Persistence of Systematic errors in the Asian-Australian monsoon Precipitation in climate models: a way forward

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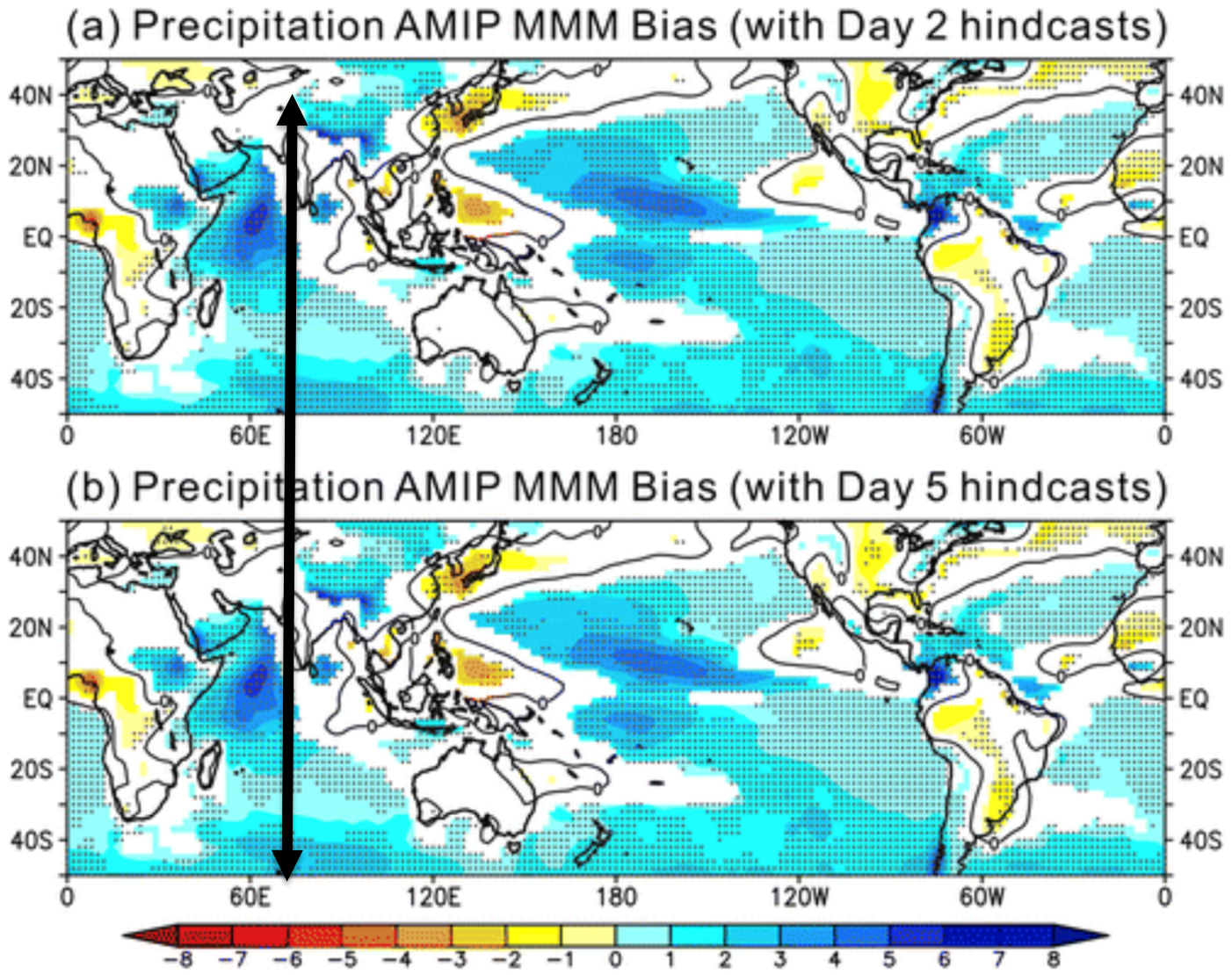
Summary (CLIVAR Exchanges article)

- Process-based diagnostics (e.g., moisture stratification, salinity stratification)
- Need for high-quality observations to constrain model physics (large investment)
- Coordinated experiments (e.g., moisture stratification, salinity stratification)
- **Close-relationship among monsoon researchers and model developers**

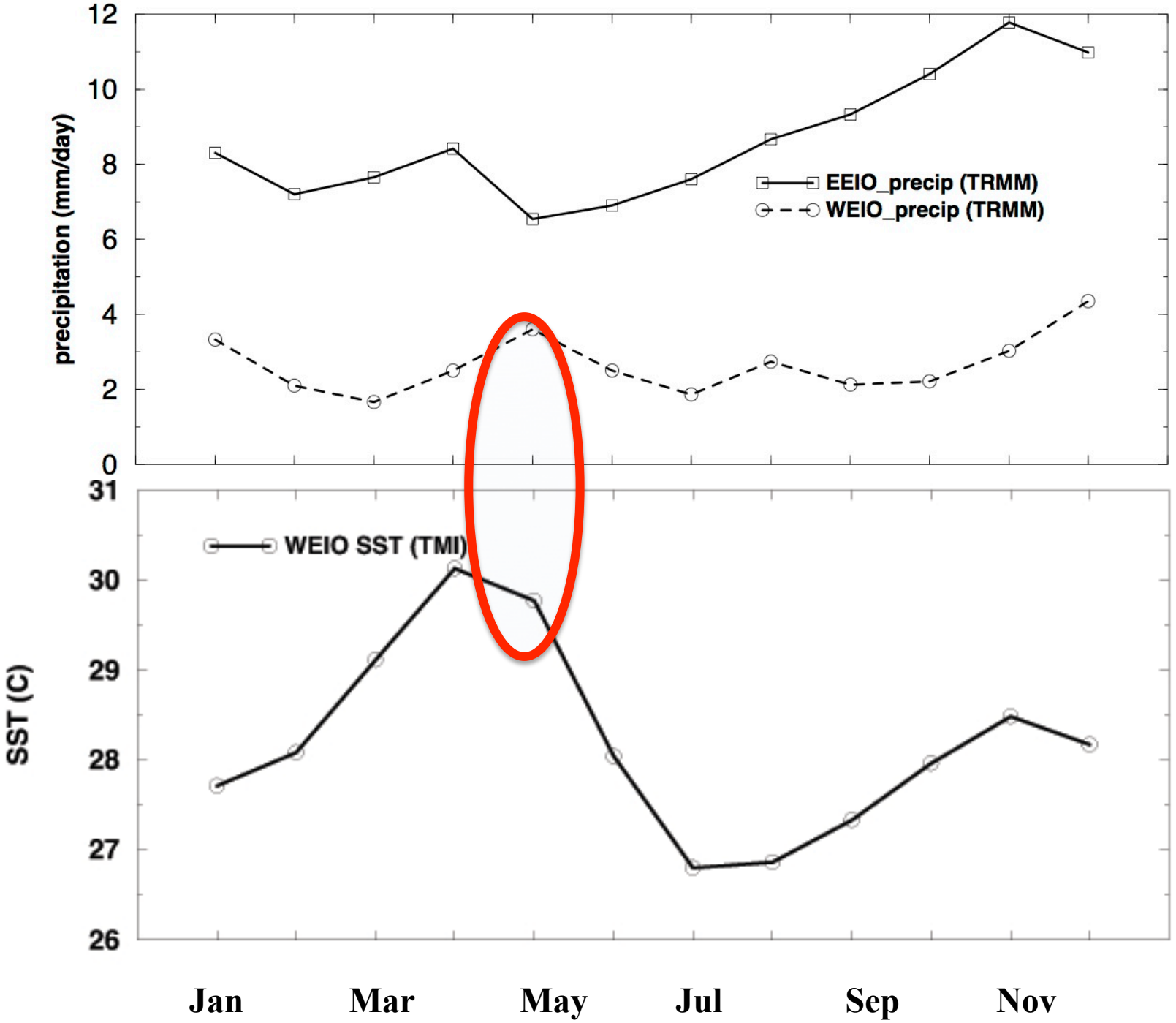
Despite dedicated efforts by the modeling community, the progress in monsoon modeling is rather slow. This leads us to wonder if there are fundamental limits to realistically simulating the AAM monsoon, or if a concerted observational and modeling effort can enhance the fidelity of models in simulating the monsoon.



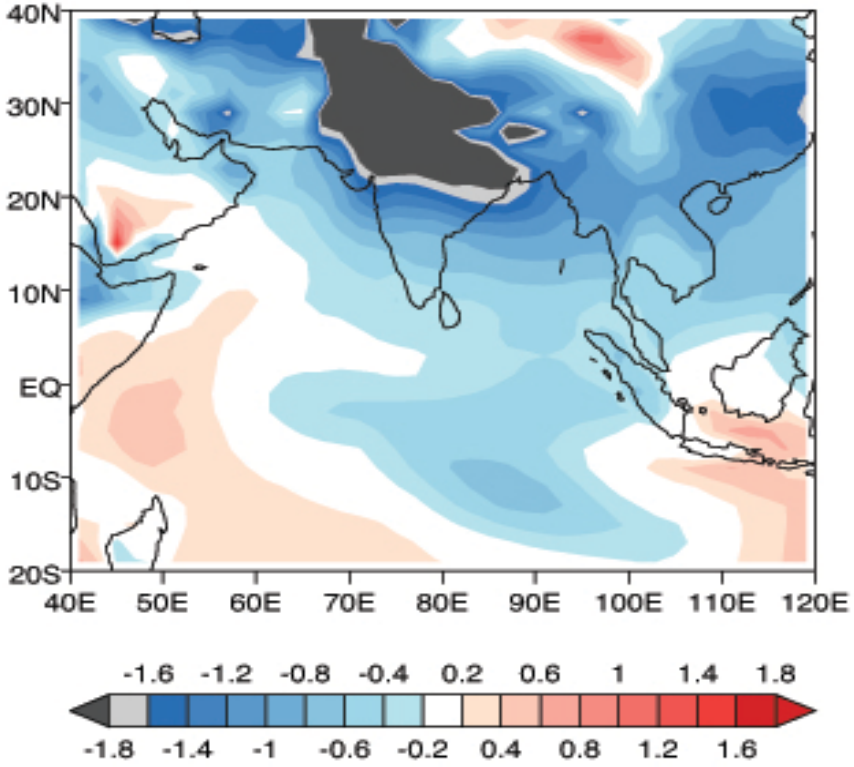
Ma et al. 2014, JC

"no SST errors"

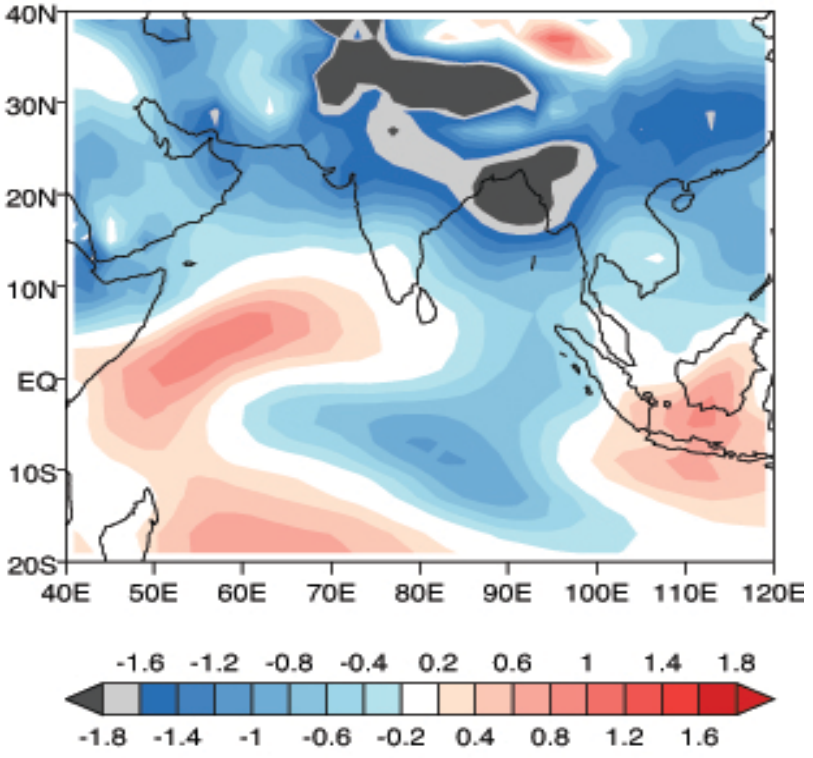
1. Dry bias over continental India – not clear
2. Rainfall errors over Maritime Continent and tropical west Pacific - unclear


precipitation (mm/day)
12
10
8
6
4
2
0
EEIO_precip (TRMM)
WEIO_precip (TRMM)
SST (C)
31
30
29
28
27
26
WEIO SST (TMI)
Jan
Mar
May
Jul
Sep
Nov

(a) Specific humidity 1000 – 850 hPa



(b) Specific humidity 700 – 400 hPa



g/kg

"issues related to entrainment parameterization in models?"

Similar to double ITCZ problems in the Pacific (Yukari)

Moisture at all levels covaries with rain, but variability is mostly above always-moist PBL (PW is area under the curve)

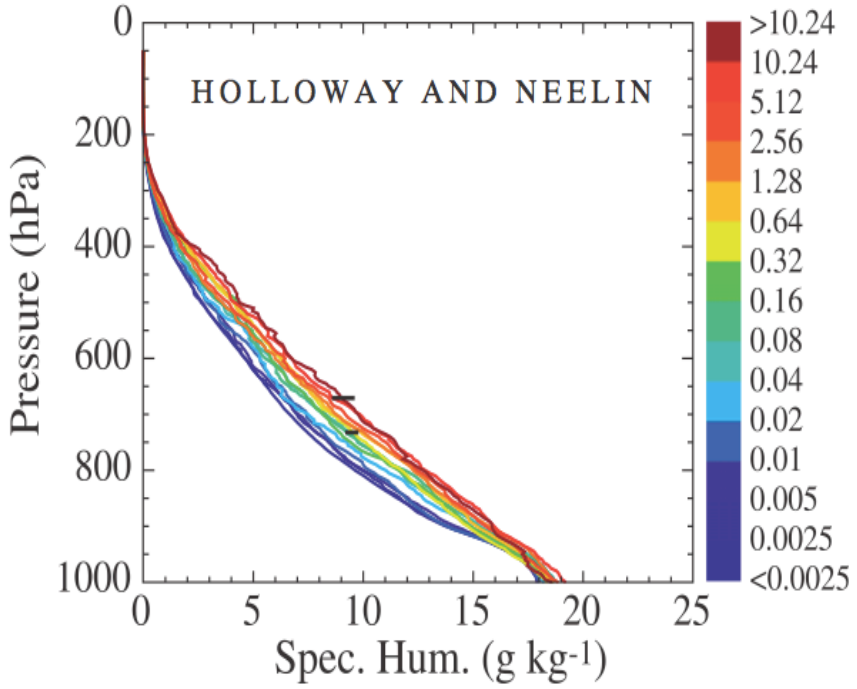


FIG. 1. Specific humidity (g kg^{-1}) profiles conditionally averaged on 1-h average precipitation rate in mm h^{-1} (color bar). Bin counts from the lowest to highest precipitation range are 2805, 93, 90, 59, 32, 40, 36, 49, 47, 43, 44, 30, 21, and 11. Horizontal bars indicate the maximum, as well as a representative, ±1 standard error of the mean (standard deviation divided by the square root of the sample number) range.

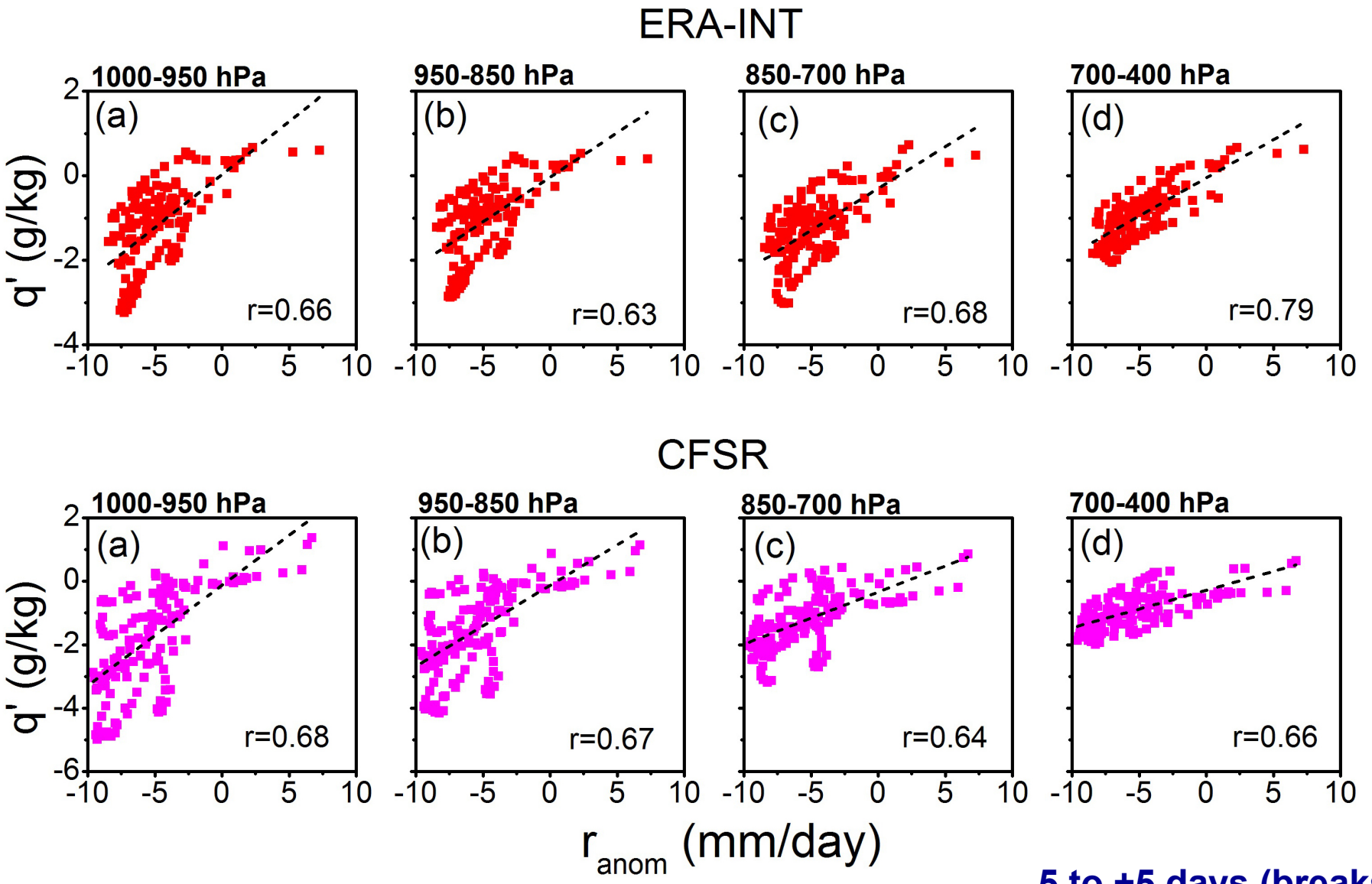
Moisture (water vapor, cloud)

Moisture-convection

Cloud - radiation

Hamada et al. 2015
note similar observations

"Courtesy – Mapes"

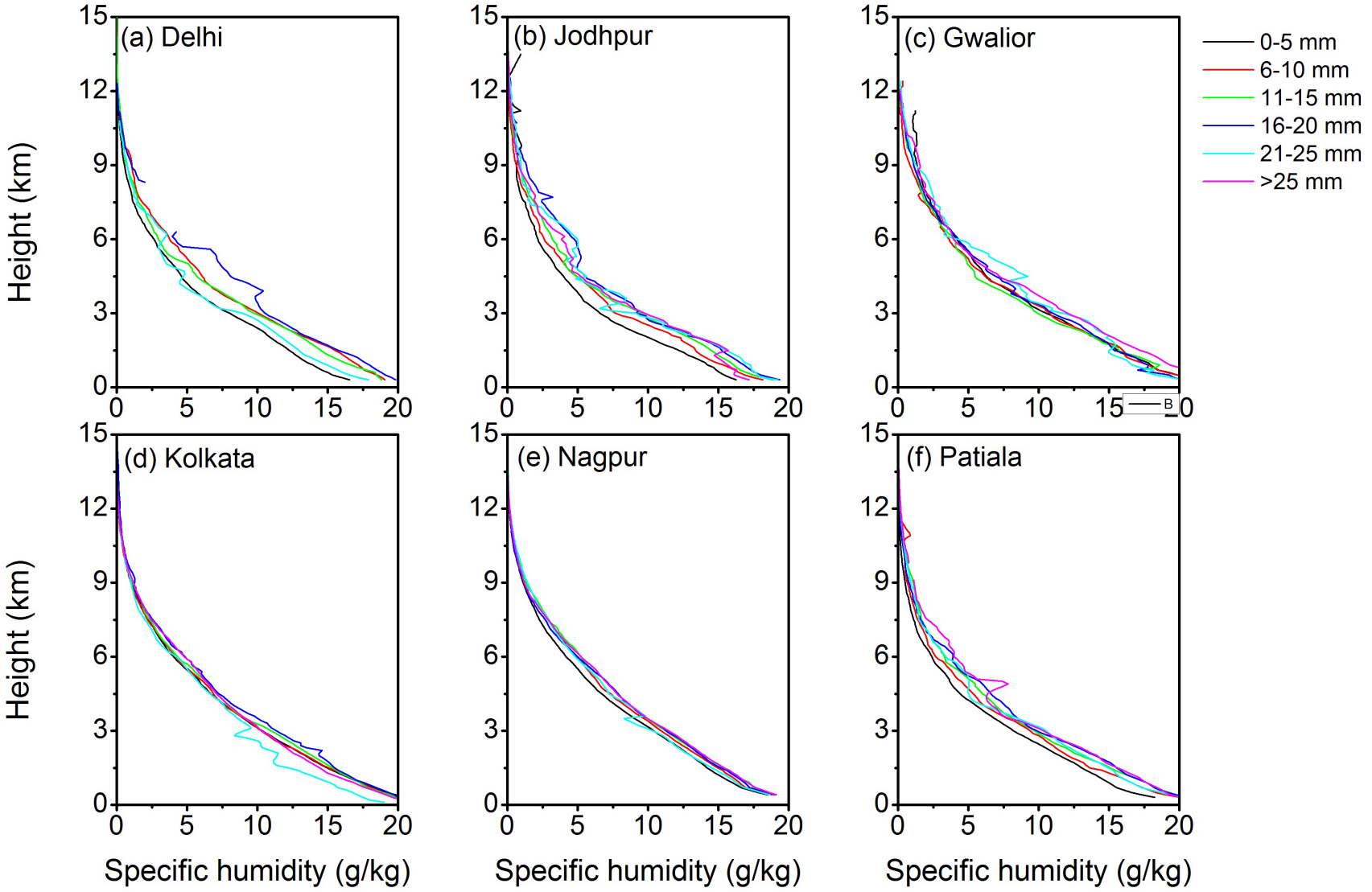


-5 to +5 days (breaks)

"sensitivity to free troposphere moisture variations is not noted in CFSR"

Mohan and Annamalai (2016)

Radiosonde observations along the monsoon trough (India)

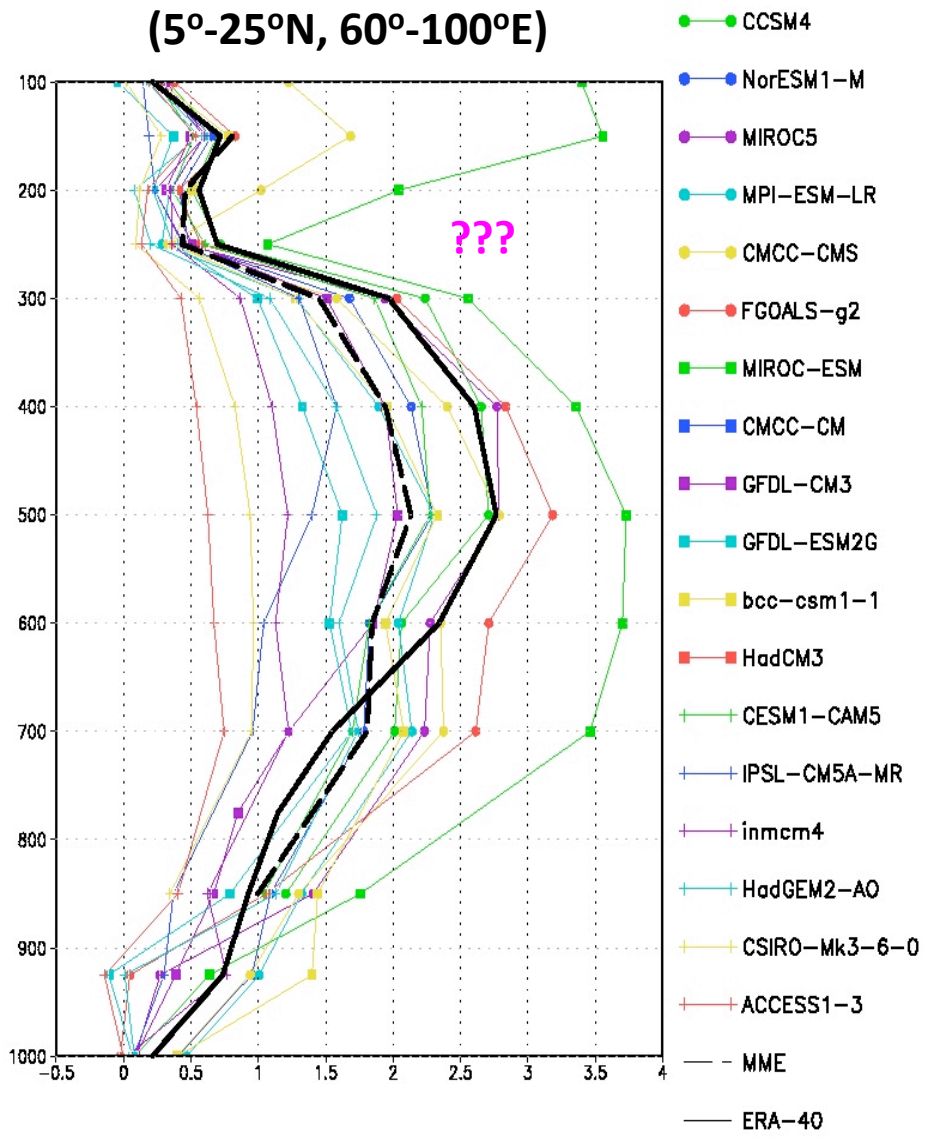


Vaisala-based observations – encouraging but not conclusive

Annamalai and Mohan (2016)

Vertical distribution of diabatic heating (Q)

1. Vertical Cloud distribution
2. Cloud-radiation interaction
3. Too much shallow?
4. Too little stratiform?

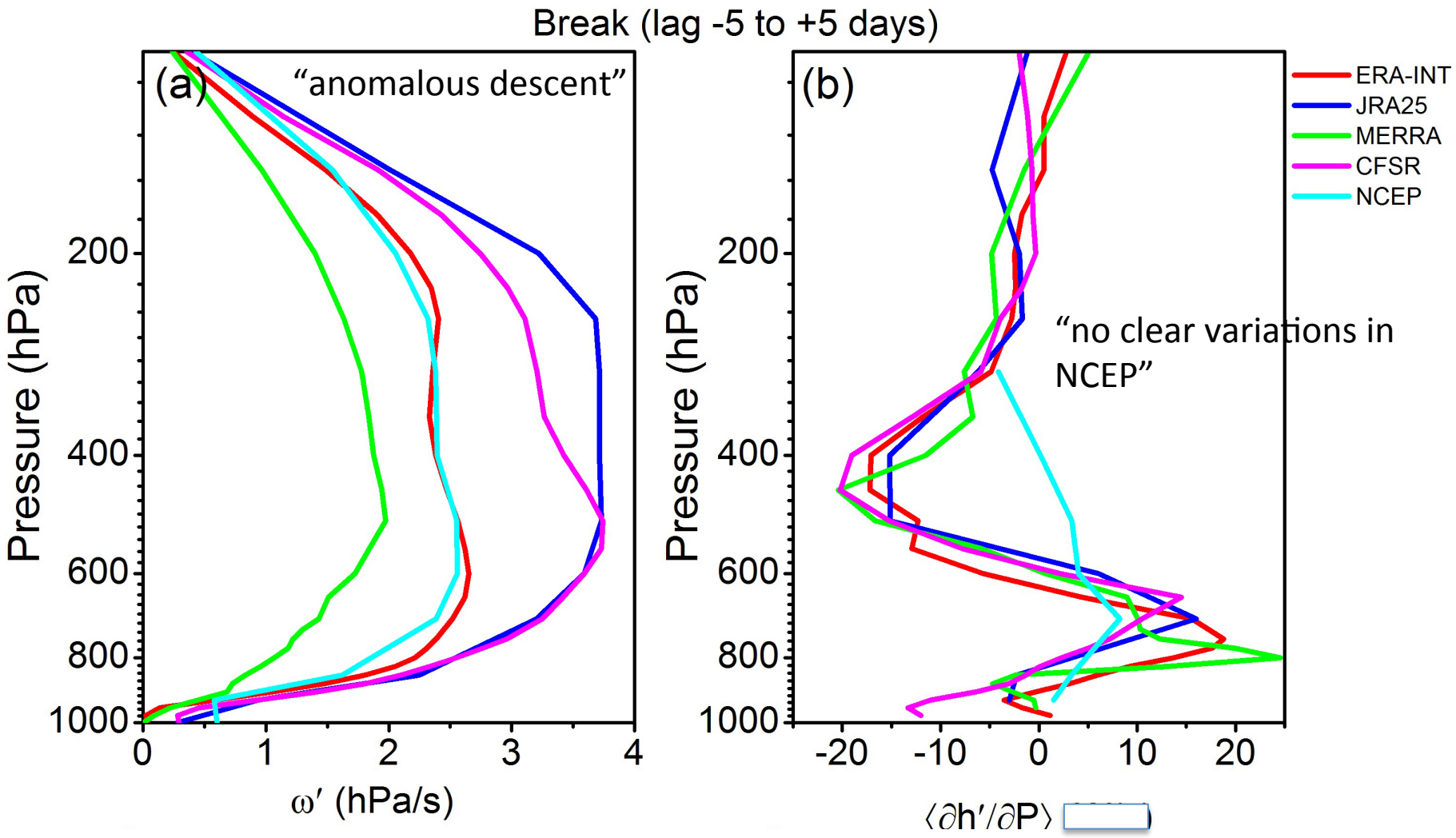


(K/day)

"moisture-convection" feedbacks

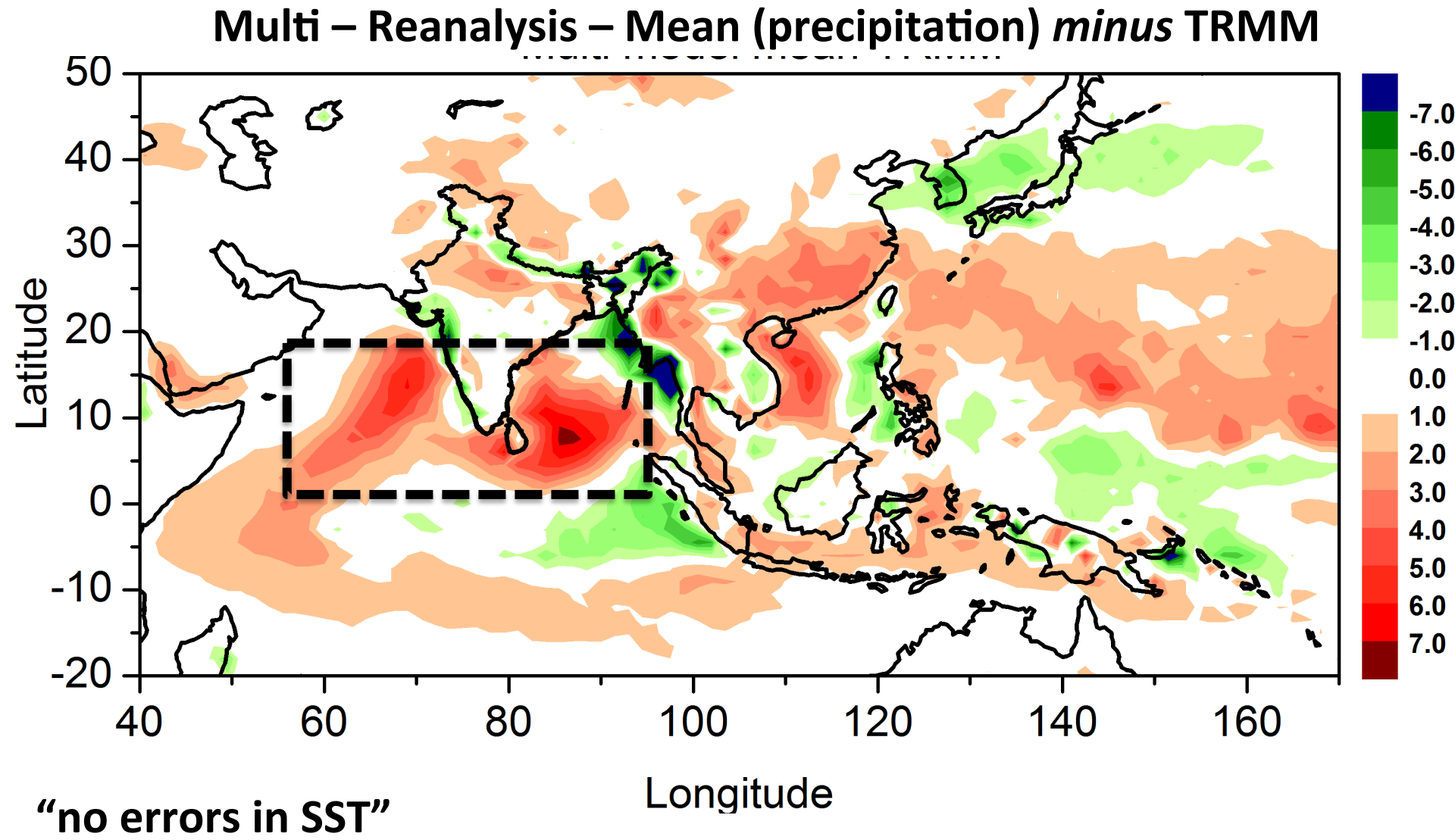
Entrainment treatment?

(Cherchi, Annamalai et al. 2014)



Gross moist stability (GMS): positive entropy gradient at low-levels and omega is positive – GMS is positive - exports MSE (DSE) –

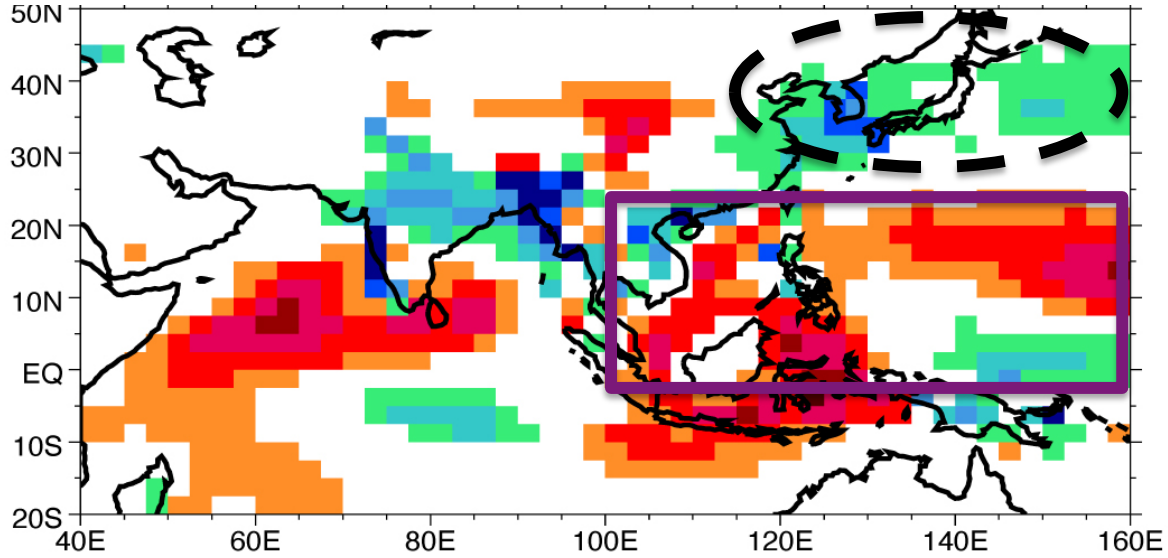
: negative entropy gradient at mid-high levels and omega positive – GMS is negative – imports low MSE – convective inhibition



"no errors in SST"

Annamalai and Mohan (2016)

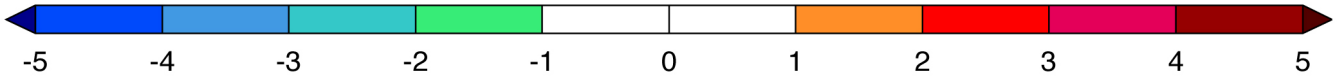
CMIP3 MMM – GPCP



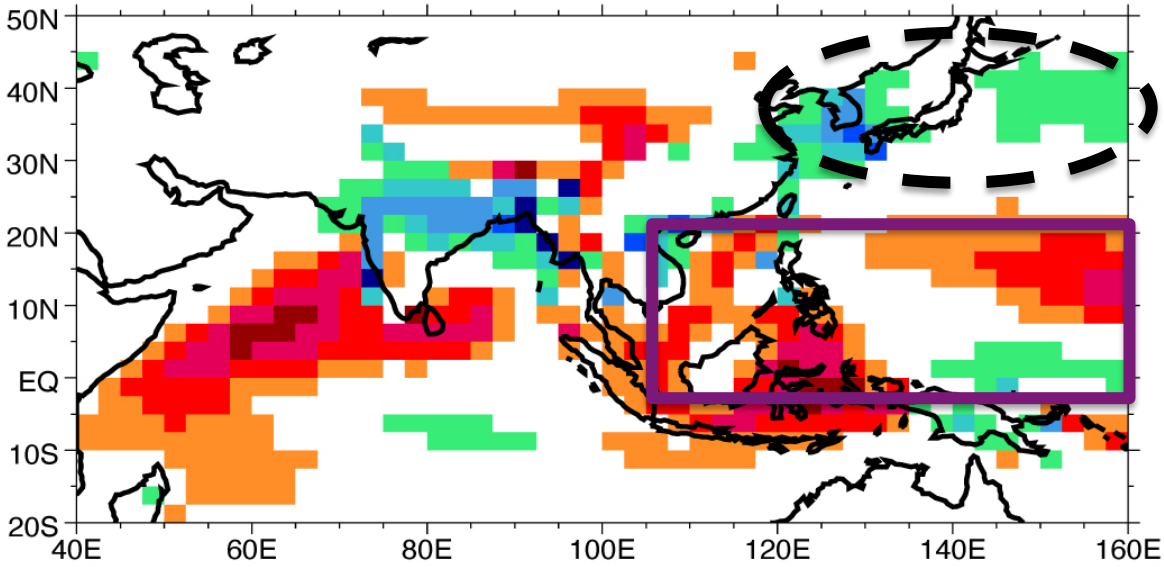
JJAS - Precipitation

(Sperber et al. 2013)

(mm/day)



CMIP5 MMM – GPCP



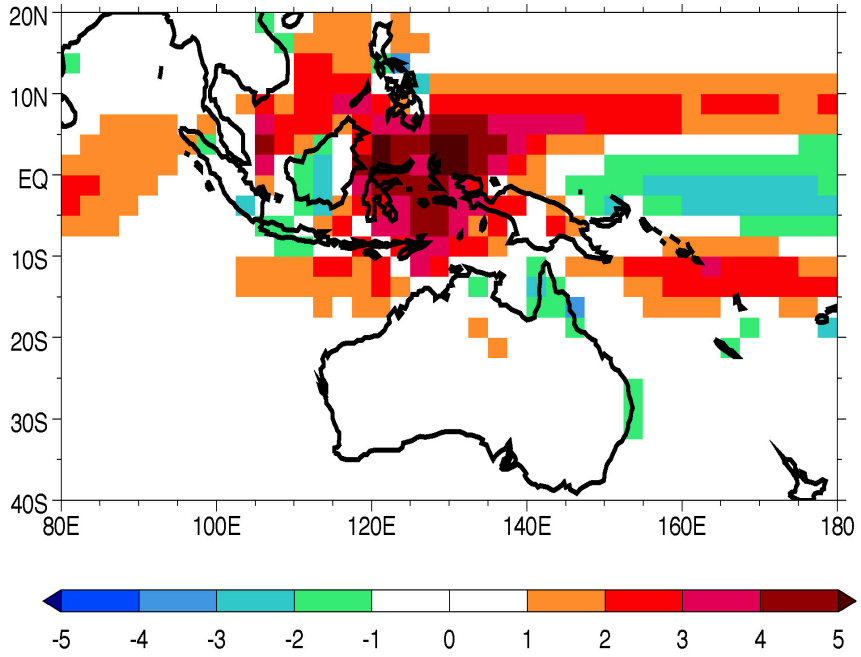
Maritime Continent?

Tropical west Pacific?

Baiu – Japan?

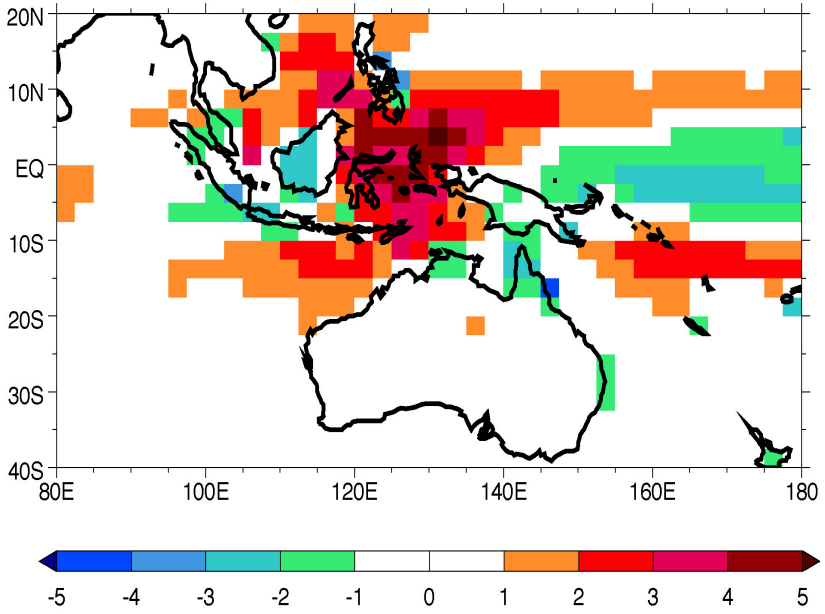
Tibet - ?

CMIP5 MMM – GPCP



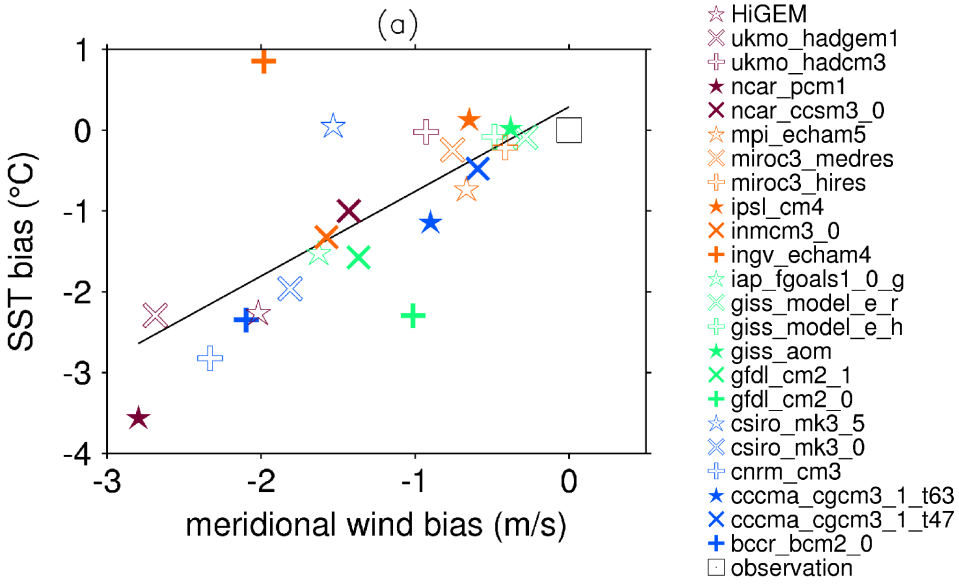
DJF - Rainfall

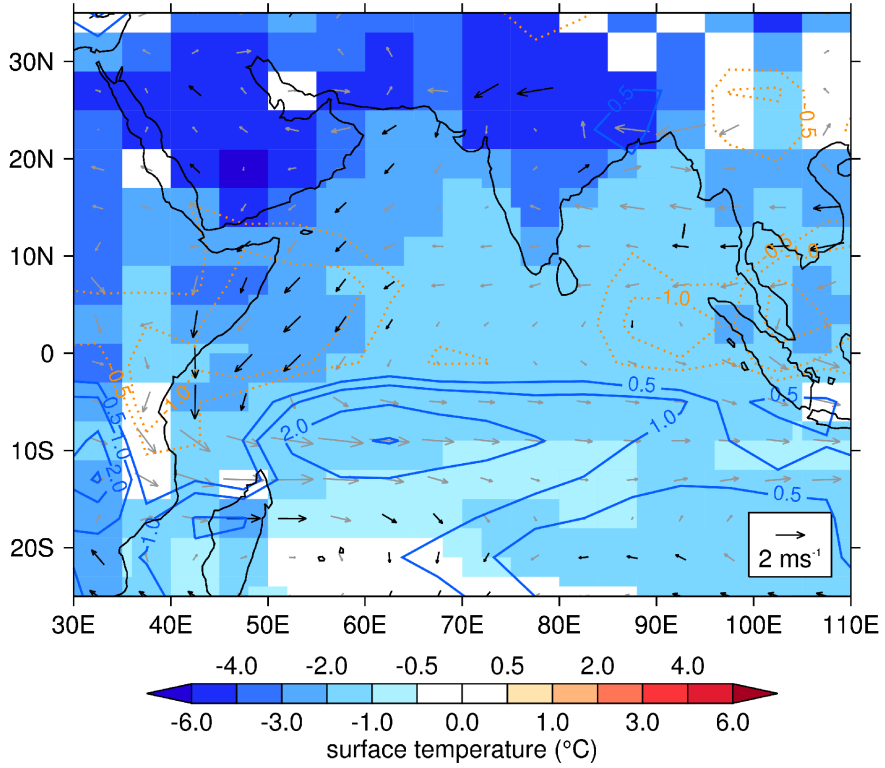
CMIP3 MMM – GPCP



Maritime Continent?

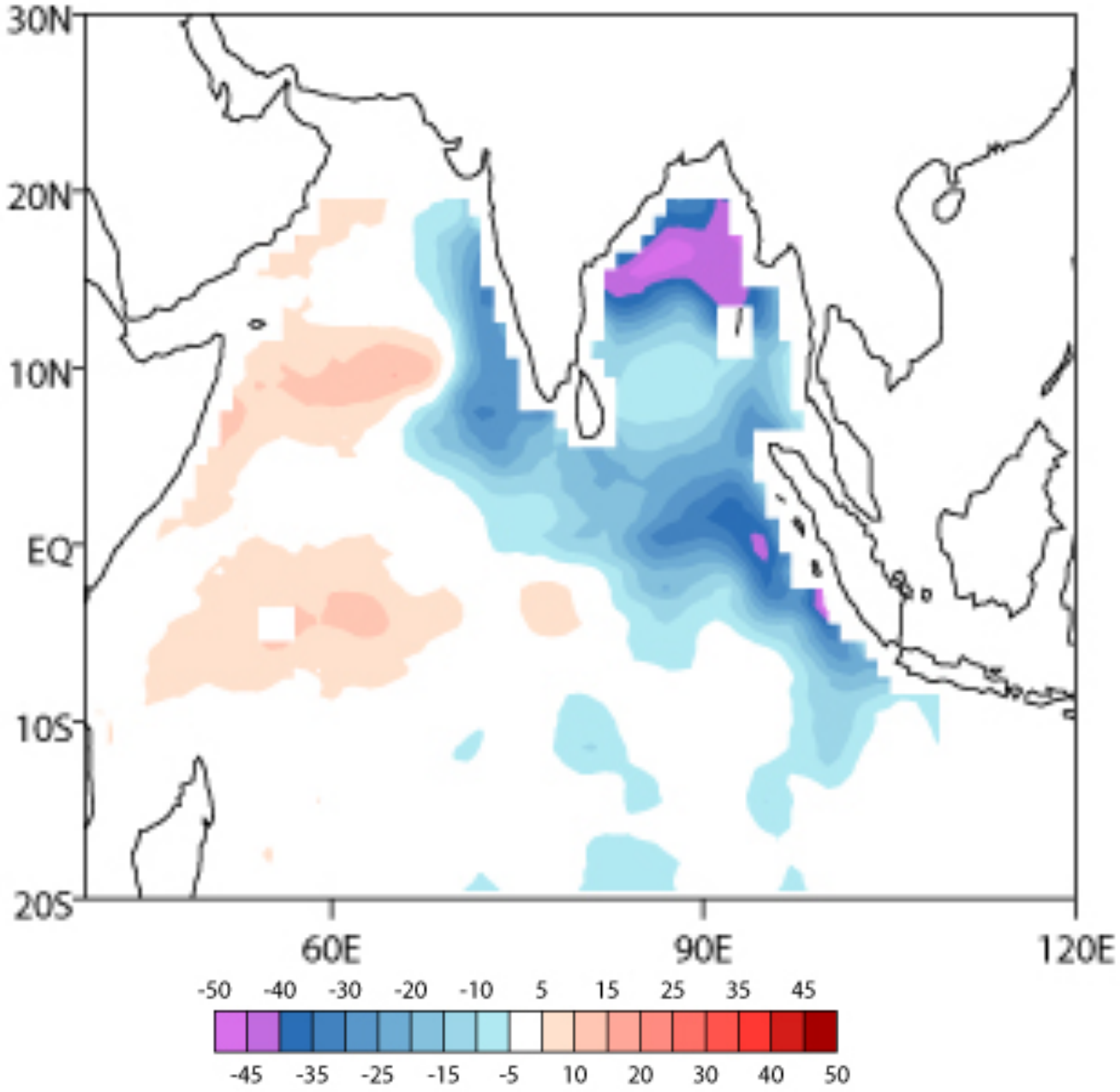
- Many CMIP models exhibit cold SSTs in the northern Arabian Sea during winter and spring. **Role of surface fluxes (radiation)**
- These link a series of coupled biases in the Indian Ocean.





From Marathayil, Turner, Shaffrey & Levine (2013) *Environ. Res. Letts.*

CMIP5 MMM errors in barrier-layer thickness (DJF)



"SST-> Pr -> SST"

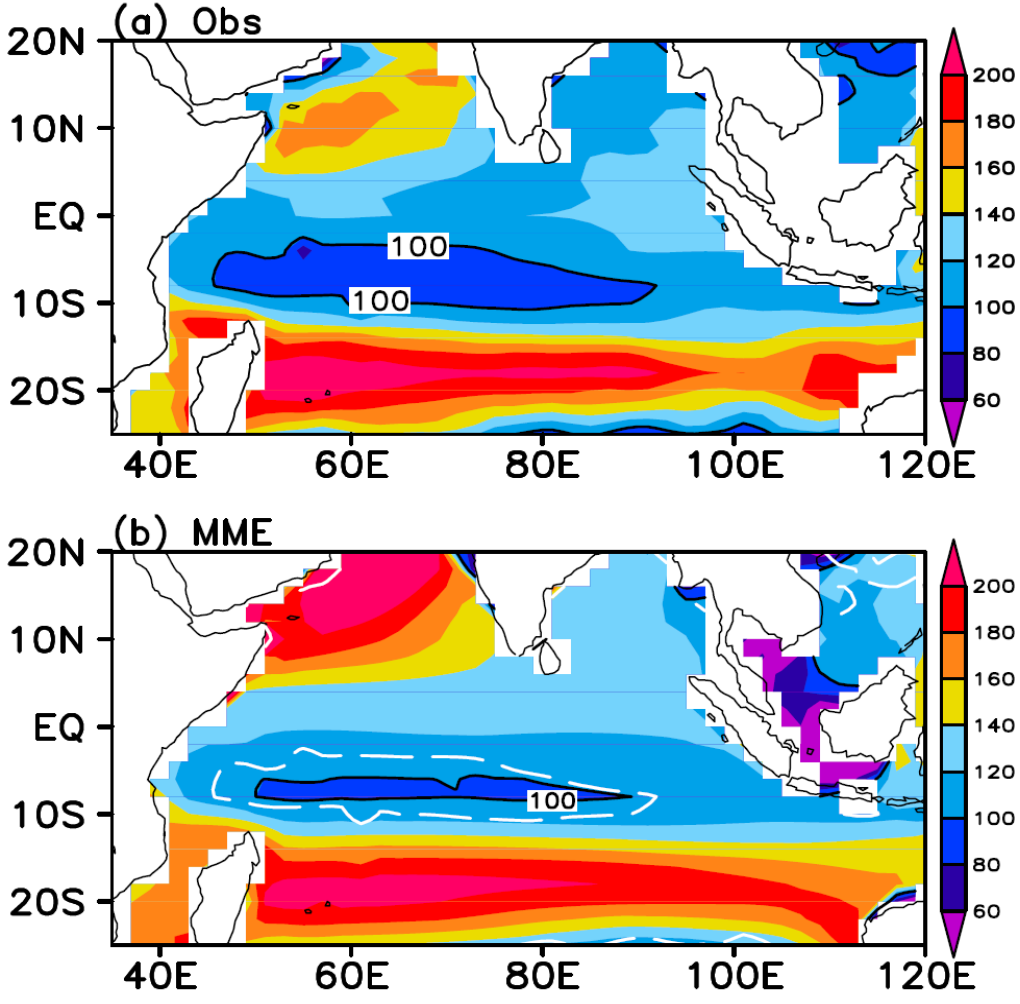
Salinity stratification

Argo floats (resolution)

Mixed-layer < 10 m

Amala --- Talk
Debasis – Talk

D20: model error

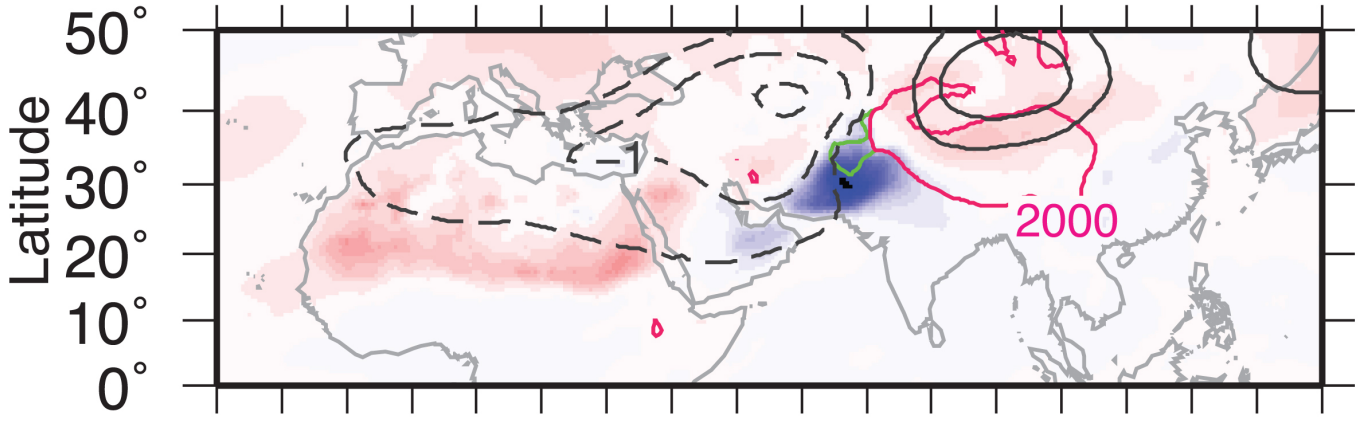


Averaged over all the CMIP5 models, **annual-mean D20 in the 5–10°S ridge is too deep**.

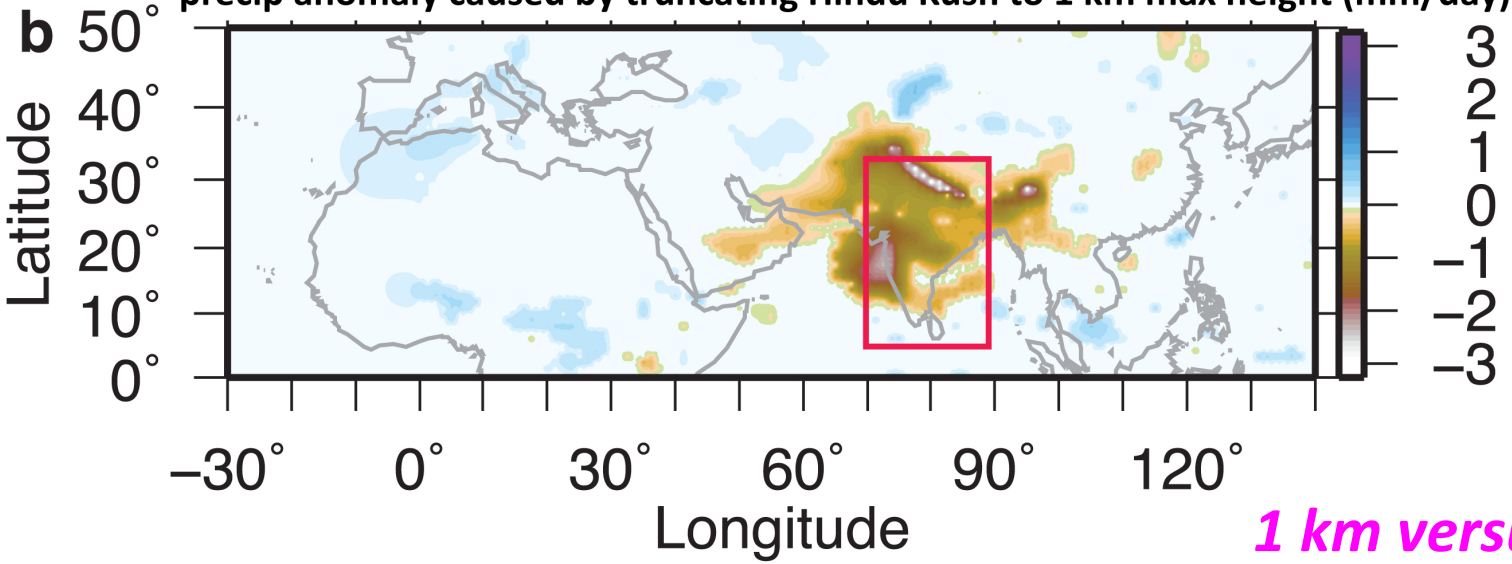
Li, Xie & Du (2015)

Modified topography recreates CMIP bias

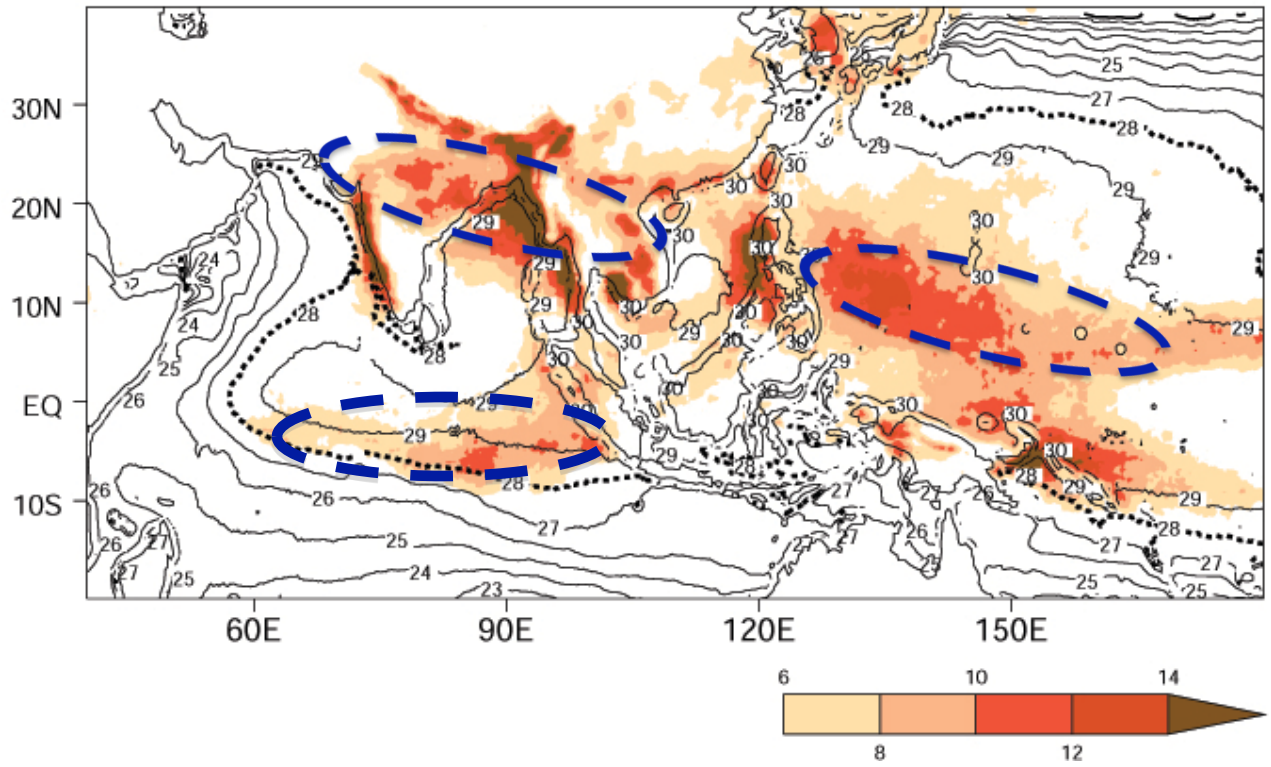
Errors in surface h (colors) and
upper-tropospheric temperature (contours, negative dashed)
green and **pink** contours are 1.5 km surface altitude in **control** and **perturbed** model
(CESM5 0.9x1.25 coupled model, rcp8.5 scenario)



precip anomaly caused by truncating Hindu Kush to 1 km max height (mm/day)



1 km versus 3 km CMIP5



Precipitation and SST

1. Regional rainfall zones
2. Different SST threshold (tropospheric T/CRH)

Convection – dynamics and thermodynamics

Parameterization schemes – regional dependence?

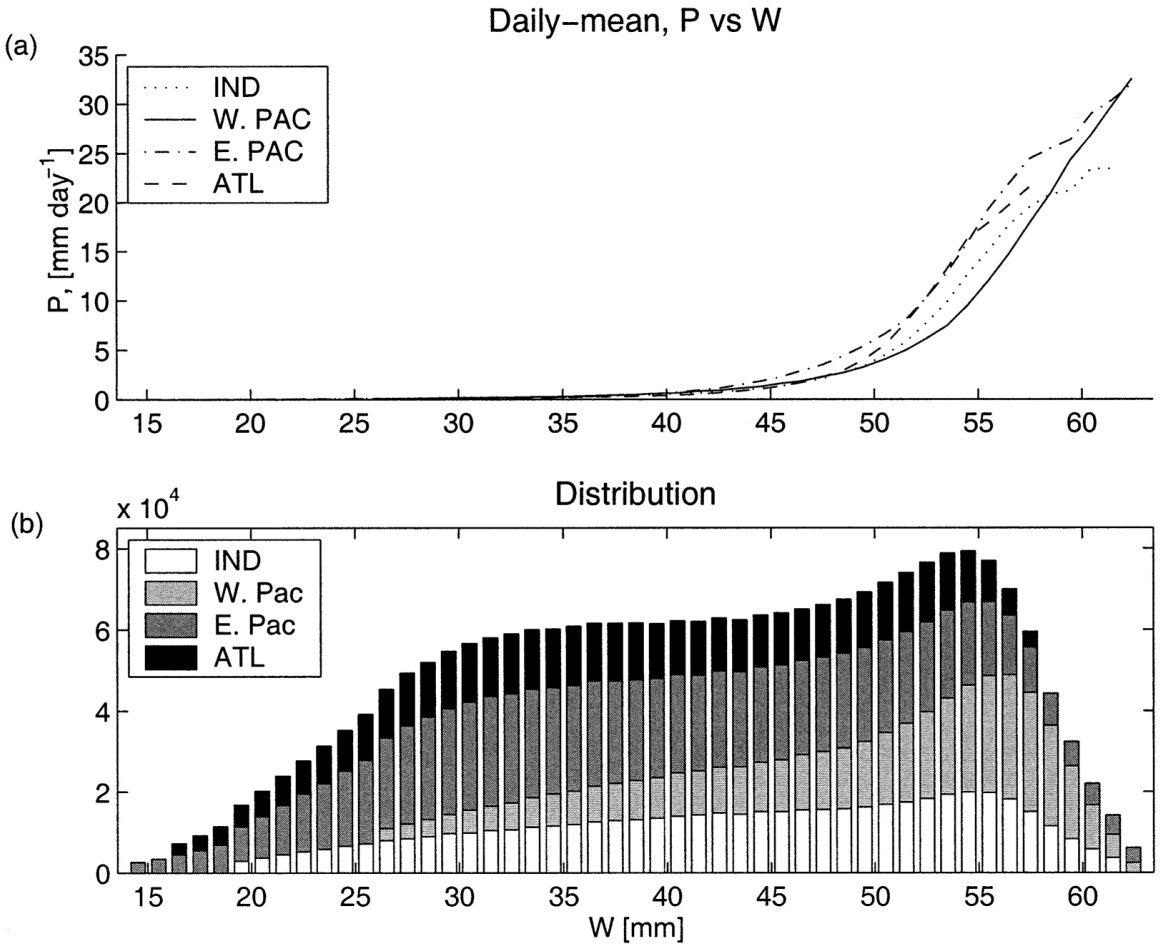


FIG. 2. (a) Mean daily averaged precipitation P in 1-mm-wide bins of water vapor path W, for the four tropical ocean regions in Fig. 1 for all months in 1998–2001. (b) Number of observations in each bin in the four regions.

Sensitivity of precip
to PW/CWV
~50-55 mm – precip pick up

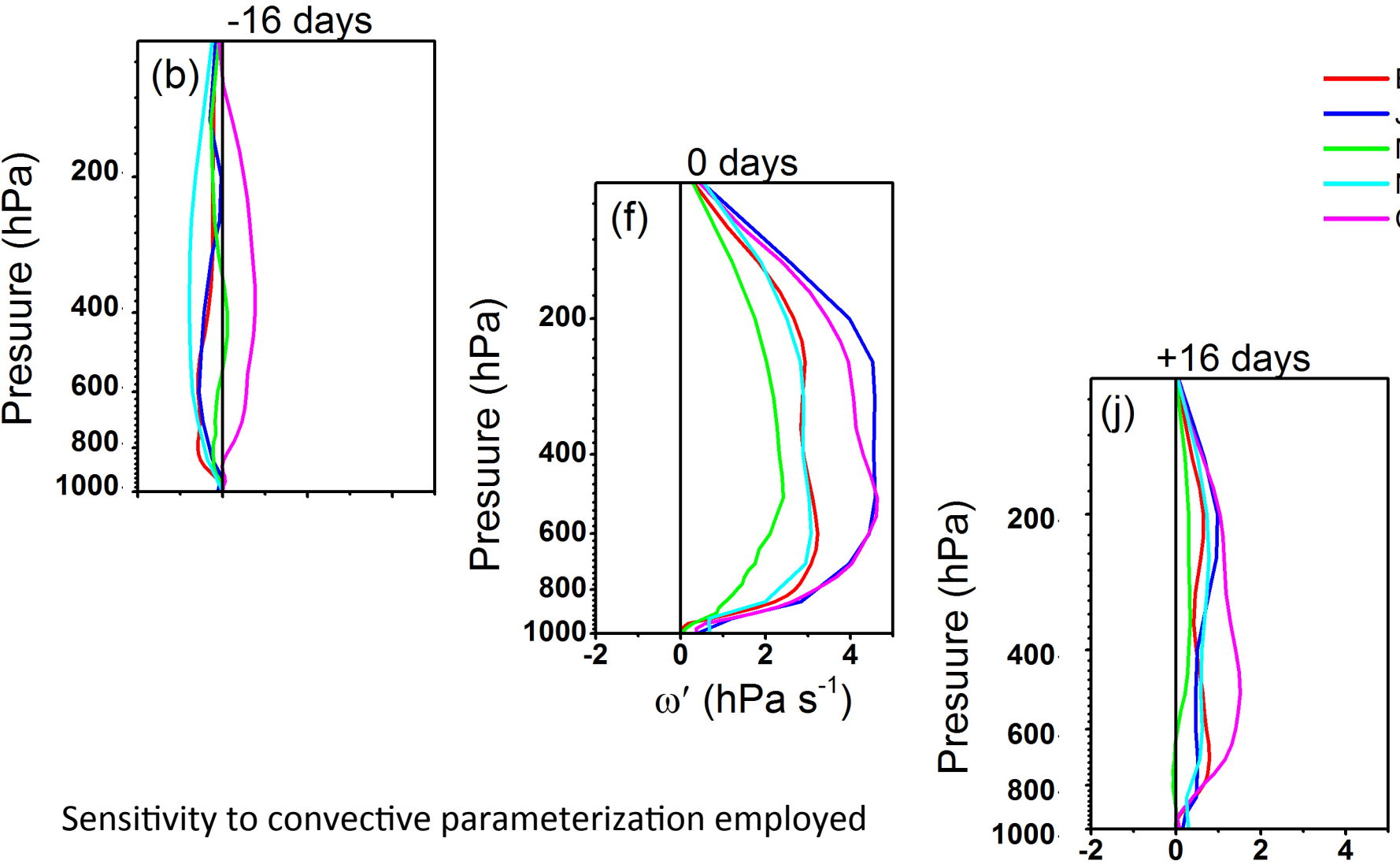
"linear relation between CWV and precip intensity"

Depends on T_{trop}

Number of observations over Indian Ocean - least

Bretherton et al. (2004)

Vertical structure of vertical velocity



Sensitivity to convective parameterization employed

Omega – determines MSE export and convective forcing

Large uncertainties among reanalysis ***– "direct field observations needed"***