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Studies on Heat Wave Extreme Events in Different Districts of Chhattisgarh

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Abstract

IMD's definition of heat wave in India is declared when either there is an excess of 5°C over a normal daily historical maximum temperature (30-year average) of less than 40° C; or an excess of 4°C over a normal historical maximum temperature of more than 40°C. If the actual maximum temperature is above 45°C, heat wave is declared irrespective of the normal historical maximum temperature. According to IPCC, the global mean surface temperatures are projected to likely experience an increase of 0.3oC (minimum of RCP 2.6) to 4.8°C (maximum of RCP 8.5) for 2081-2100 as compared to 1986-2005. For temperature extremes, it is very likely projected that heat waves will occur with greater frequency and greater duration with occasional cold winter extremes. It is routine feature in districts of Chhattisgarh plains zone and there is general crop damage as per severity. Horticultural crops and vegetable crops are more seriously damaged. Poultry and livestock get affected due to shortage of drinking water. Sometimes there is moderate effect on crops but poultry and livestock get affected extensively. To mitigate this stress, adaptation strategies like selecting heat tolerant varieties in vegetables and fruit crops, sprinkler irrigation or indigenous shade structures, mulching are being recommended.

Key words : Heatwave, temperature, spell, extreme, events, components.

Extreme weather events, particularly floods and heat waves, annually affect millions of people and cause billions of dollars of damage. In 2003, in Europe, Canada and the United States, floods and storms caused 15 deaths and US $2.97 billion in total damages. The extended heat wave in Europe caused more than 20,000 excess deaths. The impacts in developing countries were substantially larger. There is a growing body of scientific research suggesting that the frequency and intensity of extreme weather events are likely to increase over the coming decades as a consequence of global climate change. These events cannot be prevented but their consequences can be reduced by taking advantage of advances in meteorological forecasting in the development and implementation of early warning systems that target vulnerable regions and populations. At the global level, extreme temperature is emerging as major concern for society and is a significant contributor to climate-related deaths and increasing number of humans are dying from heatwaves (Basu, 2009). Indirectly or directly, morbidity and mortality are significantly influenced by heatwave (Kovats et al, 2008).

Aberrations in water cycle projected by IPCC (2013) highlight the fact that monsoon retreat would be delayed there by lengthening the monsoon season regionally along with more intense and more frequent extreme events by the end of century (Mall et al. 2016). One of the worst incidents on record worldwide was the heat wave of 1998. Heat waves cover the major states of India practically yearly, usually during the pre-monsoon season (March, April and May). They cause significant mortality rates and have a negative impact on many people's livelihoods due to health risks and agricultural problems. In most parts of the Indian subcontinent, an increase in extreme temperatures is observed in terms of decreases in cold extremes and increases in warm extremes. Previous studies show that North India suffers from the nighttime heat wave, while South Indian temperature indices are mainly due to daytime temperatures (Maniar and Pattnaik, 2019).

The WMO statements on global climate during recent two years (WMO, 2011 and 2012) indicate that the global temperatures are continuing to increase. The year 2010 was warmest year along with 2005 since 1880. The available observations till date showed that the year 2011 was the world's 10th warmest year and warmest year with La Nina on record. The 2010 Northern Hemisphere summer was marked by exceptional HWs that impacted most of the United States, Kazakhistan, Mongolia, China, Hong Kong, North Africa and the European continent as a whole, along with parts of South Asia, Canada, Russia, Indo china, South Korea and Japan. During July, 2011 number of deaths related to severe HW events were reported from various parts of USA with Oklahoma and Texas reporting their warmest months ever on record.

The 6^{th} Assessment Report of IPCC reaffirmed that climate change can affect agriculture with wide consequences (IPCC, 2021). Increase in atmospheric temperature can have direct impacts in reducing crop duration, photosynthesis and ultimately crop yield. It can affect the survival and distributions of pest populations, increase soil nutrient mineralization, decrease nutrient use efficiency and increase water loss resulting in increasing demand of irrigation water and plant nutrients. Climate change has significant indirect effects on agriculture with its effects on irrigation water availability, droughts and floods, soil fertility and erosion (Masson- Delmotte et al. 2021). Global warming, erosion of ozone layer in stratosphere and impact of greenhouse gases are the major consequences of climate change. According to another study in the 20th century, the global average surface temperature rise by 0.6°C has taken place and would rise in the range of 1.4°C to 5.8°C by 2100. Average surface temperatures have increased across the regions in the range of 0.3°C-0.8 °C over the past 100 years (IPCC, 2007).

A prolonged period of extremely high temperature during summer season is known as a heat wave. World Meteorological Organization (WMO) defines a heat wave as at least five consecutive days during which the daily TMAX exceeds the average TMAX of a location by 5 °C. According to the revised terminologies of weather forecasting provided in 2015 by the Indian Meteorological Department (IMD), a heat wave is a condition when the departure of TMAX from normal is +4 to 5°C for the regions where the climatological value of TMAX is >40 °C and the departure of the TMAX from normal is +5 to 6 °C for regions with climatological TMAX is 40 °C. Heat wave is declared only when the air temperature of at least 40 °C is observed in the plains or 30 °C in the hilly areas (IMD 2015, Pai et al, 2013; NDMA, 2015). According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), heat waves and humid heat stress will be more intense and frequent during the 21st century. In terms of monsoon, both annual and summer monsoon precipitation will increase during the 21^{st} century, with enhanced interannual variability (IPCC, 2021).

In terms of the actual maximum temperature, a station is under a heatwave when the actual maximum Temperature 45°C and severe heatwave when the maximum temperature is > 47°C. There has been increasing interest among the general public, media and local administration in predicting extremes such as the heatwave and cold wave events in India due to the associated loss of life. An increasing number of extreme temperature events have been observed in recent past over India (Singh et al 2017). Global warming, erosion of ozone layer in stratosphere and impact of green house gases are the major consequences of climate change. The mean temperature change is predicted to be in the range of 2.33°C to 4.78°C with a doubling in carbon-di-oxide (CO2) concentrations (Watson et al. 1998). Climate change projections made for India indicates an overall increase in precipitation by 9-16% and temperature by 1-4 °C in the year 2050s (Krishna et al. 2011). Considering the future growth and development of India, the IPCC has projected a temperature rise from 0.5 °C to 1.2 °C by 2020, from 0.88 °C to 3.16°C by 2050 and from 1.56 to 5.44 °C by 2080 for the Indian region.

A study conducted by the National Commission for Rural Labour (1996) stated that the number of decadal interstate migration is about 11 million, as compared to the statewise migration for economic reasons was very high for Bihar (48.7%) followed by Odisha (41.6%). In the Odisha state, this large-scale migration has mainly contributed by the population in western Odisha, especially the districts of Kalahandi, Koraput and Balangir to neighboring Chhattisgarh. The non-proft organizations like Action Aid estimated that nearly 200,000 people migrated from Western Odisha to work in brick kilns of Andhra Pradesh during the year 2010 (Thompson et al, 2005). Further, the Migration Information and Resource Centre (MIRC) shows 150,000 people migrated from Bolangir district in 2009-2010.

Materials and Method

Description of the study area : Chhattisgarh state, situated in eastern India, is located between the latitudes of 17° 46' N -24° 5' N and longitudes of 80° 15' E- 84° 20' E. It is surrounded in the west by Madhya Pradesh and Maharashtra, in the north by Madhya Pradesh, in the east by Orissa and Jharkhand and in the south by Telangana.The state has 27 districts spreading over a geographical area of137.90 lakh hectares The geographical factors like distance from the sea and altitude of the state have influenced the Chhattisgarh climate. The climatic condition during summer is hot and gusts dry wind blows over the state. During winter the temperature falls to some extent. During the summer season in Chhattisgarh, the temperature varies from 40 degree to 42.5 degree Celsius. From the month of March, the temperature starts to rise in Chhattisgarh. The summer season prevails from April to middle of June. In summer very dry wind blows over most parts of the state. This influences the Chhattisgarh climate.

Data base used

1. Long term (1991-2020) Gridded (unweighted) data of maximum temperature for 27 districts was collected from the website of IMD, New Delhi.
2. NASA power maximum temperature data (1991-2021) will be downloaded from the website of NASA power.
3. Future climatic scenario of 2030, 2050 and 2070 from different global climatic scenario (GCMs) at 4.5 RCP will be calculated from Marksim site.

Quality checking of data : After the collection of data, its quality was checked using MS Excel which was a pre-requisite step before analysis of result.

Table- Criteria of Heat Wave

Heat Wave	Heat Wave 4.5°C to 6.5°C (Departure from normal)	Based on Departure from normal temperature
	Heat Wave >45°C (When actual maximum temperature)	Based on Actual Maximum temperature

O` Resources software : Dry and wet spell analysis were worked out using O' Resources software developed by Central Research Institute for Dryland Agriculture, Hyderabad (Rao et al., 2011). Estimation of extreme rainfall events was done using "Spell Estimator", a FORTRAN based software and OS which was used to analyze the extreme events.

Mann-Kendall test for trend analysis : The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series (Hipel and McLeod, 2005). The test compares the relative magnitudes of sample data rather than the data values. One benefit of this test is that the data need not confirm to any particular distribution.

Results and Discussion

Analysis of heat wave event based on temperature in different districts of Chhattisgarh : Heat wave events were analyzed and categorized in Table 1 where 6 categories i.e.,> critical value, positive anomaly spells and days, highest value and average value are discussed.

Components > Critical value : The results of the heat wave are compiled in Table 1. The longest spells > critical value were found to have a non-significant or no trend. Total spells > critical value were found to have a non-significant trend in all districts of CG. Total days > critical value component was also found to have non-significant trend.

Highest value : The highest values component was found to have non-significant decreasing trend in 15 districts, viz., Balod, Bemetara, Bilaspur, Dhamtari, Durg, Gariyaband, Jashpur, Kanker, Korba, Koriya, Mahasamund, Mungeli, Raigarh, Raipur and Surguja. While 11 districts are non-significantly increasing, i.e., Balrampur, Bastar, Bijapur, Dantewada, Janjgir-champa, Kabirdham, Kondagaon, Narayanpur, Rajnandgaon, Sukma and Surajpur. There was found only one district is significant increasing trend, viz., Balodabazar. (Table 1).

Positive anomaly spells and days : The longest positive anomaly spell component showed that all districts having non- significant trend. Total positive anomaly spell component was found to be having non- significant decreasing trend in 6 districts,. Non-significant increasing trend was found in 20 districts while one district, i.e., Janjgir-Champa, reported an increasing significant trend. (Table 1). Total positive anomaly days component was found to be having non- significant results. There was decreasing trend in 6 districts.

Average value : Average value component was analyzed. Only one district was found to have non-significant decreasing trend, i.e., Mungeli. While 26 districts are found to have a non-significant increasing. (Table 1)

Comparison of trend of two datasets : IMD data and NASA power data in different districts of Chhattisgarh : Comparison of two data sets i.e., IMD data and NASA power data are compared and shown in Table- 2, Table-3 and Table-4. There are 6 categories: components >critical value, positive Anomaly Spell and days, Highest value and Average value.

Components > critical value : The longest spells > critical value component was analyzed. A comparison was made for two datasets of NASA power and IMD data (Table 2). There is no district according to IMD data and 13 districts according to NASA power data (*viz*., Balrampur, Bemetara, Bilaspur, Durg, Gariyaband, Janjgir-champa, Kabirdham, Korba, Mahasamund, Mungeli, Raigarh, Raipur and Rajnandgaon) which observed a significant

Table 1. Analysis of heat wave events based on temperature in different districts of Chhattisgarh

Districts	Longest spells > C.V.	Total spells > C.V.	Total days > C.V.	Highest value	Longest =+ve Anom-aly spells	Total =+ve Anom-aly spells	Total =+ve Anom-aly days	Av. value
1. Balod	NS Dec	NS Incr	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
2. Balodabazar	NS Incr	NS Incr	NS Incr	S** Incr	NS Incr	NS Incr	NS Incr	NS Incr
3. Balrampur	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
4. Bastar	No trend	No trend	No trend	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
5. Bemetara	NS Incr	NS Incr	NS Incr	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr
6. Bijapur	No trend	No trend	No trend	NS Incr	NS Dec	Dec NS	NS Dec	NS Incr
7. Bilaspur	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr	NS Dec	NS Incr	NS Incr
8. Dantewada	No trend	No trend	No trend	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
9. Dhamtari	NS Incr	NS Incr	NS Incr	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
10. Durg	NS Incr	NS Incr	NS Incr	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr
11. Gariyaband	No trend	No trend	No trend	NS Dec	NS Dec	NS Incr	NS Dec	NS Incr
12. Jangir champa	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	S* Incr	NS Incr	NS Incr
13. Jashpur	No trend	No trend	No trend	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
14. Kanker	NS Incr	NS Incr	NS Incr	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
15. Kabirdham	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
16. Kondagaon	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
17. Korba	No trend	No trend	No trend	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
18. Koriya	NS Incr	NS Incr	NS Incr	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
19. Mahasamund	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
20. Mungeli	NS Incr	NS Incr	NS Incr	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
21. Narayanpur	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
22. Raigarh	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
23. Raipur	NS Incr	NS Incr	NS Incr	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr
24. Rajnandgaon	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
25. Sukma	No trend	No trend	No trend	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr
26. Surguja	NS Dec	NS Dec	NS Dec	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr
27. Surajpur	NS Incr	NS Dec	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr	NS Incr

S*** 1% level of significant , S** 5% level of significant and S* 10 % level of significance

decreasing trend. Total spells > critical value although similar pattern was observed among two datasets as mostly value were non-significant.

Total days > critical value component was analysed as for comparison of the NASA power data and the IMD dataset. There is no district of IMD data and 11 districts of NASA power data (viz., Balrampur, Bemetara, Bilaspur, Durg, Gariyaband, Janjgir- champa, Kabirdham, Korba, Mahasamund, Mungeli and Rajnandgaon) which showed a significant decreasing trend. (Table 2)

Positive anomaly spells : Positive anomaly spells and days have been analyzed. Longest positive anomaly spells component was analyzed and observed that there was no significant trend observed in both the datasets. (Table 3). Total positive anomaly spells component was analyzed for two datasets. IMD data for one district (i.e., Janjgir-Champa) and no district under NASA power data reported a

Table 2. Comparison of trend of two datasets IMD and NASA power data/ for > critical value

Districts	Longest spells > Critical value		Total spells > Critical value		Total days > Critical value	
	IMD data	NASA power data	IMD data	NASA power data	IMD data	NASA power data
1. Balod	NS Dec	NS Dec	NS Incr	NS Dec	NS Dec	NS Dec
2. Balodabazar	NS Incr	No trend	NS Incr	No trend	NS Incr	No trend
3. Balrampur	NS Dec	S** Dec	NS Dec	NS Dec	NS Dec	S* Dec
4. Bastar	No trend	NS Dec	NT	NS Dec	No trend	NS Dec
5. Bemetara	NS Incr	S**Dec	NS Incr	NS Dec	NS Incr	S** Dec
6. Bijapur	No trend	NS Dec	NT	NS Dec	No trend	NS Dec
7. Bilaspur	NS Dec	S*** Dec	NS Dec	NS Dec	NS Dec	S** Dec
8. Dantewada	No trend	NS Dec	NT	NS Dec	No trend	NS Dec
9. Dhamtari	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
10. Durg	NS Incr	S* Dec	NS Incr	NS Dec	NS Incr	S** Dec
11. Gariyaband	No trend	S* Dec	NT	NS Dec	No trend	S* Dec
12. Jangir champa	NS Incr	S* Dec	NS Incr	NS Dec	NS Incr	S* Dec
13. Jashpur	No trend	No trend	NT	No trend	No trend	No trend
14. Kanker	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
15. Kabirdham	NS Incr	S* Dec	NS Incr	NS Dec	NS Incr	S* Dec
16. Kondagaon	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
17. Korba	NT	S**Dec	NT	NS Dec	No trend	S** Dec
18. Koriya	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
19. Mahasamund	NS Dec	S** Dec	NS Dec	NS Dec	NS Dec	S** Dec
20. Mungeli	NS Incr	S*** Dec	NS Incr	NS Dec	NS Incr	S** Dec
21. Narayanpur	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
22. Raigarh	NS Dec	S** Dec	NS Dec	NS Dec	NS Dec	NS Dec
23. Raipur	NS Incr	S* Dec	NS Incr	NS Dec	NS Incr	NS Dec
24. Rajnandgaon	NS Incr	S* Dec	NS Incr	NS Dec	NS Incr	S** Dec
25. Sukma	No trend	NS Dec	NT	NS Dec	No trend	NS Dec
26. Surguja	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
27. Surajpur	NS Incr	NS Dec	NS Dec	NS Dec	NS Incr	NS Dec

NT = No Trend S*** 1% level of significant , S** 5% level of significant and S* 10 % level of significance

significant increasing trend. No districts of IMD data and 2 districts for NASA power data (i.e., Koriya and Narayanpur) showed a significant decreasing trend.

Total positive anomaly days component was analyzed and all non-significant results were found in both the datasets. IMD datasets mostly showed non-significant increasing trend which NASA power data mostly showed non-significant decreasing trend. (Table 3)

Highest and Average value : After analysis of two datasets IMD data observed that highest value were found in one district of IMD data (viz., Balodabazar) and one district under NASA power (i.e., Rajnandgaon) showed significant increasing trend. No district under IMD data and 12 districts under NASA power (i.e., Balodabazar, Bemetara, Dantewada, Durg, Jashpur, Kabirdham, Kondagaon, Korba, Mungeli, Sukma, Surguja and Surajpur) observed significant decreasing trend. (Table-4)

Table 3. Comparison of trend of two datasets IMD and NASA power data for positive Anomaly spells and days

Districts	Longest positive Anomaly spells		Total positive Anomaly spells		Total positive Anomaly days	
	IMD data	**NASA power data**	**IMD data**	**NASA power data**	**IMD data**	**NASA power data**
1. Balod	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
2. Balodabazar	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
3. Balrampur	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
4. Bastar	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
5. Bemetara	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
6. Bijapur	NS Dec	NS Dec	Dec NS	NS Dec	NS Dec	NS Dec
7. Bilaspur	NS Incr	NS Dec	NS Dec	NS Dec	NS Incr	NS Dec
8. Dantewada	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
9. Dhamtari	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
10. Durg	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
11. Gariyaband	NS Dec	NS Dec	NS Incr	NS Dec	NS Dec	NS Dec
12. Jangir champa	NS Incr	NS Dec	S* Incr	NS Dec	NS Incr	NS Dec
13. Jashpur	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
14. Kanker	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
15. Kabirdham	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
16. Kondagaon	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
17. Korba	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
18. Koriya	NS Incr	NS Dec	NS Incr	S* Dec	NS Incr	NS Dec
19. Mahasamund	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
20 .Mungeli	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
21. Narayanpur	NS Incr	NS Dec	NS Incr	S* Dec	NS Incr	NS Dec
22. Raigarh	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
23. Raipur	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec	NS Dec
24. Rajnandgaon	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
25. Sukma	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
26. Surguja	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec
27. Surajpur	NS Incr	NS Dec	NS Incr	NS Dec	NS Incr	NS Dec

S*** 1% level of significance , S** 5% level of significance and S* 10 %level of significance.

Average value component was analyzed for two datasets and shown in Table 4. There was no district under IMD data and 19 districts of NASA power data (i.e., Balod, Bastar, Bijapur, Bilaspur, Dantewada, Dhamtari, Durg, Gariyaband, Janjgir- champa, Kanker, Kabirdham, Kondagaon, Korba, Mahasamund, Mungeli, Narayanpur, Raigarh, Rajnandgaon, Sukma) observed significant decreasing trend. No district under IMD data and one district under NASA power (i.e., Bemetara) showed significant increasing trend.

Conclusion

Analysis of heat wave events for different districts in CG state has been made. The longest spells > critical value were found to have a non-significant or no trend. Total spells > critical value were found to have a non-significant trend in all districts of CG. Total days > critical value component was also found to have non-significant trend. Comparison of two datasets trend showed that the NASA power data are more variable and significant trend has been

Table 4. Comparison of trend of two datasets IMD and NASA power data for Highest and average value

Districts	Highest value		Average value	
	IMD data	NASA power data	IMD data	NASA power data
1. Balod	NS Dec	NS Dec	NS Incr	S* Dec
2. Balodabazar	S** Incr	S* Dec	NS Incr	NS Dec
3. Balrampur	NS Incr	NS Dec	NS Incr	NS Dec
4. Bastar	NS Incr	NS Dec	NS Incr	S** Dec
5. Bemetara	NS Dec	S* Dec	NS Incr	S* Incr
6. Bijapur	NS Incr	NS Dec	NS Incr	S** Dec
7. Bilaspur	NS Dec	No trend	NS Incr	S* Dec
8. Dantewada	NS Incr	S* Dec	NS Incr	S** Dec
9. Dhamtari	NS Dec	NS Dec	NS Incr	S* Dec
10. Durg	NS Dec	S* Dec	NS Incr	S* Dec
11. Gariyaband	NS Dec	NS Dec	NS Incr	S* Dec
12. Jangir-champa	NS Incr	NS Dec	NS Incr	S** Dec
13. Jashpur	NS Dec	S** Dec	NS Incr	NS Dec
14. Kanker	NS Dec	NS Dec	NS Incr	S* Dec
15. Kabirdham	NS Incr	S* Dec	NS Incr	S* Dec
16. Kondagaon	NS Incr	S* Dec	NS Incr	S* Dec
17. Korba	NS Dec	S* Dec	NS Incr	S* Dec
18. Koriya	NS Dec	NS Dec	NS Incr	NS Dec
19. Mahasamund	NS Dec	NS Dec	NS Incr	S* Dec
20 .Mungeli	NS Dec	S* Dec	NS Dec	S* Dec
21. Narayanpur	NS Incr	NS Dec	NS Incr	S** Dec
22. Raigarh	NS Dec	NS Dec	NS Incr	S* Dec
23. Raipur	NS Dec	NS Dec	NS Incr	NS Dec
24. Rajnandgaon	NS Incr	S* Incr	NS Incr	S* Dec
25. Sukma	NS Incr	S** Dec	NS Incr	S** Dec
26. Surguja	NS Dec	S* Dec	NS Incr	NS Dec
27. Surajpur	NS Incr	S* Dec	NS Incr	NS Dec

S*** 1% level of significant , S** 5% level of significant and S* 10 %level of significant

observed in certain districts compared to the IMD data. Bilaspur and Mungeli reported highly significant decreasing trend for longest spells > critical value as per IMD dataset. There was found only one district is significant increasing trend for highest value, *viz*., Balodabazar. The longest positive anomaly spell component showed that all districts having non- significant trend. Total positive anomaly spell component was found to be having one district, i.e., Janjgir-Champa, reported an increasing significant trend. Total positive anomaly spells component was analyzed for two datasets. IMD data for one district (i.e., Janjgir-Champa) and no district under NASA power data reported a significant increasing trend. No districts of IMD data and 2 districts for NASA power data (i.e., Koriya and Narayanpur) showed a significant decreasing trend. After analysis of two datasets IMD data observed that highest value were found in one district of IMD data (*viz*., Balodabazar) and one district under NASA power (i.e., Rajnandgaon) showed significant increasing trend. No district under IMD data and 12 districts under NASA power observed significant decreasing trend. Average value component was analyzed for two datasets. There was no district under IMD data and 19 districts of NASA power data which observed significant decreasing trend. No district under IMD data and one district under NASA power (i.e., Bemetara) showed significant increasing trend.

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