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Vertical currents associated with standing waves over Mussooree

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ABSTRACT. Some observational evidences on the occurrence of vigorous vertical currents associated with standing waves over Mussooree are presented and discussed. Standing waves are found to have sufficient lift for gliders to soar to the stratosphere over Dehra Dun valley.

1. Introduction

Glider pilots are reported to be interested in vertical currents that are associated with airflow across the Mussooree ridge towards Dehra Dun valley where standing waves are believed to extend upto about 9000 metres above sea level (Raghavan 1956). A few observational evidences on the occurrence of strong vertical currents over the Mussooree range as well as over Dehra Dun valley when northerly winds blow in the lower levels of the atmosphere over Mussooree are, therefore, presented and discussed in this note mainly from the point of view of gliding.

2. Topography

The Mussooree range is situated at the northern border of the great low land plain of Hindustan between the gorges of the Jumna and the Ganges (Fig. 1). Running practically east–west it is about 17 km long and 5 km broad at its top with an averge elevation of about 2000 metres. The range is rugged with dense tropical woods at places at the foot-hills. To the east adjoining the Mussooree is the Landour range lying northwest to south-east with an average elevation of about 2300 metres.

The Mussooree ridge drops 600 m in about 2·5 km to Happy valley on the north, the slope being about 1 : 4. Bordering Happy valley which is about 3·5 km broad is situated the Nagtibba range, average elevation 2300 m, beyond which is a series of parallel ranges increasing to an average elevation of over 6000 m in a distance of 50 km upto the first line of snowy ranges. Snowy range succeeds snowy range that rises with great abruptness to elevations of about 8000 m over a belt of 50 to 70 km in width. Further north are the upper valleys of the Indus and Sanpu and the great Tibetan plateau. Mussooree is hence on the southern margin of an extensive mountain and plateau region.

The pilot balloon observatory at Mussooree (lat. 30° 27′N, long. 78° 05′E, elevation 2050 m) directly overlooks to the south an open level alluvial plain, 250 to 500 km broad. Dehra Dun valley at the foot of the Mussooree range that drops 1000 m in about 5 km (1 : 5) on the south, is about 17 km broad and 700 m in elevation on the average and lies between the Jumna and Ganges rivers. To the south is the Shivalik range which unlike the Mussooree, is at places broken and is of an average elevation of about 600 m. Dehra Dun valley with the great low land plain of Hindustan to the south and the massive range to the north is admirably situated for hill-soaring.

3. Data

One of the methods of detecting the existence of vertical currents in the atmosphere with pilot balloon ascent (Laird 1952) is by finding the deviation of the observed increases in height per minute from the estimated rate of ascent in still air. It is based on the assumption that the increase and decrease of the observed rate of ascent from the estimated rate of ascent are solely due to ascending and descending currents respectively. In Figs. 2, 3, 5 and 8 are plotted at one minute

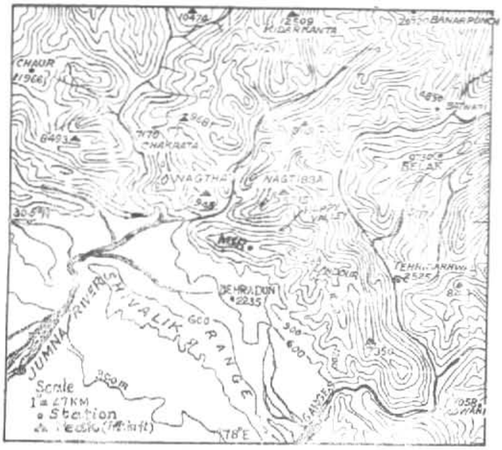

Fig. 1. Topographic map of Mussooree (MSR)

interval the observed rates of ascent against horizontal distance from the point of release of balloon at Mussooree. Height of balloon that was found spurious, judged mainly from the fluctuation of the vertical angle, has not been used for plotting the observed rate of ascent considering it to have resulted mainly from the pendulous movement of the tail attached to the balloon. Along with the plot is shown the approximate north-south profile of the Mussooree range drawn to the same horizontal scale in order to locate the region of vertical currents. The ascents discussed here were those specially conducted at Mussooree in connection with the French expedition to Daulagiri in 1950, the Japanese expedition to Annapurna in 1953 and the German-Swiss expedition to Makalu and Kanjanjunga in 1955.

4. Vertical currents over the Mussooree ridge

It is seen from Fig. 2 that at the time of the ascent A, an updraft with a speed of about 12 km hr^{-1} (654 ft min^{-1}) occurred in the atmosphere over Mussooree very close to the place of release of balloon. The ascent B conducted in the morning also registered an updraft of about $9 \cdot 6$ km hr^{-1} (525 ft min^{-1}) over the ridge. On the contrary, Fig. 3 shows that downdraft with a speed of about $6 \cdot 7$ km hr^{-1} (369 ft min^{-1}) occurred over the ridge at the time of the ascent C. Similar downdraft of about $6 \cdot 5$ km hr^{-1} (357 ft min^{-1}) occurred over the ridge in the evening also as evidenced by the ascent D.

It is a curious fact that strong up-currents and down-currents occur over the Mussooree ridge almost irrespective of the hour of the day. To the north of the Mussooree range is situated the Nagtibba range which under favourable conditions (Scorer 1951) may cause standing waves in its lee across Happy valley when northerly winds blow. Depending mainly upon the property of air stream that passes across the Nagtibba, the length of waves forming in its lee may vary (Scorer 1954) and become out of phase with the Mussooree range. Up-currents or down-currents may then be set up at the Mussooree ridge (Roper 1952, Raghavan 1956) depending upon whether the crest or trough respectively of a wave coincides with the ridge (Manley 1945). The standing waves forming in the lee of the Nagtibba thus appear to be mainly responsible for the occurrence of vertical currents over the Mussooree range.

It will be of interest specially to glider pilots to know the maximum height upto which an up-current extends in the atmosphere over Mussooree. The pilot balloon data afford us information only upto the height the balloon traversed through it. The ascent B in Fig. 2 registered an updraft of $9 \cdot 6$ km hr^{-1}, 16 minutes after the release of the balloon as given in the flight sheet. The height-time graph reproduced in Fig. 4 shows that the balloon was then at a mean height of about $3 \cdot 66$ km above ground (19,000 ft a.s.l.).

5. Vertical currents over Dehra Dun valley

The graph in Fig. 5 shows that on 4 November 1953 the ascent was conducted at Mussooree when organised up-currents and down-currents characteristic of a standing wave occurred in the atmosphere over Dehra Dun valley. The upper wind velocity that increased with altitude (Fig. 6) should have been very favourable for the occurrence of the

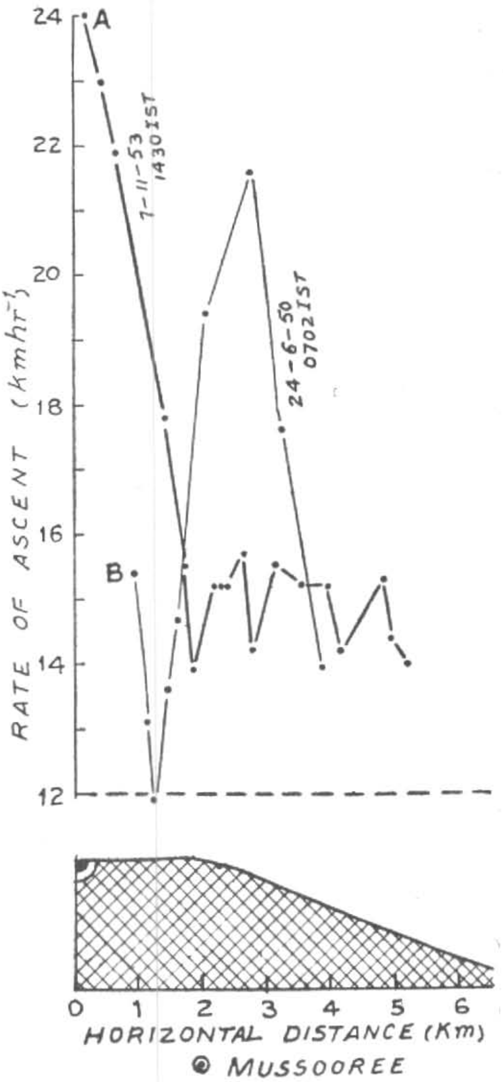

Fig. 2. Rate of ascent at one minute interval plotted against horizontal distance from the point of release of pilot balloon at Mussooree

(Assumed rate of ascent $12\cdot0$ km hr^{-1})

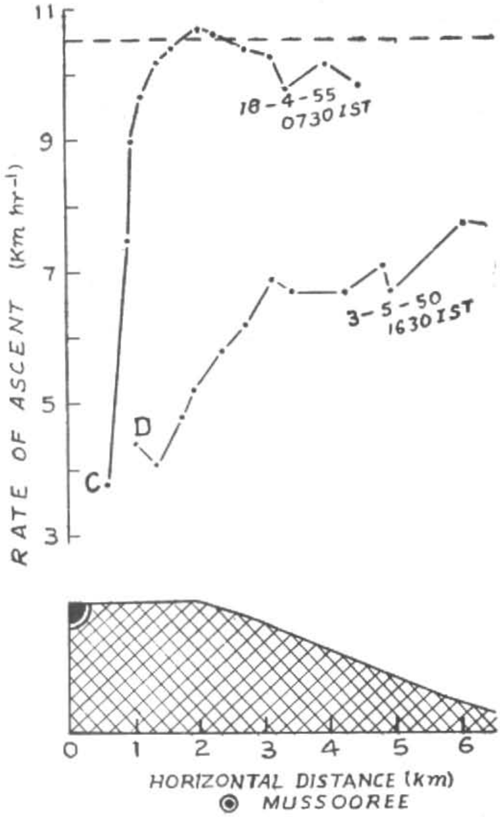

Fig. 3. Rate of ascent at one minute interval plotted against horizontal distance from the point of release of pilot balloon at Mussooree

(Assumed rate of ascent $10\cdot5$ km hr^{-1})

standing wave (Corby 1954). It is interesting to find that the areas of ascending and descending currents depended on the horizontal distance from the Mussooree ridge and were independent of height.

The mean height of the balloon 15 minutes after its release, when it recorded the maximum updraft of $1\cdot7$ km hr^{-1} (92 ft min^{-1}), was $2\cdot45$ km above ground (15,000 ft a.s.l.) as seen from the height-time graph reproduced in Fig. 7. The updraft of $1\cdot7$ km hr^{-1} need not necessarily be the maximum updraft of the wave anywhere in the valley at a height of $2\cdot45$ km, since the updraft varies in speed at different parts of a wave-upwind.

It is interesting to find that the probable streamline flow of air over Dehra Dun valley (Fig. 5), drawn in the light of the rate of ascent fluctuation, describes a standing wave comparable with the theoretical stream lines in the lee of an obstruction given by Scorer (1949). The wave length is about 5 km.

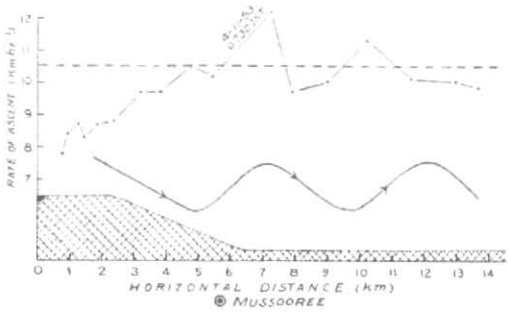

Fig. 5. Rate of ascent at one minute interval plotted against horizontal distance from the point of release of pilot balloon at Mussooree

(Assumed rate of ascent 10·5 km hr-¹)

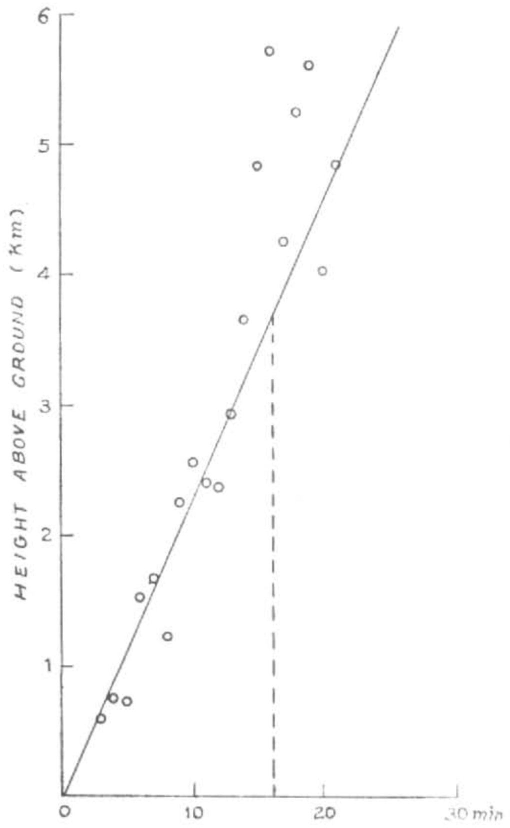

Fig. 4. Height-time graph of the pibal ascent at Mussooree on 24 June 1950 at 0702 IST

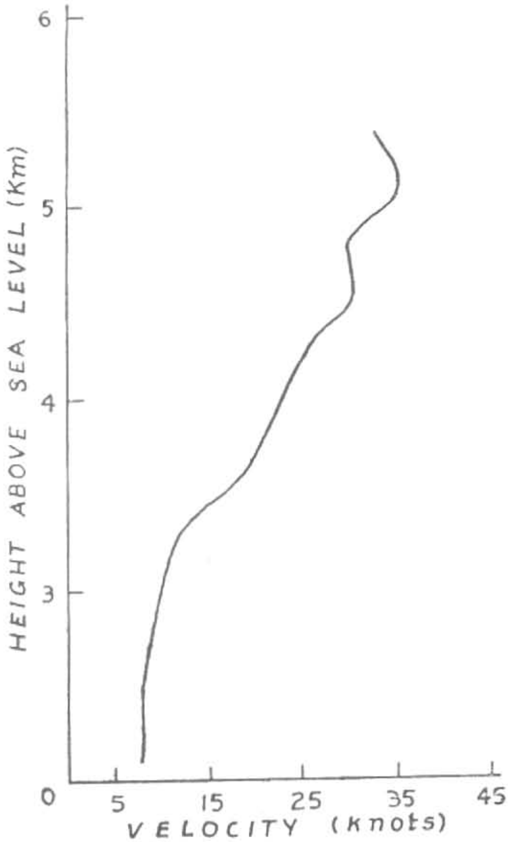

Fig. 6. Velocity profile at Mussooree on 4 November 1953 at 0730 IST

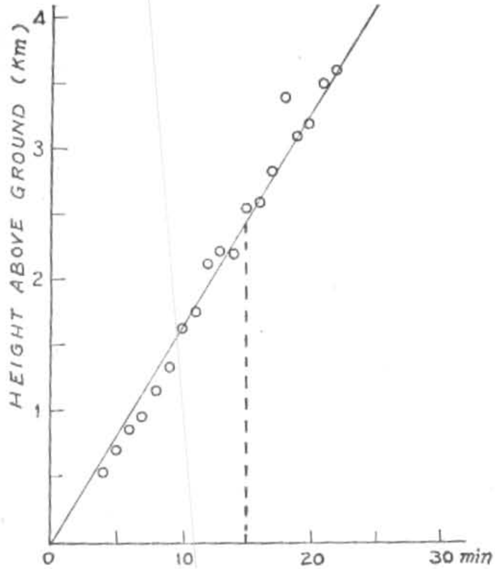

Fig. 7. Height-time graph of the pibal ascent at Mussooree on 4 November 1953 at 0730 IST

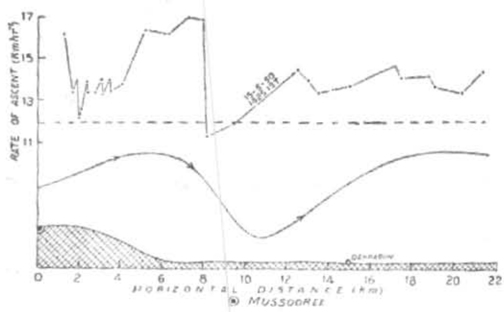

Fig. 8. Rate of ascent at one minute interval plotted against horizontal distance from the point of release of pilot balloon at Mussooree

(Assumed rate of ascent 12·0 km hr-1)

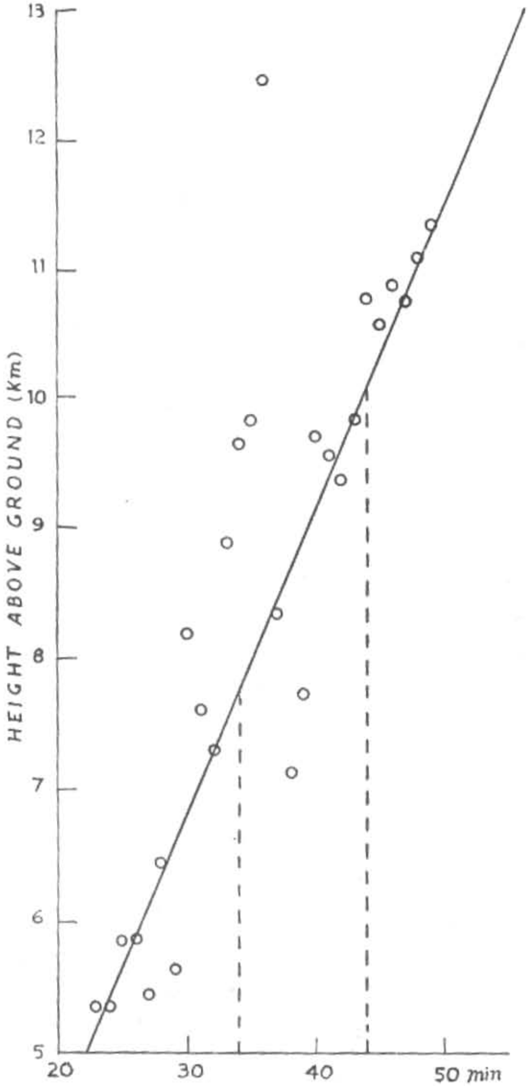

Fig. 9. Height-time graph of the pibal ascent at Mussooree on 15 May 1950 at 1425 IST

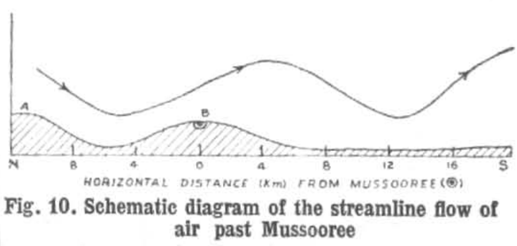

Fig. 10. Schematic diagram of the streamline flow of air past Mussooree

(A—Nagtibba range, B—Mussooree range)

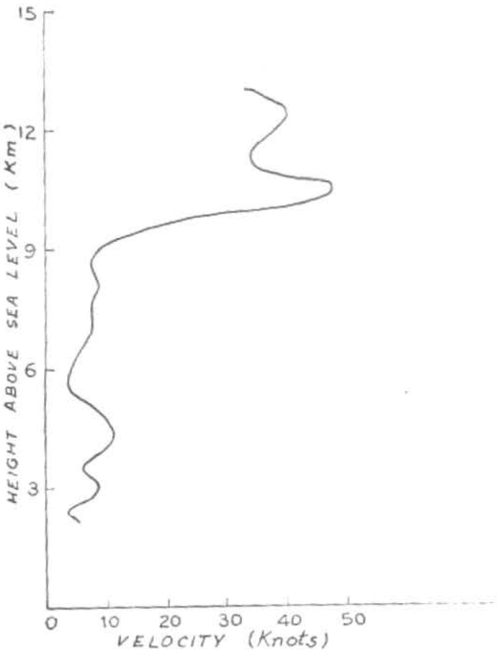

Fig. 11. Velocity profile at Mussoorie on 15 May 1950 at 1425 IST

In Fig. 8 is shown the deviation of the observed rate of ascent for another ascent conducted at Mussooree. Ascending currents occurred over the Mussooree ridge as well as at its lee slope followed by down currents in Dehra Dun valley at a distance of about 2 km from the foot of the ridge beyond which again a region of ascending currents existed. The distribution of the region of ascending and descending currents downstream independent of height shows that the currents were mainly associated with a standing wave. The maximum updraft of 5 km hr^{-1} (276 ft min^{-1}) recorded by the balloon, 34 minutes after its release, was at a mean height of about 7·75 km above ground as seen from the height-time graph reproduced in Fig. 9. Significant updraft continued upto a mean height of about 10·1 km above ground (40,000 ft a.s.l.) where the balloon 44 minutes after its release (Fig 9) experienced an updraft of 2·7 km hr^{-1} (146 ft min^{-1}) at a distance of about 17 km from Mussooree in Dehra Dun valley. It is curious to note that the up-currents persisted down to the lee slope where under wave conditions down-currents would normally prevail (Scorer 1952) as observed in the wave discussed earlier. The coincidence of the region of up-currents at the lee slope suggests that the slope was under the influence of the crest of a standing wave formed due to an adjacent barrier (Scorer 1955). To the north of the Mussooree range is situated the Nagtibba that may cause standing wave with its crest over the lee slope of the Mussooree range (Wallington 1955) as typified by the streamline in Fig. 10. Apparently the wave formed in the lee of the Nagtibba was sufficiently large to affect the airflow in the lee of the Mussooree range. The streamline in Fig. 8 may represent approximately the main features of the air-flow across the Mussooree range towards Dehra Dun valley. The wave length appears to be about 18 to 20 km.

It is worthy of note that decrease of velocity with altitude which is not theoretically conducive for waves to form (Scorer 1953) existed over Mussooree above 10·5 km a.s.l. (Fig. 11). Such occasions when glider pilots also observed standing waves are, however, not without precedent (Ross 1950, Georgeson 1956). One can reconcile this anomaly with the theoretical prerequisite considering the waves to have been observed in a state of dissipation as revealed by the report on the soaring of Milton Kuntz in the Sierra waves (Ivans 1951) and the studies on clear air turbulence and topography in England by Turner (1955). Prior to the dissipation, it follows, the waves above 10·5 km a.s.l. over Dehra Dun valley might have been more vigorous than observed.

6. Conclusion

The observations cited above provide evidence on the prevalence of vigorous up-currents associated with standing waves in the vicinity of the Mussooree ridge. The irksome topographical features of the region and the possibility of onset of strong down-currents over the Mussooree range call for great care on the part of those who soar over Mussooree. If properly used, these up-currents may serve as a powerful lift to carry a sailplane to considerable height over Mussooree. From the data discussed above, it is seen that an ordinary sailplane should continue to ascend at 12,000 metres (40,000 ft) above sea level over Dehra Dun valley. The data further suggest the possibility of the wave extending beyond 13,000 m over Dehra Dun valley. The observations of Austin (1952), Ludlam (1952) and Harper (1956) on the standing waves that formed upto a height of about 30,000 ft due to hills of hardly 1000 ft high should all the more be encouraging to glider pilots to explore this interesting phenomenon occurring in the vicinity of the Mussooree range in greater detail.

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