How does the AMOC influence the amount of global warming?

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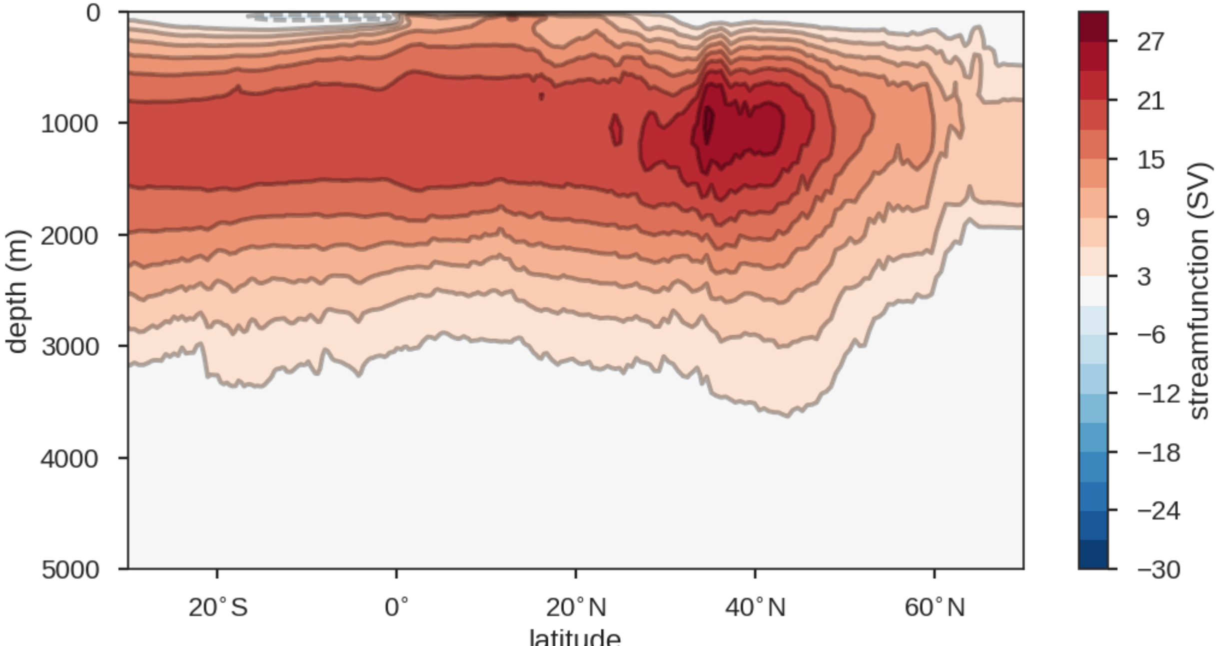
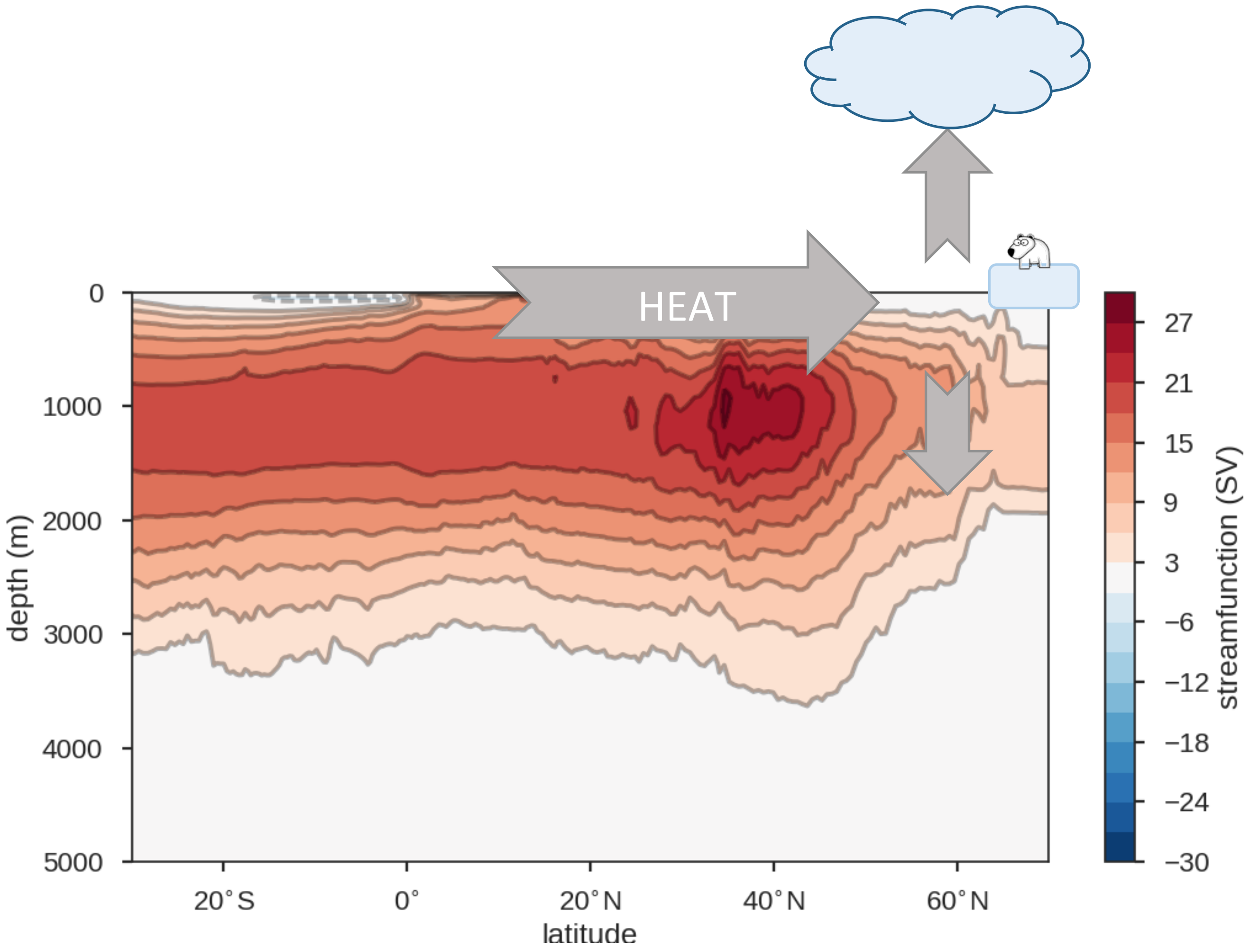


Two ways the AMOC could influence global warming:



AMOC transports heat poleward where climate feedbacks are more positive than in the tropics

↓

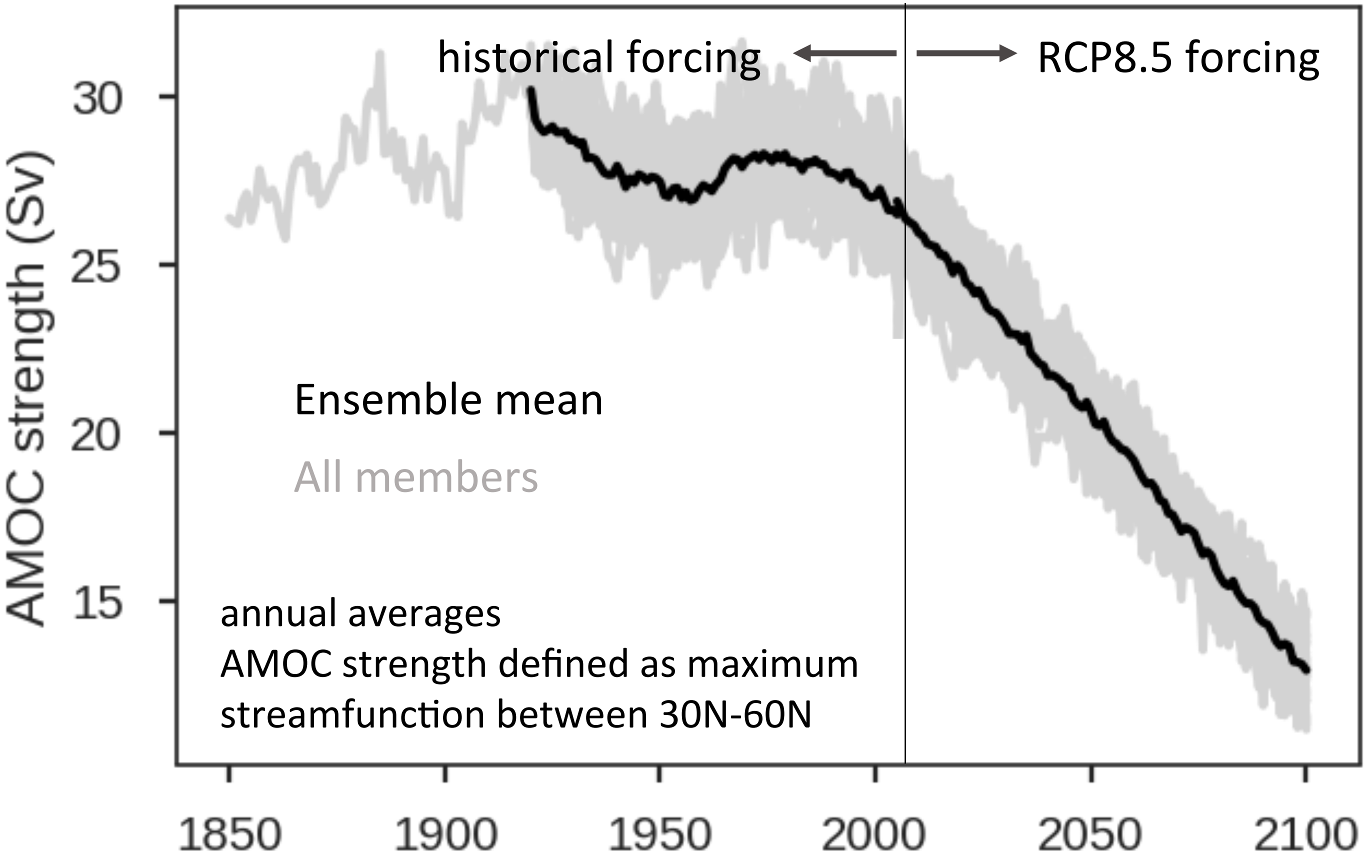
Increased global warming
(Winton et al. 2013, Rugenstein et al. 2013, Winton et al. 2014)

Stronger AMOCs sequester more heat in North Atlantic Ocean

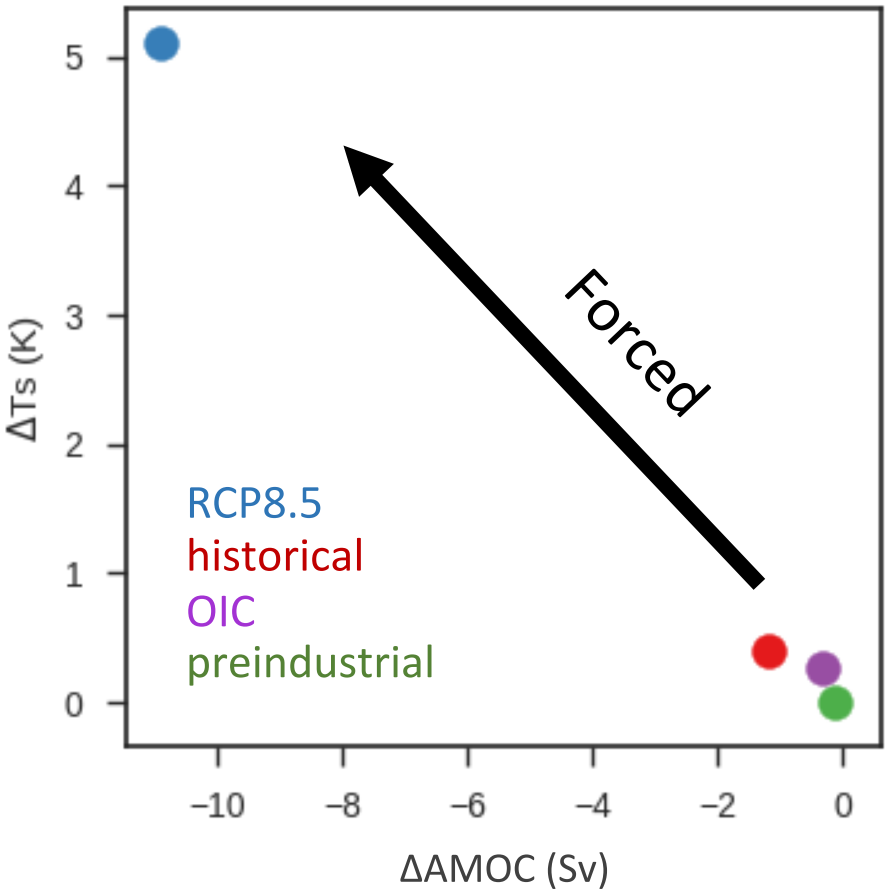
↓

Decreased global warming
(Kostov et al. 2014)

The CESM Large Ensemble enables the robust separation of forced response and internal variability



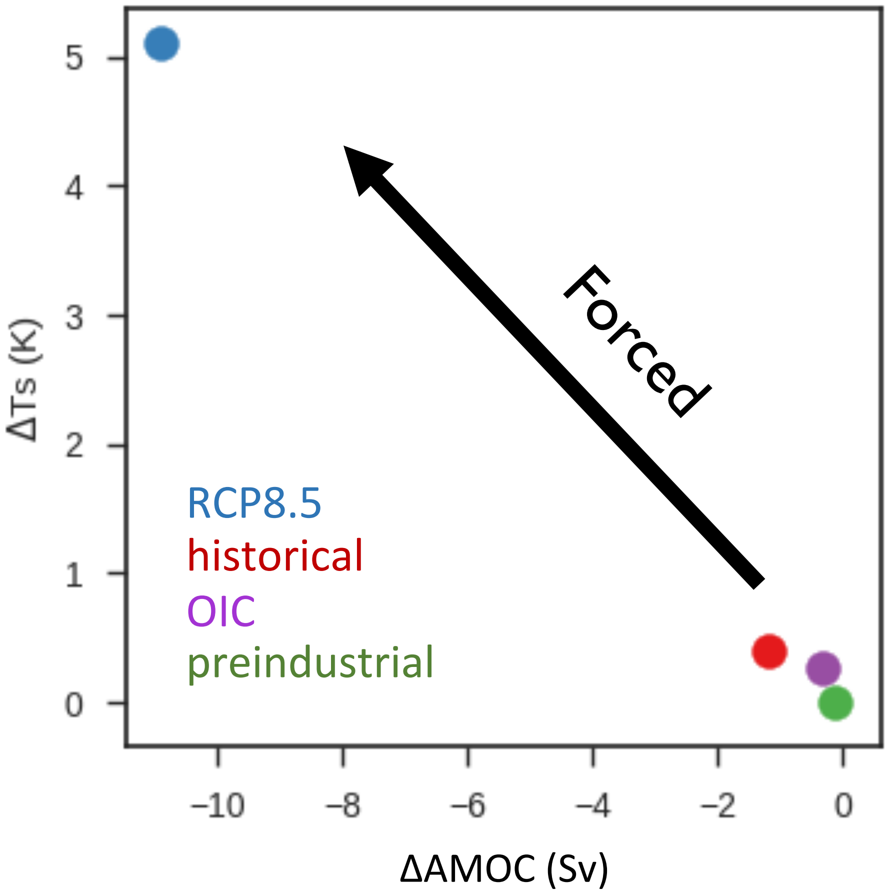
Forced response: AMOC weakening with global warming

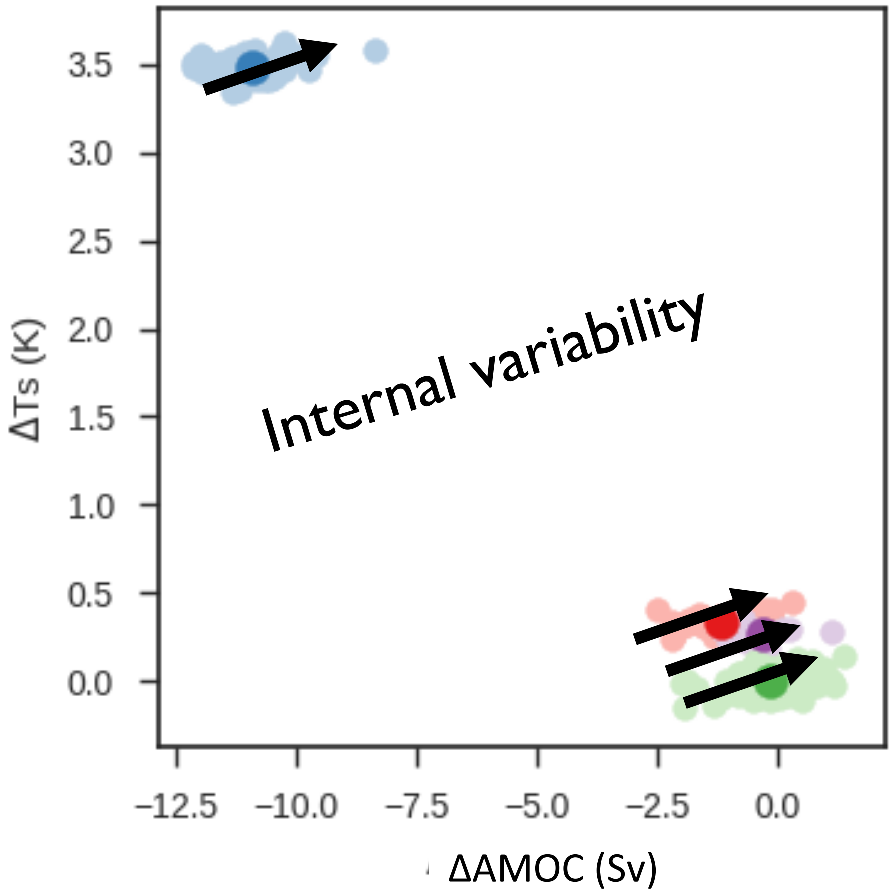


Epoch differences:
Historical period:
1985-2005 average
minus
1920-1940 average

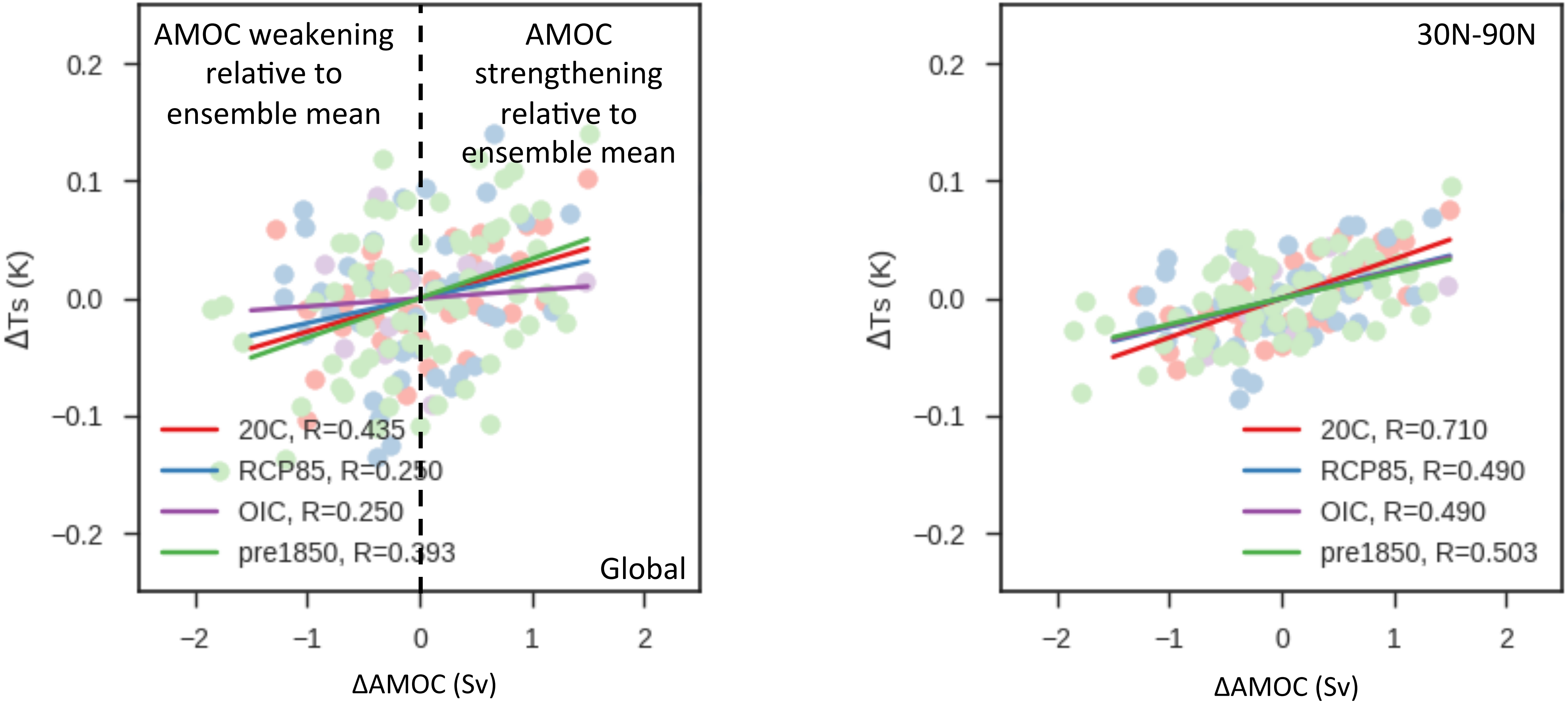
RCP8.5 period:
2080-2100 average
minus
2005-2025 average

Forced response (left, AMOC weakening with global warming) vs. Internal Variability (right, weaker AMOC with increased global warming)





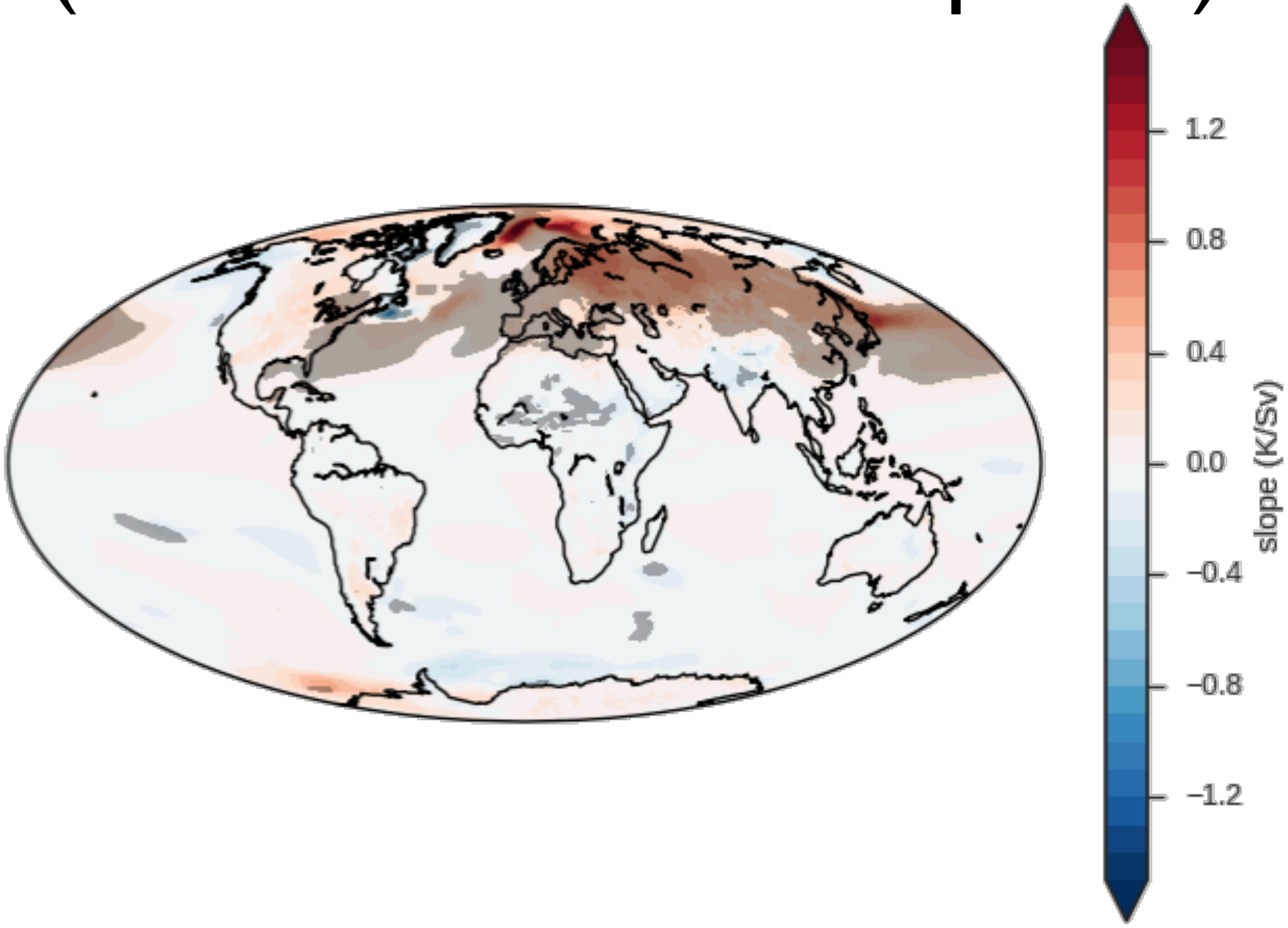
Largest warming correlations with AMOC in extratropical Northern Hemisphere – unsurprising.



North Atlantic and Eurasia warms when the AMOC strengthens (relative to forced response).

Regression of temperature trends in each member against AMOC trends in each member

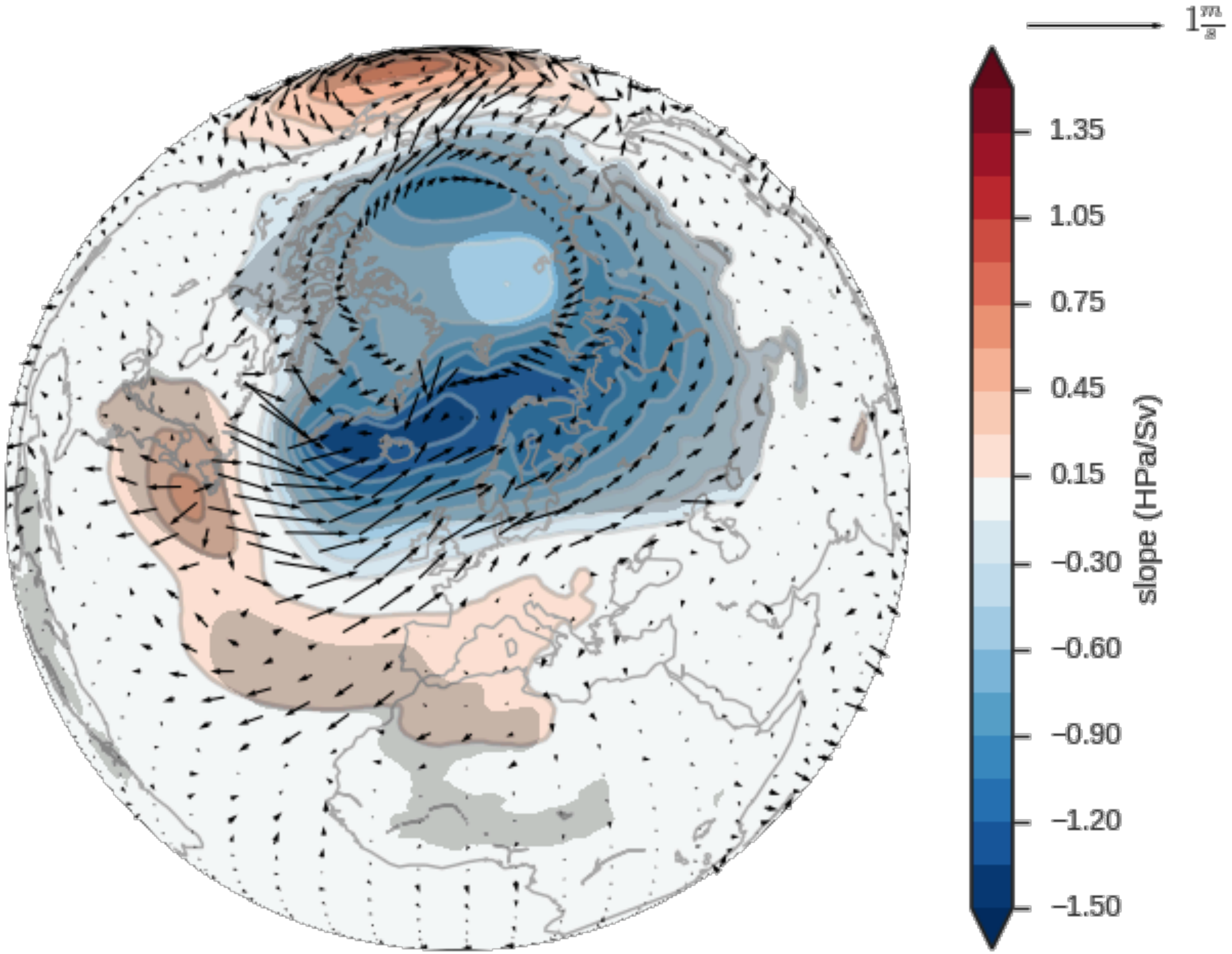
CESM LENS historical forcing
1985-2005 average
minus
1920-1940 average



shading indicates correlations significant at 99% confidence level

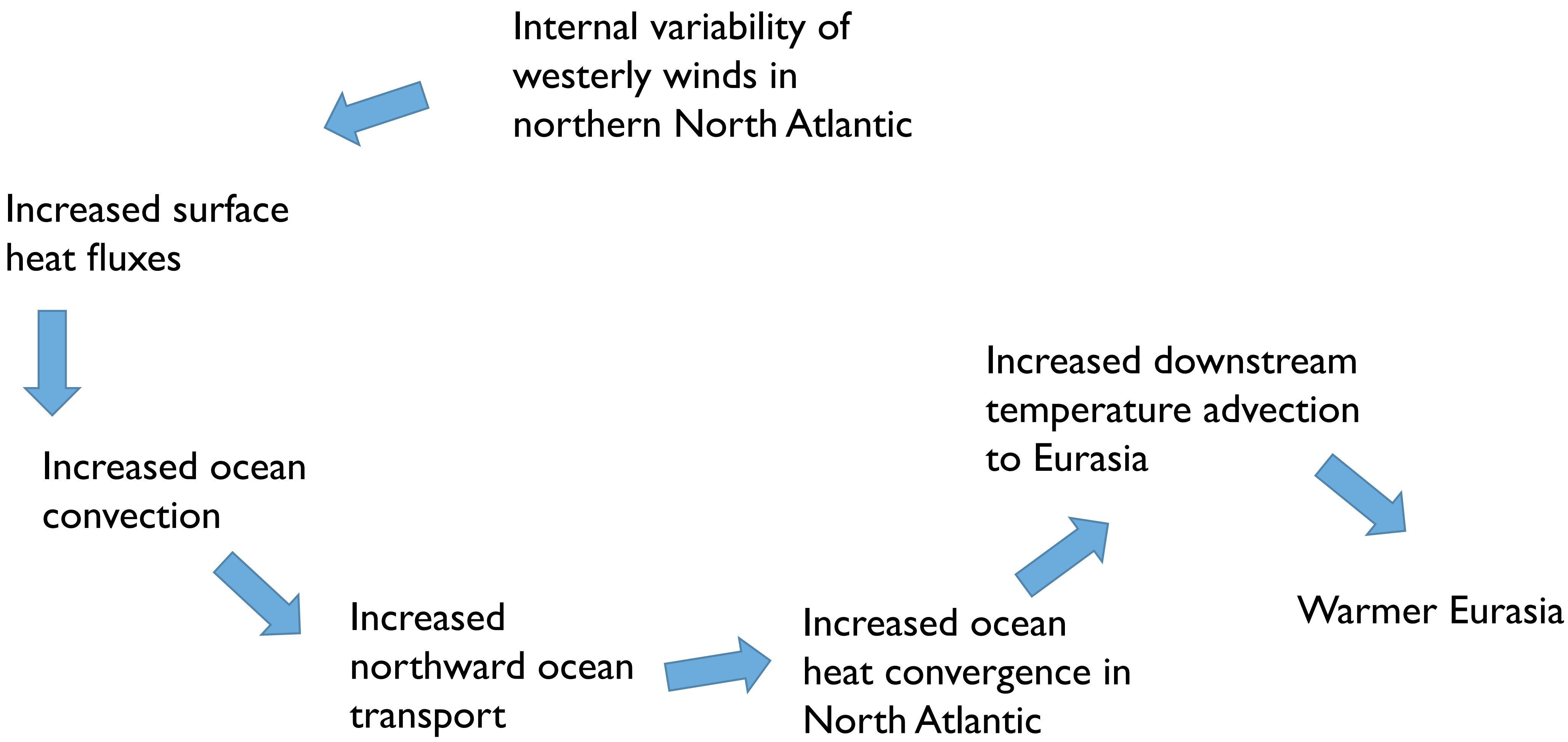
Ensemble members with AMOCs that strengthen more than the ensemble mean associated with strengthened westerlies in the North Atlantic

surface winds and surface pressure



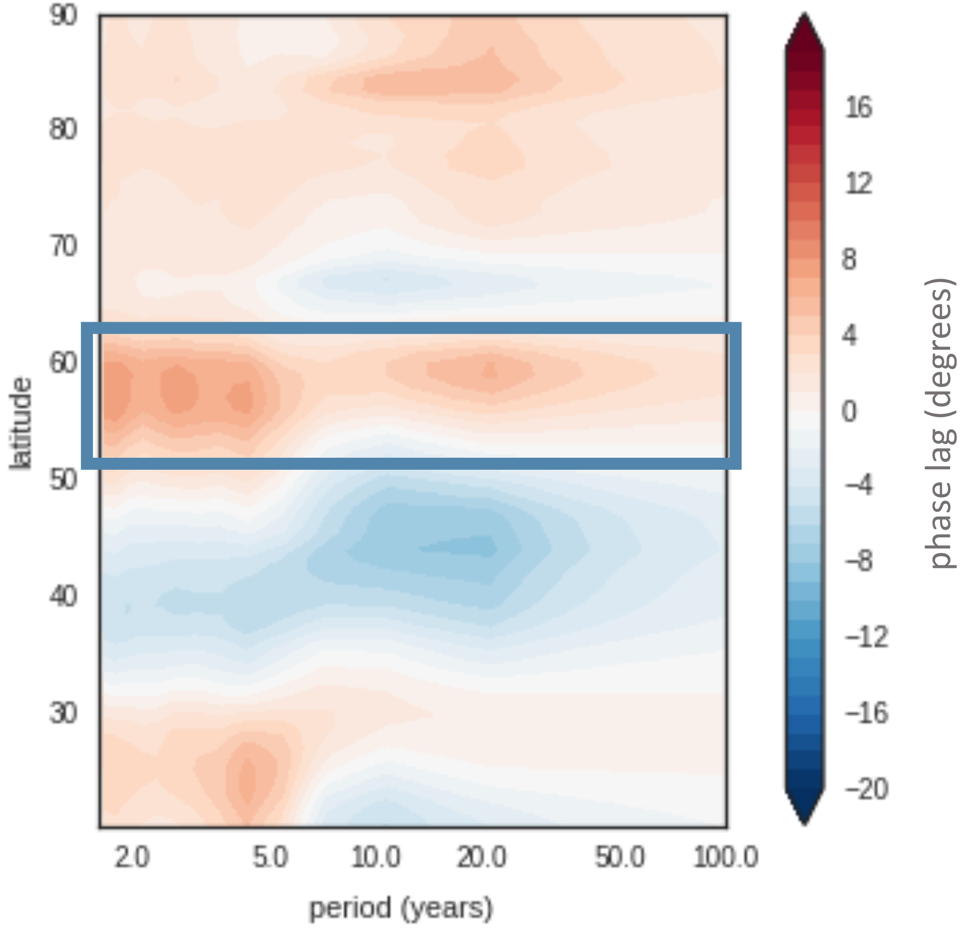
Historical forcing

Possible Mechanism



North Atlantic winds at 50-60N increase before AMOC strength increases.

Cross spectral analysis of North Atlantic zonal wind and AMOC strength



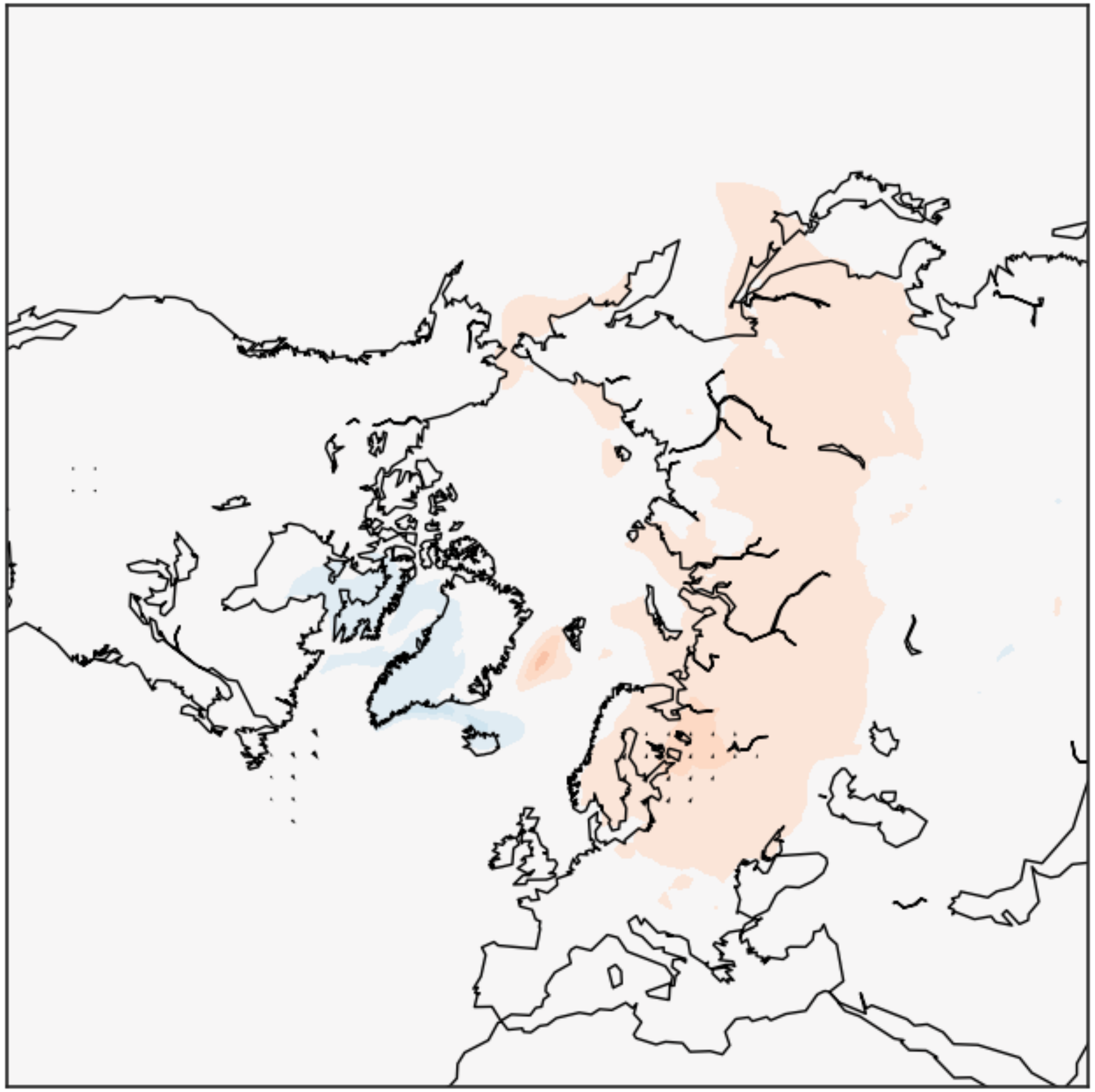
red: winds lead AMOC strength
blue: AMOC strength leads winds

Regardless of frequency, winds from 50-60N increase before AMOC strength does

Westerly winds increase before AMOC strength begins to increase

CESM LE Composite

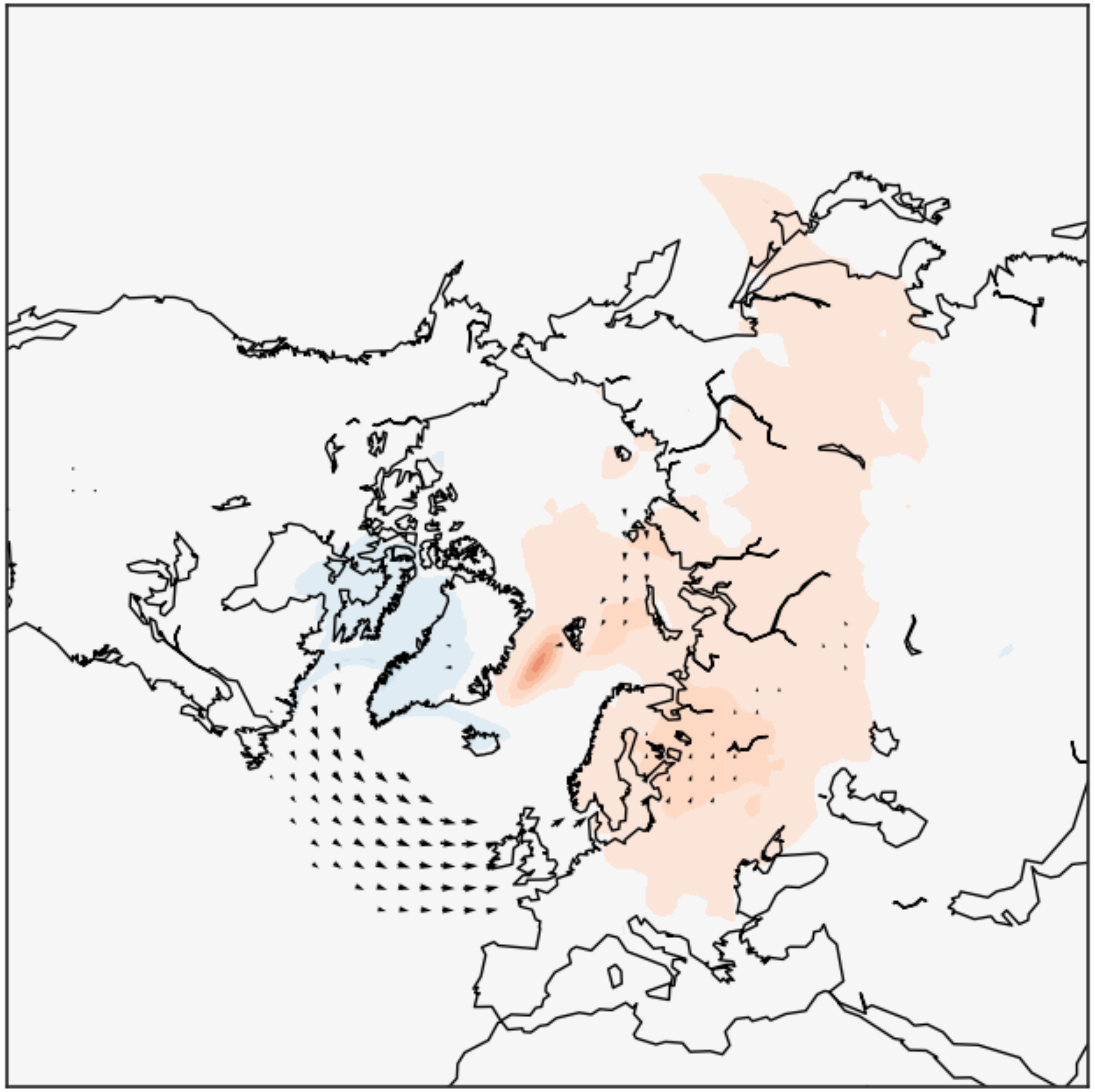
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



7 years before peak AMOC strength

CESM LE Composite

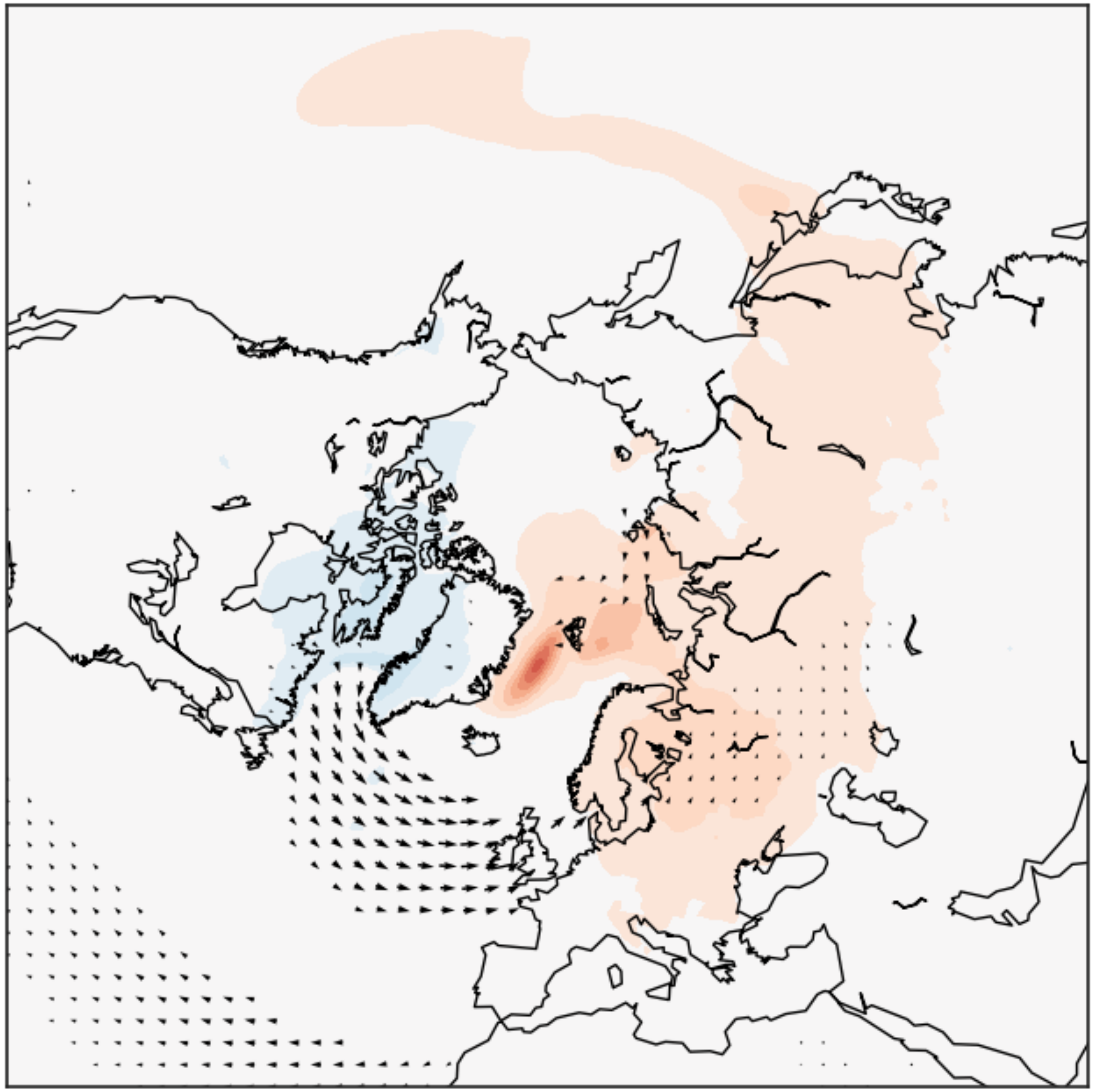
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



6 years before peak AMOC strength

CESM LE Composite

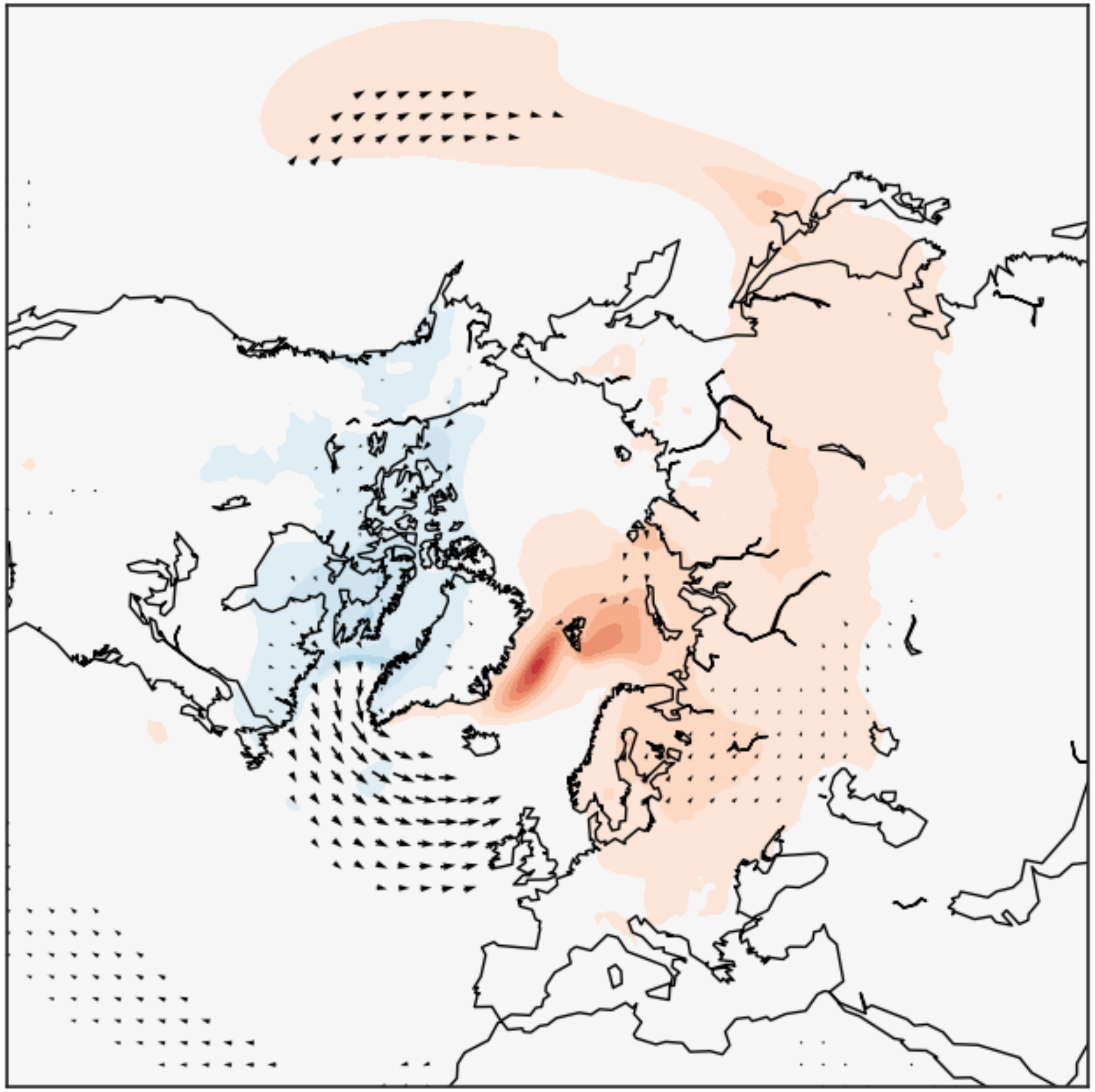
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



5 years before peak AMOC strength

CESM LE Composite

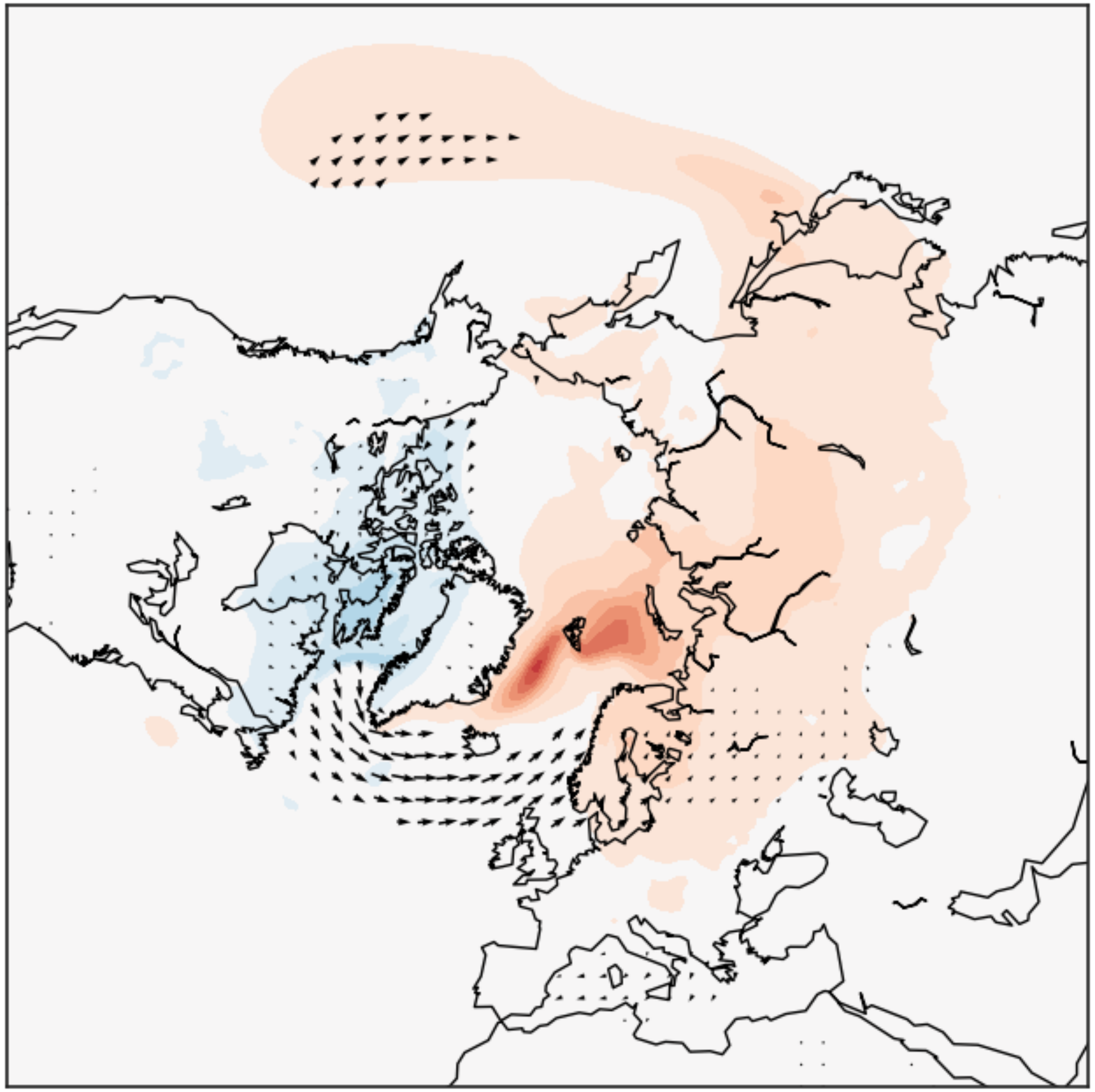
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



4 years before peak AMOC strength

CESM LE Composite

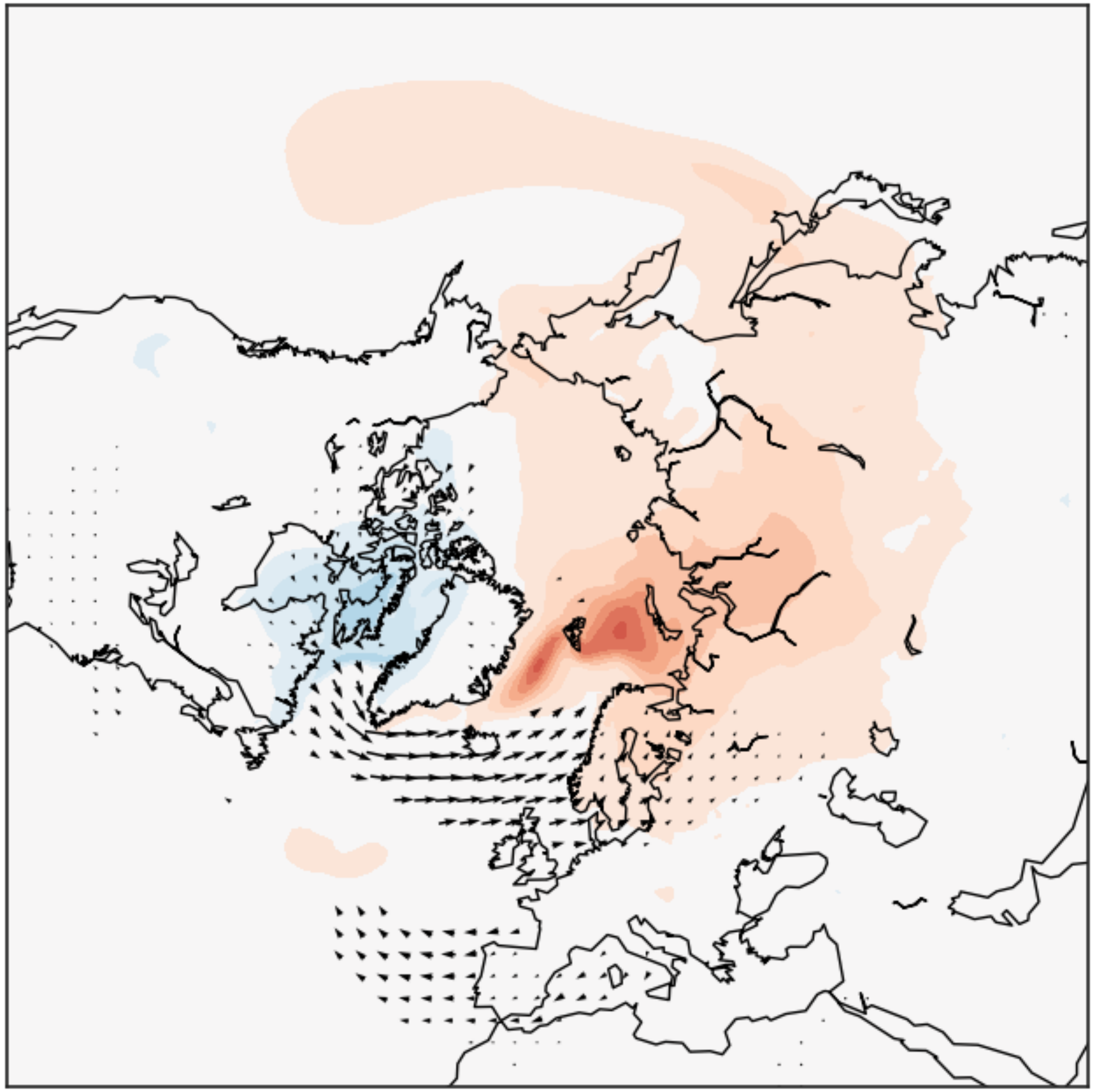
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



3 years before peak AMOC strength

CESM LE Composite

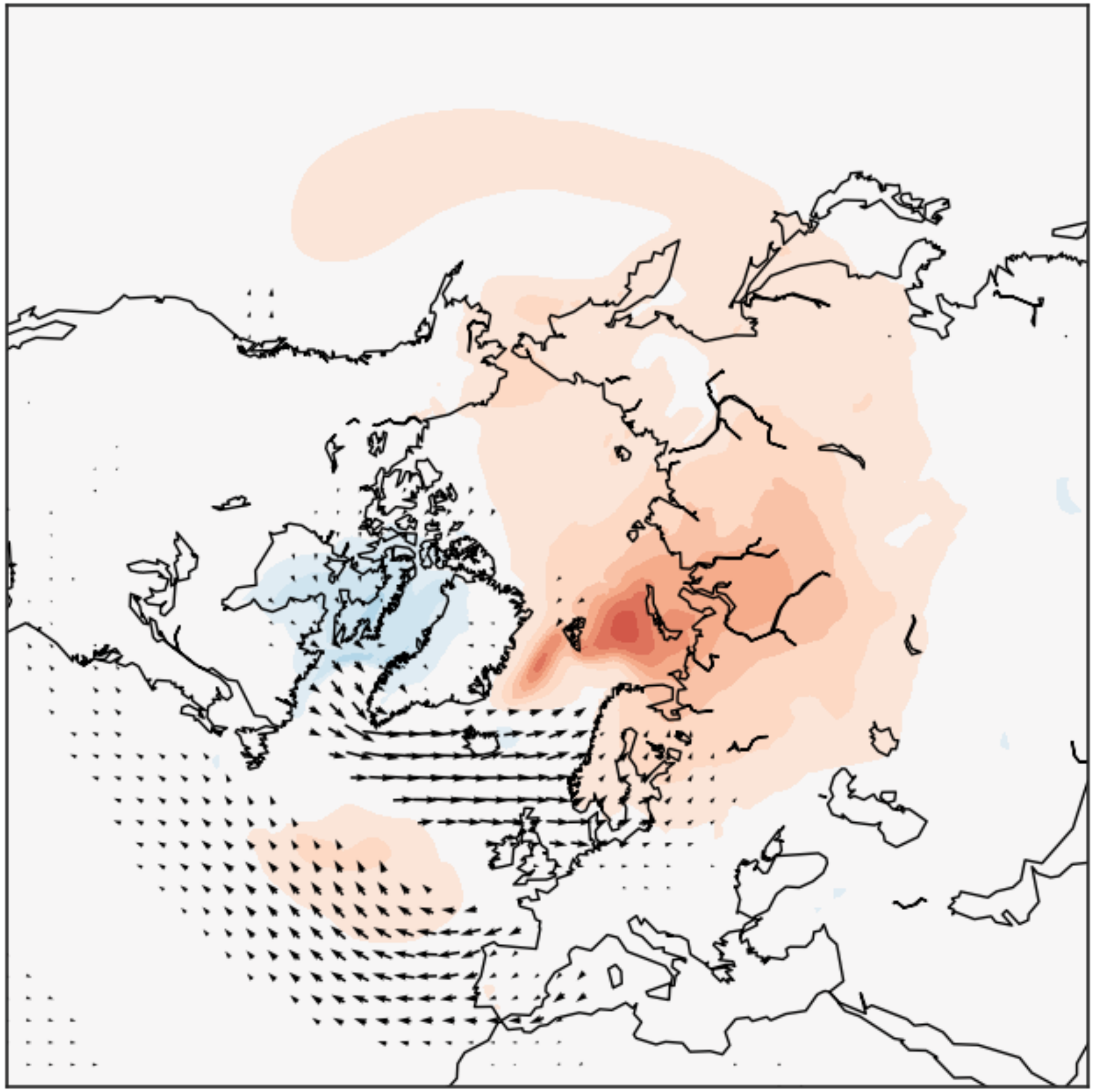
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



2 years before peak AMOC strength

CESM LE Composite

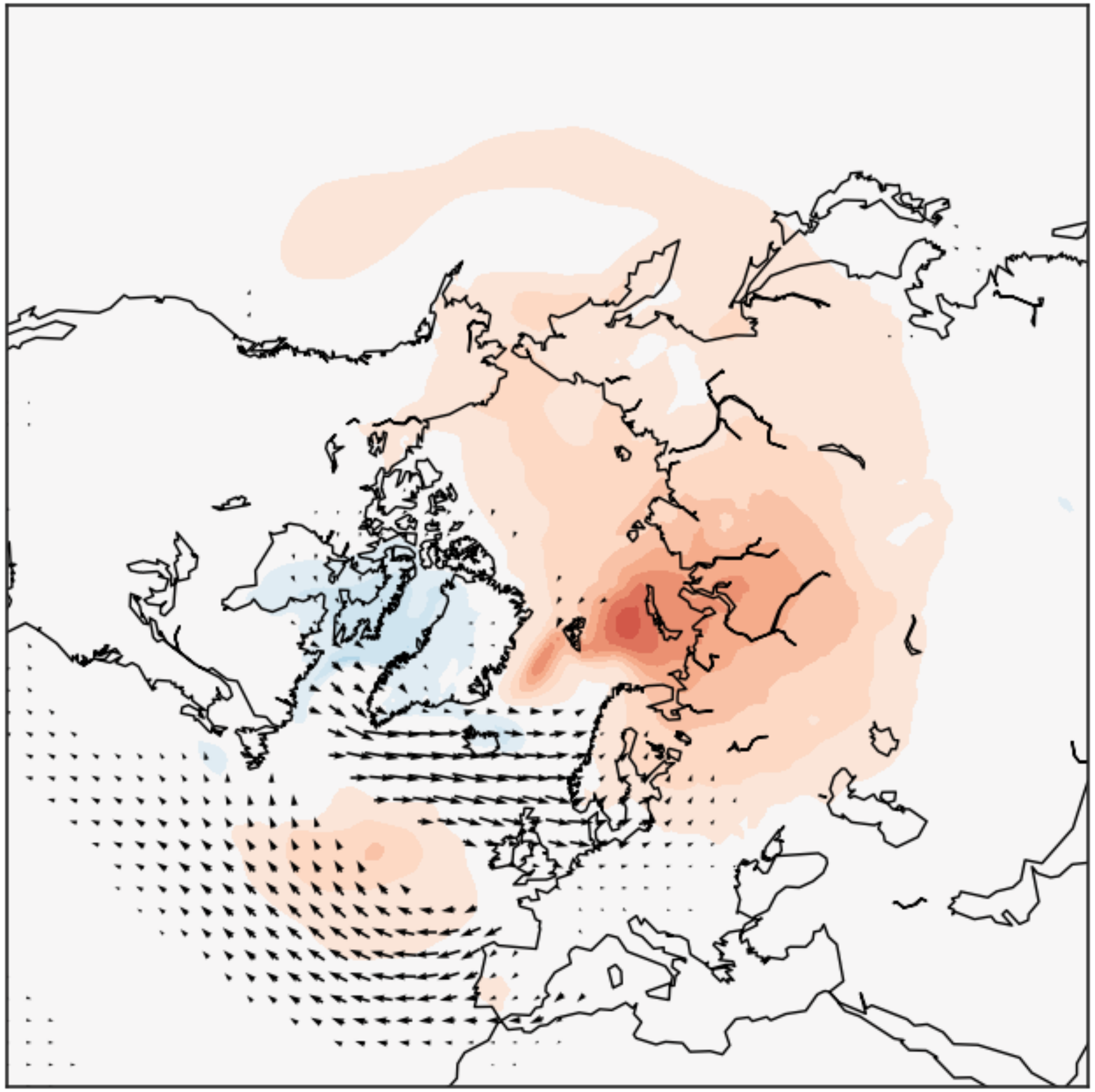
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



1 year before peak AMOC strength

CESM LE Composite

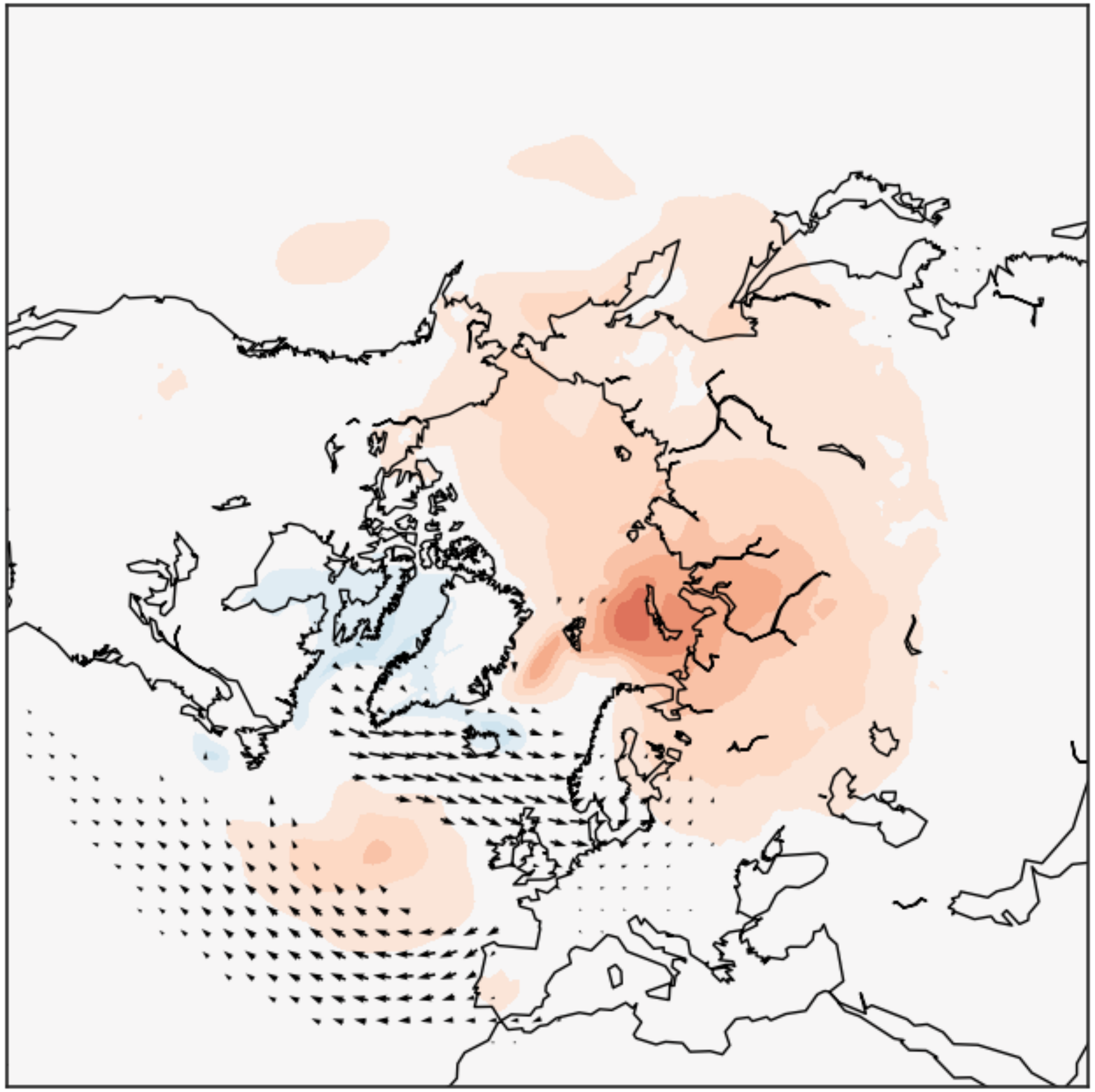
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



Zero lag with AMOC strength

CESM LE Composite

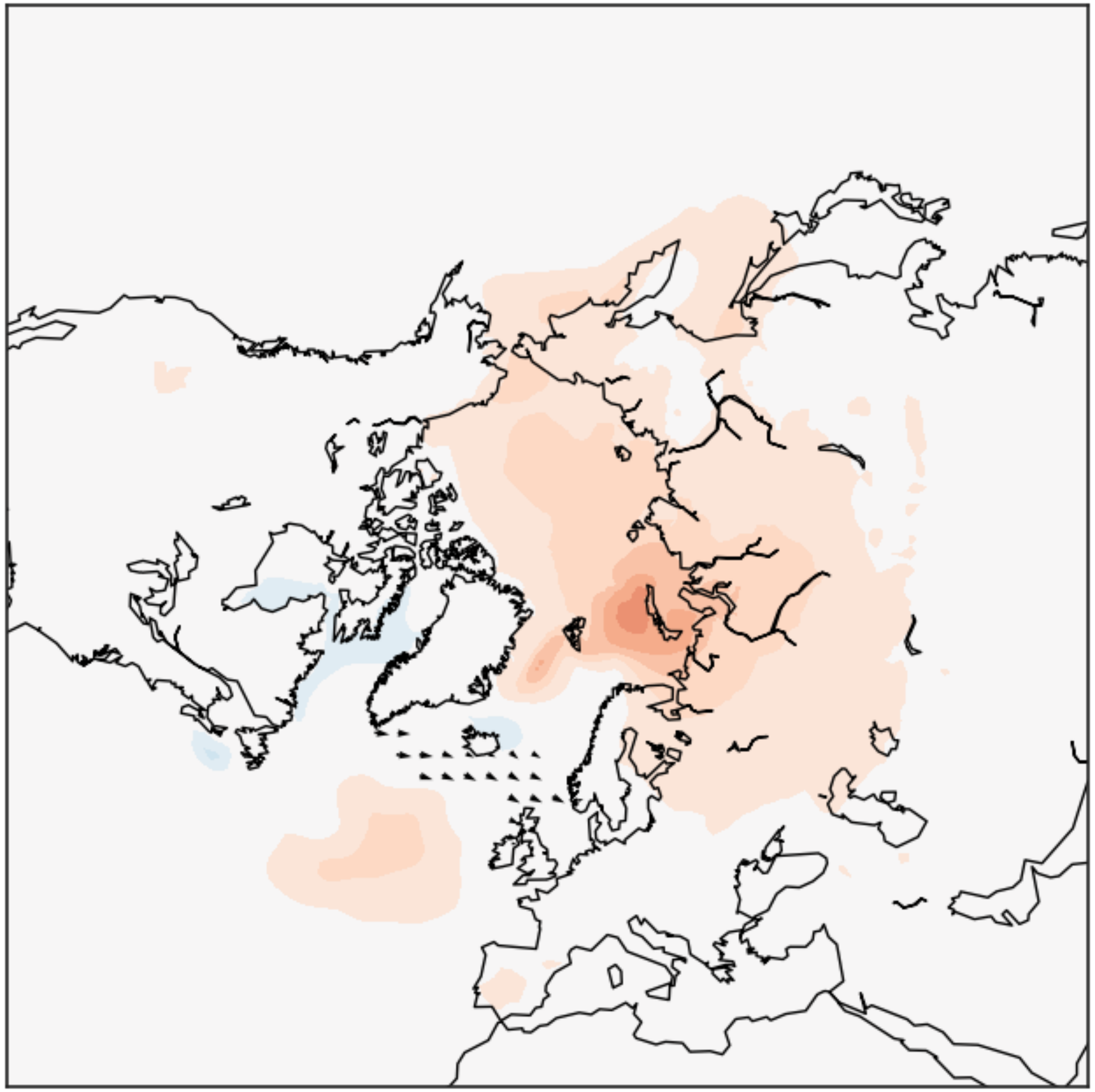
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



1 year after peak AMOC strength

CESM LE Composite

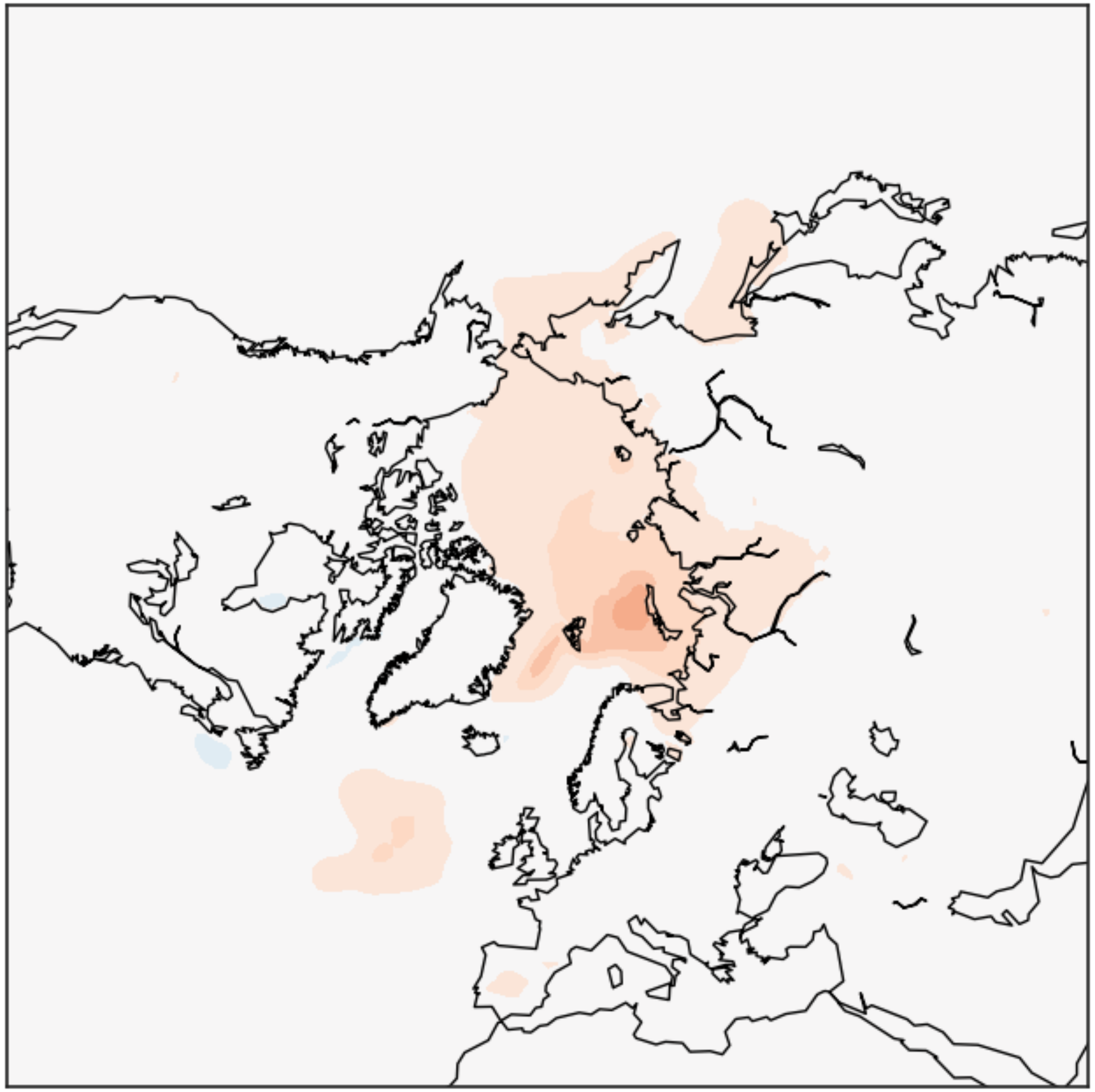
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



2 years after peak AMOC strength

CESM LE Composite

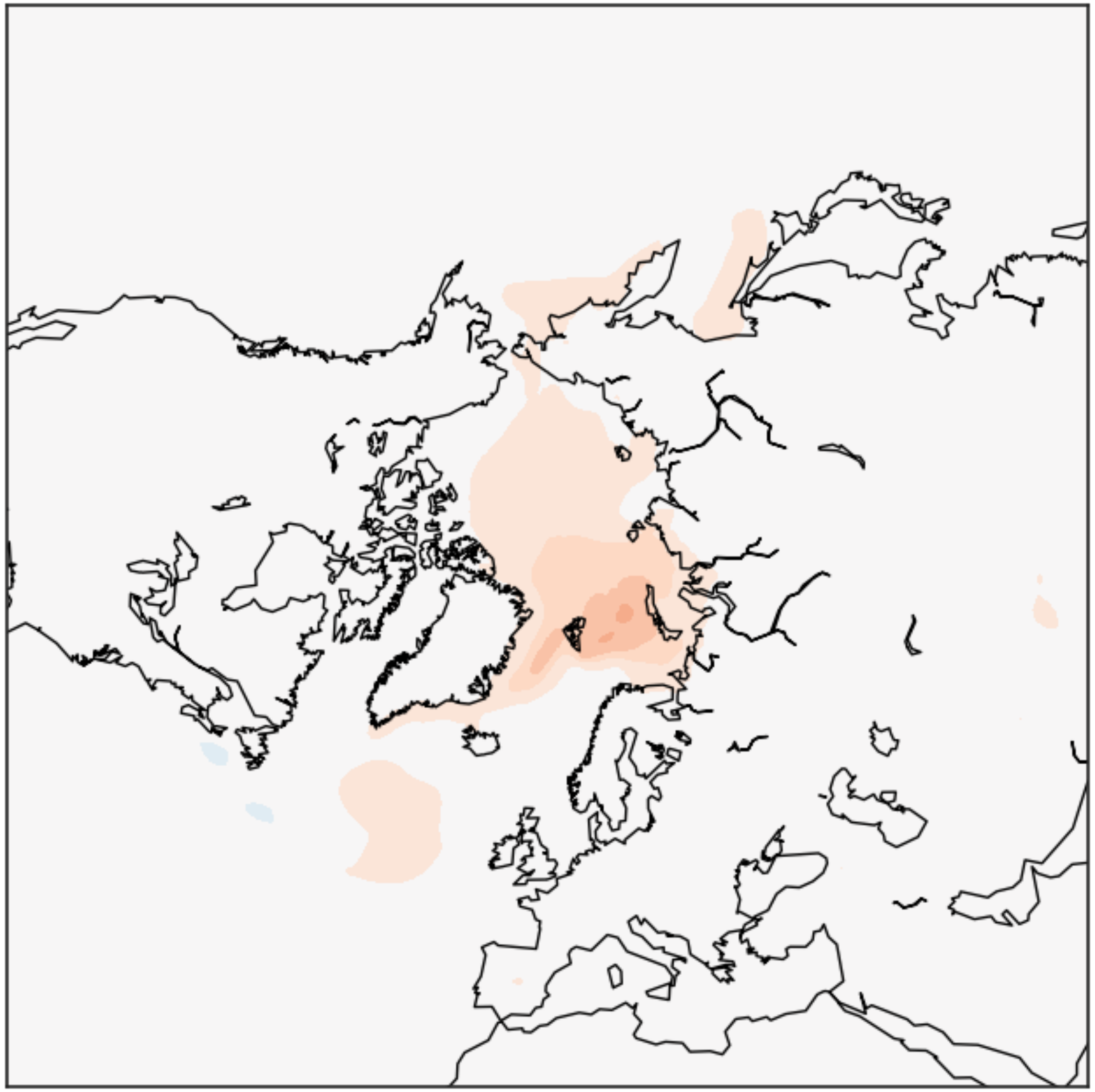
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



3 years after peak AMOC strength

CESM LE Composite

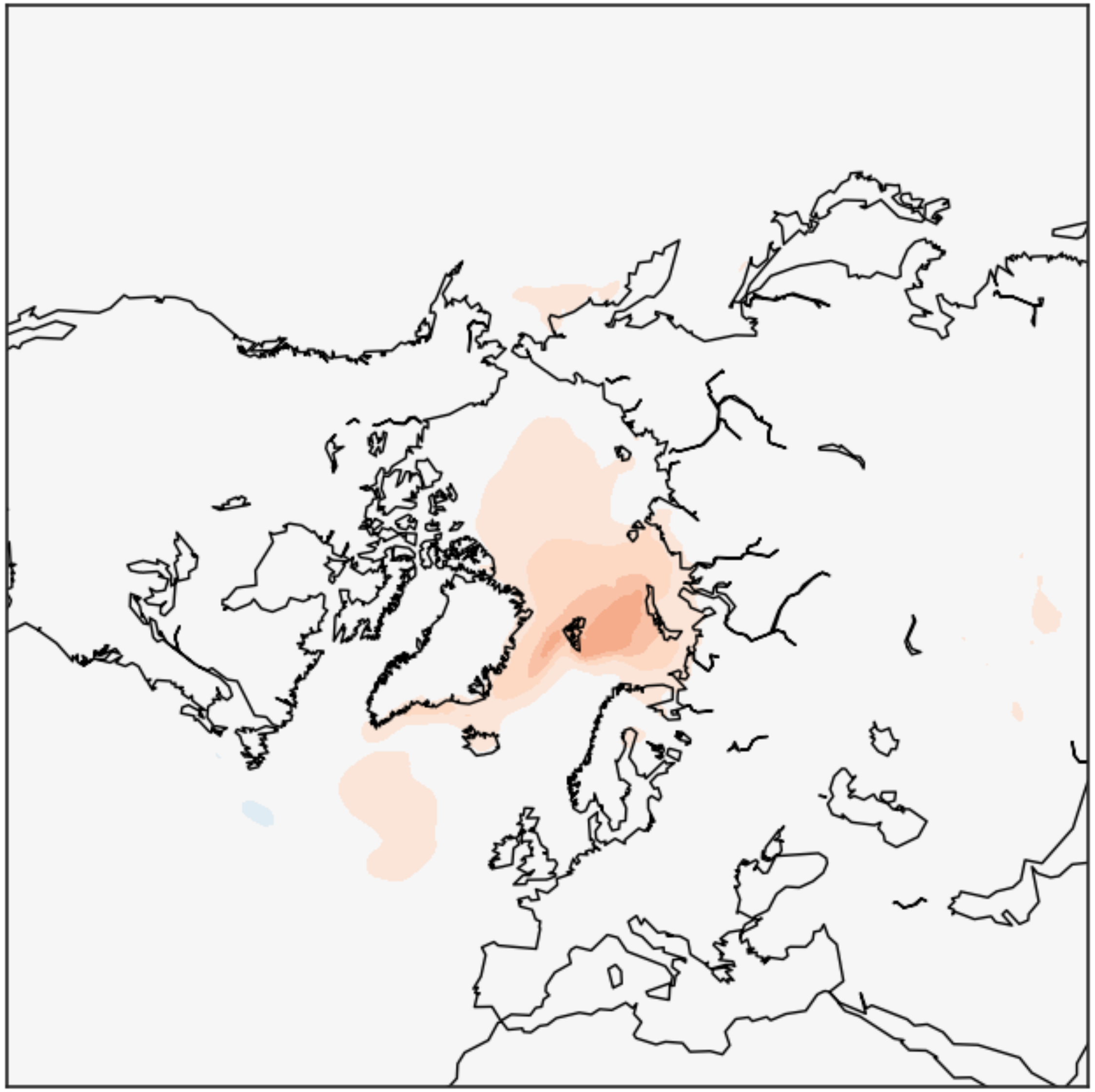
Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



4 years after peak AMOC strength

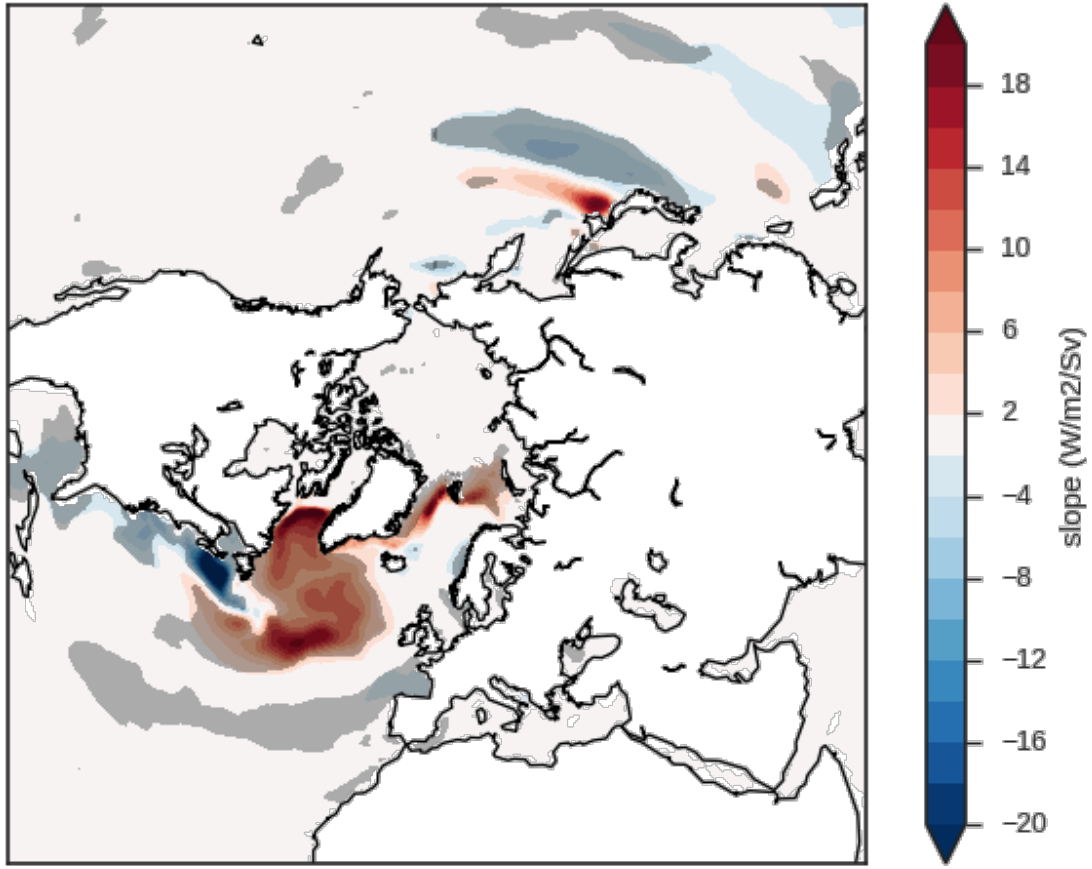
CESM LE Composite

Lead-lag regression of U,V wind and surface temperature time series with AMOC strength time series in each member (5-year low pass Lanczos filter)



5 years after peak AMOC strength

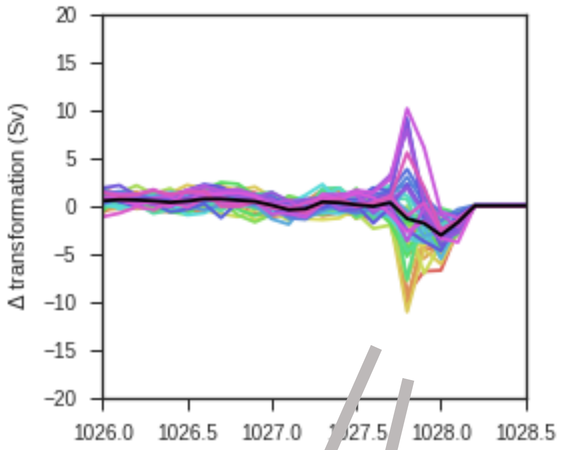
Increased surface heat flux over the North Atlantic Ocean associated with strengthening AMOC.



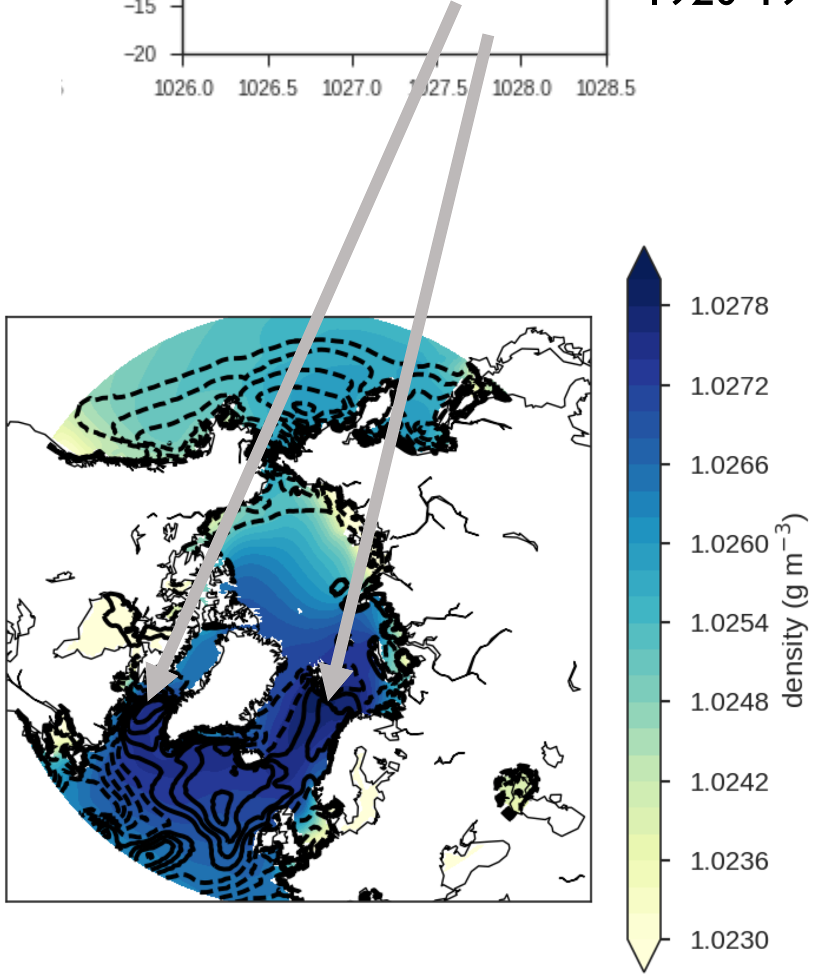
CESM LENS historical forcing

shading indicates correlations significant at 99% confidence level

Increased water mass transformation of densest North Atlantic surface water associated with increased AMOC strength

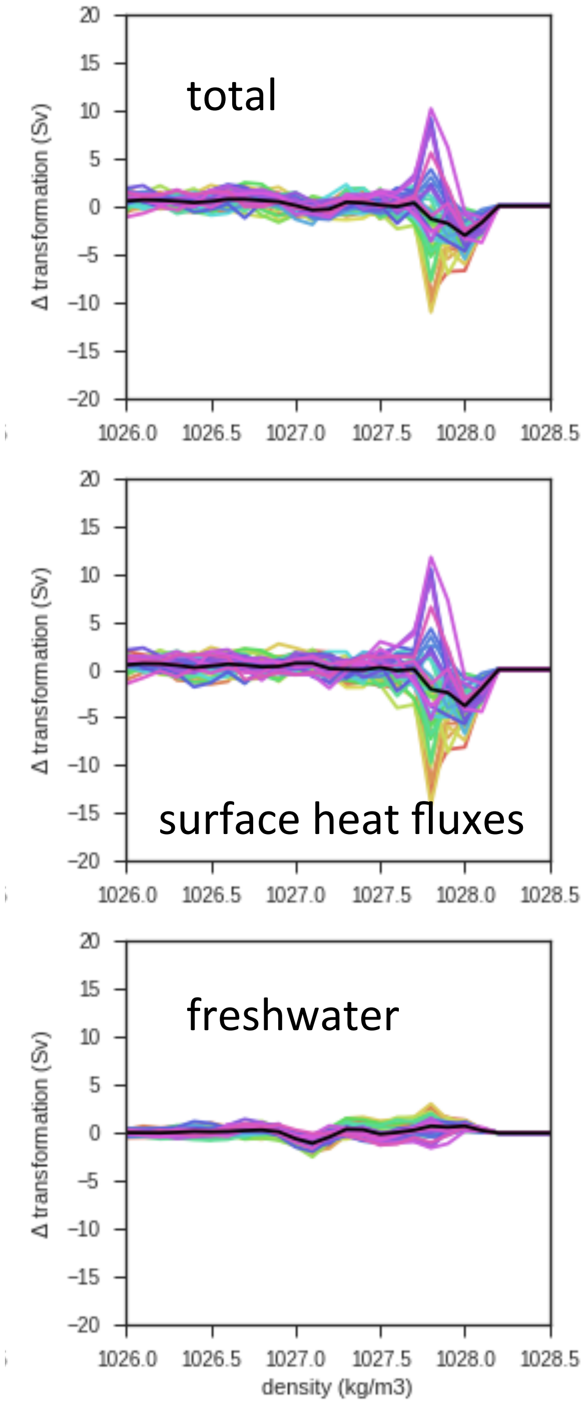


Historical CESM LE 1985-2005 avg minus 1920-1940 avg



CESM LE historical mean density and density flux

Increased water mass transformation of densest North Atlantic surface water associated with increased AMOC strength

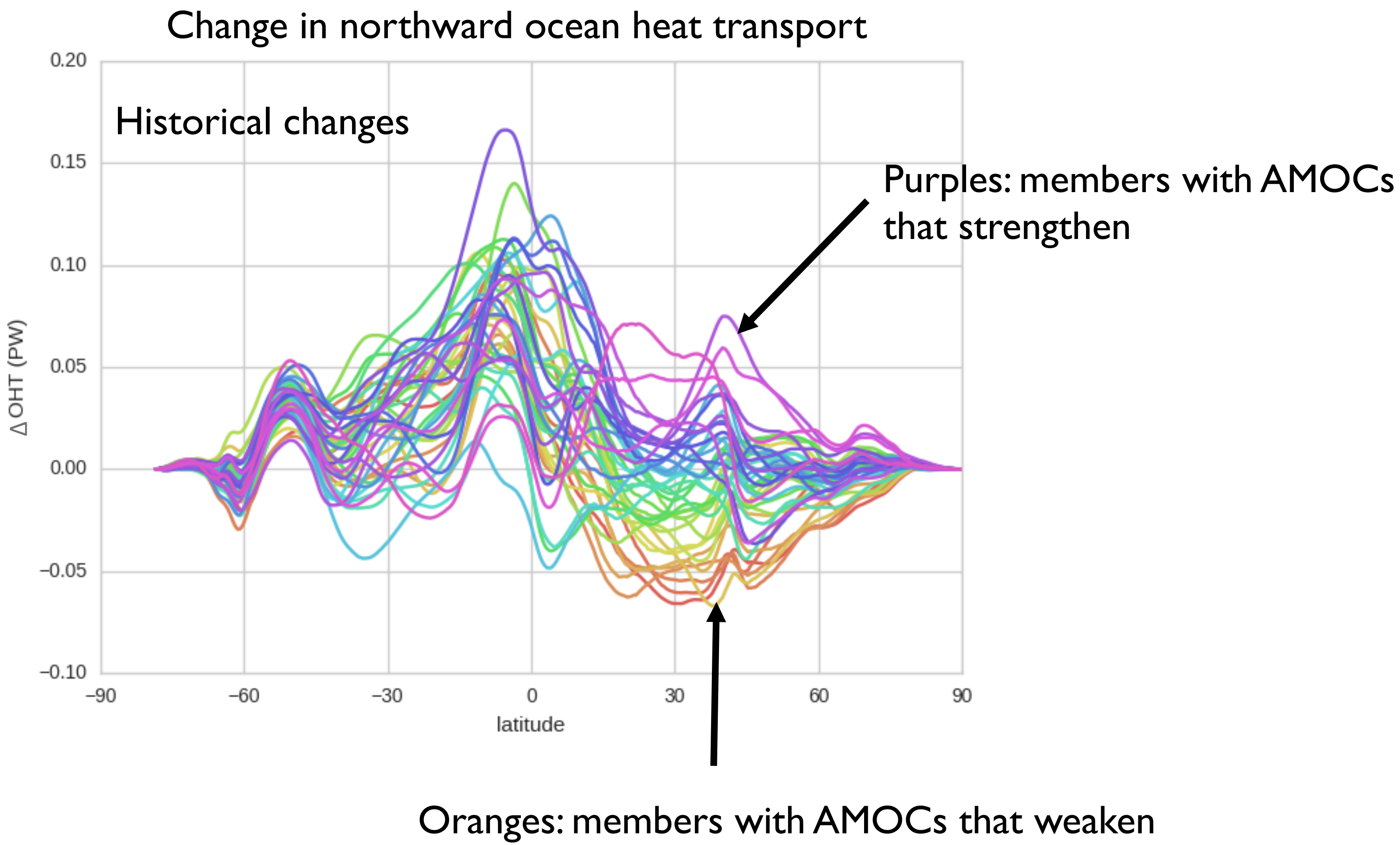


Historical CESM LE 1985-2005 avg minus 1920-1940 avg

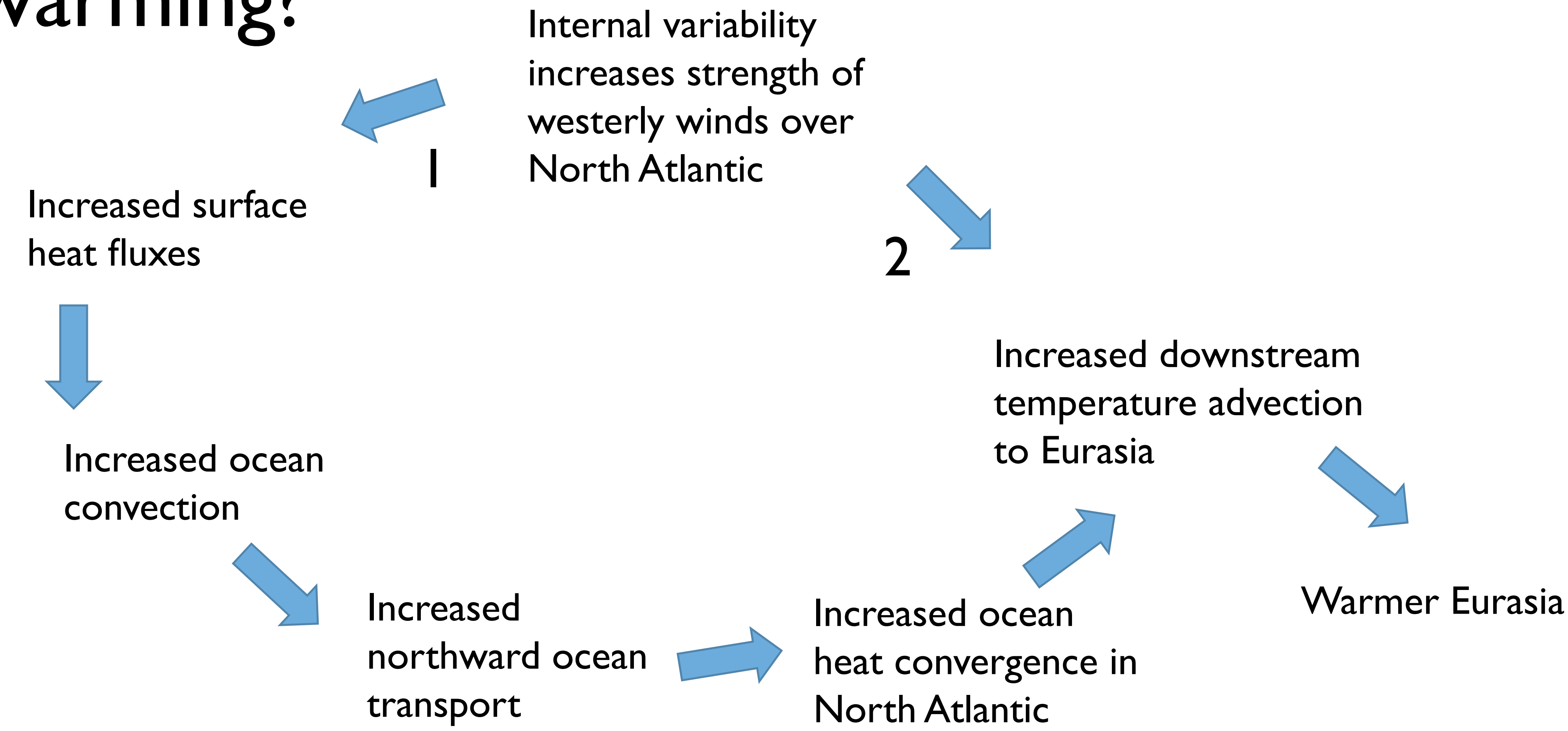
Purples: CESM member with AMOC that strengthens

Oranges: CESM member with AMOC that weakens

Increase in AMOC strength associated with increased northward OHT



Is the AMOC necessary for this Eurasian warming?



Summary

In the CESM large ensemble, when the AMOC increases in strength (relative to the forced response), surface temperature increases over the North Atlantic and northern Eurasia.

As a result, global surface temperature increases modestly with a strengthening AMOC.

Variability in midlatitude westerlies likely drives the variation in AMOC strength. Stronger westerlies increase the AMOC strength by increasing surface heat fluxes and convection.

Increased northward heat transport by the ocean reduces sea ice cover. Winds advect heat downstream from the sea ice to warm Europe/Asia.