A non-ENSO-like pattern of low-frequency internal variability in the tropical Pacific simulated by virtually all coupled models since CMIP3

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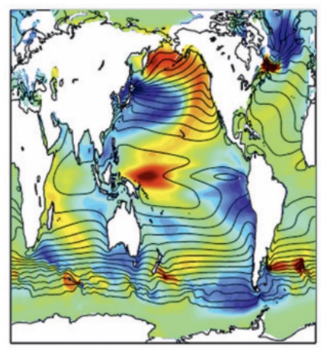
Background

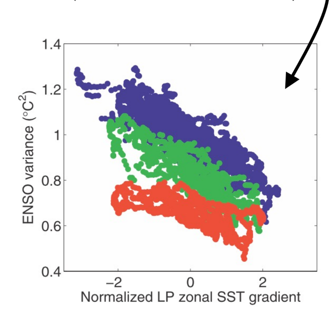
Special motivation: The western Pacific has emerged in very conspicuous ways recently, in several analyses of tropical climate dynamics with consequences for ENSO, IOD, etc. Whether or not that variability has a counterpart in the real world, it is definitely present in models and should be understood & compared to other time scales.

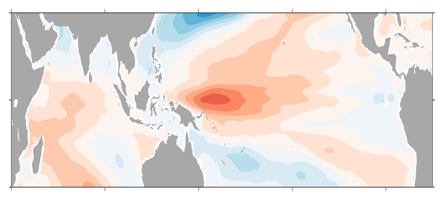
Hypothesis: *Just* beyond the interannual time scale *(surprisingly close)*, the west Pacific warm pool is the heartbeat of the climate system. It exhibits low-frequency variability that is driven by stochastic forcing (akin to Hasselmann-type model).

Caveat: This analysis pertains to the behavior of the latest generation of global climate models. In other words, if CMIP6 GCMs fail to exhibit a PDO or IPO that is distinguishable from broadband noise, that doesn't necessarily mean the real world can't exhibit such behavior as a physical modes.

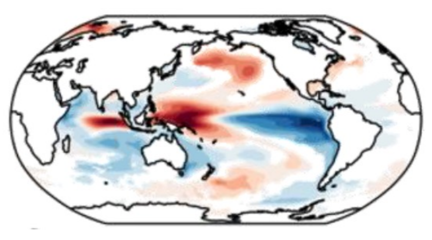


This is the mean state associated with *low ENSO variance* (Karnauskas *et al.,* 2012)





This is the mean state associated with *weak ENSO-IOD correlation* (Zhang *et al.*, 2021)



This is the mean state associated with *low IOD variability* (Abram *et al.*, 2020)

Consider the expression of the **IPO** in models and observations…

Outside of the tropics, these may look the same, but *near the equator*, the western Pacific is far more involved in models than in observations!

(Figure from Meehl *et al.*, 2016)

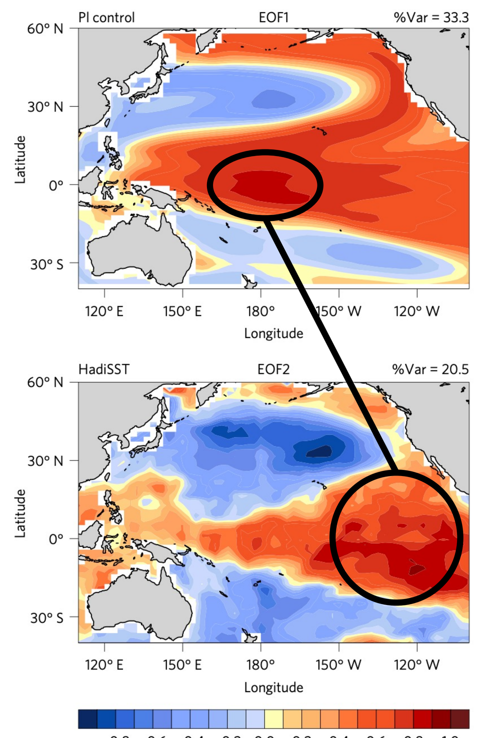


Figure 1 | Observed IPO compared to multi-model internally generated IPO and externally forced response from aerosols and greenhouse gases.

Data & Methods

Data

- 35 models from Coupled Model Intercomparison Project, phase 6 (CMIP6)
- Pre-industrial control simulations: *piControl* (1850 forcing)
- Included models with at least 450 years of output on ESGF

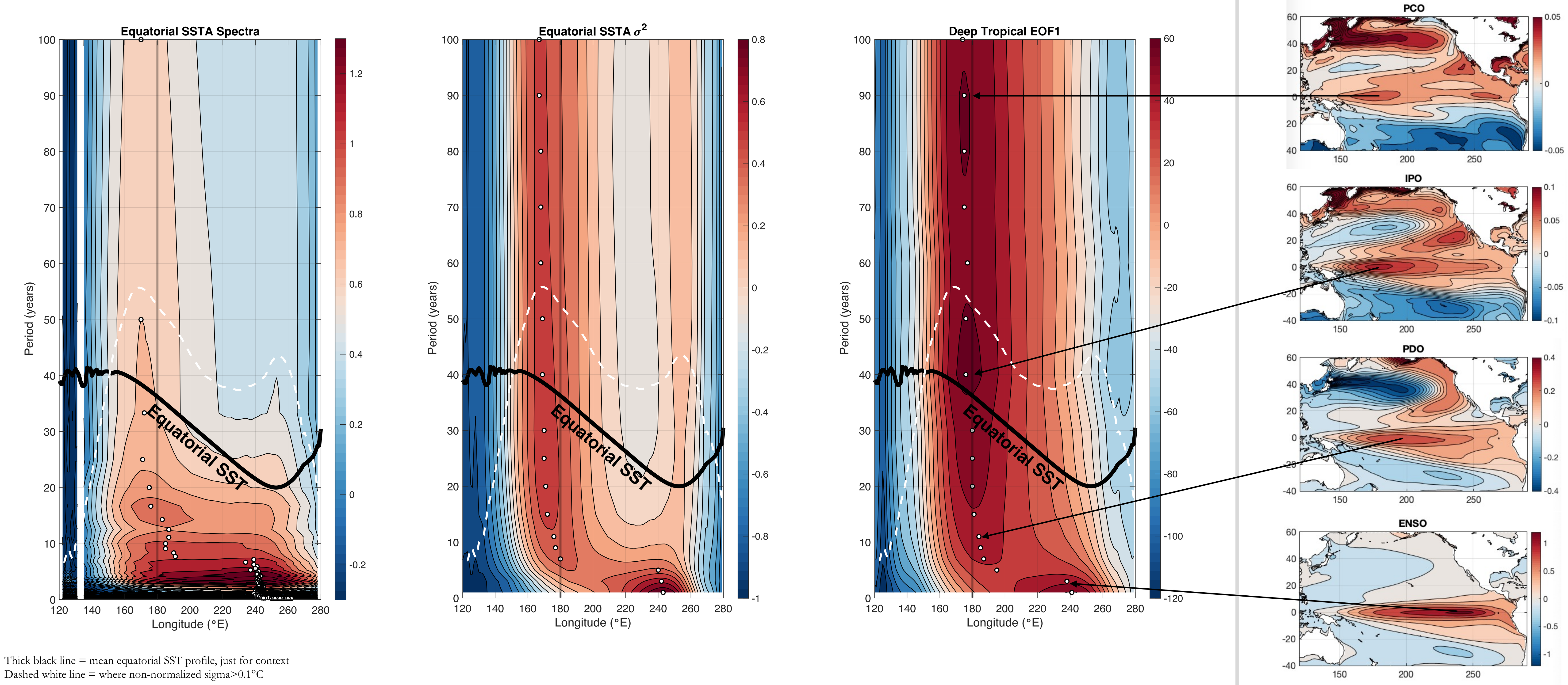
Pre-analysis steps

- Remap all SST fields to common 1° x 1° grid
- Compute monthly anomalies (remove mean seasonal cycle)
- Linearly detrend at each grid point

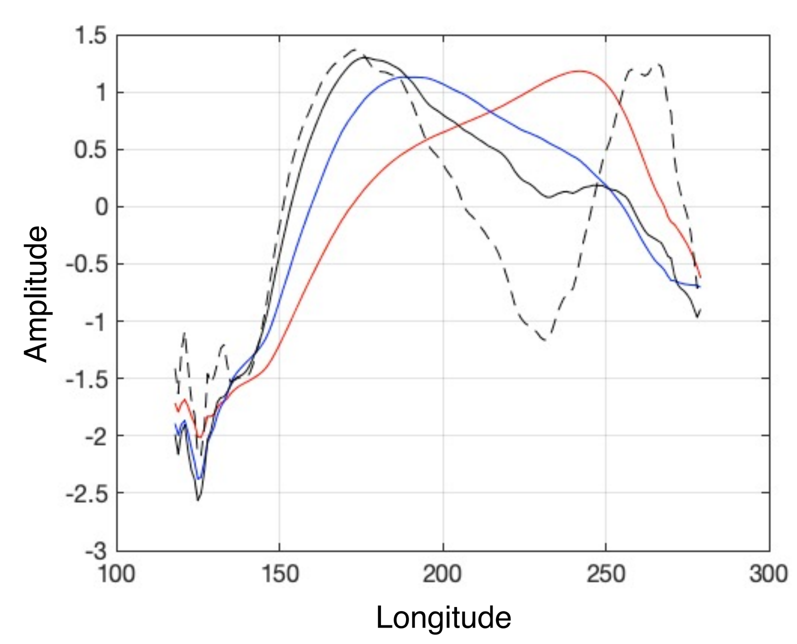
Analysis format

a. Multi-model mean *power spectra* of equatorial (1°S–1°N) SST as function of longitude
b. Multi-model mean *variance* of equatorial (1°S–1°N) SST as function of longitude and low-pass filtering period (normalized at each period)
c. Multi-model mean *leading mode* of deep tropical (10°S–10°N) SST as function of longitude and low-pass filtering period (normalized at each period)

Results



Thick black line = mean equatorial SST profile, just for context
Dashed white line = where non-normalized sigma>0.1°C



The amplitude of low-frequency SST variability in the western equatorial Pacific Ocean is clear in *canonical* calculations of modes of variability beyond ENSO, including PDO, **IPO**, and PCO (dashed), as seen above in the profiles of the aforementioned modes along the equator.

This may be an important difference with observations/the real world, even if the extratropical pattern (as a response to the tropical SST anomalies) is reasonable.

Summary and Conclusion

- International ensembles of coupled model simulations exhibit a subtle yet pervasive pattern of internal variability in the tropical Pacific at roughly the centennial time scale, which does not resemble canonical ENSO (and is even centered too far west for "Modoki").
- This mode of centennial-scale coupled variability was first identified using the relatively small number of long control runs from CMIP3 models, and was suggested to be modulated by random, low-frequency variability in ENSO amplitude. In CMIP5, the proliferation of sufficiently long control runs enabled further investigation of this pattern, and it appeared to be correlated with longstanding biases in the cold tongue (Samanta *et al.* 2018).
- This pattern is lurking in the full collection of CMIP6 models, and is readily detectable not only in the *piControl* simulations, but even in historical simulations amid significant external forcing.
- This is important to understand, even if it is just in models, because AGCM experiments demonstrate how the atmosphere has a heightened sensitivity to SST anomalies in western equatorial Pacific—right where this low-frequency variance occurs in coupled models (Zhang *et al.,* 2021).
- From these results, we cannot say anything about observations, but it seems to be a distinct possibility that there is ENSO and there is warm pool-driven variability. Or the models may be inadequately representing missing the physics underpinning variability at decadal and interdecadal that is distinguishable from that.

References

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