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Short Communication

Trends in monsoon rainfall extremes over Andhra Pradesh and Telangana

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Scientific evidence shows that climate change has begun to manifest itself, globally, in the form of increased downpours and storms, rising temperature and sea level, retreating glaciers, etc. Climate change is increasingly seen as the major threat to the food security and sustainability of agriculture in India. The effects of the change in climatic parameters are not similar in all the places throughout the country. The occurrence of extreme weather events like droughts, cyclones, high-intensity precipitation, cold day & cold nights and warm days & warm nights, etc. has changed a lot during past decades throughout India (Chakraborty *et al*., 2019). But their proportion varied from region to region. Extreme events may have major societal, economic, and environmental impacts. Precipitation is a fundamental component of the climate and changes in its patterns can have large implications for human health, ecosystems, plants, and animals in general and in agriculture in particular. Though the amount of the total monsoon rainfall and its change is important for climate change studies, the changes in the extreme events may bear large meanings starting from flood risk analysis to the proper agricultural management at the ground level. Changes in the extreme weather events can also influence the type and the distribution of monsoonal rainfall while there may not be any change in the total monsoonal rainfall. As the patterns of these extremes are highly variable over space and time, the study of the extremes at a local scale using the information stored in the historical climate datasets may provide crucial information in this regard. Goswami *et al*. (2006) have reported an increase in the rainfall extremes (both > 100 and >150 mm/day) and a decrease in the moderate rainfall events during monsoon season over central India. It has also been reported in the literature that central and peninsular India has been influenced by a thunderstorm, high rainfall, or many times drought events (De *et al*., 2005). These show that the region remains one of the crucial zones which gets to face the effects of extreme too often than other parts of the country.

Though some studies have analyzed the changes in extremes over the region, their analysis was with the mean values of the region as a whole. These studies have provided information regarding broad changes in the extremes over the region as well as their relationship with the sea surface temperature anomaly and ENSO (Goswami *et al*., 2006). But they lack the information regarding the spatial variability of rainfall extremes within the region, which are very crucial for the preparation and management of the effects of these extremes at the ground level. Hence, we have analyzed the gridded rainfall dataset of the India Meteorological Department (IMD) for understanding the spatiotemporal variability of the extremes at a scale that may be better for impact management rather than the analysis with the broad areal mean (Pal and Al-Tabbaa, 2009). The results may be helpful in understanding the patterns of rainfall extremes and their associated zone-specific impact management strategies that may be developed for risk reduction.

In this study, the focused area is the erstwhile Andhra Pradesh (AP) state which includes the present Telangana and Andhra Pradesh states of India (Fig 1). This area is situated between 13.5° – 19.5° N latitude and 77.5° – 83.5° E longitude. The total area is about 275,045 Sq. km. The state of Andhra Pradesh has a coastline of about 972 km. Due to quite a large geographical area, it is having high variation in the weather parameters throughout the state. The region is also very prone to weather vagaries starting from heat waves, heavy rainfall, floods, droughts, and cyclonic storms.

The daily gridded (1°X1°) rainfall data developed by India Meteorological Department was used for the analysis (Srivastava et al, 2009). In this study rainfall data from 1969–2019 for 24 grids covering latitudes between 13.5° – 19.5° N and longitude 77.5° – 83.5° E was used. The grids were numbered row-wise starting from the north to the south direction (Fig 1). This area covered almost all

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the parts of the erstwhile state of Andhra Pradesh.

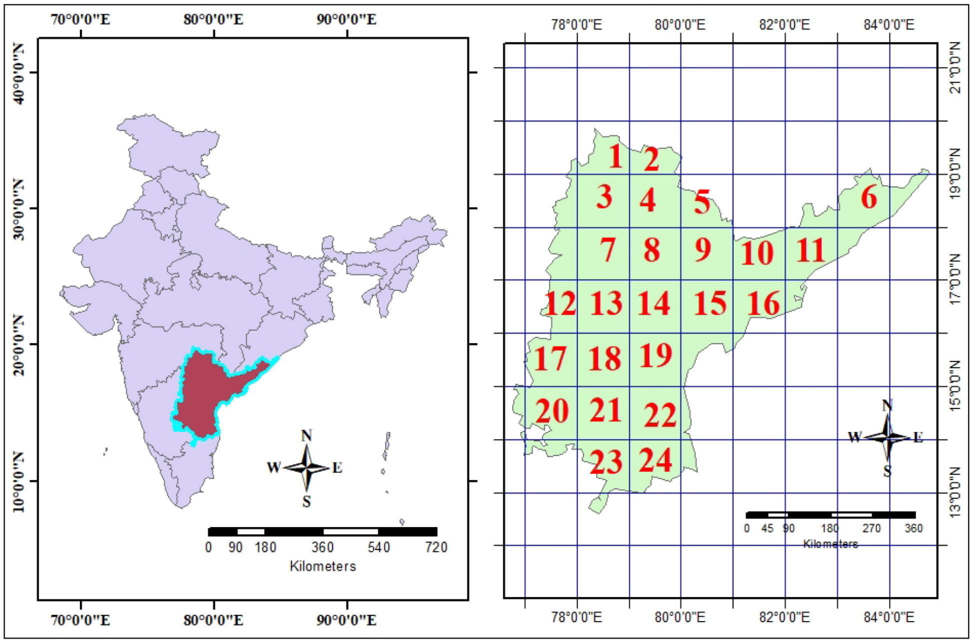

Fig. 1: Study area map of erstwhile Andhra Pradesh (AP) along with the grids used for analysis. The state now stands bifurcated into Telangana and Andhra Pradesh states.

This study has analyzed only the monsoon season using the daily gridded rainfall datasets. The total monsoon rainfall, wet days, and dry days in the monsoon season were also computed. We used the extreme precipitation indices proposed by the World Climate Research Programme on Climate Variability and Predictability Working Group on Climate Change Detection (Pal and Al-Tabbaa, 2009). The indices calculated and analyzed are Total monsoon rainfall (TRF, mm), Total dry days (TDD, Daily Precipitation <1 mm) and Rainfall above 95th Percentile value (RF95P, mm). All these indices were analyzed for their trends as well as variability.

Mann-Kendall test (MK test) is a statistical test widely used for the analysis of the trend in climatologic and hydrologic time series (Chakraborty *et al*., 2017). Further to compare the temporal variability in the time series of the extreme rainfall values we have divided the whole study period into three parts namely P-I (1969-1985), P-II (1986-2002), and P-III (2003-2019). The coefficient of variation of all these extreme indices was also calculated for three periods and compared to understand the change in variability of the extremes over the study region.

Long-term trends in total monsoon rainfall (TRF)

The trends in total monsoon rainfall over the study period were not consistent throughout the state as seen in Fig. 2 (a). This spatial variability in the TRF is possibly due to the topographical differences. Fig. 2 also showed that mostly there exist positive tendencies in TRF, only four grids showed negative tendencies. Four grids i.e. 2, 9, 10 and 15 corresponding mostly to the areas of Khammam and Guntur district had shown a significantly increasing trend in the TRF. While analyzing the annual rainfall over Andhra Pradesh, Rao *et al.* (2011) also reported mostly statistically non-significant changes over the region. They have also found an increase in the annual rainfall by over 15-20% area in the districts of Ananthpur, East Godavari, Guntur, Khamman, Krishna, Prakasam, and Vizianagaram district. But it can be clearly seen from Fig. 2 (b) that most of the southern parts of the state have experienced high variability in the TRF in the P-III (2003-2019) whereas the variability in northern grids were dominated by the P-II (1986-2002). During P-I (1969-1985) the variability in TRF was comparatively higher over only a few grids. This showed that the variation in the total monsoon rainfall over the period of 2003-2019 has become the largest in the whole period of study signifying heightened variability in this region during recent years.

Trends of total dry days (TDD)

Total dry days in the monsoon season is an indicator of water stress being experienced during monsoon season, which remains very important for *Kharif* crop growth as well as natural vegetation. Though total dry days did not increase significantly for a single grid also (Fig 3a), there was a significantly decreasing trend in the TDD over 8, 17, and 18 grids, mostly corresponding to the Nalgonda and Kurnool districts. The predominating decreasing trend of TDD may have contributed to the increasing trend of TRF in the state. Though the northern parts have a trend of increasing TDD that is statistically non-significant. There is no doubt that the variability of TDD (Fig 3b) has increased over time and most of the grids are showing high CV of TDD in the P-III. The results indicate that in recent years the occurrence of total dry days has become more uncertain, and the year-to-year variability has increased. Interestingly all the northern grids which showed a non-significant increasing trend in TDD showed high CV during P-II i.e. 1986-

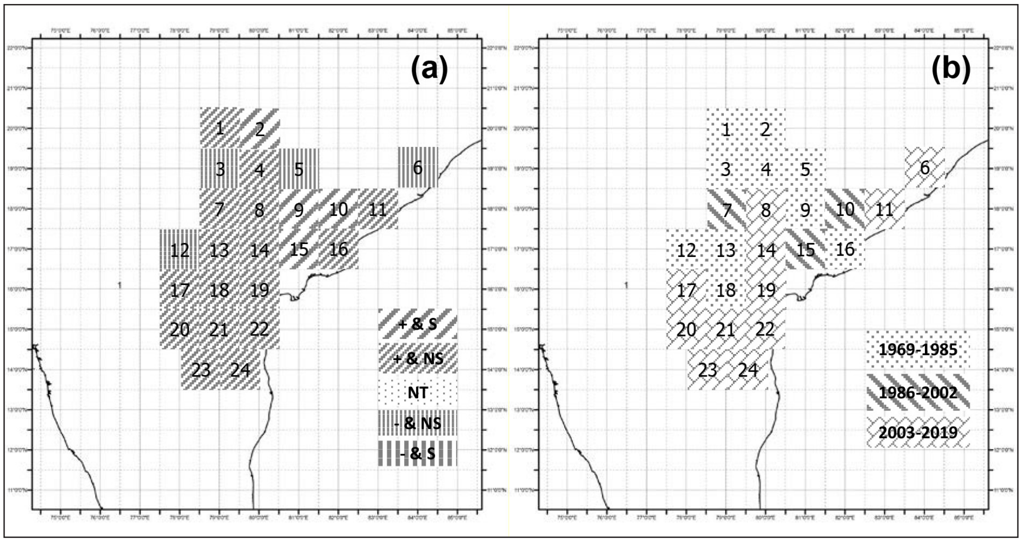

Fig. 2: Total monsoon rainfall trends (a) and coefficient of variation (b) over the study region during 1969-2019.

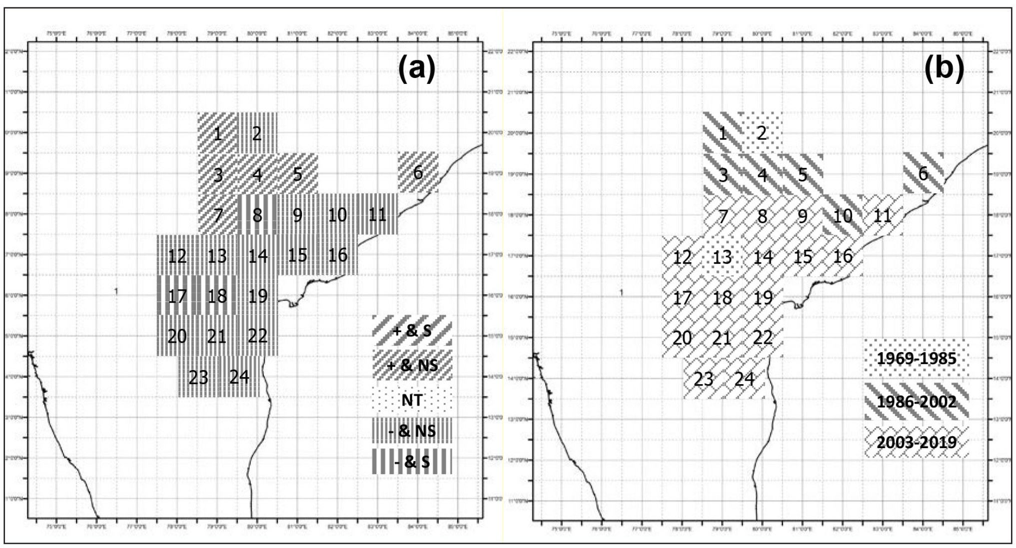

Fig. 3: Total dry days trends (a) and coefficient of variation (b) over the study region during 1969-2019.

2002.

Trends of total monsoon rainfall above long-term 95th percentile (RF95P)

This index is a direct measure of extreme rainfall. The total amount of rainfall above the long-term average 95th percentiles of daily monsoon precipitation every year and at every location was computed. The percentile rainfall values were averaged over the reference period 1969 –1999. All the extreme rainfall amounts during the monsoon season in a year are then summed up to get rainfall from daily precipitation (DP) > long-term 95th percentile (RF95P) every year. Figure 4 shows the trends in the RF95P over the study period for all the grids under the study region. 20 out of 24 grids show an increasing trend in Rainfall over 95th Percentile, but three grids mostly corresponding to the Guntur, Nalgonda, and Khammam districts were having a statistically significant trend (Fig 4a).

Goswami *et al.* (2006) used the fixed threshold-based extreme rainfall indices (100 & 150 mm/day) and could clearly show a statistically significant increase in the extreme monsoonal rainfall over central India as a whole. Figure 4 (b) showed that RF95P was having highest variability in only 3 grids during P-I, but it subsequently increased to 11 and 9 grids during P-II and P-III respectively. It is also reported that there exists an increasing trend in the variability of daily extreme precipitation over central India during the summer monsoon season (Goswami *et al.*, 2006). They argued that the increase in the monsoonal rainfall variability over the region is due to a trend in large-scale moisture availability (Trenberth *et al.*, 2005), which in turn is due to the gradual warming of sea surface temperature (SST). Though our analysis could clearly show the difference in its spatial variability, the most northern grids showed high variation in the P-II while most southern grids showed high variation in P-III.

It is very clear that across the States of Telangana and

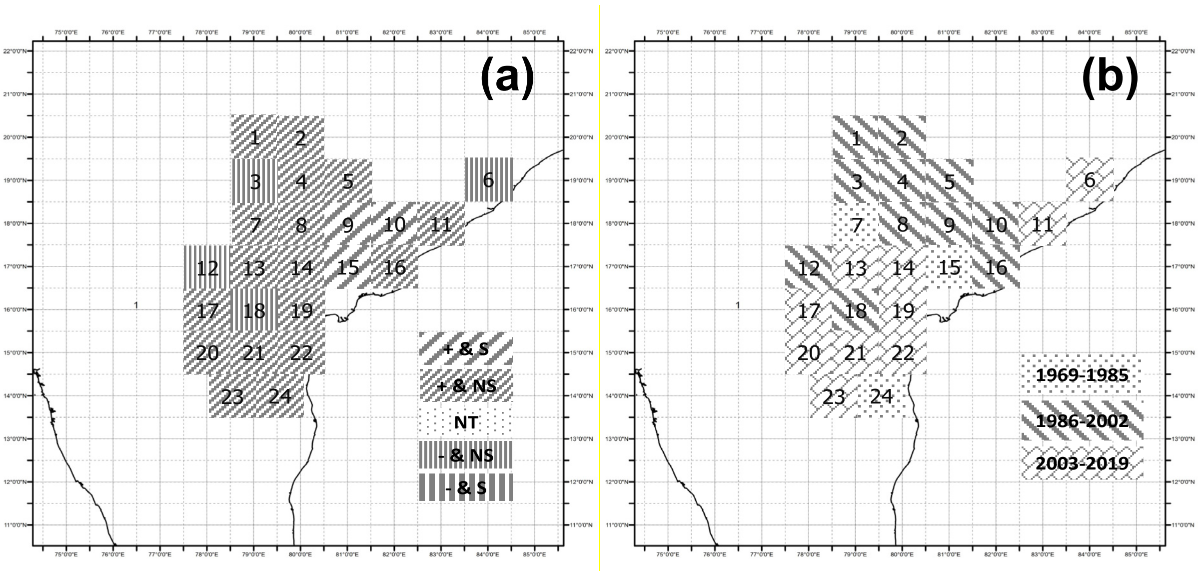

Fig. 4: The trends (a) and coefficient of variation (b) of extreme rainfall above 95thpercentile in various gridded regions over the study region

Andhra Pradesh large spatiotemporal variability in the monsoonal rainfall exists. The indices calculated also showed varied trends over the spatial extent. There was also temporal variation in the indices. But it can be clearly said that the extreme rainfall events indicated by these indices are increasing over most of the grids. This trend is most prominent in the grids corresponding to the mid to southern part of Andhra Pradesh, especially the coastal regions. On the contrary few grids corresponding to the south-western part of Andhra Pradesh have altogether shown decreasing trend in the monsoon extreme rainfall over the period of study. As it is known that the frequency and magnitudes of extreme rainfall and the number of rain days are very important decisive factors for the total monsoon rainfall in the region, these results can be used to define and assess the risk of flooding and droughts, agricultural planning and other local developments associated with the adaptation strategies for monsoonal climate change in the states or region.

Conflict of interest statement: The author (s) declares (s) that there is no conflict of interest.

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