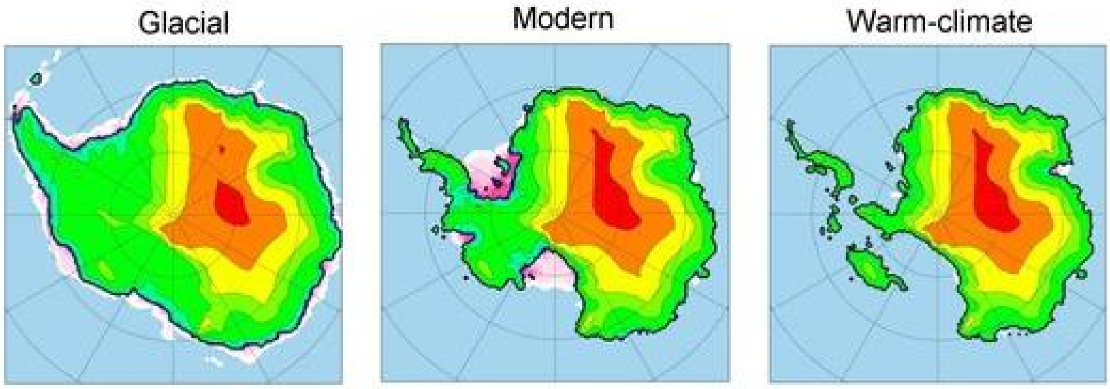
Scientist creates numerical models to predict the future of ice sheets

November 17 2015, by Katie Bohn



These models show surface elevations of ice, rising from near sea level (green) to more than three kilometers (red). Pink represents floating ice. The models represent maximum glacial cold-climate extent (left), modern day (center), and drastic warm-climate retreat (right).

David Pollard spends his days with numbers. Lots and lots of numbers.

Pollard researches how the Earth's ice sheets have changed and evolved, using data on ice extents—the amount of land and ocean that's covered by ice—and sea levels to predict how they'll continue to change in the future.

The process is called numerical modeling, and Pollard—a senior scientist in the Earth and Environmental Systems Institute in Penn State's College of Earth and Mineral Sciences—uses a blend of information technologies to help him every step of the way. Recently, he's been focusing on the Antarctic ice sheet, and the resultant models give insights to changes in the ice that could affect the entire planet.

"Basically, the model fills in a grid of points, spaced about every 10 kilometers covering all of Antarctica, with values of ice thickness, ice temperatures, and ice flow at each point," said Pollard. "Like a glacier, the ice flows slowly toward the coast by deforming and sliding over the ground below, and the computer program solves equations for these processes."

The program can then march forward in time—to make predictions about the ice in the future—or starting at a previous time, to simulate what might have happened in the past.

Pollard tests the model with data from a variety of sources.

Modern data is relatively abundant, with maps available of today's ice thickness and the depth of the ground below the ice. But because scientists weren't gathering information thousands or millions of years ago, data on what the ice sheet looked like in those time periods is more indirect and requires a little more detective work.

"Geologists look at the signs left on the landscape, like gouges made by ice dragging rocks along the ground, or moraines, which are accumulations of earth piled up by flowing ice in the past," said Pollard. "These clues, coupled with dating information, give us a good idea of how the ice extent has varied, especially over the Northern Hemisphere, during the last million years."

Scientists also drill into the sediment layers at the bottom of the ocean and bring up samples—called cores—that tell us about the total global ice sheet volume at different times in the past. Pollard says there's good evidence, for example, that every hundred thousand years or so, Canada and Scandinavia have been covered with ice a mile or two thick.

With all the clues and evidence of past variations in the ice, it's challenging for ice sheet models to match them exactly.

So Pollard runs the models with hundreds of different combinations of settings, which is called an "ensemble" of runs. He then looks at the different results to figure out which combinations are most accurate.

Pollard says these ensembles require a large number of computer processors due to the sheer amount of data being processed simultaneously. He says that since he started numerical modeling in the 1970s, the increase in available computer power has been staggering.

"When I first started, you could run a single flow line—which is a horizontal slice in one dimension—and simulate the ice for tens of thousands of years," said Pollard. "Now, you can run ice sheet models in three dimensions with realistic geography over a continent for tens of millions of years."

To perform these simulations, Pollard uses large, high-performing clusters of Linux computers at Penn State's Institute of CyberScience. The systems are kept in the Penn State Data Center in the Computer Building, where they're backed up and cooled to prevent overheating.

"With the Linux clusters, I can run up to several hundred instances of the model at any one time. The ice sheet model is written in Fortran, and I also write Unix shell scripts to automatically submit hundreds of model runs at one time with different settings," said Pollard. "In the time it takes to run one model, you can get a whole ensemble of results for hundreds of combinations."

These information technologies support Pollard as he tries to learn not only how ice sheets have changed in the past, but why. Some of his recent research about rises of sea level during the last several million years even won him the Paul F. Robertson Award for EMS Breakthrough of the Year earlier this year from the College of Earth and Mineral Sciences.

Pollard says he and his colleagues were interested in the long-standing mystery surrounding unexplained episodes of global sea-level rise in the last three million years. Although geological data suggested that sea levels may have been as high as 10 to 20 meters above modern levels at some points, Pollard and other ice sheet modelers were having a hard time getting their models to simulate the corresponding amount of ice sheet melt. They knew the ice sheets would have had to melt to cause the rise in sea level, but they didn't know what caused it.

So Pollard started looking at two "mechanisms" that could have produced greater amounts of melting. These mechanisms had been studied before but hadn't been included in most ice sheet models.

"One is liquid water from melted ice running into cracks and crevasses on the top of the ice sheet. As the water penetrates, it can fracture the crevasses and deepen them all the way through the ice," said Pollard. "The other involves huge ice cliffs where the ice edge meets the ocean. The cliffs become so tall above the water line that they exceed the basic strength of ice. Then there would be catastrophic collapse and rapid retreat of the grounded ice back into the interior."

When Pollard updated his models to account for these two mechanisms, they were able to produce ice sheet retreat—when the sheet melts and causes the edge to retreat inward—into large embayments around the Antarctic coast during warm climate periods. The retreat was enough to explain a global sea-level rise of 10 meters or more, providing a possible explanation to the mystery.

Pollard's models fit in with the mission of Penn State's Earth and Environmental Systems Institute, which aims to understand how people affect the Earth and vice versa. The Antarctic ice sheet may be more than 7,000 miles away from Penn State, but Pollard says humans are indeed affecting their melt patterns, which in turn affects the rest of the world.

"Carbon dioxide in the atmosphere is reaching levels that were last reached millions of years ago," said Pollard. "So when we go back and see what happened to Antarctica then, it gives us clues about what will happen in the future. And if we keep burning fossil fuels as rapidly as we are now, we'll reach levels that were last matched about 30 million years ago."

Pollard says he hopes his models help inform people about how Antarctica will react to warmer climates the world might be headed toward in the future.

"It's important to understand the past. Ice sheets have had a huge effect in all sorts of ways: eroding the ground, forming landscapes, and cooling and warming climates over the last million years," said Pollard. "Their contribution to sea-level rise is what's really important for the future."

Provided by Pennsylvania State University

Citation: Scientist creates numerical models to predict the future of ice sheets (2015, November 17) retrieved 12 May 2024 from

https://phys.org/news/2015-11-scientist-numerical-future-ice-sheets.html