# Polar Portal Season Report 2018

## Unusual weather resulted in an atypical melting season in the Arctic

**The 2017-18 season in the Arctic has once again been extraordinary. A cold summer with high levels of precipitation has benefitted the Ice Sheet, whilst glaciers have continued the development seen during the last six years in which they have more or less maintained their area. The sea ice, on the other hand, has been more vulnerable, with high sea temperatures and warm winds leading to a large area north of Greenland being ice-free in two separate periods – February and August respectively.**

## The heatwave in Europe and the cold Greenlandic summer are connected through the Atlantic "seesaw"

Many people in the Northern Hemisphere – and in particular northern Europe – will remember the record-breaking heat and drought of the summer of 2018. In contrast, Greenland had a rather cold and snowy summer, particularly in June and at the end of August, when a major storm dumped large amounts of snow on the Ice Sheet.

As early as AD 1230, a Norwegian book called "The King's Mirror" contained a description of the correlation between stormy weather over the eastern Atlantic and cold air, which is "sucked down" from the Ice Sheet to inhabited areas. Much later, in the 1770s, Danish missionary Hans Egede observed that "when the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely. In other words, the "seesaw" connection between warm weather in Europe and cold weather in Greenland (and vice versa) has been a recognised phenomenon for centuries. And the summer of 2018 was a particularly clear example of this circulation anomaly.

From the end of April until mid-October, a circulation pattern in the form of the Greek capital letter Ω over Scandinavia was prevailing most of the time. This type of circulation "blocks" the normal westerlies, and while warm air moves north across large parts of northern Europe, cold air from the central Arctic is present over Iceland and Greenland. This pattern is seen most clearly in the map of temperature anomalies for May 2018 shown below. But the same circulation anomaly was present during the other months as well.

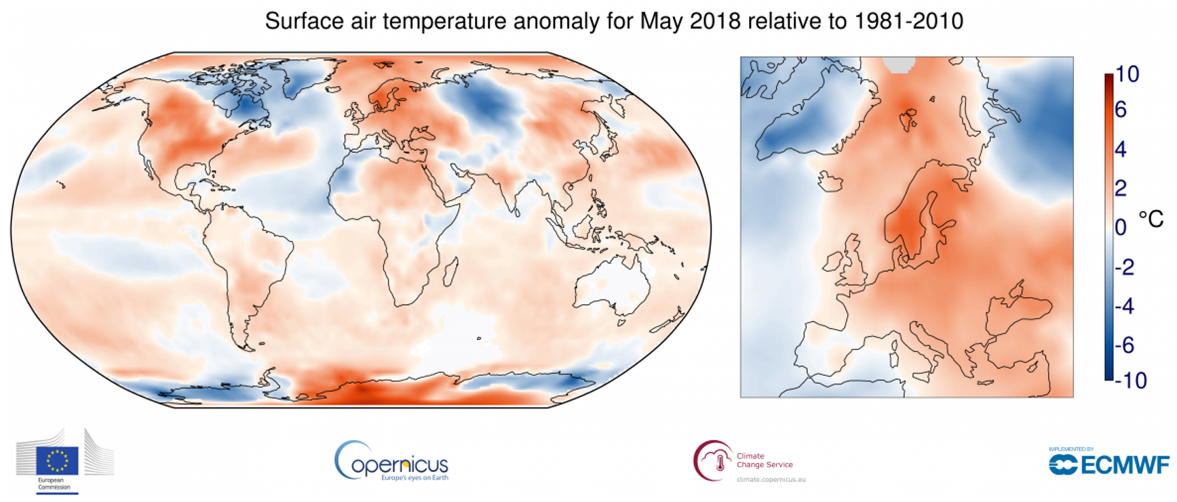


***Figure 1:*** *Temperature anomaly for May 2018 relative to the average for 1981-2010. Credit: Copernicus Climate Change Service / ECMWF.*

**In the following, we will look at the most important results monitored in the Arctic in 2018:**

- The wettest May in Greenland since 1949
- As in the previous year, 2018 was yet another year with a low degree of melting of the Ice Sheet
- Small changes in the area of the glaciers
- Still no data from GRACE Follow-On
- The albedo of the Ice Sheet was record-high in May, June and the beginning of August
- Two unusual openings in the sea ice north of Greenland in 2018

## The wettest May in Greenland since 1949

While the Danish summer in 2018 was unusually dry and hot from the beginning of May to the beginning of August, the weather was completely different in Greenland. Here the summer was cold and rather wet in a number of places, particularly in June. On the last two days of August, Greenland also experienced a major storm, which resulted in heavy snowfall on the Ice Sheet.

After the end of April, the weather was marked by persistent high pressure over Northern Europe. And when it is relatively warm over central and northern Europe, temperatures will typically be lower than normal in West Greenland. The high pressure effectively blocks the normal path of the low-pressure systems from west to east, so that these either head north through the Denmark Strait or are diverted a long way south over Southern Europe. This steady stream of low-pressure systems moving up through the Denmark Strait resulted in a lot more precipitation on the east coast than normal. With 35.6 mm of precipitation, Danmarkshavn experienced its wettest May since 1949, whilst June was the second-wettest since 1961 at Station Nord (32.2 mm).

In terms of temperature, the east coast experienced an average to slightly warmer than normal May, although the weather was otherwise generally cool in most places in both May and June. Summit, in the middle of the Ice Sheet, broke the May record on the 9$^{th}$ with a temperature of minus 46.5°C. In the middle of August the long period of hot summer weather in Europe came to an end, which meant more normal weather in Scandinavia. It also resulted in a period with strong winds from the south blowing up over northern Greenland, which experienced a record temperature of 17°C measured at Cape Morris Jesup at the northernmost point of Greenland.

## As in the previous year, 2018 was yet another year with a low degree of melting of the Ice Sheet

At Polar Portal we use two points of reference to assess when and how melting starts on the Ice Sheet. One is the beginning of the melting season, defined as the first of three days in which there is melting on more than 5% of the area of the Ice Sheet. The other is the onset of ablation, defined as the first of three days in which the Ice Sheet loses more than one gigatonne of ice. A gigatonne (Gt) is a billion tonnes, which corresponds to one cubic kilometre of ice). The melting season began on 31 May 2018. This is five days later than the median date, and thereby almost normal. The onset of ablation was on 25 June this year. This is relatively late, 13 days after the median, and the ninth latest date since 1981. This late onset is linked to the unusual circulation patterns described above.

The surface mass balance is an expression of the isolated growth and melting of the surface of the Ice Sheet. It is monitored via actual measurements and computer simulations. The modelled surface mass balance (SMB) for the 2017-2018 season (September 2017 to August 2018) returned a value of 517 Gt. This means that the season represented a sixth rank since 1981.

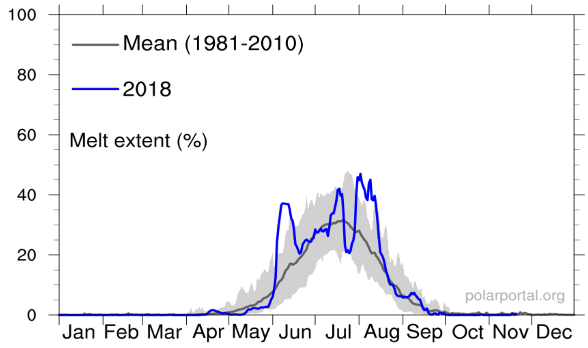


***Figure 2:*** *The graph shows how great a percentage of the total area of the Ice Sheet has seen melting, defined as minimum 1 mm melting at the surface. The blue line indicates the degree of melting in 2018, whilst the dark grey curve shows the mean value for the period 1981-2010. The light grey band shows the differences from year to year, although the highest and lowest daily values are discounted.*

Melting from the Ice Sheet is also measured directly at selected locations within the PROMICE project. Observations from the 18 weather stations in the melting region of the Ice Sheet indicate that the average degree of melting was the lowest recorded during the 10 years in which observations have been made (2008-2018). The southern and northern measurement stations (KPC, THU and QAS) registered the lowest amount of melting with 1.3 – 1.9 standard deviation in relation to the mean, whilst melting at the other measurement stations was within one standard deviation. Only two out of eight measurement positions (NUK and KAN) registered more melting than normal, although these figures did not lie outside measurement uncertainties.

Consistent with the net melting observations, summer temperatures in June, July and August were lower than average for 2008-2018 at all PROMICE measurement stations (by more than one standard deviation along the northern, north-western and southern edge of the Ice Sheet). July 2018 was the coldest month compared to the period 2008-2018 along the northern, north-western and southern part of the Ice Sheet melting area.

Looking at all measurements in the months from January to August, 28% of the monthly temperatures were more than one standard deviation below the mean. And only 3% were more than one standard deviation above the mean.

Areas with ice not covered by snow are separated from snow-covered areas by the so-called snowline. This can be used to document changes in areas of non-snow-covered ice. In 2018 the snowline was close to the average for 2000-2018, which corresponds to the positive albedo anomalies (see below) and the cold summer temperatures which reduced the amount of melting in 2018.

The extent of non-snow-covered areas has increased during the period 2000-2018 by an average of 500 km$^2$ per year. Although this increase is not significant, it nevertheless demonstrates that there has been a little more melting than accumulation of ice since 2000.

**Surface mass balance**

Surface mass balance is an expression of the isolated growth and melting of the surface of the Ice Sheet. Precipitation contributes to an increase of the mass of the Ice Sheet, whilst melting causes the Ice Sheet to lose mass. In relation to the total mass balance, the surface mass balance says something about the contribution at the surface of the Ice Sheet – i.e. excluding that which is lost when glaciers calve icebergs and melt as they meet the warm seawater. Since the 1990s, the surface mass balance has generally been declining.

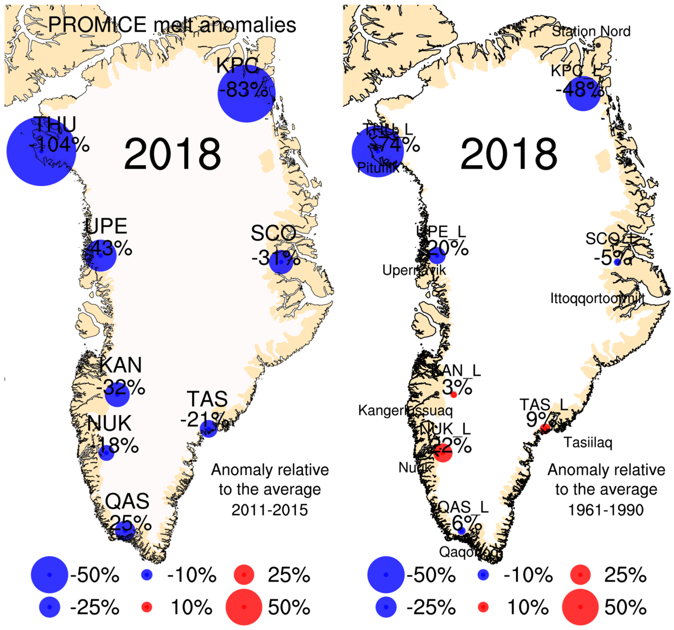


***Figure 3**: The maps show the net melting anomalies for 2018 at low-lying PROMICE weather stations seen in relation to the periods 2011-2015 (left) and 1961-1990 (right), respectively.*

The Danish Meteorological Institute (DMI) also performs daily simulations of how much ice or water the Ice Sheet loses or accumulates. Based on these simulations, an overall assessment of how the surface mass balance develops across the entire Ice Sheet is obtained (Fig. 4).

At the end of the 2018 season (31 August 2018), the net surface mass balance was 517 Gt, which means that 517 Gt more snow fell than the quantity of snow and ice that melted and ran out into the sea. This number only contains the balance at the surface, and thus not the total balance, which also includes melting of glaciers and calving of icebergs. The surface mass balance at the end of August 2018 is almost 150 Gt above the average for 1981-2010 of 368 Gt, and it makes the melting season of this year the sixth highest SMB result, just slightly less than the result for last year season, 2016-2017, when the SMB was 544 Gt. For comparison, the lowest measured SMB was 38 Gt in 2012. This clearly demonstrates how great a variation can occur in SMB from one year to the next.

Although the total SMB for the 2016-2017 and 2017-2018 seasons are similar, development during the two seasons has been very different. Last year, the season began by gaining a lot of mass during the winter, whilst the development in SMB from the summer onwards reflected the long-term average. During the 2017-2018 season, SMB remained in line with the average from 1981-2010 until the summer, after which the development in SMB was higher than average.

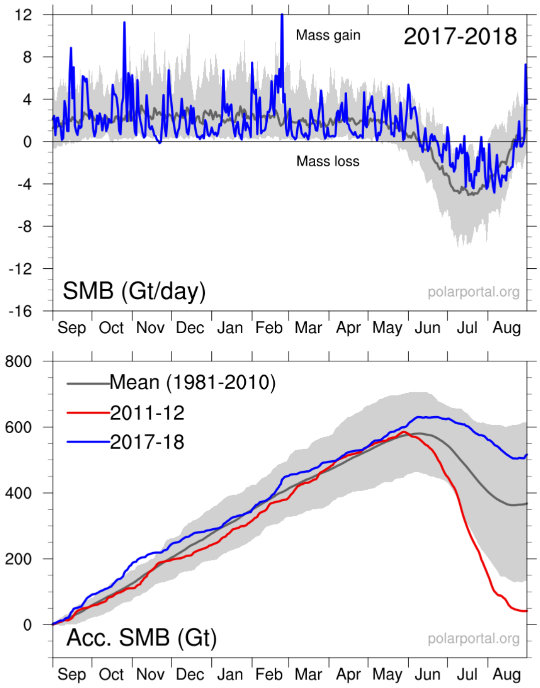


***Figure 4:** The top graph shows the total daily simulated contribution to the surface mass balance from all points on the Ice Sheet. The bottom graph shows the total accumulated surface mass. The blue line represents the 2017-18 season, and it can be seen that by the end of the season the blue line lies above the grey normal line.*

## Small changes in the area of the glaciers

The Greenland Ice Sheet loses mass via, among other things, its marine terminating glaciers that run out into the sea. If there is a state of equilibrium, the calving of the icebergs and the flow of ice towards the sea are in balance.

The area of the 47 largest glaciers has been monitored by the Sentinel-2, LANDSAT and ASTER satellites since 1999. Monitoring reveals that during the last six years from 2012-2013 until 2017-2018, there has been a minor annual loss in terms of the glaciers' area.

The change from 2016-2017 to 2017-2018 in the net area of the 47 monitored glaciers shows an increase of +4.1 km$^2$, which makes 2018 the only year with a positive balance. This is followed by the 2006-2007 season (-19.8 km$^2$). This latest loss of area is thereby 113.8 km$^2$ less than the average loss for the 19 seasons from 1999-2000 to 2017-2018, which was -109.7 km$^2$. Of the monitored glaciers, 21 retreated and 12 grew in size. In the remaining 14 glaciers the changes in area were within ±0.2 km$^2$.

The biggest change for a single glacier was the loss of area of the Humboldt glacier in Northwest Greenland (-13.3 km$^2$) and the Kangerdlugssuaq glacier in East Greenland (-8.1 km$^2$). At the same time, the Petermann glacier grew (+19.1 km$^2$), as was also the case the previous year (+11.5 km$^2$).
The Jakobshavn glacier continued its retreat and lost 2.6 km$^2$ in relation to the year before, whilst the Helheim glacier increased its area by 10.6 km$^2$. The changes are thus very small. In comparison, the Petermann glacier lost 323.4 km$^2$ in 2010 and 277.6 km$^2$ in 2012.

If only the 6 largest glaciers are considered, they have grown only slightly overall. This applies to Jakobshavn, Kangerdlugssuaq, Helheim, Petermann, Zachariae and 79° Glacier, which increased their area by an average of +3.7 km$^2$ during the year. Two of these glaciers retreated, however, whereas the other four grew in size.

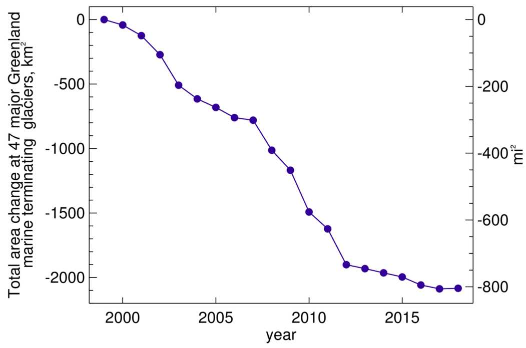


***Figure 5:*** *The graph shows the total change in the area of 47 of the largest marine terminating glaciers in Greenland. It shows that since 2012 these glaciers have lost area to a modest extent.*

## Still no data from the GRACE Follow-On mission

Data used for calculations of the melting of ice in the Arctic and the contribution of the Ice Sheet to rising sea levels has come from the GRACE satellites since 2002. However, the mission had to be abandoned in 2017 because the batteries on one of the satellites ran out of power. On 22 May 2018, two new satellites were therefore launched: the GRACE-FO satellites (GRACE Follow On), which are replacing the original GRACE satellites.
However, no useful data has yet been acquired from the new satellites, and there will therefore be a gap in gravity data until the GRACE Follow-On mission can provide data for measurement of how the total mass balance of the Ice Sheet has developed during the 2017-2018 season. As this data is unavailable, it is not possible to say whether the high SMB of this season also means that the total mass loss for the 2017-2018 season is low, as was the case in the 2016-2017 season.

During the period 2003-2011 the Ice Sheet has on average lost 234 Gt every year. This means that the slight total mass increase during the last two seasons cannot compensate for these mass losses.

## The albedo of the Ice Sheet was record-high in May, June and the beginning of August

Albedo data comes from the MODIS satellite (Moderate-resolution Imaging Spectroradio-meter), which since 2000 has observed the reflection of sunlight from the Earth. The albedo is an expression of the ability of a surface to reflect the rays of the Sun. The lighter the surface, the better it is at reflecting the rays of the sun. Dark surfaces, on the other hand, absorb large quantities of solar energy as heat.

In 2018 the albedo was record-high in May, June and the beginning of August – but not in July or the end of August. Normally, the summer snow melt will expose darker snow and ice, which absorbs more solar energy, which will in turn lead to increased melting. However, this summer's frequent snowstorms tended to refresh the clear, white surface, which slowed down the typical ice albedo feedback, which can otherwise lead to increased melting when dark areas absorb solar energy and begin to melt.

The Ω blocking referred to earlier was interrupted for a few days in the middle of August. When this occurred, the airflow over Europe was generally from the west, at the same time as which southerly winds caused melting over almost half of Greenland (see also Fig 2).

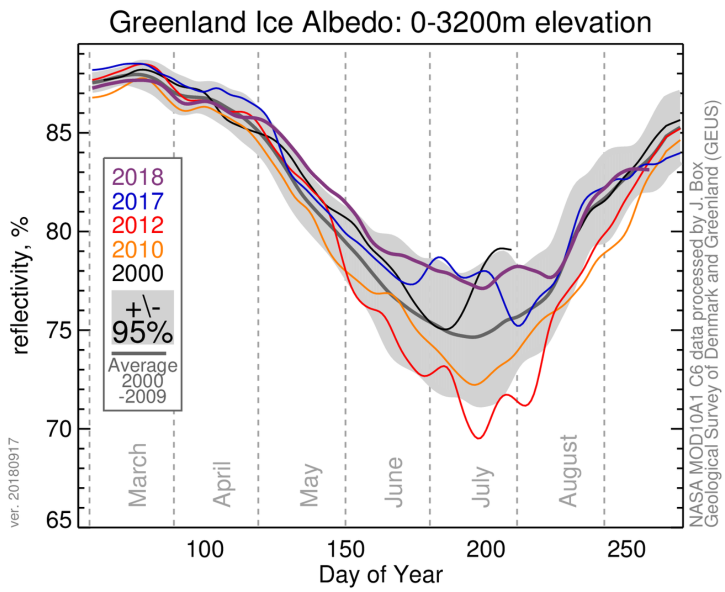


***Figure 6:*** *The figure shows the daily average of albedo measurements for 2000, 2010, 2012, 2017 and 2018. The purple line is 2018. This shows that the albedo was record-high in May, June and the beginning of August, but not in July and the end of August.*

## Two unusual openings in the sea ice north of Greenland in 2018

Sea ice is important for the climate because it is light and thus has a high albedo. The smaller the extent of the sea ice, the larger the dark water surfaces in the Arctic will be that absorb solar energy and thereby contribute to further melting of the ice. This results in further warming of the sea, which will in turn delay freezing in the autumn. This means that the ice therefore has a shorter period in which to thicken during the course of the winter, resulting in thinner ice and thus earlier spring breakup. Sea ice which melts also absorbs more sunlight than cold and frozen sea ice. When the temperature in the Arctic is above freezing, the sea ice begins its melting season. This occurred on

13 June this year, which is very close to the median, which is 12 June.

DMI's sea ice model for simulation of the thickness of the sea ice shows that the sea ice was a little thicker at the beginning of 2018 than the year before, although the extent of coverage of the sea ice was the lowest for the time of year for at least 40 years.

The season will be remembered for two unusual periods with open sea north of Greenland, where there is normally permanent polar ice cover. The first period was – somewhat unusually – at the end of February. In this case the sea ice was blown away from the north coast by a persistent and warm Foehn wind which brought temperatures as high as plus 6 degrees Celsius. This caused an opening in the sea ice with a length of several hundred kilometres and more than 100 km wide in some places. In March, however, the temperature fell to a more normal level of minus 30 to minus 20 degrees, and the opening was covered by sea ice again. The ice was so thin, however, that it melted once more in August. The open area north of Greenland lasted only a short time and did not have any major significance in terms of the extent of the sea ice as a whole. Compared to the last 40 years of satellite imagery, a new minimum record was thus not set. Although the extent of coverage of the sea ice in this season was 2 million km$^2$ below the average for 1981-2000, it was still 1.2 million km$^2$ more than the record-low coverage in 2012.

However, if the break-up of the perennial ice continues, the stability of the sea ice may be threatened. If the perennial ice breaks up and drifts south (where it will melt), there is a considerable risk that ice-free summers will occur in the Arctic Ocean.

During the 2018 melting season the temperatures were lower than average north of Canada, whilst it was warmer than normal north of Siberia. This had significance for the sea ice situation, and thereby the possibility for sailing in these areas. The northeast passage was open, whilst the northwest passage was closed with ice in certain areas.

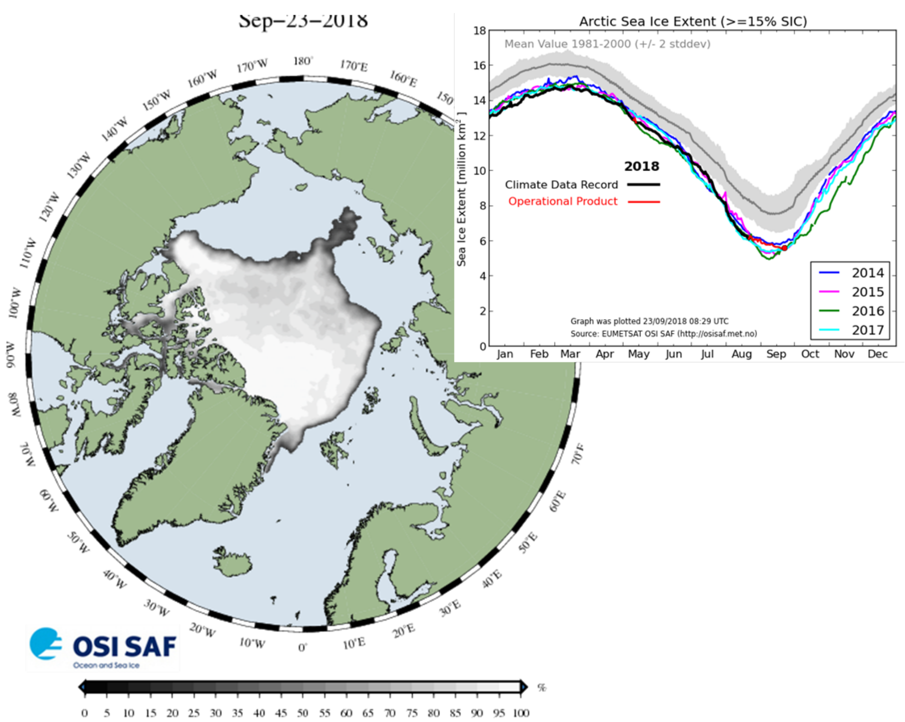


***Figure 7:*** *DMI's graph of the extent of the sea ice from 23 September, which was the date of the lowest extent of the season. The map and graphical representation are based on EUMETSAT's OSISAF ice concentration calculations and illustrate the extent of sea areas that have more than 15% ice cover. Graphics from Polar Portal.*

The sea ice has direct influence on the warming of the surface water of the sea during the summer. Along the Siberian coast, in the Bering Strait and in the Greenland Sea, summer 2018 saw large areas where the surface water was between 2°C and 4°C, in the Bering Strait and Chukchi Sea even 5°C above the norm. The high water temperatures meant that the sea ice minimum was registered as late as 23 September, and this in turn meant that the refreezing of the sea ice was correspondingly delayed. Along with 1997, this was the latest summer minimum registered since satellite observations of sea ice began. The final extent of coverage of the sea ice was the sixth lowest ever measured, with the same value as in 2008 and 2010. And the extent of the sea ice in January was the lowest and in September the ninth-lowest measured by satellites since 1979.

**Extent of the Arctic ice**

The extent of the Arctic sea ice is analysed by both the American NSIDC and the European EUMETSAT – and thus also by DMI. Both centres use the same satellite data, but they treat noise over open water and along the edges of the ice slightly differently. This means that the graphs for the extent of the sea ice are not quite identical. The European figures are compiled via data from DMI researchers and are published in the scientific journal The Cryosphere.

Observations of the extent of the sea ice reveal that the area of the Arctic summer ice has fallen annually by an average of approx. 94,000 $km^2$ since the 1970s. This is more than twice the total land area of Denmark.