Historical forcings as Main Drivers of the Atlantic Multidecal Variability in the CESM Large Ensemble

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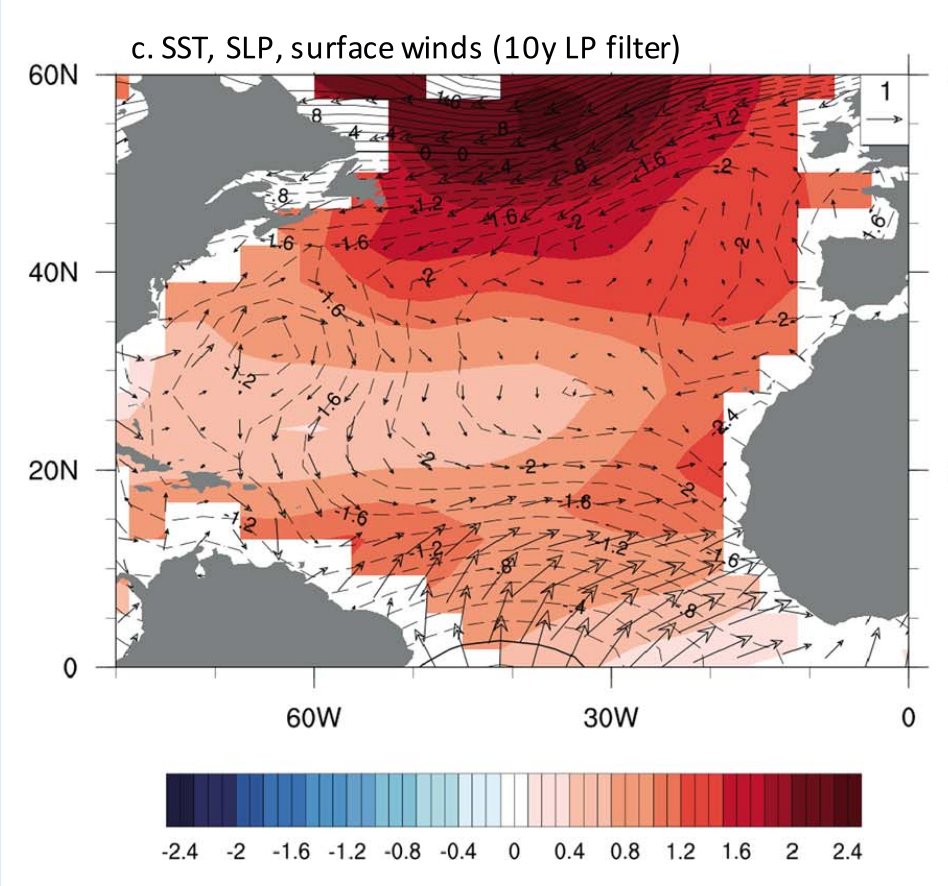
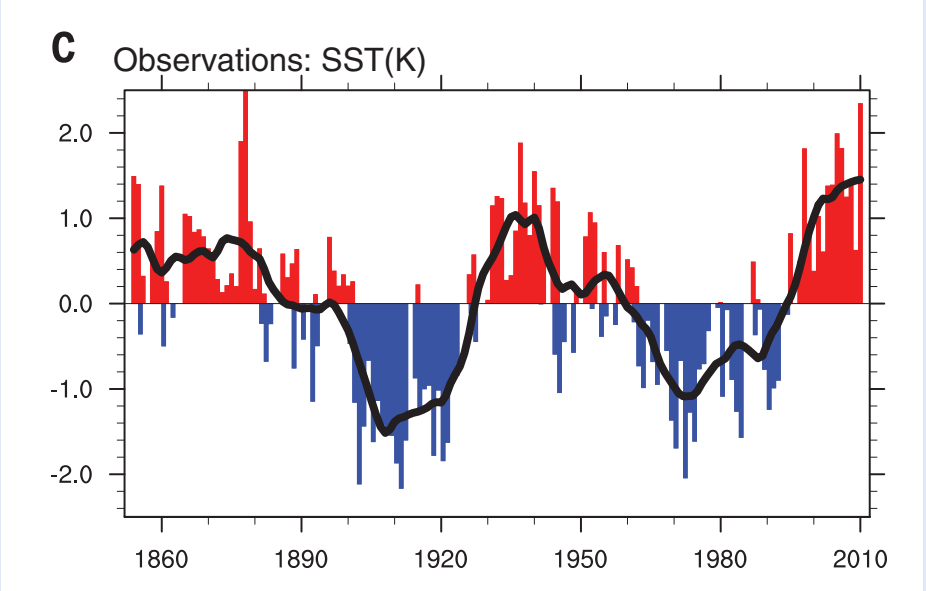
The Atlantic Multidecadal Variability (AMV) is the dominant mode of climate variability in the North Atlantic and affects temperature, rainfall and hurricanes on decadal timescales and longer





What drives the multidecadal departures of the AMV?

Internal climate variability

- The North Atlantic Oscillation (NAO) drives changes in the AMOC, which then affects SST (e.g., Delworth et al. 2017, Peings et al. 2016)
- The NAO drives changes in surface heat fluxes which are then stored into the oceanic mixed layer (e.g., Clement et al. 2015, Seager et al. 2000)

External radiative forcings

- Anthropogenic (e.g. aerosols and GHG) or natural (e.g. volcanoes) forcings (e.g., Murphy et al. 2017, Booth et al. 2012, Ottera et al. 2010)

- Observations: ERSSTv4

- CESM Large Ensemble, 1920-2005, 42 historical ensemble members with prescribed historical forcings, initialized from different atmospheric initial conditions

Internal Variability:

- CESM preindustrial control
- CESM Large Ensemble minus ensemble mean ("de-meaned")

External Forcing:

Large Ensemble mean

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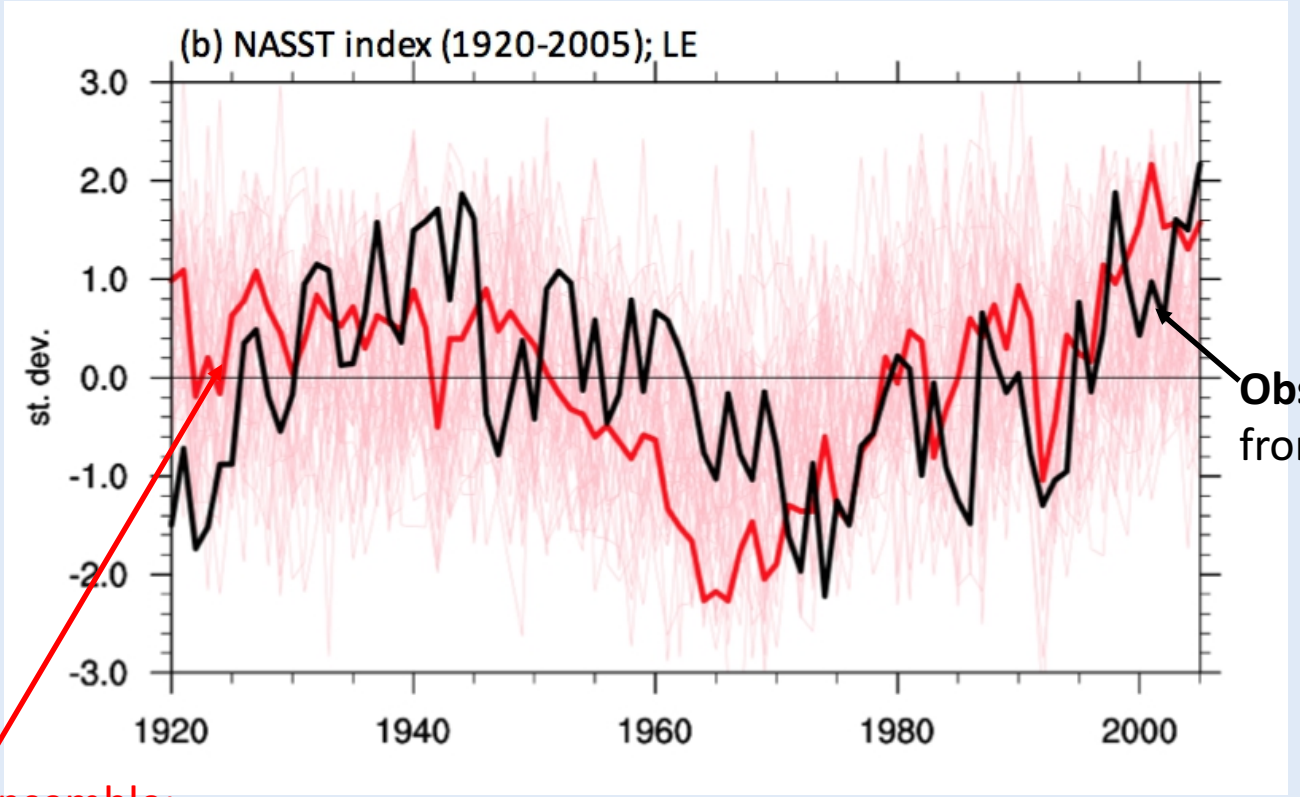
Large Ensemble mean

North Atlantic SST (NASST) index

Detrended = To remove the mean warming trend, remaining forcing due to tropospheric + stratospheric aerosols, ozone, solar, land use, orbital forcings

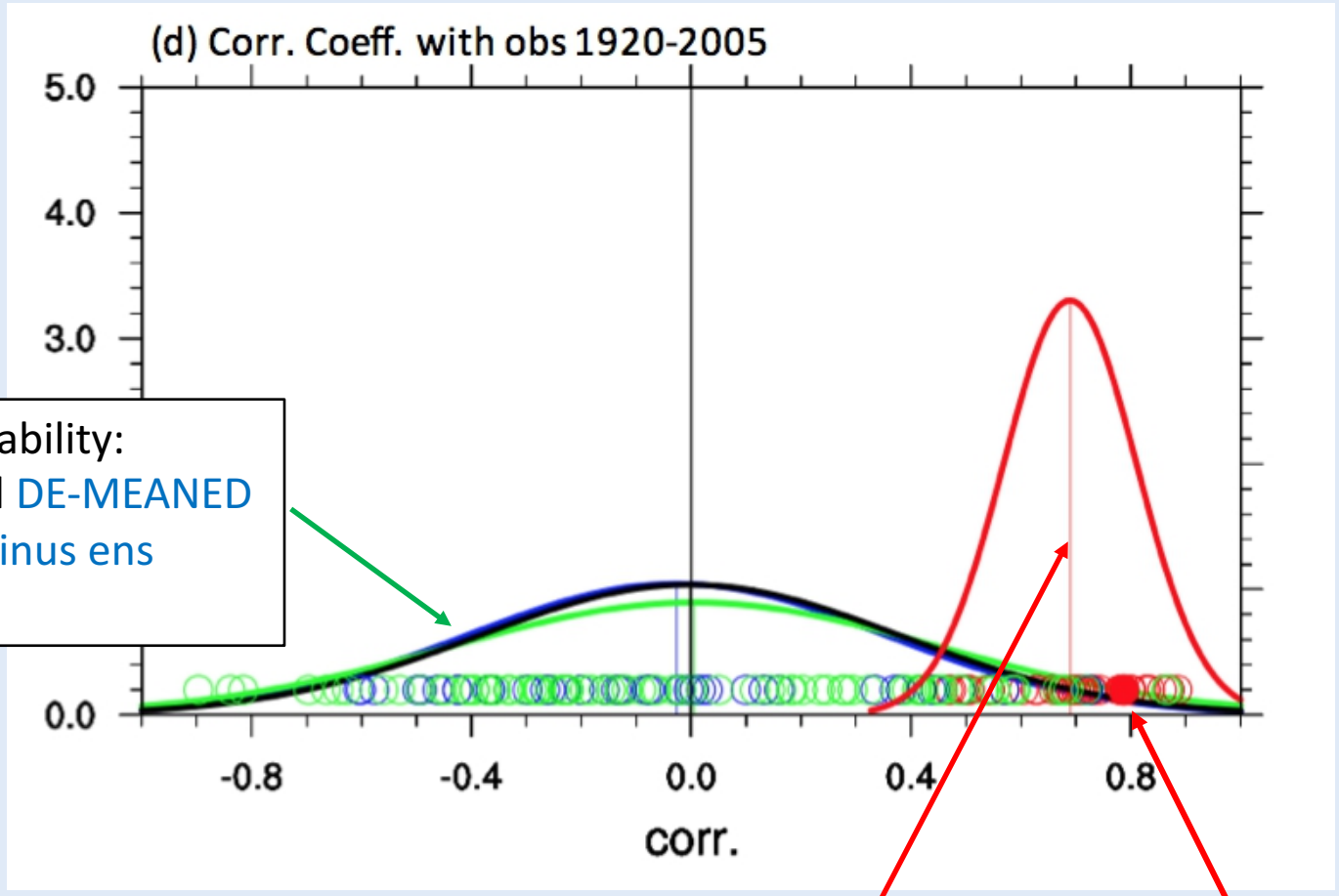


Observations: SST from ERSSTv4

CESM Large Ensemble:
1920-2005 historical forcings, 42 members
Ensemble Mean = isolates the externally forced variability

20 year Low-Pass filter (AMV index) = To examine multidecadal variability

Correlations with obs.

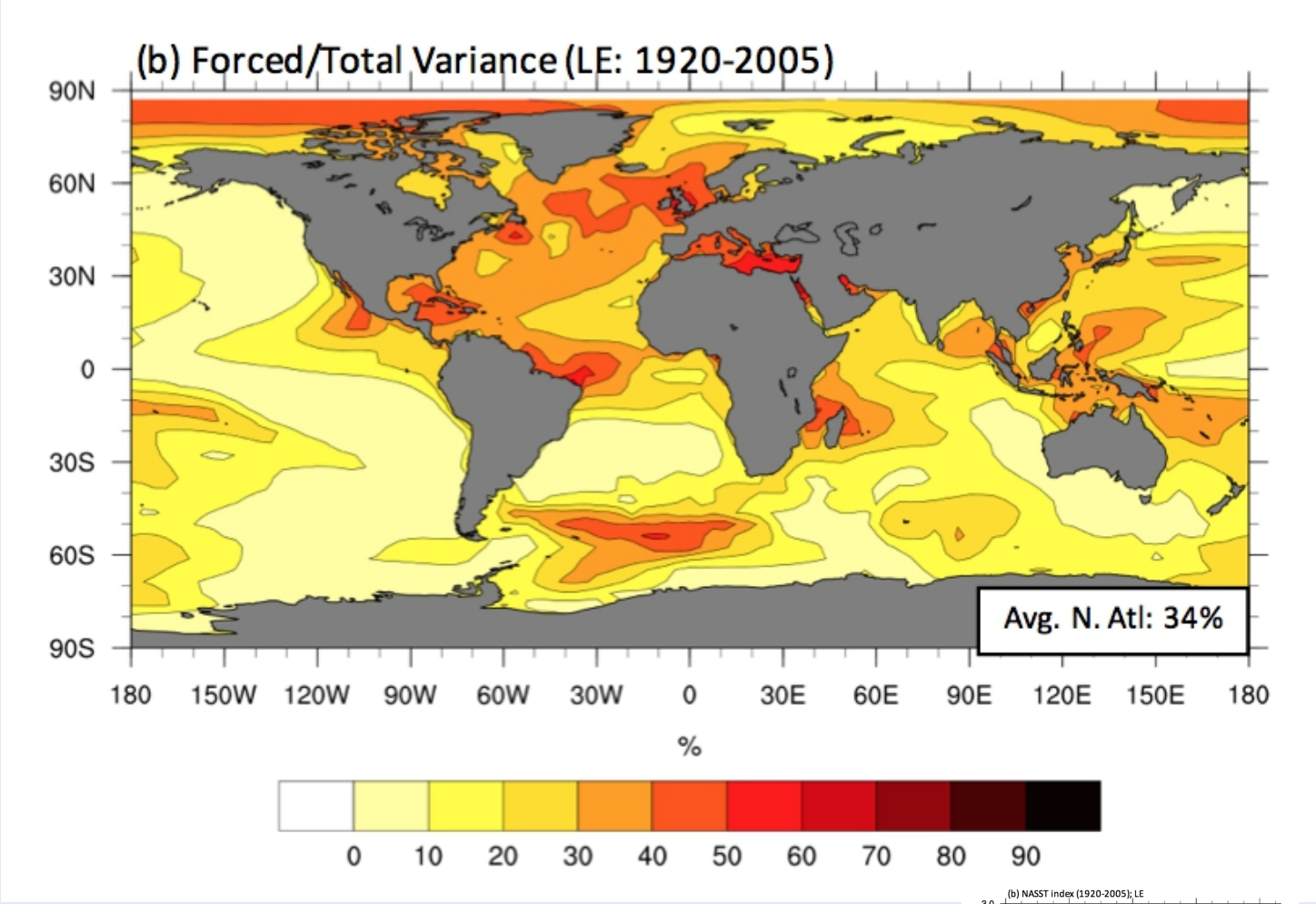


Internal Variability:
PICNTRL and DE-MEANED (historical minus ens mean)

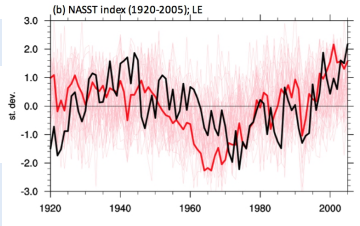
Internal Variability + External forcing:
Historical

External forcing:
Historical ens mean (filled dot)

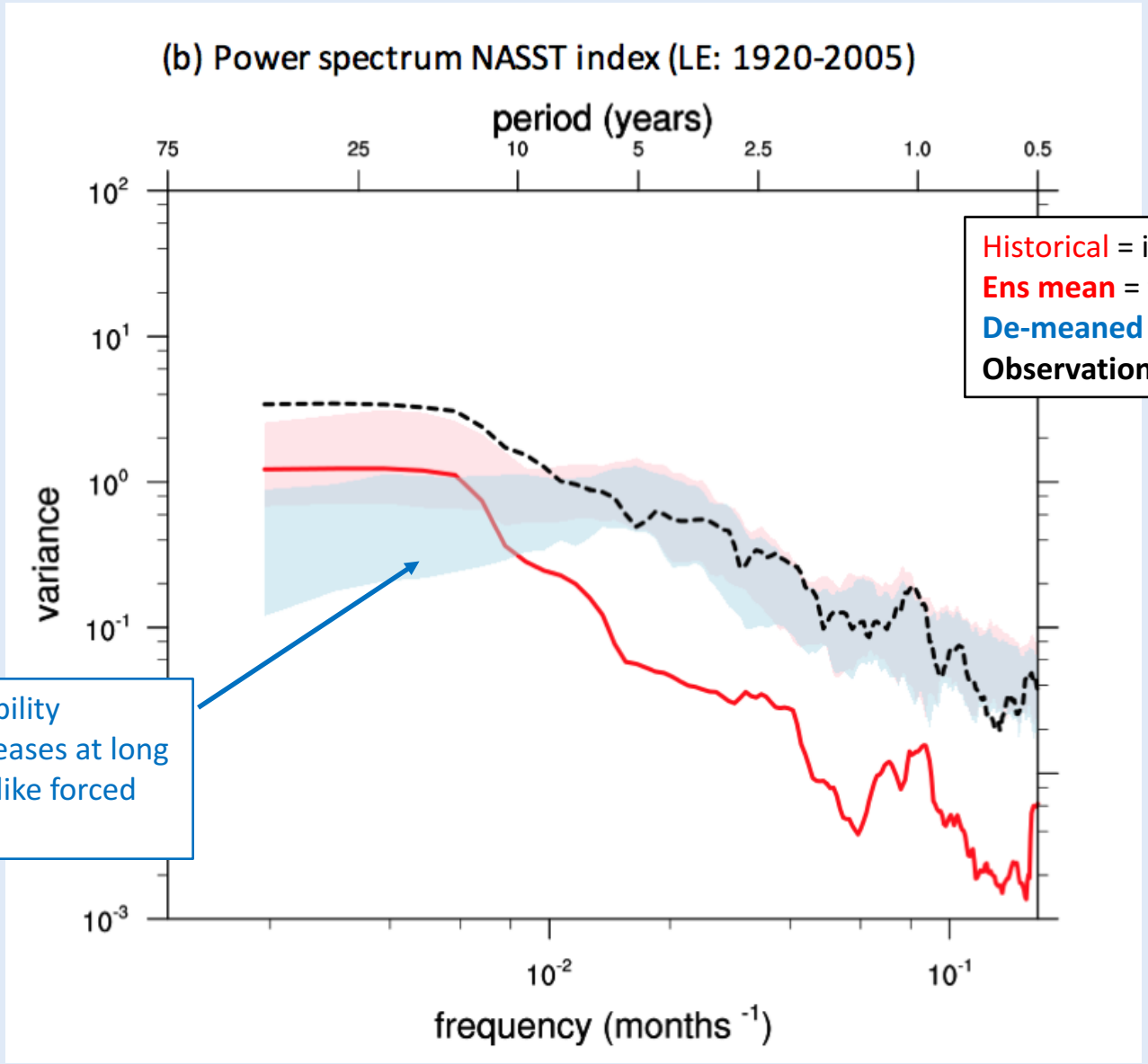
Forced/Total Variance → $\frac{\text{variance of ens mean SST}}{\text{avg variance of all ens members}}$



Forced/Total Variance for AMV index: 72%



Forced variance is at timescales > 10 years

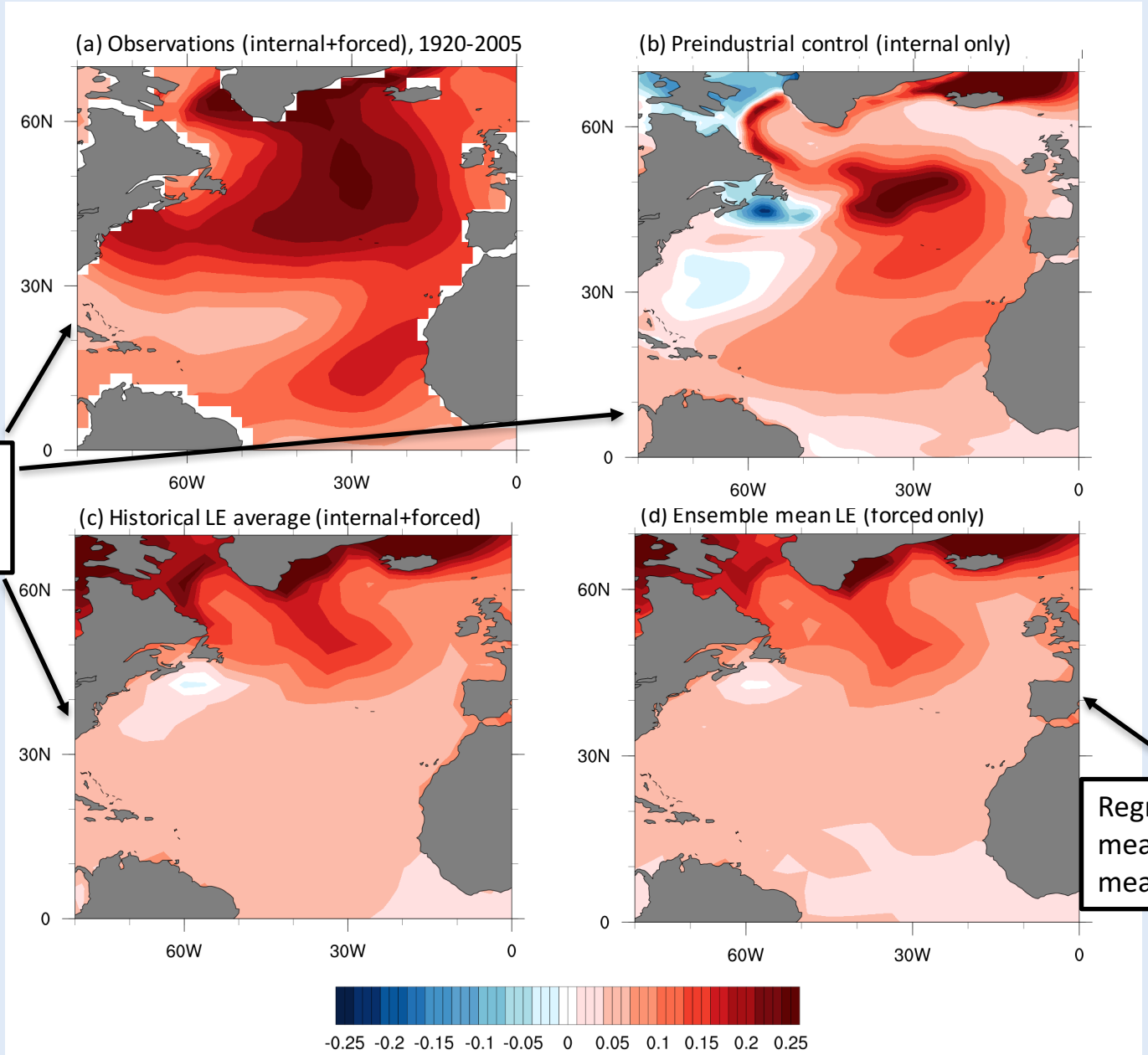


Historical = internal + forced
Ens mean = forced
De-meaned (or PICNTRL) = internal
Observations = internal + forced

Internal Variability variance decreases at long timescales unlike forced variance

External radiative forcing projects on internal variability

1920-2005



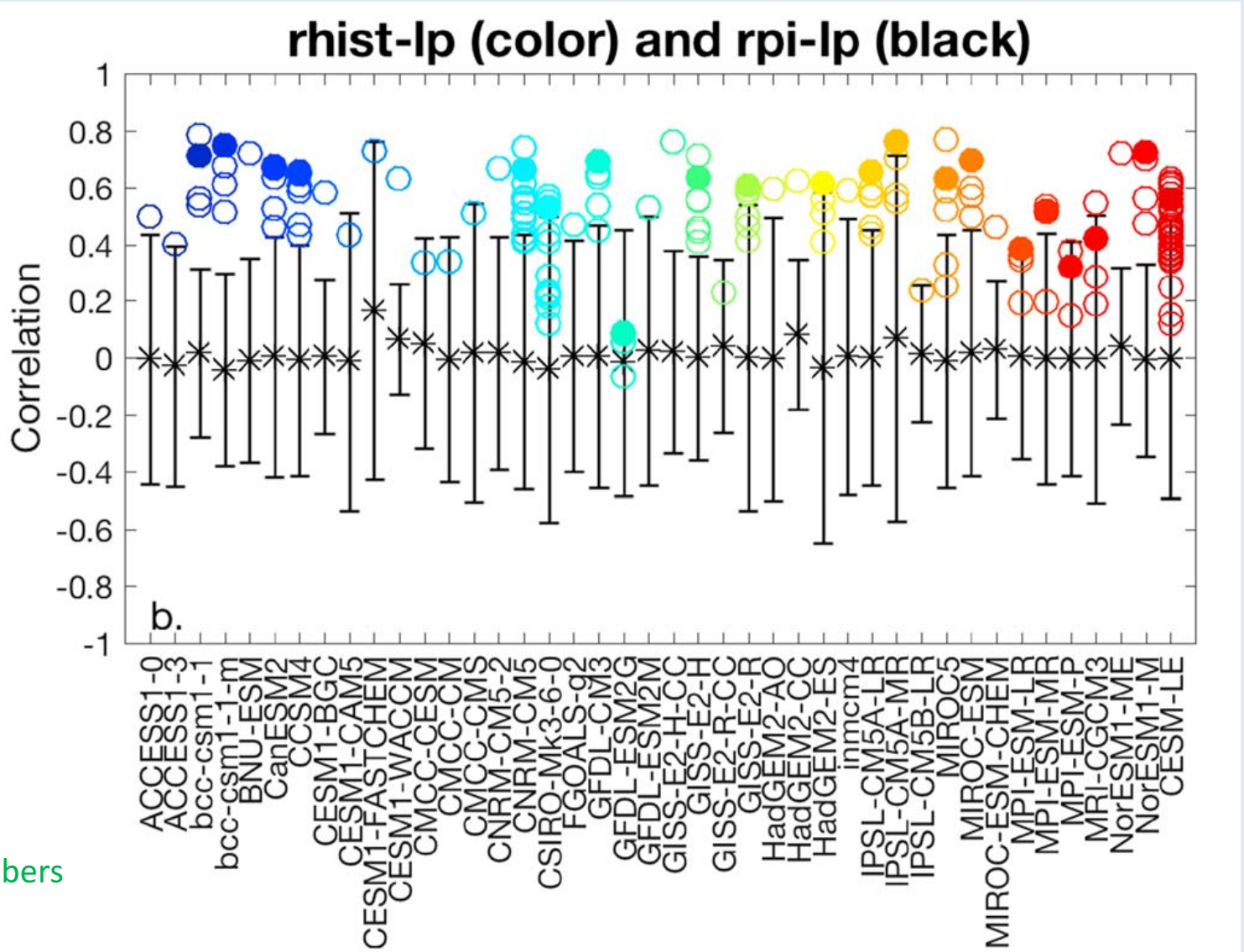
Regression of SST on AMV index

Regression of ens mean SST on ens mean AMV index

Other CMIP5 models

1865-2005

Correlations of 10 year low-pass filtered NASST index between models and obs

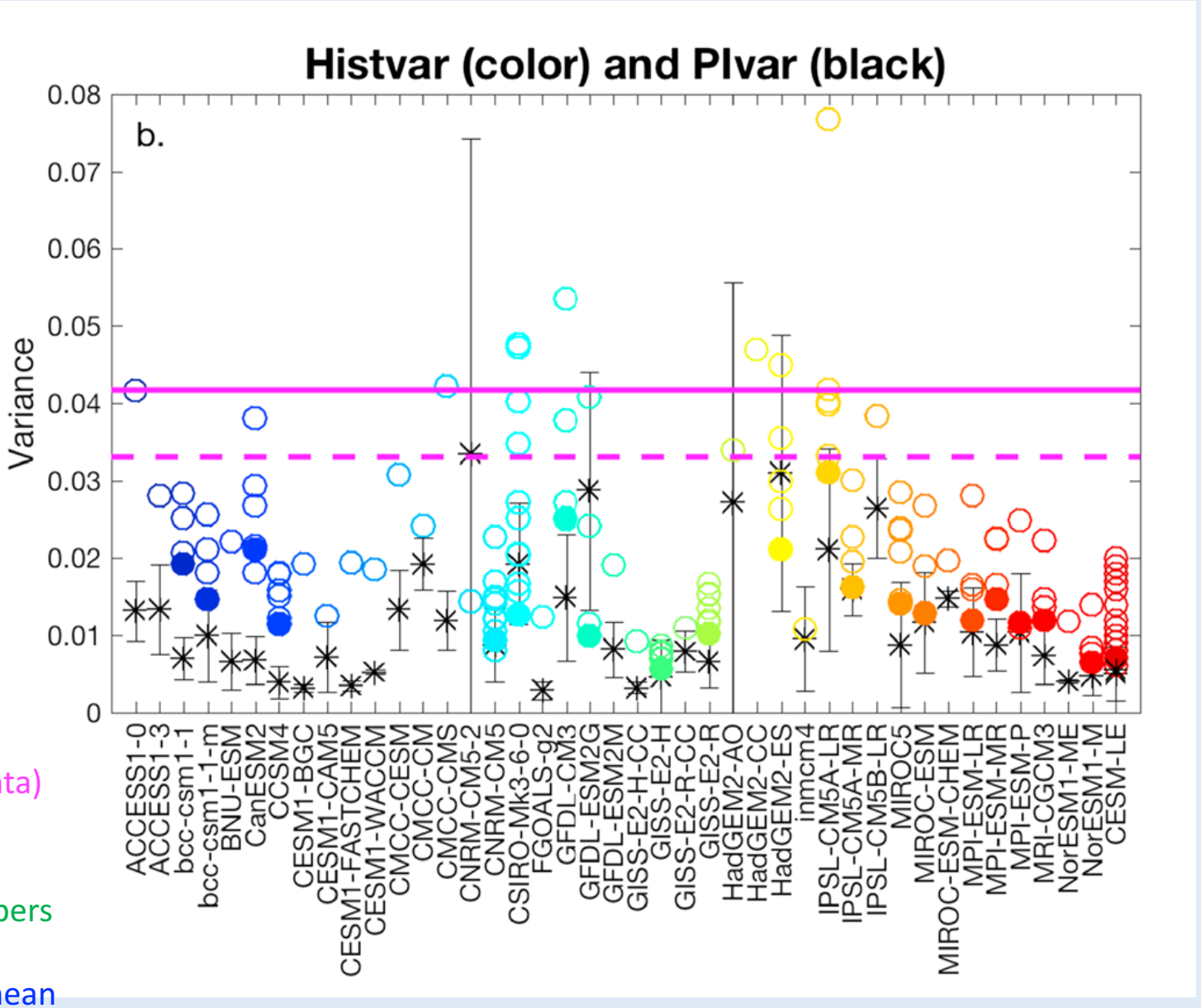


- Picntrl (black)
- Empty colored dots=historical members
- Filled colored dots=historical ens mean

Murphy et al. 2017

Most models underestimate observed AMV variance

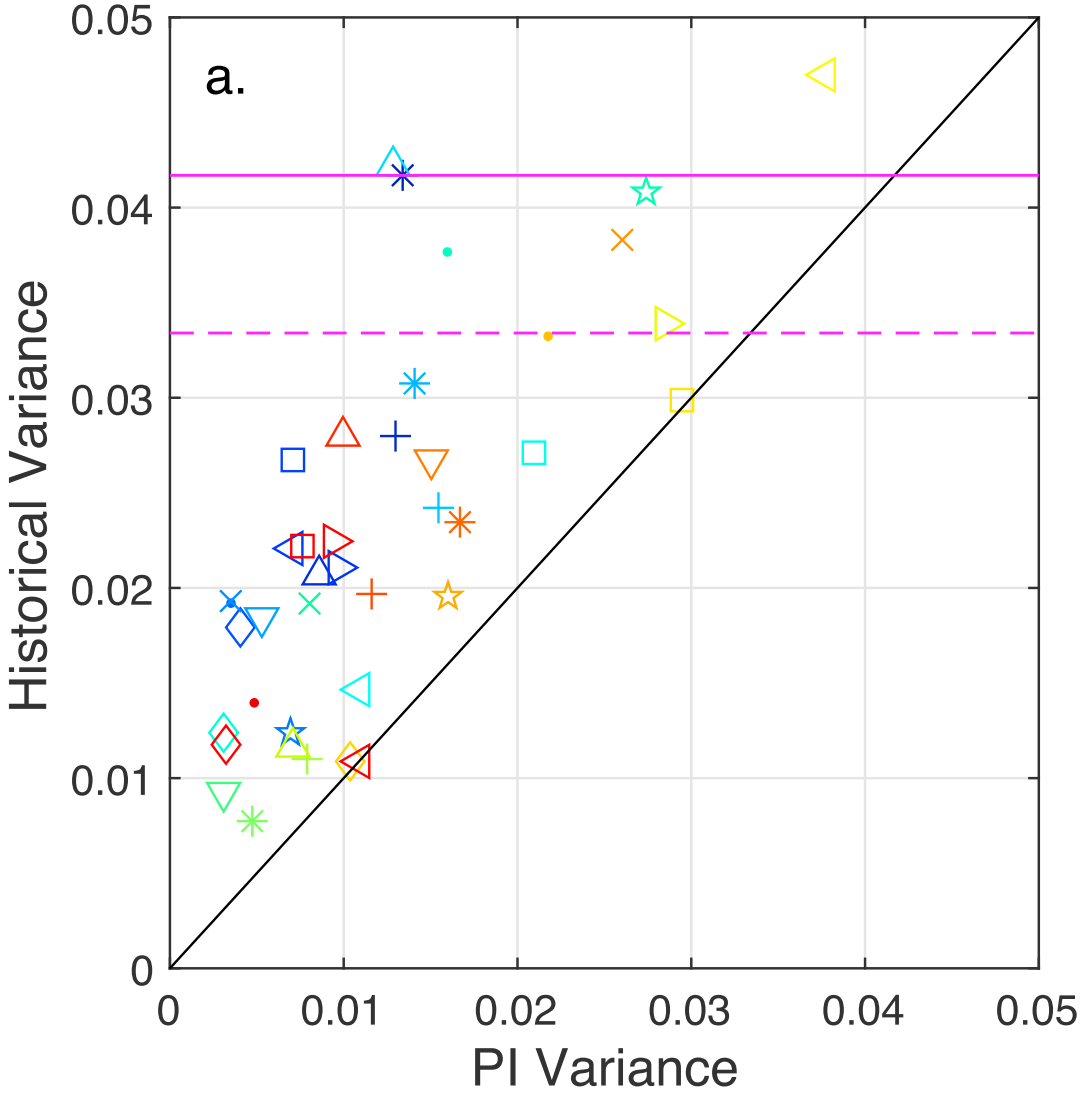
Variance of 10 year low-pass filtered NASST index



- Observations (magenta)
- Picntrl (black)
- Empty colored dots=historical members
- Filled colored dots=historical ens mean

Murphy et al. 2017

But in all models historical forcings increase the AMV variance compared to preindustrial control simulations



ACCESS1-0
ACCESS1-3
bcc-csm1-1
bcc-csm1-1-m
BNU-ESM
CanESM2
CCSM4
CESM1-BGC
CESM1-CAM5
CESM1-FASTCHEM
CESM1-WACCM
CMCC-CESM
CMCC-CM
CMCC-CMS
CNRM-CM5-2
CNRM-CM5
CSIRO-Mk3-6-0
FGOALS-g2
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H-CC
GISS-E2-H
GISS-E2-R-CC
GISS-E2-R
HadGEM2-AO
HadGEM2-CC
HadGEM2-ES
inmcm4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC-ESM
MIROC5
MIROC-ESM-CHEM
MPI-ESM-LR
MPI-ESM-MR
MPI-ESM-P
MRI-CGCM3
NorESM1-ME
NorESM1-M

Observations (magenta)

Murphy et al. 2017

Summary

- Most previous work suggest that multidecadal variability in the North Atlantic is primarily driven by internal variability.

- Here, using observations and a large ensemble to isolate external forcing in the CESM model, we claim that phase changes of the AMV and a substantial fraction of its variance **may be driven by radiative forcing**.

- The implication is that predictive skill increases if we know radiative forcings.

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- The implication is that predictive skill increases if we know radiative forcings.

Thank you!

References:

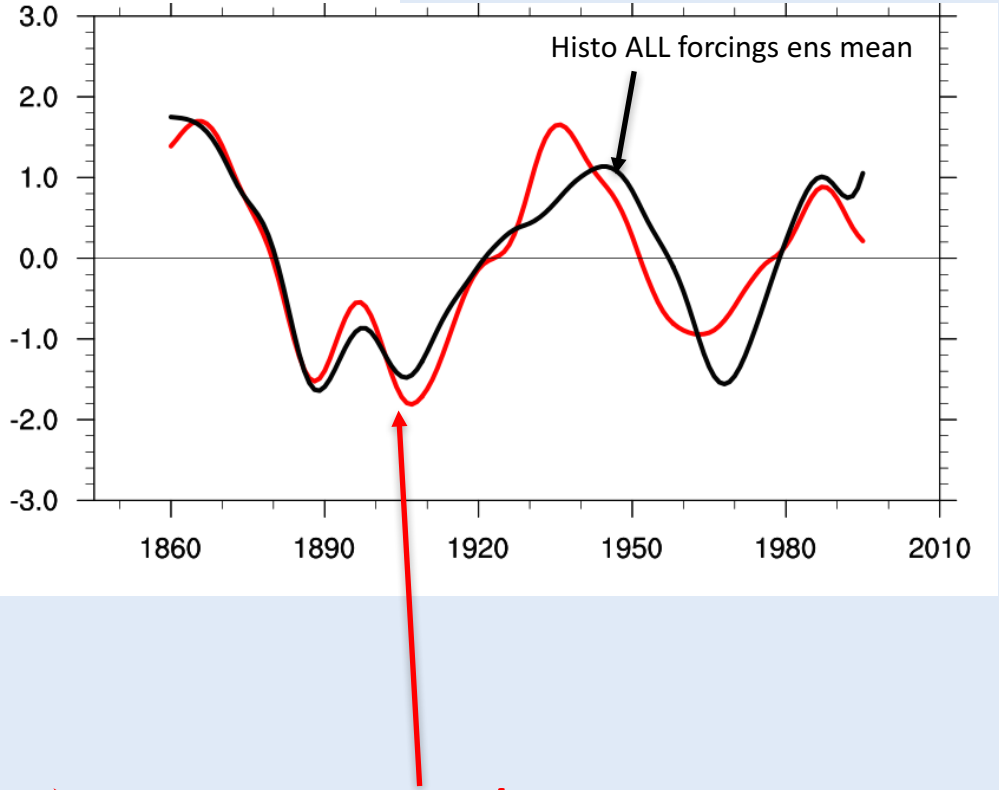
Bellomo K., L. Murphy, M. Cane, A. Clement, L. Polvani (submitted): Historical forcings as maind drivers of the Atlantic Multidecadal Variability in the CESM Large Ensemble. *Climate Dyn.*

Murphy L., K. Bellomo, A. Clement, M. Cane, 2017: The role of historical forcings in simulating the observed Atlantic Multidecal Oscillation. *Geophys. Res. Lett.*

Reconstruct the AMV index from single forcing experiments

- 1850-2005 Last Millennium Ensemble -

AMV index



(b) Corr. Coeff. between all forcings and sum of single forcings AMO index

Forcings	Corr. Coeff.
GHG	0.45
GHG+AEROSOLS/OZONE	0.83
GHG+AEROSOLS/OZONE+VOLCANOES	0.87
GHG+AEROSOLS/OZONE+VOLCANOES+SOLAR	**0.91**
GHG+AEROSOLS/OZONE+VOLCANOES+SOLAR+LAND USE	0.89
GHG+AEROSOLS/OZONE+VOLCANOES+SOLAR+LAND USE+ORBITAL	0.88

- **GHG+AEROSOLS/OZONE+VOLCANOES+SOLAR ens mean**
- Aerosols + GHG dominate from 1920 onwards

Single forcing experiments: 1920-2005

Regressions of ens mean SST on ens mean AMV index