Rethinking the Ocean's Role in the Southern Oscillation

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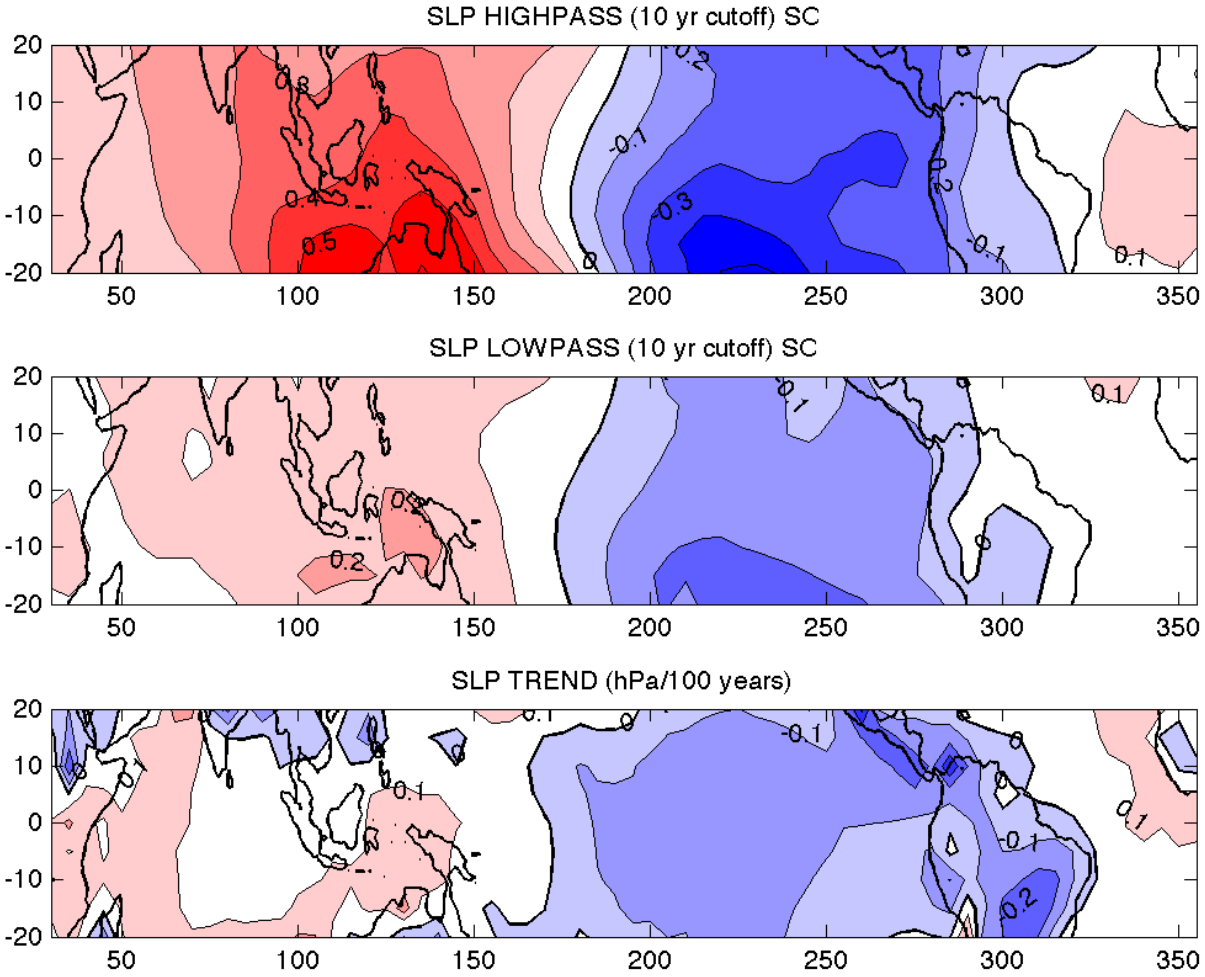
Patterns of Pacific Sea Level Pressure (SLP) variability on different timescales

Regression of SLP on normalized SOI – ***interannual timescale***

… ***decadal timescale (10 yr low pass filter)***

20th century trend of SLP (Vecchi et al. 2006, Deser et al 2010)



Is dynamical coupling between the ocean and atmosphere fundamental on all timescales?

Methodology

- Climate models with different degrees of coupling with the ocean (CMIP3)

  1. Forced with climatological SST

     Uncoupled

  2. Coupled to a SLAB ocean mixed layer (50 m)

     Thermodynamical coupling but
     No interactive ocean dynamics

  3. Coupled to a full ocean GCM

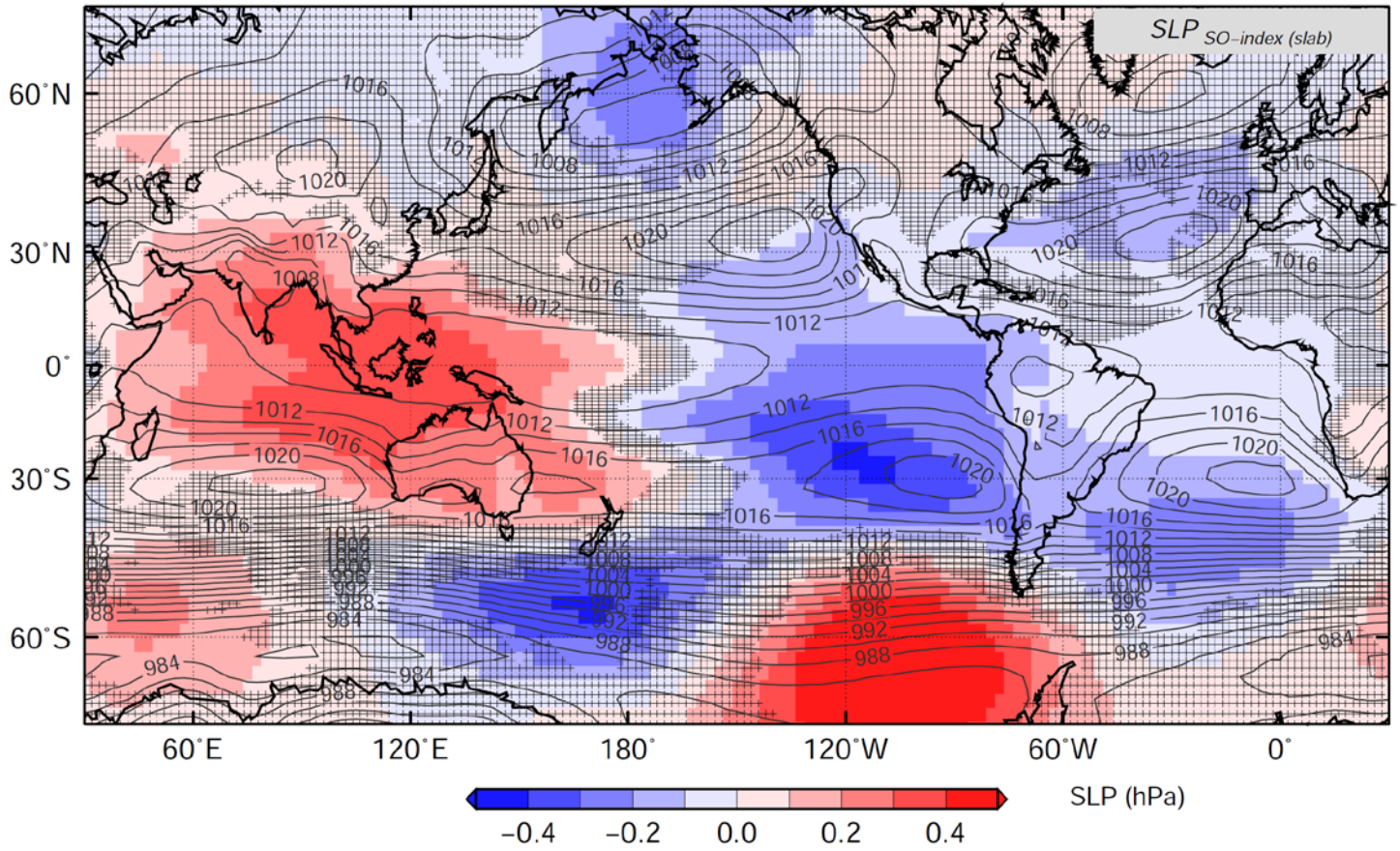
     Fully coupled

- Control experiments + 21st century simulations

- 13 different AGCMs- multi-model mean fields show structures that are not sensitive to the details of parameterizations

Thermally Coupled Walker Mode*

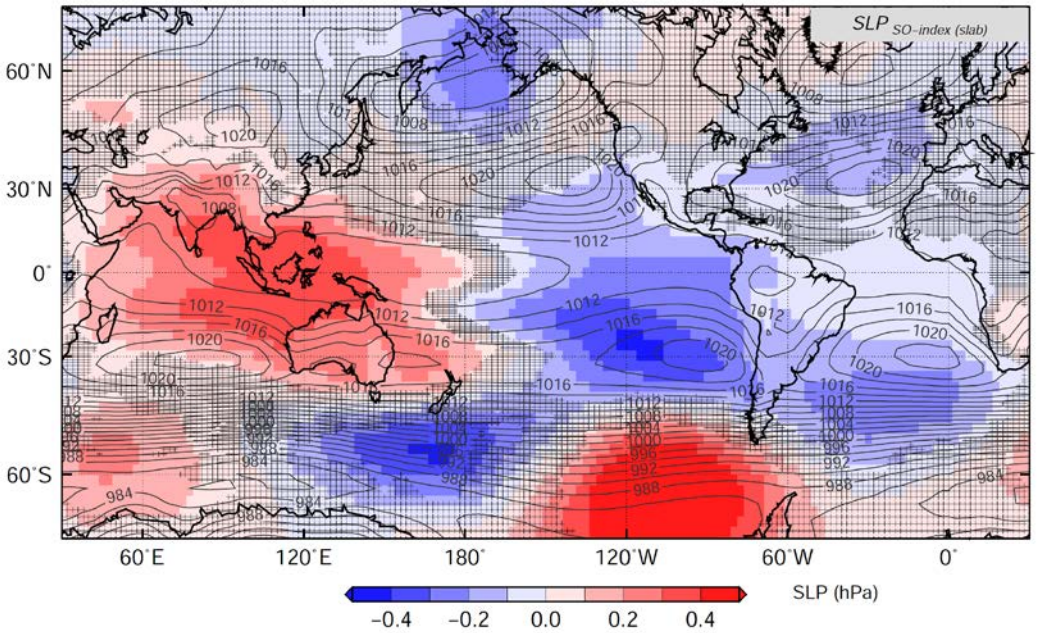
AGCM-slab multi-model mean (13 models) regression on SO Index**



* This pattern is the dominant EOF of tropical Pacific SLP variability in SLAB models
* This pattern does NOT emerge from AGCM forced by climatological SST

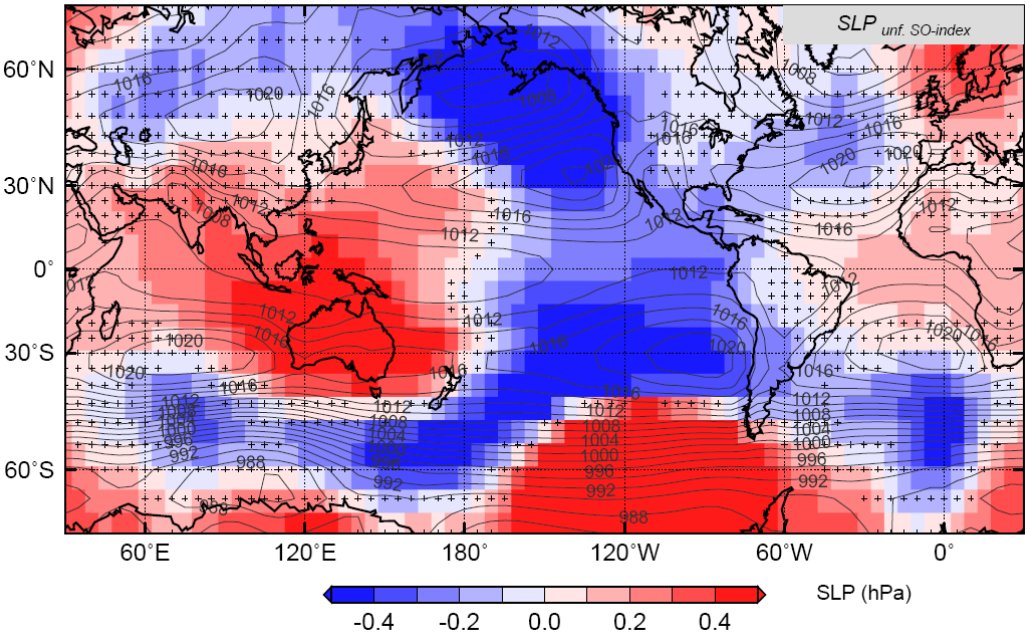
**stippling shows areas where < 10 out of 13 models agree in sign- i.e not robust

AGCM-slab multi-model mean (13 models) regression of SLP on SO index



HadSLP: SLP regression on unf. SO-index

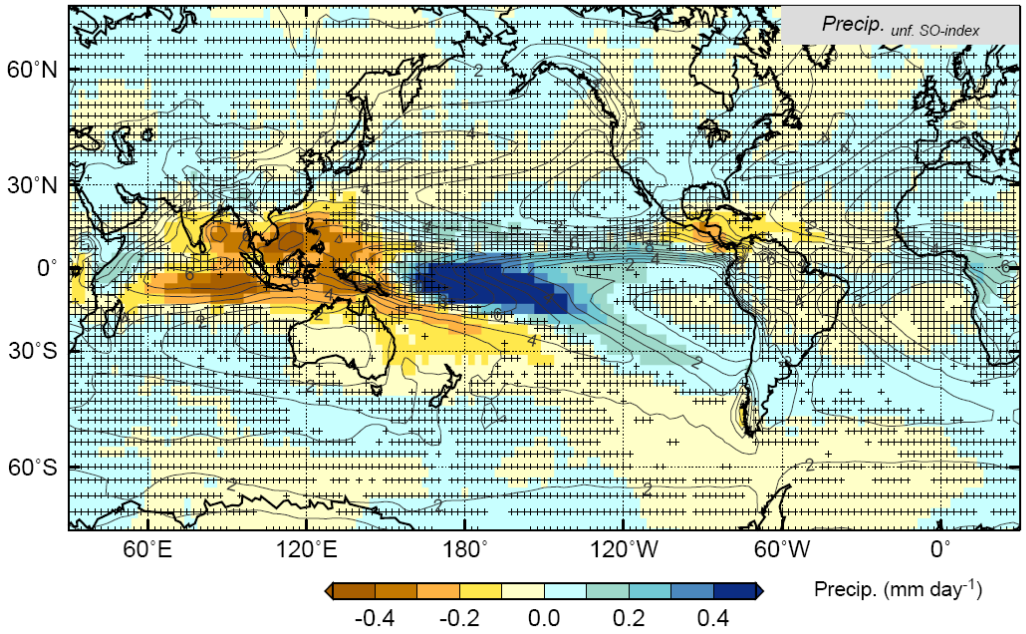
Observed regression of SLP on normalized SO index



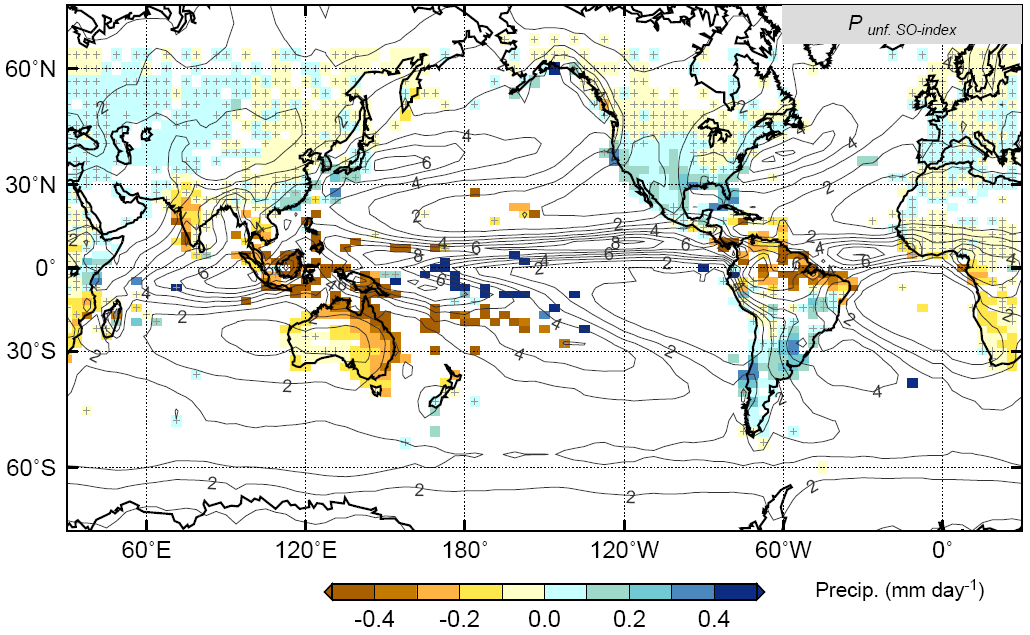
AGCM-slab multi-model mean (13 models) regression of precip on normalized SO index

Observed regression of GPCP precip (Adler et al. 2003)

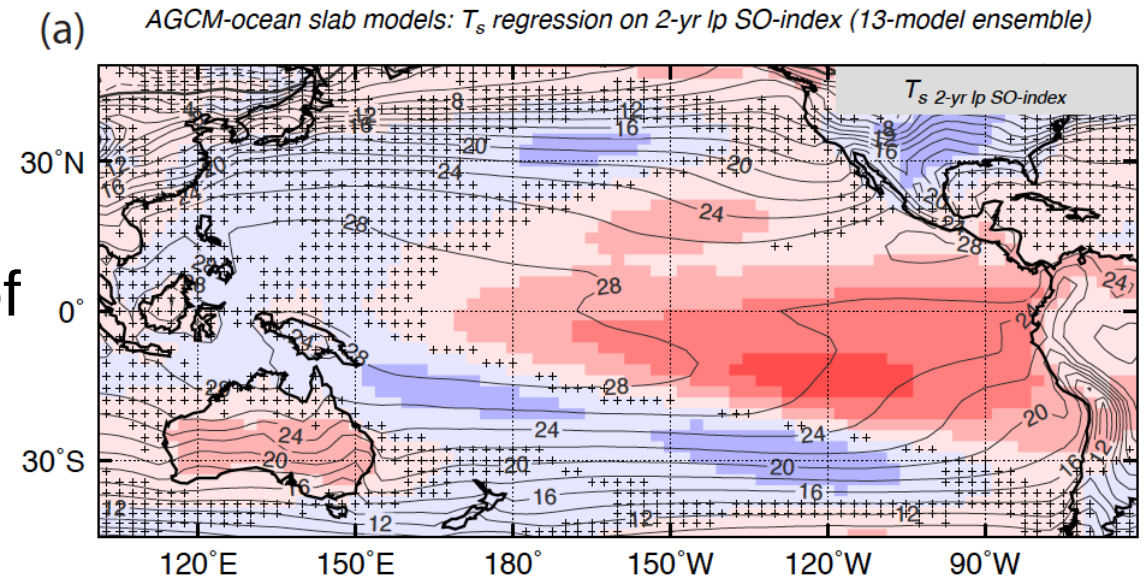
AGCM-ocean slab models: Precip. regression on unf. SO-index (13-model ensemble)



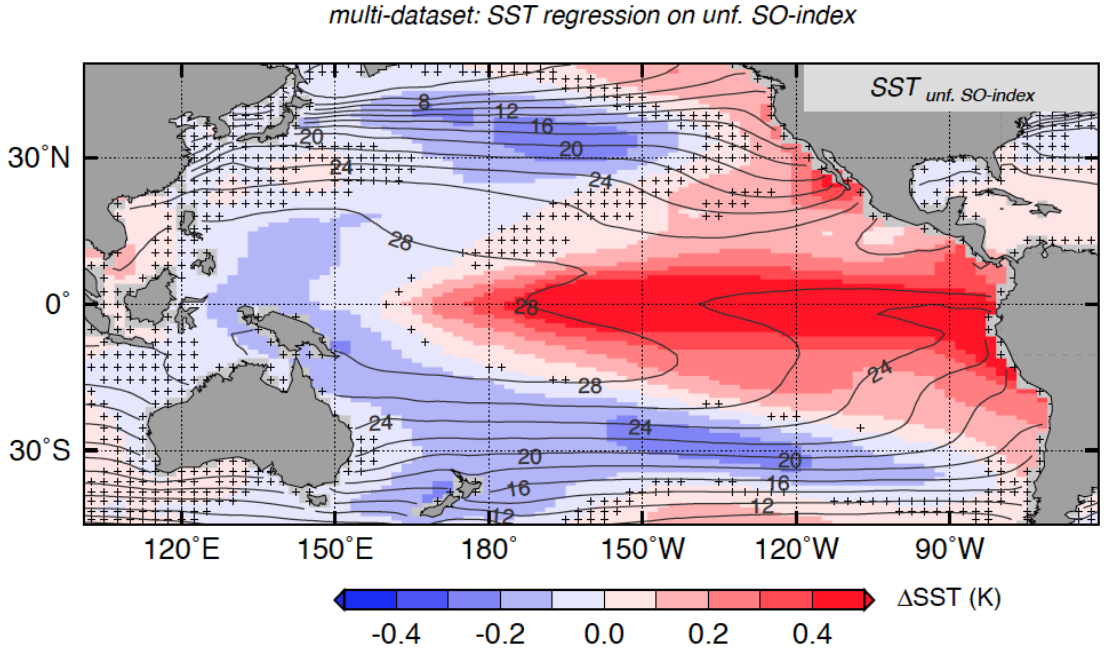
Hulme: P regression on unf. SO-index



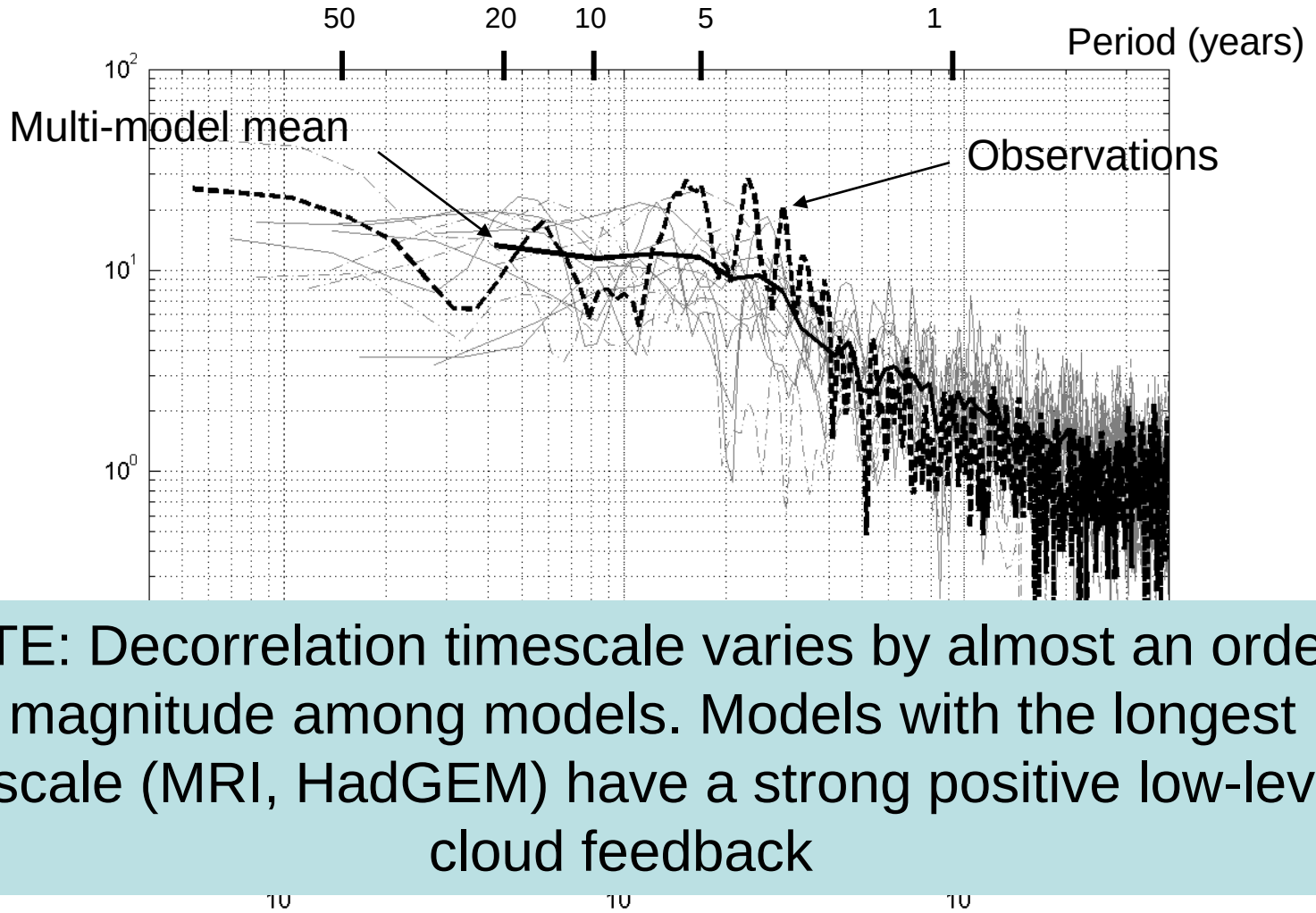
AGCM-slab multi-model mean (13 models) regression of SST on SO index



Observed regression of SST on normalized SO index



SO spectra from 13 AGCM-slab models

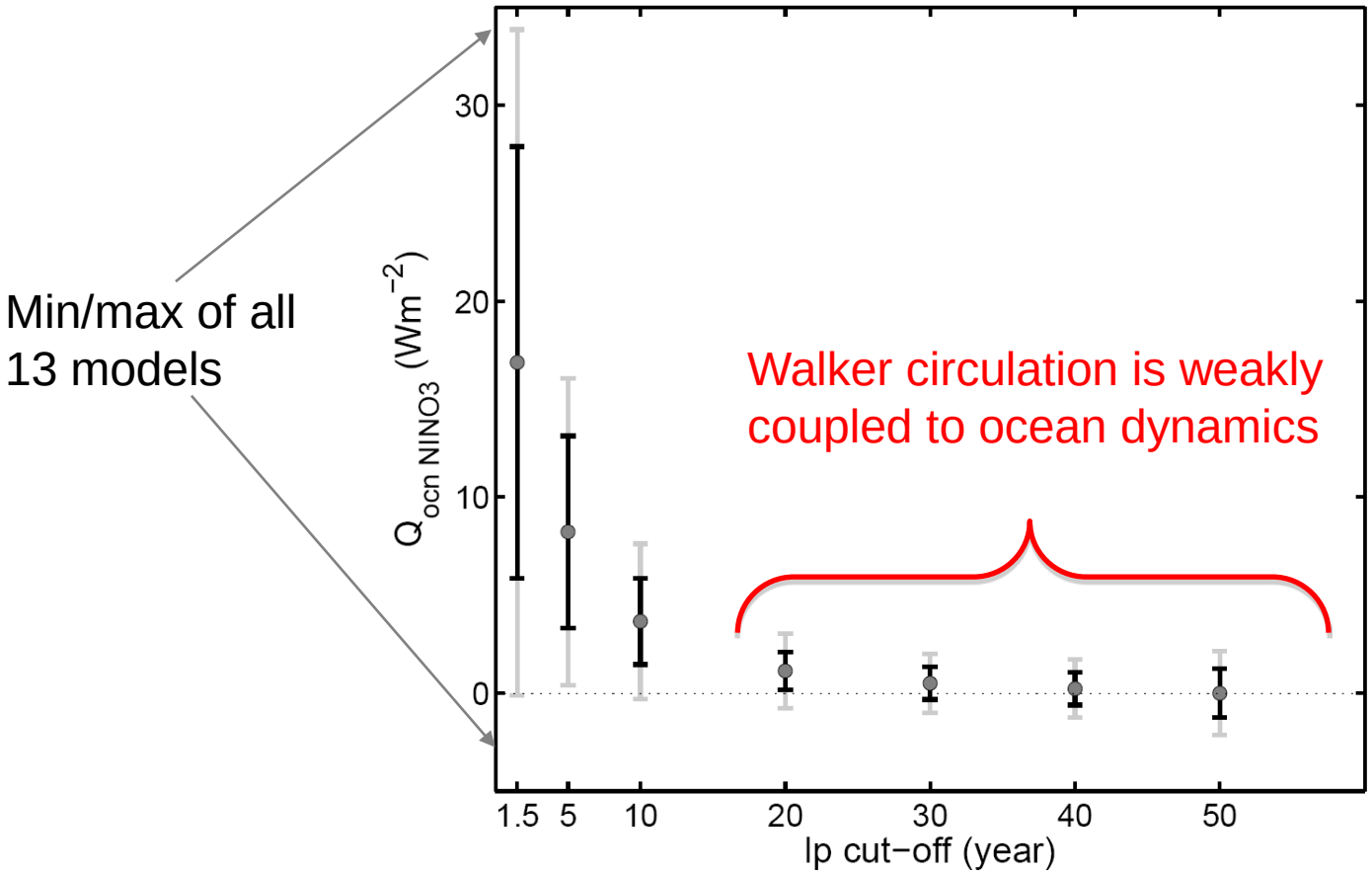


NOTE: Decorrelation timescale varies by almost an order of magnitude among models. Models with the longest timescale (MRI, HadGEM) have a strong positive low-level cloud feedback

Observed std deviation of SO index = 80 hPa

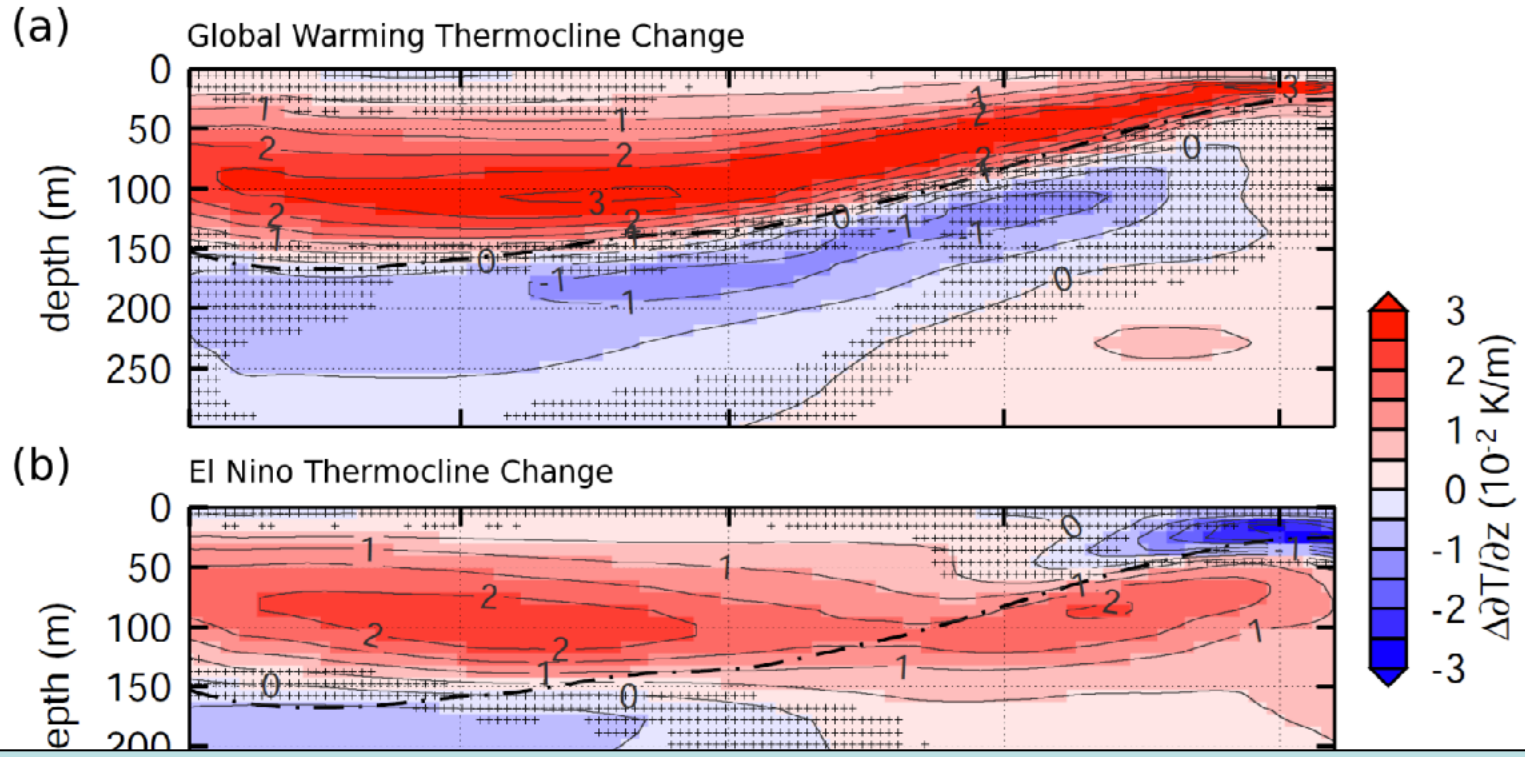
Multi-model mean std deviation = 50 hPa

Coupled GCMS: Contribution in models of ocean heat transport to NINO3 growth on different timescales



On a decadal timescale, thermocline fluctuations are small in east because of cancellation between tilt and recharge modes (Clarke 2010)→ limited Bjerknes feedback

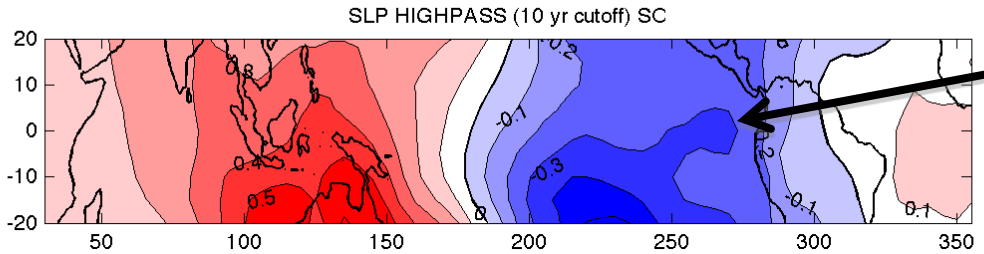
Thermocline response to greenhouse gas forcing is not El Nino-like



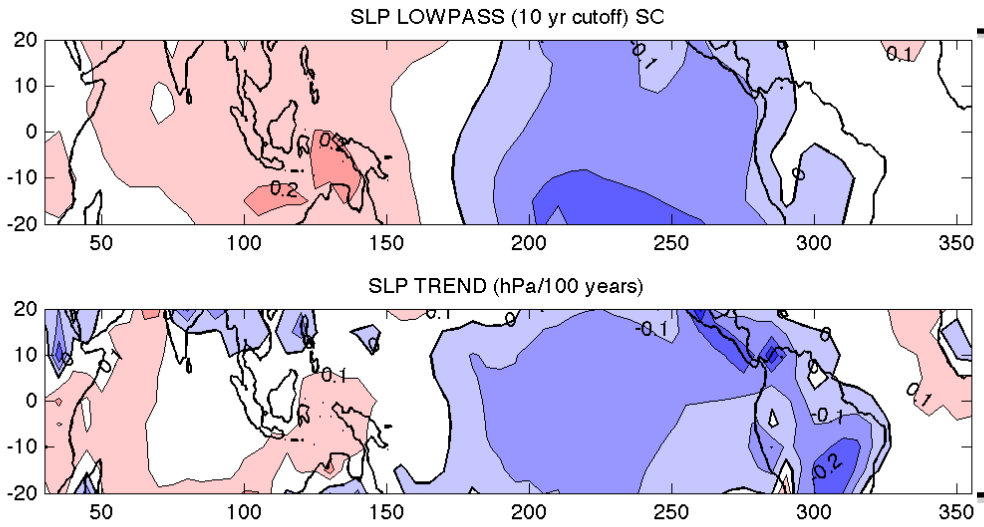
Shoaling and sharpening of the thermocline cools east Pacific in response GHG forcing: WEAKLY COUPLED WALKER CIRCULATION

DiNezio et al. (2009, 2010)

Summary: Is dynamical coupling between the ocean and atmosphere fundamental on all timescales?



This pattern emerges on interannual/decadal timescales without coupled dynamics.



Weakly Coupled Walker Circulation:

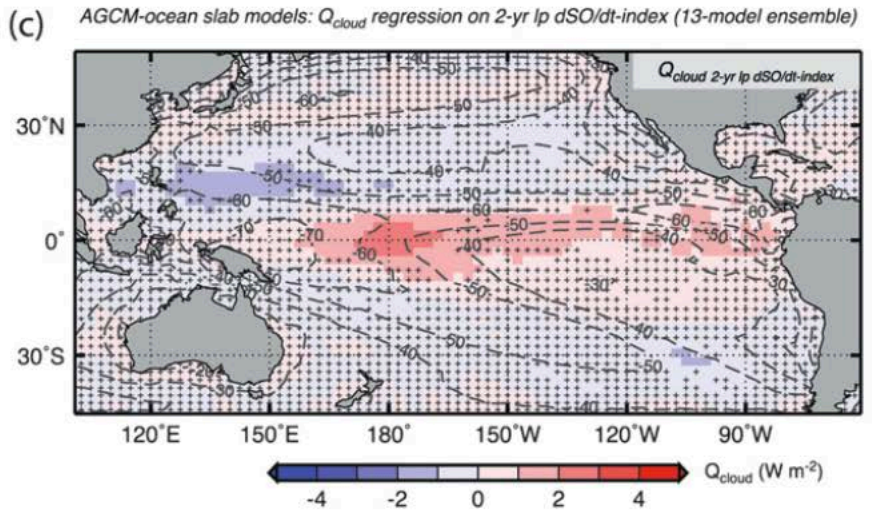
Decadal timescale: The thermocline damps variability in the central Pacific with little change in the east limiting the coupled feedback (Clement et al. 2011)

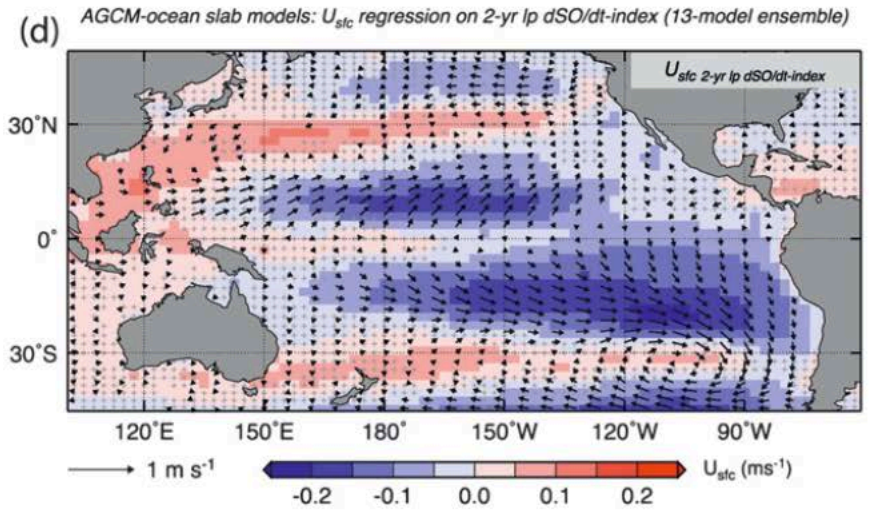
Anthropogenic forcing: The thermocline sharpens which limits warming in the east/central Pacific (DiNezio et al. 2009)

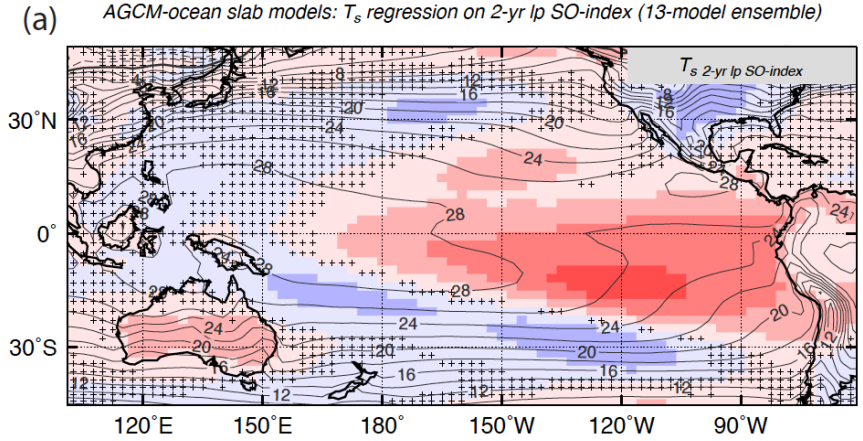
Concluding remarks

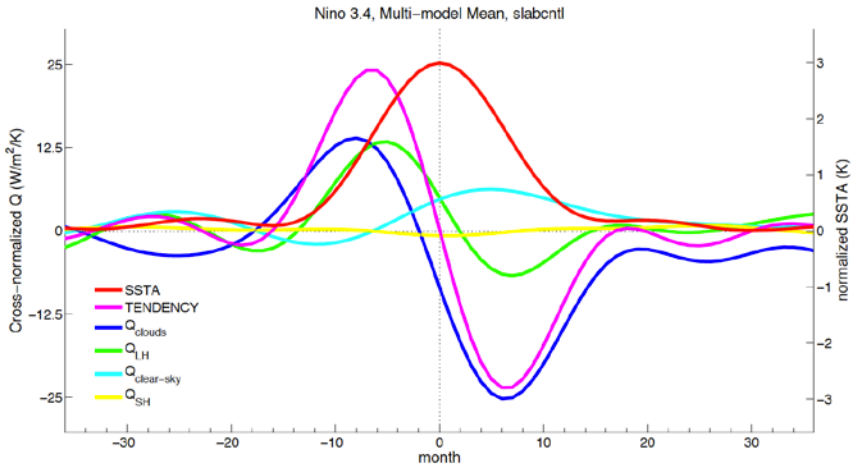
- Timescale of SO is unconstrained by current models- role of clouds??
  → Implications for detection/attribution
- Hierarchy of models

A cloud recharge mechanism?









H. Zhang et al. (in prep)

Support from ocean reanalysis

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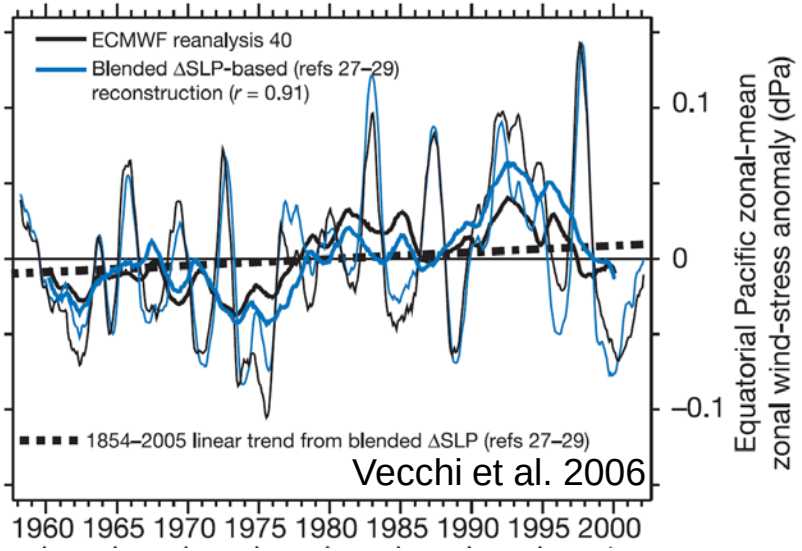
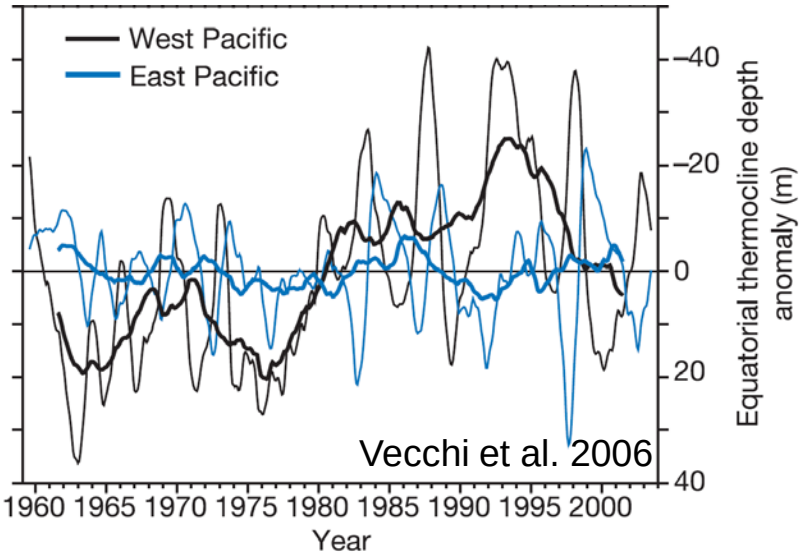
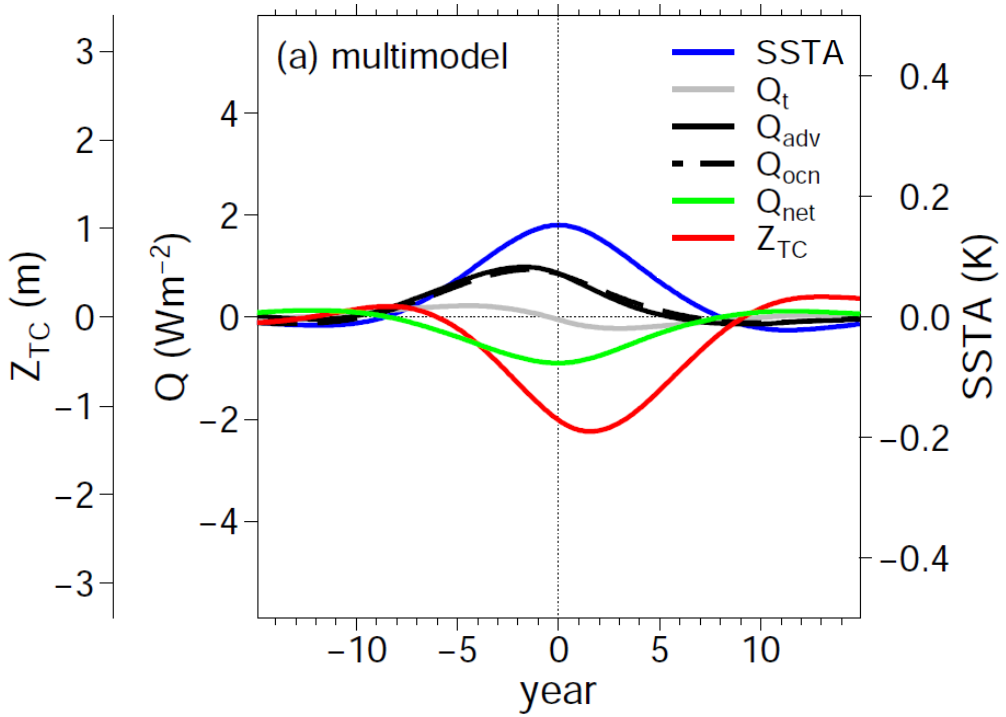


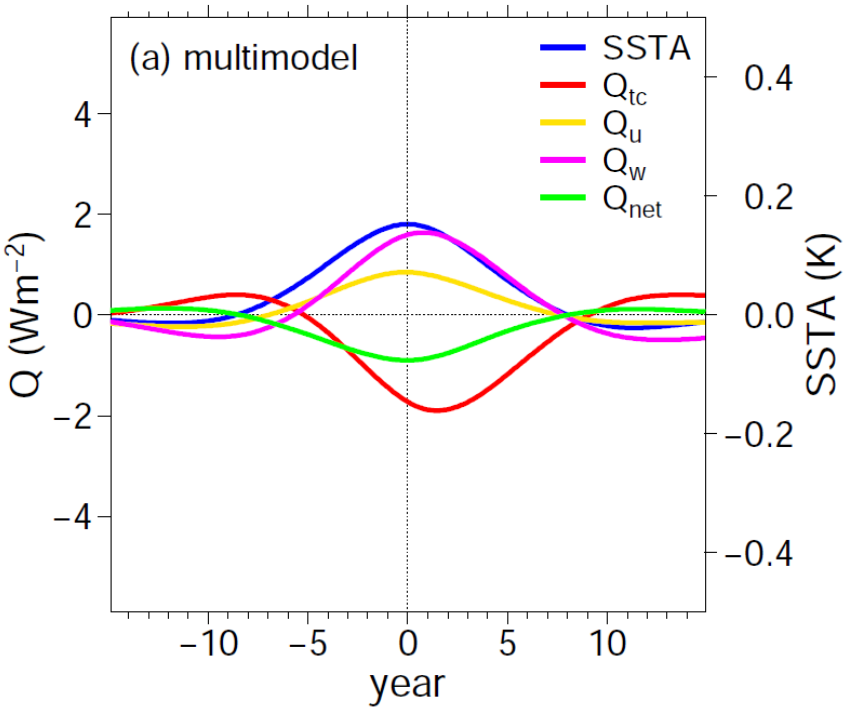
Thermocline depth in the east (blue) and west (black)



On a decadal timescale, thermocline fluctuations are small in east because of cancellation between tilt and recharge modes (Clarke 2010). In the west and central-west (Nino3.4), they are additive and signals are large.

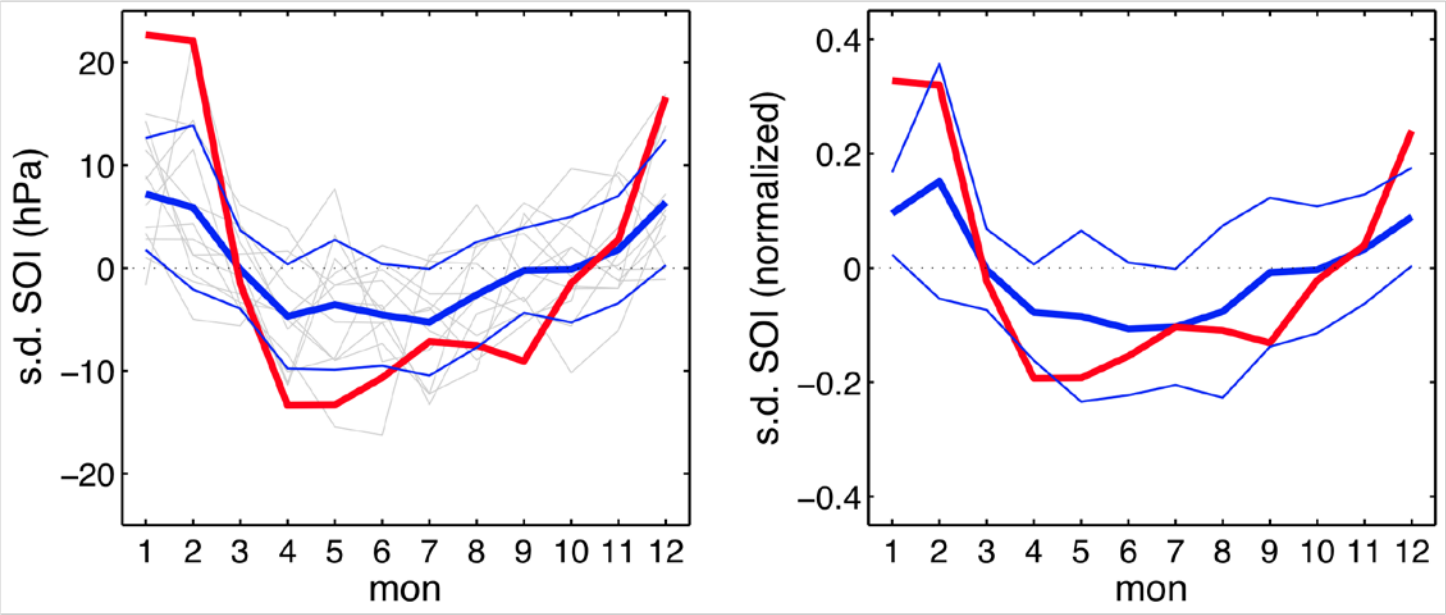
Composites of NINO3.4 evolution in coupled climate models





- Zonal advection and upwelling contribute to growth on decadal timescales.
- Thermocline is damps on decadal timescales.

DiNezio et al. *In prep*



Seasonality of the standard deviation of the SOI in the slab-ocean AGCM models (thin gray lines) and observations (red line). The mean standard deviation for all months is removed from each individual model in order to emphasise the seasonality. The multi-model mean and 1-sigma envelope are shown by the blue lines. Observations correspond to the HadSLP analysis. The climatological monthly mean seasonal cycle is removed from the SOI before computing the standard deviation for each calendar month.