

Polar Portal Season Report 2020

2020 was once again a warm year in the Arctic. While temperatures were close to normal in the western Arctic and in Greenland in particular, it was unusually warm in the eastern region of the Arctic and especially in Northern Siberia.

It was a warm year in the Arctic, but there were huge regional differences. In an otherwise more or less normal year, the last of the ice shelves, which otherwise floats on the sea but is connected to a glacier in Canada, collapsed. Further to the east, it was much warmer, and the Svalbard island group saw record high temperatures. Furthermore, high temperatures in Siberia predominated throughout almost the entire year, which led to numerous forest fires. The extent of the Arctic sea ice was very low again in 2020. And although no overall record was set, new monthly records for low coverage of sea ice were set in both July and October.

In spite of notable temperature extremes in large parts of the Arctic, the season in Greenland in 2019/2020 was relatively normal in terms of the surface mass balance of the Ice Sheet. However, calving of icebergs from outlet glaciers, was large in comparison with the satellite observations that are available since 1979.

During the first 11 months of 2020, the eastern Arctic stood out as a region with extreme and sustained temperature anomalies compared to the long-term average. This applies to both the state of sea ice and permafrost as well as temperatures and wildfires. As an example, Figure 1 shows the temperature anomalies from the 1981-2010 mean in the ERA5 reanalysis for November 2020.

During the winter of 2019/2020, the state of the weather was defined by a powerful positive phase of the so-called Arctic Oscillation, which is an expression of the variation in the air pressure north of the 20°N.

This means that large parts of Europe, most of northern Asia and north-eastern Siberia

had temperatures well above average. In Alaska, on the other hand, temperatures were somewhat below average. These patterns dominated the majority of the season.

During the course of 2020, there have been many forest fires in the Arctic – however, with major regional differences. The area north of the Arctic Circle saw the highest number of forest fires in 18 years, measured in terms of thermal radiation and CO₂ emission.

Most forest fires were concentrated in the eastern part of Arctic Siberia, which was also drier than normal.

Regional reports from eastern Siberia indicate that the season for forest fires began earlier than normal and that the season also came to a close later in some regions, leading to long-term damage to ecosystems. In contrast, significantly fewer forest fires than normal were reported in Alaska, Yukon and northwest Siberia.

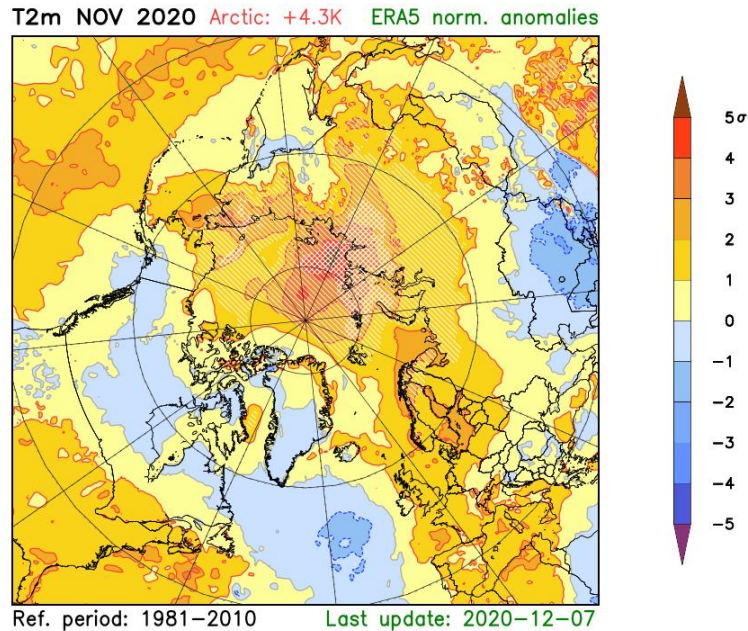


Figure 1: Temperature anomalies in the ERA5 reanalysis for parts of the northern hemisphere. Colours: Anomalies expressed as standard deviations from the 1981-2010 mean. Hatched: temperature anomalies from this mean value greater than 5°C. Double hatched: anomalies greater than 10°C.

From January onwards, a large part of Arctic Siberia exhibited temperature anomalies of at least 3°C compared to the average 1981-2010. Central coastal areas had temperature anomalies of more than 5°C in relation to average values. North of the Arctic Circle, a new temperature record was set in Verkhoyansk, where the temperature peaked at 38°C on 20 June 2020 during a prolonged heatwave. Elsewhere in the Arctic, very high temperatures were also measured. The warm conditions culminated in November, when temperature anomalies of more than 10°C were observed in the section of the Laptev Sea off the coast of the area of land which had the greatest temperature anomalies. The extent of the sea ice was especially

low along the Siberian coastline, and the Northeast Passage was ice-free from July through to October. The high temperatures were not limited to dry land, however. A “marine heatwave” affected large areas of the Arctic Ocean north of Europe and Asia (see Figure 1). In Greenland, the Ice Sheet lost around 152 gigatonnes (Gt) of ice, when both melting from the surface and calving of icebergs from glaciers (the total mass balance) are taken into account. This means that the Ice Sheet is continuing to lose ice – although at a slower rate than was the case in 2019. One gigatonne is one billion tonnes, which corresponds to one cubic kilometre of ice.

In the following, we will look at the most important results monitored in the Arctic in 2020:

- 2020 – a year with an average degree of melting of the Ice Sheet.
- Limited mass loss from calving of icebergs.
- Mass loss in the west; limited growth on the eastern part of the Ice Sheet.
- Ice Sheet whiter than in previous years.
- Second-lowest sea ice minimum in 40 years; records set in July and October.

2020 – a year with an average degree of melting of the Ice Sheet

Changes to the mass of Greenland's Ice Sheet reflect the combined effects of the surface mass balance (SMB), which is defined as the difference between snowfall and run-off from the Ice Sheet, and which is always positive over the course of a year, and the loss of mass at the coast as a result of calving of icebergs and melting of glacier tongues that meet the sea.

The surface mass balance, which is an expression of the isolated growth and melting of the surface of the Ice Sheet, is monitored via actual measurements (PROMICE stations from GEUS) and computer simulations. The Danish Meteorological Institute (DMI) per-

forms daily simulations of how much ice or water the Ice Sheet accumulates (through snowfall) or loses (through run-off). Based on these simulations, an overall measurement of how the surface mass balance develops across the entire Ice Sheet is obtained (Fig. 2). At the end of the season (31 August 2020), the surface mass balance's net result was 349 Gt. This is very close to the 1981-2020 average, which is 341 Gt. As a point of reference, the lowest calculated SMB was just 38 Gt in 2012.

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, while melting causes the Ice Sheet to lose mass. In relation to the total mass balance, the surface mass balance says something about the contribution on the surface of the Ice Sheet – i.e. excluding what 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.

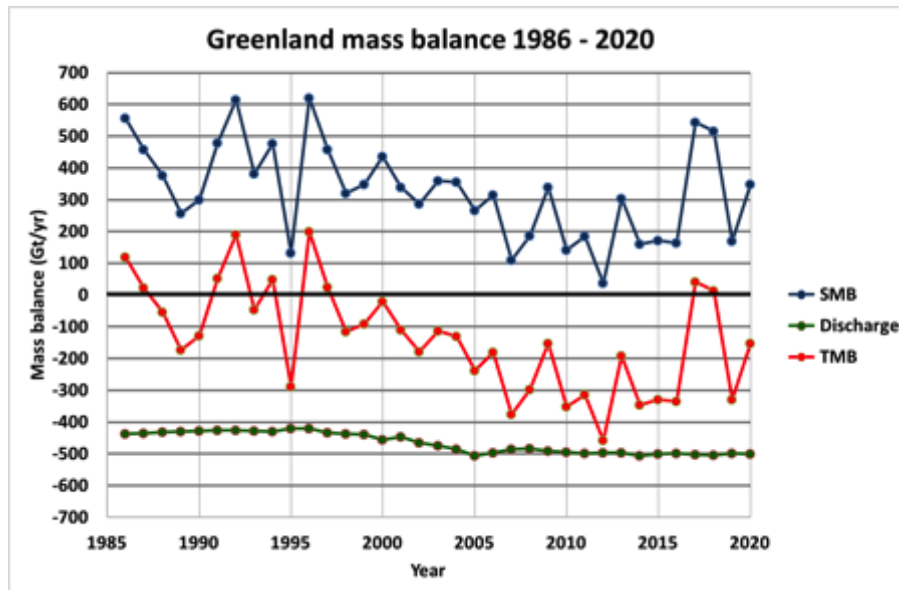


Figure 2: Elements in the total mass balance of Greenland's Ice Sheet 1986-2020. Blue: Surface mass balance (SMB). Green: Loss of ice in the form of calving of icebergs and melting. Red: Total mass balance (TMB = surface mass balance less loss of ice (blue + green)).

Figure 2 shows time series of surface mass balance, loss of ice and total mass balance, which is the sum of the first two. There is a very large variation from one year to the next in SMB, but a much smaller variation in loss of ice from melting and calving of icebergs.

The total loss of ice amounts to 4261 Gt for the period April 2002 until August 2019. This quantity of ice can be compared against the measurements from the GRACE satellites. GRACE, and its successor GRACE-FO (GRACE Follow-On), measure the small changes in the gravitational field that are the result of changes in quantities of ice. This provides an independent measure of the total mass balance. This data shows that Greenland's Ice Sheet lost around 4200 Gt ice from April 2002 until August 2019. This loss has contributed to a rise in sea level of around 1 cm, which is consistent with the calculated mass balance from SMB and melting.

The 2019-20 melting season on the Ice Sheet began on 22 June, which is 10 days later than the mean date for the period 1981-2020. The onset of the melting season is defined as the first of three days in which there is continuous melting on more than 5 % of the area of the Ice Sheet. As in previous years, there was a loss along the west coast of Greenland and growth along the east coast. In the middle of August, a number of unusually severe storms resulted in four times as much precipitation as normally falls in one month in West Greenland. This precipitation fell primarily as snow. This meant a temporary halt in the net loss of ice, which was crucial in terms of reducing the degree of melting. This situation was very different to the previous year, 2018-19, which had long periods of high pressure and sunshine, which resulted in a marked increase in the degree of melting in the summer.

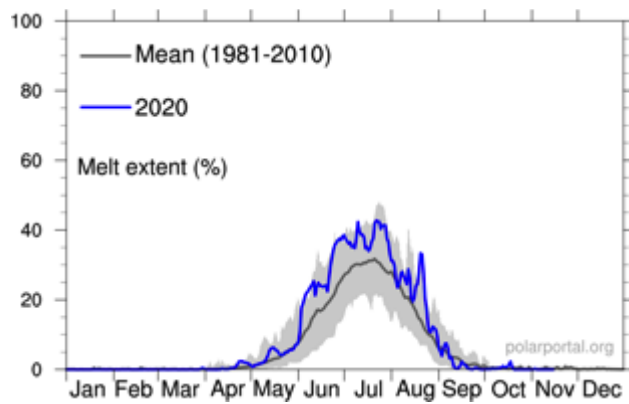


Figure 3: The graph shows on a daily basis how great a percentage of the total area of the Ice Sheet has seen melting, defined as minimum 1 mm melting at the surface. The blue line indicates the degree of melting in 2020, whilst the dark grey curve shows the mean value for the period 1981-2010. The light grey band shows the differences from year to year, although the highest and lowest daily values are discounted. As can be seen, the blue line remains above the mean value throughout almost the entire season, although within the maximum values observed earlier.

Observations from almost all of the 18 PROMICE weather stations on Greenland's Ice Sheet indicated that net ablation was very close to average for the period 2008-2020. The majority of locations experienced

negative anomalies, i.e. relatively low ablation, with the exception of the north of Greenland. All ablation observations lie within a standard deviation from the mean.

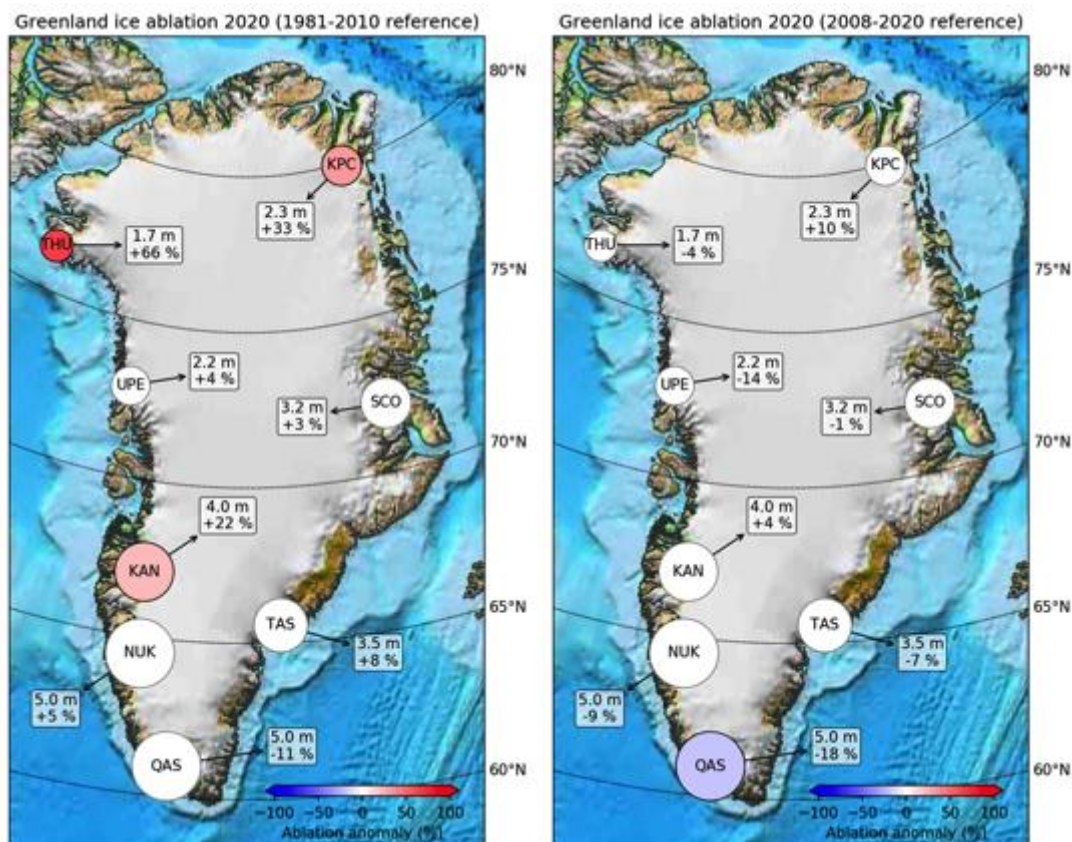
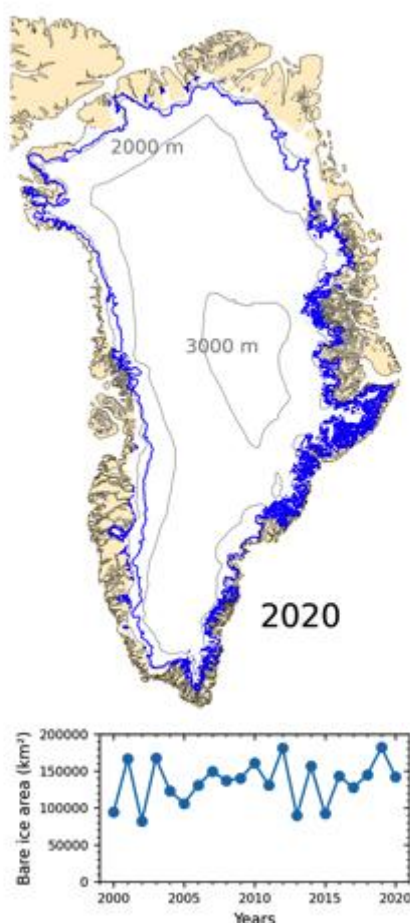


Figure 4: The maps show the net melting anomalies for 2020 at the low-lying PROMICE weather stations seen in relation to the periods 2008-2020 (left) and 1981-2010 (right) according to Van As et al. (2016).



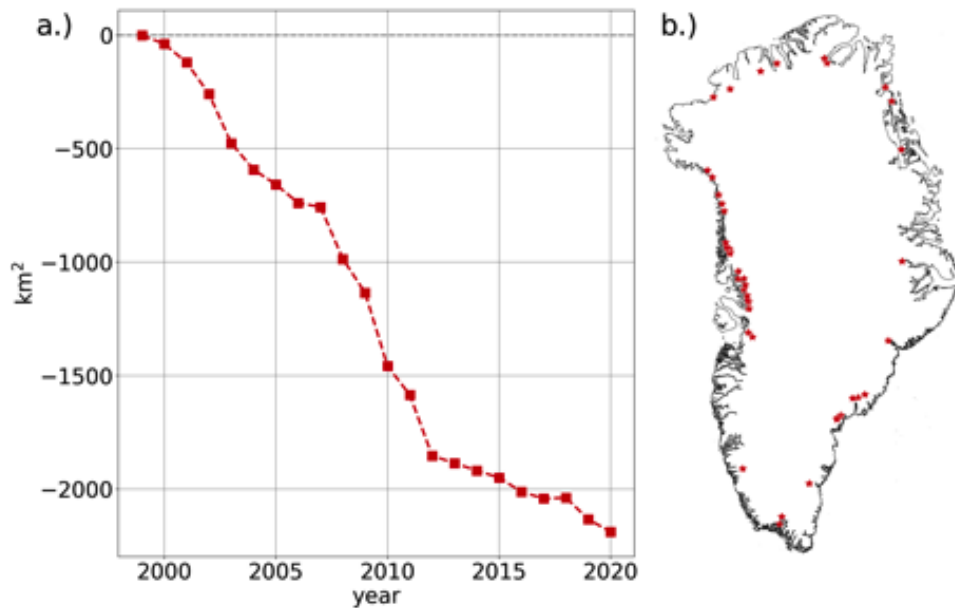
Melting from the Ice Sheet is also measured directly at selected locations under the PROMICE project. Observations at the majority of the 18 weather stations under the PROMICE project revealed a net loss of ice and snow that was close to average for the period 2008-2020. This data is consistent with the observed temperatures. The summer temperatures in June, July and August were all within a standard deviation of the mean temperatures during the period 2008-2020. Of all the measurements during the period January-August 2020, 20 % of the monthly temperatures were more than one standard deviation below average, whilst 7 % were more than one standard deviation above average for the period 2008-2020. Compared to the period 1981-2010, the temperatures for June, July and August were only above average at the weather stations at Kronprins Christian Land (KPC), Pituffik (THU), SCO and KAN.

Figure 5: The map shows the position of the snow-line at the end of the melting season, i.e. at higher elevations it is snow, whilst further down it is bare ice. The graph shows how large the area of bare ice is. The area of ice in 2020 is greater than the average for 2000-2020.

Limited 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. Each year, changes in the area of the 47 broadest Greenlandic tidal glacier fronts are surveyed when they reach the end of their melting season. This is carried out by means of optical satellite images according to Andersen et al. (2019, updated). The change in area in 2019/2020 amounted to a net loss of area of

55.4 km² compared to an average annual loss of 99.5 km² for these glaciers since 1999 (Figure 6a). Of the 47 glaciers that were measured during the course of 2019/2020 (Figure 6b), 20 retreated, 12 increased and 15 were stable within ± 0.2 km². These figures should be viewed in the context of the much higher loss of area and almost record high melting year in 2018/2019, when only 6 glaciers increased, 29 retreated and 12 remained stable.



Figures 6 a & b: The graph shows the total change in area of 7 of the largest outlet glaciers in Greenland. It shows that since 2019 these glaciers have lost an area of 55.4 km^2 .

PROMICE also assesses iceberg production based on data from the Sentinel-1A and Sentinel-1B satellites. The satellites thus 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 31 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.

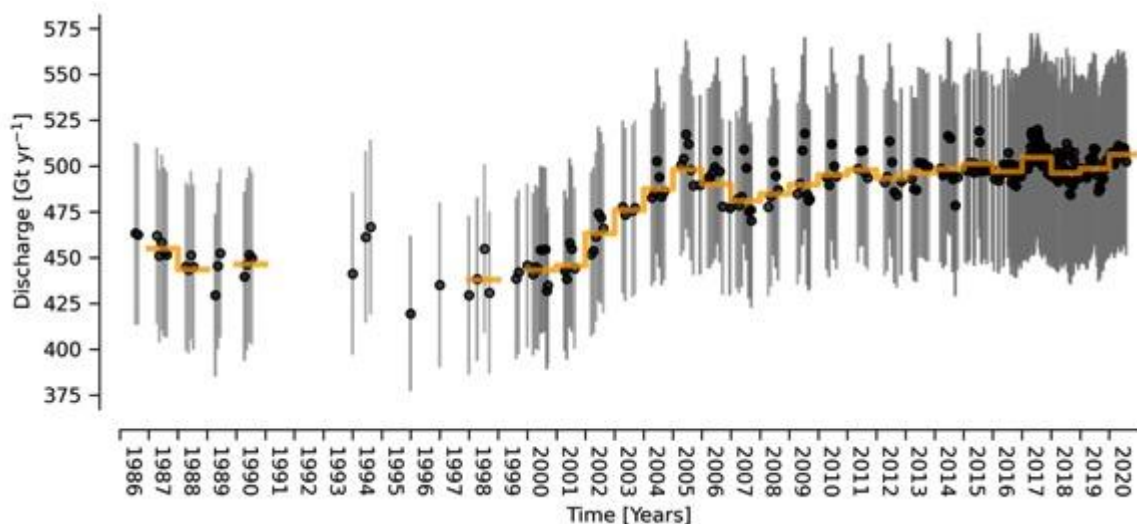


Figure 7: Time series of calving from Greenland's Ice Sheet. The dots show when the observations were made (limited to $> 50 \%$ cover). The stepped orange line shows the annual average (limited to three or more observations per year).

Mass loss in the west; limited growth on the eastern part of the Ice Sheet

The GRACE satellites and their successors, GRACE-FO, measure small changes in the Earth's gravitational field, such that changes in the mass of the Ice Sheet can be determined. Following exhaustive scrutiny and quality control, it has been determined that GRACE and GRACE-FO are consistent during the period in which there was no data (end-2017 until mid-2018). The time series is now available until the end of August 2019, whilst the latest measurements are being processed and are not yet available.

value per year during the period January 2017 until December 2019 based on data from the Sentinel-3A satellite. Sentinel and its predecessor, Cryosat-2, are so-called radar altimeter missions. The satellite emits a radar signal which is reflected from the surface of the Earth back up to the satellite. It can be clearly seen that close to many of the large glaciers the Ice Sheet has become considerably thinner, but large areas are also observed in which the ice has become thicker due to snowfall.

The map in Figure 8 illustrates the changes in the thickness of the Ice Sheet as an average

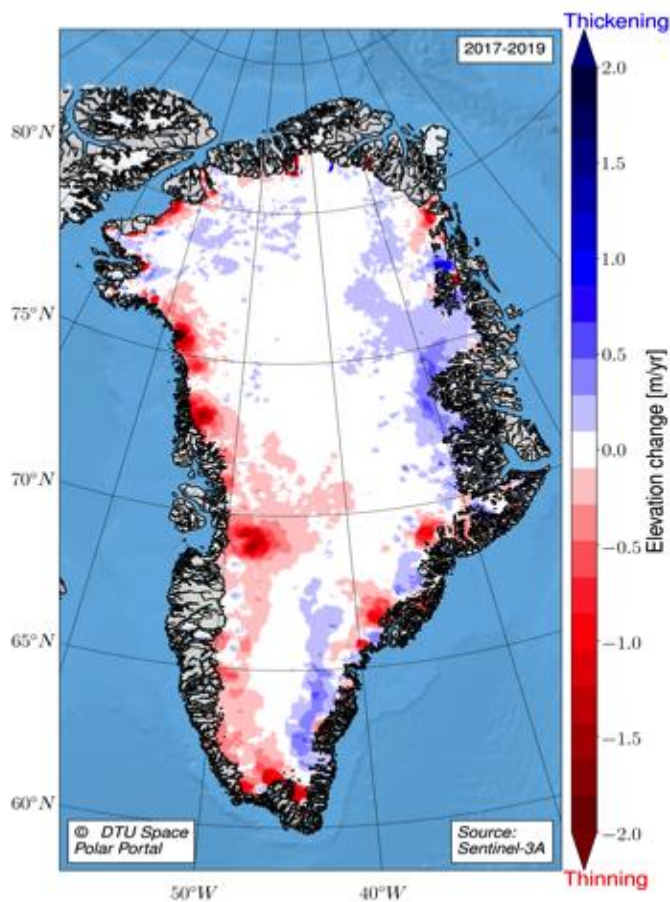


Figure 8: The map shows elevation changes per year based on Sentinel-3A data from January 2017 until December 2019.

Ice Sheet whiter than in previous years

The winter at the beginning of the Greenlandic annual cycle in 2019-20 (1 September – 31 August) was slightly drier than normal, although not characterised by almost no precipitation, as was the case in 2018-19.

The Ice Sheet began its melting season on 22 June, which is around 10 days later than average. Fresh snow at the end of May and beginning of June delayed the onset of the melting season, in contrast to the high degree of melting at the same time last year.

July was a relatively warm and sunny month in Greenland, and the areas that experienced melting had high – though not record high – melting figures.

As mentioned earlier, several unusually severe storms in the middle of August resulted in four times as much precipitation than normally falls in a month in West Greenland. This precipitation fell primarily as snow, which temporarily halted the net loss of ice. These storms probably played a crucial role

in reducing melting. Fresh new-fallen snow is light and white and reflects more energy-rich sunlight than old and darker snow and bare glacier ice that has undergone a summer with a high degree of melting.

These correlations are highlighted on the maps in Figure 9. The maps illustrate the albedo, which is a measure of how well the surface reflects sunlight. The map on the left shows the albedo in August 2020, whilst the map on the right shows the albedo in August 2019. Each map is compared to the average for the period 2000-09. The blue colour indicates a higher than average albedo, i.e. the reflection of sunlight in 2020 was higher than average. Conversely, the red colour indicates a reflection of sunlight below average in 2019. The albedo anomalies in June were minor, with the exception of an intense dark anomaly across the Humbolt glacier in the northwest. The greatest degree of melting occurred in July, where the albedo anomaly was dark across most of the Ice Sheet.

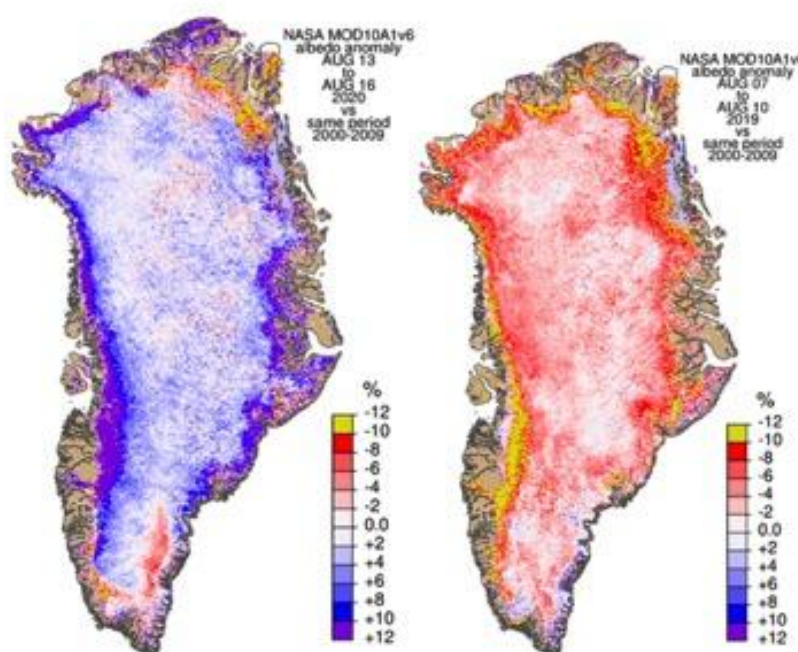


Figure 9: The maps show the albedo for 2020 (left) and 2019 (right) respectively in the middle of August compared to the average for the period 2000-09. The colours indicate that on average the Ice Sheet reflected more sunlight in 2020 than in 2019.

Permafrost

Due to COVID-19 related restrictions, it was not possible to conduct the planned visits to the permafrost monitoring stations in 2020.

Soil temperature data for the 2019/2020 season will be made available in the Polar Portal's 2021 Season Report.

Second lowest sea ice minimum in 40 years – records set in July and October

When the temperature in the Central Arctic rises above freezing point, the sea ice begins its melting season. This occurred on 11 June 2020, which is just around the point in time that is now referred to as “the new normal”. This is an expression of the average onset of the sea ice’s melting season compared to an average for the last 13-15 years.

During the course of the year there were large variations in the extent of sea ice. This was due in particular to unusually early melting and late freezing at the far end of the Arctic. The extent of the sea ice was thus smaller than ever before in April, July and October in relation to these months in previous years.

As outlined above, it was warm in large parts of the Arctic in 2020. The Arctic sea ice reached its annual minimum extent on 15 September, which is five days later than the average date for 1981-2010 (10 September). The sea ice thus also began to refreeze a little later than normal, and was further hindered by the fact that the water temperature around the ice was still 2-4 degrees warmer than normal, just like in 2019.

The ice mass fell to just below 4.3 million km². This is the second lowest value since observations began in 1979. In July and October new record minimums were observed for these months. The extent of the ice in 2020 is thus definitively lower than in 2007, 2016 and 2019, which to date have shared

the position for the second lowest level since observations began at the end of the 1970s.

The low minimum extent of the sea ice in 2020 has only been exceeded in 2012, which still has the record of the smallest extent of sea ice measured so far. When the melting of sea ice near the North Pole began in the middle of July, there were no signs that records would be set during the course of the summer. However, the heatwave in Siberia melted so much ice that the Northeast Passage remained open.

Normally, ice melts at the North Pole at a rate corresponding to twice the land area of Denmark per day in the middle of July. However, the daily melting rate in July this year was almost three times the area of Denmark. The sea areas north of Siberia experienced the greatest loss of ice.

Spring 2020 saw a significantly lower extent of ice than normal, with extremely large quantities of ice melting during the summer. As a result, July hit a historic minimum for the season. Furthermore, at the beginning of September the melting rate for the season was also historically high. Sea ice is important in terms of the climate because it is light and thus has a high albedo. The smaller the extent of 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 late shift from thaw to frost, combined with the smaller extent, has

meant once again in 2020 that the Sun has been able to heat up the water surrounding the ice, with the temperature of the surface water at many places in the Arctic up to 4°C warmer than normal for the time of year. This has the effect of driving a vicious circle. When the coverage of ice is lower, the sea-water is heated up to a greater extent. Warmer surface water leads to greater melting of the ice and delays the onset of refreezing in the autumn because the warm water has to be cooled down before it can freeze. When the ice freezes later, it cannot acquire the same thickness as it would have done if it had had more time. This makes the ice less

robust.

The combination of a smaller extent and thinner ice has also led to more than 50 % of the volume of the Arctic sea ice disappearing during the last 40-50 years. The trend towards less and less sea ice can be seen in tangible terms by the fact that certain regions of the Barents Sea and the Davis Strait now have open water seasons that are four months longer than at the beginning of the 1980s.

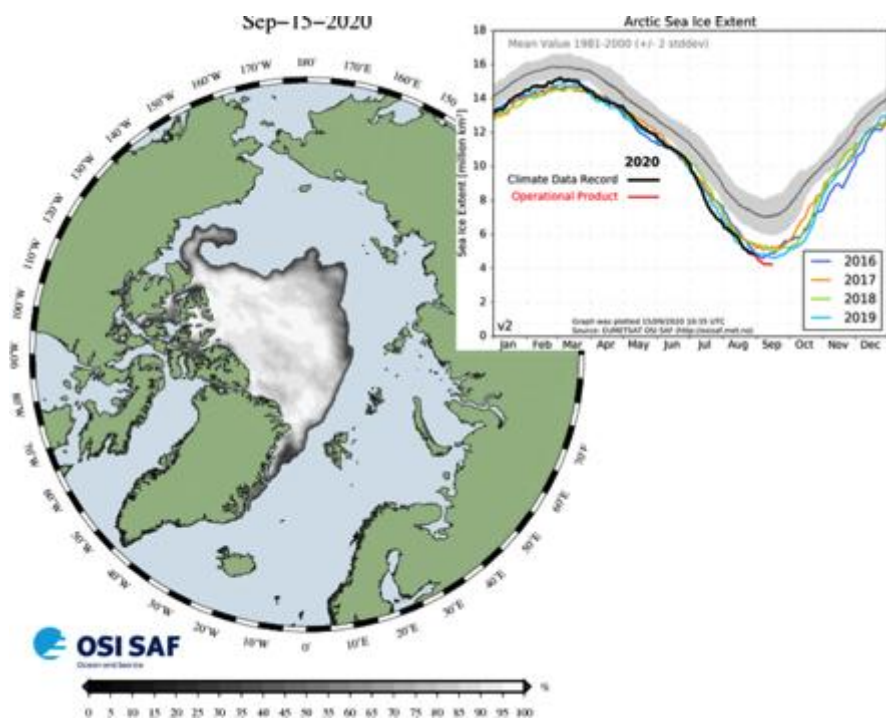


Figure 10: DMI's graph of the extent of the sea ice from 15 September 2020, which was the date of the season's lowest extent of coverage. The map and graphical representation are based on EUMETSAT's OSI SAF ice concentration calculations and illustrate the extent of sea areas that have more than 15 % ice cover. Graphics from Polar Portal.

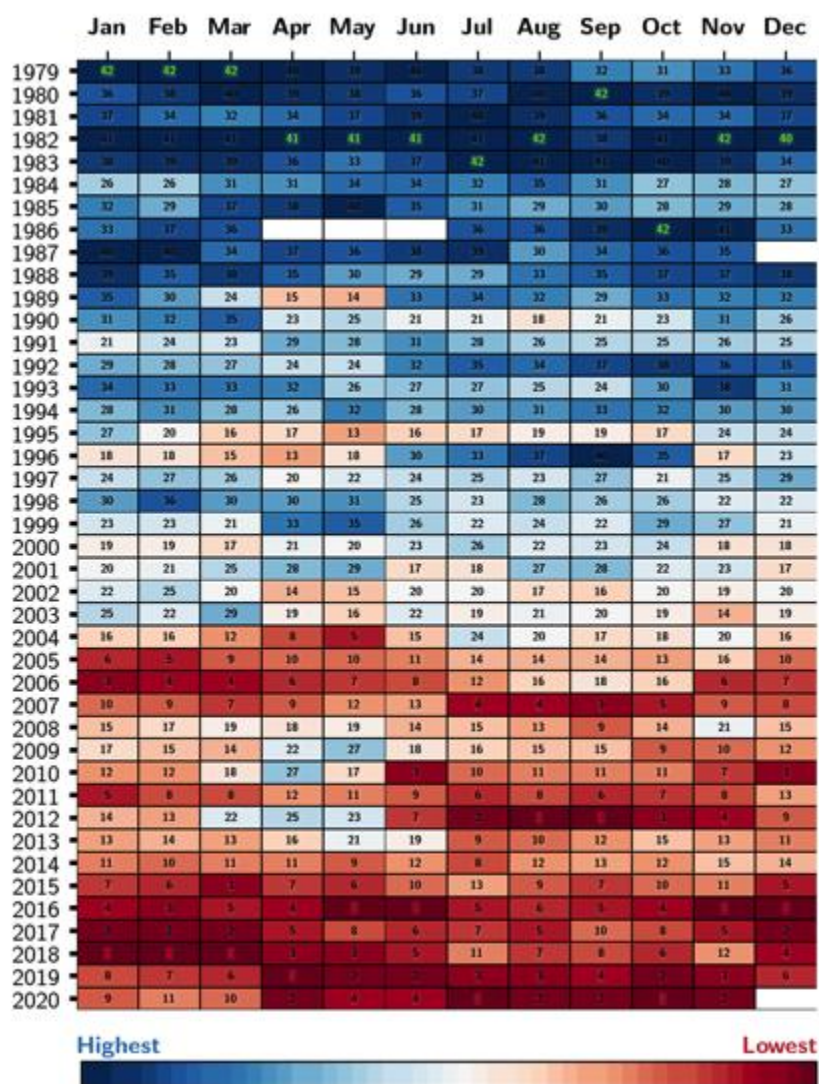


Figure 11: The figure shows how low extents of the sea ice in the Arctic are ranked month by month and year since 1979. The figures in the boxes indicate the extent of the sea ice ranked from the bottom (www.ocean.dmi.dk). The extent of the sea ice is calculated on the basis of data from OSI SAF (OSI 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.

Extent of the Arctic sea ice

The extent of the Arctic sea ice is analysed by both the American NSIDC and the European EU-METSAT – 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 km² since the end of the 1970s. This corresponds to more than twice Denmark's total land area.