

October 1996

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R. H. Kripalani

Indian Institute of Tropical Meteorology, Pune, India

Ashwini Kulkarni

Indian Institute of Tropical Meteorology, Pune, India

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Drought Network News (1994-2001). 24.

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Assessing the Impacts of El Niño and Non-El Niño-related Droughts over India

R. H. Kripalani and Ashwini Kulkarni
 Indian Institute of Tropical Meteorology
 Pune, India

Introduction

It has now been recognized that the single most important key to the earth's year-to-year climate variability is the El Niño/Southern Oscillation (ENSO) phenomenon. El Niño episodes directly affect the climate of at least half the planet and in many instances result in heavy loss of life and resources. The global impacts of El Niño events have been summarized in a review article by Bigg (1990), while the role of ENSO in Indian monsoon rainfall variability is given in Krishna Kumar et al. (1995). During the ENSO warm/cold extremes—i.e., El Niño/La Niña events—the majority of the episodes induce below/above-normal rainfall over India. However, there have been deficient monsoons over India apart from these El Niño episodes (Das, 1991). Hence this article investigates the intensity of the droughts (i.e., deficient monsoons) over India due to El Niño and non-El Niño forcings. Similarly, the intensity of floods (i.e., excess monsoons) is also examined with respect to the La Niña/non-La Niña episodes.

Interannual Indian Monsoon Rainfall Variability

About 80% of the annual rainfall over a large part of India occurs during the summer monsoon period (June through September). The time series of the Indian summer monsoon rainfall (ISMR) has been devised by Parthasarathy et al. (1994). The normal ISMR is 85.2 cm and the standard deviation is 8.4 cm. Figure 1 shows the year-to-year standardized ISMR for the period 1871–1994. Although there appear to be year-to-year random fluctuations, the most prominent variation on the interannual scale is between the so-called good monsoon seasons with above-average rainfall and the poor monsoon seasons with deficit rainfall. The long-term changes have been examined by the Mann-Kendall rank test, while the short-term climatic variations have been investigated by applying Cramer's t-test for the 11-year running means (WMO, 1966). The values of the Cramer's t-statistic for the 11-year running means are shown in Figure 2. The most striking features are the epochs of above- and below-normal rainfall. The periods 1880–95 and 1930–63 are characterized by above-normal rainfall with very low frequency of droughts. The periods 1895–1930 and 1963–90 are characterized by below-normal rainfall with very high frequency of droughts. No trends depicting a longer-term climatic change are detected.

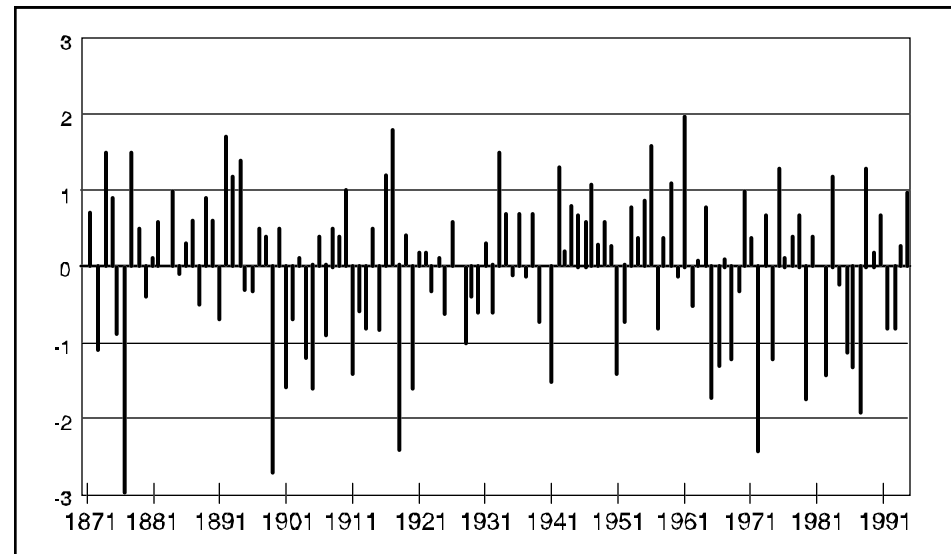


Figure 1. Year-to-year standardized ISMR for the period 1871–1994.

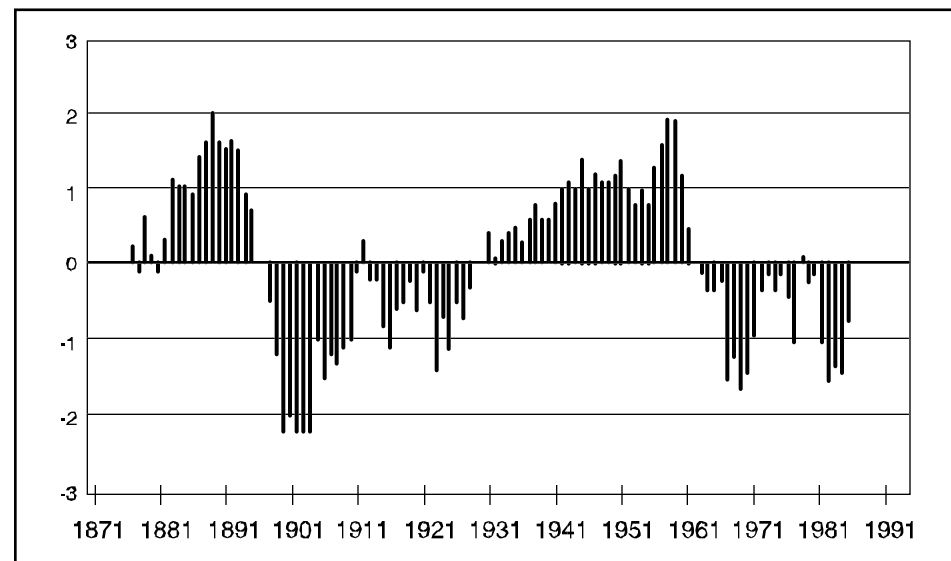


Figure 2. The values of Cramer's t-statistic for the 11-year running means of ISMR.

Droughts over India

We define a drought year as one for which the standardized ISMR is less than -1 (one standard deviation is roughly equivalent to 10% of the normal ISMR). During the period 1871–1990, there were 27 El Niño episodes and 22

monsoons associated with below-normal rainfall. However, during 11 of these events, only the standardized ISMR has been less than one. On examination of the droughts caused by non-El Niño forcing, it was found that there were 10 such cases during the same 120-year period. Table 1 lists, in decreasing intensity, the 10 worst drought situations due to El Niño and non-El Niño forcings, along with the corresponding standardized ISMR.

The average standardized ISMR for droughts caused by El Niño forcing is -2.0; for non-El Niño forcing, it is -1.3. The differences between the means have been statistically tested by the t-test (WMO, 1966) and are statistically significant at the 1% level ($t = 3.41$). Hence the intensity of droughts over India is much more severe during the El Niño episodes than during the non-El Niño episodes. An interesting point noted here is that 19 of the 20 droughts have occurred during the below-normal epochs (the exception being 1941).

Floods over India

A flood year is defined as a year when the standardized ISMR is greater than one. During the period 1871–1990, there were 23 La Niña episodes and 21 monsoons associated with above-normal rainfall. However, during 6 of these events, only the standardized ISMR has been greater than one. Incidentally, there were also 10 cases of floods not associated with the La Niña episodes during the same period. Table 2 lists the flood/excess monsoon situations over India. The average standardized ISMR for floods due to the La Niña forcing is +1.1, while for the non-La Niña forcing it is +1.5. The differences between the means are significant at the 5% level ($t = 2.52$). Hence the intensity of floods is more severe during the non-La Niña episodes. Only 11 of these 20 cases have occurred during the above-normal epochs.

Ser. No.	El Niño		Non-El Niño	
	Year	SR	Year	SR
1	1877	-3.0	1979	-1.7
2	1899	-2.7	1901	-1.6
3	1918	-2.4	1920	-1.6
4	1972	-2.4	1966	-1.3
5	1987	-1.9	1986	-1.3
6	1965	-1.7	1904	-1.2
7	1905	-1.6	1968	-1.2
8	1941	-1.5	1974	-1.2
9	1911	-1.4	1873	-1.1
10	1982	-1.4	1985	-1.1
Average		-2.0	-1.3	

Table 1. Droughts over India during El Niño and non-El Niño episodes. SR=standardized ISMR.

Ser. No.	La Niña		Non-La Niña	
	Year	SR	Year	SR
1	1892	+1.7	1961	+2.0
2	1942	+1.3	1917	+1.8
3	1975	+1.3	1956	+1.6
4	1988	+1.3	1874	+1.5
5	1916	+1.2	1878	+1.5
6	1983	+1.2	1933	+1.5
7	1970	+1.0	1894	+1.4
8	1889	+0.9	1893	+1.2
9	1964	+0.8	1947	+1.1
10	1938	+0.7	1959	+1.1
Average		+1.1		+1.5

Table 2. Floods/excess monsoons over India during La Niña and non-La Niña episodes. SR=standardized ISMR.

Summary

From the above analysis, it is apparent that droughts over India are much more severe during El Niño episodes than during non-El Niño episodes. Further droughts have a very strong tendency to occur during the below-normal epochs. However, the intriguing feature is that the floods are more severe during the non-La Niña episodes than during the La Niña episodes. The probability of occurrence of floods is practically the same during the above- and below-normal epochs.

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