Effects of Arabian Sea Parameters on Indian Monsoon

S. S. Aralikatti
Indian Institute of Tropical Meteorology
Pune: 411 008 (India)

Abstract

The relationship between All-India summer monsoon rainfall and sea surface temperatures (SSTs) over Arabian sea region for 67 grids of 2° latitude x 2° longitude have been examined for the period 1951- 80 to obtain a useful predictor for the monsoon rainfall. The correlation coefficients (CCs) between all-India monsoon rainfall and Seasonal SSTs with different lags relative to the monsoon season indicate a systematic relationship.

The average SSTs over the four grids between Lat. 14°N to 18°N and Long. 68°E to 72°E showed a highly significant CC of 0.4 for lag-1 (MAM) Season and 0.63 for the tendency parameter MAM- DJF during the period 1951-80. Inclusion of this parameter in the forecasting scheme of Indian monsoon rainfall has been discussed.

1. Introduction

The importance of Indian monsoon rainfall to the country's economy and also as a major circulation parameter has motivated many studies during the last century, pertaining to its characteristics, variability, teleconnections with regional/global circulation features and long range predictions. Efforts are being made during the last one century about the long-range forecast of Indian monsoon rainfall. Recently, Parthasarathy et al. (1988) and Gowariker et al. (1989, 1991) have made a comprehensive study of many parameters related to the Indian monsoon rainfall and developed regression equations. However, the search for new parameters continues, as no forecasting scheme is as yet consistently successful over a period of time. In the sixteen- parameter model developed by Gowariker et al. (1991), the SSTs over Indian region have not been considered. There is sufficient evidence both on empirical and theoretical basis to believe that sea surface temperatures exert significant control over the atmosphere. Many workers viz. Ranjit Singh (1983), Joseph and Pillai (1984), Rao and Goswamy (1988), Vinayachandran and Shetye (1991), Sadhuram et al. (1991) have brought out the importance of SST over Arabian sea as an input parameter for the Indian monsoon rainfall.

In view of the importance of the SSTs over the Arabian sea for the development of the monsoon, a detailed study of the relationships between All-India monsoon rainfall and the space-time variability of the SSTs over Arabian sea has been made for the period 1951-80, to obtain useful predictor for the monsoon rainfall.

2. Details of Data

Earlier studies of Hastenrath (1987) and Parthasarathy et al. (1988) on the relationships between the Indian monsoon rainfall and regional/global circulation parameters have brought out that data length of 30-years is necessary and sufficient to establish a stable correlation for prediction purposes. Further, a period of 30 years is generally considered adequate for establishing the climate norms. The present study mainly considers the data period 1951-80, for which excellent data sets on various parameters related to Indian monsoon are available.

2.1 Summer Monsoon Rainfall of India

All India (the country as a whole taken as one unit) and the 29 different meteorological subdivsions' mean summer monsoon (June through September) rainfall data sets have been prepared by properly area-weighting the rainfall at 306 well- distributed rain gauges over plain regions of the country. Parthasarathy et al. (1987, 1990) provide a detailed discussion on these data sets and listing of the data from 1871 onwards. Figure 1 shows a diagram of All-India summer monsoon rainfall for the period 1871 to 1990 prepared by Parthasarathy et al. (1992). It is seen that during the latest 30-year period (1961-90), the monsoon variability is very high compared to the other period of the data series. During this period there are 9 dry years and 5 wet years which have caused great concern to both the Government and the public.

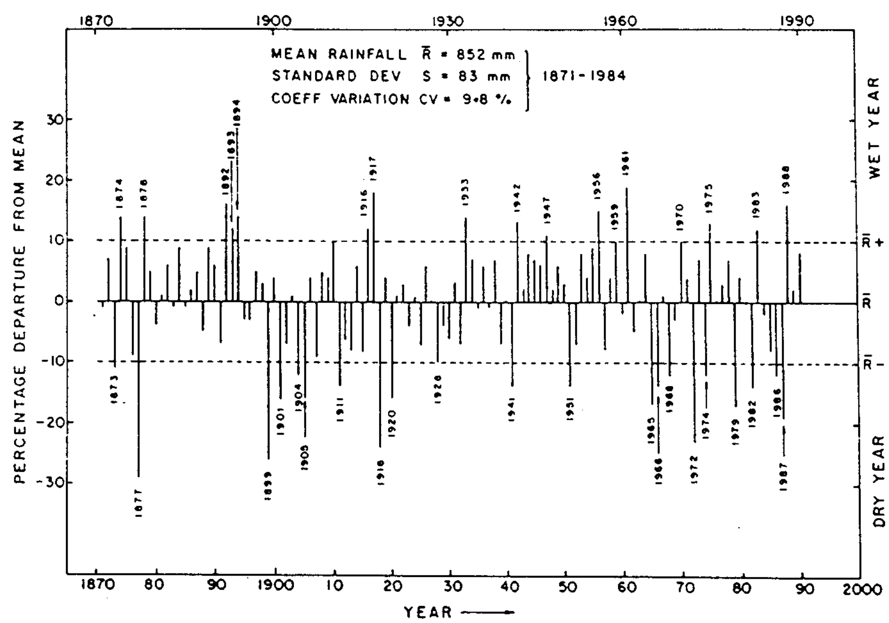

Figure 1. Year-to-year percentage departure from the mean of all-India summer monsoon rainfall: 1871-1990. Excess/deficient years are marked.

2.2 Sea Surface Temperatures Over Arabian Sea

The sea surf ace temperatures (SSTs) of Arabian sea have been obtained from Comprehensive Ocean Atmospheric Data Sets (COADS). For details the reader may refer to Woodruff et al. (1987). The data are sorted and stored in 2° Long. x 2° Lat. boxes. The period 1951-80 has been chosen since it has the best data coverage. The gridded averages for the 4 different standard seasons (DJF, MAM, JJA, SON) over the region of Arabian sea have been considered between

4°S to 24°N and 56°E to 72°E comprising of 67 square grids of 2° x 2°. Figure 2 shows the grids considered for the study over the Arabian sea.

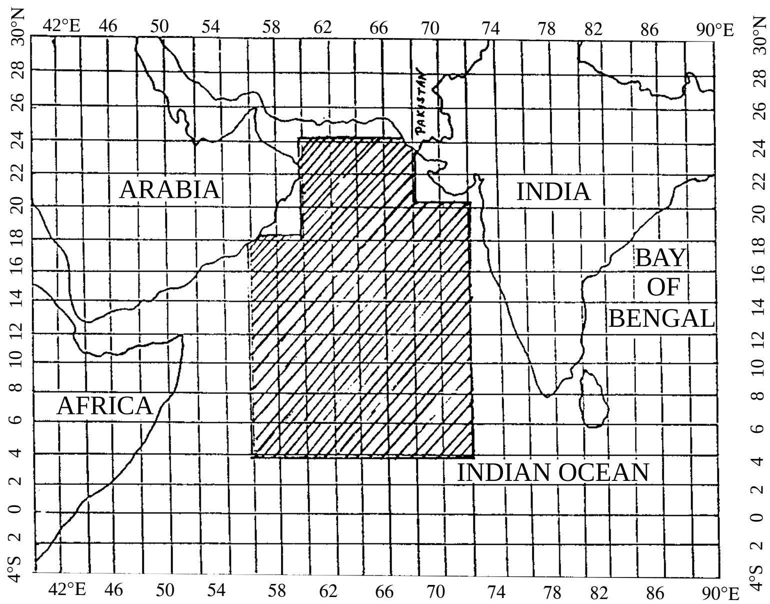

Figure 2. Details of grids (2° Lat. x 2° Long.) considered for the study over the Arabian Bea.

3. Methodology

To study the association between the Indian summer monsoon rainfall and the SSTs over the Arabian sea, the simple correlation analysis approach has been used.

To understand the temporal characteristics of the relationships between the SSTs and all-India monsoon (JJAS) rainfall, the correlation coefficients (CCs) with Seasonal SSTs upto three lags on either side of the monsoon Season has been calculated for the period 1951-80. The mean SSTs are obtained for the Seasons: lag-3 (SON), lag-2 (DJF), lag-1 (MAM), lag 0 (JJA), lag+1 (SON), lag+2 (DJF) and lag+3 (MAM). In addition, the seasonal tendency of SSTs from the previous winter (lag-2) to the current spring (lag-1), MAM minus DJF (MAM - DJF) has been considered for correlation analysis.

4. Relationships between SSTs and Indian Monsooon

The CCs between all-India monsoon rainfall and the different seasonal SST values (lag-3 to lag+3 and MAM-DJF I of all the 67 grids during the period have been computed and these values are plotted over the surface maps of the Arabian sea and isolines of the correlations are drawn. It is noticed from these correlation maps that a systematic change occurs in CCs as the season advances from lag-3 to lag+3. Fig. 3 shows the CC between all-India monsoon rainfall and SST for lag-2 (DJF) over different regions of Arabian sea. It is observed that the correlations are negative and not significant south of 14°N. However, positive CCs are significant over north of 18°N. Further, it is noticed that CCs of the order of -0.4 (significant at 5% level) are observed over a few pockets (4 grids) very near to the Indian coast between 14°N to 18°N and 68°E to 72°E. It is seen from Fig. 4 that the CCs between all-India monsoon rainfall and SSTs of lag-1 (MAM) show negative CCs south of 8°N and the rest are positive. Significant CCs with values more than 0.4 are seen very close the Indian coast. However, the SST correlation maps for lag 0 to lag+3 indicate that a small region consisting of four to eight grids over the Indian coastal region is highly related with Indian monsoon.

To make a detailed study of the SST values and to prepare a predictor candidate for the monsoon rainfall, the arithmetic average of the four grids stated above (14°-18°N; 68°-72°E) has been computed and the correlations (for lag-3 to lag+3 and MAM-DJF) for the period 1951-80 have been prepared and presented in Fig. 5. These CCs show a systematic change as the season advances from lag-3 to lag+3. The CCs of spring season (MAM, lag-1) and tendency parameter (MAM-DJF) show a strong spatial coherent association over the Arabian sea region. The positive significant association of SSTs of previous season MAM (lag-1) with all-India monsoon rainfall can be understood as the active monsoon condition over the country preceded by strong seasonal heating of the sea surface during MAM over the coastal Arabian sea.

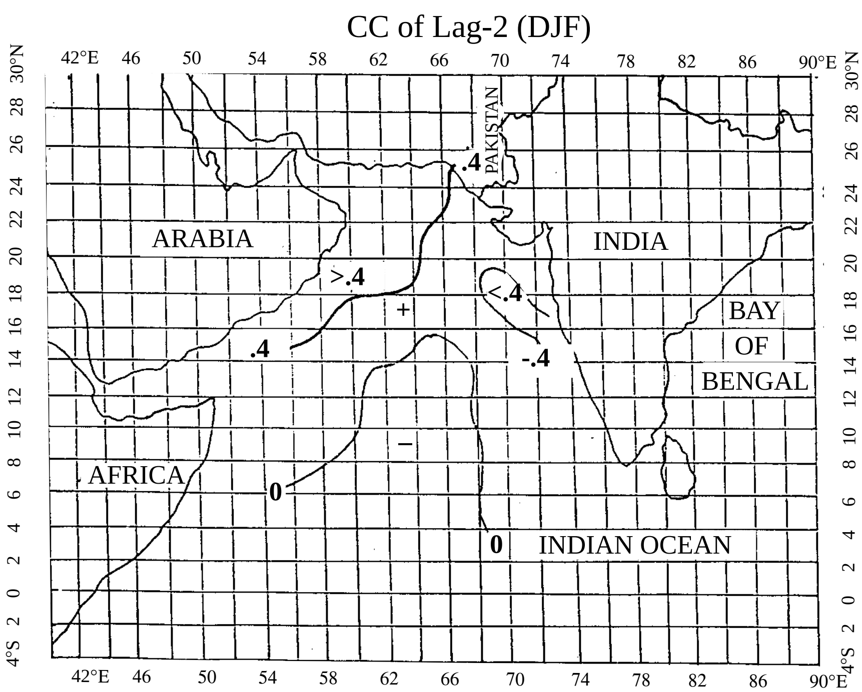

Figure 3. The correlation map over Arabian sea showing relationship between all-India monsoon rainfall and SST for DJF season (Lag-2).

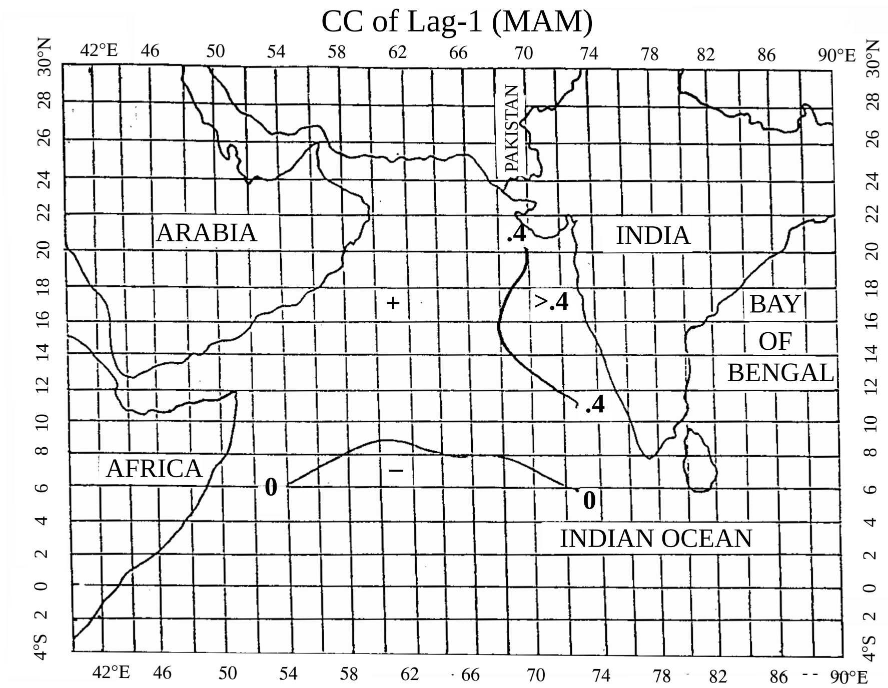

Figure 4. The correlation map over Arabian sea showing relationship between all-India monsoon rainfall and SST for the MAM season (Lag-1).

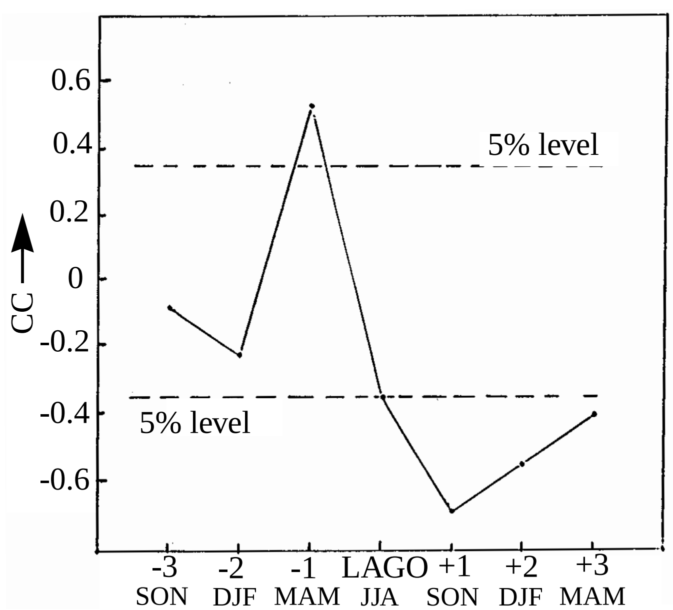

Figure 5. Relationship between all-India monsoon rainfall and SSTs averaged over the Arabian sea region for different seasons: 1951-80.

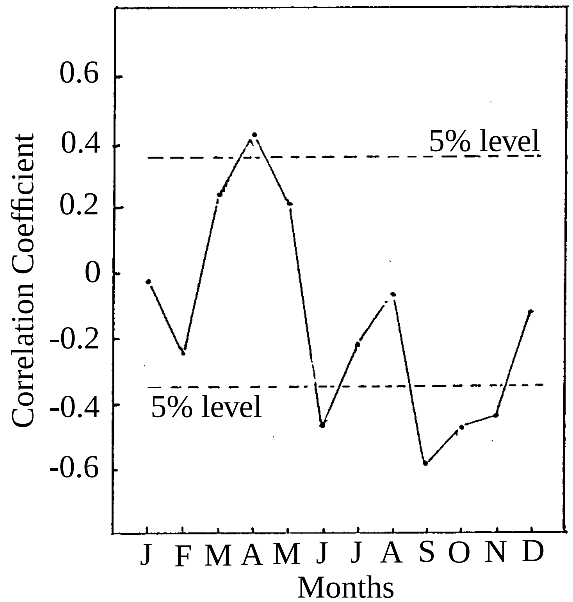

Figure 6. Relationship between all-India monsoon rainfall and SSTs averaged over the Arabian sea region for different months: 1951-80.

In order to make a further detailed examination of the SSTs, the CCs of monthly values are also calculated and these are shown in Fig. 6. It is seen from this figure, that the monthly CCs are highly variable compared to the seasonal CCs. Further, the April CC is significant at 5% level and the rest are non-significant. Thus, there is a clearly defined signal of the pre-monsoon SSTs affecting the Indian monsoon performance. However, the noise component is noticeable in the monthly correlation; therefore, the seasonal values may provide a better representation of the signal.

In order to include this SST parameter into the multiple regression equation to forecast the Indian monsoon rainfall, the CCs of the other important parameters which are involved in the scheme are tabulated in Table 1. The CC values of Arabian sea SSTs are comparable with or higher than the other parameters related to the Indian monsoon. Therefore, the new parameters which have been brought out here (MAM and MAM-DJF) will be useful one.

Table 1. Correlation coefficients between all-India monsoon rainfall and different parameters: 1951-80.

S. No.	Parameter	Season	CC
1.	WCI Temperature	MAM	0.60
2.	Bombay Pressure	MAM - DJF	-0.70
3.	500mb Ridge	April	0.70
4.	Darwin Pressure	MAM - DJF	-0.63
5.	Tahiti-Darwin Pressure	MAM - DJF	0.43
6.	Nouvelle-Agalega Pressure	MAM - DJF	0.44
7.	SST over Arabian Sea	MAM - DJF	0.62
8.	SST over Arabian Sea	MAM	0.54

Conclusions

The study of relationships of Indian monsoon rainfall and the SSTs over the 67 grids of the Arabian sea for the period 1951- 80 has brought out the following conclusions:

i) The changes in CCs during the course of the year suggest that large-scale circulation features of the monsoon system may be undergoing a low frequency transition.

ii) Average SST of the four grids over the Arabian sea has brought out a potential relationship which can be used as one of the parameters for the development of the regression model for forecasting the Indian monsoon rainfall.

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