Sea Ice — Climate Interactions & Teleconnections

AOS 801 - Lecture 13

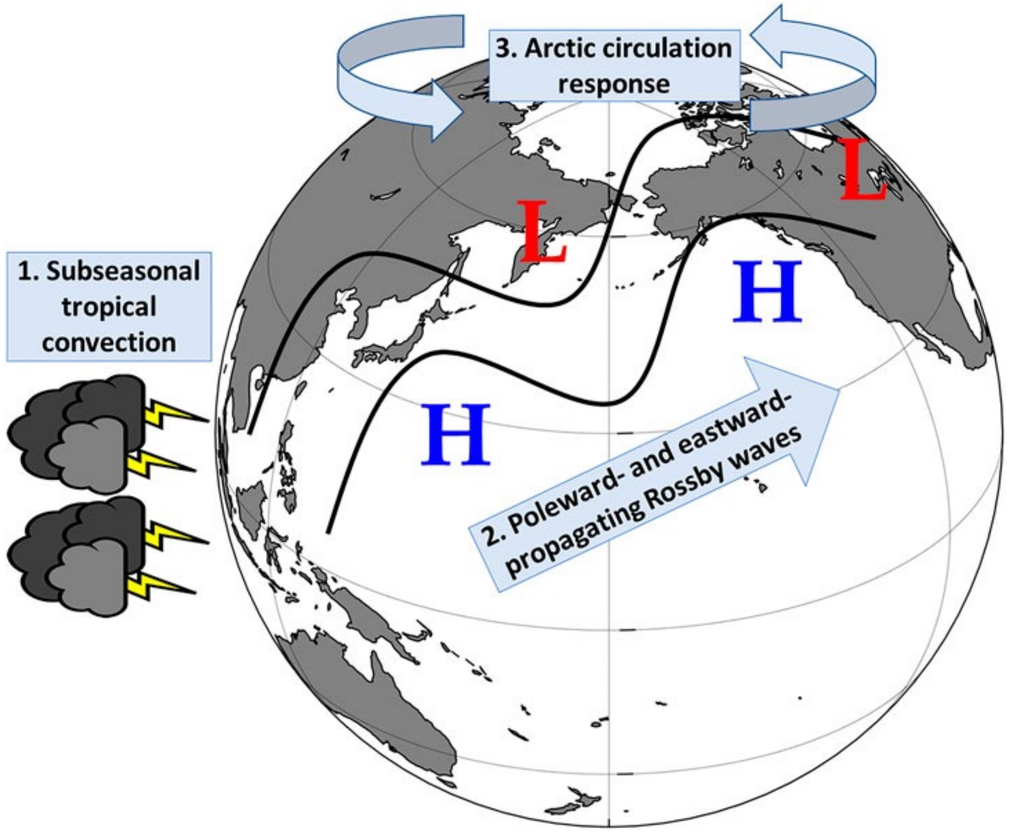
Till Wagner, Oct 19 2022

Tropics influencing the poles

The tropics can influence the poles on different timescales

- Madden Julian Oscillation (subseasonal)
- ENSO (interannual), *just talked about*
- Pacific Decadal Oscillation (multi-decadal)

Tropics influencing the Arctic (MJO)



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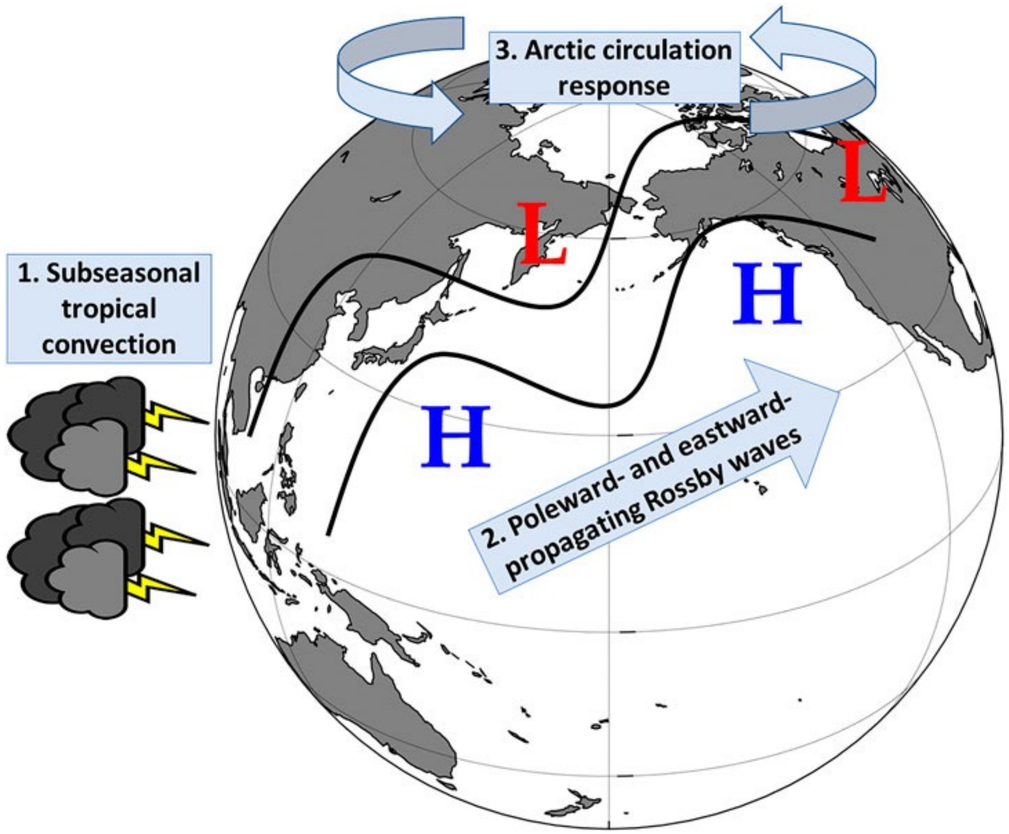
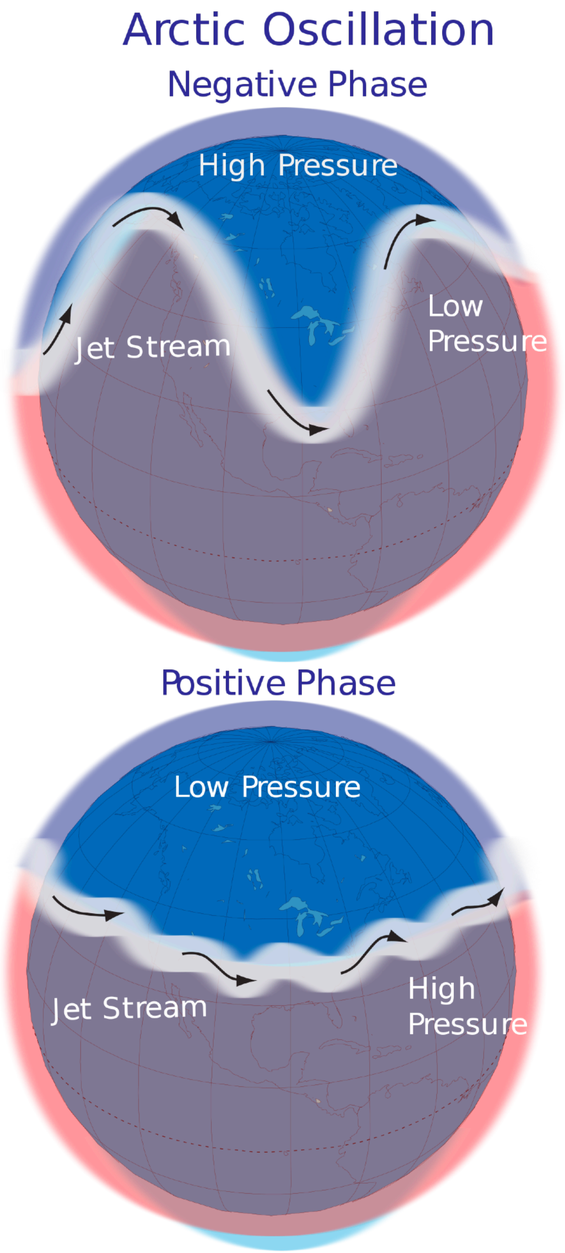




Tropics influencing the Arctic (PDO/IPO)

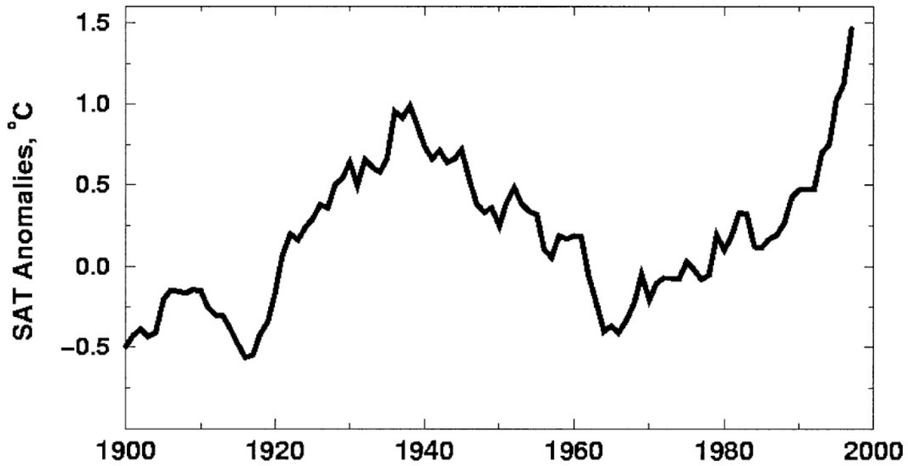


FIG. 1. Annual mean Arctic SAT anomalies (°C, area averaged from 60°–90°N) from Johannessen et al. (2004), 5-yr running mean.

Letter | Published: 06 August 2018

Pacific contribution to the early twentieth-century warming in the Arctic

Lea Svendsen ✉, Noel Keenlyside, Ingo Bethke, Yongqi Gao & Nour-Eddine Omrani

Nature Climate Change **8**, 793–797 (2018) | Cite this article

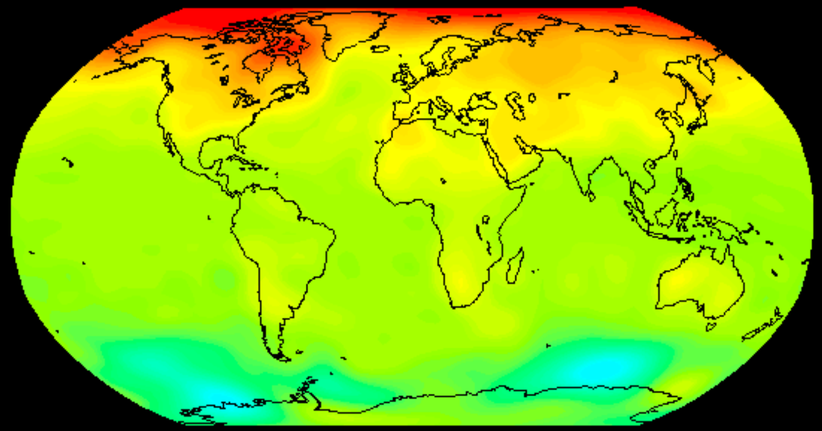
- Multi-decadal Pacific Variability has been shown to explain a large portion of the warming of the Arctic 1920-1950

Meehl et al 2018

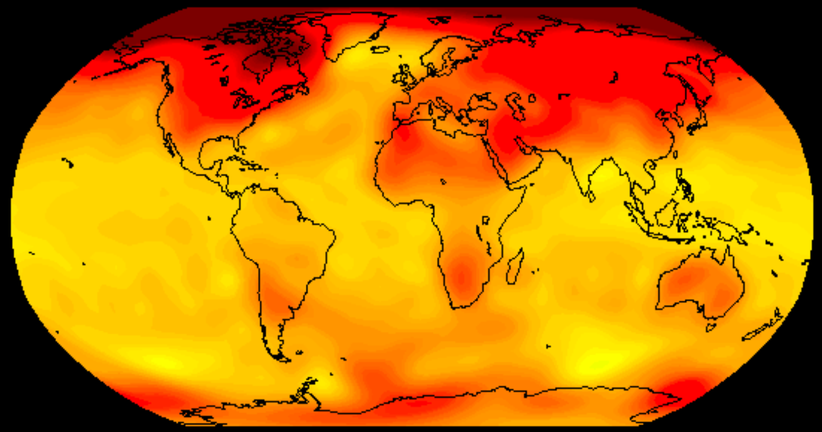
Arctic Amplification

Surface Air Warming (deg F)

$2\times CO_2$

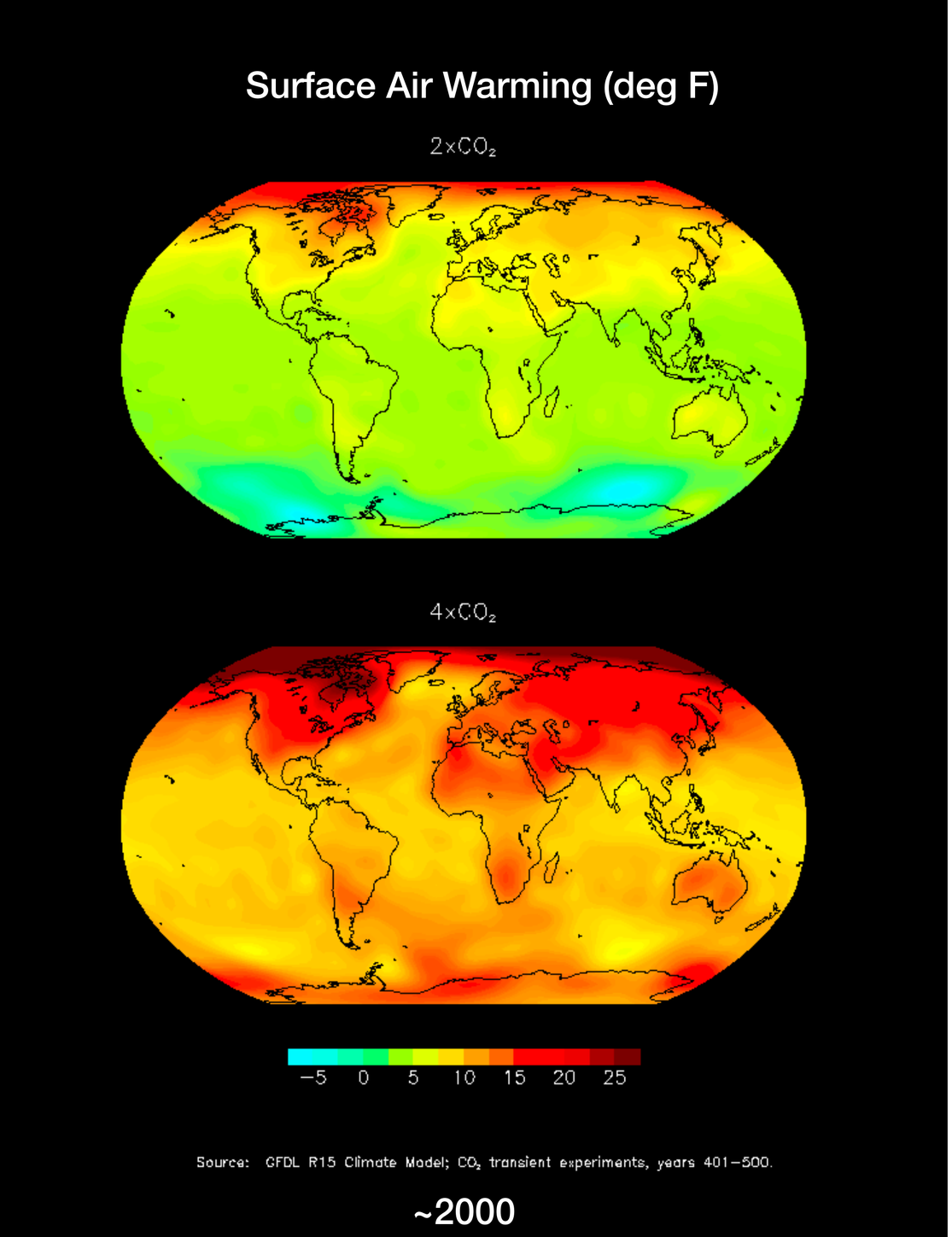


$4\times CO_2$

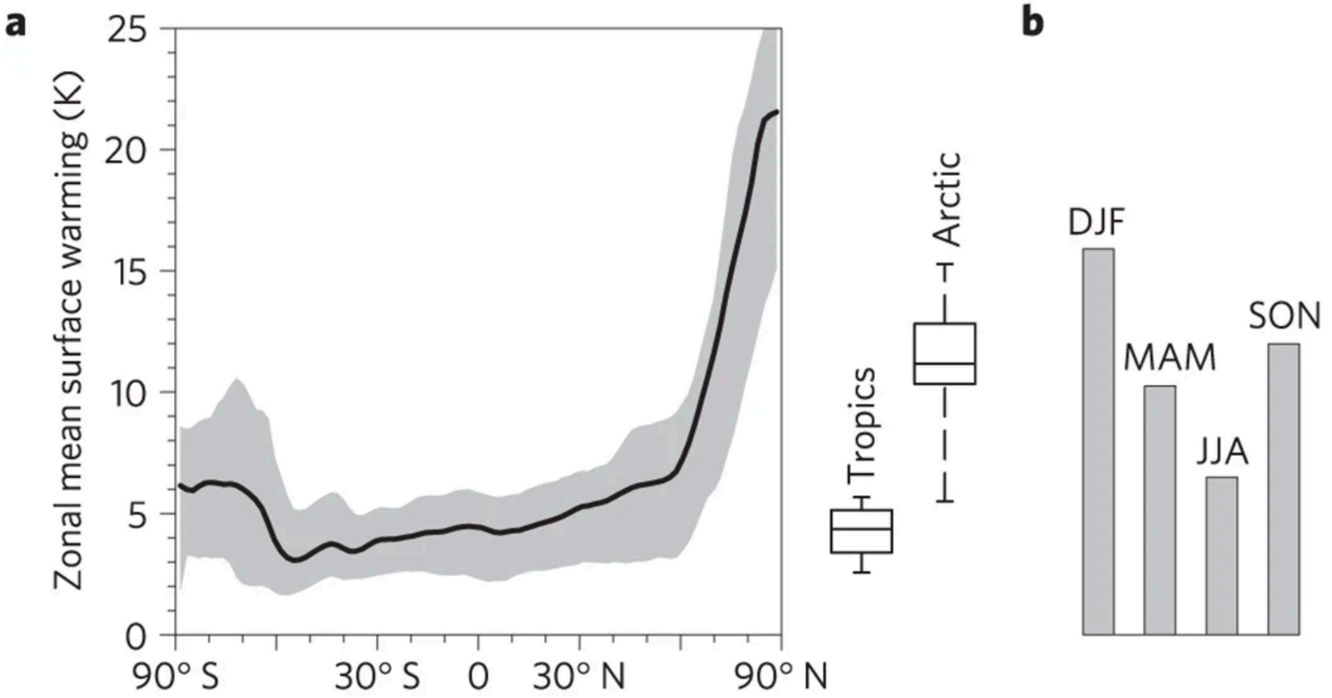


Source: GFDL R15 Climate Model; CO_2 transient experiments, years 401–500.

~2000

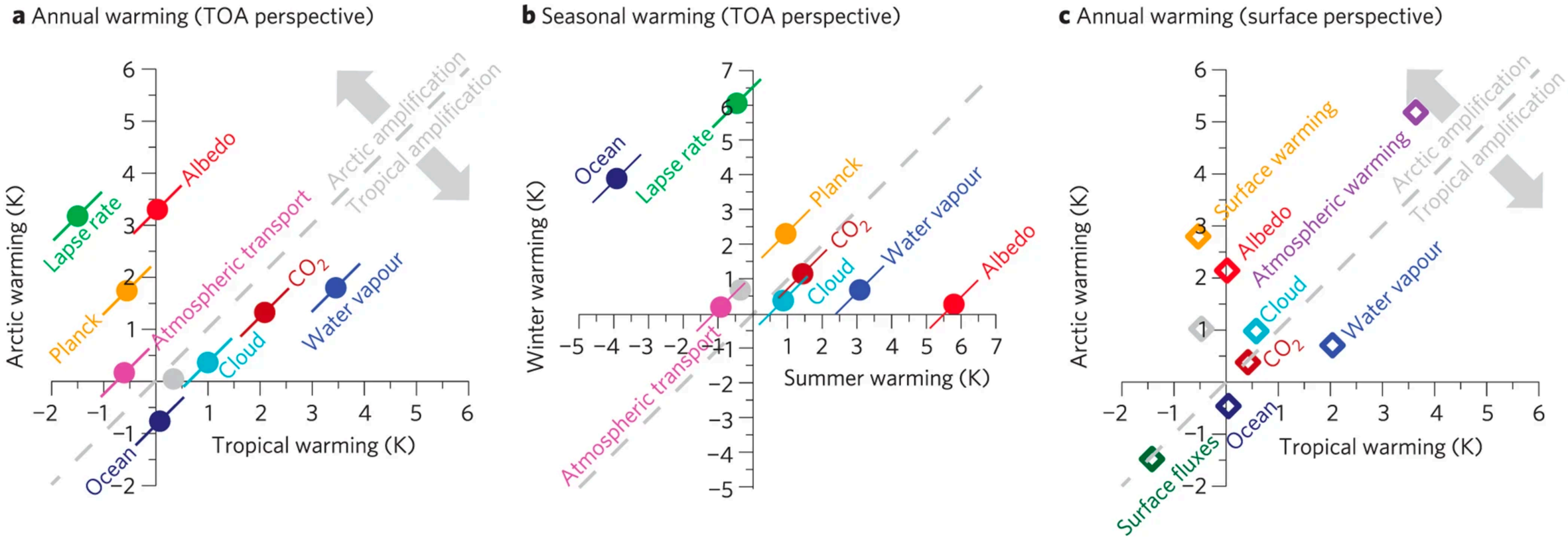


Arctic amplification in CMIP5 models (4 × CO_2)



Pithan and Mauritsen (2014)

Warming contributions of individual feedback mechanisms

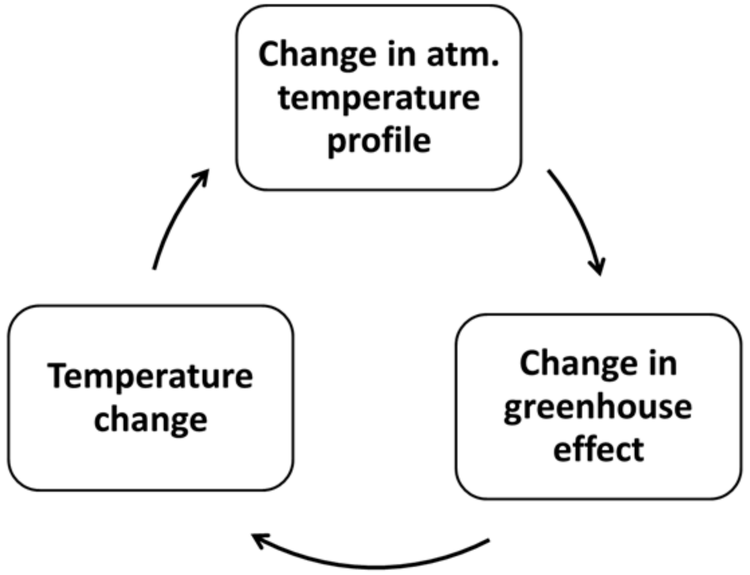


- Planck feedback: from vertically uniform warming

("For example, at 30C, an external forcing of 1W/m² can be balanced by a 0.16 C warming, whereas at -30C a 0.31C warming is required to balance the same forcing.")

- Lapse-rate feedback: from deviation of vertically uniform warming

Pithan and Mauritsen (2014)



“The lapse-rate feedback, a local mechanism, is argued as the largest contributor to amplification and the intermodel differences in projected Arctic warming (Payne et al., 2015; Pithan & Mauritsen, 2014; Stuecker et al., 2018). However, a firm mechanistic understanding of this feedback remains elusive.”

Boeke et al (2021)

inspired by Vihma 2014

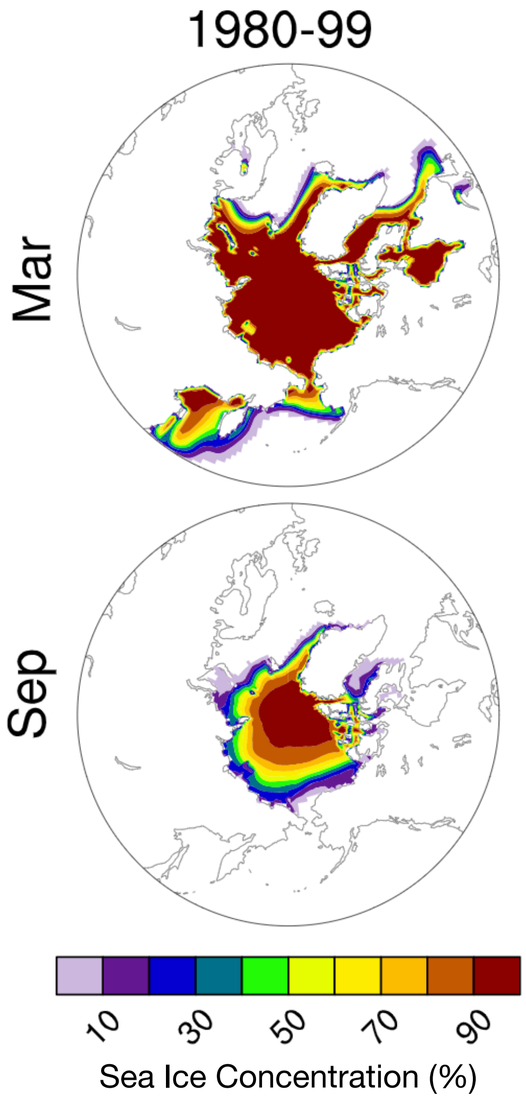
Impacts of Arctic Sea-Ice Loss

- From Observations:
  - Can identify **correlations** (e.g. between sea-ice loss and -ve Arctic Oscillation and weaker & south-shifted mid-latitude Westerlies)
  - Correlation **does not imply** causation

→ look to climate models to get at causal relations

Sea-Ice Loss Simulations - Method

In Climate Models (typically use RCP8.5 as reference)



CCSM4, Deser et al (2014)

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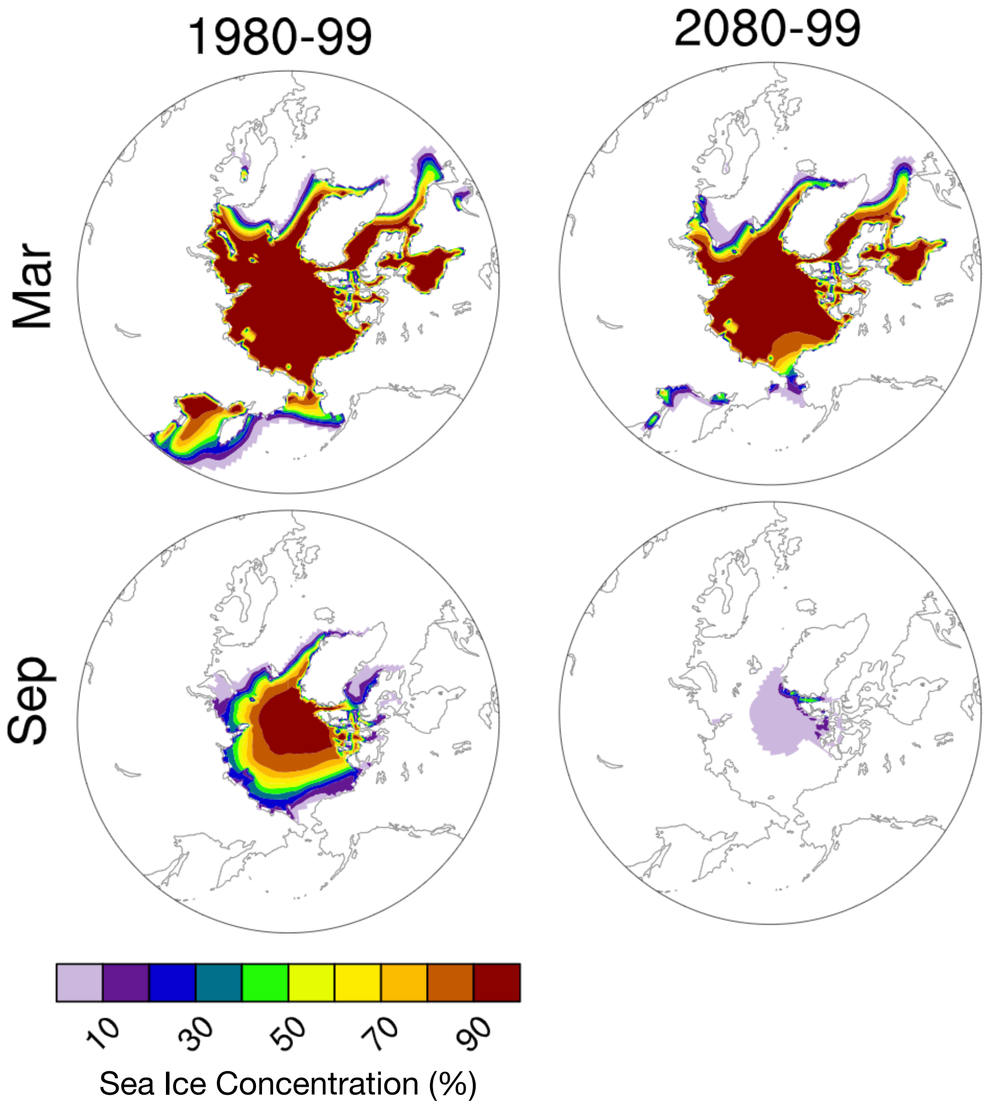

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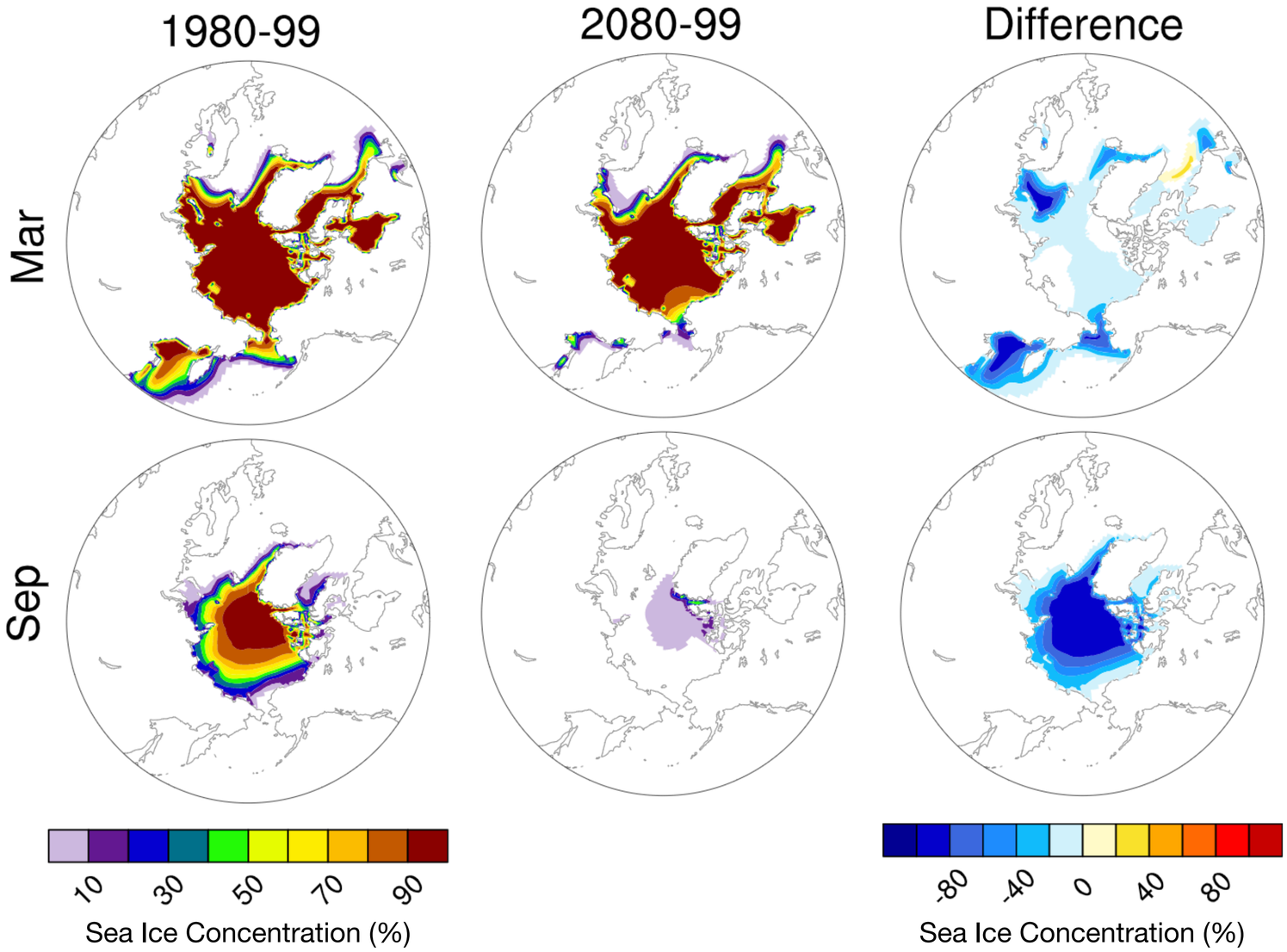

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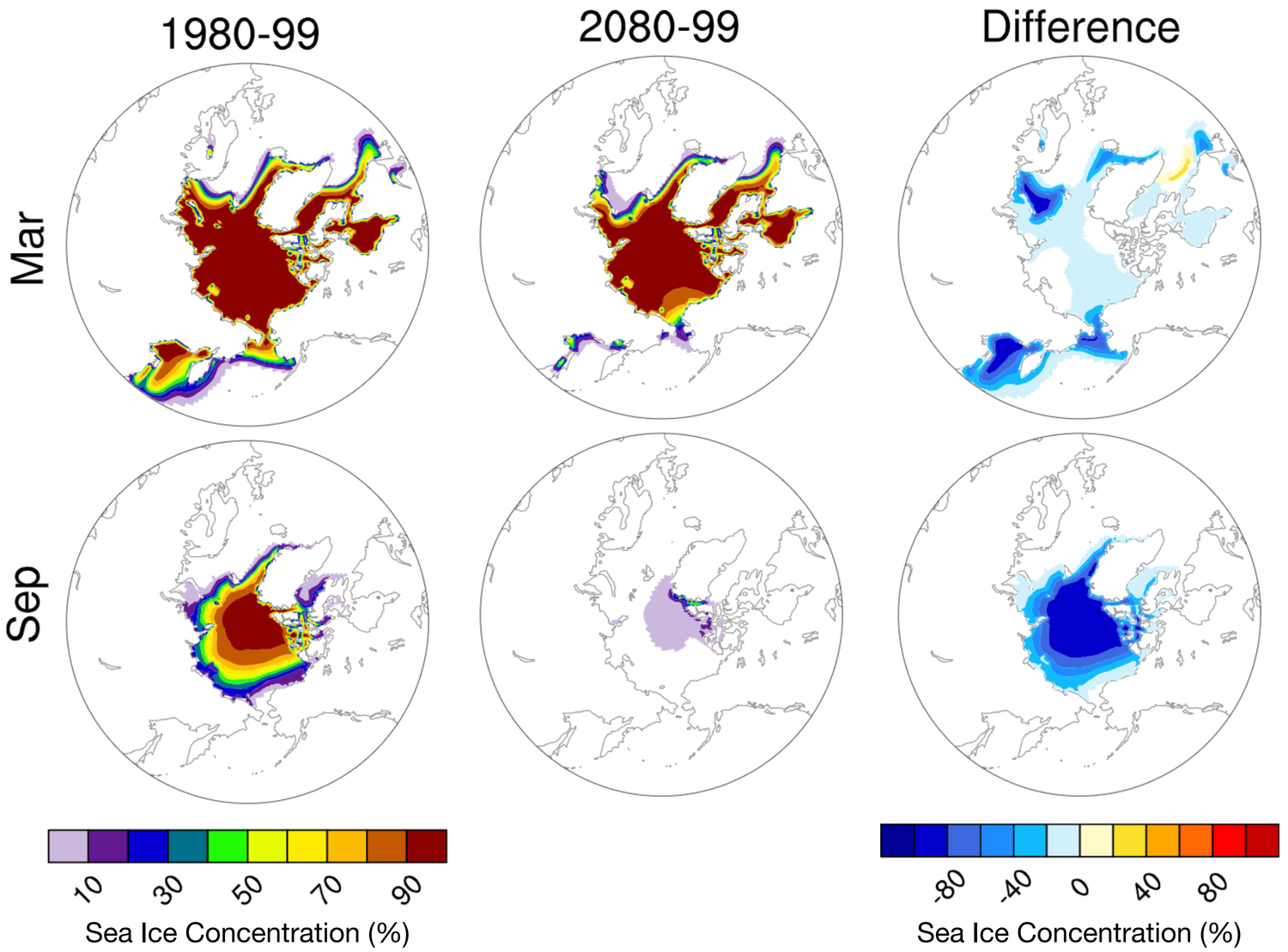

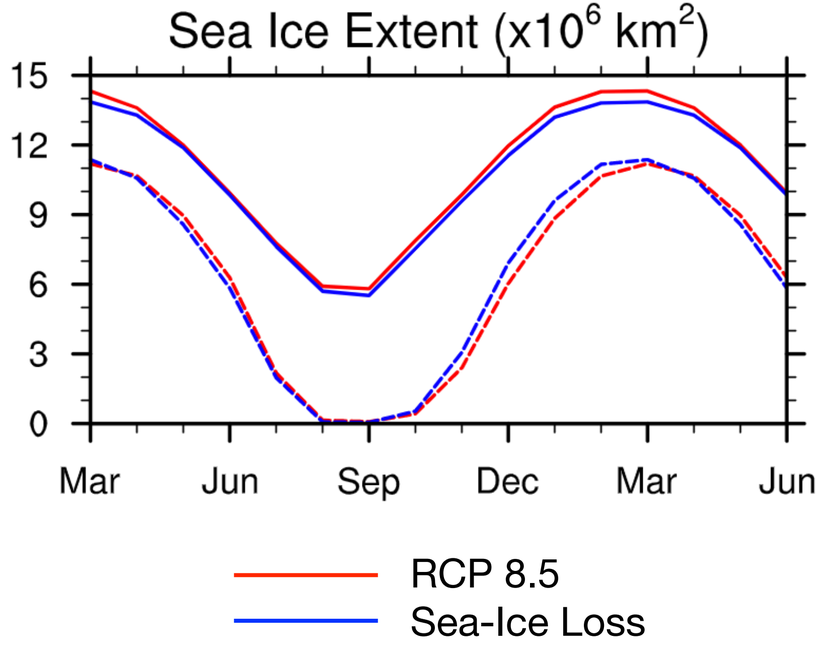

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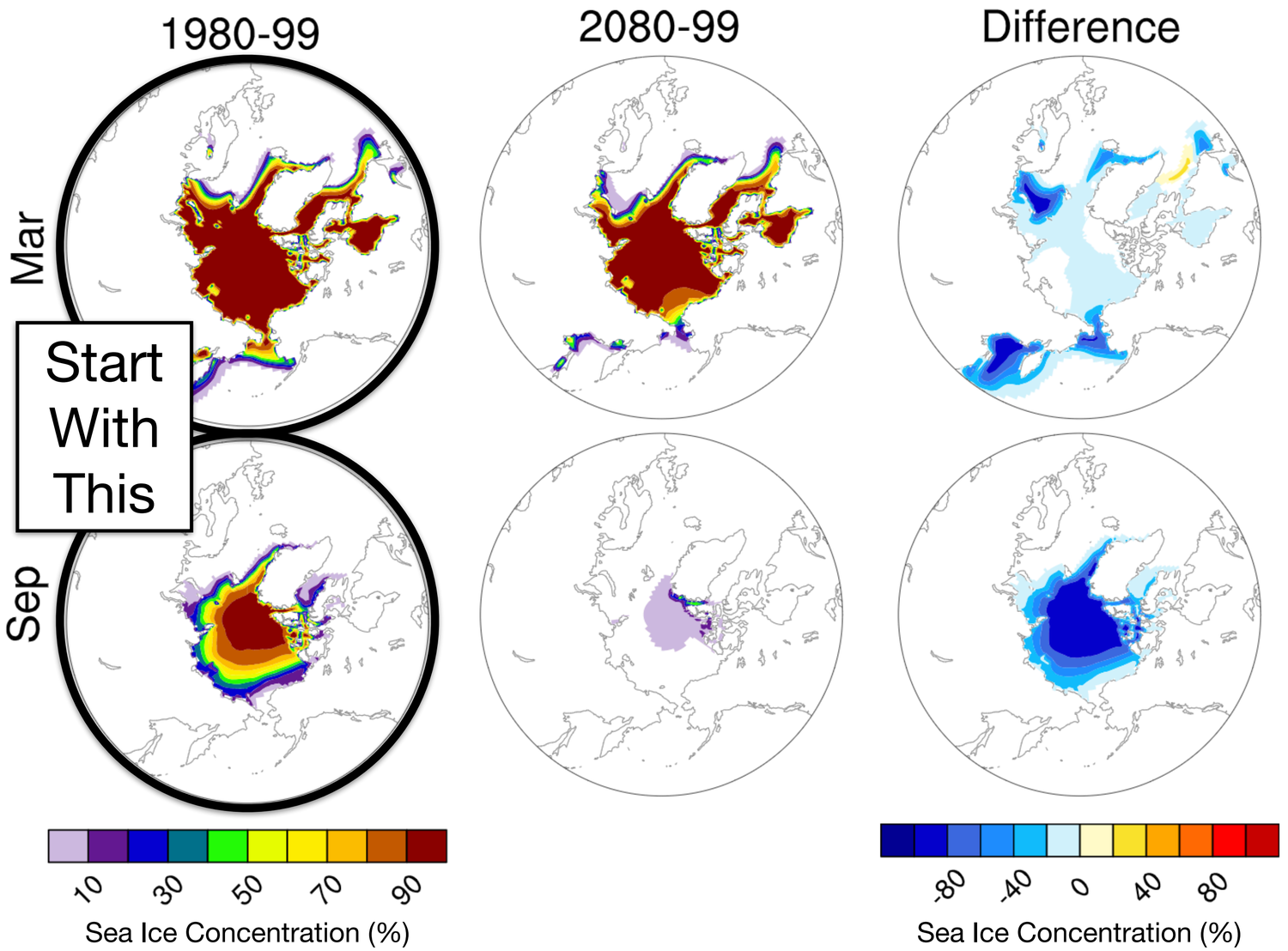

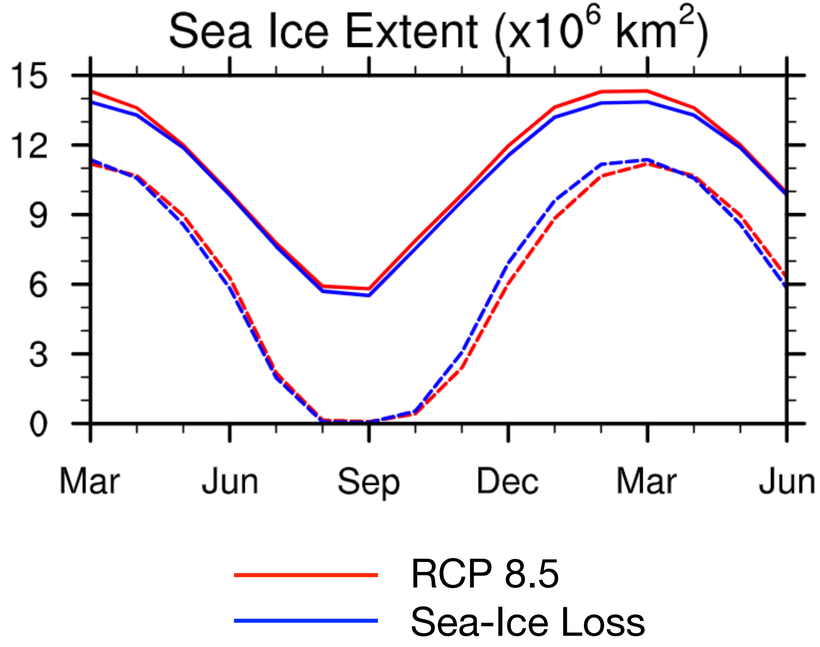

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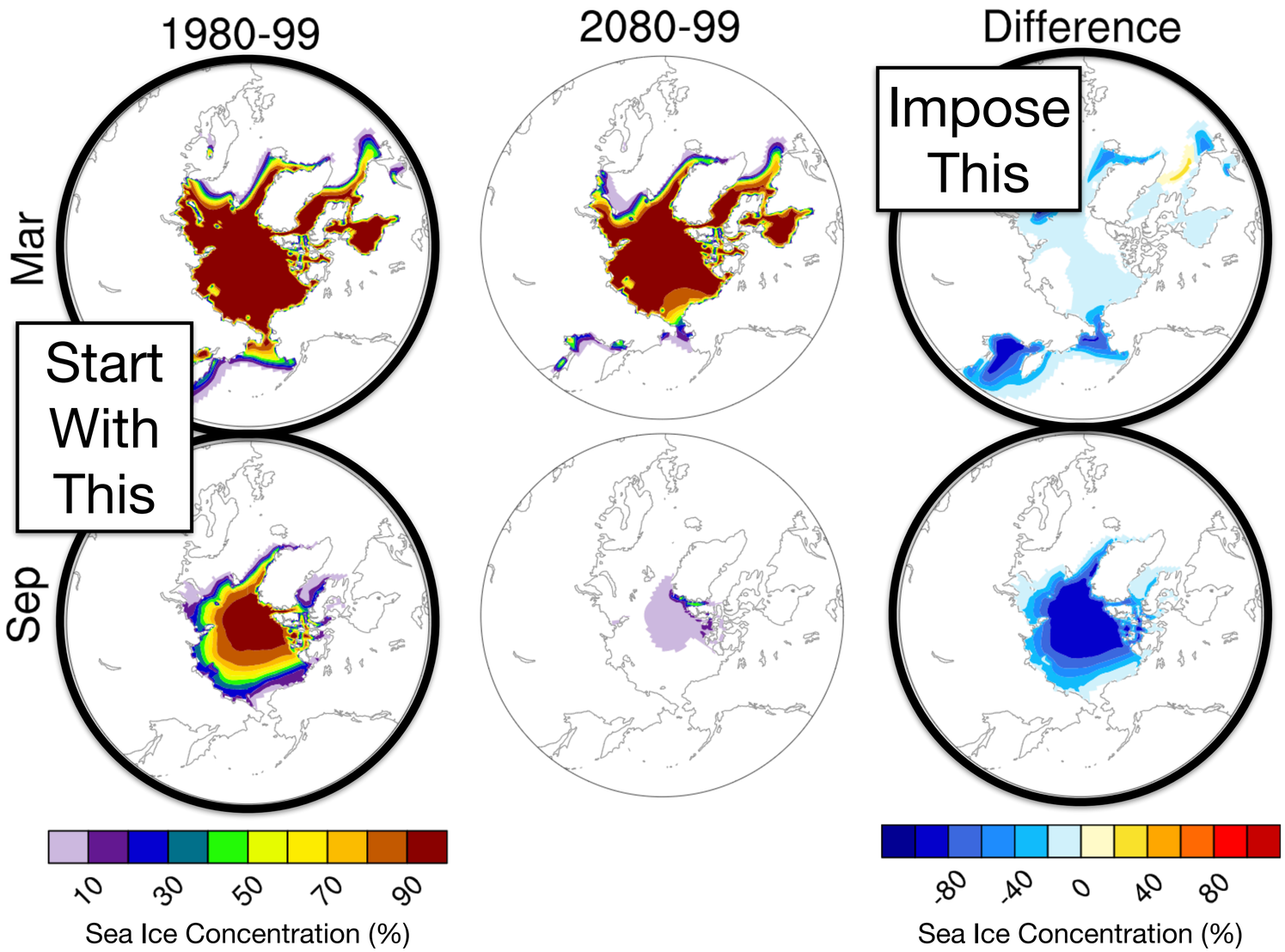

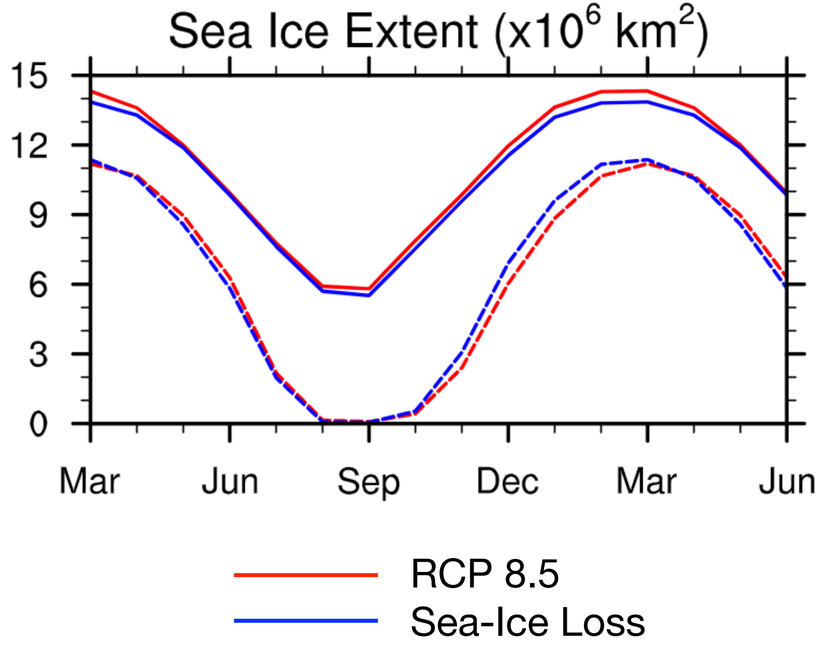

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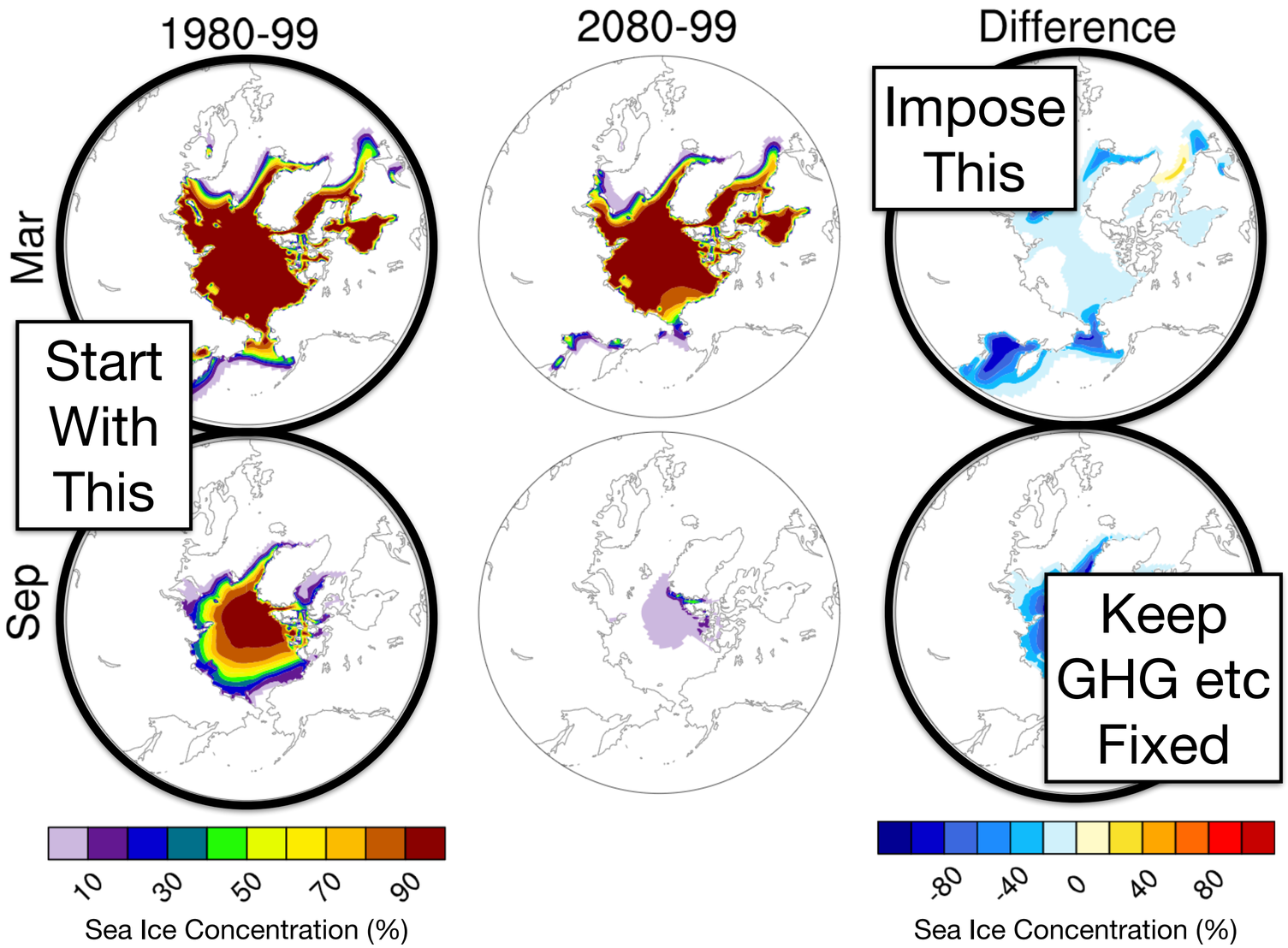

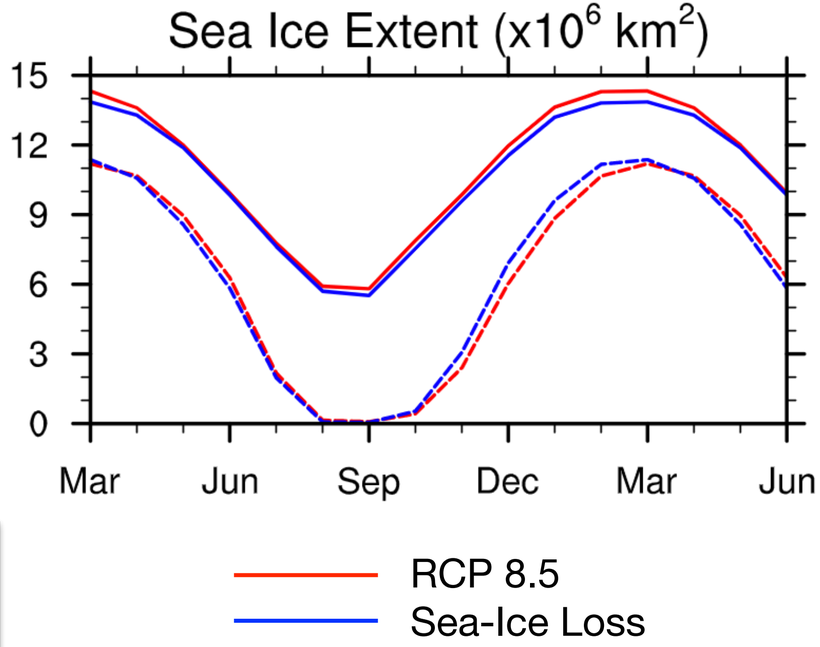

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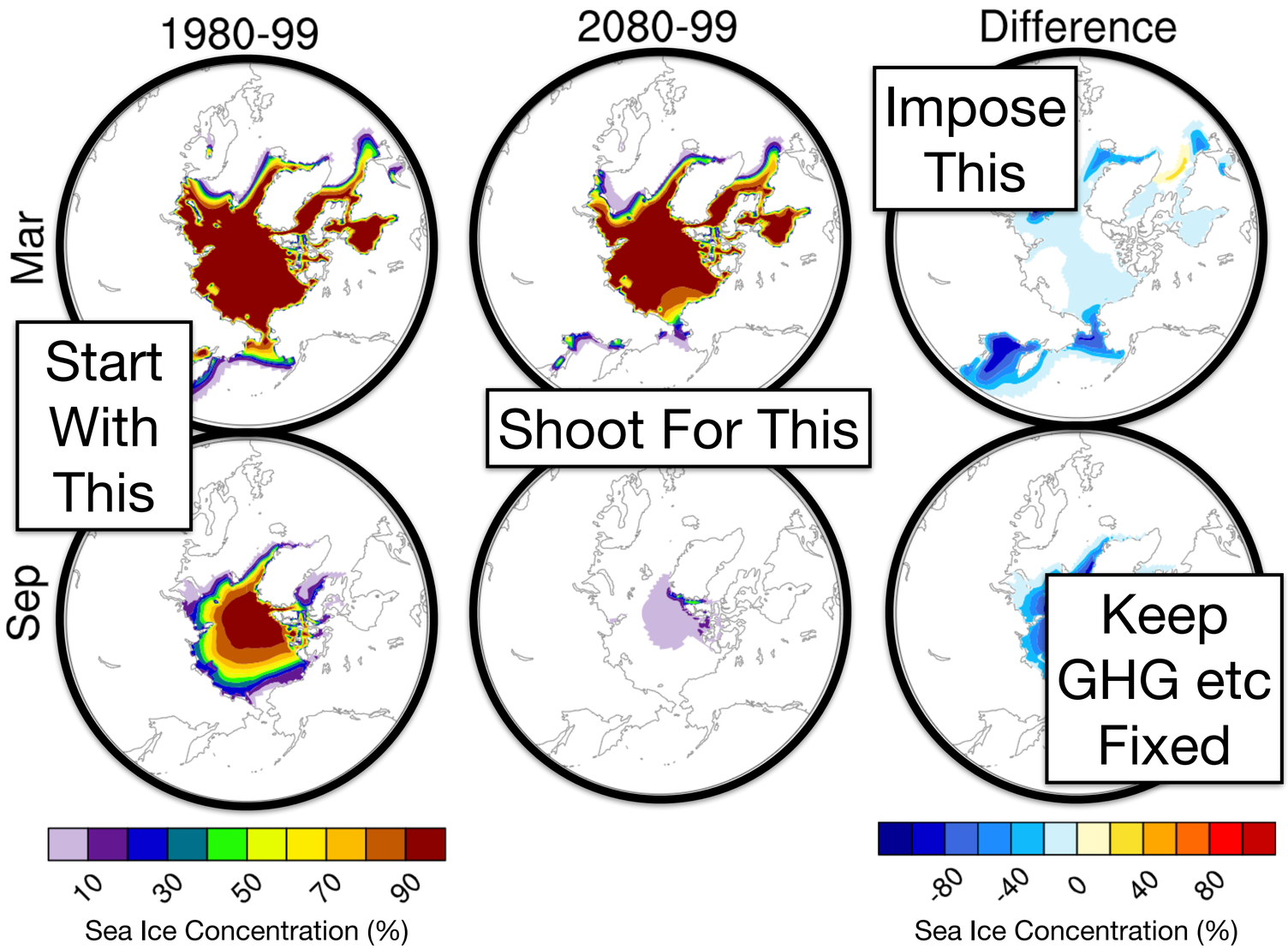

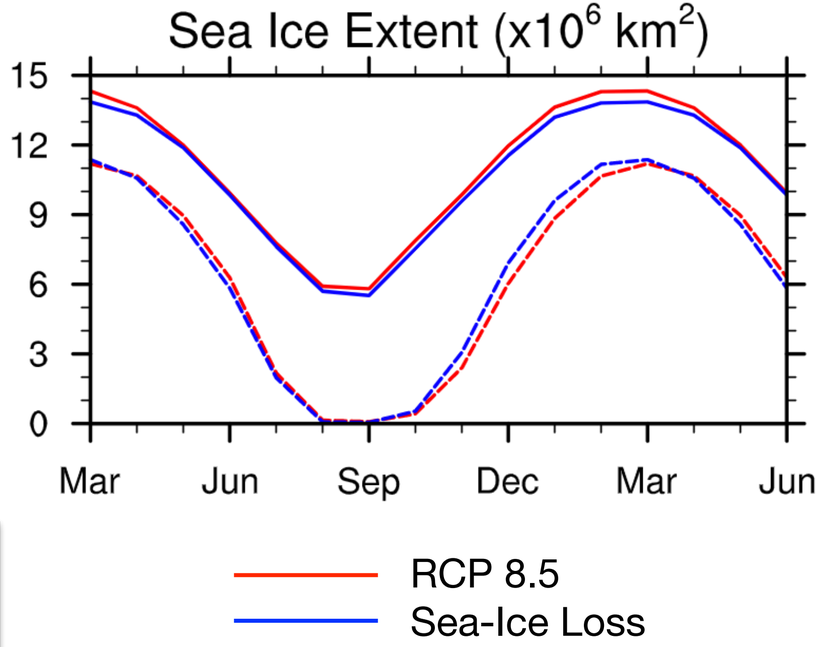

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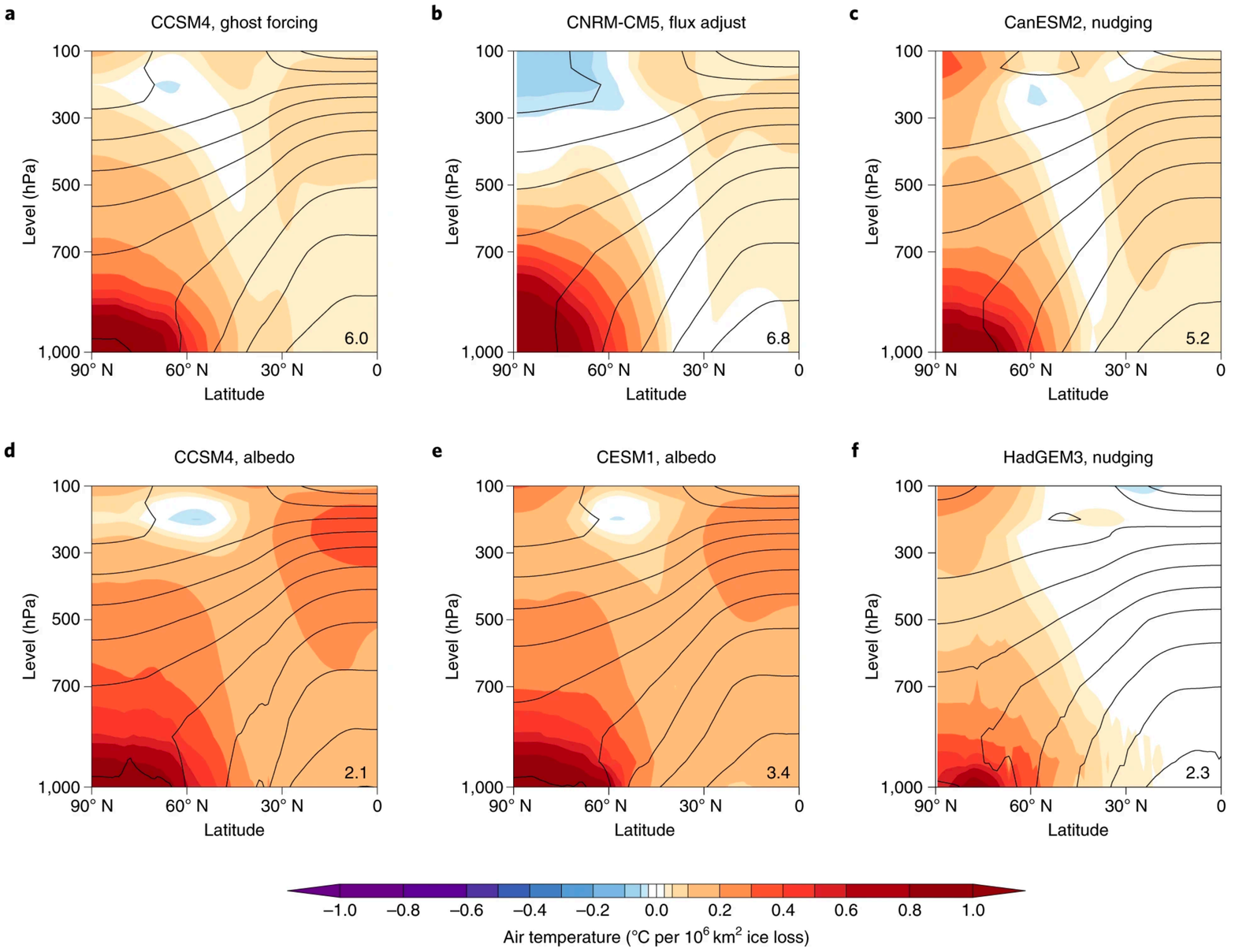
Sea-Ice Loss Simulations - Results



Screen et al (2018)

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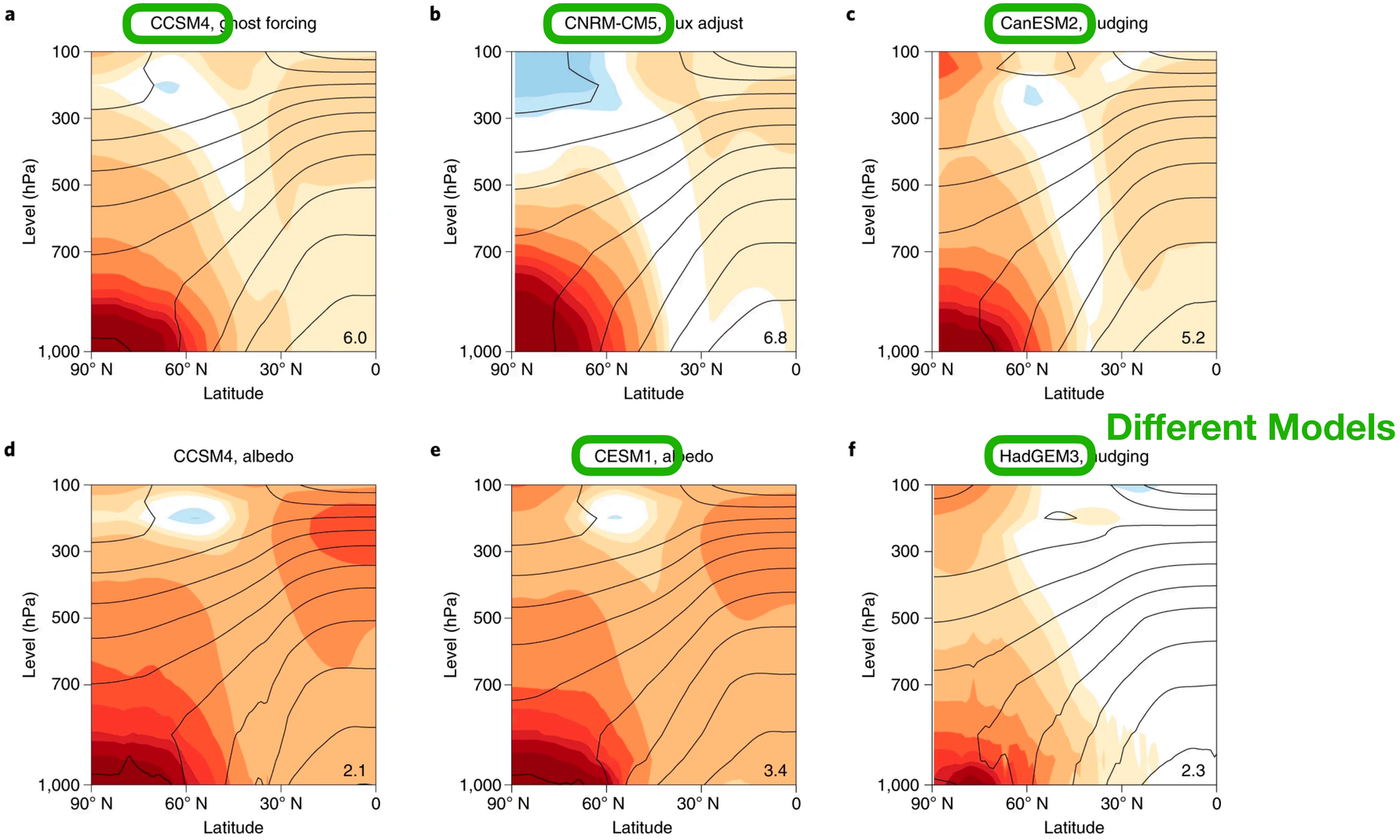

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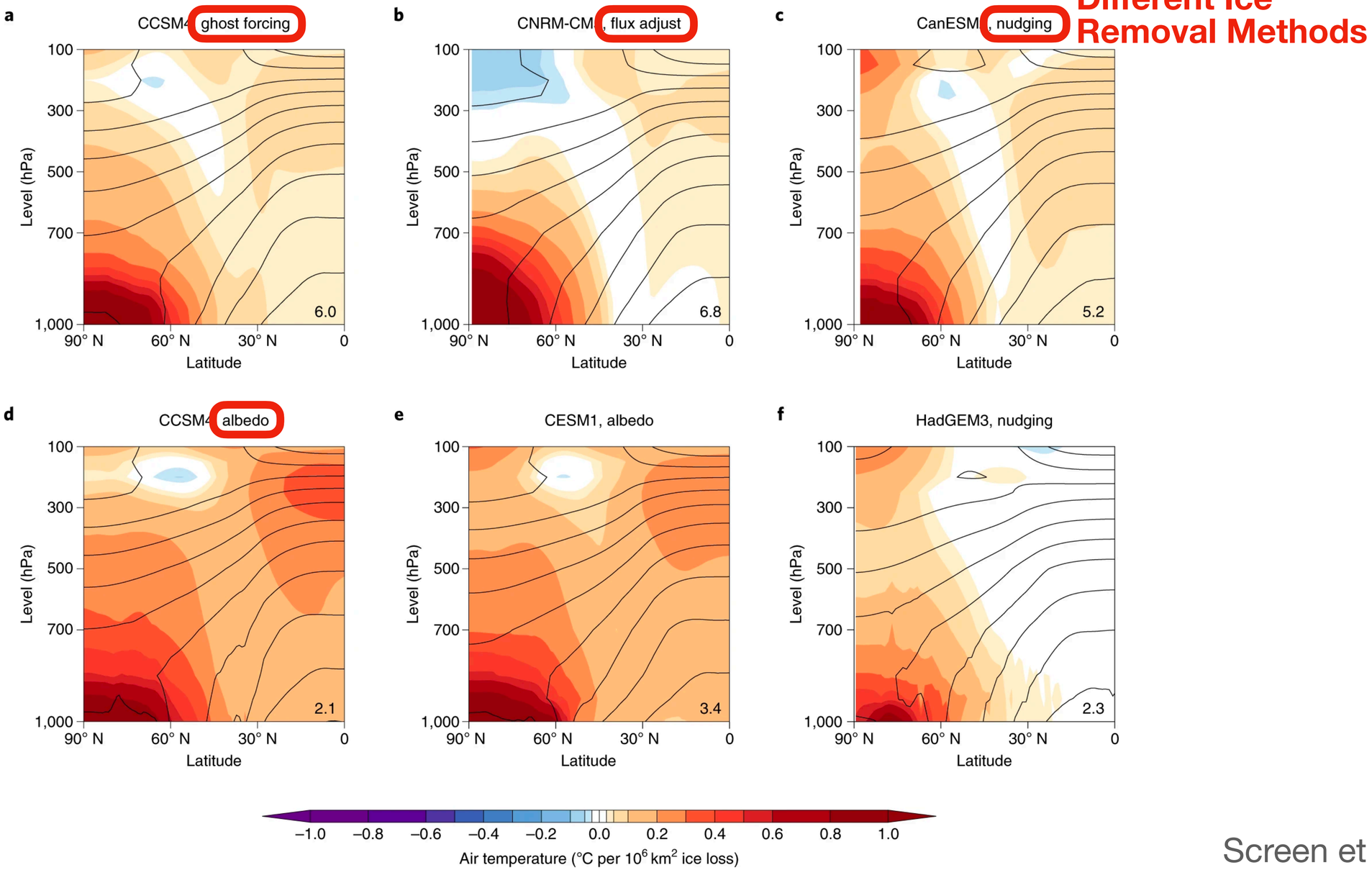
Sea-Ice Loss Simulations - Results

Different Ice Removal Methods



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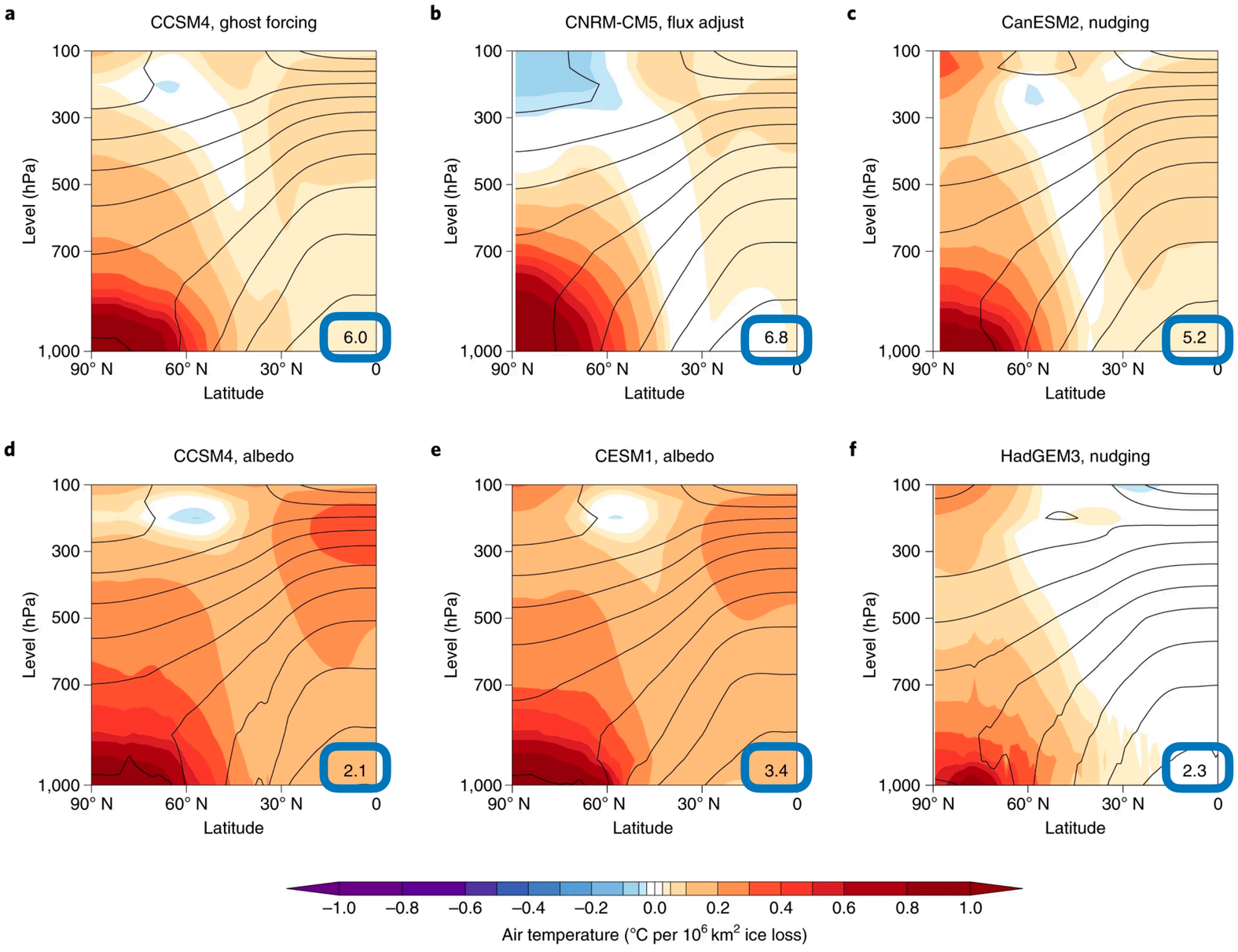
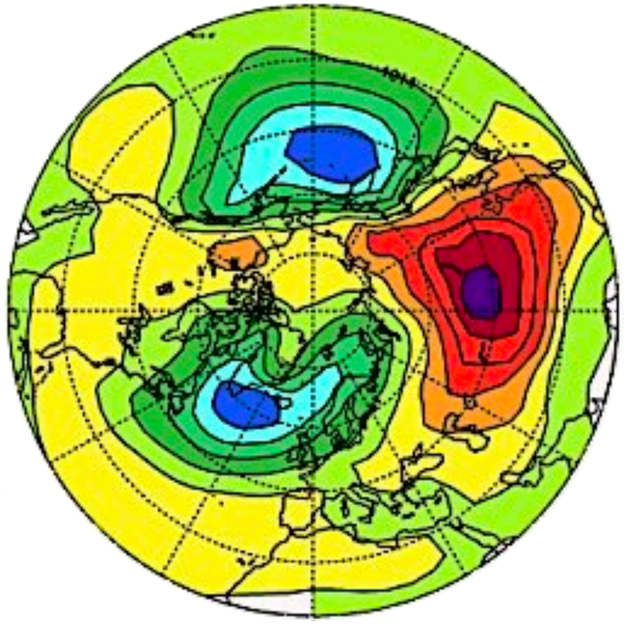


Different Ice Loss

Screen et al (2018)

Sea-Ice Loss Simulations - Results

Sea-Level Pressure Climatology (Jan)



Hurrell and Trenberth (2021)

Sea-Ice Loss Simulations - Results

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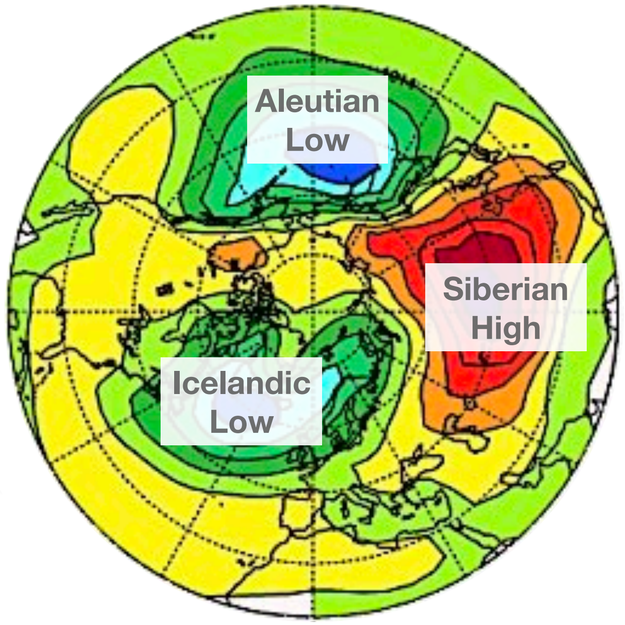

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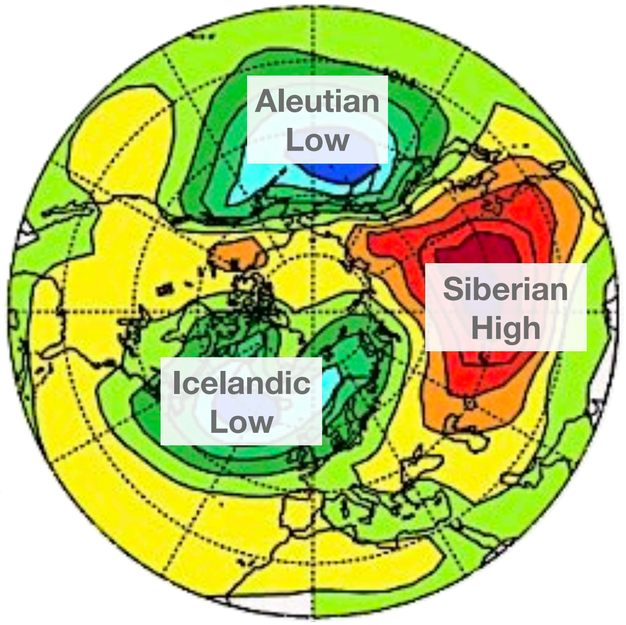

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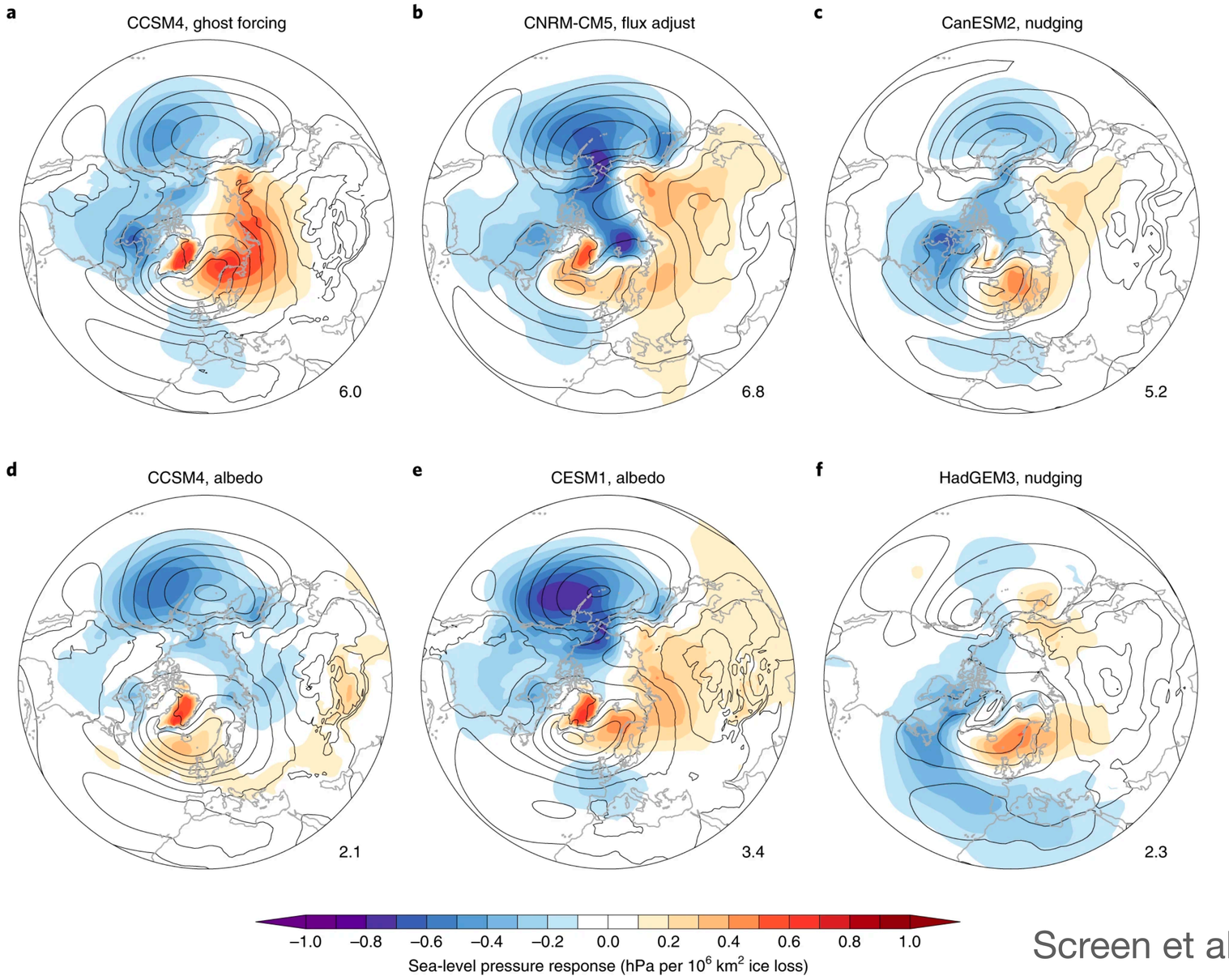

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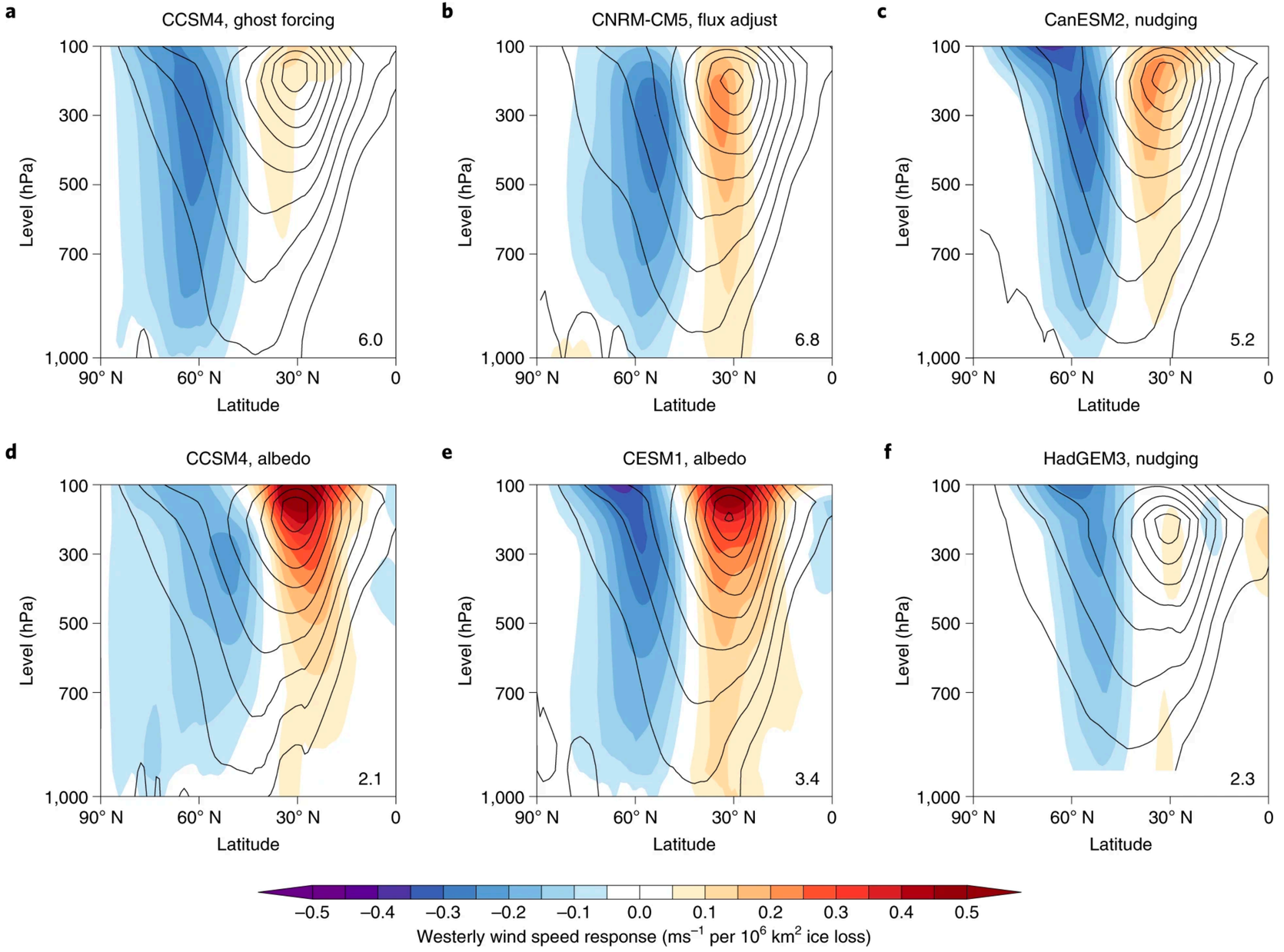

Screen et al (2018)

Sea-Ice Loss Simulations - Summary

Consistent Impacts

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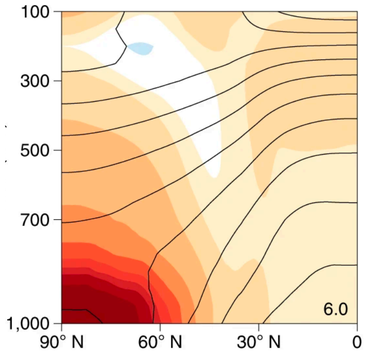
Consistent Impacts

- hemispheric-wide atmospheric **warming**, strongest in the mid-to-high-latitude lower troposphere



Sea-Ice Loss Simulations - Summary

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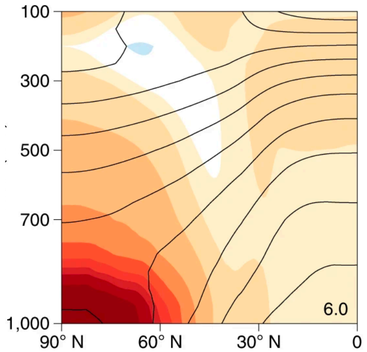
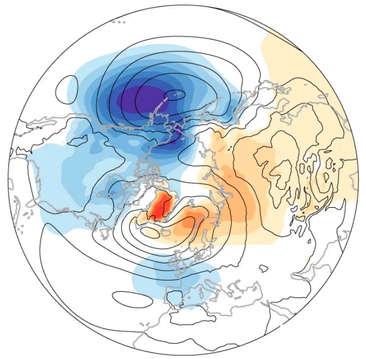
- an **intensification** of the wintertime Aleutian Low and, in most cases, the Siberian High

- a **weakening** of the Icelandic Low





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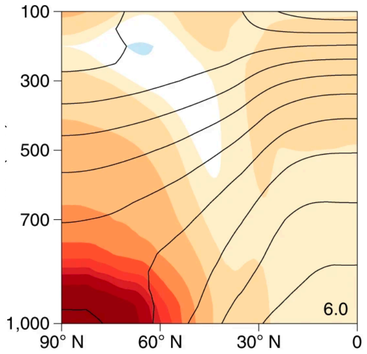
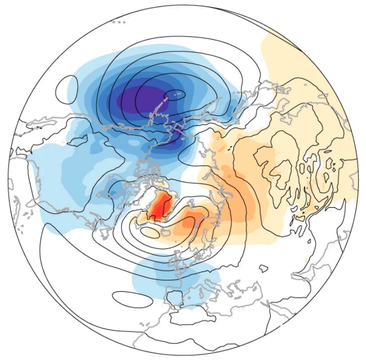
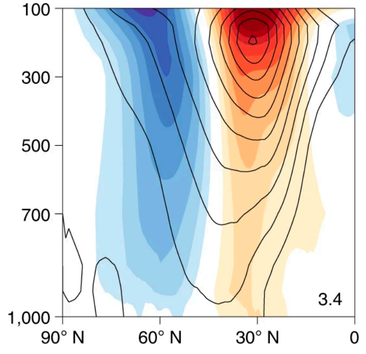
- a **reduction in strength** and **southward shift** of the mid-latitude westerly winds in winter







inspired by Vihma 2014

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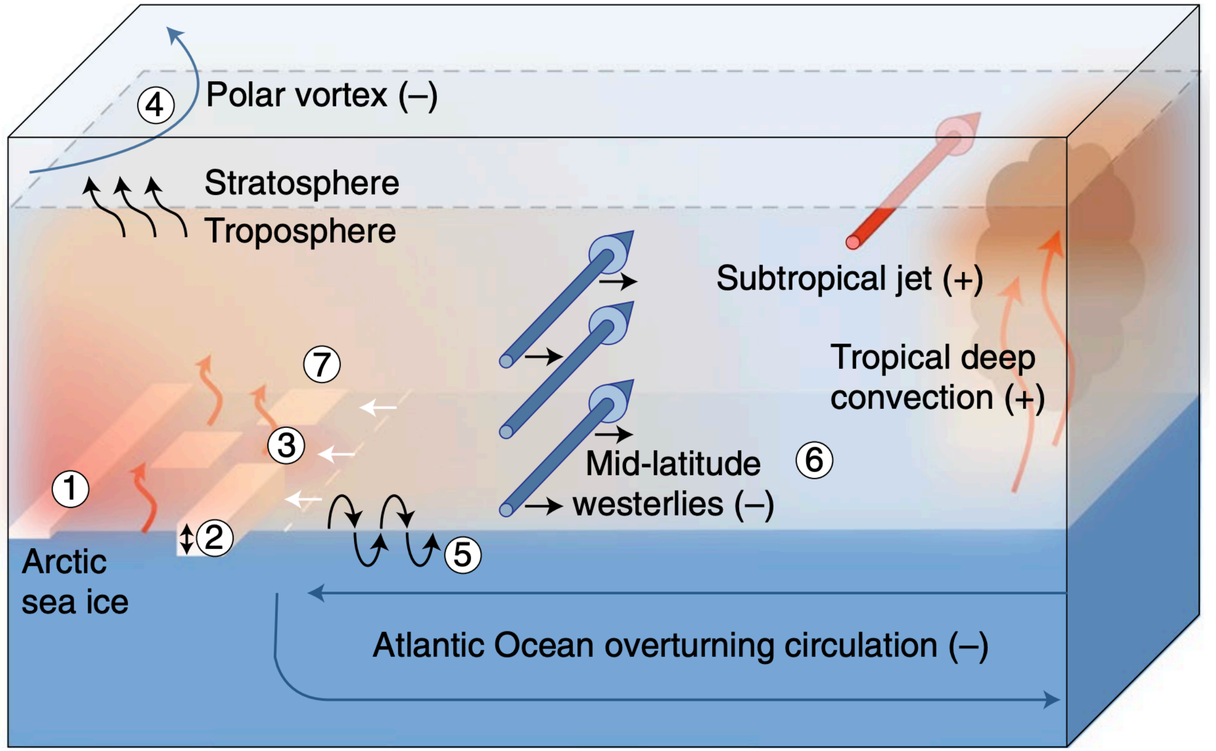
Sea-Ice Loss Simulations - Summary

Discrepancies & Uncertainties

1. Magnitude and Spatial Pattern of Sea-Ice Loss
2. Ice Thickness
3. Open Water
4. Stratospheric Representation (decreased Arctic Oscillation, weakened Polar Vortex?)
5. Ocean
6. Background State
7. Model Physics



Screen et al (2018)

One Issue

- **Sea-ice loss simulations add extra heat required to remove the ice**
- Standard methods used in coupled models are bound to overestimate warming due to sea ice.
- Warming from sea ice is conflated with warming due to radiative forcing.

CPEP Seminar: https://youtu.be/9z7le5S9u9Q

One Issue

- **Sea-ice loss simulations add extra heat required to remove the ice**
- Standard methods used in coupled models are bound to overestimate warming due to sea ice.
- Warming from sea ice is conflated with warming due to radiative forcing.
- Impact of sea ice loss on climate has likely been overestimated in climate models.

CPEP Seminar: https://youtu.be/9z7le5S9u9Q

A Note

- In **atmosphere-only** model configurations: impacts of Arctic sea-ice loss are confided to Northern Hemisphere mid and high latitudes.
- **Fully coupled** model runs show that ocean-atmosphere feedbacks lead to global signals of sea-ice loss.
- We find important impacts that extend to the **tropics**.

Arctic sea ice influencing ENSO in past climates

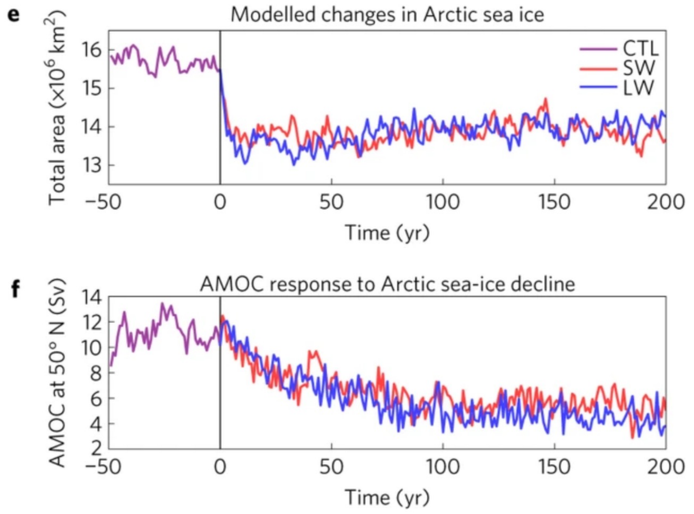
Sea ice melt

Freshwater input into North Atlantic

Substantial reduction of the
Atlantic Meridional Overturning circulation

An ocean-atmosphere-ocean bridge
which communicates the response
to the tropical Atlantic

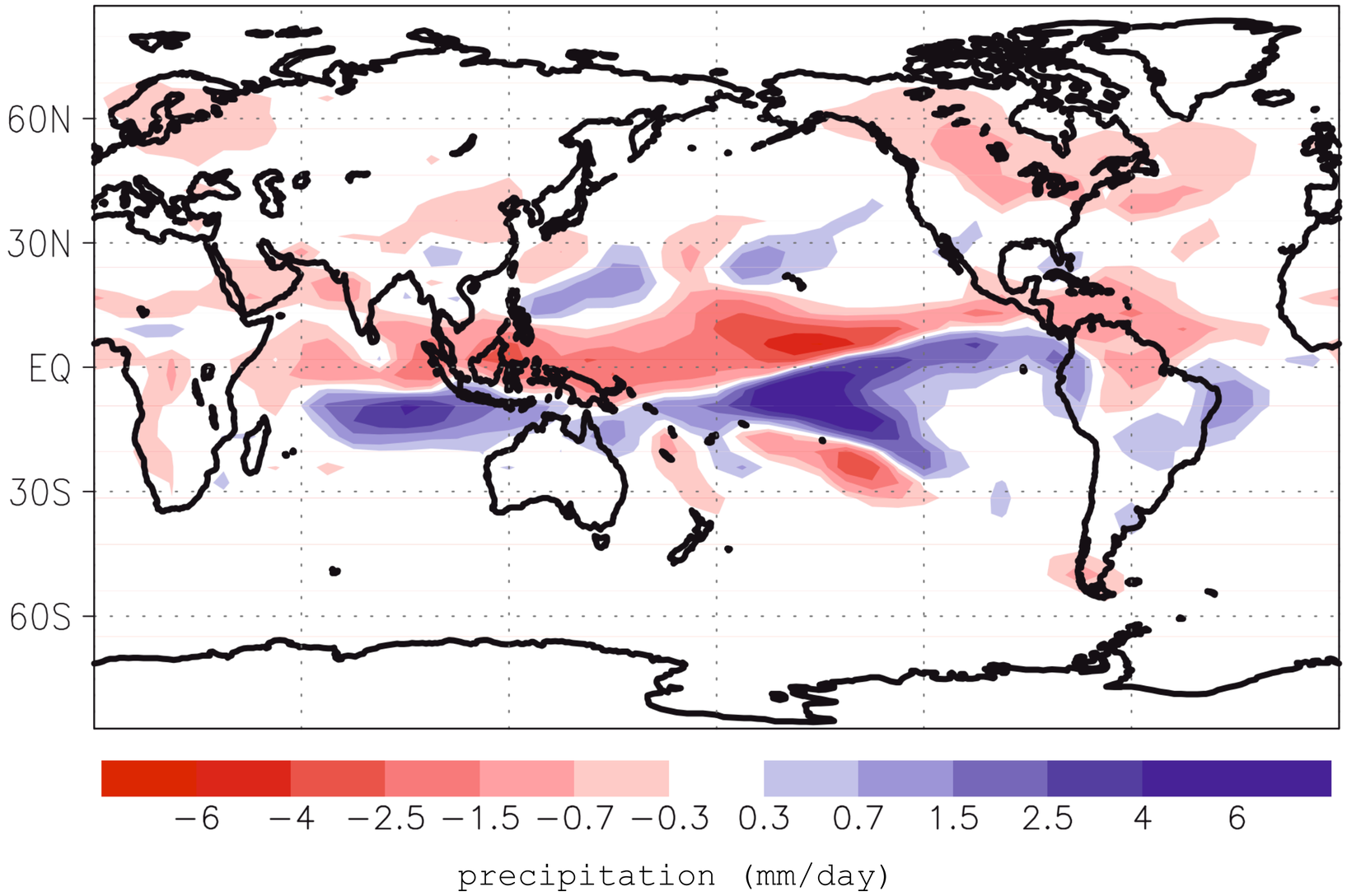
A second ocean-atmosphere-ocean
bridge which communicates from
the Atlantic to the Pacific



Sevellec et al 2017

Vettoretti et al 2008

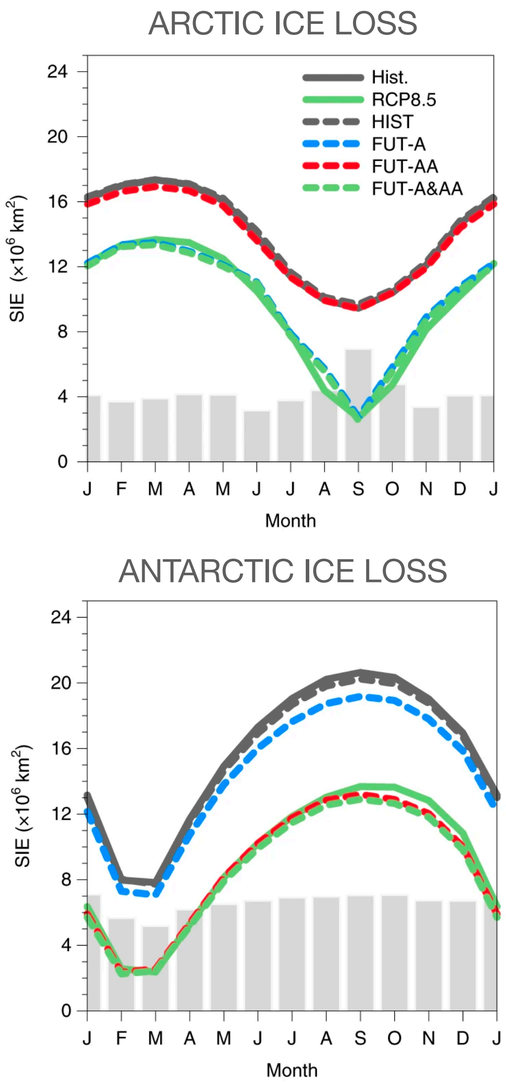
Impact of Ice Loss on Tropics



Southward
Shift of ITCZ

Chiang & Bitz (2005)

What about the Antarctic?



ENGLAND ET AL, NATURE GEOSCIENCE (2020)

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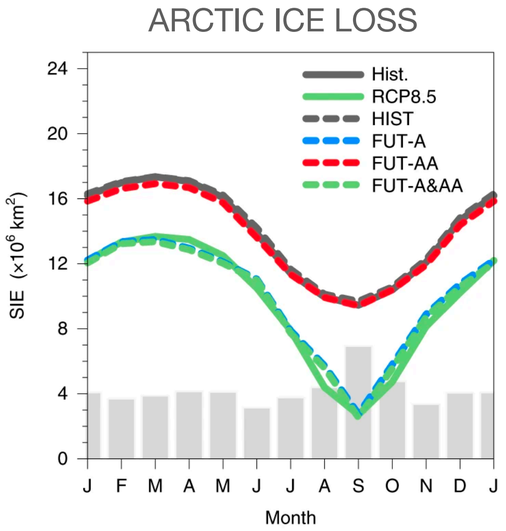
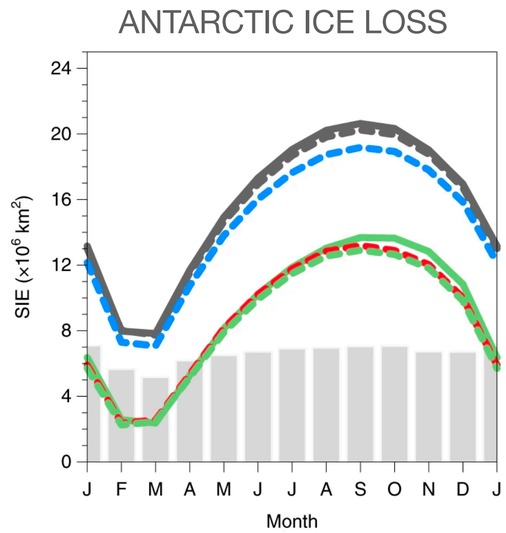
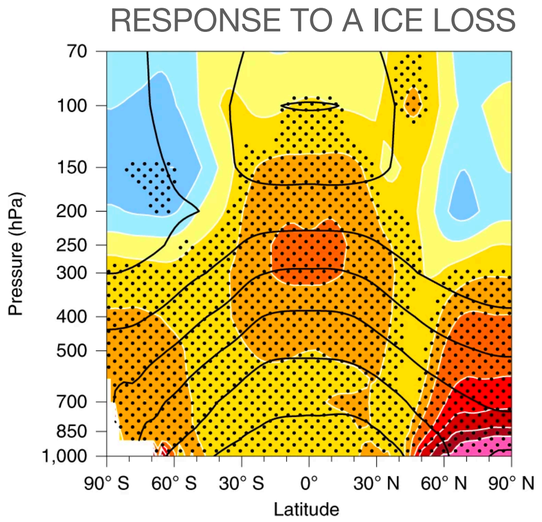
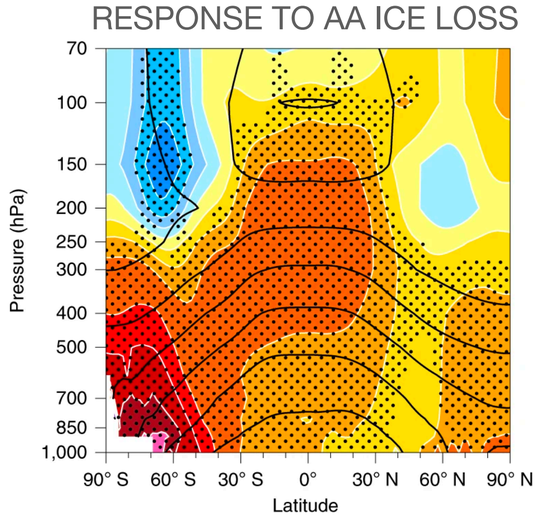
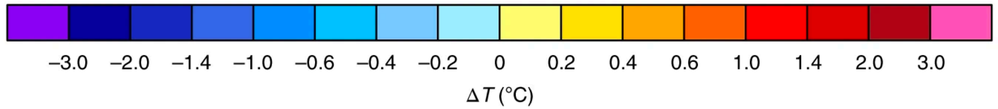






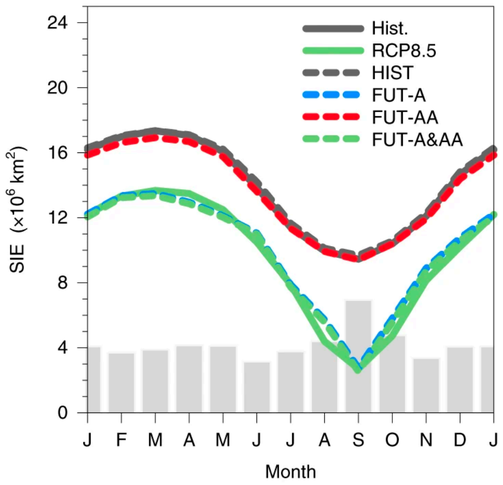




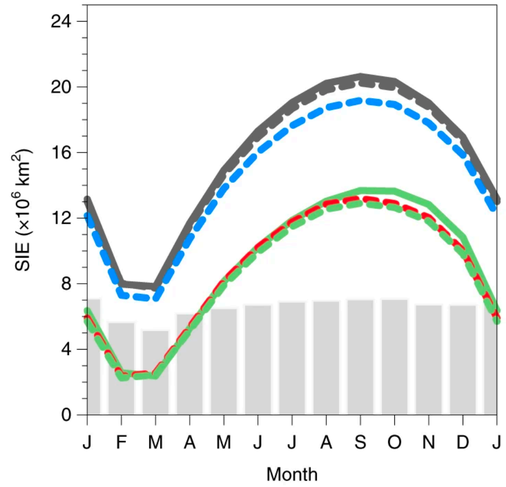
ENGLAND ET AL, NATURE GEOSCIENCE (2020)

What about the Antarctic?

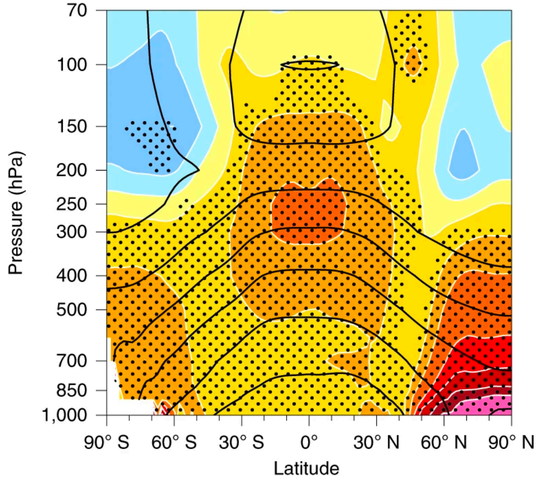
ARCTIC ICE LOSS



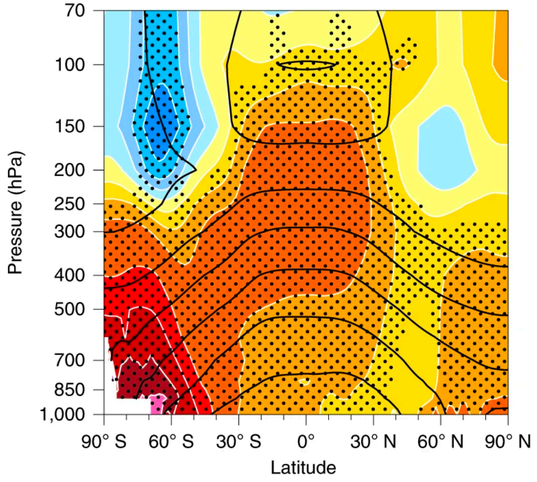
ANTARCTIC ICE LOSS



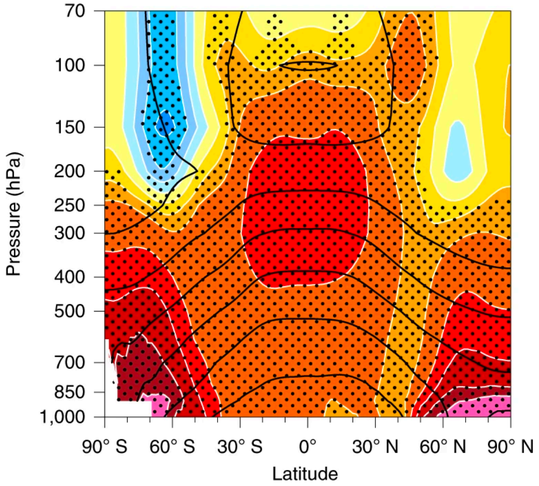
RESPONSE TO A ICE LOSS



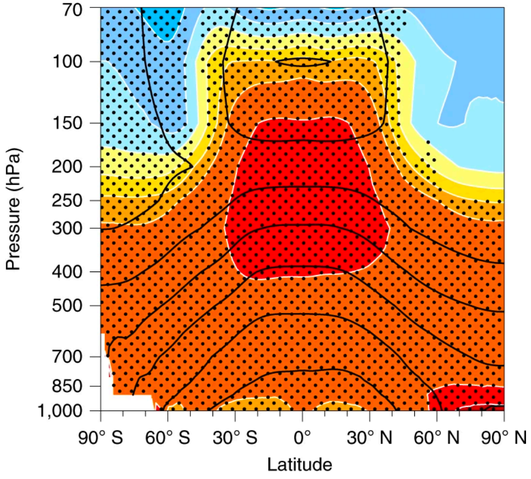
RESPONSE TO AA ICE LOSS



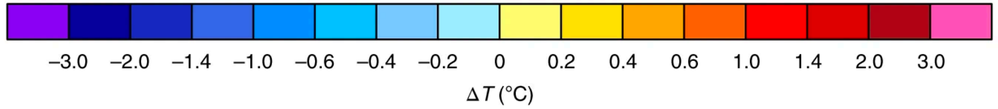
RESPONSE TO AA + A ICE LOSS



RESPONSE TO RCP 8.5



SCALED BY 1/5



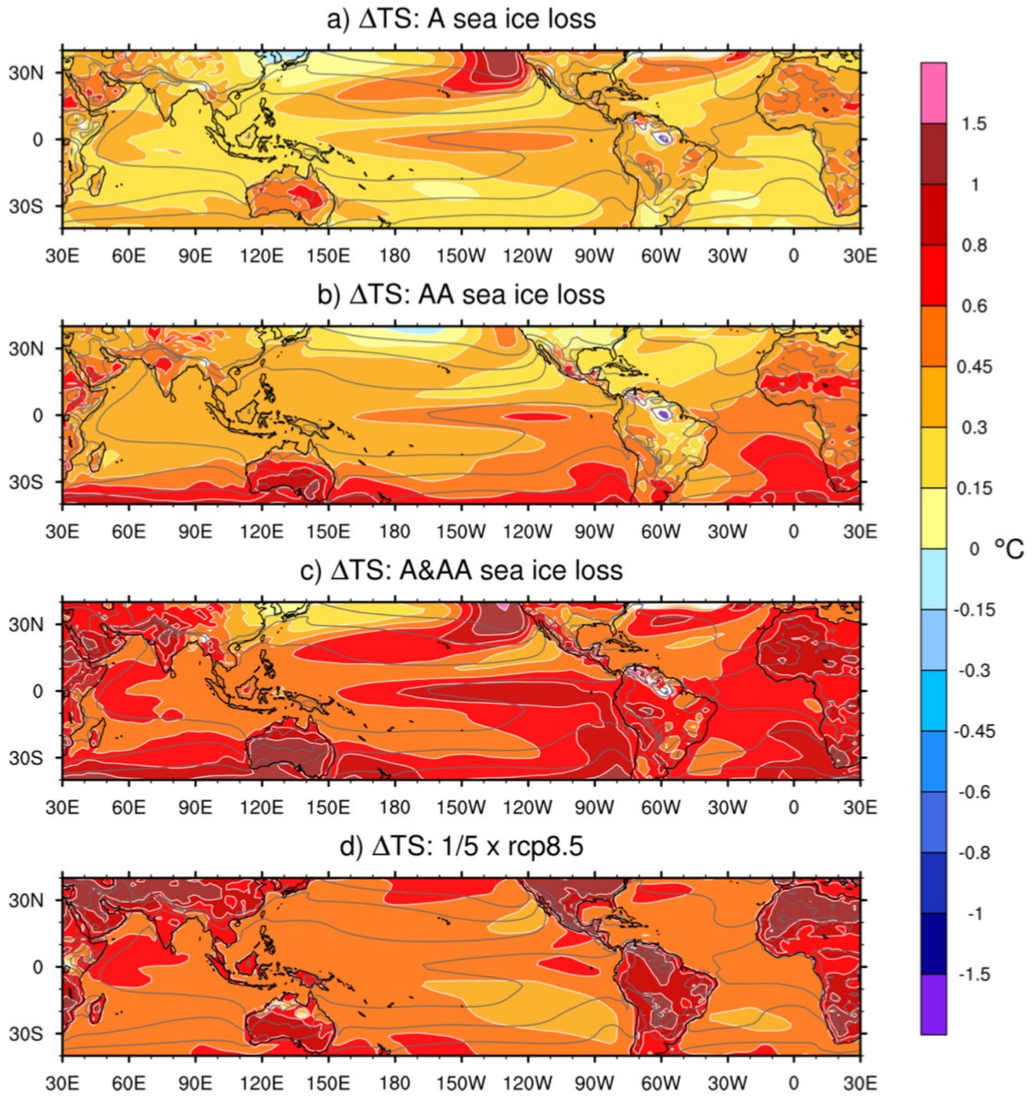
ENGLAND ET AL, NATURE GEOSCIENCE (2020)

Arctic

Antarctic

Arctic and Antarctic

RCP8.5



Extended Data Fig. 3 | Tropical surface temperature response to sea ice loss. (Shading) The annual mean surface temperature response [°C] to (**a**) Arctic sea ice loss, (**b**) Antarctic sea ice loss and (**c**) both Arctic and Antarctic sea ice loss compared to (**d**) the projected changes under RCP8.5, the 15-year average of 2085-2099 minus the 15-year average of 1955-1969, (scaled by a factor of 1/5). The contours show the climatological surface temperature with contour intervals of 4 °C.

England et al 2020