GLACIOLOGY

Tracking Icebergs for Clues To Climate Change

To learn more about climate change at the poles, daredevil scientists are getting up close and personal with icebergs to follow their every move

In January, University of Chicago glaciologist Douglas MacAyeal and two colleagues took off by helicopter from the icebreaker *Polar Sea* and sped toward a massive iceberg in Antarctica's Ross Sea. Like a wandering frozen mesa with a sheer 50-meter drop to the water, the perfectly white, flat berg, dubbed B15A, has its own weather system of high winds, blowing snow, and fog—a pilot's nightmare. When the researchers landed in the middle of this icy expanse, the ocean was nowhere to be seen. "You can't be someplace flatter or more alien," says MacAyeal.

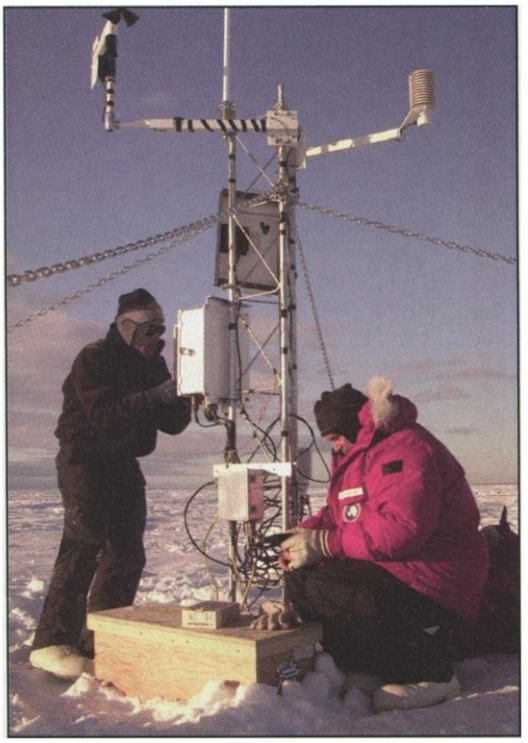
This behemoth started as part of the even more monstrous B15, which calved in March 2000 off the Ross Ice Shelf and subsequently broke up. At 11,000 square kilometers, it was the largest iceberg ever reliably measured. The researchers hastily set out automatic weather stations and global-positioning trackers at three sites on B15A—the most complex array of instruments ever deployed on an antarctic berg—then fled.

MacAyeal and his colleagues' touch-and-go trip to wire up B15A is part of an intensifying interest in icebergs, for the lives and deaths of these glacial frigates provide windows to potential changes in ocean circulation and climate. Researchers are closely watching an alarming increase in the calving of bergs in outlying parts of Antarctica —perhaps a result of climate change—for signs that the trend might presage a rapid breakup of the continent's largest ice shelves like the Ross, which lie in the deep south. Tidewater glaciers in the Northern Hemisphere, from Alaska to Greenland, also seem to be calving faster.

Cold warriors

Iceberg research is a venerable tradition. After one sank the *Titanic* in 1912, the International Ice Patrol formed and began to track as many as 2000 a year coming down "Iceberg Alley" from west Greenland, first by ship and now with airplane-mounted radar. It was Soviet researchers, however, who pioneered true iceborne science, setting up 31 Arctic Ocean ice camps from 1937 until the collapse of the Soviet Union in 1991. Among their accomplishments were invaluable long-term measurements of arctic weather, seminal studies of how sea ice forms, and maps of the arctic sea floor.

Gyring around the North Pole on circular currents, the stations were occupied for up to 8 years; many were actually on sea-ice floes, not glacial bergs, but scientists used bulky bergs from the Canadian archipelago whenever possible, for flimsier sea ice often lasted just months, ending with ominous crackles and watery chasms opening amid camp. One of the more long-lived ones, station NP8, lasted from 1959 to 1962, and the occupants twice scrambled to drag buildings to new locations when giant cracks fractured their aircraft runway. Finally, when there was nowhere left to go, they were hastily evacuated from a makeshift airstrip, leaving most of their equipment behind.



Riding the behemoth. Douglas MacAyeal (right) and Jonathan Thom install an instrument tower that enables the remote tracking of iceberg B15A.

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Fearing that the Soviets were using the ice for hostile purposes such as listening for U.S. submarines, the Americans in 1952 set up "Fletcher's Ice Island," a drifting ice-shelf chunk used off and on until it was spit into the Atlantic in the 1970s. And they raided their adversaries' sites. According to the book *Project COLDFEET* by William Leary, after the Russians evacuated NP8, Navy geophysicist Leonard LeSchack secretly parachuted in to rifle their camp for clues to what they were up to. "What a horror!" wrote LeSchack. "There was dried blood all over, and animal carcasses, including dog[s]." On the other hand, he said, the Soviets had an "extremely complete" program of oceanography and meteorology and gear "superior to U.S. drift station[s]." In a scene straight out of a James Bond movie, LeSchack escaped by floating a balloon above the ice and harnessing himself to the bottom of its tether. A B-17 bomber swooped in, grabbed the tether with a hook in midair, and winched the triumphant if breathless geophysicist to safety.

The drift stations are long gone, but their hundreds of thousands of daily measurements including air and water temperatures, precipitation, and solar radiation fluxes spanning 6 decades are now being declassified and collated by both countries. As the only such long-term data from the central Arctic, they offer a baseline for modern measurements aimed at studying changes in far northern climate and sea ice. "It's a huge treasure," says Mark Serreze, a climatologist at the National Snow and Ice Data Center (NSIDC), who is plugging in old handwritten data on solar radiation and wind to his own models of climate change. In cooperation with Russian colleagues, the center is issuing CD-ROMs of the data, including a chronological atlas of arctic sea ice, available this year.

Sophisticated new satellites and automated buoys have partly made up for the stations' demise. But "there is no adequate substitute for people on the ice," says Vladimir Radionov, chief meteorologist of the Russian Arctic and Antarctic Research Institute. "They could carry out experiments everywhere from the sea bottom to the ionosphere." This included sending up twice-daily weather balloons and lowering instruments into the deepest water—feats even modern technology cannot duplicate.

Currents, surf, and sails

Despite past experience, much about icebergs remains mysterious, including what combination of currents, tides, and winds impels them. Because of their deep keels and low profiles, it has long been assumed that subsurface currents do most of the steering; thus icebergs are considered useful proxies for studying such currents. Indeed,

many of the estimated 1500 cubic kilometers of icebergs breaking off Antarctica yearly appear to end up swirling in a powerful counterclockwise coastal current.

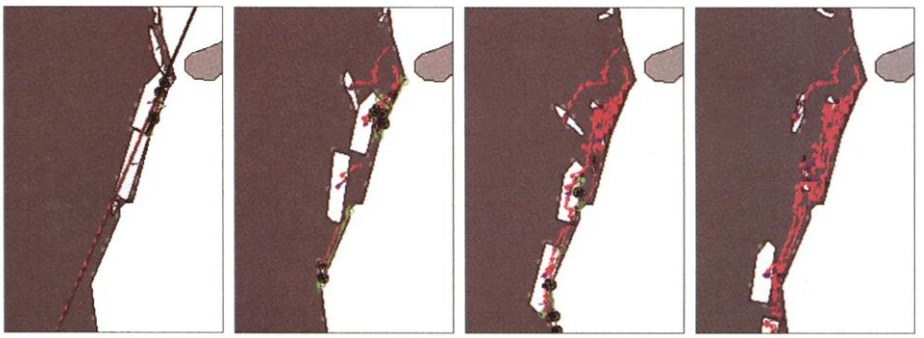
Big ones are relatively easy to follow. When one designated B9 broke off the Ross in 1987, satellites showed it moving some 2010 kilometers before stranding in 1991 in a vast shallow-water "iceberg graveyard" below western Australia where great ranks habitually stick fast; a decade later most of it is still there. Last year Neal Young of the Australian Antarctic Division tracked another piece of B9 to the continent's other side—a journey of some 10,000 kilometers. But Young says the picture is incomplete. Satellites show others spinning out of invisible "exits" from the coastal current to seas farther north, perhaps carried on regional gyres; and when some break up, fragments go chaotically in opposite directions, ending up hundreds of kilometers apart. In places like the enclosed inner Ross Sea, MacAyeal believes the main force may not be currents at all but long-length waves created by daily tides, which the flat bergs ride like lumbering surfboards.

Probably half the total mass of antarctic icebergs is in fragments a kilometer square or less, notes Rupert Gladstone, a geophysicist at the University of East Anglia in Norwich, U.K. Tracking these individuals is hard. To sample their movements, Eberhard Fahrbach, a senior scientist at Germany's Alfred Wegener Institute for Polar and Marine Research, has helicoptered to 30 in the past 3 years, planting global-positioning trackers on top—a daunting undertaking, as many small bergs are riddled with crevasses and prone to capsizing. As a result of their work, Fahrbach's co-worker Christoph Lichey will report in the *Journal of Glaciology* that some bergs embedded in sea ice appear to be steered directly by winds, previously thought to play a minor role. He says the sea ice acts like a horizontal sail, sending the bergs in unexpected directions.

Where icebergs large and small go is a matter of more than academic interest. For one, if gigantic B15A ends up in the wrong place next January, it will close the brief shipping season to McMurdo Station, which cannot subsist without the fuel, heavy equipment, provisions, and other supplies brought by ship. And the berg is now blocking access to major nesting sites of Emperor and Adélie penguins, says David Ainley, a penguin expert with H. T. Harvey & Associates, a California ecological consulting firm. The penguins migrated to sea just before it arrived but will return between October and December. "It will be interesting to see what they do if it's still there," says Ainley.

Cold warriors. The Soviet Union's NP8 drift station before it was abandoned in 1962 and later visited by a U.S. Navy geophysicist.

CREDITS: (LEFT TO RIGHT) LEARY/LESCHACK COLLECTION; DOUG MACAYEAL/UNIVERSITY OF CHICAGO



Pirouette. Iceberg B15's motion over the course of a year provides a window into potential changes in ocean circulation and climate.

Global meltdown?

While some glaciologists are tagging and tracking bergs, others are keeping an eye on an alarming trend: sudden, explosive calving in parts of Antarctica. The fear is that if this continues, it may hasten the death of glaciers at an unanticipated rate.

On the Antarctic Peninsula, which extends well north of the main landmass, average temperatures over the past 55 years have risen more than 2.5°C; apparently as a result, 1300 square kilometers of the relatively small Larsen A Ice Shelf simply fell apart into thousands of tiny bergs over the course of just a few days in 1995 without any particular warning (*Science*, 9 February 1996, p. 788). By contrast, the calving of B15, from the much colder Ross Ice Shelf, was preceded by years of preliminary cracking and is considered to be part of a long-time, regular process. David Vaughan of the British Antarctic Survey says the fast, piecemeal dissolution on the Larsen A has continued and moved rapidly south to the huge Larsen B and Wilkins shelves. "They are not calving big, healthy, periodic bergs like B15, and that is the whole point," he says. "It is not business as usual."

It is not clear exactly what is triggering the explosive breakups. They are too rapid to be explained by temperature rises alone, says the NSIDC's Ted Scambos; the ice, hundreds of meters thick, cannot soften that fast. Instead, he surmises that summer temperatures are now high enough to form melt pools on the glacial surfaces, which percolate rapidly into small weaknesses to form crevasses. Once a complex of crevasses hits sea level, seawater rushes in, refreezes, and the mass blows apart.

What will happen next is pure speculation. If the massive breakups continue, the speed of some glaciers' seaward slides could easily double. Vaughan believes it would take 200 years or more for the much bigger southerly ice shelves to be affected, but Scambos is not so sure; he asserts that the currently stable Ross could begin disintegrating within just 50 years. Worrying trends are already appearing in the Northern Hemisphere. Some of Alaska's famously scenic tidewater glaciers like the Muir are fast becoming alpine glaciers; rapid melting over the last 100 years and a quintupled calving rate since 1982 have pulled the leading edges of some glaciers back through fjords 80 kilometers or more, onto dry land. And in 1999 the International Ice Patrol saw only 22 bergs come down Iceberg Alley, raising dire warnings that global warming was about to do away with the phenomenon of icebergs altogether. However, in 2000 the denizens of Iceberg Alley came back in force—over 800 of them—showing that the warnings were off base. Ice Patrol oceanographer Don Murphy says shifting winds had probably pushed the icebergs out of shipping lanes the previous year. Unlike his colleagues working in the Southern Hemisphere, Murphy has no plans to land on any of these bergs. "Way too dangerous," he says. "We're trying to keep people away from them, not get closer."

–KEVIN KRAJICK

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