

Wind analysis links West Antarctic ice loss to humans

Anthropogenic warming is reversing the predominant winds over the region and could explain the ice sheet's destabilization.

The thinning of the West Antarctic Ice Sheet (WAIS) is contributing to global sea-level rise at a current rate of about 0.5 mm per year,¹ and the situation will probably only get worse (see *PHYSICS TODAY*, July 2014, page 10). Ice from Pine Island Glacier (see figure 1), the Thwaites Glacier, and others drain the WAIS into the sea. The glaciers melt more quickly than usual if winds diverted eastward by human activity drive warmer circumpolar water onto the continental shelf and underneath the floating ice.

Given rising greenhouse gas concentrations, that chain of events could already be under way. Average global temperatures have risen by about 0.8 °C since 1880. In the Arctic, warm air temperatures are directly responsible for the increased melting of glaciers. But for West Antarctica, determining the rate of ice loss is difficult because of episodic fluctuations. The region's climate swings between warm and cold cycles. The air pressure at sea level over the Amundsen varies more than any other place in the Southern Hemisphere.² And over a 10-year period, the amount of warm ocean water reaching the glacier there can fluctuate by about 50%.

The natural climate variability in the Amundsen Sea stems from year-to-year change associated with the tropical Pacific Ocean's El Niño–Southern Oscillation (ENSO; see the article by David Neelin and Mojib Latif, *PHYSICS TODAY*, December 1998, page 32). When tropical sea-surface temperature anomalies alter the prevailing wind patterns, the winds around West Antarctica also change. Records lack enough years of data to clearly separate how natural variability and human activity cause West Antarctic winds to change and consequently increase the rate of ice loss.

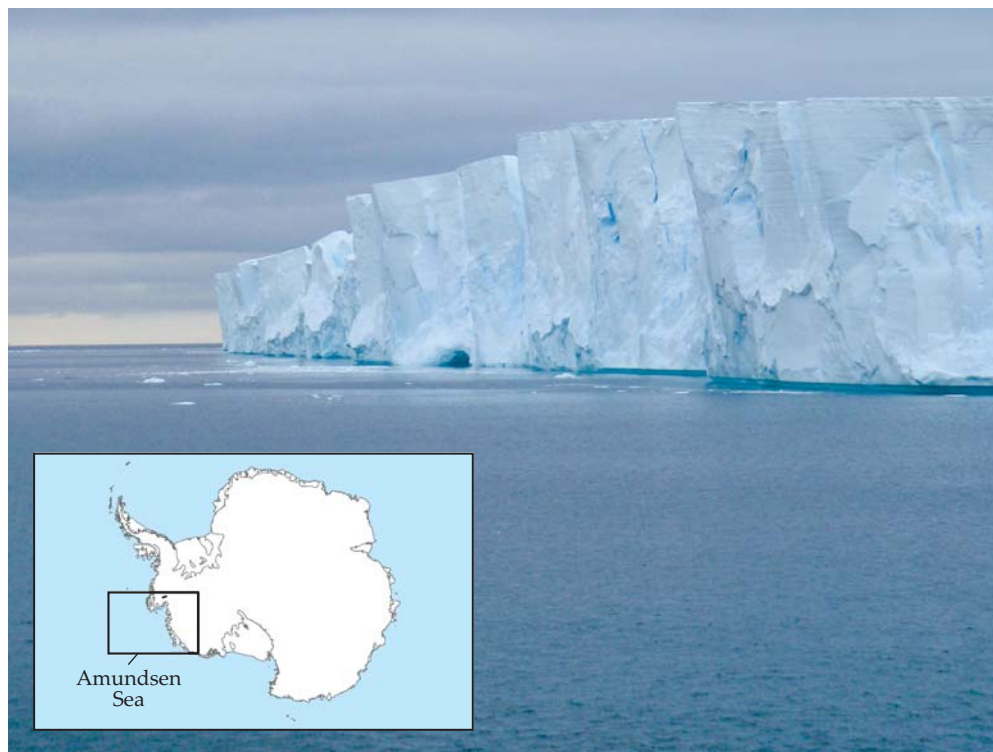


FIGURE 1. PINE ISLAND GLACIER, at the edge of the Amundsen Sea in West Antarctica, shown in the inset. More eastward winds caused by human activity drive warm, circumpolar water onto the continental shelf, where the underside of the glacier can become destabilized, lose mass, and accelerate sea-level rise. (Photo by Pierre Dutrieux; inset by Polargeo/Wikimedia Commons.)

Now Paul Holland of the British Antarctic Survey and his colleagues have disentangled the causes and established a clear connection between WAIS loss and human-induced climate change.³ The researchers combined satellite-derived data and model simulations so they could study trends over the 20th century. Their analysis indicates that an anthropogenic reversal in the direction of local winds is accelerating the ice-loss rate of the WAIS.

Tropical data mining

On-the-ground climate data around the Amundsen Sea are limited. "It was in the early 1990s that serious observations really began," says Eric Steig, a glaciologist and geochemist at the University of Washington and a coauthor of the new paper. "And that is not a very long time in terms of climate change." The available wind data over the Amundsen Sea came

from an analysis by the European Centre for Medium-Range Weather Forecasts, which uses a meteorological model to blend satellite observations from 1979 to the present.

To extend the wind record back before the satellite era, Holland and his colleagues took advantage of a climate connection between West Antarctica and the tropical Pacific Ocean. Water-temperature data have been collected by ships since at least the mid 19th century, with relatively reliable coverage and frequency starting in the early 20th century.⁴ Wind speed over West Antarctica is significantly correlated with tropical Pacific sea-surface temperature because ENSO brings tropical wind patterns to the poles by atmospheric Rossby waves.

Climate models can use the connection to fill in the gaps where past wind observations are lacking. At the National

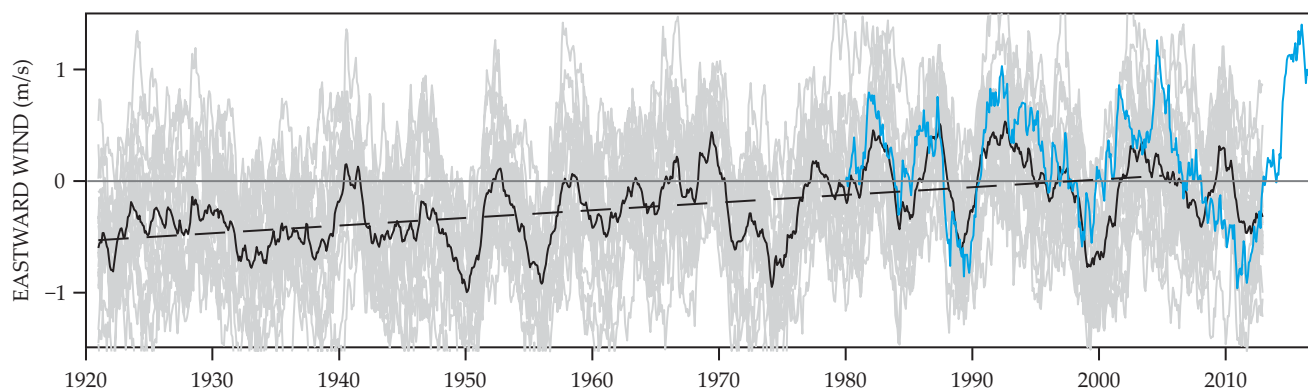


FIGURE 2. A REVERSAL OF THE PREDOMINANT WINDS over the Amundsen Sea may be thinning the West Antarctic Ice Sheet. The average winds (black solid line) of 20 climate simulations (gray) from the Community Earth System Model agree with observed winds (blue solid line) obtained from an analysis by the European Centre for Medium-Range Weather Forecasts. The trend (dashed black line) of 0.7 m/s over much of the 20th century shows that the winds changed from westward-flowing (negative values) to predominantly eastward-flowing (positive values). Rising greenhouse gas concentrations contributed 0.5 m/s to the eastward winds. (Adapted from ref. 3.)

Center for Atmospheric Research (NCAR) in Boulder, Colorado, the Community Earth System Model (CESM) incorporates historical ocean data to simulate the wind speed and direction back to 1920. There's nothing specific to how the CESM physically models the atmosphere, land, and ocean that makes it more accurate at simulating Antarctic climate than other models. Researchers have run the CESM repeatedly to more clearly separate human activity from natural variability in West Antarctica.⁵

"I've been trying to think of a way of writing this paper," says Holland, and the CESM was the tool he needed. The first 20 simulations Holland and his colleagues analyzed were constrained by the historical tropical Pacific sea-surface temperature data. Using the same data for each simulation means that the average of those 20 runs is reflective of both natural and human climate variability.

Which way the wind blows

The results of the 20 simulations, plotted in figure 2, show the strong decadal variability in the simulated wind speed and the observations. The simulations' average speed increased at a rate of 0.7 m/s per century. That change corresponds to a decrease in westward winds and an increase in eastward winds over the 20th century. The reversal in direction brings more warm water to the glaciers and consequently more WAIS ice loss.

To separate the long-term anthropogenic trend from the noisy natural variability in the time series, Holland and his

colleagues analyzed a second set of 40 simulations that was not constrained by the historical sea-surface temperature data.⁶ In those runs, the average only indicates the anthropogenic warming because the natural variability is random and cancels out.

Holland and his colleagues determined that the once-predominant westward winds have weakened by about 0.5 m/s over the past 100 years because of human activity. "Many studies have hypothesized that a link might exist" between anthropogenic climate change and the winds around West Antarctica, says Nerilie Abram of the Australian National University. "This study now clearly demonstrates the link."

The magnitude of the anthropogenic effect is about the same as the natural variability of the winds, estimated by the spread in the simulations. The result underscores the necessity of the model simulations. Observations alone didn't cover enough time, and measurements of winds and ice loss will continue to be strongly influenced by natural variability from the tropical Pacific for decades to come. Humans are changing the climate in West Antarctica to be sure, but until now the natural variability has been large enough to obscure the signal.

The not-so-distant future

Now that there's clear evidence that eastward winds in West Antarctica have increased, Holland wants to better understand how the Amundsen Sea responds to the atmosphere on a longer time scale.

Using an ocean model that precisely simulates the dynamics of each ocean layer in the region, he is exploring what happens to the flows when they are forced by the eastward winds simulated in the CESM. Once the observed rate of ice loss is reproduced, he can test whether the same atmosphere-ocean processes that operate on decadal time scales also apply to centennial time scales.

Knowledge of the processes that control ice loss on decadal and longer time scales can inform future climate change forecasts. Holland and his colleagues suggest that if humans continue to increase carbon dioxide emissions in a business-as-usual scenario, the Antarctic wind trend they found for the 20th century will continue into the 21st century.

However, the worst effects of climate change may be averted if such a trend can be avoided. In a 21st-century scenario in which greenhouse gas emissions are rapidly reduced, the Antarctic winds stabilize to the present-day state. "Reversing the change," says Holland, "is a much bigger challenge."

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References

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