2018 CVCWG Winter Meeting

Low-Frequency North Atlantic Climate Variability in CESM-LENS

Jan. 29, 2018

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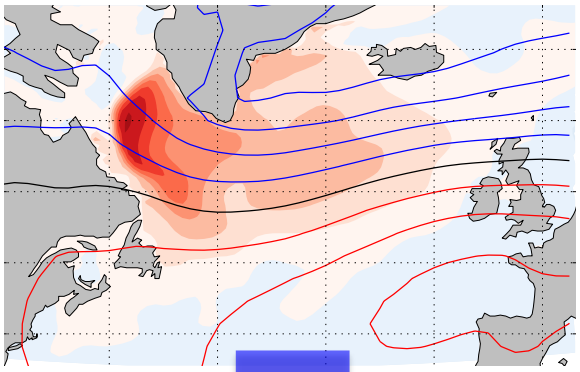
Outline

- ✓ Examine low-frequency North Atlantic variability (AMOC, SPNA SST, Sahel rainfall, and NAO) from **CESM1-CAM5 Large Ensemble** and preindustrial control simulation in comparison with observational estimates
- ✓ The simulated multidecadal variability is substantially weaker than observational estimates
- ✓ The weak simulated multidecadal variability can be traced to weak multidecadal variability in simulated NAO

Kim et al., 2018: **Low-frequency North Atlantic climate variability in the Community Earth System Model Large Ensemble simulations**. *J. Climate,* 31, doi:10.1175/JCLI-D-17-0193.1.

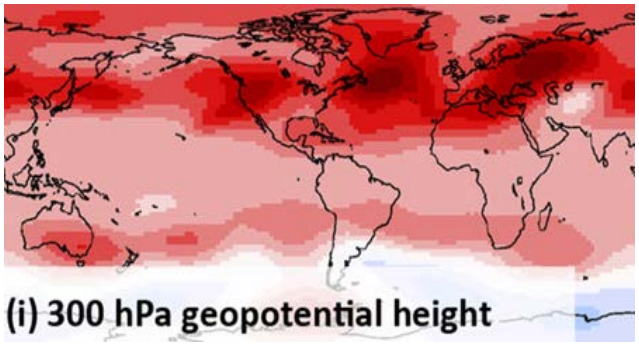
Multidecadal Variability in the North Atlantic



NAO-driven
surface buoyancy fluxes &
Deep water formation

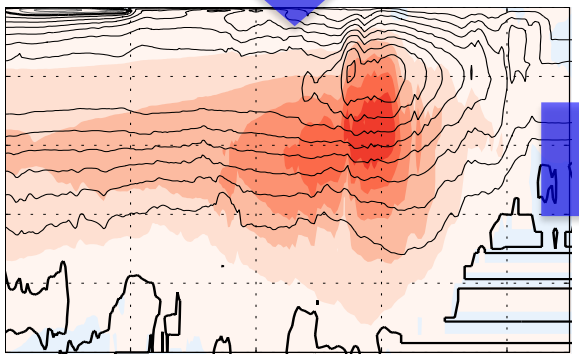
Eden & Jung (2001); Dong & Sutton (2005); Böning et al. (2006); Biastoch et al. (2008); Danabasoglu et al. (2012); Yeager & Danabasoglu (2014); Danabasoglu et al. (2016) & many more

AMV (AMO)



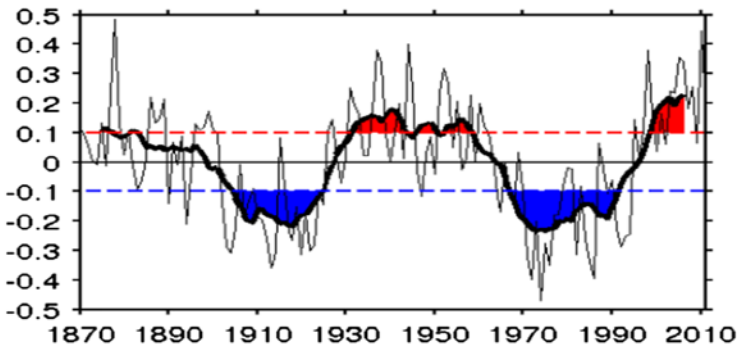
Delworth & Zeng (2015)

AMOC



Delworth et al. (1993); Knight et al. (2005); Dong & Sutton (2005); Danabasoglu et al. (2012); Tendon & Kushner (2015); O'Reilly et al. (2016); Zhang et al. (2016) & many more

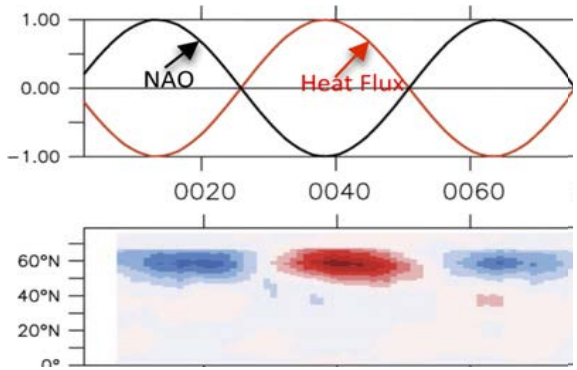
Rainfall



Zhang & Delworth (2006)

Other Proposed Mechanisms

- ✓ Driven by atmospheric noise associated with NAO (*Clement et al. 2015*)
  - ➢ Similar spatial and temporal characteristics b/w fully coupled and slab simulations
  - ➢ Disputed by *Zhang et al.* (2016) and *O'Reilly et al.* (2016)



Zonally averaged NASST

Delworth et al. (2017)

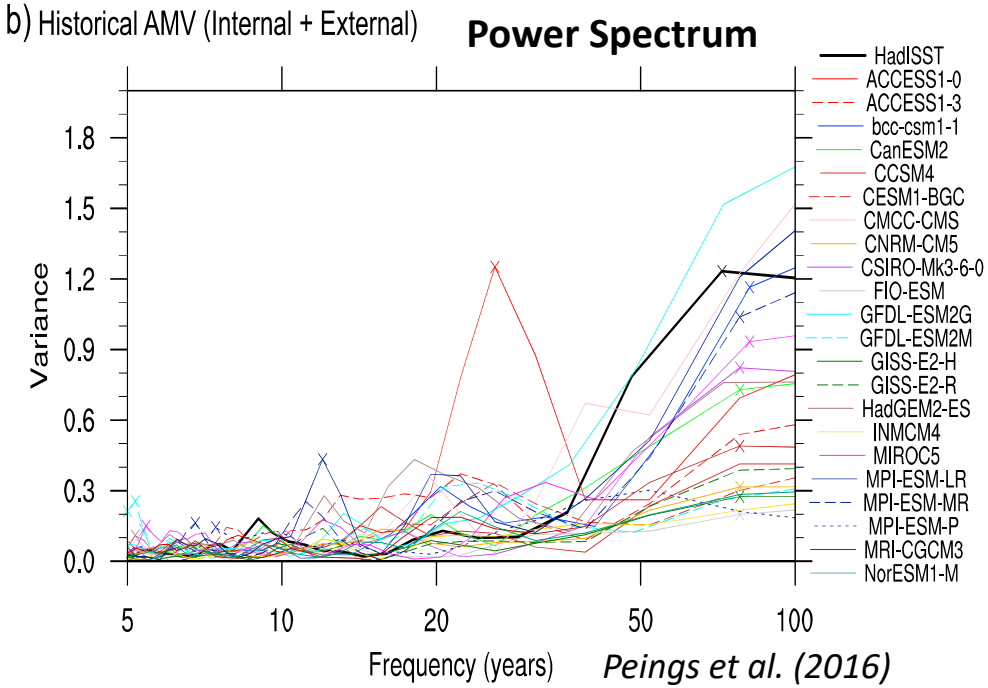
* Additional periodic heat flux forcing associated with observed NAO applied over the NA in coupled ensembles

AMOC

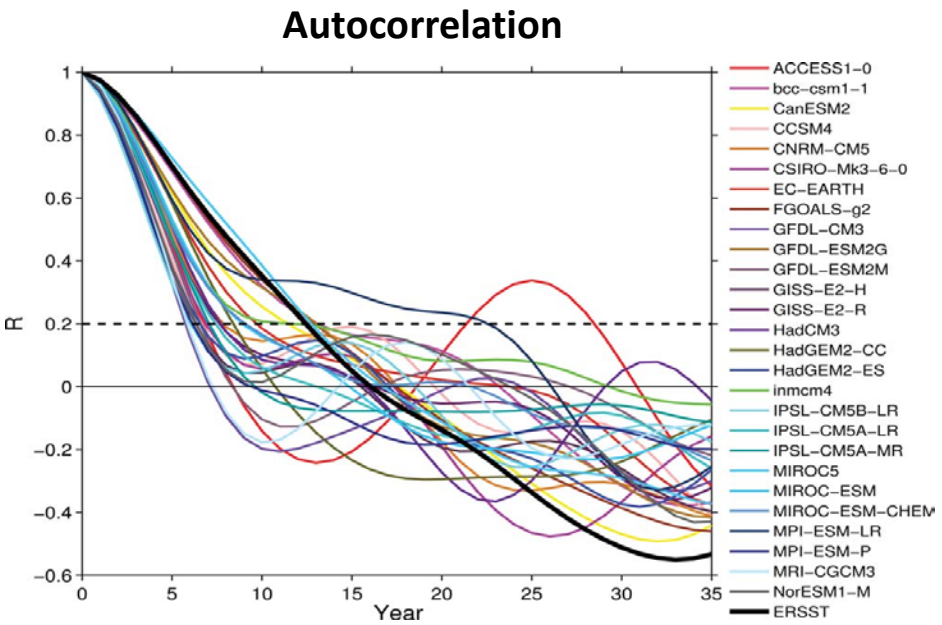
- ✓ Driven by (anthropogenic) external forcings (*Booth et al. 2012; Bellomo et al. 2017*)

Weak AMV Power in Coupled Simulations

✓ Multidecadal power of AMV in climate models seems too weak, compared to observations, comparable to one generated by noise (*Clement et al. 2015*)



Peings et al. (2016)

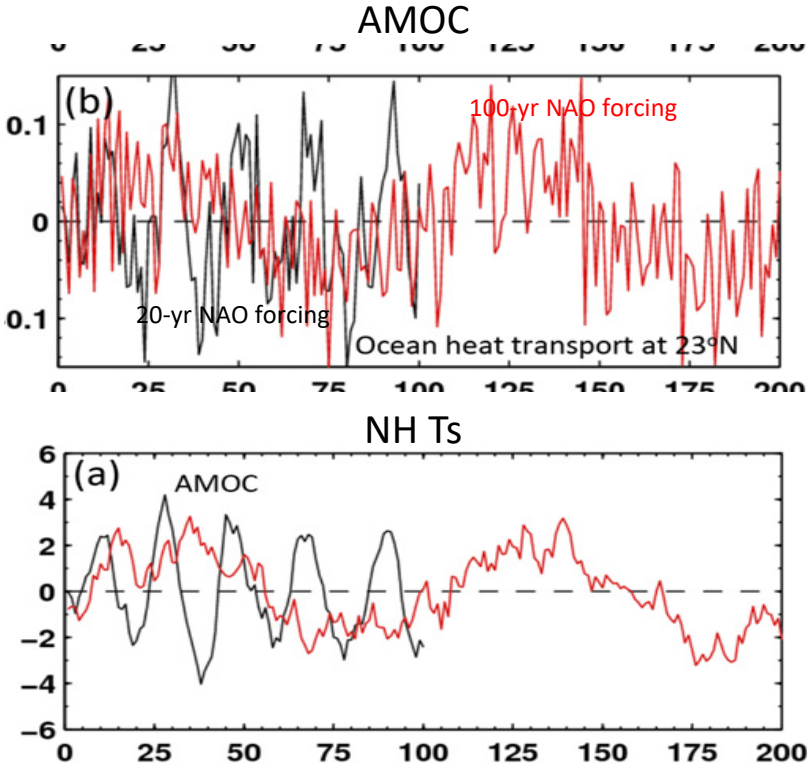


Zhang and Wang (2013)

Why is mutidecadal NASST variability (AMV) in coupled models weak compared to observations?

Relationship between NAO-AMOC-AMV

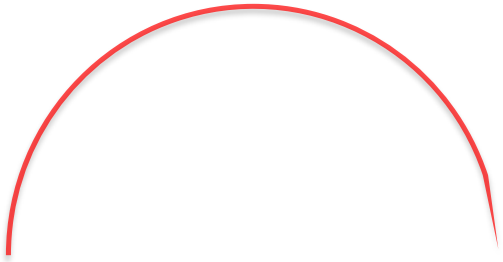
AMOC and NH Ts vary on the same time scale of imposed NAO heat flux forcing



Delworth & Zeng (2015)

Most of CMIP5 models underestimate decadal NAO variability

CMIP5



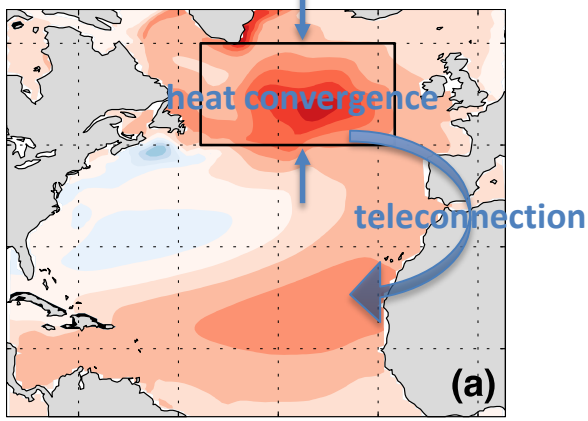
Wang et al. (2017)

Is week AMV in coupled simulations due to a weak simulated multidecadal NAO variability?

AMV/SPNA SST

AMV Regression Pattern*

LE* **HadISST**

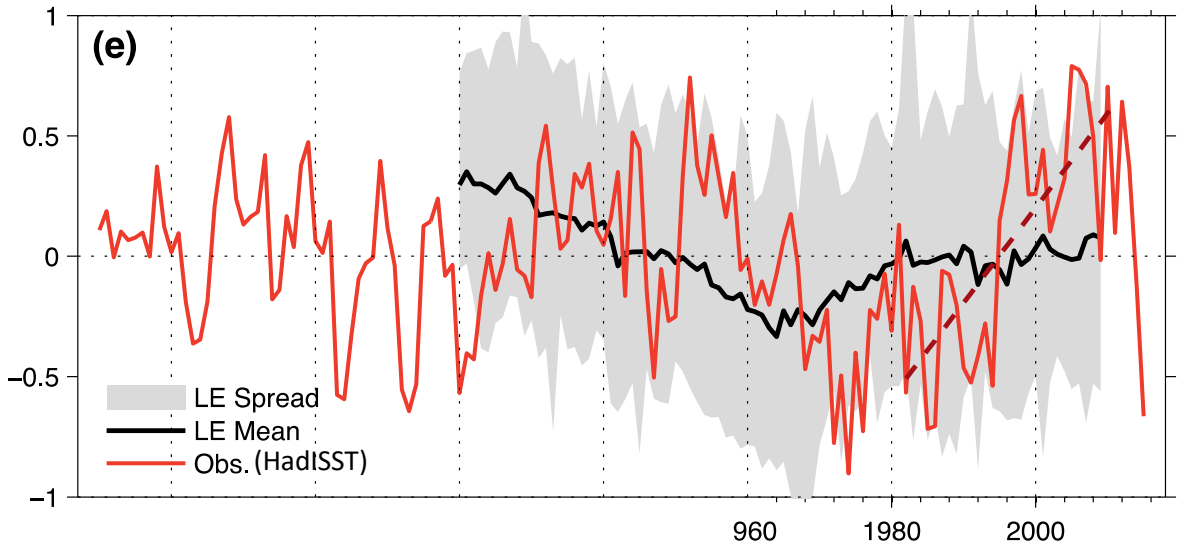


***Ensemble mean**

ºC/ºC

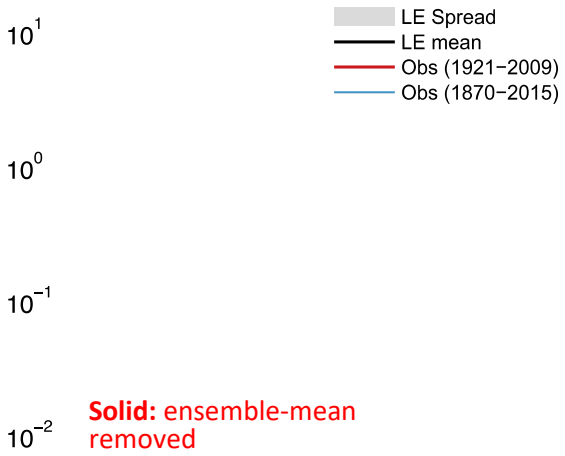
*Ensemble mean-removed and 15-yr lowpass-filetered time series are used for the regression analyses

SPNA SST Time Series



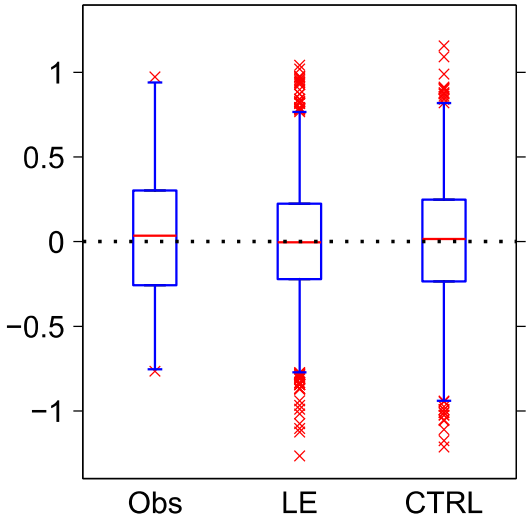
Low-frequency SPNA SST Variability

Power Spectrum



Solid: ensemble-mean removed

Distribution of Moving Trends*



99th prctile

1st prctile

*** All trends are normalized to the corresponding max trend of observational estimates**

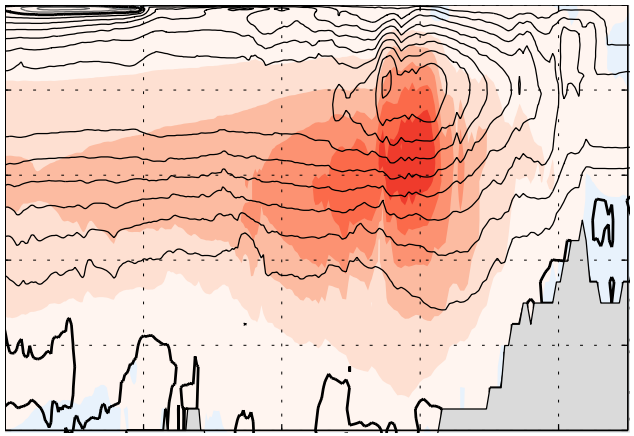
Distribution of 30-yr Moving Trends in the individual ensemble members of LE

Obs

AMOC (EOF1)

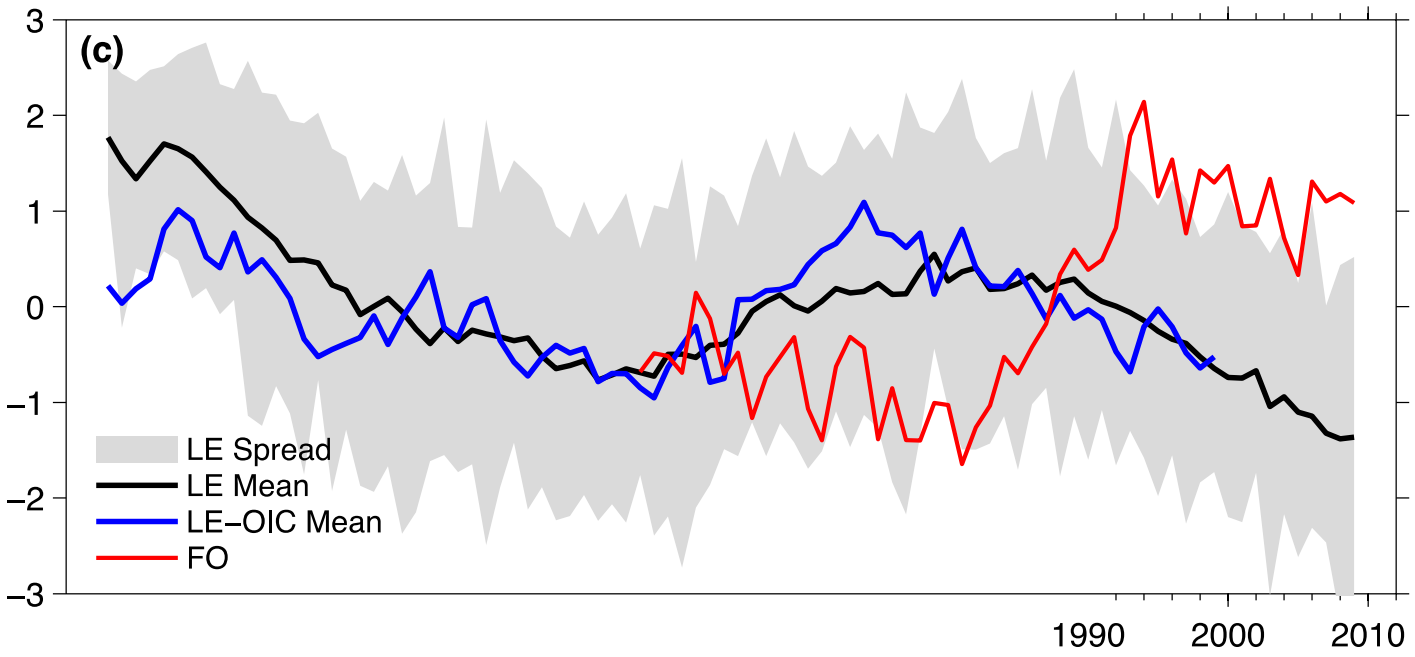
Forced ocean-ice simulation (COREII)

*



*Ensemble mean

Normalized PC1



Low-frequency AMOC Variability

AMOC-SPNA SST relationship

* 15-yr lowpass-filetered time series are used for the correlation analyses

Power Spectrum

Distribution of Moving Trends*

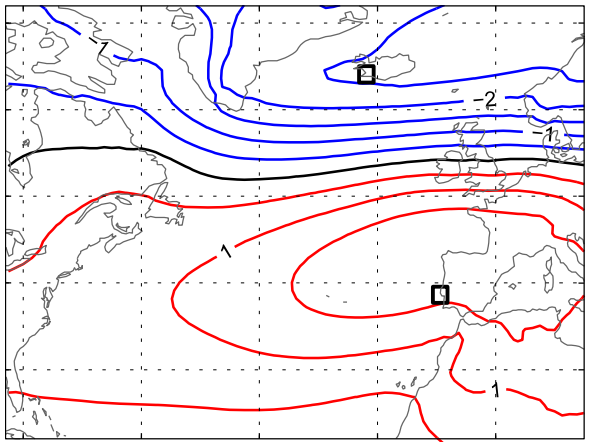
5-yr **30-yr**

NAO (DJFM)

EOF1

*

20CR

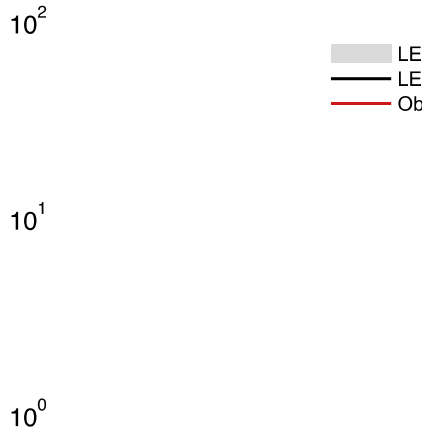


*Ensemble mean

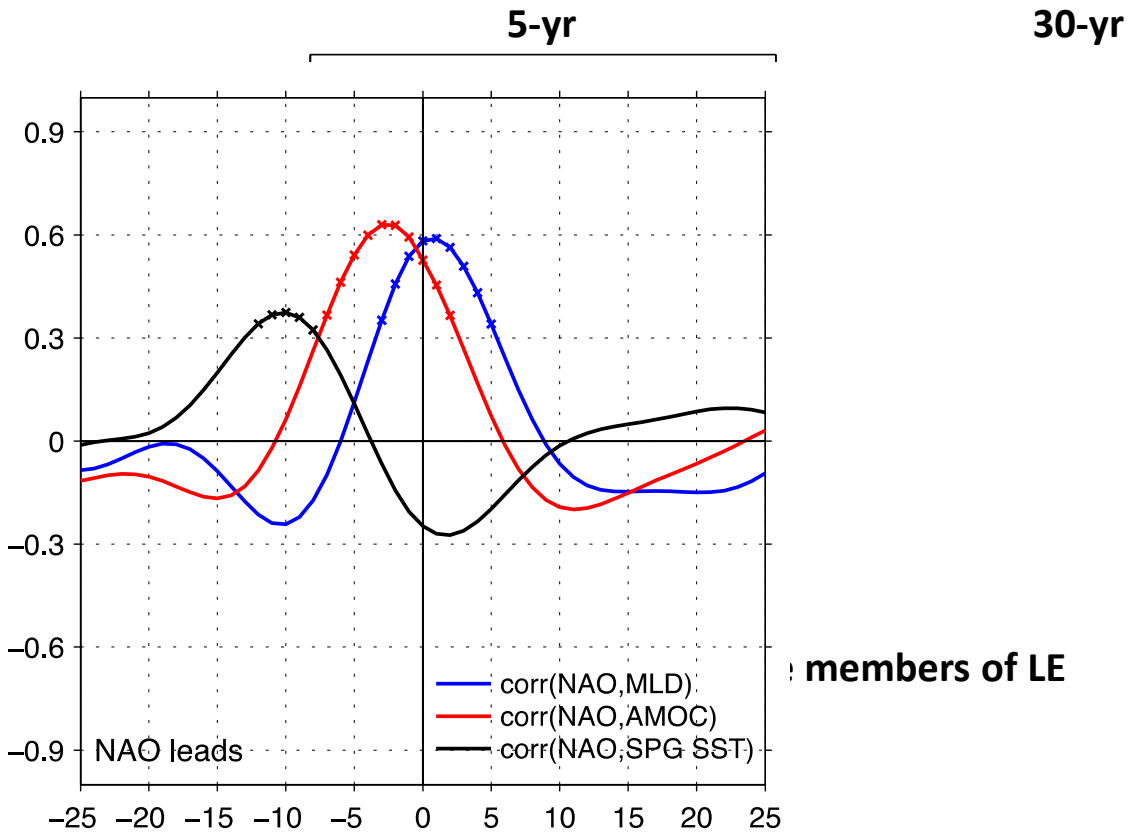
NAO index (N-S station-based; Hurrell 1995)

Low-frequency NAO Variability

Power Spectrum



Distribution of Moving Trends



Distributi **members of LE**

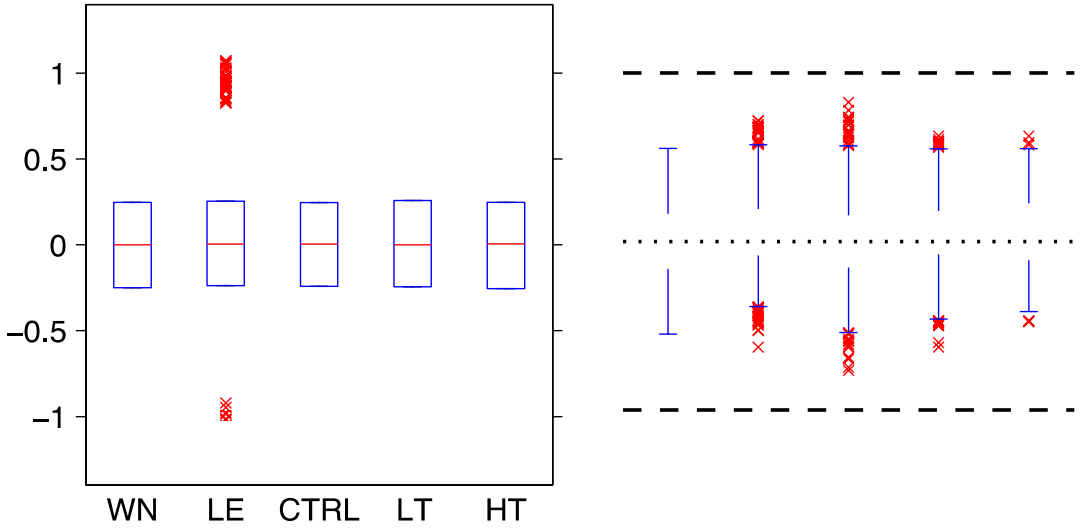
The weak multidecadal North Atlantic climate variability in CESM1 appears to be related to the weak simulated multidecadal NAO variability (i.e., NAO -> AMOC -> SPNA SST)

bs 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35

Low-frequency NAO Variability

Why is multidecadal NAO variability weak in LENS?

- **SST bias in LE**
- **Low top in CAM5 (coupling to stratosphere)**

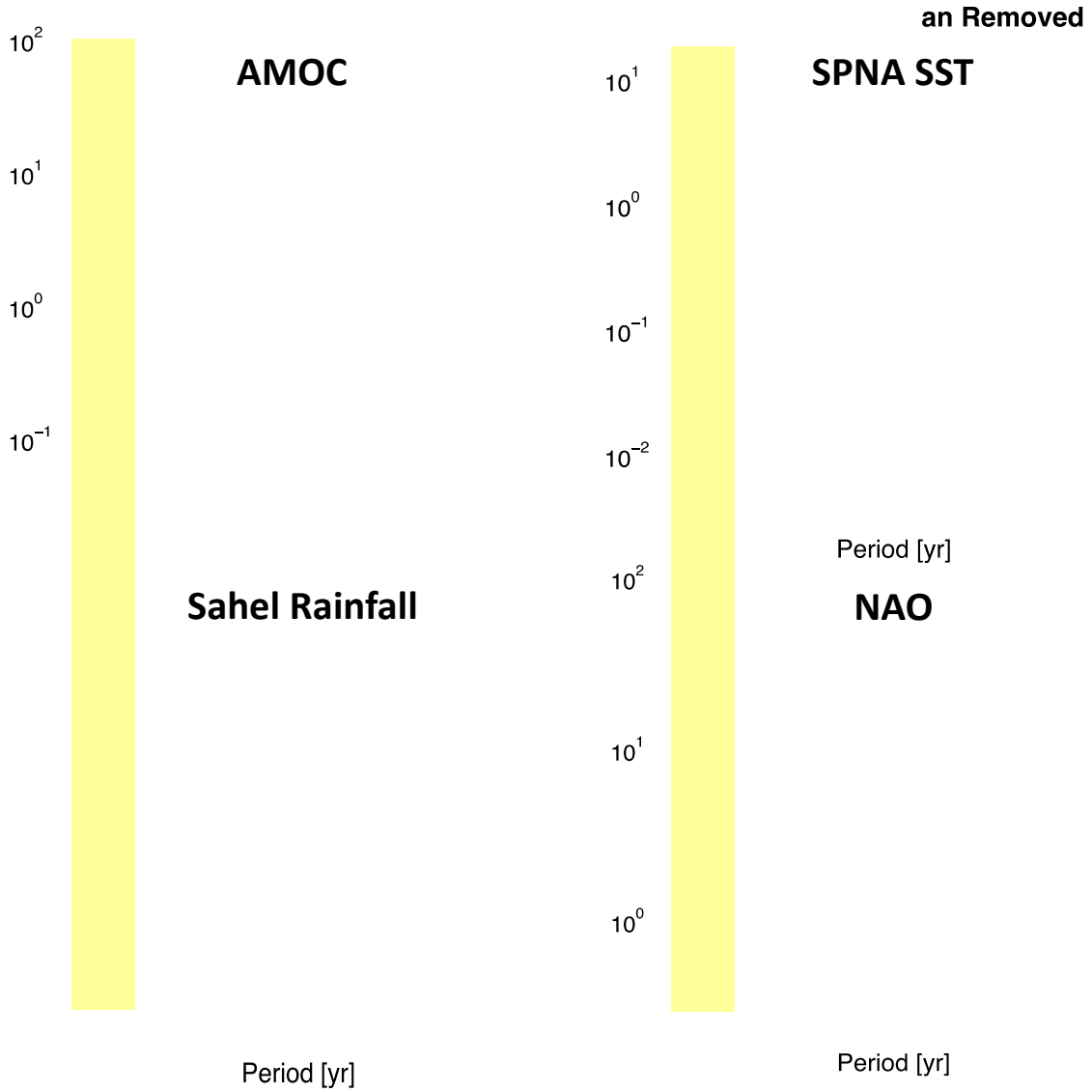


WN: synthetic white noise ensemble (89-year long x 5000 members = 445,000-year long)
LT: CAM5 historical ensemble (10 members) with interannually varying observed SST in the tropics
HT: high-top CAM5 historical ensemble (10 members) with interannually varying observed SST everywhere

- ✓ **No enhanced multidecadal NAO variability with realistic boundary conditions and better resolved stratospheric dynamics**
- ✓ **All simulated NAO variability using CAM5 is close to white noise**

Summary/Discussion

- ✓ **The multidecadal North Atlantic climate variability in LENS is weak compared to observational estimates**
  - ❖ Interannual to decadal variability is comparable



Summary/Discussion

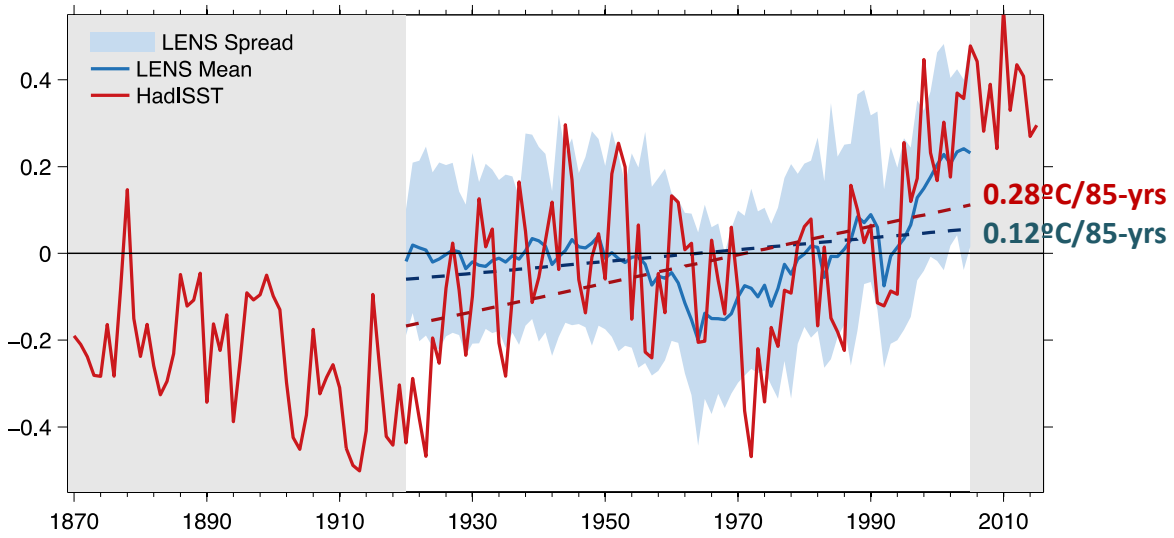
- ✓ **The multidecadal North Atlantic climate variability in CESM1-CAM5 is weak compared to observational estimates**
  - ❖ Interannual to decadal variability is comparable

- ✓ We claim that the weak multidecadal variability can be traced to **weak multidecadal variability of simulated NAO**
  - ➢ Possibly due to deficiencies in CAM5 (horizontal/vertical resolution, parameterized physics) and/or coupling methods?

- ✓ Overall weak North Atlantic climate variability, including NAO, is also found in other CMIP5 models (*Kravtosv & Callicutt* 2017; Wang et al. 2017)
  - ➢ **Weak multidecadal AMV in in these models can be due to the weak multidecadal variability of the simulated NAO**

Externally Forced vs. Internal AMV

- ✓ Some studies have argued that AMV is largely driven by external forcings (e.g., *Booth et al. 2012; Bellomo et al. 2017*), based on a high correlation between observed and simulated ensemble mean NASST

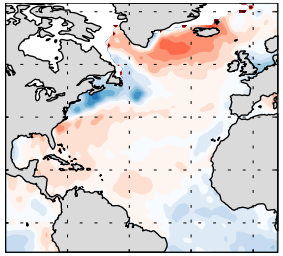


***r* and R^2 b/w forced LENS and observed NASST (20-yr lowpass-filtered)**

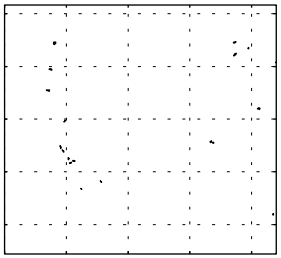
	r		R^2	
	Non-detrended	Detrended	Non-detrended	Detrended
1920-2005	0.79	0.73	0.55	0.51
1920-1990	0.37	0.58	0.09	0.34
1920-1980	0.34	0.60	0.08	0.36
1920-1970	0.27	0.49	0.03	0.14

Externally Forced vs. Internal AMV

Warm to cold



Cold to warm



Decadal anomalies relative to the 1958-2005 mean