A study of soil water dynamics in extremely dry and wet rainfall conditions over the Core monsoon zone of India.

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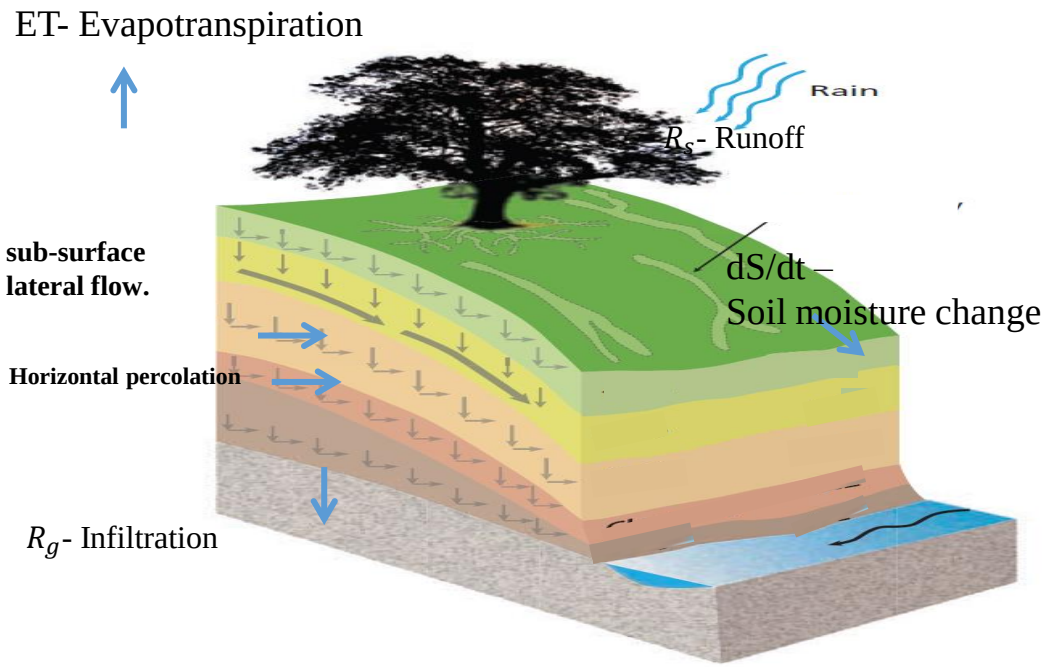
- **Motivation:**
- Understand the surface and subsurface processes and their linkage to land-atmosphere energy exchanges.
- SM affects regional hydro-meteorological extremes.

- **Objectives:**
- Analysis of Soil water dynamics using Soil moisture (SM)observations and thereby surface-subsurface coupling and SM memory.

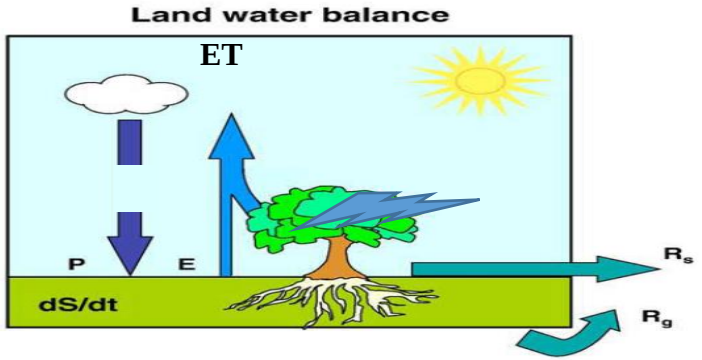
- Understanding of SWD during regional extremes on the successive winter and pre-monsoon conditions.

Introduction: Soil Water Dynamics (SWD)

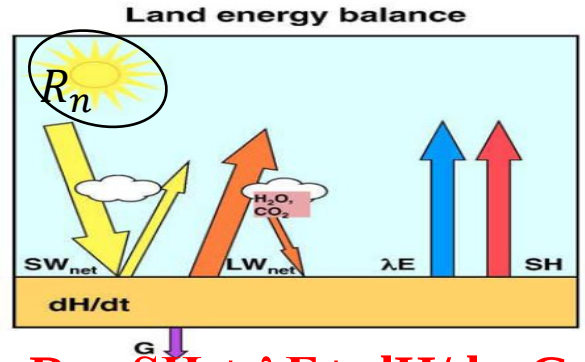
- The water stored on land (soil moisture) is a key variable controlling numerous processes and feedback loops within the climate system.
- Soil moisture (SM) plays a important role in the earths hydrological cycle and surface energy balance.
- Soil moisture not only regulates partitioning of net radiation into sensible, latent, ground heat flux and surface heat change but also it will help in partitioning of precipitation into Evapotranspiration, infiltration, changes in soil moisture and runoff.



Schematic of the land water balance (left) and land energy balance (right) for a given surface soil layer.



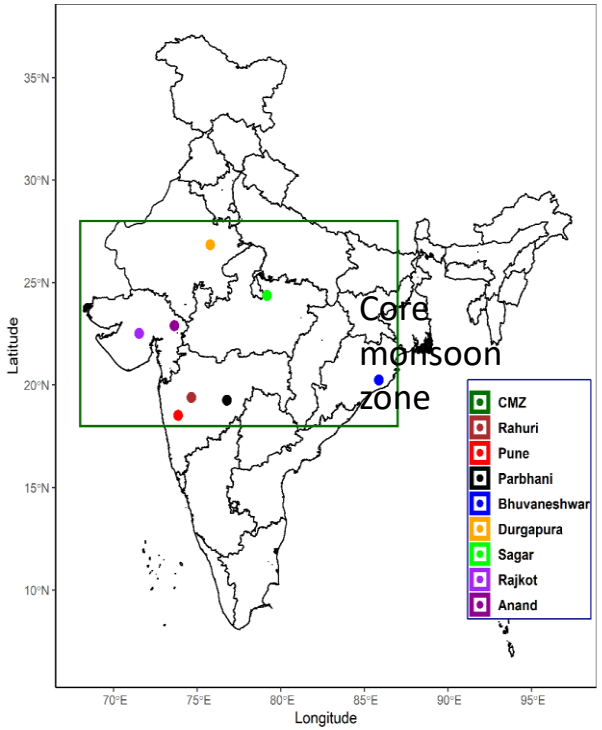
$$P=ET + R_s + R_g + dS/dt$$



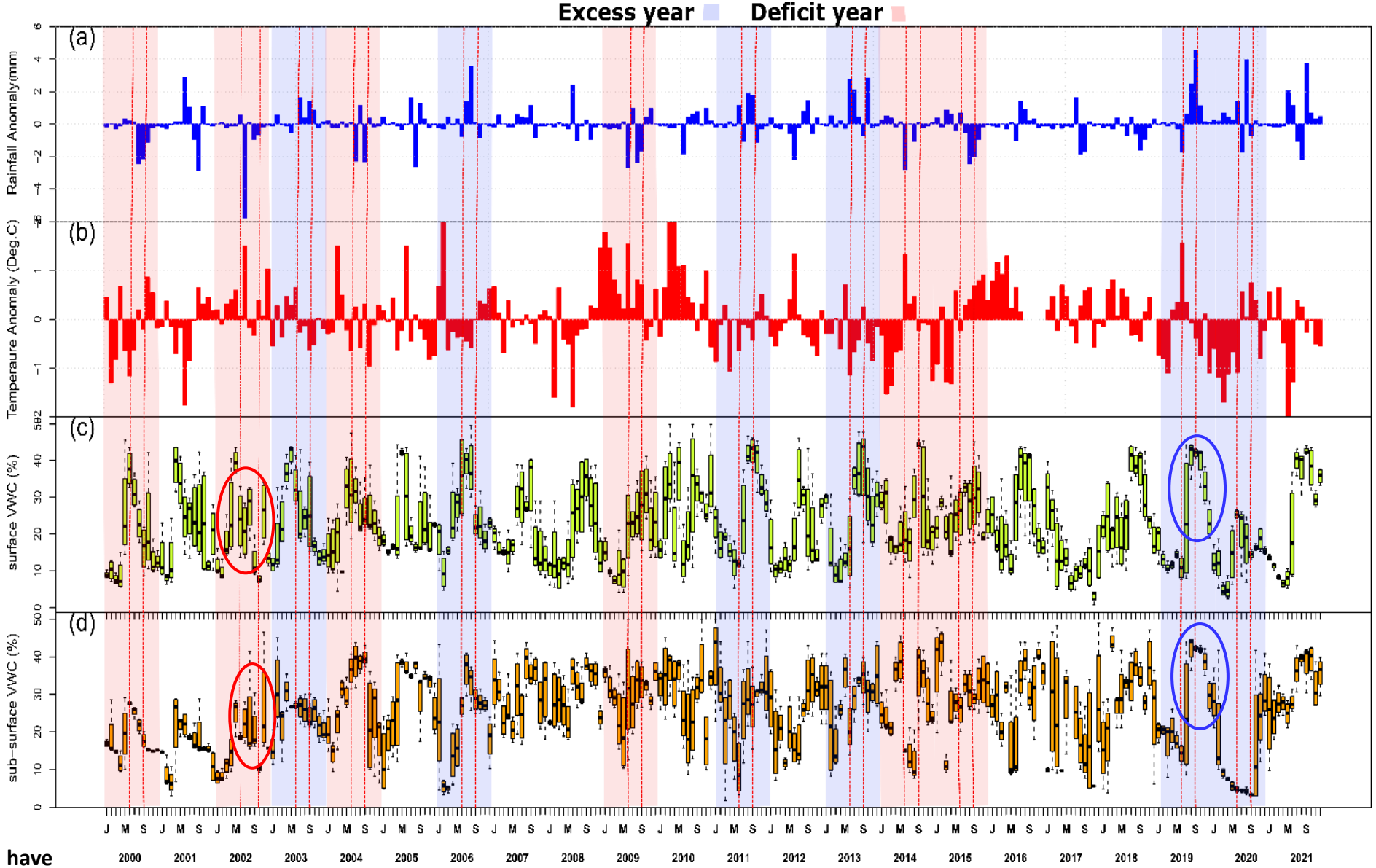
$$R_n = SH + \lambda E + dH/dt + G$$

IPCC AR4, Seneviratne 2010, Earth-Science Review

Hydro-meteorological observations over the Study Region: Core monsoon zone (CMZ)



Various IMD Hydro-meteorological observation stations across the core monsoon zone (CMZ) of India (represented by distinct colour inside the CMZ box).

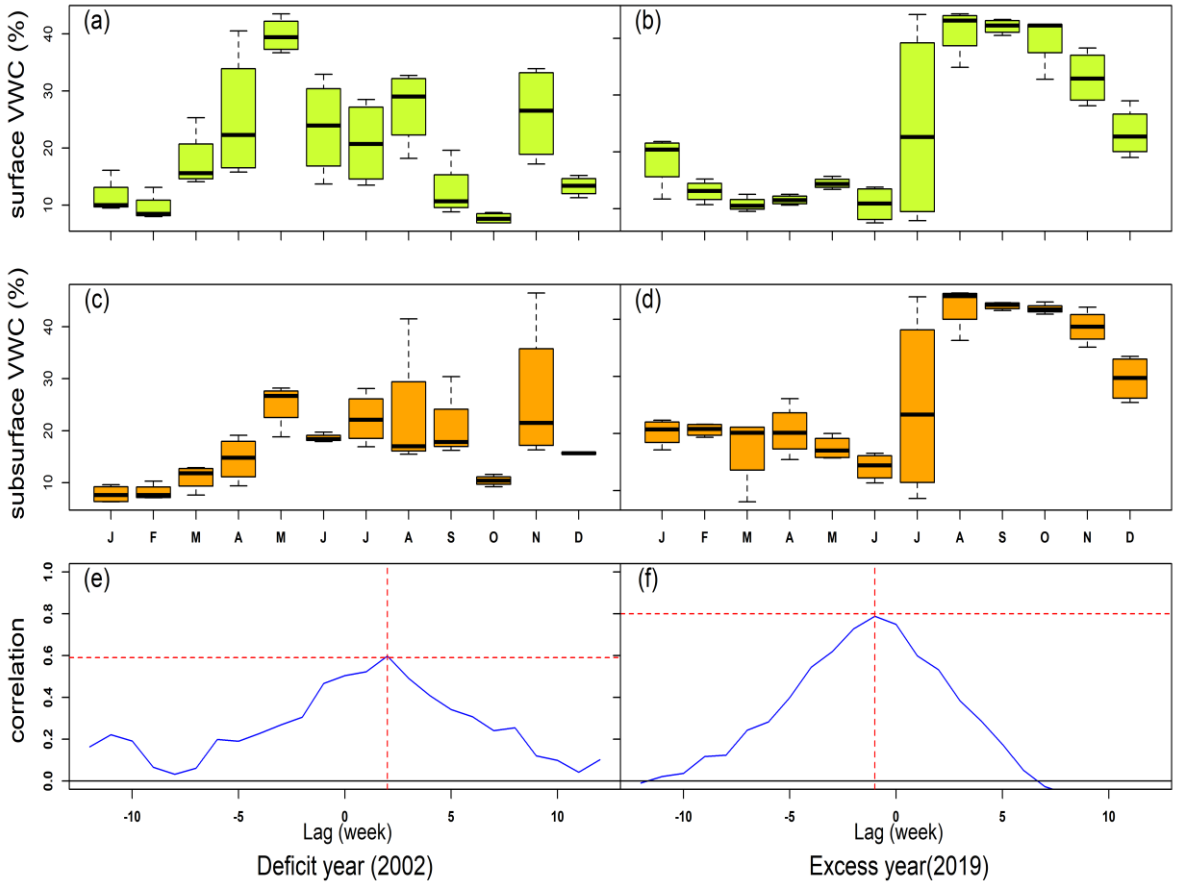


How does SM variations regulates SWD and have an impact on the successive seasonal conditions?

Goswami et al., 2023 (accepted in Jr. ERL)

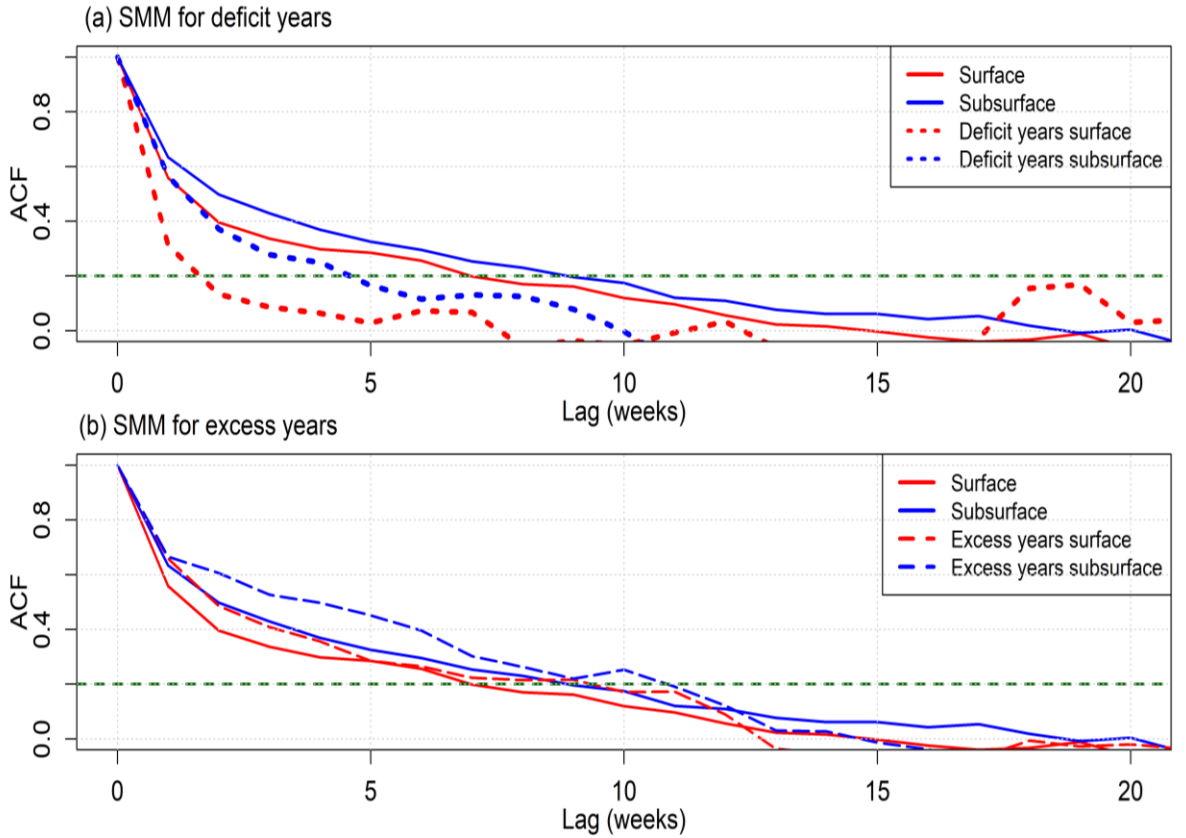
Time series of monthly (a) rainfall anomaly (mm) and (b) 2M temperature anomaly (°C). Monthly statistics represented as Box and Whisker plots for weekly (c) surface, and (d) subsurface volumetric SM (%) content based on IMD in-situ observations over the CMZ of India for the period 2000–2021. The dotted red line indicates the monsoon months (JJAS). The shaded area in red and blue indicates the deficit and excess years respectively.

Surface and subsurface Soil moisture coupling:



Upper and middle panels represent monthly surface and subsurface SM variability respectively as a Box and Whisker plot. Last panel shows lag-correlation between surface and subsurface SM. All the left panels (a), (c) and (f) are for the deficit year (2002). Whereas all the right panels (b), (d) and (f) are for the excess year (2019).

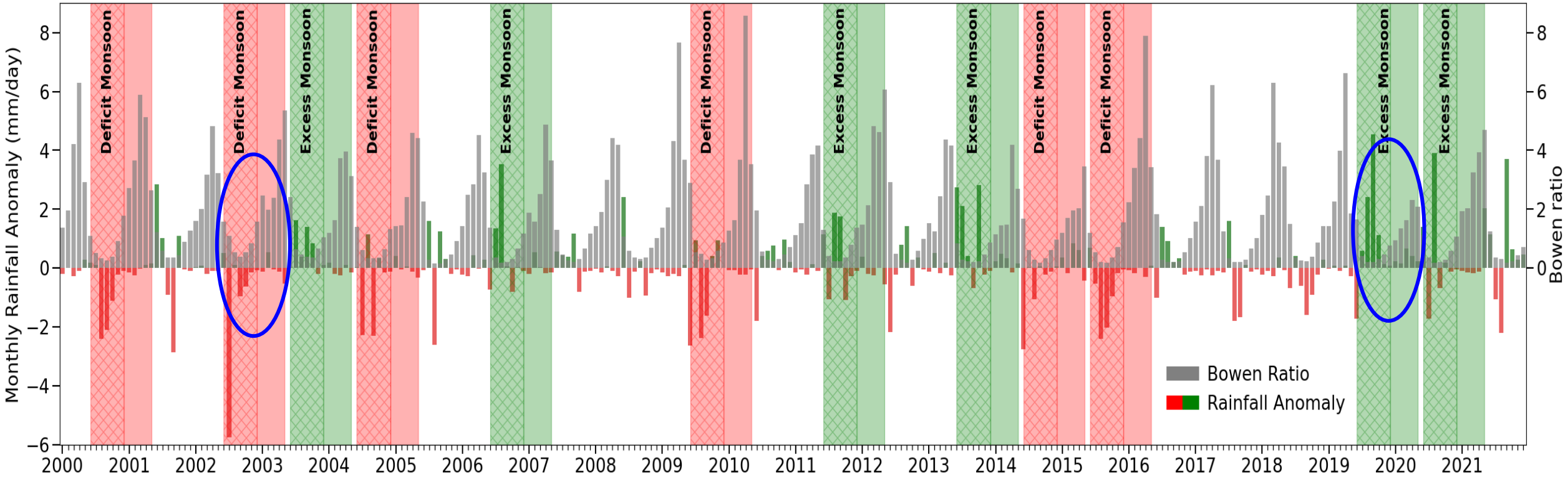
SM memory during deficit and excess years:



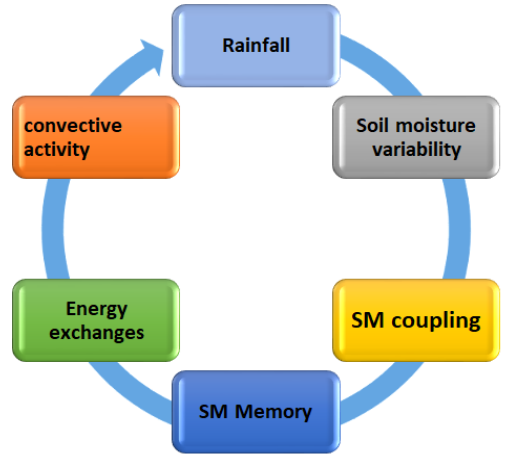
Estimates of surface (Red) and subsurface (Blue) SM persistence timescale (Soil moisture memory) during the period of 2000-2021 using 52-week lag auto-correlation function over the CMZ of India. (a) Deficit years are represented by the dotted lines and (b) excess years by the dashed lines. The dashed green line indicates 95% significance level.

Goswami et al., (conditionally accepted in Jr. ERL)

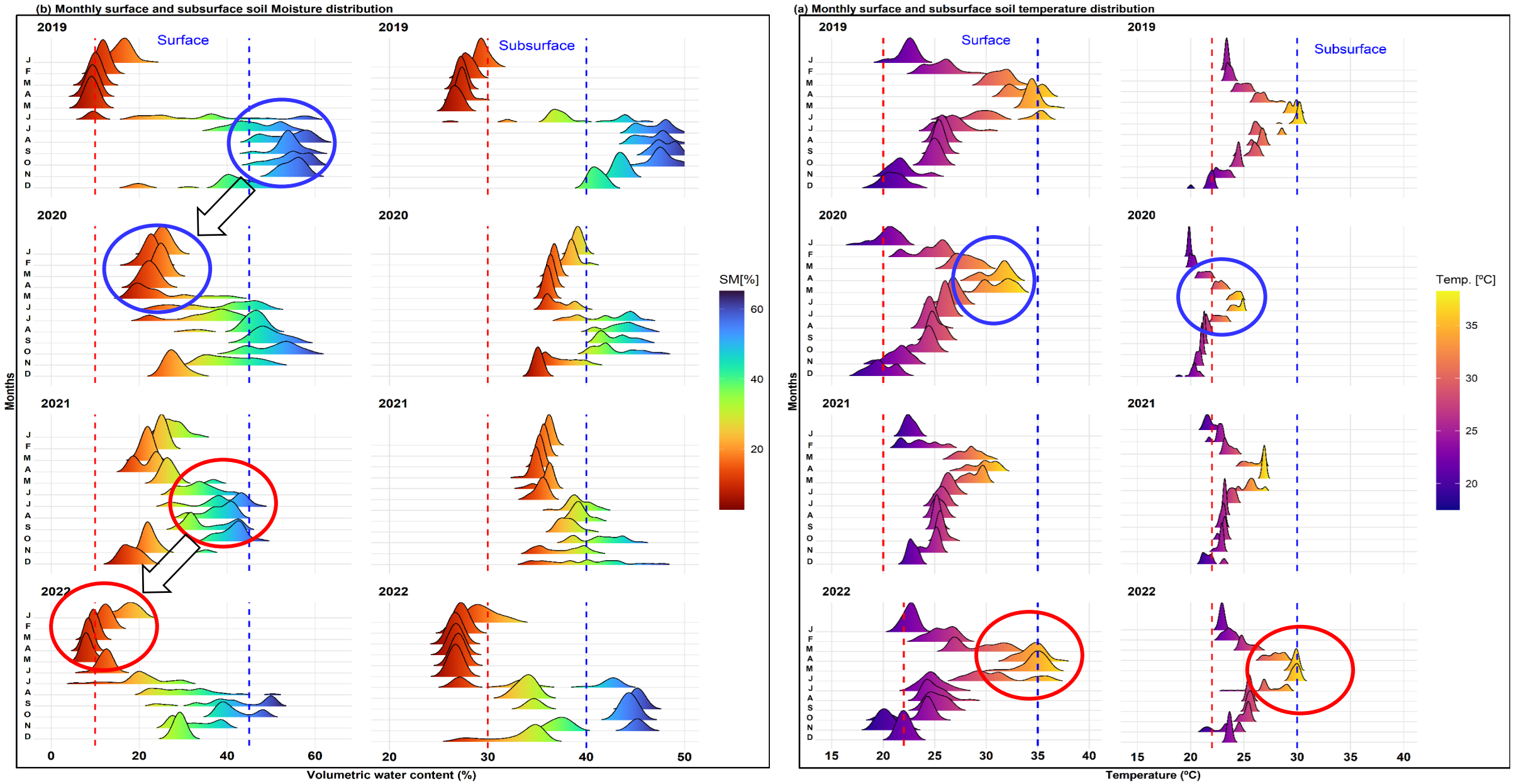
Land-atmosphere energy exchanges in successive seasons:



The monthly mean rainfall anomaly (mm/day) and Bowen ratio (ratio of sensible to latent heat flux) are shown for the period of 2000-2021 over the CMZ of India. The dark red and green colour bars indicate negative and positive rainfall anomalies respectively, while grey bars indicate Bowen ratio. The hatched region with red (green) shading represents the June-December months of deficit (excess) years. Whereas the plane shaded region with red(green) depicts the successive winter and pre-monsoon season.



Insights into the soil water dynamics:



Summary and Conclusion

- We implemented surface and subsurface observations of SM over the CMZ of India (IMD) during 2000 – 2021 and at COSMOS-IITM, Pune site during 2019 – 2022 to analyze SWD. These unique observations are essential for regional climate change.

- Along with re-analysis and model data products, observations of SM reveal - Seasonal and sub-seasonal variability in SM may influence regional weather extremes.

- **Surface – subsurface coupling with corresponding SMM characteristics shapes soil water dynamics during variable rainfall conditions. We found that this regulates convective activities during successive winter and pre-monsoon conditions:**
- excess condition that persist over post monsoon period reflects in increased coupling strength and longer persistence of the subsurface SM memory.
- This essentially improves surface SM availability during successive winter and pre-monsoon season and regulate the turbulent heat fluxes. Increased latent heat and ET drive conditions that are conducive for convective activities.
- On the contrary in successive pre-monsoon seasons of the deficit year, deprived SM makes room for sensible heat and suppresses convective activities.

- Our study therefore establishes an intricate link between **Surface and subsurface SM** and its **role in determining regional weather and climate conditions.**