Arctic sea ice influenced force of the Gulf Stream

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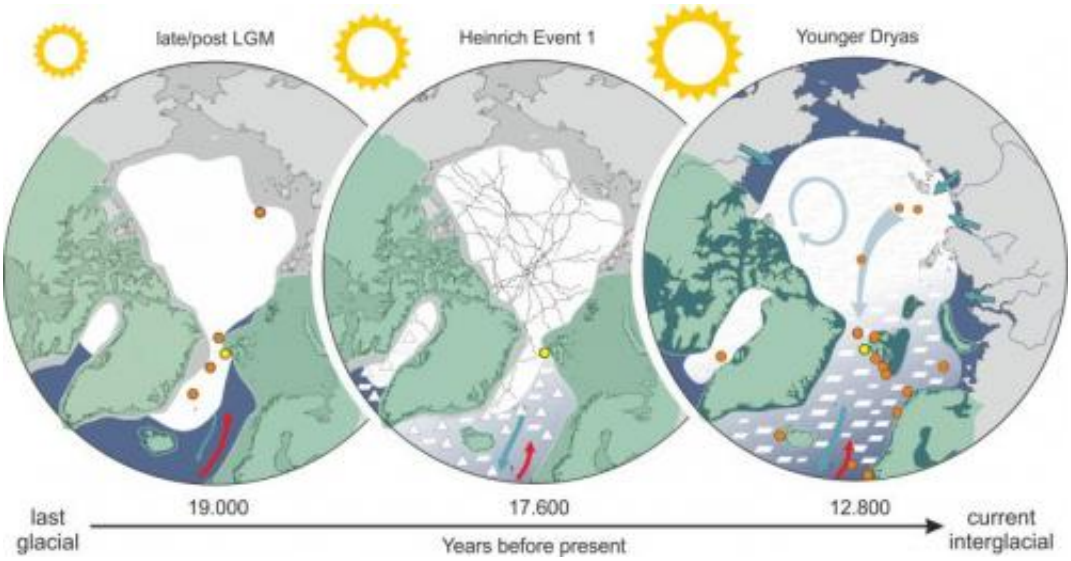


These maps give an overview of the reconstructed changes in sea ice conditions in the Fram Strait and their consequences for the Atlantic Meridional Overturning Circulation. 19,000 years before present permanent sea ice coverage had formed, which prevented any serious sea ice export from the Arctic Ocean (left). 1,400 years later this ice coverage brook up during an Heinrich Event 1 (center), starting a massive drift of sea ice and icebergs into the North Atlantic. Such an increased sea ice formation and discharge was also reconstructed for the period of the Younger Dryas, 12,800 years before present. The green shadings represent the extent of continental ice sheets; the points stand for sediment drilling sites. The sediment core used in this study was drilled at the site marked in yellow. Credit: Illustrations: Juliane Müller, Alfred-Wegener-Institut

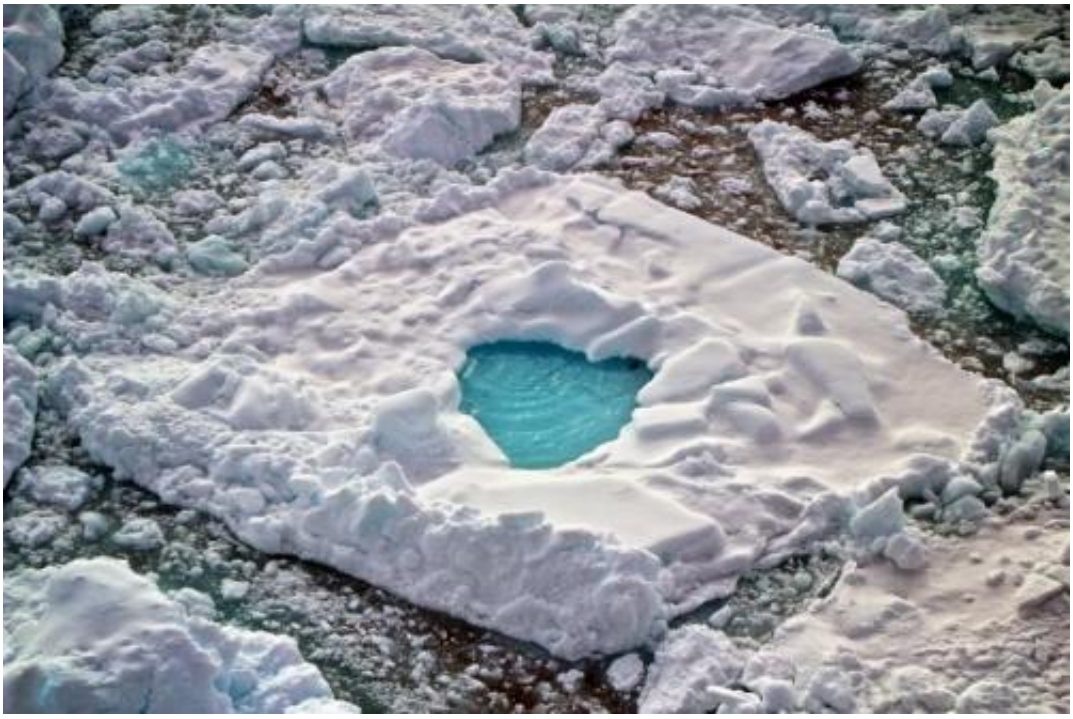
The force of the Gulf Stream was significantly influenced by the sea ice situation in the Fram Strait in the past 30,000 years. Scientists at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) come to this conclusion in a new study that appears today in the journal *Earth and Planetary Science Letters*. On the basis of biomarkers in deposits on the seafloor, the geologists involved managed for the first time to reconstruct when and how the marine region between Greenland and Svalbard was covered with ice in the past and in what way the Gulf Stream reacted when the sea ice cover suddenly broke up. They concluded that when large amounts of Arctic ice drifted through the Fram Strait to the North Atlantic, the heat transport of the Gulf Stream declined noticeably.

For AWI geologist Juliane Müller the Fram Strait is a key region in the global oceanic circulation. "On the east side of this passage between Greenland and Svalbard warm Atlantic water flows to the north into the Arctic Ocean while on the west side cold Arctic water masses and sea ice push their way out of the Arctic into the North Atlantic. A considerable portion of the Atlantic water cools here on its way to the north and sinks to deeper layers. The circulation of the water caused in this manner drives the global band of oceanic currents like a giant pump and influences, among other things, how much heat the Gulf Stream transports towards Europe," says the scientist.

If the pulse frequency of this circulation pump changes, this gives rise to direct changes in the climate – for instance, at the end of the past glacial period and during the transition to our present-day interglacial. "In the past 30,000 years the Gulf Stream has lost an extraordinary amount of force at least twice – once 17,600 years ago and about 12,800 years ago. Both times the climate in Europe consequently cooled down significantly – and now we also know why," says Juliane Müller.

She and her AWI colleague Ruediger Stein were the first scientists to

succeed in reconstructing the sea ice conditions in the Fram Strait for this critical period at the end of the last glacial and thus in finding a direct connection between changes in sea ice cover and fluctuations in the Gulf Stream.



An arctic sea ice floe with a small melt pond on it. This photo was takes during a Polarstern expedition into the Fram Strait in the year 2012. Credit: Sebastian Menze, Alfred-Wegener-Institut

A nine metre long sediment core served as a window into the past for the geologists. It was drilled on a Fram Strait expedition conducted on the research vessel Maria. S. Merian and has such clearly defined layers that the scientists can read it like a book. "This core stems from the western continental slope of Svalbard, a region with an unusually high sedimentation rate. That means a very large number of sediment particles – the stores of climate information – trickle to the seafloor.

This is the only explanation for the fact that we find the climate data from five to ten years over a length of one centimetre in this core while it could easily be as many as 1,000 years per centimetre of sediment sample in cores from low-particle regions. And, of course, 1,000 years are much too long a period to be able to clearly identify short-term climate fluctuations at all," explains Juliane Müller.

Two kinds of fossil molecules, also designated as biomarkers, served as indications of the existence and the duration of an ice cover for Juliane Müller. One kind is produced by diatoms living in the sea ice, the other by algae that prefer the open water. "The markers provide us with astonishing insights into the climate history of the Fram Strait. For instance, we now know that a thick ice cover did not form until after the actual high point of the last glacial period. However, it held for around 1,000 years and influenced the oceanic currents in the North Atlantic on a long-term basis," says Juliane Müller.

The reason for this is that the ice cover delayed the breakup of the large ice sheets that covered large sections of Europe and North America at that time. "The sea ice stabilised the glacier fronts of these ice sheets like a dam wall and prevented icebergs from calving. Export of freshwater from the Arctic to the North Atlantic, which otherwise would have been enormous, was thus checked for a certain time," explains the geologist.

When the ice cover then broke up within an extremely short time 17,600 years ago, tremendous ice masses poured into the North Atlantic. There they melted and released large volumes of freshwater. "This sudden freshening of the North Atlantic altered the density structure of the water and led to significant weakening of the Atlantic overturning circulation, or to put it more simply, to weakening of the Gulf Stream," says Juliane Müller.

According to the study, a similar chain reaction occurred yet another time during the Younger Dryas around 12,800 years ago when enormous amounts of sea ice again left the Arctic moving towards the North Atlantic and heat transport via the Gulf Stream declined. "The results of our study show how important Arctic sea ice is for the global oceanic circulation and that sudden changes in the sea ice cover of the Arctic Ocean is directly connected with abrupt climate fluctuations," says the AWI scientist.

She will now provide the newly obtained data to AWI's climate modellers. "With the help of these specific data we can check how reliably our models depict the sea ice situation of the past 30,000 years. In this way the data from the past help us to improve our models and consequently enable us to make more precise statements on the future of the Gulf Stream," states Juliane Müller.

More information: Juliane Müller / Ruediger Stein: High-resolution record of late glacial and deglacial sea ice changes in Fram Strait corroborates ice-ocean interaction during abrupt climate shifts, *Earth and Planetary Science Letters*, DOI: 10.1016/j.epsl.2014.07.016

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