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SURFACE TEMPERATURE PATTERN OF THE INDIAN OCEAN BEFORE SUMMER MONSOON

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ABSTRACT

The surface meteorological data collected during 1963 and 1964 indicate that the northward migration of the ITCZ is associated with a shift of the warm waters to the northern Indian Ocean. The warmer waters, found in the equatorial regions during the northern winter, shift northward during spring and this shift is completed by the end of May, the begining of the summer monsoon. The shifting of the warm water pool from winter till the begining of the summer monsoon, during the period 1981 to 1984, suggests that the position of the warmer areas in the Bay of Bengal in May is an indicator of the subsequent summer rainfall over India.

The statistical method adopted for the long range forecasting of the Indian summer monsoon gives very little consideration to the cause — effect relationships. None of the oceanic parameters is considered for this prediction. The storage and release of the thermal energy in the upper layers of the ocean is one of such parameters. For the lack of this information, a related parameter, the sea surface temperature is considered for a discussion on its relationship to the summer monsoon rainfall over India.

Key-words: Sea surface temperature, monsoon, Indian Ocean.

INTRODUCTION

The need for long range forcasting of the summer monsoon rainfall over India was felt as early as 1880. In 1924, Sir Gilbert Walker came out with a statistical method for forcasting the monsoon rainfall with the help of six predictors. This technique was very useful till 1950 (Das, 1968). Since then the Indian mertcorlogists have modified this method. However, statistical methods give no physical explanation of the way it predicts the rainfall amount. Though the rainfall is ultimately due to the water evavoparated from the seas, none of the oceanic parameters is considered for the present day forcast of the summer rainfall. One of such oceanic parameters is the sea surface temperature (SST).

A number of attempts have been made to understand the connection between the Indian Ocean SST and the summer monsoon rainfall (Jambunathan and Ramamurty, 1975; Keshavamurty, Korkhao and Das 1975; Shukla and Mishra, (1972); Mishra, 1981; Pisharoty, 1981; and Gadgil, Joseph and Joshi 1984). Statistical relationships between the Indian summer rainfall and the SST over the Pacific Ocean have also been attempted (Weare, 1979; Cadet and Reverdin, 1981. Pan and Oort, 1981; and Rasmusson and Carpenter, 1983). A number of model studies on the effect of variations of SST at selected regions in the Indian Ocean and its effects on the rainfall variation over India have also been undertaken. But these studies have not led to any conclusive results and some times the results are even contradictory. (Gadgil, Joseph and Joshi, 1984). They report that the SST over the Indian Ocean is not a major contributing factor on which depends the cloudiness and rainfal over the region.

The link between the atmospheric energy source and the ocean energy storage and release is reflected in the SST. However, the measured SST always represents only a thin surface layer of thickness varying from a few millimeters in the remote sensed data to a few meters in the ship sensed data. It is probably the heat content of the upper mixed layer, that is, the ocean thermal energy which may have a long lasting effect on the summer rain fall over India. In the absence of this information, SST is the next best parameter that can be considered and the discussion is a qualitative one, as quantitative relationship may not be realistic. There is also a link between the Indian summer monsoon and the global weather system. It appears that the cloud cover and rainfall over India is only a branch of a much larger region of convergence, cloud cover and precipitation existing around ranges of latitudes 10 to 20° N, and longitudes 120 to 130°E during the northern summer. This connection is evident from a number of recent works (Weare, 1979; Fleer 1981; Rasmusson and Carpenter, 1983; Shukla and Paolino, 1983; Bhalme, Mooly and Jadhav, 1983; and Parthasarathy and Pant, 1984). This paper deals with the monthly variation of the SST over the Indian Ocean before the monsoon and tries to relate it to the subsequent rainfall over India.

DATA AND ANALYSIS

The climatological data of SST on a monthly average basis has been used as the basis for this study. The data on SST and wind field for 1963 and 1964 have been adopted from Ramage, Miller and Jefferies (1972). The Global Ocean SST composite charts for the Indian Ocean supplied by NOAA, for the period 1981 to 1984 have also been utilised for this study. These data were obtained with the help of VHRR on TRIOS N series of polar orbiting satellites. The space resolution of the data is about 1° and the accuracy of the temperature measurement is about 1°C.

Certain critical values of SST are recognised in the meteorological literature. One is the Palman's threshold of 26.5°C, which is the minimum temperature required for the formation of the tropical cyclones. Another critical value is 28.5°C, Bjerknes's lower limit of SST, above which high rainfall rates were observed in the central Pacific Ocean. Here, 29°C is used to represant the Bjerknes's limit, because of lack of accuracy in the data used. The areas of temperature more than 29°C, called the warm pool, can be recognised in the central Indian Ocean and its limits in the south and north can easily be identified. The position of the warm pool in the Indian Ocean is traced and its boundaries are obtained on a monthly basis.

RESULTS AND DISCUSSION

The climatological monthly mean values of SST indicate that the southern Indian Ocean remains relatively cool throughout the year. A broad zone of temperature maximum occurs in the equatorial belt between November and February. From March to May, the zone of maximum temperature is displaced north of the equator. In contrast, the south China Sea present a somewhat different pattern, with a strong meridional temperature gradient during November to February. It weakens during March to May and disappears only by June.

The climatic mean position of the equatorial convergence zone is between 10°N and 15°S during the period November to February. The area of convergence slowly moves northward between March and April, while divergence exists in the northern Arabian Sea, Bay of Bengal and South China Sea. This is replaced by convergence only with the advent of the south west monsoon. The pattern of precipitation nearly follows the pattern of convergence in this area.

The existence of the teleconnection between the Indian summer monsoon rainfall and the Walker Circulation and the Southern Oscillation (SO) has been indicated by a number of studies. The SO is characterised by the switching of pressure systems between eastern and western equatorial Pacific Ocean and also an east ward shift of the Walker Circulation. This pressure change is associated with a shift in the warm water pool from the western part of the equatorial Pacific Ocean to the east. The equatorial warm pool, according to Bjerknes (1969) is a region of large scale upward transport of moisture and is the main branch of the Walker Circulation. An examination of the global SST distribution shows that an arm of this warm water pool in the Pacific Ocean extends to the Indian Ocean through the Bay of Bengal. It is known that the ITCZ in the equatorial Indian Ocean shifts to about 20°N, over the land, with the advent of the south west monsoon. Since the warm water pool first covers Bay of Bengal before the Arabian Sea, the movement of the ITCZ also may be in a similar manner. The observation of Krishnamurti (1980) that the centre of the divergent circulation at 200 mb during the good summer monsoon of 1967, was centered around 20°N, over the Bay of Bengal, perhaps supports this view.

The climatological monthly space variation of the warm water pool in the Indian Ocean, represented by its northern and southern boundaries, are presented in Fig. 1 (a) and 1 (b). In certain years, the equatorial reagion is cooler than 29°C during January and February. In such cases the 28°C limit has been used to demarcate the boundaries. In January and February, the warm pool is in the equatorial region, with a northward tilt in the eastern Indian Ocean. The pool slowly shifts its position northward from March and by May the entire Bay of Bengal is covered by the warm pool, while in the Arabian Sea and the South China Sea it does not reach 20°N.

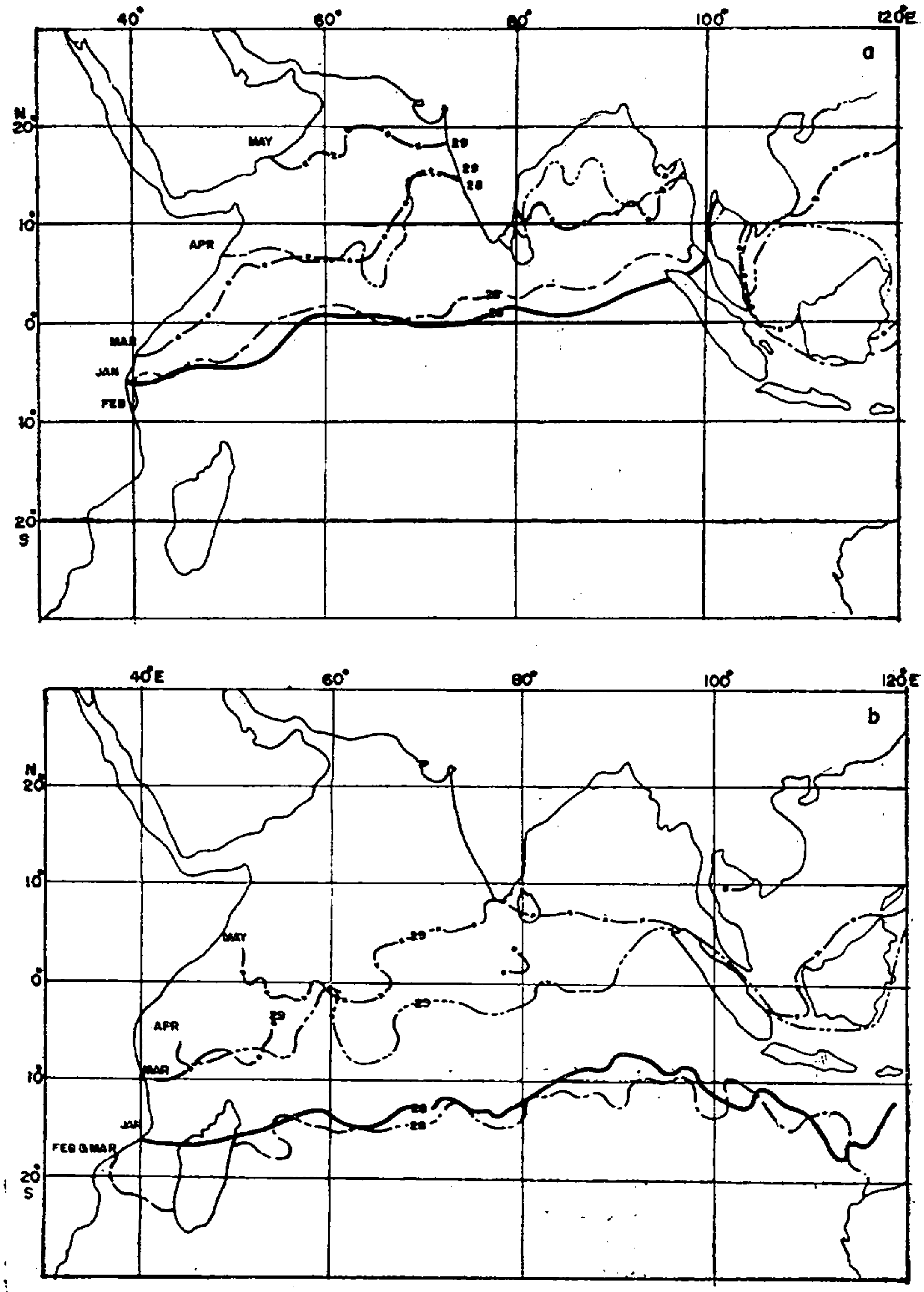

Fig. 1. The climatological mean position of warm water pool in the Indian Ocean for the period January to May. (a) the mean position of the northern boundary (b) the mean position of the southern boundary.

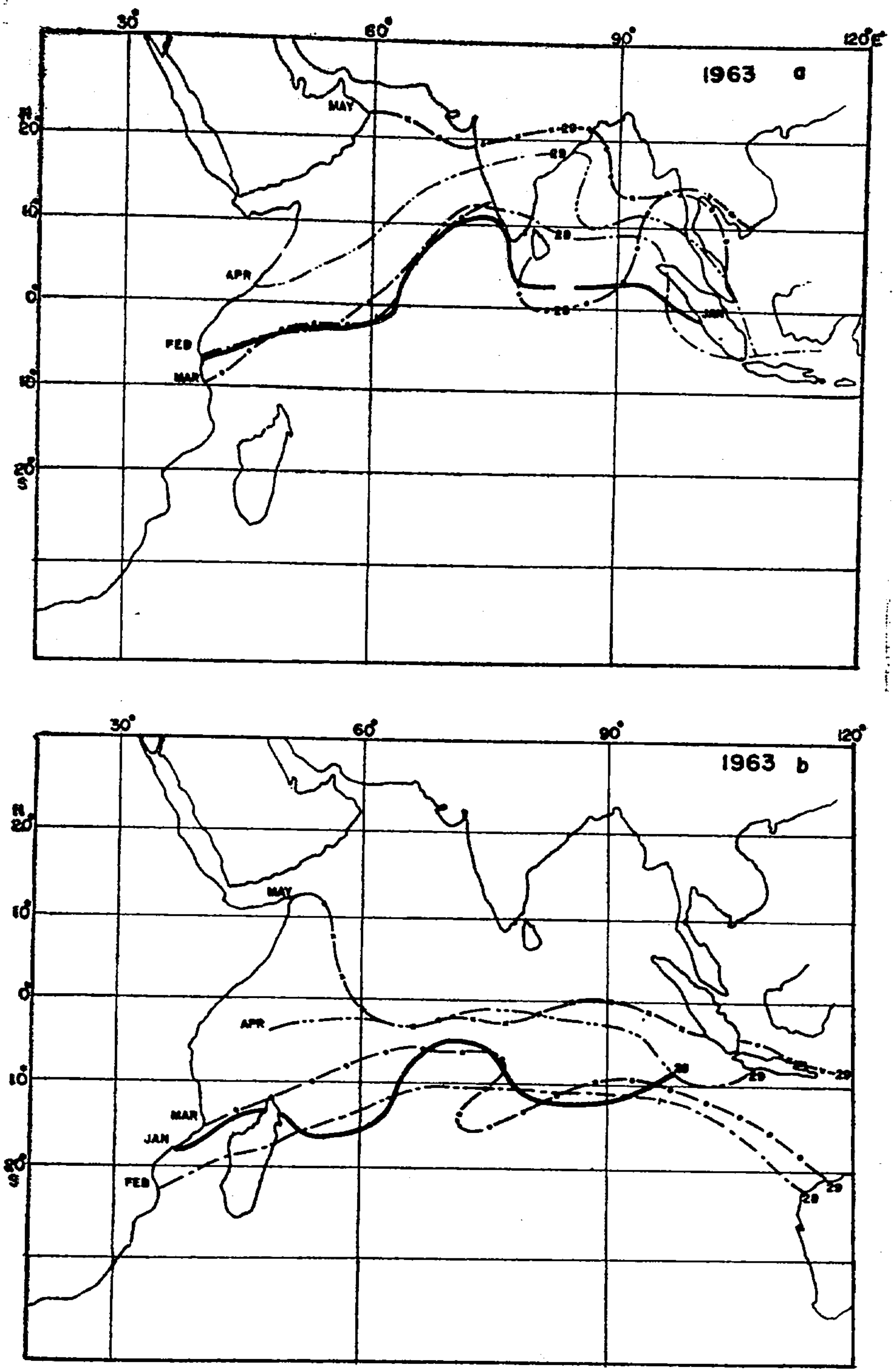

Fig. 2. The position of the (a) northern and (b) southern boundaries of the warm pool in the Indian Ocean in 1963.

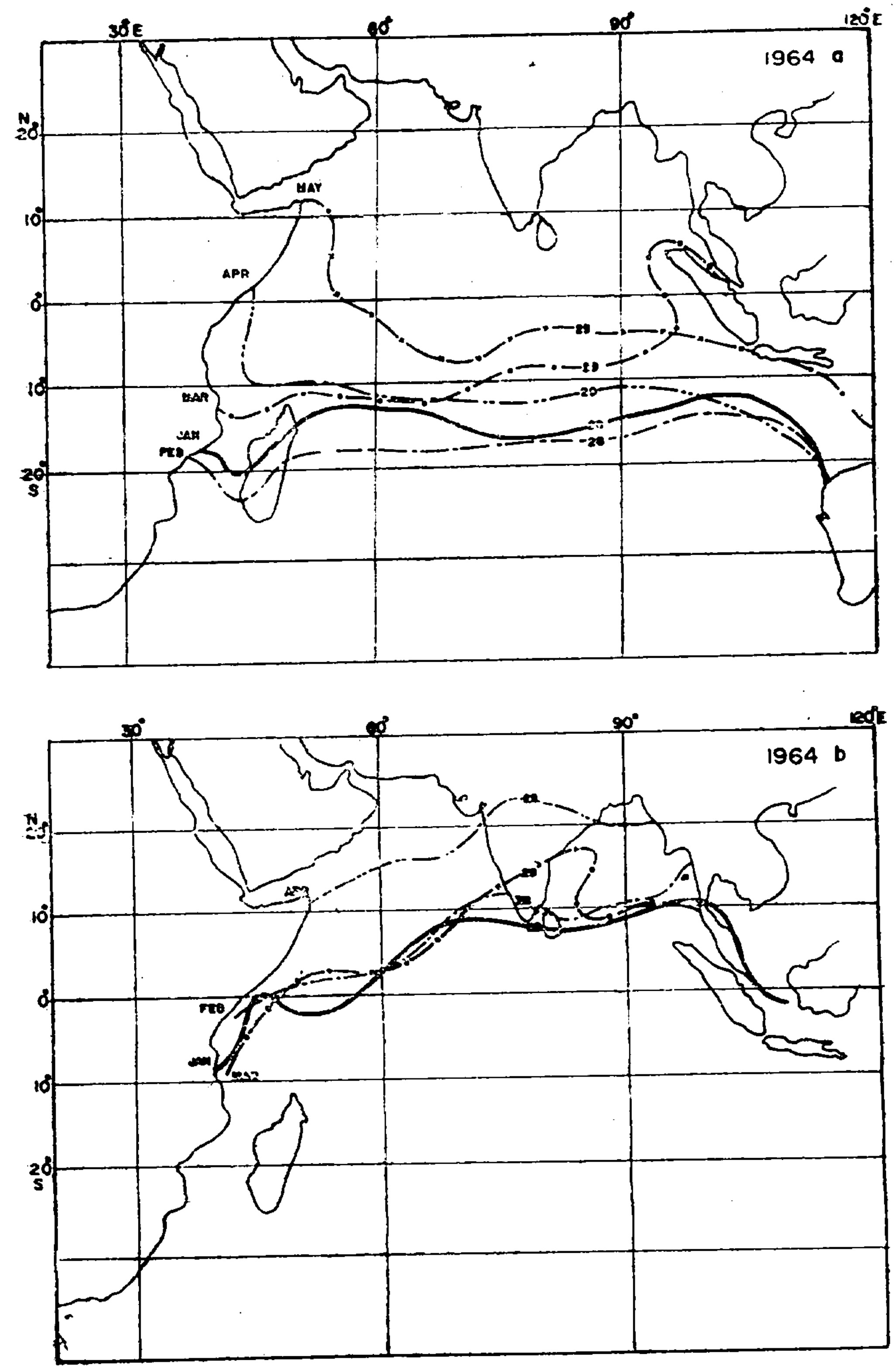

Fig. 3. The position of the (a) southern and (b) northern boundaries of the warm pool in the Indian Ocean in 1964.

The first large scale investigation of the meteorology of the Indian Ocean was carried out during 1963 and 1964 during the International Indian Oceans Expedition. The average summer monsoon rainfalls over India during those years were 86.1 cm and 93.9 cm. The climatological mean value of the rainfall over India is about 89 cm. The monthly average boundaries of the warm water pool during these years are shown in Figs. 2 & 3.

The difference in the space distribution of the warm water pool in 1963 and 1964 during April and May are noteworthy. The northern boundary of the warm pool moved northward in 1964 in a way similar to the mean climatological pattern. In 1963, it was much south of the mean position in the eastern Bay of Bengal. The southern part of the warm water pool was nearer to the equator in 1963. A comparison of the surface wind fields in April during these years are shown in Fig. 4. While anticyclonic circulation

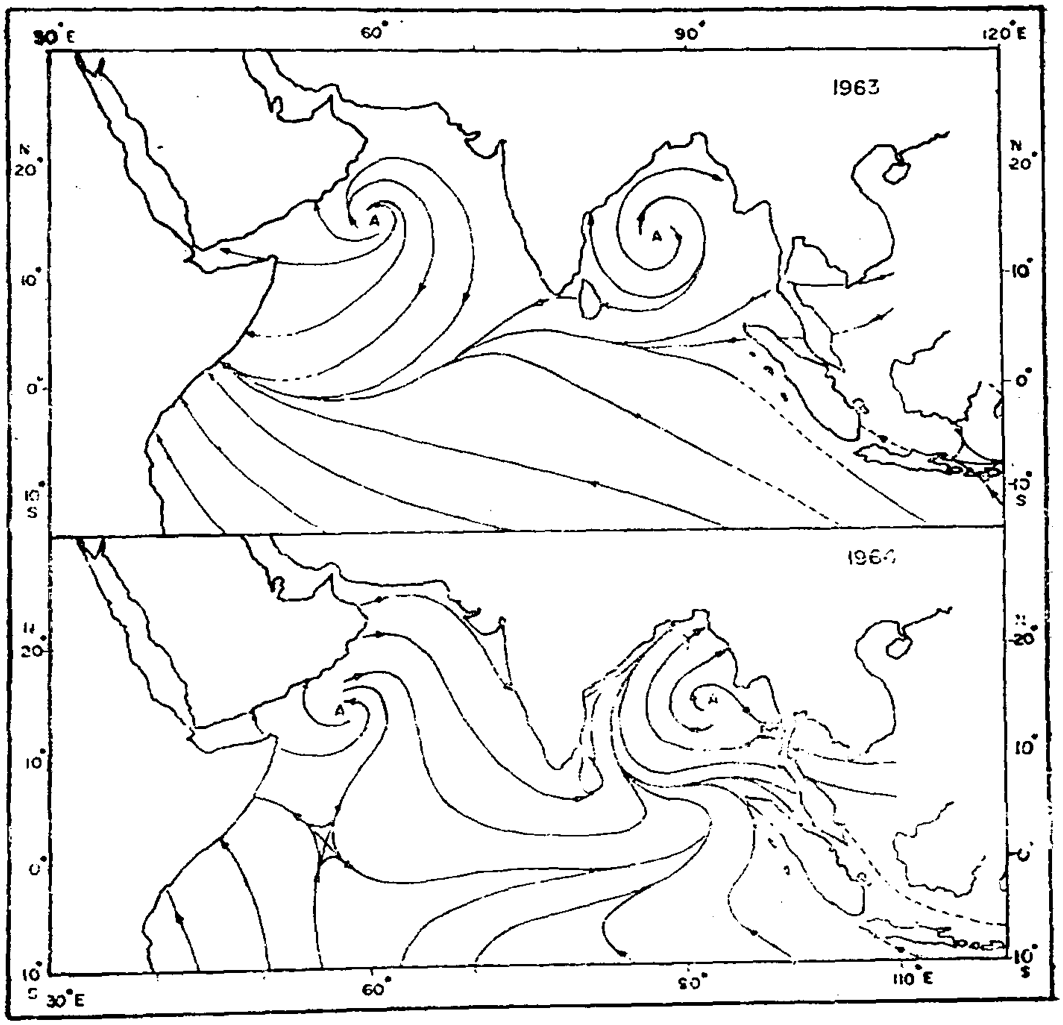

Fig. 4. A comparision of the surface wind field over the Indian Ocean during 1963 and 1964.

existed in both the years, in the Arabian Sea and the Bay of Bengal, it was very much weaker in the Bay of Bengal in 1964. The ITCZ and the south east trades seem to have moved into the Bay of Bengal associated with the spread of the warm water further northword into the Bay.

The change in position of the warm water pool, represented by its northern and southern limits during the period January to May for the years 1981 to 1984 are shown in Figs. 5 and 6 respectively. There was considerable variation in the percentage rainfall over India during this period. It was -1% in 1981, -16% in 1982, + 17% in 1983 and -6% in 1984.

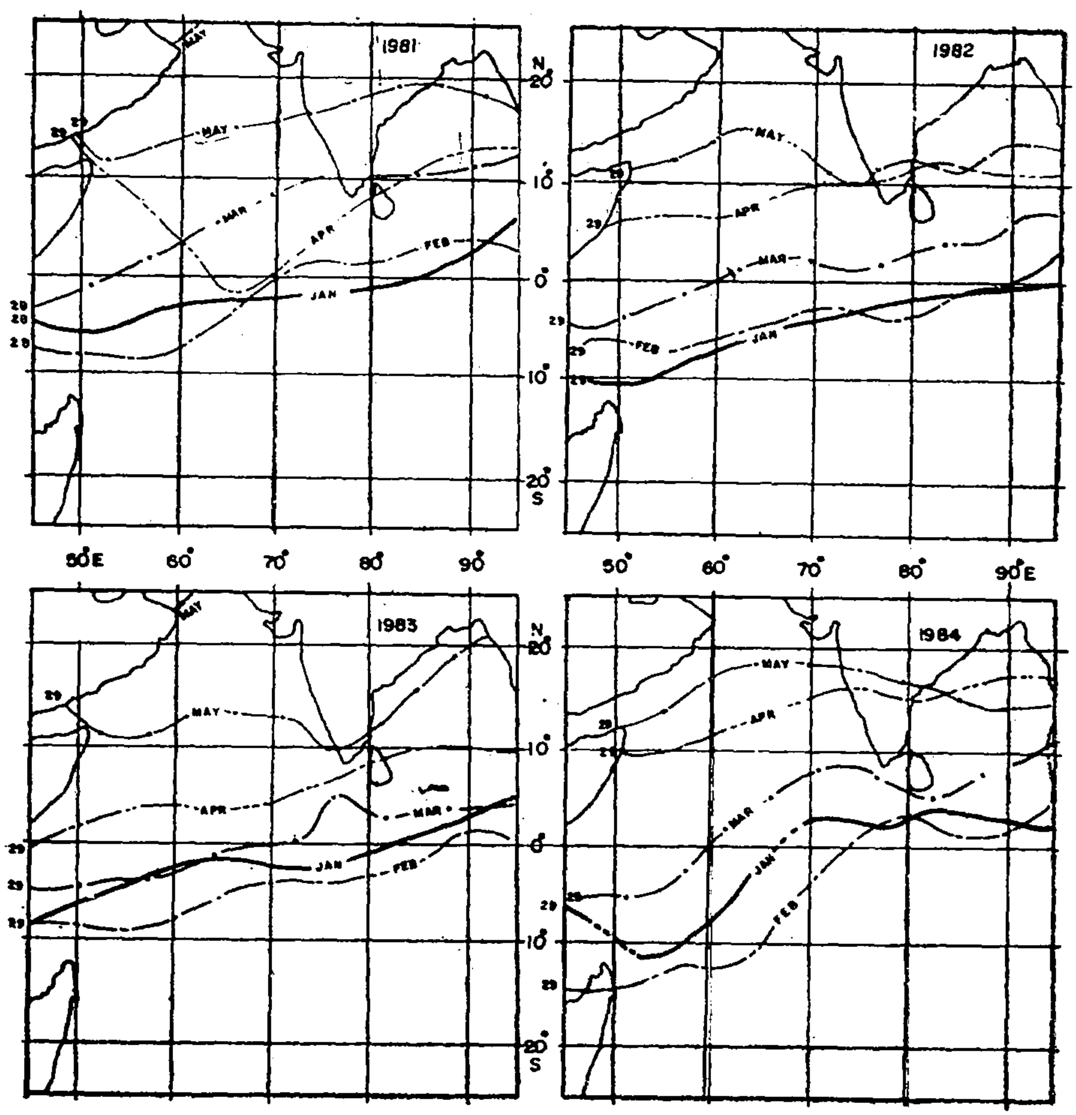

Fig. 5. The monthly mean position of the northern boundary of the warm pool during 1981-1984.

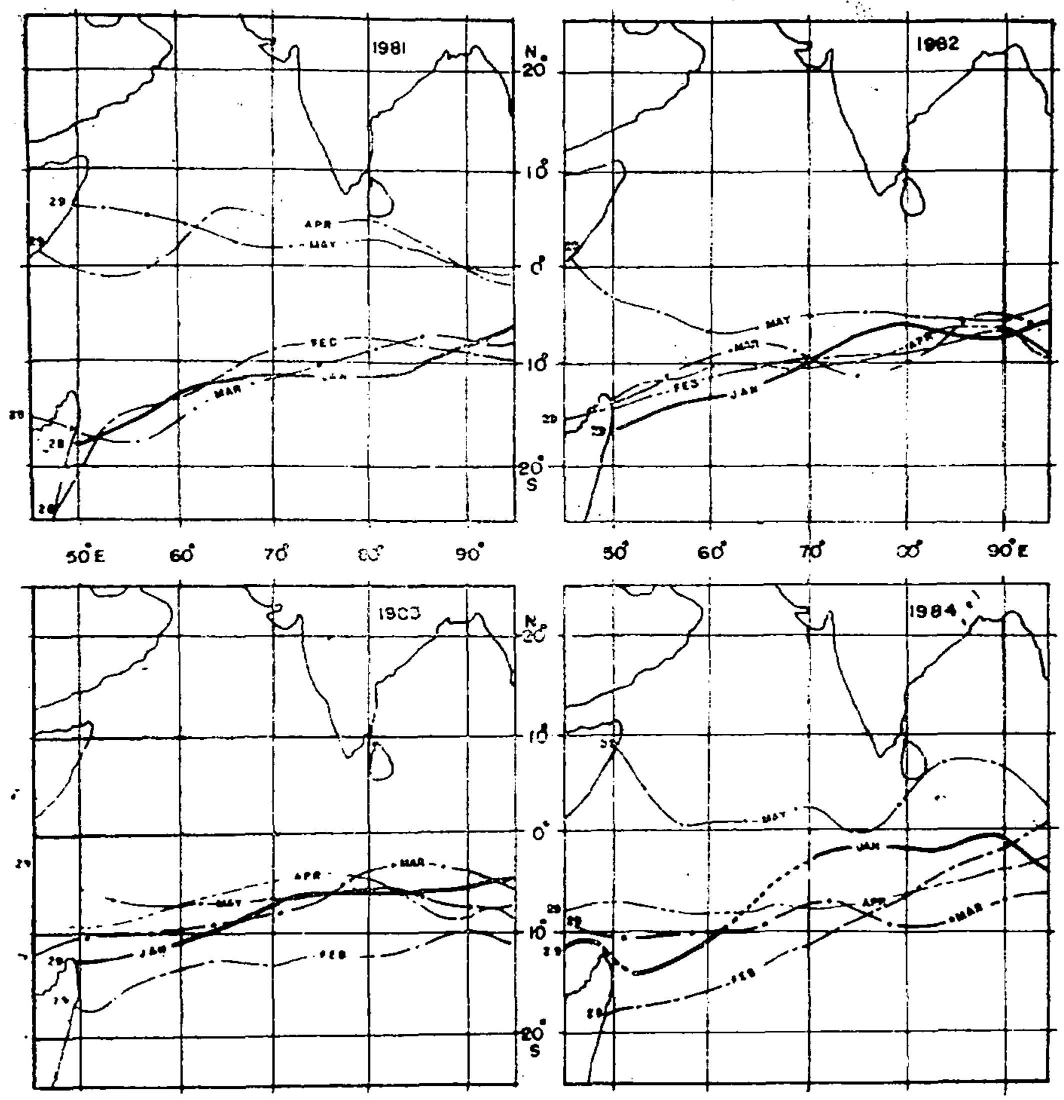

Fig. 6. The monthly mean position of the southern boundary of the warm pool during 1981–1984.

The temperature of the warm water during 1981 was somewhat less, around 28 °C, (during the period January to March) but the northern boundary moved constantly north. By May, all these areas became warmer than 29 °C and attained more or less the mean pattern. The southern boundary of the warm water area was at 15 °S in the western part and 8 to 10 °S in the eastern part till March. In April and May, this boundary was around 5 °N in the western and central part and was south of the equator, east of 90 °E.

In 1982, the equatorial area was warmer throughout the period of January to May. However, the northern boundary especially in the eastern part did not move beyond 15 °N. The Persian Gulf area also remained relatively cool. The southern boundary of the warm area was around 10 °S in the

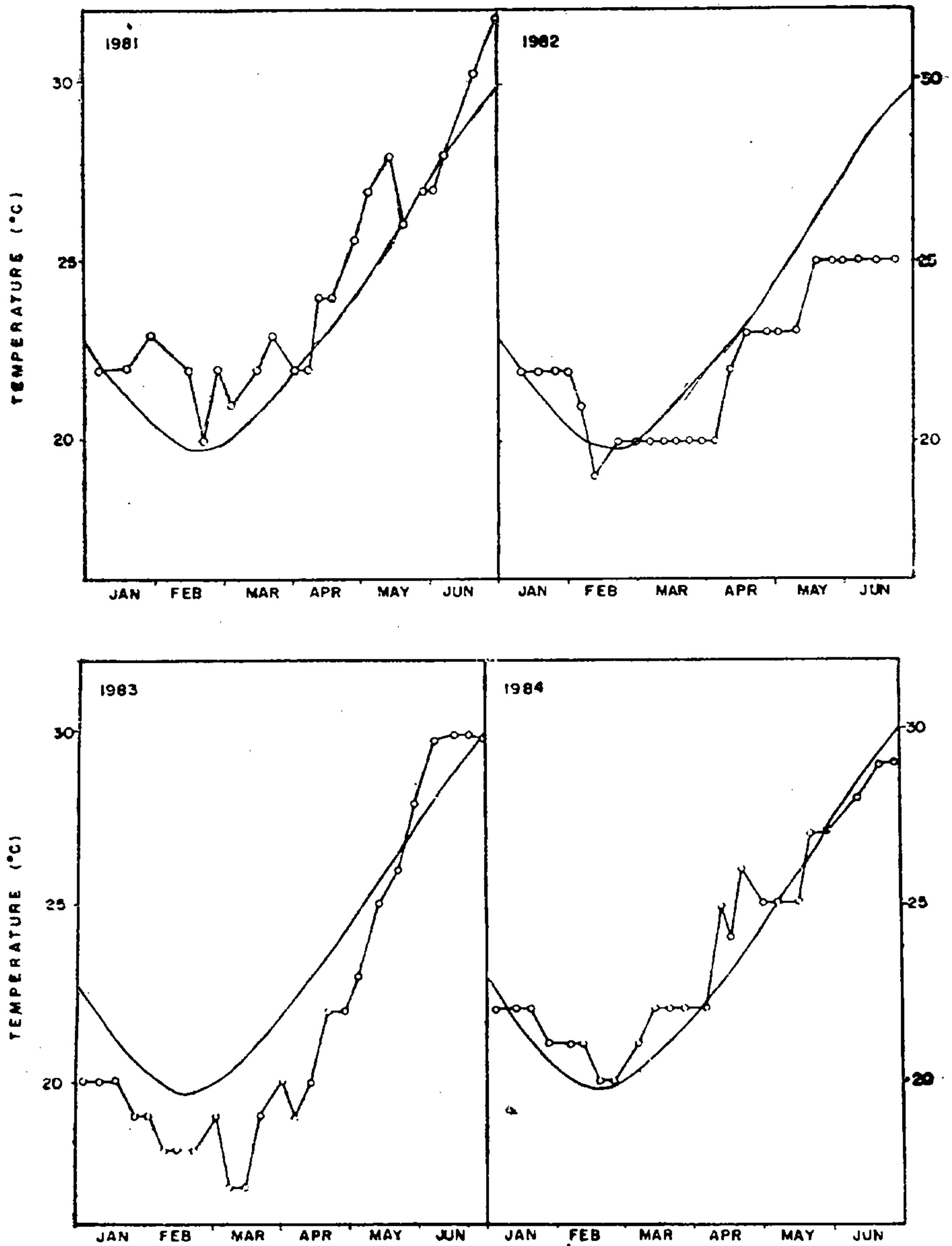

Fig. 7. The pattern of the SST variations at a station in the Persian Gulf from January to May during 1981–1984.

central Indian Ocean, around 2 to 4°N in the eastern Indian Ocean, and around 5°S in the western region. In May, the northern limit was around 12°N in general, but it was at about 15°N in the central Arabian Sea. The pattern of distribution of the warm area in 1982 was peculier, as this coincided with the 1982 El Nino, Southern Oscillation phenomena in the Pacific which was widely investigated (Cane, 1983; and Wagner, 1983).

In 1983, the northern limit of the warm pool migrated rapidly northward, especially in the Bay of Bengal where it was north of 20° N in May. It was around 12° N in the other areas. The southern boundary was around 18°S in the western part and 12°S in the eastern part. During the rest of the period from January to May it was around 5° S.

In 1984, the northern boundary of the warm area was south of 10° S in the western part of the Indian Ocean. In May, this boundary in Bay of Bengal was about 3° South of the normal position in April. Large variation in the position of the southern boundary was observed. It was around 2°S in January, about 18°S in February, 10°S in March and April. In May it was nearer to the equator between longitude range 60 to 80°E and further north in the other regions.

The sea surface temperature distribution at a station in the Persian Gulf during 1981 to 1984 are shown in Fig. 7. The solid line represents the climatological mean pattern. The pattern of the temperature distribution varied very much in 1982 and 1983. In 1982, the temperature was below normal and January temperature was much below normal. In 1983, January to March temperature was much below normal, but increased rapidly during April and May and reached above normal values in June.

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