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Certain aspects for intensification of tropical storms over Indian Ocean area

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ABSTRACT. Palmen (1956) gave three climatological and geographical conditions as pre-requisites for the formation of tropical storms. One of these being that the region of formation of storm should be over sufficiently large sea or ocean area with temperature of the sea surface so high that airmass lifted from the lowest layers of the atmosphere and expanded adiabatically with condensation remains considerably warmer than the surrounding undisturbed atmosphere at least between 500 and 200 mb. The temperature differences for island stations of Port Blair and Minicoy and the coastal stations were studied to test the above hypothesis for Indian area. In general it is found that Palmen's hypothesis holds good over the Bay of Bengal as well as the Arabian Sea.

1. Introduction

Since the number of meteorological reporting stations are few in the regions where the tropical storms generally originate, the synoptic conditions for their formation are less well-known than the climatological and geographical conditions.

According to Palmen (1956) the following climatological and geographical conditions are the pre-requisites for the formation of tropical storms.

(1) Sufficiently large sea or ocean areas with the temperature of the sea surface so high that an airmass lifted from the lowest layers of the atmosphere (with about the same temperature as the sea) and expanded adiabatically with condensation remains considerably warmer than the surrounding undisturbed atmosphere at least upto a height of about 40,000 ft (12 km).

(2) The value of the coriolis parameter larger than a certain minimum value, thus excluding a belt of the width of about 5-8° latitude on both sides of the equator.

(3) Weak vertical wind shear in the basic current, thus limiting the formation to latitudes far equatorwards from the subtropical jet stream.

Condition (1) can best be illustrated by the mean thermal conditions in the free atmosphere in different seasons, as compared with the temperature of a pseudoadiabatically ascending airmass. This has been documented (Reihl 1954, Palmen 1948) for Atlantic Ocean (Swan Island) by considering the mean temperature distribution in September and February. It was noticed that the ascending air at all levels between 900 and 160 mb was warmer than the undisturbed air and the difference was of the order of 5 to 7°C between 500 and 200 mb during the month of September. However, very little difference was noticed between the temperature of the lifted air parcel and the mean temperature between 900 and 160 mb in February. Similar contrasting features were observed between the ascents of August and February in Pacific Ocean (Guan Islands) by Kasahara (1954).

This shows that condition (1), which is fulfilled between August and September, helps in intensification of tropical disturbances into tropical storms during the season; whereas, the non-availability of this condition during February inhibits the development of cyclonic storms.

It was also observed by Palmen (1948) and Dunn (1956) that the tropical storms never reached hurricane intensity in regions where the temperature difference, between the air lifted from sea surface to 300-mb level and the atmosphere at the same level, is of the order of less than 4°C. An attempt has been made in this note to test the above hypothesis for the Indian Ocean area.

2. Discussion of results

The temperature data of the selected stations is based on normals for the period (1951-65) as published by India Meteorological Department.

It is well known that the conditions in Indian Ocean area are quite different from conditions

Temperature difference (°C) of different pressure levels

Level (mb)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Bombay (18°54′N, 72°49′E)						
850	−7·0	−7·0	−6·7	−5·5	−3·0	+0·5	+1·5	+1·2	+0·2	−2·0	−5·0	−5·0
700	−4·8	−4·3	−3·2	−0·2	+0·5	+1·2	+1·8	+1·2	+1·5	+1·2	−2·3	−3·7
500	−4·6	−5·1	−1·2	+4·6	+4·5	+3·7	+2·5	+1·5	+1·6	+1·7	−1·5	−2·8
300	−8·0	−8·0	0·0	+6·3	+6·0	+4·5	+4·0	+2·3	+2·6	+3·1	−2·2	−4·6
200	−14·5	−13·5	−7·0	0·0	+3·0	+2·5	+1·5	−0·3	0	−0·5	−7·0	−10·0
						Calcutta (22°32′N, 88°20′E)						
850	−4·3	−4·5	−4·0	−4·1	−2·7	−0·5	+0·7	+0·7	+0·9	0	−2·2	−2·3
700	−4·4	−3·3	+0·7	+1·9	+2·4	+2·3	+2·1	+2·0	+2·5	+1·7	−3·8	−7·2
500	−4·5	−3·4	+3·0	+5·4	+6·6	+5·1	+3·3	+3·7	+4·4	+4·0	−4·3	−7·5
300	−14·1	−9·4	+1·2	+7·1	+8·3	+7·2	+4·8	+6·1	+6·5	+4·0	−7·1	−12·4
200	−22·4	−16·9	−8·2	+0·7	+5·1	+5·6	+3·1	+3·1	+4·0	0	−13·0	−19·9
						Madras (13°04′, 80°15′E)						
850	−1·5	−2·6	−3·0	−2·3	−3·0	−1·3	−1·9	−0·2	−0·4	0	−0·3	−0·7
700	+1·7	−1·6	0	+1·7	+1·4	+2·3	+2·1	+2·2	+3·0	+2·6	0	−2·1
500	−2·5	−0·7	+2·1	+5·2	+4·6	+4·8	+3·4	+3·7	+4·9	+4·0	+2·2	−1·2
300	−2·5	0	+3·9	+8·1	+7·9	+7·5	+5·5	+6·5	+8·3	+6·3	+2·0	−0·8
200	−6·6	−3·7	0	+6·2	+7·0	+7·4	+3·2	+6·1	+6·9	+5·4	−1·0	−4·9
						Port Blair (11°40′N, 92°43′E)						
850	−0·2	−1·4	−0·8	−0·5	0	0	+0·3	+0·5	+0·7	+0·2	0	+0·3
700	−0·4	−0·8	+0·4	+1·5	+1·7	+1·5	+1·9	+2·0	+1·8	+1·9	+1·4	+0·4
500	+1·2	+3·6	+2·2	+3·5	+4·0	+4·2	+4·0	+4·0	+4·1	+4·0	+4·0	+2·4
300	+1·8	+1·7	+2·8	+6·1	+6·0	+5·0	+6·0	+6·2	+6·6	+6·8	+5·7	+4·2
200	−1·8	−1·4	+1·0	+4·0	+4·1	+3·9	+3·9	+4·5	+4·1	+5·8	+4·3	+0·8
						Trivandrum (08°28′N, 76°57′E)						
850	−0·5	−0·3	−0·8	−0·3	+0·7	+0·3	+0·9	+1·1	+0·5	+0·5	+0·6	0
700	0	+0·4	+0·9	+1·2	+2·1	+2·4	+1·6	+1·2	+1·1	+0·9	+0·7	+0·3
500	+1·8	+2·5	+3·0	+4·4	+4·6	+3·8	+3·9	+3·7	+2·9	+3·6	+3·4	+2·1
300	+3·0	+4·2	+5·8	+7·3	+7·1	+5·5	+5·9	+6·4	+5·4	+6·1	+5·5	+4·2
200	0	+0·9	+2·9	+5·2	+5·5	+3·0	+3·6	+4·6	+2·9	+1·6	+3·1	+2·0
						Visakhapatnam (17°43′N, 83°16′E)						
850	0	−2·6	−3·8	−3·1	−3·0	−1·2	−0·5	0	0	0	−1·3	+2·4
700	−0·5	−0·3	+0·9	+1·9	+1·9	+2·5	+1·6	+1·9	+2·2	+1·9	−1·6	−3·8
500	+0·5	−0·4	+2·5	+6·2	+7·2	+6·2	+3·7	+3·9	+4·4	+6·1	0	+2·8
300	0	+0·5	+5·1	+9·3	+9·5	+8·7	+6·7	+5·6	+5·6	+5·1	+0·6	−4·7
200	−4·6	−4·3	0	+6·3	+7·8	+7·8	+4·8	+5·0	+6·2	+3·5	−3·3	−8·7
						Minicoy (08°20′N, 73°00′E)						
850	+0·2	0·0	−0·2	+0·5	+1·2	+1·8	+1·0	+1·4	+1·5	+1·0	+1·0	+0·8
700	+0·2	+0·4	+2·0	+2·0	+3·7	+3·0	+2·3	+2·2	+2·1	+2·0	+2·2	+1·3
500	+2·0	+2·8	+4·3	+5·2	+5·5	+5·5	+4·0	+4·0	+4·0	+3·5	+3·5	+2·8
300	+4·3	+4·6	+8·0	+9·2	+9·0	+8·5	+6·2	+7·0	+6·2	+6·2	+7·5	+6·0
200	+2·1	+2·7	+5·5	+7·2	+7·5	+6·2	+4·5	+5·0	+4·5	+4·5	+5·2	+3·0

TABLE 2 (a)

No. of years when 1, 2, 3, 4 cyclonic storms occurred in the Bay of Bengal and the total No. of cyclonic storms (1891-1970)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
At least 1 storm	5	1	4	19	36	31	29	25	27	47	46	34	
At least 2 storms					3	4	7	1	4	14	18		
At least 3 storms							2		1	1	3		
At least 4 storms											1		
Total	5(2)	1(1)	4(2)	19(8)	39(26)	35(4)	38(7)	26(1)	32(10)	62(26)	68(32)	34(13)	362(132)

TABLE 2 (b)

No. of years when 1, 2, 3, 4 cyclonic storms occurred in the Arabian Sea and the total No. of cyclonic storms (1891-1970)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
At least 1 storm	2			5	16	14	3	2	4	18	23	5	
At least 2 storms						1			1	1	2		
At least 3 storms											1		
Total	2	0	0	5(4)	16(13)	15(9)	3	2	5(1)	19(7)	26(18)	5(1)	98(53)

Figures in brackets are those storms which have been severe storms

in the Atlantic as well as Pacific Oceans due to the strong influence of the Indian monsoon. In view of above the season for the formation of tropical storms in the Indian Ocean is broken into two parts — (1) Late April to early June, (2) Late September to early December, namely, the pre-monsoon and post monsoon seasons. Keeping this in view the differences between the mean temperature of the undisturbed air and the temperature of the lifted air parcel, hereafter termed as temperature differences, have been calculated all for the twelve months of the year to see the contrast between the months having good storm activity and the months having no storm activity.

Table 1 shows temperature differences for the levels 850, 700, 500, 300 and 200 mb for the stations Bombay (BMB), Calcutta (CAL), Madras (MDS), Port Blair (PBL), Trivandrum (TRV), Visakhapatnam (VSK) and Minicoy (MNC). It is seen that the differences are of the order of 4-8°C between 500 and 300 mb for all the stations except at Bombay and Trivandrum during the pre-monsoon and post monsoon months and are significantly higher than the temperature differences for the other months of the year.

Comparing the frequencies of the storms as given in Table 2 with the temperature differences, it is seen that (*i*) Months having the maximum temperature differences have the maximum number of storms except for the month of November for stations north of the latitude of VSK, (*ii*) Although frequency of storms in the month of November is large and fairly good number of storm hit the coasts, yet the differences are small for stations other than PBL and MNC. This may be so, because the stations north of VSK latitudes are rarely affected by November storms and therefore the temperature differences are small. Also by the time the storms affect TRV latitude, they normally become weak, and the temperature difference computed from monthly mean ascents do not seem therefore to satisfy the hypothesis. In view of these, it is felt that the hypothesis holds good even for November storms.

The temperature differences in the Arabian Sea, shown by BMB are less than those of the Bay of Bengal, shown by PBL, VSK, CAL, MDS. This may suggest that, based on this hypothesis, conditions are more favourable for formation and intensification of storms in the Bay than in the Arabian Sea. Also at BMB, the differences are less than 4°C for the post monsoon months.

3. Conclusions

The findings by Palmen and Kasahara that, for a month to have good cyclogenesis and for a storm to reach hurricane intensity, the temperature difference should be greater than 4° C, is true for Bay of Bengal and Arabian Sea areas.

It may be interesting to study the validity of this hypothesis on individual cases, especially when upper air data is available.

It may also be useful to plot ascent curves in the vicinity of the storm area to study the possible relation between the movement and intensity of storms with the temperature differences.

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REFERENCES

Dunn, G. E. 1956 *Mon. Weath. Rev.*, **84**, p. 47.

Kasahara, A. 1954 *J. met. Soc. Japan*, II 32, pp. 32, Tokyo.

Palmen, E. and Reihl, H. 1956 *J. Met.*, **13**, 313-315.

Palmen, E. 1948 *Geophysica*, **3**, p. 26.

Reihl, H. 1954 *Tropical Meteorology*, McGraw Hill, New York.