Improving Regional Monsoon Simulations with Statistical and Dynamic Model

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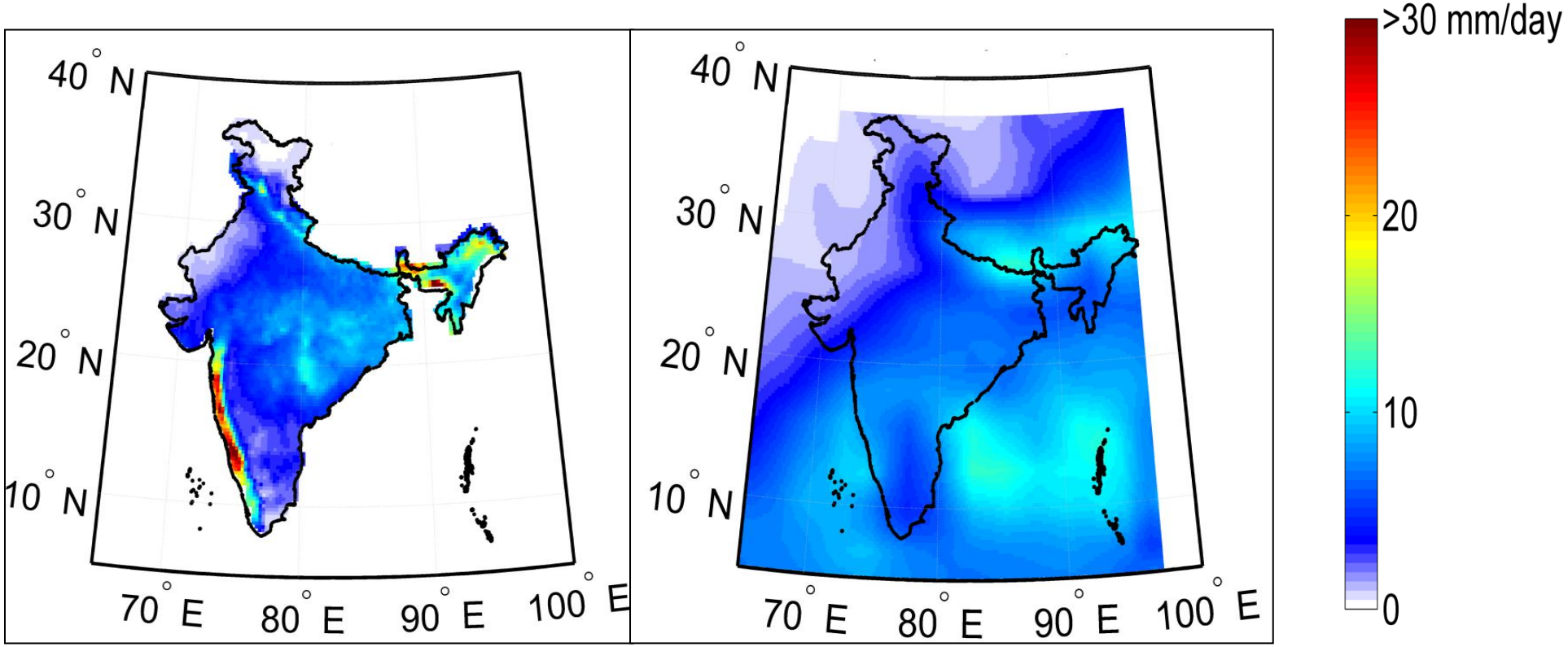
Challenges in Hydro-climatology

"sad truth of climate science is that the most crucial variables are the least well predicted" – Nature (2010)

1. Regional Projections
2. Precipitation
3. Aerosol
4. Tree-ring controversy

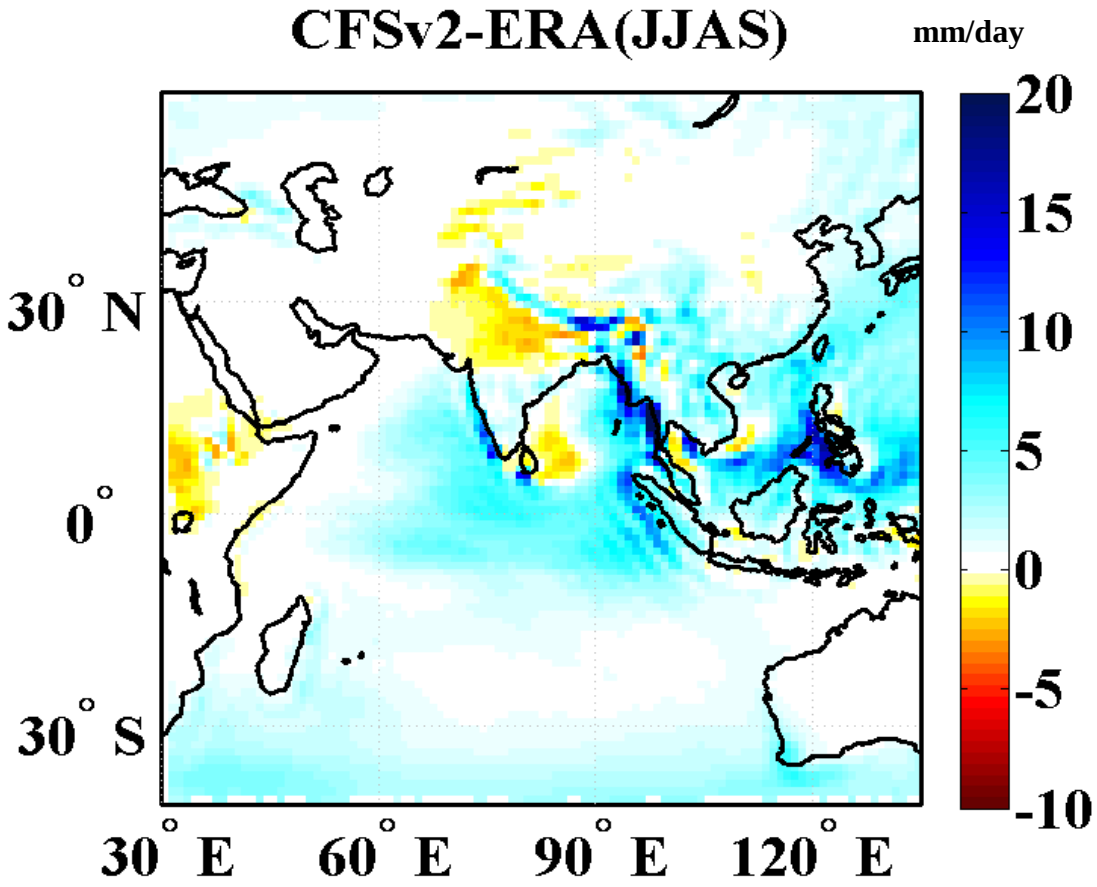
Climate Model (General Circulation Model) Simulations for Indian Monsoon Rainfall



Observed

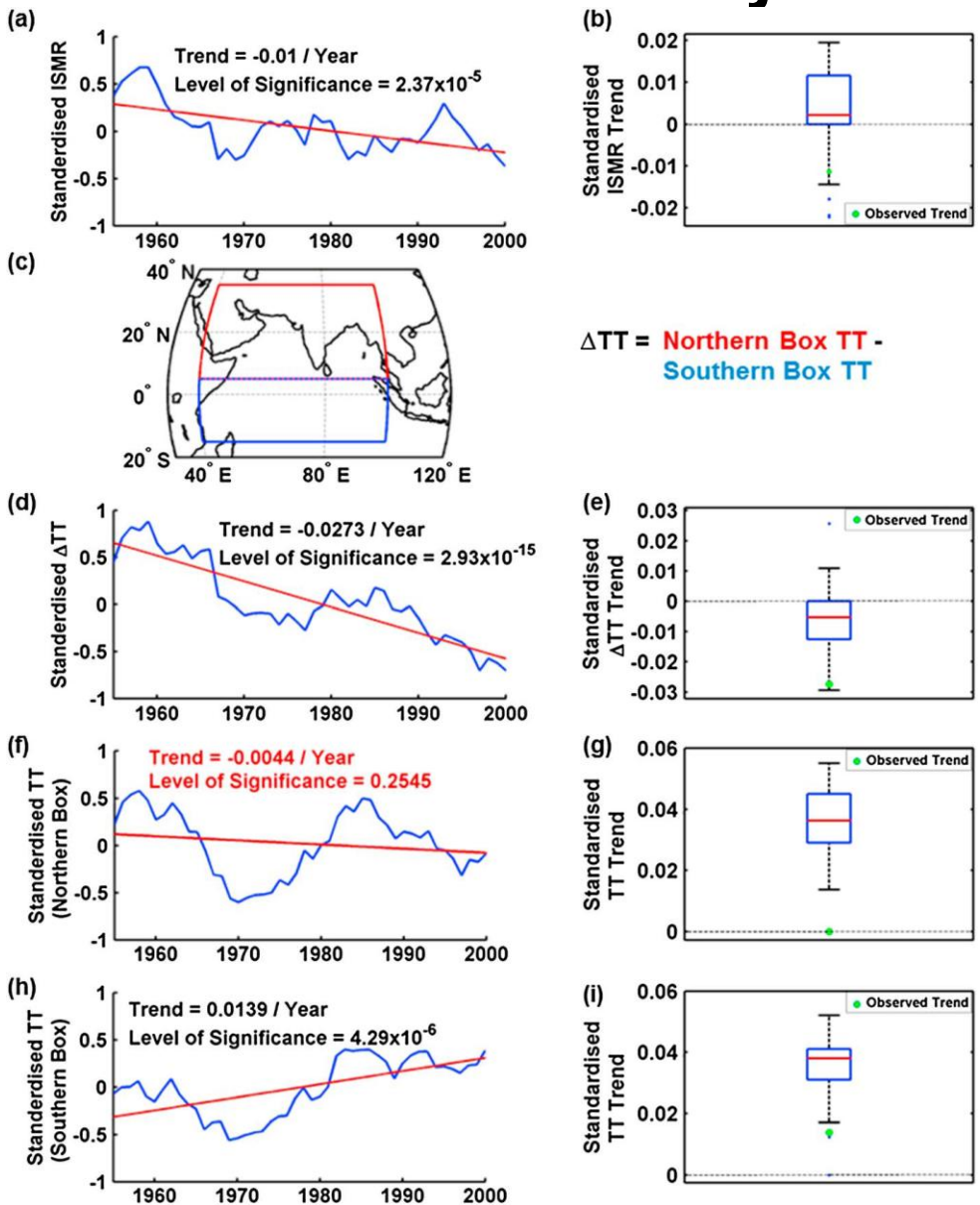
Simulated

Simulations from Operational Monsoon Model (CFSv2)



Sahana et al. (2018), Climate Dynamics

Failure of New Generation Climate Models for Indian Monsoon Projections



Saha et al. (2015), GRL

Downscaling

GCM Output

Large Scale Climate Variables

Regional Scale Hydro-meteorologic Variables, e.g., Rainfall in a city

Downscaling
- Statistical Downscaling
- Dynamic Downscaling

Impacts Assessment

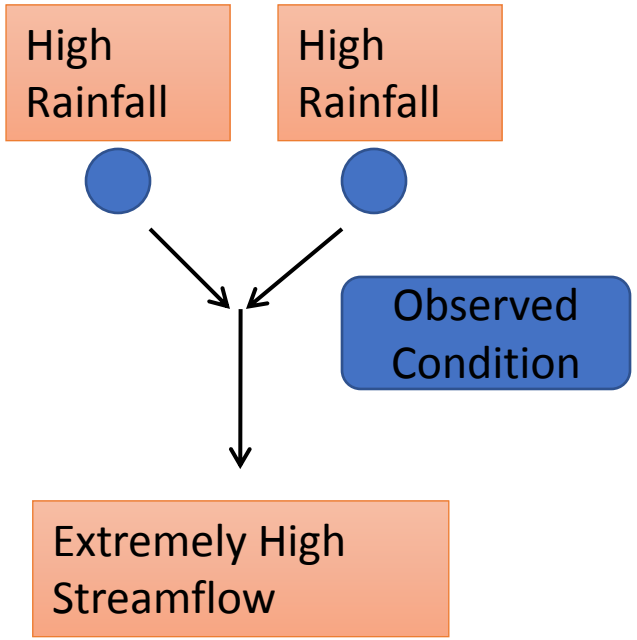
- Drought Analysis
- Agricultural Management
- Water Demand Availability Analysis
- Water Resources Management
- Hydraulic Structure Design
- Ecological Impacts
- Risk and Vulnerability Assessment of Extreme Events

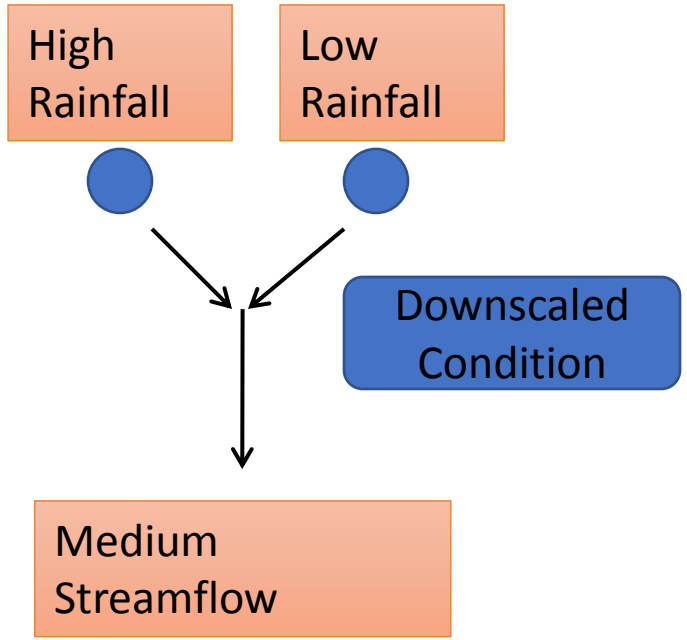
Regional Modeling

- Statistical Downscaling
  - GCMs can not simulate rainfall very well as rainfall is a regional scale phenomena
  - But GCMs simulate well some of the large scale variables, which affects rainfall.
  - Those large scale variables: Predictor
  - Rainfall: Predictand
  - Derive and apply the relationship between predictor and predictand
- Dynamic Downscaling
  - Based on Physics based approach
  - Uses nested gridding with a regional climate model

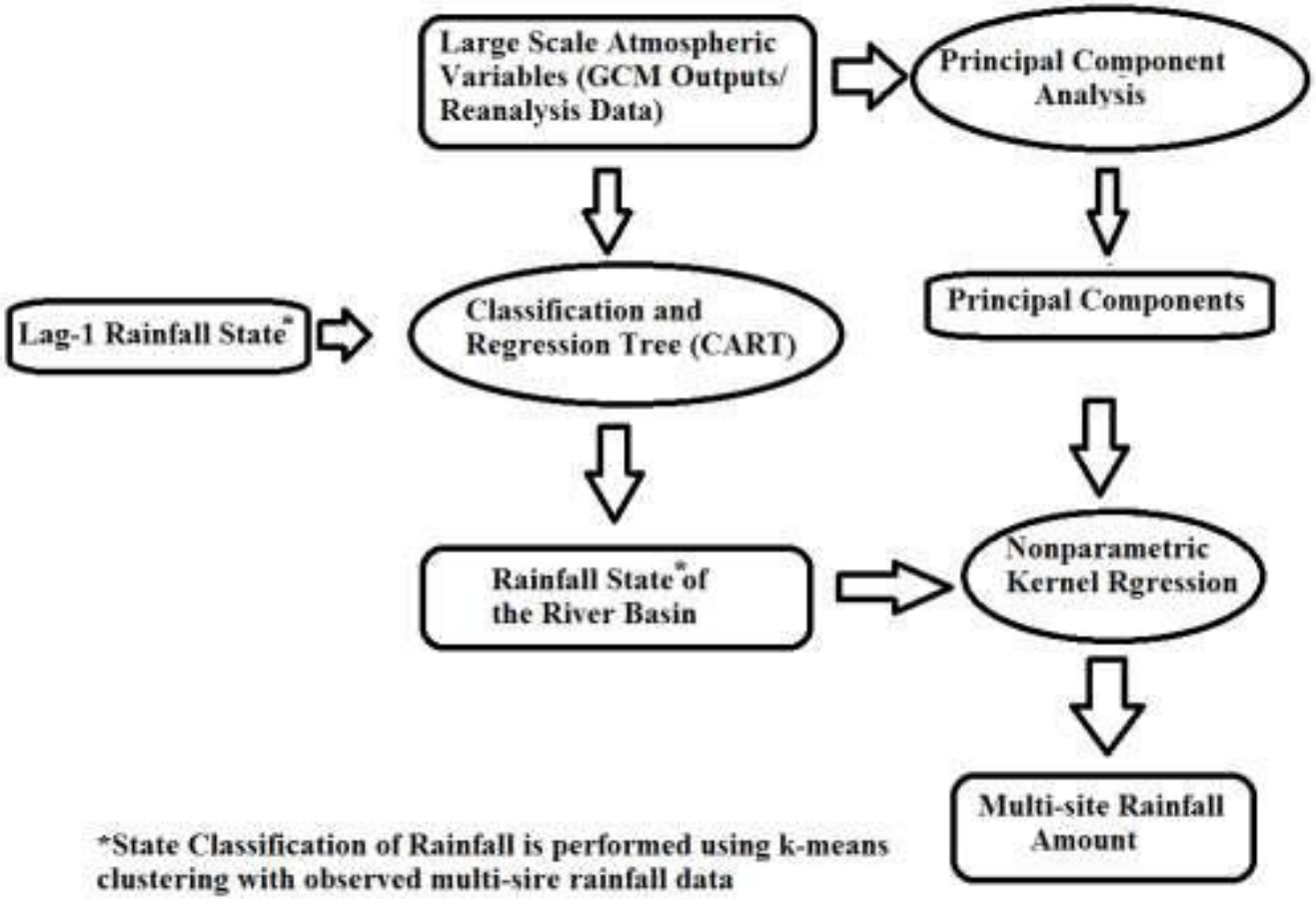
Multi-site Daily Statistical Downscaling

- Challenges
  - Cross correlation
  - Variability for daily scale



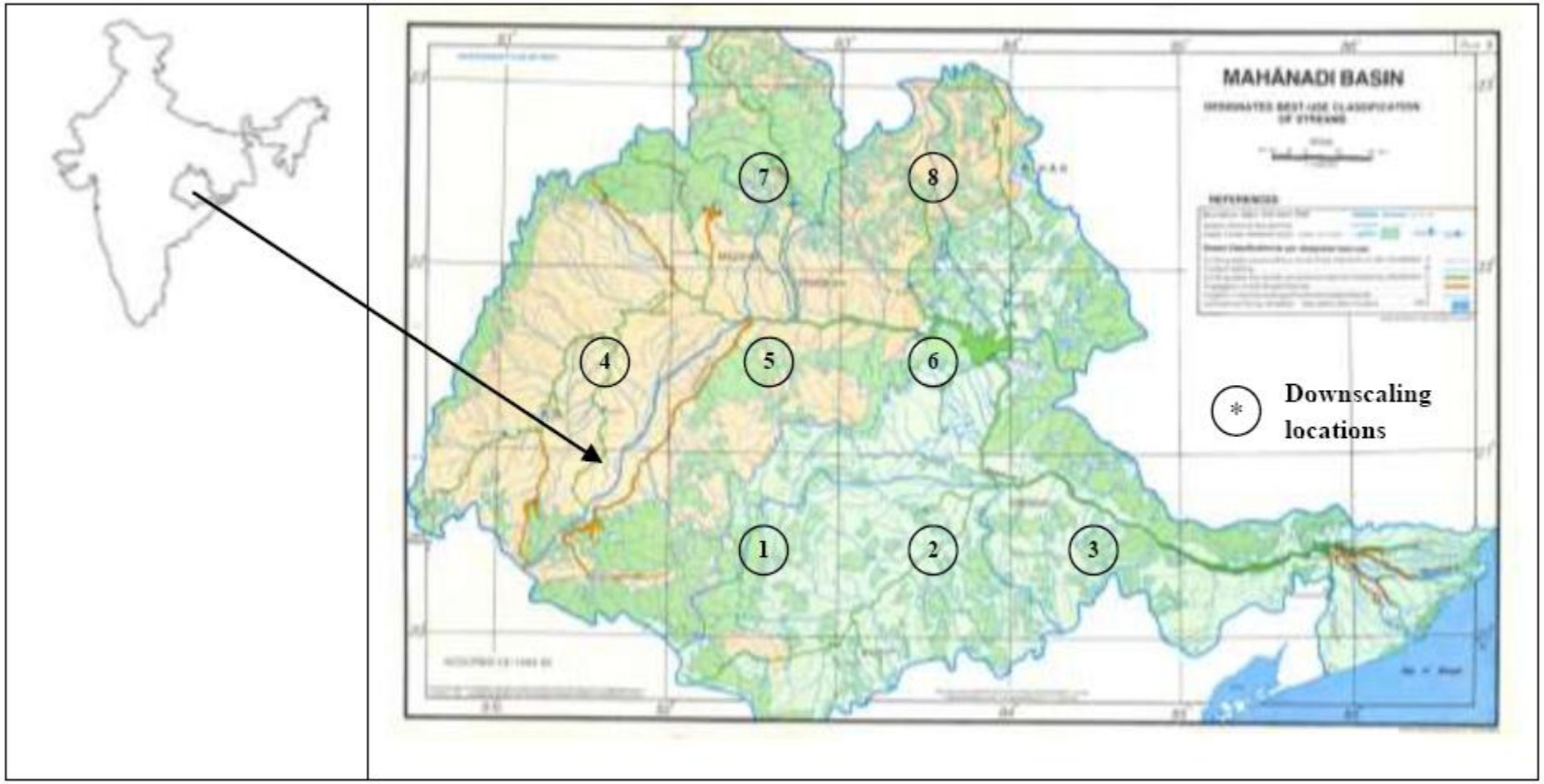


Kernel Regression Based Approach

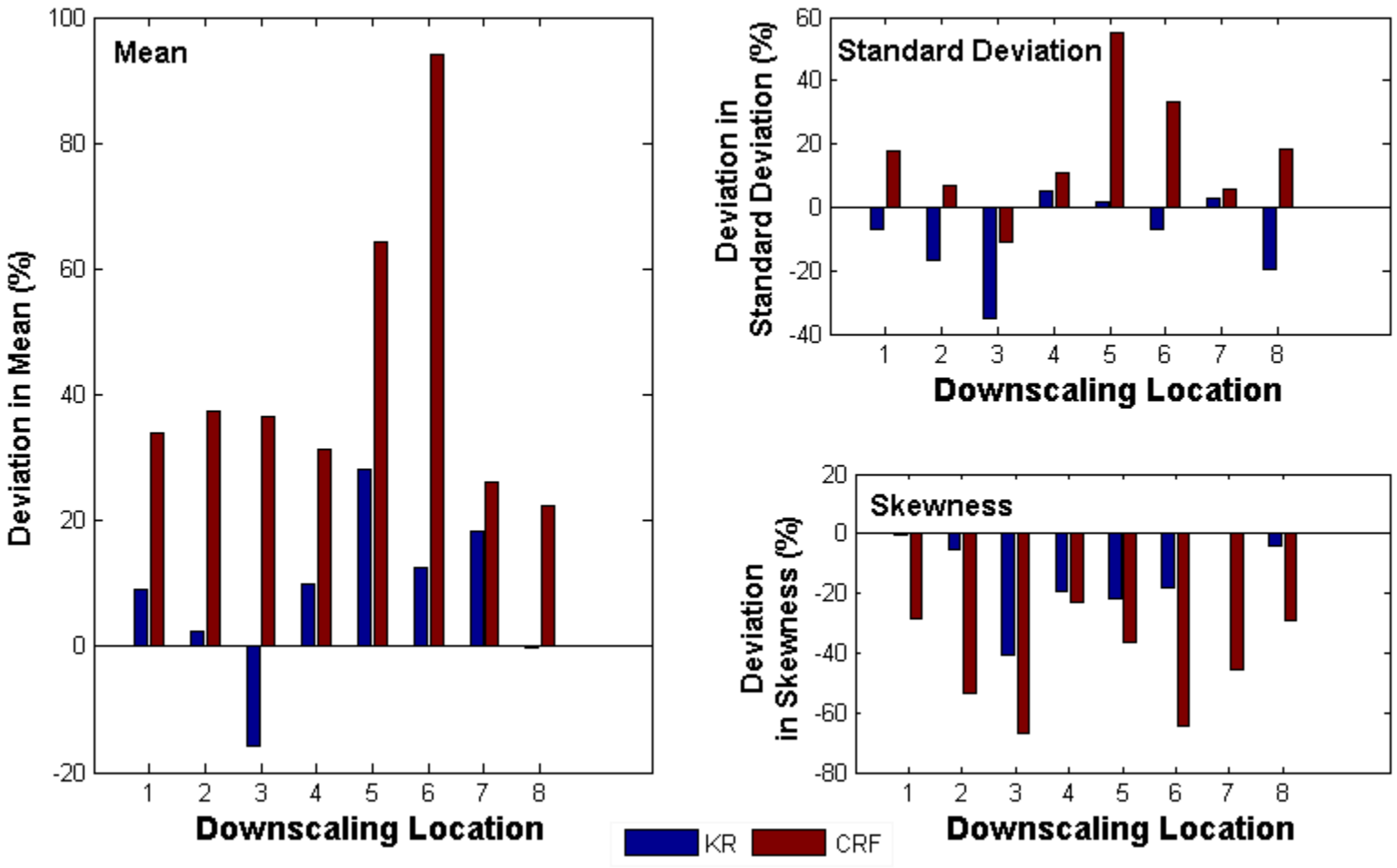


Kannan et al. (2013), WRR

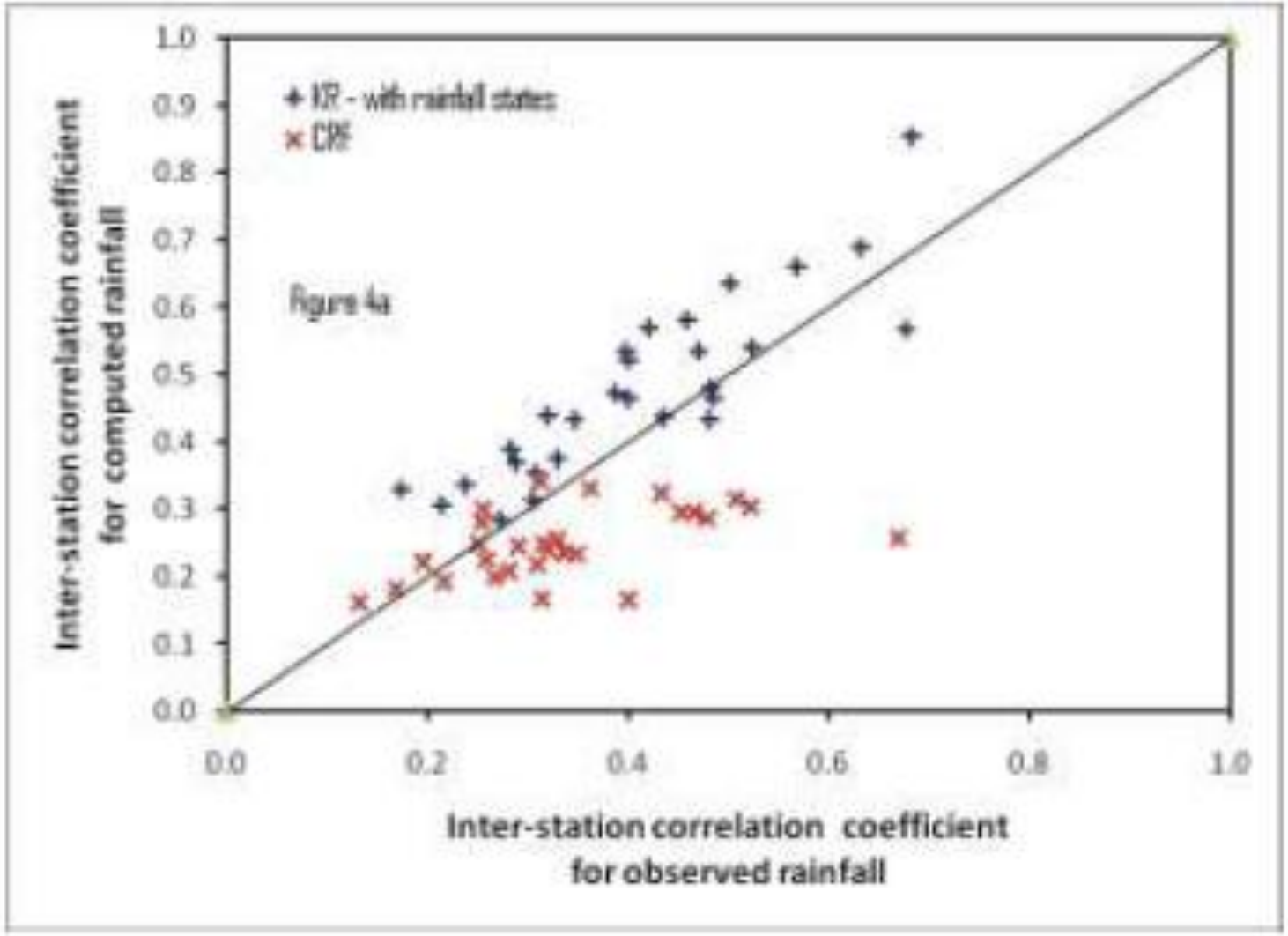
Case-study: Mahanadi River Basin



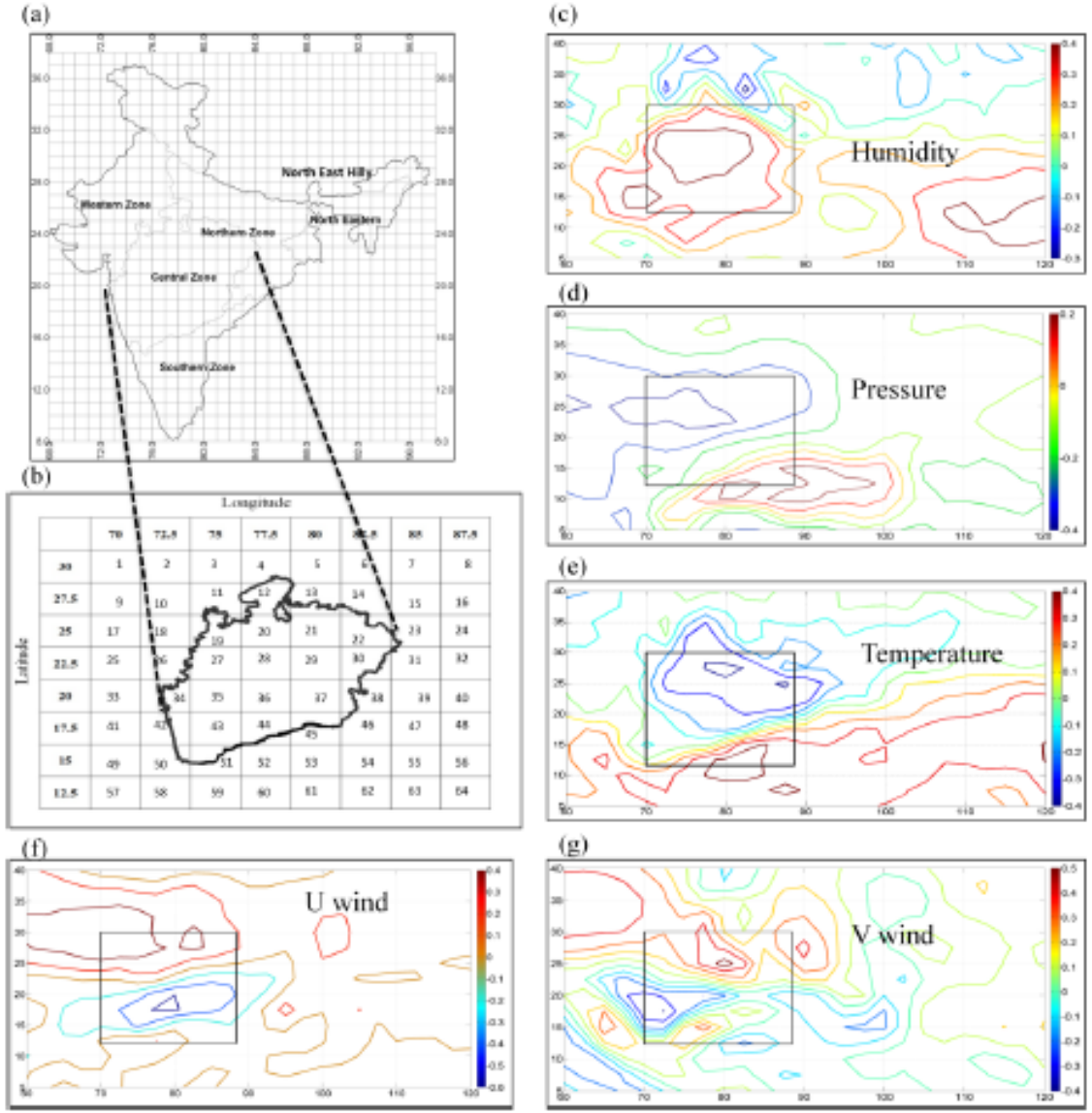
Comparison with CRF [Raje and Mujumdar, 2009] (Error Plot)



Comparison with CRF: Spatial Correlation

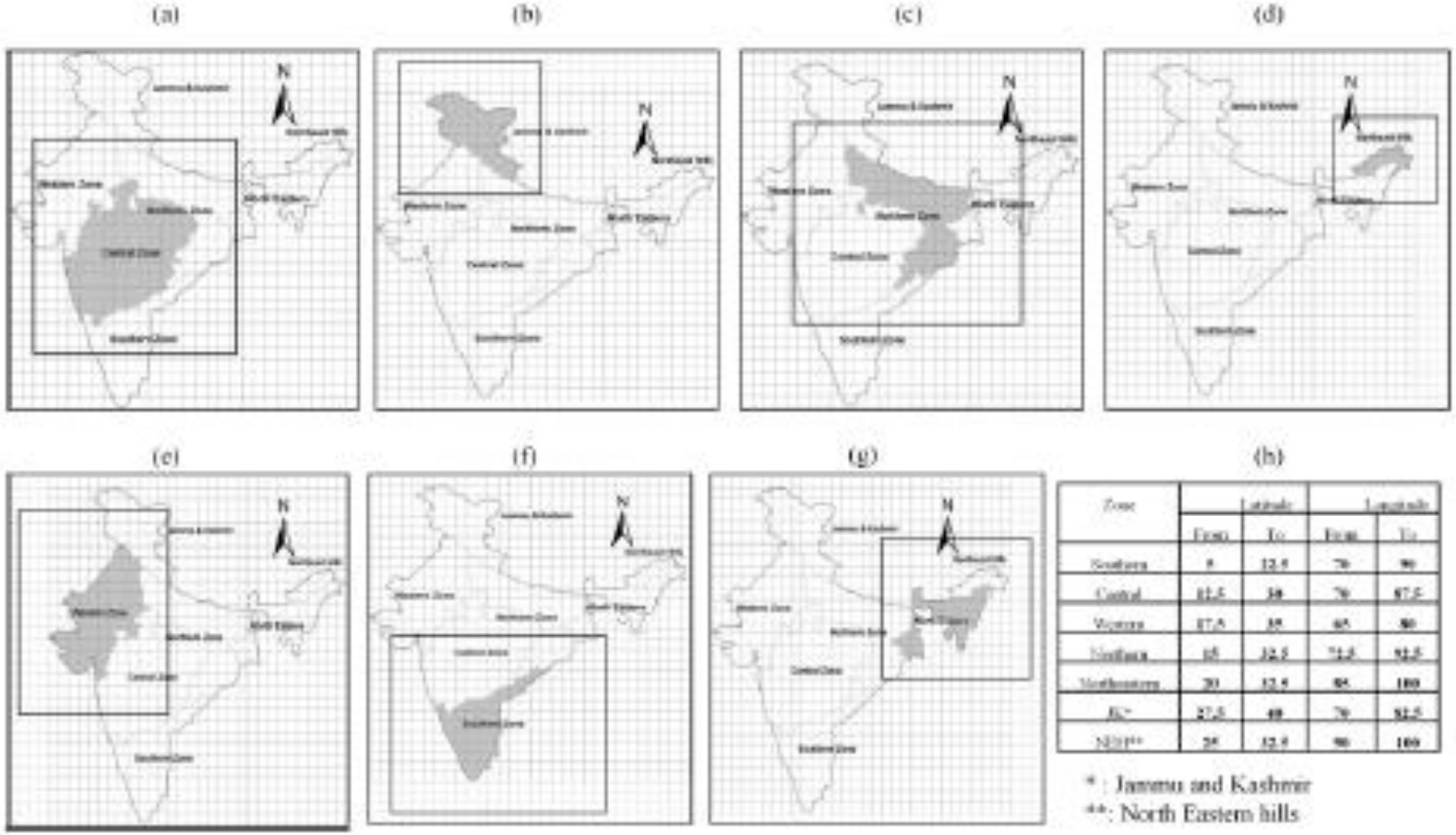


Application to All India



Salvi et al. (2013)

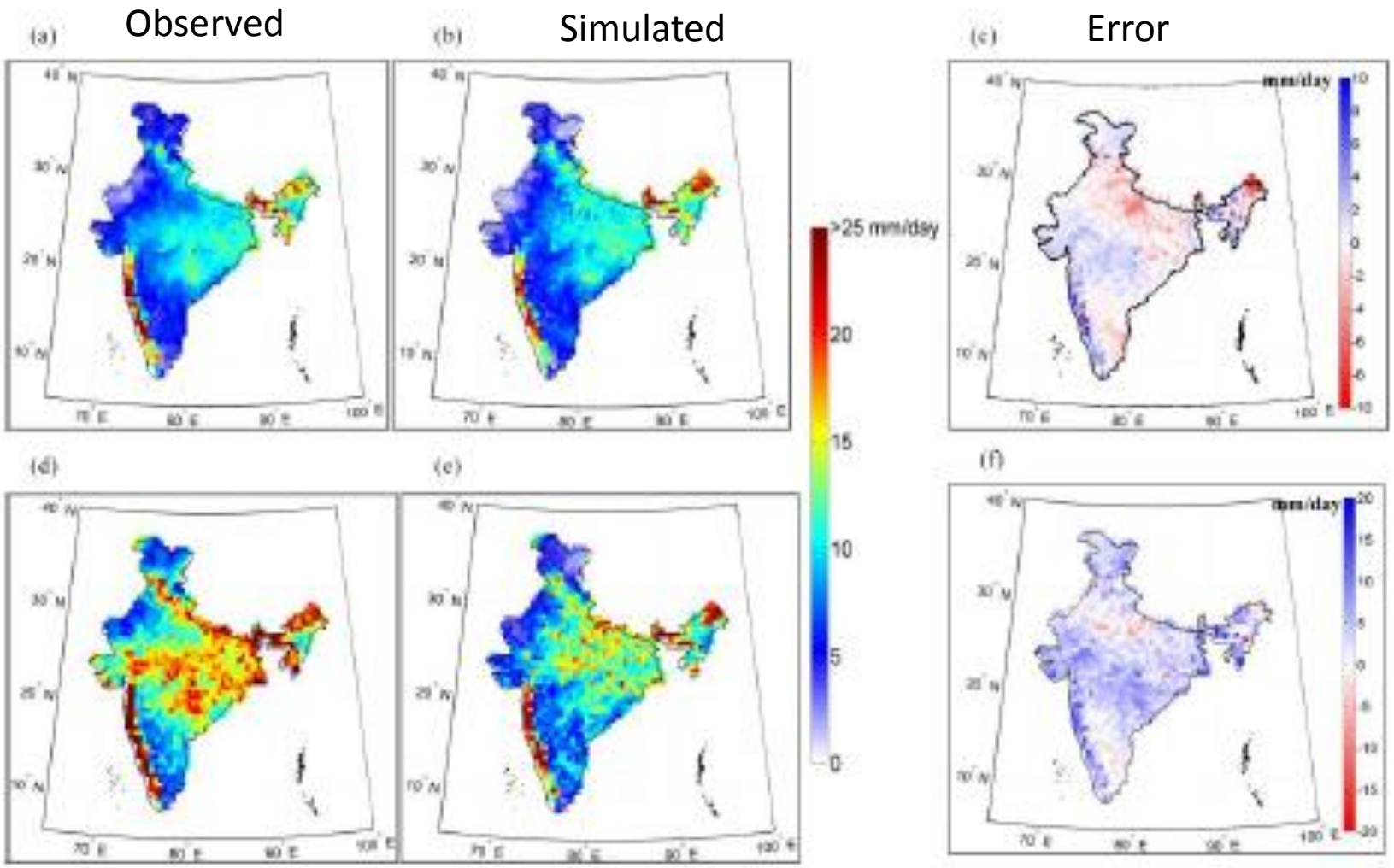
Predictor: spatial domain



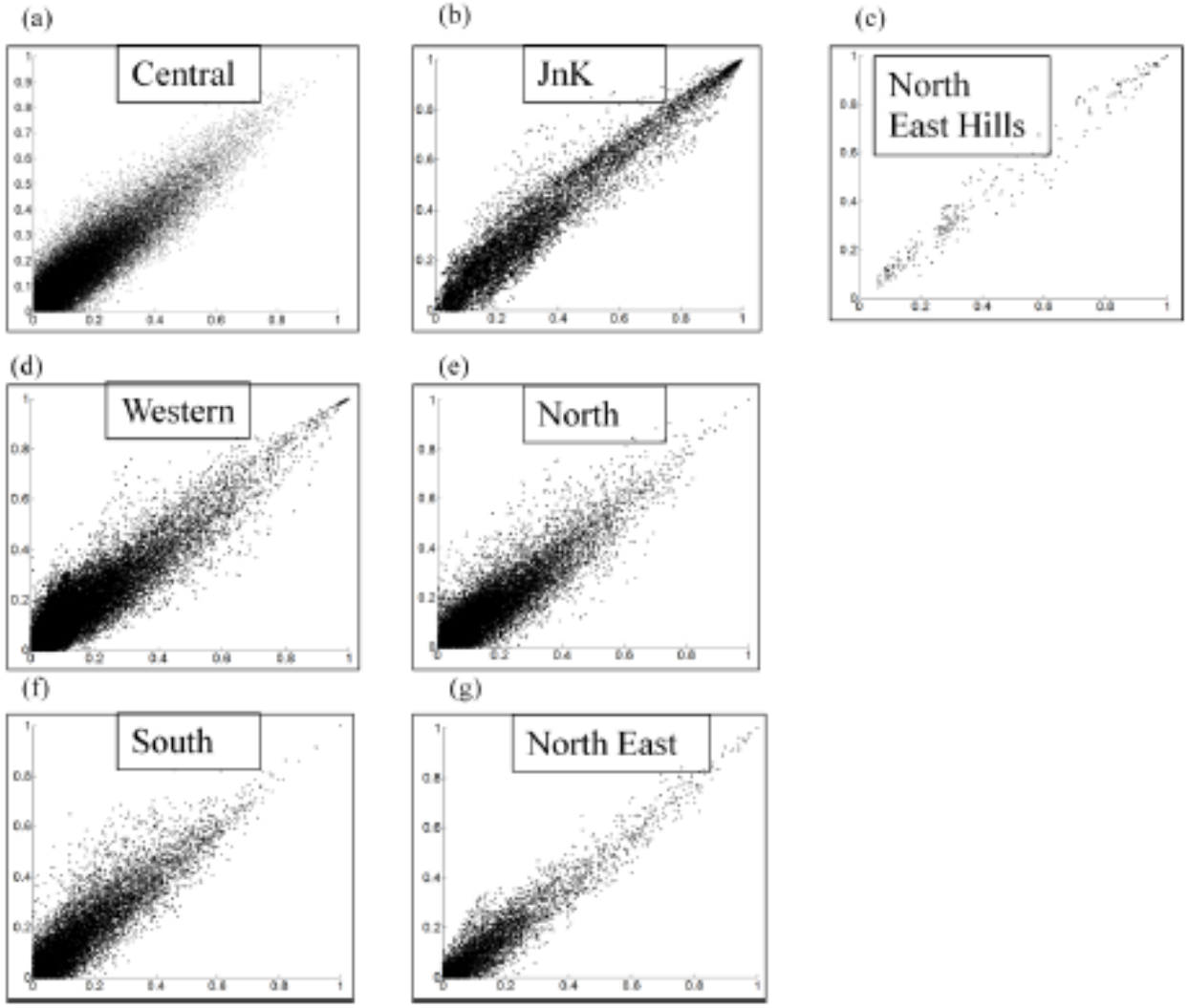
Zone	Latitude		Longitude	
	From	To	From	To
Southern	8	12.5	70	90
Central	22.5	30	70	87.5
Western	27.5	35	65	80
Northern	35	32.5	75.5	82.5
Northeastern	20	32.5	85	100
J&K*	27.5	40	70	82.5
NEH**	25	32.5	90	100

*: Jammu and Kashmir
**: North Eastern hills

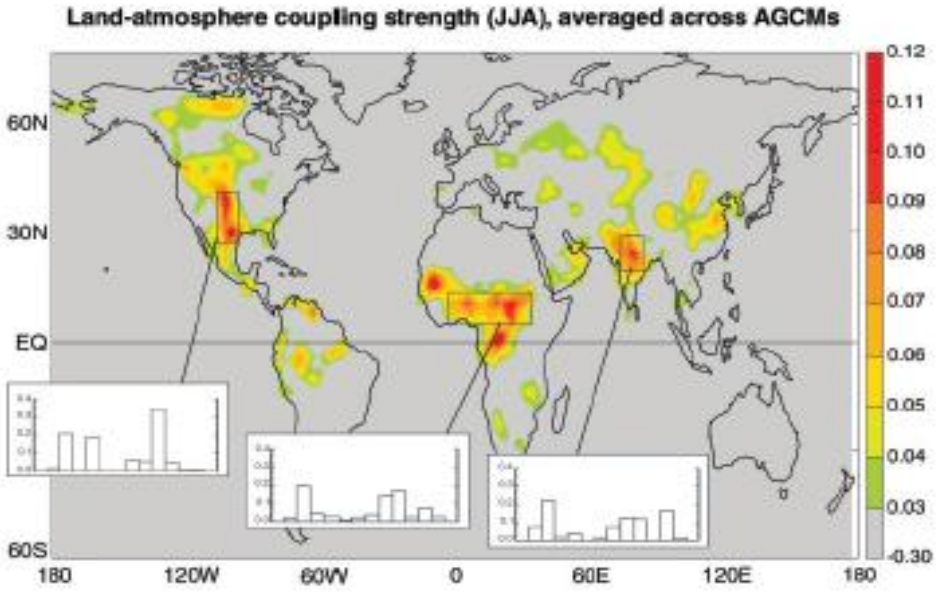
Mean and Standard deviation of simulated data



Zone-wise cross correlation



Land-Atmosphere Feedback in Monsoon

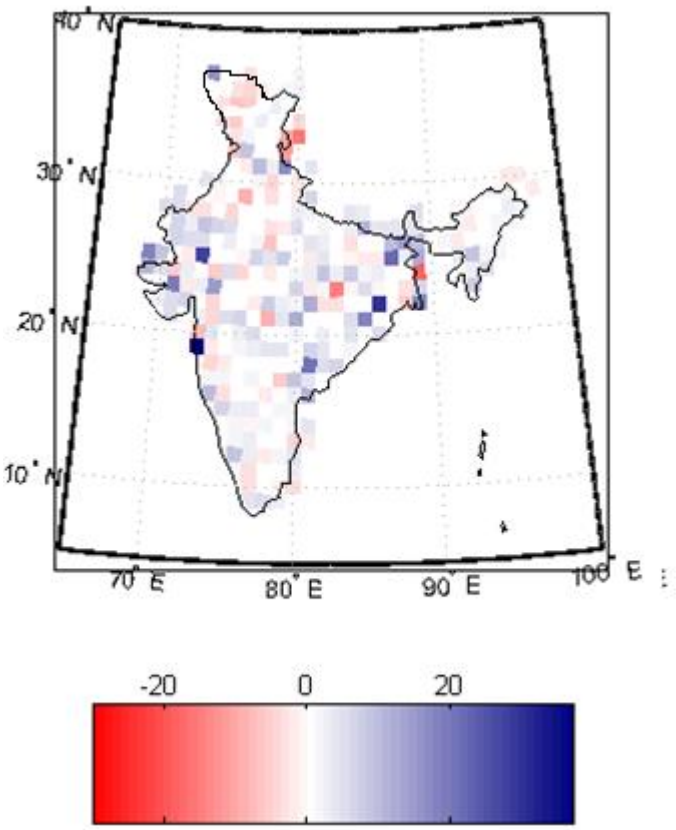


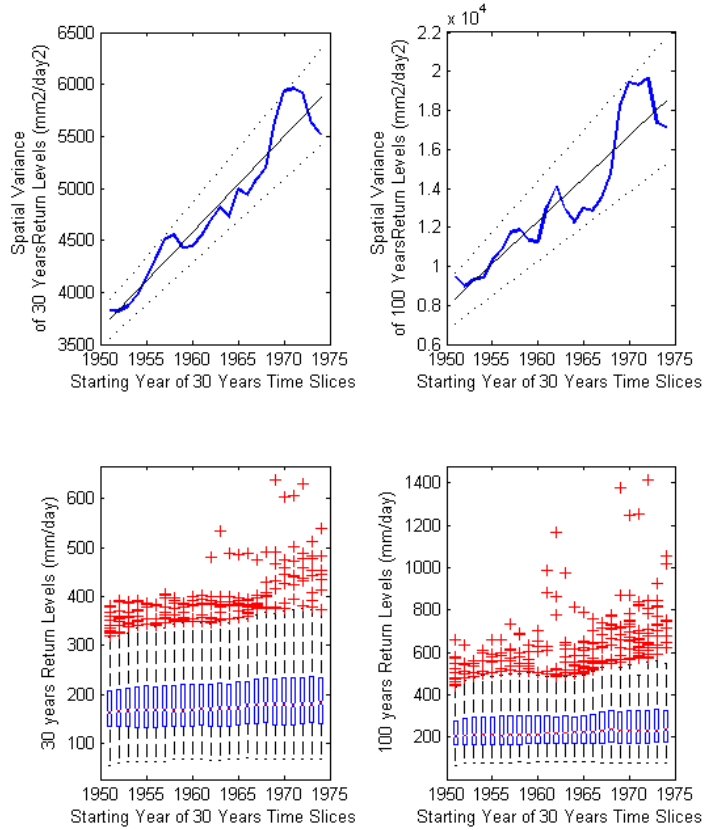
Coupling Strength Between Soil Moisture and Climate
Ref: Koster et al. (2004) [Science]

Still majority of monsoon studies do not account for land feedback
Same is true for operational monsoon model CFSV2

Indian Rainfall: Significant spatial Variability→ Land processes are Important

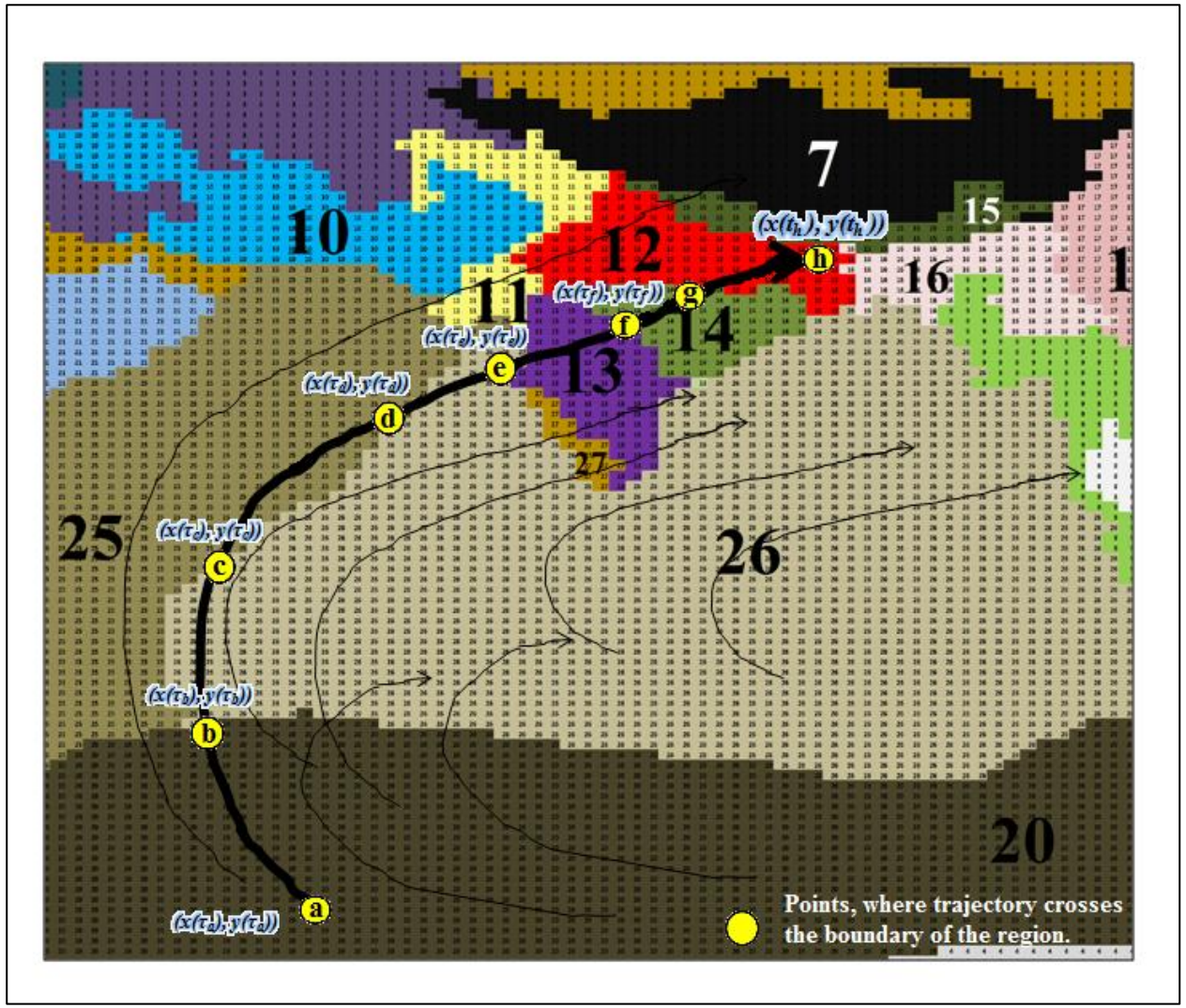
Trend of 100 year return levels





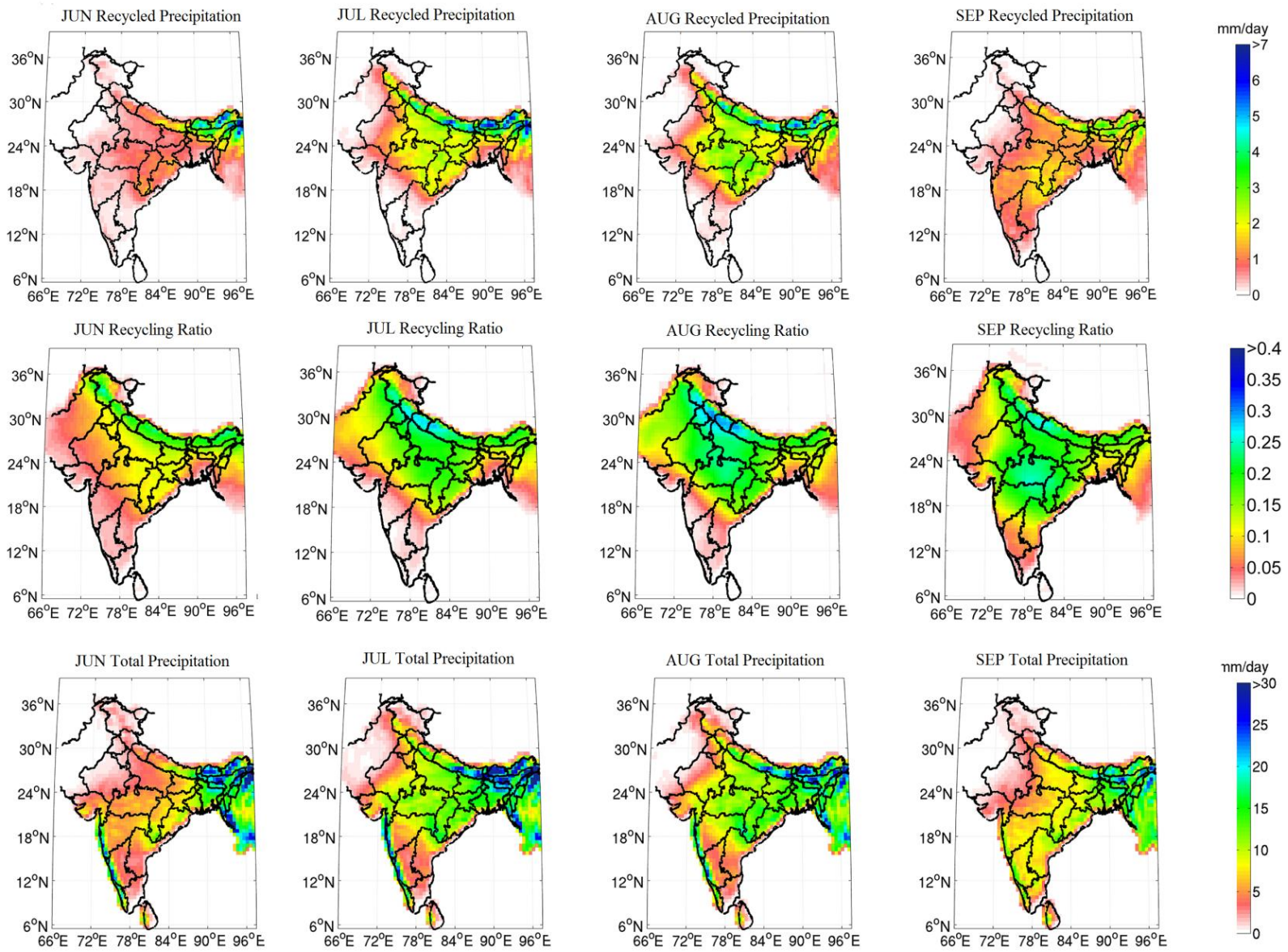
Ghosh et al. (2012) **NATURE Climate Change**

Understanding Different Land and Oceanic Sources

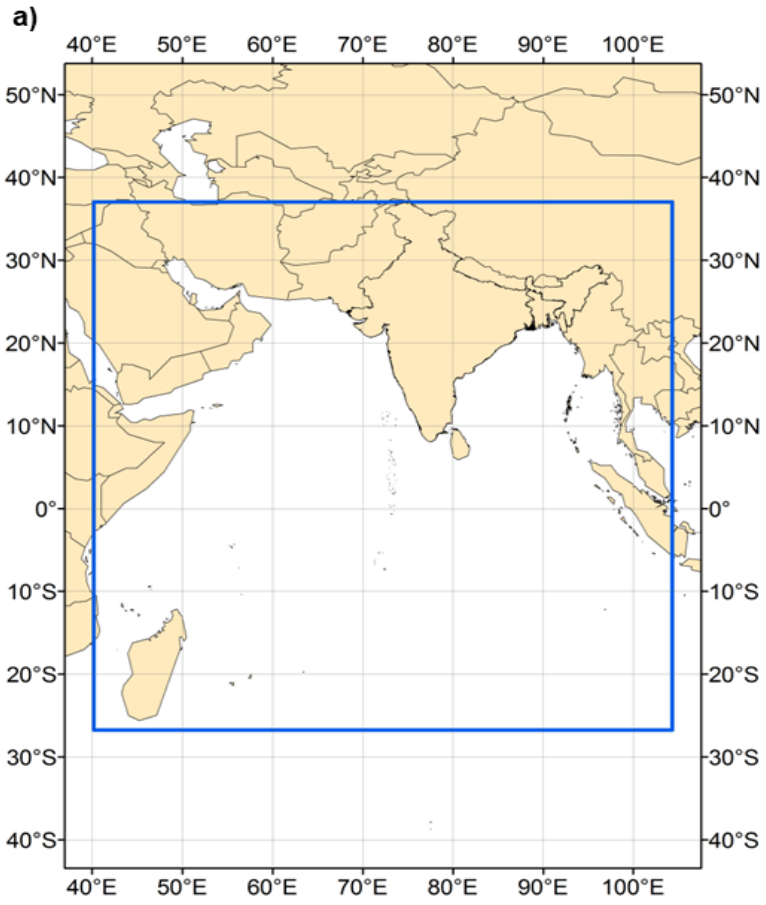


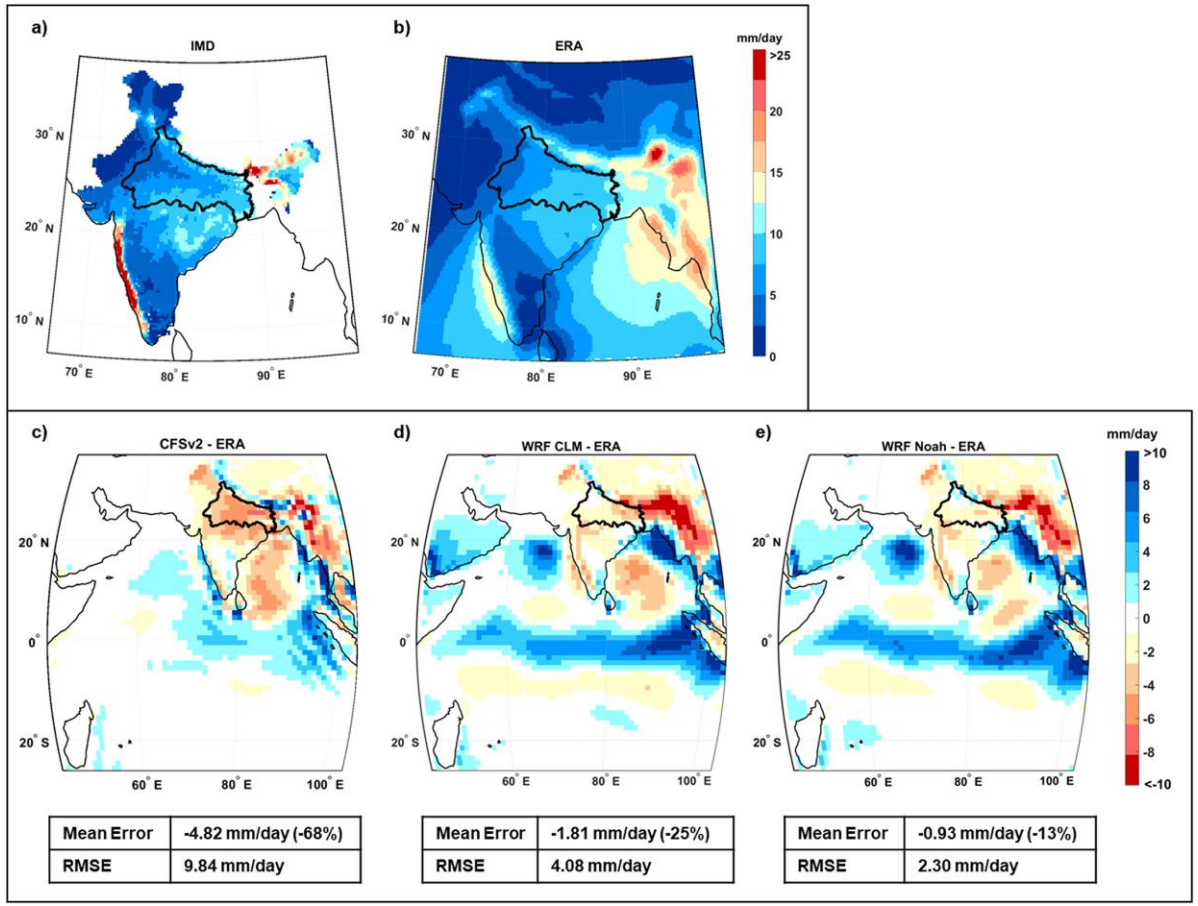
Pathak et al. (2017), Jl of Climate

Recycling Ratio in India (entire land mass)



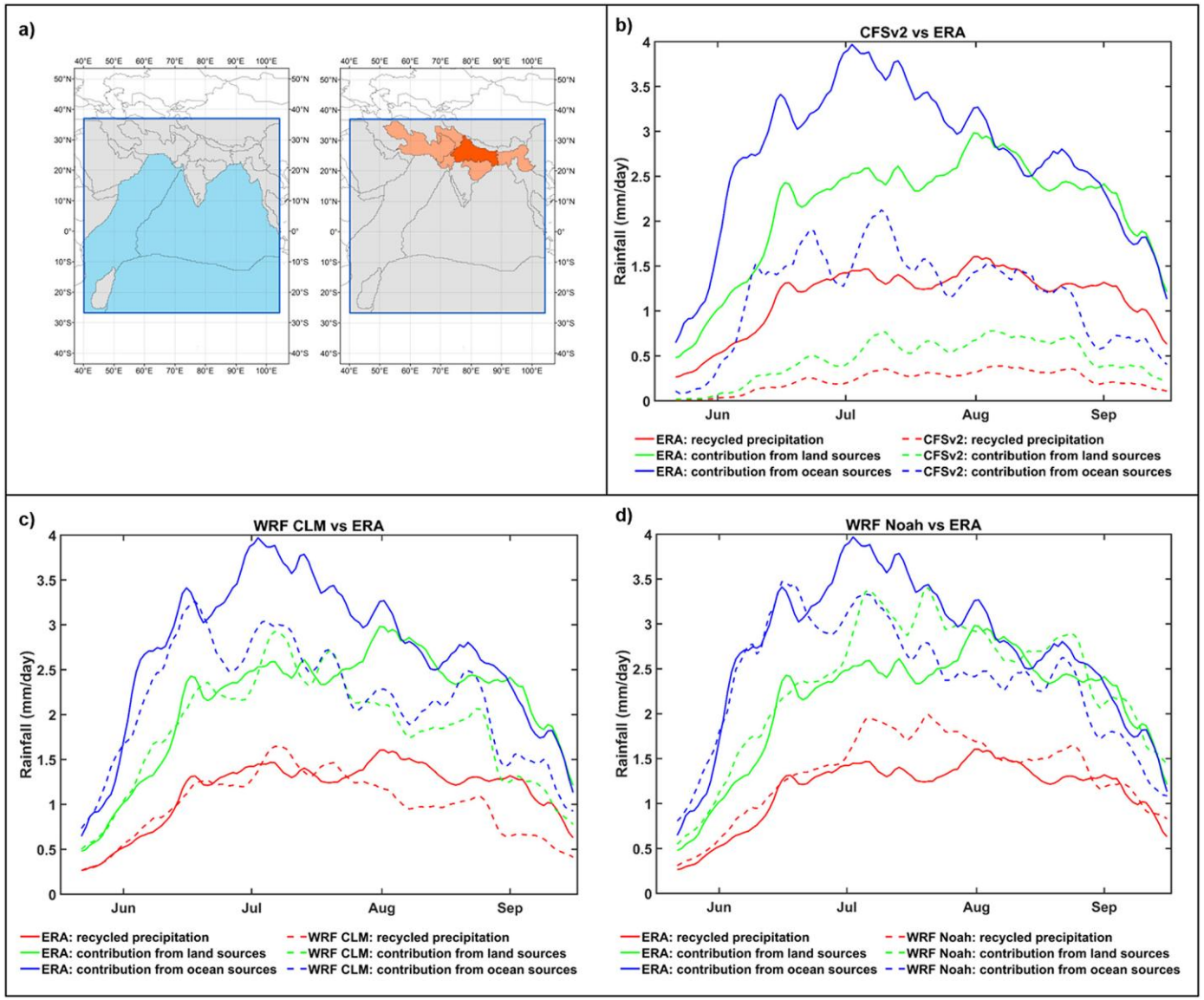
WRF-CLM Regional Simulations (Dynamic Downscaling)





Devanand et al. (2018), GRL, Selected as Research Spotlight of AGU

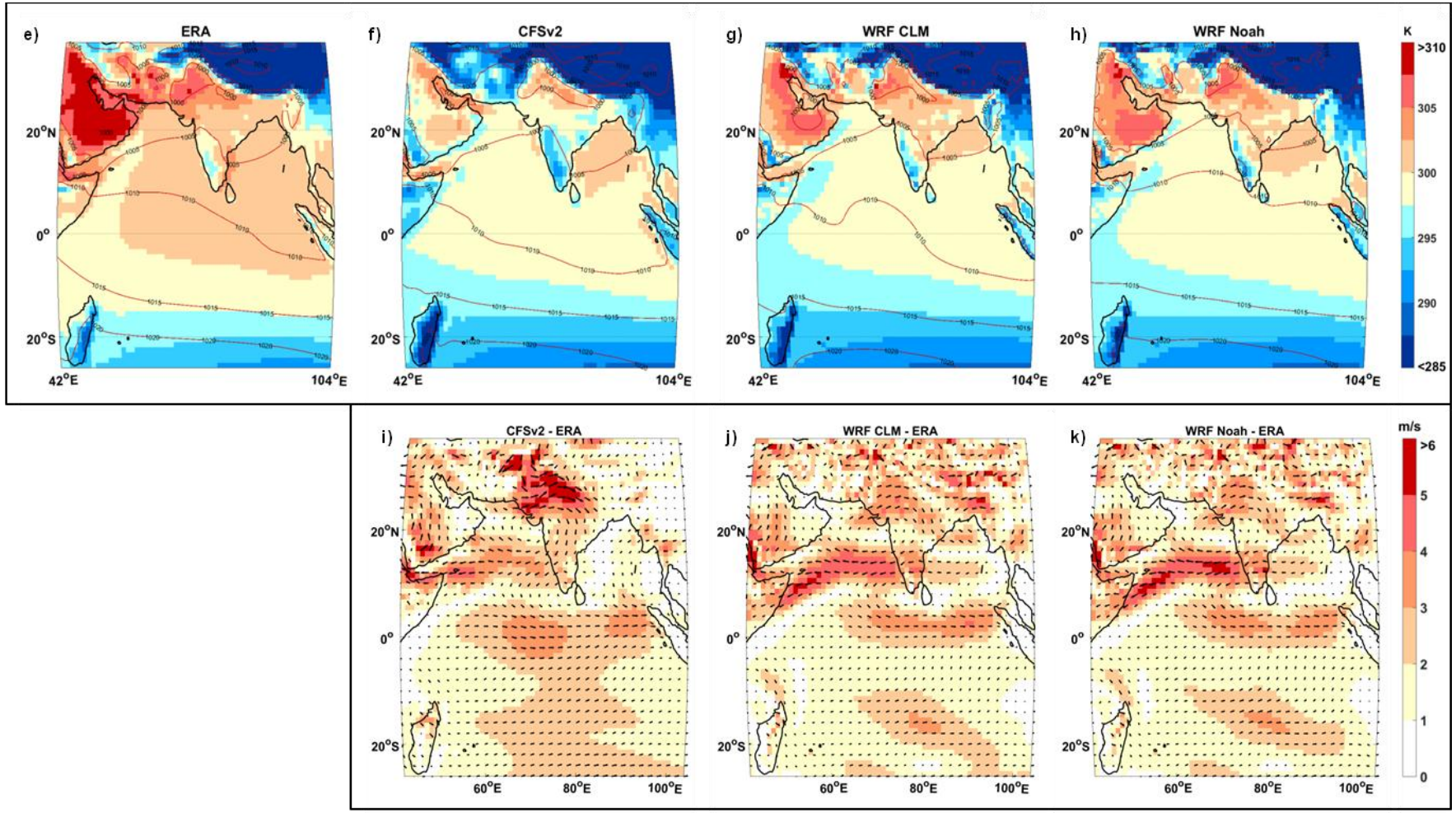
And its not a coincidence!!!!



Recycled Precipitation improved significantly as expected!!!

What about oceanic sources? Is it a MAGIC???

Its not magic!!! But a better representation of Himalayan Orography



Temperature 2m

Wind 850hPa

Key Message:

Better representation of land processes and physics guided data driven modelling improves the monsoon simulations

Acknowledgement:

All my students/ research group members who completed/ are working on one of the most challenging research topic of understanding monsoon hydroclimatology

Funding Agencies

Family

Thank you