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

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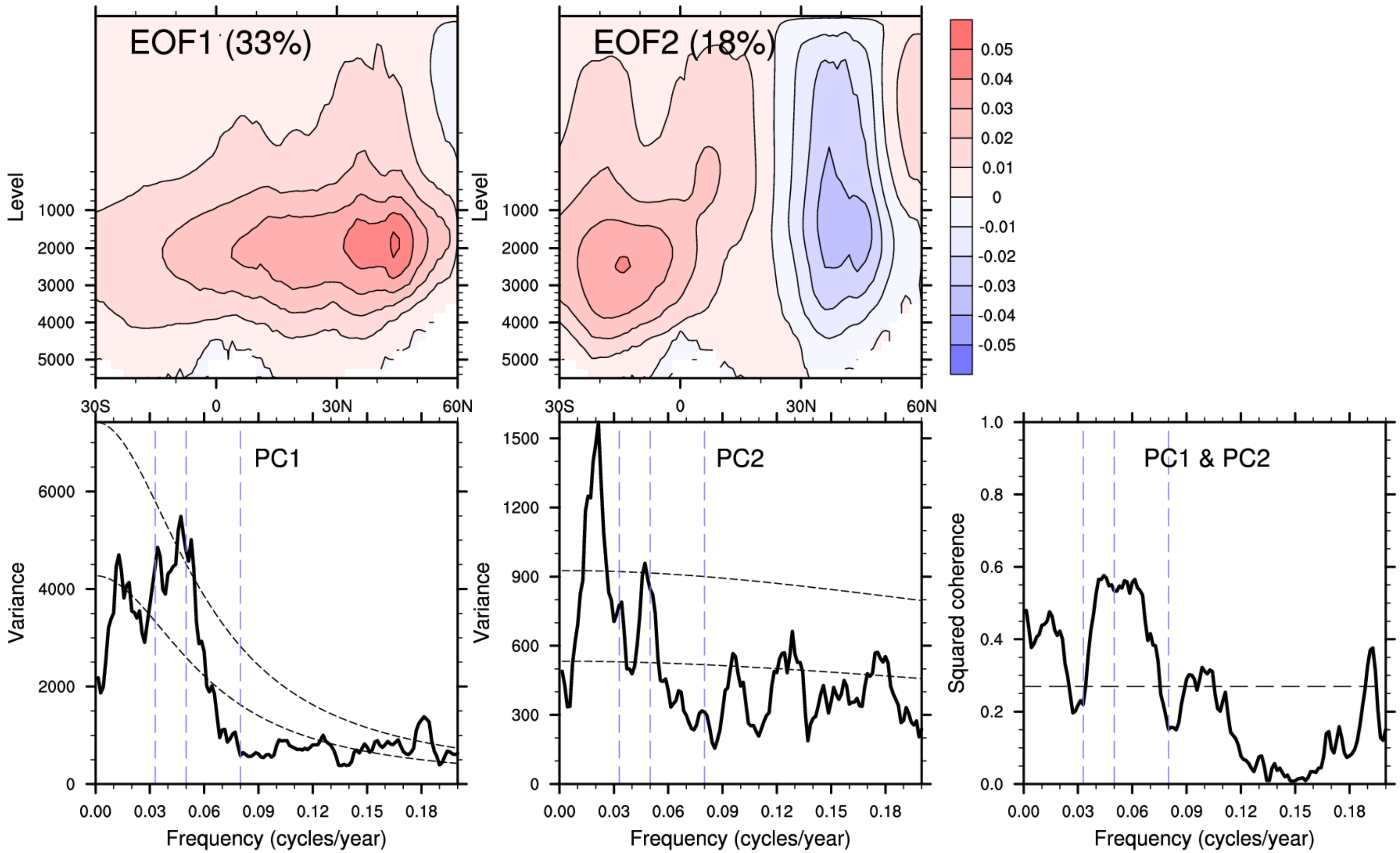
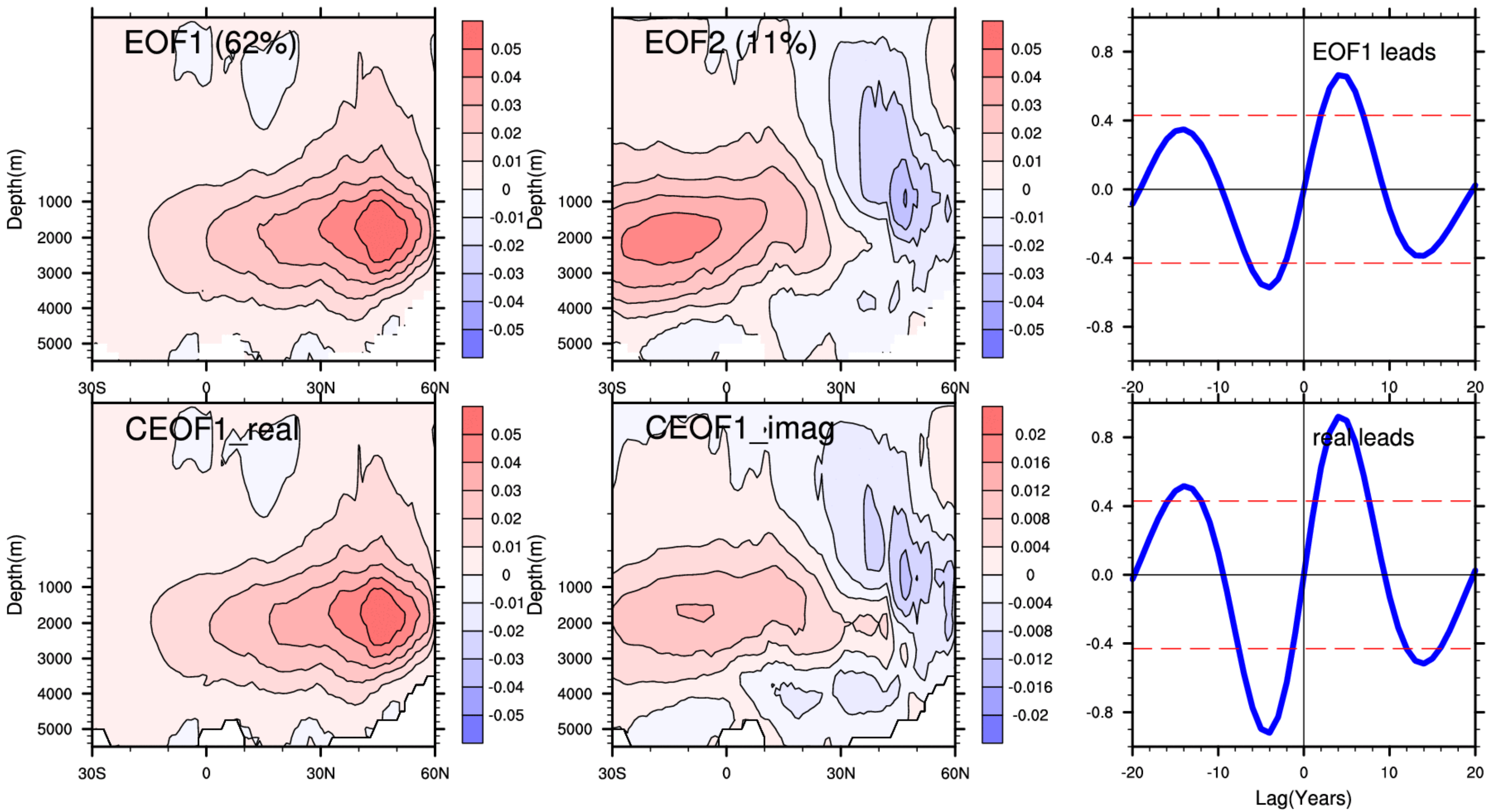
AMOC EOF1 &EOF2

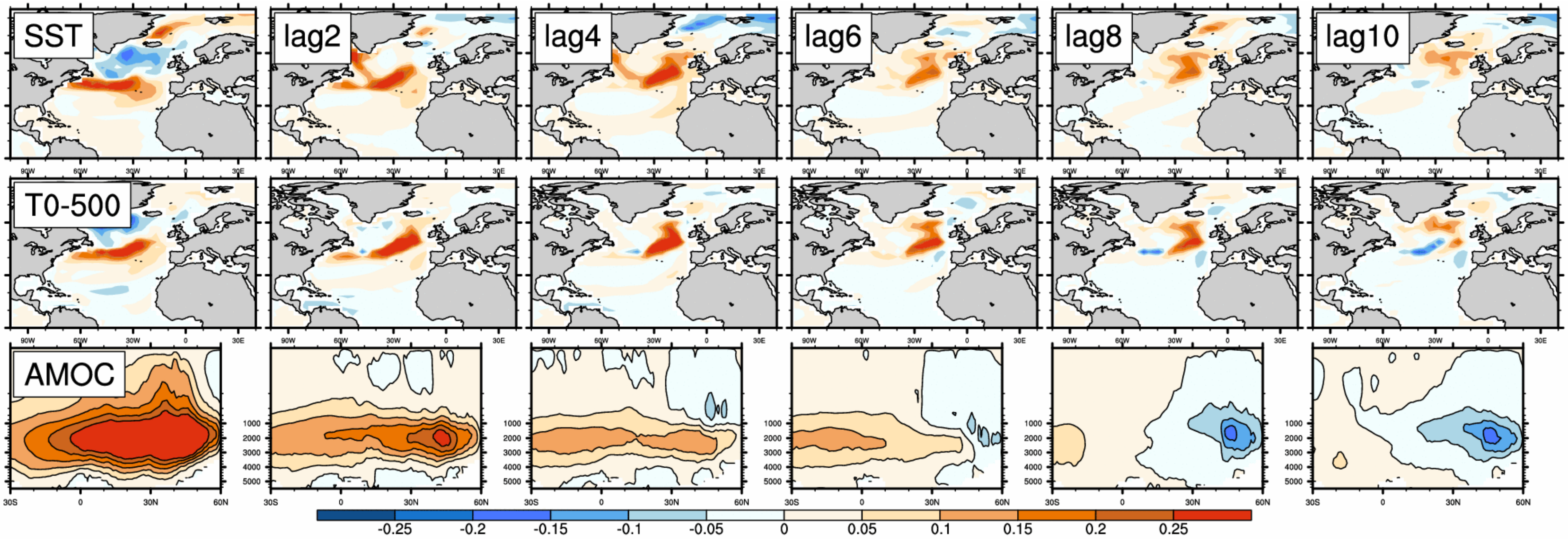


From year 300-999 of the present-day control

10-30-yr AMOC EOF1,2 & CEOF1



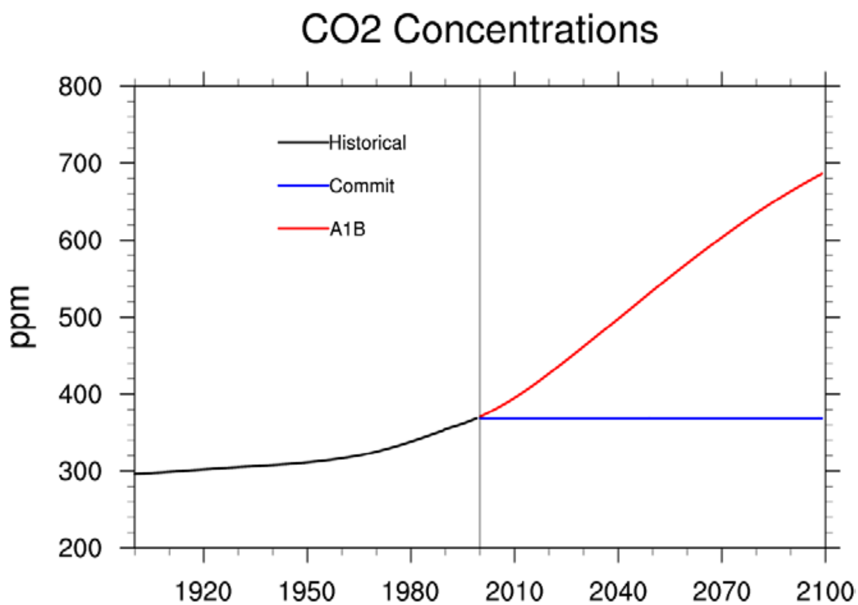
Lag regression to AMOC PC1



Tropical SST anomalies are weak!

SST 1-2-1 smoothed

Model & Experiments

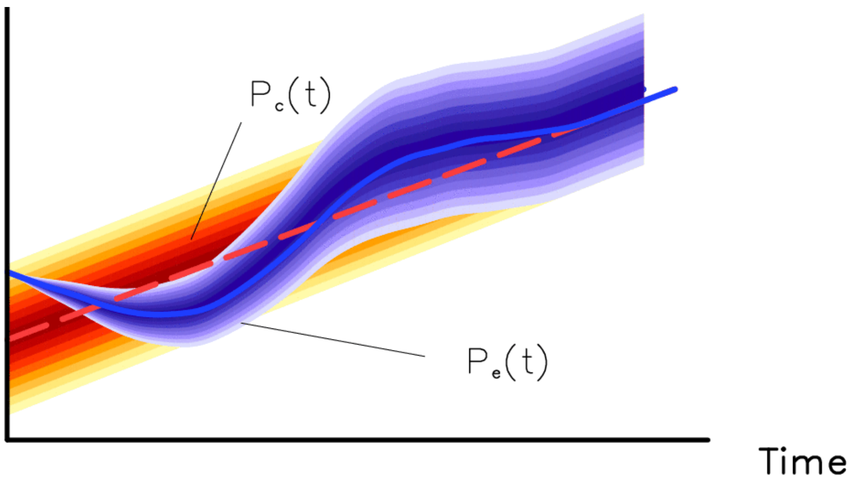


- **CCSM3.0, T42 atm, 1deg ocn**
- **40-member ensemble run**
  - **A1B, Commitment**
  - **2000-2061**
  - **atm perturbed ICs**
  - **Same ocn/lnd/ice ICs**
- **A1B (II), A1B(III), A1B (IV)**
  - **Each has unique ocn/ice/lnd ICs**
  - **20 years**
- **Last 700 yrs of the1000-yr control**

Branstator and Teng (2010), Teng and Branstator (2010)

Relative Entropy

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

Initial-value Predictability & Forced Predictability

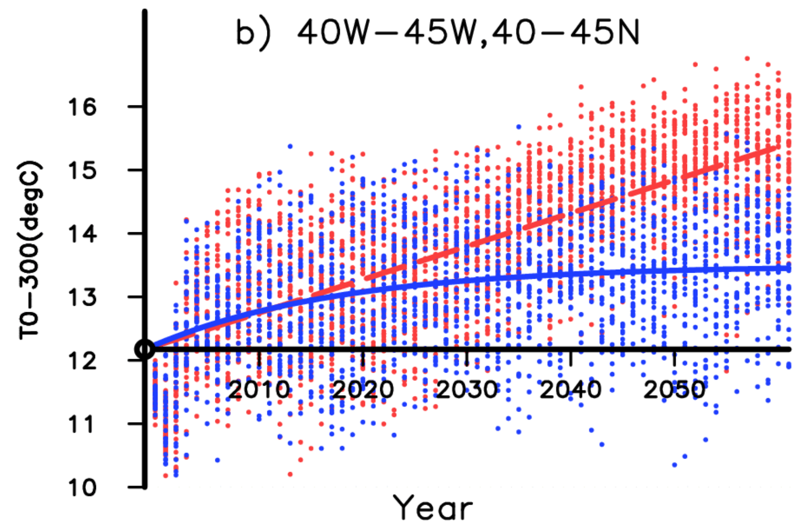
Assumptions:
1. Gaussians
2. Climate covariance does not change with time.
3. Climate mean can be well approximated by an analytical function of time.

Time evolving climate mean:

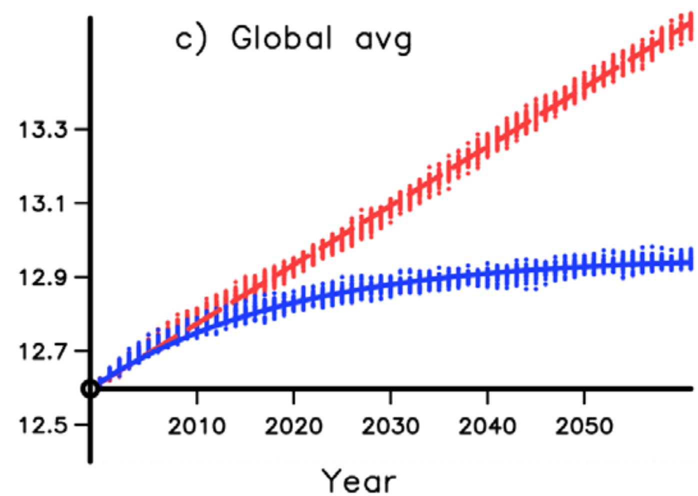
$$\overline{T}_{A1B}(t) = \overline{T}_{1999} + k(t - 1999)$$

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

✓Initial-value components
✓Forced response

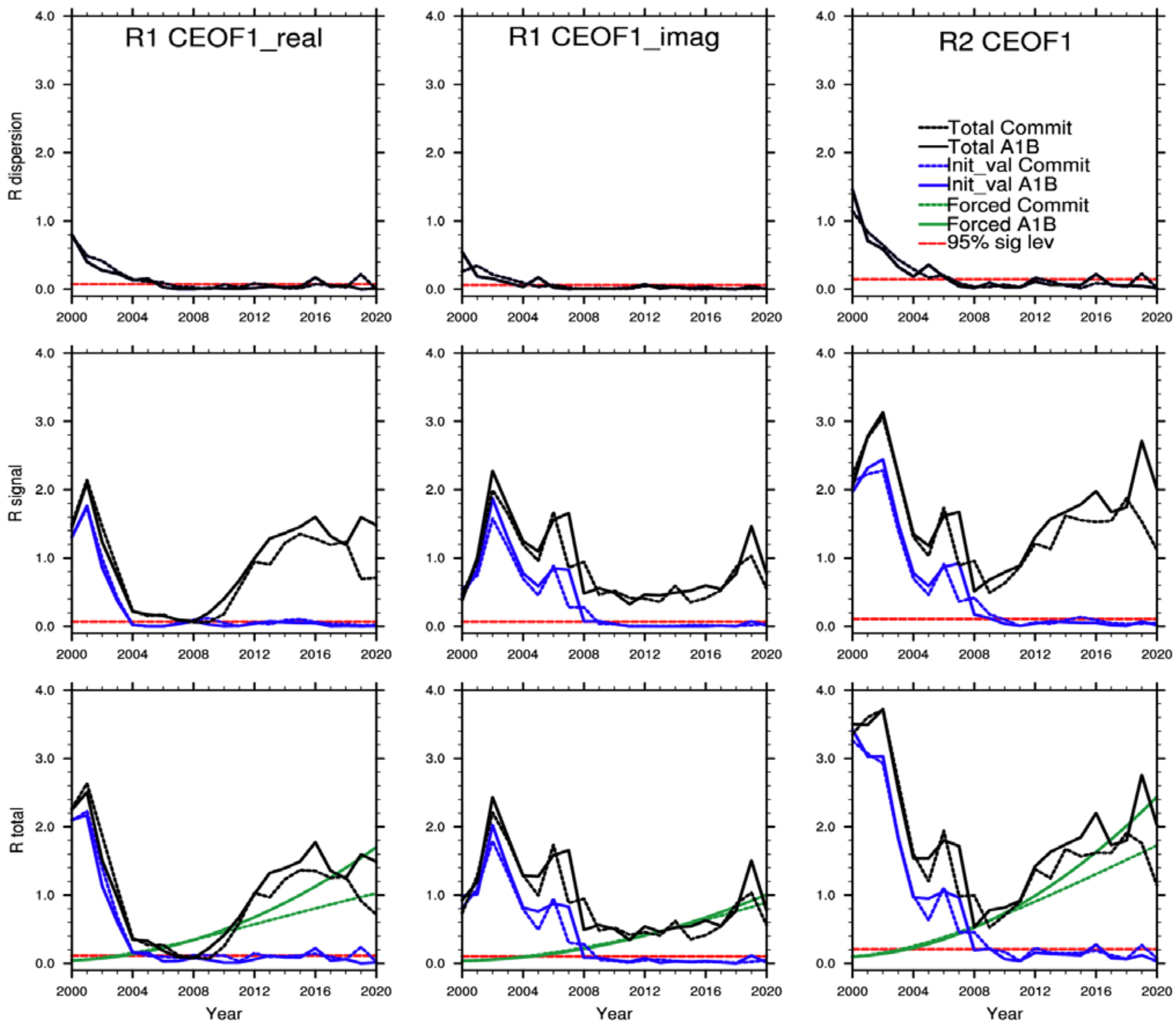


Blue: Commit, **Red: A1B**

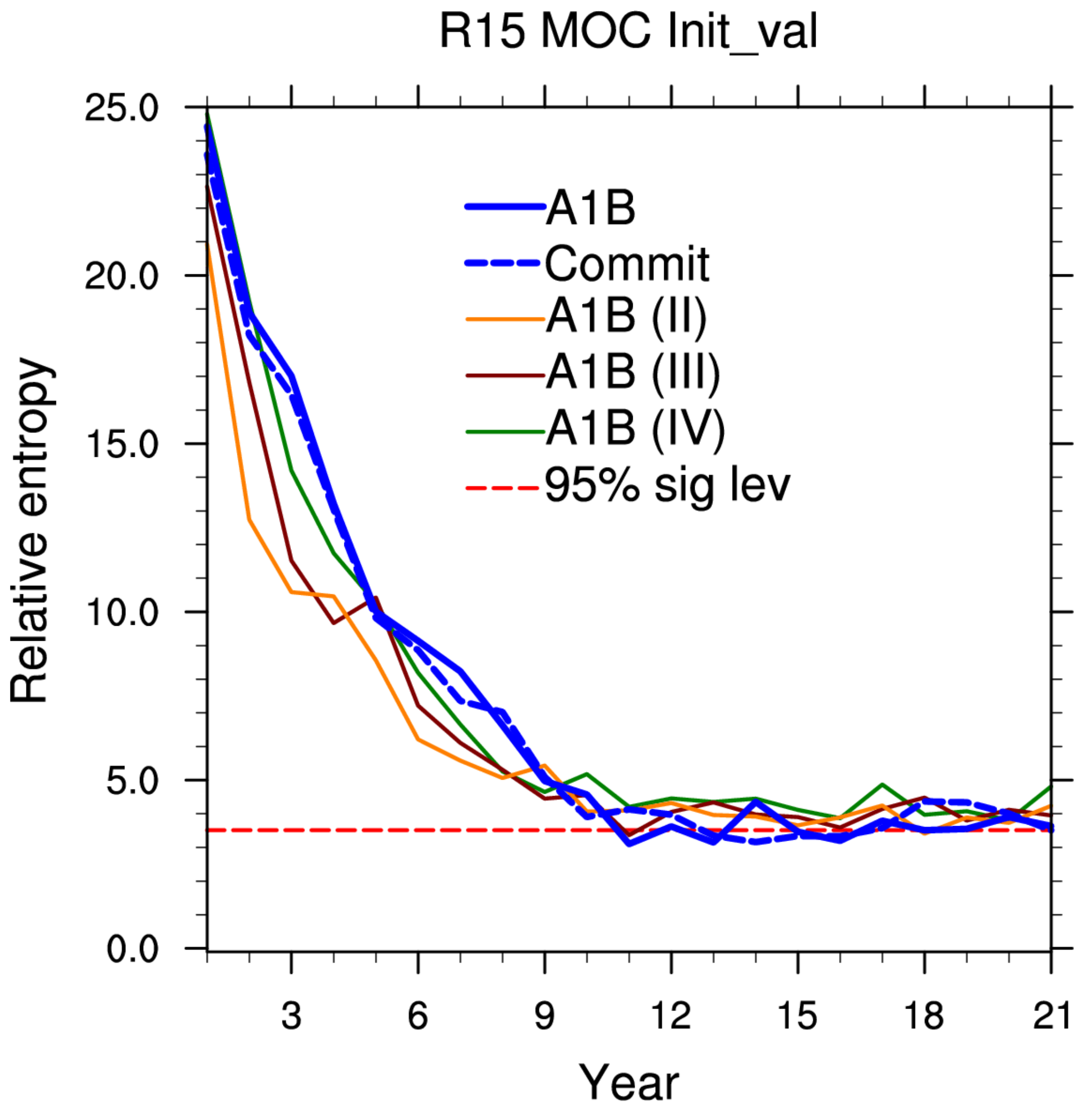


Branstator and Teng (2010)

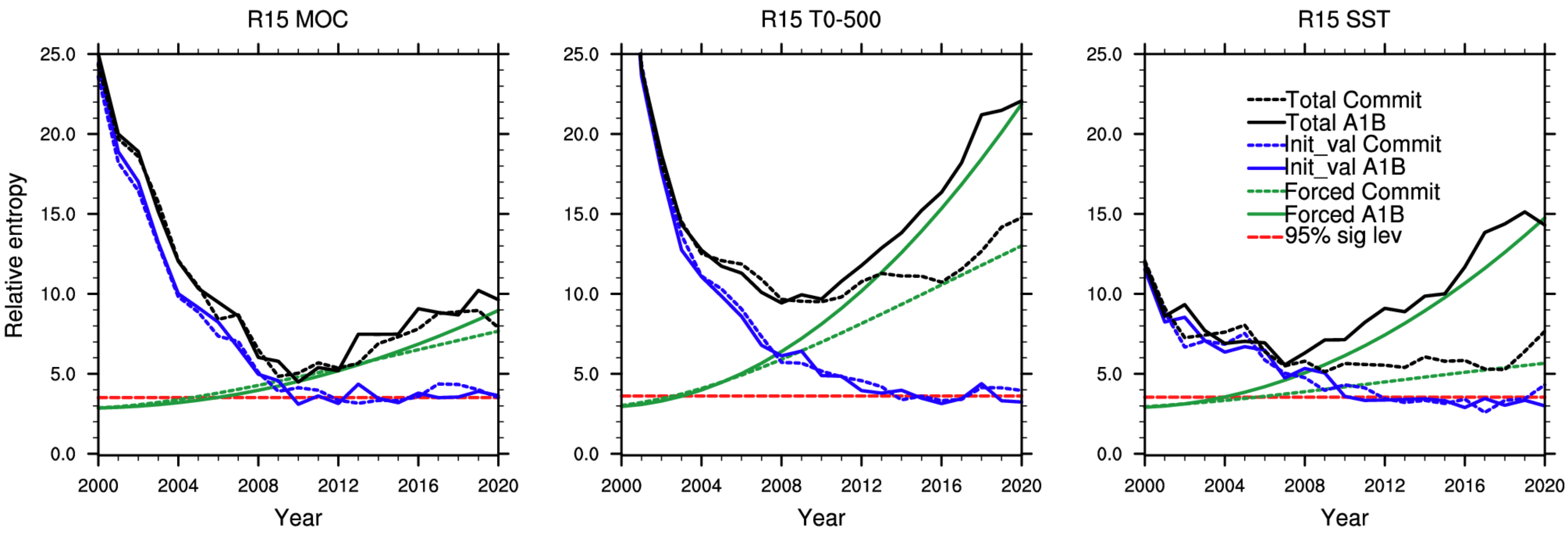
Predictability of the CEOF1 of AMOC



Predictability of the AMOC (15 EOFs)



AMOC T0-500 SST

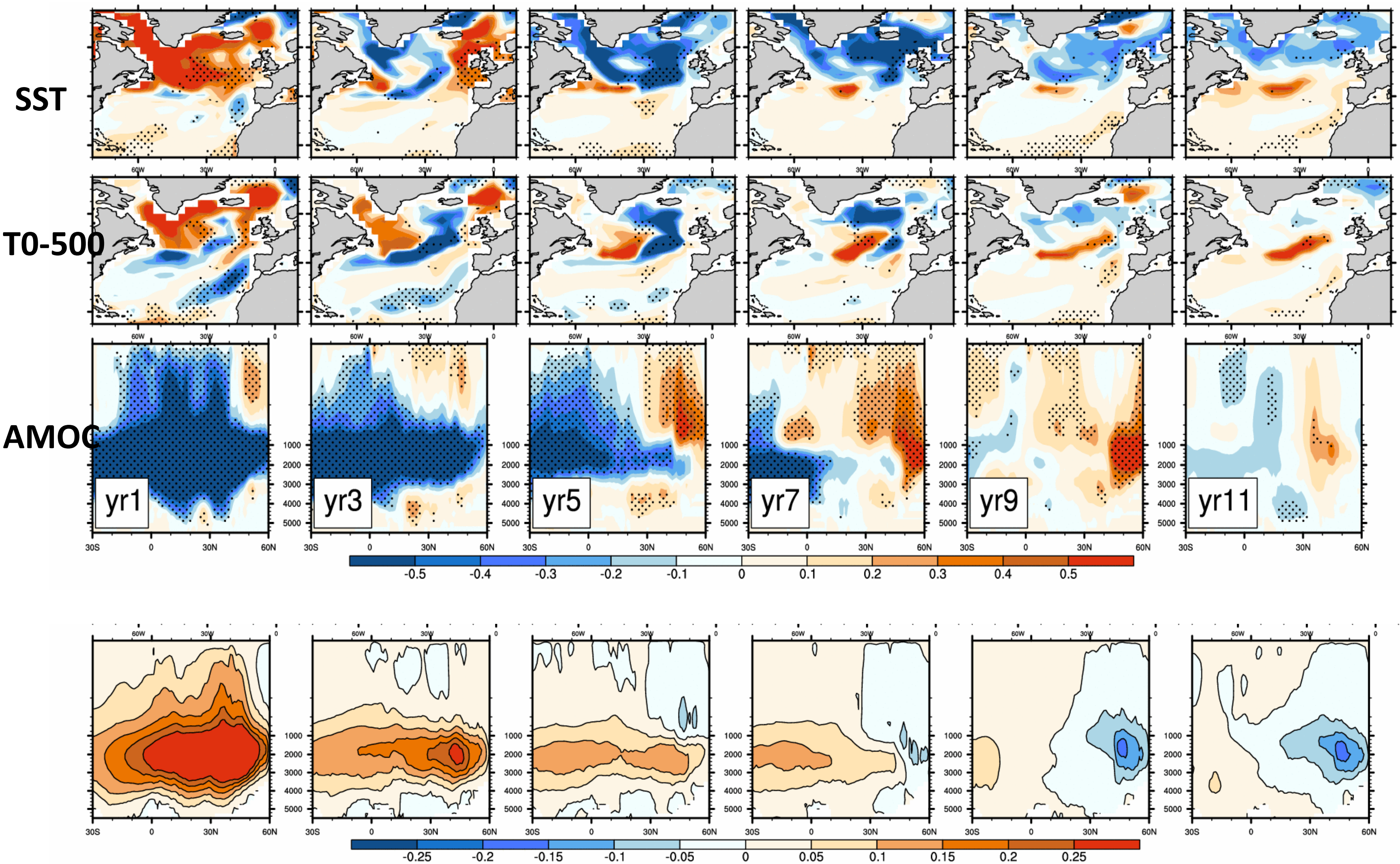


AMOC

- The initial-value component of the AMOC is predictable for about 10-15 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.

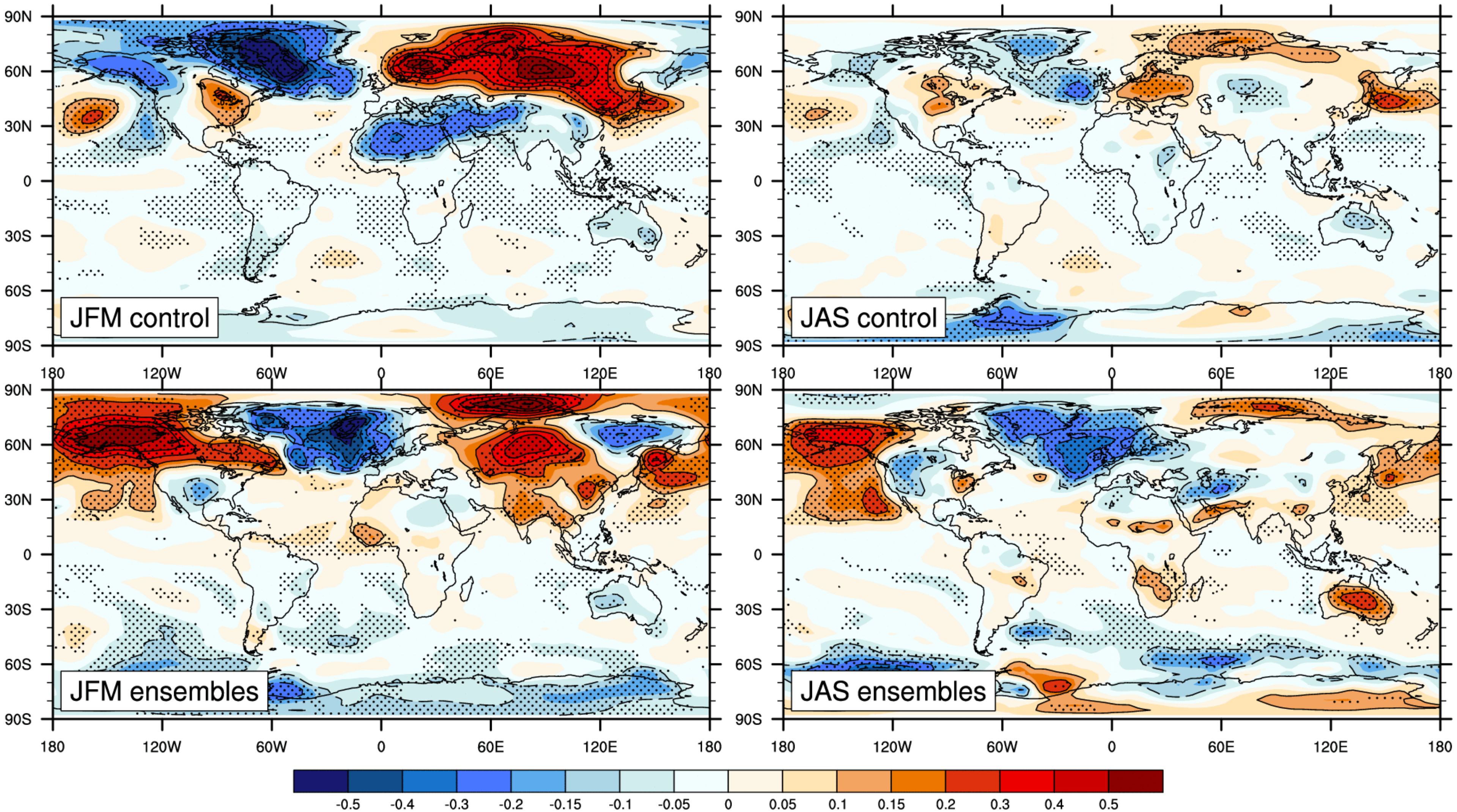
atm

- 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

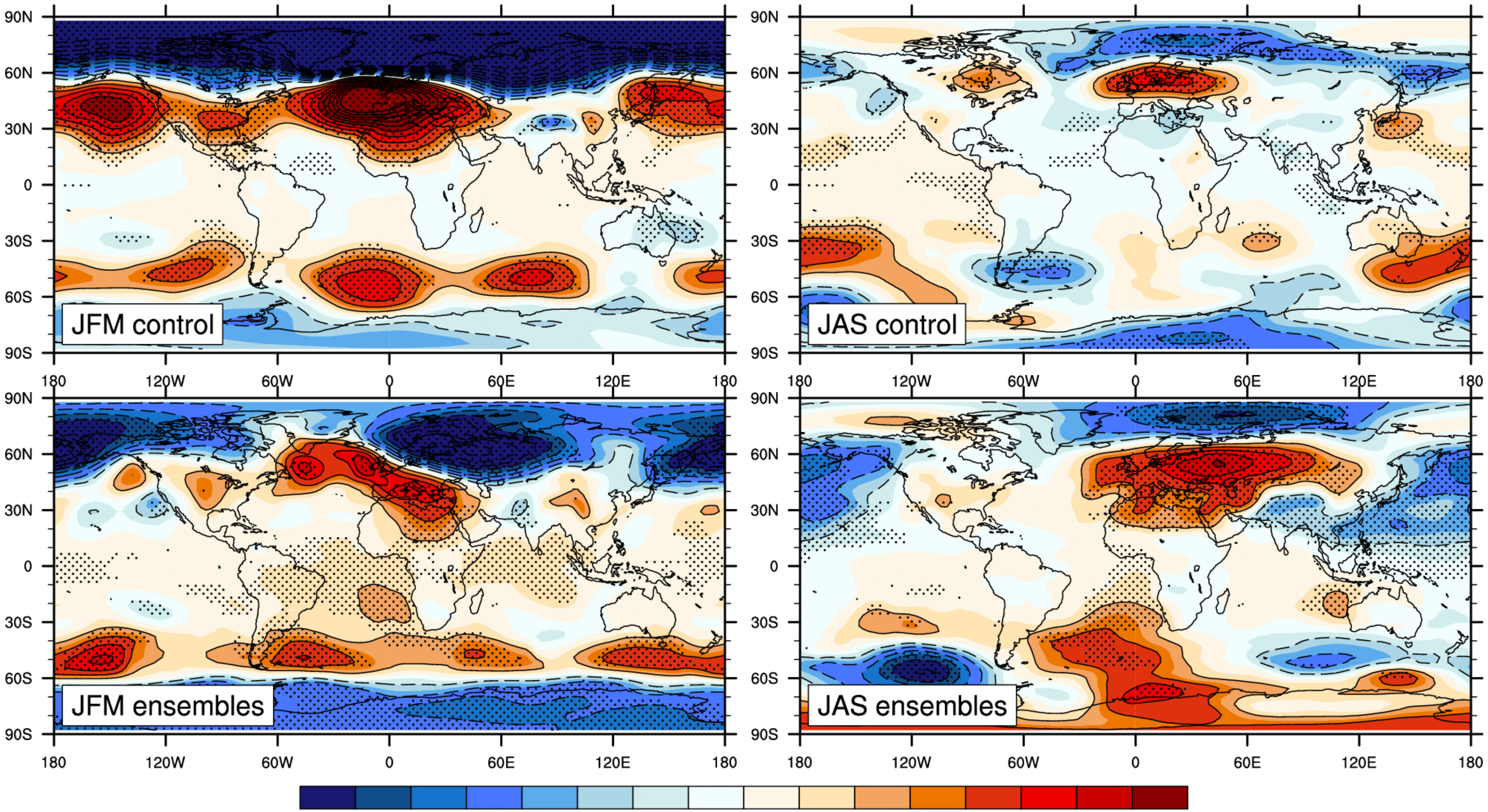


1-2-1 smoothed to remove the ENSO signals

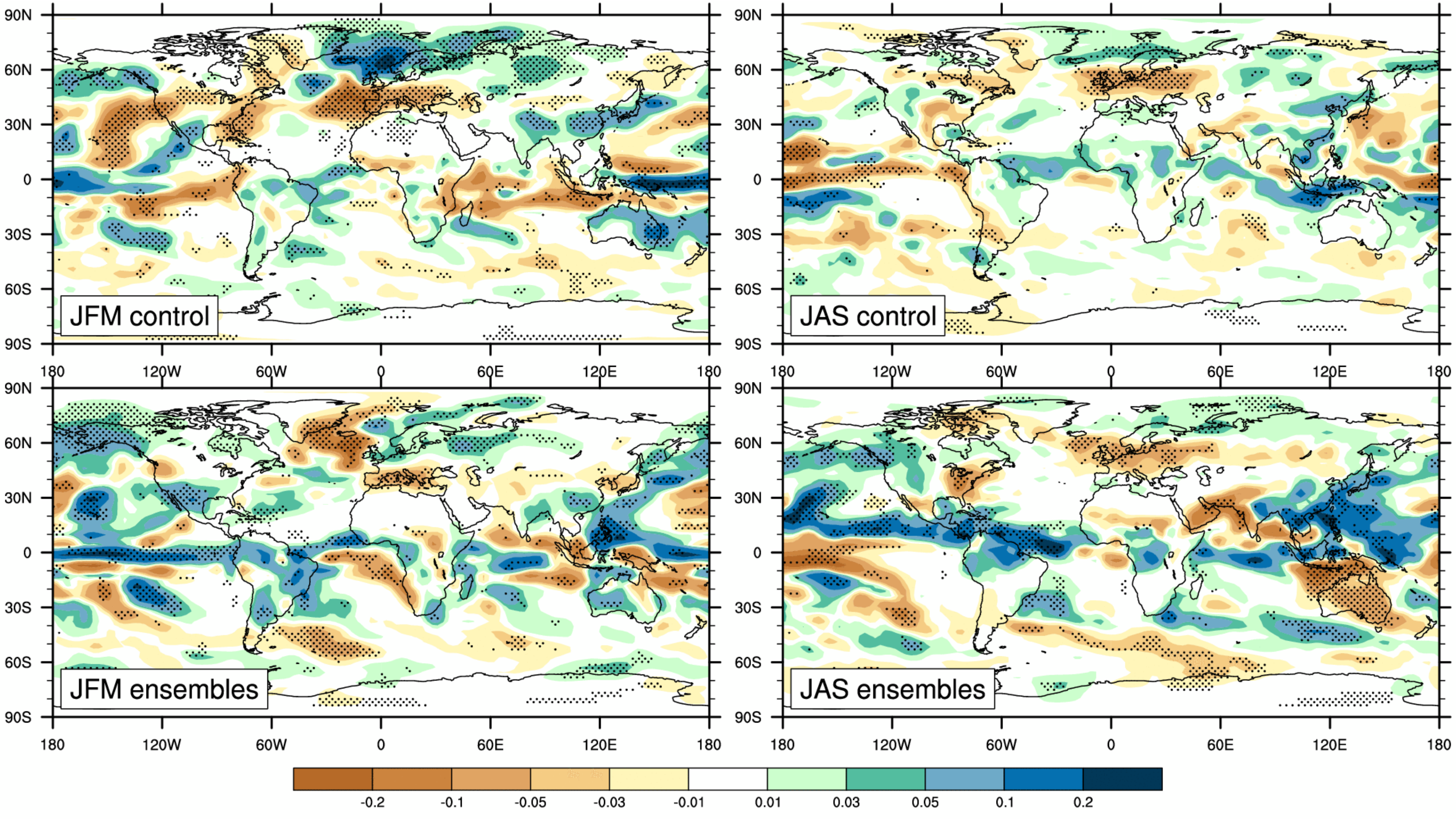
Ensemble mean TAS in yr5-10



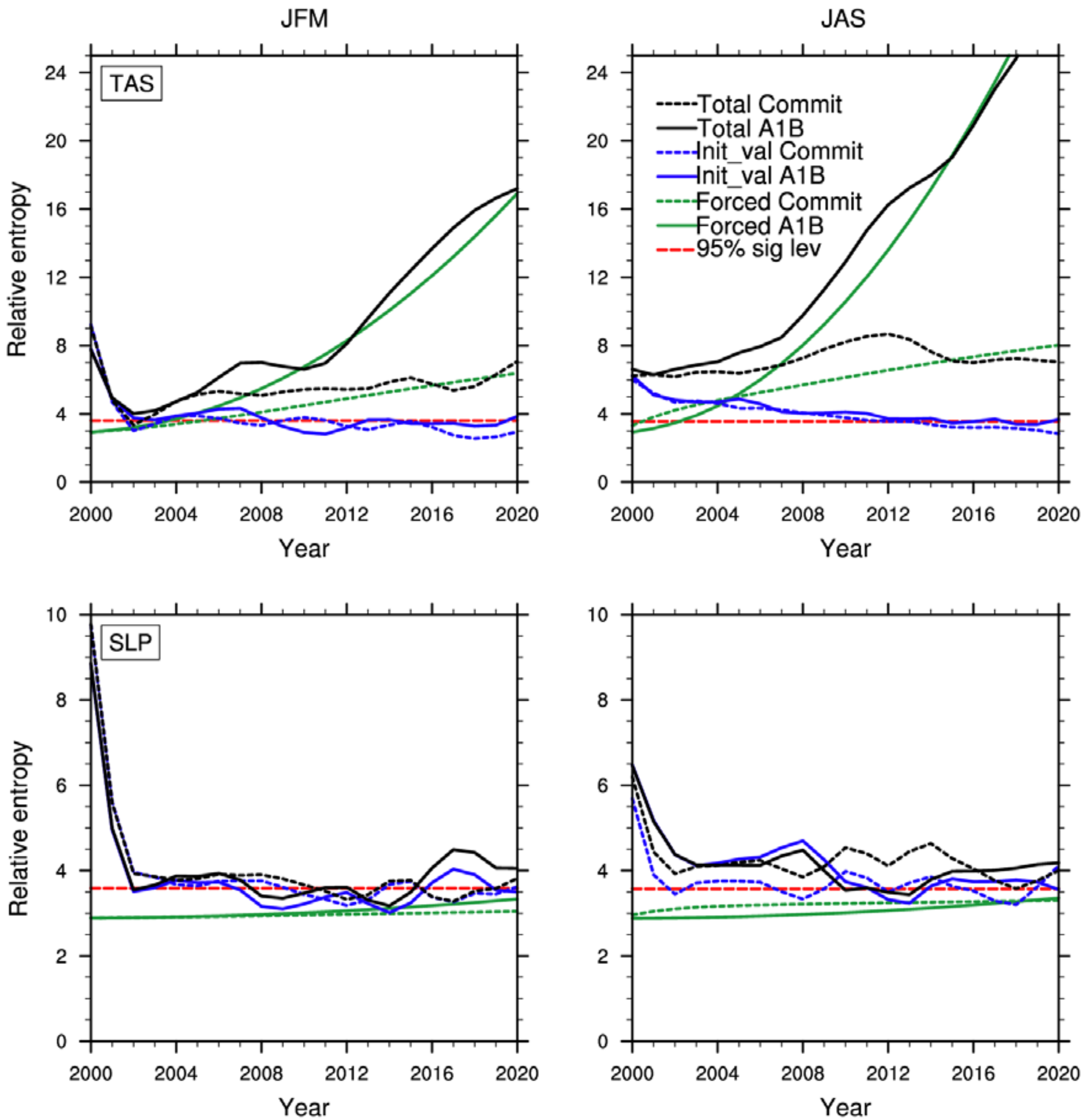
Ensemble mean SLP in yr5-10



Ensemble mean Precipitation in yr5-10



R of 15EOFs in NH (20N-90N)



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 summer atmospheric surface climate is more predictable than the winter counterpart.

- From year5 to year 10, the large ensemble means in SLP/precipitation over the North Atlantic and Europe suggest a positive NAO, and the anomalous patterns agree with the control run at the same phase of the AMOC.

Summary of the atm

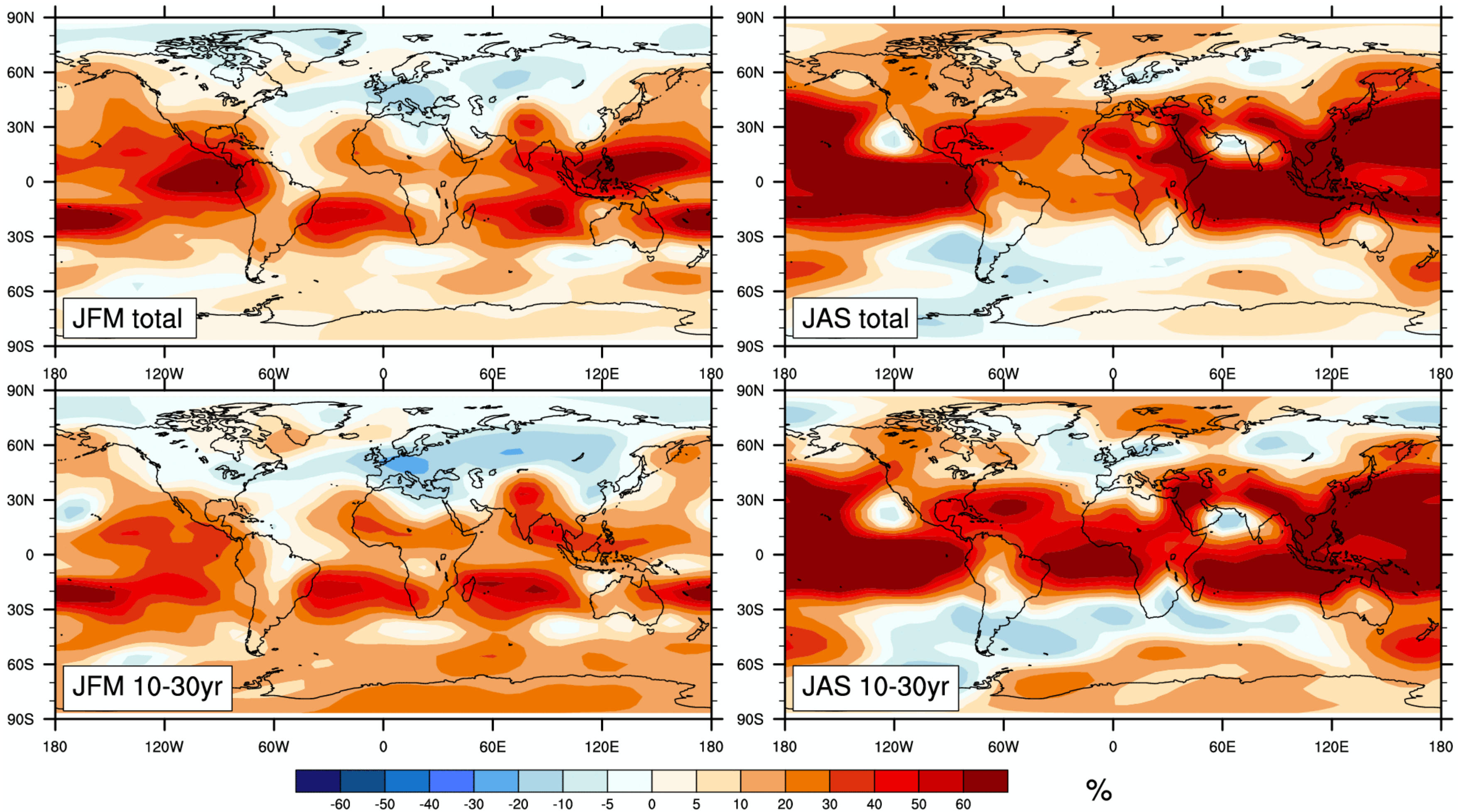
- Despite the extended initial-value predictability in the NH summer, the forced response in the TAS becomes more dominant than the initial-value predictability after about five years.

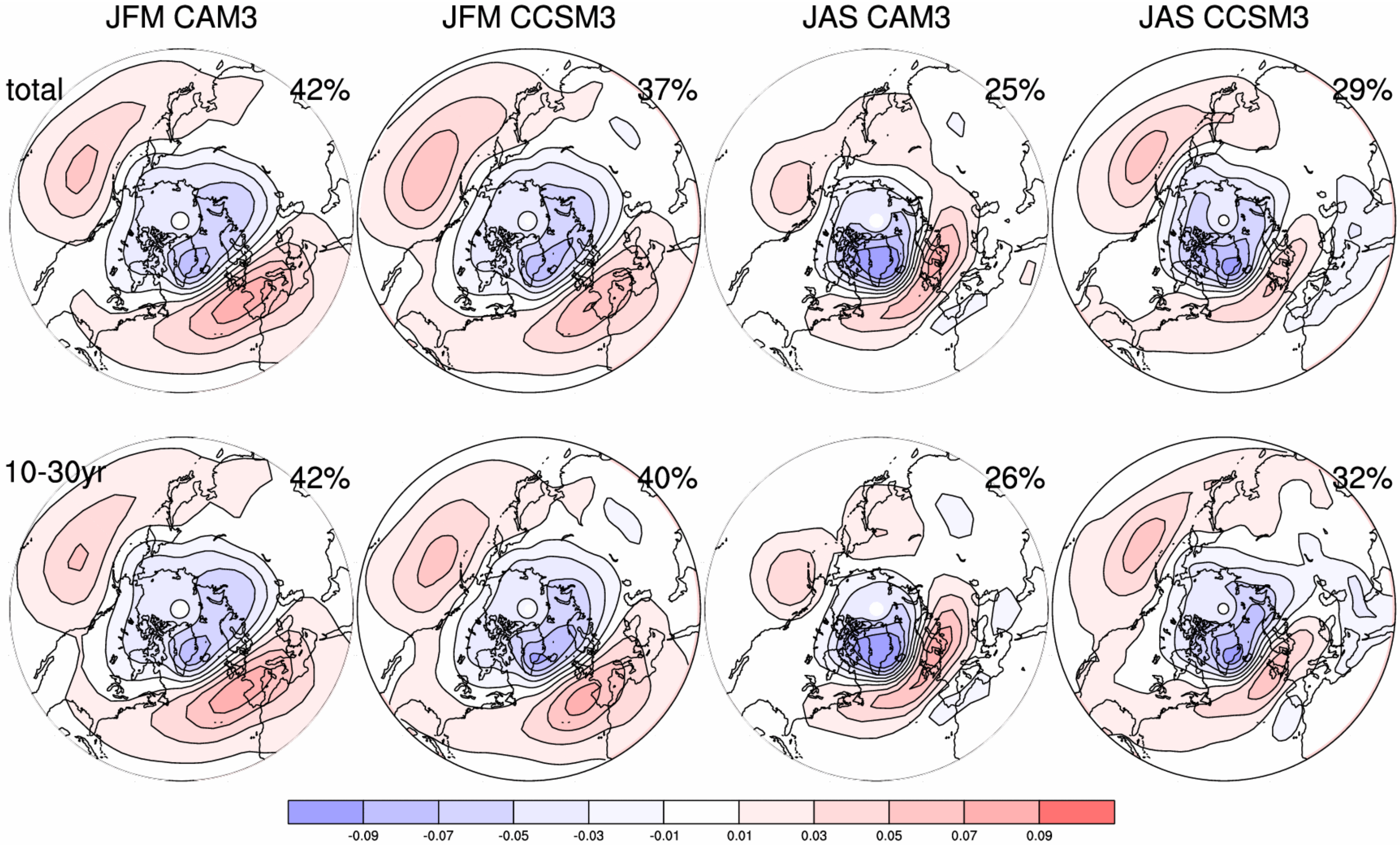
- The large ensemble mean patterns in North America are different from those in the control run composite , possibly due to the disagreement in the phase of the PDO.

- The extended predictability in the atmospheric circulation supports a two-way coupling in the midlatitudes.

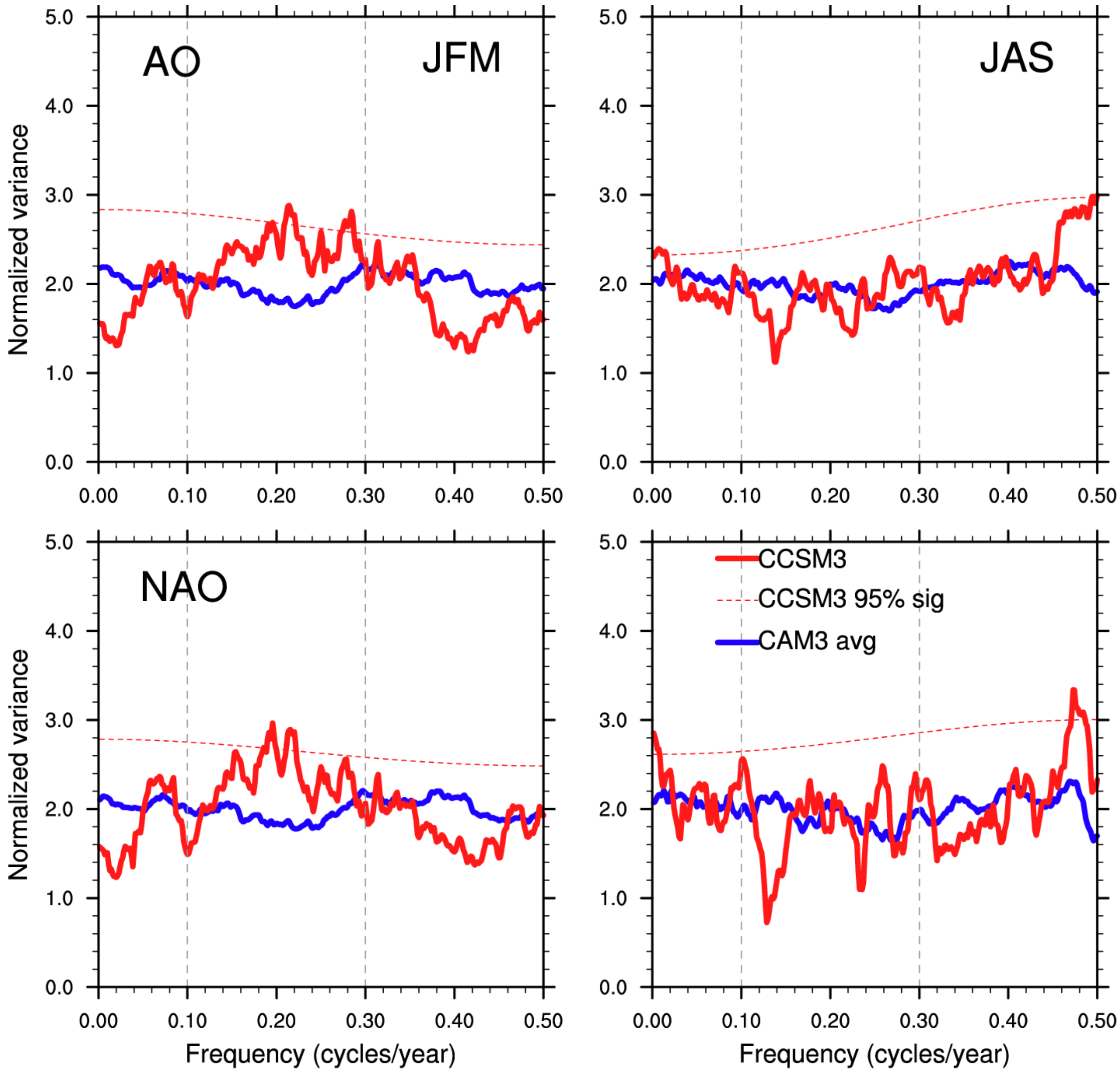

Atm has much less predictability than ocn!
air-sea coupling?

SLP Variance (CCSM3-CAM3)/CAM3





JFM CAM3
JFM CCSM3
JAS CAM3
JAS CCSM3
total
42%
37%
25%
29%
10-30yr
42%
40%
26%
32%
-0.09
-0.07
-0.05
-0.03
-0.01
0.01
0.03
0.05
0.07
0.09


AO
JFM
JAS
NAO
CCSM3
CCSM3 95% sig
CAM3 avg
Normalized variance
Frequency (cycles/year)
0.0
1.0
2.0
3.0
4.0
5.0
0.00
0.10
0.20
0.30
0.40
0.50