DISCUSSION OF RESULTS OF SOUNDING BALLOON ASCENTS AT POONA AND HYDERABAD DURING THE PERIOD OCTOBER 1928 TO DECEMBER 1931

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Summary.—The paper contains a discussion of the monthly mean values of temperature, humidity, pressure, and derived quantities like lapse-rate, density and potential temperature obtained from sounding balloon ascents at Poona and Hyderabad in the Deccan during the period October 1928 to December 1931. Mean monthly differences of pressure and temperature between the Deccan and Agra and between the Deccan and Batavia are also discussed in their relation to the general upper wind circulation. The types of transition from the troposphere to the stratosphere and their seasonal distribution are analysed. Observations on a few individual days with relevant notes on the weather situation are given to illustrate (*a*) the daily temperature differences at different levels between Agra and the Deccan and (*b*) the nature of the variation of humidity with height. Up-to-date normal winds from pilot balloon ascents are used in the clothes-line diagrams given with the mean monthly tephigrams.

1. Introduction.

In a previous Memoir[1], one of the authors has discussed the results of sounding balloon ascents made at Agra during the period March 1925 to July 1928. In October 1928, a few months after the opening of the new Meteorological Office at Poona, sounding balloon work was started in the Deccan and the present paper contains a discussion of the results obtained from the soundings during the next three years. The data of individual ascents have been published in the Upper Air Data, *Part 14*, of the India Meteorological Department.

The meteorographs employed were of the Dines type and the balloons generally of ‘ vulpro ’ tissue. A few balloons were of India-rubber and were imported. The records were made on graphited glass plates and were worked out from enlarged drawings obtained by optical projection with a magnification of 40-50. The meteorographs, balloons and graphited glass plates were supplied by the Upper Air Observatory, Agra. The total number of records used in the present discussion is 143 of which 78 were obtained from ascents at Poona and 65 from Hyderabad in the Deccan. Their monthly distribution is shown in *Table 1*. (The reason for letting off the balloons from Hyderabad instead of from Poona during the months June to October was that, owing to the prevalence of easterly winds above 6 km. in this season, the balloons would be carried westwards and fall into the sea if let off from Poona.)

TABLE 1.

Month.	J	F	M	A	M	J	J	A	S	O	N	D	Total.
Poona 18° 32′ N. ; 73° 51′ E.	12	15	7	5	8	1	3	0	2	5	7	13	78
Hyderabad 17°20′N. ; 78°30′E.	..	..	..	..	..	4	10	10	21	15	5	..	65

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All the instruments were let off between 17 hrs. and 19 hrs. (I. S. T.). It is therefore unlikely that, even at the top of the ascent, the records are affected by insolation. The numbers of records giving data up to different heights are shown in *Table 2*.

TABLE 2.

Height (gkm.).	10 or lower.	10·1 to 12.	12·1 to 14.	14·1 to 16.	16·1 to 18.	18·1 to 20.	20·1 to 22.	22·1 to 24.	24·1 to 26.	26·1 to 28.
Number . . .	143	130	125	122	110	66	31	8	5	1

It will be seen that nearly 75 per cent. of the balloons reached heights exceeding 16 dynamic kilometres. The greatest height reached was 28·1 gkm. on 3rd December 1931 and the lowest temperature recorded was 183°·0 A at 17 gkm. on 14th May 1930.

The units used are, as in the memoir on Agra results, millibars, degrees Centigrade+273, and dynamic kilometres (gkm.). When there were ascents both at Poona and at Hyderabad in a month, they have all been used in preparing the means for the month.

2. Temperature.

Table 3 shows the monthly and annual mean temperatures (see also *Fig. 1*). The number of observations and the standard deviations of temperature in each month and at each level are given in *Table 4*. The values of temperature are given for each half-km. step up to 3 gkm. and for each kilometre thereafter.

TABLE 3.—MEAN MONTHLY AND ANNUAL TEMPERATURES (°A).

Height (gkm.).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean.	Range.
25	..	14·5	..	..	..	..	..	17·0	..	..	22·0	12·5	216·5	9·5
24	..	14·0	18·0	..	..	..	..	15·5	..	..	19·0	11·0	215·5	8·0
23	..	14·5	14·0	..	..	..	..	14·5	..	..	18·0	13·5	215·0	4·5
22	..	11·5	10·0	..	..	..	..	13·5	..	..	10·0	14·5	212·0	4·5
21	17·5	07·0	06·0	..	..	..	..	11·5	10·0	08·0	02·0	14·0	209·5	15·5
20	14·0	07·0	04·0	..	04·5	..	04·5	09·0	03·0	04·5	98·5	09·5	206·0	15·5
19	04·5	01·0	98·0	94·0	99·0	..	00·0	03·0	01·0	06·0	96·0	05·0	200·5	12·0
18	00·5	99·0	95·5	93·5	94·0	93·0	96·0	02·0	96·5	00·5	95·5	00·5	197·0	9·0
17	94·5	99·0	92·0	94·5	90·5	92·5	94·5	96·5	95·0	94·5	92·0	95·5	194·5	8·5
16	94·5	00·5	95·0	94·5	91·0	94·0	93·5	96·0	94·0	93·5	92·5	94·5	194·5	9·5
15	97·5	04·5	99·0	98·5	96·0	99·0	98·0	00·0	98·0	97·5	97·0	99·0	198·5	8·5
14	01·0	09·0	05·0	04·5	04·0	06·0	06·0	07·5	06·0	05·0	04·0	05·0	205·5	8·0
13	09·0	16·0	12·0	09·0	14·0	15·5	14·5	16·0	14·5	13·0	12·5	12·0	213·0	7·0
12	18·0	23·0	20·0	18·5	22·0	24·0	23·6	23·5	23·0	21·5	21·0	20·0	221·5	6·0
11	26·0	30·0	27·0	26·5	30·0	32·0	31·5	32·0	31·5	30·0	29·5	28·0	229·5	6·0
10	35·0	37·5	35·0	35·0	38·0	39·5	40·0	39·5	39·5	38·5	38·0	35·5	237·5	5·0
9	42·5	44·5	43·0	43·5	46·0	48·0	47·5	47·0	47·5	46·0	46·0	43·0	245·5	5·5
8	49·5	51·0	50·5	50·0	53·5	55·0	55·0	55·0	54·5	53·5	53·5	51·0	252·5	5·5
7	56·5	58·0	58·5	57·5	60·5	61·5	61·5	61·0	61·5	59·5	60·0	59·0	259·5	5·5
6	63·0	63·5	64·5	63·5	67·0	67·5	66·5	67·0	67·0	66·0	66·0	64·5	265·5	4·5
5	69·5	69·0	70·5	69·5	72·0	73·5	72·5	73·0	72·5	72·0	72·0	71·0	271·5	4·0
4	76·0	75·5	74·5	76·0	78·0	79·5	78·0	77·0	78·0	78·0	77·5	76·5	277·0	5·0
3	80·5	82·0	81·5	84·0	85·5	86·0	83·5	82·5	83·5	82·5	83·0	80·5	283·0	5·5
2·5	82·5	85·5	86·5	89·0	89·0	89·0	86·0	85·0	86·5	85·5	84·5	82·5	286·0	6·5
2	86·5	90·0	91·5	93·5	93·5	91·5	89·0	89·0	89·0	88·0	87·0	86·0	289·5	7·5
1·5	91·0	94·5	96·0	98·0	97·0	96·5	92·5	92·0	92·5	92·0	91·5	90·0	293·5	7·0
1	96·0	99·0	99·5	03·0	02·0	00·5	95·5	95·0	96·5	96·0	95·0	94·0	297·5	8·5
SURFACE (0·54)	00·5	03·0	04·5	06·0	06·0	03·5	99·5	01·0	99·5	99·0	00·0	97·5	301·5	9·0

N.B.—The hundreds figure has been omitted except in the annual means.

TABLE 4.—STANDARD DEVIATIONS OF TEMPERATURES, WITH NUMBER OF OBSERVATIONS.

Height (gkm.).	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ	n	σ
20	2	1·0	8	7·6	2	1·2	..	..	3	1·8	..	..	1	0	5	1·9	2	3·5	1	0	2	2·5	5	4·4
19	6	6·4	11	8·3	3	2·6	2	1·1	3	2·4	..	..	1	0	6	4·7	3	4·1	3	4·5	3	5·2	6	4·7
18	6	4·7	14	7·1	4	2·1	3	2·2	5	2·9	2	1·8	2	0·8	8	6·6	3	5·5	8	6·7	4	4·6	9	4·0
17	8	5·0	15	5·8	5	4·0	3	0·7	5	4·6	3	2·2	4	2·9	9	5·9	9	3·9	15	5·0	4	2·9	9	3·1
16	10	4·6	15	5·3	7	4·3	4	5·0	5	5·3	4	1·5	7	3·0	9	4·4	16	4·0	16	3·4	7	2·8	9	4·2
15	10	4·4	15	4·1	7	4·6	5	6·8	6	4·7	4	1·8	9	3·3	10	5·0	16	4·5	17	3·1	7	2·9	10	4·3
14	11	5·1	15	3·0	7	3·6	5	5·1	6	3·0	4	2·0	9	3·1	10	4·8	18	3·8	17	4·2	8	2·8	11	4·0
13	11	4·8	15	2·5	7	2·9	5	4·3	6	2·5	4	2·3	9	2·6	10	4·6	19	3·6	17	3·9	8	2·5	11	4·0
12	11	3·5	15	3·9	7	2·6	5	3·5	6	2·2	4	1·8	9	2·1	10	3·5	19	2·7	18	3·2	9	2·5	11	3·1
11	12	3·8	15	3·7	7	2·0	5	3·2	6	1·9	4	1·8	10	2·1	10	3·4	19	2·1	18	2·8	9	2·5	12	2·9
10	12	3·3	15	3·8	7	2·4	5	3·6	6	1·6	4	1·8	11	1·9	10	2·7	19	2·0	18	2·5	10	2·5	12	2·4
9	12	2·6	15	3·6	7	2·0	5	3·4	7	1·2	4	1·7	11	1·9	10	3·0	21	2·0	18	2·0	10	2·3	12	2·3
8	12	3·5	15	2·9	7	1·9	5	2·8	8	1·1	4	1·3	13	1·7	10	2·6	21	1·9	18	1·9	10	1·9	12	2·5
7	12	2·5	15	2·4	7	1·6	5	3·4	8	1·8	4	1·4	13	1·3	10	2·2	21	1·6	19	1·8	11	1·0	12	2·0
6	12	2·1	15	1·8	7	1·0	5	3·3	8	1·5	5	2·5	13	1·6	10	1·6	21	1·5	19	1·7	11	1·2	13	1·6
5	12	1·8	15	1·4	7	2·2	5	2·3	8	1·7	5	2·1	13	0·9	10	1·2	22	1·4	20	1·4	11	1·2	13	1·8
4	12	2·0	15	1·5	7	1·7	5	1·4	8	2·0	5	1·9	13	1·0	10	1·4	23	1·6	20	1·6	11	1·5	13	1·6
3	12	1·6	15	1·9	7	1·5	5	1·2	8	2·7	5	1·8	13	1·2	10	1·5	23	1·2	20	1·8	11	1·1	13	2·1
2	12	1·3	15	3·0	6	2·4	5	1·3	8	2·8	5	3·0	13	1·3	10	1·5	23	1·7	20	1·8	11	1·7	13	1·7
1	12	1·8	15	2·8	6	2·2	3	0·7	5	3·7	4	2·2	8	1·6	7	1·5	22	1·1	19	2·3	10	1·2	13	1·5

[*N.B.*—n = number of observations ; σ = standard deviation.]

Seasonal mean temperatures are given in *Table 5*. For the purpose of this Table, (and also for *Table 8*), the year has been divided into four seasons as follows :—

(*a*) *Cold season.*—November, December, January and February.

(*b*) *Hot season.*—March, April and May.

(*c*) *Monsoon season.*—June, July, August and September, and

(*d*) *Post-monsoon* (*transition*) *season.*—October.

This division is slightly different from the one adopted in the memoir on Agra results, but owing to climatological differences between Poona and Agra, the difference is unavoidable.

TABLE 5.—SEASONAL MEAN TEMPERATURES.

Height (gkm.).	Temperatures (°A).				Height (gkm.).	Temperatures (°A).			
	November, December, January and February.	March, April and May.	June, July, August and September.	October.		November, December, January and February.	March, April and May.	June, July, August and September.	October.
20	207·5	204·5	205·5	204·5	10	36·5	36·0	39·5	38·5
19	02·2	197·0	01·5	06·0	9	44·0	44·0	47·5	46·0
18	199·0	94·0	197·0	00·5	8	51·5	50·5	55·0	53·5
17	95·5	92·5	94·5	194·5	7	58·5	59·0	61·5	59·5
16	95·5	93·5	94·5	93·5	6	64·0	65·0	67·0	66·0
					5	70·5	70·5	73·0	72·0
					4	76·5	76·0	78·5	78·0
					3	81·5	84·0	84·0	82·5
15	99·5	98·0	98·5	97·5	2·5	84·0	88·0	86·5	85·5
14	205·0	204·5	206·5	205·0	2	87·5	93·0	89·5	88·0
13	12·5	11·5	15·0	13·0	1·5	91·5	97·0	93·5	92·0
12	20·5	20·0	23·5	21·5	1	96·0	301·5	97·0	96·0
11	28·5	28·0	31·5	30·0					
					Surface (0·54)	300·0	05·5	301·0	99·0

The lowest temperature at all levels up to 14 gkm. occurs in the winter months December and January. The high values of temperature between 12 and 18 gkm. in February should be considered abnormal. The highest temperatures near the surface and up to 2 gkm. occur in April to May and shift over to June between 3 and 6 gkm. The high temperatures from the surface to 3 gkm. during April to June are due mainly to ground heating by insolation. From June to July, with the setting in of the monsoon there is a sharp drop in temperature at all levels up to 4 gkm. and the lower temperature continues during the rest of the year with a feeble maximum in September-October. In the months May to September, there is a flat maximum of temperature between the levels 5 and 14 gkm. This is partly caused by the liberation of heat in the atmosphere due to thunderstorm rain in May and monsoon rain in the other months. As the observations between June and September refer to Hyderabad and as the upper winds above 5 or 6 gkm. are invariably from the east, the rainfall causing the heating must be that which occurs in the Bay of Bengal, Burma and Indo-China. The seasonal variation of temperature is a maximum at the surface and decreases with height to a minimum at 5 gkm. It remains comparatively small from 5 to 12 gkm. and increases again thereafter. The secondary maximum of seasonal variation shown by Agra temperatures at 10 gkm. does not appear here.

The remarkably small variability of temperature in all the months of the year (*Table 4*) gives an estimate of the significance of the means.

3. Lapse-rates.

In discussing lapse-rates near the ground, it has to be remembered that the data refer to evening hours, generally half to one hour before sun-set and do not all refer to the same place. During July, August and part of September, low and middle clouds are very common. *Table 6* shows the mean lapse-rates in each month of the year; and *Table 7* the seasonal mean lapse-rates (see also *Fig. 2*). Seasonal frequencies of lapse-rates are given in *Table 8*. It will be seen that the most frequent values of lapse-rate occurring in any season are more or less the same as the mean lapse-rates for the season. The day to day variation of lapse-rates is largest in winter and smallest in the monsoon.

TABLE 6.—MEAN MONTHLY LAPSE-RATES (IN °C PER DYNAMIC KILOMETRE).

Layer (gkm.).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean.
20—19	—3·3	—5·1	—7·3	..	—5·6	..	—4·5	—4·1	—3·8	—4·6	—6·0	—5·3	—5·0
19—18	—4·2	—1·3	—2·3	—1·5	—5·2	..	—5·0	—3·4	—4·3	—5·0	—2·6	—5·1	—3·6
18—17	—4·3	0·1	—1·5	1·5	—3·6	—1·6	—1·3	—6·3	—3·7	—5·2	—3·3	—4·3	—2·8
17—16	0·2	1·4	3·5	2·4	0·7	1·8	0·0	—0·4	0·0	—0·7	0·1	—1·0	0·7
16—15	3·2	3·7	4·1	3·8	5·5	5·2	4·7	4·7	3·9	4·4	4·7	5·1	4·4
15—14	3·5	4·8	6·1	6·2	8·4	7·1	7·9	7·8	8·2	7·1	7·1	6·0	6·7
14—13	8·0	7·1	6·9	5·4	9·7	9·3	8·8	8·5	8·9	8·5	8·3	7·1	8·0
13—12	9·1	7·0	7·7	8·5	8·2	8·7	8·6	7·8	8·6	8·6	8·7	8·0	8·3
12—11	8·9	7·3	7·4	8·2	7·6	8·0	8·6	8·0	8·7	8·5	8·5	8·4	8·2
11—10	9·0	7·4	8·0	8·5	8·1	7·5	8·7	7·4	8·2	8·1	8·4	7·7	8·1
10—9	7·7	6·9	7·9	8·4	8·3	8·5	7·6	8·1	7·7	7·6	7·9	7·2	7·8
9—8	7·1	6·8	7·4	6·7	7·1	6·7	7·1	7·8	7·0	7·5	7·5	7·9	7·2
8—7	6·6	6·6	7·9	6·4	7·0	6·5	6·5	6·2	6·8	6·5	6·3	8·0	6·8
7—6	6·6	5·5	6·1	5·8	6·7	5·1	5·0	6·0	5·8	6·3	6·0	5·9	5·9
6—5	6·9	5·7	6·3	6·2	4·8	5·8	6·1	5·9	5·5	6·0	6·1	6·3	5·9
5—4	6·1	6·2	3·7	6·5	6·0	6·3	5·6	4·7	5·6	5·8	5·6	5·5	5·6
4—3	4·9	6·6	7·3	8·1	7·8	6·3	5·3	4·5	5·3	4·9	4·9	3·8	5·8
3—2·5	3·8	7·5	8·3	9·6	8·0	5·9	5·2	5·5	5·6	5·5	3·1	4·6	6·1
2·5—2	8·0	8·6	10·2	9·0	8·2	5·6	5·5	6·9	5·8	5·5	5·9	7·0	7·2
2—1·5	8·9	9·0	8·7	8·1	7·0	7·9	5·9	7·0	7·0	6·9	7·9	7·7	7·9
1·5—1	9·2	9·6	7·4	8·8	8·8	8·4	6·7	8·1	7·1	7·7	7·6	8·3	8·1

Table 7.—Seasonal Mean Lapse-rates.

Layer (gkm.).	Lapse-rates (°C/gkm.). November, December, January and February.	March, April and May.	June, July, August and September.	October.	Layer (gkm.).	Lapse-rates (°C/gkm.). November, December, January and February.	March, April and May.	June, July, August and September.	October.
20—19	—4·9	—6·5	—4·1	—4·6	**10—9**	7·4	8·2	8·0	7·6
19—18	—3·3	—3·0	—4·2	—5·0	9—8	7·3	7·1	7·1	7·5
18—17	—2·9	—1·2	—3·2	— 5·2	8—7	6·9	7·1	6·5	6·5
17—16	0·2	2·2	0·3	—0·7	7—6	6·0	6·2	5·5	6·3
16—15	4·2	4·5	4·6	4·4	6—5	6·3	5·8	5·8	6·0
					5—4	5·9	5·7	5·5	5·8
15—14	5·3	6·9	7·7	7·1	4—3	5·1	7·7	5·3	4·9
14—13	7·6	7·3	8·9	8·5	3—2·5	4·7	8·6	5·5	5·5
13—12	8·2	8·1	8·4	8·6	2·5—2	7·4	9·1	5·9	5·5
12—11	8·3	7·7	8·3	8·5	2—1·5	8·4	7·9	6·9	6·9
11—10	8·1	8·2	7·9	8·1	1·5—1	8·7	8·3	7·6	7·7

Table 8.—Seasonal Frequencies of Lapse-rates.

Layer (gkm.).	Range of Lapse-rates. <—3·9	—3·9 to —2·0	—1·9 to 0	0·1 to 2·0	2·1 to 4·0	4·1 to 6·0	6·1 to 8·0	8·1 to 10·0	>10·0	Total No. of Obsns.
(a) November, December, January and February.										
19—20	9	7								16
18—19	10	5	5	3	1					24
17—18	12	6	5	5	1	1	1			31
16—17	6	2	10	5	7	7				37
15—16			2	3	19	12	3	3		42
14—15			1	4	9	13	10	6		43
13—14					4	10	15	11	6	46
12—13				1	1	5	12	23	4	46
11—12					1	1	21	22	1	46
10—11						3	18	27	1	49
9—10				1	2	4	26	17		50
8—9					1	9	24	16		50
7—8				1	2	10	24	13		50
6—7				1	3	21	23	3		51
5—6					2	24	20	6		52
4—5					2	27	22	1		52
3—4				3	10	25	11	3		52
2·5—3	1		3	6	7	16	10	9		52
2—2·5			1		3	11	15	18	4	52
1·5—2						3	19	25	4	51
1—1·5					2	2	16	18	11	49

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TABLE 8.—SEASONAL FREQUENCIES OF LAPSE-RATES—*contd.*

Layer (gkm.).	Range of Lapse-rates.									Total No. of Obsns.
	<—3·9	—3·9 to —2·0	—1·9 to 0	0·1 to 2·0	2·1 to 4·0	4·1 to 6·0	6·1 to 8·0	8·1 to 10·0	>10·0	
					(b) March, April and May.					
19—20	4	1								5
18—19	2	4	2							8
17—18	3	1	5	2	1					12
16—17		1	1	3	6	2				13
15—16			1	1	3	9	1	1		16
14—15					1	7	5	3	2	18
13—14					2	4	4	4	4	18
12—13							10	7	1	18
11—12						1	11	6		18
10—11						1	9	6	2	18
9—10							10	6	2	18
8—9						5	9	5		19
7—8						3	11	6		20
6—7						7	13			20
5—6				1	3	8	6	2		20
4—5				2	4	6	6	2		20
3—4						4	7	9		20
2·5—3				1		1	4	13	1	20
2—2·5							6	9	4	19
1·5—2					1	3	5	6	2	17
1—1·5						2	3	6	1	12
					(c) June, July, August and September.					
19—20	4	4								8
18—19	4	4	1	1						10
17—18	11	1	1	2						15
16—17	3	5	6	4	6	1				25
15—16		1	2	3	9	12	5	3	1	36
14—15					1	6	15	14	3	39
13—14						1	12	21	7	41
12—13							16	23	2	41
11—12							16	23	2	41
10—11						1	21	20		42
9—10						1	25	16	1	43
8—9						3	36	6		45
7—8						11	32	3		46
6—7				1	3	29	14			47
5—6					2	28	17	1		48
4—5					6	26	16	1		49
3—4					10	26	13	1		50
2·5—3		1			9	25	13	2	1	51
2—2·5			1	6	1	18	19	4	1	50
1·5—2			1		3	14	18	9	3	48
1—1·5					5	7	13	11	3	39
					(d) October.					
19—20	1									1
18—19	2	1								3
17—18	5	2			1					8
16—17	5	2		4	3	1				15
15—16		1	3		1	5	3	3		16
14—15				1	1	1	7	7		17
13—14							4	12	1	17
12—13							4	12	1	17
11—12							5	13		18
10—11							9	9		18
9—10						1	15	2		18
8—9						3	11	4		18
7—8						5	12	1		18
6—7						9	10			19
5—6					1	9	9			19
4—5					1	11	8			20
3—4			1	1	3	9	6			20
2·5—3	1				2	10	4	3		20
2—2·5	1			2	1	8	5	2	1	20
1·5—2					2	3	10	5		20
1—1·5					2	2	6	5	4	19

In November, December and January, the lapse-rate is high up to 2·5 gkm. and this is followed by a region of small lapse-rates which in individual cases extends to 4 gkm. Analysis of the sources of air supply in this season shows that, while the air both above and below this region has ultimately its origin in the westerly zonal circulation of north-west India, the air below 2 km. over Poona has had a longer travel over land, skirting over the seasonal high pressure area which lies over Central India and the Central Provinces, and thus has had the opportunity of becoming surface-heated by day. In this connection, it has to be remembered that ground heating by day and ground cooling by night cannot produce exactly contrary effects. Ground cooling promotes stratification and is confined to the layer near the surface not exceeding half a kilometre in thickness while ground heating increases the lapse-rate and promotes mixing up of the layers. In the hot season months, March and April, the region of high lapse-rates extends upwards. In May also high lapse-rates generally extend to 4 gkm., but, owing to the effect of occasional thunder-storm rains, the lapse-rates tend to get smaller. In Agra during April and May high lapse-rates extend to 4—5 gkm. Instances of super-adiabatic lapse-rates in the lower layers (up to 2·5 gkm.) occur in all the seasons, but are rare in the monsoon.

In *Table 9* are given the frequencies of lapse-rates above 15 gkm. irrespective of season. The results of 39 ascents in 1932 have also been added in preparing this table.

TABLE 9.—FREQUENCIES OF LAPSE-RATES IRRESPECTIVE OF SEASON ABOVE 15 GKM.

Layer (gkm.).	<—9·9	—9·9 to —8·0	—7·9 to —6·0	—5·9 to —4·0	—3·9 to —2·0	—1·9 to 0	0·1 to 2·0	2·1 to 4·0	4·1 to 6·0	6·1 to 8·0	8·1 to 10·0	>10·0
28—29						1						
27—28						2						
26—27						2						
25—26						2						
24—25					1	4						
23—24				1	2	3						
22—23			2	2	1	3		1				
21—22		2	1	2	1	4						
20—21		1	2	5	11	3						
19—20	3		8	13	17							
18—19	1		10	20	20	11	4	1				
17—18	2	6	9	19	15	18	11	4	4	1		
16—17			2	16	12	21	19	31	15			
15—16				1	2	9	9	39	50	19	12	1

In all seasons, the region 10—14 gkm. is characterised by high lapse-rates. Over Agra high lapse-rates at these levels generally occur in the months May to October. The existence of a layer of high lapse-rates in the upper part of the troposphere has been explained [2, 3] as being due to a rapid change with height of the net loss of energy by radiation from the water-vapour present in those layers. Lapse-rates slightly more than the dry adiabatic and extending over a thickness of 1—2 gkm. are not uncommon at these levels; they are not confined to any particular season.

4. The Tropopause.

There is invariably a permanent inversion over Poona or Hyderabad which usually lies between 16 and 18 gkm. and which may be considered to be the " tropopause ". Its

C 2

mean height is 16·6 gkm. and mean temperature 192°·5A. Above the tropopause, as in other places in the tropics, the temperature increases with height and reaches a value of about 217°A at 24 gkm. The rate of increase is largest immediately above the tropopause and gradually decreases with height. We cannot form any definite conclusion regarding the seasonal variation of temperature in the stratosphere, except that it is small.

In the department's annual publication of Indian sounding balloon data and in the discussion of Agra soundings, the nature of the transition from the troposphere to stratosphere is classified into four types,—types I, II and III of which are defined according to the same conventions as those in use in the London Meteorological Office. Type IV is a composite type in which the transition from troposphere to stratosphere takes place in two stages. A further examination of the data shows that with a slightly extended meaning, the composite type of transition is much more common than it was originally considered to be. At Agra, in the composite type of transition which takes place in two stages and occurs fairly frequently in the months November to April with the lower transition at 12—13 gkm. and the upper at 16—18 gkm., the lower transition is usually a sharp decrease of lapse-rate sometimes getting to isothermal above the transition and extending over a thickness of 2—5 gkm. while the upper transition is invariably an inversion but just below the upper inversion there is, in many cases, a region of decreasing temperatures with height, of about 2 gkm. in thickness, where the lapse rate is of the order of 3 to 6 °C/gkm. This type of structure can be explained as being due to a meridional movement of air in the neighbourhood of the tropopause, the upper transition corresponding to the tropopause of tropical latitudes and the lower one to that of temperate latitudes [4, 5]. In Poona also, tropopauses of this type are fairly frequent but the lower transition is less conspicuous and at a higher level than at Agra. Owing to the interposition of a layer of falling temperature with height, this type of transition would not be classified as one of type IV, but the physical nature is essentially the same. A full consideration of the question would involve the discussion of the variation of temperature with height at a few other stations also and is reserved for a separate paper. A summary of the analysis of Poona and Hyderabad data may, however, be included here.

Of 86 cases examined, 20 were of the non-composite type in which the stratosphere starts abruptly with an inversion and 66 of the composite type. In 40 of the latter there was no region of positive lapse-rate greater than 2°C/km. between the lower and upper transitions and in the remaining 26 such a region was present. To prevent confusion with the previous classification, we shall call these types *A*, *B* and *C*. The mean heights of tropopause of type *A* is 16·1 gkm.; the mean upper height for types *B* and *C* 16·9 gkm. and the mean lower heights 14·7 and 14·4 respectively. The mean temperature of the tropopause is 192°·5 if we take the temperatures of *A* and those of the upper heights of *B* and *C*. If on the other hand, we take the temperatures of *A* and of the lower heights of *B* and *C*, the mean temperature is 198°. The corresponding mean heights are 16·6 and 14·9 gkm. In type *C*, the mean thickness of the region of positive lapse-rate is 1·3 gkm. and the mean lapse-rate 5°C/gkm. Representative height temperature curves of the three types are shown in *Fig. 3*.

Dividing the year into two parts, November to April and May to October, the relative distribution of the three types and the frequencies of different values of the lower and upper heights for all composite transitions are given in *Table 10*.

TABLE 10.—TYPES OF TROPOPAUSE AND FREQUENCIES OF LOWER AND UPPER HEIGHTS FOR COMPOSITE TRANSITIONS.

	No. of records with transition of type:			Frequencies of heights of											
				Lower transition.						Upper transition.					
	A	B	C	11·1 to 12.	12·1 to 13.	13·1 to 14.	14·1 to 15.	15·1 to 16.	16·1 to 17.	14·1 to 15.	15·1 to 16.	16·1 to 17.	17·1 to 18.	18·1 to 19.	19·1 to 20.
November—April.	6	22	21	1	4	12	16	10	..	..	10	14	15	2	2
May—October	14	18	5	..	..	4	5	12	2	1	2	13	6	1	..

5. Temperature-differences between Poona, Agra and Batavia.

Although the general nature of the variations of temperature with latitude at different heights is known, it is worth while examining in some detail the annual variation of the differences of temperature between Agra, Poona and Batavia as it brings out clearly the great influence of moisture and of radiation in continental and oceanic areas in altering the temperature of the atmosphere in the tropics. Differences of temperature between Poona (or Hyderabad) and Agra (*P-A*) and between Poona and Batavia (*P-B*) are given in *Table 11* (see also *Fig. 4*).

In the months November to April, Poona is warmer than Agra up to 11—13 gkm. and cooler above. The contrast of temperature is largest near the surface and at another height which lies in the neighbourhood of 8 gkm. There is an intermediate level which varies from 2 to 5 gkm. at which the temperature contrast is a minimum. This minimum appears to be due to a comparatively low temperature at Poona rather than to a high temperature at Agra and connected with the existence of a high pressure area over the Deccan, which causes the transport of air from north-west India after a clockwise circulation.

When we consider the difference of temperature between Poona and Batavia in the same months we see that, while in the lowest layer Poona temperatures are higher, they are in defect from 5 to 12 gkm. The former result is due to the difference in the times of ascent at Poona and Batavia and to the continentality of the climate of the Deccan during the larger part of the year. The height to which the higher temperatures near the surface extends at Poona is 3 gkm. in March and 4 gkm. in April; the defect of temperature at higher levels increases with the progress of the season from November to April. Near the top of the troposphere, Poona again gets to be higher in temperature. The level of least horizontal contrast of temperature lies in the neighbourhood of 12 gkm.

It will be noticed that near Poona in April, while a transport of air from either the north or south would cause a fall of temperature near the surface, the arrival of air from the north would be associated with lower temperatures at higher levels also, but air from

TABLE 11.—MEAN MONTHLY TEMPERATURE DIFFERENCES.

Poona (or Hyderabad) and Agra (*P-A*).

Height in gkm.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	1	—9	6	..	—5	..	..	..	..	..	—10	..
19	—3	—12	—4	—12	—4	..	..	..	..	1	—9	—2
18	—3	—9	—7	—11	—3	—9	..	1	—3	3	—9	—1
17	—8	—6	—8	—8	—8	—5	..	2	1	3	—11	—4
16	—9	—4	—8	—7	—11	—4	..	1	—2	—1	—9	—8
15	—6	—1	—6	—8	—11	—5	..	—3	—5	—4	—7	—8
14	—6	—1	—5	—6	—8	—4	—4	—3	—3	—3	—2	—5
13	—3	1	—5	—5	—4	—3	—5	—4	—4	—3	1	1
12	0	0	—4	—1	—2	—2	—7	—6	—4	—2	2	4
11	4	2	—1	1	—1	—3	—7	—6	—5	—1	3	7
10	8	4	1	3	—1	—3	—7	—7	—4	—1	4	8
9	6	8	2	5	1	—3	—6	—6	—4	0	5	7
8	6	8	4	4	1	—3	—5	—6	—5	1	7	6
7	6	7	5	4	2	—2	—4	—5	—3	0	7	7
6	6	7	4	3	3	—1	—6	—4	—3	1	7	6
5	6	6	4	3	1	—1	—5	—4	—1	1	7	5
4	6	6	1	3	—1	0	—4	—4	—1	1	7	3
3	5	9	2	3	—1	—1	—3	—4	—1	1	6	1
2·5	5	9	3	4	—3	—3	—3	—4	—1	0	5	1
2	6	9	5	3	—3	—4	—3	—3	—2	—1	5	2
1·5	8	10	5	4	—4	—3	—2	—2	—2	—2	7	5
1	9	11	5	5	—3	—4	—1	—3	—1	—2	7	6

Poona (or Hyderabad) and Batavia (*P-B*).

Height in gkm.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	..	..	..	..	..	..	..	..	..	..	..	..
19	..	..	..	..	..	..	..	..	..	..	..	..
18	..	..	..	..	..	..	8	..	..	..	7	..
17	7	12	5	7	..	5	6	7	5	—2	—3	11
16	2	10	4	5	4	1	1	3	—1	—4	—6	8
15	0	8	1	3	2	2	3	4	—1	—4	—9	8
14	—3	7	—1	1	2	4	6	7	2	—3	—5	7
13	—2	6	—2	—3	2	5	5	9	4	—2	—2	5
12	—1	4	—2	—3	—1	5	6	8	5	—1	—2	2
11	—1	1	—3	—4	—3	5	7	8	4	—1	—2	1
10	—1	0	—3	—4	—4	3	7	7	4	—1	—2	1
9	—1	—1	—3	—3	—4	3	6	5	3	—1	—2	0
8	—1	—1	—3	—4	—4	3	5	4	2	0	—1	0
7	—2	—1	—1	—3	—3	2	5	3	2	0	—1	1
6	—2	—2	—1	—3	—1	2	3	3	3	0	—1	1
5	0	—2	0	—2	—1	2	3	3	3	1	0	1
4	0	—1	—2	—1	—1	3	3	1	2	1	0	1
3	—1	0	0	2	2	3	2	1	2	0	0	—1
2·5	—2	1	1	4	2	3	2	1	2	—1	—1	—2
2	—1	2	4	5	4	3	1	2	2	0	—1	—1
1·5	1	3	5	7	6	6	2	2	3	1	0	0
1	3	6	6	10	7	7	3	2	4	2	1	1

the south would bring higher temperature above. This feature becomes slightly altered in May when with increasing insolation over land Agra temperatures up to 5 gkm. get higher than those of Poona while Batavia temperatures remain lower and the differences get reversed at higher levels. The bearing of this on the structure of ' fronts ' formed in the Bay of Bengal during the pre-monsoon period has been discussed elsewhere[6, 7].

The months June to September form a class by themselves, Agra being warmer and Batavia colder than Hyderabad practically at all levels in the troposphere. These are the months, especially the last three, in which the monsoon depressions have an east to west travel across the north of the Peninsula. In June the mean temperature differences at 1 and 2 gkm. are similar to those in May, but from 3—5 gkm. the contrast of temperatures between Agra and Hyderabad is very small.* The extraordinarily small difference of temperature in October between the three places and the fact that *both* Agra and Batavia are colder than Hyderabad between 3 and 7 gkm. and warmer from 11 to 16 or 17 gkm. is noteworthy. This shows that in this month the thermal equator which lay over North India in August lies over the middle of the Indian Peninsula.

6. Some simultaneous ascents at Poona, Hyderabad and Agra.

It will be useful to collect here a few representative height temperature and height humidity diagrams for both Poona (or Hyderabad) and Agra on days when there were practically simultaneous ascents at both the places, together with notes on the general weather conditions prevailing on those days. Upper wind observations are also given whenever they are available. (See *Fig. 5.*)

18-1-30.

Agra was colder than Poona at all levels up to 13·7 gkm., with the maximum temperature difference, about 16°C, near the ground up to 1·5 gkm., the difference at other levels being about 5 to 11°C. Agra was slightly warmer than Poona between 13·7 and 16·4 gkm.

The conditions are representative of clear, anticyclonic weather in winter. Both Agra and Poona had got flooded with northwesterly or westerly air during the previous two or three days. On the morning of the 18th, the centre of the anticyclone was over Rajputana at 0·5 km.; its position shifted southward with increase of height and at 3 km. there was a belt of high pressure at a latitude of about 15°N. The beginnings of the inversion at 1·4 gkm. at Agra and at 2·8 gkm. at Poona apparently mark the limit between the subsiding air above and the turbulent surface-heated air below. It will be seen from the diagram that the upper wind velocity at Poona increased rapidly from 5 m/s at 2·5 gkm. to 13 m/s at 3 gkm. and that at Agra it increased from 5 m/s at 1 gkm. to 9 m/s at 1·5 gkm. The air below the inversion was of slightly more northerly origin than air above. This is true of Poona also although the actual winds at 1·5 and 2 gkm. at Poona were from the south-west.

Attention may be drawn to the composite type of tropopause at Agra with inversions at 12·4 gkm. and 16·5 gkm. The tropopause at Poona also was composite although it was much less marked and the levels of the two transitions were only 1·4 gkm. apart.

The humidity curve also is characteristic of anticyclonic weather in the winter.

* The abnormally small difference of temperature between Hyderabad and Agra at 1 gkm. in July is apparently due to an abnormality in the Agra temperature.

17-7-31.

This was an occasion when the monsoon was giving widespread rainfall throughout the country except in Sind, Baluchistan and parts of Rajputana and the Punjab and in parts of the Madras Presidency. Agra had 0·4″ and Hyderabad 0·2″ of rainfall between 8 hrs. on the 17th and 8 hrs. on the 18th. On this day, data of soundings are available for Allahabad also in addition to those for Agra and Hyderabad. The temperature distributions at Agra and Allahabad are nearly identical, with the exception that there is a layer of feeble lapse-rate over Agra between 2·5 and 3 gkm. This inversion may be due to the interposition of comparatively dry north-west Indian air at Agra. It will be seen that there is also a sharp minimum of humidity at about 3 gkm. at Agra which is much less evident in the Allahabad curve. Both at Agra and Allahabad, the temperatures are higher than at Hyderabad by 3° to 8°, the largest differences being between 4 and 9 gkm. There is also an isothermal layer of about 0·7 gkm. thickness between 9 and 10 gkm. at Hyderabad, which probably marks the transition from the monsoon circulation to the easterly general circulation. In this connection, the sounding of 26th August 1929 which also shows the same feature may be compared. A height of 9 gkm. is, however, unusually large for the thickness of the monsoon.

26-8-29.

The temperature differences on this evening differ markedly from those on 17th July 1931. Agra was colder than Hyderabad from the surface to 2·2 gkm. and between 10 and 16 gkm. Between 2·2 and 10 gkm., the conditions were reversed.

On the morning of this day, a depression which was moving north-west from near the head of the Bay of Bengal was located at about 26°N and 77°E between Kotah and Jhansi. It had caused heavy rainfall to its south and south-west. From the few upper wind and cloud observations that are available, it appears that the air blowing over Agra on the evening of this day was coming from the Arabian Sea and had passed through the region of heavy rainfall to the south of the depression. The Peninsular portion of India had little rain recorded either on the morning of the 26th or the 27th, except a few falls west of the Ghats. The cloudiness there was also moderate and generally high or medium clouds were present. Owing to the scantiness of the observations, it is difficult to trace the trajectory of the air at either of the places to any considerable height. The low temperature of the air over Agra compared to Hyderabad at the surface and up to 2·5 gkm. is exceptional for the season and is no doubt an effect of the depression. Another unusual feature of the temperature distribution over Agra is the exceptionally low level of the tropopause (15·5 gkm.)—about 1 gkm. lower than that at Hyderabad. The weather and upper wind charts at 8 hrs. on the 26th are given in *Fig. 6*.

12-9-30.

On the morning of this day, a diffuse low pressure area characteristic of this month was extending from Gujarat to the north Madras coast. The centre of the low was near Kanker in the east Central Provinces. On the morning of the 13th, it had moved to between Khandwa and Pachmarhi in the west Central Provinces. Hyderabad recorded 0·4″ and 0·1″ of rainfall on the mornings of the 12th and 13th; while Agra recorded no rainfall on either of the days. The winds over Agra up to about 6 km. were coming from the east from the north Bay of Bengal, while at Hyderabad in the first 2 km. the wind was from the Arabian Sea. Agra temperatures were higher by 3° to 6° at all levels up to 20 gkm. the minimum difference—about 2°—being at 7 gkm. The westward movement of the depression stands in agreement with this distribution of temperature with higher temperatures to the north. At both places, there is a tendency for the humidity to fall off above 6 gkm.

Compared to the normal temperatures in this month, Agra temperatures are higher by about 2°C in the first 4 gkm. and Hyderabad temperatures lower by about the same amount up to 3 gkm. Agra's supply of air at these levels was on this day from rainy areas far out in the east instead of from the north as normally. The lower atmosphere of Hyderabad was cooled by rain in its immediate neighbourhood.

20-9-29.

The weather chart of this morning and of succeeding days showed very little gradient of pressure. On the evening of this day, rainfall accompanied by thunder occurred widespread over the extreme south of the Peninsula, in the north Bombay Deccan and in Gujarat. In north India, only Bihar, Kashmir and the Frontier Hills had scattered thundershowers.

Between 2 and 13 gkm. Agra temperatures are lower than those at Hyderabad. The monsoon conditions were gradually giving place to winter conditions in north-west India. As the wind-vectors show, the air over Hyderabad up to 8 km. was generally coming from the east or south, but the trajectory at 2 km. shows that air in the neighbourhood of this level might ultimately have been of northerly origin. The inversion at about 4·5 gkm. shown in the Agra sounding is a common feature of the upper air structure in this season and is associated with the sub-tropical high pressure ridge which is located over north-west India in this month.

15-10-31.

On this morning again, there was a depression lying over the east Central Provinces near Raipur. There had been widespread rainfall over the major portion of northern and Central India during the previous 24 hours.

On the morning of the 16th the depression had moved northward and was lying over the east United Provinces near Lucknow. Agra had skies overcast with clouds of the Stratus and Nimbus type and there was rain at intervals throughout the day.

The humidity diagram at Agra on the evening of the 15th shows that the air was practically saturated from 4·7 to 7 gkm. There is also a sharp decrease of lapse-rate at 4·7 gkm. From the upper wind charts it appears that easterly air from the north of the Bay was rising over rain-cooled air in the lower layers of the atmosphere.

At Hyderabad, there was no rain on the day in question and the winds were westerly up to about 3 km. At the time of ascent, the sky was partially clouded with alto-cumulus and alto-stratus. It is interesting to note that at Hyderabad the humidity decreased sharply at about 2·7 gkm. which also marked the beginning of a layer of smaller lapse-rate.

It may be noted that temperatures at Agra are lower than those at Hyderabad up to 6 gkm. and *vice versâ* at higher levels up to the stratosphere. The tropopause was lower at Hyderabad than over Agra.

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7. Pressure.

Table 12 gives the monthly mean values of pressure at different heights. Curves of annual variation are shown in *Fig. 7*. The annual variation of pressure at all levels over

TABLE 12.—MEAN MONTHLY AND ANNUAL PRESSURES (MB.).

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.	Range.
20	52	53	52	..	52	..	53	53	52	51	50	52	52	3
19	61	63	62	61	61	..	63	62	62	62	61	61	62	2
18	72	75	73	73	72	73	75	74	74	74	73	73	73	3
17	85	89	87	87	87	88	88	89	89	88	87	86	87	4
16	102	105	104	104	104	106	105	106	105	105	105	104	105	4
15	122	125	123	123	125	126	125	126	126	125	125	124	125	4
14	145	148	147	146	148	149	149	149	149	148	148	146	148	4
13	171	174	173	173	175	177	176	176	176	175	175	173	175	6
12	202	204	204	204	206	207	206	206	207	206	206	204	205	5
11	237	238	238	238	240	241	240	240	241	240	241	238	239	4
10	275	277	276	276	279	279	278	278	278	278	279	276	277	4
9	318	319	320	320	322	323	320	321	322	321	322	319	321	5
8	367	368	368	368	371	371	368	369	370	370	370	368	369	4
7	421	422	422	423	424	424	421	422	423	423	423	422	422	5
6	481	482	483	484	484	484	481	481	483	483	483	482	483	3
5	549	550	550	551	551	550	547	547	550	550	550	549	549	4
4	623	625	625	626	625	624	620	621	623	624	624	623	624	6
3	707	708	709	709	708	706	702	702	705	707	708	707	707	7
2·5	751	752	752	752	751	750	747	747	750	751	752	752	751	5
2	799	799	800	799	798	796	793	792	796	798	799	799	797	8
1·5	849	849	849	847	846	844	842	841	846	847	849	848	846	8
1	900	899	899	898	897	895	893	891	896	899	900	900	897	9
Surface (0·54)	950	948	948	946	944	943	943	942	946	948	949	950	946	8
NORMAL (at 8 A.M.) AT POONA.	955	954	952	951	949	945	945	947	949	952	954	955	951	10
NORMAL (at 8 A.M.) AT HYDERABAD.	957	955	954	951	949	947	946	948	950	953	956	957	952	11

the Deccan is considerably smaller than that over North India. From the surface to 2 gkm. there is a well-marked pressure-minimum at the time of the monsoon in August and a flat maximum in November-March. The occurrence of the minimum in August instead of in June or July is due to abnormally low pressures on the days of sounding balloon ascents. With increase of height, the monsoon pressure-minimum gets less and less marked and at 10 gkm. has given place to a flat maximum which prevails during the months May to November. The difference between the maximum and minimum values of monthly mean pressures is least at 6 gkm. but the value remains small at all higher levels.

8. Monthly mean pressure-differences between Poona and Agra and Poona and Batavia.

In the discussion of Agra sounding balloon results, the mean monthly pressures over Agra, Batavia and Europe were compared. It is now possible to split up the pressure-differences between Batavia and Agra into two parts: Batavia *minus* Poona and Poona *minus* Agra. The mean monthly diffrences of pressure at dynamic kilometres are contained in *Table 13* and are shown graphically in *Fig. 8*.

In the interpretation of the pressure-differences between Batavia and Poona (or Hyderabad) it has to be remembered that the two places lie on opposite sides of the equator. But as Batavia is only 6° south of the equator, while Poona is $18\frac{1}{2}°$ north, and as pressure gradients are generally weak in the neighbourhood of the equator it may generally be assumed that Batavia pressures represent pressures at the equator.

At 1 gkm., the pressure-difference $B—P$ is a maximum in August and minimum in winter. During the monsoon (July-August), the pressure-difference gradually decreases to zero at 8 gkm. and reverses sign higher up. The easterly upper winds increase in strength up to the tropopause where they seem to reach the maximum velocity. It is known from pilot balloon winds at Bangalore[8] and Hyderabad in July and August (see *Fig. 12*) that the westerly winds of the monsoon change to easterly at 5—7 km. On days when pilot balloon observations are not possible owing to the activity of the monsoon, the westerly winds may even extend higher. In the winter and hot season, there are negative pressure differences at 2 and 3 gkm. which account for the weak anti-cyclonic winds prevailing at these levels in these months in the middle and south of the Peninsula. In the first four months of the year, the mean gradient for westerly winds increases in strength above 4 gkm. and shows a maximum at 9—11 gkm. (Pressure values for May at Batavia are abnormally high.) The fact that the pressure-differences in the higher parts of the troposphere are larger in March-April than in November-December suggests that easterly upper winds are more common in the latter months than in the former. The positive differenes $B—P$ in October are not consistent with the available upper wind observations. At Bangalore, the upper winds begin to have an appreciable easterly component at about 5 km., at Hyderabad at 10 km. and at Poona at 12—13 km. The winds at lower levels are generally weak. The transitional character of the weather of the month and the smallness of the number of observations may be responsible for the disagreement.

In the first few kilometres of the stratosphere, the wind appears to be easterly in all parts of the year.

Considering the pressure-differences between Poona and Agra, the following points are noteworthy :—

(1) During the winter, the gradient is for westerly winds up to 20 gkm. It increases rapidly in strength with increasing height above surface, reaches a maximum at 8—10 gkm. and decreases again at higher levels. Owing to the decrease of density with height, the maximum wind velocity will be in the neighbourhood of 12 gkm.

(2) In March and April, besides a general decrease in the gradient at all levels, there is a comparative maximum at 2—3 gkm. This arises from the fact that there is a high pressure area at these levels over the Deccan.

(3) In May, the gradient becomes very small at 4 gkm. and a gradient for easterly winds sets in above 14 gkm.

(4) The gradient for easterly winds descends to 9 gkm. in June and to 4·5 gkm. in July, August and September. The maximum gradient for easterly winds during the monsoon occurs near 12 gkm. The exceptionally small difference of pressure in the first 4 gkm. in August is, as has already been said, due to the abnormally low pressures in Hyderabad on the days of the sounding balloon ascents.

(5) The pressure-difference is small at all levels in October, but the mean gradient is for easterly winds above 13 gkm. and for westerly winds below.

D 2

TABLE 13.—MEAN MONTHLY PRESSURE DIFFERENCES (MB.).

(a) Poona (or Hyderabad) and Agra (*P-A*).

Height (gkm.).	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	1	2	0	..	—1	..	..	..	..	..	—2	..
19	1	2	0	—2	—3	..	..	..	—1	—1	0	0
18	1	3	0	0	—3	—3	..	—2	—1	0	1	0
17	1	3	0	0	—2	—2	..	—2	—1	—1	2	—1
16	2	4	1	1	—2	—2	..	—2	—2	—1	4	2
15	4	5	0	1	0	—2	..	—3	—2	—1	5	3
14	5	6	2	2	—1	—2	—2	—3	—3	—2	5	3
13	5	7	2	3	0	—1	—4	—4	—3	0	6	6
12	7	8	3	4	1	—2	—5	—5	—2	0	7	7
11	9	9	4	5	1	—1	—4	—4	—3	1	9	7
10	10	12	5	5	2	—1	—5	—4	—3	1	9	7
9	7	9	5	5	0	0	—4	—4	—2	0	9	5
8	8	11	5	5	2	1	—3	—3	—2	1	9	5
7	6	10	5	5	1	1	—2	—2	—2	1	9	5
6	7	11	4	6	1	2	—1	—2	—1	1	8	3
5	6	10	4	5	1	1	—1	—2	0	1	7	2
4	6	11	4	5	0	3	1	0	1	1	6	2
3	5	8	5	6	1	3	2	0	1	1	6	2
2	5	8	4	4	2	5	4	0	2	0	4	2
1	1	3	1	3	2	5	4	0	2	0	1	—1

(b) Batavia and Poona (*B-P*).

Height (gkm.).	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	—4	—4	—2	..	—2	..	—4	—3	—2	0	1	—4
19	—2	—4	—2	—1	0	..	—4	—2	—1	0	0	—3
18	—1	—4	—1	—1	1	—1	—4	—2	—1	0	0	—3
17	1	—3	0	0	1	—2	—3	—4	—2	0	1	—2
16	1	—1	1	0	2	—3	—3	—4	—1	1	1	—2
15	1	—1	2	2	1	—3	—3	—4	—2	1	1	—2
14	2	0	2	3	2	—2	—3	—4	—2	2	2	—1
13	3	1	3	3	3	—2	—3	—3	—2	2	2	0
12	2	2	2	3	3	—2	—3	—3	—3	0	2	0
11	2	2	3	3	4	—1	—3	—2	—2	1	1	0
10	2	2	3	4	3	—1	—1	—1	0	2	2	1
9	3	3	2	3	3	—1	0	0	—1	1	2	1
8	2	2	2	2	1	—1	0	0	—1	0	1	0
7	2	2	2	1	1	0	1	1	0	1	1	0
6	2	2	1	0	2	0	2	2	0	2	2	1
5	2	2	1	0	2	2	3	4	1	2	2	1
4	1	0	0	—1	1	1	4	3	1	1	1	1
3	0	—1	—2	—2	0	1	5	5	2	0	—1	—1
2	—1	—1	—2	—1	0	2	5	6	2	0	—1	—1
1	0	1	1	2	3	5	7	9	5	2	0	0

9. Places of fall of sounding balloons.

The distances and directions of the places of fall of sounding balloons together with the maximum height reached by each ascent are given in *Table 14.* The places of fall for ascents from Poona and Hyderabad are also plotted in *Figs. 9 (a)* and *9 (b)*; the former

TABLE 14.—DISTANCES AND DIRECTIONS OF PLACES OF FALL OF SOUNDING BALLOONS, WITH GREATEST HEIGHTS REACHED BY THEM.

Serial No.	Date of ascent.	Distance (km.).	Direction (Degrees from N.).	Greatest height (gkm.).	Serial No.	Date of ascent.	Distance (km.).	Direction (Degrees from N).	Greatest height (gkm.).
				(a) Balloons sent up from Poona.					
1	28th Oct. 1928	33	60	18·7	33	2nd May 1930	5	95	18·6
2	10th Nov. 1928	83	85	14·1	34	8th May 1930	107	220	15·9
3	13th Nov. 1928	79	50	12·0	35	13th May 1930	27	210	18·0
4	15th Nov. 1928	61	55	10·3	36	14th May 1930	29	131	20·6
5	23rd Nov. 1928	170	100	16·3	37	15th May 1930	29	131	23·5
6	4th Dec. 1928	174	81	11·7	38	21st May 1930	66	57	18·7
7	28th Dec. 1928	114	90	18·6	39	30th Oct. 1930	68	349	12·2
8	15th Jan. 1929	104	155	11·6	40	5th Nov. 1930	94	83	21·1
9	2nd Feb. 1929	211	103	20·2	41	26th Nov. 1930	74	120	25·6
10	22nd Feb. 1929	111	135	25·9	42	29th Nov. 1930	66	57	18·5
11	7th Mar. 1929	3	90	19·5	43	5th Dec. 1930	106	30	15·5
12	7th April 1929	80	49	15·9	44	19th Dec. 1930	114	56	21·5
13	8th July 1929	81	262	11·8	45	9th Jan. 1931	283	177	17·9
14	10th Dec. 1929	88	80	18·1	46	12th Jan. 1931	176	79	19·3
15	19th Dec. 1929	109	55	23·5	47	7th Feb. 1931	332	80	19·2
16	21st Dec. 1929	117	87	18·9	48	12th Feb. 1931	274	124	20·8
17	30th Dec. 1929	117	87	18·9	49	13th Feb. 1931	274	124	19·1
18	7th Jan. 1930	117	87	21·2	50	17th Feb. 1931	332	80	20·2
19	10th Jan. 1930	139	89	20·0	51	18th Feb. 1931	258	74	18·7
20	14th Jan. 1930	228	87	16·8	52	22nd Feb. 1931	236	59	20·1
21	15th Jan. 1930	242	103	17·0	53	23rd Feb. 1931	258	74	18·7
22	16th Jan. 1930	122	89	19·5	54	24th Feb. 1931	293	72	19·3
23	17th Jan. 1930	138	95	16·8	55	25th Feb. 1931	343	77	18·9
24	18th Jan. 1930	138	95	20·2	56	11th Mar. 1931	236	99	18·8
25	31st Jan. 1930	207	75	14·5	57	16th Mar. 1931	161	44	16·7
26	3rd Feb. 1930	169	99	21·9	58	27th Mar. 1931	172	58	24·7
27	23rd Feb. 1930	228	99	17·4	59	17th April 1931	114	56	19·9
28	9th Mar. 1930	31	153	17·9	60	1st May 1931	93	83	20·3
29	12th Mar. 1930	65	57	16·4	61	1st Oct. 1931	129	270	17·6
30	8th April 1930	207	75	17·0	62	2nd Dec. 1931	290	117	14·5
31	18th April 1930	114	56	23·7	63	3rd Dec. 1931	161	120	28·1
32	20th April 1930	131	61	18·0	64	16th Dec. 1931	174	130	21·2
				(b) Balloons sent up from Hyderabad.					
1	16th Aug. 1929	170	265	18·5	20	4th Oct. 1930	13	292	17·4
2	17th Aug. 1929	232	271	15·7	21	7th Oct. 1930	93	272	19·1
3	26th Aug. 1929	57	258	17·8	22	11th Oct. 1930	93	272	19·6
4	4th Sept. 1929	136	265	16·5	23	14th Oct. 1930	1	135	15·7
5	14th Sept. 1929	287	263	16·1	24	9th July 1931	185	273	17·1
6	17th Oct. 1929	24	280	17·6	25	25th July 1931	112	271	15·7
7	6th June 1930	112	271	18·4	26	1st Aug. 1931	200	275	21·0
8	10th June 1930	267	284	17·1	27	8th Aug. 1931	112	271	19·8
9	18th June 1930	112	271	16·9	28	17th Aug. 1931	161	275	21·8
10	8th July 1930	101	255	20·4	29	22nd Aug. 1931	145	256	21·8
11	12th July 1930	70	244	16·9	30	6th Sept. 1931	578	278	17·0
12	19th July 1930	186	253	18·5	31	10th Sept. 1931	222	284	16·9
13	26th July 1930	77	251	17·0	32	13th Sept. 1931	414	275	17·6
14	17th Aug. 1930	112	271	20·5	33	18th Sept. 1931	339	273	16·8
15	19th Aug. 1930	112	271	25·9	34	29th Sept. 1931	563	255	17·4
16	6th Sept. 1930	112	271	17·6	35	13th Oct. 1931	176	251	17·1
17	12th Sept. 1930	156	251	20·4	36	15th Oct. 1931	112	271	18·3
18	24th Sept. 1930	36	280	17·5	37	18th Oct. 1931	56	315	18·9
19	29th Sept. 1930	70	244	14·9	38	24th Oct. 1931	19	43	21·0

are further sub-divided according to season. It will be seen that of the balloons sent up from Poona, those released in November to February fell invariably towards the east; the longest distances travelled being generally in February; those sent up in March to May also fell towards the east but on the average nearer than in the previous season.

All the balloons sent up from Hyderabad in June to October fell towards the west, those in October falling nearest the place of release. Of the balloons sent up from Poona or Hyderabad, the longest distance travelled was by one sent up from Hyderabad on 6th September 1931 which rose to 17 gkm. and fell 578 km. to the west. The shortest distance travelled was also by a balloon from Hyderabad on 14th October 1930 which fell within a mile of the observatory after reaching a height of about 16 gkm.

10. Density.

Mean monthly values of density are given in *Table 15*. The values have been corrected for humidity.

TABLE 15.—MEAN MONTHLY AND ANNUAL DENSITIES (GMS. PER CUBIC METRE).

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean.	Range.
20	84	89	88	..	88	..	90	89	89	87	88	86	88	6
19	103	109	108	109	106	..	109	106	107	104	107	103	106	6
18	126	131	130	131	130	131	133	128	127	129	130	127	129	7
17	152	156	157	155	158	158	157	158	158	157	157	153	156	6
16	181	183	185	185	188	189	188	187	188	188	189	185	186	8
15	214	214	215	216	222	220	220	219	221	220	221	217	220	8
14	252	247	250	249	253	252	252	250	251	252	253	248	251	6
13	285	281	284	288	285	286	285	284	285	286	287	284	285	7
12	323	319	323	325	324	322	323	322	324	325	325	323	323	6
11	362	360	364	365	363	361	361	360	362	363	365	363	362	5
10	408	405	409	409	409	406	403	404	403	406	408	408	407	6
9	456	455	459	458	456	453	450	452	454	454	456	458	455	9
8	511	509	511	511	509	506	502	504	506	508	508	510	508	9
7	570	571	570	572	567	565	561	562	562	569	567	568	567	11
6	637	638	636	641	630	629	628	626	629	633	633	635	633	12
5	709	710	706	710	703	697	697	695	699	703	703	704	703	15
4	787	789	792	787	781	773	772	777	776	779	781	783	781	20
3	875	871	875	863	858	855	857	861	861	867	869	875	867	20
2·5	922	913	912	901	901	898	904	906	907	911	917	922	909	24
2	969	957	954	941	939	944	949	949	953	959	965	968	954	30
1·5	1012	1001	997	985	983	983	995	995	999	1003	1009	1013	998	30
1	1054	1042	1041	1025	1025	1026	1043	1042	1042	1049	1045	1048	1040	29
Surface	1093	1083	1079	1068	1066	1072	1084	1079	1091	1093	1093	1104	1086	38

11. Humidity.

Mean monthly values of relative humidity up to 12 gkm. are given in *Table 16*. Although it is known that the indications of the hair hygrometer cannot be relied on at temperatures below about 255° A (heights above 8 gkm.) it is found from records that there are often significant changes occurring even above this level. The mean values above 8 gkm. may have a qualitative significance. The maximum humidity during the year occurs in August from the surface to 7 gkm. Between 8 and 12 gkm. the maximum occurs in July, but at these levels, the humidity is large and nearly the same in all the months June-September. The minimum occurs at all levels in January. A secondary maximum in February and a corresponding minimum in March are also noticeable. It is probable that like February temperatures, the February humidities are also abnormal.

TABLE 16.—MEAN MONTHLY RELATIVE HUMIDITIES.

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
12	5	29	17	44	37	53	66	56	60	25	18	16
11	11	28	18	45	36	53	70	59	62	24	17	17
10	13	28	18	45	39	56	75	59	63	26	30	20
9	13	29	18	45	44	66	79	60	69	26	29	21
8	12	27	18	51	47	69	75	72	70	31	27	21
7	11	27	17	55	48	70	74	84	64	36	29	22
6	11	30	16	61	53	66	72	89	66	41	40	25
5	12	33	28	61	65	71	80	86	74	51	41	27
4	14	37	36	77	71	74	77	92	85	65	39	37
3	26	49	32	72	65	78	78	93	80	73	46	47
2·5	35	46	29	58	64	77	78	92	76	73	65	59
2	37	40	25	49	62	76	86	88	80	74	72	63
1·5	36	36	22	43	59	67	82	87	79	74	67	63
1	37	33	22	39	54	63	79	83	76	68	60	55
Surface .	40	40	31	37	43	56	75	73	79	69	51	57

In all months (except January), humidity rises from the surface, reaches a maximum at a level varying from 1·5 to 4 gkm., and falls off more or less rapidly. The level of maximum is higher in April and May than in either the monsoon or winter months. In September, when the monsoon is weak and there are breaks in the rains, there are two maxima at 2 and 4 gkm., with an intervening minimum at 2·5 gkm. In the winter months, the fall of humidity above the maximum is most rapid, and the values above are quite small; whereas, in the monsoon, the fall is gradual and relative humidities are high upto 8 gkm. In about half the number of the winter ascents, the humidity is less than 15 per cent. above 3 or 4 gkm. The monthly means of vapour pressure and of mixing ratio are given in *Tables 17 and 18* respectively.

TABLE 17.—MEAN MONTHLY VALUES OF VAPOUR PRESSURE (MB.).

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
10	..	0·1	..	0·1	0·1	0·1	0·2	0·2	0·2	0·1	0·1	..
9	0·1	0·1	0·1	0·2	0·2	0·4	0·5	0·3	0·4	0·1	0·1	0·1
8	0·1	0·2	0·1	0·4	0·5	0·9	0·9	0·9	0·8	0·3	0·3	0·2
7	0·1	0·5	0·3	0·9	1·0	1·6	1·7	1·8	1·5	0·7	0·6	0·4
6	0·3	0·8	0·5	1·7	2·0	2·5	2·5	3·3	2·4	1·4	1·4	0·5
5	0·5	1·5	1·4	2·8	3·7	4·5	4·7	5·3	4·3	2·9	2·3	1·4
4	1·1	2·7	2·5	5·8	6·2	7·1	6·7	7·5	7·4	5·7	3·3	2·9
3	2·8	5·6	3·5	9·5	9·4	11·7	9·3	11·1	10·1	8·7	5·7	4·9
2·5	4·2	6·7	4·5	10·5	11·6	14·0	11·7	12·9	11·8	10·6	8·8	7·0
2	5·6	7·8	5·3	12·0	15·0	16·2	15·6	16·0	14·6	12·6	11·5	9·4
1·5	7·4	9·2	6·2	13·6	17·6	19·4	18·6	19·1	17·9	16·3	14·3	12·2
1	10·4	11·1	7·6	16·6	21·6	24·4	21·5	22·0	22·0	19·1	15·9	14·7
Surface .	14·7	17·0	14·3	18·6	21·6	24·5	26·0	27·7	27·4	23·2	18·1	17·5

TABLE 18.—MEAN MONTHLY VALUES OF MIXING RATIO (GMS. OF WATERVAPOUR PER KGM. OF DRY AIR).

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
10	..	0·2	..	0·2	0·2	0·2	0·4	0·4	0·4	0·2	0·2	..
9	0·2	0·2	0·2	0·4	0·4	0·8	1·0	0·6	0·8	0·2	0·2	0·2
8	0·2	0·3	0·2	0·7	0·8	1·5	1·5	1·5	1·4	0·5	0·5	0·3
7	0·1	0·7	0·4	1·3	1·5	2·4	2·5	2·7	2·2	1·0	0·9	0·6
6	0·4	1·0	0·6	2·2	2·6	3·2	3·2	4·3	3·1	1·8	1·8	0·6
5	0·6	1·7	1·6	3·2	4·2	5·1	5·3	6·0	4·9	3·3	2·6	1·6
4	1·1	2·7	2·5	5·8	6·2	7·1	6·7	7·5	7·4	5·7	3·3	2·9
3	2·5	4·9	3·1	8·5	8·4	10·5	8·3	10·0	9·0	7·8	5·0	4·4
2·5	3·5	5·6	3·7	8·8	9·8	11·8	9·9	11·0	9·9	8·9	7·4	5·9
2	4·4	6·4	4·2	9·5	12·0	13·0	12·4	12·8	11·6	10·0	9·1	7·4
1·5	5·5	6·8	4·6	10·1	13·3	14·7	14·1	14·4	13·4	12·2	10·6	9·1
1	7·3	7·8	5·3	11·7	15·4	17·4	15·4	15·8	15·7	13·5	11·2	10·3
Surface .	9·7	11·4	9·5	12·2	14·6	16·6	17·7	18·9	18·6	15·6	12·1	11·7

A few characteristic height-humidity curves with the corresponding height-temperature and upper wind diagrams are given in *Fig. 10.* Notes of weather conditions during the days are given below :—

7-4-29.

This was an occasion when a hot weather thunderstorm was in progress in the neighbourhood of Poona. At the time of ascent, there were CuN and mammato-cumulus clouds present and rain was just beginning to fall. On the morning of the 7th, a diffuse low pressure area was lying over the Konkan and the Bombay Deccan with a more extensive one over the east United Provinces and Bihar. The upper winds in the morning were south-south-easterly at 4 and 5 km. and ACu clouds were coming from the south. The balloon fell 80 km. to the north-east of Poona after reaching a height of 15·9 gkm. The rain measured at 8 hours on the 8th was 0·5″.

Note the dryness and high lapse-rate of the surface air and the high humidity of air above 2·7 gkm.

12-7-30.

The monsoon was weak in the Peninsula and there were only scattered light falls of rain there. At Hyderabad itself at the time of ascent, there were a few cumulus clouds which gradually cleared by 20 hours. Although there was high humidity at certain levels, the lapse-rates were small between 4 and 6·5 gkm.

29-7-29.

This is the record of an ascent made at Poona. The dry layer of air between 2 and 6 gkm. is exceptionally deep for the season. A depression which was lying over lower Sind on the morning of the 28th had moved off westwards on the 29th morning and become unimportant. The dry air had apparently come from the western side of the depression from Persia and Iraq. The increase of humidity above 6 gkm. indicates the beginning of easterly upper winds.

22-8-31.

On this day, a depression was lying over the Central Provinces and was causing heavy rain to its south-west. Winds at Hyderabad were westerly to south westerly up to at least the middle cloud level. The humidity pen was apparently displaced, but there is no doubt that the humidity was very high between 3 and 6·7 gkm.

13-9-31.

On the morning of this day, a diffuse low pressure area characteristic of the month was lying over the west Bay of Bengal off the north Madras Coast. Widespread thunder-showers occurred in the south of the Peninsula, Mysore and the Deccan on the 13th; Hyderabad recorded 0·3″ on the 14th morning. The sudden fall of humidity above 4·7 gkm. and the large moisture content of the lower layers are significant.

1-10-31.

On this day, there were ascents both at Poona and at Hyderabad. A practically stationary low pressure area was lying over north Hyderabad, causing widespread rain from the Konkan to the Central Provinces. The humidity curves at both the places were somewhat similar in that it was nearly saturated at the surface with a slow fall of humidity, up to 4·5 gkm. at Poona and 4·7 gkm. at Hyderabad and a more rapid fall above. This type of humidity distribution is rare and represents the condition of stable rain-cooled air.

11-10-30.

This represents conditions prior to setting in of the north-east monsoon. Surface pressure gradients were weak and rainfall was practically confined to the Peninsula south of latitude 20° mostly attended with thunder. North India had become overspread with continental air from the north-west. As the wind-vectors show, easterly air was bringing in moisture up to about 6 km.

12. Potential temperatures and tephigrams.

The following tables (*Tables 19* and *20*) give the monthly mean potential temperatures at different levels above Poona (or Hyderabad) and the mean differences of potential temperature between Poona and Agra (*P—A*) and between Poona and Batavia (*P—B*). The seasonal variation of potential temperature at Poona (or Hyderabad) is also represented diagrammatically in *Fig. 11*. In *Fig. 12* are drawn the mean monthly tephigrams and pressure-dew-point diagrams. For comparison, the tephigrams of Agra also are drawn. The full lines represent the tephigrams for Poona or Hyderabad and the broken lines those for Agra. The lines with alternate dashes and dots represent the dew-point-pressure diagrams for Poona or Hyderabad. Along a line inclined at 45° to the temperature axis, the N. and E. components of wind at Poona or Hyderabad have also been indicated in the form of " clothes-line " diagrams. These winds are based on all available pilot balloon results up to the end of 1931 and do not relate to the days of the sounding balloon ascents only. The diagrams form a convenient summary of information about upper air conditions. Most of the points that call for comment have been touched on in other connections. One interesting feature of the monsoon tephigrams may, however, be pointed out. The atmosphere over the Deccan in the region of the upper easterly winds is definitely more stable than in the corresponding region over Agra whose tephigram closely follows the saturation adiabatic. This feature and the large wind-velocities at 2 and 3 km. leading to a dynamical suction effect at higher levels are responsible for the comparative absence of thunderstorms in the Deccan during the time when the monsoon low lies over the Gangetic valley. A large rate of shear of wind above the layer of maximum humidity would make the cumulus clouds extend horizontally and prevent individual clouds growing upwards and producing the large differences of potential necessary for thunder.

TABLE 19.—MEAN MONTHLY AND ANNUAL POTENTIAL TEMPERATURES (°A, STANDARD PRESSURE BEING 1,000 MB.).

Height in gkm.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual.	Range.
20	499	479	477		477		475	465	475	480	467	488	478	34
19	57	45	39	431	43		41	51	44	57	36	50	45	21
18	25	19	13	09	11	407	14	25	14	23	13	23	16	18
17	397	399	389	393	385	388	392	394	392	391	389	397	392	14
16	76	85	76	75	67	71	70	75	72	72	70	74	74	18
15	63	72	64	63	57	60	61	64	61	61	60	64	63	15
14	51	63	57	57	57	58	58	59	57	56	55	57	57	12
13	48	58	52	49	53	56	55	57	55	53	52	52	53	10
12	46	53	48	46	50	54	53	53	52	50	50	49	50	8
11	43	48	45	43	47	51	50	50	49	48	47	45	47	8
10	41	45	41	41	44	47	48	47	47	45	45	42	44	7
9	38	40	38	39	42	44	44	43	44	42	42	38	41	6
8	34	35	35	34	38	40	41	40	39	38	39	35	37	7
7	29	31	32	30	34	35	36	35	35	33	34	32	33	7
6	25	25	26	25	29	30	29	30	30	31	29	27	28	6
5	21	20	21	20	23	25	25	25	24	23	24	22	23	5
4	16	15	14	16	18	20	19	19	19	18	19	17	17	6
3	10	11	11	14	15	16	14	13	13	12	13	09	13	7
2·5	07	10	10	14	14	13	11	10	11	10	09	·07	11	7
2	06	09	11	13	13	11	09	09	09	08	07	05	09	8
1·5	05	09	10	12	12	11	07	07	07	06	05	04	08	8
1	05	08	09	13	11	10	06	05	05	05	04	03	07	10
Surface	05	07	09	11	09	08	05	06	04	04	04	02	06	9

The tephigrams of the transition months May and October are also of particular interest as bringing out the essential difference of continental and maritime air in tropical regions. It will be seen that in both these months, while in the lower layers up to 3 or 4 gkm. the Agra tephigram lies above that of Poona, in the middle troposphere, their relative positions are interchanged. Above 8 to 10 gkm. the Agra tephigram again lies higher.

The supplementary *Tables 21—26*, in the Appendix, give :—

(*a*) the number of meteorographs sent up in each month from Poona and Hyderabad and the number recovered out of these,

(*b*) the mean monthly values of pressure, temperature and density at *geometric* kilometres, and

(*c*) the mean monthly values of heights and temperatures corresponding to principal pressure values.

The instrumental equipment required for the present work was almost entirely supplied by the Upper Air Observatory, Agra, and the sounding balloon work carried out from Poona and Hyderabad owes much of its success to the interest taken in it by Mr. G. Chatterjee, Meteorologist-in-charge of the Agra Observatory. The thanks of the Department are due to the Government of His Exalted Highness the Nizam of Hyderabad and to Mr. T. P. Bhaskar Sastri, Director of the Nizamiah Observatory, for permission and facilities for carrying on sounding balloon work from Hyderabad. Many other mem-

TABLE 20.—MEAN MONTHLY POTENTIAL TEMPERATURE DIFFERENCES.

(a) **Poona (or Hyderabad) and Agra (P-A).**

Height in gkm.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
17	—18	—18	—16	—18	—15	—7		5	2	6	—24	—7
16	—21	—12	—13	—14	—19	—5		6	—3	1	—20	—17
15	—14	—7	—12	—15	—20	—9		0	—6	—5	—15	—18
14	—14	—6	—10	—11	—12	—5	—3	—3	—5	—4	—6	—13
13	—9	—3	—9	—9	—7	—4	—6	—3	—4	—5	—2	—2
12	—3	—3	—8	—3	—3	—2	—8	—6	—4	—4	0	3
11	2	—3	—3	—2	—3	—3	—10	—7	—7	—3	0	7
10	7	2	—1	2	—2	—4	—9	—8	—5	—2	4	8
9	6	7	2	5	2	—4	—7	—8	—5	1	4	8
8	6	6	5	4	1	—4	—6	—7	—6	1	8	7
7	5	7	6	4	3	—2	—5	—6	—4	1	8	8
6	6	6	5	3	2	—1	—7	—5	—3	3	8	6
5	6	6	3	1	1	—1	—6	—4	—1	0	7	5
4	6	5	0	2	—1	—1	—6	—4	—1	0	8	3
3	4	8	2	3	—2	—2	—4	—4	—2	0	7	0
2	6	9	5	4	—4	—5	—3	—3	—2	—1	6	2
1	10	11	5	5	—4	—5	0	—3	—3	—2	7	6

(b) **Poona (or Hyderabad) and Batavia (P-B).**

Height in gkm.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
17	21	24	9	16		10	11	14	11	—1	1	25
16	9	21	15	14	12	5	2	6	0	—3	—7	17
15	7	18	7	11	8	3	7	9	—1	—2	—11	16
14	0	15	2	8	11	8	12	10	3	—1	—4	14
13	2	15	1	1	6	9	10	15	8	0	0	11
12	3	10	1	0	2	10	12	15	9	1	0	6
11	1	4	0	—2	—1	9	11	13	8	4	0	3
10	0	2	—2	—3	—3	6	12	11	7	1	—1	2
9	2	2	—1	—2	—2	6	9	8	5	1	0	2
8	1	0	—1	—3	—2	6	9	7	4	3	1	2
7	—1	0	0	—3	—1	4	7	5	4	1	1	2
6	0	—1	0	—2	0	4	5	5	5	4	1	2
5	1	—1	0	—3	0	4	5	5	4	2	2	2
4	0	—2	—3	—1	0	3	4	3	3	1	2	1
3	—1	0	0	2	3	4	3	2	3	1	1	—1
2	0	2	5	5	5	4	3	3	3	1	0	—1
1	3	6	6	11	7	8	4	3	3	1	0	1

bers of the staff of the Upper Air Section at Poona have participated in the calibration of the instruments and the working out of the records, to all of whom the authors' thanks are due.

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APPENDIX.

Supplementary Tables.

TABLE 21.—NUMBER OF BALLOONS SENT UP (n_1) AND NUMBER RECOVERED (n_2).

Year.	Jan.		Feb.		Mar.		Apl.		May.		June.		July.		Aug.		Sep.		Oct.		Nov.		Dec.		Whole Year.	
	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2
Poona.																										
1928																			3	1	8	5	4	3	15	9
1929	5	4	4	2	5	3	7	2	6	3	4	1	5	2							3	3	11	7	50	27
1930	12	8	4	2	7	2	7	3	11	5			4	2	6	2	5	3	5	4	5	3	14	3	80	37
1931	8	7	16	11	7	4	4	2	7	2	4	0	9	3	2	0	2	0	5	0			14	7	78	36
TOTAL .	25	19	24	15	19	9	18	7	24	10	8	1	18	7	8	2	7	3	13	5	16	11	43	20	223	109
Hyderabad.																										
1929															7	4	10	8	9	5	2	2			28	19
1930											9	5	8	6	8	5	20	12	10	5	2	0			57	33
1931											9	2	12	7	15	8	11	6	11	9	4	3			62	35
TOTAL .											18	7	20	13	30	17	41	26	30	19	8	5			147	87

TABLE 22.—MEAN MONTHLY TEMPERATURES (°A) AT **Geometric** KILOMETRES.

Heights in km.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	10	04	02		02		03	06	02	05	97	08
19	03	00	97	94	97		98	03	99	04	96	03
18	98	99	94	94	93	93	95	00	96	98	94	99
17	95	00	93	95	91	93	94	96	95	94	92	95
16	96	02	96	96	93	95	95	97	95	95	94	96
15	99	06	01	00	99	01	01	02	01	00	99	01
14	03	11	07	06	07	09	10	10	09	07	07	07
13	11	18	14	12	16	18	17	18	17	16	15	14
12	20	25	22	21	24	26	25	26	25	24	23	22
11	28	32	29	29	32	34	34	34	33	32	32	30
10	37	39	37	37	40	41	42	41	41	40	40	37
9	44	46	44	45	48	49	49	49	49	47	48	44
8	51	52	52	51	55	56	56	56	56	55	55	52
7	57	59	59	59	61	62	62	62	62	60	61	60
6	64	64	65	64	68	68	67	68	68	67	67	65
5	70	70	71	70	73	74	73	73	73	73	73	71
4	76	76	75	77	79	80	79	77	79	78	78	77
3	81	83	82	85	86	86	84	83	84	83	83	81
2	87	90	92	94	94	92	89	89	89	89	87	86
1	96	99	00	03	02	01	96	95	97	96	95	94

N.B.—The hundreds figure has been omitted throughout the table.

TABLE 23.—MEAN MONTHLY PRESSURES (MB.) AT **Geometric** KILOMETRES.

Height in km.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	56	57	56		56		58	58	57		54	56
19	66	68	67	66	66		68	67	67	67	66	66
18	77	80	78	78	77	78	80	79	79	79	78	78
17	91	95	93	93	93	94	94	95	95	94	94	92
16	109	112	111	111	111	113	112	113	112	112	112	111
15	130	133	131	131	133	134	133	134	134	133	133	132
14	153	156	155	154	156	157	157	157	157	156	156	154
13	180	183	182	182	184	186	185	185	185	184	184	182
12	211	213	213	213	214	215	214	214	215	215	215	213
11	246	247	247	247	248	249	248	248	249	249	250	247
10	284	286	285	285	288	288	287	287	287	287	288	285
9	327	328	329	329	332	333	330	331	332	330	331	328
8	376	377	377	377	380	380	377	378	379	379	379	377
7	428	431	431	432	433	433	430	431	432	432	432	431
6	490	491	492	493	492	492	489	489	491	492	492	491
5	557	558	558	559	558	557	554	554	557	558	558	557
4	630	632	632	633	632	631	627	628	630	631	631	630
3	713	714	715	716	715	713	709	709	712	713	714	713
2	803	803	804	803	803	801	798	797	801	802	803	803
1	902	901	901	900	900	898	896	895	899	901	902	902

TABLE 24.—MEAN MONTHLY DENSITIES (GMS. PER CUBIC METRE) AT **Geometric** KILOMETRES.

Height in km.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
20	92	98	97		95		98	96	97	94	96	93
19	112	118	117	118	116		119	115	115	114	116	113
18	136	140	140	140	141	141	142	140	139	140	140	137
17	163	166	167	166	169	170	169	169	169	169	169	165
16	193	194	196	196	200	200	199	198	200	199	200	196
15	227	225	227	227	232	231	231	229	231	231	232	227
14	262	258	261	261	263	263	262	261	262	263	264	259
13	296	292	295	298	296	296	296	295	296	297	298	295
12	333	330	334	335	334	332	333	332	334	335	335	333
11	373	371	375	376	374	372	371	371	372	373	375	374
10	419	416	420	420	419	416	413	415	414	417	419	419
9	467	466	469	469	467	464	460	462	464	465	466	468
8	521	519	521	521	519	516	512	514	516	518	518	520
7	580	581	580	582	577	575	571	572	572	579	577	578
6	646	647	645	650	639	638	637	635	638	642	642	644
5	718	719	715	719	712	706	706	704	708	712	712	713
4	795	796	799	795	789	780	780	785	784	787	789	791
3	882	877	881	869	864	861	863	867	867	873	876	881
2	972	960	957	944	942	947	952	953	957	963	968	971
1	1,056	1,044	1,043	1,027	1,027	1,028	1,045	1,044	1,044	1,051	1,047	1,050

TABLE 25.—MEAN MONTHLY HEIGHTS (GKM.) CORRESPONDING TO PRINCIPAL ISOBARIC LEVELS.

Pressure (mb.).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean.
100	16·09	16·30	16·19	16·20	16·23	16·30	16·28	16·31	16·29	16·25	16·25	16·20	16·25
200	12·08	12·13	12·11	12·12	12·19	12·23	12·18	12·18	12·21	12·19	12·19	12·12	12·16
300	9·40	9·44	9·43	9·45	9·49	9·50	9·46	9·46	9·49	9·48	9·49	9·44	9·46
400	7·37	7·39	7·40	7·41	7·44	7·43	7·39	7·38	7·42	7·41	7·42	7·39	7·40
500	5·71	5·72	5·73	5·75	5·75	5·75	5·70	5·69	5·74	5·73	5·74	5·72	5·73
600	4·30	4·32	4·35	4·33	4·33	4·31	4·27	4·26	4·31	4·31	4·32	4·31	4·31
700	3·08	3·09	3·10	3·10	3·10	3·07	3·03	3·02	3·07	3·08	3·09	3·07	3·07
800	1·99	1·99	2·00	1·98	1·97	1·95	1·93	1·92	1·96	1·98	1·99	1·99	1·97
900	0·99	1·00	0·99	0·98	0·97	0·96	0·94	0·92	0·96	0·99	1·00	1·00	0·97

TABLE 26.—MEAN MONTHLY AND ANNUAL TEMPERATURES (°A) CORRESPONDING TO PRINCIPAL ISOBARIC LEVELS.

Pressure (mb.).	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean.
100	94·0	00·0	94·5	94·0	91·0	93·0	93·0	95·0	94·0	93·0	92·0	93·5	194·0
200	17·5	22·0	19·0	17·0	20·5	22·5	20·0	22·0	21·0	20·0	19·5	19·0	220·0
300	39·5	41·0	39·5	40·0	42·0	44·0	44·5	43·0	43·5	42·5	42·5	39·5	242·0
400	53·5	55·0	55·0	55·0	57·5	58·5	59·0	59·0	58·5	57·5	57·5	56·0	257·0
500	65·0	65·0	66·0	65·0	68·0	69·0	68·0	69·0	68·5	67·5	67·5	66·5	267·0
600	74·0	73·0	73·0	73·5	75·0	76·5	76·5	76·5	76·5	76·0	76·0	75·0	275·0
700	80·5	81·0	81·0	83·0	84·5	85·5	83·5	82·0	83·0	82·5	82·5	80·5	282·5
800	87·0	90·0	91·5	93·5	94·0	92·0	89·5	89·0	89·5	88·5	87·5	86·0	290·0
900	96·0	99·0	99·5	02·5	02·0	00·5	96·0	96·0	96·5	96·0	95·0	94·0	297·0

N.B.—The hundreds figure has been omitted in all the columns of *Table 26* except in that for the Annual mean.

MGIPC—M—VIII-3-1—12-9-34—360.

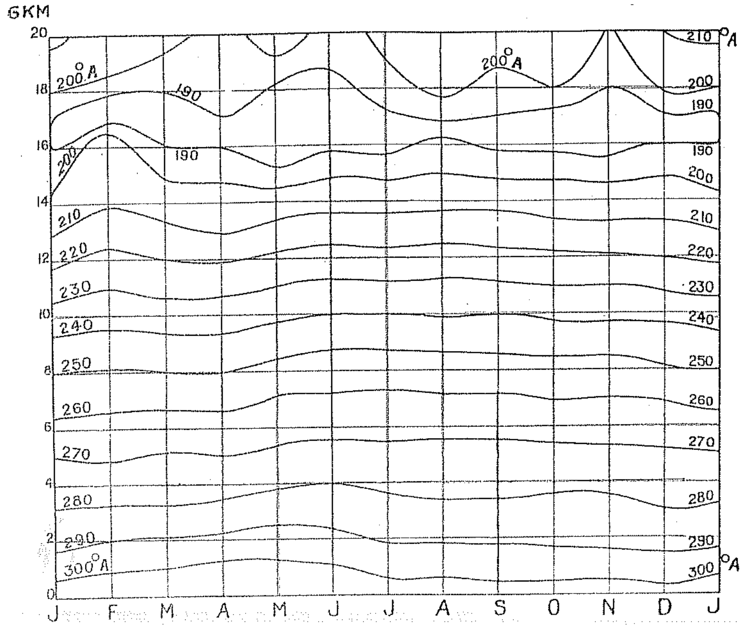

FIG. 1. SEASONAL VARIATION OF TEMPERATURE AT DIFFERENT HEIGHTS OVER POONA AND HYDERABAD.

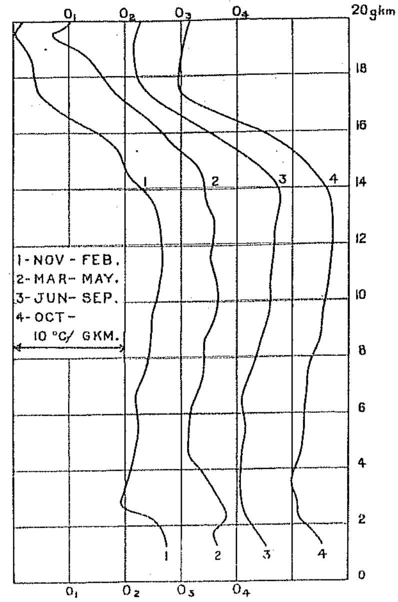

FIG. 2. VARIATION OF MEAN LAPSE-RATE WITH HEIGHT IN DIFFERENT SEASONS.

O_1 O_1 is the line of zero lapse-rate for curve 1, O_2 O_2 for curve 2 and so on.

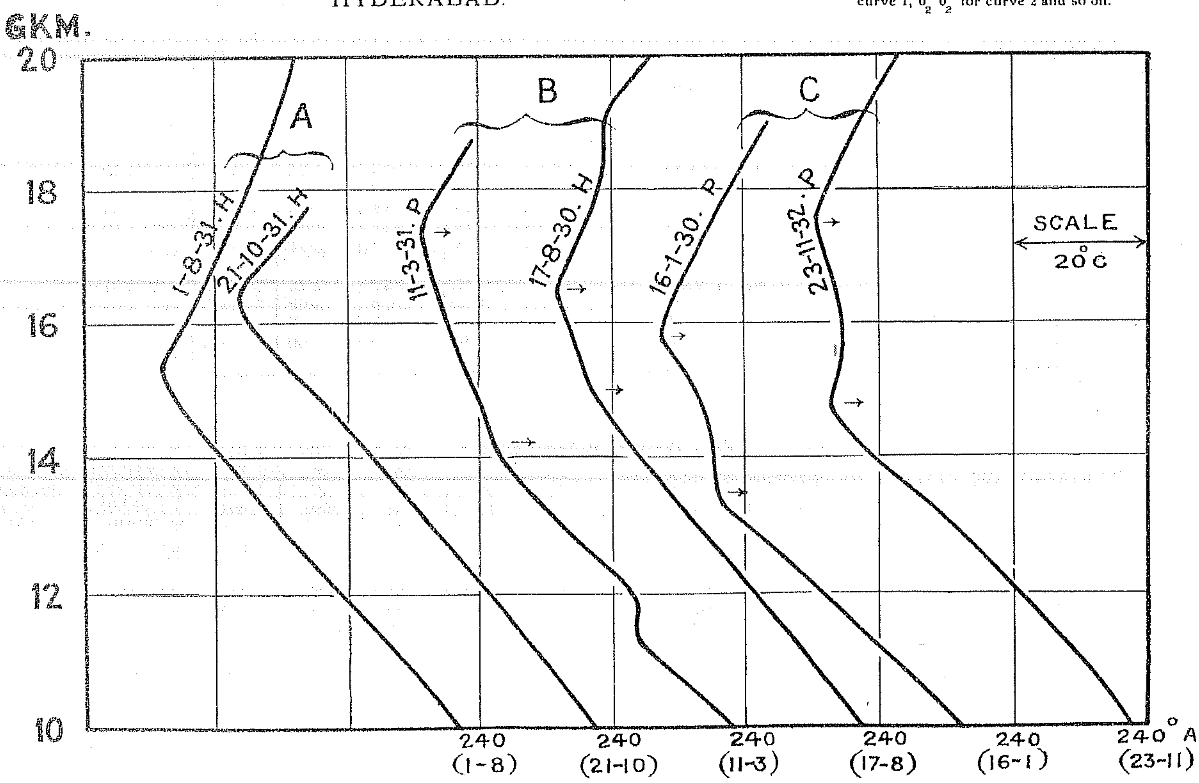

FIG. 3. HEIGHT-TEMPERATURE CURVES SHOWING DIFFERENT TYPES OF TROPOPAUSE AT POONA (P) AND HYDERABAD (H).

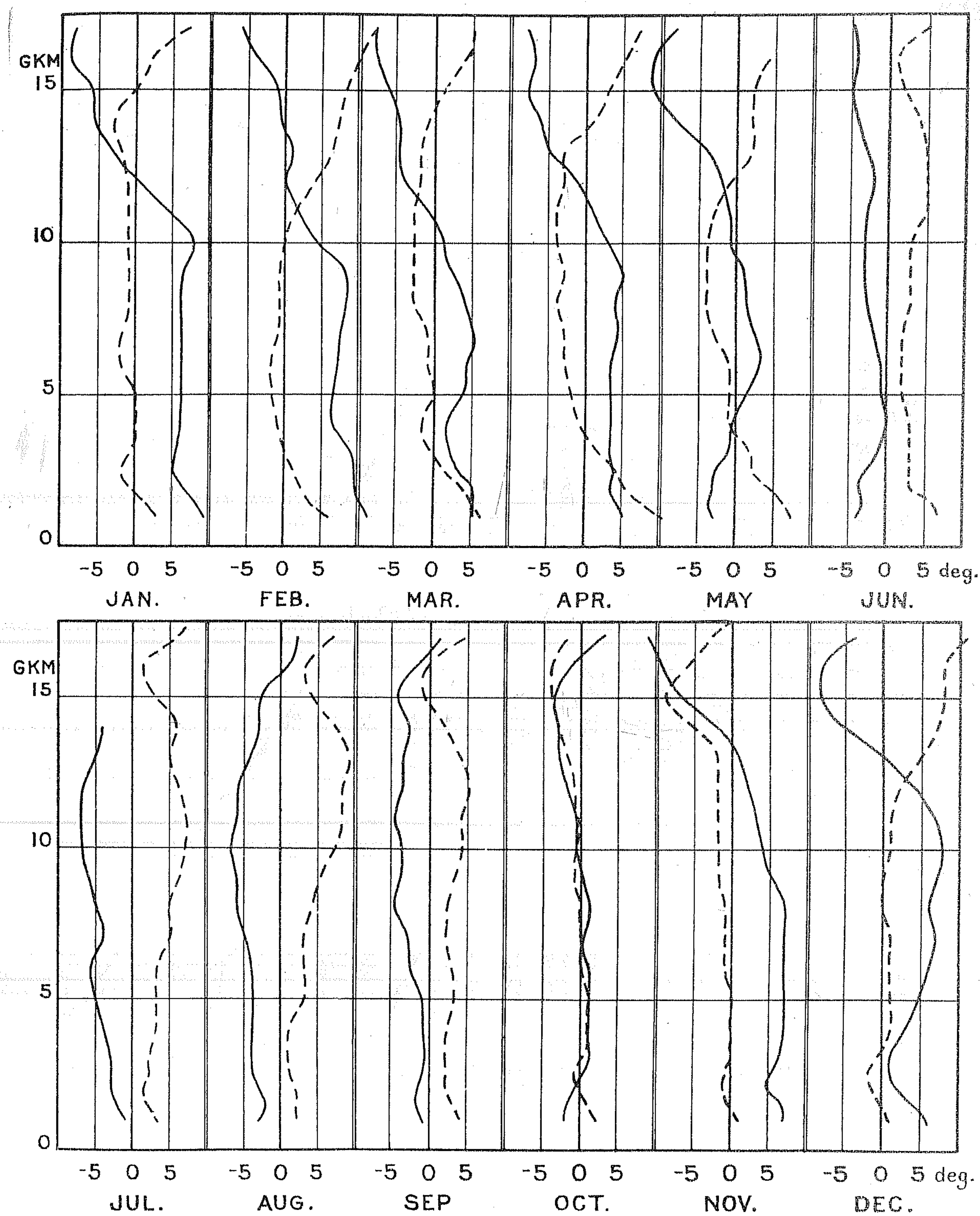

FIG. 4. MEAN MONTHLY TEMPERATURE DIFFERENCES BETWEEN POONA, AGRA AND BATAVIA.

——— POONA—AGRA - - - - - - - POONA—BATAVIA

G. I. P. Z. O. POONA, 1934

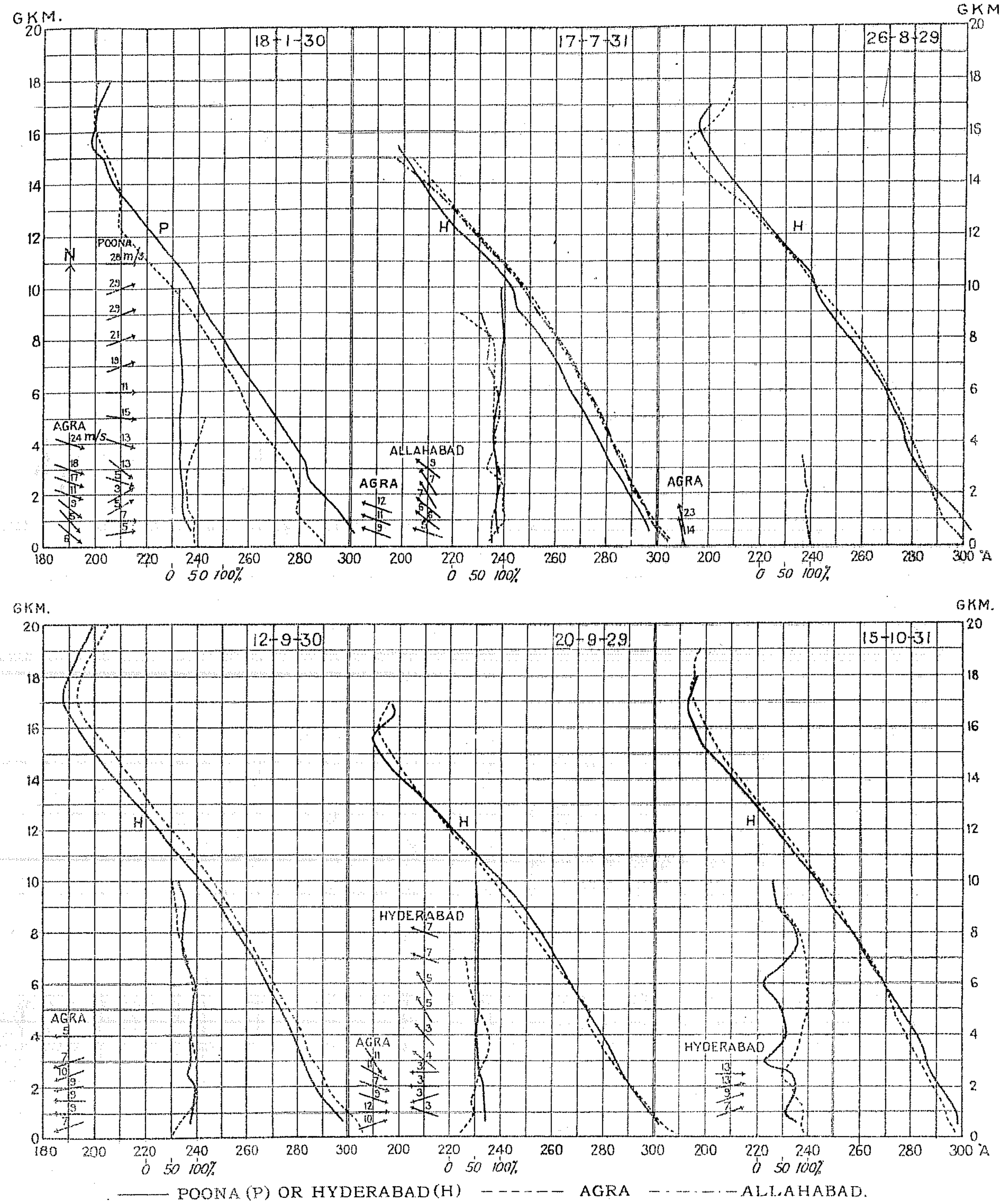

FIG. 5. SOME NEARLY SIMULTANEOUS ASCENTS AT POONA OR HYDERABAD AND AGRA.

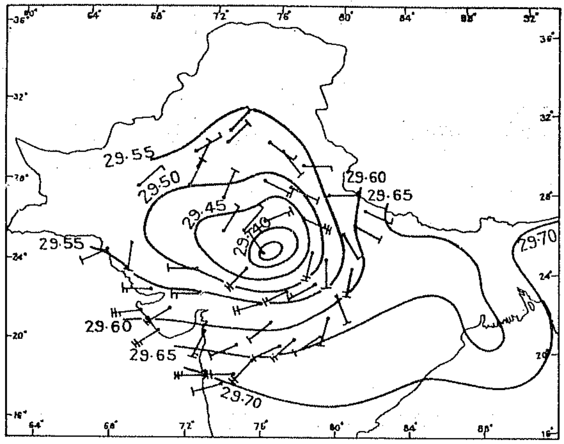

FIG. 6(a). SEA-LEVEL ISOBARS AND SURFACE WINDS AT 8 Hrs. ON 26-8-29

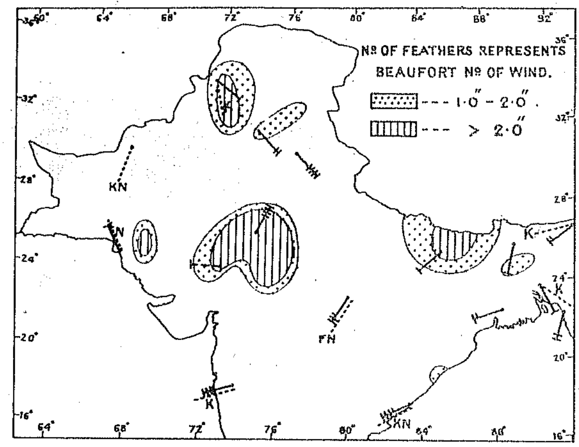

FIG. 6(b). UPPER WINDS AT 1 KM AND LOW CLOUD DIRECTIONS ON THE MORNING OF 26-8-29 AND RAINFALL IN NEXT 24 Hrs.

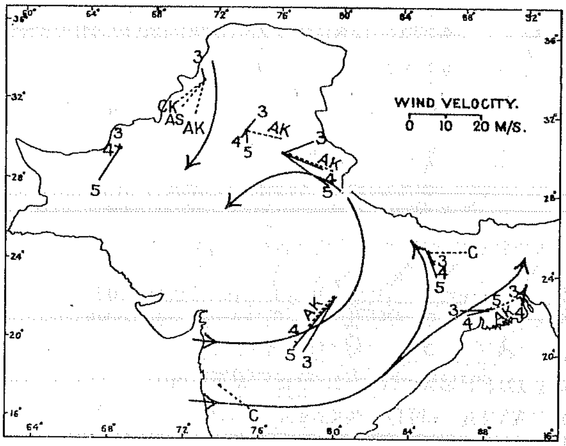

FIG. 6(c). WINDS AT 3, 4 AND 5 KM. AND MIDDLE AND HIGH CLOUD DIRECTIONS ON THE MORNING OF 26-8-29.

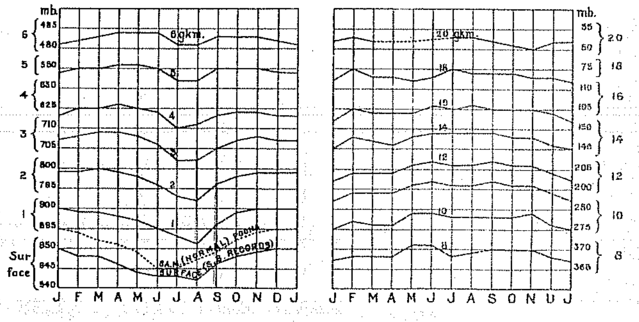

FIG. 7. SEASONAL VARIATION OF PRESSURE AT DIFFERENT HEIGHTS OVER POONA AND HYDERABAD.

(O) G. P. Z. O. POONA, 1934.

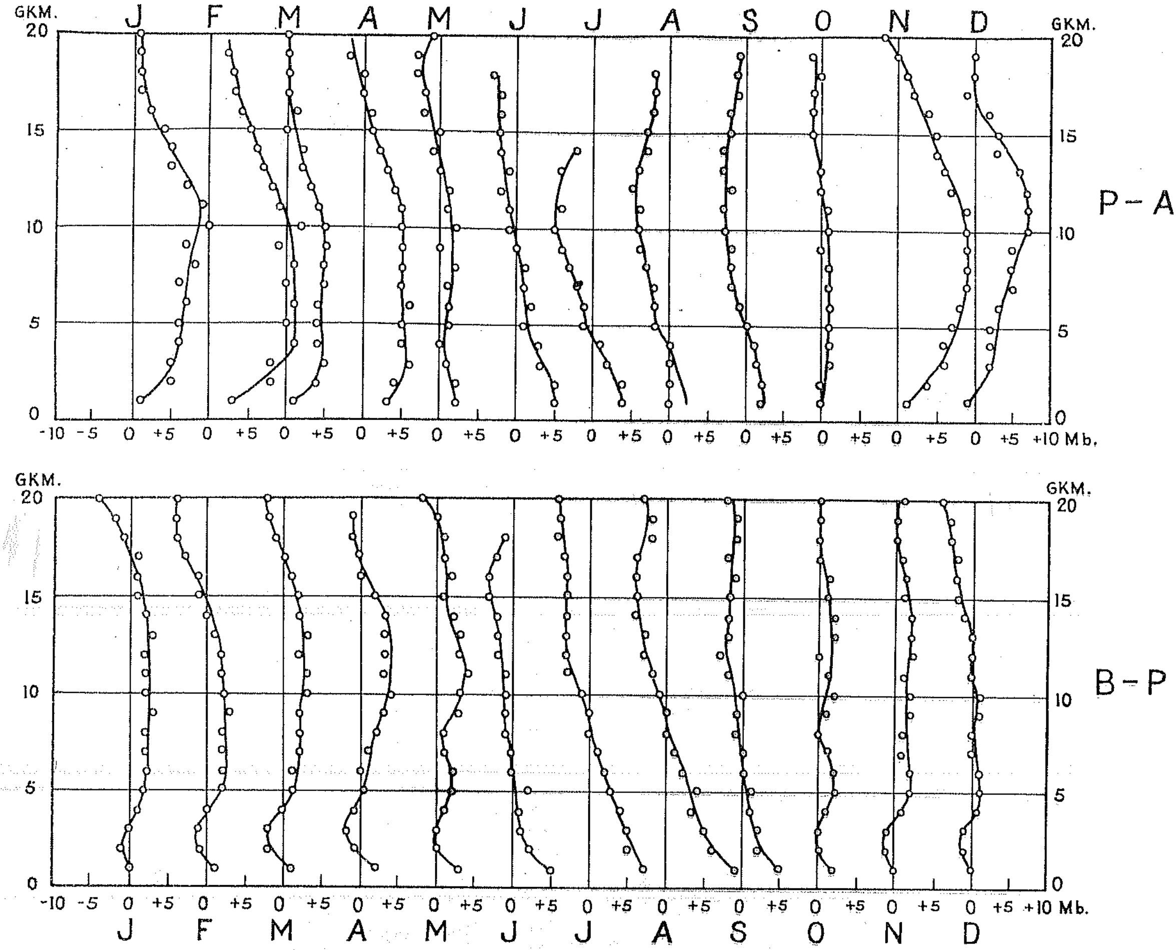

FIG. 8. MEAN MONTHLY PRESSURE DIFFERENCES BETWEEN POONA AND AGRA (P-A) AND BATAVIA AND POONA (B-P).

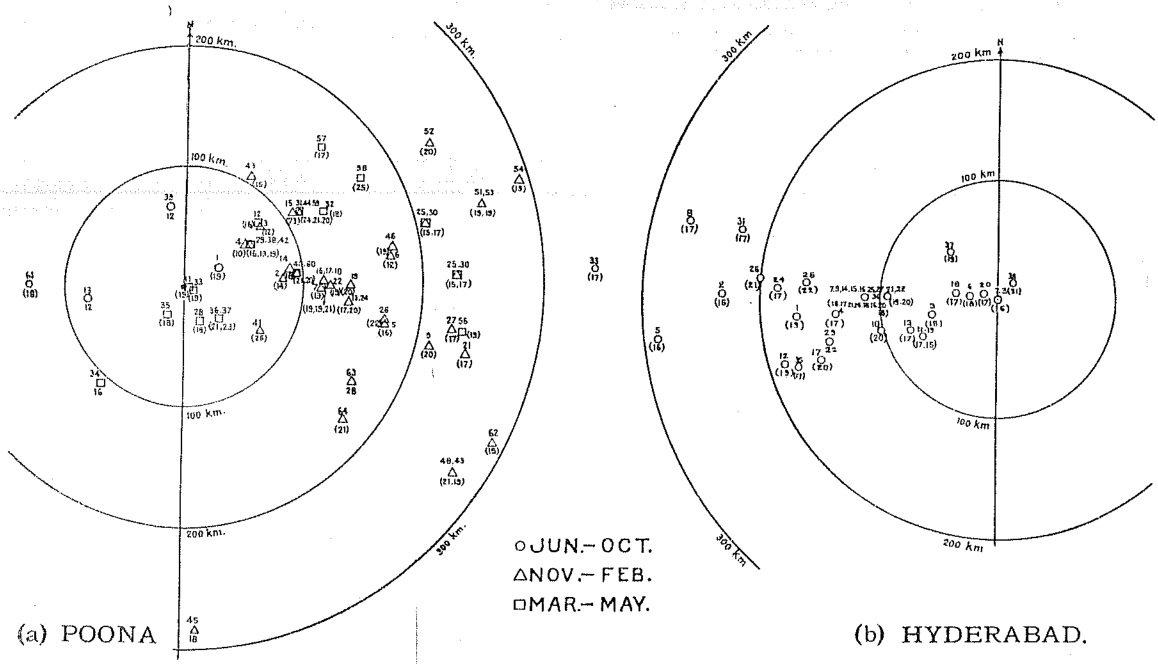

FIG. 9. PLACES OF FALL OF SOUNDING BALLOONS LET OFF FROM (a) POONA AND (b) HYDERABAD.

(o) G.P.Z.O. POONA, 1934.

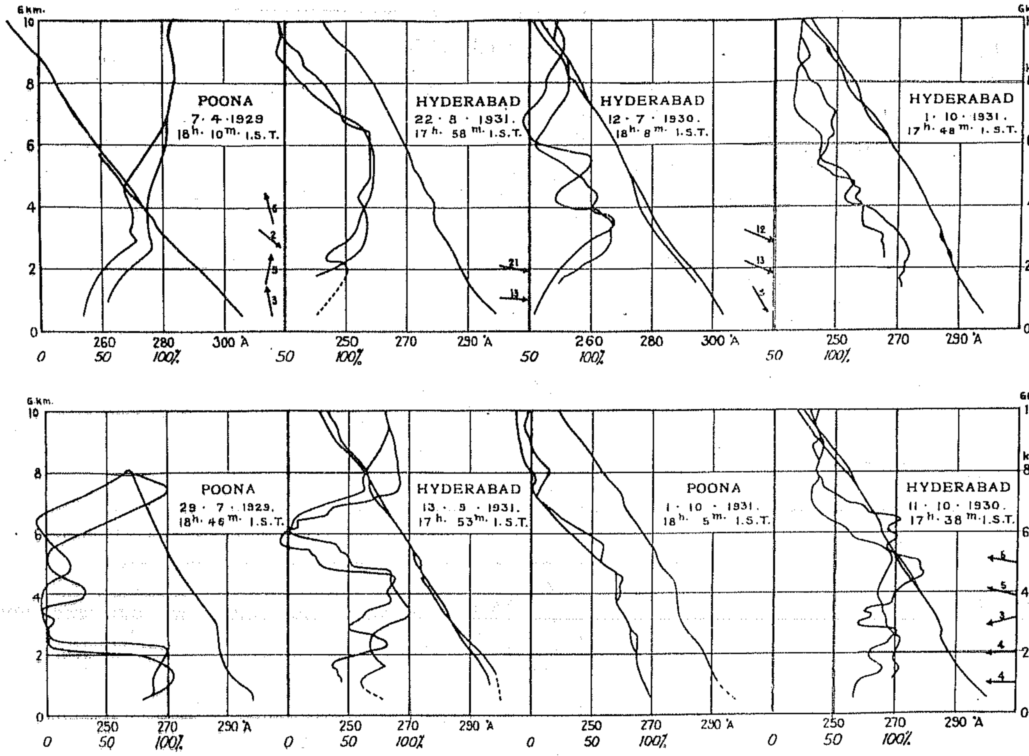

FIG. 10. SOME ASCENTS SHOWING TYPICAL HUMIDITY RECORDS.

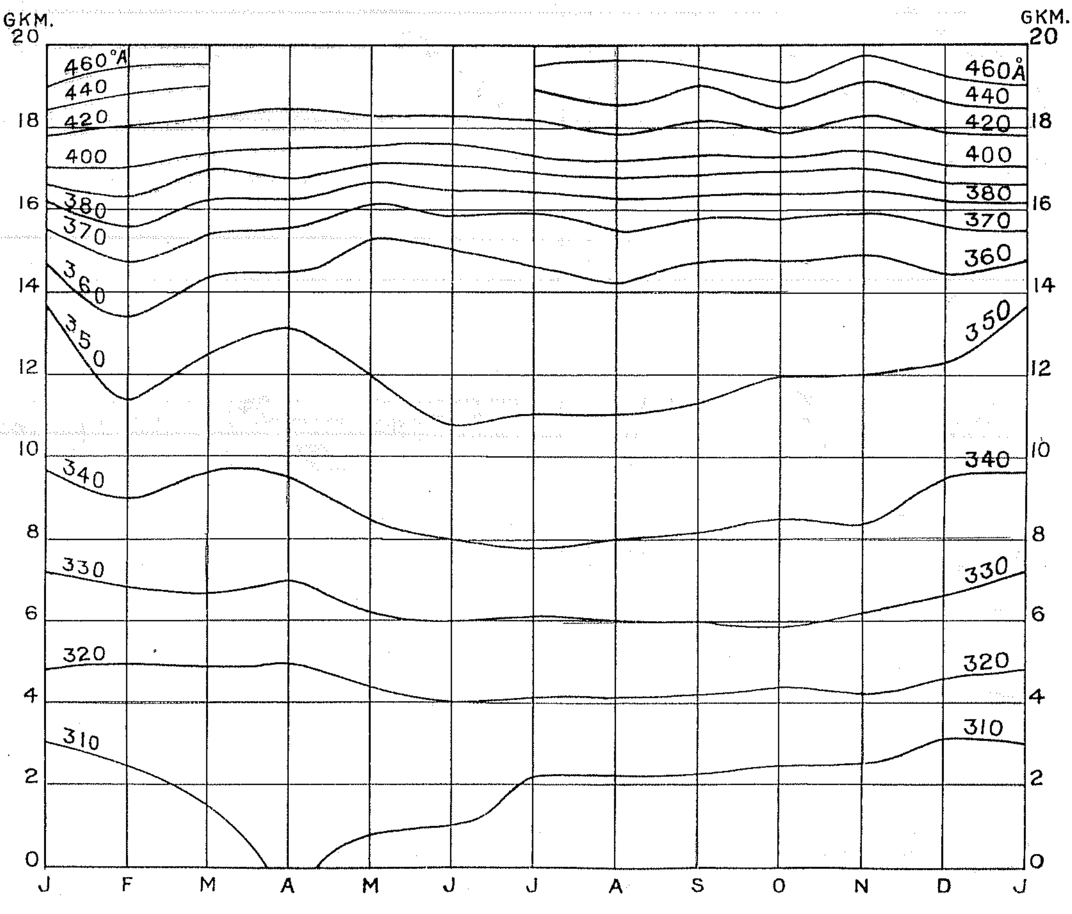

FIG. 11. SEASONAL VARIATION OF POTENTIAL TEMPERATURE AT DIFFERENT HEIGHTS OVER POONA AND HYDERABAD.

(C) G. P. Z. O. POONA, 1934.

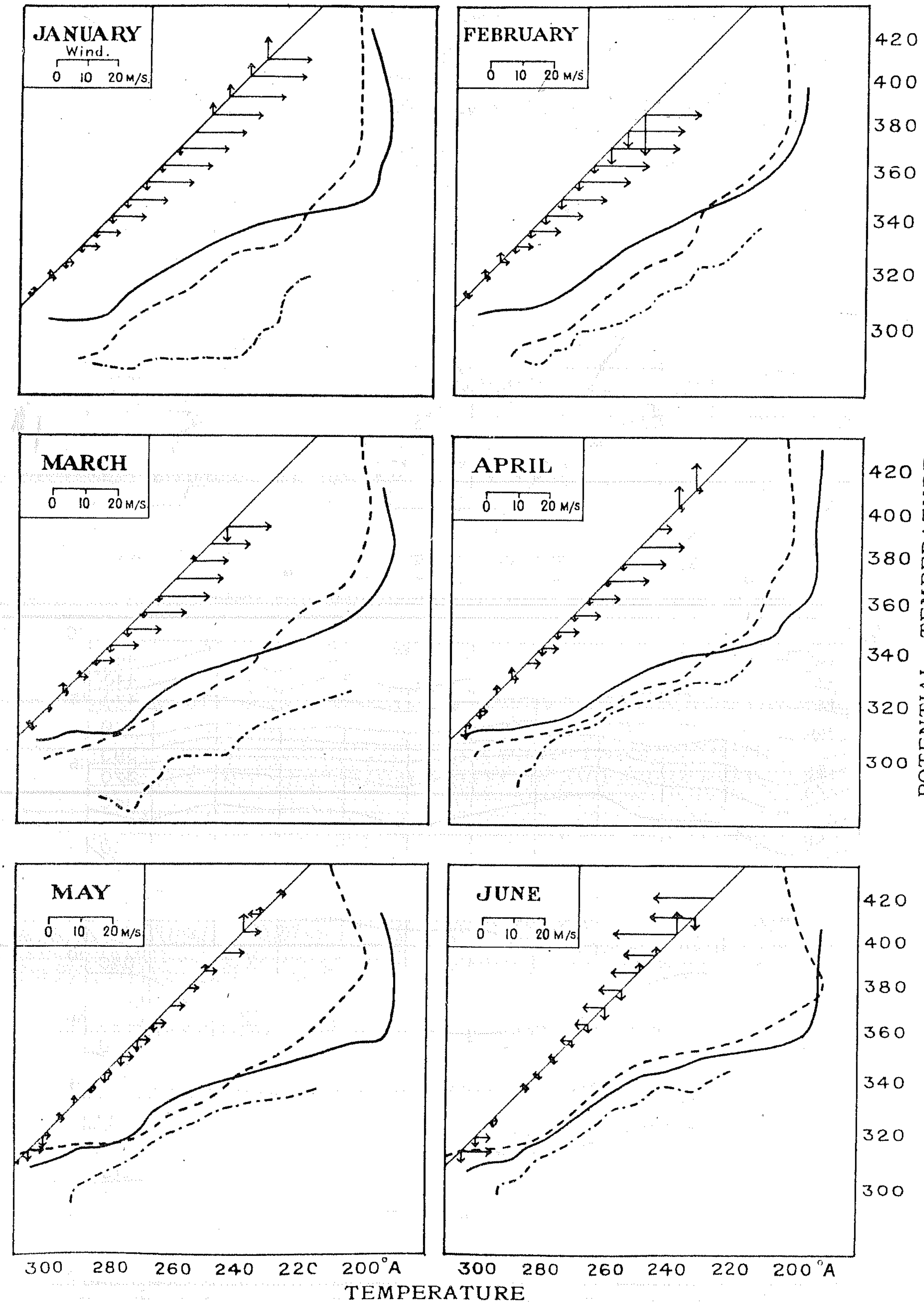

FIG. 12A. MEAN MONTHLY TEPHIGRAMS (JANUARY-JUNE).

THE FULL LINES REPRESENT THE TEPHIGRAMS FOR POONA OR HYDERABAD AND THE BROKEN LINES THOSE FOR AGRA. THE LINES WITH ALTERNATE DASHES AND DOTS REPRESENT THE DEW POINT PRESSURE DIAGRAMS FOR POONA OR HYDERABAD.

(O) G.P-Z-U. POONA, 1934

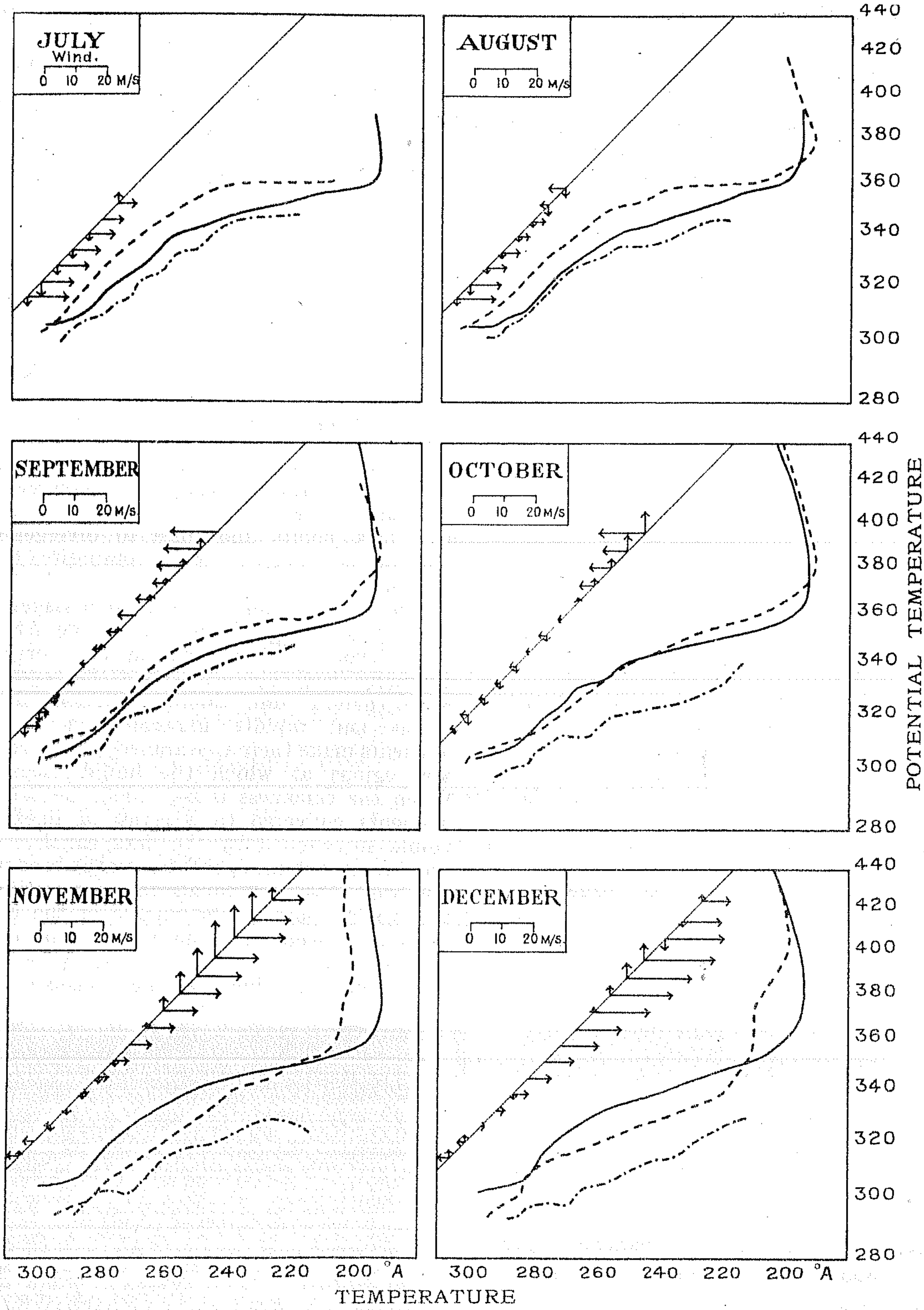

FIG. 12B. MEAN MONTHLY TEPHIGRAMS (JULY-DECEMBER)

THE FULL LINES REPRESENT THE TEPHIGRAMS FOR POONA OR HYDERABAD AND THE BROKEN LINES THOSE FOR AGRA. THE LINES WITH ALTERNATE DASHES AND DOTS REPRESENT THE DEW-POINT PRESSURE DIAGRAMS FOR POONA OR HYDERABAD.