# Reducing Uncertainty of Polar to Mid-latitude Linkages Using DOE's E3SM in a Coordinated Model Experiment

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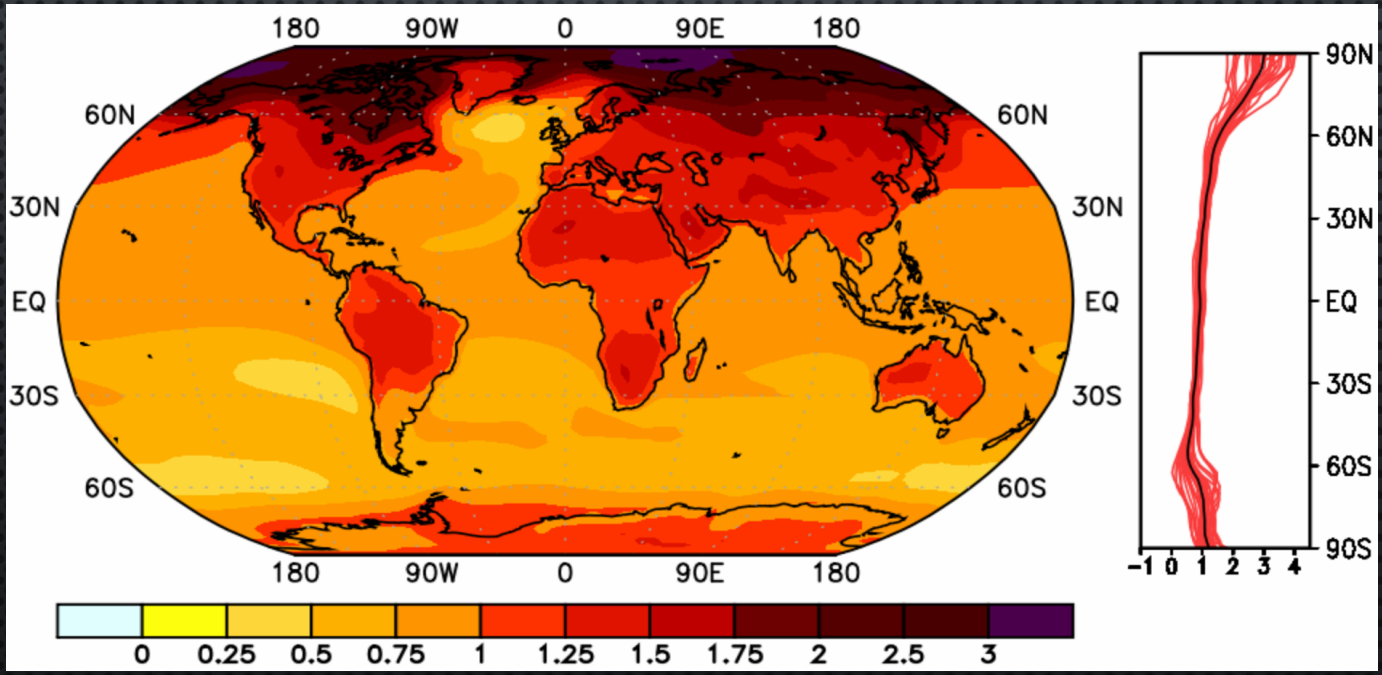
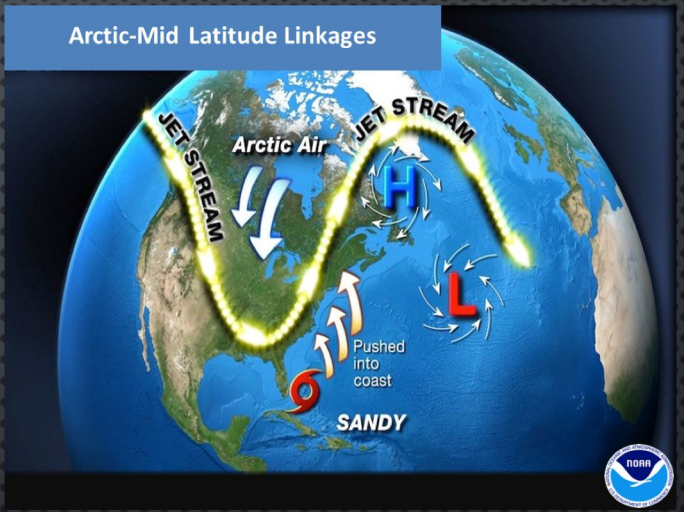
## Polar amplification of climate change

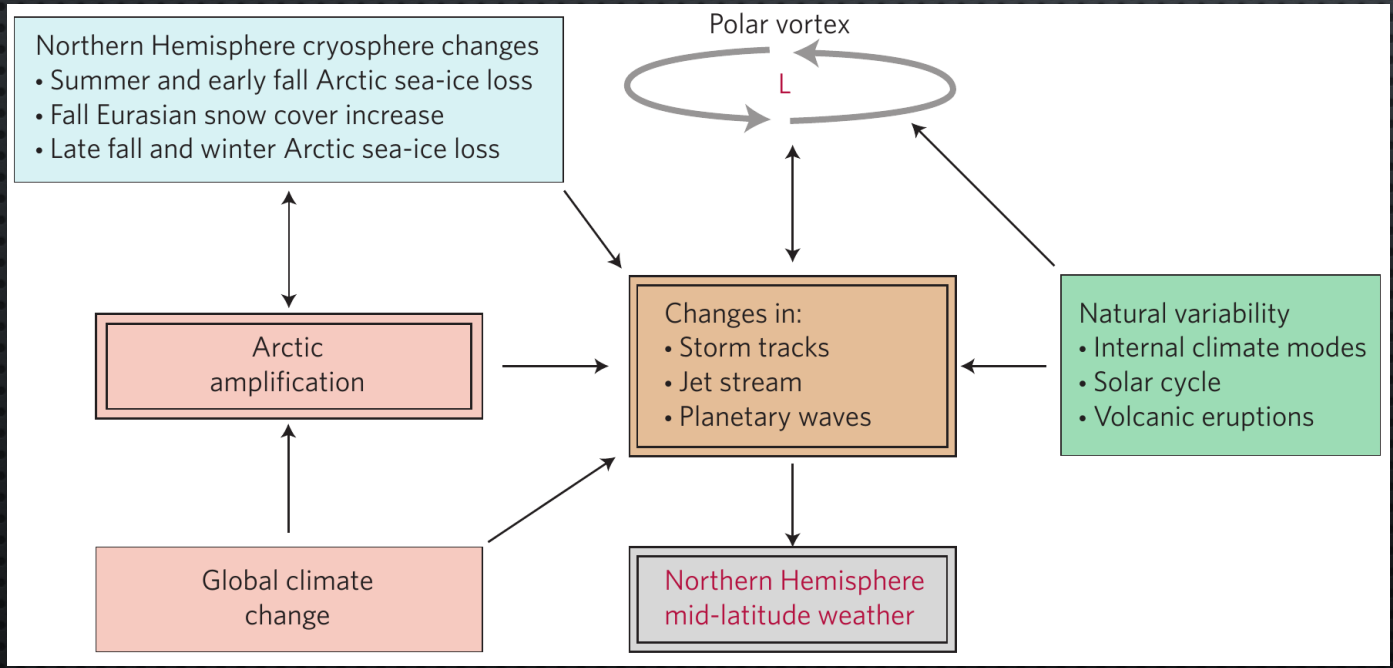



**Polar amplification in projections of future climate change.** 2080-2099 minus 1981-2000 temperature change patterns derived from 31 CMIP5 model projections driven by RCP8.5, scaled to 1°C of global mean surface temperature change. Zonal means of the geographical patterns are shown for each individual model (red) and for the multi-model ensemble mean (black).

# Impact of polar amplification on the mid-latitude climate

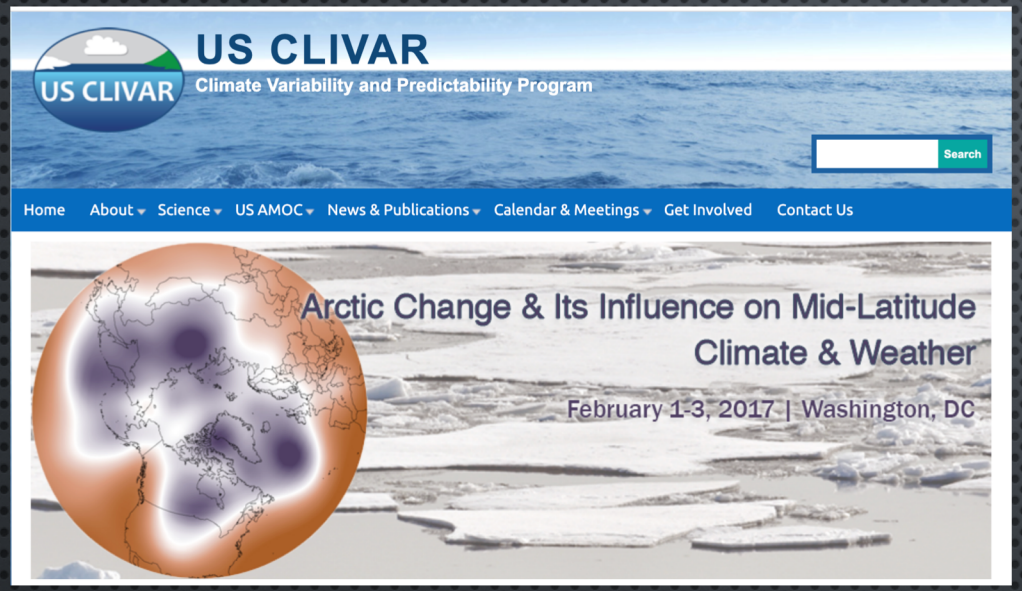
**What are the causes and consequences of polar amplification ? What is the impact of Arctic/Antarctic sea ice loss on the climate of the mid-latitudes ?**



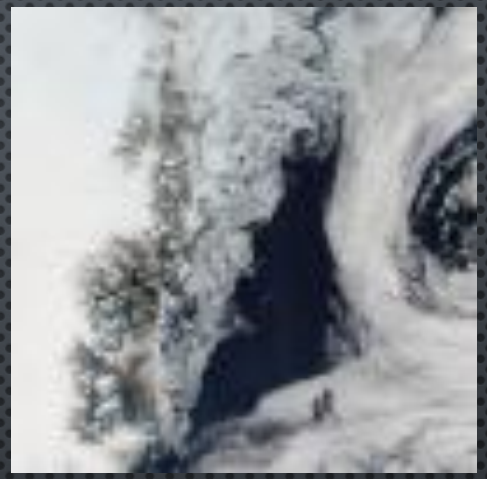




Schematic of ways to influence Northern Hemisphere mid-latitude weather (Cohen et al. 2014)

# A couple of workshops in 2017




Understanding the Causes and Consequences of Polar Amplification



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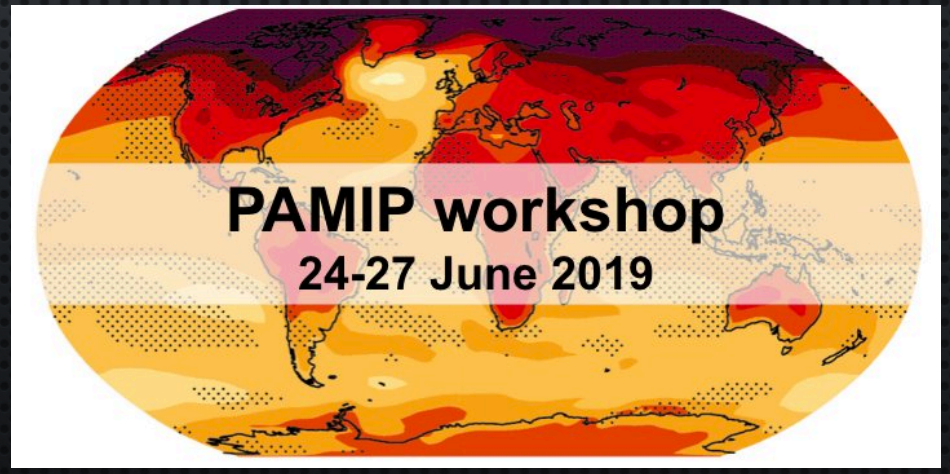
JUNE 11, 2017 TO JUNE 16, 2017

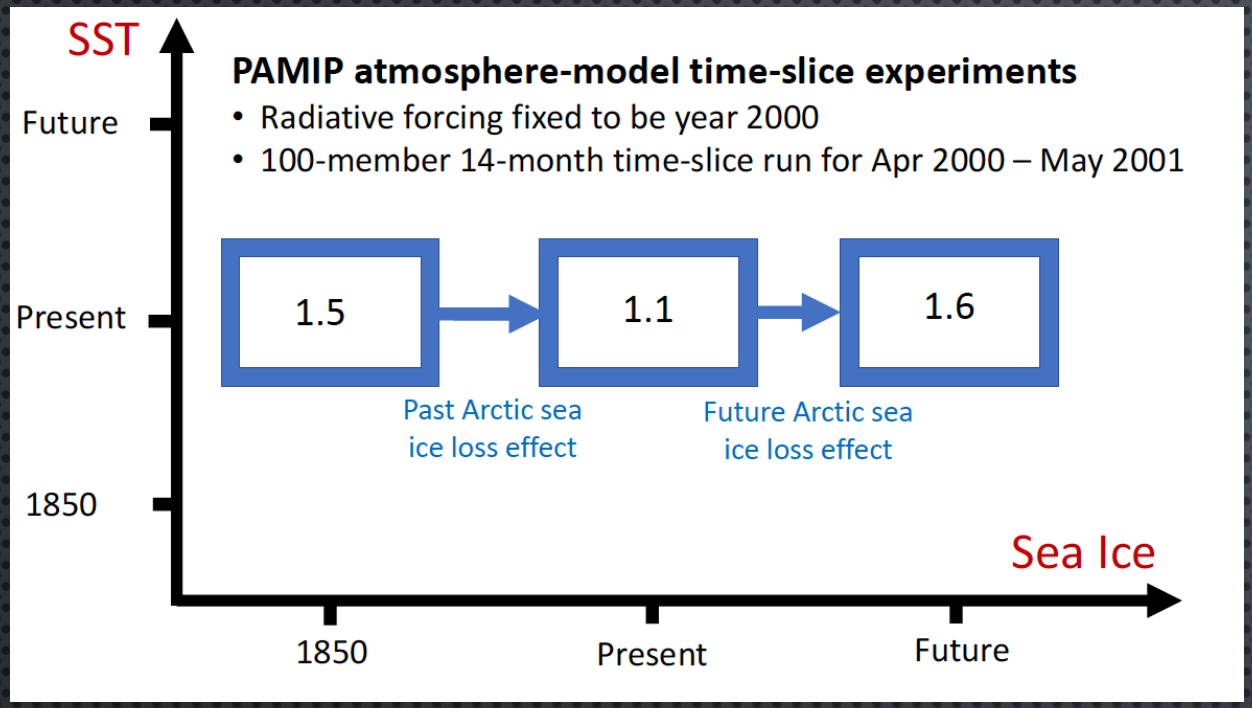
## The Polar Amplification Multi-model Intercomparison Project (PAMIP) 2017-2018

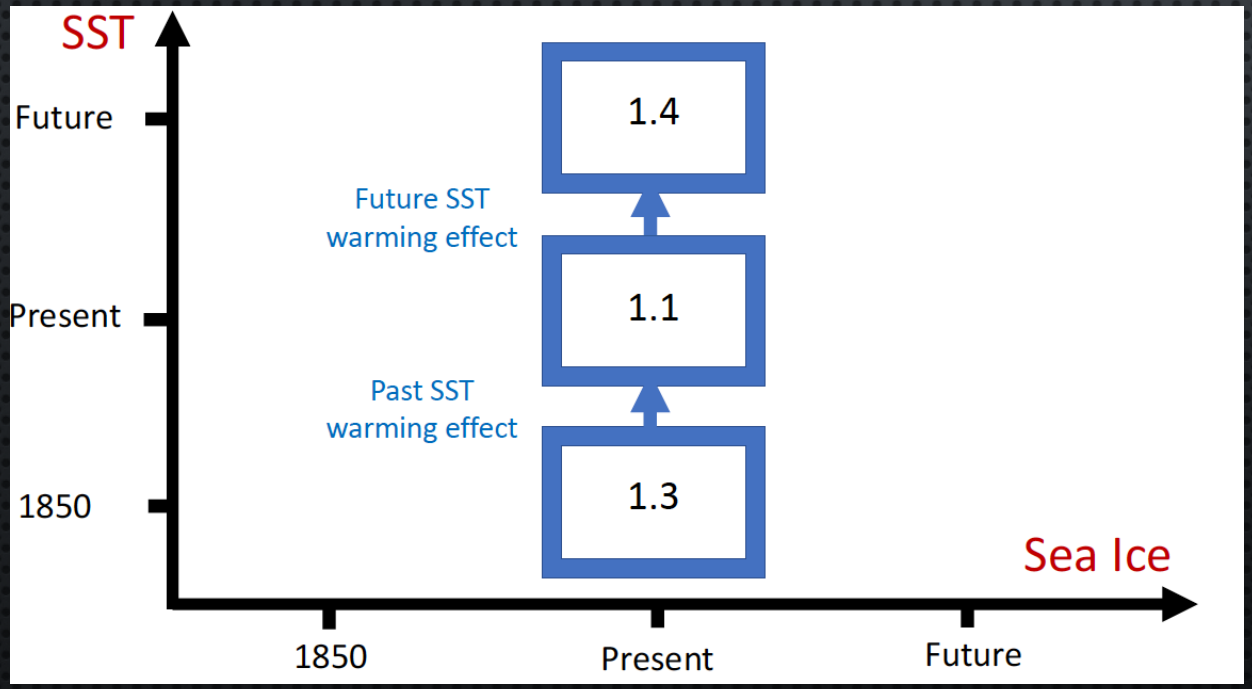
The **Polar Amplification MIP, or PAMIP** seeks to improve our understanding of causes and consequences of polar amplification through a coordinated set of numerical model experiments.



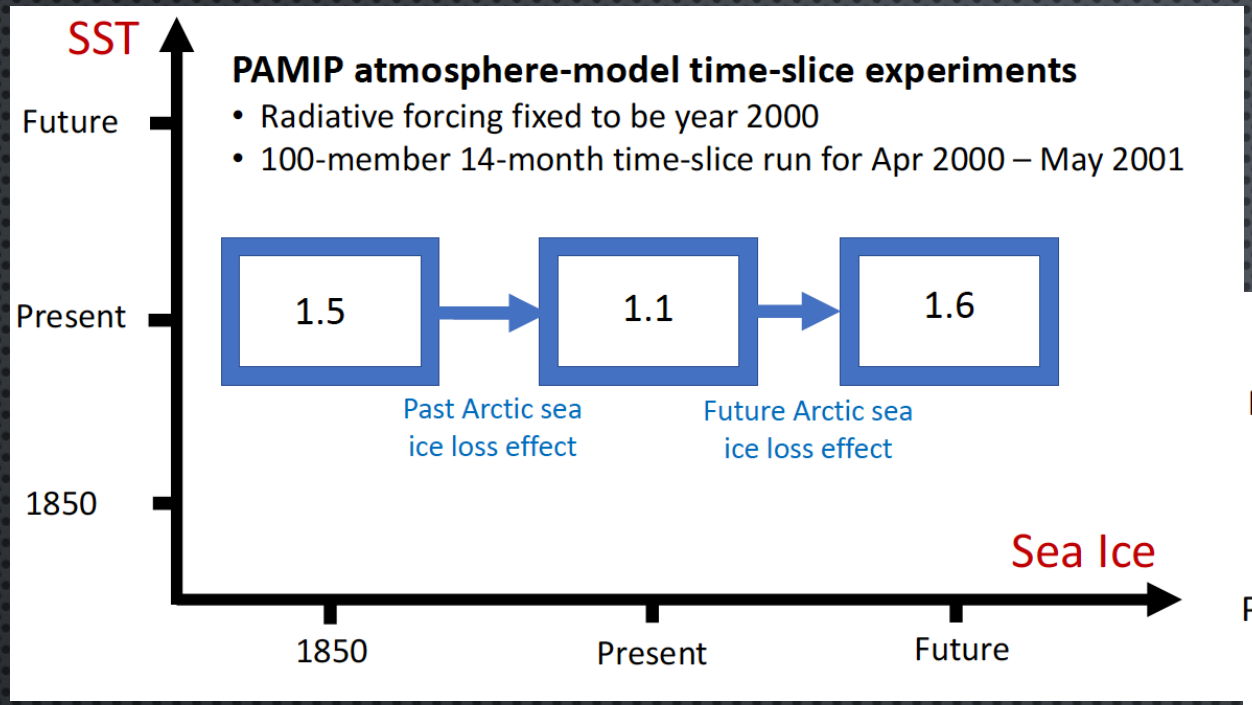

**Smith et al. (2019) PAMIP contribution to CMIP6. Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-82**

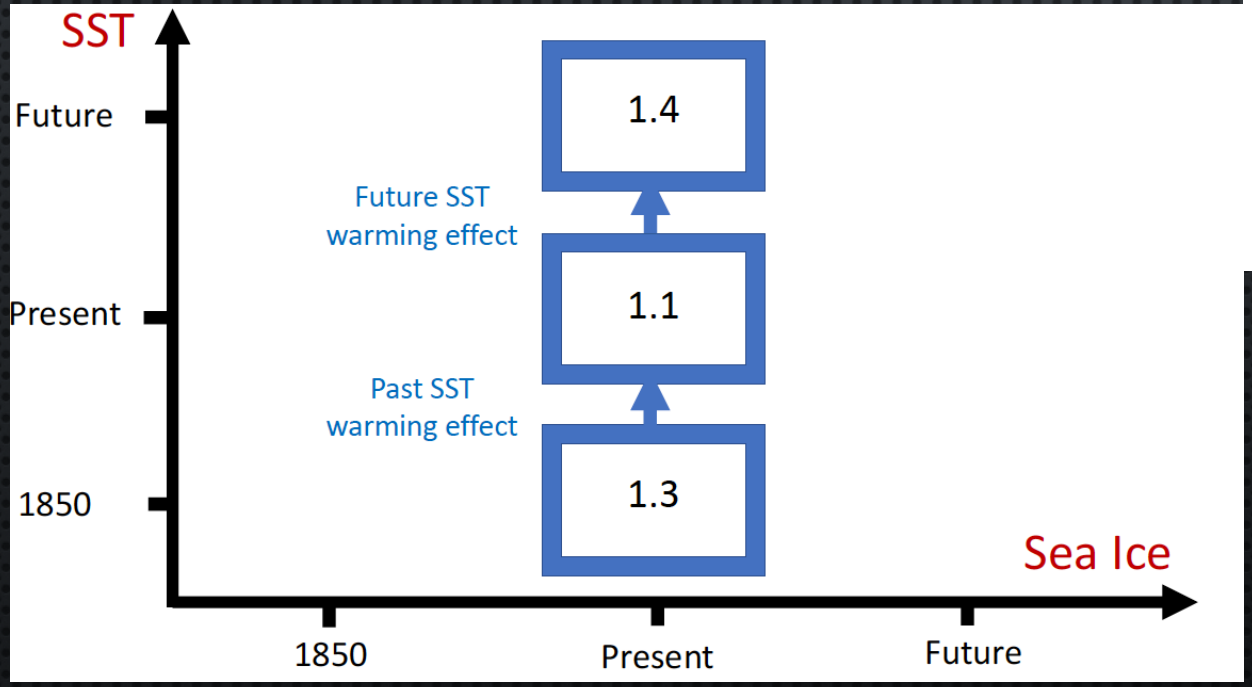
# Time-slice experiments

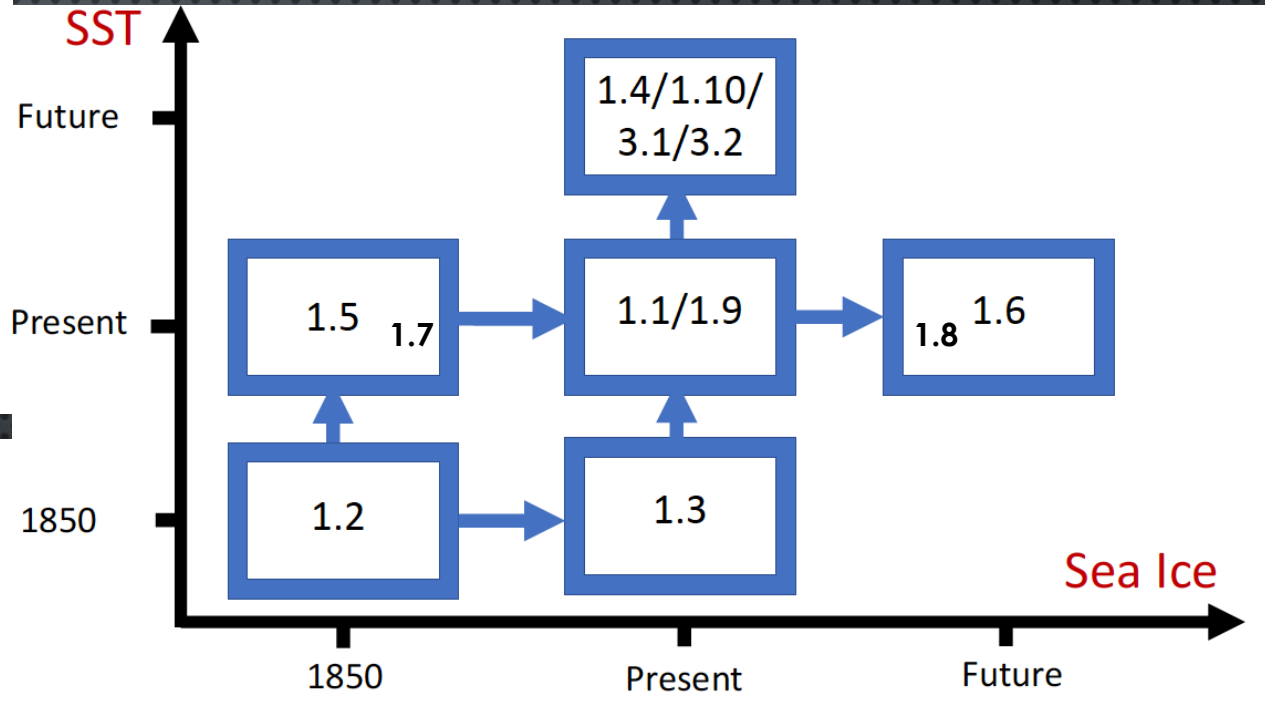


# Time-slice experiments




**Tier 2: Coupled short experiments nudging sea-ice volume to present day, pre-Industrial and future conditions**

# List of PAMIP experiments

## Atmosphere-only experiments (100 members, 1-yr runs)

| | SC-WACCM4 | E3SMv1 |
|---|---|---|
| Response to past/future Arctic SIC anomalies | ✓ | ✓ |
| Response to past/future Antarctic SIC anomalies | ✓ | ✗ |
| Role of global SST change in polar amplification | ✓ | ✓ |
| Additional role of sea ice thickness | ✓ | ✓ |
| Impact of regional anomalies (Barents-Kara, Okhotsk) | ✓ | ✗ |
| Role of model SST background state | ✗ | ✗ |
| AMIP-type with climatological SST or SIC | ✓ | ✗ |

## Short coupled ocean-atmosphere runs (100 members, 1-yr runs)

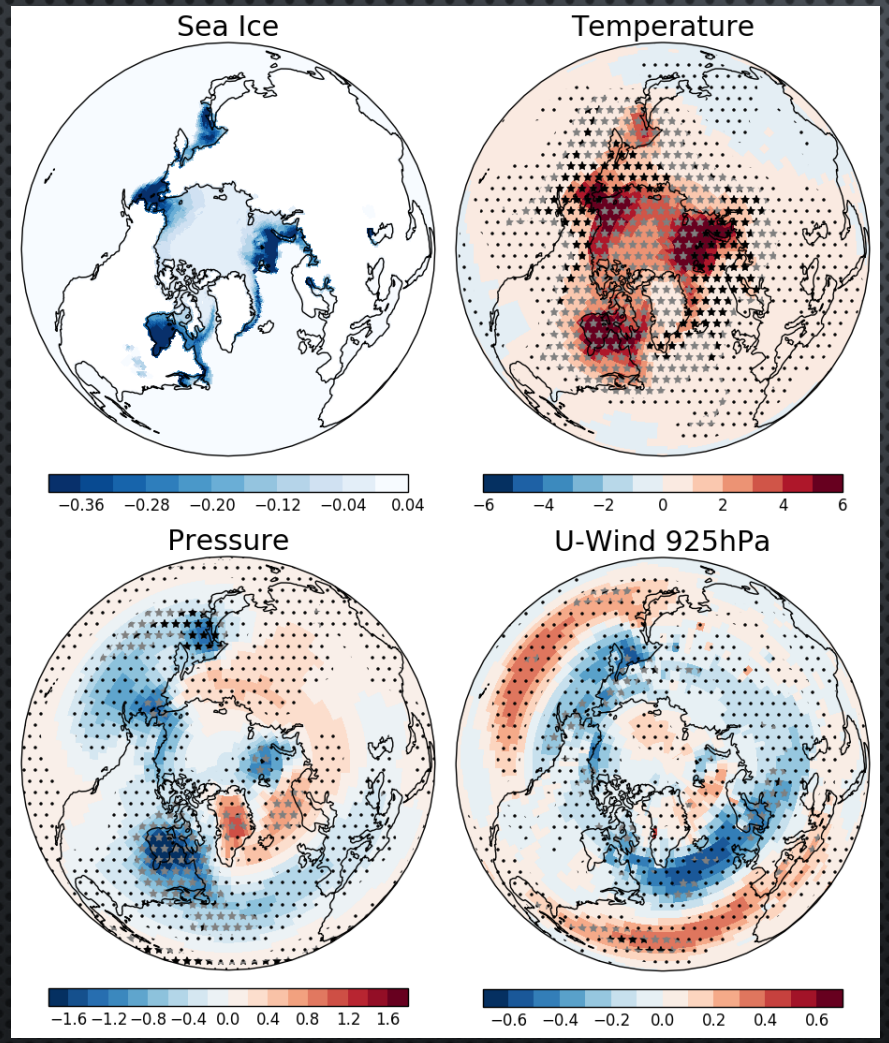
| | | |
|---|---|---|
| Response to past/future Arctic SIC anomalies | ✓ | ✗ |
| Response to past/future Antarctic SIC anomalies | ✓ | ✗ |

## Long coupled ocean-atmosphere runs (1 member, 100-yr run)

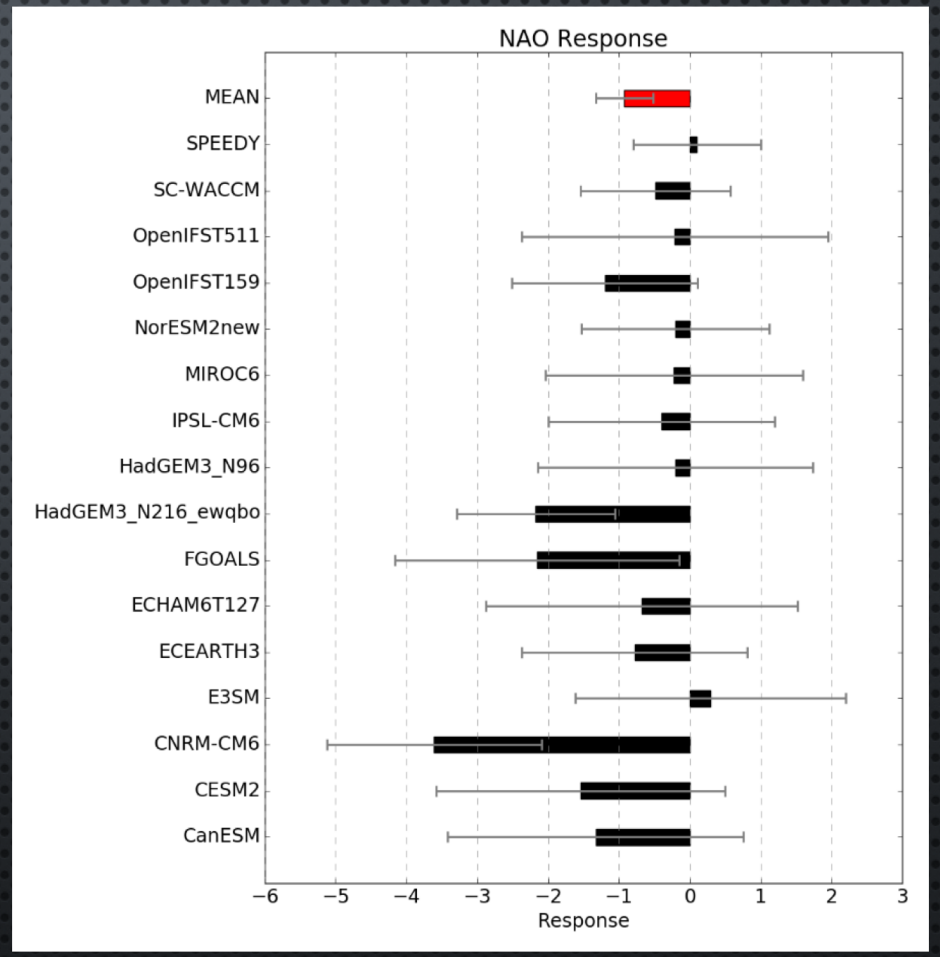
| | | |
|---|---|---|
| Response to future Arctic/Antarctic SIC anomalies | ✗ | ✗ |

# Multimodel response - future sea-ice loss compared to present day

## WINTER SURFACE RESPONSE TO ARCTIC SEA ICE LOSS




- *Multi-model Response from 16 atmosphere only models*
- *100+ members for each*
- *Future minus Present day sea ice experiments*



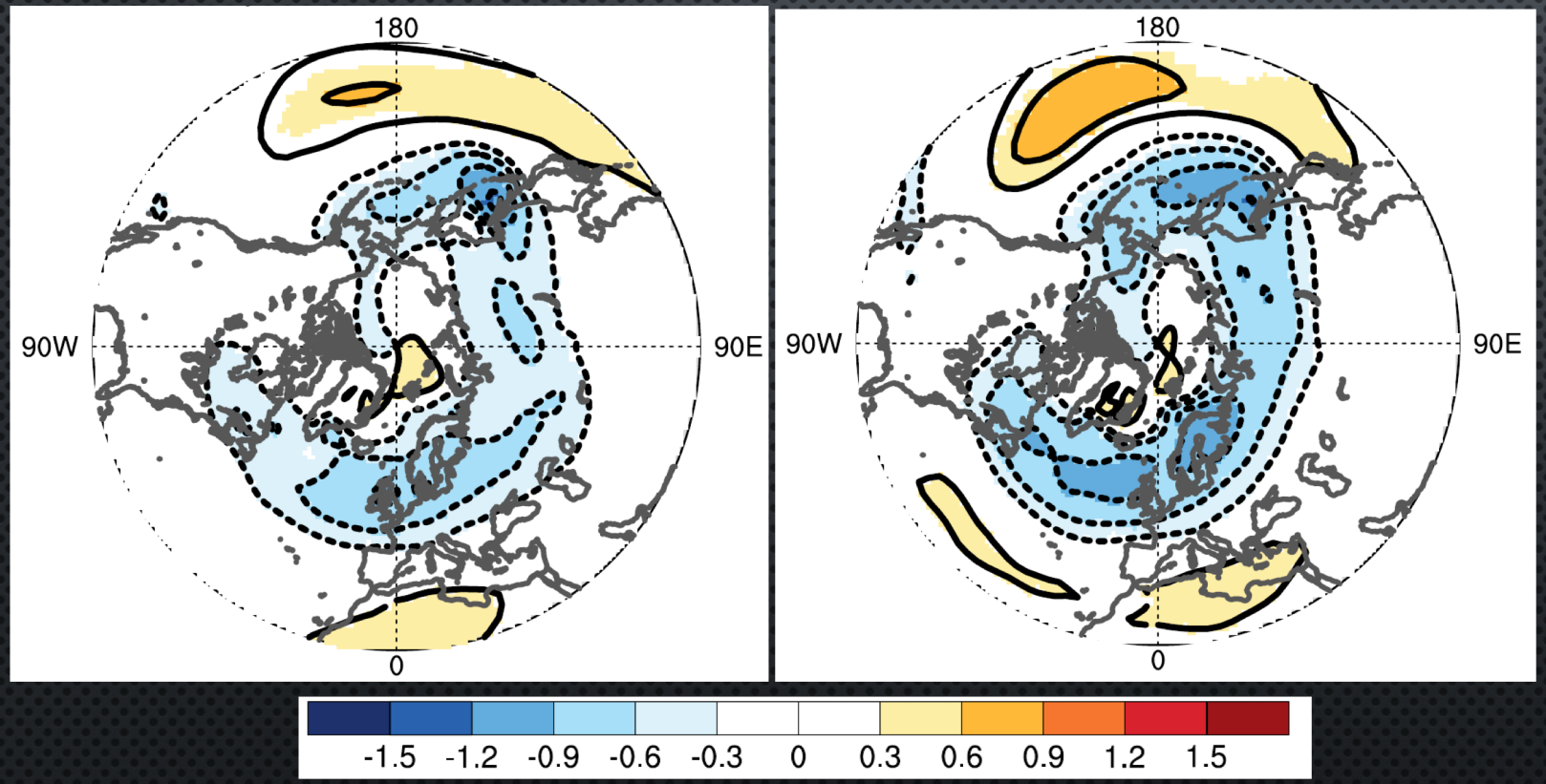

- **Consistent thermodynamic response**
- **Equatorward shift of tropospheric jet**
- **Negative NAO response, but large model spread**

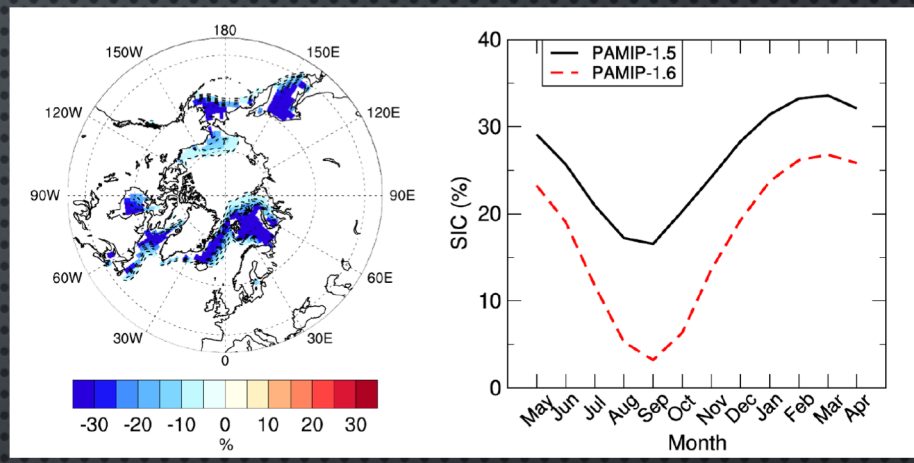
Courtesy Rosie Eade (Met Office)

# Impact of ocean-atmosphere coupling (SC-WACCM)

Future vs pre-Industrial Sea ice

**AGCM** U700 **OAGCM**



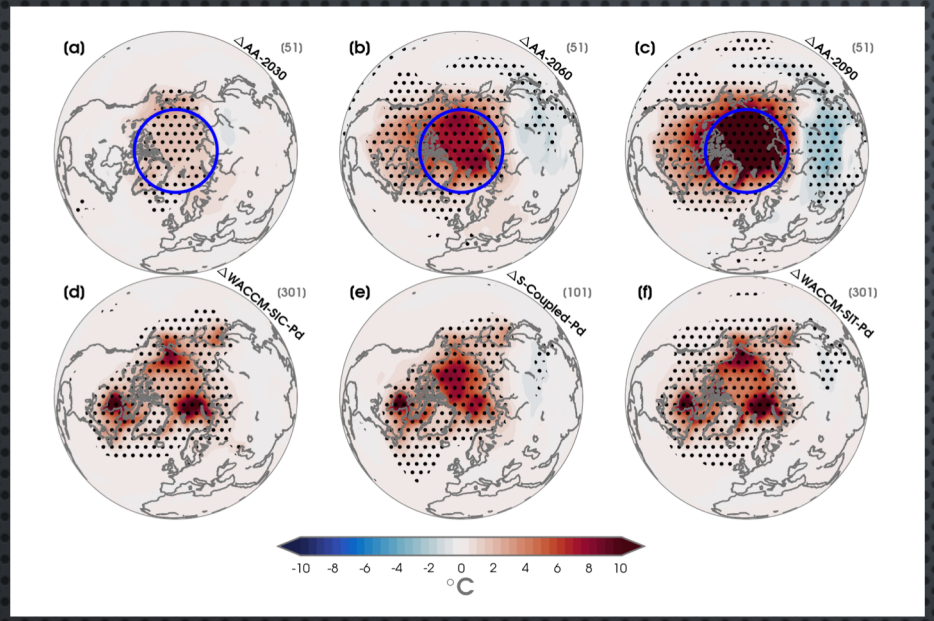




Stronger response in coupled experiments

**DJFM response of U700 in the AGCM runs (left) and in the OAGCM runs (right) of SC-WACCM4 (300-member ensemble means)**

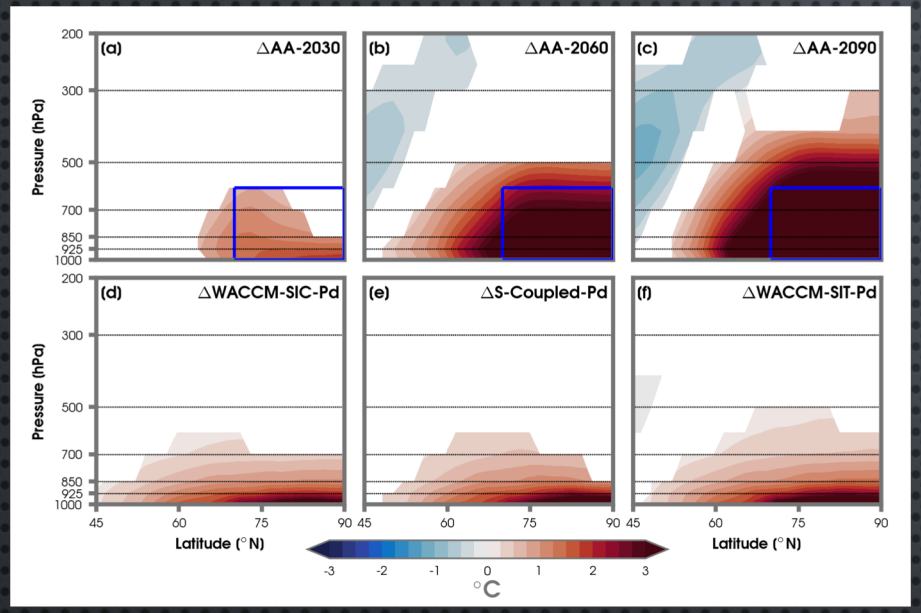
**Peings Y., Z. Labe and G. Magnusdottir (2020) Are 100 ensemble members enough to capture the remote atmospheric response to +2°C Arctic sea ice loss ? J. Climate, in revision.**

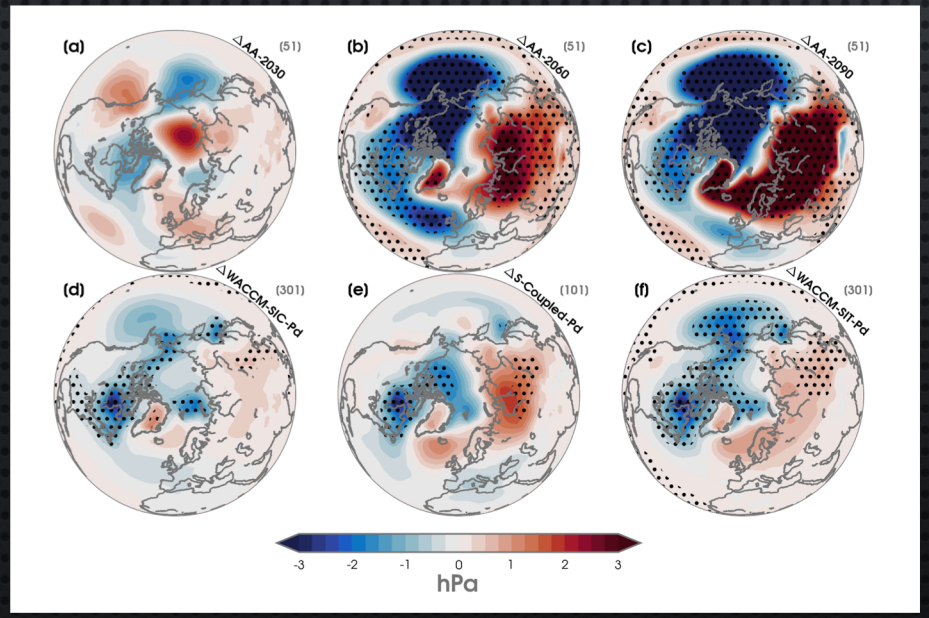
DFJ T_sfc response in nudged experiments on top, PAMIP experiments on bottom.



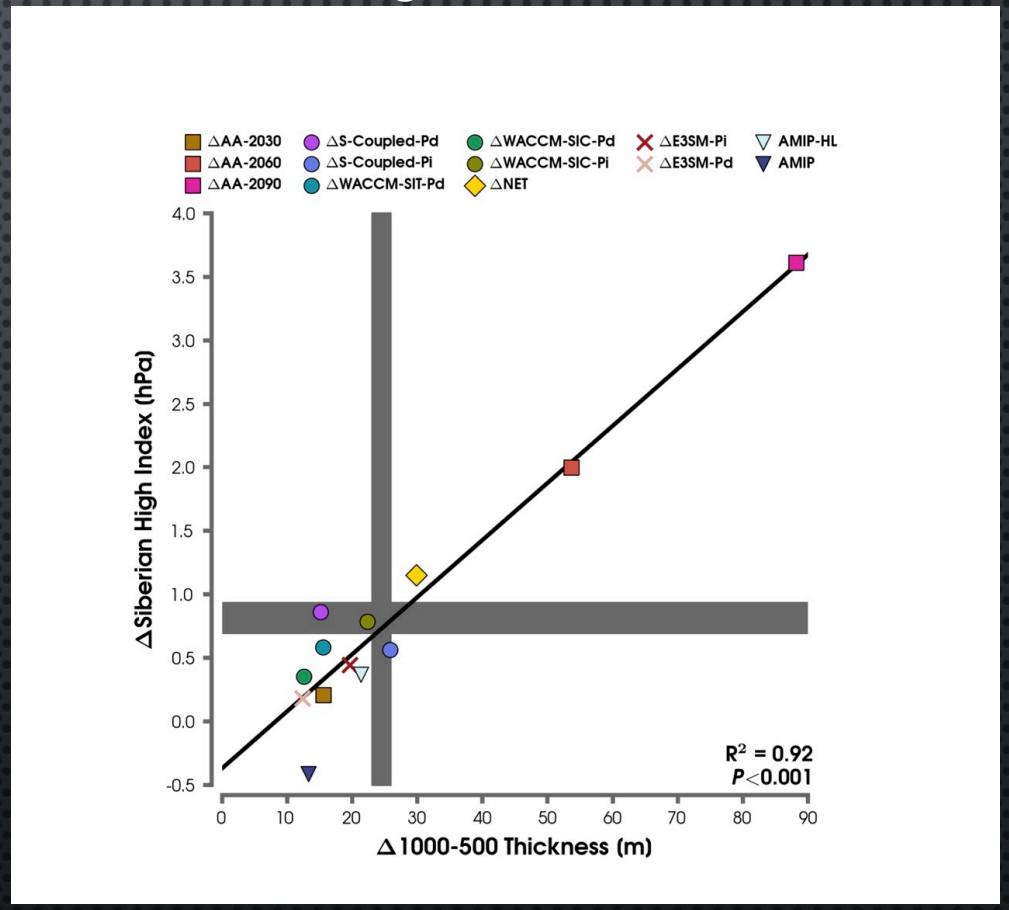

Labe et al 2020, GRL, DOI:10.1029/2020GL088583

# DFJ vertical extent of thermal response in nudged experiments on top, PAMIP experiments on bottom. Same for sfc pressure bottom panel



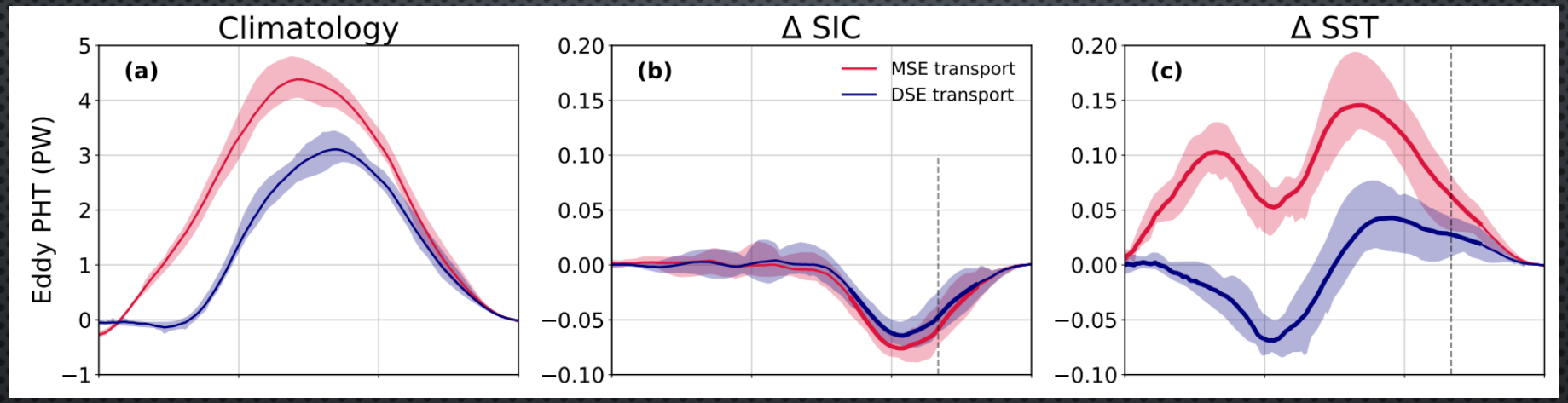

## Emergent relationship between Δ Z500 and Δ Siberian High Index




Labe et al 2020, GRL, DOI:10.1029/2020GL088583

# Eddy poleward heat transport: multi-model average from PAMIP

Future-present SIC  Future-present SST




**Global SST warming leads to increased poleward moist static energy transport**

**Arctic sea-ice loss leads to decreased poleward energy transport, both moist and dry static**

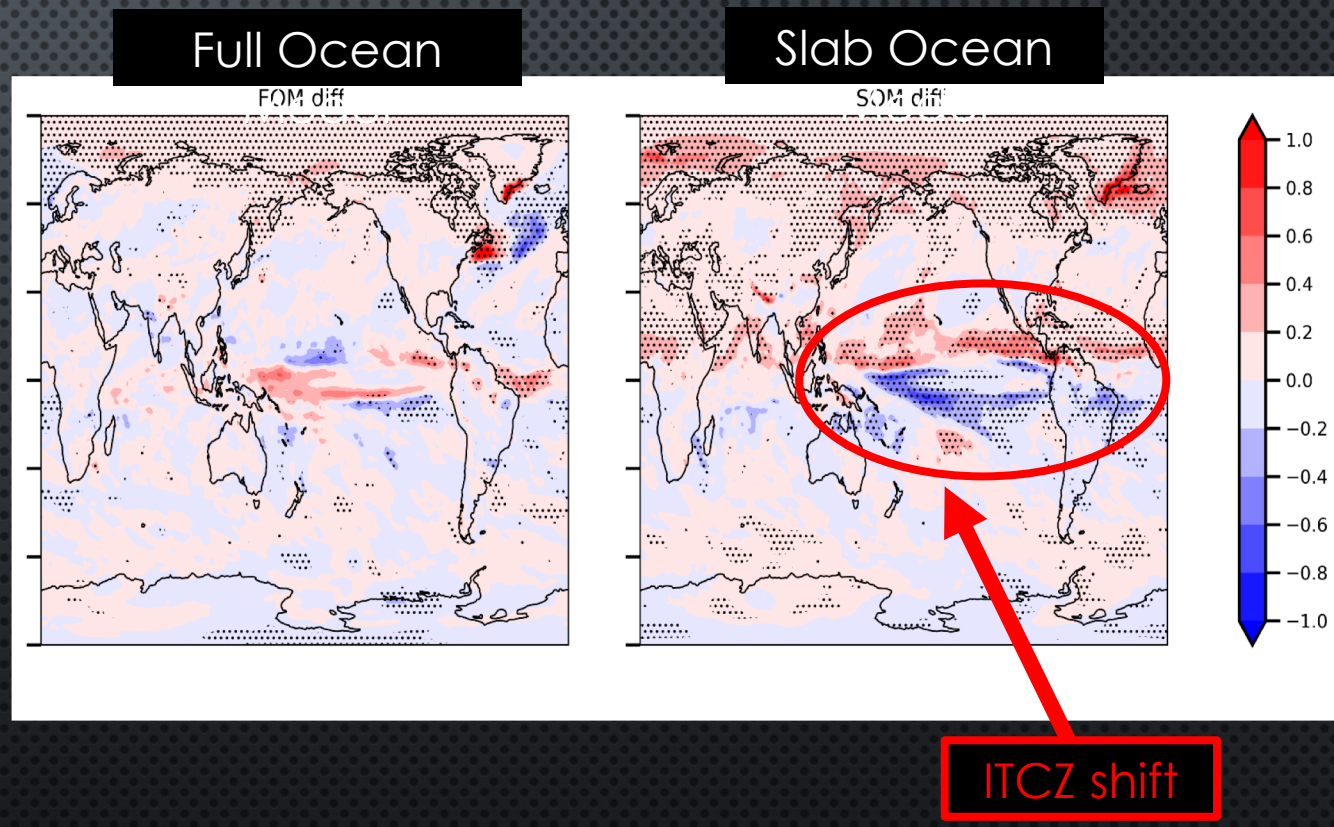

**Audette A., et al (2020) Opposite responses of the dry and moist eddy heat transport into the Arctic in the PAMIP experiments. Geophysical Research Letters, in revision.**

Built a simplified ocean model framework to explore physical processes for difference in ITCZ response to Arctic sea-ice melt

Reject the hypothesis that the response is due to response in Ekman transport associated with the subtropical cell

AMOC is reduced by 20%. Its induced ocean heat transport is doing much of the heat uptake -> sensitive to east-west forcing patterns

Precipitation response




**Hsu et al, in preparation for JAMES**

# KEY NEW RESULTS (PRESENTED IN BREAK OUTS)

- Stronger response under atmosphere-ocean coupling, but also increased internal variability. Introduce a "consistency test" to verify which part of the response is robust in only 100 members (Peings et al, revised J. Clim.)
- Role of sea-ice loss versus full Arctic Amplification in inducing a mid-latitude response (Labe et al 2020, GRL, DOI:10.1029/2020GL088583)
- Tug-of-war between the effect of sea-ice loss and global SST warming on poleward heat transport (Audette et al, Revised, GRL)
- Role of ocean dynamics in the tropical response to Arctic sea-ice loss in a hierarchy of coupled models (Hsu et al, JAMES to be submitted)