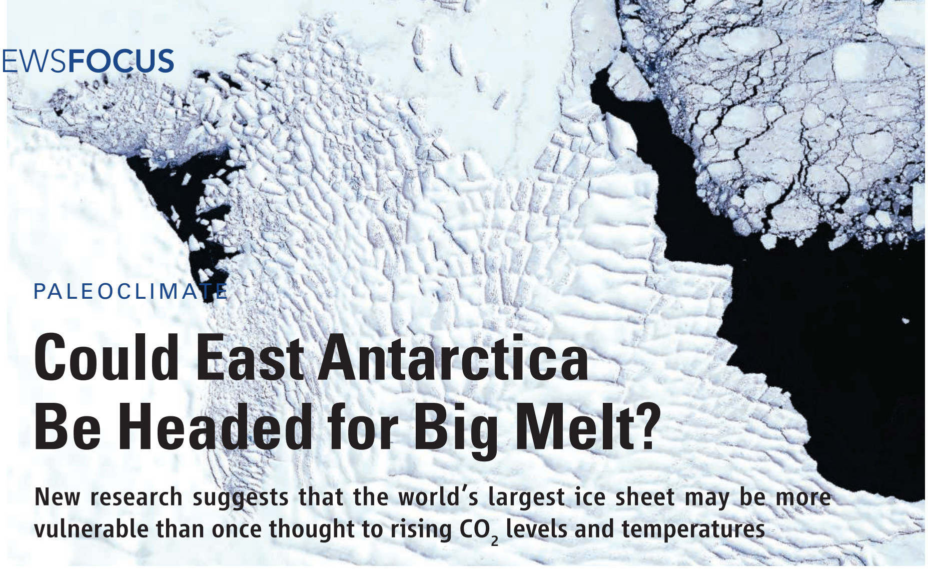


Cracked up. East Antarctica's Totten Glacier may be stretching and thinning.

PALEOCLIMATE

Could East Antarctica Be Headed for Big Melt?

New research suggests that the world's largest ice sheet may be more vulnerable than once thought to rising CO_2 levels and temperatures

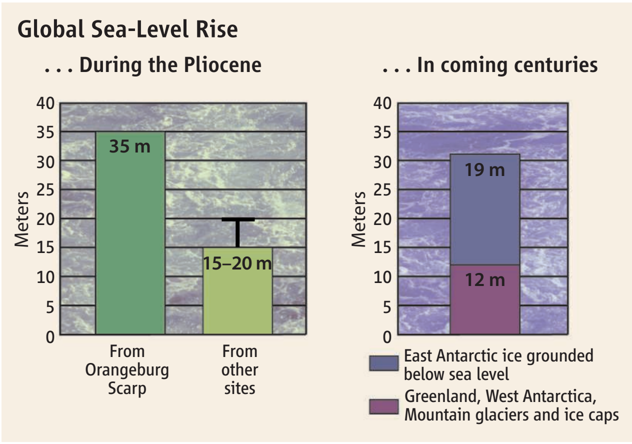
The Orangeburg Scarp, a band of hard, crusty sediment teeming with tiny plankton fossils, runs from Florida to Virginia under tobacco fields, parking lots, shopping centers, and Interstate 95, the major highway along the U.S. East Coast. It marks an ancient shoreline where waves eroded bedrock 3 million years ago. That period, the middle Pliocene, saw carbon dioxide (CO_2) levels and temperatures that many scientists say could recur by 2100. The question is: Could those conditions also result in Pliocene-epoch sea levels within the next 10 to 20 centuries, sea levels that may have been as much as 35 meters higher than they are today? The answer, say climate scientists, may lie 17,000 kilometers away in East Antarctica.

The East Antarctic Ice Sheet is the world's largest, a formation up to 4 kilometers thick and 11 million km^2 in area that covers three-quarters of the southernmost continent. Its glaciers were thought to sit mostly above sea level, protecting them from the type of ocean-induced losses that are affecting the West Antarctic Ice Sheet. But studies of ancient sea levels that focus on the Orangeburg Scarp and other sites challenge that long-held assumption. Not everybody believes the records from Orangeburg. But combined with several other new lines of evidence, they support the idea that parts of East Antarctica could indeed be more prone to melting than expected.

"That's pretty incredible when you think about it," says Maureen Raymo, a marine geologist at Boston University who studies Pliocene records. "It implies that the East Antarctic Ice Sheet is not quite as stable as we think it is."

Three studies, using different remote-sensing methods, show that East Antarctica has already begun to lose ice. A survey of laser altimetry data from the ICESat satellite, published in *Nature* in October 2009, found ice thinning in several spots along the East Antarctic coast at annual rates as high as nearly 2 meters. Another study, published in *Nature Geoscience* in November 2009, used the gravity-sensing GRACE satellites and found two areas along the East Antarctic coast each losing about 13 km^3 of ice per year. A 2008 study in *Nature Geoscience* that compared ice flux off the edges of the continent with new accumulation of snow in the interior found a loss of about 10 km^3 of ice per year at two areas.

These amounts pale in comparison to the 150 km^3 or so of ice vanishing each year from West Antarctica. But all three studies point to a handful of hot spots—including, most strongly, Totten Glacier, which is losing up to 1.9 meters of thickness per year. If East Antarctica were to start losing weight, Totten is exactly where it should happen, researchers say, because of its distinctive subglacial landscape. Seeing Totten at risk marks a sea change in the way that people think of East Antarctica, whose topography is the least-known landscape on Earth.



High water. A partial melting in East Antarctica, records indicate, raised sea levels during the Pliocene—and could do so in the future.

Donald Blankenship, a glaciologist at the University of Texas, Austin, has spent the past 2 decades compiling what data there are. He now oversees parts of a multinational survey, called ICECAP, which is using ice-penetrating radar and other sensors flown on aircraft to map the subglacial topography. "Most of these basins weren't particularly well surveyed; some weren't surveyed at all," Blankenship says.

The surveys now in progress, he says, show these basins to be "good and deep." And that's bad news. One survey, published last year in *Tectonophysics* by Fausto Ferraccioli of the British Antarctic Survey, finds the bed of East Antarctica's Wilkes Basin far lower than thought, with two long troughs plunging as far as 1400 meters below sea level. A soon-to-be-published interpolation of older radar data, using undulations in the ice surface to refine the bed topography, suggests that the much larger Aurora Basin, which includes Totten Glacier, is connected to the ocean by troughs that sit 500 to 1000 meters below sea level. These troughs deepen as they head inland, to as low as 2000 meters below sea level in one spot.

The new data are worrisome, says Jason Roberts of the Australian Antarctic Division (AAD) in Hobart, Tasmania. "That's the classic scenario where if you do get melting, you get a deepening grounding line of the ice sheet, which makes it more susceptible to further retreat," he says. "It's much more potentially vulnerable to climate change than we would have thought."

Events in West Antarctica provide a glimpse into what happens when even small amounts of deep, warm water reach glaciers that sit in deepening beds. Pine Island, Smith, Thwaites, and a handful of other glaciers along the coast of West Antarctica's Amundsen Sea are collectively hemorrhaging 100 km^3 of ice annually.

It's too early to know what the ice loss in East Antarctica really means, says Isabella Velicogna, a remote-sensing specialist at NASA's Jet Propulsion Laboratory in Pasadena, California. "What is important is to see what's generating the mass loss," she says. Reductions in snowfall, for example, might reflect short-term weather cycles that could reverse at any time. But thinning caused by accelerating glaciers—as seen in

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West Antarctica—would warrant concern.

Finding out whether Totten is accelerating will be difficult, says Neal Young, an AAD glaciologist who has studied the region for 40 years. Totten sits beyond helicopter range from Australia's Casey Station, and Young says "huge crevasses that would swallow up big buildings" make it extremely tricky to land field parties by airplane.

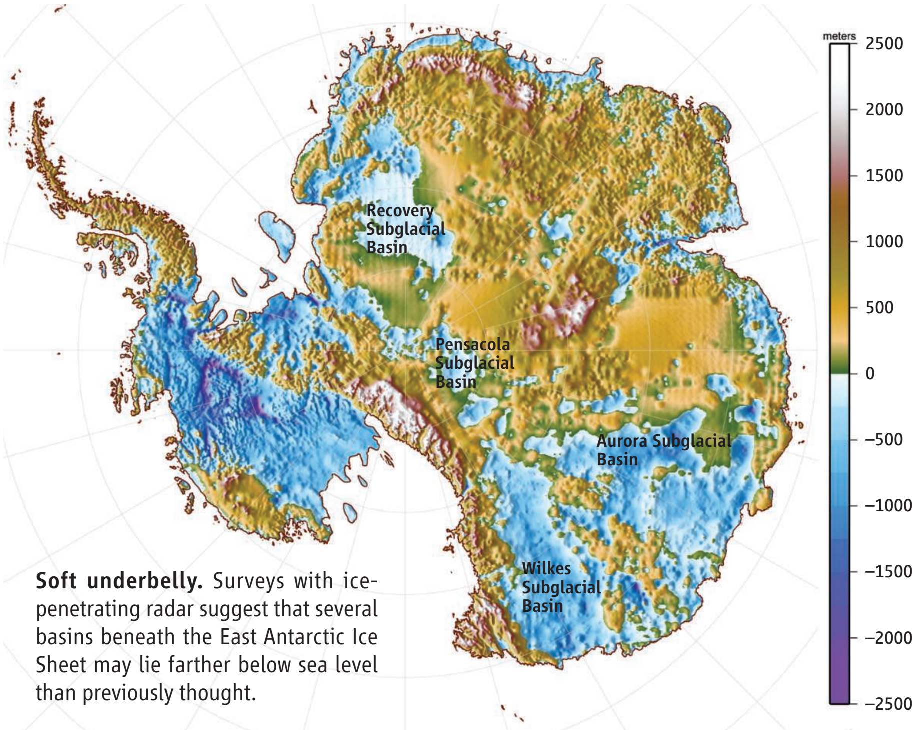
Young was part of an Australian team that rode Caterpillar tractors 200 kilometers to Totten in 1987—the first of only two human visits to the glacier's lower reaches—and measured Totten's velocity in nine places. Heavy snowfall and rapidly shifting surface features have prevented satellites from remeasuring velocity precisely enough to confirm whether Totten has sped up. And thick sea ice prevents icebreakers from getting near enough to look for warm ocean currents that could erode the glacier underneath.

Even so, the patterns of thinning reported last year suggest that it may have accelerated near the ice fronts of Totten and nearby Vanderford Glacier, causing them to stretch. Both glaciers have thinned most strongly at their ocean margins, where ice is sliding fastest. Thinning is substantially less in adjacent, slow-moving areas. "The answer is in the ocean and the dynamics of the glacier," Young says. "I think the floating ice tongue on Totten has thinned, leading to [increases in speed] that are propagating inland."

All of this suggests that CO_2 levels expected by 2030 and temperatures predicted by midrange models for 2100 could eventually—over a millennium or longer—raise global sea level by 25 to 30 meters. That's well above the 10 to 15 meters predicted from the melting of Greenland and West Antarctica, and a magnitude that would displace hundreds of millions more people.

Plenty of uncertainties remain, though. The best ice-sheet models don't predict East Antarctica losing anywhere near that much ice. But refined topographic maps expected from ICECAP in the next 18 months could change this. "If there are really deep, [narrow] basins around the edges of the continent that the model doesn't know about, then we could be underestimating the potential for retreat," says Robert DeConto, an ice-sheet modeler at the University of Massachusetts, Amherst, who published a model in March 2009 in *Nature* that successfully reproduces 5 million years of ice fluctuations in West Antarctica.

The biggest question is whether Pliocene sea levels really ever reached the heights indicated by studies of the Orangeburg Scarp. "[Pliocene sea level] is a poorly constrained number," Raymo says. "The error bars could be anywhere from 10 to 40 meters above present levels."



Soft underbelly. Surveys with ice-penetrating radar suggest that several basins beneath the East Antarctic Ice Sheet may lie farther below sea level than previously thought.

CREDIT: DUNCAN YOUNG

Timothy Naish of Victoria University of Wellington, New Zealand, hopes that a technique called backstripping will reduce these errors. Rock cores drilled from ancient coastlines show a sequence of erosion faces in which rising seas periodically chewed away at sediments. Stacked atop one another in time, such a sequence of water lines allows researchers to better correct for tectonic rise or fall, which can skew sea-level estimates.

Preliminary results of cores drilled from the Chesapeake Bay in the United States and Wanganui Basin in New Zealand suggest lower sea levels than Orangeburg would imply. "Twenty-five meters is an absolute upper number," says Naish, who works with Kenneth Miller of Rutgers University, Piscataway, in New Jersey. "We think the number is nearer to 15 to 20 meters." That estimate implies that there was some melting in East Antarctica, but not as much.

Another confounding factor is that ice-sheet melting produces uneven rises in sea level. The meltwater is redistributed to reflect changes in Earth's gravity field caused by the disappearance of a fixed ice sheet. "Sea level is a complex stew," says geophysicist Jerry Mitrovica of Harvard University, who is collaborating with DeConto and Raymo. "The bathtub model is only going to get you partway there." Just 5000 years ago, as Ice Age glaciers were still melting, for example, sea levels in New Jersey were 9 meters lower than at present—whereas those in Argentina were 5 meters higher.

Differences this large could distort interpretation of the world's handful of Pliocene sea-level records. Raymo and collaborators hope that Mitrovica and DeConto can reconcile ice-sheet masses with sea levels around the world by plugging more numbers into their models. Paul Hearty, a collaborator at the University of North Carolina, Wilmington, is looking for sea-level records in Australia and the Azores. Raymo is constructing a Web-based wiki that she hopes will attract sea-level records from around the globe.

Others are directly investigating the history of East Antarctica's low-lying basins for indications of what happened to their ice during the Pliocene. Early this year, a team with the Ocean Drilling Program extracted seven cores from the sea floor in front of Wilkes Basin. Investigators are picking those layers apart this summer in search of clues about how well the ice in Wilkes Basin held together during the Pliocene.

Together, these efforts will begin to address the bigger question of what the loss of ice in East Antarctica, if it's occurring, actually means for the world's inhabitants. "Nobody expected it," says Velicogna. "And if we just think that nothing is going to happen there, we're making a mistake."

–DOUGLAS FOX

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