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Trends in the IOD in the past decades

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CSIRO

Outline and conclusions

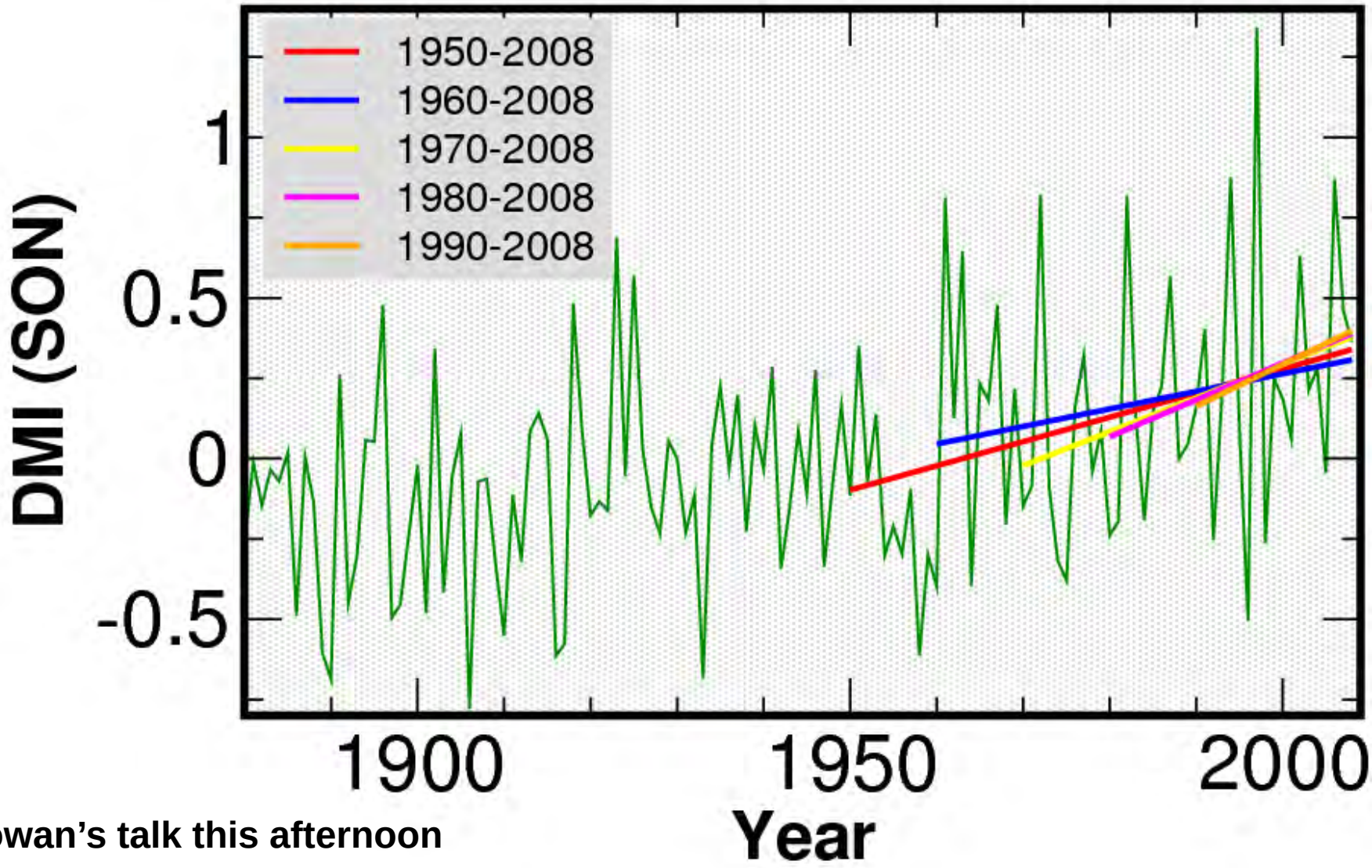
- There is an increase in the frequency of positive Indian Ocean Dipole events, with a consistent mean state trend

- 20th century climate experiments suggest that climate change is contributing to the increase.

- Although factors contributing to the mean state are less difficult to identify, the response of the associated feedback processes is not clear

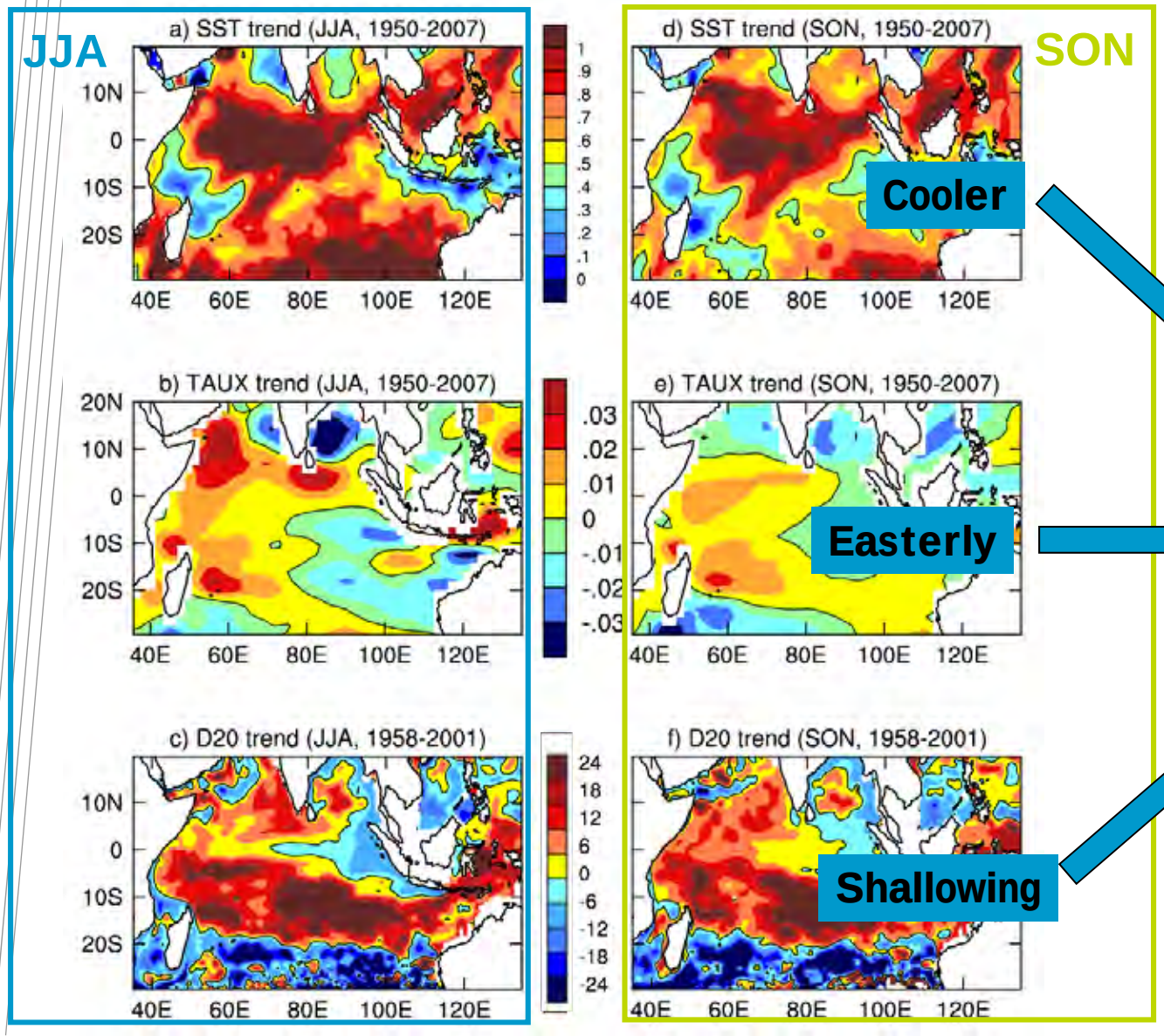
(*nonlinear dynamical feedback, SST-cloud-radiation feedback, thermocline-SST feedback, winds to SST, and thermocline to winds).*

Unprecedented high number of pIODs, low number of nIODs



Cowan's talk this afternoon

Mean circulation conditions since 1950s



Cooler

Easterly

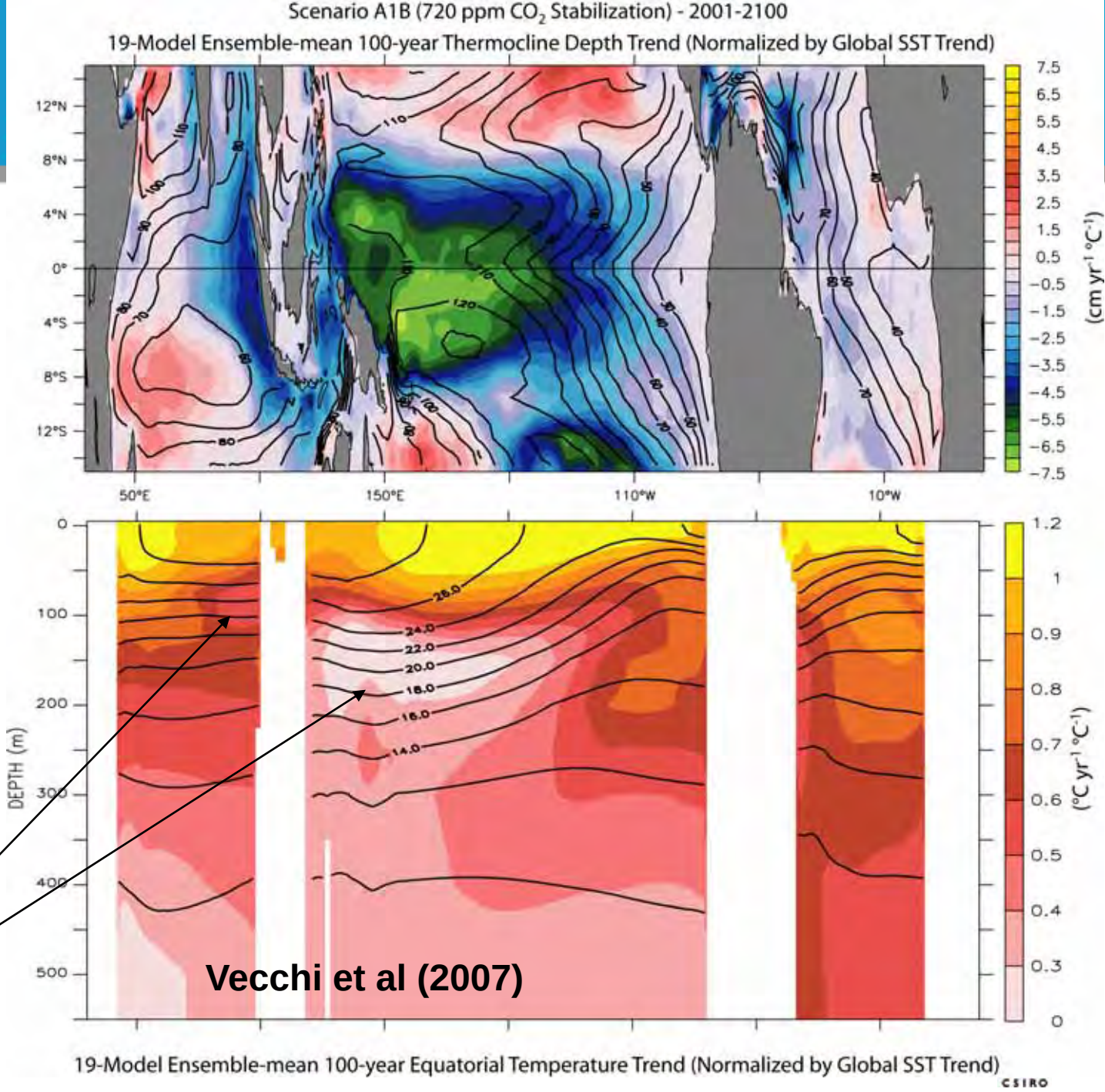
Shallowing

Consistent with pIOD-like change

Equatorial Pacific thermocline flattens and shoals.

Increased thermal stratification.

Minimum in warming

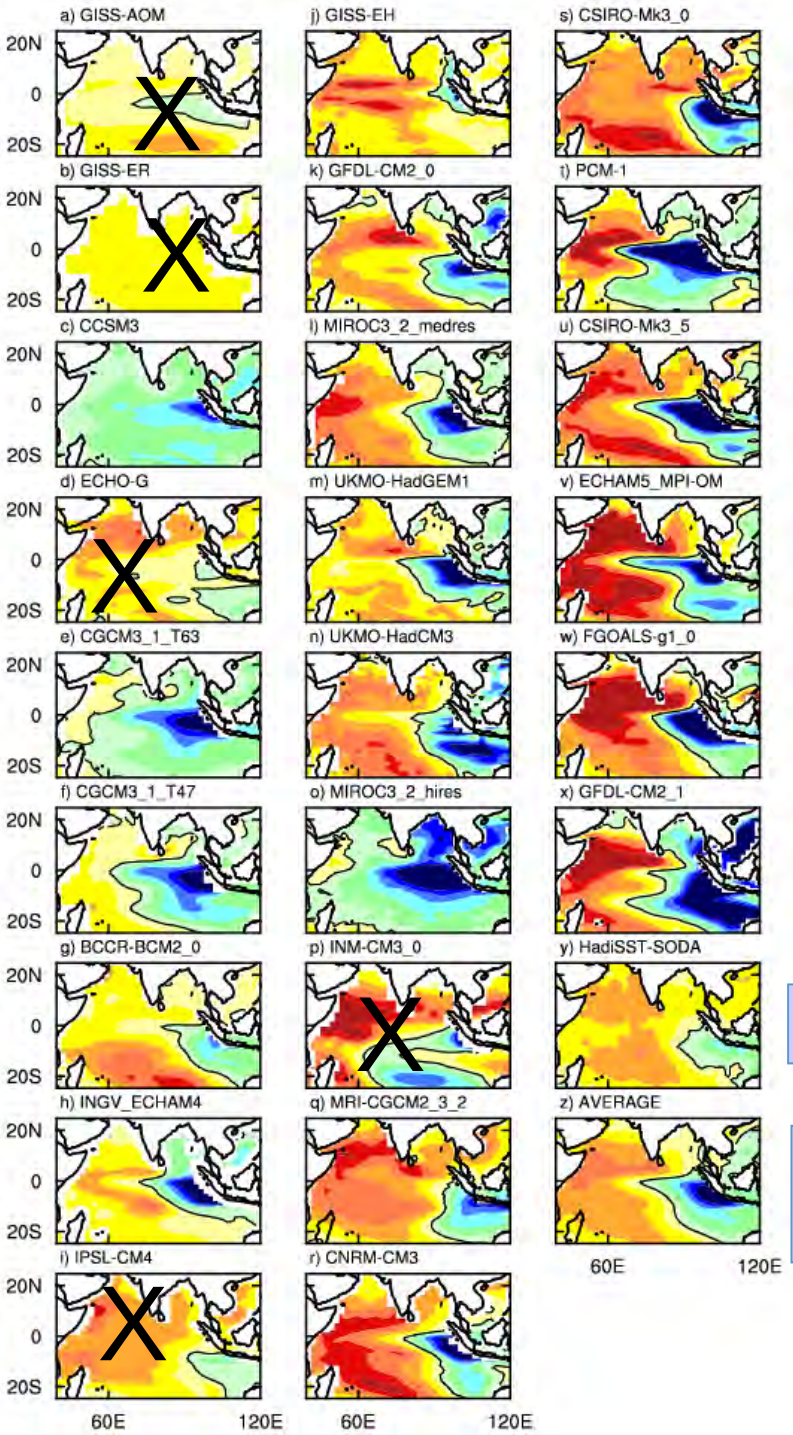


Vecchi et al (2007)

But is the observed attributable to climate change? IPCC model selections (20th century experiments)

- One experiment from each model, two versions of data since 1950
  - Detrended data to remove climate change signal
  - Raw model outputs

SON IOD patterns (detrended SST EOF)

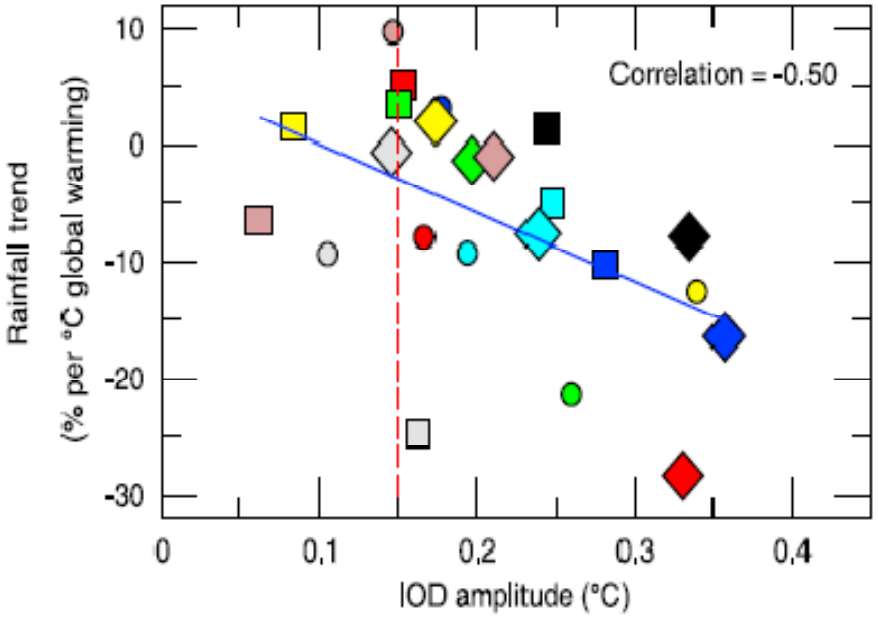


Observed

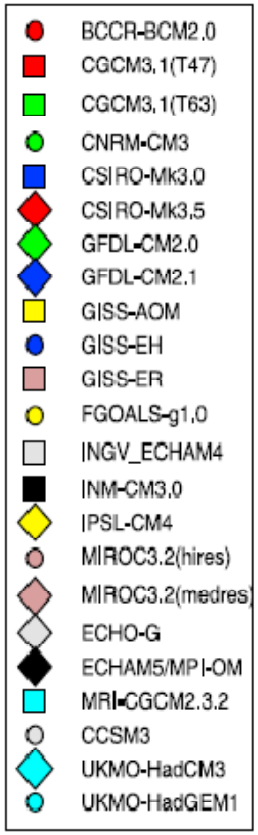
All-model average

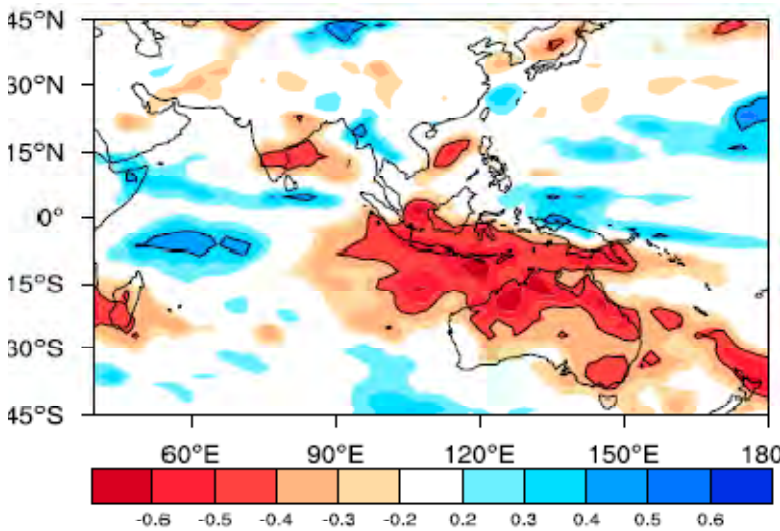
Is the IOD amplitude relevant to climate projection?

Present-day IOD amplitude & rainfall trend over the IODE region



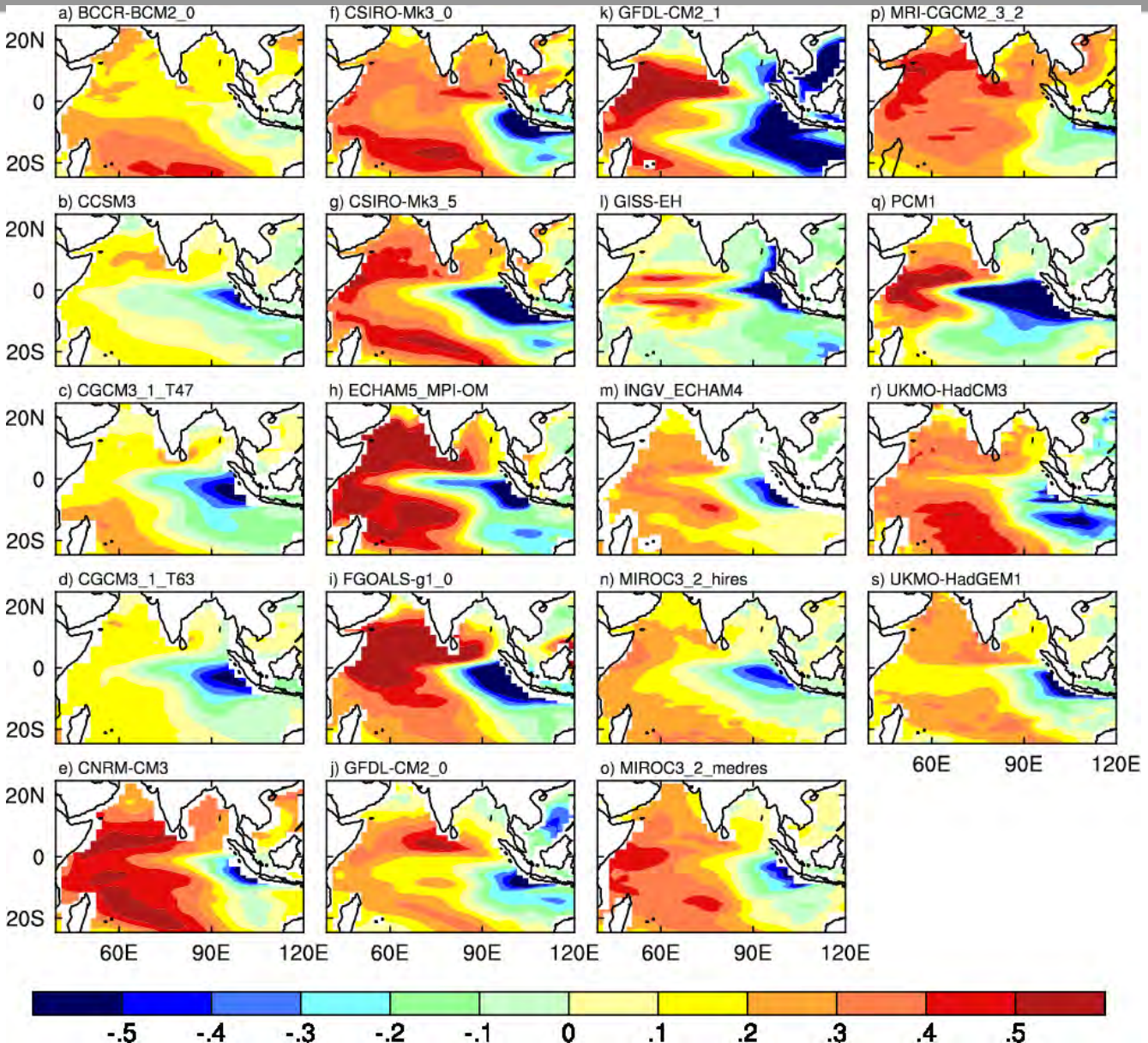
Present-day



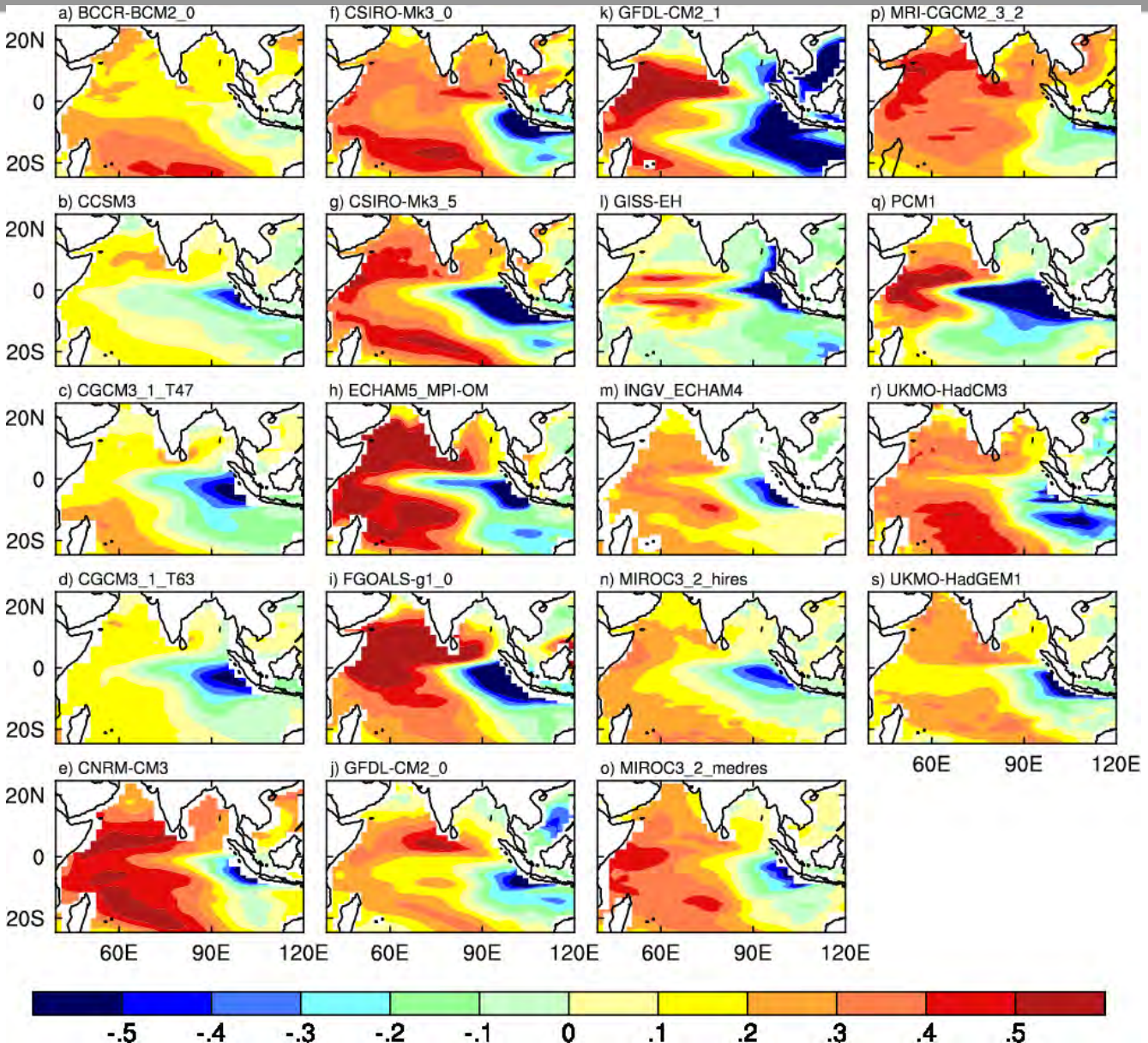


Cai et al. 2011, GRL

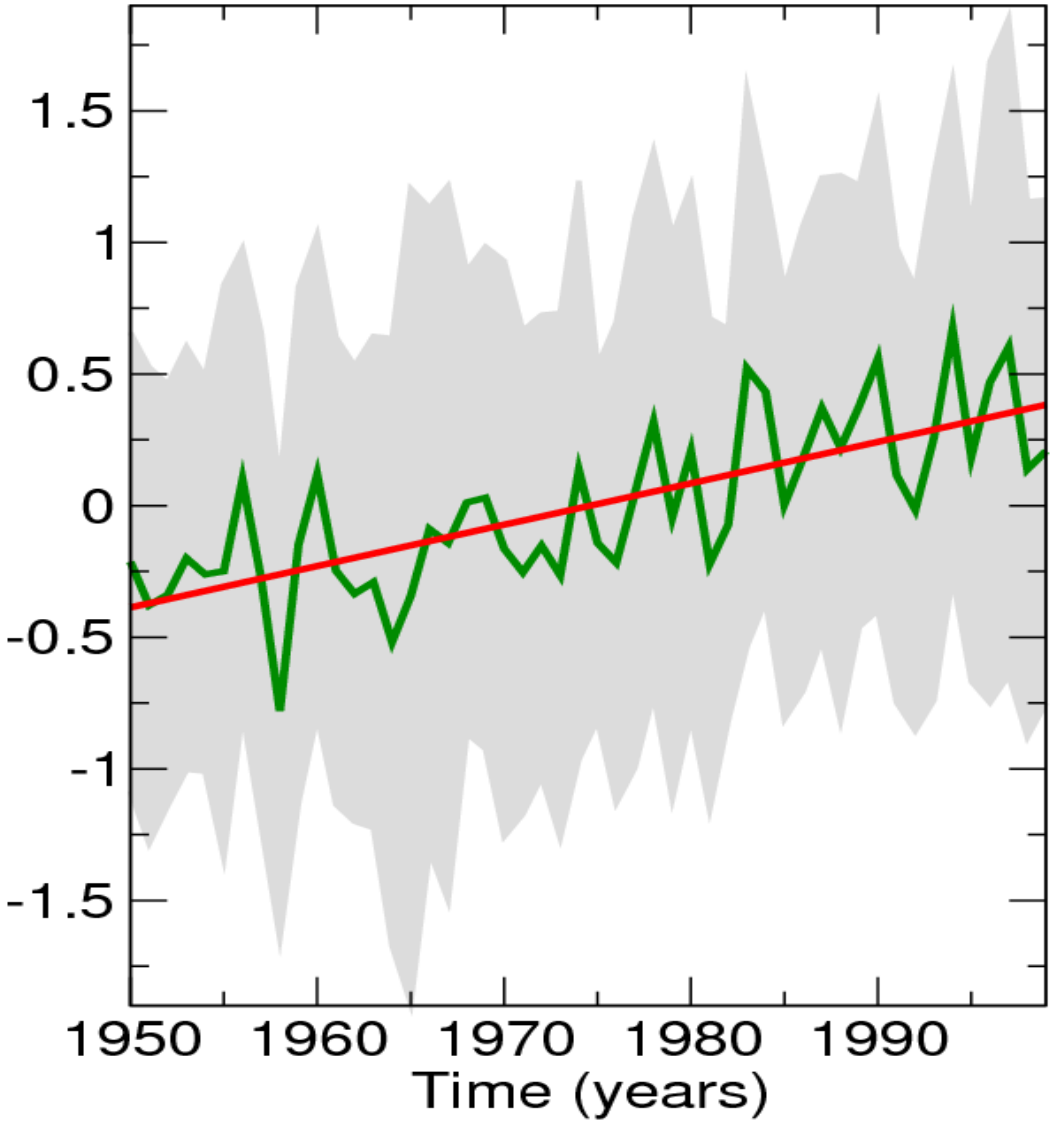
The IOD pattern in 19 models using data



The IOD pattern in 19 models using detrended data



EOF time series using outputs with trends



A trend of
0.75 Std. Dev.

Global warming and IOD frequencies
19 IPCC AR4 Climate Models, 50x19 = 950 years

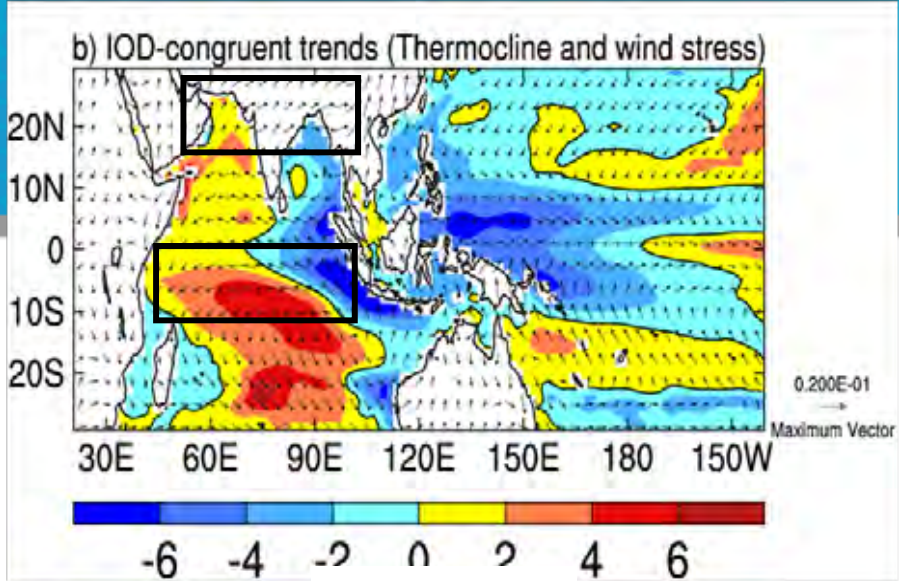
	pIOD (0.75 std. dev.)	
With Climate Change	224	
Without Climate Change	192	
	Two-consecutive pIOD	Three-consecutive pIOD
With Climate Change	42	8
Without Climate Change	32	2

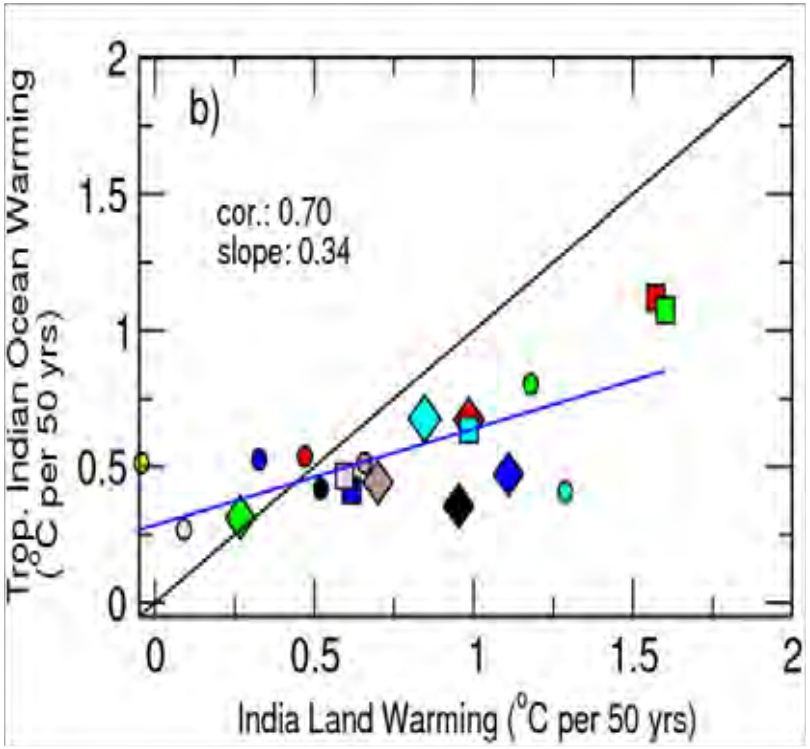
Cai et al. 2009b, GRL

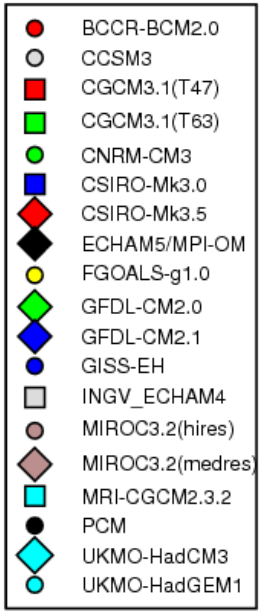
It turns out the increase in IOD frequency is NOT due to

- A trend in El Nino
- The southern annular mode (Sullivan's talk this afternoon)

Land-sea T contrast

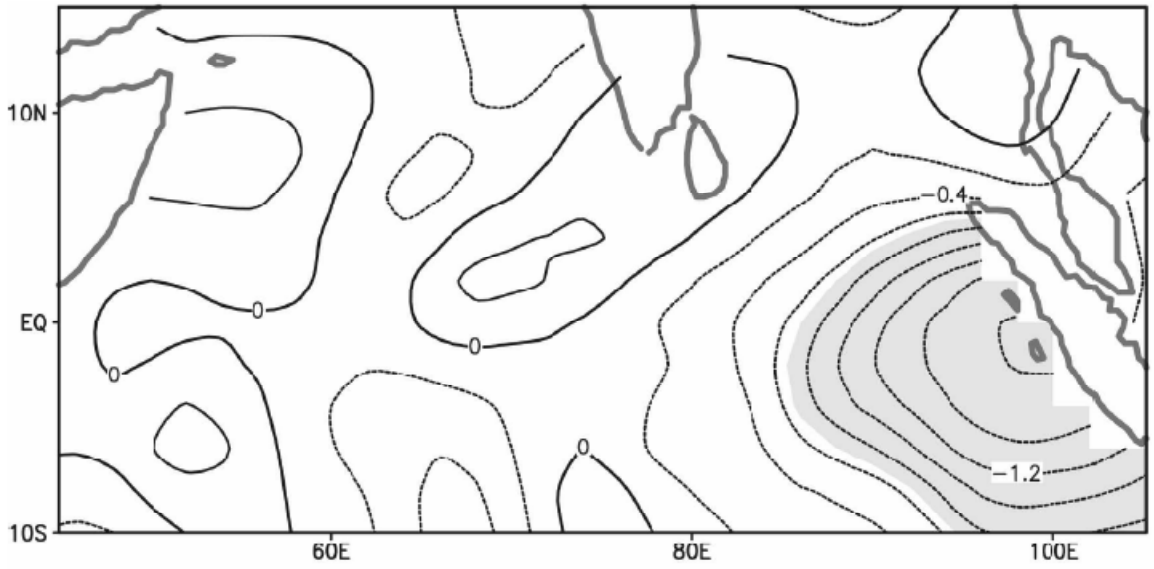






However, we don't know how those feedback processes are changing?

These are associated with an amplitude skewness of the IODE: negative SST anomalies grow to a large amplitude than positive SST



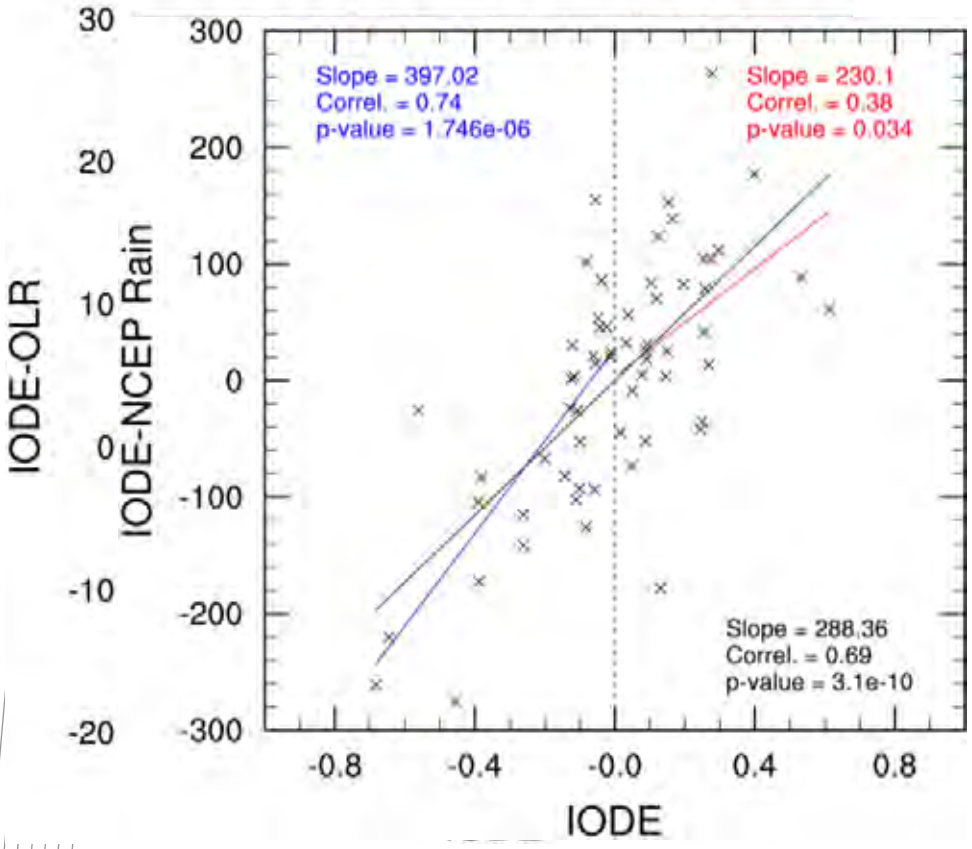
From Hong et al. 2008

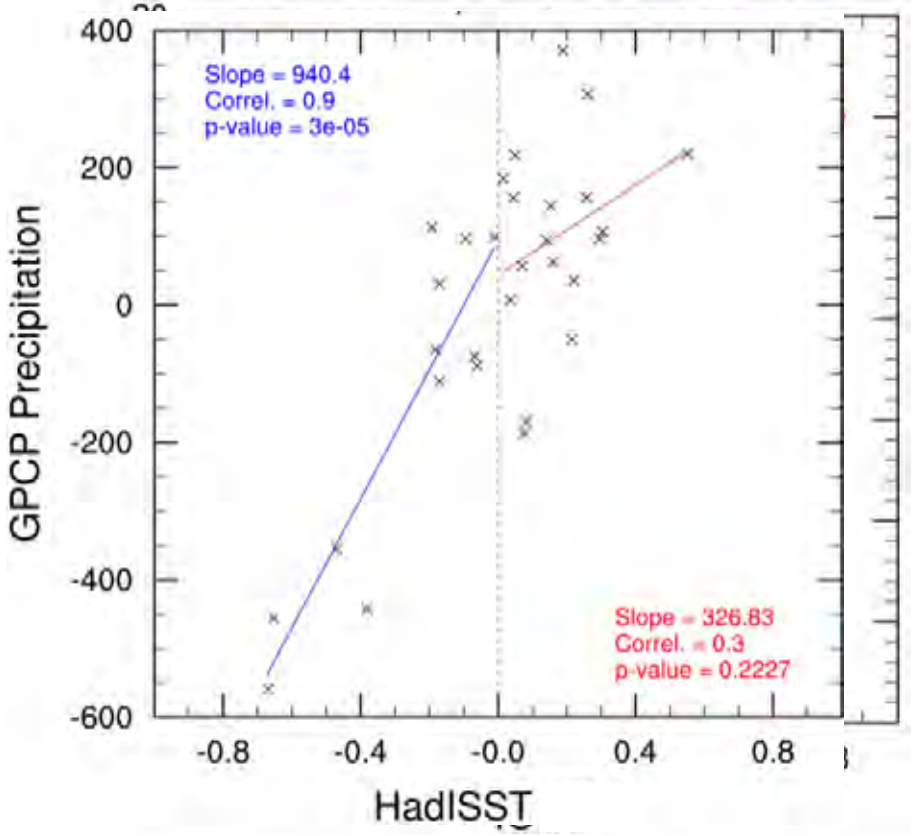
(1) Nonlinear dynamical feedback (could be positive, could be negative)

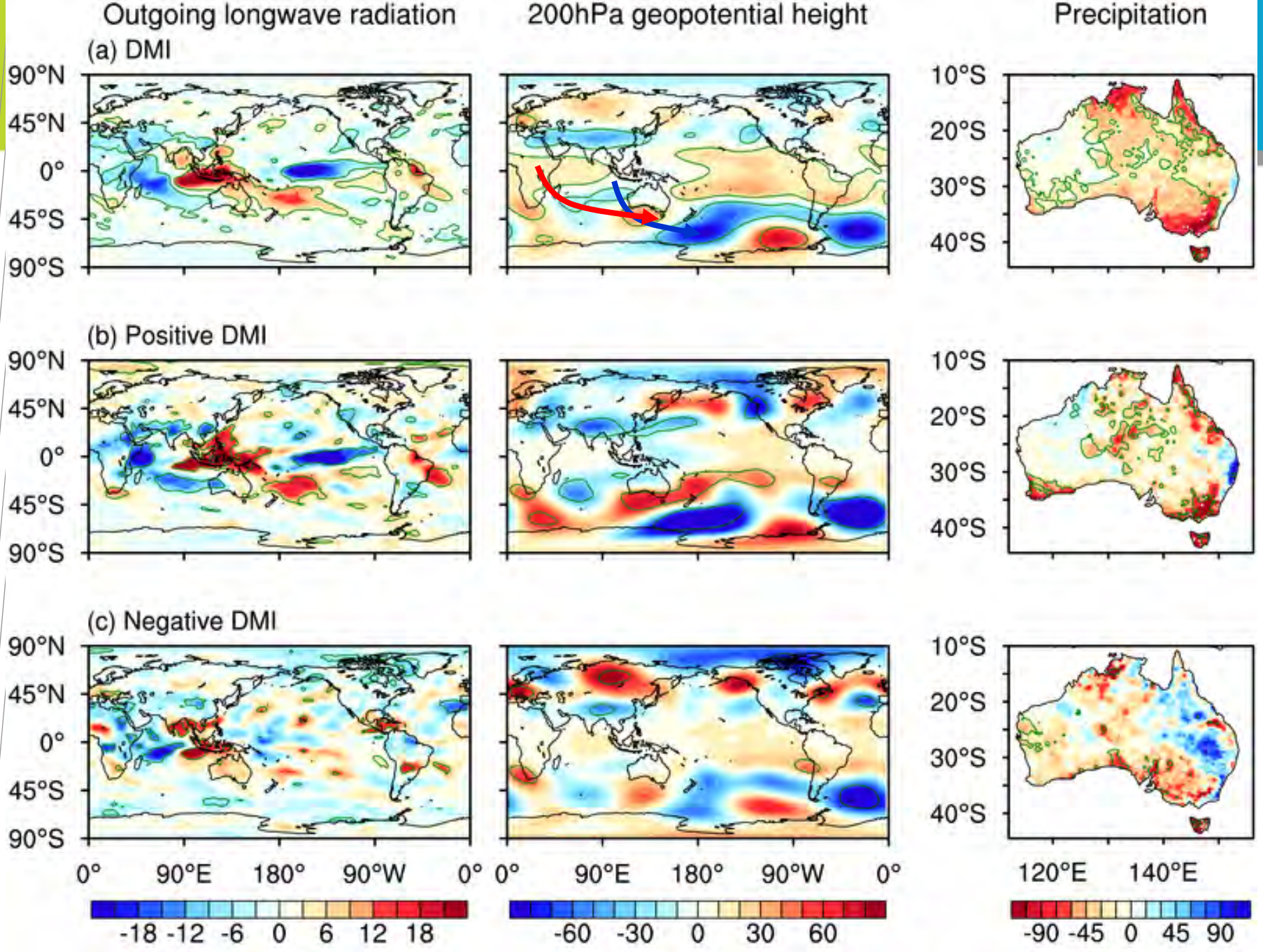
$$NAT = \left[-\acute{U}\frac{\partial \acute{T}}{\partial x}\right] + \left[-\acute{W}\frac{\partial \acute{T}}{\partial z}\right]$$

pIOD	**—**		**−**	**−**	**−**		**−**	**−**	**−**
nIOD	**—**		**−**	**+**	**+**		**−**	**+**	**+**

(2) SST-cloud-radiation feedback (damping)

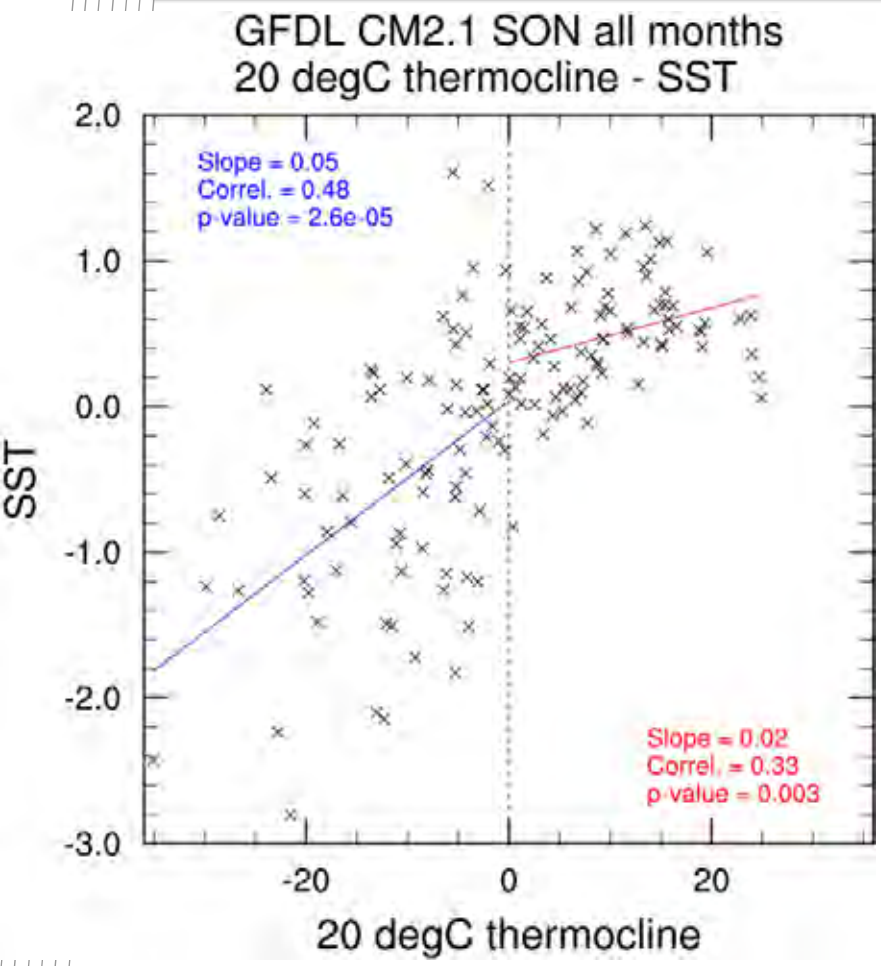


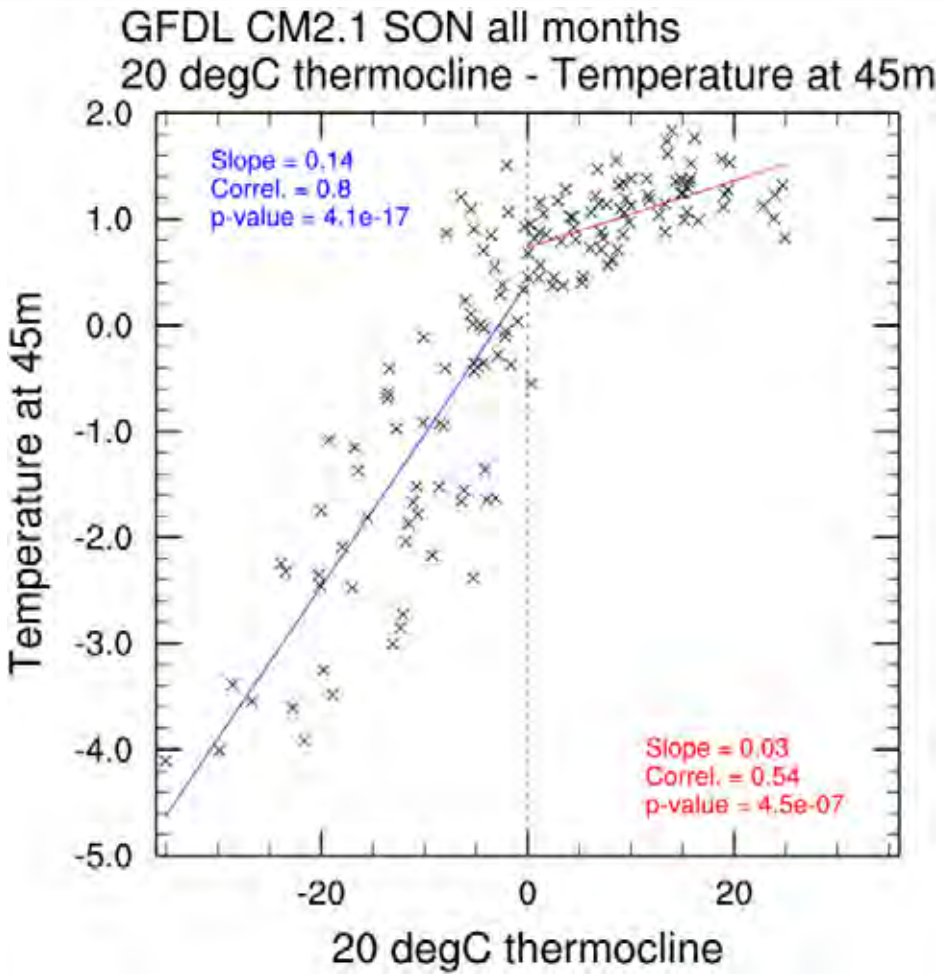




Peter van Rensch's talk

(3) Thermocline -- SST feedback (positive feedback)



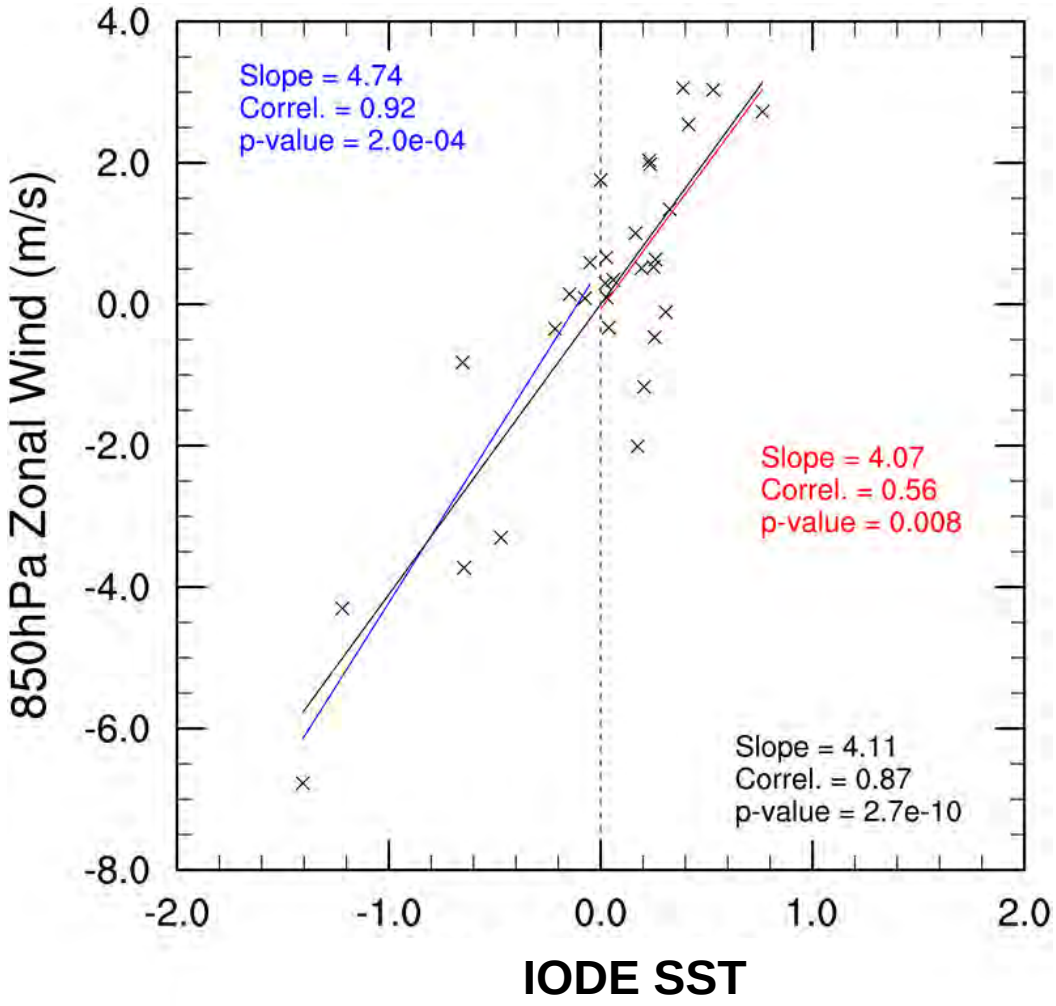


A ratio of 2.5: 1

A ratio of 3.6: 1

Zheng et al. 2010

(4) Zonal winds to IODE SST (positive feedback)



(5) Sensitivity of thermocline to winds (positive feedback

Because the stratification is changing, the sensitivity may change too.

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Recent IOD papers

- Cai, W., A. Sullivan, T. Cowan, J. Ribbe, and G. Shi (2011), Simulation of the Indian Ocean Dipole: A relevant criterion for selecting models for climate projections, Geophys. Res. Lett., 38, L03704, doi:10.1029/2010GL046242.
- Cai, W., A. Pan, D. Roemmich,T. Cowan, and X. Guo (2009), Argo profiles a rare occurrence of three consecutive positive Indian Ocean Dipole events, 2006–2008, *Geophys. Res. Lett*., 36, L08701, doi:10.1029/2008GL037038.
- Cai, W., T. Cowan, and A. Sullivan (2009), Recent unprecedented skewness towards positive Indian Ocean Dipole occurrences and its impact on Australian rainfall, *Geophys. Res. Lett*., 36, L11705, doi:10.1029/2009GL037604.
- Cai, W., A. Sullivan, and T. Cowan (2009), How rare are the 2006–2008 positive Indian Ocean Dipole events? An IPCC AR4 climate model perspective, *Geophys. Res. Lett*., 36, L08702, doi:10.1029/2009GL037982.
- Cai, W., T. Cowan, and M. Raupach (2009), Positive Indian Ocean dipole events precondition southeast Australia bushfires, *Geophys. Res. Lett*., 36, L19710, doi:10.1029/2009GL039902.
- Cai, W., T. Cowan and A. Sullivan (2009): Climate change contributes to more frequent consecutive positive Indian Ocean Dipole events, *Geophys. Res. Lett*.,.

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