The frozen sea

Photo: Peter Bondo

The extent of sea ice at the North Pole diminishes by an area equivalent to that of Denmark (almost 17000 sq. miles) each year. This is to a large extent due to global warming, but natural variations in current systems in the Atlantic also have a vital role.

By Torben Schmith and Rasmus Tonboe

One hundred years ago, in 1909, Robert Edwin Peary reached the North Pole. Before him, several other daredevils had in vain tried to be the first men to set foot there, but the Arctic Ocean ice was hard to cross. The ice is not a plane surface - the wind and the movement of the water open cracks in the ice, where new ice is formed, while ridges and fissures are formed in other places. These conditions make it difficult and dangerous to navigate the ice.

Since Peary's feat, the interest for the Arctic Ocean has not lessened - although it today does not have the same spirit of adventure and exploration. The extent of sea ice is carefully studied, because it is expected to be in the Arctic, that is around the North Pole, where climate change will be strongest felt.

At the North Pole, some 15 million km^2 of ocean are covered by ice, when winter is at its highest in March, while the corresponding figure in Antarctica is around 20 million km^2 in the winter in September. Sea ice is on average 3-4 meters thick (see box).

Will there be less ice?

We know from satellite data that the extent of sea ice in the Arctic has seen a steady decrease since the late 1970s. The extent of sea ice during winter has decreased by 10% from 16.4 million km^2 in 1979 to 14.8 in 2005 while the area covered by sea ice during summer has fallen by 25%, from 7.2 million km^2 in 1979 to 5.6 million in 2005. The extent of ice in the Arctic Ocean is significantly below the average for the 1979-2000 period. Early satellite data from 1972 show that sea ice actually increased in the mid 70s until 1978, after which the reduction began. The reduction has accelerated over the past years – for example, sea ice was reduced from 1987 to 2004 by 32,700 km^2/year but in the period 1991 to 2004 the extent of sea ice was reduced by 46,900 km^2/year, approximately the equivalent to Denmark's land area each year.

The reductions of sea ice seen in recent years surpass even the most pessimistic model scenarios. In early September of 2007 the extent of sea ice was the lowest ever recorded, coming under 3 million km^2!

The short explanation is that rising levels of greenhouse gases in the atmosphere raise the temperature at the sea's surface, and the ice reacts to that by melting faster and at higher latitudes than previously.

However, a contributing factor is that, since our data comes from satellites, accurate data on the extent of sea ice covers a very short period of time. This means that our first series of measurement start in 1972, and 37 years is generally considered a very short time in climatological terms. We cannot yet be certain that global warming is the whole reason for the meting, but there is certainly circumstantial evidence.

There is however, an interesting point to be made about the Arctic. It was very warm there in the 1940s. In fact, the temperature was on a par with current observations. Research at DMI has previously shown that the 1940s in particular were characterized by a reduced level of ice along the Greenland east coast compared to the decades before, just as we experience today. We are therefore presently endeavoring to identify what the causes of warming in the 1940s were, but it may be explained by the natural variations of the Atlantic current system, known as the Atlantic multidecadal oscillation (see the box on next page).

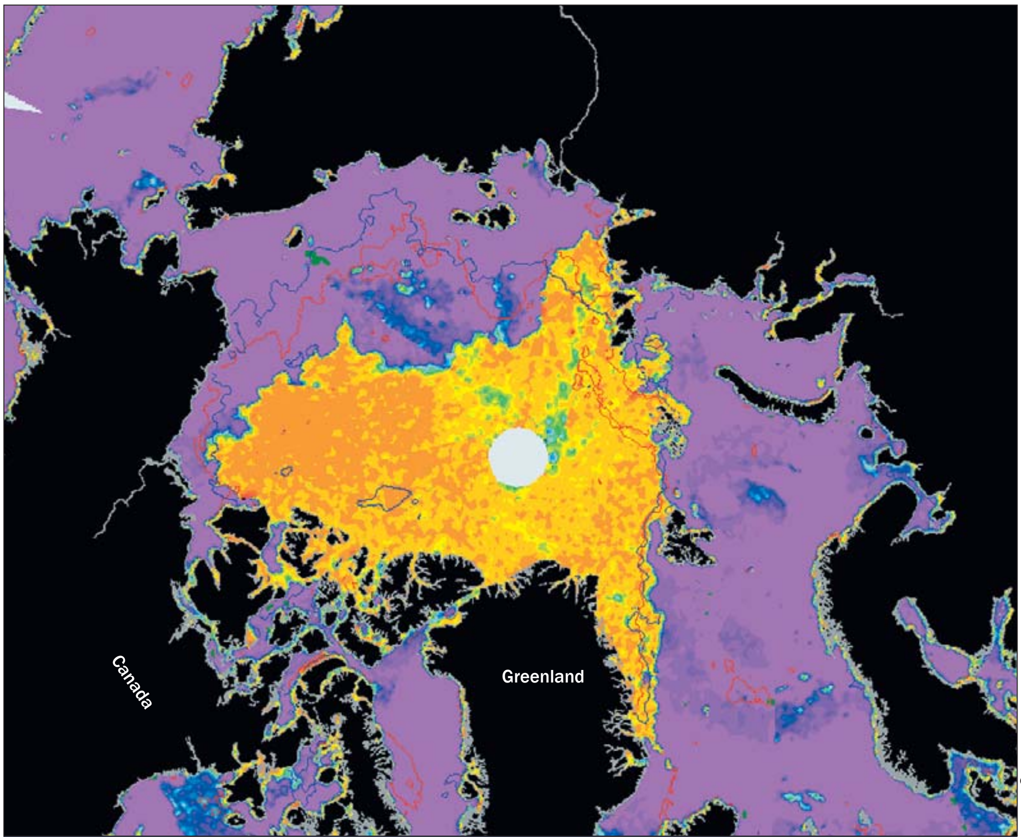


Photo: © www.seaice.dk

The image shows the extent of Arctic sea ice at the summer minimum on August 29th 2007, charted with the American radar satellite QuikSCAT SeaWind. The sea ice extent of August 29th 2006 is indicated by the blue line and the extent of August 2005 29th is indicated in red for comparison. There are yearly relatively large regional variations. 2007 is characterized by an extremely low extent of sea ice in the Arctic Ocean, even if there is slightly more ice along the Greenland east coast than there was in preceding years.

The extent of sea ice

In the Arctic Ocean the smallest extent of sea ice is approximately 8 million km^2 during the late summer (September), while the maximum extent reached in late winter (March) is about 15 million km^2. The extent in winter is partly limited by the landmasses surrounding the Arctic Ocean. Much of the ice in the central Arctic can survive the summer melting. It can survive five to six summers. Then the sea current carries it south out of the Polar Sea along the east coast of Greenland, where it melts.

The Siberian shelf region is covered by winter ice which either runs towards the central Arctic, where the thickest parts survive, or melts during the summer.

Sea ice can also be found in the southern hemisphere around Antarctica. The summer extent is at its minimum in February (some 4 million km^2) and the winter extent peaks in September with approximately 20 million km^2.

Once the sea is covered with ice the ice continues its growth on the bottom of the floating ice, but a substantial part of the ice volume is found in pack ice. The average thickness of the ice depends on both processes. The average ice thickness in the Arctic Ocean is about 4 meters in March and about 3 meters in September. The thickest ice is found north of Greenland, in the Lincoln Sea and is 5 to 7.5 meters thick.

The role of sea ice in the climate system

Ice has a high albedo, which means that because ice is white it better reflects incoming energy in the form of solar radiation. If the ice melts away completely, the underlying and much darker seawater, which absorbs much more solar radiation, will be exposed, heating the atmosphere. Thus, reduced ice cover leads to higher temperatures, which in return lead to even less ice cover. Sea ice therefore represents a negative or destabilizing feedback, the so-called ice-albedo feedback, which is compensated for by the other feedbacks in the climate system. But due to the ice-albedo feedback, sea ice is an important factor for how much the global climate system changes, when the system is affected by large emissions of greenhouse gases, such as carbon dioxide. This makes it important to understand the magnitude of the ice-albedo feedback when trying to ascertain the future climate with increased volumes of atmospheric carbon dioxide.

Aside from its reflective properties, sea ice also represents a significant quantity of fresh water. Since the temperature on Earth has risen (and is expected to keep rising) it is to be expected that this quantity of sea ice will melt within the next 50 years, meaning that the Arctic Ocean will be ice free dur-

Photo: © DAMOCLES

The expeditionary vessel, Tara, drifted in the Arctic ice since freezing in October 2006 and passed over the North Pole to the Fram Strait as part of the DAMOCLES project. During the expedition it carried out measurements of atmosphere, ice and sea.

ing summers. Combined with expectations of increased precipitation over the Arctic and the increased melting of the Greenland ice sheet, this will cause a lower salt concentration in the surface of the North Atlantic, which already has been observed in hydrographic profiles. It is feared that this freshening could affect the thermohaline circulation in the North Atlantic. The thermohaline circulation is powered by the cooling of water in the North Sea between Norway and Greenland. This cooling produces more dense water, which sinks to great depth and makes way for warm salty water coming from the south. This circulation is responsible for the relatively warm climate of Western Europe. If the surface water becomes less salty, which as mentioned earlier, has already been observed, it will not readily sink and thus the thermohaline circulation will be hampered. However, experiments with ocean and climate models, performed at DMI, show that these changes are relatively small, and indications are that a sudden change is unlikely.

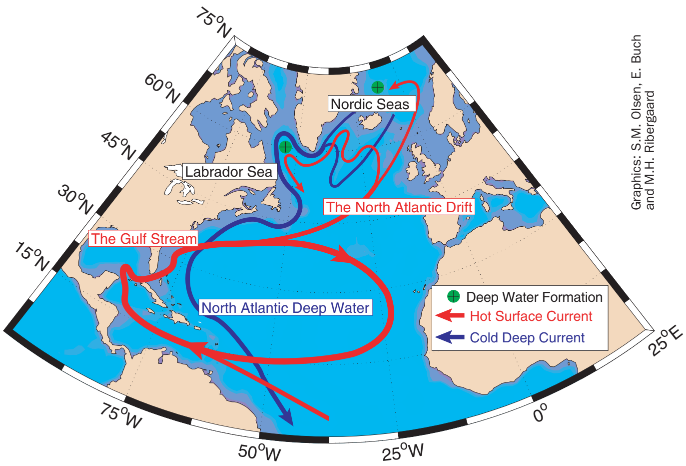
Ice and climate variations

A significant part of the sea ice formed in the Arctic Ocean drifts through the Fram Strait (between East Greenland and Svalbard) and with the East Greenland Current moves along the coast of East Greenland, around Cape Farewell and sometimes along the southwest coast of Greenland. At this stage the ice is known as Storis and can cause problems for maritime traffic in the spring and summer months. Researchers at the DMI have made studies of historical records and observations of this Storis and have been able to reconstruct the ice drift through the Fram Strait. They were able to conclude that there is a significant variability. Thus, the ice drift was relatively modest in the 1940s, which coincided with a warm period in the Arctic. Around 1970 there was much greater drift, but that has since declined once more. It would appear that the ice drift varies

Variation in ice drift and sea currents

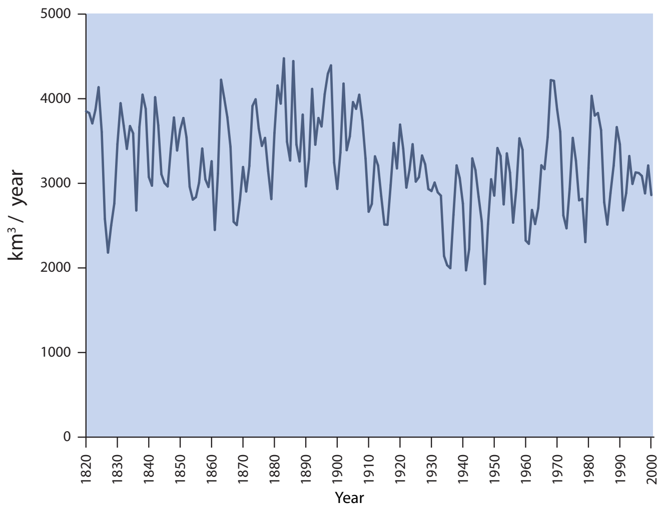
The Atlantic has a sea current system consisting of a northbound warm ocean current, which slowly cools and sinks deep into the Greenland waters, and returns as a southbound current. This is why we in Northwestern Europe, have a relatively mild climate.

But the strength of this ocean current varies. Thus, it was weak in the 1970s, while it was strong in the 1940s, and if we dig deeper into the past we will see that this pattern continues. The amount of ice drifting from the Arctic Ocean into the East Greenland current, varies along with variations in the thermohaline circulation. These variations are called AMO (the Atlantic Multidecadal Oscillation).

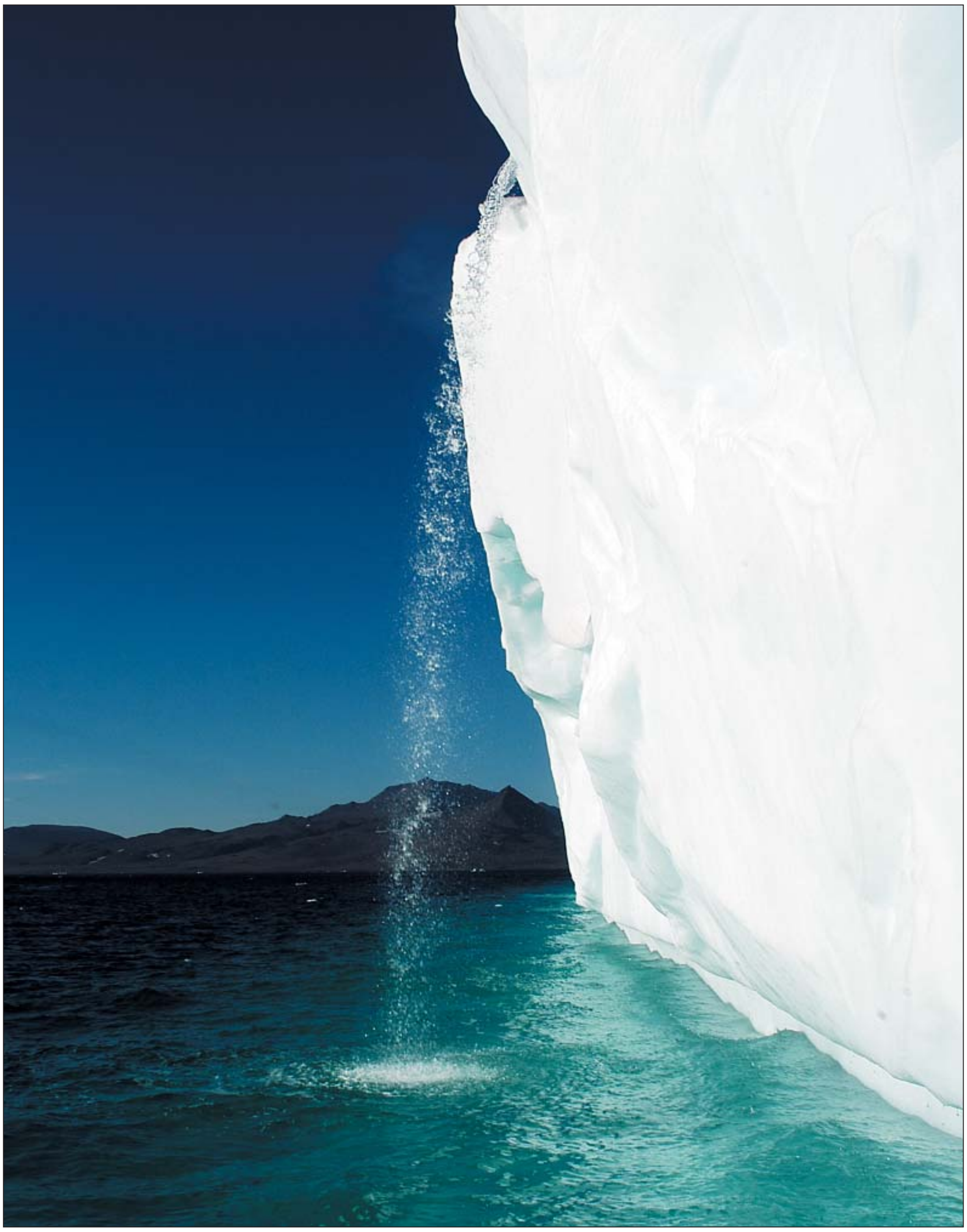


Graphics: S.M. Olsen, E. Buch and M.H. Ribergaard

Illlustration of the thermohaline circulation, characteristic of the North Atlantic. Circulation is powered by the cooling of water in the North Sea between Norway and Greenland.



Reconstruction of ice drift through the Fram Strait in the years 1820 to 2000. There is significant interannual variability.



Melting glaciers such as this one can be a great nuisance to shipping.

with a timescale of 50-100 years, which could be linked to corresponding variations in the thermohaline circulation (the aforementioned Atlantic Multidecadal Oscillation). The previously mentioned reduction of sea ice observed from satellites since the 1970s could therefore in part be attributed to a downward phase of a natural cycle.

Heading for an ice-free Arctic?

While there is consensus that the Arctic Ocean ice shrinks with rising temperatures, there is still disagreement as to the degree of the reduction. According to most climate models, the Arctic will largely be ice-free by the end of this century and if the observed trend continues it might happen in the next 20 years. It could have great significance for the shipping, oil and gas industries among others but the price will also be very steep as far as the environment is concerned, with the loss of many animal species and irreplaceable natural amenities.

However, the melted sea ice will not cause the global sea level to rise. Just as a ship, the ice "sails" on the water and displaces a volume of water equal to its weight – the ice's volume in the water is simply replaced by water from the melted ice. With regard to the global sea level the melting of land based ice sheets in Antarctica and Greenland represents the actual threat. A melting of these much larger volumes of ice will occur over a much longer time scale (thousands of years) compared to the melting of sea ice. ■

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Further Reading:
Polar View:
www.seaice.dk og
www.polarview.org

The Damoclesproject:
www.damocles-eu.org