



Annual Monsoon Workshop

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Jointly organized by IMSP, IMD, IITM & OSI

Review of Seasonal Forecast of Monsoon 2023

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**भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT**

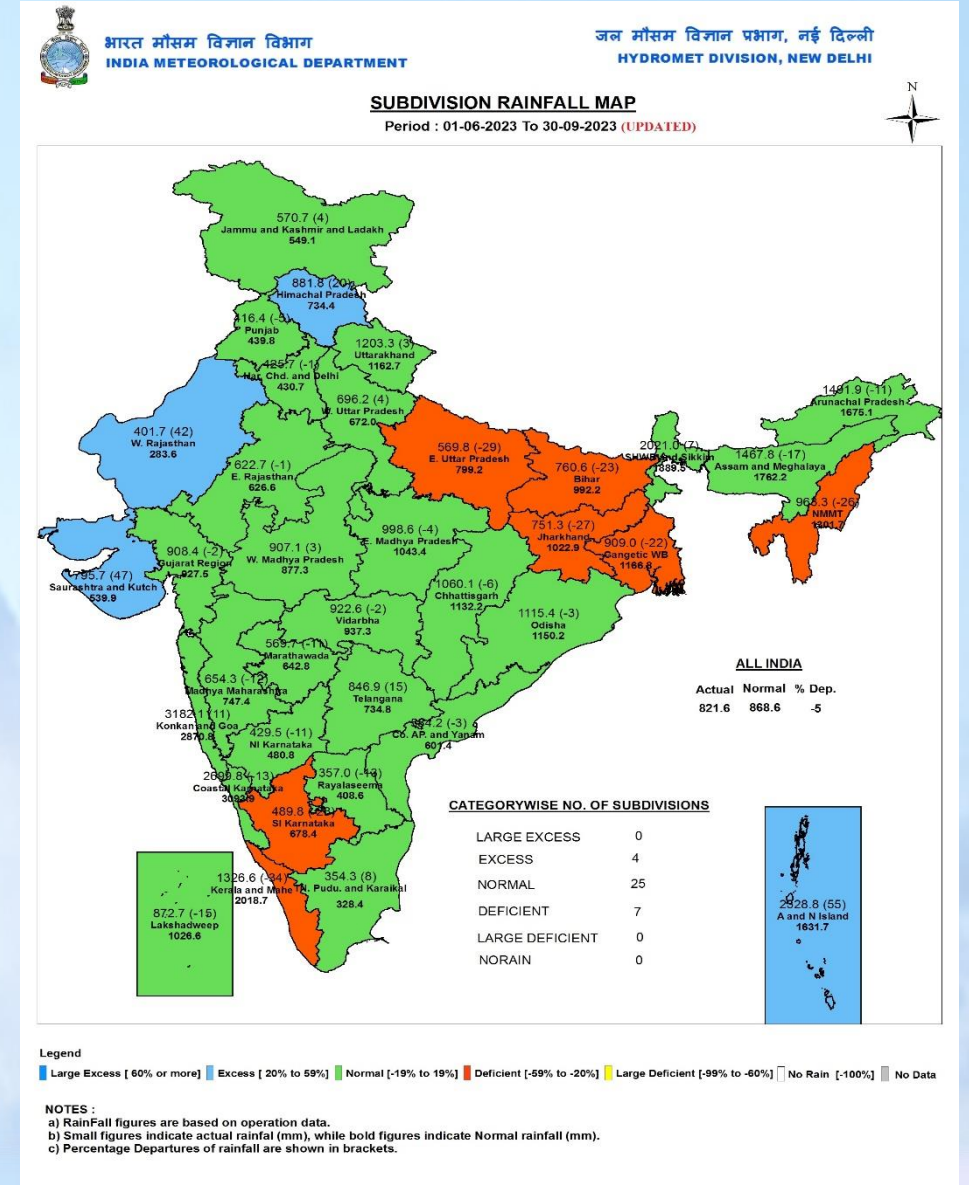
Outline

- ❖ **Salient Features of Monsoon 2023**
- ❖ **Onset and withdrawal of SW Monsoon 2023**
- ❖ **Present Seasonal Prediction System in India**
- ❖ **Verification of Long Range Forecast**
- ❖ **Significant weather and Heavy Rainfall event**
- ❖ **El Nino and IOD influence on 2023 JJAS Rainfall**
- ❖ **Intra-Seasonal Variations**
- ❖ **Verification of Seasonal/Monthly Heatwave outlook issued for 2023 Hot weather season**
- ❖ **Summary**



Salient Features of Monsoon 2023

- Rainfall over the country as a whole during monsoon season (June-September), 2023 was 95 % of its long period average (LPA).
- Seasonal rainfalls over Northwest India, Central India, South Peninsula and Northeast (NE) India were 101%, 100%, 92% and 82% of respective LPA. Rainfall over the monsoon core zone, which consists of most of the rainfed agriculture regions (Core Monsoon Zone) received 101% of LPA and thus was normal (94-106% of LPA).
- Monthly rainfall over the country as a whole was 91% of LPA in June, 113% of LPA in July, 64% of LPA in August, and 113% of LPA in September.
- Out of the total 36 meteorological subdivisions, 4 subdivisions constituting 9% of the total area of the country received excess, 25 subdivisions received normal rainfall (73% of the total area) and 7 subdivisions (18% of the total area) received deficient season rainfall. (Nagaland, Manipur, Mizoram & Tripura (NMMT), Gangetic West Bengal, Jharkhand, Bihar, East UP, South interior Karnataka and Kerala.)

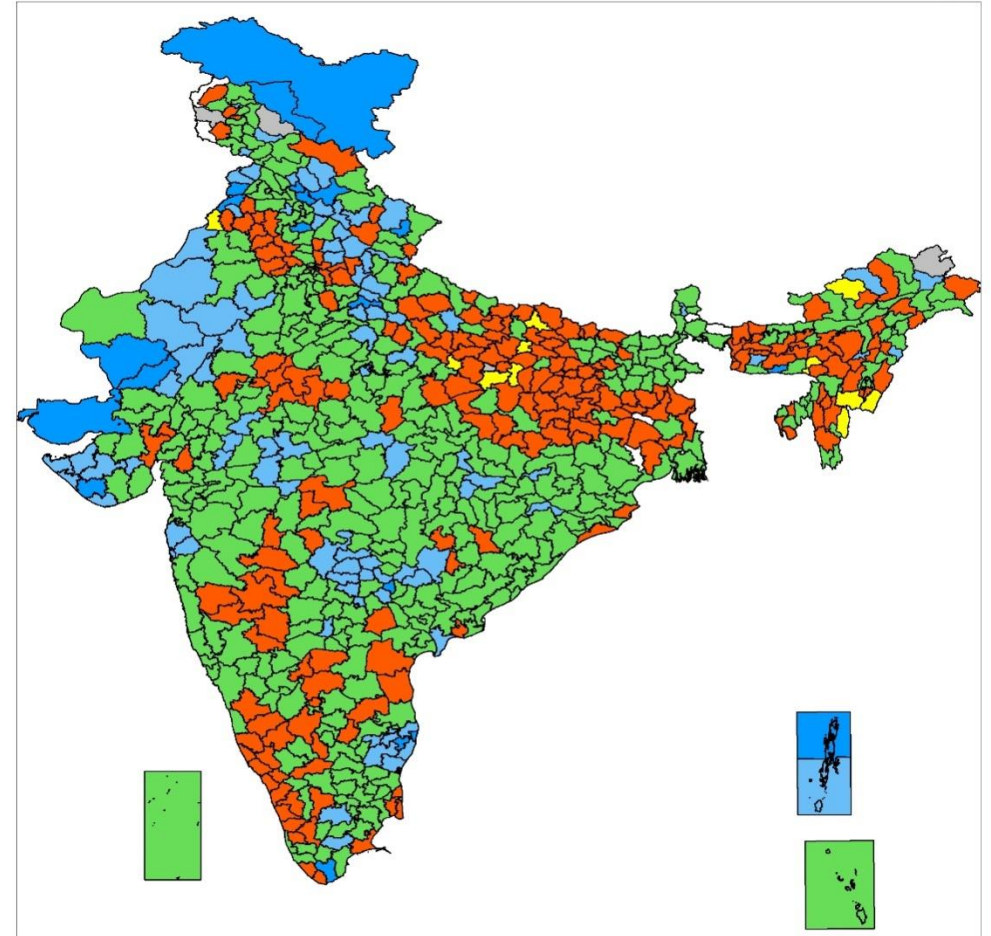


Current Status of Monsoon 2023

All India Summer Monsoon Rainfall



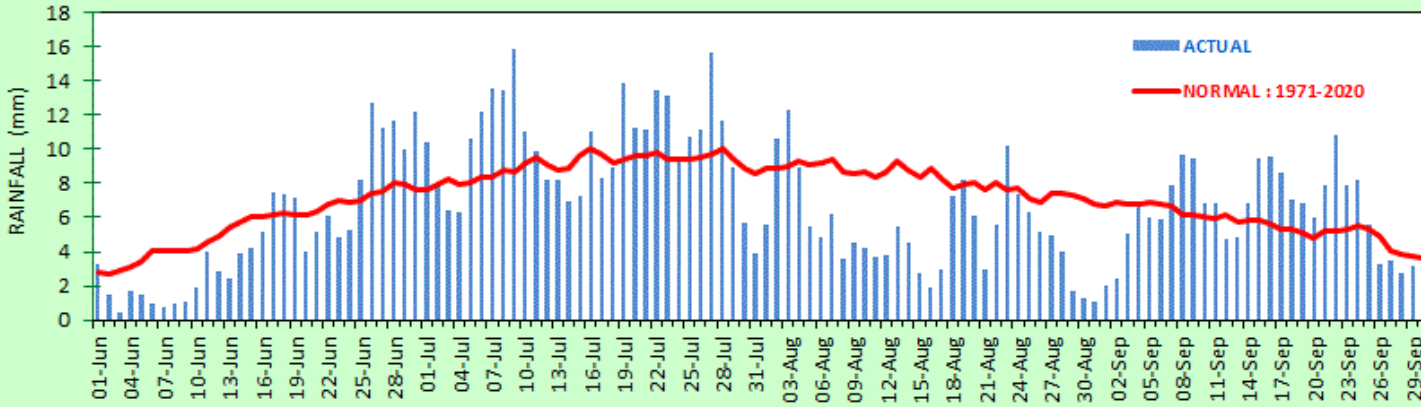
DISTRICT RAINFALL MAP
Period : 01-06-2023 To 29-09-2023



Legend
 ■ Large Excess [60% or more] ■ Excess [20% to 59%] ■ Normal [-19% to 19%] ■ Deficient [-59% to -20%] ■ Large Deficient [-99% to -60%] ■ No Rain [-100%] ■ No Data

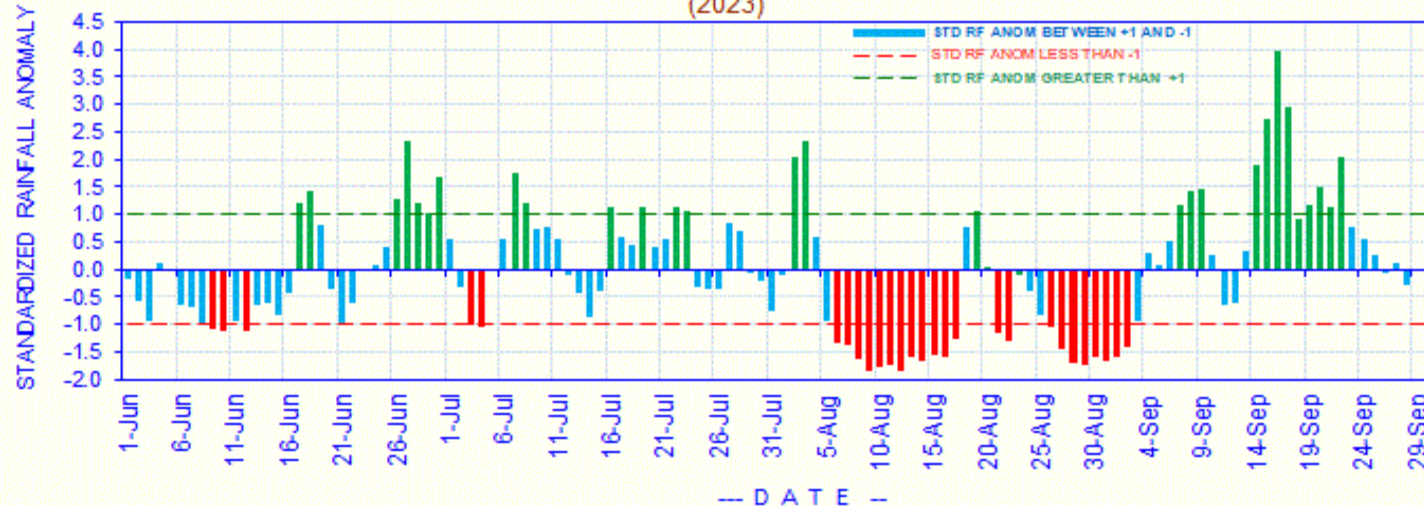
NOTES :
 a) RainFall figures are based on operation data.

DAILY MEAN RAINFALL (mm) OVER THE COUNTRY AS A WHOLE (2023)



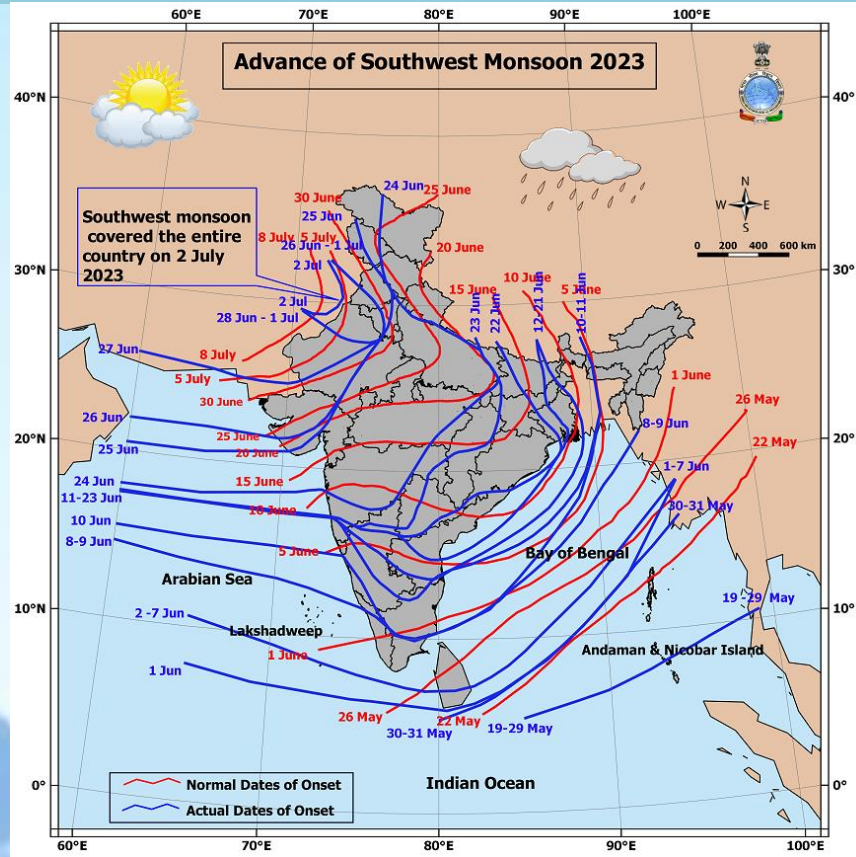
Rainfall Anomaly over Core Monsoon Zone

STANDARDIZED RAINFALL ANOMALY OVER THE CORE MONSOON ZONE REGION (2023)

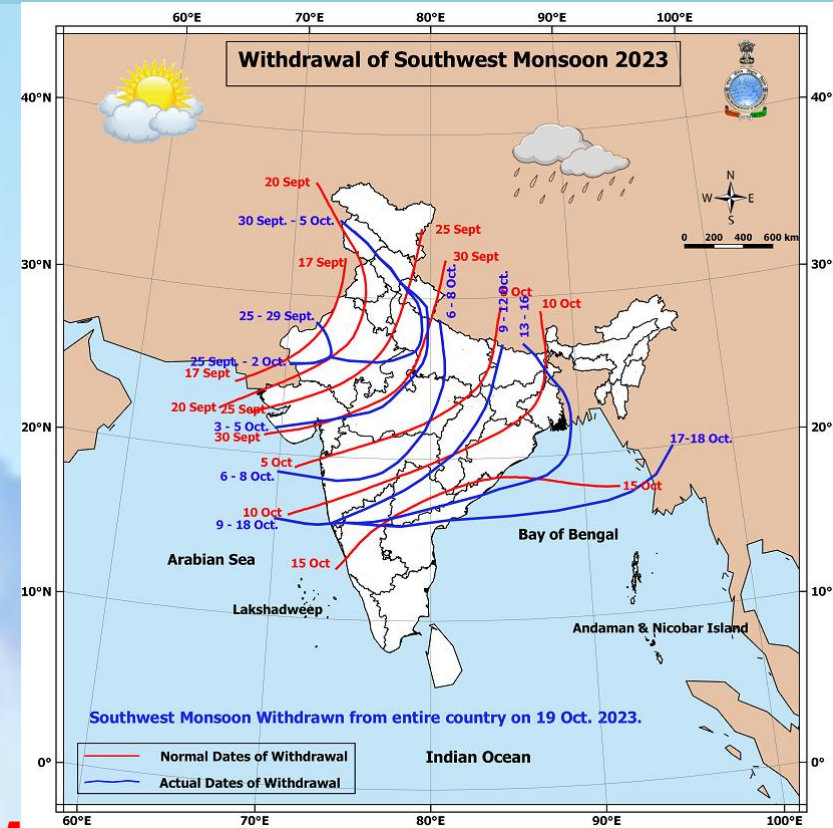


Monsoon onset and withdrawal 2023

Monsoon Onset 2023



Monsoon withdrawal 2023



Monsoon withdrawal commenced from west Rajasthan on 25th September (with a delay of 8 days) and The southwest monsoon withdrew from entire country on 19th October 2023 against its normal on 15th October.

Southwest monsoon current advanced to the south Andaman Sea and Nicobar Islands on 19 May (3 days ahead of its normal date). It set in over Kerala on 8th June, 7 days behind the normal date and covered the entire country by 2nd July, 6 days ahead of normal date.



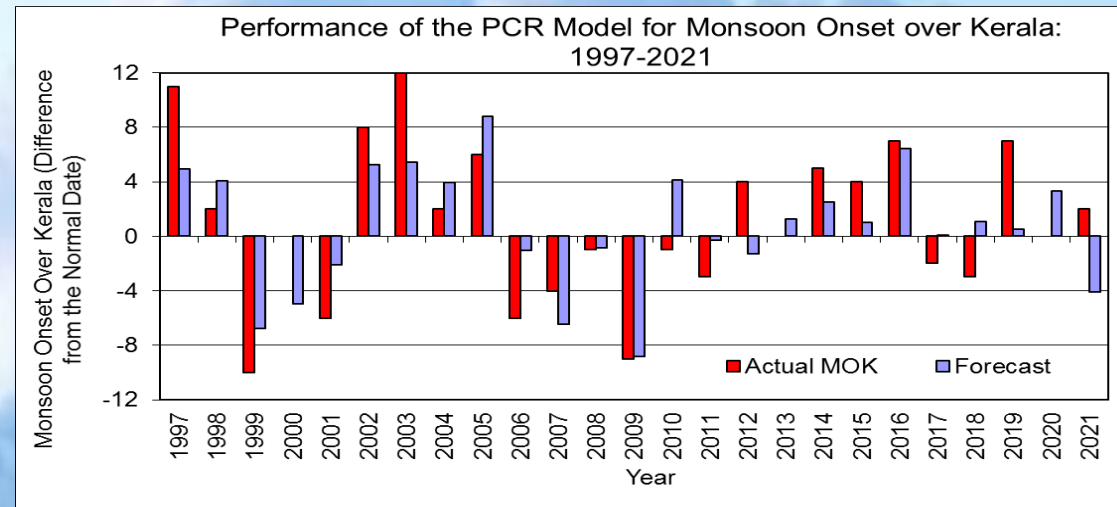
Forecast for Monsoon onset over Kerala 2023

This year, the onset of southwest monsoon over Kerala is likely to be delayed as compared to normal date of onset.

The monsoon onset over Kerala (MOK) is likely to be on 4th June with a model error of ± 4 days.

No	Name of Predictor	Period	C.C (1975-2000)
1	NWI MIN. TEMP. (6 STATIONS) ANOMALY	16-30 APR	-0.30
2	SUB TROPICAL NWPAC MSLP	16-30 APR	0.57
3	NE INDIAN OCEAN U925	16-30 APR	-0.52
4	INDONESIAN REGION U200	16-30 APR	0.48
5	SOUTH CHINA SEA OLR	16-30 APR	0.39
6	PRE-MONSOON RF PEAK DATE	APRIL-MAY	0.48

Year	Actual Onset Date	Forecast Onset Date
2005	7th June	10th June
2006	26 th May	30 th May
2007	28th May	24th May
2008	31 st May	29 th May
2009	23rd May	26th May
2010	31 st May	30 th May
2011	29 th May	31 st May
2012	5 th June	1 st June
2013	1 st June	3 rd June
2014	6 th June	5 th June
2015	5 th June	30 th May
2016	8 th June	7 th June
2017	30 th May	30 th May
2018	29 th May	29 th May
2019	8 th June	6 th June
2020	1 st June	5 th June
2021	3 rd June	31 st May
2022	29 th May	27 th May
2023	8 th June	4 th June



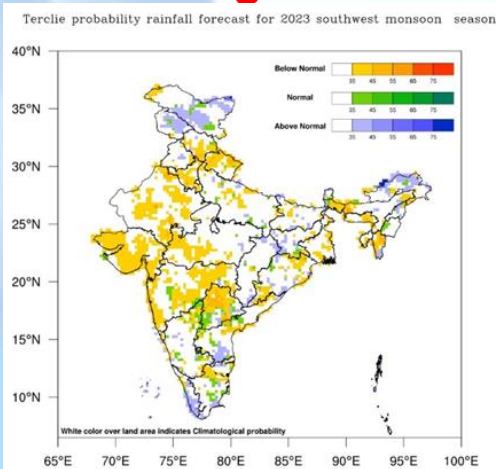
Model error ± 4 days



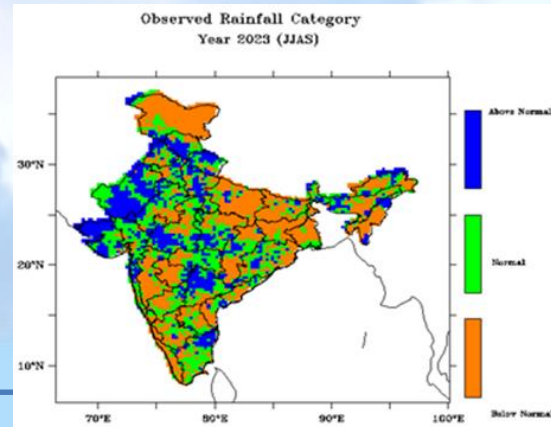
Climate Prediction Services: Presently issued Monthly and Seasonal Forecasts for the Country

Sr. No.	Forecast Outlook for	Issued in	Method/ Model
1	Rainfall during the Winter Season (Jan-March)	December	Statistical, MME
2	Temperatures during Hot Weather Seasons (March to May) & (April-June)	February & March	Dynamical / MME
3	Rainfall during the SW Monsoon Season (June to September)	April	Statistical, MME
4	Rainfall During the NE Monsoon Season (October to December) Rainfall	September	Statistical, MME
5	Temperatures during the Cold Weather Season (Dec- Feb) Temperature	November	Dynamical/ MME
6	Monthly Outlook for Rainfall & Temperature	Every Month	Dynamical/ MME

First stage forecast



Observed Category



New Seasonal Forecasting System Based on the Multi Model Ensemble (MME): 2021

New Strategy for Long Range Forecast

1st Stage Forecast

April

All India averaged Season (June – September) Rainfall



Spatial pattern of probability forecast for the Season Rainfall over the country

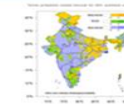


Based on Statistical and MME

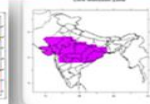
2nd Stage Forecast

May

Update for the April forecast for the All India averaged Season Rainfall and spatial pattern of probabilistic forecast over the country



Forecast for Season Rainfall: for the Four Homogeneous Regions & Monsoon Convergence Zone (MCZ)



Based on Statistical and MME

Monthly Forecast

End of May, June, July & August for subsequent one month

Probabilistic Forecast for Monthly rainfall

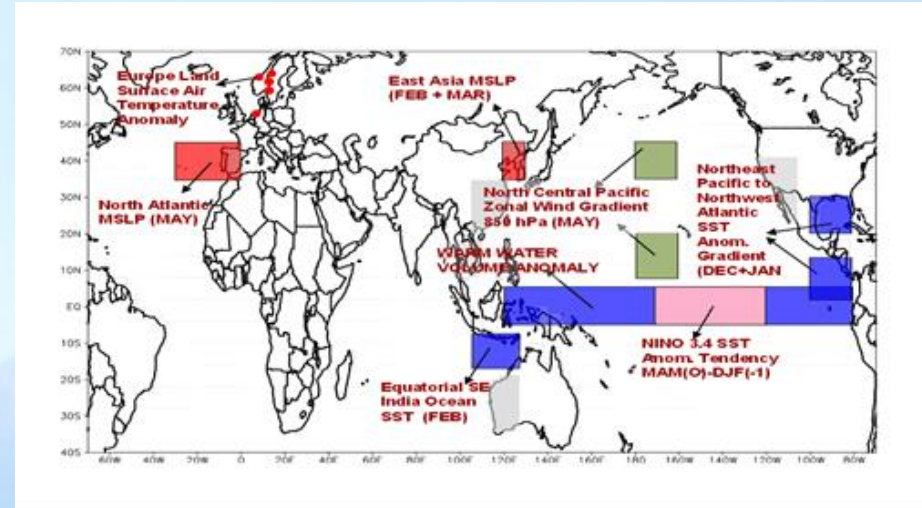
Based on MME of Dynamical models

In addition, Forecast for Date of Monsoon Onset over Kerala in May

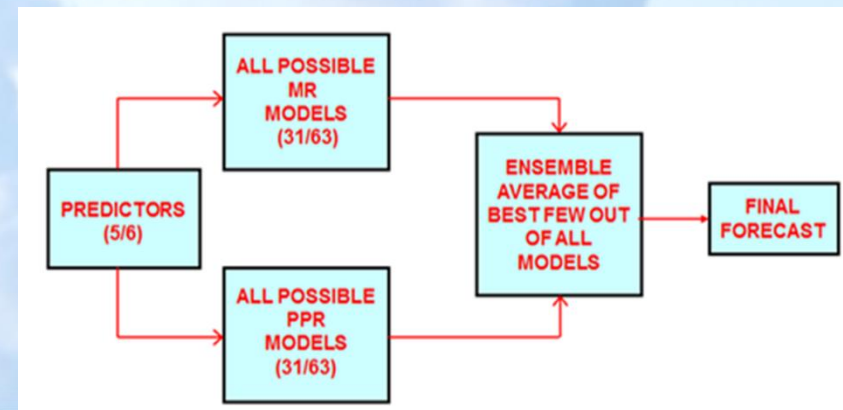


Statistical Ensemble Forecasting System (SEFS) for Seasonal Rainfall over Country as a whole

S.No	Predictor Used	Issued in
1	Europe Land Surface Air Temperature Anomaly (January)	April
2	Equatorial Pacific Warm Water Volume (February + March)	April
3	SST Gradient Between Northeast Pacific and Northwest Atlantic (December +January)	April and June
4	Equatorial SE Indian Ocean SST (February)	April and June
5	East Asia Mean Sea Level Pressure (February + March)	April and June
6	Nino 3.4 Sea Surface Temp (MAM + Tendency (MAM-DJF))	June
7	North Atlantic Mean Sea Level Pressure (May)	June
8	North Central Pacific Zonal Wind Gradient 850 hPa (May)	June



Schematic Diagram of the SEFS



The average of the ensemble forecasts from best out of all possible MR (multiple regression) and PPR (projection pursuit regression) models gives the final forecast.



Climate Models Used for Multi Model Ensemble forecast

S.NO	System name	Centre / Country	Hindcast Ensemble size	Hindcast /Forecast Period
1	CanCM4i	NMHS/Canada	10	1981 - 2020
2	GEM-NEMO	NMHS/Canada	10	1981 - 2020
3	CMCC SPSv3	Italy	40	1993 - 2020
4	NCAR-CCSM4	NCAR/USA	10	1982 - 2020
5	DWD GCFS2p0	NMHS/Germany	30	1993 - 2020
6	GFDL	NOAA/USA	10	1993-2020
7	GEOS2S	NASA/USA	4	1981 - 2020
8	JMA	NMHS/Japan	10	1979 - 2020
9	Meteo-France 7	NMHS/France	25	1993 - 2020
10	GloSea-5	NMHS/ UK	28	1993 - 2017
11	NCEP CFS2	NMHS/ USA	24	1982 - 2020
12	MMCFS	NMHS/IMD	14	1982-2020
13	ECMWF, SEAS-5	ECMWF	25	1981 - 2016



Performance of LRF Southwest Monsoon 2023

Forecast	Observed –	
11 April 2023-1 st Stage For Season as a whole	26 th May 2023-2 nd stage -	
<ul style="list-style-type: none"> ➤ El Niño conditions likely during monsoon season ➤ Positive IOD conditions are likely to develop during the southwest monsoon season. ➤ Stated that Eurasia snow cover has been less during December to February 2022-2023, Which will favour Monsoon over India. IOD conditions also will counter adverse impact of El-Nino. ➤ It was predicted that despite El-Nino, the monsoon will not be affected severely and Quantitatively ISMR likely to be 96 % of Long Period Average(LPA) with model error of $\pm 5\%$. ➤ It was also told that monsoon would get impacted “in 2nd half of season and not likely in the 1st half of season.” 	<ul style="list-style-type: none"> ➤ El Niño conditions during the upcoming monsoon season. ➤ Development of positive IOD conditions over the Indian ocean during the monsoon season. ➤ Same forecast was reiterated in 2nd Stage LRF issued on 26th May 2023 $96 \pm 4\%$. 	<ul style="list-style-type: none"> ➤ Weak El Niño conditions developed in July became moderate in Aug and Sept . ➤ IOD remained neutral till 3rd week of Aug and became positive thereafter. ➤ Rainfall is (95% of LPA).



Forecast	Observed –Summery of Monsoon Season
<p>31 July -3rd Stage (For 2nd half of Monsoon 2023 (Aug-Sept))</p>	
<ul style="list-style-type: none"> ➤ Weak El Niño conditions are prevailing over the equatorial Pacific region. The El Niño conditions are likely to intensity further and continue upto early next year. ➤ Neutral IOD conditions are prevailing and positive IOD conditions are likely to develop during remaining part of the monsoon season. ➤ Rainfall to be normal but on negative side of the normal (94 to 99% of LPA). 	<ul style="list-style-type: none"> ➤ Weak El Niño conditions developed in July became moderate in Aug and Sept . ➤ IOD remained neutral till 3rd week of Aug and became positive thereafter. ➤ 1st half of the monsoon season 2023 got more rainfall(10%, above normal). It was below normal during 2nd half the season(17% below normal)



Performance of monthly Rainfall Forecast during SW Monsoon 2023

Month	Forecast	Realized
June 2023	Rainfall to be below normal (<92 % of LPA).	91% of LPA
July 2023	Rainfall to be normal but on positive side of the normal (100-106 % of LPA).	113% of LPA
Aug 2023	Rainfall to be below normal (<91 % of LPA).	64% of LPA
Sept 2023	Rainfall to be normal (91-109 % of LPA). However extended range forecast indicated good rainfall in Sept. Also predicted formation of Low Pressure Systems one after another causing good rainfall over Central and South India	113% of LPA
Aug-Sept 2023	Rainfall to be normal but on negative side of the normal (94 to 99% of LPA).	88% of LPA

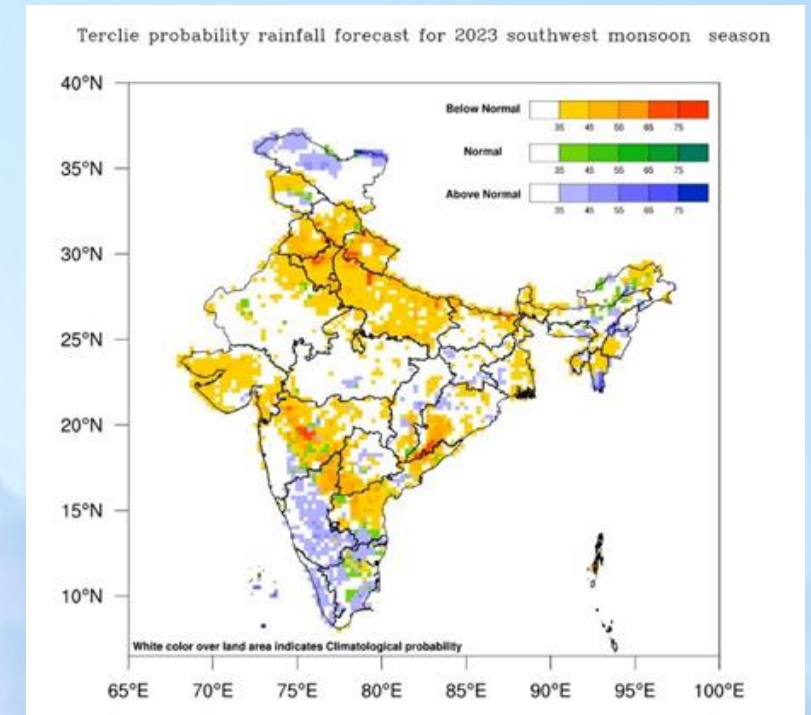
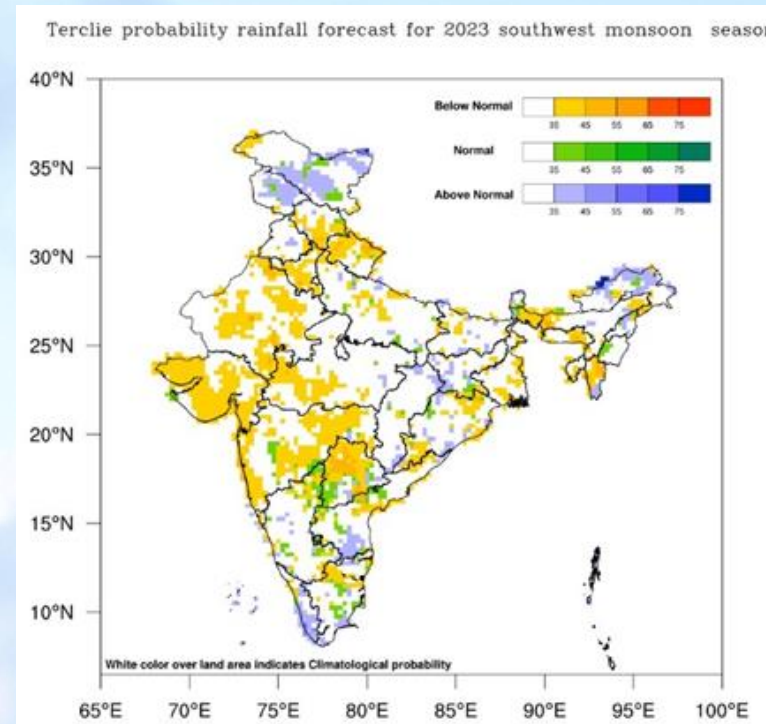
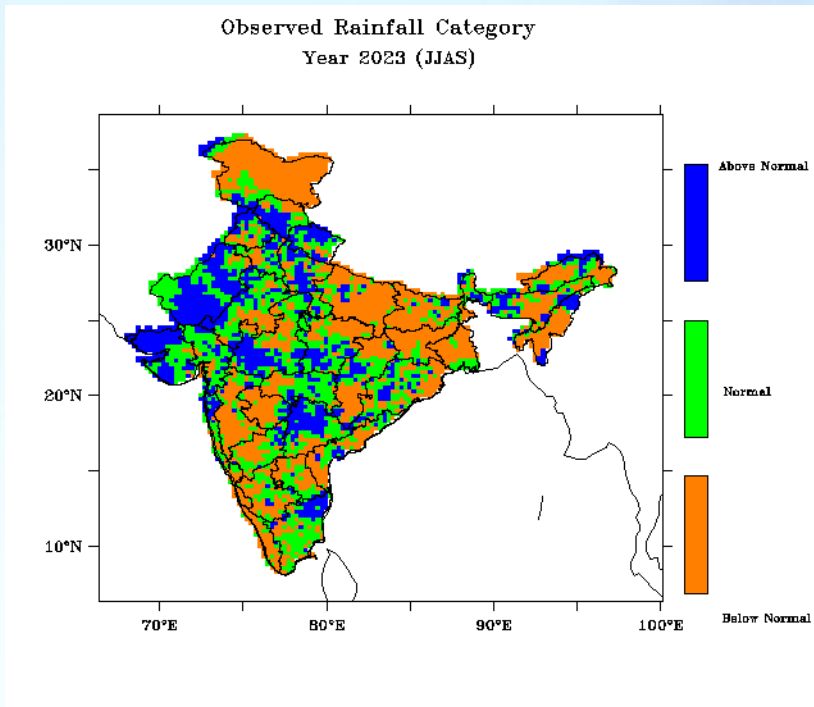


Verification of JJAS Rainfall forecast 2023

Observed Rainfall during SW Monsoon 2023

First Stage forecast
(issued on 11th April 2023)

Second Stage forecast
(issued on 26th May 2023)



Normal to above normal rainfall was experienced over most part of Northwest and Some regions of Central India. Below normal rainfall over Northeast India, Indo-Gangetic Plains and some regions of Peninsular India. Seasonal outlook is not matching with observed rainfall category in many regions.



3/12/2024

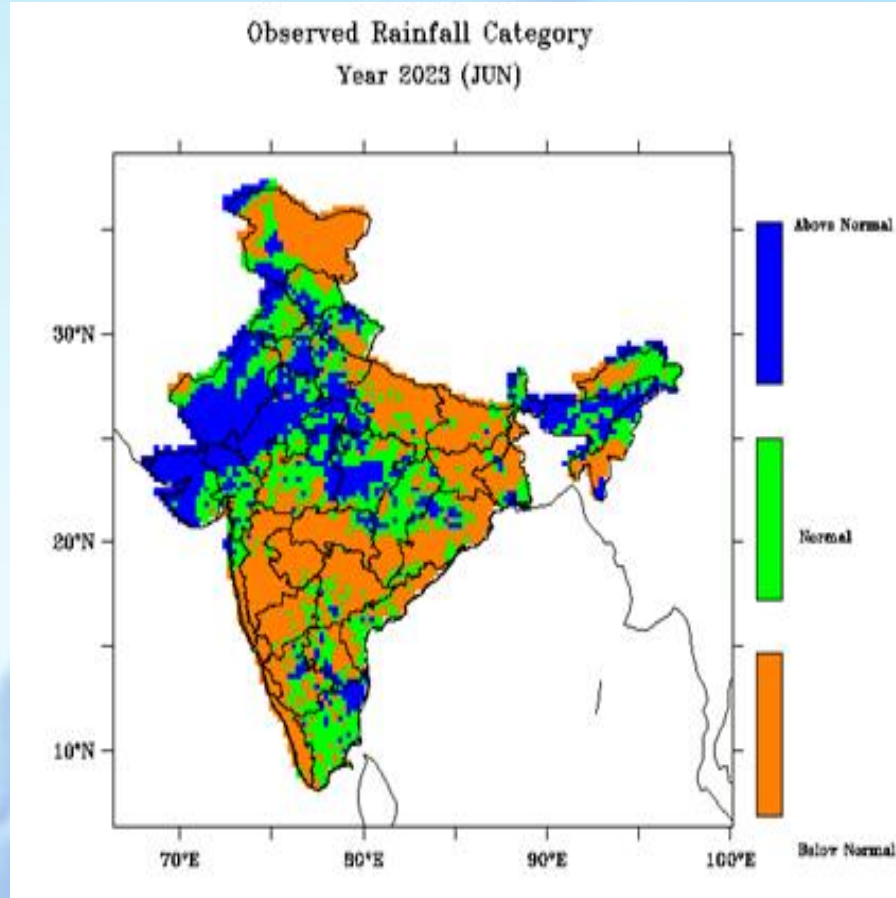
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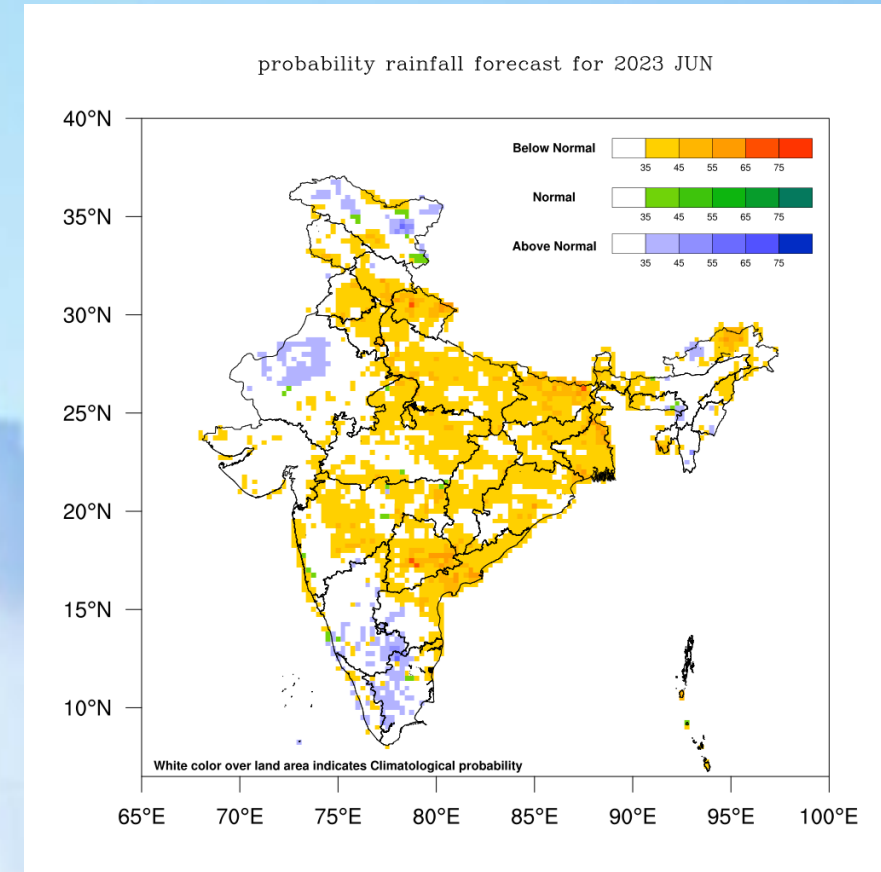


Verification of JUN 2023 rainfall forecast

Observed Rainfall Category (Jun 2023)



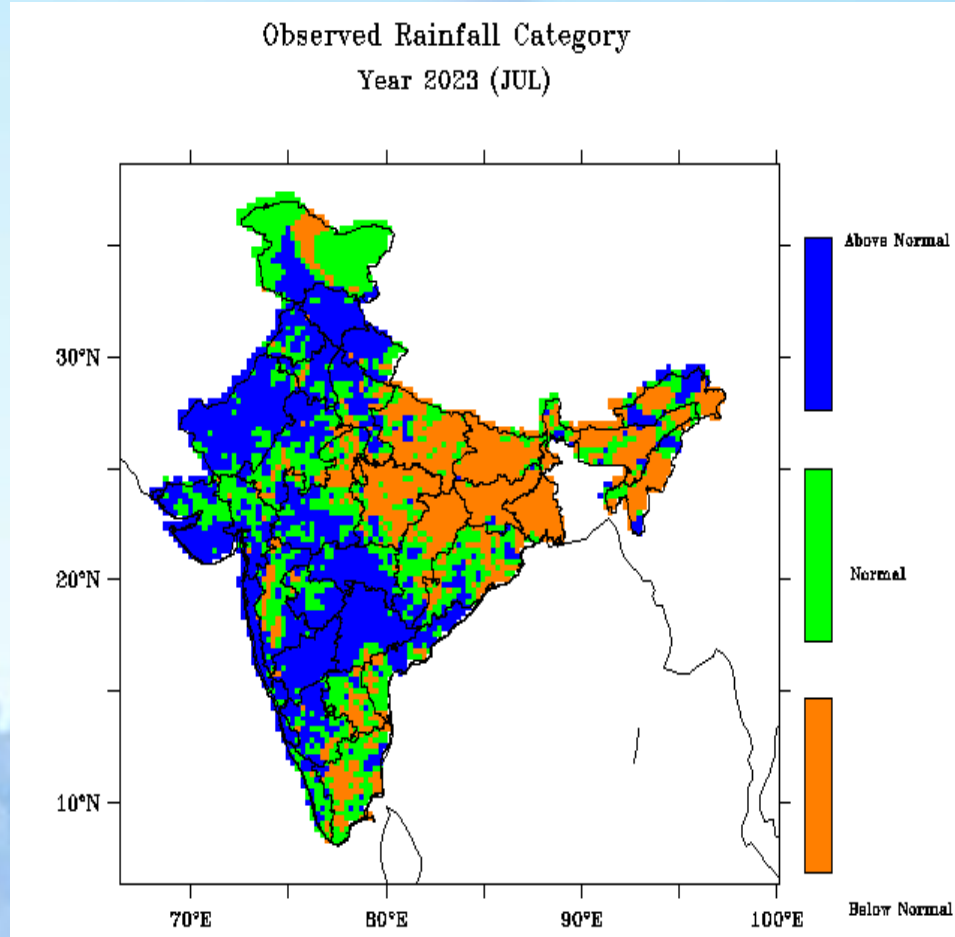
Rainfall forecast for Jun Month (issued on 26 May 2023)



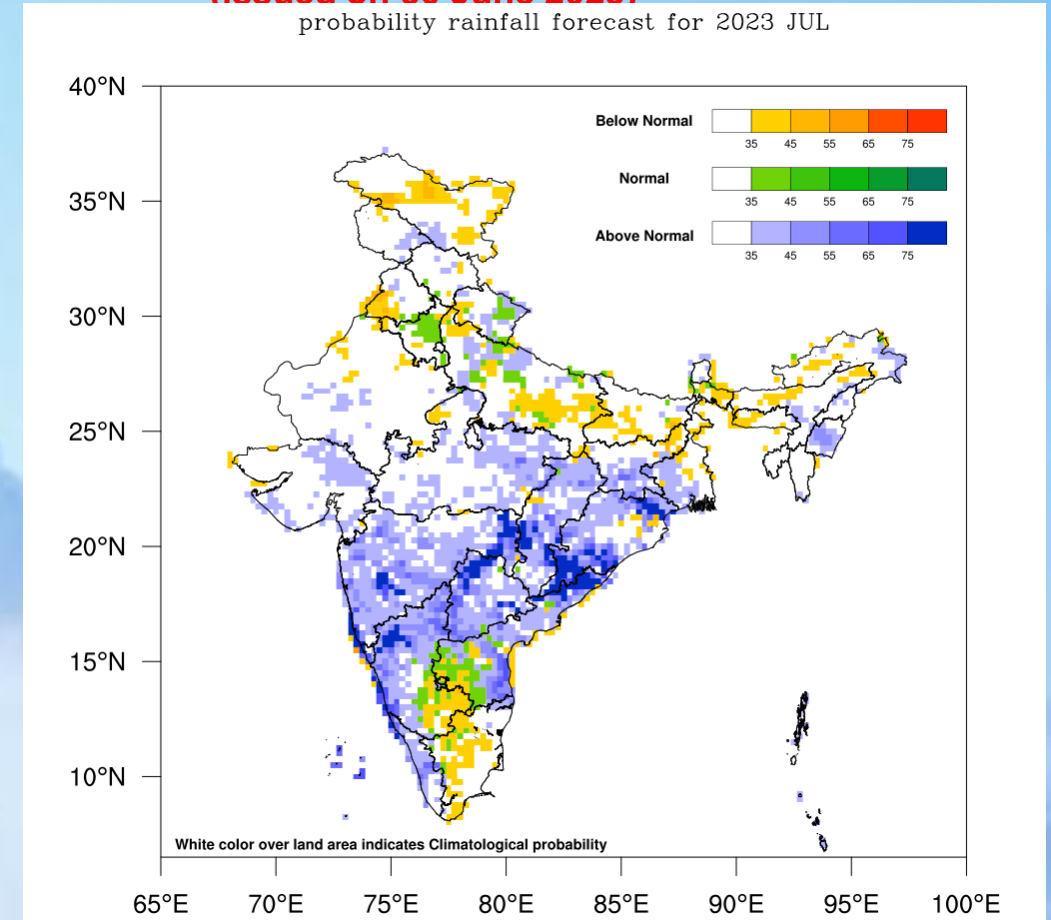
- Above normal rainfall over many parts of Northwest and Northeast India and some areas of South Peninsular India were correctly predicted.
- Below normal rainfall over many regions of the Country also correctly predicted.

Verification of JUL 2023 rainfall forecast

Observed Rainfall Category (Jul 2023)



Rainfall forecast for Jul Month (issued on 30 June 2023)

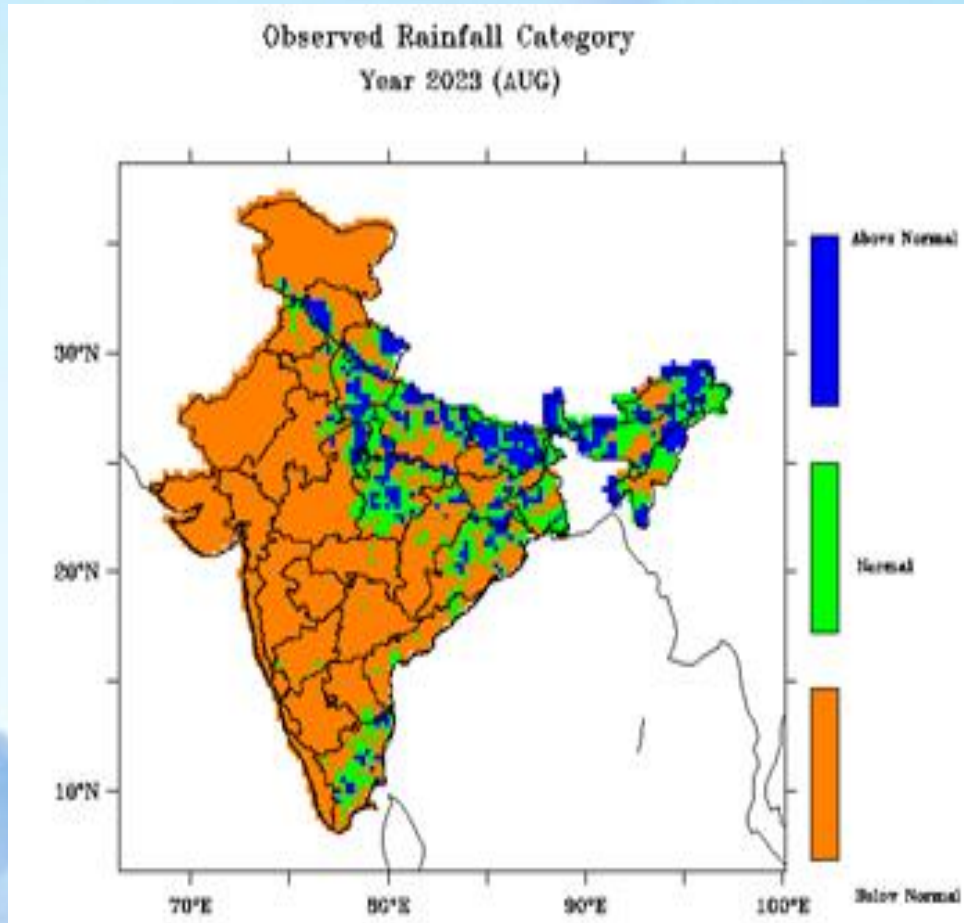


- Above normal rainfall over many parts of west Central and Peninsular India and some areas of Northwest India were correctly predicted.
- Below normal rainfall over many regions of the Northeast India and southeast Peninsular India and east UP and Bihar also correctly predicted.

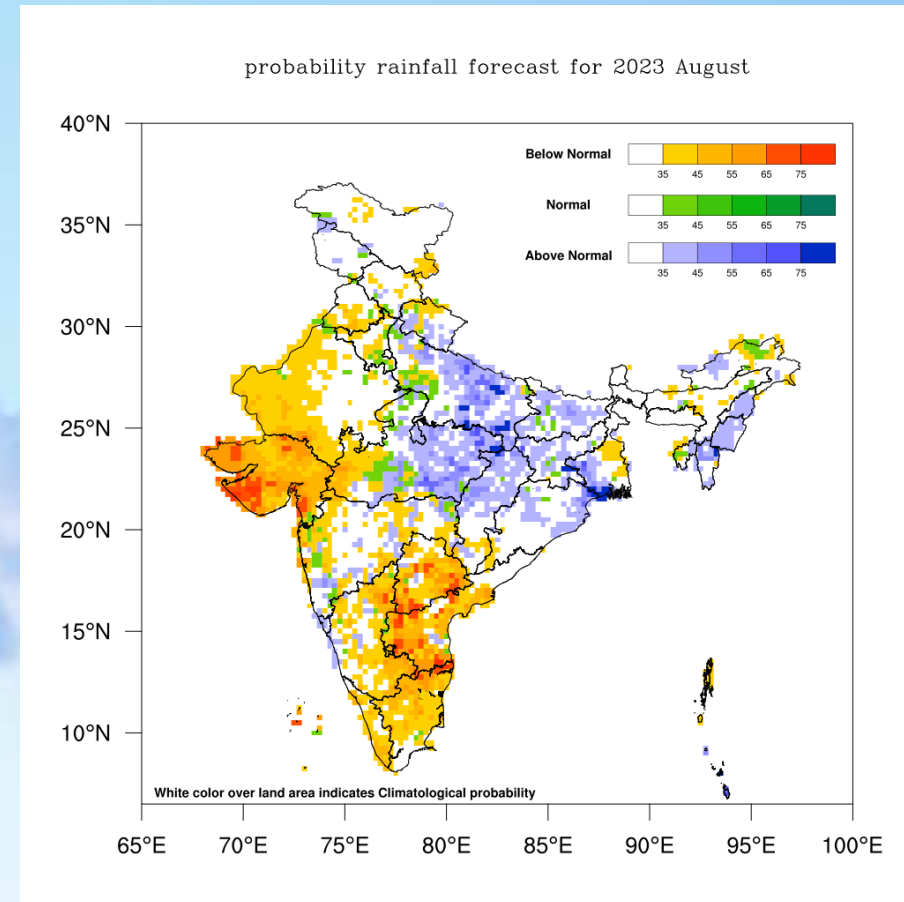


Verification of August 2023 rainfall forecast

Observed Rainfall Category (August 2023)



Rainfall forecast for August Month (issued on 31 July 2023)



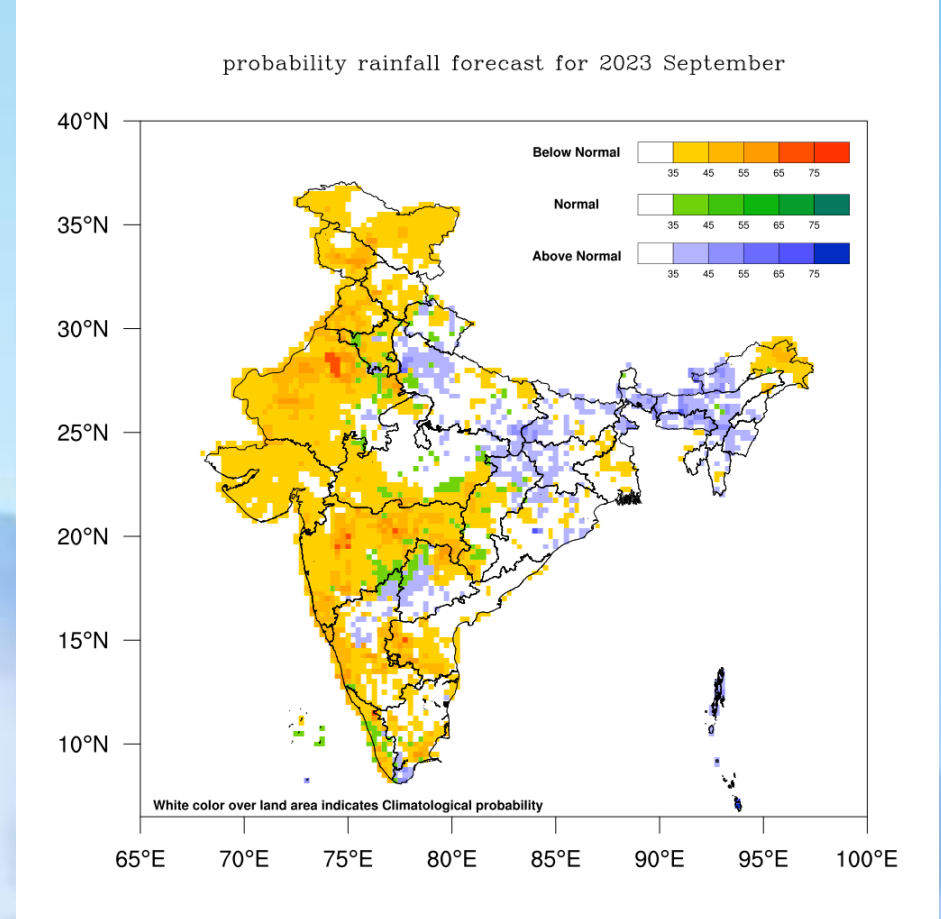
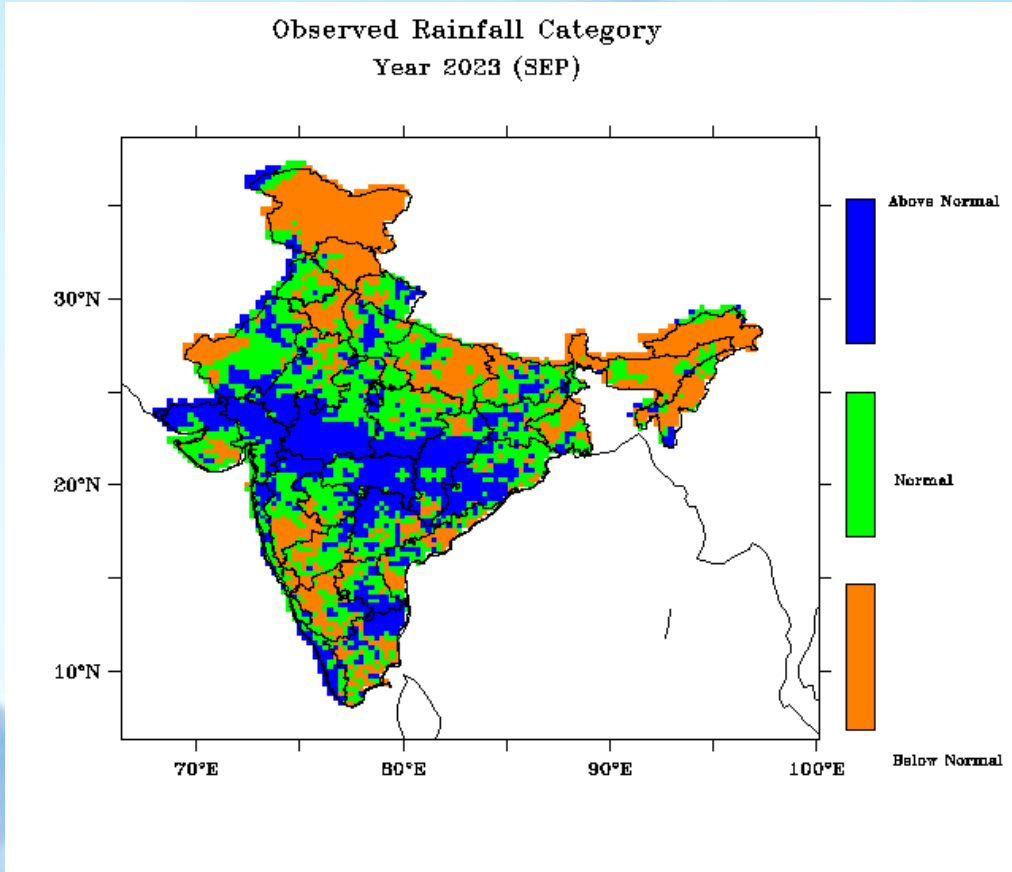
It is seen that normal to below normal rainfall was experienced many areas over Peninsular, Central and Northwest India as indicated in the Monthly outlook. Above normal rainfall observed over Northeast India and some areas of South Peninsula and below normal rainfall over East India and Foot Hills of Himalayas also correctly indicated in the outlook.



Verification of 2023 September Rainfall forecast

Observed Rainfall Category

Rainfall forecast for September Month (issued on 31st August 2023)

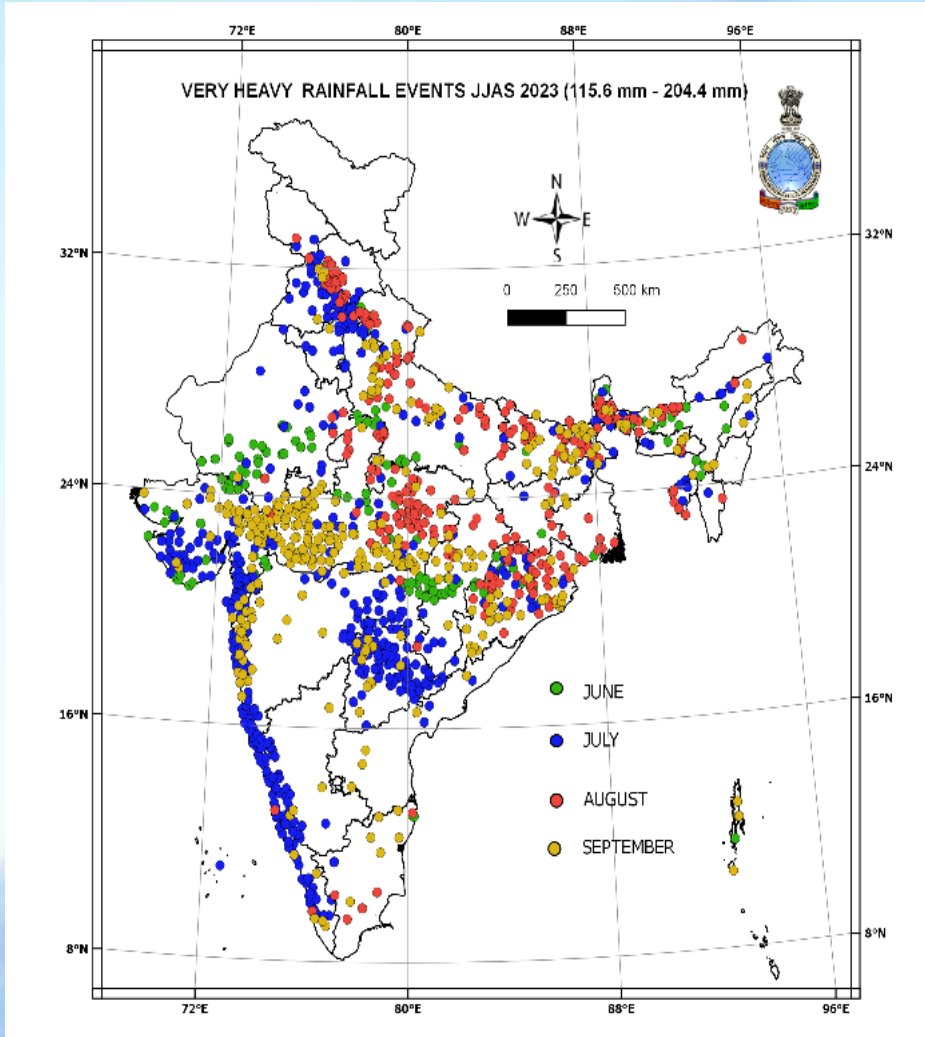


Normal to above normal rainfall was experienced over most areas over Central India and northwest India. Below normal rainfall received over Northeast India.

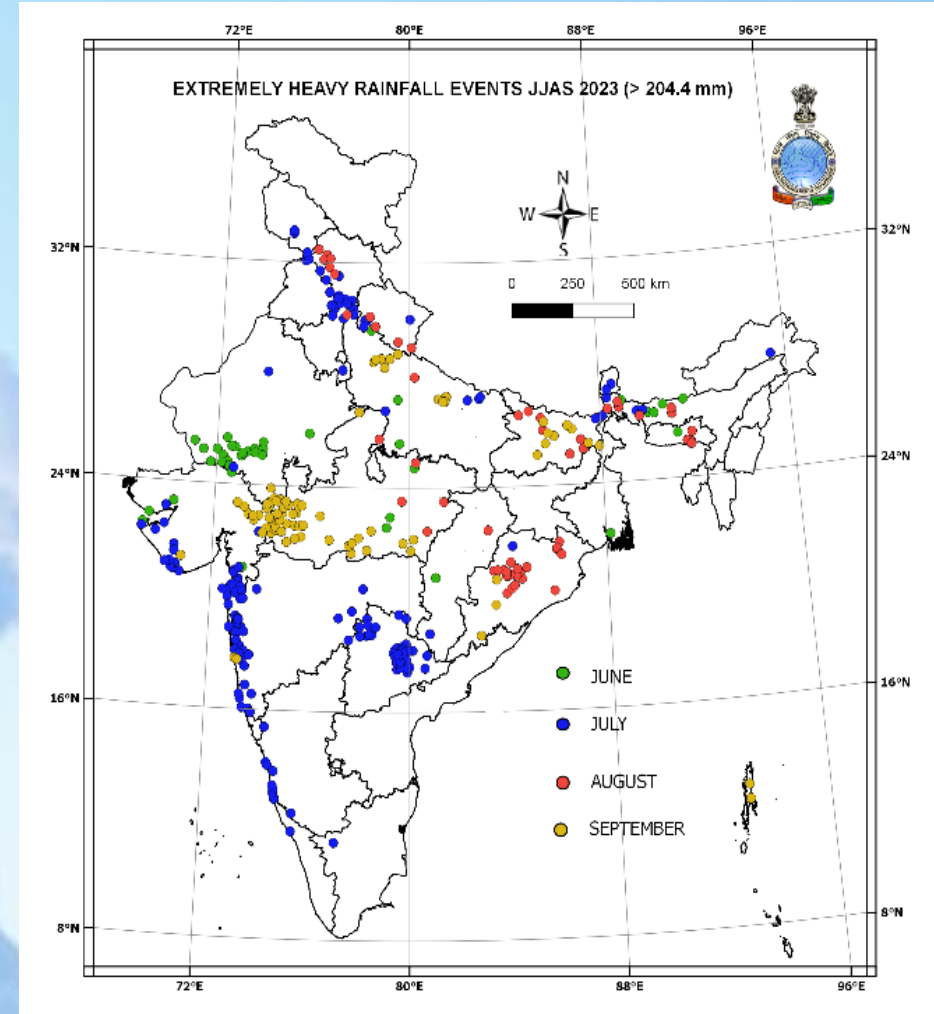


Heavy Rainfall Events occurred in June to September 2023

Location of Very Heavy Rainfall Events

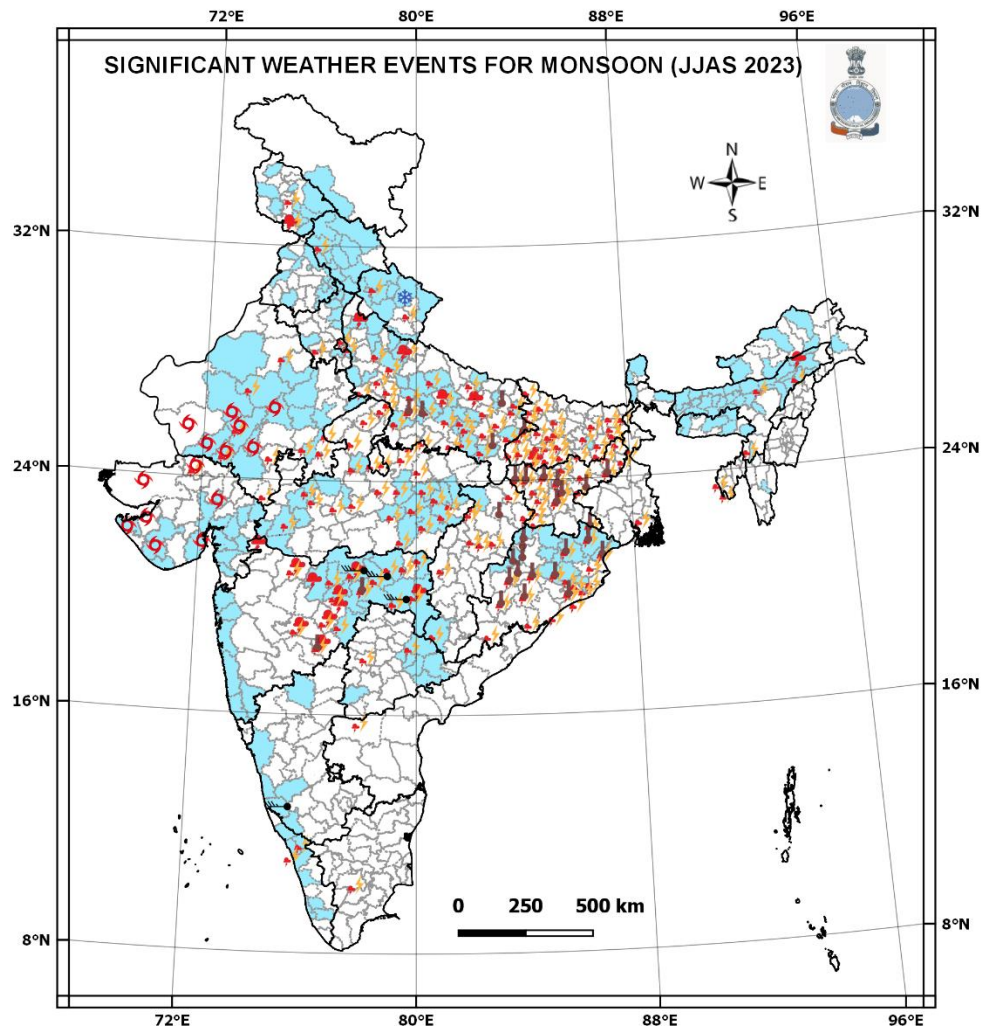


Location of Extremely Heavy Rainfall Events



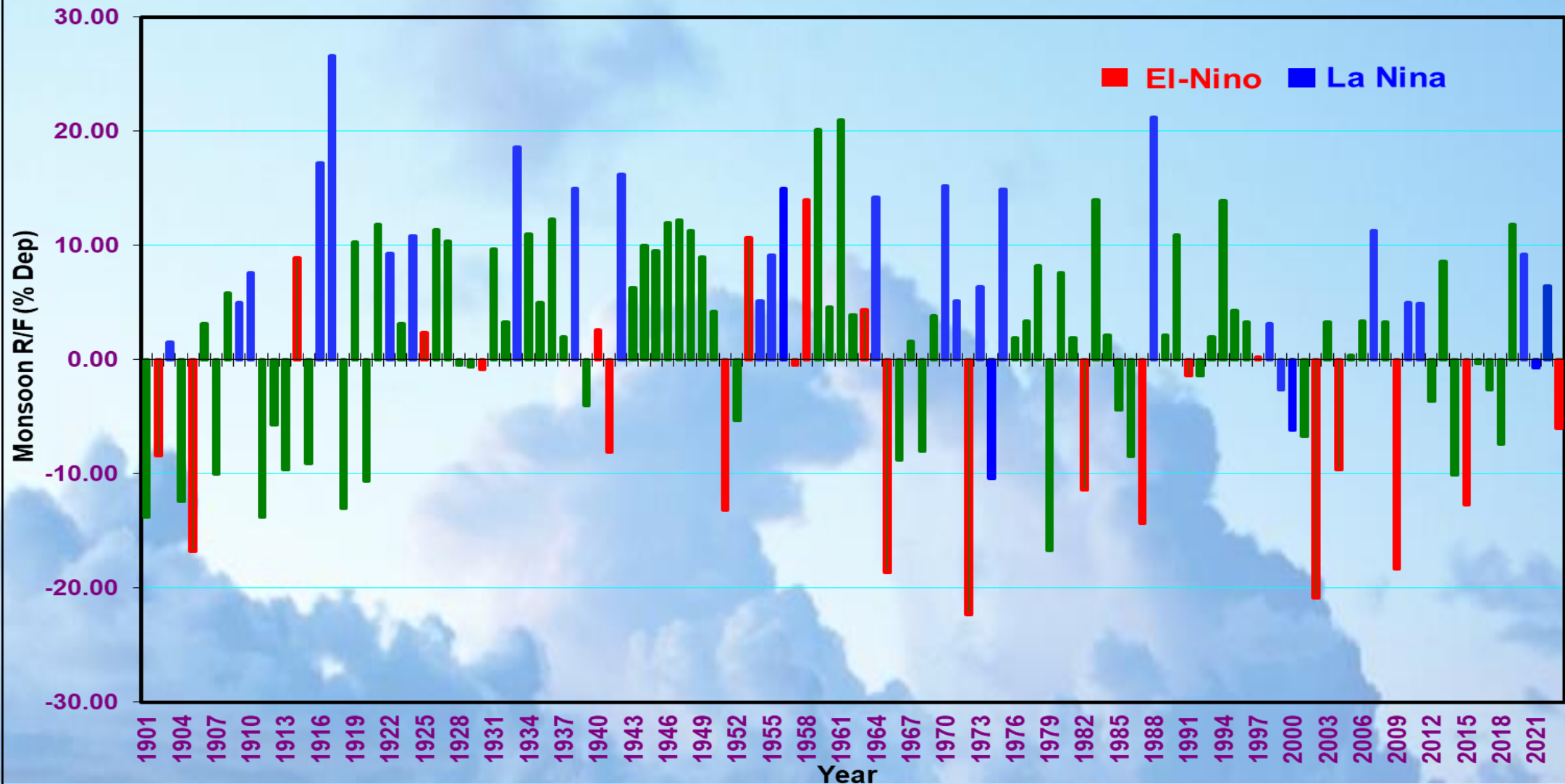
1 Significant Weather Events in June-Sep. 2023

State / UT	FLOODS & HEAVY RAINS	HEAT WAVE	LIGHTNING	THUNDERSTORM
Andhra Pradesh			2	
Arunachal Pradesh	8			
Assam	20		5	1
Bihar	1		85	
Chandigarh	1			
Chhattisgarh	1	2	26	
Dadar and Nagar Haveli	2			
Delhi	2			
Gujarat	3		2	
Haryana	7		1	
Himachal Pradesh	123		2	
Jammu & Kashmir	31		2	
Jharkhand		25	62	
Karnataka	7			
Kerala	24		2	
Ladakh	5			
Madhya Pradesh	14		35	
Maharashtra	69	3	47	2
Meghalaya	9			
Mizoram	1			
Odisha	4	1	36	
Punjab	8			
Rajasthan	45		20	
Sikkim	2			
Tamil Nadu			1	
Telangana	29		4	
Tripura			3	
Uttar Pradesh	57	83	81	7
Uttarakhand	68		1	
West Bengal	3		11	
Grand Total	544	114	428	10

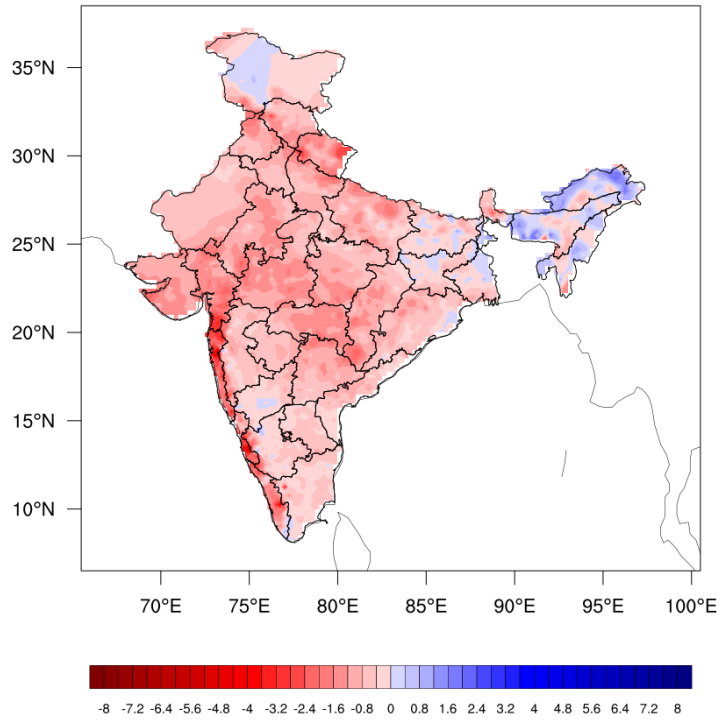


 SNOWFALL
  HEAT WAVE
  GALE
  LIGHTNING
  THUNDERSTORM
  FLOODS / HVY RAIN
  CYCLONIC STORM

All India Southwest Monsoon Rainfall (1901-2023)



EI NINO COMPOSITE JJAS



Positive IOD COMPOSITE JJAS

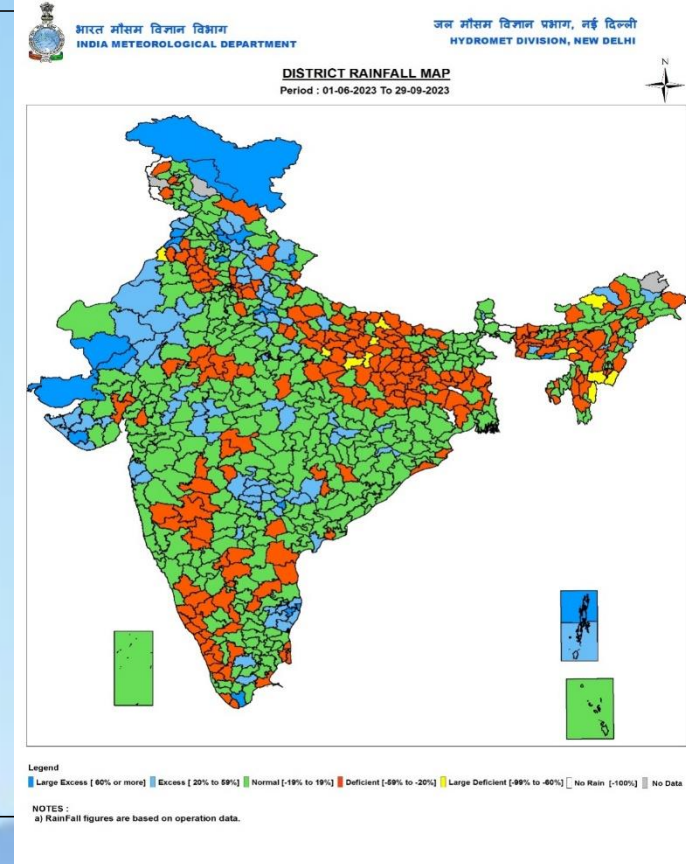
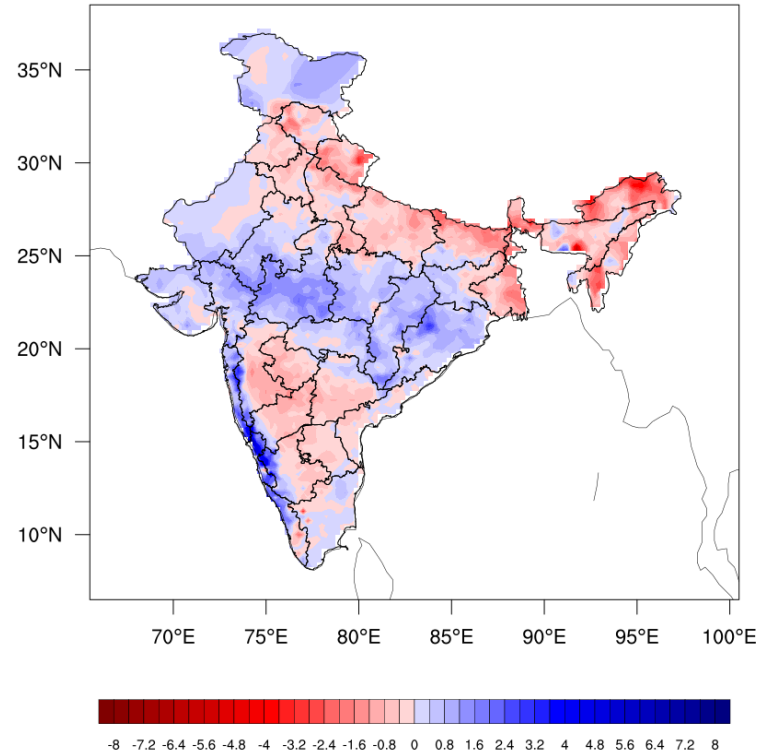
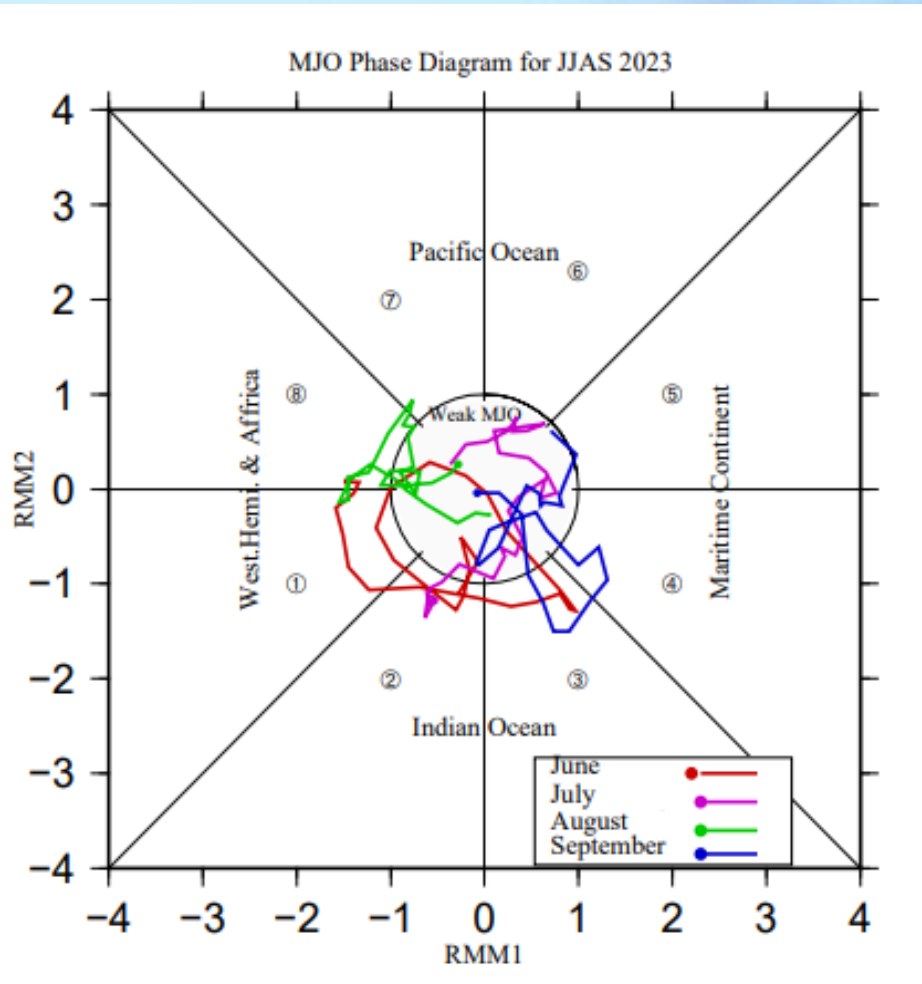


Fig.12(a) Rainfall anomaly composite during southwest monsoon season for the past El Niño events

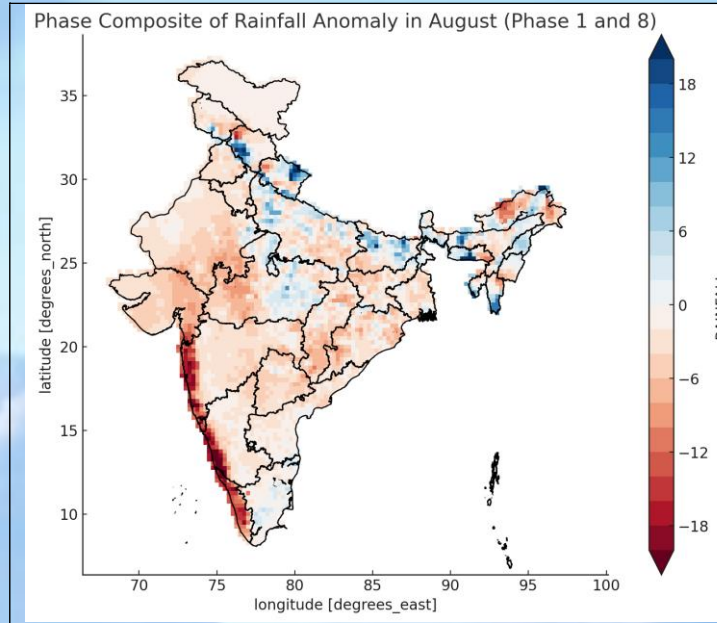
Fig.12(b) Rainfall anomaly composite during southwest monsoon season for past Positive IOD events

MJO influence during 2023 Monsoon Season

MJO Phase during JJAS 2023 Season

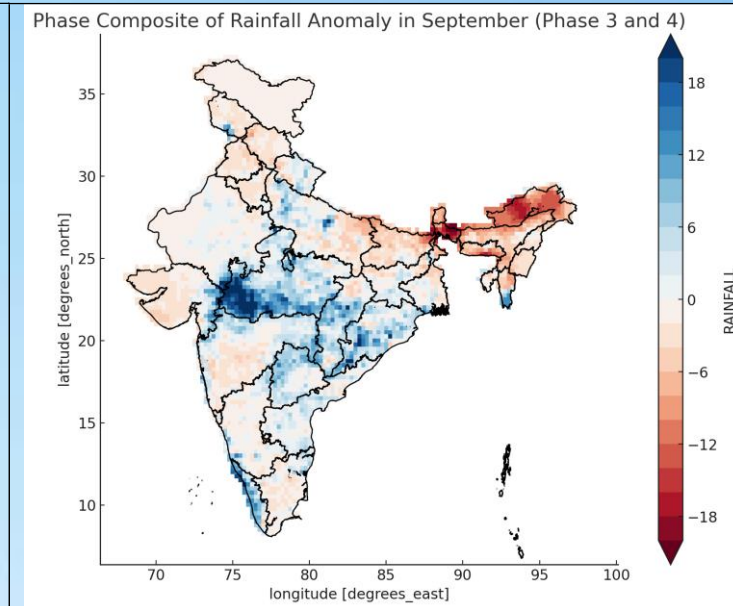


Rainfall Anomaly Composite Phase 1 & 8 (August 2023)



The MJO was in unfavourable phase most (Phase 8 & 1) during most of the of the days in August, which caused for large monsoon rainfall deficiency over most of the Indian Region.

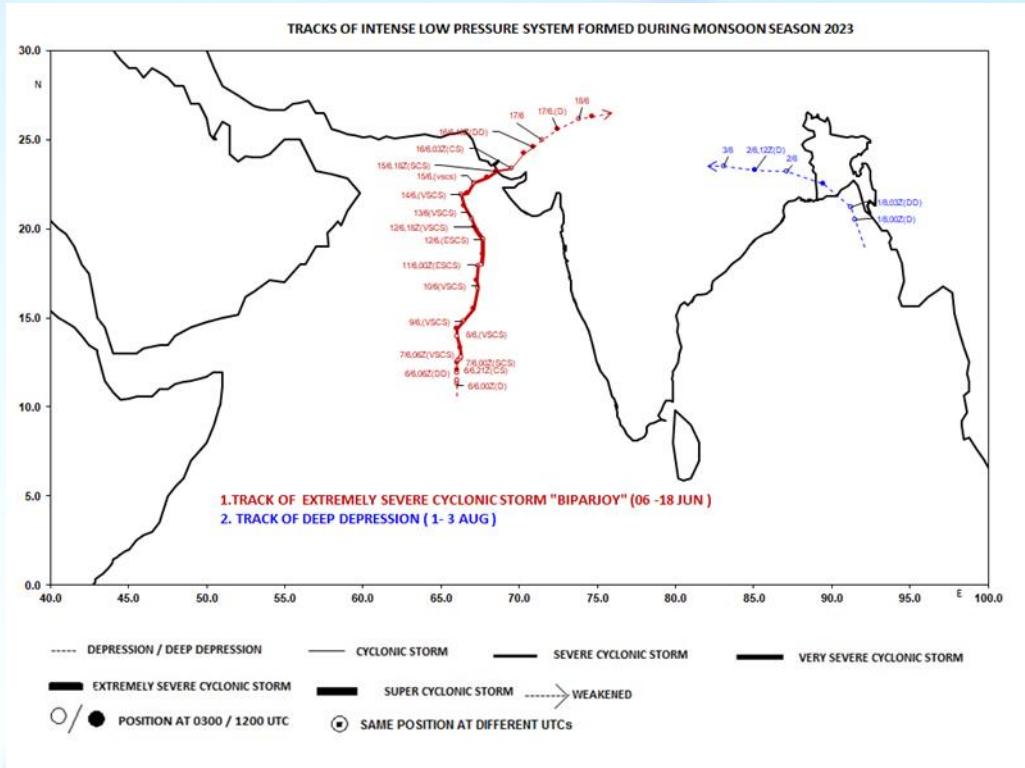
Rainfall Anomaly Composite Phase 3 & 4 (September 2023)



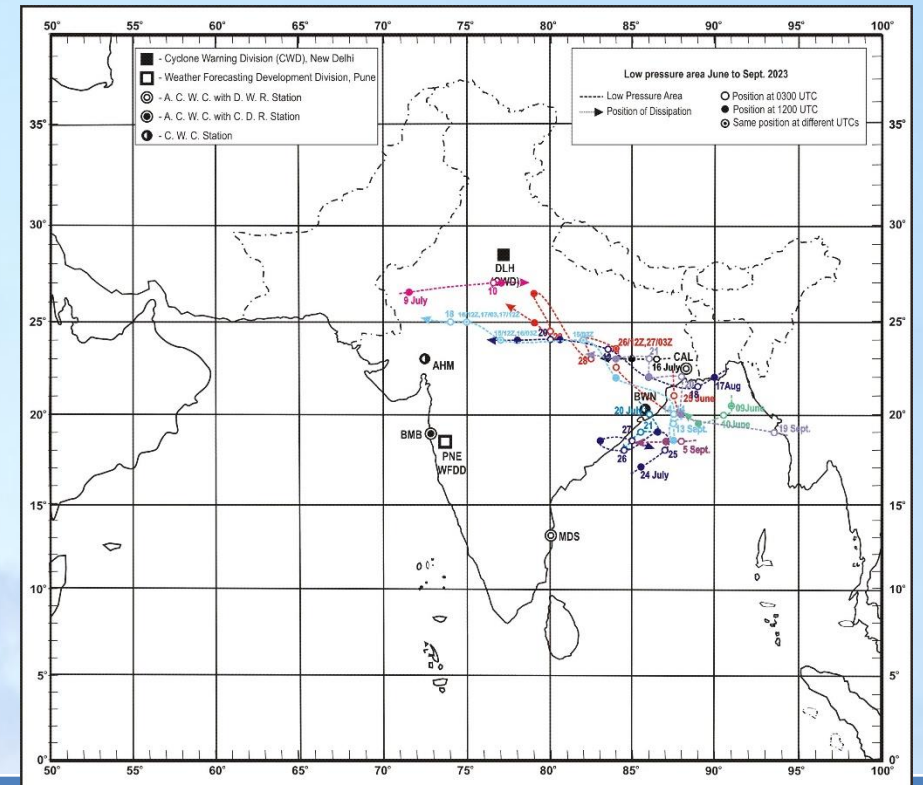
MJO was in the favorable phase 3 & 4, which helps to get good rainfall during September.

Synoptic Scale System over Indian Region JJAS 2023

Tracks of Ext. Very Severe Cyclonic (BIPARJOY) Storm



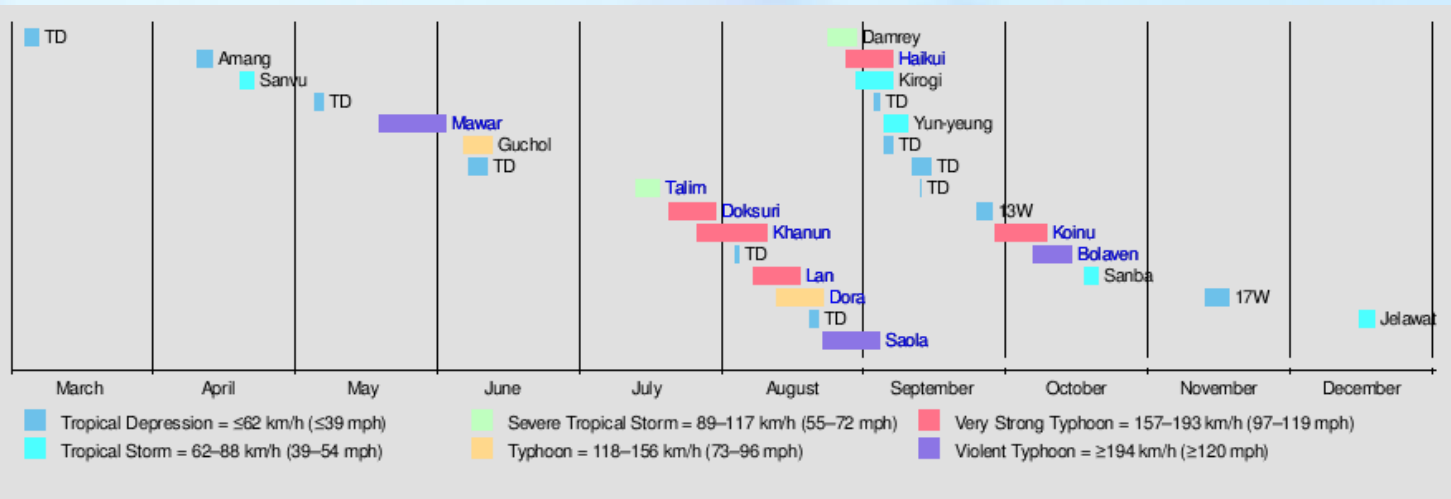
Tracks of Low Pressure Systems



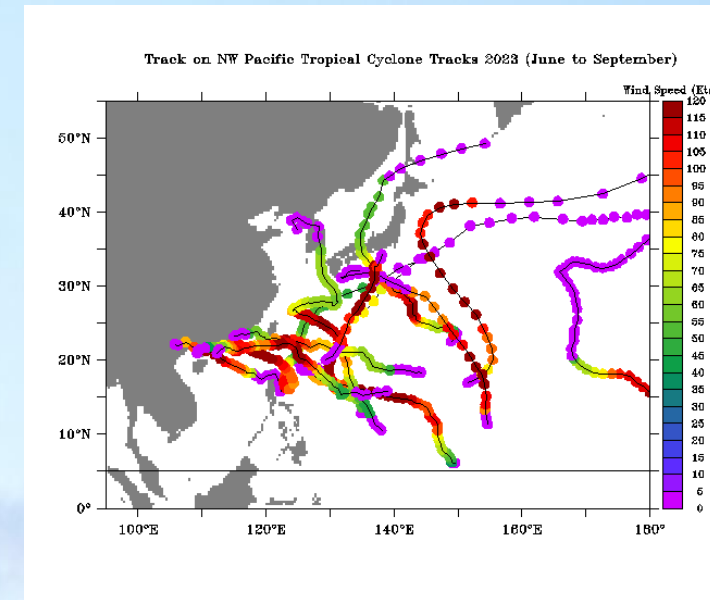
Category	CS	DD	D	WML	LPA	Land LPA	Total Systems	Long period Average of Total monsoon systems
June 2023	1	0	0	2	0	0	3	3
July 2023	0	1	0	1	2	1	5	3
Aug 2023	0	0	0	0	1	0	1	4
Sept 2023	0	0	1	2	2	0	5	3
Season's Total	1	1	1	5	5	1	14	13

Synoptic Scale System over NW Pacific during JJAS 2023

West Pacific Storm during JJAS 2023

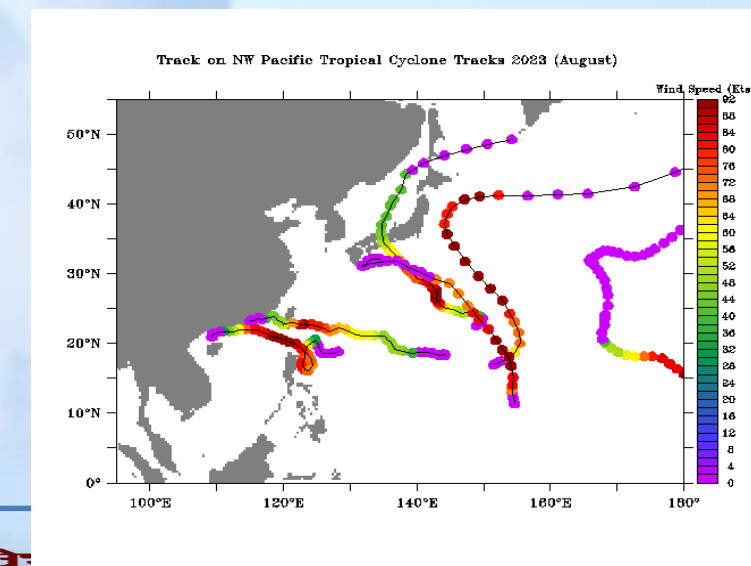


Tracks of Typhoons during JJAS Season 2023



JJAS

There were many intense systems formed over North West Pacific Storm during August months and systems recurved. So there was no chance for formation of Low Pressure System over Bay of Bengal due to Remnants of West Pacific Typhoons



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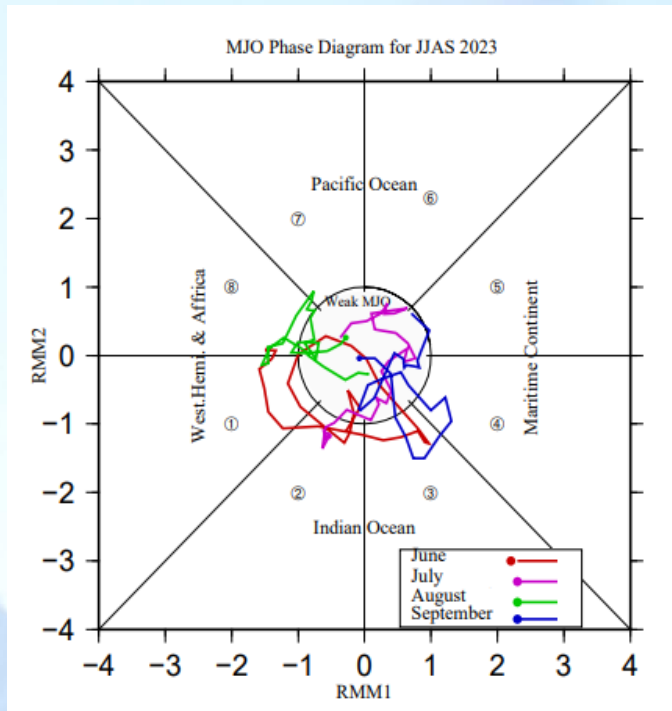


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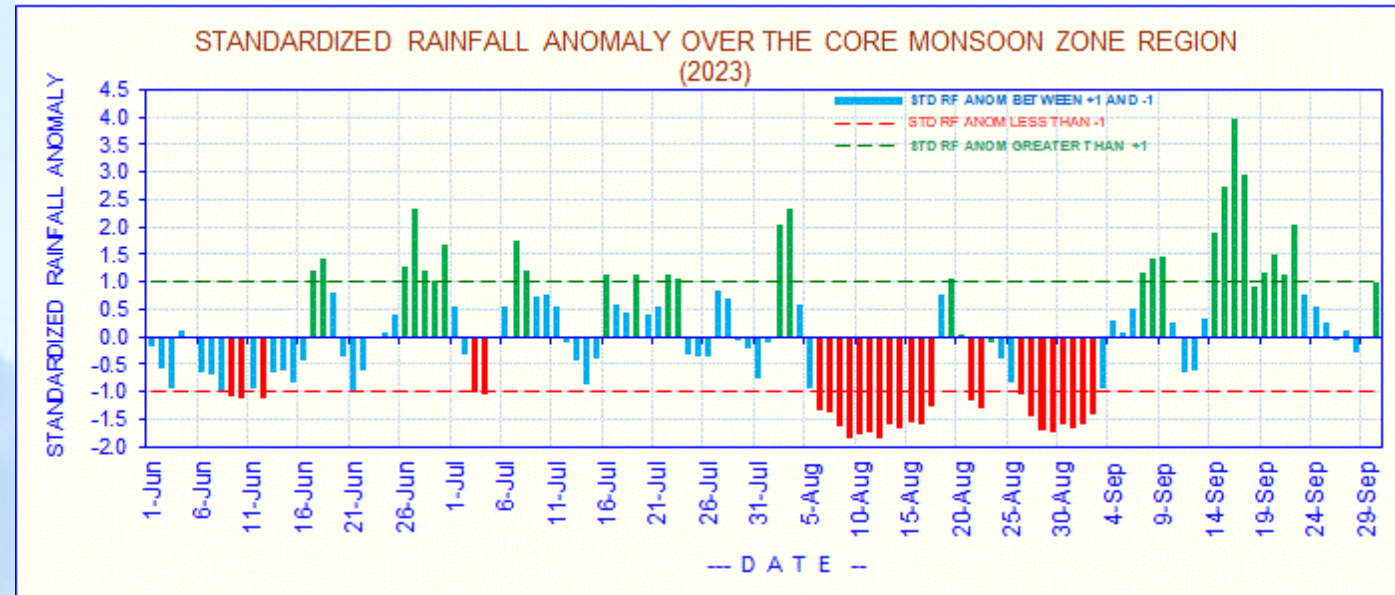


Active Break Cycle & MJO

MJO Index JJAS 2023



Rainfall Anomaly over Core Monsoon Zone



MJO activity was mostly over the phase 1 and 8 during the month of August, which are unfavorable for monsoon rainfall. However MJO was in favorable phase (3 & 4) during many days in September which helps to get good rainfall. MJO was weak in September month.

Negative rainfall anomaly observed over the core monsoon zone most of the days in August. Received good amount of rainfall during September month.

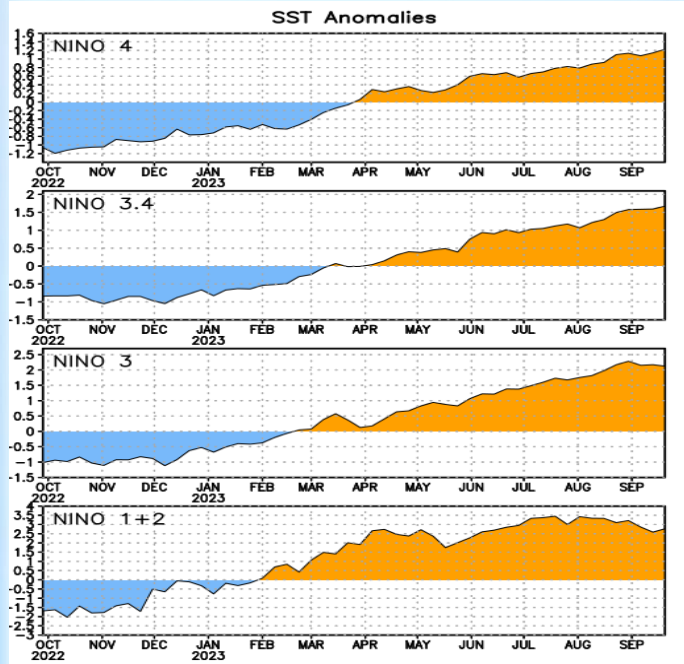
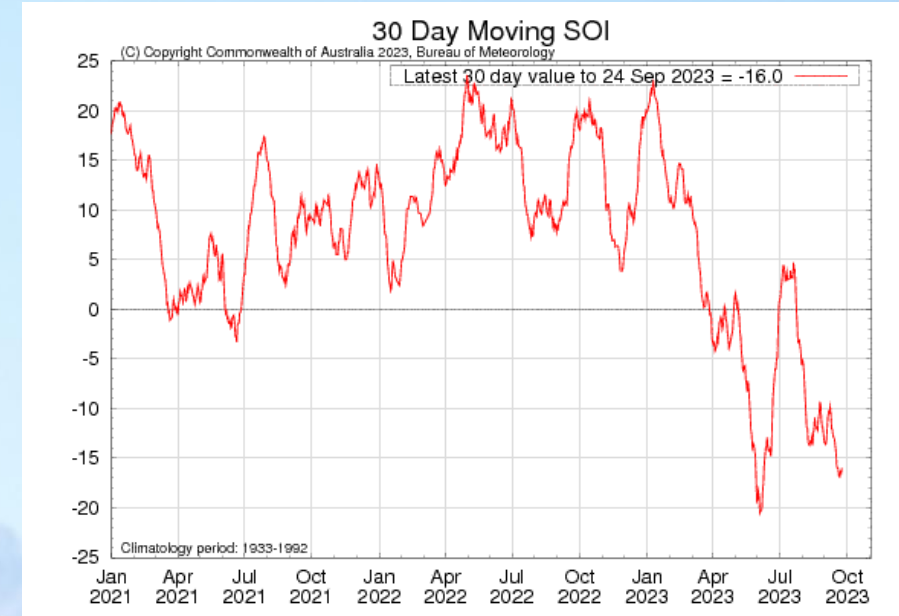


ENSO & IOD Conditions during 2023

Time series of SST anomalies (°C) in the Niño regions

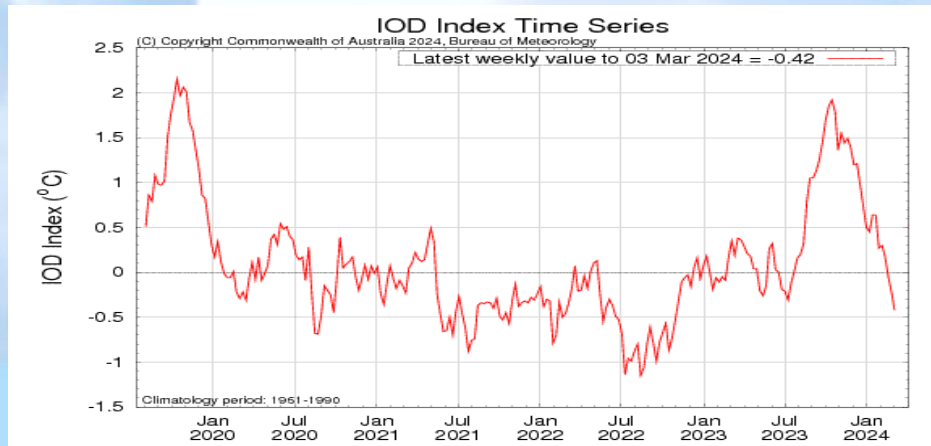
Southern Oscillation Index (SOI)

El Niño conditions prevailed over Equatorial Pacific during the Southwest monsoon season. Which cause large rainfall deficiency over many regions during the season. Atmospheric conditions were also respond to SST conditions and indicate El Niño pattern during monsoon season .



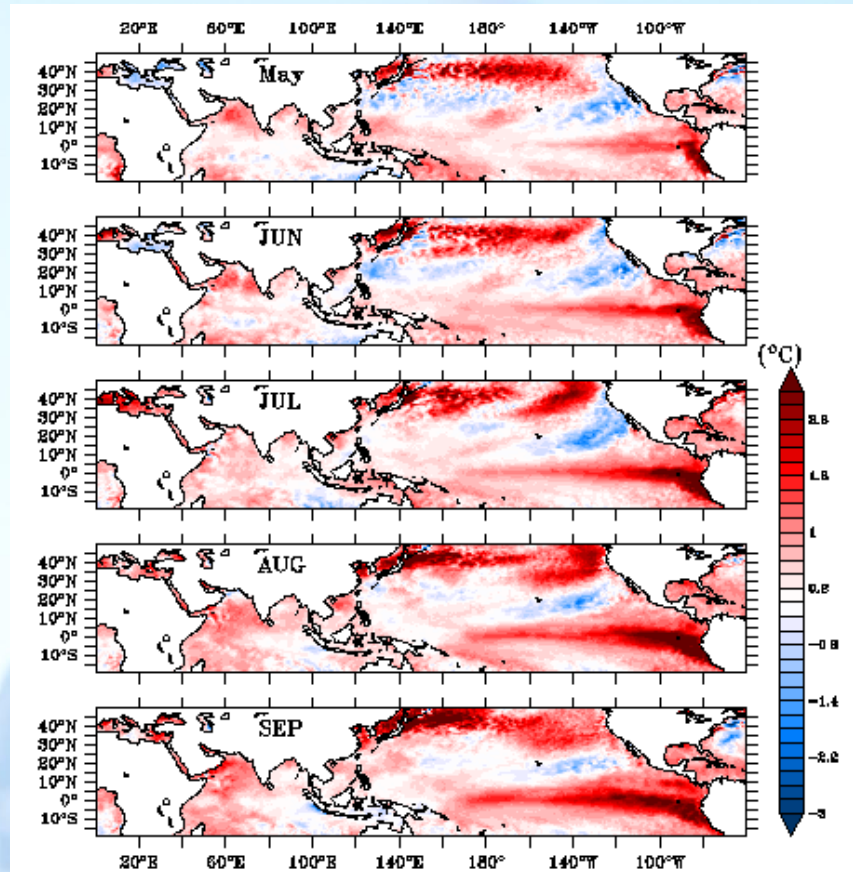
Dipole Mode Index (DMI)

Positive IOD conditions Developed during end of the monsoon season over the Indian Ocean which helps to compensate the adverse effect of El Nino.

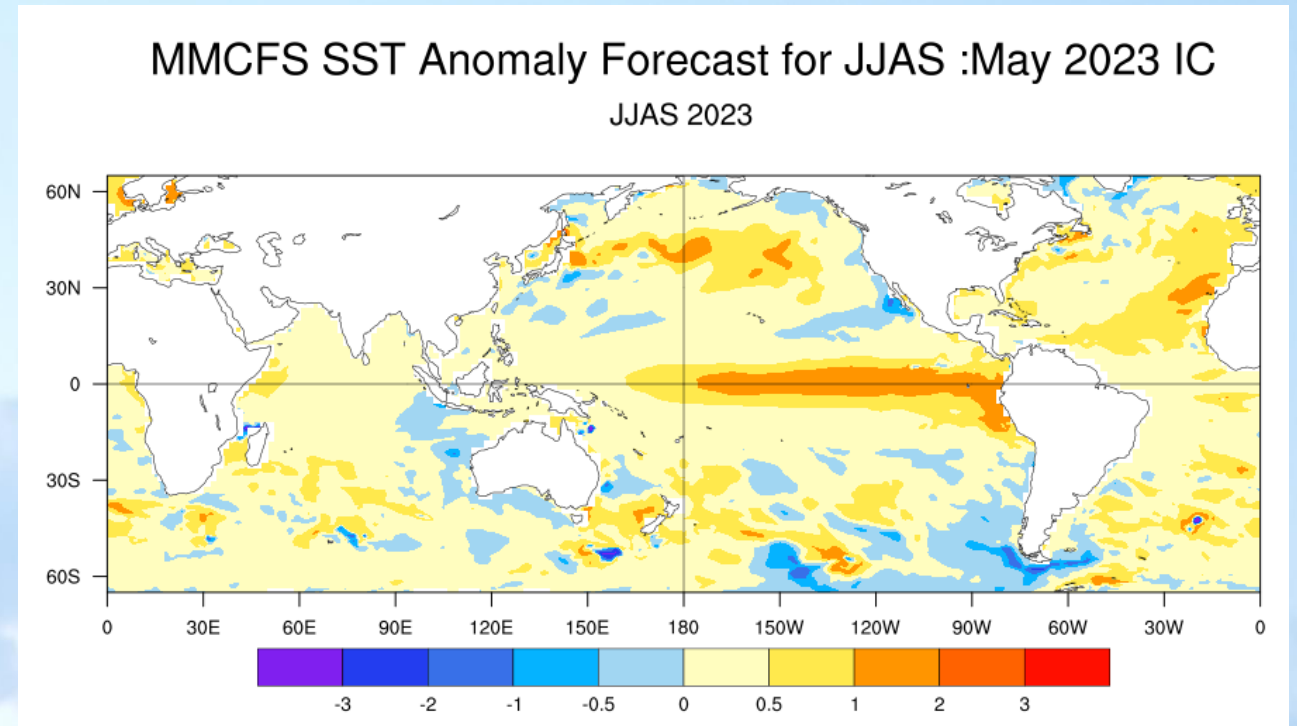


El Niño Conditions prevailed during 2023 SW Monsoon Season

Observed SST May to Sep 2023



MMCFS SST forecast May IC (2023)



El Niño Conditions were prevailed over Equatorial Pacific during the 2023 SW monsoon season correctly Indicated by the MMCFS and other Climate Models.



Verification of Heat wave Seasonal & Monthly Outlook 2023



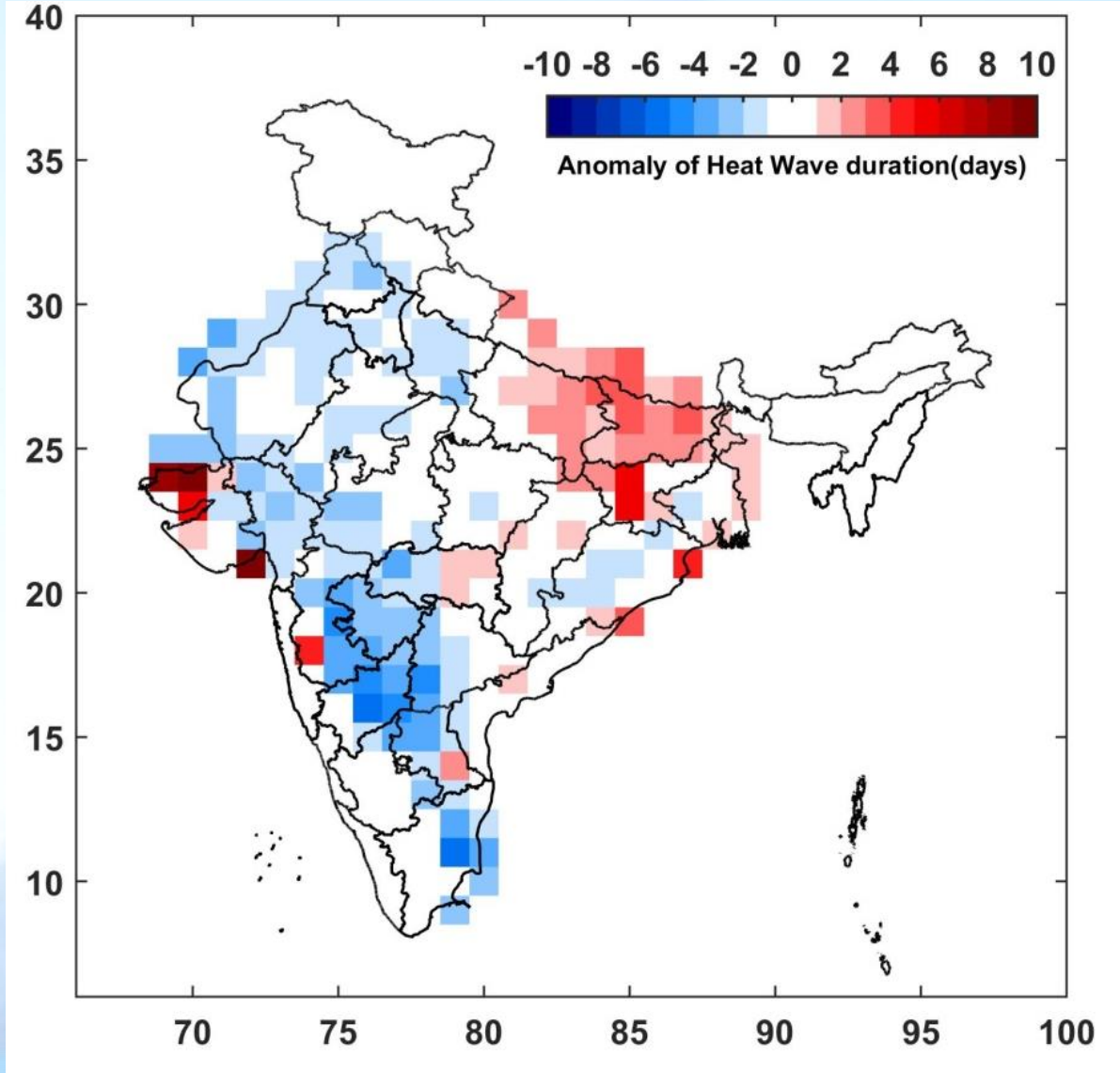
3/12/2024

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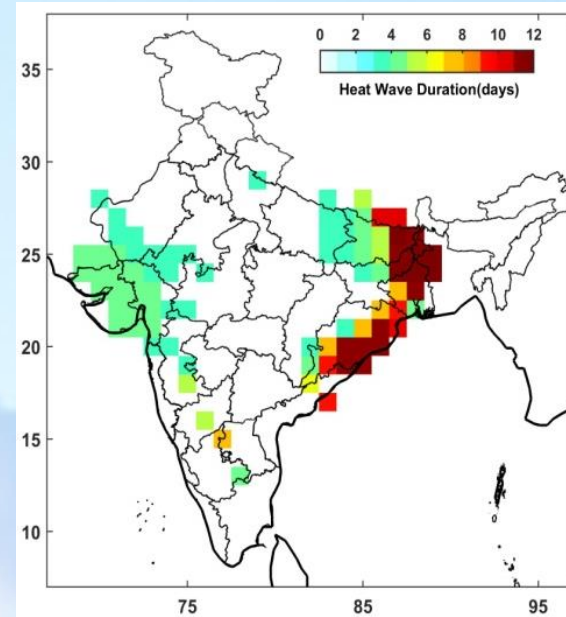
28



Outlook for Heat wave duration Anomaly MAM Season 2023 (Feb IC)

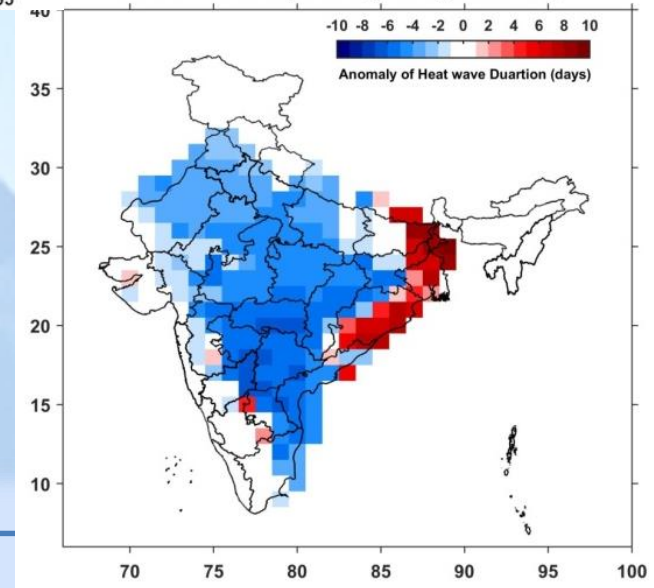


Observed Heat wave duration MAM Season 2023 (IMD)

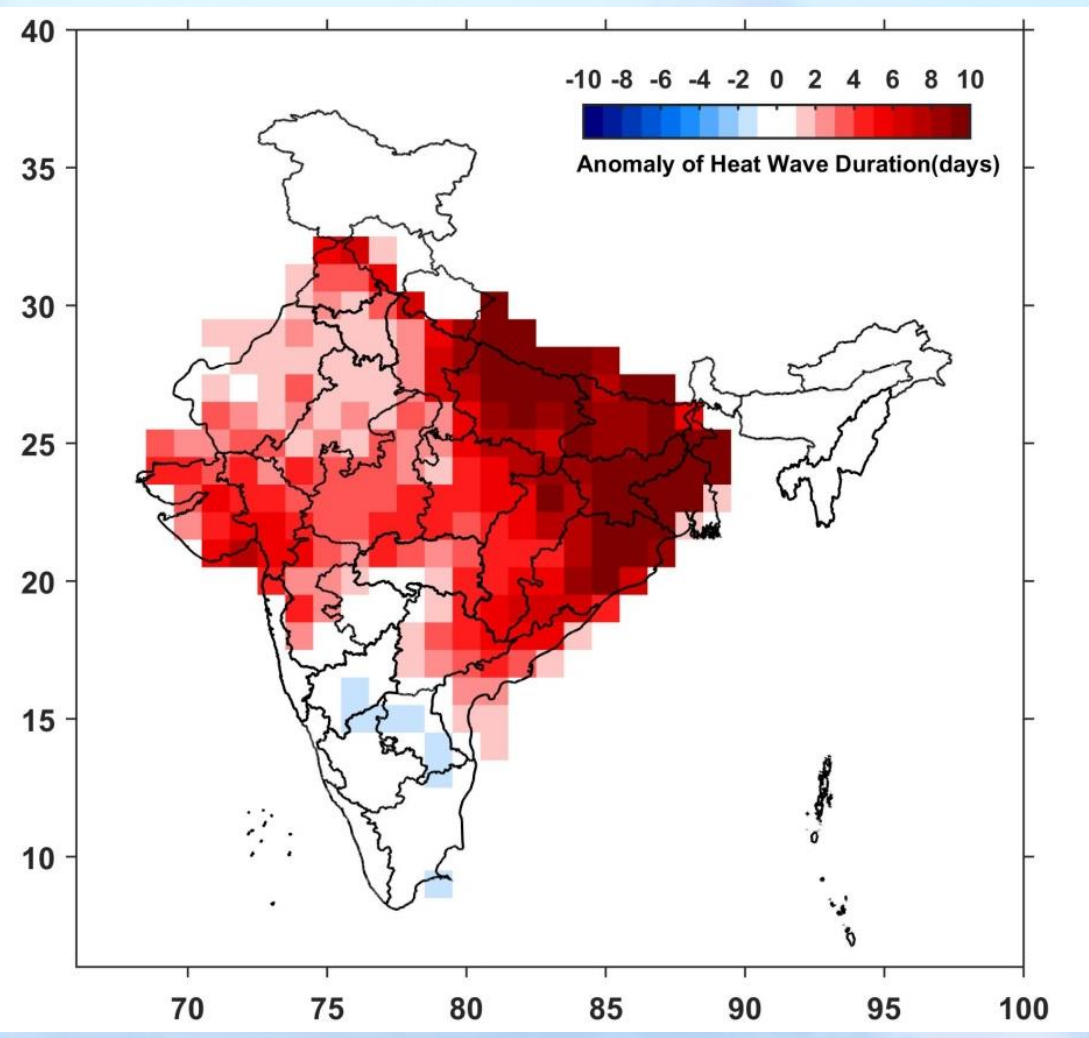


Observed Heat wave duration Anomaly MAM Season 2023

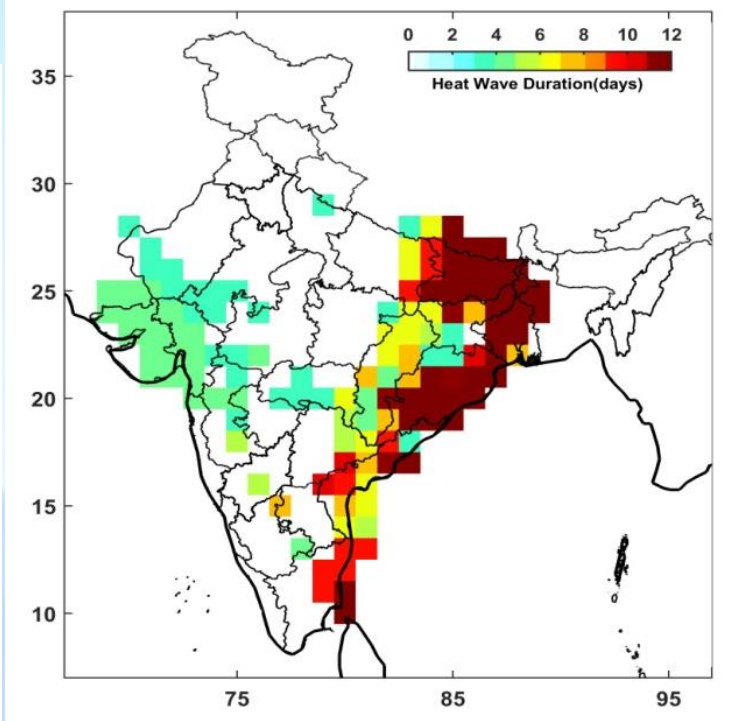
Heat wave duration (Anomaly) during March-May 2023



Outlook for Heat wave duration Anomaly AMJ Season 2023 (Mar IC)

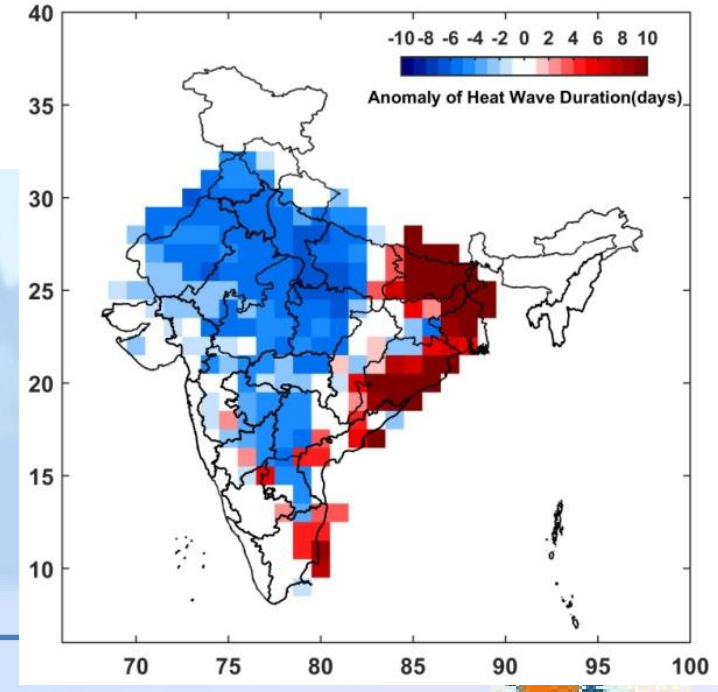


Observed Heat wave duration AMJ Season 2023 (IMD)



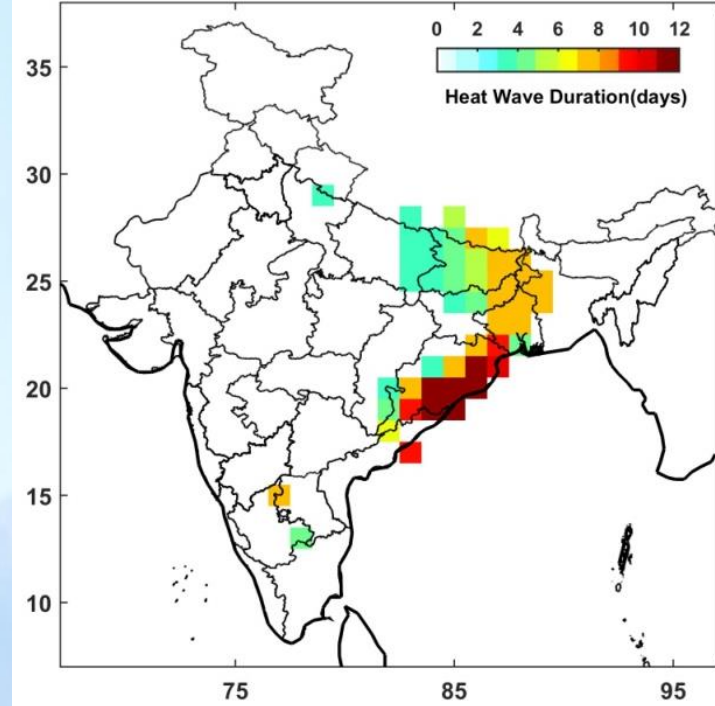
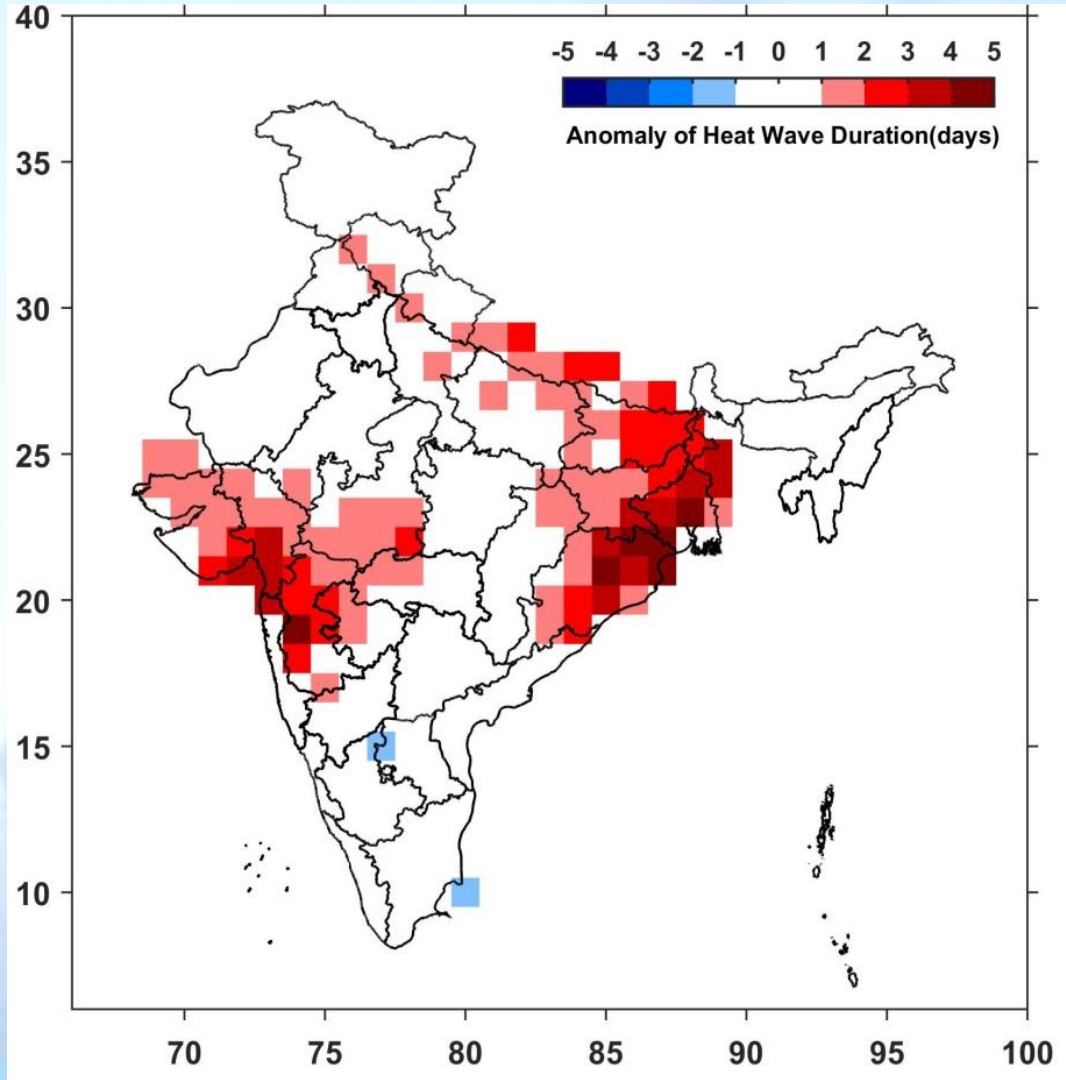
Observed Heat wave duration Anomaly AMJ Season 2023

Heat wave duration(Anomaly) during April-June 2023

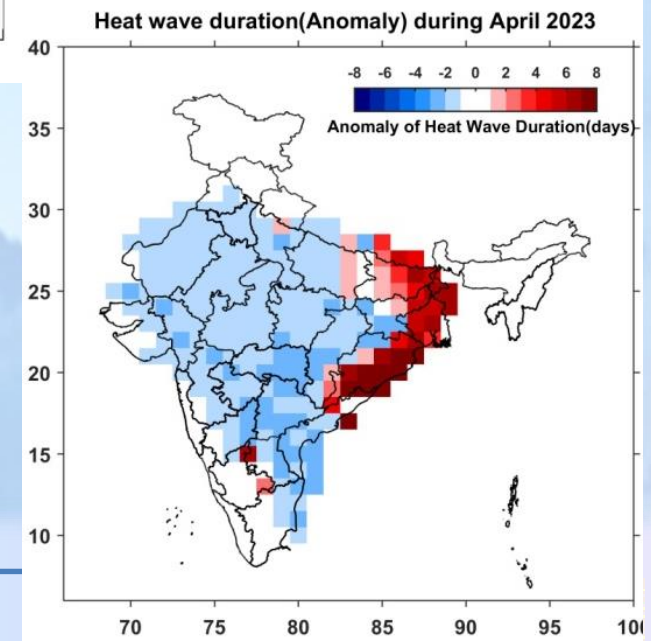


Observed Heat wave duration April Month 2023 (IMD)

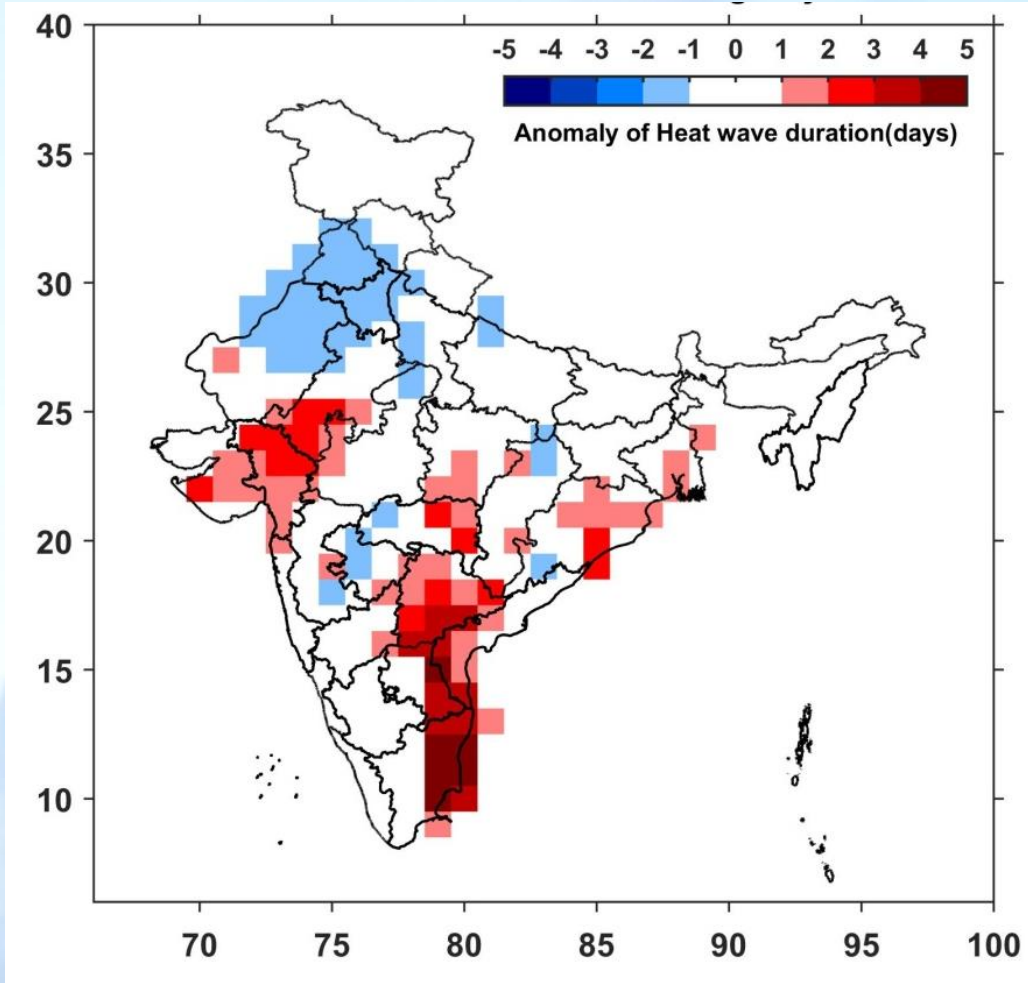
Outlook for Heat wave duration Anomaly April month 2023 (Mar IC)



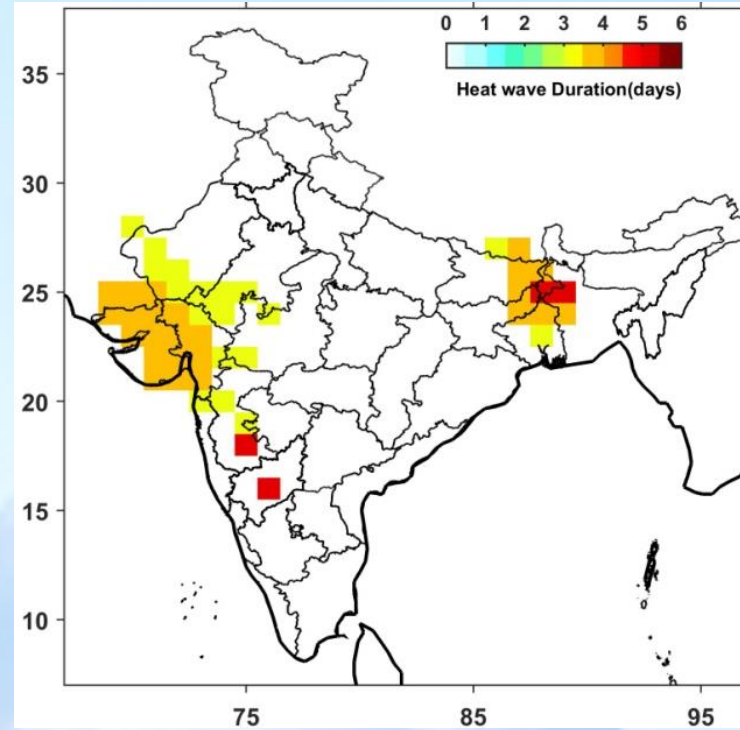
Observed Heat wave duration Anomaly April 2023



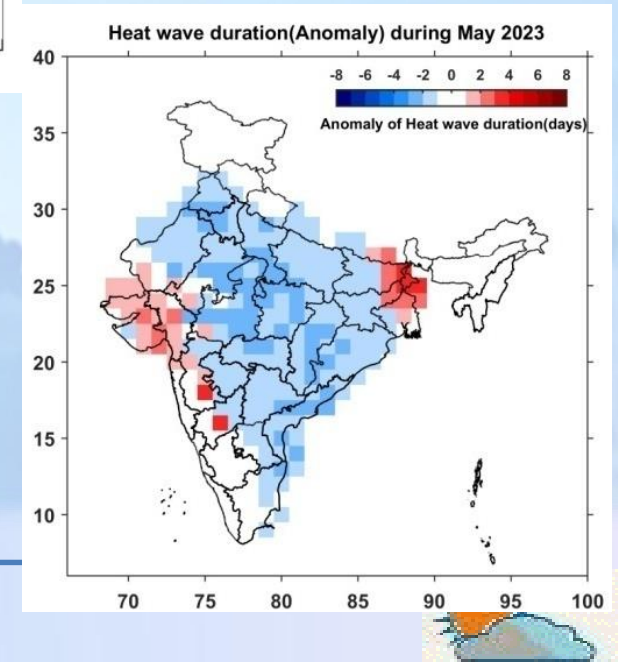
Outlook for Heat wave duration Anomaly May month 2023 (Apr IC)



Observed Heat wave duration May Month 2023 (IMD)

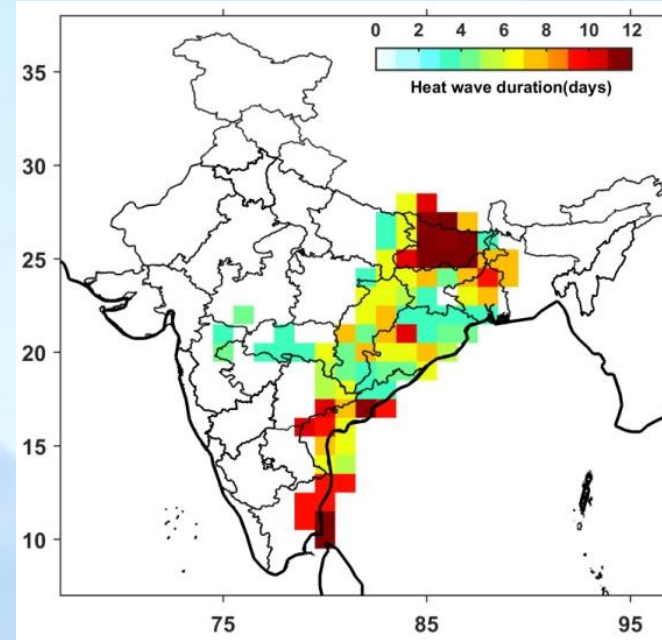
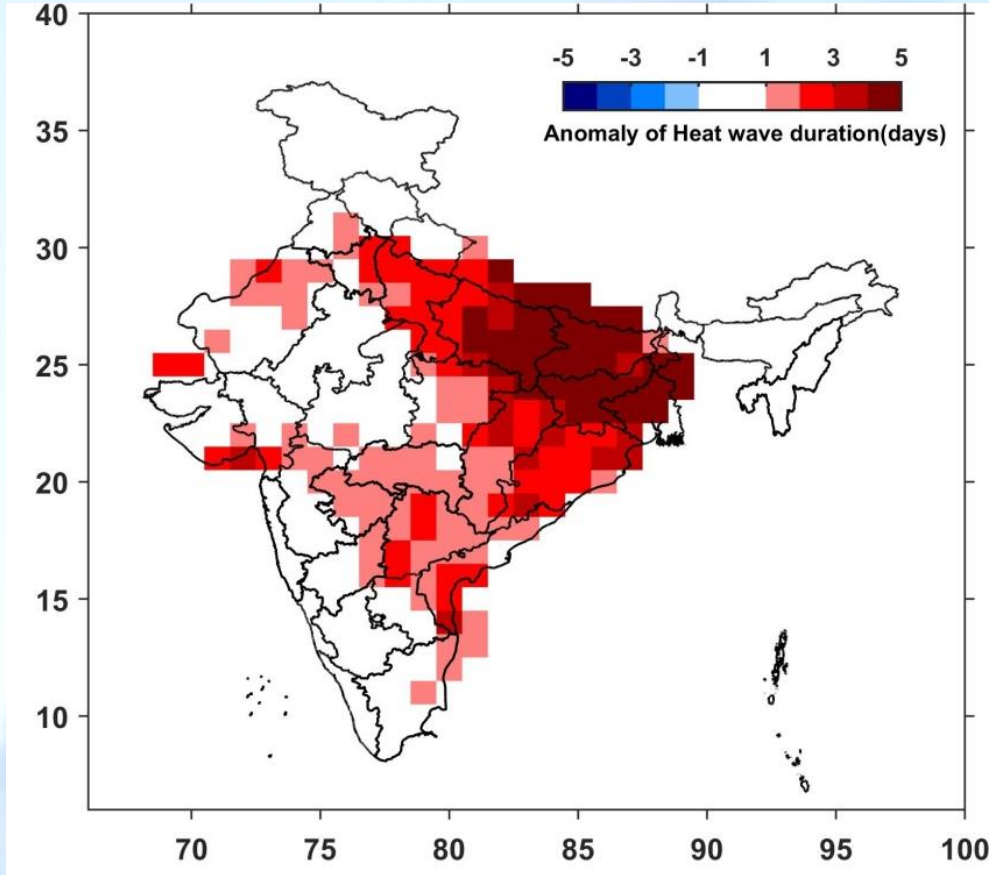


Observed Heat wave duration Anomaly May 2023

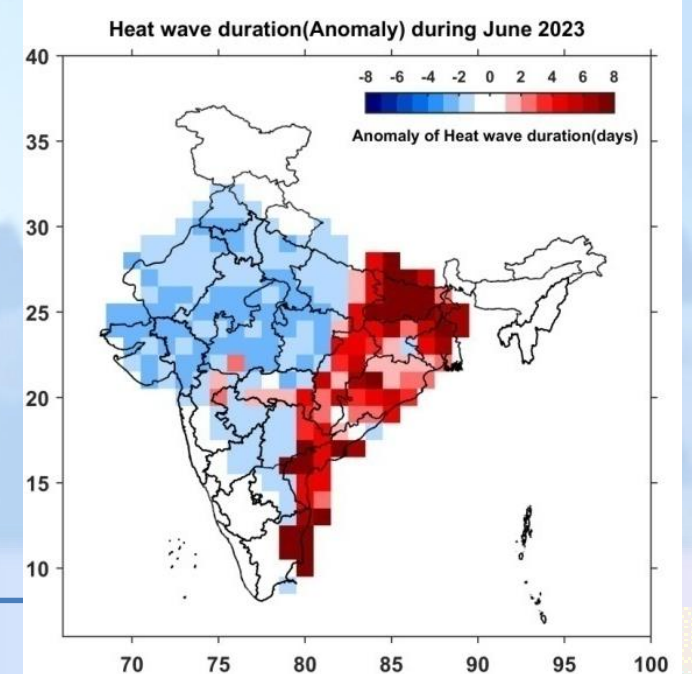


Observed Heat wave duration June 2023 (IMD)

Outlook for Heat wave duration Anomaly June month 2023 (May IC)



Observed Heat wave duration Anomaly June 2023



Silent features of SW monsoon Rainfall 2023

- **El Nino conditions Prevailed over the tropical Equatorial Pacific during the monsoon season. However, during season received good rainfall over northwest India and large rainfall deficiency over Northeast India is not indicate the El Nino impact is less during the monsoon season.**
- **The Positive Indian Ocean Dipole (IOD) developed over Indian Ocean during end of the monsoon season.**
- **Positive IOD is an important factor which helps to compensate the impact of El Nino on rainfall during the 2023 monsoon season.**
- **The large intra seasonal variation observed during the monsoon season, especially in the month of August and September. Mainly associated with absence of formation of Low pressure systems and unfavourable phase of MJO. The recurving of West Pacific Typhoons also one factor for formation of less LPS over Bay of Bengal in August.**
- **The impact of Synoptic Scale systems on the performance was significant resulting increased uncertainty in the predictability of Seasonal and extended range prediction.**
- **Dynamical Model Correctly Indicate the development of El Niño and positive IOD during 2023 SW monsoon season.**





Thank You All



3/12/2024

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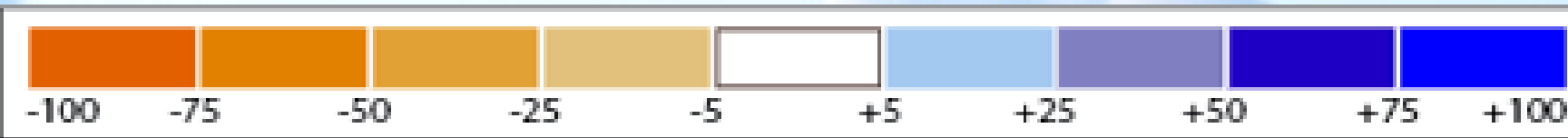
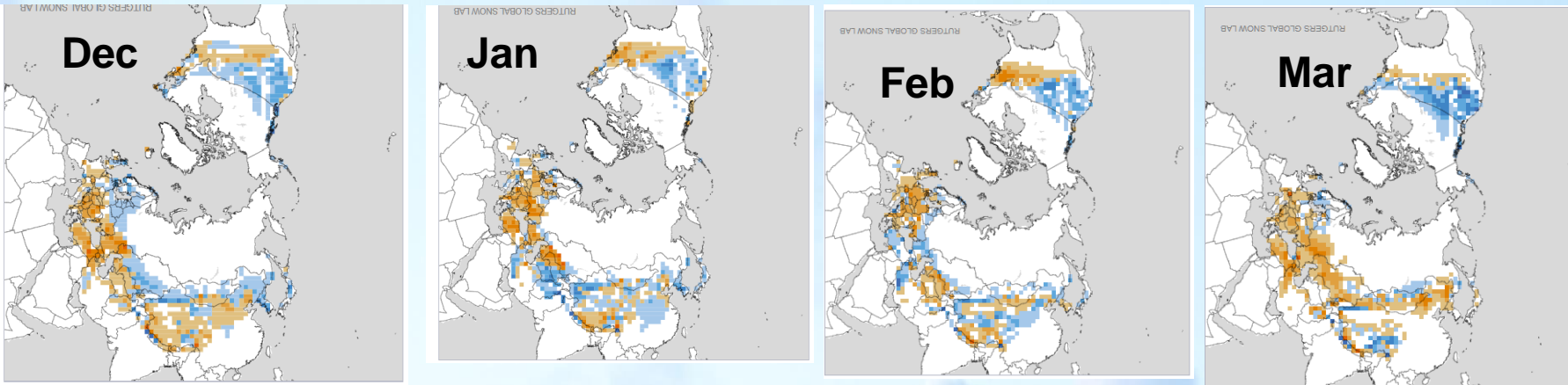
35



Monthly Snow Cover Area - 2023

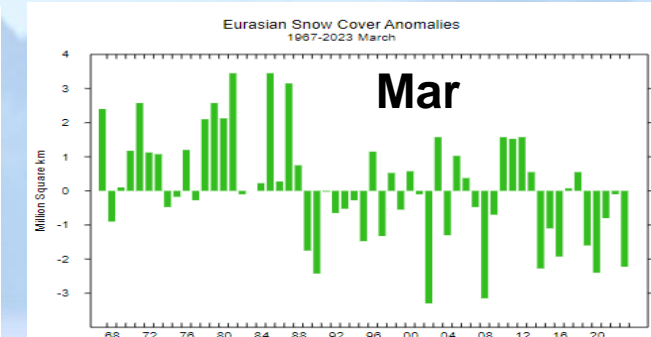
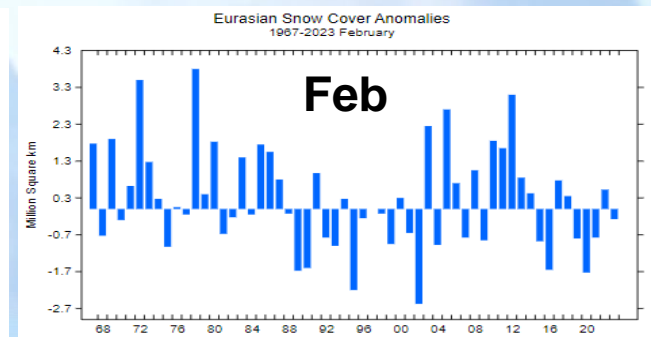
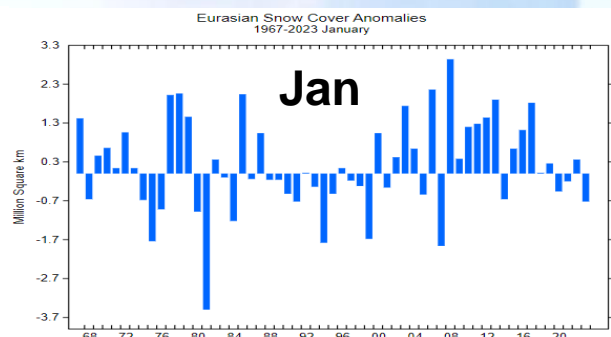
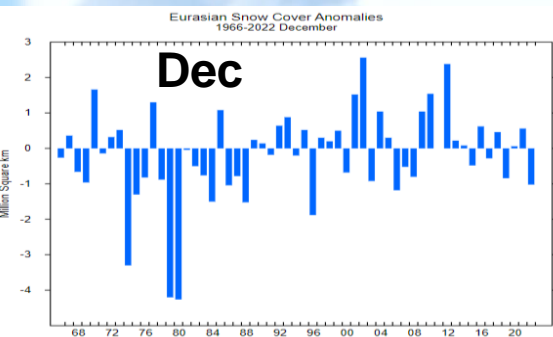
Snow Cover Departure from Normal

Data source:
RUTGERS UNIVERSITY



❖ The snow-covered area over NH as well as Eurasia was below normal during December 2022 and March 2023.

❖ NH snow cover during winter and spring has a general negative relationship with the subsequent Asian summer monsoon.



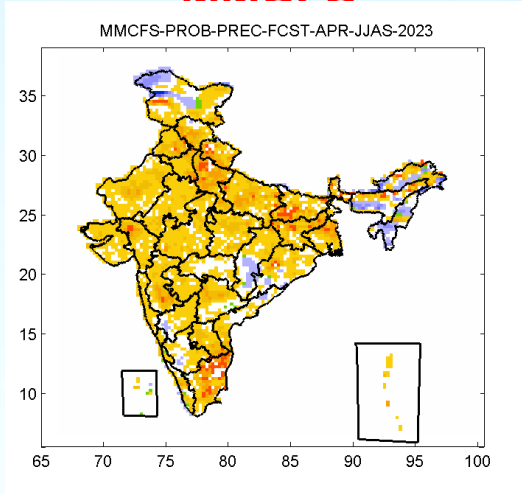
SEFS parameters SW 2023

S.No	Parameter	C.C. (1981-2010)	Standardized value	F/U/N
		with ISMR	(2000-2022)	
1	SST Gradient Between Northeast Pacific and Northwest Atlantic	0.42	0.59	U
	(December +January)			
2	Europe Land Surface Air Temperature Anomaly (January)	0.39	2.24	F
3	Equatorial SE Indian Ocean SST	0.55	0.43	U
	(February)			
4	Equatorial Pacific Warm Water Volume Anomaly	-0.36	0.67	U
	(February + March)			
5	East Asia Surface Pressure	0.54	1.22	F
	(February + March)			

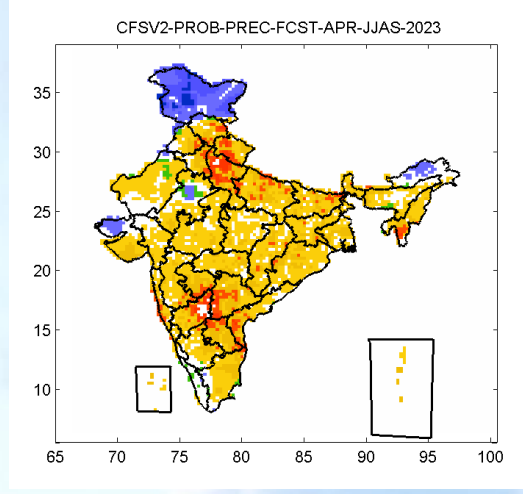


Climate Model Forecast 2023 SW monsoon season (Apr IC)

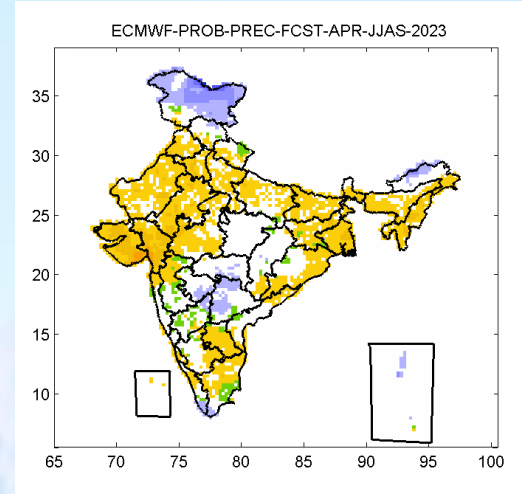
MMCFS



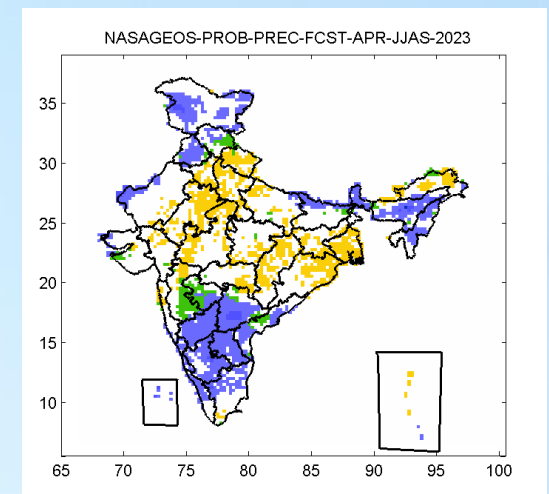
CFSv2



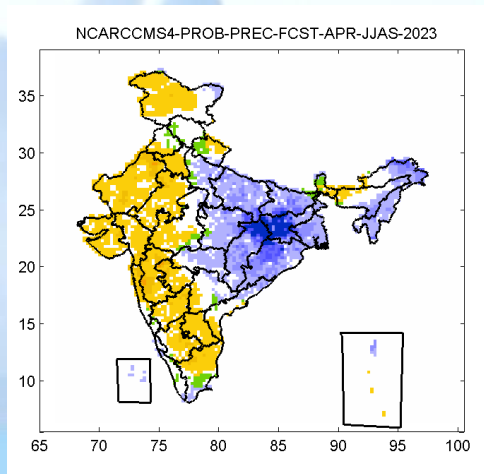
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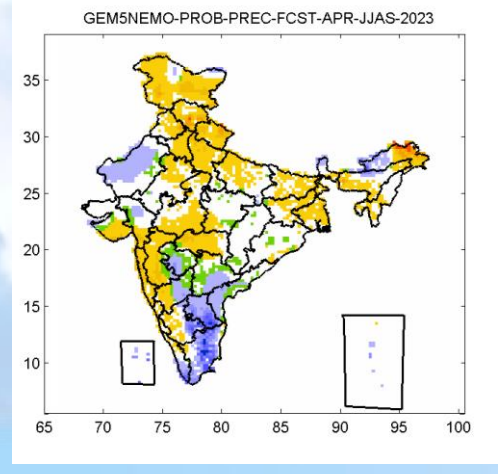
NASA



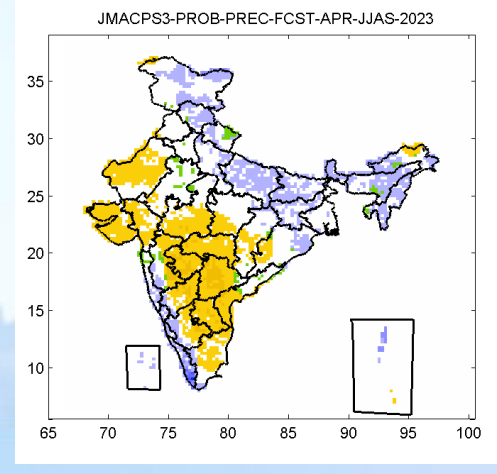
NCAR-CCSM



GEM-NEMO



JMA



CANCM-4i

