

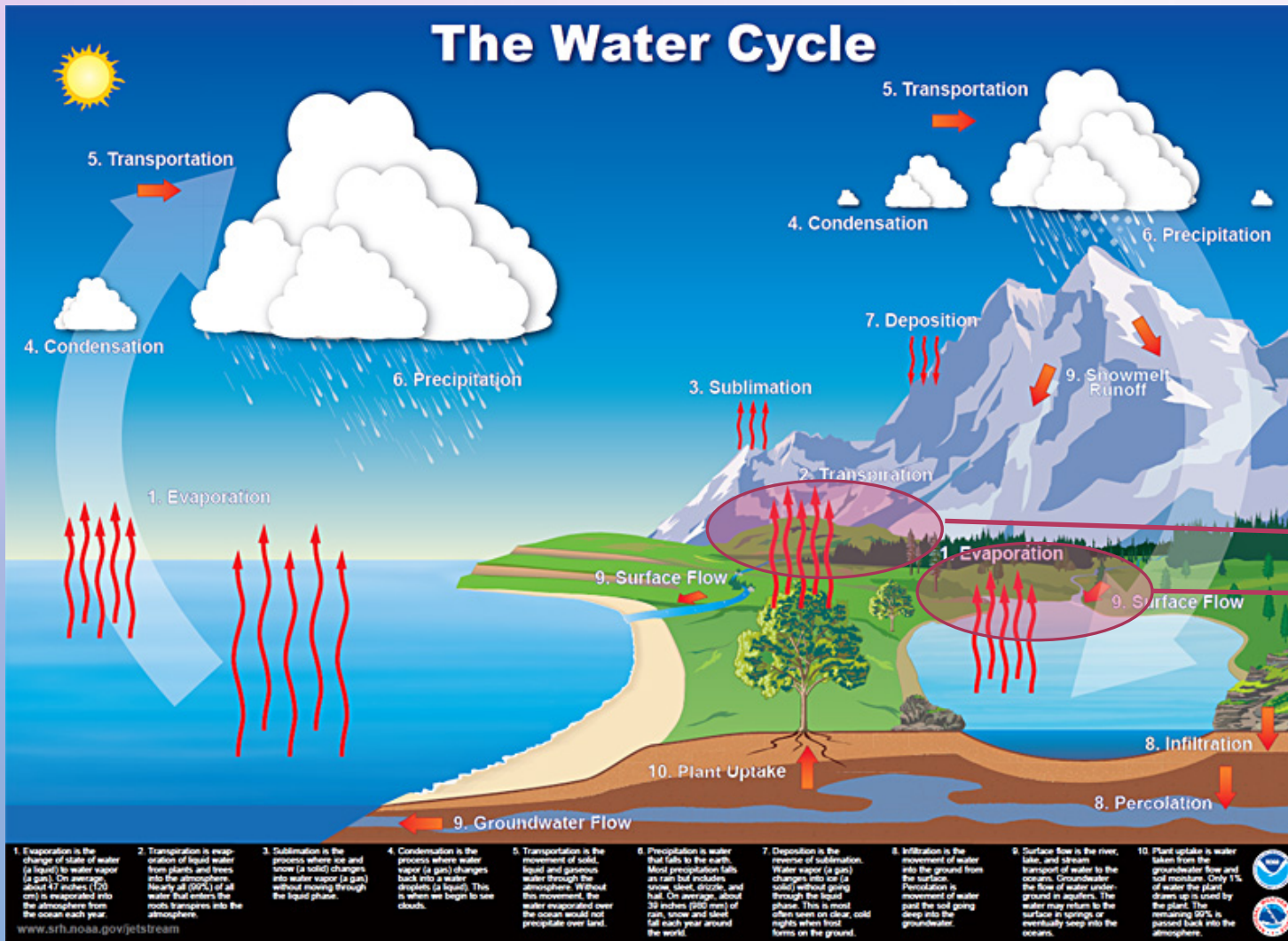
*Role of Oceanic and Land Moisture Sources
and Transport in the Seasonal and Inter-
Seasonal variability of Summer Monsoon in
India*



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Introduction



Monsoon: Traditionally believed to be governed by large scale moisture transport from ocean



- What are their contributions?
- Can we quantify them?

Quantifying Feedback: Moisture Tracking

Isotopic Analysis

Regional Climate Model

Numerical Water Vapor Tracer

Physics based Recycling models

Dynamic Recycling Model

Conservation of atm. Water vapor mass

$$[(\text{Change in atmospheric moisture storage}) + (\text{zonal moisture fraction}) + (\text{meridional moisture fraction})] = [(\text{evaporation}) - (\text{precipitation})]$$

$$\frac{\partial w}{\partial t} + \frac{\partial(wu)}{\partial x} + \frac{\partial(wv)}{\partial y} = E - P$$

The contribution of the locally evaporated water to the precipitation in the same region is known as **'Precipitation Recycling'**.

'Precipitation Recycling' is characterized by **Recycling Ratio**.

$$R(\chi, \xi, \tau) = 1 - \exp\left[-\int_0^\tau \frac{\varepsilon(\chi, \xi, \tau')}{\omega(\chi, \xi, \tau')} d\tau'\right]$$

Evapotranspiration

Time step

1

Local Recycling Ratio (R or ρ)

Precipitable water

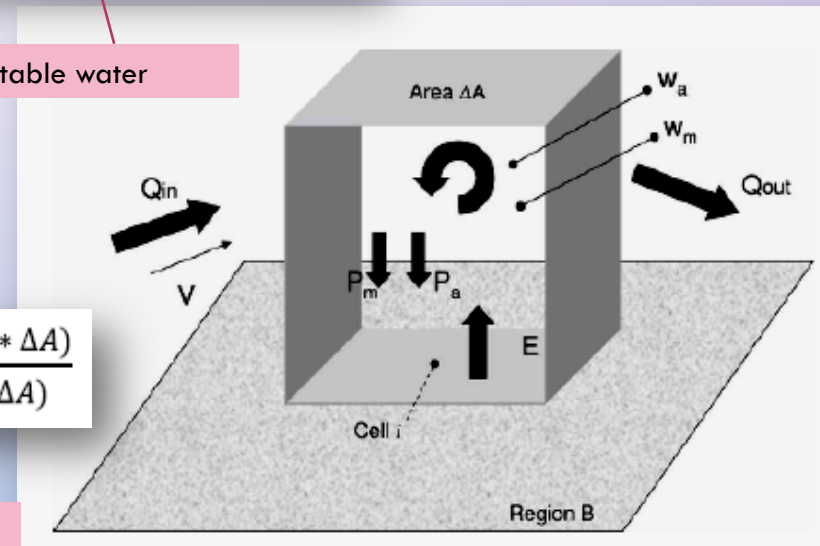
2

Regional Recycling Ratio

$$r = \frac{P_m}{P} = \frac{\sum_{i=1}^n (\rho_i * P_i * \Delta A)}{\sum_{i=1}^n (P_i * \Delta A)}$$

3

Recycled and Total Precipitation

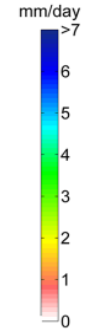
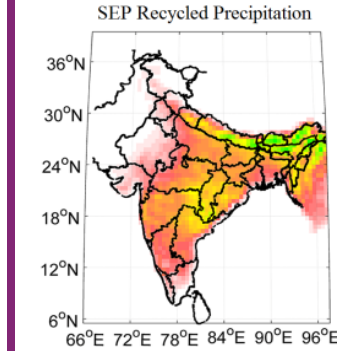
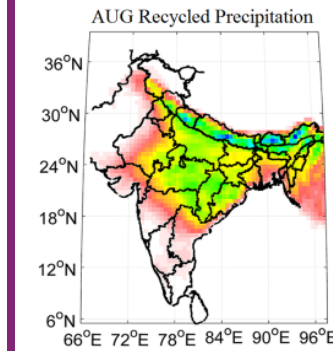
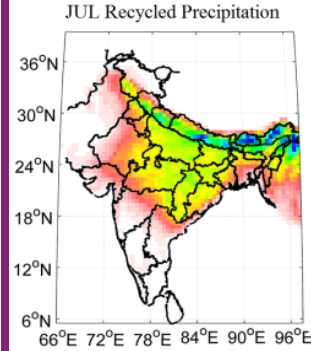
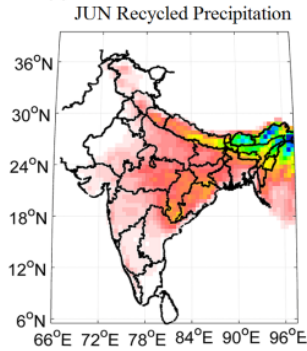


Schematic representation Precipitation Recycling

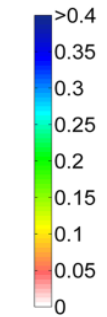
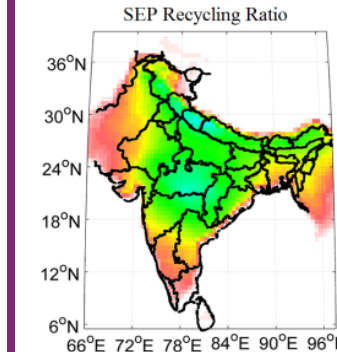
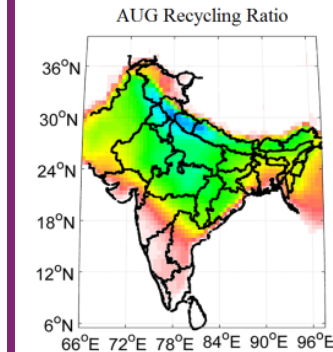
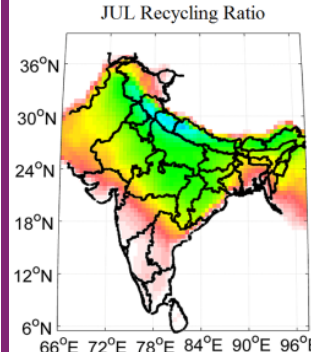
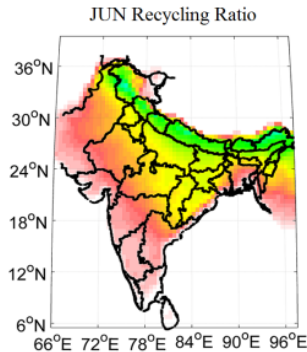
(Source: Dominguez, et al. 2006).

Recycling Ratio

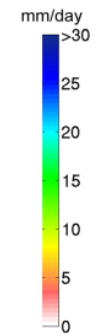
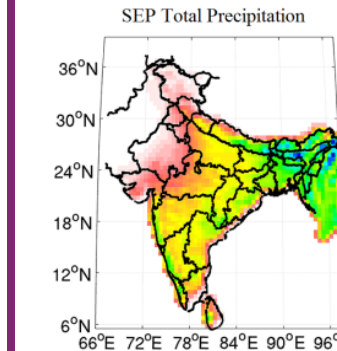
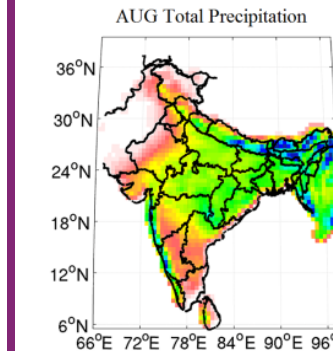
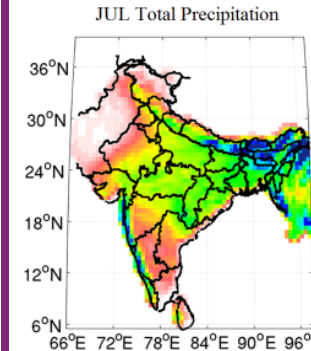
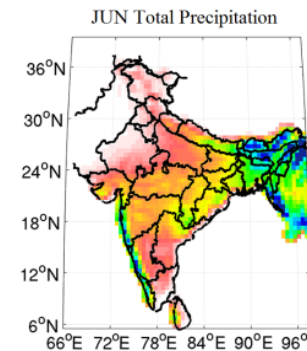
Recycled Precipitation



Recycling Ratio



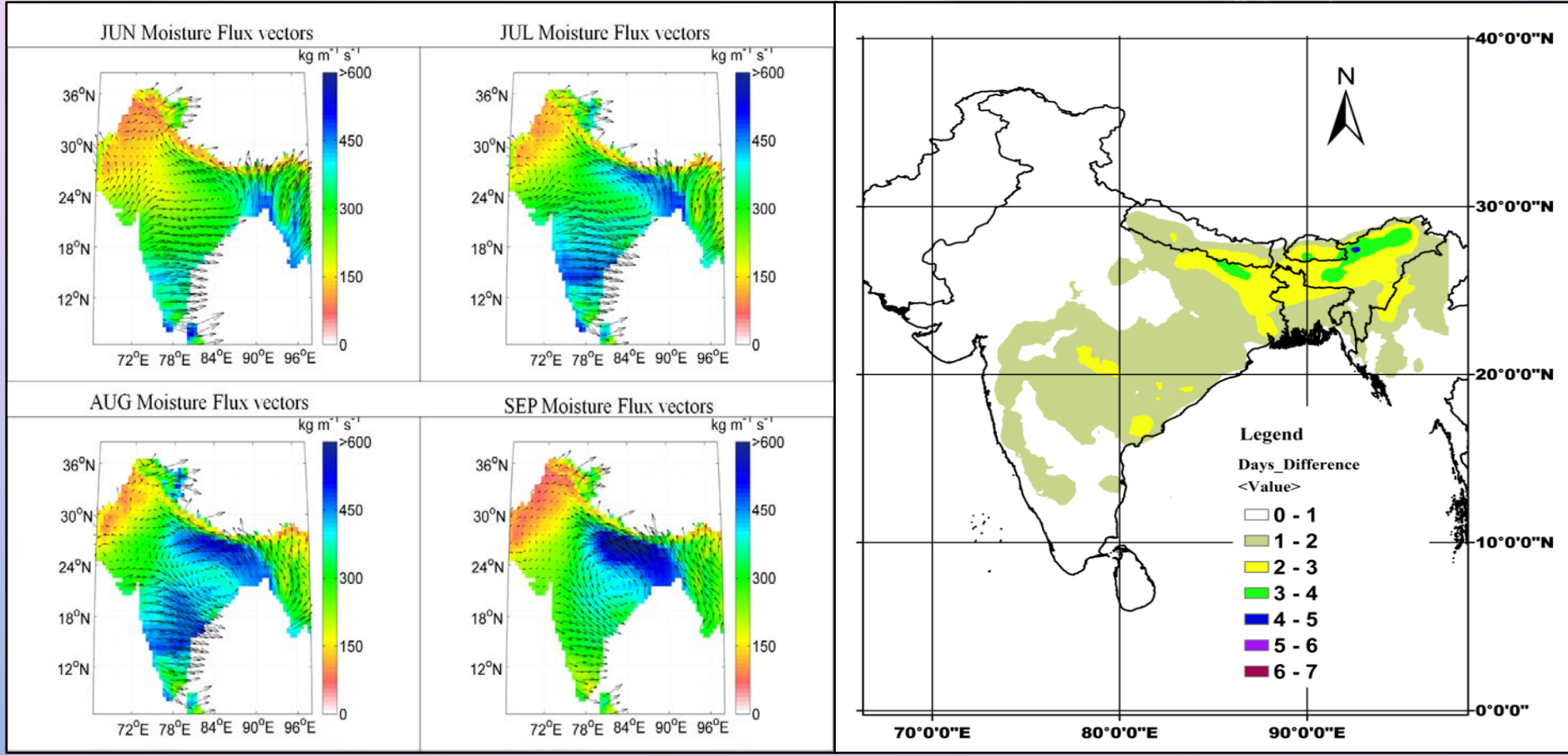
Total Precipitation



Pathak et al.,
(2015), JHM

Recycled precipitation, Recycling ratio, and Total Precipitation during JJAS by considering entire sub-continent as one zone.

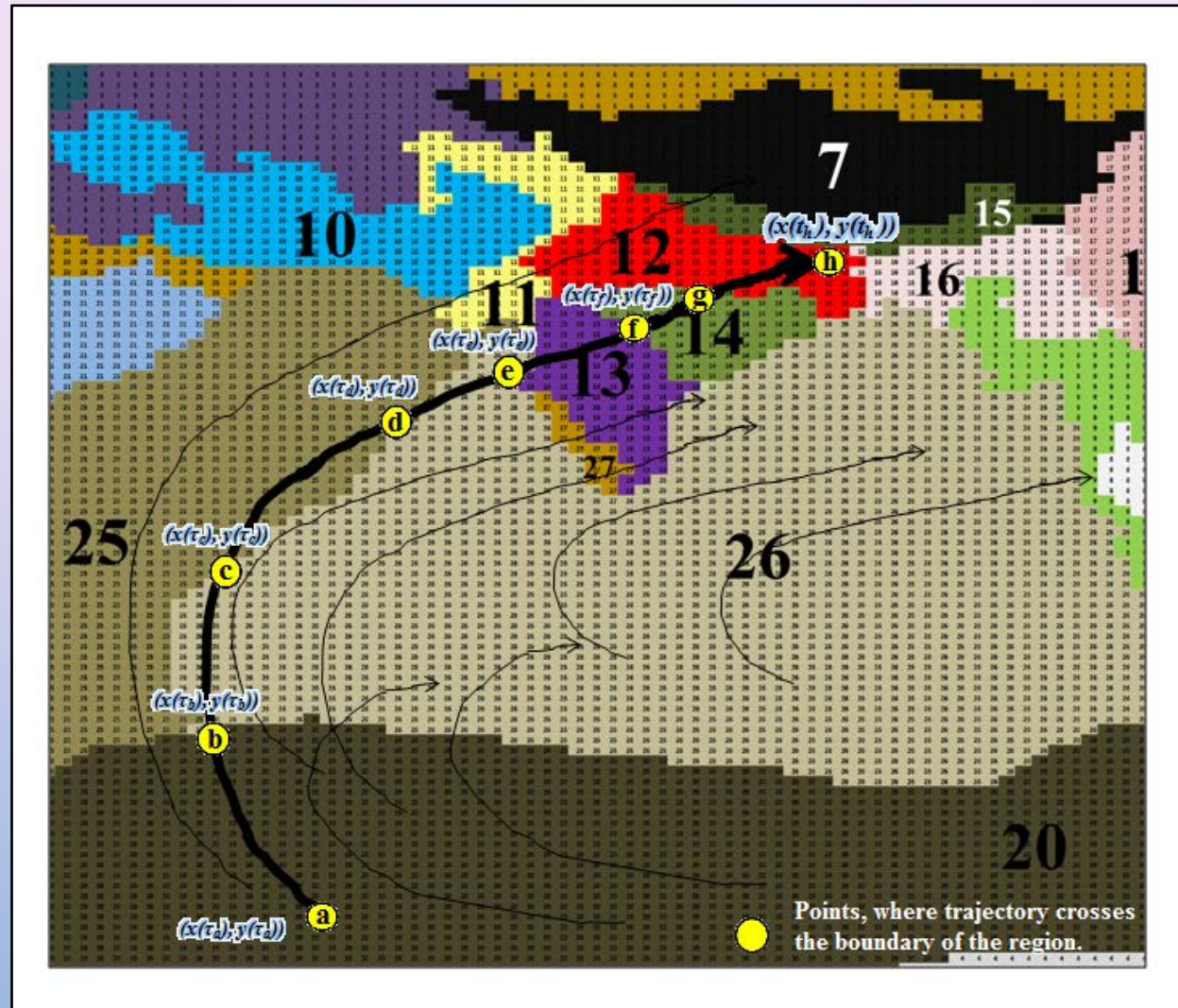
Precipitation Recycling and monsoon withdrawal



Moisture flux vectors during JJAS, over Indian sub-continent. Local moisture contributes significantly to the precipitation over central and north-eastern India.

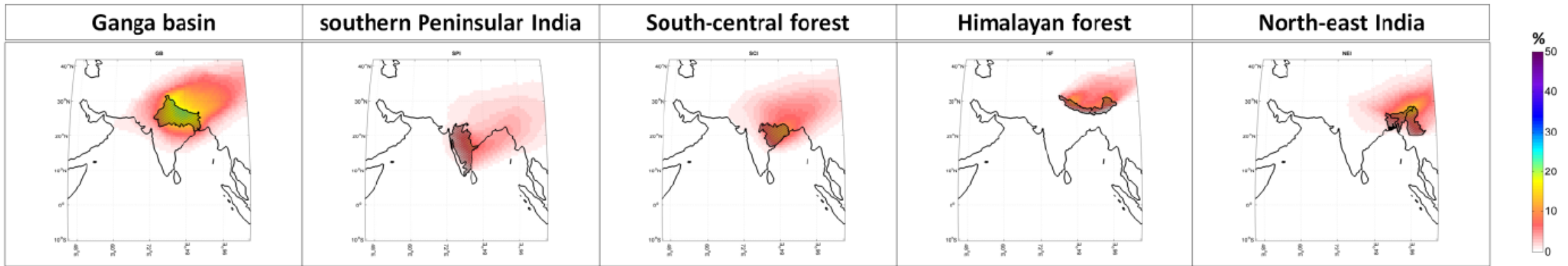
Difference in monsoon withdrawal (Total- Advective)

Understanding Different Land and Oceanic Sources

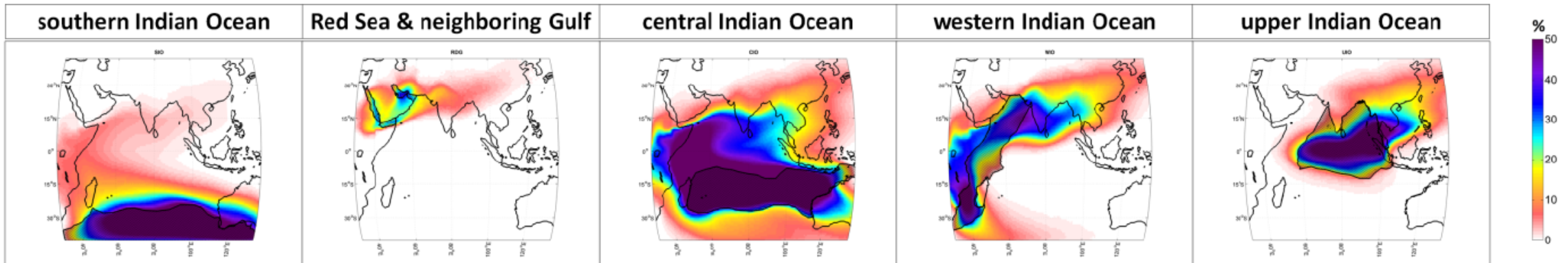



Contributions from Different Sources

(a) Contributions from the land sources (%)

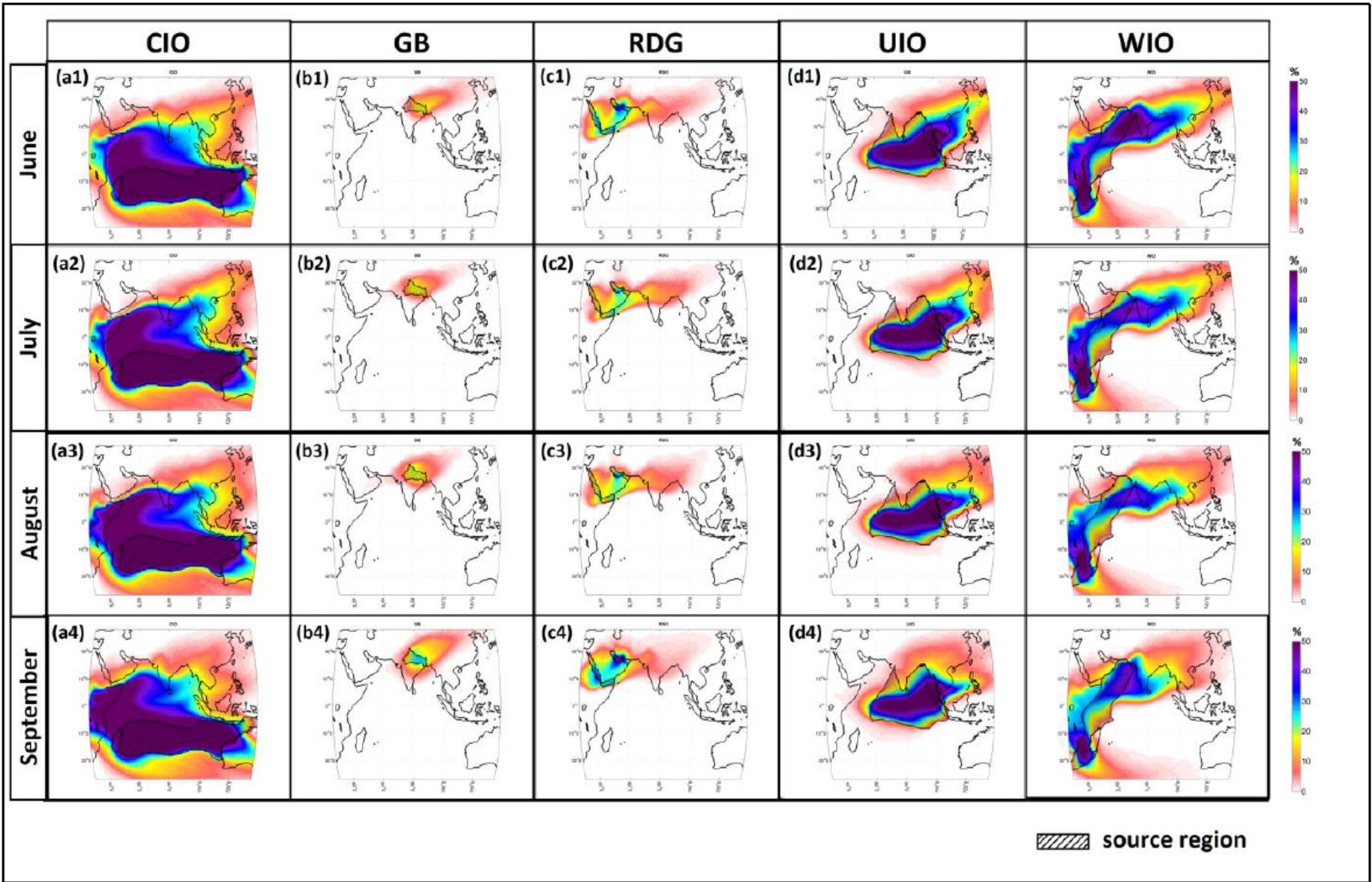


(b) Contributions from the oceanic sources (%)

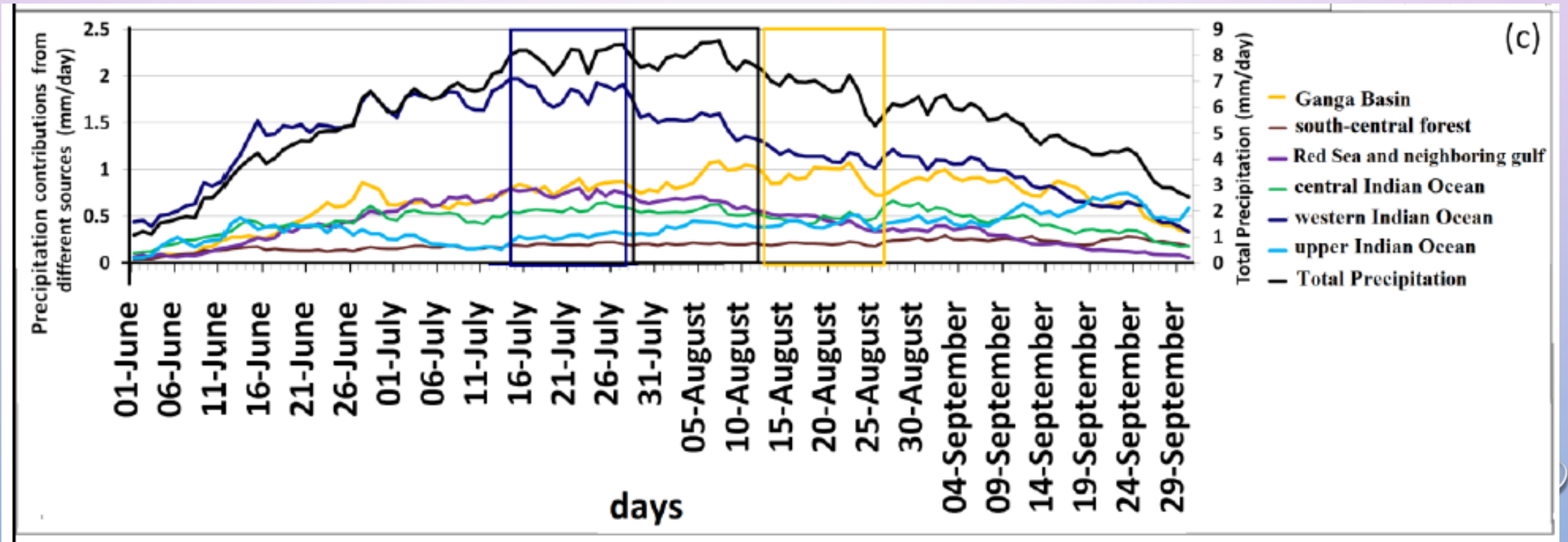


 source region

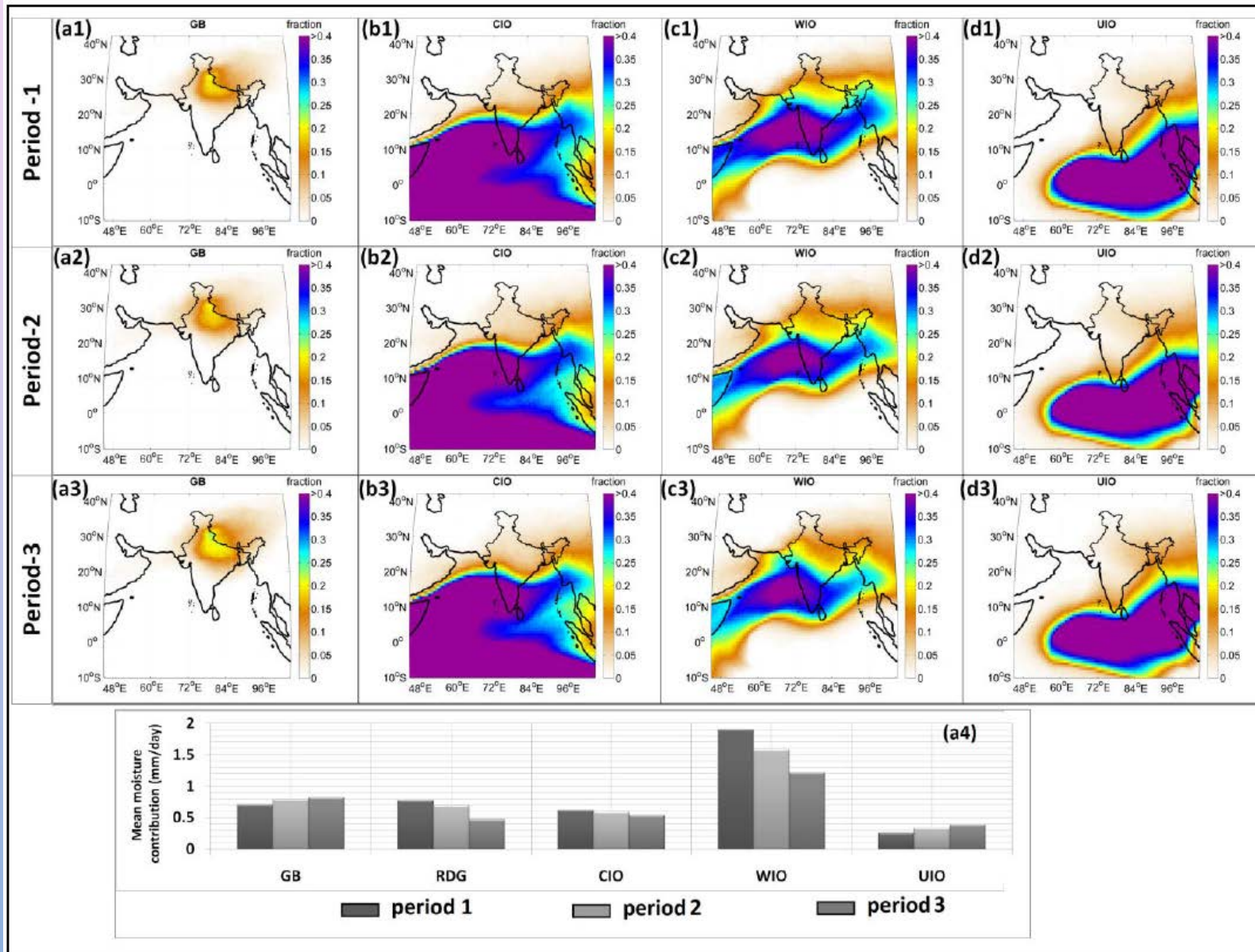
Climatology of Contributions



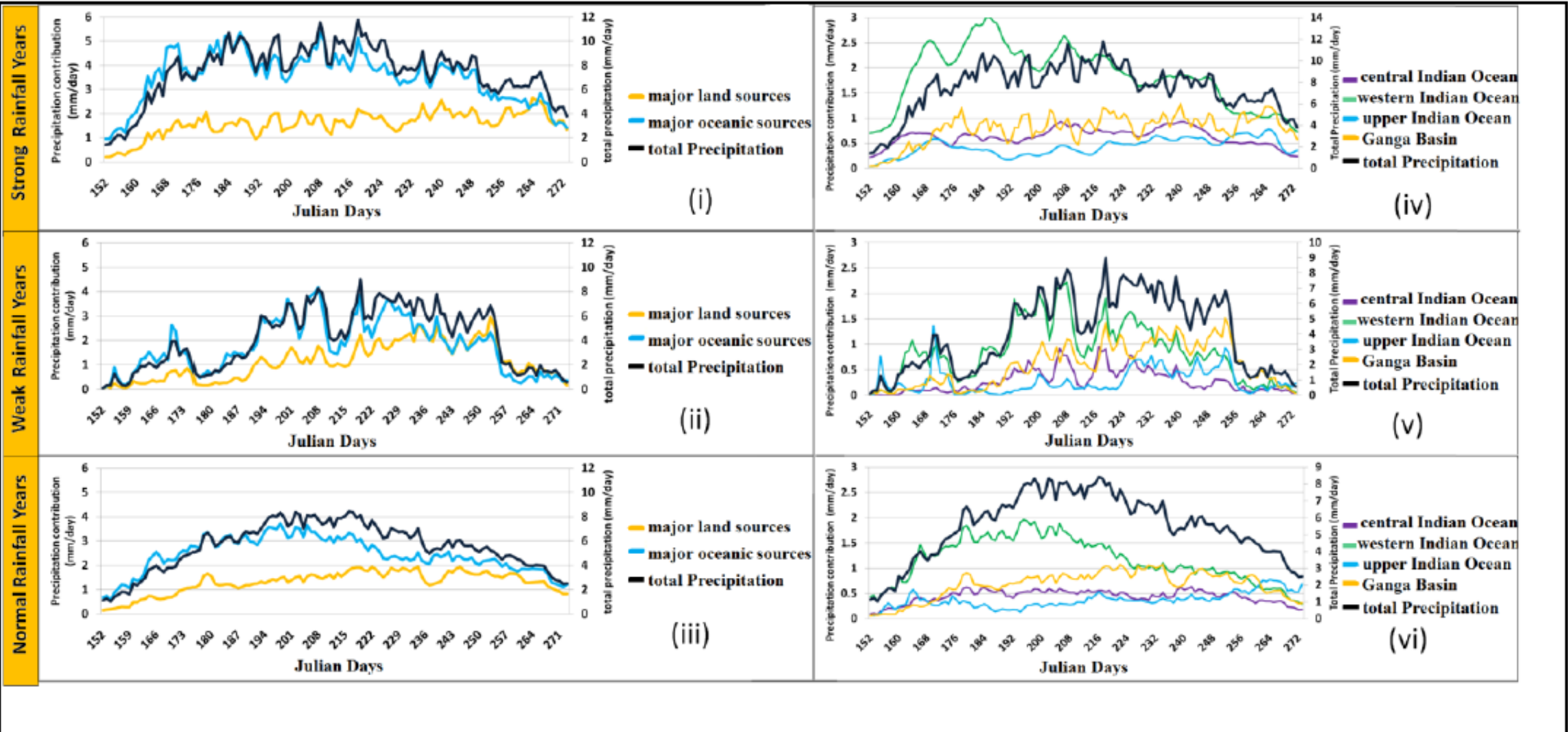
Climatology (For Core Monsoon Zone)



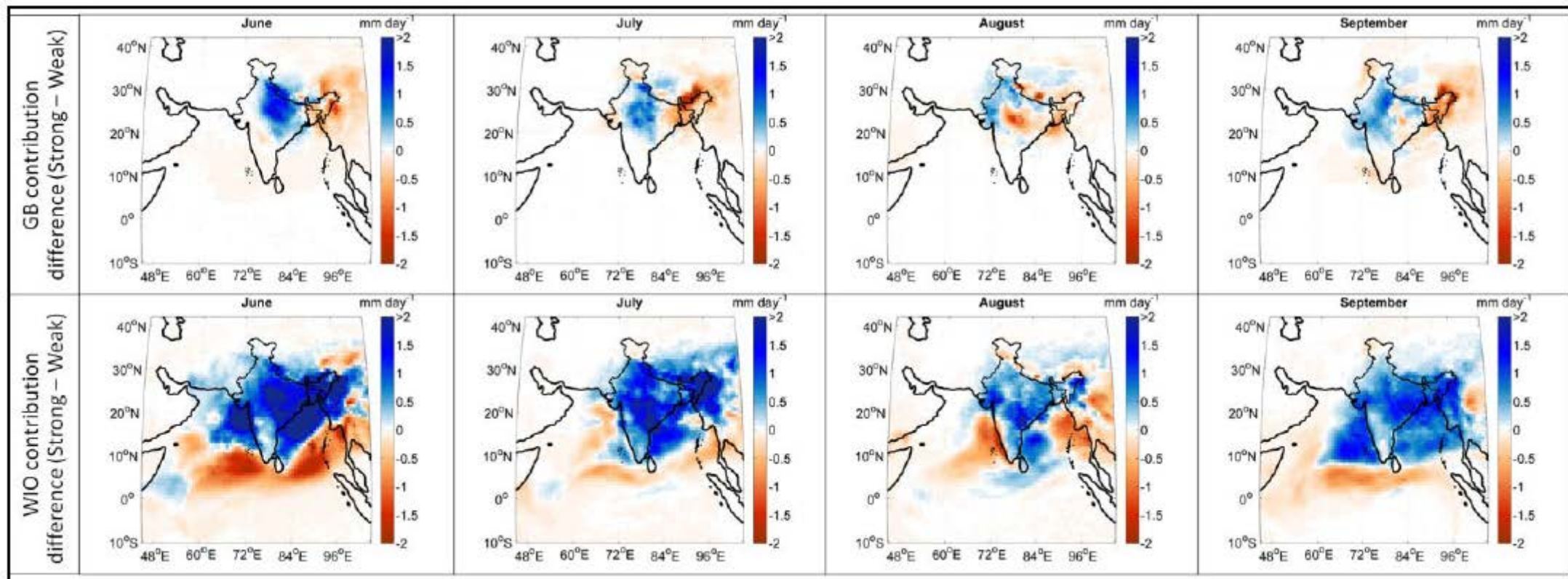
Contributions During Different Peaks



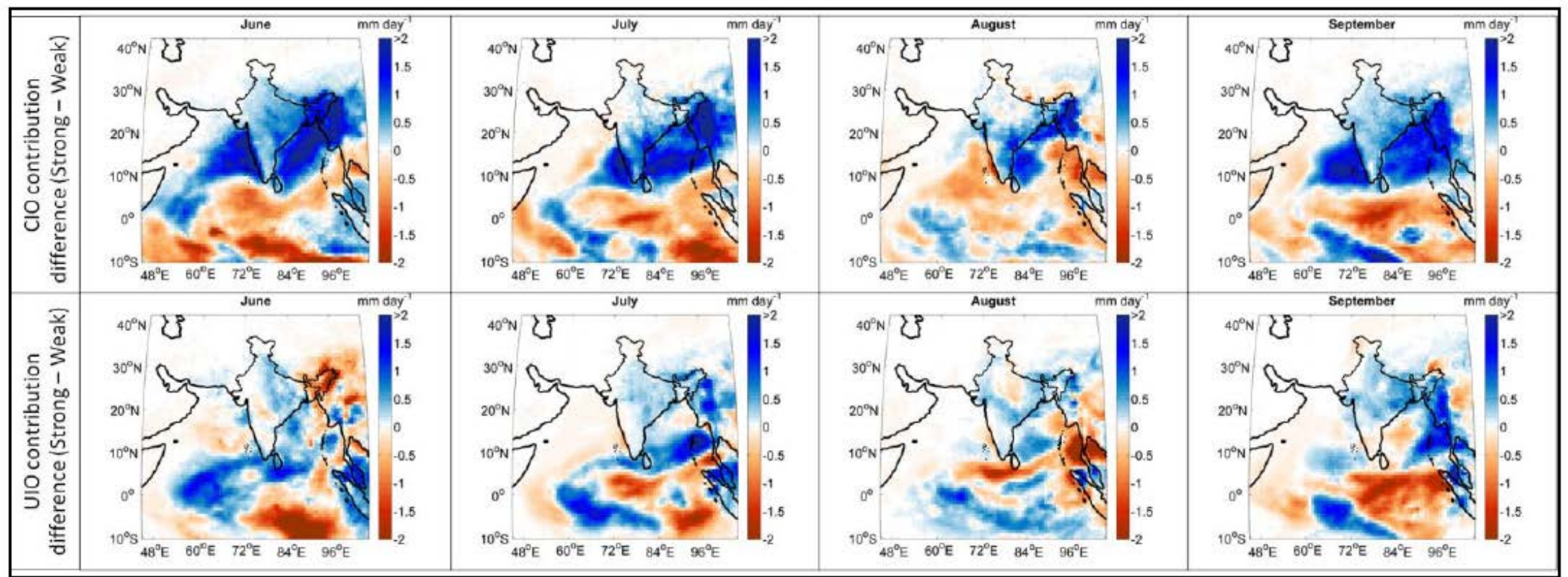
Inter-annual Variability



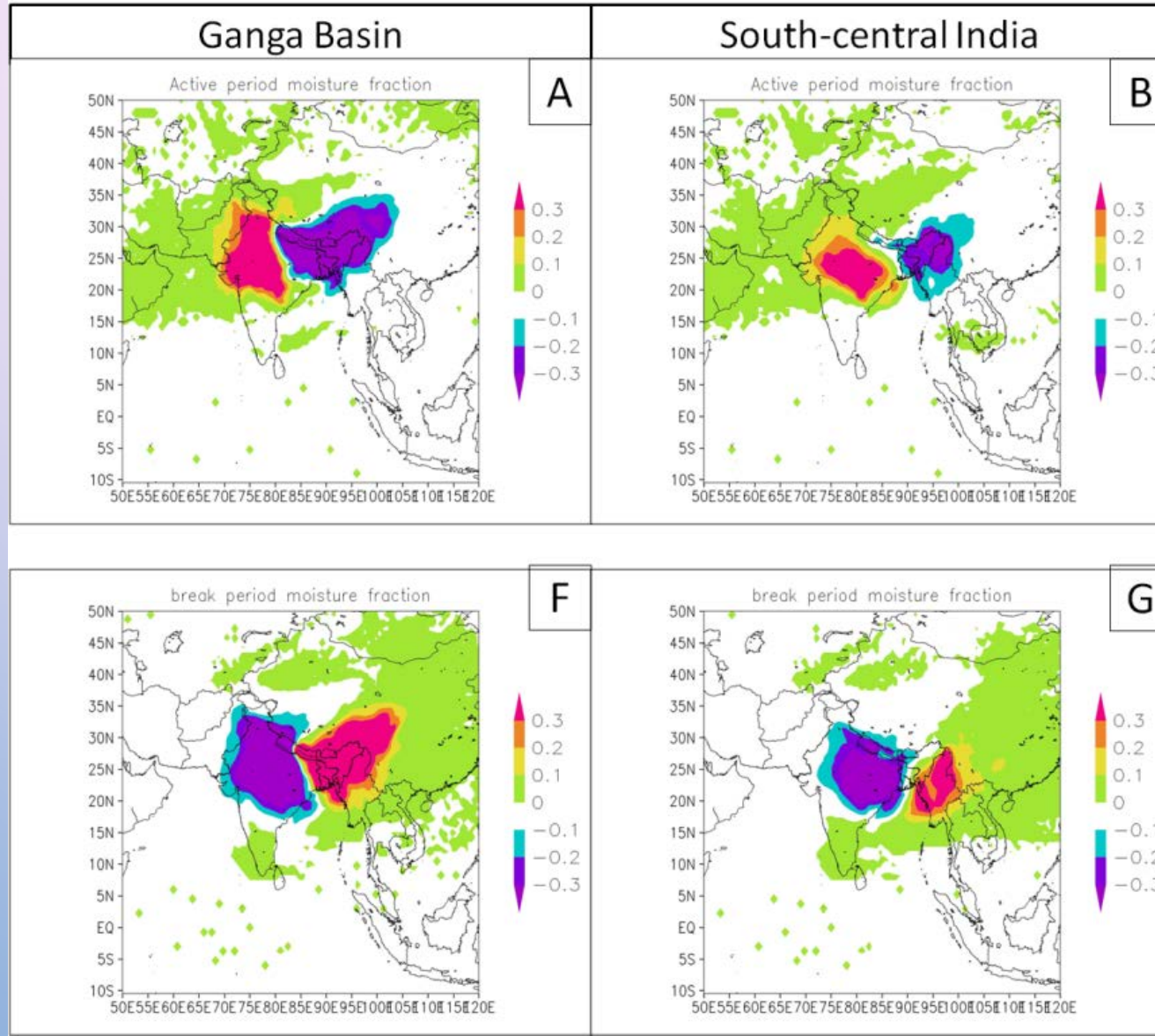
Inter-annual Variability



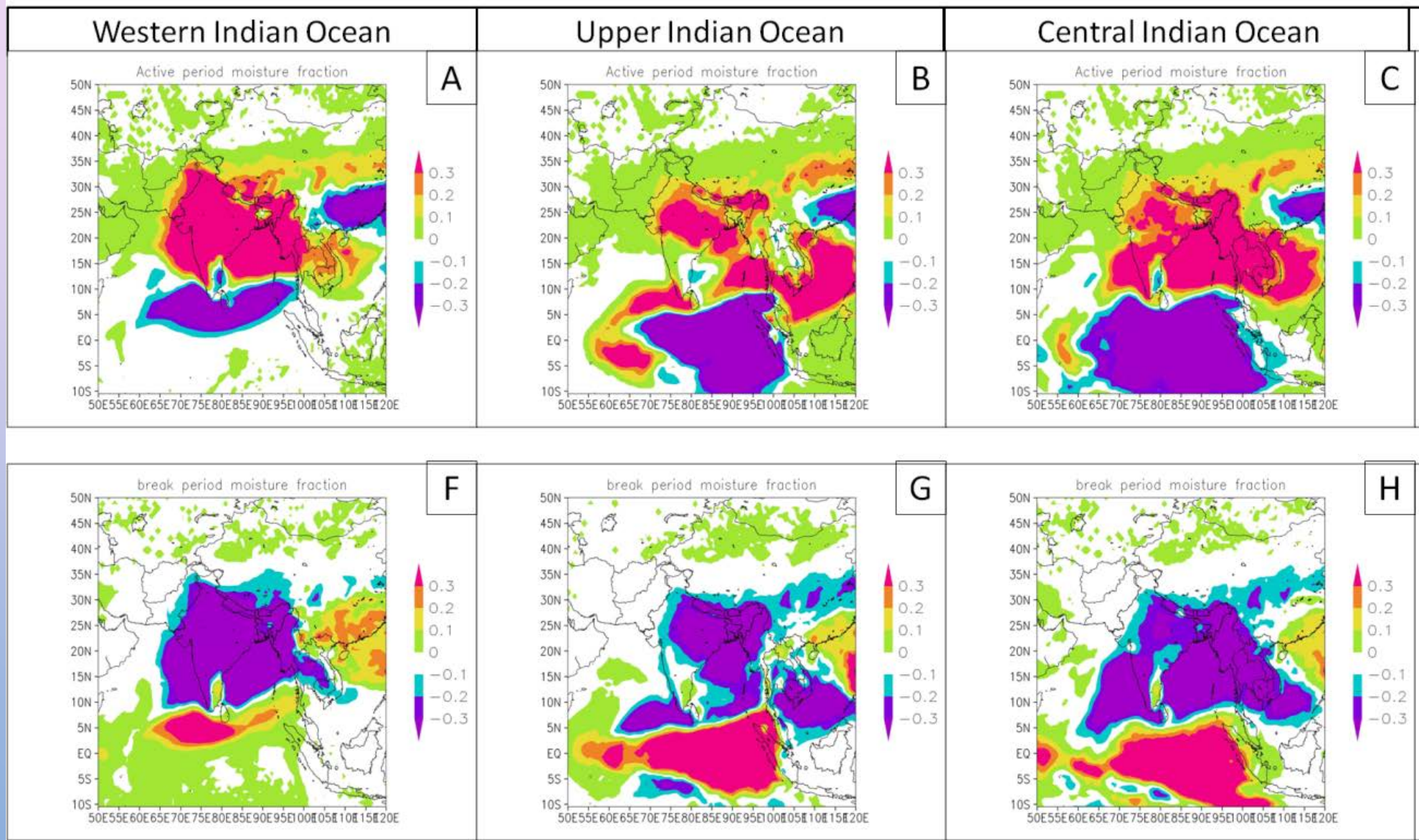
Link To Intra-seasonal Variations



Intra-seasonal Variations (For Land Sources)



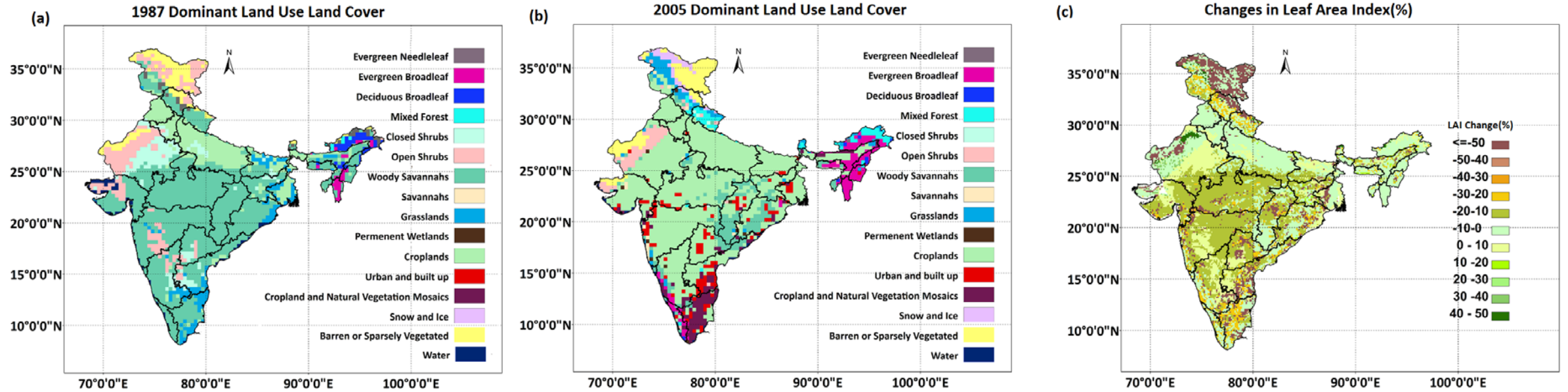
Intra-seasonal Variations (For Oceanic Sources)



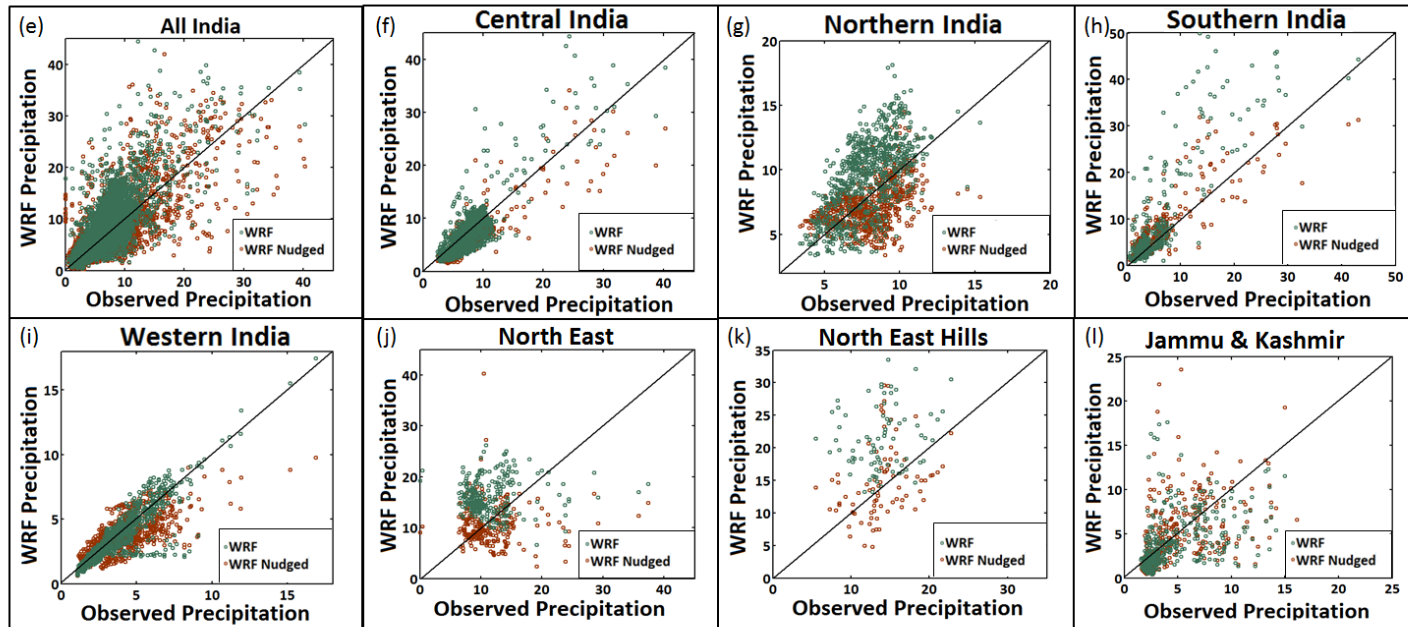
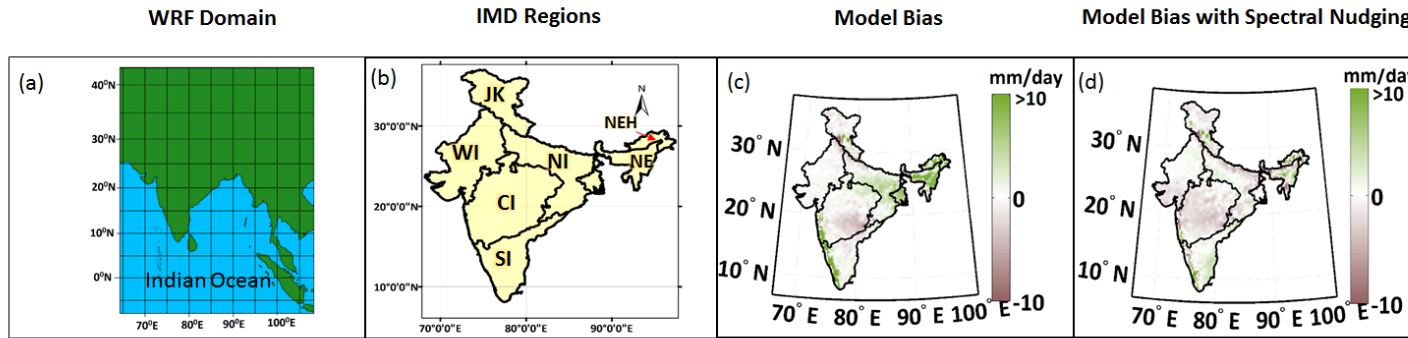


Role of recent LULC changes

LULC Changes in India

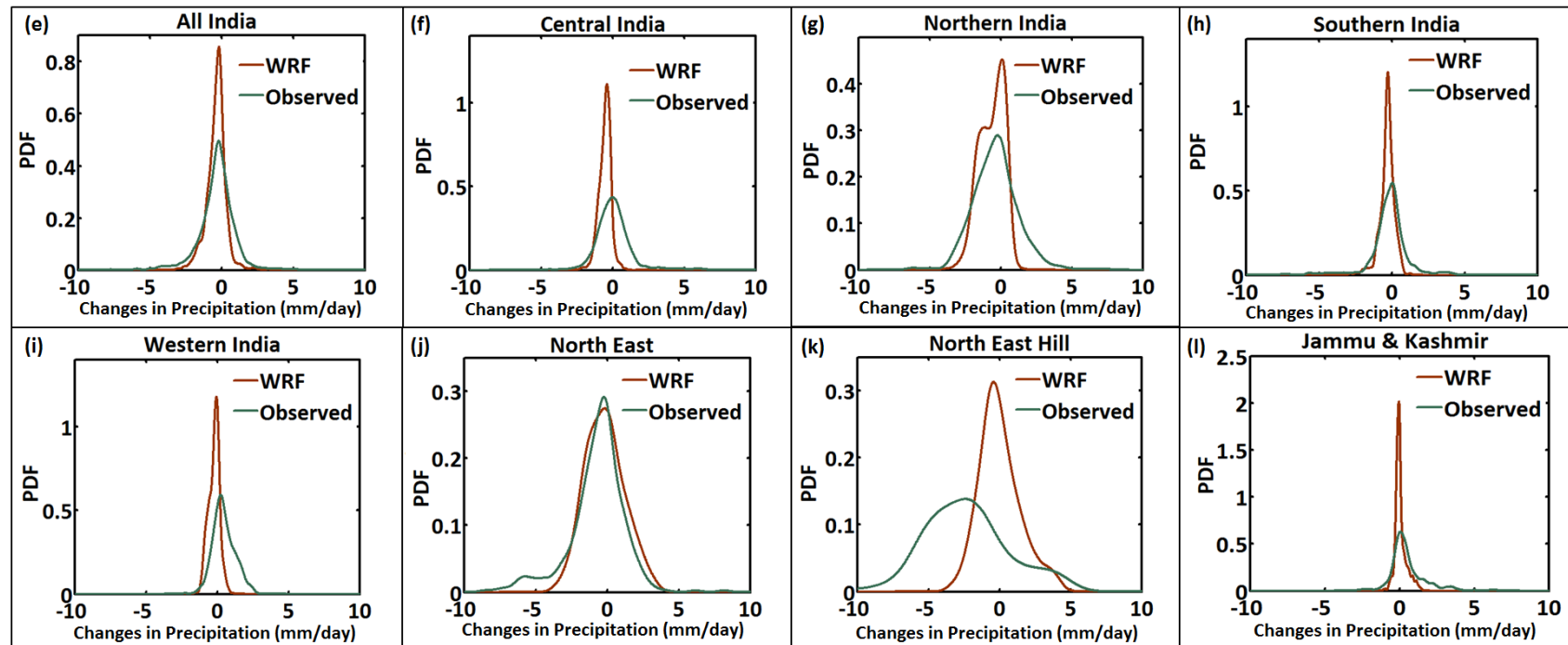
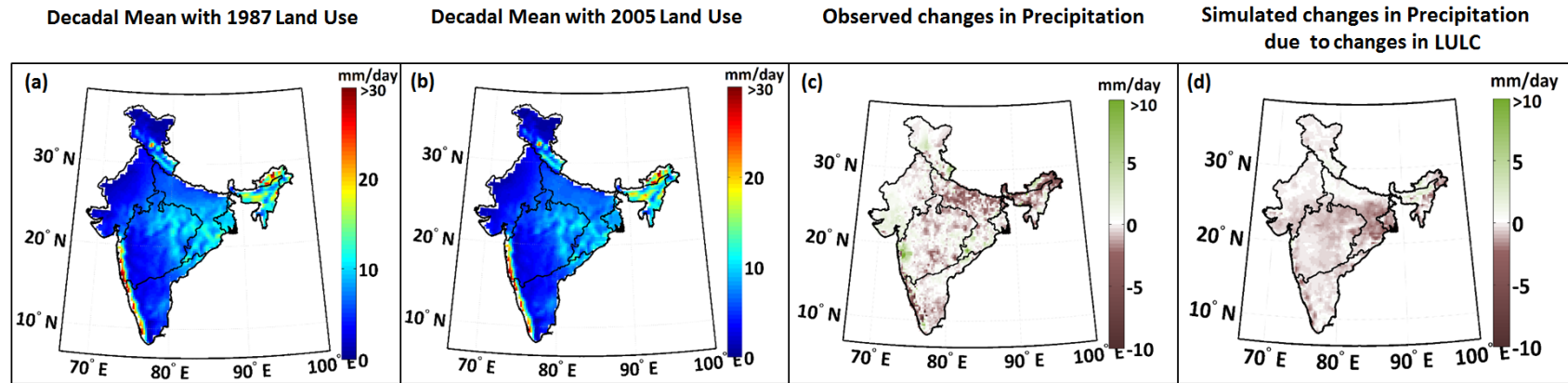


WRF Simulations: Evaluation



Physics	Schemes used for this study
Cloud Micro physics	WSM 5-class scheme ^{S2}
Sub grid scale cloud	Kain-Fritsch (new Eta) scheme ^{S3}
Planetary Boundary-layer(PBL)	YSU scheme ^{S4}
Long wave radiation	rrtm scheme ^{S5}
Short wave radiation	Dudhia scheme ^{S6}
Surface-layer physics	Revised MM5 Monin-Obukhov scheme ^{S7-S10}
Land-surface physics	Community Land surface model ^{S12}

Impacts of LULC: Changes Partially Consistent with Observed Changes





Thank You