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Some high pilot balloon ascents at Poona

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ABSTRACT. To supplement available observed winds at high levels, about 40 special ascents were made with big balloons at Poona in winter 1952-53. Tails of 200 metres were attached and weighted to reduce slant. 15 of the ascents reached heights above 60,000 feet. The paper gives—(*i*) height-time curves of the individual ascents, (*ii*) vertical time-section diagrams for the four months upto 22 km, with isotachs and general wind directions and (*iii*) diagrams of departures from normal of temperatures upto 16 km from daily radiosonde ascents. The vertical currents and winds are discussed in relation to the synoptic situations and major temperature changes.

1. Introduction

With aircraft operating at greater heights interest in, and utility of, actual observations of winds and temperatures from these heights has increased greatly. Limits to heights up to which observations can extend are set by (*i*) ability of the balloon tissue to stand the difference in pressure between inside and outside, (*ii*) the range of distance upto which the observing method can operate and (*iii*) atmospheric obscuration by cloud or mist. Due to these, observations of winds from levels above 30,000 feet are not too common. Of the pilot balloons that were let off at Poona in the normal observational programme, in the year 1952, 35 reached a height of 40,000 feet, 4 reached 50,000 feet and only 2 reached 60, 000 feet. Some special ascents using bigger balloons, with the specific object of getting winds at least up to 60,000 feet with as great an accuracy as possible, were, therefore, made at Poona during the cold weather season of 1952-53, 16 of which went above 60,000 feet. Some points of interest shown by these ascents are presented in this paper.

2. Particulars about balloons etc

40 balloons were let off during the period 28 October 1952 to 5 May 1953. 6 of the balloons used were of NR 875 type (mean weight 875 gm) and the remaining NR 575. The attempt was to have 2 to 3 ascents per week, *i.e.*, every third or fourth day; but days when ascents were not expected to be high due to clouding were generally ruled out. The ascents fall into two main spells, 28 October to 14 November 1952 and 17 December 1952 to 17 February 1953; later, there were just a few occasional ascents.

On 4 days, two separate balloons were let off within about half an hour of each other and were followed by two independent pair of observers.

The free lifts given were varied rather widely at first in order to find out the optimum; later, they were kept within narrower limits.

The tail method of finding heights was used and in order that tail readings may not be too low even at the greatest heights, 200 metre tails with muslin sheets nearly $5' \times 3'$ were used as flags. The substitution of muslin for paper was found to be of real help by ensuring that the flags did not get torn. To enable the release of such long tails, a fuse arrangement was used by which the tail gradually unwound itself out of a paper drum. With the object of keeping slant of tail and errors in height due to it to a minimum, a sandbag weighing 100 gm was attached to the end of the tail, with the flag.

3. Maximum heights attained

The greatest heights reached by these balloons, together with particulars regarding

TABLE 1

Particulars about the balloons and heights reached

Serial No.	Date	Time of release of balloon (IST)	Kind of special balloon	Net free lift (gm)	Height reached by special balloon (km)	Height reached by routine afternoon pilot balloon (km)
1	20-10-52	1535	NR 575	1070	18·4	9·2
2	28-10-52	1610	,,	880	18·2	9·2
3	29-10-52	1533	NR 875	1500	20·9	7·8
4	29-10-52	1533	,,	1830	18·4	7·8
5	30-10-52	1511	NR 575	750	6·0	16·3
6	30-10-52	1548	,,	1250	22·0	16·3
7	4-11-52	0800	,,	640	14·8	6·8
8	4-11-52	0821	,,	1100	14·2	6·8
9	5-11-52	1507	,,	860	13·8	7·2
10	6-11-52	1610	,,	1210	11·8	12·6
11	7-11-52	1549	,,	1290	20·1	7·3
12	11-11-52	1550	NR 875	1190	18·0	10·0
13	12-11-52	1545	,,	1390	19·0	11·1
14	13-11-52	1545	,,	1360	19·3	8·0
15	14-11-52	1530	,,	860	19·8	14·1
16	17-12-52	1528	NR 575	1060	19·5	8·7
17	22-12-52	1527	,,	1100	11·9	5·1
18	23-12-52	1500	,,	1190	14·6	4·2
19	26-12-52	1521	,,	1080	18·0	6·0
20	31-12-52	1514	,,	940	21·9	11·8
21	15-1-53	1519	,,	1100	18·9	10·1
22	16-1-53	1515	,,	1030	13·4	9·0
23	19-1-53	1525	,,	1030	19·8	6·8
24	20-1-53	1515	,,	1200	20·1	7·3
25	21-1-53	1520	,,	1300	15·7	9·2
26	22-1-53	1515	,,	1400	8·6	6·5
27	23-1-53	1524	,,	1480	17·0	7·9
28	30-1-53	1520	,,	1250	12·9	9·9
29	2-2-53	1515	,,	1400	21·4	7·8
30	5-2-53	1511	,,	1380	18·9	7·9
31	13-2-53	1525	,,	1420	13·3	8·2
32	16-2-53	1508	,,	800	10·6	9·6
33	17-2-53	1525	,,	1460	12·2	9·1
34	13-3-53	1540	,,	1360	16·9	10·8
35	17-3-53	1530	,,	1300	7·4	7·8
36	20-3-53	1636	,,	1300	20·3	6·2
37	24-3-53	1700	,,	800	17·2	10·7
38	31-3-53		,,	1240	11·7	7·2
39	29-4-53	1625	,,	1300	13·4	10·6
40	5-5-53	1600	,,	1330	15·3	6·5
				Mean	16·1	8·8
				Gain in mean height	7·3	

TABLE 1 (*contd*)

	No. of balloons reaching the maximum height range (km) of											
	<10	10·0 to 10·9	11·0 to 11·9	12·0 to 12·9	13·0 to 13·9	14·0 to 14·9	15·0 to 15·9	16·0 to 16·9	17·0 to 17·9	18·0 to 18·9	19·0 to 19·9	20·0 or more
Routine balloon	29	5	2	1	..	1	..	2	..	..	..	..
Special balloon	3	1	3	2	4	3	2	1	2	7	5	7

times of release, free lifts given and the greatest heights reached by the routine unrestricted ascents for the days at Poona are given in Table 1. The distribution of the heights reached by the special and routine balloons have been shown in a frequency table and the mean heights have also been given in the same table. The mean additional height gained is *7·3 km*. While 16·3 km was the greatest height reached by the routine balloons, nearly 22·0 km was reached by two of the special balloons. 29 of the 40 routine balloons (72 per cent) were lost below 10 km, while only 3 (7 per cent) of the special balloons failed to reach 10 km. Thus increasing use of these NR 575 balloons, will lead to our getting more and more observations from the layer 10-20 km which observations are useful in connection with high altitude flying.

4. Effect of the weighting in reducing tail slant and thereby increasing accuracy of the heights

It is well known that, when heights of pilot balloons are computed by the tail method, the principal source of error is due to non-verticality of the tail (Field 1924, Ramakrishnan 1939). In every ascent of the present series, a sandbag weighing 100 gm was attached to the tail, so as to reduce slant of tail. In conformity with general practice even with routine ascents, a remark regarding slant of tail was made in the observation sheet, whenever such slant was observed. The percentage of instances when tail was slanting in the special ascents was about 3/5 of the corresponding percentage in the routine ascents. Although such weighting of the tail has the disadvantage of increasing the hydrogen consumption, the increase in accuracy of heights would seem to justify the procedure. Regarding the optimum weight, some trials may be necessary.

5. Further evidence on the accuracy of the results

It is the general experience of those who have worked with pilot balloon winds that they show a fairly high degree of internal consistency. On four days, in this series, two separate balloons, with nearly same free lift, rate of ascent etc were let off within half an hour of each other. The directions and speeds of wind at various heights of these are given in Table 2; and the height-time curves of three of them in Fig. 1. The general agreement, it will be seen, would suggest that the values of direction and speed obtained on different days could be assumed to be correct within 20 degrees and 5 knots respectively. The few levels where the values from the 2 ascents differed by more than these limits are given in bold types in Table 2. Probably these changes are real and occurred in the interval between the two ascents. May be they represent the gustiness of the wind at the levels.

6. The height-time curves and vertical currents

The height-time curves of the ascents with every height value plotted are shown in Figs. 2 to 5. It will be seen that in general, most of the points could be fitted into smooth curves. This enables one to infer from the height-time curves the presence of vertical currents with greater confidence. Points in the height-time curves, where sharp changes occur, have been indicated by short arrows. Side by side with each height-time curve, a straight line has also been drawn to show which height-time curve that particular balloon would have given had there been no vertical current at

TABLE 2

Directions and speeds of pairs of ascents

Height (km)	Ascent No.	Date and time (IST) of 1st/2nd ascent: 28-10-52 1555/1610 dd	vv	29-10-52 1533/1553 dd	vv	30-10-52 1511/1548 dd	vv	4-11-52 0800/0821 dd	vv
1·0	1st	05	11	13	1	03	3	11	10
	2nd	04	7	36	5	07	2	12	9
2·0	1st	05	5	06	6	07	9	15	2
	2nd	08	6	05	5	05	8	14	4
3·0	1st	08	8	09	9	05	12	36	4
	2nd	07	10	07	9	05	12	31	6
4·0	1st	10	21	08	14	05	15	35	9
	2nd	09	19	09	15	06	14	36	8
5·0	1st	09	29	10	19	06	16	19	5
	2nd	10	29	11	21	09	21	20	6
6·0	1st	10	28	13	21	07	24	21	8
	2nd	11	19	11	27	11	21	22	5
7·0	1st	12	25	13	21			22	6
	2nd	12	21	13	22			23	9
8·0	1st	15	22	14	15			25	15
	2nd	15	25	14	15			22	9
9·0	1st	14	17	14	18			25	16
	2nd	13	13	15	14			24	15
10·0	1st	12	6	17	13			25	18
	2nd	14	4	18	12			26	19
11·0	1st	21	6	19	13			25	19
	2nd	15	4	22	13			25	17
12·0	1st	22	8	23	13			26	18
	2nd	19	8	21	7			26	15
13·0	1st	20	11	19	11			24	20
	2nd	19	11	17	10*			24	21
14·0	1st	19	17	16	12			24	17
	2nd	20	15	10	13*			24	17
15·0	1st	17	19	15	12				
	2nd	19	17	13	11*				
16·0	1st	17	20	13	18				
	2nd	16	17	09	11*				
17·0	1st	11	17	09	14				
	2nd	07	15	08	13*				
18·0	1st	10	23	10	15				
	2nd	13	18	09	11*				

dd in tens of degrees, *vv* in knots

* Extrapolated

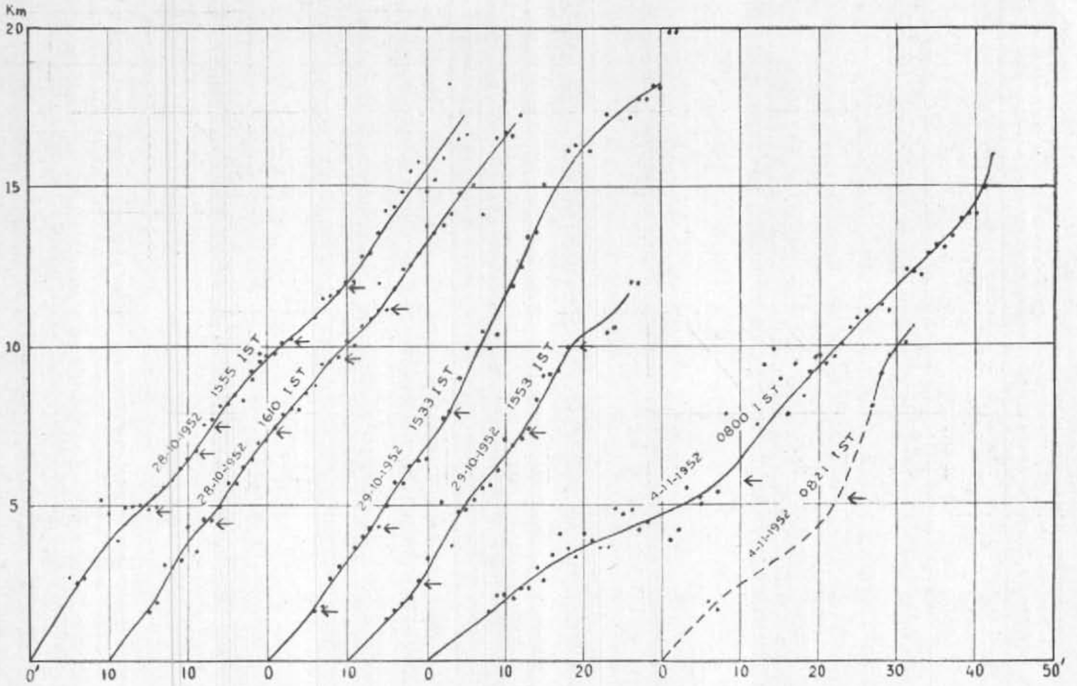


Fig. 1. Height-time curves of pairs of balloons

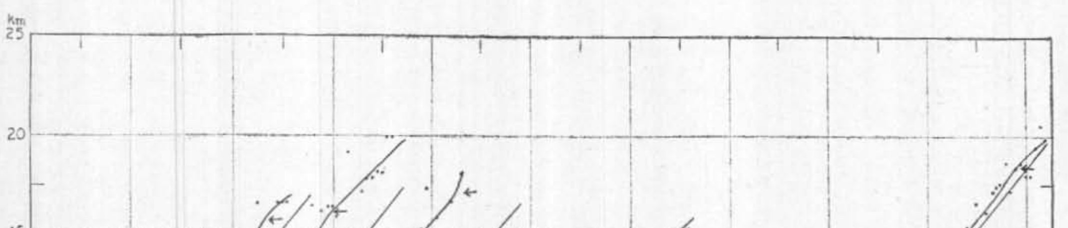
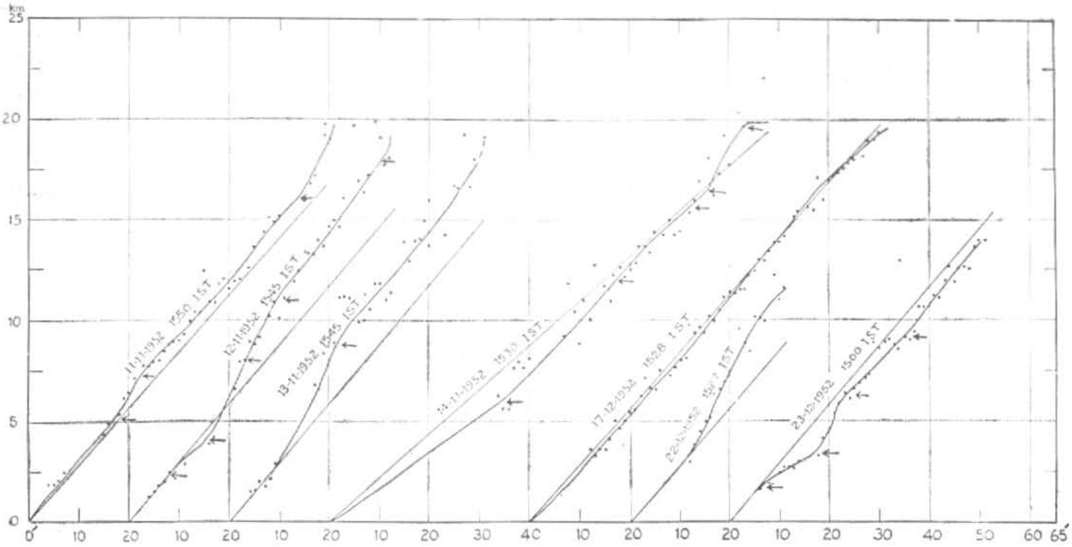


Fig. 2


Km
25
20
15
10
5
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0'
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20
10
20
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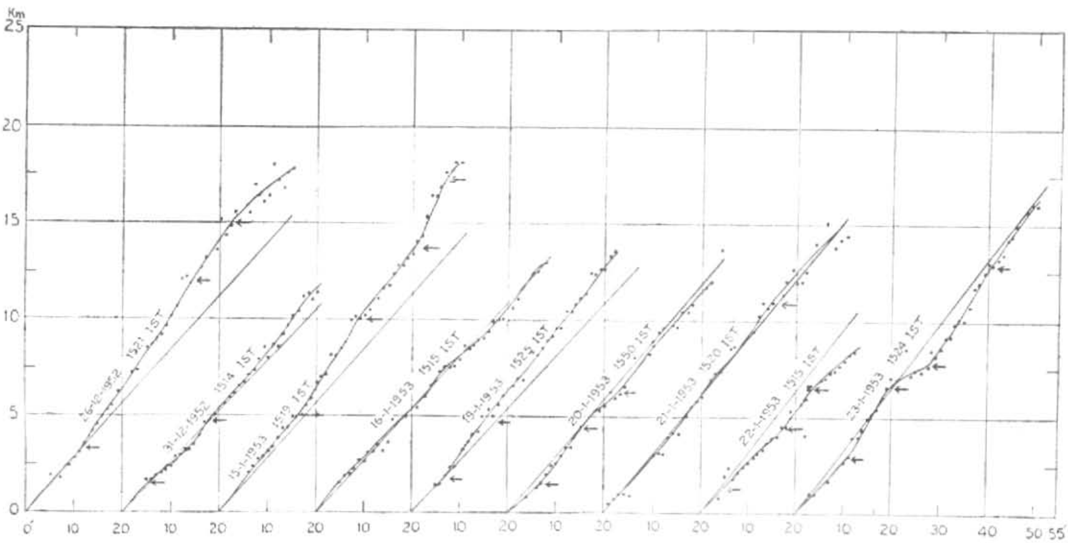
50
60
65'

Fig. 3


Km
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55'

Fig. 4

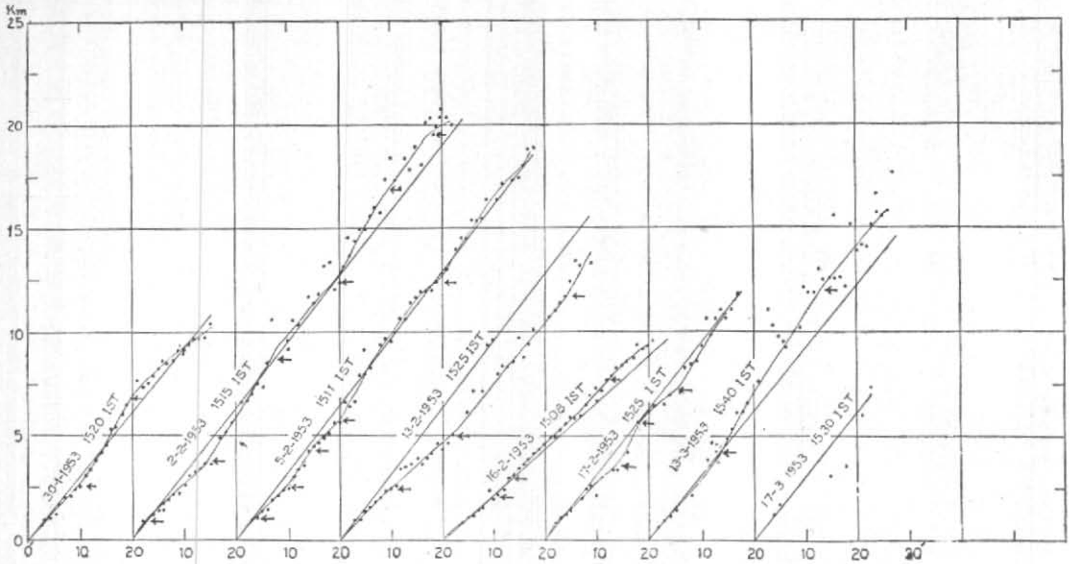

Fig. 5

that time. This straight line (the expected height-time curve) has been drawn on the following basis.

Each of the smoothed height-time curves was first divided into sections with very nearly uniform rate of ascent, and the rates of ascent in each section worked out. These rates were plotted against the quantity $L^{\frac{1}{2}}/(L+W)^{\frac{1}{3}}$ for the particular ascent. Fig. 6 shows this plot for all the ascents together. A curve giving the best fit was then drawn. The expected height-curves were drawn by using this curve and the known values of L and W for each ascent. This procedure amounts to using the usual expression for rate of ascent, *i.e.*,

$$q \frac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}}$$

with the value of q derived from the present series of ascents themselves.

The departures from the expected rate of ascent may in fact be due to either (*i*) quality of the individual balloon used or (*ii*) vertical currents in the atmosphere which accelerate or retard the upward movement of the balloon. The applicability of a value of q so derived is obviously justifiable in the first case but not so in case 2. It may be argued that large vertical currents may exist in particular regions with a net flow going either upward or downward and that the mean rate of ascent derived from such a scatter diagram may be biassed. However, the points in the scatter diagram were obtained only for each section with a homogeneous rate of ascent irrespective of their duration and a perusal of Figs. 2 to 5 will show that there are on the whole as many cases of gradients greater than the expected in each ascent as less than the expected. The departures from expected rate are not always confined to particular heights but seem to occur anywhere in the height line. Hence it seems that the acceptance of a mean rate of ascent from the scatter diagram may not be far wrong.

Table 3 gives the percentage frequencies of departures of different ranges from expected rates of ascents.

The important points brought out by this table are—

1. An appreciable number of observations (23 per cent) are in a range of $\pm$ 1 km hr^{-1} within the expected rate of ascent.

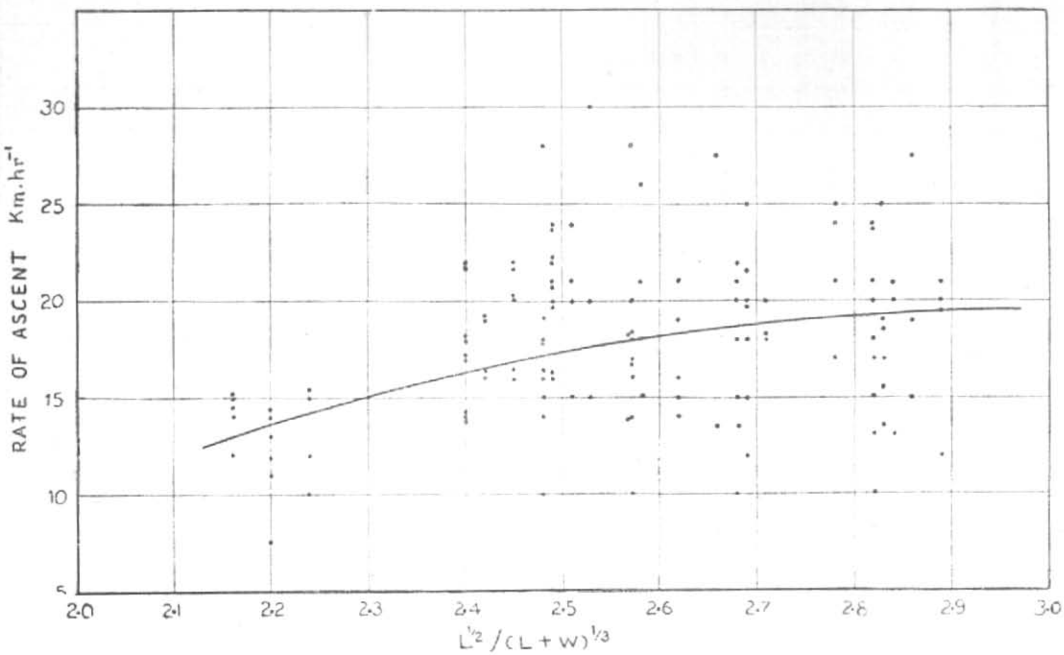

Fig. 6

TABLE 3

Percentage frequencies of departures from expected rate of ascent

Range of departure (km·hr⁻¹)	Duration (min) <5	5 to 20	>20
<−10	—	—	—
−5·1 to −10	1	8	—
−1·1 to −5	—	24	2
+1·0 to −1·0	—	20	3
+1·1 to +5·0	6	20	4
+5·1 to +10·0	—	8	1
>+10·0		2	

2. Departures—positive and negative—from the expected rates are also high, 50 per cent and their durations are also fairly long but not constant throughout the flight. Hence it can be concluded that—

(*i*) The constants derived from Fig. 6 are fairly accurate.

(*ii*) The departures from expected rates are real and are not due to unsatisfactory performance of the balloons since same rates of ascent are maintained for fairly long intervals, 5 minutes and above.

(*iii*) The departures are fairly high and cannot be ignored and they are a valuable source of information regarding the order of vertical currents met with.

The existence of vertical currents of such high orders in weather situations characteristic of high convection like thunderstorms is well recognised. However, the vertical currents in clear weather as prevailed in all the ascents of this series are generally considered to be of much smaller magnitudes.

The changes from one rate of ascent to another often occur quite sharply. If these give a true picture of the actual situation, then the boundaries of such currents are quite sharp. This fact can considerably vitiate computations of vertical motion made from velocity fields (Panofsky 1946).

TABLE 4

Distribution of vertical currents with height

Height a.g. (km)	No. of ascents	No appreciable current	Descending current			Ascending current		
			>5 km/hr	1·1–5·0 km/hr	Total	1·1–5·0 km/hr	>5 km/hr	Total
1	31	35	..	42	42	20	3	23
2	31	26	6	52	58	16	..	16
3	31	26	13	32	45	19	10	29
4	31	26	3	29	32	29	13	42
5	31	33	6	16	22	29	16	45
6	31	33	6	10	16	33	18	51
7	31	27	3	16	19	46	18	64
8	29	28	3	7	10	38	24	62
9	29	28	3	10	13	31	28	59
10	29	31	3	7	10	31	28	59
11	28	25	..	14	14	36	25	61
12	27	30	..	11	11	37	22	59
13	22	36	..	5	5	41	18	59
14	19	37	..	5	5	32	26	58
15	16	25	..	6	6	44	25	69
16	14	22	..	14	14	50	14	64
17	13	15	..	24	24	46	15	61
18	10	30	..	30	30	20	20	40
19	8	38	..	37	37	..	25	25
20	1	100	..	..	..	..	..	..

Table 4, giving the percentage distribution with height of the vertical currents, brings out the following—

(*i*) The currents in the lower levels, *i.e.*, upto 3 km are predominantly downward, although the observations relate to afternoons.

(*ii*) Between 4 and 18 km, the currents are mainly upward.

(*iii*) Above 18 km, *i.e.*, in the stratosphere they are once again pr dominantly downward, though upward currents occur on occasions. The upward currents in the stratosphere probably occur when warm air is brought by advection.

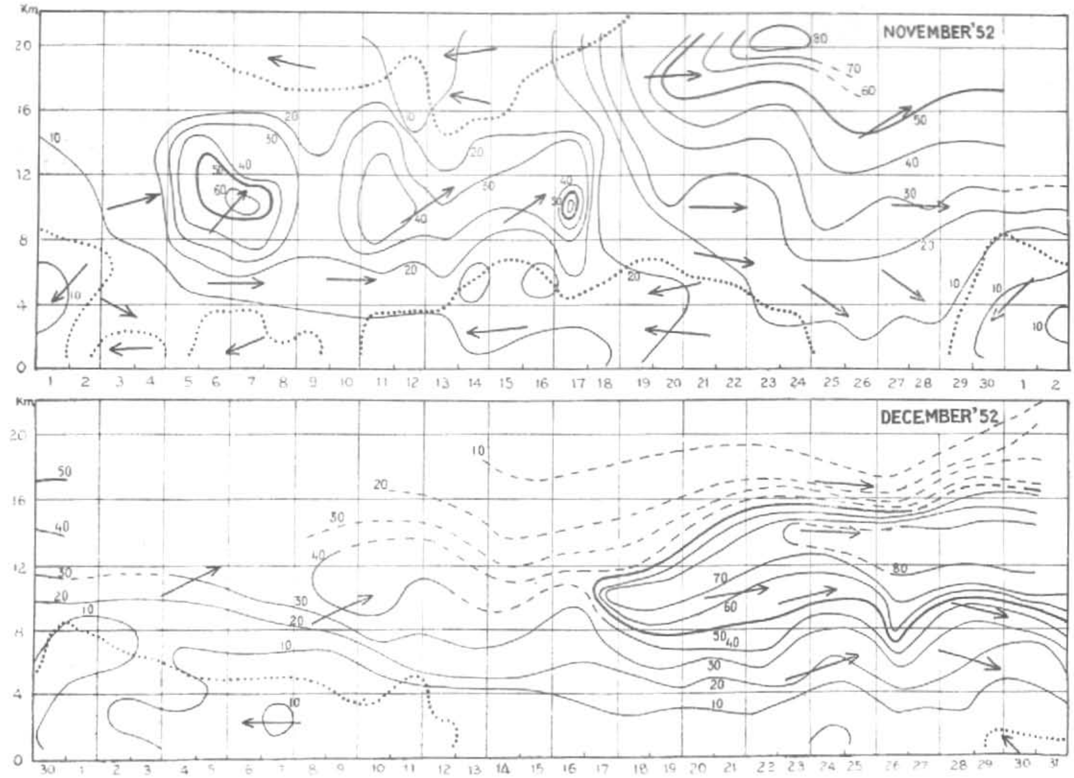

Fig. 7

7. The wind pattern of the whole season

Table 5 gives the directions and speeds of the wind at each kilometric level up to the maximum height, obtained from these special ascents. In order to get a complete picture of the wind pattern during the whole season, taking these special observations with the usual ones on the remaining days, Figs. 7 and 8 have been drawn. In these, isotachs are drawn at 10 knot intervals. They are shown broken where observations did not reach. Arrows indicate the general wind directions. The dotted lines separate easterly winds from westerlies.

7.1. *Important features of the wind in the troposphere (4 to 16 km)*

Till about 5 November, winds were generally weak. They then strengthened, and remained mostly so till about 22 February. Futher surges of strengthening, lasting for periods varying from 2 to about 15 days separated by comparative lulls occurred even within this period. The maximum speed (60 to 80 kts) occurred generally between 10 and 14 km above which height, the speed decreased. In one spell, centred about 24 November, wind went on increasing up to 21 km.

Broadly speaking, the variations of the wind over Poona during November to January are controlled by (*i*) the formation of depressions (or cyclones) in the Bay of Bengal to the southeast of Poona and their movement and (*ii*) by the passage of western disturbances to the northwest of Poona.

A cyclonic storm existed near lat. 15°N, long. 87°E on the evening of 8 November from where it moved over to lat. 20°N, long. 91°E by 10th evening. The

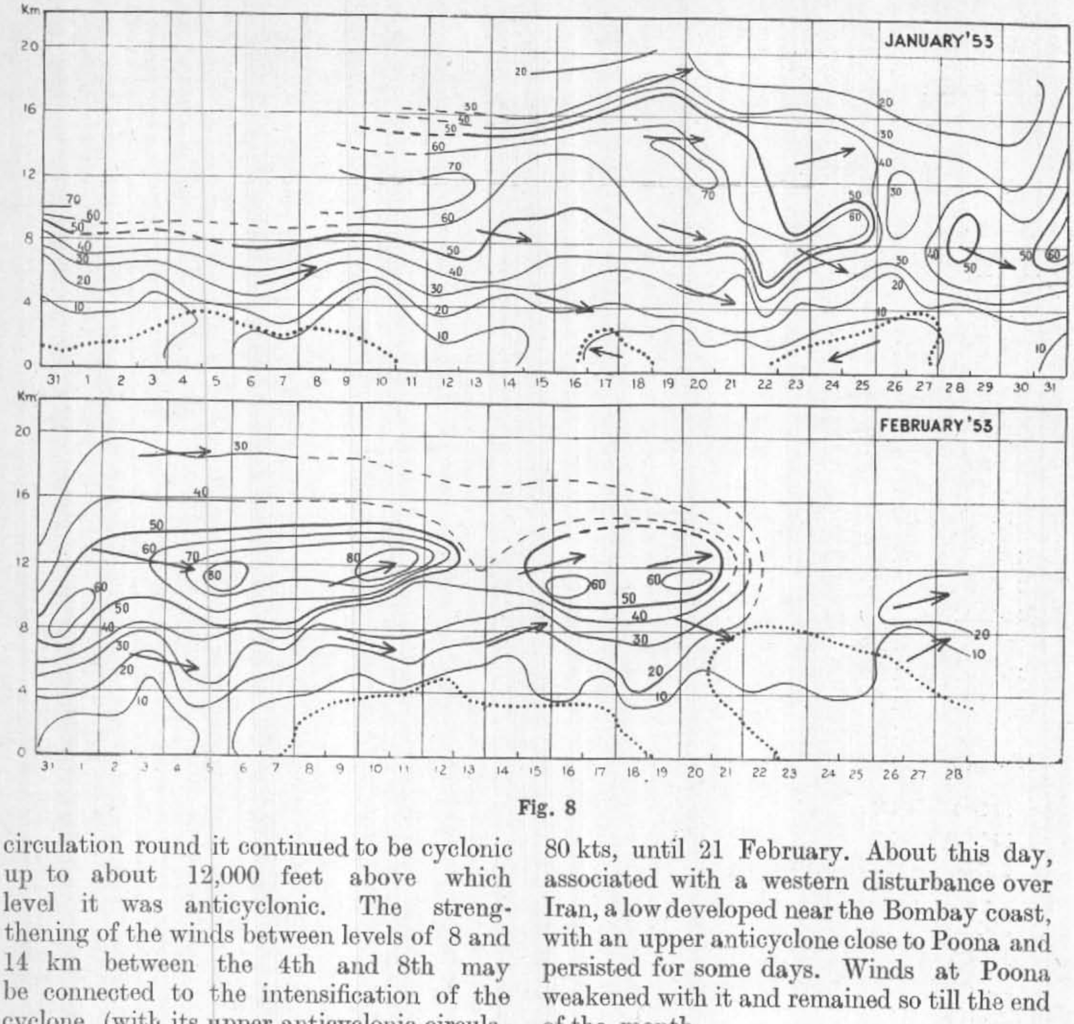

Fig. 8

circulation round it continued to be cyclonic up to about 12,000 feet above which level it was anticyclonic. The strengthening of the winds between levels of 8 and 14 km between the 4th and 8th may be connected to the intensification of the cyclone (with its upper anticyclonic circulation producing a strong gradient near Poona) and the temporary drop on the 9th to the fact that the upper anticyclone was practically in the same latitude as Poona on that day with the stronger pressure gradient farther away. With the receding and weakening of the cyclone, winds at Poona started strengthening again.

The first strong western disturbance of the season, near enough to India, appeared over Iran on 17 December. With it, the westerly winds from 8 to 14 km strengthened. At the level of maximum, which varied from 10 to 14 km, it was at least 50 kts, often 70 to 80 kts, until 21 February. About this day, associated with a western disturbance over Iran, a low developed near the Bombay coast, with an upper anticyclone close to Poona and persisted for some days. Winds at Poona weakened with it and remained so till the end of the month.

7·2. *Winds in the lower stratosphere*

Till about 20 November, winds in the stratosphere continued to be easterly, as earlier in the season (Venkiteshwaran 1950). The cyclonic storm in the Bay in the first half of November, with which the winds in the upper troposphere over Poona strengthened, had little influence on winds in the stratosphere. No easterly wind was observed after that date till the end of the present series of ascents.

In the latter part of November, one spell of really strong westerly occurred and a

TABLE

Direction and speed

Date	Time	HEIGHT (Km)																					
		1		2		3		4		5		6		7		8		9		10		11	
	(IST)	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*
28-10-52	1555	05	11	05	5	08	8	09	21	09	29	10	28	12	25	15	25	14	17	12	6	21	6
29-10-52	1533	13	1	06	6	09	8	08	14	10	19	13	21	13	21	14	15	14	18	17	13	19	13
30-10-52	1548	07	2	05	8	05	12	06	14	09	21	11	21	13	17	14	13	16	14	22	6	29	5
4-11-52	0800	11	10	15	2	36	4	35	9	19	5	21	8	22	6	25	15	25	16	25	18	25	19
5-11-52	1507	35	5	05	6	21	4	33	5	27	10	24	13	26	18	23	30	23	39	22	41	22	42
6-11-52	1610	07	4	04	5	02	4	29	7	29	15	27	20	23	27	23	38	23	43	23	49	20	57
7-11-52	1549	04	4	05	5	07	2	27	7	23	13	25	22	23	32	23	46	22	48	21	61	21	53
11-11-52	1550	07	4	13	6	15	8	28	15	30	19	27	22	25	27	27	45	25	43	25	42	25	38
12-11-52	1545	11	4	15	7	18	6	29	18	29	9	28	11	25	21	25	25	23	35	23	41	23	39
13-11-52	1545	11	6	12	6	35	6	29	11	27	14	24	21	25	25	23	31	22	39	22	30	22	26
14-11-52	1530	06	10	05	15	..	..	..	..	..	..	..	..	..	..	22	25	21	27	20	33	20	39
17-12-52	1528	28	3	22	4	15	10	21	14	20	11	23	22	25	29	25	31	27	45	26	75	26	52
22-12-52	1527	02	5	18	4	24	9	25	15	27	27	27	33	27	42	26	46	24	57	23	54	24	60
23-12-52	1500	07	9	14	6	14	4	30	11	26	21	27	20	27	26	27	32	27	43	25	52	26	59
26-12-52	1521	21	13	19	6	24	12	24	17	24	29	27	33	26	48	26	61	24	68	34	73	25	78
31-12-52	1514	11	5	12	7	20	6	17	8	26	19	26	19	26	19	26	36	26	49	26	72	25	78
15-1-53	1519	32	11	27	14	26	17	31	25	31	40	29	29	30	32	27	39	29	43	30	59	31	64
16-1-53	1515	30	6	29	12	28	19	29	21	29	27	29	33	28	34	28	49	29	41	29	46	29	51
19-1-53	1525	29	7	22	6	29	10	31	22	29	29	28	34	26	40	26	63	29	67	29	67	27	55
20-1-53	1515	27	5	23	12	24	19	31	26	30	32	30	41	27	40	29	60	29	68	28	68	28	65
21-1-53	1520	03	3	21	5	25	23	28	21	29	23	29	25	22	38	30	48	29	68	29	59	30	69
22-1-53	1515	24	4	23	16	27	21	29	3	30	45	30	62	31	68	29	59						
23-1-53	1524	07	3	31	7	35	13	31	17	32	20	33	34	33	35	32	76	30	56	27	46	26	42
30-1-53	1520	27	13	26	12	30	19	33	26	32	31	31	42	31	45	28	44	27	41	27	39	25	35
2-2-53	1515	07	7	14	6	01	15	31	14	31	29	29	27	32	26	31	42	30	47	31	55	30	47
5-2-53	1511	27	16	22	15	24	13	29	23	30	38	31	44	29	36	28	56	29	66	29	84	29	81
13-2-53	1525	10	6	13	8	15	7	23	8	25	9	29	15	30	23	28	26	26	35	25	39	24	49
16-2-53	1508	10	7	11	7	11	4	14	12	17	10	23	13	24	21	24	31	24	47	24	61		
17-2-53	1525	12	3	15	6	15	6	15	7	22	9	22	21	23	26	25	38	25	45	25	51	25	57
13-3-53	1540	35	2	29	4	29	4	29	13	28	19	29	18	30	15	26	23	26	49	24	59	23	65
17-3-53	1530	05	8	33	5	35	4	05	8	09	6	29	6	26	31								
20-3-53	1636	03	2	36	3	04	8	04	4	25	4	26	8	31	30	30	10	26	27	24	51	28	34
24-3-53	1700	32	10	31	10	07	7	05	7	27	4	25	4	33	10	33	19	34	37	34	33	34	24
31-3-53	1703	26	3	32	2	09	3	13	7	10	5	16	19	19	19	20	31	22	31	20	44	20	64
29-4-53	1625	30	15	29	4	08	10	07	15	01	6	01	13	36	8	01	12	33	9	30	13	27	19
5-5-53	1600	28	9	27	13	25	12	05	6	06	8	04	8	02	17	29	13	26	18	25	17	25	15

dd in tens of degrees, *vv* in knots

5

at different heights

HEIGHT (Km)																						Time	Date
12		13		14		15		16		17		18		19		20		21		22			
dd	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	*dd*	*vv*	(IST)	
22	8	20	11	19	17	17	19	17	20	11	17	10	23	11	31							1555	28-10-52
23	13	19	8	16	7	13	17	13	23	10	19	14	17	10	17	13	14	07	17			1533	29-10-52
30	4	16	12	14	12	16	15	18	16	12	19	08	5	07	21	11	29	10	23	16	9	1548	30-10-52
26	18	24	20	24	17	23	15															0800	4-11-52
23	41	21	34	20	40																	1507	5-11-52
21	59																					1610	6-11-52
21	37	21	38	21	37	22	33	27	17	22	9	17	14	10	13	11	19					1549	7-11-52
23	39	23	45	23	27	23	37	23	27	17	15	08	16									1550	11-11-52
23	25	21	25	23	29	20	7	07	7	18	9	21	8	24	4							1545	12-11-52
26	21	27	11	18	14	11	15	12	16	13	6	15	7	06	9							1545	13-11-52
22	25	20	20	20	21	19	19	17	14	14	15	17	17	07	15	09	14					1530	14-11-52
27	34	23	30	25	32	24	17	20	18	21	6	34	10	05	6	10	5					1528	17-12-52
																						1527	22-12-52
23	65	23	73	26	81																	1500	23-12-52
24	86	25	82	27	83	28	51	29	26	02	13	32	4									1521	26-12-52
25	87	27	80	27	89	26	65	26	66	23	36	22	36	25	21	26	18	16	21	25	7	1514	31-12-52
29	53	27	51	29	66	28	47	26	29	29	18	28	21	26	31							1519	15-1-53
27	33	27	49																			1515	16-1-53
28	52	29	65	30	71	28	45	27	54	28	66	27	40	27	25	27	29					1525	19-1-53
28	72	29	64	29	57	24	56	27	60	31	25	26	25	24	17	26	19					1515	20-1-53
29	55	29	57	28	62	27	59	29	33													1520	21-1-53
																						1515	22-1-53
25	45	25	46	30	41	31	49	32	39	29	22											1524	23-1-53
27	29	28	21																			1520	30-1-53
29	52	28	57	27	43	29	43	30	37	29	27	28	35	26	35	27	21	26	24			1515	2-2-53
29	65	29	71	29	43	29	47	27	31	28	21	26	35	28	23							1511	5-2-53
25	38	25	35																			1525	13-2-53
																						1508	16-2-53
25	66																					1525	17-2-53
22	73	23	51	25	45	26	35	25	17	28	18											1540	13-3-53
																						1530	17-3-53
29	38	29	38	28	25	28	24	29	20	23	12	25	19	26	19	26	10					1636	20-3-53
30	13	29	17	29	19	22	5	23	6	29	8											1700	24-3-53
																						1703	31-3-53
26	25	28	17																			1625	29-4-53
22	13	23	16	20	10	17	7															1600	5-5-53

dd in tens of degrees, *vv* in knots

speed of 100 kts was reached at 21 km on 23 November. It is significant that a depression formed in the Bay of Bengal quite soon after the appearance of this strong wind in the stratosphere. The role of such strong stratospheric winds in the formation of cyclones or depressions, if any, can be established only by further observations and study.

8. Vertical currents and synoptic situations

Vertical currents should be expected to be predominantly upward in (*i*) the warm sector of the confluence region of entrance to jet streams (Namias and Clapp 1949, Murray and Daniels 1953) and (*ii*) regions where a low is intensifying in the lower levels and a high is correspondingly building up and extending in the higher levels. On the other hand, they should be expected to be predominantly downward (*iii*) near the core of jet streams and (*iv*) in regions where the anticyclone in upper levels is dissipating or spreading.

Situations of types (*i*) and (*ii*) can be recognised by winds at Poona backing with height and those of types (*iii*) and (*iv*) by their being steady or veering with height, so long as the general direction is westerly, *i.e.*, when Poona is on the northern edge of the anticyclone. When the anticyclone is further north and Poona is in the easterly regime, veering of winds with height represents type (*ii*) and backing type (*iv*). For examining the nature of the upward currents under these different categories of synoptic situations, the vertical currents have been sorted into three classes, ascending, negligible and descending and the frequency of each class with backing, steady and veering winds have been shown in Table 6. It will be seen that in most of the cases, the currents are in the sense in which they should be anticipated, except that with veering and steady westerlies, more of the negligible currents cases ought to have shown downward currents.

TABLE 6

Distribution of ascending, negligible and descending current with backing, steady and veering winds

		Ascending	Negligible	Descending
Easterly	backing	—	—	4
,,	steady	—	—	—
,,	veering	6	—	—
Westerly	veering	4	7	4
,,	steady	3	6	1
,,	backing	25	8	1

9. Temperature changes associated with the wind pattern

Poona being a station with daily radiosonde ascents, day-to-day temperatures at various levels upto about 16 km are available. With a view to giving a picture of the main fluctuations of temperatures at the different levels associated with the wind changes discussed and described earlier, departures of temperatures at each level from the normal for the season November to February are shown in Figs. 9 and 10. Departures from normal were chosen in preference to actual daily values, because the changes at the different levels will be almost masked by the larger changes from level to level if the latter were plotted.

It is interesting to note that the surges of stronger westerlies in the levels 10 km and above are most often associated with high temperatures at levels 12 to 16 km. The higher temperatures generally start a few days before the increase in wind speed.

The spell of strong stratospheric westerlies which preceded the Bay storm was also associated with high temperatures (6 to 10 degrees) in the levels 12 to 16 km.

10. Conclusions

(*i*) Vertical currents, going often upto 5 km hr^{-1}, and on occasions to 10 km hr^{-1}, occur in and near Poona during the winter.

(*ii*) The levels where they begin and end are quite well-marked.

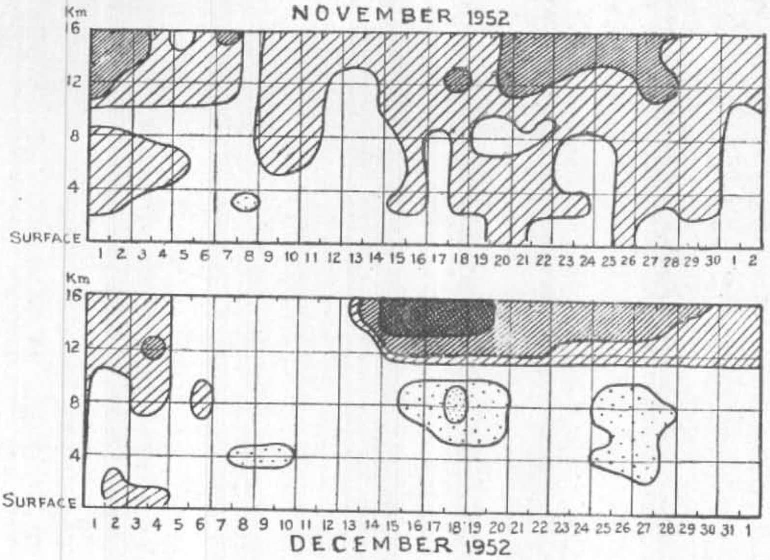
NOVEMBER 1952
Km
16
12
8
4
SURFACE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2
Km
16
12
8
4
SURFACE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1
DECEMBER 1952

Fig. 9

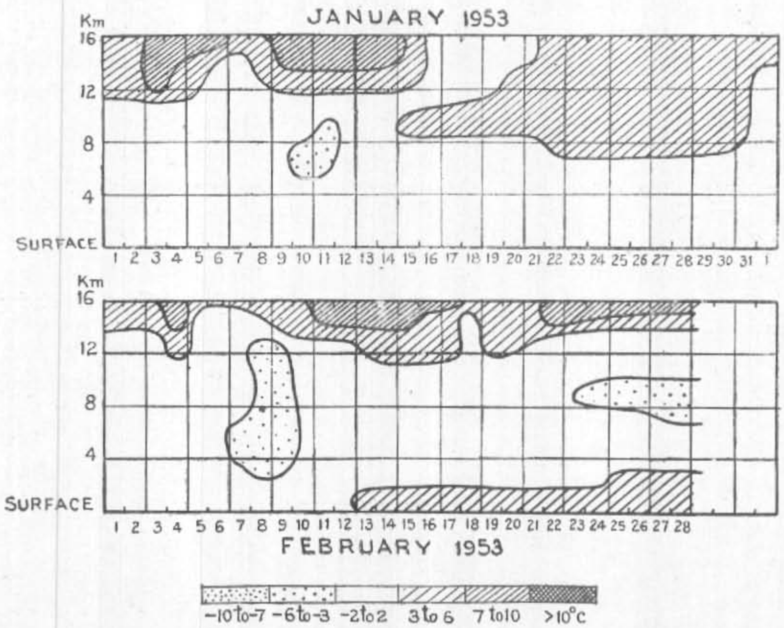
JANUARY 1953
Km
16
12
8
4
SURFACE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1
Km
16
12
8
4
SURFACE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
FEBRUARY 1953
-10 to -7
-6 to -3
-2 to 2
3 to 6
7 to 10
>10°C

Fig. 10

(*iii*) They are predominantly downward below 3 km and above 18 km; between 4 and 18 km, they are predominantly upward.

(*iv*) The sense of the currents is as they would be expected from their location with respect to the upper level anticyclones.

(*v*) Winds in the lower stratosphere were easterly in the beginning of the season; once they changed to westerly, apparently they remained so till the end of the season.

(*vi*) Usually the maximum speed of the westerly occurred at or below 14 km. In one spell, however, the maximum occurred at 21 km; and this was very soon followed by the formation in the Bay of Bengal of a depression, which eventually developed into a severe cyclonic storm.

(*vii*) The westerly winds near Poona in the upper troposphere may strengthen due to either (*a*) surface depressions to the south of Poona with corresponding upper level anticyclones bringing in a strong pressure gradient near Poona or (*b*) heightening of the south-north temperature fall caused by arrival of cooler air to the north with western disturbances.

11. Acknowledgement

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