

A new criterion for identifying breaks in monsoon conditions over the Indian subcontinent

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Abstract

[1] The presence or absence of prolonged breaks over the Indian subcontinent during the mid monsoon months of July and August decides the fate of the monsoon rainfall. Using a new criterion for identifying the breaks, we have catalogued them for the period 1901 to 2002. We refer to a situation as a break, if the all India rainfall is less than 9 mm/day and the condition persists for a minimum of three days and if it occurs in the mid monsoon months of July and August. The majority of the breaks in the months of July and August were of 3-4 days duration (49%). Breaks identified by our method were in general consistent with those identified by the conventional methods. Further, the correlation between the seasonal monsoon rainfall and break (active) days identified by the present criteria is -0.80 (0.38) which is more robust than that of the previous studies.

1. Introduction

[2] The southwest monsoon (June-September), which gives about 60-90% of the mean annual rainfall of the various meteorological sub-divisions of India, is the most outstanding feature of the Indian meteorology (Ananthakrishnan et al., 1983). In a typical monsoon season, the monsoon sets in over Kerala by 1st June and covers the entire country by 15th of July. The quantum of monsoon rainfall also varies from year to year. The monsoon rainfall is not continuous within the life cycle of a monsoon; there are several spells of active, weak and break in monsoon conditions. The summer monsoon months June to September contribute 21%, 33%, 28% and 18% of the seasonal rainfall respectively. Thus it can be seen that the mid monsoon months of July and August together contribute about 61% of the mean seasonal rainfall. Hence prolonged breaks in these two mid monsoon months can create deficit monsoon or drought conditions as in the case of the recent year, 2002, which incidentally had the longest break spell of 34 days according to our criteria.

[3] Different authors have used the term 'break' to refer different features such as convection and circulation etc. over different regions. Further, the authors have used different durations to refer the break as well as looked them in different months.

[4] By analyzing 80 years (1888-1967) of rainfall data, Ramamurty (1969) suggested various synoptic situations responsible for the break in monsoon conditions. They include (i) The migration of monsoon trough to the foot hills of Himalayas, (ii) The absence of low level easterly winds over the northern India and (iii) The increased rainfall activity in the foot hills of Himalayas and decrease of rainfall over the rest of the country. The criteria used by him for a break was based on surface pressure distribution and circulation. He looked for the breaks only in the period 1st July to 31st August.

[5] De et al., (1998) have further classified the breaks for the 30 year period (1968-1997) and found some more additional features during the break in monsoon conditions, which include, a) The movement of cyclonic circulation or trough over low latitudes as over southwest bay or south Tamil Nadu b) Presence of a trough in mid tropospheric westerlies over northern parts of the country. c) Weak pressure gradient over west coast, and some times isobars running parallel to west coast and d) Strong westerly winds in the northern parts of the country as compared to the westerlies over peninsula. They looked for the breaks only in the period 1st July to 30th September.

[6] Krishnan et al., (2000) define break days as days with large positive outgoing longwave radiation (OLR) anomalies for at least four consecutive days or more over a wide region covering the northwest and central India. They also kept an objective criterion that the OLR anomaly averaged over the region (18° - 28° N ; 73° - 82° E) should exceed 10 W m^{-2} during all the days of the break period. Further, the breaks only in the period 15th June to 15th September were considered.

[7] Goswami and Mohan (2001) define breaks on the basis of the strength of the 850 hpa wind at a reference point just south of the "monsoon trough" (15° N ; 90° E). They also found that the frequency of the occurrence of 'active' and 'break' conditions were found to be distinctly different during excess (deficit) monsoon years. Further, they found that most frequent pattern associated with an excess (deficit) monsoon year is the 'active' ('break') condition with enhanced (decreased) cyclonic vorticity and convection over the monsoon trough.

[8] Gadgil and Joseph (2003) in a recent study, has looked into the breaks over Indian subcontinent

using rainfall over the monsoon zone, which they feel is representative of the all India summer monsoon rainfall. They obtained a negative and significant correlation between all India summer monsoon rainfall and number of rain break days ($r = -0.56$). They also obtained a positive and significant relationship between active days and monsoon rainfall ($r=0.47$).

[9] During the break monsoon conditions, according to Joseph and Sijikumar (2004), the strong cross equatorial low level jetstream (LLJ) with its core around 850 hpa is oriented south eastwards and it flows east between Sri Lanka and the equator. During active monsoon conditions, the LLJ axis passes from central Arabian Sea eastwards through peninsular India and it provides moisture for increased convection in the Bay of Bengal and for the formation of monsoon depressions over there.

[10] In the present study, we have used a new parameter, namely, the all India daily rainfall, which we feel is truly representative rainfall conditions over the entire Indian subcontinent and hence will be a better parameter suited to identify the breaks rather than the traditional parameters such as increase in surface pressure or circulation features over the Indian subcontinent. We have further, shown that the breaks identified by this method are consistent with the breaks obtained by the previous studies and the duration of the breaks identified by the new criteria also matches very well with the earlier estimates of Ramamurty (1969) and Gadgil and Joseph (2003).

2. Data

[11] The daily all India precipitation data for the summer monsoon season used in the present study is obtained from the Indian Institute of Tropical Meteorology, Pune, India for the period 1901-2002. We tried several thresholds for the all India Rainfall and finally arrived at the value of 9 mm/day, which when used as the threshold, the breaks so identified were by and large consistent with those identified by the traditional methods (Ramamurty, 1969 and De et al., 1998). Thus, we have classified a day as a break day if the all India rainfall was less than 9 mm/day and it persisted for a minimum of three days and it occurred in the months of July and August. We have three reasons for using the breaks only of July and August, a) a delayed onset or an early withdrawal of the monsoon can create an artificial break if we consider the months of June and September respectively b) the monsoon months of July and August, together contribute to **about 60%** of the seasonal total, hence a prolonged break in these months can have a profound effect on the seasonal rainfall c) we assume that the monsoon covers the

entire Indian subcontinent within a month, in fact there are large inter-annual variability as it covered the entire country in 22 days (1972) and it took almost 61 days (1969). We have further classified the years into deficit ($< M - S.D$), excess ($>M + S.D$) and normal ($>M - S.D$ and $< M + S.D$) years based on the mean seasonal rainfall (M) and standard deviation ($S.D$).

3. Results

[12] The percentage of days during July and August for different rainfall ranges is given in Table 1. In order to obtain, a further insight into the monsoon activity during these months, we have further classified the days as break days (rainfall less than 9 mm/day), normal days (rainfall between 9 mm/day and 15 mm/day) and active days (rainfall > 15 mm/day). From the table it can be seen that about 33% of the days have rainfall less than 9 mm/day in July, while in the case of August, 53% of the days have rainfall less than 9 mm/day. Using this threshold, the breaks identified by us for the study period (1901-2002) were consistent with the breaks identified by the previous studies (Ramamurty, 1969; De et al., 1998, Gadgil and Joseph, 2003).

[13] The frequency of breaks of different duration is given in Table 2. It is seen from the table that 45% of breaks were of 3-4 days duration. The percentage of the duration of the rain breaks identified by this method compared reasonably well with that of previous studies of Ramamurty (1969) and Gadgil and Joseph (2003). Table 3 gives a comparison of the break days identified by the present method with some of the previous studies for some selected deficit and excess years. From the table it can be seen in general that the breaks identified by the present method are more than those of earlier studies. The breaks identified by the De et al., (1998) were the least, in fact, for a deficit year (1982), there were no breaks at all according to their criteria, whereas both Krishnan et al., (2000) and Gadgil & Joseph (2003) had 8 and 9 days respectively and according to our criteria there were 21 days. In the case of an excess year (1975), our study showed there were 6 break days, whereas G&J (2003) had no break days, but De et al. (1998), had 5 break days. Another reason for the discrepancies between the breaks determined by different authors could be that only two studies have used rainfall whereas the rest have used surface pressure/wind distribution, circulation or convection and different regions are used.

[14] We have considered active days as days, when all India rainfall is greater than 15 mm/day and last for a minimum of 3 days consecutively in the months of July and August. Table 4 gives a comparison of the active days obtained by our criteria for the period

1979-1990 with the study Joseph and Sijkumar (2004). In fact all the active days identified by us using the above method fall within the days identified by them. The only difference is that they have considered active days for the month of June also.

[15] Figure 1 gives the correlation between the break days and the seasonal summer monsoon rainfall and the number of break days during July and August for the study period. From the figure it can be seen that the number of break days are negatively and significantly correlated with summer monsoon rainfall at 0.1 significance level with the correlation coefficient of -0.80 , which is more robust than the correlation coefficients obtained by Ramamurty (1969) and Gadgil and Joseph (2003). Figure 2 gives the correlation between the active days and the seasonal summer monsoon rainfall and the number of break days during July and August for the study period. From the figure it can be seen that the number of active days are positively and significantly correlated with summer monsoon rainfall at 0.1 significance level with the correlation coefficient of **0.38**, which is more robust than the correlation coefficient Gadgil and Joseph (2003).

4. Conclusions:

[16] A new criteria based solely on all India daily rainfall has been used for identifying the breaks over the Indian subcontinent, and the breaks so identified are largely consistent with those identified with the earlier studies. The study further shows that the breaks are twice likely to occur in August than in July. The year 2002 had the longest spell of 34 days (1st July to 3rd August) and the year 1908 had no breaks at all. The break (active) days identified by this criteria are negatively (positively) and highly significantly correlated with the monsoon rainfall and the correlation coefficients are much more robust than those obtained by the previous studies.

[17] Acknowledgements

The rainfall data for the present study is obtained from the Indian Institute of Tropical Meteorology. The authors are grateful to Prof. S. Gadgil, Centre for Ocean and Atmospheric Sciences, Indian Institute of Science, Bangalore for useful suggestions in greatly improving the manuscript. They are also thankful to two anonymous reviewers for their useful suggestions. This NIO Contribution. No. 3904.

Table 1: Percentage of days in July and August with rainfall (mm/day) in different ranges.

0 – 9	33.71	52.94
9 –15	50.03	40.92
15– 33	16.25	6.11

Table 2: Comparison of the percentage of duration of the breaks with earlier studies.

Duration	Present Study	Gadgil & Joseph (2003)	Ramamurty (1969)
3-4	45.4	44.8	49.5
5-6	23.2	22.8	19.8
7-8	11.7	14.3	16.2
9-10	6.1	6.7	6.3
11-12	3.6	4.8	4.5
13- 14	3.4	3.8	1.0
>15	2.2	2.8	2.7

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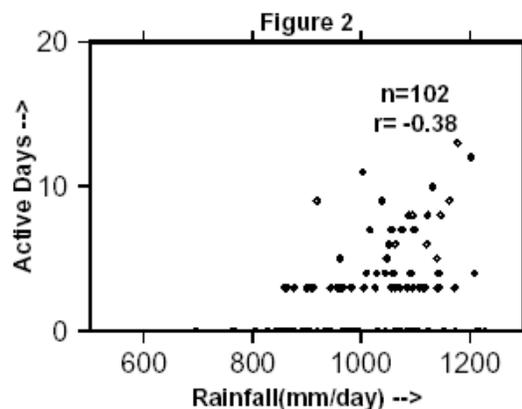
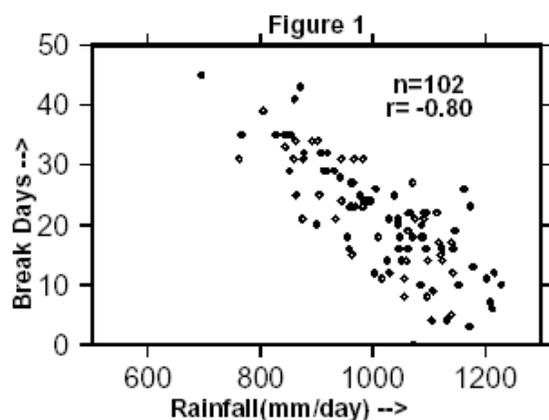


Table 3: A comparison of break days for selected deficit (D) and excess (E) years for the months of July (J) and August (A).

Year	Present study	G&J (2003)	De et al (1998)	Krishnan et al (2000)
1972 (D)	11J-7A, 19-22A, 29-31A	19J-3A	17J-3A	
1975 (E)	23-25J, 24-26A	_____	24-28J	
1979 (D)	2-7J, 17-20J, 13-31A	2-6J, 15-31A	17-23J, 15-31A	1-6J, 18-22J, 12-27A
1982 (D)	1-11J, 15-18J, 26-31A 26-31A	1-8J	_____	1-7J
1983 (E)	5-10J, 24-28A	8-9J, 24-26A	22-25 A	4-8J
1987 (D)	11-13J, 15J-6A, 8-11A, 15-18A	16-17J, 23-24J, 31J-4A, 11-13A	28J-1A	14J-3A
1988 (E)	13-16A, 29-31A	14-17A	5-8J, 13-15A	_____

Table 4: A comparison of active days for the selected years for the months of July(J) and August(A) by the present study and Joseph and SijjiKumar(2004) for June(Jn), July(J) and August(A).

Year	Present study	Joseph & SijjiKumar(2004)
1980	1J - 3J	21Jn-7J
1983	25J-27J	11A-15A
1986	12-14A	19Jn-27Jn, 16J-21J, 6A-11A
1988	16-19J	15-20J, 31J-2A
1989	21-25J	21-26J