The AMOC's role in the changing relative importance of the North Atlantic and Southern Ocean in anthropogenic ocean heat uptake

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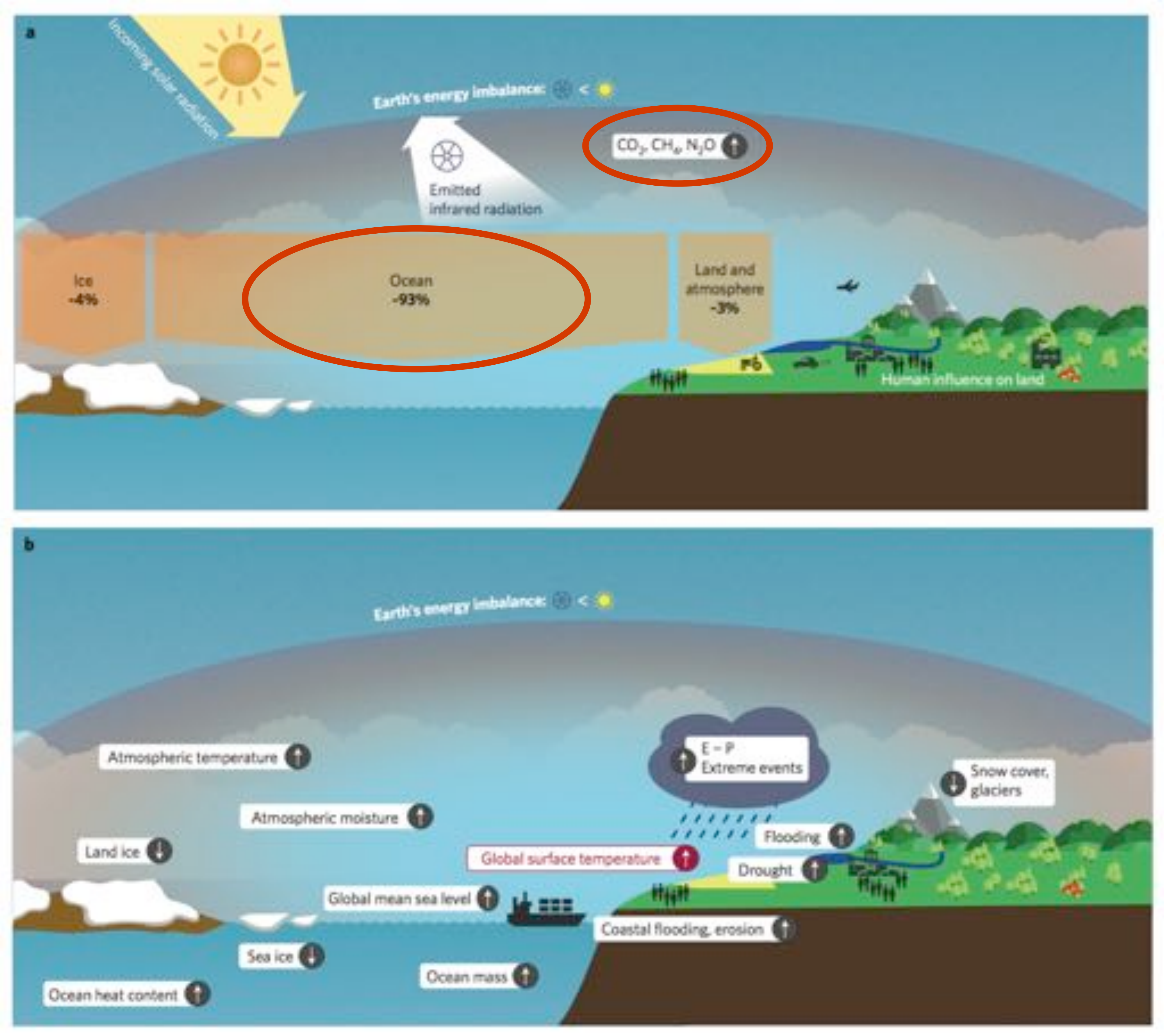
2018 International AMOC Science Meeting, July 26

Shi, J.-R., S.-P. Xie, and L. D. Talley, 2018: Evolving Relative Importance of the Southern Ocean and North Atlantic in Anthropogenic Ocean Heat Uptake. J. Clim. doi:10.1175/JCLI-D-18-0170.1.

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Background: Earth Energy Imbalance



(von Schuckmann et al. 2016)

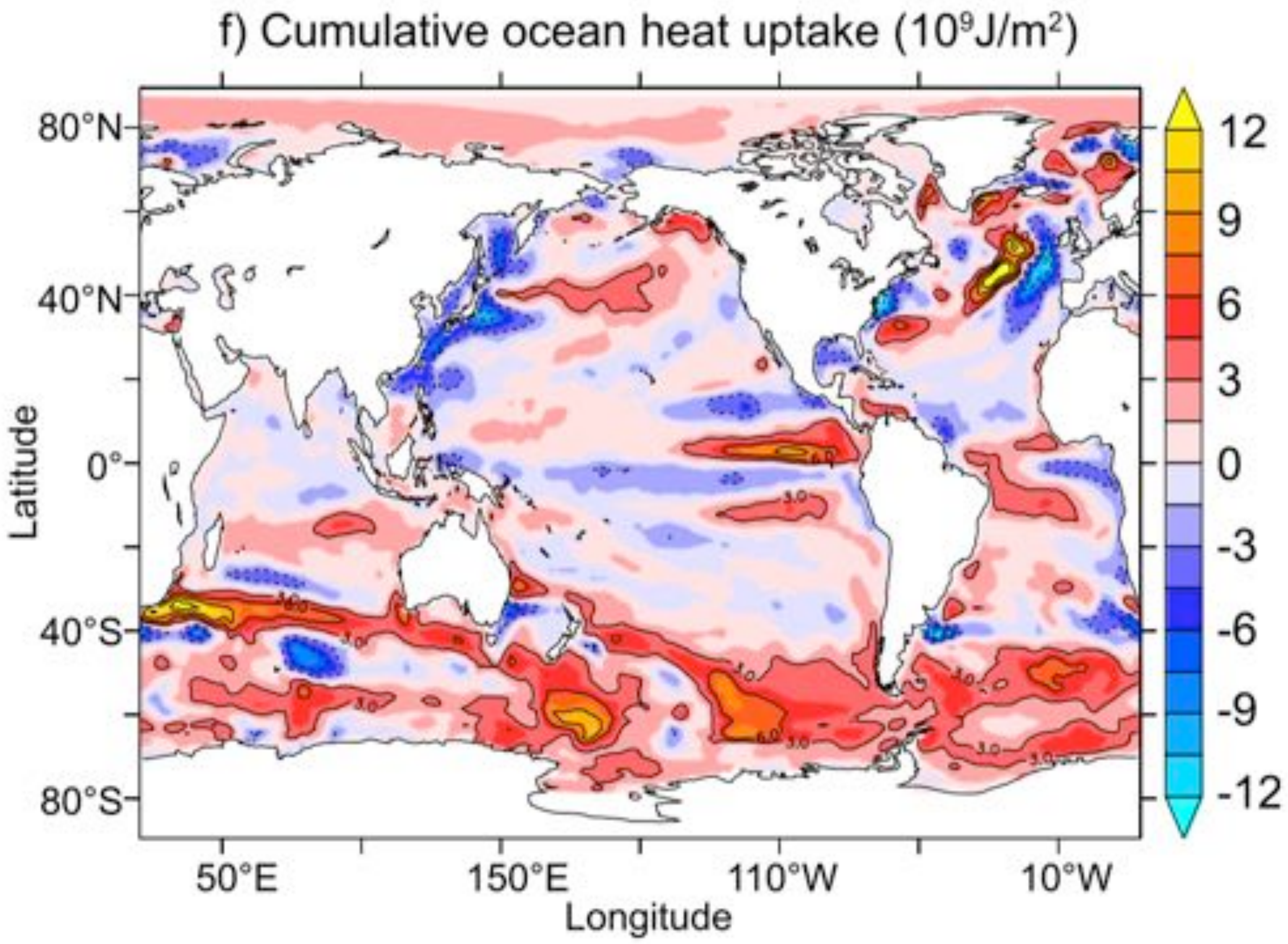
Background:

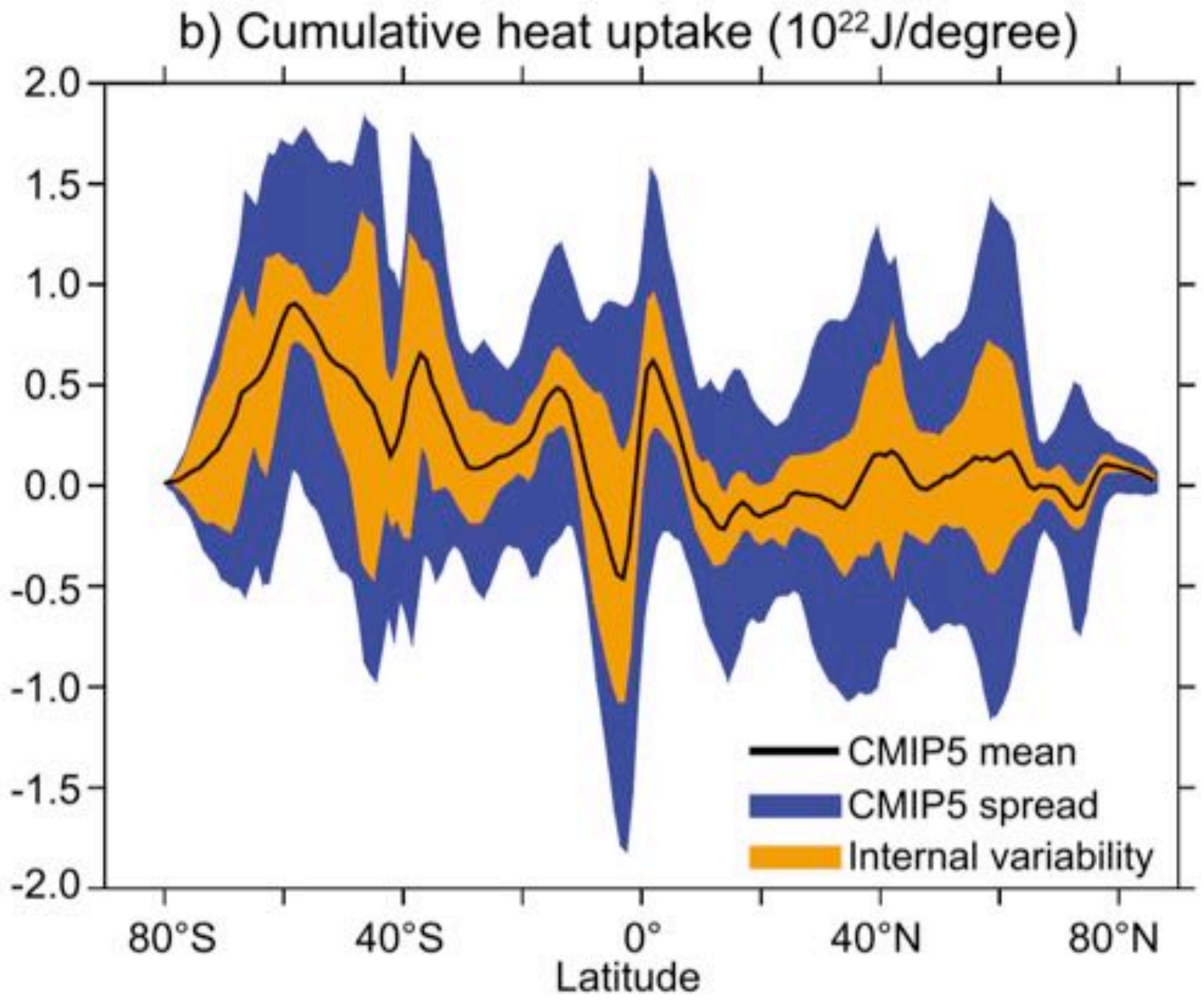
TOA $\xrightarrow{\text{surface heat flux}}$ **OHC change**

The Southern Ocean currently accounting for most of the global (anthropogenic) ocean heat uptake.

Simulation:

(Frolicher et al. 2015)





CMIP5 multimodel mean: Cumulative heat uptake between 1870 to 1995.

Southern Ocean (south of 30˚S) accounts for 75%±22% of global ocean heat uptake over the historical period.

Background:

Observation:

(Roemmich et al. 2015)

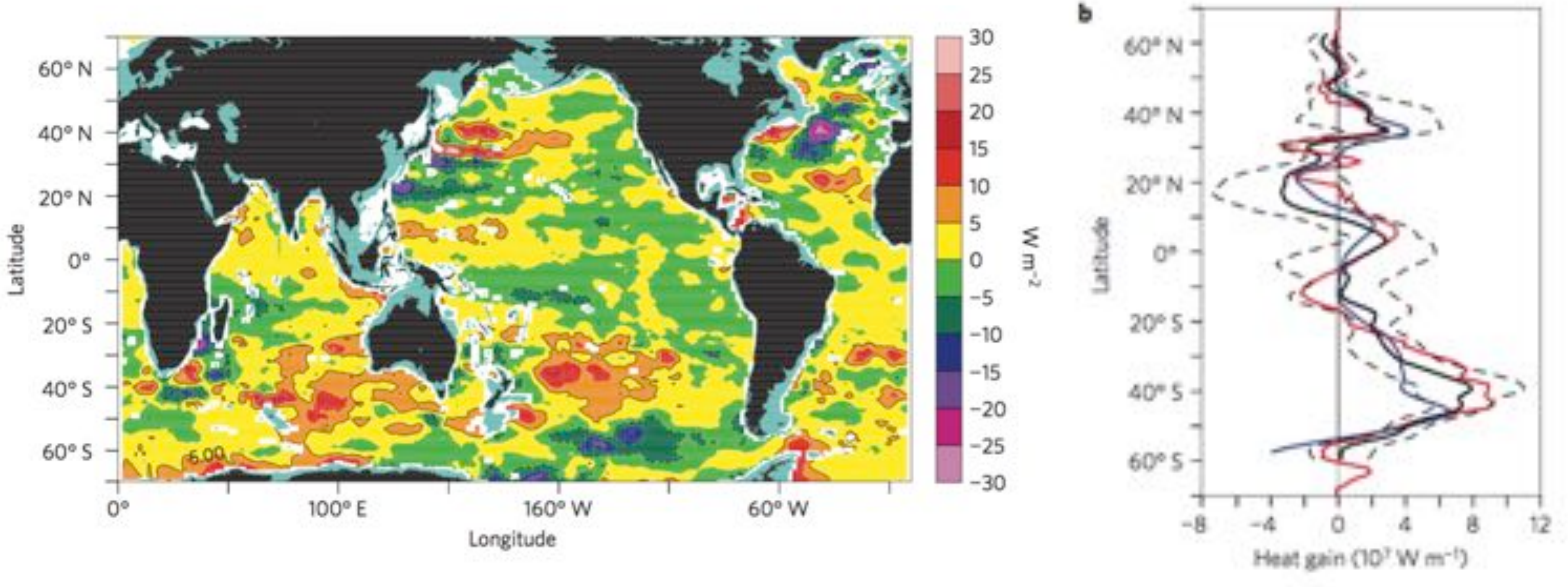


Fig: trend in heat content (0-2000m) through Argo
from 2006 to 2013

Most of heat gain (67%~98%) occurred in the
S.H. extratropical ocean (south of 20˚S)

Background:

(Cheng et al. 2013)

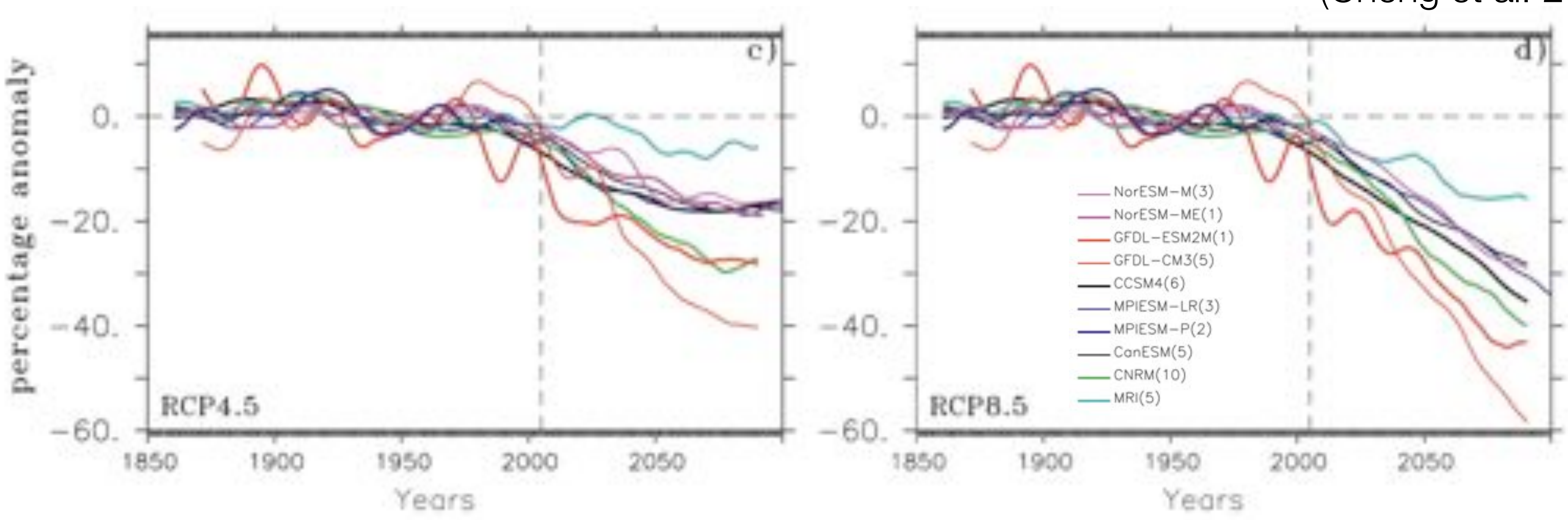


Fig: AMOC intensity from CMIP5 models (1850-2100).

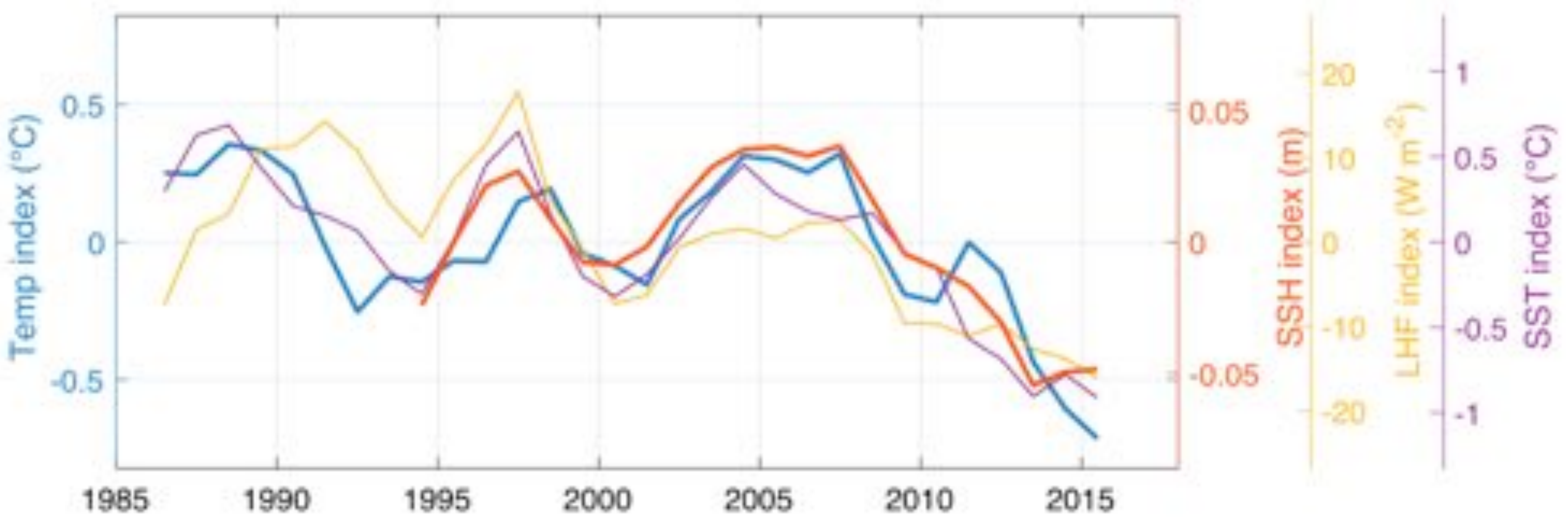


Fig: AMOC index based on observations.

(Smeed et al. 2018)

How does the AMOC affect the regional OHU in response to the anthropogenic radiative forcings?

GHG:

GHG: global warming, global mean surface temperature (GMST) ↗

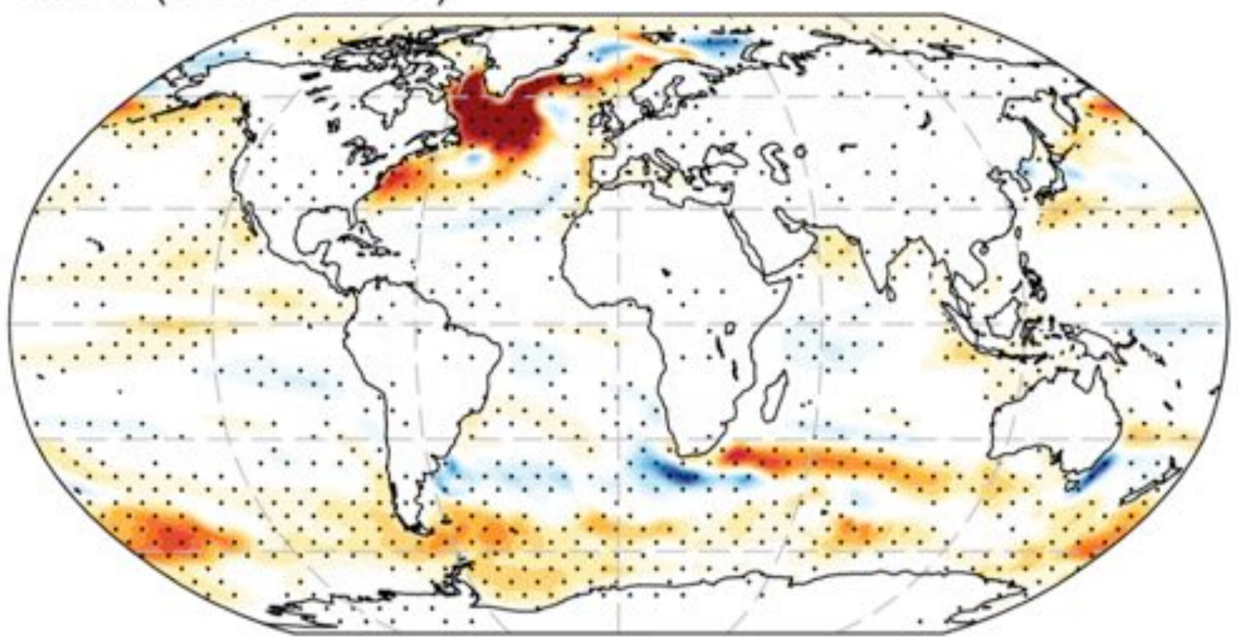
→ **Ocean heat uptake in response to perturbed GHGs or CO_2. (Bryan et al. 1988; Manabe et al. 1990, 1991; Kuhlbrodt and Gregory 2012; Marshall et al. 2015; Armour et al. 2016)**

Q: Does the GHG determine the response pattern of ocean heat uptake over the historical period?

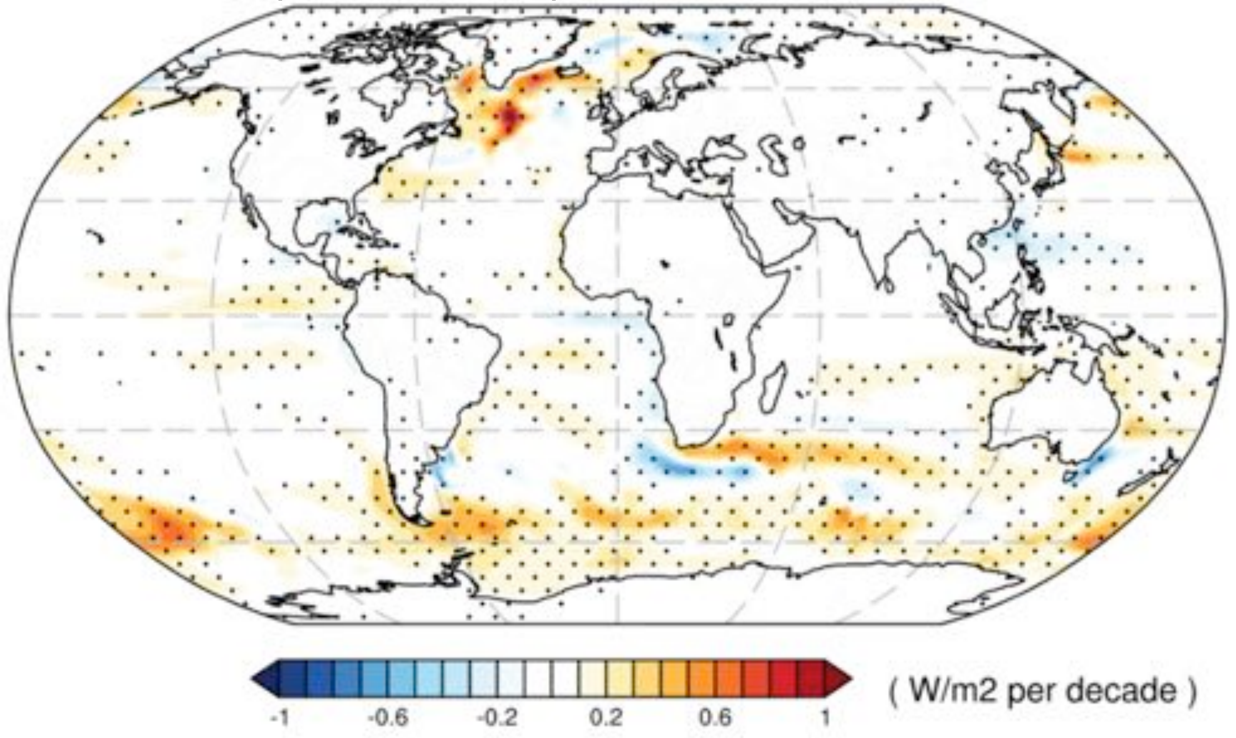
Response of surface heat flux:

Ensemble mean of 9 CMIP5 models:

GHG (1861-2005)



Historical (1861-2005)



Area-integration over:

NA: 30˚N-70˚N, 80˚W-10˚W
SO: south of 30˚S

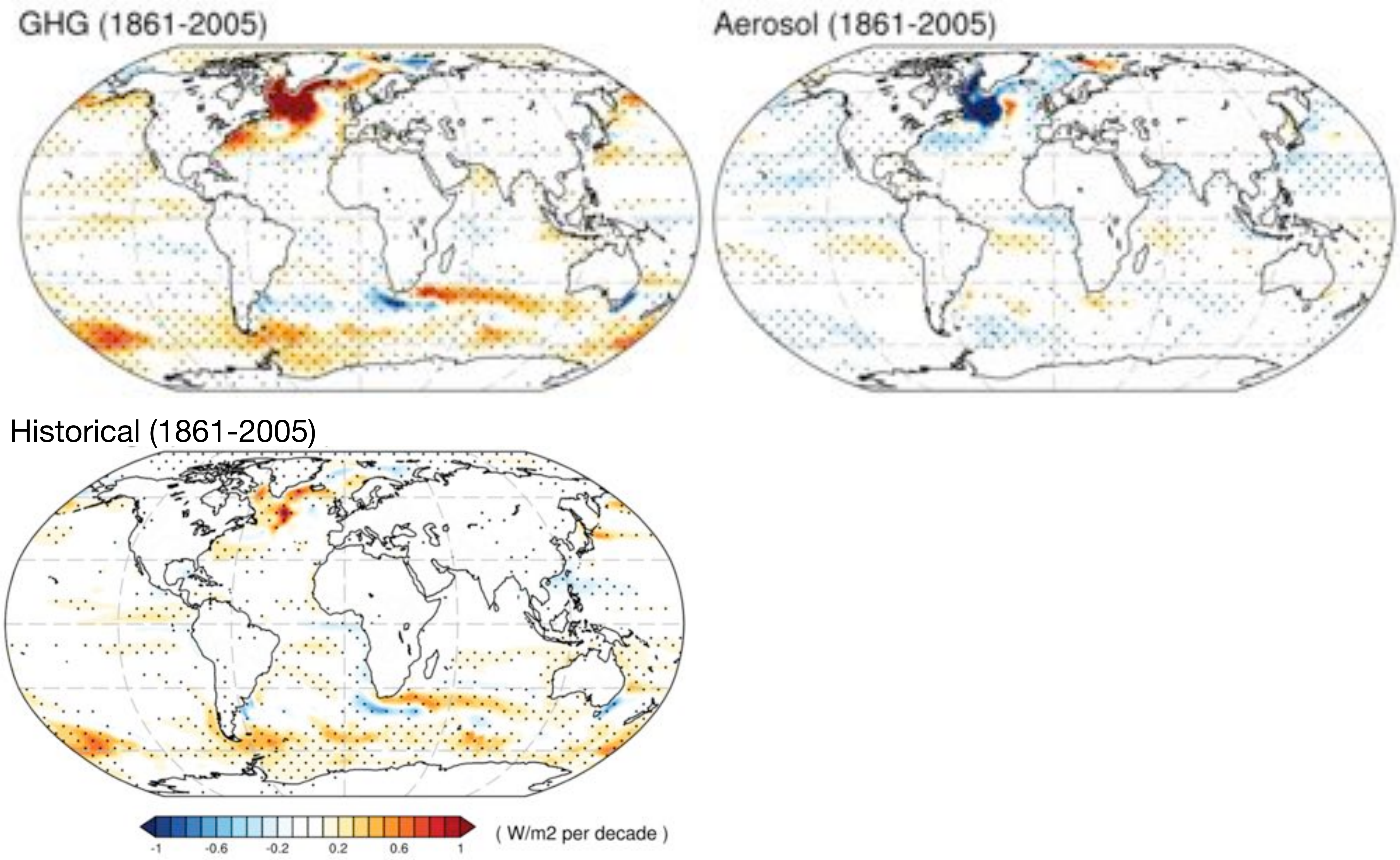
Cumulative Heat Uptake over the 20th century:

NA: 24%±11%
SO: 45%±10%

NA: 6%±39%
SO: 72%±28%

Response of surface heat flux:

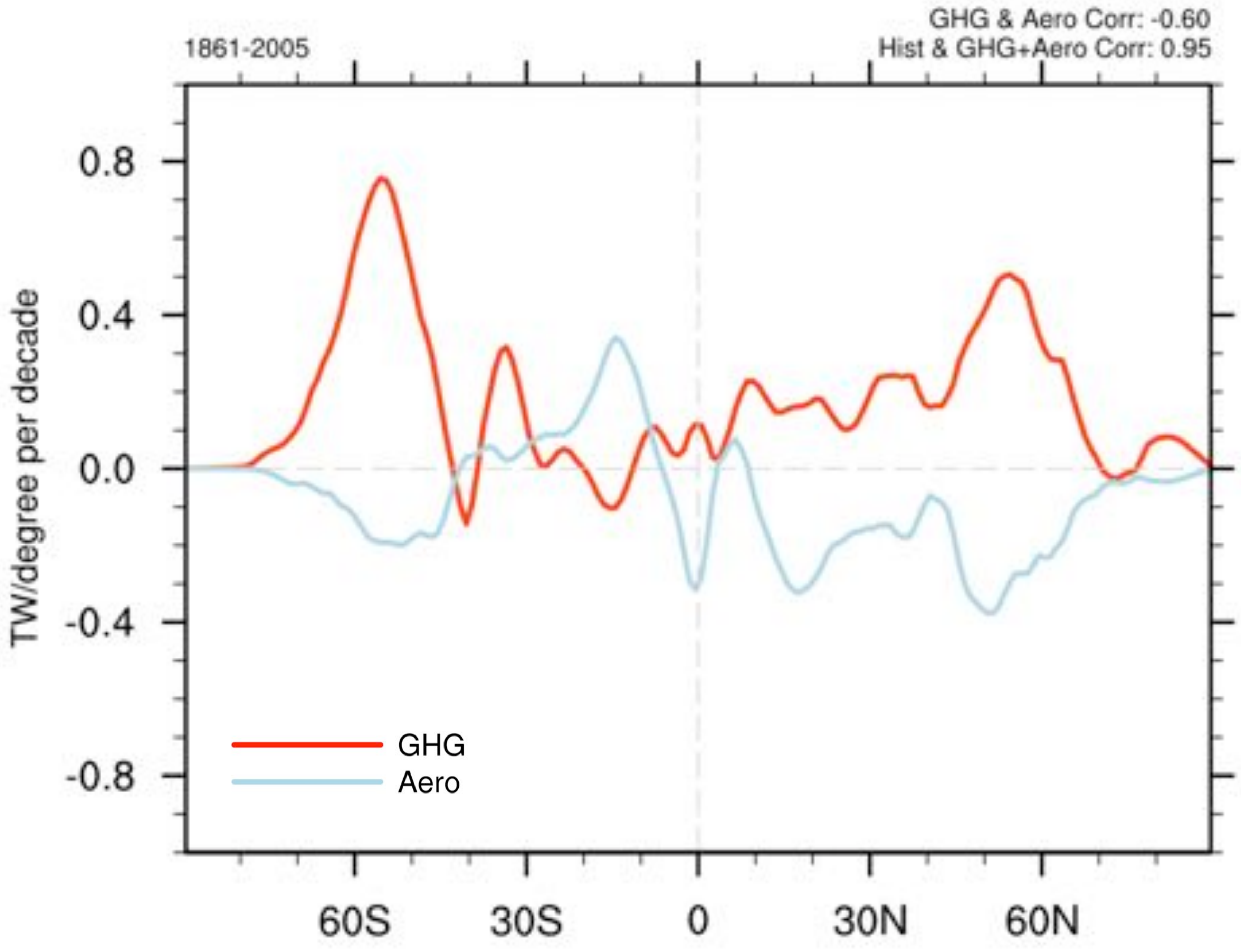
Ensemble mean of 9 CMIP5 models:



Response of surface heat flux:

Ensemble mean of CMIP5 models:

Zonally integrated heat flux trend



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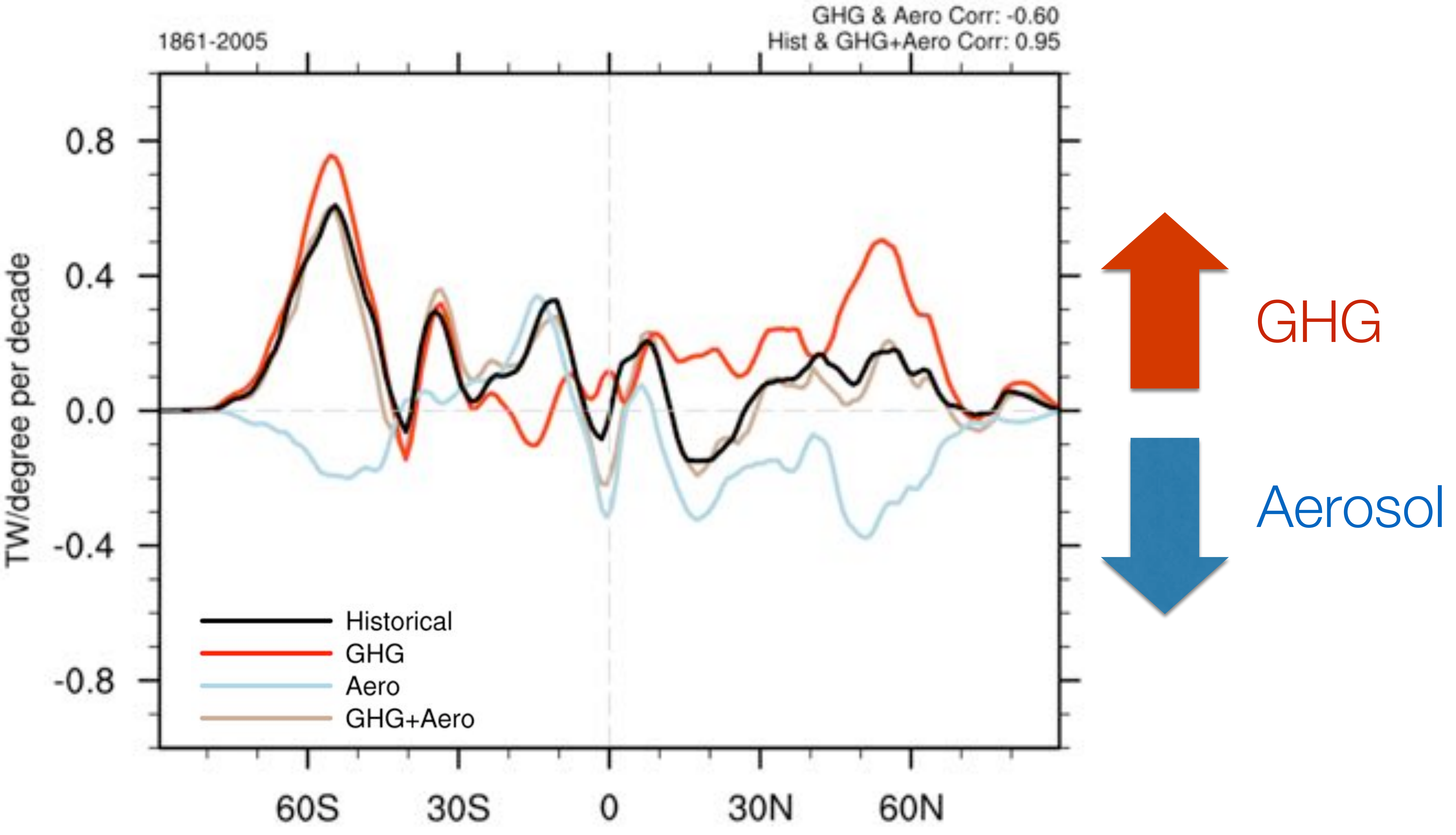
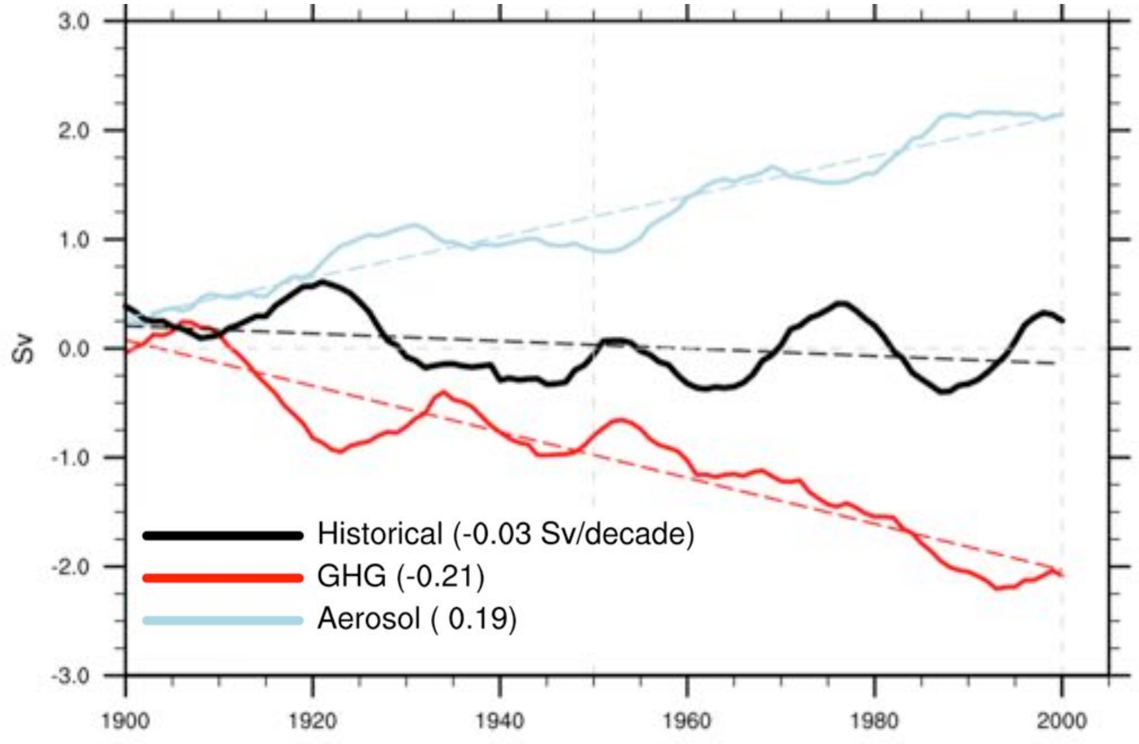


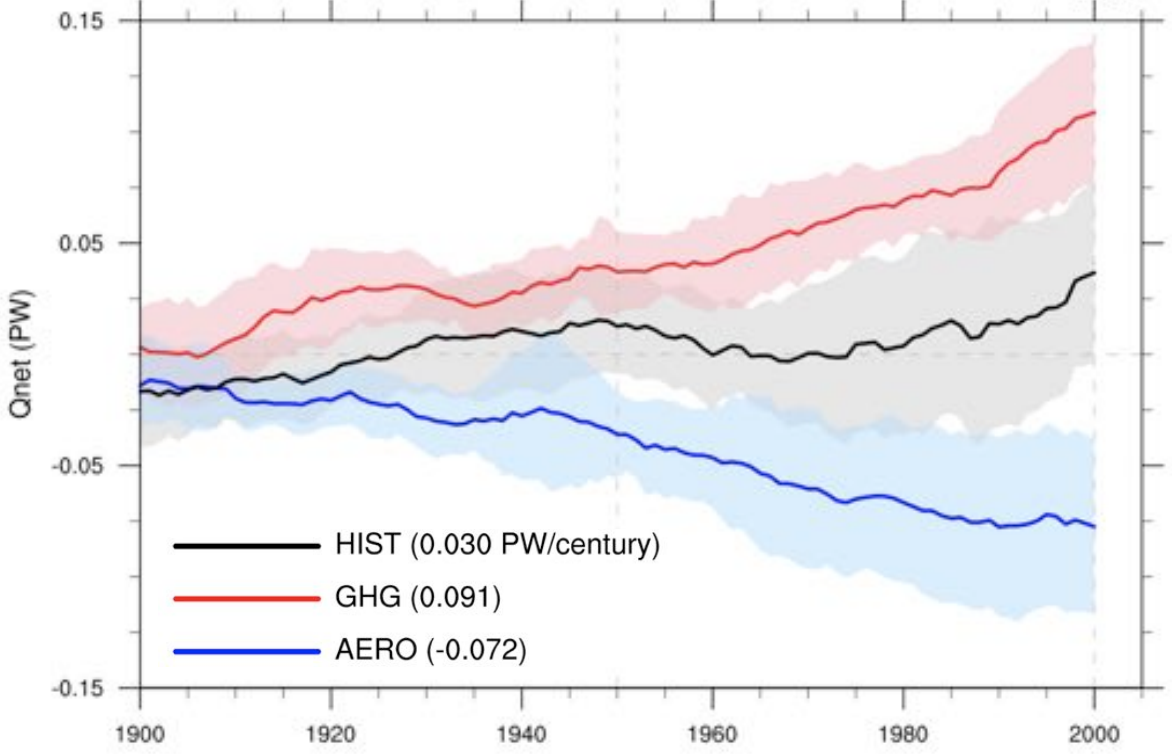
Ocean circulation impact:

NA: the AMOC change

AMOC anomaly from CMIP5



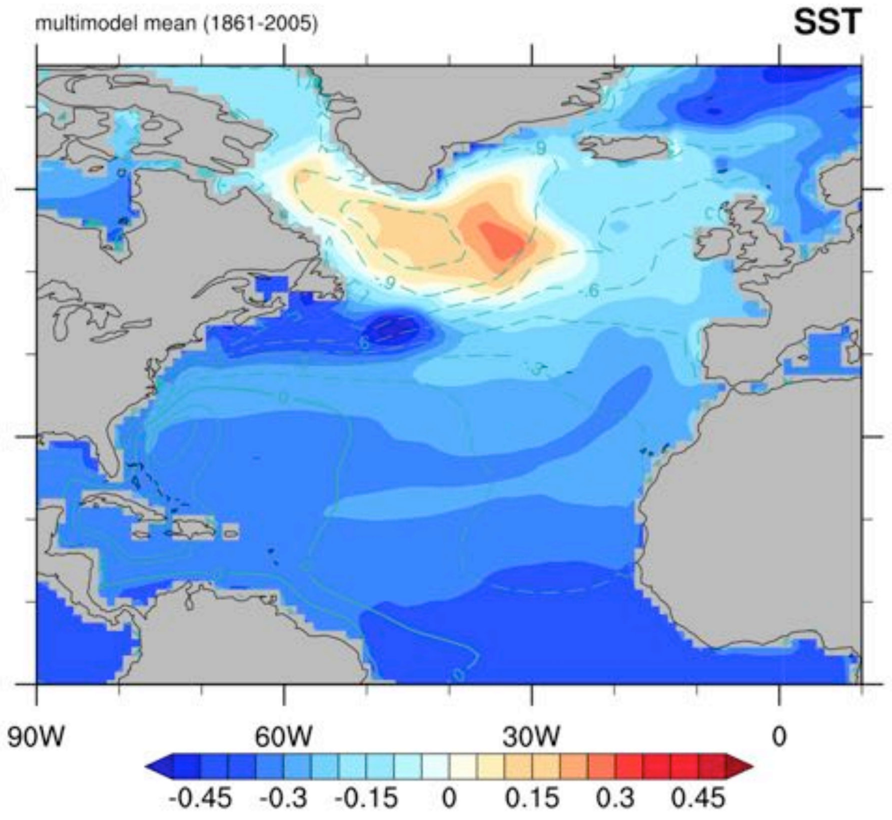
Heat uptake NA



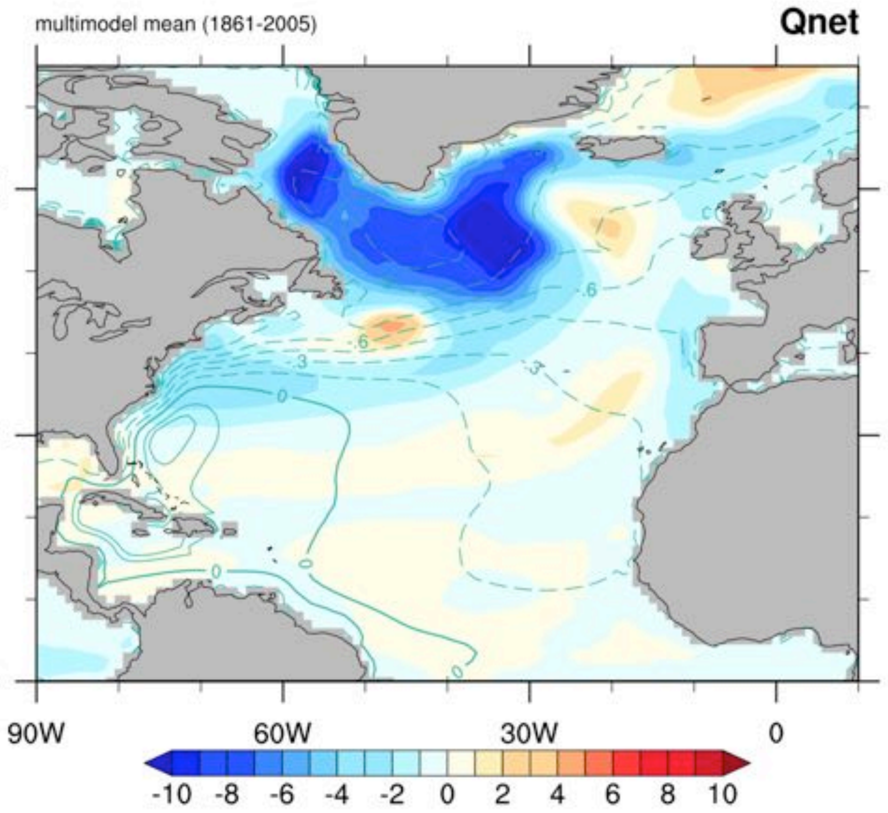
SO: mean ocean circulation (Marshall et al. 2015; Liu et al. 2018)

Regression maps of the North Atlantic (a) SST and (b) surface heat flux (Qnet) anomalies on the AMOC intensity.

a)



b)



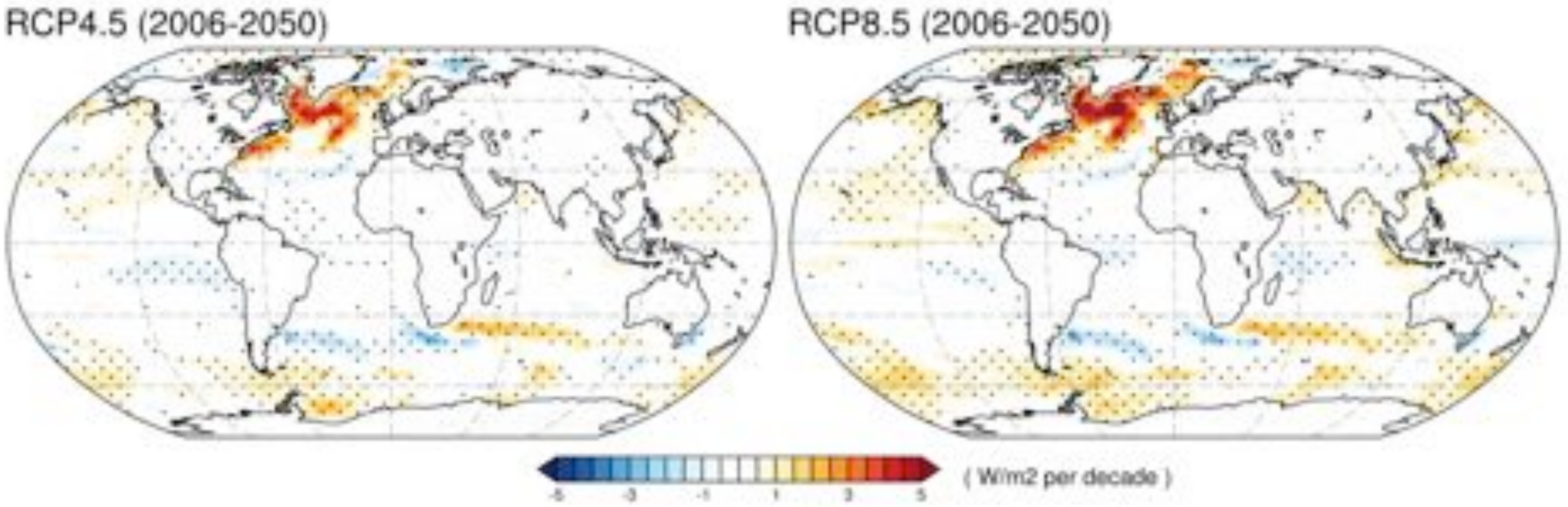
Future projections:

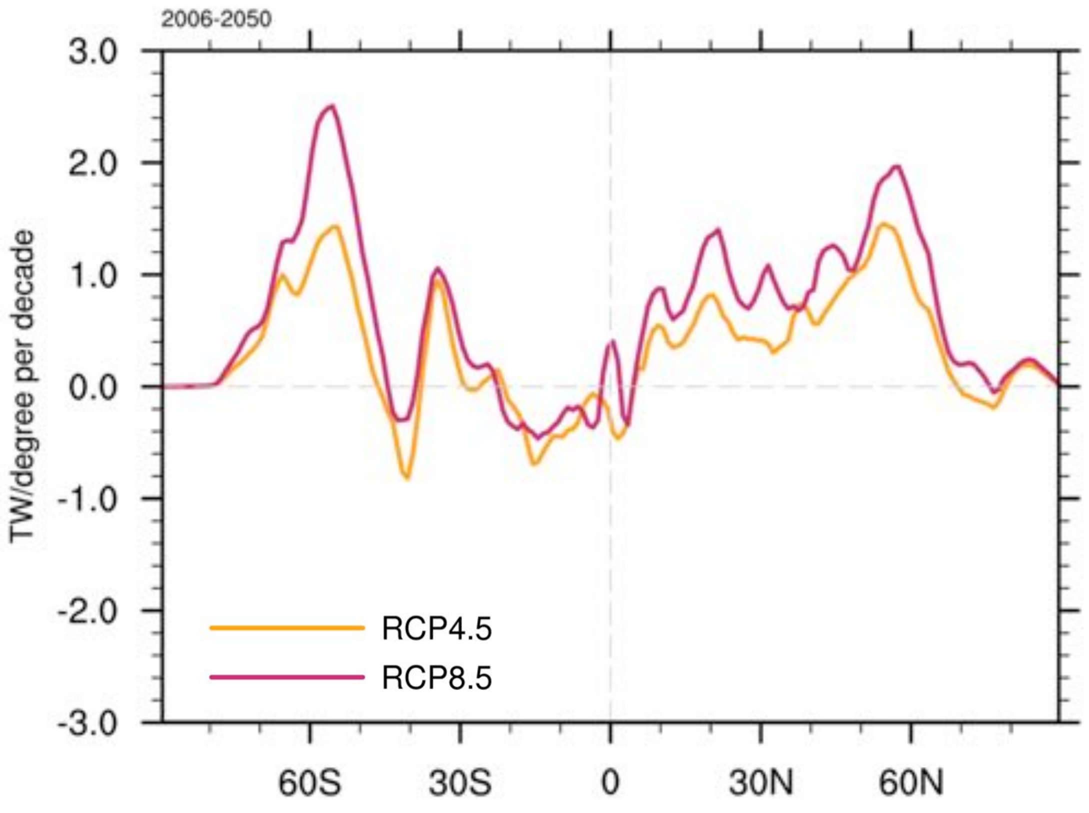
In future projections, will the ocean heat uptake pattern be similar with that in the Historical runs?

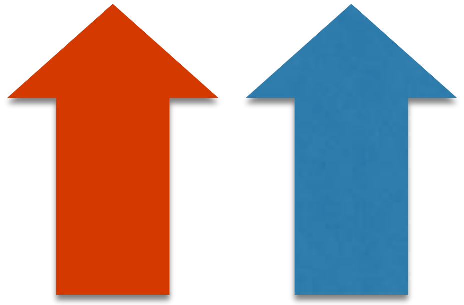
Future projections:

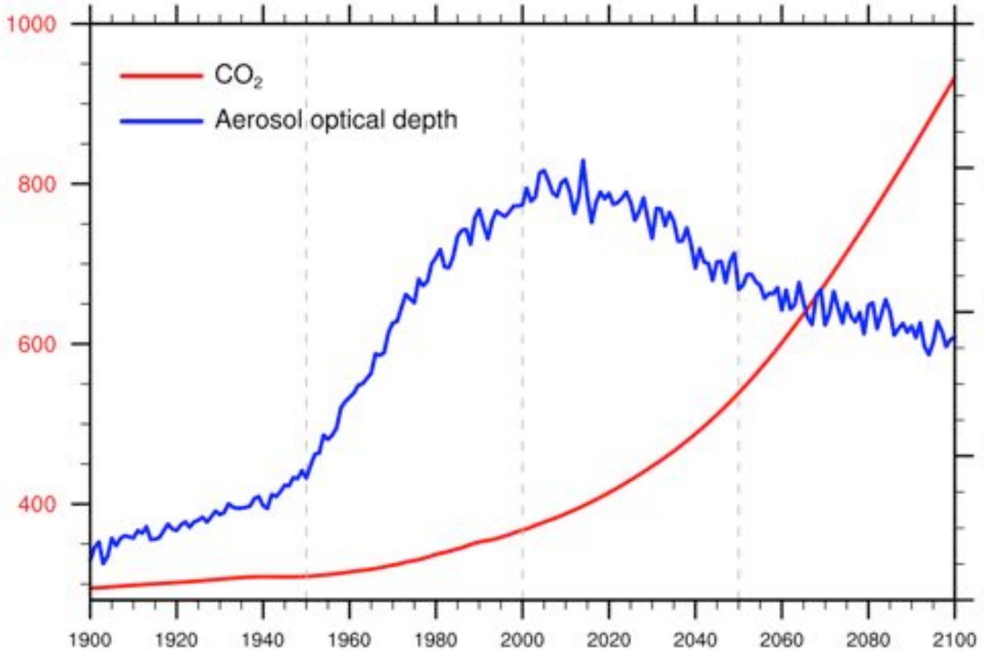
Ensemble mean of CMIP5 models:

Surface heat flux trend



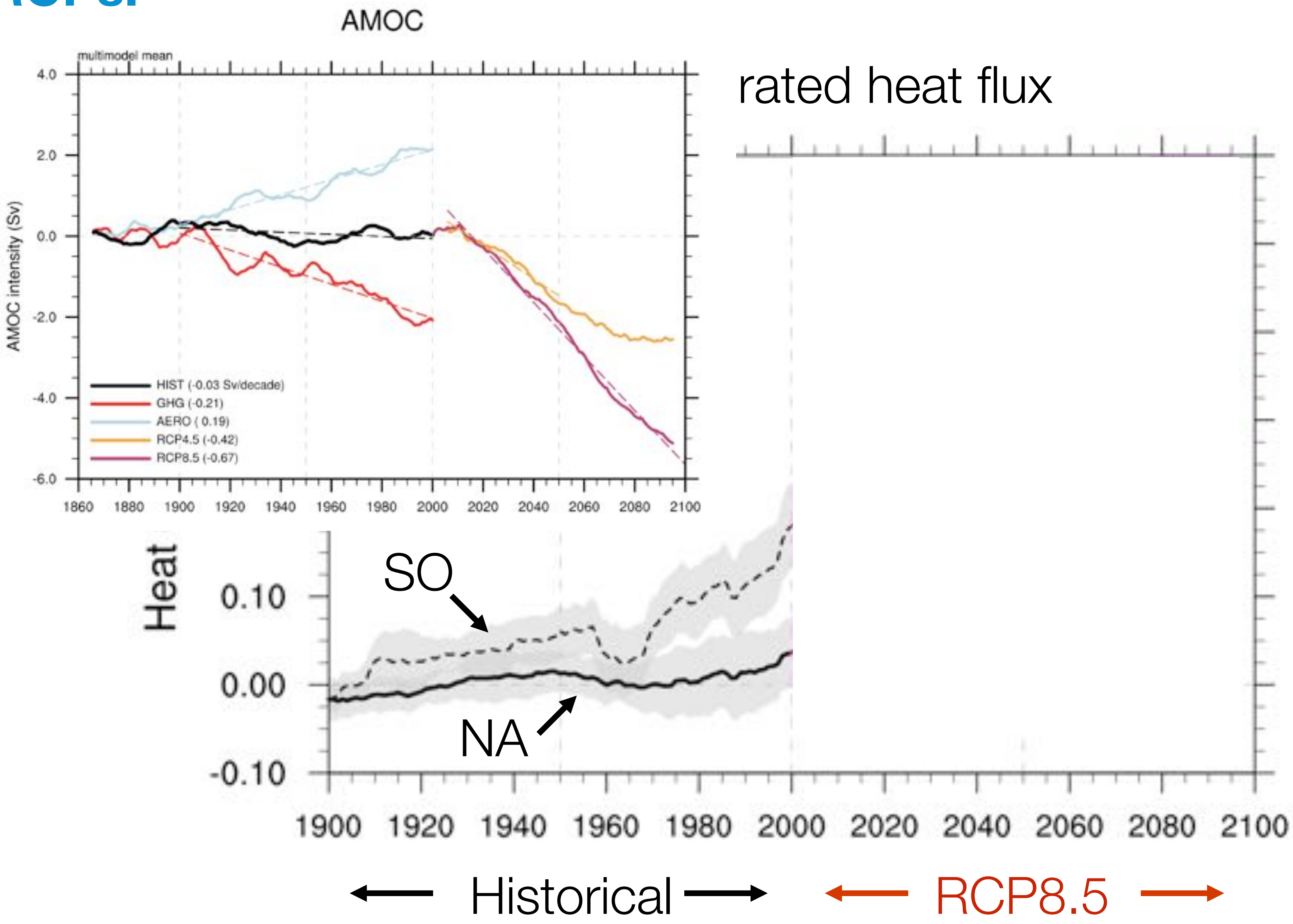






GFDL-CM3

Hist vs RCPs:


AMOC
multimodel mean
AMOC intensity (Sv)
4.0
2.0
0.0
-2.0
-4.0
-6.0
1860 1880 1900 1920 1940 1960 1980 2000 2020 2040 2060 2080 2100
HIST (-0.03 Sv/decade)
GHG (-0.21)
AERO (0.19)
RCP4.5 (-0.42)
RCP8.5 (-0.67)
rated heat flux
Heat
0.10
0.00
-0.10
SO
NA
1900 1920 1940 1960 1980 2000 2020 2040 2060 2080 2100
Historical
RCP8.5

SO vs NA:

Contribution to global ocean heat uptake

Cumulative OHU (ZJ)	Historical	RCP4.5	RCP8.5
SO/Global	190±81 (72%) →	829±145 (52%)	1187±208 (48%)
NA/Global	16±82 (6%) →	443±114 (28%)	632±115 (26%)

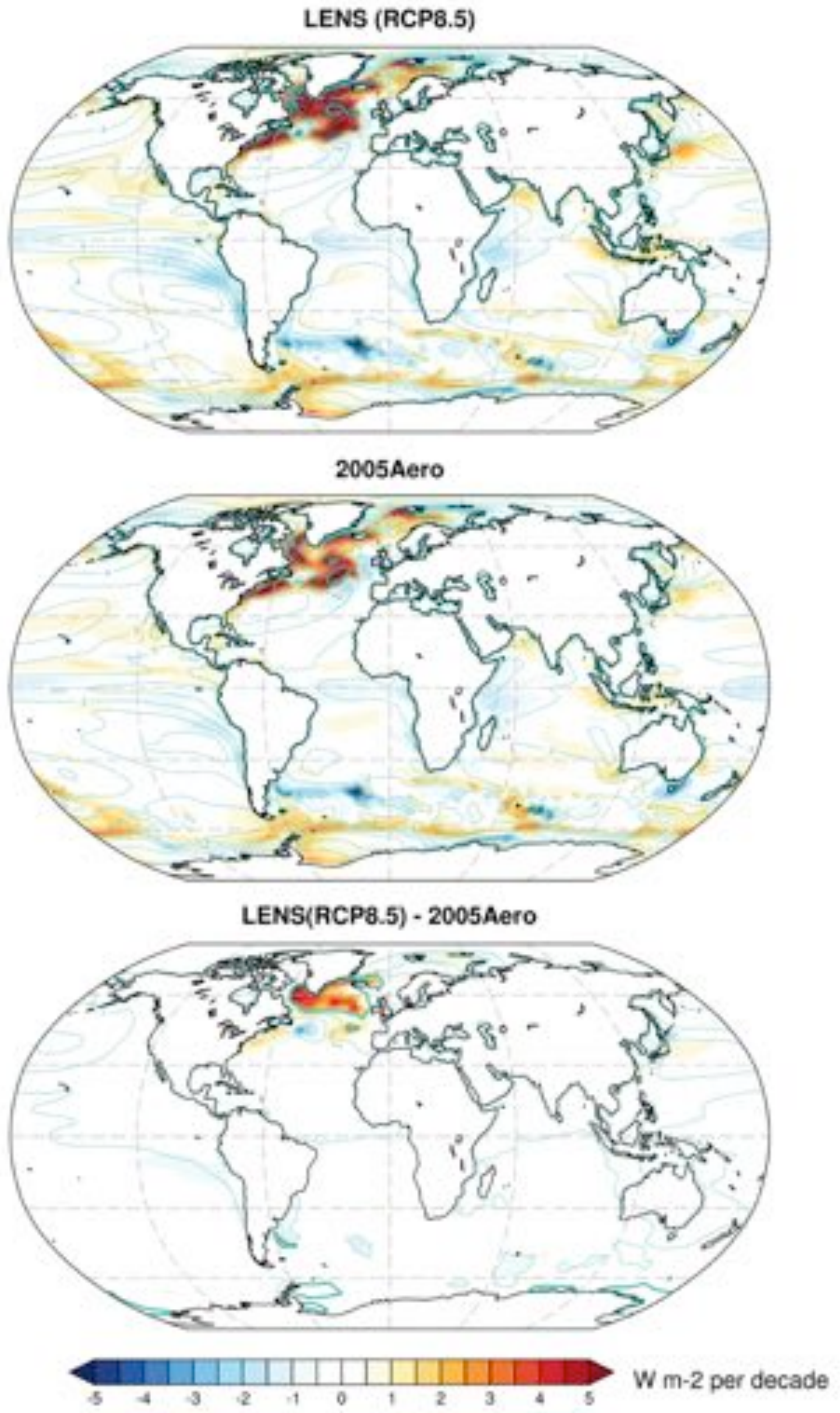
The relative importance of SO & NA vary between Hist/RCPs:

different spatial distributions and trajectories of GHG and aerosol radiative forcing.

Contribution of declining aerosol:

Simulations: A) **LENS**: Large Ensemble from CESM (1920 - 2100, Historical & RCP8.5)

B) **2005Aero**: RCP8.5 with anthropogenic aerosol emissions fixed at 2005-level



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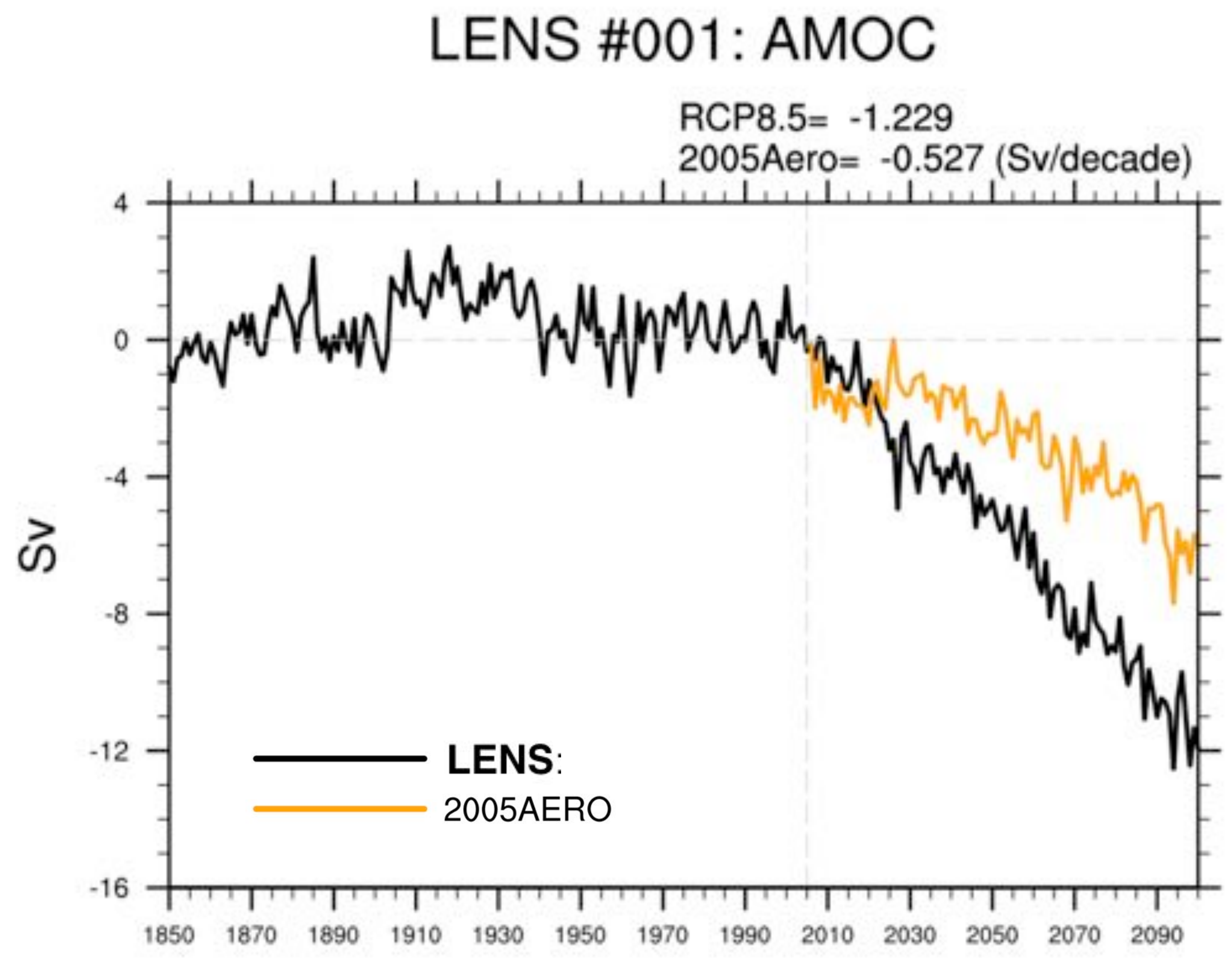
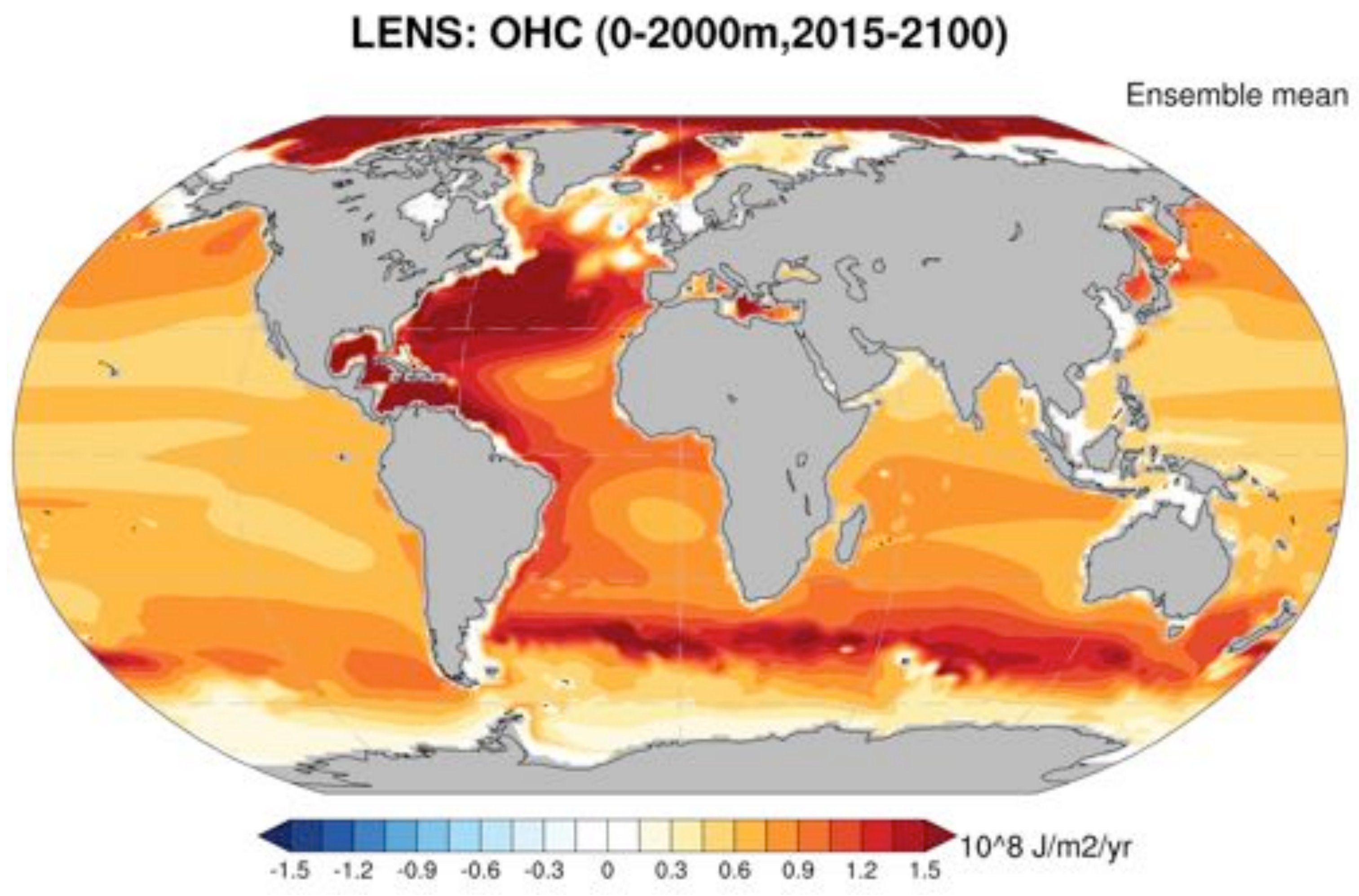


NA heat uptake (2006-2100):

712±22 ZJ => 503±17 ZJ (decrease by 29%)

~**15%** of global heat uptake
is attributed to declining aerosol.

Future projections: 2015-2100



Summary:

1. The **AMOC change** in response to the anthropogenic radiative forcing is associated with the North Atlantic heat uptake by affecting the meridional heat advection.

2. **Less aerosols and higher GHG concentrations** will weaken the circulation and strengthen the heat uptake in the North Atlantic, which will join the Southern Ocean into the future as a major repository of anthropogenic heat.