POLAR PORTAL
IS- OG KLIMAOVERVÅGNING I ARKTIS

Polar Portal Season Report 2019

Dry and warm weather resulted in a high degree of melting in the Arctic

The 2018-19 season in the Arctic was generally drier than normal, whilst the summer was warm and featured periods in which melting was very high. This means that the Ice Sheet ended the season in a weaker state. Glaciers lost a slightly larger area than the average for the period 1986-2018. Sea ice once again suffered this year. The extent of the sea ice was already low during the spring, and the warm summer only made the situation worse.

Dry and warm summer in Greenland connected to the Atlantic "seesaw"

There are several factors that play a role in the considerable loss of ice seen during the 2018-2019 season. The season began in September 2018 with a period which in most parts of Greenland was a lot drier than normal. This meant that the Ice Sheet had only a thin protective layer of snow when the melting season began early on 30th April 2019. The summer in 2019 was very long, dry and warm, which resulted in a huge amount of melting all over the Ice Sheet, in particular in the west and north of the country.

The long, dry summer can in part be explained by the North Atlantic Oscillation, NAO, which describes the winds in the eastern North Atlantic. These currents of air have a great influence on our weather throughout the year (in particular during winter).

The NAO is defined as the difference between the sea level pressure over or near the Azores and the pressure over Iceland. Normally, air pressure is high over the Azores and low over Iceland. This results in the wind coming from westerly directions, and the NAO index is thus referred to as positive. Occasionally the pressure difference can be small, or the pressure over Iceland can even be higher than that over the Azores. We then get weak westerlies or even wind from the east, and the NAO index is thus small or even negative. The NAO is an element in determining which "routes" areas of low pressure take across the Atlantic. It is therefore of great importance for the weather in Northern Europe. A positive NAO typically means grey, mild, rainy and windy weather in Central and Northern Europe. A negative NAO tends to push storms further south. The long, dry summer in 2019 was due to the NAO index being negative for a long period. A negative NAO pushes rain and snow away from Greenland, which in turn means clear skies or thin cloud cover, which further accelerates the melting of the ice.

Several recent studies indicate that the NAO index plays a key role in melting in Greenland. Studies also show that the low rate of melting in recent years correlates with months with a positive NAO index. It is crucial that future climate models represent the index in a realistic way, as there are indications that the warming of the global climate promotes negative NAO indexes, which mean greater melting in the Arctic.

In the following, we will look at the most important results monitored in the Arctic in 2019:

- Dry and warm summer in Greenland in 2019
- High degree of melting of the Ice Sheet
- Loss of mass from calving of icebergs
- First data from GRACE Follow-On, although not yet operational
- Record-low Ice Sheet albedo in 2019
- Lowest extent of sea ice in July since records began 40 years ago

Dry and warm summer in Greenland in 2019

The summer in Greenland in 2019 was both dry and warm. At the beginning of June and the end of July very warm air blew across the Ice Sheet, which meant that the melting season received a further boost. When the second heatwave peaked during the three days from 31st July until 2nd August, the Ice Sheet lost 31 Gt, which, in isolation, resulted in a rise in sea level of 0.1 mm. In comparison, average daily melting throughout the entire melting period was around 3 Gt. During the heatwave, melting was thus three times higher than the average.

The 2018-2019 season was yet another year in which melting was measured at Summit. By counting individual layers of ice, it can be concluded that this has only happened six times previously during the last 2000 years. The seasons in 2016-2017 and 2017-2018 saw a slight increase in the Ice Sheet. In contrast to these seasons, the surface mass balance of the Ice Sheet was low in 2018-2019.

2019 was a year with a high degree of melting of the Ice Sheet

The surface mass balance (SMB) 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 Danish Meteorological Institute (DMI) performs daily simulations of how much ice or water the Ice Sheet loses or accumulates. Based on these simulations, an overall measurement of how the surface mass balance develops across the entire Ice Sheet is obtained (Fig. 1). At the end of the season (31st August 2019), the net surface mass balance was 169 Gt (one gigatonne equals one billion tonnes, which corresponds to one cubic kilometre of ice). This means that this season returned the seventh lowest result in terms of surface mass balance. It also means that 9 of the 10 lowest results for the surface mass balance – which have been calculated since 1981 – have occurred during the last 13 years.

In other words, 169 Gt more snow fell than what melted and ran off into the sea. This figure is almost 200 Gt below the 1981-2010 average of 368 Gt. As a point of reference, the lowest calculated SMB was only 38 Gt in 2012. However, as the name implies, this applies only to the balance on the surface, and thus not the total balance, which also includes melting of glaciers that come into contact with warm seawater and calving of icebergs.

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.

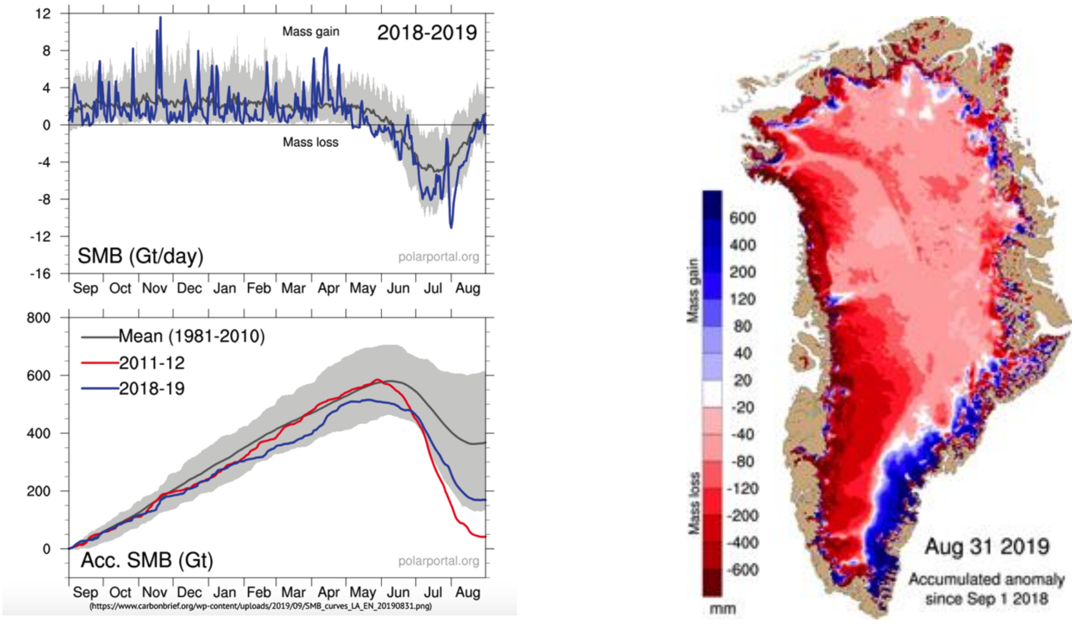


Figure 1: *The top left graph shows the total daily simulated contribution to the surface mass balance from all points on the Ice Sheet. The bottom left graph shows the total accumulated surface mass balance. The blue line represents the 2018-19 season. The top graph shows the huge amount of melting in July/August 2019, and on the bottom graph we can see that the end of the season indicates a very low, but not a record value in relation to the 40 years of data available. The map on the right shows the distribution of the accumulation. Most of Greenland has lost mass; only in Southeast Greenland was there a mass increase.*

At the Polar Portal, we use two points of reference to assess when and how melting starts on the Ice Sheet. The first of these is the beginning of the melting season, defined as the first of three days in a row during which there is melting on more than 5% of the area of the Ice Sheet. The second point in time is the onset of ablation, which is defined as the first of three days in a row during which the Ice Sheet loses more than one gigatonne of ice from its surface on a daily basis.

The melting season began on 30th April 2019. This is almost one month earlier than the median of the start of the Ice Sheet's melting season, which is 26th May. This puts 2019 near the top of the list of earliest starts to the melting season, second only to 2016.

The onset of ablation was 11th June, and this is very close to the median, which is 12th June. Ablation, however, as defined above, almost began much earlier. At the end of May a number of days with high temperatures caused early melting. This did not last long enough, however, to satisfy the definition of the onset of ablation.

Throughout the period from February until the middle of June, the surface mass balance stayed below that of the record-low season in 2011-2012. By the end of the melting season, however, 2018-2019 had recovered to a higher level than the all-time low in 2012 – although it was still well below average.

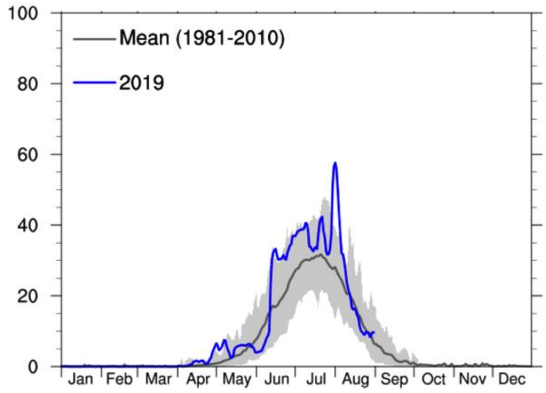
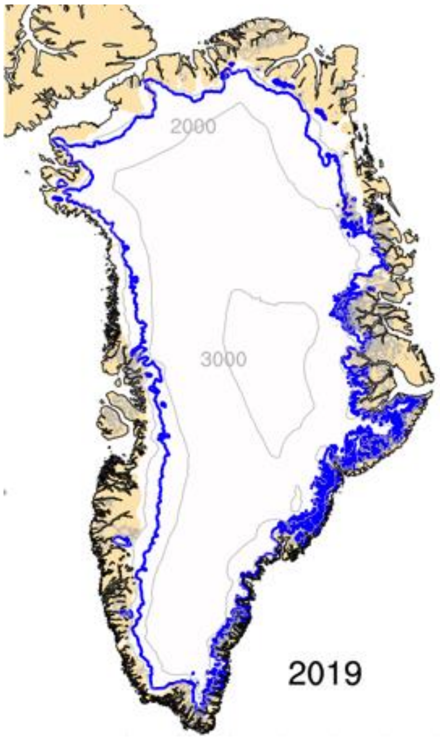


Figure 2: *The graph shows on a daily basis how great a percentage of the total area of the Ice Sheet has seen melting, defined as minimum 1 mm melting at the surface. The blue line indicates melting in 2019, whilst the dark grey curve shows the mean value for the period 1981-2010. The light grey band shows the differences from year to year, with the highest and lowest daily values excluded. As can be seen, the blue line remains above the mean value throughout almost the entire season. During the melting event at the end of July and beginning of August, melting occurred on 58% of the surface of the ice, a figure exceeded only in 2012.*



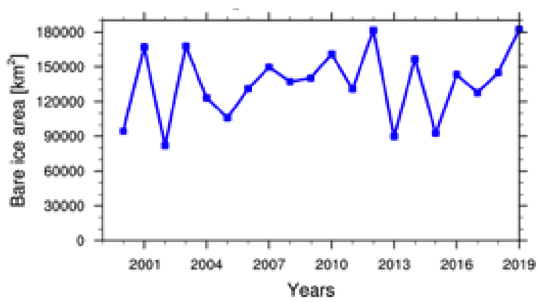


Figure 3: *The map shows the position of the snow-line at the end of the melting season. Above the snow line, there is snow, further down it is bare ice. The graph shows how large the area of bare ice is. 2019 has the biggest ice area measured to date, only slightly higher than in 2012.*

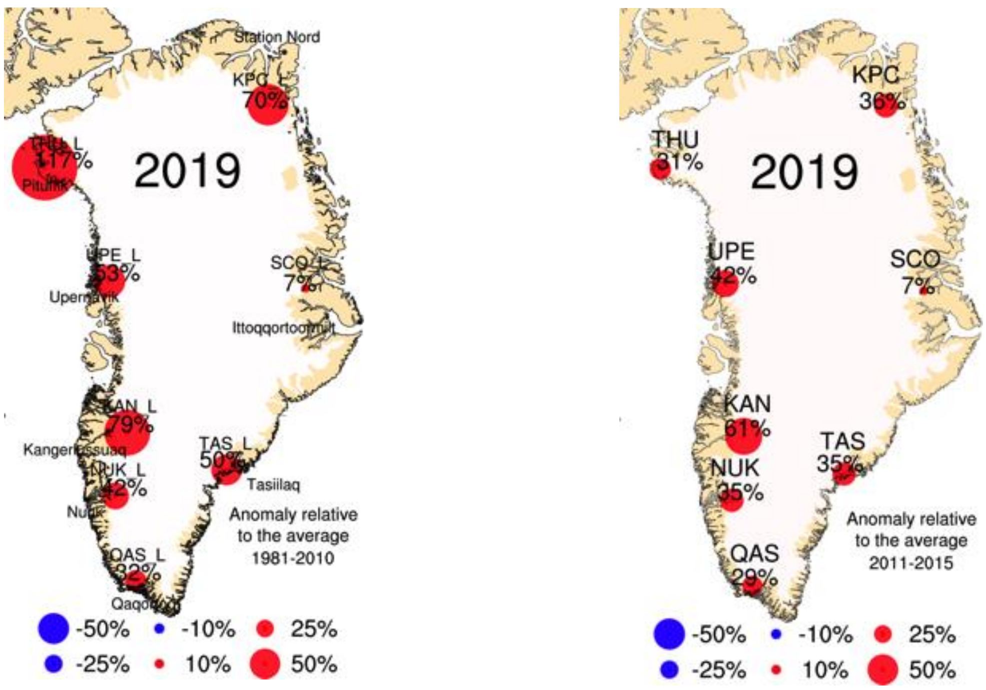


Figure 4: *The maps show the net melting anomalies for 2019 at low-lying PROMICE weather stations seen in relation to the periods 1981-2010 (left) and 2011-2015 (right).*

Melting from the Ice Sheet is also measured directly at selected locations under the PROMICE project. Observations at all 21 weather stations under the PROMICE project revealed a net loss of ice and snow that was higher than the average for the period 2008-2019. The greatest degree of melting occurred in West, Northwest and North Greenland – at the stations Kronprins Christian Land (KPC), Pituffik (THU) and Upernavik (UPE). There are weather stations at different altitudes, and the results from the low-lying stations were compared to the mean for the standard climate period 1981-2010. All of these stations reported melting in 2019 that was higher than the mean value in the standard climate period.

The high degree of melting reflects the high summer temperatures in June, July and August, which were above the mean values for 2008-2019 at all of the weather stations.

Mass loss from calving of icebergs

Greenland's Ice Sheet loses mass when its marine terminating glaciers run out into the sea. If there is a state of equilibrium, the calving of icebergs and the flow of ice towards the sea are in balance.

Since 1999 the change in area of the marine terminating glaciers has been monitored by the Sentinel-2, LANDSAT and ASTER satellites. These observations reveal that since 2018 the seven biggest marine terminating glaciers have lost an area of -71.2 ±1.4 km^2. This loss is the biggest loss following an otherwise stable period without major loss during the years 2013-2018.

The glaciers concerned are Helheim, Kangerdlugssuaq, Jakobshavn, Rink, Petermann, Zachariae and Nioghalvfjerdsfjordenbræ. The greatest loss in area was suffered by Nioghalvfjerdsfjordenbræ. Three of these glaciers lost area (Helheim, Zaccaria and Nioghalvfjerdsfjordenbræ), two gained area (Kangerdlugssuaq and Petermann) and two (Jakobshavn and Rink) remained stable. The biggest loss occurred at Nioghalvfjerdsfjordenbræ in connection with the detachment of the Spalte ice shelf area. The growth of Petermann suggests that there were no major calving events. However, a large fissure is moving forward, and a loss of area of several dozen km^2 can be expected in the future.

PROMICE also assesses iceberg production from the Sentinel-1A and Sentinal-1B satellites. The satellites measure the speed of the marine terminating glaciers along the edge of the ice. Based on this speed, the amount of ice that is calved into the sea can be calculated. The average loss of ice from calving was 449 Gt during the period 1981-2010. During the period 2005-2018 the average loss had risen to 484-503 Gt per year. During the 2018-2019 season the loss was slightly higher, reaching 497 Gt on 31st August 2019. Most areas have seen reasonably stable losses over the last 10 years. Northwest Greenland has seen a constant rise in loss of ice of around 21 % during the period 1998-2018.

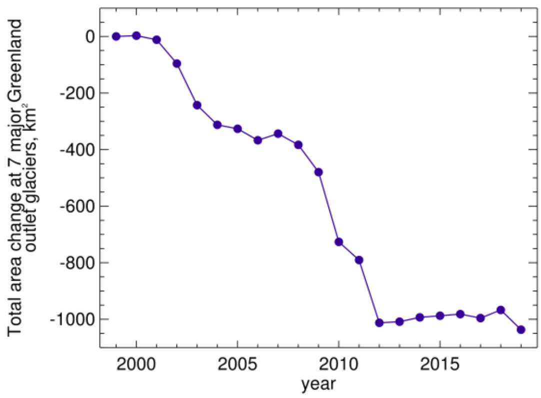


Figure 5: *The graph shows the total change in area of 7 of the largest outlet glaciers in Greenland. It shows that since 2018 these glaciers have lost an area of -71.2 ±1.4 km^2. This loss is the biggest loss following an otherwise stable period without major losses between 2013 and 2018.*

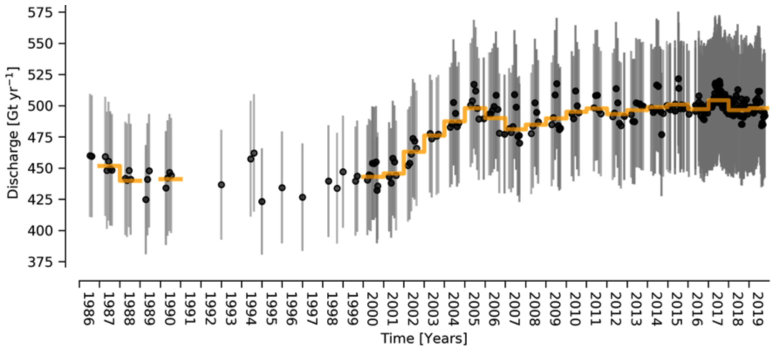


Figure 6: *Time series of calving from Greenland's Ice Sheet. The dots show when the observations were made (limited to > 50% cover). The stepped orange line shows the annual average (limited to three or more observations per year).*

Height and mass changes

Between 2002 and 2017, the GRACE satellites provided data for calculations of the Ice Sheet's total mass balance, which includes contributions from both the surface mass balance and the loss from glaciers calving in the sea. This data shows that on average the Ice Sheet lost 260 Gt of ice per year until 2012, and that the melting season in 2012 was unusual with a loss of 458 Gt. This is the total mass balance, i.e. SMB minus calving of icebergs and melting of glacial tongues.

The GRACE mission had to be abandoned in 2017 because the batteries on one of the satellites had lost all power. Unfortunately, no replacement satellite was in orbit at the time; it was not until 22nd May 2018 that two new satellites were launched, the GRACE-FO satellites (GRACE Follow On) replacing the original GRACE satellites.

There have been problems with one of the instruments on the GRACE-FO satellite, and work is ongoing to validate and analyse the data in depth. Overall, the provisional data for Greenland shows that GRACE-FO is functioning reasonably well for Greenland. Work is being carried out to make the final GRACE-FO results for Greenland available at the Polar Portal as soon as possible.

During the current season, 2018-2019, it has been possible to use data from the Copernicus Sentinel-3A satellite to supplement the GRACE-FO data. The Copernicus Sentinel-3A satellite has now measured elevations for long enough to enable the data to be used to observe stable changes in the height of the Ice Sheet. However, there are still issues with regard to the satellite's data from the edge of the ice, and therefore Sentinel-3A is combined with data from the CryoSat-2 satellite. Figure 6 shows the annual elevation changes over a three-year period from January 2016 until December 2018. The map is based on elevation measurements carried out by means of radar altimetry. These measurements show that Jakobshavn Isbræ has become thicker at its leading edge during recent years.

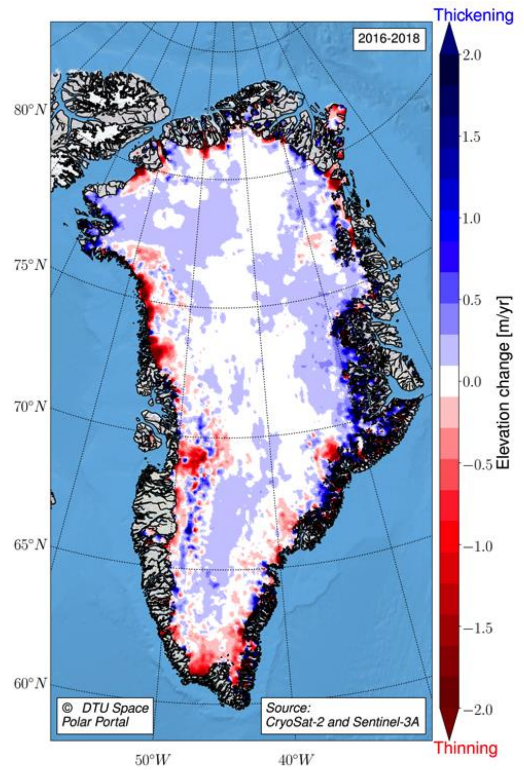


Figure 7: *The map shows elevation changes per year based on Sentinel-3A and CryoSat-2 data from January 2016 until December 2018.*

Record-low Ice Sheet albedo in 2019

When calculating the surface mass balance, a "surface energy budget model" is used, in which albedo data is incorporated. The albedo is an expression of the ability of a surface to reflect the sun's rays. 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. The MODIS satellite (Moderate Resolution Imaging Spectroradiometer) has supplied albedo data since 2000 via observation of the reflection of sunlight from the Earth.

In late summer 2019 the albedo was record-low, which means that the ice reflected considerably less energy than the average value over large areas.

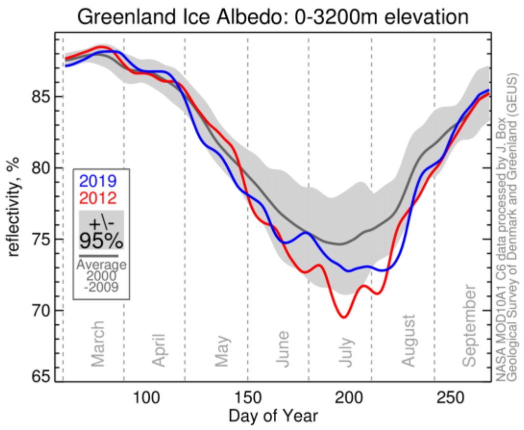


Figure 8: *The figure shows the daily average of albedo measurements for 2012 and 2019. It shows that the albedo was record-low in August 2019. This means that the ice reflected considerably less energy than the average value over large areas.*

Lowest extent of sea ice in July since records began 40 years ago

When the temperature in the Central Arctic region exceeds freezing point, the sea ice begins its melting season.

The sea ice began melting earlier than normal in 2019 – up to a whole month earlier in certain areas.

The extent of the sea ice was already record-low in the spring, with the warm summer only making things worse. July 2019 saw the lowest July amount of ice in the 40 years that observations have been made by satellite.

The areas in which the sea ice had already disappeared in June were heated up by the Sun, so these areas were up to 4°C warmer than average in the Baffin Bay on the west coast of Greenland and in the Laptev Sea and the Kara Sea, northeast and northwest of Siberia respectively. Warm seawater means that more ice will melt.

On 17th September the Arctic sea ice reached its annual minimum extent, with coverage of 4,583,125 km^2. This corresponds to around 100 times the area of Denmark. This figure means that 2019 shares a second place with 2006 in terms of the lowest minimum extent of the sea ice. 2012 is still the year in which the minimum extent of the sea ice was at its lowest.

The sea ice began to refreeze from 17th September, but was hindered by the fact that the water temperature surrounding the ice was still 2-4°C warmer than normal.

Sea ice is important in terms of 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.

The Sun's energy also means greater warming of the sea, which will in turn delay freezing in the autumn. This means that the ice has a shorter period in which to thicken during the course of the winter, which may mean that it will be thinner during the spring and thus break up earlier. Sea ice which melts also absorbs more sunlight than cold and frozen sea ice.

In other words, higher than usual melting of the sea ice has a self-perpetuating effect that leads to even greater melting. 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.

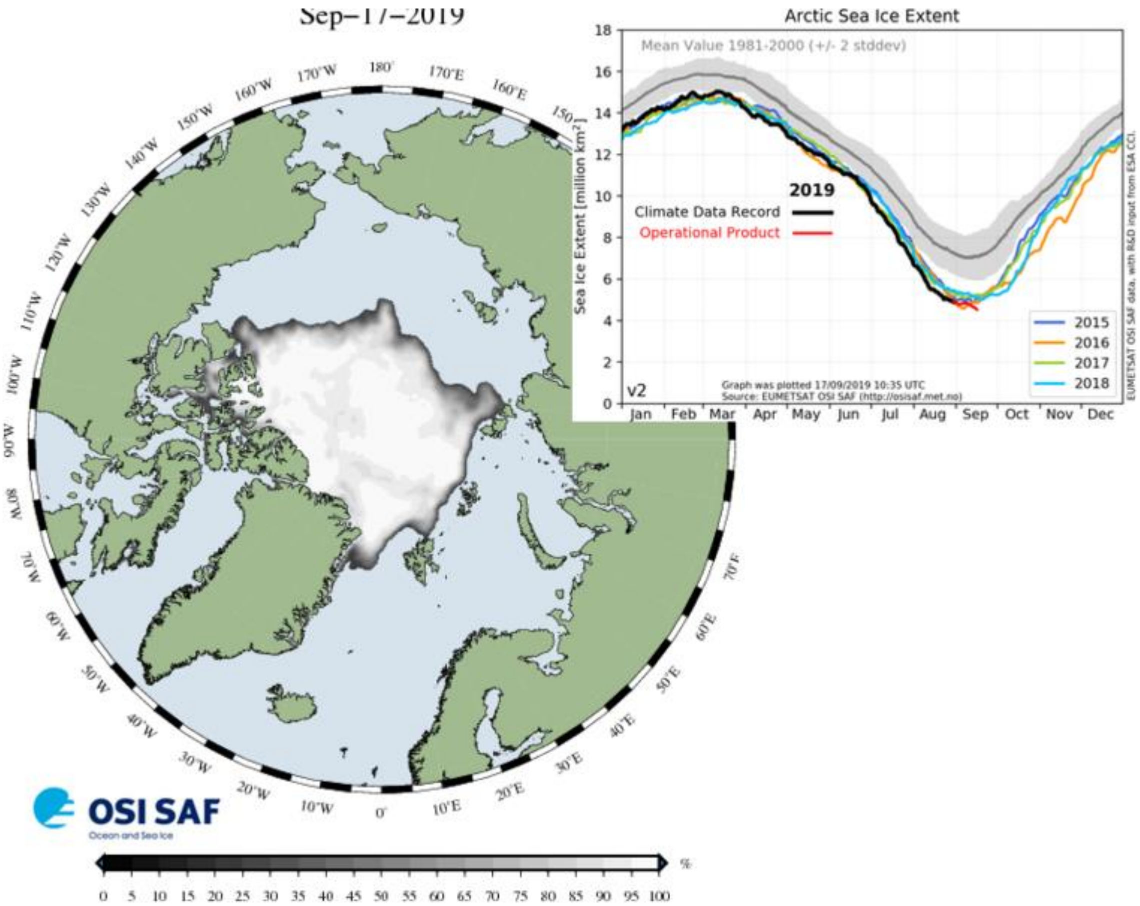


Figure 9: *DMI's graph of the extent of the sea ice from 17th September 2019, which was the date of the season's lowest extent of coverage. The map and graphical representation are based on EUMETSAT's OSI SAF ice concentration calculations and illustrate the extent of sea areas that have more than 15% ice cover. Graphics from Polar Portal.*

Extent of the Arctic sea ice

The extent of the Arctic sea ice is analysed by both the American NSIDC and the European EUMETSAT – and thus in turn 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 Cryosphere scientific journal

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 corresponds to more than twice Denmark's total land area.

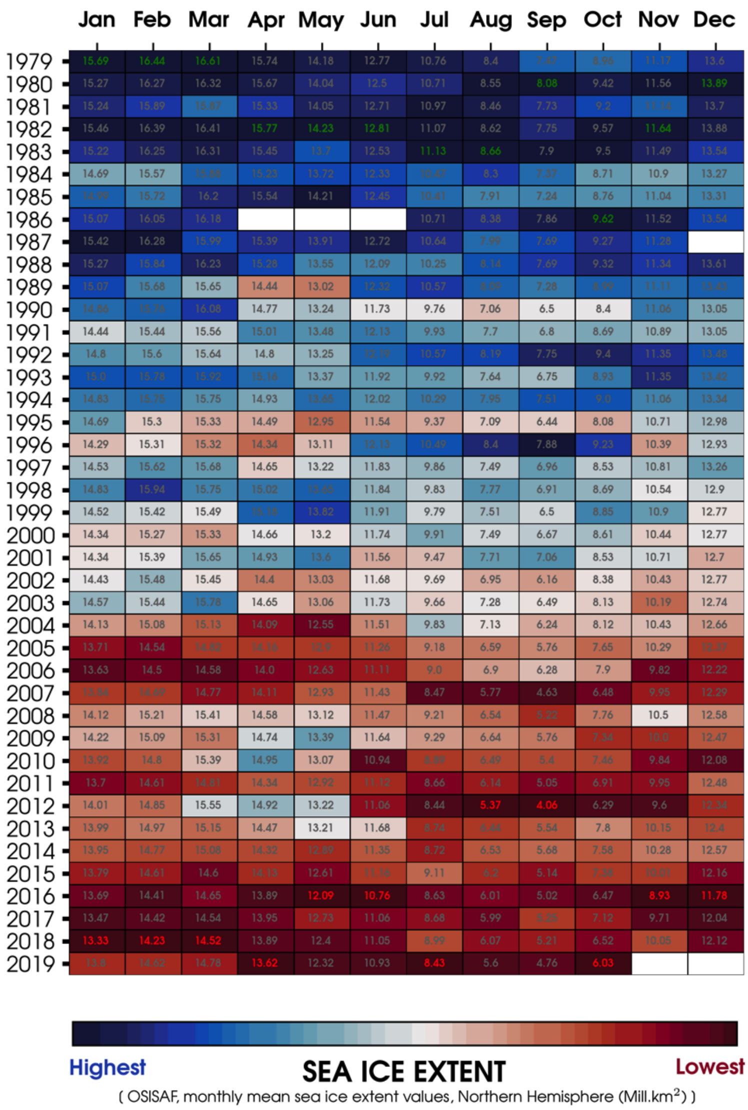


Figure 10: *The figure shows how the monthly mean values of the extent of Arctic sea ice have developed since 1979 until October 2019. The extent of the sea ice is calculated on the basis of data from OSI SAF (OSI 450), temporary climate data registration ICDR, OSI-430-b and a Near-Real-Time (NRT) product. The monthly record-high melting values are shown in red.*