What will happen to the Greenland ice sheet if we miss our global warming targets

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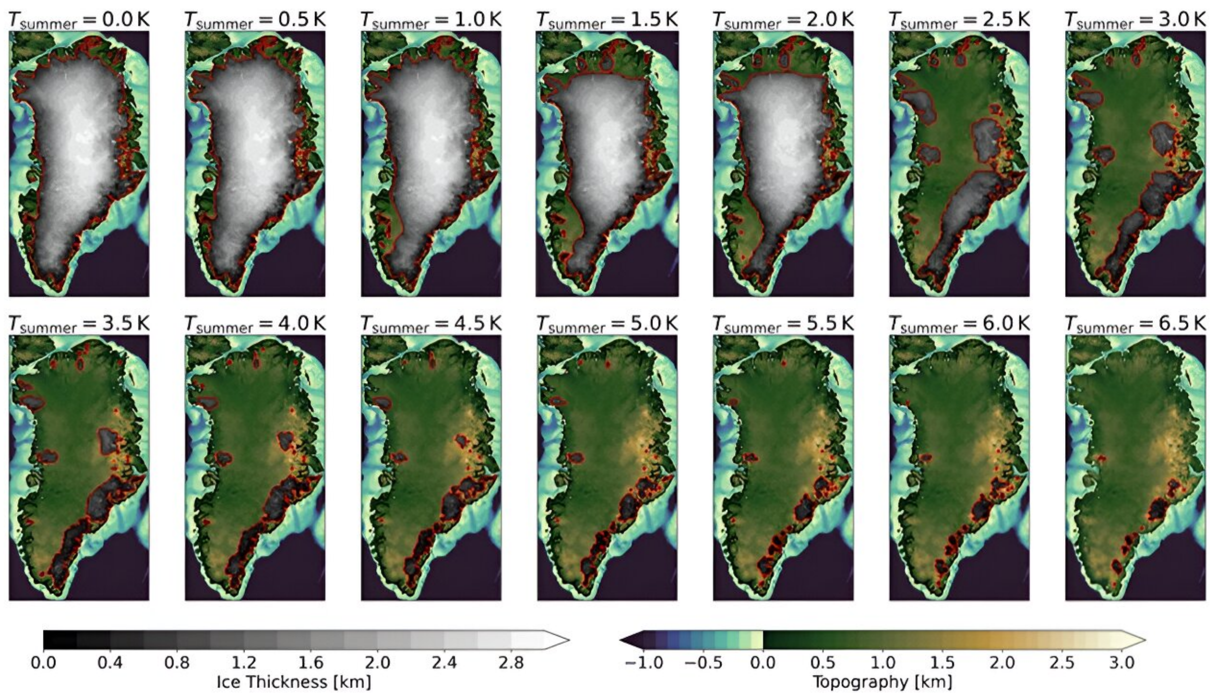

Greenland after 100,000 years of convergence temperatures of 0°C to 6.5°C. With no warming (top left) things stay as they are. With extreme climate change (bottom right) ice remains only on a few isolated mountains. Credit: *Nature* (2023). DOI: 10.1038/s41586-023-06503-9

It's hard to overstate how crucial Greenland, and its kilometers-thick ice layer, is to climate change. If all that ice melted, the sea would rise by about seven meters—the height of a house.

But what happens if we fail to limit warming to 1.5°C (as looks increasingly likely)? And what happens if we do subsequently manage to rectify that "overshoot" and bring temperatures back down? A team of researchers writing in the journal *Nature* have now published a study exploring these questions.

In a nutshell, their work shows the worst case scenario of ice sheet collapse and consequent sea-level rise can be avoided—and even partly reversed—if we manage to reduce the global temperatures projected for after 2100. Moreover, the lower and sooner those temperatures fall, the more chance there is of minimizing that ice melt and sea-level rise.

We already know that the Greenland ice sheet is losing more than 300 billion cubic meters of ice per year, currently driving global sea levels up by a little less than a millimeter per year. One major worry is that further warming could cross critical thresholds, sometimes referred to as "tipping points". For example, as the air warms more ice will melt, lowering the elevation of the ice surface and hence exposing it to warmer air temperatures and more melting—even without continued atmospheric warming.

Although far more complex and nuanced in reality, it is feedback processes such as this which dictate that global warming be limited to 1.5°C above pre-industrial levels in order to avoid catastrophes, such as wholescale ice-sheet collapse.

How to simulate a huge ice sheet in a computer

It is critically important that we are able to predict how the Greenland ice sheet will respond to future warming. To achieve this, researchers generally use computer models of ice motion. In essence, these divide the ice sheet into tens of thousands of 3D segments and apply physical laws of ice motion to compute how each segment changes over thousands of individual time steps, factoring in things like anticipated climatic change, ice thickness, ice slope and the temperature of the ice interior and ice base.

However, these projections are subject to substantial uncertainties. It's tough to know exactly how ice moves over bedrock, or what its internal temperature might be. And the climate is made up of many moving parts. Atmospheric and oceanic circulations may also change radically over the thousands or tens of thousands of years it takes for the ice sheet to settle in to a new equilibrium.

In the face of such challenges, a team of researchers led by Nils Bochow of the Arctic University in Norway have published their new study. They ran two independent state-of-the-art computer programs that were able to simulate how the Greenland ice sheet would respond to various possible levels of global warming, over tens of thousands of years. To mimic the effects of overshooting the critical 1.5°C threshold, they include a gradual warming trajectory to a "peak" temperature, followed by a period during which temperature stabilizes to a generally lower final "convergence temperature".

Good news and bad news

The results are fascinating. If temperatures peak at 2°C or so, and remain there, then the models—as expected—predict substantial ice sheet collapse after several thousands of years.

However, things change if warming is seriously mitigated post-2100. In those models, inertia in the ice sheet's response—a bit like the time it takes for a ripple to settle down as it passes across a pond—means that an overshoot is at least partly reversible as long as temperatures are quickly brought back down.

For example, if temperature stabilizes by the year 2200 at less than 1.5°C of warming, then the ice sheet should remain smaller than at present, but stable. This is the case irrespective of how far (within reason) peak temperatures overshot 1.5°C in the year 2100. In such cases the sea rise would likely be restricted to a meter or so.

However, such a recovery becomes impossible if it takes too long to get temperatures down or if the convergence temperature remains too high. In those scenarios, ice-sheet collapse and substantial sea-level rise become all but inevitable.

Perhaps the very worst can be avoided then, if we continue to work to reduce global temperatures right through this century and next. Although heartening to some degree, these projections are subject to substantial uncertainty and there is more work to do. In this regard, the authors are at pains to note that their results are not necessarily specific predictions but rather provide insight into possible pathways.

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