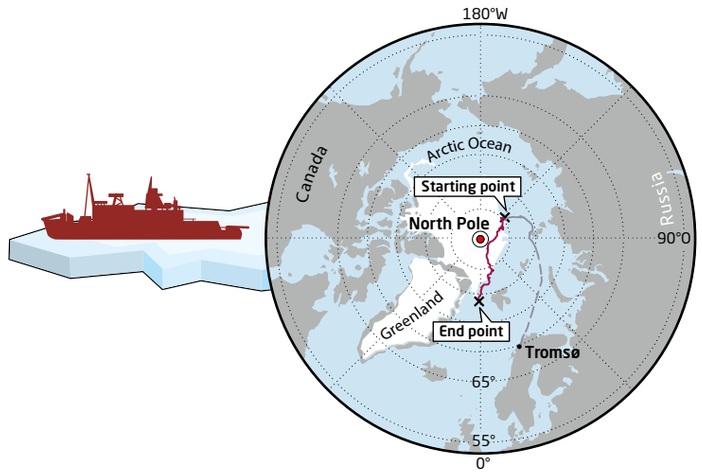


Embarking on the voyage of a century

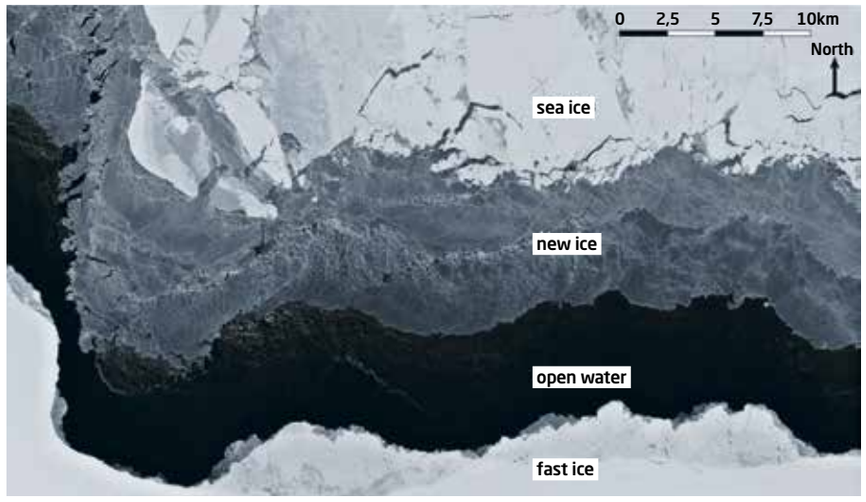
Spending an entire winter researching on an ice floe in the Arctic Ocean was, until now, just a pipe dream for most sea-ice experts. It was always assumed that such an expedition would be too costly, the polar weather too unpredictable. But September 2019 saw the start of something that had long been considered impossible. The German research icebreaker Polarstern allowed itself to become trapped in the Arctic sea ice, offering researchers from 20 countries a once-in-a-lifetime opportunity. In a camp on the Central Arctic ice, around the clock they investigated the sea ice, ocean, atmosphere and life in the sea. They witnessed a dramatic transformation of the North Pole region, the consequences of which are likely to affect the sea ice first.

By the light of her headlamp, AWI atmospheric researcher Anja Sommerfeld hecks one of her measuring instruments. During the Polar Night, it is permanently dark, so you lose all sense of time.

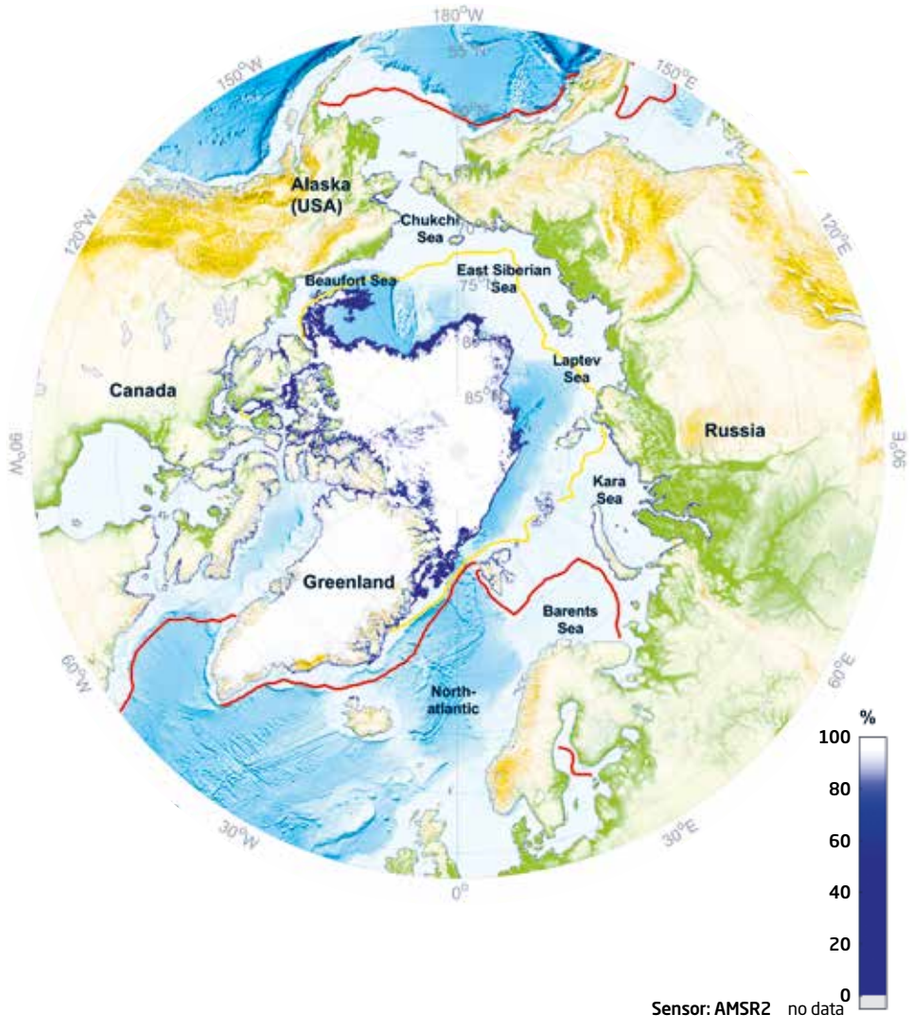
The Arctic Ocean's most prominent characteristic is its sea ice. For at least 18 million years, i.e., since the dawn of humanity, the world's smallest ocean has been covered in ice in both summer and winter. The ice area waxes and wanes with the seasons. As a rule, at the end of winter it is two to three times greater than at the end of summer.
The Arctic sea ice is one of the most important components in Earth's climate system: the white, snow-covered ice reflects up to 90 percent of the solar radiation back into space. As a result, the ice and snow not only cool the North Pole region; they also form the basis for global wind and ocean currents, which distribute heat from the tropics over the entire globe and make the planet inhabitable for us humans.
We now know that the Arctic sea ice influences the weather and climate in the entire Northern Hemisphere. What happens in the Arctic is therefore highly relevant for millions of people south of the Arctic Circle.

IN THE NURSERY OF SEA ICE

Sea ice mainly forms in coastal areas of the shallow Russian marginal seas of the Arctic Ocean. There, in the Kara Sea, Laptev Sea and East Siberian Sea, strong offshore winds with air temperatures as low as minus 40 degrees Celsius blow over the sea in winter. These constantly allow open areas of water to form, the surface of which freezes to ice, breaks up and is driven out to sea by the wind. The cycle can then start again from the beginning, and sea ice is formed as if on a conveyor belt.
Most of the ice that eventually forms the sea-ice cover in the Central Arctic originates in this region. The remainder forms directly in the vicinity of the North Pole or off the coasts



This satellite image, taken over the Laptev Sea, shows the process of new sea-ice formation in March 2019. Sea ice that is frozen to the coast is known as fast ice.



The consequences of a far-too-warm summer

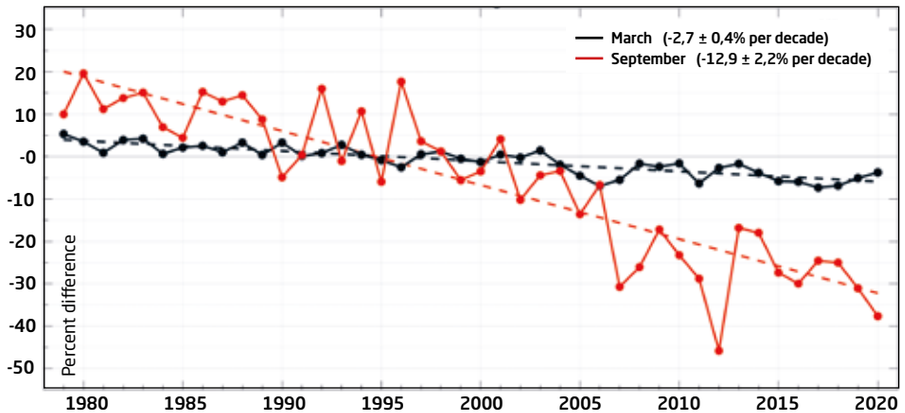
Long-term average sea ice extent 1981 – 2010
March
September

During the MOSAiC expedition, the Arctic experienced one of its warmest summers since weather records began. As a result, by September the sea-ice extent had shrunk to the second-lowest level ever measured by satellite – 3.8 million square kilometres of remaining ice. For comparison: at the end of the winter (March 2020) ice covered an area four times as large (15.2 million square kilometres). The figure above shows the minimum sea ice concentration 9 September 2020.

of Greenland and North America. Since the wind blows landwards in many coastal areas, it doesn't push the ice out to sea, but instead compacts it along the coast, making the ice there especially thick.

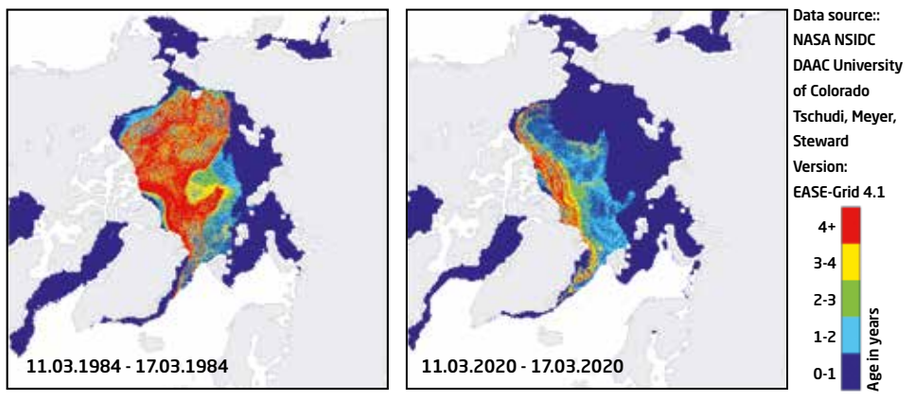
The statistics of change

SEA ICE EXTENT ANOMALY TO LONG-TERM MEAN 1981-2010



In the Arctic, the rule is: the older, and therefore thicker, sea ice is, the longer it can withstand the warmth of the sun and ocean in summer. Since now only a fifth of the ice is older than two years (bottom), the sun and ocean have an increasingly easy time melting it. In summer, ever-larger areas of ice melt as the top graph shows (development of sea ice extend compared to the long-term mean of 1981-2010) and the various melt ponds on the ice indicate (photo right); in winter, the ice forms later and barely reaches the thickness needed to survive the next summer.

SEA ICE AGE



THE BEGINNING OF THE END

Young sea ice grows as long as the air above its surface is cold enough for heat from the water beneath it to escape upwards. When this is the case, the water on the underside of the floe freezes; the sea ice grows from below. But as a result of climate change, these initial conditions – consistently cold air and cold surface water – aren't always given. Dramatically rising air and water temperatures in the Arctic have created a downward spiral for sea ice, which is likely to end in the Arctic Ocean being ice-free in summer in the foreseeable future – probably even before the middle of the 21st century, i.e., in less than 30 years. The Arctic is warming more than twice as fast as the global average.

If you compare today's Arctic with conditions 30 years ago, now only half as much of the sea ice survives the summer. The 14 lowest summer sea-ice extents since satellite observations began in 1979 were recorded in the last 14 years (2007 – 2020). The ice quantity – or volume – has declined by three quarters (75 percent), because the sea ice is significantly thinner today. At the same time, there are hardly any floes that are older than two years and have therefore had time to grow into massive ice floes, more than three meters thick.

Today, in the Russian marginal seas only thin new ice forms in winter, and melts in the following spring before it even reaches the central Arctic Ocean. That means significantly less sea ice begins the long journey known as the transpolar drift, which carries ice from the Russian marginal seas across the Arctic Ocean – and past the North Pole – to the region between East Greenland and Svalbard. There, in the Fram Strait, the ice leaves the Arctic Ocean and melts in the warmer waters of the North Atlantic.

The dimensions that climate change has now assumed in the Arctic have rarely been as evident as in 2020. In January, researchers from the Alfred Wegener Institute (AWI) observed the second-lowest sea-ice volume since the beginning of recordkeeping; further, the maximum winter sea-ice extent in March was well below average. In April the first heat wave of the year spread across Siberia. At the time, air temperatures over the Russian Arctic were up to 6 degrees Celsius higher than normal.

The heat continued throughout the summer: while on the mainland, the Siberian tundra burned and meteorologists reported record temperatures of up to 38 Grad Celsius in the Arctic, the sea ice rapidly retreated. In July, the extent reached a historical low. The **ice-free** regions, which were then completely exposed to the sun, warmed to such an

For scientists, the Arctic Ocean is considered to be ice-free when the remaining ice area in summer amounts to less than 1 million square kilometres. The reason: the thick ice near the coast in Greenland and Canada melts later than the drift ice in the Central Arctic. As such, the definition represents a compromise.

extent that the ocean and atmosphere together caused the Arctic ice cover to shrink to its second-lowest summer extent to date. Subsequently, the warm waters delayed winter ice formation by nearly four weeks.

THE MOSAiC EXPEDITION: AN UNPRECEDENTED OPPORTUNITY

There can be no doubt: the Arctic is more intensively affected by climate change than virtually any other region on Earth, and is currently undergoing a rapid transformation. The once eternally frozen realms of the Far North are steadily losing their protective shield of ice and snow. Researchers are observing these sweeping changes with satellites, on expeditions, and with the aid of numerous monitoring stations on the ice and in the ocean. But until now, they were unable to create a cohesive and above all conclusive picture of changes in the Arctic, because as a rule their fieldwork was done in various places and at different times of the year, and almost never examined the sea ice, snow, atmosphere, ocean and biology simultaneously.

MOSAiC stands for Multidisciplinary drifting Observatory for the Study of Arctic Climate, the expedition's English title.

Addressing this serious gap in our data and knowledge called for an exceptional research approach. An expedition to the Central Arctic, on which experts could spend an entire year measuring and recording relevant environmental parameters in the same surroundings – on (and in) the sea ice itself, high above and far below it.

It soon became clear to the experts involved that the plan could only succeed through collaboration; in response, 20 countries engaged in polar research, led by Germany's Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, joined forces for **MOSAiC** – the expedition of a century.

meereisportal.de is an independent science and data platform, launched by the Helmholtz Climate Initiative Regional Climate Change and Humans (REKLIM) and the Climate Office for Polar Regions and Sea Level Rise at the Alfred Wegener Institute. It offers real-time data from the Arctic and Antarctic, as well as the latest information on sea-ice conditions, for everyone.

For an entire year – from October 2019 to October 2020 – the German research icebreaker Polarstern drifted through the Arctic Ocean moored to an ice floe. The scientists on board erected an extensive research camp on the ice, where they conducted for the first time interdisciplinary experiments on the sea ice, snow, ocean, and atmosphere, as well as biological investigations – using state-of-the-art research methods, and in the face of adversities like darkness, storms and bone-chilling polar temperatures.

TEN TALES FROM THE RESEARCH CAMP ON THE ICE

The editorial team of the **meereisportal.de** (seaiceportal.de) accompanied the sea-ice specialists taking part in the expedition during their work on the ice and reported on their backgrounds, methods, advances and findings in the portal's DriftStories.

This publication brings together all ten stories with the goal of offering interested readers insights into the fascinating and surprisingly complex world of Arctic sea ice. Like our protagonists, you, too, can witness the transformation of the Arctic and experience, perhaps for the last time, the drift of the Arctic sea ice as we know it: the days of the Arctic's hallmark snow and ice are numbered.

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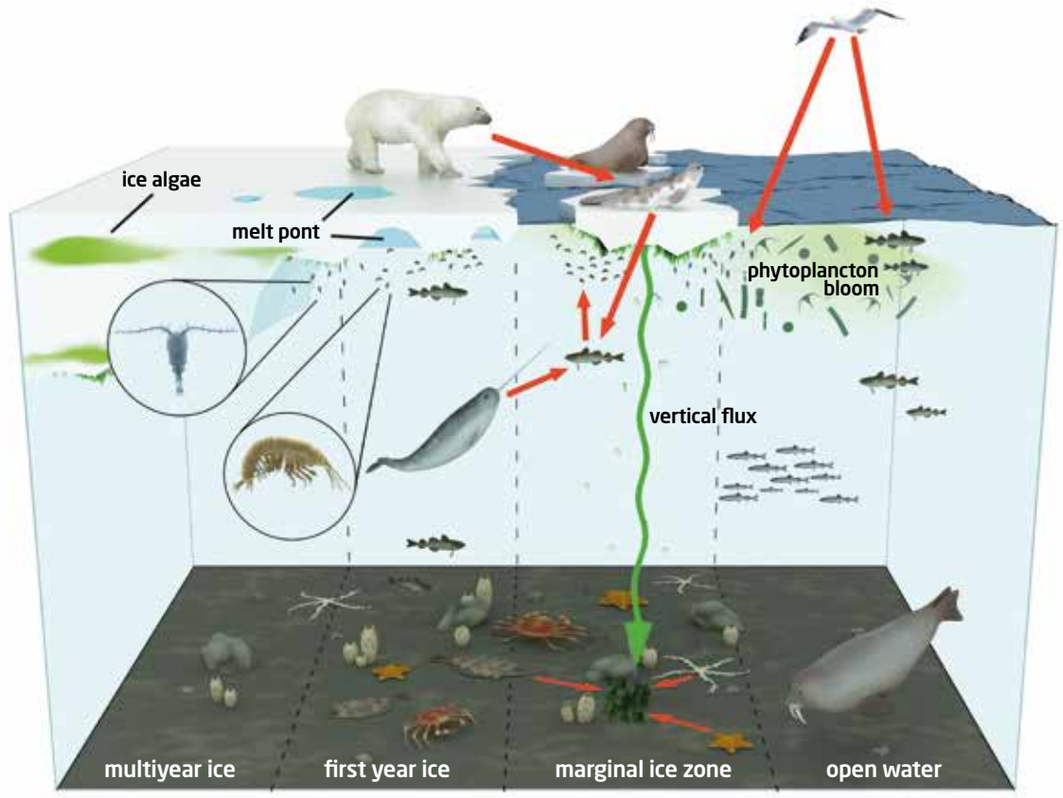
Science writer

Shelter and pantry



The sea ice influences not only the Arctic's heat balance; it also provides the basis for life in the Arctic Ocean, serving as a shelter for ice algae and microorganisms (zooplankton) and as a pantry. Both groups of organisms endure the harsh winter in the sea-ice's brine channels. With the return of the sun in spring, the ice algae reproduce and provide copepods and other zooplankton with a rich source of nutrients. In turn, the zooplankton provide food for fish such as the polar cod, which is one of the key species in the Arctic Ocean, since it is hunted by whales and seals, as well as puffins and other seabirds (l.). Walruses (r.) on the other hand find their prey on the seafloor, whose species communities live on the remains that sink to the depths from the surface – the ice is therefore vital for their survival, too.