Pacific ENSO-like variability: The timescale-dependent role of ocean dynamics

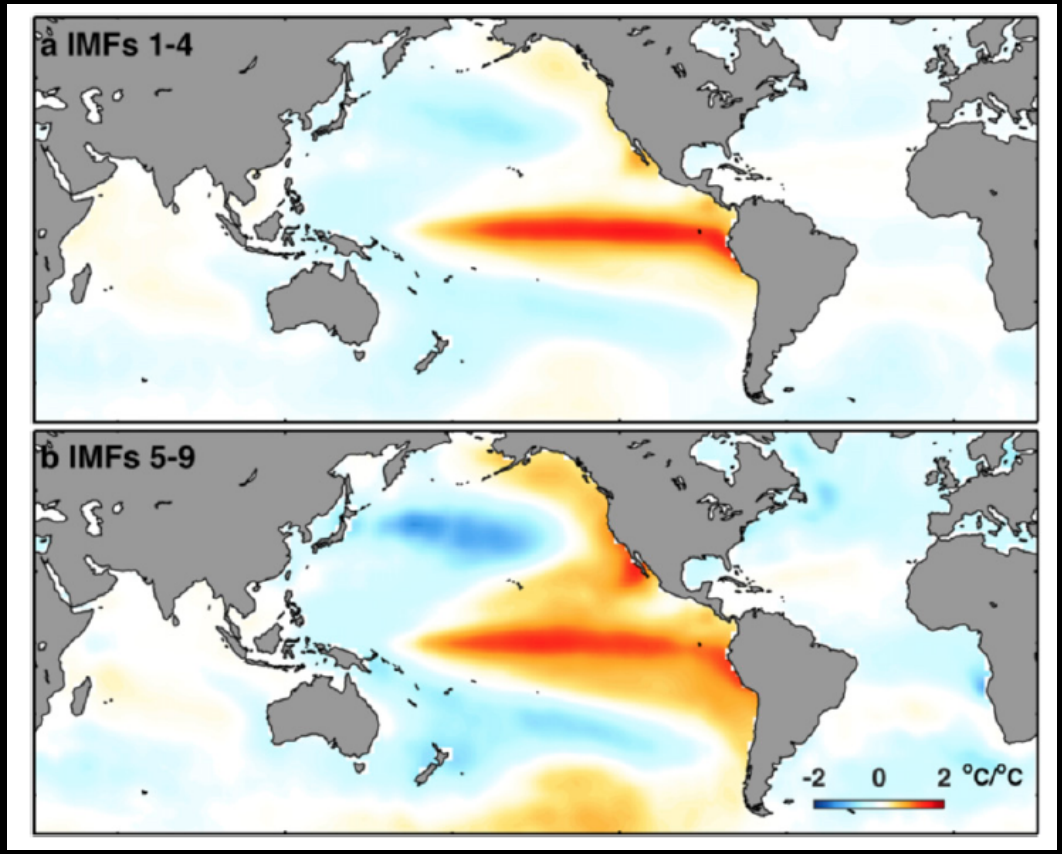
Amy Clement

With contributions from Pedro DiNezio, Katinka Bellomo, Eleanor Middlemas, Honghai Zhang, and Clara Deser

Observed ENSO-like variability (Chen and Wallace 2015)

< 6 year

> 6 year



Are the mechanisms that produce this variability physically analogous?

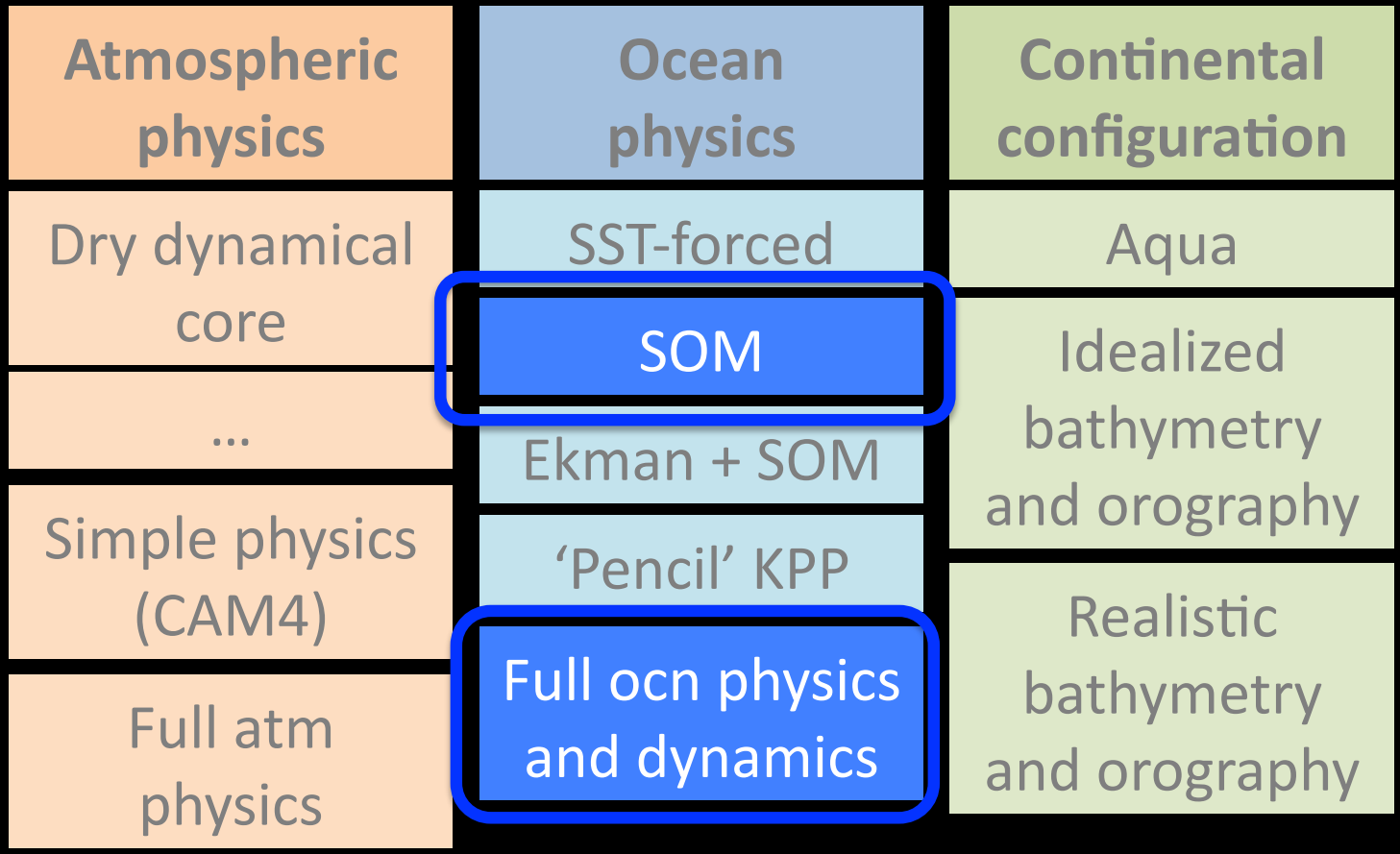
Is there some decadal predictability?

Testing with a (part of) a climate model hierarchy

Atmospheric physics	Ocean physics	Continental configuration
Dry dynamical core	SST-forced	Aqua
…	SOM	Idealized bathymetry and orography
Simple physics (CAM4)	Ekman + SOM	
Full atm physics	‘Pencil’ KPP	CLM+ Realistic bathymetry and orography
	Full ocn physics and dynamics	

Schematic inspired by Pedro DiNezio
(who is developing a version of CESM with aqua/idealized bathymetry)

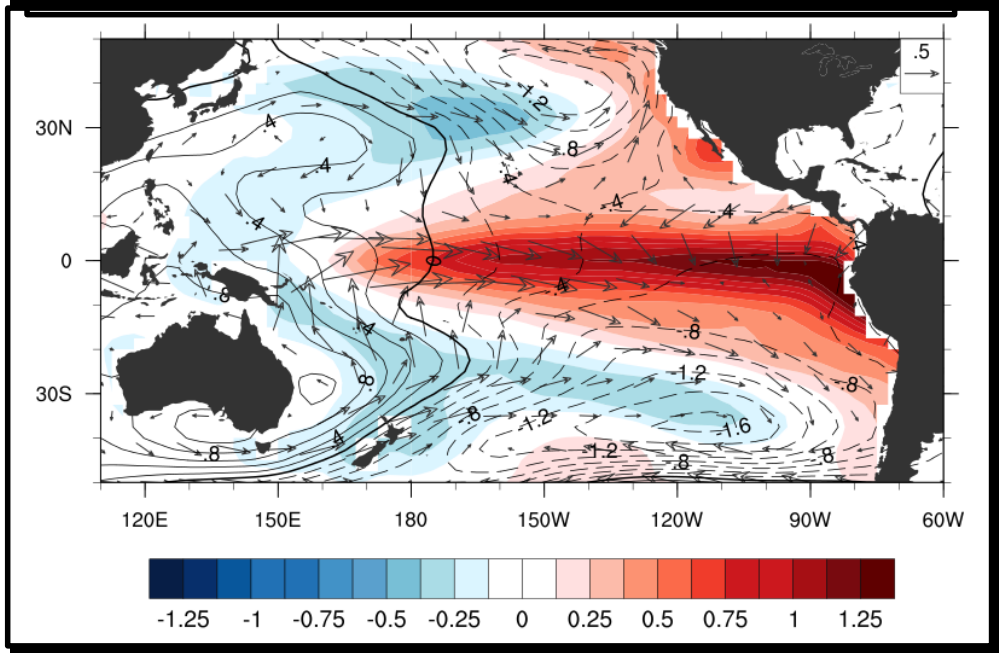
Testing with a (part of) a climate model hierarchy



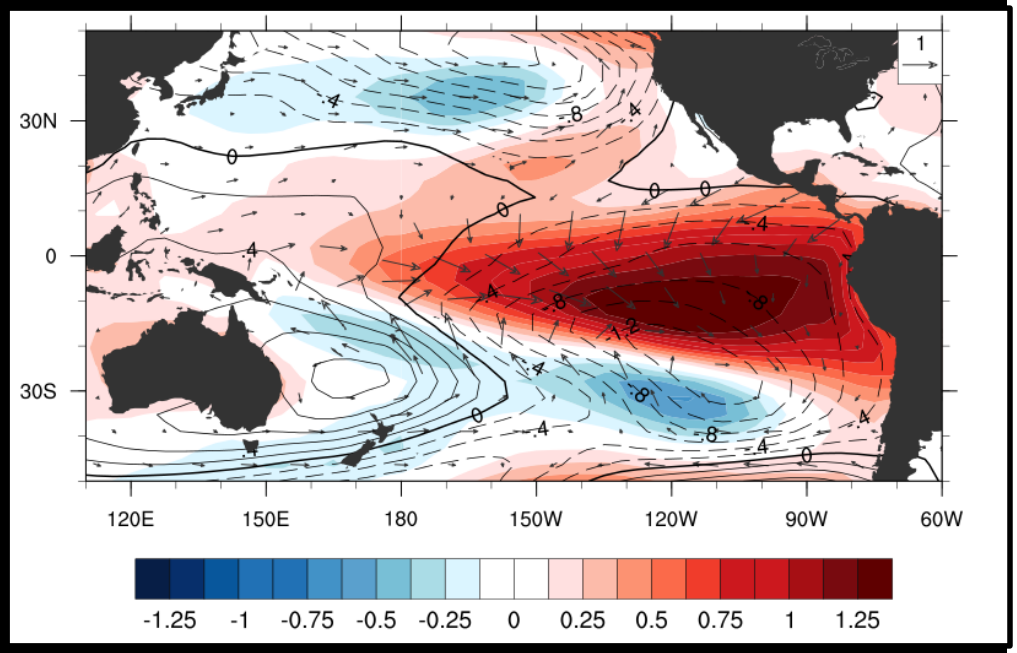
Schematic inspired by Pedro DiNezio
(who is developing a version of CESM with aqua/idealized bathymetry)

ENSO-like variability is a robust feature of AGCM-slab ocean models

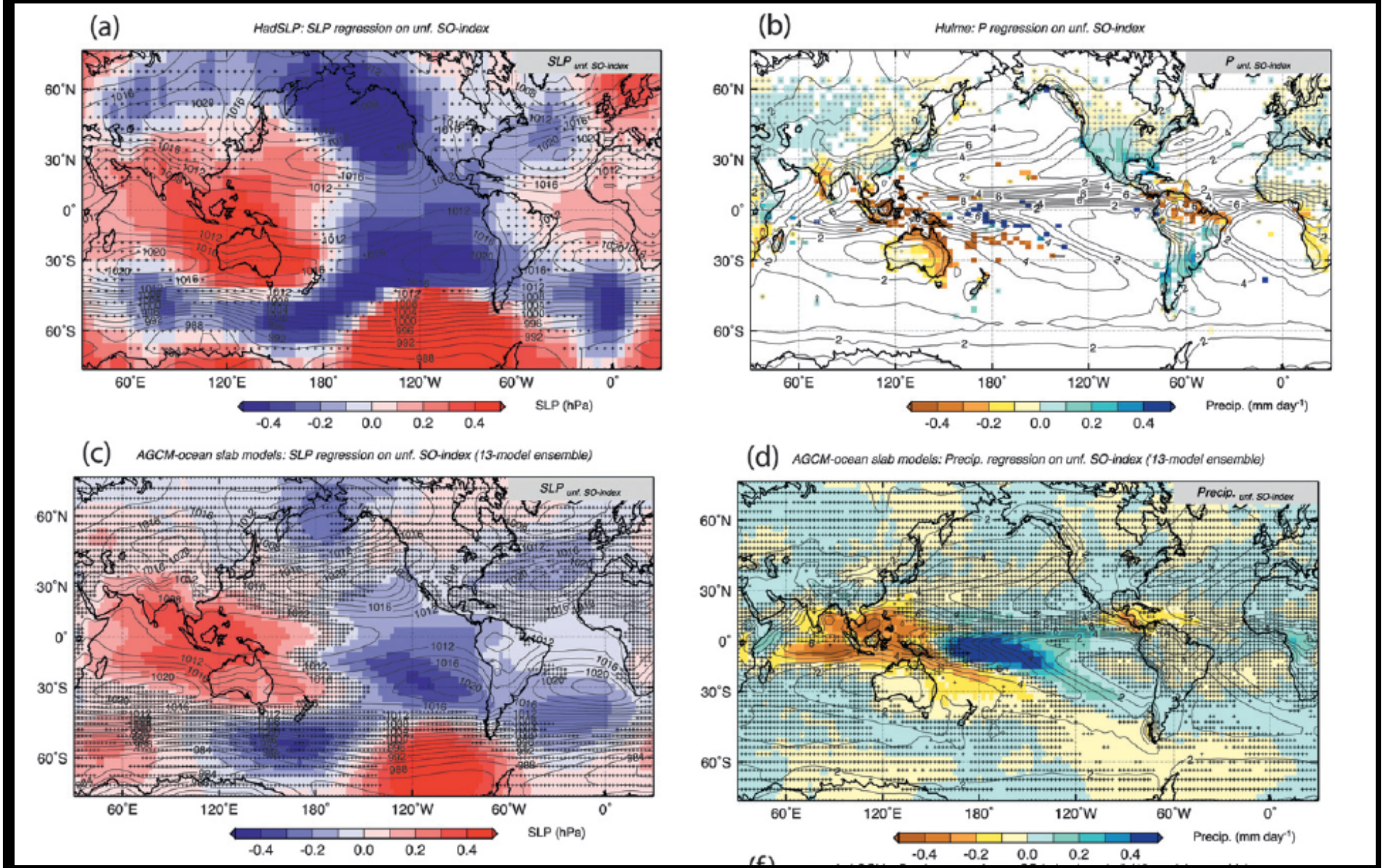
Observations: Regression on unfiltered SO index



Multi-model mean of 10 AGCM – slab ocean models



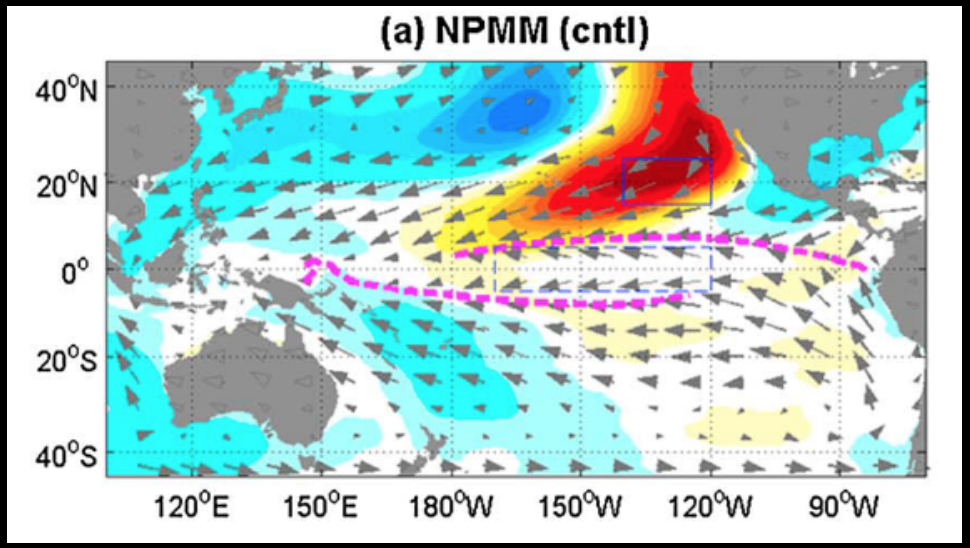
Clement, DiNezio, Deser (2011)



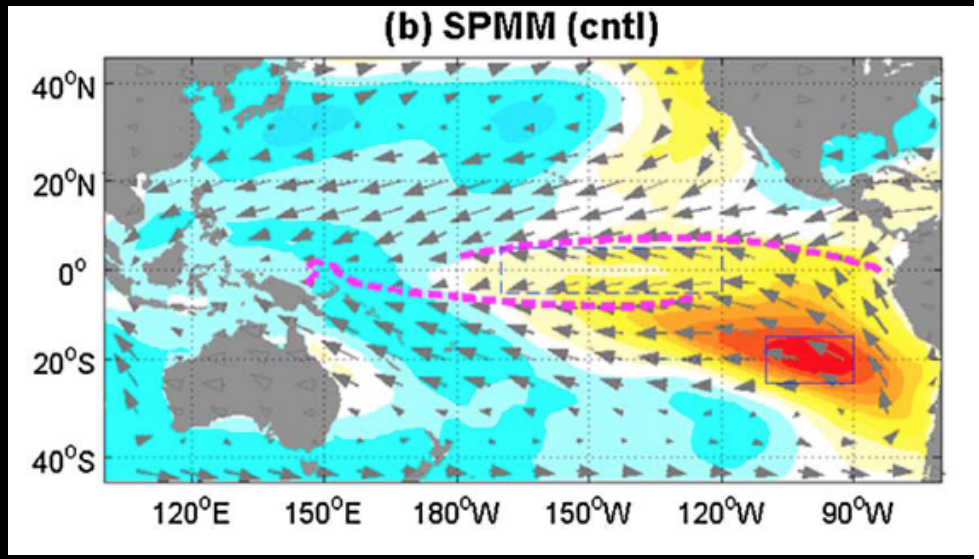
Clement, DiNezio, Deser (2011)

AGCM-SOM Mechanism: Equatorial extension of meridional modes

Regression of SST on NE Pacific index



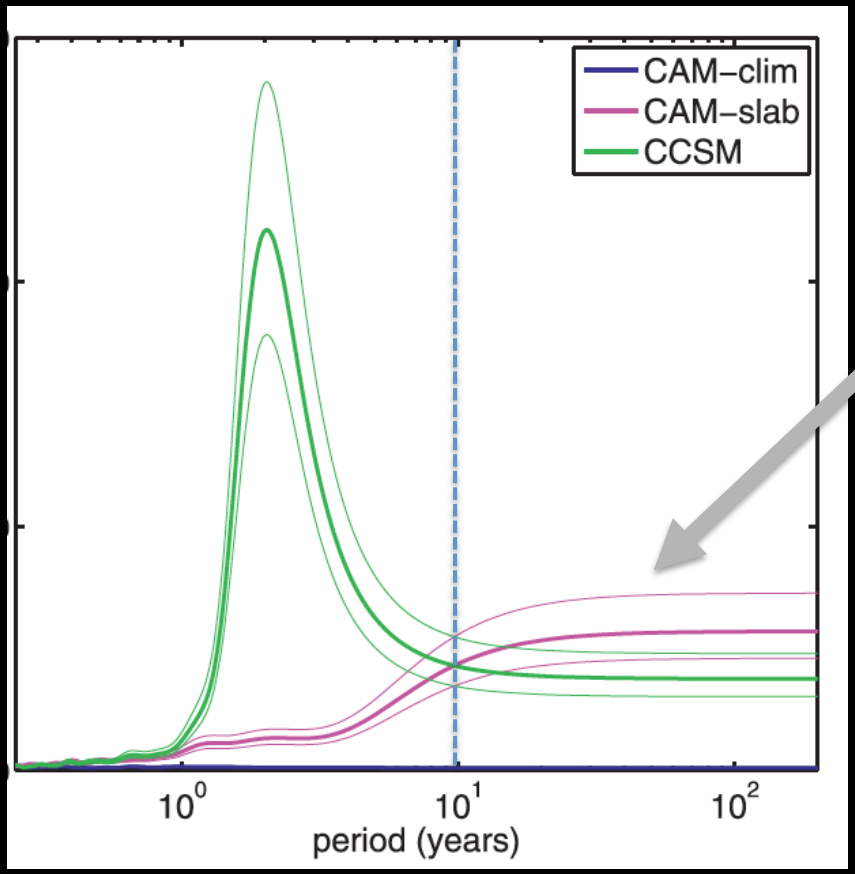
Regression of SST on SE Pacific index



Zhang et al. 2014a, 2014b

Differing ocean roles on interannual and decadal+ timescales in the Pacific

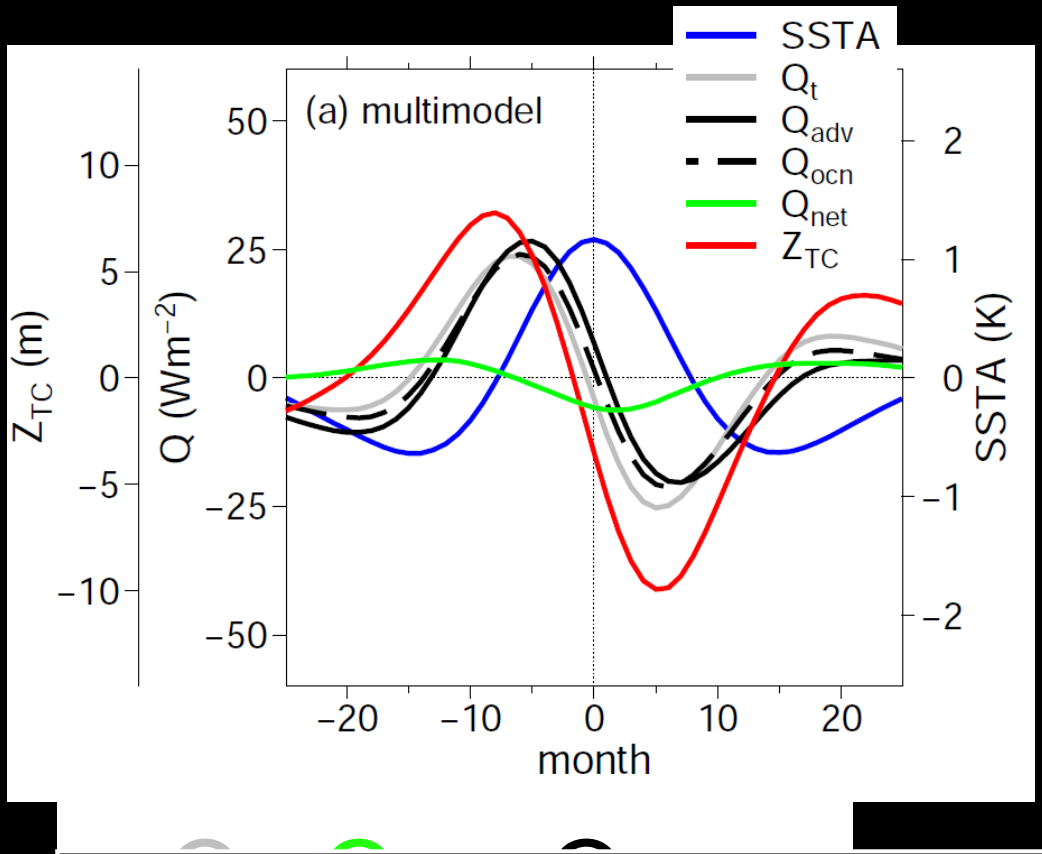
Spectra of SO index

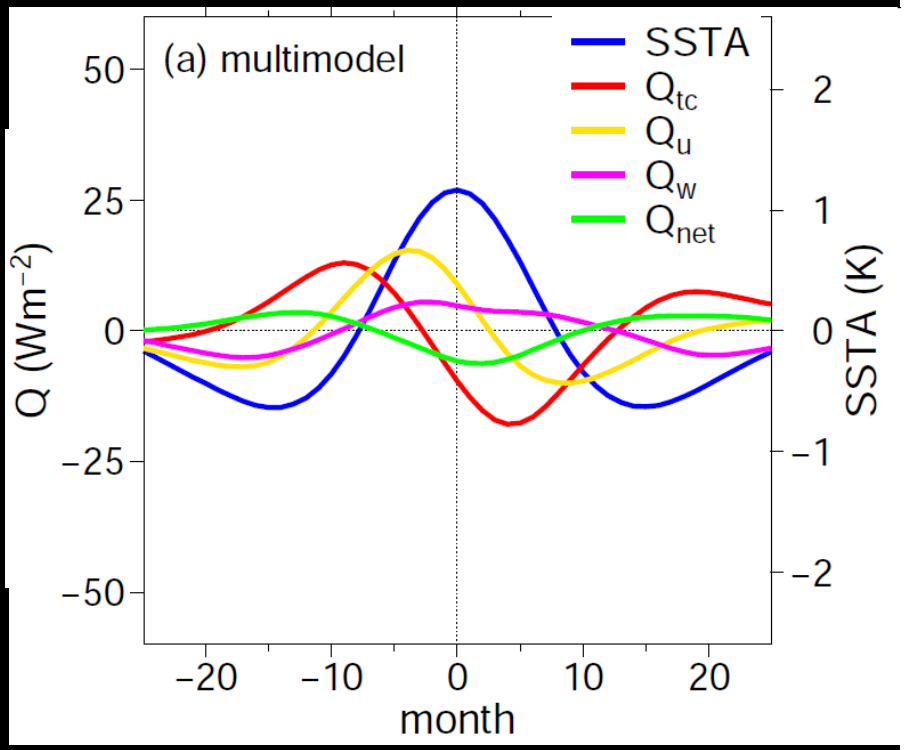


Is this the same thing in slab and coupled models?

Answer: almost

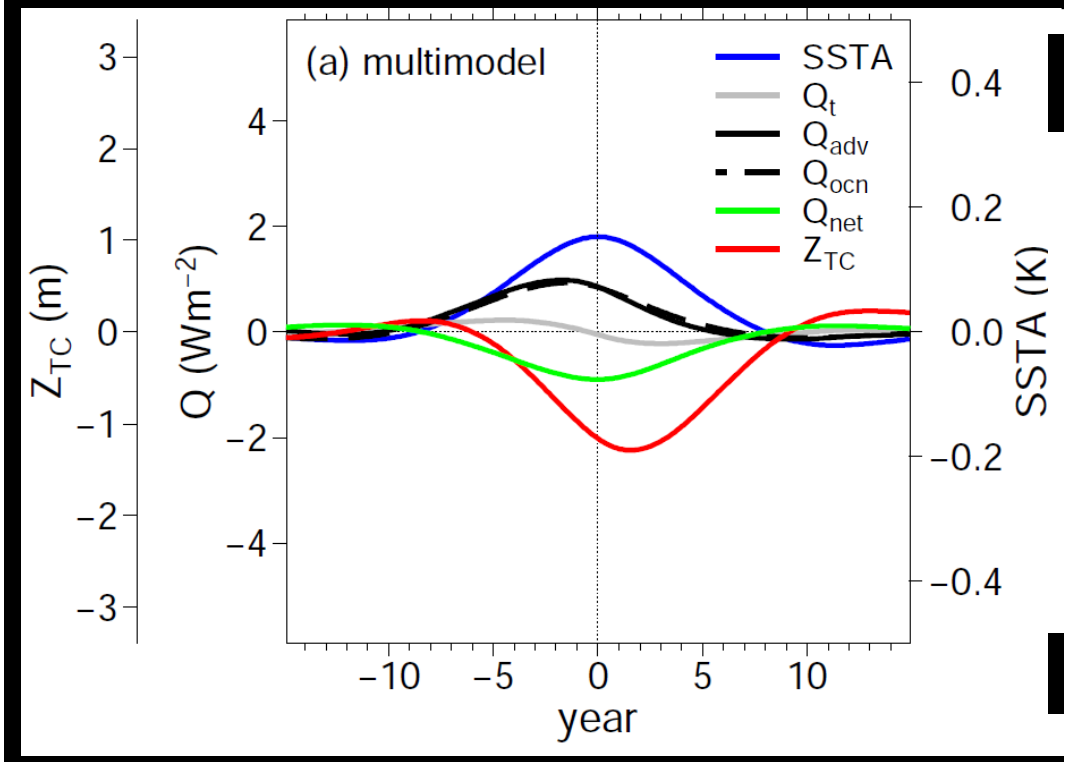
Lead-lag relationships on interannual timescales

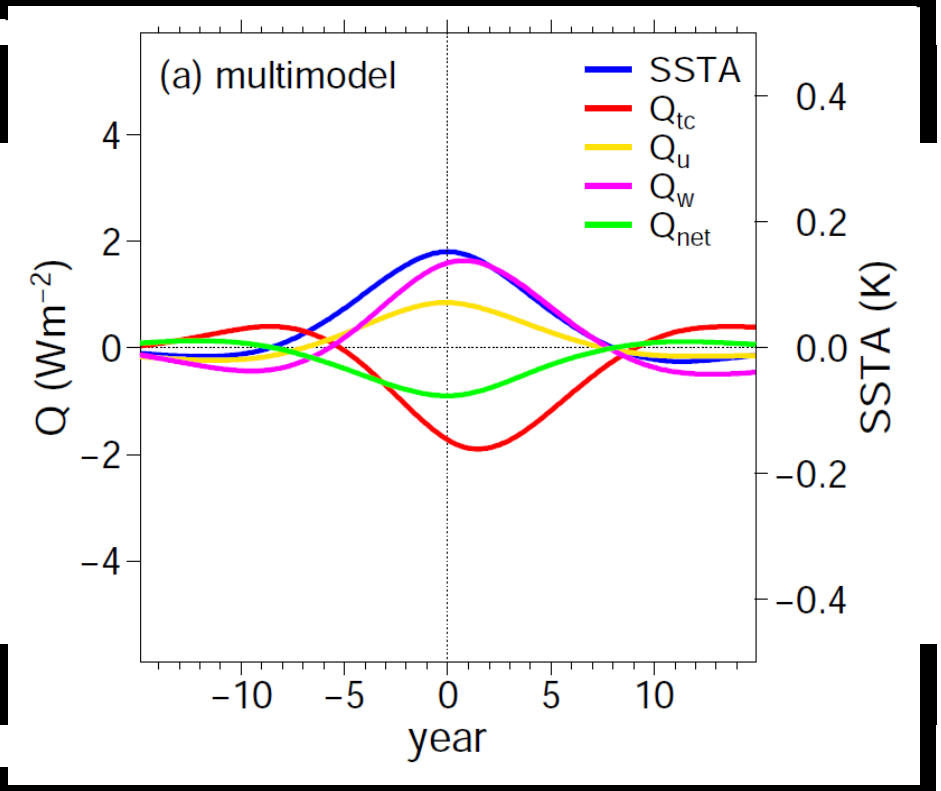




- Deepening of thermocline (recharge) initiates the development of ENSO events.
- Zonal advection contributes once the winds weaken.
- Lesser role for upwelling.
- Themocline shoaling (discharge) drives the transition from warm to cold phase.

Low frequency composites





$$Q_t = Q_{net} + Q_{ocn}$$

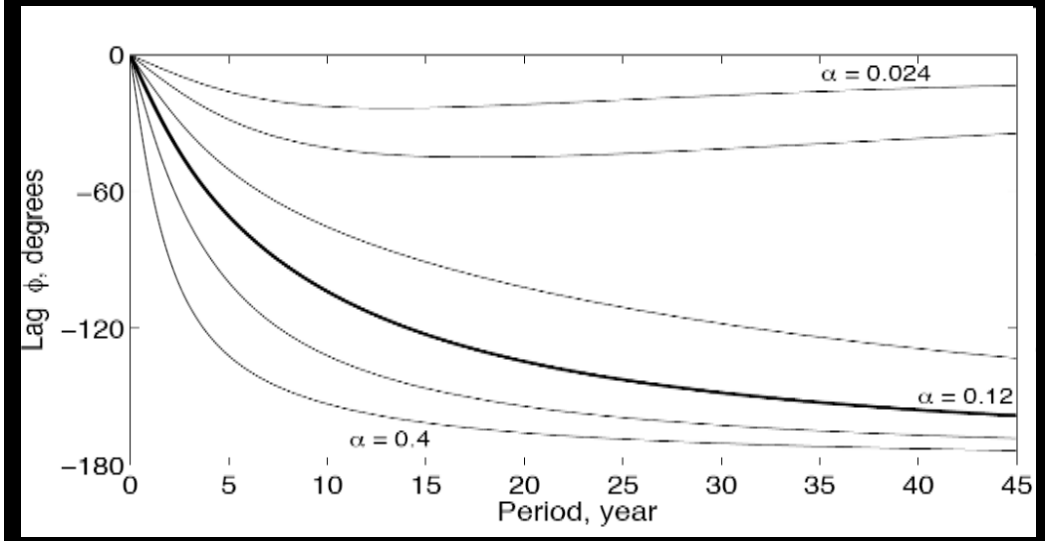
$$Q_{net} \sim Q_{ocn}$$

Thermocline opposes zonal advection and upwelling on decadal timescales.

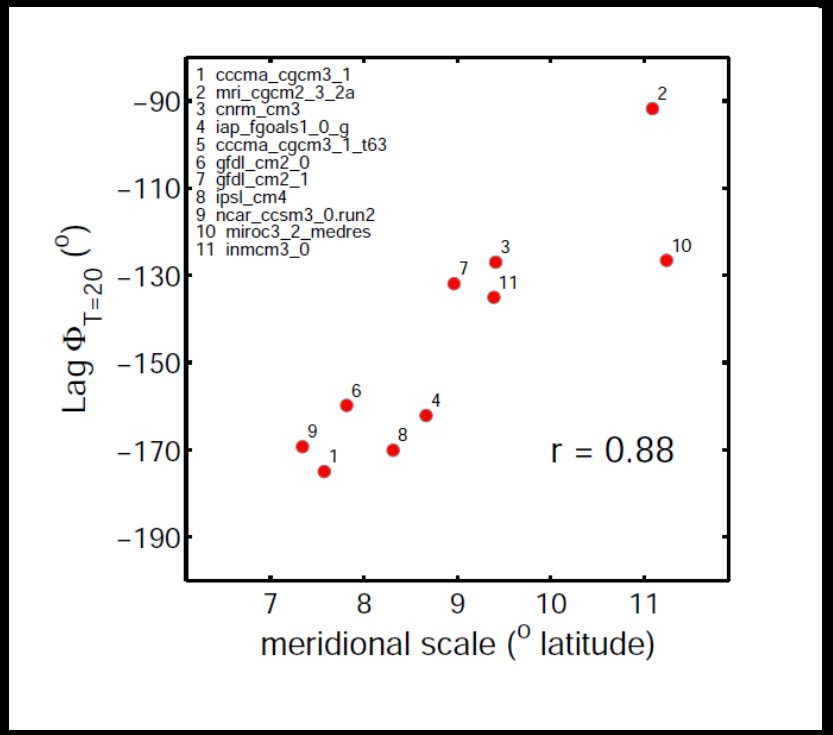
DiNezio et al., in prep.

At what timescale does the thermocline become a damping? When it lags winds by 180°

The phase lag between variations in the temperature of the eastern equatorial Pacific and the mean thermocline depth



CMIP3 model dependence of meridional scale and phase lag

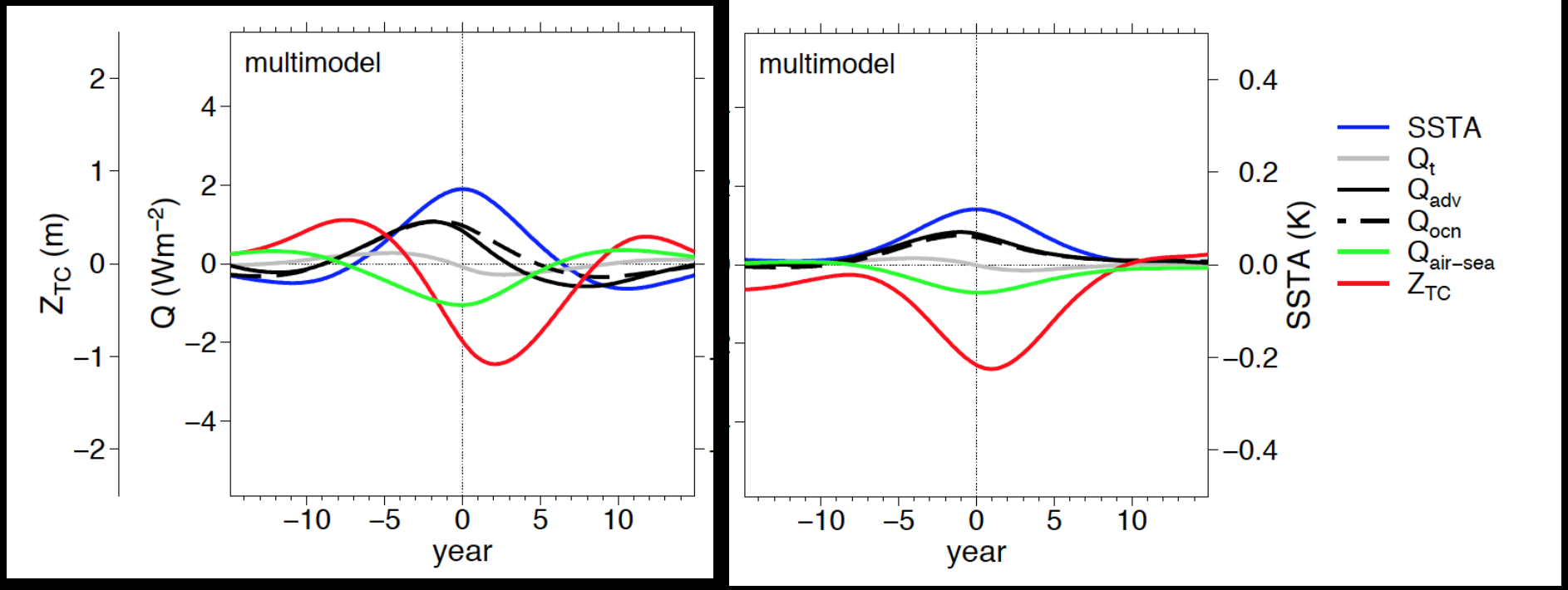


Fedorov 2010

Low-pass leads?

Models with wide winds

Models with narrow winds

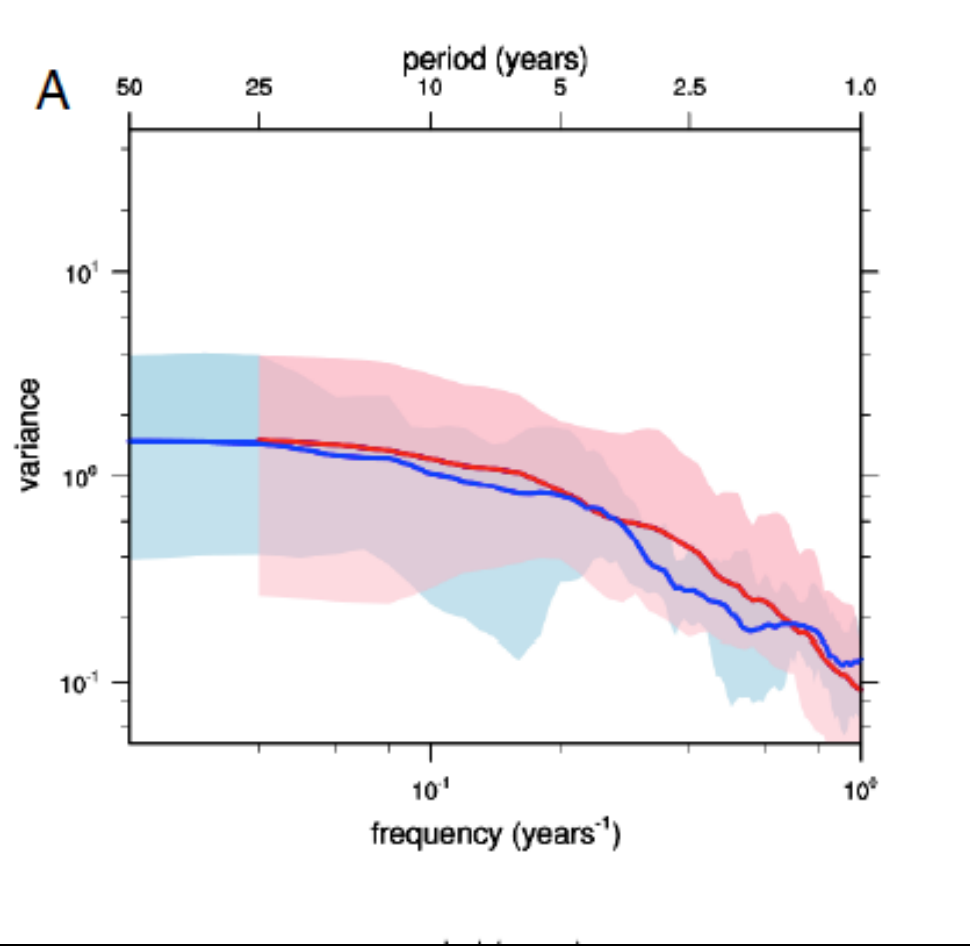


DiNezio et al., in prep.

Conclusions

- ENSO-like variability is a robust feature of AGCM-slab ocean models. It is the equatorial extension of meridional modes and requires no ocean dynamics.
- The role of the ocean depends on a timescale:
  - At seasonal-interannual, there are clear leads and lags and thermocline drives transitions
  - At low frequencies (long compared to the adjustment timescale of the thermocline), the thermocline opposes upwelling and zonal advection → little net ocean dynamical influence and the coupled model is similar to the slab
  - But models with broad meridional scale may have some low frequency *predictability*?
- The story is different in the Atlantic ….

AMO index (average NA SST) in CMIP3 slab models (red) and CMIP3 coupled models (blue)



Clement et al. 2015