Ice Moves in a Cascade of Quakes

Observations of a new deformation mode of ice could improve models of sea-level rise.

By **Rachel Berkowitz**

Predictions of sea-level height for the year 2100 vary enormously, ranging from a drop of 5 cm compared to today to a rise of 43 cm. Now Andreas Fichtner of the Swiss Federal Institute of Technology (ETH) Zurich and his colleagues have identified a never-before-observed process in our planet's ice sheets that could resolve the discrepancy [**1**]. They found cascades of tiny icequakes deep within the massive Greenland ice sheet that propagate over hundreds of meters. Incorporating these icequakes into today's best models could help better predict how fast ice moves toward the sea.

Ice streams in the Antarctic and in Greenland carry ice from inland ice sheets to the shore. There, the water bound in these ice streams joins the sea, impacting sea-level height. Climate models rely on simulations of ice-stream dynamics to predict sea-level rise—but these dynamics are estimated based on ice-sheet deformations measured at the surface. "Ice is traditionally assumed to behave like a highly viscous fluid. It is supposed to flow, loosely speaking, like honey and to not rupture," Fichtner says. But a new ice-rupture mechanism, which he discovered through observations, adds a new piece in the ice-stream physics puzzle.

Andreas Fichtner and his team lowered a fiber-optic cable into a borehole in order to record signals from inside an ice stream in the Greenland ice sheet.
Credit: Lukasz Larsson Warzecha/LWimages

In 2022 Fichtner's team performed experiments designed to record how controlled explosions generated at the surface of the Greenland ice sheet manifested deep within the ice. From the resulting seismic data, the researchers calculated the mechanical properties of ice in the area. That involved lowering a fiber-optic cable into a 2700-m-deep borehole and measuring vibrations in real time along the entire vertical cable, a technology known as Distributed Acoustic Sensing.

In between the ten explosions the team performed over a 14-hour period, Fichtner and his colleagues expected total silence inside the borehole. But to their surprise, there was a lot of activity. After each explosion, the cable started vibrating, registering on the seismometer as a bump in an otherwise flat line. Over the course of just a few seconds, that signal propagated from 1500-m depth upward to the top of the cable at 900-m depth. Other bumps where then observed, with each bump following on from the last. Fichtner describes it as a cascade of hundreds of tiny icequakes that triggered each other over hundreds of meters of distance, like a giant game of dominoes.

Fichtner attributes these icequake cascades to two important ingredients. The first is the release of large internal stresses by the explosion. The second is new and, he says, most likely caused by volcano-related impurities in the ice, the positions of which correlated with the depths of the observed quakes. At these very specific depths, microscopic sulfate anomalies and volcanic ash mechanically weaken the ice. This weakness makes the ice break at these predefined depths, thereby producing icequakes. The correlations with volcanic impurities "really convinced us that this is not just some exotic data rubbish," Fichtner says.

Alex Brisbourne, a geophysicist at the British Antarctic Survey, calls the work "really impressive." He says, not only are the measurements incredibly difficult to make, but the signals are tiny and quite unexpected. "It would have been easy for the researchers to discard them as instrument noise and move on. I probably would have!" he says. Aurélien Mordret, a seismologist at the Geological Survey of Denmark and Greenland, points out that the cable achieved a spatial resolution that's out of reach of other instruments. "What can it do that standard seismometers cannot do? This study is a good answer," he says.

Long-term predictions of sea-level change depend on models that simulate the evolution of the Antarctic and Greenlandic ice sheets. The main source of uncertainty in these models stems from an incomplete understanding of ice-stream physics. Calculations of strain and rupture displacement suggest that icequake cascades are a plausible explanation for the current discrepancy between the simulated deformation of ice streams, the researchers say.

"We thought we had a good empirical model for predicting ice flow," Mordret says, but Fichtner's new work shows that unknown processes affect glacier dynamics. "What they have observed could be a missing link," Brisbourne adds. Still, both point out, caution is needed for interpreting the results, as this is a first observation at one site. "It will certainly get the community thinking and looking into the significance of this type of ice deformation that we just haven't considered previously," Brisbourne says.

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REFERENCES

1. A. Fichtner *et al.*, "Hidden cascades of seismic ice stream deformation," **Science 0, eadp8094 (2025).**