Vol. 18, No. 1, pp. 21-30 (2018)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Micro-level Extreme Weather Event Analysis for Odisha State, India

A.V.M. SUBBA RAO[1], V. NARASIMHA RAO[1], M.A. SARATHCHANDRAN[1], S.K. BAL[1], RAJKUMAR DHAKAR[1,2]* AND P. VIJAYA KUMAR[1]

[1]*ICAR-Central Research Institute for Dryland Agriculture, Hyderabad-500059, Telangana*
[2]*ICAR-Indian Agricultural Research Institute, New Delhi-110012*

ABSTRACT

The impact of climate change is most visible through extreme weather events. The information on extreme weather events in India are scattered and there has been very less efforts to analyze it. There is an immediate exigency to collect, compile and analyze micro level data on incidence of extreme weather events. This information is used for designing early warning systems and adaptation/mitigation measures. This study is about district level analysis of extreme weather events like hail storm, heat wave and extreme rainfall for Odisha state of India, which is frequently prone to these natural disasters. Long-term meteorological data analysis at district level showed that frequency of heat waves ranged from 17-23 days were observed during 1996-2006 to 1986-1995. May month recorded highest frequency of heat wave events. Hailstorm intensity analysis showed that maximum of 7 Heavy, 2 Moderate events were observed at Cuttack and least number of occurrences observed at Bolangir (1). Trend analysis of different rainfall intensity categories revealed significant increasing trend in southwest monsoon rainfall at northern districts of Odisha and significant decreasing trend in northeast monsoon at majority of districts of the state in the recent decade (2002-11). The information generated out of this work will aid in developing early warning systems and preparation of contingency plans for the state.

Key words: Extreme weather events, micro level, hail storm, heat wave, extreme rainfall, trend analysis

Introduction

Changes in magnitude and frequency of extreme weather events have become eminent since mid of 20th century. Impacts from recent climate-related extremes, experienced in many parts of the world such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and human systems to current climate variability (IPCC, 2014). Climate has shown warming of 0.89 (0.69 to 1.08) °C over the period 1901–2012 which is mainly attributed to anthropogenic activities (IPCC, 2013). Surface temperature averaged over the country (India) has a significant increasing trend during the past three decades (Kothawale *et al*., 2010). The trends of the seasonal mean (JJAS) Indian summer monsoon rainfall (ISMR) over different sub-divisions of the country are different (Guhathakurta and Rajeevan, 2008) with largely positive trends (with the exception of Kerala). India is experiencing several kinds of extreme events in the recent decades. The recent ARS report 2015 of IPCC projected that Asia is expected to face the increasing events of floods, droughts and heat waves. In India, the information on extreme events like hail/ thunderstorms are scattered and some data is available with IMD. De *et al.* (2005) has reviewed the extreme weather events that occurred in India during 1991-2004. Socio-economic impacts of the

*Corresponding author,
Email: bal_sk@yahoo.com

extreme weather events such as floods, droughts, cyclones, hail storm, thunderstorm, heat and cold waves have been increasing due to large growth of population and its migration towards urban areas which has led to greater vulnerability. These extreme events are locale specific and varies with ecological regions. As climate change has become a reality, these changes in extreme weather and climate events are of major concern for agrarian as well as civic society (Bal *et al*., 2017). Thus the need of the hour is to collect the information with better resolution preferably at micro level (district/taluk) in order to develop any forewarning system and adaptation strategies and weather based insurance indices.

Odisha state is situated in the eastern coast of India and agriculture provides direct or indirect employment to 64% of the total workforce here. However, climate induced natural disasters like drought, flood, cyclone, dry spells, heat wave, hailstorm occurring alone or in combination cause untold misery to the farmers of this state by creating instability in their economic condition as well as agricultural production. The existing productivity of food grains in Odisha is very low (1.65 t ha^{-1}) which is much lower than that of national average of 2.12 t ha^{-1} (DES, 2013). The main technological constraints of low productivity in Odisha particularly in rainfed areas are vagaries of south-west monsoon, occurrence of dry spells and natural calamities like drought, flood and cyclone etc.

Almost every year, significant crop losses in rainfed areas of Odisha has been reported due to aberrant weather conditions and natural calamities. Therefore, proper understanding of agroclimate and extreme weather events, their frequency, probability, extent of damage etc. are very much necessary to develop strategies in the affected areas. A detailed study on extreme rainfall events covering the entire Odisha region using the latest data is needed to obtain a clear idea about the impact of climate change on the extreme weather events of the state. It may be mentioned that understanding the changes in extreme weather events is more important than the changes in mean pattern for better disaster management and mitigation. As variability in rainfall is related to the occurrence of extreme rainfall events and their intensities, there is a need to quantify the magnitudes of extreme rainfall events over different parts of the state/region under study.

Data and methodology

Study area

Odisha state is located between 17°.49' and 22°.34' North Latitude and between 81°.27' and 87°.29' East of Greenwich (Fig. 1). The State occupies of 4.74 percent of India's total land area, coast line of nearly 482 kilometer long, forest-clad hills and mountain ranges of the Eastern Ghats. Odisha possesses a varied physiography

Fig. 1. Study area (Odisha State, India)

due to its peculiar geographical location and wide range of physical features. The economy of Odisha is more agricultural, less industrial and less service-oriented.

The Odisha state receives about 1,500 mm (60 inches) of rainfall annually, with a variability of 25-30 per cent. About 77% of the rainfall comes from the south-west monsoon (June to September). It has long sensitive coast line, which is a periodic recipient of events such as cyclones and floods. Most part of Odisha has not access to irrigation and totally depends on rain. Based on ecological land classification, recognizing various components like soils, climate, topography, vegetation, crops etc., the NARP (National Agricultural Research Project) delineated Odisha into 10 major agro-climatic zones under four physiographic divisions or geo-climatic zones viz., (i) Northern Plateau (Mayurbhanj, Keonjhar, Sundergarti and part of Dhenkanal, Jajpur, Balasore) (ii) The Central Table Land (part of Bolangir, Dhenkanal, Sambalpur, Phulbani) (iii) Eastern Ghat Zone (Koraput, Kalahandi, Phulbani) (iv) Coastal zone (Balasore, Cuttack, Pun, Eastern Ganjam).

Data and analytical methods used

Long term weather data for extreme events (1985-2008) for Odisha state was collected from India Meteorological Department (IMD) records. District-wise analysis was carried out for heavy rainfall events, heat wave, cold wave, hailstorm and their trends. During the last two decades, more attention has been given to study the extremes in daily temperatures and their variability due to their adverse socio-economic impacts (Kothawale *et al.*, 2011). Rainfall intensity analysis was carried out using weathercock software.

For heat wave and cold wave analysis, criteria defined by IMD was taken (Heat wave: Departure of daily maximum temperature from normal is +5°C to +6°C for regions where the normal maximum temperature is ≤ 40°C; Cold wave: Departure of daily minimum temperature from normal is -5°C to -6°C, where normal minimum temperature is ≥ 10°C).

Daily weather data (rainfall, maximum temperature, minimum temperature) of 27 districts of Odisha was provided by AICRPAM centre, OUAT, Bhubaneswar. The period of 1981-2012 was used for investigating the changes in extreme rainfall and temperature events occurred in the state. Climate extremes were computed using the RClimDex 1.1software (Xuebin Zhang *et al.*, 2004) which computes all 27 core indices recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) as well as some other temperature and precipitation indices with user defined thresholds. The extreme climate indices (temperature and rainfall) which were calculated for 28 districts located in Odisha are given in table 1.

Table 1. ETCCDMI core climate indices used in the study

ID	Definitions	Unit
TXx	Monthly maximum value of daily maximum temp	ºC
TNx	Monthly maximum value of daily minimum temp	ºC
TXn	Monthly minimum value of daily maximum temp	ºC
TNn	Monthly minimum value of daily minimum temp	ºC
TN10p	Percentage of days when TN<10th percentile	Days
TX10p	Percentage of days when TX<10th percentile	Days
TN90p	Percentage of days when TN>90th percentile	Days
TX90p	Percentage of days when TX>90th percentile	Days
RX1day	Monthly maximum 1-day precipitation	mm
Rx5day	Monthly maximum consecutive 5-day precipitation	mm
R10	Annual count of days when PRCP>=10mm	Days
R20	Annual count of days when PRCP>=20mm	Days
Rnn	Annual count of days when PRCP>=nn mm, nn is user defined threshold	Days

Trend analysis

For identifying the trend, most commonly used method is non-parametric Mann–Kendall (MK) trend test. Mann (1945) derived the test and Kendall (1975) subsequently derived the test statistic commonly known as the Kendall's tau (τ) statistic. Under the null hypothesis H_0, a series $\{x_1, ..., x_N\}$ is obtained from a population where the random variables are independent and identically distributed (i.e., null hypothesis has no trend), the MK test statistic is:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sgn(x_j - x_i)$$

where

$$sgn(x) = \begin{cases} +1, & x > 0 \\ 0, & x = 0 \\ -1, & x = 0 \end{cases}$$

And tau (τ) is estimated as:

$$\tau = \frac{2S}{N(N-1)}$$

Results and Discussion

Heat wave

Extreme positive departures from the normal maximum temperature results in heat wave during the summer season. The rising maximum temperature during the pre-monsoon months often continues till June, even in rare cases till July over the northwestern parts of the state (Fig. 2). The analysis inference that the number of heat wave days are increasing over the decades. The detailed analysis reports are as under.

Decadal changes of heat wave events in Odisha

Heat wave database for Odisha was available from 1985-2008. This database was organized

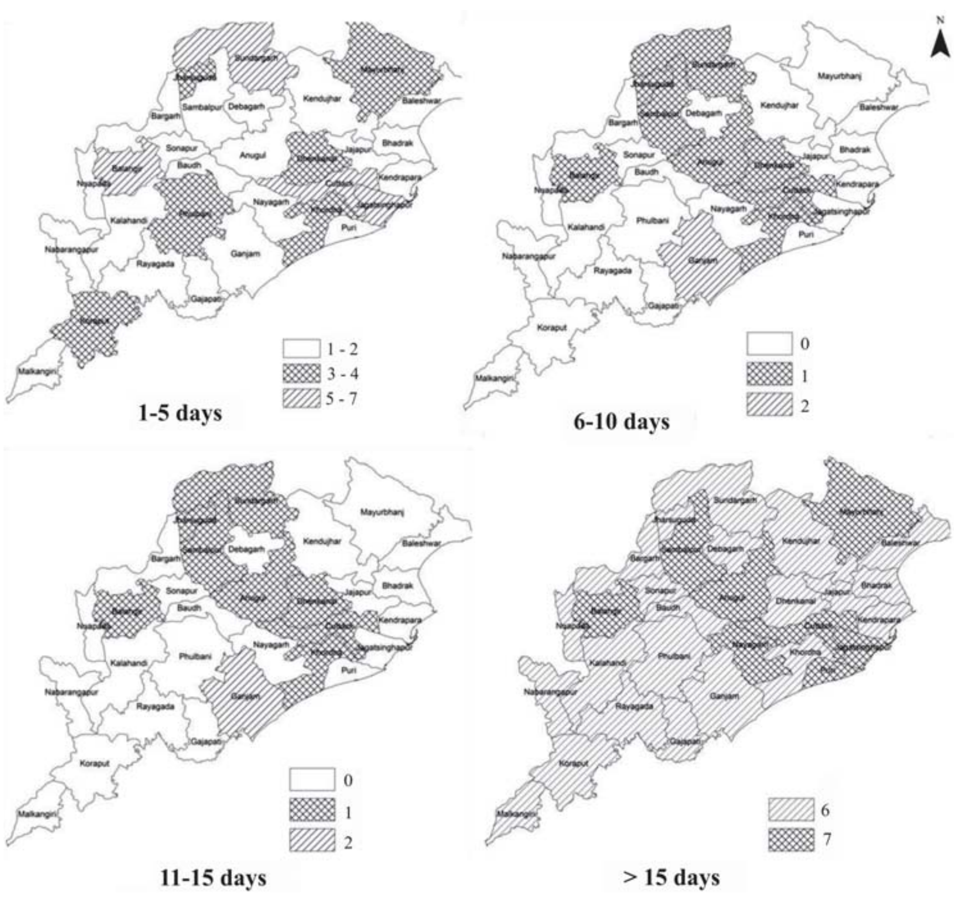
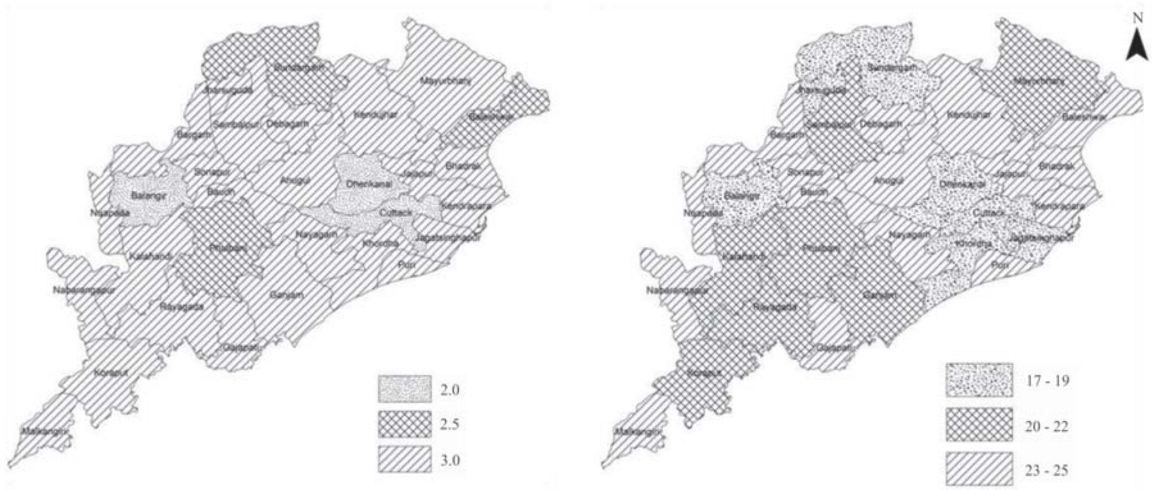


Fig. 2. Heat wave events of different duration observed in Odisha



1985-1995 (Decade 1) **1995-2008 (Decade 2)**

Fig. 3. Decadal changes in heat wave frequency in Odisha

into decades *viz.* 1985-1995 (Decade-I) and 1996-2008 (Decade-II). The comparison in number of events in between two decades showed (Fig. 3) that there is an increase in the occurrence of heat waves over Odisha. The magnitude of the events was also observed to be high in the 2^{nd} Decade. The range of events observed in the 1^{st} decade was 2-3 while in the 2^{nd} decade it was 17.2 to 23.8.

Monthly changes of heat wave events in Odisha

Monthly analysis of the occurrences of heat waves reveal that from March to June the number of heat wave events gradually increase and reach 24 in April through 11 in March in almost all the districts of Odisha except Ganjam, Jagatsinghapur, Mayurbhang, and Khordha. In May, the number of occurrences reached around 27 in all the districts and in June it came down to around 15. This indicates that number of heat wave events are more in the month of May compared to other months

Rainfall intensity analysis

Decadal rainfall intensity analysis was done for Odisha using district data for the period 1982-91, 1992-2001 and 2002-11. The rainfall intensity classes considered were 25-50 mm, 50-75 mm, 75-100 mm and > 100 mm. After estimating the frequency of rainfall events coming under each class, trend analysis was conducted for each decade using Mann-Kendall test and the results are presented in Fig. 4 and 5. During southwest monsoon, Mayurbhanj district has shown significant increasing trend in 25-50 mm, 50-75 mm, 75-100 mm (p=0.01) and for > 100 mm (p=0.1) rainfall events. Significant observations for the rainfall intensity category 25-50 mm during southwest monsoon are:

- Koraput and Nabarangapur districts showed increasing trend during all the three decades (with p= 0.01, 0.1 and 0.01during 1982-1991, 1992-2001 and 2002-2011, respectively)
- Sundargarh district: showed decreasing trends during 1982-1991 (p=0.01) and 1992-2001 (p=0.1), but increasing trend during 2002-2011 (p=0.01).
- Sambalpur district: showed decreasing trend during 1982 (p=0.05) and 1992-2001(p=0.01), but showed increasing trend during 2002-2011 (p=0.01).

Important observations for the rainfall intensity category 50-75 mm during southwest monsoon are:

- Sundargarh, Kendujhar and Mayurbhanj districts : showed decreasing trend during 1982-91, while all of them are showing increasing trend during 2002-11.
- Phulbani district showed a contrasting trend. The increasing trend during 1982-91 (p=0.05)

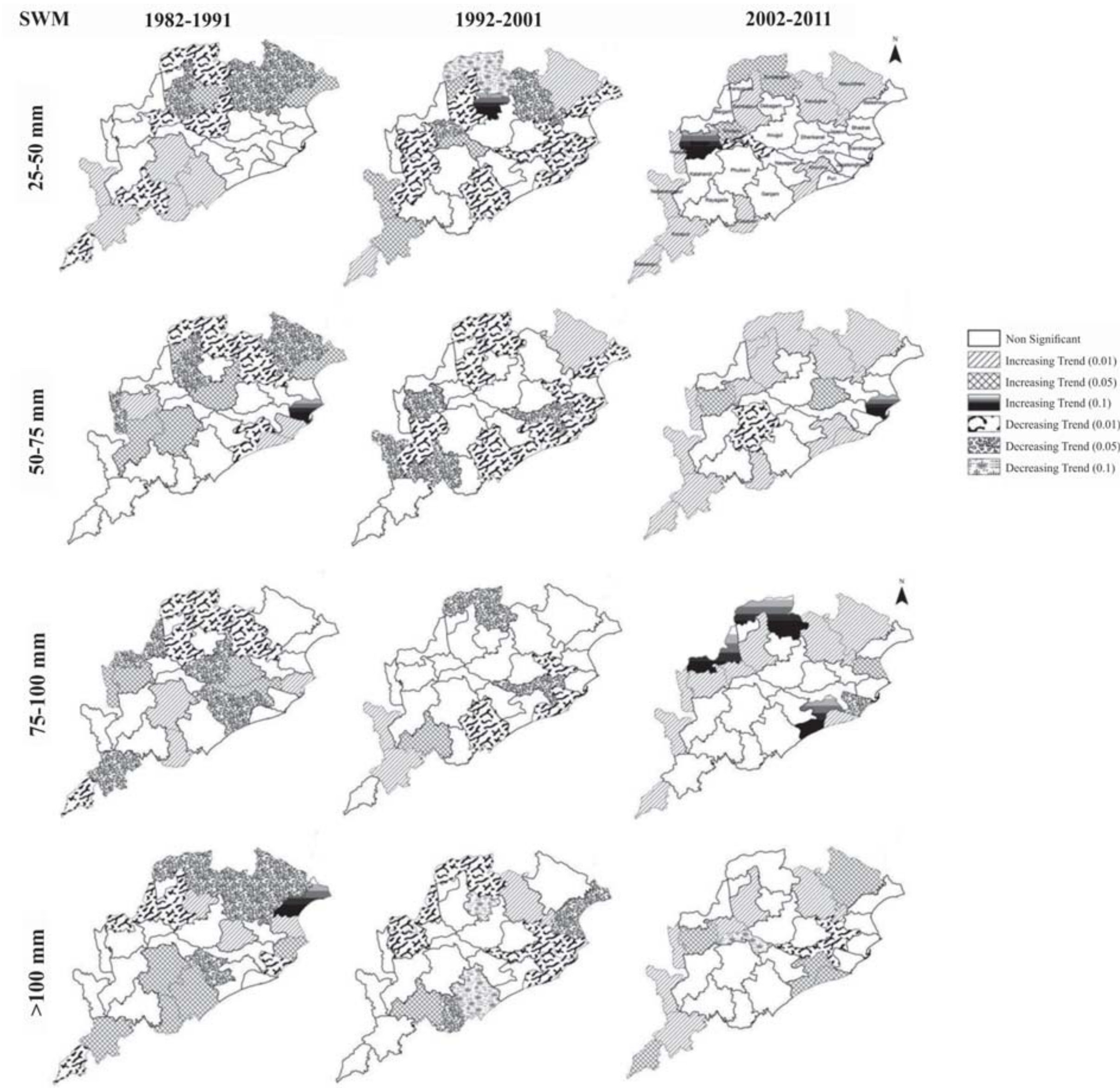


Fig. 4. Decadal trends in southwest monsoon rainfall intensity over Odisha

changed to non-significant during 1992-01 and decreasing trend during 2002-11 (p=0.01).

Important observations for the rainfall intensity category 75-100 mm during southwest monsoon are:

- Norther districts like Sundargarh, Kendujhar, Sambalpur, Bargarh showed decreasing trend during 1982-91, where as it showed the reverse during 2002-11. Similar trend was shown for > 100 mm rainfall intensity category also.

This indicates that the single-day heavy rainfall events like 75-100 mm and > 100 mm are increasing in the northern districts of Odisha. Along with this, southern districts like Koraput and Nabarangpur also showed increasing trend (p=0.01) of > 100 mm rainfall during 2002-11.

Rainfall intensity analysis followed by trend test for northeast monsoon indicated that definitive pattern in Odisha, which is presented in figure 6. Important observation for the different rainfall intensity categories during northeast monsoon are:

- 25-50 mm category: 16 districts showed increasing trend during 1982-91, which got reduced to 3 districts during 1991-01. The trend got reversed during 2002-11, whereas 21 districts showed decreasing trend. Interestingly, all districts showed decreasing trend during 2002-11.

- 50-75 mm category: 9 districts showed increasing trend during 1982-91, whereas all other districts showed non-significant changes. But, during 2002-11, 22 districts showed decreasing trend (majority with p=0.01).
- Similar trend was observed for 75-100 mm category and > 100 mm category.

The trend is very clear and alarming for northeast monsoon. i.e., there is a significant decreasing trend in northeast monsoon rainfall in Odisha across all intensity classes during 2002-11 compared to 1982-91 and 1992-01.

The trend analysis of different rainfall intensity classes for three decades of Odisha provides vital information regarding southwest and northeast monsoons. There is a significant increasing trend in receipt of southwest monsoon rainfall, especially in the northern districts of Odisha, across different intensity categories. But, most importantly, there is a significant decreasing trend in northeast monsoon rainfall, with more spatial coverage across majority of districts of Odisha. The implications of these observations are manifold.

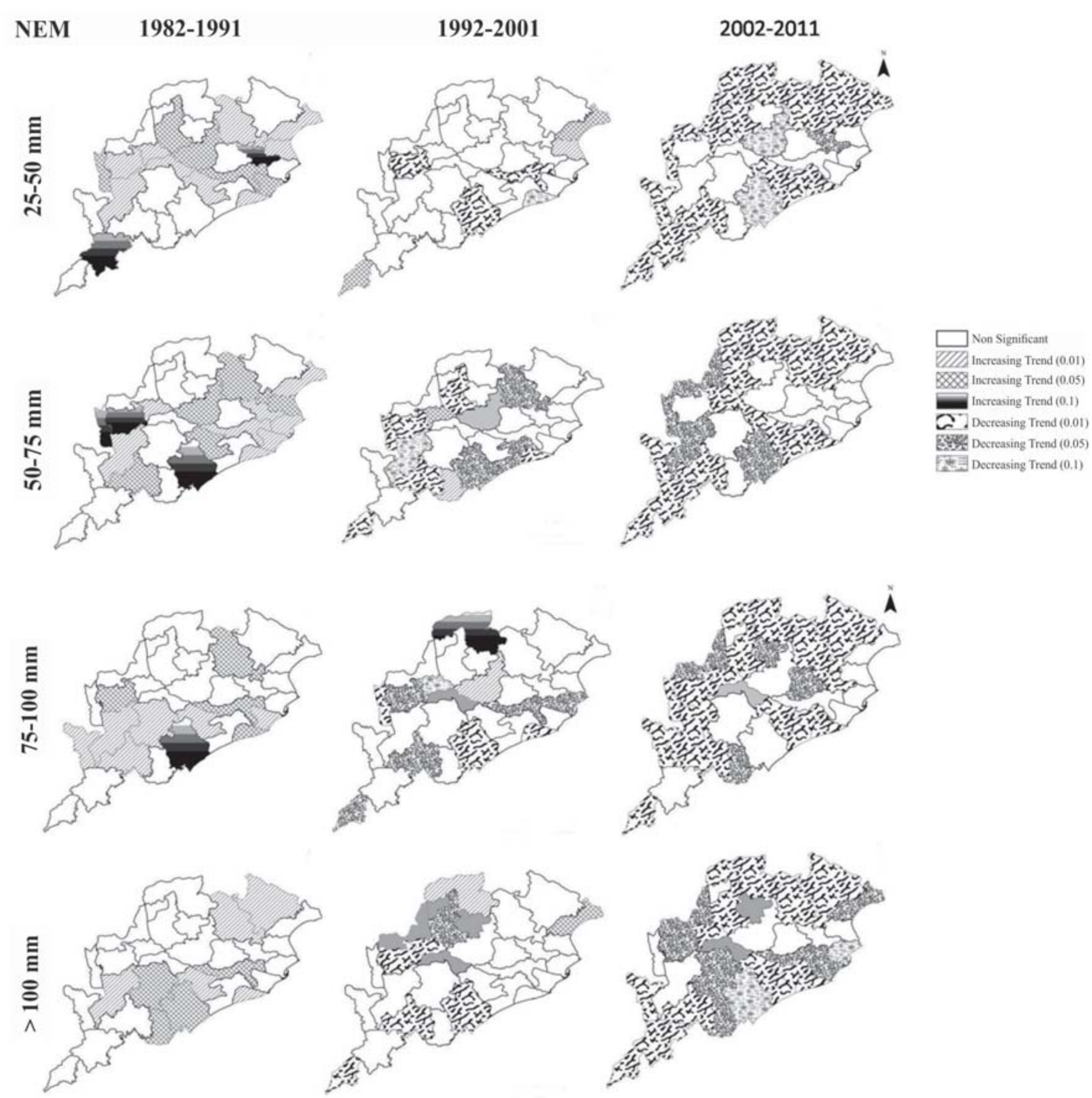


Fig. 5. Decadal trends in northeast monsoon rainfall intensity over Odisha

- The decreasing trend in northeast monsoon rainfall will affect crops especially in rabi season and also the drinking water for farm activities.
- The increasing trend in southwest monsoon rainfall may necessitate to enhance rain water harvest mechanisms so that the excess water can be harnessed and loss due to soil erosion may be reduced.

Singh and Patwardhan (2012) had studied ten weather related extreme events in India during 1967-2006. Their study revealed that total number of climate extremes was significantly increasing in India. They also observed suggested that 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. Our study attempts to have a better spatial (district level) and temporal (30 years data) resolution to meet the same objectives.

Hailstorms

Hailstorm analysis for Odisha was also carried out based on the data available from IMD (1985-2008). In Cuttack and Sambalpur districts of Odisha, 9 events were observed from December to June. Baleshwar, Ganjam, Keonjhar, Puri each observed 6 occurrences in the same period where as Khorda had only 1 occurrence. Out of all months, April recorded the maximum number of hail events, compared to other months (Fig. 6).

Hailstorm intensity analysis showed that maximum of 7 Heavy, 2 Moderate events were observed at Cuttack and least number of occurrences were observed at Bolangir (1) and 2 each in Dhenkanal, Koraput, and Mayurbhanj districts under Heavy category (Table 2). Overall, 37 events were observed under heavy hailstorms and under moderate more number of events (5) were observed at Sambalpur. A total of 15 events were observed under moderate category. This indicates that more number (37) of heavy hailstorms events were observed during 1985-2008.

Trend Analysis of weather parameters

The trend analysis of extreme rainfall and

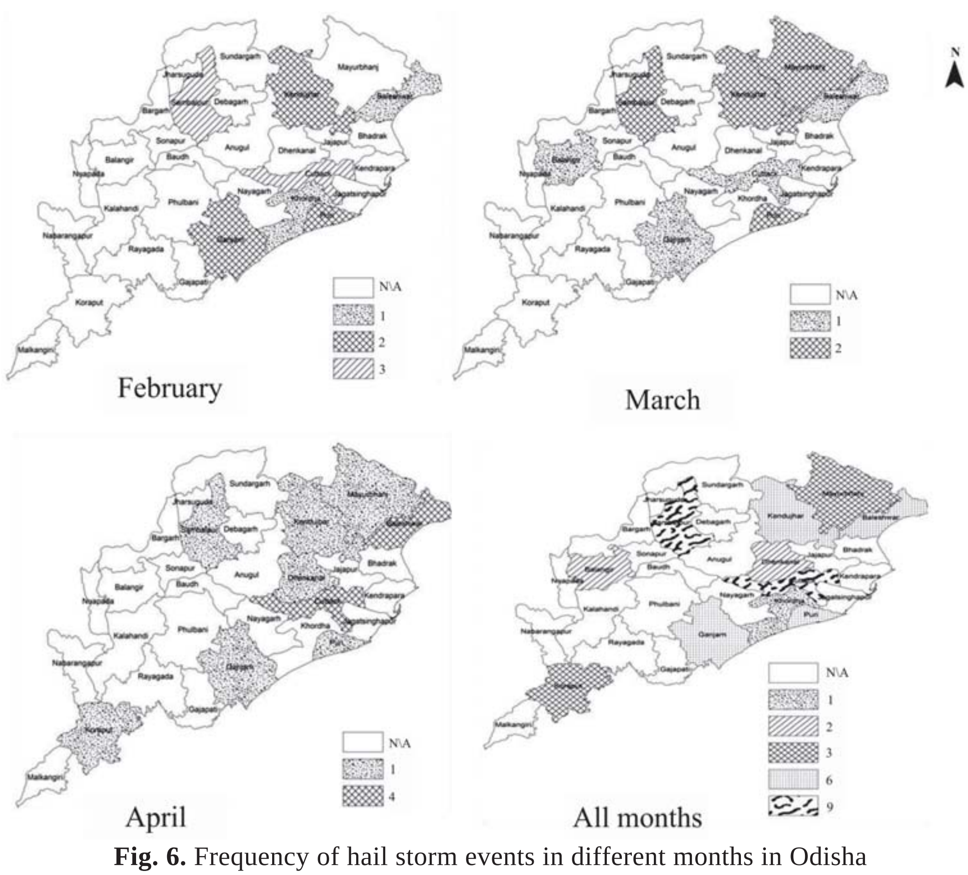


Fig. 6. Frequency of hail storm events in different months in Odisha

Table 2. District wise intensity-wise number of hailstorm occurrences in Odisha

District	Heavy	Moderate	Severe	District	Heavy	Moderate	Severe
Baleshwar	4	2		Khorda			1
Bolangir	1	1		Koraput	2	1	
Cuttack	7	2		Mayurbhanj	2	1	
Dhenkanal	2			Puri	5	1	
Ganjam	5	1		Sambalpur	4	5	
Keonjhar	5	1		Grand Total	37	15	1

Table 3. Significance of different weather parameters in different districts of Odisha

Station	TXn	tnx	tnn	tx90p	tn10p	tn90p	rx1day	r20mm	r25mm
Angul			**Significant at 1% level	**Significant at 1% level					
Balasore				**Significant at 1% level					
Bargarh				*Significant at 5% level					
Bhadrak				**Significant at 1% level	**Significant at 1% level	*Significant at 5% level			
Bolangir	*Significant at 5% level								
Boudh			*Significant at 5% level						
Deogarh				*Significant at 5% level					
Dhenkanal			*Significant at 5% level						
Gajapati		*Significant at 5% level							
Ganjam		*Significant at 5% level							
Kalahandi			**Significant at 1% level					*Significant at 5% level	*Significant at 5% level
Khurdha	* Significant at 5% level								
Nawarangapur			* Significant at 5% level						*Significant at 5% level
Nayagarh	*Significant at 5% level								
Nupara	*Significant at 5% level								
Phubani							*Significant at 5% level	*Significant at 5% level	*Significant at 5% level
Sonepur	*Significant at 5% level	*Significant at 5% level							
Surendragarh							**Significant at 1% level		

temperature events was done using RClimDex software and the results are given in table 3.

From the analysis, it is clear that the monthly maximum 1-day precipitation trend has shown positive trend at Surendragarh (1% level) and Phulbani (5% level) (Table 3). Occurrence of warm-nights have shown positive trend at Angul, Balasore, Bhadrak (1% level), Bargarh and Deogarh (5% level). Monthly minimum value of daily minimum temperature (^{o}C) has shown positive trend at Angul, Kalhandi (At 1% level), Boudh, Dhenkanal and Nawaragapur (at 5% level)

Conclusions

As extreme events' occurrences are becoming frequent due to climatic aberrations, state like Odisha already suffering due to its geographic position has become more vulnerable. The state is agriculture based and therefore is highly prone to these extremes events. The current study looked at the occurrence and trends of heat waves, hail storms and different categories of rainfall events. The results of this study indicates that duration of heat waves in Odisha has increased during 1996-2008 as compared to the previous decade 1985-1995 and May is the crucial month in which maximum number of heat waves were recorded. Hence, measures need to be employed to protect the cattle, poultry and small ruminants from the heat stroke. Ventilated sheds and making drinking water available should be at top priority. Odisha experienced 37 heavy and 15 moderate hail events and April is the critical month for hailstorms. Capabilities for the thunderstorm forecast need to be strengthened so as to alert people to keep the cattle in a safe place during the storm period. For high value horticultural crops, hail nets and fruit bags may be used to save the produce during the hail period. The non parametric Mankendall trend analysis showed that one day maximum rainfall events showed significant increasing trends at Sundergarh at P=0.01 level. This study also indicated that the single-day heavy rainfall events viz. 75-100 mm and > 100 mm are increasing in the northern districts and in southern districts like Koraput and Nabarangpur of Odisha also showed increasing trend of > 100 mm rainfall (p=0.01) during 2002-11. Good drainage facility may be created in these districts to safeguard the crops from sudden flooding. Whereas, Phulbani district showed a decreasing trend (p=0.01) of rainfall under category 50-75 mm in the period 2002-2011.

Reference

Bal, S.K. and Minhas, P.S. 2017. Atmospheric Stressors: Challenges and Coping Strategies. In: P.S. Minhas *et al*. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer Nature Singapore Pvt. Ltd., pp. 9-50.

De, U.S., Dube, R.K. and Rao, G.S.P. 2005. Extreme weather events over India in the last 100 years. *J. Ind. Geophys. Union*. **9**(3): 173-187.

Kothawale, D.R., Munot, A.A. and Krishna Kumar, K. 2010. Surface air temperature variability over India during 1901-2007, and its association with ENSO. *Climate Research* **42**: 89-104.

Guhathakurta, P., Sreejith, O.P. and Menon, P.A. 2011. Impact of climate change on extreme rainfall events and flood risk in India. *J. Earth Syst. Sci.* **120**(3): 359-373.

Goswami, B.N., Venugopal, V., Sengupta, D., Madhusoodanan, M.S. and Xavier, P.K. 2006. Increasing trend of extreme rain events over India in a warming environment; *Science* **314**: 1442-1445.

IPCC. 2014. Climate change 2014-Synthesis report of the United Nations Intergovernmental Panel on Climate Change

Kar, Gouranga, James, B., Singh, R. and Mahapatra, C. 2004. Research Bulletin NATP, RRPS - 3 Agro. climate and Extreme Weather Analysis for Successful Crop Production in Odisha.

Rajeevan, M., Bhate, J. and Jaswal, A.K. 2008. Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data. *Geophys. Res. Lett.* **35** L18707, doi: 10.1029/2008GL035143.

Singh, A. and Patwardhan, A. 2012. Spatio-temporal distribution of extreme weather events in India. *APCBEE Procedia* **1**: 258-262.

Xuebin Zhang and Yang Feng. 2004. The RClimDex 1.1 software developed and maintained at Climate Research Division. The software was used first at the South Africa Workshop in Cape Town, South Africa, in June 2004 and has been used in other ET workshops.

http://climatechangemedia.ning.com/profiles/blogs/odisha-climate-change-action-plan-what-need-to-be-done-and-what.

Received: May 20, 2018; Accepted: June 21, 2018