Will there be a significant change to El Niño in the 21st century?

Results from CCSM4

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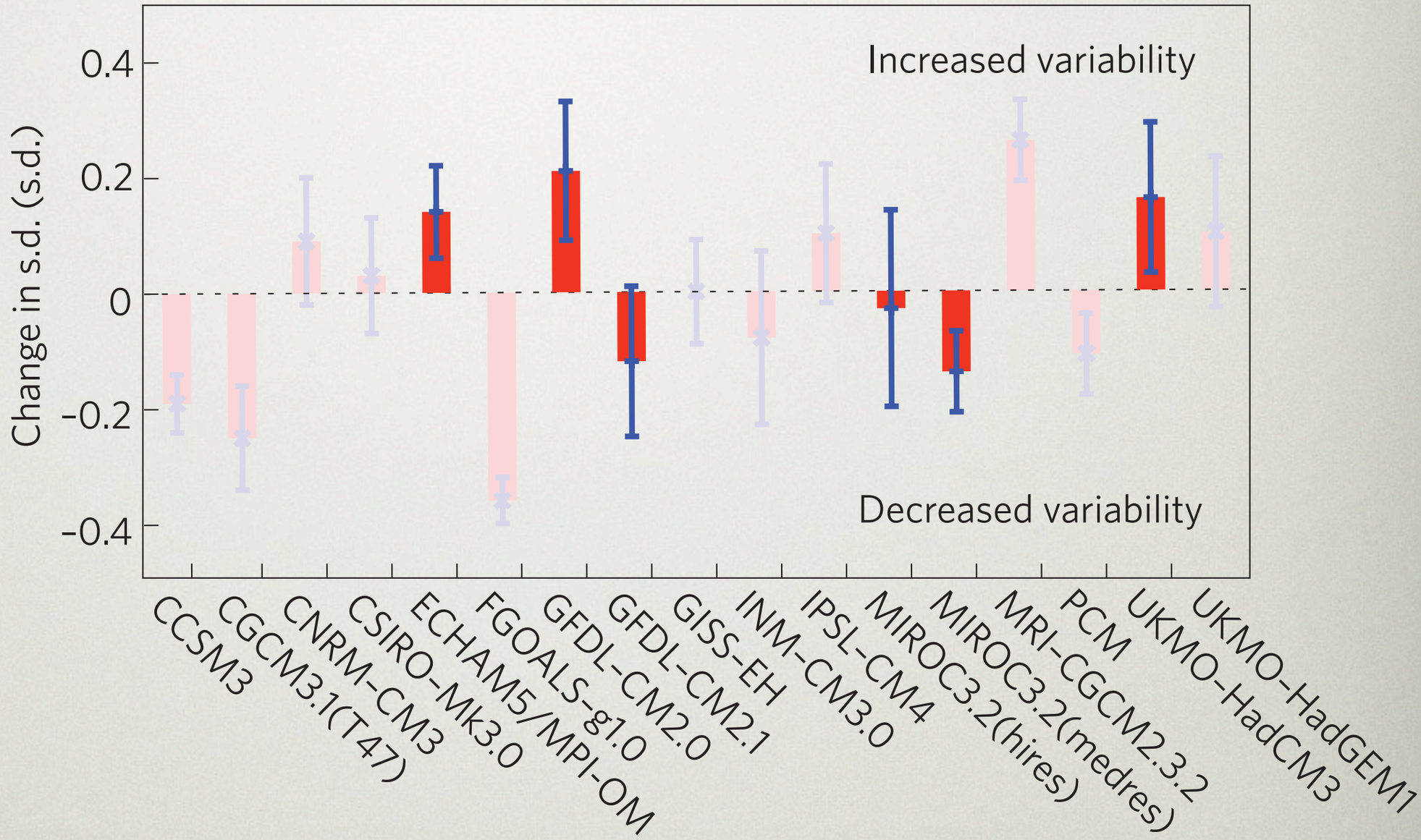
Goal:
Understand how El Niño/Southern Oscillation (ENSO) will change in the 21st century

CMIP3: huge variations in ENSO amplitude projections



Collins et al. (2010)
bold -> "best" ENSO representation

CMIP5 CCSM4 experiments

20th century ensemble: 6 members, 1850-2005

Representative Concentration Pathway (RCP) ensembles:
3 ensembles, 5 members each, 2006-2100

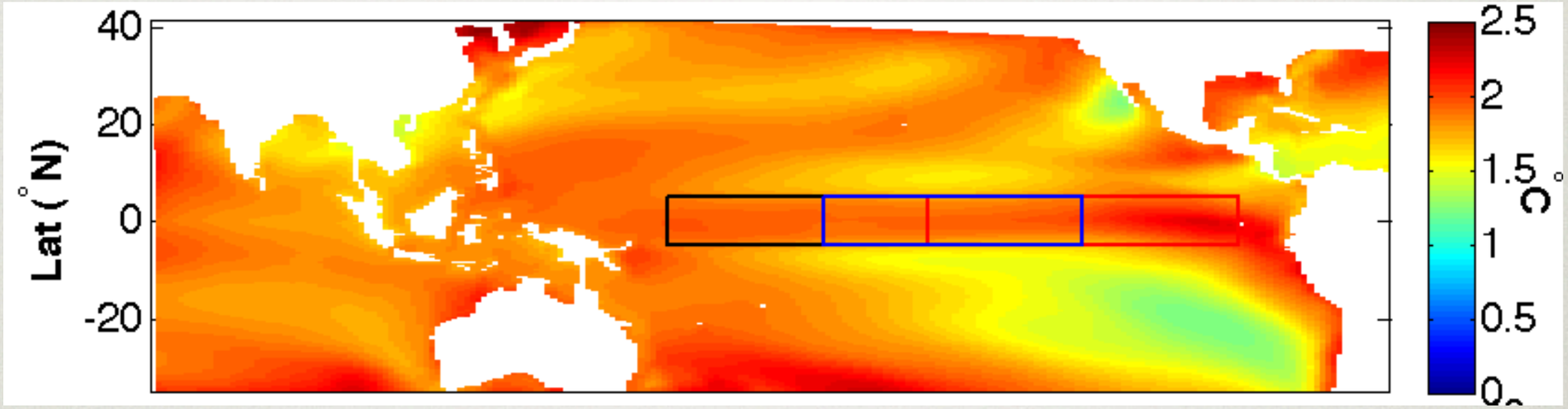
1850 control: 250 ppm CO_2, 1300 year integration

Does ENSO become stronger/weaker with CO_2 in CCSM4?
What are the mechanisms for changes to ENSO?

CCSM4: mean state changes

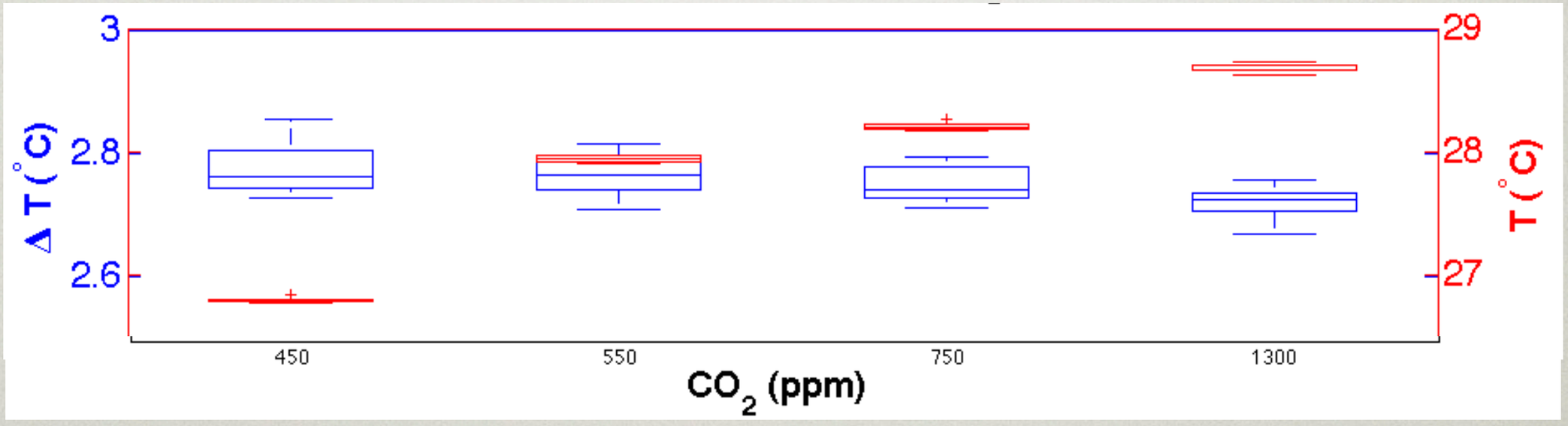
Enhanced eastern Pacific warming

RCP 8.5 - 20th c.



Decreased zonal SST gradient

All ensembles

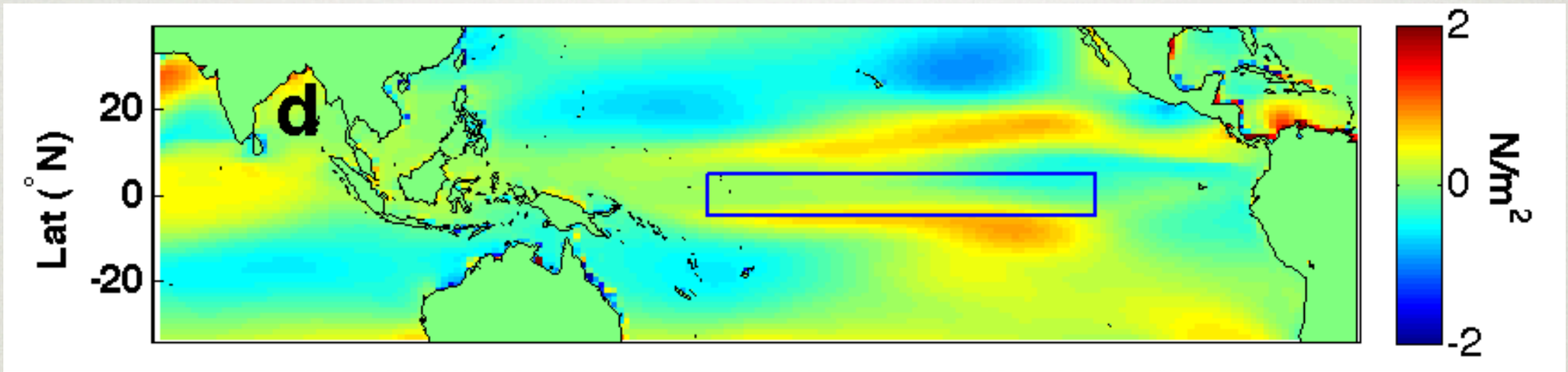


CCSM4: mean state changes

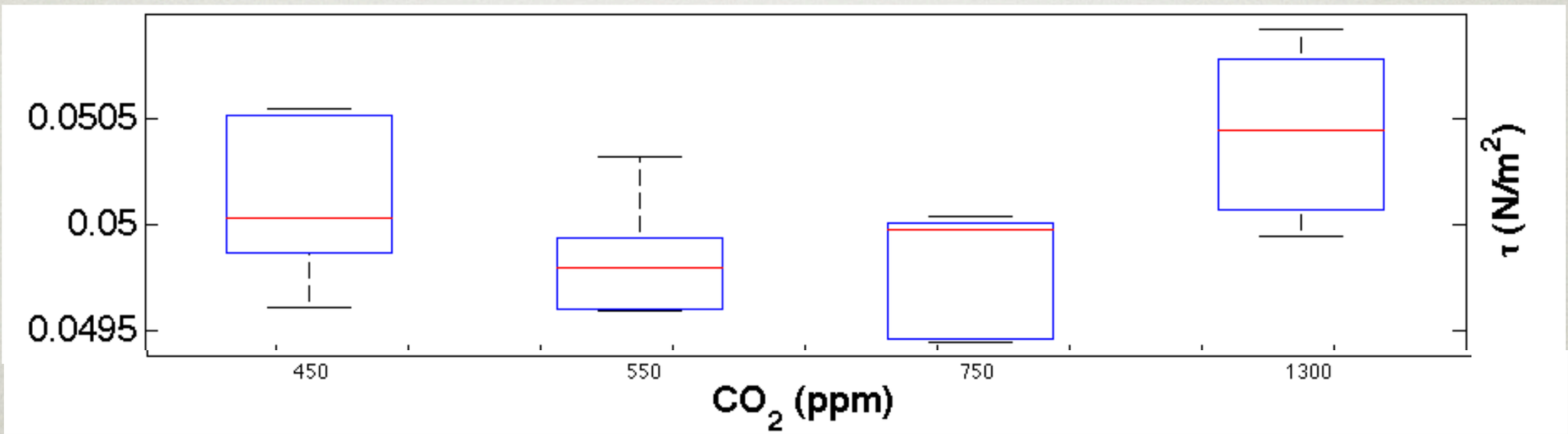
Weakened equatorial trade winds

Note: plots show magnitude of wind stress

RCP 8.5 - 20th c.



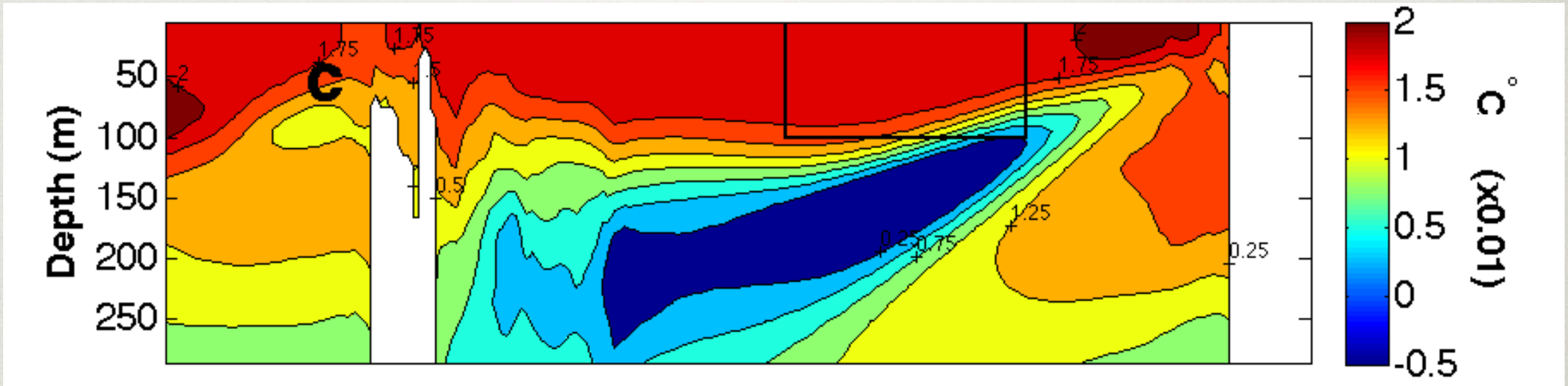
All ensembles



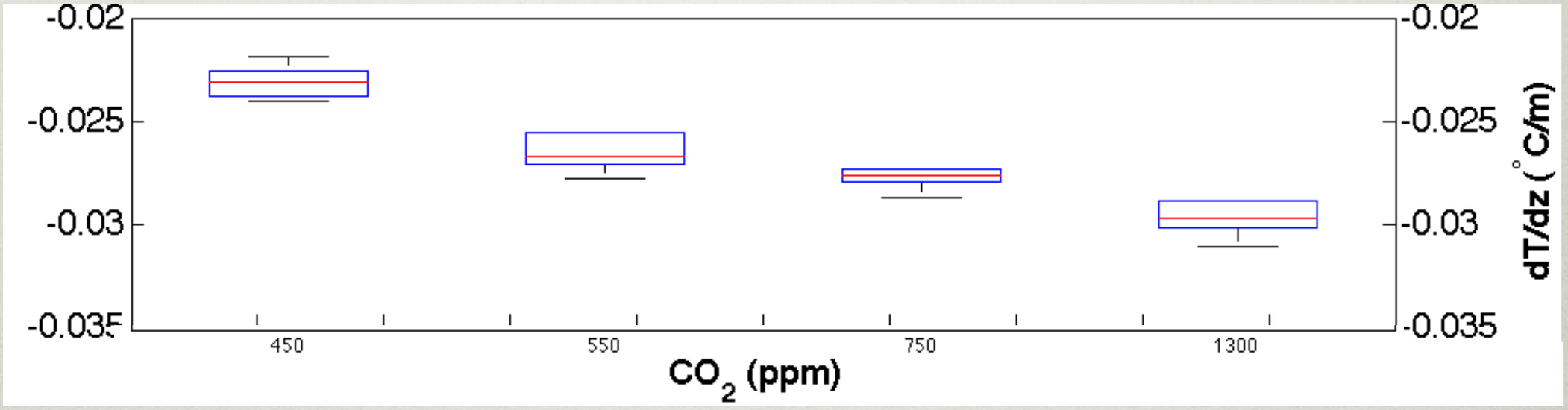
CCSM4: mean state changes

Increased vertical thermal stratification

RCP 8.5 - 20th c.

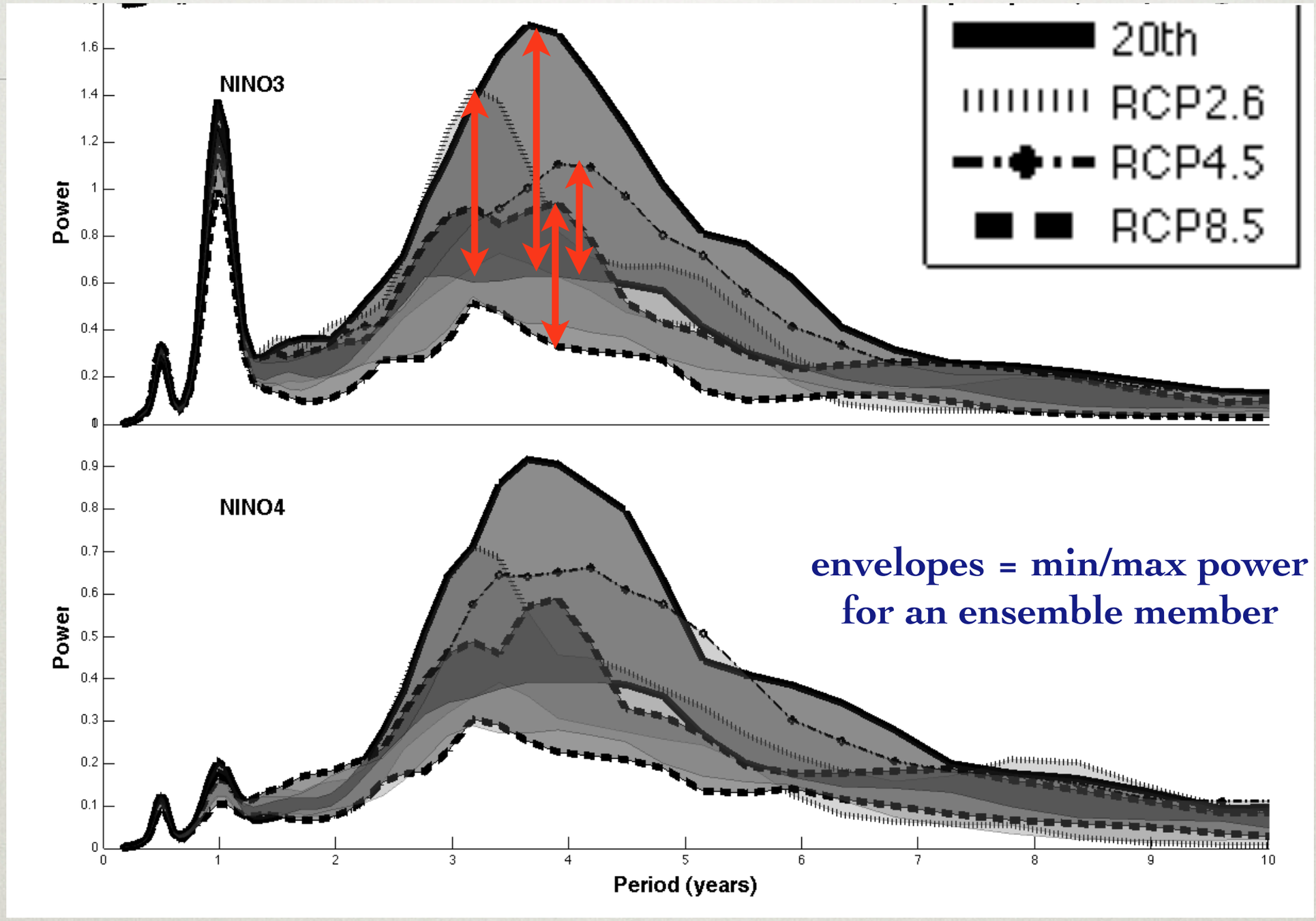


All ensembles

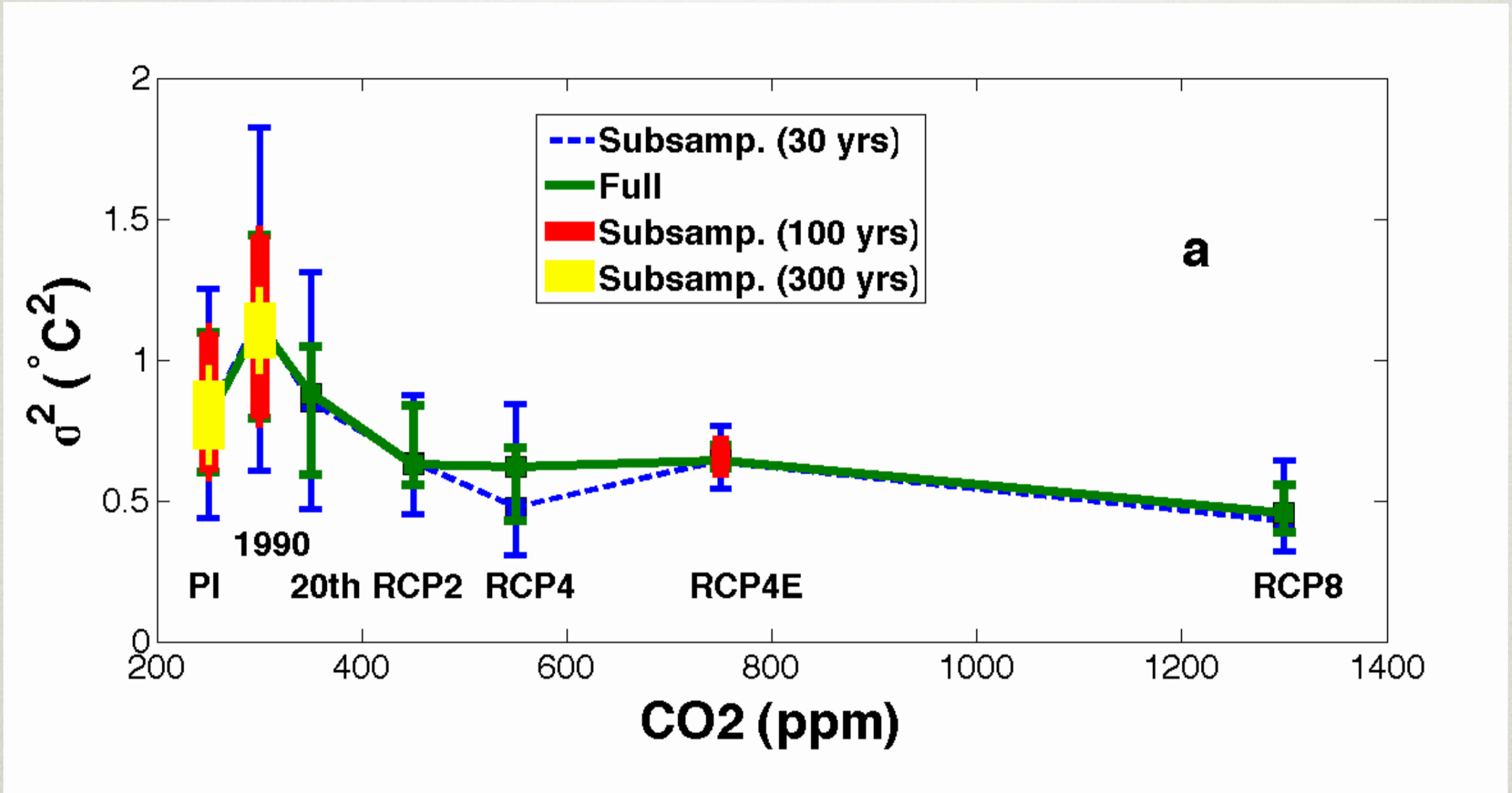


Mean state changes seem physically consistent…
but what about ENSO changes?

Ensembles overlap in NINO3, NINO4 spectral power



2-7 year variance is statistically identical between 20th, 21st centuries



Long control simulations -> ENSO weakening likely will become statistically significant, but not for several hundred years

Consistent with Stevenson et al. (2010):
~250 years of data/model output required for stable ENSO statistics

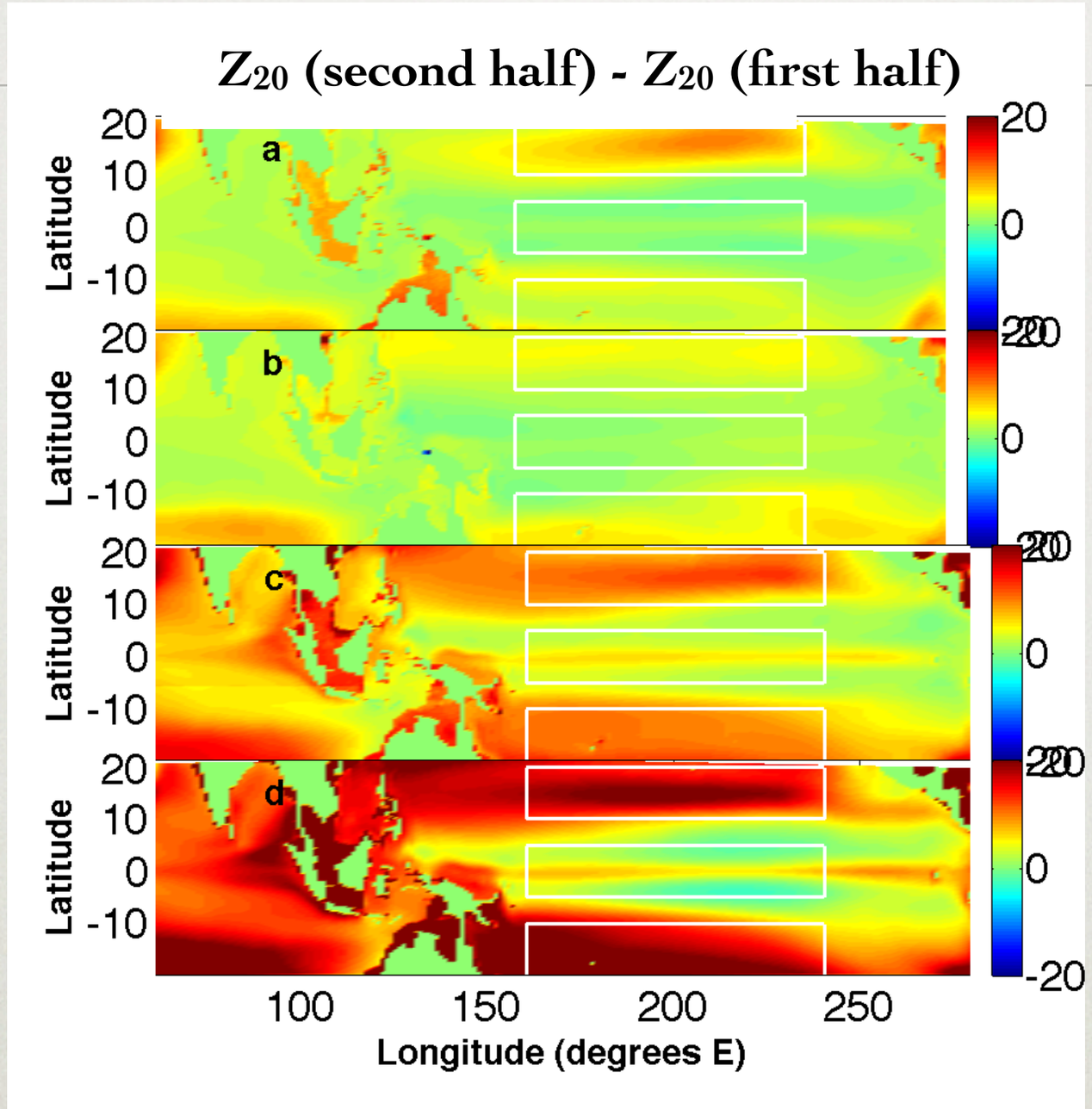
Why so little change? Ocean dynamical adjustment

20th c.

RCP 2.6

RCP 4.5

RCP 8.5



Extratropical thermocline signal persists out to end of 21st century

"First half": 2006-2050 (RCPs), 1850-1925 (20th c.)

"Second half": 2051-2100 (RCPs), 1926-2005 (20th c.)

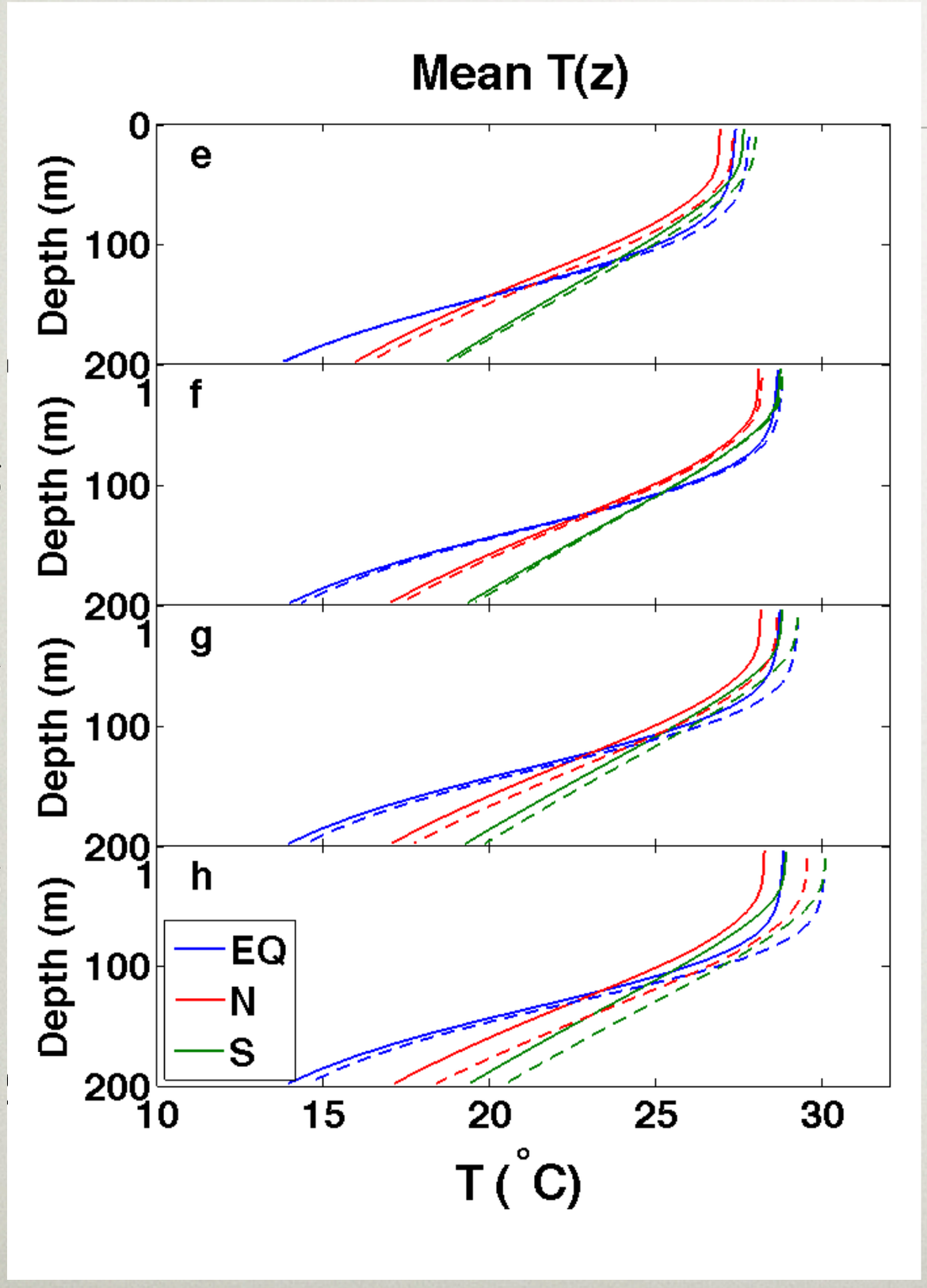
Why so little change? Ocean dynamical adjustment

20th c.

RCP 2.6

RCP 4.5

RCP 8.5



Solid line: first half
2000-2050 (RCPs),
1850-1925 (20th c.)

Dashed line: second half
2050-2100 (RCPs),
1926-2005 (20th c.)

Change persists throughout upper 200m => Trend is not an artifact of the thermocline definition

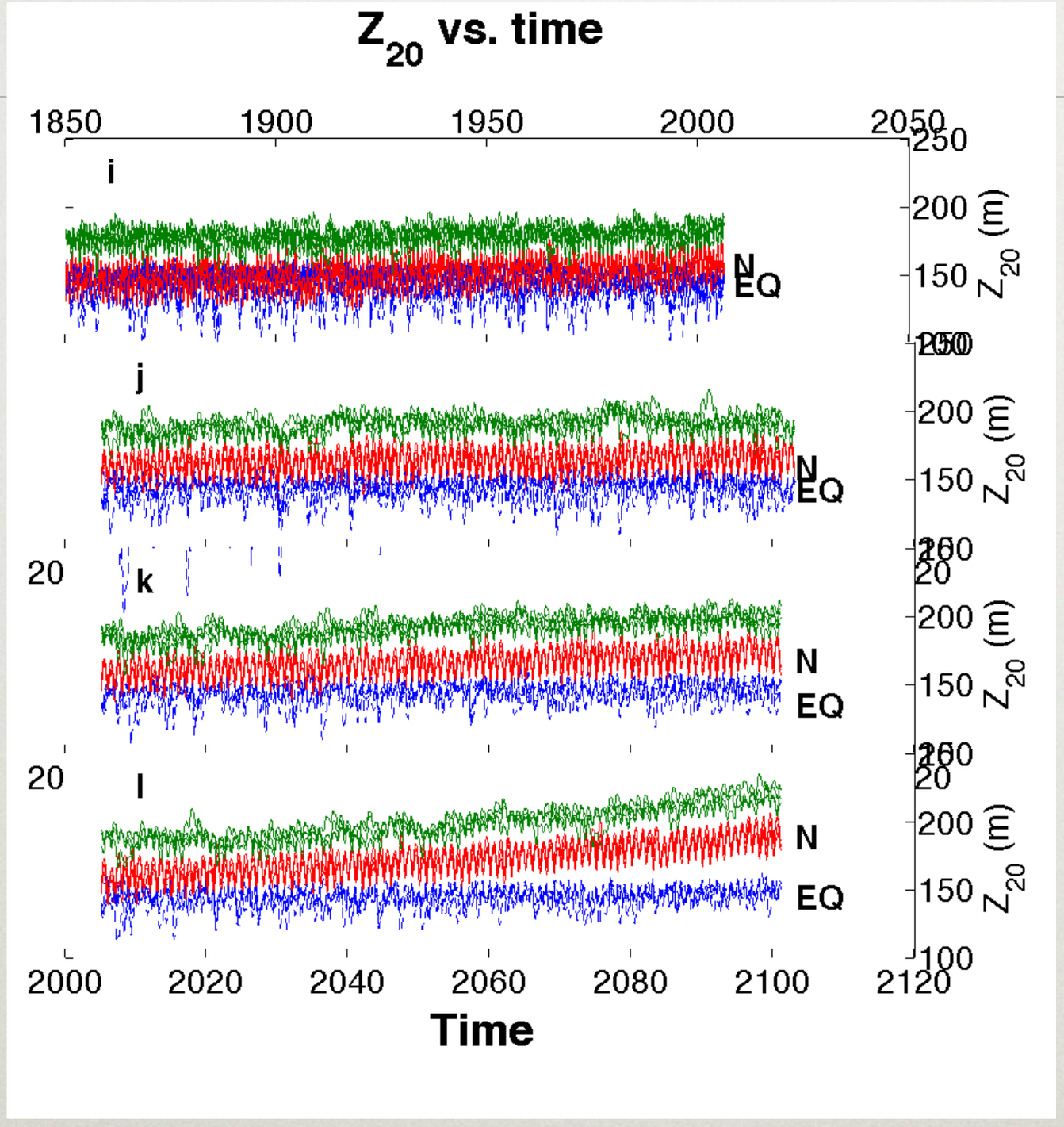
Why so little change? Ocean dynamical adjustment

20th c.

RCP 2.6

RCP 4.5

RCP 8.5



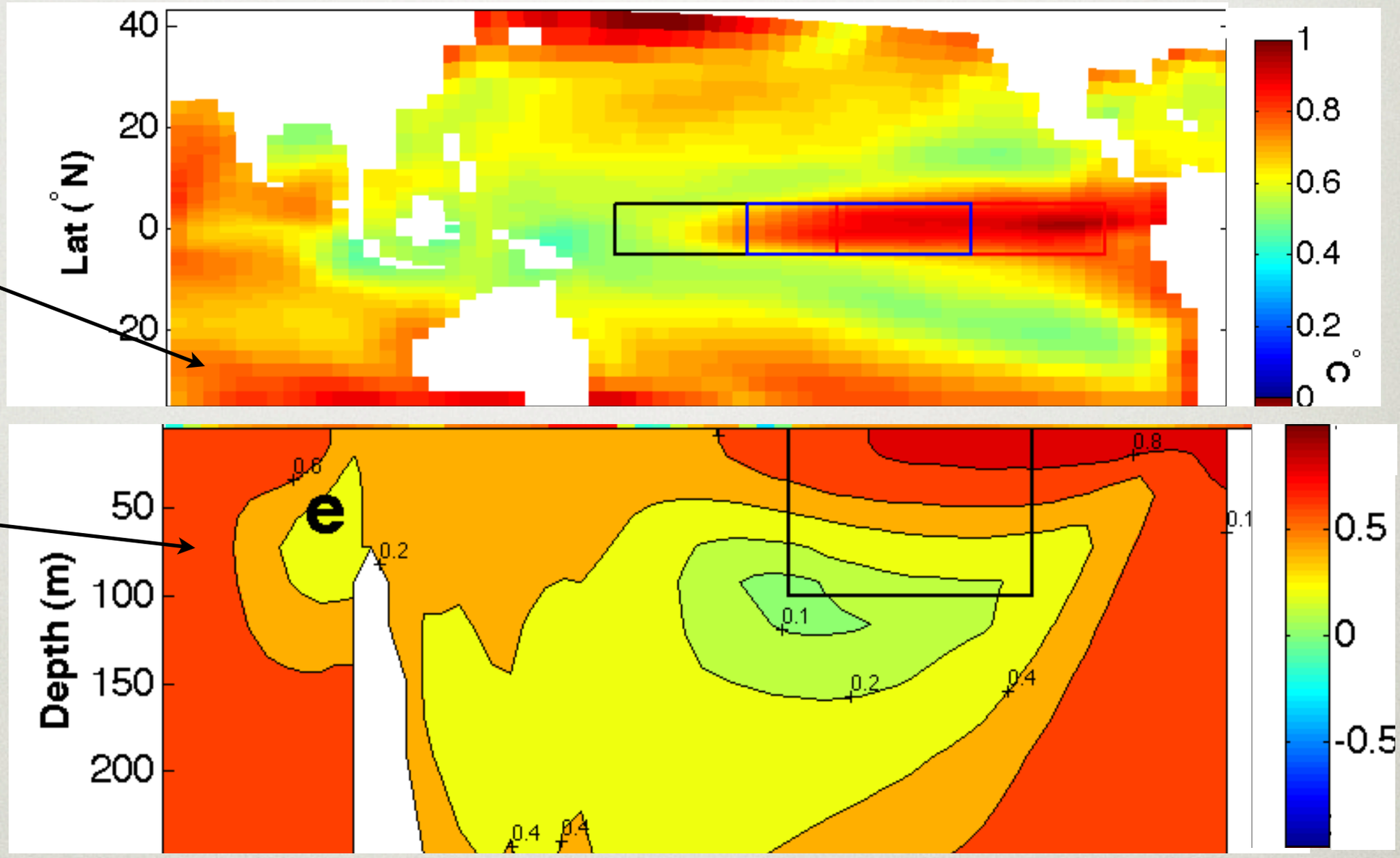
Extratropical thermocline signal persists out to end of 21st century

Understanding ENSO climate sensitivity requires stable, multi-century integrations

Comparison with Stabilized Simulations

CCSM3.5 T31x3: 1000 years @ 255,355,455 ppm CO_2

355 - 255: SST

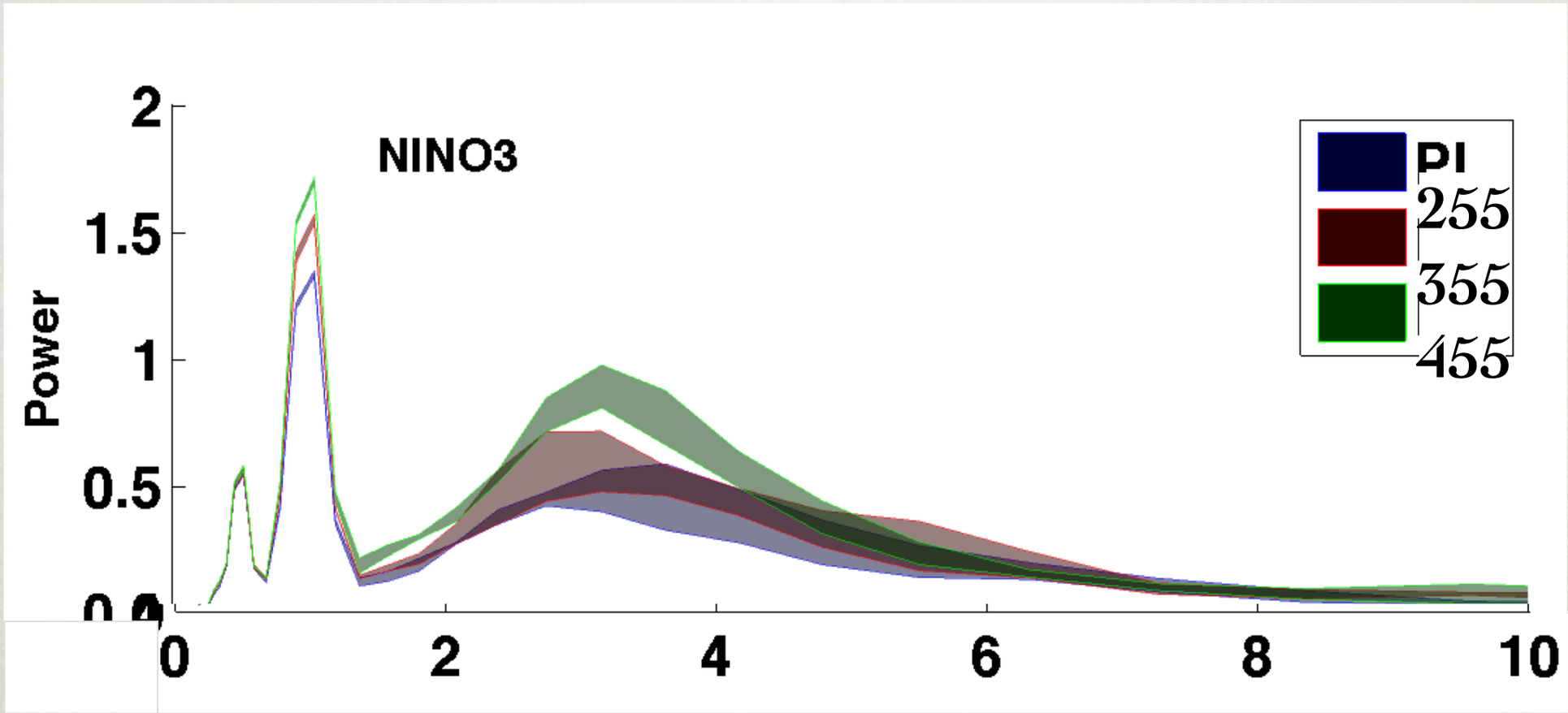


T(z)

Mean state response to CO_2 increase very similar to the climate-change case: reduced zonal SST gradient, higher vertical stratification

Comparison with Stabilized Simulations

CCSM3.5 T31x3: 1000 years @ 255,355 ppm CO_2



But ENSO response to CO_2 increase is reversed: now it STRENGTHENS with CO_2!

Response in same direction as stable CCSM4 simulations

Differences in model physics?

Forced vs. stable mean climate??

Conclusions

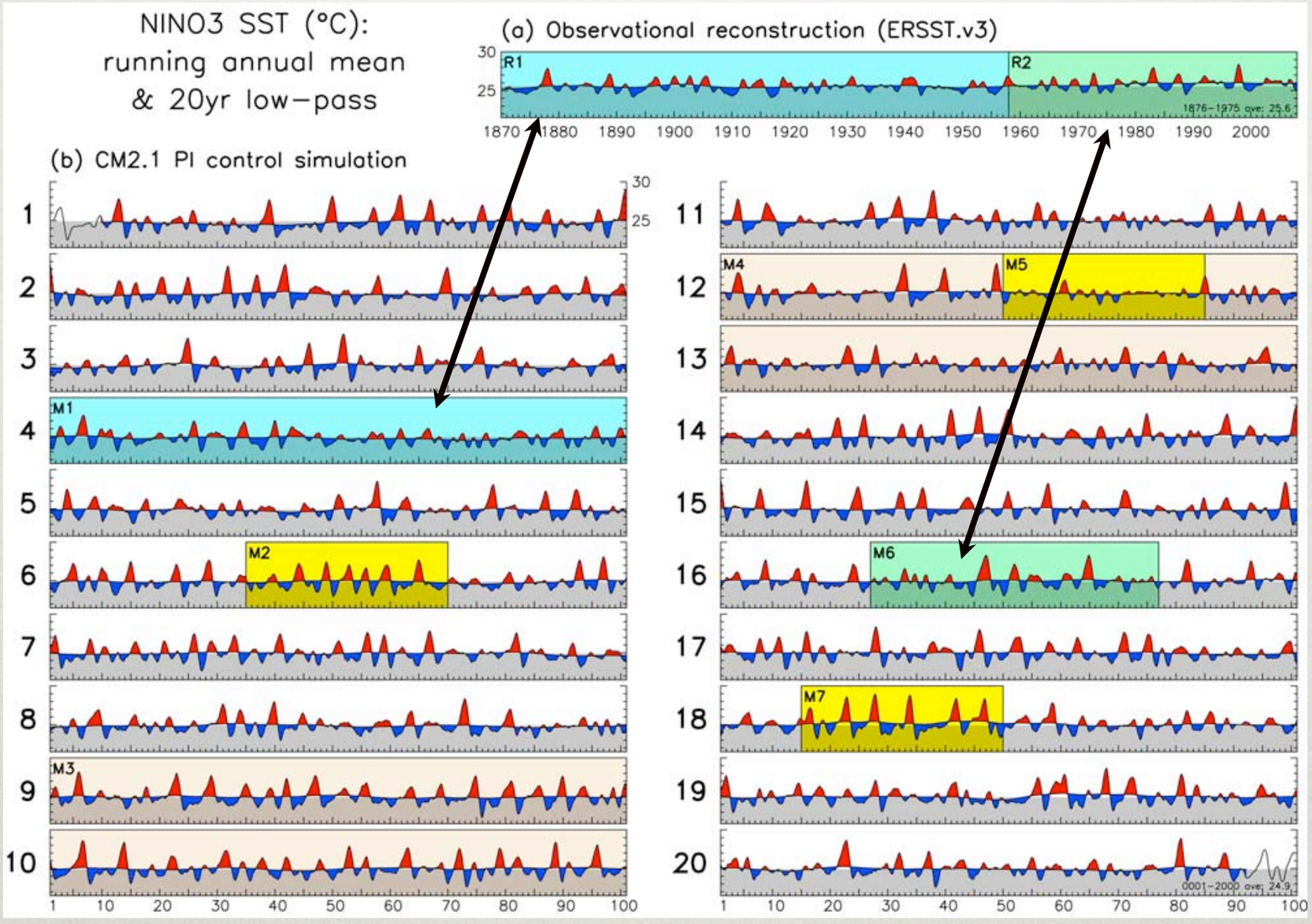
Tropical Pacific mean-state response to climate change is consistent with previous multi-model experiments

ENSO seems to weaken with CO_2... but the signal is not statistically significant in the 20th/21st century CCSM4 projections

Stable CCSM3.5, CCSM4 simulations indicate that hundreds of years are required for a robust signal, and the response differs between forced & stable mean climate simulations

Understanding the true ENSO climate sensitivity requires millennial integrations of multiple CMIP-class models

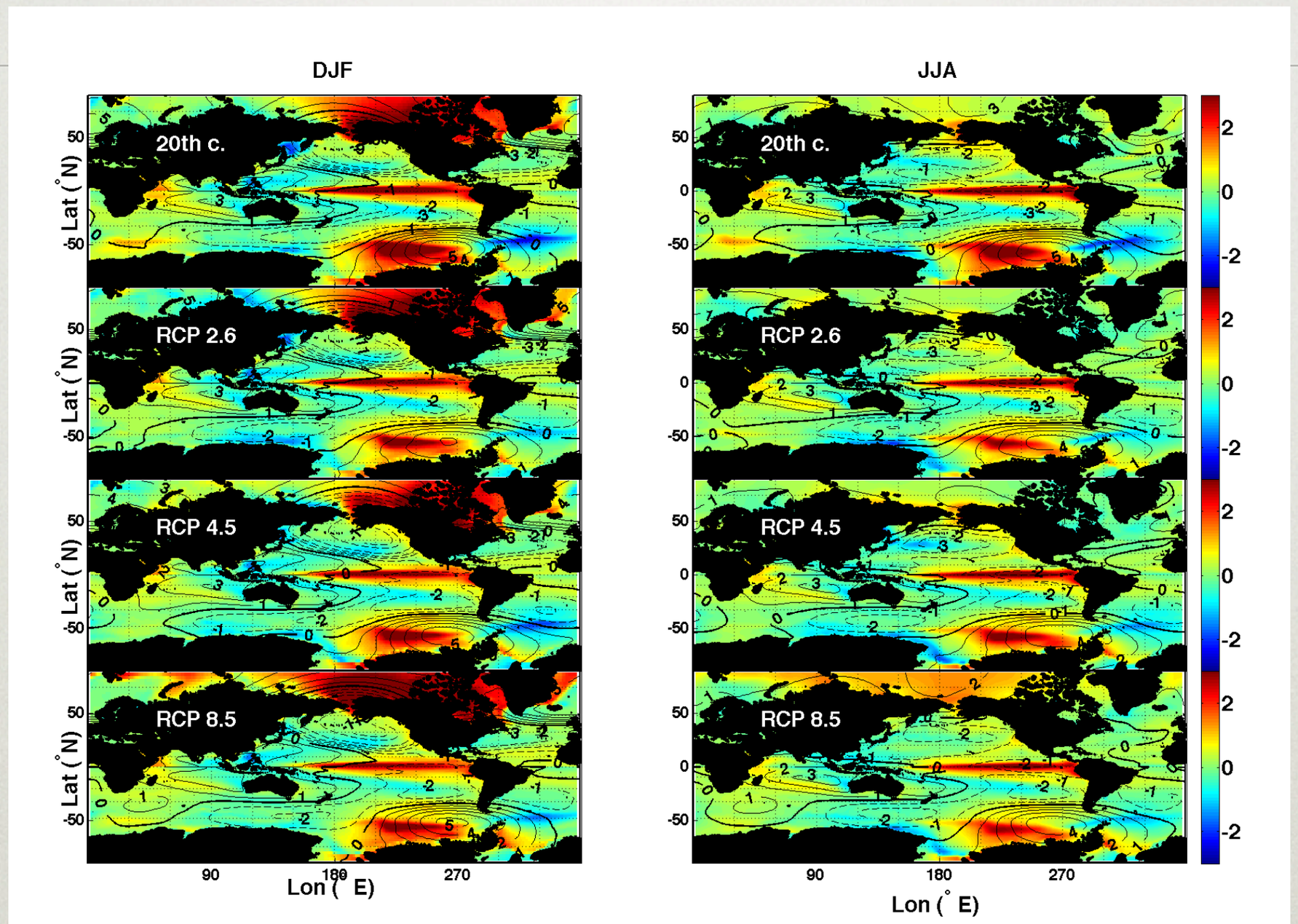
What is the contribution of natural variability?



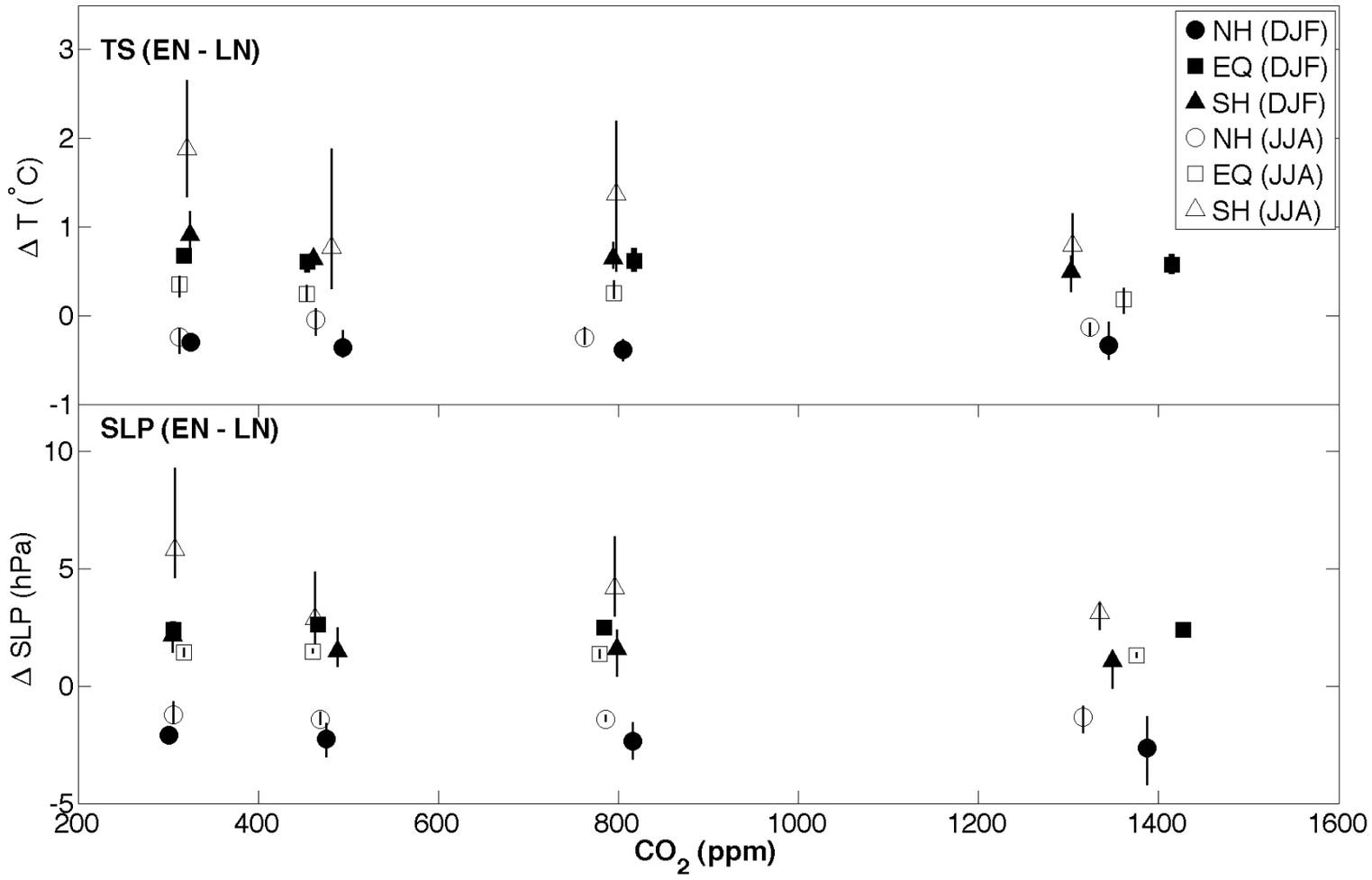
Wittenberg (2009): 2000 year simulation with GFDL CM2.1

same behavior is observed in CCSM4

What about atmospheric teleconnections? Could they be different?



...Guess not.


TS (EN - LN)
ΔT (°C)
3
2
1
0
-1
NH (DJF)
EQ (DJF)
SH (DJF)
NH (JJA)
EQ (JJA)
SH (JJA)
SLP (EN - LN)
Δ SLP (hPa)
10
5
0
-5
200
400
600
800
1000
1200
1400
1600
CO2 (ppm)