

# A Breakdown of Controls on Observed Arctic Warming Using CESM2

NCAR PCWG Meeting 2023

February 6th, 2024



Ash Gilbert<sup>1,2</sup> and Jen Kay<sup>1,2</sup>

<sup>1</sup>Atmospheric & Oceanic Sciences, University of Colorado-Boulder

<sup>2</sup>Cooperative Institute for Research in Environmental Sciences



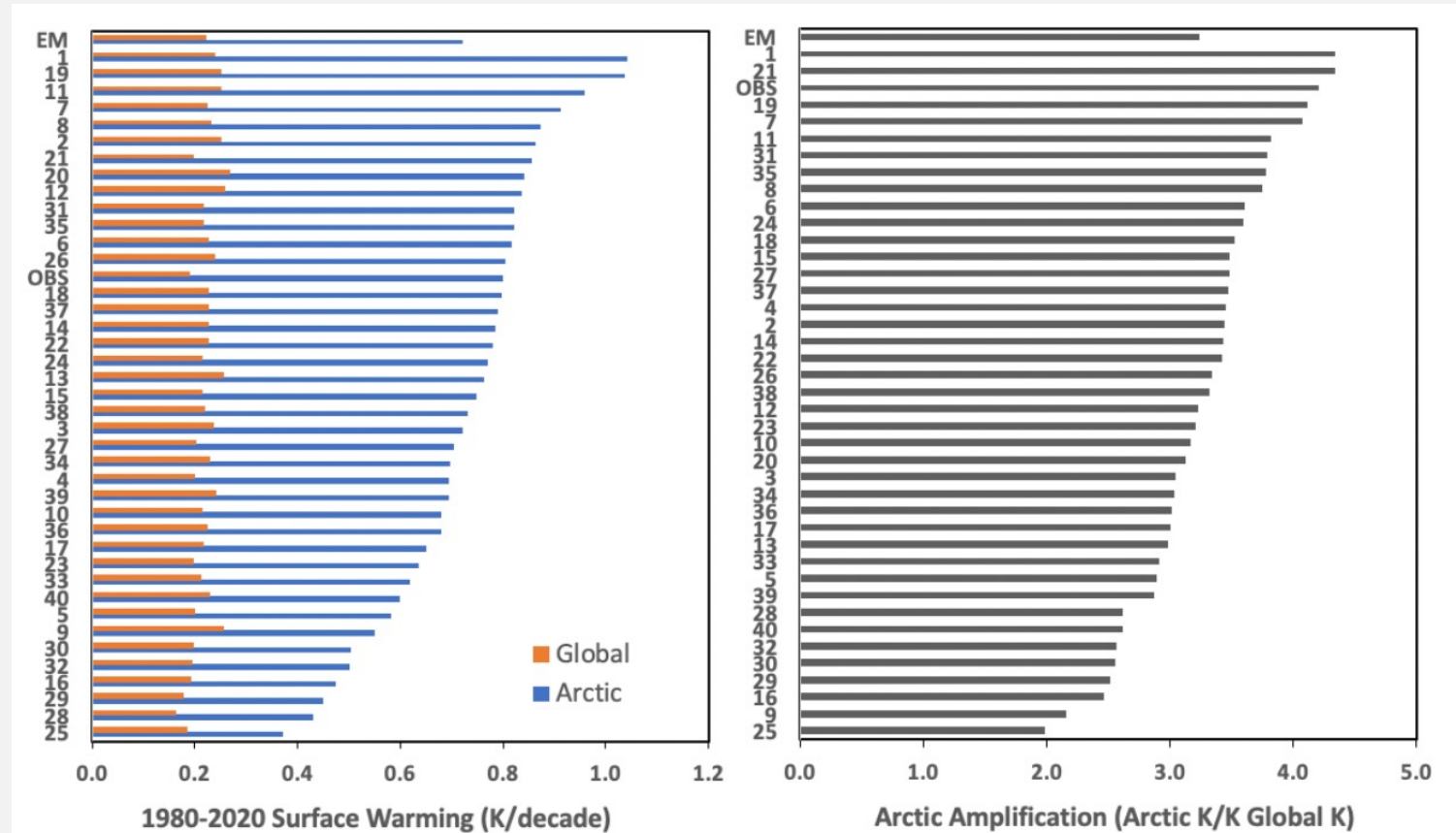
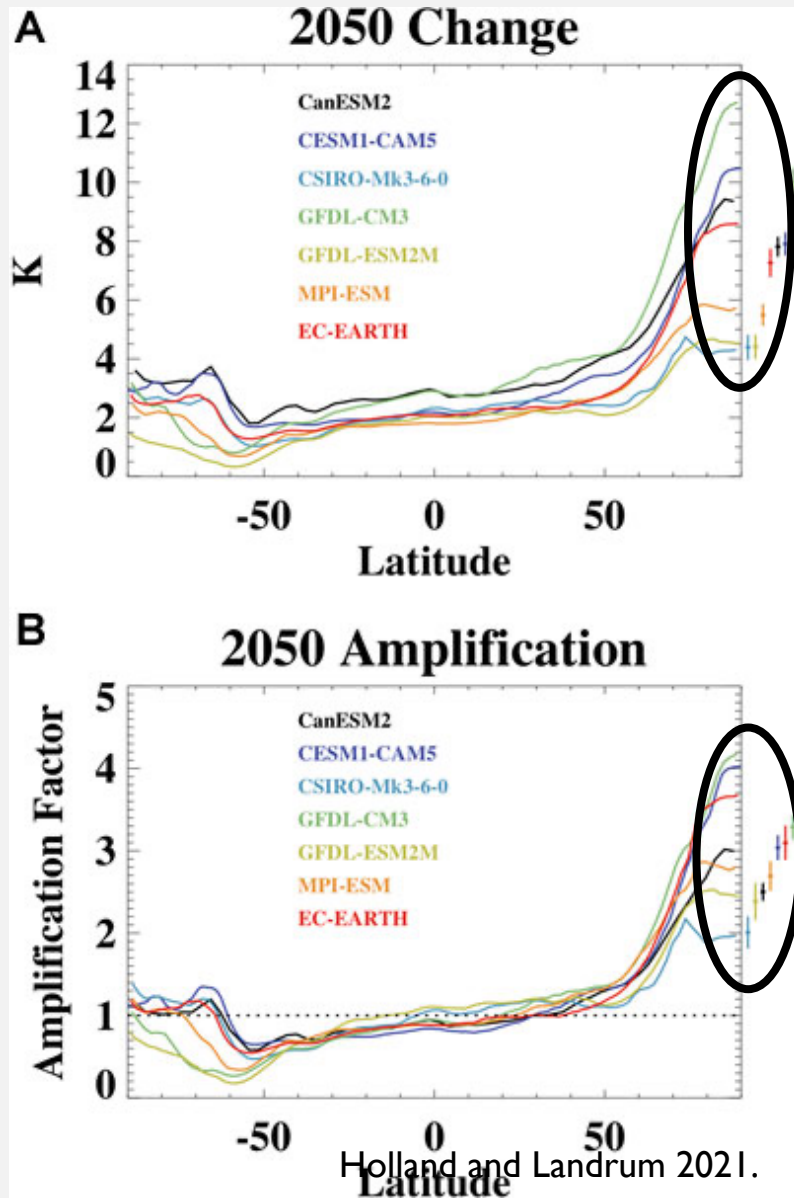


A landscape photograph showing a large glacier in the background, with a mountain range behind it. The foreground is a rocky, grassy slope. A white rectangular box with a black border is centered over the image, containing the text "Motivation & Previous Work".

# Motivation & Previous Work

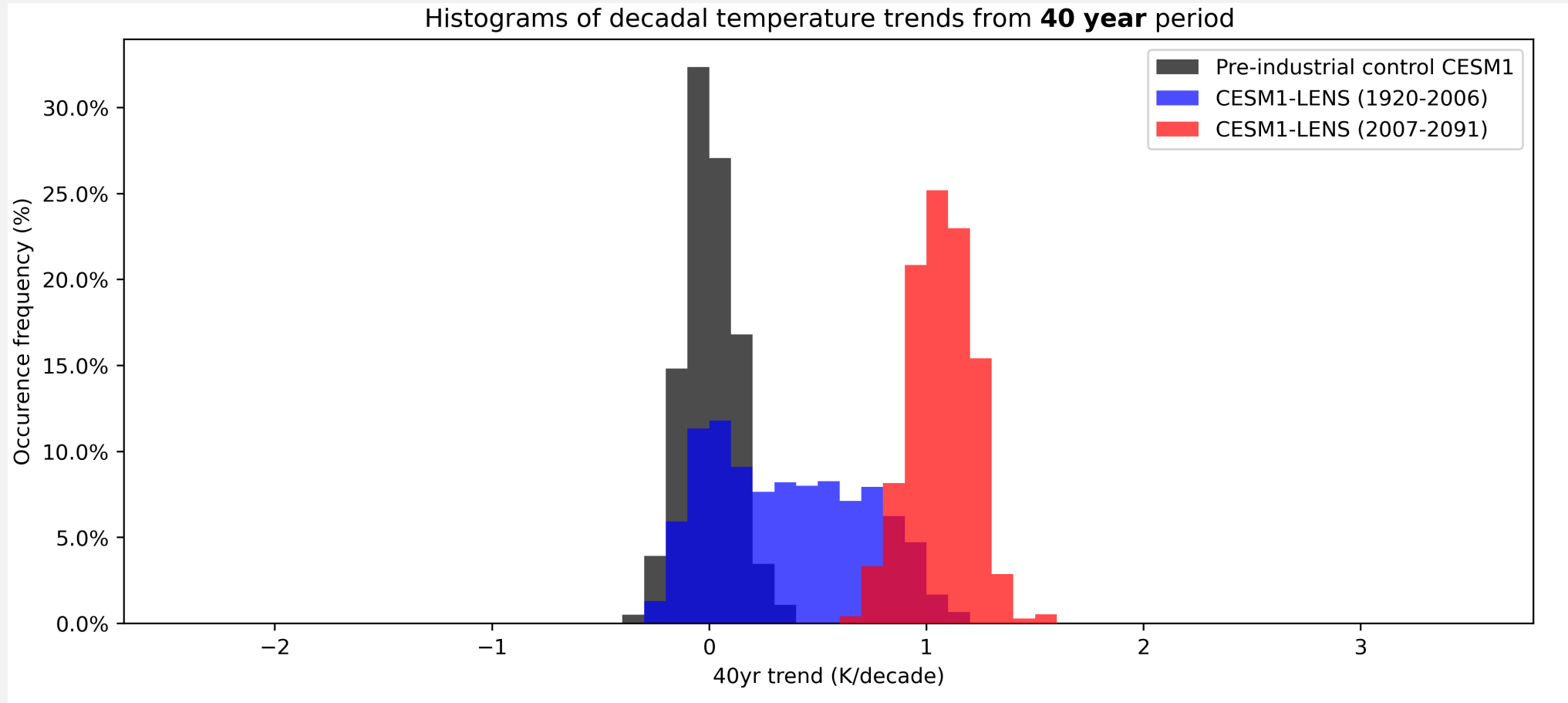


# The Arctic is warming faster than the globe, but uncertainties remain



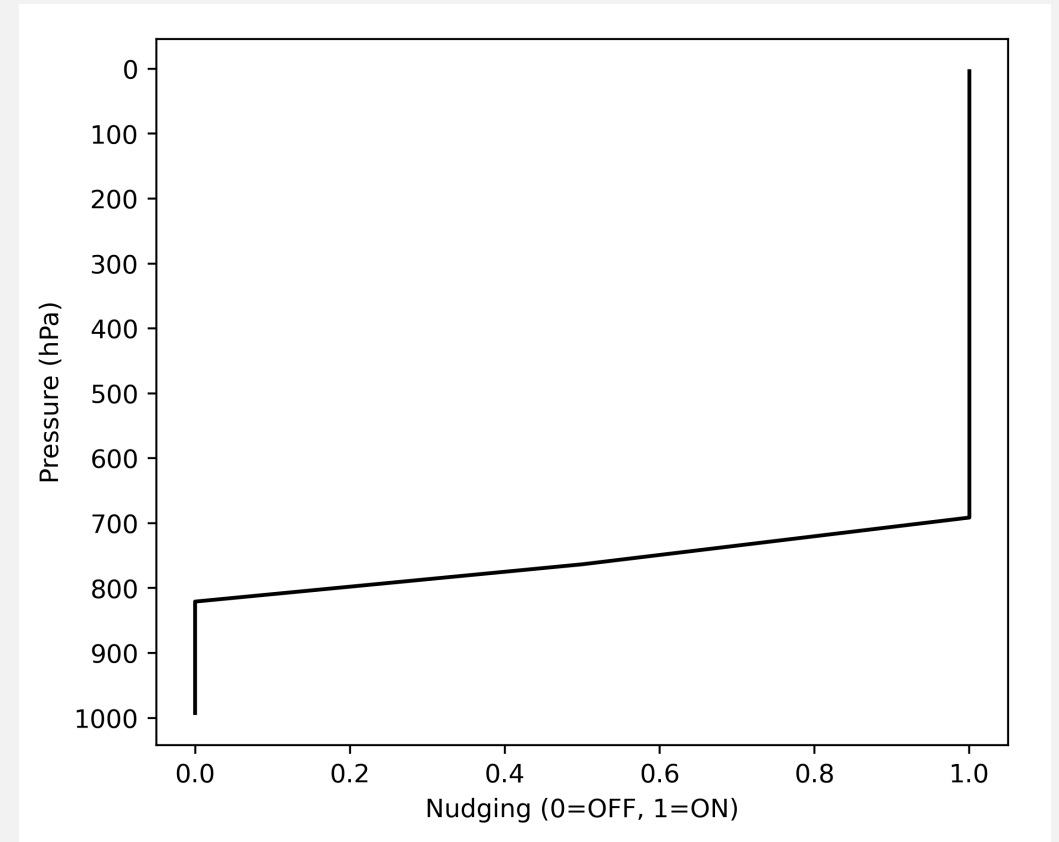
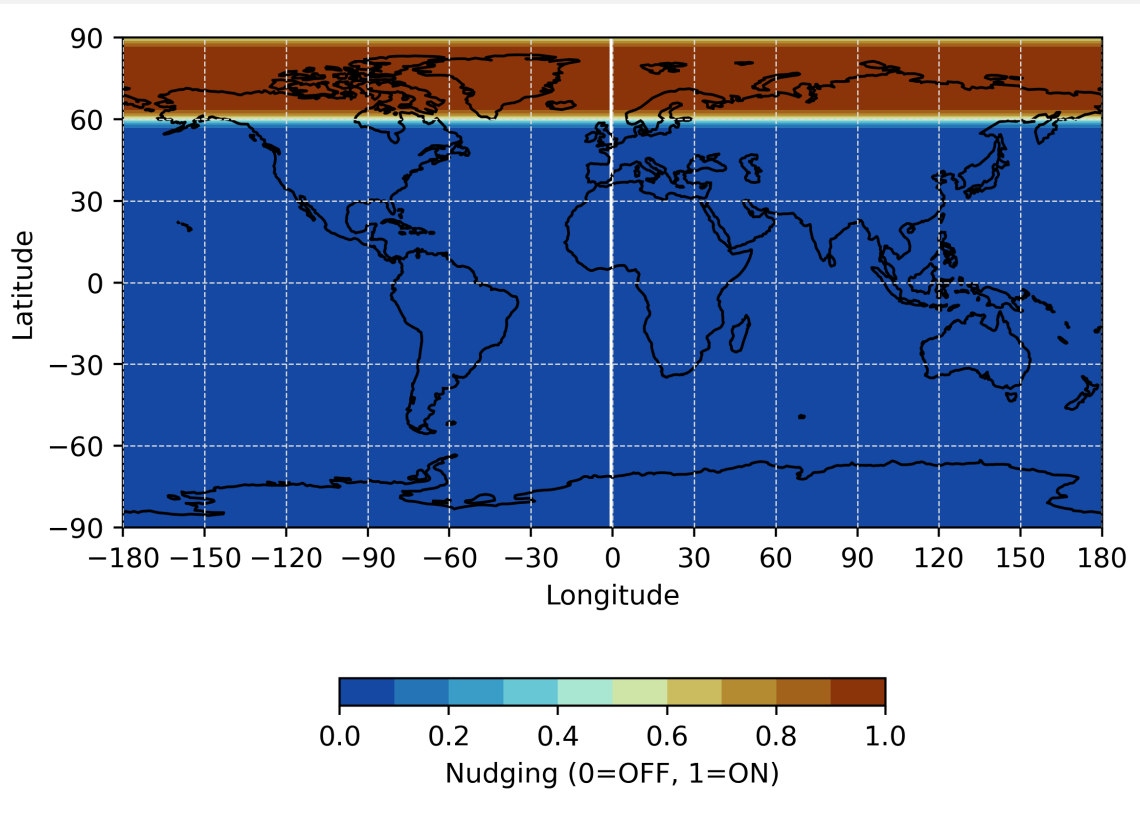
**Figure 1.** Arctic (70-90 °N) and Global warming (left) and Arctic Amplification (right). Values for individual members and ensemble mean (EM) of the CESM1 Large Ensemble (Kay et al. 2015) and for observations (GISTEMP Team, 2021).

# Longer trends help parse forced response and internal variability



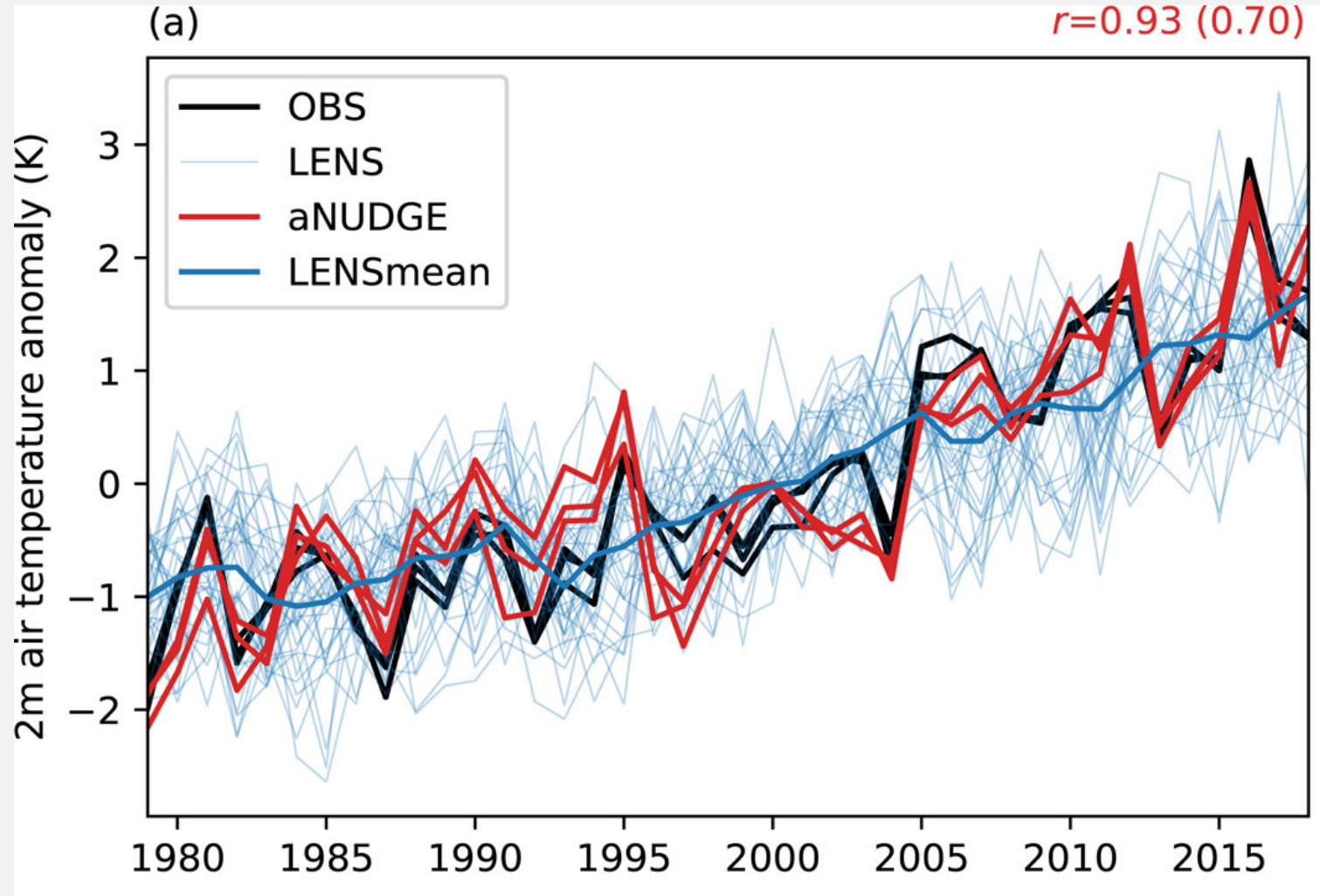


# Wind nudging is a powerful tool that constrains internal variability



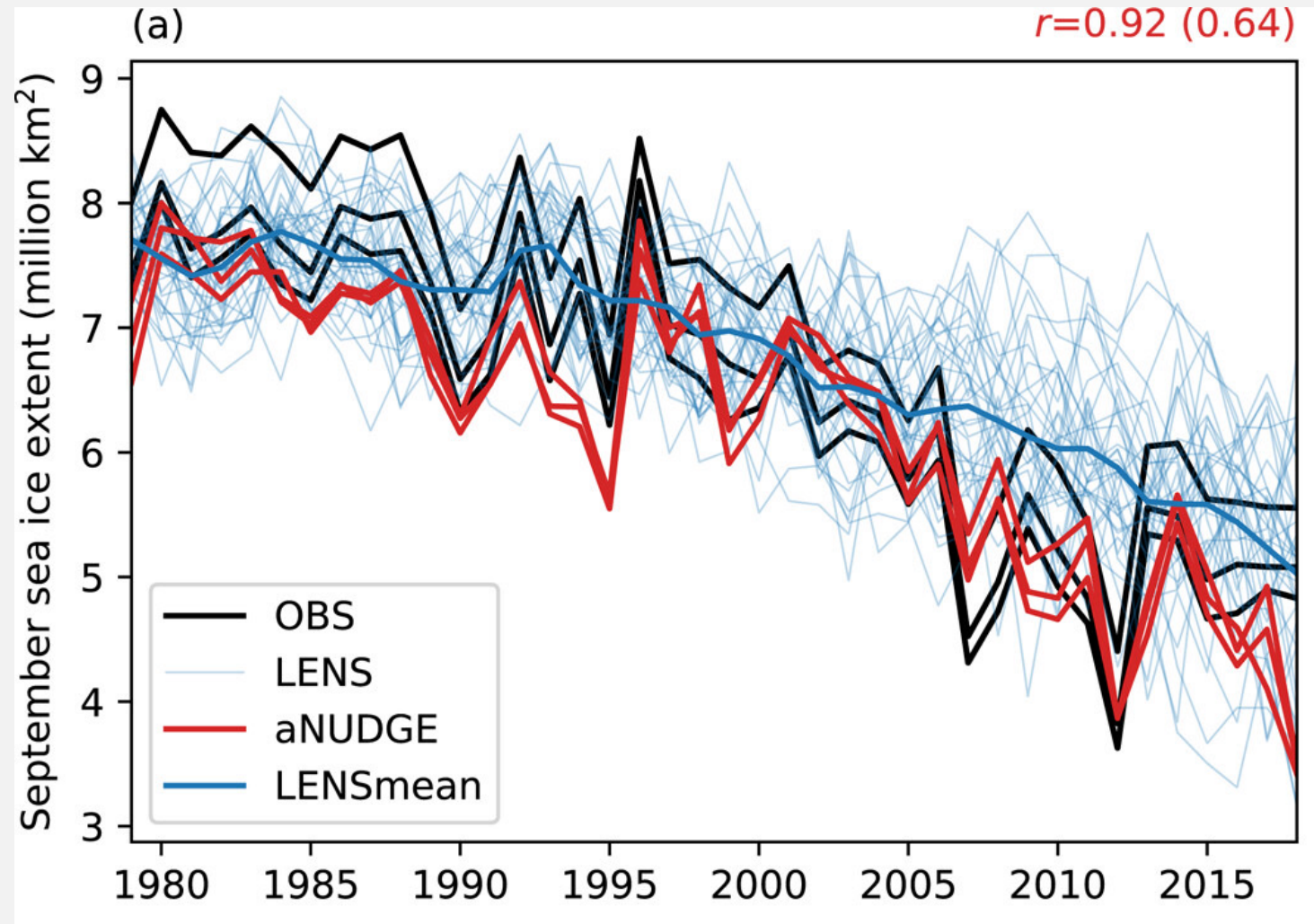


# Nudging winds reproduces Arctic temperature trends and interannual variability



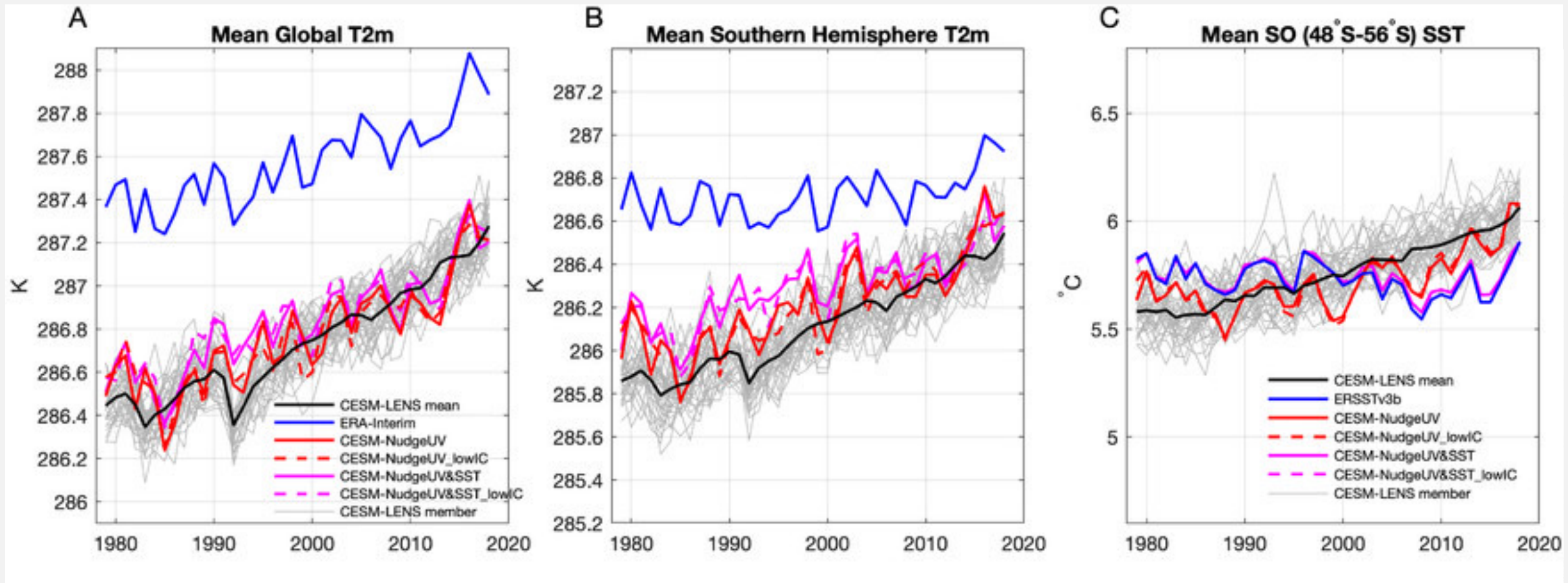


# Nudging winds reproduces Arctic September sea ice trends and interannual variability





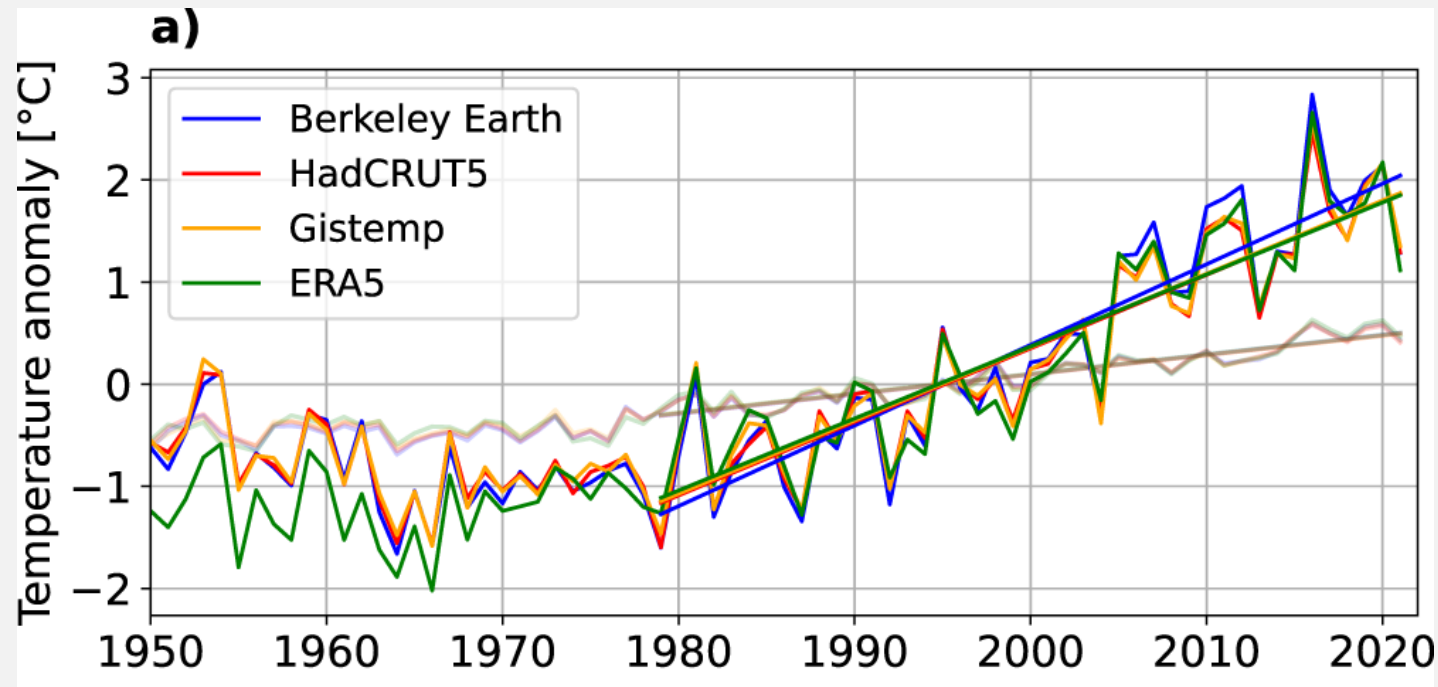
# Nudging both winds and SSTs improves model reproduction of Antarctic temperature and sea ice trends and variability





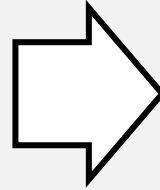
# My Research Questions

- 1) How much of the observed Arctic warming trend and variability (1980-2018) can we attribute to the **winds alone**?
- 2) How can we reproduce the **full** observed trend and interannual variability?



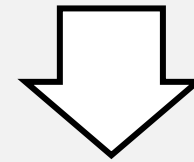
$N = 0$

- All 1850 (no wind nudging):
  - e.g. CESM2-LE Pre-industrial control



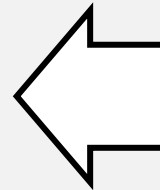
$N = 1$

- 1850 with wind nudging:
  - 1850-windnudge-atm
  - 1850-windnudge-coupled



$N = N$

- Historical with wind nudging
  - e.g. CESM1 - Roach & Blanchard-Wrigglesworth 2021.



...



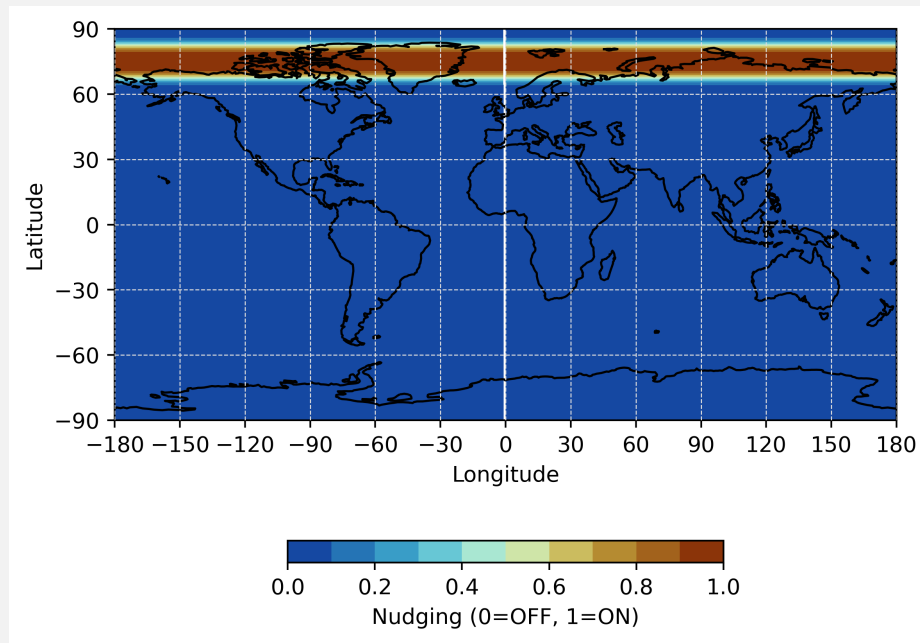
A wide-angle landscape photograph showing a massive glacier in the background, with a small body of water in front of it. The foreground consists of dark, rocky terrain with sparse green vegetation. The sky is a clear, bright blue with some light clouds. A white rectangular box with a thin black border is centered horizontally and vertically, containing the text "Initial Results".

# Initial Results



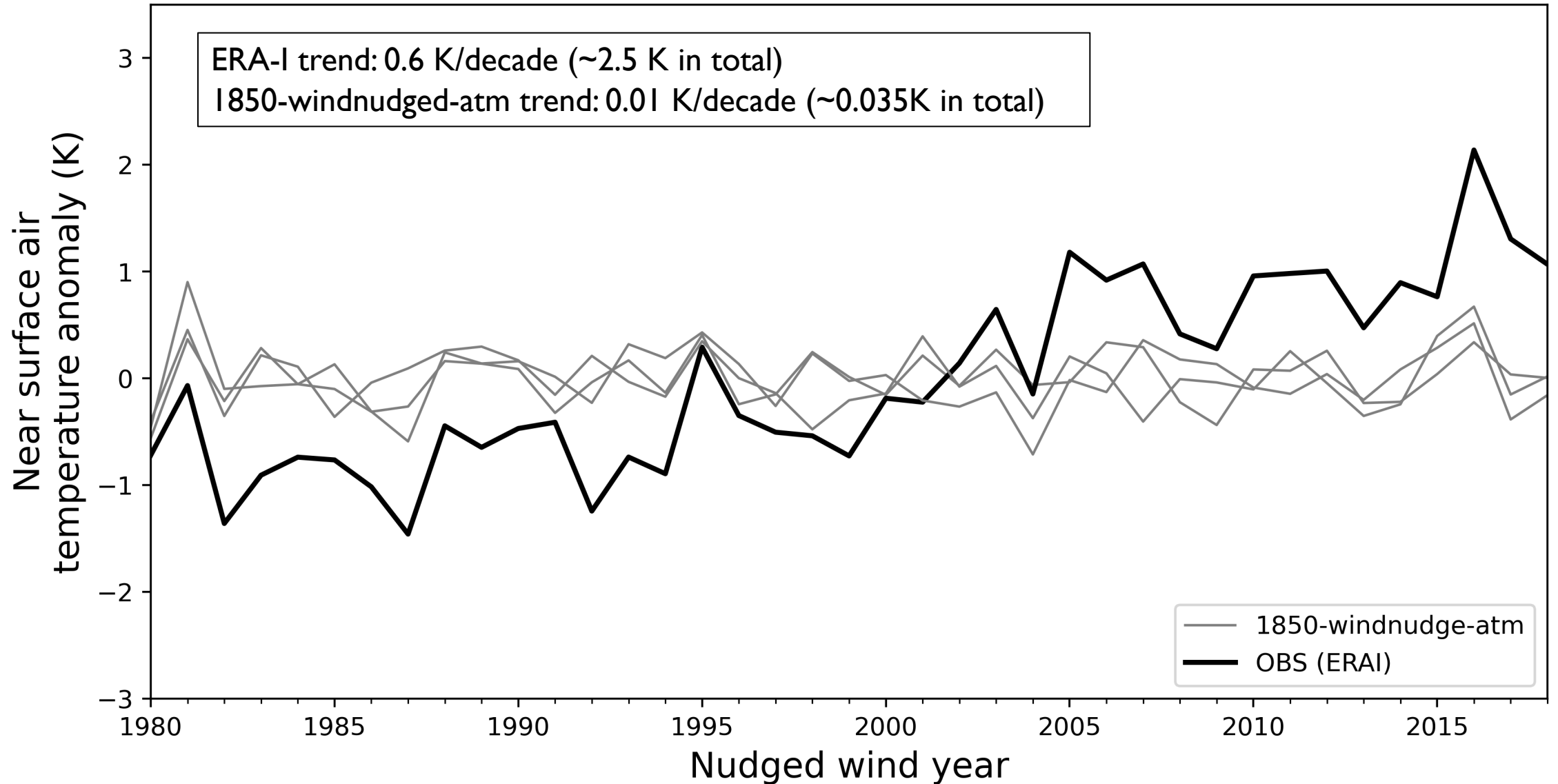
# New wind nudging experiments

Experiment Name	Forcing	Wind Nudging	Length/Ensemble Members	Coupling?
1850-windnudge-atm	1850	U & V to ERAI (1980-2018) above 850 hPa and between 67.5-82.5°N	39 years/3 members	Atmosphere-only
1850-windnudge-coupled	1850	U & V to ERAI (1980-2018) above 850 hPa and between 67.5-82.5°N	39 years/3 members	Coupled

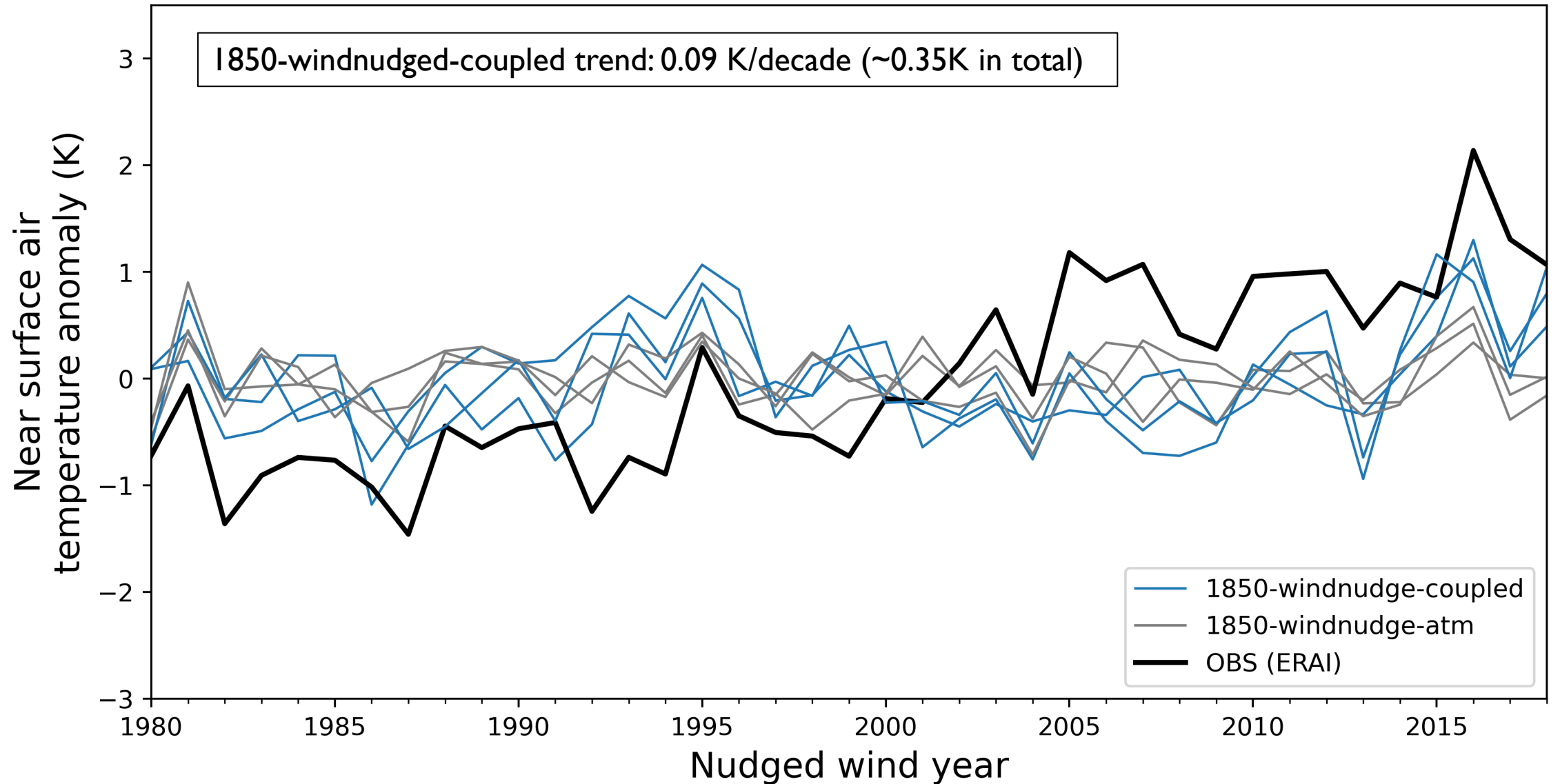




# Nudging an atmosphere-only pre-industrial climate with historical winds *doesn't* reproduce the trend

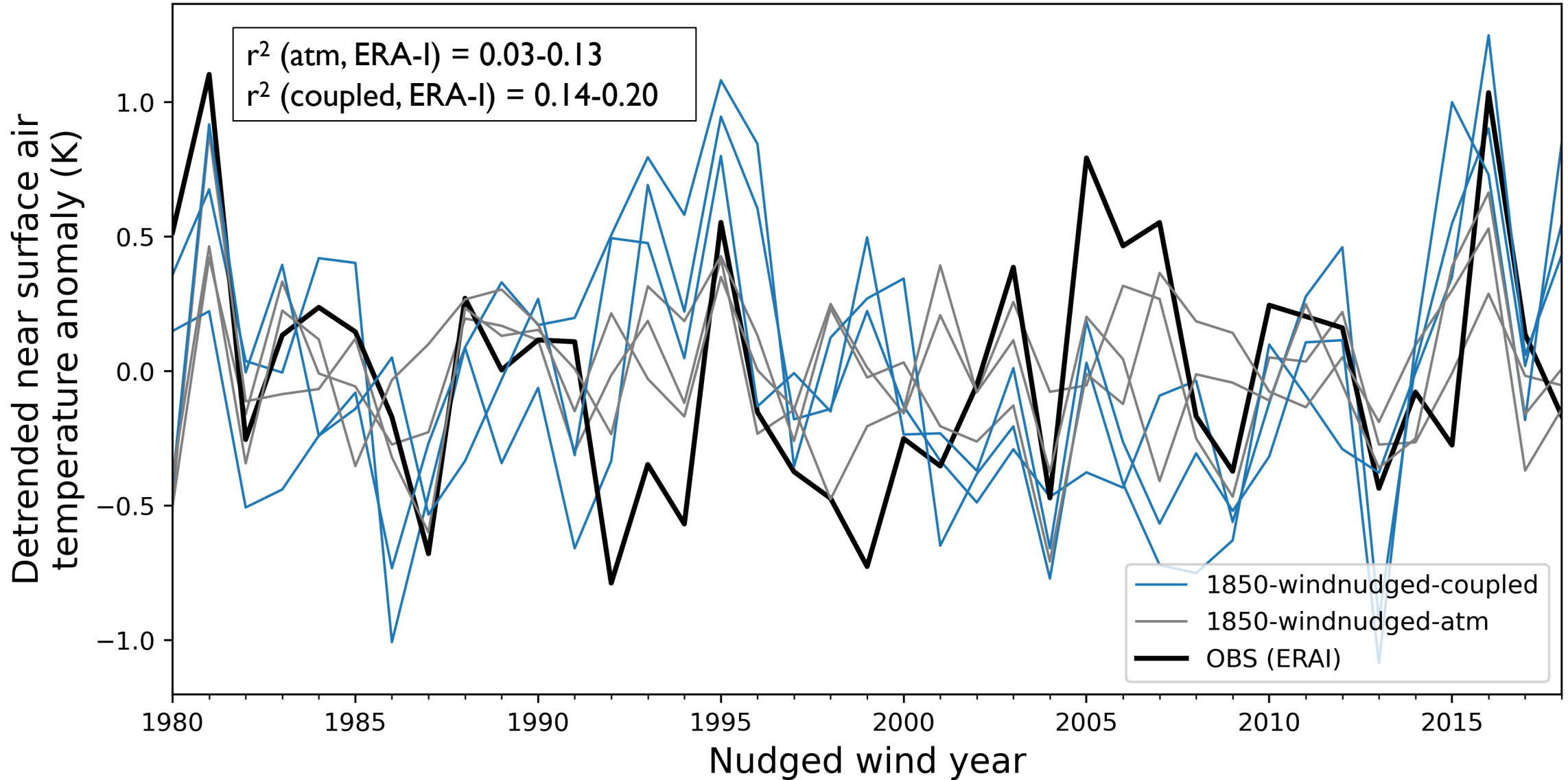


# Nudging a coupled pre-industrial climate with historical winds *doesn't* reproduce the trend



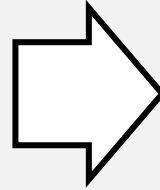


# Nudging a pre-industrial climate with historical winds alone **can** reproduce some of the interannual variability



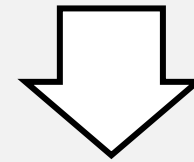
$N = 0$

- All 1850 (no wind nudging):
  - e.g. CESM2-LE Pre-industrial control



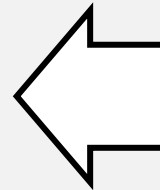
$N = 1$

- 1850 with wind nudging:
  - 1850-windnudge-atm
  - 1850-windnudge-coupled



$N = N$

- Historical with wind nudging
  - e.g. CESM1 - Roach & Blanchard-Wrigglesworth 2021.



...



A landscape photograph showing a large glacier in the background, with a mountain range behind it. The foreground consists of a rocky, grassy slope. A white rectangular box with a black border is centered over the image, containing the text "Future Experiments".

# Future Experiments



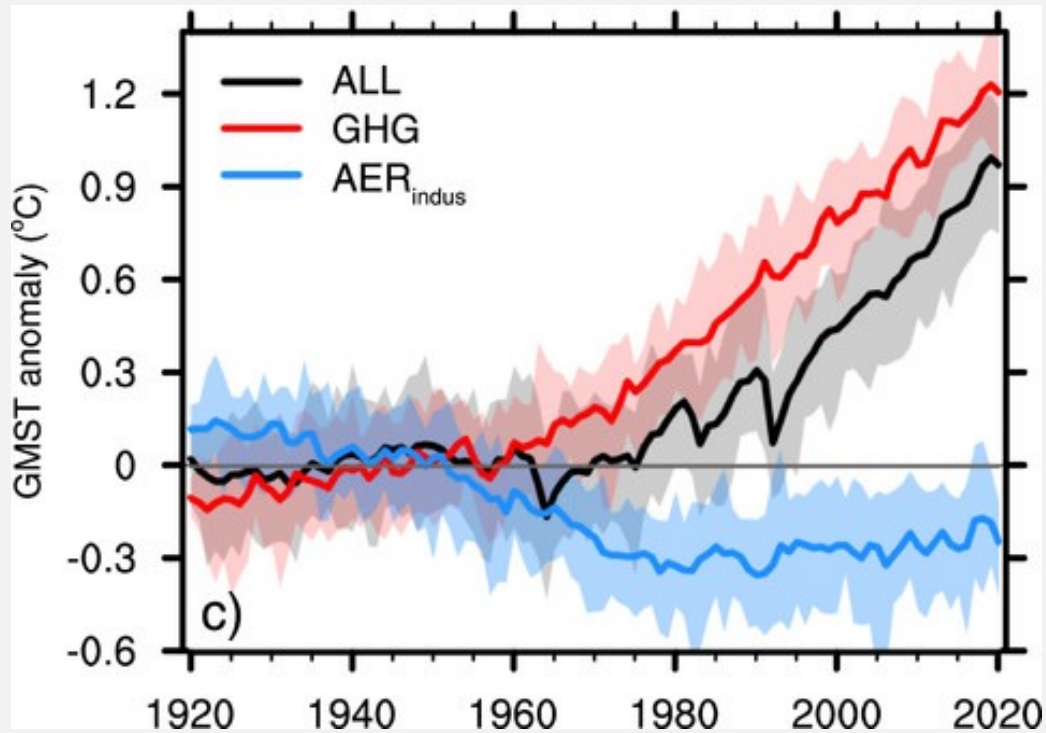
# Historical CESM2 run with wind nudging

<b>Experiment Name</b>	<b>Forcing</b>	<b>Wind Nudging</b>	<b>Length/Ensemble Members</b>	<b>Coupling?</b>
HISTALL-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-lowSIC-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-lowSIC-cldlock-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled



# Proposed future experiments – forcing changes (N=2)

Experiment Name	Forcing	Wind Nudging	Length/Ensemble Members	Coupling?
HIST-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled

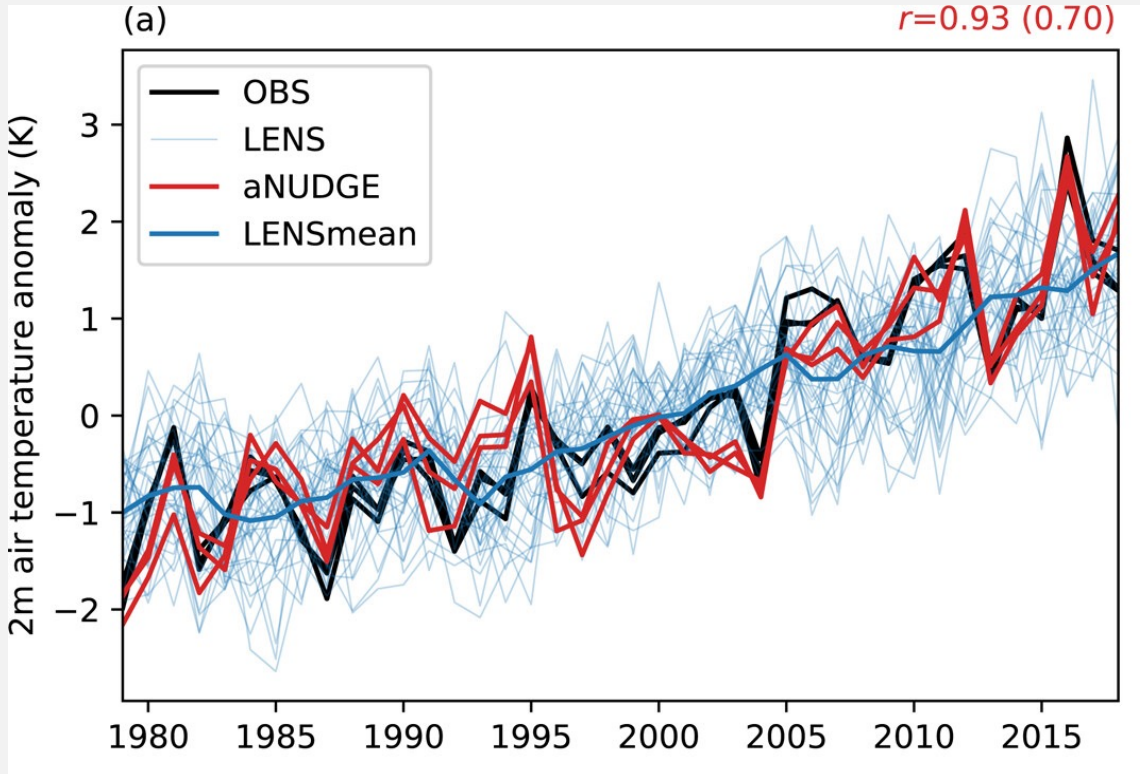


Deser et al. 2020.

- Adding historical greenhouse gas concentrations and/or aerosol concentrations

# Proposed future experiments – mean state changes (N=3)

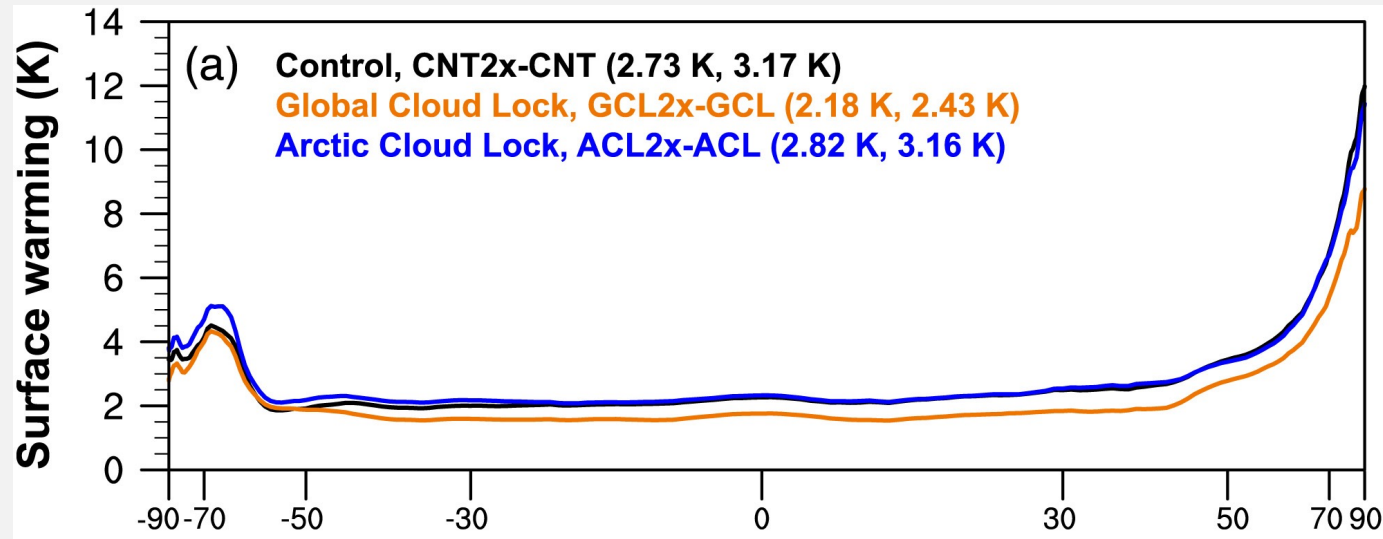
Experiment Name	Forcing	Wind Nudging	Length/Ensemble Members	Coupling?
HIST-lowSIC-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled



- Initial conditions with sea ice thinner than pre-industrial and/or warmer ocean surface

# Proposed future experiments – cloud locking (N=4)

Experiment Name	Forcing	Wind Nudging	Length/Ensemble Members	Coupling?
HIST-lowSIC-cldlock-windnudge-coupled	1850	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled



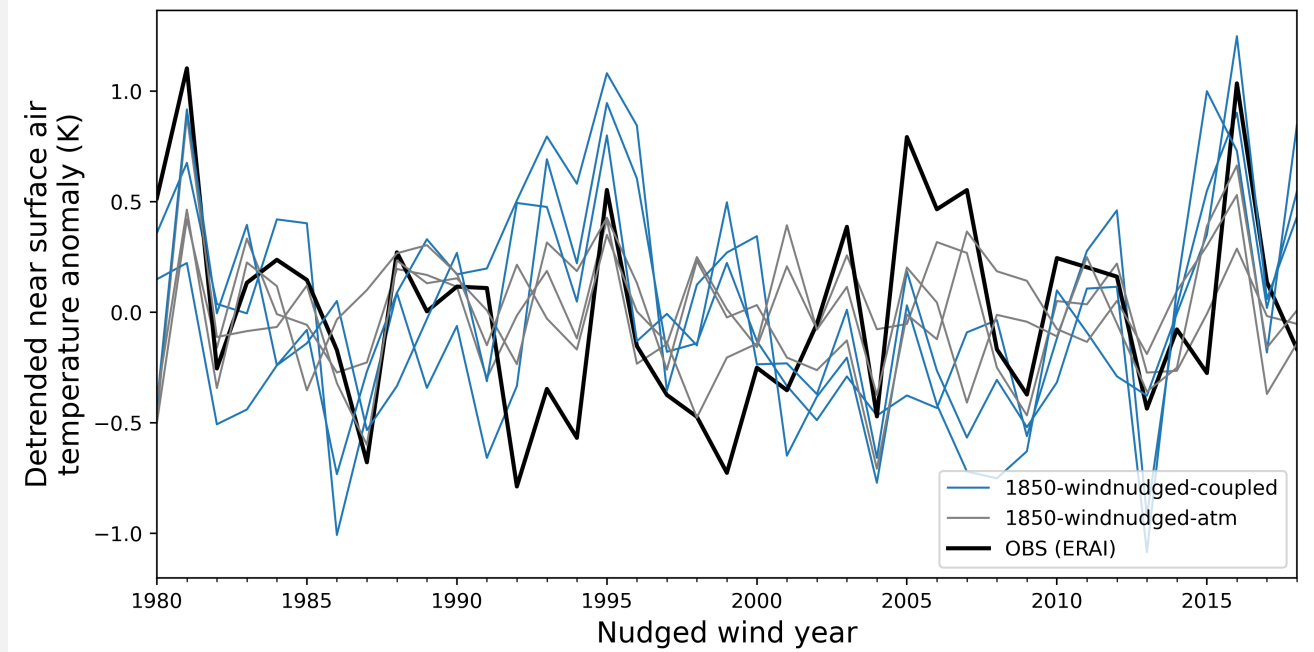
- Lock cloud properties to fixed values (i.e. no cloud feedbacks or cloud-aerosol interactions)

Middlemas et al. 2020.



# Summary

- Winds alone can help explain interannual variability in the observed Arctic temperature, but do not explain the trend (N=1)
- Future work will determine how much the trend and variability we can attribute to mean state and forcing changes (N=2, 3, ... N-1)



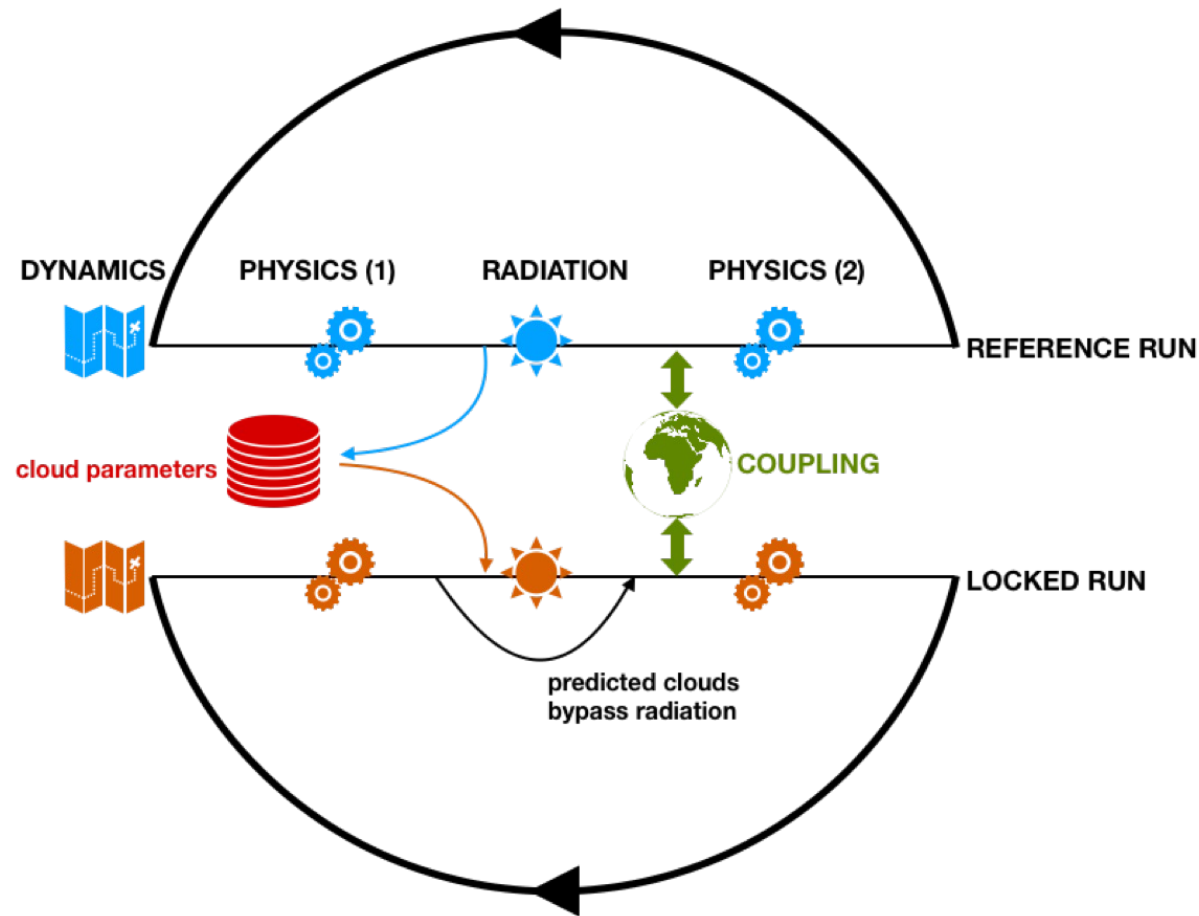
Contact info:

[ash.gilbert@colorado.edu](mailto:ash.gilbert@colorado.edu)

# All experiments – completed and proposed

<b>Experiment Name</b>	<b>Forcing</b>	<b>Wind Nudging</b>	<b>Length/Ensemble Members</b>	<b>Coupling?</b>
HISTALL-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-lowSIC-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
HIST-lowSIC-cldlock-windnudge-coupled	Historical	U & V to ERAI (1980-2018) above 850 hPa and between 60-90°N	39 years/3 members	Coupled
I850-windnudge-atm	I850	U & V to ERAI (1980-2018) above 850 hPa and between 67.5-82.5°N	39 years/3 members	Atmosphere-only
I850-windnudge-coupled	I850	U & V to ERAI (1980-2018) above 850 hPa and between 67.5-82.5°N	39 years/3 members	Coupled

# Let's disable cloud radiative feedbacks (i.e., cloud locking)!!



*Courtesy: Brian Medeiros; Middlemas et al. 2019; Grise et al. 2019*