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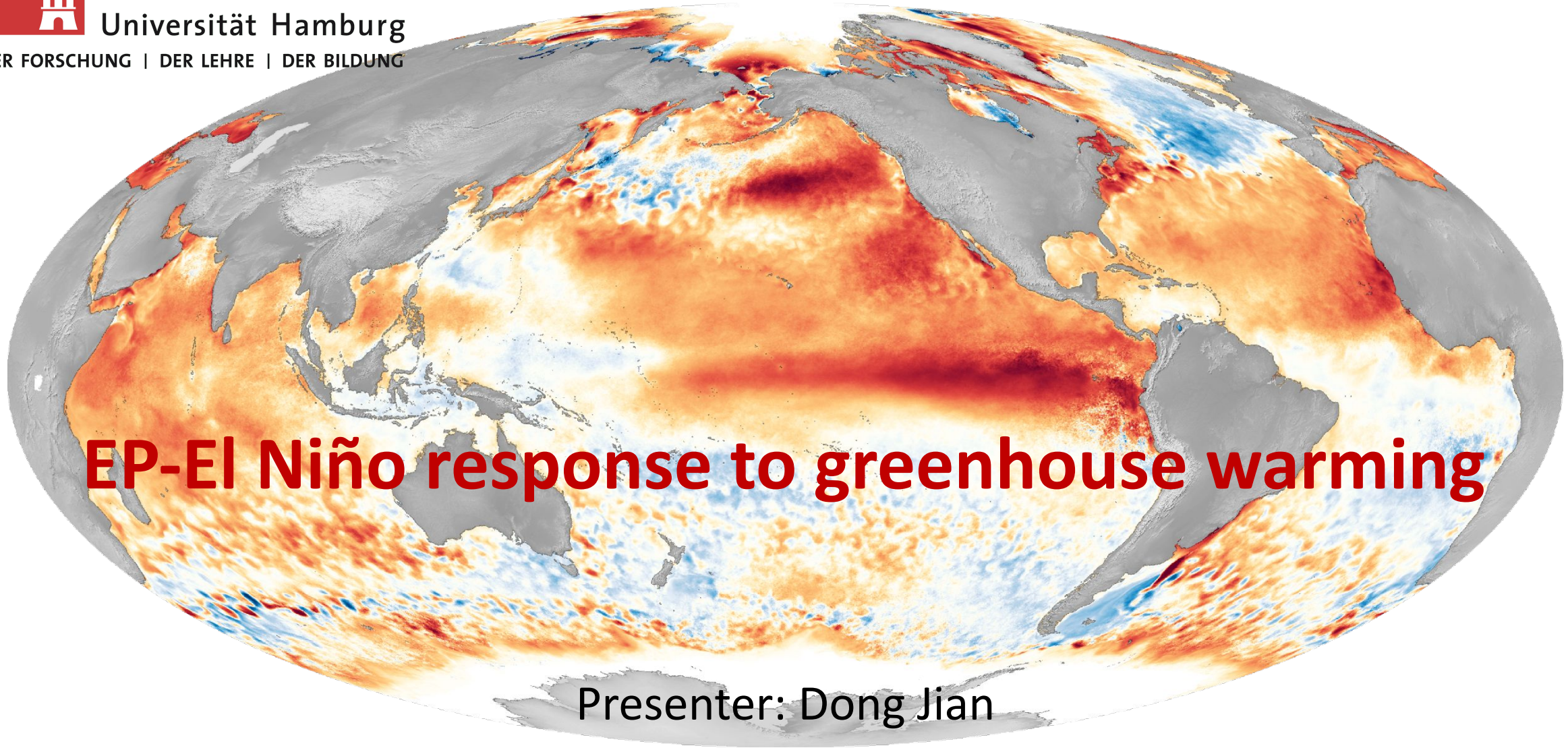


EP-El Niño response to greenhouse warming

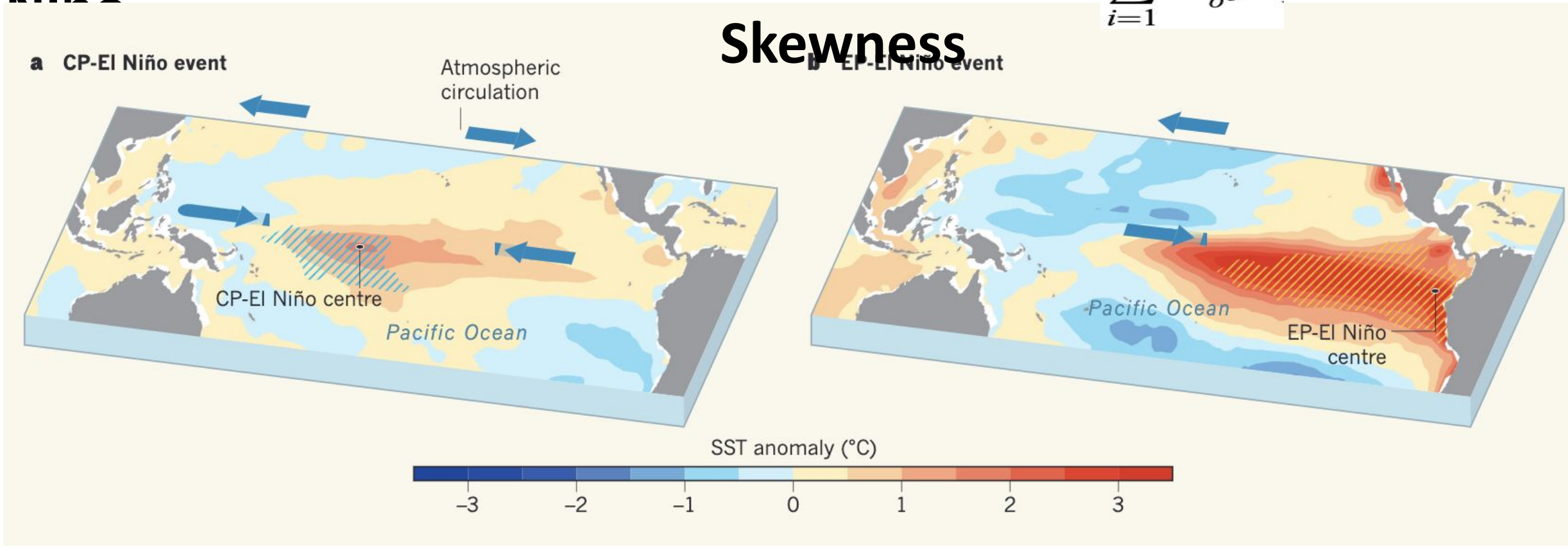
Presenter: Dong Jian

Cai, W., Wang, G., Dewitte, B. *et al.* Increased variability of eastern Pacific El Niño under greenhouse warming. *Nature* **564,** 201–206 (2018). https://doi.org/10.1038/s41586-018-0776-9

Two types of El Niño

SST Skewness

$$\sum_{i=1}^{N} \frac{(x_i - \overline{X})^3}{\sigma^3}$$



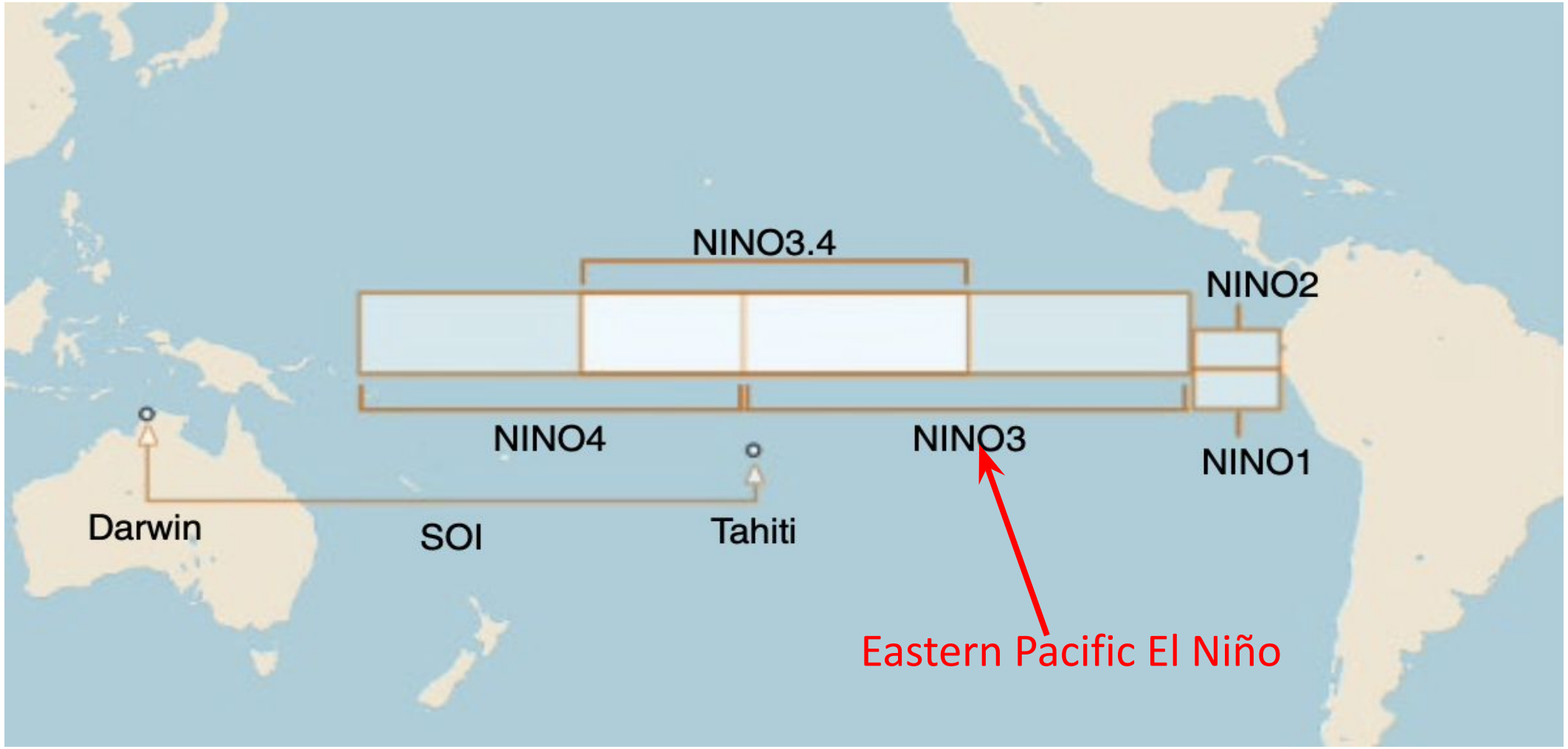
CP-El Niño:

- Max anomaly in the CENTER
- Moderate
- SST anomalies are negatively skewed
- Anomalies in blue shading region negatively skewed by more than 0.1 °C in DJF

EP-El Niño:

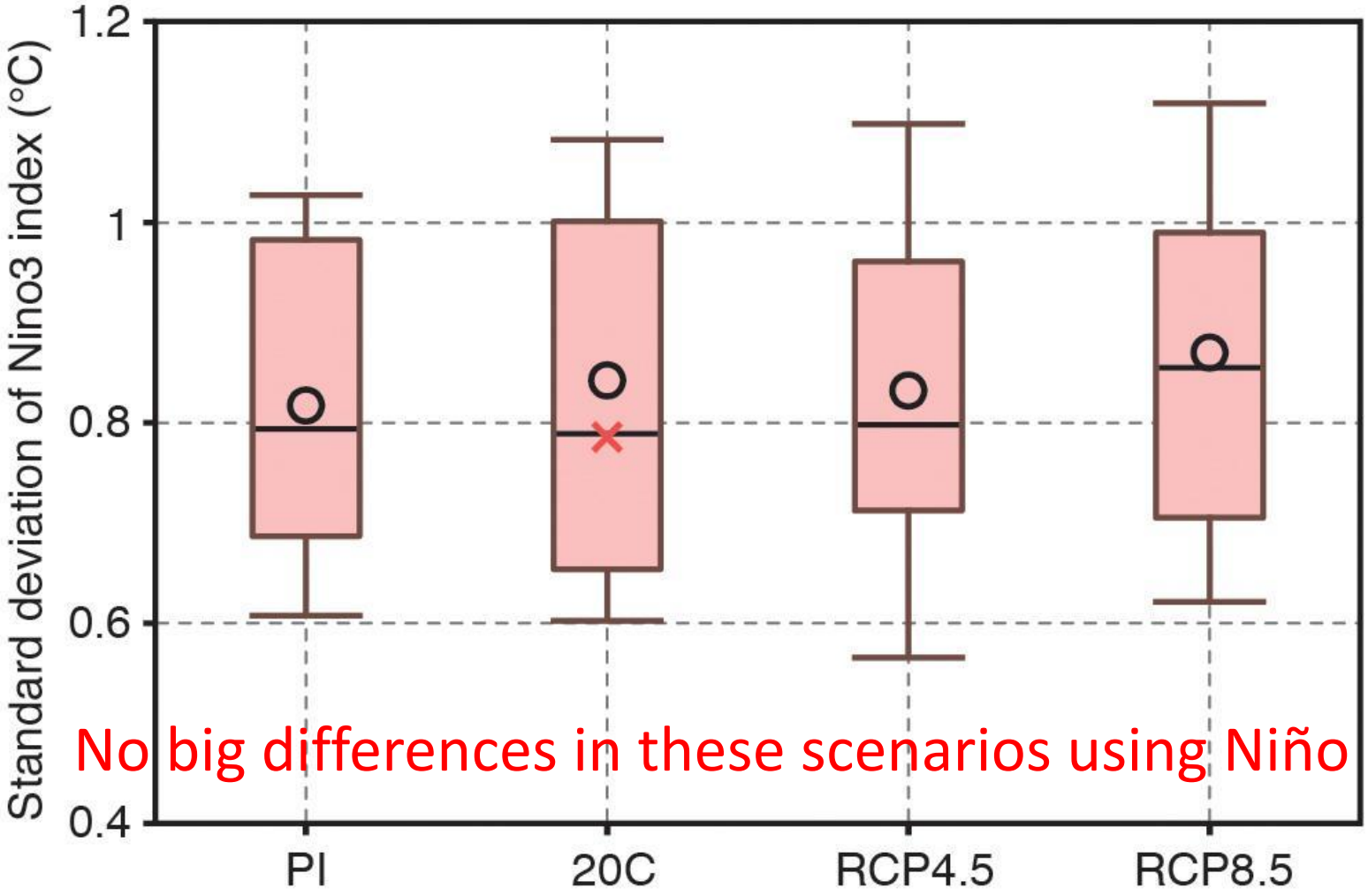
- Max anomaly in the EAST
- Much stronger than CP-El Niño
- SST anomalies are positively skewed
- Anomalies in yellow shading region positively skewed by more than 0.5 °C

Traditional SST indices of ENSO



Niño3 index: mean monthly SST anomaly in 5° S–5° N, 150°–90° W

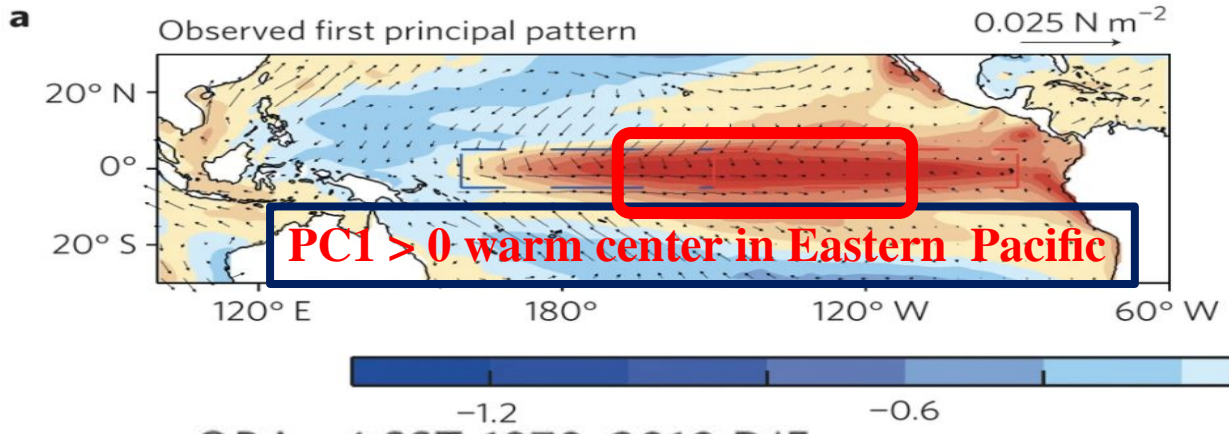
Standard deviation of SST using Niño 3 index

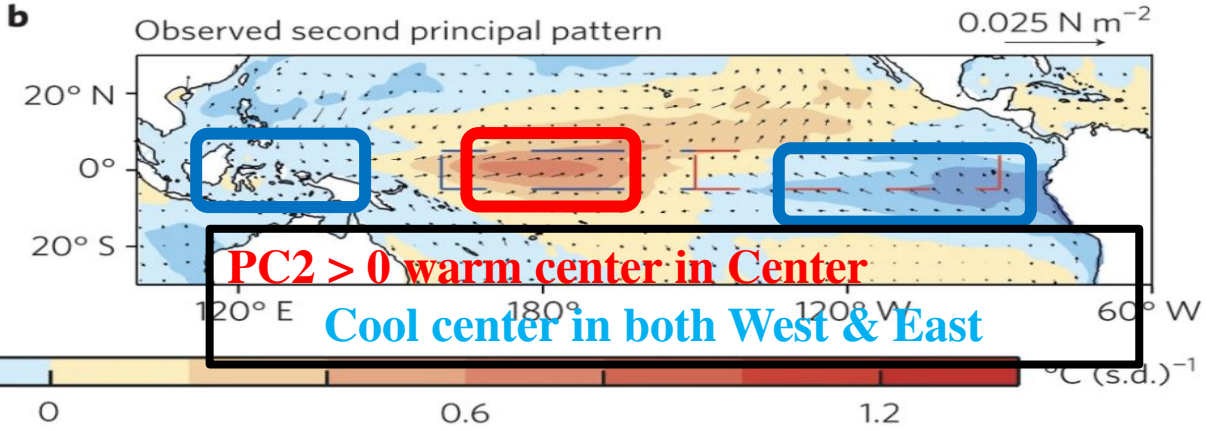


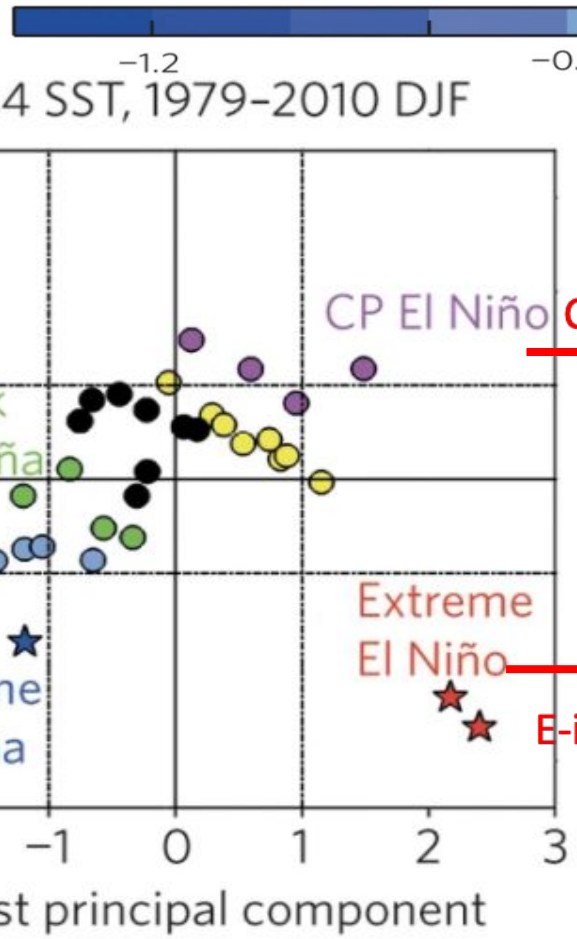
No big differences in these scenarios using Niño 3 index

Standard deviation in CMIP5 multi-model ensembles of SST variability over the eastern equatorial Pacific Ocean (Nino3 region: 5°S to 5°N, 150°W to 90°W)

Distinguish SST anomaly centers (EOF)

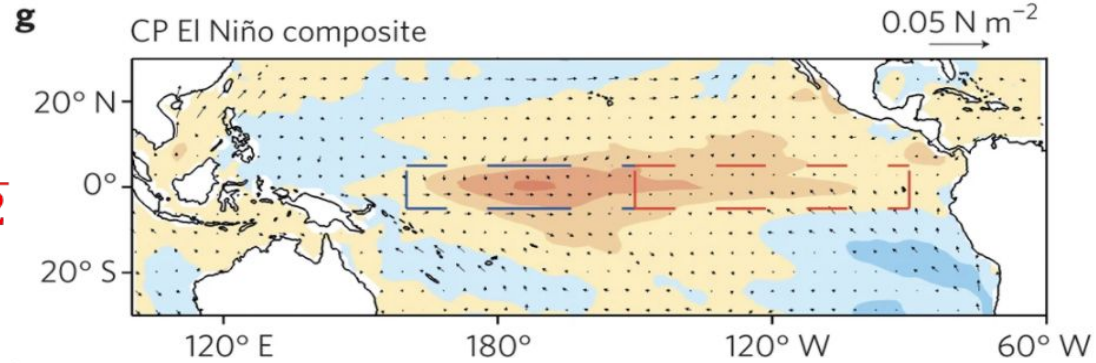


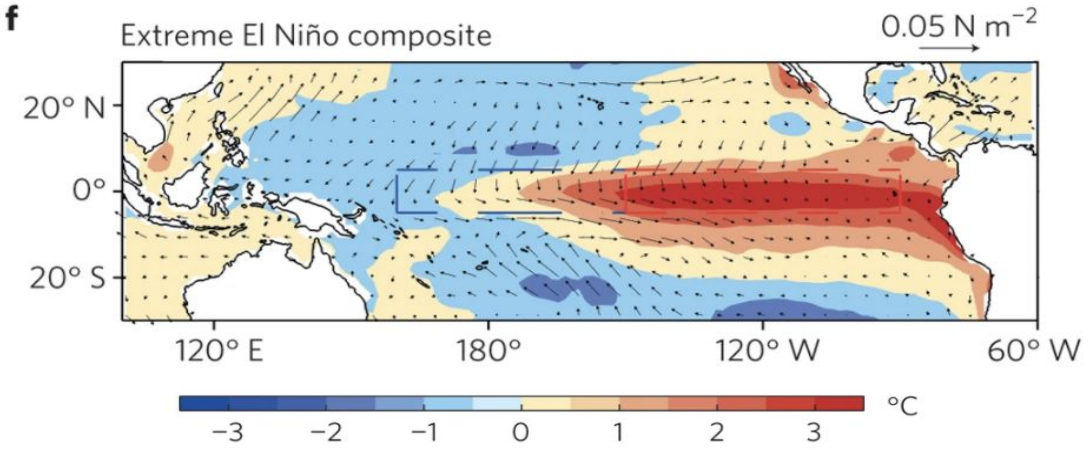




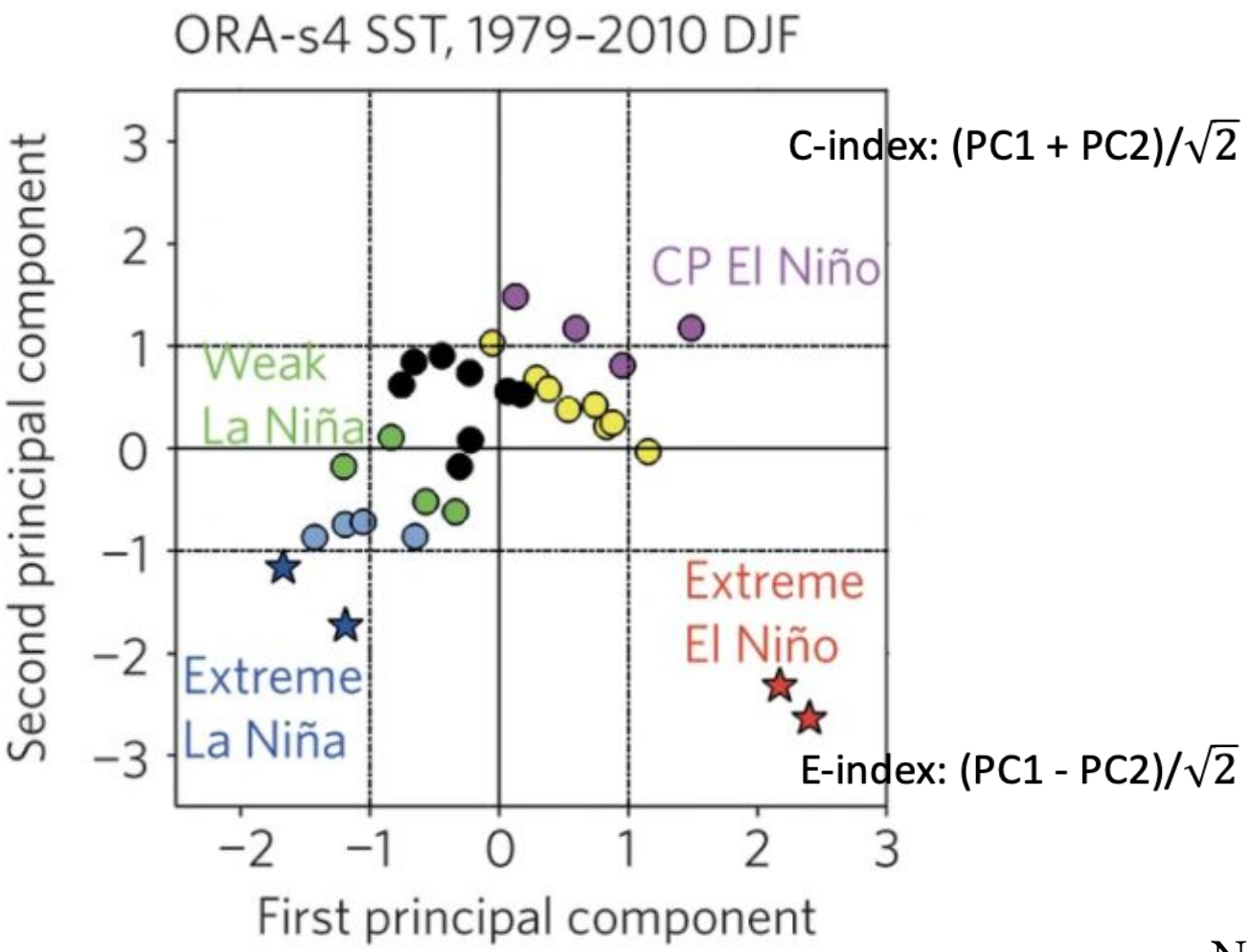
C-index: (PC1 + PC2)/$\sqrt{2}$

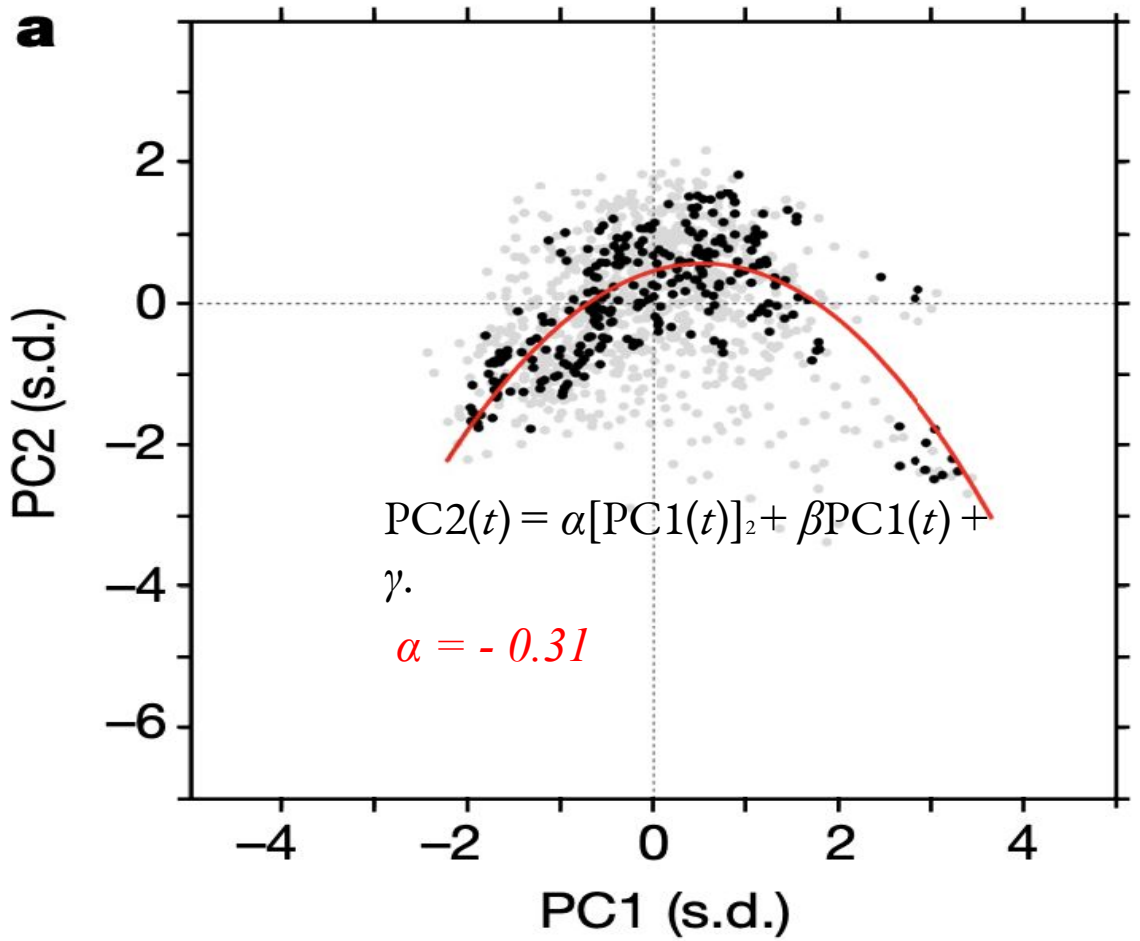
E-index: (PC1 - PC2)/$\sqrt{2}$





Using 5 SST reanalysis products

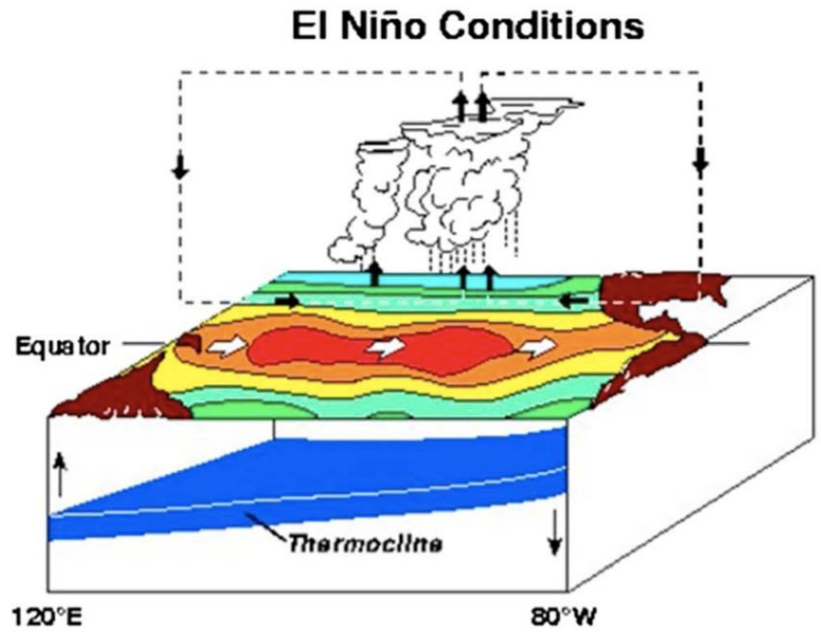


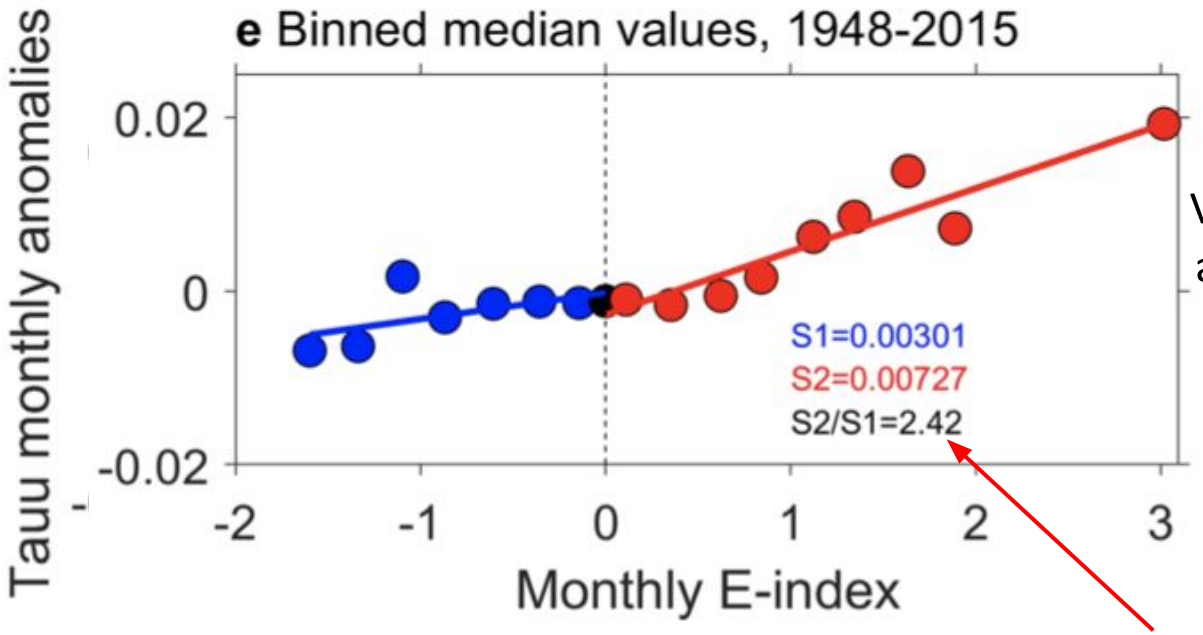


Nonlinear relationship between PC1 and PC2 of SST anomalies averaged over December–February (block dots)

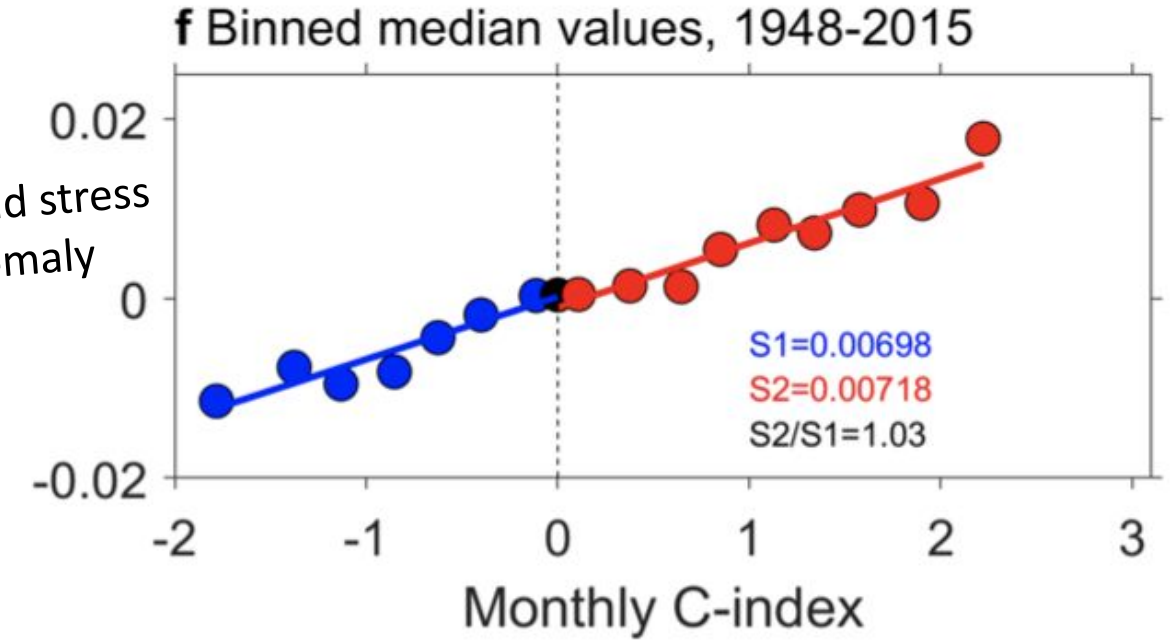
Diagnosis of nonlinear Bjerknes feedback

- nonlinear Bjerknes feedback:
  the response of zonal winds increases with positive SST anomalies, contributing to the positive SST skewness in the eastern equatorial Pacific.



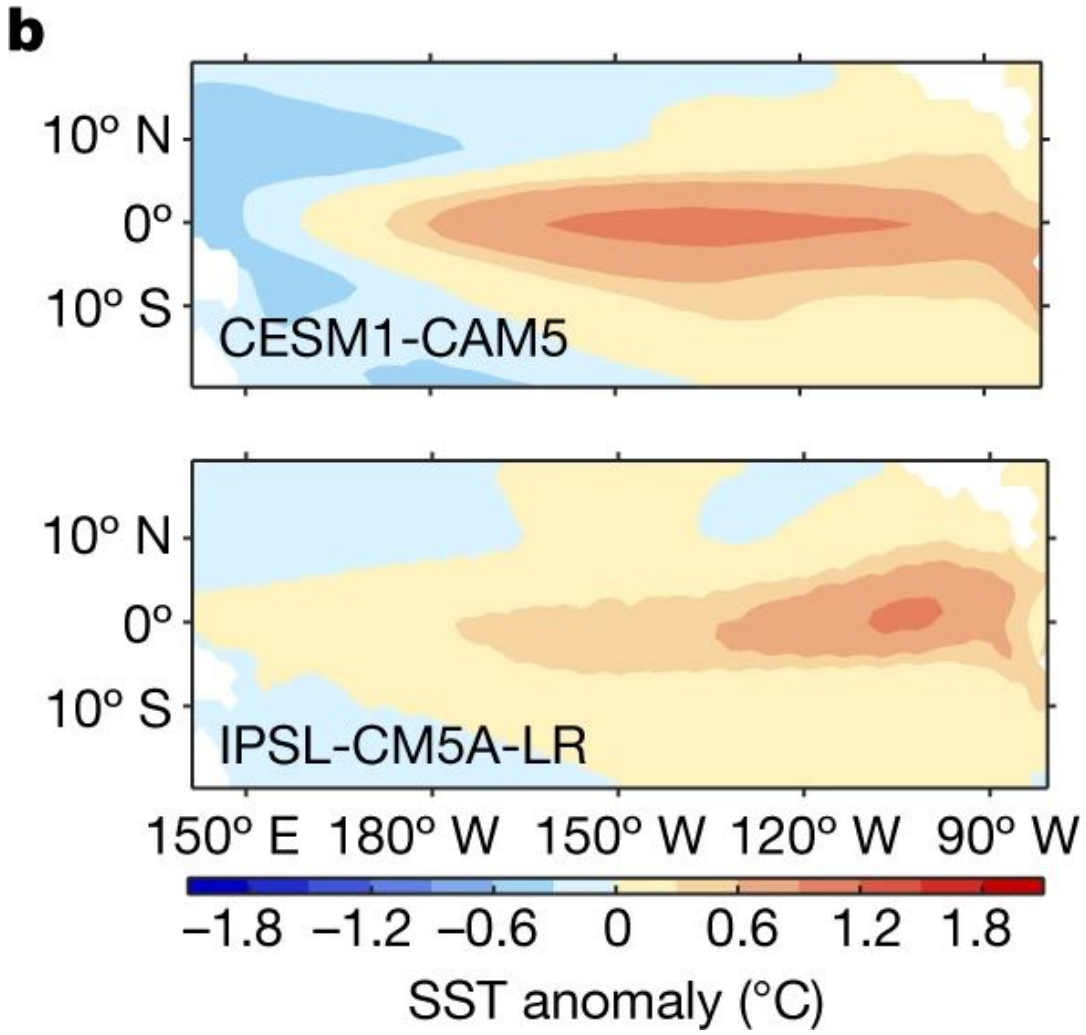


Wind stress anomaly



indication of the nonlinear Bjerknes feedback

34 CMIP5 models apply EOF



SST anomaly of EP-ENSO in two models

construct E-index

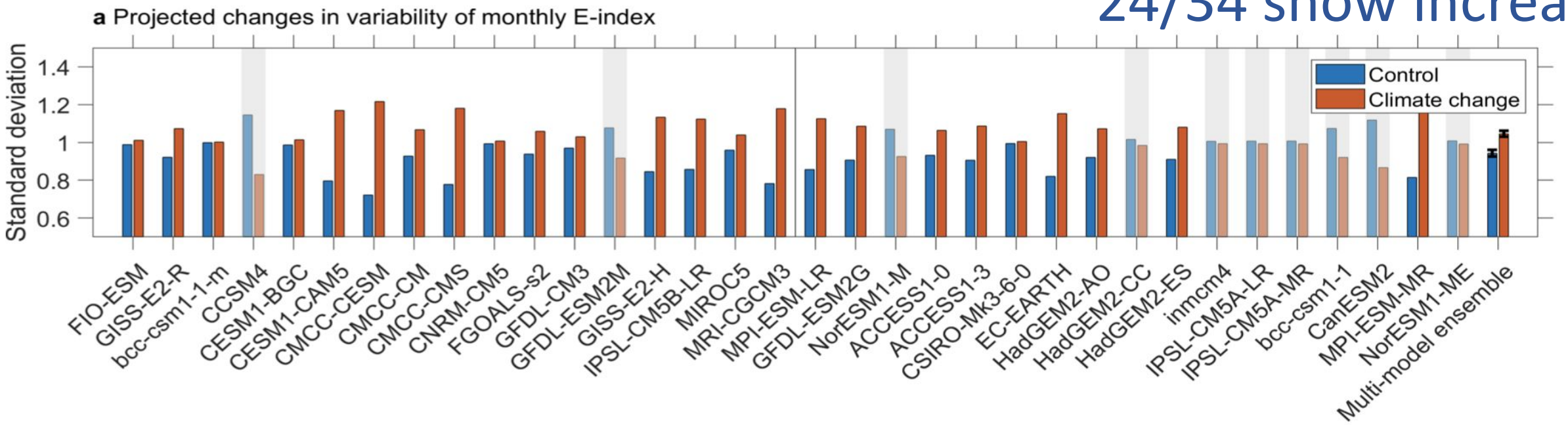
- ❑ Huge difference in SST anomaly centre

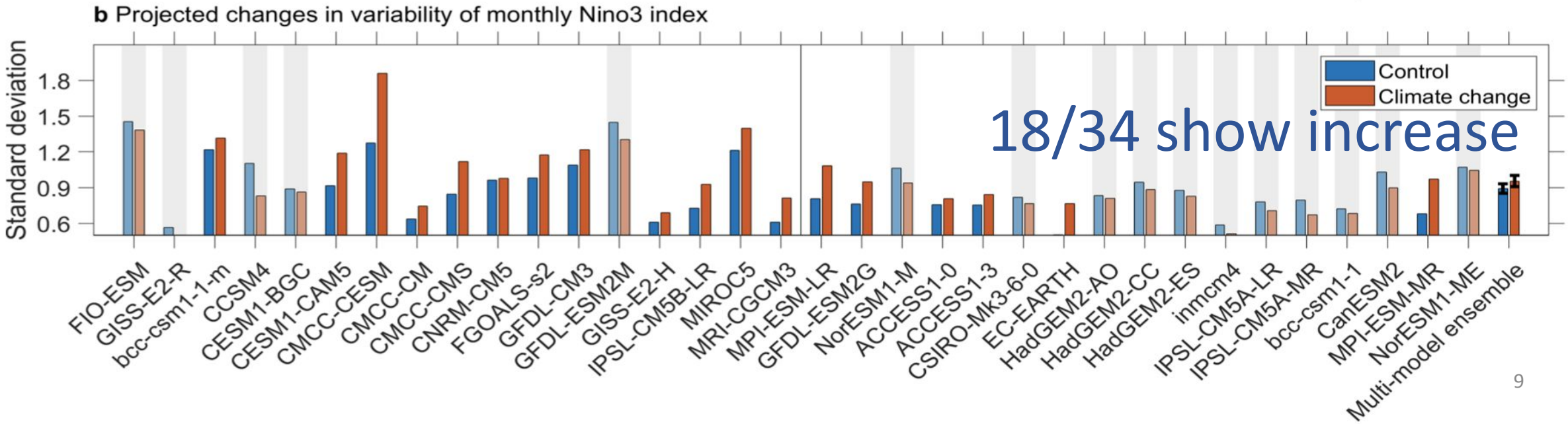
Some Climate models can't simulate distinctive CP- and EP-El Niño events

- ❑ Not appropriate to be represented by Niño 3
- ❑ But should be represented by E-index

Projected EP-ENSO change (E-index VS Nino 3)

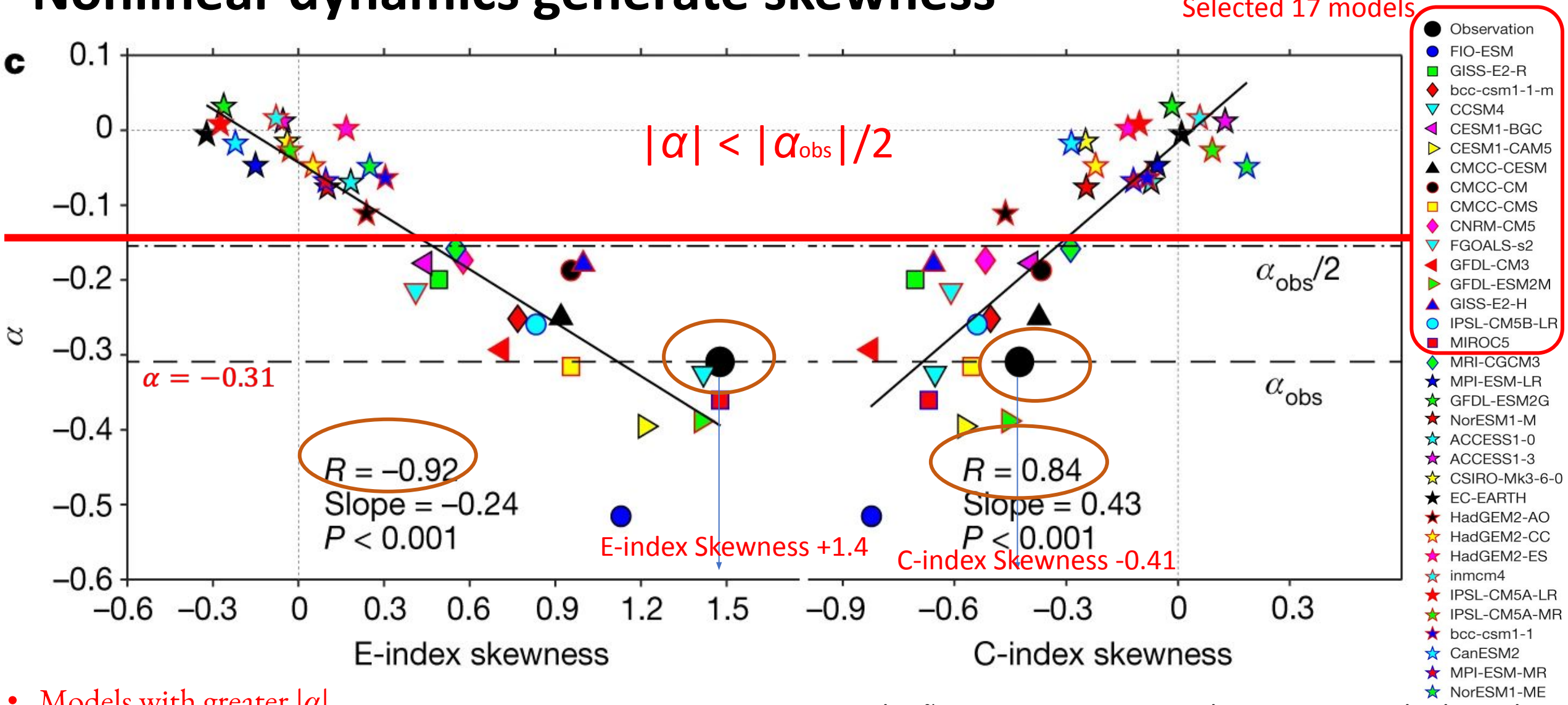
24/34 show increase





18/34 show increase

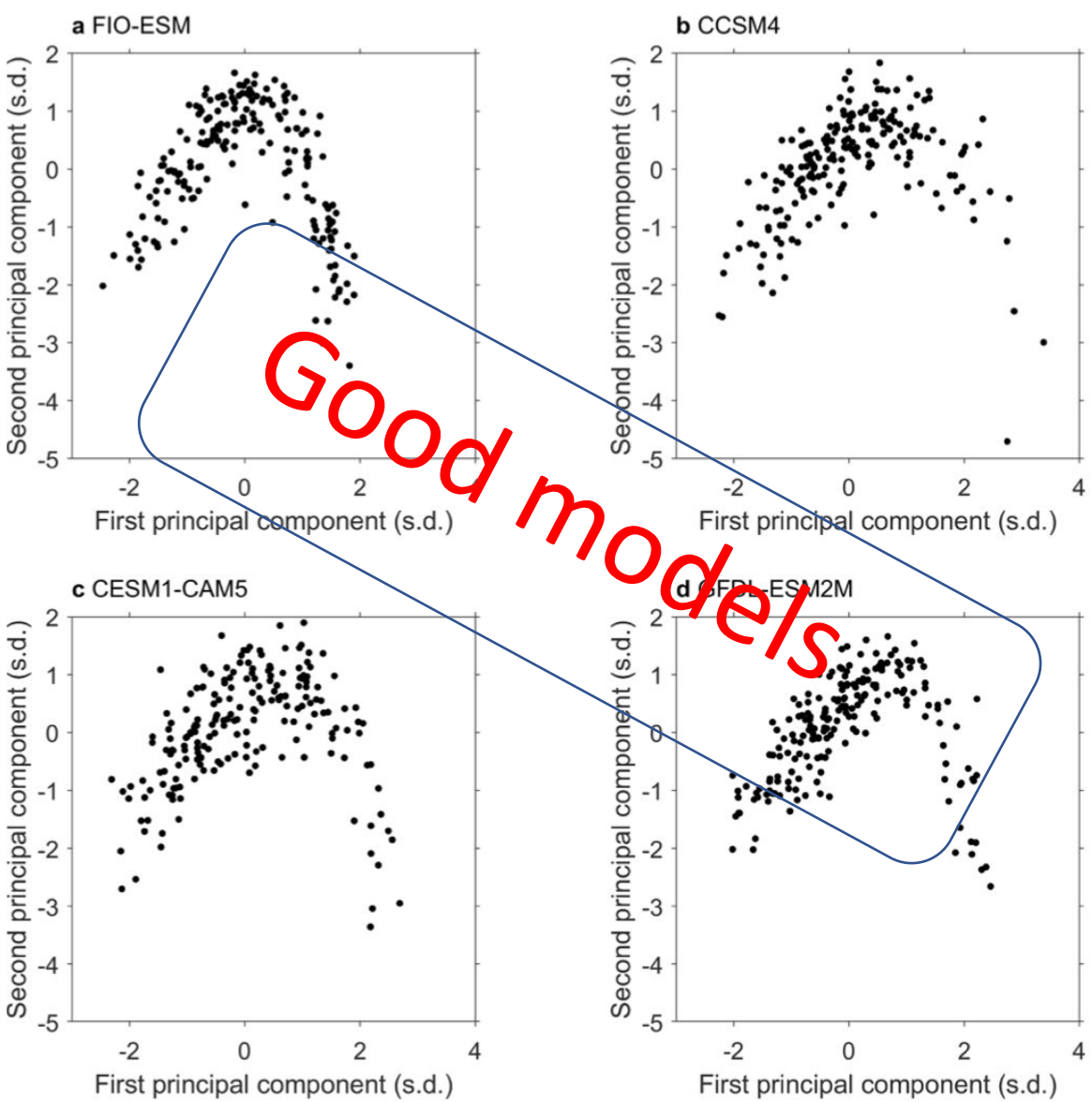
Nonlinear dynamics generate skewness

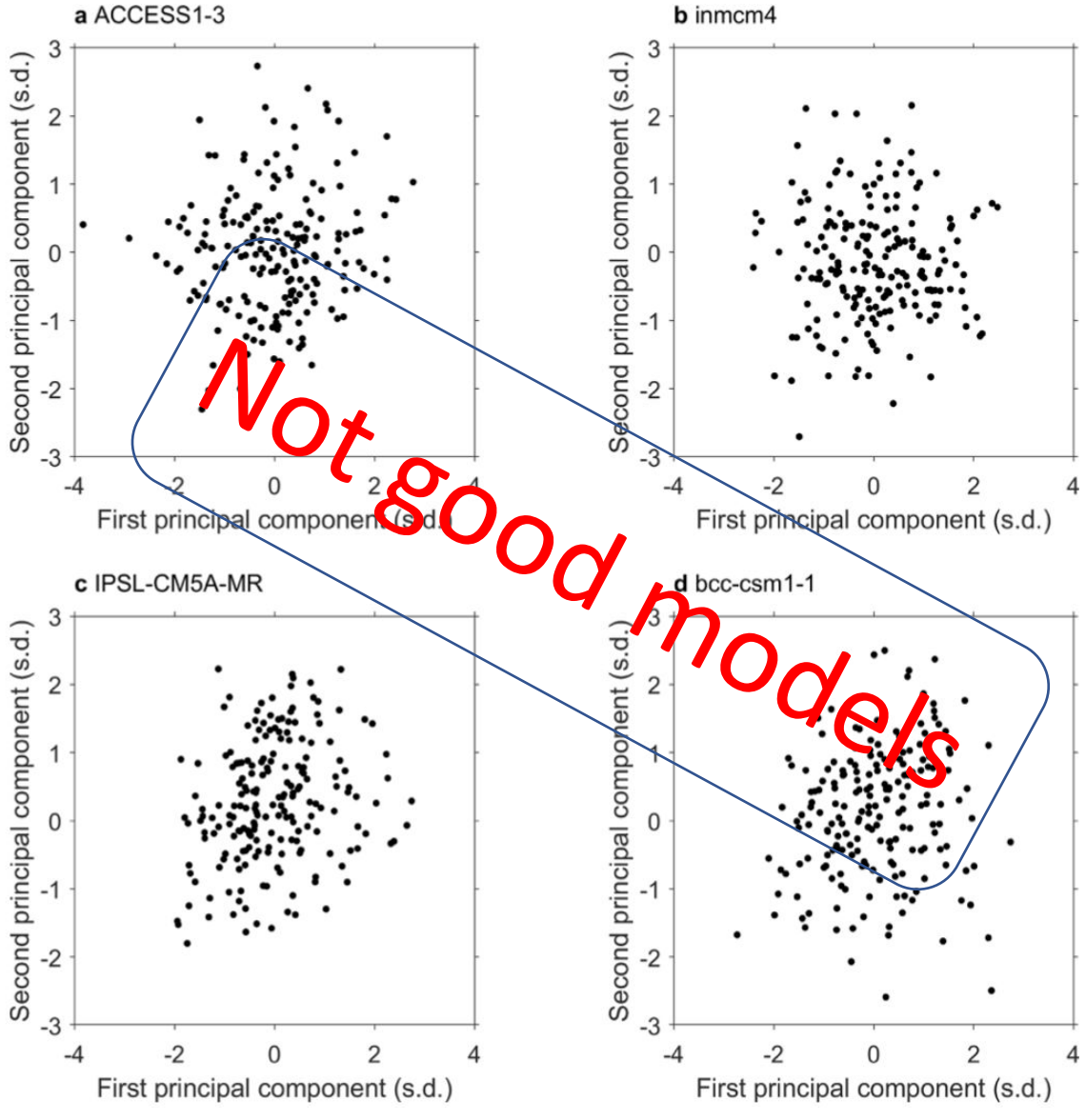


- Models with greater $|\alpha|$
- greater positive skewness in the E-index (Correlation of 0.92)
- greater negative skewness in C-index (Correlation of 0.84)

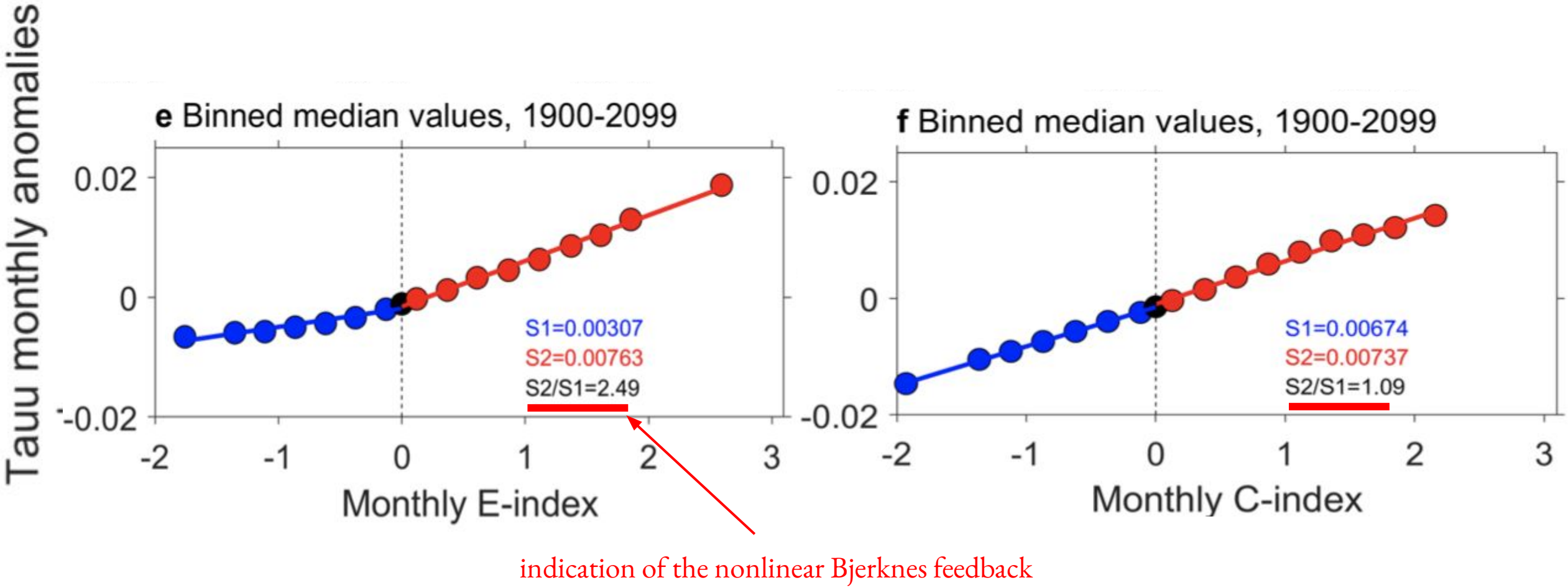
CP-El Niño events — SST anomalies are negatively skewed.
EP- El Niño events — SST anomalies are positively skewed.

Selected models VS non-selected models



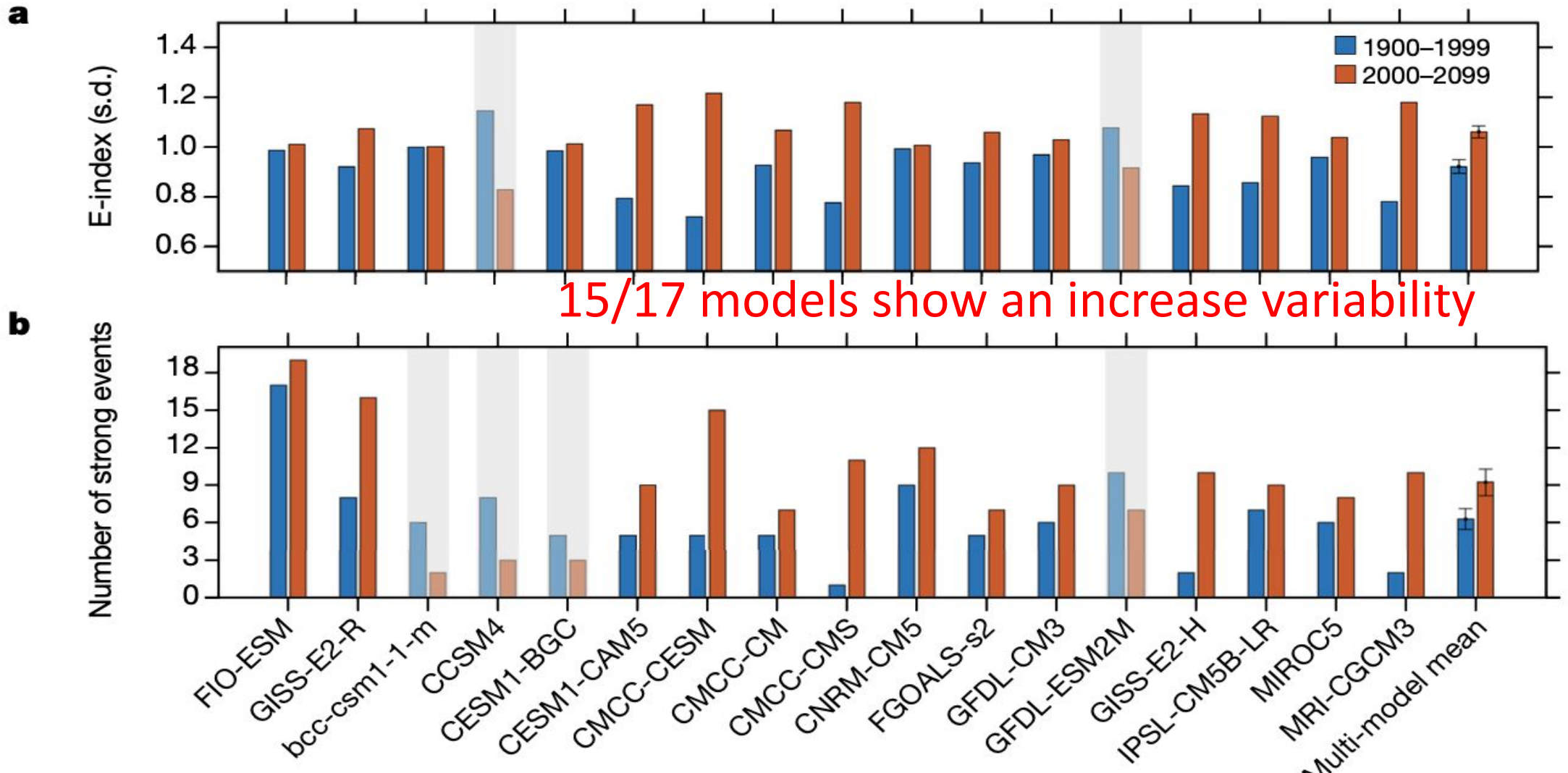


Diagnosis of nonlinear Bjerknes feedback on selected models



indication of the nonlinear Bjerknes feedback

Enhanced consensus in 17selected models



15/17 models show an increase variability

Translating into 50% increased frequency of extreme El Niño events

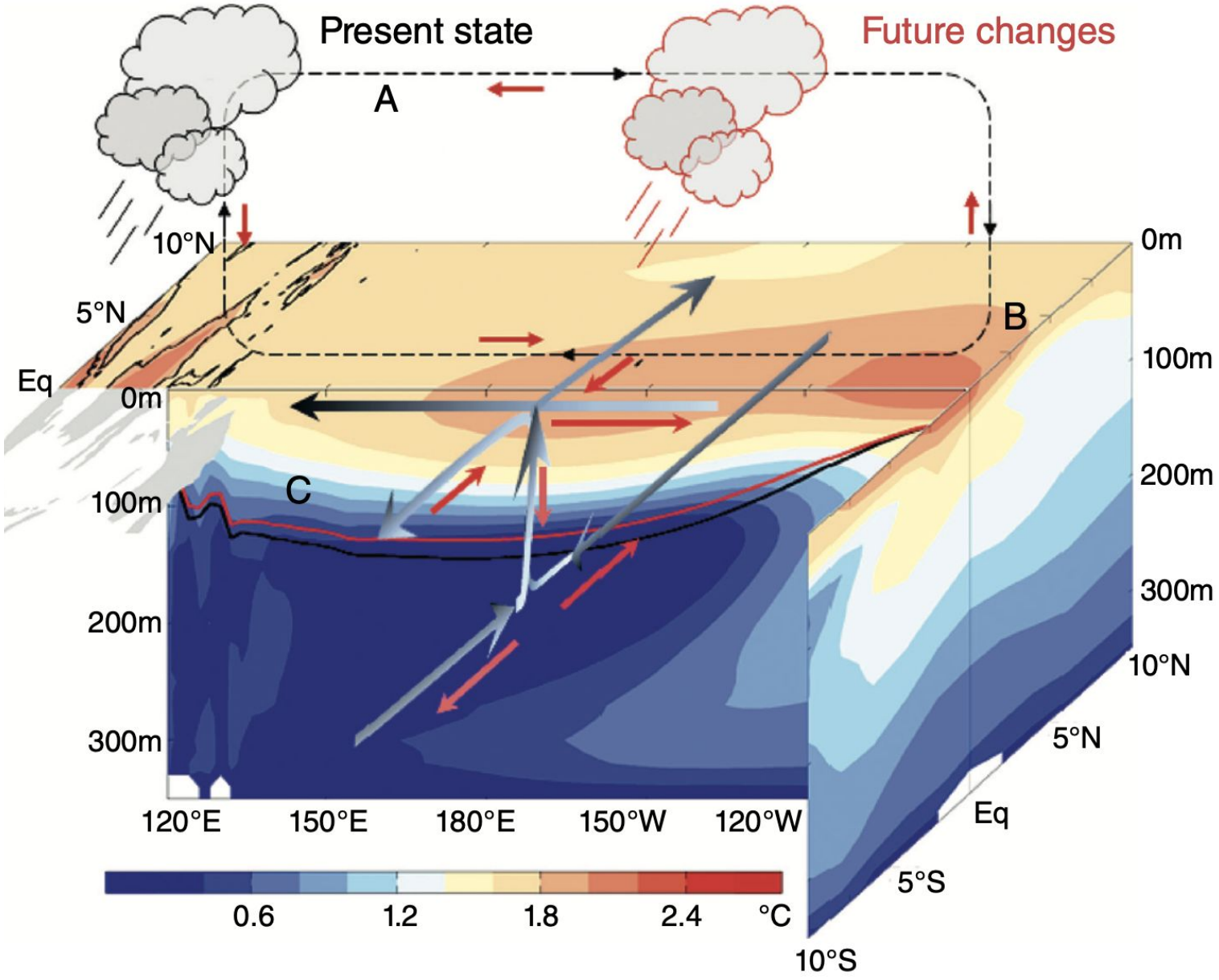
Projected increase in EP-ENSO variance

Mean state change under warming

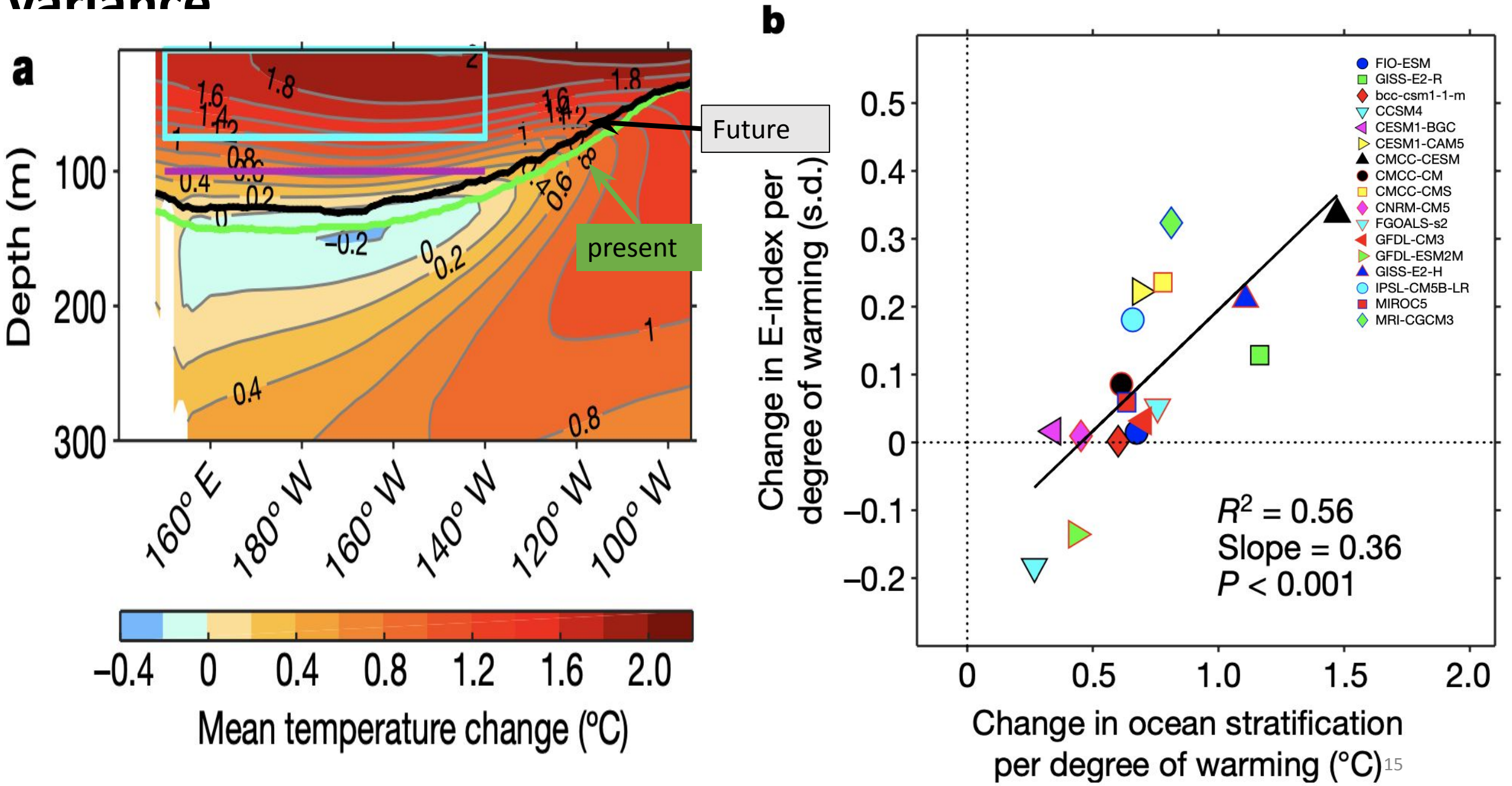
A: Weakening Walker Circulation, trade wind and upper ocean current

B: Faster warming in East & the equatorial than the central & off equatorial Pacific

C: Vertical temperature gradient increase due to surface forcing--> shoaled thermocline



Mechanism for projected increase of EP-ENSO variance



Summary

- Despite inter-model differences in ENSO, a robust increase variability of EP-ENSO under greenhouse warming

- Increase in variability is largely due to greenhouse warming-induced intensification of upper ocean stratification in the equatorial Pacific which enhances ocean-atmosphere coupling

- An increase in SST variance indicates more extreme events in the future