Indian J. Met. Hydrol. Geophys. (1976), 27, 2, 194-200

551.501.1 : 551.507.362.1 : 551.506.7

Data processing of M-100 meteorological rocket system*

V. NARAYANAN

Vikram Sarabhai Space Centre, Trivandrum

(*Received 11 December 1974*)

ABSTRACT. Regular weekly synoptic data of the stratospheric and mesospheric temperature, pressure and wind over Thumba (Lat. 8°32'N, Long. 76°52'E) have been obtained since 9 December 1970 using Soviet meteorological M-100 rockets. Methods employed for processing the various types of data and their analysis procedure utilised in these Soviet meteorological rocket soundings are described. The preliminary processing of the radar and telemetry data is carried out manually, while the final data reduction is done by either Minsk-22 or IBM-360/44 computer. The chaff wind data reduction method adopted in the piggy back fibre glass and copper chaff cloud experiments using M-100 rockets is also explained briefly.

1. Introduction

The M-100 vehicle is a two-stage solid propellant rocket which can reach a maximum altitude of 90 km, when fired at 83° elevation carrying a meteorological payload of weight 66 kg. The standard M-100 rocket payload consists of the following:

(*a*) Four tungston rhenium (40 micron) wire thermometers for measuring temperature in different ranges covering —100°C to +350°C.

(*b*) Two Pirani (hot wire) manometers for measuring pressure from 50 to 5×10^{-3} mm of mercury.

(*c*) Other supplementary thermometers for monitoring payload housing temperature and manometer temperature.

(*d*) Electronic devices including a mechanical 60 channel commutator, telemetry transmitter 22 MHz, 1780 MHz, radar transponder, antenna system and power supply.

The unbalanced Wheatstone's bridge circuit is used for telemetering the manometer and thermometer data to the ground. Two telemetry receivers with panoramic and photographic attachments record them along with the timing pulses (10 pps) from lift-off. The steeple portion of the payload containing the sensors opens at 60 seconds and the whole payload is separated at 70 seconds from the rocket and attains maximum altitude of 90 km at 140 seconds. A 35 square metre area hemispherical nylon non-reflecting parachute exerts a stabilizing influence on the payload and fully opens during descent at an altitude of 60-65 km around 200 sec.

The Meteor radar (1780 MHz) tracks the payload in the transponder mode and the tracking data — azimuth, elevation and slant range — are photographed every second for the first 10 minutes. Processing the telemetry and radar films, initial data are obtained. The preliminary data are fed to either Minsk-22 or IBM-360/44 computer for getting the final results. Computer programmes have been worked out for obtaining the ROCOB data in the format as per the latest WMO recommendation introduced from 1 January 1972, in the punched tape form ready for transmission to all national as well as international meteorological centres. The preliminary and final data reduction techniques used in the M-100 rocket system are briefly described.

2. Processing of telemetry data

All the telemetry signals in one cycle of 5 seconds characterise the readings of the atmospheric parameters recorded on the photographic film (Fig. 1). Each signal is registered on the film as three dot points that are plotted close to one another. These points are usually well distinguished from other interference signals. The vertical displacement of a signal from the zero line on the photographic film varies proportionately to the voltage supplied from the bridge output to the transmitter and depends upon the value of the parameter being measured. The initial processing of the telemetered data includes a deciphering of the signals available on the film in certain time intervals and their conversion into values of temperature and pressure with the help of graduated graphs. The deciphering consists of finding out the signals of a given transmitter on the film with the aid of a code table and taking their readings (voltages) against time (Fig. 2). Ten pps records are

*This paper was presented in the Symposium on 'Numerical Weather Prediction' held in New Delhi during 25-27 July 1973.

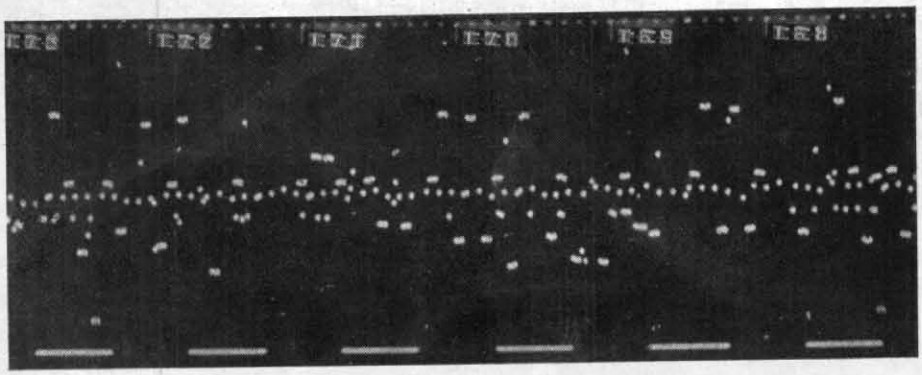


Fig. 1. Typical telemetry signals recorded on photographic film in one cycle 5 seconds 60 channels (Flight No. 08·50.)

1	K-1	-101									
2	K-2	-50									
3	0	219	224	229				250	255	260	265
4	K-3	51									
5	K-4	102									
6	B-1a	78	90								
7	B-1δ										
8	B-2a						-80	-93	-38	-25	-2
9	B-2δ	-68	--	28	36						
10	0				235	240	245				
11	T-1a	49	12	-17	-39	-49*	-52*		-80	--	-75
12	T-2a		--	85	62	53	46	43	40	--	29
13	T-3a	47	12	-16	-38	-48	-53	-58	-57	--	-74
14	T-4a		--	78	60	50	44	42	38	--	27
15	0	220	225	230				251	256	261	266
16	B-1a	86									
17	T-3δ	-61	-92								
18	T-3a	45	12	-15	-38	--	--	-55	-58	-70	-74
19	B-1δ										
20	0				236	241	246				
21	T-1δ	-65	-94								
22	T-2δ	20	-12	-36	-49	-56	--	-65	-66	-73	-80
23	T-3δ	-65	-96								
24	T-4δ	21	-13	-37	-51	-59	--	-65	-66	-75	-78
25	0	221	226	231						262	267
26	T-1a	40	3	-25	-41	-50	-57	-56	-63	-71	-80*
27	T-1δ	-65	-98								
28	T-2a		--	75	60	52	44	44	40	30	26
29	T-2δ	19	-14	-37	-51	-56	-63	-63	-67	-72	-81
30	0					242	247	252	257		

*SIGNALS FROM TELEMETRY 2.

31	T-1a	40	3	-29	-42	-49	-56	-60	--	-68	-74
32	T-2a		--	75	52	52	46	43	--	29	26
33	T-3a	37	3	-25	-42	-46	-54	-62	-69*	-69	-72
34	T-4a		--	77	56	49	45	40	--	28	26
35	0		227	232	237						
36	B-1a	88									
37	B-1δ										
38	B-1a	96									
39	B-1δ										
40	0	222				243	248	253	258	263	268
41	D-1										
42	T-ab	-5	-5	-5	-5	-5	-5	-6	-6	-7	-7
43	T-aw	17	15	13	14	13	14	12	10	7	6
44	T-ag										
45	0			233	238						
46	B-2a						-104	--	-26	-16	-12
47	B-2δ	-55	18	54	60						
48	D-1										
49	D-2										
50	0	223	228					234	259	264	269
51	T-1δ	-81									
52	T-2δ		-20	-45	-54	-60	-64	--	-70	-74	-80
53	T-3δ	-82									
54	T-4a		90	66	52	45	43	--	35	--	26
55	0				239	244	249				
56	T-1a	23	-8	-35	-48	-56	-57	--	-66	-70	-75
57	T-2a	116*	90	69	56	47	47	40	34	27	26
58	B-1a	94									
59	B-1δ										
60	0			234							

FIGURES GIVEN IN ◯ DENOTE TIME IN SEC.

Fig. 2. Deciphered telemetry data (Flight No. 08·50)

also available on the side of the film for taking the time accurately.

The telemetry signals are deciphered by means of a decoder which projects the enlarged signals from the telemetry film to a special screen. The voltages obtained during the operation of transmitters can be taken from the film making use of numbered scales which can be moved on the screen.

Deciphering is carried out for all cycles beginning from 70 seconds to 300 seconds every cycles, every alternate cycles from 300 seconds to 600 seconds, every third cycle from 600 seconds to 1000 seconds, and thereafter every tenth cycle. The voltage readings taken from the film are converted into values of temperature and pressure with the help of graduated curves after calibration and plotted on graph paper with the aid of typewriter against time with the following scales :

1 cm = 2 sec from 50 to 300 sec.

1 cm = 10 sec from 300 to 1000 sec.

1 cm = 200 sec from 1000 sec till end.

Average curve is fitted to the data plotted for the four thermometers (Fig. 3). Manometer data processing is done separately (Fig. 4). Filament temperature, steeple temperature, log P and manometer temperature values are picked up from the above plots.

3. Meteor radar data processing

A typical film record of the Meteor radar tracking data — azimuth, elevation and slant range — is shown in Fig. 5. The readings are tabulated every 5 sec interval starting from 70 to 600 sec and every 30 sec intervals from 450 sec till elevation falls below 10 mils (6°). The readings are taken after 10 min from the Meteor data print out record. These readings are plotted for assessing the tracking data (Fig. 6). Wherever radar tracking data are not good, smoothed readings are taken from the graph accurate to 0·01 km for slant range, one mil for elevation and azimuth. The tracking values of the angles and slant range at 5 sec interval are used for computing the rocket trajectory co-ordinates, speed as well as wind velocity.

4. Final data reduction

Manually processed preliminary data — radar tracking data, temperature and manometer data at 5 seconds interval — are tabulated (Fig. 7); punched on tape and fed to Minsk-22 computer along with the standard M-100 computer programme for the final data reduction. The computer programme permits to solve the following problems —

(1) Preparation of original data for processing.

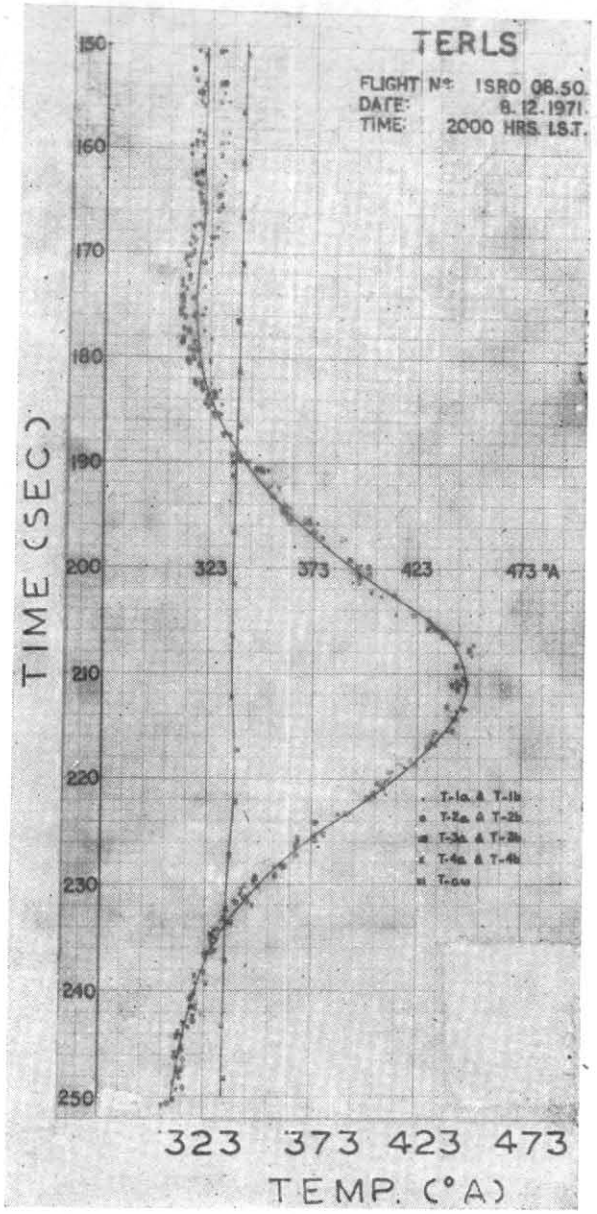


Fig. 3. Plotted telemetry data of temperature (Flight No. 08·50)

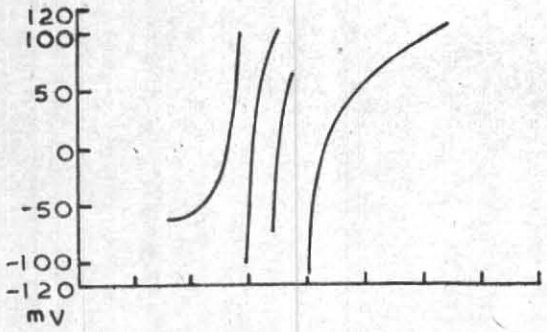
(2) Processing of radar data :

(*a*) calculation of the co-ordinates of rocket and trajectory,

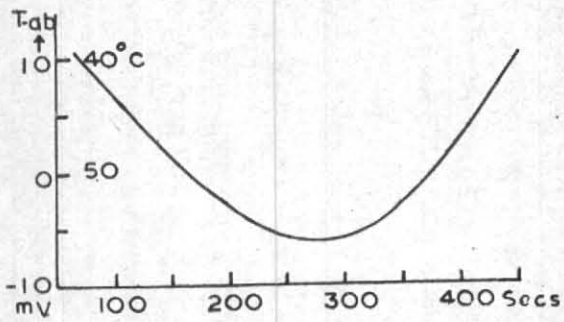
(*b*) calculation of the components and total velocity of rockets, and

(*c*) calculation of the wind components, speed and direction.

(3) Co-relation of original data to standard altitude and restoration of the results of tracking.



	B-1b		
+70	191	52.3	-2.08
+80	192	52.4	-1.98
+90	193	52.5	-1.86
+100	194	52.5	-1.79
	B-1a		
-100	195	52.6	-1.79
-90	196	52.7	-1.71
-80	197	52.8	-1.65
-70	198	52.9	-1.59
-60	199	52.9	-1.53
-50	200	53.0	-1.48
-40	201	53.1	-1.43
-30	201	53.1	-1.38
-20	202	53.2	-1.34
-10	203	53.3	-1.29
0	203	53.3	-1.25
+10	204	53.4	-1.21
+20	206	53.5	-1.16
+30	207	53.6	-1.11
+40	209	53.7	-1.06
+50	211	53.9	-0.99
+60	213	54.0	-0.93
+70	216	54.2	-0.85
+80	219	54.4	-0.76
+90	222	54.6	-0.68
+100	226	54.9	-0.54
	B-2b		
-70	219	54.4	-0.63
-20	223	54.7	-0.52
+30	231	55.2	-0.41
	B-2a		
-70	252	56.1	-0.19
-20	260	56.4	-0.06
+30	281	56.6	+0.13
+80	326	55.2	+0.45
+100	362	52.6	+0.75



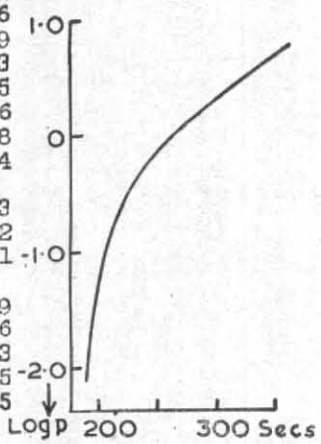


Fig. 4. Manometer data processing (Flight No. 08·50)

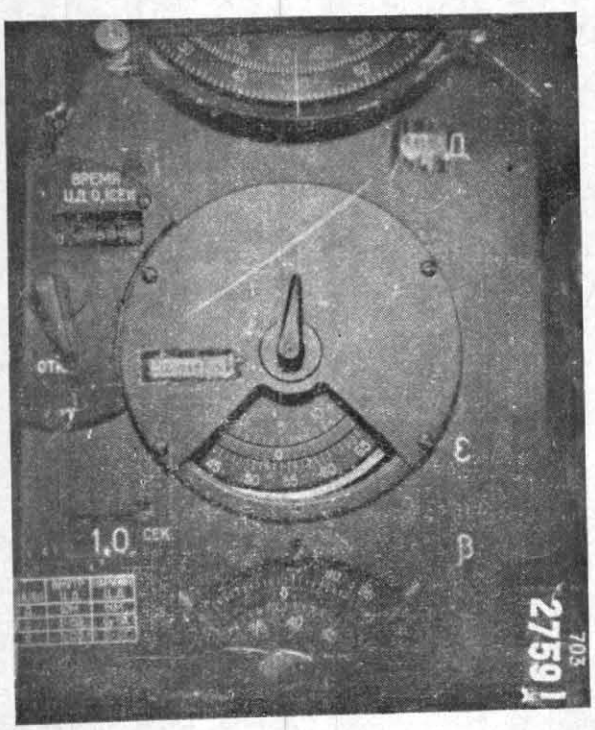


Fig. 5. Typical film record of Meteor reader tracking data

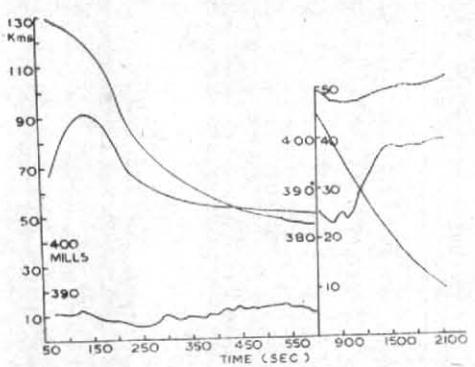


Fig. 6. Meteor data smoothing—azimuth, elevation and slant-angle

TIME (SEC)	ELEVATION (r)	AZIMUTH (w)	SLANT RANGE (D)	T_θ °K	T_{wn} °K	lgP	tM°C
215	92,3	383,6	7260	435,0	332,0	-0,82	54,1
220	90,4	383,3	7065	407,0	332,0	-0,68	54,5
225	88,0	383,0	6894	374,0	331,0	-0,56	54,8
230	86,0	382,8	6750	346,0	331,0	-0,47	55,1
235	84,0	382,6	6648	326,0	331,0	-0,38	55,4
240	82,0	382,5	6547	315,0	330,0	-0,30	55,6
245	80,5	382,4	6473	310,0	329,0	-0,24	55,8
250	79,1	382,8	6393	308,0	328,0	-0,18	56,0
255	78,1	382,7	6321	304,0	326,0	-0,12	56,2
260	77,0	382,7	6261	301,0	325,0	-0,07	56,4
265	75,6	382,7	6201	294,0	324,0	-0,03	56,5
270	74,5	383,1	6135	288,0	323,0	0,03	56,6
275	73,1	383,2	6094	284,0	322,0	0,07	56,6
280	72,2	383,6	6047	281,0	321,0	0,12	56,6
285	71,0	384,1	6000	280,0	320,0	0,16	56,6
290	70,1	384,9	5947	278,0	318,0	0,20	56,5
295	69,6	385,0	5912	274,0	316,0	0,24	56,5
300	69,1	384,9	5878	266,0	313,0	0,28	56,3
305	68,0	384,7	5836	264,0	312,0	0,32	56,2
310	67,4	383,9	5795	260,0	311,0	0,36	56,0
315	66,5	384,4	5720	257,0	309,0	0,40	55,7
320	65,9	384,0	5676	255,0	307,0	0,44	55,5
325	65,2	384,0	5634	253,0	305,0	0,47	55,2
330	64,5	384,2	5624	252,0	303,0	0,51	54,9
335	64,0	384,3	5600	251,0	301,0	0,55	54,6
340	63,2	384,5	5570	250,0	299,0	0,59	54,3
345	62,6	384,6	5542	249,0	298,0	0,63	54,0
350	62,0	384,5	5529	248,0	296,0	0,66	53,6
355	61,5	384,5	5519	247,0	294,0	0,70	53,2
360	60,8	384,4	5519	246,0	292,0	0,74	52,7

Fig. 7. Preliminary data for computer feeding

(4) Processing of telemetry data :

(*a*) calculation of temperature, pressure and density at standard altitudes using the results of thermometer measurements, and

(*b*) calculation of atmospheric pressure at standard altitudes as per the results of manometer measurements.

(5) Storage and formulation of the results.

5. Method of verification and checking

The computer print out results are plotted for further analysis and checking in respect of velocity altitude, temperature, density and wind. Typical M-100 flight data analysis are shown in Figs. 8-10 (velocity, height, time curve, temperature and wind profiles). Nearest available high level radiosonde RAOB and CIRA 1965 data are also plotted along with the ROCOB for comparison. In case of telemetry data failure, only wind data is reported. In the absence of accurate radar tracking data, but telemetry data available, temperature computation is less reliable. However, approximate temperature calculation can be carried out upto 50 km altitude based on the nearest available flight having the same apogee and other trajectory characteristics. If the steeple thermometer does not function properly in any flight the previous flight data can be utilised for computation. Normally the steeple temperature may not vary from flight to flight in a particular season.

6. Chaff wind data processing

Additional fibre glass and copper chaff payloads

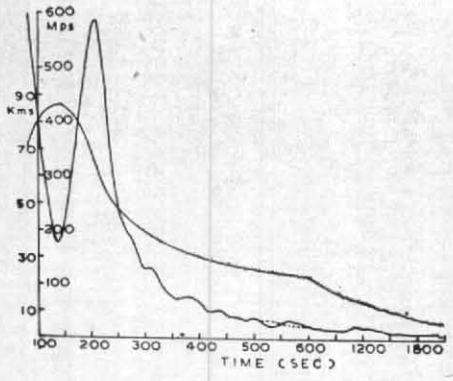


Fig. 8. Velocity height curve (Flight No. 08·50)

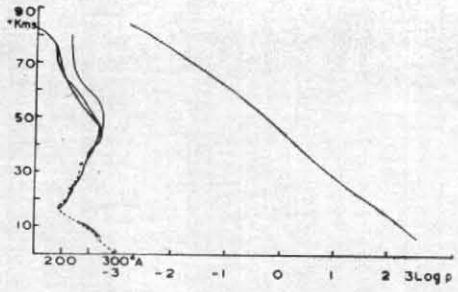


Fig. 9. Temperature profile (Flight No. 08·50)

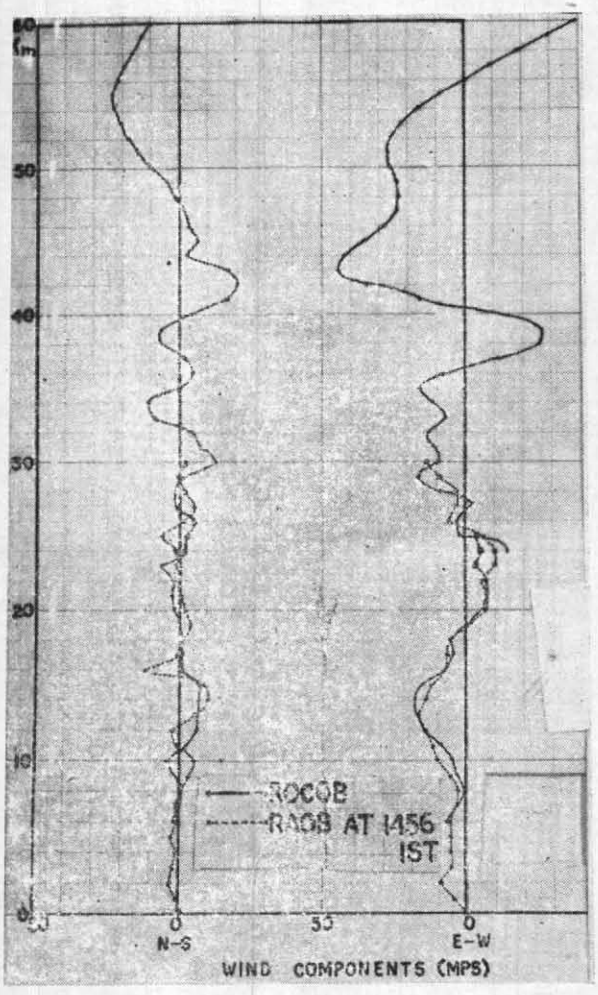


Fig. 10. Wind profile (Flight No. 08·50)

have been flown successfully in M-100 rockets from Thumba since November 1972 to collect wind data in the upper mesospheric region 60-90 km which is not normally covered by the standard M-100 rocket system. The copper chaff data provide interesting overlapping wind observation below 60 km with parachute. In the Soviet system 3 or 4 fibre glass chaff bundles are ejected at 10 km intervals from 90 km downwards and the different chaff clouds are tracked by a single radar system. As this special radar facility is not available at Thumba, two type chaffs — copper and fibre glass — are ejected at 70 sec and 145 sec corresponding to altitudes 70 and 90 km respectively. The cotal LV-300 radar is utilised to track the two chaff clouds alternately at 10-minute interval. The chaff cloud tracking data recorded on three strip charts in the cotal radar system are analysed manually and the readings converted into azimuth, elevation and slant range at 5 sec interval for the first 10 min and thereafter every 30 sec by a simple computer programme. Final chaff wind data reduction is carried out by a standard computer programme in IBM-360/44 computer giving due allowance for the radar hunting and smoothing. The computed height is smoothed by fitting a second degree curve taking 13 points each. Average winds over one km thickness are computed and printed out along with wind components and fall velocity. Extrapolated values are rejected while reporting.

7. Concluding remarks

The Pirani gauge manometer data processing at Thumba was not found to be satisfactory mainly due to pre-flight calibration inaccuracy. In a large number of flights, pressure sensors did not

operate well. Pressure and density data were computed, extrapolating radiosonde pressure data at the levels of 10, 15, 20, 25 and 30 km. The pressure values thus computed were found to be in good consistency. Meteor radar tracking data are very important in the data reduction of temperature from telemetry records. The accuracy of temperature measurement is ± 3°C below 50 km, ± 5°C from 50 to 60 km and ± 7 to 10°C above 60 km. The error in the wind measurement is of the order of 5 m/s in the region 40-50 km and 10 m/s above 50 km.

Acknowledgements

The author is grateful to Shri R. Aravamudan, Head, Thumba Equatorial Rocket Launching Station and his team of engineers for the cooperation extended in carrying out the regular M-100 rocket soundings. Thanks are also due to Prof. P. R. Pisharoty, Director, Remote Sensing and Meteorology Division, Satellite Application Centre, Ahmedabad for the discussion and guidance during the course of this research work. He is grateful to Dr. A. V. Fedynski and Dr. Y. P. Koshelkov and other Soviet specialists who have trained him in the analysis of the data. The author wish to thank all the operational personnel in TERLS especially Met. Office, Minsk-22 and IBM-360/44 computer staff for their co-operation and assistance in the computational work.

REFERENCES

Gaigerov, S. S. *et al.*	1970	*Space Research*, **X**, North Holland Publishing Co., Amsterdam, p. 169.
Ivanov	1968	*Processing of Rocket data*, Central Aerological Observatory, Moscow, USSR.
Kokin, G. A.	1964	French Reprint, Published by Met. Soc., France.
Kats, A. L.	1970	*Stratospheric & Mesospheric Circulation*, Israel Program for Sci. Translation, Jerusalem.
Willis, L. Webb	1969	*Stratospheric Circulation, Progress in Astronautics & Aeronautics*, **22**, Acad. Press, New York.