How unusual is the decade-long pause in Arctic summer sea ice retreat?

Patricia DeRepentigny[1], François Massonnet[1], Roberto Bilbao[2], and Stefano Materia[2]

[1]Université catholique de Louvain, [2]Barcelona Supercomputing Center

Contact: **patricia.derepentigny@uclouvain.be**

Motivation

The Earth has warmed significantly over the past 40 years, and the fastest rate of warming has occurred in and around the Arctic. The warming of northern high latitudes at a rate of almost four time the global average (Rantanen et al., 2022), known as Arctic amplification, is associated with sea ice loss, glacier retreat, permafrost degradation, and expansion of the melting season. Since the mid-2000s, summer sea ice has exhibited a rapid decline, reaching record minima in September sea ice area in 2007 and 2012. However, after the early 2010s, the downward trend of minimum sea ice area appears to decelerate (Swart et al., 2015; Baxter et al., 2019). This apparent slowdown and the preceding acceleration in the rate of sea ice loss are puzzling in light of a steadily increasing rate of greenhouse gas emissions of 2 ppm yr^{-1} in the past decade that provides a steady climate forcing. Recent studies suggest that low-frequency internal climate variability may have been as important as anthropogenic influences on observed Arctic sea ice decline over the past four decades.

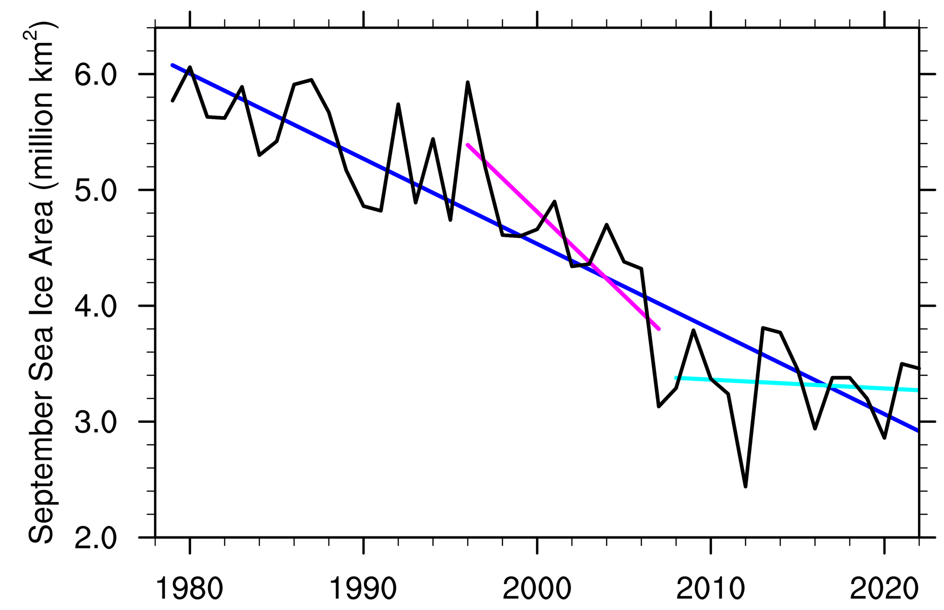

Figure 1. Timeseries of September sea ice area. The blue line shows the linear trend over the whole observational period, the pink line from 1996-2007 and the cyan line from 2008-2022.

DCPP-hindcast simulations

EC-Earth3:

- dcppA-hindcast simulations (Bilbao et al., 2021)
- Initialized in November of years 1960-2020
- Full-field initialization
- 10 ensemble members with 10 forecast years + 10 ensemble members with 3 forecast years

CanESM5:

- dcppA-hindcast simulations (Sospedra-Alfonso et al., 2021)
- Initialized in November of years 1960-2019
- Full-field initialization
- 20 ensemble members with 10 forecast years

Poor forecast skill in March but re-emergence in September

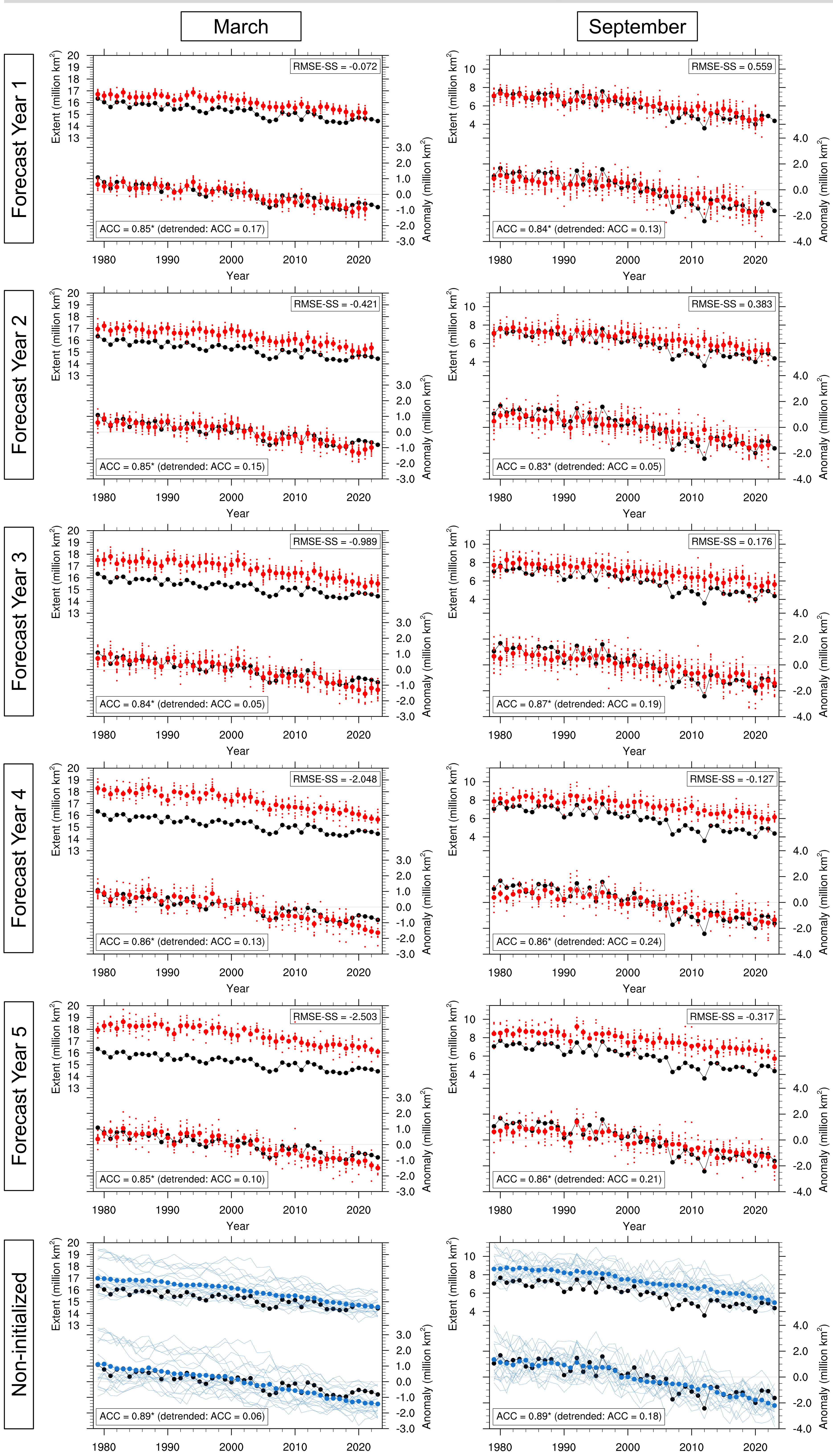

Figure 2. Timeseries of March (left) and September (right) sea ice extent for the EC-Earth3 DCPP-hindcast simulations initialized in November at forecast year 1-5 (top) and for the EC-Earth3 non-initialized CMIP6 historical + SSP5-8.5 simulations (bottom). In each panel, the top part show the sea ice extent and the bottom part the sea ice extent anomaly. Observations are shown in black, individual ensemble members are shown by small dots/thin lines and the ensemble mean is show by big dots. The ACC and RMSE-SS are indicated in each panel, with * indicating significance.

Not unusual, but the rapid decline in the late 2000s is!

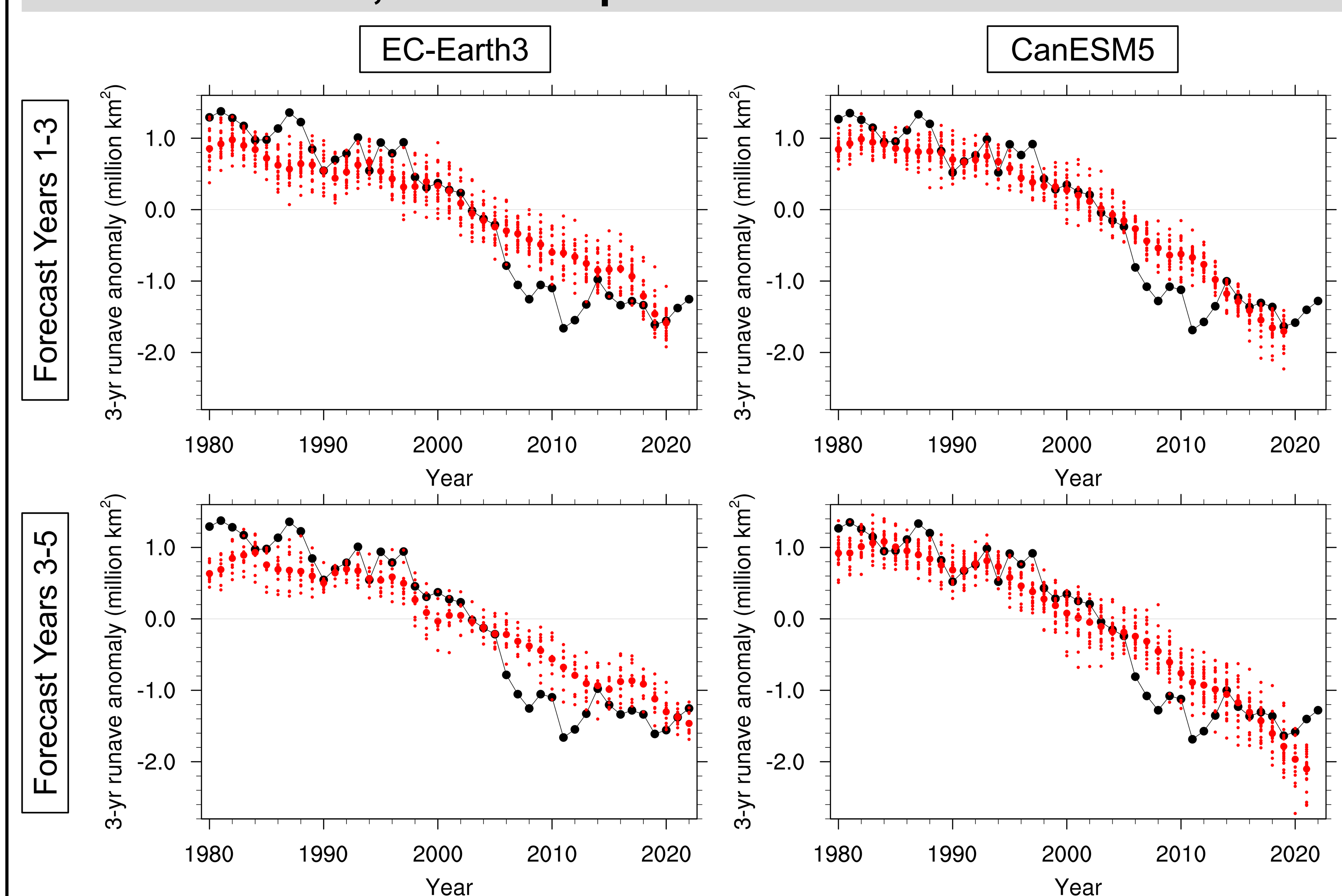

Figure 3. Timeseries of 3-year running mean September sea ice extent anomaly for the EC-Earth3 (left) and CanESM5 (right) DCPP-hindcast simulations initialized in November averaged over forecast years 1-3 (top) and 3-5 (bottom). Observations are shown in black, individual ensemble members are shown by small dots/thin lines and the ensemble mean is show by big dots. Note that the panel for EC-Earth 3 forecast years 3-5 only included 10 ensemble members instead of 20.

Summary

- The EC-Earth3 DCPP-hindcast simulations show poor skill in simulating the March Arctic sea ice extent, even for forecast year 1 (i.e., only 5 months after initialization).
- Despite this, the skill in September is quite good and does better than the non-initialized runs up to forecast year 3
- The poor skill in March followed by good skill in September hints at the summer-to-summer reemergence of predictive skill that has been proposed before (Blanchard-Wrigglesworth et al., 2011).
- Both EC-Earth3 and CanESM5 do not represent the accelerated sea ice loss over the late 2000s. This suggest that internal variability, particularly summertime atmospheric variability potentially connected to internal modes of variability connecting the Arctic to the lower latitudes (Baxter et al., 2019), most likely drove the observed accelerated sea ice loss and that models struggle to capture these teleconnections.

Future Work

- Multi-model analysis by including more models that participated in the DCPP.
- Looking at the influence of the initialization method (full-field vs anomaly initialization) and the time of initialization on the predictive skill.
- Investigate some of the physical mechanisms (e.g., ocean mixed layer heat content, large-scale modes of atmospheric variability, etc.) that could help understand the difference in skill between different months/models.
- Spatial analysis between the Atlantic and Pacific sectors – does the initialization problem in the Labrador Sea impact the ability of the model to correct predict the sea ice retreat in this region?

Rantanen et al., (2022). The Arctic has warmed nearly four times faster than the globe since 1979. *Communications Earth & Environment.*

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