Exploring the Combined Influence of ENSO, IOD, and MJO on the Indian Summer Monsoon Dynamics

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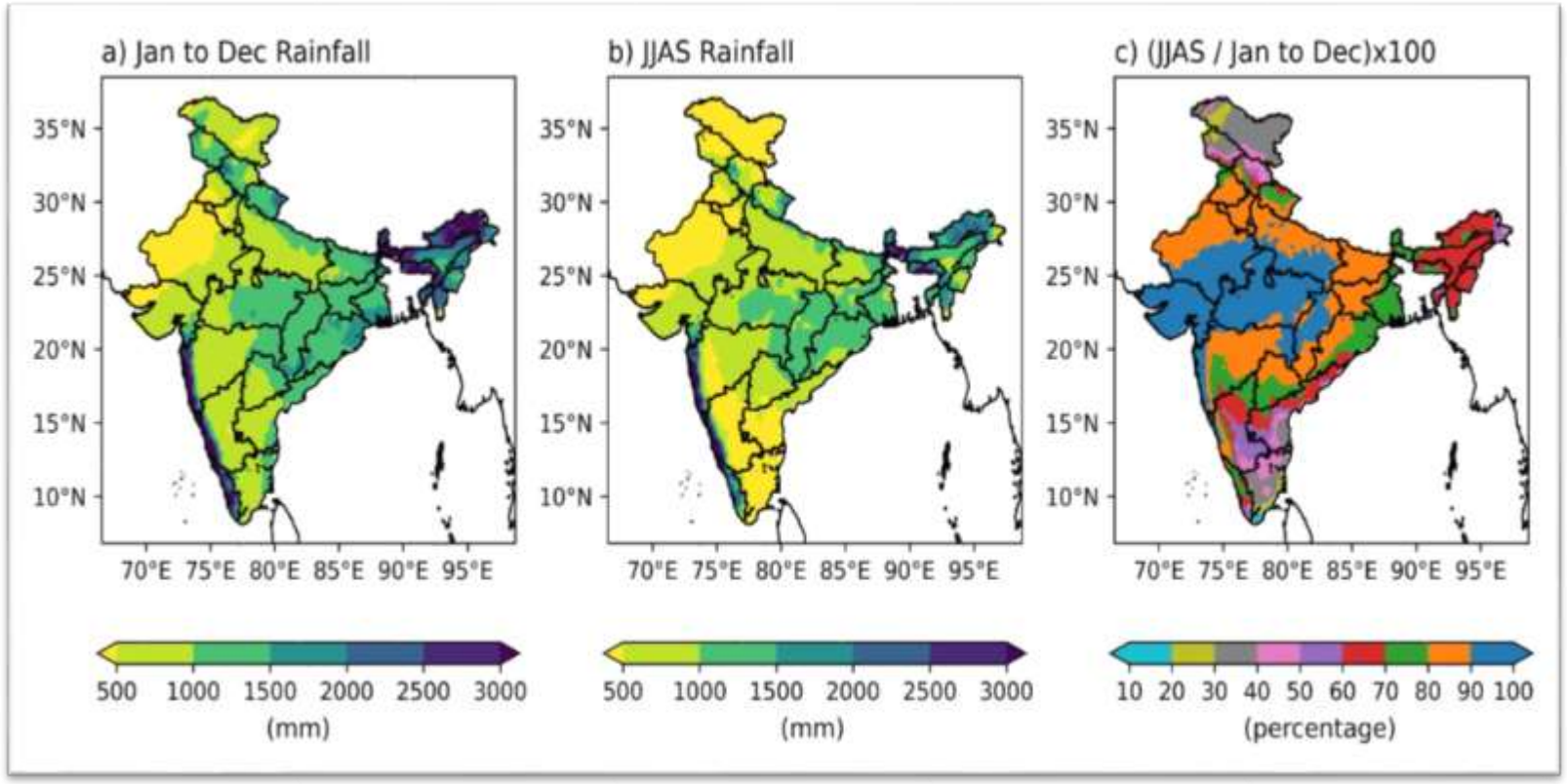
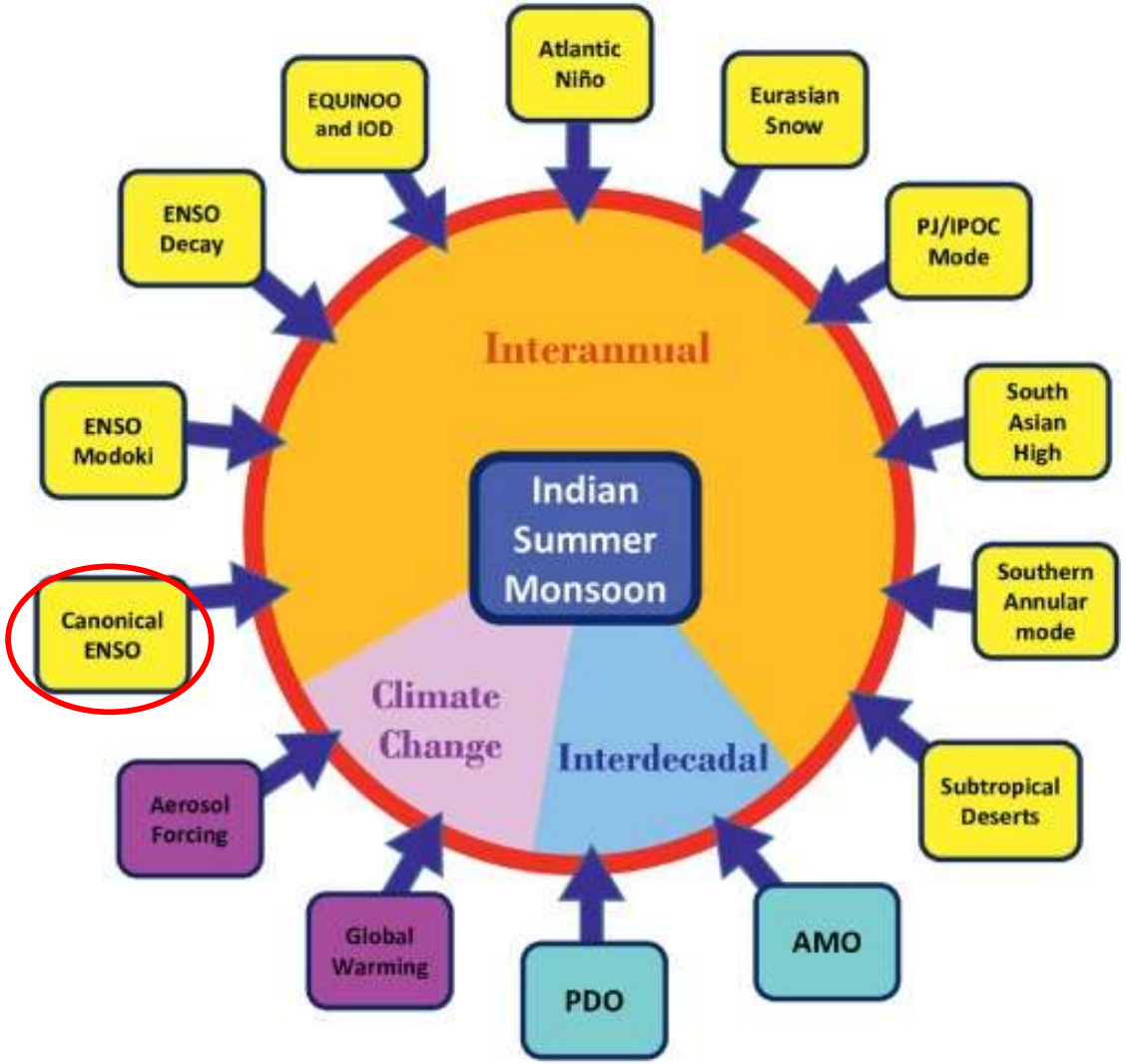
Introduction



Indian summer monsoon rainfall (ISMR), from June to September (JJAS) season, is a land-atmosphere–ocean coupled system that contributes about 70% of the total annual rainfall over India.

The prediction of spatio-temporal variation of the ISMR remains challenging due to the complex interplay of global teleconnections, intraseasonal variability, and regional land-atmosphere interactions.

Possible Climate Drivers for ISMR variability

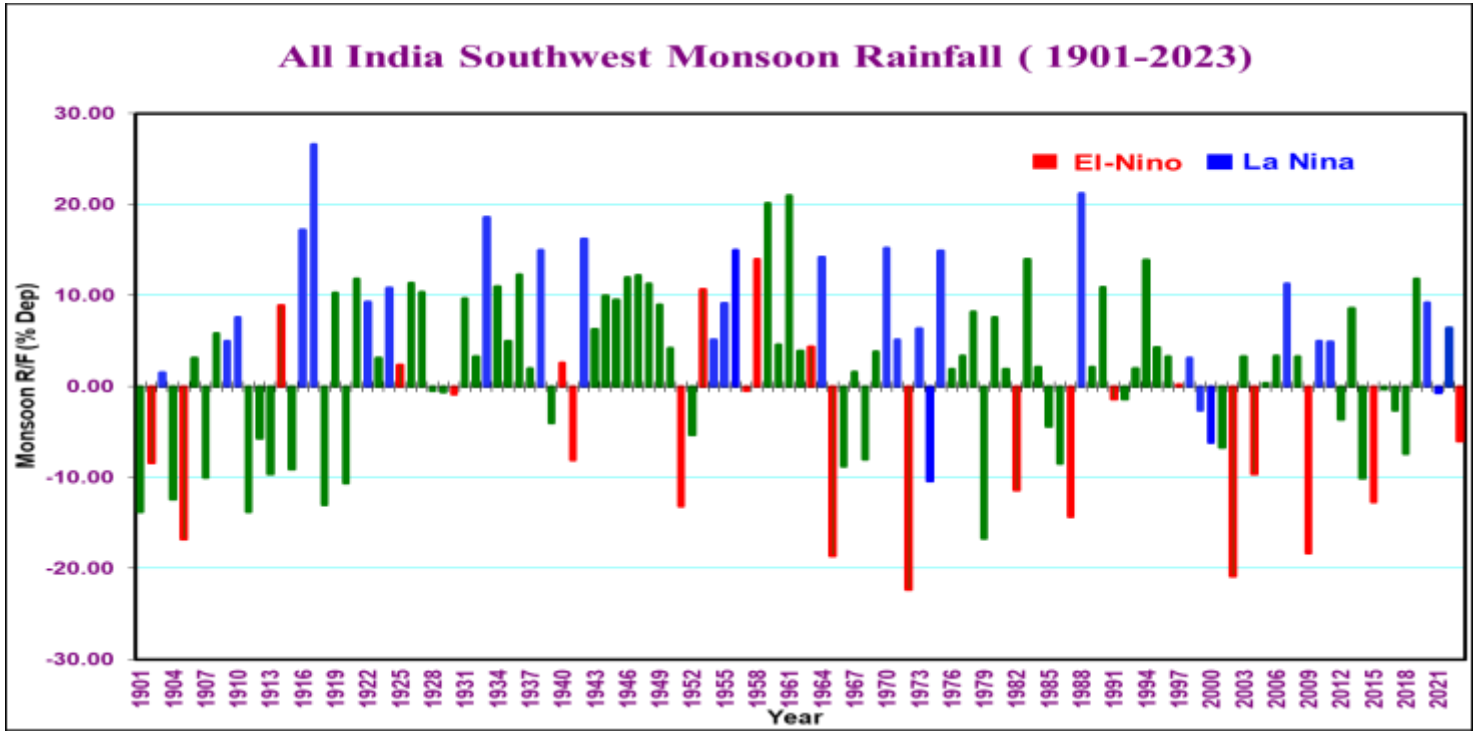


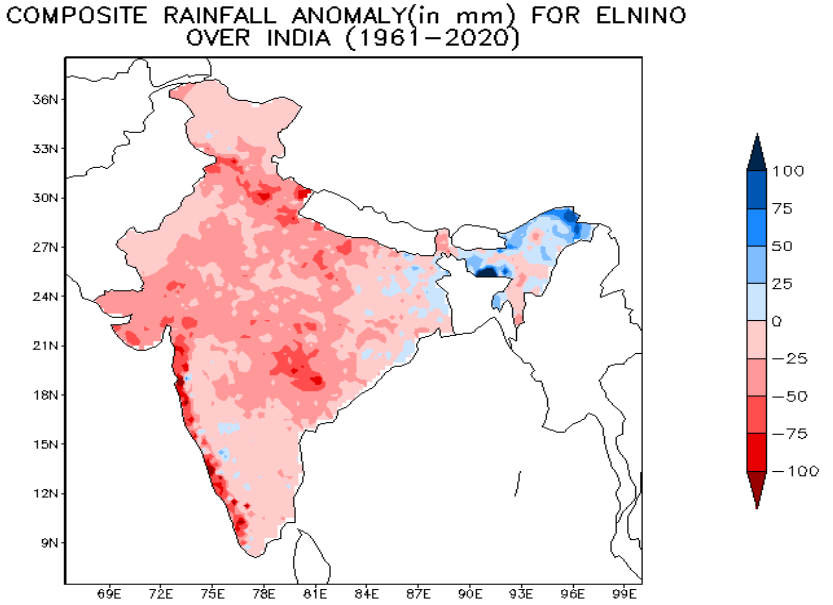
Chowdary et al., (2021)

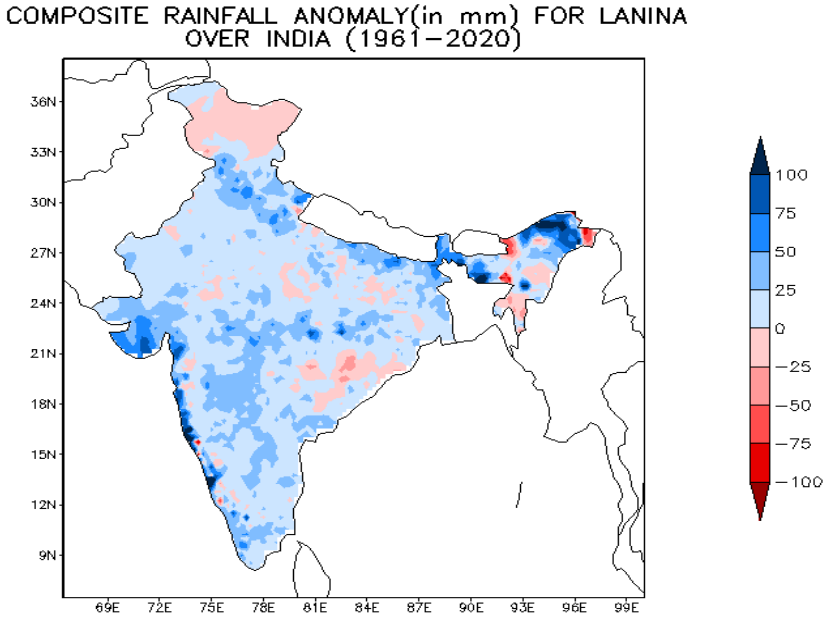
The prediction of ISMR at an interannual timescale depends on many factors, out of which the ENSO influence is the strongest.

Understanding the relative impact of these large-scale climate forcings on the ISMR each year is crucial for the improved predictions of the ISMR.

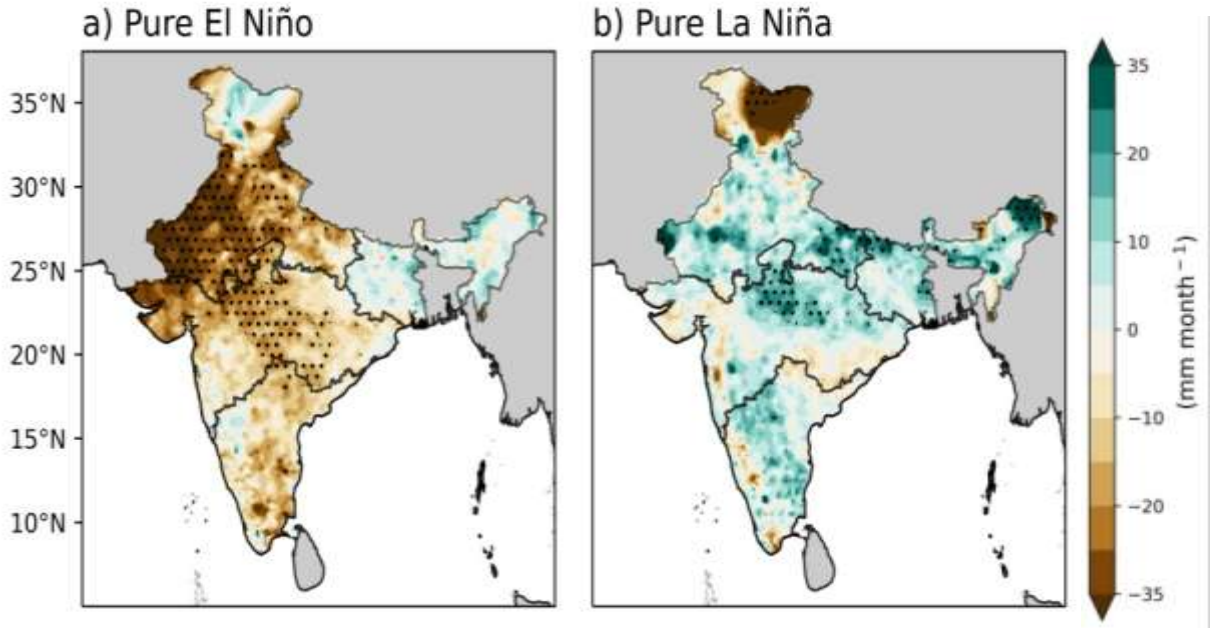
Interannual variability of Indian Summer Monsoon Rainfall (ISMR)

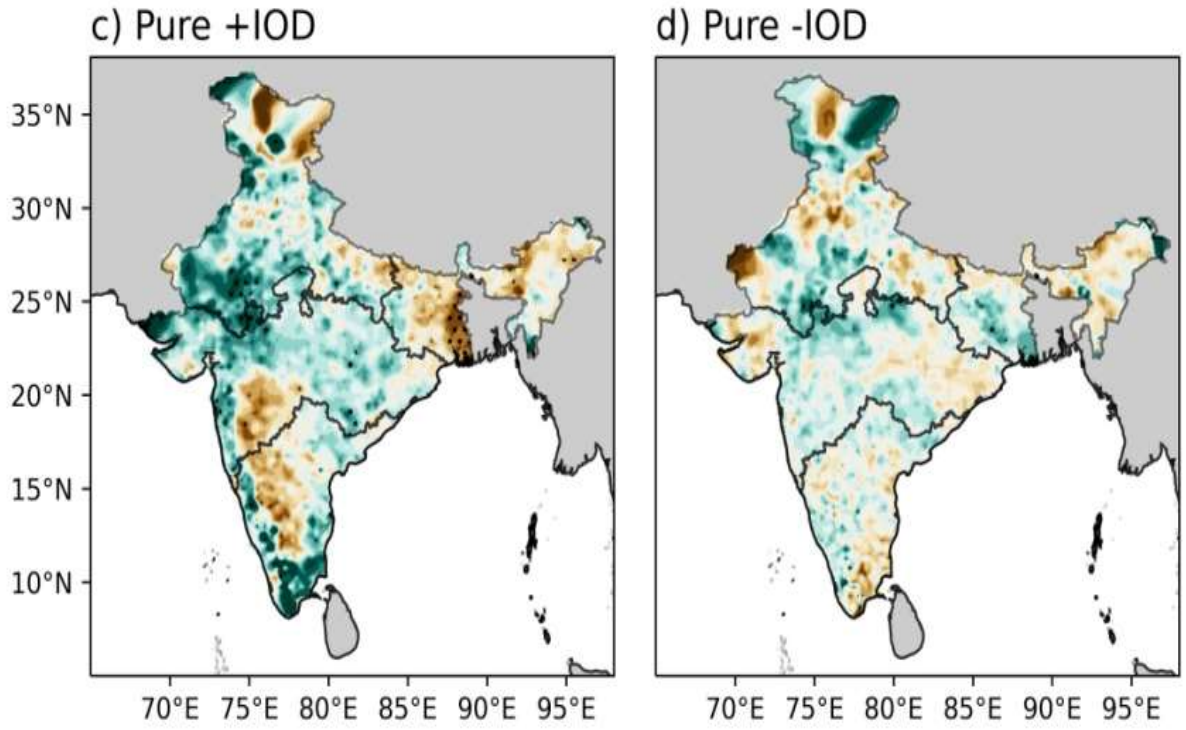






Composite rainfall anomaly for JJAS

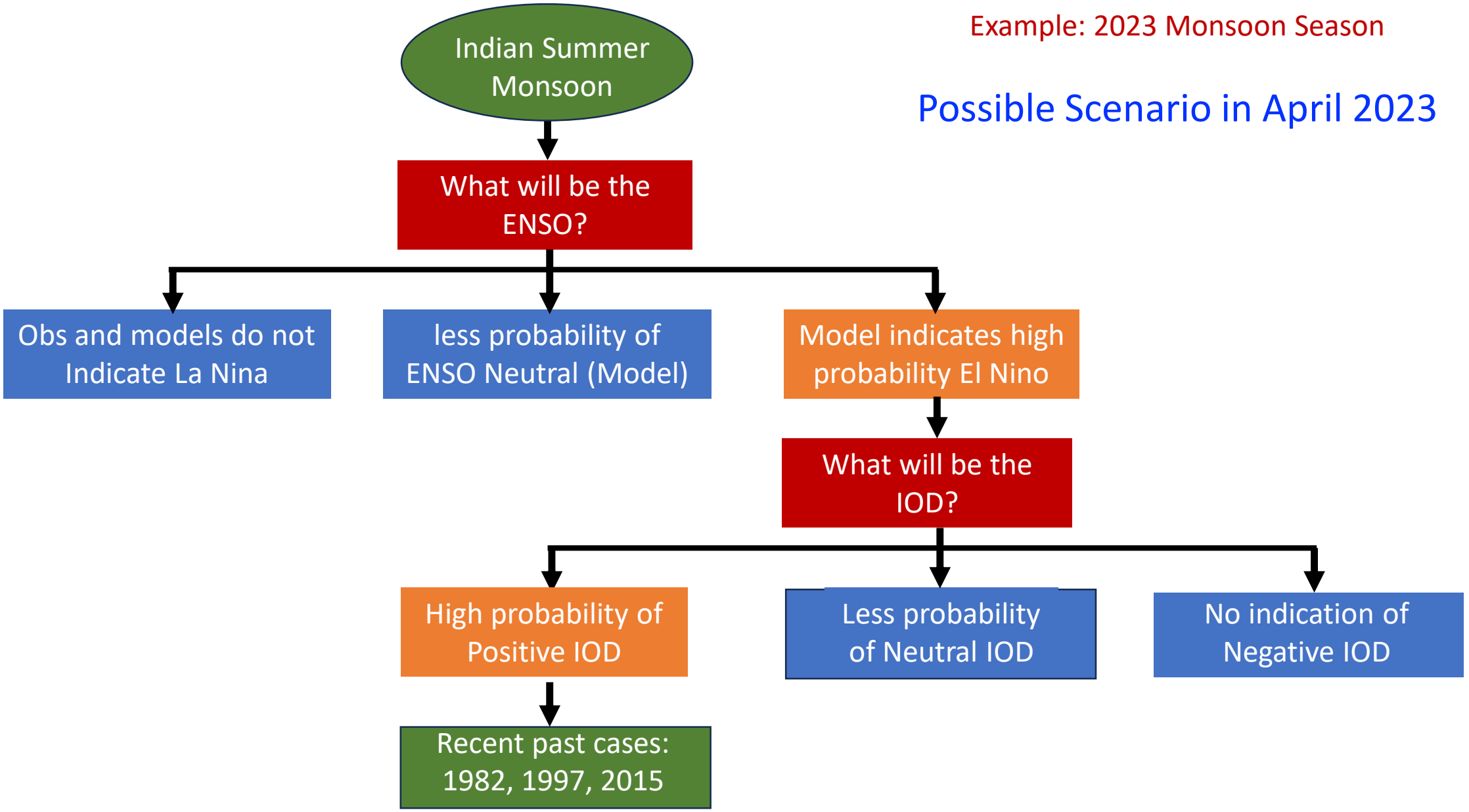




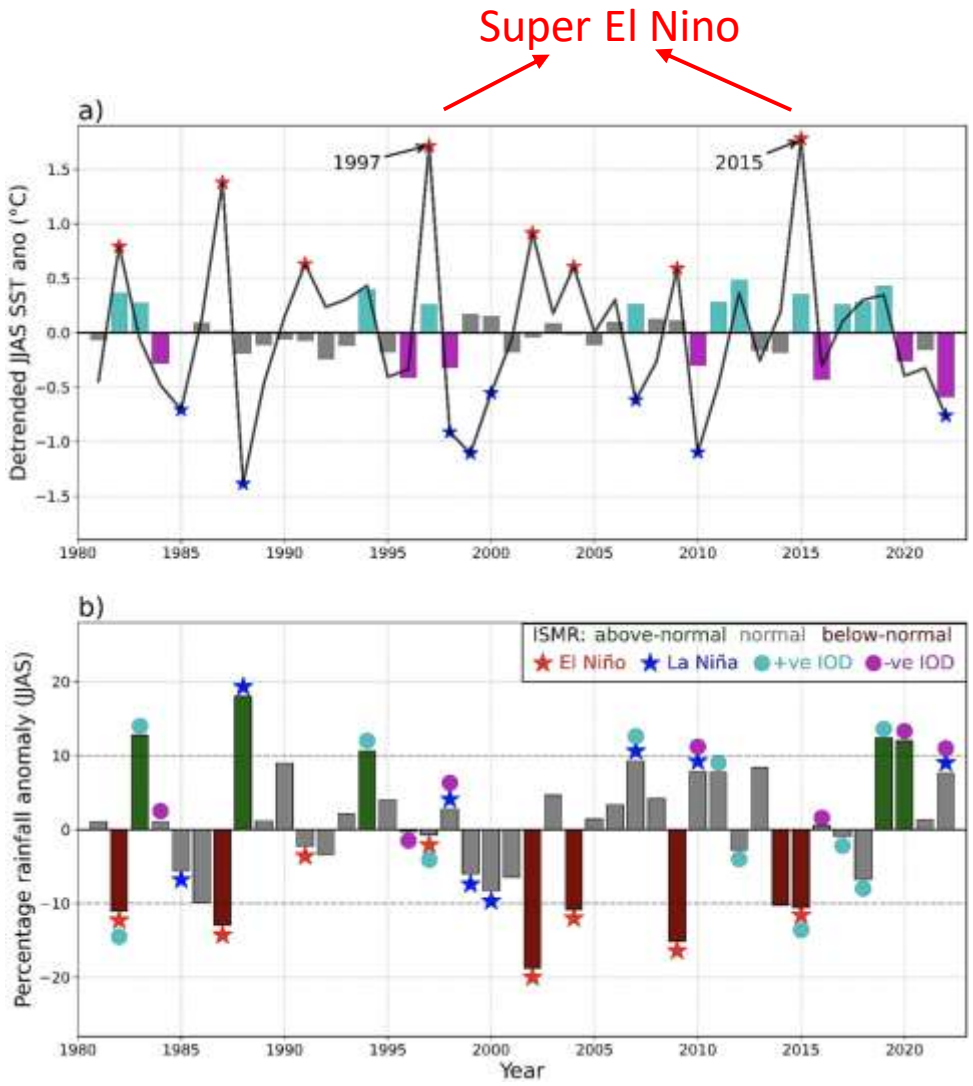
Indian Summer Monsoon and possible Large-scale Drivers

Example: 2023 Monsoon Season

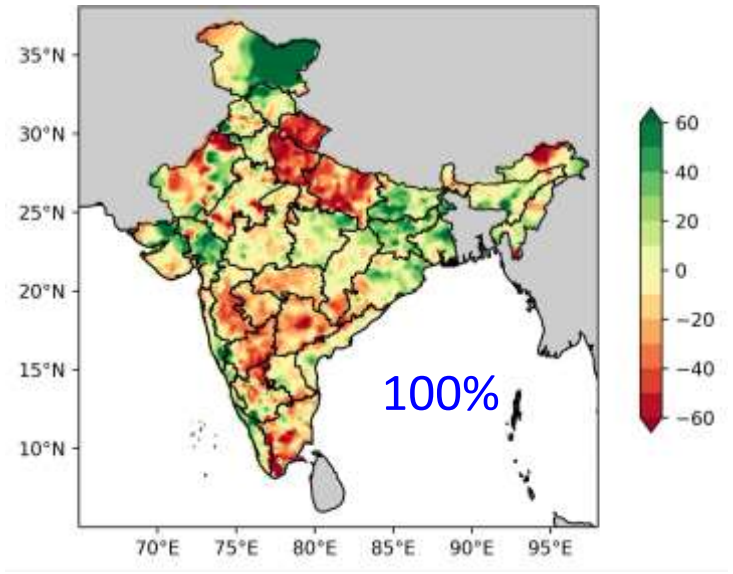
Possible Scenario in April 2023



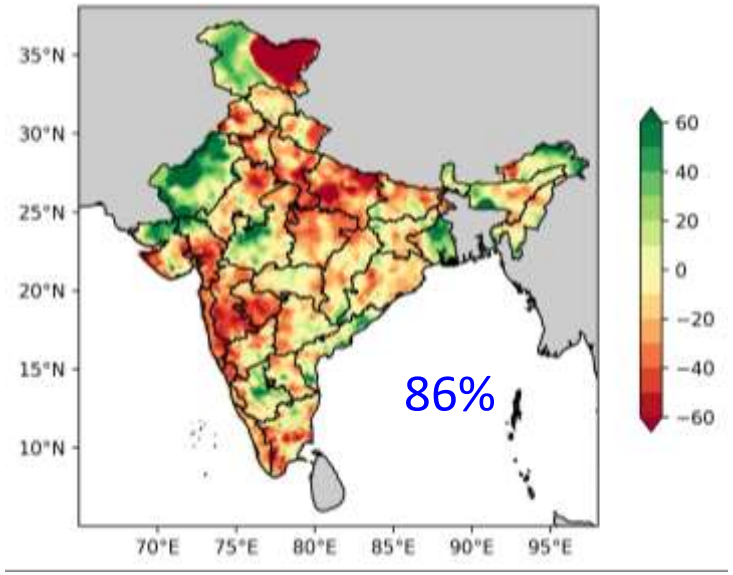
ENSO, IOD and ISMR (JJAS 1981-2022)



Before 2023, there were two such cases in the recent decades where such a super El Niño and positive IOD occurred together.



1997 (Normal)

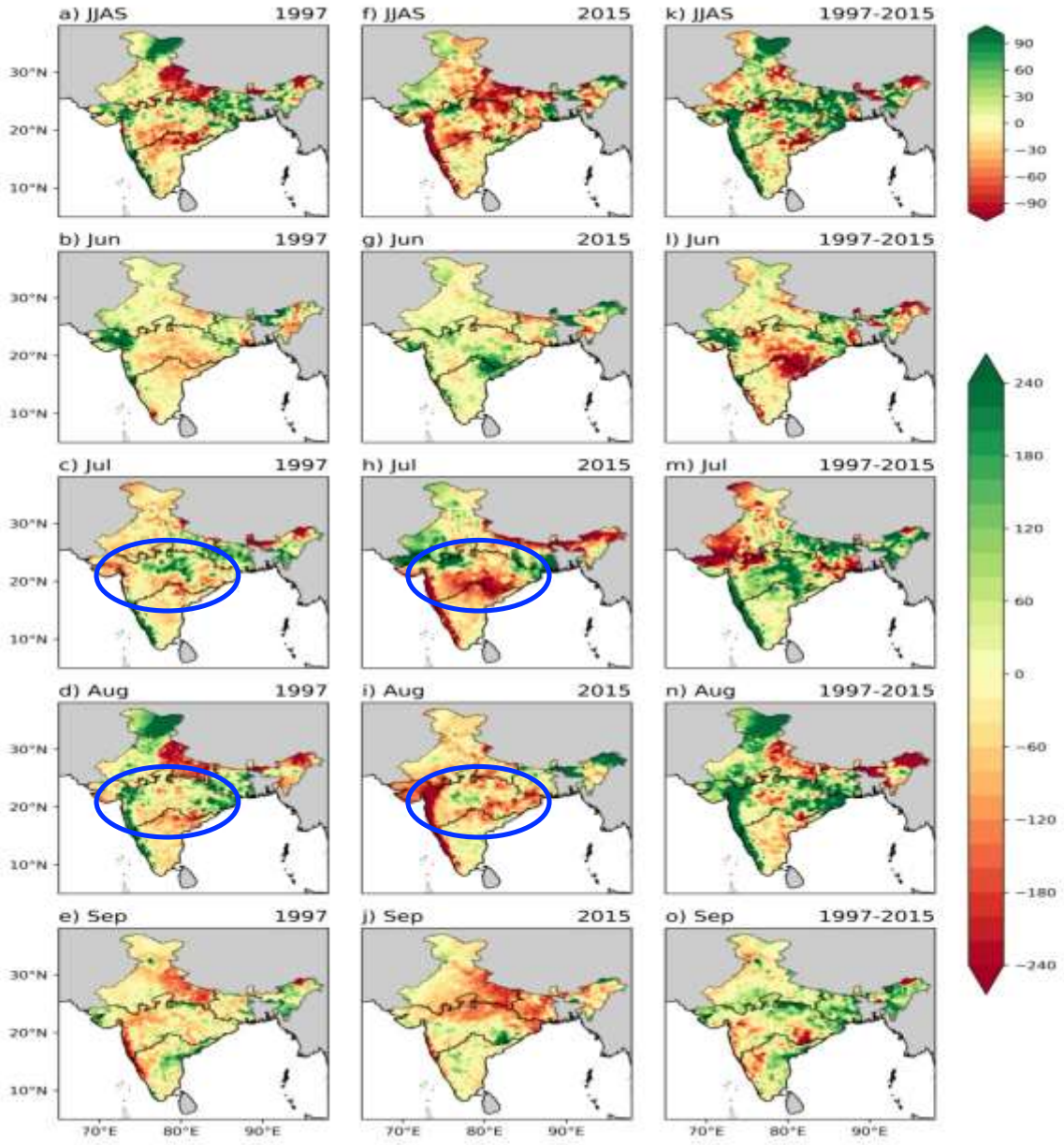


2015 (Deficient)

Monthly rainfall variation (June-Sep)

The rainfall was better during the active monsoon months (July and August) in 1997 whereas the rainfall was better during the onset and withdrawal months (June and September) in 2015.

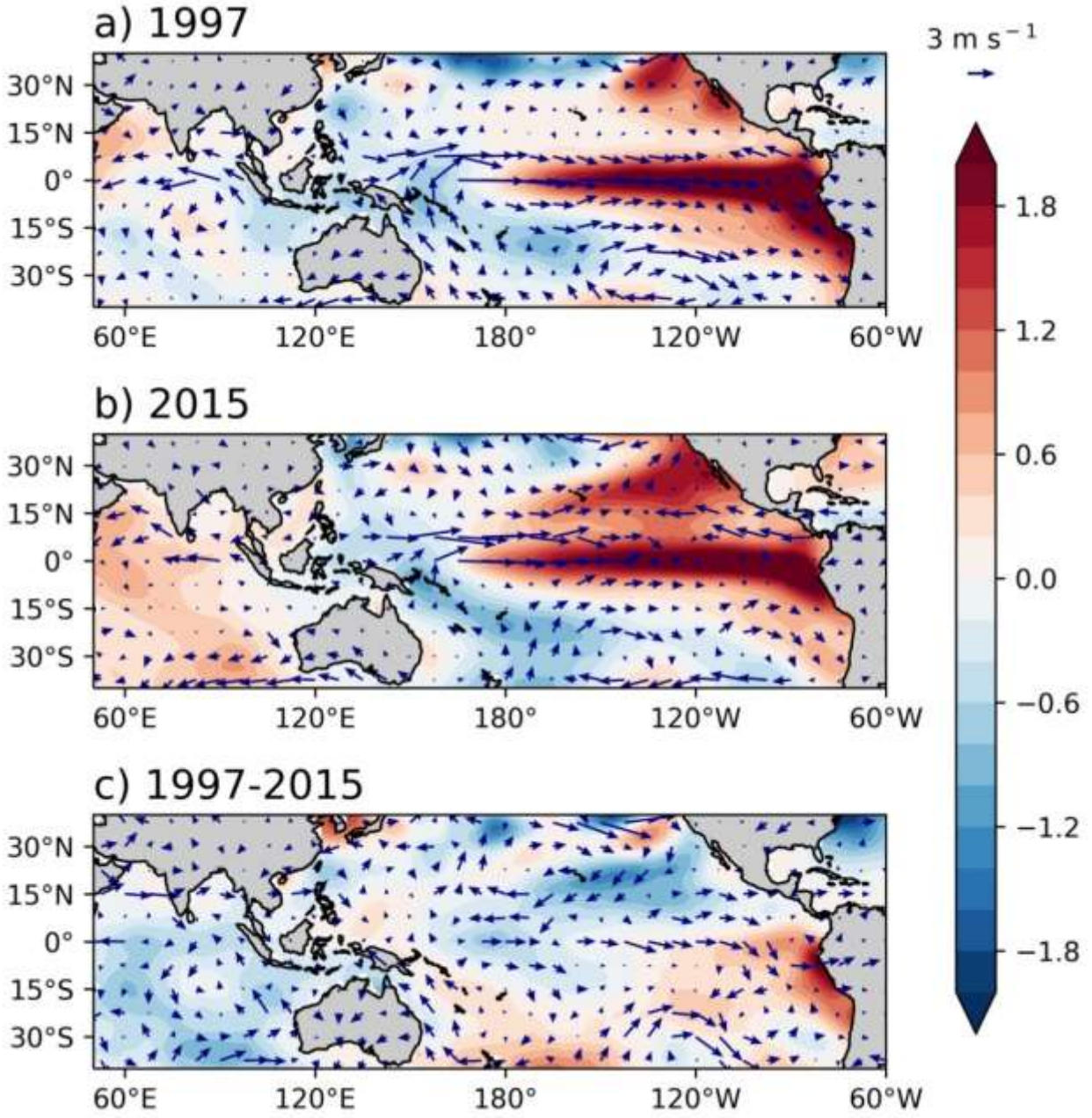
The higher rainfall received in India during the active monsoon months in 1997 contributed to more seasonal rainfall compared to 2015.



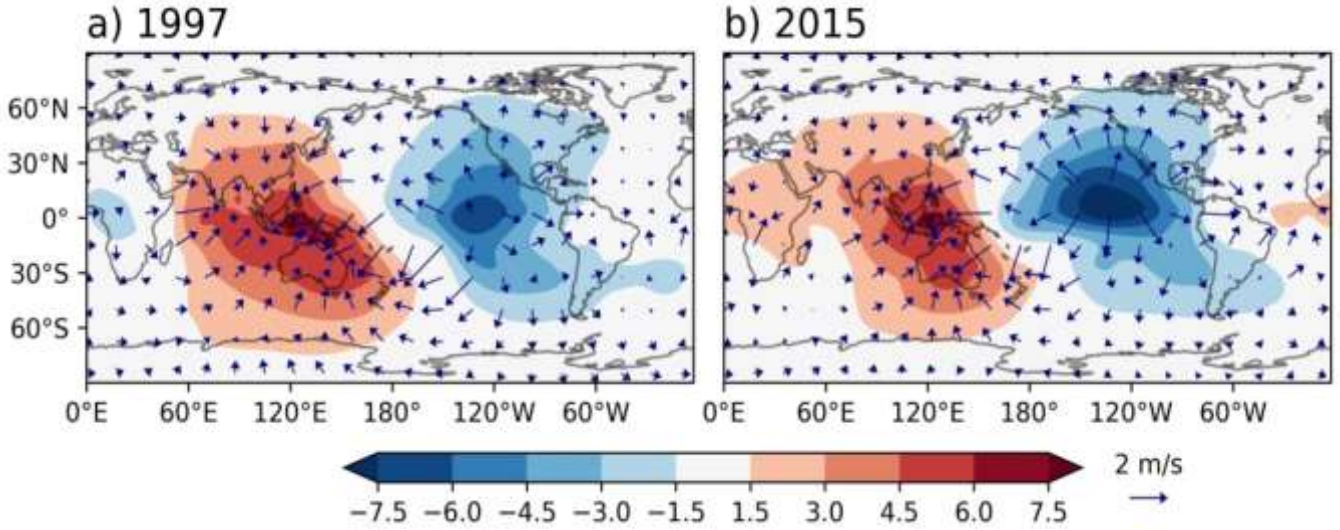
1997: Eastern Pacific (EP), also known as canonical type El Niño
2015: Combination of the EP and El Niño Modoki-II (EM-II) type El Niño.

Two types of C entral Pacific (CP) El Niño (Wang and Wang, 2013)

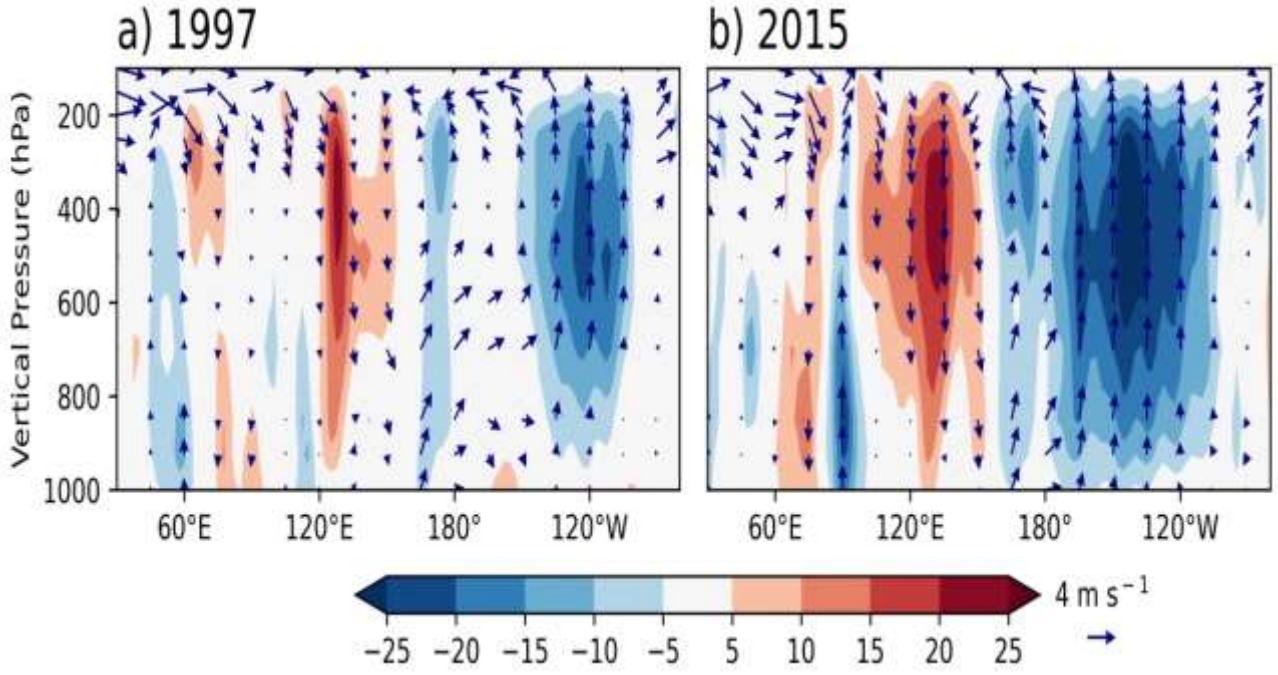
(i) The El Nino Modoki (EM-I): Warm SST anomalies over the equatorial CP,
(ii) EM-II: Warm SST anomalies extending from the subtropical north-eastern Pacific to the equatorial CP.



200 hPa velocity potential



Walker circulation anomalies over the Indo-Pacific region (averaged over 30 N - 5 S).



• During 1997, there were negative OLR anomalies over the WEIO, which indicates enhanced convection over WEIO; that favors ISMR (Gadgil et al., 2004).

• The stronger north-south pressure gradient enhanced the cross-equatorial flow and strengthened the moisture-containing low-level south-westerly winds which contributed to higher rainfall in 1997 compared to 2015.

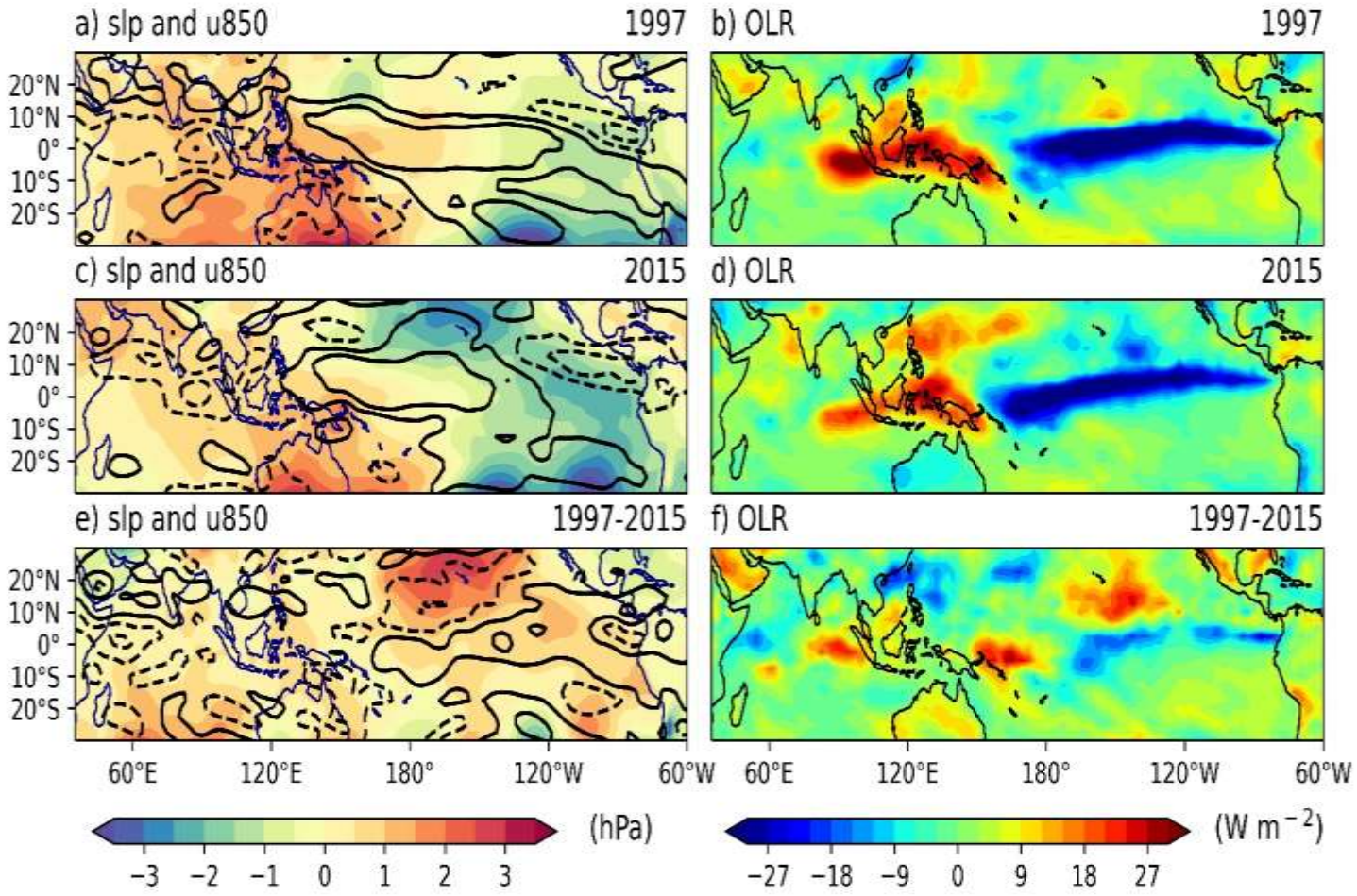
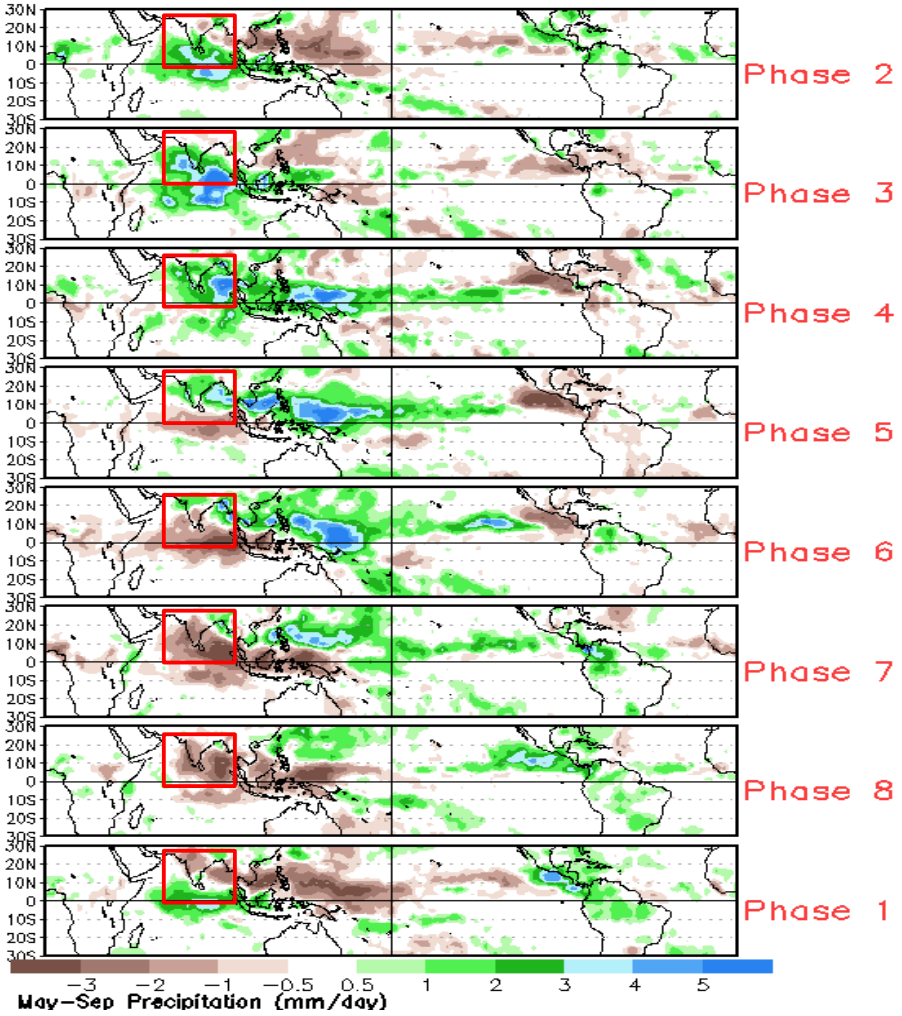


Figure: JJAS anomaly for a) sea level pressure (shading, hPa) and zonal wind at 850 hPa (line contour at intervals of 2 m s^{-1}, solid (dotted) lines represent westerly (easterly) wind anomalies) and b) Outgoing Longwave Radiation (shading, W m^{-2}) for the year 1997. c), d) are the same as a), b) but for the year 2015. e) and f) are same as a) and b) but for the difference.



Source: NOAA

MJO phases 3–6 are known to be favourable phases for ISMR. Conversely, phases 7, 8, 1, and 2 are known to be unfavourable. (Pai et al., 2011).

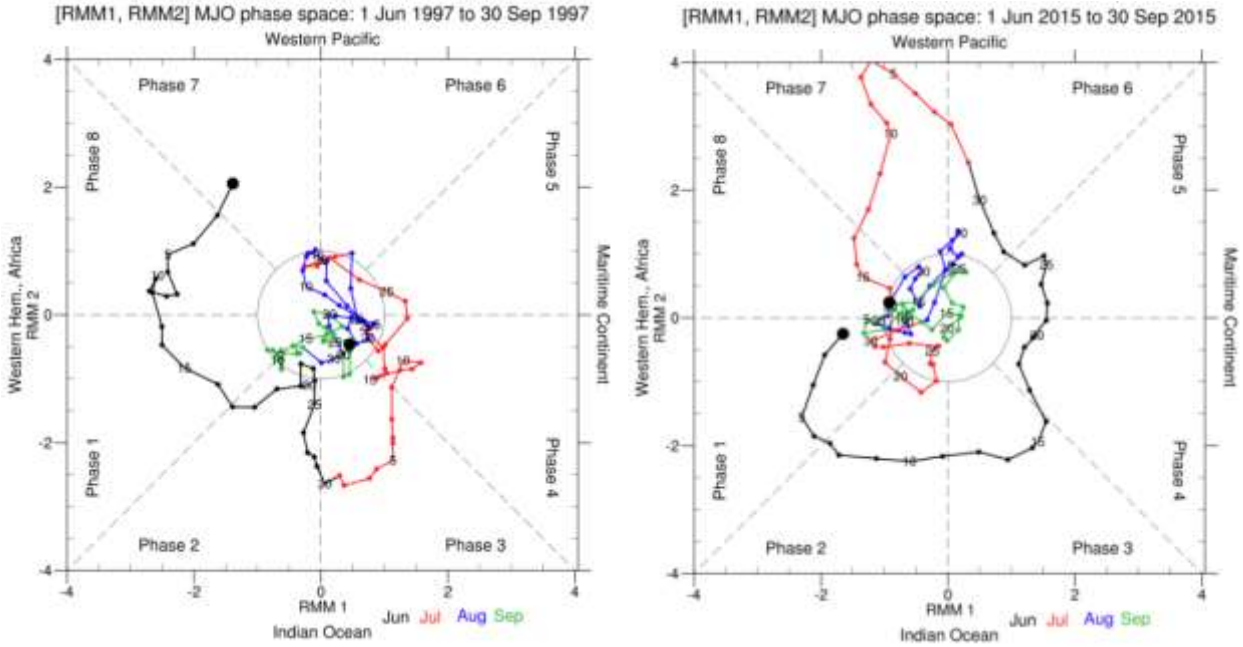
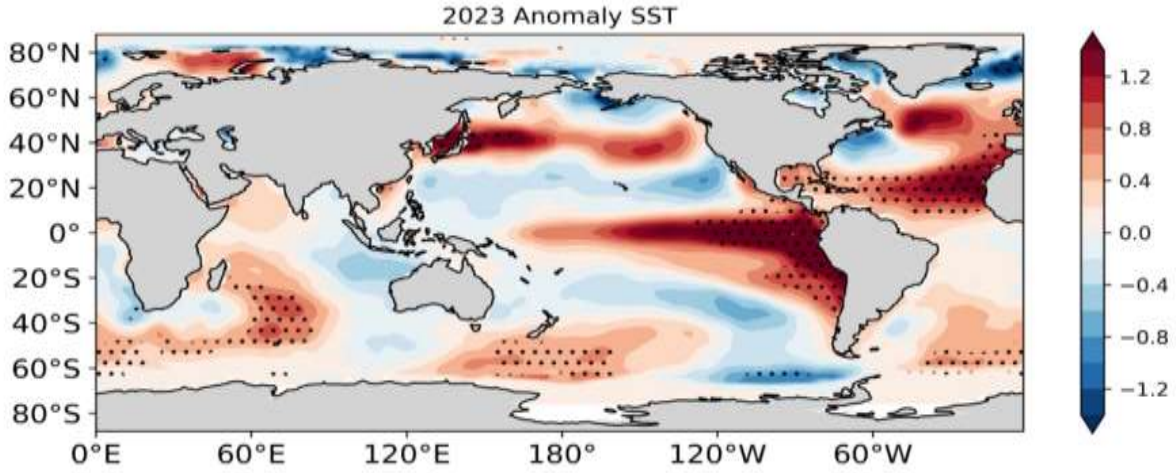


Table 1. The number of days with favorable and unfavorable phases during the JJAS seasons of 1997 and 2015.

Number of Days	1997					2015				
	Jun	Jul	Aug	Sep	JJAS	Jun	Jul	Aug	Sep	JJAS
Favorable MJO Phase (3, 4, 5, 6)	2	23	–	2	27	20	–	–	7	27
Unfavorable MJO Phase (1, 2, 7, 8)	26	–	1	3	30	10	30	7	5	52

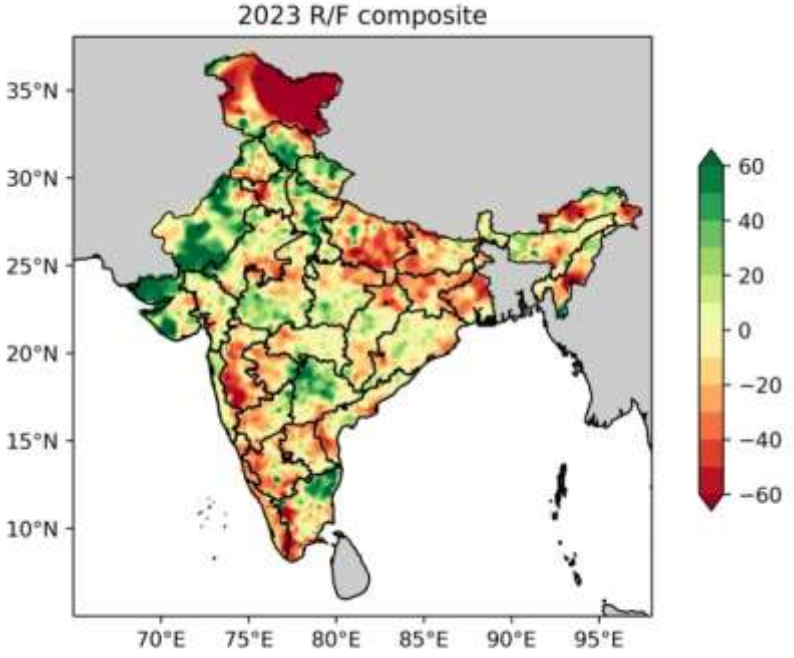
• During the 2015 CP El Niño, the horizontal as well as vertical moisture advection over the CP is stronger than during the EP El Niño, resulting in the further eastward propagation of the MJO (Chen et al. 2016)

2023 Monsoon

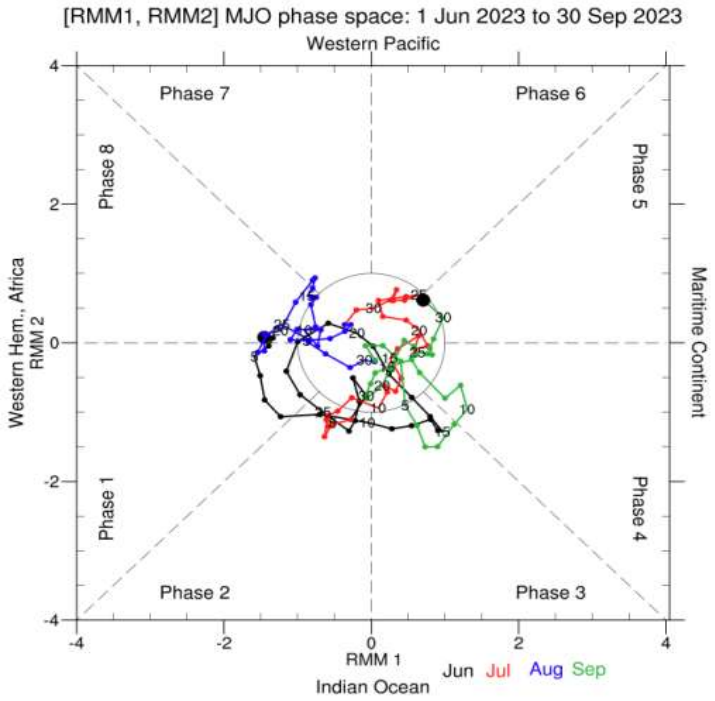


- 2023 experienced moderate strength EP+CP El Nino conditions over the Pacific Ocean and positive DMI over the Indian Ocean.

- However, MJO showed prolonged activity over the western Pacific region (unfavorable phase for ISMR), similar to 2015 MJO conditions.

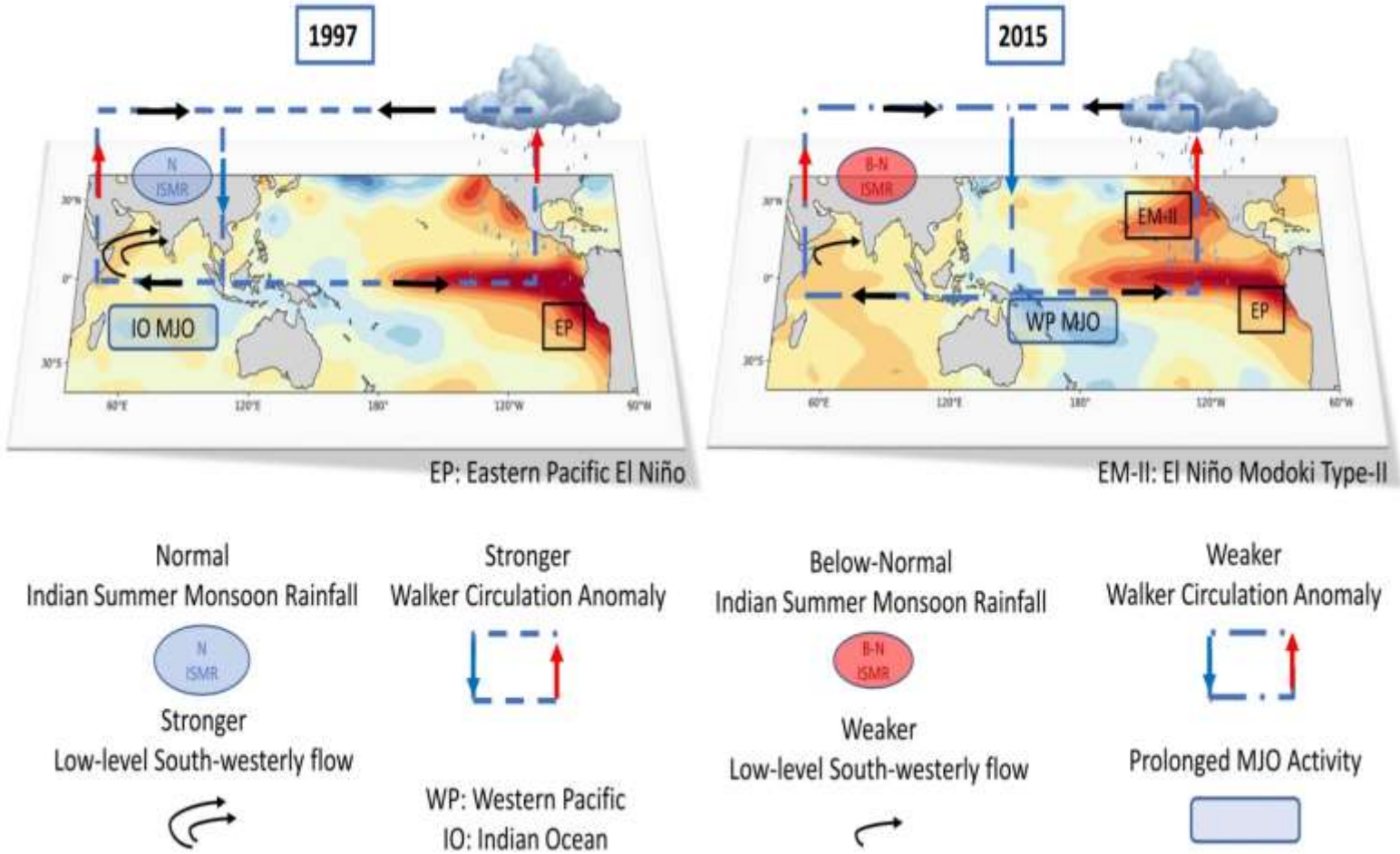


All India rainfall was 94% of the normal.



MJO (2023)	Favorable Phase (3,,4,5,6)	Unfavorable Phase (1,2,7,8)
No of active Days	15	37

Summary



Ratna et al. (2024)

Thank you