

Wind field in the lower and middle troposphere over the Arabian Sea during the southwest monsoon 1973

R. JAMBUNATHAN and K. RAMAMURTHY

Meteorological Office, Poona

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ABSTRACT. Utilising the MONEX (Monsoon Experiment) data 1973, the wind field over the Arabian Sea in the lower and middle troposphere during two epochs, one of active and one of weak monsoon over the Indian Peninsula and the central parts of the country, was analysed and the results are presented in this paper. The study shows that the low level westerlies attain a mean maximum velocity of 50 to 55 kt over the west central Arabian Sea both in active and weak monsoon, the level of the maximum wind being at about 900 mb in active monsoon and 950 mb in weak monsoon. But in east Arabian Sea, the westerlies weaken considerably during weak monsoon. The slope and other features associated with the low level westerly maximum are also discussed.

1. Introduction

In 1973, the southwest monsoon advanced over Kerala on 4 June and covered most of the Arabian Sea, the Peninsula, central and northeast India by 13 June. The monsoon did not advance further over the country during the rest of June, when there was a lull in the monsoon. Further, the monsoon during the latter half of June was also weak over the Peninsula and the central parts of the country where the rainfall was less than 50 per cent of the normal.

The monsoon, however revived in the beginning of July and covered the entire country by the 6th. It was active during the first fortnight of July. The present study is concerned with the westerly wind regime over the Arabian Sea during the periods, 19 to 25 June (representing a spell of weak monsoon) and 4 to 8 July (representing a spell of active monsoon). During the weak monsoon period, the axis of the seasonal trough was close to the foot of the Himalayas, while during the active monsoon, the monsoon trough extended from Gujarat to Head Bay of Bengal, with a well marked low over Gujarat and a depression moving from northwest Bay to north Madhya Pradesh both of which are usual features associated with the monsoon.

2. Data

In this study, upper wind data reported by the four Russian Ships, viz., (1) *Priliv*, (2) *Voeykov*, (3) *Okean* and (4) *Shokalskiy* which made extensive cruises in the Arabian Sea during the periods mentioned above, have been utilised in respect of the ocean area. Along the west coast of India the upper air data from the rawin and pilot

balloon stations have been used. Along the Arabia and Pakistan coasts, available upper air observations from Masirah, Karachi and Jiwani during the above periods have also been used. No observations were available along the Somalia coast and from Socotra Island in the west Arabian Sea for the periods under study. For a proper coverage of data over these areas to enable a complete and confident analysis of the wind field, the charts of Weather Central, Poona, for the years 1943-45 were gone through. Surface wind observations of Socotra (12° 38' N, 53° 55' E) Seusciuban (10° 18' N, 50° 14' E) and Mogadiscio (02° 02' N, 45° 21' E) were available on almost all the days of July during 1943 to 1945. Upper wind observations were available only for Mogadiscio on many days. Mean surface winds for Socotra and Seusciuban and mean surface and upper winds for Mogadiscio were worked out for spells of active and weak monsoon during these years from the available data. Mean upper winds for active and weak monsoon spells for Seusciuban and Socotra were estimated on the basis of the actual surface winds of these stations and from the trend of the winds at surface and aloft as shown by the MONEX ships' data near 11° N 56° E and at Mogadiscio. The data coverage for upper air analysis during active and weak monsoon is shown in Figs. 1 (a) and 1(b) respectively. For surface analysis, all other available ships' data in addition to the data of Russian ships have been utilised.

3. Analysis

Vertical profiles of wind speed were constructed for every ascent made by the Russian ships utilising the data at standard and significant levels.

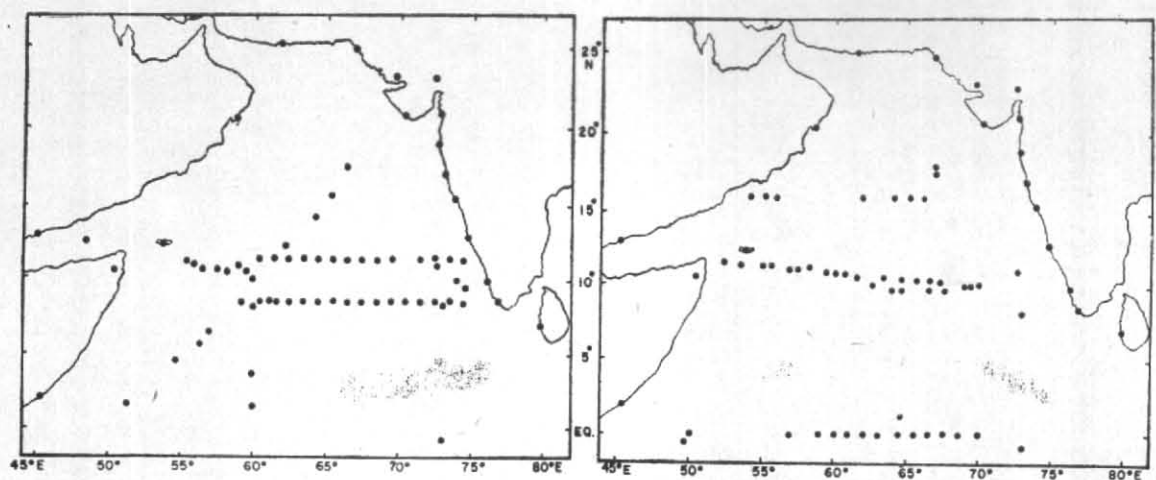


Fig. 1

Data coverage of (a) active and (b) weak monsoon

From these profiles, wind speeds at every 50 mb interval upto 700 mb and at 100 mb interval from 700 to 400 mb were extracted and plotted in different charts at all positions of the ships (irrespective of time) for all the days during the active and weak monsoon spells referred to in the introduction. Instead of choosing a typical day for analysis, a period of 5-7 days during active and weak monsoon situations has been chosen to get the maximum coverage of data over the Arabian Sea. As there was not sufficient coverage of data over west central Arabian Sea during the active monsoon spell (4-8 July 1973), data of ship *Shokalskiy* which was in that area during the period 7-11 June, have also been made use of, as this period was also one of active monsoon (advancing phase) over the Arabian Sea and the Peninsula.

Over the Arabian Sea, data over 3 to 4 degrees longitude have been averaged and the mean value put in the centre of the longitudinal belt for the final analysis, giving due weightage to the more consistent values. It may be mentioned that only during the MONEX 1973, such a wide coverage of upper wind observations was available over the Arabian Sea and as such, the analysis of the wind field could be done with a fair degree of confidence. Streamlines and isotachs were drawn for the levels referred to above and are discussed in the ensuing paragraphs. Diagrams for the standard levels only have been reproduced. In these diagrams the isotachs are in knots, the broken lines representing the westerly field.

4. Discussion

4.1. Streamlines and isotach field during active monsoon (4-8 July 1973)

(i) *Surface (Fig. 2a)*—Winds of more than 20 kt cover most parts of the Arabian Sea with a maximum of about 37 kt over west central Arabian Sea. The axis of the maximum wind runs from off Somalia coast northeastwards to central Arabian Sea and thence east-southeastwards to Kerala coast with a branch running east-northeastwards from west Arabian Sea to south Maharashtra coast. The winds are about 10 to 15 kt between equator and 5° N east of 60° E. The streamline chart shows cross-equatorial flow over the entire longitudinal belt of Arabian Sea.

(ii) *950, 900 and 850 mb*—At these levels there is a considerable increase in wind speed over most parts of the Arabian Sea as compared to the speed at the surface. At 950 mb and 900 mb the 30 kt isotach extends from Somalia to the west coast of India. At 850 mb (Fig. 3a) a 35 kt isotach covers this area. The axis of the maximum wind runs from Somalia to south Kerala and adjoining Comorin through 12-13° N over central Arabian Sea without any appreciable displacement between 950 and 850 mb. Westerlies are strongest at 900 mb with a maximum of 55 kt over west Arabian Sea with central region near 12°N, 59°E. At 950 and 850 mb the westerly maximum is of the order of 47 kt and 52 kt respectively. The location of the region of maximum wind does not show any significant displacement

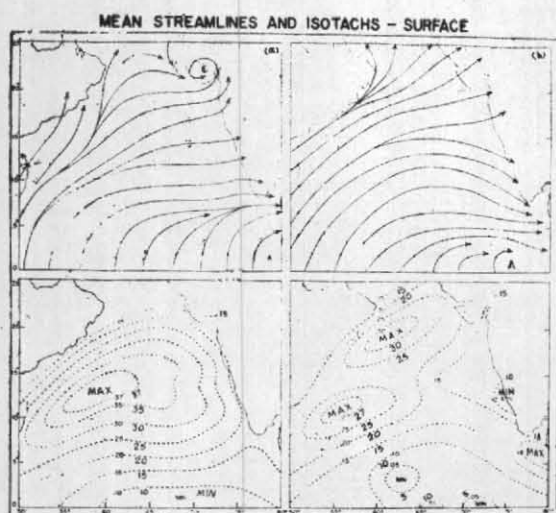


Fig. 2. Surface

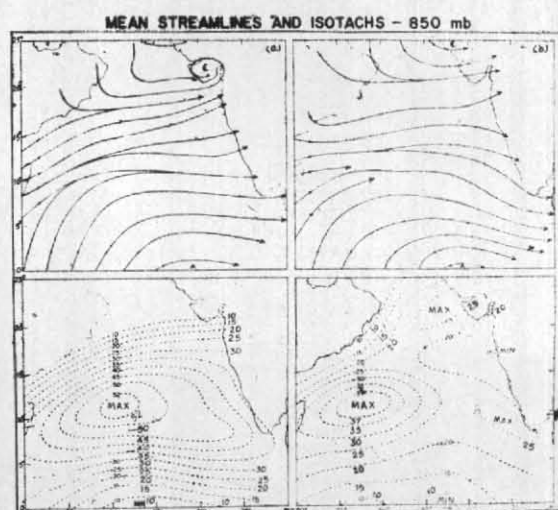


Fig. 3. 850 mb

Streamline and isotach field during (a) active and (b) weak monsoon

between 950 and 900 mb but at 850 mb level it is displaced towards the east by about two degrees. The other branch of the axis of the maximum wind continues to run from west Arabian Sea to south Maharashtra coast at these levels as at the surface. The cross-equatorial flow persists over the entire longitudinal belt of the Arabian Sea at 950 and 900 mb while at 850 mb level it is mainly confined to the west of 65° E.

(iii) 800 mb — The wind field at this level is nearly similar to that at 850 mb. However the westerly maximum has decreased to 47 kt and the wind near the equatorial region has strengthened to 20/25 kt. The cross-equatorial flow is seen at this level west of 60° E.

(iv) 750 mb — The significant changes that are observed at this level as compared to 850 mb are:

- (a) The two branches of the axis of the maximum wind are disconnected and appear as two separate axes.
- (b) The northern branch runs from central Arabian Sea (12° N, 62° E) to south Maharashtra coast. At its western end, the maximum has weakened from about 52 kt at 850 mb level to about 35 kt at this level.
- (c) The southern branch has shifted southwards. At its eastern end (over Comorin - Lakshadweep area) the wind speed has increased to 47 kt.

(v) 700 mb (Fig. 4a) — At this level the main axis of the maximum wind has shifted further

south and runs east-west from Somalia to Comorin roughly along 6 to 7° N. At its eastern end a maximum of about 45 kt is maintained. There is no change in the location of the northern branch. However at its western end the speed has further decreased while at its eastern end, the speed continues to be about 35 kt. The streamline chart shows that at this level the cross-equatorial flow is practically absent over the Arabian Sea (except perhaps close to Somalia coast). Westerlies of 20/25 kt generally prevail over the equatorial region.

(vi) 600 and 500 mb — The configuration of the isotachs at these levels is nearly similar to that at 700 mb with the two axes located at more or less the same positions. However, there is progressive weakening of the wind speed in the southern branch. The maximum wind speed in both the branches is about 30 to 35 kt at these levels. Fig. 5(a) shows the streamlines and isotach field at 500 mb.

(vii) 400 mb — The monsoon westerlies continue to prevail over south and east central Arabian Sea with a maximum of 25 kt extending from 6° N, 62° E to coastal Karnataka.

4.2. Streamlines and isotach field during weak monsoon (19-25 June 1973)

(i) Surface (Fig. 2b) — Winds of 20 kt prevail over northwest central and southwest Arabian Sea. The axis of the maximum wind runs from off Somalia coast to Comorin through central Arabian Sea (12.5° N, 63° E) with a maximum of 27 kt near 11.5° N, 56° E. Another region with maximum wind of 30 kt is seen over northwest and adjoining

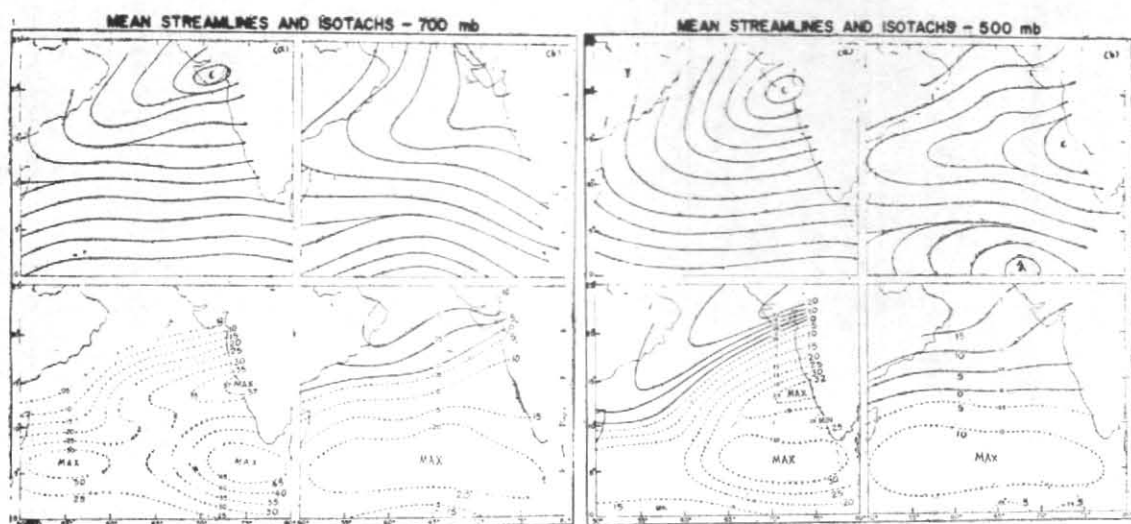


Fig. 4. 700 mb

Fig. 5. 500 mb

Streamline and isotach field during (a) active and (b) weak monsoon

west central Arabian Sea. A wind minimum is observed over east central Arabian Sea with its axis running roughly along $13-15^{\circ}\text{N}$. This occurs over the region where the streamlines show diffluence. Winds are very weak (5 to 10 kt) from equator to 7°N between 60 and 75°E . Throughout the longitudinal belt of Arabian Sea there is cross-equatorial flow.

(ii) *950, 900 and 850 mb*— The axis of the maximum wind runs from Somalia to Comorin through about 12°N , 60°E at these levels without any displacement between 950 and 850 mb. Westerlies are strongest at 950 mb with a maximum of about 50 kt over west Arabian Sea with central region near 12°N , 55°E . The westerly maximum is 47 kt at 900 mb and 37 kt at 850 mb (Fig. 3b). The location of the region of the maximum wind is more or less the same at 950 and 900 mb while at 850 mb, it is displaced by about 3 degrees to the east. The other maximum which lies over north-west Arabian Sea at the surface is seen progressively shifting northeastwards at these levels and the maximum value decreases from 30 kt at surface to 25 kt at 850 mb. The axis of the minimum wind which is seen near 13° to 15°N at the surface progressively shifts northwards and runs along 17°N at 850 mb.

The winds near the equatorial region have gradually strengthened to 10–15 kt and the cross-equatorial flow persists practically over the entire longitudinal belt of the Arabian Sea upto 900 mb while it is seen to the west of 65°E at 850 mb.

(iii) *800 mb*— The isotach configuration is the same as at 850 mb. The maximum over west Arabian Sea has weakened to 30 kt while the other maximum over north Arabian Sea is maintained. The cross-equatorial flow is mainly seen west of 57°E .

(iv) *750, 700, 600 and 500 mb*— The westerlies have progressively weakened at these levels. There is no preferred location of maximum wind. The strongest wind of about 20 kt at 700 mb (Fig. 4b) and about 10 kt at 500 mb (Fig. 5 b) covers the south Arabian Sea with its axis roughly along 5 to 7°N . The axis of the minimum wind along about 17°N at 850 mb, forms the trough between the easterlies and the westerlies at these levels over the central Arabian Sea with a southward slope in the vertical. The streamlines show that between 750 and 600 mb winds are westerlies near the equator while at 500 mb a ridge has developed between the equator and 5°N .

(v) *400 mb*— Westerlies are practically absent over the Arabian Sea at this level the winds being mainly northeast to east except near the equator where they are variable.

The important features of the wind field during the active and weak monsoon epochs are summarised in Table 1.

4.3. Meridional cross-sections of the mean wind profile over the Arabian Sea

From the isotach analyses at the various levels discussed earlier, wind profiles along meridians

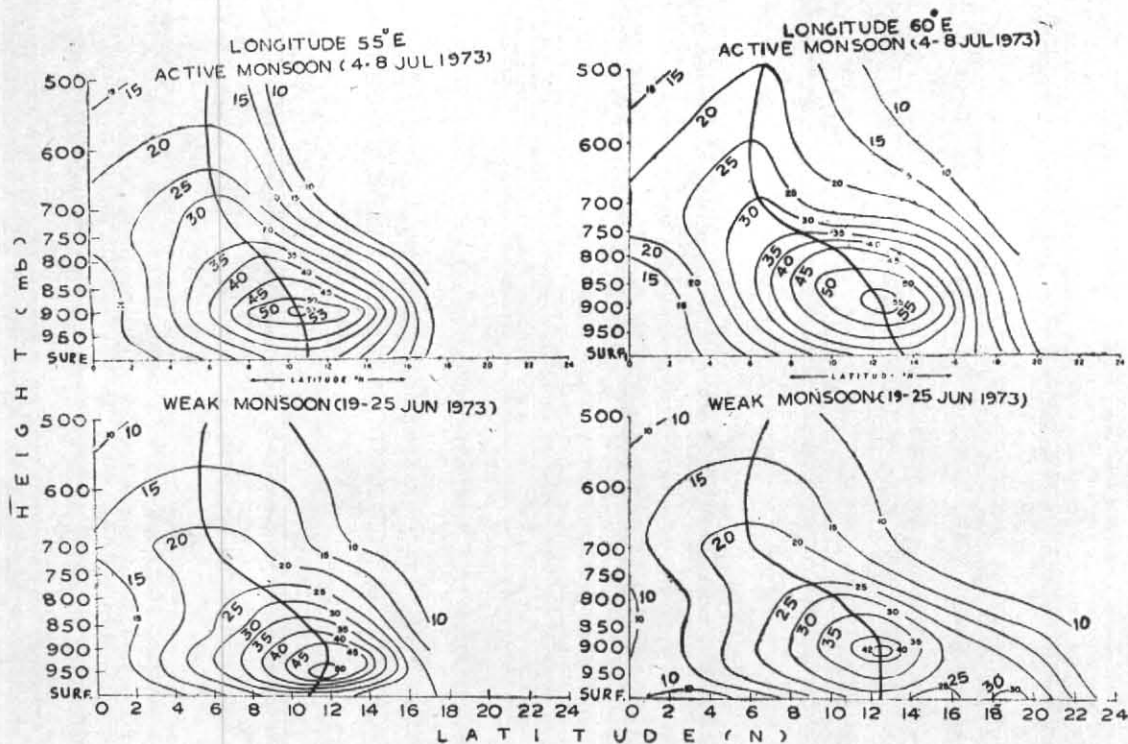


Fig. 6

Fig. 7

TABLE I

Important features of wind field	Active monsoon	Weak monsoon
Strength of mean max. wind	55 kt	50 kt
Level of the above max. wind	About 900 mb	About 950 mb
Location of the above max. wind	Around 12°N, 55°E	Around 12°N, 55°E
Location of the axis of the mean max. wind	Generally from Somalia to Comorin through central Arabian Sea sloping southwards with height.	Nearly the same as in active monsoon
Location of the other branch of the max. wind	From west Arabian Sea to south Maharashtra coast.	Absent but a second maximum occurs in north Arabian Sea.
Axis of the other wind between these two branches	Poorly defined upto 850 mb. Higher up, it is seen off south Karnataka coast with a southerly slope in the vertical	Well defined upto 800 mb off Karnataka Maharashtra coasts with a northward slope in the vertical.
Vertical extension of westerlies	400 mb	500 mb

55, 60, 65, 70 and 75° E were constructed for the active and weak monsoon spells by picking out the speeds at every degree latitude along the meridian. The profile for 75°E is made up of ships data over the sea area upto 12°N and data of coastal stations further north. The cross-sections are depicted in Figs. 6 to 10. The thin

continuous lines in these diagrams are isopleths in knots. The thick continuous line represents the orientation of the core of the maximum wind in the vertical. The thick broken line represents the orientation of the axis of the minimum wind in the vertical. The salient features noticed are discussed in Table 2.

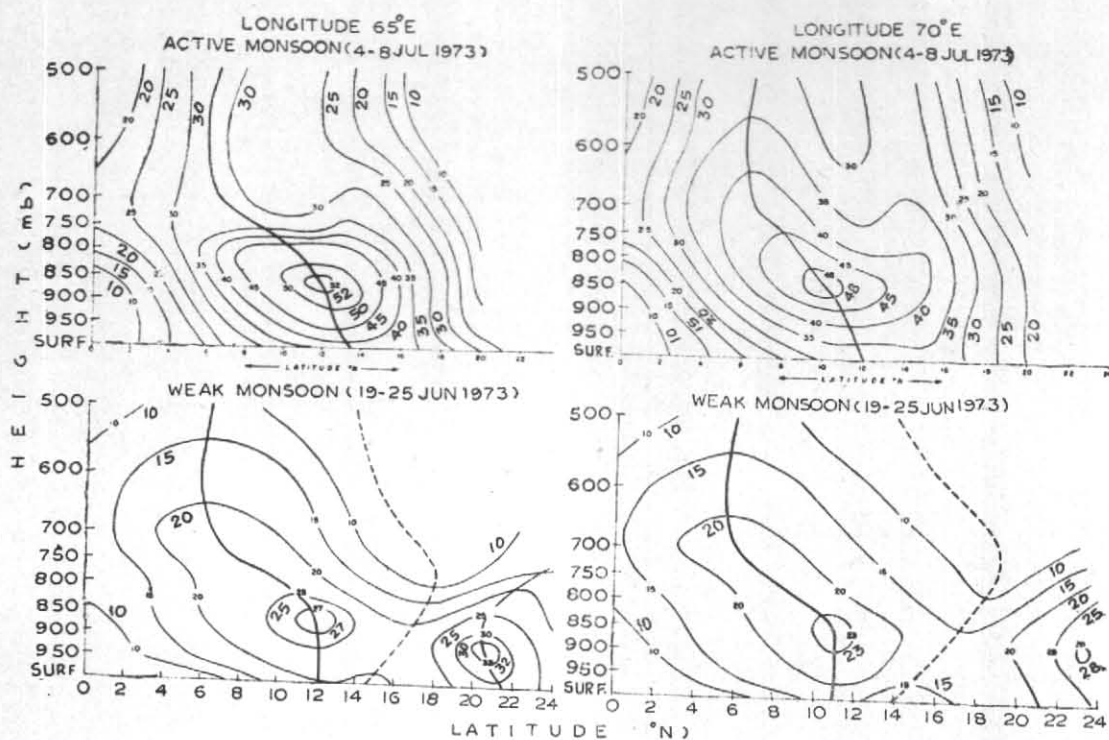


Fig. 8

Fig. 9

TABLE 2

Observed features	Active/weak monsoon	55°E (Fig. 6)	60°E (Fig. 7)	65°E (Fig. 8)	70°E (Fig. 9)	75°E (Fig. 10)
Strength of mean max. wind	Active	53 kt	55 kt	52 kt	48 kt	47 kt
	Weak	50 kt	42 kt	27 kt	23 kt	25 kt
Level of strongest wind	Active	900 mb	885 mb	865 mb	835 mb	785 mb
	Weak	950 mb	900 mb	875 mb	860 mb	875 mb
Lat. of strongest wind	Active	10.5° N	12.0° N	12.0° N	10.0° N	7.5° N
	Weak	11.5° N	12.5° N	12.0° N	10.0° N	9.0° N
Southward slope of the axis of the max. wind (°Lat.) upto 500 mb	Active	5	7.5	7.5	6	4
	Weak	6.5	6.5	6	5.5	4.5

NOTE: Figures against weak monsoon refer to the primary max. occurring south of Lat. 15°N

4.4. Some important features associated with the low level westerly maximum

The horizontal orientation of the main axis of the westerly maximum wind at the standard levels, viz., Surface, 850, 700 and 500 mb are reproduced in Figs. 11(a) and 11(b), representing active and weak monsoon epochs respectively. These diagrams show that the axis of the maxi-

mum wind has a southward slope in the vertical, particularly between 850 and 700 mb without any significant difference between active and weak monsoon epochs.

Findlater (1971) has given the mean maximum wind over the Arabian Sea as 25 kt for June and as 35 kt for July at 900 m. This is based only on Socotra wind. The present study based on

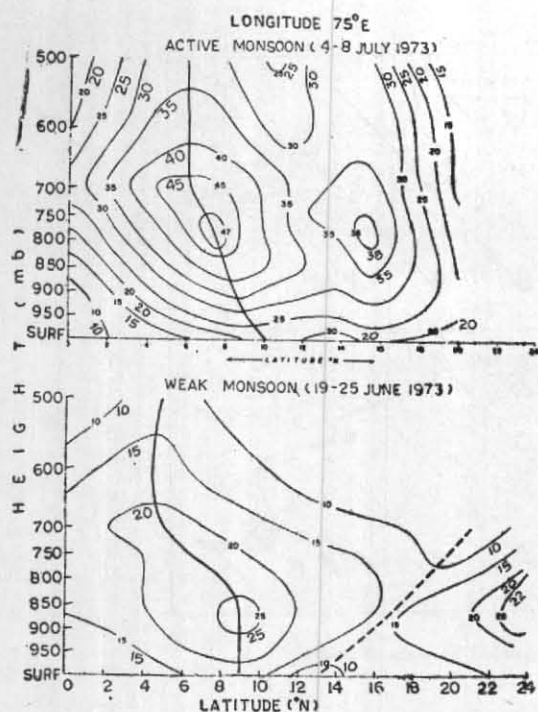


Fig. 10

MONEX data in that area however shows that the mean westerly maximum is as high as 50 to 55 kt in active and weak monsoon spells in June-July 1973. During the IIOE period Bunker (1965) also found the westerly maximum in the Arabian Sea occurring near about the same location with winds of 25 m/sec.

The vertical orientation of the core of the maximum wind across the Arabian Sea is shown in Fig. 12. The core slopes upwards from west to east during both active and weak monsoon spells being as low as 950 mb at its western end (55°E) and as high as 785 mb at its eastern end (75°E). However it is interesting to note that while during active monsoon the core of the maximum wind has a considerable upward slope towards the east, it is nearly horizontal east of 65°E during weak monsoon.

The temperature and wind profiles plotted for all the ascents during active and weak monsoon spells reveal that the low level westerly maximum occurs generally just below or in the layer of low level inversion. A few typical illustrations of the above feature are given in Fig. 12(a).

5. Conclusions

The foregoing study brings out the following features associated with the wind field in the

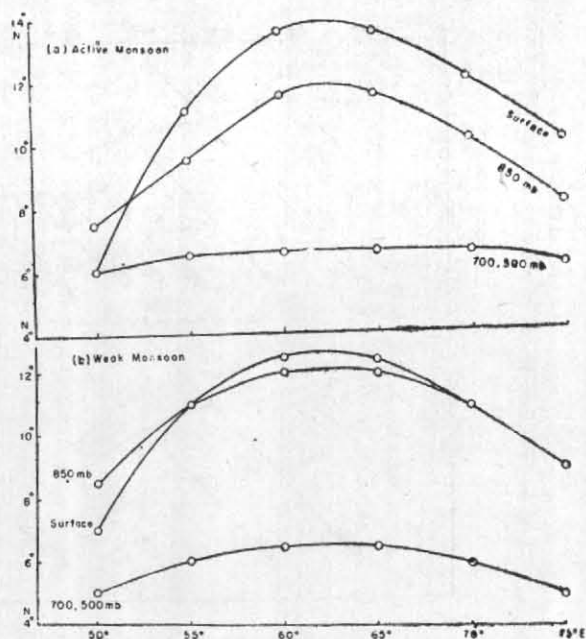


Fig. 11. Horizontal orientation of the axis of maximum wind

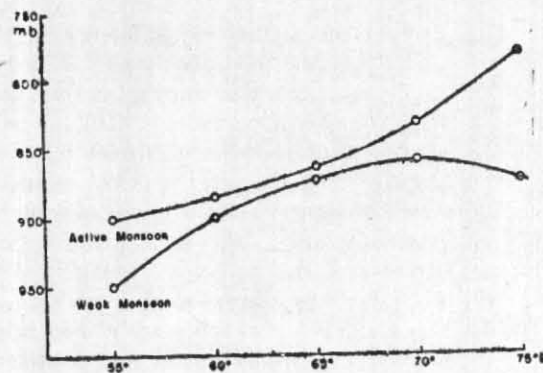


Fig. 12. Vertical orientation of the core of maximum wind

lower and middle troposphere over the Arabian Sea during the southwest monsoon 1973:

- (i) The low level westerlies attain a mean maximum velocity of about 50-55 kt over west Arabian Sea in the longitudinal belt of 55°E to 60°E near latitude 12°N.
- (ii) Over the above area the maximum wind occurs near about 900 mb during active monsoon. During weak monsoon it occurs at a lower level, viz., about 950 mb.
- (iii) The westerly maximum is found to be even as high as 70 kt on a few individual occasions in the above area.

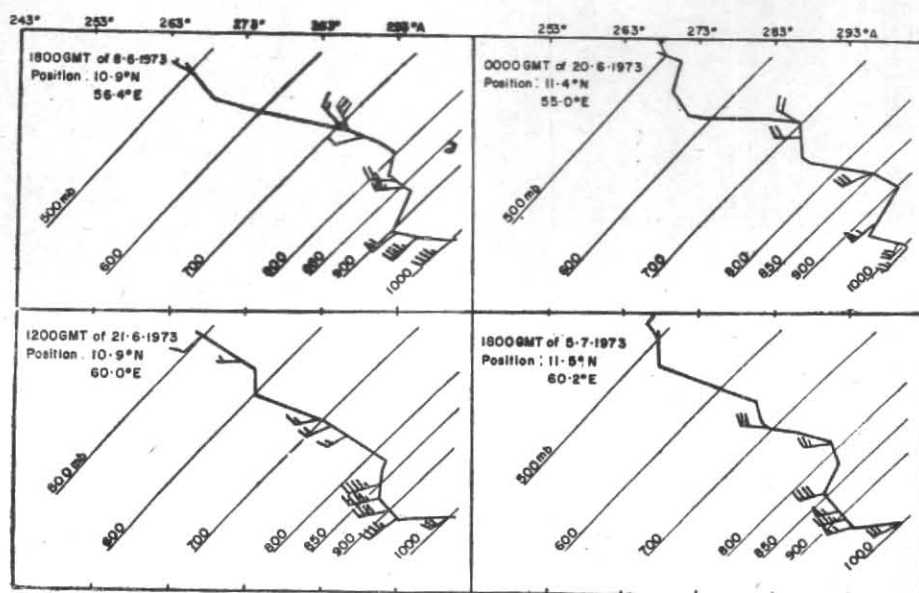


Fig. 12(a). Wind and dry bulb temperature reported by ship *Shokalskiy*

- (iv) There is no significant difference in the velocity of the westerly maximum in the west Arabian Sea during active and weak monsoon epochs. This would suggest that there is no direct relationship between the activity of the monsoon over the country and the low level westerly maximum over the west Arabian Sea. However, the maximum is confined to a smaller area during weak monsoon and the low level westerlies are considerably weaker over east central and southeast Arabian Sea with an anticyclonic curvature.
- (v) The winds crossing the equator particularly west of 60° E upto 850 mb are also weaker during weak monsoon.
- (vi) The axis of the maximum wind generally slopes upwards from west to east and

has a southward tilt between surface and 700 mb.

- (vii) The low level maximum wind occurs generally just below or in the layer of low level inversion.
- (viii) The westerlies extend to 400 mb or slightly higher up during active monsoon, while they are confined to generally 500 mb during weak monsoon.

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