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CMIP5 coordinated analysis – monsoon future change

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University of Reading

Outline

- General results in IPCC AR5
- South Asian monsoon in CMIP5
- EASM in CMIP5
- What can the community do better together?
- Links with the WCRP Grand Challenges / CLIVAR Research Opportunities

General results in IPCC AR5

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Chapter 14 summary statement, "There is growing evidence of improved skill of climate models in reproducing climatological features of the global monsoon. Taken together with identified model agreement on future changes, the global monsoon, aggregated over all monsoon systems, is *likely to strengthen in the 21st century with* increases in its area and intensity, while the monsoon circulation weakens. Monsoon onset dates are *likely to become earlier or not to change much and monsoon retreat dates are very likely to delay,* resulting in lengthening of the monsoon season."

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General results in IPCC AR5: A-AM

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Model skill in representing regional monsoons is lower compared to the global monsoon and varies across different monsoon systems. There is *medium confidence that overall precipitation associated with the Asian*-Australian monsoon will increase but with a north-south asymmetry: Indian and East Asian monsoon precipitation is projected to increase, while projected changes in Australian summer monsoon precipitation are small. There is m*edium confidence that the Indian summer monsoon circulation will weaken, but this is* compensated by increased atmospheric moisture content, leading to more precipitation. For the East Asian summer monsoon, both monsoon circulation and precipitation are projected to increase. There is *medium confidence that the increase of the Indian summer monsoon rainfall and its extremes throughout the 21st* century will be the largest among all monsoons.

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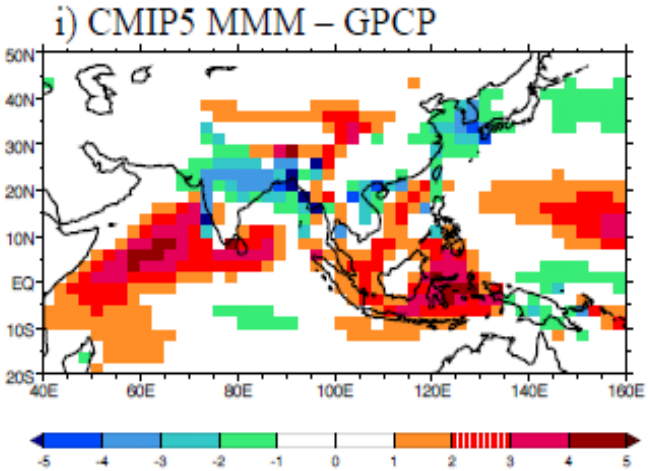
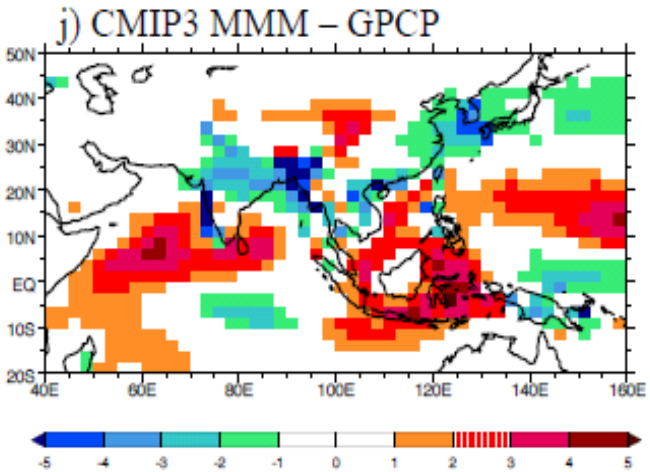
Asian Summer Monsoon
Model performance and metric efforts

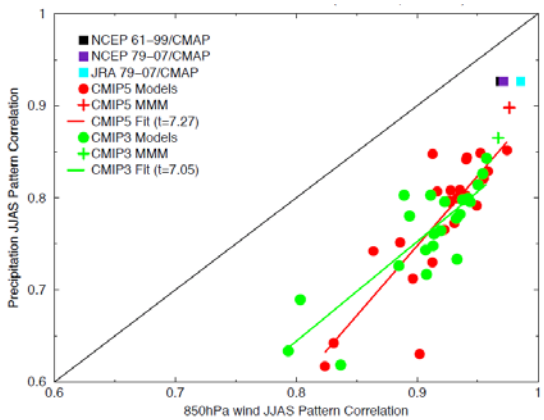
- Numerous efforts to quantify error and compare CMIP3/CMIP5
- CMIP models still have large dry biases for South Asia
  - CMIP3/CMIP5 error pattern virtually identical, CMIP5 RMSE reduced compared to CMIP3
  - Rainfall intensity skill correlated with skill in representing the rainfall climatology
- Marginal improvement across all metrics from CMIP3→CMIP5

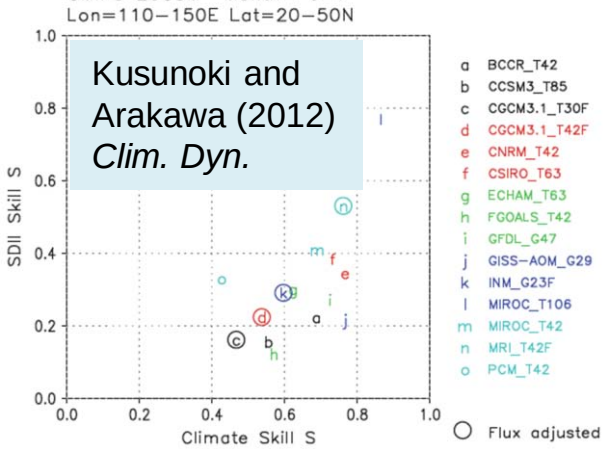
Sperber et al. (2012) *Clim. Dyn.*

Wang et al. (2013) *Clim. Dyn.*

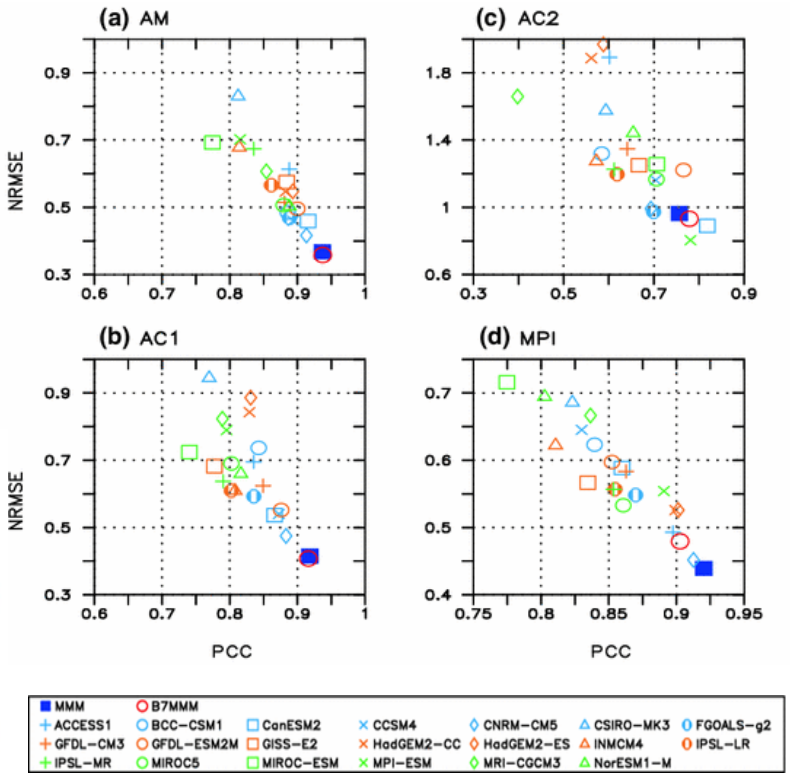








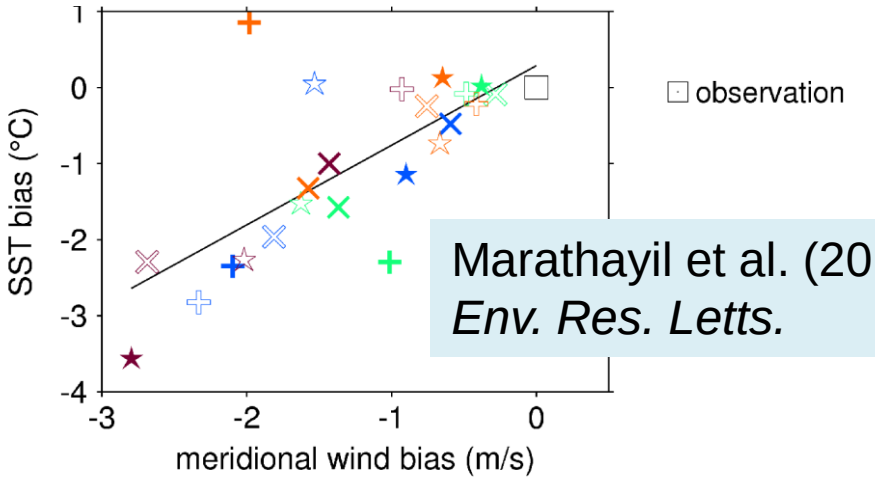
Kusunoki and Arakawa (2012) *Clim. Dyn.*



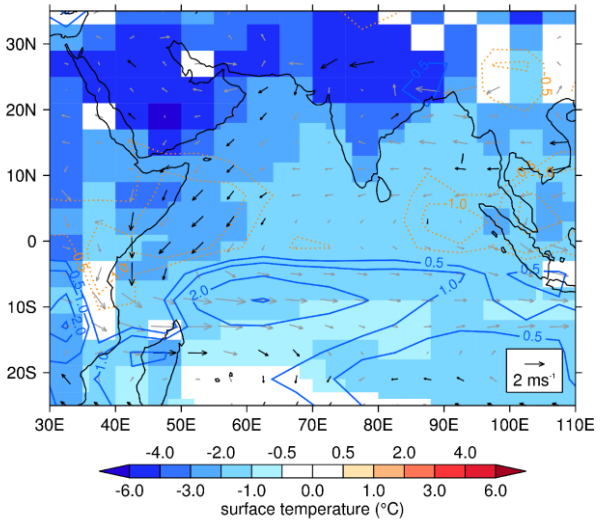
Many other studies!

Model SST biases: e.g., Arabian Sea impact on monsoon annual cycle

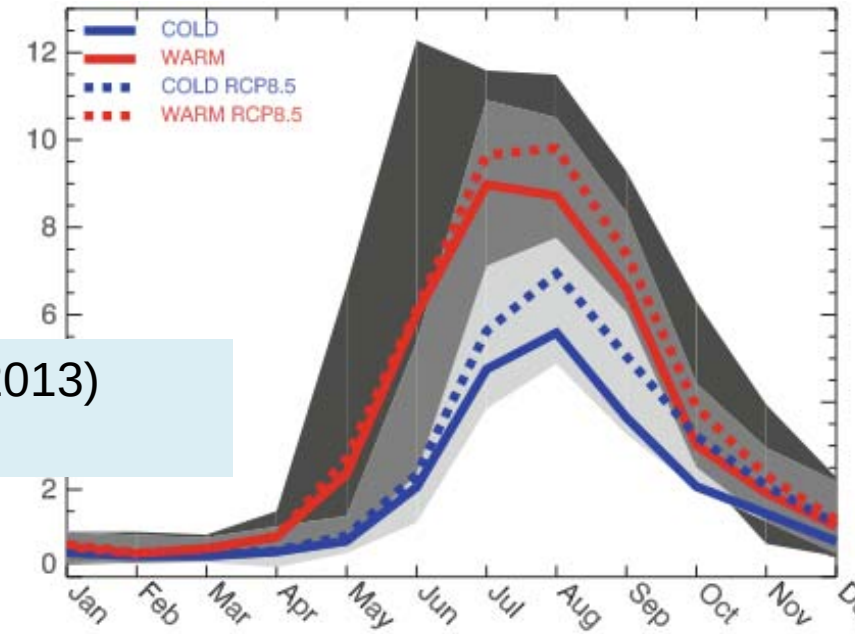
Many CMIP3/5 models exhibit cold northern Arabian Sea during winter and spring, linking a series of coupled biases in the Indian Ocean.



Marathayil et al. (2013)
Env. Res. Letts.

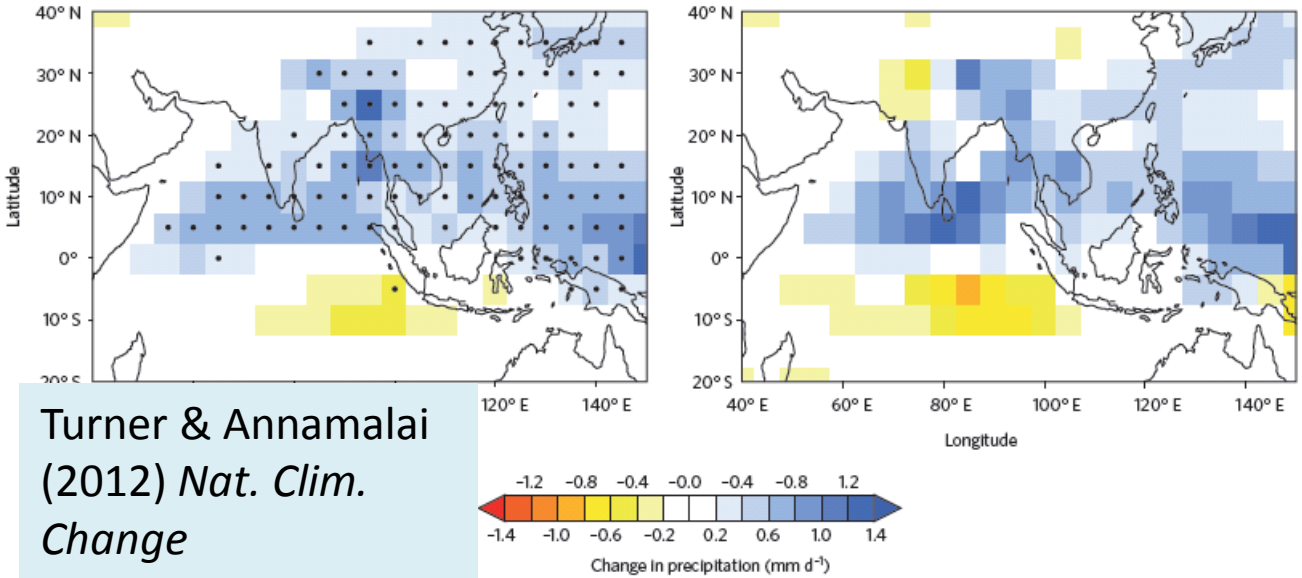


CMIP5 models with cold spring Arabian Sea have weakened annual cycle of rainfall at present and in RCP8.5



Levine et al. (2013)
Clim. Dyn.

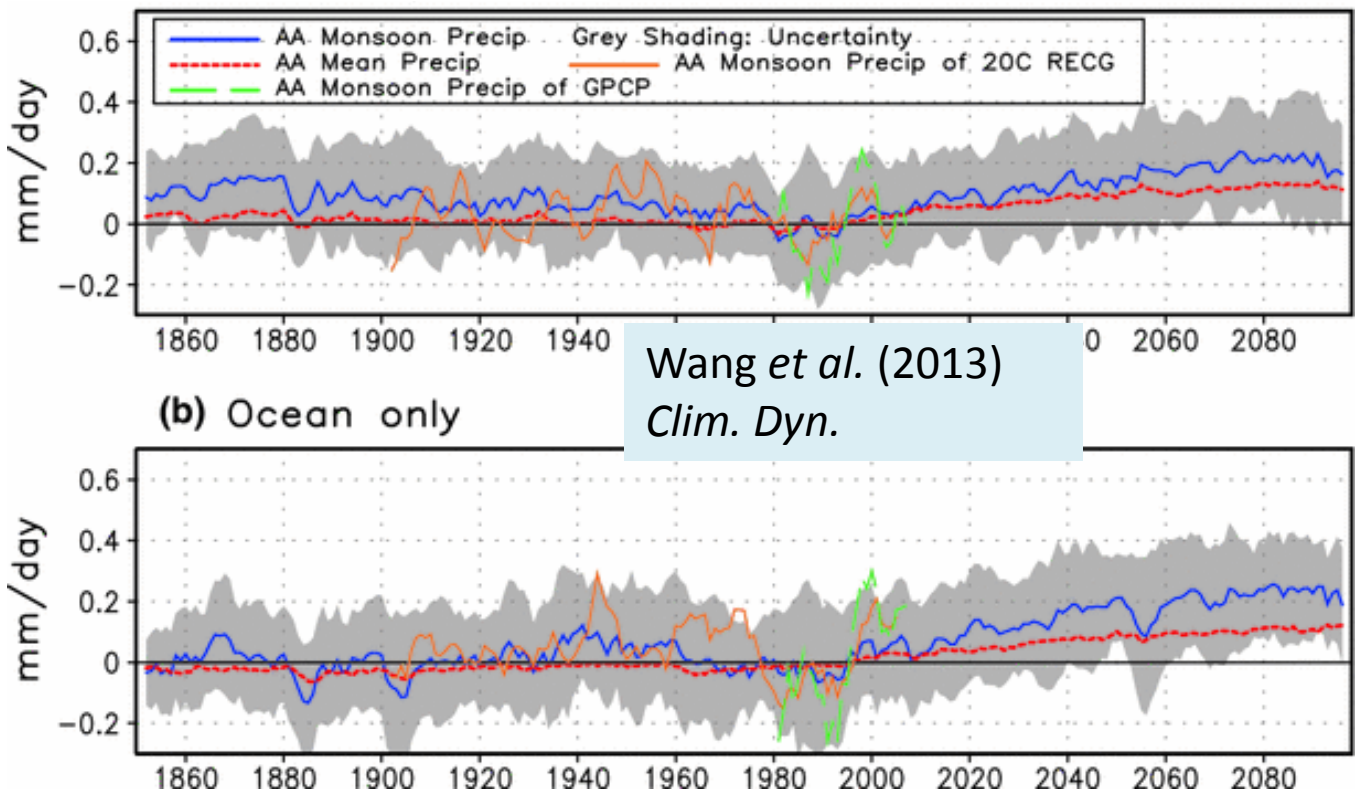
South Asian summer monsoon: Climate change



Turner & Annamalai (2012) *Nat. Clim. Change*

- Consistent picture of rainfall increases relating to increased moisture availability
- Simple selection methods yield similar patterns of change

- Expansion of global monsoon domain and intensity.
- More complex model selection methods also developed: consistent increases in AAM domain precipitation in the future.



Wang *et al.* (2013) *Clim. Dyn.*

The uncertain role of aerosol for the South Asian monsoon: Liang Guo

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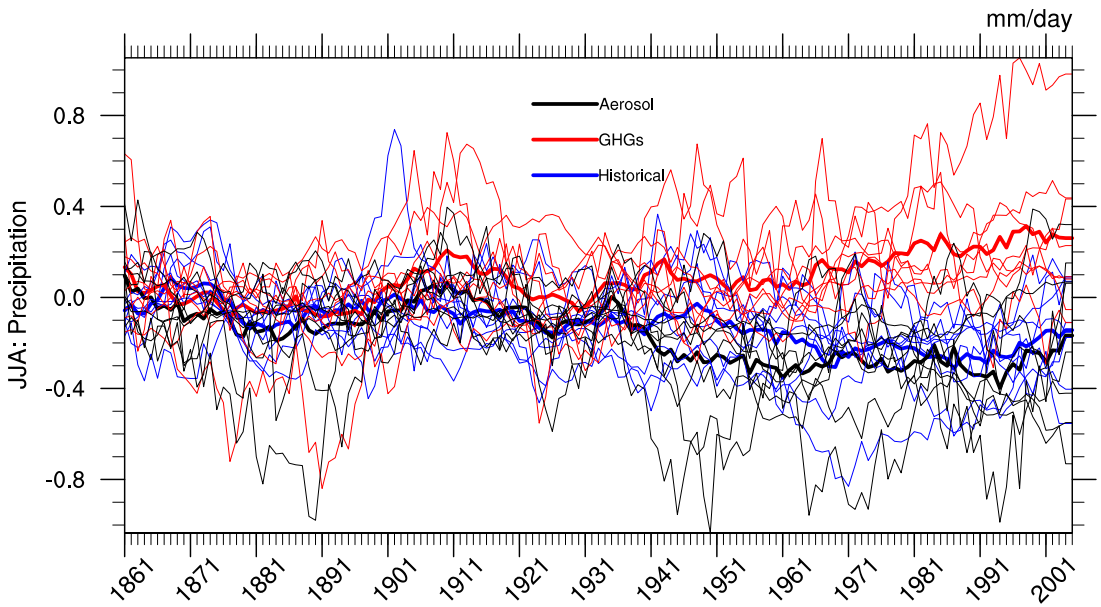
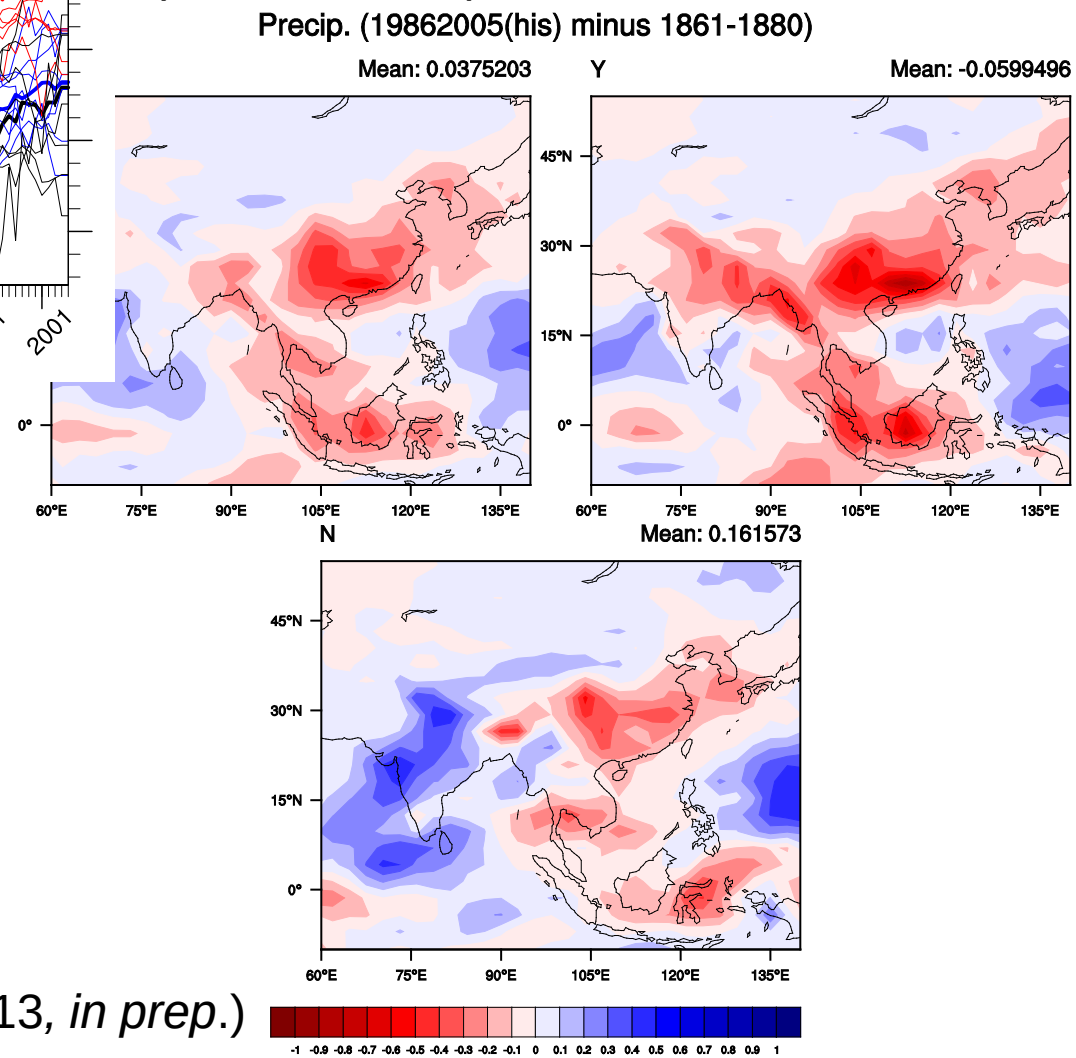


All: 25 GCMs
Y: 14 GCMs with aerosol indirect effects
N: 11 GSMs with direct effect only.
Area mean is calculated over South Asia (5-35N,65-90E).



Seasonal (JJA) South Asia precipitation, CMIP5 historical runs: (a) timeseries and (b) late 20th century minus pre-industrial

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Guo, Highwood & Turner (2013, *in prep.*)

East Asian Summer Monsoon

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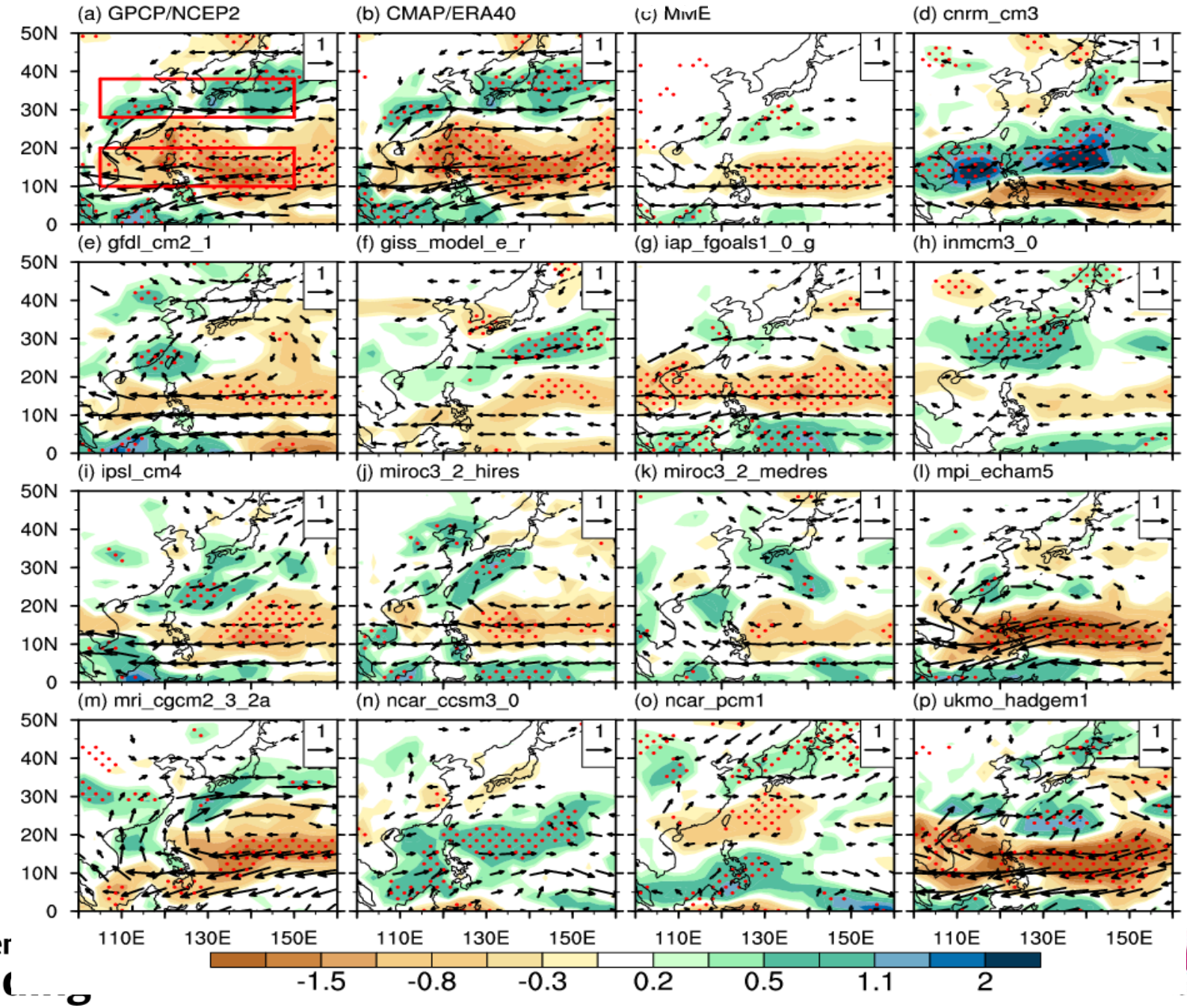
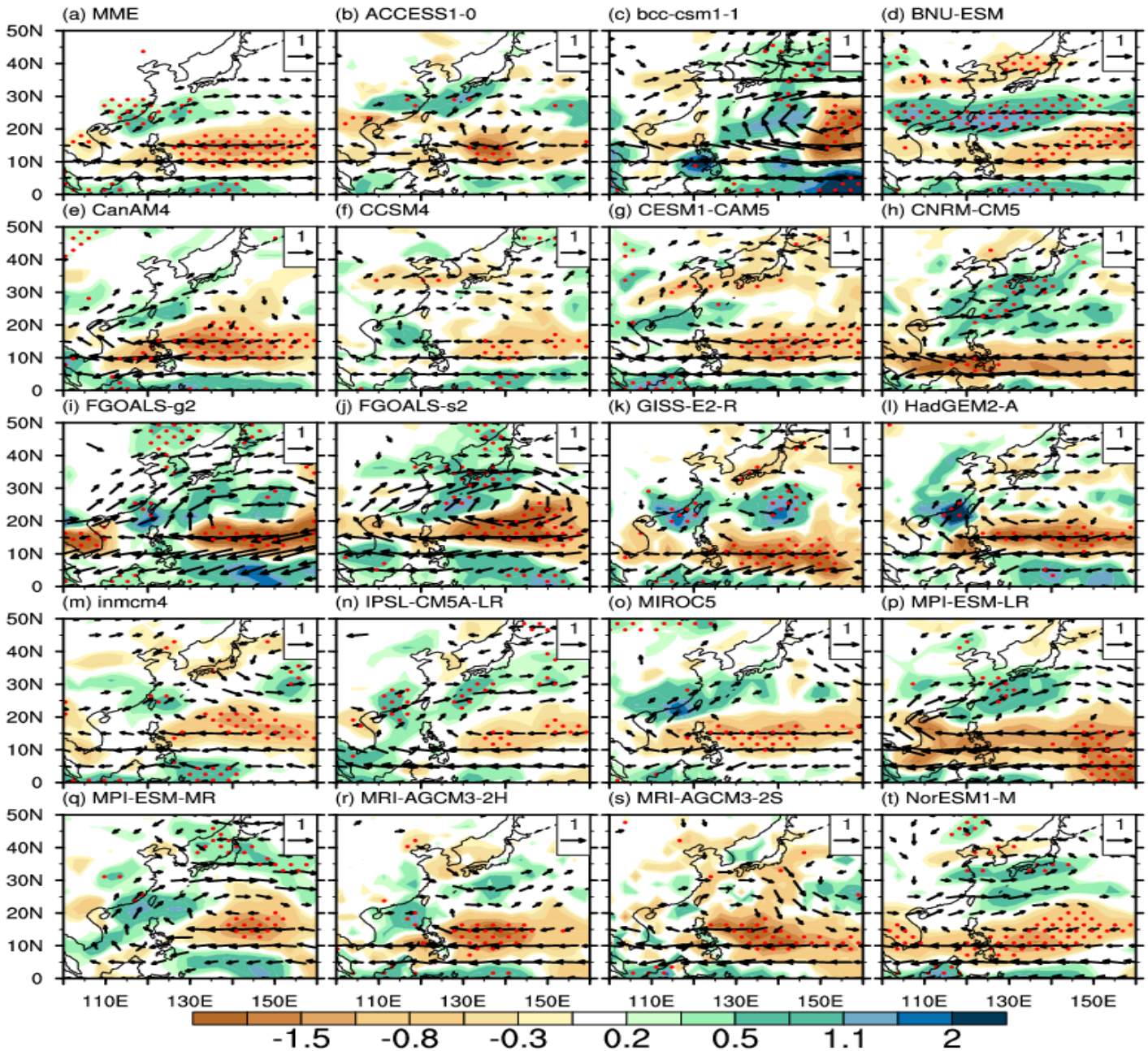
Interannual variability of monsoon in CMIP3 models



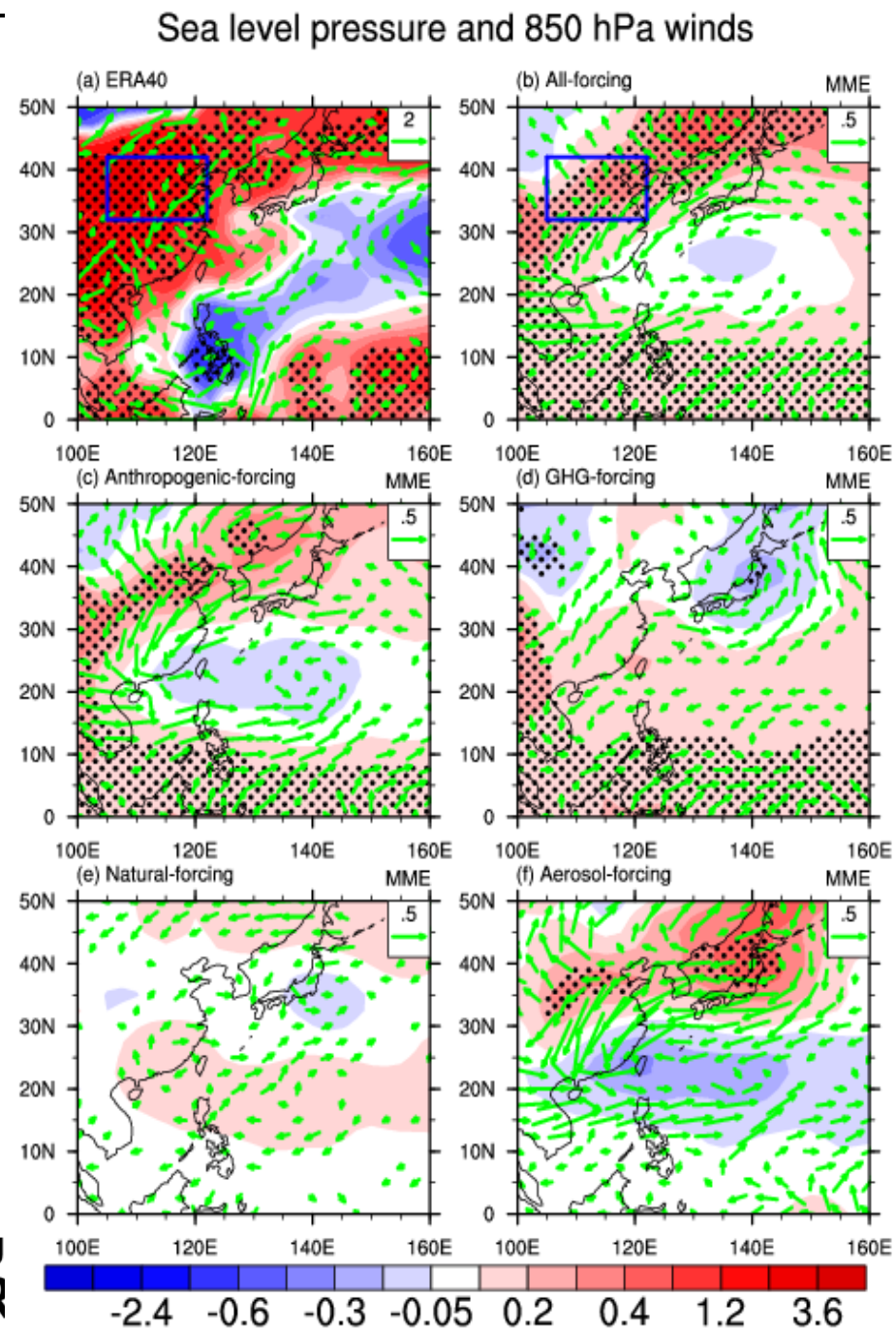
(Song &Zhou)

Interannual variability of monsoon in CMIP5 models



(Song &Zhou)

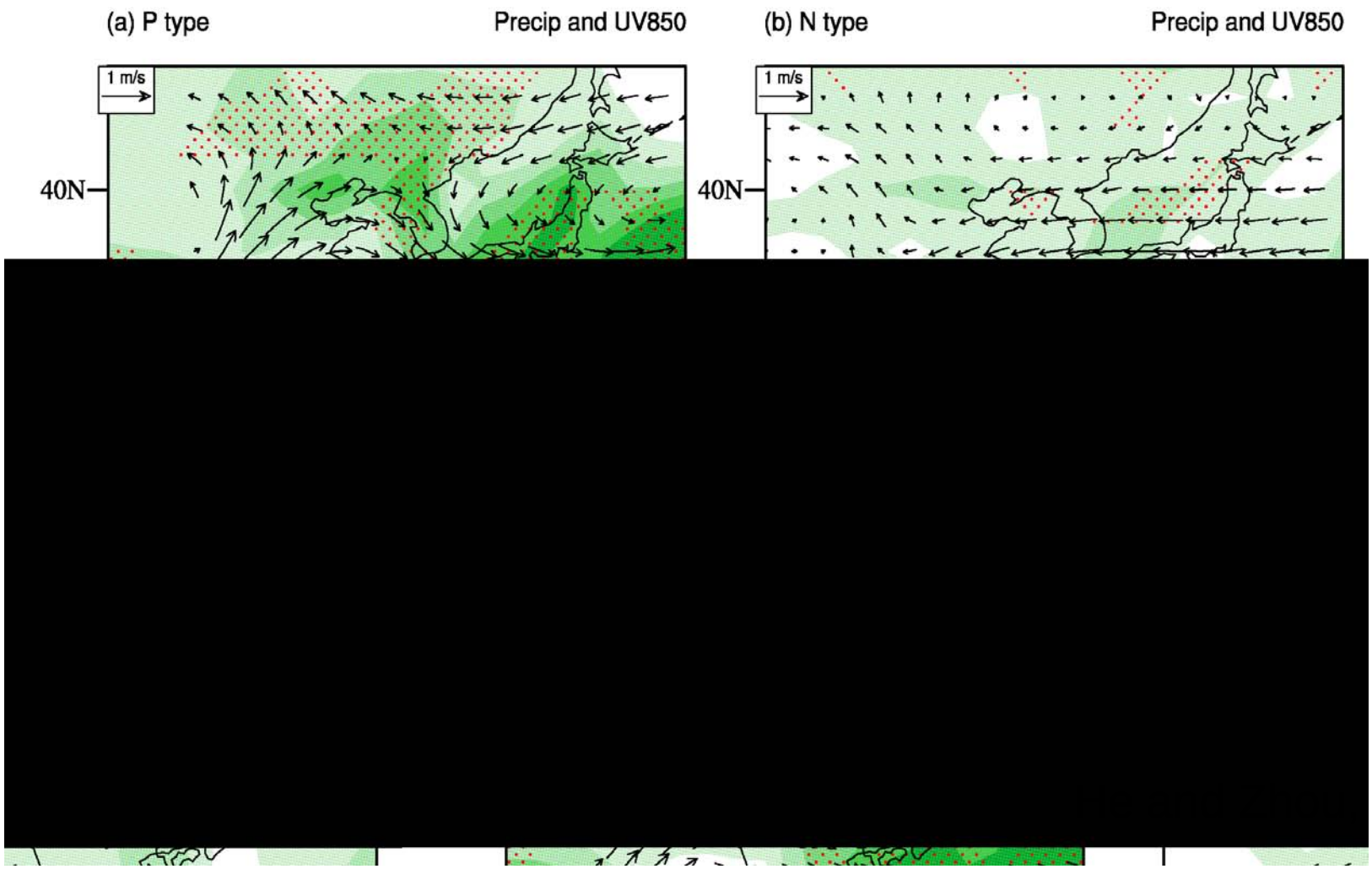
EASM response to Aerosol forcing



- **The decadal weakening of EASM is well reproduced in the all forcing runs, although with weaker magnitude.**
- **Among all external forcings, the aerosol forcing plays a primary role.**

Song, Zhou, Qian (2013)

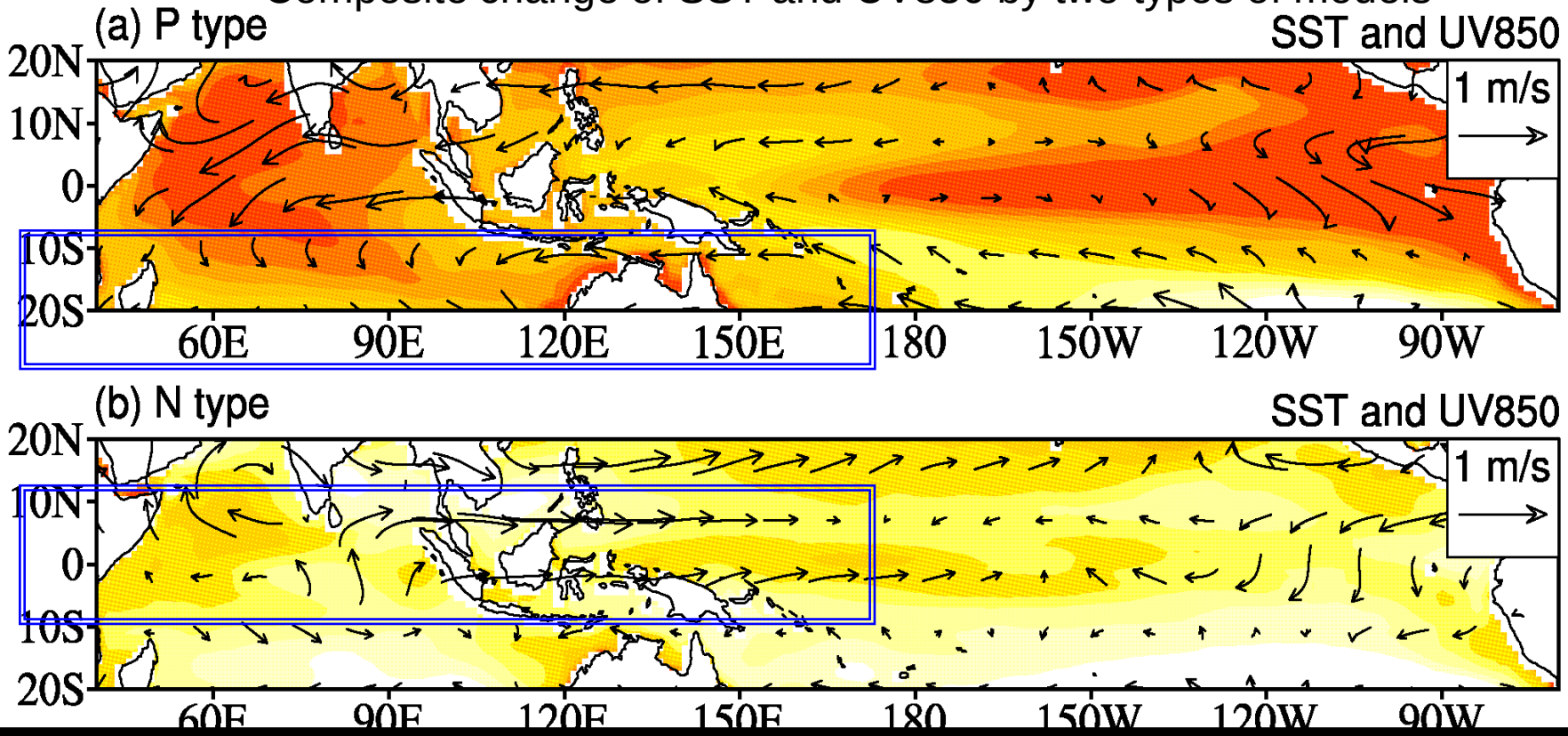
- Projected changes of EASM under RCP4.5 (2050-2099)- (1950-1999)



2013

- Q: Why are there two types of WNPSH changes?
- A: Because the change in the zonal SST gradient over the IWP are different

Composite change of SST and UV850 by two types of models



[redacted]

He and Zhou, 2013

Key scientific questions: processes

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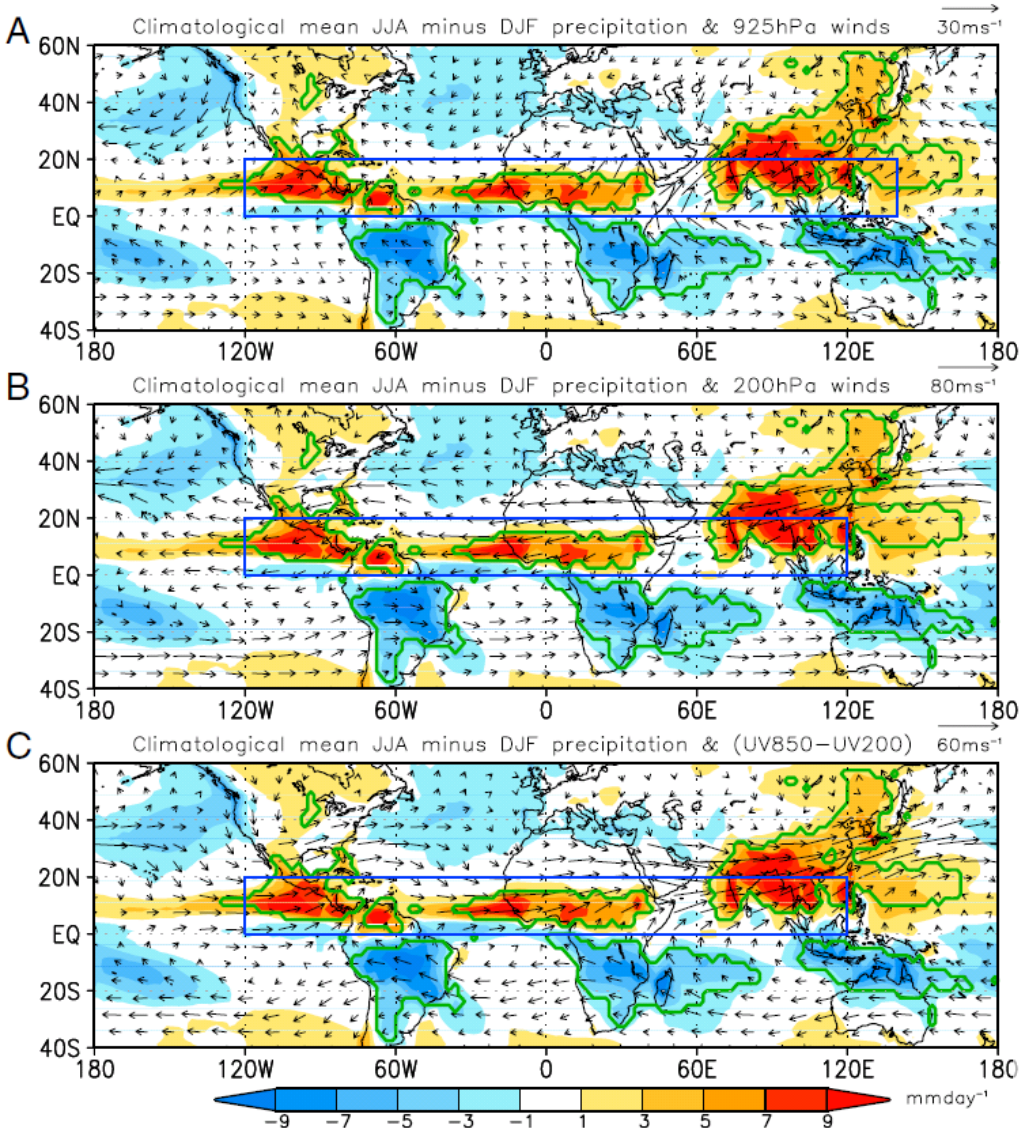
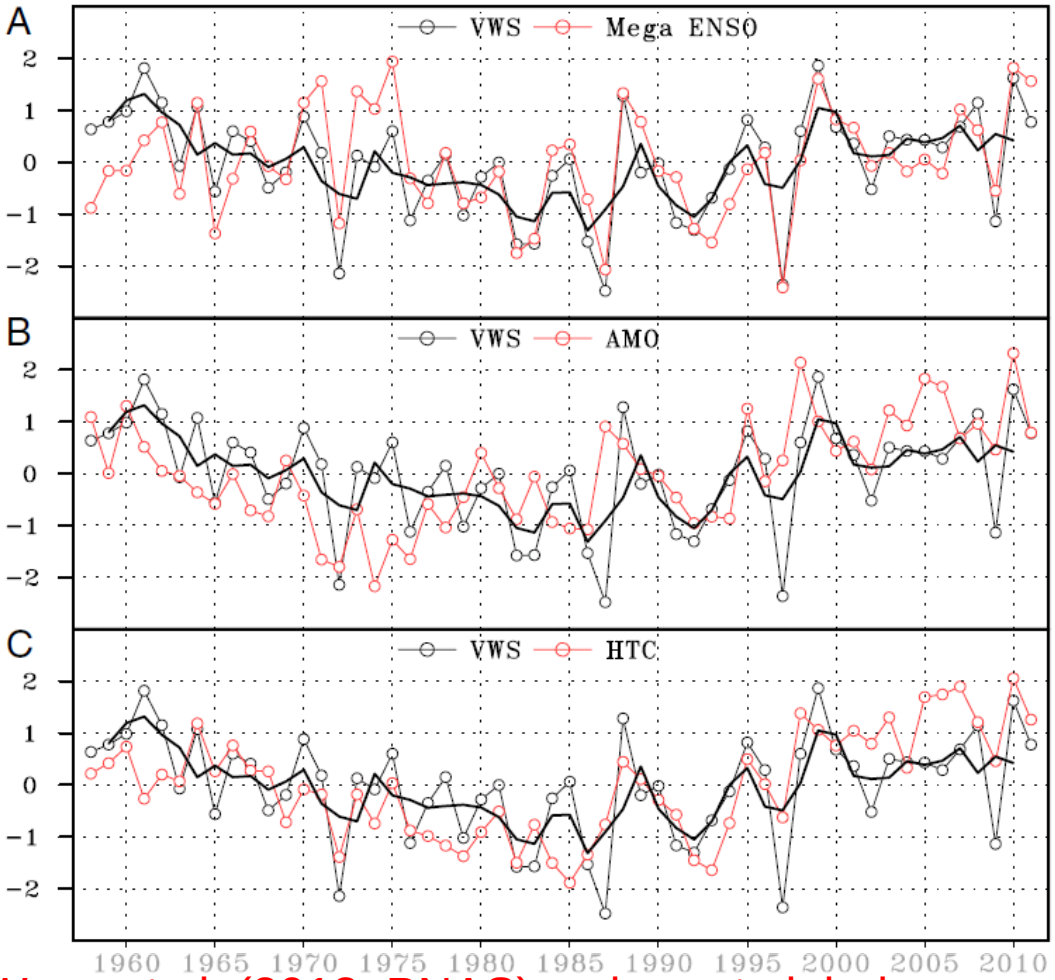
- What can we gain by considering the global monsoon and its relationship to large-scale drivers?





Wang et al. (2013, PNAS): coherent global monsoon mode and relationships

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Key scientific questions: processes

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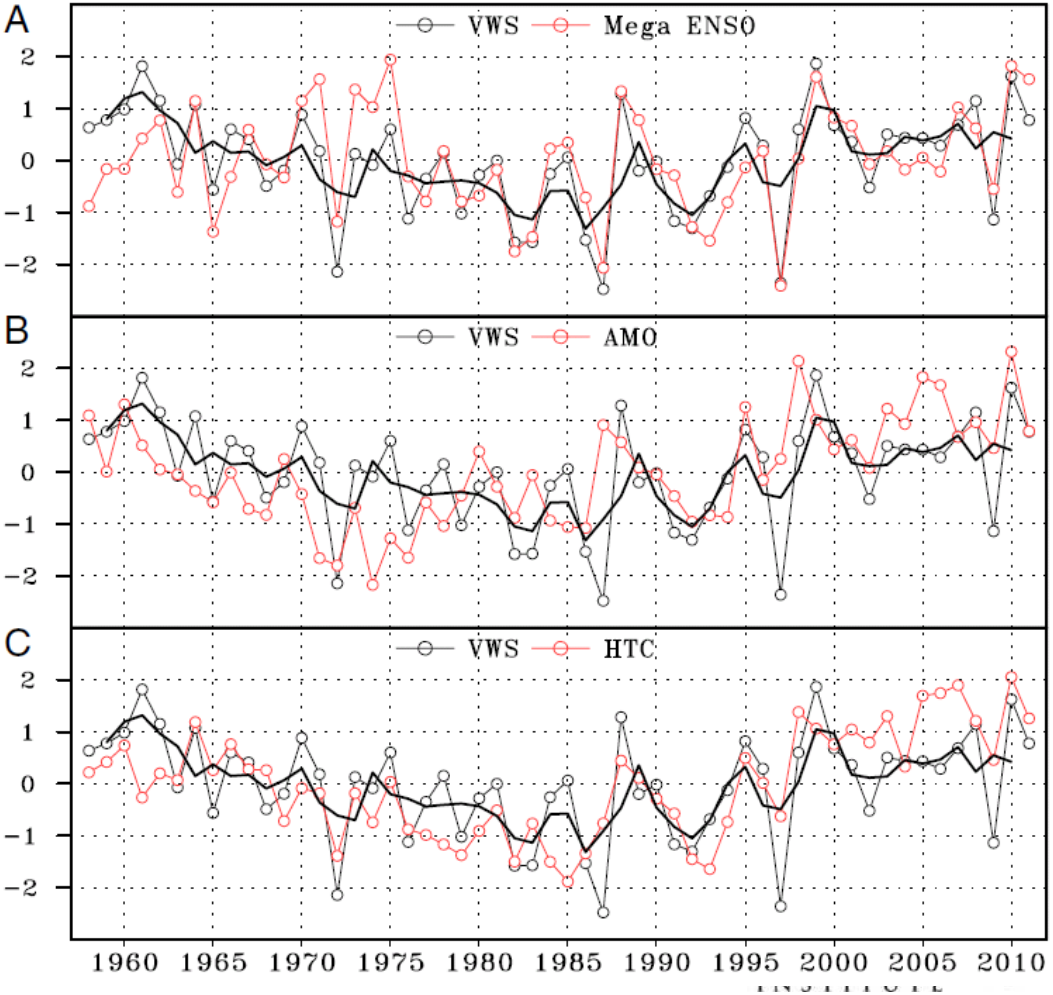
- To what degree do cross-hemispheric forcings contribute to variability in the timing and strength of monsoons [regional versus local forcings]?



Wang et al. (2013, PNAS): coherent global monsoon mode and relationships

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Key scientific questions: processes

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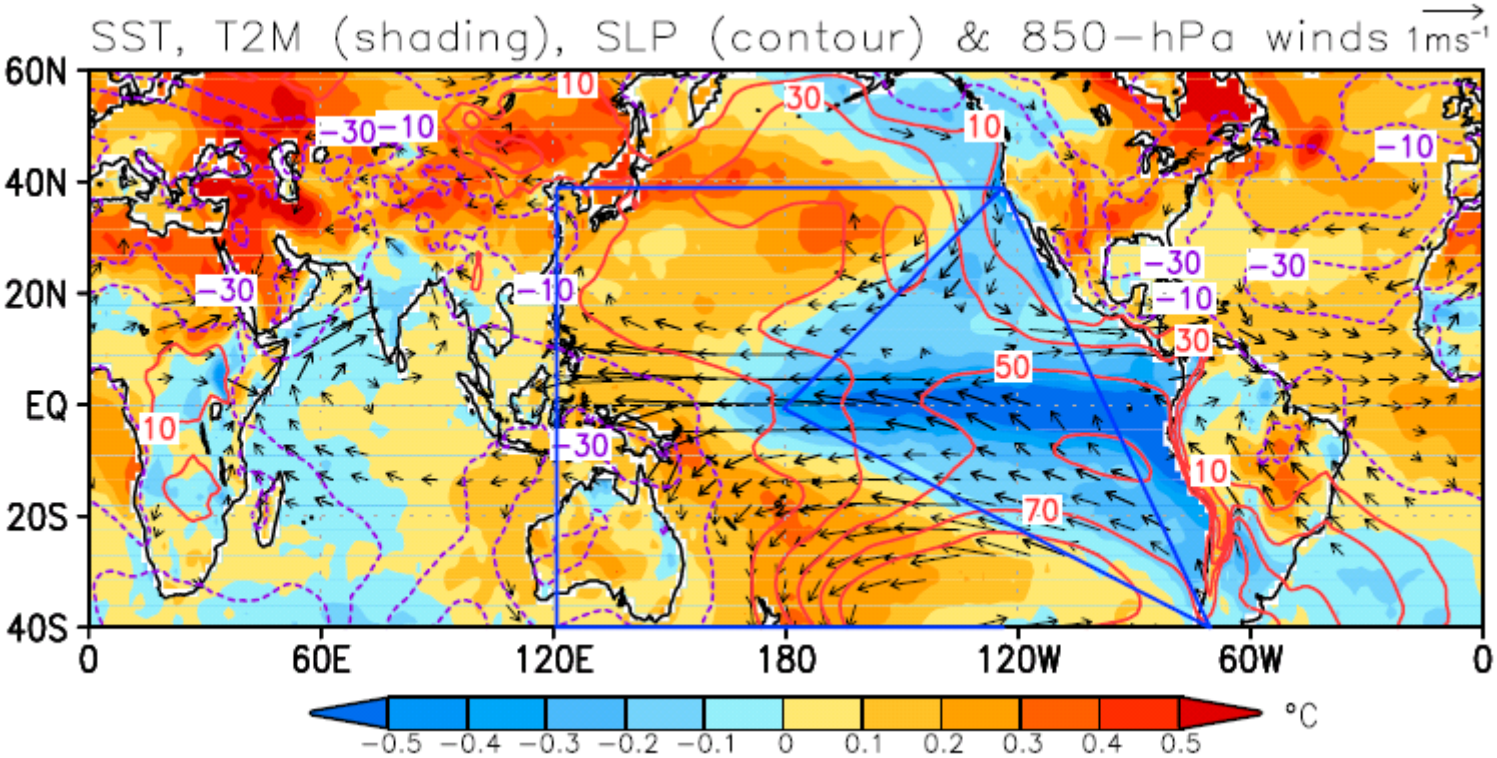
- Are the regional monsoons driven by the same drivers at interannual and interdecadal time scales?



Wang et al. (2013, PNAS): ENSO versus PDO?

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What can the community do better together?

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- Regional/global modellers working together?
- Commonalities and differences between regional and global drivers
- Coordinated action on other sources of predictability (land, aerosol)
- Improved understanding of links between climate and water availability/demand
- Better CLIVAR/GEWEX engagement

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Links with the WCRP Grand Challenges

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GC Water Availability: there could be a lot of connection with GC5 on the role of land surface/cover:

- Model biases
- Land-atmosphere coupling
- Initialisation
- More realistic land schemes in model

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Links with the WCRP Grand Challenges

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GC Regional climate information:

- Need to address perception of poor forecast skill in stakeholders (anecdote UoR Malaysia trip)
- Keen to understand predictability from other factors than SST (soil moisture, aerosol…)
- Big opportunity for coordinated regional modelling research, linking with CORDEX South Asia, CORDEX East Asia.

The end

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Thank you for your attention

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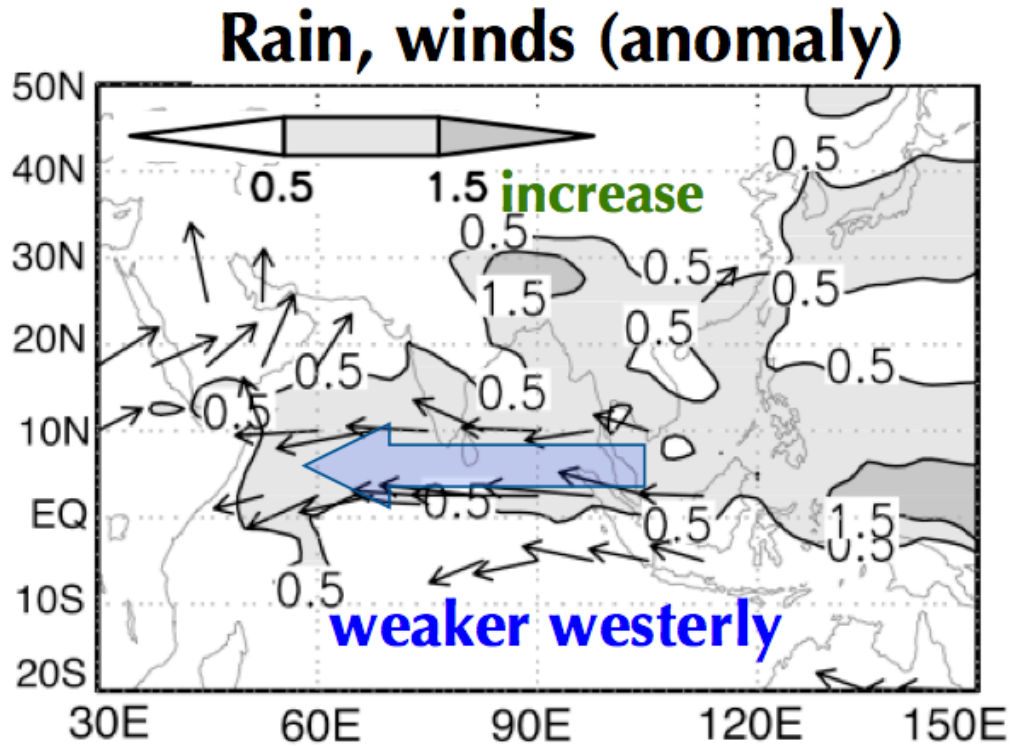
Scientific questions

- CMIP3 vs CMIP5
  - Different wind changes over South Asia. Why?

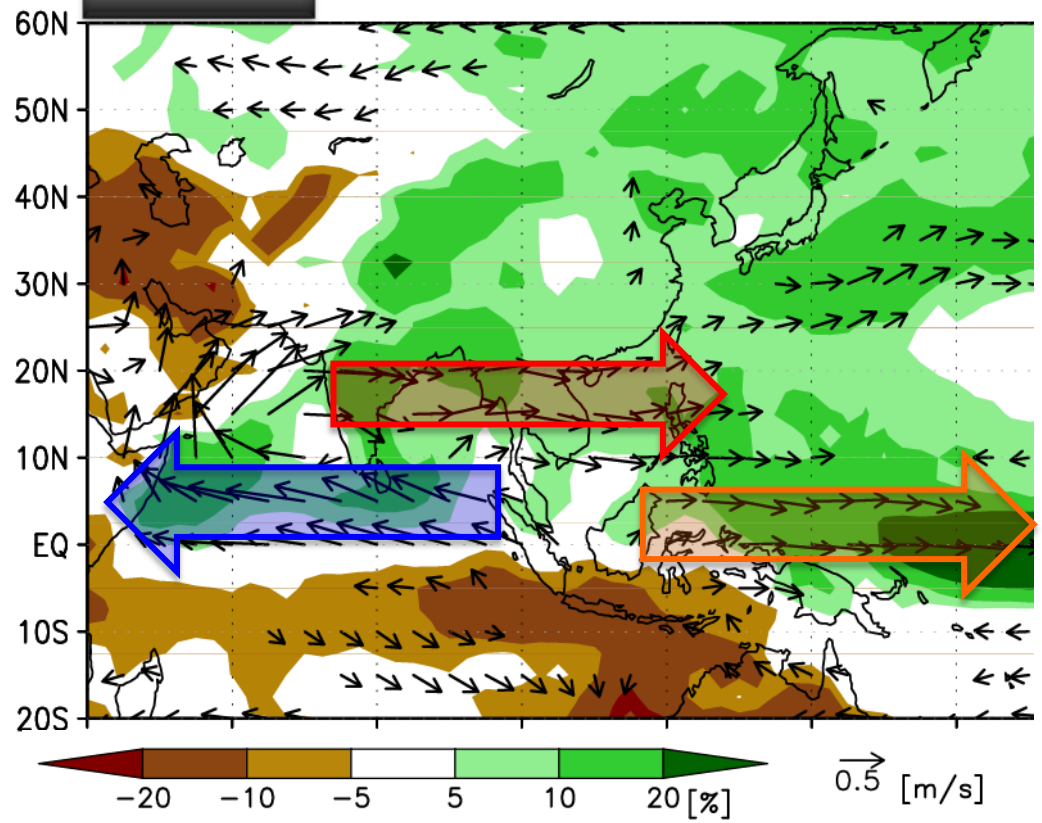
- Is the Asian monsoon different from others?
  - Increase rate of Asian monsoon rainfall is much larger than other monsoons
  - Dynamical weakening of the Asian monsoon is less than other monsoons
  - Why?

Comparison between CMIP3 and CMIP5

CMIP3



CMIP5

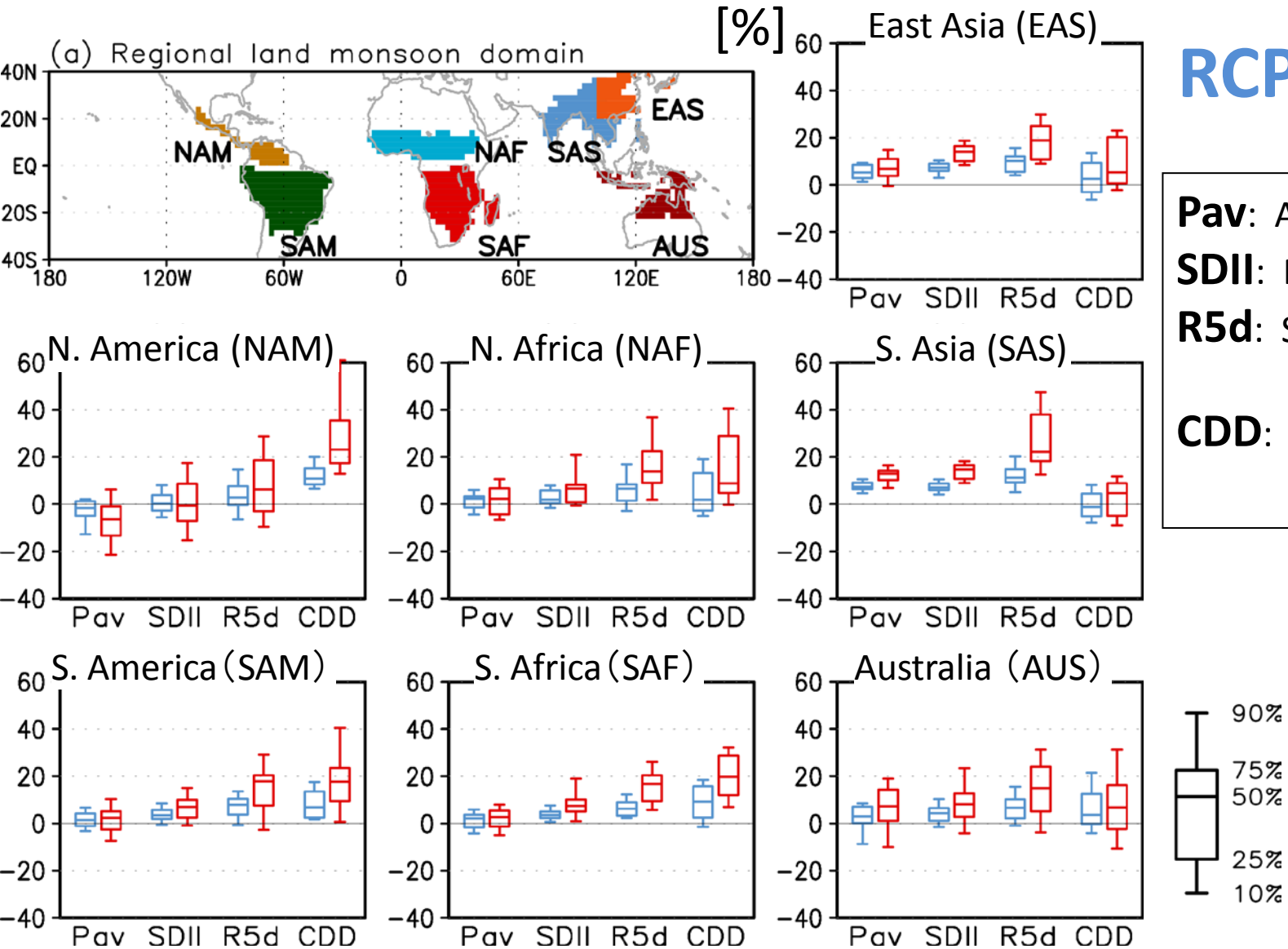


Ogata, Ueda, Hayasaki et al.(submitted)

In the CMIP5, the monsoon flows in the tropical Indian Ocean are projected to decrease, however…. outside of the tropical Indian Ocean, **enhanced monsoon westerlies** and **weakened trade winds** newly emerge.

Future change of the precipitation indices

- Largest increases over the Asian monsoon domains
- Large increases in extremes over America and Africa



RCP4.5 **RCP8.5**

Pav: Average precipitation

SDII: Precipitation intensity

R5d: Seasonal maximum of 5-day precipitation

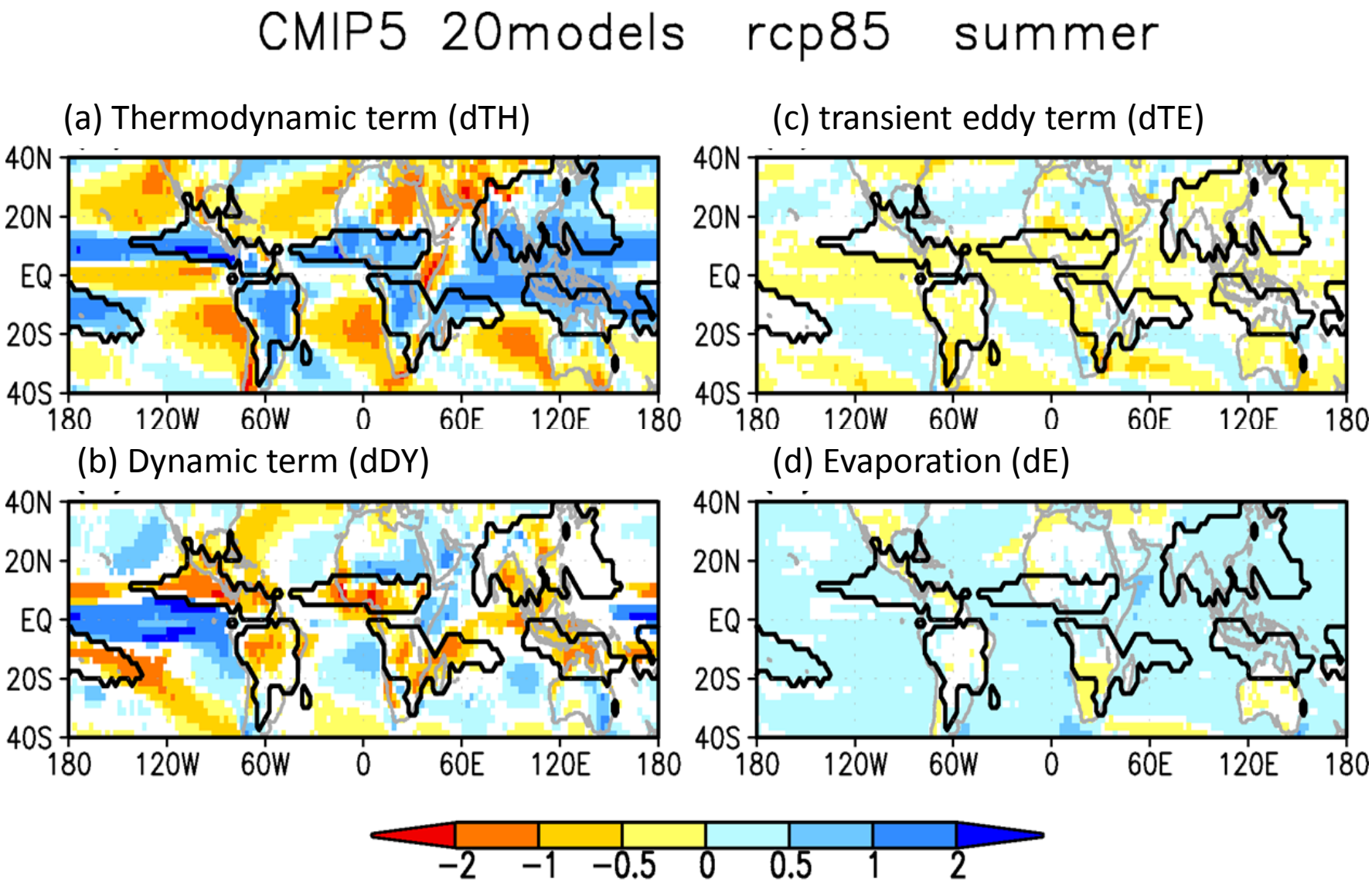
CDD: Seasonal maximum of consecutive dry days

Future change of the precipitation indices

Change rate of indices in the 50th percentile

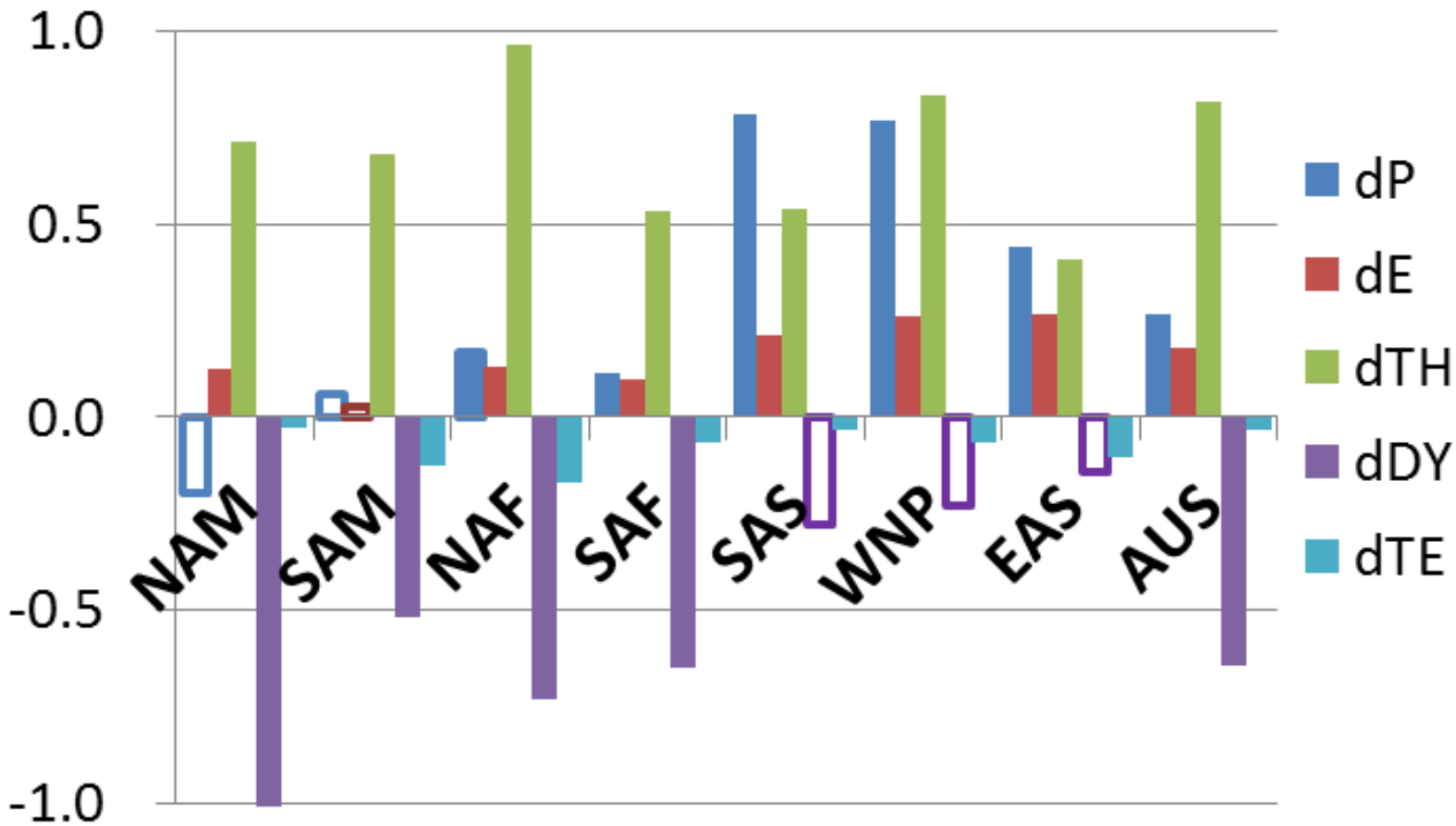
Large change ratios in EAS and SAS

Changes in moisture budget



Thermodynamic effect is mostly compensated by dynamic effect, except for the Asian monsoon, where dynamic effect is small ⇒ large increase in monsoon rainfall

Contribution of each term



Over Asia, dynamic effect is small and local evaporation is large than other regions