551.577·3 (54)

Variability of Upper Winds over India

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ABSTRACT. Information about the normal upper winds as well as their variability with respect to direction and speed are useful factors for aviators. Based on normal upper winds at the pibal stations in India and neighbourhood, the steadiness factor and the standard vector deviation have been computed at selected levels for four typical months, January, April, July and October. Charts depicting these parameters have been prepared and the results discussed.

1. Introduction

With the rapid growth in aviation it has become necessary for the forecasters to supply accurate forecasts of upper winds upto very high levels. In the absence of actual wind data for the higher levels one has necessarily to base these forecasts on the normal upper wind charts supplemented with the latest synoptic charts.

For a proper understanding of the upper wind patterns at the various levels it is necessary to know the degree of steadiness of the winds with respect to direction and speed over and above the normal winds since the normal resultant winds become representative only if the variability is small. Wind being a vector, its variation is contributed by variation in direction as well as in speed. The steadiness factor q which is the percentage ratio of the vector mean wind V_R to the mean wind speed irrespective of direction V_s, (q=100 V_R/V_s) provides a useful measure for the scatter of winds with regard to direction. Another measure of variability of winds which takes into account variations both in direction and in speed is the standard vector deviation σ . This parameter is defined as the root mean square of the scalar part of the vector departure between the observed and vector mean winds. Brooks and others (1946) derived an approximate relation between q and σ/V_R for a normal distribution and presented a table for estimating σ when V_R and V_s are known. Their results have been made use of in this paper for calculating σ.

2. Data used

In the present study, afternoon wind data for the levels 1·5, 3·0, 5·0 and 9·0 km a.s.l. for the four representative months January, April, July and October have been examined for 57 Indian pibal stations and 13 extra-Indian stations. Normals based on all data upto 1950 have been utilised for Indian stations while the data for the remaining stations relate to the period upto 1947. The number of observations upto 5 km in each month were of the order of 200 or more for many stations; for the highest level the numbers were only about 10 per cent of those for the lower levels especially in the monsoon months. The q and σ values for all the 70 pibal stations for the levels and months referred to above were computed.

3. Results

Charts showing steadiness factor (in per cent) and values of standard vector deviation (in knots) in respect of the four months for the selected levels are shown in Figs. 1 to 4 and 5 to 8 respectively. The isopleths for steadiness factor are drawn for 30, 50, 70 and 90 per cent, while those for standard vector deviation are drawn at intervals of 5 knots. The main features of these charts are discussed below in the light of the general circulation over India and neighbourhood as presented by Ramanathan and Ramakrishnan (1937) and the charts depicting the normal winds with stream lines indicating the direction of flow and isotachs upto 8 km a.s.l. available in the *Climatological Atlas for Airmen* (India met. Dep. 1943).

In the discussion, the following convention has been followed for describing the steadiness of upper winds.

Steadiness factor	Type of Winds
>90 per cent	Extremely steady
Between 70 and 90 per cent	Highly steady
Between 50 and 70 per cent	Steady
Between 30 and 50 per cent	Variable
Below 30 per cent	Highly variable

3.1. *January*—The main feature of the upper air circulation during this month is the anticyclone over central parts of the country at levels below 2 km and its gradual shift towards south as we go to the higher levels. To the north of the seasonal high, winds from north to west occur while to its south, northeasterlies or easterlies prevail. In the vicinity of the anticyclone winds are generally weak and variable. The westerlies to the north of the anticyclone gradually increases in strength with height.

At 1·5 km (Fig. 1) winds are highly steady in east Uttar Pradesh, Bihar and West Bengal where westerly to northwesterly winds occur as well as in the south Peninsula where east to northeasterly winds prevail. They are extremely steady over parts of Bihar and the extreme south Peninsula. The winds are variable in north Assam and the belt of the country from Saurashtra/Gujarat to Kashmir and are highly so over most of Saurashtra, certain area in West Pakistan and northeastern portion of the Punjab (India) and adjoining Kashmir, Himachal Pradesh and over north Assam. The high variability of winds over Assam at this level might be associated with the variation in the level of transition between the easterly flow from Assam down the Brahmaputra valley in the lower levels and the normal west to northwesterly flow higher up. The passage of western disturbances may also partly be responsible for this. The high variability of winds over northeast Punjab (India), Himachal Pradesh and adjoining Kashmir is largely contributed by the more frequent occurrence of southerly and southeasterly winds in association with western disturbances.

At 3·0 km the local features, which are apparent at the lower levels, are practically absent. The winds are highly steady between the latitudes 20°N and 30°N where the west to northwesterly winds blow; the region of extremely steady winds over Bihar has become more extensive. To the north and south of the above mentioned area, winds become more and more variable. They are highly variable in the vicinity of the anticyclone around 15° N and also over Kashmir, where the passage of western disturbances might be the contributory factor.

As already mentioned, the position of the anticyclone shifts south at the higher levels with a corresponding shift in the region of variable winds. At 5 km, the northern limit of the region of highly steady westerlies is around 33° to 35° N. At 9 km the winds are extremely steady over north India.

The standard vector deviation does not show much spatial variation over the country in the lower levels in January. The standard vector deviation is around 10 knots at 1·5 km and gradually increases to 15 knots at 5·0 km. The pattern of isopleths at 9·0 km is more complicated, the values ranging from 20 to 40 knots. This shows that even in the region of steady westerlies their day-to-day variations in strength is appreciable.

3·2. *April*—This month is representative of the hot weather of pre-monsoon season (March—May). The main difference in the circulation in this season from that in winter is that below 1 km the anticyclone over central India has weakened and is replaced by a shallow trough. There is, however, no large alteration in the pattern at the higher levels. The westerlies over north India at the higher levels are, however, weaker than in January.

At 1·5 km (Fig. 2) the wind is highly variable between 15°—20°N over the Peninsula and the adjoining Bay of Bengal, *i.e.*, roughly in the vicinty of the anticyclone. The winds are steady to highly steady in the region of the westerly flow between 20° and 27°N. Over northwest India the winds are weak and variable.

As we go higher up, the steadiness gradually increases over practically the entire country as the westerlies go on building up in strength and extending further south. The anticyclone which is around 20°N over the Peninsula at 2 km gradually shifts southward and is at the extreme south of the Peninsula at 9 km.

At 3·0 km winds are steady over the entire country except in the vicinity of the anticyclone over the Peninsula between 15° and 20°N where they are highly variable. The winds are extremely steady over north India east of 80°E.

More or less the same features are evident at the 5·0-km level also. The region of highly steady winds noticed at the lower level is still discernible at this level also.

At 9·0 km, the region of highly steady winds extends further west and north than at the lower levels. The steadiness continuously decreases towards the south and becomes minimum around 12°N over the Peninsula, where the winds are also generally weak.

There does not seem to be much of a variation from January to April in the values of standard vector deviation, at levels upto 5 km. At 9·0 km the values are lower. At 1·5 and 3·0 km the values are between 8 and 12 knots and at 5 km they vary between 12-16 knots. At 9·0 km the standard vector deviation is nearly 18 knots in the Bay Islands, West Bengal, Bihar, Madras, Mysore and Kerala and is between 20—30 knots over the rest of the country.

3·3. *July*—By July, the monsoon is established throughout the country and the wind system at the lower levels is dominated by the low pressure area over Sind and the low pressure trough along the Gangetic valley. During this month, depressions move more or less regularly in a westerly to northwesterly direction form the head of the Bay to west central India and Rajasthan.

At 1·5 km the region of highly variable winds practically coincides with the Indo-Gangetic trough. The winds become more steady on either side of the trough and are extremely steady in the Peninsula south of 20°N where the monsoon westerlies blow. There is another region of highly variable winds over extreme northwest India and adjoining parts of West Pakistan.

At 3 km, the monsoon westerlies are confined to the Peninsula south of 20°N where the winds are highly steady. West of 80°E and north of 20°N dry northerly and northwesterlies, which are generally weak and variable prevail. Winds are also highly variable along and around the position of the monsoon trough at this level.

In the transition zone between the lower monsoon westerlies and the higher easterlies winds are highly variable. This is particularly reflected in the chart for 5 km. At 9·0 km easterlies are well established over the entire country south of 25°N and the winds are highly steady in this area. Over the rest of the country the winds are variable.

The charts showing the standard vector deviation (Fig. 7) are in conformity with the mean circulation pattern and climatic features of the season described earlier. At 1·5 km the standard vector deviation is highest (10—15 knots) in the vicinity of the monsoon trough and at 3 km it is generally between 10 and 15 knots over the entire country, except over south Peninsula, sub-Himalayan West Bengal and the Punjab. As already stated, the majority of the pilot balloon observations on which the present study is based do not extend to sufficiently high level in the monsoon season. Hence the charts for 5·0 and 9·0 km are based on fewer number of observations than those for lower levels. But it can be seen that, in general, the standard vector deviations at these levels are less in the monsoon season, especially over the Peninsula, than in January and April.

3·4. *October*—By October, the southwest monsoon withdraws from most of the north and central parts of the country. An anti-cyclonic circulation tends to get established over northwest India at about the same time. At the lower levels (1 and 2 km) winds are northwesterly to northerly in the region north of 25°N and they are northwesterly to westerly farther south. At the extreme south of the Peninsula, westerlies are observed. At the higher levels, westerlies prevail to the north of 20°N and easterlies to the south; the westerlies strengthen with height.

Winds are generally weak and unsteady over the entire country at the lower levels (1·5 and 3·0 km) during this month. At the higher levels, the westerlies strengthen with height in the region north of 20°N and the winds become more steady. The steadiness gradually increases with height in this region, until at 9·0 km the winds become highly steady over the whole of north India. Further, at 9·0 km the easterlies to the south of 15°N are also steady and the region of highly variable winds around 17°N coincides with the transitional zone between the easterlies and westerlies.

The standard vector deviation does not show much spatial variation at the lower levels (1·5 and 3·0 km) and is around 10 knots. At 9·0 km the values are higher and lie between 10 and 25 knots with the highest values over northwest India.

4. Acknowledgement

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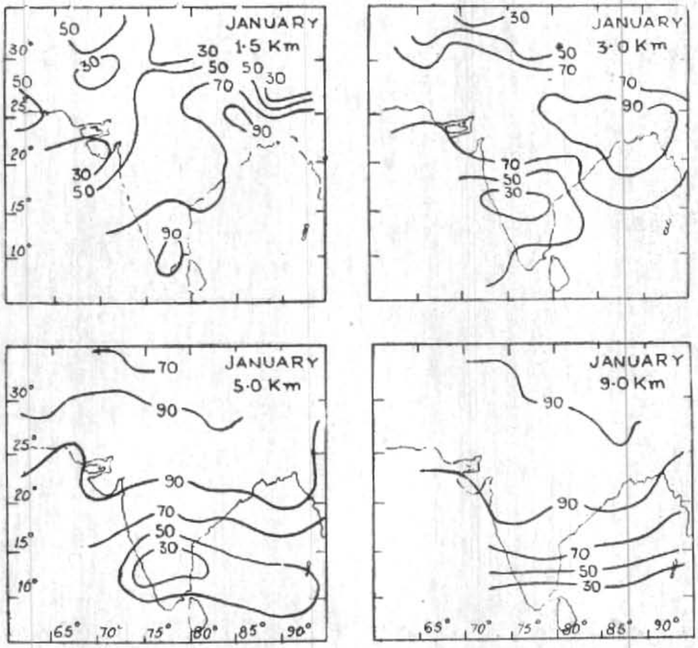

FIG. 1

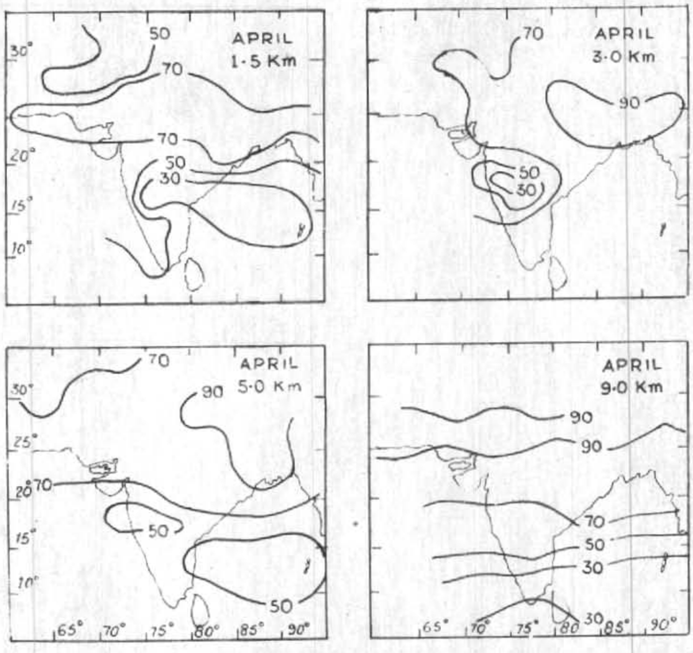

FIG. 2.

STEADINESS FACTOR OF THE WIND (%)

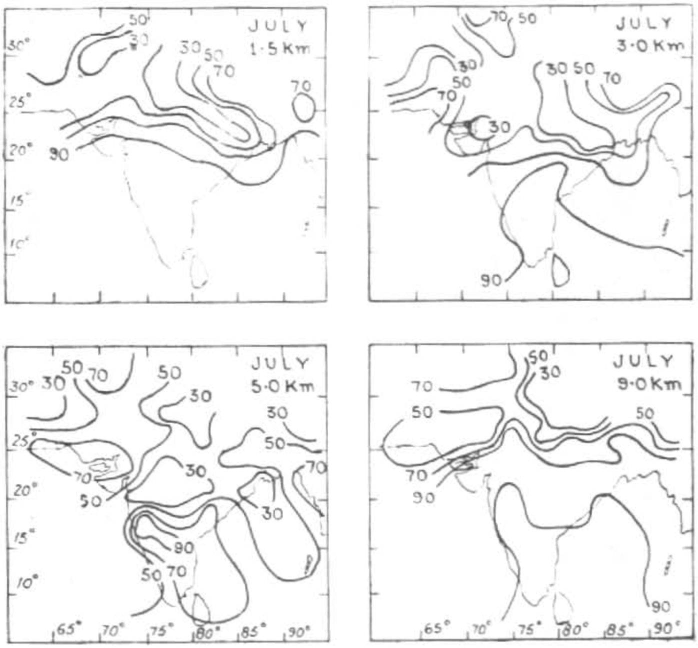

FIG. 3

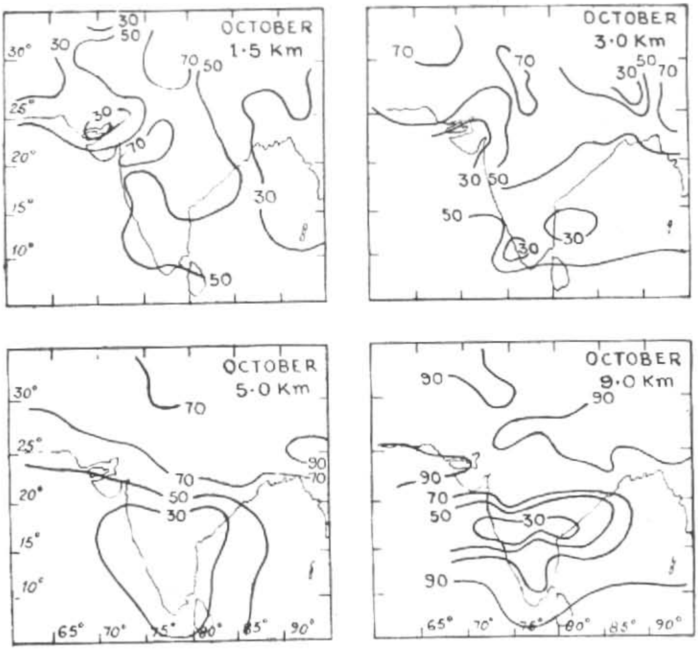

FIG 4

STEADINESS FACTOR OF THE WIND (%)

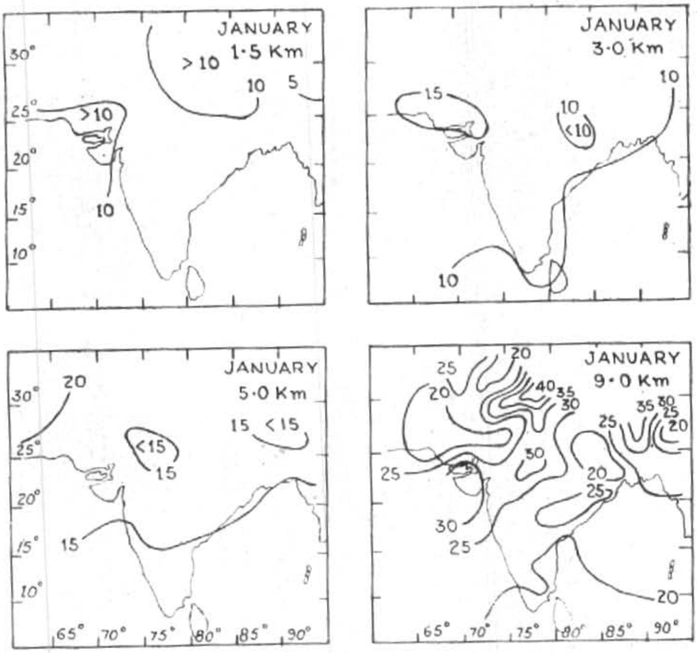

FIG. 5

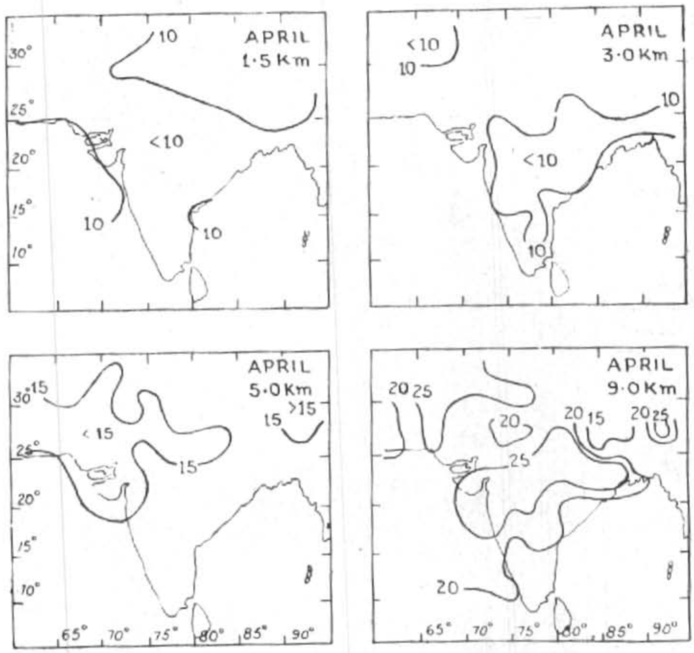

FIG. 6

STANDARD VECTOR DEVIATION IN KNOTS

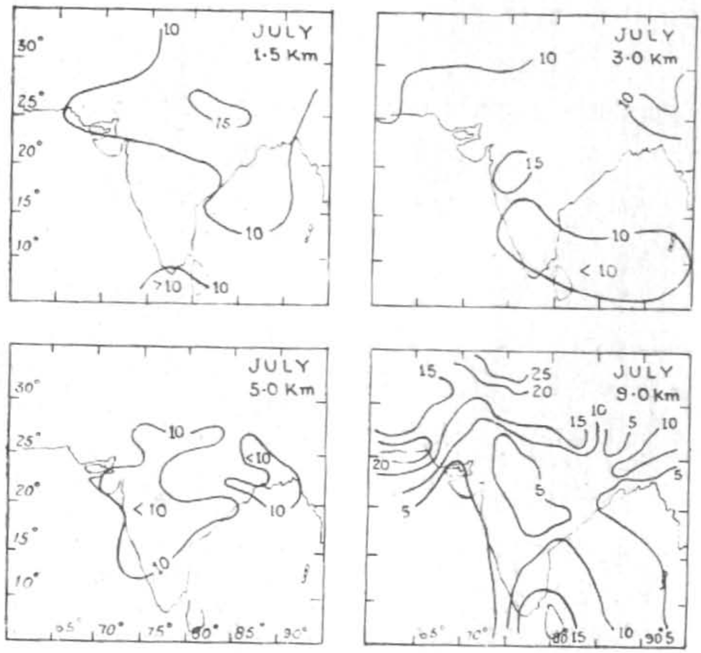

FIG. 7

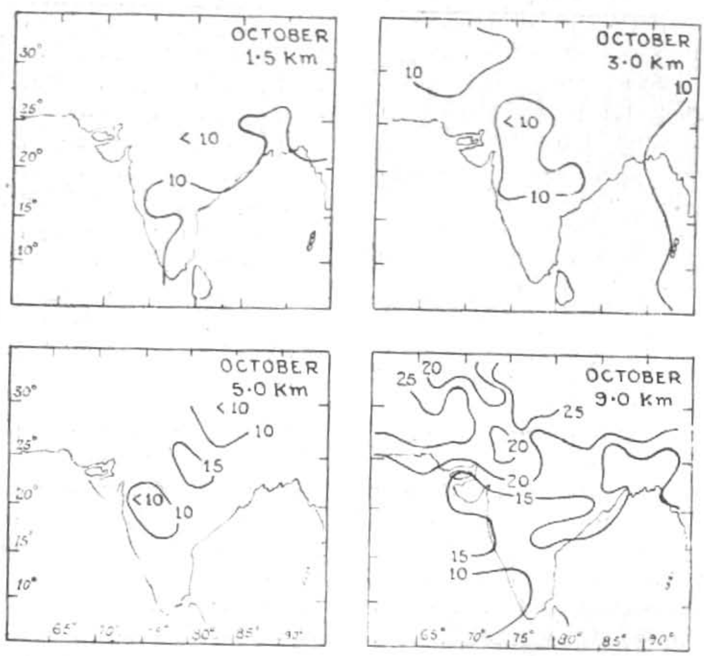

FIG. 8

STANDARD VECTOR DEVIATION IN KNOTS