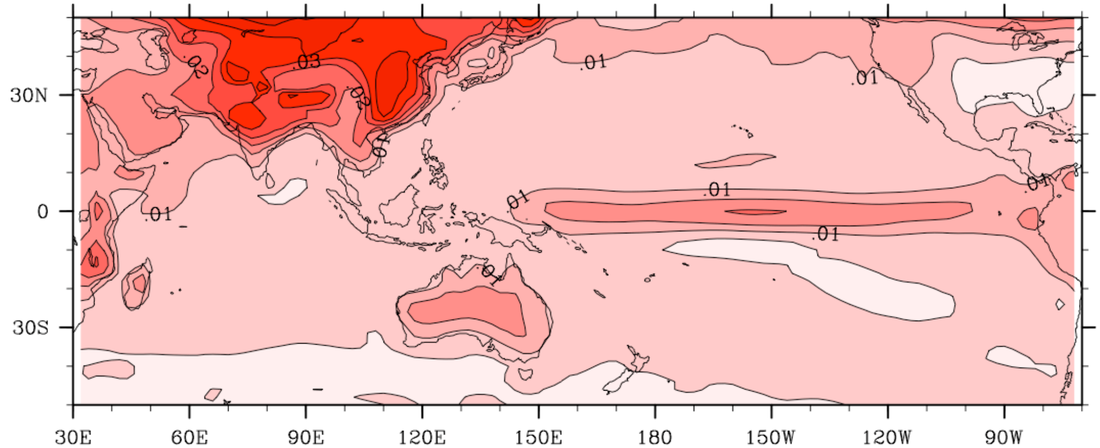
Decadal predictability of tropical Indo-Pacific Ocean temperature trends due to anthropogenic forcing

CCSM3 DJF A1B Surface Temperature Trend 2018-2062



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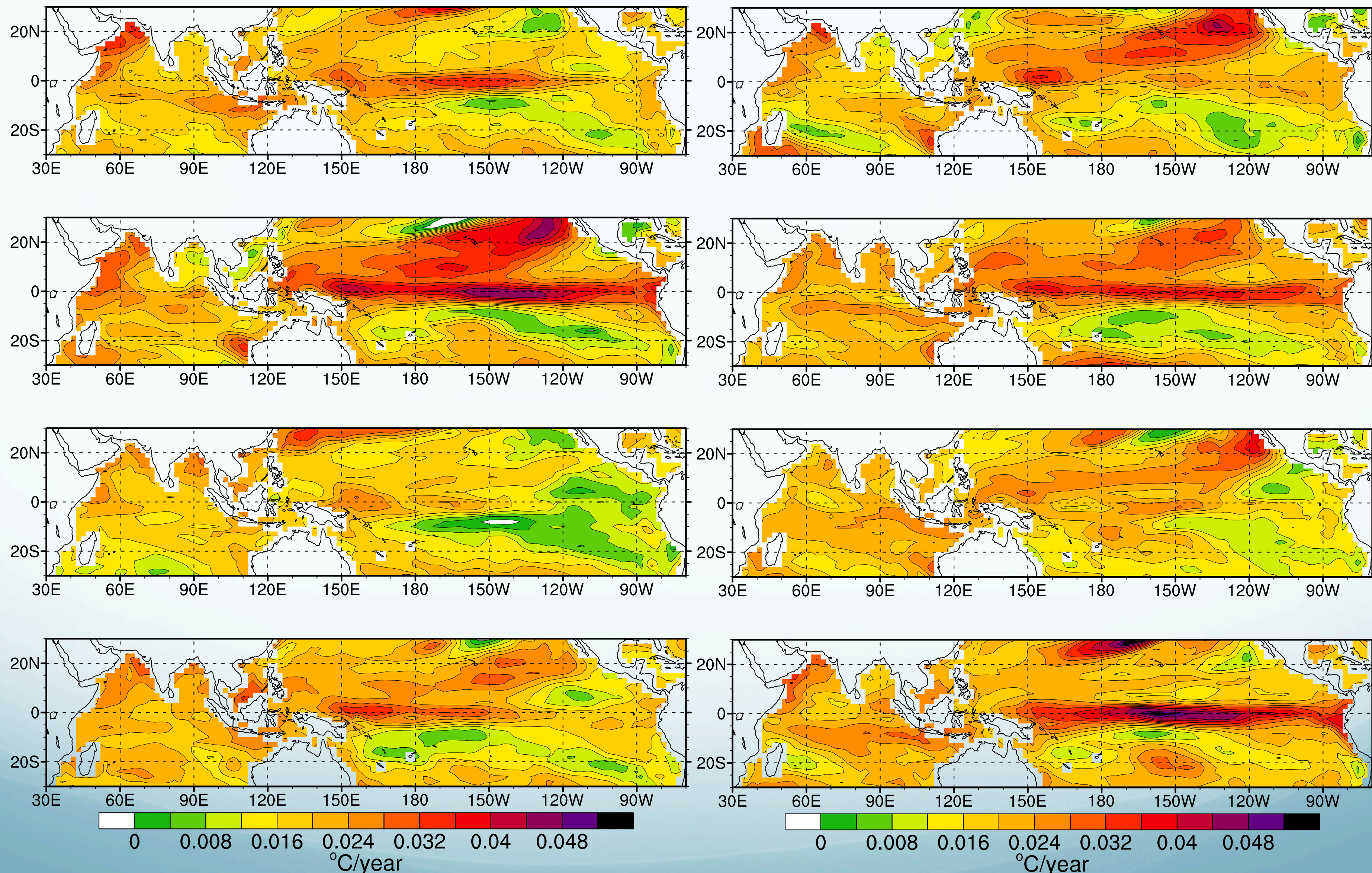
Outline

1) CCSM3 Large Ensemble (40 members, 60 years, A1B)
   1) Unfiltered trend patterns
   2) Defining natural variability (ENSO)
   3) Isolating a predictable signal

2) Application to CCSM4 RCP8.5 (5 members, 2005-2100)

50-year Tropical Indo-Pacific 10m Temperature Trends from 8 A1B CCSM3 Ensemble Members



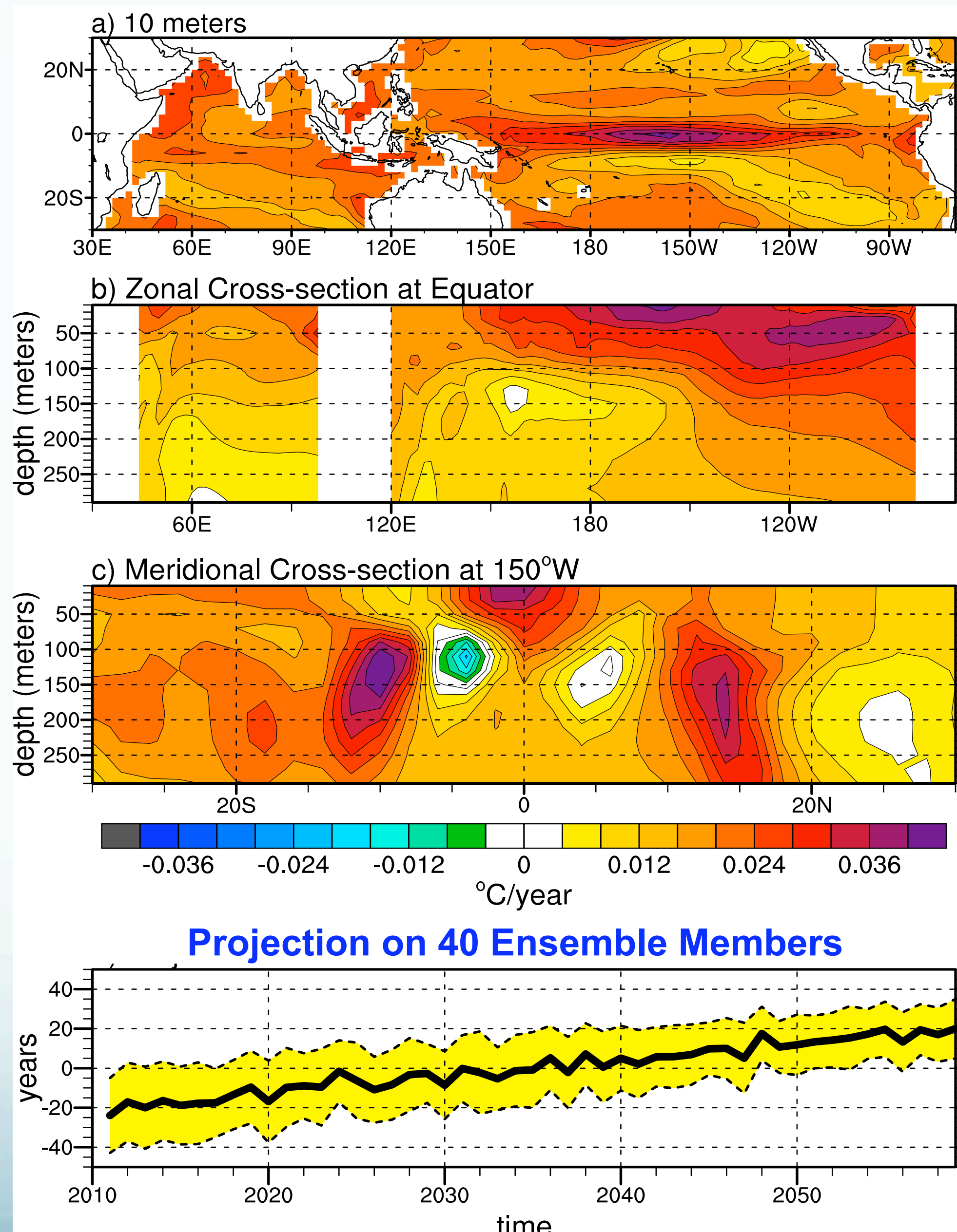
Motivation

For decadal climate forecasts to be useful they must provide verifiable regional skill on 10-30 year time scales

Since on these time scales natural variability and the response to external forcing are of the same order a strategy is needed to…

- ◆Assess the skill of decadal forecasts in a way that will provide insight into the contributions (and potential interactions) of forced and natural variability
- ◆Compare this skill across models

CCSM3 A1B Ocean Temperature Trend

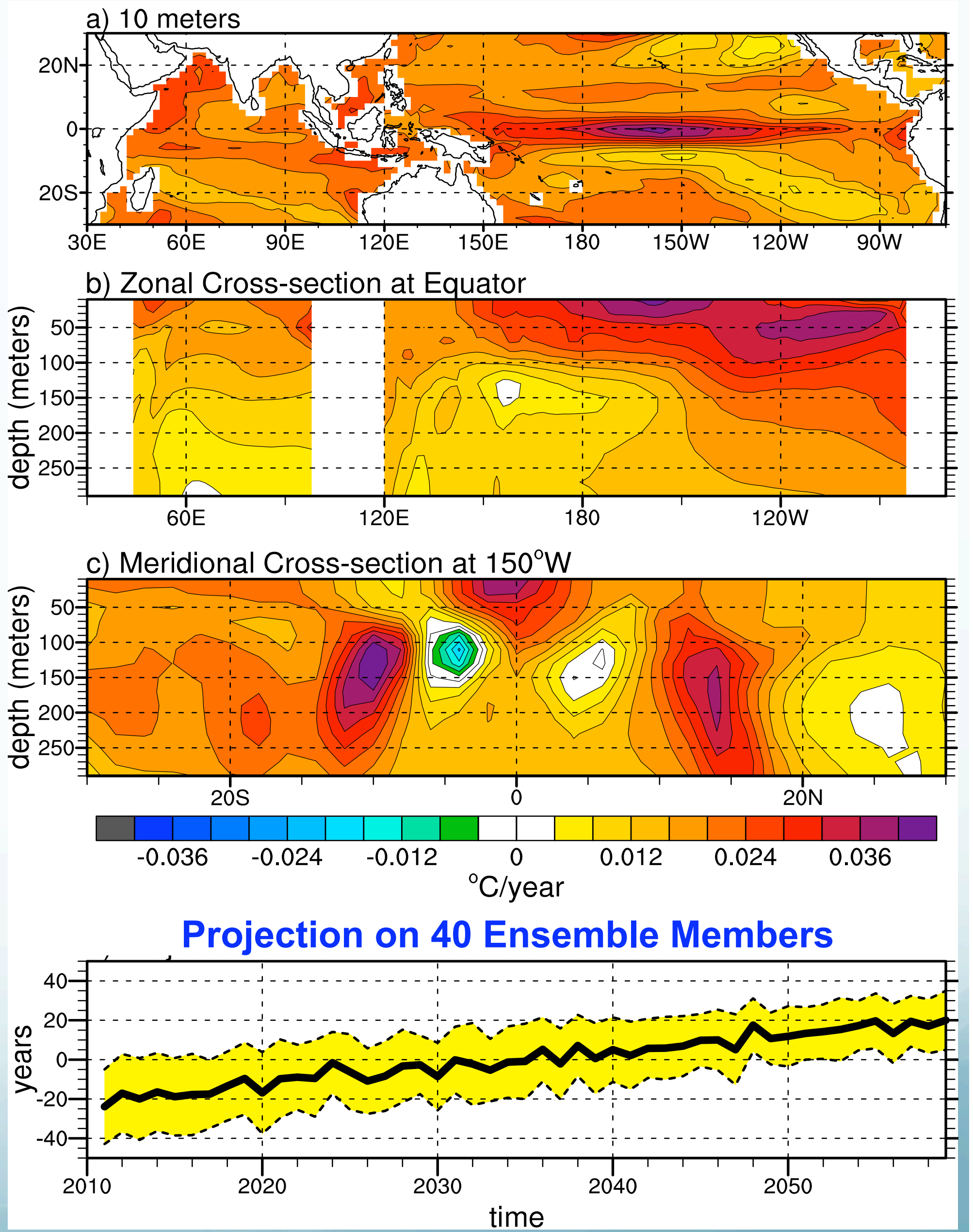


Assumptions of Analysis

1) Skill on decadal time scales comes from the forced response of the climate system to steadily increasing greenhouse gases

2) Skill on decadal time scales is limited by natural variability much of which acts as climate noise

CCSM3 A1B Ocean Temperature Trend



Details of Analysis

With a Focus on----

Wintertime (DJF) variability

Using---

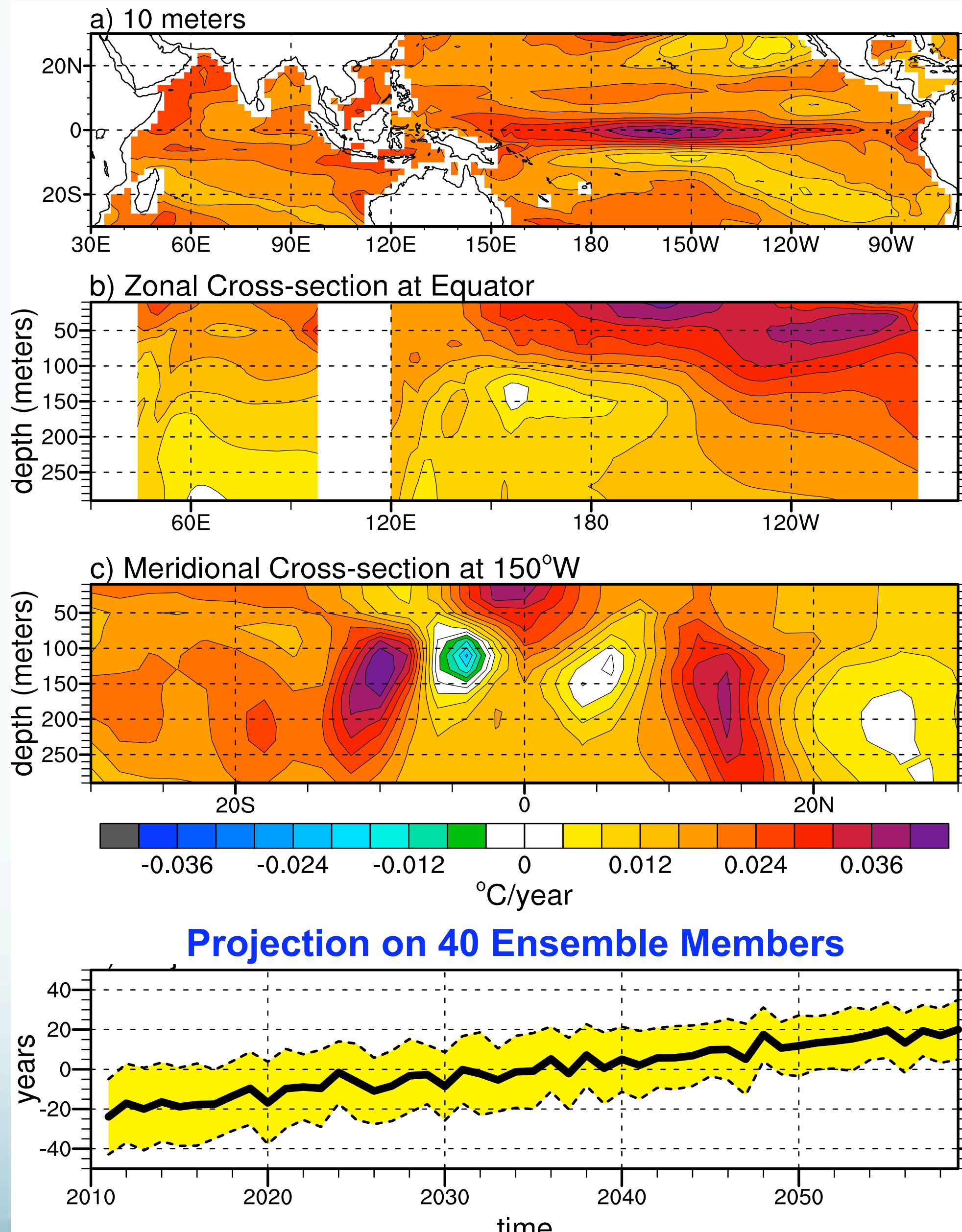
1) CCSM3 A1B Large Ensemble
--40 60-year integrations
--same Jan 1, 2000 ocean state
--A1B+Commitment runs

Ocean temperature down to 300m

In the ---

Tropical Indo-Pacific Basin

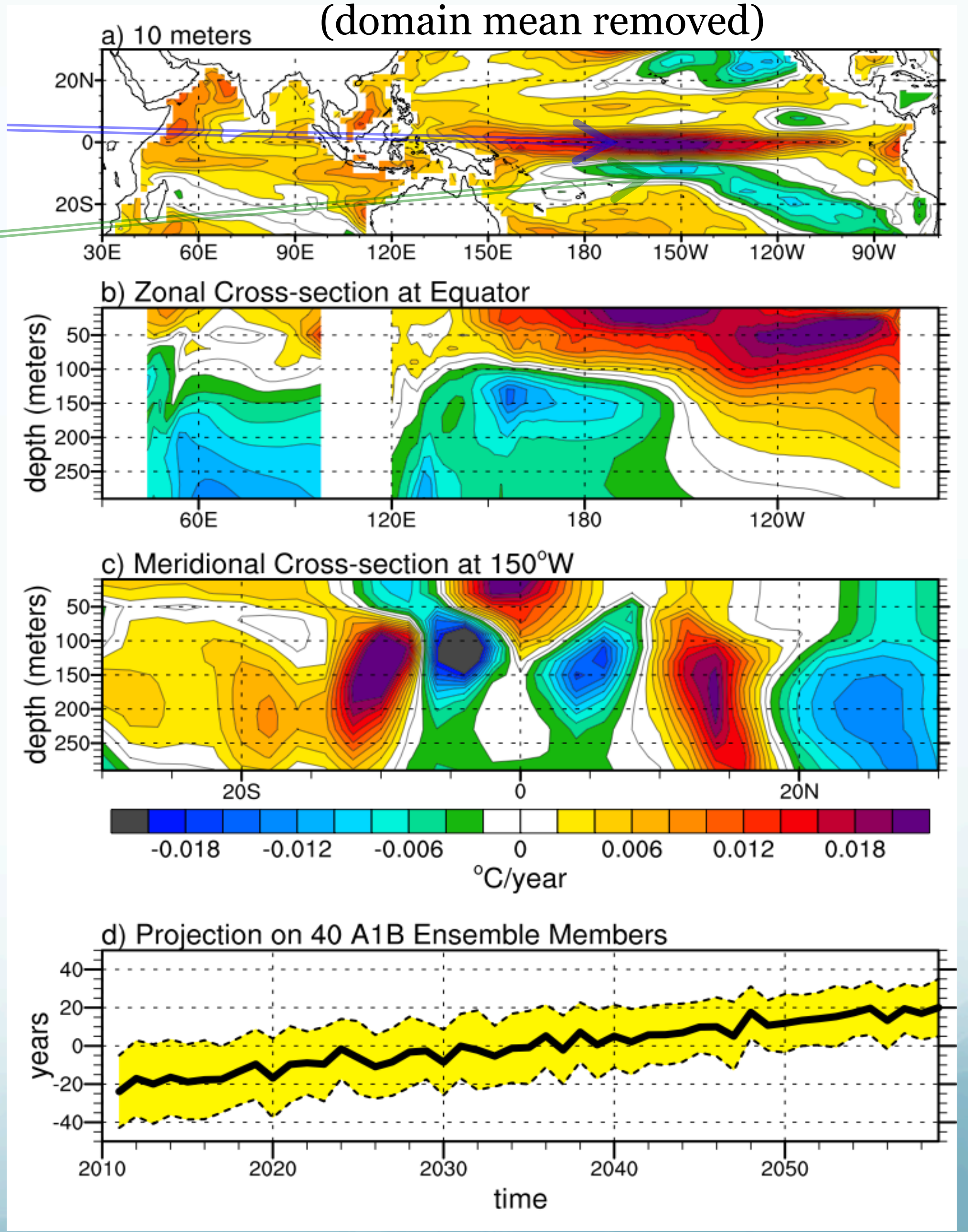
CCSM3 A1B Ocean Temperature Trend



Is the A1B Trend El Niño-like?

Maximum warming in the central equatorial Pacific --- **“El Niño-like”**
Asymmetric North-South warming --- **not “El Niño-like”**

A1B Ocean Temperature Trend
(domain mean removed)



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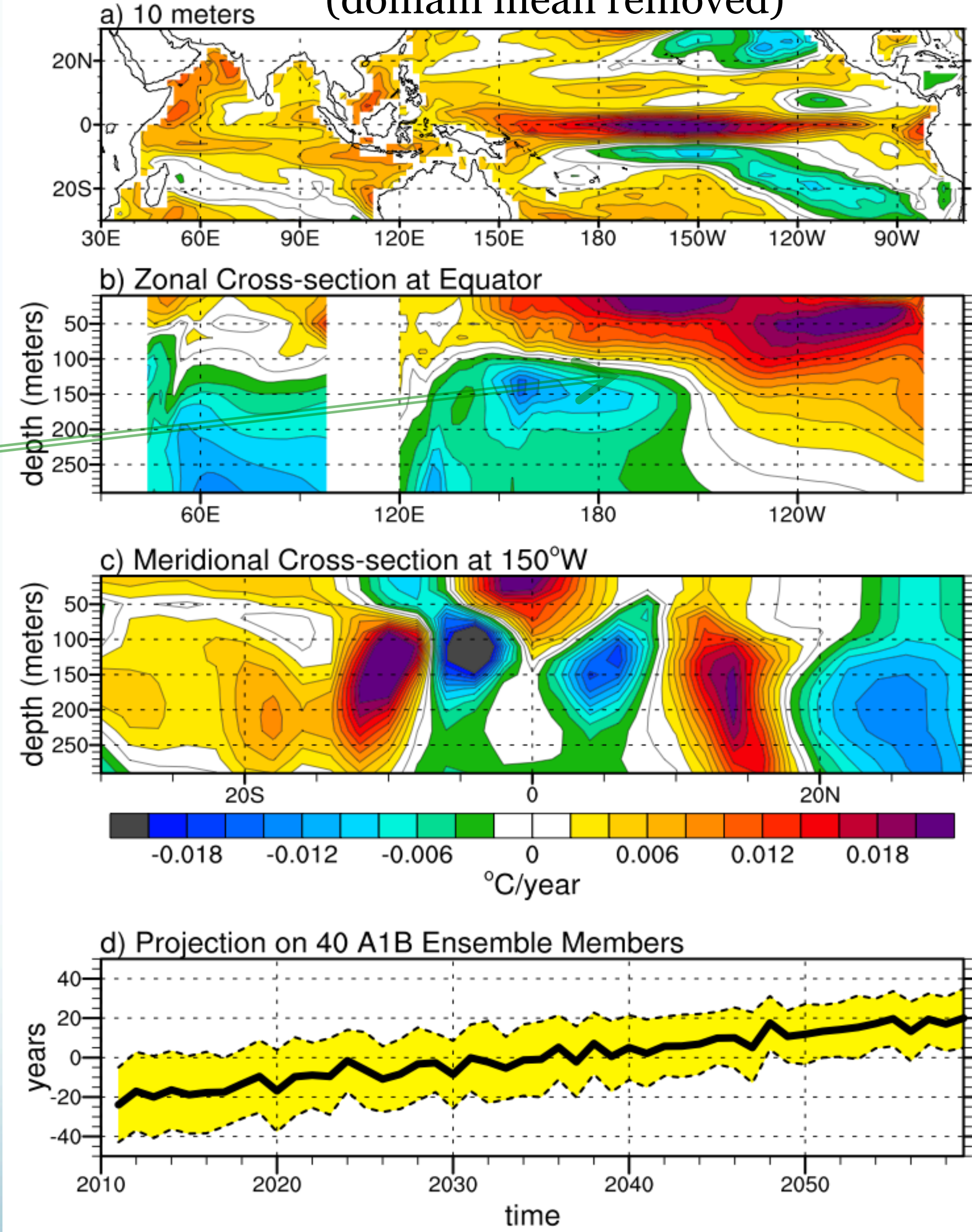
Sharpening of the equatorial thermocline

--- **not "El Niño-like"**

A1B Ocean Temperature Trend

(domain mean removed)



Is the A1B Trend El Niño-like?

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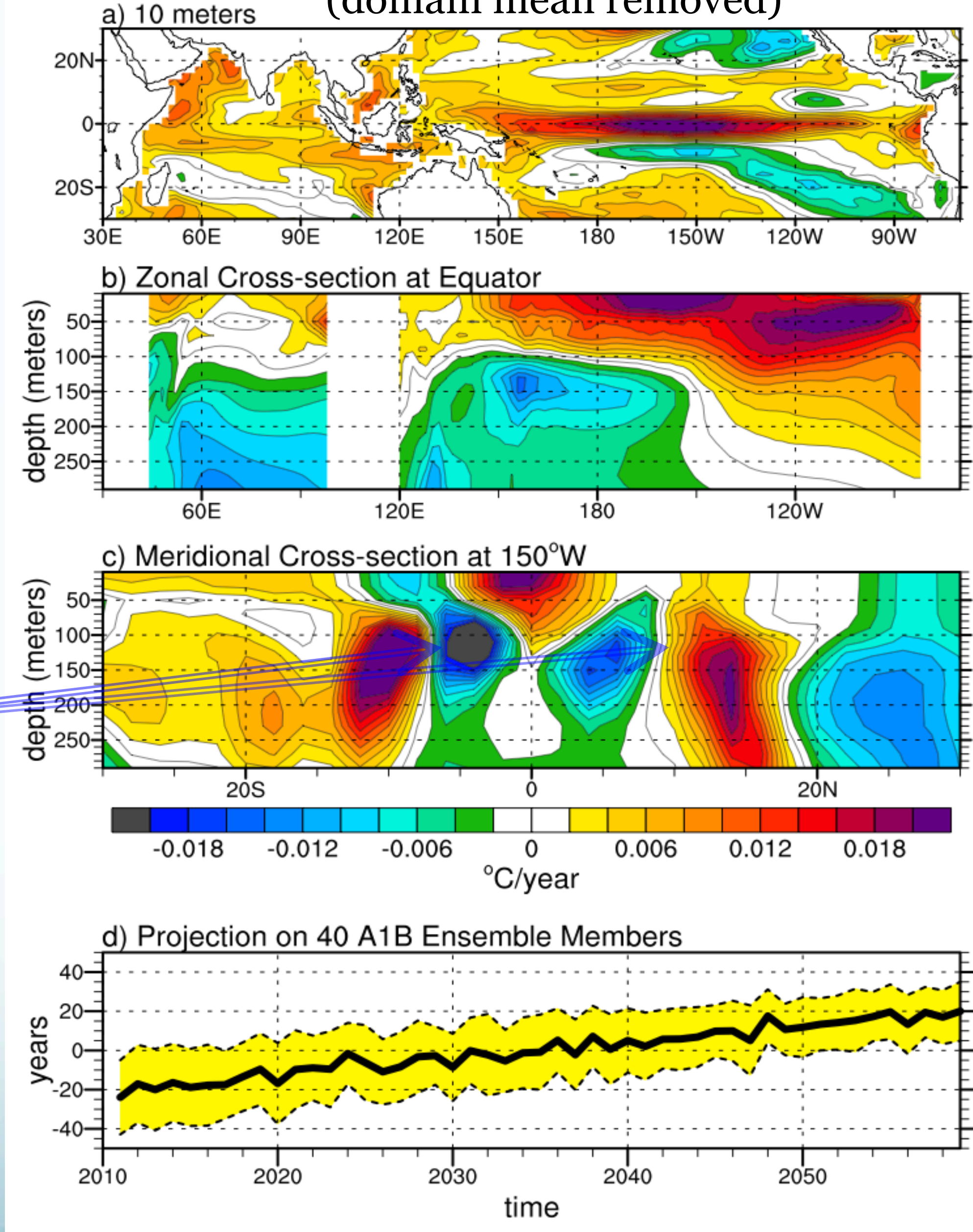
Sharpening of the equatorial thermocline
--- not “El Niño-like”

Off-equatorial steepening of the thermocline --- **“El Niño-like”**

A1B Ocean Temperature Trend
(domain mean removed)



Is the Trend Predictable on Decadal Time scales?

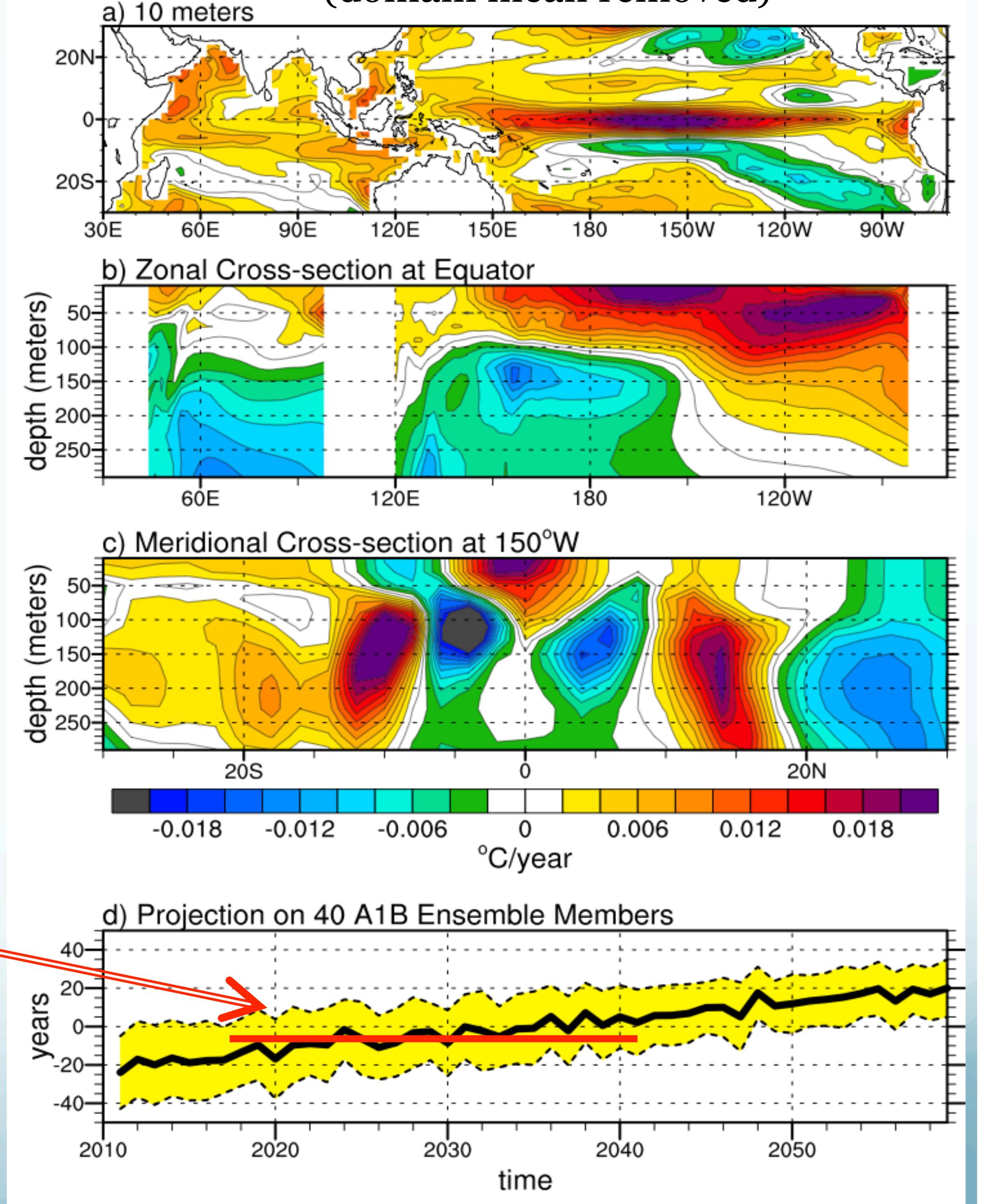
Maximum warming in the central equatorial Pacific --- **"El Niño-like"**
Asymmetric North-South warming
--- not "El Niño-like"

Sharpening of the equatorial thermocline
--- not "El Niño-like"

Off-equatorial steepening of the thermocline --- **"El Niño-like"**

Signal > Noise for timescales greater than ~25 years

A1B Ocean Temperature Trend
(domain mean removed)



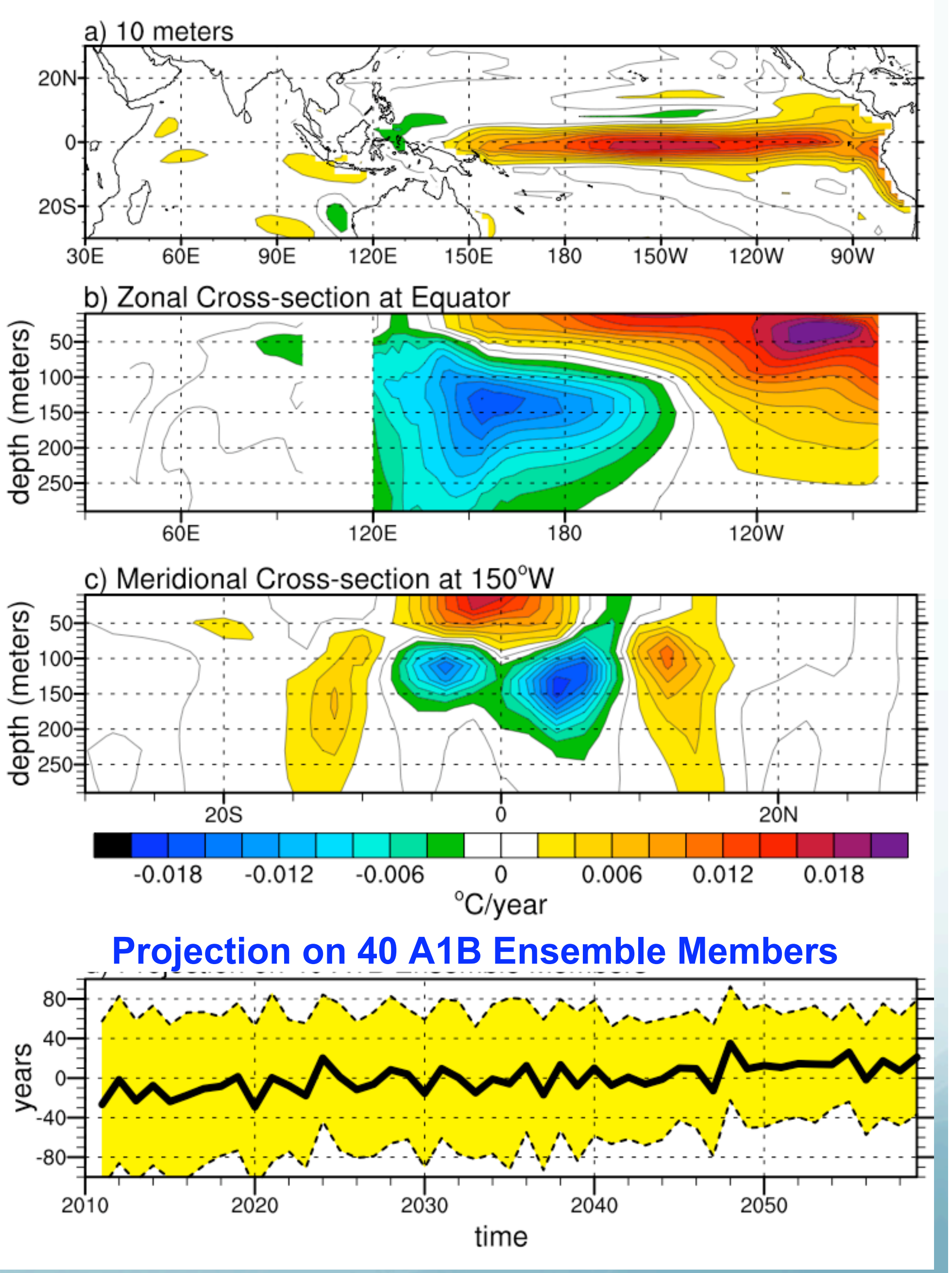
CCSM3 ENSO Structure

Natural patterns of variability isolated in control (fixed forcing) simulations

- ◆ prevents aliasing of trend onto natural patterns
- ◆Useful when working with small forced ensembles

Using 3D EOFS of Ocean Temperature

With a focus on ENSO variability as the dominant source of "noise" in the IndoPacific



CCSM3 ENSO Structure

Natural patterns of variability isolated in control (fixed forcing) simulations
- ◆ prevents aliasing of trend onto natural patterns
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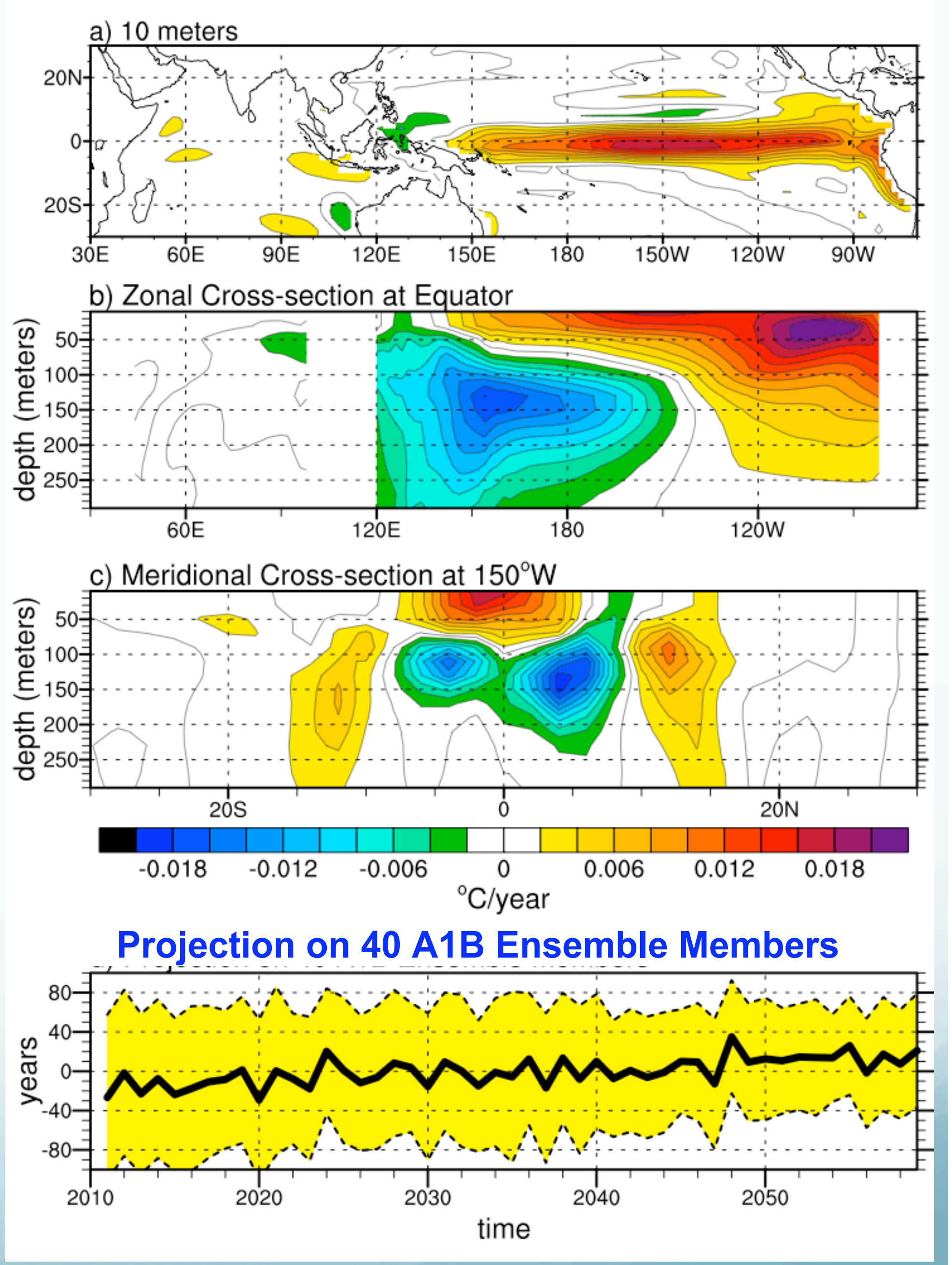
Using 3D EOFS of Ocean Temperature

----Initial focus on ENSO variability----

Projection of ENSO variability on A1B Ensemble has a trend...

...that is not predictable on decadal time scales

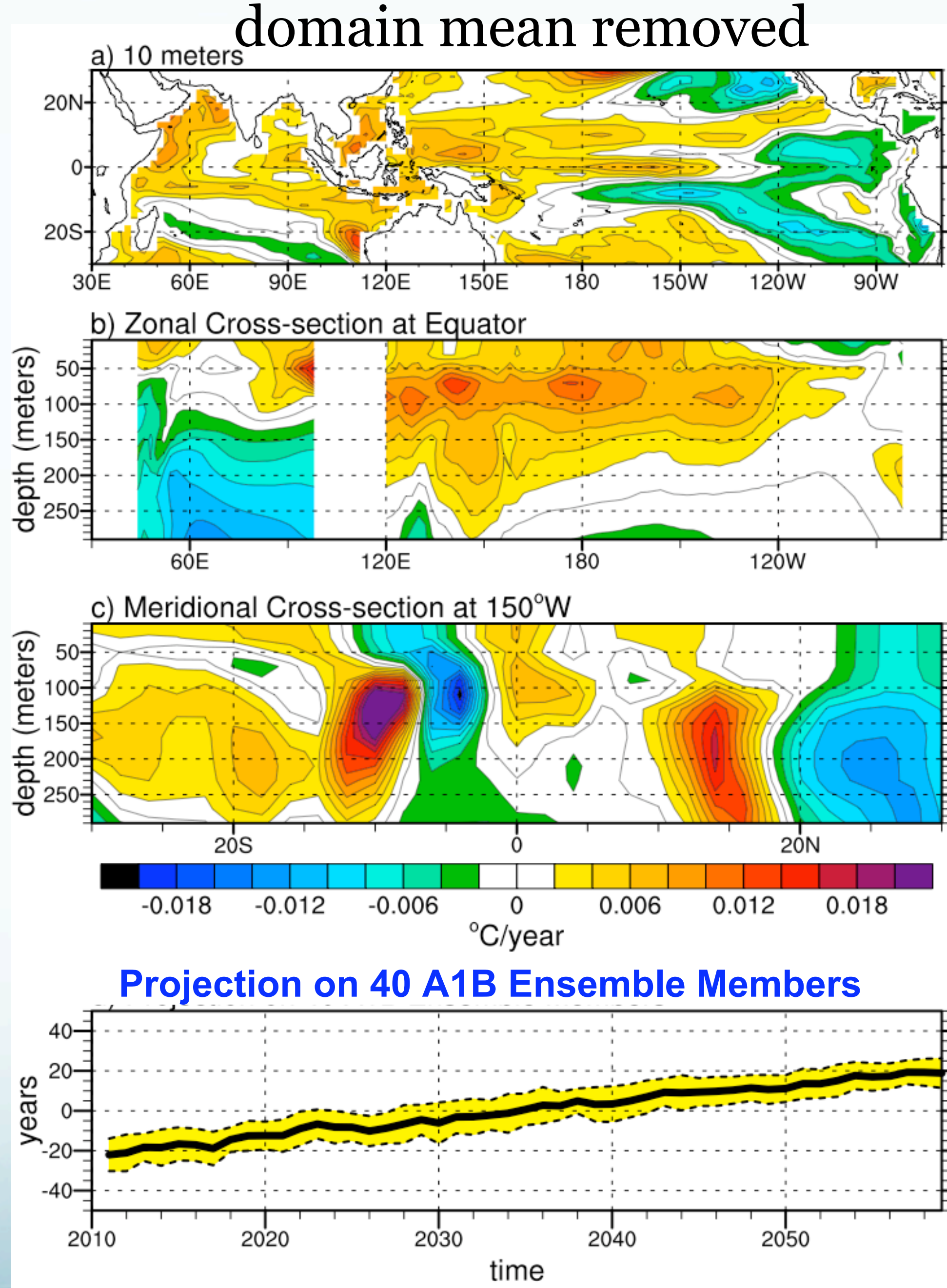


CCSM3 A1B "Non-ENSO" Trend

Straightforward strategy to remove the contribution of natural variability (ENSO) to the A1B Trend:

Remove the projection of the dominant 3DEOFs from the control run from each A1B ensemble member

domain mean removed



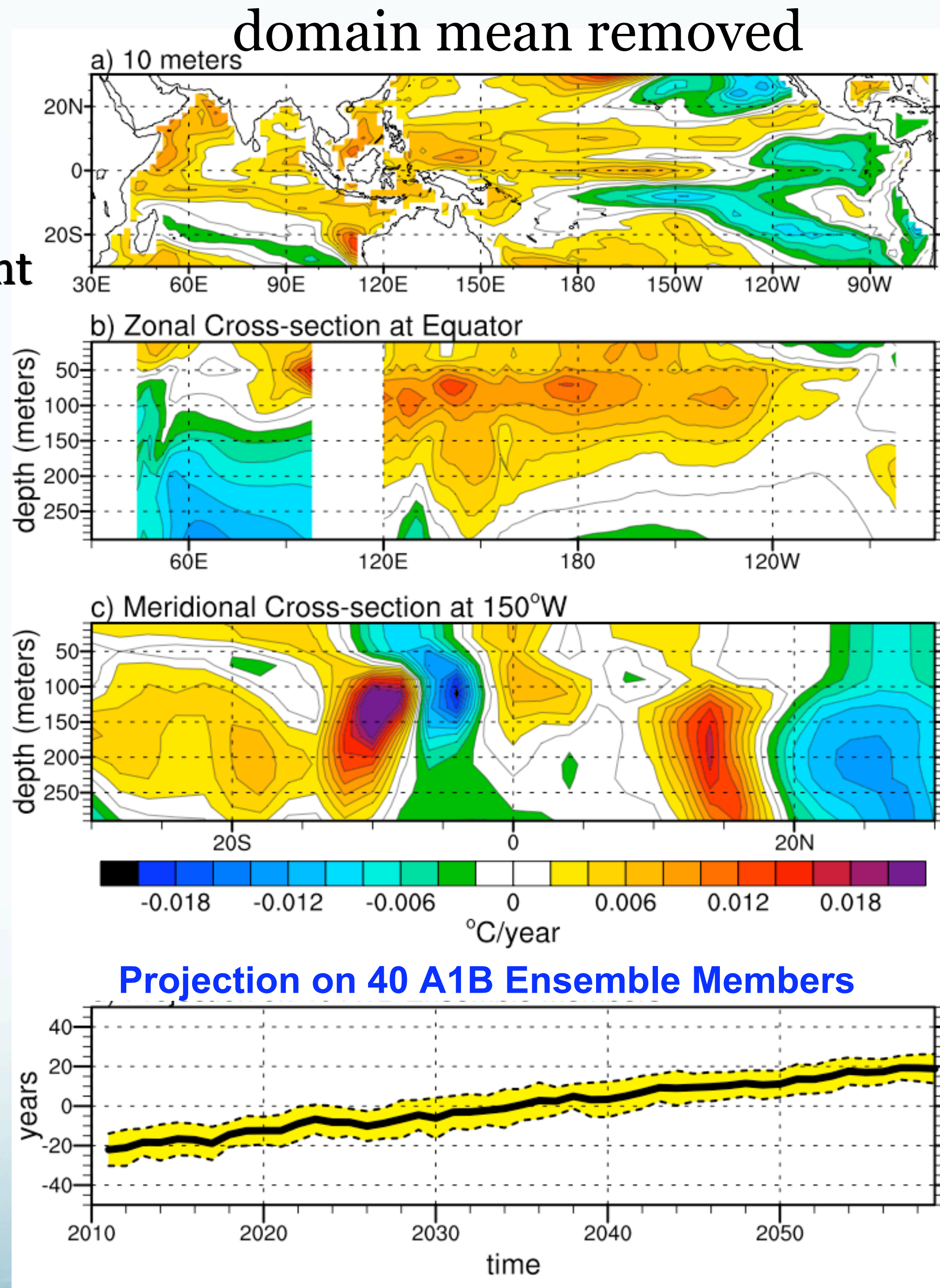
CCSM3 A1B "Non-ENSO" Trend

Increase in near-surface equatorial temperature gradient --- consistent with the ocean thermostat hypothesis (Clement et al. 1996) and upwelling of cooler subtropical waters (Seager and Murtugudde 1997)

Largest trends in the Warm Pool

Prominent steepening of the off-equatorial thermocline --- in the S. Pacific only --- consistent with increase in southeast trades (Xie et al. 2010)

Significant collapse of ensemble spread!

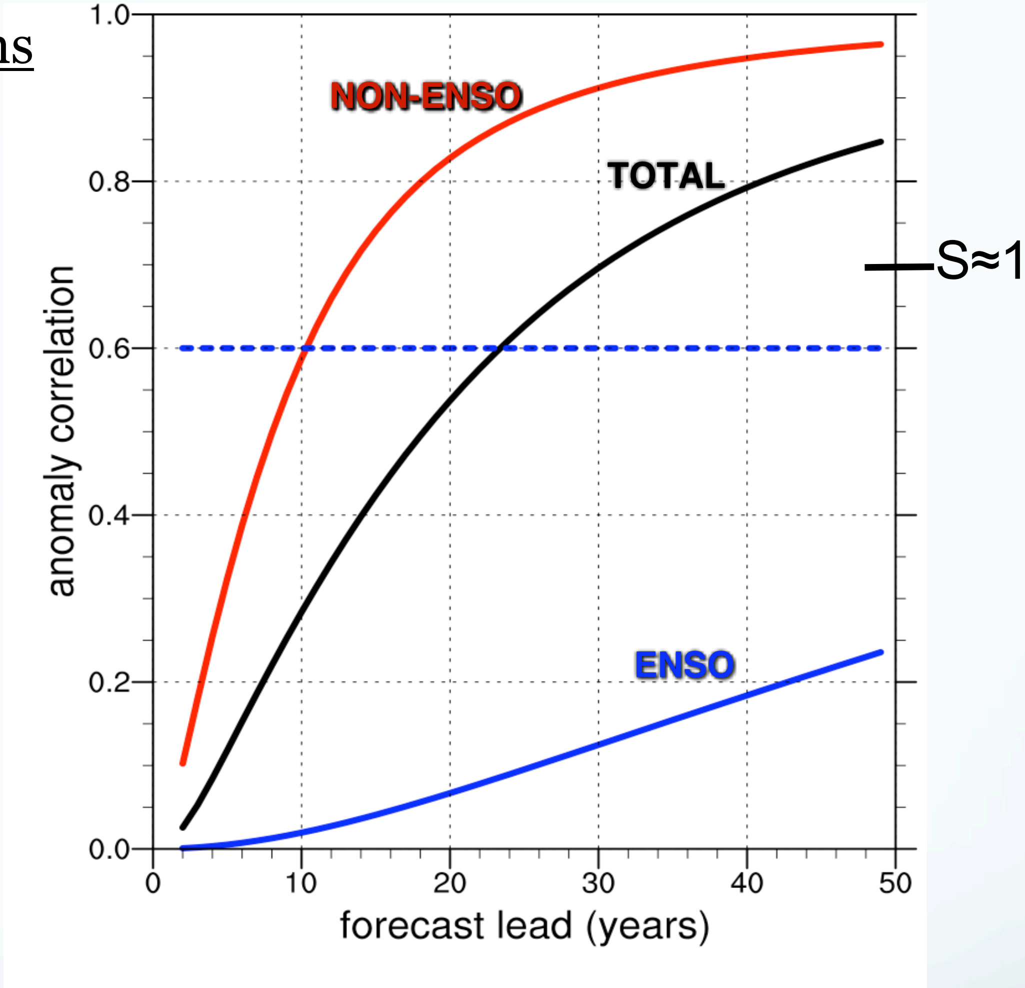


Perfect Model Skill of Trend Patterns

Amplitude of **Total trend pattern** is predictable after **23** years

Amplitude of **ENSO trend pattern** is **not predictable** in these 50-year simulations

Amplitude of **Non-ENSO trend pattern** is predictable after **10** years

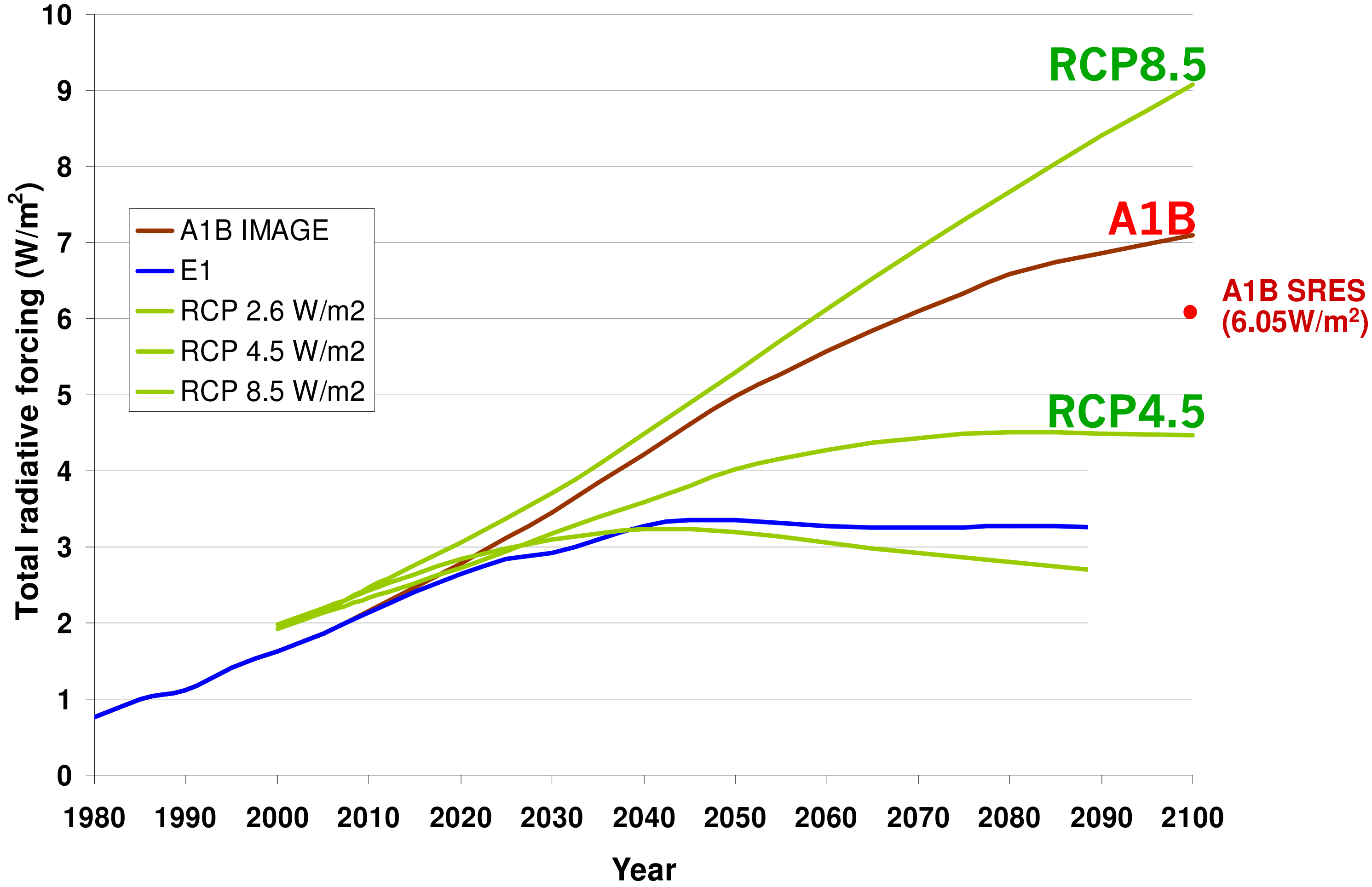


Average anomaly correlation ($\rho(\tau)$) between individual ensemble members and ensemble mean as a function of forecast lead (τ)

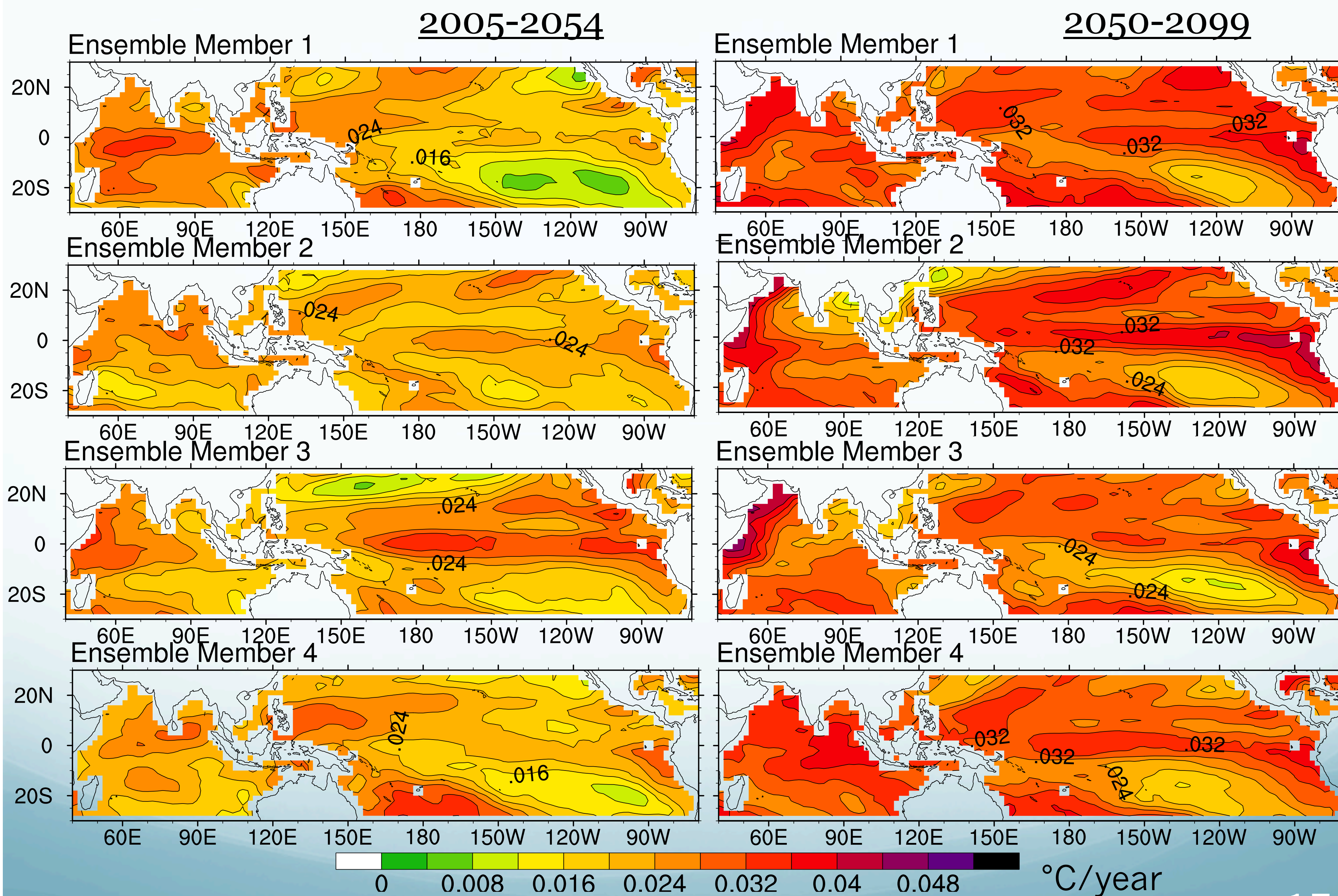
$\rho(\tau) = S(\tau) / (1 + S(\tau))^{1/2}$

S= ensemble mean / ensemble spread

Comparison of A1B vs. RCP Simulations

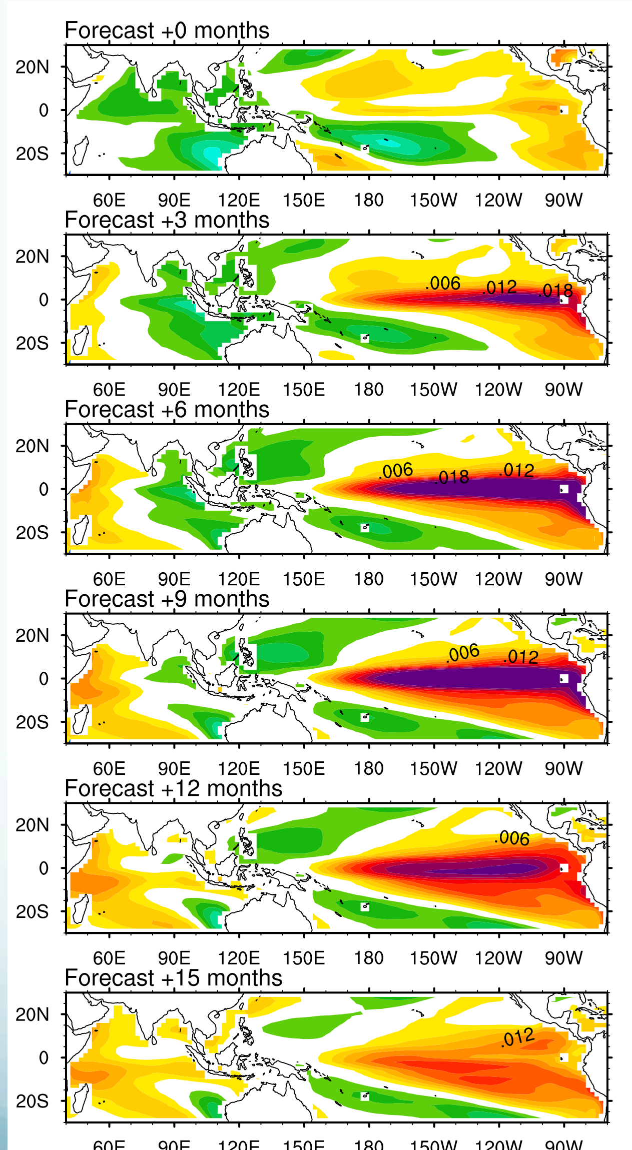


CCSM4 RCP8.5 5m 50-Year Trends

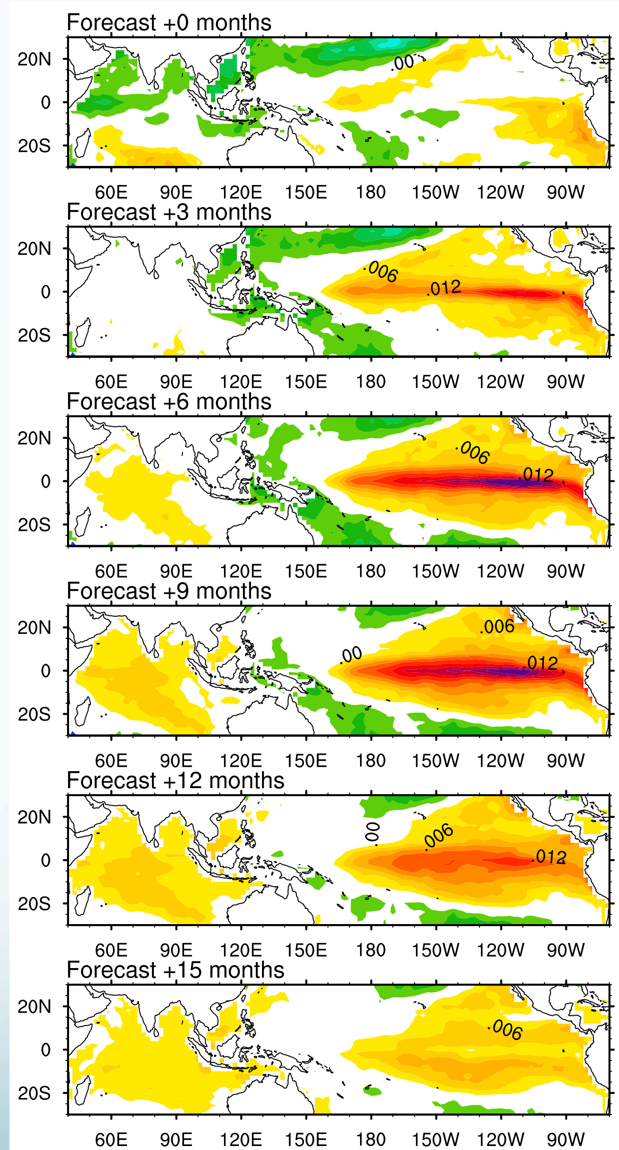


Evolution of Optimal Singular Vector

CCSM4 PICNTRL

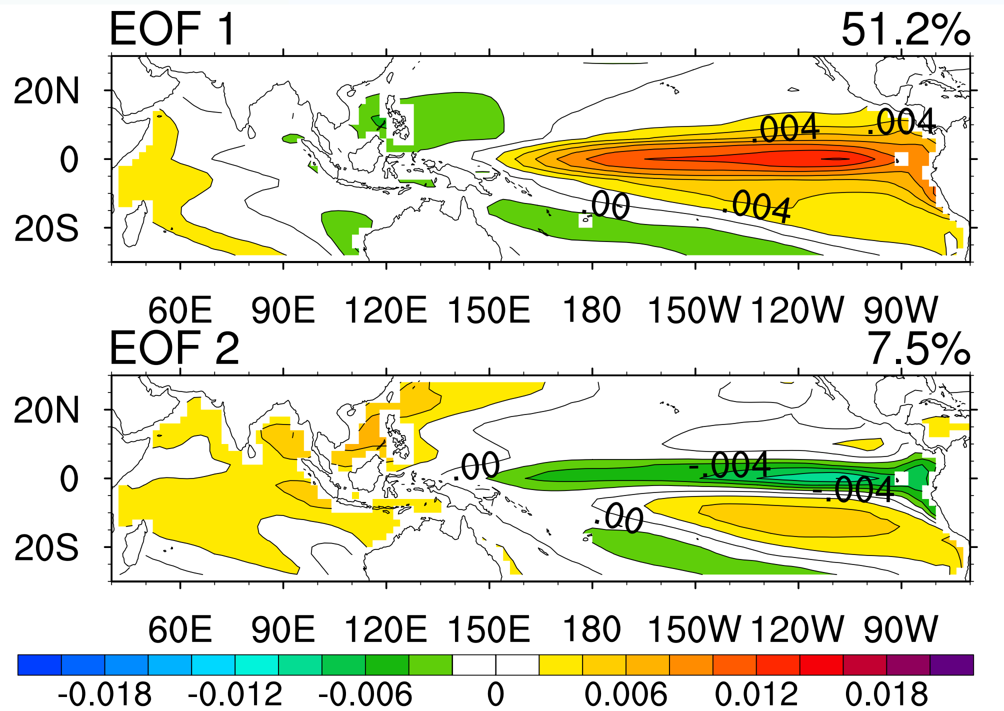


SODA 1958-2007

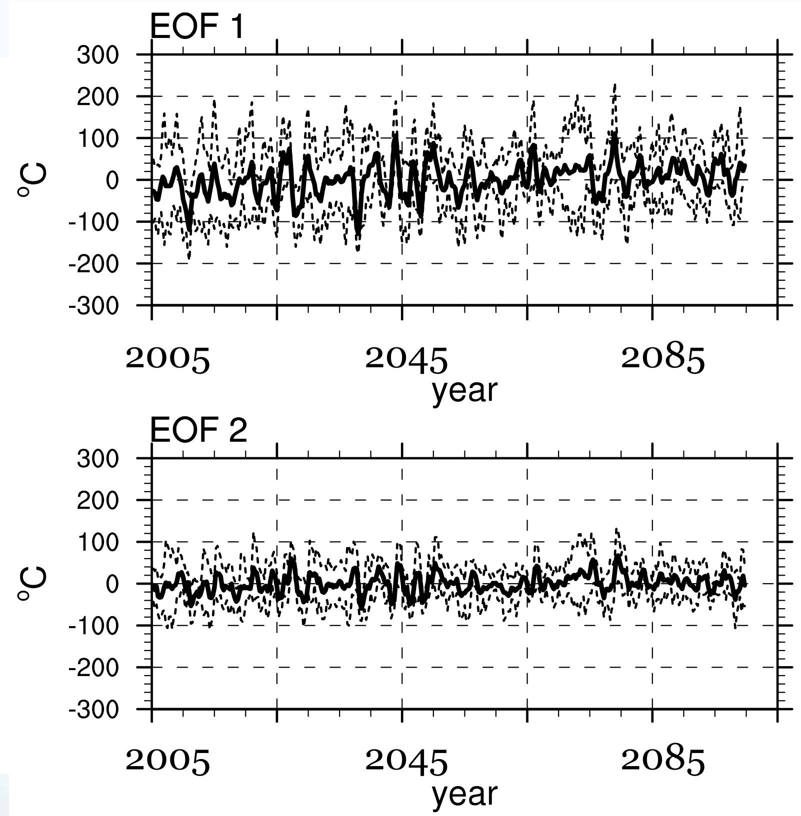


CCSM4 RCP8.5 Projection on PICNTRL EOFS

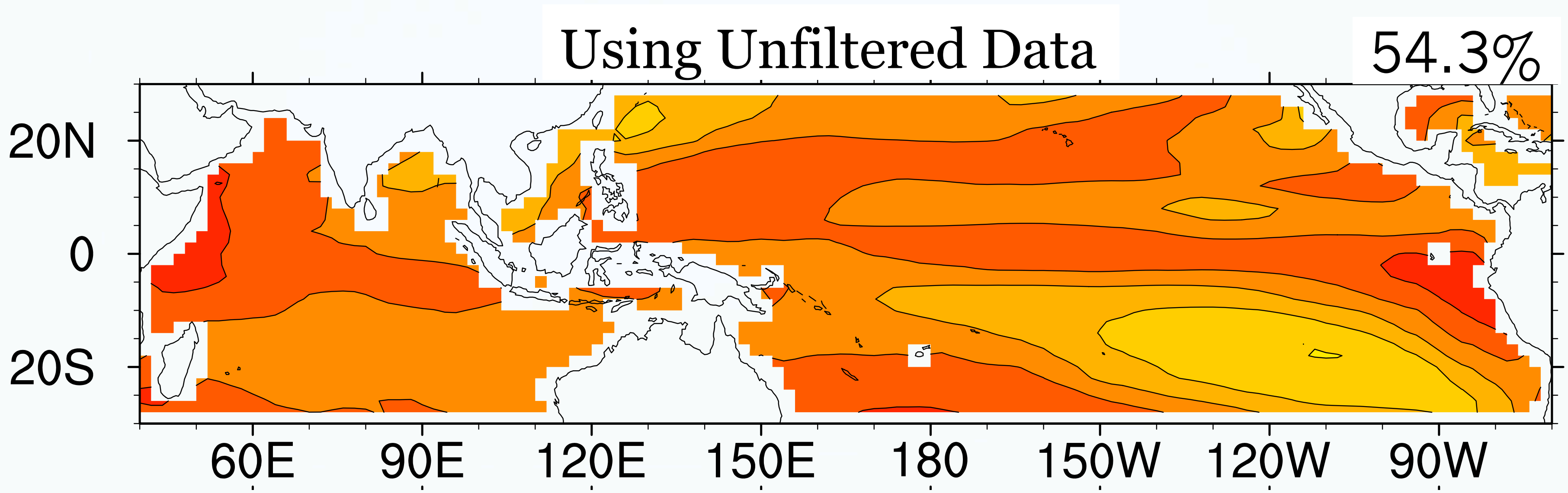
CCSM4 PICNTRL EOFs



Projection on RCP8.5

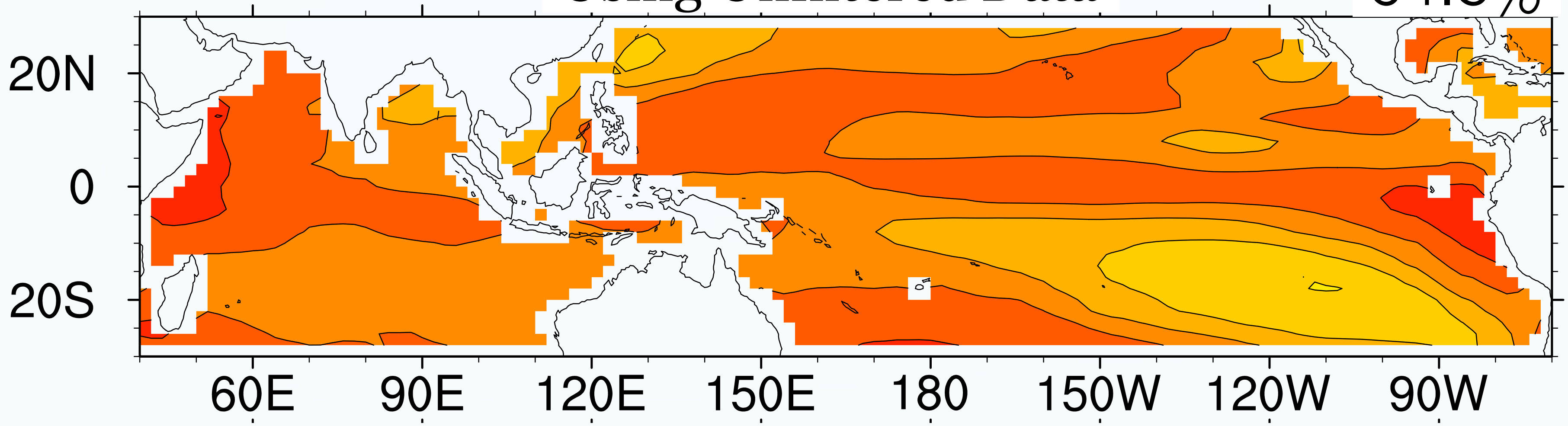


CCSM4 RCP8.5 S/N-MAX-3DEOF at 5meters

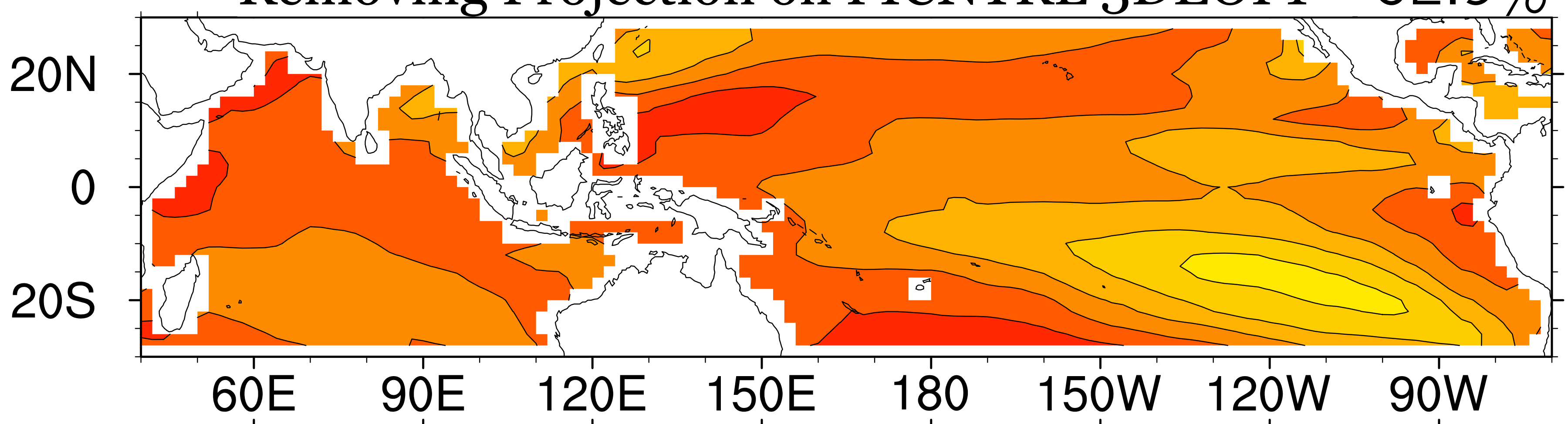


CCSM4 RCP8.5 S/N-MAX-3DEOF at 5meters

Using Unfiltered Data 54.3%

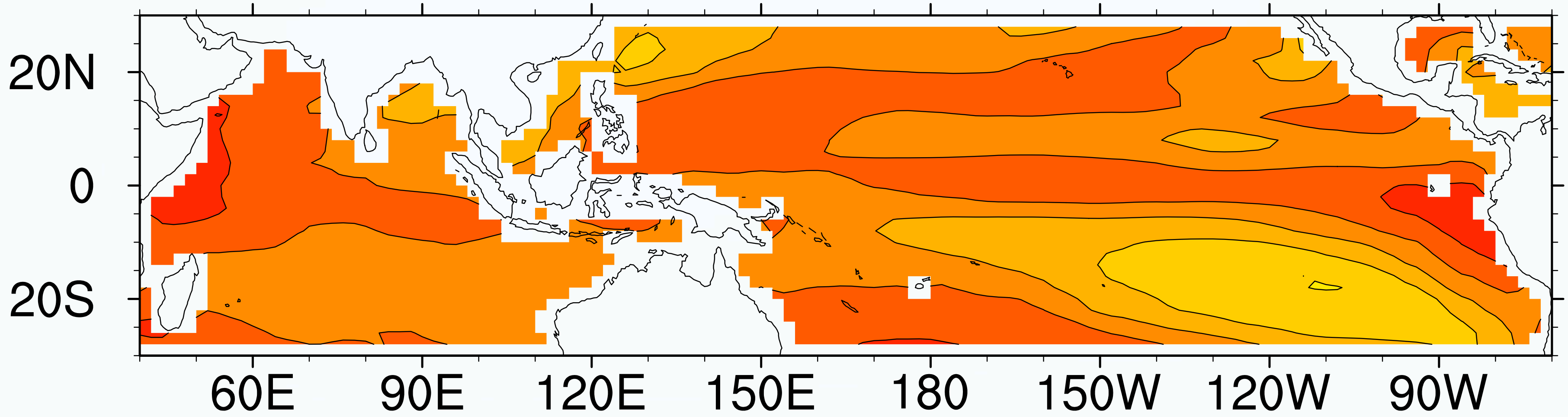


Removing Projection on PICNTRL 3DEOF1 52.9%

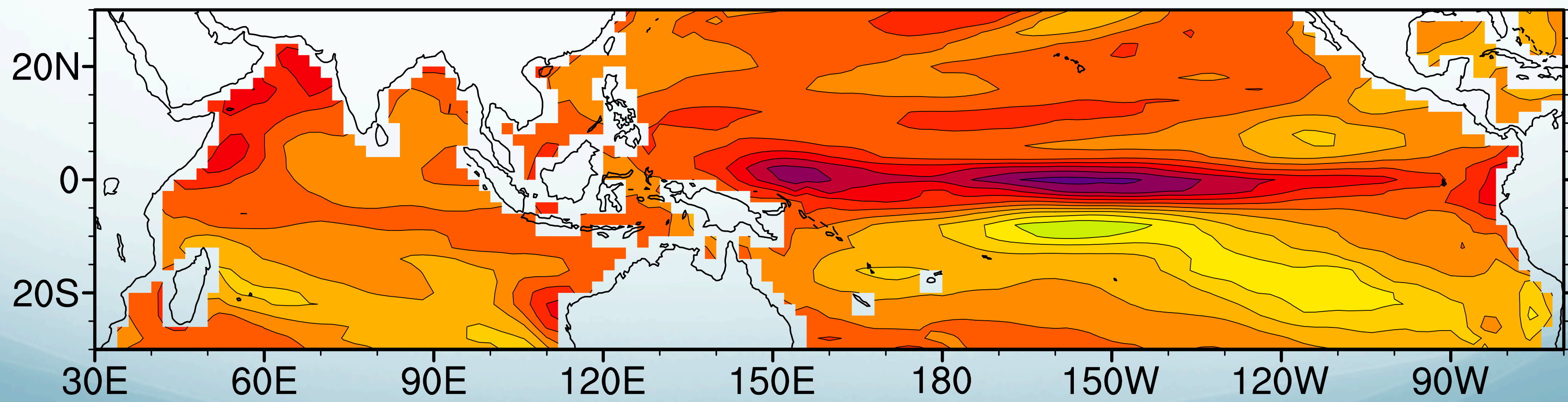


Trend Patterns at 5meters

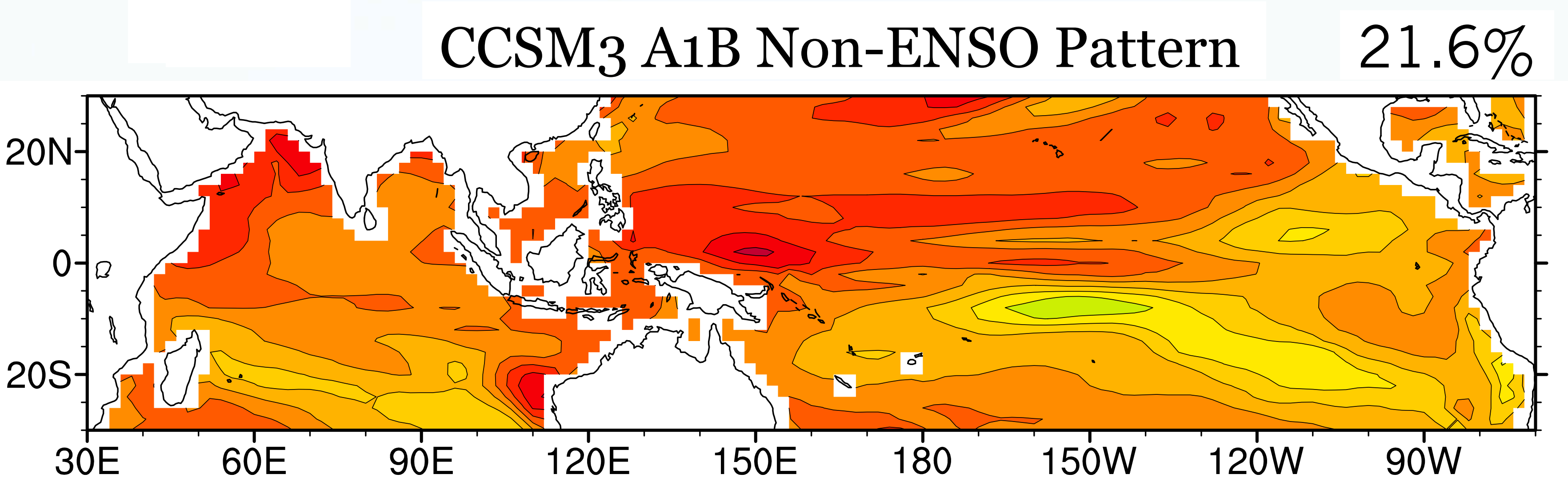
CCSM4 RCP8.5 Total Trend Pattern

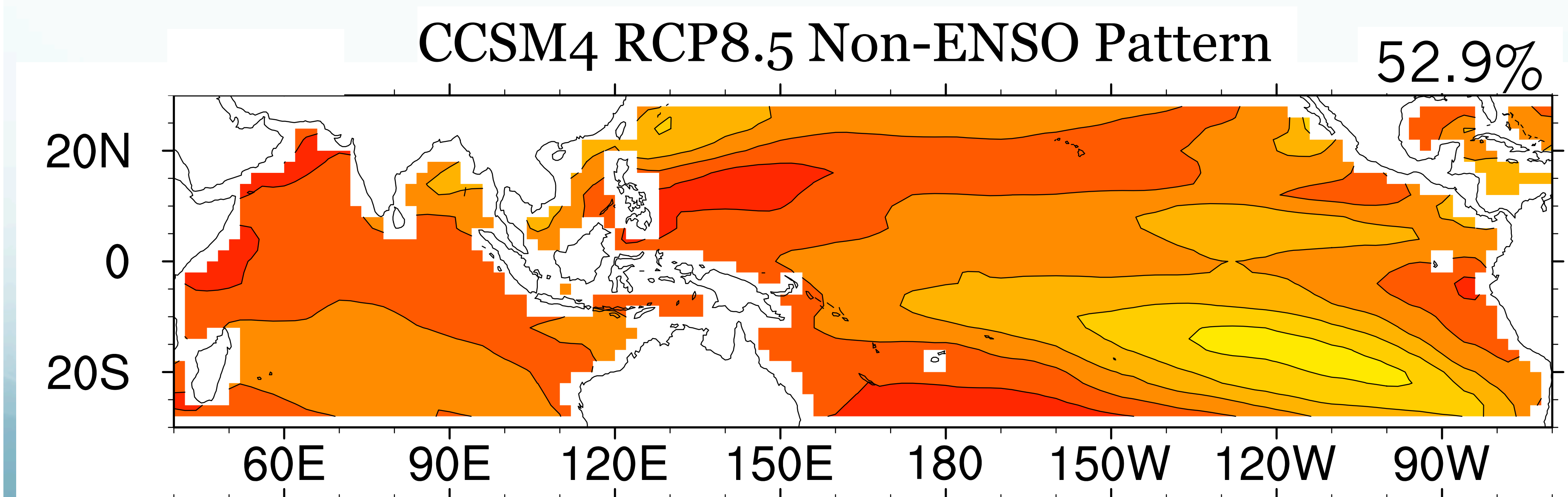


CCSM3 A1B Total Trend Pattern



Non-ENSO Ensemble Mean 3D-EOF1 at 5-10 meters





Thank you for your attention!

Questions?

CCSM4 RCP8.5 Skill of Trend Patterns