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Mean upper air flow patterns associated with spells of strong and weak northeast monsoon conditions over the Madras State in the month of November

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ABSTRACT. Mean upper air flow patterns have been worked out for spells of strong and weak northeast monsoon conditions over the Madras State in the month of November and compared with the normal patterns for the month. It is noticed that the winds at 1·5 and 3·0 km a.s.l. over the Peninsula are mainly easterlies when the monsoon is strong, but become northerlies, when the monsoon is weak. At 6·0 and 9·0 km a.s.l, anticyclonic cell over the Bay of Bengal is prominent during strong monsoon conditions but becomes diffuse during weak monsoon conditions, when the high pressure cell over the Arabian Sea becomes dominant.

1. Introduction

Krishna Rao and Jagannathan (1953) have made an exhaustive study of the northeast monsoon rainfall of Tamilnad (the present Madras State), utilising the rainfall data for the 80 years, 1870 to 1949. They have discussed the abnormalities with reference to the incidence of depressions and cyclonic storms in the south Bay of Bengal. They find that large excesses of rainfall occur when depressions and cyclonic storms strike or come very near to the Coromandal coast and large defects occur when such depressions and storms do not come close to the Coromandal coast but move northwards. It has also been pointed out by them that good northeast monsoon rains can occur even without a depression if a large number of active low pressure waves move from the Bay of Bengal into the Arabian Sea across the extreme south Peninsula. They were, however, precluded from determining the upper air flow patterns due to paucity of data particularly when the monsoon is strong. K.V. Rao, from his studies (*see ref.*) of the 500-mb patterns as well as the 6·0 km mean wind flow patterns during the strong and weak northeast monsoon conditions of the years 1946 and 1949 respectively, has come to the conclusion that during strong northeast monsoon, the high pressure cell over the Bay and the adjoining Peninsula is well marked, while during weak monsoon conditions the anticyclonic cell over the Arabian Sea and adjoining Peninsula becomes dominant. The present paper deals with a study of the mean upper air flow patterns over India and neighbourhood associated with spells of strong and weak northeast monsoon conditions over the Madras State in the month of November during the decade 1951—1960.

2. Method of analysis

2.1. *Determination of strong and weak monsoon spells*—The daily rainfall data of the ten India met. Dep. observatories in the Madras State having 'rainfall normals' (*viz.*, Madras, Vellore, Cuddalore, Salem, Nagapattinam, Tiruchirappalli, Coimbatore, Madurai, Pamban and Palayamcottai) for the month of November for the 10-year period, 1951—1960 have been used for the study. The average rain over Madras State on a day has been taken to be the arithmetic mean

TABLE 1

Spells of strong northeast monsoon

S. No.	Period	Duration (days)	Excess of mean rainfall over normal (entire spell) (%)	Smallest excess on individual day in the spell (%)
1	3 to 17 Nov 1960	15	229	26
2	4 to 9 Nov 1957	6	153	76

TABLE 2

Spells of weak northeast monsoon

S. No.	Period	Duration (days)	Defect of mean rainfall (entire spell) (%)	Smallest defect on individual day in spell (%)
1	13 to 20 Nov 1959	8	89	60
2	6 to 13 Nov 1958	8	89	66
3	6 to 18 Nov 1955	13	94	58
4	5 to 16 Nov 1954	12	94	68
5	23 Nov to 2 Dec 1954	10	99	95
6	3 to 13 Nov 1953	11	98	83
7	26 Oct to 17 Nov 1952	23	92	73
8	23 to 29 Nov 1952	7	96	72

of the rainfall reported by the above ten stations. Spells of strong and weak northeast monsoon have been defined as follows.

(*a*) *Spell of strong northeast monsoon conditions*

(*i*) The duration of the spell should be more than five days.

(*ii*) The mean rainfall for each of the days in the spell should be at least 20 per cent more than the normal for the day.

(*iii*) The mean rainfall for the entire spell should exceed the normal rainfall for the period by 100 per cent or more.

(*b*) *Spell of weak northeast monsoon conditions*

(*i*) The spell should be more than five days.

(*ii*) The mean rainfall for each of the days in the spell should be at least 60 per cent less than the normal for the day.

(*iii*) The mean defect over the entire spell should be at least about 90 per cent. The details of the spells are given in Tables 1 and 2. The data for November alone have normally been considered, but when the spell extends into December or commences from late October, the entire period has been taken. Detailed studies have been made of the strong monsoon situation in 1960 and weak monsoon conditions in 1955.

2.2. *Determination of flow patterns*— The pibal ascents were made at 0200 and 0900 GMT and radar wind observations at 0300 and 1500 GMT in 1955. The main synoptic hours of observations in 1960 were 00 and 12 GMT both for pibal and rawin ascents. Mean vectoral winds at 1·5, 3·0, 6·0 and 9·0 km a.s.l. at the various pibal/rawin stations have been determined separately for the morning ascents. By taking the morning ascents, it is ensured that the observations at the various upper wind stations correspond as nearly as possible to the same synoptic hour. The mean flow patterns at 1·5 and 6·0 km a.s.l. for the strong monsoon spell in 1960 are shown

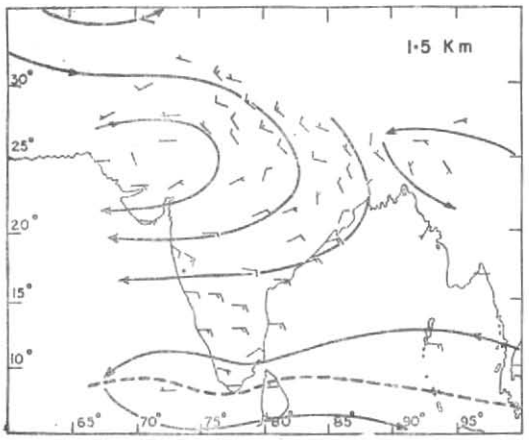

Fig. 1(a)

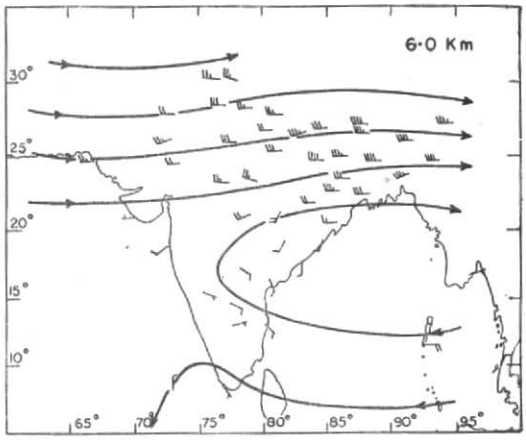

Fig. 1(b)

Fig. 1. Mean flow pattern, 3-17 Nov 1960 (Strong Monsoon)

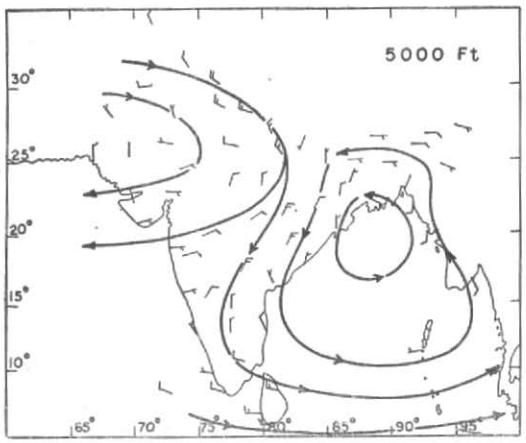

Fig. 2(a)

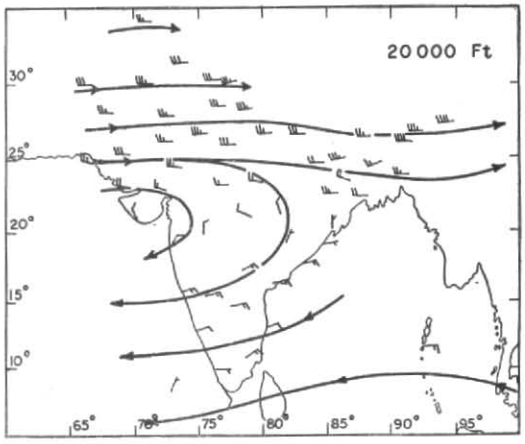

Fig. 2(b)

Fig. 2. Mean flow pattern, 6-18 Nov 1955 (Weak Monsoon)

in Figs. 1 (a) and 1(b). The corresponding flow patterns for the weak monsoon spell in 1955 are given in Figs. 2 (a) and 2 (b). The flow patterns at 9·0 km a.s.l. for the strong and weak monsoon spells are given in Figs. 3(a) and 3(b). The flow patterns at 3·0 km a.s.l. were found to be similar to the patterns at 1·5 km a.s.l. and hence have not been reproduced.

3. Synoptic features

3.1. *3 to 17 November 1960* — Three low pressure areas moved across the extreme sou th Peninsula, one after the other. One of them concentrated into a depression on 10th with centre about 200 km southeast of Nagapattiu m, but weakened into a low pressu area the next day and then moved westwards across the extreme south Peninsula.

3.2. *5 to 17 November 1955* — A depression formed in the southeast Bay of Bengal on 4th with centre about 300 km southwest of Port Blair. It intensified into a cyclonic storm on 5th evening and became severe the next day, when it was centred about 250 km eastsoutheast of Kakinada. Thereafter, it recurved and

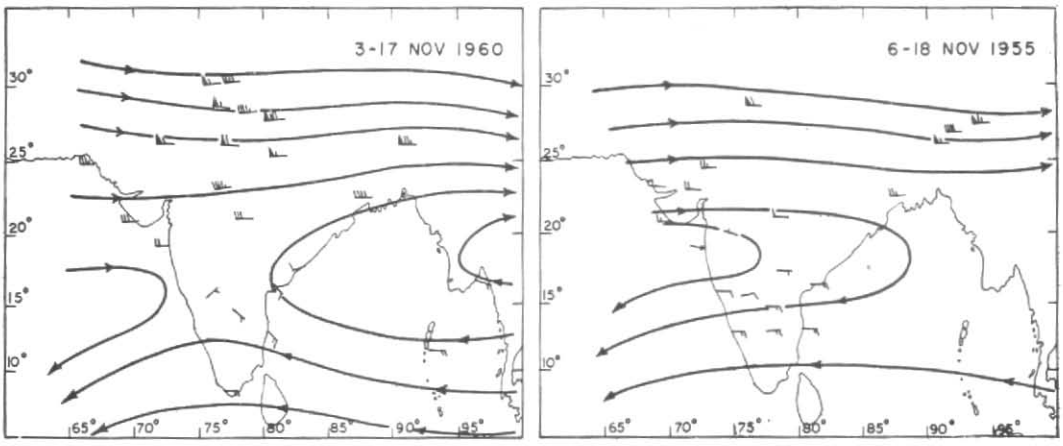

Fig. 3 (a). Strong Monsoon

Fig. 3 (b). Weak Monsoon

Fig. 3. Mean flow pattern at 9·0 km a.s.l.

weakened into a depression with centre near Visakhapatnam on 7th. Continuing its northeasterly movement and weakening at the same time, it filled up over East Pakistan and neighbourhood by 11th.

4. Discussion of the results

4.1. *Flow pattern at 1.5 km a.s.l.*— The seasonal pattern consists of a trough of low over the extreme south Bay of Bengal and the adjoining Arabian Sea, the axis of the trough running roughly along Lat. 8°N. The winds over the Peninsula are mainly northeasterlies. During strong monsoon conditions, the winds over the Peninsula are mainly easterlies, *i.e.*, the easterly component becomes pronounced, the northerly component becoming weak while during the weak monsoon conditions northerlies dominate over the Peninsula.

4.2. *Flow pattern at 6·0 km a.s.l.*— The chief feature of the seasonal pattern is a ridge extending extensively over the latitudinal belt 15°N to 20°N, with one cell over the Bay of Bengal and another over the Arabian Sea. It is seen that during strong northeast monsoon conditions , the high pressure cell over the Bay and the adjoining Peninsula is well marked and the one over the Arabian Sea is ill-defined whereas during weak monsoon conditions, the anticyclonic cell over the Arabian Sea and the adjoining Peninsula becomes dominant and the one over the Bay becomes diffuse. These results are in agreement with conclusions arrived at by Rao (*see* ref.).

4.3. *Flow pattern at 9·0 km a.s.l.*— It will be seen that the observations north of Lat. 20° to 25°N are scanty during the weak monsoon spell of 1955. The discussion will hence be restricted to the flow patterns over the Peninsula. The axis of the sub-tropical anticyclone lies roughly along 17°N in both the cases. However, as in the case of the 6·0 km pattern, the high pressure cell over the Bay of Bengal and adjoining Peninsula is very pronounced during the active monsoon conditions but becomes diffuse during weak monsoon conditions. It is also noticed that south of 25° N, the westerly components decrease and the easterly components increase during the weak monsoon conditions. No definite conclusions could be drawn regarding the flow pattern north of 25°N.

4.4. *Anomaly patterns*—The anomaly patterns (departures from the normal) at 1·5 and 6·0 km a.s.l. have been worked out for the two spells and shown in Figs. 4 and 5 respectively.

4.4.1. *Anomaly pattern at 1·5 km a.s.l.*— The anomaly pattern during the strong

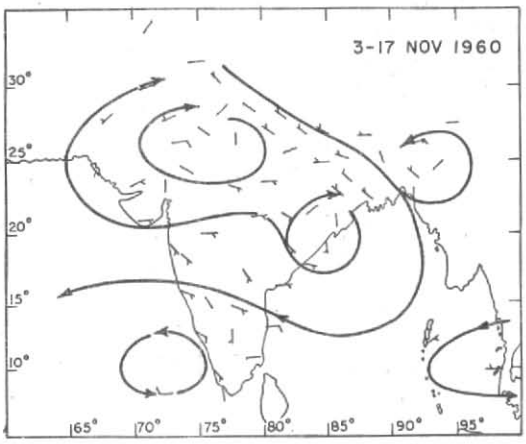

Fig. 4 (a). Strong Monsoon

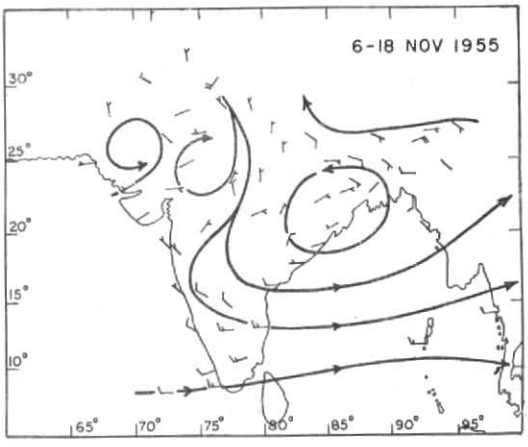

Fig. 4 (b). Weak Monsoon

Fig. 4. Anomaly pattern at 1·5 km a.s.l.

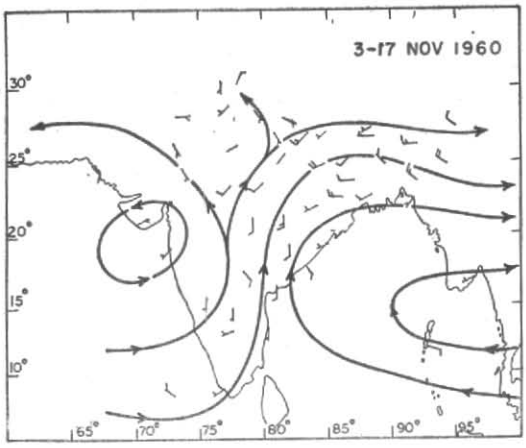

Fig. 5 (a). Strong Monsoon

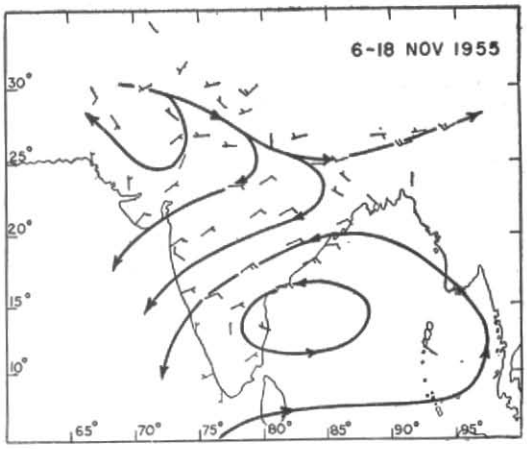

Fig. 5 (b). Weak Monsoon

Fig. 5. Anomaly pattern at 6·0 km a.s.l.

monsoon spell (Fig. 4a) shows anticyclonic flow extending from northwest India to the north Bay of Bengal. The anomaly pattern during the weak monsoon (Fig. 4b) shows cyclonic flow extending from the central Bay to east Uttar Pradesh. In other words, strong monsoon spell is associated with accentuation of the seasonal sub-tropical ridge over north India and the flow of maritime air over the south Peninsula. The weak monsoon spell is associated with the weakening of the sub-tropical ridge and the flow of continental air over the south Peninsula.

4.4.2. *Anomaly pattern at 6·0 km a.s.l.*—The anomaly pattern during weak monsoon (Fig. 5b) shows cyclonic flow over the Bay while the anomaly pattern during strong monsoon conditions (Fig. 5a) shows anticyclonic flow over east central Bay and cyclonic flow around east Arabian Sea.

4.5. *Upper air structure*—The mean evening upper air soundings for the two periods for the stations, Madras, Trivandrum and Port Blair have been

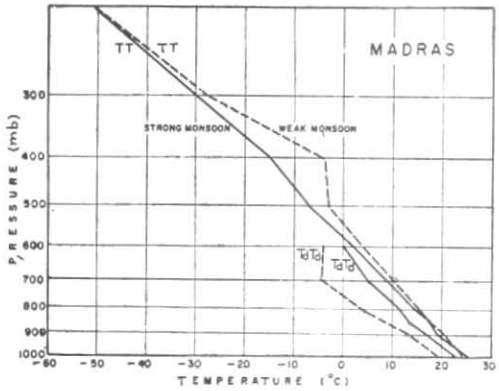

Fig. 6

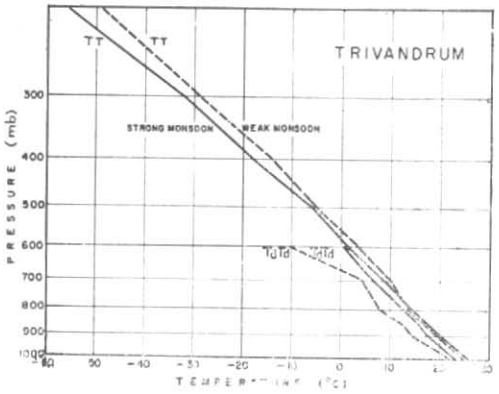

Fig. 7

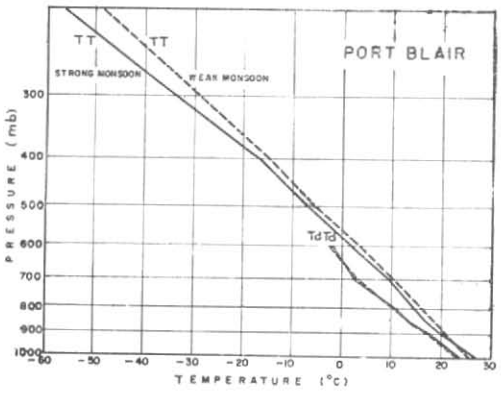

Fig. 8

plotted on log p—T diagrams and given in Figs. 6, 7 and 8 respectively. The continuous curves are for the strong spell and the broken ones for the weak spell. The atmospheric layers over Madras and Trivandrum are quite dry in 1955, but moist in 1960. The moisture content over Port Blair has remained nearly the same during both periods. It is also noticed that at all the stations, the temperature of the troposphere, at least upto about 200-mb level is lower during strong northeast monsoon conditions. Data for higher levels are not available.

4.6. *Mean flow patterns for the other spells* — The mean flow patterns at 1·5 and 6·0 km a.s.l. for the second strong monsoon spell, *viz.*, 4 to 9 November 1957 are shown in Figs. 9 (a) and 9 (b) and agree well with the corresponding patterns for the spells in 1960 (Figs. 1 a and 1 b). The mean upper air flow patterns have not been worked out for the other weak monsoon spells, but the upper air charts for the different spells have been looked into. They show a general agreement with the above findings, but for one or two cases where the flow pattern at 6·0 km a.s.l. shows the characteristics of strong monsoon conditions towards the end of the spell. There were only one or two days in November 1952 and 1954, when the rainfall exceeded the day's normal. The mean rainfall amounts for both the months were in defect by about 80 per cent. The mean monthly winds at 1·5 and 6·0 km have been taken from the respective monthly weather reports published by the India Meteorological Department and the mean flow patterns are shown in Figs. 10 and 11. They are found to be in good agreement with the patterns shown in Fig. 2.

5. Conclusion

Both the strong monsoon spells are associated with two or three low pressure areas moving across the extreme south Peninsula, in accordance with the findings of Krishna Rao and Jagannathan (1953).

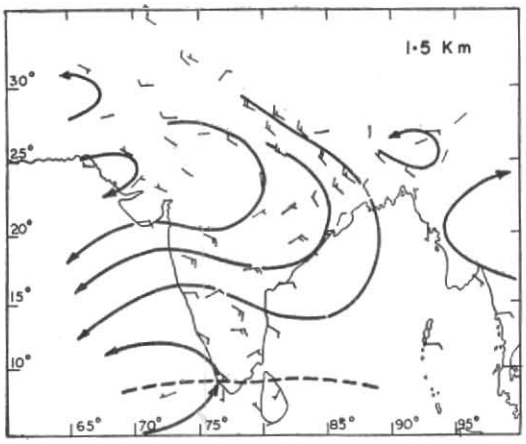

Fig. 9 (a)

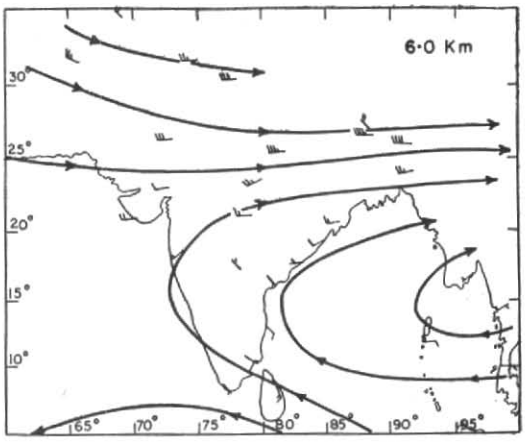

Fig. 9 (b)

Fig. 9. Mean flow pattern, 4-9 Nov 1957 (Strong Monsoon)

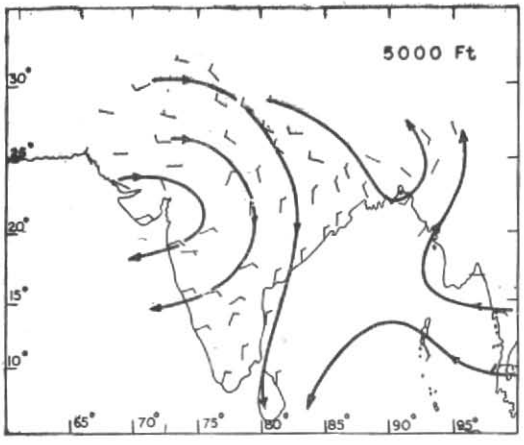

Fig. 10 (a)

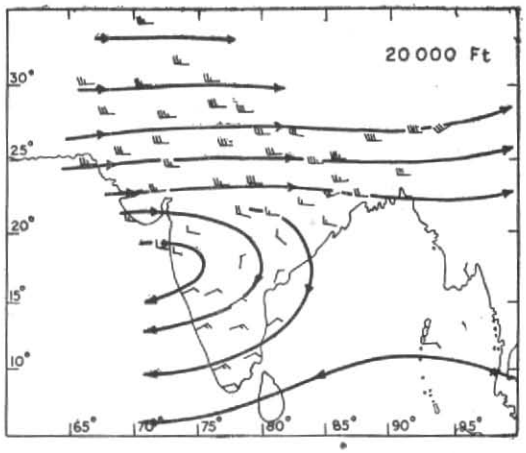

Fig. 10 (b)

It has been shown by Krishna Rao and Jagannathan (1953), that weak northeast monsoon conditions are associated with depressions and cyclonic storms in the Bay of Bengal which move northwards without coming nearer the Coromandal coast. Using this criterion it was found that the spells 2, 3, 6 and 7 (Table 2) could be attributed to movement of such systems. However, the other 4 spells could not come under this category. Rather, it was found that all the 8 weak spells come under the following

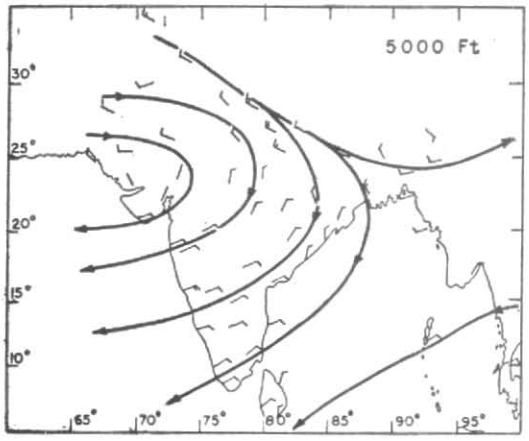

Fig. 11 (a)

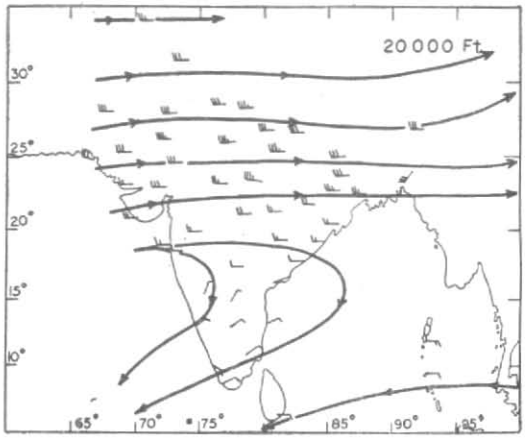

Fig. 11 (b)

general category—mainly dry northerly winds upto 6·0 and 9·0 km a.s.l. with the anticyclone at 6·0 and 9·0 km a.s.l. over the Bay of Bengal becoming diffuse. Thus the criterion given by Krishna Rao and Jagannathan appears to be a particular case of the more general criterion referred to above.

6. Acknowledgements

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