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Research Paper

Assessment of climate extremes and its long term spatial variability over the Jharkhand state of India ☆

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A B S T R A C T

This study examines the spatial climatic variability and climate extremes over the state of Jharkhand during 1984 to 2014. The climate extremes and the long-term fluctuation of climate parameters viz. maximum temperature, minimum temperature, rainfall, and solar radiation were assessed using least squares statistical method, for 71 locations in Jharkhand and interpolated spatially in Geographical Information System. The spatial analysis of the trend maps and climate index maps, demonstrates the regions with increasing number of summer days, increasing trend of maximum temperature and solar radiation, decreasing rainfall and thereby increased periods of consecutive dry days during monsoon season. The negative impact of climate extremes was observed as delay in transplanting/vegetative phase and reduced crop production, whereas an increase in the frequency of heat waves with 29 instances during 2004, 41 during 2005 and 100 during 2010 were observed. The findings of this study showed that average maximum temperature during 1984 to 2014 fluctuates with an increase of 1–1.5 °C to a decrease of 0.82–0.14 °C whereas the average minimum temperature fluctuates with a decrease of 0.79–0.39 °C to an increase of 0.59–0.41 °C. Rainfall fluctuates with a decrease of 26–270 mm to an increase of 19–440 mm. The highest average number of summer days is observed in Simdega with 340–348 days whereas the average consecutive dry days for the whole of Jharkhand has an increasing trend particularly in Palamu, Garhwa and Latehar districts, with 3.8–4.2 days of dryness during monsoon.

1. Introduction

Climate variability is amongst the major phenomenon occurring worldwide which has caused major changes in climate variables such as precipitation, air temperature, relative humidity, and solar radiation (Haskett et al., 2000; Bates et al., 2008; Yu et al., 2013). Because of these alterations, there is a consistent warming trend which is clearly reflected by the increasing occurrence of extreme climate events like droughts, floods and heat waves (Meehl et al., 2007). The natural disasters worldwide are a result of extreme events rather than just a variation of the mean climate (Plummer et al., 1999). According to the fifth report of Intergovernmental Panel on Climate Change (IPCC, 2013), the average maximum and minimum temperatures over land have increased worldwide by an excess of 0.1 °C per decade since 1950, including India, thereby affecting agriculture, water demands, and more rapid melting of glaciers. The report also stated that extended intervals of monsoon failures and dry spells have struck India and southeastern Asia, in the last few years leading to prolonged and intense droughts, which are a recurring feature of Holocene paleoclimate, also, the frequency of heavy precipitation events is increasing while light rain events are decreasing. The climate variability has lead to increased evapotranspiration rates, decline in soil moisture, and socio-economic consequences with longer dry periods, and greater number of extreme events (Izrael et al., 1997; Cruz et al., 2007; Ramos et al., 2012). Higher or lower rainfall or changes in its spatial and seasonal distribution influences the spatial and temporal distribution of runoff, soil moisture and groundwater reserves, and thereby affects the frequency of droughts and floods (Kumar et al., 2010; Jhajharia and Singh, 2011). In this context, several studies have been carried out to determine the impact of climatic variability on trends of annual and seasonal rainfall and its intensity (Parthasarathy et al., 1993; Naidu et al., 1999; Patra et al., 2005; Goswami et al., 2006; Ramesh and Goswami, 2007; Kothawale et al., 2010), the number of rainy days in various regions

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of India, and temperature trend (Feidas et al., 2004; Arora et al., 2005; Sen Roy and Balling, 2005; Andrighetti et al., 2009; Pal and Al-Tabbaa, 2010). Pant and Kumar (1974) analyzed the seasonal and annual air temperatures from 1881 to 1997 and observed an increasing trend of mean annual temperature, at the rate of 0.57 °C per 100 years. Rupakumar et al. (1994) pointed out that the countrywide mean maximum temperature of India has risen by 0.6 °C, and the mean minimum temperature has decreased by 0.1 °C. Rupakumar et al. (1992) observed that areas of the northeast peninsula, northeast India and northwest peninsula experienced a decreasing trend in summer monsoon rainfall while, Kothyari and Singh (1996) found that rainfall has a decreasing trend and temperature has increasing trends in the Ganga basin of India.

The changes in climate extremes have drawn the attention of researchers worldwide because of their critical impacts on human society, economic development, natural ecosystem, and environment (Vincent and Mekis, 2006; Torma et al., 2011; Ji-Yun et al., 2012). Indices for climate variability and extremes have been used for a long time, by assessing days with temperature or precipitation observations, which provide insight into local conditions, physically based on relative thresholds that describe features by examining the distributions of meteorological parameters through well distributed meteorological stations over the study area (Moberg and Jones, 2005; Zhang et al., 2011; Dutta et al., 2015). Amongst all the climate change indicators, the indicators for temperature and precipitation or their derivative quantities are widely used in monitoring and quantifying the extreme meteorological and hydrological climatic events (floods and droughts) (Wang et al., 2011). Researchers like Frich et al. (2002), found an increase in warm summer nights, decrease in the number of frost days, and a decrease in intra-annual extreme temperature ranges, while extreme precipitation showed more mixed patterns of change globally, and significant increases were seen in the amount derived from wet spells and the number of heavy rainfall events.

In applications of statistics to climatology for analyzing trends, both parametric and non-parametric methods are vastly used (Reghunath et al., 2005; Sarkar and Ali, 2009; Shamsudduha et al., 2009). Parametric trend tests are regarded to be more powerful than the non-parametric ones (Moberg and Jones, 2005; Hamed and Rao, 1998). The Sum of Least Squares (SLS) method is based on simple linear regression method and is widely used to calculate trend (Gupta and Gupta, 2008) in almost every field, from business forecasting, economics, engineering, physics, groundwater level fluctuations, climatological applications and so on (Korkmaz, 1988; Pal and Al-Tabbaa, 2011; Tirkey et al., 2012). The SLS method checks for a linear trend and is suitable for time series analysis and hence is applied in the present study to analyze the climate variability (viz. maximum temperature, minimum temperature, rainfall and solar radiation) of Jharkhand, India and to determine if climate over Jharkhand has a general increasing or decreasing trend with time.

The climatic variability over the state of Jharkhand has been analyzed in the present study as it follows a similar drift of global warming scenario as reflected worldwide. The northwestern region of Jharkhand like Palamu and Garhwa in particular, has been suffering from an extended dry spell which has led to a number of severe impacts in the region. Thus, detailed monitoring and assessment of climate trends over Jharkhand requires to be evaluated for analyzing the impact of rainfall and temperature on society, agriculture, and environment. The analysis of rainfall and temperature time series will help to recognize the long-term trends, temporal fluctuations and spatial distribution and magnitude of rainfall and temperature trends and thus provide an insight for economic planning and decision making. Hence, the major objective of the present study is to analyze the climatic fluctuations and the net change in the climate with respect to temperature (minimum and maximum temperature), rainfall, and solar radiation (during the Kharif crop growing season of June-Oct and Rabi season during Dec-March) in the Jharkhand state of India on spatial and temporal scales. Secondly, it aims at investigating the climate extremes based on climate indices using the daily data pertaining to temperature and precipitation, in Jharkhand.

2. Study area

The study was conducted for the entire state of Jharkhand which lies between 25°30′ N to 22°N latitude and 83°E to 88°E longitude covering an area of 79,714 km^2 where most of the state comes under the Chota Nagpur Plateau. Climatically, the state's weather is significantly variant with the northwest and west central parts of the state being hot with less rainfall and the southwest receiving more of rainfall. The three most prominent seasons in Jharkhand are characterized by summer, winter and rainy season, wherein the summer season comprises the months from March to June with May being the hottest month and the winter season consist of the months of November to February and is the most pleasant part of the year. The southwest monsoon precipitation from mid-June to October is primarily responsible for the state's annual rainfall where most of the precipitation falls in July and August. The annual precipitation ranges from about 1000 mm in the west-central part of the state to more than 1500 mm in the southwest (www.jharkhand.gov.in). The agricultural land and forest cover 49% and 30% of the total geographical area of Jharkhand respectively. The location map of the study area is shown in Fig. 1.

3. Material and methods

The daily time series data of rainfall, solar radiation, maximum temperature and minimum temperature, from 1984 to 2014 (30 years) were downloaded from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) dataset (globalweather.tamu.edu) in comma separated values (.csv) file format which are authenticated data sources (Sharma et al., 2015).

The world meteorological organization (WMO) has referred the period 1961 to 1990 as 'base line' and a significant shift of tropical rainfall is found during the period 1979 to 2003 (Lau and Wu, 2007). Therefore, only the second half of the 20th century is considered in many planning decisions. Keeping this in mind, in the present study, the 30 year period of 1984 to 2014 is considered. The CFSR weather data was obtained for a bounding box of latitude 25°30′ N to 22° N and longitude 83° E to 88° E covering the entire state of Jharkhand. The CFSR weather data included the information such as latitude/longitude, elevation, and the daily time series data of maximum temperature, minimum temperature, precipitation, and solar radiation for a period of 30 years for 193 NCEP CFSR data locations both in and around the state of Jharkhand.

The location data in .csv format was then projected as real world coordinates (as shapefile) in ArcGIS and assigned a coordinate system. The shapefile was then clipped by Jharkhand's boundary map, and out of the 193 locations, only 71 NCEP CFSR data locations fell entirely within the state's boundary, which were then processed for further analysis. The Fig. 2 depicts the spatial distribution of the NCEP CFSR data locations analyzed in this study.

3.1. Trend analysis

The daily maximum temperature, daily minimum temperature, and daily solar radiation data of all the 71 NCEP CFSR data locations were averaged month wise in Microsoft office excel, for the obser-