Mausam, (1980), 31, 4, 601-608

551.526.6 : 551.54(267)

A study of sea surface temperature and pressure patterns over the Indian Ocean regions in some years of contrasting SW monsoon rainfall in India

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(*Received 24 April 1979*)

ABSTRACT. A study is made of the sea surface temperature and pressure patterns for different months over Indian Ocean (north of 15 deg. S and between 40 deg. E and 100 deg. E) with the help of marine annual summary data published for the years 1961, 1964 and 1965, 1966.

The zone of warmest sea surface waters during the months of April and May was observed to be located northward in the years 1961 and 1964, the years of good monsoon over India as compared to 1965 and 1966, the years of bad monsoon over India. The values of SST were also higher for most of the oceanic areas in the years 1961 and 1964 as compared to 1965 and 1966.

Well defined pressure patterns with isobars 1008 and 1009 mb encircling and pressure gradient directed towards Indian Peninsula were observed during the months of April in 1961 and 1964 but in 1965 these features in the pressure pattern were absent.

A general fall of SST values ranging from 1 deg. to 3 deg. C was observed during the monsoon months in most of the oceanic areas.

Besides, a study has been made of the seasonal variation of SST and pressure and some probable explanation has been offered for the appearance of coldest waters along north Somali coast to east Arabia coast during monsoon season (June to September).

1. Introduction

In recent years a number of studies have been made on the sea surface pressure (SSP) and sea surface temperature (SST) patterns over the tropical Atlantic and East Pacific Oceans with respect to the extreme climatic events in sub-Saharan region of Africa (10-20 deg. N) and some key regions of tropical Americas. While studying the two contrasting sub-Saharan rainy seasons (July-September) of 1968 and 1967, Lamb (1978a) found that the near equatorial pressure trough and the zone of maximum sea surface temperature (SST) were located 300-500 km further south in the deficient rainy season. In another similar type of study Lamb (1978b) observed that the North Atlantic subtropical High (NAH) extended equatorward from average in case of dry season. Similarly Hasternath (1978) prepared departure maps of sea surface pressure and sea surface temperature for the tropical Atlantic and Eastern Pacific Oceans and studied their relationship with the extreme climatic events like drought in Central American Caribban regions and northeast Brazil and Elnino along the Ecuador/Peru coast of South America.

In the present paper study is made of the sea surface temperature and pressure patterns for different months over the Indian Ocean (north of 15 deg. S and between 40 deg. E and 100 deg. E) with the help of marine annual summary data published for the years 1961, 1964, and 1965, 1966 to correlate them with the contrasting southwest monsoon activity. The years 1961, 1964 and 1965, 1966 are the two contrasting sets of good and bad southwest monsoon rainfall years for India,

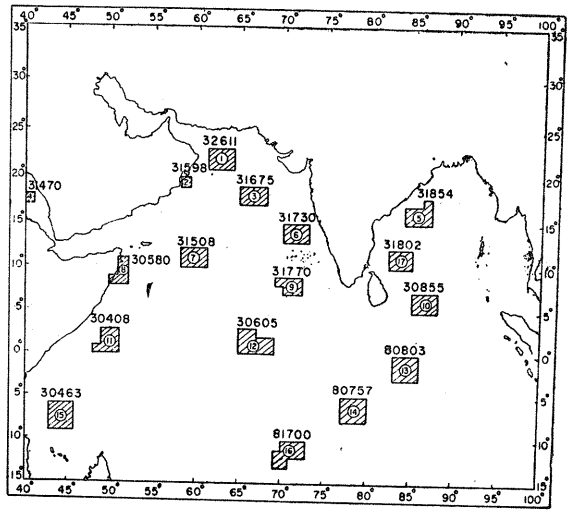

Fig. 1. 17 selected representative areas for which annual climatogical summaries are prepared (Figs. within area—S. No. of the area; 5-digit No. above area—WMO index of area)

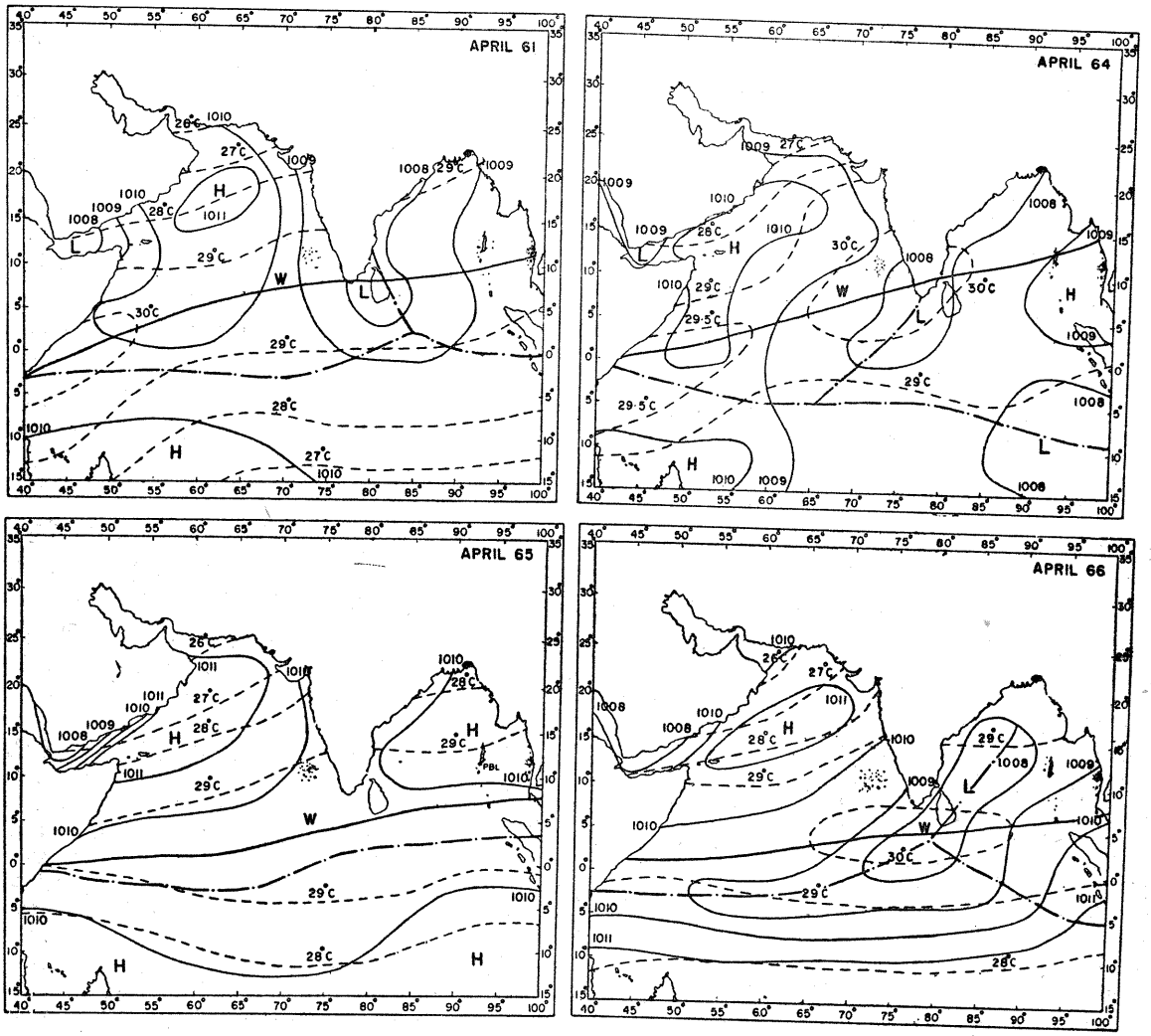

Fig. 2. Sea surface pressure and temperature (SST) patterns for the month of April 1961, 64, 65 and 66
(1) —— Isobars, (2) - - - - Isotherms, (3) — - — - — Pressure trough axis,
(4) —— Thermal ridge axis)

2. Data used

India is one of the nine 'responsible member' countries charged with the responsibility (under WMO Fourth Congress Res. No. 35) of preparing annual marine climatological summaries beginning from 1961 of surface meteorologocal observations recorded mostly by ships of national as well as international voluntary observing fleet (VOF). Three such annual summaries for the years 1961, 1964 and 1965 have been prepared and printed whereas fourth summary for the year 1966 is under print. In these summaries detailed frequency tables etc are prepared for different areas (Fig. 1) fairly uniformly distributed over the area of responsibility. Monthly averages of various parameters, like dry bulb temperature, dew point temperature, sea surface temperature, barometric pressure for the main synoptic 00, 06, 12, 18 hours including one for all hours are also given for each area. Incidentally, the years 1961 and 1964 were marked for good rainfall activity during southwest monsoon season in India while in 1965 and 1966 rainfall was deficient. Pressure and temperature fields over the oceanic areas were critically examined in these two sets of years of contrasting monsoon rainfall over India with a view to identify the difference in the organisation of their mean pattern in various months and whether such difference in patterns could be useful for an advance prediction of good and bad monsoon rainfall in India.

3. Discussion

3.1. *Sea level pressure*

Mean seal level pressure values were analysed for the months April, May, June, July, August and September for years 1961, 1964, 1965 and 1966. Except in the month of April the pressure patterns in the months May, June July, August and September were found to be similar in the two contrasting monsoons. The pressure gradient in these months was mainly directed from south to north. The highest pressure values were invariably found in the southwest sector (Area 15 of Fig. 1) with the axis of the pressure ridge oriented from SW to NE extending to southeastern Arabian Sea. The lowest pressure values were found over head Bay of Bengal, where eastern end of the seasonal monsoon trough lay. Secondary low occurred over north Arabian Sea. However, it was observed that except in the month of May, the pressure values in June, July, August and September were higher in most of the oceanic area in 1965, a year of bad monsoon, as compared to those in 1961 and 1964 when monsoon rainfall was good over India.

A difference was however noticed in the structure of the pressure field of April 1961, 1964 from that of April 1965 (Fig. 2). Closed isobars of 1008 mb and 1009 mb were encircling India from Arabian Sea to Bay of Bengal with pressure gradient directed towards land from all sides in both the years of 1961 and 1964 whereas this pattern was not present in 1965. The pressure values were higher for most of the oceanic areas in 1965 than in 1961 and 1964. 1966 was also a year of bad monsoon. But the pattern of pressure field in this year was closer to those of 1961 and 1964 (Fig. 2d) than of 1965. The mean April pressure value in Bay of Bengal was reduced by the formation and intensification of cyclonic storm in the region during the past weak of April 1966. However, the pressure values in Arabian Sea continued to be higher in 1966 as compared to those of 1961 and 1964.

3.2. *Sea surface temperature (SST)*

The SST charts of April, May, June, July, August and September for the years of 1961, 1964, 1965 and 1966 were prepared and analysed. The axis of warmest waters (thermal ridge) was located north of equator in April and ran northeast to southwest, from Bay of Bengal to east Somali coast. A general rise of temperature and northward movement of the thermal ridge was observed in May when the temperature rose to 30 deg. C and above around the ridge axis. However, near Somali coast the portion of the ridge axis remained unchanged and was same as in April. This axis of warmest waters moved further northward in the head Bay of Bengal and northeast Arabian Sea in June but a general fall of temperature was observed in this month in most of the oceanic areas and continued through July. The fall was found to be maximum in August. In July a second axis of warm waters appeared in the equatorial region and remained there in August also. The general cooling that was noticed in Arabian Sea, Bay of Bengal and the rest of Indian Ocean may be due to evaporation as can be inferred from the evaporation charts of Venkateswaran (1956) for the months June to August. The excessive cooling off north Somali and east Arabian coasts may be attributed to the additional factor of upwelling ocean currents under the influence of cross equatorial southerly and southwesterlies as was pointed out by Colan (1964). In this transition month of September, the axis of warmest waters was again discernible running from north head Bay of Bengal to equator in the south central Arabian Sea.

An examination of the SST charts for April and May (the pre-monsoon months) showed that the axis of warmest waters was located more northward in 1961 and 1964 (the years of good

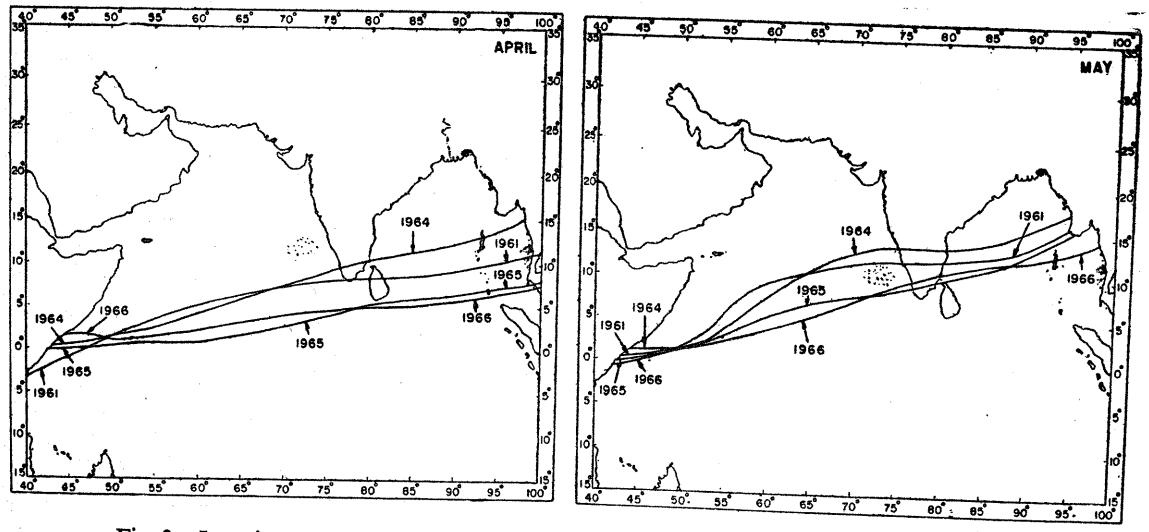

Fig. 3. Location of thermal ridge (warmest nature) in April & may for the years 1961-1966

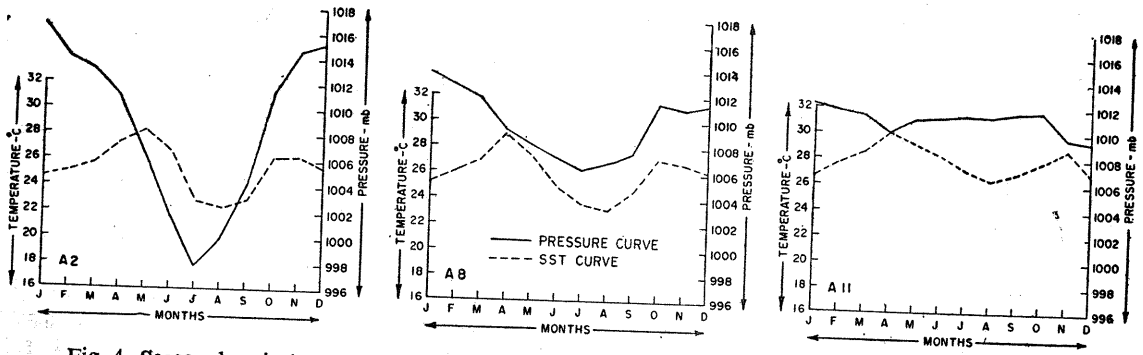

Fig. 4. Seasonal variation of sea surface temperature (SST) and pressure for areas A2, A8 & A11 along Arabia & Somali coast

SW monsoon in India) as compared to its position in 1965 and 1966 (the years of monsoon failure — Fig. 3). The temperatures were also higher for most of the oceanic areas during these two months in 1961 and 1964 than in 1965 and 1966. This contrasting feature may provide a useful index for future behaviour of monsoon.

3.3. *The seasonal variation of pressure and SST*

The seasonal variation of the pressure and SST values in the year 1961 for the areas 5, 17, 10 along east Indian coast; 3, 6, 9 along the west Indian coast and 1, 2, 8 along the east Saudi Arabia and north Somali coast and for the areas 11, 12 and 13 along the equator are shown in Fig. 4 and have been discussed below:

3.3.1. *Pressure*

Table 1 gives the departure of pressures values for April, July and October from January for

TABLE 1

Seasonal variation of pressure along the coastal areas difference of pressure values of the representative months from the month of January)

	Jan-Apr (mb)	Jan-Jul (mb)	Jan-Oct (mb)
East Arabian and Somali coast			
A1	6.0	19.1	4.9
A2	5.7	18.8	5.3
A8	3.9	13.6	3.6
A11	2.3	1.0	0.6
West coast of India			
A3	3.9	13.6	3.6
A6	3.4	5.9	1.8
A9	2.0	2.5	0.9
East coast of India			
A5	7.0	13.1	5.9
A17	3.9	6.6	2.4
A10	2.2	2.3	0.9

Note : A1, A2 etc. refer to areas marked in Fig. 1 as 1' 2, ... etc.

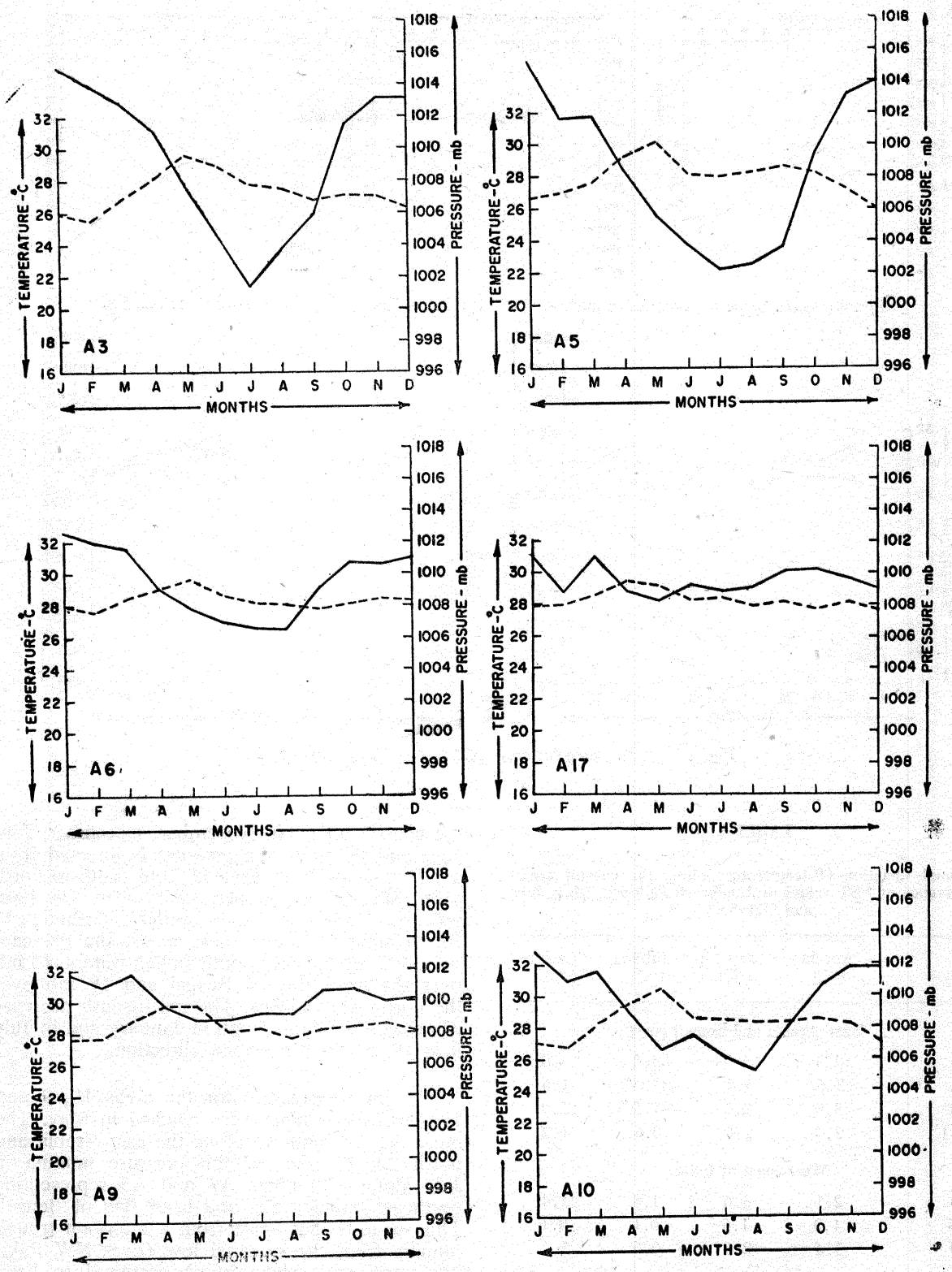

Fig. 4 (*contd.*) Same for Areas A3, A6 & A9 along west coast & areas A5, A17 & A10 along east coast of India

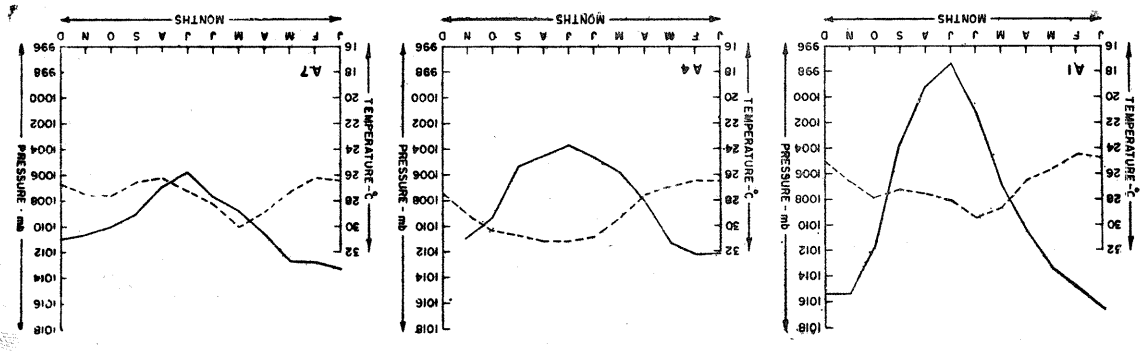

Fig. 4 (*contd*). Same for area A1 in norh Arabian Sea, A4 in Red Sea & A7 in central Arabian Sea

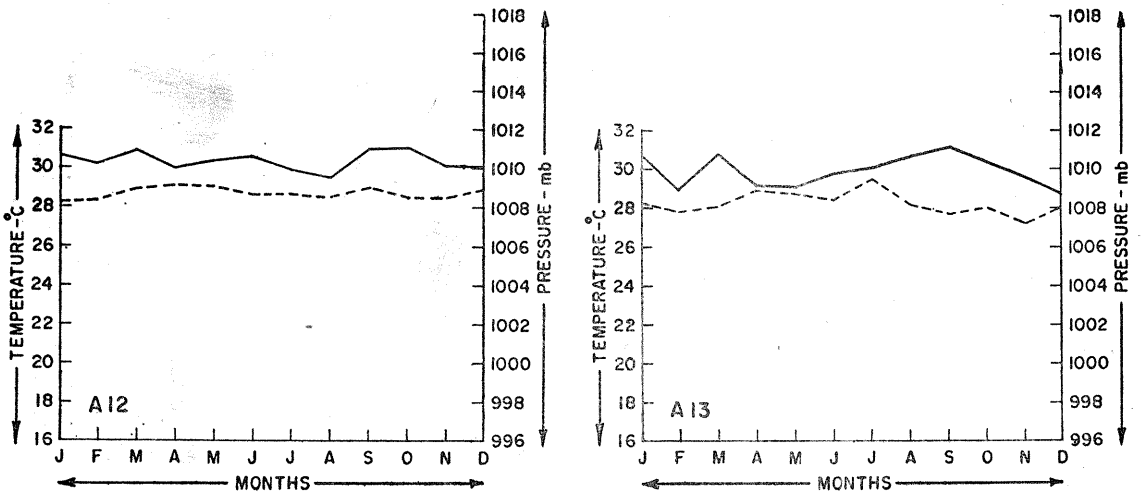

Fig. 4 (*contd*). Same for areas A12 & A13 along equator

TABLE 2

Seasonal variation of temperature along the coastal areas (Difference of SST values of January from April, May, July and October)

	Apr-Jan (°C)	May-Jan (°C)	Jul-Jan (°C)	Oct-Jan (°C)
East Arabia and Somali coast				
A1	1.7	3.9	3.2	3.0
A2	2.6	3.4	—2.0	1.6
A8	3.8	2.2	—1.5	1.9
A11	3.4	2.6	0.6	1.2
West coast of India				
A3	2.1	3.6	1.8	1.4
A6	1.0	1.6	0.1	0.1
A9	3.4	2.6	0.6	1.2
East coast of India				
A5	5.2	5.9	5.2	4.0
A17	2.5	3.4	1.4	1.4
A10	1.6	1.3	0.5	—0.2

the coastal areas. In November, December, January and February the pressure is directed from north to south. It is directed from south to north from May to September. The mean sea level pressure decreases from January (winter) to July (Summer) along these areas, the decrease being 2.5 mb over the south Indian waters, 13 mb over the head Bay of Bengal and 19 mb over the north Arabian Sea. The north-south decrease of pressure is about 5 mb in January and in July it is 12 mb in the reverse direction.

The lowest pressure for the areas 10, 9 and 17 (primary minima) are reached in May. The areas A1, A2 and A3 along the east Arabia and north Somali coast exhibit pressure minima in July along with areas A3 and A5 representing northeast Arabian Sea and head Bay of Bengal. This suggests that apart from a monsoon trough running from the seasonal low (over NW Pakistan, Iran and Afghanistan) eastward to head Bay of Bengal, another low pressure trough emanating from it perhaps runs southwestward along east Arabia and north Somali coast where a steep pressure fall is observed from January to July.

TABLE 3

Mean SST anomaly in °C for different monsoon months from January values along representative coast area

	1961				1964				1965				1966			
	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
East Arabia and Somali coast																
A2	+2.1	—1.8	—2.2	—0.6	+2.6	—1.0	—3.0	+0.6	+1.1	—0.8	—0.9	+1.6	+1.5	—0.6	—1.1	+0.7
A8	—0.2	—1.5	—2.0	—0.6	—1.5	—3.1	—5.9	—3.8	—2.1	—1.2	—1.2	—2.1	—2.2	—3.4	—2.4	—1.9
A11	+1.7	+0.6	—0.2	+0.3	—0.1	—1.7	—1.3	—1.4	+1.0	—0.9	+0.1	+1.1	+0.0	—0.5	—1.1	—0.3
Kerala coast																
A9	+0.4	+0.6	+0.0	+0.5	—0.7	—0.3	—0.3	—1.0	+1.2	+0.7	+0.5	+0.4	+0.8	+0.1	+0.1	+0.3

3.3.2. *Sea surface temperature (SST)*

Table 2 gives the departure of SST values for the months of April, May, July and October from January. This reflects following significant features :

(*i*) SST values over Somali coast (A8) and Arabia (A2) are least during July (monsoon month). The same is true for region A11 (close to equator near east Africa coast). Near north-west Arabian Sea (A1) the SST is least during April. This is probably so because this region is least influenced by monsoon activity.

(*ii*) Over west coast of India, represented by regions A3, A6 and A9, the SST values are generally least during the month of July. Although October values are also not very different than July.

(*iii*) Over Bay of Bengal and adjoining east coast of India, SST values are least during October month, July being next to that.

Similar information for a few regions A2, A8, A11 (east Arabia and Somali coast) and A9 (Kerala coast) for individual years 1961, 1964, 1965 & 1966 for the monsoon months (June to September) is given in Table 3. It is interesting to note that during 1961 and 1964 (good monsoon years), August is generally the month of the least SST value whereas the same is not true during 1965 and 1966 (below normal monsoon years).

3.3.3. *SST and pressure field*

In Fig. 4 has been presented seasonal variation of SST and pressure field for various regions in Arabian Sea and Bay of Bengal. The interesting features which these plots bring out may be summarized as follows:

(*i*) Variations in pressure and SST values are in the same phase beyond April for region A2, A8 (Arabia) and A7 (central Arabian Sea). These are in opposite phase for A11 (Somali coast), A4 (north Arabian Sea) and nearly in same phase for A3 (north Arabian Sea), A5 (Bay of Bengal), A10 (south Bay of Bengal) and apparently indifferent in other regions.

(*ii*) Maximum variation in seasonal SST in encountered in the region A2 which is 6 deg. C, being minimum during August and maximum in May. In the other regions the variation is of the order of 2 deg. C.

(*iii*) Significant pressure variation of the order of 18 mb is noticed in the regions A1, A2, A3, A4 and A5. In the other regions the pressure variation are less significant.

4. Conclusion

(1) Well defined pressure pattern with isobars of 1008 and 1009 mb encircling and the pressure gradient directed towards Indian Peninsula was observed during the month of April in 1961 and 1964, the years of good monsoon but was absent in 1965 when monsoon rainfall was deficient over India.

(2) The pressure values were also generally found to be lower in most of the oceanic areas during the monsoon months in 1961 and 1964 as compared to those in 1965 and 1966. They were in particular lower over Arabian Sea during the month of April.

(3) The axis of thermal ridge for SST during the months of April and May was found to be located northward in the years 1961 and 1964 as compared to 1965 and 1966. The values of

SST were also comparatively higher in most of the oceanic areas in the years 1961 and 1964.

(4) A general fall of SST values ranging from 1 deg. to 3 deg. C, was observed during the monsoon months in most of the oceanic areas.

(5) The low pressure trough running NE to SW along east Arabia and north Somali coast appears to be responsible for the strong cross equatorial southerly or southwesterly winds in this region which in turn appear responsible for coldest waters for reasons of upwelling.

Acknowledgement

The author is grateful to Dr. R. P. Sarker, Deputy Director General of Meteorology (Climatology & Geophysics) for encouragement and Shri A. K. Banerjee and Shri T. S. S. Anjaneyulu, Meteorologists for valuable discussions.

References

Colon, J.A., 1964, On the interaction between the southwest monsoon current and the sea surface over the Arabian Sea, *Indian J. Met. Geophys.*, **15**, pp. 183-200.

Coney, Danyl L. and Hasternrath, Stefan, 1978, The Pacific Elnino Phenomenon and the Atlantic Circulation, *Month. Weath. Rev.*, **106**, **9**, 1280-1287.

Hasternrath, Stefan, 1978, On Modes of Tropical Circulation and Climatic Anomalies, *J. atmos. Sci.*, **35**.

Jambunathan, R. and Ramamurthy, K., 1975, Sea and air temperature distribution over the Arabian Sea during southwest monsoon, 1973, *Indian J. Met. Hydrol. Geophys.*, **26**, 4, pp. 465-478.

Keshavamurthy, R.N., Korkhao, J.M., Das, S.K. and Mukhopadhya, R.K., 1975, The Indian Summer Monsoon and Variation of Ocean Temperature over the neighbouring seas, Pre-Pub. Sci. Report 220.

Lamb, P.J., 1978(a), Case Studies of Tropical Atlantic Surface Circulation Patterns during recent sub-Saharan Weather Anomalies 1967 and 1968, *Mon. Weath. Rev.*, **106**, 4, p. 482-491.

Lamb, P.J., 1978(b), Large Scale Tropical Atlantic Surface Circulation Patterns associated with sub-Saharan Weather Anomalies, *Tellus*, **30**, 3, pp. 240-250.

Venkateswaran, S.V., 1956, On evaporation from Indian Ocean, *Indian J. Met. Geophys.*, **7**, 3, pp. 265-283.