Monitoring of Changes in Arctic and Antarctic Sea Ice Over the Past 40 Years

SUMMARY

Key Points

- In the Arctic, temperatures rose by about 2 °C since the start of the industrial era (IPCC, 2021). Among other impacts, this warming resulted in a decrease in the area and thickness of Arctic Sea ice in both summer and winter, with sea ice becoming younger, thinner, and more dynamic. In fact, the area of late summer Arctic Sea ice is now smaller than it has been at any time in at least the past 1000 years.
- In the Antarctic, temperatures rose between 1.0 and 1.5 °C since the start of the industrial era (IPCC, 2021). Although the Antarctic is responding less rapidly to climate change than the Arctic, this is due to large regional differences between the two. The interior continent of Antarctica and the East Antarctic Ice Sheet, both of which were considered unlikely to be affected by climate warming, show a very moderate warming of about 0.1 ± 0.2 °C per decade (see Figure 1). Across the Antarctica's Peninsula, however, temperatures increased at similar pace as over the Arctic, recording an increase of more than 0.3 ± 0.1 °C per decade (Nicolas and Bromwich, 2014).

Service

- Adaptation
- Marine ecosystems
- Mitigation

End users

- General public
- Government agencies
- Policymakers
- Researchers

Intermediate User(s)

- Intergovernmental Panel on Climate Change (IPCC)
- WMO Regional Climate Centers (RCCs)
- Climate modeling community
- Research institutes
- Academia

Application(s)

- Sea ice concentration and sea ice volume are among the main indicators of climate change. Changes in sea ice concentration and volume moderate the Earth energy balance through atmosphere-ocean-ice exchanges of energy and moisture and, consequently, may drive the Earth-system to a new equilibrium state.

Essential Climate Variables

—Ocean

- Sea ice

Models

- The Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS, Zhang and Rothrock, 2003) of the Polar Science Centre (PSC) .
- The Thickness and Enthalpy Distribution (TED) Sea-Ice Model (Zhang and Rothrock, 2003).

Climate Data Records

- EUMETSAT Ocean and Sea Ice Satellite Application Facility, Global Sea Ice Concentration Climate Data Record v2.1 - Multimission, over the period 1979-2015, OSI-450, doi: 10.15770/EUM_SAF_OSI_0008 , data extracted from OSI SAF FTP server, *accessed 2022-10-05. RecordID 10662*.
- EUMETSAT Ocean and Sea Ice Satellite Application Facility, Interim Global Sea Ice Concentration Climate Data Record v2.1 - Multimission, over the period 2016-onwards, OSI-430-b, doi: 10.15770/EUM_SAF_OSI_NRT_2008, data extracted from OSI SAF FTP server, *accessed 2022-10-05. RecordID 11765*.

Agencies

- European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)
- Ocean and Sea Ice Satellite Application Facility (OSI SAF)
- Polar Science Centre (PSC), University of Washington
- European Space Agency (ESA) Climate Change Initiative (CCI)

Satellite Observations

- SMMR on Nimbus-7
- SSM/I on DMSP-08 till DMSP-15
- SSMIS on DMSP-16 till DMSP-18

Sustainability

This use case demonstrates the use of sea ice concentration and volume data records from satellite observations and model data for monitoring changes in the sea ice of the Antarctic and Arctic oceans over a span of more than 40 years.

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DESCRIPTION

In its 6th assessment report, the Intergovernmental Panel on Climate Change (IPCC) of the United Nations states that human influence is very likely the main driver of the global retreat of sea ice during the last 40 years.

The Antarctic is responding less rapidly to climate change than the Arctic. However, there are large regional differences between the two. The interior of the Antarctica continent and the East Antarctic ice sheet, both of which were considered unlikely to be affected by climate warming, show a very moderate warming of about 0.1 ± 0.2°C per decade (see Figure 1). Most warming, however, is recorded across Antarctica's Peninsula, where temperatures increased by more than 0.3 ± 0.1°C per decade (Nicolas and Bromwich, 2014).

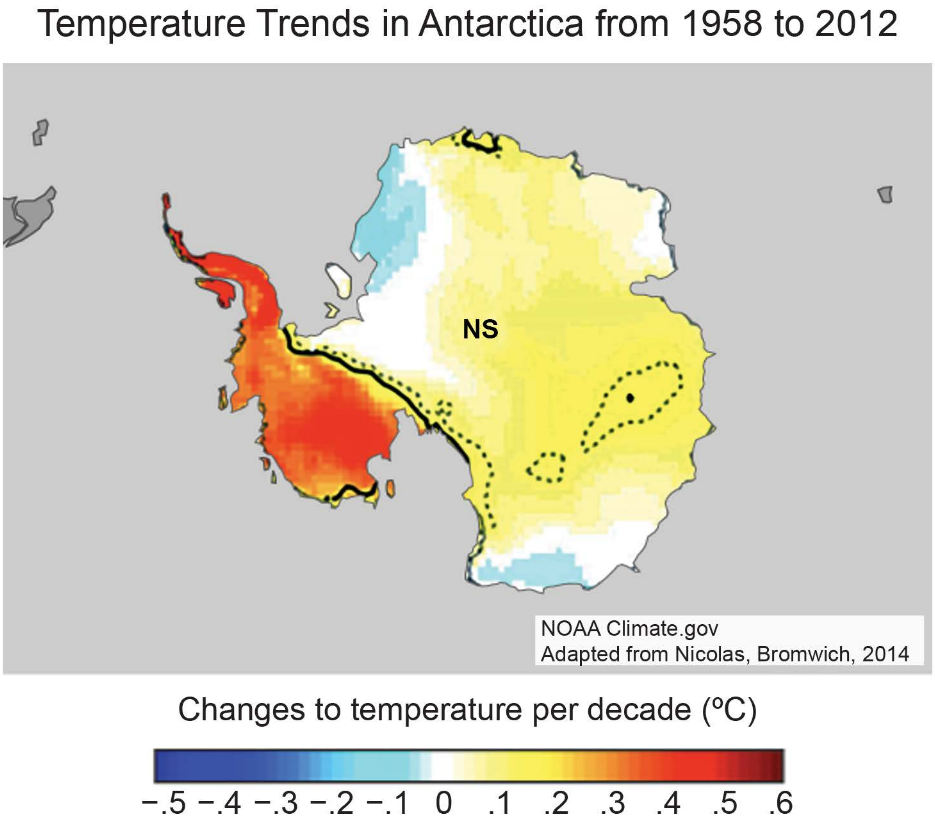

Figure 1. Temperature trends in °C per decade since the 1950s. The thick black line delineates the area of high confidence (West Antarctica and Antarctica's Peninsula). NS indicates that the area east of the thick black line has confidence levels that are not statistically significant. Within that region, dotted lines indicate areas of medium confidence. This figure was taken from a NOAA blog and is based on the paper of Nicolas and Bromwich (2014).

Sea Ice variability observed from space

Getting a coherent picture of the current sea ice state over the Arctic and the Antarctic requires analysis of long-term climate data records of sea ice parameters, such as its area and volume.

EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSI SAF) provides a unique long-term climate data record of sea ice concentration covering the period from 1979 onwards. It derives sea ice concentrations from passive microwave observations from the SMMR, SSM/I, and SSMIS missions (U.S.A.), and from the Advanced Microwave Scanning Radiometer missions AMSR-E and AMSR2 (Japan). The ESA Climate Change Initiative (CCI) programme contributed to the development of the algorithms (Lavergne et al., 2019). For a more complete picture of the changes in sea ice, one should also look at changes in its volume (Paul et al., 2018). Hereto, a sea ice volume data record from the Polar Science Centre (PSC, Seattle, USA) that spans 40 years is used.

Changes in the Arctic

In the Arctic, sea ice cover grows throughout the winter, reaching its maximum in March. As the Sun returns in March and gets stronger during spring and summer, the sea ice starts to melt, reaching its minimum in September.

Since the start of the industrial era, the Arctic has warmed twice as fast as other parts of the world, with average temperatures increasing by about 2°C. The warmer temperatures are affecting both the Arctic Ocean and Arctic land. Satellite observations show that the Arctic experienced large losses of sea ice during the last 40 years (see Figure 2). Arctic sea ice has predominantly diminished around the time of the ice minimum in September. More specifically, summer Arctic Sea ice area has reduced by approximately 40% since 1979. This equates to about 2.5 Million km², or one-fifth of the Northern Hemisphere's average sea ice area. The reduction in the Arctic Sea ice area at the end of the winter season is more moderate at approximately 10%. The decline in Arctic Sea ice volume is even greater however, with a decrease of 35% at the end of the winter season and a decrease of 75% at the end of the summer season (see Figure 2).

Reduced sea ice is causing fewer days of snow cover each year in the Arctic. This has a compounding effect because it exposes darker ground surfaces and ocean waters, which allows more solar radiation to be absorbed. This, in turn, leads to more snow and ice melt. Based on observed trends and model predictions, IPCC expects that the annual Arctic Sea ice area minimum will likely fall below 1 million km², a decrease of almost 90% since the 1980s, at least once before the middle of the 21st century (IPCC. 2021).

In the most recent years, the sea ice area has been substantially lower than the mean area observed between 1970 and 2021. The OSI SAF High Latitude Processing Center (*accessed 2022-10-05*) provides daily updates of the sea ice situation in the Arctic and Antarctic (see Figure 4).

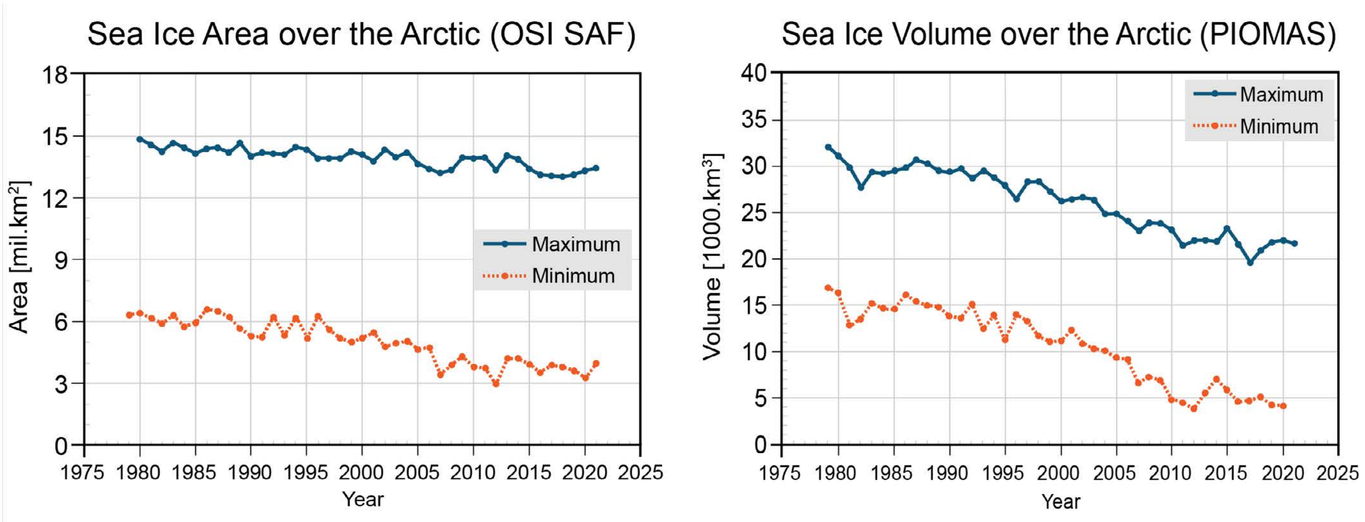

Figure 2. Trend in Arctic Sea ice area (Data taken from the OSI SAF) and volume (Data taken from Polar Science Centre (Zhang, and Rothrock, 2003)) for the months of March (maximum) and September (minimum) during the years 1979-2021.

Changes in the Antarctic

Similar to the Arctic, the Southern Ocean around Antarctica freezes in winter and melts in summer. However, the Antarctic differs in many ways from the Arctic. Among other differences is the fact that the Arctic is an ice-covered ocean surrounded by landmasses, whereas Antarctica is a continent surrounded by ocean. The maximum ice area of the latter is usually reached around September and minimum ice area around March. Due to these differences, the sea ice area in the Antarctic is smaller than in the Arctic at the end of summer and larger at the end of winter.

Since the start of the industrial era, the Antarctic has warmed between 1.0 and 1.5 °C (Martin et al., 2019). This warming slowed down significantly around 40 years ago. Since then, overall temperatures have been showing a moderate increase of about 0.2 °C (HadCRUT4 temperature data from the Climatic Research Unit, *accessed 2022-10-05*). In satellite observations, no significant trend in sea ice area and volume occurred during the last 40 years, be it winter or summer. In fact, Antarctic sea ice area and volume remained stable or even increased slightly, both at the end of summer and the end of winter (see Figure 3). However, the observed gains in Antarctic sea ice are almost an order of magnitude smaller than the observed sea ice loss over the Arctic (see Figure 3).

Despite moderate warming, sea ice area and volume over the Antarctic show no significant trend. The latter may be attributed to regionally opposing trends and large internal variability (IPCC, 2021). There are several theories explaining the drivers of the 'quasi stable' situation in Antarctic sea ice. Among other possibilities, it may be explained by increased cooling of the Antarctic Sea due to increased melt of Antarctica's glacier (Bintanja et al., 2013) or by changes in wind patterns (Schroeter, et al., 2018). In general, the sea ice area maxima and minima remained close to the long-term average during recent years (see Figure 4).

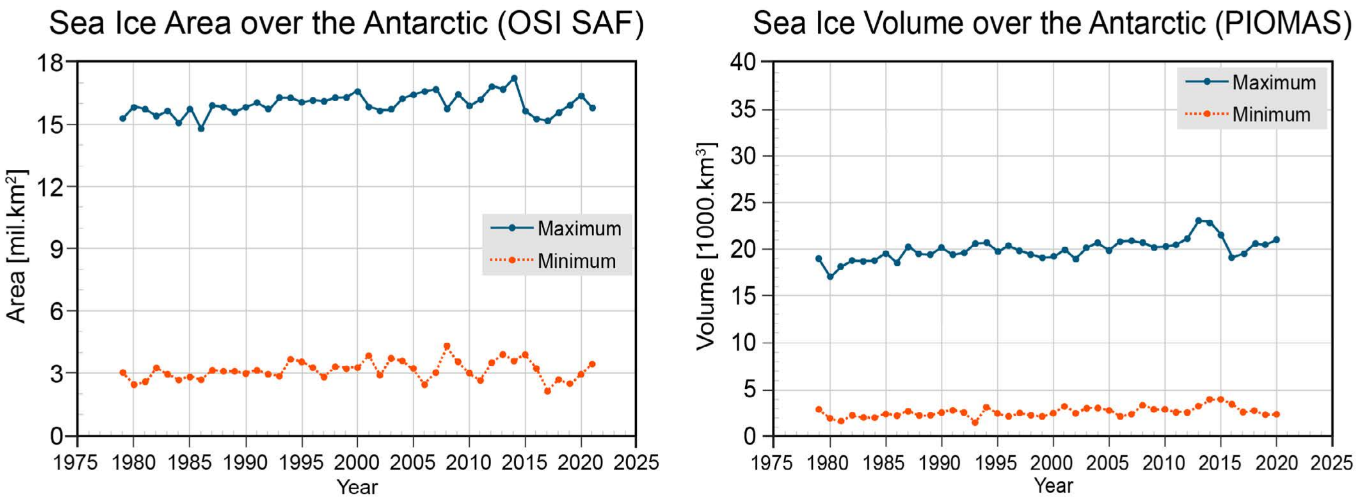

Figure 3. Trend in Antarctic Sea ice area (Data taken from the OSI SAF) and volume (Data taken from Polar Science Centre (Zhang, and Rothrock, 2003)) for the months of March (minimum) and September (maximum) during the years 1979-2021.

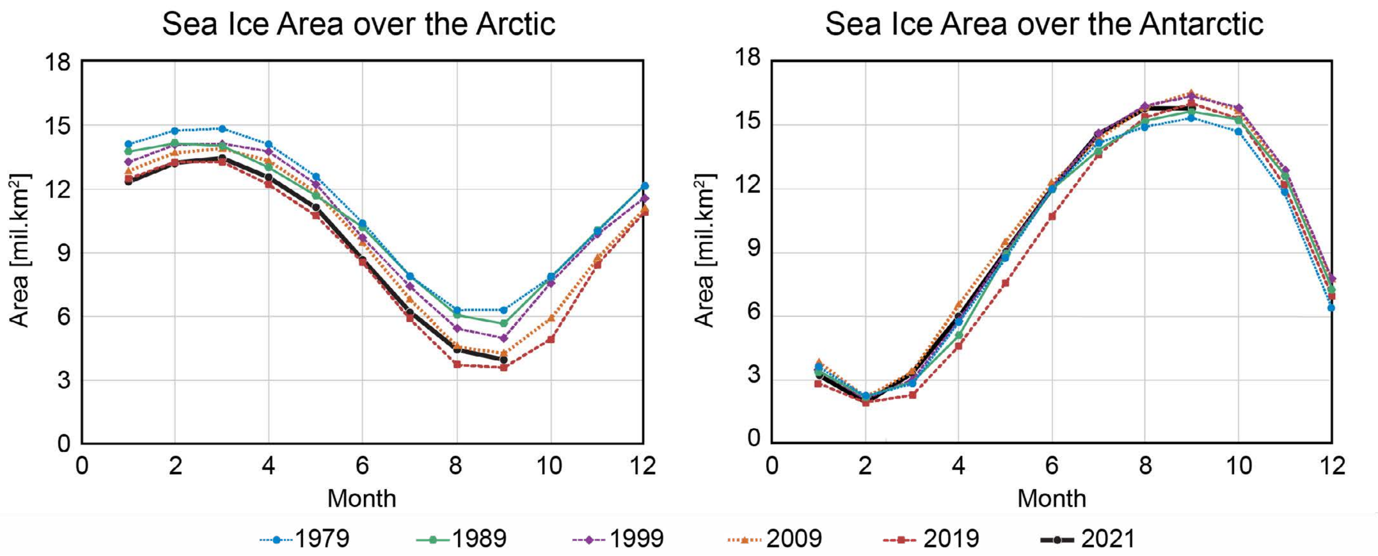

Figure 4. Changes in annual cycle of Arctic and Antarctic Sea ice area since the 1980s. The black line shows the annual cycle of 2021. This figure is based on data provided by the OSI SAF. More details can be found on the sea ice dashboard of OSI SAF partner Met Norway (see https://cryo.met.no/en/sea-ice-index, accessed 2022-10-05)

Conclusion

The ongoing reduction in sea-ice area and volume impacts the climate system as a whole: ranging from changes in global ocean and atmospheric circulation, which influences weather patterns, to changes in the Earth radiation budget through a decrease of surface albedo, which amplifies the warming. Monitoring changes in sea ice and understanding underlying processes is crucial for predicting future climate change and its impacts.

This Use Case demonstrates the use of satellite data for monitoring more than 40 years of sea ice area and volume over the Arctic and Antarctic. Over the Antarctic, only a slight change in sea ice parameters has manifested since the 1980s, staying mostly within +/- 5%. The bulk of the changes have been occurring from the 1980s onward in the Arctic, where the sea ice area reduced quickly (up to 40% at the end of summer) and its volume even more quickly (up to 75% at the end of summer). The annual minimum sea ice area in the Arctic will likely fall below 1 million km² at least once before 2050 (IPCC. 2021).

	Sea Ice Area change (1979–2021)		Sea Ice Volume change (1979–2021)	
	Winter maximum	**Summer minimum**	**Winter maximum**	**Summer minimum**
Arctic	−10%	−40%	−35%	−75%
Antarctic	+3%	+3%	+10%	+10%

Table 1. Summary of changes in Sea Ice Area and Sea Ice Volume in the Arctic and Antarctic over the period 1979 to 2021.

INFORMATION FLOW

Sense

- 40 years of heritage microwave imagers data of the SMMR instrument on Nimbus-7, the SSM/I instrument on DMSP-08 until DMSP-15, and the SSMIS instrument on DMSP-16 until DMSP-18.

Climate data

- Sea ice concentration climate data records from the Ocean and Sea Ice Satellite Application Facility (OSI SAF) with doi: 10.15770/EUM_SAF_OSI_0008 and doi: 10.15770/EUM_SAF_OSI_NRT_2008
- Sea ice volume climate data record from the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) of the Polar Science Centre (PSC).

Apply

- Monitoring of the long-term evolution of sea ice coverage and volume in support of studies analyzing the impact of changes in the Earth's energy balance through atmosphere-ocean-ice exchanges of energy and moisture.

Decision making

- International climate bodies, such as IPCC and UNFCCC, need accurate information on the evolution and state of sea ice in order to assess the impact of global warming on polar regions and how changes in sea ice affect the Earth's energy and atmospheric moisture budget.

Use additional data

- Ensuring continued and improved sea ice monitoring capabilities using new satellites and better algorithms. Among others, the high-resolution visible and thermal imaging radiometers, radar altimeters on-board Sentinel-3, the microwave imager and scatterometer on-board the future EPS-SG satellites, and the future Copernicus Imaging Microwave Radiometer (CIMR) with a planned launch around 2029.

https://climatemonitoring.info/use-cases/