

Clues to Rising Seas Are Hidden in Polar Ice

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Few consequences of global warming pose as severe a threat to human society as sea-level rise. But scientists have yet to figure out how to predict it.

And not knowing what to expect, policymakers and others are hamstrung in considering how to try to prevent it or prepare for it.

To calculate sea-level rise, the key thing researchers need to understand is the behavior of the major ice sheets that cover Greenland and Antarctica. The disintegration of one would dramatically raise the ocean. But while computer models now yield an increasingly sophisticated understanding of how a warming atmosphere would behave, such models have yet to fully encapsulate the complex processes that regulate ice sheet behavior.

"The question is: Can we predict sea level? And the answer is no," said David Holland, who directs New York University's Center for Atmosphere Ocean Science. Holland, an oceanographer, added that this may mean researchers will just have to watch the oceans to see what happens: "We may observe the change much more than we ever predict it."

In its executive summary report for policymakers in February, the Intergovernmental Panel on Climate Change, composed of hundreds of leading climate scientists, barely hazarded a guess on sea level, predicting that it would rise between 7.8 inches and two feet by the end of the century. However, the United Nations-sponsored panel -- which operated under the assumption that, by 2100, the Greenland ice sheet would lose some mass but that the Antarctic ice sheet would gain some -- did not venture a best estimate or an upper limit for possible sea-level rise.

The panel could agree to say only there is a 50-50 chance that a global temperature increase of between 1.8 and 7.2 degrees Fahrenheit would lead to a partial melting of the ice sheets over a period of several hundred to several thousand years.

Because so much is at stake -- a three-foot increase in sea level could turn at least 60 million people into refugees, the World Bank estimates -- ice sheet modelers are working furiously to try to unravel the mystery of how these sheets accumulate and lose mass.

Michael Oppenheimer, a Princeton University professor of geosciences and international affairs, does make a prediction: He figures that if the Greenland ice sheet disintegrates, sea level would rise about 23 feet. If the West Antarctic sheet melts, as well, it would add an additional 17 feet or so.

"If either of these ice sheets were to disintegrate, it would destroy coastal civilization as we know it," Oppenheimer said.

One of the biggest challenges facing researchers is that ice sheets are under "attack from the edges," in the words of Richard B. Alley, a Pennsylvania State University geosciences professor. Each sheet amounts to a pile of snow compressed over time into a two-mile thick, continent-spanning sheet of ice, which spreads out under its own weight, Alley said.

Near the coast, the pile develops quick-moving "ice streams," which flow between slower-moving sections of ice and float out onto the ocean in an "ice shelf." While recent satellite data have indicated that these ice streams are flowing faster and delivering more water to the oceans, many uncertainties remain.

David Vaughan, a glaciologist with the British Antarctic Survey in Cambridge, said the terrain beneath the ice streams helps determine how they move, but the contours of the land are largely unknown because it is buried so far under the ice. The streams may run aground on elevated bedrock, slow down as they move past rocky fjord walls or speed up as they move over mud.

"There's a continent of topography sitting under Antarctica," Vaughn said. "Everything there has an impact on how the ice sheet flows, and very little of that has been mapped."

Researchers are also trying to measure the layer of water that lies under the ice sheets, as that also helps regulate ice stream flows.

"They're essentially afloat on their own sub-glacial water, even if there's not much water there," said Garry Clarke, a glaciology professor at the University of British Columbia. "We don't know very much about how water flows underneath ice sheets."

Another uncertainty is how much the oceans surrounding the ice sheets are warming, something that is difficult to measure because the areas are remote. Vaughan and his colleagues suspect that warmer waters around Antarctica have contributed to melting the Western Antarctic ice sheet, but there is little good data because few ships venture there.

Researchers are now going to extraordinary lengths to collect the data they need. Holland at NYU recently returned from a trip to Greenland, where he was collecting information about the Ilulissat glacier, which has doubled its speed over the past decade as it flows toward the ocean and melts. To test the temperature and salinity of the water surrounding the glacier, Holland and other researchers had to hover in a helicopter and lower their instruments into an opening in the ice.

"It's kind of beautiful, and scary and fun," he said.

Even with better data, scientists find it difficult to enter the information into computer models. Most models do not attempt to calculate what could happen to ice sheets at their edges.

Adding to the challenge, Oppenheimer said, is that models "are only good at explaining things that happen at a large scale. Ice sheets are very complex beasts, and the water moves at a very small scale."

Ice streams move along narrow channels, and plugging such detail into a computer model takes a long time. But without that level of detail, the results are incomplete.

Researchers have made some progress in ice sheet science over the past decade by using satellites to measure the sheets' changing mass.

Last month, for example, a team of NASA and university scientists used readings from NASA's QuikScat satellite to measure snow accumulation and melt in Antarctica from July 1999 through July 2005. They discovered that broad areas of snow had melted in west Antarctica in January 2005 in response to warmer temperatures. The finding was surprising because Antarctica had shown relatively little warming in the recent past.

Konrad Steffen, director of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder, who led the study, said increases in snowmelt "definitely could have an impact on larger-scale melting of Antarctica's ice sheets if they were severe or sustained over time."

Because ice sheet modeling has not ranked as a high priority for government laboratories and has not been integrated into large-scale climate models, scientists from around the world are now collaborating to develop more sophisticated models to inform policymakers about potential sea-level rise. The researchers have convened two major meetings this year, one at the NOAA Geophysical Fluid Dynamics Laboratory at Princeton University and one at the University of Texas at Austin, in an effort to generate a new generation of ice sheet models.

Vaughan, who attended both conferences, said he is hopeful that he and others will solve the question of ice sheet modeling by the time he ends his career: "It will be 15 years before I retire, and I want it nailed by then."

But other researchers are less optimistic. Holland, who like Vaughan is in his mid-40s, doubts that scientists will master the problem before greenhouse gas emissions trigger significant melting of the ice sheets that he studies.

"We will get there eventually, but it won't be for a long time. It won't be in my lifetime," Holland said. "There's no plan; there's no program. There's no one responsible for sea-level rise."