Mausam, (1985), **36**, 2, 235-240

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Characteristics of composite low level jet over the Arabian Sea during the spell 21-27 June of Monsoon Experiment (MONEX) 1979

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सार — यह शोध पत्र 21 से 27 जून 1979 की अवधि के दौरान जब इस क्षेत्र में कोई भी निम्न स्तरीय विक्षुब्ध नहीं होता अरब सागर के ऊपर 8° से 12° उत्तर अक्षांश तथा 56° पूर्व से 66° पूर्व देशान्तर के बीच मिश्र निम्नतल जैट के अस्तित्व को उजागर करता है। यह शोध पत्र मोनेक्स 1979 के आंकड़ों पर आधारित है।

ऐसा देखा गया है कि इस अवधि में निम्नतल जैटों की दो शाखाएं होती है तथा निचली शाखा प्रबल पछुआ क्षेत्रीय बहाव तथा अपसरण क्षेत्र में अन्तःस्थापित महान देशान्तरीय अवधि सहित एक निम्नतल जैट की चौड़ी पट्टी है।

इस अवधि में मिश्र माध्य टीफाईग्रामों का परीक्षण यह उद्घाटित करता है कि 850मि०बार पर निम्नतल जैट अधिकतर संतृप्त रूद्धोष्म ह्रास ऊंचाई के साथ नम तथा खुश्क वायु की सीमा पर होता है। अब तक अभिलेखित विचारों की विश्वसनीयता की वर्तमान अनुसंधानों के प्रकाश में जाँच करने के लिये मिश्र निम्नतल जैट के कुछ परिणामों की देसाई इत्यादि (1976) के निम्नतल जैट के कुछ व्यक्तिगत अध्ययनों पर आधारित प्रेक्षणों से तुलना की गई है। परिणामों की यह तुलना कुछ मामलों में पर्याप्त अनुकूल पाई गई।

ABSTRACT. The paper reveals the existence of the composite low level jet over the Arabian Sea in the latitudinal belt of 8 deg. and 12 deg. N from longitude 56 deg. E to 66 deg. E based on MONEX-1979 data during the spell 21-27 June 1979, when no low level disturbance is present over the region.

It is observed that during the spell the low level jets have two branches and the lower branch is a broad band of low level jet with great longitudinal span embedded in strong westerly zonal flow and divergence field.

An examination of the composite mean tephigrams during the spell reveals that the low level jets at 850 mb level occur mostly at the boundary of moist and dry air masses with saturated adiabatic lapse aloft. To test the reliability of the ideas reported so far in the light of the present investigation some of the results of the composite low level jet have been compared with observations mainly those by Desai *et al.* (1976) based on individual case studies of the low level jet and the results compare favourably well in some aspects.

1. Introduction

The Monsoon Experiment (MONEX-79) was launched under the sub-programme of Global Atmospheric Research Programme (GARP) in two parts — the winter Monex and summer Monex. This formed the part of the First GARP Global Experiment (FGGE). The main aim of MONEX was to study the monsoon behaviour in different parts of the world. The present study relates to the period 21-27 June 1979 (part of the Arabian Sea phase of the summer Monex). Dropsonde observations from Monex data set supplied by International Monex Management Centre of India Met. Dep. have been extensively used. This period is chosen because it provides excellent data coverage and is considered to be the best for the Arabian Sea monsoon studies. Such a spell has been selected with a view to examine the composite mean structure of the low level jet over the Arabian Sea and some related synoptic aspects of low level mean monsoonal flow in the region during an active phase of the monsoon. The rainfall totals on 13 stations of west coast when compared with the rainfall totals of the preceding spell 14-20 June, brings out the intensity of the monsoon.

Based on pilot-balloon and aircraft observations, many authors have reported in the past the existence of high speed flow at low levels with cores of about 60-100 kt at heights 1-2 km in some months of the year over east Africa and western areas of Indian Ocean. Bunker (1965) has considered aircraft observations during August and September 1964 for weak monsoon conditions and reported maximum wind speed

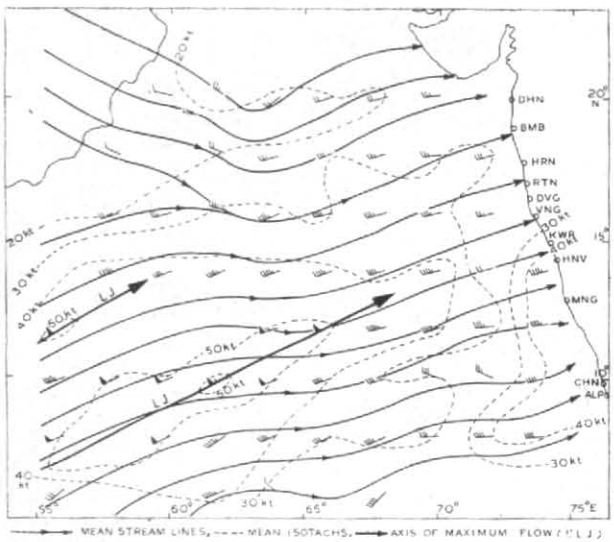


Fig. 1. 850 mb composite mean streamlines and isotachs analysis during spell (21-27 June 1979)

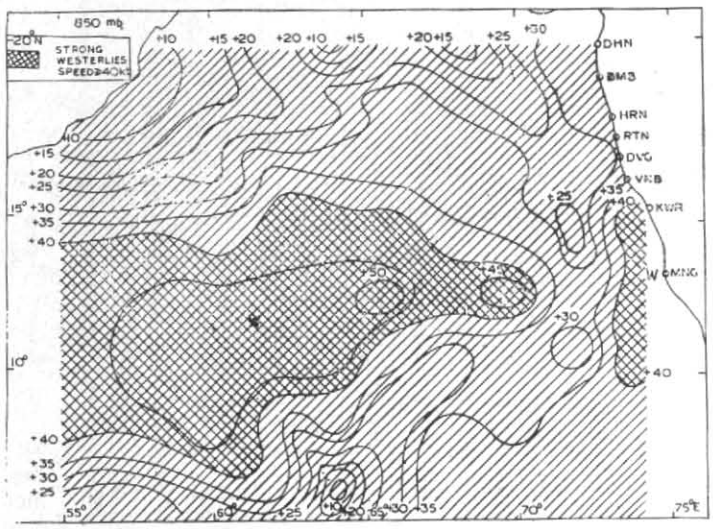


Fig. 2. Horizontal distribution of mean zonal wind component (kt) for period 21-27 June 1979. (Positive : Westerly)

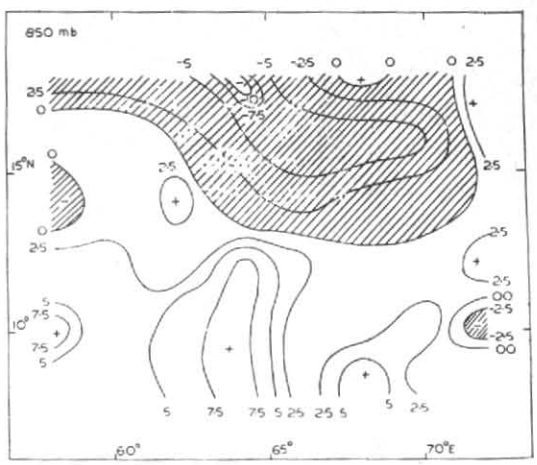


Fig. 3. Mean divergence field ($\times 10^{-5}$ sec) : 21-27 June 1979 (Divergence, positive : Hatched area, convergency)

of 50 kt associated with jet at 1 km at latitude 11 deg. N, longitude 58 deg. E in south Arabian Sea on 1 September 1964.

Joseph and Raman (1966) showed that most favoured level of occurrence of the low level jet is 1.5 km level while studying the low level jet over Peninsula during July. Desai (1968) reported the existence of the low level jet over the Peninsula simultaneously at different places and at different levels. Findlater (1969) and Desai (1972) observed low level jet over Somalia and adjoining Arabian Sea, the

Peninsular India embedded in the south west monsoon flow. The low level jet in southern hemisphere has been observed over and off the east coast of Africa, Madagascar and to the east of Mauritius. Various workers in mid-latitude have also observed low level jet ahead of cold fronts over U.K. (Browning and Paradoe 1973) or associated with well developed tongues of warm moist air on the forward side of trough crossing United States Midwest (Means 1952, 1954).

Desai *et al.* (1979) utilising June and July observations of Monsoon Experiments (ISMEX-1973) have also reported the low level jet over the Arabian Sea between latitudes 7 deg. and 16 deg. N east of about longitude 53 deg. E and over the Peninsula during active or strong monsoon conditions.

In recent studies Sikka and Datta (1979) reported the low level jet of about 65 kt 850 mb on 18 June 1979 when a cyclonic storm lay over the central Arabian Sea. They have further reported that convective weather was experienced by the aircraft in the vicinity of the trough zone (10 deg. to 12 deg. N). The low level jet was also experienced in the southern limit of the flight but could not be proved in details.

The purpose of the present study is to locate the composite low level jet over the Arabian Sea.

2. Compositing procedure and analysis

The area selected for the present study covers latitudinal belt between 5 deg. to 21 deg. N and longitudes from 57 deg. to 75 deg. E of the Arabian Sea. The whole area is subsequently divided into 2 deg. latitude-longitude grid squares. The data for the spell 21-27 June are composited and the means of the meteorological parameters plotted at the centre of the respective grid square taking all the hours and all the days of observations falling in each grid square during the spell 21-27 June. As a consequence of the above procedure the study is more quasi-synoptic than synoptic and is justified because the purpose of this paper is to examine the gross mean features of low level jet.

The above process of compositing has been carried out for constructing and analysing :

(*i*) 850 mb composite charts of mean streamlines and isotachs,

(*ii*) Composite latitudinal cross-section of mean wind and mean temperature, and

(*iii*) Composite mean tephigrams during the spell.

The present study is restricted upto 500 mb level because generally the dropsonde observations are confined to 500 mb level.

3. Mean synoptic conditions during the spell (21-27 June)

3.1. *The* 850 *mb composite mean streamlines and isotachs analysis*

An examination of the composite mean chart (Fig. 1) during the spell reveals following interesting features :

A feeble trough is discernible over the central Arabian Sea north of 15 deg. N with an axis oriented north to south. To the south of 15 deg. N the two branches of low level jet with core speeds of 50-55 kt are located on the chart. It is seen that the upper branch remains practically at the position of 12 deg. N, 56 deg. E. The lower branch is a well marked broad band of strong maximum jet speed winds of 50 kt. The 40 kt mean isotach is seen to be wide enough and prominent extending northeastwards from longitudes 55 deg. E to 76 deg. E. Another marked zone of strong wind of 40 kt exists very close to the west coast in the latitudinal belt of 8 deg. to 14 deg. N.

During this spell the active or strong monsoon condition prevailed over west coast in terms of rainfall.

3.2. *Composite* 850 *mb zonal wind component field*

Fig. 2 shows isotach analysis of the zonal wind component of motion at standard level 850 mb during the spell 21-27 June. In the figure the cross hatched region indicates a positive zonal component (speed $\geqslant$ 40 kt), westerly being positive, the contours are drawn at every 5 kt interval.

The broad features are summarised as :

(*i*) The zonal flow over the Arabian Sea is predominantly westerly with a well marked broad tongue of strong westerlies protruding eastwards as 40 kt isotach of zonal weterlies extends from Long. 55 deg. E to Long. 71.5 deg E in the latitudinal belt 8 deg. to 14 deg. N. The zonal westerlies are at their strongest attaining a core of 50.2 kt at Lat. 12 deg. N and Long. 66 deg. E. This feature appears to bear obvious relationship with the existence of a broad belt of low level westerly jet at 850 mb,

(*ii*) Another feature noticed is the existence of a separate zone of strong zonal westerlies flow off the west coast along Long. 74 deg. E at the same level,

(*iii*) A relatively weak zone of westerlies in between two regions of strong westerlies at 850 mb level suggests a speed convergence, and

(*iv*) Isolated regions of light zonal components are also found scattered elsewhere over Arabian Sea.

3.3. *Mean divergence field*

Based on the composite wind field charts for the active monsoon 21-27 June 1979 the distribution of divergence field was computed using kinematic method using grid size of 2 degrees. Fig. 3 presents the mean divergence pattern at 850 mb level from Long. 58 deg. to 72 deg. E in the latitudinal belt 8 deg. to 18 deg. N. The values of winds were interpolated at the centroid of the grids where the data were not available.

It is interesting to note that the divergence is predominant with maximum at Long. 64 deg. in the latitudinal belt 8 deg. to 12 deg. N embedded with low level jet. Another zone of maximum divergence is noticed at Lat. 10 deg. N, Long. 58 deg. E. To the north of the divergence field the area of convergence is well elongated over a major portion of east central Arabian Sea with maximum at Lat. 18 deg. F probably associated with the westerlies trough at the same level.

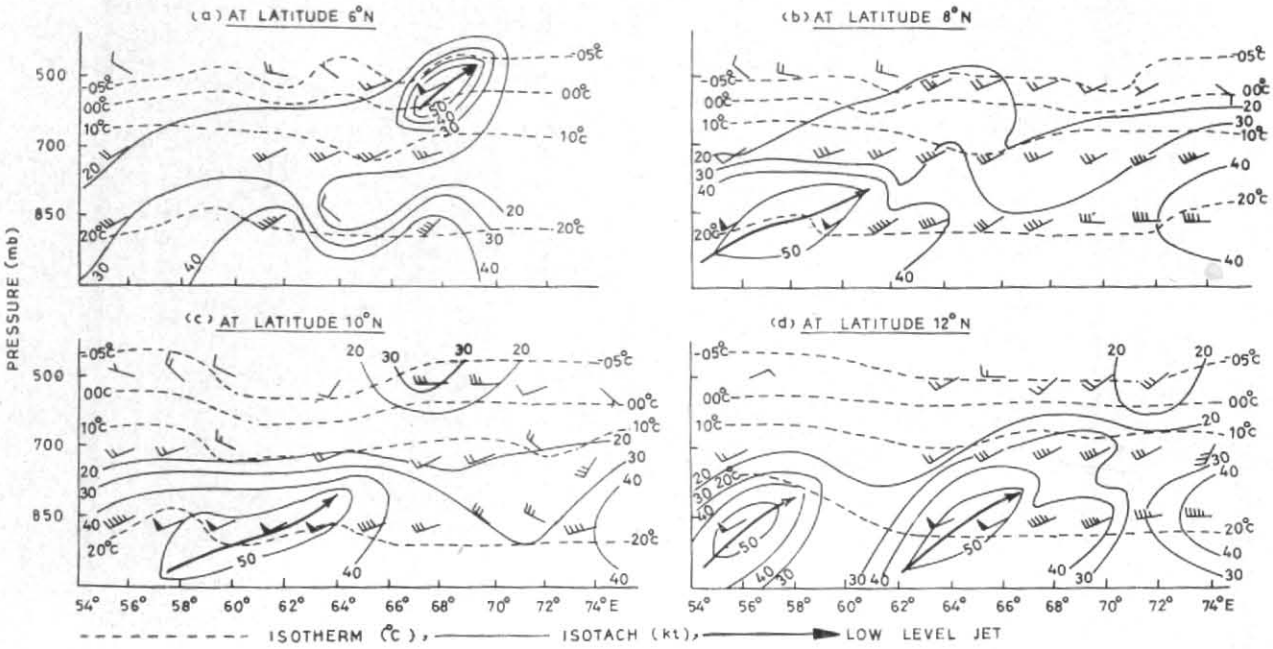


Fig. 4. latitudinal cross-section of mean vector wind and mean temperature at latitudes 6° N, 8° N, 10°N and 12°N, 21-27 June 1979

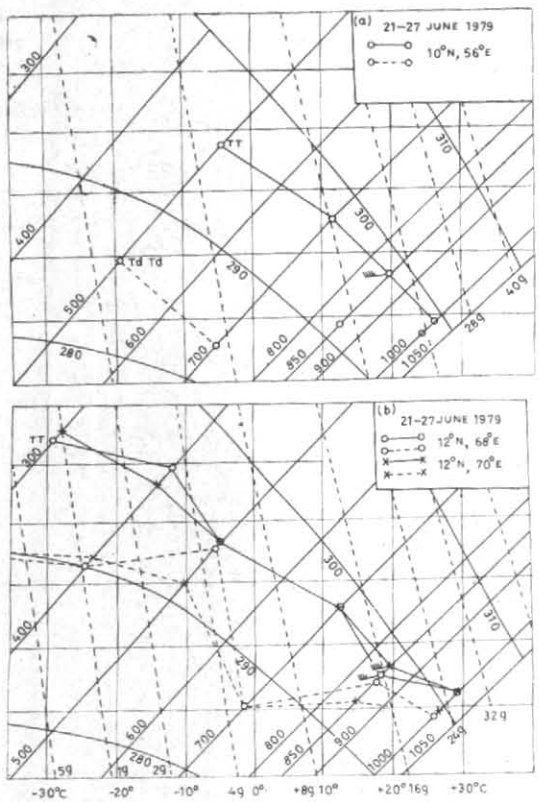


Fig. 5 (a & b). Mean tephigrams associated with low level jet (21-27 June 1979)

4. Composite latitudinal cross-sections of the vector mean wind and mean temperature fields (Fig. 4)

4.1. The salient features which emerge from isotach analysis of these cross-sections are given below :

(*a*) *At latitude* 6 *deg. N* — One low level jet is discernible at 500 mb level located at Long. 68 deg. E with core speed of 50 kt during the spell.

(*b*) *At latitude* 8 *deg. N* — During the spell there appears to be a single stream of maximum wind speed of 50 kt located at longitudes 56 deg. and 60 deg. E respectively.

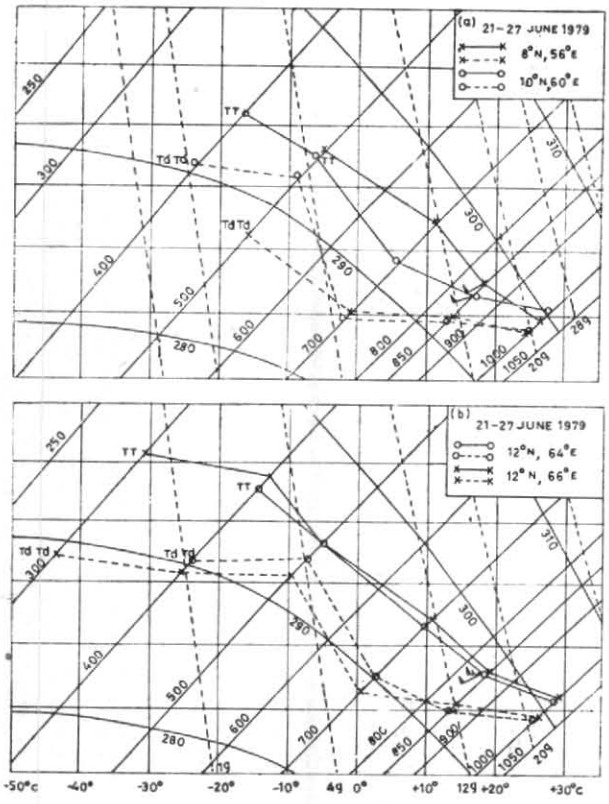
(*c*) *At latitude* 10 *deg. N* — It is significant to note that a strong continuous stream of maximum wind with jet core speed of 55 kt of great longitudinal span (58 deg. to 64 deg. E) is well marked and confined in the shallow layer near 850 mb level.

(*d*) *At latitude* 12 *deg. N* — During the spell, there are two streams of maximum wind with jet core speeds of 50 kt each at longitudes 56 deg. and 65 deg. E at the same level of 850 mb.

4.2. From an isotherm analysis, it is evident that the low level jets at 850 mb and 500 mb levels lie near isotherms of 20 deg. C and — 05 deg. C respectively.

5. Composite mean tephigram analysis

To understand the thermodynamic feature separate mean tephigrams were derived for grid points associated with low level jet and not associated with jet for the spell under consideration.



Figs. 6(a&b). Mean tephigrams not associated with low level jet (21-27 June 1979)

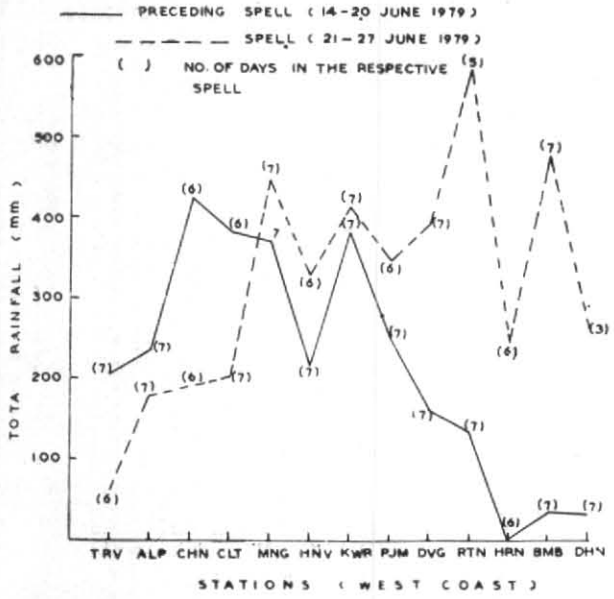


Fig. 7. Distribution of rainfall totals (mm) over west coast of India

The important features regarding thermal structure of the low level jet are stated below :

(*i*) Figs. 5 (a & b) represent mean tephigrams for four locations with which jet speed winds are associated. It may be seen from the tephigrams that moist layer prevails upto 850 mb with lapse rate between dry and moist adiabatic. Above upto 700 mb there is a relatively drier layer with nearly saturation adiabatic lapse rate. The moisture is showing a gradual increase between 700 mb and 500 mb with a near moist adiabatic rate and a relatively drier air aloft.

Thus it is inferred that the jet speed winds at 850 mb occur at the boundary of moist layer of air with lapse rate between dry adiabatic and moist adiabatic and dry air mass aloft with nearly saturated adiabatic lapse rate.

(*ii*) The mean tephigrams for three locations at 10 deg. N 56 deg. E, 12 deg. N 68 deg. E and 12 deg. N 70 deg. E, when jet speed winds are not associated, are shown in Figs. 6 (a & b). The tephigrams show more or less identical features as evidenced in cases when jet speed winds are associated.

(*iii*) The tephigrams do not suggest the existence of inversion or isothermal layer at any level above the 850 mb.

6. Wind shear

The vertical scalar wind shear above the jet speed wind at 850 mb as observed with latitudinal cross-section during the spell 21-27 June 1979 is shown below :

Position	*Shear (kt/km)*
8°N, 62°E	13
10°N, 62°E	11
10°N, 68°E	6
12°N, 56°E	2
Average	8

It is seen that average vertical wind shear above the jet is about 8 kt per km during the spell. The vertical wind shear below the jet core could not be calculated due to paucity of data below 850 mb.

7. Coastal rainfall

A preliminary examination of rainfall totals along 13 stations of west coast made during the spell 21-27 June and preceding spell 14-20 June (Fig. 7) shows that the intensity of monsoon has increased considerably during the spell 21-27 June from Mangalore (13 deg. N) to Dahanu (DHN) as is evident by increased rainfall.

8. Discussion

From the discription of the various derived parameters presented in the foregoing paragraphs the following features are brought out :

(*i*) This study indicates the existence of low level jets over south and south west Arabian Sea between 8 deg. to 12 deg. N in the longitude belt of 56 deg. to 68 deg. E at 850 mb (Fig. 1) and no sign of jet appears either to the northern latitudes beyond 12 deg. N and east of 68 deg. E during the spell. However, there is one occasion when low level jet is observed at 500 mb level at 6 deg. N, 68 deg. E (Fig. 4). Thus the present results compare favourably well with the observations of Desai *et al.* (1976).

(*ii*) Comparing Findlater's (1971) observation with the present investigation at 1.5 km level, it is evident that during the spell one branch of the low level jet positioned at 12 deg. N, 56 deg. E (Fig. 1) would appear to be an extension of Somalia jet and coincide fairly well with the position of the upper branch of the Findlater jet.

A significant difference observed is that the lower branch of the low level jet in the present case appears to be heading northeastwards towards west coast in contrast to taking a course towards southern tip of the Peninsula as reported by Findlater.

Findlater (1969) has reported the depth of the jet speed winds as about 0.5 km. This study shows the existence of the composite low level jet in shallow layer during the spell.

The jet stream observed over south Arabian Sea can probably be considered to be a continuation of these over southwest Arabian Sea.

(*iii*) The 850 mb composite mean charts (Figs. 1 and 2) reveal that the low level jet embedded in strong westerly flow and is confined to the same latitudinal belt over the Arabian Sea associated with strong westerly wind component, during the spell. The low level jet is further seen to decelerate initially and thereafter accelerate as it approaches the west coast south of 15 deg. N during the spell (Fig 2). The present observations agree with the statement of Bunker (1965) to some extent that the speed of the jet stream declerates in the east Arabian Sea.

(*iv*) The marked divergence in the SW and SE Arabian Sea (Fig. 3) appears to be associated with accelerating low level jet.

(*v*) From isotherm analysis it is obvious that the low level jets would not appear to originate due to any thermal conditions as no east-west temperature gradient has been observed (Fig. 4) as reported by Desai *et al.* (1976), but they generally occur at the top of the moist layer of air between the boundary of moist and dry airmasses at lower level (850 mb) as is evident from mean tephigram analysis (Figs. 5 and 6).

9. Conclusions

From all evidences described in the preceding paragraphs the following conclusions can be drawn :

(1) A striking feature that has been noticed in the spell is the presence of low level jets at 850 mb level in a latitudinal belt of 8 deg. to 12 deg. N and longitudinal belt between 56 deg. to 66 deg. E. The jet speed wind has also been noticed at 6 deg. N at higher level (500 mb) but comparatively rare.

(2) Low level jets during the spell have been observed to be embedded in a shallow filaments near 850 mb level.

(3) The low level jets in the spell would appear to be a continuation of Findlater jet except that the lower branch has been observed in the present case to be heading northeastwards towards the coast instead of bending towards the tip of the Peninsula as indicated by Findlater (1971).

(4) The low level jets occur at the top of the moist layer between the boundary of the moist and dry airmasses with saturated adiabatic lapse rate aloft as revealed in the composite tephigrams.

(5) The low level jets are associated with the maximum zonal westerly wind component ranging between 40 to 50 kt and maximum divergence field.

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References

Browning, K. A. and Paradoe, G. W., 1975,. 'Structure of ϕ low level jet streams ahead of mid-latitude cold fronts,' *Quart. J. R. met. Soc.*, **99**, pp. 619-638.

Bunker, A.F., 1965, 'Interaction of the summer monsoon air with the Arabian Sea', Proc. Symp. Met. Results of IIO E, Bombay, India, pp. 22-26.

Desai, B.N., 1968, 'Interaction of the summer monsoon current with water surface over the Arabian Sea', *Indian J. Met. Geophys.* 10, pp. 159-166.

Desai, B.N., Rangachari, N. and Subramanian, S.K., 1976 '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', *Indian J. Met. Hydrol. Geophys.*, **27**, pp. 263-274.

Findlater, J., 1969, 'A major low level air current near the Indian Ocean during the northern summer', *Quart. J. R. met. Soc.*, **95**, pp. 363-380,

Findlater, J. 1971, 'Mean monthly air flow at low levels over the western Indian Ocean, ϕ London M.O., *Geophys. Mem.*' **16**, No. 115.

Joseph, P.V. and Raman ,P.L., 1966, Existence of low level westerly jet streams over Peninsular India during July', *Indian J. Met. Geophys.*, **17**, pp. 407-410.

Mean, L.L., 1952, *Mon Weath. Rev.*, **80**, pp. 165-189.

Mean, L.L. 1954, *Bull Am. Met. Soc.*, **35**, pp. 66-170.

Sikka, D.R. and Datta, R.K., 1979, 'Summer Monex, Field phase, *Yayu Mandal*, **9**, Nos. 3 and 4, pp. 5-15.