The Recent Emergence of Arctic Amplification

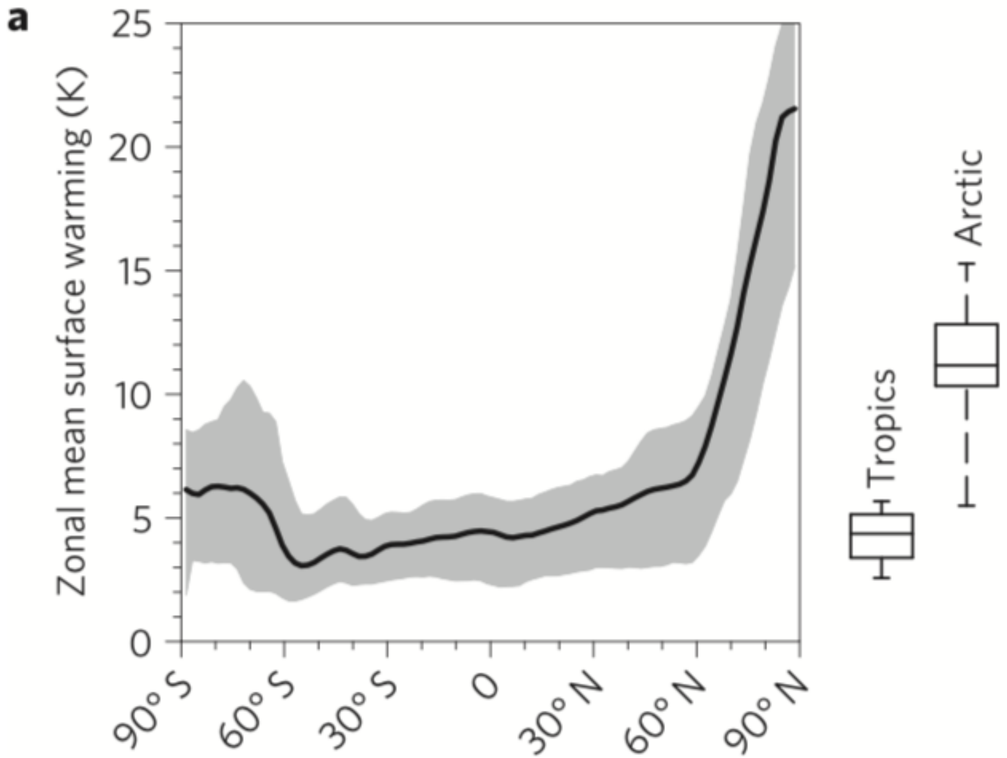
Mark England, UNCW and SIO
Ian Eisenman, SIO
Nick Lutsko, SIO
Till Wagner, UNCW

Manuscript in preparation

email: mengland@ucsd.edu
markrossengland.com
@markrossengland

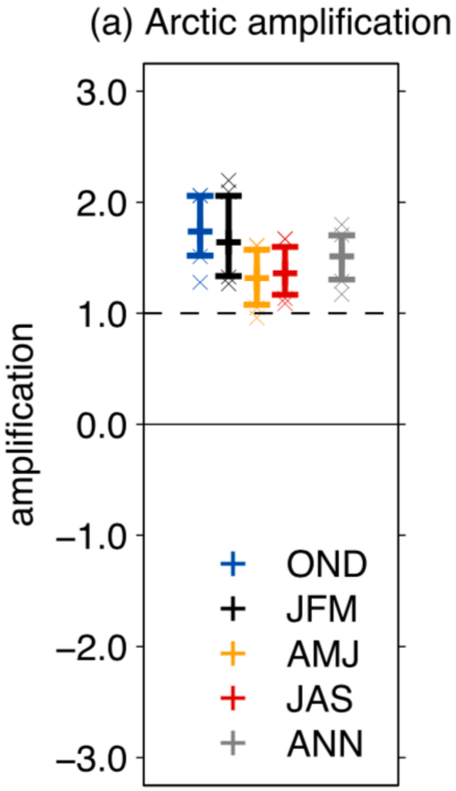
Arctic Amplification is a robust phenomenon found in climate model simulations and even in past climates

4xCO_2 CMIP5



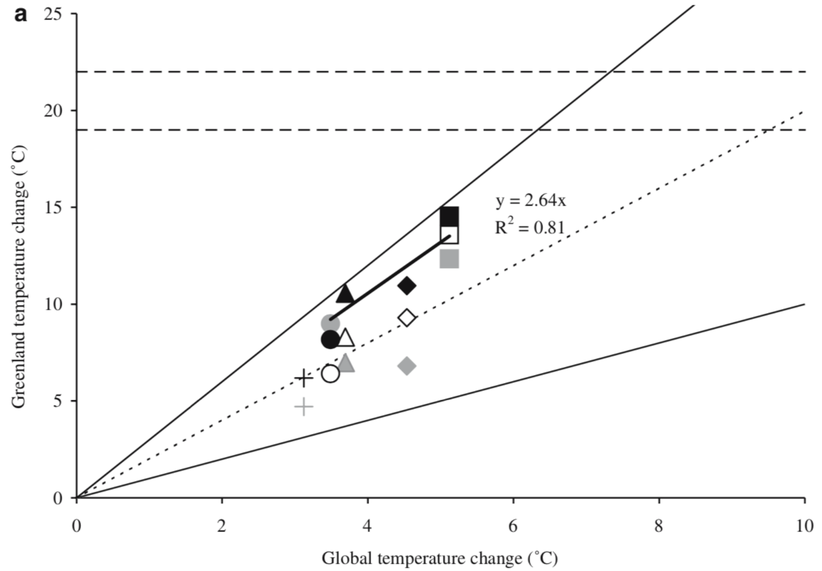
Pithan and Mauritsen, 2014

RCP8.5 CMIP5



Barnes and Polvani, 2015

PMIP2 and reconstructions



Masson Delmotte et al, 2006

We investigate the extent to which - and why - Arctic Amplification occurred over the last century

Many studies have investigated the causes and effects of Arctic Amplification, but relatively little attention has been paid to Arctic Amplification in the observational record.

- **We investigate this question using a range of observational and reanalysis products.**
- **We then use the CESM-LE and the CESM single forcing ensembles to understand the contributions of aerosols, greenhouse gases and internal variability to the observed trends.**

Methods

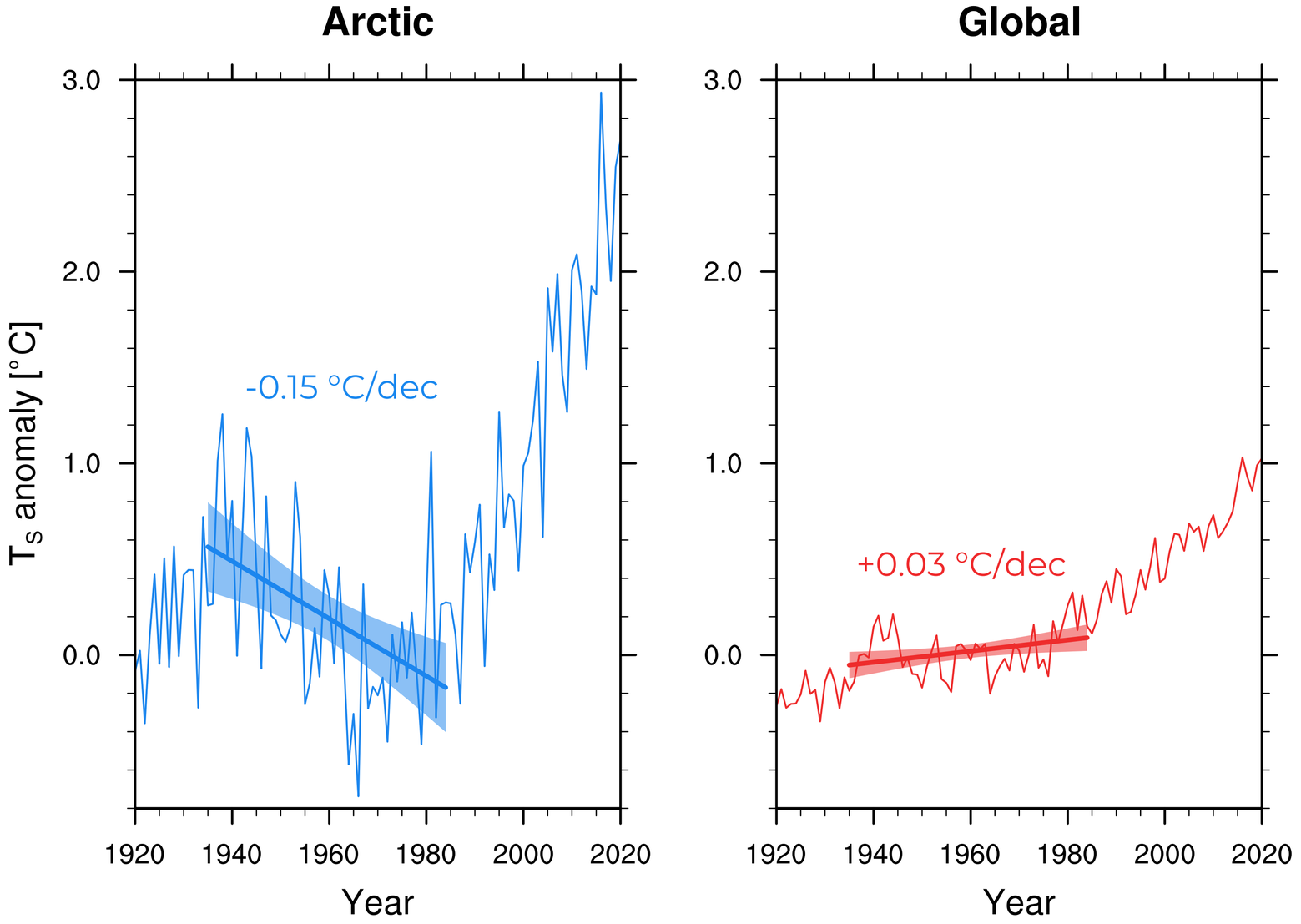
- Global and Arctic (60-90°N) means
- 50-year linear trends in near surface air temperature
- Arctic Amplification occurs when

$$\frac{\text{Arctic SAT trend}}{\text{Global SAT trend}} > 1$$

Observational and reanalysis datasets

Dataset	Time period
GISTEMPv4	1920 – 2020
HadCRUT5	1920 – 2020
Cowtan and Way (2014)	1920 – 2018
ERA-20C	1920 – 2010
ERA5	1950 – 2020

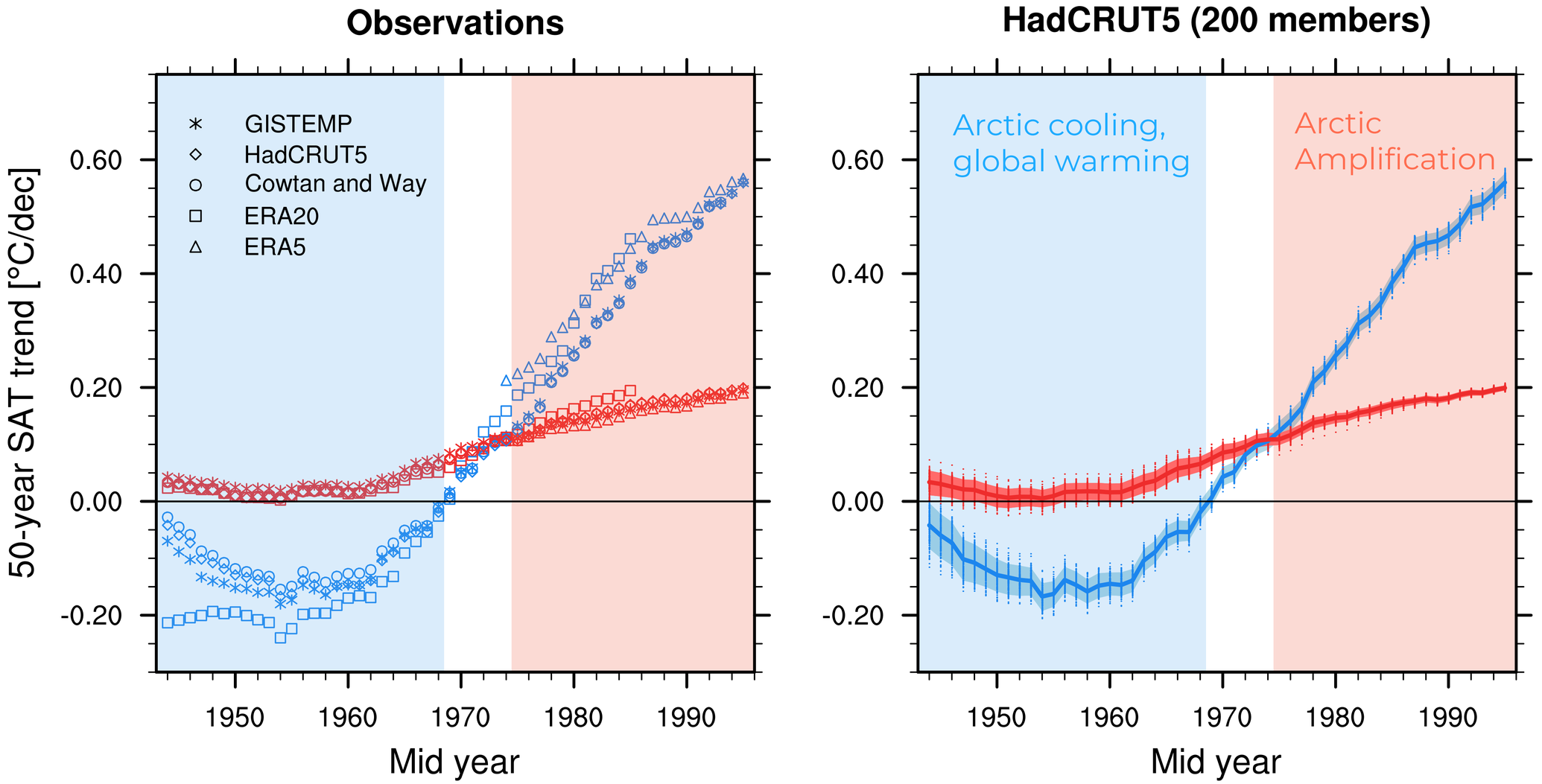
Arctic Amplification did not occur throughout the mid-20th century (robust in all five datasets)



Arctic cooling during global warming

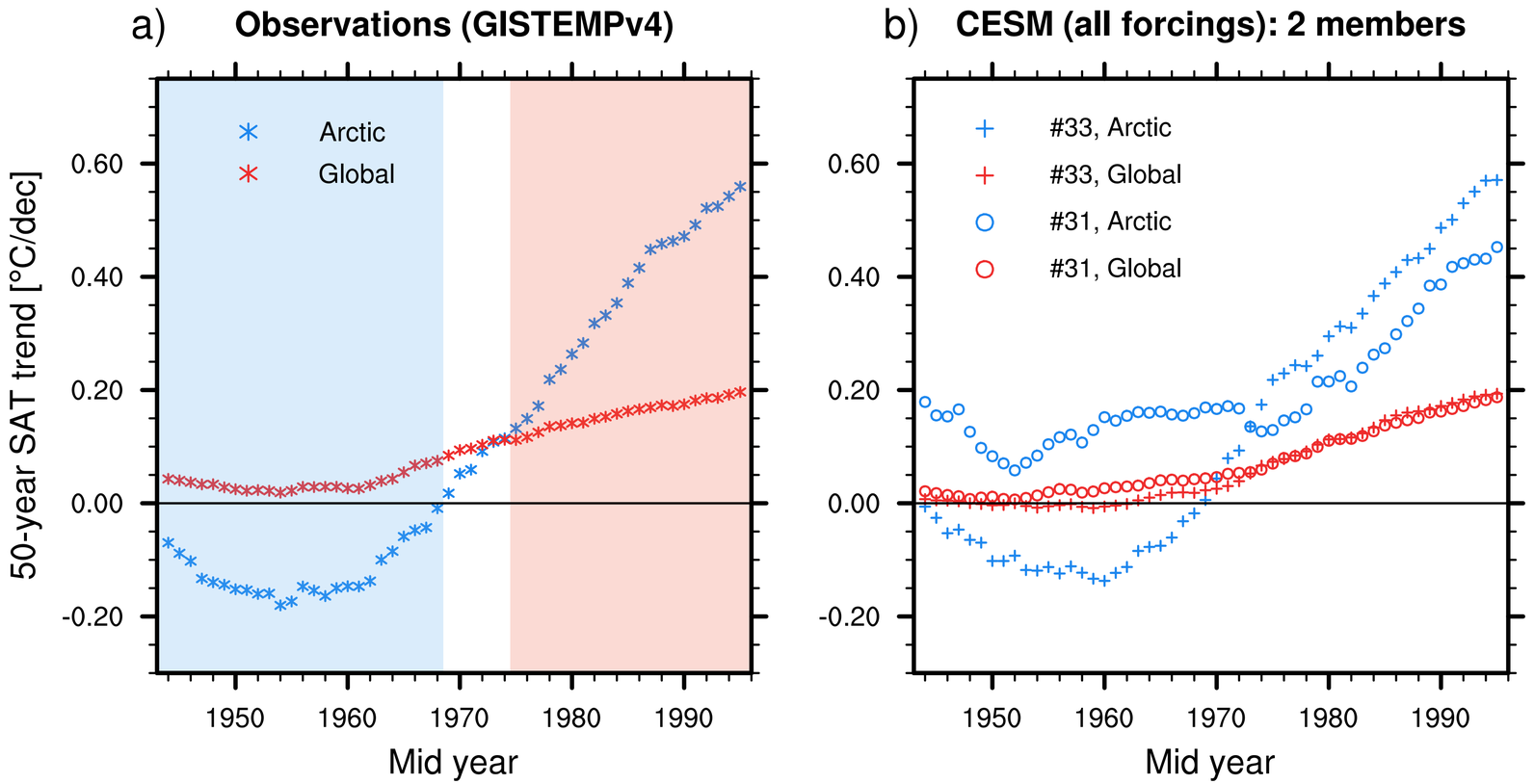
GISTEMPv4

Arctic Amplification did not begin until 1970s



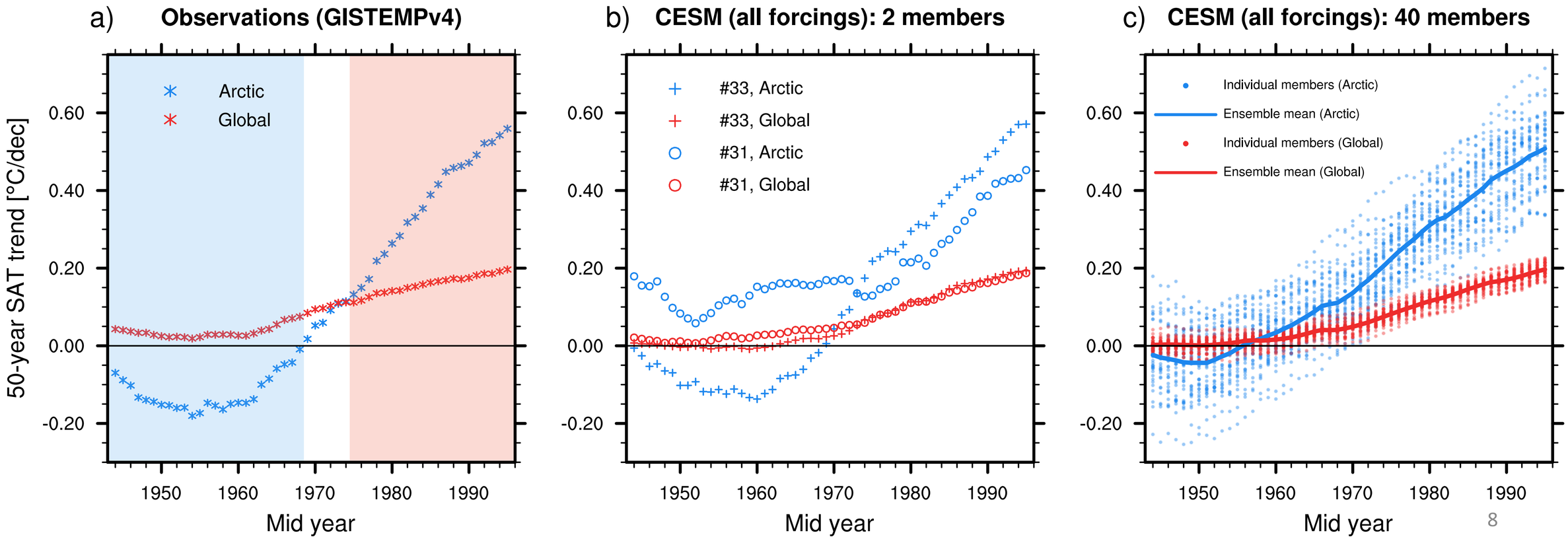
Does the CESM-LE reproduce the observed trends?

- There are some members (member #33) which capture the characteristics of the observed trends well
- Other members (member #31) show Arctic Amplification throughout the last century
- Indicates potentially important role for internal variability



Does the CESM-LE reproduce the observed trends?

- Ensemble mean response features weak Arctic cooling in mid-20th century.
- Observed Arctic cooling trends are at the edge of the distribution simulated by the CESM-LE
- All members show unambiguous Arctic Amplification by second half of 20th century
- 31 out of 40 members show some periods of Arctic cooling under global warming

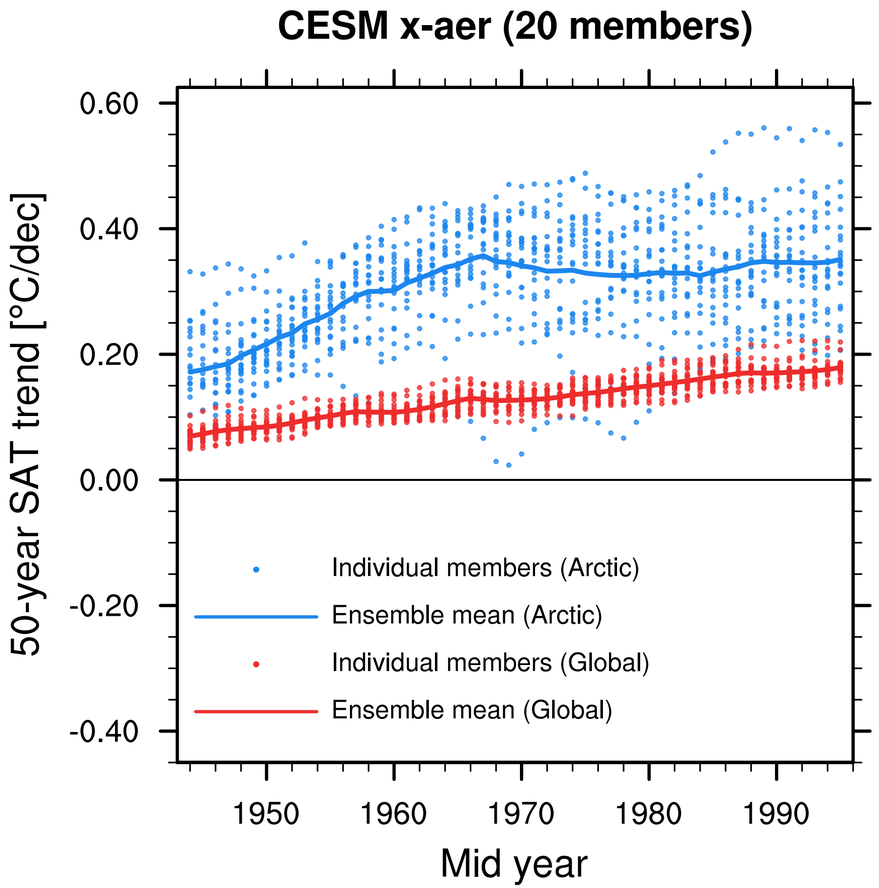


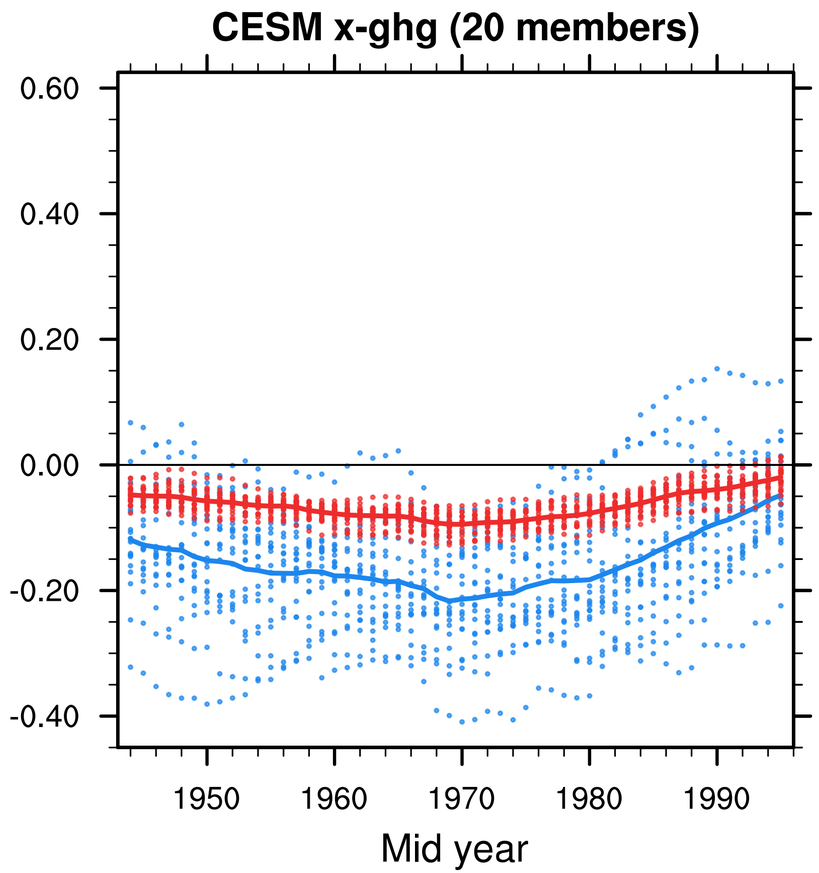
What has contributed to the lack of Arctic Amplification?

- Industrial aerosols (Fyfe et al, 2013; Gagne et al, 2017; Deser et al, 2020)
- Greenhouse Gases (Stjern et al, 2019; Polvani et al, 2020; Deser et al, 2020)
- Internal variability

Dataset	Members	Forcing	Reference
CESM-LE	40	All forcings	Kay et al, 2015
CESM x-aer	20	Industrial aerosols fixed in 1920	Deser et al, 2020
CESM x-ghg	20	GHGs fixed in 1920	Deser et al, 2020

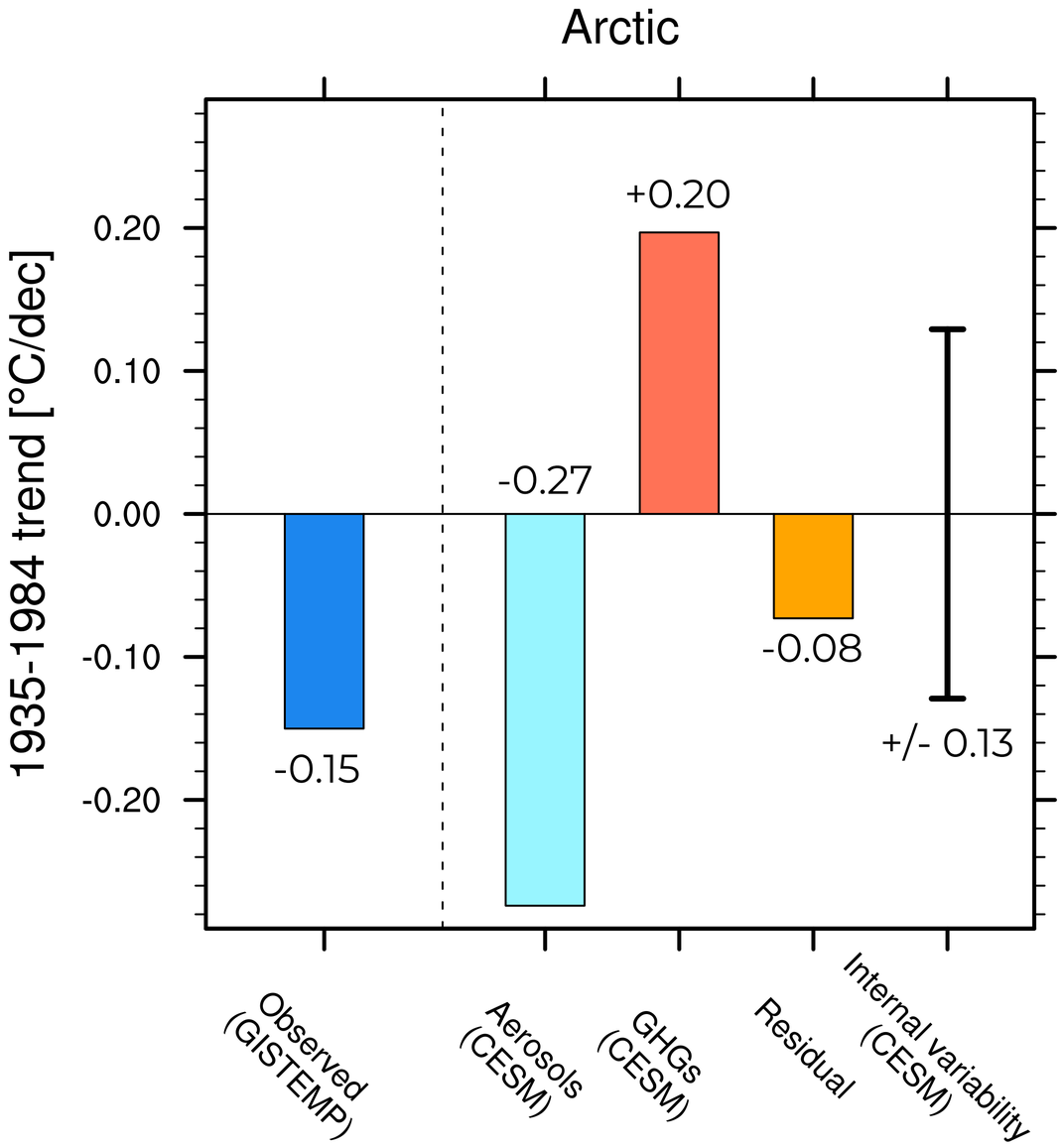
What has contributed to the lack of Arctic Amplification?





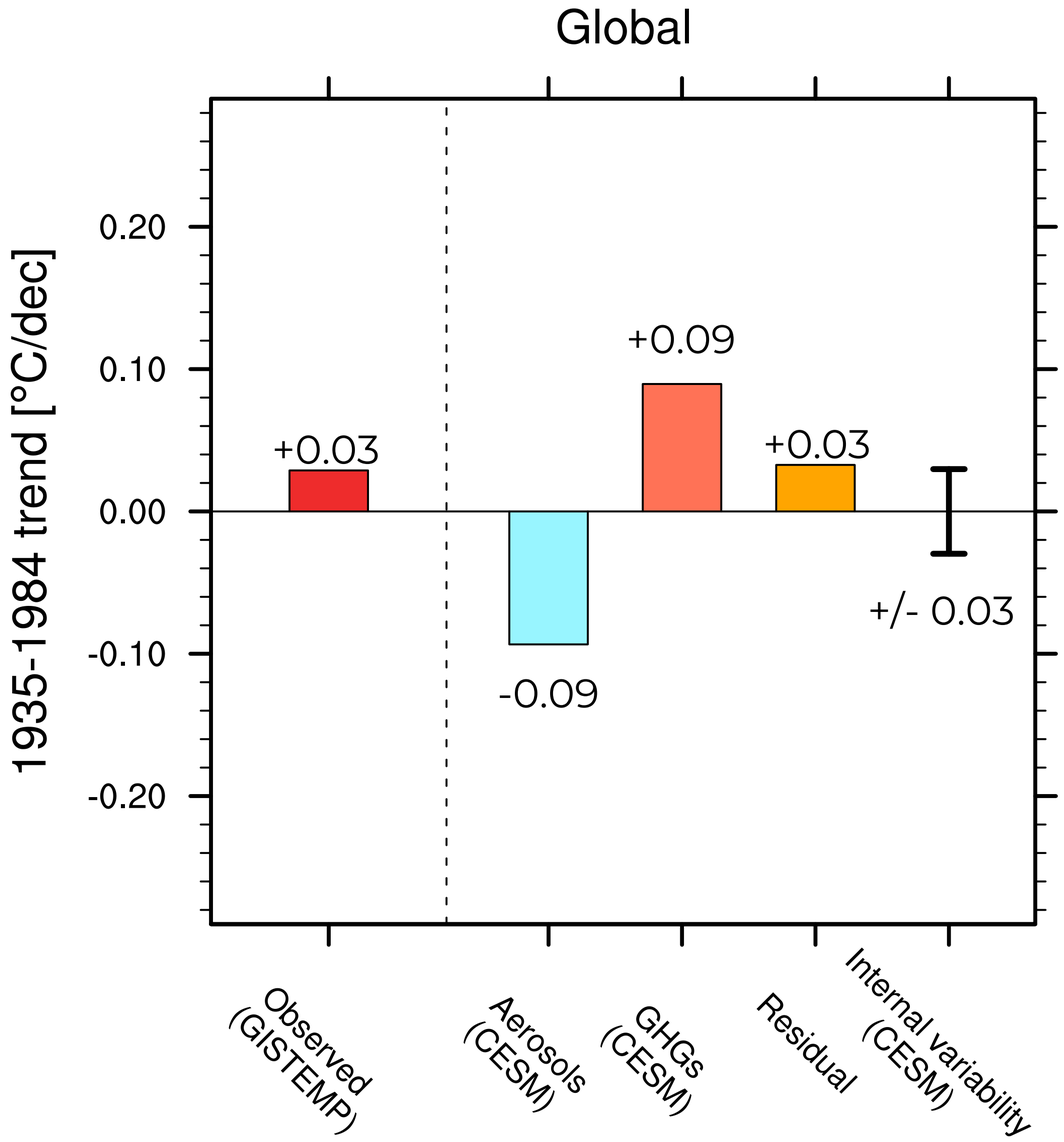
- Without aerosols, Arctic cooling would not have occurred
- Without GHGs, global warming would not have occurred
- In both ensembles, Arctic Amplification is pervasive through the last century
- Specific combination of aerosols and GHGs created setting where Arctic Amplification doesn't occur

Calculating contributions to 1935-1984 Arctic trend



- Net anthropogenic impact of -0.07 °C/dec
- AA factor of aerosols is 3.0 whereas AA factor of GHG is 2.2
- Residual is well within bounds of internal variability simulated by CESM
- A different configuration of internal variability could have overcome the net anthropogenic cooling and resulted in Arctic warming
- Lack of Arctic Amplification not inevitable

Calculating contributions to 1935-1984 global trend



- Near total cancellation in response to aerosols and GHGs
- Residual is at edge of internal variability simulated by CESM
- A different configuration of internal variability could have resulted in global cooling
- Lack of Arctic Amplification not inevitable

Conclusions

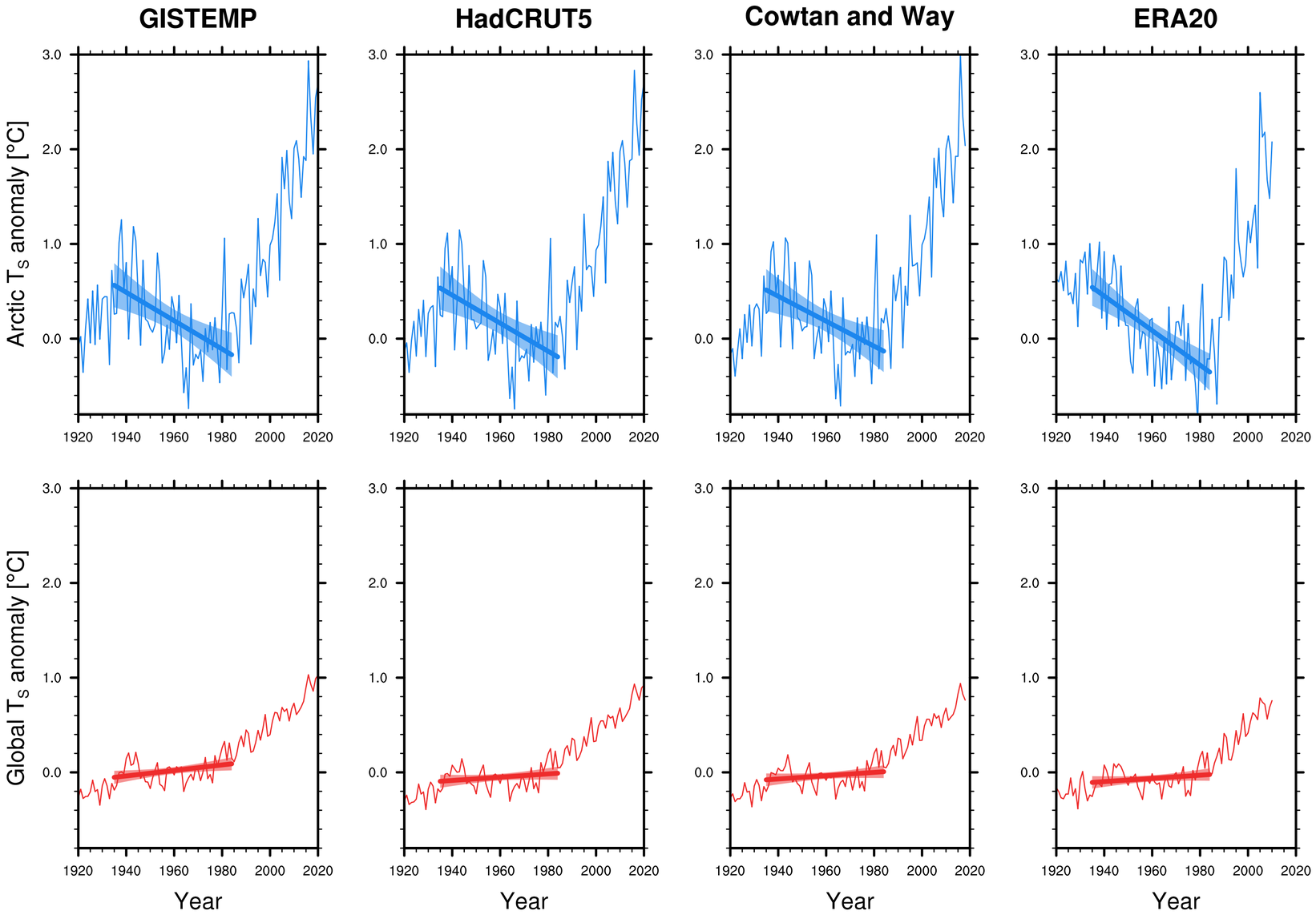
We investigate the extent to which Arctic Amplification occurred in the last century

- Arctic Amplification in 50-year trends only began to occur in 1970s
- Prior to this, the Arctic cooled under weak global warming

Why? (according to CESM…)

- In the absence of the emission of aerosols or GHGs, Arctic Amplification would have occurred.
- The combination of aerosol and GHG forcing created the conditions for Arctic Amplification not to occur
- Internal variability also played an important role

Results consistent among different observational and reanalysis datasets

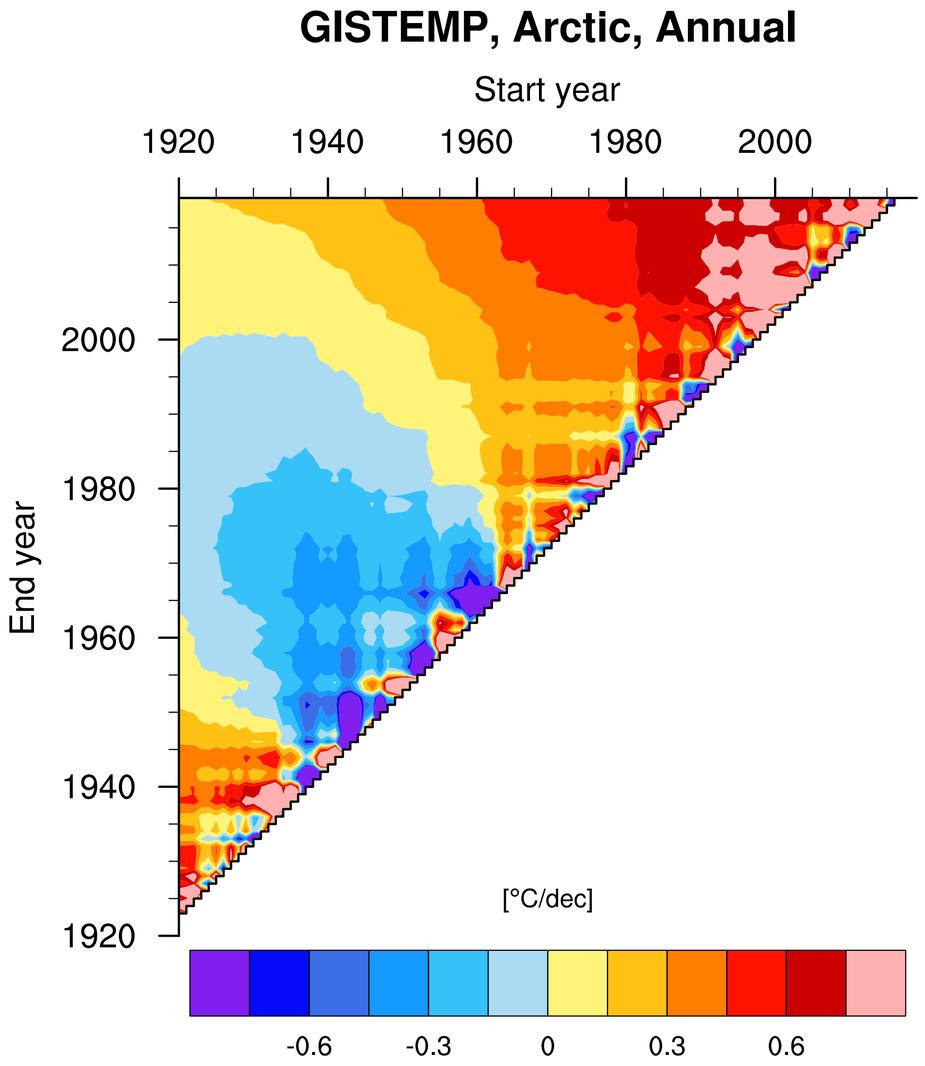


Observational and reanalysis datasets

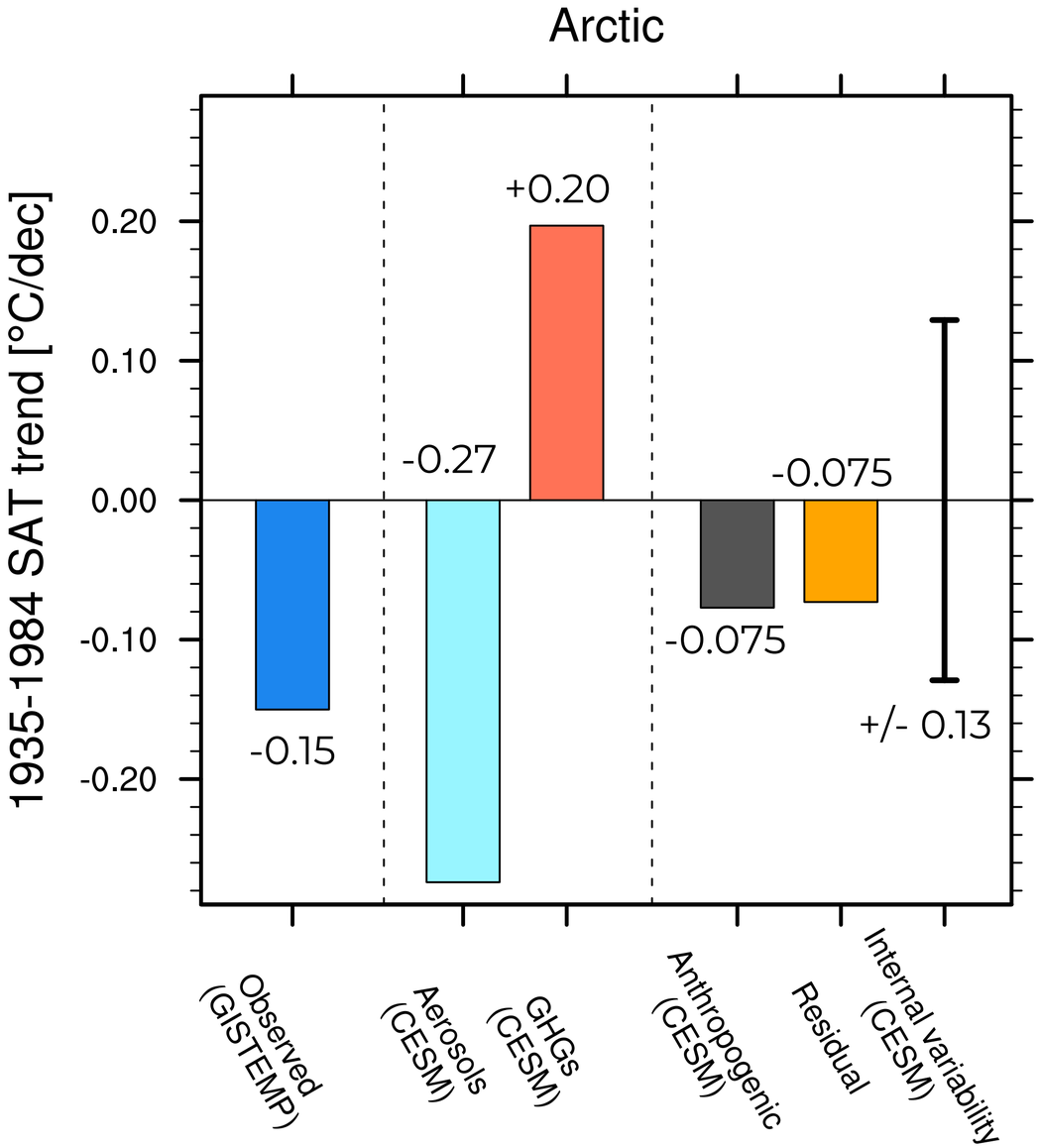
Dataset	Time period
GISTEMPv4	1920 – 2020
HadCRUT5	1920 – 2020
Cowtan and Way (2014)	1920 – 2018
ERA-20C	1920 – 2010
ERA5	1950 – 2020

← 200 member ensemble

Arctic surface temperature trends

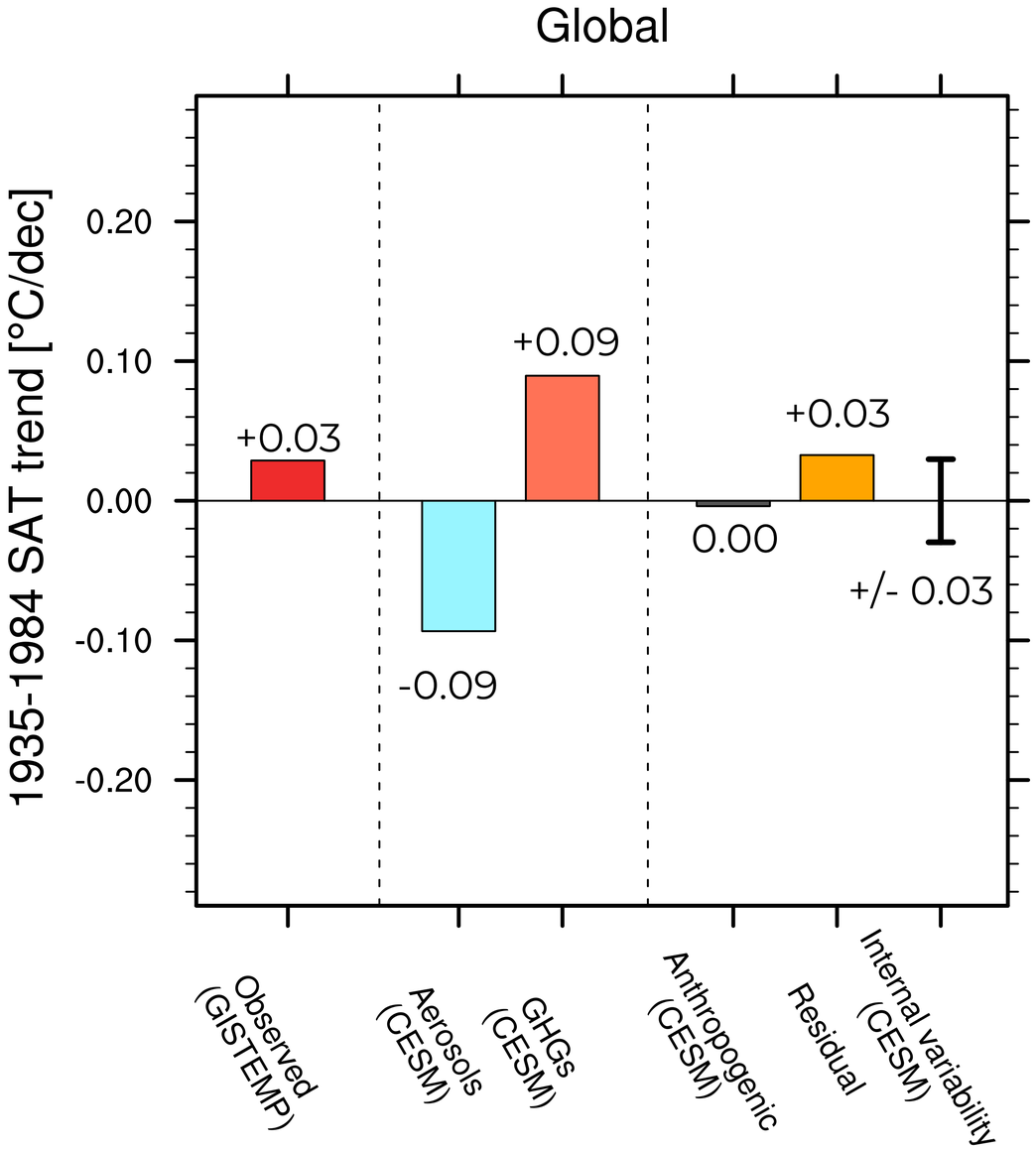


Calculating contributions to 1935-1984 Arctic trend



- Net anthropogenic impact of -0.075 °C/dec
- AA factor of aerosols is 3.0 whereas AA factor of GHG is 2.2
- Residual is well within bounds of internal variability simulated by CESM
- A different configuration of internal variability could have overcome the net anthropogenic cooling and resulted in Arctic warming
- Lack of Arctic Amplification not inevitable

Calculating contributions to 1935-1984 Arctic trend



- Near total cancellation in response to aerosols and GHGs
- Residual is at edge of internal variability simulated by CESM
- A different configuration of internal variability could have resulted in global cooling
- Lack of Arctic Amplification not inevitable

Other Large Ensembles