3D radar scan provides clues about threats to iconic Alaskan glacier

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Located in southeast Alaska, Malaspina Glacier spills out from the St. Elias Mountains onto the coastal plain as a "pancake of ice". New research revealed certain features make the glacier particularly vulnerable to melting. Credit: Brandon Tober

A detailed "body scan" of Malaspina Glacier, one of Alaska's most iconic glaciers, revealed that its bulk lies below sea level and is undercut

by channels that may allow ocean water to gain access, should its coastal barrier erode. This makes the glacier more vulnerable to seawater intrusion than previously thought and may cause it to retreat faster than predicted.

The findings, published by University of Arizona researchers in the *Journal of Geophysical Research*, underscore the fragility of a very large glacial system that could lead to the loss of a significant volume of ice and National Park Service land and would contribute a measurable volume to global sea level rise.

"The loss of this glacier would likely be the largest loss of ice from an Alaskan glacier within this century," said lead study author Brandon Tober, a doctoral student in the UArizona Department of Geosciences.

The area in front of Malaspina Glacier, a permafrost zone with pure ice beneath the surface, is "wasting away" in the face of rising global temperatures, Tober said. Permafrost refers to ground that remains frozen for two or more years.

"As this coastal barrier erodes and gives way to large lagoons, primarily through the collapse of ice cliffs, ocean water may eventually gain access to the glacier," Tober said. "Once it gets to the front of the glacier, it may melt the ice even faster and initiate the glacier's retreat."

Forming an expansive ice sheet located right on the shore of southeast Alaska, Malaspina is the world's largest piedmont glacier, a type of glacier that flows from steep mountains onto a broad plain, essentially forming a "pancake of ice" that spills out onto a broad coastal plain from the St. Elias Mountains. A thin land barrier separates the glacier from the relatively warm waters of the Gulf of Alaska. Historical satellite imagery shows these water bodies expanding over time, forming a lagoon system directly in front of the glacier over the past few decades.

Traditionally, researchers rely on mathematical models to gauge the thickness of glaciers, Tober said, but they vary widely in their ability to accurately predict the thickness of glaciers. These models often rely on measurements of how fast the glacier moves across the surface to make predictions about the glacier's depth, similar to the way a river's water flow rates are used to gain insights about its depth and the shape of its bed.

"We know that glaciers in Alaska are melting and thinning rapidly in many places, but we don't accurately know how thick they are, and therefore we can't accurately predict future mass loss," Tober said. "If we don't know the thickness and bed topography, we can't accurately model their future evolution."

To gain a better idea of Malaspina's future, the researchers needed to get a detailed "body scan" of its shape and thickness. To do this, Tober's research group used the Arizona Radio Echo Sounder, or ARES, an instrument designed and built by a team led by Jack Holt, a professor at the UArizona Lunar and Planetary Laboratory and Department of Geosciences, and one of the paper's co-authors. Holt's research group specializes in using geophysical research methods, primarily radar, to study features on Earth and Mars.

ARES was mounted in an airplane as part of Operation IceBridge, a mission tasked with measuring annual changes in the thickness of glaciers, sea ice and ice sheets in Greenland, Alaska and Antarctica from airplanes between 2009 and 2021.

While the plane crisscrossed the vast, icy expanse, its ice-penetrating radar "X-rayed" the glacier, resulting in a full "3D body scan" of the glacier and underlying bedrock. The measurements revealed that Malaspina glacier sits largely below sea level and is cut by several channels at its bed that extend at least 21 miles from where the glacier

meets the shore up toward its source in the Saint Elias Mountains.

The combination of the glacier's location with respect to the sea level and the continued loss of its coastal barrier may provide pathways for ocean waters to access large areas of the glacier's bed along these channels, the researchers write in their paper. Assuming this leads to large-scale shedding of ice masses and the glacier's retreat, the researchers conclude that Malaspina has the potential to contribute 560 cubic kilometers, or 134 cubic miles, of ice to the ocean. In other words, Malaspina alone could raise global sea level by 1.4 millimeters, or just under 1/16 of an inch.

Vegetation growing atop massive ground ice – a crevassed forest – is seen in this aerial photo of the land strip that separates Malaspina Glacier from the Pacific Ocean. This coastal barrier "wastes away," the researchers say, as ice cliffs collapse and form a growing expanse of lagoons. Credit: Brandon Tober/University of Arizona

"This might not sound like much, but to put this in perspective, all Alaskan glaciers combined contribute about 0.2 millimeters per year to global sea level rise—a rate that tops all other glaciated regions on Earth apart from the Greenland and Antarctic ice sheets," Tober said.

The study makes Malaspina the most extensively radar-mapped glacier in Alaska, according to Tober's team. While glaciers in other parts of the world have been mapped to similar levels of detail, their Alaskan counterparts have eluded accurate measurements because they consist of what is known as temperate or "warm" ice.

"The glacier's crevasses often have water in them, and that makes it difficult to get radar energy down to the bed of the glacier and back up to the instrument," Tober said.

Overcoming that challenge was part of the motivation to build ARES.

The radar scans revealed that glaciological models overestimate Malaspina's volume by more than 30%. Still, the glacier, which was measured to be just over half a mile thick at its center, boasts 10 times the total volume of all the glaciers in the Swiss Alps.

"We can speculate that the channels, the big troughs beneath the glacier, are routing meltwater that comes out at the coast," Tober said.

Donning flight suits, Jack Holt (left) and Brandon Tober await a helicopter ride back to base camp after completing a geophysical survey on Malaspina Glacier. Credit: Jack Holt/University of Arizona

The observed expanse of lagoons across Malaspina's foreland over the past few decades is largely what alerted a team of researchers including Holt to the fact that the coastal barrier in front of Malaspina Glacier is wasting away, raising questions about the glacier's stability. The team, which consists of researchers from the UArizona, the University of Alaska Fairbanks, the University of Montana and the National Park Service, was awarded a grant by the National Science Foundation to

further investigate the potential demise of the world's largest piedmont glacier.

Sydney Mooneyham, a co-author on this paper who graduated from the UArizona School of Geography, Development and Environment, mapped the expanse of the lagoons across Malaspina's foreland over the course of about 50 years' worth of images taken by Landsat, a series of Earth-observing satellites launched to study and monitor Earth's landmasses.

Another motivation to focus on Malaspina Glacier, Tober said, came from the fact that it is located in the largest national park in the U.S., the Wrangell Saint Elias National Park and Preserve. At 13.2 million acres, it is larger than Yellowstone National Park, Yosemite National Park and the country of Switzerland combined, according to the National Park Service.

"The potential loss of Malaspina and opening of a new bay along Alaska's coastline may be the largest landscape transformation within the U.S. that we could witness during this century," Tober said, "and it may lead to the loss of up to 500 square miles of park land."

More information: B. S. Tober et al, Comprehensive Radar Mapping of Malaspina Glacier (Sít' Tlein), Alaska—The World's Largest Piedmont Glacier—Reveals Potential for Instability, *Journal of Geophysical Research: Earth Surface* (2023). DOI: 10.1029/2022JF006898

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