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SECULAR VARIATIONS OF SEA-SURFACE TEMPERATURE IN THE BAY OF BENGAL

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ABSTRACT

Secular variations of sea-surface temperature in particular and some atmospheric parameters in general in six different locations in the Bay of Bengal are studied using ship data for the decade 1970-1979. Some significant inter-annual and intra-seasonal variations in the sea surface temperature have been discussed

Key-words: SST, Bay of Bengal.

INTRODUCTION

The sea-surface temperature (SST), is a very important ocean parameter as it affects weather, climate and atmospheric circulation. Convection and convective precipitation over oceans and the neighbouring land regions, formation and development of tropical cyclones, location and displacement of the inter-tropical convergence zone and a number of other meteorological phenomena are known to depend on SST. Hastenrath and Heller (1977), Hirst and Hastenrath (1983) have related the droughts in northeast Brazil, Sahel and several African countries and the location of the ITCZ over Atlantic to SST anomalies.

Aperiodic warming of the surface waters of the eastern tropical Pacific ocean called *El Nino* phenomenon, which is found to occur once in a 3 to 7 years, has gained importance because of its close connection with the southern oscillation (SO) and its teleconnections with world wide climatic abnormalities (Bjerknes 1966, 1969; White and Walker 1973; Fleer 1977 and Pan and Oort 1983). Angel (1981) and Rassmusson and Carpenter (1983) reported significant negative effect of *El Nino* on the summer monsoon over India.

In the Indian Ocean area Sukla and Misra (1977) noted positive correlation between the SST in South Arabian Sea and the monsoon rainfall over Western and Central parts of India during July and August. Joseph (1981) reported that failure of the monsoon causes heating of the north Indian Ocean. Later Joseph and Pillai (1984) found positive correlation of monsoon rainfall with the SST of Arabian Sea during January to May and negative correlation with that in June to December. They also noted a 3-year periodicity in the SST patterns of the Arabian Sea.

In the Bay of Bengal, practically no studies have been made on the SST variations and its effect on the local climate. The authors in this paper have attempted to find out significant periods in the SST of Bay of Bengal in the range of sub-seasonal to inter-annual periods using the data for the decade 1970-79 and also the relationships between SST and some meteorological parameters. Subbaramayya and Rao (1984) have examined the mean conditions over the Bay of Bengal using the data for the same period and arrived at fairly reliable results. The current international programme on Tropical Oceans and Global Atmosphere envisaged for a period of 10 years is considered to be long enough for the study of inter-annual variations.

DATA

The sea surface temperature, air temperature, atmospheric pressure and wind data for the period 1970-1979 have been taken from the ship observations published in the Indian Daily Weather Reports. The distribution of number of observations for 5° lat/5° long. grid is given in Fig. 1.

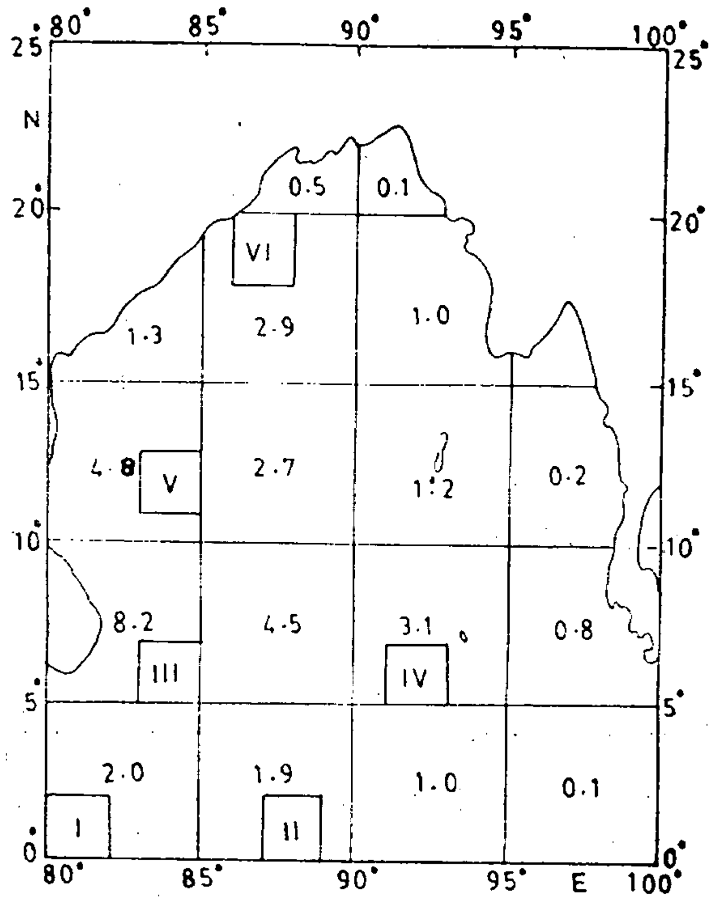

Fig. 1. Distribution of data (in thousands) and location of the six areas selected for time series studies.

2° lat/2° long. square areas have been selected in different localities of the Bay of Bengal in the high data density areas as shown in Fig. 1, for the present study of time variations of sea surface temperature and other atmospheric parameters and are labeled as I, II, III, IV, V and VI. The total number of observations in each square area are given in Table I.

Table 1. Number of observations in different squares

Square number	I	II	III	IV	V	VI
Total observations	382	624	1886	966	1374	661
Number of months with more than 3 observes	67	89	120	112	120	104
Number of months without observs.	13	9	0	0	0	0
number of months without SST observs.	16	13	1	2	10	25

In areas III, IV, V and VI, there are no individual months in the ten-year period without any observations and in regions III an V there are three or more observations in every month while in IV and VI there are 112 and 104 such months respectively.

The number of SST observations have been found to be somewhat less than the other observations. However, the SST data are fairly good in the first five regions while in the region VI there are considerable number of missing months. Nevertheless the authors have attempted time series analysis of data in all the six areas.

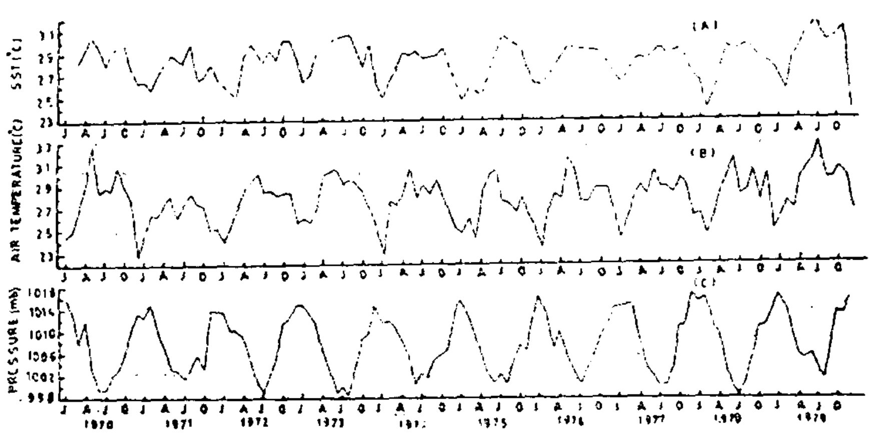

Fig. 2. Monthly variations of (A) Sea-Surface Temperature (B) Air temperature (C) Atmospheric Pressure for region VI.

Time variations of ocean and atmospheric parameters

The monthly mean values of different parameters when plotted in the time series form (graphs for region VI are presented in Fig. 2 as an example) showed systematic long-period variations besides the annual cycle. The annual cycle was quite dominant in regions V and VI while it was comparable to the long-period variations in III and IV regions. The annual cycle though was less prominent in regions I and II, but it was conspicuously prominent in region II, during the 1974-76.

The averages for the different calender months over the 10-year period for each of the parameters in each region are evaluated and their mean annual variations are presented in Fig. 3. It can be seen that the annual range of SST variation is around 1° C in the Equatorial region and it increased to 4°C in the area VI which lies in the latitude band 18-20° While the SST and air temperature variations are similar, the variations in the atmospheric pressure are opposite to those of the SST.

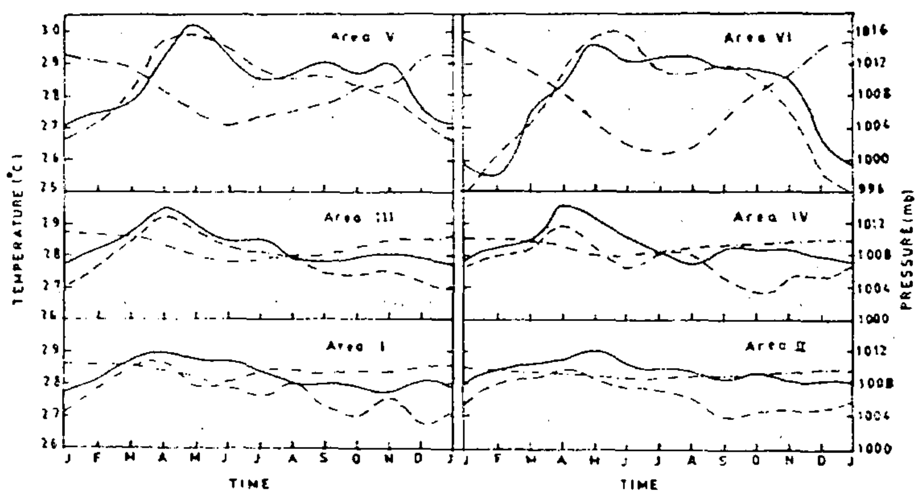

Fig. 3. Mean annual variations of Sea-Surface Temperature (———), Air temperature (- - -) and Pressure (-·-·-) in the six selected areas.

In all the six regions, the air temperature showed good positive correlation ranging from 0.40 to 0.74 with sea surface temperature. The atmospheric pressure did not show significant correlation (either positive or negative) in the first four areas which actually lie in the Equatorial region, while in regions V and VI, significant negative correlations (-0.50 and -0.63) have been noted. The calendar-month mean values are subtracted from the respective individual monthly mean values to eliminate the annual cycle and correlations between the residuals of SST and pressure also have been calculated. These correlations varied from 0.50 to 0.68 in five of the six regions. This shows that the rise/fall of the sea surface temperature in the annual mode of variation results in decrease/increase in the pressure while in the interannual and probably the other modes of variation, the rise/

fall of SST would contribute to increase/decrease in the atmospheric pressure. The former relationship is understandable but the later needs explanation.

The mean monthly SST anomalies, obtained by subtracting the calendar-month averages from the individual monthly means as mentioned above, in the six areas are presented in Fig. 4. The anomaly values are smoothened by 12-month moving averages and are presented in the same diagram. They clearly indicate the existence of long-period variations which may have periods ranging from 2 to 5 years besides some short-period variations as mentioned earlier. To get a precise idea of the apparent periodicities the anomaly values are subjected to power spectrum analysis.

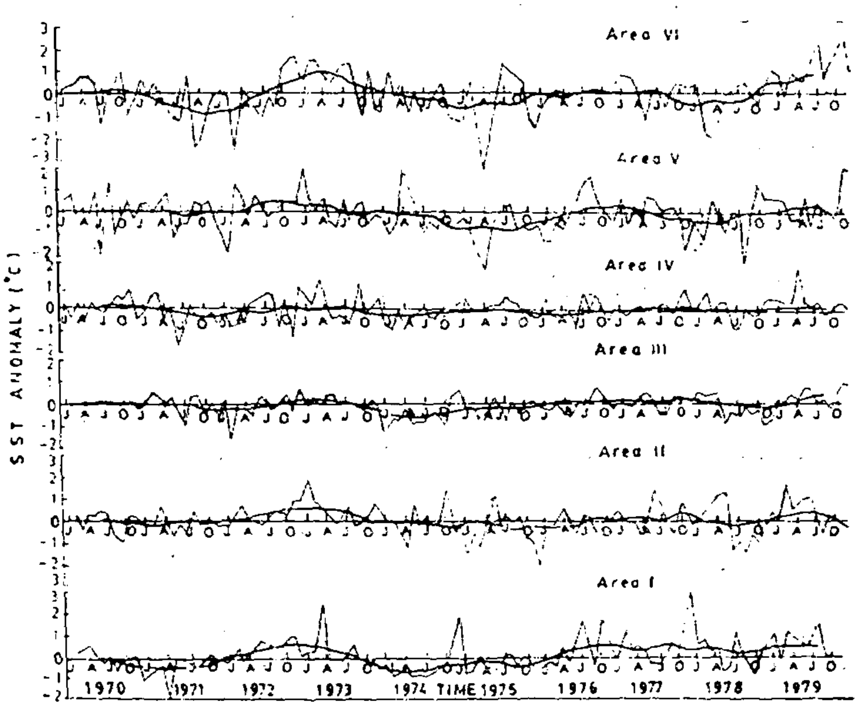

Fig. 4. Sea-Surface Temperature anomalies.

Power Spectra

Power spectra are evaluated using the procedure described by Maruyama (1968). Power per unit frequency at an interval of ½ M Δt in the frequency range O to ½ Δt is obtained by the equation

$$P_k = 4 \Delta t \sum_{L=O}^{M} V_L \cdot \cos \frac{KL\pi}{M} \cdot D_L \, \delta L$$

wher P_K is power at frequency $K/2M \Delta t$, V_L is autocovariance of the time series of length n for lag L, Δt is the time interval between the time series and is one month in the present case, M is maximum lag, k=0, 1, 2, 3,.... M,

$$D_L = Cos^2 \frac{L\pi}{2M}, \text{ and } \delta L = \tfrac{1}{2} \text{ for } L = 0, M \text{ and } 1 \text{ for } L = 0, M$$

The significance of any power maximum is determined from its deviation from the null continuum. In the case of white noise, the average of all the spectral estimates is taken as the null continuum value. In the case of red noise i.e., when the lag one auto correlation coefficient is significant, the null continuum at different values of k is calculated by the equation

$$S_K = \bar{S} \left[\frac{1 - r_1^2}{1 + r_1^2 - 2 r_1 \cos \frac{k}{M}} \right]$$

where $\bar{S}$ is the average of the spectral estimates, r_1 is the lag one auto correlation coefficient.

The values of the null continuum, whether it is white or red noise, are multiplied by the $\chi\nu/\nu$ values at 95% confidence limit, where ν is degree of freedom and is given by $\frac{2n-M/2}{M}$. If any spectral estimate exceeds the 95% confidence limit, it is considered to be significant.

The power spectra of sea surface temperature in the six areas are presented in Fig. 5. Power peaks at 2.3 months period in areas II and III and at 2.8 month in area IV are significant at the 95% level. In area I there are two power peaks at 3.3 and 4.1 months periods which are also significant at the 95% level. In area V there is one power peak at 3.2 months period but is not statistically significant. The statistical significance of the power peaks in general and their occurrence in the contiguous areas I to V suggest that there is a significant 2.2 to 4.1 months period in the south Bay of Bengal. The power in this range is highest in area IV. Hence it is possible that the origin of this period could be around the Andaman Sea region. Significant SST fluctuations of 2 to 3 months period have been reported in other tropical ocean also (Lau., Boyle and Chang, 1984).

There is a significant power peak at 11-months period in area II. This was due to the pronounced annual cycle in the years 1974 to 1976 as mentioned earlier. Because of this non-uniformity of the annual variations in different years, the filtered time series still contained as significant annual cycle.

Two power peaks appeared at 27-months period in areas III and IV. These peaks obviously correspond to the quasibiennial oscillation, but they did not

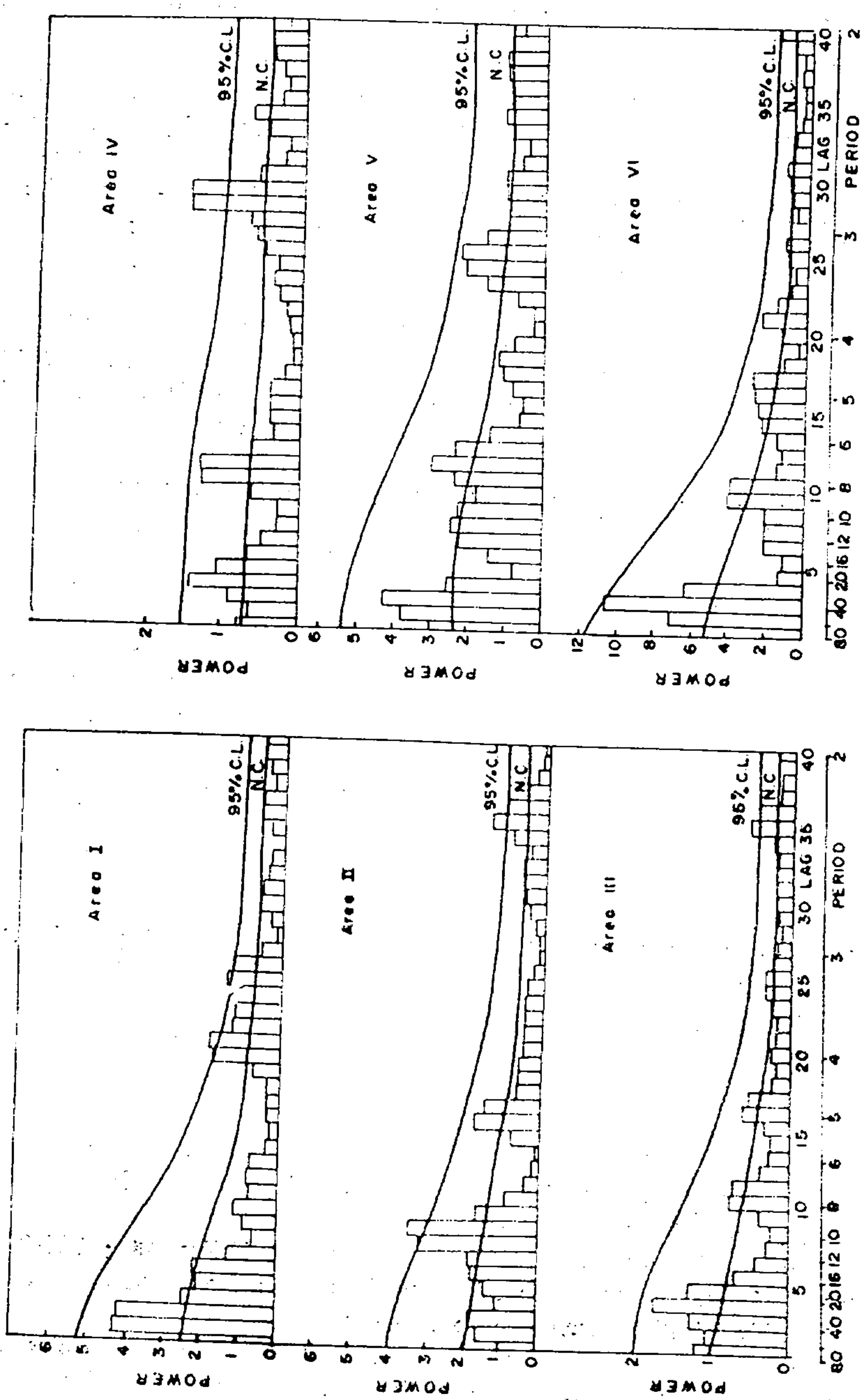

Fig. 5. Power spectra of Sea-Surface Temperature anomalies.

come out as statistically significant peaks and were also not observed in the other areas.

In areas V and VI, there are power peaks at the 40-months period. The peak in area VI is significant at the 95% level. The smoothned lines in Fig. 4 corresponding to area VI show prominent minima around October, November & December of 1971; November, December and January of 1974-75 and October and November of 1978; and maxima around February, March and April of 1973; September, October & November of 1976 and October, November & December of 1979. The periods of maxima in the present case agree with the occurrence of the *El Nino* phenomenon of 1972-73, 76-77 and 1979-80. Maxima and minima can also be observed in the area V during the same seasons as that in area VI. These maxima and minima must be essentially responsible for the observed peak at the 40-months period in the power spectrum. A 3-year period in the monsoon rainfall and the Arabian Sea surface temperature was reported by Joseph and Pillai (1984). Similarlly a 3-year period in the post-monsoon cyclones of the Bay of Bengal was earlier reported by Subbaramayya and Rama Mohana Rao (1984). All these observations firmly indicate the existence of a 3.0 to 3.5 year period variations in the climate over India and neighbouring seas.

It may therefore be stated that there is no significant correlation between the atmospheric pressure and the sea surface temperature in the equatori l region but there is good negative correlation at relatively higher latitudes. The negative correlation is found to be due to essentially the annual cycle in the two parameters. When the annual cycle is eliminated, the two time series showed a significant positive correlation in almost all the six areas indicating possibly an atmospheric control on the variations.

There is a clear indication of the existence of a 2 to 4 month period variation in the SST of the equatorial region while at higher latitudes in the north Bay there is a pronounced 40-month period.

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