Enhanced Atlantic water inflow warms the Arctic

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Never in the last 2,000 years was the Atlantic Water entering the Arctic in the Fram Strait between Greenland and Svalbard as warm as today. This was revealed by a study of marine sediments from the western Svalbard continental margin which was led by researchers from IFM-GEOMAR.

The Arctic region is responding to global warming more rapidly than other areas on earth. The only ca. 2 m thick sea ice cover has shown a dramatic decrease in areal extent in the last three decades of satellite observations. It is expected to disappear in summer in the second half of the 21st century, provided continuous warming. Compilations of circum-Arctic terrestrial climate data series from tree rings, ice cores etc. have shown that modern atmospheric temperatures in the Arctic are unprecedented in the last 2000 years and have reversed a long-term cooling trend (Kaufman et al., 2009). The variability of oceanic heat flux to the Arctic on such times scales, however, had remained unknown due to the lack of available high-resolution marine sedimentary archives from the Arctic.

Suitable sedimentary archives which truthfully record oceanic changes on times scales of decades can be found only in areas of unusually high deposition rates, e.g., near the mouths of large rivers. Similar conditions can be found on Arctic continental margins where fine-grained sediments are exported from partly glaciated fjords. In August 2007, an international geoscientific working group led by scientists from IFM-GEOMAR surveyed the western continental margin off Svalbard (Spitsbergen) with the German research vessel Maria S. Merian. Here, in the eastern part of the >2,500 m deep Fram Strait between Greenland and Svalbard, relatively warm (6-7°C in summer) and saline water masses from the North Atlantic enter the Arctic (Fig. 1). This current, the northernmost extension of the so-called "Gulf Stream", provides ice-free conditions in the waters west of Svalbard even in winter. The working group found sheltered places on the sea floor where fine-grained material from Svalbard fjords could settle due to diminished bottom currents. Long and short sediment cores were obtained in such places and analyzed later in the laboratories of IFM-GEOMAR and institutions in Tromsö (Norway) and Boulder (USA) for various paleoclimatic proxies. Ages of the sediment layers could be assigned based on radiocarbon datings of calcareous microfossils found in the sediments.

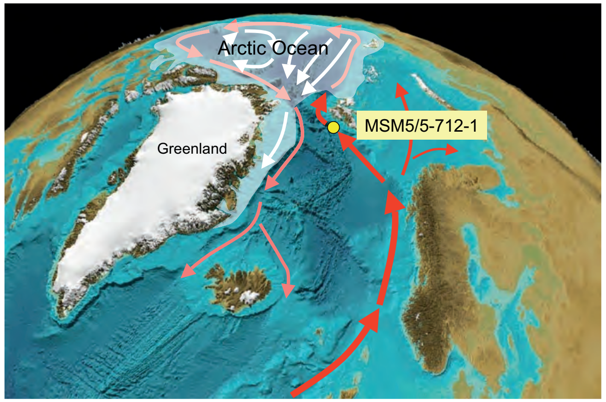

Fig. 1: Atlantic Water flow (red arrows) from the North Atlantic to the Arctic Ocean and ice drift (white arrows) in the Arctic. Pink arrows show subsurface recirculation of Atlantic Water. The yellow circle marks the site where the analyzed sediment core was obtained.

A major success of the work was the reconstruction of summer water temperatures for the last 2,000 years of the Atlantic Water entering the Arctic Ocean (Spielhagen et al., 2011; Fig. 2). The team used specific foraminifers from a sediment core as a paleothermometer. These protozoans live in water depths of 50 to 200 m and build calcareous shells. When they die, the shells sink and accumulate on the sea floor together with other particles. Because specific foraminiferal species prefer specific water temperatures, the species associations in sediment samples of a known age can be used to determine past oceanic and climatic conditions. In addition, the group analyzed the Magnesium/Calcium ratio of the calcareous shells which also allows reconstructing the water temperature

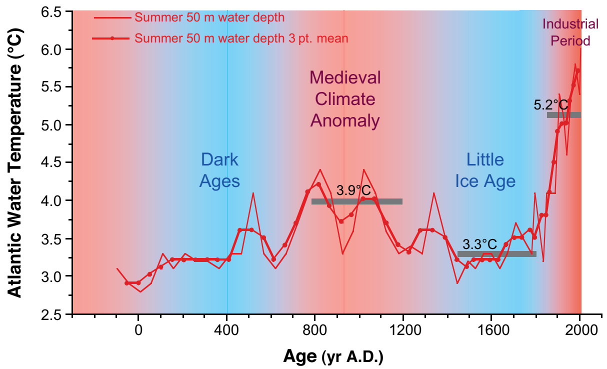

Fig. 2: Temperature reconstruction of Atlantic Water entering the Arctic Ocean over the last ca. 2,000 years. Bluish and reddish background colors mark cool and warm climatic periods, respectively.

in which the foraminifers lived. Using these two independent methods, it was found that there were several warmer and cooler intervals in the Fram Strait during the past 2,000 years. Temperatures of the northward inflowing Atlantic Water had varied several tenths of a degree Celsius in the past 2,000 years (Fig. 2). It was especially cold during the ‚Little Ice Age' from the mid-15th to the late 19th century, followed by a dramatic temperature increase of approximately 2°C, which was unprecedented in the past 2,000 years. This warming of the Atlantic Water significantly differed from all climate variations in the past 2,000 years. As a result, modern temperatures of the Atlantic Water in the Fram Strait are approximately 1.5 degrees Celsius higher than even during the climatically warm Medieval Period.

To obtain further information about the impact of variable water temperatures on the sea ice cover in the Fram Strait, the isotopic composition of the calcareous foraminifer shells was analyzed at IFM-GEOMAR. The results indicate that the perennially ice-free conditions off Svalbard are a relatively young feature (Werner et al., 2011). During most of the last 2,000 years the study area has been covered by sea ice at least in winter.

The results from the Fram Strait indicate that the accelerated decrease of the Arctic sea ice cover and the warming of ocean and atmosphere in the Arctic, as measured during the past decades, are in part related to an increased heat transfer from the Atlantic. A lack of sea ice amplifies climate change in the Arctic because sunlight is no more reflected by the ice. Instead, solar energy is absorbed by the ocean water ("ice-albedo effect") and in part released as heat to the atmosphere. The new findings support results from another study performed by IFM-GEOMAR scientists, together with Russian colleagues within the project "Laptev Sea System" in the Russian Arctic (Dmitrenko et al., 2010). Their data suggest that the warm Atlantic Water layer on the Siberian shelf of the Laptev Sea is found in significantly shallower waters than in the 80 years before. A further warming and extension of the Atlantic Water layer in the Arctic can have dramatic consequences for the sea ice formation and sea ice coverage in the Arctic Ocean.

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