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Spatio-Temporal Distribution of Extreme Weather Events in India

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Abstract

Alteration in characteristics of extreme weather events is projected in most part of the world, in changing climate due to increase in greenhouse gases and aerosols in the atmosphere. The changes in patterns in extreme weather events would lead to issues including energy, water and food securities. Therefore, it is important to study pattern in the events. In the study, we have selected ten key climate extreme events namely, flood, tropical cyclone, heat wave, cold wave also gale, squall, lightning, dust-storm, hailstorm and thunderstorm to study their recent past spatio-temporal pattern over India. Data on the occurrence have been acquired from India Meteorological Department and other relevant government agencies. Flood constitutes major share of the events. Cyclonic events with negligible share in occurrence have sizeable impact on socio-economic system. Regression analysis on the annual total number of occurrences of the combined events reveals a significant increasing trend. Except cyclone, all the events show increasing trend. Leading states by event category has also been computed and found that few states are relatively more prone to the repeated occurrence of particular events. Finally, we have concluded with the suggestions for the improvement in data collection and key recommendations for further study.

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Keywords: extreme weather events; distribution; occurrence; trend; regression; India

1. Introduction

The assessment of impact, vulnerability and adaptation forms an important input to the National Communication submitted by parties under the convention. Climate change may be perceived most through the impacts of extremes, although these are to a large degree dependent on the system under consideration, including its vulnerability, resiliency and capacity for adaptation and mitigation. An

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extreme weather event becomes a disaster when society and/or ecosystems are unable to cope with it effectively. Growing human vulnerability is increasing the risk, while human endeavors try to mitigate possible effects. At the same time, there is increasing concern that extreme events may be changing in frequency and intensity as a result of human influences on climate. Analysis of long-term temperature and precipitation records has revealed changes in the mean climatic state as atmospheric carbon dioxide (CO2) levels have increased since the industrial revolution [1- 4]. Research employing global climate models (GCMs) indicates potentially greater changes for future climate states [5- 8]. Changes in the mean climate state have been found to affect the frequency and intensity of extreme climatic events as well [9- 12]. Extremes in temperature and precipitation have important impacts on vital aspects of society, including crop yield, power consumption and production, and human health [12- 14].

Changes in extremes are assessed at a range of temporal and spatial scales, for example, from extremely warm years globally to peak rainfall intensities locally. To span this entire range, data are required at a daily (or shorter) time scale. However, the availability of observational data restricts the types of extremes that can be analysed. The rarer the event, the more difficult it is to identify long-term changes, simply because there are fewer cases to evaluate [15- 16]. Responses to climate change and mitigation adaptation of negative impacts must be resolved at regional and local levels in order for effective action to be taken; therefore, it is important to assess the occurrence of climate extremes on a regional level. Identification of changes in extremes is also dependent on the analysis technique employed [17- 18]. To avoid excessive statistical limitations, trend analyses of extremes have traditionally focused on standard and robust statistics that describe moderately extreme events. Two recent studies [19- 20] directly links rising greenhouse-gas levels with the growing intensity of rain and snow in the Northern Hemisphere, and the increased risk of flooding in the United Kingdom. The study by Pall et al. [19] is one of the first attempts at establishing a consistent relationship between a specific event (2000 autumn floods in UK) and global warming.

In Indian scenario information on extreme climate events are scattered and very few attempt has been carried out [21]. Significant rising trends in the frequency and the magnitude of extreme rain events in central India have been reported in a study using recent gridded dataset [22]. A significant mortality caused by heat and cold waves in few northern states and Orissa is reported in a few studies [23- 24]. Remaining paper is organized as follows: Next section describes data and methodology used in the study. Subsequent section deals with the results and interpretation. And finally we conclude with future scope and suggestions for further study.

2. Data and Methodology

Data on the occurrence of extreme climate events and their impacts have been extracted from the reports on 'Disastrous Weather Events' an annual publication of India Meteorological Department (IMD). These reports on the weather events are available from 1967 to 2006 (missing year 1977). After 2006 the reports are yet to be published. However in the first decade, information is more qualitative in nature and detailed quantification of impacts is lacking. For this reason, the data on extreme weather events have been cross checked with some of available data from other agencies such as Ministry of Home Affairs and Ministry of Agriculture. We have extracted from the reports the information about characteristics and damage estimates of ten categories of events viz. flood, tropical cyclone, heat wave, cold wave, also gale, squall, lightning, duststorm, hailstorm and thunderstorm. These reports provide information about the extreme event's characteristics including intensity, magnitude, location and date of occurrence. It also contains data on damage caused by these events. Damage data include information about mortality, persons affected, villages affected, crops affected and total economic loss; however, for the purpose of this paper, we focus on mortality, as that it is a damage indicator consistently reported across different years and different event types. The annual data have gone through regression analysis to get secular trend in the variable. Various descriptive statistics on state as well as country level has been generated with the help of data on occurrence of the events.

3. Results and Interpretation

All India total number of reported events has increased drastically from about 80 in year 1978 to about 460 in year 2006 (Figure 1). A significant increasing linear trend has been observed. On a linear scale there is increment of about 10 events per year. Initial few years from 1967 to 1976 seems to have reporting bias as the reporting is organized in textual form rather than tabular form which are seen since 1978. Further analysis on data has excluded 1967- 1976 because of qualitative nature. Even if the data from 1967 to 1976 are ignored, there is a highly significant increasing trend in the total number of events. Top four events by impact (mortality) are flood, cyclone, heatwave and coldwave. It is revealed that flood (38%) constitutes major share of the events. Further, lightning, thunderstorm and hailstorm follows share in decreasing order. It is noted that cyclone's share is the least in number. Trend analysis of annual number of extreme climate events has been carried out and their significance level has been computed (Table 1). All the extreme events except cyclone and gale have significant increasing linear trend. However, cyclone has non-significant decreasing and gale has insignificant increasing trends. In view of the above observation, we conclude that number of extreme climate events has significant increasing trend.

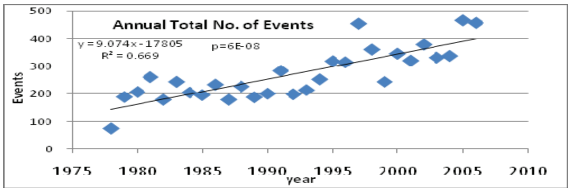

Fig. 1. Annual total number of extreme climate events in India

Table 1. Top weather related hazards in India and trends in their occurrences (1978-2006)

Event	Total No.	Mortality	Percent Mortality	Trend	p-value
flood	**2973**	**43573**	**50.2**	**3.42**	**0.00**
cyclone	**62**	**18853**	**21.7**	**-0.04**	**0.08**
heat wave	**373**	**8514**	**9.8**	**0.55**	**0.00**
cold wave	**376**	**6668**	**7.7**	**0.29**	**0.00**
thunder storm	1123	3490	4.0	1.90	0.00
lightning	1353	3395	3.9	2.75	0.00
hail storm	934	989	1.1	1.00	0.00
dust storm	146	584	0.7	0.17	0.00
squall	284	362	0.4	0.35	0.00
gale	245	291	0.3	0.12	0.25

Table 2. Leading states in the extreme events by number and mortality

Extreme Event	No. of Event	Mortality
Cold wave	BR	BR
Cyclone	AP	OR
Dust storm	UP	UP
Flood	MH	UP
Gale	KL	OR
Hail storm	MH	BR
Heat wave	RJ	AP
Lightning	MH	MH
Squall	AS	WB
Thunder storm	WB	WB
Total events	MH	OR

Spatial distribution of events has been examined by associating each event with one (or more) states. Leading states in the extreme events by their numbers and impacts are calculated and presented in table 2. Maharashtra leads the occurrence of total number of the extreme events. It also leads in number of occurrence of flood, hailstorm and lightning. Bihar is in forefront with maximum number of cold wave occurrence. Cyclone landfall is highest in Andhra Pradesh. UP leads in duststorm. Gale activity is greatest in Kerala. Heatwave occurrence is highest in Rajasthan. Squall occurrence is in its peak spatially in Assam. Thunder storm activity is greatest in West Bengal. It is evident that leading sates in mortality does not necessarily correspond to those leading in occurrences. For example AP leads in occurrences of cyclone while Orissa leads in its mortality. This reveals that exposure of the people to the events and their adaptive capacity play important role in weather hazards impact.

4. Conclusions

Foregoing analysis depicted following conclusions:

- Major share of occurrence of climate extremes is due to floods; and cyclone which has most devastating impact has least share.
- Total number of climate extremes considered in the study is significantly increasing in India.
- Except cyclone and gale all the extremes depict significant increasing trend.
- Cyclones crossing Indian coasts are insignificantly decreasing.
- Maharashtra is the leading state in total number of events and floods while Rajasthan, Bihar and Andhra Pradesh are leading in heat wave, cold wave and cyclone respectively.
- Almost all the states depict increasing trends in heatwave and flood occurrences.
- Assessment of occurrence of the climate extremes needs more spatio-temporal details for the study and formulation of policy for impact, vulnerability and adaptation of climate sensitive sectors and regions.

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