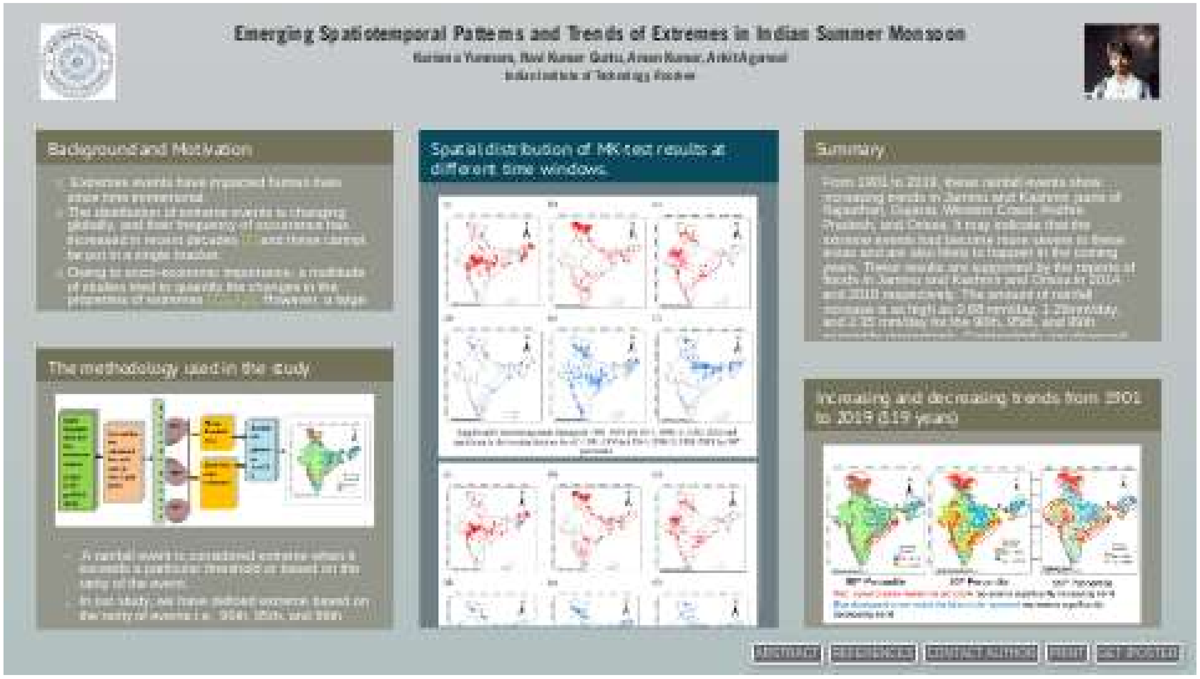
Emerging Spatiotemporal Patterns and Trends of Extremes in Indian Summer Monsoon



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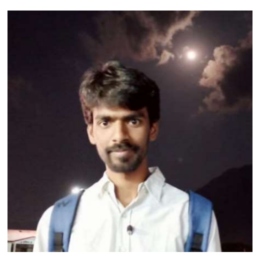



PRESENTED AT:

BACKGROUND AND MOTIVATION

1. Extremes events have impacted human lives since time immemorial.
2. The distribution of extreme events is changing globally, and their frequency of occurrence has increased in recent decades [1] (https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015JD024310) and these cannot be put in a single bracket.

3. Owing to socio-economic importance, a multitude of studies tried to quantify the changes in the properties of extremes [2 (https://science.sciencemag.org/content/314/5804/1442.full),3 (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL067841),4 (https://www.nature.com/articles/nclimate2208),5] (https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/wea.3259). However, a large number of uncertainties are present at these extreme events

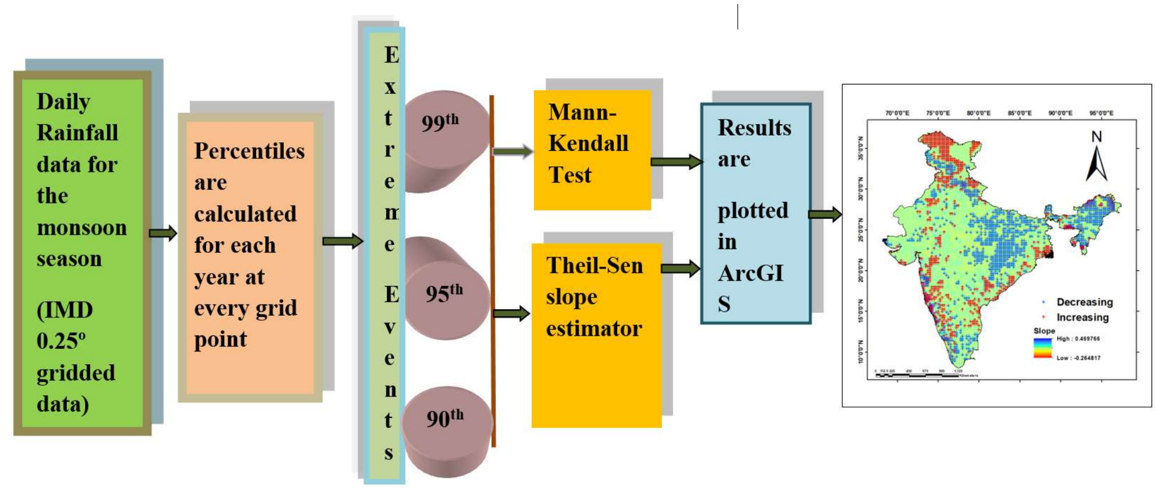
4. Also, due to large geographical area of India (3.287 million square kilometer), different climatic regimes which differ metrologically and topographically are inherent, and these probably leads to different extremes at different locations at the same or different time.

5. In order to address the mentioned issues, we have used high-resolution long-term IMD (http://www.imdpune.gov.in/Clim_Pred_LRF_New/Grided_Data_Download.html) grided (0.25 x 0.25 degree) data for 119 years (1901-2019) and the objective of our study are:

- to quantify the trends in extreme rainfall events during the Indian Summer Monsoon

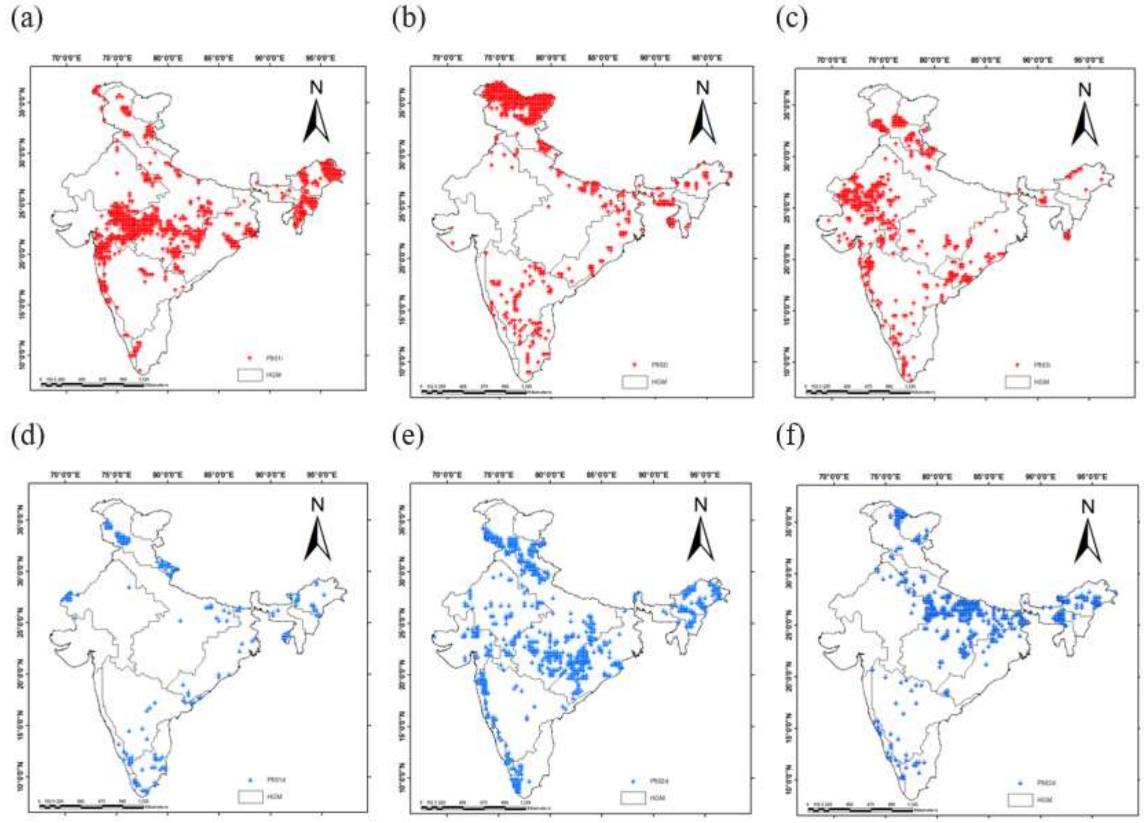
- to examine the consistency of the trends both spatially as well as temporally

THE METHODOLOGY USED IN THE STUDY

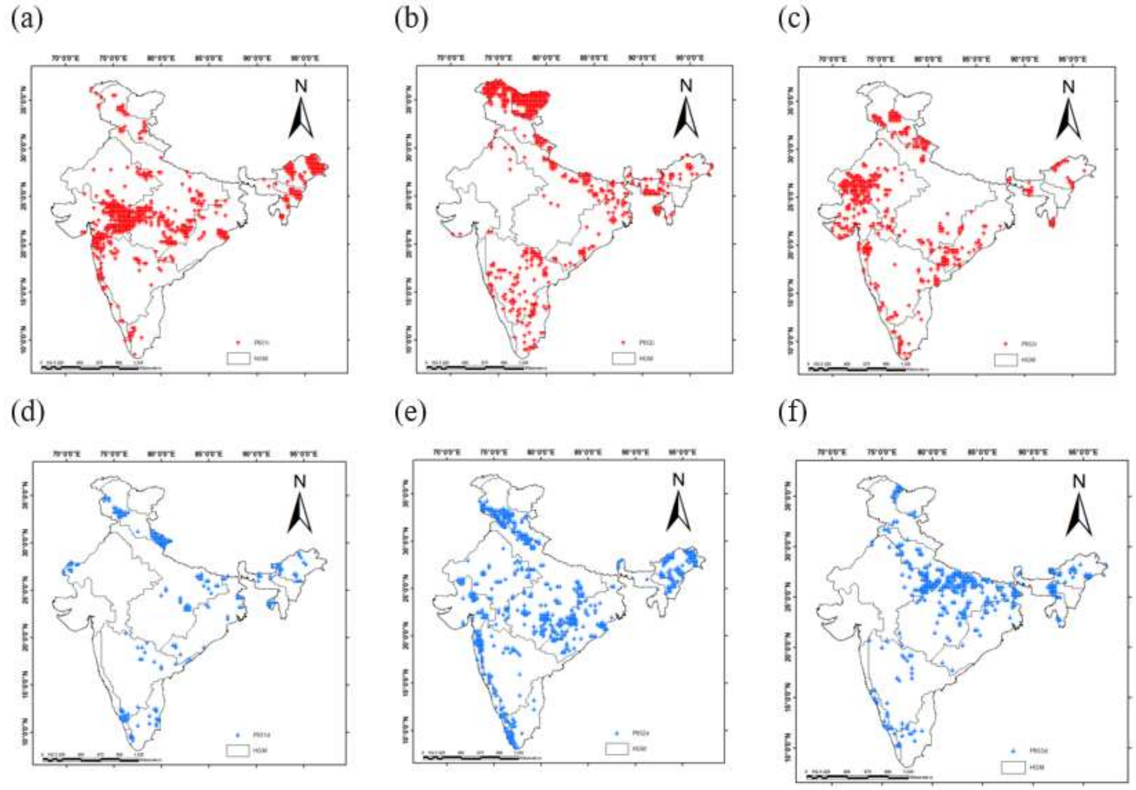


- A rainfall event is considered extreme when it exceeds a particular threshold or based on the rarity of the event.
- In our study, we have defined extreme based on the rarity of events i.e, 90th, 95th, and 99th percentile[6] (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2006GL026451).
- We analyze the trends in these percentiles for the Indian summer monsoon(June, July, August, September) from 1901 to 2019 using the Mann-Kendall test and Sen slope method.
- Mann–Kendall (MK) test is a non-parametric test, widely used for detecting significant trends. However, this does not give the magnitude of the trends.
- In other to quantify the increasing and decreasing trends, another robust non-parametric Theil-Sen estimator is used.
- After calculating the Sen slope using the Theil-Sen slope estimator in MATLAB, it is plotted in GIS.
- The plotted points are converted into a raster dataset using inverse distance weighted extension in spatial analyst tool in GIS.
- The significantly increasing and decreasing points obtained in the Mann-Kendall test is also plotted.
- The analysis is done for four different time window namely, 1901 to 2019, 1901 to 1950, 1941 to 1990, and 1981 to 2019

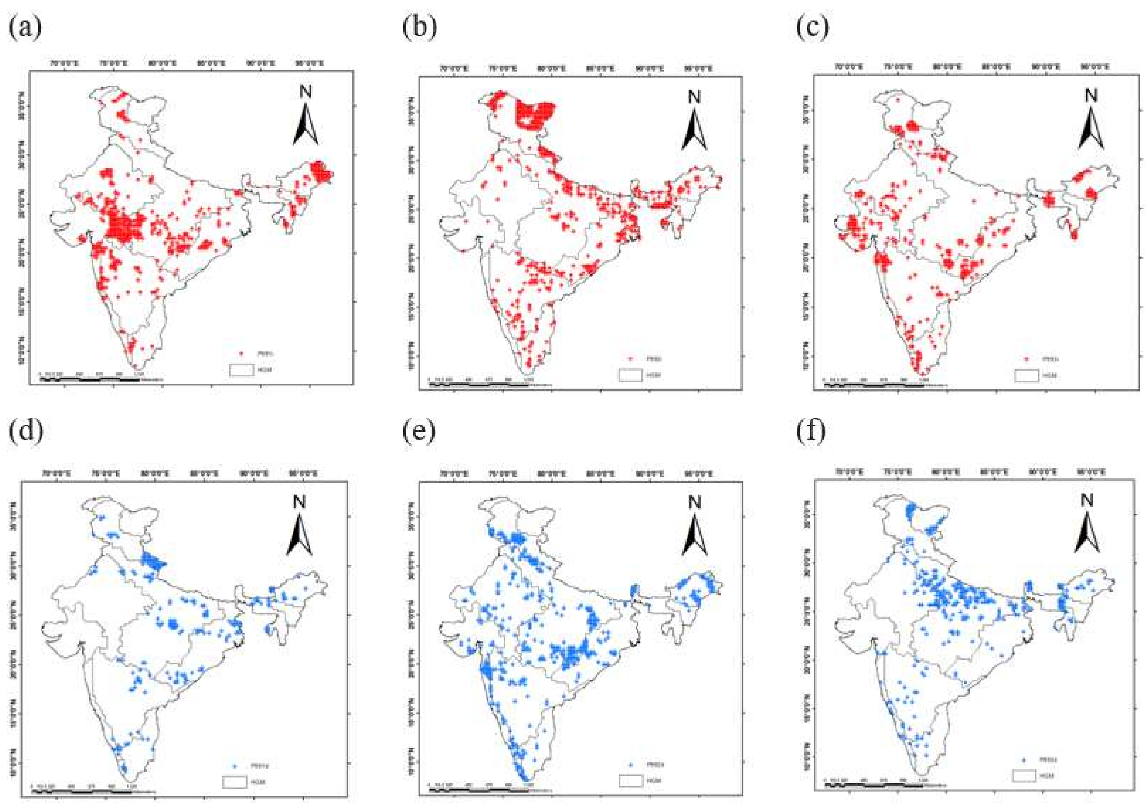
SPATIAL DISTRIBUTION OF MK-TEST RESULTS AT DIFFERENT TIME WINDOWS.



Significantly increasing areas during (a) 1901-1950 (b) 1941-1990 (c) 1981-2019 and significantly decreasing stations for (d) 1901-1950 (e) 1941-1990 (f) 1981-2019 for 90^{th} percentile



Significantly increasing areas during (a) 1901-1950 (b) 1941-1990 (c) 1981-2019 and significantly decreasing stations for (d) 1901-1950 (e) 1941-1990 (f) 1981-2019 for 95th percentile



Significantly increasing areas during (a) 1901-1950 (b) 1941-1990 (c) 1981-2019 and significantly decreasing stations for (d) 1901-1950 (e) 1941-1990 (f) 1981-2019 for 99th percentile

- As can be observed from the figure, the spatial patterns of all the three percentiles are similar at all the time window. However, the pattern changes from one time-window to the other.
- From 1901 to 1950, significantly increasing trends were observed in the western part of central India and parts of north-eastern India, and decreasing trends in Himachal Pradesh.
- From 1941 to 1990, increasing trends were shifted to the northern part of India and are prominent in Jammu and Kashmir and parts of southern India. The central and western Ghats region have significantly decreasing trends during this time period.
- During the period from 1981 to 2019, the increasing trends shifted back to western India, parts of Rajasthan, Gujarat, and the West coast. The decreasing trends shifted northwards towards the Ganga basin and parts of Delhi

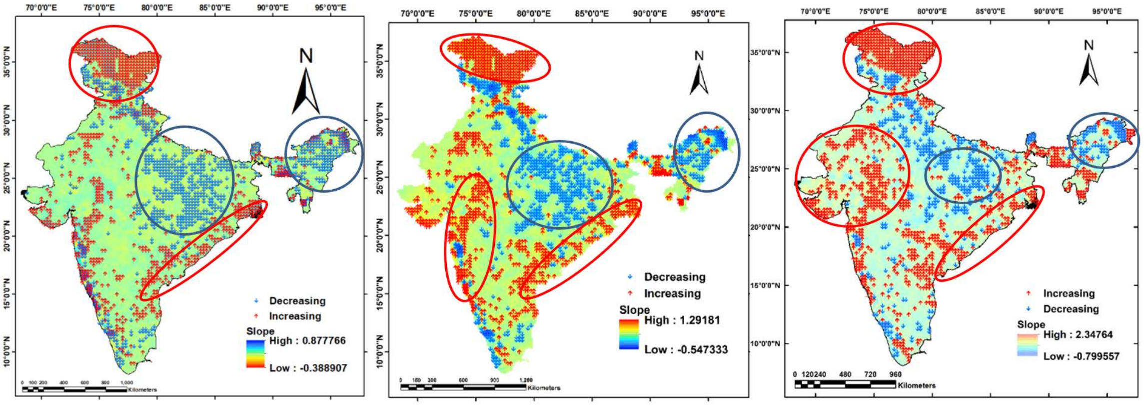
SUMMARY

From 1901 to 2019, these rainfall events show increasing trends in Jammu and Kashmir, parts of Rajasthan, Gujarat, Western Coast, Andhra Pradesh, and Orissa. It may indicate that the extreme events had become more severe in these areas and are also likely to happen in the coming years. These results are supported by the reports of floods in Jammu and Kashmir and Orissa in 2014 and 2018 respectively. The amount of rainfall increase is as high as 0.88 mm/day, 1.29mm/day, and 2.35 mm/day for the 90th, 95th, and 99th percentile respectively. Contrastingly, we observed decreasing trends in Central and North-east India, indicating that the magnitude of these rainfall events has decreased over the years. These may indicate a lesser risk of floods in these areas.

On further investigation at different time windows(1901-1950, 1941-1990, and 1981-2019), we observed that the spatial pattern of these changes spatially at different time scales. There is a significantly increasing trend in parts of central India in the early 90s, in Jammu and Kashmir in the late 90s, and parts of Gujarat and Rajasthan at the most recent time scale. However, parts of central India, Western Coastal areas, Assam, and Arunachal Pradesh show a significantly decreasing trend during 1941-1990. Parts of the Northeaster region and the Ganga Basin show decreasing trends during 1981-2019.

Conclusively, our results showed a possible spatial shift of trends across the different time periods, probably due to climate change and atmospheric dynamics, which might interest future studies.

INCREASING AND DECREASING TRENDS FROM 1901 TO 2019 (119 YEARS)



90th Percentile　　95th Percentile　　99th Percentile

Red upward arrow inside the red circle represents significantly increasing trend
Blue downward arrow inside the blue circle represent represents significantly decreasing trend

- Upon considering the 1901 to 2019 time window, significantly increasing trends were observed in Central India for the 90th and 95th percentile. However, the decreasing trend shifted northwards for the 99th percentile.
- The increasing trends are similar for all the percentiles i.e at Jammu and Kashmir and also at the western coast
- Based on the results of the Sen slope, the maximum increasing(decreasing) trends are 0.88mm/day(0.39mm/day), 1.29mm/day(0.55mm/day), and 2.35mm/day(0.80mm/day) for the 90th, 95th, and 99th percentile respectively.
- The maximum magnitude in both increasing and decreasing trends was observed for the 99th percentile.
- This indicated that the magnitude of the extreme rainfall events are likely to increase severely over some areas, whereas the same is likely to reduce in some areas.

ABSTRACT

Understanding spatiotemporal patterns and trends of Indian Summer Monsoon extremes have always been an important task mostly because the impacts of extreme events have an enormous effect on agriculture, economy, life and eco-system. In general, findings from the exploration of extreme events with limited data will have high uncertainty, and it is important to investigate the trends with a high long-term dataset for improved understanding of extreme events. Further, the patterns and interactions become unusual, unexpected and unpredictable,coupled with the existing challenges of global warming-induced climate change. Hence,the study was primarily prompted by these realizations and an implied aspiration to quantify spatiotemporal patterns and trends of Indian Summer Monsoon extremes.In the present study, extreme rainfall is defined in three categories, namely severe (99^{th} percentile), very high (95^{th} percentile) and high (90^{th}percentile) during the monsoon season in each year. The temporal changes in extreme rainfall have been detected over the period 1901–2019 using non-parametric Mann-Kendall and Sen's slope estimator tests, respectively.The analysis revealed significantly intensifying rainfall magnitudes in Jammu and Kashmir, parts of Gujarat, Rajasthan and Peninsular India. The outcomes indicate that the magnitudes of extreme rainfall are likely to increase in future in these regions.On the contrary, Central and some regions of North-eastern India shows deceasing trends in the extreme rainfall significantly. Consistency of the trends, both temporally and spatially has been explored considering three time windows with an overlap of 10 years. The findings of the temporal evolution of extreme rainfall reveal spatiotemporal pattern is not consistent in different periods of the study. The results of the present study will provide an improved understanding of spatiotemporal patterns of the daily rainfall extremes during the Indian summer monsoon.

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