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Atmospheric circulation at altitudes upto 37 km over India in the latitude belt 17°-19°N

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ABSTRACT. Mean monthly winds in the 7-37 km range for the months of September to May through December, based on 155 balloon ascents made over the period 1957-66 in the latitude belt 17°—19°N in India, are reported. It is shown that except for few short periods during winter and spring, when weak westerlies prevailed, the stratospheric circulation was predominantly zonal with winds generally increasing with altitude.

1. Introduction

During the period between April 1957 and April 1966, we have carried out 91 plastic balloon and 64 rubber baloon ascents from Bombay (19°N, 73°E) and Hyderabad (17·6°N, 78·5°E). These flights have provided us with a considerable amount of information relating to atmospheric circulation at altitudes upto 37 km over India at these latitudes. In this paper we wish to present these observations since the available published data in this regard is meagre.

The programme of high altitude ascents using large polyethylene balloons was initiated at the Tata Institute of Fundamental Research in 1956 for research on primary cosmic radiation. These flights were all tracked with optical theodolites based at two or more stations, for determining the altitude-time curve as also for finding out the prevalent wind-structure, information concerning which is necessary for speedy recovery of the cosmic-ray pay-load. Wind observations during the flights in the first few years showed quite interesting features at stratospheric altitudes. The number of observations was, therefore, augmented by making rubber balloon ascents in those months in which plastic balloon flights are not usually made.

Successful operations with plastic balloons of large volume are possible only when surface winds are low. Our flights were, therefore, made during the period from September through to May, and not during the summer and monsoon period (June, July, August), when the surface winds tend to be high. Most flights carried radiosondes and/or self-recording pressure gauges which were used to deduce and to check altitudes using standard atmospheric tables (Murgutoryd 1957). The winds were calculated at intervals of five minutes in all flights, *i.e.*, 1·5-3 km altitude intervals; because of this, it has not been possible to deduce fine features such as the level of the maximum velocity in the tropospheric westerly jet.

2. Observations

In Table 1, we have shown the number of flights by month and year over the period from April 1957 to May 1966. Since the total number of flights for any particular month in a year is small, we have pooled together for each month the data from all the years and tried to deduce an *average* picture of the circulation. The monthly mean winds thus obtained are given in Table 2 at intervals of 1 km for the altitude range 7-37 km along with the steadiness factor [(vector mean/scaler mean) × 100], which is a measure of variability in the wind at each level. The monthly mean winds in metres/sec have been plotted in Fig. 1. The number of observations are also marked for each month.

3. General features of the circulation

The following general features clearly show up in Fig. 1 —

(*a*) *Troposphere* (7-20 km)

We have only one observation for the month of September as the sky is usually cloudy during this month. This single observation is, however, presented, since it shows only easterlies in the troposphere and the complete absence of westerly winds characteristic of the winter circulation. The tropospheric circulation in these latitudes in summer (June, July, August) in India is known to be characterised by a strong easterlies (Venkiteshwaran 1950). The weak easterlies observed in the September flight may, therefore, be taken as representative of summer to winter transition, similar to the weak westerlies in May, during winter to summer transition.

The circulation in the troposphere is characterised by strong westerly winds in winter (December, January, February) and relatively weak westerlies in October-November and March-April. The westerly jet builds up in strength with the advance of winter reaching a maximum of 30 metres/sec at 14 km in December-January, and weakens

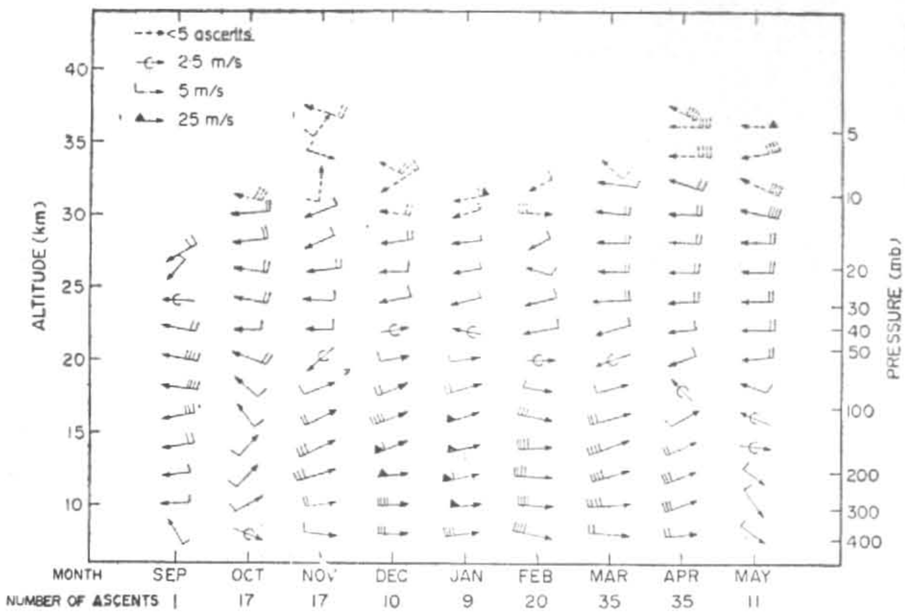

Fig. 1. Mean wind over Bombay (19°N, 73°E) and Hyderabad (17·6°N, 78·5°E), 1957—1966

towards April with the beginning of summer. It is also interesting to note that the wind is predominantly zonal, *i.e.*, steady westerly flow, which becomes southwesterly as a rule, whenever the meridional component is present.

(*b*) *Lower Stratosphere* (20–25 km)

The circulation in the lower stratosphere is, in general, characterised by weak variable winds except during October and May, when it is replaced by weak but steady easterly winds. The calm conditions which are present around 20 km in winter are observed around 15 km in October and May, the transition months.

(*c*) *High Stratosphere* (>25 km)

The circulation in the high stratosphere is predominantly zonal with steady easterly flow. A preliminary analysis of the zonal winds based on data for the period April 1957 to May 1964 was reported earlier (Gokhale 1965). Our observations showed weak westerlies in the stratosphere in two periods, *viz.*, March—April 1959 and February-April 1961, whereas for the remaining years the stratospheric circulation was characterised by only easterlies, except on few occasions when weak westerlies were observed in winter and spring. The meridional component is generally weak and when so, does not show any directional regularity. However, in a few cases, when a strong meridional component was present, it was southerly. At times, the zonal flow was weak and the southerly dominated. The easterlies usually build up in strength with increasing altitude; furthermore, at all altitudes, the easterly stream strengthens with increasing proximity to summer.

In conclusion, we wish to point out that the number of observations on which our conclusions based is limited, and is also not uniformly spread over the entire period as seen from Table 1. In fact out of a total of 155 flights, only 39 were made in the first five years (1957–1961) while the remaining 116 were made in the last five years (1962–1966).

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TABLE 1

The number of flights against month and year for the period April 1957 to April 1966

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Total
September	—	—	—	—	—	—	1*	—	—	—	1
October	—	—	—	—	—	4*	9(8*)	2*	2(1*)	—	17
November	—	1	1	1	—	5*	3*	3	3(2*)	—	17
December	2	1	2	—	—	2*	1	2*	—	—	10
January	—	—	1	—	—	—	2*	2*	3*	1*	9
February	—	1	—	1	6	3*	3*	—	3*	3*	20
March	—	1	1	6	3	5(1*)	7(3*)	1*	—	11(4*)	35
April	1	1	3	—	4	2	7	7(2*)	6	4	35
May	—	1	1	—	—	1	3*	3	2	—	11
Total	3	6	9	8	13	22	36	20	19	19	155

*Indicates rubber balloons Rubber balloons=64 Plastic balloons=91

TABLE 2

Mean wind

Altitude (km) (1)	Pressure (mb) (2)	Direction of mean resultant vector wind (with respect to north) (3)	Mean resultant vector wind (metres/sec) (4)	Steadiness factor (per cent) (Vector mean/scaler mean) (given only for $n < 5$) (5)	No. of observations n (6)
SEPTEMBER					
7	425	180	2·0	—	1
8	370	160	3·8	—	1
9	322	120	4·7	—	1
10	280	90	6·0	—	1
11	240	80	6·6	—	1
12	205	85	6·5	—	1
13	177	100	7·1	—	1
14	150	80	11·2	—	1
15	128	85	14·0	—	1
16	108	85	16·6	—	1
17	90	85	19·1	—	1
18	78·5	100	21·3	—	1
19	66	100	21·3	—	1
20	55·5	100	18·2	—	1
21	47·5	100	15·2	—	1
22	40·5	100	11·2	—	1
23	34·0	95	6·1	—	1
24	29·0	90	1·0	—	1
25	24·5	315	2·1	—	1
26	20·9	40	5·7	—	1
27	18·0	60	8·2	—	1

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)
		OCTOBER			
7	425	315	2·1	37	12
8	370	290	2·3	38	12
9	322	260	4·2	55	15
10	280	245	5·4	62	15
11	240	240	6·9	69	15
12	205	255	7·1	67	15
13	177	230	6·3	64	17
14	150	220	5·1	64	17
15	128	180	3·9	50	17
16	108	155	5·5	66	17
17	90	145	6·3	72	17
18	78·5	135	6·9	81	15
19	66·0	115	8·2	95	14
20	55·5	110	8·0	91	14
21	47·5	90	7·0	85	14
22	40·5	90	6·1	78	14
23	34·0	95	5·7	73	14
24	29·0	95	7·8	76	11
25	24·5	95	8·4	74	11
26	20·9	95	9·1	79	11
27	18·0	90	9·9	90	10
28	15·4	85	10·0	90	9
29	13·3	80	11·2	96	8
30	11·45	85	9·2	92	5
31	9·8	100	16·3	—	1
		NOVEMBER			
7	425	280	4·0	57	10
8	370	275	6·4	66	12
9	322	275	9·3	79	13
10	280	260	11·9	87	13
11	240	260	13·9	91	13
12	205	250	15·6	92	13
13	177	250	17·0	94	16
14	150	250	16·2	93	17
15	128	245	13·3	89	17
16	108	250	9·5	74	17
17	90	240	5·9	58	17
18	78·5	245	3·5	49	17
19	66·0	300	1·3	24	17
20	55·5	50	1·1	22	17
21	47·5	75	3·4	62	17
22	40·5	85	5·8	84	17
23	34·0	85	6·3	79	16
24	29·0	90	7·2	78	15
25	24·5	90	7·6	78	14
26	20·9	85	8·5	90	14
27	18·0	80	8·1	92	13
28	15·4	70	6·8	90	11
29	13·3	70	7·8	83	11
30	11·45	70	7·4	81	8

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)
		NOVEMBER (*contd*)			
31	9·8	80	3·6	48	6
32	8·5	185	4·2	—	3
33	7·4	265	6·5	—	2
34	6·45	285	6·4	—	2
35	5·55	270	2·0	—	2
36	4·82	215	2·5	—	2
37	4·22	105	9·2	—	1
		DECEMBER			
7	425	275	9·2	82	9
8	370	270	13·1	87	9
9	522	270	17·5	91	9
10	280	270	22·2	95	9
11	240	270	25·3	95	9
12	205	265	27·1	94	9
13	177	255	28·5	96	10
14	150	250	28·4	97	10
15	128	250	24·6	98	10
16	108	250	20·6	97	10
17	90	250	17·0	97	10
18	78·5	250	11·4	91	10
19	66·0	250	6·7	97	9
20	55·5	265	4·9	85	9
21	47·5	270	3·3	75	9
22	40·5	265	1·0	25	9
23	34·0	100	1·2	25	9
24	29·0	85	3·0	52	9
25	24·5	90	4·2	61	9
26	20·9	90	5·3	62	9
27	18·0	85	7·9	71	8
28	15·4	85	12·4	89	7
29	13·3	90	12·8	94	6
30	11·45	95	10·9	—	4
31	9·8	90	15·3	—	3
32	8·5	60	10·7	—	2
33	7·4	115	8·9	—	1
		JANUARY			
7	425	260	13·7	97	9
8	370	265	18·4	95	9
9	322	265	22·9	96	9
10	280	260	26·6	96	9
11	240	260	30·4	100	9
12	205	255	30·4	97	9
13	177	255	29·0	100	9
14	150	255	26·9	96	9
15	128	255	25·6	96	9
16	108	255	22·5	95	9
17	90	255	16·5	99	9
18	78·5	255	12·4	98	9
19	66·0	245	7·1	90	8
20	55·5	260	3·3	66	8
21	47·5	175	1·5	36	8
22	40·5	80	3·0	52	8
23	34·0	85	4·3	66	8

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)
		JANUARY (*contd*)			
24	29·0	75	4·7	72	8
25	24·5	65	5·0	77	8
26	20·9	80	4·7	80	8
27	18·0	85	4·9	78	8
28	15·4	85	4·5	74	8
29	13·3	85	5·4	77	8
30	11·45	75	6·4	—	5
31	9·8	80	27·8	—	3
				—	1
		FEBRUARY			
7	425	285	14·6	85	11
8	370	285	18·1	85	11
9	322	280	20·5	86	11
10	280	275	20·9	83	11
11	240	270	20·8	83	14
12	205	270	19·0	86	18
13	177	265	19·4	88	20
14	150	265	18·6	92	20
15	128	270	16·4	90	20
16	108	275	13·0	85	20
17	90	275	9·7	82	20
18	78·5	270	7·2	80	20
19	66·0	270	4·4	66	20
20	55·5	270	1·7	28	20
21	47·5	260	0·7	12	20
22	40·5	80	2·9	48	20
23	34·0	75	2·7	38	19
24	29·0	75	3·5	47	19
25	24·5	90	4·7	66	19
26	20·9	100	4·8	58	18
27	18·0	75	3·0	37	15
28	15·4	60	4·1	49	10
29	13·3	85	4·4	39	5
30	11·45	275	13·7	—	2
31	9·8	15	10·4	—	1
32	8·5	60	5·8	—	1
		MARCH			
8	425	270	10·2	76	17
8	370	270	12·3	78	25
9	322	265	15·7	82	27
10	280	265	17·9	81	29
11	240	260	20·2	85	29
12	205	255	20·8	88	31
13	177	255	20·2	90	32
14	150	250	19·0	88	33
15	128	255	16·5	92	33
16	108	255	13·4	91	33
17	90	265	8·7	84	33
18	78·5	255	5·2	71	33
19	66·0	235	2·1	36	33
20	55·5	70	0·6	11	33
21	47·5	80	3·3	60	33
22	40·5	75	5·0	82	30
23	34·0	75	6·9	87	29

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)
		MARCH (*contd*)			
24	29·0	85	8·0	94	29
25	24·5	85	8·8	96	29
26	20·9	90	9·3	90	26
27	18·0	90	9·4	88	26
28	15·4	90	9·7	84	25
29	13·3	90	10·0	89	18
30	11·45	95	8·6	85	17
31	9·8	105	5·4	61	11
32	8·5	95	5·5	53	9
33	7·4	130	7·3	—	4
		APRIL			
7	425	265	9·7	83	14
8	370	265	10·9	82	17
9	322	265	13·4	84	17
10	280	255	15·5	87	20
11	240	250	15·6	84	24
12	205	250	16·7	87	25
13	177	250	15·3	84	26
14	150	245	12·2	80	26
15	128	245	8·4	68	27
16	108	240	3·5	35	29
17	90	185	1·6	19	29
18	78·5	140	1·8	25	29
19	66·0	90	2·3	33	28
20	55·5	70	4·6	66	28
21	47·5	80	5·8	75	28
22	40·5	85	7·0	84	28
23	34·0	85	7·9	87	29
24	29·0	85	9·1	91	29
25	24·5	90	10·3	96	29
26	20·9	90	10·0	88	29
27	18·0	90	9·4	89	24
28	15·4	95	9·3	85	22
29	13·2	90	10·1	81	19
30	11·45	90	10·1	75	18
31	9·8	90	11·4	74	13
32	8·5	95	11·7	75	12
33	7·4	90	13·9	90	8
34	6·45	90	18·7	97	5
35	5·55	100	22·4	—	2
36	4·82	95	17·6	—	1
37	4·22	110	19·8	—	1
		MAY			
7	425	315	1·0	11	5
8	370	305	3·0	33	5
9	322	340	3·2	37	7
10	280	325	4·3	49	7
11	240	315	4·4	56	7
12	205	305	4·2	57	7
13	177	290	4·0	66	7
14	150	275	2·4	37	8
15	128	355	0·9	16	8
16	108	105	1·9	25	9

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)
		MAY (*contd*)			
17	90	100	5·1	67	9
18	78·5	105	7·1	79	9
19	66·0	100	7·5	80	9
20	55·5	85	8·1	80	9
21	47·5	85	8·6	85	9
22	40·5	90	9·1	91	10
23	34·0	85	10·0	94	11
24	29·0	90	10·7	92	11
25	24·5	90	12·0	97	11
26	20·9	90	11·8	94	11
27	18·0	95	12·5	95	11
28	15·4	90	12·1	88	11
29	13·3	90	17·2	97	8
30	11·45	100	20·3	97	7
31	9·8	95	21·5	99	7
32	8·5	110	18·6	—	3
33	7·4	95	21·6	—	1
34	6·45	80	21·8	—	1
35	5·55	90	21·8	—	1
36	4·82	90	23·6	—	1