# Initial-value Predictability of Prominent Modes of North Pacific Subsurface Temperature in a CGCM

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**NCAR CGD**

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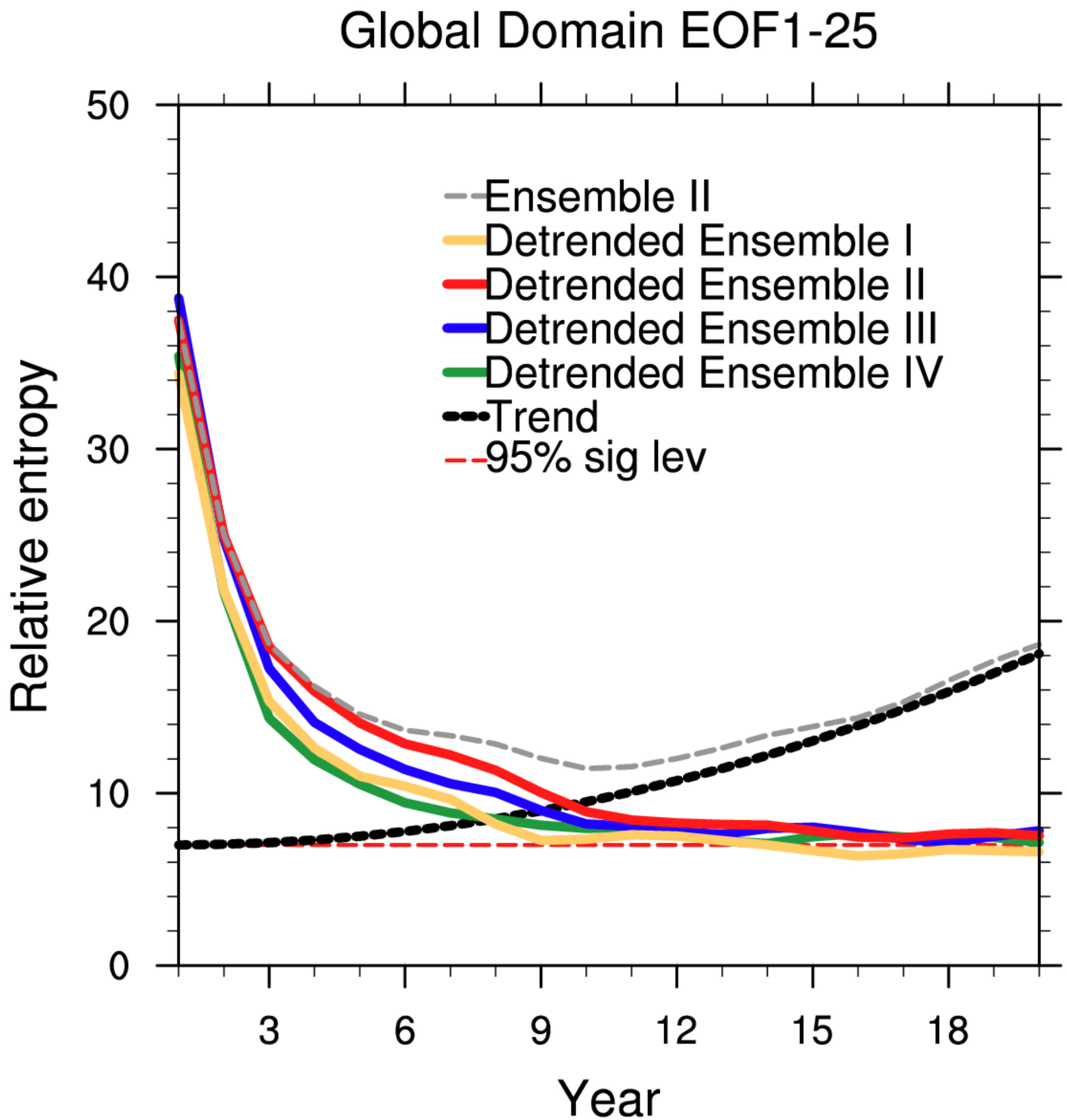
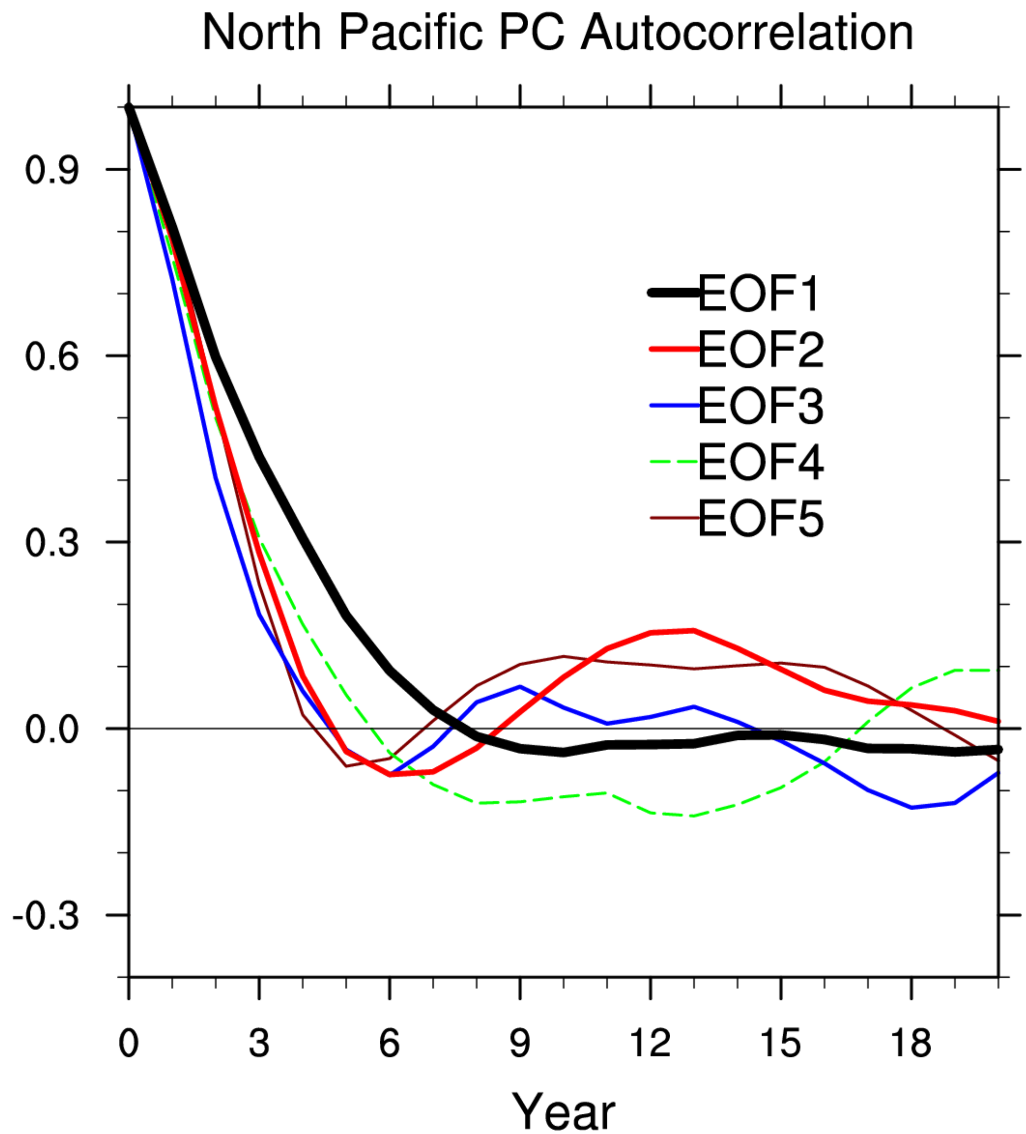



*Branstator talk, yesterday*

# Why are we interested in the prominent modes?



# Questions

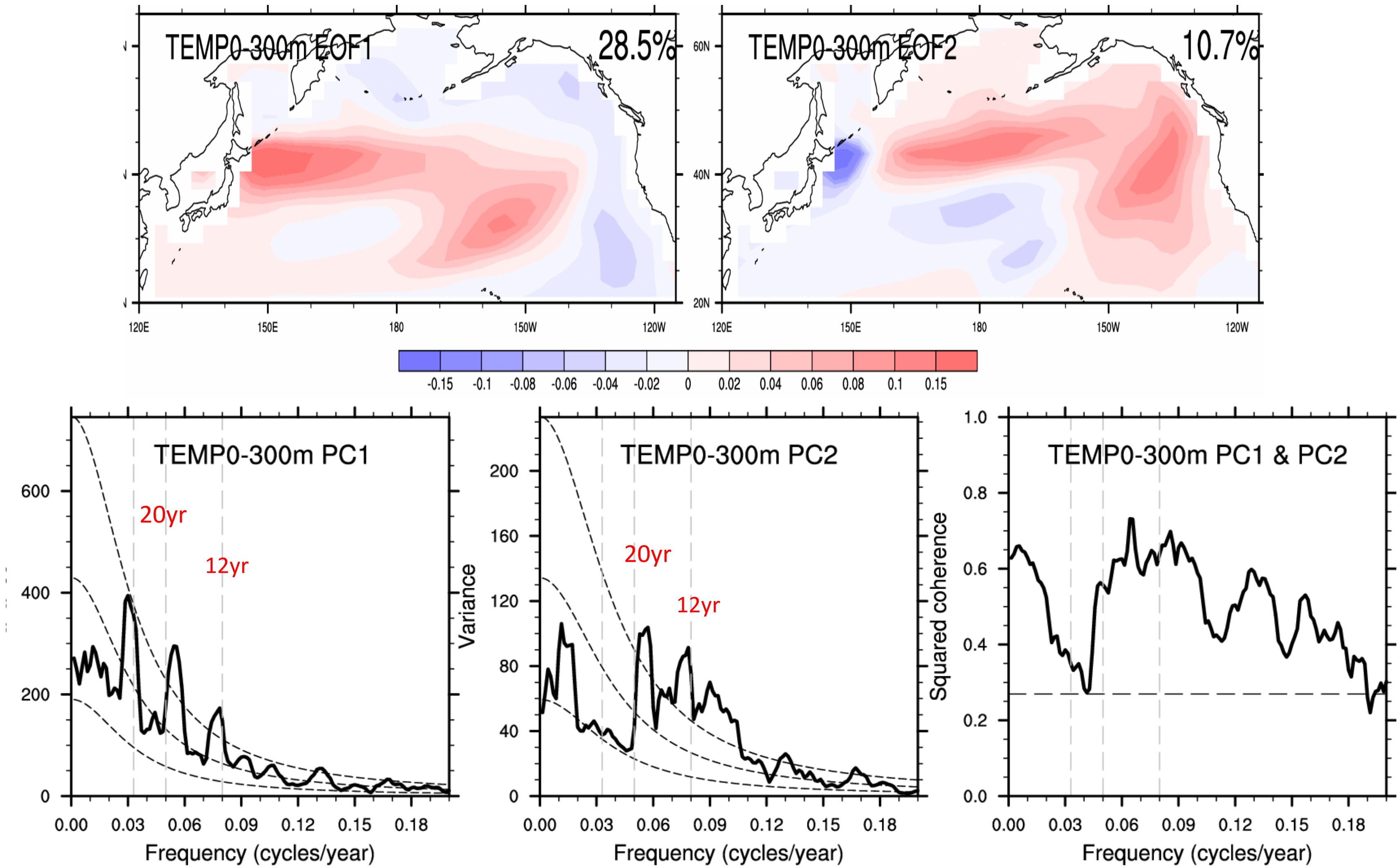
- *To what extent is there predictability in the prominent modes in the subsurface temperature?*

- *How much do the prominent modes contribute to the predictability of the entire North Pacific region?*

# Experiments

| CCSM3 Experiments | Period | External forcing | Initial perturbation | Initial ocean state |
|---|---|---|---|---|
| **Present-day control** | 0300-0999 | control | | |
| **Ensemble I (40 members)** | 2000-2061 | SRES A1B | Different atm/ same ocn, ice, lnd | Close to neutral EOF1(PDO) |
| **Ensemble II (40 members)** | 2008-2028 | SRES A1B | Infinitesimal differences in the solar constant | Very warm EOF1(PDO ) |
| **Ensemble III (40 members)** | 2008-2028 | SRES A1B | Infinitesimal differences in the solar constant | Warm EOF2, weak EOF1(PDO) |

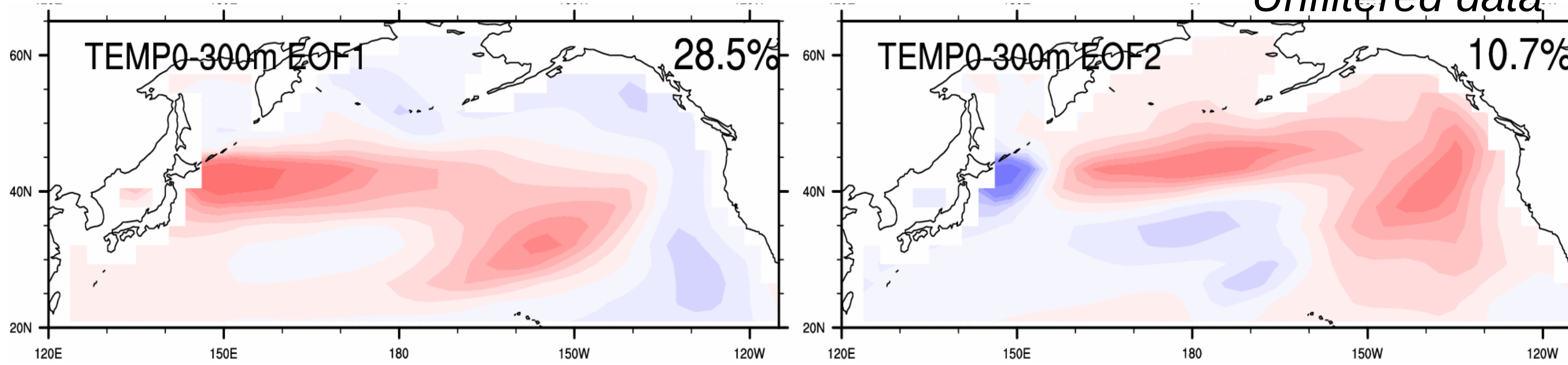
# Leading EOF Modes




*From 700-yr control*

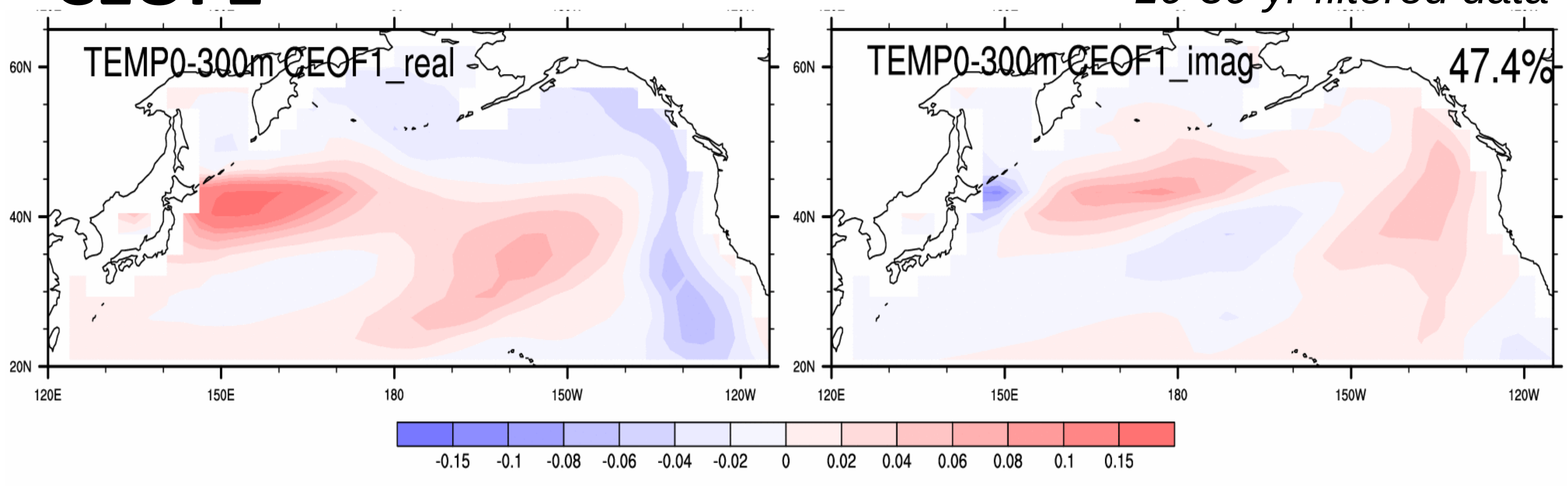
# EOF1,2

*Unfiltered data*

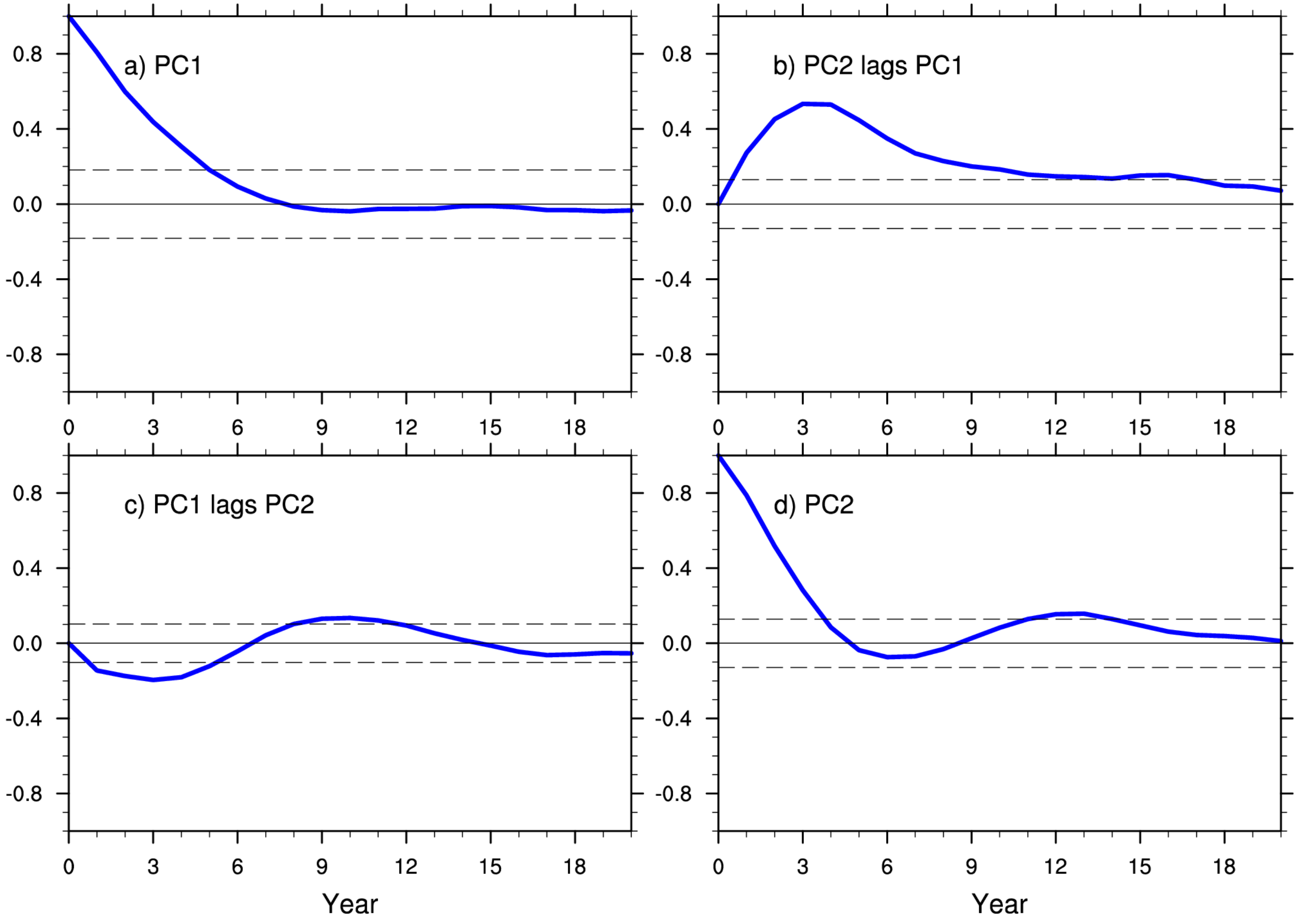



# CEOF1

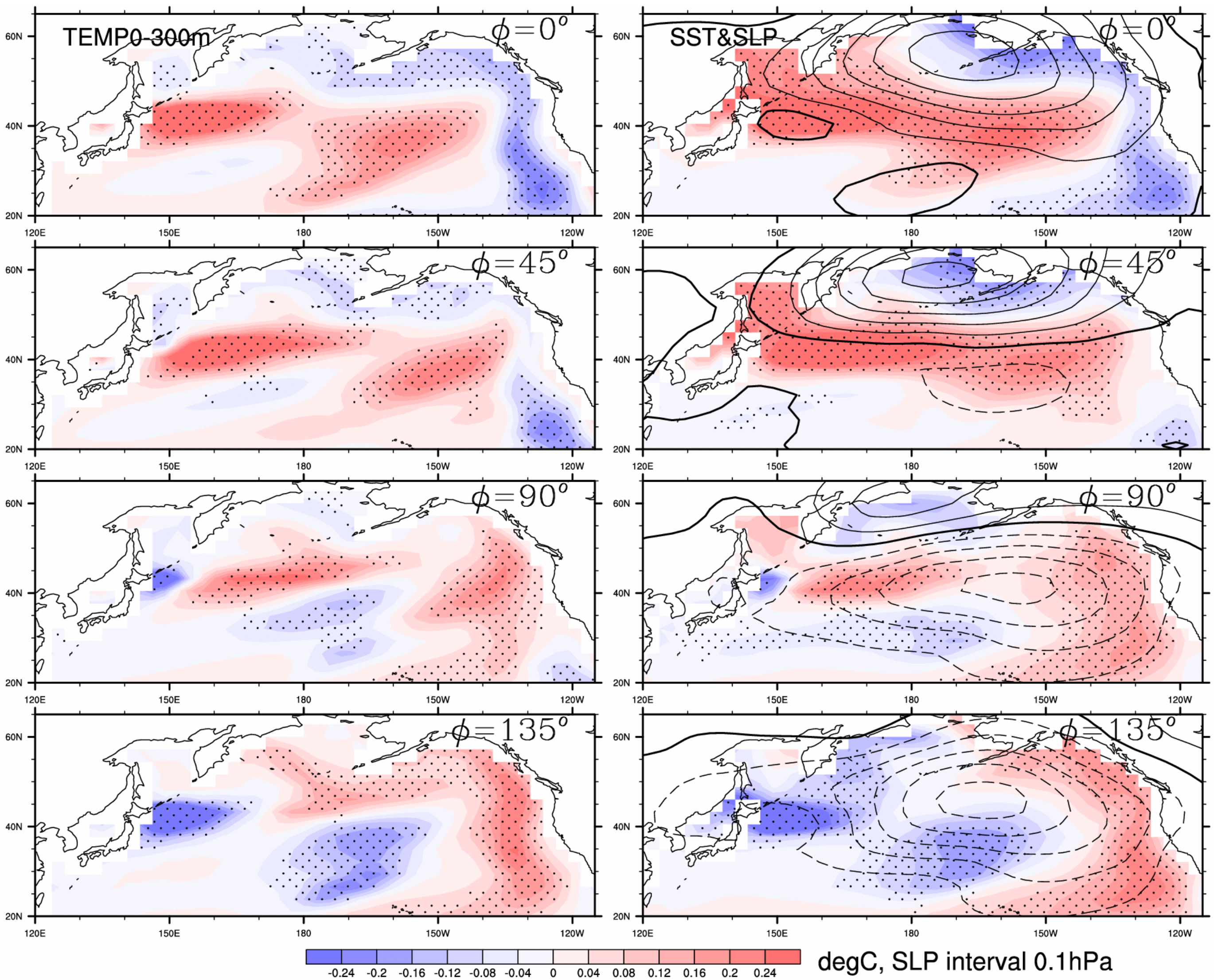
*10-30-yr filtered data*



# Lag and autocorrelations of the leading PCs



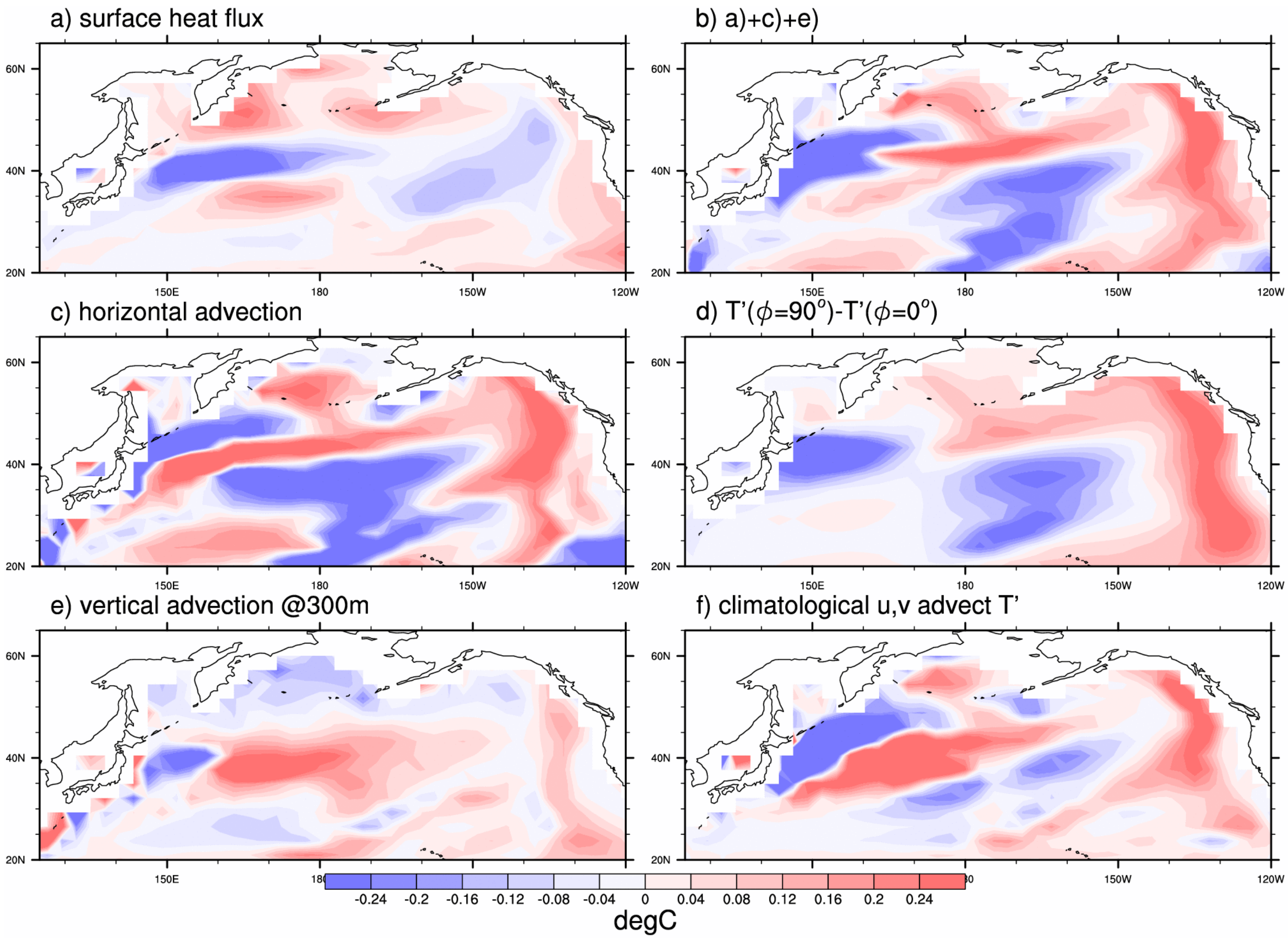
# Evolution of Subsurface Temperature CEOF1 & SST, SLP



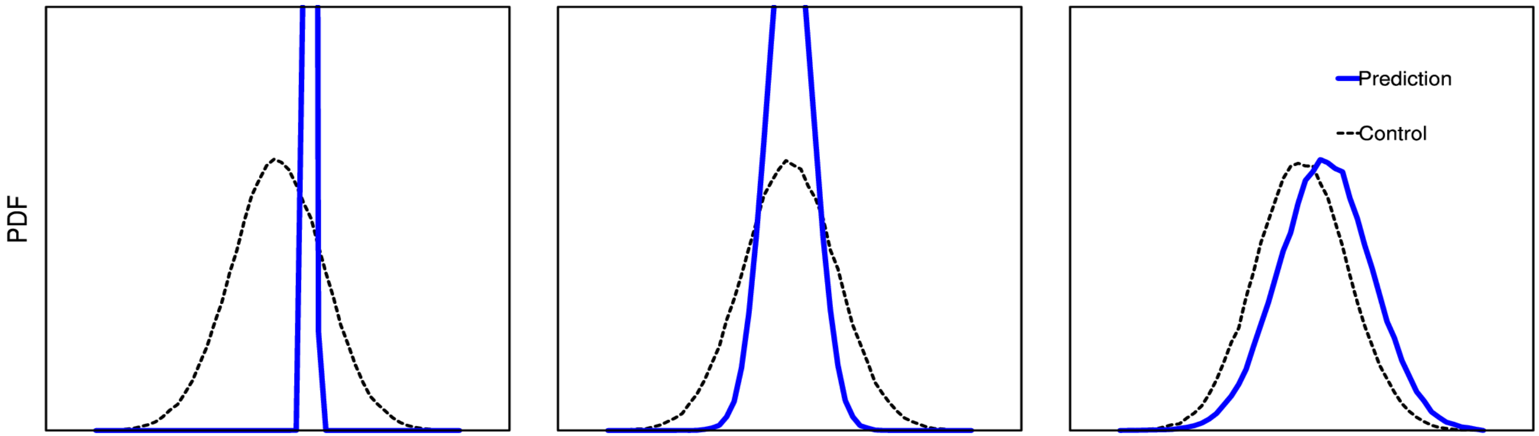

*composite based on 10-30-yr filtered data, ~ 60 episodes in 700-yr control*

# Heat Budget Analysis of the leading propagating mode

$$\frac{\partial T}{\partial t} = -\frac{Q_{net}}{\rho_0 C_p H} - \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) - w\frac{\partial T}{\partial z}\Big|_{z=300\,m}$$



# Measure of Predictability: Relative Entropy




*Kleeman (2002)*

$$R = \sum_i p_i \ln(\frac{p_i}{q_i}) \qquad p_i: \textit{ Prediction,} \qquad q_i: \textit{ Climatological distribution}$$

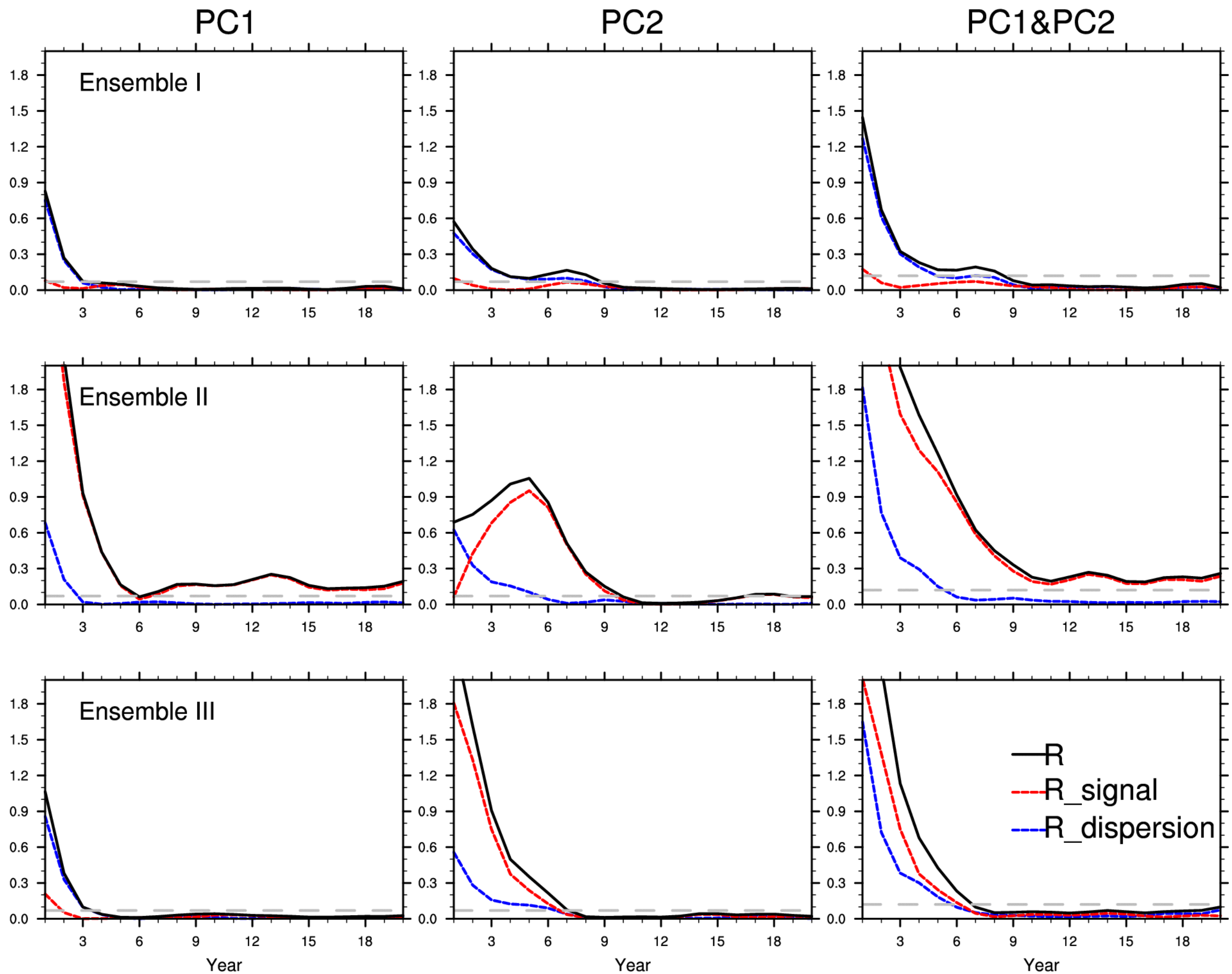
*For normal distribution:*

$$R_1 = \frac{1}{2}\left[\ln\left(\frac{\sigma_c^2}{\sigma_e^2}\right) + \frac{\sigma_e^2}{\sigma_c^2} + \frac{(\mu^e - \mu^c)^2}{\sigma_c^2} - 1\right]$$

$$R_n = \frac{1}{2}\left\{\ln\left[\frac{\det(\sigma_c^2)}{\det(\sigma_e^2)}\right] + tr\left[\sigma_e^2(\sigma_c^2)^{-1}\right] + (\vec{\mu^e} - \vec{\mu^c})^t(\sigma_c^2)^{-1}(\vec{\mu^e} - \vec{\mu^c}) - n\right\}$$

**dispersion** **signal**

# Relative Entropy of the Leading PCs



# Predictability Estimated from a Linear Stochastic Model

## Linear Inverse Model (LIM)

### Penland (1989)

$$\frac{dX}{dt} = BX + \xi$$

$$X(t+\tau) = e^{B\tau}\, X(t)$$

$$B = \tau_0^{-1} \ln\{C(\tau_0)C(0)^{-1}\}$$

$$C(\tau_0) = \left\langle X(t+\tau_0)X^T(t) \right\rangle$$

$$C(0) = \left\langle X(t)X^T(t) \right\rangle$$

$$G \equiv \exp(B\tau) = [G(\tau_0)]^{\tau/\tau_0}$$

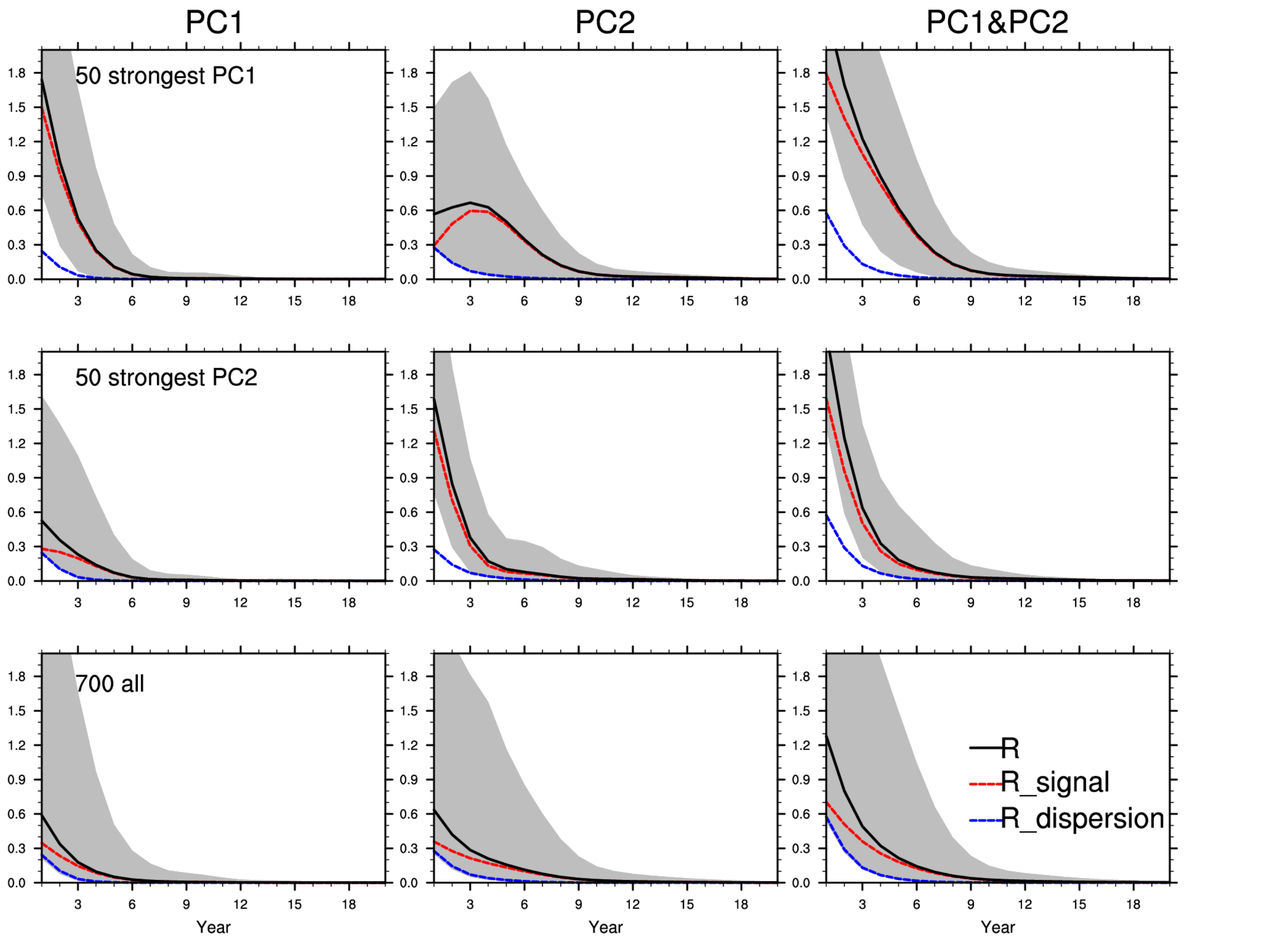
- For initial state $\tilde{X}(t)$ , forecasts at t+τ has mean

$$\bar{X}(t+\tau) = G(\tau)\tilde{X}(t)$$

and covariance

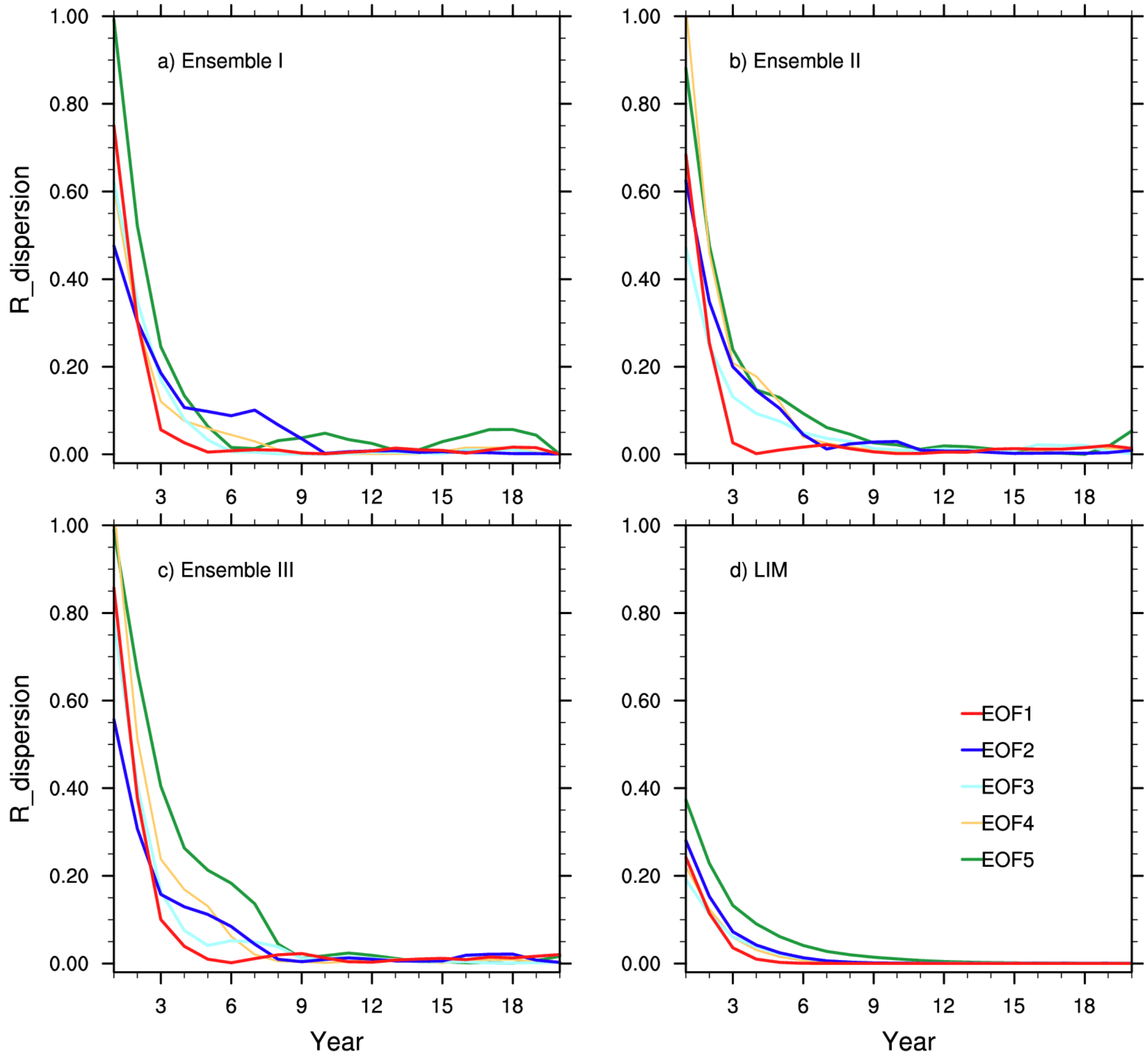
$$\left\langle X(t+\tau)X^T(t+\tau) \right\rangle = C(0) - G(\tau)C(0)G^T(\tau)$$

# Relative Entropy of the Leading PCs from LIM



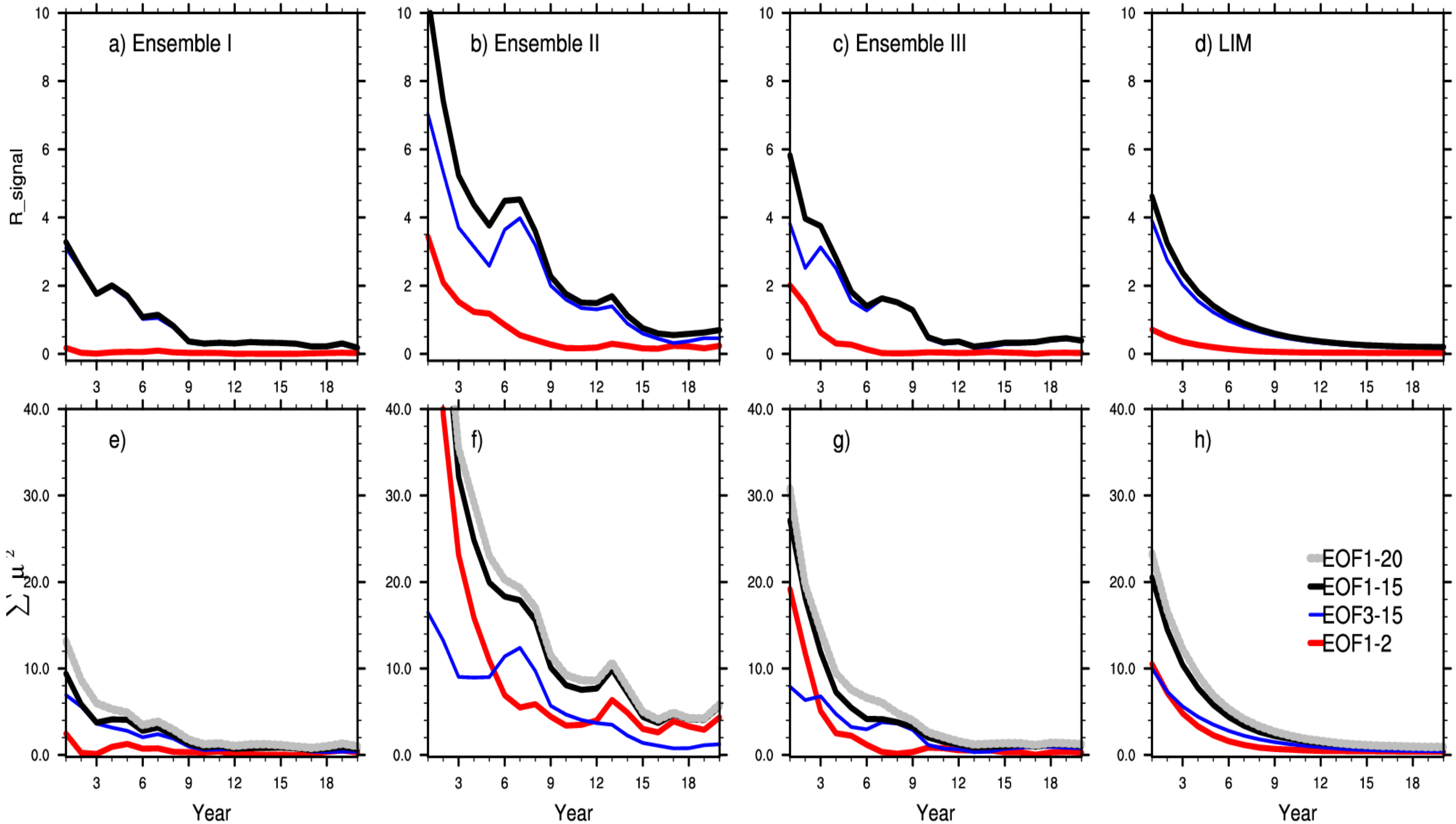
# Dispersion Component of Relative Entropy of the Leading PCs

$$R_1 = \frac{1}{2}\left[\ln\left(\frac{\sigma_c^2}{\sigma_e^2}\right) + \frac{\sigma_e^2}{\sigma_c^2} + \frac{\mu_e^2}{\sigma_c^2} - 1\right]$$

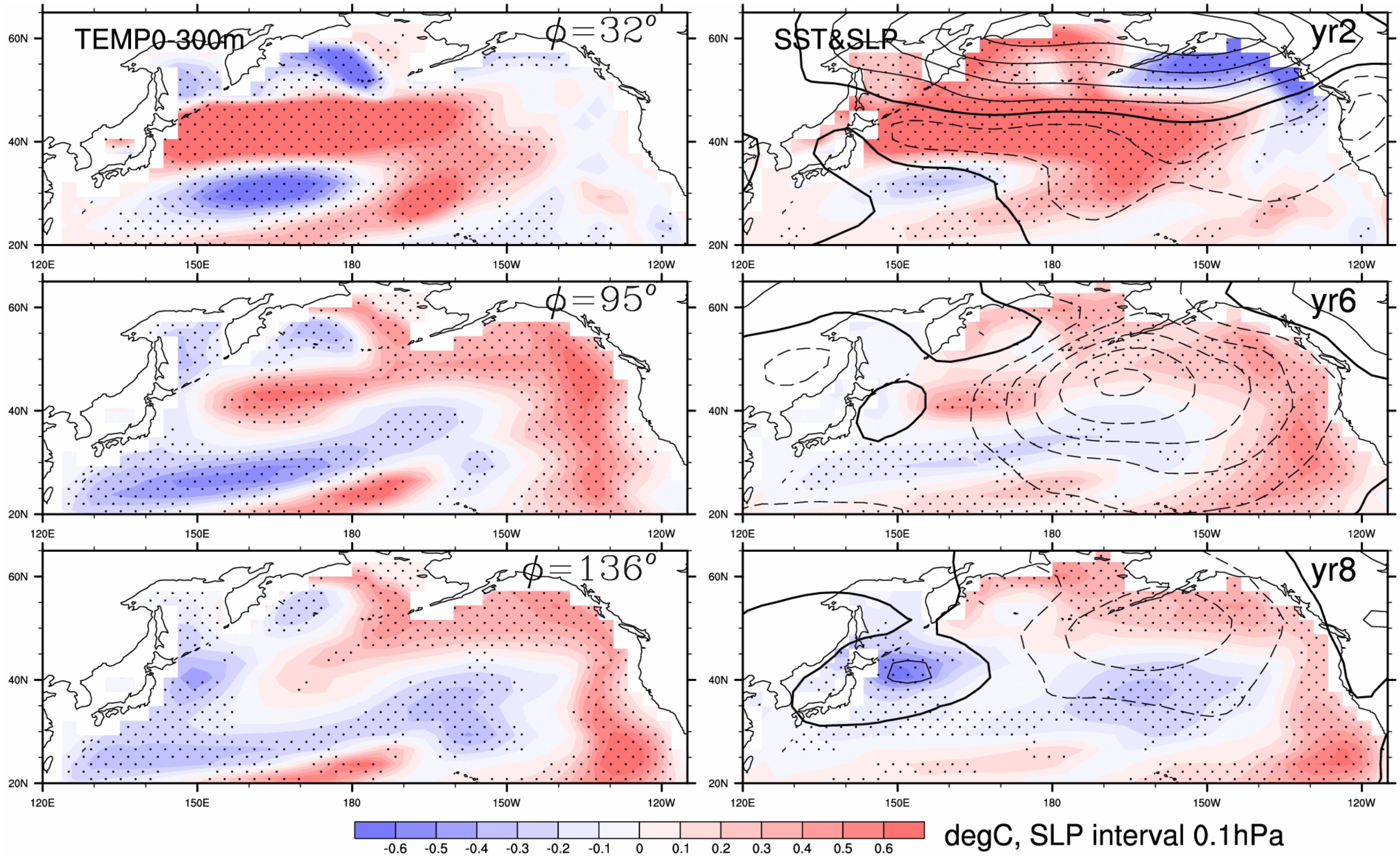


# Signal Component of Relative Entropy of the Leading PCs

$$R_n = \frac{1}{2}\left\{ \ln\left[\frac{\det(\sigma_c^2)}{\det(\sigma_e^2)}\right] + tr\left[\sigma_e^2(\sigma_c^2)^{-1}\right] + (\mu^e - \mu^c)^T(\sigma_c^2)^{-1}(\mu^e - \mu^c) - n \right\}$$



# Subsurface Temperature, SST, and 10-30-yr SLP in Ensemble II



# Lessons

- The **intrinsic time scale** of a pattern is **not necessarily a good indicator** of its predictability.
- Allow for **time evolving modes** when examining predictability.
- Both the **mean and spread** of an ensemble should be taken into account when assessing initial-value predictability.