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Upper and mid-tropospheric temperature changes associated with upper level troughs over north India

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ABSTRACT. Time-sections of upper air temperatures over Delhi and Calcutta based on two radiosonde ascents daily during the period 14 to 27 April 1952 are studied in relation to the synoptic situation and compared with similar time-section available for Ahmedabad. A detailed study of an upper level trough which passed across north India between 19 and 23 February 1954 have also been attempted. It is noticed that large fluctuations of temperature in the upper and mid-troposphere are associated with the migration of upper level troughs, the temperatures generally rising to the rear of the trough line. A possible explanation for this feature is suggested.

1. In a recent paper, Venkateswaran and Desai (1953a) have discussed the radiosonde ascents made thrice daily at Ahmedabad with Vaisala instruments during the period 14 to 27 April 1952 and have given an interesting diagram showing the cross-section of the ascents. They find that day-to-day variations of temperature in the upper atmosphere are much more pronounced than what are observed in the surface layers. They have not suggested an explanation for these temperature changes but have called them "damped temperature waves" of approximately three to four days at these heights, the amplitude of these waves increasing rapidly in the region of 200 mb.

2. Delhi and Calcutta were making two ascents daily during this period, the times of ascents being approximately 0500 and 2030 IST, and 0830 and 2030 IST respectively. The instruments were C-type at Delhi and F-type at Calcutta. It was considered worthwhile to study these data and correlate them to the synoptic situation as such a correlation does not appear to have been attempted by the above workers.

3. Figs. 1 and 2 show the time-section of the ascents at Delhi and Calcutta respectively. The time axis runs from right to left, and each ascent is represented by a vertical line erected at the corresponding time and date on the axis. The ordinates give the pressure levels. The smoothed lines are the isotherms drawn at intervals of 5°C.

4. It will be noticed that as in the case of Ahmedabad there are large fluctuations of temperature at Delhi and Calcutta, the magnitude of the changes increasing with height.

5. Venkateswaran and Desai (1953a) have shown that the diurnal variation of temperature at Ahmedabad, which is a maximum at the surface, decreases rapidly with height and vanishes nearly at 800 mb. The mean temperature for Calcutta and Delhi during April 1952 for early morning and late evening also shows that the diurnal variation is negligible above about 800 mb. The large variation of temperature at higher levels from ascent to ascent cannot, therefore, be regarded as being due to any diurnal variation particularly in view of the fact that the fluctuations do not occur in 24-hour cycles. On the contrary there is good justification for the assumption that these are directly or indirectly influenced by upper tropospheric disturbances, as the following considerations will show.

6. A study of the constant pressure charts shows that an upper level trough was moving eastwards across north India between 12 and 18 April 1952. The trough line at 300-mb

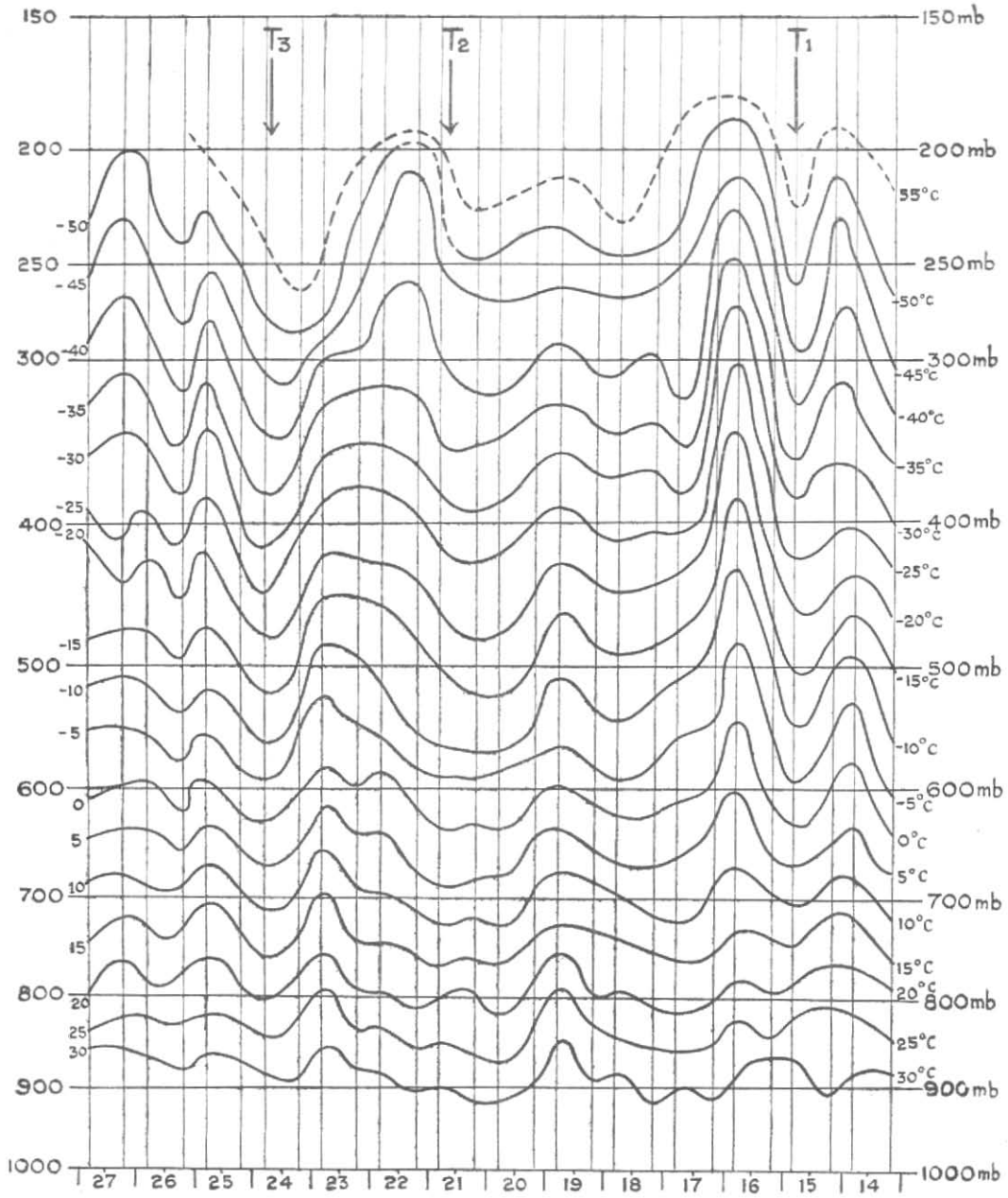

Fig. 1. Time-section of the serial ascents taken at Delhi in April 1952

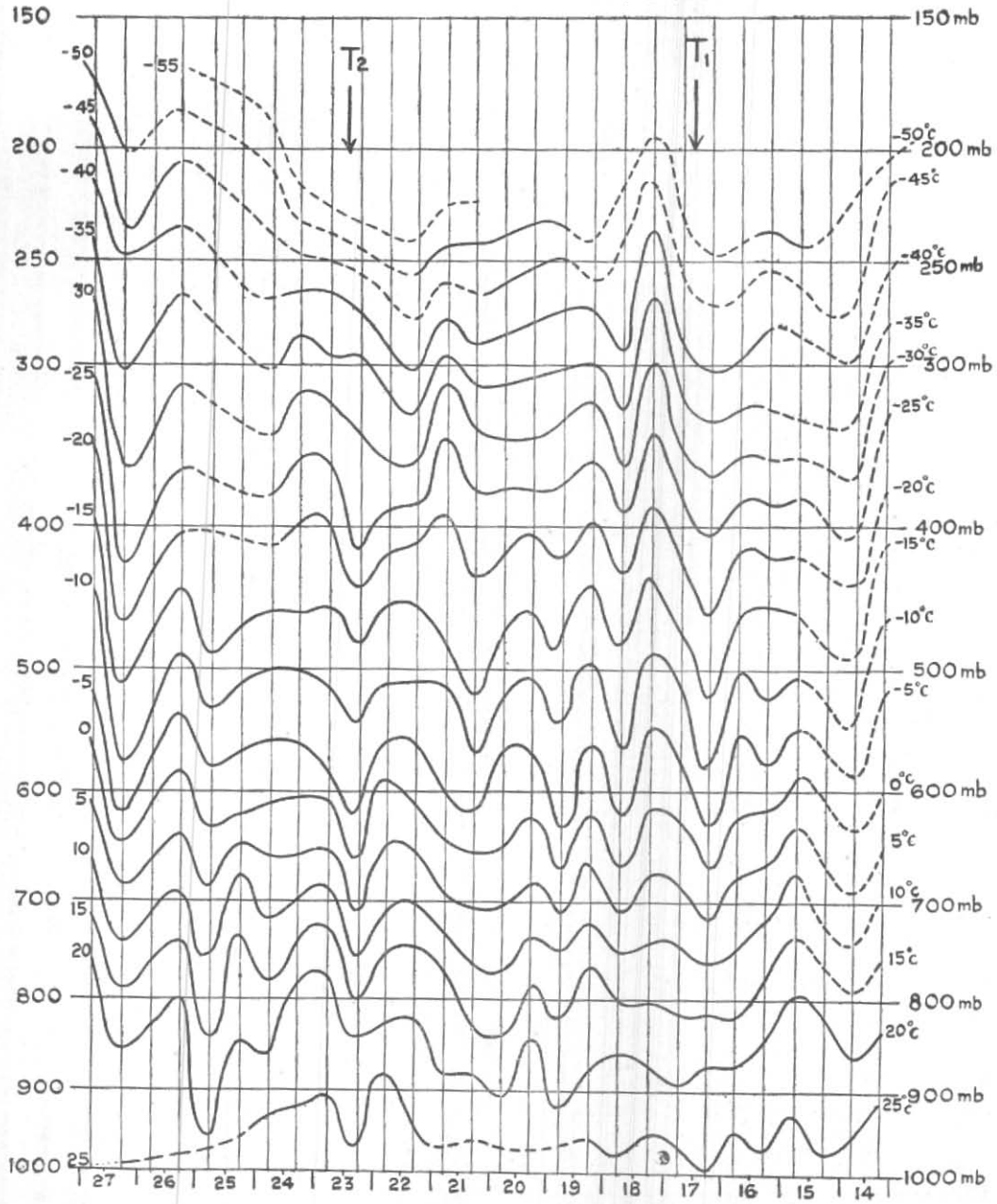

Fig. 2. Time-section of the serial ascents taken at Calcutta in April 1952

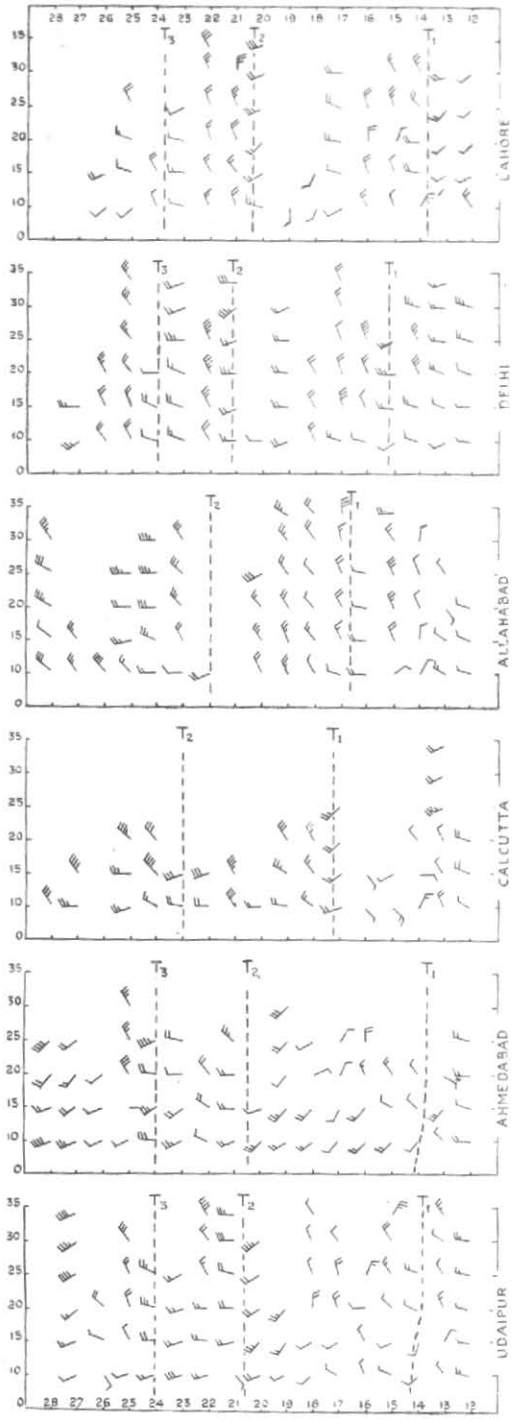

Fig. 3. Time cross-section of upper winds during 12-28 April 1952

level was located roughly along long. 65°E on the 12th and 90°E on the 18th. Another upper level trough was seen to be moving eastwards across north India between 19 and 25 April, the associated trough line shifting from about long. 65°E on the 19th to 90°E on the 25th. A weak trough was also apparently moving across the extreme north of the country between the 23rd and 25th. In all these cases the passage of the trough line across stations to the north of 20°N was marked by a strengthening and veering of the upper level winds from a southwesterly/westerly direction to a northwesterly/northerly direction. In the last case, however, the windshift was not noticeable at stations to the east of long. 80°E.

7. Fig. 3 gives the time cross-section of upper winds at Lahore, Delhi, Allahabad, Calcutta, Ahmedabad and Udaipur above 10,000 ft during the period 12 to 28 April 1952. The winds at 0900 GMT have been plotted since night and morning ascents did not reach high levels. The trough lines have also been indicated in the figure. The approximate passage of the trough line across Delhi and Calcutta has been marked T_1 T_2 T_3 in Figs. 1 and 2. It is possible that the trough line may not have been sufficiently sharp all the time but a rough estimate has been made from the available constant pressure charts and the windshifts at higher levels as given by Fig. 3.

8. It is significant that the large fluctuations of temperature at higher levels synchronised with the passage of the migrating upper level troughs. In general, there was a rise of temperature at Delhi and Calcutta in the rear of the trough line. At Ahmedabad (Venkateswaran and Desai 1953b) too, in spite of its more southerly location, there was a rise of temperature on 21st-23rd and again on 24th-25th which coincided approximately with the passage of the trough line across the station. The feeble trough line which passed Ahmedabad on about the 14th does not appear to have affected the upper air temperatures to any appreciable extent. The rise of temperature on 18th-19th

TABLE 1

Height (mb)	Karachi (20—19)	Jodhpur (20—19)	Delhi (21—20)	Allahabad (22—21)	Shillong (23—22)
850	+2°C	—7°C	+ 3°C	+ 2°C	..
700	+5	—3	+ 3	+ 5	—5°C
600	+6	+1	+ 6	+ 7	+1
500	+9	+3	+11	+10	+1
400	..	0	+12	..	+2
300	..	+8	..	..	+8
200	..	..	— 2	..	..

above 300 mb does not seem to have been associated with any upper level trough. Thunderstorms were in progress at Calcutta at the time of the second ascent on the 16th, 21st, 22nd and 25th, but it is noticed that they did not, in general, vitiate the isotherms at higher levels. The crest in Fig. 2 on the 21st evening does not affect the main arguments in this section.

9. A recent instance of a well-marked upper level trough which swept over north India during the period 19 to 22 February 1954 may, in this connection, be cited and discussed in detail. The trough was noticeable up to very great heights, and the progressive eastward displacement of the trough line on successive charts was conspicuous.

The contour charts for 300-mb level for this period with the trough line marked on them are given in Fig. 4. The temperature data were obtained from the radiosonde ascents made at different stations in the evening. The 30,000 ft winds of 0900 GMT pibal or Rawin winds (marked R) of 1500 GMT are shown on these charts. In a few cases where pibals did not reach that height the winds at 25,000 ft have been plotted in broken feathers.

10. A vertical cross-section roughly along a line from Jacobabad to Calcutta, which is at right angles to the trough line, for a typical day during the period, 21 February 1954, is given in Fig. 5. The winds are those of 0900 GMT pibals except at Delhi, Allahabad and Calcutta where they are based on 1500 GMT Rawin ascents. The trough line, it would appear, had just passed the longitude of Gwalior at this time.

11. It is noticed that there was an increase of temperature to the rear of the trough line as detailed in Table 1 which shows the temperature change from the day preceding the passage of the trough line to the succeeding day.

It is interesting that the air at higher levels in the region of the northerlies to the rear of the trough line was warmer than that in the forward portions where the winds were from the south.

12. Isopleths of thickness values 300-500 mb are drawn in broken lines at intervals of 200 ft in Fig. 4. In drawing these lines the thermal winds through this layer (not put in the diagram to prevent overcrowding) have been taken into account. On the 19th there was a pronounced thermal ridge over north Arabia as seen from the thickness values and thermal winds at Nicosia, Habbaniyah and Bahrein (Fig. 6) and a cold trough over east Iran and Baluchistan. The eastward movement of these thermal systems on the succeeding days is conspicuous. The successive positions of the 12,200-ft thickness line (which is common to all the charts) during this period are reproduced in Fig. 7. The eastward displacement of the portion of the line having a north-south orientation is much greater than the northward displacement of the rest of the line probably due to the

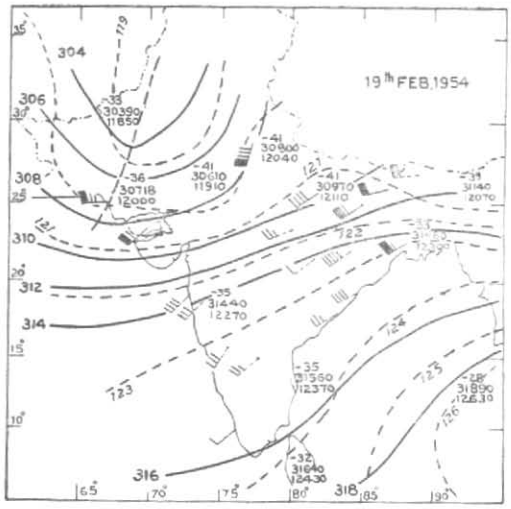

Fig. 4 (a)

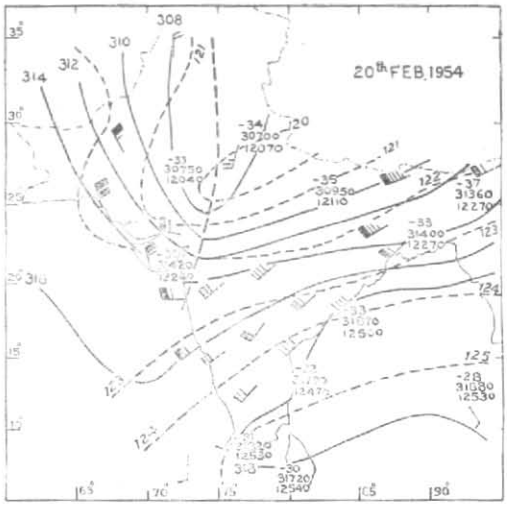

Fig. 4 (b)

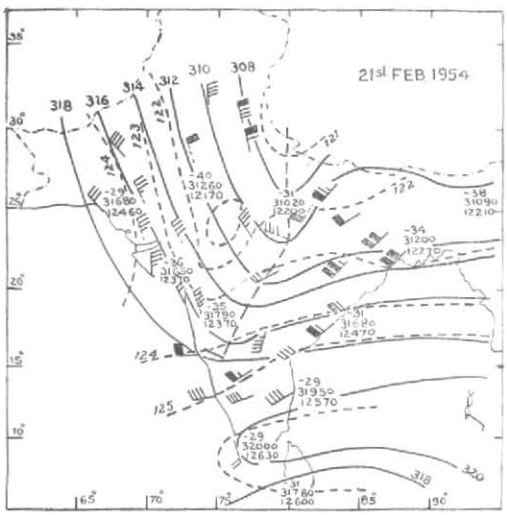

Fig. 4 (c)

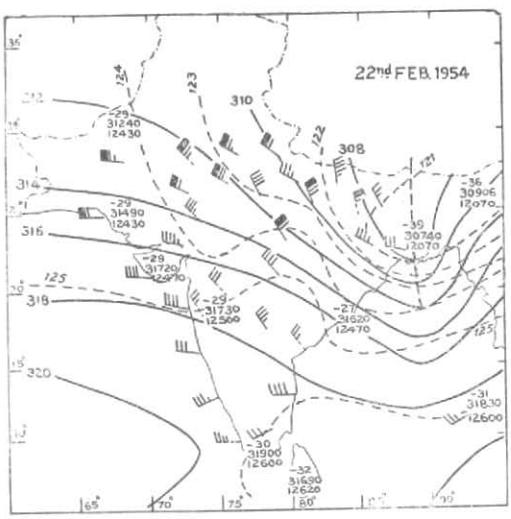

Fig. 4 (d)

Fig. 4. Constant pressure charts (300 mb)

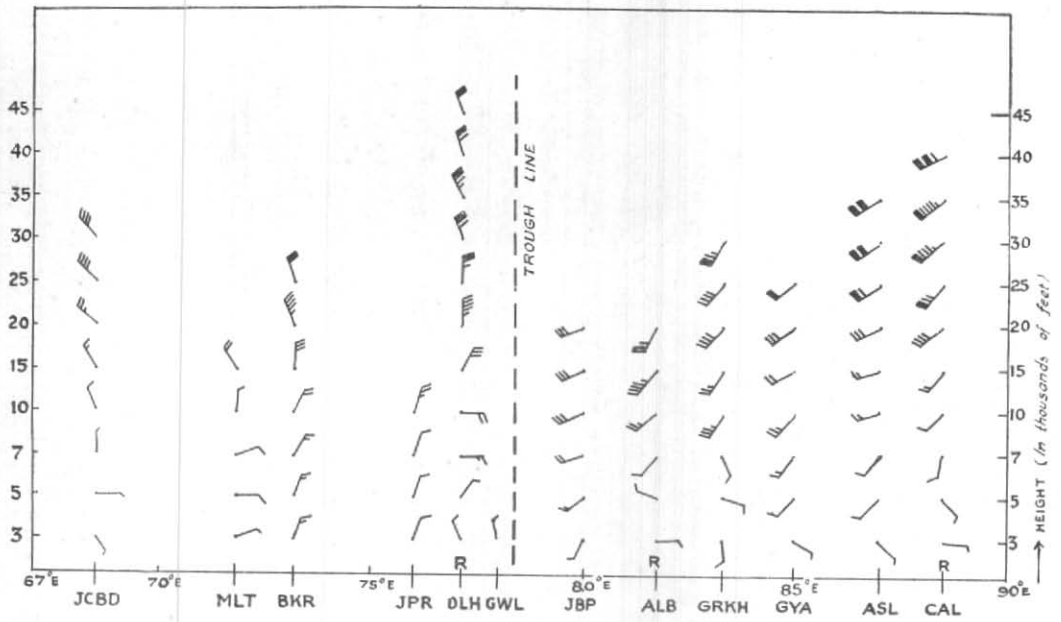

Fig. 5. Vertical section of upper winds on 21 February 1954

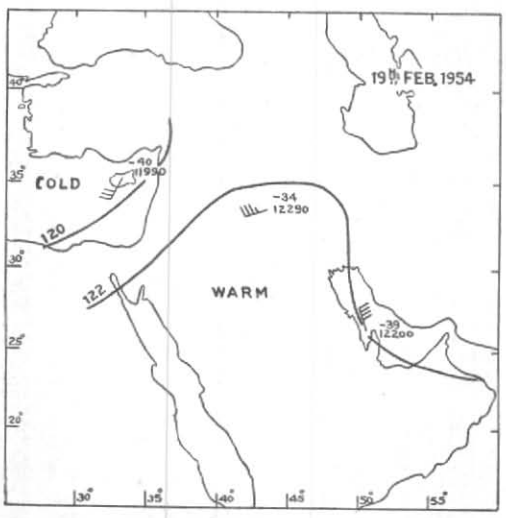

Fig. 6. Thickness chart (300-500 mb) and thermal winds for 19 February 1954

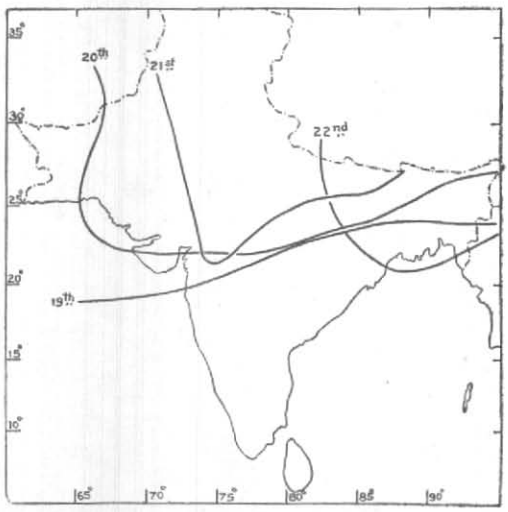

Fig. 7. 12,200-ft thickness lines during 19-22 February 1954

greater component of the wind vector in the direction of the thickness gradient (Sutcliffe and Forsdyke 1950). From the above considerations it would appear that warm advection was taking place to the rear of the trough line.

13. Another significant fact is that at Jodhpur and Allahabad the temperatures commenced rising one to two days prior to the passage of the trough line. Delhi 300-mb temperature showed a rise one day prior to the passage of the trough line. The wind velocities in the field of the trough were much greater than the speed of the trough line. As such, the air from the rear of the trough was overtaking the trough line and passing into the forward portions. As shown earlier, temperatures in the rear were greater than in advance. As a result, the temperatures in the forward portions of the trough were continually increasing. On the 19th, Delhi, Jodhpur and Allahabad in advance of the trough line recorded a temperature of about —41°C at 300 mb. On the 20th Delhi and Allahabad, still in advance, recorded about —35°C, and on the 21st Allahabad recorded —31°C. There is thus a gradual warming up in advance of the trough due to the incursion of warm air.

14. In conclusion, I wish to thank Dr. B. N. Desai for his valuable guidance and Mr. Y. P. Rao for his helpful suggestions during this investigation.

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	1953b	*ibid*, 38A, p. 338, Fig. 10.