Met Office

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Alex West, Jeff Ridley and Ed Blockley

Briefing on the state of sea ice during winter 2016-17

Arctic sea ice

Executive summary

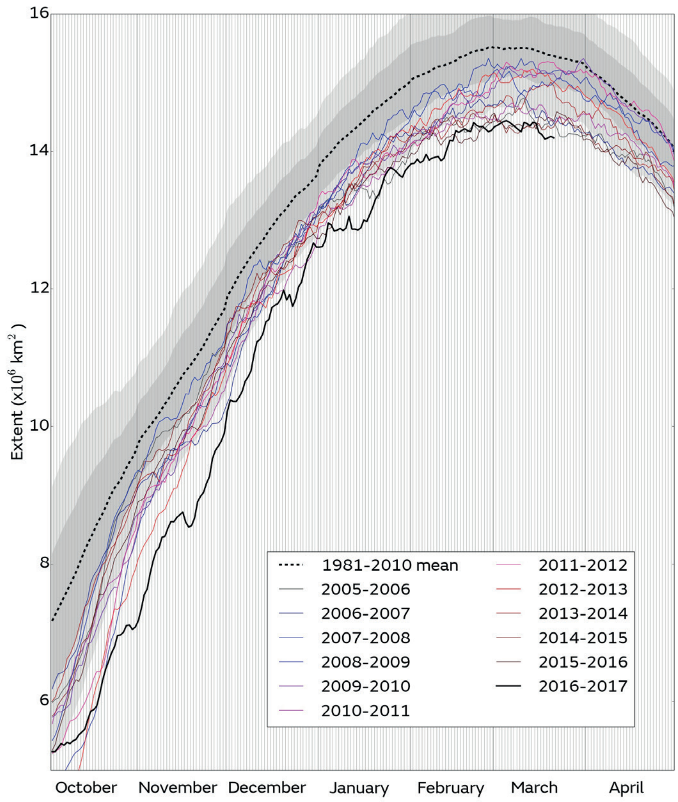
- Arctic sea ice extent during winter 2016-17 has been exceptionally low; as measured by the National Snow and Ice Data Center (NSIDC), maximum sea ice extent was the lowest on record at 14.42 million square km.
- The low extent is associated with very mild Arctic winter temperatures, caused by frequent southerly winds around the ice edges in the Atlantic and Pacific sectors, and enhanced storm activity at high latitudes.
- Ice thickness at the end of winter is likely to be very low, rendering large regions of ice very vulnerable to melting out during the summer. However, the extent of summer melt still depends strongly on Arctic summer weather.

State of the sea ice

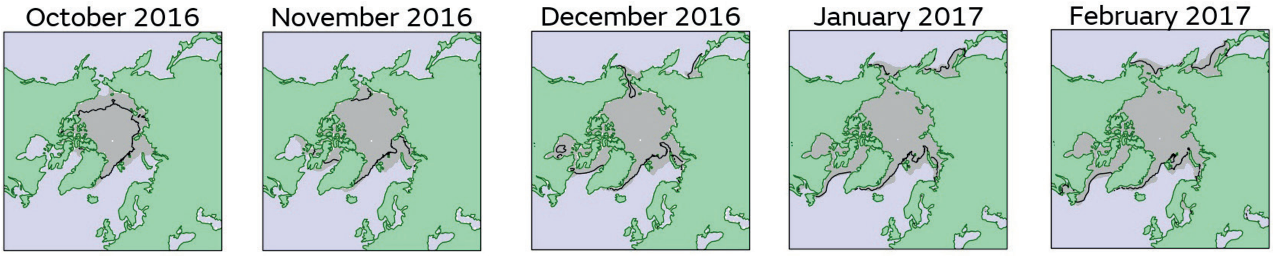
Arctic sea ice extent during winter 2016-17 has been exceptionally low. The maximum extent this winter of 14.42 million square km on 7 March was the lowest in the satellite record (since 1979). Additionally, as measured by the HadISST1.2 dataset (Rayner et al, 2003), monthly sea ice extent was third lowest on record in October, and lowest on record in November, December, January and February. Sea ice extent was 30%, 18%, 9%, 8% and 7% below the 1981-2010 average in these five months respectively.

Winter in the Arctic is normally a time of rapidly growing sea ice extent. As the sun sets on the Arctic, temperatures drop quickly, allowing refreezing of open water exposed during the summer. In 2016, Arctic Ocean ice formation slowed in early October, and by late October extent was lowest on record for the time of year as measured by the NSIDC dataset. Since late October, all but 33 days have seen a record low Arctic sea ice extent for the time of year (Figure 1). Regions of lower than average sea ice coverage have been situated almost exclusively at the ice edge (Figure 2), reflecting the slower, delayed expansion of the ice pack seen during the winter.

Estimates of sea ice volume are published by scientists at the University of Washington, based on the ice-ocean model PIOMAS, forced with observed atmospheric winds and temperatures. According to these, ice volume also became record low for the time of year in late October, and has remained so throughout the winter.



▲ **Figure 1**: Daily Arctic sea ice extent for winter 2016-2017, compared with recent years, and the 1981-2010 average, with +/- 1 and 2 standard deviation intervals indicated by the shaded areas. Data are from the National Snow and Ice Data Center (NSIDC).



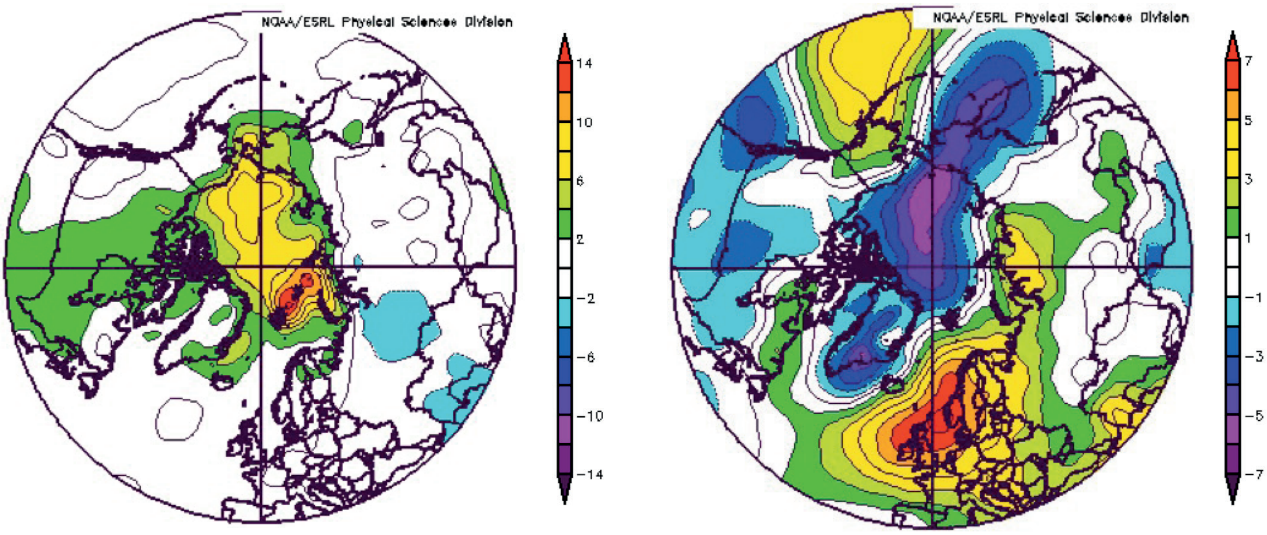
▲ **Figure 2**: Monthly average Arctic sea ice extent for the months October 2016 – February 2017 (black line) compared to the 1981-2010 average (grey shaded area), according to the HadISST1.2 dataset.

Arctic winter weather

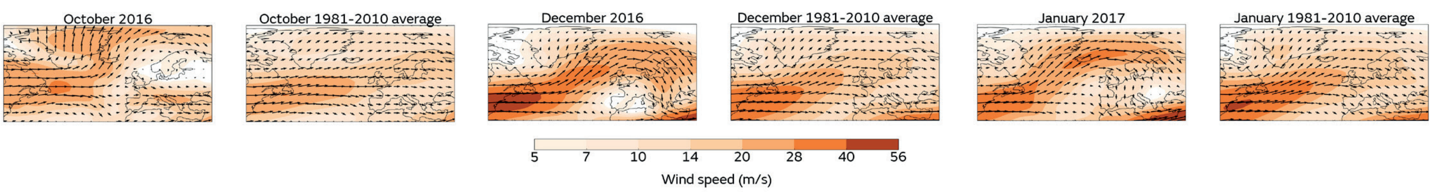
The very low sea ice extent observed throughout winter has been associated with air temperatures in the Arctic Ocean region that have been well above average, particularly near Svalbard and in the southern Beaufort Sea (Figure 3a). Measurements at Svalbard Airport show temperatures to have been 8.7°C, 9.6°C, 7.4°C, 5.0°C and 9.6°C above the long-term average for October 2016 to February 2017 respectively, according to data from the Norwegian Meteorological Institute.

Some part of the mild conditions can be attributed to high sea surface temperatures in the Arctic Ocean at the end of summer, due to unusually early sea ice melt in 2016 and consequent exposure of the sea surface to sunlight for longer than normal. The winter weather in the Arctic has also played a part. In the Fram Strait and the Bering Strait, where large portions of the winter ice edge are situated, winds have been very often from the south, bringing mild air and pushing back the ice edge (Figure 3b & 4). In addition, stormy weather has been very frequent in the Arctic Ocean since early October; stormy conditions in the Arctic winter tend to be associated with higher air temperatures due to the formation of mixed-phase (ice and water) clouds which radiate more heat downwards toward the surface.

The unusual weather conditions are due in part to blocking high pressure systems frequently situated over Scandinavia and Alaska (Figure 3b); in the Atlantic, storms have frequently been deflected north of their usual tracks into the Arctic Ocean, due to the jet stream often taking a more northward track than usual, particularly during October, December and January (Figure 4).



▲ **Figure 3**: (a) Surface air temperature anomaly (C); (b) sea level pressure anomaly(hPa) relative to the 1981-2010 average, 1 October 2016 – 28 February 2017. Data are from the NCEP reanalysis.

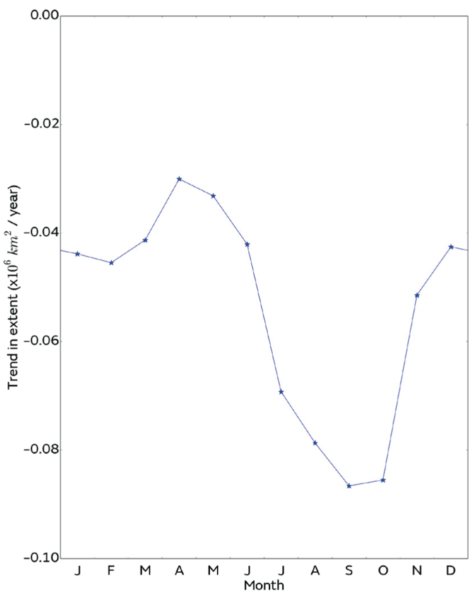


▲ **Figure 4**: Average wind speed at 300hPa in the North Atlantic compared to 1981-2010 average, in October 2016, December 2016 and January 2017. Data are from the NCEP reanalysis.

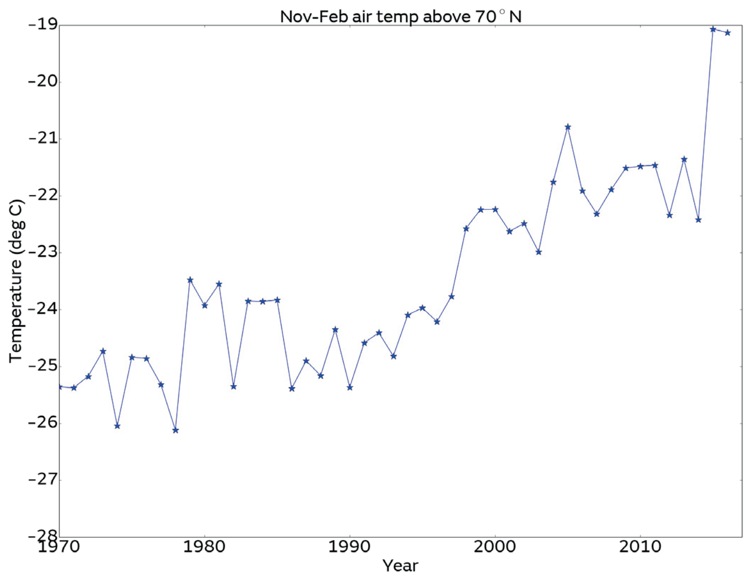
Long-term context

The very low sea ice conditions of winter 2016-2017 occur against a backdrop of rapidly declining Arctic sea ice extent and volume over the satellite record, with sea ice extent having declined by 0.54 million square km per decade since 1979, and evidence of declining sea ice thickness from submarine and satellite records (Lindsay and Schweiger, 2015). The decline in winter extent has generally been less severe than that during the summer (Figure 5), with a decline in February extent of 0.45 million square km per decade comparing to a September decline of 0.87 million square km per decade.

Rapid warming of the Arctic during winter is well established, and has likely played a part in the decline of summer sea ice extent by reducing winter growth of ice, allowing more extensive melt in the summer. Until recently, this warming may have had little visible effect on winter ice extent, as much of the climatological winter ice edge is situated outside the Arctic Ocean, beyond the direct influence of the warming temperatures. However, according to the NCEP reanalysis the past two winters have been exceptionally warm in the Arctic even by the standards of recent years (Figure 6), while ice extent during the past 3 winters has also been extremely low even in the context of the long-term decline.



▲ **Figure 5**: 1979-2016 linear trend in Arctic sea ice extent according to the HadISST1.2 dataset.

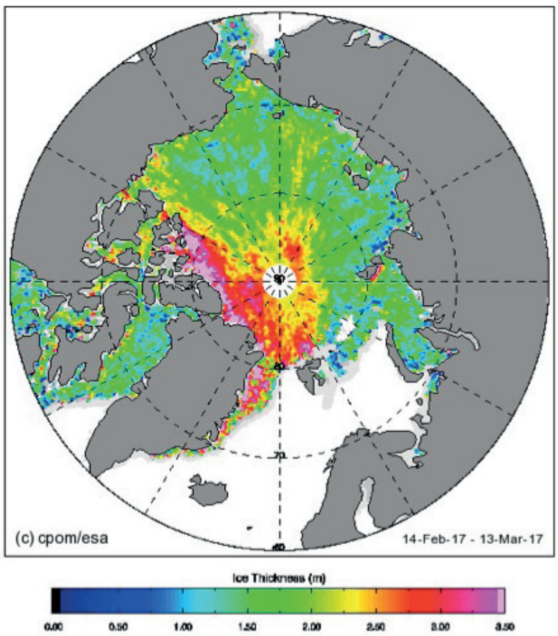


▲ **Figure 6**: Average November – February surface air temperature north of 70°N, according to the NCEP-NCAR reanalysis.

Outlook for the summer

The low sea ice extent of winter 2016-17 is likely to have little direct impact on sea ice melt in summer 2017 because the areas in which sea ice has failed to form tend to be areas in which sea ice melts away completely in any case during the summer. However, the associated very warm Arctic winter temperatures will likely have further attenuated ice growth.

Available evidence suggests that Arctic sea ice thickness at the end of winter is likely to be very low; according to measurements from the radar altimeter aboard ESA's CryoSat-2, very large areas of the Arctic Ocean were filled with sea ice of thickness under 2m during late February and early March (Figure 7). Evidence from models suggests that sea ice of less than 2m thickness at the end of winter is likely very vulnerable to melting out during the summer (Keen et al, 2013). However, the severity of summer sea ice melt depends strongly on Arctic summer weather conditions, so while a very low summer minimum extent has an enhanced likelihood this year, it is by no means certain to occur.



▲ **Figure 7**: Average sea ice thickness according to Cryosat-2, 14 February – 13 March 2017. Image credit: Centre for Polar Observation and Modelling.

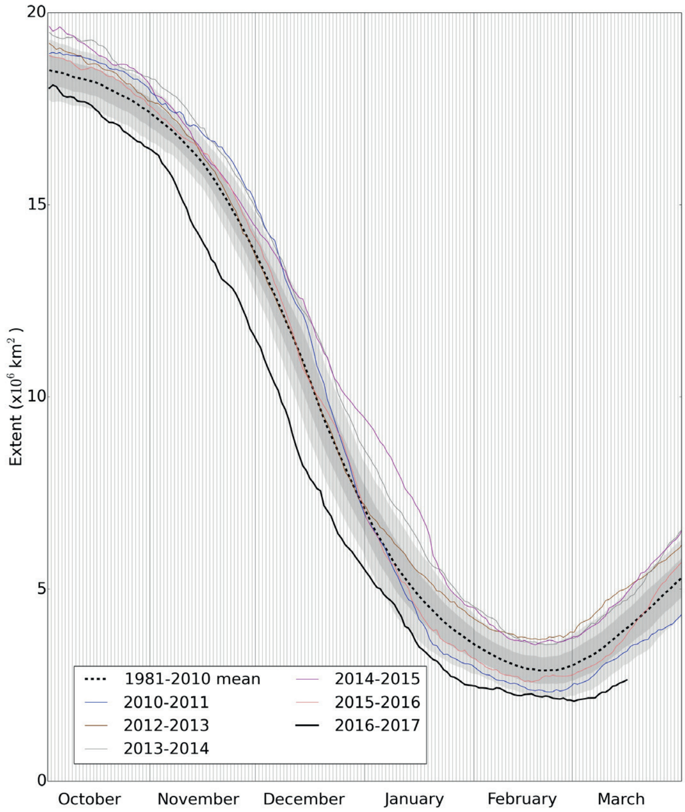
Antarctic sea ice

Summary

The Antarctic sea ice has been at a record low since September 2016 and remains at a record low throughout this Southern Hemisphere summer. The events leading to the current state of the sea ice are more likely the result of natural variability than a change in the climatic state of the Antarctic.

Background

The Antarctic minimum sea ice extent occurs in late February to early March. This year the minimum ice extent will be the lowest since satellite records began in 1979, the previous low ice extents being in 1993, 1997 and 2011. The climatic trend for Antarctic ice extent has been for an increase over the last 38 years, but the trend for February is not statistically significant due to large levels of natural variability. The current record high Southern Hemisphere winter ice extent occurred in 2014 (Figure 8) and the ice extent remained unusually high until the following winter. In winter 2016 non-typical winds pushed the Antarctic ice extent to a new low, where it has remained through to this Southern Hemisphere summer (Figure 8).



▲ **Figure 8**: The recent minimum and maximum annual cycle of Antarctic sea ice extents. Data are from the National Snow and Ice Data Center (NSIDC).

Antarctic sea ice melt

The current minimum extent is associated with a lack of ice in the Amundsen Sea and Ross Seas (Figure 9). Various cursory studies have suggested that this year's anomaly is associated with:

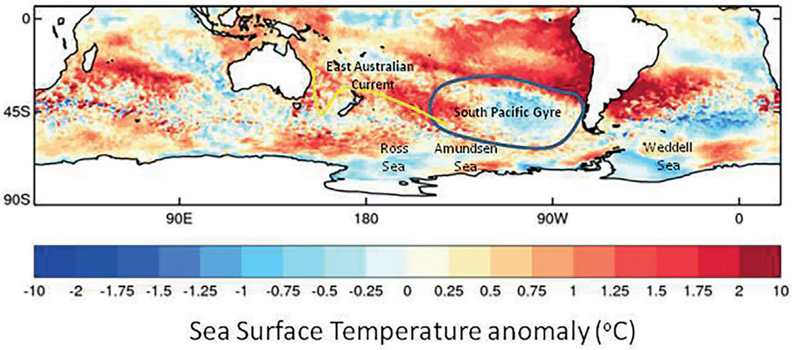
1. A shift in the Pacific Decadal Oscillation (PDO) from a predominately negative state since the mid-1990s to a positive state since late 2014, leading to warm water upwelling in the Bellingshausen and Amundsen seas.
2. An exceptionally high positive index for the Southern Annular Mode (SAM) in November 2016, which would suggest stronger than average westerly winds around Antarctica. These winds may bring warmer surface Pacific water southwards.

However, the final state of the Southern Hemisphere Summer sea ice cover does not seem to be temporally or spatially consistent with that expected from the SAM or PDO.

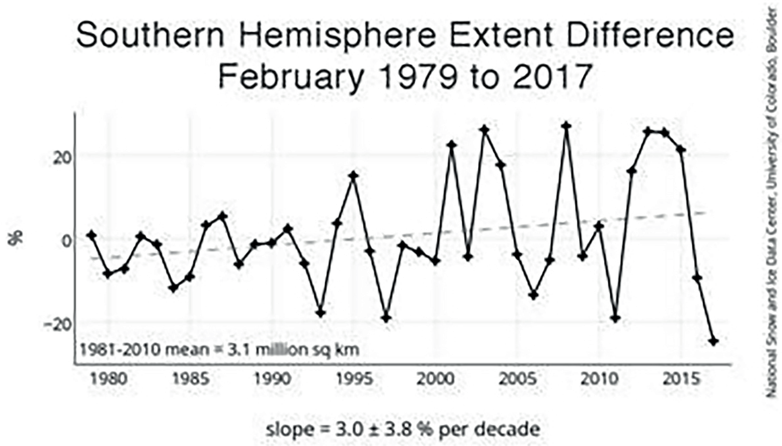
▲ **Figure 9**: Sea ice extent in February 2017. The long-term average, 1981-2010, February extent is shown in orange.
(Image courtesy of NSIDC)

Our own analysis indicates that the current state is associated with warm water in the East Australian current, a residual from the 2015 El Nino, which has been transported by storms from the south Pacific gyre into the Ross and Amundsen Sea (Figure 10). It appears that this warm water has led to the sea ice anomaly off West Antarctica, the region responsible for this year's record low sea ice extent.

If this is the case then this year's low sea ice anomaly may be attributable to natural variability. There is no evidence as yet, that a tipping point has been reached, although with warming oceans we can expect the Antarctic ice to decline in the future, albeit with large interannual variability. The variability of the summer sea ice extent has been increasing over recent decades (as shown in Figure 11), although the cause of this is not yet understood.



▲ **Figure 10**: Southern Ocean sea surface temperature anomaly on 1 March 2017 provided by the OSTIA analysis (Donlon et al., 2012). The grey curve encloses the South Pacific gyre and the yellow line indicates the pathway of the East Australian Current.



▲ **Figure 11**: The Antarctic February ice extent anomaly since routine satellite records began in 1979. The trend is not statistically significant but the interannual variability appears to have been increasing.

Arctic Sea Ice References

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