

Impact of 1990 - '95 ENSO / WEPO event on Indian monsoon rainfall

C K Gopinathan

National Institute of Oceanography, Dona Paula, Goa. - 403 004, India

Received 9 December 1996, revised 1 July 1997

The negative phase of the 1990 - '95 El Niño-Southern Oscillation (ENSO) and the associated Warming of the Equatorial Pacific Ocean (WEPO) was the longest observed in the 113 years of its recorded history, compared to its normal duration of 1 to 2 years. In case of earlier 11 ENSO events, the Indian South West Monsoon Rainfall (ISWMR) was below normal in 73 % cases and above normal only 9% of the cases during the starting year of the negative epoch. The ISWMR was slightly above normal in 1990, the first year of the current negative epoch, and below normal in 1991 and 1992, normal in 1993, above normal in 1994 and normal during 1995.

The classical Southern Oscillation (SO), as measured by the sea level pressure difference between Tahiti and Darwin, has an approximate period of 3 to 4 years. The warming and cooling cycle of the equatorial Pacific Ocean also has the same mean period. The negative or positive phase of the cycle has an approximate interval of 1 to 2 years. However, the most recent Southern Oscillation (SO) had a negative phase lasting from 1990 to 1995. Such a long negative phase was rare in the history of ENSO and also the WEPO events.

Though the interaction between the ENSO and the Indian SW monsoon is complex¹, there are some general areas of agreement. As will be explained later, the year in which warming of the equatorial Pacific started and the Southern Oscillation Index (SOI) turned negative was associated with a bad SW monsoon year. If the ENSO/WEPO continued for a second year, India had nearly equal chance of receiving normal, good or bad rainfall. The years in which cooling started and the SOI turned positive were usually good monsoon years². It is also generally agreed that the ENSO/WEPO has global scale impacts^{2,3} and the observed changes on the Indian rainfall pattern appear to be a part of it.

There are a number of studies that related the Indian SW monsoon rainfall to Pacific Ocean changes, mainly SST⁴⁻⁷. The more recent studies⁸⁻¹⁰

are on theoretical nature of the relationships between Asian monsoon and the SO. Attempts to predict the SW monsoon rainfall more precisely have also continued¹¹⁻¹³.

The most recent ENSO (WEPO) event with a negative (warm) phase of more than 5 years, was the longest negative phase in the last 113 years¹⁴. This paper is an attempt to compare the impact of this ENSO / WEPO and earlier events on the observed ISWMR patterns.

Materials and Methods

The time series monthly data of Southern Oscillation Index (SOI) have been collected from the Climate Analysis Center, Washington, USA. SOI, according to Troup, are obtained from the Australian Meteorological Agency, Darwin. The data on SST anomaly for the equatorial Pacific Ocean are from Japan Meteorological Agency, Tokyo, Japan. The data on the sub-divisional rainfall for different years were obtained from the publications of India Meteorological Department (IMD), Pune. The all India rainfall was computed, after excluding the northern and north-eastern hilly regions of the country, as was done by Mooley & Parthasarathy¹⁵. The classification of the rainfall is as per IMD pattern. The data on SOI presented in the form of figures have been smoothed by suitable filters.

Results

Southern Oscillation Index (SOI)

Figure 1 shows the change in the monthly values of Southern Oscillation Index over a 40 year period prior to 1995. The long term best fitting curve of the monthly index values is shown by the thick dotted line which shows a negative bias after 1980. The largest positive swing of the index, of 2.5 SD, occurred during 1973 - '74 and the largest negative swing, of about 3 SD, occurred during 1982 - '83. The negative epochs of the last 11 episodes are hatched.

Figure 2 shows the changes in the Troup's Index and its 5 monthly running mean for 11 years, from 1985 to 1995. A prominent negative swing of the index prior to 1990, occurred during 1987 - '88 and its corresponding positive epoch occurred during 1988 - '89. The recent negative epoch of the index started in mid-1990 and continued till the end of 1995. Earlier a less longer prominent negative epoch was observed (not shown) between 1938 and 1942.

The negative epoch of the SOI started during the beginning of 1990, it bounced back to its positive phase during the first half of the year, before going

negative again by the end of the year. Thus, though 1990 was the first year of the negative epoch, its real impact on the Indian rainfall was felt only after 1990.

Table 1 shows the years of 11 earlier ENSO negative epochs of one (or two years) duration and the year of the next positive swing, called the recovery year. The table also gives the percentage variation of the Indian South West Monsoon Rainfall (ISWMR) during the years. It is noticed that the events with numbers 1,2,4,7,9 and 10 had only negative epochs of one year duration and the events 3,5,6,8,and 11 had negative epochs of two years duration. Considering the events of one year long negative epochs, notice that below normal ISWMR occurred 67 % of times during the first year of event and above normal rainfall occurred 50% of times during the recovery year. Above normal and normal rainfall contributed to 17 % each during the first year and normal and below normal rainfall contributed 33 % and 17 % of the occasions during the recovery year. Considering the events of 2 years negative epochs, 80 % (40 %) of the occasions the ISWMR was below normal during the

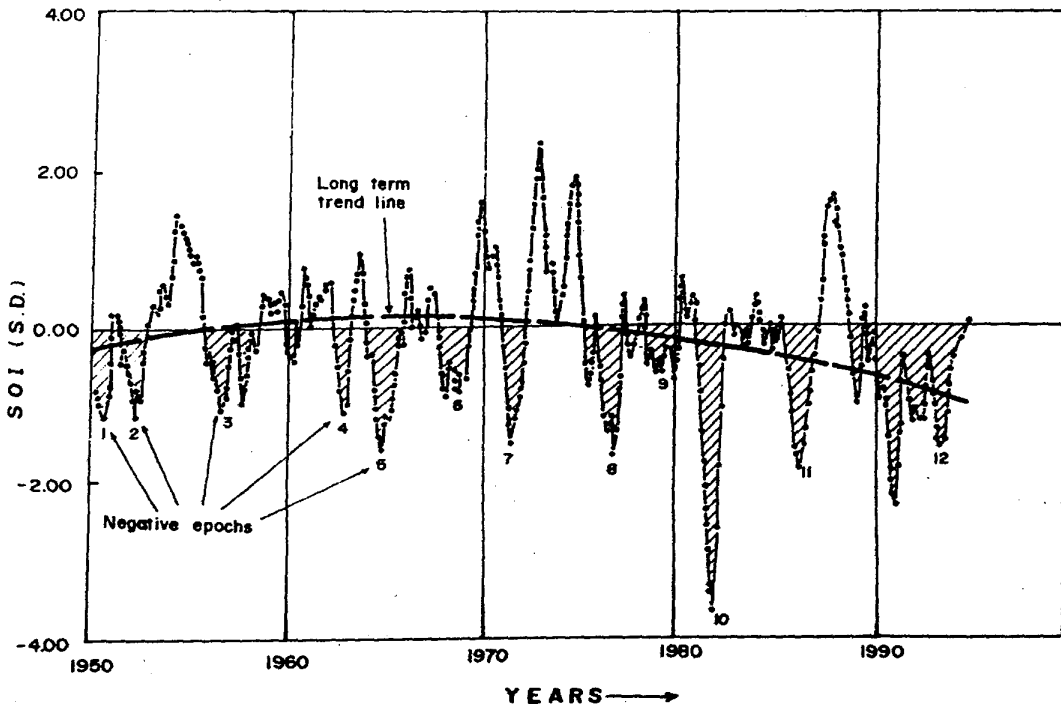


Fig. 1—A 1-2-1 smoothed monthly values of the SOI and its variation from 1951 to 1995.

first (second) year. It was above normal 80 % of the times and normal 20 % of the times during the recovery year.

Considering all the 11 episodes, 73 % of all the first years had below normal rainfall while only 9 % had above normal rainfall. If the negative epoch continued for a second year, it had 60 % chances of receiving normal rainfall and 40 % chances receiving below normal rainfall. During the recovery year, ISWMR had a chance of being above normal 64 % of the times while its chance of being below normal was only 9 %.

Warming of Equatorial Pacific Ocean (WEPO)

The SST anomalies at four selected regions of Pacific Ocean are shown in Fig. 3. The warming, as indicated by the positive swing of SST of the NINO-4 region almost coincided with the time of the negative epoch of the SOI. The NINO 4 region experienced continuous warming pattern during 1990-1995. Though the other NINO regions also showed a warming pattern, it was less consistent and not fully comparable to the SOI changes. The duration of warming of the Pacific Ocean was less in NINO-3 as well as NINO 1+2 regions compared to NINO-4 region during 1986 - '87 WEPO period. The same pattern followed during the 1990 - '95 warming.

Table 1—ISWMR during 11 ENSO events between 1950 and 1990

Event no.	Years of negative epoch	First Year of next positive epoch	ISWMR (%)
1	1951		-13.5
		1952	-7.0
2	1953		+8.0
		1954	+3.9
3	1957		-8.0
	1958		+4.0
		1959	+10.1
4	1963		+0.4
	1964		+8.0
5	1965		-17.0
	1966		-13.7
		1967	+0.8
6	1968		-11.5
	1969		-2.7
		1970	+10.2
7	1972		-23.4
		1973	+7.1
8	1976		+0.4
	1977		+3.4
		1978	+6.6
9	1979		-16.9
		1980	+3.7
10	1982		-13.1
		1983	+12.1
11	1986		-13.7
	1987		-21.5
		1988	+16.0

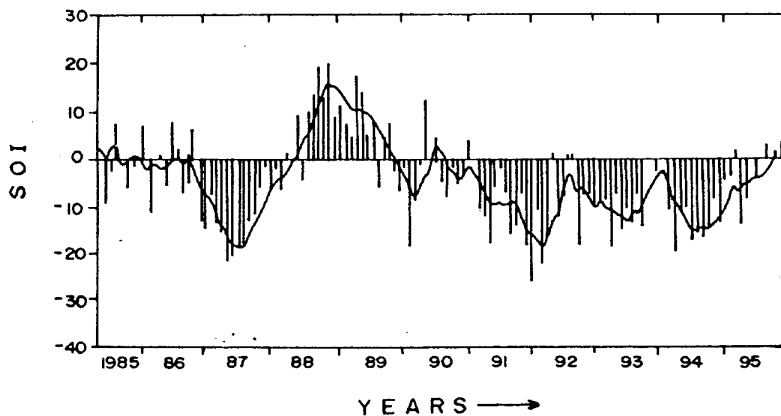


Fig. 2—The long period nature of the negative epoch observed from 1990 to 1995 in the 5 month mean of the Troup's SOI.

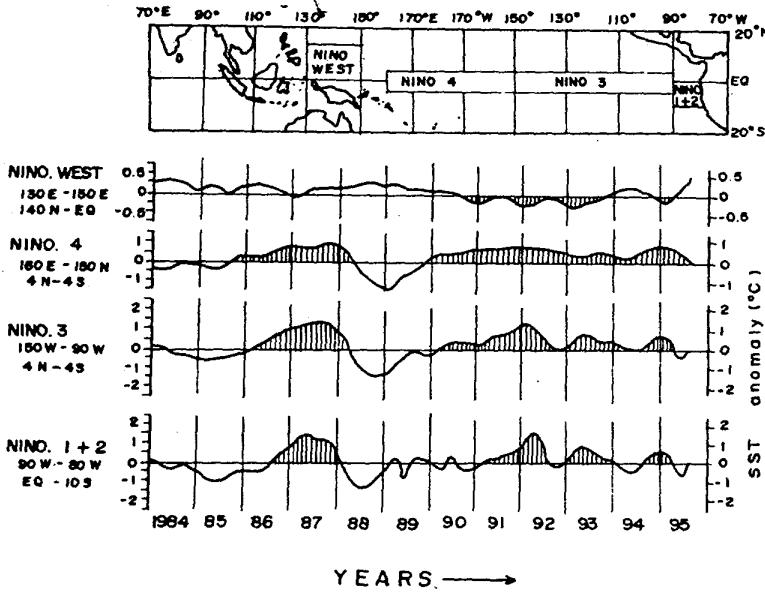


Fig. 3—Locations in the equatorial Pacific Ocean for which SST anomalies were computed.

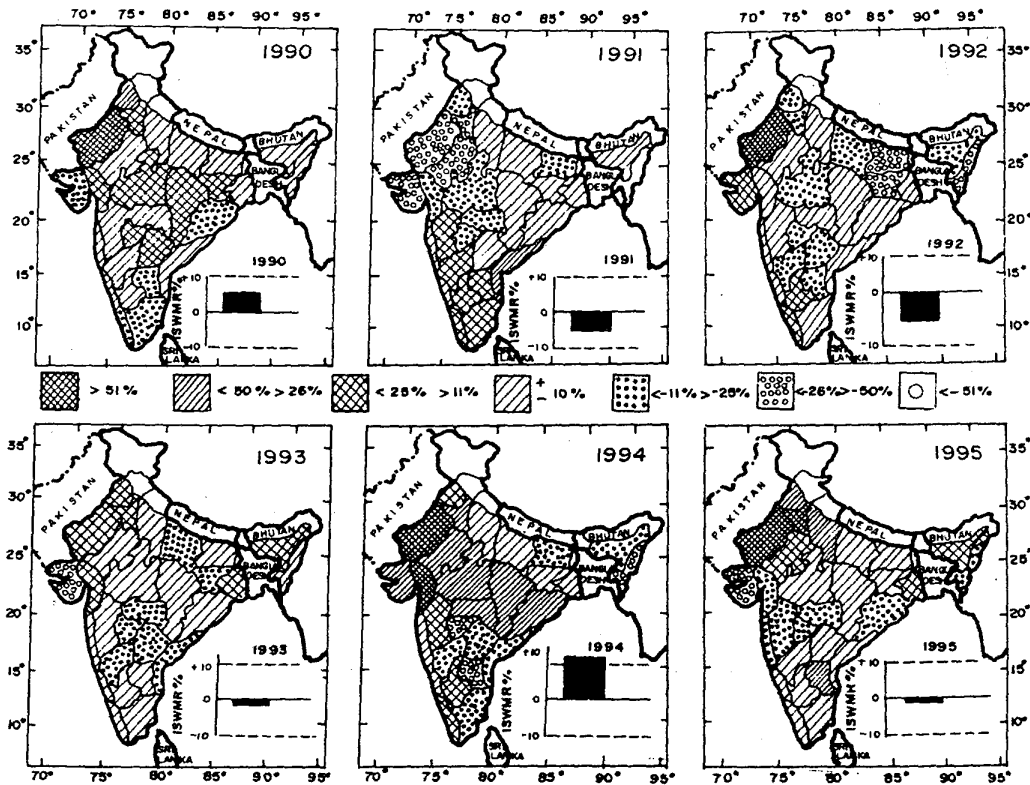


Fig. 4—Distribution pattern of rainfall in 28 main sub-divisions of India and percentage departure of ISWMR during 1990 to 1995.

Indian SW monsoon rainfall

The all India rainfall were 1 SD (about 8 %) or more below normal during 1979, 1982, 1986, 1987 while it was 1 SD or more above normal during 1983, 1988 and 1994. The detailed pattern of distribution of rainfall during 1990-'95 in major 28 sub-divisions of the country comprising the mainland as well as the percentage of ISWMR are shown in Fig. 4.

In 1990, while most of the sub-divisions received normal to above normal rainfall, some areas especially on the southern part of the country received slightly deficient rainfall. In 1991, most of the sub-divisions of north and north-western regions received slight to moderate deficient rainfall. In 1992 and 1993, some sub-divisions scattered over the country received deficient rainfall. In 1994, all sub-divisions, except some in the north east and south-central regions, received moderate to excess rainfall. In 1995, mostly the central western parts of the country received below normal rainfall.

The ISWMR, calculated as percentage of normal, were +4.4 % in 1990, -4.5 % in 1991, -7.6 % in 1992, -0.3 % in 1993, +11.5 % in 1994 and 0 % in 1995. Thus, the rainfall was slightly above normal during the first year of the current ENSO / WEPO event, below normal during the second and third years and much above normal during the fifth year of the current event.

Discussion

The principal component analysis of long term ISWMR by Bedi & Bindra¹⁶ has indicated 4 main components which explain 26.9 %, 8.79 %, 6.6 %, and 5.1 % of the total rainfall variability. The prime "cause" of the SW monsoon variability, characterised by the opposite response of rainfall between north east India and north west India, appears to be related to circulation over monsoon Asia¹¹. Contribution from the other components are less than 10 % and the exact causes are not understood. One of them may be the ENSO / WEPO effect.

The Southern Oscillation and Warming of Equatorial Pacific Ocean thus appears to be not the major cause of ISWMR variability and would cause

about 10 % of the SW monsoon rainfall variability on its own. It may also happen that the primary cause may itself be influenced by the Pacific Ocean event of ENSO / WEPO. This may explain the observed fact that while on some occasions, as much as 20 % SW monsoon rainfall variability is associated with the ENSO / WEPO, at a few occasions no effect is felt. No adverse effect may be observed on the ISWMR during an ENSO / WEPO event year, when the south Asian atmospheric circulation pattern is very strong.

Normally, one would have expected a SW monsoon failure during 1990, the first year of the current ENSO negative phase and WEPO. But this happened in 1991 (and 1992). In this case, the bad monsoon year was delayed by at least one year and the good monsoon occurred in 1994, at least one year before the recovery year.

Acknowledgement

The author is thankful to Dr. E. Desa, Director, NIO for encouragement.

References

- 1 Sikka D R, *Proc Indian Acad Sci (Earth & Planet Sci)* 89 (1980) 179.
- 2 Ropelewski C F & Halpert M S, *J Climate*, 2 (1989) 268.
- 3 Ropelewski C F & Halpert M S, *Mon Wea Rev*, 115 (1987) 1606.
- 4 Mooley A & Paulino D A, *Mausam*, 40 (1989) 369.
- 5 Kesavamurty R N, *J Atmos Sci*, 39 (1982) 1241.
- 6 Varma R K, *Mausam*, 45 (1994) 205.
- 7 Bhalme H N, Sikder A B & Jadhav S K, *Mausam*, 41 (1990) 279.
- 8 Nigam S, *J Climate*, 7 (1994) 1750.
- 9 Palmer T N, Brankovic C, Viterbo P & Miller M J, *J Climate*, 5 (1992) 399.
- 10 Mo K C, *J Climate*, 5 (1992) 1249.
- 11 Shukla J & Mooley D A, *Mon Wea Rev*, 115 (1987) 695.
- 12 Krishnamurti T N, Subramaniam M, Daughenbaugh G, Oosterhof D & Xue J, *Mon Wea Rev*, 120 (1992) 1191.
- 13 Prasad K D & Singh S V, *J Climate*, 5 (1992) 1357.
- 14 Trenberth K E & Hoar T J, *Geophys Res Letters*, 23 (1996) 57.
- 15 Mooley, D A & Parthasarathy B, *Climatic Change*, 6 (1984) 287.
- 16 Bedi H S & Bindra M S, *Tellus*, 32 (1980) 296.