Sea Surface Temperature

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Headlines

- August 2023 mean sea surface temperatures (SSTs) were ~5-7°C warmer than 1991-2020 August mean values in the Barents, Kara, Laptev and Beaufort Seas.
- Anomalously cool August 2023 SSTs (~1-3°C cooler) were observed in Baffin Bay, the Greenland Sea and parts of the Chukchi Sea.
- August mean SSTs show warming trends for 1982-2023 in almost all Arctic Ocean regions that are ice-free in August, with mean SST increases over regions between 65° N and 80° N of ~0.5°C per decade.

Arctic Ocean sea surface temperatures (SSTs) in the summer (June-August) are driven by the amount of incoming solar radiation absorbed by the sea surface and by the flow of warm waters into the Arctic from the North Atlantic and North Pacific Oceans. Solar warming of the Arctic Ocean surface is influenced by sea ice distribution (with greater warming occurring in ice-free regions), cloud cover, and upper-ocean stratification. Discharge of relatively warm Arctic river waters can provide an additional heat source to the surface of marginal seas.

Arctic SST is an essential indicator of the role of the ice-albedo feedback cycle in any given summer sea ice melt season. As the sea ice cover decreases, more incoming solar radiation is absorbed by the darker ocean surface and, in turn, the warmer ocean melts more sea ice. In addition, higher SSTs are associated with delayed autumn freeze-up and increased ocean heat storage throughout the year. Marine ecosystems are also influenced by SSTs, which affect primary production and available habitat.

Here we present August 2023 mean SSTs in context with the climatological record. The SST data analyzed are monthly mean values for August (1982-2023) (see Reynolds et al. 2002, 2007; Huang et al. 2021), and comparisons are made to the 1991-2020 baseline period (see *Methods and data*). August mean SSTs provide the most appropriate representation of Arctic Ocean summer SSTs because sea-ice extent is near a seasonal low at this time of year, and there is not the influence of surface cooling and subsequent sea-ice growth that takes place in the latter half of September.

August 2023 mean SSTs were as warm as ~11°C in the Barents, Kara, and Beaufort Seas and reached values as warm as ~8°C in other Arctic basin marginal regions (eastern Chukchi Sea and Laptev Sea, Fig. 1a,b). August 2023 mean SSTs were anomalously warm compared to the 1991-2020 August mean (around 5-7°C warmer) in the Barents, Kara, Laptev, and Beaufort Seas, and anomalously cool in Baffin Bay and parts of the Greenland and Chukchi Seas (around 1-3°C cooler than the 1991-2020 mean; Fig. 1c). These regional variations vary significantly from year-to-year. For example, there were considerably warmer SSTs in the Beaufort Sea in August 2023 compared to August 2022, with differences of up to 7°C (Fig. 1d).

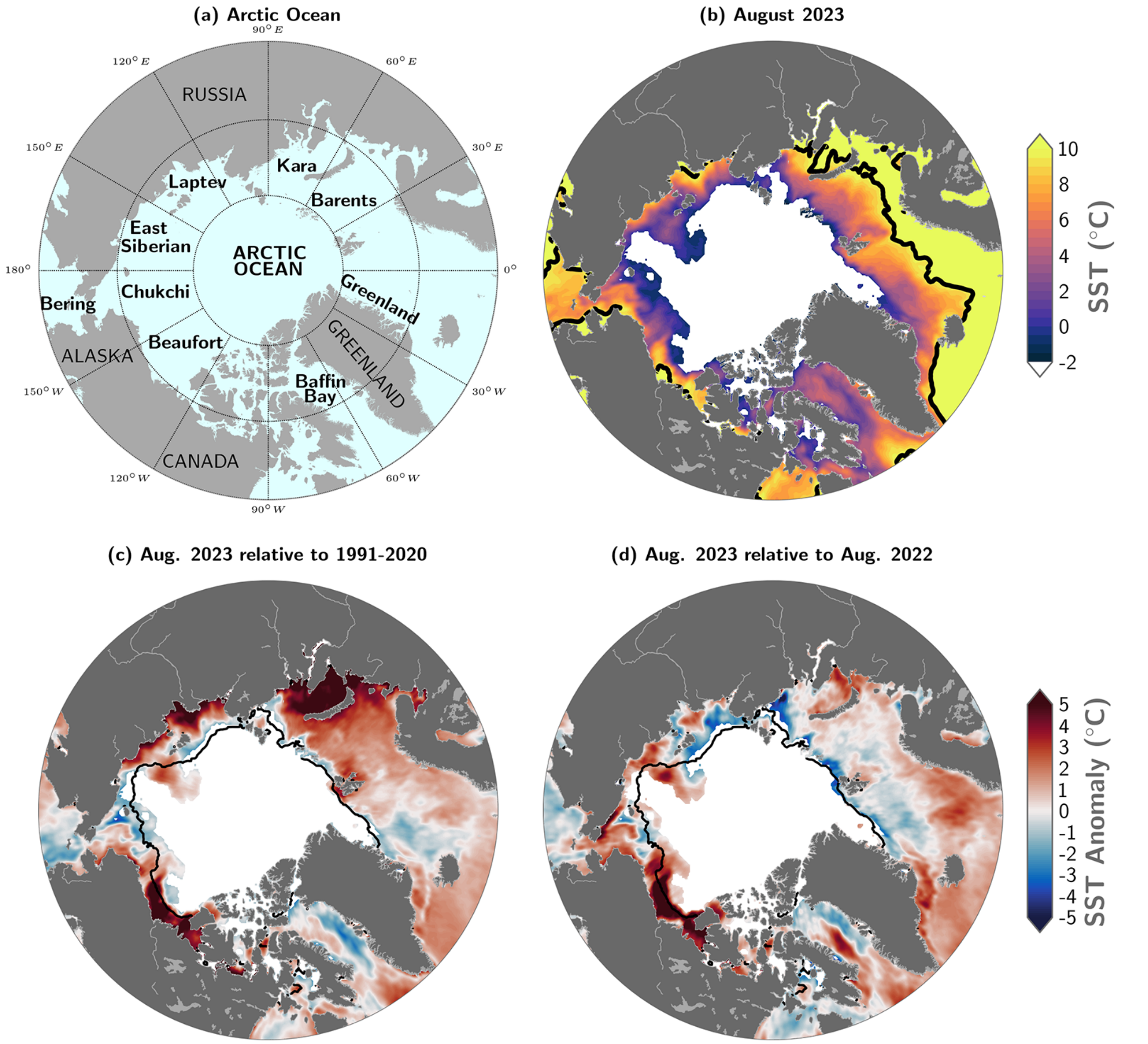

Fig. 1. (a) Arctic Ocean map showing marginal sea locations. (b) Mean sea surface temperature (SST; °C) in August 2023. Black contours indicate the 10°C SST isotherm. (c) SST anomalies (°C) in August 2023 relative to the Aug 1991-2020 mean. (d) Difference between August 2023 SSTs and August 2022 SSTs (negative values indicate where 2023 was cooler). White shading in all panels is the August 2023 mean sea ice extent. Black lines in (c) and (d) indicate the August 1991-2020 median ice edge. See *Methods and data* for data-source information.

Warm river inflows may have influenced marginal sea SSTs with anomalously warm August 2023 SSTs in the Beaufort Sea where the Mackenzie River enters, in the Kara Sea in the vicinity of the Ob and Yenisei River outflows, and in the Laptev Sea where the Lena River enters (Fig. 1c). This corresponds with anomalously warm surface air temperatures in June-August 2023 over northern North America and Siberia (see essay *Surface Air Temperature*).

The above normal August 2023 SSTs in the Beaufort Sea, which were also observed in July (Fig. 2b), relate to relatively low August 2023 sea-ice concentrations in the region (second only to the record low August 2012 conditions for the area extending from the Beaufort to East Siberian Seas; see essay *Sea*

Ice). The timing of seasonal sea-ice retreat from the Beaufort Sea, where sea ice was almost entirely absent by July 2023 (Fig. 2), also links to warm SSTs via the ice-albedo feedback (see essay *Sea Ice*).

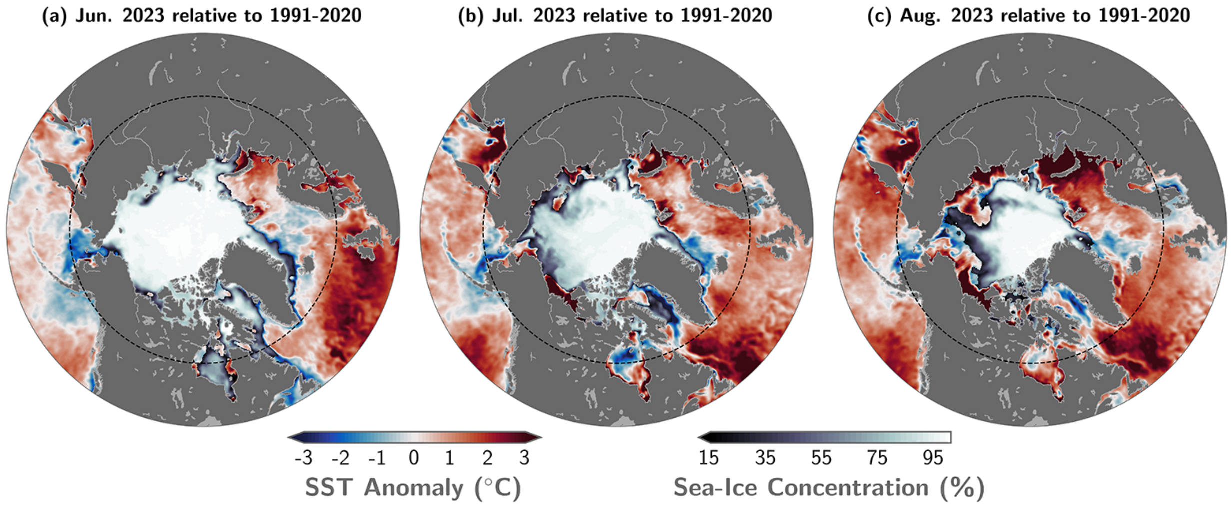

Fig. 2. SST anomalies (°C) for (a) June 2023, (b) July 2023, and (c) August 2023 relative to the 1991-2020 mean for the respective months. The sea-ice concentration for the corresponding month is also shown. The evolution of sea-ice concentration over the months of June to August illustrates why it is not appropriate to evaluate long-term SST trends in June and July over most of the Arctic marginal seas, which still have significant sea-ice cover in those months. The dashed circle indicates the latitudinal bound of Figs. 1 and 3 map images. See *Methods and data* for data-source information.

The cooler-than-normal August 2023 SSTs in Baffin Bay are commensurate with below normal surface air temperatures in the region in June-August 2023 (see essay *Surface Air Temperature*). Early summer sea-ice extent in Baffin Bay was close to the climatological average, with almost full ice cover in June 2023 (Fig. 2a), which is further consistent with the anomalously cool SSTs (see essay on *Sea Ice*).

The Arctic Ocean has experienced mean August SST warming trends from 1982 to 2023, with statistically significant (at the 95% confidence interval) linear warming trends in almost all regions (Fig. 3a). Mean August SSTs for the Arctic Ocean and marginal seas between 65° N and 80° N exhibit a linear warming trend of 0.05 ± 0.01°C/year (Fig. 3b; SSTs for 80° N-90° N are omitted since this region is largely perennially ice covered). Even while anomalously cool SSTs in Baffin Bay were prominent in August 2023 (Fig. 1c), SSTs show a linear warming trend over 1982-2023 of 0.07 ± 0.02°C/year (Fig. 3c) for this region, although with considerable interannual variability in mean August values.

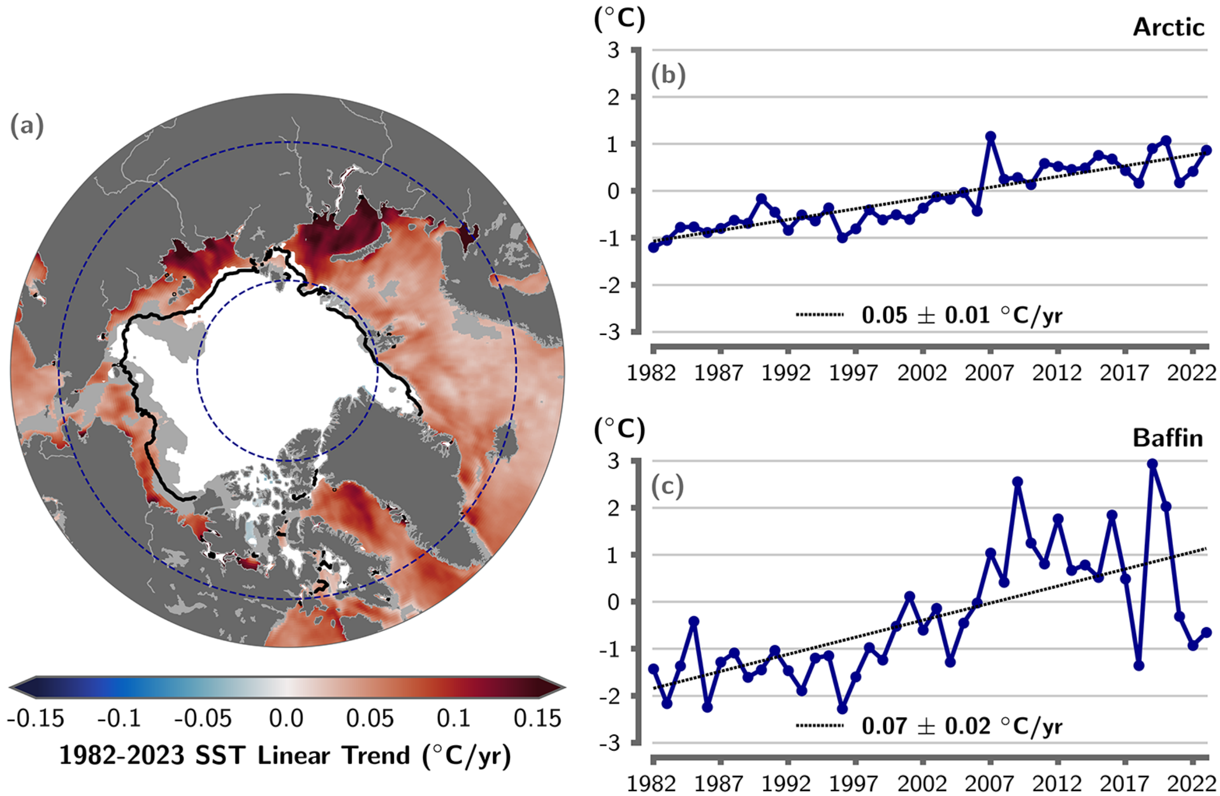

Fig. 3. (a) Linear SST trend (°C/yr) for August of each year from 1982 to 2023. The trend is only shown for values that are statistically significant at the 95% confidence interval; the region is shaded light gray otherwise. White shading is the August 2023 mean sea ice extent, and the black line indicates the August 1991-2020 median ice edge. (b,c) Area-averaged SST anomalies (°C) for August of each year (1982-2023) relative to the 1991-2020 August mean for (b) the Arctic Ocean between 65° N and 80° N (indicated by the dashed blue circles in (a)), and (b) Baffin Bay (see Fig. 1a). The dotted lines show the linear SST anomaly trends over the period shown and trends in °C/yr (with 95% confidence intervals) are indicated on the plots. See *Methods and data* for data-source information.

Methods and data

The SST data presented here are from the 0.25° × 0.25° NOAA Optimum Interpolation Sea Surface Temperature (OISST) Version 2.1 product, a blend of in situ and satellite measurements (Reynolds et al. 2002, 2007; Huang et al. 2021). Details are found here: https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html. The datafile "sst.mon.mean.nc" (comprising monthly means from the daily data) was retrieved from: https://downloads.psl.noaa.gov/Datasets/noaa.oisst.v2.highres/, [accessed 4 September 2023]. The period of analysis is June 1982 to August 2023, with 1991-2020 used as the climatological reference period for the June, July, and August means.

OISST Version 2.1 (v2.1) replaced the 1° × 1° NOAA OISST Version 2 (v2), which was discontinued in January 2023. Version 2.1 is the same as v2 (aside from the horizontal resolution difference) for the period prior to 1 January 2016. After 1 January 2016, v2.1 differs from v2 in multiple ways, including different correction methods and buoy datasets used (see Huang et al. 2021 for a full description). Notably for interpretation of Arctic Ocean SSTs, v2.1 employs a different method than v2 for setting a proxy SST in sea-ice covered regions. Version 2 uses a linear relationship with sea-ice concentration to infer SST under sea ice (Reynolds et al. 2007), while v2.1 modifies this (following Banzon et al. 2020) to set SST equal to the freezing temperature (computed using a climatological sea-surface salinity) where ice concentrations are greater than 35%. We focus primarily on waters that are ice free in August, although the uncertainty in inferring SSTs (and SST trends) may be significant in the vicinity of the sea-ice edge, which varies in location each year.

For comparison with previous-year SST sections of the Arctic Report Card (e.g., Timmermans and Labe 2022), which used monthly-mean v2, we briefly note some important differences by way of example: comparison of the monthly mean August 2022 SST anomaly (relative to 1991-2020) between v2 (Fig. 4a) and v2.1 (Fig. 4b). The broad spatial patterns and their magnitudes are similar between the two products (e.g., generally cooler waters in the Norwegian Sea and the vicinity of Bering Strait, and warmer waters in the Barents and Laptev Seas). However, there are notable differences in the vicinity of the ice edge; for example, Beaufort Sea temperatures adjacent to the ice edge are ~2°C cooler in v2.1. This likely results from differences in the algorithm for proxy SST in the presence of sea-ice cover, and the differences in resolution between v2 and v2.1. Other notable areas are the marginal seas off the coast of Siberia where SSTs are warmer in v2.1. The source of these differences is unclear, although Huang et al. (2021) present a detailed analysis of differences in long-term averages between the two products. Nevertheless, the trends in August mean SSTs reported here (Fig. 3b,c) are statistically indistinguishable between v2 and v2.1, lending confidence to the conclusions and consistency with past Arctic Report Cards.

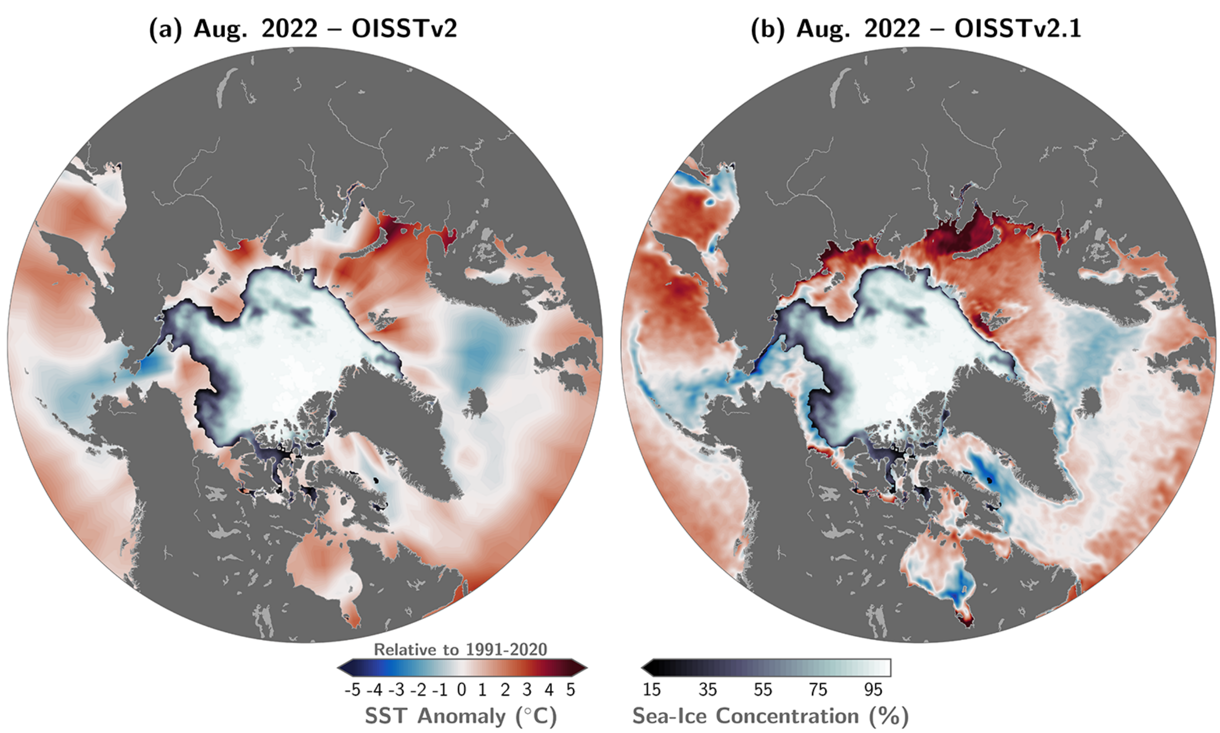

Fig. 4. August 2022 (monthly mean) SST (°C) anomaly (relative to the August 1991-2020 average) from OISST (a) Version 2 and (b) Version 2.1. White and grey shading indicates the mean sea-ice concentration for August 2022. See *Methods and data* for data-source information.

Sea ice concentration data are the NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 4 (https://nsidc.org/data/g02202) for the 1982-2022 period of record, and Near-Real-Time NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 2 (https://nsidc.org/data/g10016) (Peng et al. 2013; Meier et al. 2021a,b) is used for June-August 2023, where a threshold of 15% concentration is used to calculate sea ice extent.

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