Recent Results with the GFDL High-Resolution Coupled Modeling Systems

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References:

- 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 (2011): Simulated climate and climate change in the GFDL CM2.5 high-resolution coupled climate model. *Submitted to J. Clim.*
- Doi, T., G.A. Vecchi, A.J. Rosati and T.L. Delworth (2011): Tropical Atlantic biases in the mean state, seasonal cycle, and interannual variations for a coarse and a high resolution coupled climate model. *Submitted to J. Clim.*

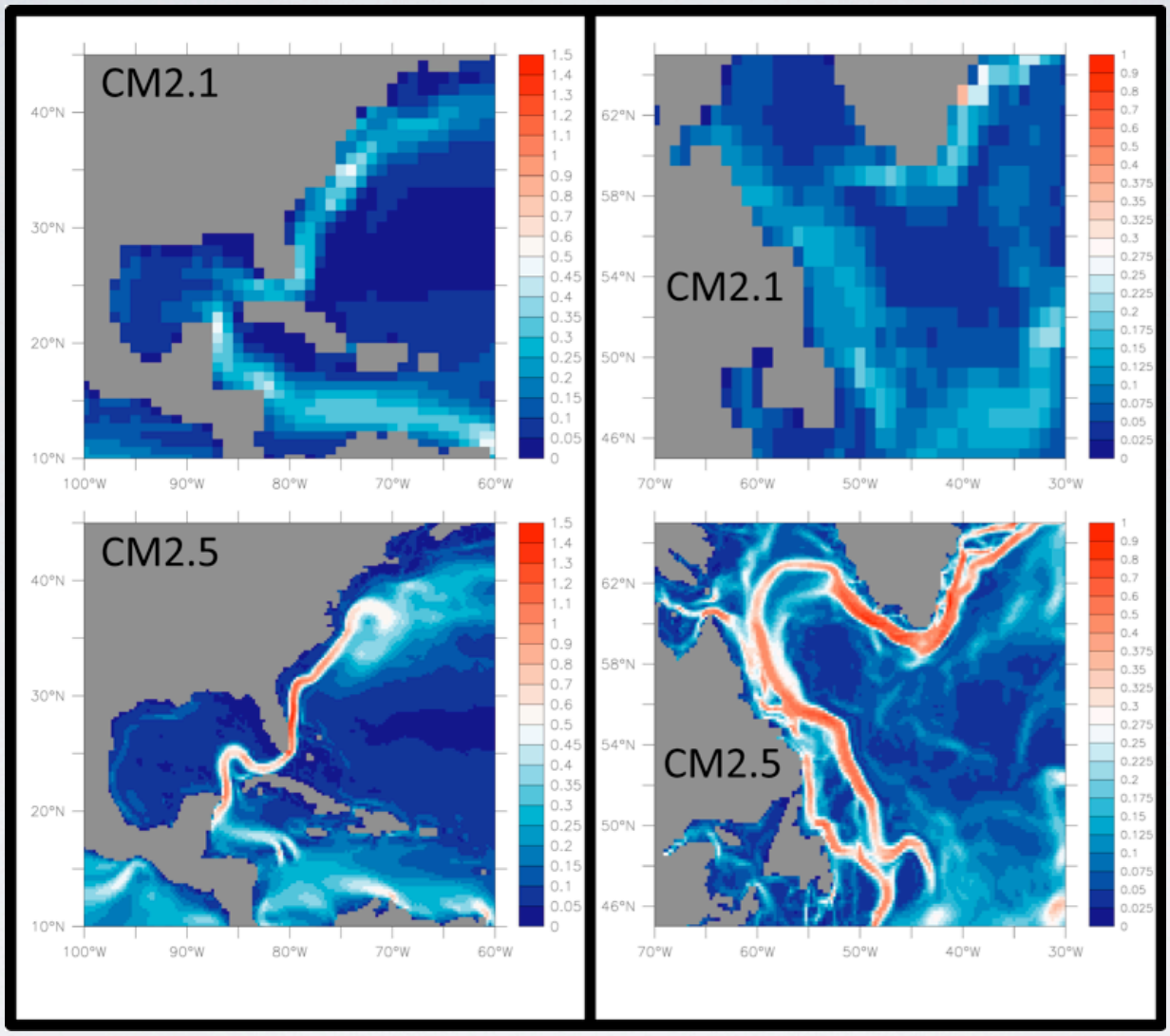
High Resolution Model Development

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 model
- New global coupled models: CM2.4, CM2.5, CM2.6

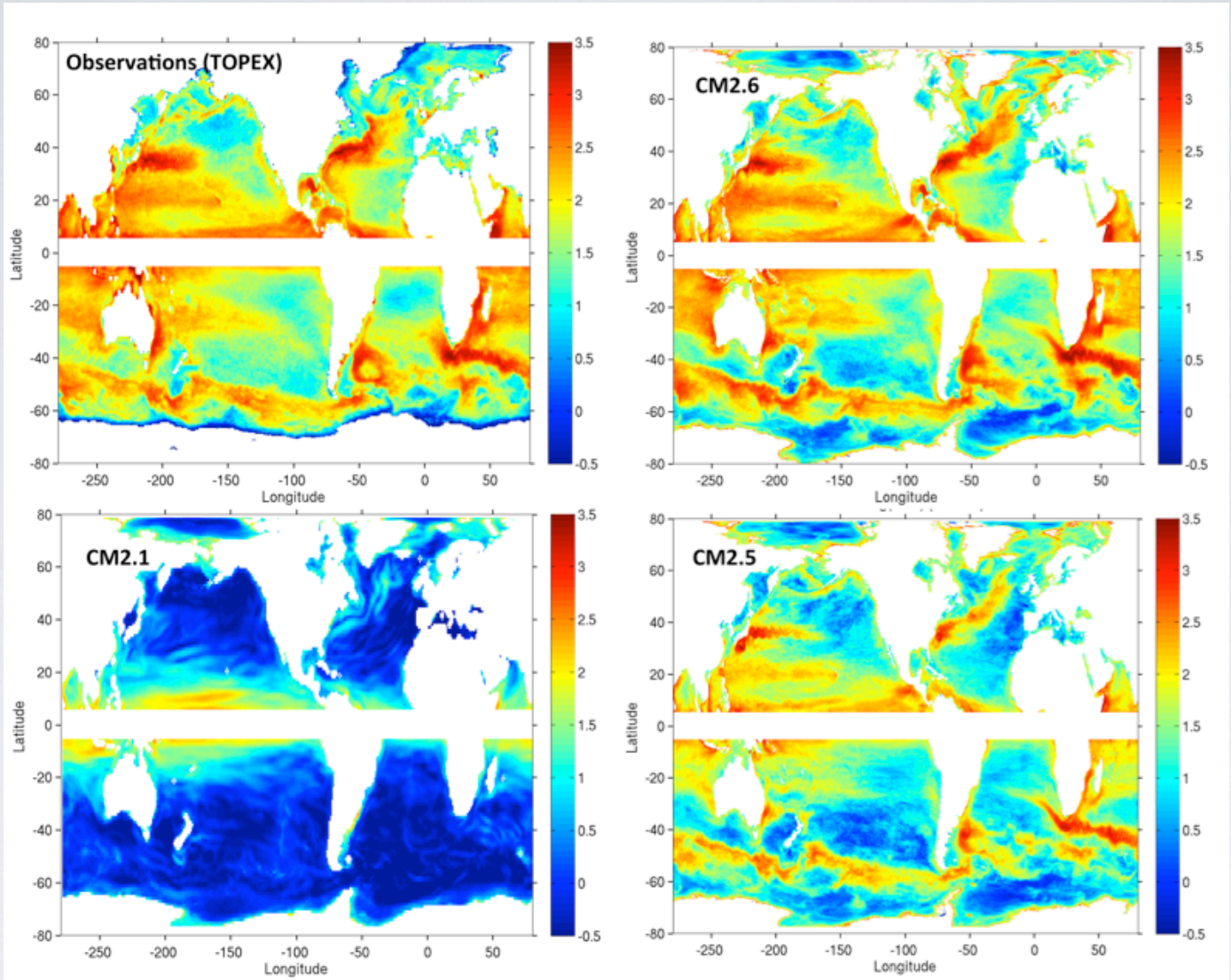
	Ocean	Atmos	Computer	Status
CM2.1	100 Km	250 Km	GFDL	Running
CM2.3	100 Km	100 Km	GFDL	Running
CM2.4	10-25 Km	100 Km	GFDL	Running
CM2.5	10-25 Km	50 Km	ORNL/GFDL	Running
CM2.6	4-10 Km	50 Km	ORNL	Running

Surface currents much more energetic



Delworth et al (2011)

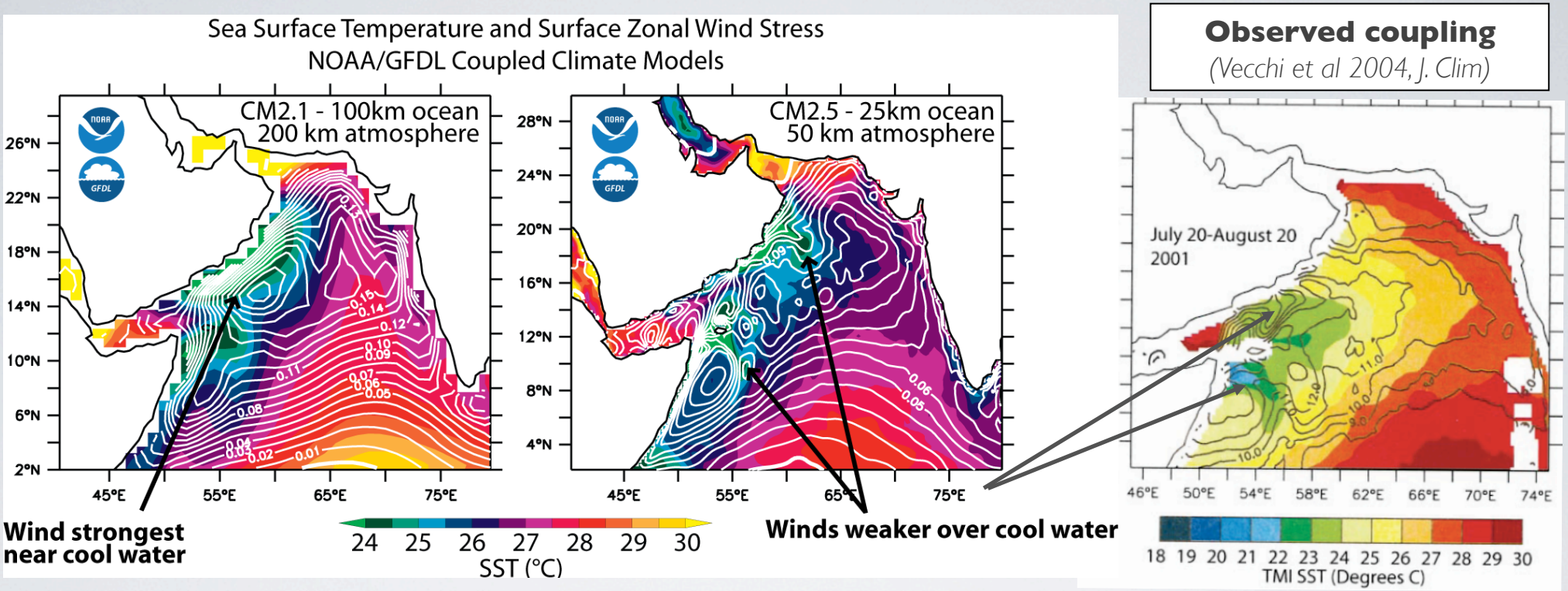
However, to Reproduce Observed EKE Need Higher Resolution Yet



Resolution enhancement allows model to better represent processes

Delworth et al (2011)

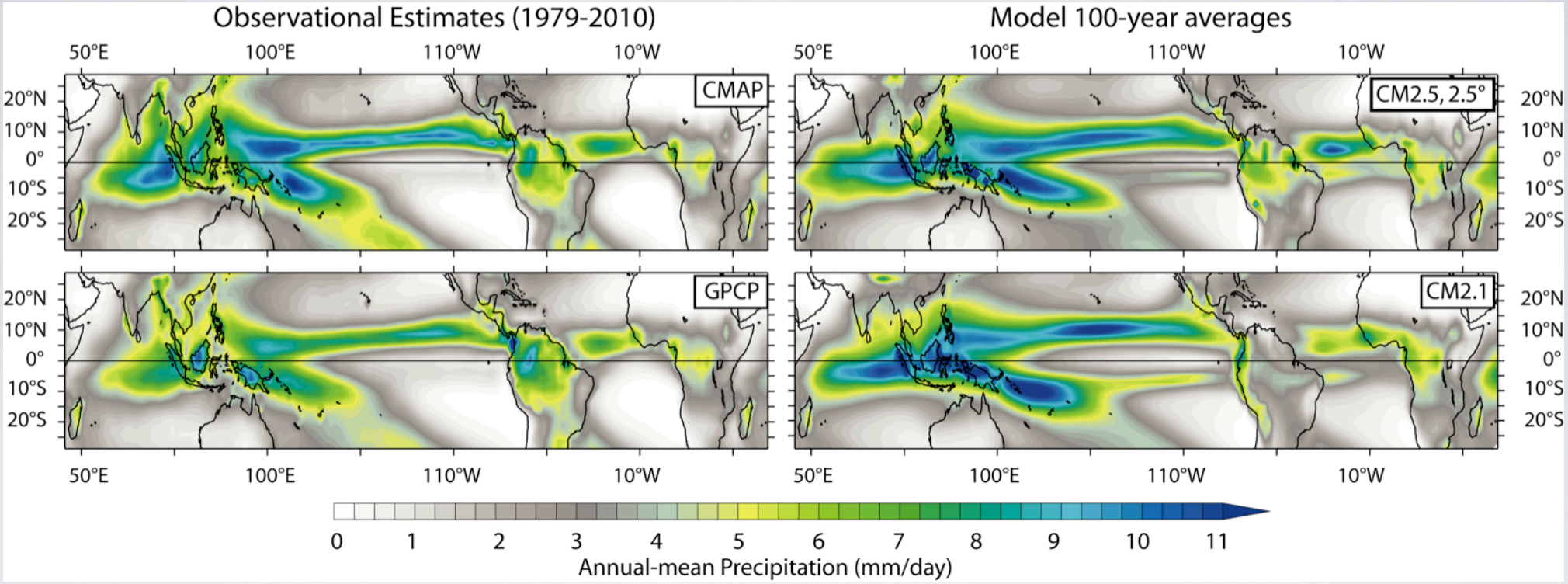
Oceanic Mesoscale Coupling in Western Arabian Sea



Resolution enhancement allows model to better represent processes

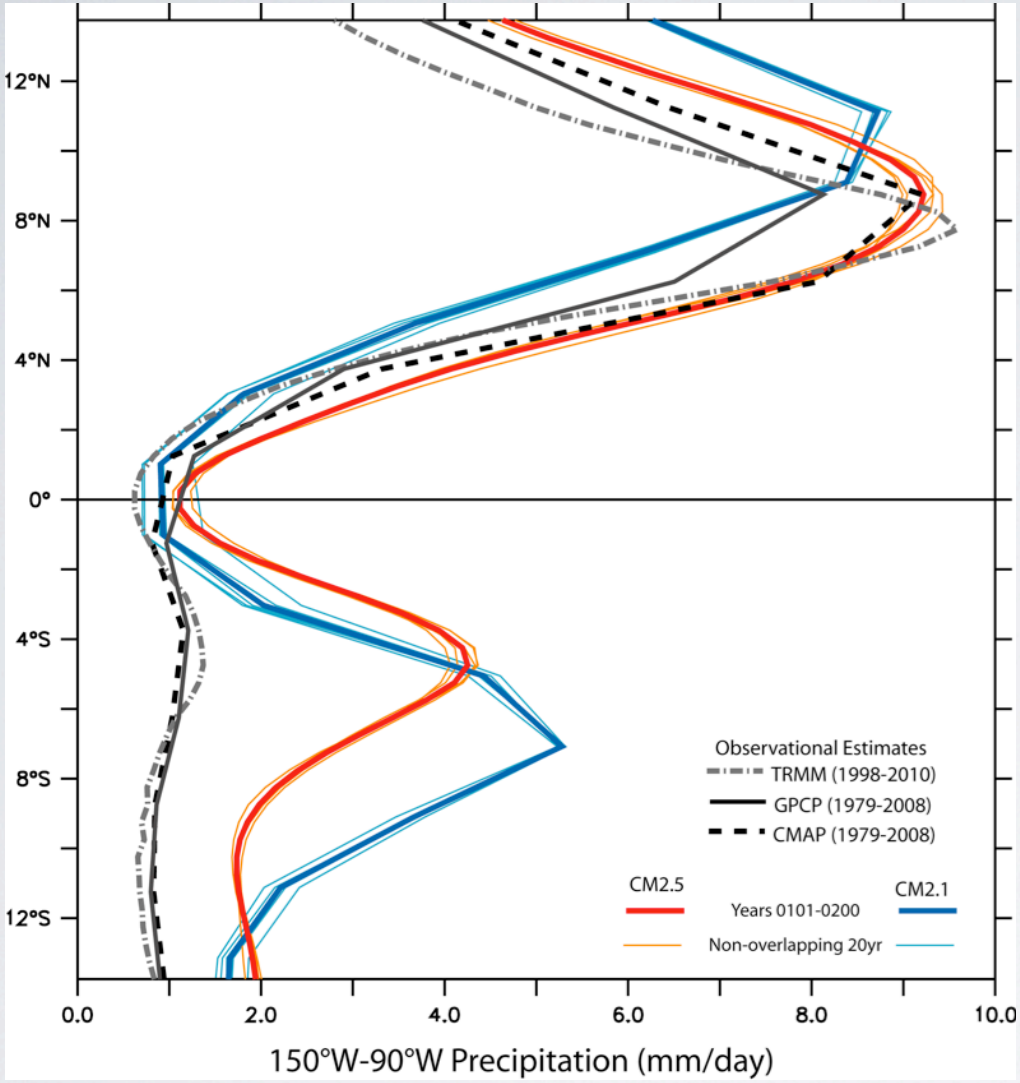
Some Aspects of Tropical Climate Improve with Resolution

Annual Tropical Precipitation on 2.5x2.5 Grid



Adapted from Delworth et al (2011)

Some Aspects of Tropical Climate Improve with Resolution

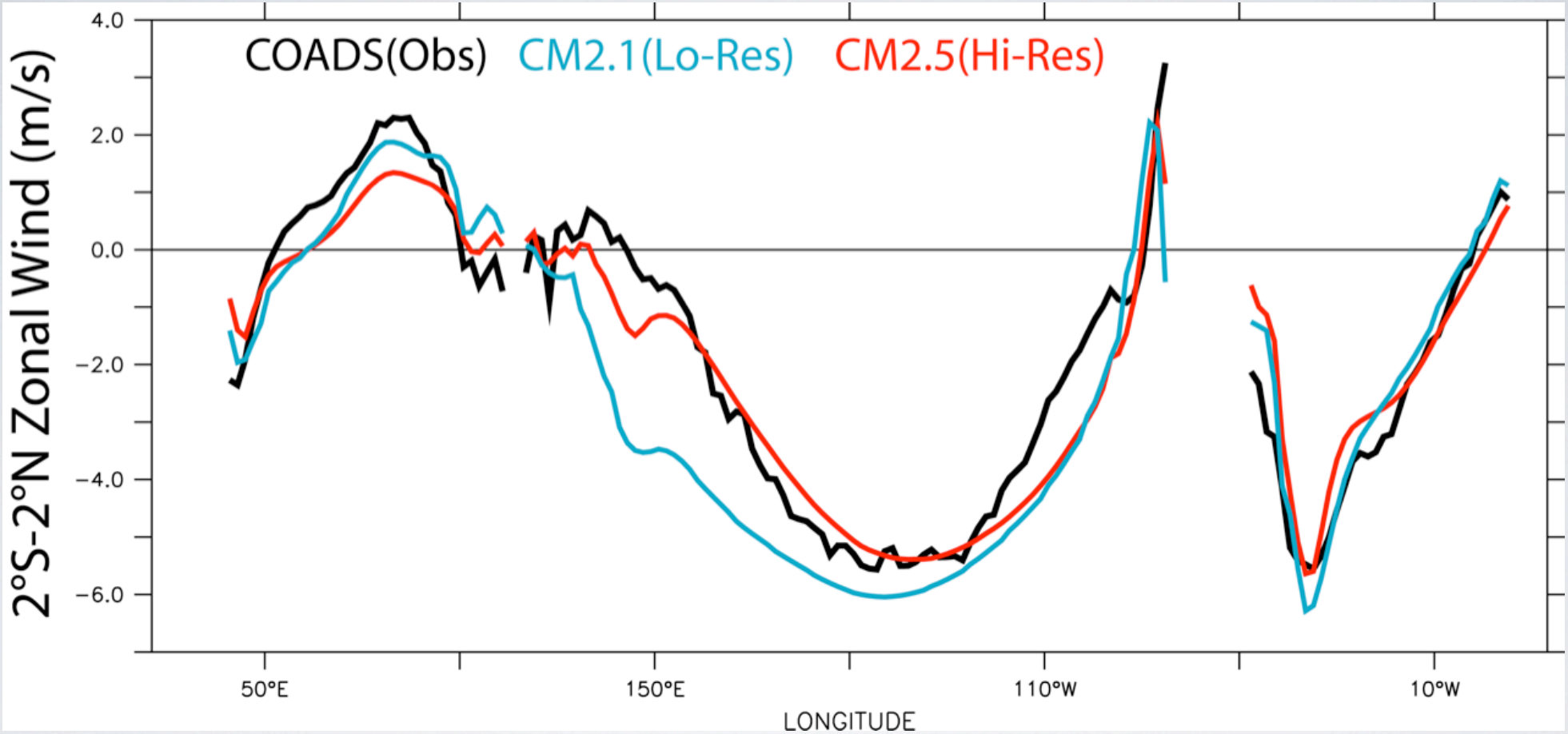


East Pacific Rainfall:
"Double-ITCZ" reduced

Delworth et al (2011)

Some Aspects of Tropical Climate Improve with Resolution

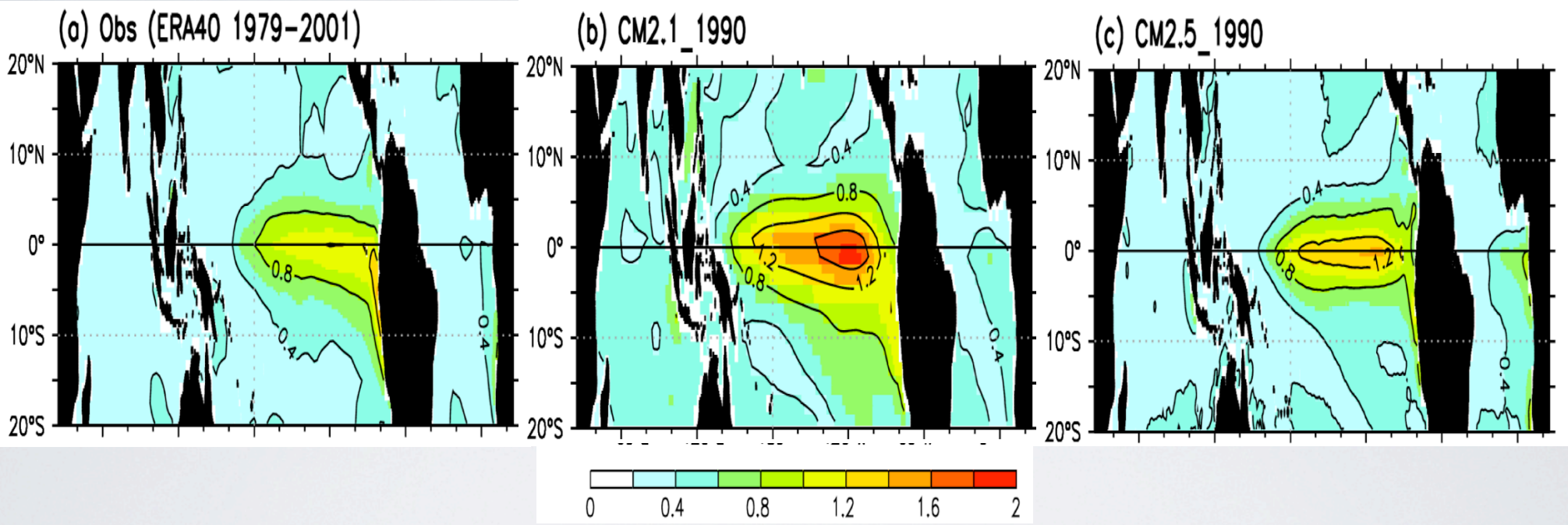
Near-equatorial Zonal Winds



Delworth et al (2011)

Some Aspects of Tropical Climate Improve With Resolution

Structure of tropical SST variability

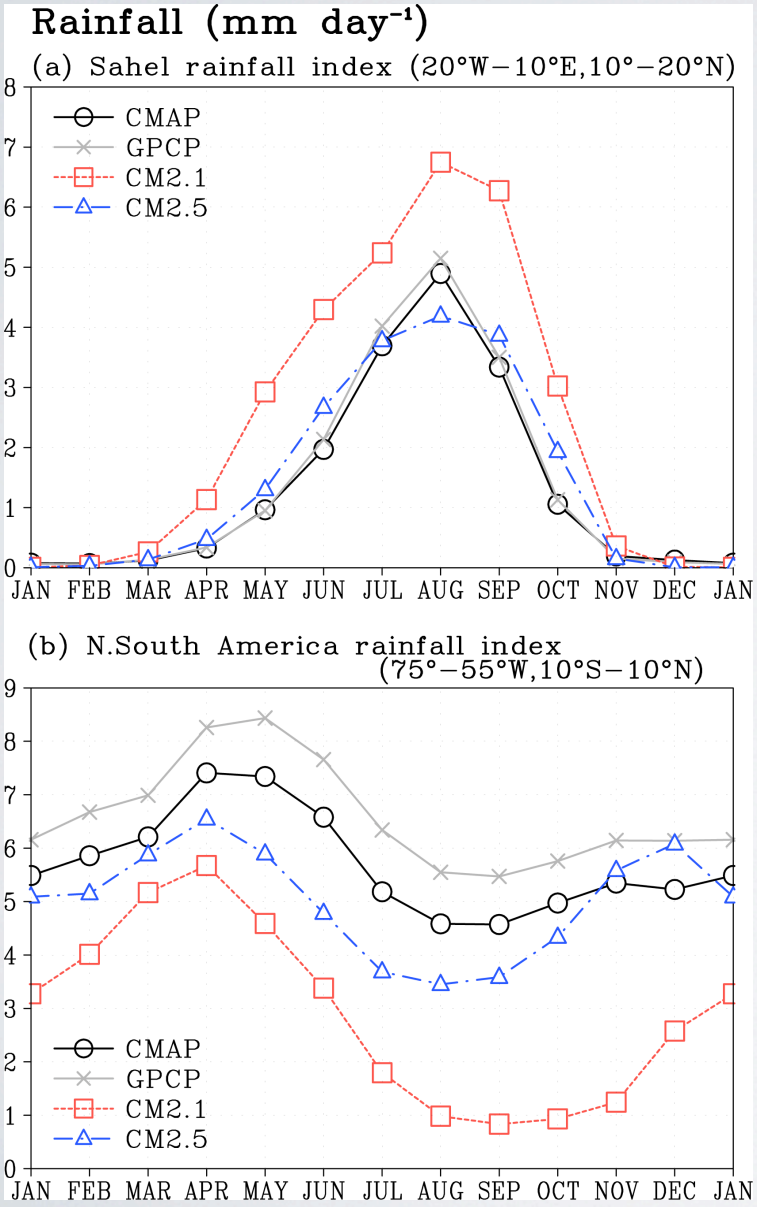


SSTA Standard deviation (°C)

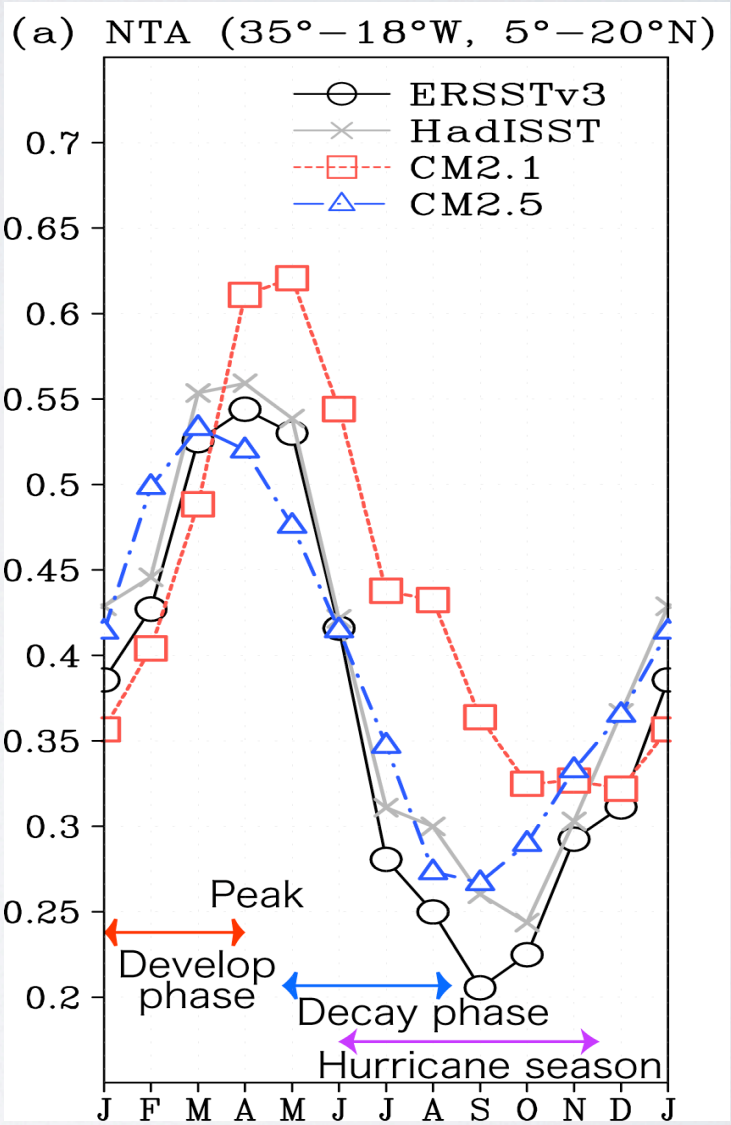
Delworth et al (2011)

N. Tropical Atlantic Climate Shows Improvement Associated with improved Atlantic ITCZ simulation

Climatological Rainfall



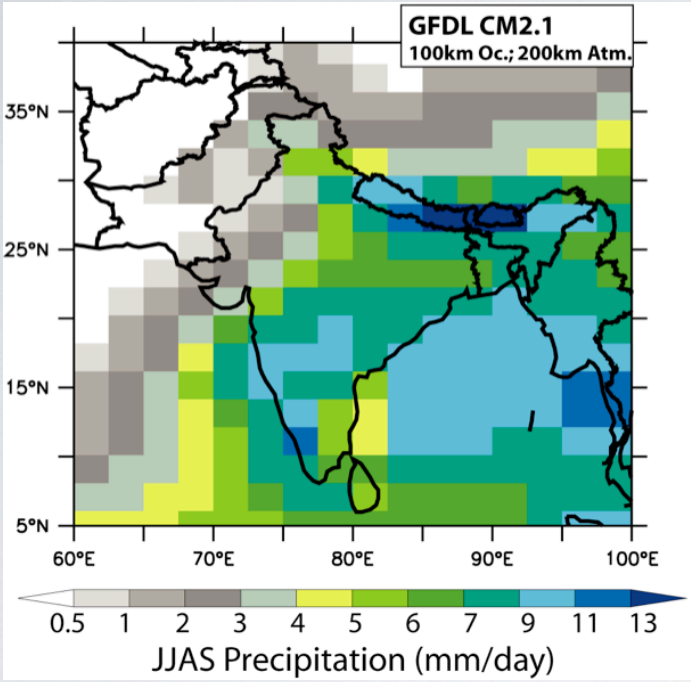
Interannual SST Standard Dev.



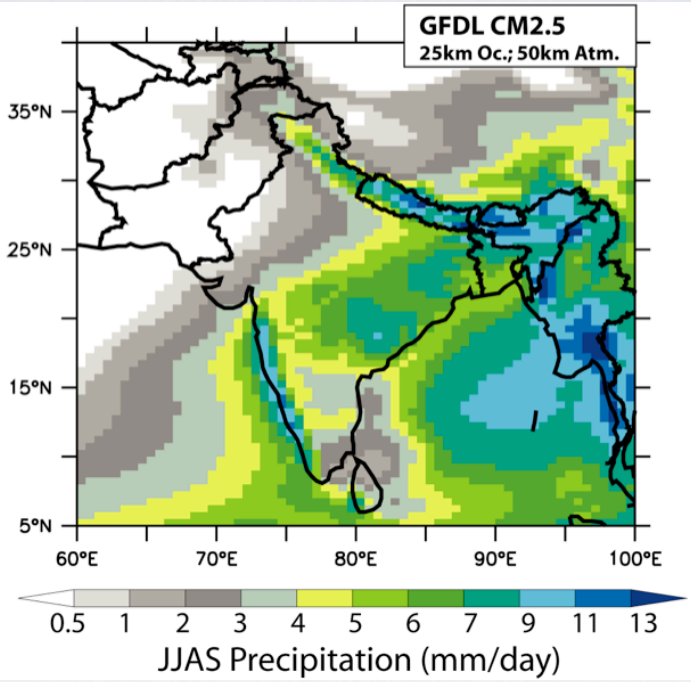
Doi et al. (2011)

South Asian Monsoon Rainfall Improves with Resolution

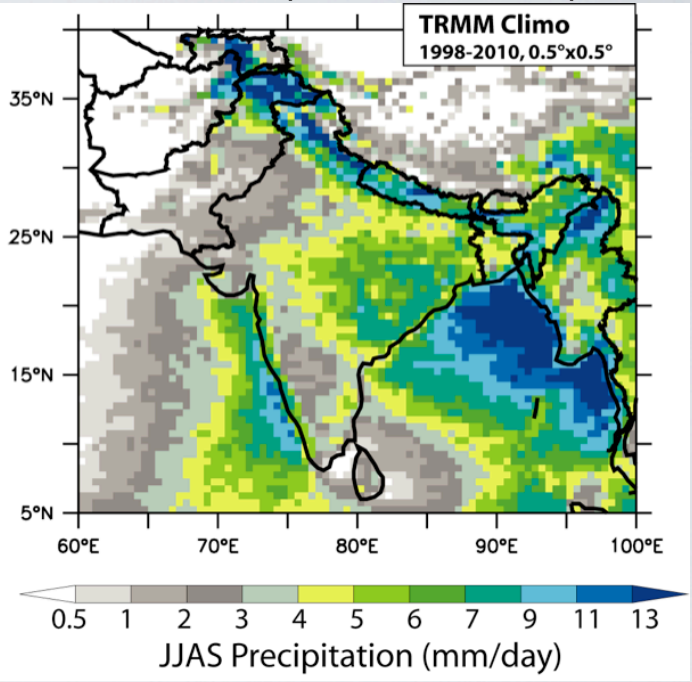
CM2.1 (lo-res)



CM2.5 (hi-res)

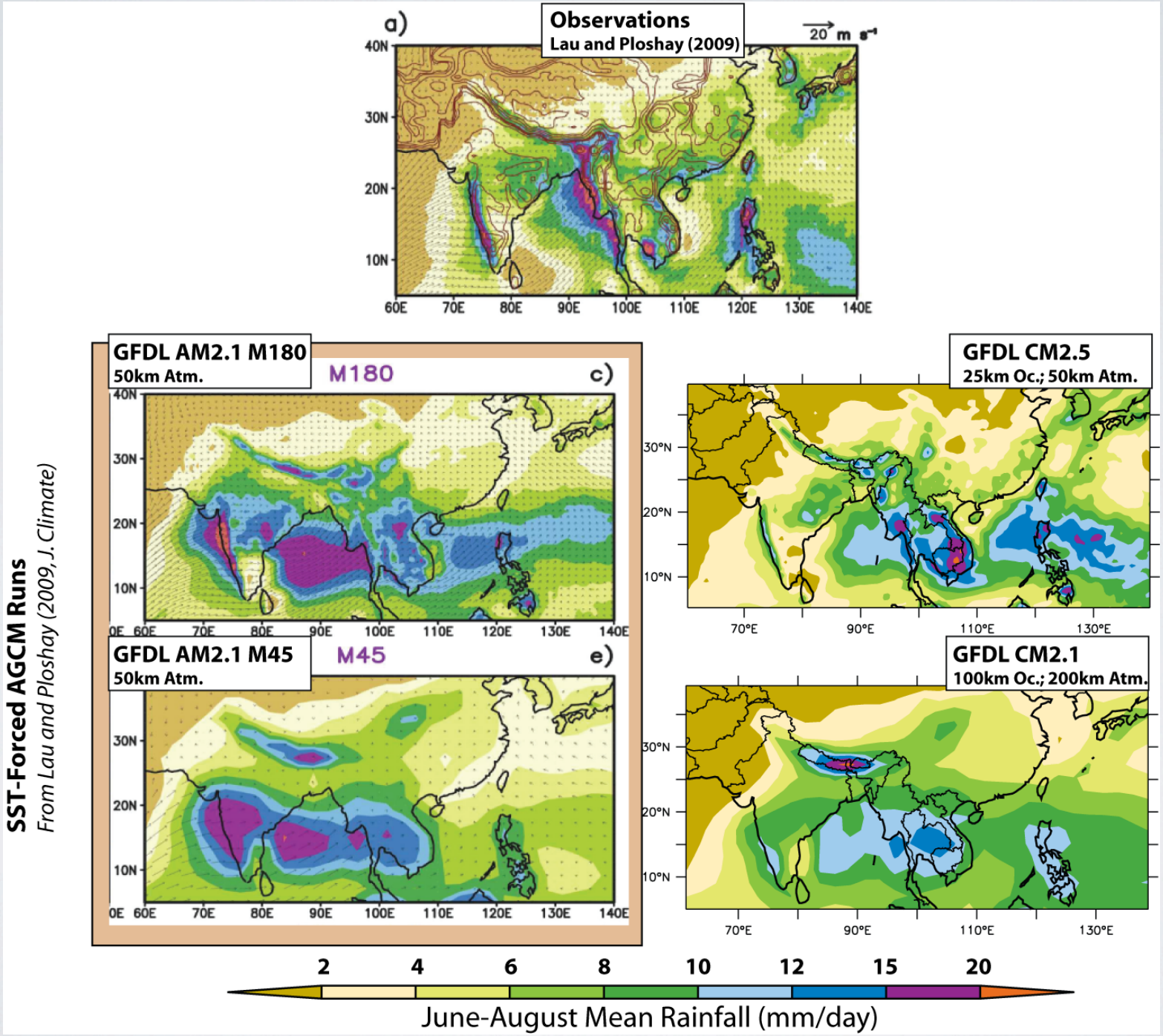


TRMM (1998-2010)



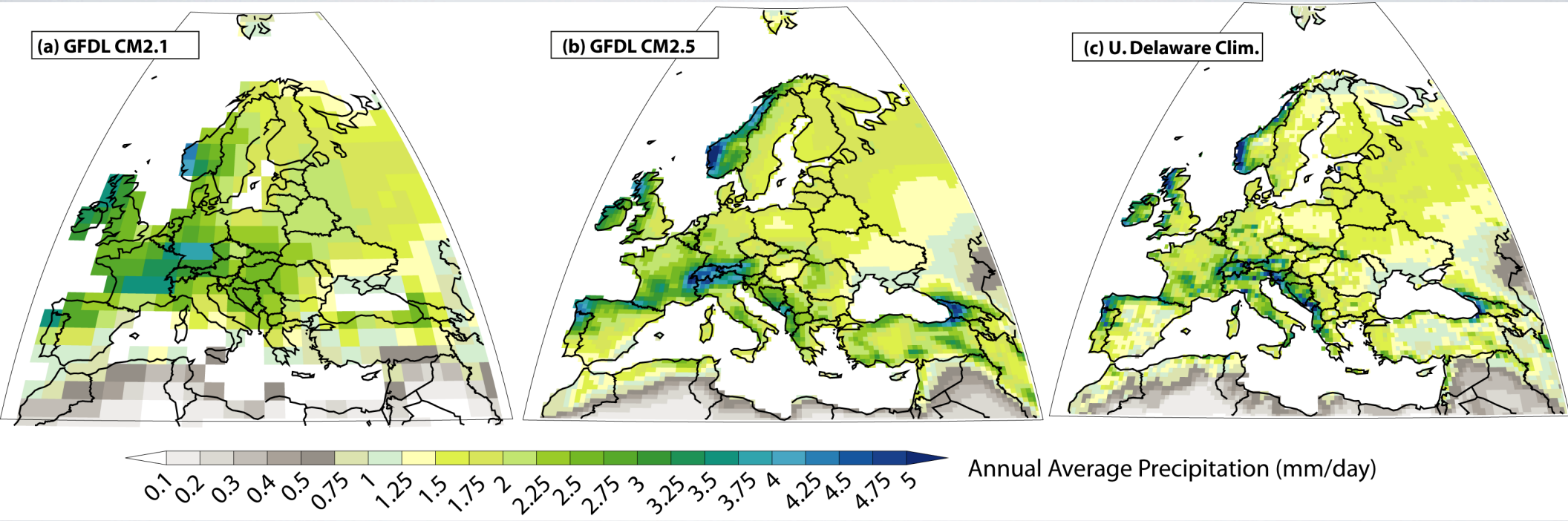
Delworth et al (2011)

Enhanced Resolution and Coupling Improve Asian Monsoon Rainfall



Resolution Impacts European Rainfall

CM2.1 (lo-res) CM2.5 (hi-res) U. Delaware Obs.



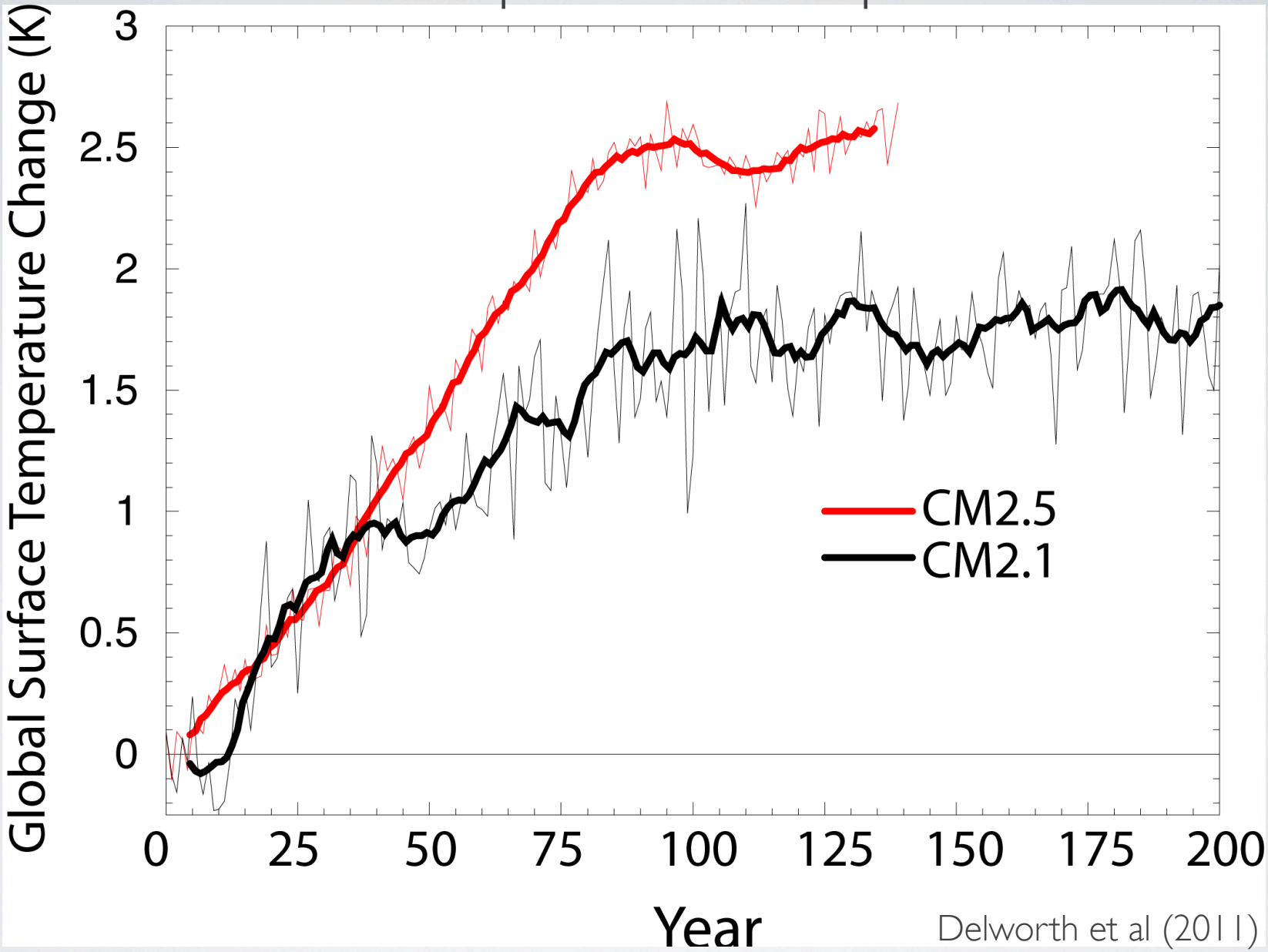
Delworth et al (2011)

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 mean "better".

Global Surface Temperature Response to $2xCO_2$

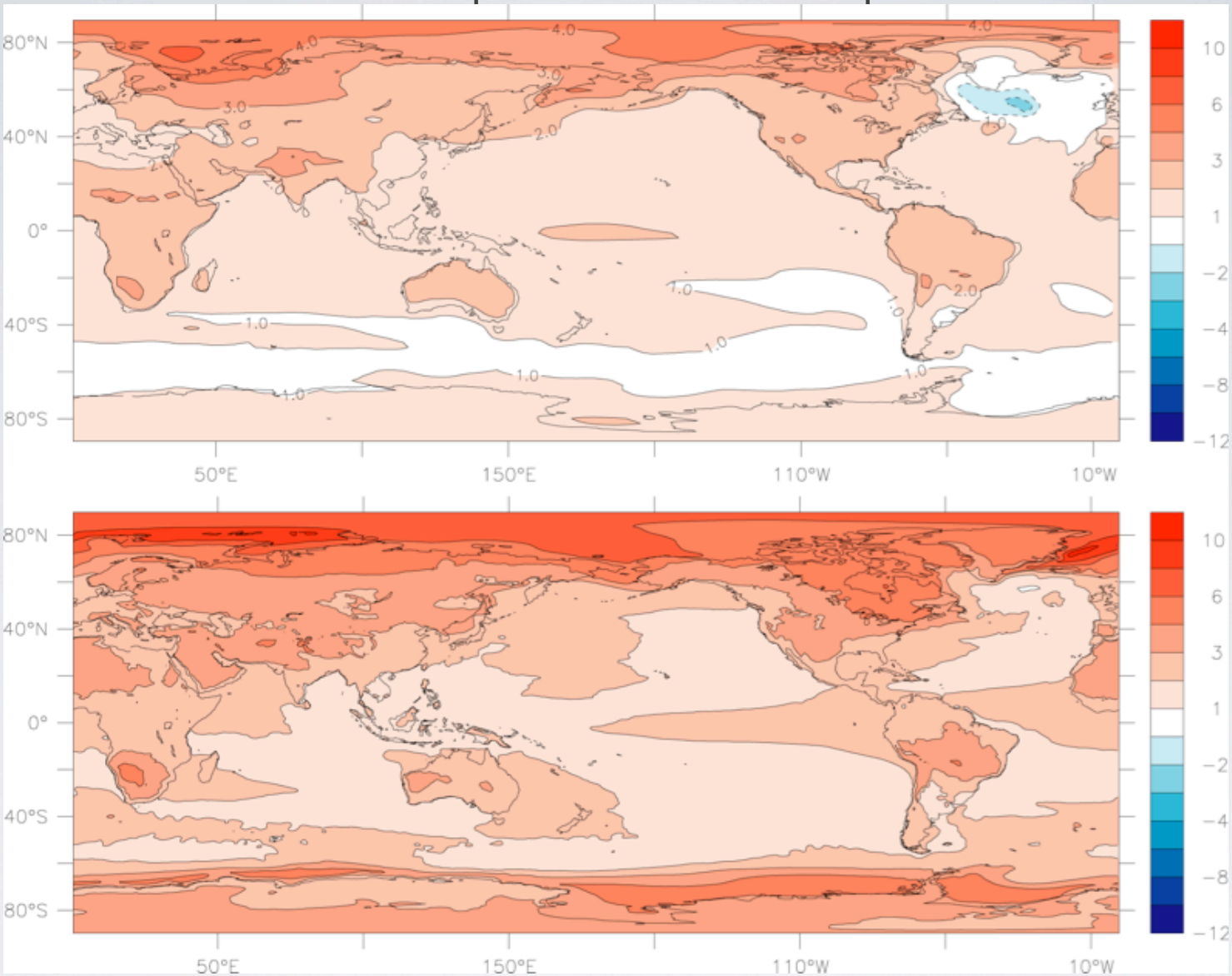


Delworth et al (2011)

Global Surface Temperature Response to $2xCO_2$

CM2.1
(lo-res)

CM2.5
(hi-res)

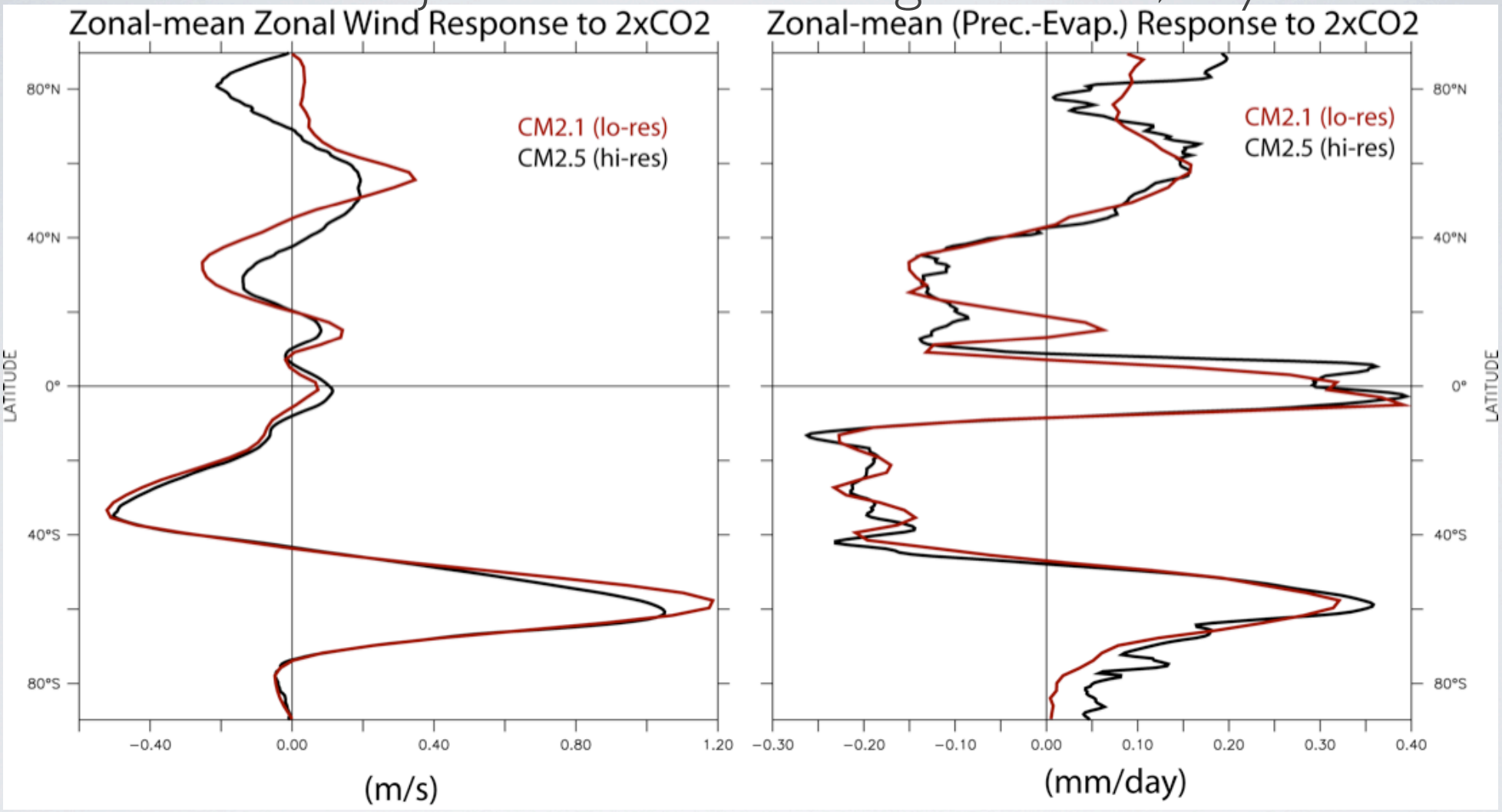


Delworth et al (2011)

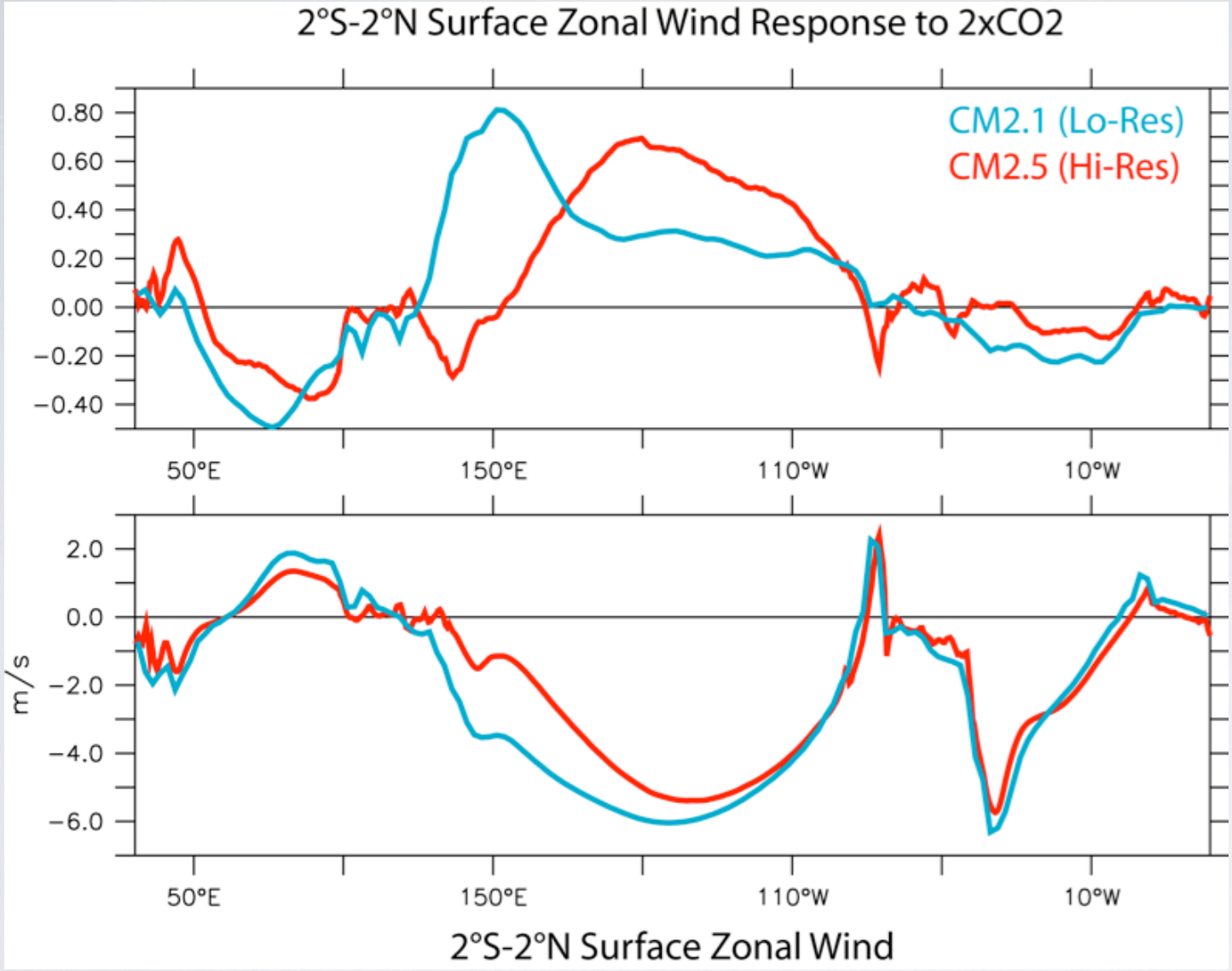
Global Zonal-mean Response to 2xCO_2

Poleward jet shift

"Wet get wetter, dry drier"



Equatorial Zonal Wind Response to $2xCO_2$

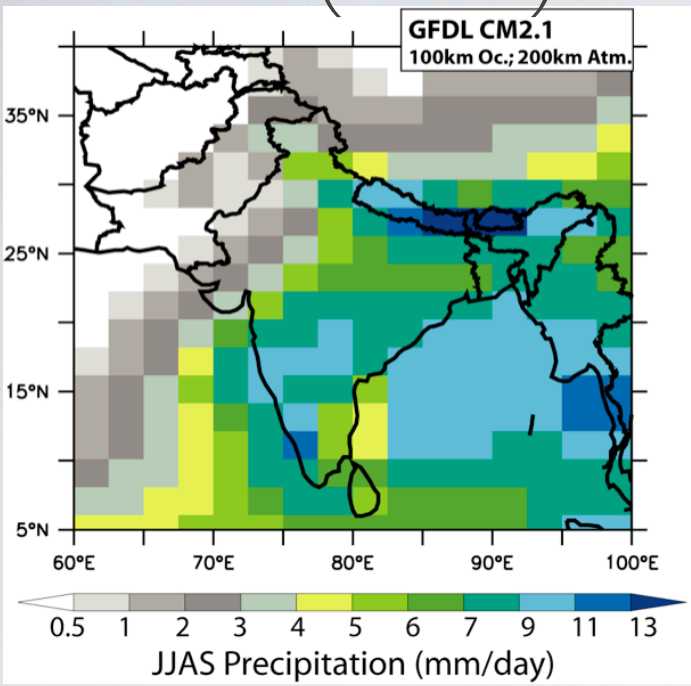


Equatorial winds weaken in both models.

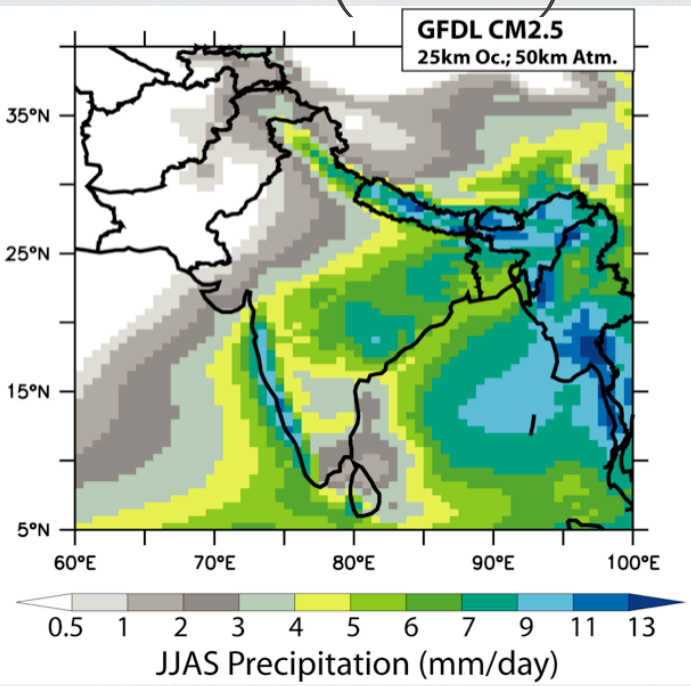
Location of weakening in Pacific different.

South Asian Monsoon Rainfall Improves with Resolution

CM2.1(lo-res)



CM2.5(hi-res)



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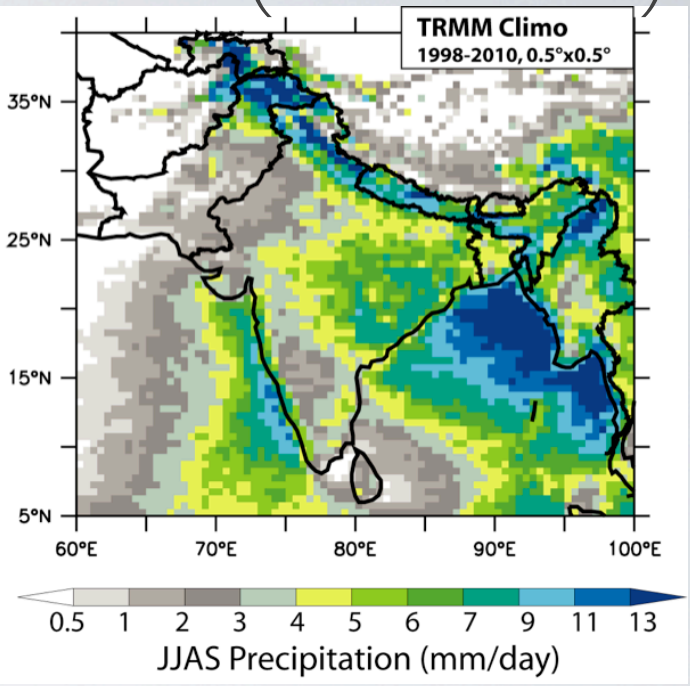
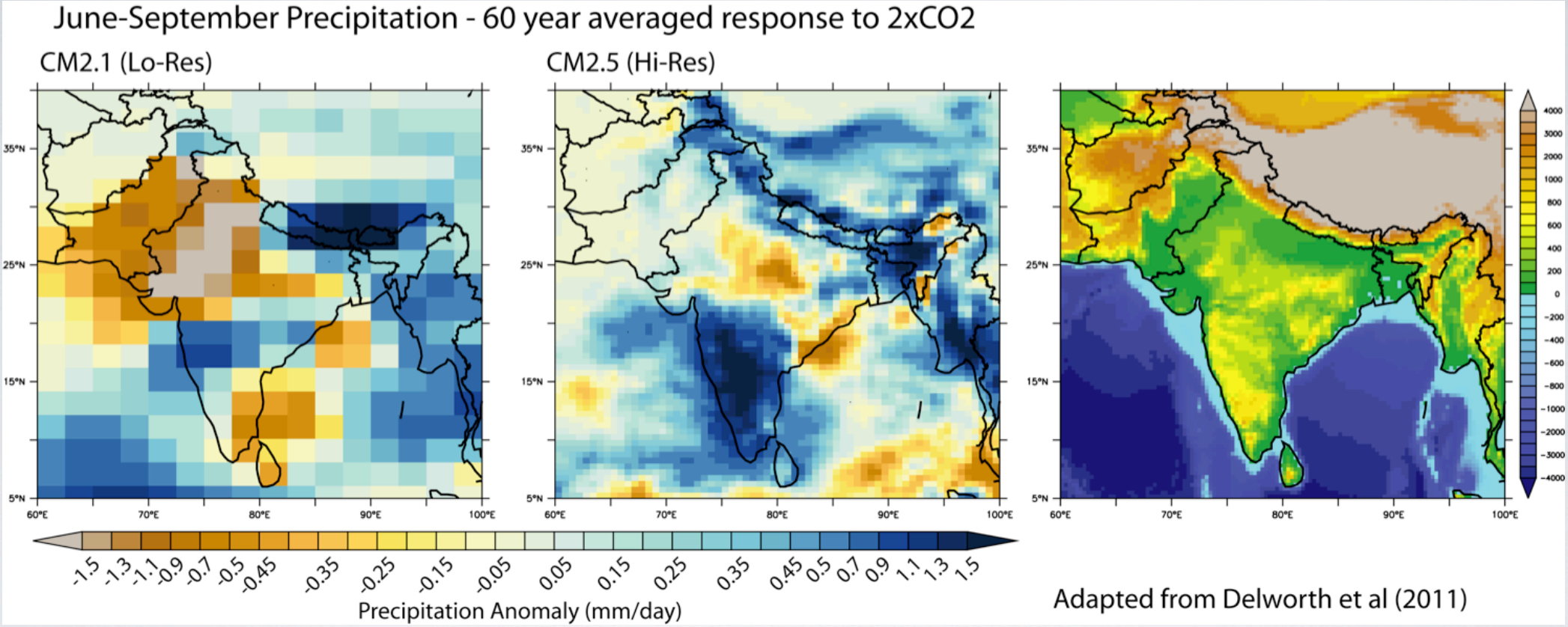


Delworth et al (2011)

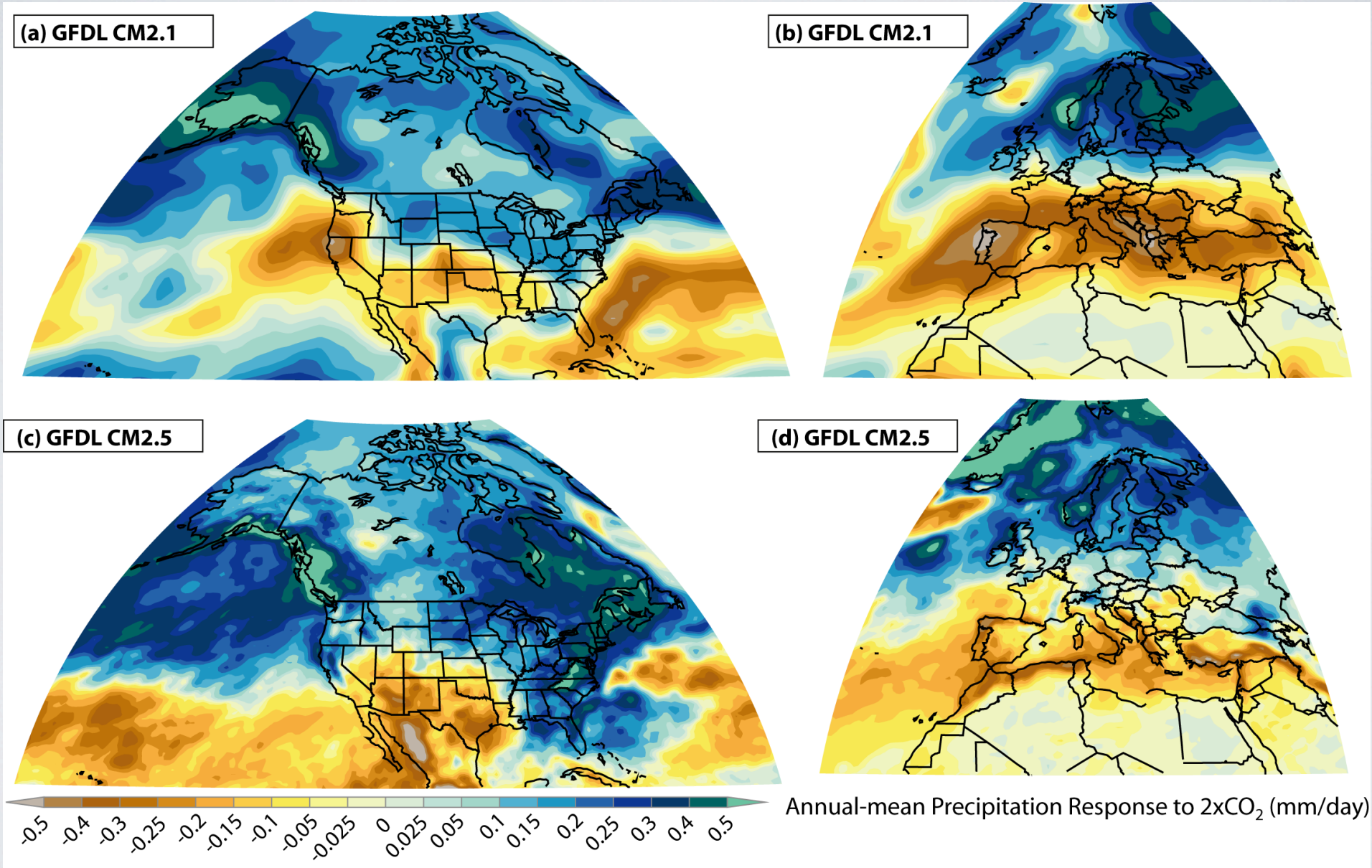
South Asian Monsoon Response to $2xCO_2$

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



Why is response different?

North America and European Response to 2xCO_2

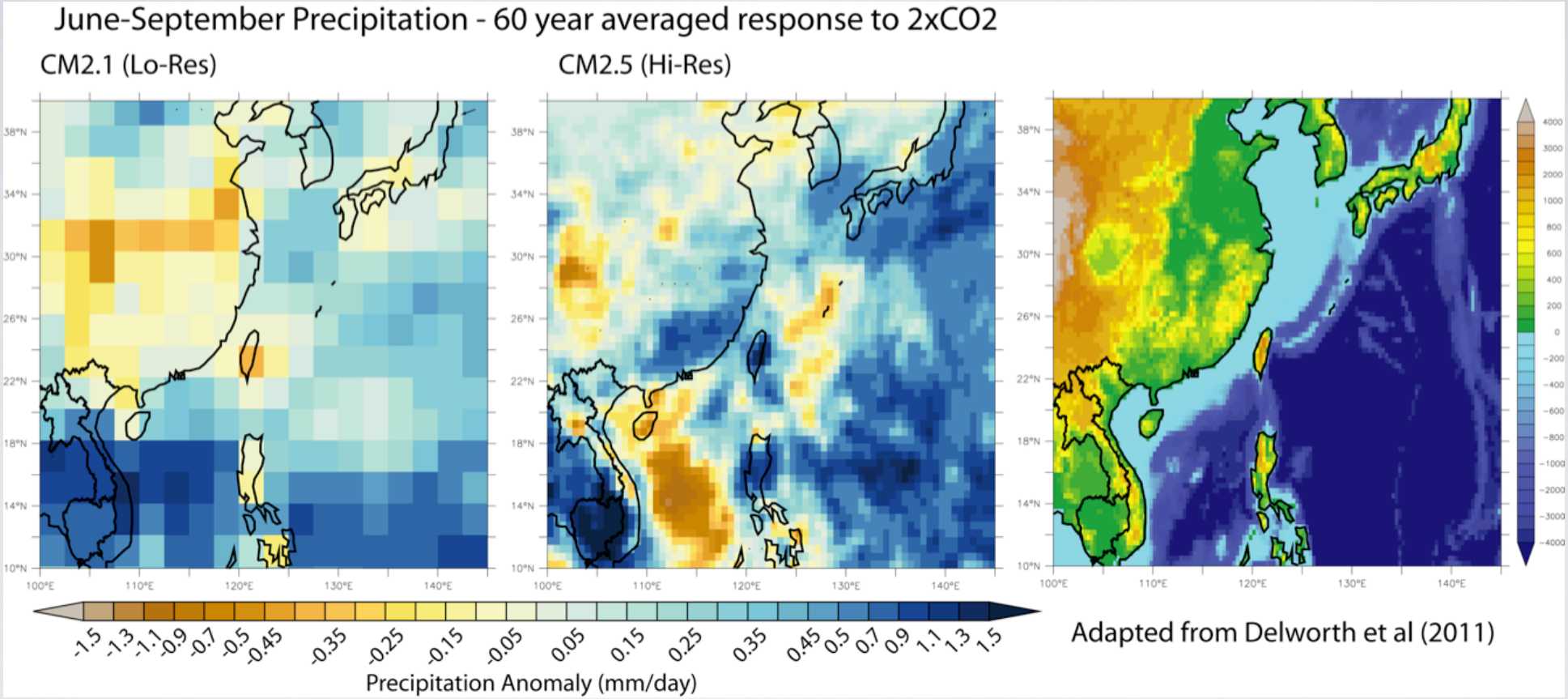


Summary

- 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).
- Aspects of tropical climate improve from increasing atmospheric and oceanic resolution: tropical precipitation, near-equatorial winds, structure of interannual SST variability, regional monsoon rainfall structure.
- Some aspects of large-scale response to CO2 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 CO2 can differ fundamentally between models of differing resolution. High-res model shows orographically-tied features: what are mechanisms?
- Why do models differ? Is one of the responses more plausible? Higher resolution does not necessarily mean a "better" model/response.

East Asia JJAS Rainfall Response to $2xCO_2$

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



Why is response different?