A new record minimum for Antarctic sea ice

Marilyn N. Raphael[1,2,†] and Mark S. Handcock[3]
[1] Department of Geography, University of California Los Angeles, Los Angeles, CA, USA
[2] Institute of the Environment and Sustainability, University of California Los Angeles, Los Angeles, CA, USA
[3]Department of Statistics, University of California Los Angeles, Los Angeles, CA, USA

[†]Email: raphael@geog.ucla.edu

Standfirst: Antarctic sea ice extent reached a new record low of 1.935 million km^2 on **February 28, 2022.** This extent is approximately 32% below climatological values, and might indicate a transition to new, more extreme, annual fluctuation.

Typically, Antarctic sea ice reaches its maximum extent in mid-September, thereafter retreating to a February-March minimum that averaged 2.917 million km^2 over 1981-2010 (**Fig. 1**). On February 28th 2022, however, Antarctic sea ice extent (SIE) reached a record minimum of 1.965 million km^2, 0.918 million km^2 lower than the climatological average and 0.085 million km^2 lower than the previous record set in 2017 (**Fig. 1a**).

The causes of this new record minimum are yet to be identified, but can likely be related to an early winter maximum and a subsequent early retreat at the end of August 2021 (**Fig. 1b**), dominated by accelerated melt in the Bellingshausen and Weddell Seas. An early retreat in this instance means a longer melt season and a better than even chance of reaching below normal values in February. A combination of atmospheric and oceanic drivers likely contributed to this early retreat. The world ocean reached record temperatures in 2021, and the Southern Ocean, an important anthropogenic heat sink[1], also exhibited warmer subsurface temperatures[2]; a warmer ocean leads to thinner ice formation, allowing easier breakup by wind and wave action. Surface pressure was also lower than normal and there was a persistently strong Amundsen Sea Low for most of the year (***SOTC Ch. 6 2022, under review*)**.

This 2022 record comes a mere five years after the February 2017 minimum when SIE shrank to 2.049 million km^2, 0.834 million km^2 lower than the average (**Fig. 1b**). Not only was the 2017 minimum a record, the size of the reduction in SIE over the period 2015 – 2017 was unprecedented in both the satellite record (**Fig. 1a**) and the 20th century[3]. There are interesting similarities between the 2016-2017 and 2021-2022 seasons. Both were marked by early winter maxima and early retreat, within a day of each other, and both were led by rapid melting in the Bellingshausen Sea rather than synchronous retreat around the continent. The early retreat of sea ice leading to record minima emphasizes the influence of phase (the timing of advance and retreat) on the variability of Antarctic sea ice. The phase contributes about two-thirds of the variability in the daily annual cycle of Antarctic sea ice and was the main contributor to the record minimum in sea ice extent in 2017 (ref [4]). The early retreat of sea ice in 2016 and subsequent melting to the 2017 record low was attributed to a confluence of factors, atmospheric and oceanic and the changing phase of the IPO[5], reflecting the complexity of the system that supports the variability in Antarctic sea ice.

Both the 2017 and 2022 record minima are standouts in an observed record marked by a small, but significant, positive (increasing) SIE trend since 1979 (Fig. 1a, yellow), contrasting the decline observed in the Arctic. Record-level interannual variability greatly influences the perception of such long-term trends. For instance, the record minimum in 2017 reduced the net SIE trend (Fig. 1a, purple) by almost 26 %, from 21,348 $km^2\ yr^{-1}$ to 15,717 $km^2\ yr^{-1}$ (ref [3]). The subsequent years of lower-than-average SIE culminating in this new record minimum further reduced that trend by 74%, to 4,137 $km^2\ yr^{-1}$ (**Fig. 1a**, maroon).

Reconstructions of Antarctic sea ice suggest that negative trends existed across most of the 20th century, and that the positive trend observed over the satellite era might have started in the late 1960s or early 1970s[1]. When the record minimum was reached in February 2017, it seemed to mark the start of a reversal of that positive trend. However, after maintaining subaverage values for 2018 and 2019, sea ice extent gradually reached average values by 2020. Given the history of SIE variation over the observational period, the SIE would be expected to stay at average levels or become above average for several more years. This current abrupt return to record minimum is thus surprising.

The level of variability exhibited in 2016-2017 and 2021-2022 is unprecedented in the satellite record and *might* signal a change in the Antarctic sea ice regime as a response to anthropogenic warming. This change might not be a reversal of the trend, but rather a shift to a new state of stability where extremes become more common. Indeed, the new 2022 and 2017 minimums are part of the increased variability in Antarctic SIE that began around 2011, including the record winter maximum of 2014 (**Fig. 1b**). These record fluctuations thus suggest a new period of extremes –a changing sea ice regime.

Further data and analysis are required to evaluate and verify any claims for a changing Antarctic sea ice climate. However, sustained low SIE and increasing variability have substantial consequences for the climate and ecology of the Antarctic. Sea ice can act as a buffer for ice shelves, protecting them from wave action which can hasten disintegration, ultimately affecting the surface mass balance. Sea ice is habitat for penguins, seals and other animals around Antarctica, with emperor penguin populations threatened by current and projected loss of sea ice[6]. ENDING

Figure 1. **Antarctic sea trends and variability**. **a|** Annual Antarctic sea ice extent . and trends over 1979-2016 (yellow), 1979-2017 (purple) and 1979-2022 (maroon). **b|** Annual cycle of Antarctic sea ice extent for the 1981-2010 mean (black), 2014 (green), 2016 (yellow), 2017 (purple), 2021 (blue) and 2022 (maroon). Pale grey lines are the annual cycle of all individual years from 1979 – 2021.

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Competing interests

The authors declare no competing interests.

Acknowledgements

M.R. and M.S.H are supported by the National Science Foundation, Office of Polar Programs (grant no. NSF-OPP-1745089).