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Climate regionalization to assess change in extreme rainfall over Indian subcontinent

Chandrani Chatterjee[1,*] and Saurabh Das[2]
Department of Astronomy, Astrophysics and Space Engineering
Indian Institute of Technology, Indore, India
[1*]Email: chandrani.chatterjee9@gmail.com
[2]Email: das.saurabh01@gmail.com

Abstract

Climate change and resulting increase in extreme events have become major sources of concern for the society today. Rainfall cycle and lightning extremities are among the most evidenced effects of recent climatic changes. However, quantifying the climate change effect over a region is challenging especially for a country like India with such enormous topographic and climatic variabilities. The current work attempted to regionalize Indian subcontinent based on the major climatic factors using machine learning techniques. The resulting regions have showed distinct interrelationship between the climate variable. Two regions showed significant increasing trend in number of extreme rainfall days(>40 mm) whereas, two other showed decreasing trends.

1. Introduction

The recent climatic changes witnessed all over the globe, is a potential threat to the human today. Significant changes have been observed in all the important climate variables. The rise in global temperature is among the fundamental changes catalyzing the extremities in a large number of climatic factors. [1] reported a rise of 0.40 C in the global surface during the last century. This temperature increase, in turn influencing the water cycle intensification largely [2]. The precipitation extremities have been projected to witness severe extremities due to the changes in global surface temperature [3].

The global scenario of water cycle uncertainties is not much different over Indian subcontinent. The extremities and uncertainties have been reportedly increasing in the country in the recent past [4]. India, being an agriculturally dependent economy has to rely largely on the monsoon rainfall. Any change in the rain cycle here is therefore crucial. Several instances of one day extreme rain have been reported from different parts of the country like like Orissa, West Bengal whereas, the frequency of flood has also been reported to increase in the coastal areas [5]. Besides, the rainfall uncertainties, increasing lightning fatalities is probably the most threatening concern the country is witnessing currently. Almost 2800 people lost their lives to it in the year 2018-2019 (https://indianexpress.com/article/explained/explained-why-lightning-still-kills-so-many-indians-7128058/). The increase in surface temperature has been reported to influence the number of lightning strikes largely [6]. Convective Available Potential Energy (CAPE) aids in the charge generation process in a thundercloud [7].

However, the changes in rainfall and lightning are complex and depend on large number climatic factors [8]. Especially, for a country like India, with such enormous topographic inhomogeneity the spatial variation of rain and other climate parameters have to be taken care of. It is imperative to say that, the vulnerability of different regions of the country to the climatic changes will also be different. Several researchers have identified different rain climatologies over the country and reported significant spatial rain inhomogeneity over different parts [9]. However, it is also reported that the rain climatologies have changed significantly in the recent climate change scenario [10].

The current work attempted to regionalize the country in different climatologies prevailing over different parts of the country based on the rainfall, lightning, surface temperature and CAPE in order to identify the regions, most vulnerable to recent climatic changes. Seven different climatologies have been reported over the country four of which showed visible trend in number of extreme rainy days during 20 years (2003-2018).

2. Data and Methodology

2.1 Data

The monthly data of rainfall, lightning strikes and Convective Available Potential Energy (CAPE) and surface temperature for a period of January, 2003 – December, 2014 have been used here.
The rain data were obtained from GPCP monthly precipitation data provided by the NOAA/OAR/ESRL

PSL, Boulder, Colorado, USA, from their Web site at https://psl.noaa.gov/ in. Mean monthly monsoon rainfall measurements with 2.5 ^{0}x 2.5^0 resolution were used. Lightning data has been obtained from Lightning Imaging Sensor (LIS) onboard ISS (International Space Station). The current has used LIS/OTD Monthly Climatology Time Series (LRMTS) dataset with 2.5° × 2.5° [11] resolution. The surface temperature and CAPE measurements was procured from ERA5 monthly data product [12].

The statistics of extreme rainfall days/year (>40mm/day) are obtained from high resolution (0.50 X 0.50) daily raingauge measurements from CPC(Climate Prediction Center) Global Unified Precipitation data provided by the NOAA/OAR/ESRL PSL, Boulder, Colorado, USA, from their Web site at https://psl.noaa.gov/ in.

2.2. Methodology

The Indian subcontinent were regionalized using K-medoids [13] clustering scheme based on 1) mean monthly rainfall 2) number of lightning strikes 3) Surface temperature and 4) CAPE. The features are normalized before the clustering to combat for the computational disproportions.

The inert relationships between the atmospheric variable in the resulting clusters are studied. The consistency of the clusters are verified with the long term trend of extreme rainy days/ month in the different clusters using CPC data.

3. Results and Discussion

The clustering process has resulted in seven different climatologies over the subcontinent. The consistency of the clustering method has been confirmed by the dominance of the positive Silhouette coefficients in each of the clusters. 95 % samples showed positive silhouette values (Fig.1).

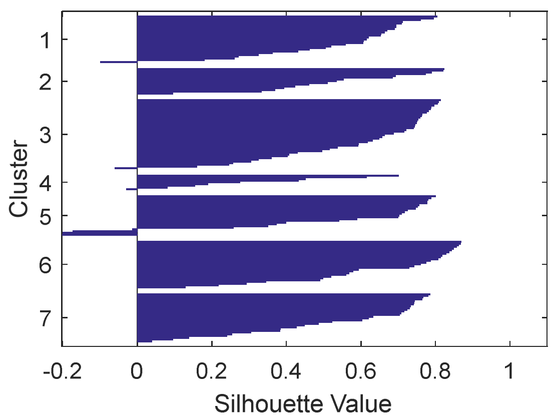

Fig. 1 Silhouette plot for clustering

The associated between the different climate variable have been investigated. Fig. 2(a-b) showed the correlation between lightning, rain and CAPE in different clusters. It is evident that the relationships are clearly distinguishable in different clusters e.g. rain and lightning strikes seemed to correspond linearly in cluster 2 whereas the relation seems to be negative in cluster 1 (Fig. 2(a)) . This confirms the presence of different climatologies over different parts of the country and the necessity of the regionalization process.

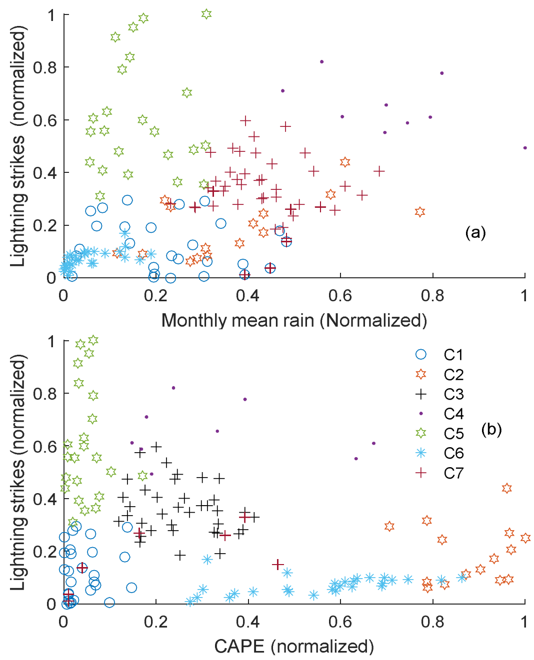

Fig. 2 Relation between (a) lightning and rain and (b) lightning and CAPE in different clusters

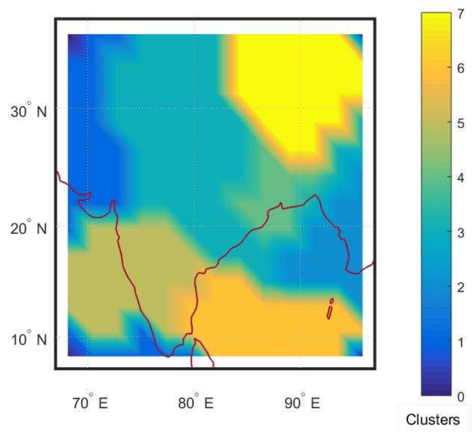

Fig. 3 Cluster representing different climatologies over Indian subcontinent

Fig. 3 indicated the seven distinguishable clusters resulted after the clustering process (Fig.1). The clusters seemed to be mostly the neighboring areas.

The extreme rainfall days are vital in the climate change scenario over any parts of the globe. Therefore, the recent trend in number of extreme rainfall days(>40mm) have been studied in different clusters to investigate whether the clusters represent the vulnerability of the regions to recent climatic changes.

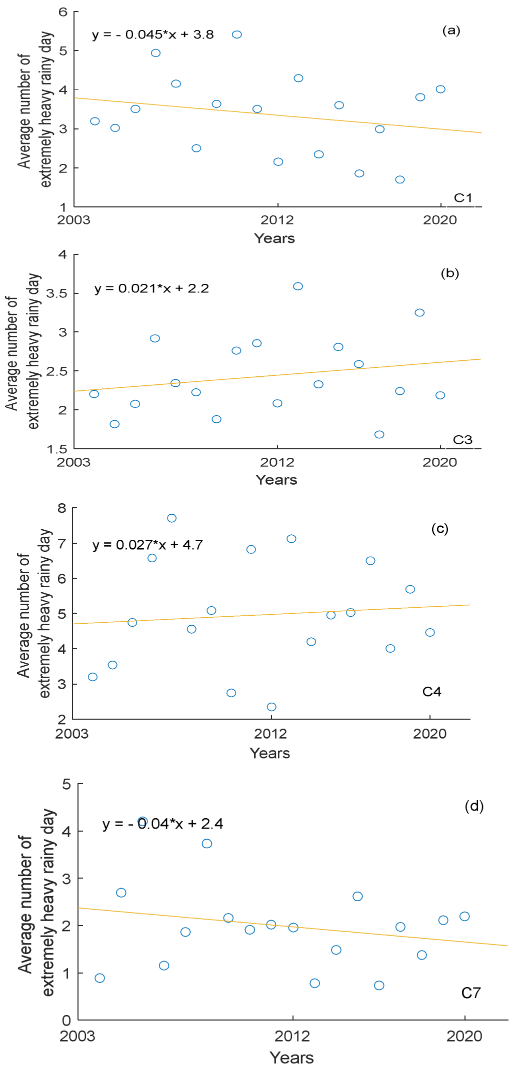

Fig. 4 Trend of extreme rainfall days

Significant increasing trend of extreme rainfall days were observed in two clusters 3 and 4 i.e. the eastern coast and central and northern parts of India (Fig. 4(b-c)). This finds good agreement with the previously reported frequency of extreme rain events in those areas (Guahthakurata et. al. 2011). Clsuters 1 and 7 on the other hand witnessed a sharp decrease in extreme rainy days over the years 2003-2018 (Fig.4(a-d)).

The different variation of rain extremity in the different clusters once again point towards the existence of different climate change vulnerability areas over the country.

4. Conclusion

Climatic changes and the increasing number of extreme events are emerging out as a threatening concern for the society. The proper prediction of climate change effects on a region requires proper understanding of its climatology and its vulnerability to climate change. The current work has regionalized Indian subcontinent in seven distinct climatologies. The distinguishable association between climatic variable in the resulting clusters confirms the presence of separate climatologies in different parts of the country. Different susceptibilities to climatic changes were also ascertained by the increasing rain extreme trend in two of the clusters whereas, two others seemed to have decreasing numbers of extreme rainfall days. The use of satellite data makes this approach suitable for any global region with any spatial coverage.

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