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FORESIGHT Brief
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Early Warning, Emerging Issues and Futures

The shrinking Arctic Sea Ice

Background

The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 28th edition of UNEP's Foresight Brief looks at the global ecological, climate, economic and geopolitical implications of the loss of Arctic sea ice.

Abstract

The Arctic is a remote and sparsely inhabited area. It is connected to the rest of the world by our climate system, the atmosphere surrounding our Earth and by global ocean currents.

Since satellite measurements started 40 years ago, about half of the sea ice area in the Arctic has been lost. The shrinking summer sea ice cover is a visible manifestation of global warming, and affects marine ecosystems, ocean circulation, and potentially weather events further south of the Arctic such as experienced in Texas, USA and Greece in 2021.

The sea ice edge is not a sharp line in the ocean, but a gradual shift from open water to solid ice
Photo credit: Morven Muilwijk

Introduction

In the Arctic, sea ice covers most of the ocean surface. After a long summer with sunlight 24/7, the ice reaches its minimum in September. Come October, along with lesser sunlight, the ice again starts to grow into the long, dark polar night.

Since satellite measurements began in 1979, about half of the summer sea ice volume has been lost. Most of this loss is caused by global warming. There has been an extensive loss of sea ice both in expansion and thickness (Kwok and Rothrock 2009; Cohen, Jones, Furtado, Tziperman 2013; Comiso, Meier and Gersten 2017). All regions of the Arctic have lost sea ice, and all months throughout the year have significant sea ice loss. (Onarheim *et al*. 2018).

The quality of ice is also changing. The old ice is replaced by new ice and this has many implications. Old ice is more resilient than the new ice, which melts faster. This new ice contains more salty water, and is more subject to melting, whereas old ice has a higher share of water coming from snow precipitations and is a source of freshwater.

The sea ice edge is not a sharp line in the ocean. It covers a vast area where we go from blue open ocean to gradually transitioning into sea ice. This transition area is a very important place for the ice-dependent life. A common definition of the sea ice edge is where the sea ice covers more than 15% of the ocean surface.

A polar bear is checking out research instruments during the MOSAiC expedition, summer 2020. The consequences of shrinking sea ice for marine ecosystems including seals, polar bears and fish stocks in the Arctic Ocean is unclear.
Photo credit: Lianna Nixon, AWI)

Why is this issue important?

Nowhere is climate change more evident than in the Arctic, with a warming at more than twice the global rate (SROCC, Intergovernmental Panel on Climate Change (IPCC) 2019 and IPCC 2021). Several studies tell us we are right now, in 2021, following a pathway where the Arctic Ocean will be ice free in summer by 2050. (Notz and SIMIP Community 2020; Årthun *et al*. 2021)

The sea ice in the Arctic is not a flat solid ice cover. Floating at the ocean surface, it is dependent on weather. Wind, waves and ocean currents are constantly pushing the ice around. In the same manner, the sea ice edge is not a sharp line in the ocean. This transition area between open water and pack-ice is home to a diversity of organisms (**Figure 1**).

Along the ice edge, on top and within the sea ice itself, there is a whole range of creatures, like bacteria, algae, shrimps, fish and seals. The sea ice edge supports a large and distinct biological community of specified plants and animals that have evolved to adapt to this special place. Species that depend on sea ice face extinction if most of the sea ice is lost (Conservation of Arctic Flora and Fauna, 2017).

An ice-free Arctic is a new situation, and has important ecological, climate, economic and geopolitical implications, as well as consequences for indigenous populations - not only the polar bear needs ice to hunt. At the same time, a changing Arctic opens up for new industries to emerge, such as tourism, resource extraction, fisheries and shipping, threatening the fragile ecosystem.

The sea angel Clione limacine lives in Arctic and sub-Arctic Waters in two versions
Photo credit: Christine Gawinski

When the Polar cod lay its eggs, it is dependent on the ice for their eggs to develop successfully. Their larvae feed on zooplankton growing in the ice when the sunlight returns in spring. As the sea ice now is declining, their spawning ground is shrinking. The population of this key species in the northern Barents Sea has been reduced this century. Read more here (Eriksen, Huserbråten, Gjøsæter, Vikebø and Albretsen 2019).
Photo credit: Erling Svensen/Institute of Marine Research

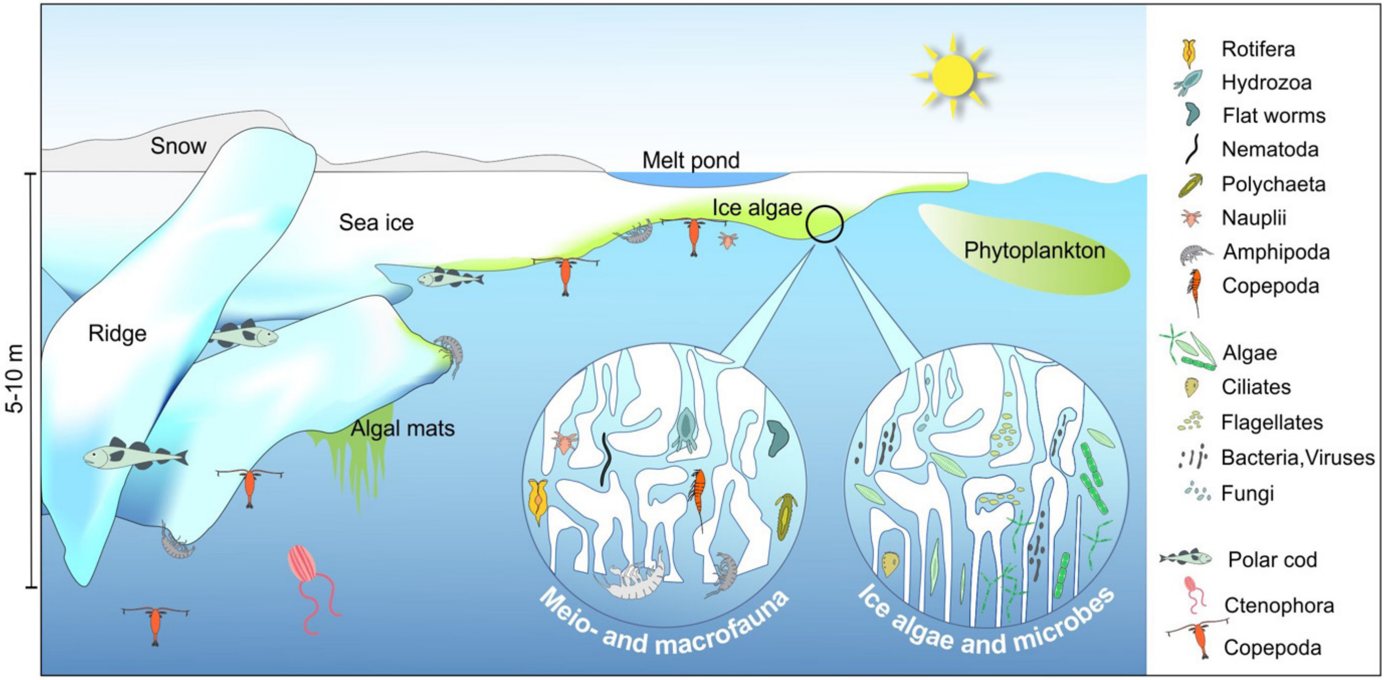


Figure 1: *The sea ice is home to a diversity of organisms, some of them finding shelter in the ice.*
Credit: by Malin Daase, modified from CAFF 2017

When melting, the sea ice has almost no effect on sea level since it already floats within water. But polar warming also affects the vast amount of ice on land like the Greenland and Antarctic ice sheet. Together these ice sheets have the potential to cause global sea levels to rise by several meters.

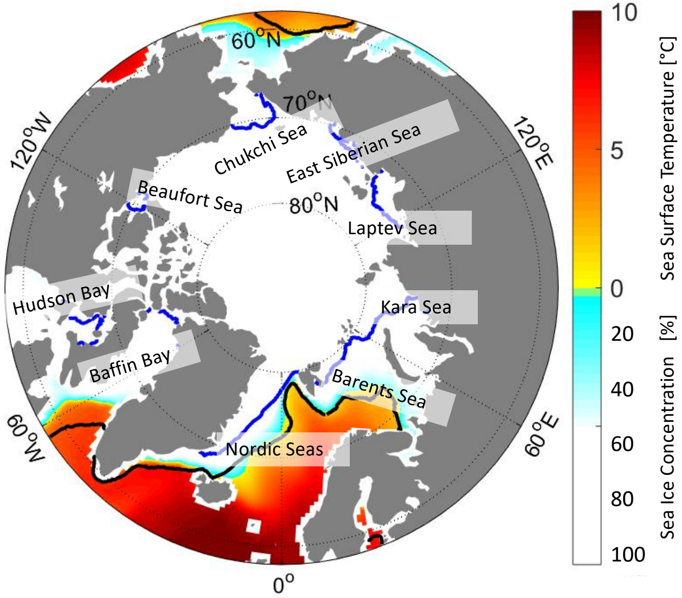


Figure 2: Map of the Arctic Ocean and its seas. The blue line shows sea ice edge in summer, and the winter sea ice edge in solid black. The colors show sea ice concentration and sea surface temperature in summer on a long term (1900 – 2000) simulated annual mean.
Figure credit: Lars H Smedsrud

A new ice-free situation in the Arctic

When we talk about global warming, we talk about the global average. But the globe is not heated evenly. Since the industrial revolution, the global mean temperature rise is approximately 1.1°C (IPCC 2021). At Svalbard, with one of the worlds northernmost settlements, the mean temperature has increased by an astonishing 7°C over the last fifty years (Hanssen-Bauer et al 2019).

The polar regions are warming at a fast pace, visualized by disappearing ice. In the Atlantic region, the sea ice retreat is influenced by the inflowing warm waters from the south, entering the Arctic Ocean via the North Atlantic and the Nordic Seas. As a result, the loss of winter sea ice is most pronounced in the Barents Sea and north of Svalbard, as shown in **Figure 2.**

The tropics have not experienced temperature rises to the same extent as the polar regions. Temperatures in polar regions are increasing more than five times the global average in some places.

New findings show that even with a moderate warming in line with the Paris agreement, the Arctic summer sea ice will be lost in most regions by 2050. Ice-free conditions in winter before the end of this century only occur in the Barents Sea, but significant winter loss in many of the Arctic seas is projected (Årthun *et al* 2021) (**Figures 3 and 4**).

Ice work
Photo credit: Christian Morel/christianmorel.net/Nansen Legacy

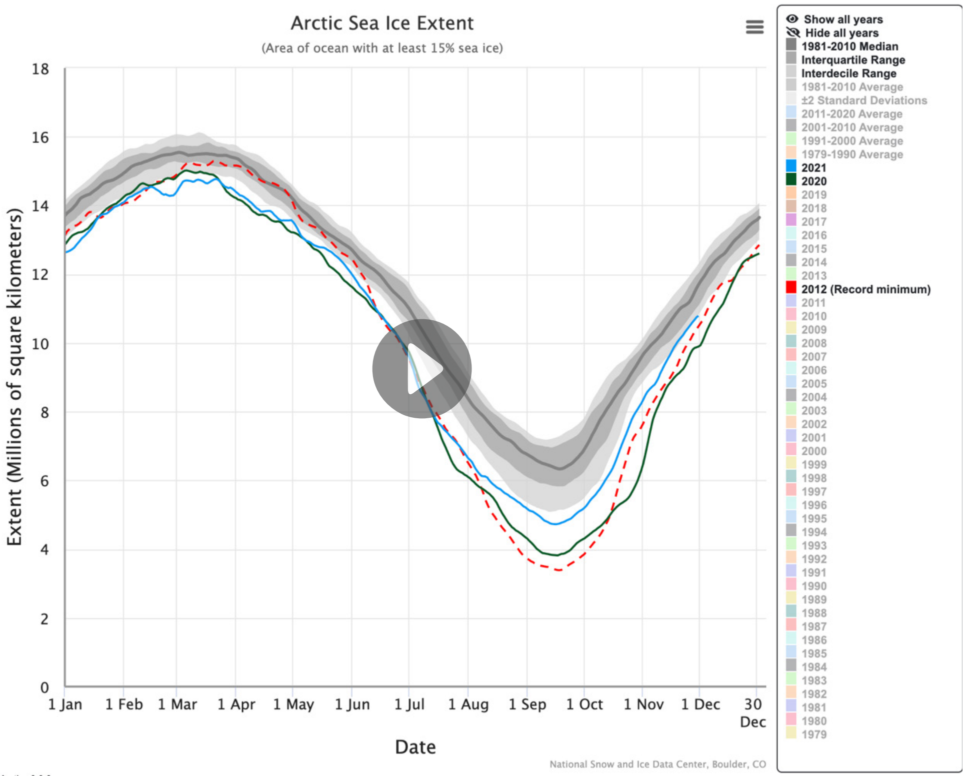


Figure 3 shows the area of ocean covered by at least 15% of sea ice. The record minimum of sea ice extent was reached in summer 2012 (red dotted line). The following eight years were all below the average of the years 1981-2010, shown by the grey line. Sea ice extent for 2020 is shown in the dark green line, 2021 in blue.

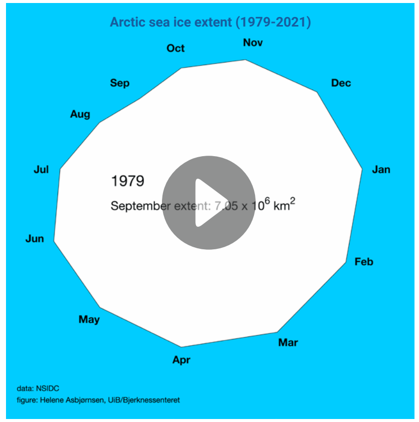
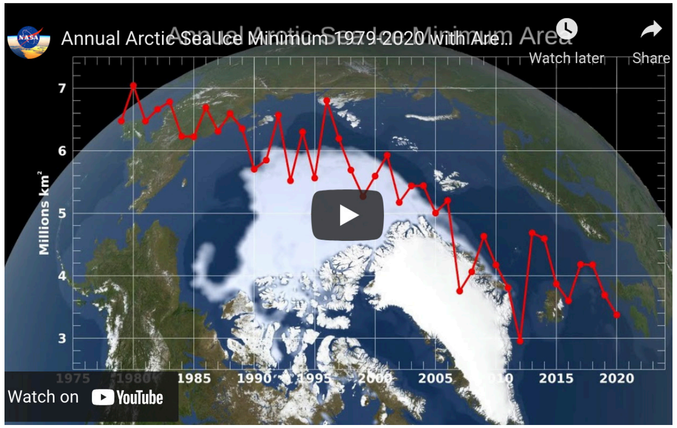


Figure 4 shows the shrinking sea ice extent from 1979-2021 based on sea ice data NSIDC
Figure credit: Helene Asbjørnsen, UiB/ Bjerknes Centre



This visualization shows the expanse of the annual minimum Arctic sea ice for each year from 1979 through 2020, with a graph overlay. Credit: NASA/Goddard Space Flight Center [*Scientific Visualization Studio*](). *The Blue Marble data is courtesy of Reto Stockli (NASA/GSFC).*

Sea ice helps cool the planet

Ocean temperature and the ocean circulation are crucial for the Arctic sea ice. When we have a look at the big picture of ocean circulation around the globe, the ocean is heated by the sun in the tropics and cooled in the polar seas. In the upper parts of the ocean, warm water flows from the tropics towards the poles, where it loses heat to the atmosphere, and becomes denser and sinks, and then return towards the tropics as deep ocean currents.

Relevant for the Arctic, the Gulf stream flows from the Gulf of Mexico, crossing the North Atlantic and enters the Arctic Ocean via the Barents Sea and the Fram Strait. Measurements of the water flowing into the Arctic show that the temperature is approximately 1˚C higher now than in the 1980s, when observations started (Smedsrud *et al* 2013). There are also large variations from year to year, driven by natural variations in the climate system (Smedsrud *et al* 2013; Zhang 2015; Årthun *et al*. 2019 (**Figure 5**).

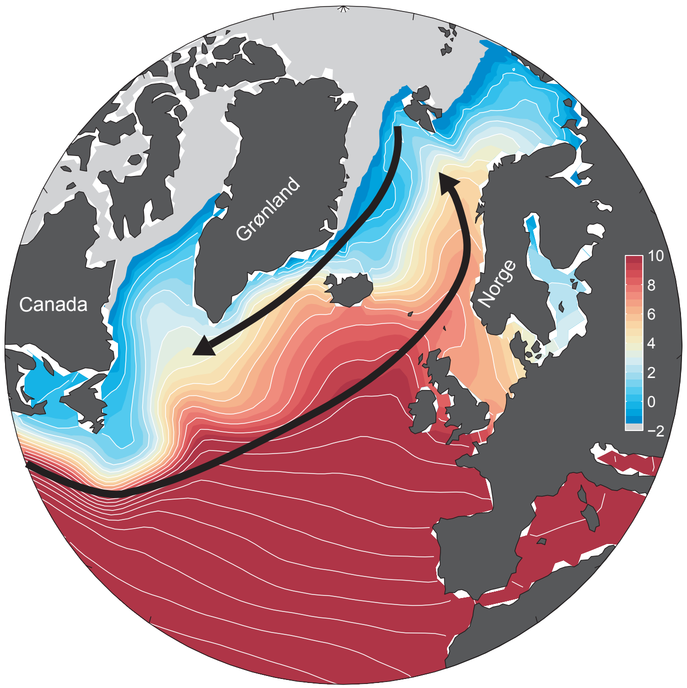


Figure 5: *The Gulf Stream's poleward pathway. The figure shows how the warm Gulf Stream is gradually cooled on its northward journey through the North Atlantic and Nordic Seas until it eventually meets the Arctic sea ice (grey shading). The green boxes show the location of measurements used to track the northward propagation of temperature anomalies. Illustration: Marius Årthun, University of Bergen and the Bjerknes Centre for Climate Research. Temperature data by www.metoffice.gov.uk/ hadobs/hadisst/.*

In the Barents Sea, this warm Gulf Stream water comes in direct contact with the ice, and, as a consequence, the Barents Sea is where we find the most severe winter sea ice loss in the Arctic. During the last 40 years, almost half of the sea ice has disappeared (Onarheim *et al* 2018).

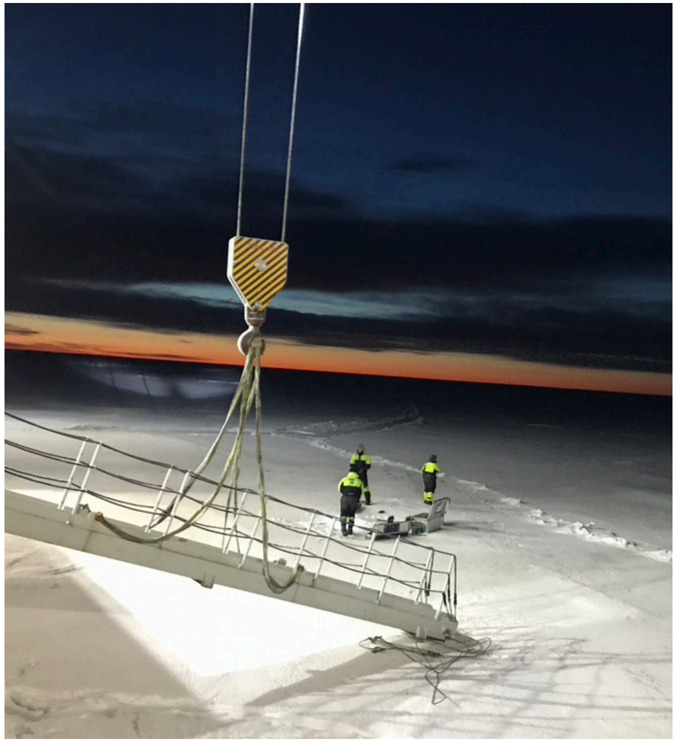
In the summer, the sun heats the dark open water surface waters, but during wintertime, there is no sunlight in the Arctic. A main driver for removing ice through winter is the direct melting from contact with warm ocean currents, as observed in the Barents Sea and north of Svalbard.

A second driver is winds acting to push the sea ice out of the Arctic, especially along the east coast of Greenland.

Sea ice is also crucial for the energy balance on Earth. Areas that have lost the sea ice cover absorb almost all incoming solar radiation. In summer, the sea ice cover helps cooling our planet as it effectively reflects solar radiation. When the ice disappears, more heat is being absorbed by the ocean, amplifying the warming effects in the Arctic. This is called the Albedo effect.

These are examples of how the Arctic sea ice is intimately connected to crucial climate processes, including world ocean circulation, sea level rise and global warming itself.

Filtrating
Photo credit: Christian Morel/christianmorel.net/Nansen Legacy



Researchers from the UIT Arctic University of Norway on the sea ice east of Greenland in November 2020.
Photo credit: Danielle Grant, NORCE/ Bjerknes Centre for Climate Research

The present rate of Arctic ice loss has not been observed

What is being done?

The Arctic is still a remote and unknown area
As the Arctic still holds many secrets, several research campaigns and projects have been set up to improve our understanding of the region, the climate, the physical processes and the sea-ice related ecosystems living in, on and under the sea ice. An extended knowledge base of what has been observed is important for sustainable management of the Arctic.

During the MOSAIC expedition in 2019 -2020 an interdisciplinary team of researchers drifted with the sea ice for a full year. The amount of data collected is unique in the history of polar exploration and will be analyzed by the scientific community in the coming years (Alfred Wegener Institute 2019).

In the Barents Sea we see extremely rapid changes in the marine climate and ecosystem, as a shift from Arctic to Atlantic type of conditions, is taking place. The Nansen Legacy is a Norwegian governmental research project set up to monitor and understand these widespread changes to the Barents Sea environment (UiT The Arctic University of Norway 2017).

The Synoptic Arctic Survey aims to understand ongoing transformations by launching an international research program crossing the entire Arctic and observe the

systems and is important to look at Ocean and atmosphere are highly connected in the global climate and weather systems, as well as in the Arctic. Global changes affect the Arctic and changes in the Arctic can influence areas further south.

New ice-free conditions might disturb the formation of cold and dense water. This dense-water formation process in high-latitude oceans is part of the global ocean circulation system, bringing cold and oxygen-rich water into the deeper layers of the World Oceans, returning to the tropics in deep ocean currents. Disturbances in this process might impact the large-scale ocean circulation (Sévellec, Federov and Liu 2017).

The question of how a warming Arctic and sea ice retreat is influencing weather further south is still heavily debated among scientists (Blackport and Screen 2020). Some scientists speak of a warming Arctic with less sea ice causing more climate extremes on the continents farther south. The very cold weather observed in Texas and Greece in February 2021 is in line with this hypothesis known as “warm Arctic, cold continents”. On the other hand, many scientists do not find evidence for such a connection between a warming Arctic and cold weather events in Europe, Asia and North America.