

The Diurnal Variation of Upper Winds over Bombay and Poona

S. PARTHASARATHY and J. NARAYANAN

Meteorological Office, Poona

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ABSTRACT. The study has been made from mean monthly velocities. The land and sea breezes which are the most important variations in Bombay, are found to be related with diurnal variation in pressure distribution over a wide area especially caused by the land distribution of that region. The land breeze is associated with a 'high' and the sea breeze with a 'low'. The vertical extent of the sea breeze is found to coincide with the level where the 'low' changes to 'high'.

The afternoon winds over Poona are found to be antitriptic in the lower levels and they continue to be weak at higher levels due to weak pressure gradient. In some of the non-monsoon months katabatic winds over Poona are found perceptible even up to 150 metres above ground level.

1. Introduction

Since 1944 the India Meteorological Department is collecting upper wind data from pilot balloon ascents at more frequent height intervals in the lower levels over stations in India for climatological study. It is proposed to utilize the monthly normals computed from the data for a discussion of the diurnal variation of winds in the lower levels upto about 2 km above ground level. In order to have uniform number of observations at least in the lower levels, only normals based on data after 1944 for five years have been utilised. The means for higher levels have been accepted only when the number of observations available for each month during the five years exceeded 30, *i.e.*, about one fifth of the total number of days. In all but the monsoon months a fairly high percentage number of observations are available upto the 2 km level and hence the data can be taken to represent the mean conditions of the respective months. The means for the monsoon months above 1 km, however, represent only clear weather conditions.

The normals have been worked out separately for the three different times of the day, *viz.*, night, morning and afternoon corresponding to 0000-0230, 0730-0900 and 1430-1600 IST. The normals for four months January, April, July and October representing the typical seasons of India, are given in the form of diagrams on pages 198 and

199. Figs. 1(a) and 2(c) contain the graphs of mean wind speeds against altitude. In Figs. 1(b) and 2(b) the resultant wind vectors at height levels are drawn from a fixed origin and the ends of the vectors have been connected by straight lines giving hodographs. The values given at the end of the vectors are heights in kilometres above sea level at which these resultants occur. Fig. 3 has also been added to indicate the mean sea level pressure distribution over this region corresponding to 0800 and 1700 IST. The normals of pressures upto 1940 were utilised for the construction of these charts.

2. General features

Both over Bombay and Poona the diagrams indicate considerable amount of diurnal variation of winds, very prominent upto 1 km above ground level. Excepting in July the sea level pressure gradients over this region at 0800 IST (Fig. 3) are shallow and the pattern changes with height as is evident from the rapid changes of winds above 1 km. The diurnal variation of pressure distribution is also quite marked. The anticyclonic curvatures at 0800 IST in January and October change to cyclonic patterns at 1700 IST. The shallow 'low' of April intensifies in the afternoon. The diurnal variation is least only in July.

Before studying the effect of these diurnal variations of pressure distribution on winds the topographic effect of this region should be

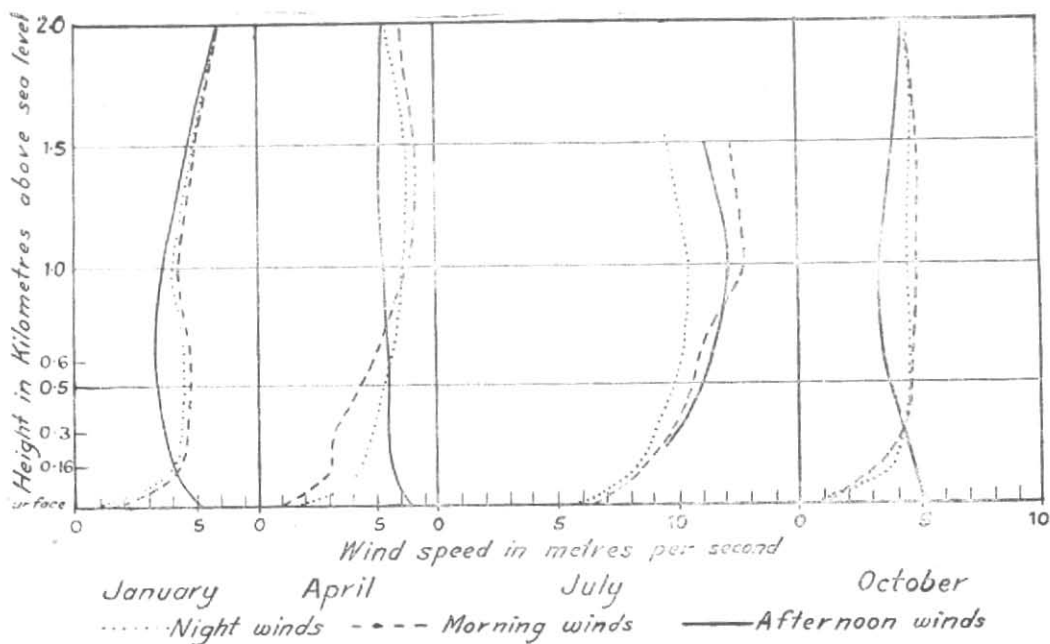


Fig. 1(a). Mean wind speeds over Bombay

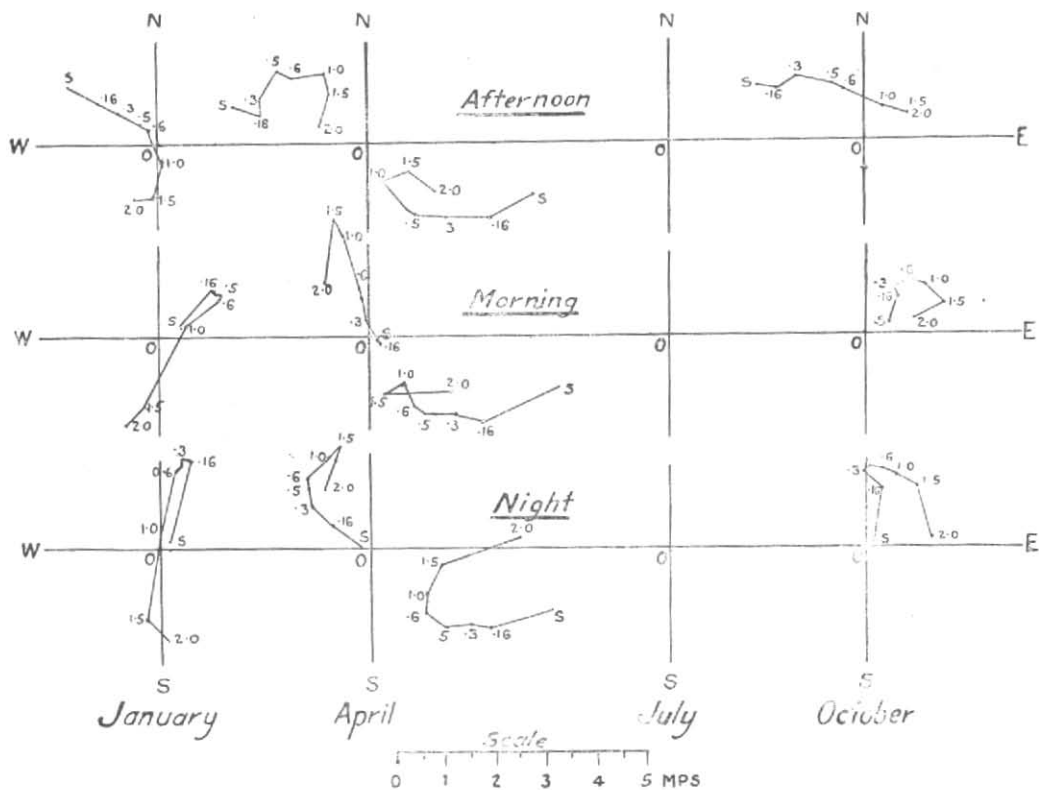


Fig. 1(b). Hodograph of resultant wind vectors—Bombay

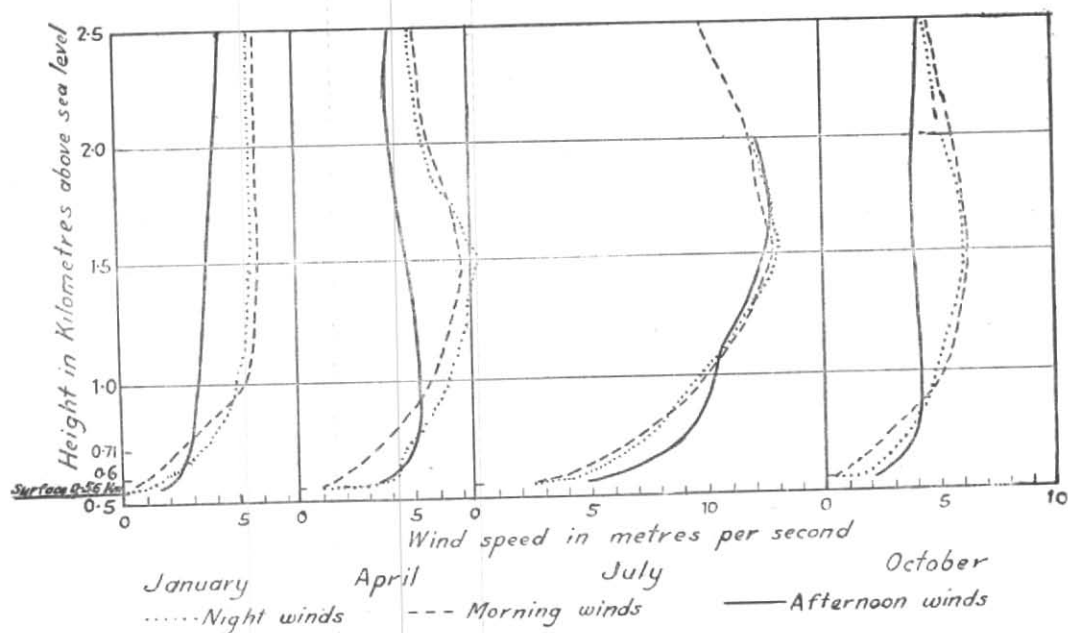


Fig. 2(a). Mean wind speeds over Poona

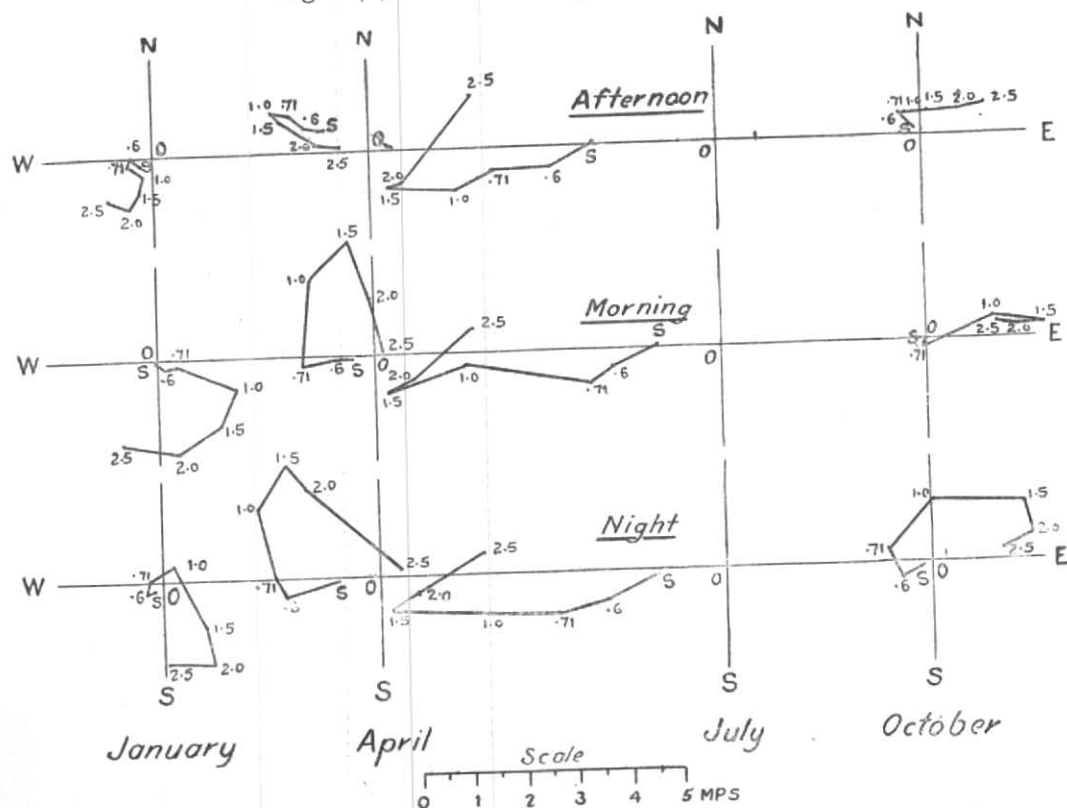


Fig. 2(b). Hodograph of resultant wind vectors—Poona

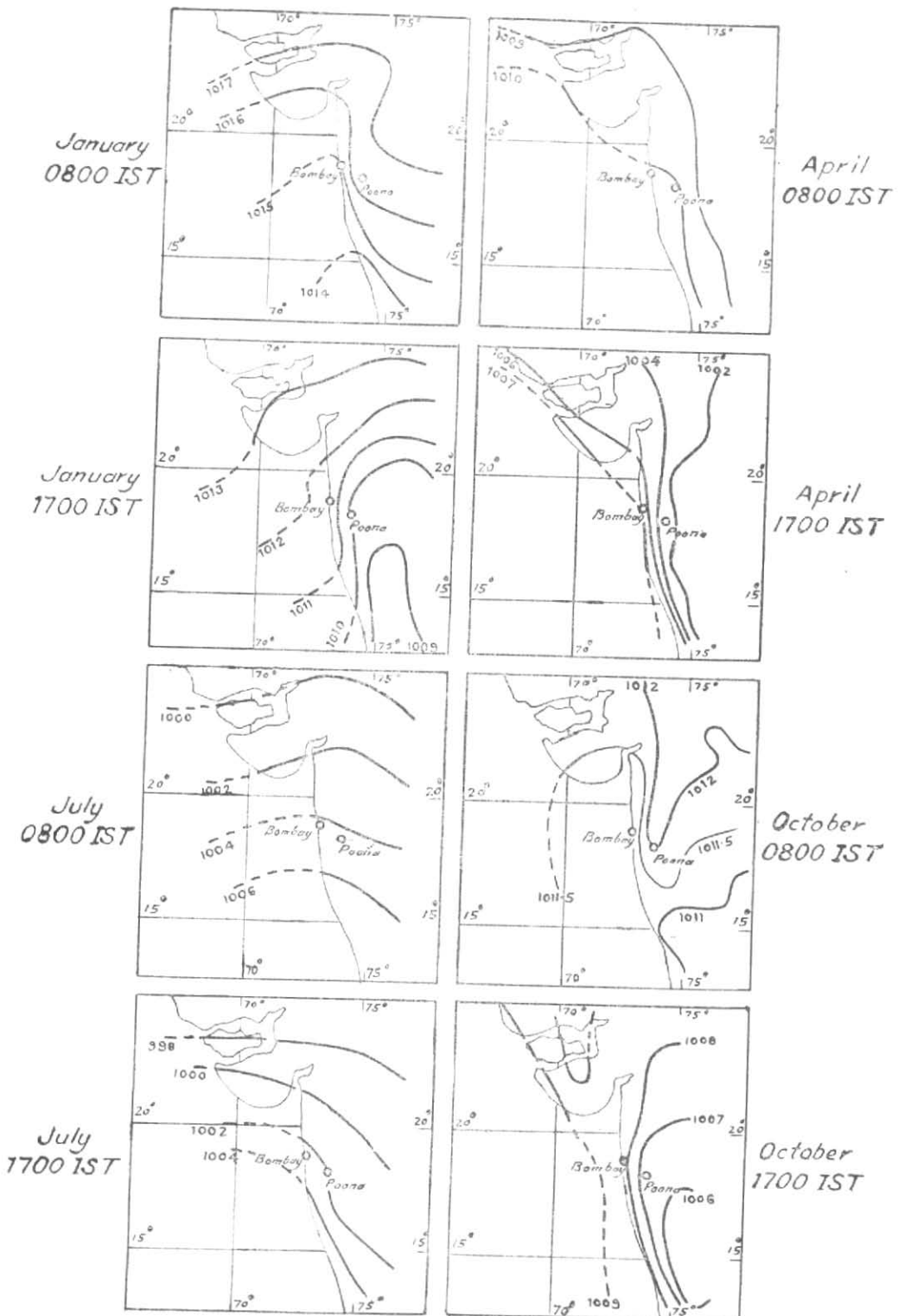


Fig. 3

borne in mind. The Deccan Plateau begins almost abruptly from the west coast and it is protected from the coastal influence by the Western Ghats on its border. The diurnal heating of the plateau is, therefore, much higher and the pressures over this area reduced to sea level cannot be comparable with those of the coast. This discontinuity is well brought out in the form of crowded isobars along the Western Ghats in the afternoon. Hence the sea level pressure distribution west of Poona, which is only 30 miles from the Western Ghats, cannot be relied upon for having an idea of the winds in that region. The morning pressure maps, however, do not reveal glaring abnormality and hence represent almost a true picture.

Even allowing for the unreliability of the sea level pressure distribution in the afternoons, there can be no doubt regarding the existence of the low over the Deccan in the afternoon during January and October since this continues even to the plain regions of Kathiawar. As this low has been formed solely due to heating of the land, it gradually diminishes in intensity with height until it is replaced by the high of the region as can be inferred from the similarity of wind patterns above 1 km above ground level. Large variations in wind velocity are, however, seen even upto 2 km above sea level.

In the morning when the conditions are stable, wind at about 0.5 km above ground level have been found to approach the gradient winds calculated from the sea level chart. Winds above this level during the non-monsoon months alter considerably due to changes in pressure distribution. In the afternoons, due to diurnal heating vertical mixing occurs and because of the peculiar positions of the two places the gradient wind is not attained in the lower levels. As pointed out earlier winds at higher levels are considerably different from the gradient winds at sea level. Even in July there is considerable difference between winds and the sea level isobars, the gradient winds having greater northerly components.

3. Diurnal variation over Bombay

The land and sea breezes are the most important diurnal variations which are

prominent during the post-monsoon and winter months. In April, the winds have westerly components throughout the day, the components being stronger in the afternoon upto 1 km. July has the least diurnal variation.

The interesting peculiarity about the land and sea breezes are that (1) they do not blow perpendicular to the coast thereby revealing the influence of the geostrophic components, and (2) they are associated with considerable diurnal changes of pressure showing that the phenomena are not entirely local.

In the months of October and January, the land breezes are associated with the 'highs' in the morning, the direction of the winds upto 0.6 km almost coinciding with the isobars. In the afternoons the region has a low with the consequent reversal of wind. The winds blow nearly across the isobars at surface and veer steadily higher up showing that the frictional effect becomes unimportant at higher levels. At the same time the winds are also decreasing since the low becomes shallower to be replaced by the characteristic high of the region. The northerly components of the winds seen even at the surface taken together with the orientation of the isobars from northeast to southwest which are due to the position of the Kathiawar peninsula, show beyond doubt that the geostrophic component has considerable importance. The same has also been found true in the other months November, December and February.

In April, the wind speed in the afternoon decreases upto 0.16 km above sea level the direction almost remaining constant as in the case of sea breezes in January and October. Above this level, there is considerable veering until the direction becomes almost parallel to the sea level isobars. At the same time there is no appreciable change in wind speed upto 0.6 km indicating that the pressure gradient is almost the same upto that level (In fact the low which is permanent throughout the day, is replaced by the high only above 2 km). Since at higher levels the geostrophic terms are more important the hodograph can be taken to represent the thermal winds. Above 1 km the shear wind from north to south

shows lesser temperatures over the land area and the extent of the sea influence can, therefore, be fixed upto 1 km. The same type of wind is found to occur in the other pre-monsoon months and the vertical extents were found to be between 1 and 1.5 km.

Thus it is evident that though the land and sea breezes over Bombay are produced by temperature differences, it is the marked diurnal variation in the pressure distribution caused by the diurnal heating of the land mass east and northwest (Kathiawar) which influence these winds. Hence the winds are not purely antitriptic and the geostrophic terms are also important which come into greater play at higher levels. This perhaps, accounts for the absence of return currents. The vertical extent of the sea breeze coincides with the transition layers between the low and the high and this is found to vary from 0.3 km in November and December to about 0.6 km or higher in October, January and February.

The same reason, *viz.*, the occurrence of the transition from low to high can be given for the steady decrease in the afternoon wind speeds upto 0.6 km seen in Fig. 1(a) for January and October and also noticeable in the other months November, December and February. On the other hand during the morning the high is the usual feature from surface upwards with only a change in the pattern and hence winds are almost constant above the layer of skin of friction.

4. Diurnal variation over Poona

Just as in Bombay, considerable diurnal variation of winds exists over Poona, but extending to even 2 km above ground level. The morning winds in January and October are easterly which are in agreement with the pressure distribution. The afternoon winds are considerably weaker and flow from the west. Above 2 km the hodographs are similar throughout the day though differences are prominent. In April the winds are westerly with considerable diurnal variation. Only July has the least variation.

The afternoon winds at surface and lower levels are southwest to northwesterly. These directions are peculiar only to Poona and winds at other stations around Poona like

Hyderabad Malegaon and Bombay are not having westerlies at such levels in the afternoon and hence according to Jeffreys¹, the winds in the lower levels over Poona cannot be considered geostrophic. The winds are antitriptic. This will mean that winds flow from a lower temperature to a higher temperature showing a west to east gradient over Poona. Thus the diurnal variation in the lower levels during the non-monsoon months are almost similar to the land and sea breezes. At the higher levels, the higher temperature over Poona and the lower temperature over the west coast diminish considerably the pressure differences so that the low over the Deccan becomes very shallow and is ultimately replaced by the high. This is revealed by the very weak westerly winds at higher levels.

One exception to these uniformly light winds is seen in the afternoon winds of April steadily blowing from northwest and increasing upto 1 km, though still comparatively lighter than the morning winds. As purely antitriptic winds cannot show increase, the geostrophic component should have some influence and hence the winds cannot be local. At the same time as Bombay is having the sea effect upto 1 km with northwest winds, we can conclude that the sea breeze is penetrating into Poona. This is in agreement with Ramanathan's conclusions².

In all the diagrams in Fig. 2(b) excepting July, the tendency of the winds below 0.15 km above ground level during nights and mornings is to have a southwest component, the vertical extent being least when winds above are eastsoutheasterly. Also night winds at surface layers are stronger than the morning winds. The following table reveals the same tendency in the other non-monsoon months.

In his discussion of katabatic winds over Poona, Atmanathan³ has summarised that (1) katabatic winds are almost of daily occurrence during the non-monsoon months, (2) the prominent katabatic winds are southwesterlies from the Sinhgad-Bhuleshwar hills (1700 ft higher than Poona) and (3) they occur between 2200 and 0700 IST with maximum frequency at 0400 IST.

TABLE 1

		October		November		December		January		February		March	
		V	D	V	D	V	D	V	D	V	D	V	D
Surface	Night	0.4	251	0.2	225*	0.2	80	0.4	240*	0.8	255*	1.0	252*
	Morning	0.1	220*	0.2	182	0.1	225*	0.1	248*	0.5	249*	0.5	247*
40 metres above ground level	Night	1.3	250*	0.7	135	0.4	156	0.7	241*	1.5	258*	2.4	266*
	Morning	0.2	213*	0.7	91	0.5	109	0.3	128	0.4	233*	0.6	247*
150 metres above ground level	Night	1.6	287	1.8	91	1.2	90	0.4	269*	2.3	279	3.0	280
	Morning	0.2	212*	1.9	90	1.7	103	0.9	103	0.4	221*	0.8	253

V—Mean resultant velocity in metres per second D—Mean resultant direction in degrees from north

*Winds with tendency to flow from southwest

These were arrived at on the basis of observations of winds at 40 metres above ground level. The means given in the table are in agreement with the general features of the katabatic winds and they show that such winds are perceptible even at 150 metres above ground level in some months. Such corroboration even from the means obtained from pilot balloon ascents confirms

the steady nature of these winds from day to day.

REFERENCES

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3. Atmanathan, S., *Ind. met. Dep. Sci. Notes*, **4**, 40 (1931).