

Association between premonsoonal SST anomaly field in the eastern Arabian Sea and subsequent monsoon rainfall over the west coast of India

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Interannual variability of premonsoonal (April-May) surface heat flux parameters together with sea surface temperature (SST) anomaly field in the eastern Arabian Sea has been examined for the period 1975-1984 in relation to the post onset (June-September) summer monsoon rainfall over the central west coast of India. Premonsoonal warm SST anomaly seems to be mainly the result of higher atmospheric subsidence over the ocean and may not be considered as predictor for a good ensuing monsoon, emphasizing the importance of global forcings in the long range forecast of Indian summer monsoon rainfall.

Sea surface temperature (SST) anomalies alter the latent and sensible heat fluxes from the ocean to the atmosphere and as such they are believed to be important in affecting the atmospheric circulations. Several authors¹⁻³ have attempted to correlate SST anomalies in different parts of the Indian Ocean with monsoon rainfall over India on both shorter and longer time scales. In the context of long range forecasting of Indian monsoon, it is necessary to consider the mechanisms for the formation of premonsoonal SST anomalies^{4,5}. However, these studies have not dealt with the causative factors responsible for interannual variability of premonsoonal SST anomaly field.

In the present paper, role of atmospheric subsidence on positive SST anomalies is shown through the study of interannual variability of surface meteorological parameters and heat exchange processes in the eastern Arabian Sea over which the uplift of monsoonal airmass is predominant⁶. The selection of study area also facilitates understanding whether any abnormal ocean warming before the monsoon can help the local ascent of airmass over the eastern Arabian Sea and post onset monsoon rainfall at the neighbouring west coast of India.

Materials and Methods

Relevant marine meteorological data of SST, air temperature, wind speed, dew point temperature, surface atmospheric pressure and cloudiness for April and May over the eastern Arabian Sea (12° to

18°N; 64°E to west coast) together with seasonal (June-September) rainfall observations at Bombay, Ratnagiri, Karwar, Goa and Mangalore coastal stations during 1975-1984 have been extracted from the Indian Daily Weather Reports⁷. The mean monthly heat fluxes at a 2 degree square resolution derived through bulk aerodynamic formulae are considered to have a bias <10% due to spatial gradients and temporal variability including the observational errors as each grid area contains a required minimum number of 11 marine observations as shown by Weare and Strub⁸.

The following equations have been used to compute various heat flux parameters:

$$Q_a = (1 - \alpha) Q_i \quad \dots 1$$

$$Q_b = \epsilon \sigma T_s^4 (0.254 - 0.00495 e_a) (1 - 0.7C) \quad \dots 2$$

$$Q_e = \rho C_e L (q_s - q_a) U \quad \dots 3$$

$$Q_s = \rho C_h C_p (T_s - T_a) U \quad \dots 4$$

where Q_a is total incoming radiation absorbed at the sea surface after reflection; Q_b , effective back radiation; Q_e , latent heat flux; Q_s , sensible heat flux; Q_i , total incoming radiation; α , albedo of the sea surface; ϵ , emissivity of the sea surface; σ , Stefan-Boltzman's constant; T_s , sea surface temperature; e_a , vapour pressure of the air; C , cloud amount in tenths; ρ , density of air; C_e , exchange coefficient for latent heat flux; L , latent heat of vaporisation; q_s , saturated specific humidity at T_s ; q_a , specific humidity of air at anemometer level; U , wind

speed at anemometer level (10 m); C_h , exchange coefficient of sensible heat flux; C_p , specific heat of air at constant pressure; and T_a , dry bulb temperature of air at anemometer level (10 m).

The total incoming solar radiation Q_i is computed using standard routine as given in the Smithsonian Meteorological Tables⁹. Necessary corrections in Q_i due to clouds are applied following Reed¹⁰ and a constant value of 0.06 is assigned for the mean albedo (α) according to Payne¹¹. The exchange coefficients C_e and C_s have been evaluated following Kondo's method¹² which takes care of their dependance on wind speed and atmospheric stability.

The net surface heat exchange Q_n is given as

$$Q_n = Q_a - Q_b - Q_e - Q_s \quad \dots 5$$

Results and Discussion

The rainfall observations at Bombay, Ratnagiri, Karwar, Goa and Mangalore provide regional average rainfall over the coast. The mean seasonal rainfall (\bar{X}) for the decade 1975-'84 was about 280 cm (Fig. 1A). In the years 1975 and 1983 excess rainfall ($> \bar{X} + \Sigma$, where Σ is the standard deviation) had been recorded while year 1979 had witnessed much deficit rainfall ($< \bar{X} - \Sigma$) during the decade. In general, a tri-annual oscillation is seen in surface pressure (Fig. 1B) while such regular oscillations are absent in other parameters of SST, wind speed and cloud amount (Fig. 1C-E). However, the highest premonsoonal SST ($> 30^\circ\text{C}$) during the decade was in 1979 associated with corresponding decadal lowest wind speed and cloud amount and further, it preceded the decadal weakest monsoon. The corresponding decadal lowest SST (28.6°C) observed in 1975 was followed by the best monsoon of the 1975-1984 decade. These results indicate that the relation between premonsoonal SST over the east-central Arabian Sea and monsoon rainfall at west coast of India is negative.

To identify the causative factors for the observed SST anomalies, various surface heat exchange parameters in the region have been computed and the interannual variations in their areal averages are presented in Fig. 2. All the surface heat fluxes except Q_e were enhanced considerably in 1979 (Fig. 2 A-D) in association with atmospheric subsidence characterised by weaker winds, lesser clouds and higher surface pressure as mentioned earlier. It is interesting to note that the net surface heat gain (Q_n) has been more than doubled in 1979 in contrast to a rather steady decline in the decade. Comparing SST (Fig. 1) and Q_n (Fig. 2) variations, it is also inferred that higher premonsoonal SST especially around the middle of decade is likely to be caused by higher

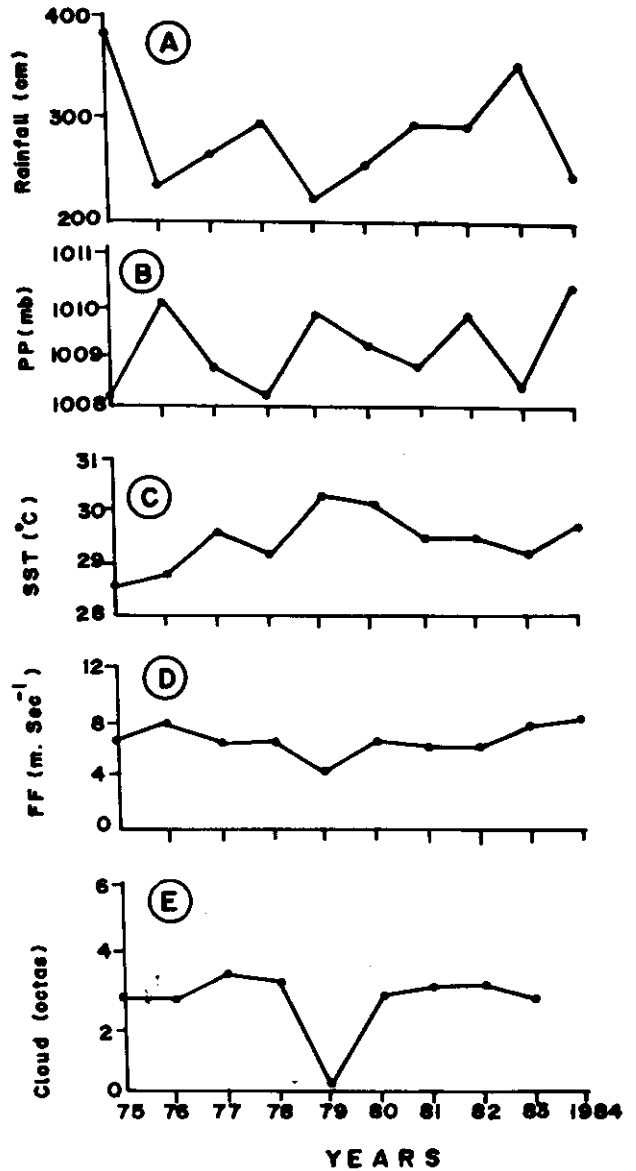


Fig. 1—(A) Interannual variability of seasonal rainfall (June-September) over the west coast of India; (B-E) Interannual variability of premonsoonal (April-May) areal averages of meteorological parameters over eastern Arabian Sea

surface heat gain. In general, premonsoonal Q_e appeared to be positively associated with the monsoon activity. The decade's most deficit rainfall during 1979 followed the corresponding lowest premonsoonal Q_e ($\sim 100 \text{ W.m}^{-2}$). This deficit premonsoonal evaporation would not help in building up the moisture content of the monsoonal air mass to be set over the area subsequently.

Areal average anomalies of various surface meteorological parameters and heat fluxes preceding the most active (1975) and weak monsoons (1979)

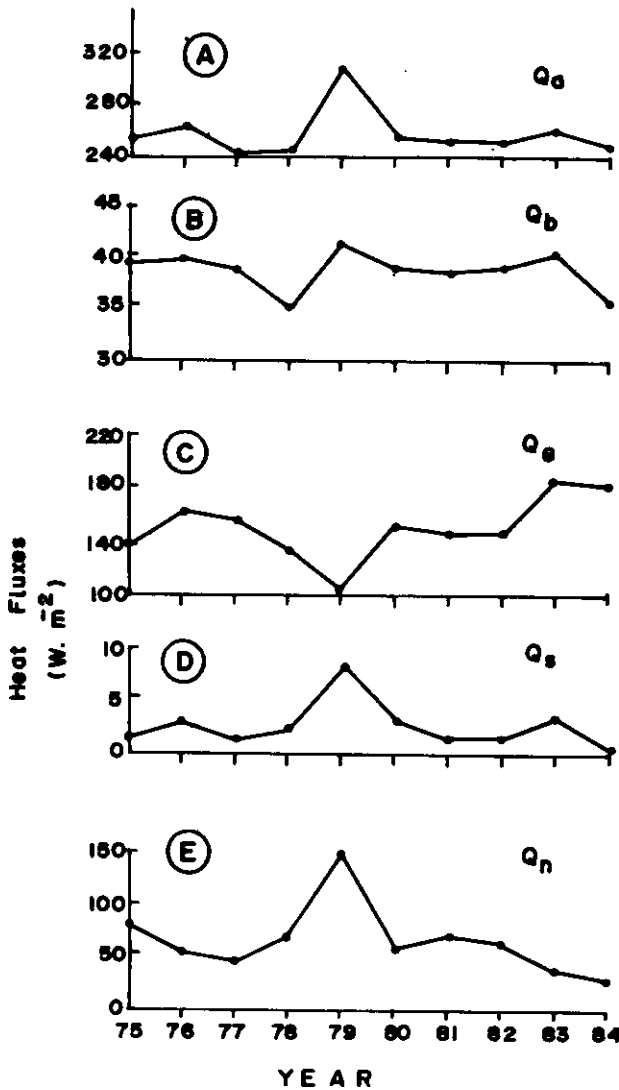


Fig. 2—Interannual variability of premonsoonal (April-May) areal averages of surface heat flux parameters over the eastern Arabian Sea

during 1975-1984 are shown in Table 1. Negative premonsoonal anomalies of wind speed (-2.7 m.sec^{-1}) and clouds (-2 octas) existed in 1979. Under such situations, larger heat absorption confines to shallower layer of the ocean causing positive anomalies in SST and thereby the vapour pressure gradient ($e_s - e_a$). However, it is the weak wind field mainly responsible for larger negative evaporative heat flux anomaly (-49 W.m^{-2}). The surface pressure was abnormally high ($+0.6 \text{ mb}$) during 1979, reflecting higher subsidence activity in the overlying atmosphere.

Excessive premonsoonal ocean warming in the eastern Arabian Sea does not likely to enhance ensuing monsoon rainfall even over the neighbouring

Table 1—Areal averages of surface meteorological parameters and heat fluxes over the eastern Arabian Sea during 1975-1984 and their anomalies in the active (1975) and weak (1979) monsoon years

Parameter/flux	Decade av. (1975-1984)	Active monsoon (1975)	Weak monsoon (1979)
SST ($^{\circ}\text{C}$)	29.5	-0.9	+0.8
N (octas)	2	1	-2
PPP (mb)	1009.2	-0.8	+0.6
FF (m.sec^{-1})	6.9	+0.2	-2.7
$e_s - e_a$ (mb)	10.1	-1.5	+1.9
Q_a (W.m^{-2})	258	-4	+53
Q_b (W.m^{-2})	39	0	+4
Q_c (W.m^{-2})	152	-16	-49
Q_d (W.m^{-2})	3	-2	+6
Q_n (W.m^{-2})	64	+14	+92

west coast of India and it gets manifested as the result of the higher atmospheric subsidence (positive surface pressure anomaly) over the area suggesting anomalous forcings from distant places. Several studies¹¹⁻¹⁷ have related the Indian monsoon to SST anomalies over the tropical Pacific Ocean region and Southern Oscillation Index. The present study further establishes the dominance of global forcings on the interannual variability of the Indian monsoon rainfall, and the influence of premonsoonal local warming in the seas around India is likely to be offset by these strong events. It is not advisable to issue a long-range forecast of good monsoon rainfall at west coast of India following simply a premonsoonal warm SST anomaly in the nearby eastern Arabian Sea. However, an examination of a longer time-series data is necessary for establishing the negative association of local premonsoonal Arabian Sea warming with the ensuing Indian monsoon before one could give weightage for the other distant forcing parameters in the multiple regression model of the Indian long range forecasting of the summer monsoon.

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