Consequences of Arctic Sea Ice Loss in Recent Decades

Marianne Williams-Kerslake – marianne.williams-kerslake@nersc.no

1. Introduction

The Arctic Ocean has experienced a **20%** decrease in annual mean sea-ice extent since the 1980s with the largest decline observed in summer (Stroeve et al., 2007, Eisenman et al., 2011). The decline in Arctic sea ice in recent decades has been attributed, in large part, to increasing greenhouse warming and we are expected to observe an ice-free summer in upcoming decades. As a result of the above trends in observed Arctic sea ice, it is important to understand the consequences of Arctic sea ice loss for both local and global climate patterns and marine ecosystems. The main consequences of Arctic sea ice loss in recent decades include; disturbance of global weather patterns, a threat to coastal communities, and extreme temperatures (Vihma, 2014; Constable , et al., 2022; Lo, et al., 2023). A decline in sea ice in the AO will also drive further Arctic warming and sea ice loss; and thus plays a critical role in Arctic warming Amplification. To understand the consequences of ice loss in the Arctic, we present a review of recent studies that investigate the implications of Arctic sea ice loss. We will, in particular, focus on sea ice decline in the Barents Sea (20-60°E, 67.5-85°N).

2. Arctic Sea Ice Loss: Barents Sea

One region where a decline in sea ice has been observed is the **Barents Sea**, defined previously as (20-60°E, 67.5-85°N). Using Topaz4b model output (Xie, et al., 2017) the mean winter (January-March) sea-ice edge in the Barents Sea has been plotted at 5-year intervals from 1991-2021 **(Figure 1)**. Using methods adapted from Docquier & Fuentes-Franco, (2020), the mean winter sea-ice edge is defined here as a sea ice concentration of 15%. Figure 1 highlights that the mean winter sea-ice edge has retreated considerably in recent years. The largest retreat is in 2006-2010 and 2016-2021. The Southeast and Northeast Barents Sea have experienced the largest change in winter ice cover.

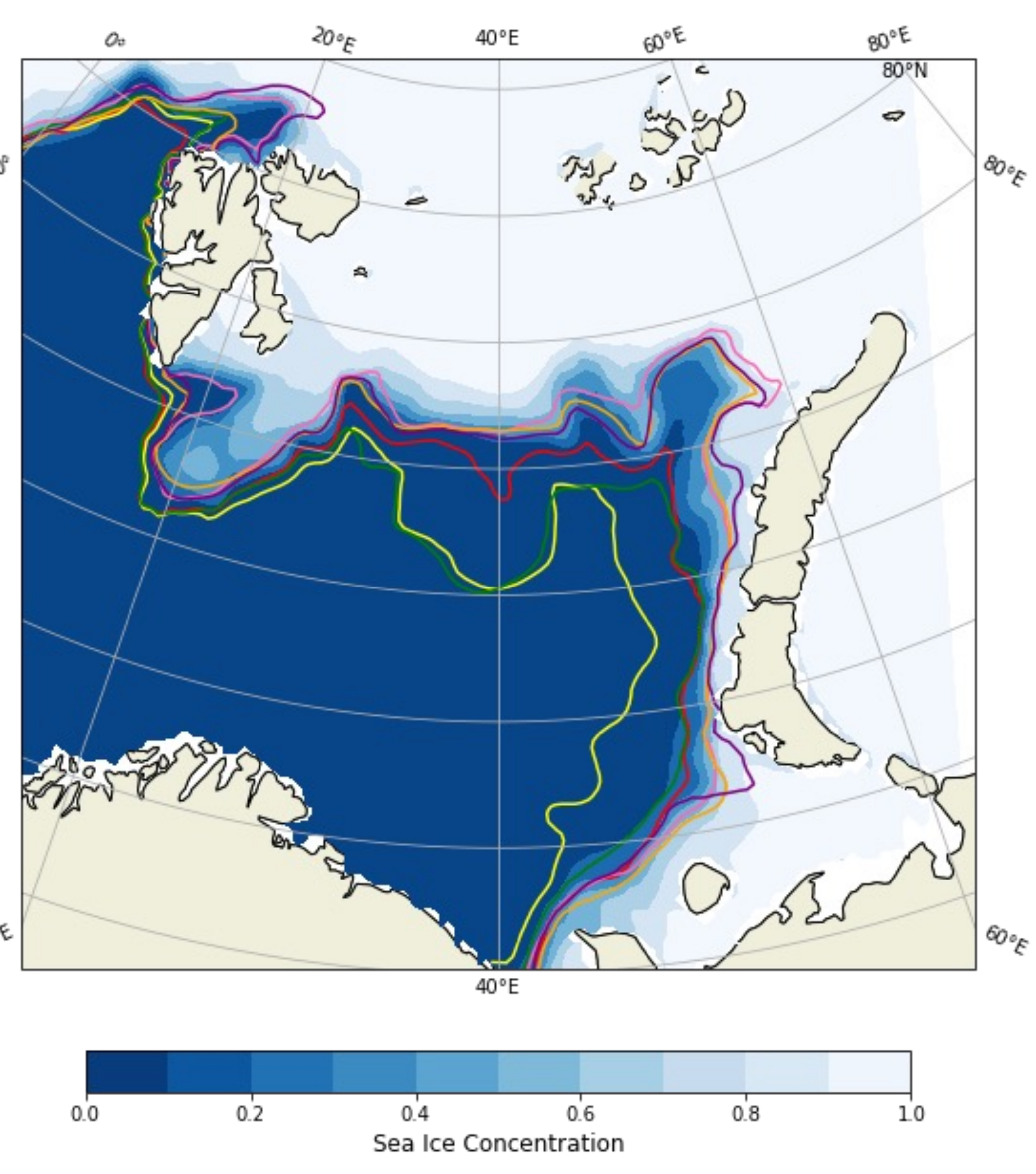


Figure 1: January-March sea-ice concentration in the Barents Sea averaged over 1991-2021 from TOPAZ4b model output. Contours show mean January-March sea-ice edge (where sea-ice concentration is 0.15) every 5 years for **1991-1995 (red), 1996-2000 (yellow), 2001-2005 (green), 2006-2010 (pink), 2011-2015 (orange)** and **2016-2021 (purple)**.

SCAN ME

3. Extreme Temperatures

- Arctic sea ice loss can lead to extreme warm temperatures in the Arctic Ocean. In the Barents Sea, warming has been strongly linked, both in space and time, to the large reduction of sea ice (Isaksen, et al., 2022). Exceptional warming has been shown in the Barents Sea in observations and reanalyses **(Figure 2a,b)**.
- A negative correlation has been shown between the annual surface temperature and sea ice concentration in CARRA and ERA5 reanalyses in regions of the Barents Sea **(Figure 2c)**, implying that as sea ice declines we will observe more extreme temperatures in the Arctic Ocean.

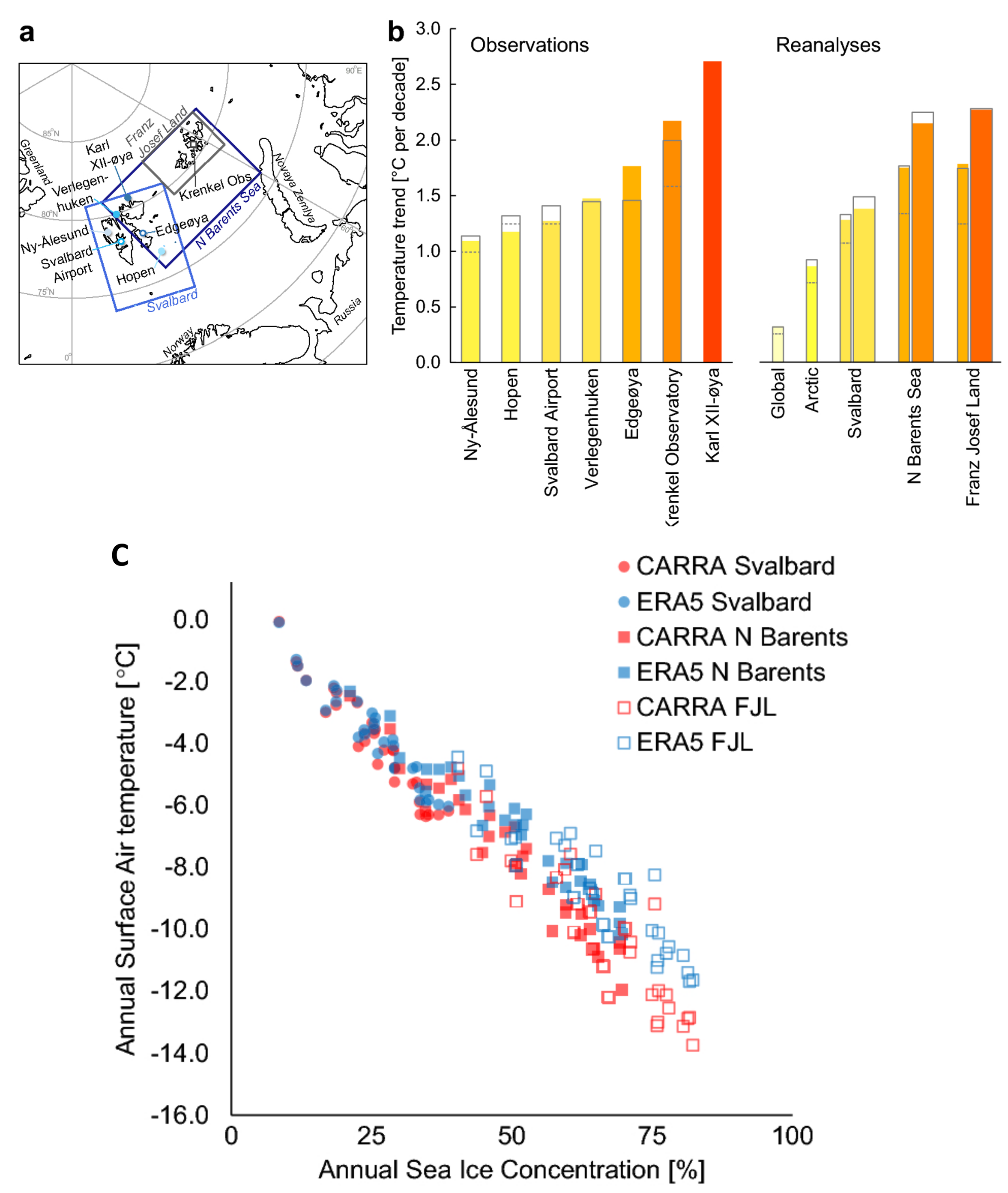


Figure 2: (**a**) Study locations in the Barents Sea. (**b**) Temperature trends for annual surface air temperature (SAT) (2001–2020). On the right the ERA5 and CARRA reanalyses are shown as thin and thick bars, respectively. SAT trends for ERA5 for the Arctic (i.e. north of 65° latitude) and global mean are shown**. c)** Correlation between sea ice concentration and SAT in CARRA and ERA5 reanalyses (Isaksen, et al., 2022).

4. Further sea ice loss

Arctic Amplification (AA) refers to the enhancement of near-surface air temperature change over the Arctic compared to lower latitudes; a feature increasingly apparent in observations from recent decades (Serreze, et al., 2009). AA is leading to a decline in sea ice extent by driving ice melt. Through a positive feedback loop such trends can lead to a further decline in sea ice extent. When sea ice is lost, sunlight is no longer reflected back to the atmosphere and is instead absorbed into the open ocean, this amplifies ocean warming and forms a feedback loop. Warmer water temperatures delay the growth of ice in the autumn and winter and ice melts faster in the spring, exposing patches of open ocean for longer periods during the summer, further warming the ocean and melting sea ice **(Figure 3)**.

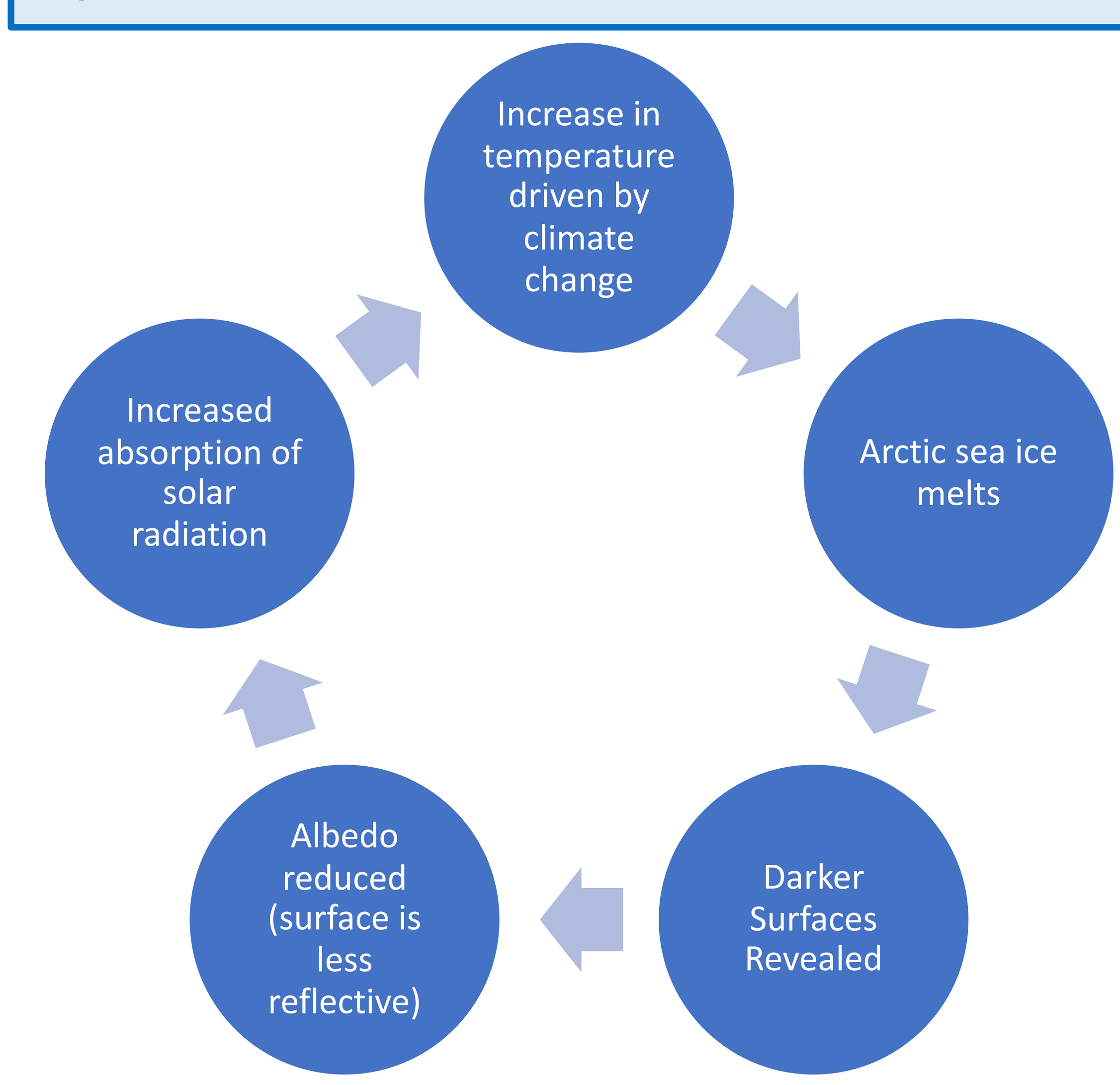


Figure 3: Feedback loop resulting in a decline in Arctic sea ice extent.

5. Disturbance of global weather patterns

- Arctic sea-ice loss will have consequences for global weather patterns. Arctic sea-ice loss is projected to lead to more frequent strong El Niño events (Liu, et al., 2022). El Niño is a weather pattern that involves warming of sea surface temperatures (SST) in the central and eastern tropical Pacific Ocean. El Niño influences weather extremes, including tropical drought and global mean temperature (Goddard & Gershunov, 2020).
- A seasonally ice-free Arctic is shown to result in large and significant below-normal (above-normal) winter sea-level pressure (SLP) anomalies over the Arctic Ocean and the extratropical North Pacific and North America (Siberia and Europe) **(Figure 4)**. A modelled seasonally ice-free Arctic also results in a band of positive SST anomalies extending from the northeastern Pacific to the tropical Pacific and a zonal band of negative SST anomalies along ~30°N **(Figure 4)** (Liu, et al., 2022).

ICEp2 = Seasonally ice–free Arctic model simulation.
ICEhist = Climatological Arctic sea-ice cover (expected ice cover).

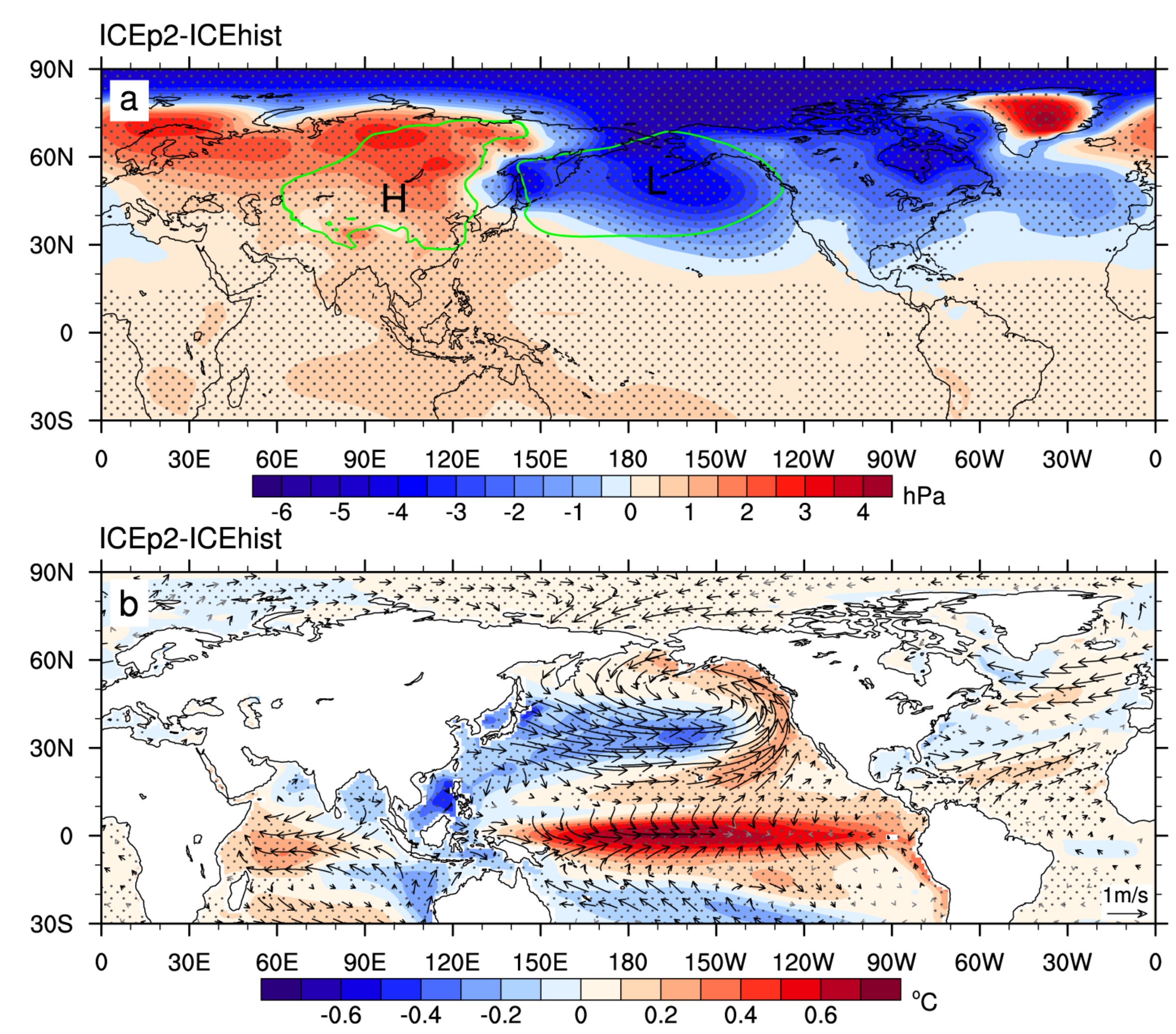
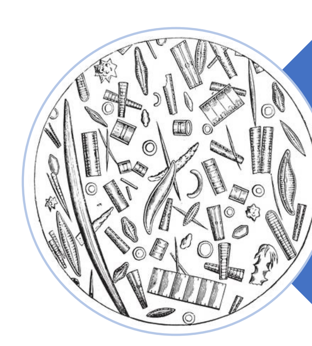
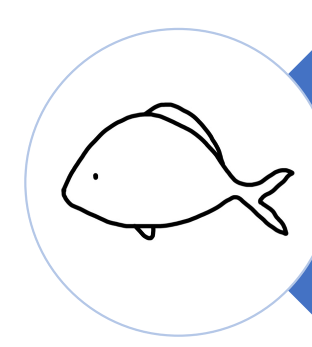


Fig. 4: Changes in a) winter sea-level pressure (SLP), and b) sea-surface temperature (SST) and near-surface winds induced by the seasonally ice-free Arctic (Liu, et al., 2022).

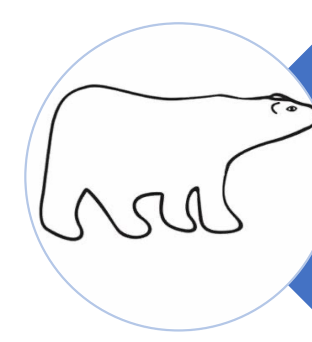
6. The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems under sea ice loss



Increasing light penetration will initiate earlier seasonal primary production (PP) and an increase in PP.



Replacement of polar communities by sub-polar communities.



Decline in common species to the Arctic, including, beluga whales, polar bears and polar cod.

Content adapted from Lannuzel, et al., (2020).

7. Summary/Conclusions

- The consequences of Arctic sea ice loss include; extreme temperatures, further sea ice loss, disturbance of global weather patterns and a threat to some Arctic species.
- Disturbance of global weather patterns will pose a threat to coastal communities.
- The above consequences provide a rationale for continued monitoring of Arctic sea ice.

References

Constable, A. J. et al., 2022. *Cross-Chapter Paper 6: Polar Regions. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.,* Cambridge: Cambridge University Press.
Docquier, D. & Fuentes-Franco, R., 2020. Sea Ice—Ocean Interactions in the Barents Sea Modeled at Different Resolutions. Frontiers in Earth Science , Volume 8.
Eisenman, I., Schneider, T., Battisti, D. S. & Bitz, C. M., 2011. Consistent Changes in the Sea Ice Seasonal Cycle in Response to Global Warming. Journal of Climate, Volume 24, p. 5325–5335.
Goddard, L. & Gershunov, A., 2020. Impact of El Niño on Weather and Climate Extremes. In: M. J. McPhaden, A. Santoso & W. Cai, eds. El Niño Southern Oscillation in a Changing Climate. Washington, D.C: American Geophysical Union.
Isaksen, K. et al., 2022. Exceptional warming over the Barents area. *Scientific Reports,* 12(9371).
Lannuzel, D. et al., 2020. The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems. *Nature Climate Change,* Volume 10, p. 983–992.
Liu, J. et al., 2022. Arctic sea-ice loss is projected to lead to more frequent strong El Niño events. *Nature communications,* 13(4952).
Lo, Y. T. E., Mitchell, D. M., Watson, P. A. G. & Screen, J. A., 2023. Changes in Winter Temperature Extremes From Future Arctic Sea-Ice Loss and Ocean Warming. *Geophysical Research Letters,* 50(3).
Serreze, M. C., Barrett, A. P., Kindig, D. N. & Holland, M. M., 2009. The emergence of surface-based Arctic amplification. *The Cryosphere,* Volume 3, pp. 11-19.
Stroeve, J., Holland, M. M., Meider, W. & Scambos, T., 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters, 34(9).
Vihma, T., 2014. Effects of Arctic Sea Ice Decline on Weather and Climate: A Review. *Surveys in Geophysics,* Volume 35, pp. 1175-1214.
Xie, J. et al., 2017. Quality assessment of the TOPAZ4 reanalysis in the Arctic over the period 1991–2013. *Ocean Science,* Volume 13, pp. 123-144.