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Regime Change at Jakobshavn

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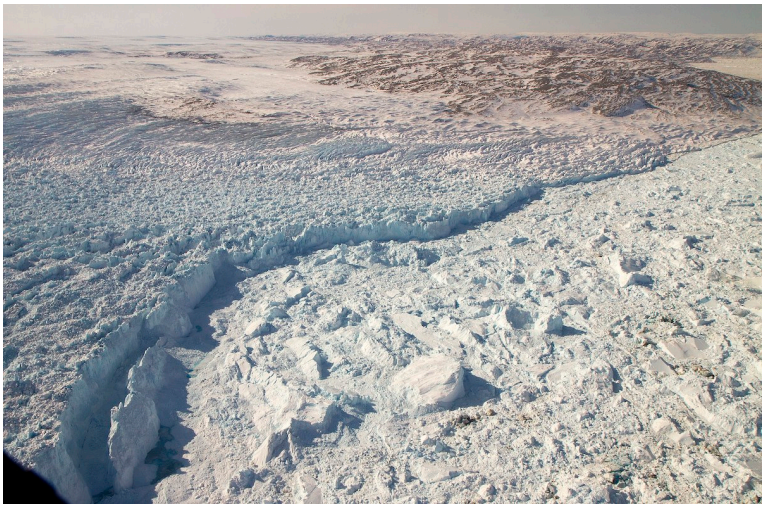
ABSTRACT

Observations by NASA of Greenland's biggest glacier and largest contributor to sea-level rise reveal how vulnerable the ice sheets can be to changes in ocean temperatures, with implications for their future ice loss to the ocean.



Front of Jakobshavn Isbrae, where the glacier reaches the sea.
Image credits: NASA - CC0

Jakobshavn Isbrae is a glacier of superlatives. Located in central west Greenland, it is the ice sheet's (possibly the world's) fastest flowing glacier. Furthermore, it is the largest by ice volume discharge, and, for two decades, the most significant contributor to sea-level rise. Lately, Jakobshavn has been undergoing dramatic changes that are forcing a reassessment of its evolution and, more generally, offering valuable clues into ice-sheet interactions with the ocean.

Understanding those interactions is at the heart of the efforts to predict the contributions of Earth's ice sheets in Greenland and Antarctica to sea-level rise. Since this contribution accelerated over the past 30 years, glaciologists came to realize that ice does not even need to melt at the surface by warming air temperatures to be lost. Glaciers could also raise seas by transporting more ice into the ocean at higher rates.

Glaciers are intricate systems. Glaciologists over the past few years identified two factors that can affect glaciers' dynamics greatly. 1) the glaciers are perturbed at the fronts (where they meet the ocean) by higher melting at their *bottoms* as ocean water warms; 2) those glaciers are lying on beds that deepen farther inland. If these two ingredients are combined, glaciers could start flowing faster and discharging more ice.

Motivated by those questions, NASA launched a 5-year airborne mission in 2016 to make observations at the margins of Greenland, where glaciers flowing from the interior reach the ocean. The main approach of the mission Oceans Melting Greenland

(OMG, quiet unintentionally) is to measure properties of both the ice and the ocean as concurrently as possible. Changes in ice volume from year to year are obtained by an airborne radar that measures the surface elevation of the ice. Probes dropped from the air measured changes in ocean properties on the continental shelf.

When radar observations from the first two years became available, we started quantifying surface elevation changes around Greenland. Jakobshavn had been persistently thinning for 20 years, the surface of the glacier dropping by 160 meters between 2003 and 2016. So when the OMG data revealed that between 2016 and 2017 the glacier thickened by 30 meters, skepticism ensued. But days spent combing through the computer codes used in analyzing the data detected no renegade minus signs or other mishaps. Months later the thickening was further confirmed by a different set of NASA observations. Attention now turned to OMG's concurrent measurements of the ocean in the vicinity of Jakobshavn. The changes in ocean temperatures were similarly remarkable: between 2014 and 2017 they had cooled by 2°C to levels not seen since the mid-1980s.

We then complemented the measurements by observations from other sources to extend the analyses farther back in time. What emerged was a large-scale natural experiment 20 years in the making. Previous studies had shown that the intrusion of warmer waters onto Greenland's western continental shelf in the late 1990s coincided with Jakobshavn starting to retreat, accelerate and thin persistently. The OMG observations two decades later were showing the reversal of those earlier events, as the return of cooler waters coincided with Jakobshavn re-advancing, slowing down and thickening. Significantly, between those two salient bookends, we found a strong correlation between ocean temperature variability and glacier behavior changes throughout the extended study period. Ocean temperature variability was in turn linked to large-scale regional oceanic patterns. The events over the past two decades, therefore, provide compelling evidence of the ocean's strong influence on the evolution of the glacier.

Jakobshavn's recent slower ice loss to the ocean is a silver lining that should not distract from the enduring cloud. Despite the several factors that can affect glacier behavior, ocean's warming temperatures appear to be largely responsible for Jakobshavn's episodes of retreat, flow acceleration, and thinning. And warmer waters will most likely return, given the regional context of ocean variability. The bed of the glacier lies hundreds of meters below sea level - and it continues to deepen for tens of kilometers inland. Thus, it is inevitable that as the glacier retreats, the ocean's warm embrace of Jakobshavn will last for decades to come. This scenario can only mean more ice loss to the sea.

Greenland and Antarctica have several giant glaciers that share Jakobshavn's vulnerability to warmer ocean waters and the shape of its bed--OMG indeed!

Acknowledgments

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