Recent Results with the GFDL High-Resolution Coupled Modeling Systems

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Delworth, T.L., A. Rosati, W. Anderson, A. Adcroft, V. Balaji, R. Benson, K. Dixon, S.M. Griffies, H.-C. Lee, R.C. Pacanowski, G.A. Vecchi, A.T. Wittenberg, F. Zeng, R. Zhang (2012): Simulated climate and climate change in the GFDL CM2.5 high-resolution coupled climate model. *J. Clim. (in press)*

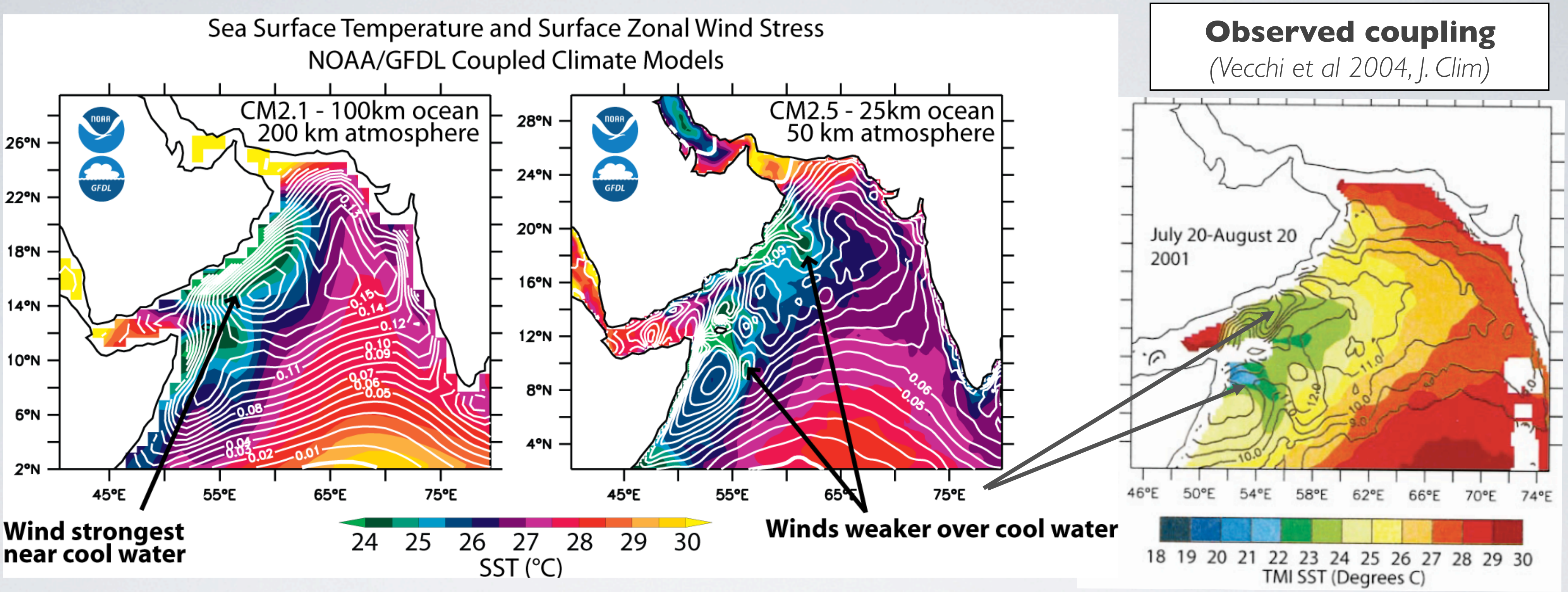
High Resolution Model Development

Scientific Goals:

- Developing improved models (higher resolution, improved physics, reduced bias) for studies of variability and predictability on intra-seasonal to decadal time scales
- Explore impact of atmosphere and ocean on climate variability and change using a high resolution coupled models
- New global coupled models: CM2.4, CM2.5, CM2.6

	Ocean	Atmos	Computer	Status
CM2.1	100 Km	250 Km	GFDL	Running
CM2.3	100 Km	100 Km	GFDL	Running
CM2.4	10-25 Km	100 Km	GFDL	Running
CM2.5	10-25 Km	50 Km	GAEA/GFDL	Running
CM2.6	4-10 Km	50 Km	GAEA	Running

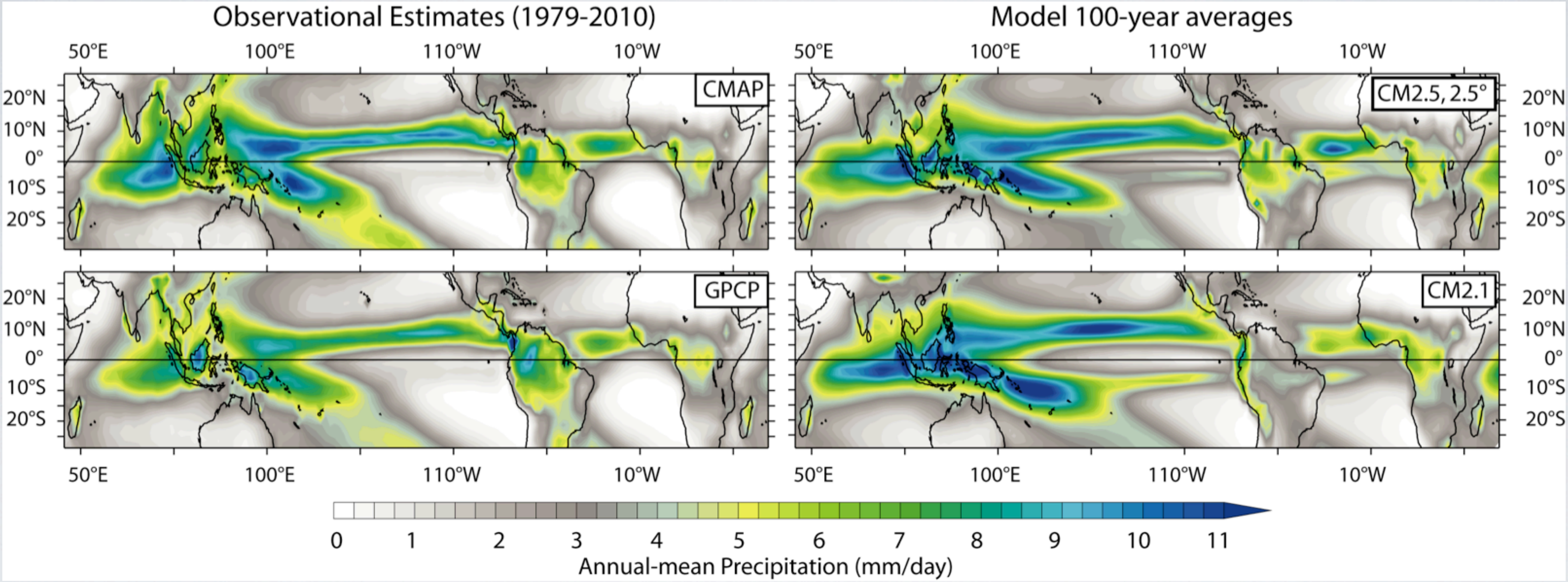
Coupling on Oceanic Mesoscale in Western Arabian Sea



Resolution enhancement allows model to better represent processes

Some Aspects of Tropical Climate Improve with Resolution

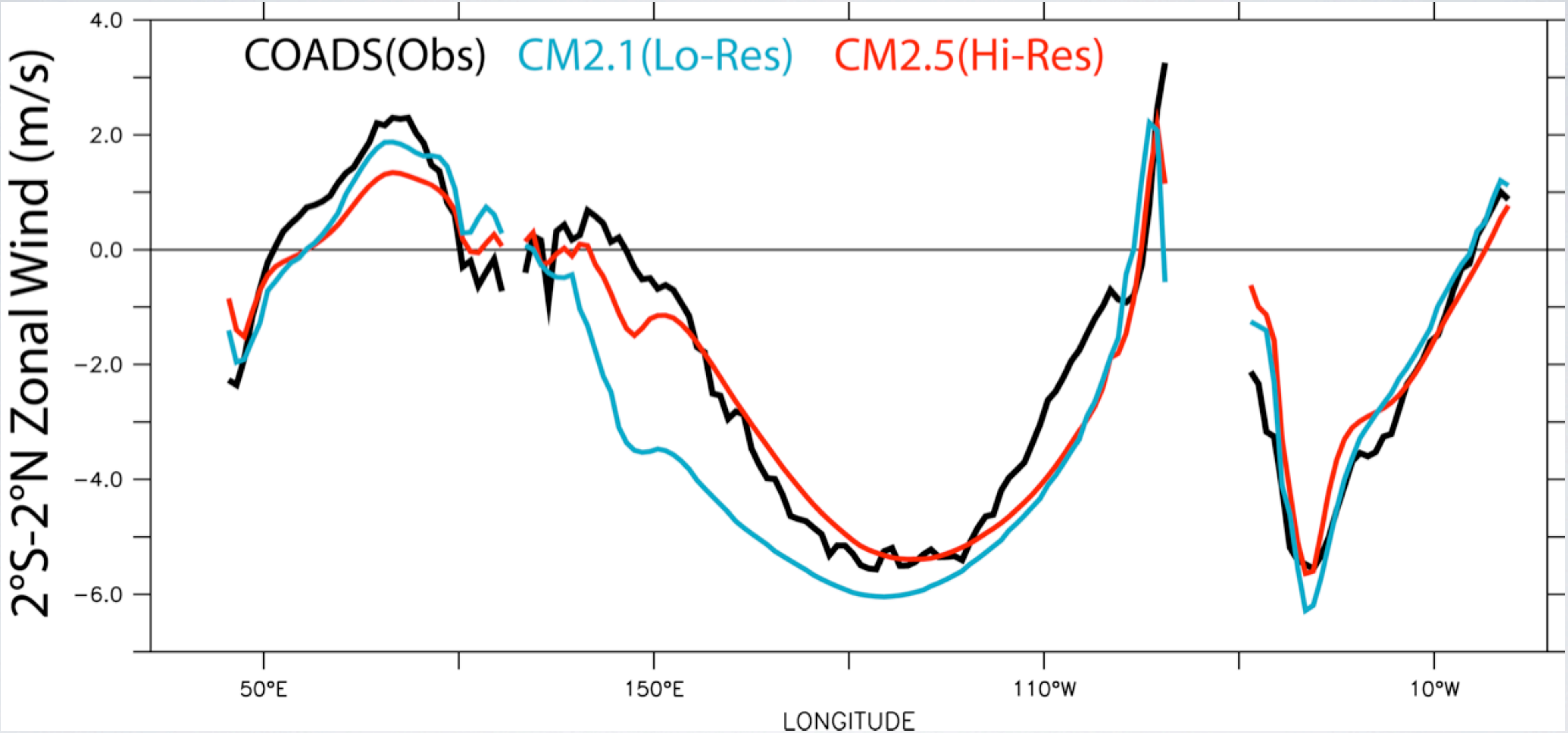
Annual Tropical Precipitation on 2.5x2.5 Grid



Adapted from Delworth et al (2012)

Some Aspects of Tropical Climate Improve with Resolution

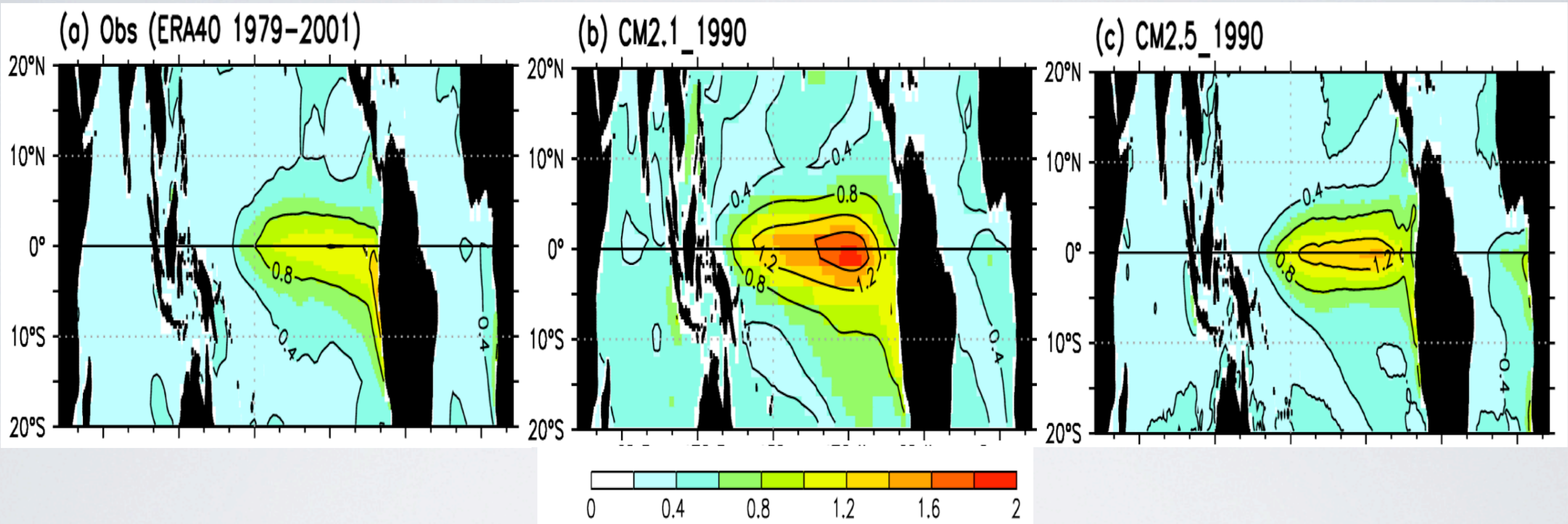
Near-equatorial Zonal Winds



Adapted from Delworth et al (2012)

Some Aspects of Tropical Climate Improve With Resolution

Structure of tropical SST variability

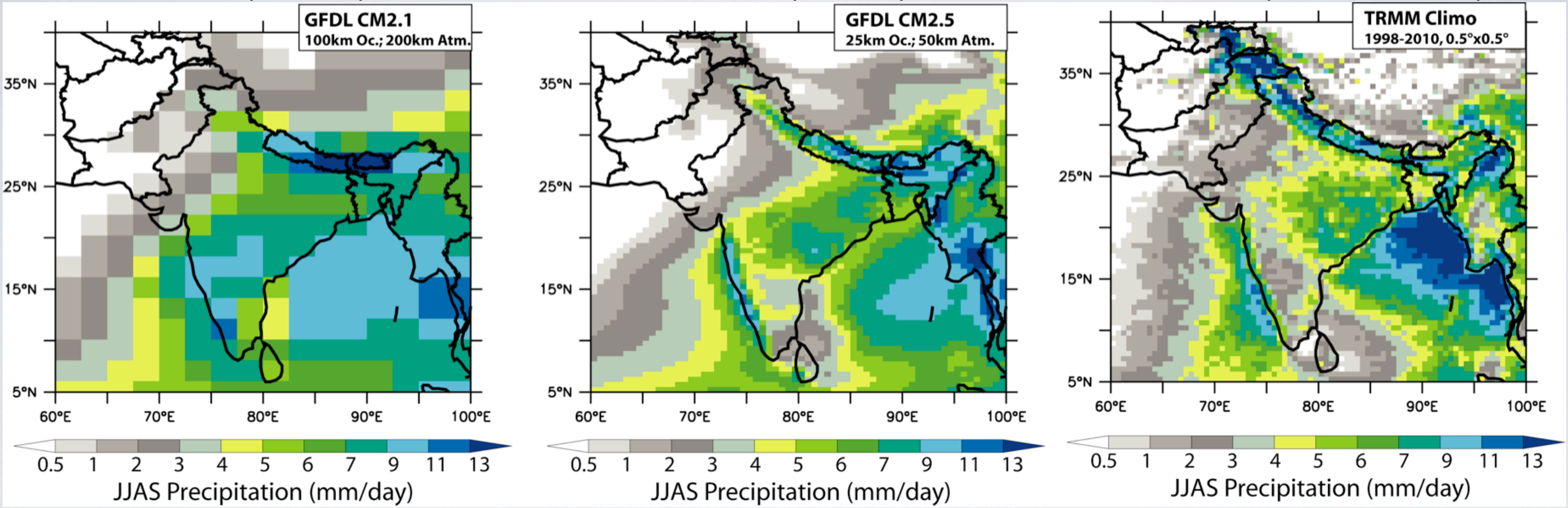


SSTA Standard deviation (°C)

Delworth et al (2012)

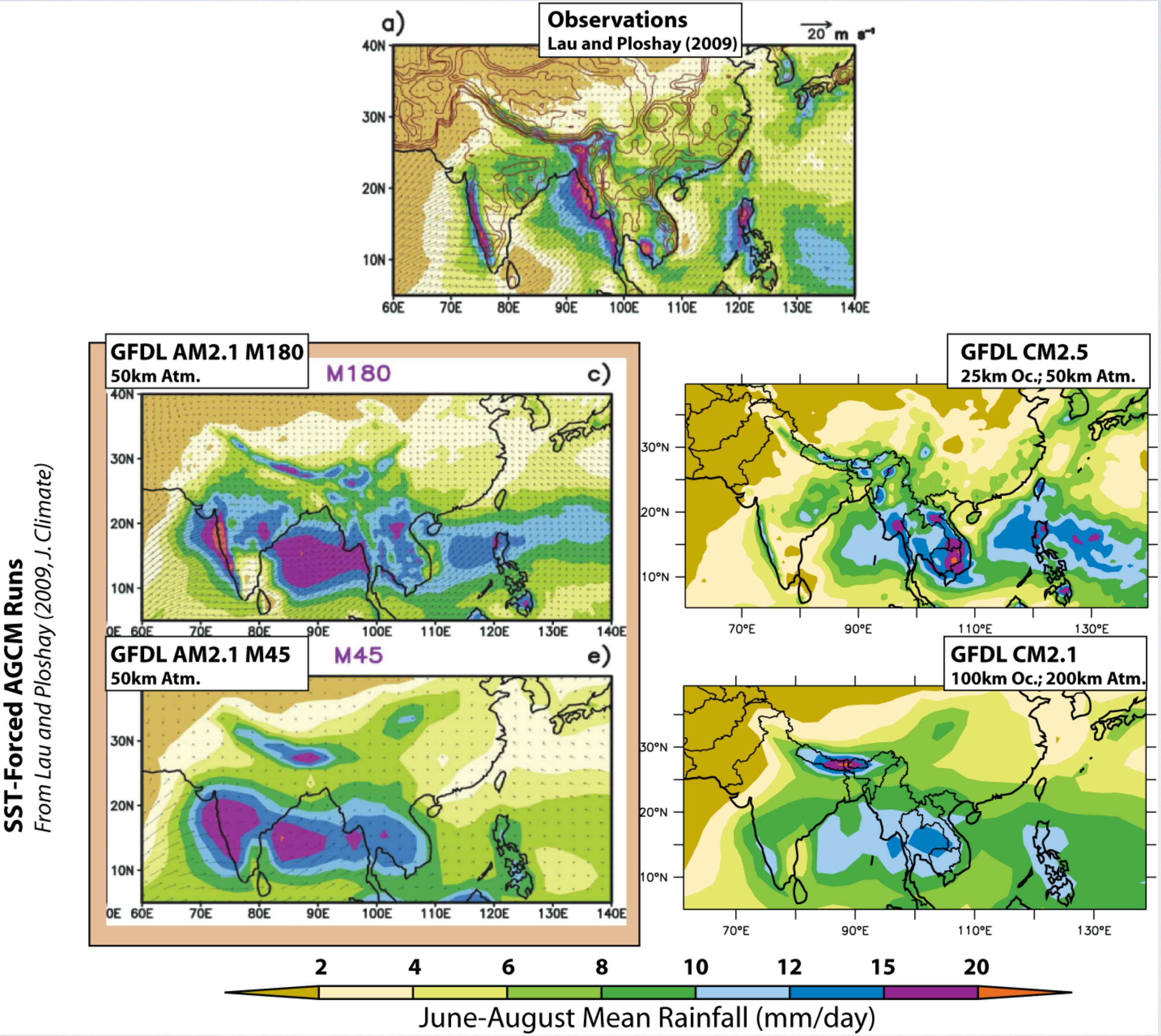
South Asian Monsoon Rainfall Improves with Resolution

CM2.1(lo-res) CM2.5(hi-res) TRMM(1998-2010)



Delworth et al (2012)

Enhanced Resolution and Coupling Improve Asian Monsoon Rainfall



Intraseasonal Variability

Daehyun Kim (LDEO, Columbia U.) and Bill Stern (GFDL)

- Physics
- Resolution
- Coupling

MJO improvement from one can depend on the others.

Coupling appears to improve GFDL high-res model's MJO

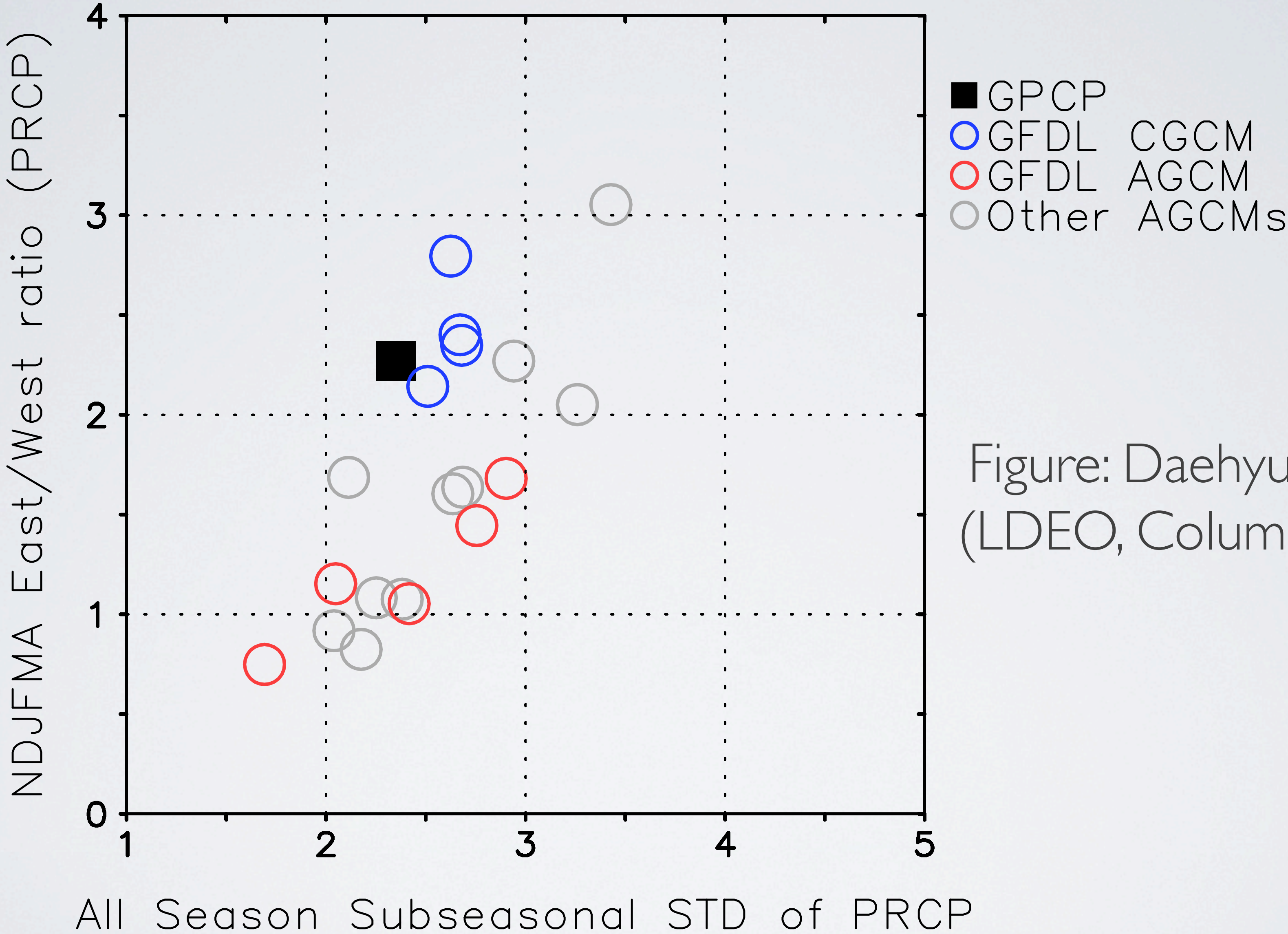
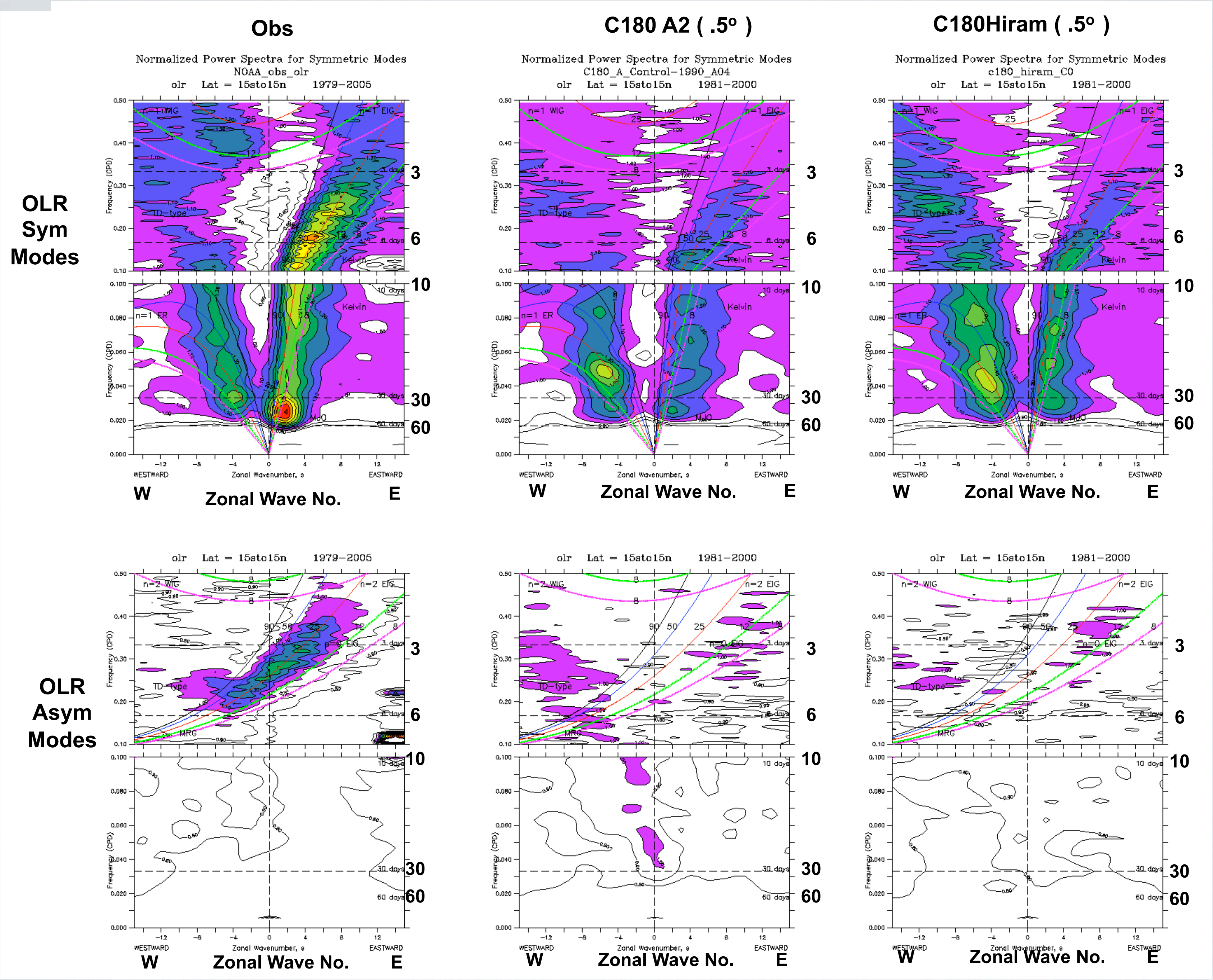
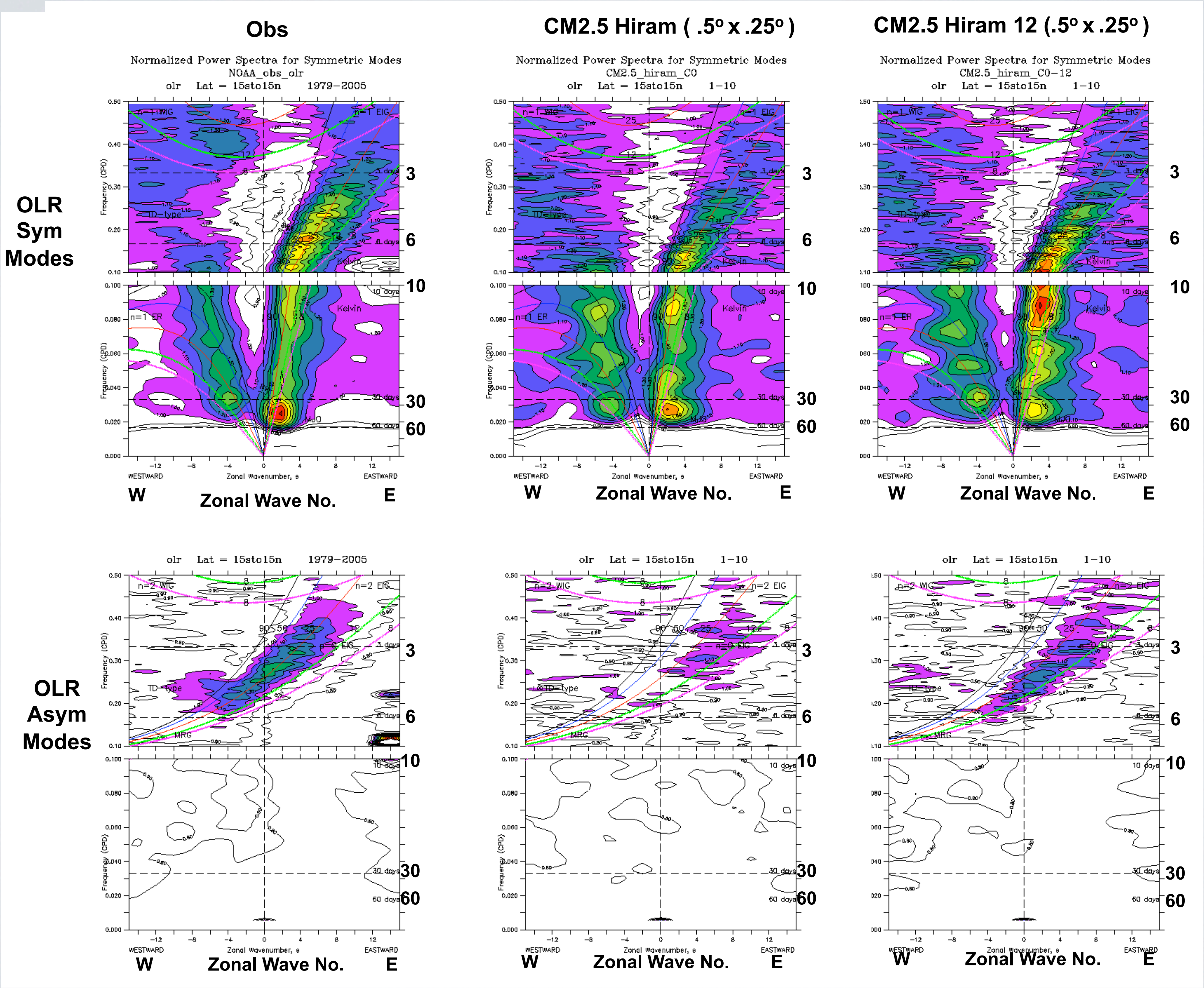


Figure: Daehyun Kim (LDEO, Columbia U.)

Impact of Physics: AM2.1 vs. HiRAM



Impact of coupling: HiRAM C180 AGCM vs. Coupled

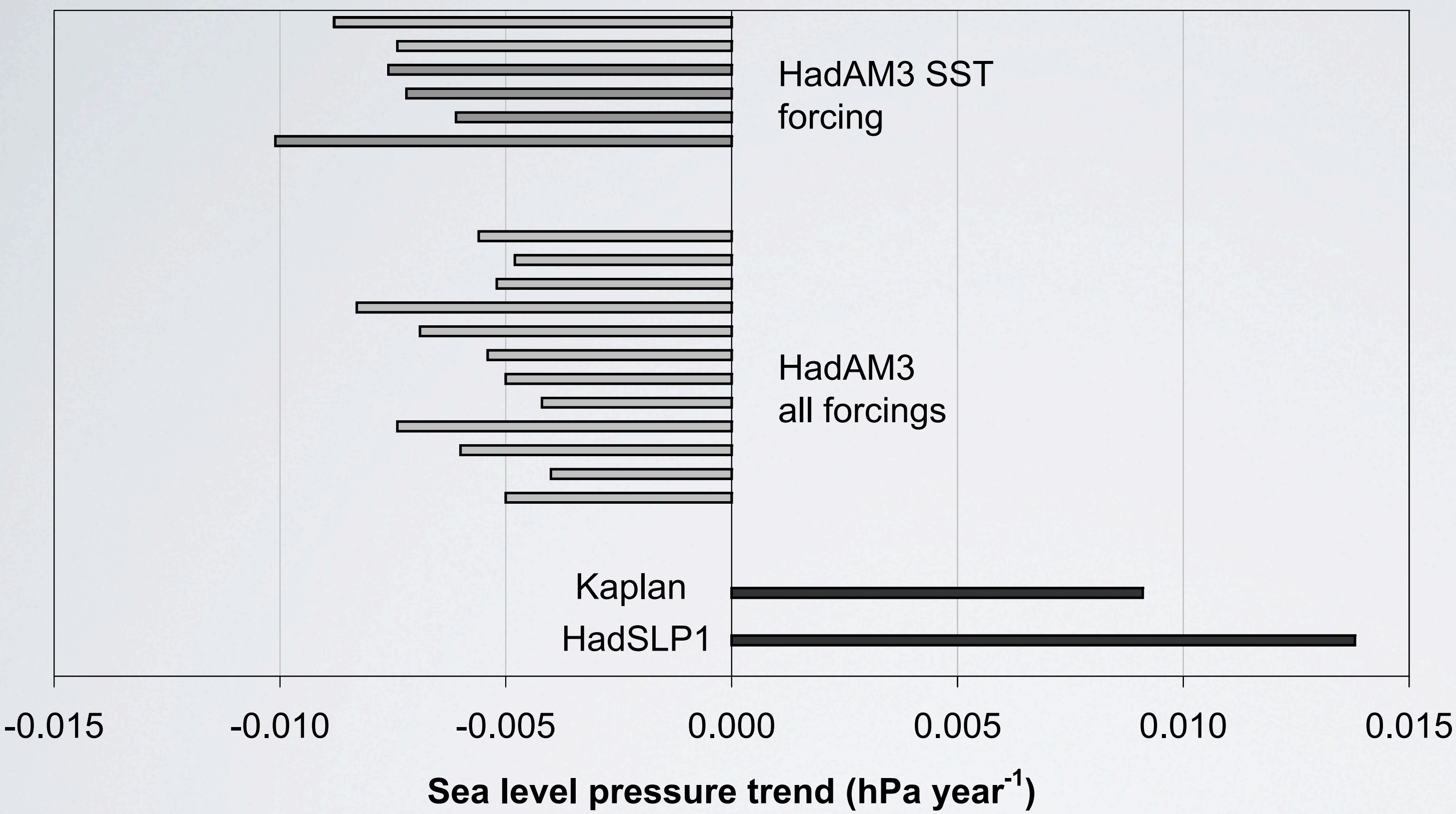


Response to $2xCO_2$

- Global-scale response (with a few exceptions) similar between high and low resolution models
  - High resolution model has higher climate sensitivity and warms more quickly.
  - Southern Ocean warms robustly in high-res model, but not in low-res model
- Regional rainfall response can differ considerably
- Must understand sources of difference in order to judge relative plausibility.

Higher-res does not necessarily mean "better".

Indian Ocean 1950-2000 SLP changes in an SST-forced AGCM differ from observed changes

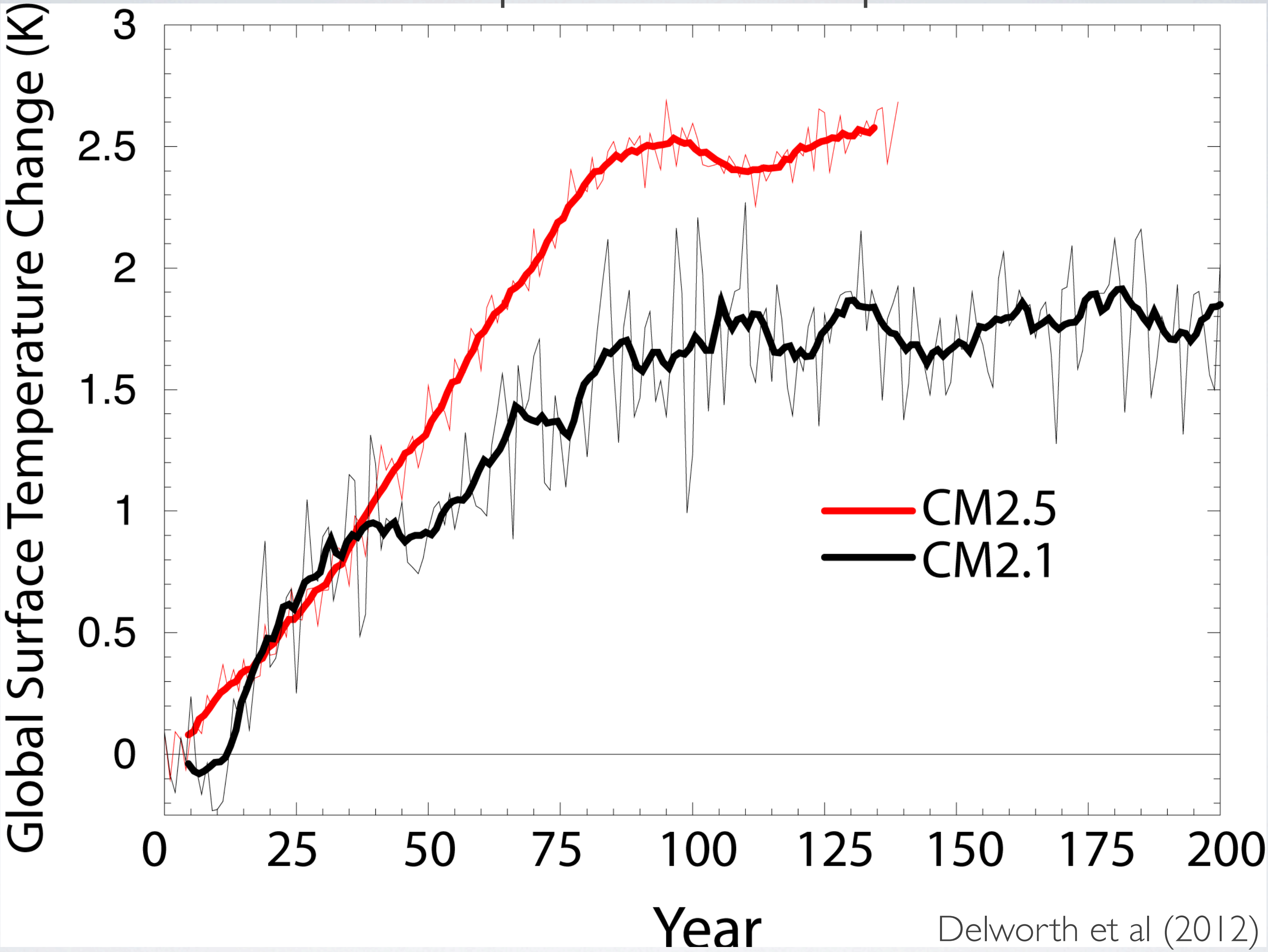


1950-2000 trend in Indian Ocean SLP in obs and HadAM3

Copsey et al. (2006, GRL)

GFDL-CM2.1 CGCM shows an SLP increase over this period when forced with radiative forcing…but different model.

Global Surface Temperature Response to 2xCO_2

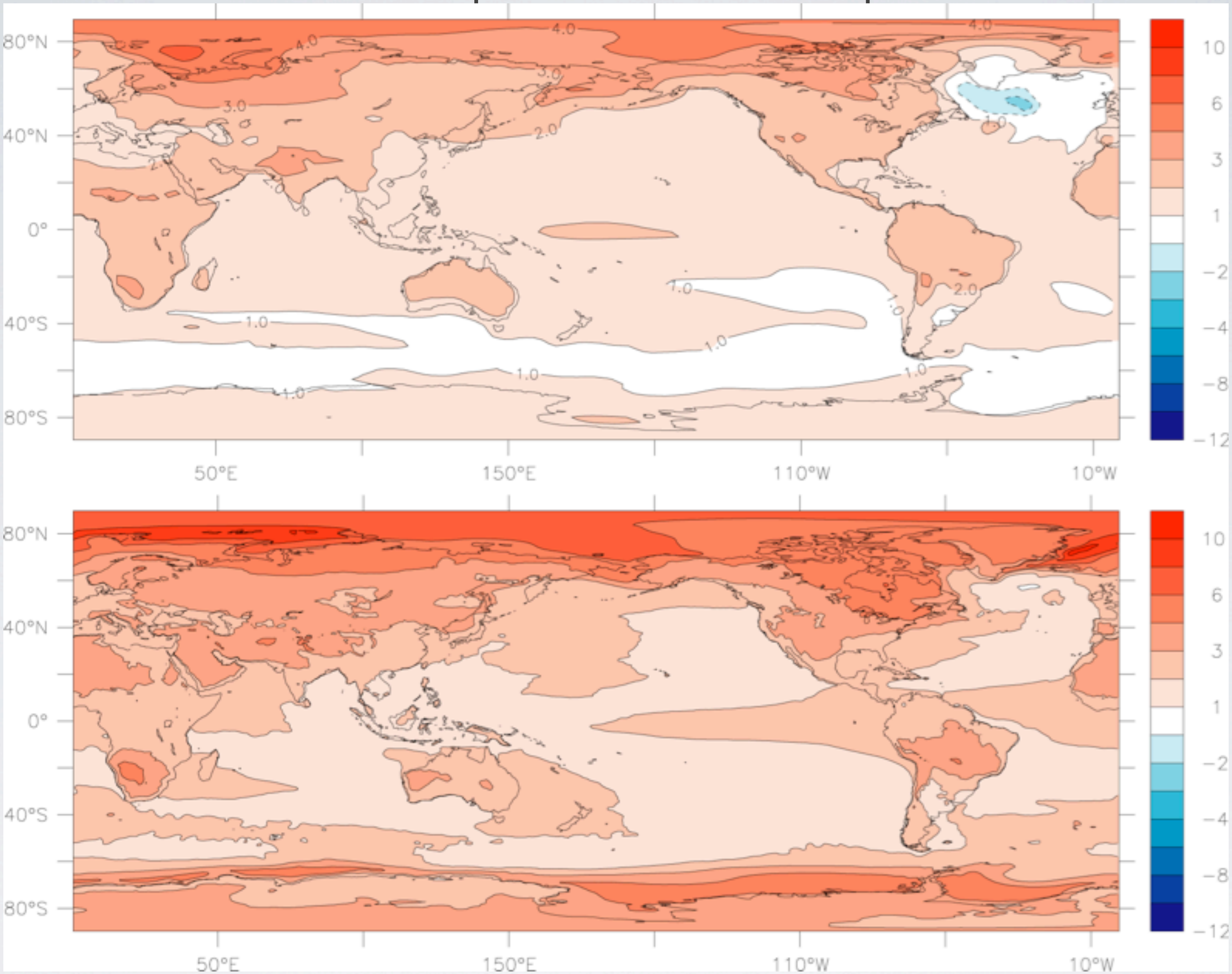


Delworth et al (2012)

Global Surface Temperature Response to $2xCO_2$

CM2.1 (lo-res)

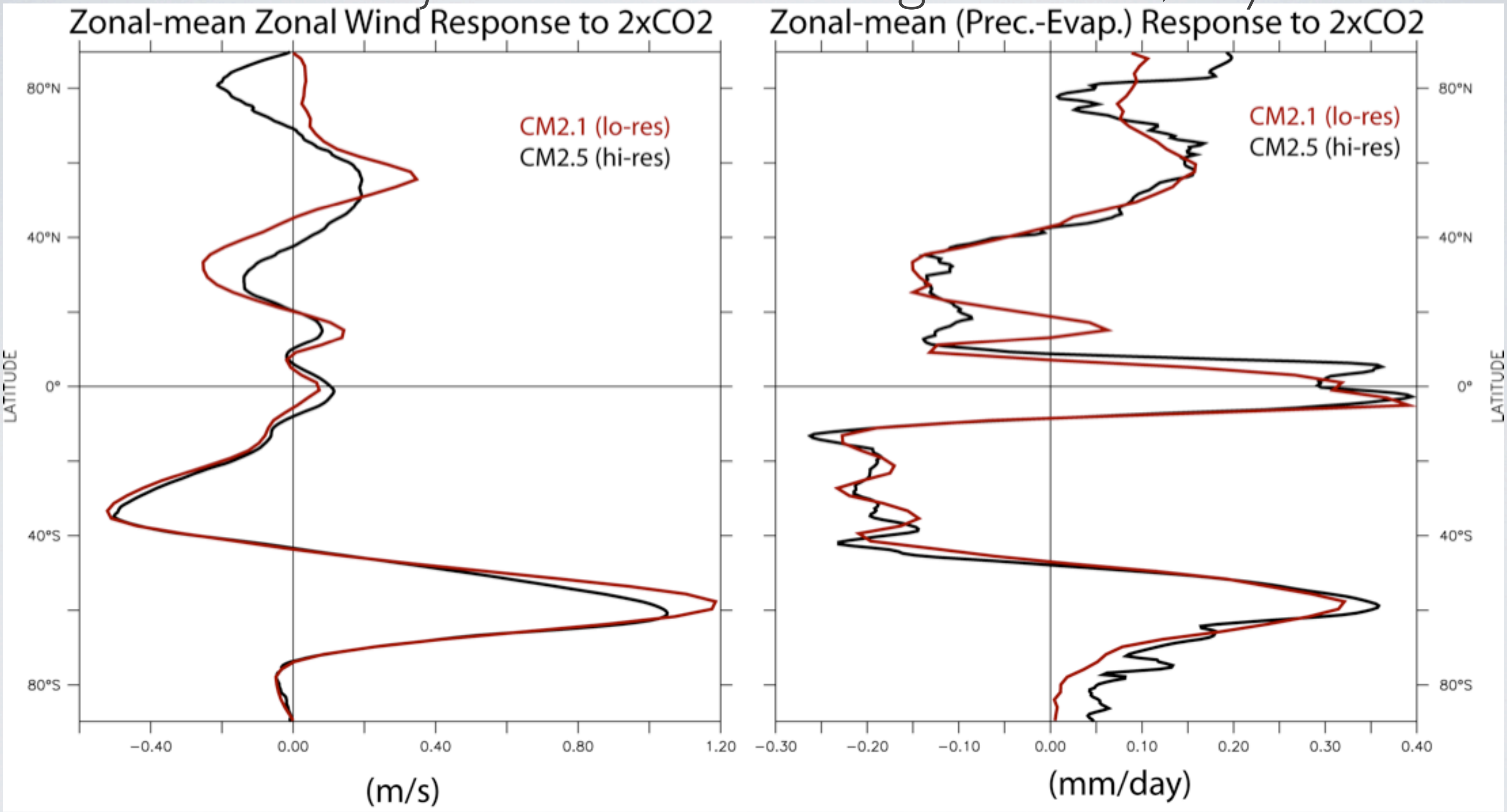
CM2.5 (hi-res)



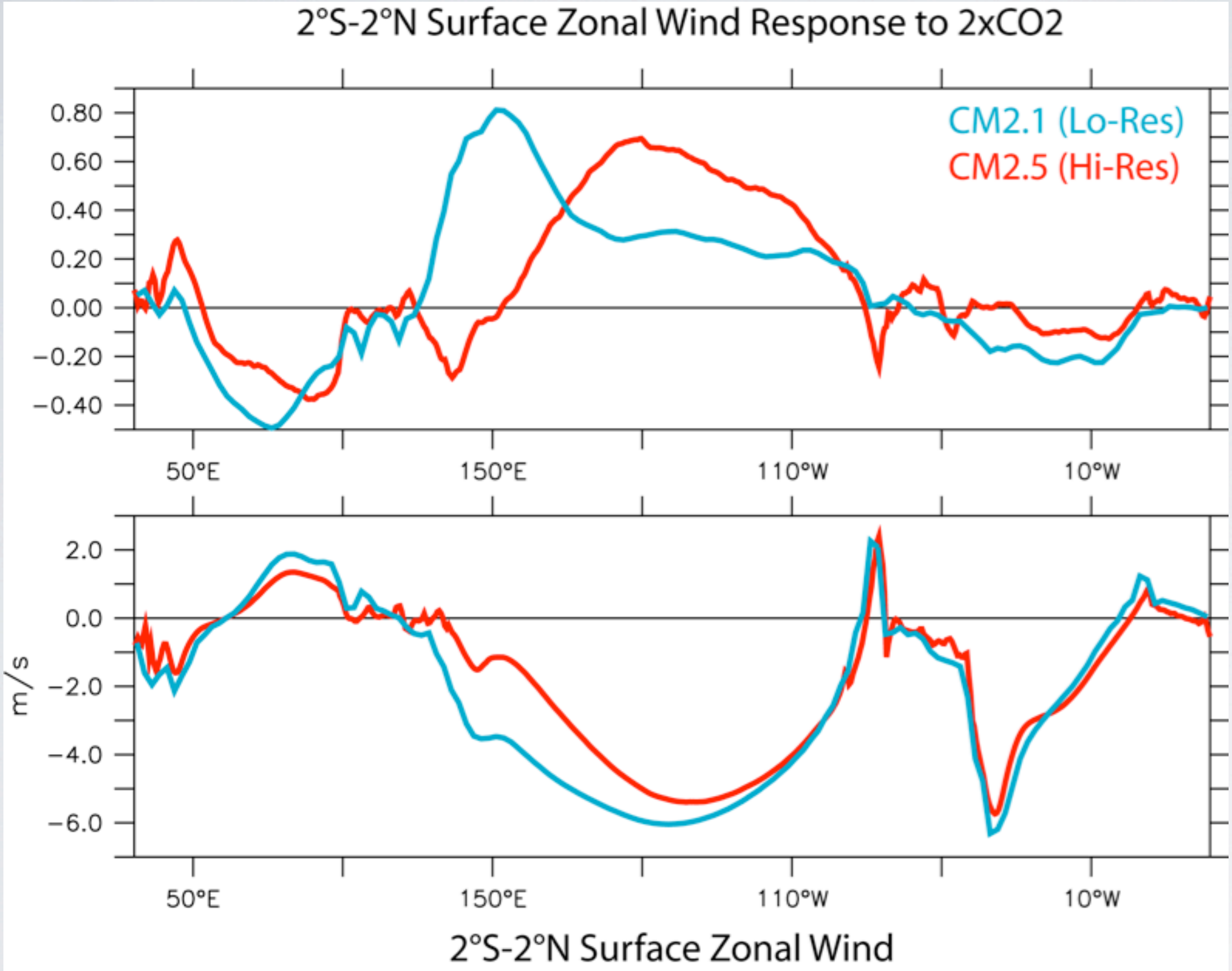
Delworth et al (2012)

Global Zonal-mean Response to $2xCO_2$

Poleward jet shift "Wet get wetter, dry drier"



Equatorial Zonal Wind Response to $2xCO_2$

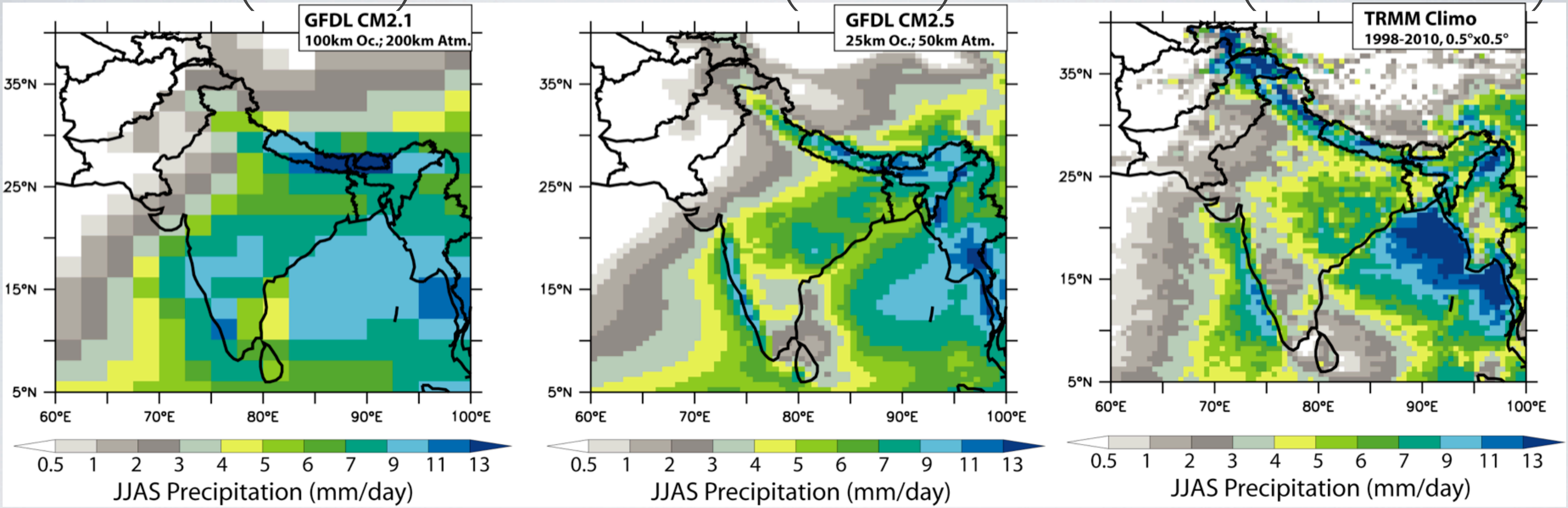


Equatorial winds weaken in both models.

Location of weakening in Pacific different.

South Asian Monsoon Rainfall Improves with Resolution

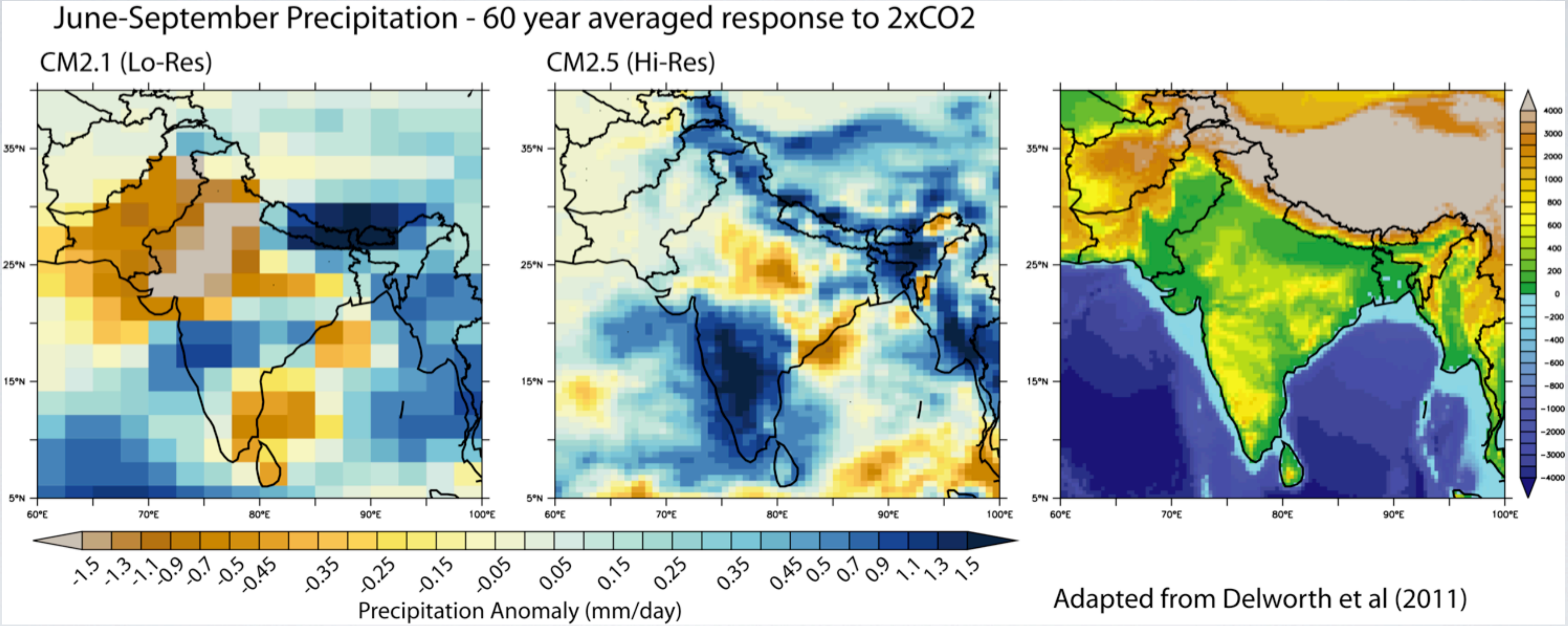
CM2.1(lo-res) CM2.5(hi-res) TRMM(1998-2010)



Delworth et al (2012)

South Asian Monsoon Response to $2xCO_2$

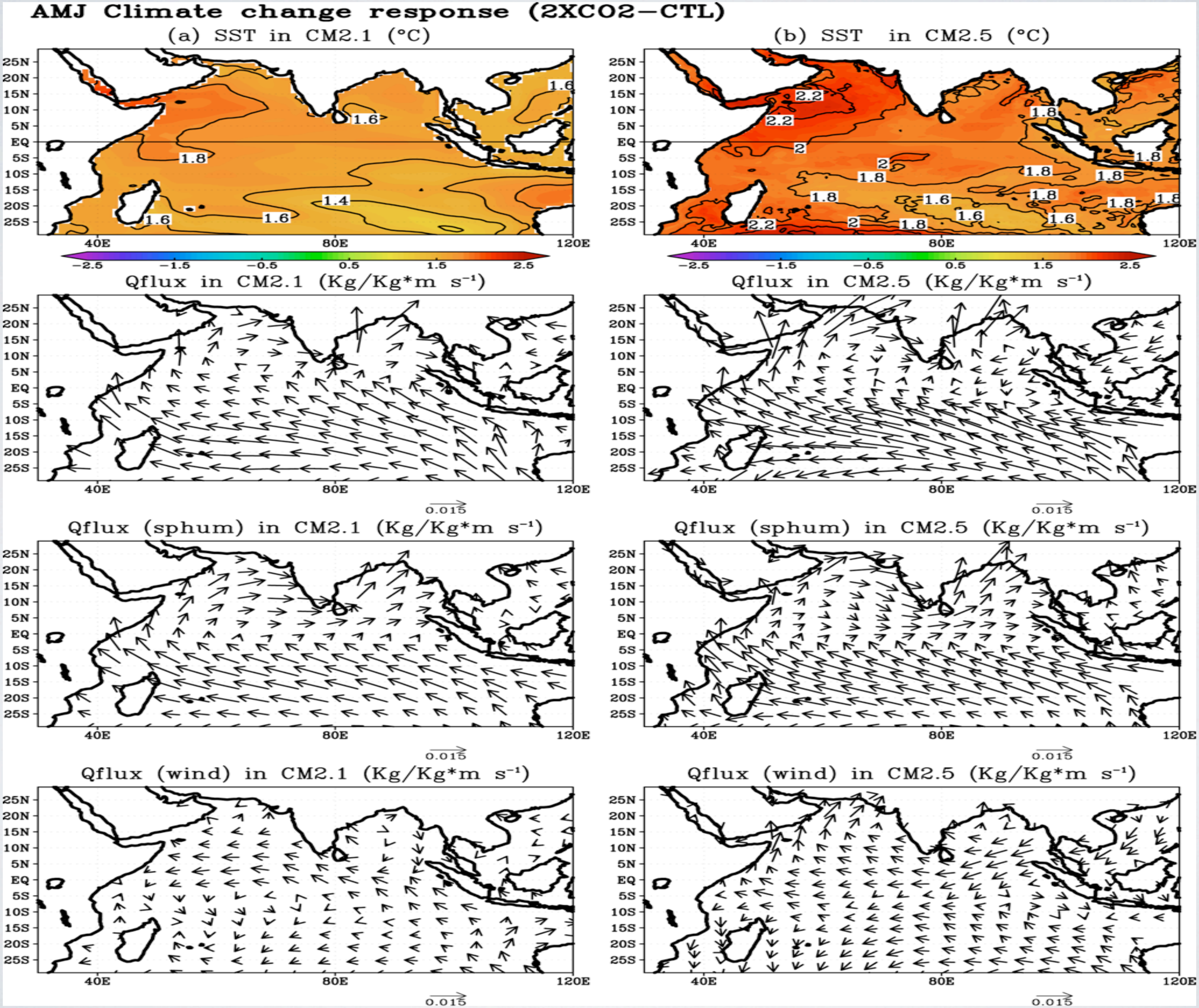
Response model dependent, hi-res model shows orographically-tied features



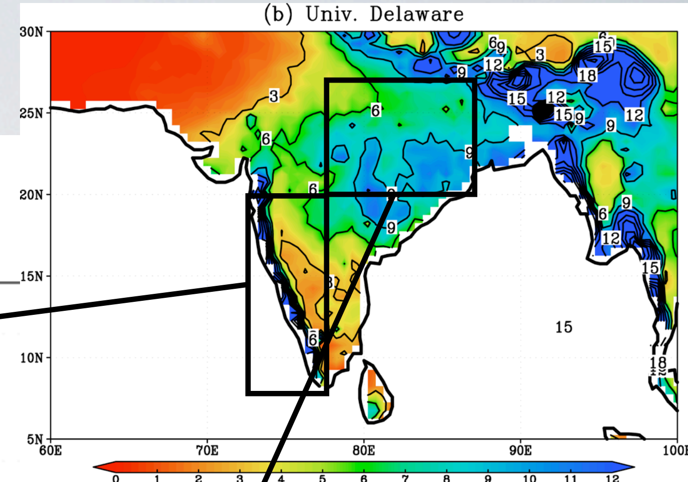
Why is response different?

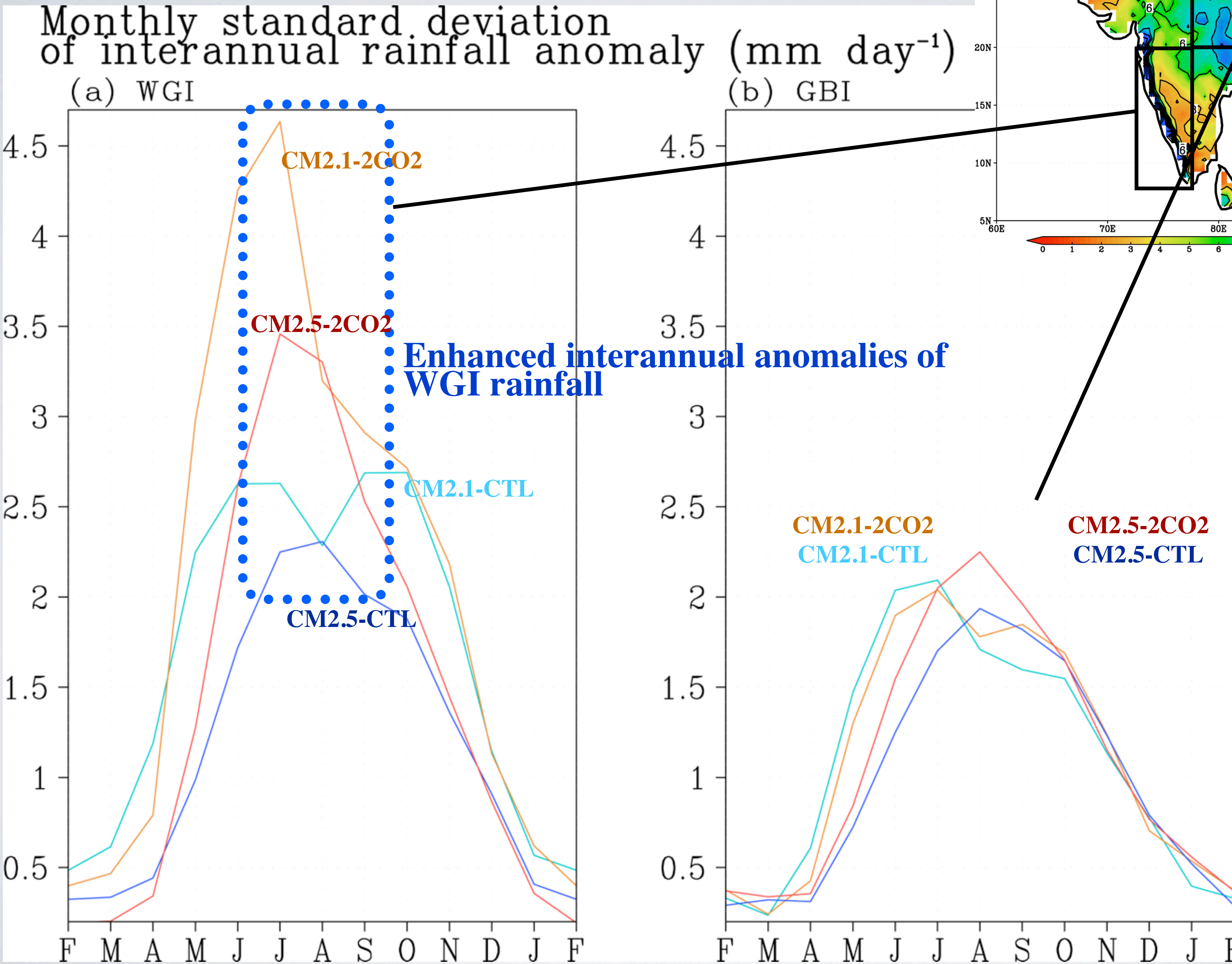
Response to 2xCO2

Figures: Takeshi Doi



Monsoon Variability Changes from CO_2



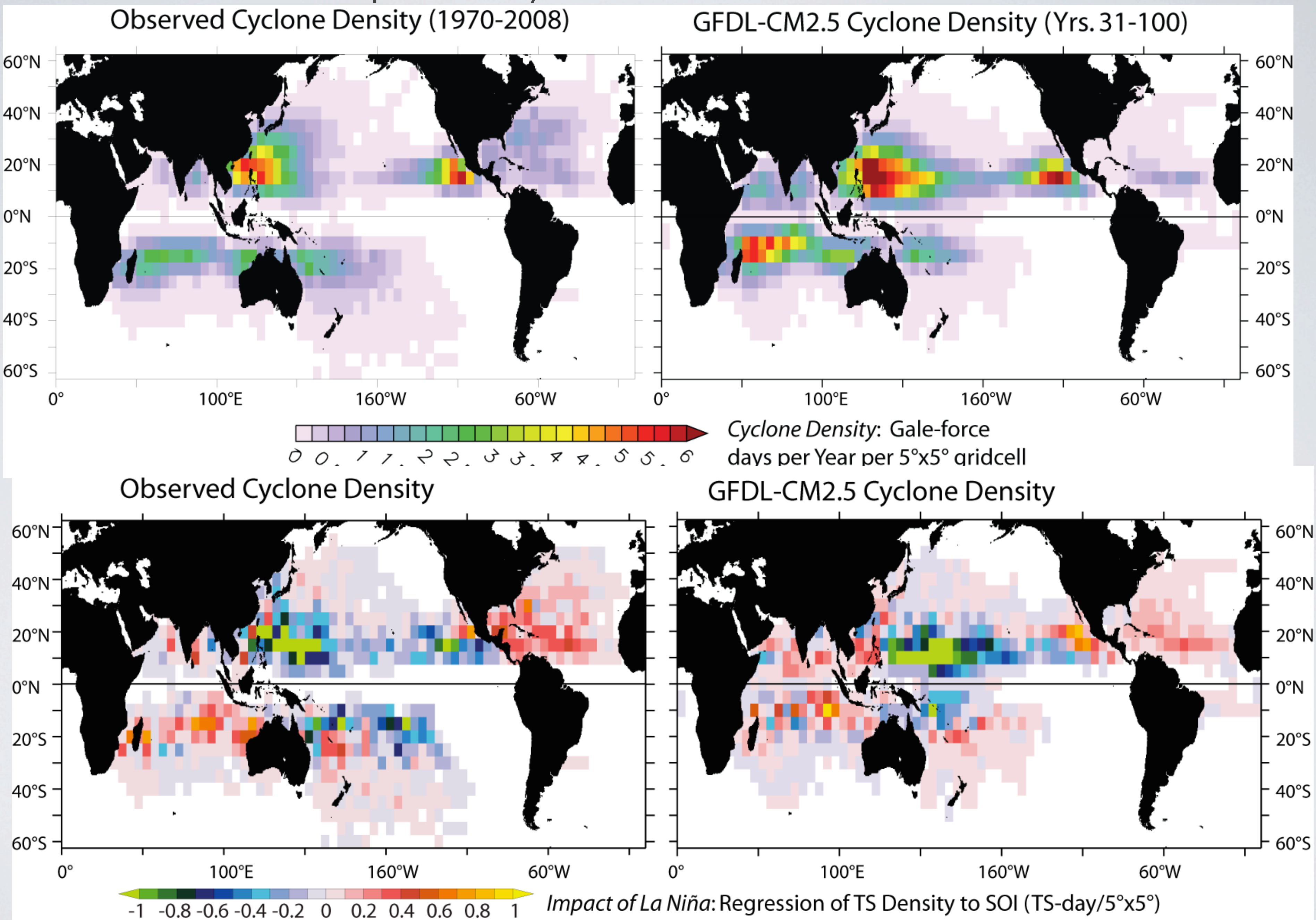


Figures: Takeshi Doi

Tropical Cyclones in CM2.5

Mean

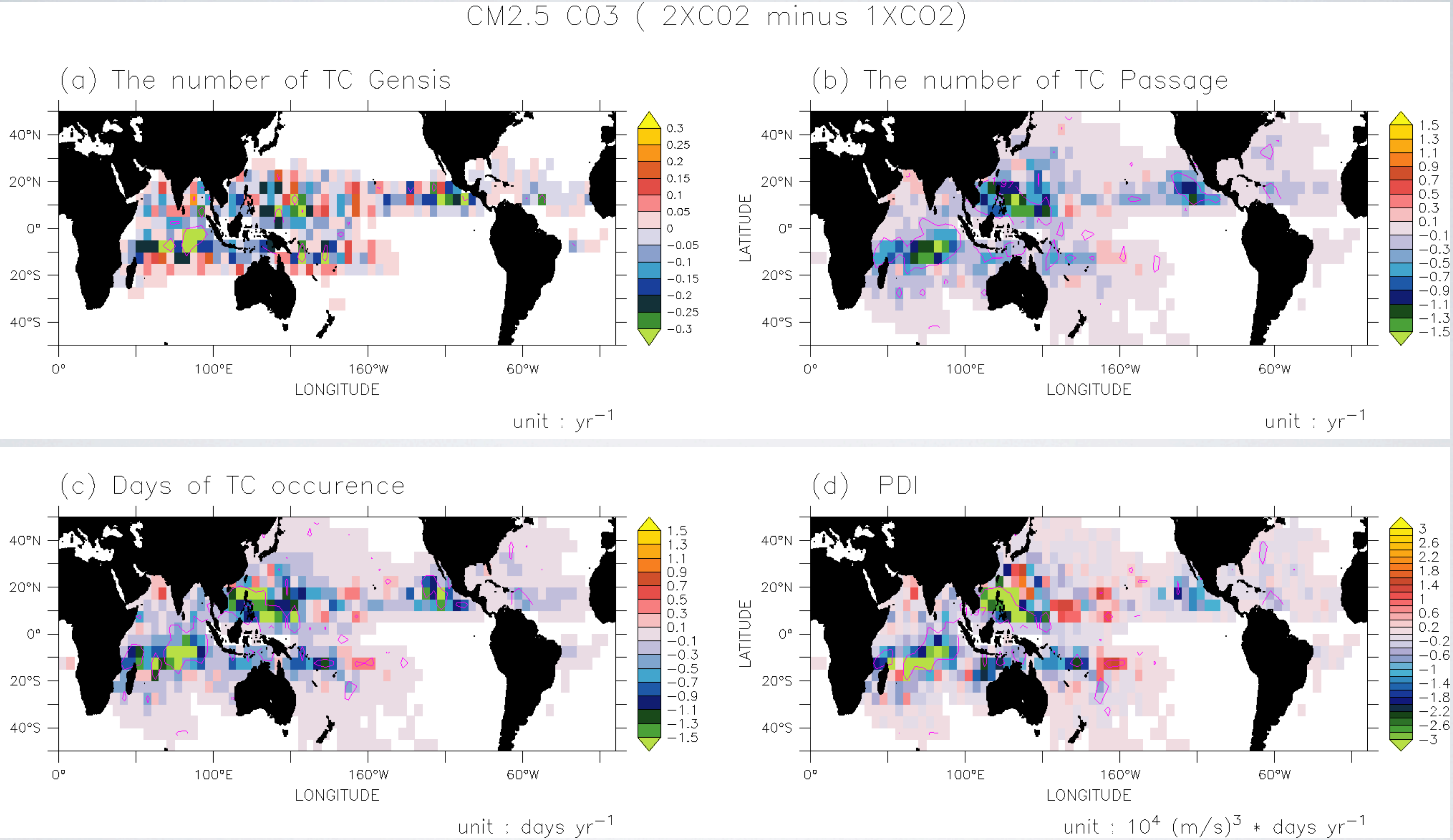
Regression to SOI



Figures: Hyeong-Seog Kim

Kim et al. (2012, in prep.)

Tropical Cyclone Response to CO_2 in CM2.5



Figures: Hyeong-Seog Kim

Kim et al. (2012, in prep.)

Summary

- New high-resolution coupled climate models being developed and run at GFDL.
- Enhanced resolution important both to resolve phenomena/features (cyclones, orography), and to resolve processes (eddies, etc).
- Some aspects of tropical climate improve from increasing resolution: tropical precipitation, near-equatorial winds, structure of interannual SST variability, monsoon rainfall.
- Some aspects of large-scale response to CO_2 similar in climate models with very different resolution, but others differ: in hi-res model climate sensitivity larger, southern hemisphere warming stronger, more eastern equatorial Pacific warming, weakened equatorial Pacific easterlies more to the east.
- Regional precipitation response to increased CO_2 can differ fundamentally between models of differing resolution. High-res model shows orographically-tied features: what are mechanisms for various differences?
- Why do models differ? Is one of the responses more plausible?

  Higher resolution does not necessarily mean a "better" model/response.