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Characteristics of occurrence of heavy rainfall events over Odisha during summer monsoon season

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ABSTRACT

During summer monsoon season heavy to very heavy rainfall events have been occurring over most part of India, routinely result in flooding over Indian Monsoon Region (IMR). It is worthwhile to mention that as per Geological Survey of India, Odisha is one of the most flood prone regions of India. The present study analyses the occurrence of very light (0–2.4 mm/day), light (2.5 – 15.5 mm/day), moderate (15.6 – 64.4 mm/day), heavy (64.5 – 115.4 mm/day), very heavy (115.5 – 204.4 mm/day) and extreme (≥ 204.5 mm/day) rainy days over Odisha during summer monsoon season for a period of 113 years (1901 – 2013) and a detailed study has been done for heavy-to-extreme rainy days. For this purpose, India Meteorological Department (IMD) gridded (0.25° × 0.25° lat/lon) rainfall data and the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-Interim) (0.125° × 0.125° lat/lon) datasets are used.

The analysis reveals that the frequency of very light, light and moderate rainy days persists with almost constant trend, but the heavy, very heavy and extreme rainy days exhibit an increasing trend during the study period. It may be noted that more than 60% of heavy-to-extreme rainy days are observed in the month of July and August. Furthermore, during the recent period (1980–2013), there are a total of 150 extreme rainy days are observed over Odisha, out of which 47% are associated with monsoon depressions (MDs) and cyclonic storms, 41% are with lows, 2% are due to the presence of middle and upper tropospheric cyclonic circulations, 1% is due to monsoon trough and other 9% of extreme rainy days does not follow any of these synoptic conditions. Since a large (nearly half) percentage of extreme rainy days over Odisha is due to the presence of MDs, a detailed examination of MDs is illustrated in this study. Analysis reveals that there are a total of 91 MDs formed over the Bay of Bengal (BoB) during 1980 – 2013, and out of which 56 (61.5% of total MD) MDs crossed Odisha. Further spatial analysis of extreme rainfall days exhibits that the maximum frequency of extreme rainy days is present over the south west region of Odisha.

1. Introduction

Indian summer monsoon is manifested by the presence of semi-permanent features such as monsoon trough, heat low, mascarenes high, Tibetan anticyclone, cross-equatorial westerly jet stream (Somali jet) and tropical easterly jet stream at 200–150 hPa pressure level (Patwardhan et al. 2016). The monsoon trough provides a track for the rain-bearing low pressure systems (LPSs), such as lows and depressions formed over the Bay of Bengal (BoB) (Krishnamurthy and Ajayamohan, 2010). Mooley (1973) have found that the LPSs like lows, monsoon depressions (MDs), monsoon deep depressions etc. intensify the activity of monsoon trough. The spatial

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distribution of the monsoon seasonal (June–September and hereafter; JJAS) mean rainfall averaged for the period 1951–1995 suggests a maximum along the west coast of India, North-East India, and central India; rainfall minimum is observed over North-West India as well as over South-East India (Rajeevan et al., 2006).

In recent years, heavy rainfall events have resulted in serious destructive floods in India. It is more important to understand the changes in extreme weather events than the changes in mean pattern. According to the latest report of the Intergovernmental Panel on Climate Change (IPCC, 2007), it is found that the wet climatic zones are projected to become wetter, and dry climatic zones are projected to become drier. At the same time, the Asian monsoon region and other tropical areas will be experiencing more flood events (Guhathakurta et al., 2011).

By using IMD daily gridded rainfall data of $1^{\circ} \times 1^{\circ}$ lat/lon spatial resolution for the period 1951–2005, Pattanaik and Rajeevan (2009) have found that there is an increase of extreme rainfall events during June and July, but no such significant trend has been found during August and September. Goswami et al. (2006) have found that there is a decrease in heavy rainfall events (5 mm $\leq$ 24 h accumulated rainfall $\leq$ 100 mm), and the number of very heavy rainfall events (24 h accumulated rainfall $\geq$150 mm) has doubled indicating a large increase in disaster potential over central India. Increase of extreme rainfall event in central India is associated with an overall increase in synoptic activity (Ajayamohan et al., 2010). There is an increase in the number of weak storms which can dominate and produce an upward trend in overall synoptic activity that is accompanied by an increase in extreme rain events over the same period (Goswami et al. 2006; Ajayamohan et al., 2010).

According to Mooley (1973), the rainfall over central India, which includes Odisha, is directly correlated with the frequency of LPS days over Indian region. The monsoon rainfall is very complex over Odisha than that over India due to the larger influence of LPS developing over northern BoB and its basic interaction with the varied physiography of Odisha which includes Eastern Ghat hill ranges (Mohapatra et al. 2003). Mohapatra and Mohanty (2004) have suggested that Odisha gets about 117 cm of rainfall during the summer monsoon as per the climatological data analysed for the period 1901–1970. Also during JJAS, the rainfall over Odisha increases significantly with increase in LPS days over northwest Bay and Odisha.

It is worthwhile to mention that the state Odisha is affected due to a number of natural disasters. The state Odisha has been declared a disaster affected for 93 years out of the 105 years (2005 - 1900), out of which 50 years by flood, 32 years of drought and 11 years by cyclone (ENVIS Newsteller 2007, Odisha). The flood in Odisha mostly occurs due to very heavy precipitation (Annual report on natural calamities 2009–2010). Dhar and Nandergi (1993) found that during the period from 1880 to 1990, 8 rainstorms have occurred over Orissa out of total 97 affecting the whole country. As there is a spatial and temporal variation of rainfall distribution over Odisha and flooding, the mostly occurring disaster over Odisha are mainly associated with heavy precipitation events, thus it is important to study the climatological perspective of these heavy rainfall events.

1.1. *Significance and uniqueness of the study*

Dash et al. (2009) have studied the rainfall characteristics over India and its six homogeneous regions, however, there is a limited study of regional scale like over Odisha. Mohapatra and Mohanty (2004) have studied the correlation of the frequency of lows, depressions and cyclonic disturbances during the summer monsoon period with the monsoonal rainfall over Odisha. However, the actual days of occurrence of cyclonic disturbance and the rainfall over Odisha have not been analysed and there is a lack of the study on other large scale features during the monsoon period and which can influence the extreme rainfall over Odisha. So, the present study describes the spatio-temporal characteristics of heavy-to-extreme rainfall events over Odisha during Indian summer monsoon season for a period of 113 years (1901–2013). The study emphasizes on rainfall frequency, pattern of distribution and above all the basic characteristic of heavy-to-extreme rainfall events. Also, the study is extended towards the synoptic disturbances during the extreme rainfall events and the climatology of temperature, and wind pattern over Odisha. So this study can give an idea about how the rainfall has been varied during last 113 summer monsoon season and what are the synoptic disturbances responsible for these extreme rainy days over Odisha.

The geographical distribution of 30 districts of Odisha is discussed in Section 2. The type of data used and the methodology applied in this study have been discussed in Section 3. The results drawn from this study are discussed in Section 4 followed by conclusions in Section 5.

2. Study Area

The state Odisha extends its boundary between latitudes 17°49′N and 22°36′N and longitudes 81°36′Eand 87°18′E with a coastline of 560 km (< http://iasri.res.in/agridata/02data%5Cchapter%204%5Cdb2002tb4_5.htm >) and surrounded by the BoB in the East, Chhattisgarh in the West, West Bengal in the North East, Jharkhand in the North, and Andhra Pradesh in the South.

The district wise division map of Odisha is shown in Fig. 1. Odisha has 30 districts and are stated as follows. Those 30 districts are: Balasore (BLS), Bhadrak (BHD), Mayurbhanj (MYBHG), Keonjhar (KNDJHR), Jajpur (JPR), Dhenkanal (DHKL), Sundargarh (SUND), Jharsuguda (JHSGD), Sambalpur (SMBLR), Deogarh (DEO), Anugul (ANG), Kalahandi (KLH), Nuapada (NPD), Balangir (BNGR), Baragarh (BRG), Sonepur (SNR), Boudh (BDH), Kendrapada (KNDP), Jagatsinghpur (JSR), Puri (PURI), Khordha (KHD), Cuttack (CTC), Nayagarh (NGRH), Ganjam (GJM), Malkangiri (MKG), Nabarangpur (NBR), Koraput (KRP), Rayagada (RGD), Kandhamal (KNM), and Gajapati (GPT). Out of 30 districts, six coastal districts (Balasore, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam) are more prone to coastal vulnerabilities.