Performance Evaluation For Extreme Climatic Event Analysis

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Abstract

Since human and natural systems are directly or indirectly affected by the changes of extreme climatic events, the main focus of our research is to detect the possible changes of intensity and frequency of these extreme events and to evaluate performance of the code used to derive the indices of climatic change. The IMD gridded daily temperature dataset is used and the guidelines suggested by **ETCCDI** (Expert Team on Climate Change Detection and Indices) are followed to characterize the extreme categories of surface air temperatures (1969-2005).All temperature based climatic extreme indices defined by **ETCCDI** are analysed for entire Indian region.

Introduction

Changes in extreme weather and climate events have significant impacts and are among the most serious challenges to society in coping with a changing climate [1]Indeed, "confidence has increased that some extremes will become more frequent, more widespread and/or more intense during the 21st century"[2]. As a result, the demand for information services on weather and climate extremes is growing. The supportability of monetary advancement and living conditions relies on upon our capability to deal with the dangers connected with extreme events.

Many practical changes in extreme weather and climate events have significant impacts and are among the most serious problems require knowledge of the behaviour of extreme values. In particular, the infrastructures we depend upon for food, water, energy, shelter and transportation are sensitive to high or low values of meteorological variables. For example, high precipitation amounts and resulting stream flows affect sewerage systems, dams, reservoirs and bridges. The motivation for analysing extremes is often to find an optimum balance between adopting high safety standards that are very costly on the one hand, and preventing major damage to equipment and structures from extreme events that are likely to occur during the useful life of such infrastructure on the other hand[3].

Extremes and its consequences

"Extreme climatic condition is defined as a situation in which the value of climatic parameter such as temperature,

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precipitation etc. exceeds a predefined threshold value."

Weather and climate extremes (Figure.1) have always posed serious challenges to society. Changes in extremes are already having impacts on socioeconomic and natural systems, and future changes associated with continued warming will present additional challenges. Increased frequency of heat waves and drought, for example, could seriously affect human health, agricultural production, water availability and quality, and other environmental conditions[1].

Extremes are a natural part of even a stable climate system and have associated costs and benefits. For example, extremes are essential in some systems to keep insect pests under control. While hurricanes cause significant disruption, including death, injury, and damage, they also provide needed rainfall to certain areas, and some tropical plant communities depend on hurricane winds toppling tall trees, allowing more sunlight to reawaken low-growing trees. But on balance, because systems have adapted to their historical range of extremes, the majority of events outside this range have primarily negative impacts. The impacts of changes in extremes depend on both changes in climate and ecosystem and societal vulnerability. The degrees of impacts are due, in large part, to the capacity of society to respond. Vulnerability is shaped by factors such as population dynamics and economic status as well as adaptation measures such as appropriate building codes, disaster preparedness, and water use efficiency. Some short-term actions taken to lessen the risk from extreme events can lead to increases in vulnerability to even larger extremes. For example, moderate flood control measures on a river can stimulate development in a now "safe" floodplain, only to see those new structures damaged when a very large flood occurs.

Human-induced warming is known to affect climate variables such as temperature and precipitation. Small changes in the averages of many variables result in larger changes in their extremes. Thus, within a changing climate system, some of what are now considered to be extreme events will occur more frequently, while others will occurs less frequently *e.g.*, more heat waves and fewer cold snaps (Figures 1). Rates of change matter since these can affect, and in some cases overwhelm, existing societal and environmental capacity. More frequent extreme events occurring over a shorter period reduce the time available for recovery and adaptation. In addition, extreme events often occur in clusters. The cumulative effect of compound or back-to-

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back extremes can have far larger impacts than the same events spread out over a longer period of time. For example, heat waves, droughts, air stagnation, and resulting wildfires often occur concurrently and have more severe impacts than any of these alone.

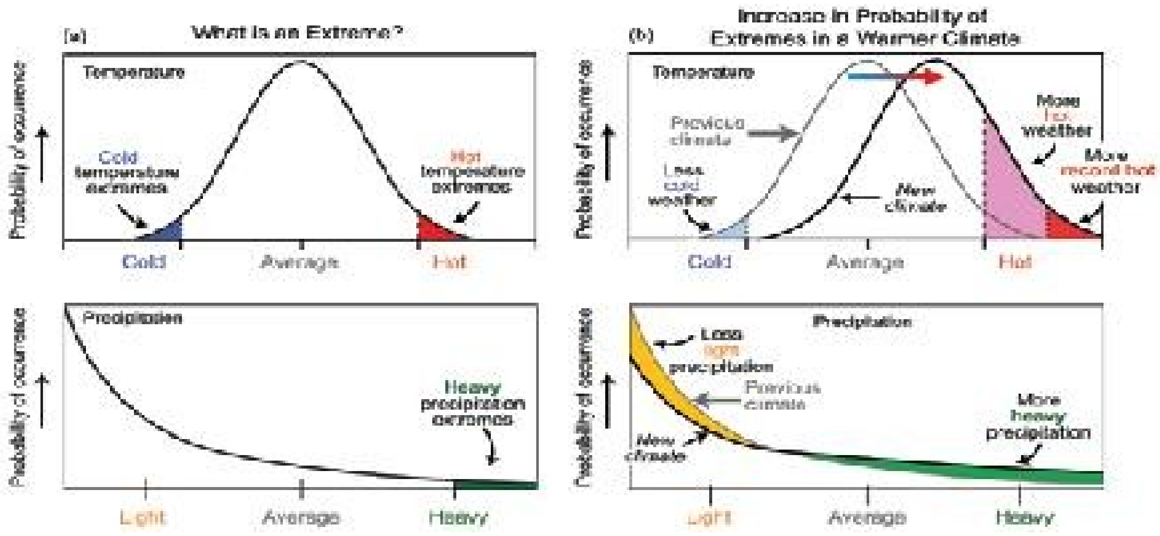

Figure 1. Extremes are denoted by the shaded portion.

Definition of temperature based core indices

S.NO.	ID	Indicator Name	Indicator Definitions	Units
1	FD	Frost days	Number of days in a year in which TN (daily minimum temperature) stay below 0 ^{0}C.	days
2	SU	Summer days	Number of days in a year in which TX (daily maximum temperature) stay above 25 ^{0}C.	days
3	ID	Icing days	Number of days in a year in which TX (daily maximum temperature) stay below 0 ^{0}C.	days
4	TR	Tropical nights	Number of days in a year in which TN (daily minimum temperature) stay above 20 ^{0}C.	days
5	GSL	Growing season length(not applicable for Indian region)	Number of days in a year (1st Jan to 31st Dec in Northern Hemisphere (NH), 1st July to 30th June in Southern Hemisphere (SH)) in which count between first span of at least 6 days with (daily mean temperature) TG stay above 5^{o}C and first span after July 1st (Jan 1st in SH) of 6 days with TG stays below 5^{0}C.	days
6	TX_x	Max Tmax	Monthly maximum value of daily max temperature.	^{0}C

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7	TN_x	Max Tmin	Monthly maximum value of daily min temperature.	^{0}C
8	TX_n	Min Tmax	Monthly minimum value of daily max temperature.	^{0}C
9	TN_n	Min Tmin	Monthly minimum value of daily min temperature.	^{0}C
10	TN10p	Cool nights	Percentage of days when TN < 10th percentile.	%
11	TX10p	Cool days	Percentage of days when TX < 10th percentile.	%
12	TN90p	Warm nights	Percentage of days when TN>90th percentile.	%
13	TX90p	Warm days	Percentage of days when TX>90th percentile.	%
14	WSDI	Warm spell duration indicator	Number of days in a year in which at least 6 consecutive days has TX above 90th percentile.	days
15	CSDI	Cold spell duration indicator	Number of days in a year in which at least 6 consecutive days has TN less 10th percentile.	days
16	DTR	Diurnal temperature range	Monthly mean difference between maximum and minimum temperature.	^{0}C

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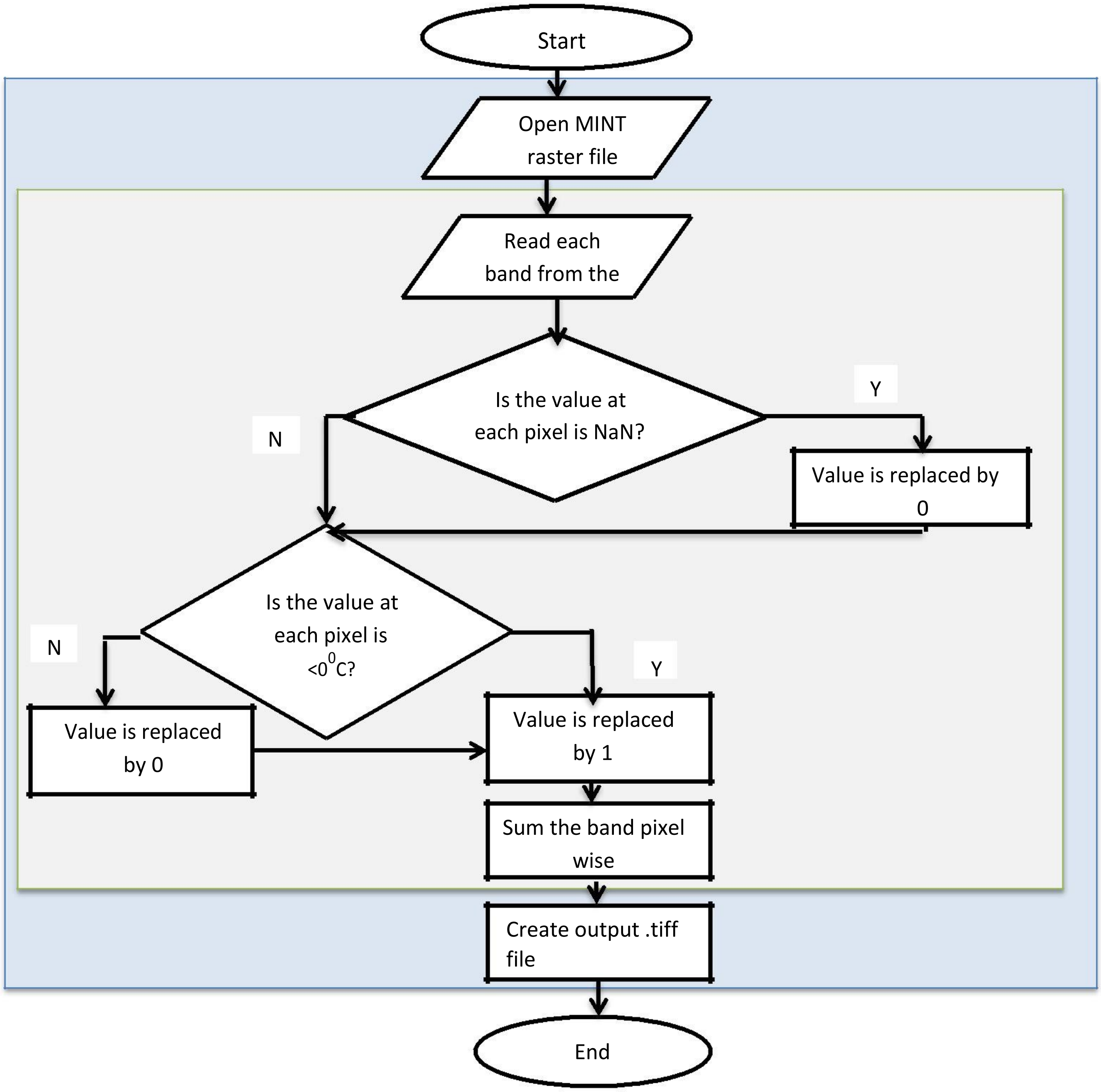
Flow chart for the calculation of number of frost days



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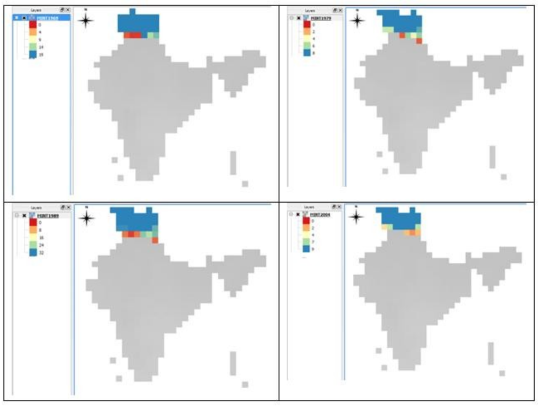
Result

Output .tiff file for the annual count of days when TN (daily minimum temperature) < 0 ^{0}C is described in fig 3.



The value of number of frost day vary from 0-19 in 1969 to 0-32 in 1989.

Execution time for the calculation of frost day is found to be 49.99 microseconds using python programming language.

Conclusion and future work

The current study attempts to do a "Performance Evaluation for Extreme Climatic Event Analysis" except GSL and icing day all the ETCCDI indices were derived using python and other scientific libraries. Integration of multiple data set and multiple technologies is a long standing research problem in Computer Science and Engineering. This study is an ideal example of how these obstacles can be overcome using open source technologies.

In view of the current changing climate, global warming and strong indicators of change in IPCC reports, this study is highly relevant and important for global and societal causes. The current trend in climatic change research has migrated from studying long term time series data to study extreme climatic events. The results shown are highly indicative of the increasing frequency of extreme climatic events. Current disaster such as the Kedarnath "Himalayan Tsunami" emphasize the importance of collecting ground data and analysing them for extreme event on regular basis.

The value of summer days remains the same (0-364) in 1969 and 2004.

The work however has the much scope for enhancement. As listed below:

1. Longer duration data/ more data could give better picture of extreme climatic events.
2. Frequency of data used was daily: On availability of higher frequency data such as hourly, 3 hourly etc could enhance our understanding of diurnal events.
3. The spatial resolution of the data used was 1° and 0.5° for temperature and rainfall respectively on availability of higher spatial resolution data could enhance our understanding of effect of topography, distance from sea and mountains and other geo-morphological factors.
4. The analysis was performed on a system with 2.1 GZ Intel i3 processor and 3GB RAM. Execution of the programmes on higher specification systems could give lesser execution times.
5. As the code was run pixel wise there is immense opportunity to improve the execution time by parallelising the code through Open MPI, multithreading and GPU based computing.

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