POLAR PORTAL
MONITORING ICE AND CLIMATE IN THE ARCTIC

Polar Portal Season Report 2015

The melting season 2015 on the Greenland Ice Sheet ended with a larger than normal surface melting, despite the fact that the beginning of the summer was cold and snowy, and that the melting season started late. The summer on Greenland was relatively cold but featured a heat wave in July in the north and northwest. In 2015 the Arctic sea ice reached its fourth lowest extent since 1979.

The most important results of climate monitoring in the Arctic in 2015 are:

- The latest beginning of the melting season on the Greenland Ice Sheet since 1991
- The Greenland Ice Sheet contributed about 0.5 mm to sea-level rise
- The surface mass balance of the Greenland Ice Sheet was lower than the average for 1991-2013
- The albedo of the Greenland Ice Sheet from June to August was higher than the average for 2000–2009
- The glaciers lost a smaller area than the average for 1999-2010
- Sea ice continued to decrease in thickness and reached its fourth lowest extent since 1979

Latest beginning of the melting season since 1991

In 2015, melting on the surface of the Greenland Ice Sheet was larger than normal, despite the late start and short duration of the melting season. The melting season began on 12 June, which is the latest start over the calculation period (since 1991). For comparison, the earliest beginning of the melting season was 29 April 1996. On the other hand, 2015 featured some short, intense warm periods in July, which brought the melting up above normal. Thus, there is no certain connection between the starting date and the amount of melting of the surface.

Abnormally cold conditions and large amounts of snow over large parts of Greenland explain the late start of the melting season. In contrast, Siberia and Alaska experienced record high temperatures during spring, and even the North Pole had a “heat wave” in April.

The melting season was short, finishing at the end of August, when the season abruptly ended with a cold spell. Thus, on 27 August a low-temperature record of −39.6° C was set at DMI’s station on Summit. That is the lowest temperature measured at that station in the month of August. The previous August record is from 2004, when the temperature was −39.2° C.

As part of the PROMICE (Programme for Monitoring of the Greenland Ice Sheet) project of GEUS, temperature and other meteorological parameters are measured at stations along the margin of the Greenland Ice Sheet. In the period from January to August, many stations recorded monthly averages that were considerably lower than the corresponding averages since 2007, and only a few were warmer than average. The summer period from June to August was relatively warm in the north and northwest, with July records set at the stations near Kronprins Christian Land (KPC in Figure 2a), Pituffik (THU) and Upernavik (UPE). On the other hand, winter, spring and summer were relatively cold in the southern half of the ice sheet. This pattern was reflected in both the surface mass balance and the albedo, as described below.

The Greenland Ice Sheet contributed about 0.5 mm to sea-level rise

The cumulative loss of mass (total mass balance) in the period from August 2014 to August 2015 was 176 Gt, corresponding to a global sea-level rise of 0.5 mm (see Box). This means that 2015 saw 30% less mass loss than the average of about 250 Gt (0.7 mm sea-level rise) since 2003. As seen in Figure 1, the loss of mass from the Greenland Ice Sheet again follows approximately the same trend as before the record year 2012, when there was a record large surface melting and a large cumulative loss of mass, corresponding to a sea-level rise of 1.4 mm.

In Figure 1 it can also be seen that the annual minimum typically occurs in September, and occasionally in August. This means that September should be included in the current melting season. However, the data for September are not yet available, and thus the figures given here are for August to August. The calculated mass loss for this year based on gravity data from the GRACE satellites thus includes September from the 2013/2014 melting season but not September in the 2014/2015 season. It nonetheless still represents a full year's loss and gives a good indication of the cumulative contribution of the melting season 2014/2015.

In previous seasonal reports, two estimates of total mass balance were given. One was, as here, based on the gravity measurements from the GRACE satellites. The other was based on a statistical relationship between GRACE data and satellite observations of albedo from MODIS. However, since then doubts have been raised concerning this relationship and, therefore, this is not included in this year's seasonal report.

Mass loss and sea-level increase

Satellite observations with GRACE since 2002 indicate that the Greenland Ice Sheet has lost a mass of approximately 250 Gt per year over more than a decade. One Gt is 1 billion tonnes and corresponds to 1 cubic kilometer of water. A mass loss of 100 Gt corresponds to a sea-level rise of 0.28 mm. Thus, a mass loss of 250 Gt per year corresponds to an annual sea-level rise of about 0.7 mm, and the total mass loss over the GRACE period (since 2002) corresponds to a contribution to sea-level rise of about 1 cm from Greenland.

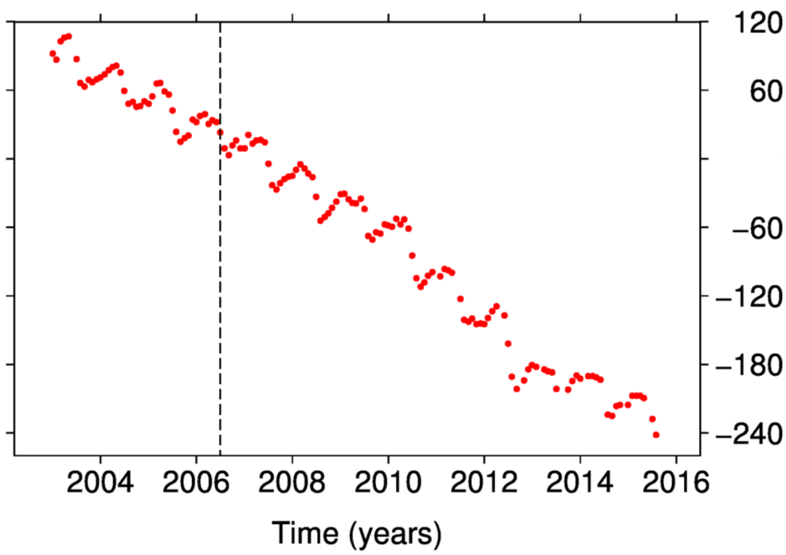

Figure 1. Mass loss of the Greenland Ice Sheet as measured by the GRACE satellites, and calculated by DTU-Space. The total mass loss again follows approximately the trend from before the record year of 2012, when there was an unusually large melting. The ice sheet is still losing mass, but not as dramatically as in the 2012 season.

The surface mass balance of the Greenland Ice Sheet was lower than the average for 1991-2013

The surface mass balance is an expression of the isolated growth and melting of the surface of the ice sheet. Precipitation causes an increase in the mass of the ice sheet, while melting diminishes it. In relation to the total mass balance reported above, the surface mass balance indicates the contribution at the surface and this excludes what is lost when glaciers calve off icebergs and melt in contact with the warm ocean water. The surface mass balance has been decreasing since the 1990s.

The surface mass balance is monitored using both actual measurements and computer simulations.

Melting from the ice sheet is measured directly under the PROMICE project, and was in 2015 determined by 19 measurement stations with two to three in each region (Figure 2a). The farthest northwest station at Pituffik (THU) registered somewhat larger melting than the average for 2011-2015, while all the other stations registered lower than average melting (Figure 2a). This was especially clear in the south and southwest at stations near Qassimiut, Nuuk and Kangerlussuaq. The largest melting was 5.1 m of ice, and this was registered at the station QAS_L near Qassimiut. That is less than the record melting of 9.3 m in 2010 and also less than the average for 2001-2015, which was at 6.4 m at this station.

DMI performs daily simulations of how much ice or water is released or accumulated on the ice sheet surface. Based on these simulations, an overall measure of the development of the surface mass balance can be obtained (Figures 2b and 2c). The melting in the period from June to August 2015 was about 330 Gt, while combined over the entire year from September 2014 until August 2015 about 220 Gt was added to the ice sheet surface (snowfall minus melting). This is somewhat lower than the normal of about 290 Gt for the period 1990-

2013, but very far from the record low of about 0 Gt in 2012.

When the melting season in 2015 finally began, melting gained speed quickly. This occurred, among others, owing to the warm weather in the month of July, which was particularly pronounced in northern Greenland. Thus, once again a heat record was registered this year. It occurred in Qaanaaq, where the temperature was measured at 20.4° C on 8 July. Over a six-day period, the surface of ice sheet lost over 10 Gt every day, and in the week from 5 to 11 July the ice sheet lost approximately 30% of the amount that normally melts over an entire melting season. A similar period with intense melting occurred at the end of July.

Both measured and simulated patterns showed intense melting in the north and lesser melting in the south. This was strengthened by the fact that the previous winter provided less snow than normal in the north and more in the south (overall the winter snowfall added about 20 Gt more than the average for 1991-2013). The result is seen in Figure 2, with a surface mass balance that is larger than normal in the south and less than normal in the northwest.

The albedo of the Greenland Ice Sheet from June to August was higher than the average for 2000–2009

During the past decade, using MODIS data researchers at GEUS have recorded a general decrease in the albedo (reflection of sunlight by the ice) of the ice sheet, whereby 2012 had so far the ”darkest summer” overall during June to August.

In 2015 the average summer albedo was also below the average for 2000-2009 in the northwestern part of the Ice Sheet, but above the average in the southwestern part of the Ice Sheet. In July, when high temperatures and large melting were recorded especially in the northwest, the overall albedo for the entire Ice Sheet was 68.1%, which is one of the lowest average albedos measured. However, over the entire summer period, the albedo was considerably higher. That may result both from the large amounts of snow during the preceding winter and also that snow fell early in August.

The low albedo in July is associated with the intense melting through a self-reinforcing effect: when the albedo is low, more energy is absorbed from the sun, and the melting goes more rapidly. At the same time, the melting contributes to further reducing the albedo. This interplay can also be seen by comparing the maps in Figures 2 and 3. They show low surface mass balance and albedo in the northwest and high surface mass balance and albedo in the southwest.

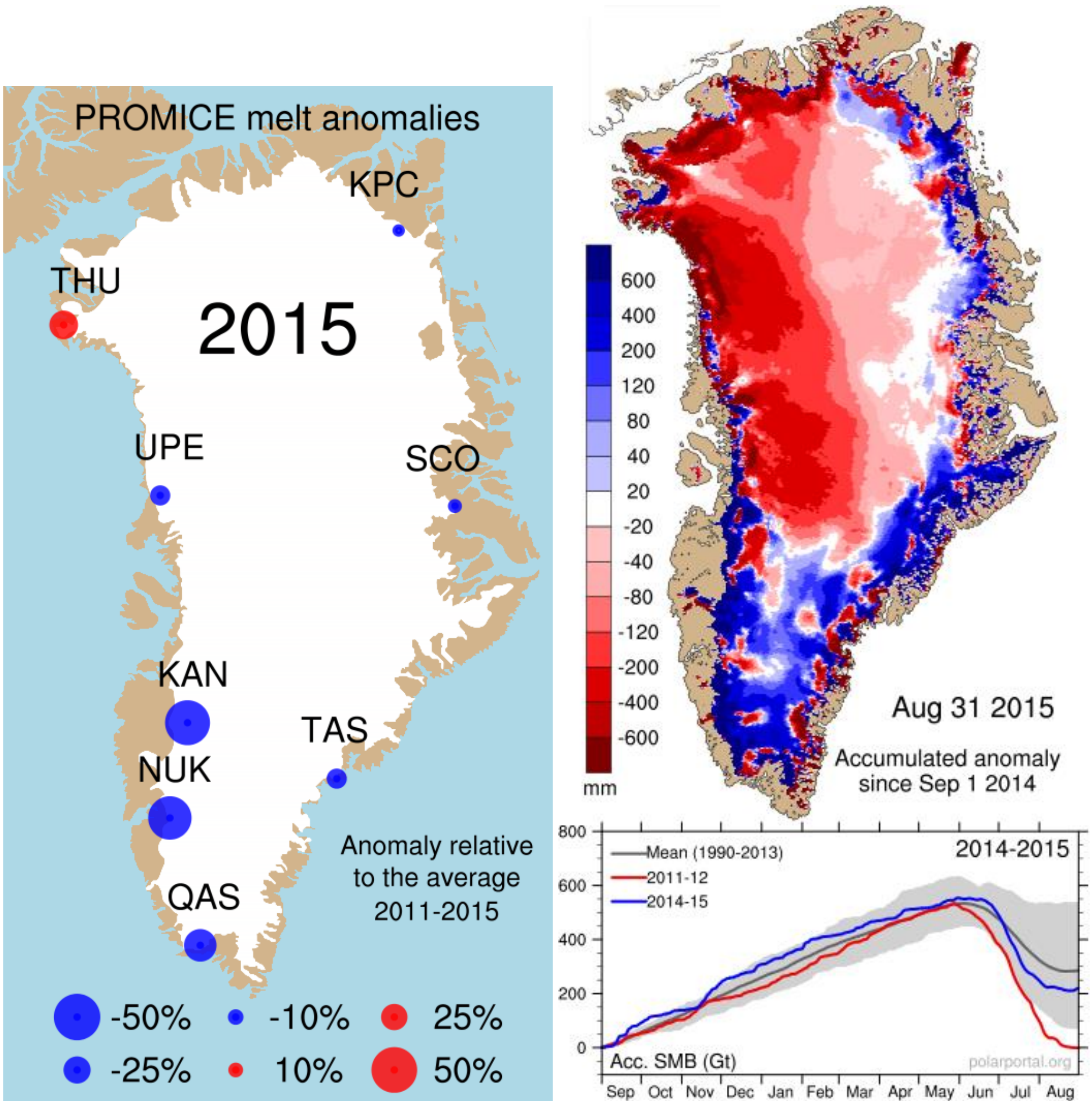

Figure 2.

a) The map on the left shows where the ice sheet melted more or less (in percent) in 2015 in relation to the average for the period 2011-2015. The source is PROMICE measurements of melting for each of the regions: Kronprins Christian Land (KPC), Ittoqqortoormiit (SCO), Tasiilaq (TAS), Qassimiut (QAS), Nuuk (NUK), Kangerlussuaq (KAN), Upernavik (UPE) and Pituffik (THU).

b) The map on the right shows where more or less mass than normal accumulated from 1 September 2014 until 31 August 2015 in relation to the same period in 1990 to 2013. These data are from the simulated surface mass balance. The blue areas show where more mass than normal has accumulated, while the red areas show where less mass than normal has accumulated.

c) The graph on the lower right shows the overall accumulated surface mass. The blue curve shows the season 2014/2015 and it can be seen that at the end of the season the curve is lower than the grey normal curve, but not outside the normal range, as was the case for 2012 (red curve).

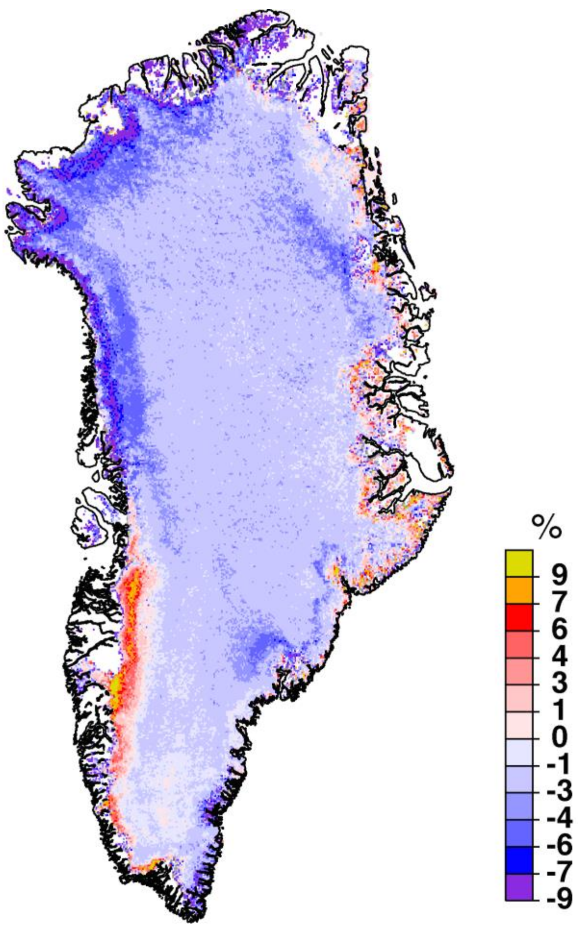

Figure 3. The map shows the percent deviation of the albedo measured by MODIS for June to August 2015 in relation to the same period from 2000 to 2009. The albedo fell under the average in northwest Greenland but over the average in southwest Greenland.

The glaciers lost a smaller area than the average for 1999-2010

Researchers at GEUS have examined satellite images of 45 of the widest glaciers among the 200 glaciers on Greenland that terminate in the sea. In relation to the average during the period 1999-2010, these glaciers lost a much smaller area in the year from mid-2014 to mid-2015.

The 45 glaciers lost 16.2 km^2, while the average loss from 1999-2010 was 119.6 km^2. More than half of the 45 glaciers lost area, but this was somewhat balanced by the fact that 11 of the glaciers increased their area.

The low loss of area occurred in a series with low values during the previous two years, with a loss of 27.6 km^2 in 2012/2013 and 25.9 km^2 in 2013/2014.

Part of the explanation is that the Petermann glacier increased its area by 11.8 km^2 in 2014/2015 and the Kangerdlugssuaq glacier moved 1.7 km forward and increased its area by 10.1 km^2. Other glaciers such as Ryder, Zachariae and Hayes also increased their area by 4.7 km^2, 3.1 km^2, and 1.9 km^2, respectively. The largest retreats occurred for the glaciers Storstrømmen, Humboldt, Upernavik B and Helheim with losses of, respectively, 14.3 km^2, 5.3 km^2, 4.2 km^2 and 3.0 km^2. A large calving event, or a sequence of events, took place between 14 and 16 August and affected an area of at least 6 km^2 at the terminus of Jakobshavn Isbræ.

Recording sea-ice thickness still involves a number of uncertainties

Sea-ice thickness cannot be measured directly, as is the case with the sea-ice extent. Thus, as sea-ice thickness often is calculated based on models it is associated with some uncertainty. Different estimation methods thus produce different results. While DMI's model determined that 2015 had the fourth-lowest volume since 2004, an estimate from another model, the Pan-Arctic Ice Ocean Modelling and Assimilation System (PIOMAS), showed that the minimum ice volume this year was the fifth-lowest in their estimation period since 1979. The years with the four lowest values were 2010 to 2013.

Sea ice continued to decrease in thickness and reached its fourth lowest extent since 1979

In monitoring sea ice, we are interested in both the thickness and the areal extent. Therefore, starting this year, Polar Portal also shows model simulations of daily ice thickness in the Arctic.

Ice thickness is important because it indicates the robustness of the sea ice and whether it is sufficiently thick to be able to survive the summer's melting. The thicker the ice, the more robust it is toward individual warm summers or extreme wind effects. Once the ice has disappeared, it is much more difficult to reform and regain its original thickness.

Satellites and algorithms are being developed to determine the thickness of ice, but particularly for meter-thick ice there are still large uncertainties in the results. As an alternative, to provide daily updates, Polar Portal uses DMI's operational sea and sea-ice model (HYCOM/CICE) to calculate the thickness and total volume.

The total volume of Arctic ice has increased since the record minimum in the summer of 2012. On its own, this is good news for the condition of the sea ice. Nonetheless, the volume of the sea ice still remains under the average for the first half of the 2000s. Even though the ice appears to be regaining some of its stability and strength, it is currently far from being as well-equipped against summers with unusual temperatures and wind conditions as previously.

The HYCOM/CICE modelled minimum ice volume in the summer of 2015 fell to nearly the same level as in 2011. Thus, 2015 experienced the fourth-lowest modelled volume in the period since 2004. The modelled ice thickness became markedly thinner along the northern coast of Greenland and correspondingly along the Canadian Archipelago Sea, which is the most pronounced difference in relation to last year.

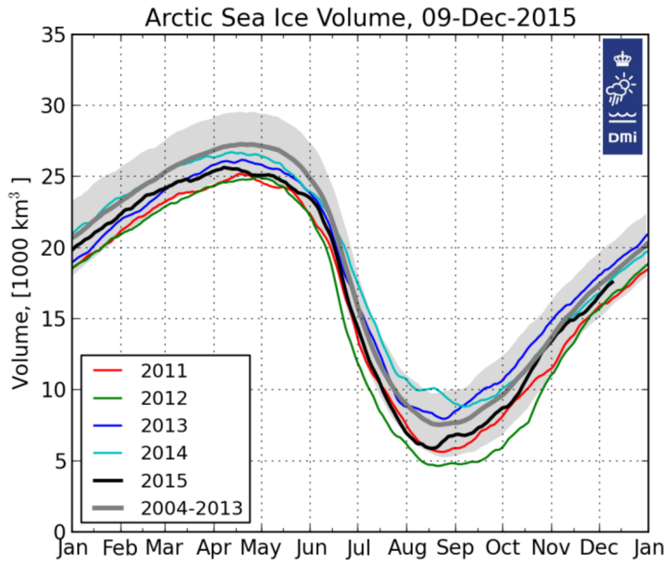

Figure 4. Daily values of the total sea-ice volume in the Northern Hemisphere since 2011 calculated using DMI's operational sea and sea-ice model (HYCOM/CICE).

In relation to sea-ice extent, the Arctic sea ice shrank to it fourth-lowest extent since satellite measurements began in 1978. The nine years with the lowest sea-ice extent are the last nine years. The sea-ice evolution this year is in line with a clear trend during the last 37 years: the Arctic sea ice forms later, melts earlier, and the summer minimum extent is smaller than previously.

This trend is clear in nearly all regions of the Arctic. This means that the number of days with open water is increasing. In the Barents Sea, for example, the season with open water is now three months longer than at the beginning of the 1980s, and in Baffin Bay it is over one month longer. Both the Northeast Passage (the waterway between the Atlantic and the Pacific Oceans north of Europe and Asia) and the Northwest Passage (the waterway between the Atlantic and Pacific Oceans north of North America) are open this year, even though the deep passage through the M'Clure Strait is still partly ice-covered.

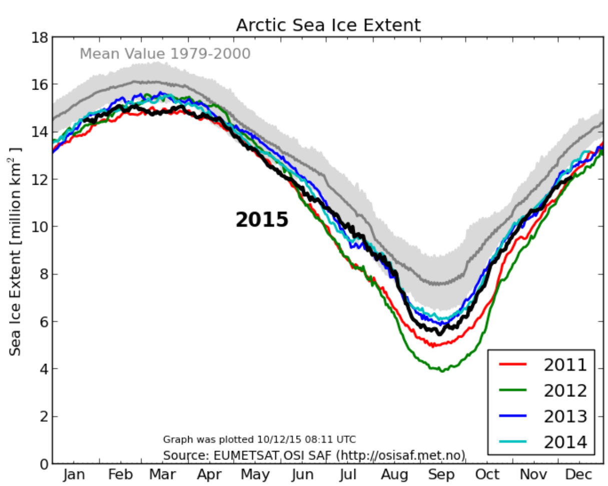

Figure 5. Daily values of the total area of sea ice in the Northern Hemisphere since 2011.

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