# Predictability of Atlantic Overturning Circulation and Associated Surface Patterns in Two CCSM3 Large Ensemble Experiments

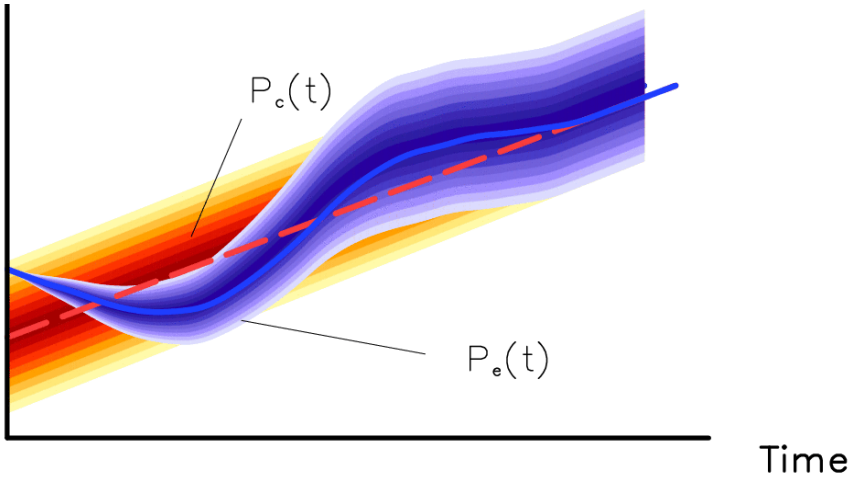
**Haiyan Teng**
**Grant Branstator**
**Jerry Meehl**

June 29, 2011

*Teng et al. 2011, J Climate, in press*

# Predictability

**Total predictability:** $P_e(t)$ vs. $P_c(0)$
**Initial-value predictability**: $P_e(t)$ vs. $P_c(t)$
**Forced predictability**: $P_c(t)$ vs. $P_c(0)$




***Kleeman (2002)***

$$R = \int_S P_x(s) \log_2 \left[ \frac{P_x(s)}{P_b(s)} \right] ds$$

$P_x(s)$: prediction
$P_b(s)$: base

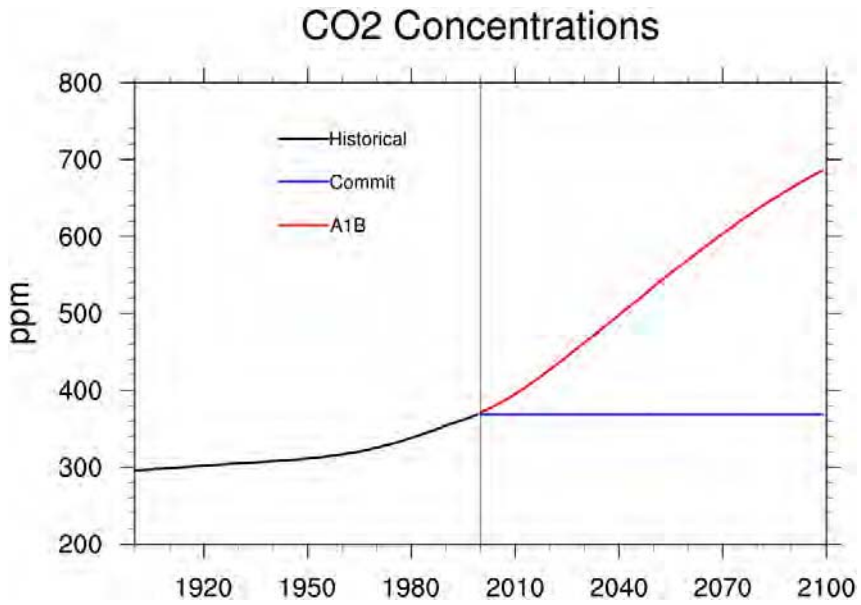
*For normal distribution:*

$$R = \frac{1}{2} \log_2(e) \left\{ \ln \left[ \frac{\det(\sigma_b^2)}{\det(\sigma_x^2)} \right] + trace\left(\frac{\sigma_x^2}{\sigma_b^2}\right) + (\mu_x - \mu_b)^T (\sigma_b^2)^{-1} (\mu_x - \mu_b) - n \right\}$$

**signal**

**dispersion**

# Model & Experiments




- **CCSM3.0, T42 atm, 1deg ocn**
- **40-member ensemble run**
  - **A1B, Commitment**
  - **2000-2061**
  - **atm perturbed ICs**
  - **Same ocn/lnd/ice ICs**
- **A1B (II), A1B(III), A1B (IV)**
  - **Each has unique ocn/ice/lnd ICs**
  - **20 years**
- **Last 700 yrs of the1000-yr control**

*Branstator and Teng (2010), Teng and Branstator (2011)*

# Initial-value Predictability & Forced Predictability

Assumptions:

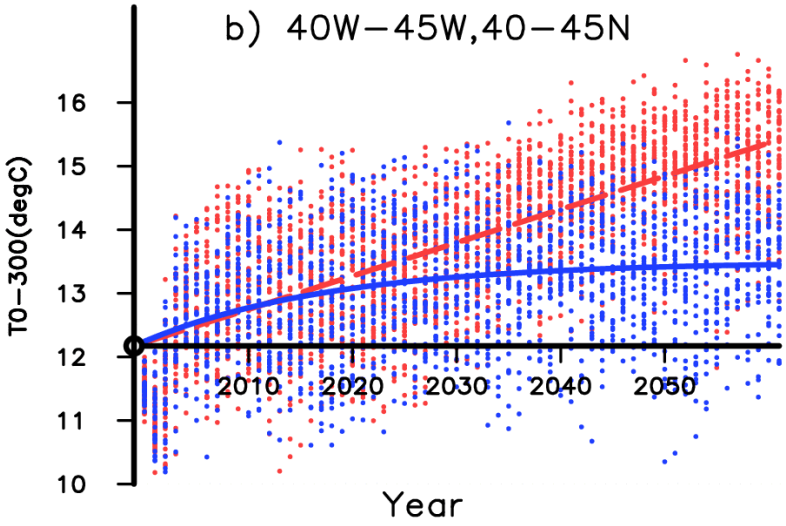
1. Gaussians
2. Climate covariance does not change with time.
3. Climate mean can be well approximated by an analytical function of time.

Time evolving climate mean:

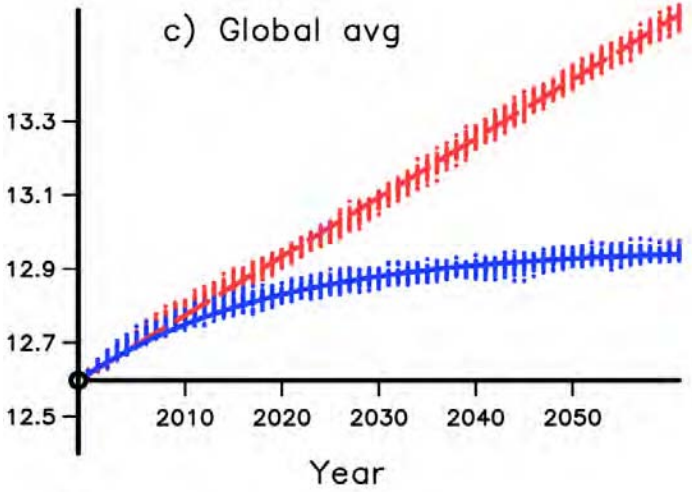
$$\overline{T}_{A1B}(t) = \overline{T}_{1999} + k(t - 1999)$$

$$\overline{T}_{commit}(t) = \overline{T}_{1999} + A(1 - e^{-t/\tau})$$

✓Initial-value components
✓Forced response

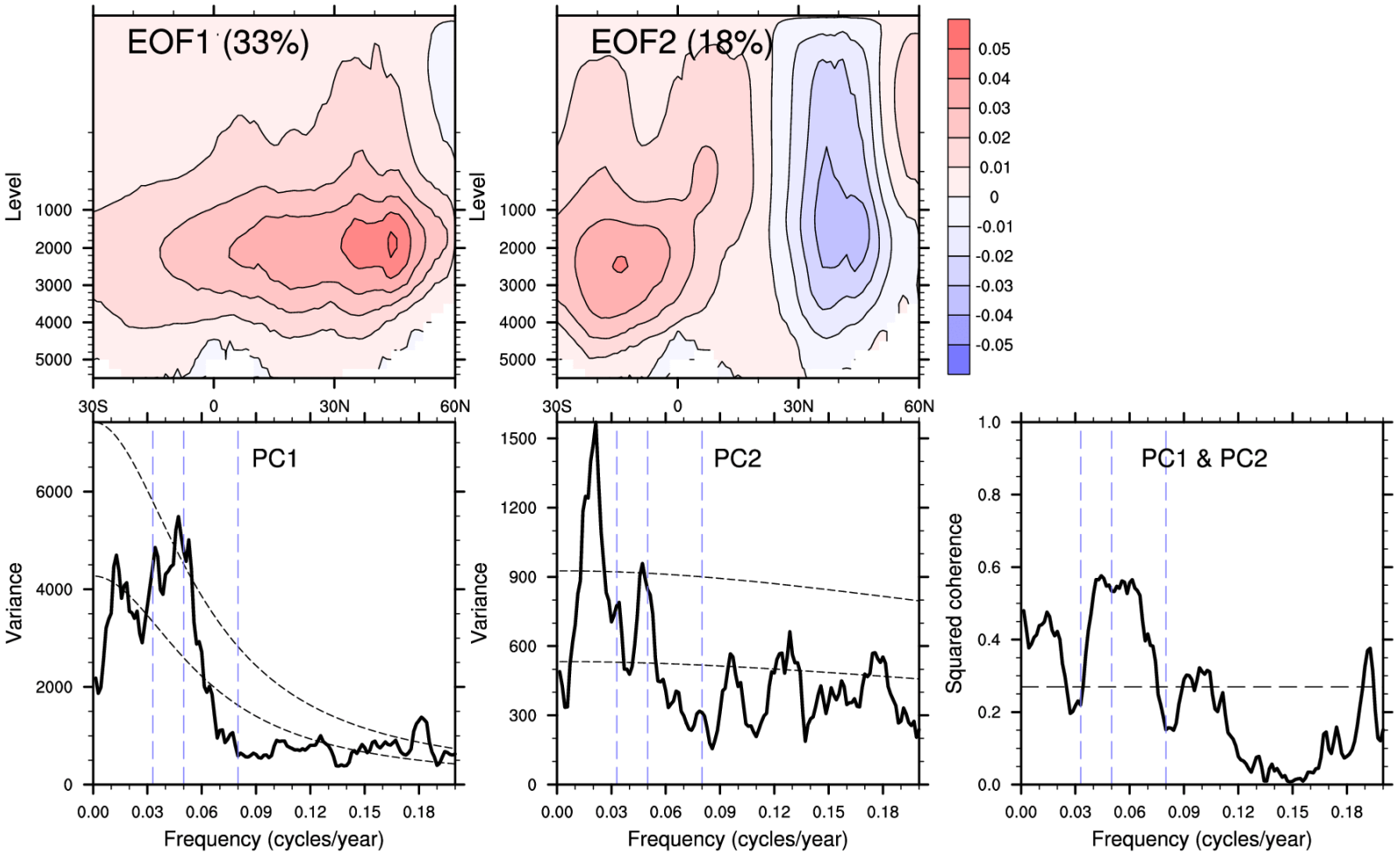



**Blue: Commit, Red: A1B**

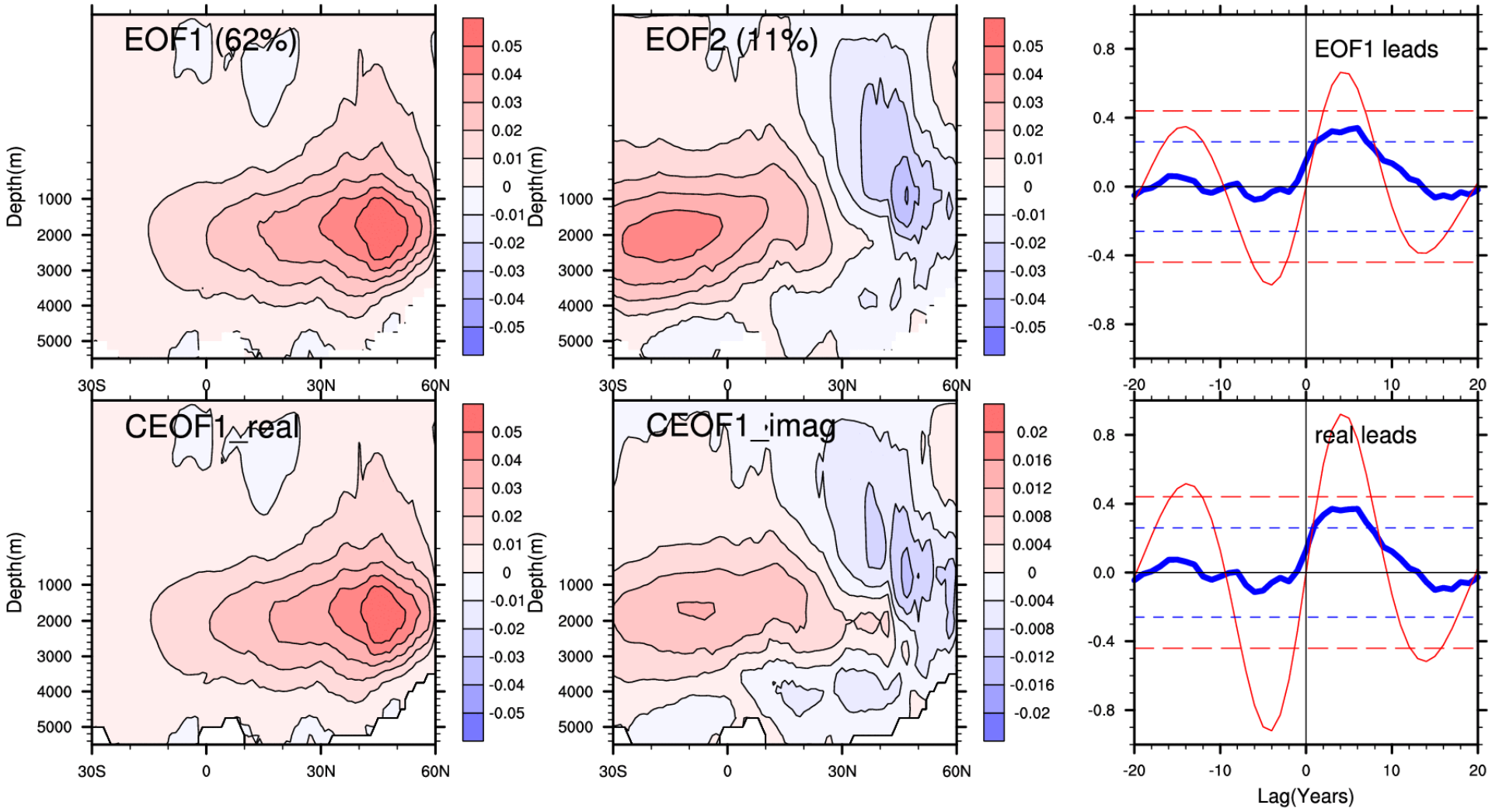



*Branstator and Teng (2010)*

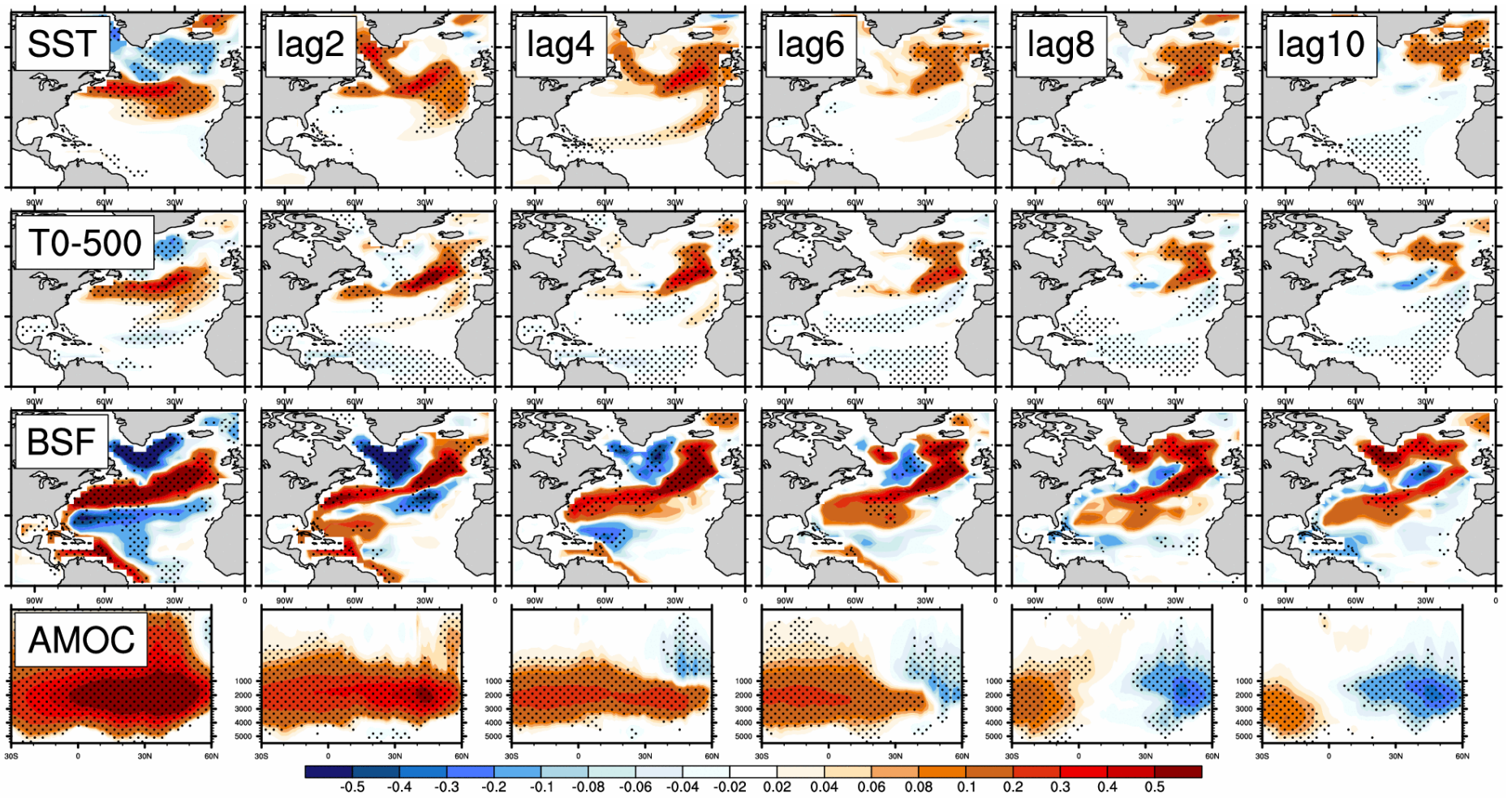
# AMOC EOF1 &EOF2 in control run



# 10-30-yr AMOC EOF1,2 & CEOF1

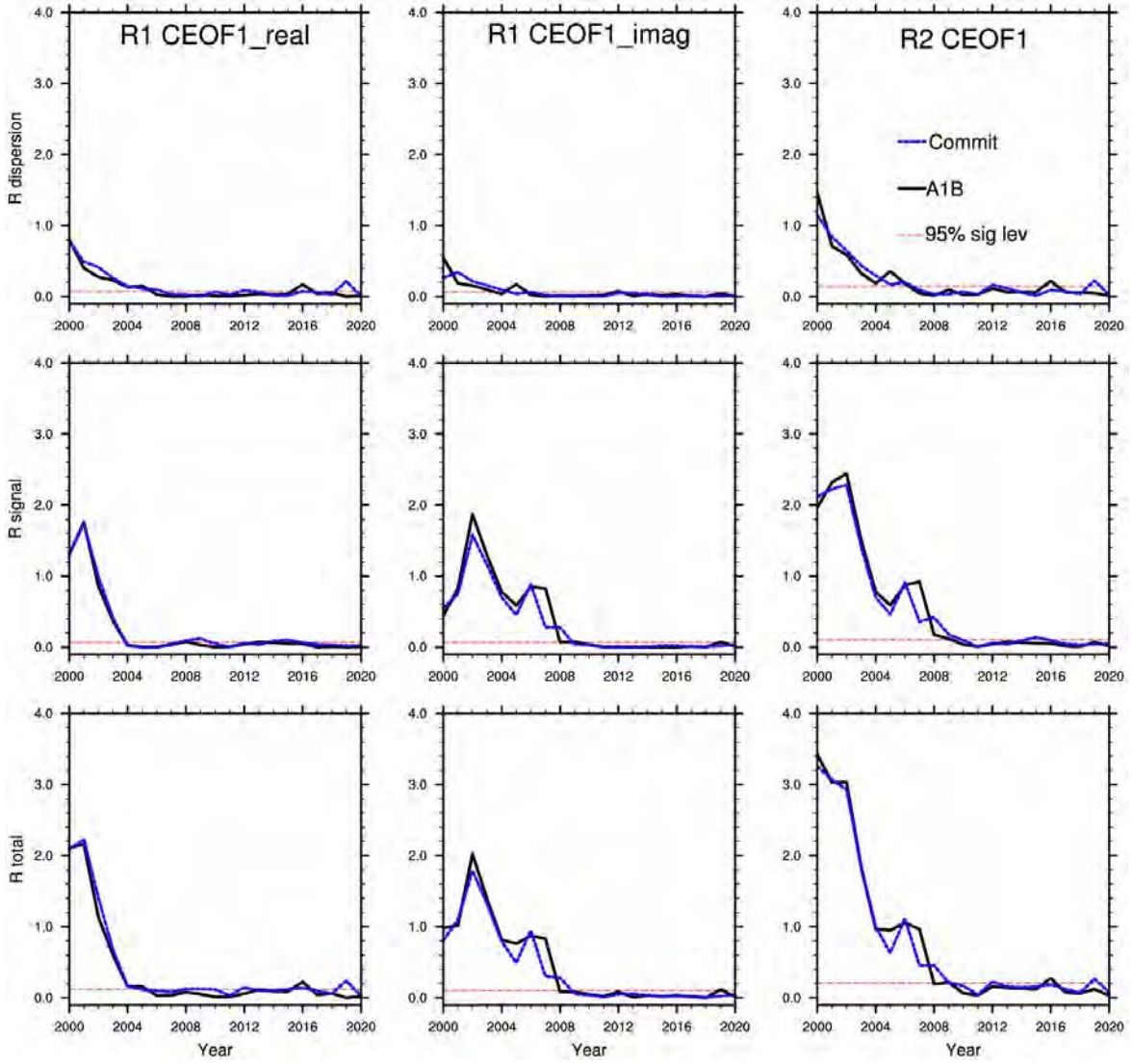


# Lag regression to AMOC PC1

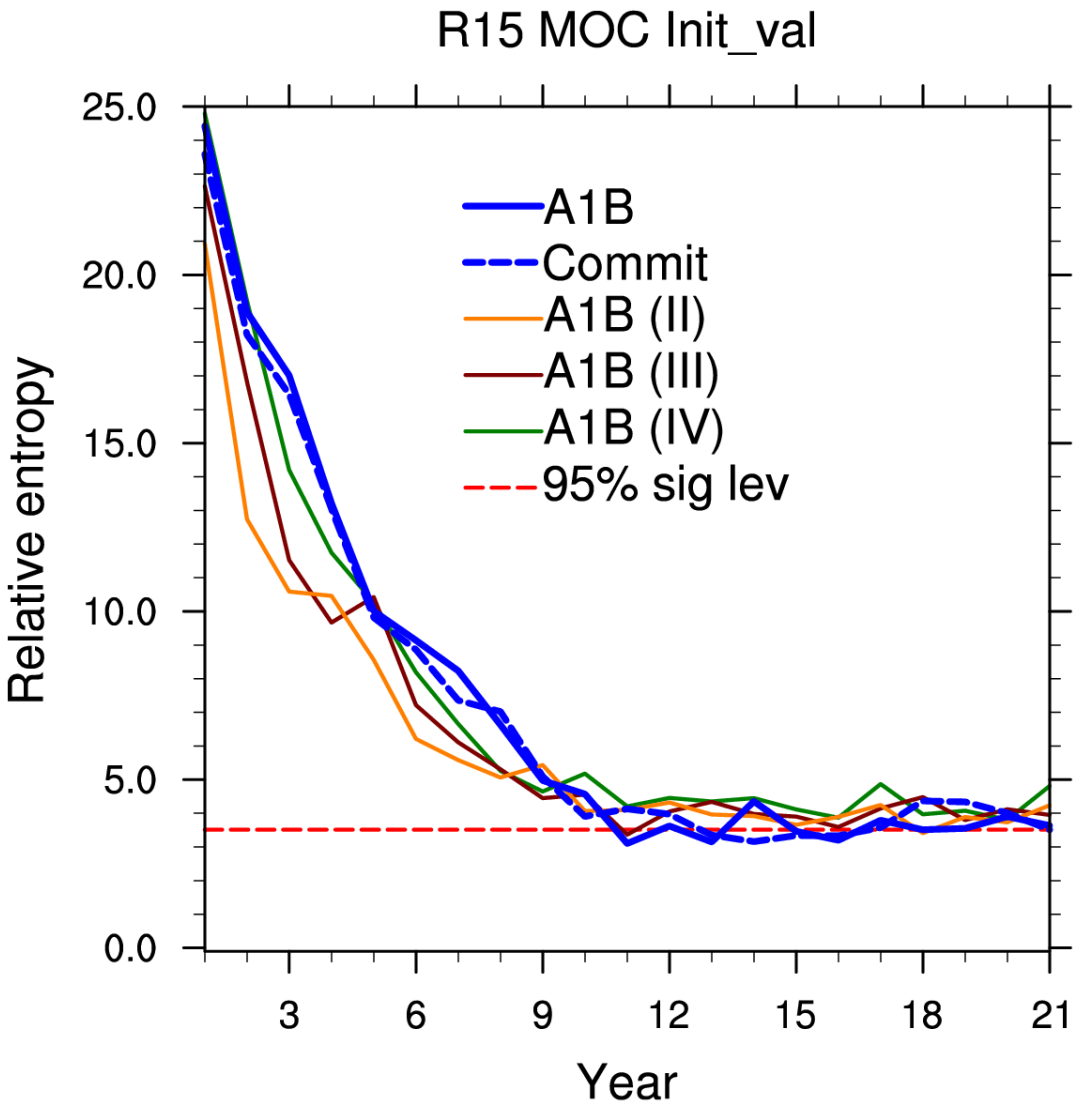


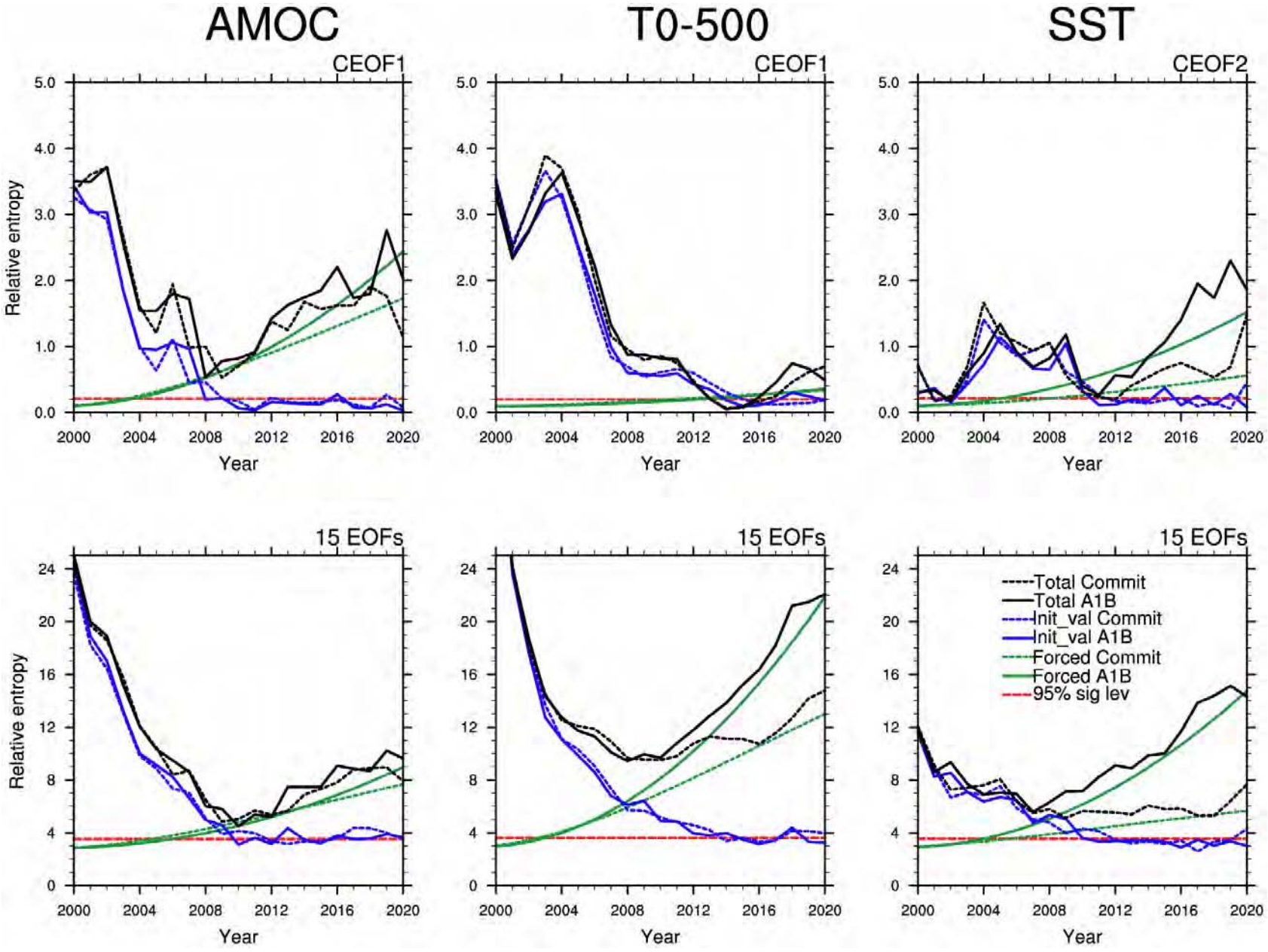

*SST 1-2-1 smoothed*

# Initial-value Predictability of AMOC CEOF1



# Initial-value Predictability of the AMOC (15 EOFs)




AMOC
T0-500
SST
CEOF1
CEOF1
CEOF2
15 EOFs
15 EOFs
15 EOFs
Relative entropy
Relative entropy
Year
Year
Year
Year
Year
Year
Total Commit
Total A1B
Init_val Commit
Init_val A1B
Forced Commit
Forced A1B
95% sig lev

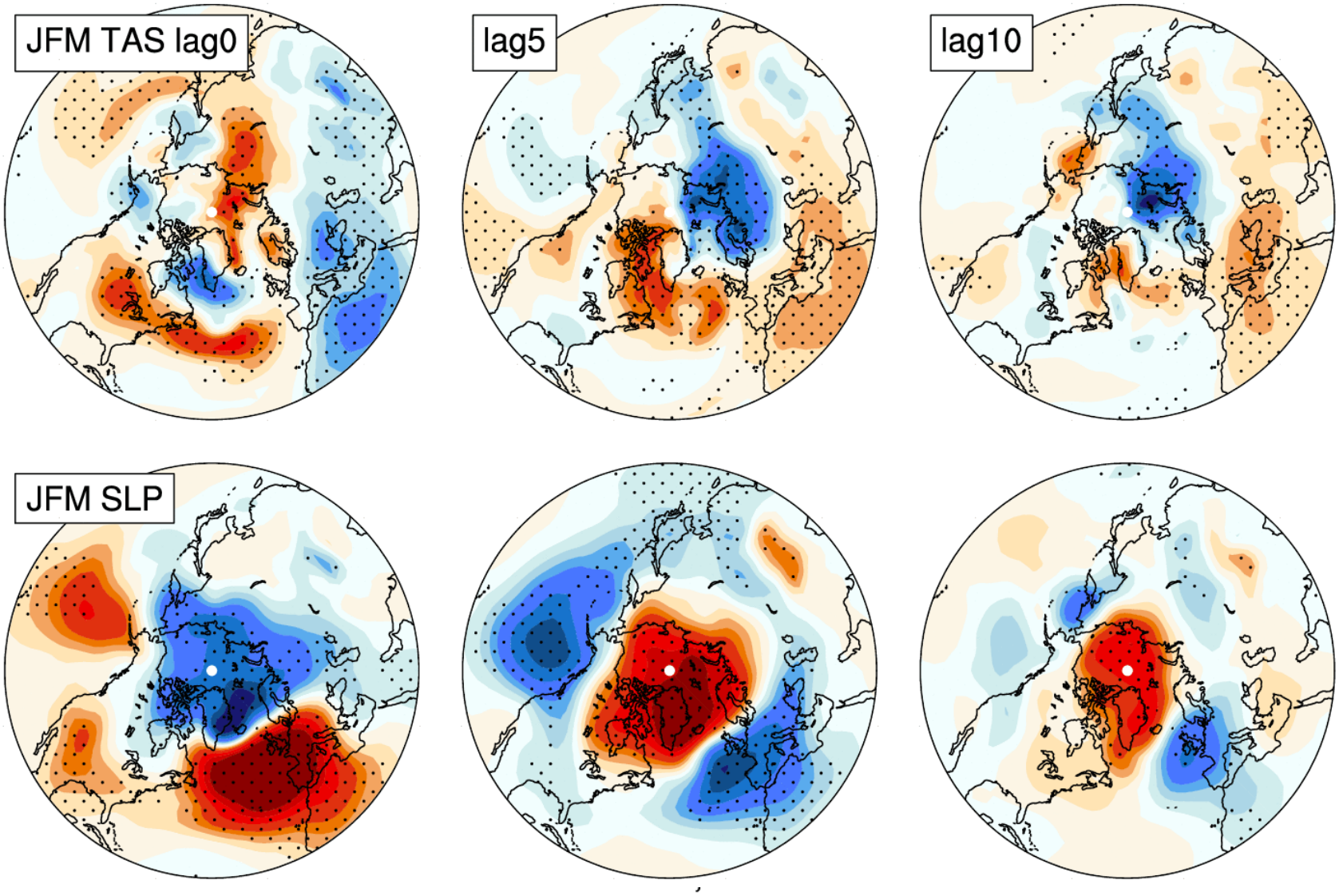
**AMOC**

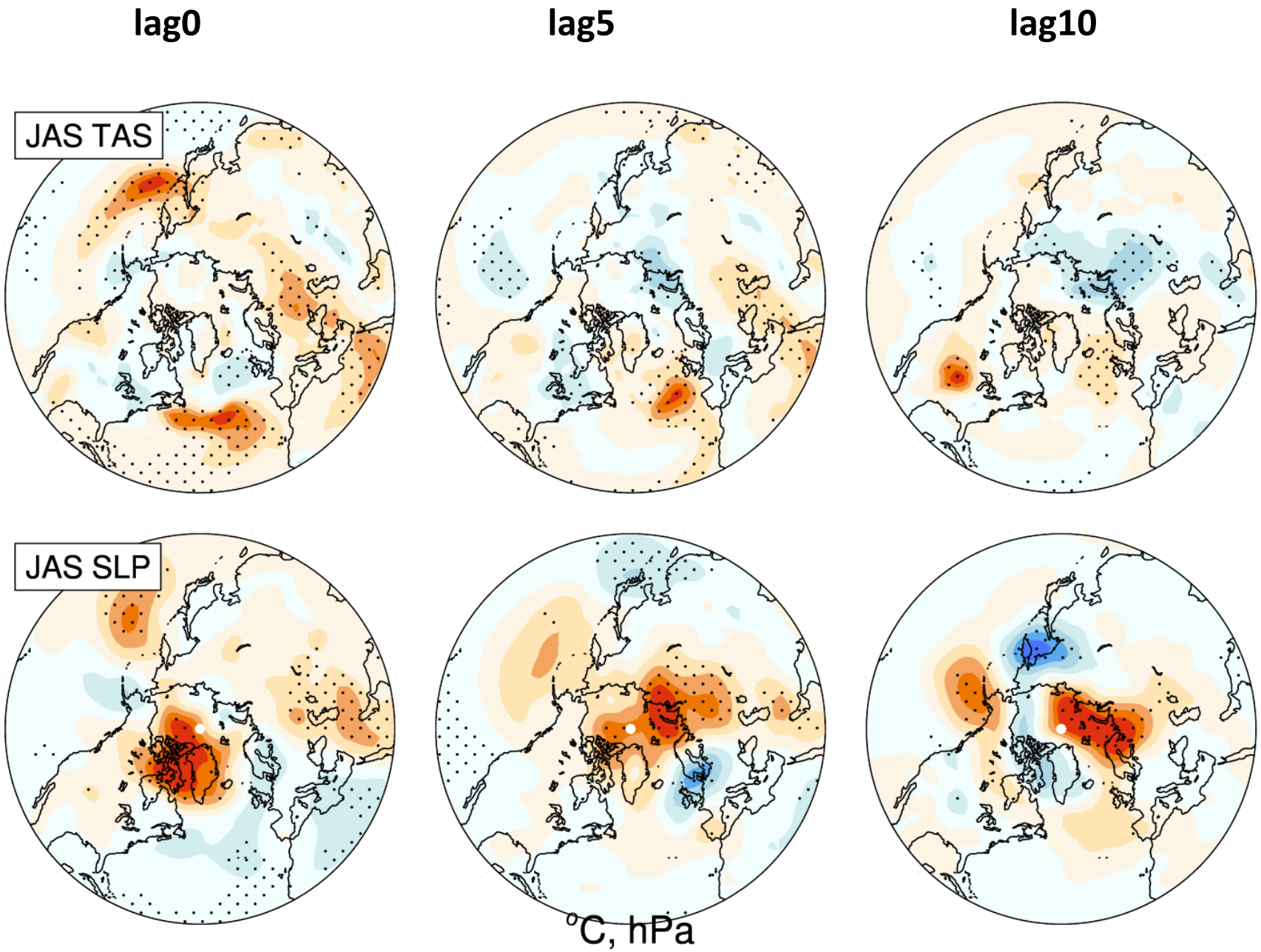
- The initial-value component of the AMOC is predictable for about 15 years in the CCSM3 large ensemble experiments.
- The predictability mainly comes from the signal component.
- There is a tendency of the EOF1 to evolve to the EOF2 on the decadal time scale.
- The forced response is more predictable than the initial-value component after 10 years.
- The AMOC is no more predictable than the subsurface temperature.

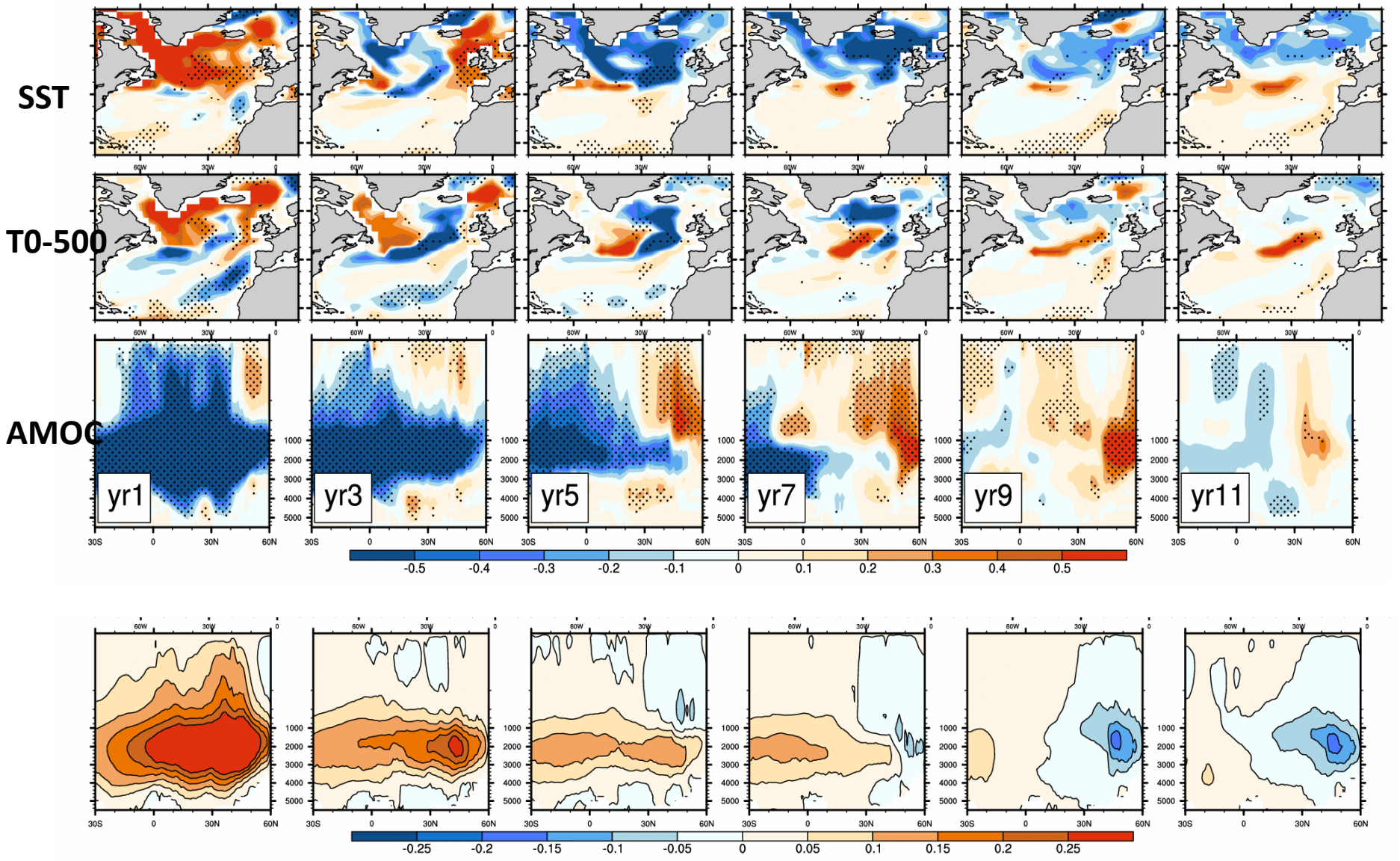
**atm**

- Are there signals in the atmospheric large-scale surface climate?
- Are the signals associated with the AMOC?
- Relative importance of the natural variability and the forced response

Lag correlation from the 700-yr control run

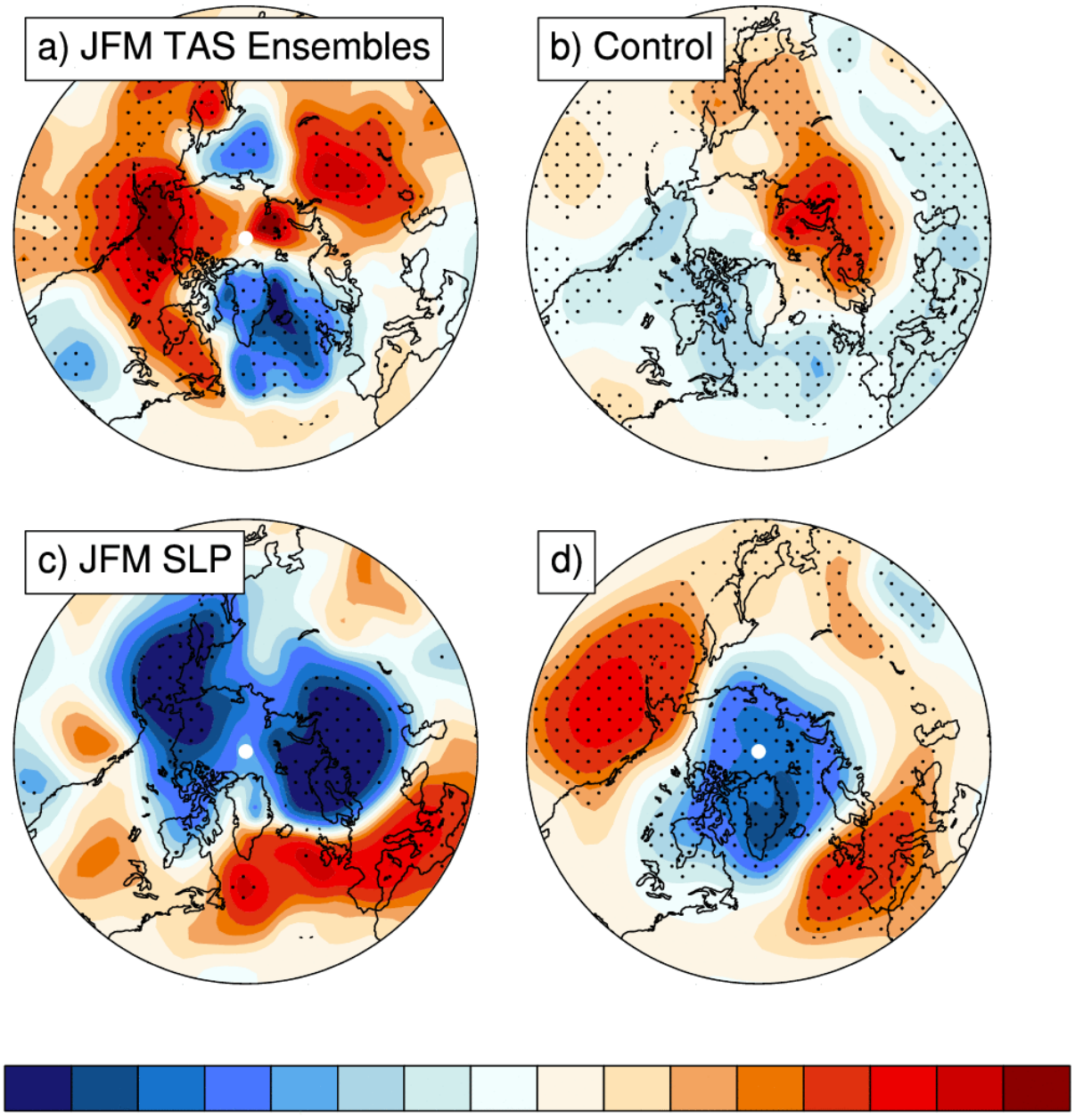


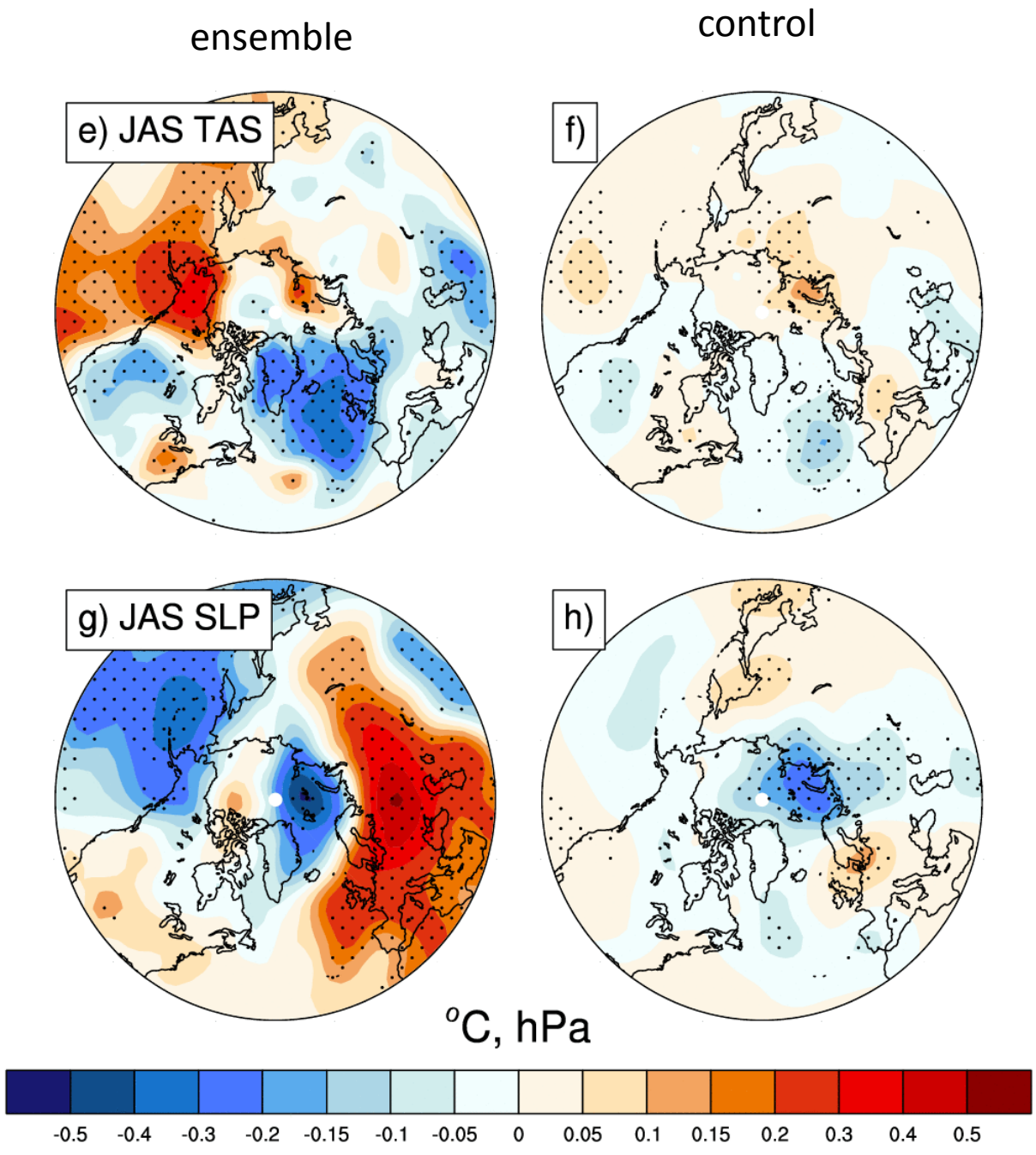

lag0
lag5
lag10
JAS TAS
JAS SLP
°C, hPa
-0.5
-0.4
-0.3
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.3
0.4
0.5



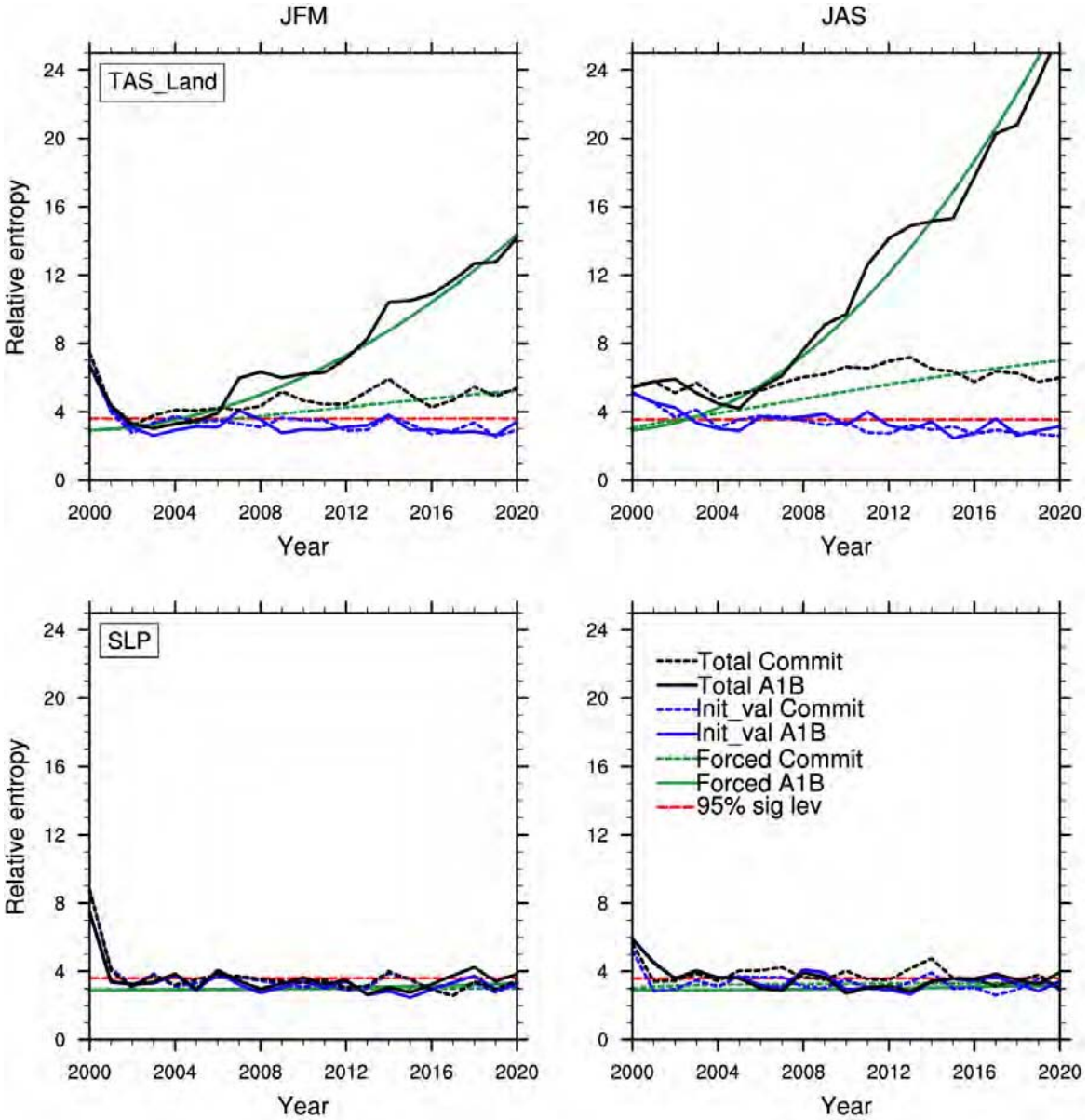

*1-2-1 smoothed to remove the ENSO signals*

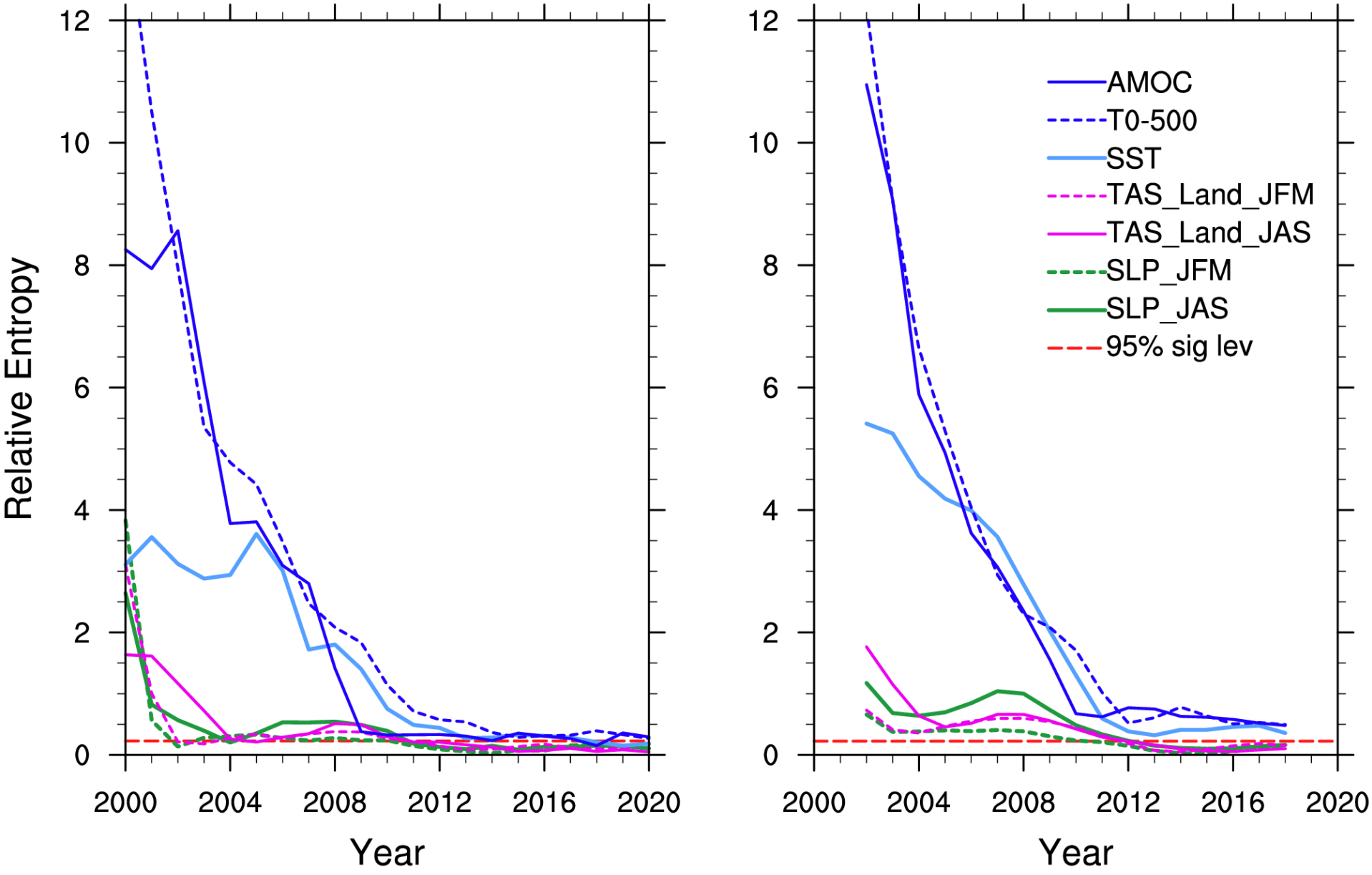
yr5-10


a) JFM TAS Ensembles
b) Control
c) JFM SLP
d)
-0.5 -0.4 -0.3 -0.2 -0.15 -0.1 -0.05 0 0.05 0.1 0.15 0.2 0.3 0.4 0.5


ensemble
control
e) JAS TAS
f)
g) JAS SLP
h)
°C, hPa
-0.5
-0.4
-0.3
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.3
0.4
0.5

# Relative entropy of 15EOFs in NH (20N-90N)



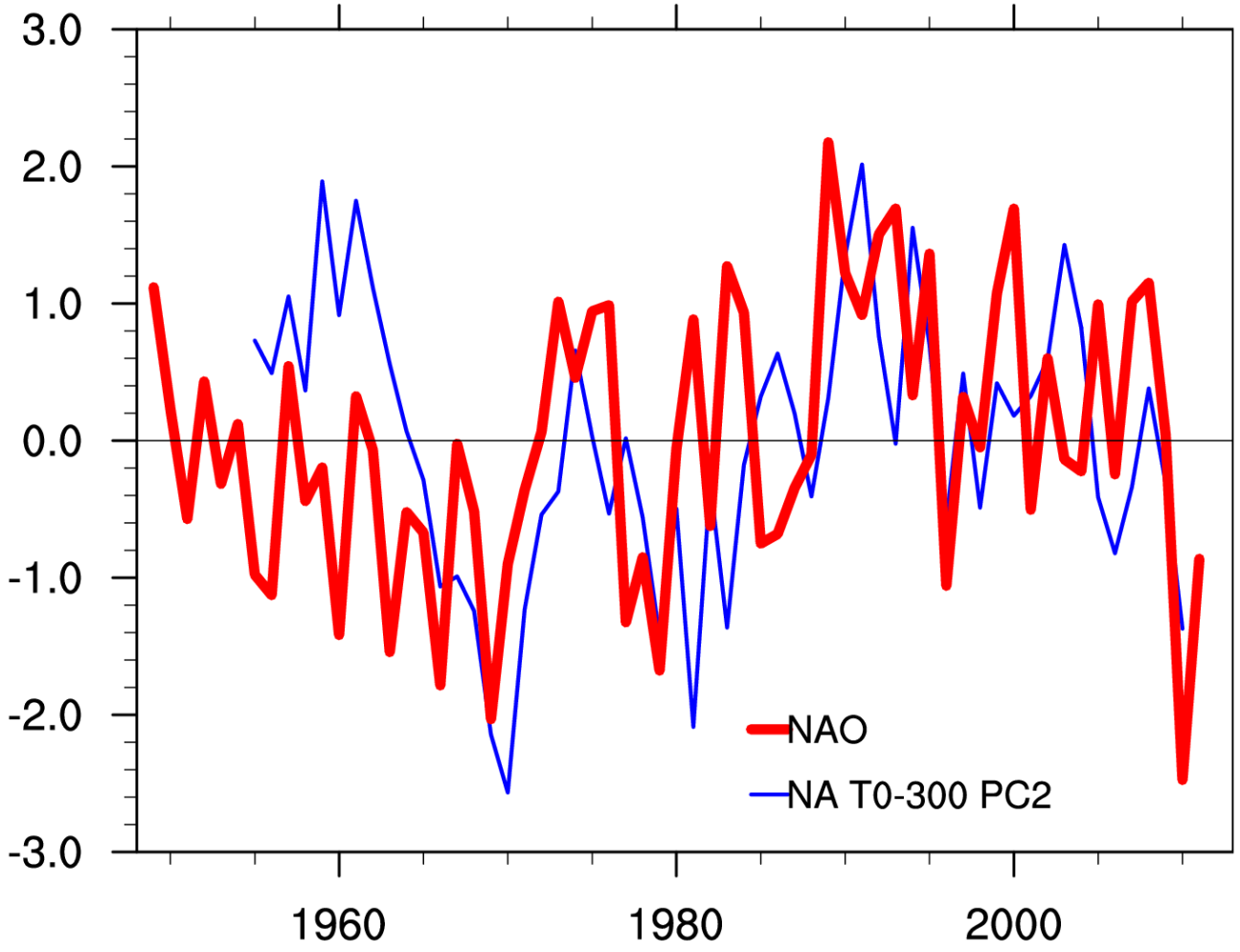

Relative Entropy
12
10
8
6
4
2
0
2000
2004
2008
2012
2016
2020
Year
AMOC
T0-500
SST
TAS_Land_JFM
TAS_Land_JAS
SLP_JFM
SLP_JAS
95% sig lev

# Summary of the atm

- The large ensemble mean indicates that the AMOC grows from –EOF1 to –EOF2 in the first decade. Both the subsurface temperature and SST signals are consistent with the control run composite at the same AMOC phase.

- The subpolar gyre SST anomalies associated with the AMOC variability can influence the atmosphere and produce surface climate predictability that goes beyond the ENSO time scale. However, the resulting initial-value predictability in the atmosphere is very weak.

# Multidecadal Variability in the NAtl .




5-yr running mean

Levitus upper300m T