2017 Winter OMWG Meeting

Low-Frequency North Atlantic Climate Variability in the CESM-LENS

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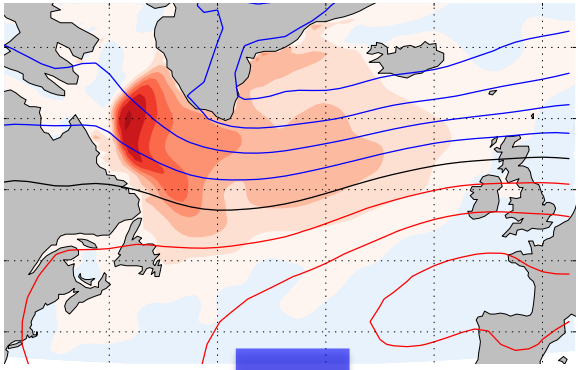
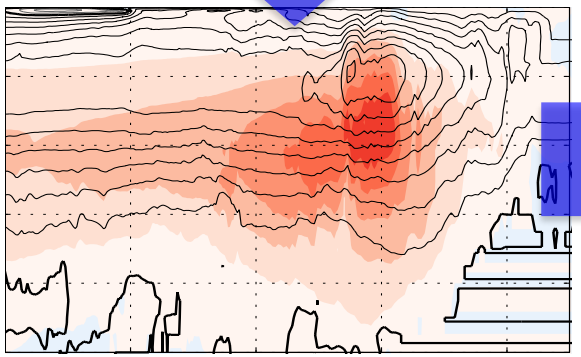
Multidecadal Variability in the North Atlantic



NAO-driven
surface buoyancy fluxes &
Deep water formation

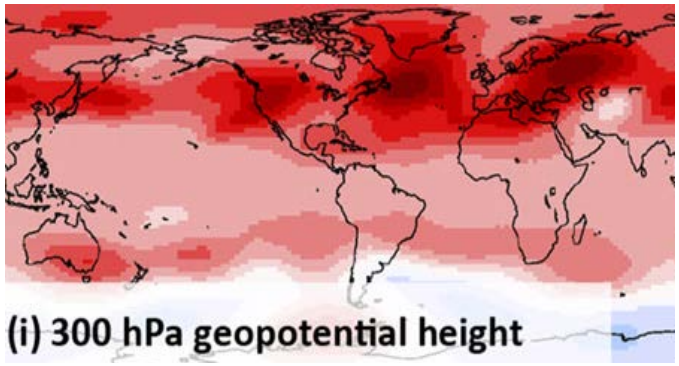
Eden & Jung (2001); Dong & Sutton (2005); Böning et al. (2006); Biastoch et al. (2008); Danabasoglu et al. (2012); Yeager & Danabasoglu (2014); Danabasoglu et al. (2016) & many more

AMOC



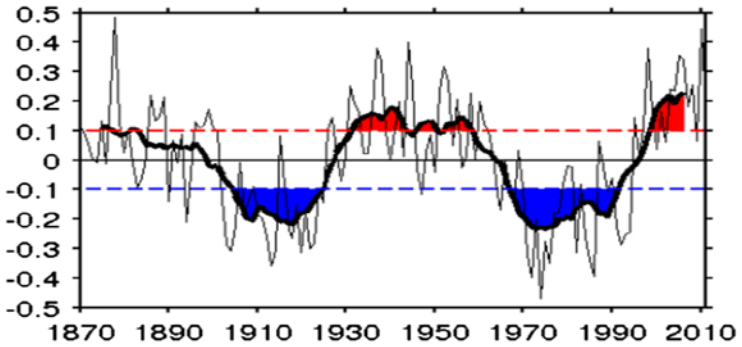
Delworth et al. (1993); Knight et al. (2005); Dong & Sutton (2005); Danabasoglu et al. (2012); Tendon & Kushner (2015); O'Reilly et al. (2016); Zhang et al. (2016) & many more

AMV (AMO)



Delworth & Zeng (2015)

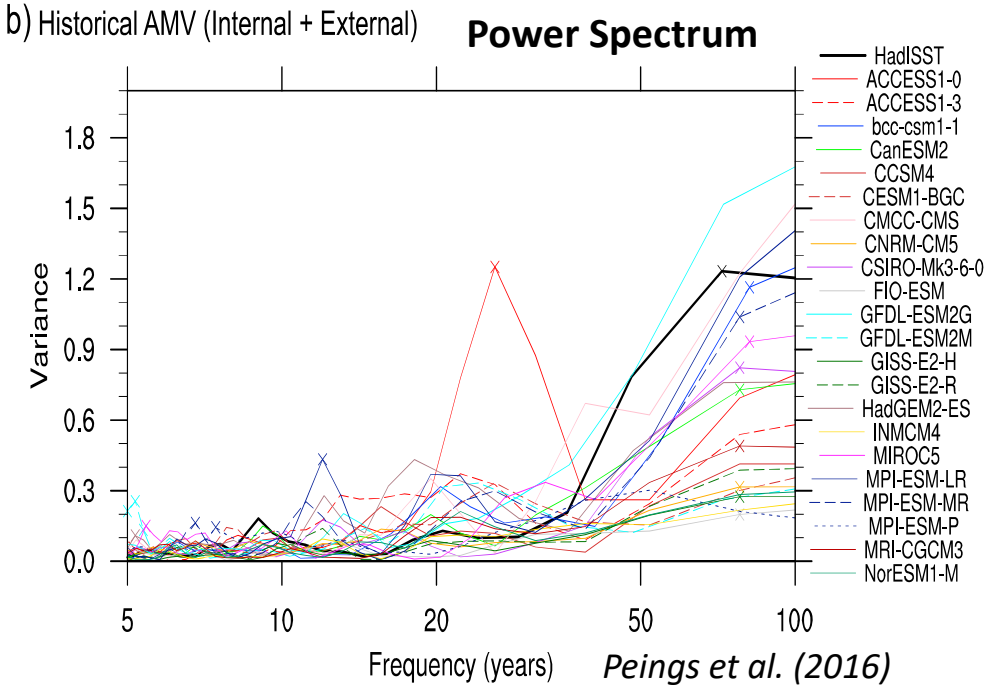
Rainfall



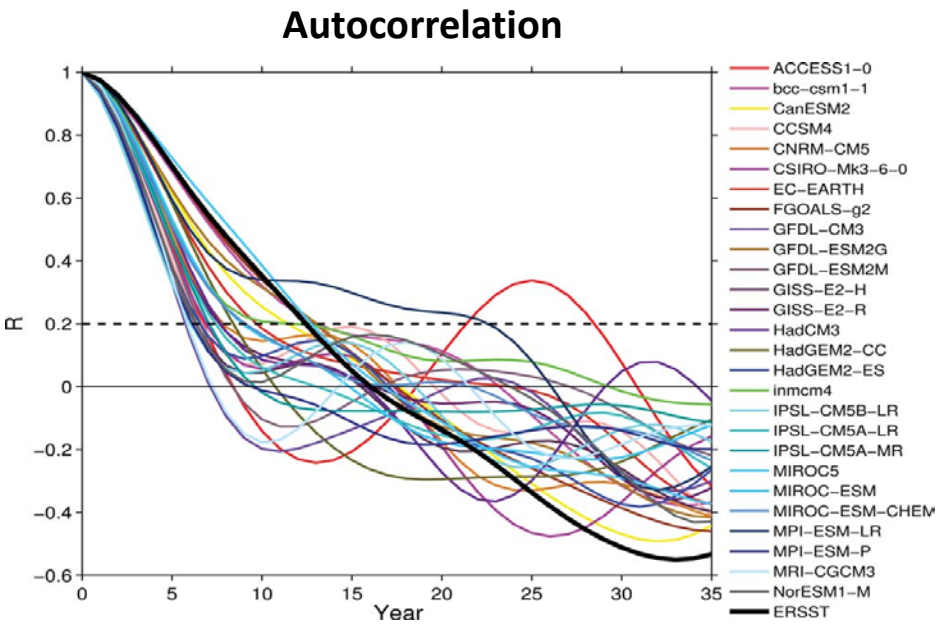
Zhang & Delworth (2006)

Weak AMV Power in Coupled Simulations

- ✓ The observed AMV pattern is generally captured in CMIP coupled models, but…
- ✓ Low-frequency power of the simulated NASST (AMV) in such models seems to be too weak compared to observations



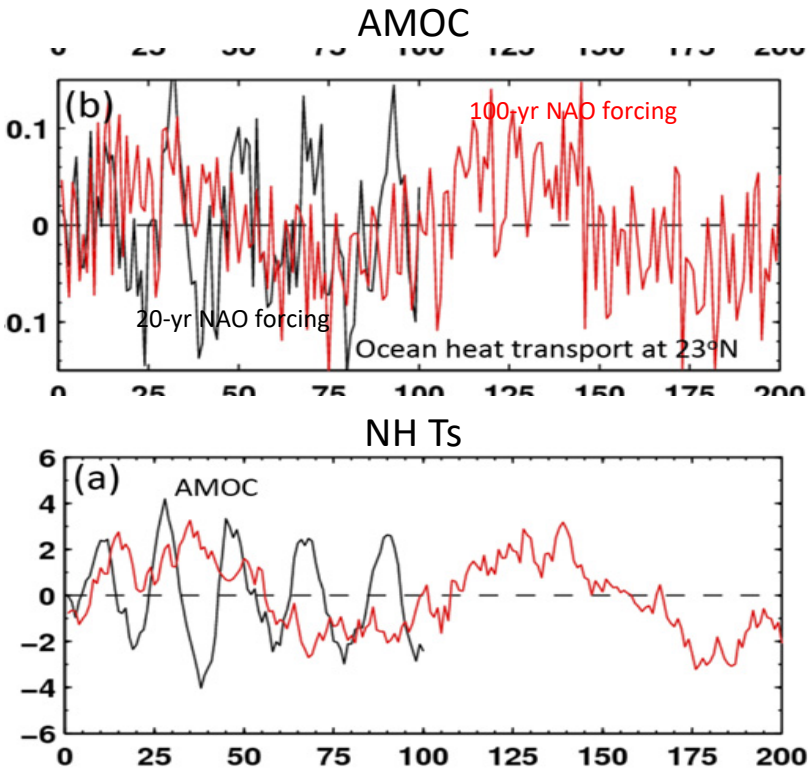
Peings et al. (2016)



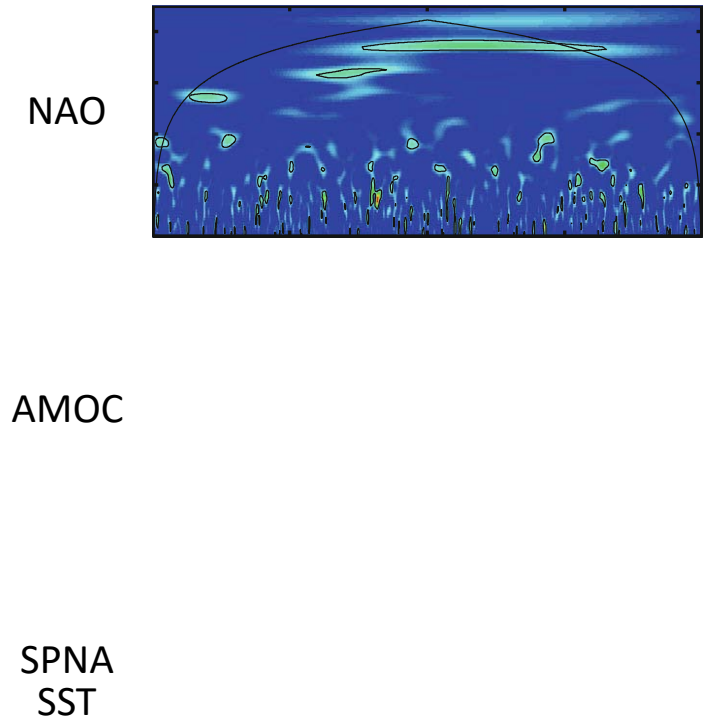
Zhang and Wang (2013)

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

Linear relationship between NAO-AMOC-AMV



*Delworth & Zeng (2015)**



*Mecking et al. (2015)**

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

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

Linear frequency relationship between NAO, AMOC, and SPNA SST on > multidecadal time scales

* An ocean-only simulation forced with synthetic stochastic NAO forcing (2000 yr)

Outline

- ✓ **Examine low-frequency North Atlantic variability (AMOC, SPNA SST, Sahel rainfall, and NAO) from CESM1-CAM5 Large Ensemble (LE; 35 members) and control simulation (CTRL; 800-2200), and compare to observational estimates**

- ✓ **Show the simulated multidecadal variability is substantially weaker than observational estimates**

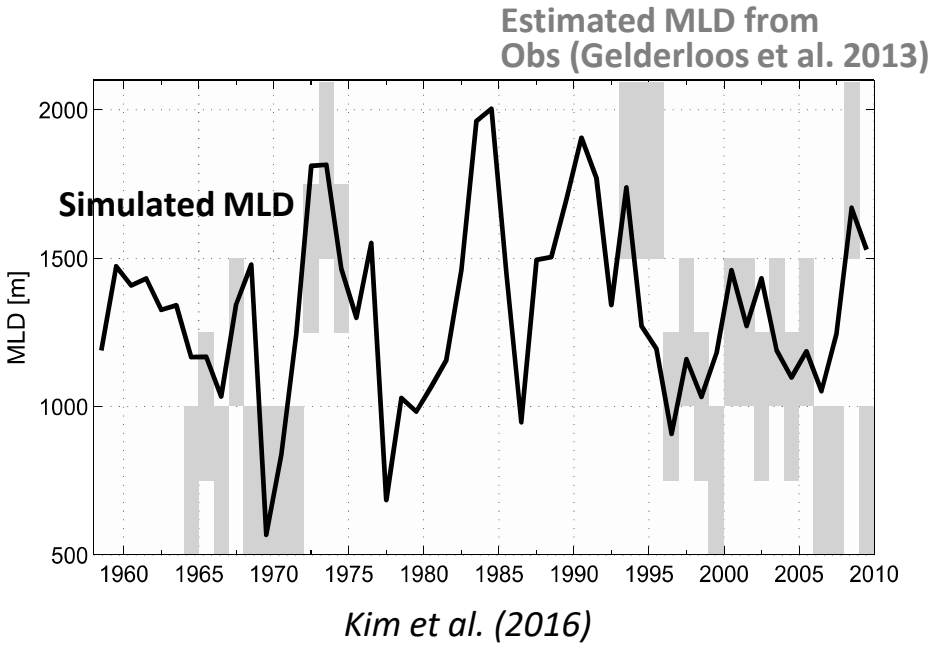
- ✓ **Argue the weak simulated multidecadal variability can ultimately be traced to weak multidecadal variability in simulated NAO**

- ✓ **Explore why the simulated NAO variability is weak on multidecadal time scales**

AMOC Estimates

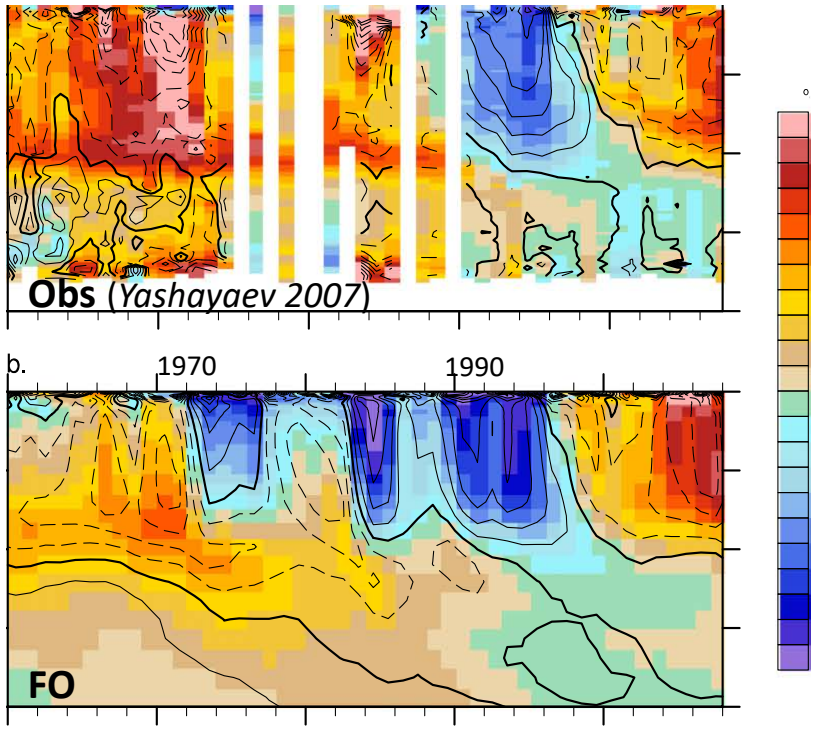
✓ **Forced ocean (POP) simulation (FO**; *Yeager & Danabasoglu, 2014*)

- Forced with CORE-II interannual forcing (1948-2009; 1958-2009 analyzed)
- **Same ocean component and configuration as in LE**
- **Shows a good agreement with available observations for AMOC-related variables**



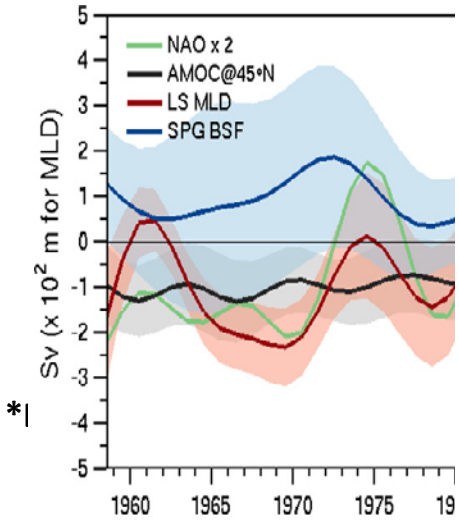
Kim et al. (2016)

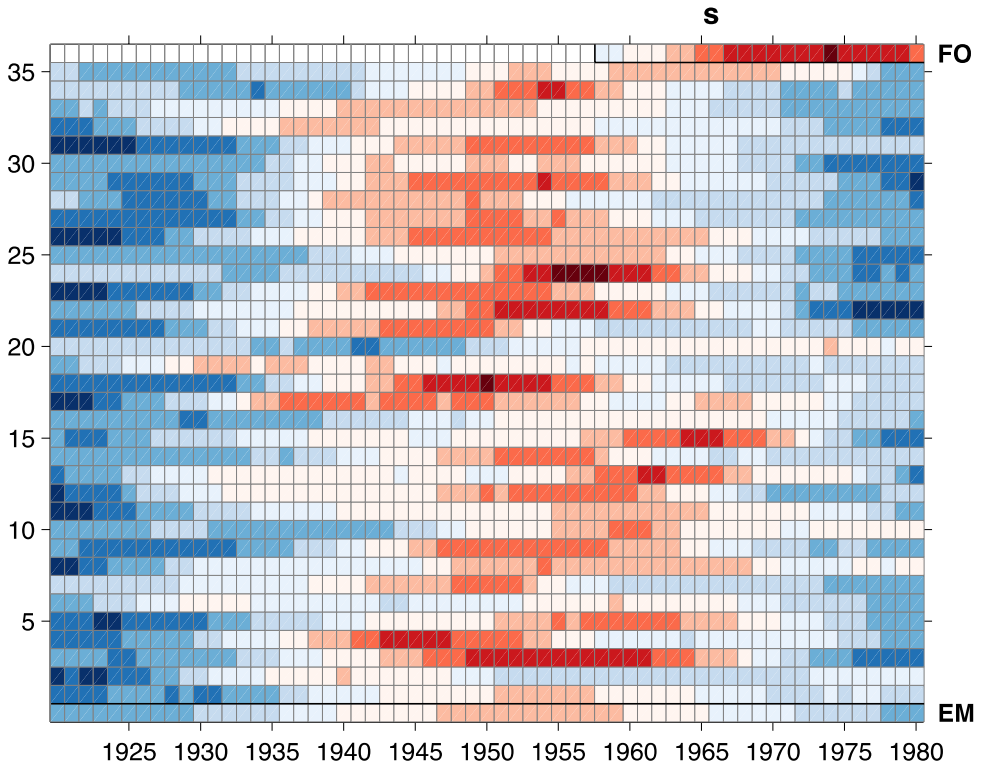
Lab. Sea Temperature

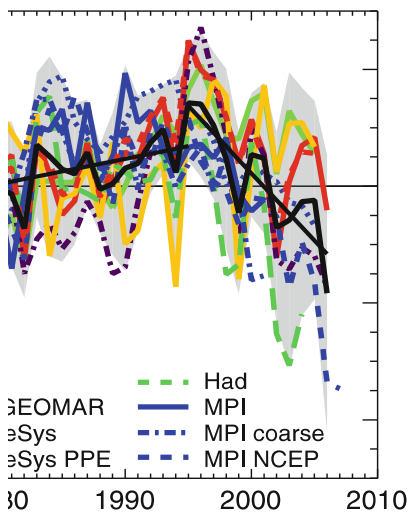


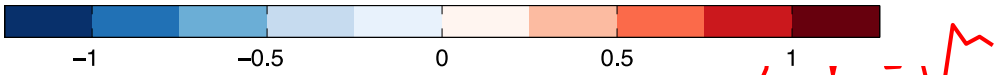
Yeager & Danabasoglu (2014)

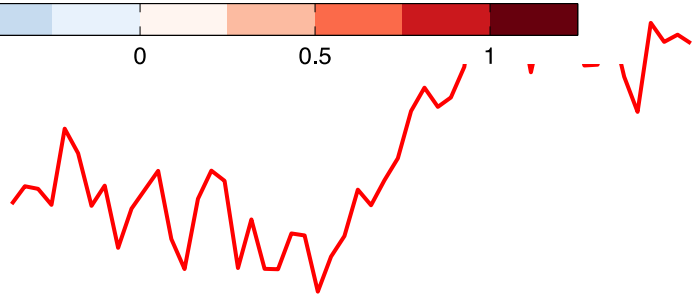
AMOC (EOF1)







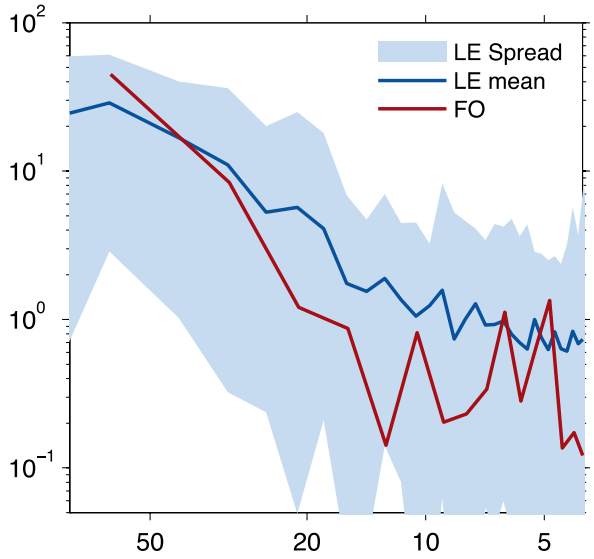




LE Spread
LE Mean
HC

Low-frequency AMOC Variability

Power Spectrum



Dashed: Ensemble-mean of LE removed from FO

Distribution of Moving Trends

5-yr **30-yr**

Maximum trend after the LE ensemble mean removed

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

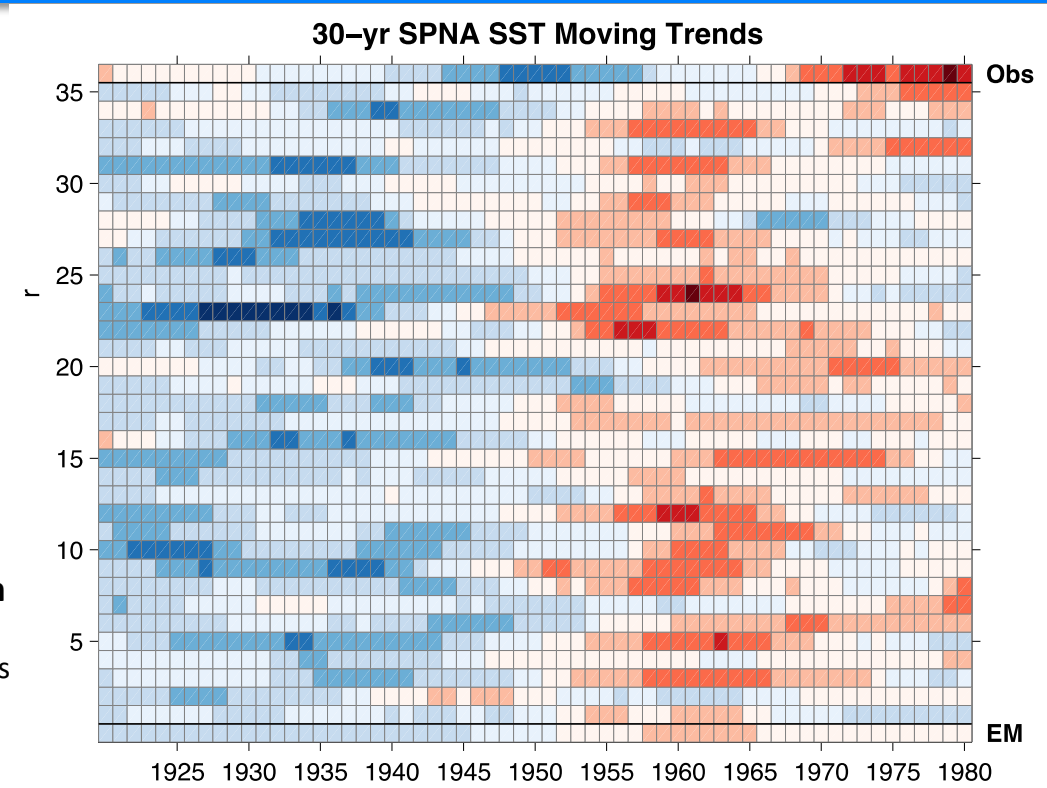
99th prctile

Normalized Unit

1st prctile

Moving trends from all 35 ensemble members of LE

AMV/SPNA SST

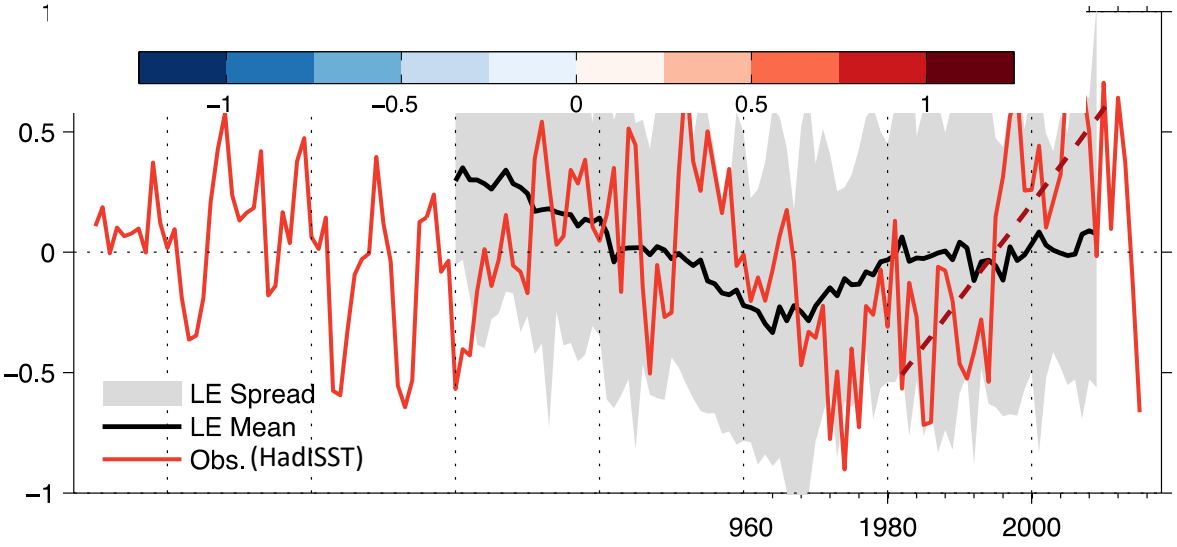


*Ensemble mean

*Ens

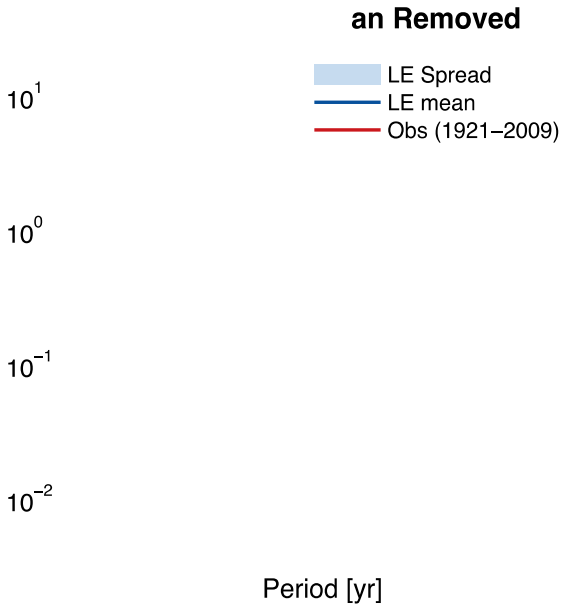
ºC/ºC

egression analyses

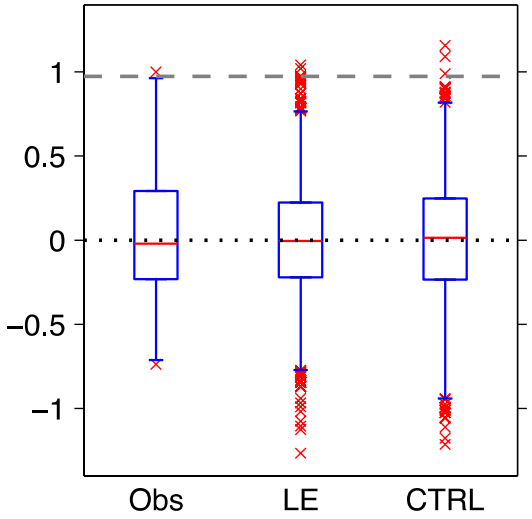


Low-frequency SPNA SST Variability

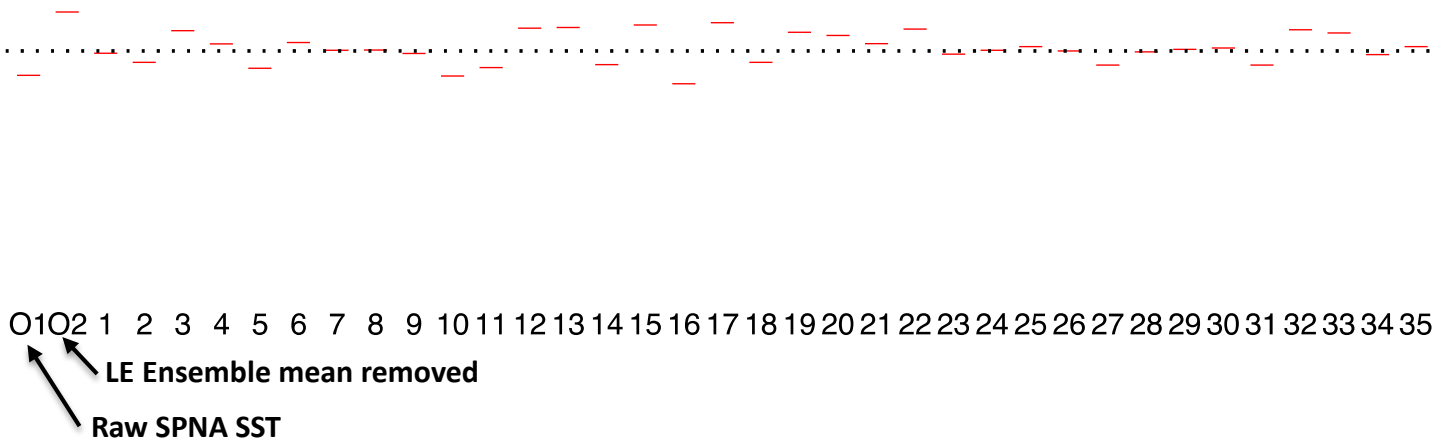
Power Spectrum



Distribution of Moving Trends



Distribution of Moving Trends in the individual ensemble members of LE

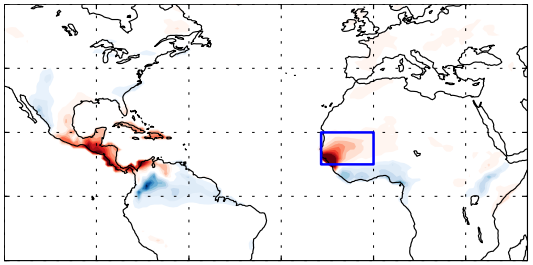


Sahel Rainfall (JJAS)

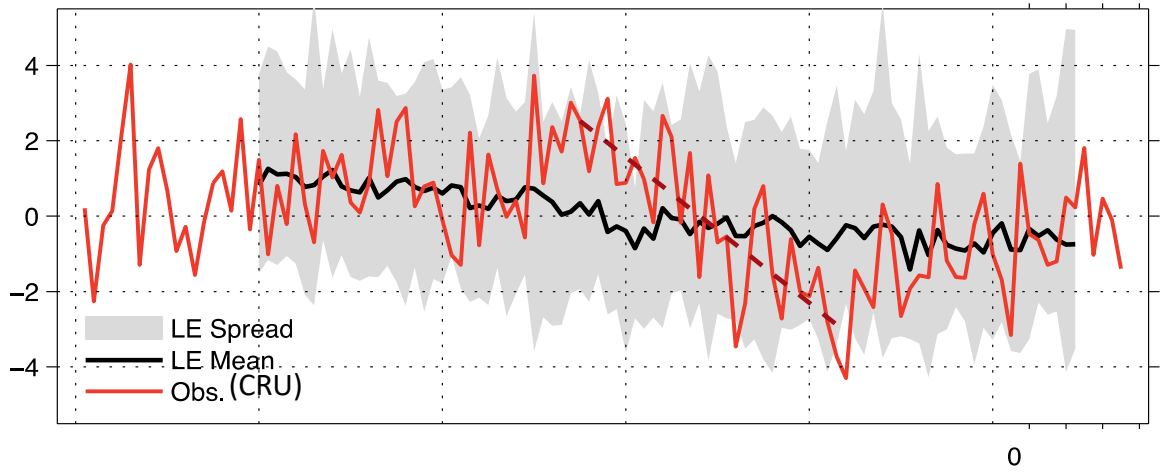
Regressions onto the NASST (AMV)

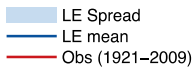
(CRU-HadISST)

***Ensemble mean**



Area-averaged (boxed area) precipitation time series





(c)

Unit

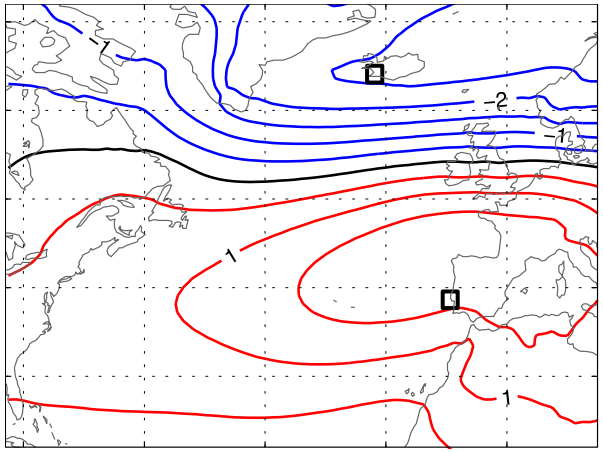
Period [yr]

NAO (DJFM)

EOF1

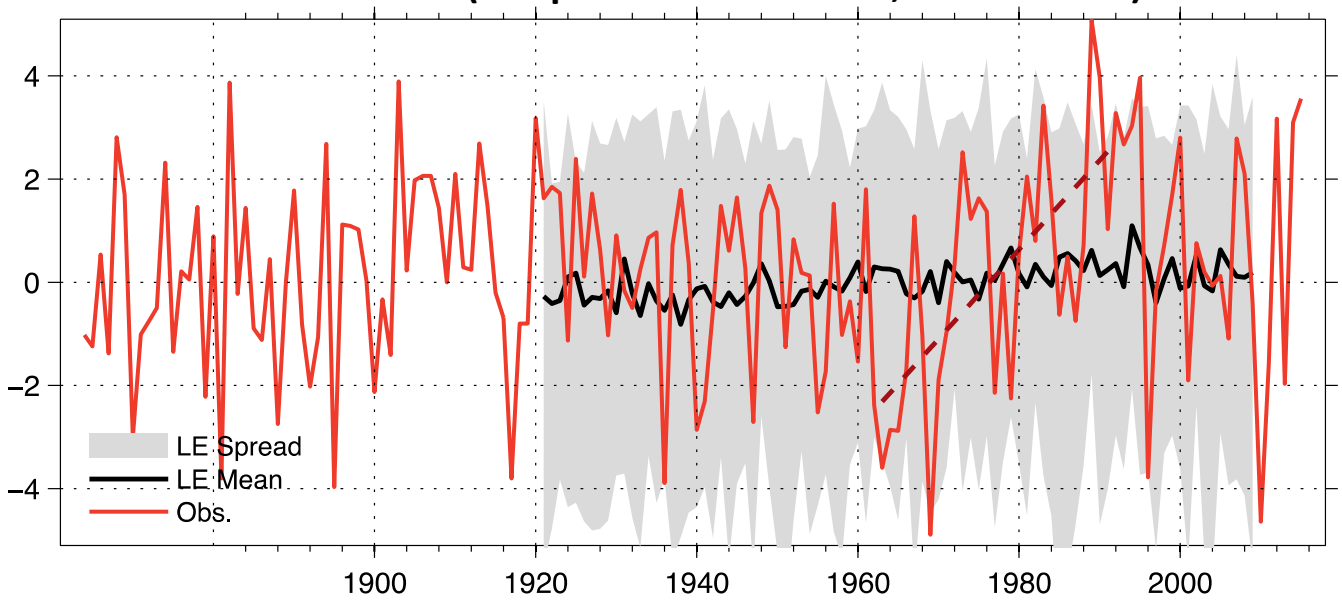
*

NCEP



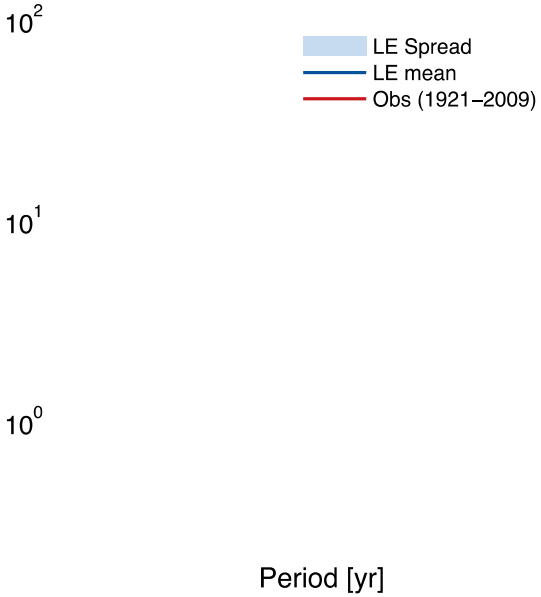
*Ensemble mean

NAO index (N-S pressure difference; Hurrell 1995)

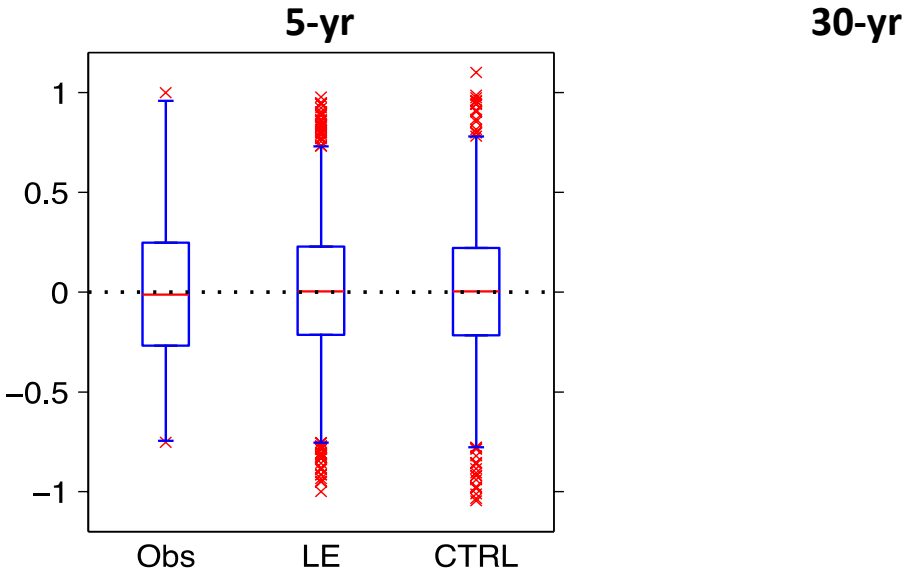


Low-frequency NAO Variability

Power Spectrum



Distribution of Moving Trends

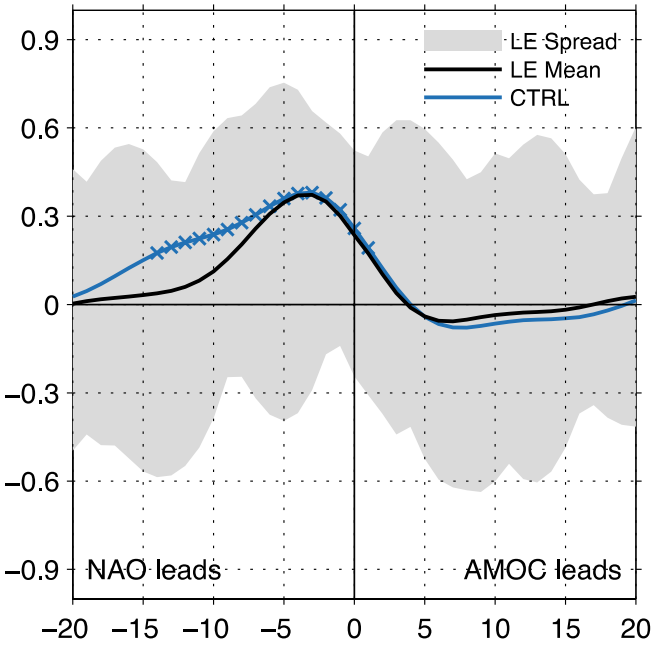


Distribution of Moving Trends in the individual ensemble members of LE

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

Mechanistic Links

Correlations b/w NAO and AMOC



Correlations b/w AMOC and SPNA SST

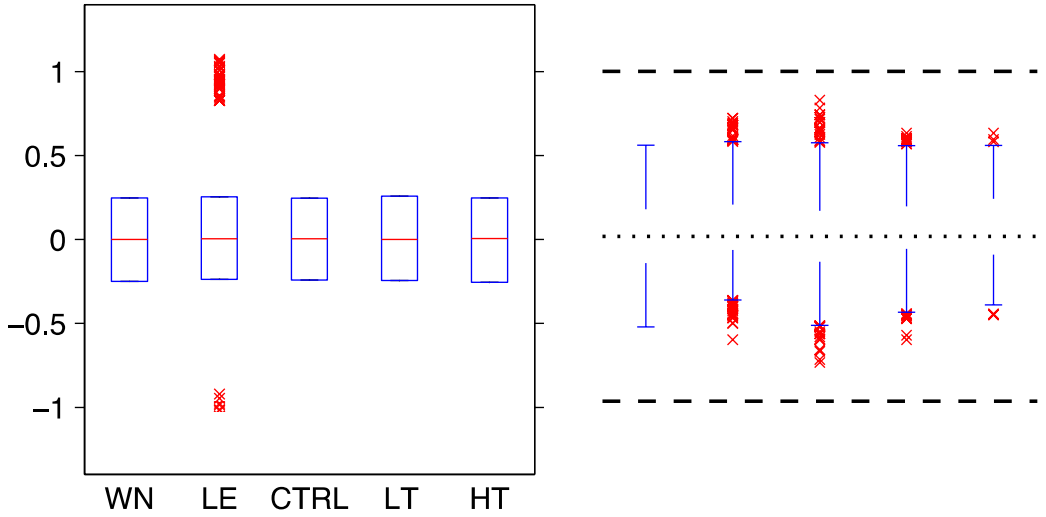
*Ensemble mean-removed and 11-yr lowpass-filetered time series are used for the correlation analyses

This mechanistic links suggest that the weak multidecadal North Atlantic climate variability in CESM1 is related to the weak simulated multidecadal NAO variability

Some Remarks on the Multidecadal NAO Variability

What is the source of the observed multidecadal NAO variability and why it is weak in CESM1?

- **SST forcing and stratosphere–troposphere coupling are suggested as possible sources for low-frequency NAO variability**

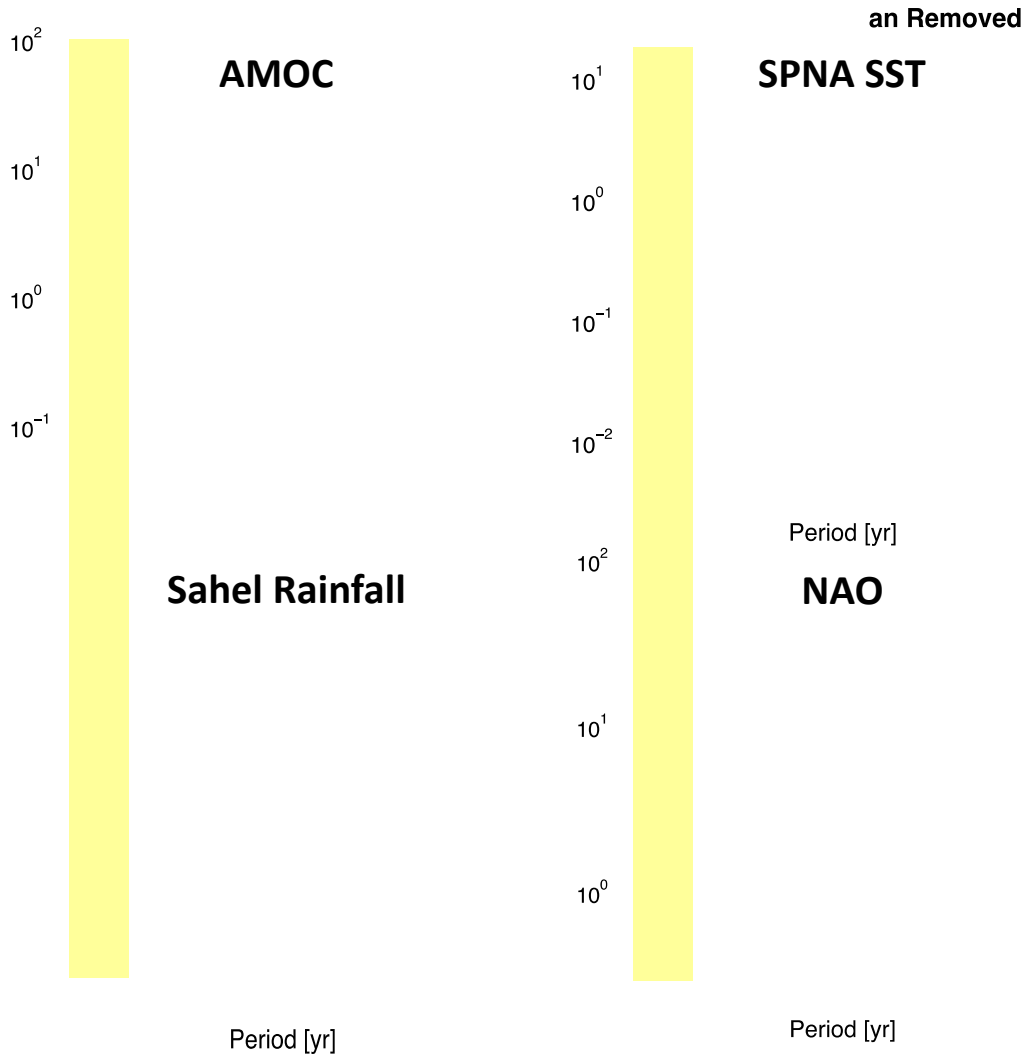


WN: synthetic white noise ensemble (89-year long x 5000 members = 445,000-year long)
LT: CAM5 historical ensemble (10 members) with interannually varying observed SST in the tropics
HT: high-top CAM5 historical ensemble (10 members) with interannually varying observed SST everywhere

- ✓ **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**
- ✓ **Suggesting deficiencies in CAM5 in simulating low-frequency NAO variability**

Summary/Discussion

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



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 ultimately be traced to **weak multidecadal variability of simulated NAO**
  - ➢ Possibly due to deficiencies in CAM5 (horizontal/vertical resolution, parameterized physics, and/or coupling method?)
- ✓ Overall weak North Atlantic climate variability, including NAO, is also found in a recent study (*Kravtosv & Callicutt* 2017) analyzing CMIP5 models
  - ➢ **Indicating that weak multidecadal AMV in CMIP coupled models can be due to the weak multidecadal variability of simulated NAO**