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Structure of low-level jet-stream over the Arabian Sea and the Peninsula as revealed by observations in June and July during the monsoon experiment (Monex) 1973 and its probable origin

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ABSTRACT. Surface and upper air observations recorded by the four Russian ships during Monsoon Experiment (MONEX) 1973 over the Arabian Sea and the Indian Ocean upto the equator and by the observatories over Kenya and the Peninsular India, have been examined to study details about the jet-speed winds noticed over the area during active or strong monsoon conditions. The following points are brought out by the study :

(1) The low-level jet was noticed simultaneously over the Arabian Sea between Lats. 7° and 16° N east of about Long. 53° E and over the Peninsula at (*i*) different levels over the same place, (*ii*) different latitudes at the same time, and (*iii*) different latitudes and levels at different times.

(2) The extent of the jet in the horizontal and vertical was generally larger over land than over sea. It may be at as high a level as 3·0 km over sea and 3·8 km over land.

(3) When a jet-stream persisted over an area for a day or two, the lowest jet over the sea would appear to be at a lower level during the morning than evening hours.

(4) The low-level jet over the Peninsula and the Arabian Sea would not appear to originate due to thermal conditions off Somalia and over the Arabian Sea. Jet-speed winds occurred over sea in the moist air and not near the boundary of moist and dry airmasses; they occurred below or above or in the isothermal layers or in the airmass with nearly moist adiabatic lapse or at the boundary between moist airmasses, one having unstable lapse and the other moist adiabatic lapse.

(5) The low-level jet over the Peninsular India is a continuation of that over the Arabian Sea, which in turn would appear to be a continuation of that which crosses equator between Longs. 37° and 45°E and has its origin in the southern hemisphere as seen from papers of Findlater (1969) and as discussed by Desai (1972); the cold fronts in the mid-latitudes of that hemisphere moving eastwards initiate the low-level jet, the topographical features to the west of the eastern coast of Africa and of Madagascar directing it northwards across the Mozambique channel and also enhancing its speed.

(6) The need for closer network of Rawin and Radiosonde observations over the equator between longitude of Nairobi and 45 degrees East in any future MONEX expeditions has been emphasized.

1. Introduction

Bunker (1965) reported jet-speed (50 kt) at 1000 m at Lat. 11°N, Long. 58°E in the South Arabian Sea on 1 September 1964.

Joseph and Raman (1966) have shown the existence of low-level jet over the Peninsula in India during July, and stated that 1·5 km level was the most favoured level of occurrence of the low-level jet. The jet persisted for a few days at a time and moved northward and southward. The vertical wind profiles given in Fig. 1 of their paper (1966) indicate only one level below 500 mb (about 6 km) where jet-speed winds occurred.

Desai (1968) reported that the low-level jet occurs over the Peninsula simultaneouly at two different places 500 to 800 km apart and also at different levels at different places.

Findlater (1969) found presence of a persistent high speed air current embedded in the southwest monsoon flow from Somalia to India in the form of a system of low-level jet stream; the same was an extension of the high speed flow from Mauritius area to Kenya to Somalia in the Western Indian Ocean and an integral part of the general circulation of the southwest monsoon season. In Fig. 11 of his paper (1969), Findlater has given some typical vertical wind profiles of the low-level jet which show the existence of jet speed winds (48 kt or more) only at one level below 3 km.

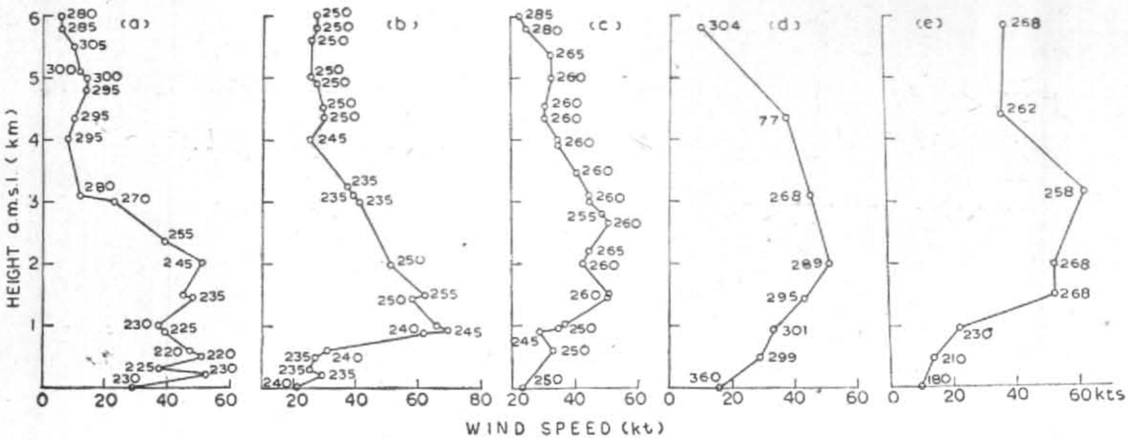


Fig. 1. Selected wind profiles on occasions of occurrence of jet speed winds

(a) Ship *UAAX* at Lat. 07·9° N, Long. 57·8°E at 0100 GMT of 5 July 1973, (b) Ship *UAAX* at Lat. 8·5°N, Long. 67·5° E at 1300 GMT of 7 July 1973, (c) Ship *EREI* at Lat. 8·5°N, Long. 72·5°E at 0900 GMT of 8 July 1973 (d) Trivandrum at 1200 GMT of 10 July 1973, (e) Madras at 0000 GMT of 7 July 1973

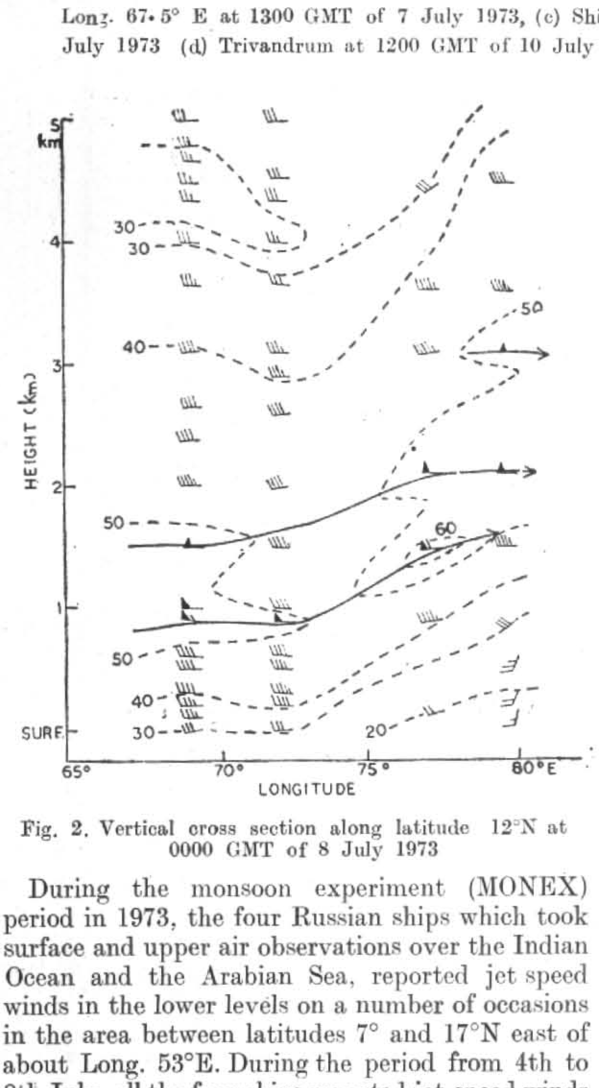


Fig. 2. Vertical cross section along latitude 12°N at 0000 GMT of 8 July 1973

During the monsoon experiment (MONEX) period in 1973, the four Russian ships which took surface and upper air observations over the Indian Ocean and the Arabian Sea, reported jet speed winds in the lower levels on a number of occasions in the area between latitudes 7° and 17°N east of about Long. 53°E. During the period from 4th to 8th July, all the four ships reported jet-speed winds on many occasions. During June also, some ships on some days reported jet-speed winds in some of their observations. Their positions were so distributed that it is possible to get a picture of the jet-stream its position and structure in the vertical and horizontal planes by analysing those observations. Further, these ships took four observations in a day (00, 06, 12 and 18 GMT) and reported upper winds at short intervals whenever any significant changes in wind speed and/or direction were observed. During the period 6 to 8 July 1973, a number of stations over the Peninsula also reported jet-speed winds. In this paper, an attempt has been made to analyse the upper air observations by the Russian ships together with the observations over the Peninsula during said periods.

2. Discussion

(a) Selected wind profiles — Fig. 1

On an examination of the vertical wind profiles over the places where low-level jet-speed winds* (48 kt or more) were reported, it is revealed that the jet-speed winds below 500 mb occurred simultaneously at different levels at the same place. Some typical examples of the vertical wind profiles have been constructed from the upper air reports by the Russian ships and of two stations— Trivandrum and Madras, in the Peninsula and are shown in Fig. 1.

Fig. 1(a) shows the simultaneous occurrence of jet-speed wind at 0·2, 0·5 and 2·0 km a.s.l.; wind directions at different levels are also given in the figure. Similarly Fig. 1(b) shows jet-speed winds in the layer between 0·8 and 2·0 km a.s.l. with maximum of 70 knots near 1 km. Fig. 1(c) indicates a double maximum at 1·5 and 2·6 km a.s.l. In

*The broad stream with wind speed 48 kt or more without any reference to the magnitude of shear has been regarded as a jet by the authors — *Editor*.

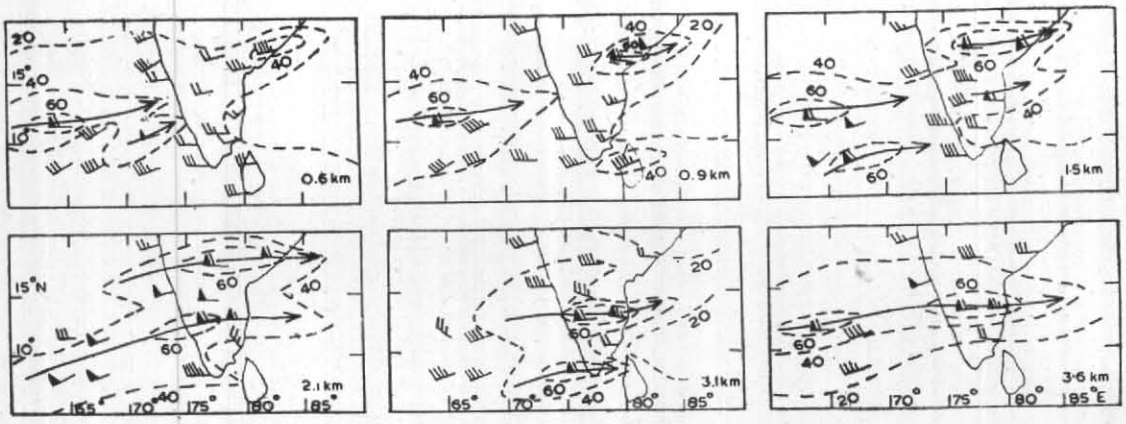


Fig. 3. Isotach analysis for different levels over the Arabian Sea and the Peninsula at 0000 GMT of 7 July 1973

Fig. 1(d) is given the vertical wind profile over Trivandrum on 10 July 1973 at 12 GMT when jet-speed winds were reported at 2·1 km a.s.l. Fig. 1 (e) gives the vertical wind profile over Madras on 7 July 1973 at 00 GMT with jet-speed winds occurring in the layer between 1·4 and 3·8 km a.s.l. and with maximum speed of 63 knots near 3 km. According to Findlater (1969), the depth of jet-speed winds is about 0·5 km, whereas in Figs. 1(b) and 1(e), the depth is more than 1 km; this may probably be an instance when the jet-stream occurring simultaneously at different levels converged and merged into a deep single stream resulting in an increase in depth.

(*b*) *Vertical cross-section along Lat. 12°N at 00 GMT on 8 July 1973 — Fig. 2*

As the jet-speed winds have been reported on 8 July 1973 at 00 GMT by the two Russian ships near Lat. 12°N in the Arabian Sea and by the land stations at Madras and Bangalore which also are located around Lat. 12°N, a vertical cross-section of the wind field has been given in Fig. 2 for that date and hour along that latitude from Long. 65°E to 85°E.

From the isotach analysis, it is evident that (1) simultaneously two streams of maximum winds with jet-speeds in segments occurred both over the Peninsula and the Arabian Sea, (2) the streams of maximum wind corresponding to the two jet-streams at different levels over the Peninsula were presumably a continuation of the jet-stream over the Arabian Sea, and (3) the height of the level of the same stream of maximum winds increases as it approaches the coast of the Peninsula, *i.e.*, it appears to be at a lower-level over the Arabian Sea than over the Peninsula.

(*c*) *Isotach analysis for different levels at 00 GMT on 7 July 1973 over the southeast Arabian Sea and Peninsula — Fig. 3*

In Fig. 3 are given wind speed and direction at different levels in the lower troposphere as reported at 00 GMT of 7th July by various stations over Peninsular India together with those of the reports by the Russian ships plying in the southeast Arabian Sea to locate the streams of maximum wind speed and the jet-cores along the streams and isotach analysis of the same data is also presented in the figure. The following points are brought out by Fig. 3 :

(1) It is evident that the low-level jet can occur simultaneously at different latitudes over the Peninsula as reported by Desai (1968) and also over the southeast Arabian Sea.

(2) Low-level jets over the Peninsula can probably be considered as a continuation of those over the south Arabian Sea, as both are occurring along the same streams of maximum wind speed in segments in the lower levels (1·5 km and below) and as a single continuous jet-core at 2·1 km and above. The break in the jet-core into segments along the west coast at 1·5 km and below, might appear to be due to the presence of the Western Ghats, although the possibility that the break in the jet-stream at a given level can also be due to either slight decrease or increase in the levels in which the wind might be of jet-speed, cannot be ruled out.

From Fig. 3, it can be seen that upto 1·5 km low-level, jets appear in two segments on either side of the Western Ghats, one over the Arabian Sea and the other over the Peninsula. Above 1·5 km, it appears as a continuous stream of jet-speed winds from the Arabian Sea across the Peninsula. This would show the absence of Ghats' influence above about 1·5 km.

(3) The depth as well as the width of the jet-stream is generally more over land than over sea areas. One would expect that, as a result of high

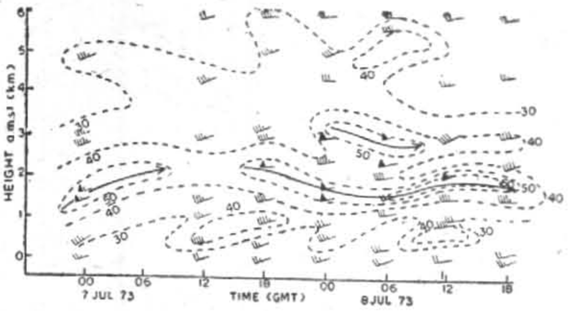


Fig. 4. Diurnal variation in the jet stream on 7 and 8 July 1973

frictional turbulences over land there will be transport of momentum both in the vertical and horizontal as a result of which there should be decrease in the wind speed at the jet core over land. It is, however, noticed that there is not much difference in the wind speeds at the jet core over sea and over land and actually on some occasions jet-core speeds over land are more than those over sea. This anomaly might possibly be due to the effect of the Western Ghats.

(4) Over the Arabian Sea, more than one low-level jets occur at different latitudes and a different altitudes at different times as well as simultaneously and they are confined east of Long. 57°E to the south of Lat. 15 N and and north of Lat. 7°N, as seen from an examination of upper wind reports received from the Russian ships at different locations over the Arabian Sea except for the fact that the period of reports elsewhere might not have coincided with the occurrence of jet-streams.

(5) The latitudinal extent upto which the low level jet appears over the Indian Peninsula depends upon the southerly component of the wind field over the Arabian Sea and the Peninsula which may change from layer to layer and from time to time. Hence the jet-stream passes through the higher latitudes as it moves eastwards in a wind field with southerly component. From Fig. 3 it can be seen that the levels in which the wind field is WSW, the jet-stream appeared over the Peninsula as far north as 18°N. It can be stated that in a wind field which is westerly, the low-level jet will be confined to the same latitudinal belt both over the Peninsula and the Arabian Sea, other influences being absent. From Fig. 3 it is actually seen that above 2·1 km where the southerly component decreased and wind field was more or less westerly, the jet stream over the Peninsula was confined to south of Lat. 15 N.

It may be mentioned that on most of the occasions, the Russian ships recorded jet-speed winds in the southeast Arabian Sea with speeds at times as high as 70 kts. This would mean that the speed of the jet-stream does *not* necessarily decelerate in the East Arabian Sea, a contrast to the statement of Bunker (1965) that convective processes and showers in the east Arabian Sea, would indicate deceleration of winds over that area.

From the foregoing discussions, it would appear that the chances of occurrence of low-level jet over the same location and at the same time at different heights, one at a lower level and the other at a relatively higher level, are more to the south of Lat. 15°N than to its north as under normal conditions of the southwest monsoon season, the winds veer with height, southerly component decreasing. In addition, the position and core-speed of the jet-stream may perhaps be influenced to a certain extent by the depressions and lower tropospheric circulation patterns over the North Bay of Bengal and northeast India and over the North Arabian Sea.

The statement of Joseph and Raman (1966) that the low-level jet moves northwards and southwards over the Peninsula, would not appear to be correct. Although there may be minor fluctuations in the position of the low-level jet around a latitude within a given longitudinal belt, one cannot accept the view that it can shift by a few degrees to the north or south in the same longitudinal belt in a strong westerly field of winds. Presumably Joseph and Raman could not detect from available data the simultaneouly existence of more than one core of jet-speed winds at different latitudes wide apart as noticed by Desai (1968) and hence their conclusion.

The low-level jets which appear on consecutive days at different latitudes few degrees apart over the Peninsula need not be one and the same, but might be two different jet-streams coming from the Arabian Sea some time lag.

(*d*) *Diurnal variations in the jet-stream — Fig. 4*

As the Russian ships took upper air observations four times a day, an attempt has been made to see whether there are any diurnal variations in the jet-stream by taking an instance when all the four observations (00, 06, 12 and 18 GMT) showed jet-speed winds.

The ship *EREI* reported jet-speed winds in all the observations from 00 GMT of 7th July to 1800 GMT of 8th July while being to the east of Long. 68°E with an eastward course along Lat. 8.5°N. As the ship was moving with an average speed of 20 kt towards east, the relative velocity of jet-stream with reference to the ship was much less than what it would have been if the ship was stationary; the changes in the jet-stream from observation to observation are considered to represent the local time rate of changes. The likely modifications due to change in location can be neglected as the ship moved during the period by only about 4 degrees. The wind data for different hours are given in Fig. 4. It would appear that for the lower jet, the lowest height occurred around 00 GMT on the 7th and between 00 and 06 GMT on the 8th. As the upper jet-streams were present only at 00 and 06 GMT on the 8th, no inferences can be drawn about diurnal variation of their height.

Browning and Paradoe (1973) have mentioned about theoretical studies showing intensification of jet at night. While this might hold good for land areas where nocturnal inversions occur, it is doubtful if the same arguments will apply for the sea areas, as the question of nocturnal inversion formation there does not arise. The lowering of the jet-current noticed in Fig. 4 in the morning hours can be even taken to mean that the speed of wind in those layers had increased and hence appearance of the jet speed winds; one cannot, however, understand the causes for the same, although in some cases as shown in the next section, the jet occurs not only above an isothermal or inversion layer, but even below the same and in some cases, it is even not associated with inversion or isothermal layers.

On an examination of the upper winds of Garissa located near equator and 40°E in Kenya during the MONEX (1973) period, it is seen that although there may be jet-speed winds at some levels at 00 GMT, the speeds are reduced at 1200 GMT; however, on one day the jet-speeds appeared at 12 GMT, they being absent at 00 GMT presumably due to some changes in synoptic conditions over the area.

(*e*) *Structure of the low-level jet on the basis of MONEX upper air data — Fig. 5*

The tephigrams for the days for which the wind profiles are given in Fig. 1 (Fig. 5 a to 5 e) and for some other days Fig. 5 (f to h) are given to get an idea about the thermal conditions with which the jet-speed winds were associated. The following points regarding the thermal structure of the jet-stream winds are brought out :

(1) The jet-speed winds generally occur in moist layer of air.

(2) They occur either in the dry adiabatic or saturation adiabatic lapse layer and at the bottom, in, and at the top of the isothermal or near isothermal layer.

There were also occasions without jet-speed winds when the temperature-height curves were more or less identical with those when jet-speeds occurred. Such tephigrams are, however, not reproduced here.

It would appear from the above that no definite thermal structure is associated with the jet-speed winds, but they generally occur in moist layer of air.

It would appear that the low-level jet over the Peninsular India and the Arabian Sea is *not* caused due to thermal conditions off Somalia as contemplated by Bunker (1965) and discussed by Rao and Desai (1970). Reiter (1963) has stated that it is hard to estimate from the available analysis to which circumstances the low-level jet owes its existence in individual cases.

Browning and Paradoe (1973) have studied low-level jets associated with anacold fronts over the British Isles. In a study of one such case, they observed that the front was characterised by a narrow band of shallow but vigorous convection at the surface; this convection was essentially two-dimensional and termed line convection. In each case, the line convection is bounded on its forward side by a low-level jet reaching 50 to 60 kt; behind the line convection the winds decreased abruptly. The low-level jet was embedded within a "convective boundary layer", reaching its maximum velocity at 900 to 850 mb and it consisted of a tongue of anomalously warm moist air, which had a trajectory even on a warmer sea. As far as the Arabian Sea is concerned, the jet currents are not associated with any cold fronts moving from west to east over the area and the tephigrams reproduced in Fig. 5 show that there was no definite thermal structure associated with them.

(*f*) *Origin of the low-level jet* (*Figs. 6-8*) *and its structure at source and over the equator*

As indicated by Findlater (1969) and Desai (1972), it appears that the low-level jet over Somalia and the adjoining sea areas over the Arabian Sea and over the Peninsular India, owes its origin to the areas in the southern hemisphere over and off the east coast of Africa and over Madagascar and to the east of Mauritius.

Desai (1951) suggested that the transport of air across the equator into the Indian Seas is stimulated by the intensification of the permanent 'highs' in the south Indian Ocean and a change in their orientation and position as a result of the migratory anti-cyclones and of the extra-tropical cyclones in that hemisphere and of the influence of the associated cold fronts which induce surges or waves in the southeast trades. In a later paper, Desai (1972) further suggested that the cold fronts

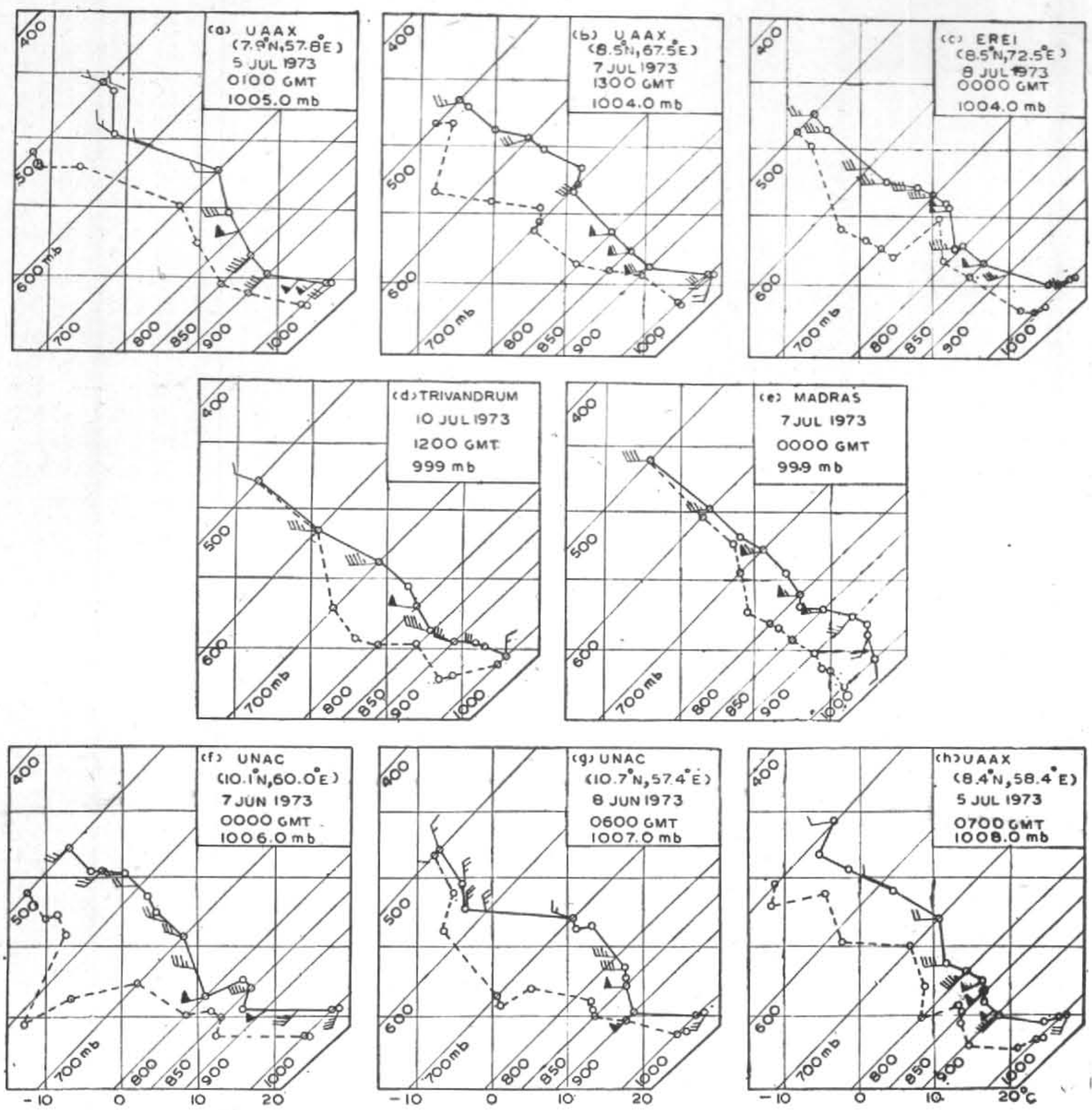


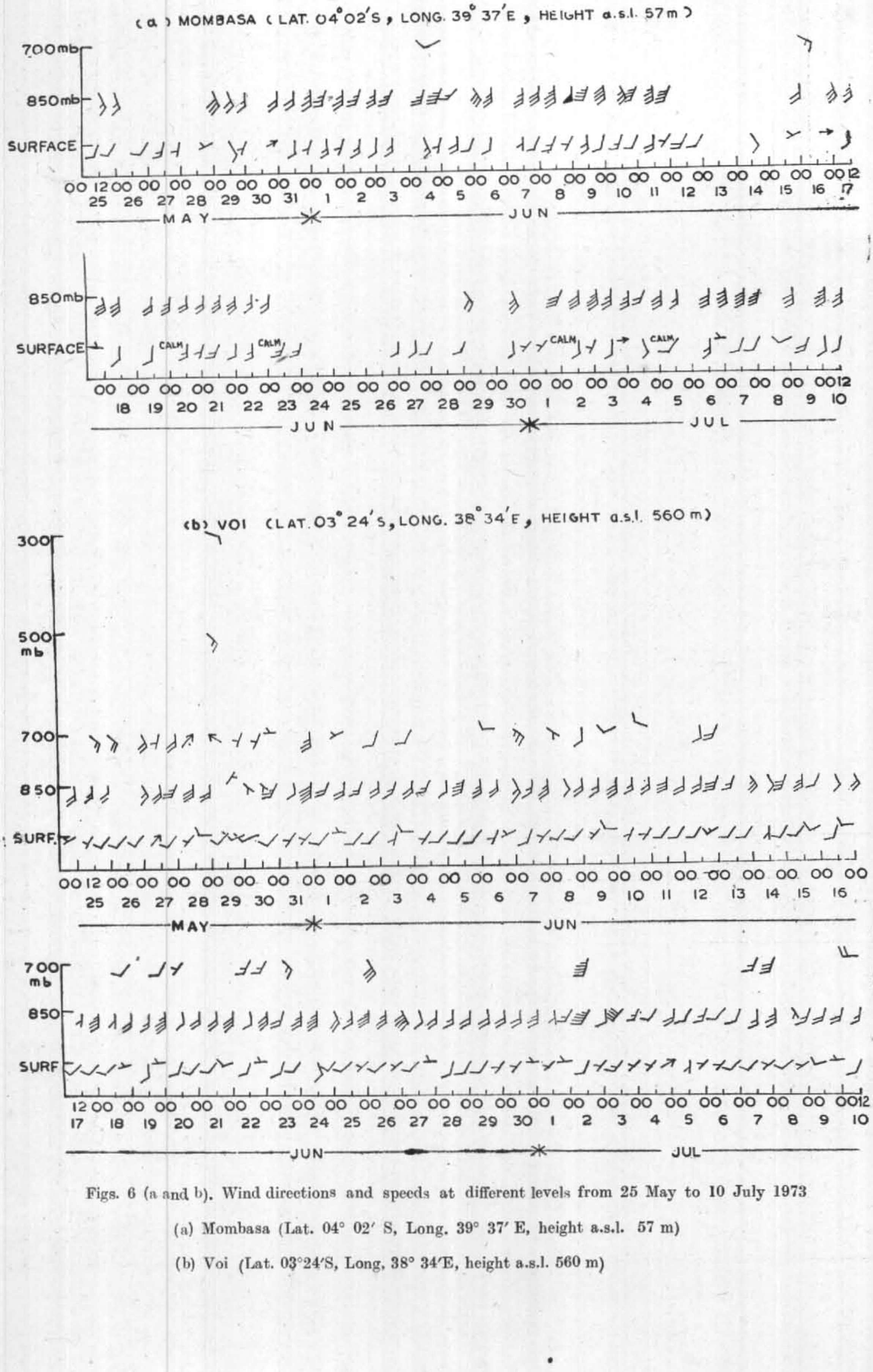
Fig. 5. Tephigrams of selected days of occurrence of jet speed winds

(a) Ship *UAAX* at Lat. 7·9°N, Long. 57·8°E at 0100 GMT of 5 July 1973
(b) Ship *UAAX* at Lat. 8·5°N, Long. 67·5°E at 1300 GMT of 7 July 1973
(c) Ship *EREI* at Lat. 8·5°N, Long. 72·5°E at 0000 GMT of 8 July 1973
(d) Trivandrum at 1200 GMT of 10 July 1973
(e) Madras at 0000 GMT of 7 July 1973
(f) Ship *UNAC* at Lat. 10·1°N, Long. 60·0°E at 0000 GMT of 7 June 1973
(g) Ship *UNAC* at Lat. 10·7°N, Long. 57·4°E at 0600 GMT of 8 June 1973
(h) Ship *UAAX* at Lat. 8.4°N, Long. 58·4° E at 0700 GMT of 5 July 1973

moving eastwards in the mid-latitudes of the southern hemisphere during the northern summer and canalising effect over the Mozambique channel of the topographical features to the west of the coast of eastern Africa on one side and of Madagascar on the other side in directing the flow northwards and in enhancing its speed, are responsible for initiating the low-level jet. The association of the jet current with the cold fronts makes it of a pulsatory nature.

According to Browning and Paradoe (1973), the low-level jets unrelated to topographical effects are often encountered in association with the mid-latitude fronts sometimes ahead of warm fronts, more often ahead of cold fronts. The low-level jets are often modified and sometimes enhanced by topographical effects.

No data are available in India to trace the cold fronts of the middle latitude of the southern hemisphere which are considered to give rise to the low-level jets and the dynamical causes associated with them unrelated to topography.



Figs. 6 (a and b). Wind directions and speeds at different levels from 25 May to 10 July 1973

(a) Mombasa (Lat. 04° 02′ S, Long. 39° 37′ E, height a.s.l. 57 m)

(b) Voi (Lat. 03°24′S, Long, 38° 34′E, height a.s.l. 560 m)

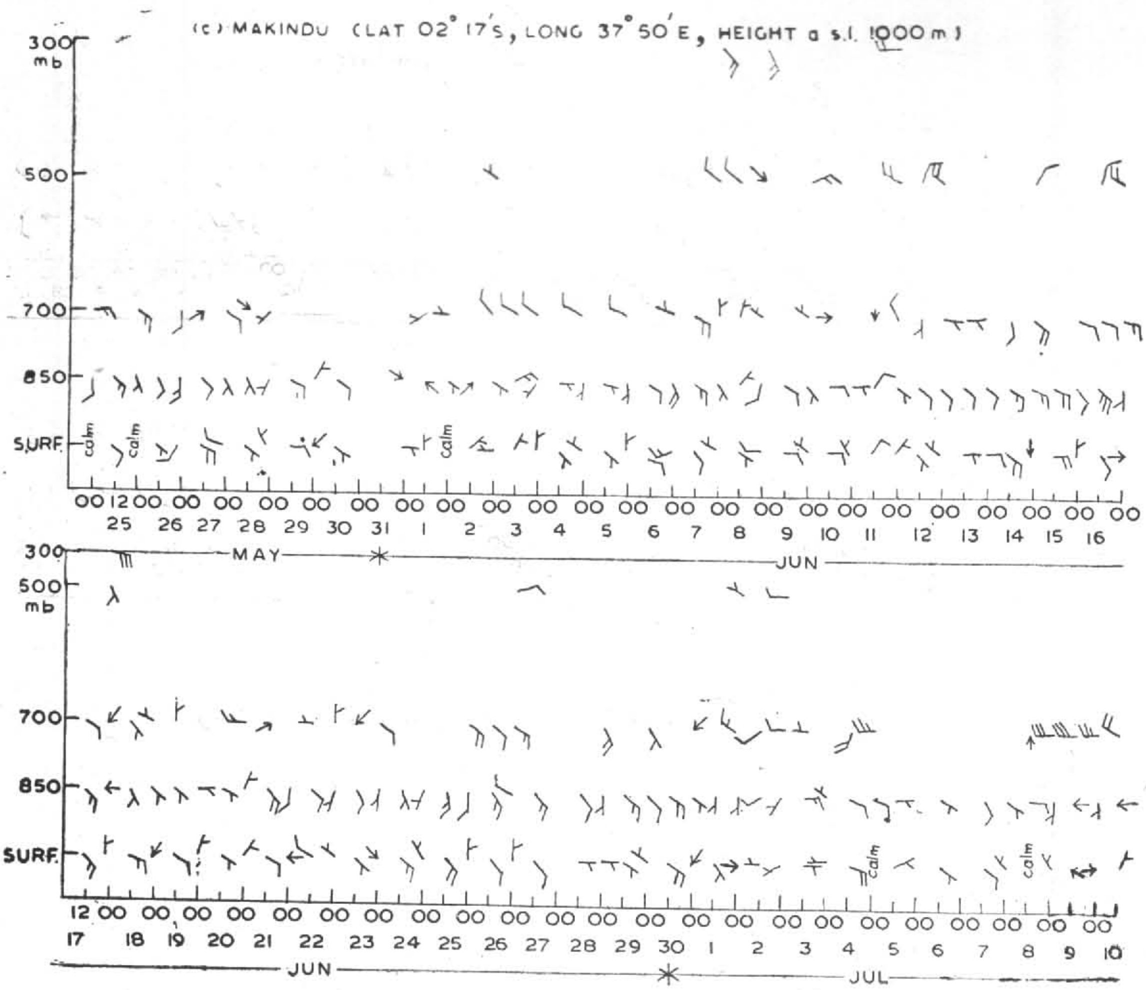


Fig. 6 (c). Wind directions and speeds at different levels from 25 May to 10 July 1973
Makindu (Lat. 02° 17'S, Long. 37° 50'E, height a.s.l. 1000 m)

TABLE 1

Hours of observ-ations	4 July			5 July			6 July			7 July			8 July		
(GMT)	Gari-ssa	Djib-outi	Masi-rah	Gari-ssa	Djib-outi	Masi-rah	Gari-ssa	Djib-outi	Masi-rah	Gari-ssa	Djib-outi	Masi-rah	Gari-ssa	Djib-outi	Masi-rah
							Surface								
00	250/05	..	..	180/03	..	..	180/10	..	..	180/07	..	..	180/07	..	..
12	180/12	..	..	190/10	..	..	190/20	..	..	180/07	..	..	180/13	..	..
							850 mb								
00	190/49	320/05	..	..	330/15	305/16	185/30	330/20	290/12	..	..	..	185/63	310/15	010/05
12	190/22	..	350/07	210/12	310/25	355/14	175/18	..	340/15	185/28	..	350/10	200/22	330/30	305/07
							700mb								
00	245/14	300/10	..		330/10	060/15	275/16	320/15	010/14	..	320/15	340/15		330/39	350/30
12	265/20	340/15	055/18	..	300/20	015/17	..	..	030/15	..	..	005/22	..	290/25	030/29
							500mb								
00	..	050/15	..	..	030/1	065/24	..	360/20	075/24	..	010/10	..	..	360/25	040/45
12	..	060/10	040/17	..	010/15	030/30	..	..	010/30	..	..	350/40	..	..	045/27

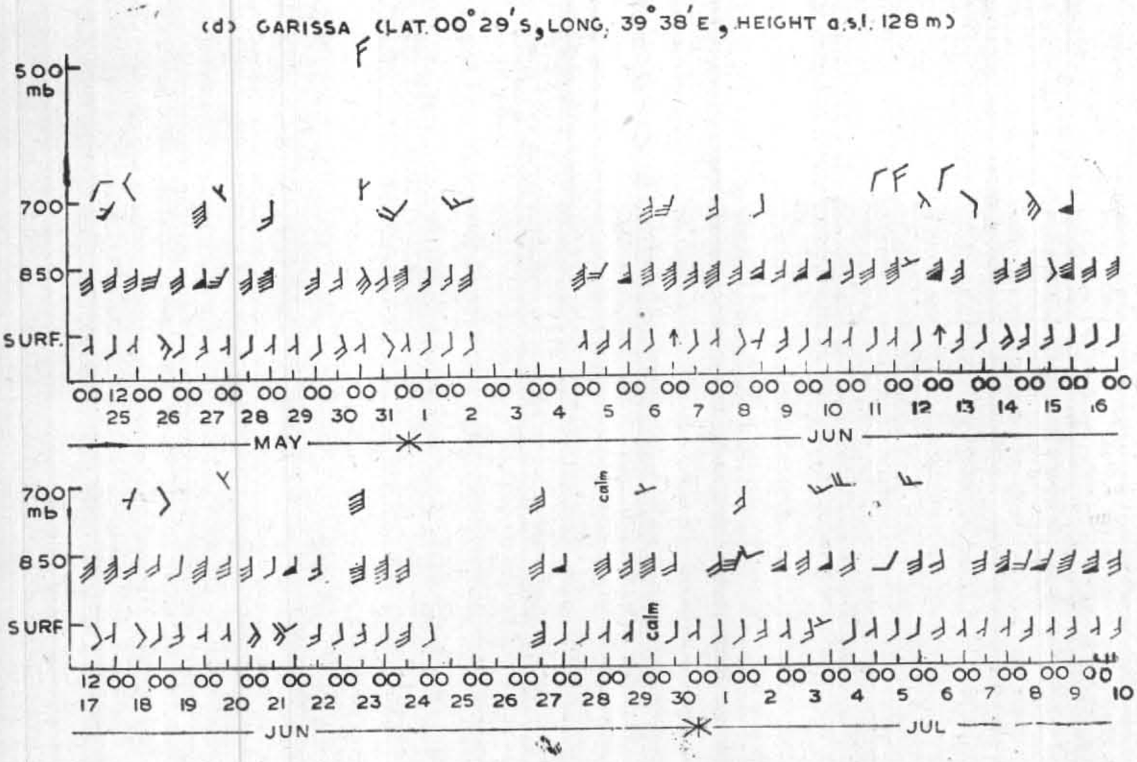


Fig. 6 (d). Wind directions and speeds at different levels from 25 May to 10 July 1973

Garissa (Lat. 00° 29′ S, Long. 39° 38′ E, height a.s.l. 128 m)

In Table 1 are given winds at surface, 850, 700 and 500 mb for 00 and 12 GMT of 4 to 8 July 1973 of Garissa, Djibouti and Masirah to see if one can get any idea from the same about jet-speed winds noticed by the Russian ships over the Arabian Sea on the days in question. It will be clear from the winds at Masirah and Djibouti that the jet-speed winds do not originate in Arabia or Northeast Africa; they may, however, originate in the southern hemisphere and cross the equator between about longitudes 37° to 45° East, as seen from Findlater's papers (1969).

In order to get an idea where the jet-speed winds actually cross over the equatorial area, winds at different levels of available stations in Kenya during the MONEX 1973 period are plotted and given in Figs. 6 (a to e). On comparison of Figs. 6(a) and 6(d) for Mombasa and Garissa, which are practically along the same meridian, it may be seen that at Mombasa, the jet-speeds have occurred only on 9 June at 850 mb at 00 GMT, while at Garissa about four degrees to the north and near the equator, the jet-speed winds occurred on a number of days at 850 mb and at times, even extending to 700 mb (Data are not available for 700 mb on all days).

It is further noticed that at Voi, Fig. 6(b) and at Makindu, Fig. 6(c), which are nearly southsouthwest of Garissa and about 2-3 degrees south of equator, no jet-speed winds were recorded. At Mandera (Fig. 6 e), which is to the northnortheast of Garissa and about 4 degrees north of equator, no jet-speed winds were noticed on any of these days.

It would appear from the above Figs. 6(a-e) that the jet-speed winds cross equator to the east of 38° East and move in a northeasterly direction under directive force of topography (Fig. 7—Desai 1972) and the prevailing pressure pattern over the southwest Arabian Sea and the adjoining western Indian Ocean and Somalia. It is not possible from the available data to fix the eastern limit of the jet-speed winds crossing the equator, as no observations are available, the Russian ships taking part in the MONEX 1973 expedition having not moved to the west of longitude 45 degrees East. It would appear that in order to get an idea about the amount of cross equatorial flow from the southern to the northern hemisphere in the Indian southwest monsoon season, it is necessary to have observations at intervals of 1 degree longitude over the equator

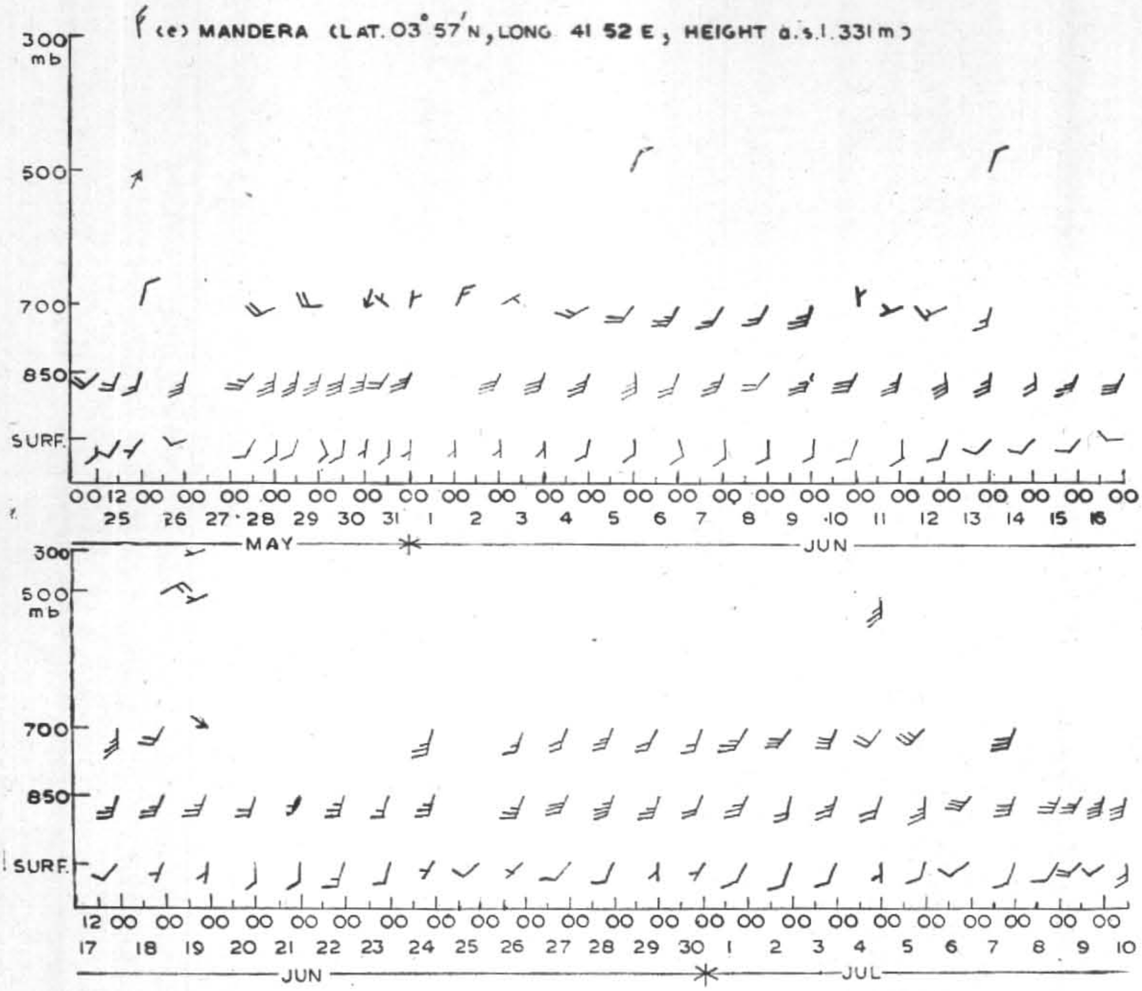


Fig. 6 (e). Wind directions and speeds at different levels from 25 May to 10 July 1973 Mandera (Lat. 03 °57'N, Long. 41° 52' E, height a.s.l. 331 metres)

between longitudes 38 and 45 degrees East, both over land and sea in any MONEX expedition which is planned in future.

The larger number of occasions of jet-speed wind at Garissa than at Mombasa would show that the South-East trades, while moving to the plateau of Africa (Fig. 7), veer and blow from a southerly direction near Garissa area and get reinforced by southerly winds from Mozambique channel side (Desai 1972).

The available upper winds over the Arabian coast during the MONEX period, as stated before, also show that the origin of the jet-speed winds recorded to the east of Long. 57°E in the belt between Lats. 7° and 15°N could not be in Arabia and northeast Africa. The tephigrams over Aden are markedly different from those given in Fig. 5.

Pisharoty and Sreenivasiah (1967) have stated that the air which crosses the equator from the southern hemisphere, turns towards the east by the time it reaches 10°N and it, therefore, does not apparently participte in the circulation of the heat-low over Pakistan and the Gangetic Valley trough; the zone of the airmasses of the northern hemisphere and southern hemisphere origins appears to run more or less east-west along 5° to 10°N. Thus, according to them, the airmass which strikes the west coast of the Peninsula during the monsoon season, was of northern hemisphere origin. From Findlater's papers (1969 a, 1971), it is clear that the argument advanced by Pisharoty and Sreenivasiah is untenable and they would not appear to appreciate the manner in which the Gangetic Valley trough develops as well as its structure and the associated rainfall when it is normally active in the absence of a depression (Rao and Desai 1973). The jet-stream being embedded in the monsoon current, it follows that the jet-speed winds recorded during the MONEX period over the Arabian Sea as far north as 16°N and over the Peninsula upto 18°N, had also their origin in the southern hemisphere and *not* in the northern hemisphere.

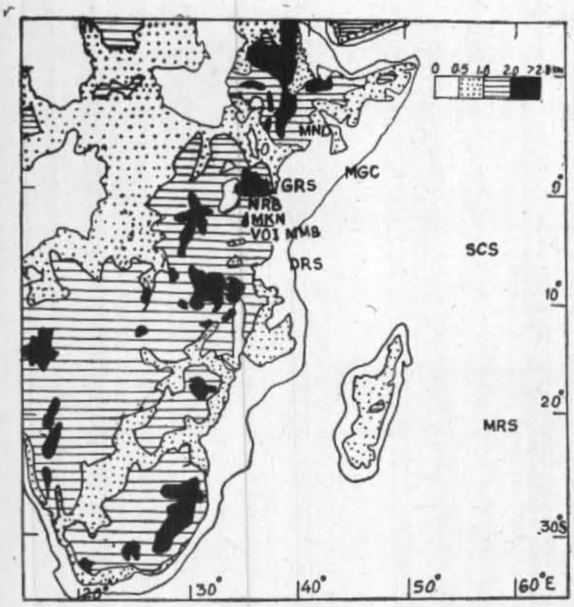


Fig. 7. Topographical features of the eastern parts of Africa and neighbouring areas

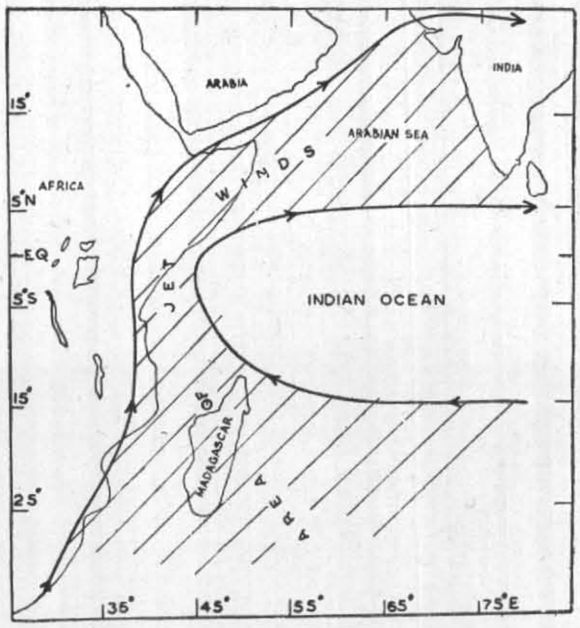


Fig. 8. Area of probable occurrence of jet winds over the western Indian Ocean and the Arabian Sea

The area of probable occurrence of jet-speed winds on the basis of Findlater's paper (1969 a) and MONEX data is shown in Fig. 8 by thick lines. The Russian ships did not record jet-speed wind west of Long. 53°E in the area of the jet in Fig. 6 because either the period of observations there might not have coincided with the occurrence of the jet or the observations in the area were not taken for sufficiently long period to notice the same even if it was present. Further, the Russian ships did not move over the equator west of Long. 45°E where only the jet-speed winds occur as seen from Findlater paper (1969 a).

Findlater (1972) has made aerial explorations of the law level cross equatorial current over eastern Africa and found that (*i*) the cross-equatorial current had well defined western edge near 38° E and had a multi-cored structure over the flat low lying land areas, speed decreasing significantly towards the coast; (*ii*) the cloud patterns were complex and arranged in regions originating along the southerly flow, there being cloud-free zones particularly at 39°E and near the coast; (*iii*) the wind-speed in the core of the current near 38°E was nearly 50 kt, and (*iv*) temperature and moisture content changes across the current were generally small. Detailed analyses of the core of the jets shown in Figs. 2, 3 and 4 are not possible, there being no data across the jet current over the Arabian Sea. It is also not possible to find out what changes have taken place in the nature of the jet current both in the horizontal and vertical over the Arabian Sea while it moved from the southern hemisphere across the equator as neither observations were taken by the Russian ships over the equator west of 45° E to the coast nor observations in the equatorial area were made or are available in India.

(*g*) *Jet-current and associated weather*

Findlater (1972) has stated that over the equator there is ascending motion in the core of the jet current and descending motion on its two sides; this gives rise to clouds of considerable vertical devel pment in the core a d shallower clouds on its two sides. Such clouds might also be noticed over the Arabian Sea, and when the current strikes the west coast of the Peninsula, there might be little rain on the two sides of the jet core unless the normal component of the wind to the Western Ghats is such that the effect of the descending motion is wiped out on and good rain occurs also on both its sides. A preliminary examination of rainfall over the Peninsula made during June to August 1973, showed as under :

(*i*) Active to vigorous monsoon conditions over the west coast and the interior of the Peninsula were preceded by 24 to 48 hours of the appearance of the low-level jet over the Arabian Sea.

(*ii*) Absence of jet-speed wind in the lower troposphere over the Arabian Sea and the Peninsula was necessarily marked by break monsoon conditions or lull in the monsoon activity over the country.

(*iii* It was noticed that the appearance of the low-level jet was not necessarily associated with active to vigorous monsoon conditions over the west coast.

The above inferences about monsoon activity with reference to the low-level jet can be understood if one remembers that the latter is embedded in the monsoon current and is initiated in the manner discussed earlier. During weak or break monsoon conditions, the southern hemisphere air flow across the equator is either weak or even if it is normal, the same is not allowed to flow north of about Lat. 10°N over the Arabian Sea due to adverse pressure distribution (Rao and Desai 1973).

A detailed study about rainfall over the west coast with reference to the jet-speed winds in the lower troposphere there, is being undertaken.

The statement of Bunker (1965) that the low level jet-speed decreases in the eastern Arabian Sea is not supported by MONEX 1973 data. The hypothesis (Saha 1974) that the low level jet occurs at the boundary between the cold ocean current and its adjacent warm ocean because of the horizontal pressure gradient that develops locally across such a boundary in response to large temperature differences, is not tenable in view of the low level jet observed during MONEX 1973 period over areas where such conditions are not likely to occur.

3. Concluding remarks

It is seen that the jet-speed winds occur over the Arabian Sea and the Peninsula during active or strong monsoon conditions and are generally absent during weak or break monsoon conditions. Appearance of jet-speed current over the Arabian Sea helps in predicting strengthening of monsoon in terms of rainfall over the west coast of the Peninsula. From the upper air data over the Arabian coast during the MONEX period, it can be stated that the jet-current does not originate in northeast Africa or Arabia; it would appear to have its origin in the southern hemisphere as seen from the paper of Findlater (1969) and from the data at stations in the equatorial area of Kenya presented in this paper. The pulsatory nature of the low-level jet is due to its being associated with the strong southerly flow which occurs in connection with the movement eastwards of cold fronts in the middle latitude westerlies of the south Indian Ocean; the topographical features to the west of eastern coast of Africa and of Madagascar helping in directing the jet-stream to the Arabian Sea across equator as well as in increasing its speed.

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