ICFM Webinar No. 9

Impact of Climate Change on Droughts and Vegetation

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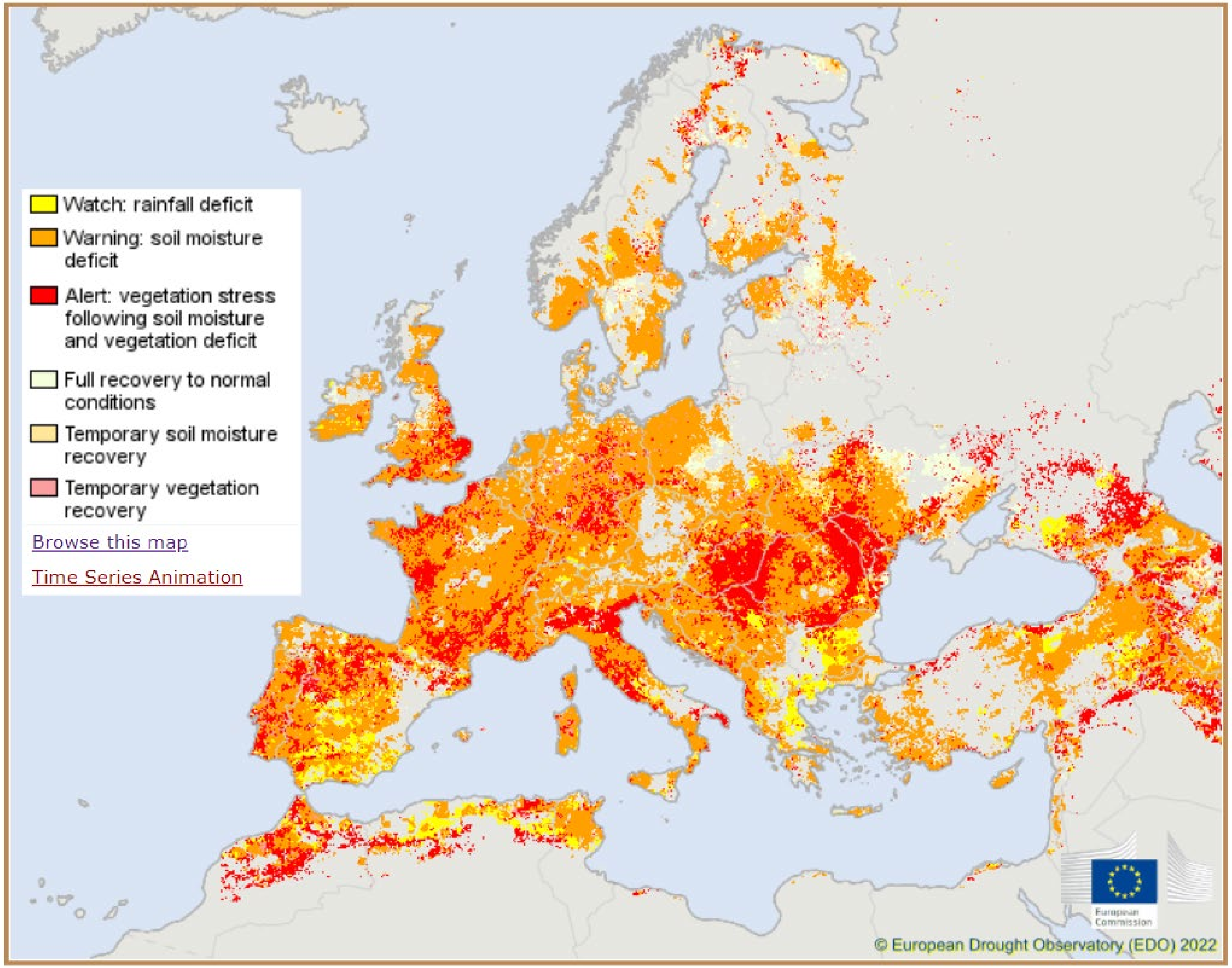
Current Drought Situation

Rhine River, 25 August, 2021

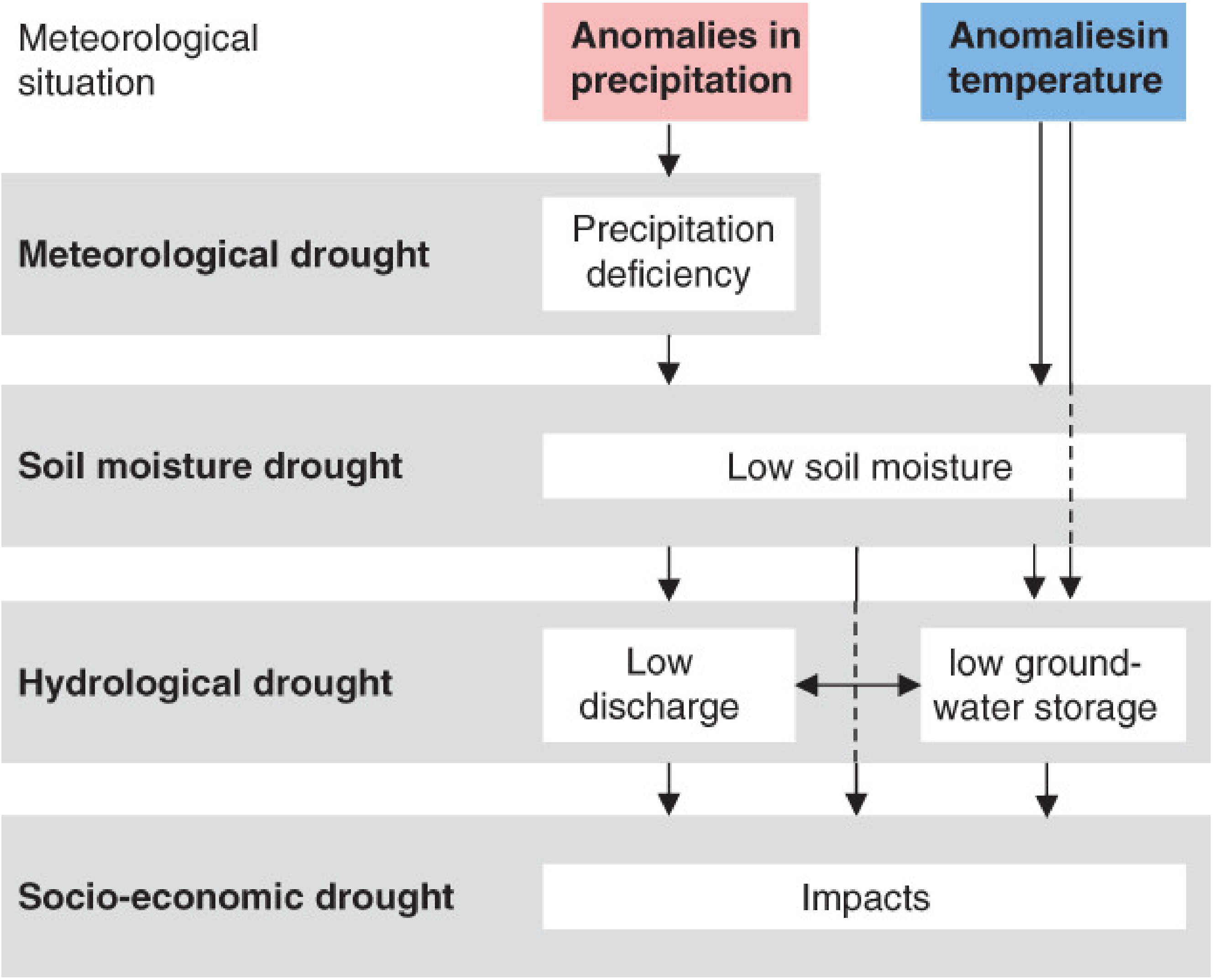
Rhine River, 12 August, 2022

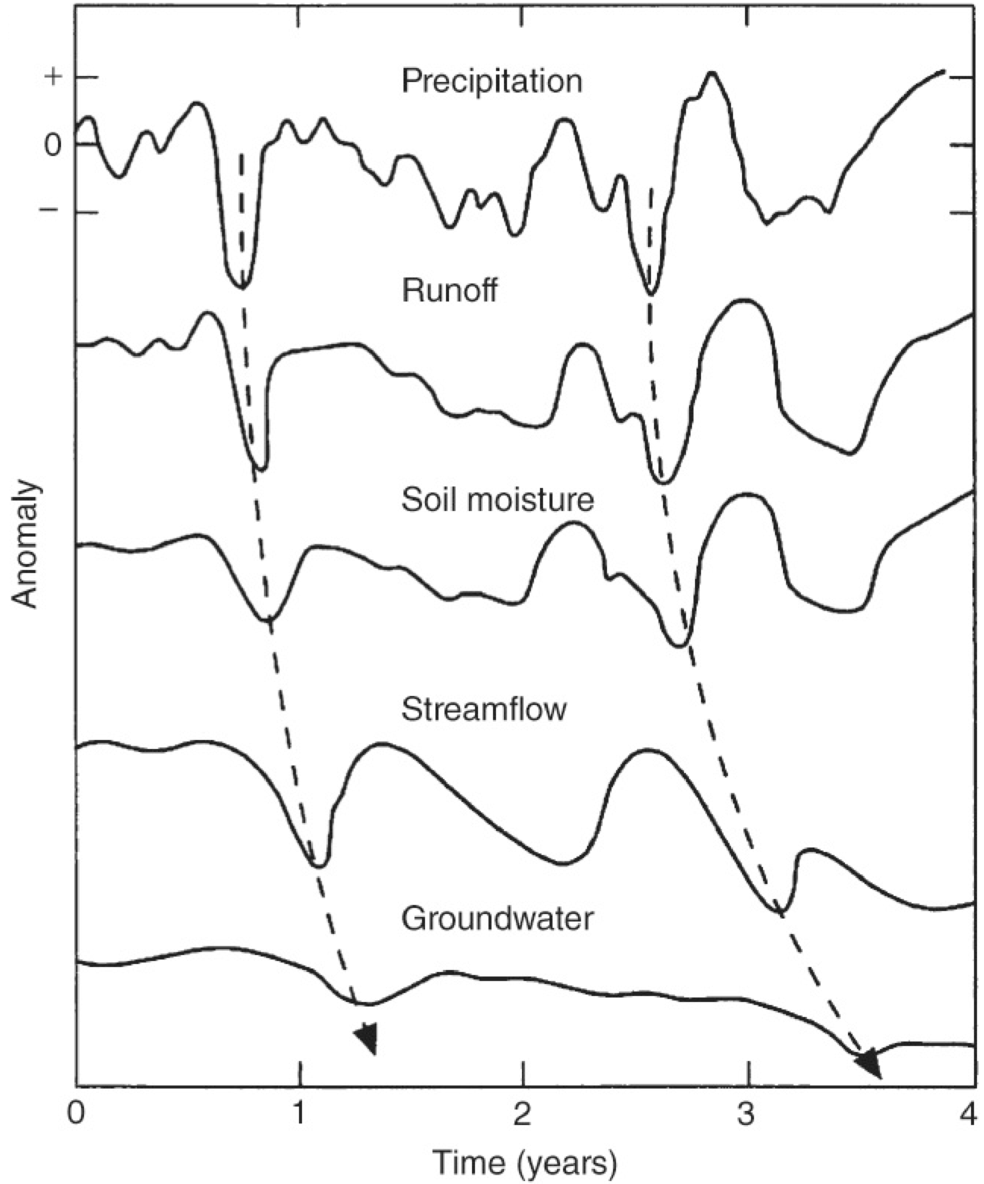
Source: ESA Copernicus Sentinel-2

Drought Situation in Europe (1st August 2022)



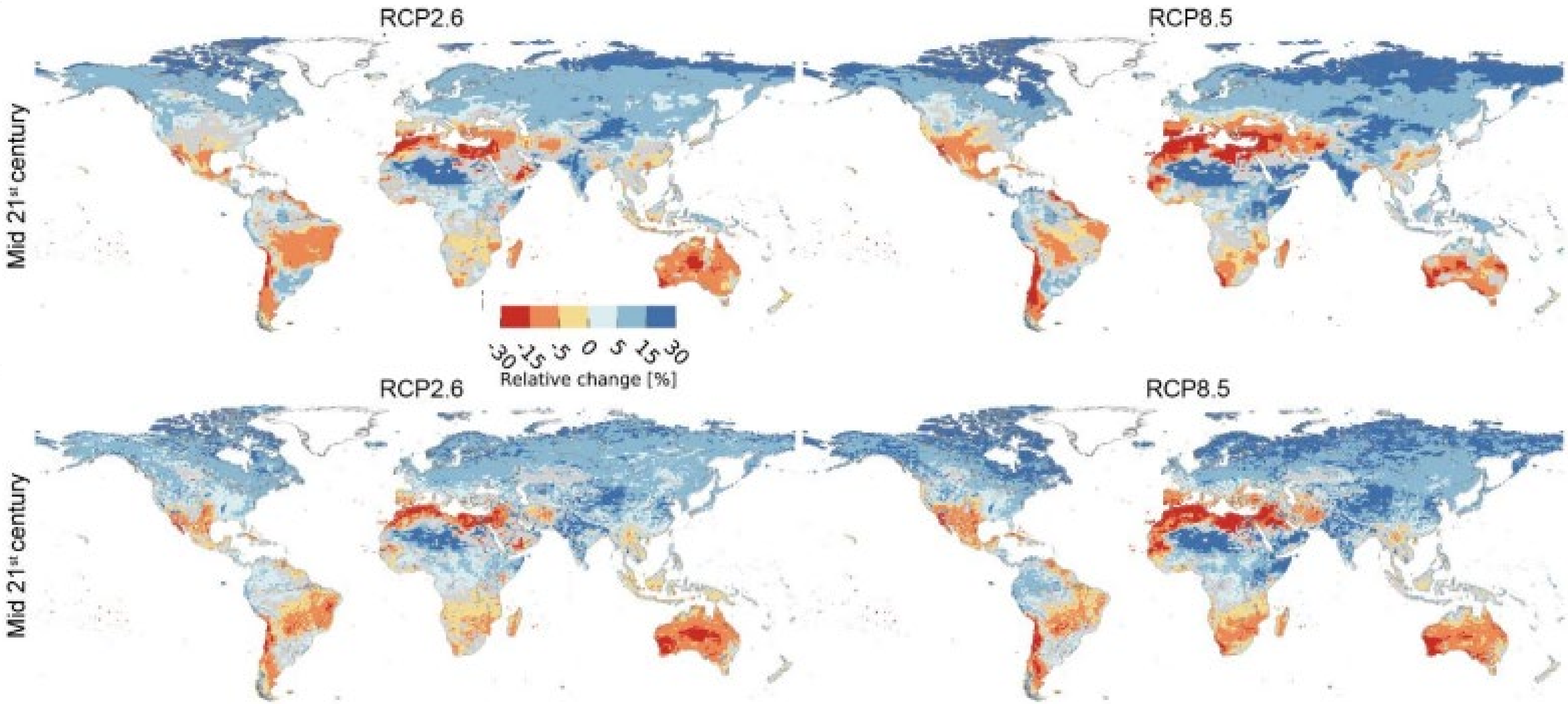
Drought Propagation





Van Loon, 2015, WIRES: Water

Projected Changes in Precipitation and ET (ISIMIP2b)

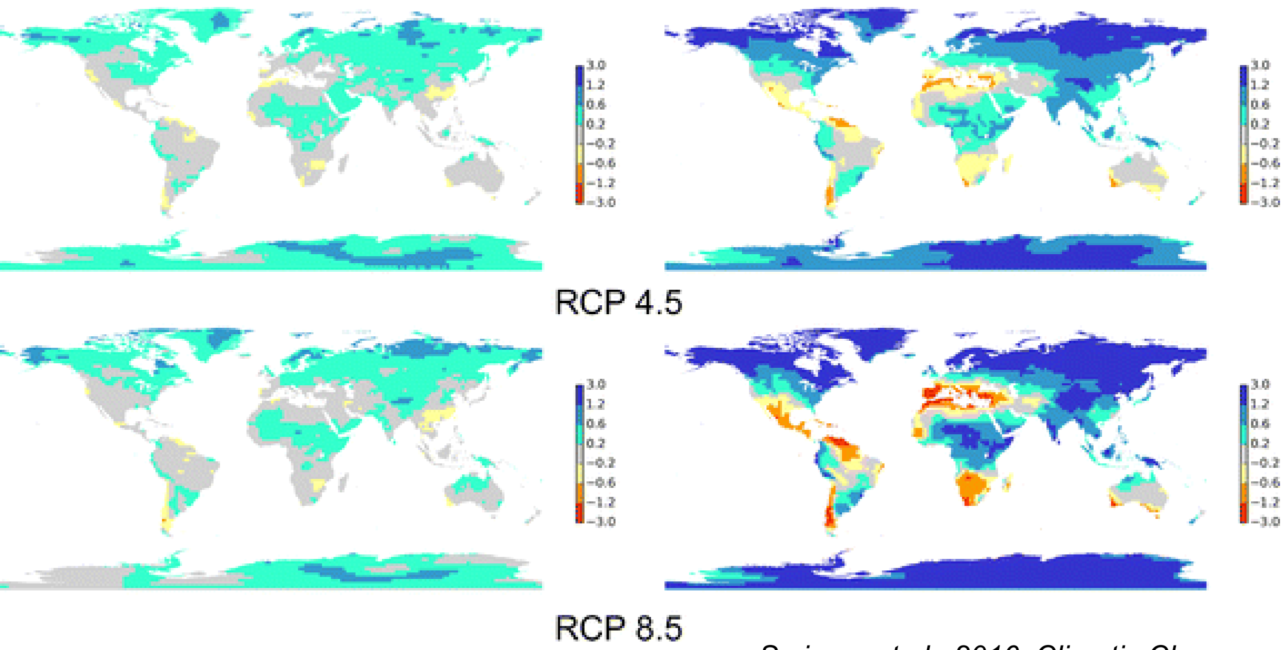


Satoh et al., 2022, Nat. Comms.

Relative Importance of Climate Change and Population Growth on Drought Exposure

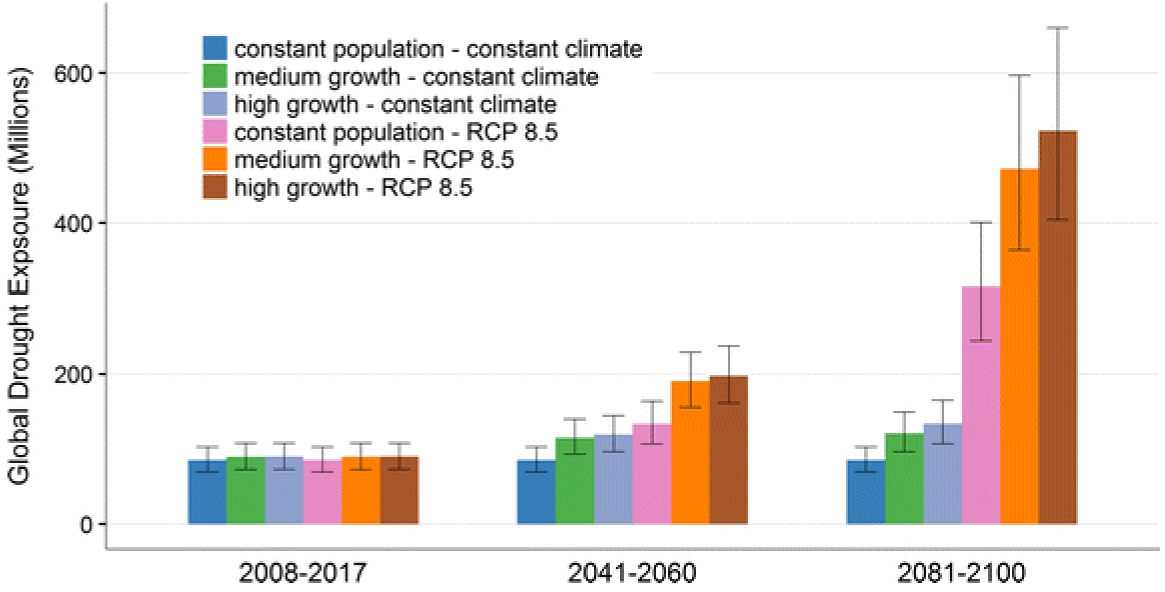
SPEI-12 Historic and Future Projections

2008 – 2017 2081 – 2100



Smirnov et al., 2016, Climatic Change

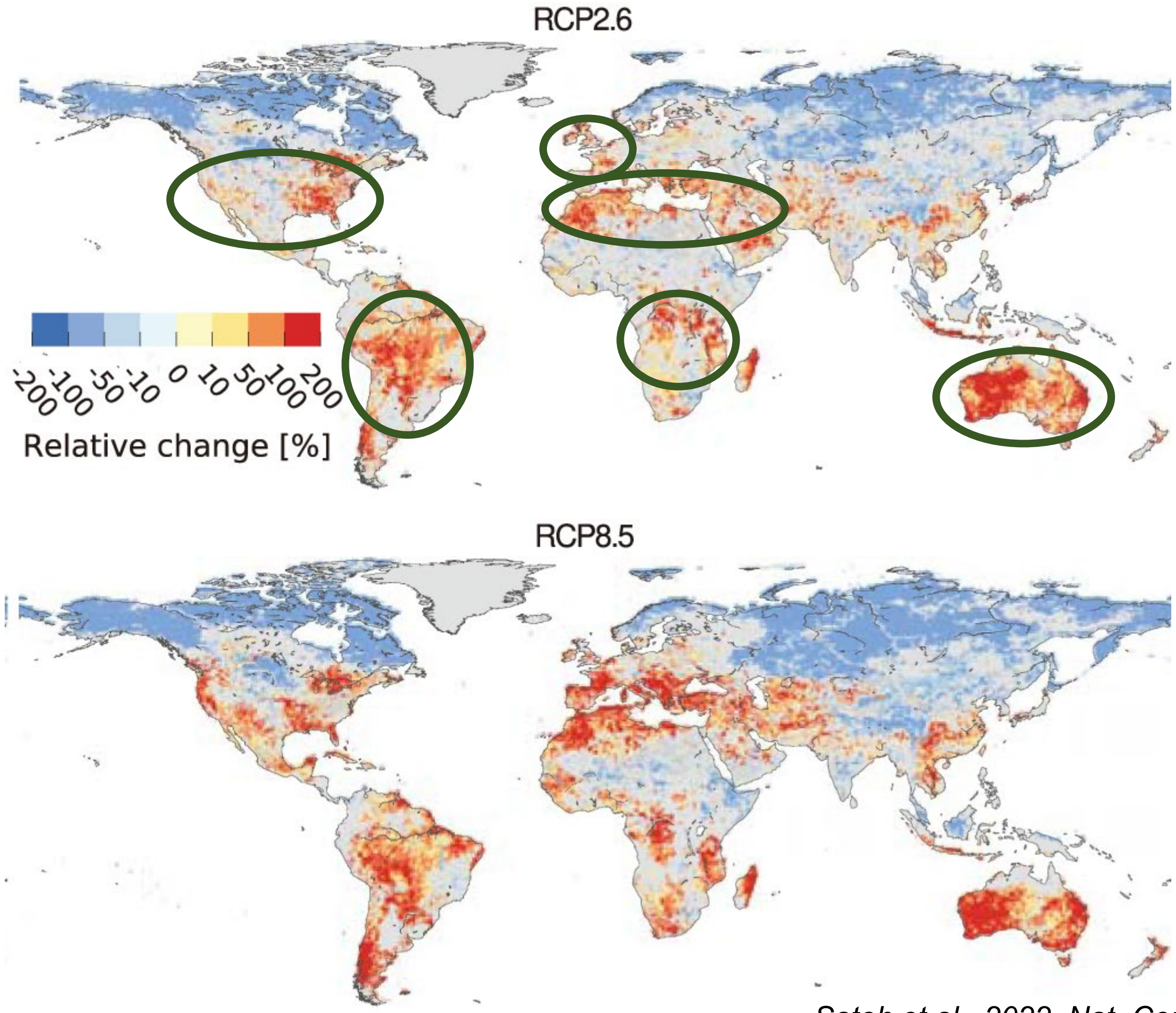
Population Exposure to Droughts



Smirnov et al., 2016, Climatic Change

Under RCP 8.5 and during the period 2081–2100, in global terms climate change alone is responsible for 59.5 % of drought exposure, with the climate change and population growth interaction accounting for 31.4 %. Population growth alone causes a relatively minor 9.2 % increase.

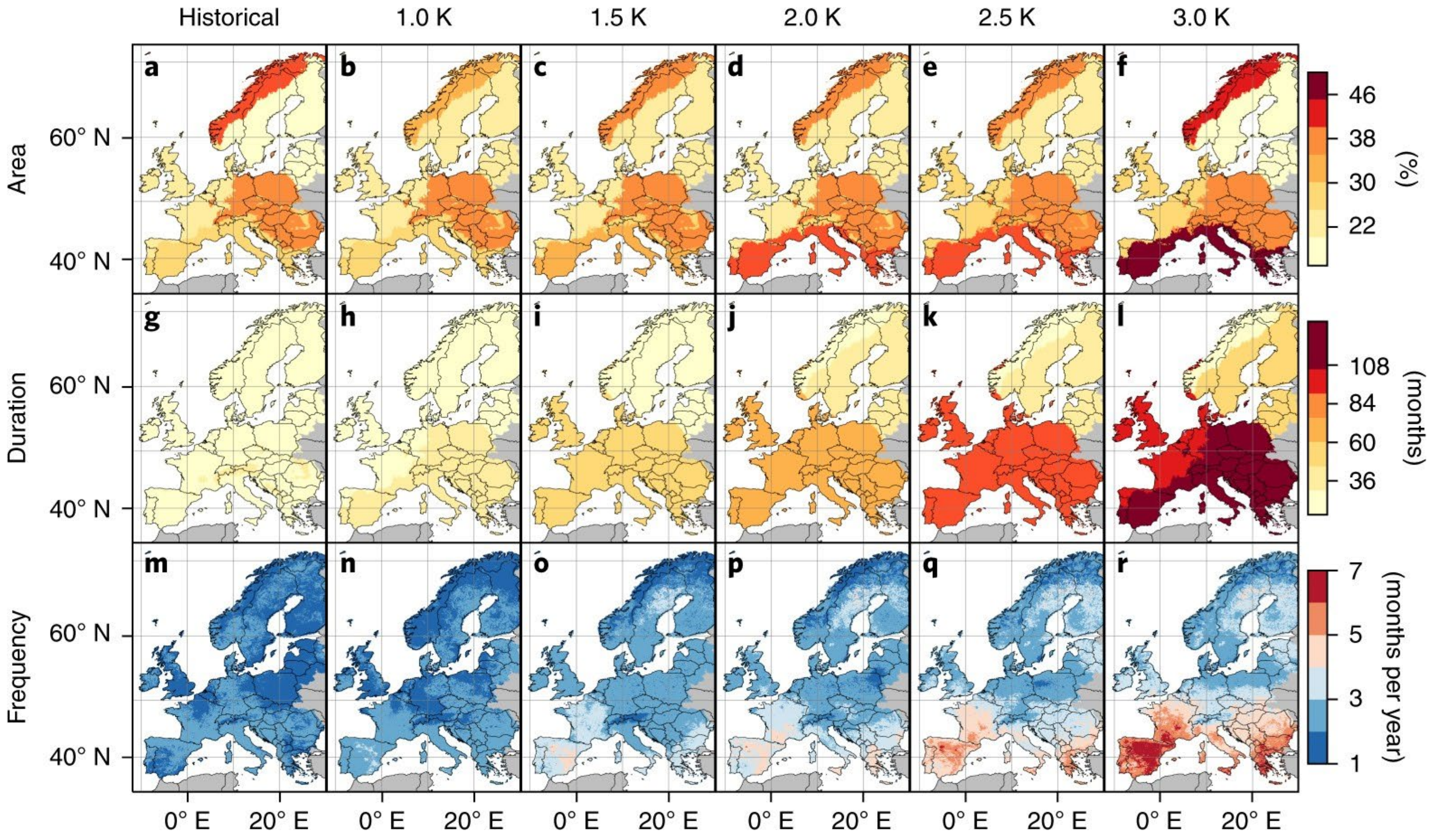
Frequency of Hydrological Droughts under Climate Change



Frequency of hydrological droughts is projected to increase in drought-intensification hotspots in the mid 21st century (2036-2065) compared to historical period (1971-2005).

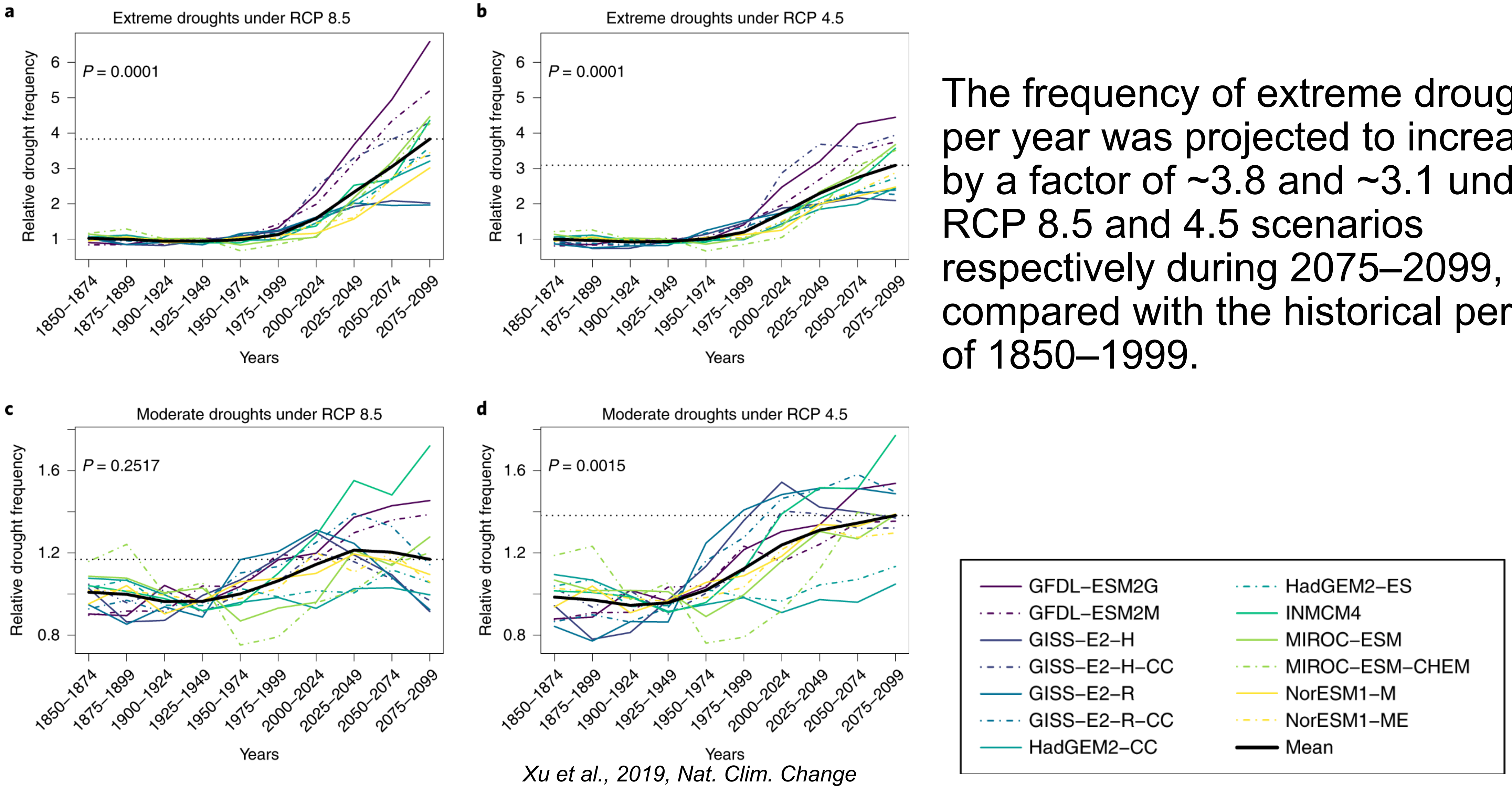
Satoh et al., 2022, Nat. Comms.

Changes in Soil Moisture Droughts under Climate Change



Samaniego et al., 2018, Nat. Clim. Change

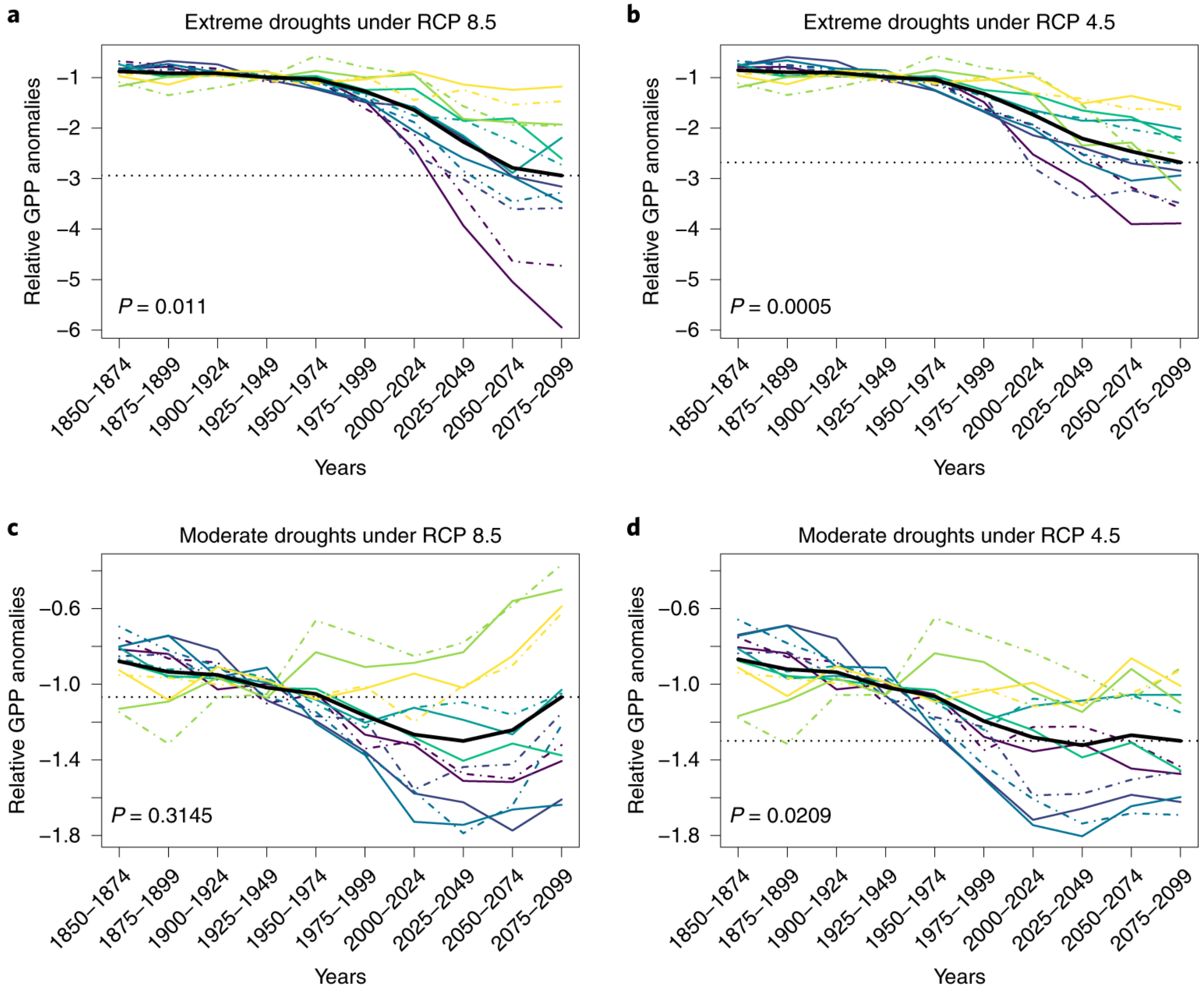
Future Projections of Soil Moisture Drought Frequency



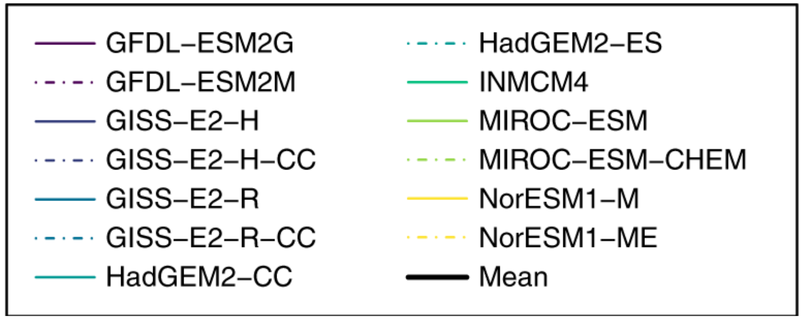
Xu et al., 2019, Nat. Clim. Change

The frequency of extreme droughts per year was projected to increase by a factor of ~3.8 and ~3.1 under RCP 8.5 and 4.5 scenarios respectively during 2075–2099, compared with the historical period of 1850–1999.

Future Projections of Reduction of Vegetation Productivity



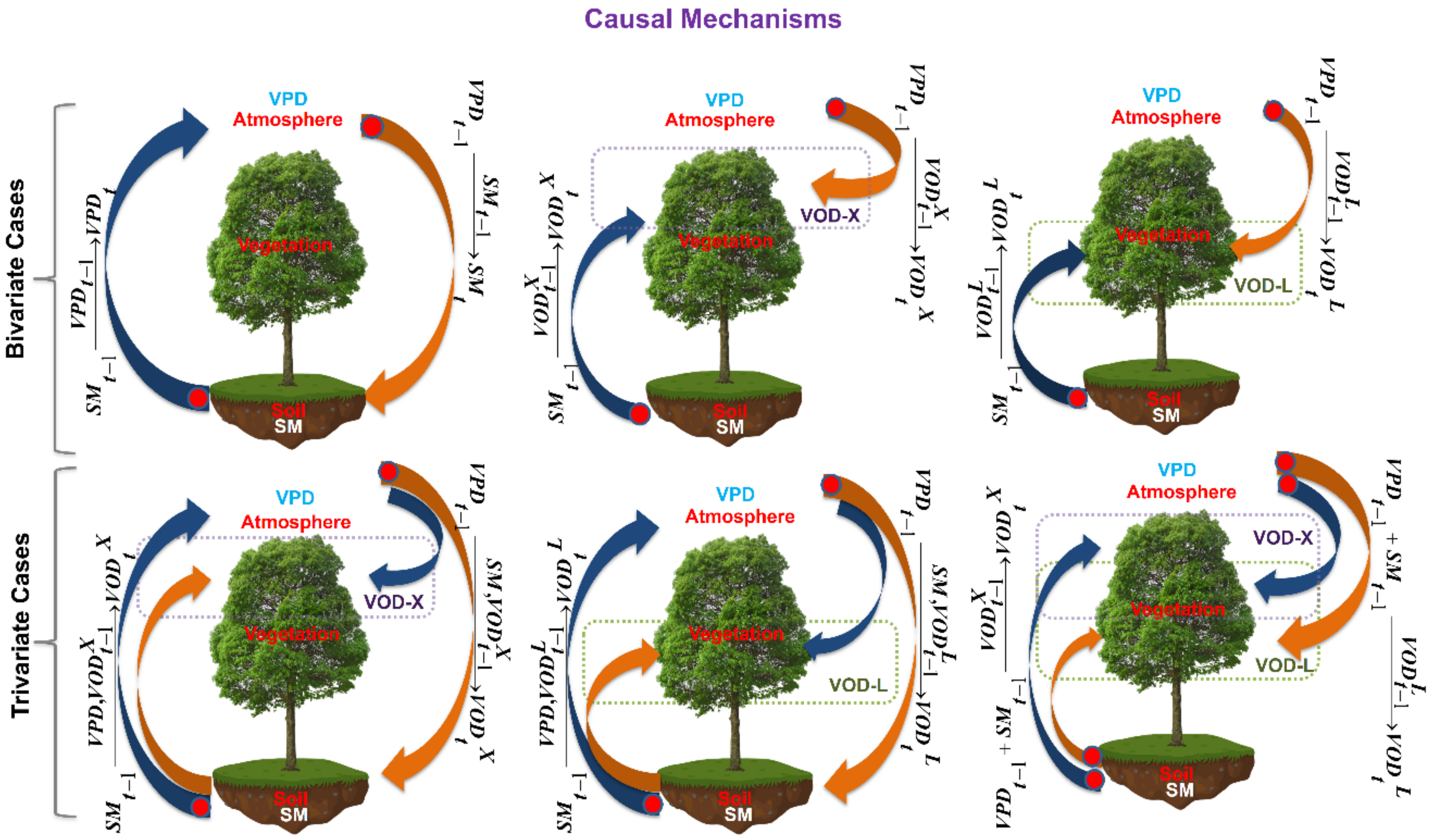
Annual reduction in GPP under extreme droughts was projected to increase by a factor of ~2.9 and ~2.7 under RCP 8.5 and 4.5 scenarios respectively during 2075–2099, compared with the historical period of 1850–1999.



Xu et al., 2019, Nat. Clim. Change

Plants Response to Soil Moisture Droughts – An interplay between soil moisture, VPD, and vegetation water content

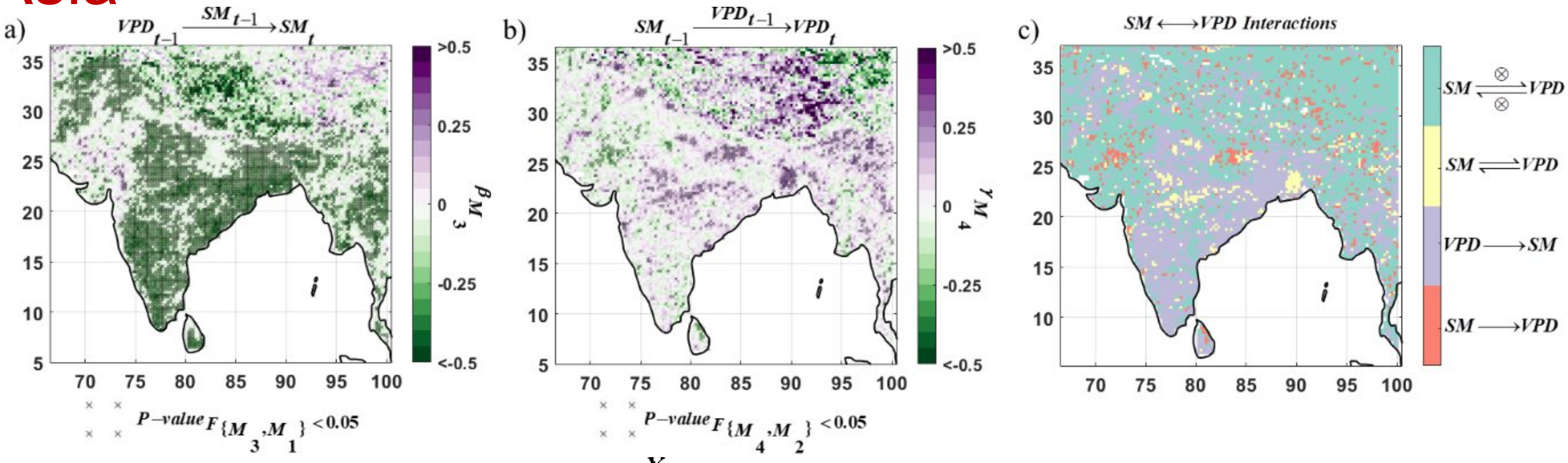
Vegetation Optical Depth (VOD) – A satellite-based indicator of vegetation water content

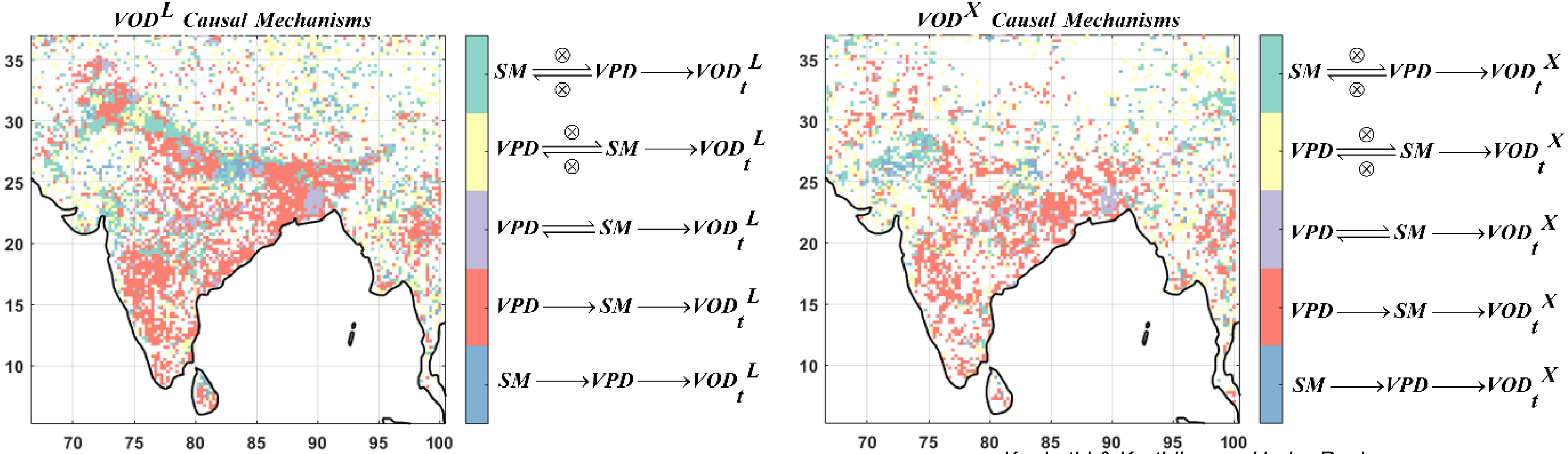


Konkathi & Karthikeyan, Under Review

Causal Mechanisms of Plant Water Response to Soil Moisture Droughts in South Asia

Soil Moisture – VPD interactions

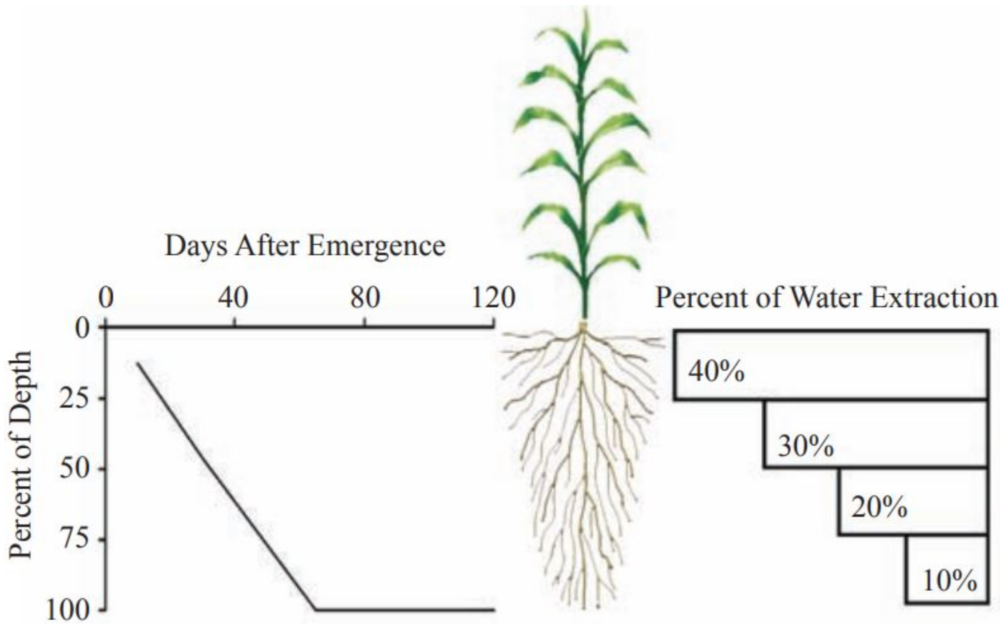




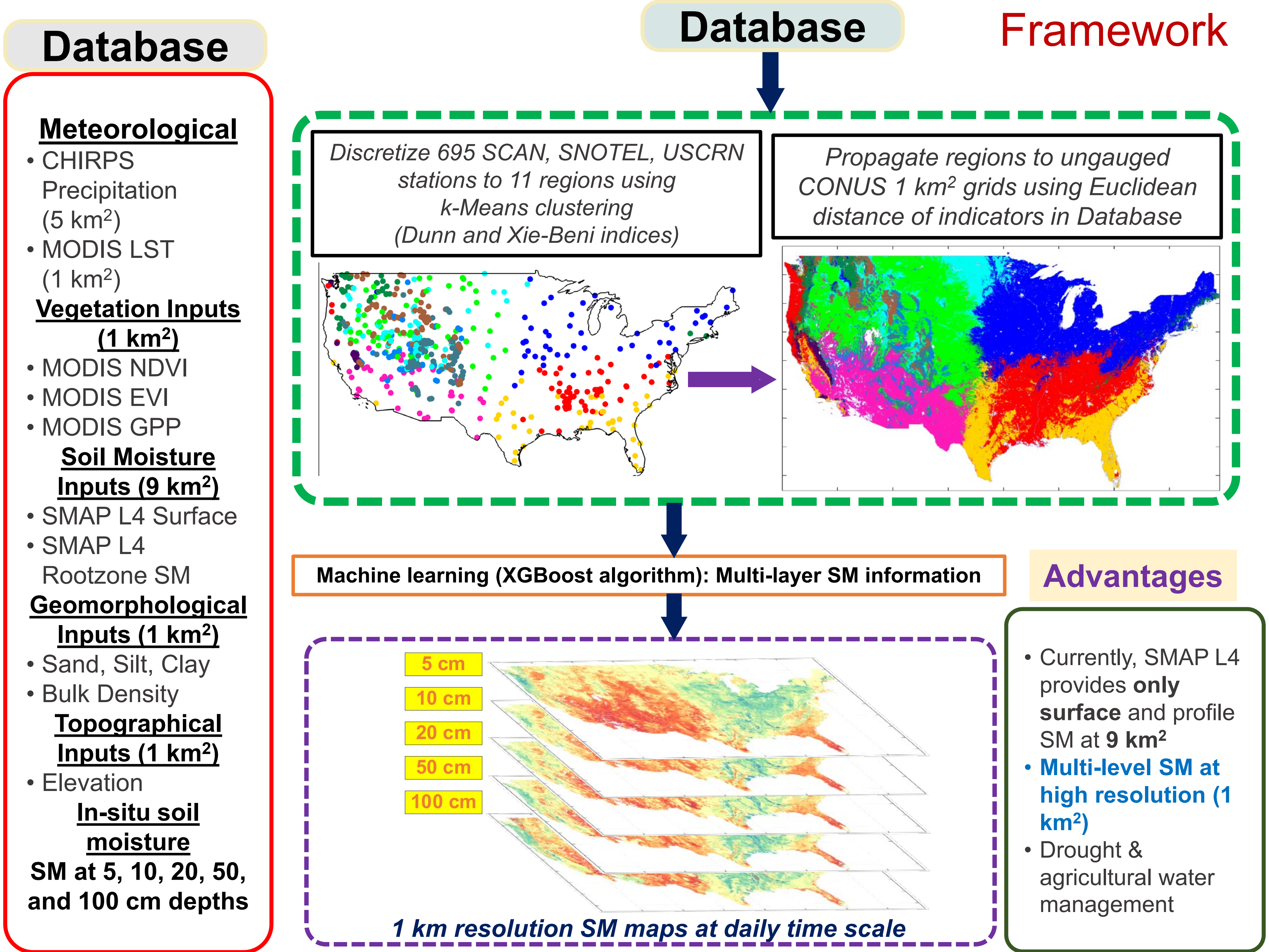
Konkathi & Karthikeyan, Under Review

Estimation of Multi Layer Soil Moisture

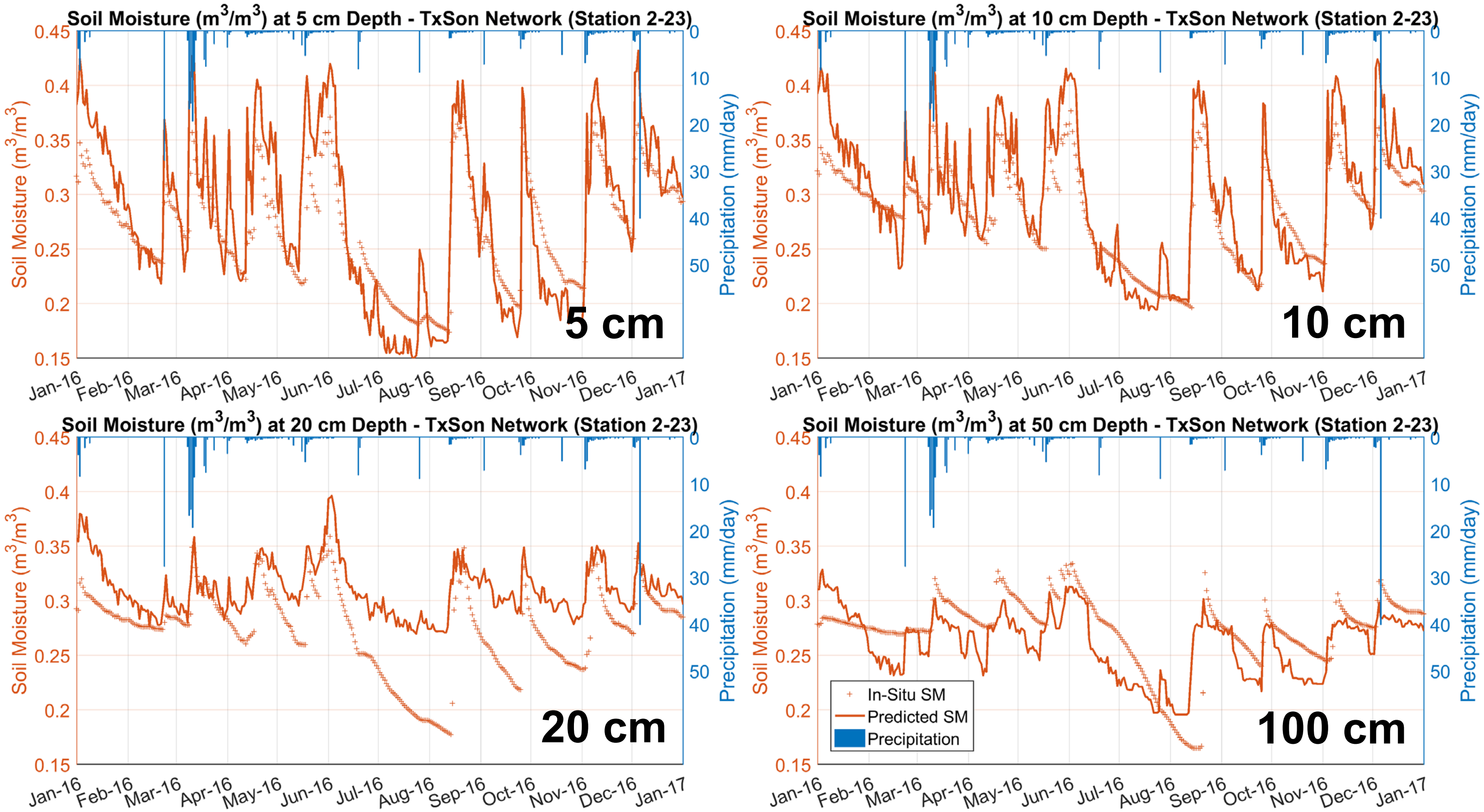
- The root depth of vegetation varies spatially based on the plant species
- Under agricultural drought condition, plants are subjected to water stress when there is deficit of soil moisture at the rootzone layer of that plant
- High resolution multilayer soil moisture information will assist in accurate modelling and monitoring of agricultural droughts
- Currently, SMAP L4 and LSMs provide rootzone soil moisture.
- But, one value for 0-100 cm of soil profile!

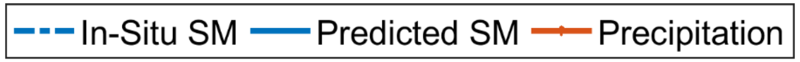


Kranz et al., 2008


Database
Meteorological
• CHIRPS Precipitation (5 km²)
• MODIS LST (1 km²)
Vegetation Inputs (1 km²)
• MODIS NDVI
• MODIS EVI
• MODIS GPP
Soil Moisture Inputs (9 km²)
• SMAP L4 Surface
• SMAP L4 Rootzone SM
Geomorphological Inputs (1 km²)
• Sand, Silt, Clay
• Bulk Density
Topographical Inputs (1 km²)
• Elevation
In-situ soil moisture
SM at 5, 10, 20, 50, and 100 cm depths
Database
Framework
Discretize 695 SCAN, SNOTEL, USCRN stations to 11 regions using k-Means clustering (Dunn and Xie-Beni indices)
Propagate regions to ungauged CONUS 1 km² grids using Euclidean distance of indicators in Database
Machine learning (XGBoost algorithm): Multi-layer SM information
5 cm
10 cm
20 cm
50 cm
100 cm
1 km resolution SM maps at daily time scale
Advantages
• Currently, SMAP L4 provides only surface and profile SM at 9 km²
• Multi-level SM at high resolution (1 km²)
• Drought & agricultural water management

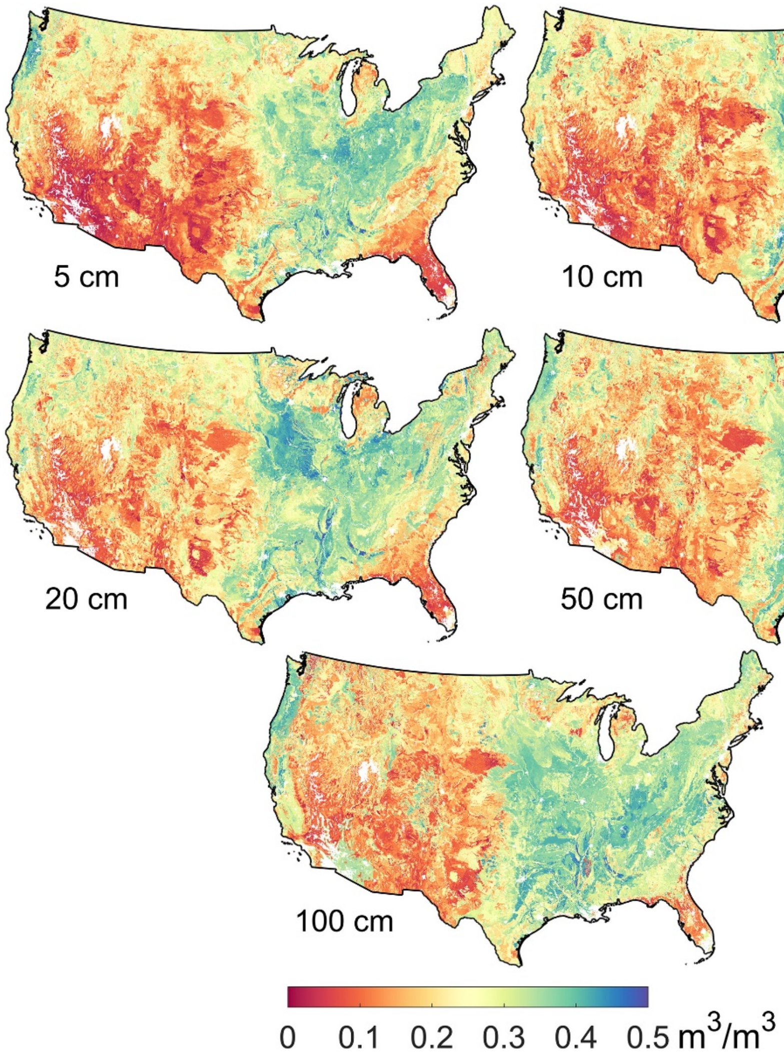
Validation



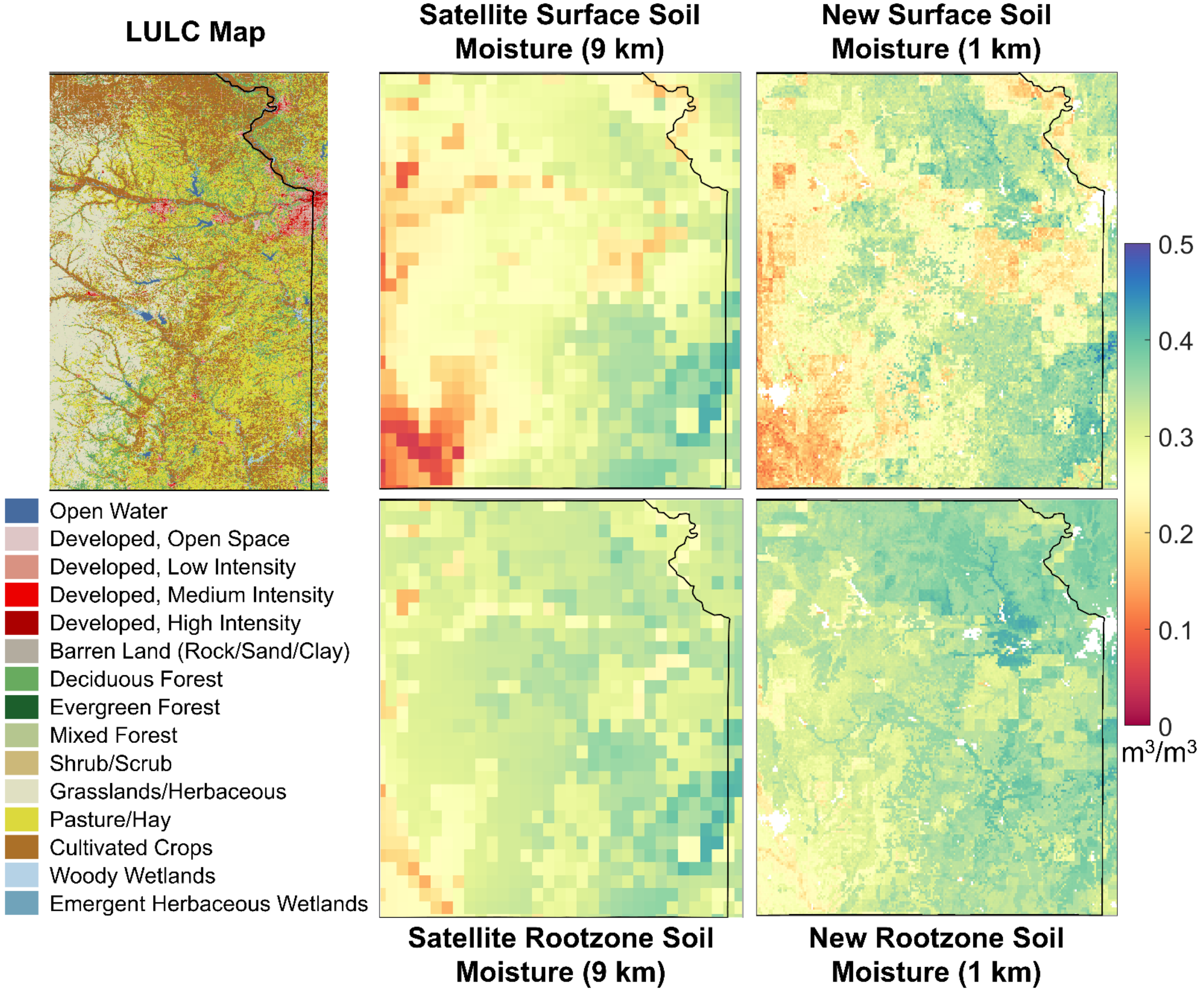


	ubRMSE (m³/m³)	R	Bias (m³/m³)
5 cm	0.043	0.859	0.011
10 cm	0.036	0.840	0.025
20 cm	0.034	0.754	0.054
50 cm	0.039	0.741	0.012

Multi-Layer 1 km Resolution Soil Moisture

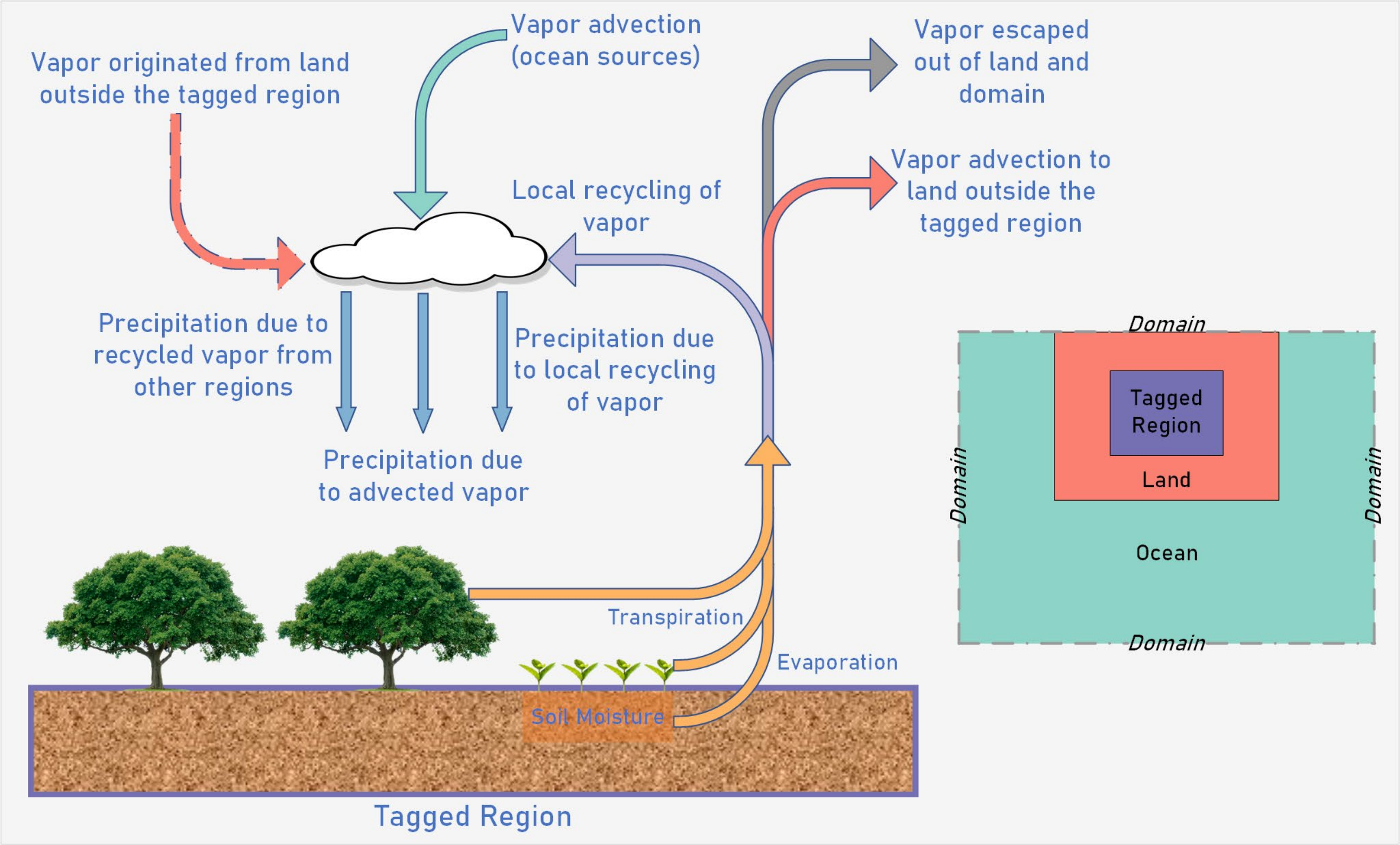


Maps at 1 km^2 resolution



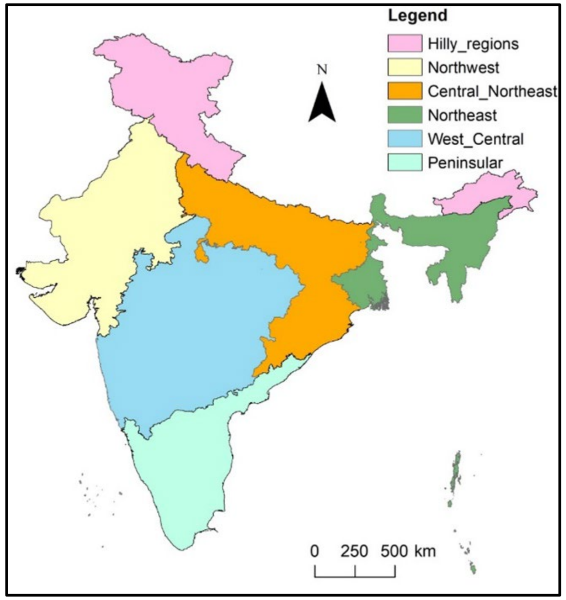
Karthikeyan & Mishra, 2021, RSE

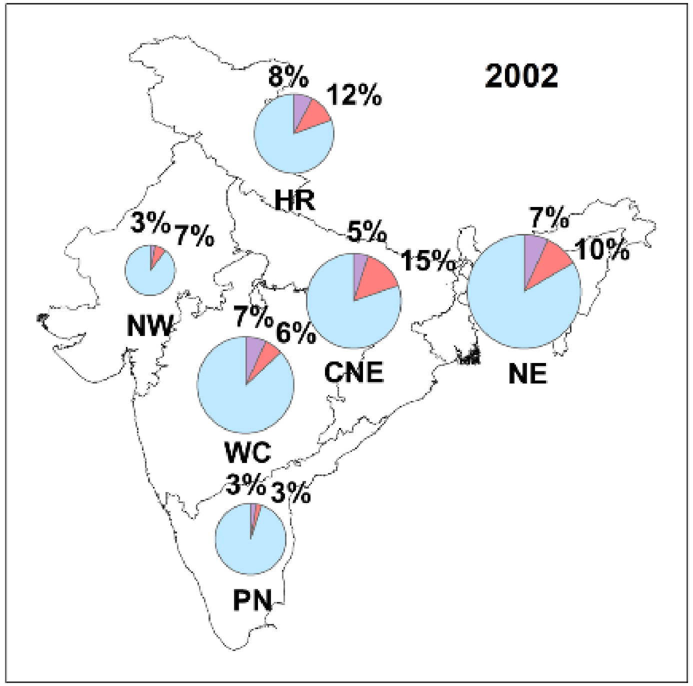
Land Atmosphere Interactions – Influence on Precipitation

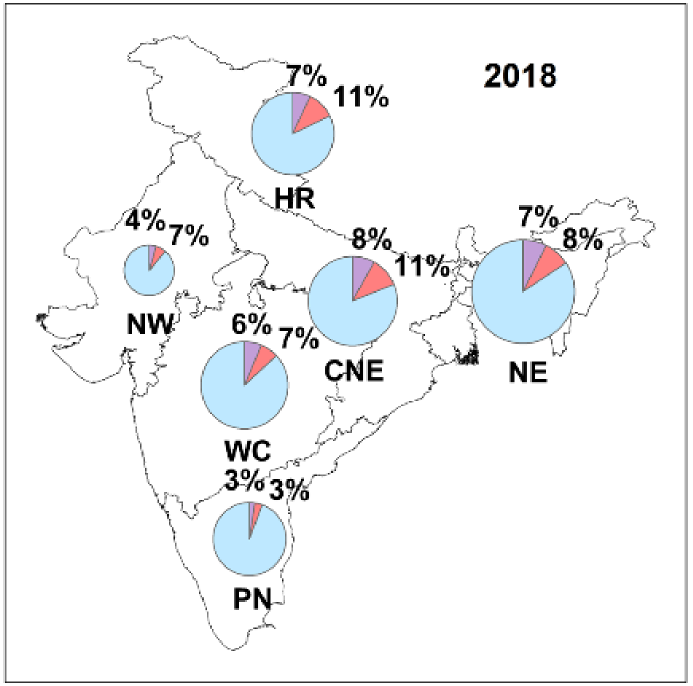


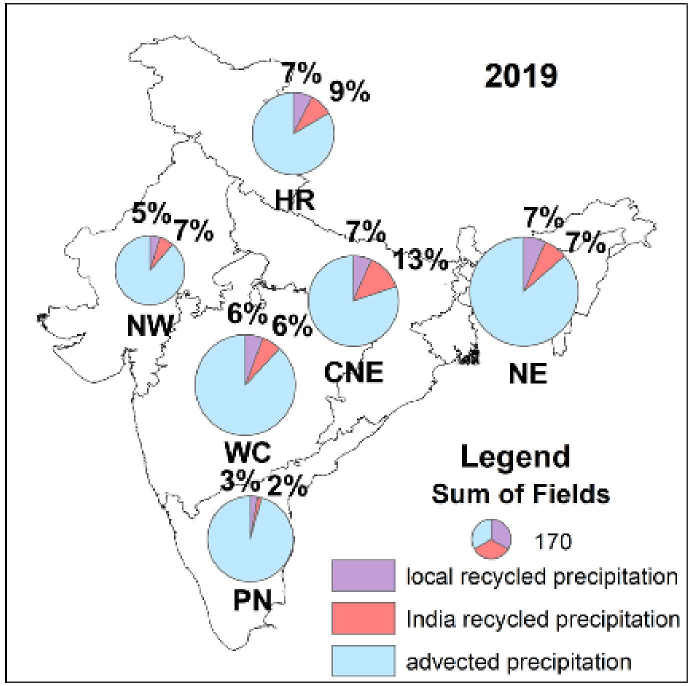
Navale & Karthikeyan, Under Review

Inter-Regional Exchanges of Recycled Precipitation



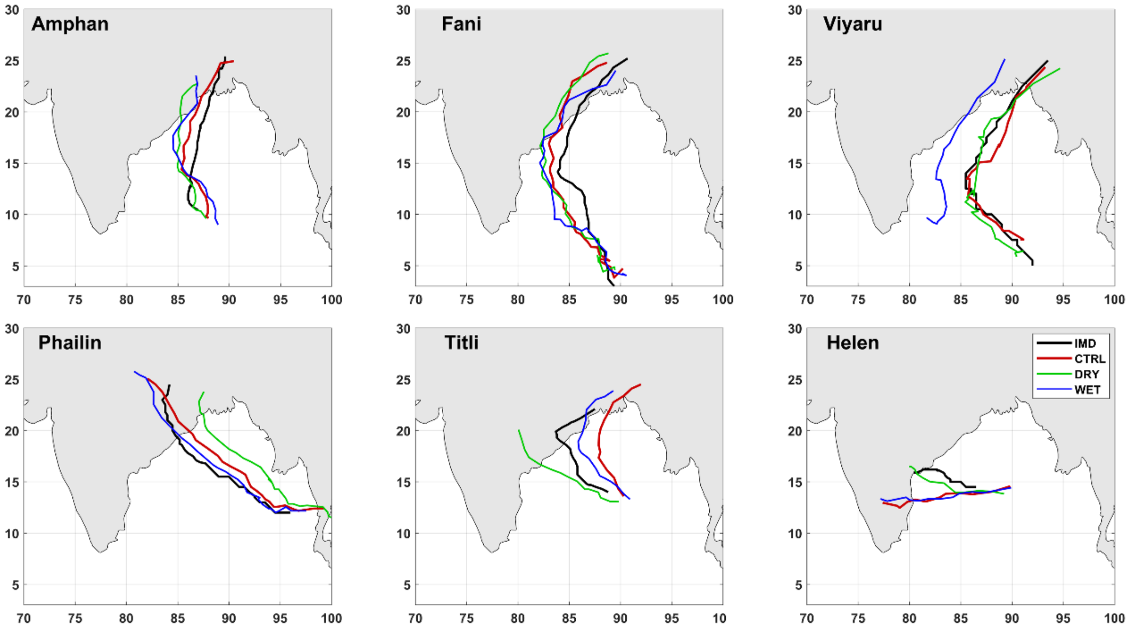


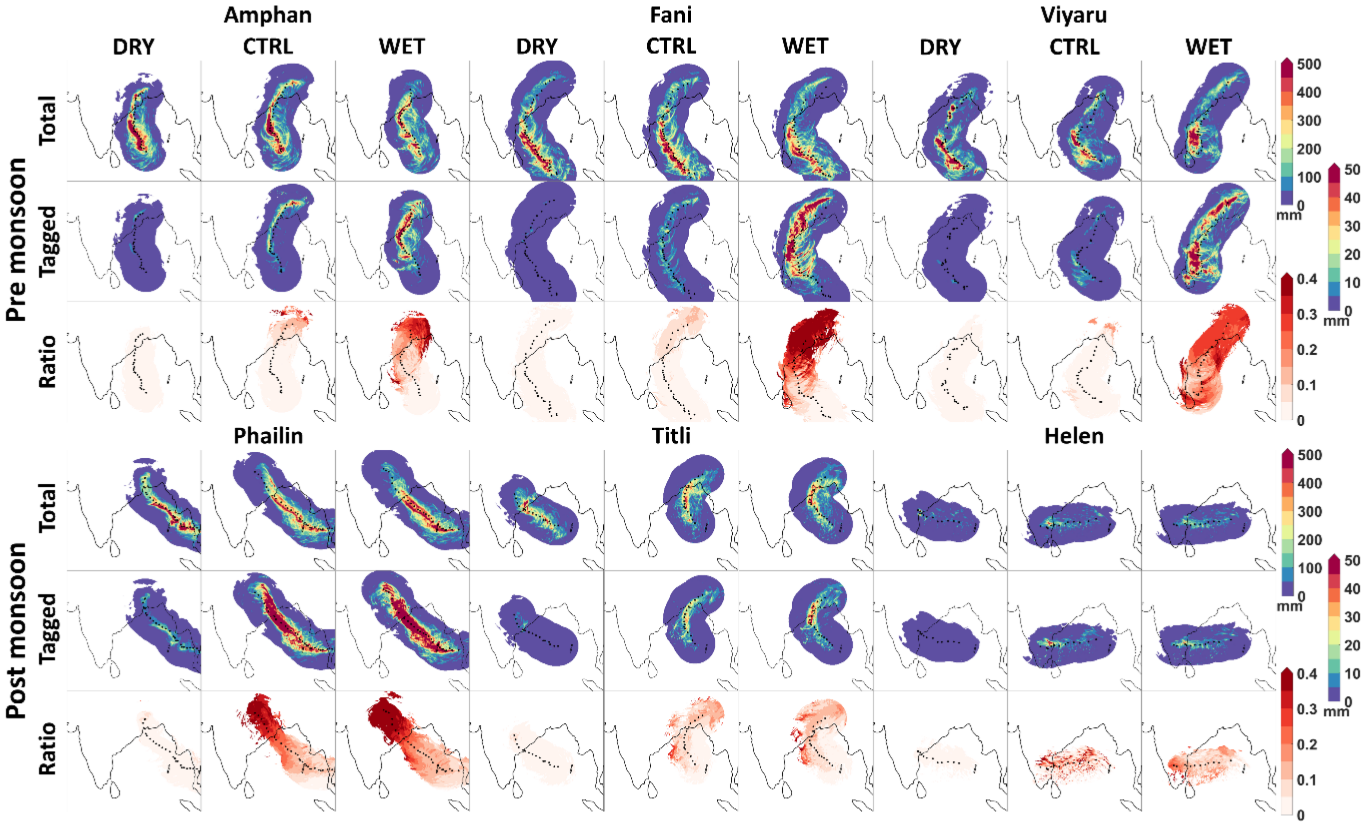




Navale & Karthikeyan, Under Review

Role of Soil Moisture in Evolution of Tropical Cyclones

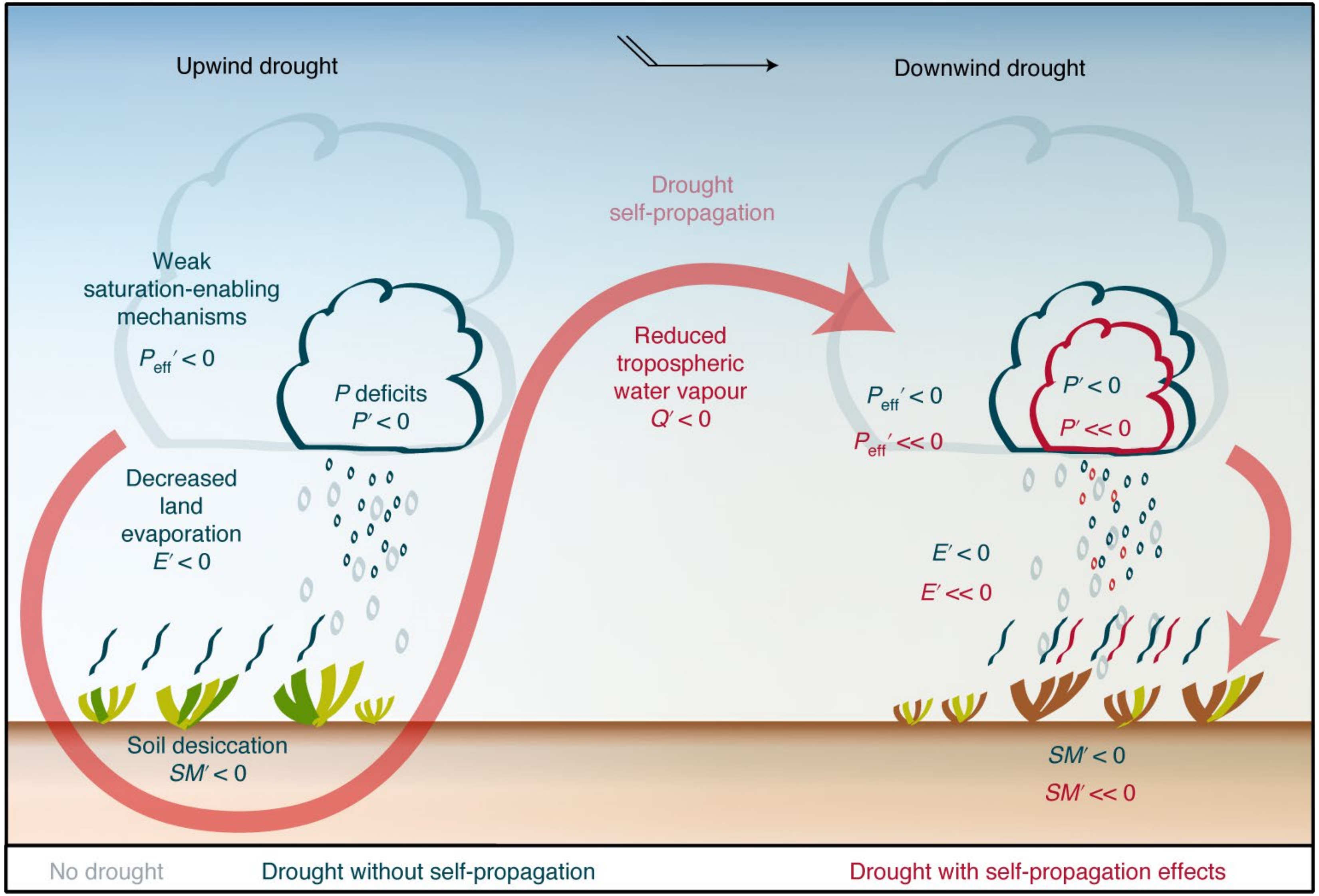




The recycling ratio post-landfall is around 5-10% for the pre-monsoon TC, and around 20-30% for post-monsoon TC originating in the BoB.

Navale & Karthikeyan, Under Review

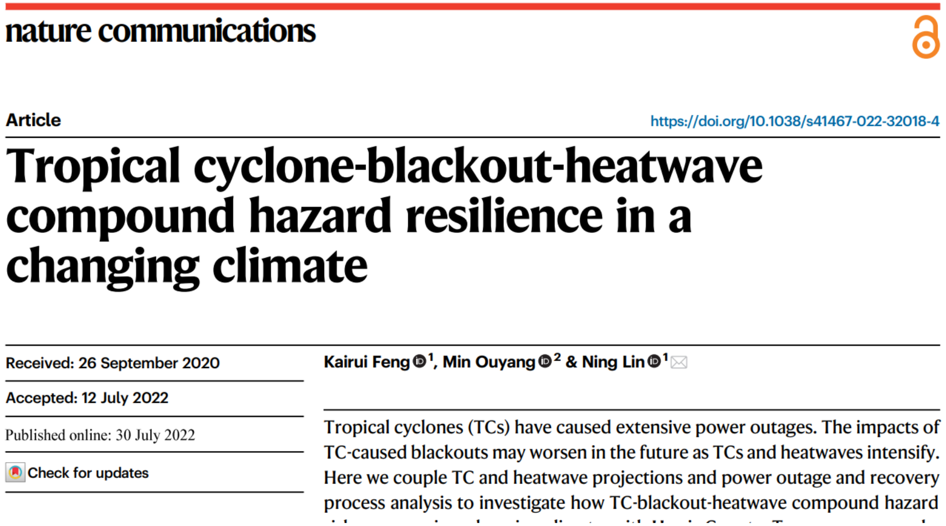
Drought Propagation



Schumacher et al., 2022, Nat. Geosc.

Future Scope

- Use of Vegetation Water Content as vegetation indicator to complete soil-plant-atmosphere continuum for better assessment of ecosystem's response to droughts
- Robust causal analysis has to be carried out to determine causal links between factors that lead to droughts (Correlation is not causation!)
- Spatial transport mechanisms of atmospheric vapor to be considered while assessing spatial propagation of droughts
- Increased efforts to estimate soil moisture in deeper layers, which include changes due to natural and anthropogenic forcing (better assimilation strategies?)


nature communications

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Tropical cyclone-blackout-heatwave compound hazard resilience in a changing climate

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Check for updates

Kairui Feng[1], Min Ouyang[2] & Ning Lin[1]

Tropical cyclones (TCs) have caused extensive power outages. The impacts of TC-caused blackouts may worsen in the future as TCs and heatwaves intensify. Here we couple TC and heatwave projections and power outage and recovery process analysis to investigate how TC-blackout-heatwave compound hazard

Thank You