Ocean Case Study 1
Decades of Melting

The ocean is the principal absorber of solar radiation within Earth's climate system. Near the poles, sea ice, which forms from the freezing of ocean water, covers about 14–16 million km^2 (5.4–6.2 million $mi.^2$) in late winter in the Arctic and 17–20 km^2 (6.6–7.7 million $mi.^2$) in the Antarctic. About 29% of Earth's surface is covered by land. Of this land area, about 10% is covered by terrestrial ice sheets, ice caps, and mountain glaciers. This amounts to a total ice-covered area of about 15 million km^2 (5.8 million $mi.^2$).

The Arctic climate is more sensitive to changes in Earth's surface properties than any other region, enhancing climate feedback processes in the Arctic. **Polar amplification**, the greater rate of warming at higher latitudes, is primarily due to the increasing rate of melting sea ice.

Arctic Sea Ice Extent

The National Snow & Ice Data Center (NSIDC) archives years of sea ice extent data for both the Arctic and Antarctic. To visualize the differing and changing trends, we utilize the NSIDC Ch*arctic* interactive sea ice graphing tool.

Figure 1 presents satellite data of Arctic sea ice extent yearly since 1981, reported in millions of square kilometers. The thick, dark gray curve is the 1981–2010 median extent. The lightly shaded background contains values within ±2 standard deviations of the 1981–2010 median. The dashed red line represents the extent of Arctic sea ice during 2012, the year with the lowest minimum extent. The orange line represents the Arctic sea ice extent in 2024, and the dark green line represents the 2025 extent.

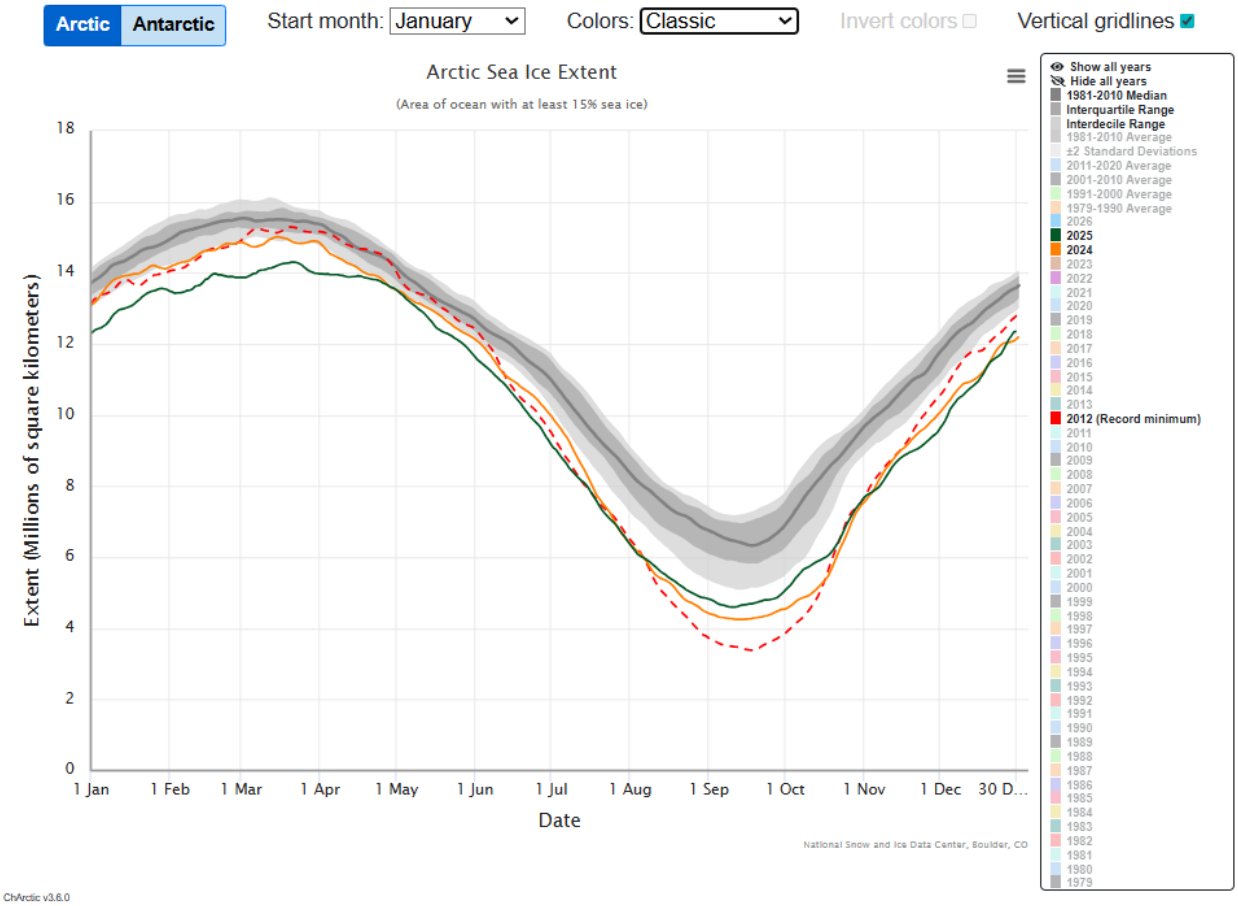

Figure 1. Arctic sea ice extent, with the 1981–2010 median as the dark gray line, 2025 in dark green, 2024 in orange, and 2012, the record minimum, in dashed red. [NSIDC]

1. The annual curves in Figure 1 show _____ has the lowest monthly Arctic sea ice extent, while _____ has the highest monthly sea ice extent.

   a. late January … late August
   b. late August … early January
   c. late September … early March
   d. early March … late September

2. According to the 1981–2010 median in Figure 1, the minimum sea ice extent averages _____ million km^2.

   a. 3.9
   b. 4.7
   c. 6.3
   d. 7.6

3. The record minimum Arctic sea ice extent occurred on 16 September 2012 (dashed red line). This minimum extent was approximately _____ million km^2.

   a. 2.8
   b. 3.4
   c. 4.7
   d. 6.8

4. The 2025 minimum extent occurred on 11 September 2025 (solid dark green line), when the NSIDC reported that Arctic sea ice covered 4.6 million km^2, or _____% of the average annual minimum you found in #2.

   a. 26
   b. 59
   c. 68
   d. 73

For a more interactive way to compare Arctic sea ice extent annual curves and the current year's record, visit Ch*arctic* Interactive Sea Ice Graph.

Minimum Arctic Sea Ice

Because ice reflects such a high percentage of incoming sunlight, it helps to keep temperatures in the polar regions cold. When sea ice melts, areas of open Arctic Ocean have decreased solar reflectivity and thus increased absorption by surface waters. Greater absorption leads to greater heating. This heated ocean water, in turn, warms the overlying atmosphere. Additionally, sea ice insulates ocean water from the overlying atmosphere; less ice cover increases heat exchange between ocean and air.

The end of the melting season is the year's minimum sea ice extent, which falls in September. Provided by the NSIDC, **Figure 2** shows the Arctic sea ice extent for September 1979–2025, which includes areas covered by 15% or more ice. For over four decades, the extent of Arctic sea ice trend has decreased by 0.8 million km^2 per decade from 1979 through 2025.

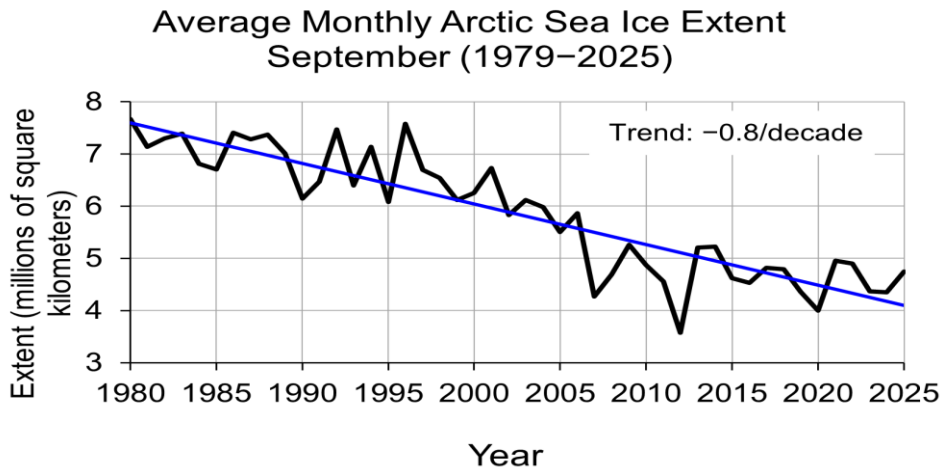

Figure 2. The 1979–2025 average Arctic sea ice extent for SEP, representing the minimum sea ice extent. [NSIDC]

5. According to Figure 2, the average Arctic sea ice extent for September 2025 was about _____ million km^2.

   a. 2.9
   b. 3.4
   c. 4.8
   d. 5.2

6. The 1980–1989 minimum September average was 6.99 million km^2. During the most recent decade, from 2016 to 2025, the lowest minimum was observed in _____.

   a. 2016
   b. 2019
   c. 2020
   d. 2023

The Arctic is losing 8% of its sea ice extent per decade, which is consistent with the warming at high northern latitudes. These declines profoundly affect ocean conditions and circulation, weather and climate at local, regional, and global scales, and society and ecosystems.

Antarctic vs Arctic

The Antarctic is the geographic opposite of the Arctic. They are on opposite sides of the planet with opposite seasons, and the Arctic is an ocean with continents and islands around it, while Antarctica is a land mass surrounded by ocean. The Southern Ocean allows the forming sea ice to move more freely, resulting in higher drift speeds. Also, because there is no land boundary, the sea ice around Antarctica can more easily float away into warmer waters, where

it eventually melts. As a result, almost all the sea ice that forms during the Antarctic winter melts during the summer.

While the Arctic rate of sea ice loss has increased over the last few years, the Antarctic has experienced different impacts. The NSIDC reports that the Antarctic sea ice minimums in 2024 and 2025 were only slightly above the 2023 record-low Antarctic sea ice extent. However, the variability in Antarctic sea ice patterns is inconsistent across its regions, making it difficult to predict how the ice could grow and shrink with climate change.

Figure 3 displays the changes in the minimum extent of the Arctic (blue) and Antarctic (red) sea ice, along with their trends.

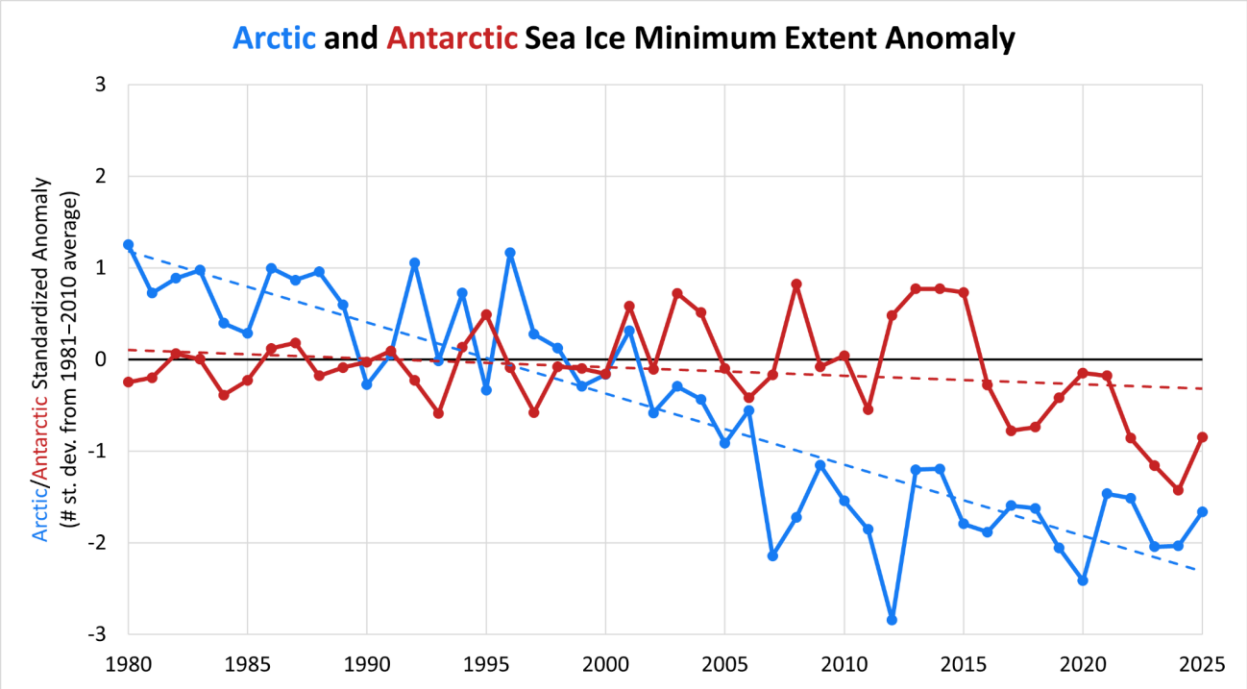

Figure 3. Changes in the minimum extent of Arctic (blue) and Antarctic (red) sea ice, 1980–2025, relative to 1981–2010. Trends are dashed lines. [Data from Fetterer, F., et al., 2017, Sea Ice Index]

7. Figure 3 shows the Arctic trend of declining sea ice. The Antarctic trend was nearly flat until the last _____ years, which have all had below-average annual minimum sea ice extents.

   a. 3
   b. 9
   c. 13
   d. 15

8. In addition to the decreasing annual minimum sea ice extents, the yearly variability, or change in extent from one year to the next, has _____ since 2000. This means that the sea ice is _____ predictable from year to year.

    a. increased ... more
    b. increased ... less
    c. decreased ... more
    d. decreased ... less

The satellite record for Antarctic sea ice extent spans four decades and shows periods of increasing and decreasing sea ice. Only a few of those patterns, however, have been statistically significant. While Arctic sea ice displays a clear trend, the Antarctic trend is less certain.

Antarctic Sea Ice Extent

Similar to Figure 1, **Figure 4** presents satellite data of Antarctic sea ice extent since 1981, reported in millions of square kilometers. The thick, dark gray curve is the 1981–2010 median extent. The lightly shaded background contains values within ±2 standard deviations of the 1981–2010 median. The dashed red line represents the Antarctic sea ice extent during 2023, the year with the lowest recorded minimum extent. The solid orange line shows the Antarctic sea ice extent for 2024, and the dark green line shows the 2025 extent.

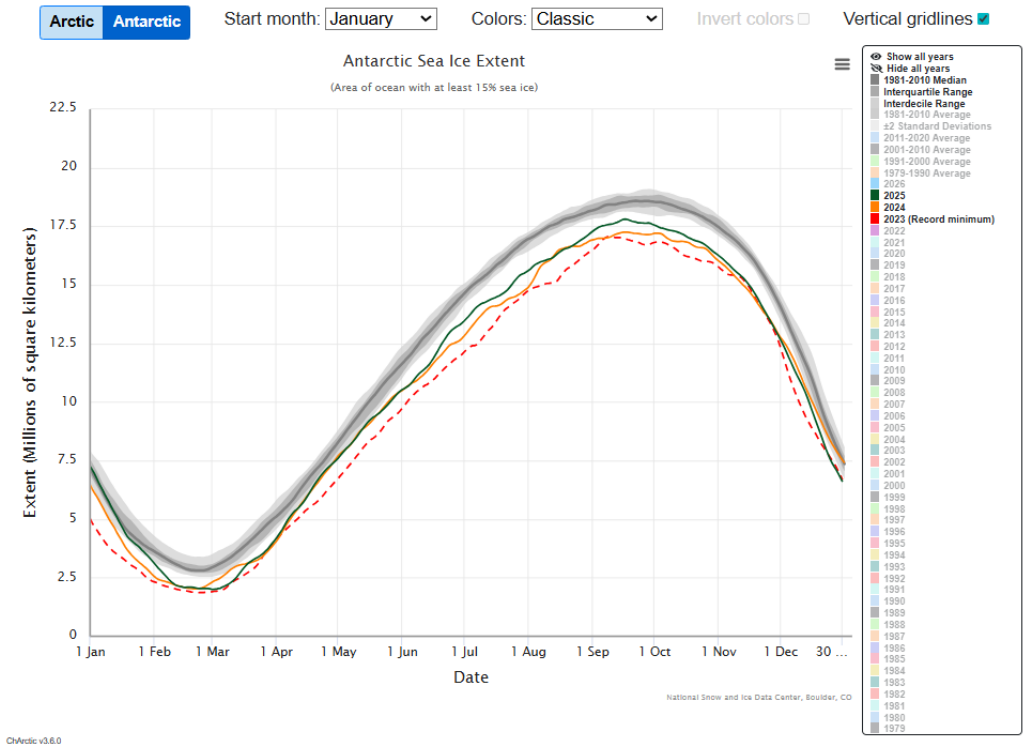

Figure 4. Arctic sea ice extent, with the 1981–2010 median as the dark gray line, 2025 in dark green, 2024 in orange, and 2023, the record minimum, in dashed red. [NSIDC]

9. The minimum sea ice extent for the Antarctic occurs around _____, and the maximum occurs around _____. Compare that to Figure 1 and the Arctic trends.

    a. late January ... late August
    b. late August ... early January
    c. late September ... late February
    d. late February ... late September

10. The 2023 minimum extent in Antarctica (red dashed line) set a new record low of _____ million km^2.

    a. 1.8
    b. 2.6
    c. 2.9
    d. 3.4

Because of the unprecedented Antarctic sea ice melt, Earth had a record-low global sea ice cover in 2023. 2024 and 2025 followed suit with a minimum ice extent only slightly higher than 2023.

Summary

Arctic sea ice extent has decreased dramatically since 1979, and the minimum sea ice extent continues to decline. While the Antarctic was fairly stable in prior decades, it experienced record high sea ice extents in 2013 and 2014, dropped below average in 2016, and reached record lows in 2022 and again in 2023. Because ice reflects a higher percentage of incoming sunlight, while open ocean absorbs a larger portion of it, changes in ice cover will impact global temperatures.

References

Figure 1 – NASA NSIDC, 2025: Arctic sea ice extent. Accessed 5 January 2026, https://nsidc.org/sea-ice-today/sea-ice-tools/charctic-interactive-sea-ice-graph.

Figure 2 – NASA NSIDC, 2025:Sea Ice Index Daily and Monthly Image Viewer. Accessed 5 January 2026, https://nsidc.org/data/seaice_index.

Figure 3 – Fetterer, F., K. Knowles, W. N. Meier, M. Savoie, and A. K. Windnagel, 2017: Sea Ice Index, G02135, Version 3. National Snow and Ice Data Center, accessed 5 January 2026, https://doi.org/10.7265/N5K072F8.

Figure 4 – NASA NSIDC, 2025: Antarctic sea ice extent. Accessed 5 January 2026, https://nsidc.org/sea-ice-today/sea-ice-tools/charctic-interactive-sea-ice-graph.

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