

2017 US AMOC Science Team Meeting

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

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# Outline

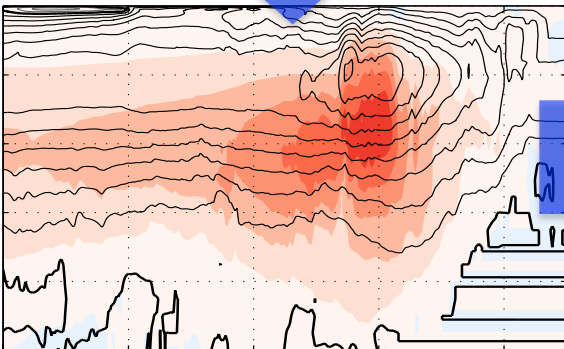
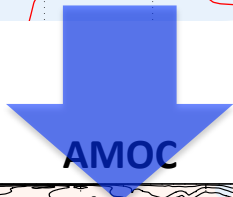
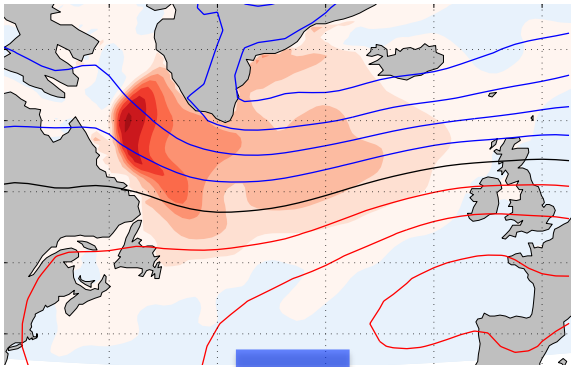
- ✓ Examine low-frequency North Atlantic variability (AMOC, SPNA SST, Sahel rainfall, and NAO) from **CESM1-CAM5 Large Ensemble** (LE; 35 members) and **control simulation** (CTRL; 800-2200), and compare to observational estimates
- ✓ Show the simulated multidecadal variability is substantially weaker than observational estimates
- ✓ Show the weak simulated multidecadal variability can be traced to weak multidecadal variability in simulated NAO

Kim et al., 2017: **Low-frequency North Atlantic climate variability in the Community Earth System Model Large Ensemble simulations**. Submitted to *J. Climate* (in revision).

# Multidecadal Variability in the North Atlantic

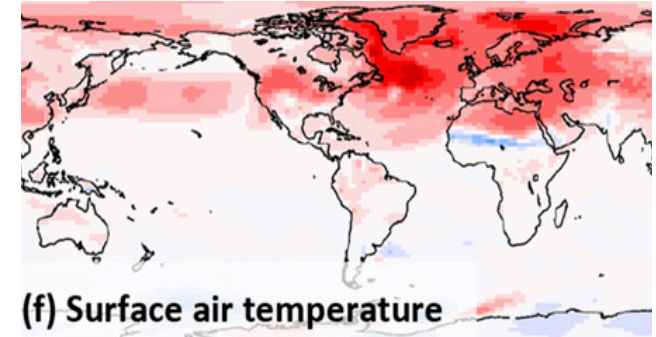
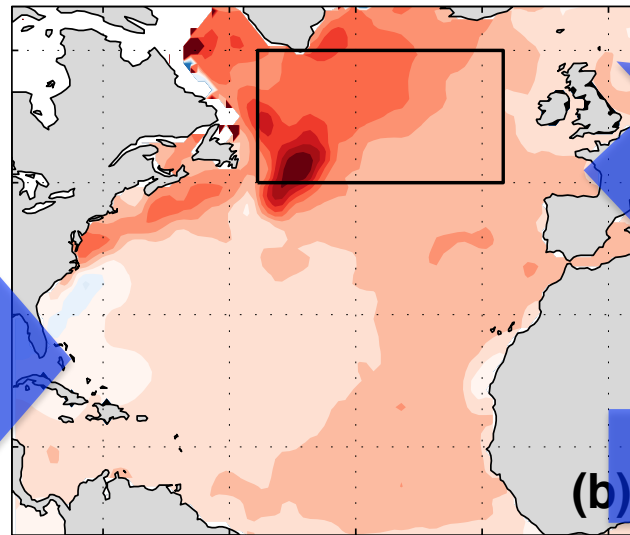
## NAO-driven surface buoyancy fluxes & Deep water formation

*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*



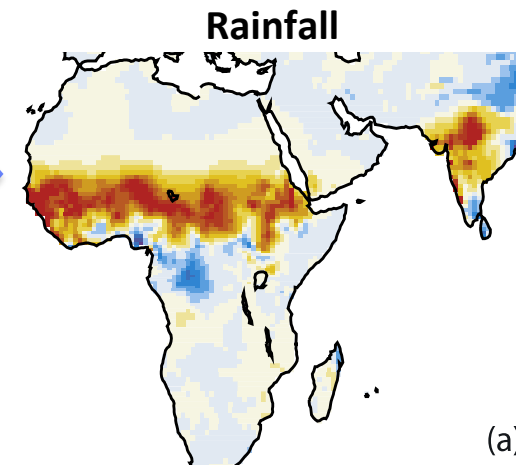
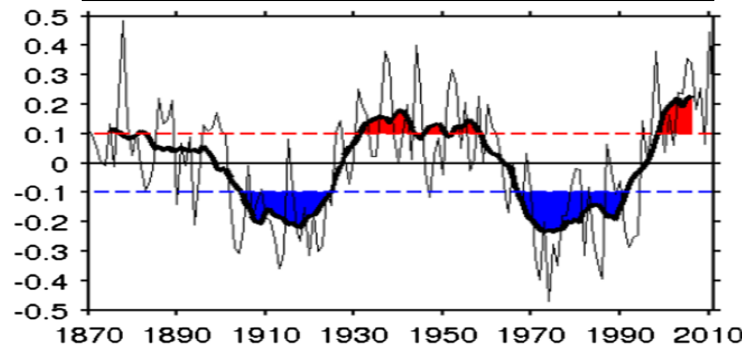
*Delworth et al. (1993); Knight et al. (2005); Dong & Sutton (2005); Danabasoglu et al. (2012); Tendon & Kushner (2015); O'Reilly et al. (2016); Zhang et al. (2016) & many more*

## AMV (AMO)



Delworth & Zeng (2015)

(f) Surface air temperature



Zhang & Delworth (2006)

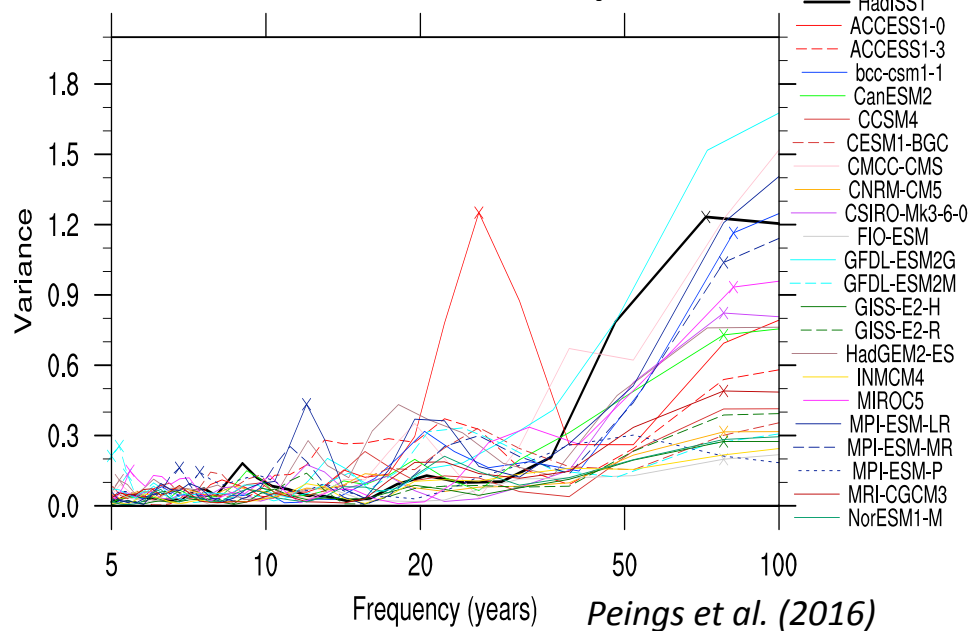
(a)

# Weak AMV Power in Coupled Simulations

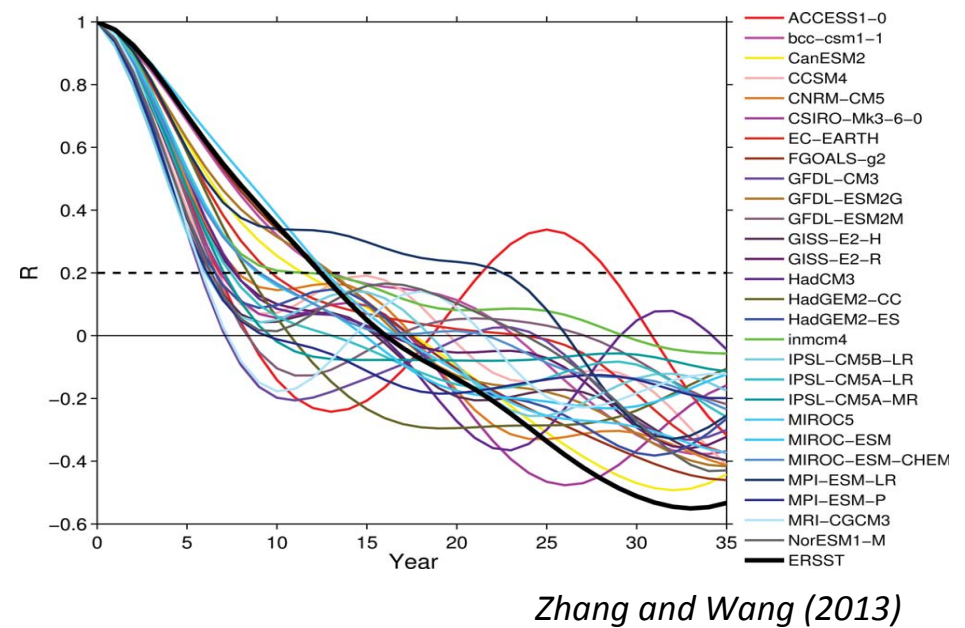
- ✓ The observed AMV pattern is generally captured in CMIP coupled models, but...
- ✓ Low-frequency power of the simulated NASST (AMV) in such models seems to be too weak compared to observations

b) Historical AMV (Internal + External)

**Power Spectrum**

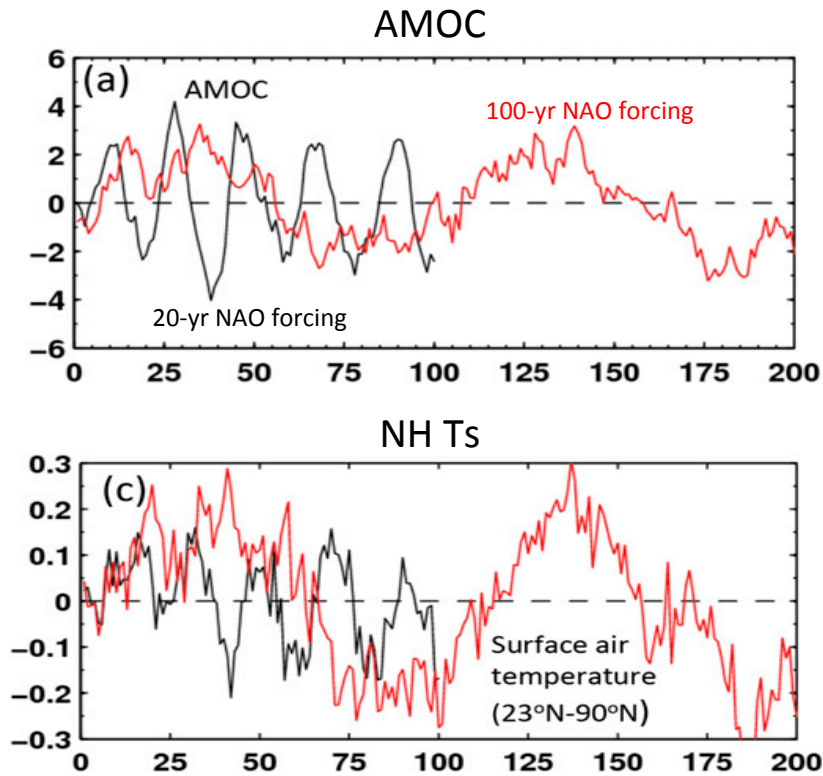


**Autocorrelation**

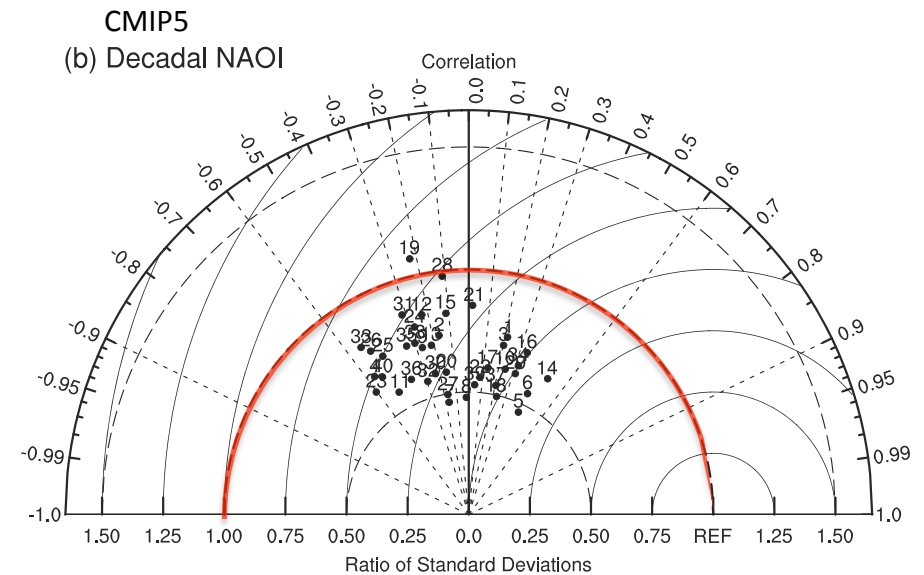


**Why is multidecadal NASST variability (AMV) in coupled models weak compared to observations?**

# Relationship between NAO-AMOC-AMV



*Delworth & Zeng (2015)\**



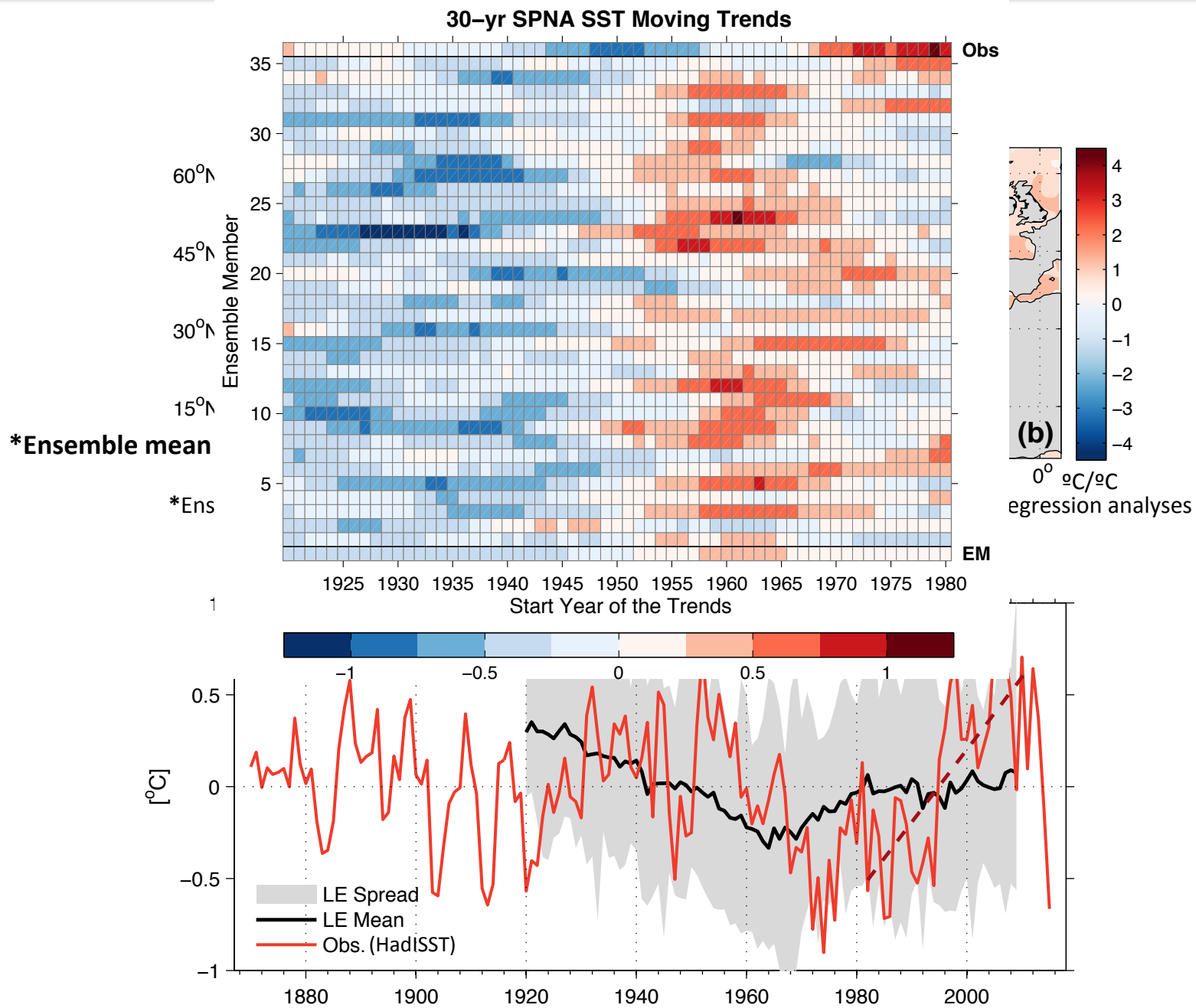
*Wang et al. (2017)*

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

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

**Most of CMIP5 models underestimate decadal NAO variability**

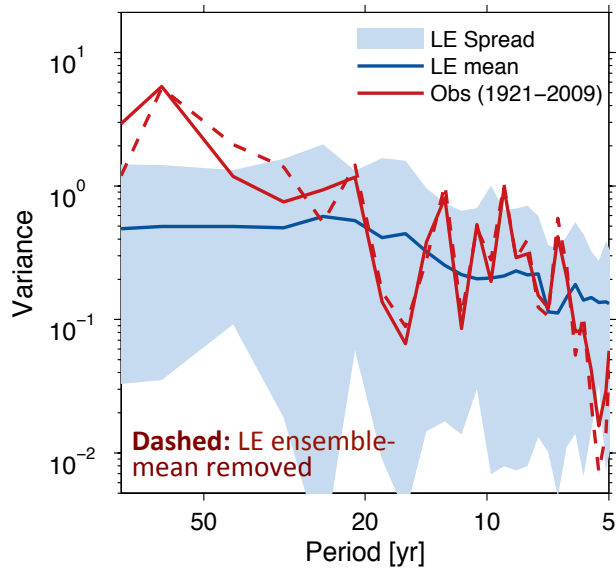
# AMV/SPNA SST



# Low-frequency SPNA SST Variability

## Power Spectrum

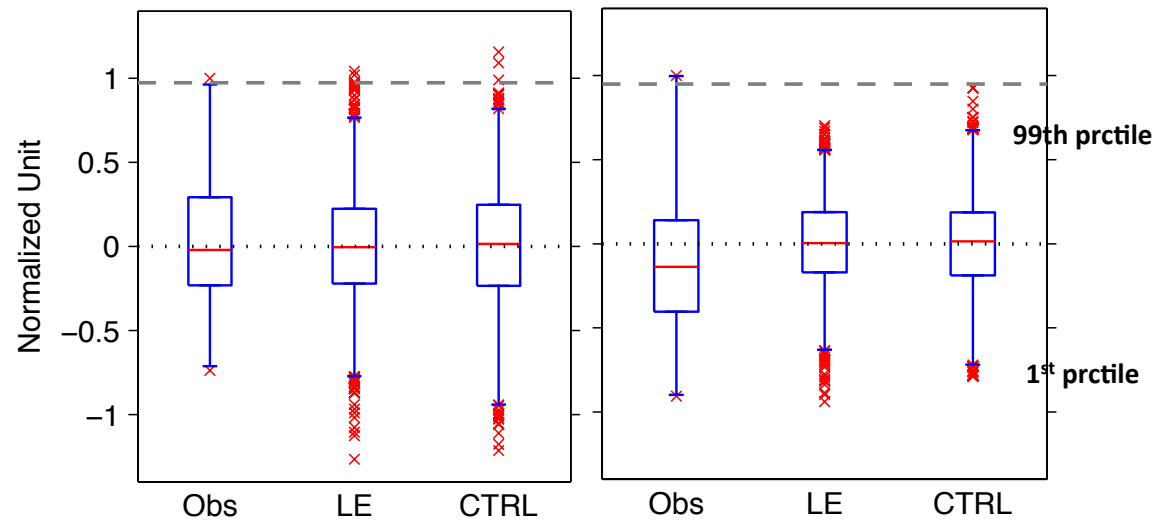
(b) Ensemble Mean Removed



## Distribution of Moving Trends\*

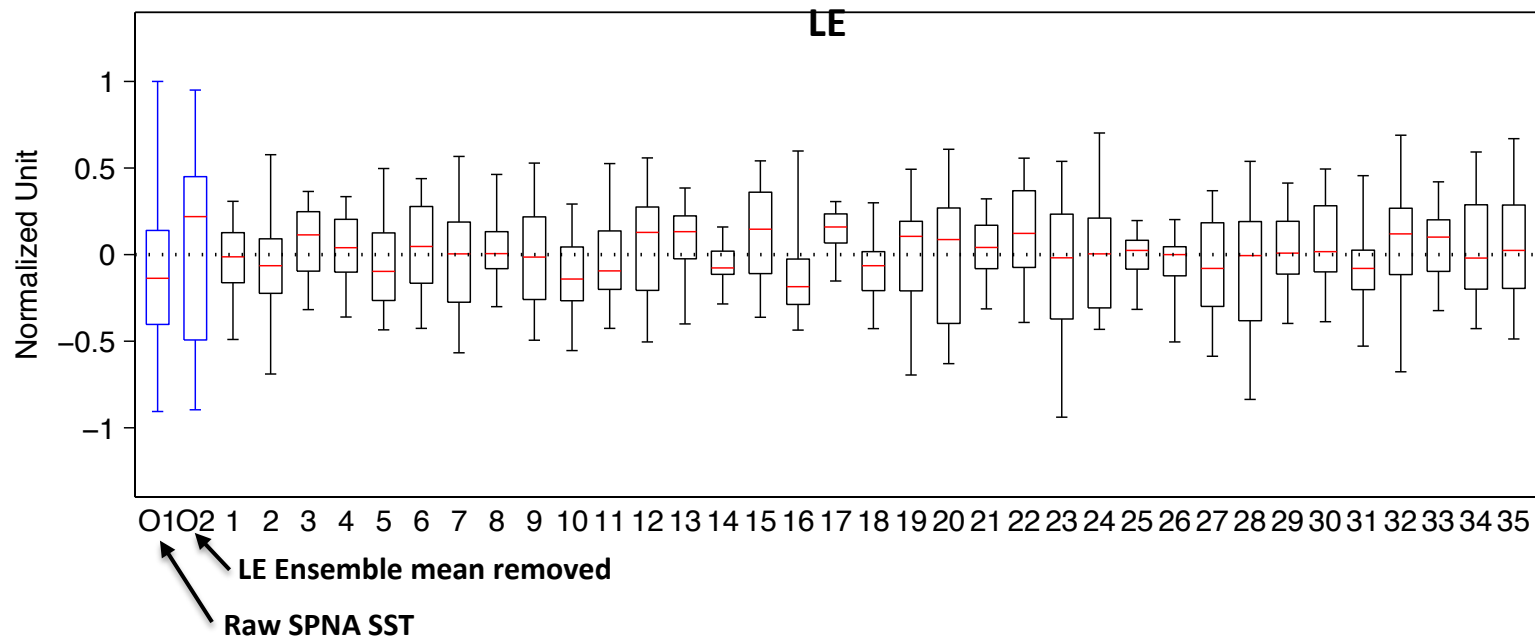
5 yr

30 yr



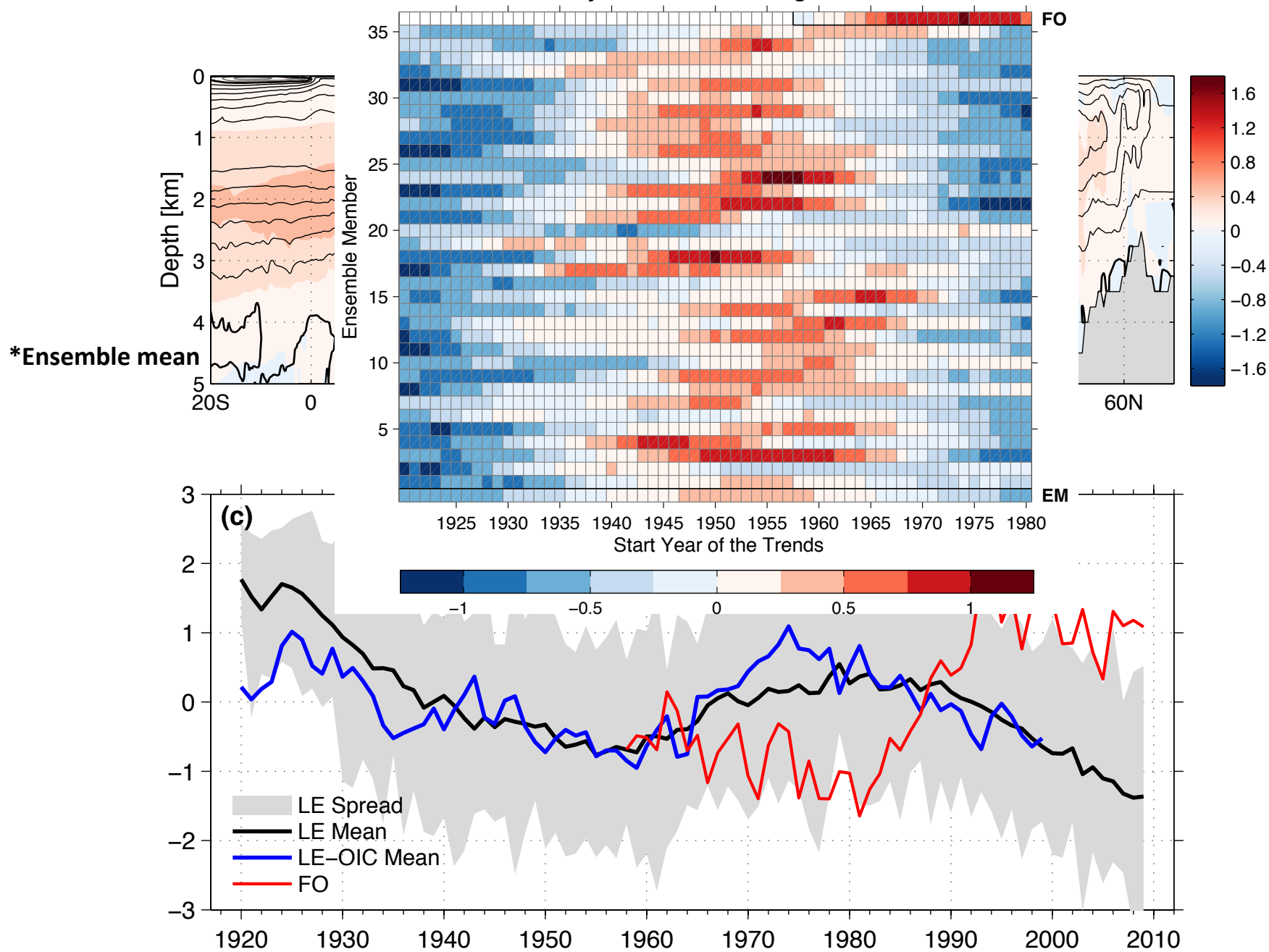
\* All trends are normalized to the corresponding max trend of observational estimates

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



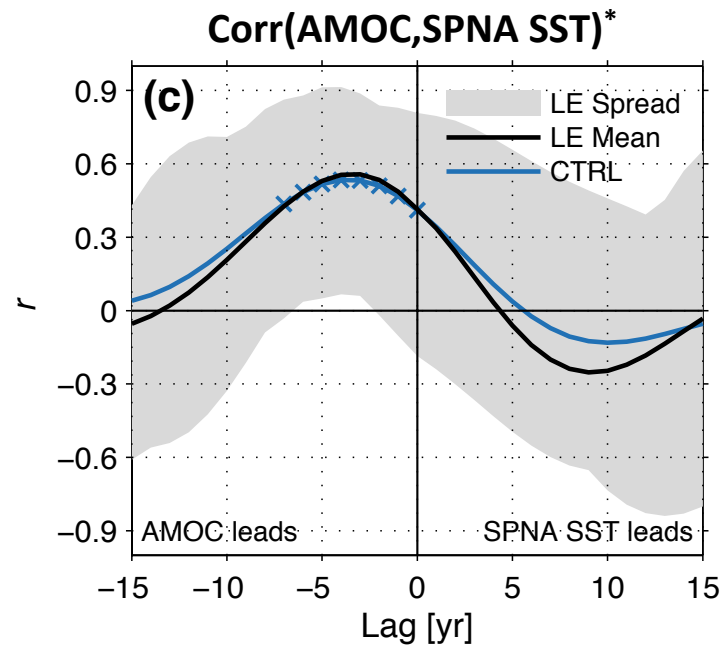
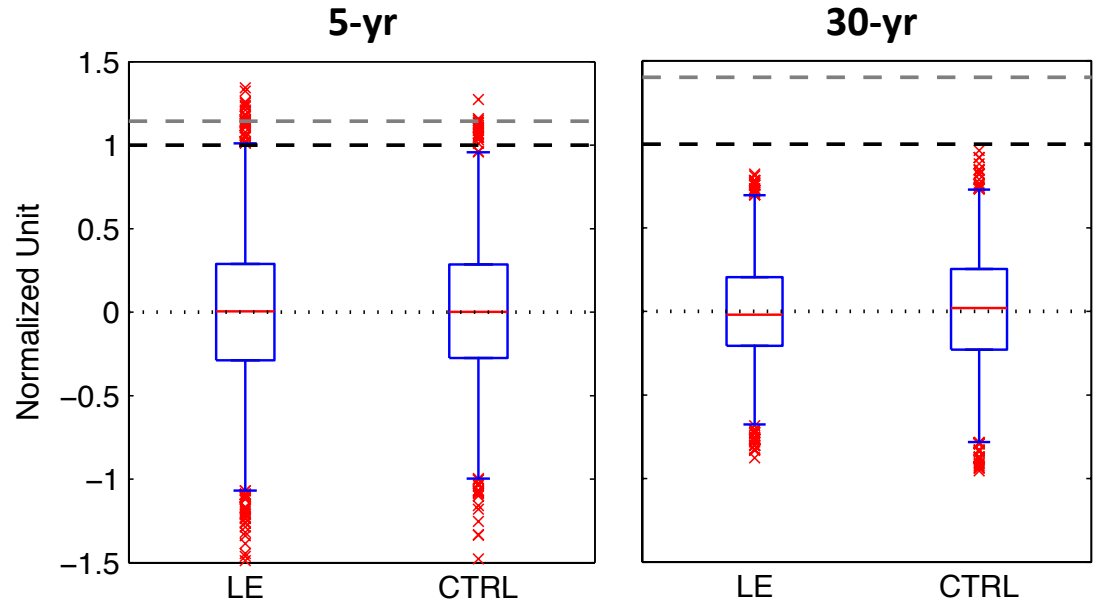
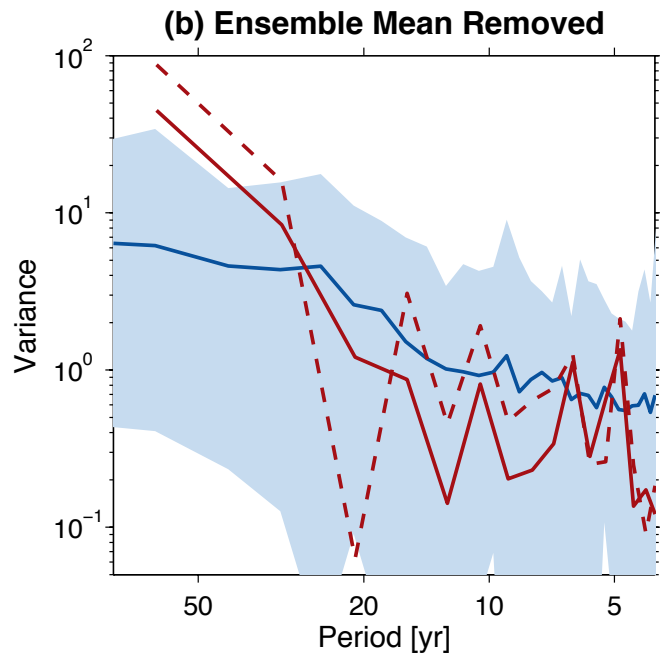
# AMOC (EOF1)

30-yr AMOC PC1 Moving Trends





# Low-frequency AMOC Variability



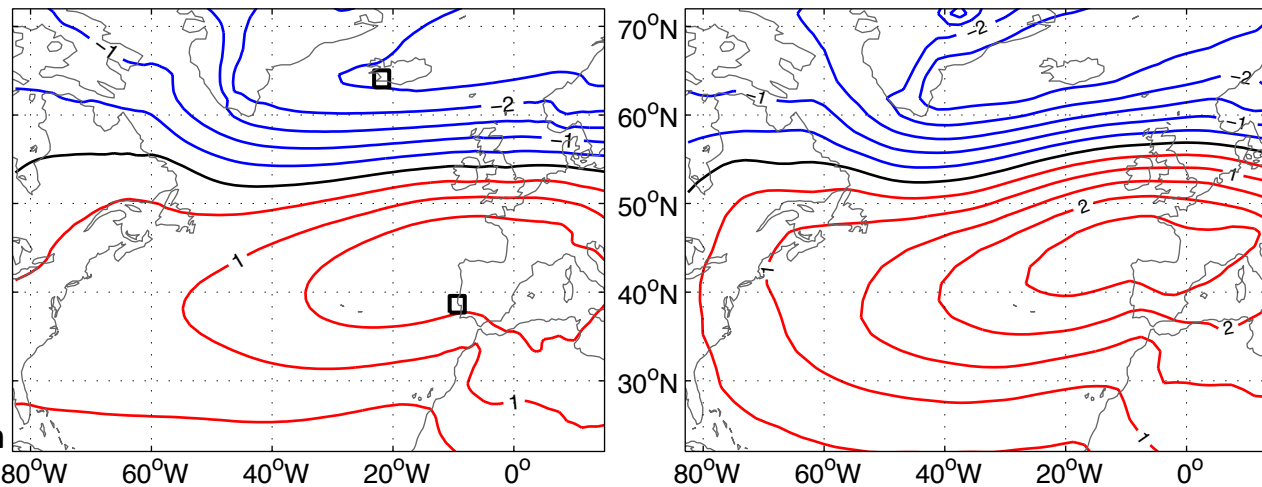
\*Ensemble mean-removed and 15-yr lowpass-filtered

# NAO (DJFM)

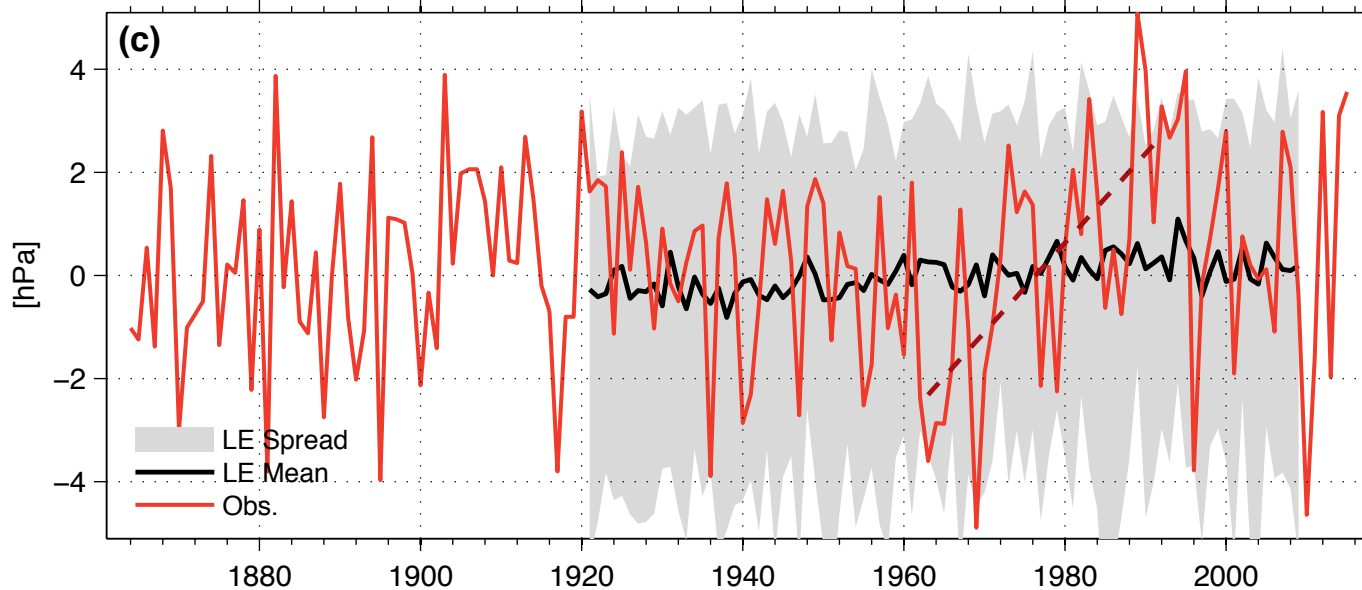
## EOF1

(a) LE (44.0%)\*

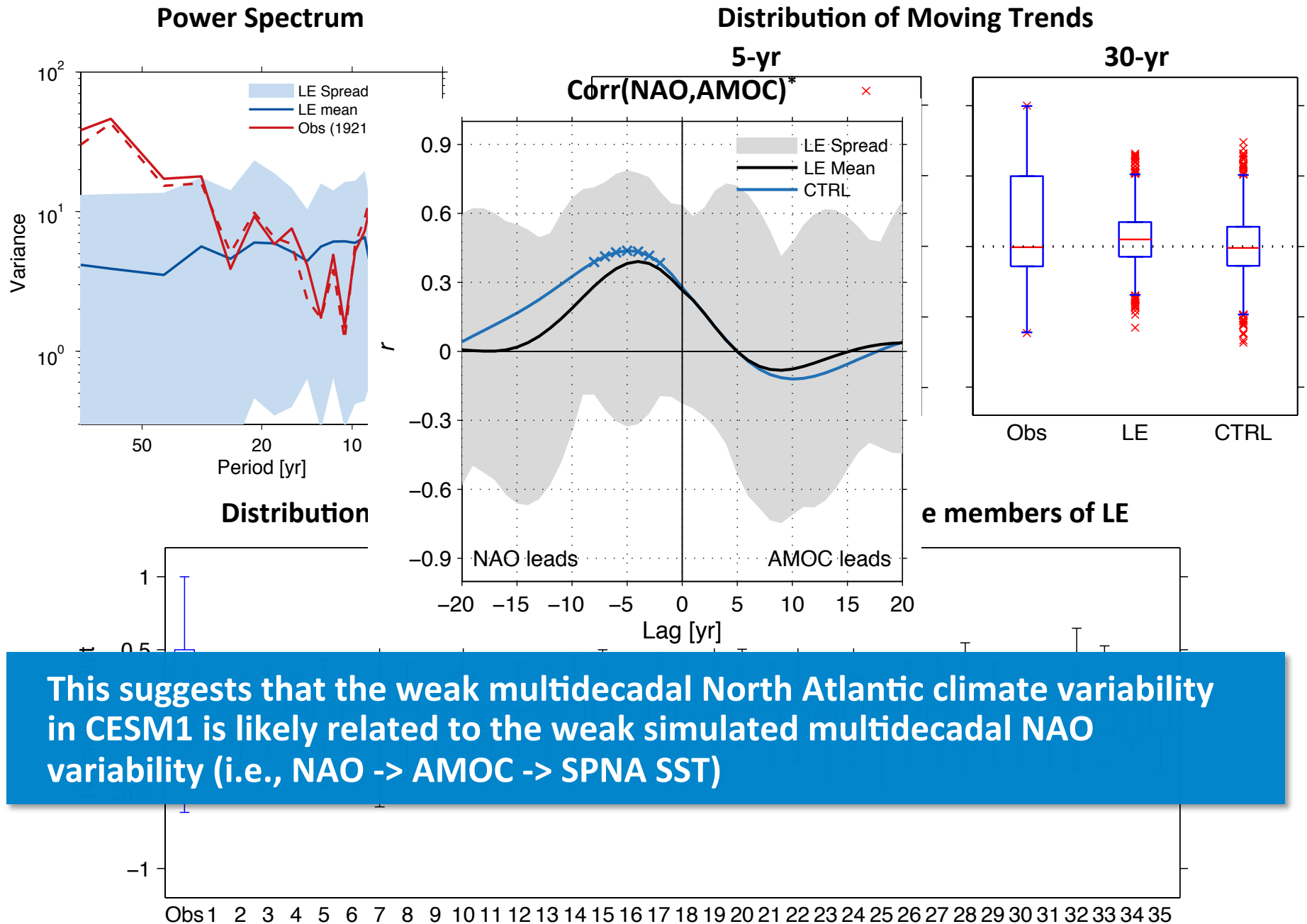
(b) Obs (46.8%) NCEP



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



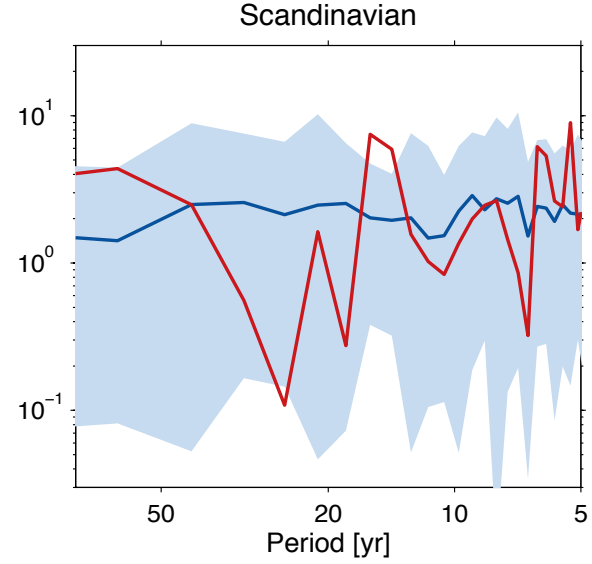
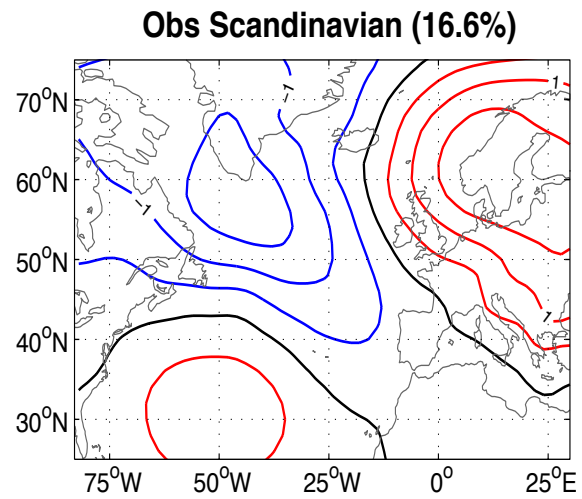
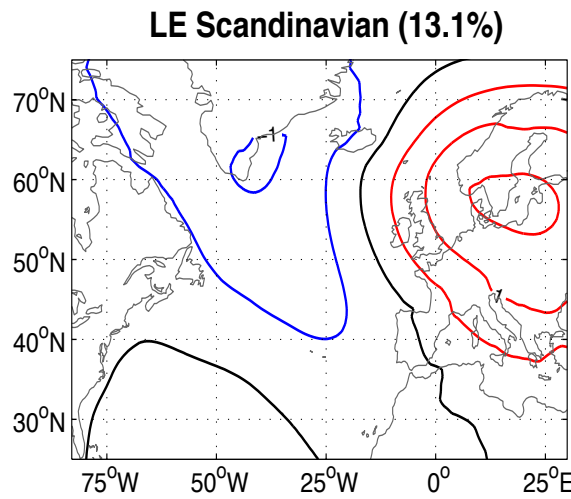
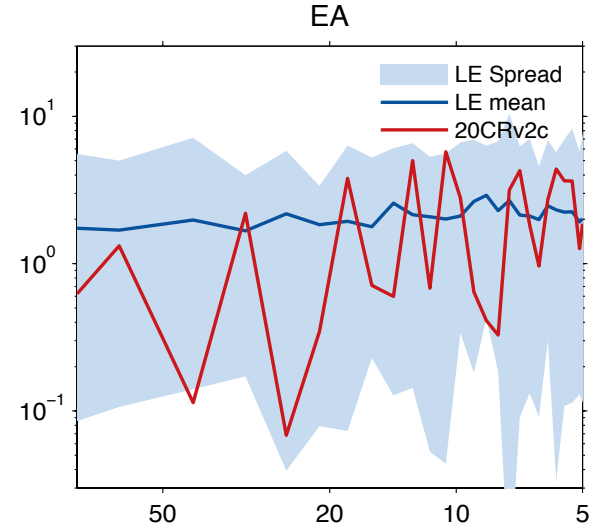
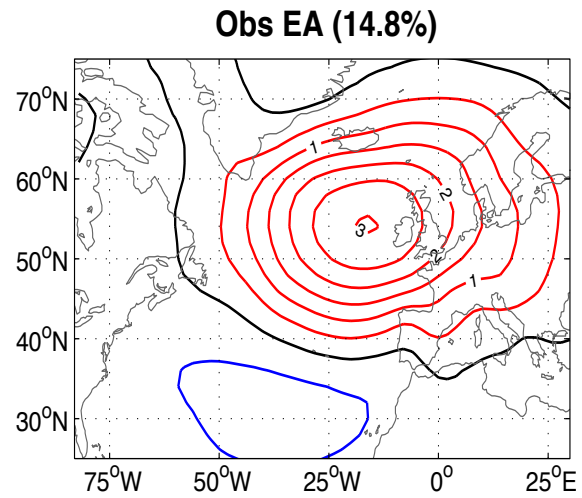
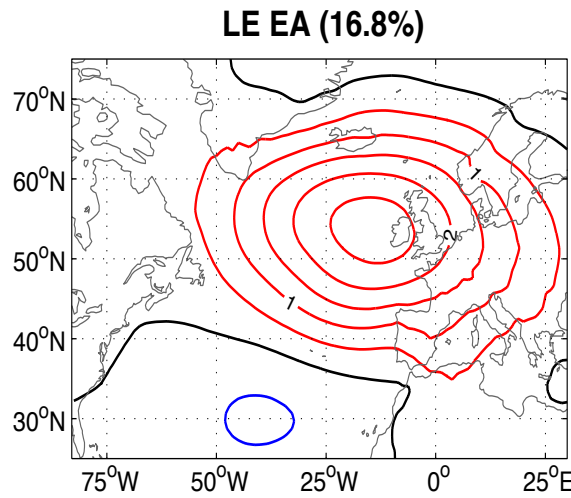
# Low-frequency NAO Variability



This suggests that the weak multidecadal North Atlantic climate variability in CESM1 is likely related to the weak simulated multidecadal NAO variability (i.e., NAO → AMOC → SPNA SST)

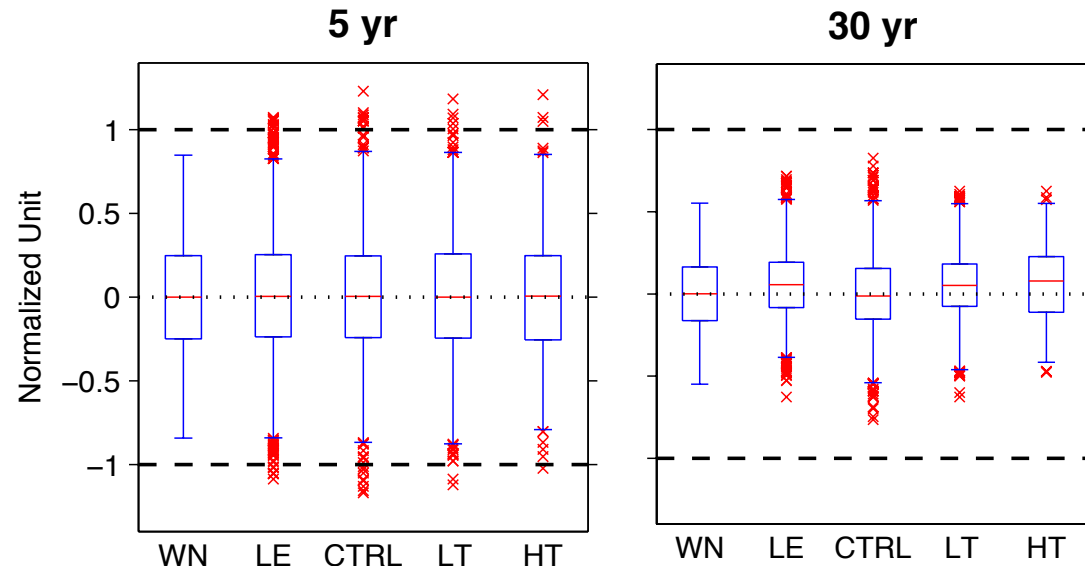
# Low-frequency Variability in Other Atmospheric Modes

Some studies suggests that decadal NA variability is associated with EA or Scandinavian patterns



# Some Remarks on the Multidecadal NAO Variability

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)

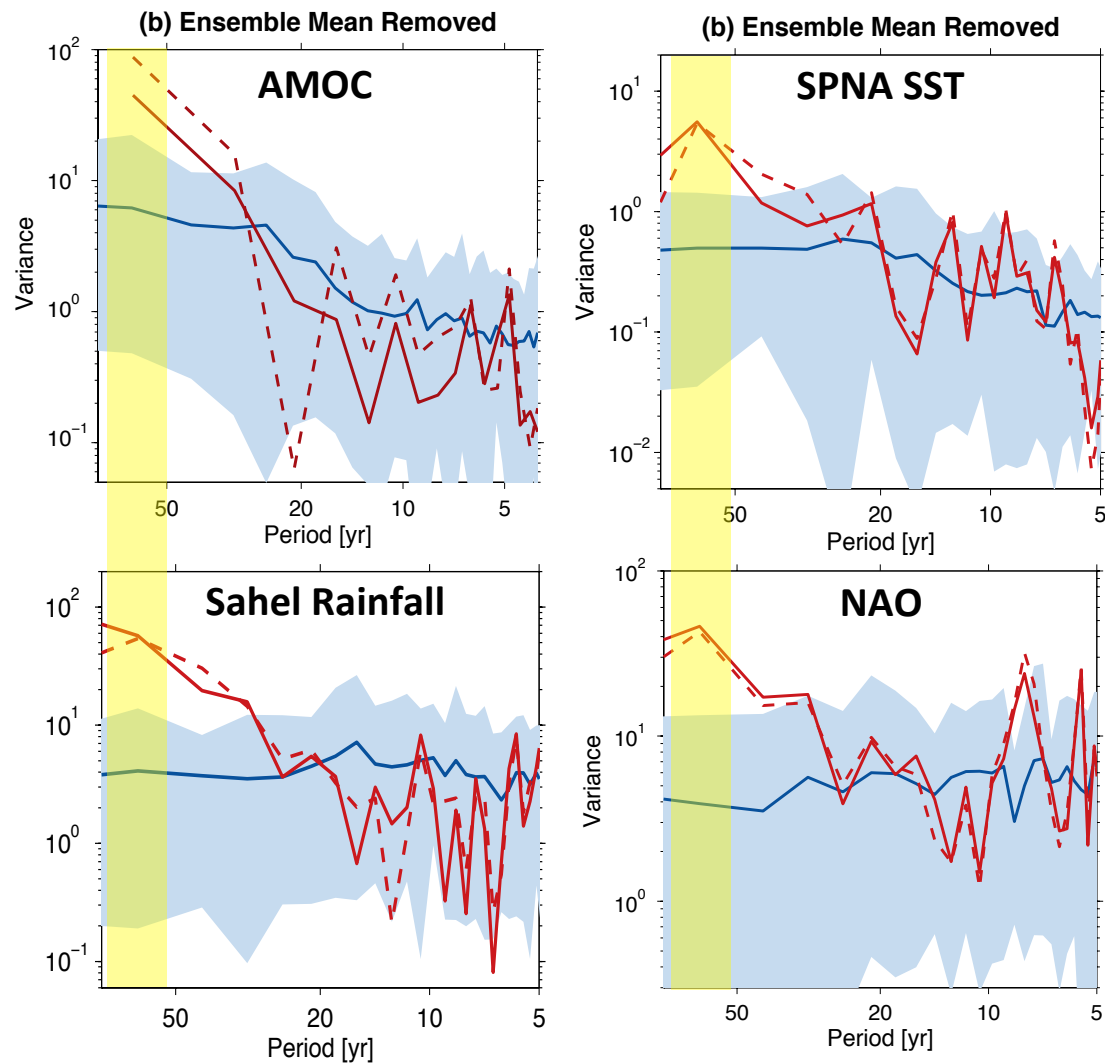
**LT:** CAM5 historical ensemble (10 members) with interannually varying observed SST in the tropics

**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 a deficiency in simulating low-frequency NAO variability in CAM5 or coupling methods**

# Summary/Discussion

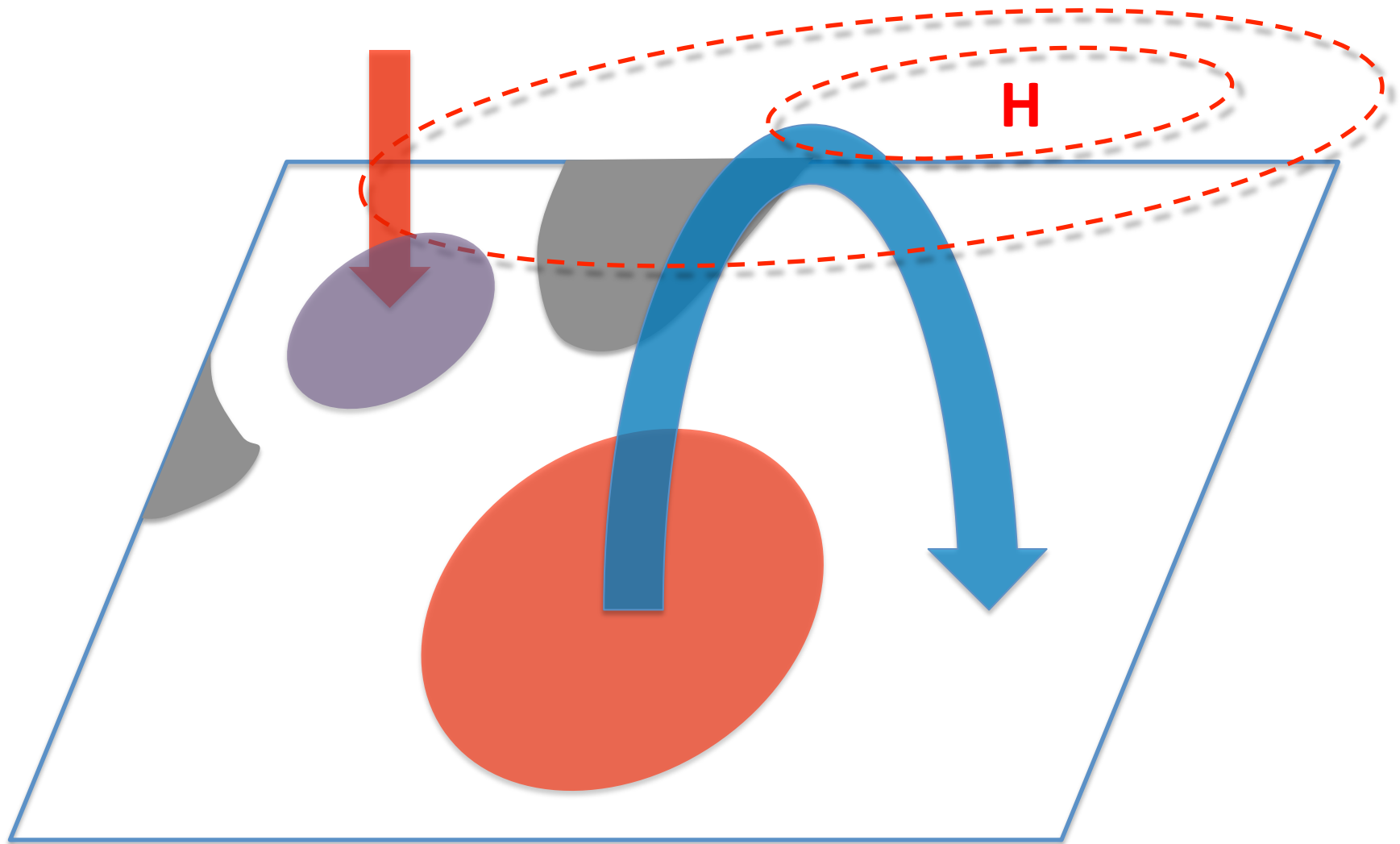
- ✓ The multidecadal North Atlantic climate variability in CESM1-CAM5 is weak compared to observational estimates



# 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 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 other CMIP5 models (*Kravtsov & Callicutt 2017; Wang et al. 2017*)
  - **Weak multidecadal AMV in coupled models can be due to the weak multidecadal variability of the simulated NAO**

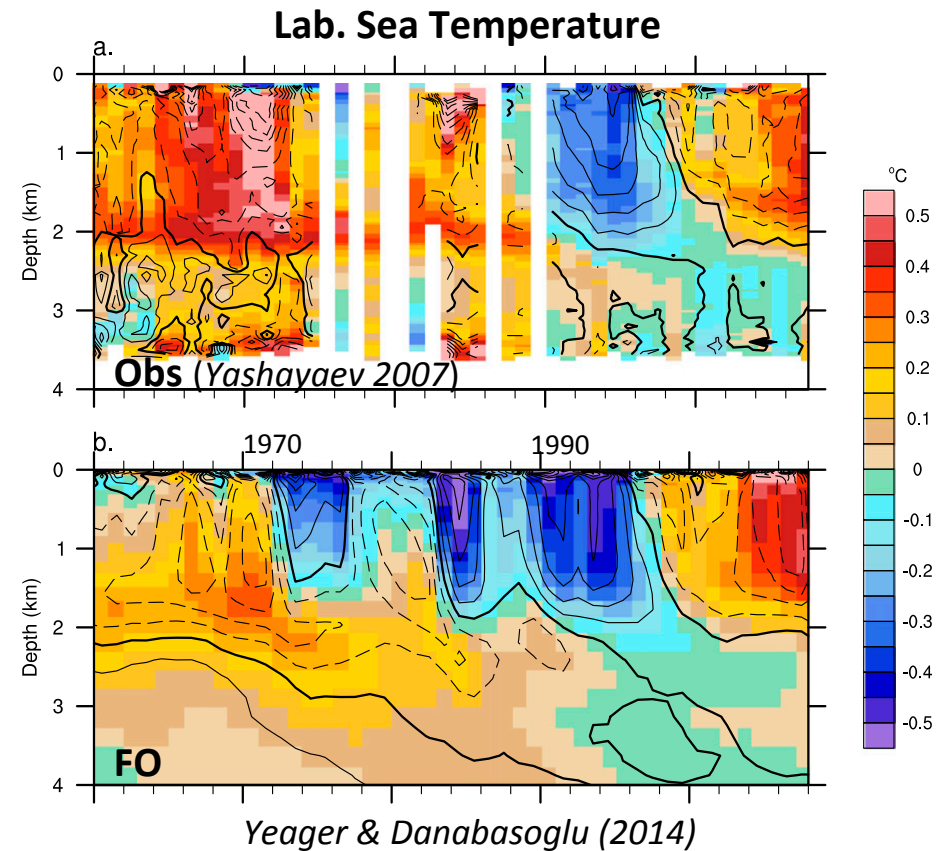
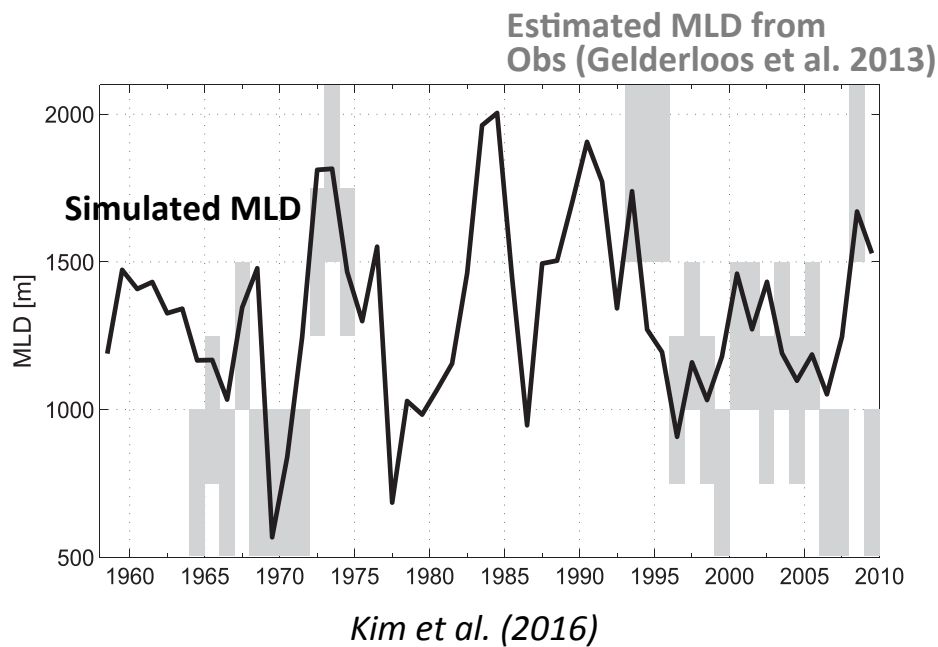
# SPNA SST-NAO-Lab. Sea Heat Flux Coupling





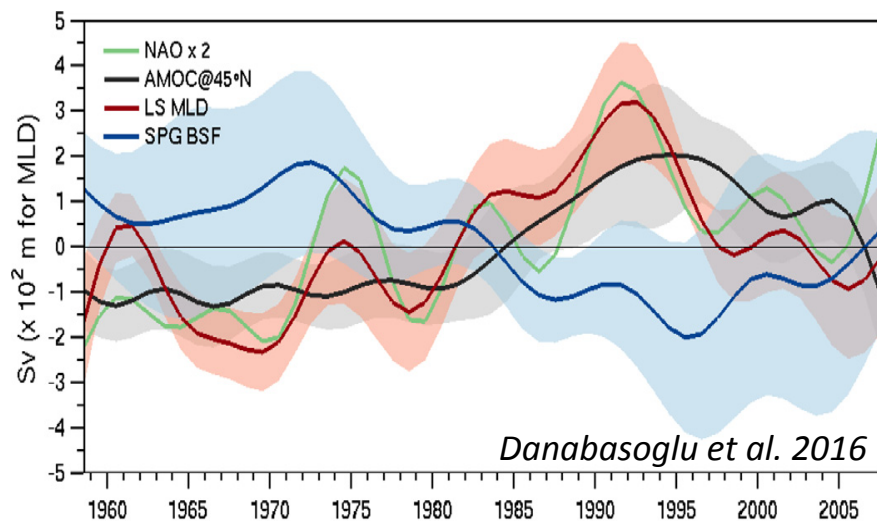
# AMOC Estimates

- ✓ **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**

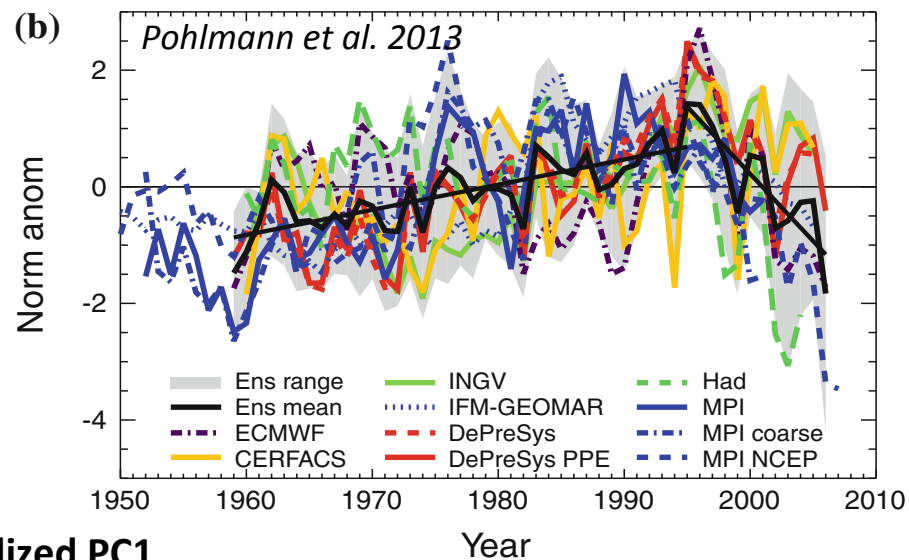


# AMOC (EOF1)

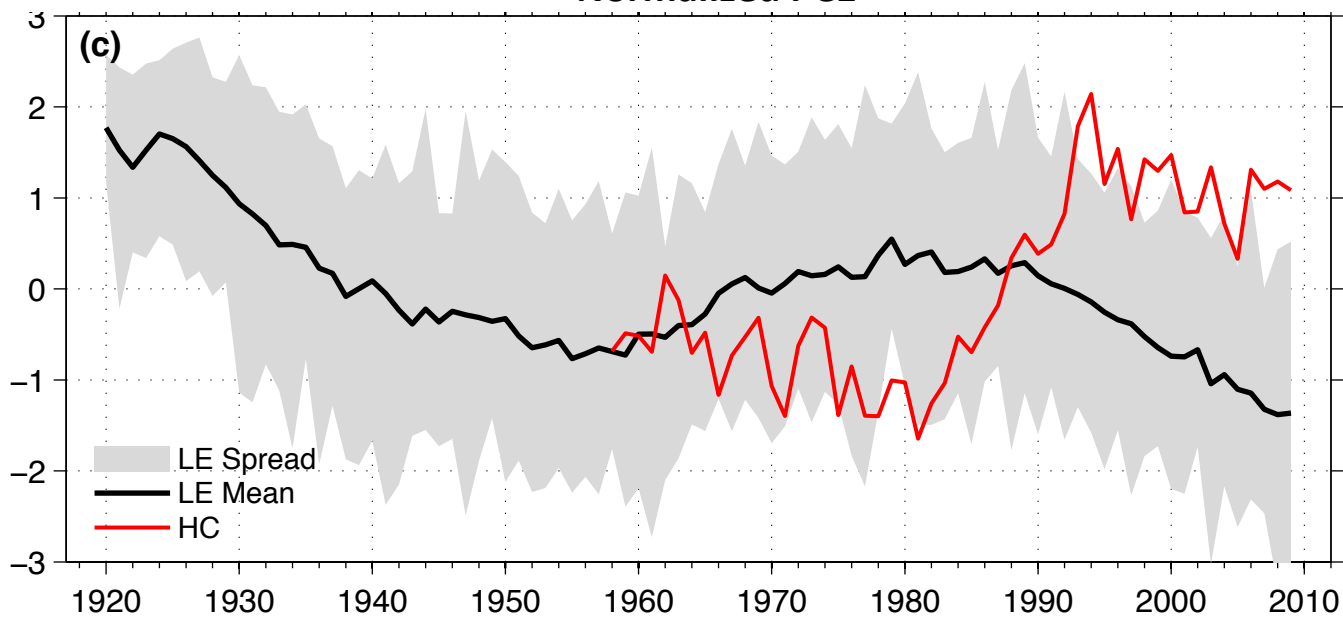
19 CORE-II Hindcast simulations



Ocean Reanalysis



Normalized PC1

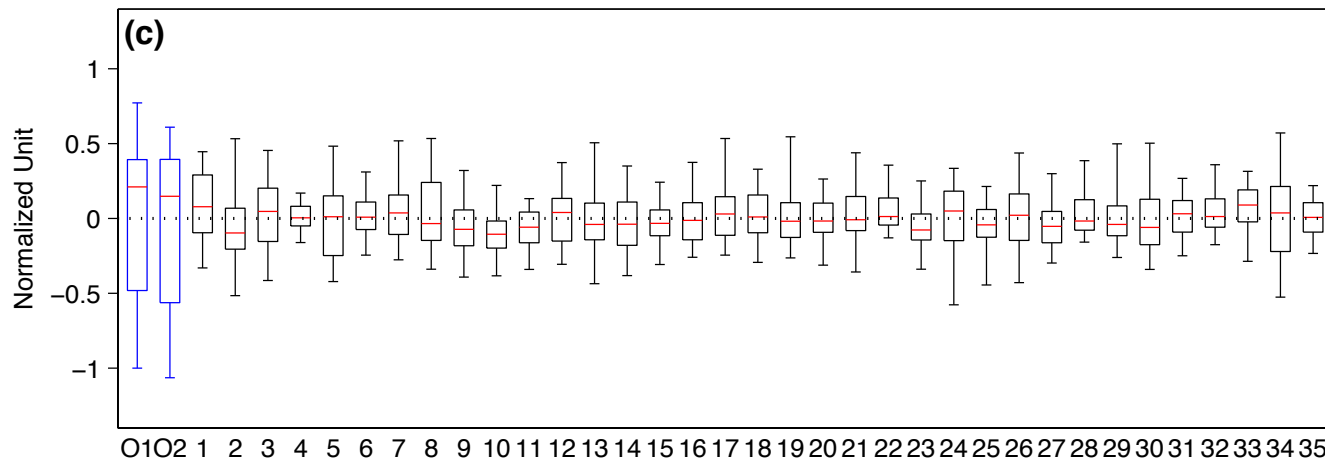
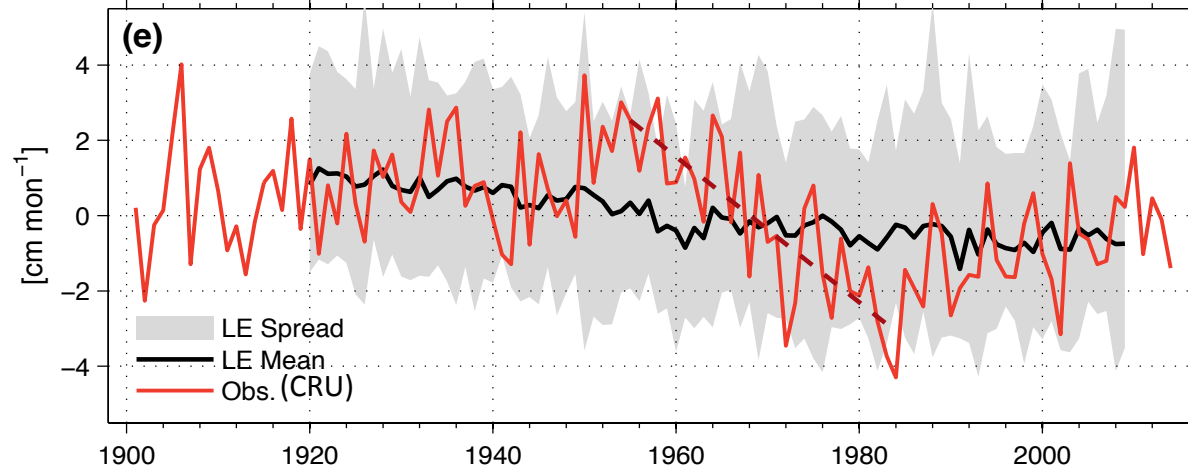
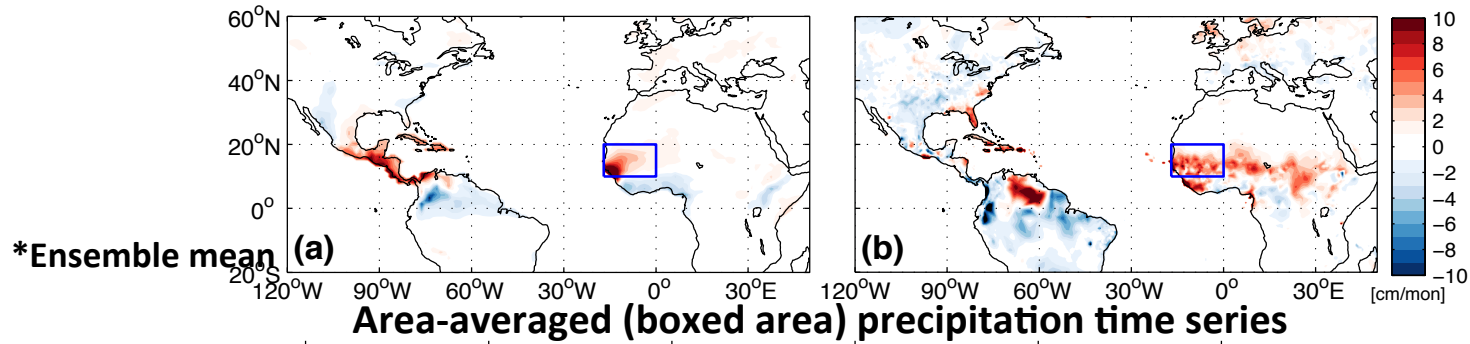


# Sahel Rainfall (JJAS)

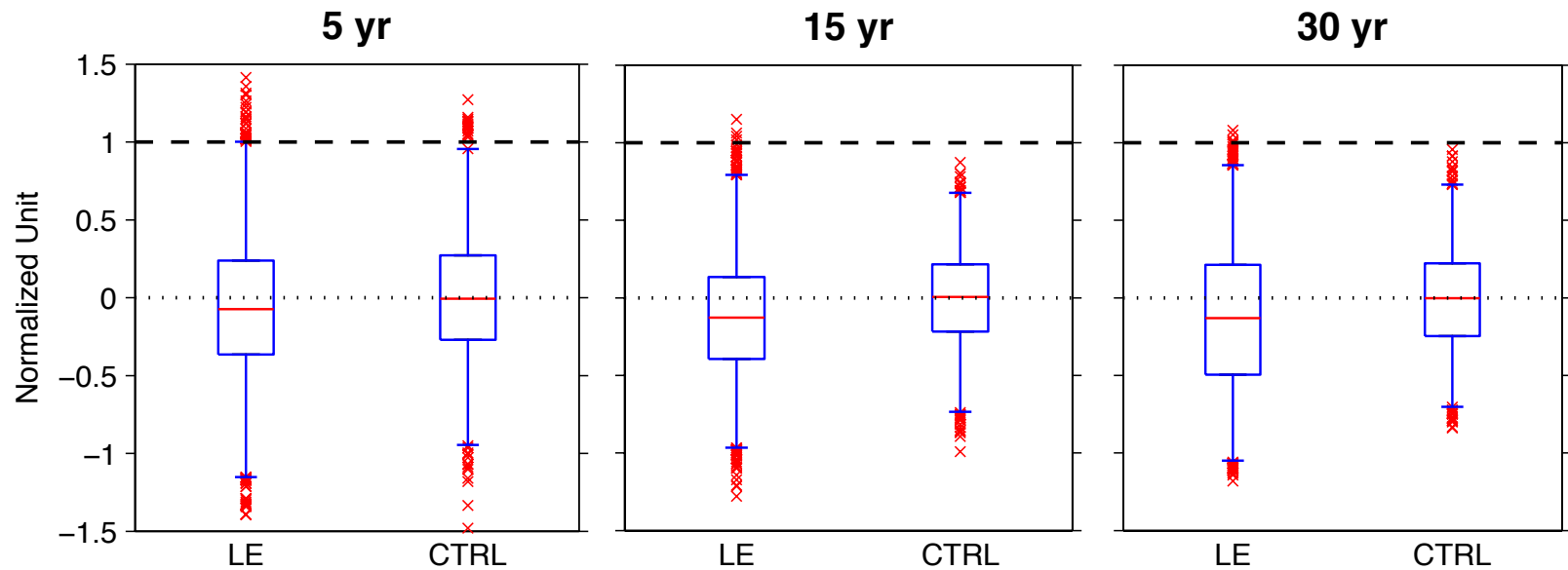
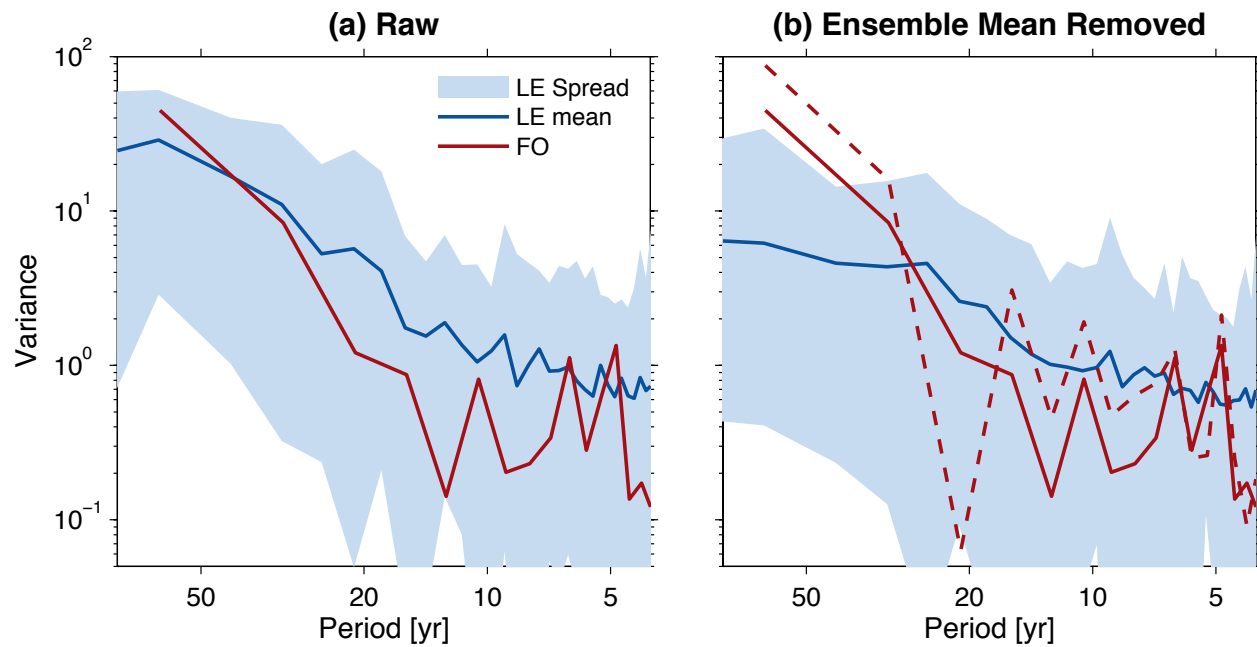
## Regressions onto the NASST (AMV)

LE

Obs (CRU-HadISST)

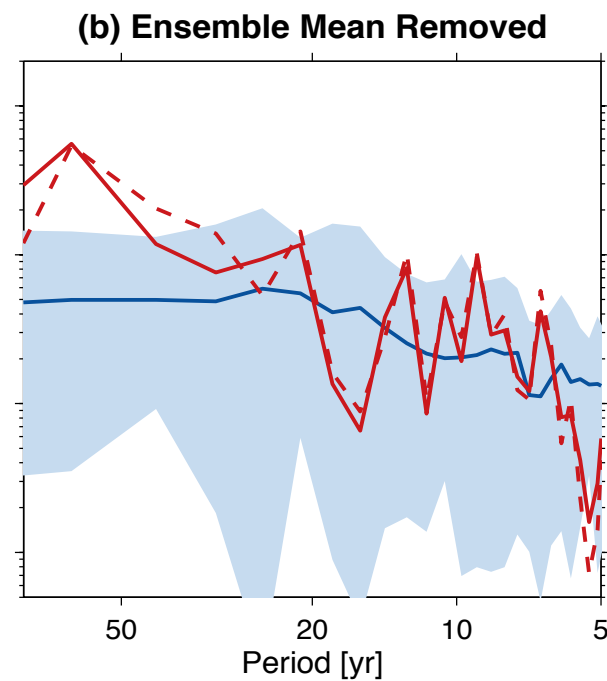
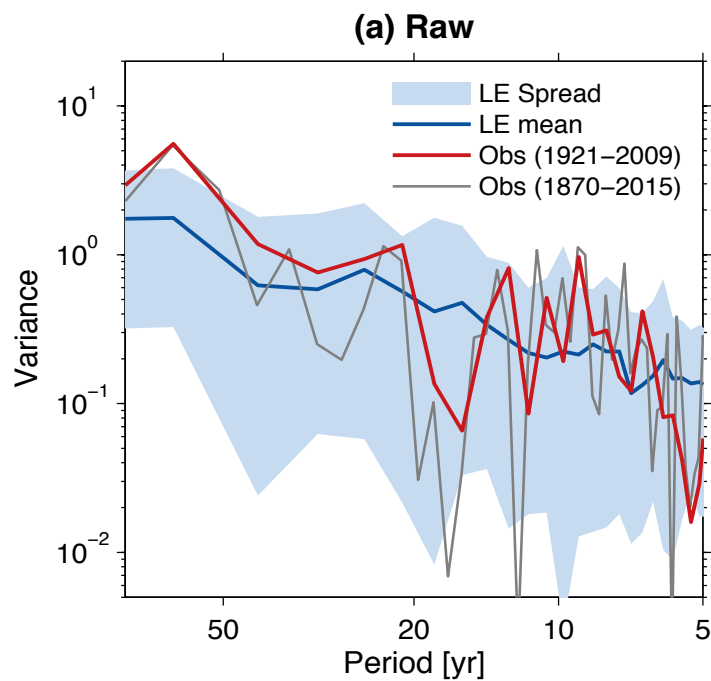


# External + internal AMOC Variability

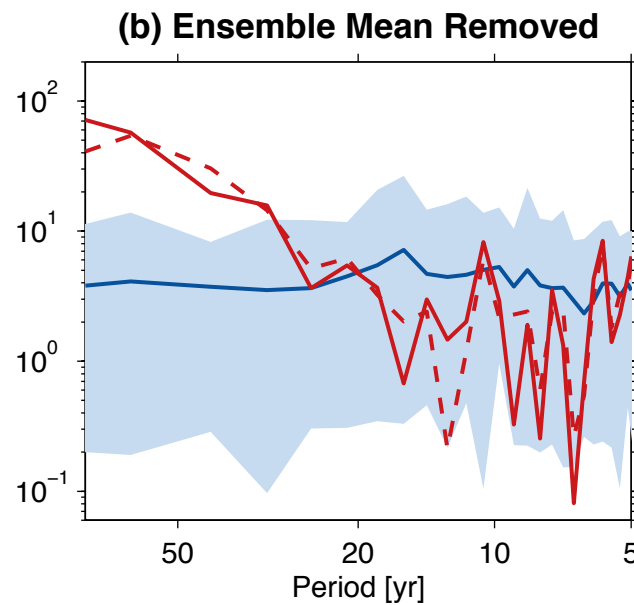
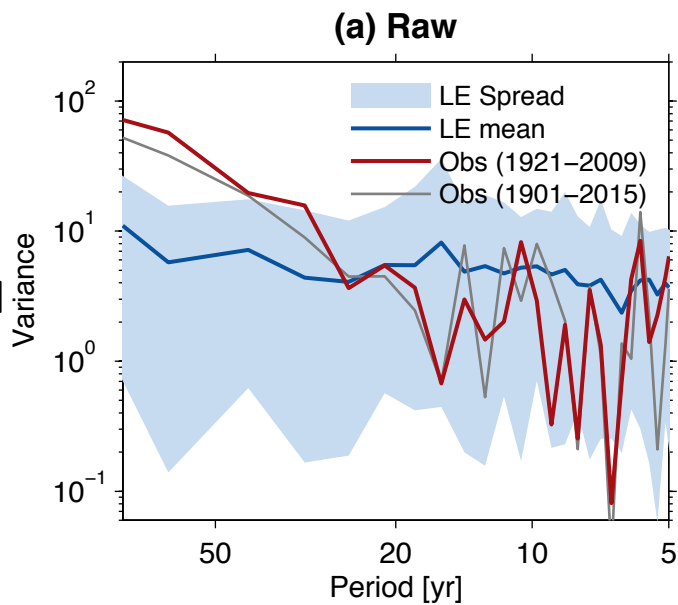


# External + internal SPNA SST/Sahel Rainfall Variability

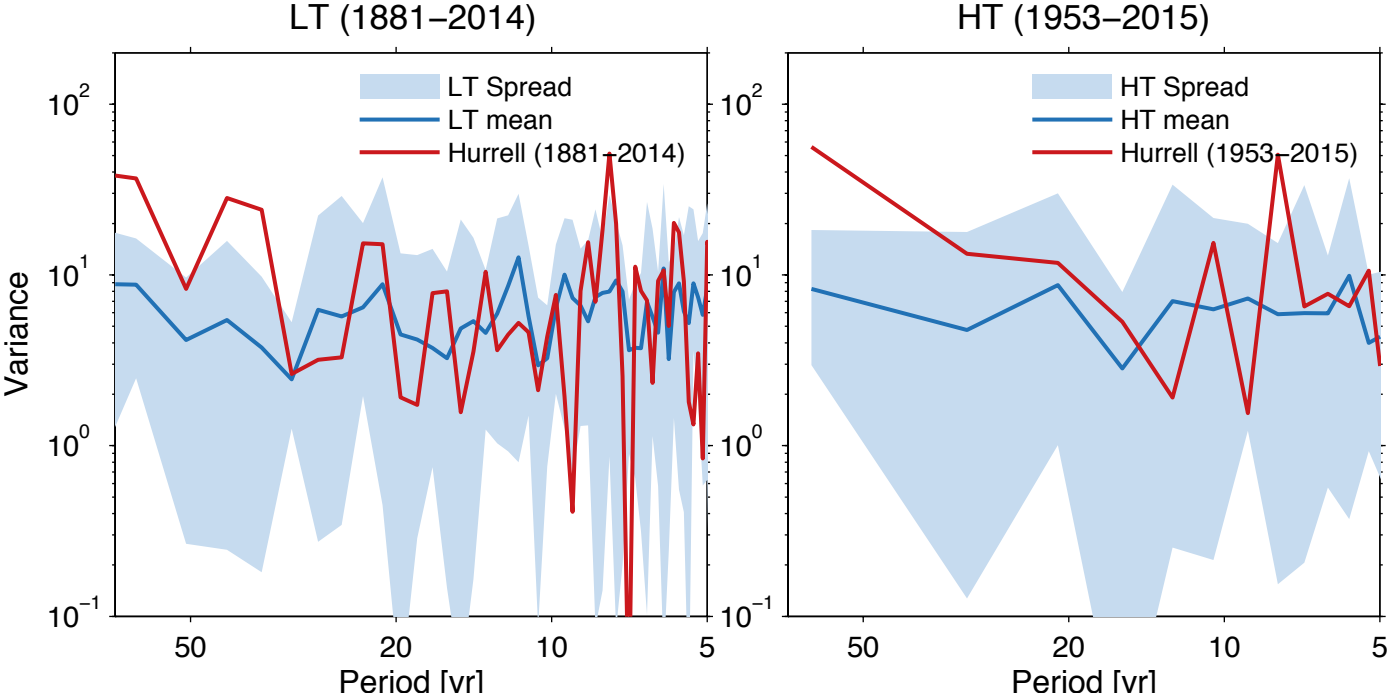
SPNA SST



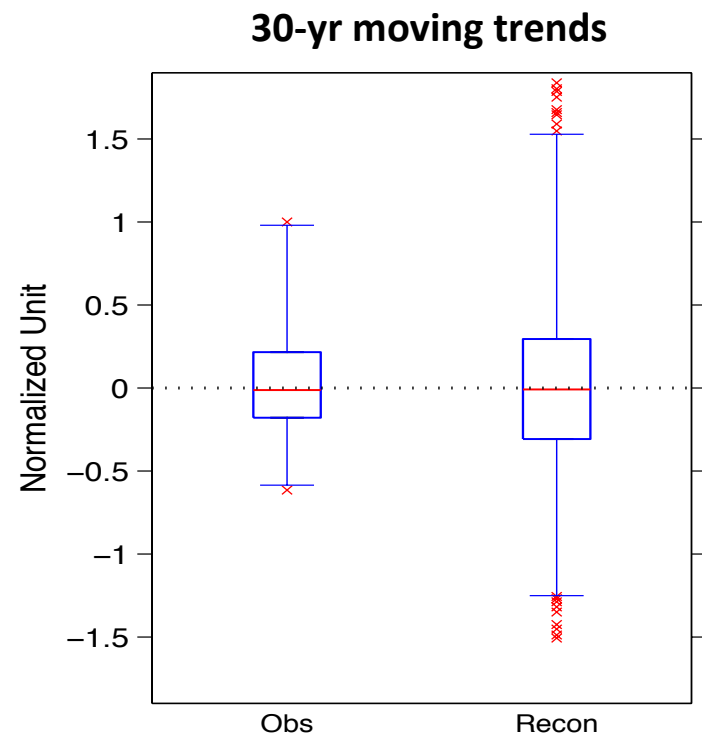
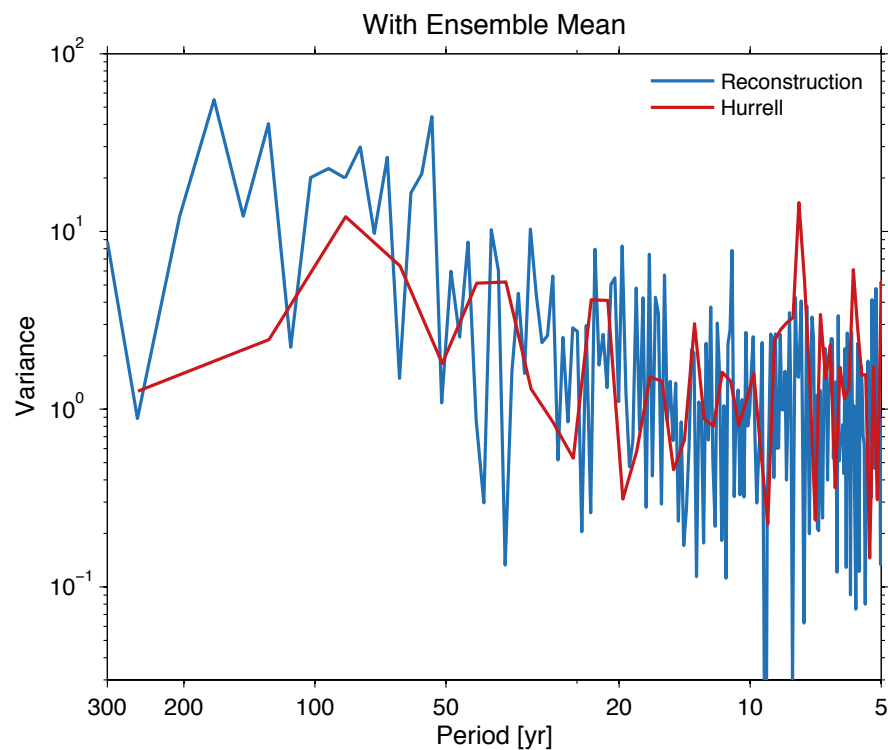
Sahel Rainfall



# Low-frequency NAO Variability in CAM5 Ensembles



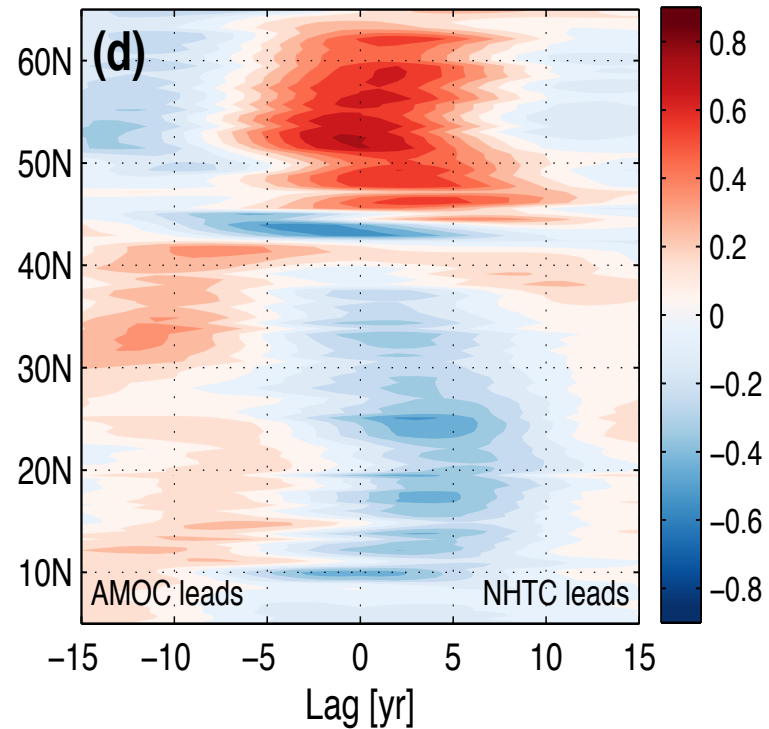
# Low-frequency NAO Variability in Reconstruction



\* Ortega et al. (2015),  
based on multiple  
proxy records and for  
the 1049-1969 period

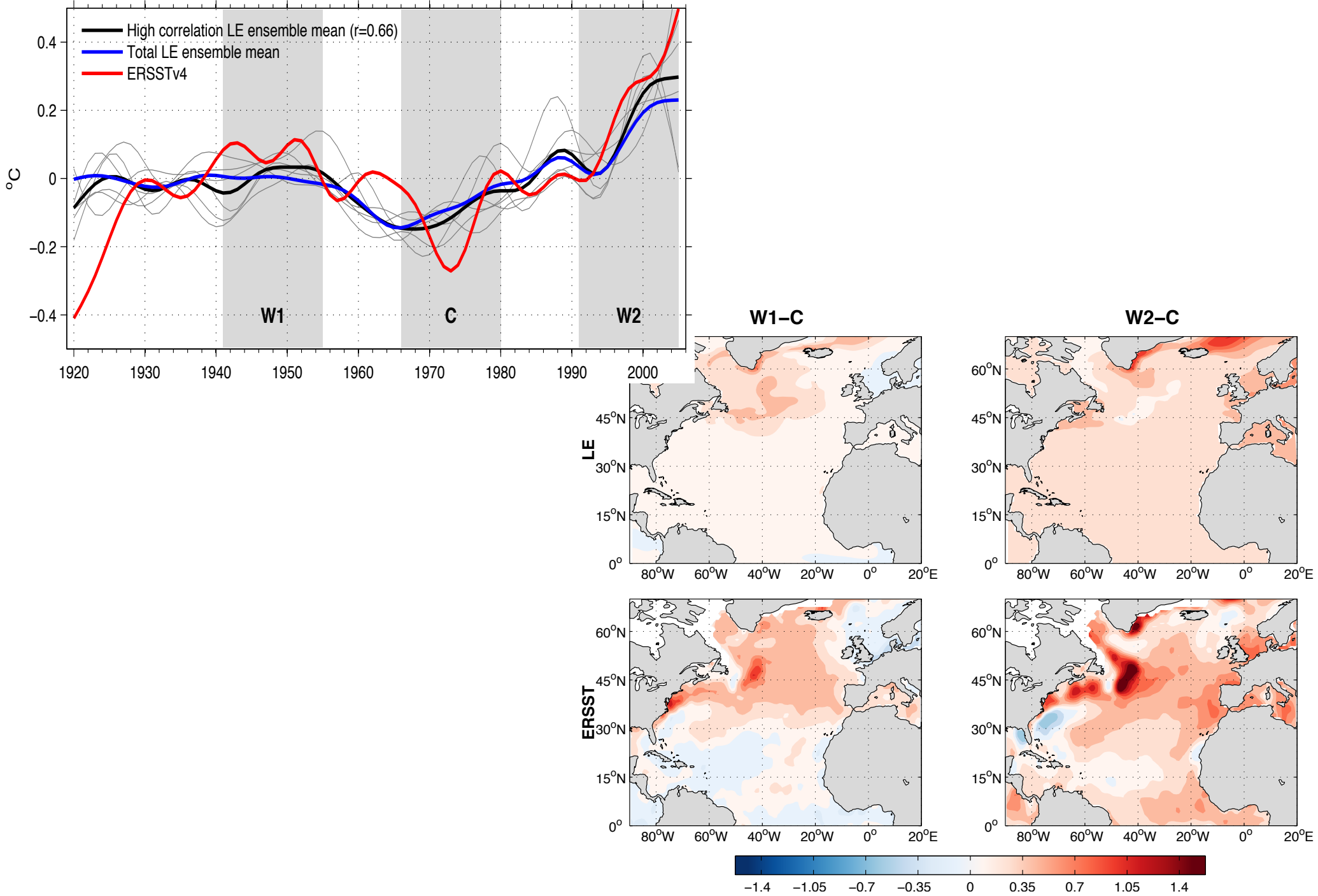
# Northward Heat Transport Convergence associated w/ AMOC

Lead-lag correlations between AMOC PC1 and NHTC as a function of latitude

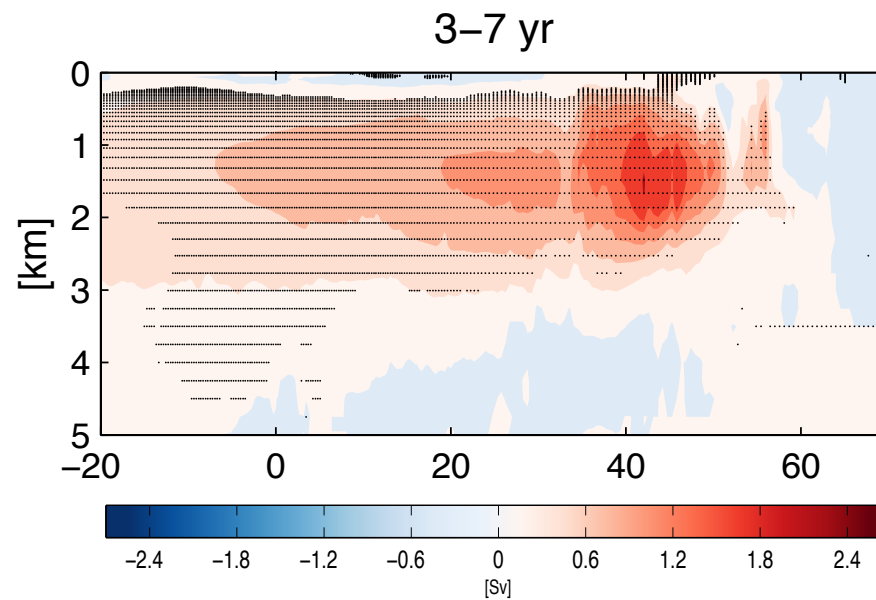




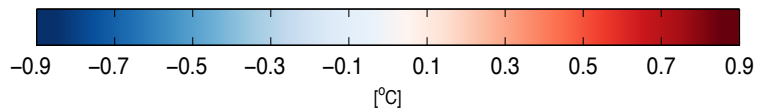
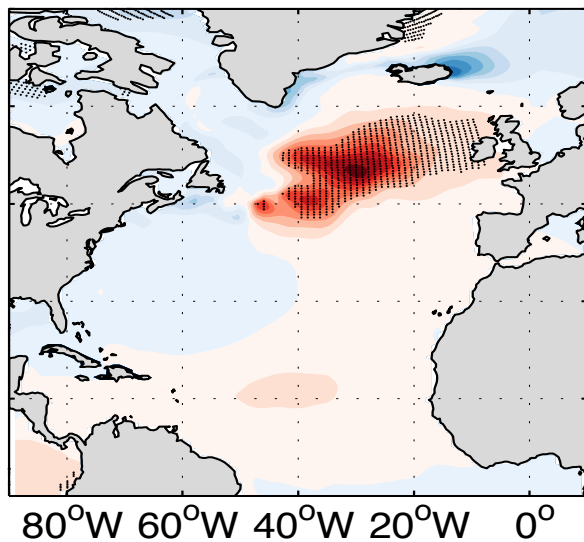
# AMV LE vs. Obs



# Lab. Sea NAO Heat Flux Forcing Coupled Experiments



yr 3-7



Annual SPNA SST (45-60°N, 15-45°W)

