Changing North Atlantic variability under global warming

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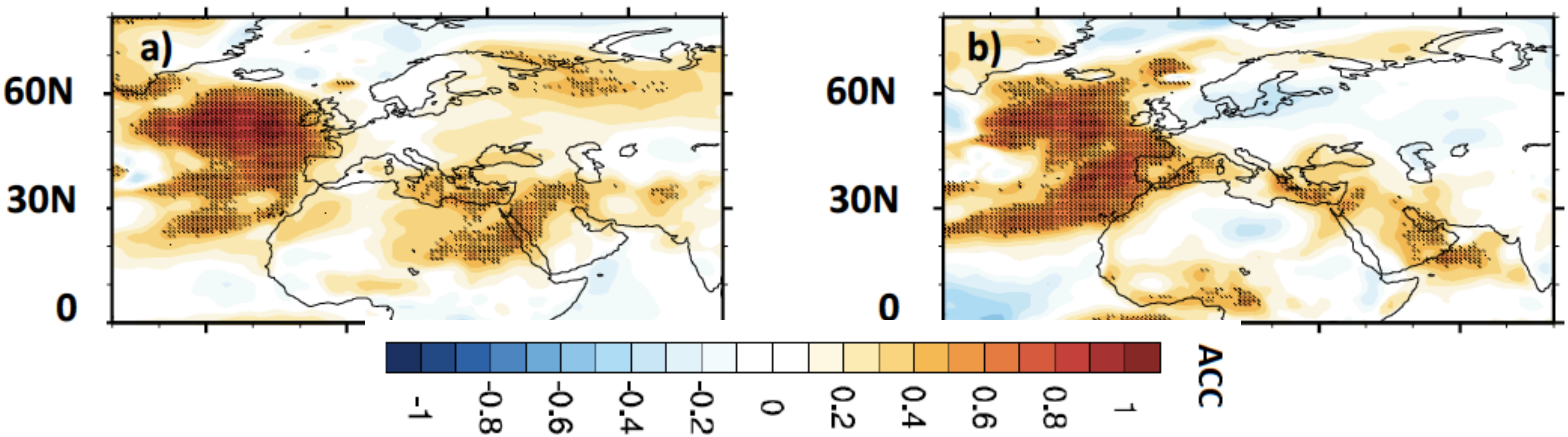
Ocean circulation and predictability

ACC* for surface air temperatures at lead year 3-5 after strong (left column) and weak (right column) OHT phases at 50N

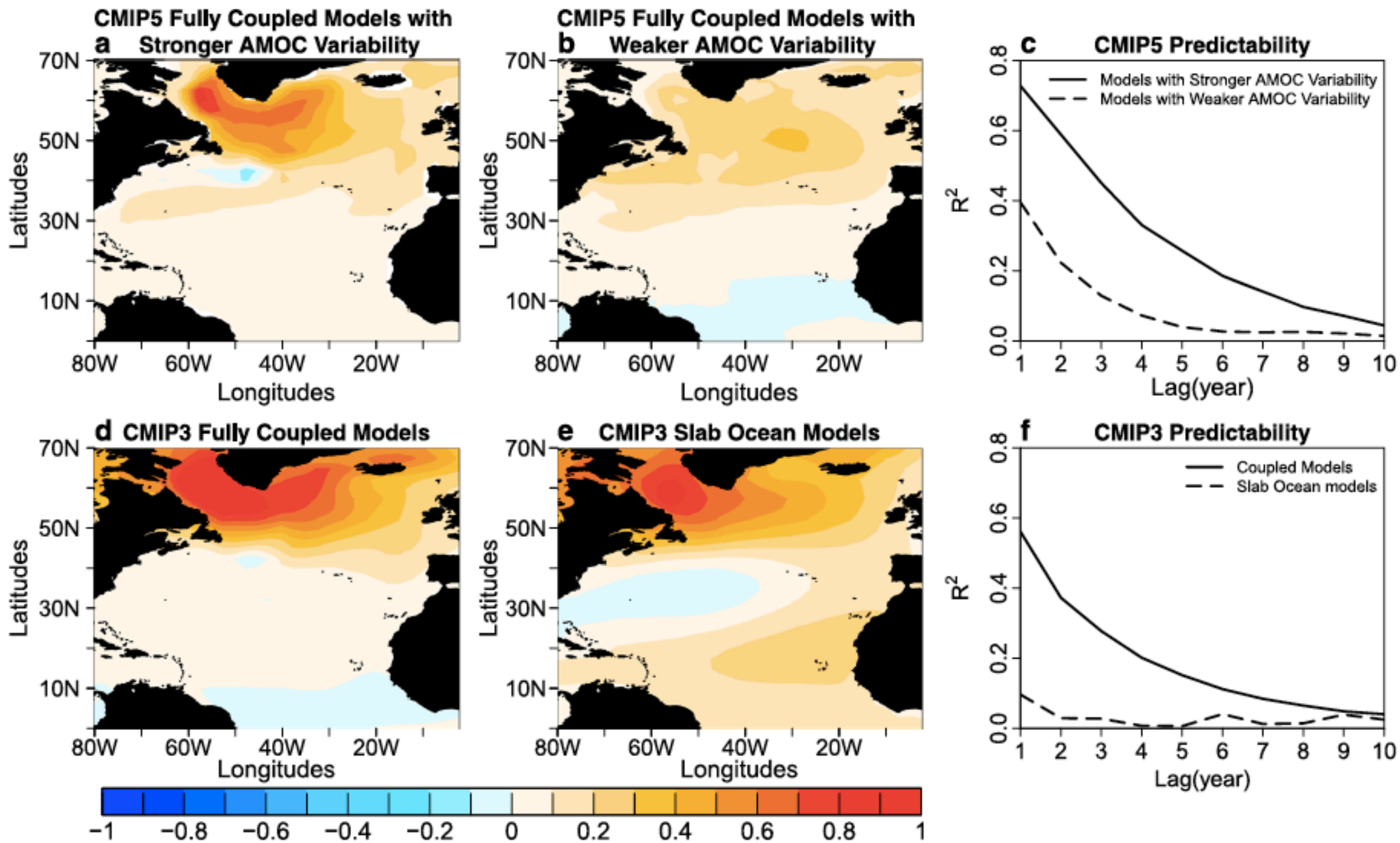


- Atlantic northward ocean heat transport (OHT) at 50°N influences surface temperature variability in the North Atlantic region for several years.
- Interannual-to-decadal SST predictability of initialized hindcasts is linked to this SST pattern

*Anomaly correlation coefficient

Borchert et al., J Clim, 2018

Ocean circulation and predictability



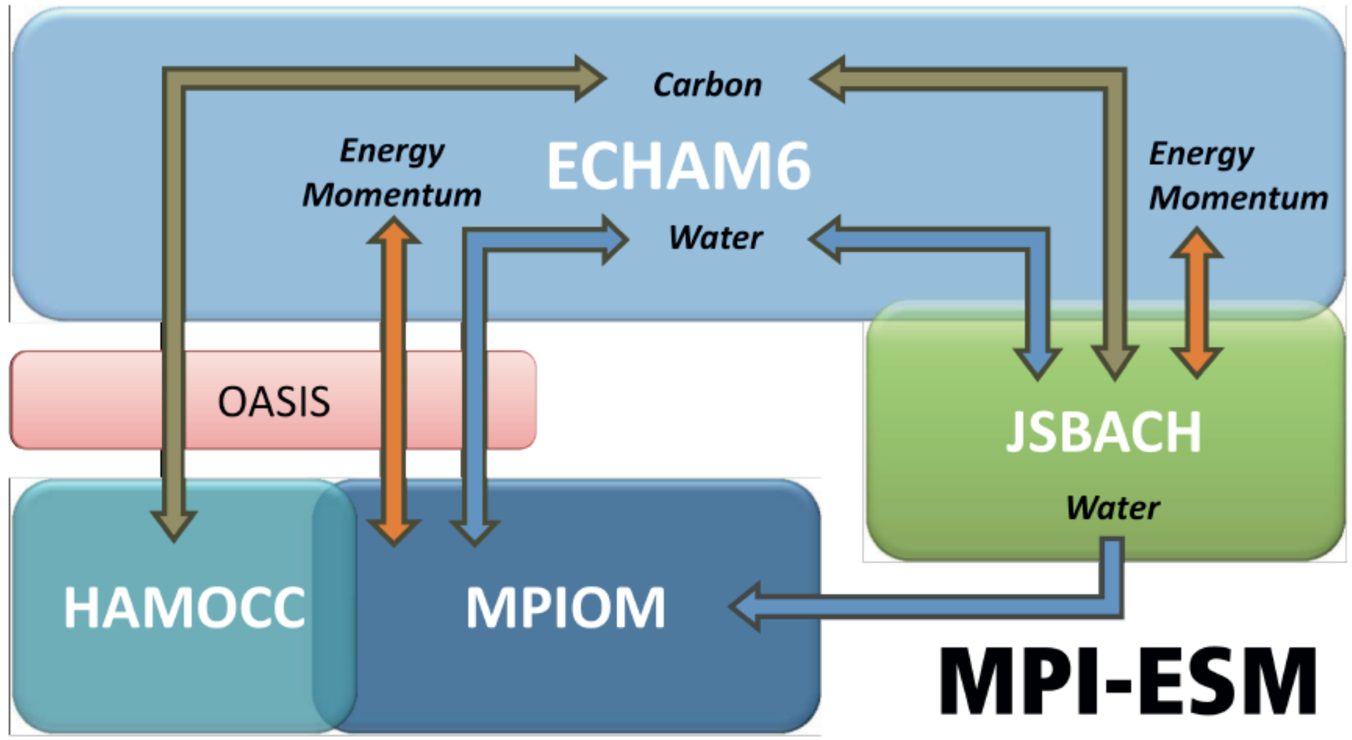
Models with stronger AMOC variability provide longer predictability* time scales

Slab ocean models: almost no predictability

*Srivastava and DelSole, 2016

Yan et al., GRL, 2018

MPI-EARTH SYSTEM MODEL



MPI-ESM1.2 configurations

	LR	HR	ER	XR	NR
atmosphere	T63	T127	T127	T255	T127
ocean	GR15	TP04	TP6M (0.1^0)	TP04 (0.4^0)	TP1.0 (1.0^0)

CMIP6, FAFMIP **PRIMAVERA, HIGHRESMIP, (FAFMIP)**

Mueller et al., JAMES, 2018; Mauritsen et al., JAMES 2019; Gutjahr et al., GMD 2019

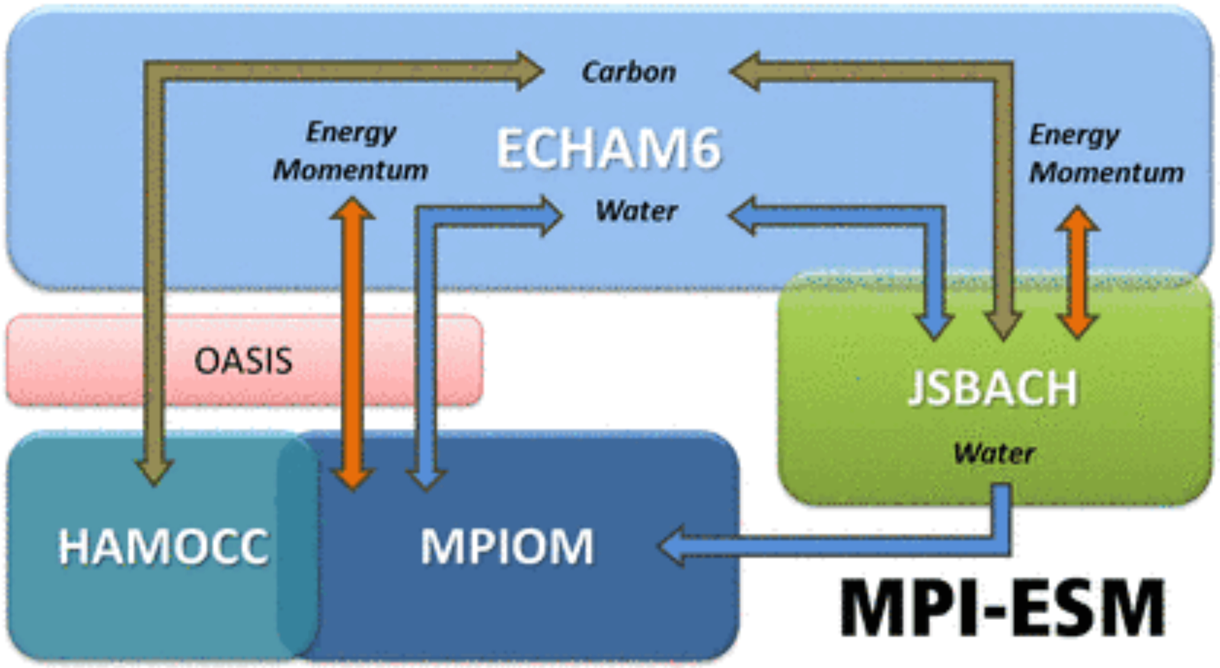
The MPI-ESM "Grand Ensemble" (MPI-ESM-GE)

MPI-ESM-LR (Giorgetta et al., 2013;

Jungclaus et al., 2013)

ECHAM6: T63L47

MPIOM: GR1.5L40



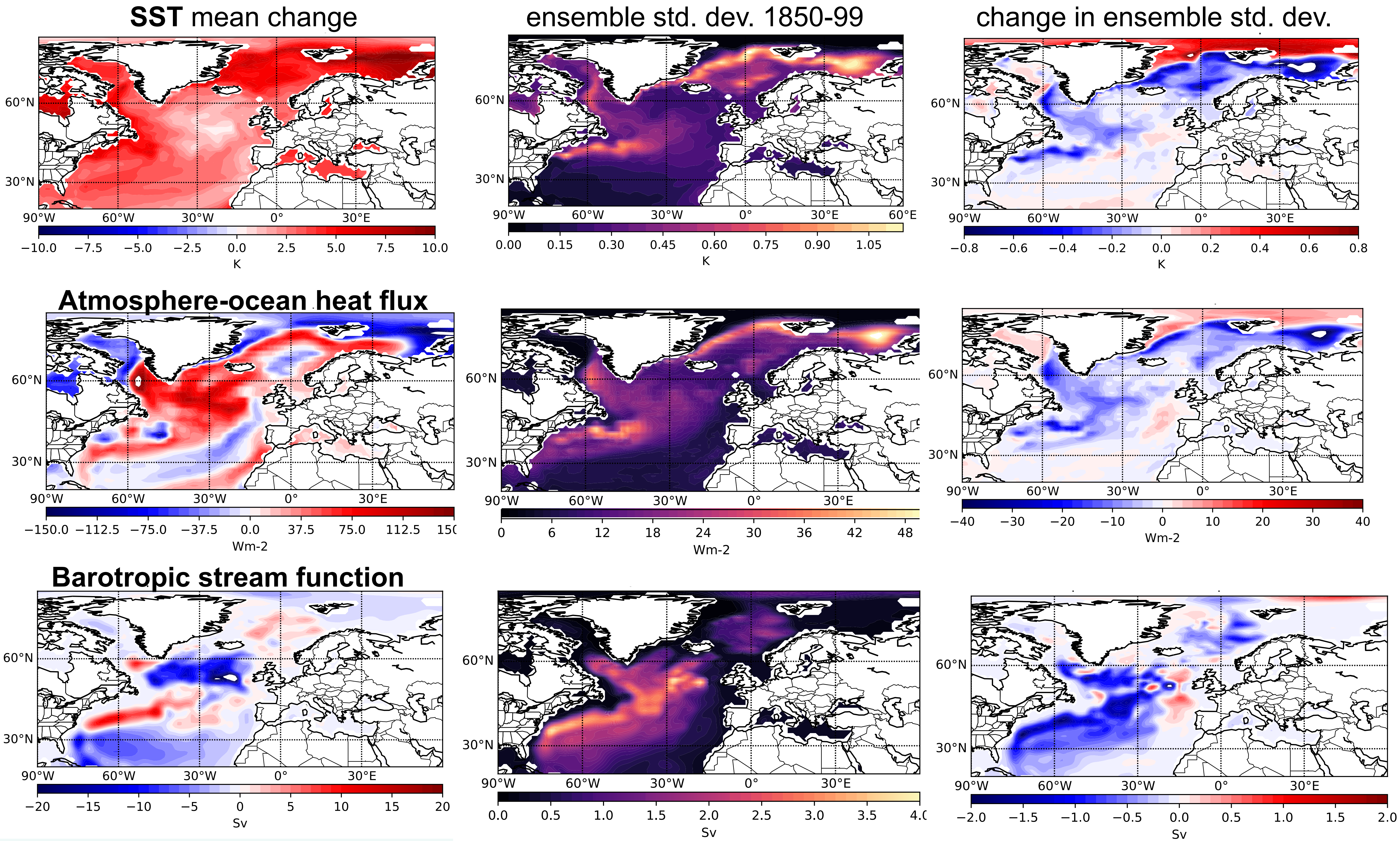
- Control run: 2000 years
- 100-member ensemble "historical" 1850-2004 (CMIP5 forcing)
- 100-member ensemble idealised global warming for 150 years (1% CO_2 increase per year)
- 3x 100-member ensembles for CMIP5 future scenarios RCP2.6, RCP4.5, RCP8.5

- **Data sets publicly available via ESGF**

Maher et al., JAMES 2019

North Atlantic climatic changes in MPI-ESM-GE

Historical + rcp8.5 scenario



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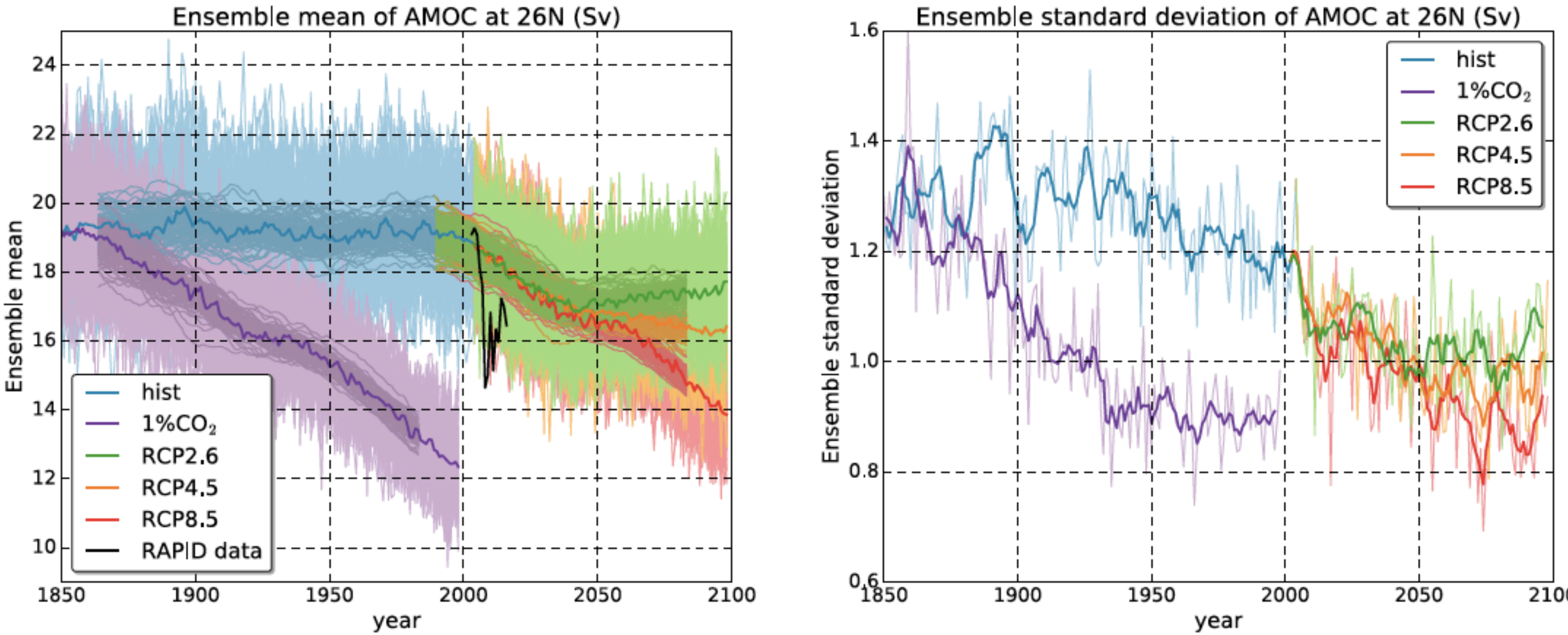
The AMOC in MPI-ESM-GE



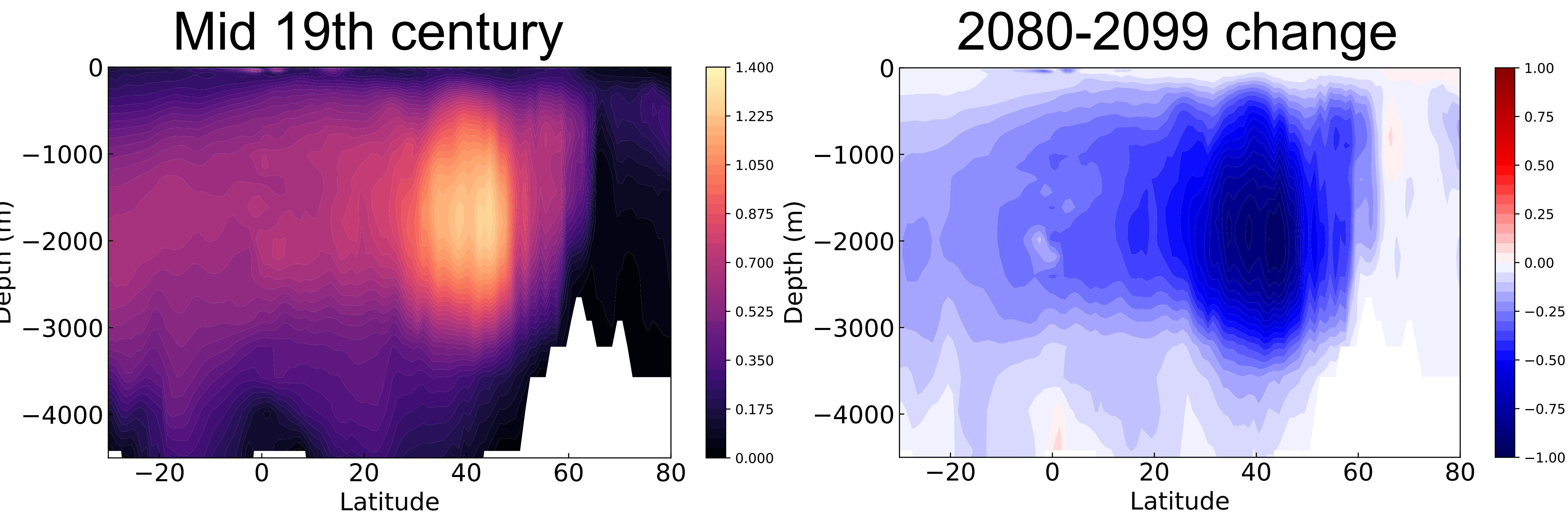
- strong internal variability (IV); present observed decline within IV range
- Forced decline is visible in ensemble mean

- Internal variability amplitude (ensemble standard deviation) declines as well

Maher et al., JAMES 2019

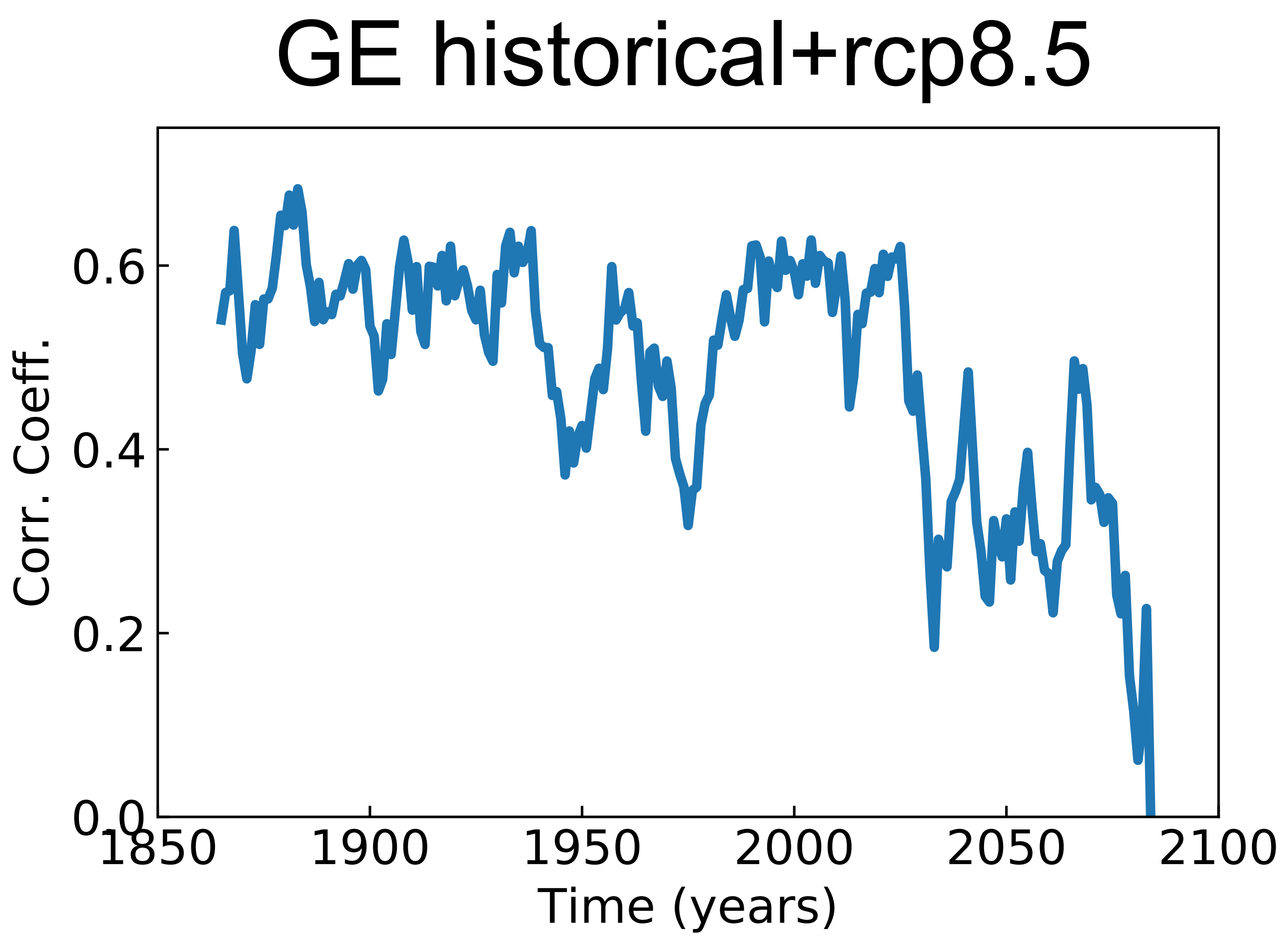
The AMOC in MPI-ESM-GE

AMOC ens. std.dev [Sv] in Historical and RCP8.5



- changes in AMOC variability internal variability (IV); present observed decline well within IV
- Forced decline is visible in ensemble mean
- This variability pattern is closely related to Labrador Sea deep water formation (Hand et al., in review)

NATL variability in ensemble domain

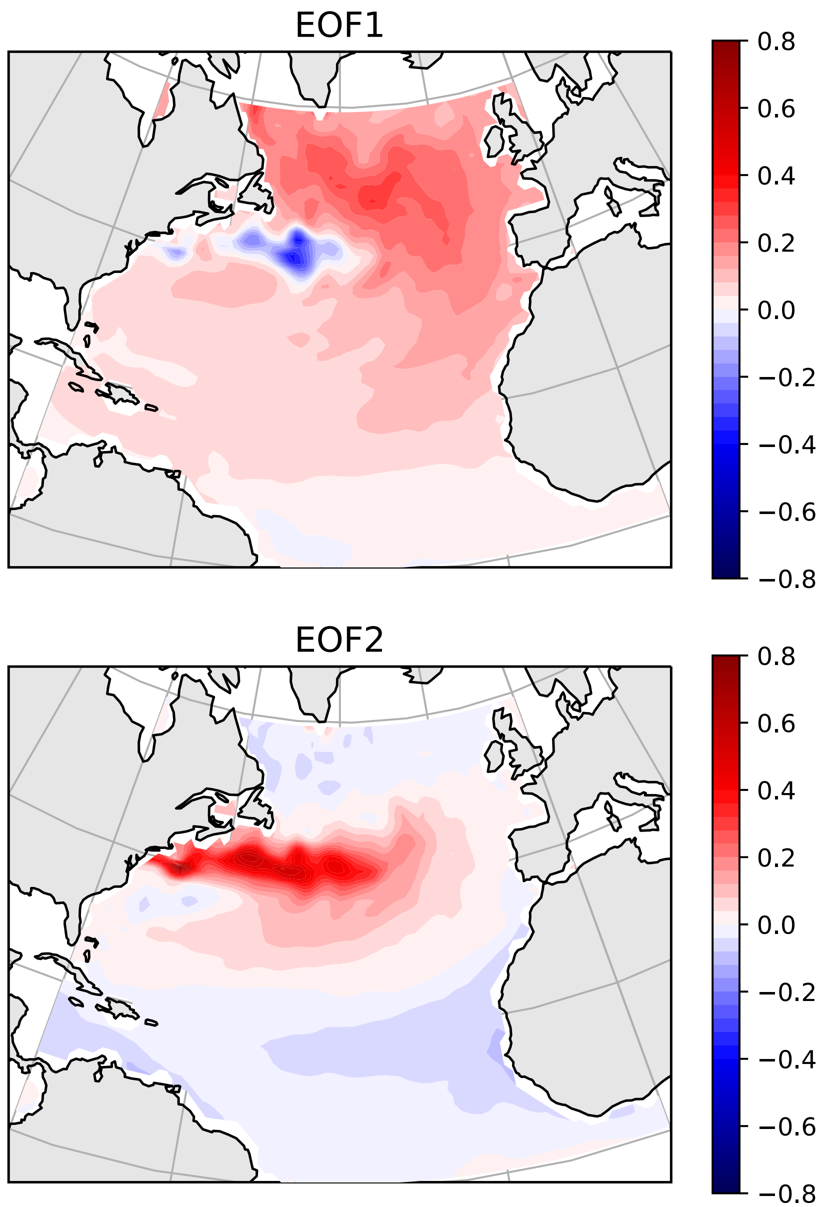


- Strong correlation seen in control and historical simulations between surface heat flux & deep water formation in Labrador Sea and AMOC strength can be retrieved in ensemble domain
- connection breaks down in the early decades of 20th century (c.f. Sgubin et al., 2016)

Hand et al.,under review J. Clim; Jungclaus et al., in prep.

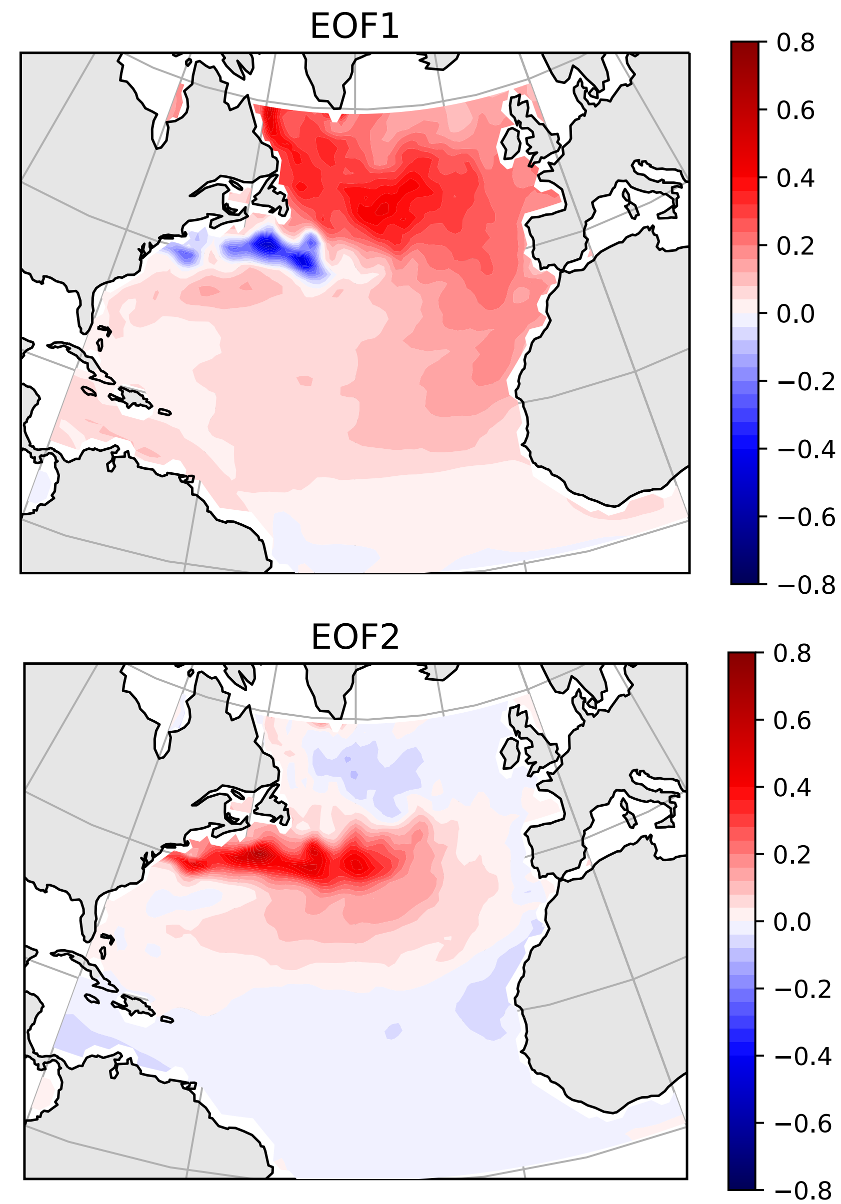
NATL variability in time/ensemble domain

PiControl



EOFs in time domain

GE historical, year 1851

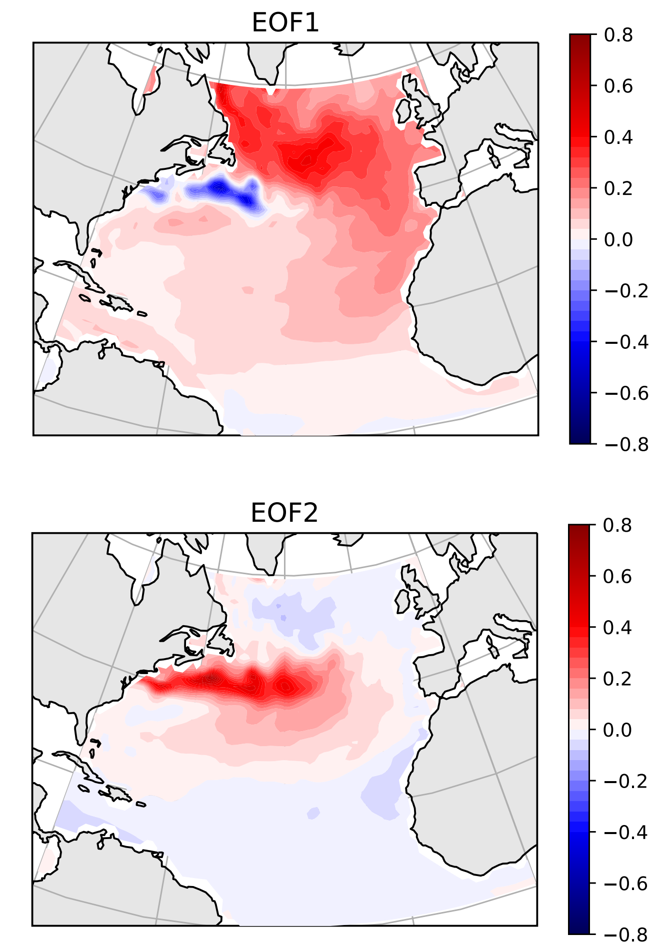


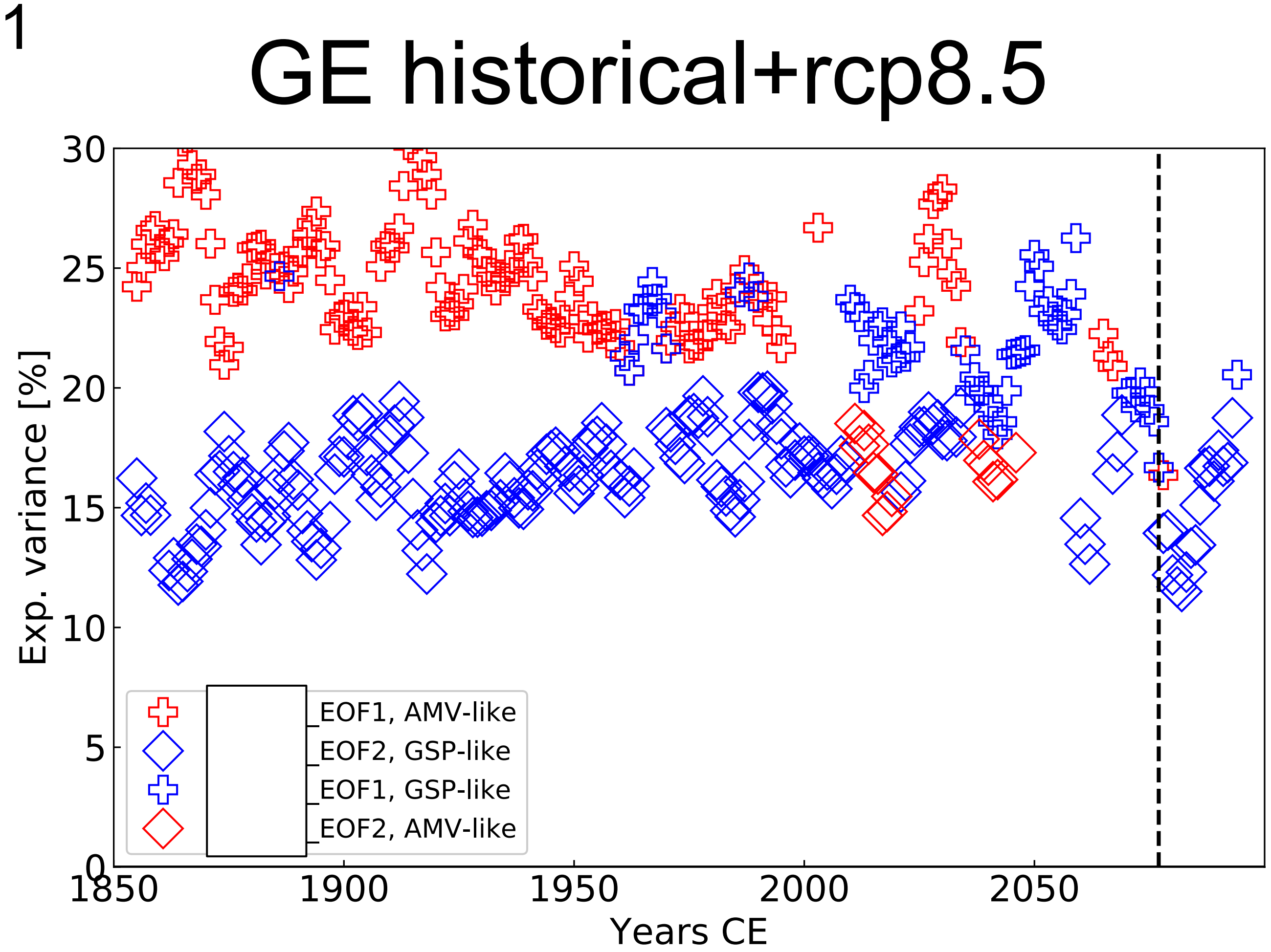
EOFs in ensemble domain

- EOFs in ensemble space retrieve the patterns in the time domain

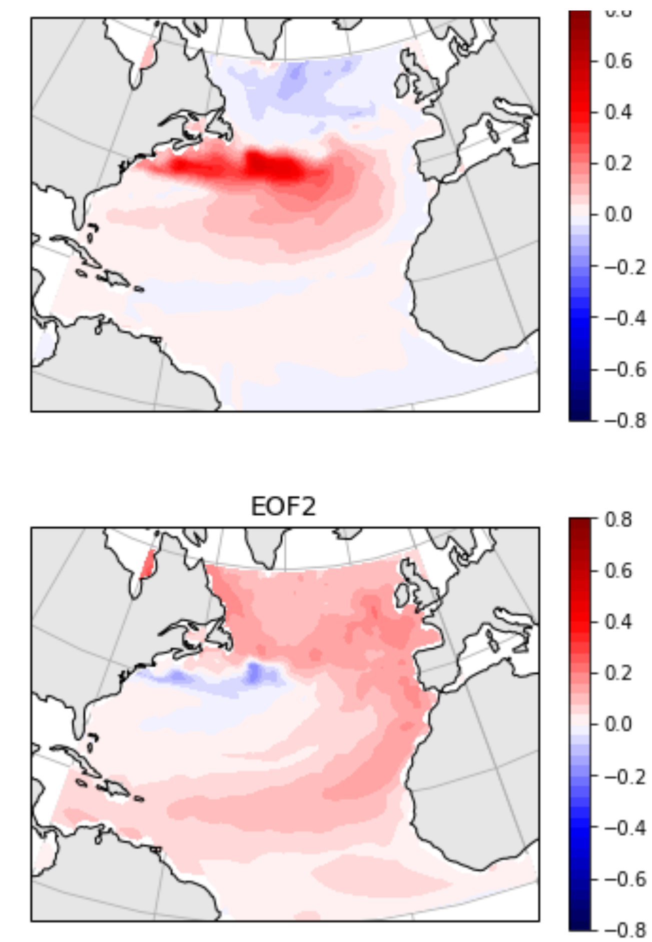
NATL variability in ensemble domain

GE historical, year 1851





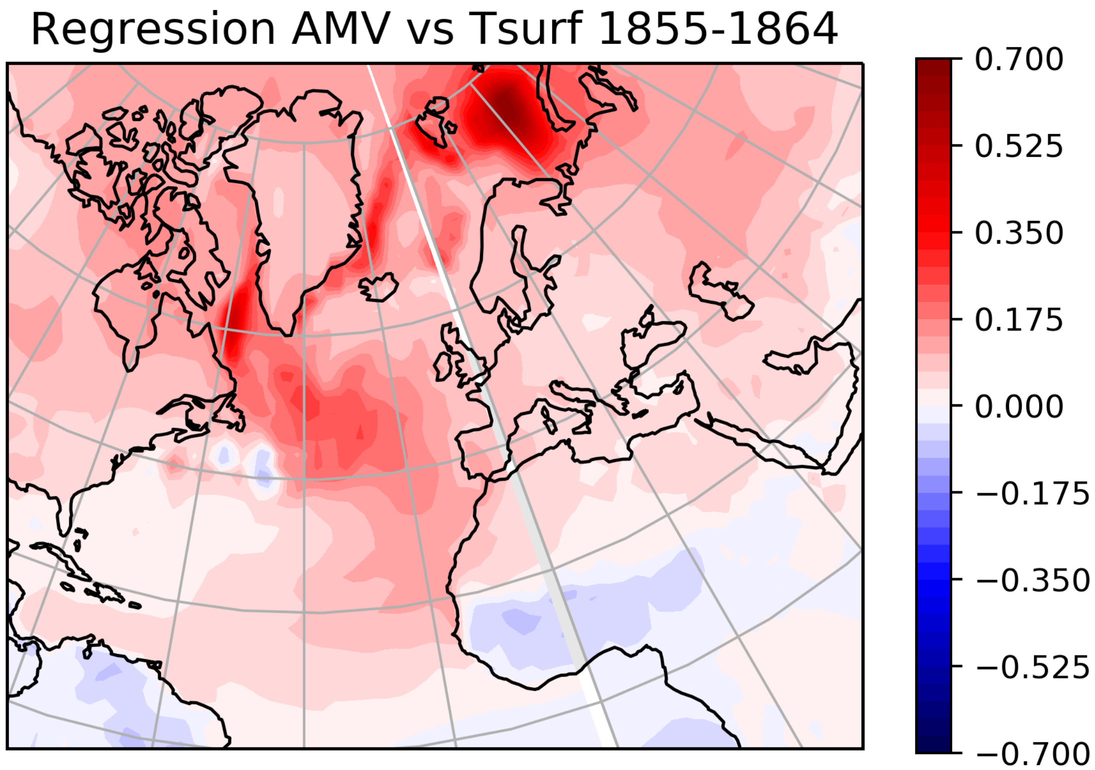
GE rcp85, year 2077

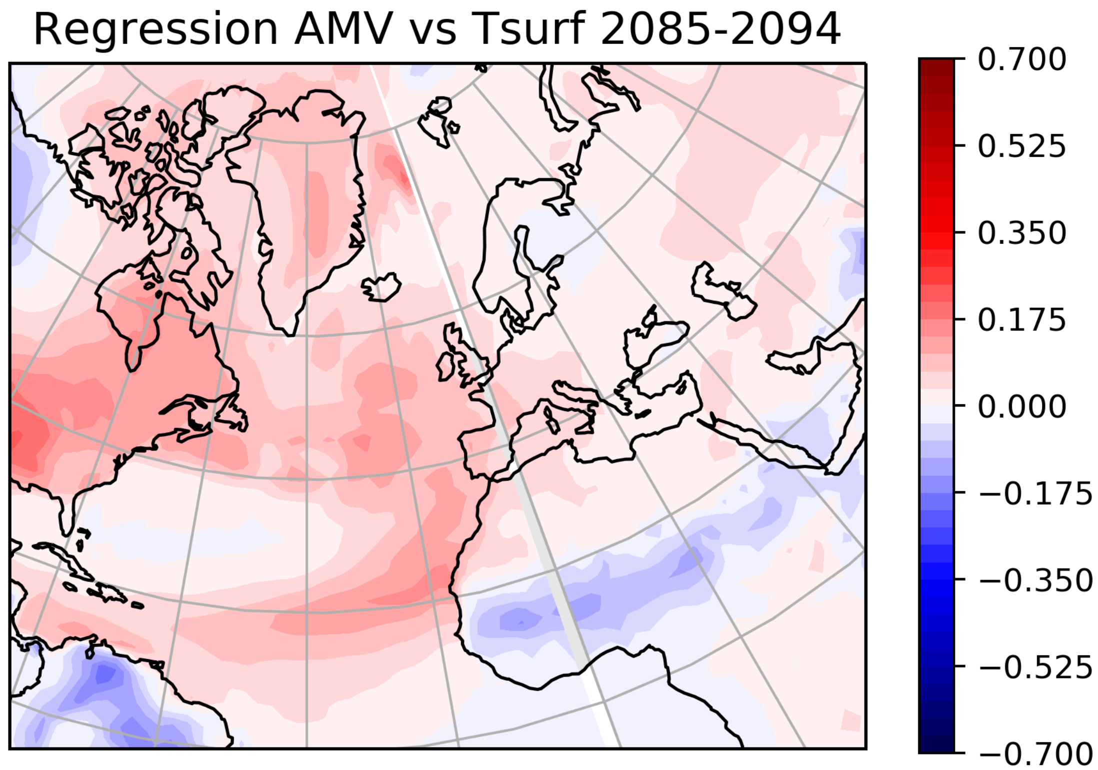


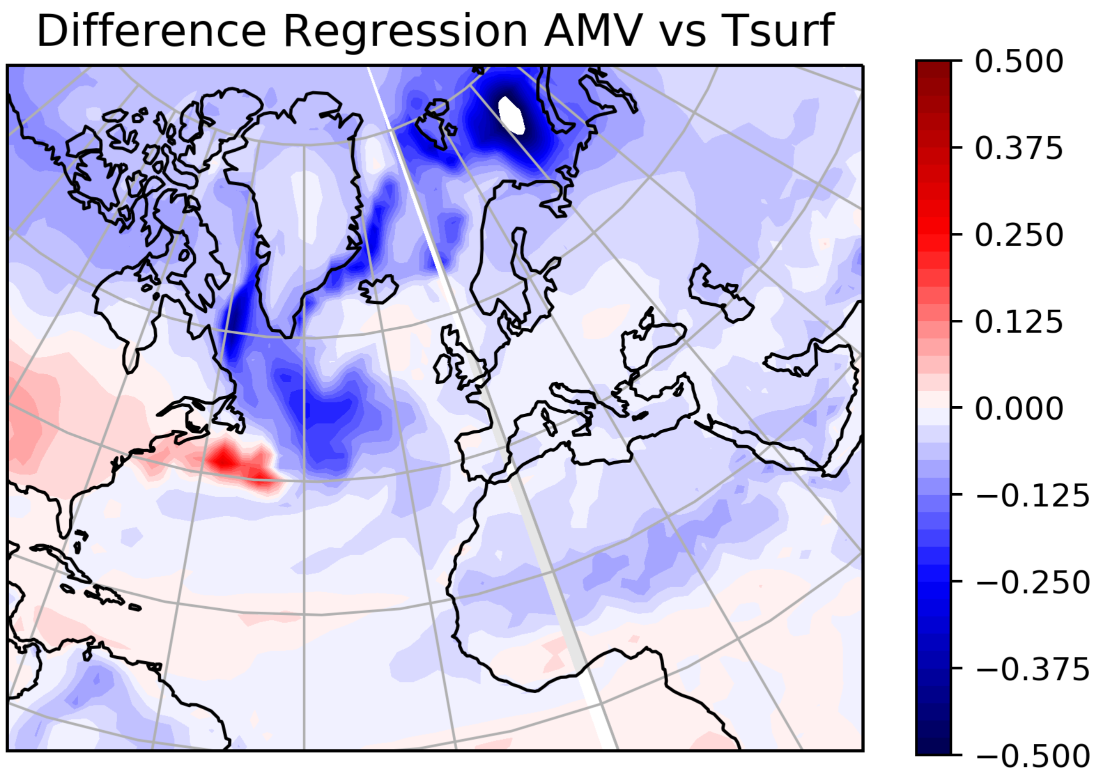
- While there is a general decline in SST variability amplitude, the spatial patterns of variability also change as well as their relative importance

Jungclaus et al., in prep.

Changing regression patterns

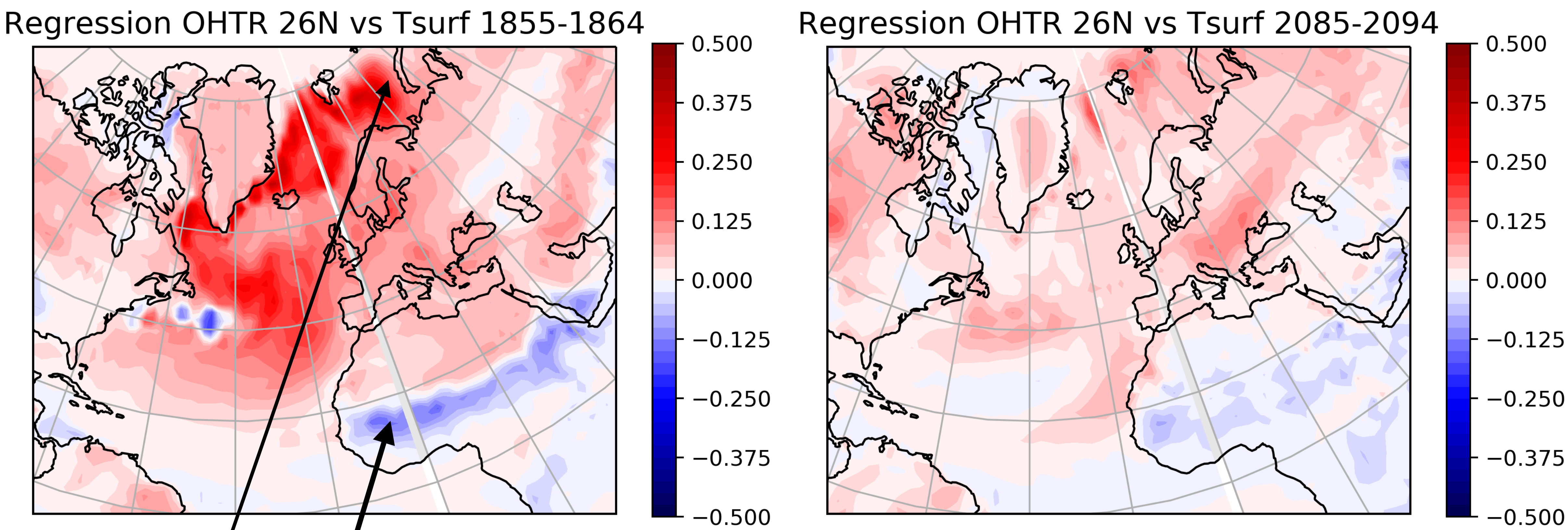


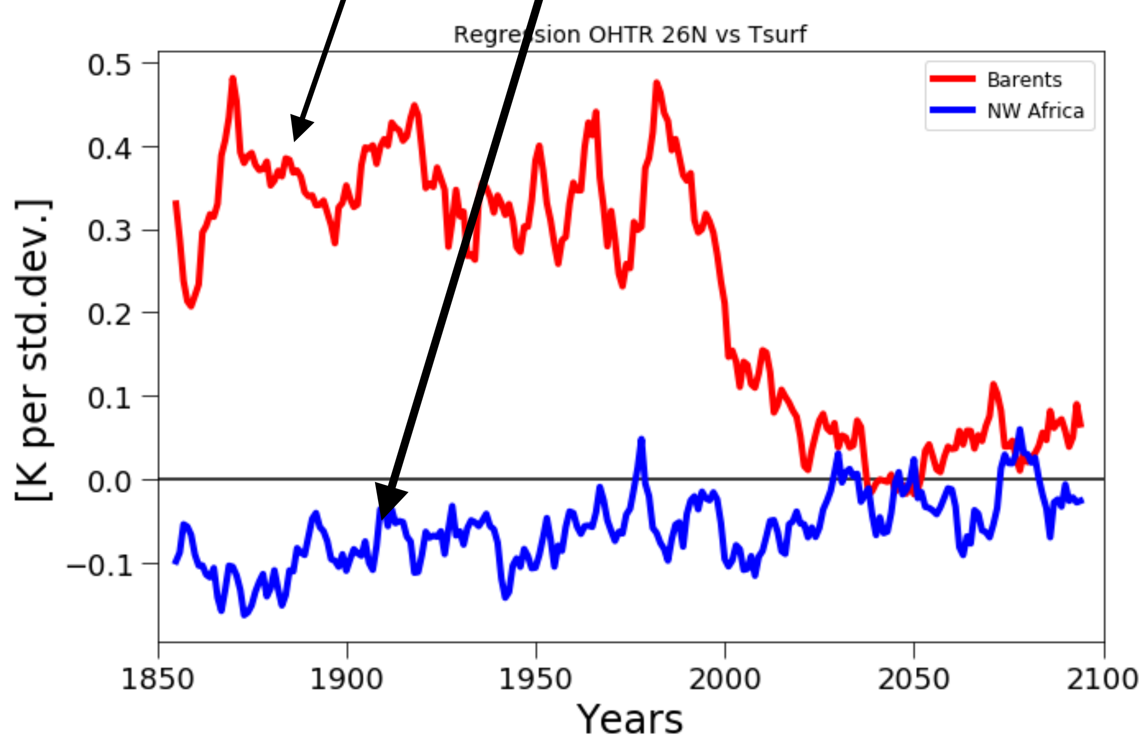




- Subpolar North Atlantic less active in terms of varying ocean heat transport convergence/divergence
- Reduced connection to Barents Sea SSTs and ocean-atmosphere heat exhanges

Changing regression patterns





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Changes in spatial coherence

Do we see changes in remote regions (tele-connections)?

- calculate power and cross spectra for first and last 20 years of 1%CO_2yr^{-1} increase experiment (ensemble here helps to blow up the size of the data set), average over ensembles

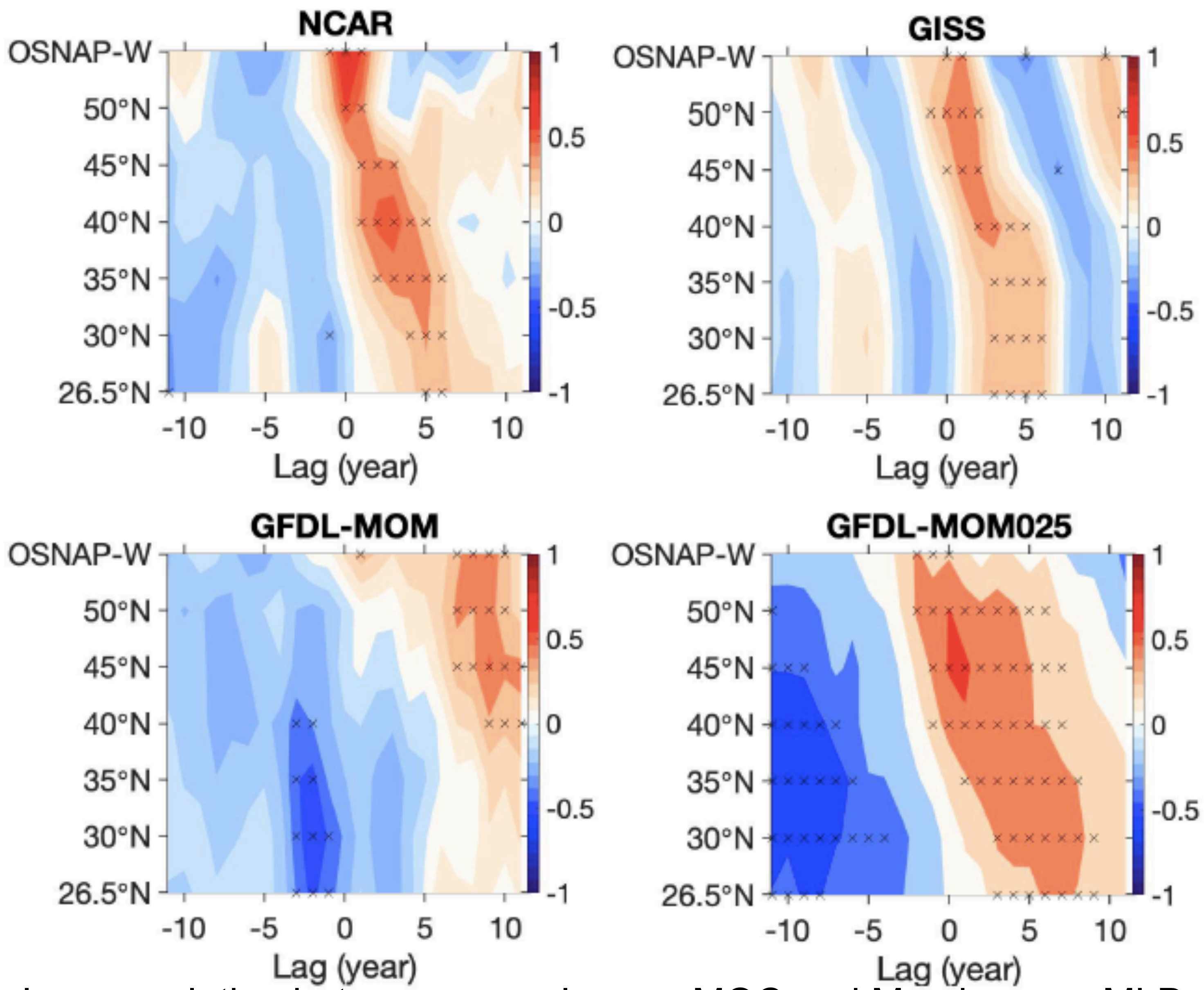
- compare difference in coherence for different periods

- assess significance using random samples from control simulation

Changing coherence

Challenges: How good are our models?

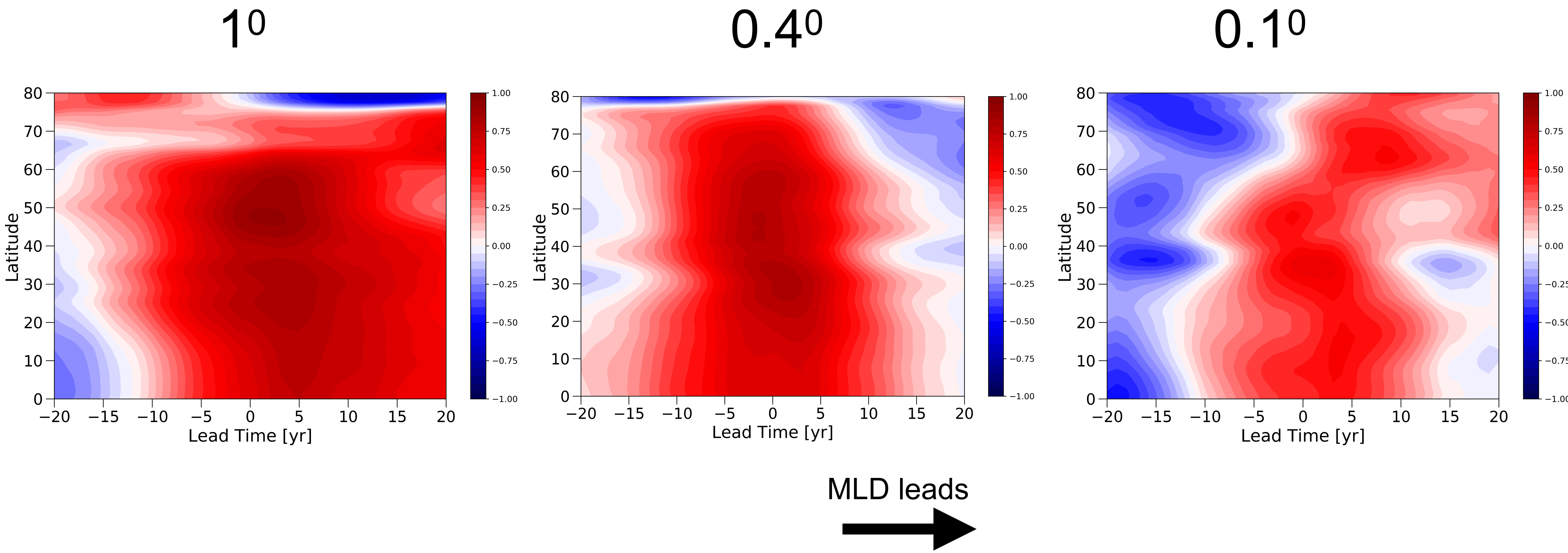
Downstream relationship between LSW formation and AMOC in models



Lag correlation between annual-mean MOC and March-mean MLD, based on the linearly detrended data. MLD leads for positive lags.

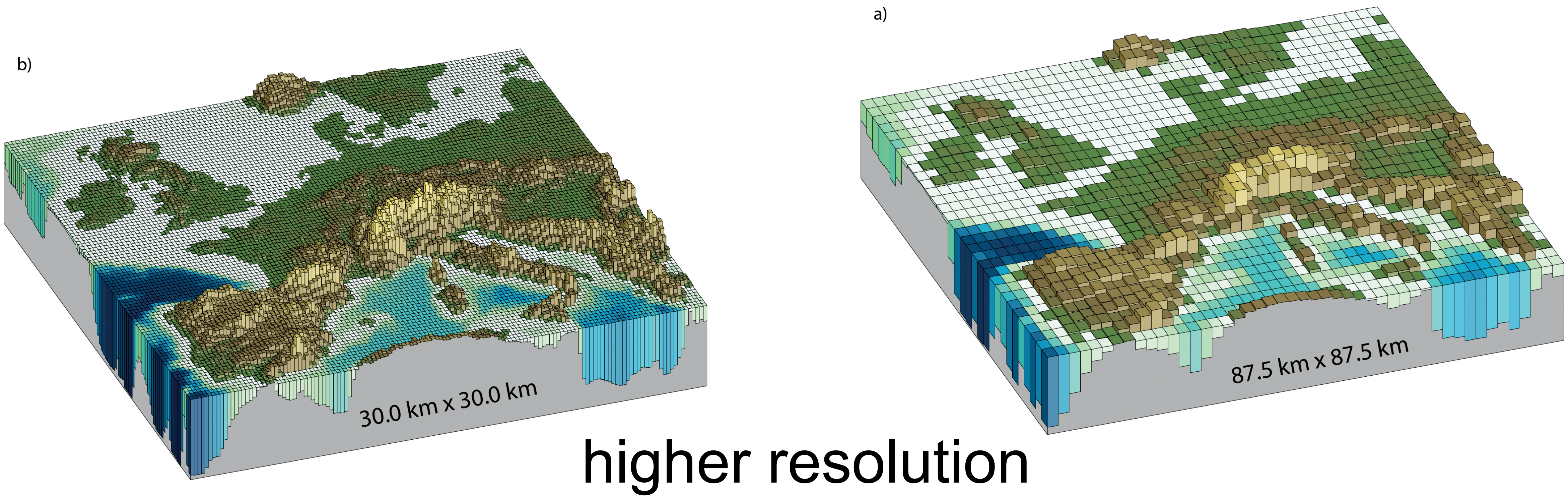
F. Li, JClim, 2019

Downstream relationship between LSW formation and ocean heat transport in MPI-ESM with different ocean resolutions

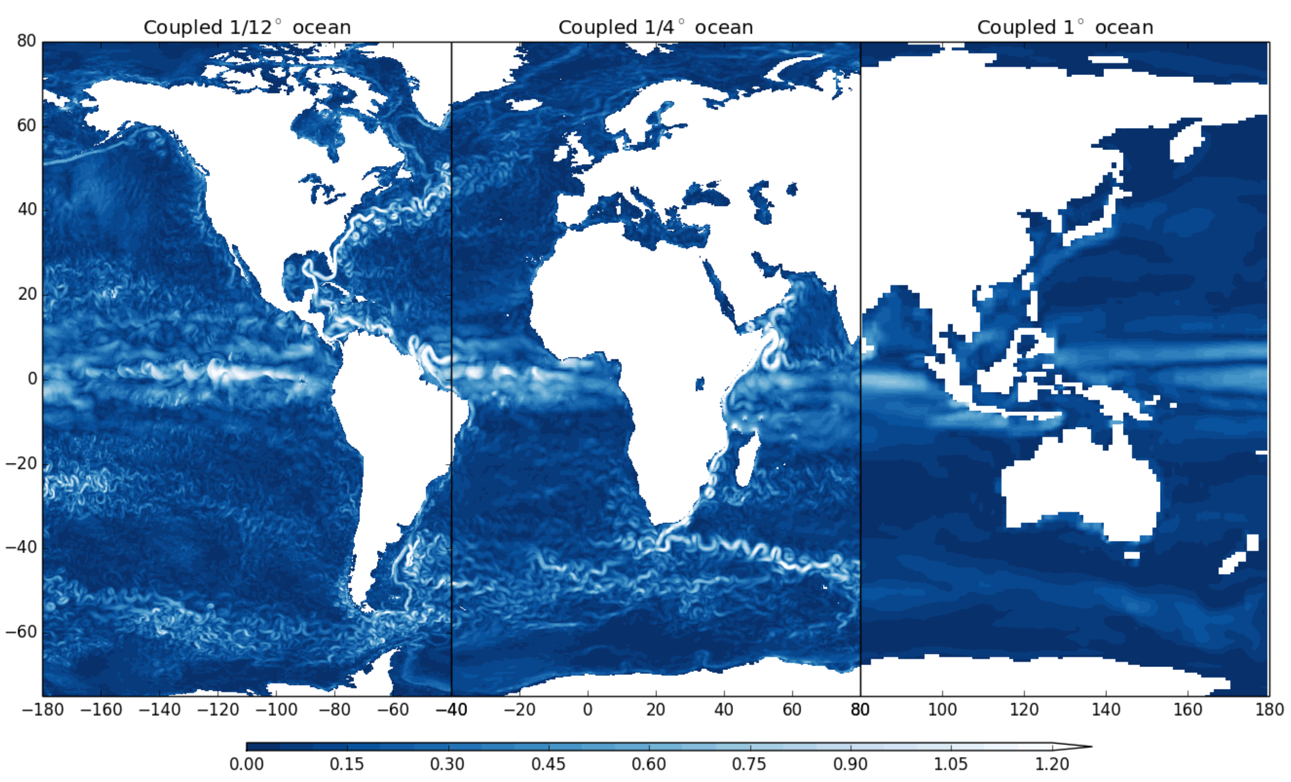


- Substantial differences with ocean resolution; less coherence for higher (eddy-resolving) configurations

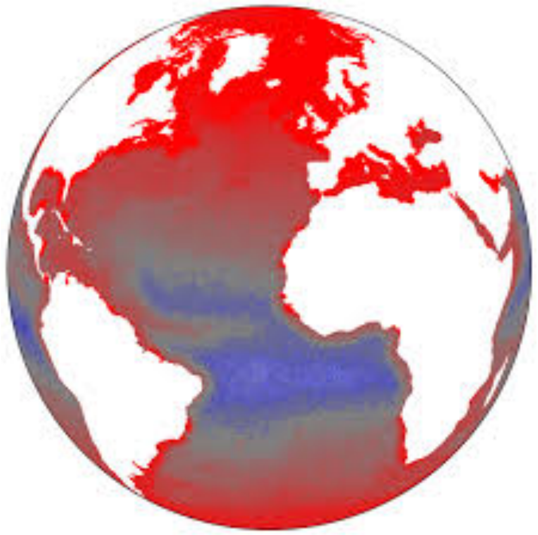
TOWARDS HIGH RESOLUTION COUPLED ESMS



higher resolution



new models with unstructured grids



AWI FESOM, MPI ICON-O

NEMO
MPIOM

PRIMAVERA

Conclusions

- Large ensembles are useful tools for investigations on the relative role of internal variability and forced changes
- At large-enough ensemble sizes, analyses in ensemble space can give important information on temporal evolution and abrupt changes
- Under global warming conditions, both AMOC strength and variability decline in the MPI-ESM Grand Ensemble
- Decline in variability are linked to changes in deep-water formation
- This results in changing surface patterns, ocean heat transport convergence, ocean-atmosphere fluxes, predictability, and tele-connections (work in progress..)
- Results depend on the representation of mean state and variability of Atlantic Circulation in a particular model
- Further research needs to investigate realism of particular processes and the dependence on resolution and model physics