9 August 2024

Dear Reviewer 1,

We appreciate your time reviewing and providing constructive feedback on our paper. We have considered and responded to each comment offered, and our responses follow below in **bold**. In addition to manuscript revisions stemming from your comments, we have also slightly modified the title and some of the wording of the text to reflect the nature of the "concurrent" Arctic extremes we are documenting. A new paragraph has been added toward the end of the Introduction section to better frame our study around this relatively new research space emerging on concurrent weather extremes.

Thank you again for your constructive review of our paper.

Sincerely,
Tom Ballinger
Corresponding Author

RC1 Comments

The authors investigated the effects of the SSW and La Nina teleconnections on the unseasonal melt events of the tandem ice loss over the Bring and Labrador Seas in March 2023. Associated large-scale anticyclonic anomalies funneled warm and atmospheric rivers to the bi-regional ice melt events. These results are generally interesting, focusing on the combination of stratospheric and La Nina-related tropospheric effects on Arctic surface thermal conditions. However, the atmospheric circulation features and characteristics associated with La Nina are rather unclear. I would like to propose further research into the effects of La Nina on the Arctic.

Thank you for your thoughtful remarks on our paper. We agree the mentioning of La Niña in the Abstract and text in the absence of more detailed analysis was a rather hasty mention at best. We elaborate further on this teleconnection's links with Arctic sea ice melt in our response to your second point below.

1. It is quite clear that the SSW occurred around 15 Feb and then propagated downward to the surface around 6 Mar, and the Greenland and Alaska blocking intensified. The first question is, how can we link the SSW to the increased mid-tropospheric blocking? Could the authors provide more evidence of the evolution and pattern of the polar vortex?

To better illustrate the connection between the SSW and the mid-tropospheric blocking, Figure R1 shows the 45-75°N eddy geopotential height anomalies (Z*) as a function of pressure vs longitude (where Z* is calculated as the deviation from the zonal-mean), for the periods March 2-6 and March 7-11 2023 (using ERA5 reanalysis data; anomalies are calculated relative to the 1979-2023 climatology). The influence of the SSW shows up as anomalously positive Z* from the mid-stratosphere to the surface over the

Greenland/North Atlantic sector (this feature begins to extend downward from the stratosphere towards the end of February; not shown here, but matches the timing in Figure 4). Also evident is the persistent tropospheric ridge over the N. Pacific/Alaskan region, which amplifies and extends vertically during the March 7-11 period.
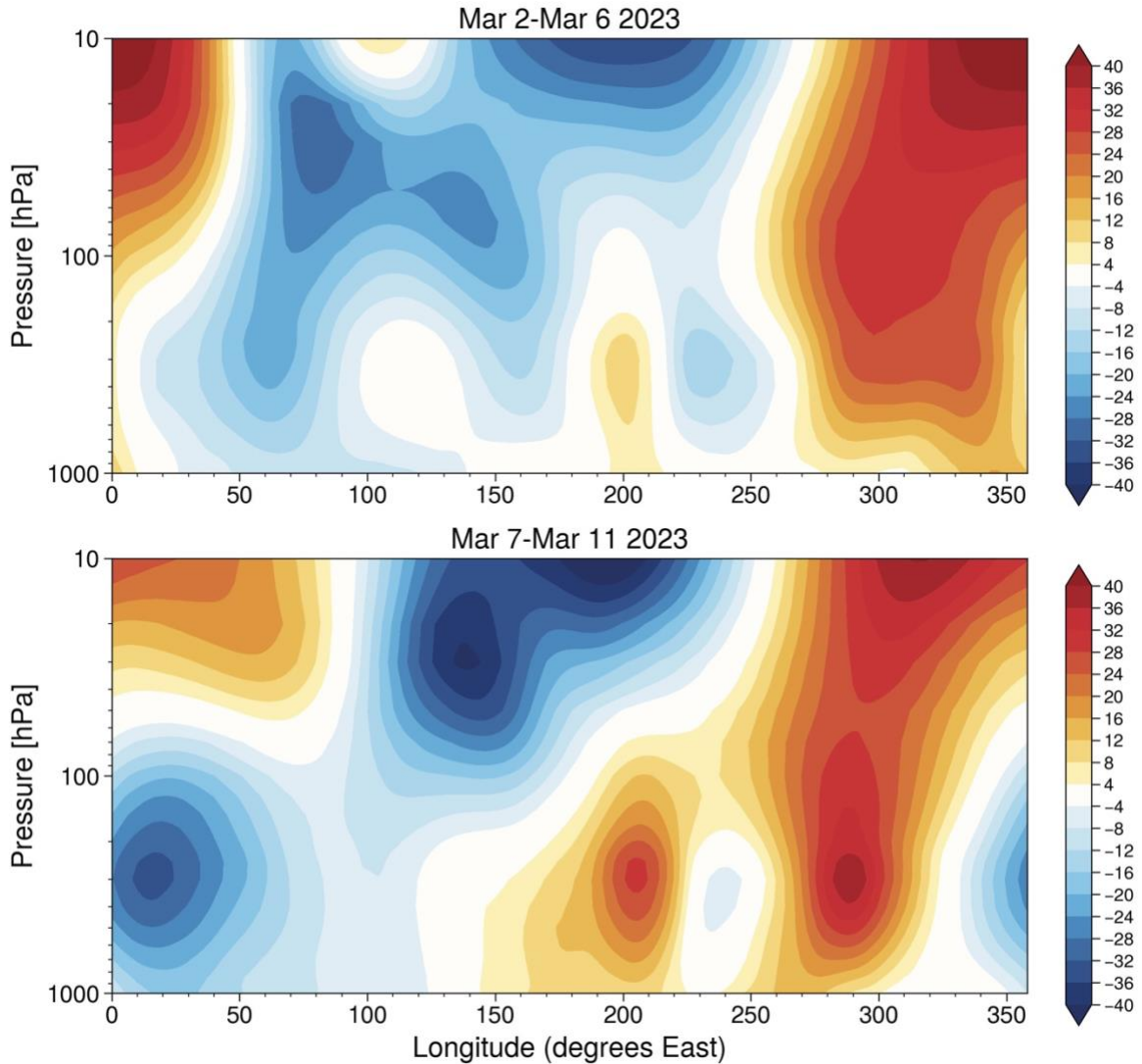

Figure R1. The 45-75°N eddy geopotential height anomalies as a function of pressure vs longitude. These anomalies are calculated as the deviation from the zonal-mean for the periods relative to the 1979-2023 climatology for March 2-6 (top) and March 7-11 2023 (bottom).

2. The La Nina teleconnections are highlighted in the abstract and the main paper, but the associated atmospheric circulation and physical mechanisms are missing. I do not think the present evidence is sufficient to guarantee such a causal link between La Nina and Arctic sea ice melt.

We agree with the reviewer's comment and have removed mention of La Niña from the Abstract as our primary analyses shown in the paper do not explicitly analyze or compare the winter sea ice response of 2023 to past ice cover states during La Niña events. That said, we elect to keep the brief mention of La Niña as a potential background forcing mechanism of ridging atop Alaska in Section 3.2 as a prelude to elaborating more within our Discussion in Section 4.2 on La Nina's role in shaping this upper-level feature. In the latter section, Figure S3 is referenced which compares z500 and T2m conditions in the 2023 SSW under La Niña conditions (Figure S3a) to those same fields during other such La Niña phases of similar winter periods in 1984, 1989, 1999, 2001, 2006, 2008, 2009, and 2018 (Figure S3b). While explicit links to between tropical Pacific-origin teleconnections and Arctic sea ice are not focused upon in our study, we feel it is important to include mention of links between past La Niña events and upper-level circulation and surface temperatures in the Arctic as compared with the 2023 case we focus upon.

3. Surface air temperature anomalies reach up to 15K over the Labrador and Bering Seas, but the extent and area of sea ice melt is quite small. Could the authors quantify the relative changes in area, extent and concentration?

It is true that despite the warm surface air temperature anomalies of ~15K that persisted over the Labrador and Bering Seas concurrently from 5-7 March (Figure 7d-f), the sea ice concentration (SIC) fluctuations in the respective marginal seas are not all that extreme (Figure 2). We believe showing the area and extent series would not change this argument. What stands out, however, are the large 4-day changes in early March SIC that occurred concurrently in both areas (Figure 3). These concurrent SIC loss features and their complex set of atmospheric drivers is what we focus upon in the paper.

On a related note, the idea of "concurrent extremes" is one gaining traction in the literature. As such we elect to replace "simultaneous" with "concurrent" in the title and several places in the text. We have added a paragraph on the nature of such events in the second to last paragraph of the Introduction section in an effort to place this study in line with papers recently published on this topic.

4. The atmospheric river plays an important role in Arctic warming in March. I am curious about the atmospheric water vapour transports associated with the blockings and the role of water vapour on surface temperature. Is the water vapour converted into snow or rain to lower the temperature, or is the surface warmed by increased longwave radiation?

Observations suggest that rain and increased longwave during atmospheric river passage may have impacted the melt events. Rain was measured in multiple rain gauges in coastal observations near the ice pack edge (Nuuk, Kobbefjord, and Aasiaat in west Greenland and Kotzebue and Nome in northwest Alaska). As mentioned in the second to last

paragraph of Section 4.2, a surface energy budget (SEB) analysis including the contribution of latent heating and humidity fluxes into the melt anomalies is subject of follow-on study.

In lieu of SEB analyses over both regions, we have made new winter-long new time series plots of two-meter air temperature, total column water vapor, net longwave (LW) radiation, and downwelling LW over the Labrador Sea and Bering Sea. These are shown below and have been inserted, along with accompanying text, into the revised paper as new Figures 9 and 10, respectively. These plots clearly show how the respective peak four-day melt events coincide within +/-1 day of maximum temperature, moisture, and net/downwelling LW radiation in the respective areas. We comment on these new findings in the last paragraph of Section 3.3.
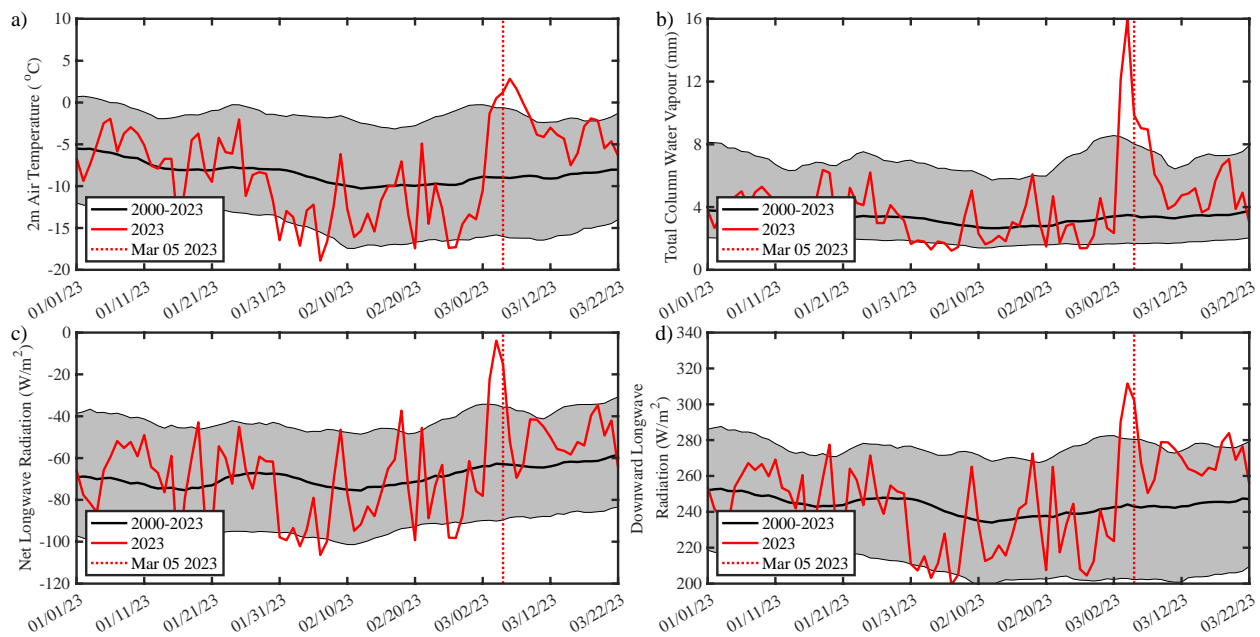

Figure 9. Time series (red curves) of ERA5: a) two-meter air temperature (°C), b) total column water vapor (mm), c) net longwave radiation (W/m²), and d) downward longwave radiation (W/m²) averaged over the Labrador Sea region, indicated in Figure 1b, for the period January 1 to March 26, 2023. The black line represents the climatological mean value for the period 2000-2023 with shading incorporating values between the 5th and 95th percentiles. The ending date for the 4-day window with the largest change in sea ice concentration is shown with the dotted red line.
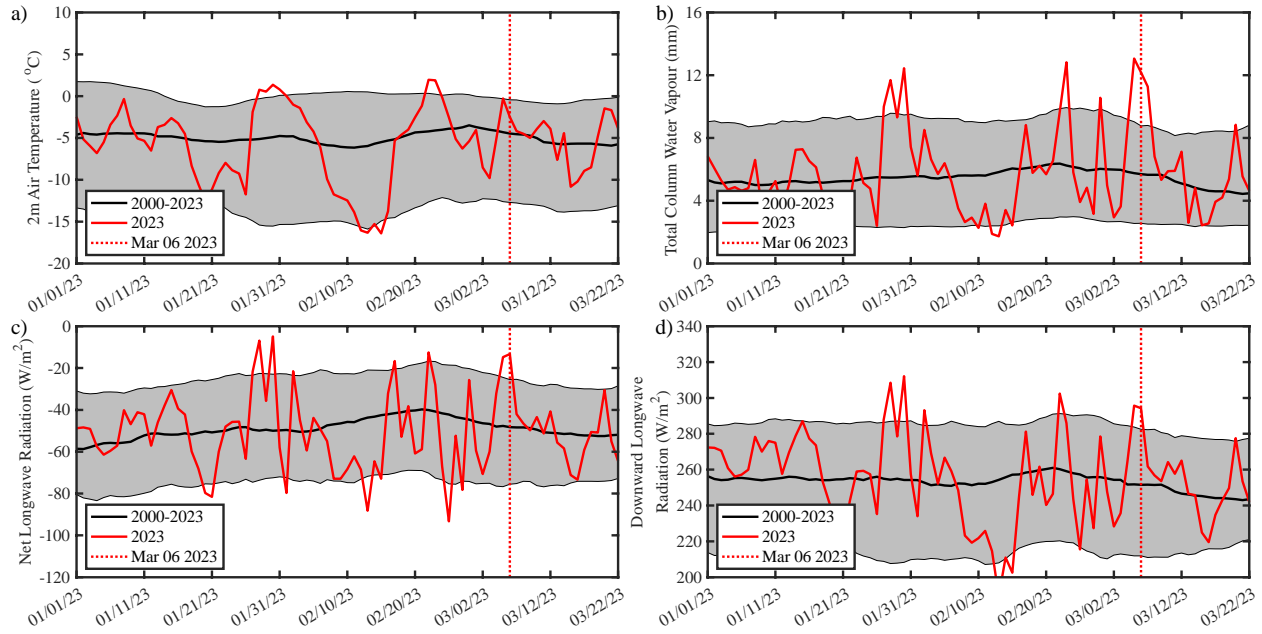
Figure 10. Time series (red curves) of ERA5: a) two-meter air temperature (°C), b) total column water vapor (mm), c) net longwave radiation (W/m^2), and d) downward longwave radiation (W/m^2) averaged over the Bering Sea region, indicated in Figure 1e, for the period January 1 to March 26, 2023. The black line represents the climatological mean value for the period 2000-2023 with shading incorporating values between the 5th and 95th percentiles. The ending date for the 4-day window with the largest change in sea ice concentration is shown with the dotted red line.

5. Figure 5: I would suggest that the authors show the climatological daily evolution to facilitate contrasts between the extreme event and the climatology, so that the magnitude of the anomalies is more apparent. I am also curious about the magnitude of the geopotential height and 2m temperature, which reach 500m and 16k respectively. Is this correct?

Below we have included the daily means (orange lines in Figure R2 below) for each variable's full period of record for reference. As there is minimal difference between these values and the full winter period averages from 1 January to 31 March (solid black lines) as shown in existing Figure 5, we prefer to keep the time series as presented, which are consistent with Figures 8 and 9.

In terms of the second comment, we checked the data and the z500 and two-meter air temperature anomalies are correct as plotted in Figures 6 and 7, respectively.
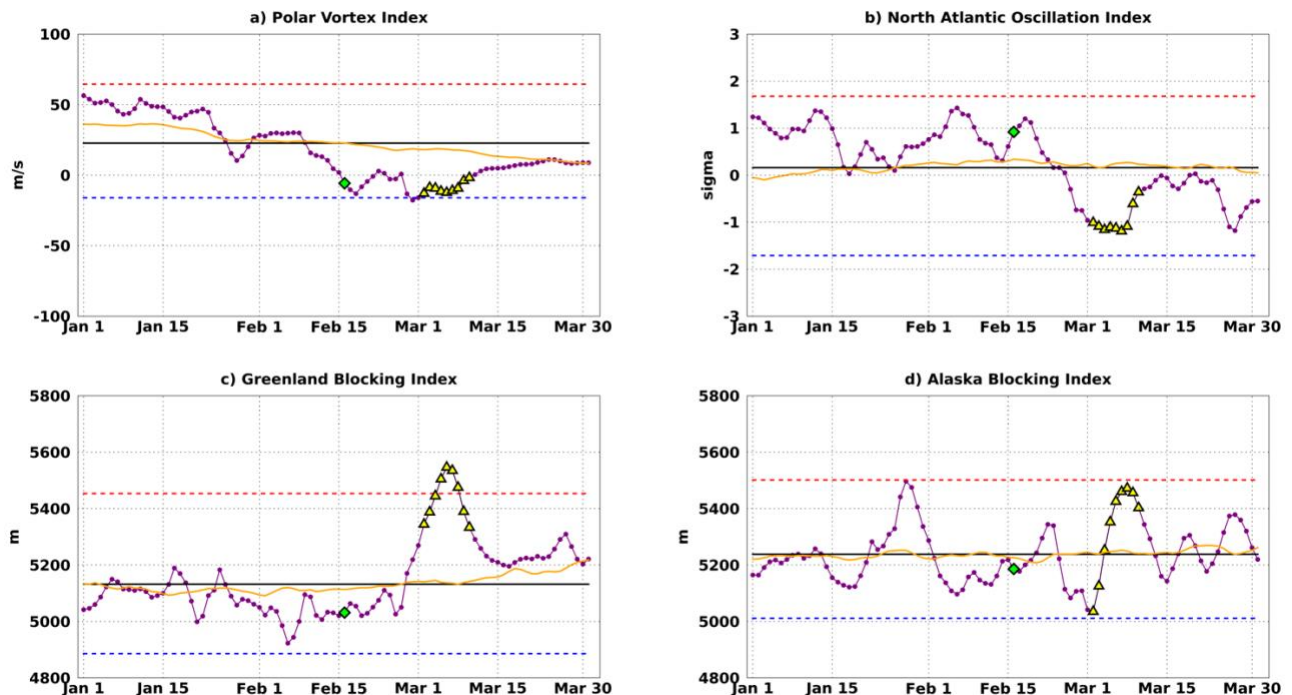

Figure R2. Daily atmospheric indices for 1 January – 31 March 2023 (purple lines) overlapping the multi-sectoral melt event for the a) Polar Vortex Index (m/s), b) North Atlantic Oscillation Index (standardized), c) Greenland Blocking Index (m), and d) Alaska Blocking Index (m). Considering all days from 1 January to 31 March for the respective indices full periods of record (see Section 2.1), the mean of each variable (black line), 1st percentile (blue dashed line), and 99th percentile (red dashed line) are shown in each graphic. Daily means are also shown by the solid orange lines. The sudden stratospheric warming event on 16 February 2023 is labeled with a green diamond, and to draw attention to the dates around the Labrador Sea and Bering Sea melt events, the period from 2-10 March 2023 is identified by yellow triangles.