MELT:

Encountering Antarctica through remote sensing technology

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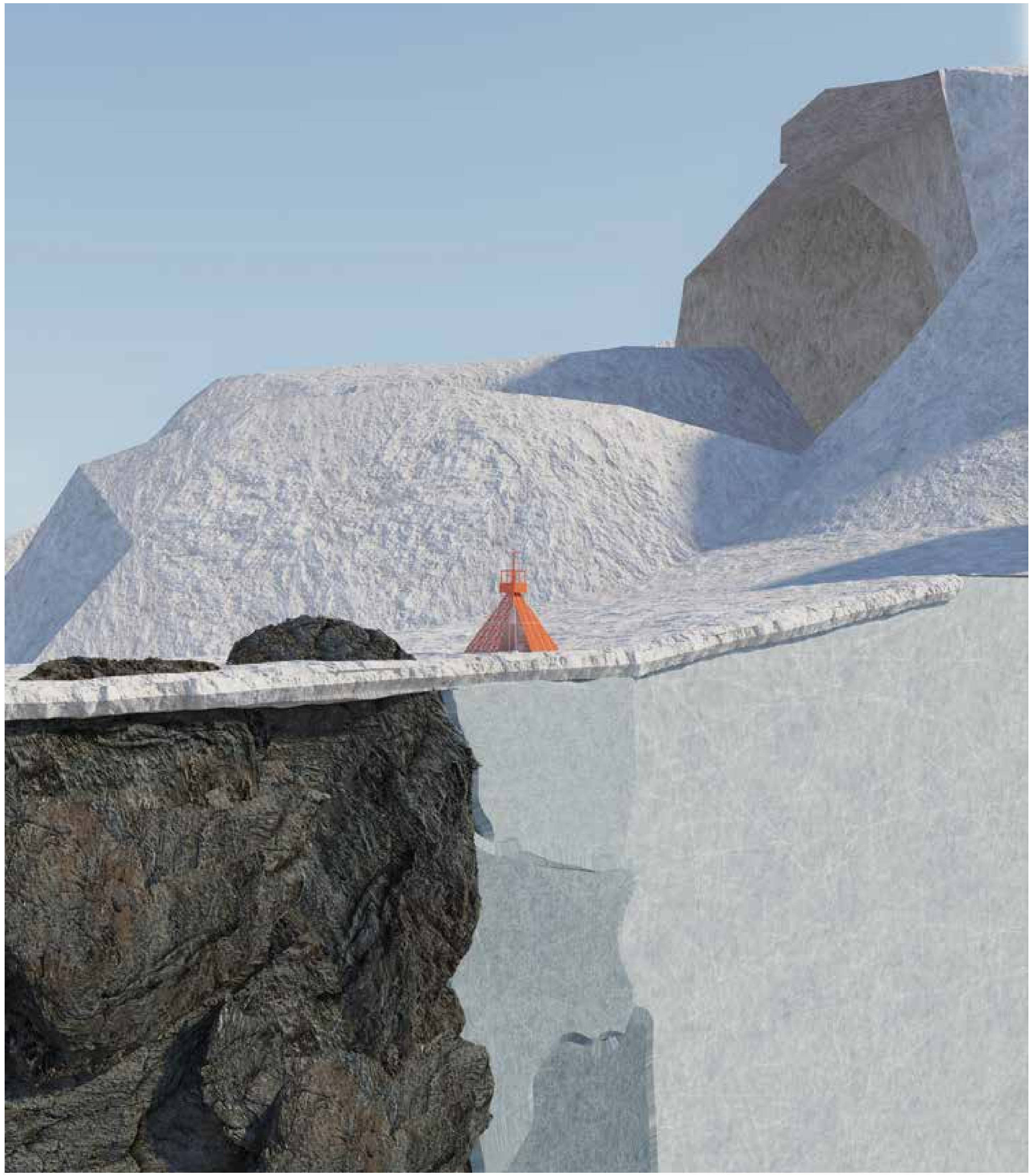
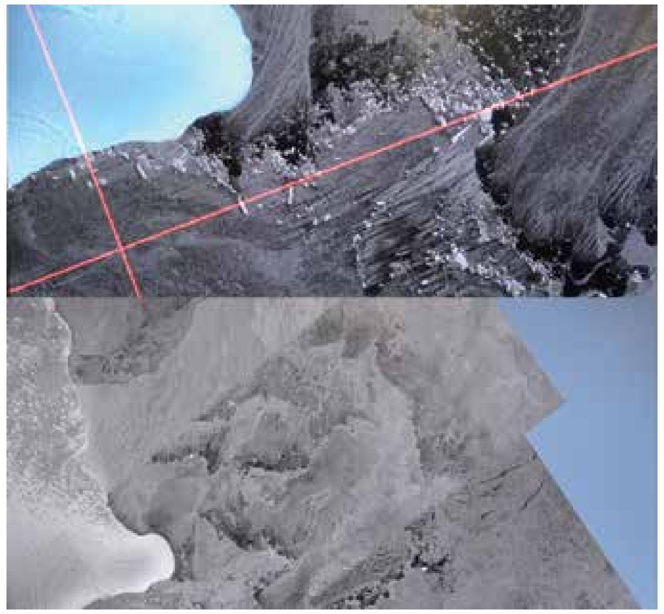


Left: A small, speculative sensing apparatus anchors into the honeycomb ice of the Amery, tracking inconsistencies as it moves.
Credit: Mariam Mesiha

Right: A group of students and teachers huddle around the computer of a glacier sensor, tracking live Landsat data of the Totten Glacier.
Credit: Louisa King



To encounter the precarious Antarctic landscape is to engage simultaneously with extreme wildness and techno-civilisation. Antarctica is a hostile place for the human body; scouring katabatic winds and sub-zero temperatures make movement difficult, combined with frequent storms and ice instability frustrate human habitation of the continent. Yet the remote polar south is a calibrated register of human activity,[1] deeply connected to global transfer and planetary exchange stored in the palimpsest of ice during a time of accelerated glacial melt and shelf collapse.[2] Between the gaps of glacial understanding,[3] scientists operate in intimacy with ice-landscapes through remote sensing and digital models.[4] Remote sensing enables information of an object or phenomenon to be collected without obtaining physical contact – acquisition in short of touching. The information coming from this sensing is mechanical more than human, an extension of reach.

Understanding the workings of a glacier relies on commandeering the instruments of the military-industrial complex; satellite, radar, sonar, seismic and GPS tracking. Monitoring invading borders and unsettled citizens transmutes into the audit of frozen ontologies, an aperture into an icy world otherwise omitted from view. In the Arctic, remote sensing data connects knowledge with sovereignty and extraction. In the Antarctic, where multiple levels of treaty and international jurisdiction overshadow human profit-based exploitation, for now, the entanglements are less clear – research is open-source, unpicking levels of melt and the chronicles of warming; histories of carbon release, the monitoring of melt, and how systems motivate publics to act or enable conditions to carry on as usual.

To work with ice requires scientists to engage with indeterminacy. Remote sensing of the Cryosphere (the portion of the earth covered in ice) tracks the indeterminacy of glacial retreats, movements and flows – working between data that is gathered on site in the frozen geographies of Antarctica, the metrics of remotely generated global data and pure speculation. Relationships between phenomena, temporality and scales of variability determine the choice of remote sensing strategy,[5] a removed study of landscape.[6] In our discussion with glaciologists, we questioned this distance and touch. When sensing ice, distanced gazing upon Antarctic glaciers is also an embodied act.

Theoretical and physical models interact with ice data collected in the field. The realm of virtual dataspace operates through digital input and analysis as the data feedback with observed ground conditions. Landsat images accumulate daily as satellites pass over the continent, recording a chronology of retreat. This 'knowing' through satellite images – the seeing – is always seeing from afar. To comprehend projections requires scientists to engage with the scalar shift between the intimate detail of glacial features and the larger-scale view of the changing ice shelf or glacier. The process of observation comes from direct intimacy with the image-mapping each pore, any unfamiliar expression or stresses logged and charting the broad changes warming brings about.

The Totten – Mapping the grounding line

In November 2019, Landsat,[7] captured by The Sentinel-1 satellite imagery, recorded a chunk of ice equivalent to the area of Sydney breaking off from the terminus of the Totten glacier floating into the Southern Ocean. The melting Totten, if retreated, would raise global sea levels by three metres. Totten is the largest glacier in East Antarctica: it runs forty kilometres across and over two kilometres deep. The Totten's structure and mechanics are unclear. How does the glacier bed rest on the rock beneath? At what velocity does the ice travel across the continental shelf towards the sea? Where does the surface crumple and fracture? Where do its edges melt? We debated Alex Fraser, a remote-sensing glaciologist at the Institute for Marine and Antarctic Studies (IMAS), about the challenges of developing glacial knowledge. These topics include the physical conditions of melt, methods of visualising these conditions and the various registers of measuring instruments.

The Totten is a tidewater glacier as its geomorphology ends in the ocean. Warmer water carves at the glacier from both the terminus and, more concerningly, underneath where the ice meets the continental shelf. The scientific community, perplexed by why the Totten is changing so fast when the glacier just next to it doesn't change much, point to the discrete and specific features of how the glacier rests upon the continental shelf. Glaciers grounded on bedrock below sea level, like the Totten, are particularly vulnerable to changes in ocean temperature and currents because the ocean can penetrate deep under the glacier.[8] An important demarcation on the glacier is where the ice flow stops resting on the continental rock: the grounding line. The line delineates a tipping point, or a point of no return. If warm water comes onto the shelf, accessing the rear of the formation, it melts the surface area of the ice and changes the grounding line, resulting in a phenomenon called a grounding line retreat.

Grounding line retreat is a feedback loop; the Totten catchment is a massive 538,000 km^2. Glacier ice is an incredibly toughened, thick, firm formation. It acts as a plug for the ice/water catchments behind it.[9] Suppose the main terminus of the glacier is eroded by warm water, the ice sheet behind the glacier up on the continental highlands will be pushed by the katabatic winds down toward the ocean, nothing standing in its way. The freshwater held in the glacier itself is not the object of concern; the grounding line, if breached, would unleash enough water to submerge most coastal settlements in Australia.

In Antarctica, the grounding line is what atmospheric chemist Will Steffen refers to as a 'planetary boundary', one which delineates a 'safe operating space for humanity' within earth systems. This datum, once crossed, enacts feedback loops at rates we cannot yet predict towards climate situations we can only imagine. The grounding line is inscribed on a map as a vector running perpendicular to the flow of the glacier. To glaciologists, the line is a charged limit; as suggested in conversation at IMAS, the 'grounding lines are always contentious', a 'true' vector would always be a problematic way to draw a map.

When redrawing the glacier with the remote sensing experts at IMAS, we came across a curious issue of delay; peering down upon the A1 printed map made by UTS researchers, the glaciologists saw we were working off data that was already 18 months old. 'I don't think that there's a connection going through this part of the grounding area anymore,' one researcher said to the mapmaker. 'The data you used is already out of date!'[10] In our discussion with remote sensing specialists at IMAS we understood that traditional cartographies of glaciers are redundant. The intention of sensing and plotting is not to capture the ice form itself; instead, the goal here is to illuminate the forces of glacial flows, crumpling and calving. This rejection of traditional cartography responds to the rate and speed at which remote sensing generates cryospheric data – stable cartography is redundant. Recording the narrative of the grounding line, the vector moved from what sociologist Bruno Latour refers to as 'matters of fact' to 'matters of concern'.[11]

The Ronne/Filchner Ice Shelf – model as apparatus

Ice shelves form the primary connection between Antarctica and the Southern Ocean, covering three-quarters of the Antarctic coastline. While warming climates affect melt, there is still poor knowledge of the processes that lead up to ice shelf collapse. The ice shelf floats over and into the briny complexities of stratified ocean currents; the shelf surface stretches and spreads in each dimension, continually reformed, while seasonal snow, internal ice and basal melt regimes, and under-shelf oceanic freezing and brine extraction, add and subtract in ways that aren't always predictable. It is a synthesis of crystal chemistry; the physics of fluid dynamics and oceanic systems; the full intricacies of which are unknown.

Models become the prime remote sensing tool for measurement and prediction when mapping glaciers. They are used to better unpick and predict complex processes, translating data into feedback systems of representation. The Filchner-Ronne Ice Shelf (FRIS), in West Antarctica, plays a crucial role in global climate stability. A large cavity underneath the shelf allows cold dense water to form and circulate outwards. Shifting water temperatures, salt densities and benthic currents[12] underneath the shelf, directly affects ocean circulation and, therefore, global climate regimes. Simulation modelling, an exercise of nested mechanics, attempts to rebuild complex ice dynamics into a form that may adhere to the algorithmic investigation, testing relationships between the deep water and the ice cavity through an array of registers.[13]

To visualise the ice mechanism, models need to simplify ice landscapes. The sheer complexity and constant variation make predicting ice shelf behaviour and melt not only difficult, but in some ways unknowable. The simplification recognises a gap that arises between an observation, reality and the model's ability to run in virtual space. The gap is an unknown constant within the model.

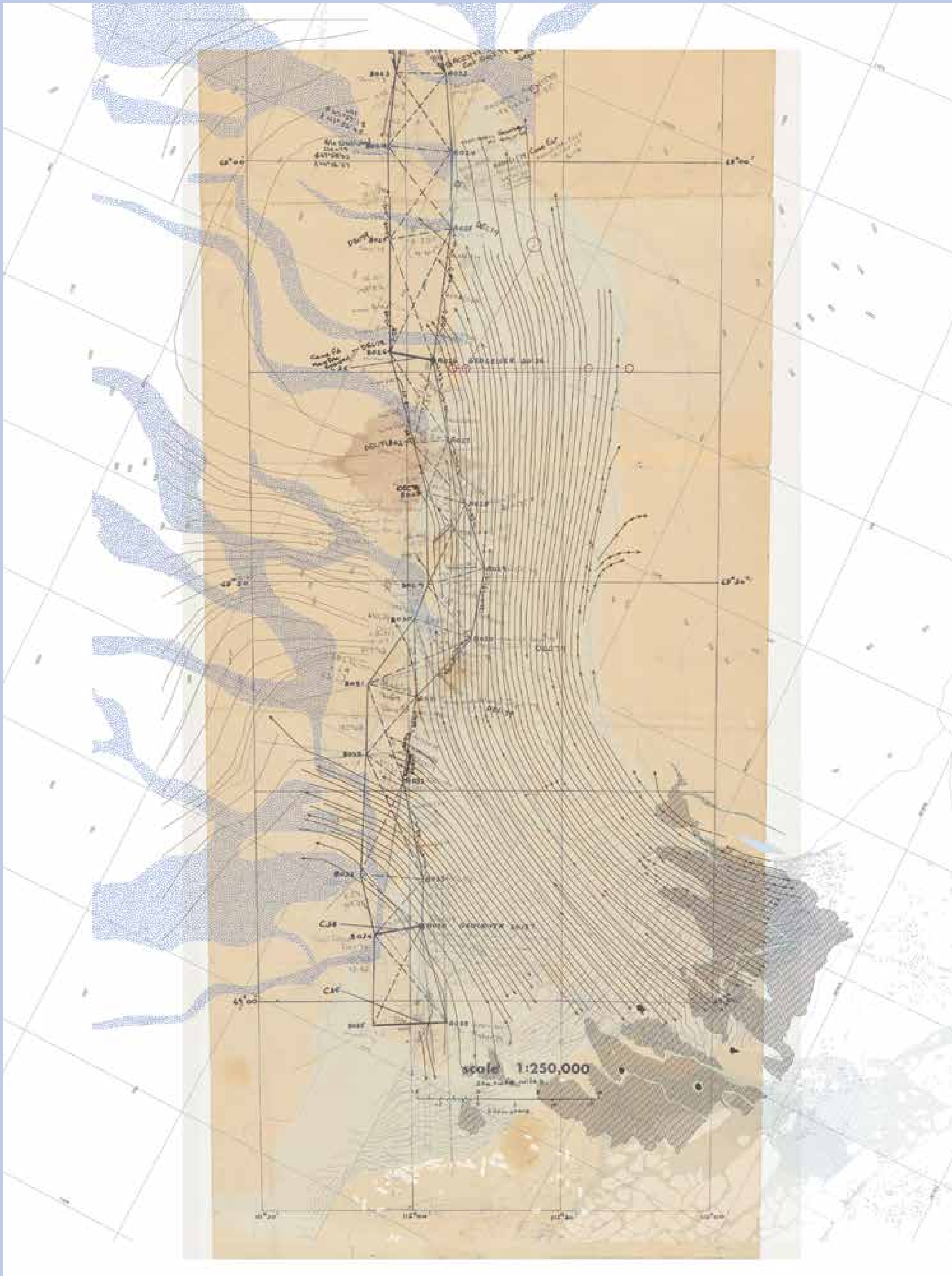
The unknown constant becomes a useful condition – a nod to the unknowable complexity of ice. Ethnographer Jessica O'Reilly refers to this as the 'known unknown',[14] born of an intimacy that allows glaciologists to recognise the complexity of the system to stand in for itself. Scientists speak about this gap as an unknowable constant – the space between reality and computation. It's an intimacy that deep knowledge of site, systems and data draw together to make a space for trust that the constant can be held as abstract.

Melt events are revealing a deeper understanding of mechanics and ecologies through ice shelf collapses. Problematically, this understanding comes at a point of significant ice loss. Remote sensing is focussing on these collapse events as spaces of illumination. Near the FRIS on the West Antarctic Peninsula, the collapse of Larsen B ice shelf led to an international collaboration focusing remote technologies towards geographies of collapse. Scientists came together to mine data as it was disappearing.[15] The model is precarious. In Antarctica, in this time of global melt, the model is in tension with its own temporality.

Amery – sensing gap, vision, embodiment

Data, framed as a disconnected encounter with landscapes, dismisses the individual from the process of knowledge production. To track Antarctic conditions requires a deep and intimate awareness of the ground, akin to close reading – an intimate activity asking the self to create a space to enter the page. The body of the reader becomes still. Sensing and seeing slipping into an internalised space where haptic response to place is substituted with abstract cues. Reading data undergoes

A map becomes a model through the sensing history of the Totten Glacier, which highlights underground glacier streams, crumple zones and historic flight paths.
Credit: Louisa King, Polly Davis and Grace De Rome
Source material: Australian Antarctic Division



a similar set of transmissions. To read Antarctic landscapes, an intimacy with ice processes and Antarctic conditions is necessary. With a precision of measurability, data collections are combined. This linking of sensing and modelling requires an intimacy born of understanding, which comes from a close relationship with the site.

In 2012, a real-time video camera probe, deployed with boiling water, was submerged down a borehole into the Amery Ice Shelf. The camera's down-looking in the water below and side-looking across the edge of the borehole captured passive data that defied the algorithmic investigation of computer analysis. Scientists were looking for the Miocene unconformity in the ice sheet, which is textural and not determined by density. Therefore, radar and laser couldn't register it.

The camera footage showed a marked transition from white bubbly transient ice above to dark marine ice below, this was unexpected, the visual result was a transition that was neither microscopically sharp nor flat, demonstrating the rugged nature of the ice-shelf base upstream where the marine ice first accumulated. Looking at these pockets, deep time can be examined through the ice. Paleoclimatologists and glaciologists work together to uncover the deep time responses of melting and cooling.

The footage defied computer analysis. Instead, this remote sensing required scientists to watch the photographic images, allowing the human eye to chart the subtlety and detail of change in a way that the instrument of analysis could not. The eye is a highly evolved tool, recording down through the kilometre deep ice shelf. Between the primacy of the ocular and inevitability of intuition, they identified subtle changes in the crystalline structure. The space between seeing and knowing, or types of seeing and ways of noticing is always charged. The visual analysis of the Amery ice structures is an example of how embodiment of matter and image resists a landscape of data supremacy, it becomes a conjoined production.

Ice forms glaciers as slow moving, dense and multifarious crystal structures. Glaciers form differently depending on whether the ice has fallen as snow, refrozen as meltwater, or shifted through pressure. This is also temperature and salt dependent: whether formed at freezing point, or, at many degrees below, from marine or terrestrial conditions. On ice shelves and floating ungrounded glacial terminals, ice oozes slowly into the sea from ice streams. If the sea is cold enough, freshly arrived ice doesn't dissolve right away. Instead, it may hover on the surface, propagating more ice, growing its volume, pressed by glacial ice behind it. Antarctic glaciers hold frozen water from a million years ago. Every time ice forms on our poles it holds with it part of the global environment in which it formed.

East Antarctica's Amery Ice Shelf is an ancient formation: it is a narrow but deep ice shelf fed by the Lambert glacier. Re-established during the mid-Miocene after a long period of climatic warming, the ice sheet has formed under accelerated climatic situations. The warming and cooling that occurred was sudden, resulting in a physiological precariousness. For the Amery, this abrupt re-cooling has left susceptible pockets within its ice sheet – and scientists predict that changes transpired 15 million years ago will determine the outcome of the Amery over the next 20 years.

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The Antarctic displays qualities of both complexity and remoteness. A logic of reduction rarely makes space for the unseen or unknown elements of a complex ecological system and its rich scalar sensitivity. Complexity, as a condition of abundance which a system or body expresses, often defies a linear description. To come close is to embrace the unknowability of the system. O'Reilly adds: 'These sensory engagements (with ice) are not primary, primitive, or entirely outside of culture, but are trained, learned, disciplined, and contextual.' This is the "known unknown" that Antarctic scientists work with. The models of these ice sheets and glaciers grapple with knowability. The gaps that are present are part of a working complex which can be recognised as ontologically generative. In addition to the physical remoteness of the Antarctic continent is an inscrutability that requires an intimate engagement. The intimacy of virtual sensing of ice landscapes is entangled in the politics of climate change, where techno-civilisation creates a point of encounter for scientists working with extreme wildness. Seeing by remote sensing relies on an intimacy which, during this time of the global pandemic, speaks of the distance of separation between bodies that can't share geographies.

1. Minute changes which occur many thousands of kilometres away are locked frozen in air bubbles capturing a history of air, pollen, heavy metals, pollution and dust. These register globally distant extractive industries, changes in vegetation, shifts in landscape use–a time-stamped image of the earth and human transgression recorded.

2. Antarctica is affected by a multi-scalar vulnerability, a threatened environment where human disturbance causes local destruction and human global activity has a directly negative outcome on the continent.

3. We know more about the surface of Mars than we do about glacier movement.

4. A. Skoglund and K. Matsuoka 'Quantarctica: An Antarctic GIS package', QGIS, August 2013 (accessed May 15, 2021) https://www.qgis.org/en/site/about/case_studies/antarctica.html

5. J. Dozier, 'Remote Sensing of the Cryosphere' in Warner, T., Nellis, M.D., and Foody, G.M. (eds), The Sage Handbook of Remote Sensing, London, SAGE Publications, 2009.

6. Researchers need to use a particular form of site based knowledge in order to both make this choice and again in interpretation although both data and cited experience is always incomplete and always other.

7. The Landsat program is the longest-running enterprise for the acquisition of satellite imagery of earth. It is a joint NASA / USGS program.

8. S. Rich Rintoul et al., 'Ocean Heat Drives Rapid Basal Melt of the Totten Ice Shelf', Science Advances, vol.2, no.12, 2016, DOI: 10.1126/sciadv.1601610.

9. The lateral connections of the shelf to glacier and grounding lines depend on ice mechanics – gravity and the flow of ice streams.

10. A. Fraser, interviewed by Louisa King at IMAS, 18th September 2019.

11. B. Latour, 'Why Has Critique Run Out of Steam?: From Matters of Fact to Matters of Concern', Critical Inquiry, vol. 30, no. 2, 2004, p. 231.

12. Benthic currents are the currents that flow along the ocean floor.

13. C. Bull et al., 'Remote Control of Filchner-Ronne Ice Shelf Melt Rates by the Antarctic Slope Current', JGR Oceans, vol. 126, no. 2, 2021, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JC016550, (accessed on March 9, 2021).

14. J. O'Rielly, 'Sensing the ice: field science, models, and expert intimacy with knowledge' Journal of the Royal Anthropological Institute (N.S.), vol. 20, no. S1, 2016, 35, https://rai.onlinelibrary.wiley.com/doi/pdf/10.1111/1467-9655.12392.

15. J. Ingels et al., 'Antarctic ecosystem responses following ice-shelf collapse and iceberg calving: Science review and future research.' WIREs Clim Change vol. 12 (1), 2021, 682. https://onlinelibrary.wiley.com/doi/epdf/10.1002/wcc.682.

Top: A lantern slide from an early Antarctic scientific expedition in 1930 demonstrates how ice and field practice merge in extreme cold landscapes.
Credit: Eric Douglas
Source material: 'Inside the field work cabin', British, Australian and New Zealand Antarctic Research Expedition (BANZARE) voyage 1, Antarctica, March 1930

Bottom: Ice flows travel down the Ronne Ice Shelf imparting lateral pressures on the shelf boundaries.
Credit: Louisa King, Mitchell Roseby and Marian Messiah
Source material: Australian Antarctic Division