Mapping Compound Hazard Potential of Tropical Cyclone & Anomalous Heat in Eastern Coast of India

Dr. Poulomi Ganguli[1] and Ning Lin[2]

[1]Indian Institute of Technology Kharagpur, India

[2]Princeton University, USA

The work presented here is the part of Fulbright-Kalam Climate Fellowship of the first author at Princeton University, NJ.

Global Coastlines are Vulnerable to 'Warm-Dry' and 'Warm-Wet' Compound Hazard

Quasi-stationary
Rossby wave train

Atmospheric Blocking

Landfalling
Tropical Cyclone

Peak heatwave: Pre-
/post-TC landfall

Increased solar
radiation

Little to no Cloud

Warm Troposphere

Urban thermal
boundary layer

Cloud cover

Cool Troposphere

Marine
Heatwave

Strong Winds

High SST

Mountains

Advection of
warm Air

Suppressed Precipitation

High Temperature

High CIN

10 km

H

Low CIN

High Precipitation

Surface Runoff

d-day time lag

Storm Tide

Mean Sea Level

Urban Terrain

Dry urban surfaces,
low evaporation

$H \geq h$

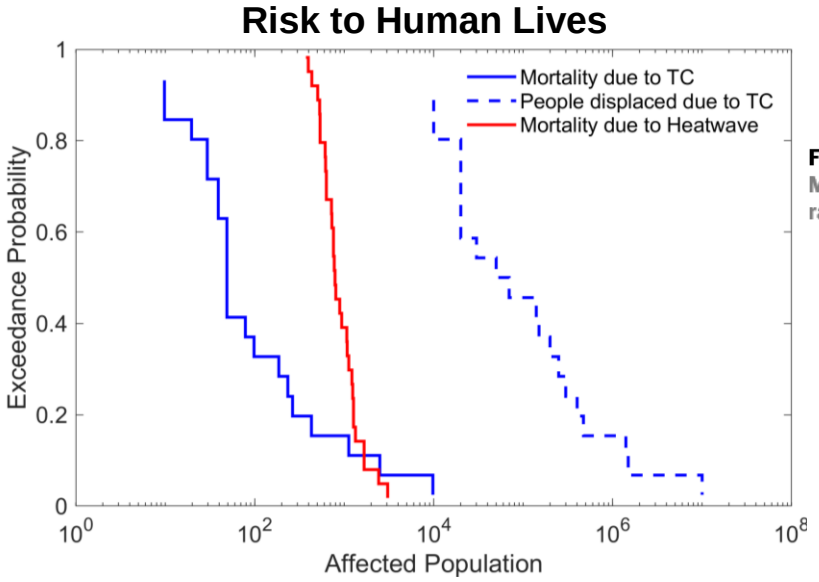
Sub-surface
drainage networks

Storm surge

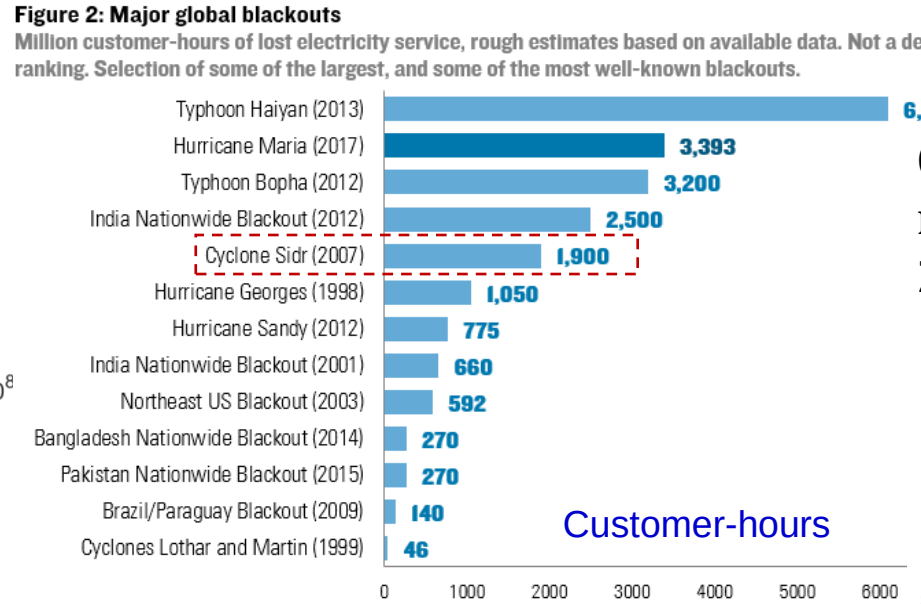
Back water effect

Height & density of buildings $\propto \frac{1}{sea\ breeze}$

Tropical Cyclone-Heatwave Compound Stressors Can Threat Energy Nexus

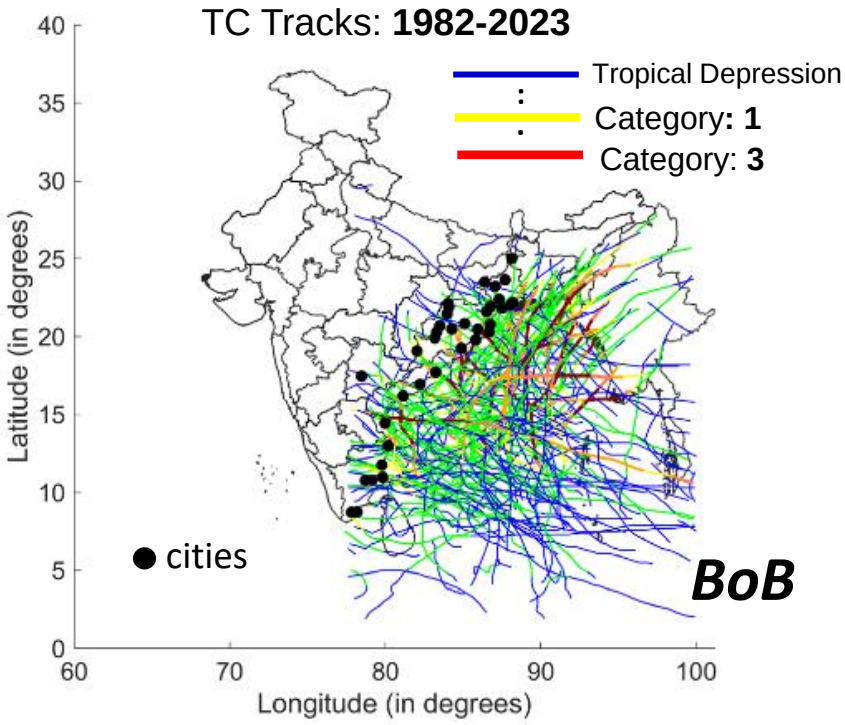


Source: DFO Flood observatory, 2022; GSDMA, 2019



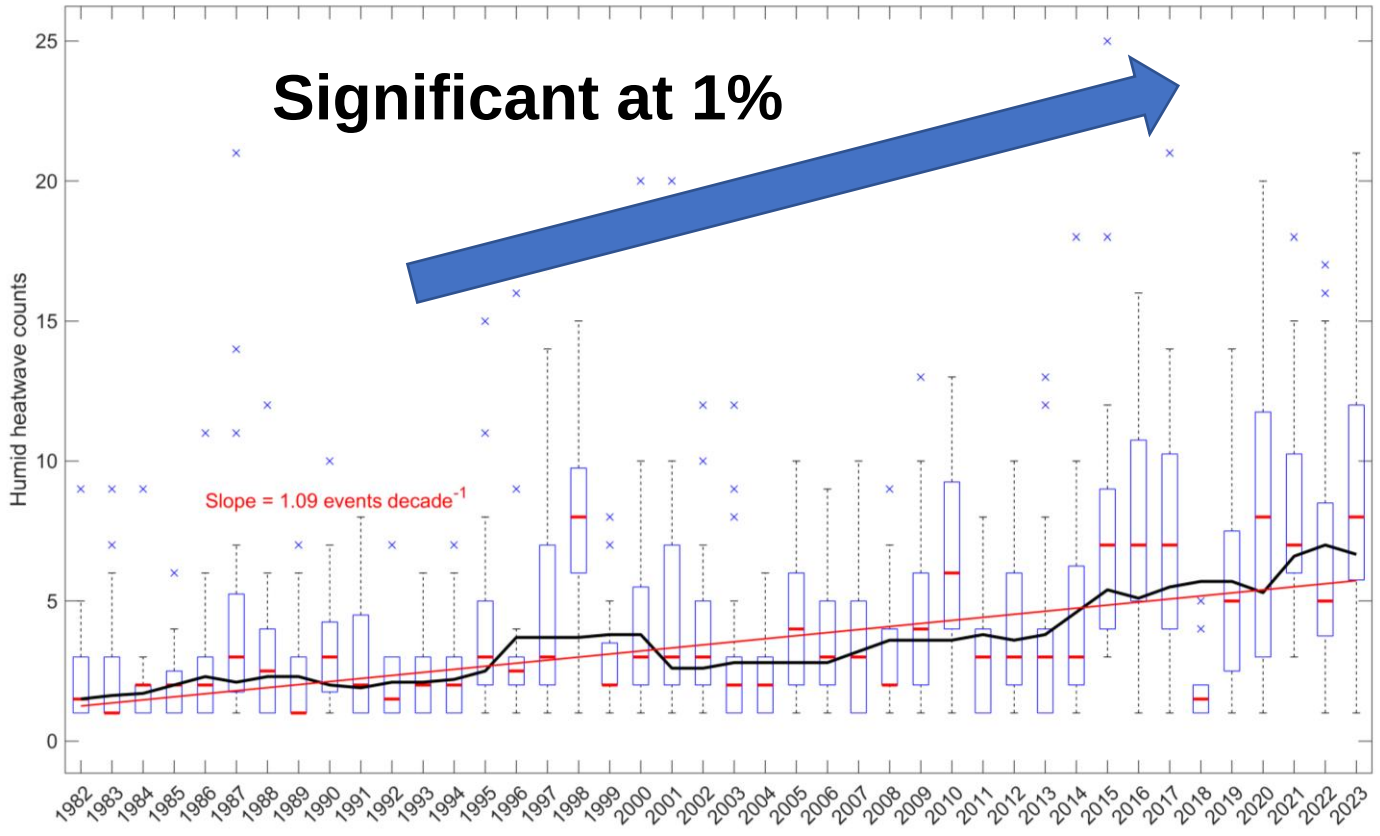
Rhodium Group Report. (2024)

Globally, TCs are the cause of 15% of major power outages between 2000 and 2021 (Garland et al., 2024).



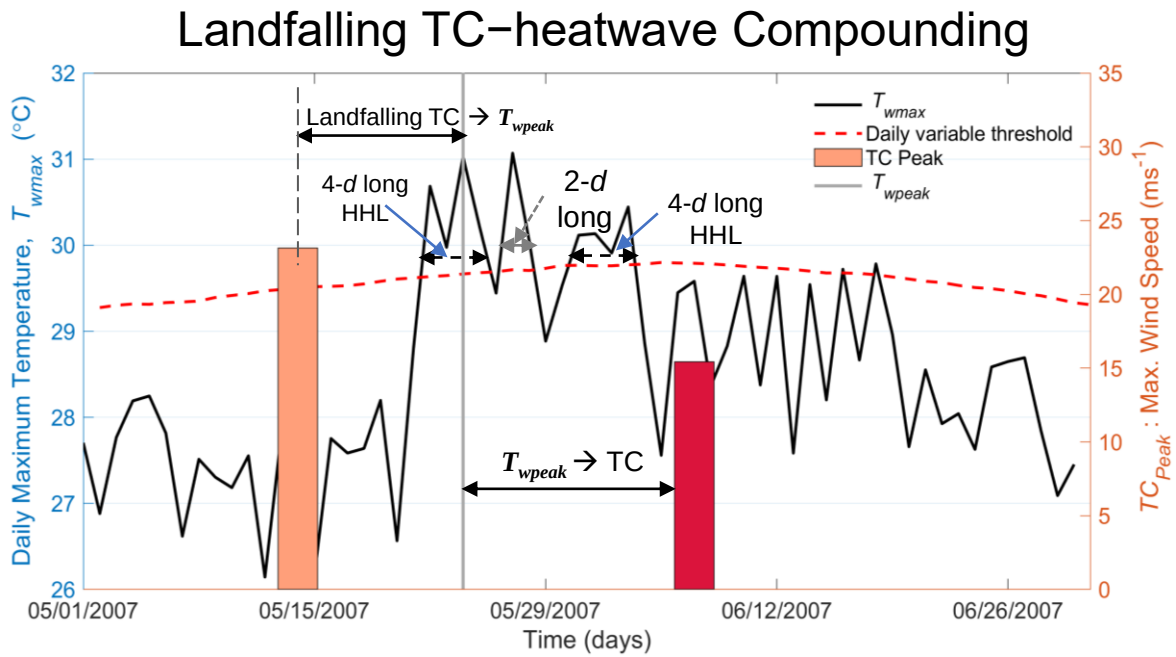
During March–May is very hot & cloud-free season with severe heatwaves – demand for Air Conditioning is highest (Hunt & Bloomfield, 2025)

Humid Heatwaves is showing Significant Increasing Trends across Eastern Coast of India

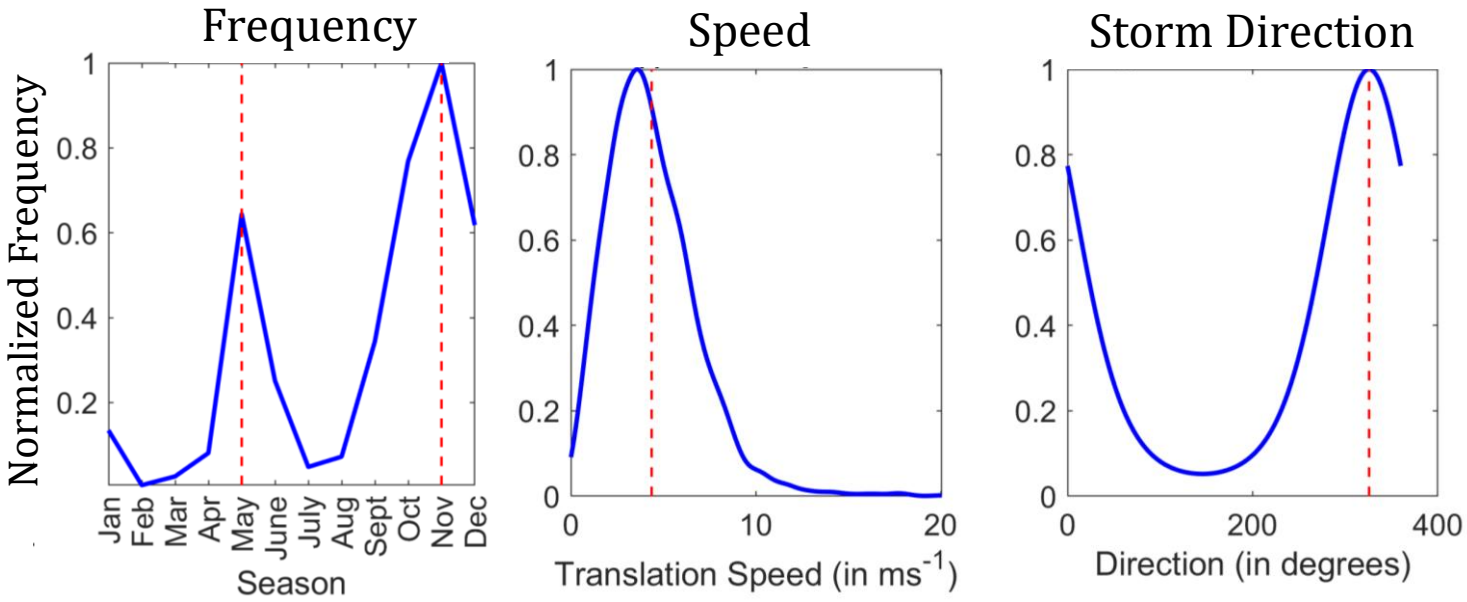


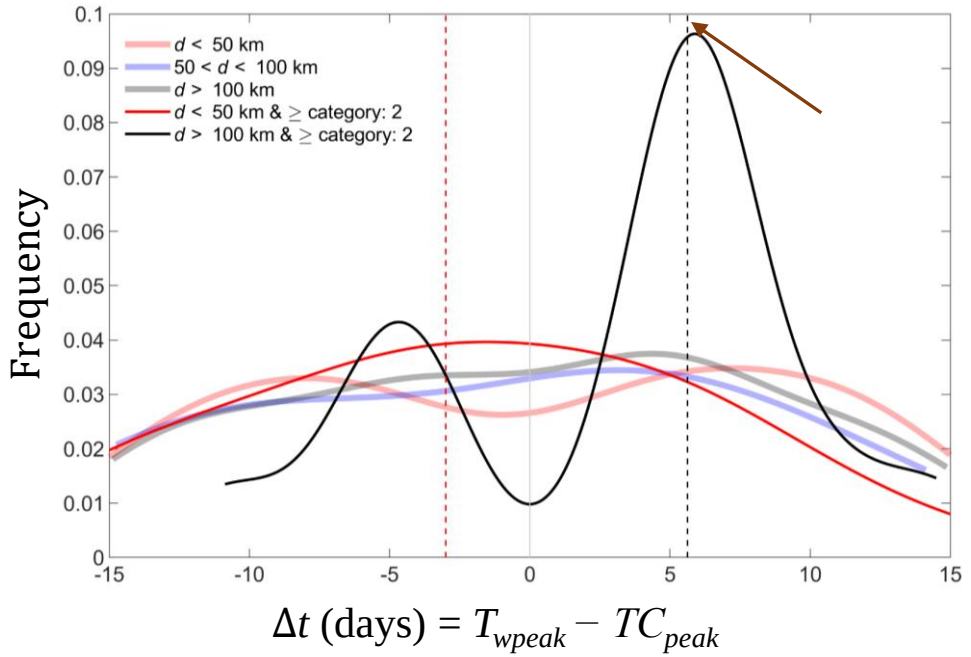
At-site trend is **statistically significant**, considering 33 urban & peri-urban sites <u>across coast</u> (within 200 km)

Approx. **17% of heatwaves** are TC Compounded (1982–2023)

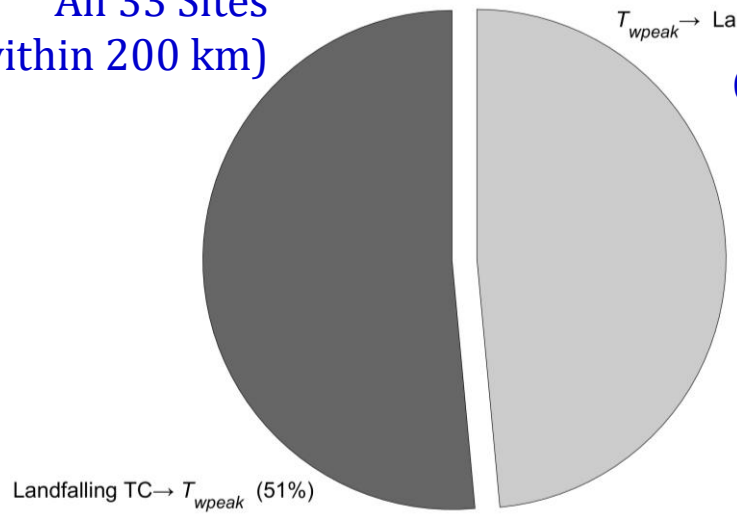


Uniqueness of Tropical Cyclone-Heatwave Compounding in Bay of Bengal

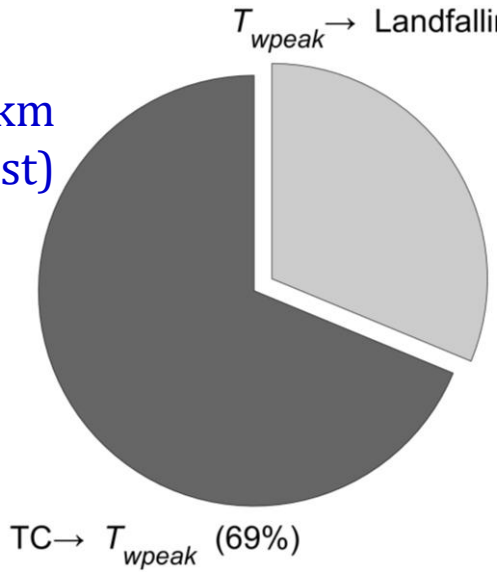


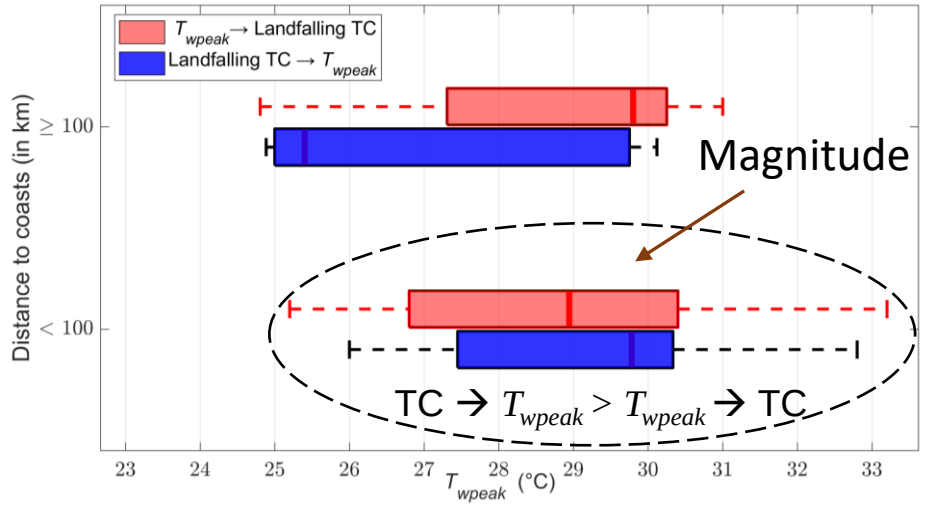


All 33 Sites (within 200 km)

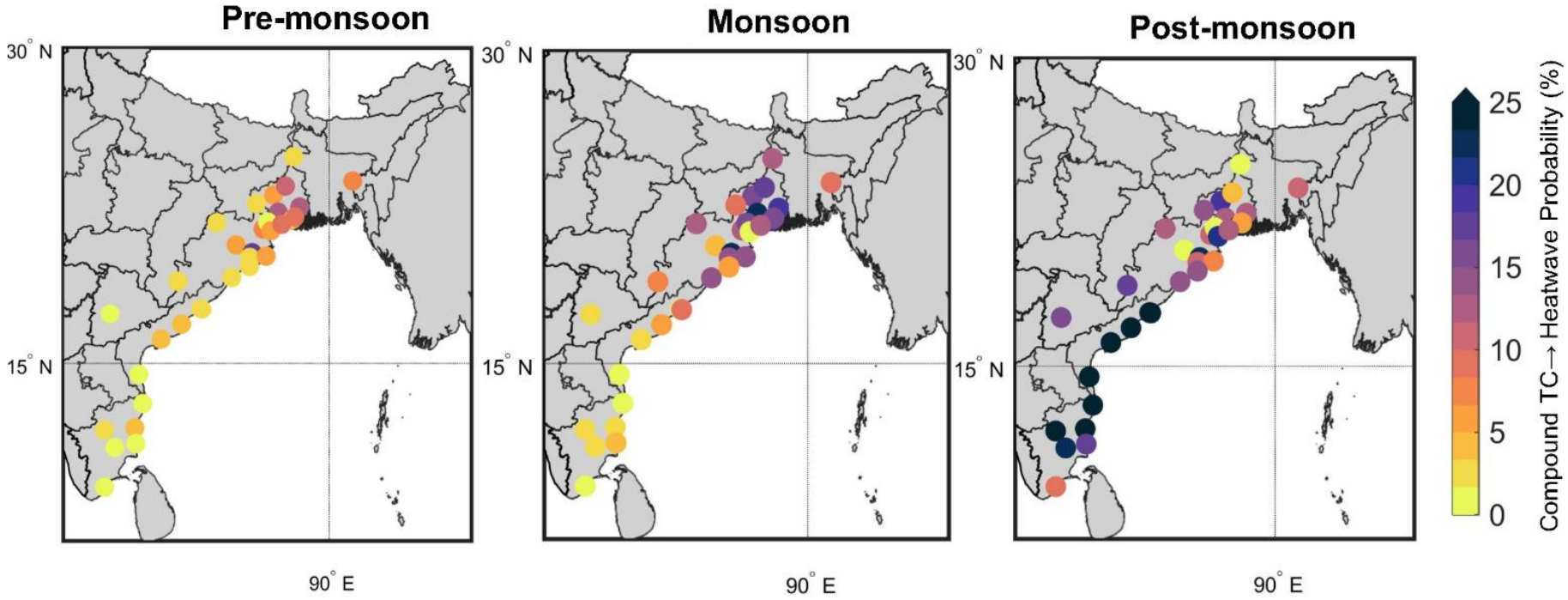


Chennai (~9km from coast)

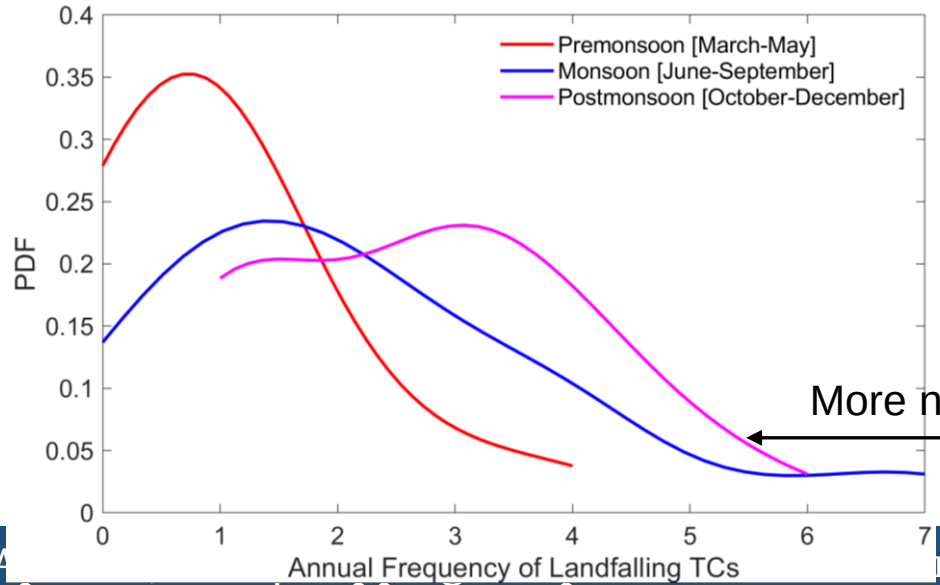




Likelihood of Humid Heatwave over Land Preceded by TC



Probability of HHL being preceded by TC ≤ 30%

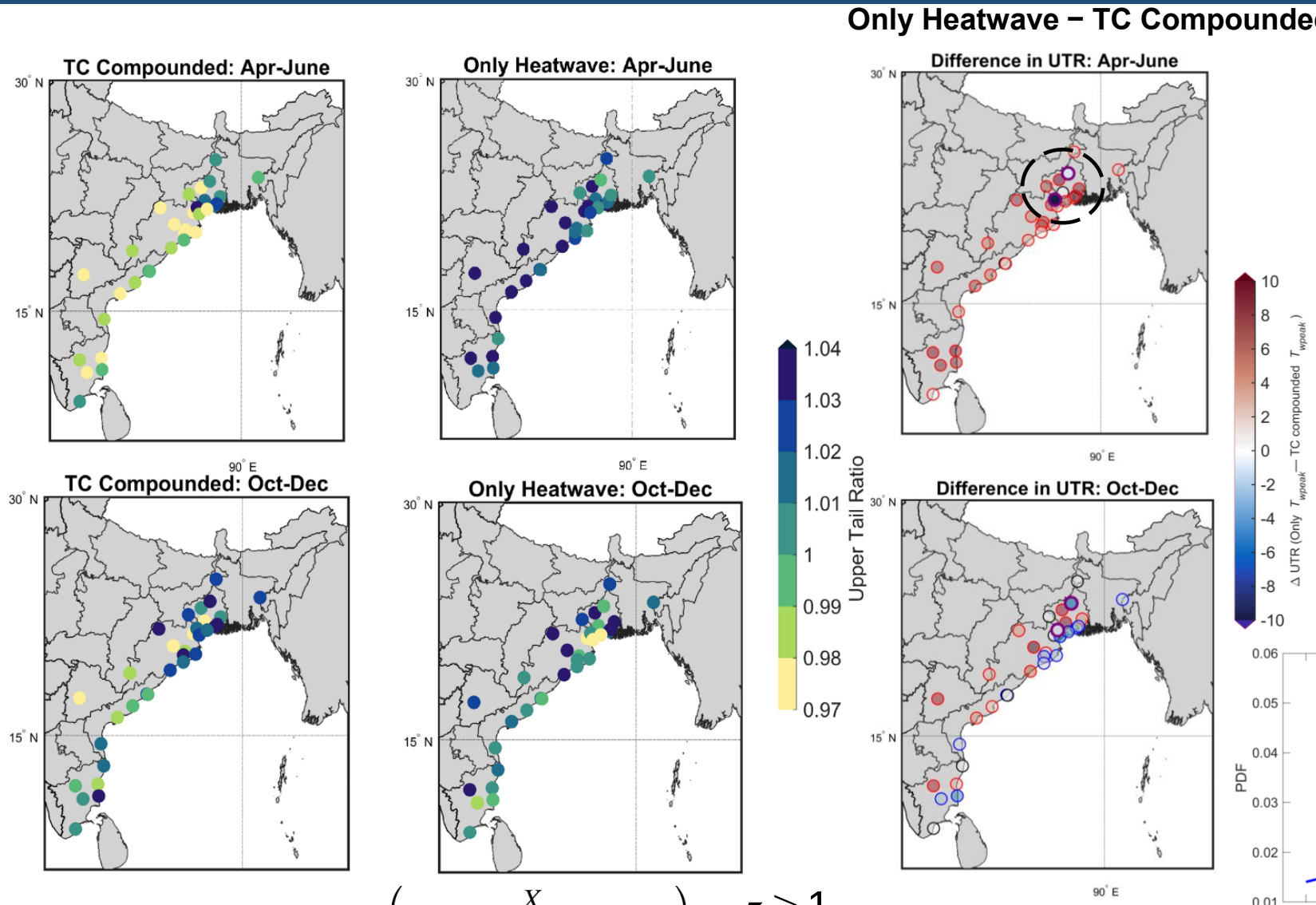


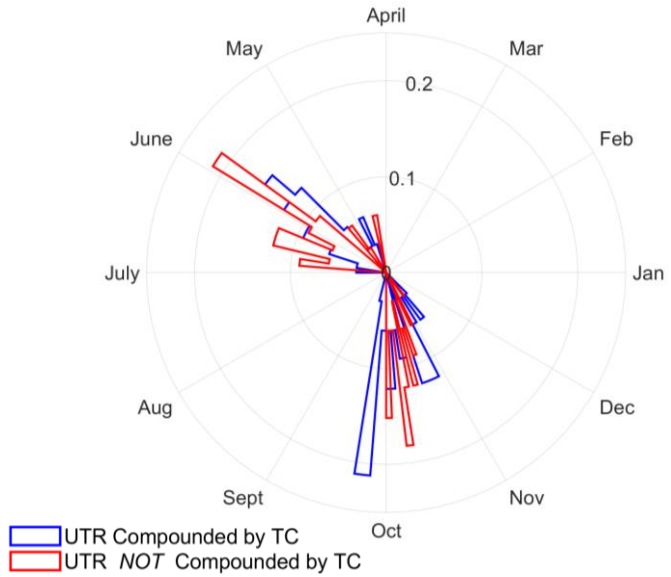
More number of post-monsoon landfalling TC

$$Probablity_{HHL} = \frac{Number\ of\ T_{wpeak}\ after\ TC}{Total\ number\ of T_{wpeak}}$$

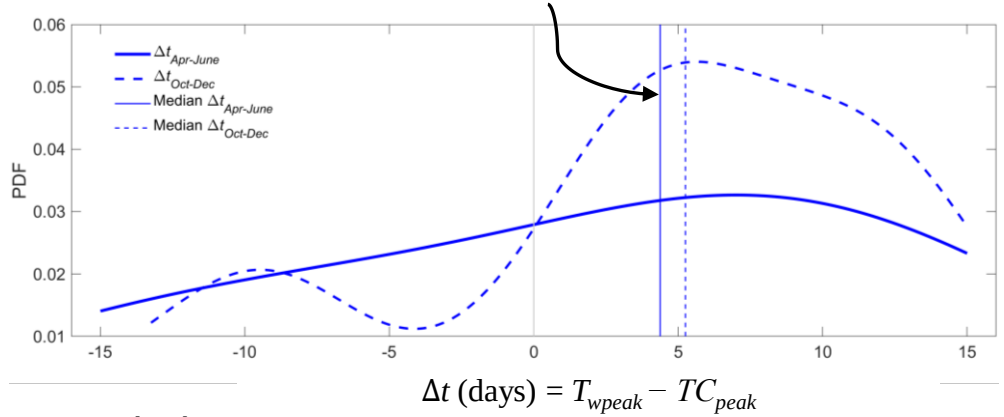
HHL: Humid Heatwave over Land

Higher Severity of TC-Compounded Heat Stress during Post-monsoon Season





Smaller Δt for summer

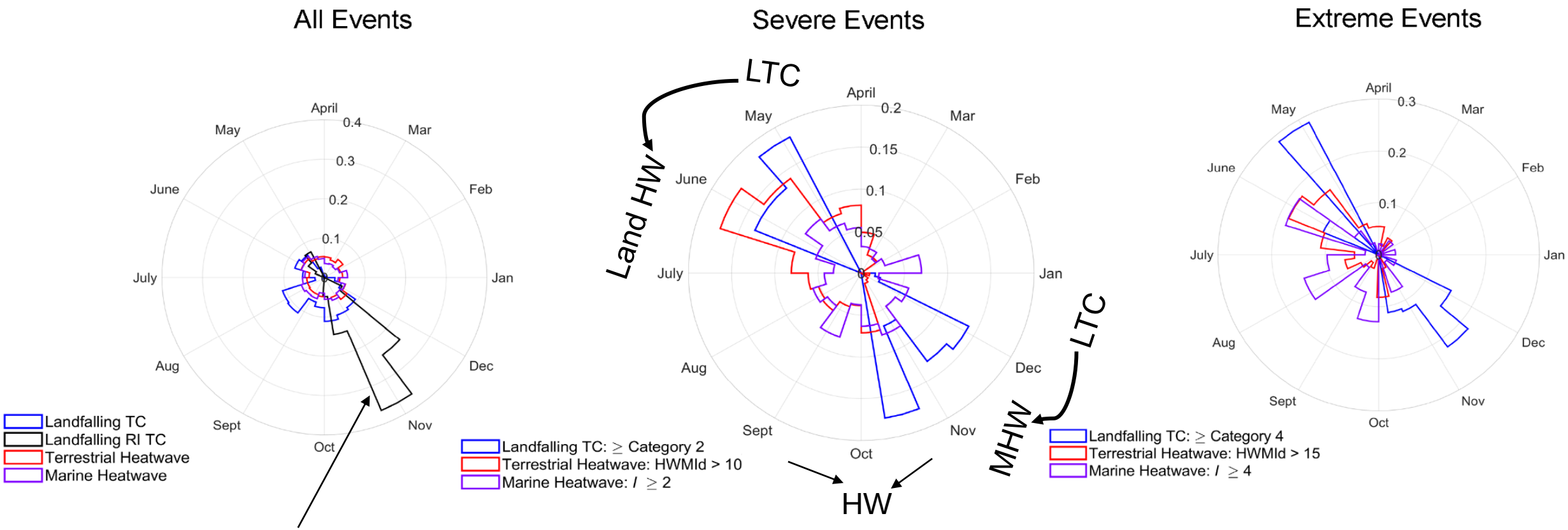


Upper tail Ratio, UTR $z = max\left(\frac{X_n}{q^{-1}\left(T_W = 10 - year\right)}\right)$

$z \geq 1$

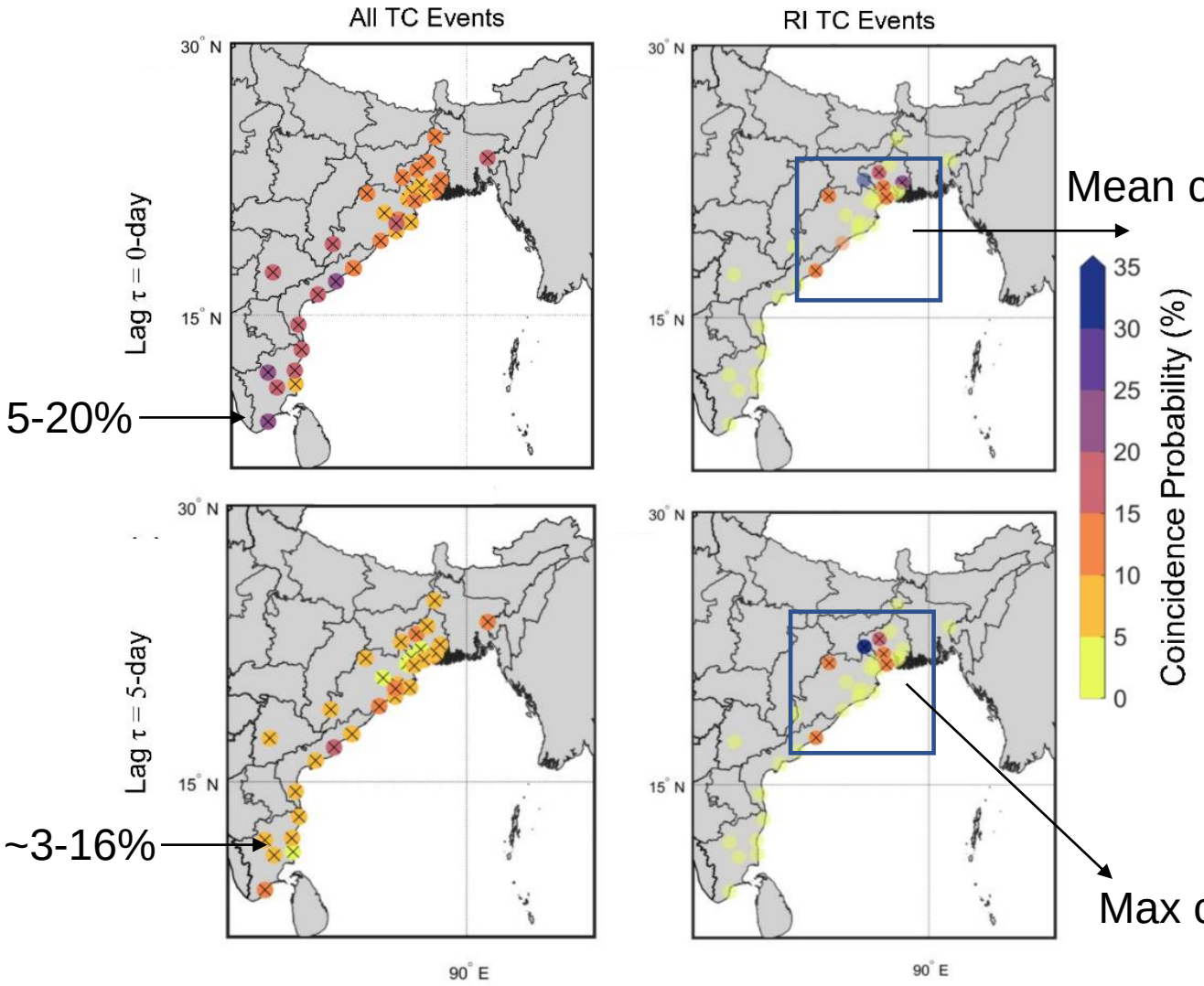
TC-compounded $T_w \geq$ Uncompounded T_w

Synchronicity in Timing of Marine Heatwave – Landfalling TC – Terrestrial Heatwave

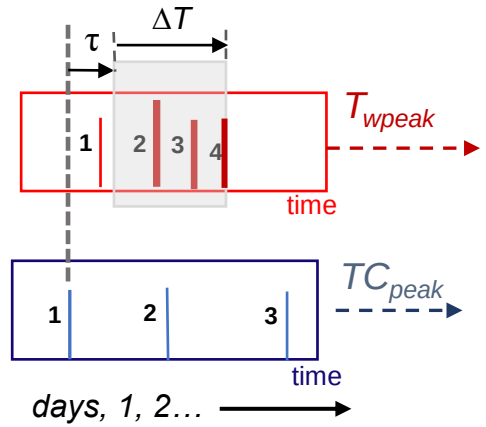


Rapidly intensified TC (15.4 ms^{-1} intensity changes/24-hr)

Coincidence Probability of Landfalling TCs Followed by Humid Heat Peaks



Fraction of TC_{peak} *followed* by *at least* one T_{wpeak} event



ΔT = 15-*d*, τ = 5-*d*

Precursor

CR increases for RI storms, while spatial extent decreases

Ganguli, P., Lin, N. (In Review)

Key Findings

- Unlike in most basins globally, where extreme humid heat stress is likely to occur before peak TC (Guido et al., 2022; Wang et al., 2023), over Bay of Bengal anomalous heat *often* follows extreme landfalling TCs (category 2/higher).
  - This phenomena is prominent for sites > 100 km from the coast, which show up to 10% increase in seasonal average (median) temperature.
- Over 40% of sites show record TC-compounded heatwave peaks, which exceeds fall season (October−December) uncompounded heatwave peaks.
  - Of this 78% of sites show record heatwave peaks following the TC. These sites are located near the coast.
- The record TC-compounded heatwave peaks during the summer (April−June) show faster transition times from TC peaks to heatwave peaks (< 5-day) − indicating less time for recovery.
  - In this season, extreme land heatwaves follows landfalling TCs. The temporal compounding is due to hot and cloud-free condition owing to transitioning sun during pre-monsoon summer season.

Thank You

Contact: Dr. P. Ganguli (pganguli@agfe.iitkgp.ac.in)

Cyclone ‘Dana’ (Oct. 2024) offshore (~460 km) to Paradeep coast, in eastern India