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Vertical Movements of F-type Radiosonde due to collection of snow on the balloon fabric

N. R. KACHARE, ANNA MANI, C. N. VENKATARAMAN and S. P. VENKITESHWARAN

Meteorological Office, Poona

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1. Introduction

Some of the special features of the F-type radiosonde technique have been described by Venkiteshwaran (1952). Suryanarayana and Kachare (1951) observed the up and down movements of an F-type radiosonde on two consecutive days (6 and 7 October 1950) at Poona, when ascents were made during rain. On this occasion, the rainfall was steady and similar to that of a warm frontal type. It was shown by them that when the balloon reached the freezing level, there was accumulation of snow on the balloon fabric to such an extent that it exceeded the free lift and the balloon descended. After it had descended far below the freezing level, the snow melted and the balloon rose again. This was repeated a number of times during the rain. In the case of all other types of radiometeorographs, though one can observe the movements of the balloon up and down in the atmosphere from the pressure and temperature data, it cannot be ascertained whether these are caused by vertical currents of air or by accumulation of snow. In the case of the F-type radiosonde, however, if the balloon descends due to a strong downward current of air, the fan will continue to rotate (Venkiteshwaran and Tilakan 1952), while if it is forced down due to accumulation of snow, there will be no signals as the fan does not then rotate.

Radiosonde ascents were made immediately after thunderstorm rain over Poona on 28 and 29 September 1955. It was only raining very lightly at the time of release of the balloon. The balloons descended due to accumulation of snow a number of times and ascended again on the snow melting at lower levels. Details of the weight and thickness of water film and of snow accumulating on the balloons during such ascents and descents, are discussed in this paper. Some features of the dissipating stages of thunderstorms observed from the ascents of 28 and 29 September 1955, are also described.

2. The radiosonde ascents on 28 and 29 September 1955

A thunderstorm occurred over Poona on the evening of 28 September 1955. The rainfall chart for the day is shown in Fig. 1(a). The F-type radiosonde was released at 2104 IST, *i.e.*, about one hour and 45 minutes after the beginning of rain and when it was raining lightly over the station at the rate of about 20 cents per hour. After about 19 minutes, when the balloon had reached the pressure level of 592 mb (3973 gpm above station) where the temperature was of the order of about 3·5°C, signals stopped for nearly 6 min. The signals started again at the 25th minute, but from a level corresponding to 670 mb (2943 gpm about station) where the temperature was of the order of about 8·6°C. Obviously, the balloon had descended by nearly 1030 metres in 6 minutes. The signals again stopped after another 5 minutes. The levels from which the balloon ascended and descended on this date and the temperatures corresponding to these levels are given in Tables 1–3.

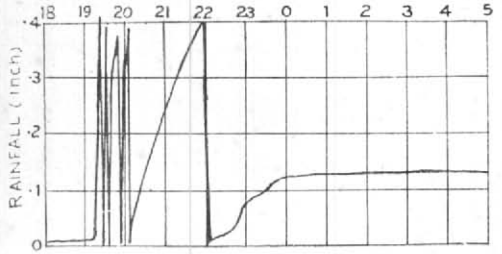

Fig. 1(a). Poona rainfall chart (28-29 September 1955)

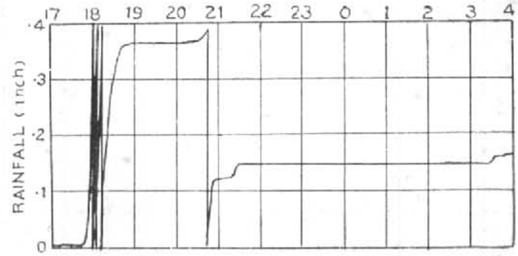

Fig. 1 (b). Poona rainfall chart (29-30 September 1955)

A similar performance of the F-type radiosonde balloon was observed on the next day also (29 September 1955) when a thunderstorm occurred at about 1800 IST. Fig. 1(b) shows the rainfall chart on this day. The radiosonde balloon was released at 2020 IST, *i.e.*, about 2 hours after the onset of the thunderstorm when there was light rain over the station. Radiosonde records were obtained for 21 minutes when the balloon reached the 530-mb level (4893 gpm above station) where the temperature was 1·2°C. The signals stopped and started again from a height of 3793 gpm above the station where the temperature was 8·4°C. No signals were received after the balloon rose to a height of 4783 gpm above the station where the temperature was about —3·6°C.

3. Discussion

Details of the levels upto which ascent or descent took place, the rates of ascent and descent, the temperatures at these levels etc, for these two flights and those of 6 and 7 October 1950 are given in Tables 1 to 3. There was also a similar experience in the F-type radiosonde ascent at Madras on 29 November 1955. Details of this ascent are also included in the tables.

(a) Weight of water on the balloon fabric and the thickness of the water film

It will be observed that the expected rate of ascent of all the 4 balloons (Table 1) was of the order of 21 kmph. The value was derived assuming the rate of ascent formula, *viz.*,

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

(where V is the velocity of ascent, L is the free lift, W is the weight of attachments, and q is a constant), to hold good for the radiosonde balloons. The value of q was calculated separately for NR 155 balloons used in 1950 and the Beritex balloons employed in 1955, from the observed rates of ascents on a number of days when the sky was clear.

However, as the balloons were released on all the 5 occasions during light rain, the rate of ascent had been reduced by accumulation of water on the balloon. The values of the weight of water that caused the reduction in the rate of ascent are given in Table 1. It is observed that the weight of water on one particular type of balloon is almost the same. The deposition of water on NR 155 balloons which are filled with more hydrogen and which therefore have a larger volume, is greater. The amount of water on the balloon increases with the area of wet fabric. It appears that the weight due to the film of water during the first phase of the ascent is about 20 to 25 per cent of the total lift, *viz.*, weight of balloon and attachments and free lift.

The thickness of the water film on the balloon was estimated for the ascent on 28 September 1955. The total lift due to hydrogen was 2600 gm and buoyancy of hydrogen being 1·2 kgm per cubic metre, the volume of gas in the balloon is approxmately 2·17 cubic metres. The ground pressure being 948 mb and the pressure experienced

TABLE 1

Date	Type of balloon	Weight of balloon (gm)	Weight of attach-ments (gm)	Free lift (gm)	Constant q* (min)	Calculated rate of ascent (kmph)	Actual rate of ascent immediately on release (kmph)	Weight of water film on balloon (gm)
6-10-50 (Poona)	NR.155	510	1080	1420	134	21	14·1	768
7-10-50 (Poona)	NR.155	520	1090	1410	134	21	12·8	877
28-9-55 (Poona)	Beritex	350	1300	950	153	21	12·5	596
29-9-55 (Poona)	Beritex	350	1000	1000	153	22	13·7	594
29-11-55 (Madras)	Beritex	500	2500	1000	153	18	12·8	510

* Constant q in the formula $V = q \dfrac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}}$ (V in metres/min)

TABLE 2

Date	Beginning of ascent		Beginning of descent	
	Height (gpm)	Temp. (°C)	Height (gpm)	Temp. (°C)
6-10-50 (Poona)	ground 557	23·5	5300	—0·7
	2830	10·8	5540	—2·2
	3550	12·5	4340	1·2
	3260	9·3		
7-10-50 (Poona)	ground 557	23·5	4350	2·7
	2940	10·2	4540	2·2
	3330	5·8	4350	2·3
	3330	6·0	5100	—3·6
	3070	5·1		
28-9-55 (Poona)	ground 557	21·5	4530	3·5
	3500	8·6	4350	2·9
	3550	8·1	4740	1·1
	3540	6·3	4350	4·0
	3350	8·1	4530	2·1
29-9-55 (Poona)	ground 557	24·0	5450	—1·2
	4350	8·4		
29·11-55 (Madras)	ground 15	23·5	4390	0·3
	3060	4·3	3990	2·1
	3380	3·3	4080	—4·7
	3490	2·8		

TABLE 3

Date and station	Time from release of balloon	ASCENT Ht. at beginning	ASCENT Ht. at end	ASCENT Ht. ascended	ASCENT Time	ASCENT Rate of ascent	Load on balloon	Time from release of balloon to beginning of descent	DESCENT Ht. at beginning	DESCENT Ht. at end	DESCENT Ht. descended	DESCENT Time	DESCENT Rate of descent	Load on balloon water and ice
	(min)	(gpm)	(gpm)	(gpm)	(min)	(kmph)	(gm)	(min)	(gpm)	(gpm)	(gpm)	(min)	(kmph)	(gm)
28-9-55 (Poona)	0	G557	4530	3973	19	12·5	596	19	4530	3500	1030	6	10·3	1200
	25	3500	4350	850	5	10·2	600	30	4350	3550	800	5¼	9·1	1146
	35¼	3550	4740	1190	5¼	13·6	533	40½	4740	3540	1200	5	14·4	1471
	45½	3540	4350	810	5	9·7	737	50½	4350	3350	1000	8½	7·1	1066
	59	3350	4530	1180	11½	6·1	864	70½	4530	3870	660	7	5·6	1021*
29-9-55 (Poona)	0	G557	5450	4893	21½	13·7	594	21½	5450	4350	1100	15¾	4·2	1040
	37¼	4350	5340	990	10	5·9	926	47¼	5340					
6-10-50 (Poona)	0	G557	5300	4743	20	14·2	768	20	5300	2830	2470	16½	9·0	1695
	36½	2830	5540	2710	14¾	11·0	1027	51¼	5540	3550	1990	23¾	5·0	1501
	75	3550	4340	790	9½	5·0	1338	84½	4340	3260	1080	18¾	3·5	1459
	103¼	3260	5570	2310	11¾	11·8	970	114	5570					
7-10-50 (Poona)	0	G557	4350	3793	17¾	12·8	877	17¾	4350	2940	1410	13¼	6·4	1547
	31	2940	4540	1600	10	9·6	1112	41	4540†	3330	1210	13	5·6	1513
	66¾	3330	4350	1020	8¾	7·0	1253	75½	4350	3330	1020	10½	6·0	1532
	86	3330	5100	1770	9½	11·0	1008	95½	5100	3070	2030	15¼	8·0	1625
	110¾	3070	4870	1800	11	9·9	1097	121¾	4870					
29-11-55 (Madras)	0	G15	4390	4375	20½	12·8	510	20½	4390	3060	1330	13¾	5·8	1100
	34¼	3060	3990	930	8½	6·6	870	42¾	3910	3380	610	9¼	4·0	1050
	62	3380	4080	700	7¾	5·4	931	59¾	4080	3490	590	12¾	2·8	1023

G—Ground

*Remained between levels 3870 and 3930 metres from 77½ to 91½ min. during which one pressure cycle was received due to a slow ascent

† Balloon floated at about 4540 metres for 12¾ min. when one cycle for temperature was received (1·5°C)

by the balloon before its first descent being 542 mb, the radius of the balloon corresponding to a mean pressure of about 640 mb is approximately 0·9 metre. If we assume that only the upper half of the balloon (*viz.*, 5 sq. metres) is wet, due to a weight of 596 gm of water, the thickness of the water film on the balloon will be about 0·12 mm. The thickness of the water film on the balloon calculated in the above manner for the flight of 7 October 1950 comes out to be 0·13 mm for the NR 155 type of balloon.

(*b*) *Weight and thickness of snow on the balloon fabric*

It will be observed from Table 2 that the descent takes place generally from about the freezing region. On most occasions, the rate of descent is less than the rate of first ascent. Lower levels are reached by the balloon when the rates of descent are greater or when larger accumulation of snow takes place. One can estimate the weight of snow deposited on the balloon from the rate of descent. For example, on 28 September 1955, the rate of first descent was 10·3 kmph, *i.e.*, 172 metres/min. If X is the weight of snow above that of the free lift of the balloon which casued this rate of descent,

$$172 = 153 \frac{X^{\frac{1}{2}}}{(X+350+1300+950)^{\frac{1}{3}}}$$

Solving this equation gives a value of 250 gm to X. As the free lift of the balloon was 950 gm, and it already had a film of water weighing 596 gm, the weight of snow deposited becomes 950—596+250 = 604 gm. This weight of snow has an approximate volume of 6000 c.cm. If it is spread uniformly on one square foot it would be only about three inches in depth.

This amount of snow is collected during the balloon ascent and can, therefore, take place in a comparatively short time. If the deposition is gradual, the rate of ascent will also be reduced gradually and this will be reflected in the rate of rotation of the fan.

TABLE 4

Time of beginning of cycle from release of balloon (min)	Legth (inches)
1	78
2·75	101
4·75	94
6·75	93·5
8·75	95
10·75	114
13	90
14·75	92
Fan becomes very slow from 18 min. and stops at 19 min. It again starts rotating slowly from 24·5 min. and faster from 26 to 28 min.	
24·75	115
27	83
Very slow after 30 min. and suddenly stopped at 30·5 min. Signals started at 35·25 min; slow up to 36 min.	
35·75	99
37·75	87
Slow after 40 min; stopped at 40½ min. Signal started at 45½ min; stopped at 50½ min.	
47·5	86
Started at 57½ min; very slow.	
60	165
64·25	146
Stopped at 70 min. Fan very slow; full cycles not available	

The variations in the rate of rotation of the fan indicates qualitatively the variations in the rate of ascent of the balloon (Venkiteshwaran 1952). The length of the paper tape for a complete Olland cycle is a measure of the rate of rotation and, therefore, the rate of ascent. The longer the length of the tape per cycle, the slower the rate and *vice versa*. The length of the complete cycles during the various ascents of the balloon on 28 September 1955 are given in Table 4.

Table 4 gives an idea of the way in which snow collects and falls off the balloon. It appears that the deposition of sufficient snow to bring the balloon down (about 600 gm) takes place within a minute. The balloon starts rising slowly and the loss of ice by melting seems to take a little more time, *viz.*, about one to two minutes. The acceleration and deceleration of the balloon in the beginning of its ascent and towards the end of the ascent has, however, to be allowed for.

One should generally expect the load due to the water film to be greater and greater for each successive ascent as the area of wet surface will generally increase. This is generally confirmed in all the four ascents.

It is also interesting to note from the records of 28 September 1955 that the balloon floated after its fifth descent. No signals were received during the fifth descent from 4530 to 3870 gpm, when the total load was 1021 gm. This descent occurred 70½ minutes from time of release: after this descent, two slow pressure signals were received at 77½ minutes (640 mb corresponding to 3870 gpm) and 91½ minutes (635 mb corresponding to 3930 gpm). This shows that by this time the balloon fabric had become so wet and heavy that the balloon did not rise for some time.

On 7 October 1950, after the second ascent to the level of 4540 gpm (temperature 2·2°C) at 41 minutes from time of release of balloon, there were no signals for nearly 12¾ minutes, when just one temperature signal was received corresponding to 1·5°C. The balloon later came down to the 3330 gpm level and began to rise after another 13 minutes (*i.e.*, 66¾ minutes after release). It may be inferred that on this occasion the deposition of snow was so critical as to make the balloon just float for some time in the freezing region.

(c) *Temperatures in the region of accumulation of snow on the balloon fabric and their relation to the "Bright Band"*

The level from which the radiosonde balloon will descend depends on the rate of accumulation of snow on the fabric. If the precipitation is light, the balloon may rise to levels above freezing level before it can descend. Observations of the four ascents described above show that the balloon descended from levels where temperatures were of the order of 2 to 3°C. It, therefore, appears that snow cannot accumulate on the balloon at temperatures higher than about 2-3°C and that in free atmosphere snow does not exist at higher temperatures.

Observations of rain have often been made at Poona using radar, type 717C operating on 9·1 cm. It was generally observed that when there was steady drizzle or rain, the *Bright Band* occurred at heights below the freezing level (Gupta, Mani and Venkiteshwaran 1955). The observations with the radiosonde balloon confirms the view that the *Bright Band* is associated with the melting of snow, occurs when steady conditions are obtained in the atmosphere and that the region of melting snow is stratified and not disturbed by vertical currents or turbulence.

(d) *Some features of the dissipation stages of thunderstorms at Poona*

On 28 September 1955, the thunderstorm started over the station at 1915 IST. The balloon was released after about 109 minutes, when it was raining very lightly. There was neither thunder nor lightning over the station or in the vicinity at the time of the flight. The conditions at the time of release of the balloon were similar the next day. If the total time from the building stage of a thunderstorm till the vertical motion within the cloud becomes insignificant, is taken to be approximately one hour (Byers and Braham 1949), it may be assumed that the balloons were released during their dissipating stage. On 28 September 1955, the balloon ascended and descended for nearly two hours after release. During this period, the air below the freezing level was stratified without any convection or turbulence in the dissipating thunderstorm.

The precipitation was from regions higher than the freezing level, and the origin of steady deposition of snow on the balloon (or the drizzle on the ground) was due to the settling down of the frozen water from high levels formed during the earlier stages of the thunderstorm. These steady conditions extend over a wide area and presumably throughout the dissipating thunderstorm cell.

It may be mentioned in conclusion, that the wetting of the balloon has appreciably contributed to the reduction of the free lift by more than half; the wet surface should have facilitated the collection of snow and forced the balloon down. This is a serious handicap in releasing balloons during rain, but it can be mitigated to an appreciable extent if the balloons are treated suitably so that no water can stick to the fabric.

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