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STUDIES ON SOME ASPECTS OF THE INCIDENCE OF CYCLONIC STORMS VIS-A-VIS SEA TEMPERATURE DISTRIBUTION OVER THE ARABIAN SEA*

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ABSTRACT

In contrast to a single maximum in cyclone activity over the north Atlantic and Western Pacific in August–September, the cyclonic storms in the Indian seas, particularly those over the Arabian Sea, show two maxima in May and November with minimum activity in August. This is shown to be closely related to the changes in sea temperature conditions over the Indian seas in association with the southwest monsoon. It is also pointed out that the temperature conditions over the Arabian Sea (except in the month of May) generally inhibit the intensification of westward moving storms, many of them actually dissipating over the sea.

INTRODUCTION

A number of studies have been made on the influence of sea temperatures on the genesis, intensification and movement of tropical storms. Notable among these are those made by Palmen (1946), Dunn (1960), Fischer (1957) and Jordan (1964). Most of these studies relate to storms over the north Atlantic Ocean, the Carribean Sea and the Gulf of Mexico. Similar studies on storms over the Indian seas are few. Koteswaram and Gasper (1956) have studied the surface characteristics of the storms over the Bay of Bengal, including the sea temperature distribution. The influence of the sea temperature distribution has been studied for two Arabian Sea storms for the May 1959 storm by Mukherjee, Korkhao and Srinivasan (1961) and for the November 1964 storm by Vittal Sarma (1968). While making a comparative study of the climatological behaviour of the storms and depressions in the Indian seas, with that of the tropical cyclones in the north Atlantic and the western Pacific, Ananthakrishnan and Thiruvengadathan (1965) have touched upon the influence of the sea surface temperature. Results of a more detailed study are presented in this paper.

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SOURCES OF DATA

The publications, *"Tropical cyclones in the Western Pacific and China Sea area from 1884 to 1953"* by Chin (1958), *"North Atlantic Tropical Cyclones"* by Cry, Haggard and White (1959) and the *"Tracks of storms and depressions in the Bay of*

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Table 1. *Tropical cyclones in 70 year period*

Sea area		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Bay of Bengal	T	9	3	5	26	45	69	109	119	118	109	88	44	744
	C	4	1	4	18	28	34	38	25	27	53	56	26	314
(1891–1960)	S*	1	1	2	7	18	4	7	1	8	19	23	9	100
Arabian Sea	T	4	0	1	7	19	24	7	1	7	28	31	8	137
	C	2	0	0	5	13	13	3	1	4	17	21	3	82
(1891–1960)	S*	0	0	0	4	11	8	0	0	1	7	16	1	48
N. Atlantic	C	0	1	1	0	8	33	35	127	186	129	22	2	544
(1889–1958)	S**	0	0	1	0	2	13	19	93	118	60	9	1	316
W. Pacific	C	18	10	10	22	69	108	263	305	310	213	148	65	1541
(1884–1953)	S**	11	6	4	13	43	58	198	223	211	142	98	26	1033

(Month columns Jan.–Dec. are grouped under the heading "Month".)

T : Tropical storms and depressions
C : Tropical cyclones (wind speed over 34 knots)
S* : Severe storms (wind speed over 47 knots).
S** : Hurricanes/Typhoons (wind speed over 63 knots)

Bengal and Arabian Sea, 1877-1960" published by the India Meteorological Department (1964) form the source material for computing the statistics and details of the tracks over the relevant ocean areas. The sea temperature values over the north Atlantic and north Pacific have been extracted from the relevant Oceanographic Atlases published by the U. S. Naval Oceanographic Office, Washington and the values over the Indian Ocean from the Atlases published by the Hydrographic Institute, Hamburg and Royal Netherlands Meteorological Institute.

CLIMATOLOGY OF TROPICAL STORMS

Table 1 gives the frequency of cyclonic storms that occurred over a 70 year period over the North Atlantic, Western Pacific and the China Sea, the Bay of Bengal and the Arabian Sea. The Table also shows the number of hurricanes (wind force exceeding 63 knots) over the north Atlantic and the west Pacific and the severe storms (winds exceeding 47 knots). Over the Indian seas, the frequencies of depressions and storms are also shown. Taking the year as a whole, about 40% of the depressions in the Bay of Bengal and 60% of the depressions in the Arabian Sea intensify into cyclonic storms. If the disturbances during the monsoon months are excluded the percentage comes to about 60 both over the Arabian Sea and the Bay of Bengal. A third of the Bay of Bengal storms and nearly two-thirds of the Arabian Sea storms attain severe intensity. Nearly two thirds of the tropical storms of the north Atlantic and Northwest Pacific attain hurricane intensity.

Figure 1 shows the monthly percentage frequency of the tropical storms over the Indian seas and over the North Atlantic and Pacific. Over the Atlantic, the frequency of tropical storms increases rapidly from July reaching a maximum in September after which there is a steep decline through October and November. Over the western Pacific the increase starts from June. Although the maximum is reached in September the peak is much flatter, the number of storms being practically equal in August and September. Over the Bay of Bengal, if depressions and storms are considered together, the frequency is maximum during the months August and September. However if only the disturbances which attained storm intensity are considered one notices two maxima one in June–July and the other in October–November. Considering severe cyclonic storms only, there are two pronounced maxima in the months of May and October–November. In the Arabian Sea the total number of tropical disturbances, those that reached storm intensity and severe cyclonic storms all show two maxima in May–June and November. Thus we find that while the cyclonic storms attain their maximum frequency over the North Atlantic and Western Pacific in August their frequency is minimum over the Bay of Bengal and Arabian Sea, the minimum being very pronounced over the Arabian Sea. This remarkable feature of the tropical storms in the Indian seas has a parallel in the seasonal variation of sea surface temperature.

SEASONAL VARIATION OF SEA SURFACE TEMPERATURE

Over most of the tropical oceans, surface water temperature shows a maximum in late summer and a minimum in late winter. In contrast to this, the surface waters of the Bay of Bengal and the Arabian Sea show two maxima in May–June and October–November with minima in August and January–February. The monthly variation of sea surface temperatures at 15°N along 120°E (Western Pacific) 90°E (Bay of Bengal) 60°E (Arabian Sea) and 85°W (North Atlantic) are shown in Fig. 2. The parallelism between the monthly frequency of tropical storms and the monthly variation of sea surface temperature is very striking. With

the onset of the south west monsoon in May–June there is a progressive lowering of the sea surface temperature over the Indian seas. North of 10°N the Arabian Sea

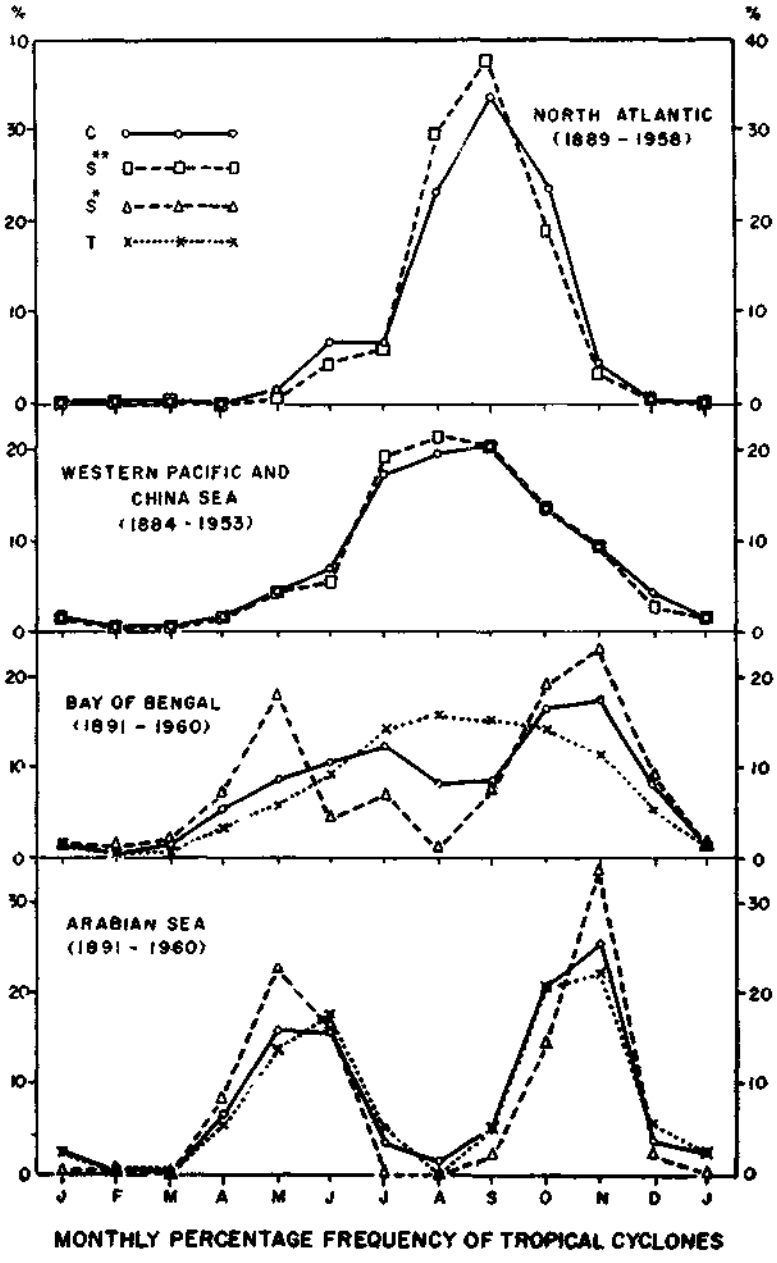

Fig. 1

is cooler than the Bay of Bengal during the months June–October. This feature has also been pointed out by Colón (1964).

The cooling of the sea surface with the onset of the monsoon which is pronounced over the Arabian Sea inhibits the development of tropical disturbances over this sea during the months July to September.

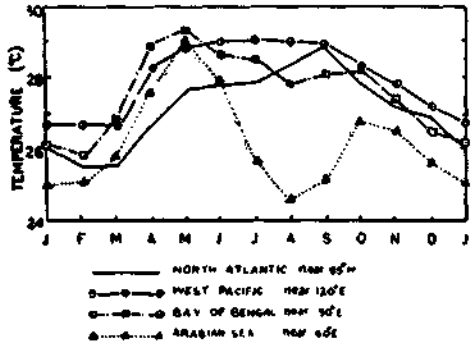

Fig. 2. Seasonal variation of sea surface temperature.

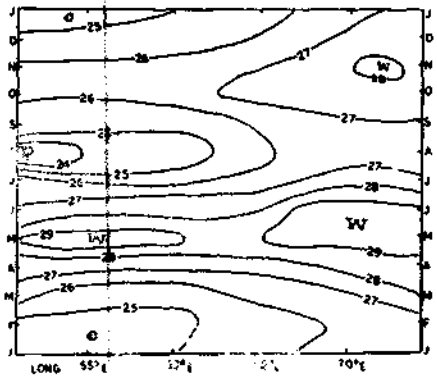

Fig. 3. Seasonal variation of sea surface temperature along lat. 15°N.

The low frequency of the storms over the Indian seas during the monsoon months is no doubt associated with the position of the equatorial trough which lies generally over the land. It may, however, be pointed out that during the monsoon months, while tropical storms are practically absent over the Arabian Sea and originate over the Bay of Bengal between lat. 18°N and 22°N, they form over the entire belt from 10°N to 25°N over the Pacific and the Atlantic. The small amplitude of oscillation of the equatorial trough over India is possibly associated with the unfavourable sea temperature conditions over the Indian seas in general and the Arabian Sea in particular. It may also be pointed out that the low pressure areas that form over the south Bay of Bengal during the 'break monsoon' conditions, never intensify beyond the depression stage and dissipate either after crossing coast or on entering the Arabian Sea, since the sea temperature conditions are unfavourable for their intensification.

SEA SURFACE TEMPERATURE DISTRIBUTION

Another noteworthy feature of the sea surface temperature distribution over the Arabian Sea is that generally the sea surface temperature decreases from east to west. This is in contrast to the general distribution over the tropical seas where the water is usually warmest in the western part of the ocean, both the sea and air having had an opportunity to store heat continuously on the long track westward across the tropics (Riehl, 1954).

Figure 3 shows the seasonal variation of the sea surface temperature over the Arabian Sea along 15°N. The sea surface temperature is warmest in the month of May, exceeding 29°C over the entire longitudinal belt. The east to west temperature gradient is practically nil during the month. While the temperature continues to be about 29°C over the east Arabian Sea in June also, it begins to decrease over the west Arabian Sea. With the onset of monsoon the sea surface temperature falls

rapidly, the rate of fall being particularly large over the western parts. East-west temperature gradient begins to get established and persists till March or April. The sea surface temperature reaches a minimum in August when it lies between 26° and

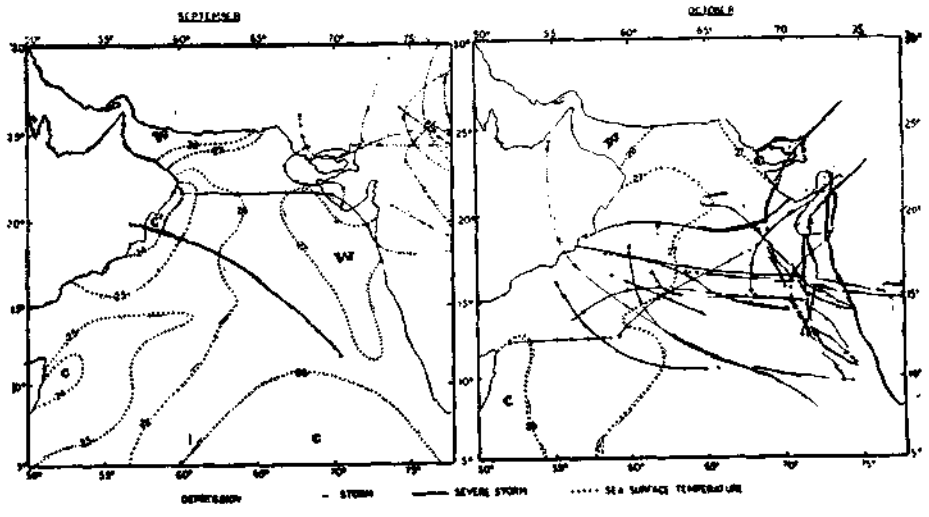

Fig. 4. Tracks of cyclonic storms and sea surface temperature.

27°C over the east Arabian Sea and below 23°C over the extreme western parts. The temperature begins to rise after August, but the rate of increase of temperature is much smaller than the fall with the onset of monsoon. It reaches a secondary maximum in October-November. The other minimum value is reached in January–February.

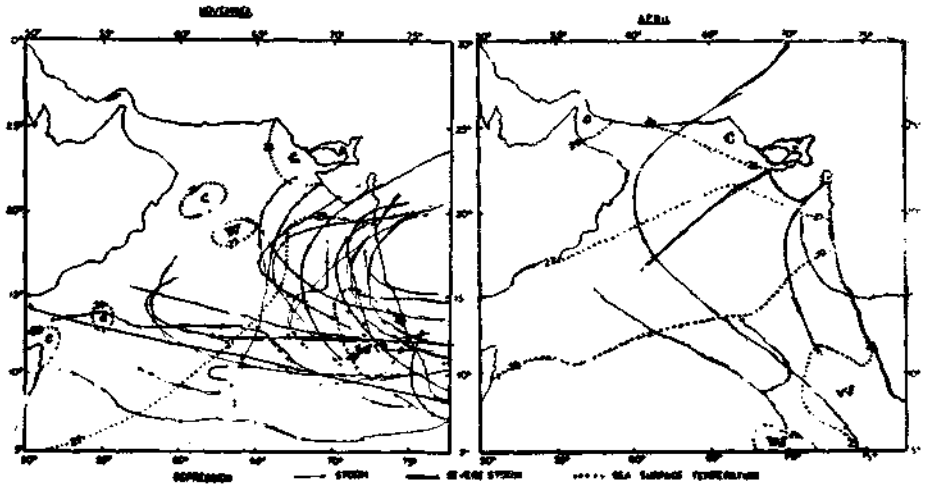

Fig. 5. Tracks of cyclonic storms and sea surface temperature.

The east to west temperature gradient over the Arabian Sea has a pronounced influence on the life history of the storms over the area. Figs. 4 to 9 show the monthly tracks of the storms over the Arabian Sea (1891 to 1960) and the corresponding monthly mean sea surface distribution for the months of September, October, November, April, May and June. It will be seen that a large number of storms dissipate on moving into colder seas, due to the removal of the surface heat source. It would be seen that generally, except in the month of May, westward moving storms dissipate over the sea, while moving into colder waters. However, in the month of May, there is very little east to west temperature gradient and the westward moving storms retain their intensity till they cross the Arabian Coast.

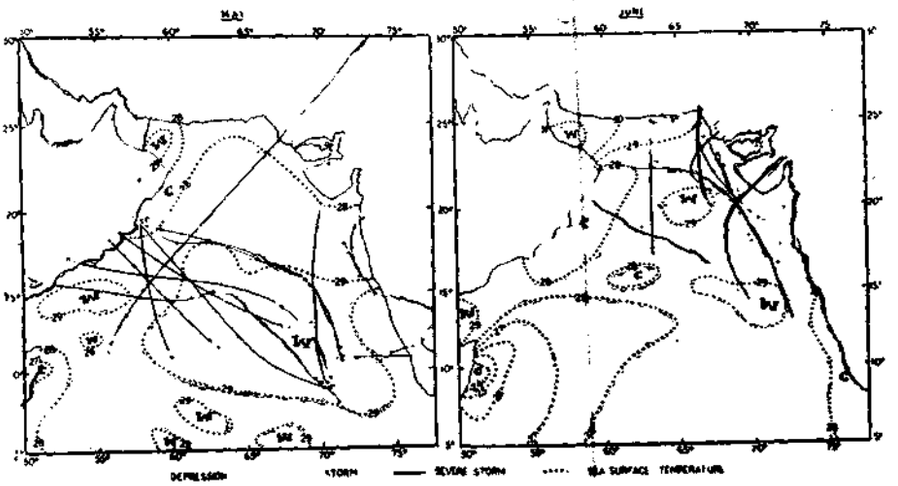

Fig. 6. Tracks of cyclonic storms and sea surface.

CONCLUSION

It has been shown that on a climatological basis, there is a close relation between the sea temperature distribution and the formation and development/dissipation of storms over the Arabian Sea. Sea temperature value is thus found to be an important parameter to be reckoned within forecasting the formation and intensification/dissipation of tropical storms. However the accuracy of the measurement of this parameter and the density of reporting network are to be improved considerably, before it can be utilised effectively for forecasting purposes. An accurate knowledge of this parameter is likely to be particularly useful over the central and north Bay of Bengal during the post monsoon months when most of the storms moving towards the north or northeast dissipate over the seas, but a few retain their intensity and strike the East Pakistan Coast, causing terrible havoc and disaster.

REFERENCES

ANANTHAKRISHNAN, R. AND A. THIRUVENGADATHAN 1965. Fourth Technical Conference on Hurricanes, Miami, Florida, 1965.

CHIN, P. C. 1958. *"Tropical cyclones in the Western Pacific and China Sea area from 1884 to 1953"*. Royal Observatory, Hongkong.

COLON, J. A. 1964. *Indian Jour. of Met. & Geophys.*, **15**: 183.

CRY, G. W., W. H. HAGGARD AND H. S. WHITE 1959. *"North Atlantic Tropical cyclones"*. U. S. Weather Bureau, Technical Paper No. 36, Washington D. C.

DUNN, G. E. 1950. *Atlantic Hurricans*. Louisiana University Press.

Deustches Hydrographisches Institut, Hamburg. 1960. Monatskarten, fur den Indischen Ozean.

FISCHER, E. L. 1957. National Hurricane Research Project, 8 (1 & 2).

India Meteorological Department. 1964. Tracks of storms and depressions in the Bay of Bengal and the Arabian Sea 1877–1960.

JORDON, C. L. 1964. *Proc. Sym. Trop. Met.*

KOTESWARAM, P. AND S. GASPER 1956. *Ind. Jour. Met. & Geophys.*, **7**: 339.

MUKHERJEE, A. K., J. M. KORKHAO AND V. SRINIVASAN 1961. *Ibid.*, **12**: 598.

PATMEN, E. 1948. *Geophysica, Helsingfors*, **33**: 36.

RIEHL, H. 1954. Tropical Meteorology, Mc. Graw Hill Publishing Co. Ltd.

ROYAL NETH. MET. INST. 1952. Indian Ocean Oceanographic and Meteorological Data.

U. S. Naval Oceanographic Office, Washington. 1967. Oceanographic Atlas of the north Atlantic Ocean Section II-Publication No. 700.

—— 1969. Monthly charts of mean maximum and minimum sea surface temperature of the north Pacific Ocean.

VITTAL SARMA, V. 1968. *Ind. Jour. of Met. & Geophy.*, **12** : 73.