Underwater mapping reveals new insights into melting of Antarctica's ice shelves

July 31 2024

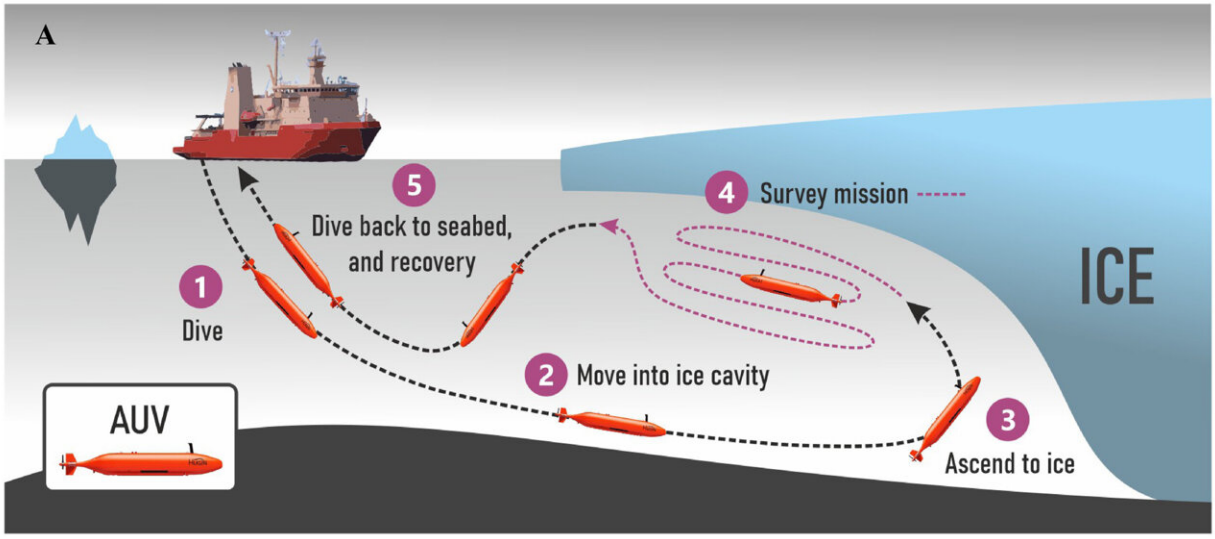
The expedition was carried out in regions of drifting ice in West Antarctica in 2022. On the return visit in 2024, Ran disappeared without a trace under the ice. Credit: Filip Stedt

An international research team—including scientists from the University of East Anglia (UEA)—deployed an unmanned submersible beneath the Dotson Ice Shelf in West Antarctica. The underwater vehicle, "Ran," was programmed to dive into the cavity of the 350 meter thick ice shelf and scan the ice above it with an advanced sonar.

Over 27 days, the submarine traveled more than 1,000 kilometers back and forth under the shelf, reaching 17 kilometers into the cavity.

An ice shelf is a mass of glacial ice, fed from land by tributary glaciers, that floats in the sea above an ice shelf cavity. Dotson Ice Shelf is part of the West Antarctic ice sheet—and next to Thwaites Glacier—which is considered to have a potentially large impact on future sea level rise due to its size and location.

The researchers report their findings of this unique survey in a paper, "Swirls and scoops: Ice-base melt revealed by multibeam imagery of an Antarctic ice shelf," published in the journal *Science Advances*.



The autonomous underwater vehicle Ran was programmed to perform missions under the ice shelf. An advanced multibeam sonar system was used to map the underside of the ice at a distance of about 50 meters. Credit: Anna Wåhlin /*Science Advances*

They found some things as expected. For example, the glacier melts faster where strong underwater currents erode its base. Using the submersible, they were able to measure the currents below the glacier for the first time and prove why the western part of Dotson Ice Shelf melts so fast. They also found evidence of very high melt at vertical fractures that extend through the glacier.

However, the team also saw new patterns on the glacier base that raise questions. The mapping showed that the base is not smooth, but there is a peak and valley ice-scape with plateaus and formations resembling sand dunes. The researchers hypothesize that these may have been formed by flowing water under the influence of Earth's rotation.

Lead author Anna Wåhlin, Professor of Oceanography at the University of Gothenburg in Sweden, said, "We have previously used satellite data and ice cores to observe how ice shelves change over time. By navigating the submersible into the cavity, we were able to get high-resolution maps of the ice underside. It's a bit like seeing the back of the moon for the first time."

The expedition was carried out in regions of drifting ice in West Antarctica in 2022 during a research cruise for the TARSAN project, an initiative that is part of the International Thwaites Glacier Collaboration. The project is studying how atmospheric and oceanic processes are influencing the behavior of the Thwaites and Dotson Ice Shelves—neighboring ice shelves which are behaving differently.

Co-author Dr. Rob Hall, from UEA's School of Environmental Sciences, co-led the cruise on the RV Nathaniel B Palmer, on which the observations were made in January to March 2022. He said, "Anna and her team successfully piloted their autonomous underwater vehicle 'Ran' over 1,000 km under Dotson Ice Shelf, collecting a huge range of data and samples, which will take several years to process and analyze.

"The incredible high-resolution images of the underside of the ice shelf are the icing on the cake and will open up a whole new avenue of scientific research."

Prof Karen Heywood, also from UEA and a co-author, is UK lead scientist on the TARSAN project. She said, "This has been such an exciting project to work on. When Anna sent round the first images of the underside of the Dotson ice shelf we were thrilled—nobody had ever seen this before. But we were also baffled—there were cracks and swirls in the ice that we weren't expecting. It looked more like art!

"We wondered what could be causing these. All of the glaciologists and the oceanographers in the TARSAN project got together to brainstorm ideas. It's been like detective work—using fundamental ocean physics to test theories against the shape and size of the patterns under the ice. We've been able to show for the first time some of the processes that melt the underside of ice shelves.

Prof Heywood added, "These ice shelves are already floating on the sea, so their melting doesn't directly affect sea level. However, ultimately the melting of ice shelves causes the glaciers on land further upstream to flow faster and destabilize, which does lead to sea level rise, so these new observations will help the community of ice modelers to reduce the large uncertainties in future sea level."

Scientists now realize there is a wealth of processes left to discover in

future research missions under the glaciers.

The Dotson glacier is 350 meters thick. Credit: Anna Wåhlin

"The mapping has given us new data that we need to look at more closely. It is clear that many previous assumptions about melting of glacier undersides are falling short. Current models cannot explain the complex patterns we see. But with this method, we have a better chance of finding the answers," said Prof Wåhlin.

"Better models are needed to predict how fast the ice shelves will melt in the future. It is exciting when oceanographers and glaciologists work

together, combining remote sensing with oceanographic field data. This is needed to understand the glaciological changes taking place—the driving force is in the ocean."

In January 2024, the group returned with Ran to Dotson Ice Shelf to repeat the surveys, hoping to document changes. However, they were only able to complete one dive before Ran disappeared under the ice.

"Although we got valuable data back, we did not get all we had hoped for," said Prof Wåhlin. "These scientific advances were made possible thanks to the unique submersible that Ran was. This research is needed to understand the future of Antarctica's ice sheet, and we hope to be able to replace Ran and continue this important work."

More information: Anna Wåhlin, Swirls and scoops: Ice-base melt revealed by multibeam imagery of an Antarctic ice shelf, *Science Advances* (2024). DOI: 10.1126/sciadv.adn9188. www.science.org/doi/10.1126/sciadv.adn9188

Provided by University of East Anglia