*Journal of Agrometeorology 22 (2) : 215-219 (June 2020)*

***Short Communication***

# Extreme rainfall trends over Chhattisgarh state of India

**HEMANT KUMAR SINHA, N. MANIKANDAN[1]*, J.L. CHAUDHARY and SAHDEV NAG**

*Department of Agrometeorology, IGKV, Raipur-492 012, Chhattisgarh*

*[1]ICAR - Indian Institute of Water Management, Bhubaneswar-751 023, Odisha*

*[*]Corresponding Author: metsate@gmail.com*

Indian sub-continent is highly vulnerable to heavy rainfall and flash floods as it wreaks havoc the properties, lives, agricultural / horticultural crops and livestock which may lead to crisis in rural economy, livelihood and environment also (Kripalani *et al.,* 2003; De *et al.,* 2005). Many studies suggest that the recent jump in increased high rainfall events is due to global warming. Analysis of observed precipitation data and simulation output from climate models revealed that global warming is augmenting the atmospheric moisture content (Willett *et al.,* 2007) which in turn become the main cause for heavy / extreme precipitation events occurred over the globe (Hennessey *et al.,* 1997; Ghosh *et al.,* 2012; Mishra *et al.,* 2012) and increased risk of floods (IPCC, 2007). Even though the seasonal mean monsoon rainfall over the past century in India shows no significant decreasing trend, Goswami *et al.,* (2006) have shown that the number of extreme rainfall events over India is increasing in recent decades. Rajeevan *et al.,* (2008) studied high resolution daily gridded rainfall over India, and reported significant inter-annual and inter-decadal variations in the frequency of extreme rainfall events. They also opined that increased sea surface temperature and surface latent heat flux over Indian Ocean could be reasons for rise in extreme rainfall events over India. It is very important to note from studies of Goswami *et al.,* (2006) and Rajeevan *et al.,* (2008) that, the occurrence of extreme rainfall events would increase in central India which may lead increased flood hazards over this region in the coming decades.

The challengeable issue in this regard is the episode of heavy rainfall events and its intensities which are highly uneven temporally and spatially. For better management of heavy / extreme rainfall related hazards, in depth study on changes that occur in extreme / heavy rainfall pattern is for more important rather the mean pattern change. A meticulous study on spatial variability of frequency of heavy rainfall could be useful for planners and policy makers. Extreme / heavy rainfall analysis using station level data would give convincing results when compared to gridded rainfall data as the interpolation method involving in gridded data may nullify the extreme rainfall events. Therefore, analysis of station level data located in different districts of Chhattisgarh is imperative and need of hour for developing coping strategy for increased disaster preparedness. Keeping the above points in view, the present study is aimed to find out trend in extreme rainfall events in 26 stations of Chhattisgarh state using RClimDex software.

Daily rainfall data of 26 stations representing 26 districts of the Chhattisgarh state (except Balrampur district for which data is not available) were collected from Indira Gandhi Krishi Viswavidyalaya, Raipur.

Zhang and Yang (2004) developed FORTRAN program source for calculating different indices which were written in R statistical software. RClimDex user manual would give detailed information about input file preparation, installation of R and running the program. The RClimDex software is robust and easy to use as many researchers at national (Lunagaria *et al.,* 2015; Dharmaveer Singh *et al.,* 2016; Manikandan *et al.,* 2018) and international level (Victor M. Rodríguez-Moreno *et al.,* 2015; Hashnat Badsha *et al.,* 2016) used this software for their studies on extreme rainfall events. A total of 27 indices based on daily rainfall and temperature were developed by the joint WMO Commission for Climatology (CCl)/ World Climate Research Programme (WCRP) Climate Variability and Predictability (CLIVAR) project's Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) (Peterson, 2005). In the present study, set of five indices related to rainfall *viz.,* RX1 Day, RX5 day, SDII, CDD and CWD were computed for the selected 26 stations. Descriptions of the five indices are furnished in Table 1. Non parametric Mann-Kendall test (MK test) was opted to find statistical significance of the climatic indices computed using Trend Toolkit software (Chiew *et al.,* 2005). This test has widely been employed for time series analysis of weather data (Mirza *et al.,* 1998; Lazaro *et al.,* 2001; Libiseller and

**Table 1:** Definition of the precipitation indices used in this study

| Sl.No. | Index | Descriptive Name | Definition | Unit |
|---|---|---|---|---|
| 1 | RX1day | Maximum 1 day precipitation | Highest one-day precipitation in a year | mm |
| 2 | RX5day | Maximum 5 day precipitation | Highest 5 consecutive days precipitation in a year | mm |
| 3 | SDII | Simple daily intensity index | Annual precipitation divided by number of wet days (Rainfall ≥ 1 mm) | mm /day |
| 4 | CDD | Consecutive dry days | Maximum number of consecutive dry days (Rainfall<1 mm) | days |
| 5 | CWD | Consecutive wet days | Maximum number of consecutive wet days (Rainfall ≥ 1 mm) | days |

Grimvall, 2002). If the time series values (X1, X2, X3,….., Xn) are replaced by their relative ranks (R1, R2, R3,….., Rn), then according to Salas (1993) test statistic S is:

$$S = \sum_{i-1}^{N-1} \sum_{j=i+1}^{N} sgn(R_j - R_i) \qquad \text{(ii)}$$

where:

$$sgn(X) = \begin{cases} +1\ for(X) > 0 \\ 0\ for(X) = \ \ 0 \\ -1\ for(X) < 0 \end{cases} \qquad \text{(iii)}$$

If the null hypothesis Ho is true, then S is approximately normally distributed with:

$$E[S] = 0$$

$$\text{var}\ (S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k\,(t_k - 1)(2t_k + 5)}{18} \qquad \text{(iv)}$$

The z-statistic is therefore (critical test statistic values for various significance levels can be obtained from normal probability tables):

$$Z = \frac{|S|}{\sigma^{0.5}} \qquad \text{(v)}$$

A positive value of S indicates that there is an increasing trend and vice versa.

***Trend in maximum one-day rainfall (RX1 Day)***

There was no significant increasing or decreasing trend of maximum one-day rainfall in majority of stations (22 out of 26) (Table 2). Study on changes in extreme rainfall events over India using station level data (1901-2005) also opined that there was significant decline in annual one-day extreme rainfall events over Chhattisgarh state (Guhathakurta *et al.,* 2010). However, significant increasing trend was observed in Bemetara, Gariyaband, Narayanpurat 5% level and in Raipur at 1% level (Fig 1). It is explained that the increased frequency of very high rainfall events in central India associated with increasing trend of Indian Ocean Sea Surface Temperature and surface latent heat flux over the tropical Indian Ocean (Rajeevan *et al.,* 2008).

***Trend in maximum cumulative five-day rainfall (RX5 Day)***

A significant increasing trend in maximum 5-days cumulative rainfall has been observed in the stations located in the Chhattisgarh plain agro-climatic zone*viz.,*Bemetara, Gariyaband and Raipur at 1% level (Fig 1). This shows that these three stations are vulnerable to flood risk as number of one-day maximum rainfall are also increasing. The findings of Goswami *et al.,* (2006) and Rajeevan *et al.,* (2008) also confirmed that there would be increased flood risk over central India which covers Chhattisgarh state too. A non-significant decreasing trend was observed in remaining stations of Chhattisgarh during the study period (Table 3).

***Trend in simple daily rainfall intensity (SDII)***

Simple daily rainfall intensity is estimated by dividing the annual rainfall by the number of wet days (Rainfall ≥ 1mm) in each year. Out of 26 stations analyzed, only Gariyaband and Bemetara showed significant increasing trendat 5% level in daily rainfall intensity. On the other hand, 6 stations *viz.*, Baloda-Bazar, Bilaspur, Dhamtari, Kondagaon, Koriyaand Rajnandgaon showed a significant declining trend at 5% level in daily rainfall intensity (Table 2).

***Trend in maximum length of dry spell (CDD)***

Length of dry spell is estimated by counting the period with consecutive number of days < 1 mm is taken into account as dry spell period. No significant increasing or decreasing trend has been noticed in majority of stations under study (18 out of 26). However, a significant increasing trend at 5% level has been evident in Ambikapur, Baloda Bazar, Bemetara, Durg and Gariyaband. On the other hand, a significant declining trend at 95% confidence level was observed in the length of dry spell in, Dantewada, Kondagaon

**Table 2:** Trend in different extreme rainfall indices at 26 stations of Chhattisgarh state

| Sl.No. | Stations | RX1Day | RX5Day | SDII | CDD | CWD |
|---|---|---|---|---|---|---|
| 1 | Ambikapur | Inc | Dec | Dec | Inc (S)* | Dec |
| 2 | Balod | Inc | Inc | Dec | Inc | Inc |
| 3 | Baloda Bazar | Dec | Dec | Dec(S)* | Inc(S)** | Inc |
| 4 | Bemetara | Inc (S)* | Inc (S)** | Inc (S)** | Inc (S)** | Dec |
| 5 | Bijapur | Dec | Dec | Dec | Inc | Inc |
| 6 | Bilaspur | Inc | Inc | Dec(S)** | Dec | Dec |
| 7 | Dantewada | Dec | Dec | Dec | Dec(S)** | Dec |
| 8 | Dhamtari | Inc | Inc | Dec(S)** | Dec | Inc (S)* |
| 9 | Durg | Dec | Inc | Inc | Inc(S)** | Inc |
| 10 | Gariyaband | Inc(S)* | Inc(S)** | Inc(S)* | Inc(S)** | Inc |
| 11 | Jagdalpur | Inc | Dec | Dec | Inc | Inc |
| 12 | JanjgirChampa | Inc | Inc | Dec | Dec | Dec |
| 13 | Jashpurnagar | Inc | Dec | Inc | Inc | Dec(S)** |
| 14 | Kanker | Inc | Inc | Dec | Dec | Inc |
| 15 | Kawardha | Dec | Dec | Dec | Dec | Inc |
| 16 | Kondagaon | Dec | Dec | Dec(S)* | Dec (S)* | Dec |
| 17 | Korba | Inc | Inc | Inc | Dec | Inc |
| 18 | Koriya | Inc | Inc | Dec(S)** | Dec | Inc |
| 19 | Mahasamund | Inc | Inc | Inc | Inc | Inc |
| 20 | Mungeli | Dec | Inc | Dec | Inc | Inc |
| 21 | Narayanpur | Inc (S)* | Inc | Dec | Dec | Dec |
| 22 | Raigarh | Inc | Inc | Dec | Inc | Dec |
| 23 | Raipur | Inc(S)** | Inc(S)** | Inc | Inc | Inc |
| 24 | Rajnandgaon | Inc | Inc | Dec(S)** | Inc | Inc |
| 25 | Sukma | Inc | Inc | Inc | Dec(S)* | Dec |
| 26 | Surajpur | Inc | Dec | Dec | Inc | Dec |

Inc – Increasing; Dec – Decreasing; (S) – Significant trend; *significant at 5% level; **significant at 1% level

and Sukma of Chhattisgarh (Table 2). This indicates that dry spell period may increase in stations located in Northern Hills and Chhattisgarh Plain agro-climatic zones where as reverse trend is true in stations located in Bastar Plateau agro-climatic zone.

***Trend in maximum lengths of wet spell (CWD)***

Length of wet spell is calculated by that duration in consecutive number of days when rainfall quantity is > 1 mm. There is no significant increasing or decreasing trend noted in the length of continuous wet spell in 24 out of 26 stations. The length of wet spells showed a significant increasing trend at 95% confidence level in Dhamtari located in the Chhattisgarh plain zone (Fig. 1). A significant decreasing pattern is observed only in Jashpurnagar at 5% level.

From the above, it is observed that maximum one-day rainfall (RX1 Day) indicated that significant increasing trend was observed in Bemetara, Gariyaband, Raipur and Narayanpur; and significant increasing pattern in maximum 5 day (RX5 day) cumulative rainfall in Bemetara, Gariyaband and Raipur stations. Increase in frequency of maximum one-day and five-days rainfall events could lead to flood related hazard and hence development of strategic measures to avert the losses due to flood hazard is need of hour. The trend in length of dry spell showed an increasing pattern in

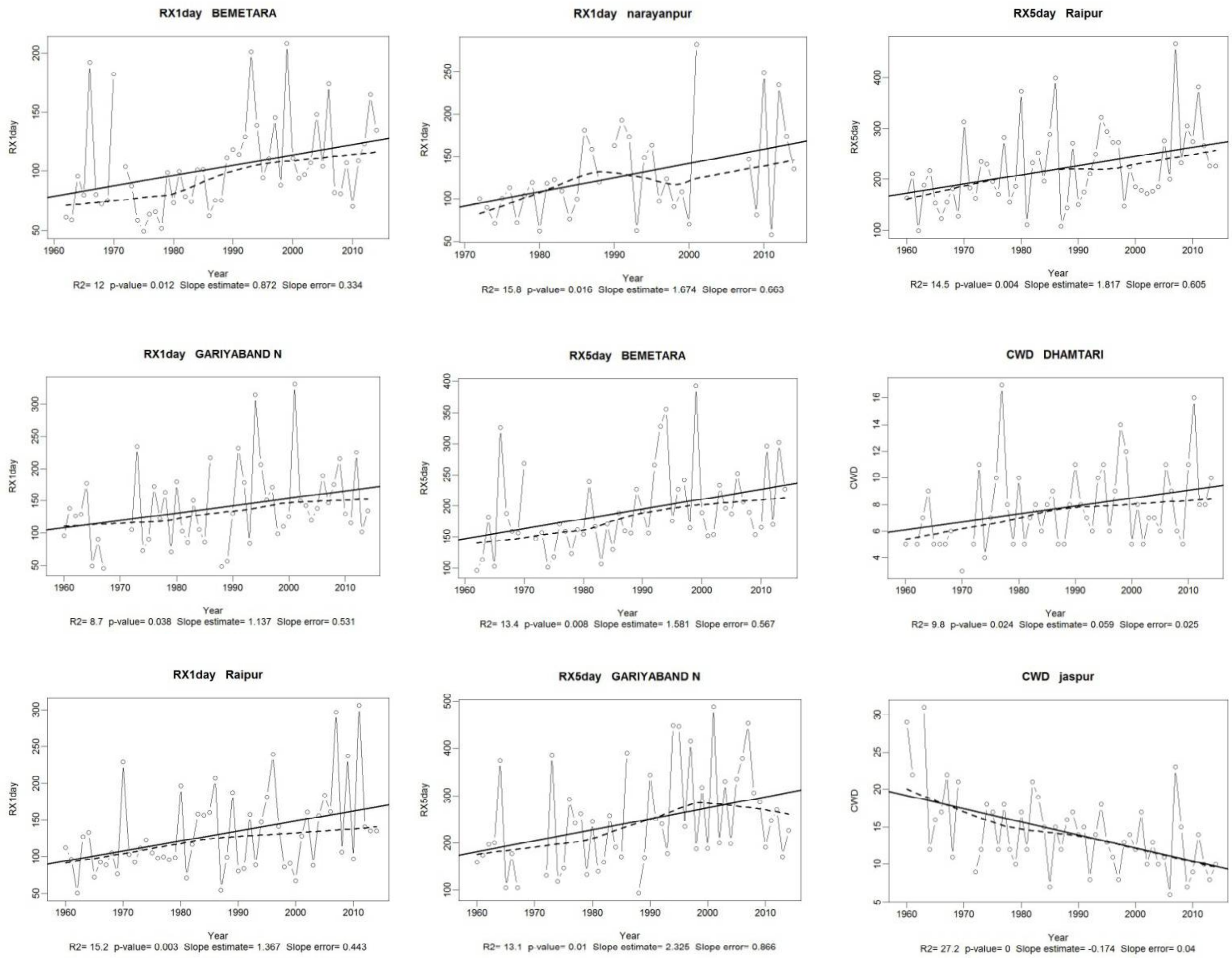


**Fig. 1:** Stations showing significant linear trend line of RX1day, RX5day and CWD indices withstatistical significance

stations located in Northern hills and Chhattisgarh plain agro climatic zones (Ambikapur, Balod, Baloda Bazar, Bemetara, Durg and Gariyaband) whereas decreasing pattern was noticed in stations of Bastar Plateau agroclimatic zone (Dantewada, Kondagaon and Sukma).

## ACKNOWLEDGEMENT

Authors are thankful to Dr. Sanatan Pradhan, Senior Scientist, ICAR-Indian Institute of Water Management, Bhubaneswar for rendering help for improving the quality of article.

## REFERENCES

Chiew, F. and Siriwardena, L. (2005). Trend change detection software and user guide, *CRC for Catchment Hydrology, Australia*. www.toolkit.net.au/trend.

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

Dharmaveer Singh., Jain, S.K., Gupta, R.D., Sudhir Kumar, Rai, S.P. and Neha Jain. (2016). Analyses of observed and anticipated changes in extreme climate events in the northwest Himalaya. *Climate*, 4(9), doi:10.3390/cli4010009

Ghosh, S., Das, D., Kao, S.C. and Ganguly, A.R. (2012). Lack of uniform trends but increasing spatial variability in observed Indian rainfall extremes. *Nat. Clim. Change,* 2: 86–91.

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

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

Hashnat Badsha, M.A., Kafi, M.A.H., Islam, M.Z. and Tanaz Islam. (2016). Analysis of the trends in temperature and precipitation variables for Sylhet city of Bangladesh using RClimdex toolkit. Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD 2016), 12-14 February 2016, KUET, Khulna, Bangladesh

Hennessey, K.J., Gregory, J.M. and Mitchell, J.F.B. (1997). Changes in daily precipitation under enhanced greenhouse conditions. *Clim. Dyn.,* 13: 667-680.

IPCC. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (Ed Solomon *et al.,*) Cambridge Univ. Press, Cambridge, U. K.

Kripalani, R.H., Kulkarni, A., Sabade, S.S. and Khandekar, M. (2003). Indian monsoon variability in a global warming scenario. *Natural Hazards*, 29(2): 189-206

Libiseller, C. and Grimvall, A. (2002). Performance of partial Mann-Kendall test for trend detection in the presence of covariates. *Environmetrics,* 13: 71-84.

Lunagaria, M.M., Dabhi, H.P. and Pandey, V. (2015). Trends in the temperature and rainfall extremes during recent past in Gujarat. *J. Agrometeorol.,* 17(1): 118-123.

Manikandan, N., Das, D.K., Mukherjee, J., Seghal, V.K. and Krishnan, P. (2018). Extreme temperature and rainfall events in National Capital Region of India (New Delhi) in the recent decades and its possible impacts. *Theor. Appl. Climatol.,* https://doi.org/10.1007/s00704-018-2652-9

Mirza, M.Q., Warrick, R.A., Ericksen, N.J. and Kenny, G.J. (1998). Trends and persistence in precipitation in the Ganges, Brahmaputra and Meghna river basins. *Hydrol. Sci. J.,* 43: 845-858.

Mishra, V., Wallace, J.M. and Lettenmaier, D.P. (2012). Relationship between hourly extreme precipitation and local air temperature in the United States. *Geophys. Res. Lett.*, 39: L16403.

Peterson, T.C. (2005). Climate Change Indices. *WMO Bulletin*, 54 (2): 83-86.

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(18), doi:10.1029/2008GL035143

Rodríguez-Moreno, V.M., Ariel Ruíz-Corral, J., Saúl Padilla-Ramírez, J., Peña-Ramos, A. and Kretzschmar, T.G. (2015). Serial Analysis of Ten Precipitation-Based Indices by Land Use in Semiarid Regions. *Adv. Meteorol.,* doi.org/10.1155/2015/797434

Salas, J.D. (1993). Analysis and modeling of hydrologic time series. In: Handbook of Hydrology (Ed. Maidment, D.R.), McGraw-Hill, New York, pp. 19.1–19.72.

Willett, K.M., Gillett, N.P., Jones, P.D. and Thorne, P.W. (2007). Attribution of observed surface humidity changes to human influence. *Nature,* 449: 710–712.

Zhang, X. and Yang, F. (2004). RClimDex (1.0) user manual, Climate Research Branch, Environment Canada, Ontario, Canada, 23p.

*Received : July 2019; Accepted: April 2020*