Increasing Uncertainty in Large Drought and Flood Projections over Central India

Rajendran Saran[1], Sukumaran Sandeep[1]

[1]Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, India

Email: Saran.Rajendran@cas.iitd.ac.in

INTRODUCTION

- The interannual variability of the Indian Summer Monsoon (ISM) significantly impacts the livelihoods of people living in the Indian subcontinent.
- Projections from various studies indicate a potential increase in the ISM Rainfall by the end of the century (Katzenberger et al., 2021, 2022; Gupta et al., 2020; Moon and Ha, 2020; Rajbanshi and Das, 2021; Long and Li, 2021; Banerjee and Singh, 2022).
- The formation of low-pressure systems in Bay of Bengal and central India has crucial role in defining the flood and drought events of ISM.
- In this study, we investigated large floods (LF) and large droughts (LD), defined as the seasonal mean precipitation exceeding ±10%for historical all forcing run and future climate projections from the Coupled Model Intercomparison Project phase 6 (CMIP6).

DATA

❖ IMD Gridded Rainfall data
- 0.25°x0.25°
- 1901-2023

❖ Coupled Model Intercomparison Project Phase 6
- 25 CMIP6 Models (All available models)
- Scenarios- Historical(1901-2014), SSP126, SSP245, SSP585(2015-2100)
- Variant Label- r1i1f1p1
- Precipitation , Sea Level Pressure, Sea Surface Temperature

METHODOLOGY

❖ **Identification of Large floods and large droughts**
- The mean of percentage anomalies exceeding +10% for floods and below -10% for droughts.
- This mean value is used as the threshold for identifying LF and LD events, effectively filtering out only the 'large events' from the overall ISM flood and drought occurrences.
- The thresholds derived for the historical scenario are consistently applied to future scenarios.
- Return period of LF and LD calculated using generalized extreme value (GEV) distribution. The GEV distribution is fitted to the annual maxima and minima of JJAS precipitation anomalies for floods and droughts, respectively.

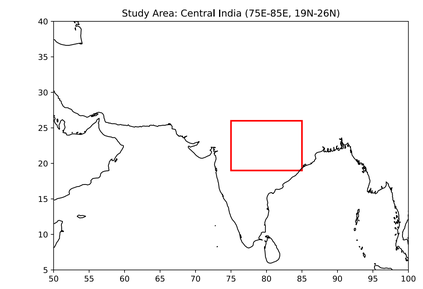

Figure 1. Study Area: Central India

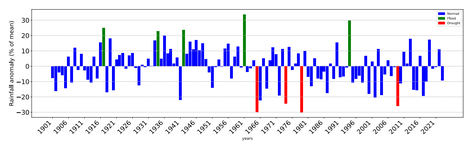

Figure 2. JJAS mean rainfall departure (in percentage) from IMD gridded rainfall data over Central India (75 °E – 85 °E and 19 °N – 26 °N) during 1901 to 2023

Sl.No	Model/observation	LF mean threshold	LD mean threshold
1	IMD	22.4	-23.2
2	CESM2-WACCM	36	-43
3	MPI-ESM1-2-LR	18.6	-22
4	NorESM2-LM	42.4	-49.7
5	MIROC6	26.4	-28.8
6	AWI-CM-1-1-MR	16.3	-20.5
7	TaiESM1	34	-45
8	FIO-ESM-2-0	29	-27
9	CAMS-CSM1-0	22	-23
10	CanESM5	99	-66
11	CAS-ESM2-0	22	-23
12	CIESM	27	-30.8
13	CMCC-CM2-SR5	28	-36
14	CMCC-ESM2	34	-41.8
15	FGOALS-f3-L	55	-59
16	FGOALS-g3	76	-45
17	GFDL-ESM4	40	-40
18	IITM-ESM	35	-39.5
19	INM-CM5-0	31	-34
20	IPSL-CM6A-LR	19.6	-23
21	KACE-1-0-G	105.5	-83
22	KIOST-ESM	48	-41
23	MRI-ESM2-0	50	-52
24	NESM3	26	-26.6
25	ACCESS-CM2	119	-87
26	ACCESS-ESM1-5	118.6	-81

Table 1: The mean threshold for large flood and large drought in IMD rainfall data and CMIP6 models

METHODOLOGY

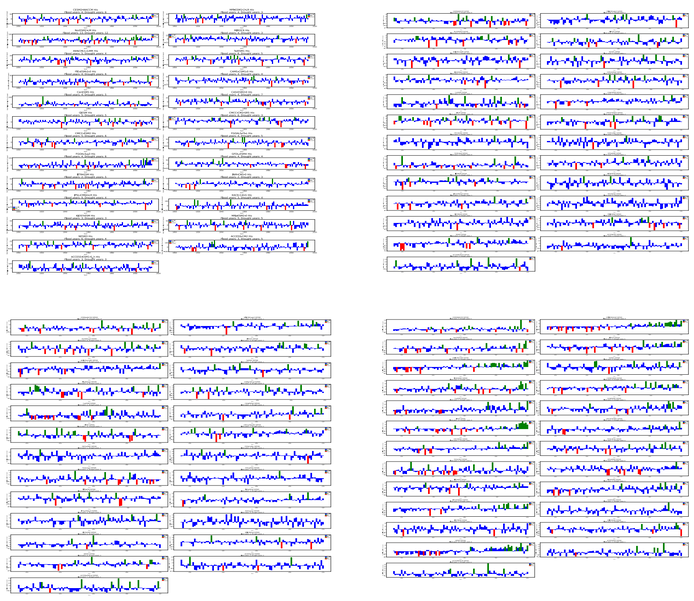

Figure 3. JJAS mean rainfall departure (in percentage) in CMIP6 Models over Central India (75 °E – 85 °E and 19 °N – 26 °N) for Historical, SSP126, SSP245 abd SSP585.

❖ **LPS tracking algorithm**
- We used the tracking technique of (Praveen et al., 2015) to follow the paths of LPS in the ERA-5 reanalysis data and CMIP6 models.
- Using gridded daily sea level pressure (SLP) data, this technique finds closed isobars at intervals of 1 hPa to detect and track LPS.

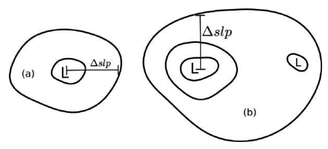

Figure 4. Schematic diagram showing the identification of the LPS center and calculation of the pressure gradient for (a) a single-center system and (b) a multicenter system. (Praveen et al., 2015)

RESULTS

❖ **Number and Return Period of Meteorological large Floods and large Droughts over Central India in Different CMIP6 Scenarios**

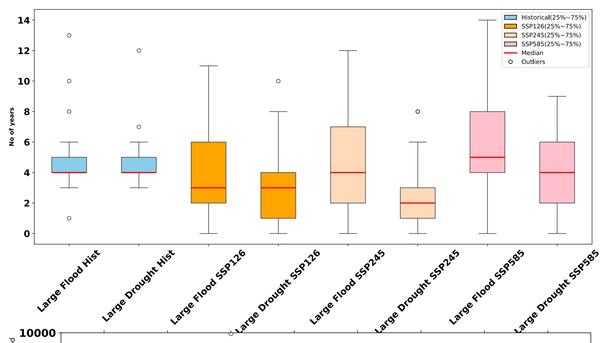

Figure 5. Box-Whisker plot of number of large flood and large drought years in different CMIP6 scenarios

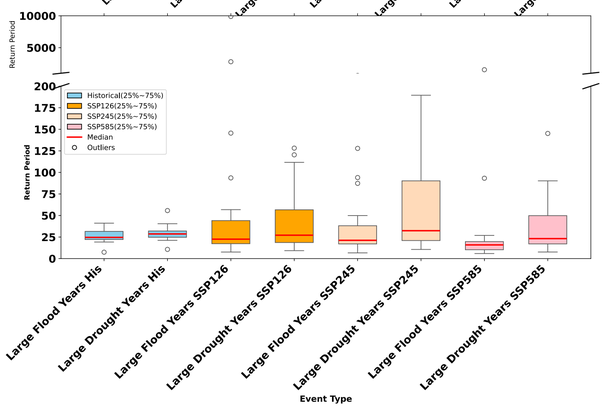

Figure 6. Box-Whisker plot of return period of large flood and large drought years in different CMIP6 scenarios

- The number of LF shows an increase, while the median count of LD exhibits a decrease with an increase in the spread across ensembles in future scenario simulations.
- The return period for LF gradually decreases across different scenarios. In contrast, the return period for LD in future scenarios exhibits greater uncertainty compared to that of LF.

❖ **Relation between Low Pressure Systems(LPS) and Meteorological large flood and large Drought Events**

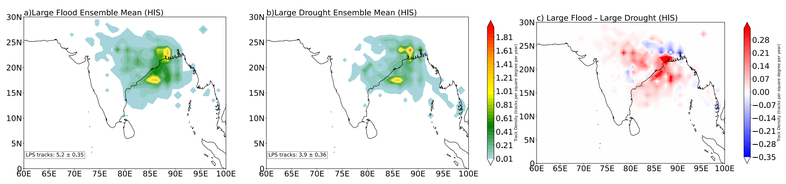

Figure 7. a-b)Multi model LPS composite for large floods and large droughts for the historical scenario(1901-2014), c) difference between large flood and large drought multi model composite of LPS.

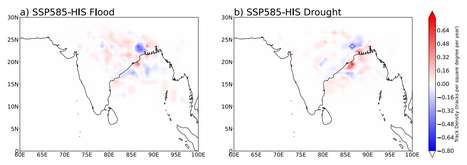

Figure 8. a) Difference between SSP585 and historical large flood multimodal LPS composite , b)Same for large drought

RESULTS

- LF years display a coherent north-westward propagation of LPS into the Indian land region, whereas LD years exhibit reduced northward propagation and a more prominent eastward propagation of LPS away from the Indian landmass.
- In future projections, the number of LPS tracks per year decreases by 3.27% during LF events and by 7.69% during LD events compared to historical events.

❖ **Examination of coincidence of ENSO with Meteorological large floods and large drought Events**

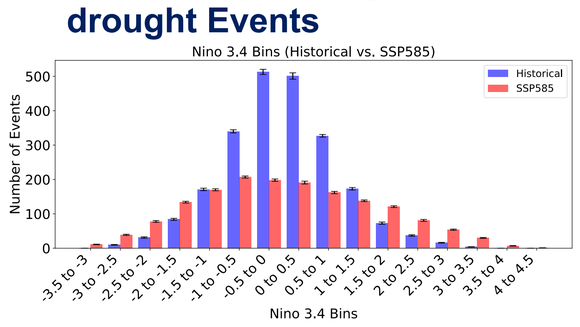

Figure 9. The number of Niñ o3.4 Index Bin Counts across all models in both historical and SSP585 Scenarios

- Moderate ENSO events are projected to decrease under future scenarios of greenhouse warming compared to the historical period, while extreme ENSO events are expected to increase.

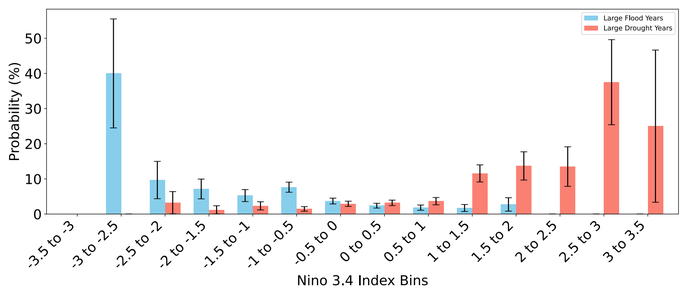

Figure 10. Probability of occurrence of large floods and large droughts across Niñ o3.4 bins (Historical)

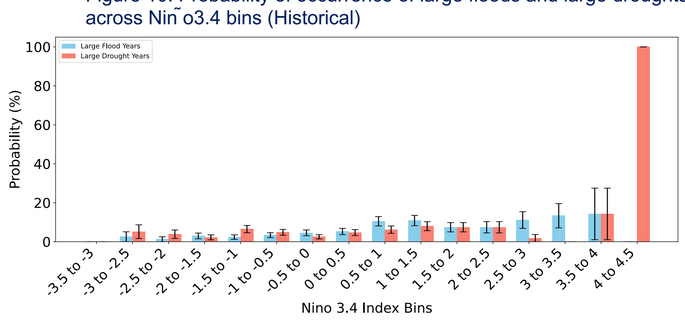

Figure 11. Probability of occurrence large floods and large droughts across Niñ o3.4 bins (SSP585)

- The relationship between El Niñ o and La Niñ a events with large floods and large droughts becomes more uncertain in future projections.

CONCLUSIONS

- The increase in LF count and decrease in its return period over central India in future scenarios, compared to LD occurrences, suggests that future climates are likely to experience more frequent extreme wetter seasons.
- The return period for LD in future scenarios exhibits greater uncertainty compared to that of LF.
- The higher track density and more pronounced north-westward propagation of LPS over the Indian landmass during LF compared to LD indicate the role of sub-seasonal synoptic activity in extreme wet events.
- LF events are projected to occur more frequently during El Niñ o years in the SSP585 scenario, suggesting a fundamental change in the link between ENSO and ISM extremes.

FUTURE SCOPE

- Investigation of the role of thermodynamical and dynamical contributions to the large flood and large droughts in historical and future projections

REFERENCES

1. Singh, D., Ghosh, S., Roxy, M. K. and McDermid, S. (2019), 'Indian summer monsoon: Extreme events, historical changes, and role of anthropogenic forcings', Wiley Interdisciplinary Reviews: Climate Change 10(2), e571.
2. Katzenberger,A.,Levermann,A.,Schewe,J.andPongratz,J.,2022.Intensificationofv erywetmonsoonseasonsinIndiaunderglobal warming. *Geophysical Research Letters*, *49*(15), p.e2022GL098856