Can Soil Moisture Anomalies Trigger Extreme Precipitation Events over India?

Ashish Manoj J[1], Ravi Guntu[1], and Ankit Agarwal[1]

[1]Indian Institute of Technology Roorkee

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Abstract

One of the unresolved and debated topics in climatic and atmospheric sciences is whether soil moisture (SM) anomalies can trigger extreme precipitation (P) events? Researchers have used coupled atmospheric model experiments, models based on simple water budget equations, and water vapour tracing studies; however, a consensus is lacking. Some studies reported that the excess SM anomalies trigger subsequent P; a few also postulate about a negative feedback loop. In the present study, we used a novel Event Coincidence Analysis to investigate this trigger relationship between SM and P. Using SM and P data from 2004-2020, we identified hotspots of SM-P coupling over India. A statistical significance test ($\alpha = 0.10$) was carried out to ensure that the observed coincidences are not by chance. On increasing, the temporal window from one day to three-day the extent and severity of the hotspots increased significantly. The highest values of trigger coincidence rates are observed over central India (>70%). Our observed results agree with the widely regarded hypothesis of stronger SM-P coupling in transitional regions between wet and dry climates. The results obtained in our work has vast potential for atmospheric forecast purposes, including flood early warning systems for India.

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Ashish Manoj J*

Ravi Kumar Guntu

Ankit Agarwal

Department of Hydrology

IIT Roorkee, India

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AGU FALL MEETING

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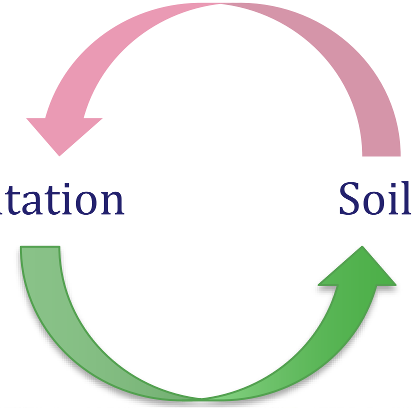
Motivation



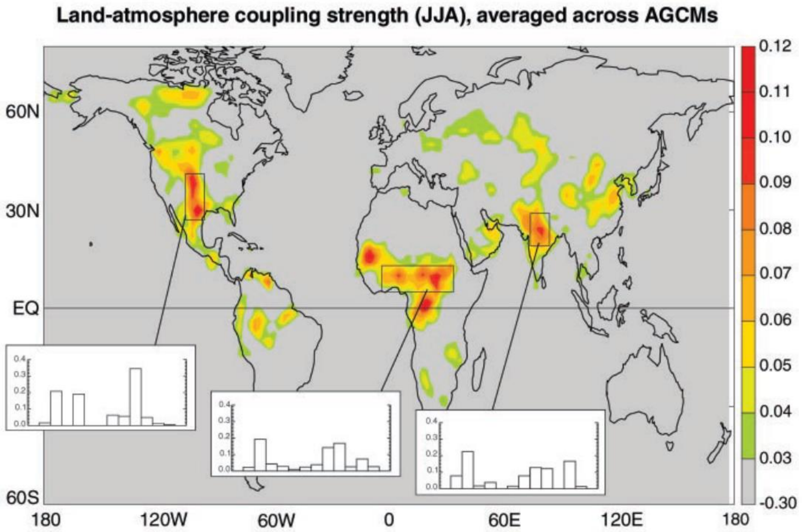


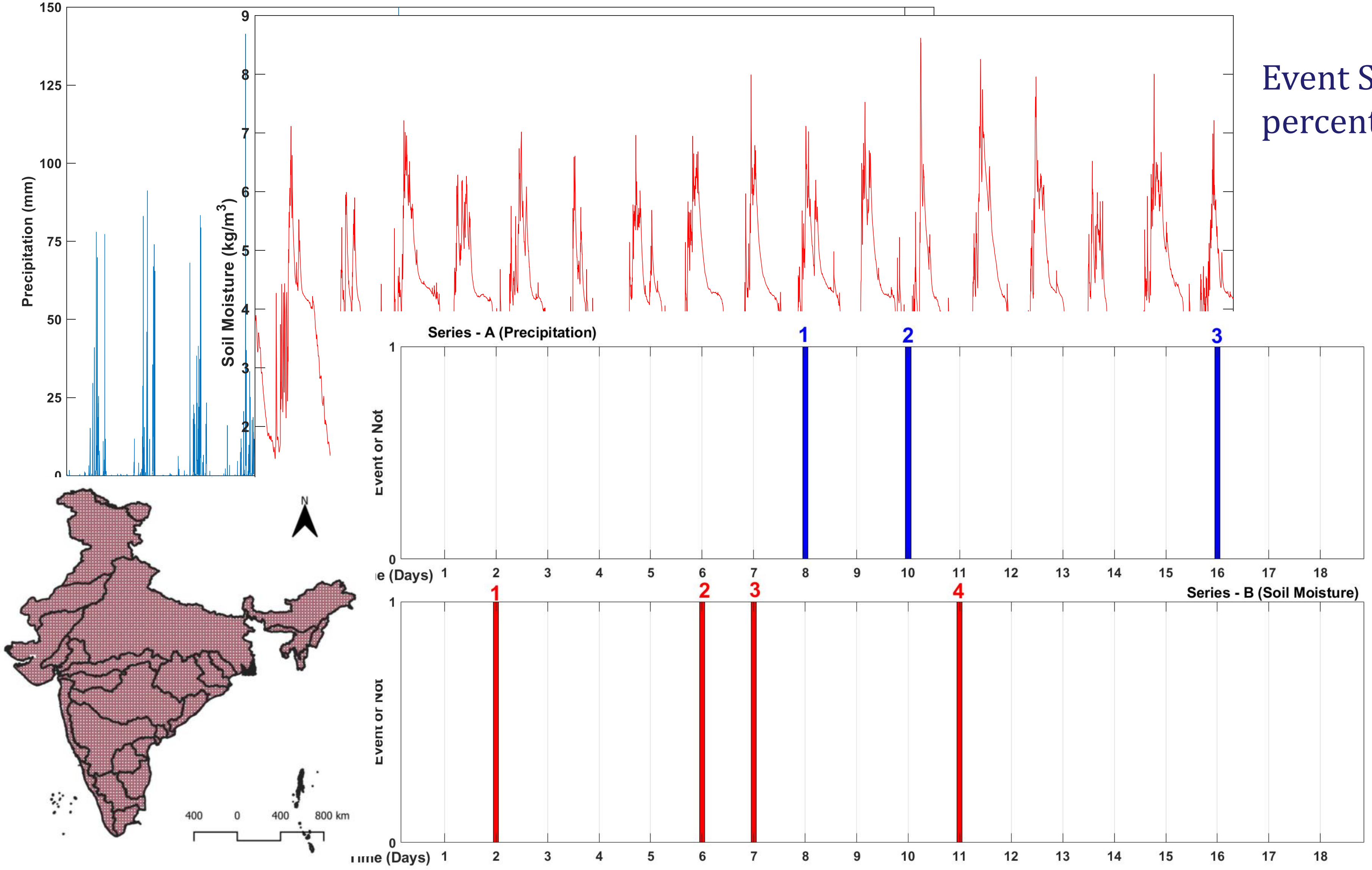
Image from Koster *et al.*, 2004

- SM – P coupling studies – yet unresolved problem
- Modelling studies, moisture recycling and water vapour tagging
- Indirect interaction should also be considered[2,3]
- Positive feedback / negative feedback
- Difficulties in establishing causal relationship
- Need for data driven exploratory tools

1) Koster et al., 2004
2) Seneviratne et al., 2010
3) Brimelow et al. 2011

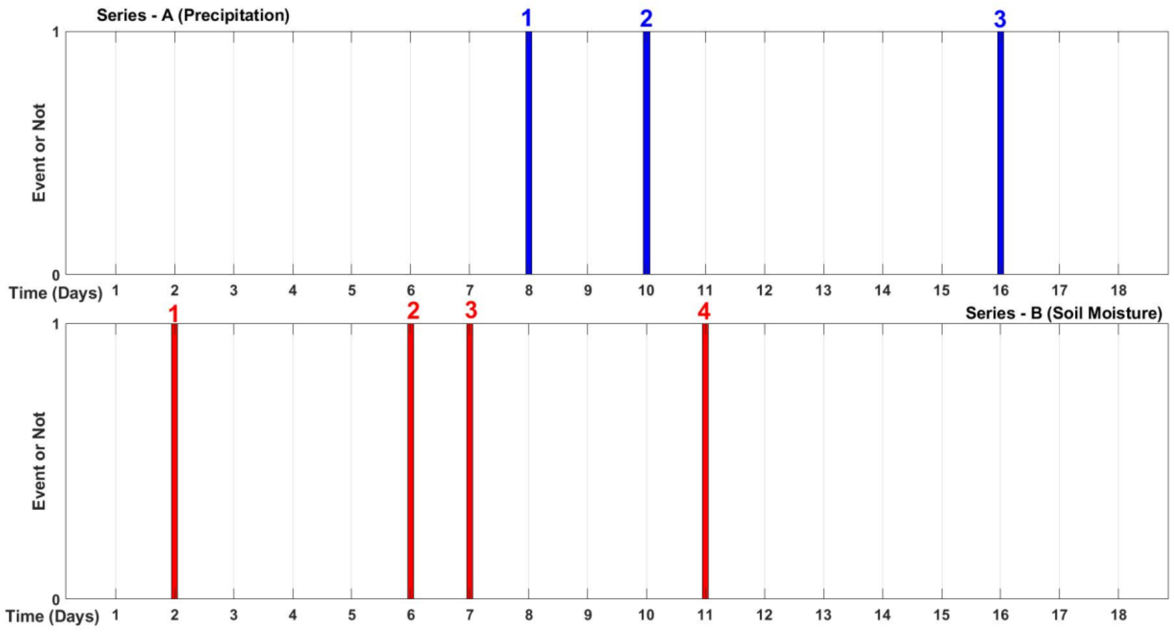
Photos by James Frid, Nothing Ahead, Flash Dantz from Pexels

Methodology



Event Series is extracted by using percentile cut-offs (90th Percentile)

Methods - ECA



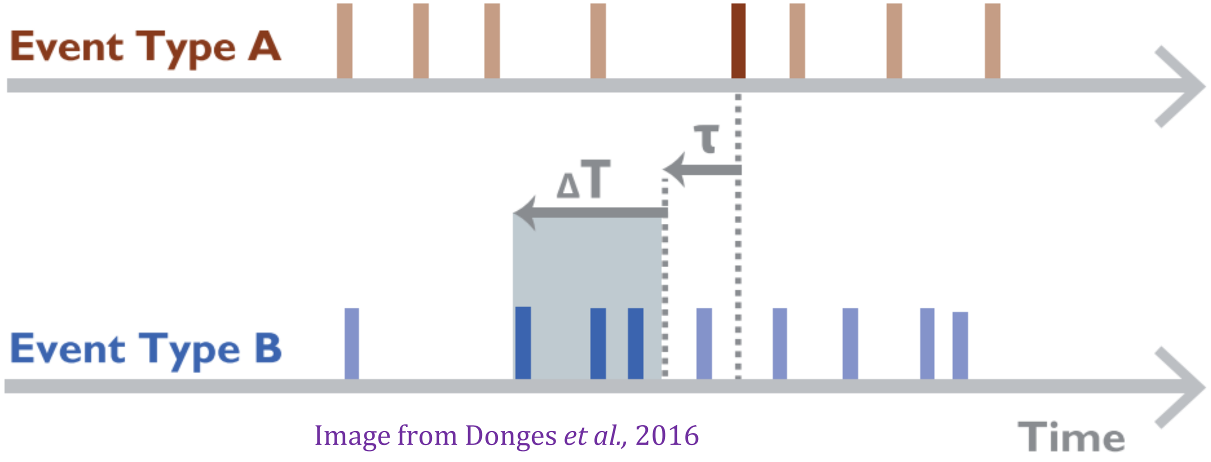


Image from Donges *et al.,* 2016

$$I_{[0,\Delta T]}(x) = \begin{cases} 1, & x \in [0, \Delta T] \\ 0, & else \end{cases}$$

$$Precursor\ coincidence\ rates, r_p(\Delta T, \tau) = \frac{1}{N_A} \sum_{i=1}^{N_A} H\left(\sum_{j=1}^{N_B} I_{[0,\Delta T]}\left(t_i^A - \tau\right) - t_j^B \right)$$

$$H(x) = \begin{cases} 1, & x \geq 1 \\ 0, & else \end{cases}$$

$$Trigger\ coincidence\ rates, r_t(\Delta T, \tau) = \frac{1}{N_B} \sum_{j=1}^{N_B} H\left(\sum_{i=1}^{N_A} I_{[0,\Delta T]}\left(t_i^A - \tau\right) - t_j^B \right)$$

Significance test (α = 0.10) to ensure that observed coincidences are not due to randomness

Reference: Donges *et al.,* 2011, 2016, Siegmund *et al.*, 2017 and Sun *et al.* 2018

Data

Soil Moisture

- NASA's Global Land Data Assimilation System
- 0.25° × 0.25°
- GLDAS – CLSM 2.2

Li *et al.,* 2019, Rui *et al.*, 2020

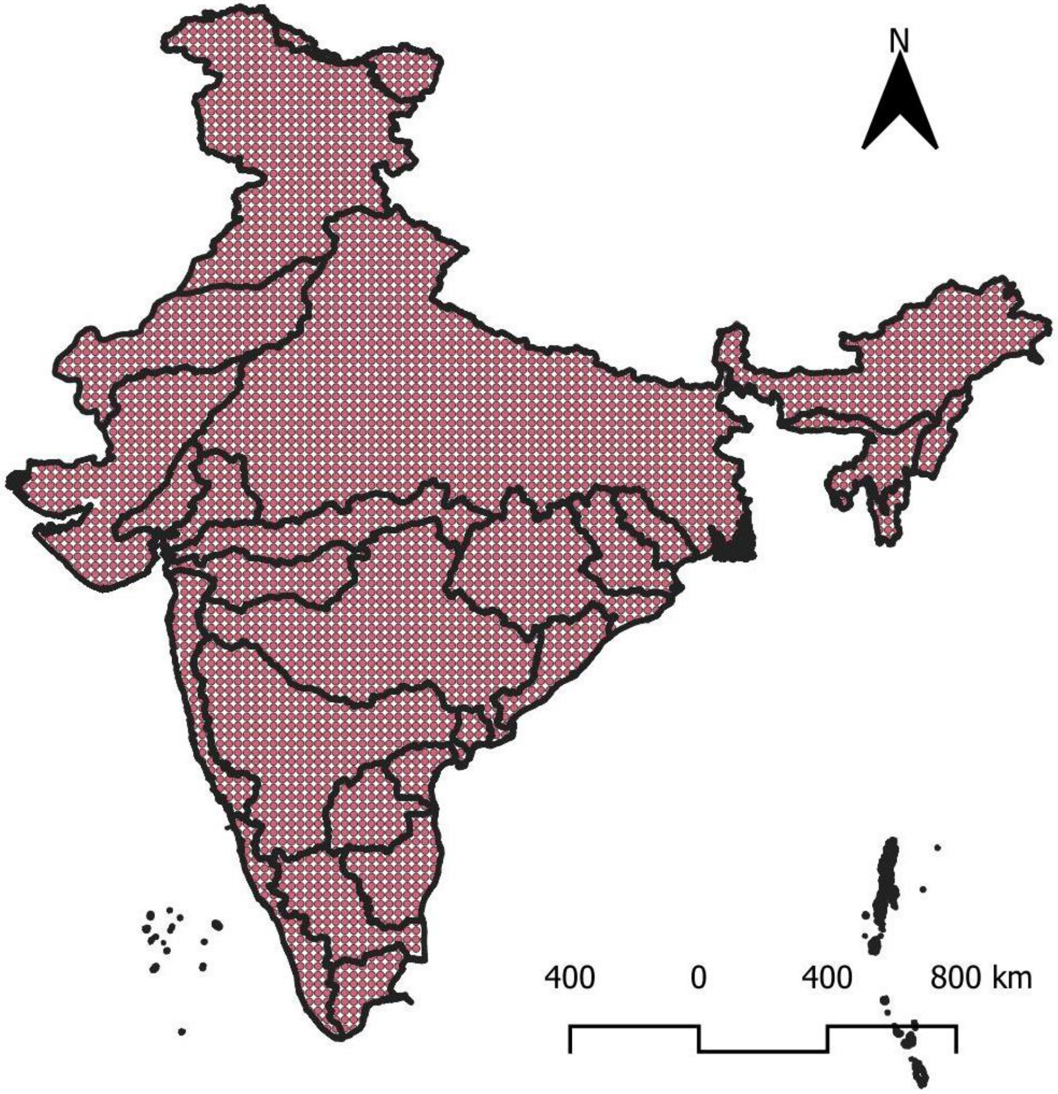
https://doi.org/10.5067/TXBMLX370XX8

Precipitation

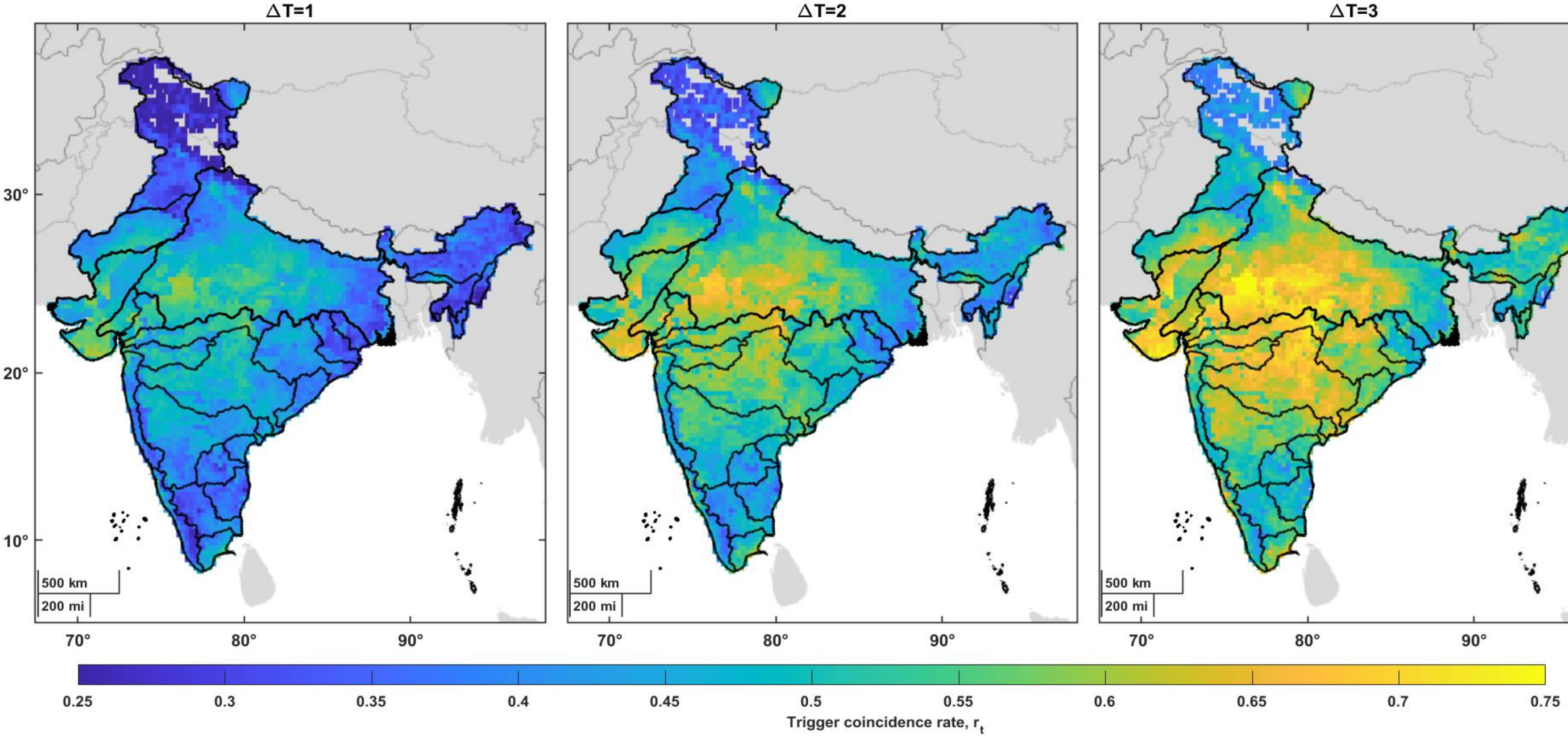
- GPM – Global Precipitation Mission
- 0.1° × 0.1°
- IMERG – Version 06

Huffman *et al.*, 2020

https://doi.org/10.5067/GPM/IMERGDF/DAY/06

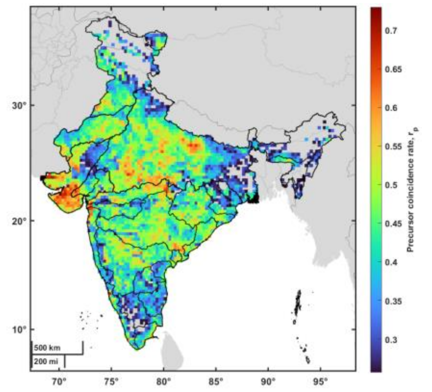


Results

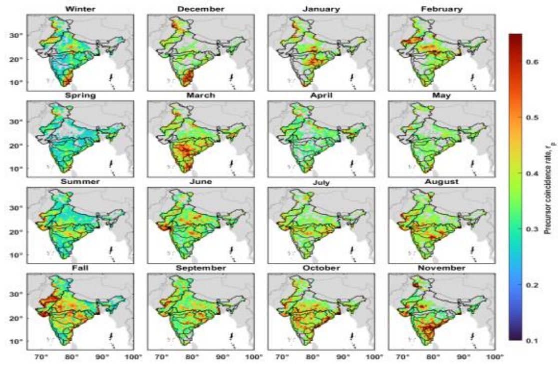


ΔT=1
ΔT=2
ΔT=3
30°
20°
10°
70°
80°
90°
500 km
200 mi
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
Trigger coincidence rate, r_t

TAKE HOME MESSAGE



- ECA used to disentangle SM-P coupling over India
- Trigger hotspots bear similarity to continental hotspots – Koster et al. 2004
- Tendency of the hotspots to concentrate over the middle of Central India
- Results support the hypothesis of increased coupling in transitional regions
- Early warning systems can be modelled to consider such coupling phenomenon
- May prove helpful in flood forecast purposes.



THANK YOU

Ashish Manoj J

Master Student – IIT Roorkee, India

ashishmanoj@outlook.com

https://hydroclimx.com

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