Extreme rainfall events over Odisha state, India

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ABSTRACT. Extreme rainfall events are a significant cause of loss of life and livelihoods in Odisha. Objectives of the present study are to determine the trend of the extreme rainfall events during 1991-2014 and to compare the events between two periods before and after 1991. Block level daily rainfall data were used in identifying the extreme rainfall events, while district level aggregation was used in analysing the trend in three categories, viz., heavy, very heavy and extremely heavy rainfall as per criteria given by India Meteorological Department (IMD). The state as a whole received one extremely heavy, nine very heavy, and forty heavy rainfall events in a year. When percentage of occurrence of each category out of the total extreme events over different districts was considered, maximum % of extremely heavy rainfall occurred in Kalahandi (5.8%), very heavy rainfall in Bolangir (23.8%) and heavy rainfall in Keonjharhgarh (85.4%). Trend analysis showed that number of extreme rainfall events increased in a few districts, namely, Bolangir, Nuapada, Keonjharhgarh, Koraput, Malkangiri, and Nawarangapur and did not change in other districts. In Puri district, extremely heavy rainfall frequency decreased. New all-time record high oneday rainfall events were observed in twenty districts during 1992 to 2014, surpassing the earlier records, which could be attributed to climate change induced by global warming. Interior south Odisha was found as the hot spot for extreme rainfalls.

Key words – Extreme rainfall events, Block level, Odisha, Trend analysis, Climate change, All-time record high.

1. Introduction

Odisha state is frequently impacted by the weather hazards and extreme rainfall is one of them. Most of the extreme rainfalls are generally associated with the cyclonic circulation forming over the land or over the Bay of Bengal. Climate model simulations (Hennessey et al., 1997), reports of Intergovernmental Panel on Climate Change (IPCC, 2007) and empirical evidences confirm that warmer climates, owing to increased water vapor, lead to more intense precipitation events and therefore, increases risks of floods. As most of the people of Odisha depends upon agriculture, such changes on rainfall events is more important than the changes in mean pattern of rainfall for agriculture [Guhathakurta et al. (2010)]. Moreover, such changes in rainfall events warrant to
review and reorient the disaster management and mitigation practices. Secondly, northern parts of the state are greatly affected by flood as a result of extreme rainfall. General perception in the state is that extreme rainfall events are increasing with respect to intensity and frequency and such changes in rainfall would pose a great risk on crop production and productivity. Earlier, Rakhecha and Pisharoty (1996) studied the heavy rainfall events during the southwest monsoon season for some selected stations over the country. Stephenson et al. (1999), using the data for the period June to September 1986 to 89, have investigated extreme daily rainfall events and their impact on ensemble forecasts of the Indian Monsoon. Rajeevan et al. (2008) analysed the variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data. Sen Roy and Balling (2004) studied the trends in extreme daily precipitation indices. Most of the studies on extreme rainfall were on macro-scale and all India basis. However, not much studies have been made on a micro-scale (block level) for the states in general and Odisha in particular. Hence, the present studies were carried out to determine the trend of the extreme rainfall events during 1991-2014 and to compare the intensity of events between two periods, before and after 1991.

2. Materials and method

The state of Odisha is located between 17.49′ and 22.34′ N latitudes and 81.27′ and 87.29′ E longitudes. The coastal state has 30 districts, which are further divided into 314 revenue Blocks. Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Government of Odisha for the period from 1991 to 2014 and processed by using Statistical Analysis Software (SAS, 2014). The extreme rainfall events were categorized into three categories as per criteria of India Meteorological Department (website : IMD Monsoon Report 2014). These were (a) Heavy Rainfall (64.5-124.4 mm one-day rainfall), (b) Very Heavy Rainfall (124.5-244.5 mm one-day rainfall) and (c) Extremely Heavy Rainfall (≥244.5 mm one-day rainfall). Year wise total number of events under each category was calculated block wise and their aggregation using algebraic sum was done to get district wise events for all the 30 districts of Odisha (Pasupalak, 2015). Percent events under each category out of total of all the three categories in a year were calculated district wise. The time series data on number of category wise events were subjected to Mann-Kendall test (Kendall, 1970) for trend analysis. The trend analysis software, Weather Crock (Rao et al., 2015), based upon the algorithm used in RC LimDex V.1 (Zhang and Feng, 2004), was used to detect the trends of the occurrence of events. Significance tests were made at 90, 95 and 99% confidence interval.

Besides the trend analysis, extreme rainfall events were compared between the two periods, before 1991 and during 1991-2014. The first period included all-time record high one-day rainfall reported by India Meteorological Department (IMD, 2002,) while the second was based on the SRC data used for trend analysis as above. For the first period only one all-time high rainfall for a district reported by IMD (2002) was considered, while for the second period, three highest rainfall events in a district were identified.

3. Results

3.1. Extreme rainfall occurrence

The state of Odisha as a whole received one extremely heavy, nine very heavy and forty heavy rainfall events in years during 1991 to 2014. The average frequency of extremely heavy rainfall at district level was highest in Kalahandi, 4.8 events per year. In 12 districts the frequency was one or more than one per year. As regards to very heavy rainfall, highest occurrence was in Mayurbhanj (19.3/year), followed by Kalahandi (18.4/year) and Puri (16.1/year). All the districts received very heavy rainfall, minimum being in Deogarh (1.5/year). The Mayurbhanj district received maximum heavy rainfall events (95.5/year), followed by Ganjam (65.4/year) during the period. Most of the districts
receiving more frequent heavy rainfall were the coastal districts. When percent share of each of these three events was analysed, it was 1.9, 18.0 and 80.1% respectively for the state. Among the districts, Kalahandi, received maximum percent of extremely heavy rainfall events (5.78%), followed by Sambalpur (3.09%). Most of the western Odisha districts, namely, Bargarh, Bolanlingir, Sonepur and Sambalpur got more than 2% extremely heavy rainfall events (Fig. 1). In the districts of north coastal and central Odisha, namely, Mayurbhanj, Balasore, Bhadrak, Keonjhargarh, Angul and Dhenkanal, it was only 1 to 2%. In case of the second category, very heavy rainfall events, most of the districts of Odisha received 15 to 20% of total extremes in a year. Puri is the only coastal district, which got maximum percentage (24.05%) of very heavy rainfall events. Other districts, which got more than 20% occurrence of very heavy rainfall events were Boudh, Kandhamal, Kalahandi, Bargarh, Bolangir and Sambalpur and all are locsted interior. As regards to the occurrence of the third category, heavy rainfall events, it was high in case of north and north-western districts of Odisha, namely, Keonjhargarh, Sundargarh, Deogarh and Dhenkanal. Among them the district of Keonjhargarh received it most frequently (85.39%), while the Kalahandi district received the lowest (72.11%). Other than the above districts had the range within 75 to 80% frequency of Heavy Rainfall events.

3.2. Extreme rainfall trend

Number of extreme rainfall events showed an increasing trend in few districts, but remained unchanged in all other districts except Puri. During the period between 1991 and 2014, the Extremely Heavy Rainfall event increased significantly (95% significance) in Nawarangapur district, while it decreased in Puri district (Fig. 1). Such a decreasing trend in Puri was significant even at 99% confidence level, which showed a definite decreasing trend of Extremely Heavy Rainfall. Rest of the districts did not show any trend of Extremely Heavy Rainfall even at lower confidence level (90%). The second category, very heavy rainfall events, increased significantly (95% significance) in Keonjhargarh, Nawarangapur and Koraput. In Bolangir and Nuapada the increase was significant at 90% confidence level (Fig. 2). The third category of extreme rainfall, heavy rainfall, increased in Nawarangapur at 99% confidence level, in Bolangir at 95% of confidence level and in Malkangiri and Boudh at 90% confidence level (Fig. 3).

3.3. Record one-day rainfall events

All-time record high one-day rainfall events during two periods, (a) before 1912 and from 1991 to 2014 are given in Table 2. Comparison of data between these two periods should be taken cautiously due to different...
**TABLE 1**

Occurrence of extreme rainfalls over Odisha

| District      | Frequency per year | % of total extremes | Extremely heavy | Very heavy | Heavy |
|---------------|--------------------|---------------------|-----------------|------------|-------|
|               |                    |                     | Extremely heavy | Very heavy | Heavy |
| Angul         | 0.65               | 5.75                | 26.10           | 2.00       | 17.69 | 80.31 |
| Balasore      | 1.02               | 12.75               | 60.40           | 1.35       | 17.19 | 81.46 |
| Bargarh       | 1.20               | 11.55               | 42.75           | 2.16       | 20.81 | 77.03 |
| Bhadrak       | 0.50               | 5.90                | 28.10           | 1.45       | 17.1  | 81.45 |
| Bolangir      | 1.40               | 11.40               | 42.10           | 2.55       | 20.77 | 76.68 |
| Boudh         | 0.15               | 3.25                | 10.25           | 1.1        | 23.81 | 75.09 |
| Cuttack       | 1.55               | 14.15               | 61.25           | 2.01       | 18.39 | 79.6  |
| Deogarh       | 0.15               | 1.55                | 9.10            | 1.39       | 14.35 | 84.26 |
| Dhenkanal     | 0.35               | 5.05                | 29.15           | 1.01       | 14.62 | 84.37 |
| Gajapati      | 0.75               | 4.65                | 20.15           | 2.94       | 18.2  | 78.86 |
| Ganjam        | 1.00               | 12.20               | 65.45           | 1.27       | 15.51 | 83.22 |
| Jagatsinghpur | 0.55               | 9.20                | 36.00           | 1.2        | 20.11 | 78.69 |
| Jajpur        | 1.55               | 9.05                | 53.50           | 2.42       | 14.12 | 83.46 |
| Jharsugada    | 0.20               | 3.30                | 17.60           | 0.95       | 15.64 | 83.41 |
| Kalahandi     | 4.80               | 18.35               | 59.85           | 5.78       | 22.11 | 72.11 |
| Khandimal     | 1.70               | 15.55               | 51.95           | 2.46       | 22.47 | 75.07 |
| Kendrapara    | 1.05               | 10.75               | 49.00           | 1.73       | 17.68 | 80.59 |
| Keonjhargarh  | 0.70               | 6.60                | 42.65           | 1.4        | 13.21 | 85.39 |
| Khurda        | 0.65               | 8.20                | 39.30           | 1.35       | 17.03 | 81.62 |
| Koraput       | 0.80               | 10.35               | 44.10           | 1.45       | 18.73 | 79.82 |
| Malkangiri    | 0.70               | 5.10                | 24.10           | 2.34       | 17.06 | 80.6  |
| Mayurbhanj    | 1.55               | 19.30               | 95.55           | 1.33       | 16.58 | 82.09 |
| Nawarangapur  | 1.40               | 10.90               | 45.65           | 2.42       | 18.81 | 78.77 |
| Nayagarh      | 0.45               | 6.05                | 27.65           | 1.32       | 17.72 | 80.97 |
| Nuapada       | 0.30               | 3.10                | 13.75           | 1.75       | 18.08 | 80.17 |
| Puri          | 1.60               | 16.10               | 49.25           | 2.39       | 24.05 | 73.56 |
| Rayagada      | 0.55               | 5.30                | 30.35           | 1.52       | 14.64 | 83.84 |
| Sambalpur     | 1.45               | 9.65                | 35.80           | 3.09       | 20.58 | 76.33 |
| Sonepur       | 0.70               | 5.45                | 25.30           | 2.23       | 17.33 | 80.45 |
| Sundargarh    | 0.50               | 9.80                | 55.05           | 0.77       | 15    | 84.24 |
| State         | 1.00               | 9.01                | 39.71           | 1.90       | 17.98 | 80.12 |

sources, although IMD data were mostly from the same rain gauge stations as of SRC (monitored by IMD). However, it would indicate whether new records have come up in the second period due to global warming because 1990 is considered as the base year. Twenty out of 30 districts in the state have registered new all-time high records during 1991-2014. Kalahandi recorded 825 mm at Th. Rampur on 28th July, 1991, which is the all-time high state record so far. It surpassed the previous record of 344.8 mm at Jayapatna on 22nd June, 1967. The
TABLE 2
Record one-day rainfall events in different districts of Odisha

| District    | Date    | Block     | Rainfall (mm) | Date       | Block     | Rainfall (mm) |
|-------------|---------|-----------|---------------|------------|-----------|---------------|
| Angul       | 19 Aug 1975 | Pallahara | 332.7         | 05 Aug 2014 | Pallahara | 402           |
|             |         |           |               | 28 Jun 2005 | Pallahara | 340           |
|             |         |           |               | 12 Aug 1991 | K.Nagar   | 339           |
| Balasore    | 18 Jul 1987 | Balasore  | 398.8         | 11 Aug 1993 | Baliapal  | 455           |
|             |         |           |               | 31 Oct 1999 | Oupada    | 400           |
|             |         |           |               | 30 Oct 1999 | Oupada    | 345           |
| Bargarh     | 07 Sep 1939 | Padampur  | 368.3         | 28 Jul 1992 | Bijepur   | 475           |
|             |         |           |               | 15 Jun 1994 | Bhatali   | 402           |
|             |         |           |               | 13 Aug 2006 | Bheden    | 360           |
| Bhadrak     | 18 Jun 1879 | Chandahali | 514.6        | 31 Oct 1999 | Bhadrak   | 446           |
|             |         |           |               | 30 Oct 1999 | Bhadrak   | 361           |
|             |         |           |               | 31 Oct 1999 | Basudevpur | 335           |
| Bolangir    | 02 Aug 1967 | Titilagarh | 266.6        | 30 Aug 2006 | Bangomunda | 459           |
|             |         |           |               | 28 Aug 2003 | Gudvella  | 448           |
|             |         |           |               | 14 Jun 2004 | Gudvella  | 380           |
| Boudh       | 15 Jun 1936 | Balandapada | 395         | 13 Aug 1991 | Kantamal   | 271           |
|             |         |           |               | 18 Sep 2008 | Kantamal   | 259           |
|             |         |           |               | 28 Jul 1992 | Kantamal   | 249           |
| Cuttack     | 10 Aug 1934 | Cuttack   | 416.8         | 18 Aug 2012 | Banki-Dampada | 478      |
|             |         |           |               | 13 Oct 2013 | Banki-Dampada | 381      |
|             |         |           |               | 18 Jun 1993 | Niali     | 345           |
| Deogarh     | 01 Aug 1943 | Deogarh   | 330.2         | 17 Jul 2001 | Deogarh   | 308           |
|             |         |           |               | 05 Aug 2014 | Barkote   | 290           |
|             |         |           |               | 05 Aug 2014 | Deogarh   | 263           |
| Dhenkanal   | 17 Jul 1915 | Bhuban    | 305           | 17 Jul 1991 | Hindol    | 305           |
|             |         |           |               | 25 Oct 2013 | Hindol    | 300           |
|             |         |           |               | 17 Jul 1991 | Odapada   | 278           |
| Gajapati    | 04 Nov 1990 | Mohana    | 319.2         | 21 Jul 2012 | R.Udaygiri | 407           |
|             |         |           |               | 30 Apr 2012 | Nuagada   | 400           |
|             |         |           |               | 10 May 1995 | Nuagada   | 350           |
| Ganjam      | 02 Jul 1984 | Digapahandi | 485        | 18 Oct 1999 | Polasara   | 350           |
|             |         |           |               | 13 Oct 2013 | Buguda    | 323           |
|             |         |           |               | 18 Oct 1999 | Kukudakhundi | 297      |
| Jagatsingpur | 02 Jul 1989 | Jagatsinghpur | 498.6 | 30 Jul 1997 | Erasama    | 540           |
|             |         |           |               | 15 Nov 1998 | Erasama    | 450           |
|             |         |           |               | 27 Jul 1992 | Tirtol     | 315           |
| Jajpur      | 11 Aug 1992 | Sukinda    | 350           | 30 Oct 1999 | Sukinda    | 390           |
|             |         |           |               | 30 Oct 1999 | Bari       | 375           |
|             |         |           |               | 11 Aug 1992 | Dharamasala | 350      |
| Jharsuguda  | 29 Jun 1925 | Jharsuguda | 350           | 16 Aug 2012 | Laikera    | 350           |
|             |         |           |               | 07 Aug 2004 | Laikera    | 306           |
|             |         |           |               | 16 Aug 2012 | Jharsuguda | 277           |
| Kalahandi   | 22 Jun 1967 | Jaypatna  | 344.8         | 28 Jul 1991 | Th. Rampur | 825           |
|             |         |           |               | 03 Jul 2006 | Th. Rampur | 700           |
|             |         |           |               | 24 Jun 2013 | Th. Rampur | 660           |


| District          | Date    | Block    | Rainfall (mm) | Date    | Block    | Rainfall (mm) |
|-------------------|---------|----------|---------------|---------|----------|---------------|
| Kandhamal         | 12 Aug 1991 | Phiringia | 331           | 29 Jul 1991 | Kotagarh | 371           |
|                   |         |          |               | 07 Sep 2003 | Tumudibandha | 355          |
|                   |         |          |               | 12 Aug 1991 | Phiringia  | 331           |
| Kendrapara        | 24 Jun 1925 | Kendrapada | 401.8         | 29 Oct 1999 | Mohakalpara | 495           |
|                   |         |          |               | 29 Oct 1999 | Garadpur   | 487           |
|                   |         |          |               | 29 Oct 1999 | Derabis    | 482           |
| Keonjharhgarh     | 09 Jul 1941 | Anandapur | 343.4          | 31 Oct 1999 | Ghatagaon | 423           |
|                   |         |          |               | 31 Oct 1999 | Anandapur  | 415           |
|                   |         |          |               | 26 Jul 2013 | Champa | 360           |
| Khordha           | 07 Jul 1974 | Balianta | 325           | 31 Oct 1999 | Balianta | 372           |
|                   |         |          |               | 30 Oct 1999 | Bhubaneswar | 364          |
|                   |         |          |               | 30 Oct 1999 | Balianta | 340           |
| Koraput           | 14 Oct 1931 | Pottangi | 546.1          | 08 Jul 2001 | Bandhuang | 501           |
|                   |         |          |               | 04 Aug 2006 | Nandapur | 341           |
|                   |         |          |               | 04 Sep 1994 | Dashamantpur | 318         |
| Malkangiri        | 17 Jun 1907 | Malkangiri | 306.3          | 17 Jun 1999 | Korukonda | 392           |
|                   |         |          |               | 18 Jun 1999 | K.Gumma | 338           |
|                   |         |          |               | 04 Aug 2006 | Khoirput | 336           |
| Mayurbhanj        | 12 Oct 1973 | Baripada | 461.4          | 18 Jun 2008 | Bahalda | 424           |
|                   |         |          |               | 13 Aug 2007 | Bijatala | 375           |
|                   |         |          |               | 10 Aug 1993 | Bahalda  | 361           |
| Nabarangpur       | 03 Jul 1945 | Dasapala | 273.1          | 05 Aug 2010 | Dabugaon | 486           |
|                   |         |          |               | 03 Jul 2006 | Jharigaon | 478           |
|                   |         |          |               | 04 Jul 2006 | Jharigaon | 456           |
| Nayagarh          | 29 Oct 1917 | Nuapada | 279.4          | 13 Jul 2009 | Khandapara | 412           |
|                   |         |          |               | 13 Jul 2009 | Nayagarh | 345           |
|                   |         |          |               | 13 Oct 2013 | Raipur   | 296           |
| Nuapada           | 01 Oct 1973 | Deogarh | 350           | 18 Sep 2008 | Boden  | 350           |
|                   |         |          |               | 18 Sep 2008 | Khariar | 295           |
|                   |         |          |               | 21 Jul 2014 | Nuapada  | 265           |
| Puri              | 21 Oct 1862 | Puri    | 480.1          | 28 Jul 1991 | Puri  | 483           |
|                   |         |          |               | 10 Aug 1991 | Puri   | 342           |
|                   |         |          |               | 14 May 1995 | Puri   | 336           |
| Rayagada          | 18 Aug 1890 | Raygada | 355.6          | 03 Jul 2006 | Kashipur | 400           |
|                   |         |          |               | 07 Aug 2007 | Chandrapur | 397          |
|                   |         |          |               | 03 Jul 2006 | Raygada  | 299           |
| Sambalpur         | 19 Aug 1917 | Sambalpur | 581.9          | 13 Aug 2006 | Jujumura | 375           |
|                   |         |          |               | 05 Aug 1997 | Dhankuda | 371           |
|                   |         |          |               | 17 Jul 2001 | Kochinda | 369           |
| Subarnapur        | 16 Jun 1918 | Sonepur | 365.5          | 13 Aug 2006 | Binika  | 402           |
|                   |         |          |               | 13 Aug 1991 | Sonepur  | 297           |
|                   |         |          |               | 28 Aug 2003 | Tarba  | 293           |
| Sundargarh        | 20 Jul 1920 | Bonai   | 333.5          | 20 Jun 2003 | Sundargarh | 347           |
|                   |         |          |               | 20 Aug 2007 | Lathikata | 328          |
|                   |         |          |               | 29 Jun 2005 | Lahunipara | 280          |
same station also registered 700 mm on 3rd July, 2006 and 660 mm on 24th June, 2013. The same station also registered 700 mm on 3rd July, 2006 and 660 mm on 24th June, 2013. Extremely Heavy rainfall of 483 mm at Puri on 28th July, 1991 surpassed the century old record high of 480.1 mm on 21st October, 1862.

4. Discussion

Four features of spatial distribution of extreme rainfalls were revealed from the trend analysis. First, the districts receiving Extremely Heavy Rainfall events are in two clusters. The first cluster comprised of seven coastal districts, namely Mayurbhanj, Balasore, Jajpur, Kendrapada Cuttack, Puri and Ganjam. The second cluster consisted of five interior districts, namely Samabalpur, Bargarh, Bolangir, Kandhamal and Nawarangapur. Secondly, the second category, Very Heavy Rainfall events, increased in four south interior districts, Nawarangapur, Koraput, Bolangir and Nuapada and only one north Odisha district Keonjharaghar. Paradoxically, these districts included Bolangir and Nuapada, which are most often affected by drought. Thirdly, all three categories of rainfall extremes increased in Nawarangapur. The districts adjoining to Nawarangapur also showed increasing trend of extreme events. Kalahandi, showing highest one-day rainfall, is one such adjoining district. Fourthly, most of the districts showing increasing trend of occurrence (except Keonjharaghar) are in interior south Odisha. The frequency of extreme rain events increased in all the interior districts, namely Jharsuguda, Nawarangapur, Bolangir, Gajapati, Jagatsinghpur and Malkangiri, while decreased in coastal districts of Odisha, namely Puri, Khorda, Balasore, Bhadrak and Kendrapada. The results were partly similar to that of Goswami et al. (2006), who reported significant rising trends in the frequency and the magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events over central India.

Trend analysis of all three categories showed a mixed trend in different districts of Odisha. For example, Kalahandi, Keonjharaghar, Koraput, Nuapada, Bolangir and Nawarangapur showed increasing trend in extreme rainfall events, while coastal district Puri showed decreasing trend. Such types of results were also reported by Rakhecha and Pisharoty (1996), mixed trends in different parts of the country. Parts of the Peninsula showed a significant increasing trends at 95% level of confidence. The decreasing trend in Puri was similar to that of southern Peninsula and the lower Ganga valley, exhibiting a decreasing trend at the same level of significance. When frequency and time series trend are considered together, it is found that extreme events are spread across the state, north-south and east-west. The results confirm the findings of Ramesh and Goswami (2007) that in genesis and evolution of extreme rainfalls of intensity greater than 350 mm/day during the June to August period, the oceanic environment has a minor role to play.

New record high one-day rainfall events were found in 20 out of 30 districts of the state. No spatial pattern was found on the districts registering new records, as these included both coastal and interior districts across the state. Repeated occurrence of new record high rainfalls in Kalahandi, three new records during 1991 to 2014, is phenomenal, which needs to be analysed further. In the present studies new all-time high records occurred in 1990s, 2000s and 2010s. Thus the results differed from Kripalani and Kumar (2004), who reported inter-decadal variation due to cyclic occurrence of negative and positive phases of the Indian dipole.

5. Conclusion

Analysis of extreme rainfall events in all three categories during 1991-2014 showed a mixed trend in different districts of Odisha. The state as a whole received one extremely heavy, nine very heavy, and forty heavy rainfall events in a year. In terms of percentage of occurrence of each category out of the total extreme events, maximum % of extremely heavy rainfall occurred in Kalahandi (5.8%), very heavy rainfall in Bolangir (23.8%) and heavy rainfall in Keonjharaghar (85.4%). Trend analysis showed that number of extreme rainfall events increased in few districts, namely, Bolangir, Nuapada, Keonjharaghar, Koraput, Malkangiri, and Nawarangapur and did not change in other districts. Puri district observed decrease in frequency of extremely heavy rainfall category. New all-time record high one-day rainfall events were recorded in twenty districts during 1992 to 2014, surpassing the earlier records, which could be attributed to climate change induced by global warming.

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