and moved into open water in Pine Island Bay.

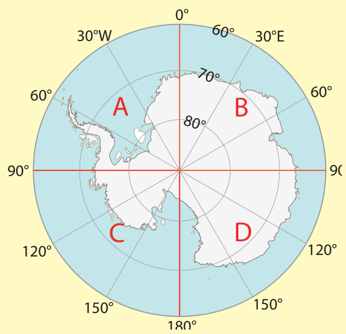
This was ideal timing for us, as we had just started a NERC Urgency Grant on 1 November, gained in response to the July separation, to track and model the trajectory of this iceberg, now named B31 (see Box). While B31 is a very large iceberg, calving of similar or even larger icebergs from Antarctica occurs irregularly but not infrequently. At any one time there are generally 30–40 icebergs in the Southern Ocean larger than 18 km (10 nautical miles) along one axis, the minimum size required for an iceberg to be categorized as 'giant'. Over the 11 years 2003–2013, 286 icebergs larger than 500 km^2 calved from Antarctica, with at least half a dozen larger than B31. What merits more attention than usual for this iceberg is its possible trajectory. Icebergs calved from many regions of the Antarctic follow relatively predictable paths, if not with predictable speed, as they are normally entrained into the Antarctic Coastal Current, with most of those that survive entering the Southern Ocean proper through the cyclonic circulation of the Weddell Gyre (Figure 2). Past icebergs calved from the Amundsen Sea sector of Antarctica, however, have followed one of two radically different trajectories, either the 'normal' one within the eastward-flowing Coastal Current, or one where the iceberg is quickly carried out into the Southern Ocean enough to travel eastward, eventually towards Drake Passage. The latter pathway would mean that the giant iceberg, or a field of icebergs if it breaks into several pieces along route, could be a threat to shipping routes through the Drake Passage, and into the South Atlantic.

Figure 1 *Satellite image (visible light) of B31 soon after release, when it was ~ 30 km along its long side. Note the initial break-up of ice from the south-east corner of the iceberg, closest to the Pine Island Glacier, and the moderately sized icebergs breaking off from the west side.*



Naming giant icebergs

Why 'B31'? For icebergs greater than 10 nautical miles in any one horizontal direction, the US National Ice Center uses a naming convention which relates to the sector of Antarctica from which the iceberg calved. The iceberg retains its label even if it drifts into another sector, and if it fractures into two or more pieces above the length threshold then these are given secondary labels. Thus, the Pine Island iceberg was the 31st giant iceberg to be calved from sector B (essentially West Antarctica) since regular observation from satellite became possible the early 1990s. If it splits into two substantial pieces then these will be labelled B31a and B31b. These large icebergs cease to be monitored once they are not sighted for 30 days, or their size drops below the threshold.

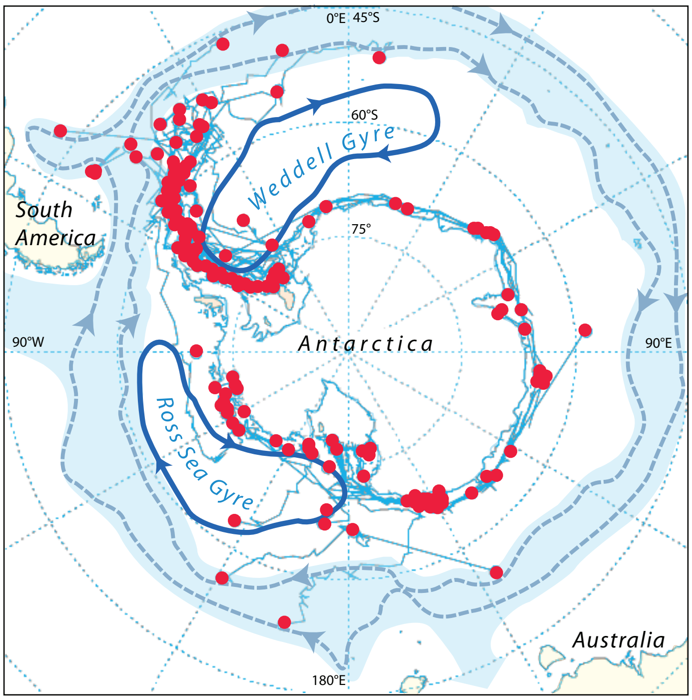


Iceberg tracking

Icebergs can be tracked in a range of ways. GPS trackers can be placed on the iceberg and their position monitored in virtual real time through satellite. BAS deployed two ADIOS trackers on Pine Island Glacier seaward of the crack in 2012, but unfortunately they ceased to transmit a few days after the calving event. In the first few days of the iceberg's life it lost approximately a third of its mass as the ice between the original calving crack and a secondary, seaward, crack fractured and largely disintegrated. Smaller icebergs also broke off from some of the sides in response to the changes in internal and external stresses following calving. It is likely the trackers were a casualty of this initial phase.

Icebergs can also be tracked through various types of satellite-based instruments, all with advantages and disadvantages. Long-term monitoring of giant Southern Ocean icebergs has been carried out by NASA and Brigham Young University using microwave scatterometer data since 1992. This dataset is revised several times a month but, due to the relatively coarse footprint of the various scatterometers used over the years, only a position is given. Smaller icebergs can be recorded using the much smaller footprint of an altimeter, with a minimum size of 400–500 m being typical, and a measure of length becoming possible. Even better resolution is achievable with satellite-borne Synthetic Aperture Radar (SAR) instruments, from 400 m down to sub-50 m, depending on the specifications of the SAR product. However, the large volume of data produced by SAR imagery means that the instruments are not always switched to record mode, especially over the open ocean, and interpretation can be difficult, especially in areas with sea-ice or rough seas. Larger icebergs are also seen with the various resolutions of visible imagery, although cloud and light conditions need to be suitable. We are using a range of approaches to track B31 and its change in orientation and size over time.

Figure 2 *Trajectories of giant icebergs as tracked by the National Ice Center, 1987–2003. Red dots mark the track ends. The pale blue band is the Antarctic Circumpolar Current, and the dashed blue lines are average positions of more intense current within it.*



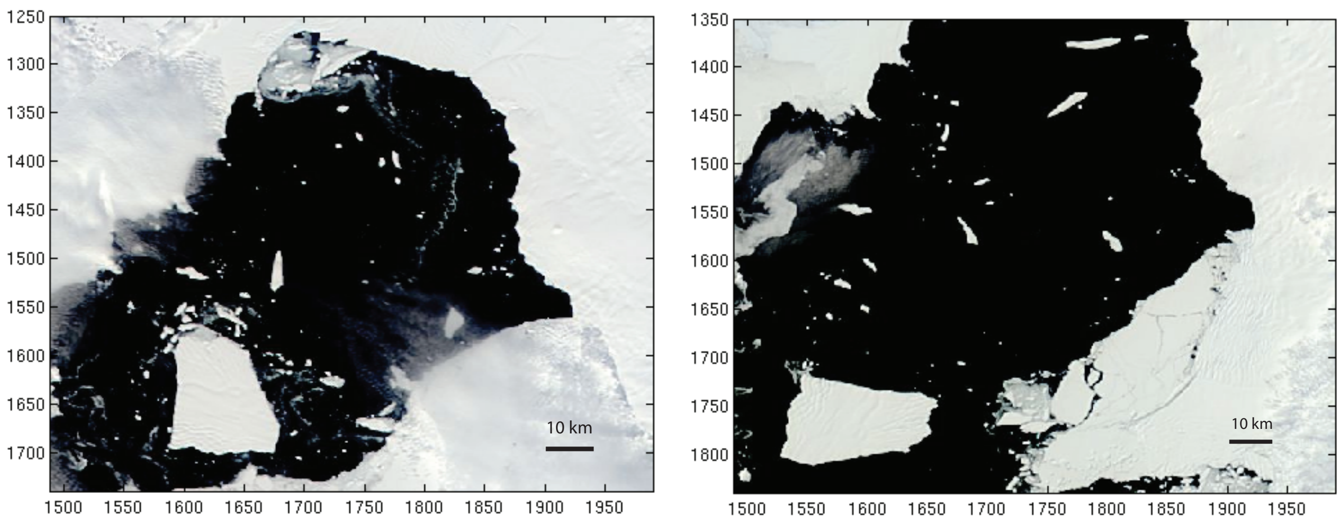
Iceberg data reproduced with permission from T.A.M. da Silva

At the time of writing B31 has only been adrift for a few months, but some interesting variation in its trajectory and size, and evidence of iceberg–ocean interaction, has been seen (Figure 3). B31 initially moved down the centre of the fjord, but break-up of a large part of its south-east corner led to initiation of a clockwise rotation. This caused the berg to move closer to the fast ice on the western side of the Bay, an interaction that caused it to move quickly offshore again, and then resume its clockwise rotation. Near the mouth of the fjord B31 essentially came to a halt for around two weeks before resuming its outward motion and clockwise rotation. As of mid-January B31 has rotated through roughly 180° since it began this behaviour in late November. Whether these motions are due to ocean or atmospheric forcing is not yet clear. The smaller icebergs that have broken off along-route are behaving rather differently and are more clearly responding to circulation within the fjord. As can be seen from Figures 1 and 3, B31 was large enough to be a major obstacle to circulation in the fjord, and its movement is likely to be caused by a combination of down-glacier katabatic air flow, existing fjord circulation, and interaction of the iceberg movement with the surrounding ocean and land/ice. With B31 moving into the main part of Pine Island Bay we expect larger scale ocean circulation to begin to have a major effect on its motion over the next few months.

Iceberg modelling

Modelling iceberg motion at local to regional scale has been possible since the 1980s, and is used routinely by the US Coast Guard's International Ice Patrol to monitor iceberg movement in the Labrador Sea, to assist in the ice warning service they provide to shipping in the north-west Atlantic. However, it is only since 1996 that is has been possible to model the movements of melting icebergs over entire hemispheres, and only since the mid to late 2000s that such models have been coupled to first ocean and then climate models. We are using a recent implementation of iceberg modelling in the Nucleus for European Modelling of the Ocean (NEMO) modelling structure to study the likely motion of B31 in the months to years ahead.

Figure 3 *Two B31 satellite images, from 10 December 2013 and 18 January 2014, showing the clockwise rotation. The coordinate system of both images is relative to the same origin, and is in pixels of size 250 m.*



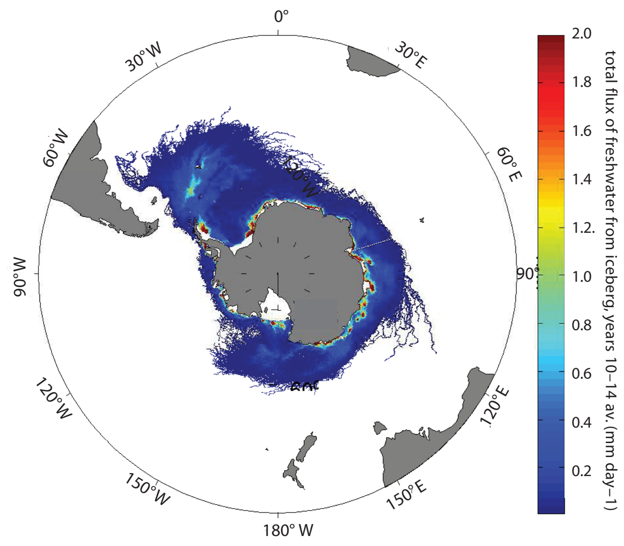


Figure 4
Average freshwater flux from Antarctic icebergs, according to the ORCA025 model (which has 0.25° resolution) (averages for years 10–14 of the simulation)

The icebergs are modelled as a sequence of releases of a range of size classes, the maximum depending on the estimated or observed calving flux of each marine-terminating glacier or ice stream. These are forced by a combination of physical drivers of the iceberg motion – water, wind and sea-ice drag, Coriolis force, sea-surface pressure gradient and waves – and thermodynamic drivers of iceberg size-change including basal melting, wave erosion, buoyant convection and several smaller terms relating to snowfall and the surface radiation balance. The icebergs can roll over when dynamically unstable, ground and re-float. From the model trajectories both the iceberg density and their meltwater contribution to the ocean surface can be found. In significant parts of the Southern Ocean, particularly near the coasts and in the South Atlantic, the annual iceberg meltwater input to the ocean is as large, or larger, than the local precipitation–evaporation balance (Figure 4).

While there is a range of both dynamic and thermodynamic factors affecting iceberg motion, the water drag is normally the most important force on the iceberg, so simple particle tracking is a useful way to gauge the range of possible iceberg paths over a wide range of forcings. Just comparing two successive years shows the chaotic nature of the iceberg dispersion from the Pine Island area – particle releases into NEMO for 2000 went west, towards the Ross Sea, while those for 2001 went east, towards Drake Passage (Figure 5).

Navigational hazard

Icebergs are fascinating in their own right as expressions of abrupt natural change, examples of the interplay between land, ocean and atmosphere, and as modifiers of climate, both locally and, in mass, at larger scales. However, it is because they pose a potentially lethal navigational hazard that they have greatest potential for short-term impact. The sinking of the RMS *Titanic* in the north-west Atlantic in April 1912 after collision with an iceberg was not an exceptional event (for more on this, see pp. 42–7). In the late 19th century an average of more than one vessel a year in the North Atlantic was lost, with several times this number damaged, through iceberg collision. There are still occasional iceberg–ship collisions, with a cruise ship, MV *Explorer*, sinking in the Bransfield Strait, just north of the Weddell Sea, as recently as November 2007.

There is a distinct iceberg stream spreading north-east in the Weddell Gyre from east of the northern tip of the Antarctic Peninsula. The crew of ships entering this area will be used to monitoring ice warning services in the region. However, if B31 follows the eastward path it, and its fragments from any fracturing, may reach the Drake Passage and so pose a hazard to shipping in a region normally iceberg-free. It won't be known for a year or more whether this eventuates but using the NEMO iceberg model we can attempt a prediction. At the time of writing (February 2014) our work is still at a preliminary stage, and the iceberg has not yet moved very far, but before next austral summer we will have a prediction ready.

Further Reading

BYU database: http://www.scp.byu.edu/data/iceberg/database1.html

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Figure 5 *Passive drift with ORCA025 hindcast currents at 47 m, for 38 particles released in Pine Island Bay every 5 days from November to May (sea ice-free season) of **(a)** 2000 and **(b)** 2001. Particle position is plotted daily for 1.5 years and colour-coded for time (years) since calving.*