Rainfall Extremes: Not Only Getting More Intense but Bigger in Size as Well

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Abstract

Changing characteristics of precipitation extremes have been reported mainly using parameters like the frequency of occurrence and the magnitude. As climate changes, the spatio-temporal characteristics of rainfall extremes are also likely to get modified. Though there exist studies noting the changing the temporal distribution, the spatial extent of extreme rainfall events has received less attention. We show that 31% of the fractional increase in the number of rainfall extremes of the Indian summer monsoon from 1951 to 2015 is size-change related. We find that the average size of rainfall extreme is significantly increasing after 1980. Depending on the number of connected grids experiencing simultaneous extreme rainfall, we classify them as small, medium and large events. 90 % of large events have occurred after 1980 and these have the strongest rainfall intensity among all types. They are more likely to cause floods, hence important. These events are invariably associated with a monsoon low-pressure system (LPS) and occur in the southwest sector of an LPS within 400 km from its centre. Strong surface pressure anomalies that persist for more than a week are present in different parts of the globe when these events occur, suggesting preferred planetary-scale conditions that favour their formation. Thus giving hopes of their advanced prediction and facilitating flood hazard mitigation.

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1. Introduction

A synoptic system may produce extreme rainfall at several grids on a given day (Fig. 1). Physically it is a single event; but methods used in the past studies count it as multiple events because of its spread over a number of grids with extreme rainfall[1].

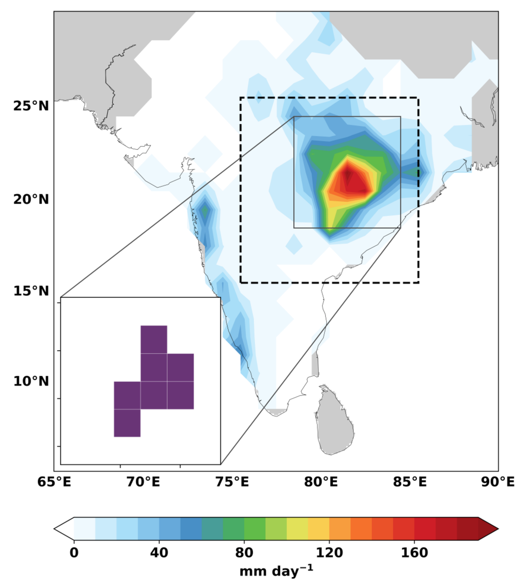


Fig.1. An example of extreme rainfall event that occurred on 22 July 2014, covers seven 1° × 1° grids. In this study, it is identified as a single event of the size 7 rather than 7 different events by the method used in the past studies.

We identify a continuous area of grid points simultaneously experiencing extreme rainfall and define it as a single extreme rainfall event (ERE).

Using the new definition, we revisit the observed trend of EREs, classify them based on the size, and study underlying physical processes.

2. Data and methods

The daily gridded rainfall dataset of IMD[2] from 1951 to 2015.

Study region: Central India (15°-25°N,75°-85°E; Outer inset box in Fig.1)

Connected component algorithm[3] to identify a continuous area experiencing extreme rainfall.

LPS track data by Hurley and Boos[4].

The ERA-Interim dataset for meteorological fields.

3. Revisiting the trends in rainfall extremes

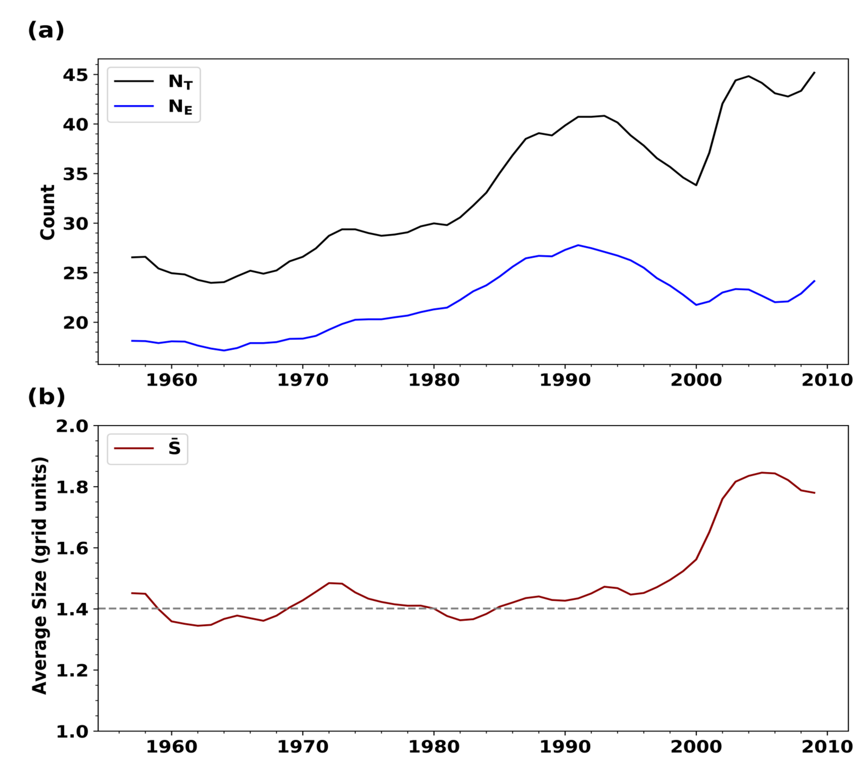


Fig. 2. Smoothed time series (11-point moving average) of **(a)** the total number of (1° × 1°) grids having extreme rainfall (N_T), the number of EREs (N_E) and **(b)** average size ($\bar{S}$). $N_T = \sum_{k=1}^{N_E} S_k$ where S_k is the size of the k^{th} ERE. The average size ($\bar{S}$) of EREs in a season is given by $\bar{S} = \frac{N_T}{N_E}$. N_T is proportional to the area occupied by EREs.

Quantification of contribution

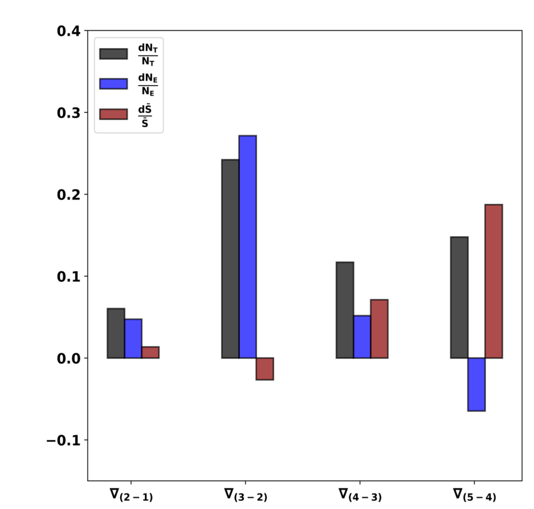


Fig.3. Fractional change contribution of N_E and $\bar{S}$ to N_T for 5 equal intervals over the study period.

The changing contribution of N_E and $\bar{S}$ to N_T can be obtained from the fractional changes,

$$\frac{dN_T}{N_T} = \frac{dN_E}{N_E} + \frac{d\bar{S}}{\bar{S}}$$

For the last two intervals i.e. after 1990, the fractional increase in the total area of EREs ($\frac{dN_T}{N_T}$) is primarily due to their increasing size ($\frac{d\bar{S}}{\bar{S}}$).

Consideration of a spatial extent while defining rainfall extremes reveals that their recent increase over Central India is due to their growing size, instead of the frequency of occurrence.

4. Classification of rainfall extremes

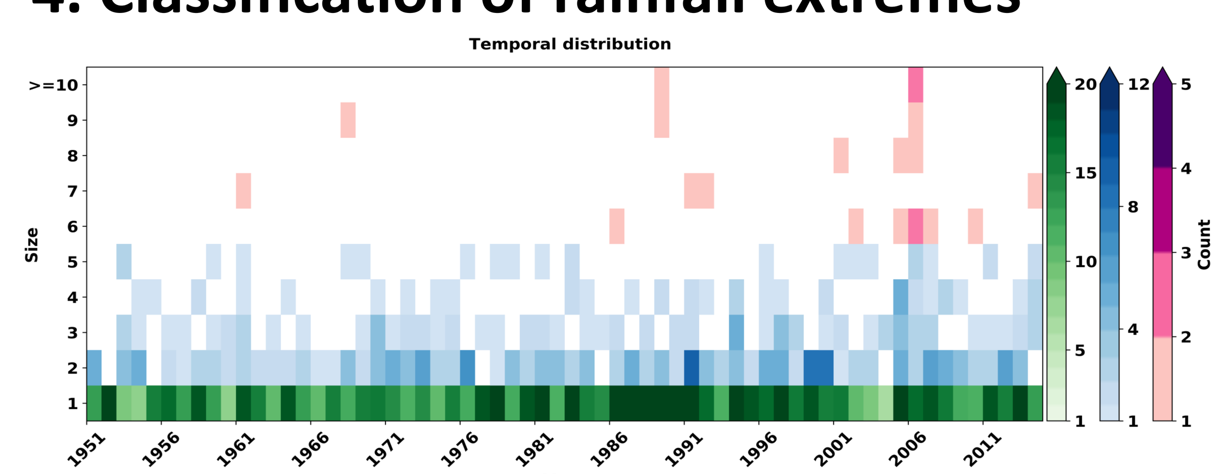
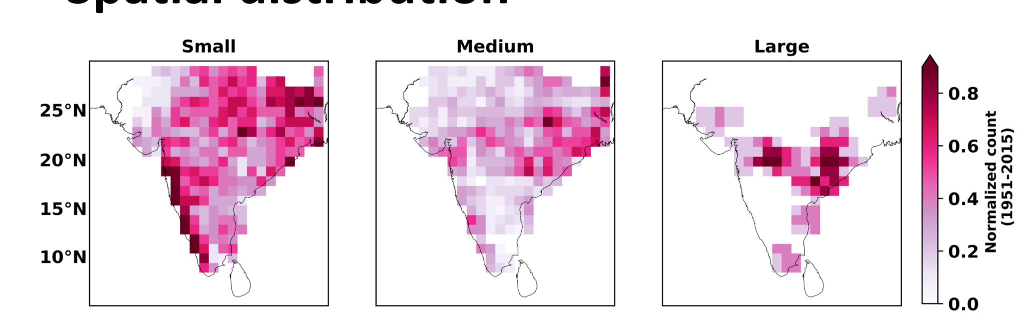


Fig.4. Temporal distribution of rainfall extremes of different sizes. Green, blue and pink colours indicate the count of Small, Medium and Large EREs, respectively.

Classification based on the size (number of 1° × 1° grids)
Small : 1, Medium : 2- 5, Large : >= 6

The Medium and Large show significant increasing trend over the study period.

Spatial distribution



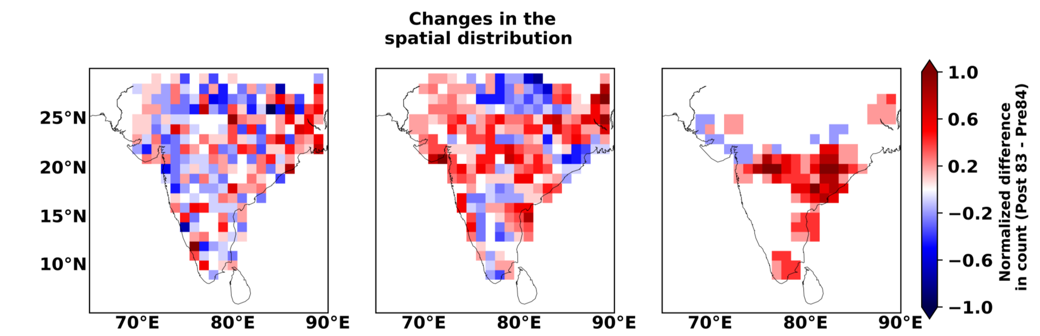


Fig.5. Spatial distribution of EREs of different types. They show geographical preference. The Medium and Large EREs occur in the path of monsoon Lows. The Small EREs mainly occur near the Western Ghats.

5. Association with LPSs

Low Pressure Systems (LPSs) were present 83%, 92% and 100% of the time when Small, Medium and Large EREs occurred.

The Large EREs occur in the southwestern sector and Small and Medium on the western flank of LPSs.

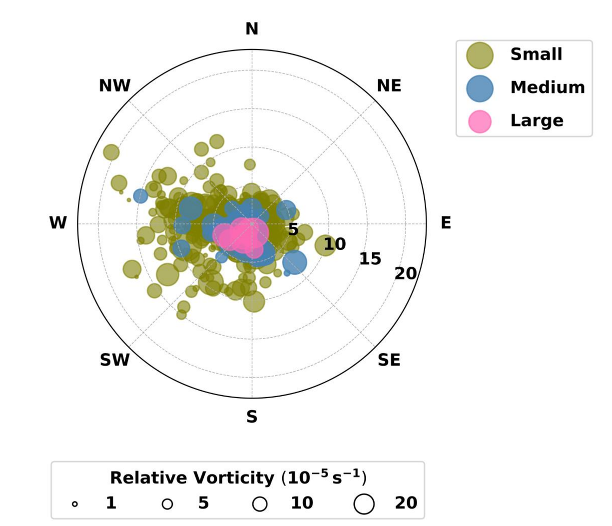


Fig.6. Relative locations of the centre of mass of EREs w.r.t. the LPS centre . The radial distance from the origin is in degrees.

6. Summary and conclusions

1. Since 1990 the observed increase in the area of rainfall extremes over Central India is primarily due to their increasing size.

   -> The spatial extent of Extreme Rainfall Events (EREs) is significantly increasing since 1980, however, their number of occurrence remains unchanged.

   -> The Medium and Large EREs show significant increase over the study period. The isolated rainfall extremes (Small EREs) do not show any trend.

2. Rainfall extremes of Central India are strongly associated with LPSs.

   -> The Large EREs occur in the southwestern sector of LPSs within the first 400 km of its center.

   -> The Medium and Small EREs occur mainly on the western side of LPSs.

3. Classification of EREs based on the size could prove useful in understanding the underlying physical processes and forecasting.

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Further information

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