

## 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 28<sup>th</sup> 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 Mulwijk

### 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 limacina* lives in Arctic and sub-Arctic Waters in two versions

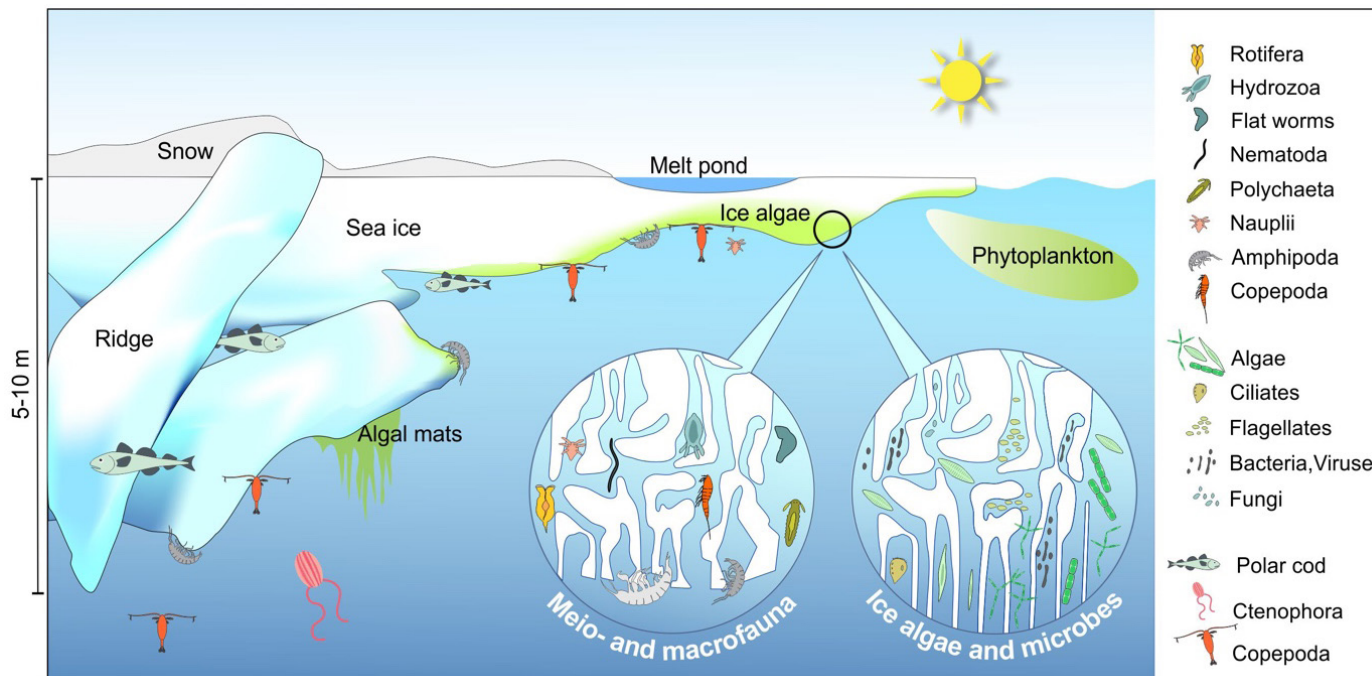
Photo credit: Christine Gawinski



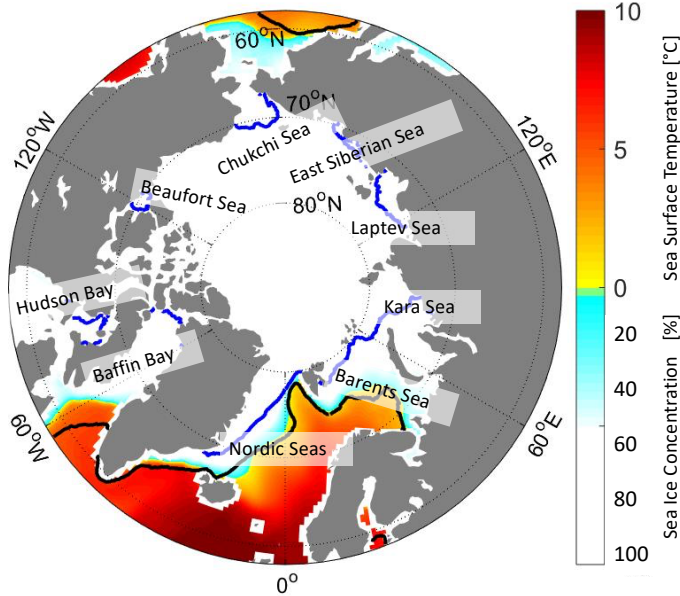
When the Polar cod lay its eggs, it is dependent on the ice for their eggs to develop successfully. Their larvae feed on zooplankton growing in the ice when the sunlight returns in spring. As the sea ice now is declining, their spawning ground is shrinking. The population of this key species in the northern 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

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 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



**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).

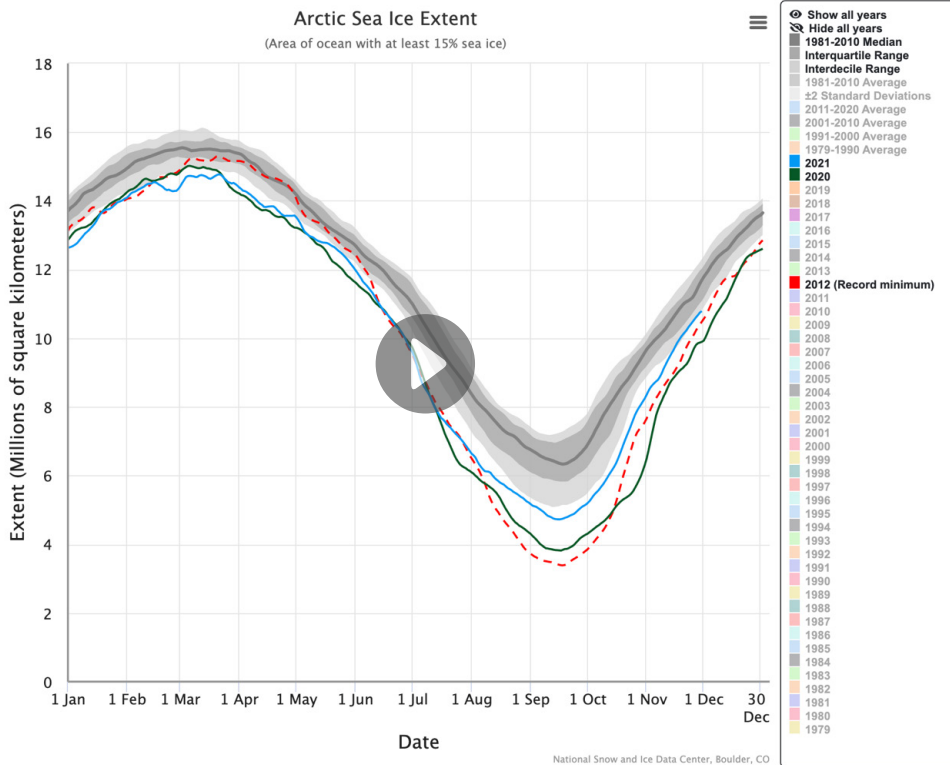
The polar regions are warming at a fast pace, visualized by disappearing ice. In the Atlantic region, the sea ice retreat is influenced by the inflowing warm waters from the south, entering the Arctic Ocean via the North Atlantic and the Nordic Seas. As a result, the loss of winter sea ice is most pronounced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

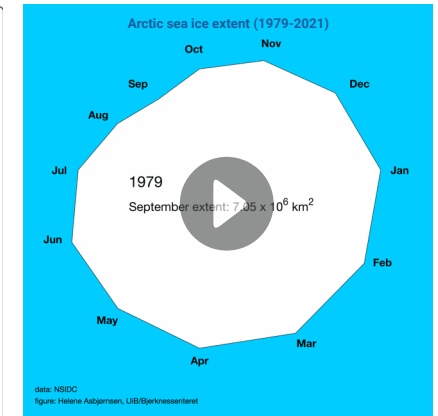
New findings show that even with a moderate warming in line with the Paris agreement, the Arctic summer sea ice will be lost in most regions by 2050. Ice-free conditions in winter before the end of this century only occur in the Barents Sea, but significant winter loss in many of the Arctic seas is projected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



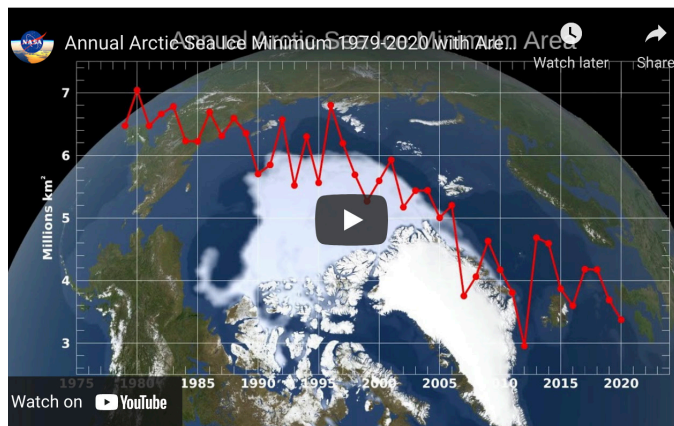
Ice work  
*Photo credit: Christian Morel/christianmorel.net/Nansen Legacy*



**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 NSDIC](#). *Figure credit: Helene Asbjørnsen, UiB/ Bjerknæs 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).

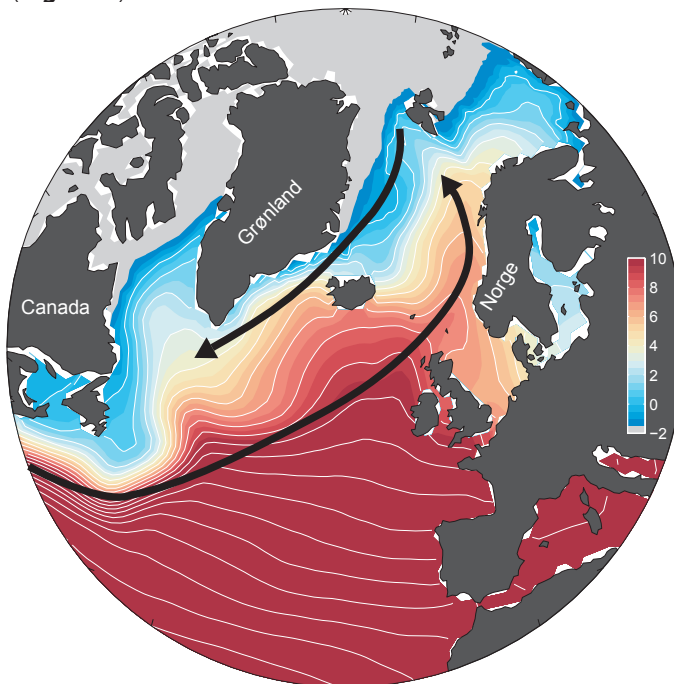
**Sea ice helps cool the planet**

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/](http://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.

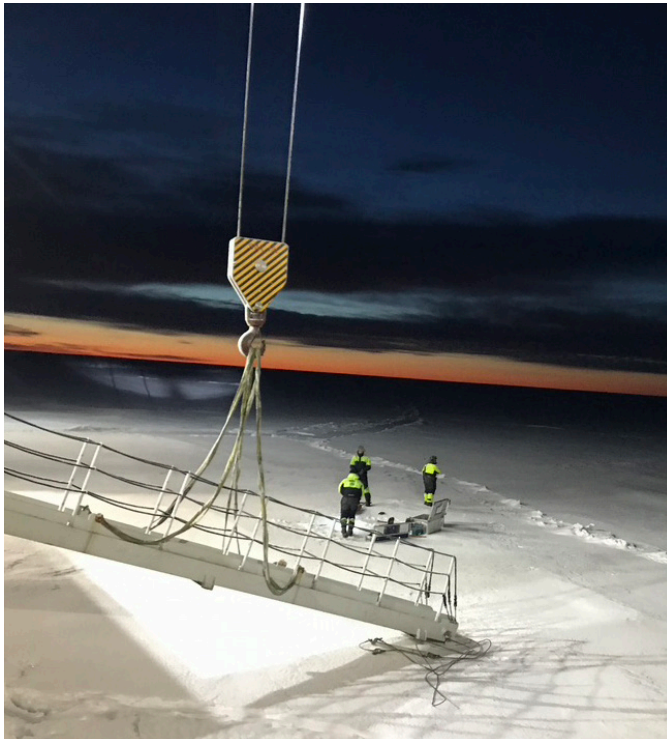
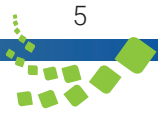
A second driver is winds acting to push the sea ice out of the Arctic, especially along the east coast of Greenland.

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](http://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 previously. We know with certainty that global warming strongly affects the Arctic, but there are also large natural variations due to shifts in ocean currents and atmospheric wind patterns.

We know that natural variations in climate occur on all time scales, from years to centuries and millennia, but observations back in time are very scarce. Satellite images showing sea ice extend back to the late 1970s, while ocean currents have really only been observed routinely since the 1990's. It is therefore not straightforward to quantify natural variations in recent sea ice loss and the effect by global warming.

## 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 present state of the Arctic climate system. Multiple research cruises through 2022 will give scientists datasets that can characterize the Arctic of today (University of Bergen 2018).

The [UN Decade of Ocean Science for Sustainable Development](#) (2021-2030) hosts several ocean science programmes and activities to address knowledge gaps in the Arctic Ocean.

The Arctic Sea Ice is floating in water. Melting sea ice do not affect sea level rise across the world. However shrinking ice does impact global climate and weather

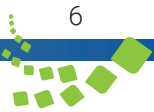
systems and is important to look at Ocean and atmosphere are highly connected in the global climate and weather systems, as well as in the Arctic. Global changes affect the Arctic and changes in the Arctic can influence areas further south.

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.



In summer the sun never sets in the Arctic. Researcher Morven Muilwijk and his fellow researchers at the MOSAIC Expedition lived onboard the RV Polarstern.  
Photo credit: Lianna Nixon, AWI



During winter research cruise through the sea ice, the conditions are hard. The polar night means darkness 24/7, and the ship can get stuck in the ice.

*Video by Danielle Grant NORCE/ Bjerknes Centre for Climate Research*

*Photo credit: Shutterstock.com / ginger\_polina\_bublik*

## What are the implications and links for policies?

The Arctic Sea Ice creates harsh conditions for human operations. As the sea ice is retreating, the Arctic region is becoming easier accessible for commercial activity such as fisheries, shipping, tourism and exploration of new resources and rare minerals on the ocean floor. This new accessibility gives new dilemmas for policies, and attract new geopolitical attention. The Arctic represents one of the world's last wilderness and fragile ecosystems. Higher accessibility for commercial activity and rare minerals is causing new geopolitical attention.

The many unknowns of the Arctic ecosystem, gave rise to concern for unregulated fishery in the Arctic Oceans (Arctic Council 2020). In 2018 the Arctic Coastal states Canada, USA, Russia, Norway, Iceland and Denmark reached an agreement together with China, Japan and South Korea “to prevent unregulated High Seas Fisheries

in the Central Arctic Ocean” The negotiations included the [Inuit Circumpolar Council](#) recognizing the Arctic's Indigenous peoples interests (Canada Government 2021).

In January 2017, the Polar Code entered into force. This is a regulation by the International Maritime Organization (IMO) to reduce risk and secure shipping operations in the Arctic and Antarctic Oceans.

The unfriendly conditions in the oceans surrounding the two poles requires a focus on ship design and construction, equipment, training, and search and rescue. These are requirement for safe navigation and equally important, to protect the “unique environment and eco-systems of the polar regions” (IMO, 2017).

Shipping along the Northern Sea Route along Russia's Arctic coastline, through the Northeast Passage have grown extensively the last years. This route is shorter than the Suez Canal Route between Europe and Asia but have large environmental risks and operational costs. In January 2021 three cargo vessels successfully navigated through the Northern Sea Route for the first time in history in the middle of the winter without an icebreaker escort (Humpert 2021).

Concerning the sea ice, preventing a dramatic future sea ice loss is a task closely connected with reducing global warming. As global warming is largely a consequence of human activities and emissions of greenhouse gases, the solution is scientifically as straightforward as it is politically complex: cut emissions of greenhouse gases.

In 2015 most of the world nations saluted the Paris Agreement. This is a framework to avoid dangerous climate change by limiting global warming to well below 2°C and make effort to limit warming to 1.5°C. While implementation of renewable energy is underway, we are at present nowhere near fulfilling the 2°C target, and on a path to losing the Arctic Sea Ice entirely within the next 50 years.

The United Nations Decade of Ocean Science for Sustainable Development was launched this year and lasts until 2030. The Ocean Decade seeks to strengthen “the management of the ocean and coasts for the benefit of humanity and to mitigate the impacts of climate change” (United Nations Educational, Scientific and Cultural Organization (UNESCO) 2021). Enhancing the Ocean-Climate Nexus, the term describing how the ocean plays a key role in our Earth's weather systems and long-term climate changes, and how “A healthy, resilient ocean holds extraordinary potential to address climate change and improve overall human health and well-being” (UNESCO 2021).

The Ocean Decade is for everyone, all of us can participate, if you would like to be engaged in activities of simply want to learn more ([www.oceandecade.org](http://www.oceandecade.org)).

## Conclusion

The Arctic, with the most fragile of ecosystems, is a hotspot of climate change. A visible sign of change is the steady retreat of the sea-ice cover since the 1970s. Changes in Arctic sea ice can potentially affect other regions through altered weather patterns and ocean circulation. An ice-free Arctic is creating new business opportunities, political challenges, and threats to the ecosystems and local communities.

Improved monitoring and understanding of the Arctic and the Arctic Sea Ice cover are therefore important to ensure sustainable management of the changing Arctic environment and its associated resources.

Sustainable management of the Arctic Ocean is of a societal need also for people outside of the Arctic. It is a great scientific challenge, and several international research programs have been launched to fill knowledge gaps in the Arctic Ocean, and the sea ice role in the Arctic ecosystem and climate.

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**How to get properly dressed as a polar researcher in one minute.** Video by [Morven Mulviqj and Zoe Walker](#)



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