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Evidence of Turbulence in the Stratosphere

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Arnold (1954) has observed considerable turbulence in the stratosphere on four different occasions at Belmar, New Jersey, while tracking balloons with a telescope and a radio direction finder. The turbulence was so severe that the radiosonde separated from the balloon, though it was suspended with a cord with a nominal breaking strength of about 70 lbs. During three observations in June 1950, the instrument separated from the balloon at heights ranging from 28 to 32 km, while in the observation in October it separated at 24 km. He has estimated that a descending current of about 11 m. sec^{-1} could provide the necessary conditions for a free fall of the sonde of about 10 ft which could break the line.

Records of Dines meteorograph ascents made in India have often indicated that the end of the trace when the balloon bursts in the stratosphere, is associated with a blur, indicating violent jerking oscillations. This jerk is noticed not only on the temperature trace, but also on the humidity trace and in the datum pen also at corresponding positions (Fig. 1). Since all these pens are fixed to a frame which shifts with pressure, it appears that the blurs are associated with vibrations experienced by the aneroid. The only possible cause of such vibrations appears to be the existence of turbulence in the stratosphere.

Sinha (1954) has examined the blur occurring in the records of Dines meteorograph ascents made at Agra. In the 250 records examined by him, he found the occurrence of blur on 66 occasions above the 100-mb level (about 16 km). Of these 26 occasions were above the 50-mb level (20 km).

All records of Dines meteorograph ascents made at Poona (Lat. 19°N, Long. 74°E) and Hyderabad (Lat. 17°N, Long. 78°E), Madras (Lat. 13°N, Long. 80°E) and Bangalore (Lat. 13°N, Long. 78°E) were examined in order to study the frequency of occurrence of blurs at the end of the trace at the time of bursting of the balloon above the 100-mb level. The ascents at Agra, Poona, Hyderabad, Madras and Bangalore give a fair representation of the occurrence of turbulence in the region of the tropopause and above, over almost the whole of India.

Table 1 shows the monthly distribution of the number of Dines meteorograph ascents terminating in the regions 100–50 mb and above the 50-mb level due to the bursting of the balloon. It also gives the number of occasions when the termination of the record was associated with a blur, over Poona—Hyderabad and Madras—Bangalore.

At Agra, out of about 180 records which reached levels above 100 mb, about 66 had blurs. The corresponding figures for Poona—Hyderabad are 126 and 22 and for Madras—Bangalore 180 and 79. The frequency of bursting of balloons at Poona—Hyderabad between the 100 and 50-mb levels is greater than those at higher levels. The occurrences of blur at burst are small. Most of the flights over this area were prior to 1935 and the balloons then available did not reach greater heights. One cannot, therefore, infer from the lower percentage of blurs over this area, that it is an indication of any special feature in the atmosphere.

The bursting of the balloon due to turbulence depends upon the quality and strength

TABLE 1

No. of balloon flights terminating between 100—50 mb and above 50-mb level and the frequency of occurrence of blur

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
					(*a*) POONA—HYDERABAD								
No. of flights terminating at levels above 50 mb	6	7	4	4	2	2	..	4	..	2	8	12	51
No. of flights terminating above 50-mb level with blur	0	0	1	1	0	1	..	0	..	1	7	5	16
No. of flights terminating at levels between 100-50 mb	11	9	5	6	1	2	3	5	10	14	6	3	75
No. of flights terminating between 100 and 50 mb with blur	1	2	0	0	0	0	0	0	0	3	0	0	6
					(*b*) MADRAS—BANGALORE								
No. of flights terminating at levels above 50 mb	12	7	5	8	5	6	3	5	1	10	20	11	93
No. of flights terminating above 50-mb level with blur	8	4	1	4	4	5	1	3	1	6	6	6	49
No. of flights terminating at levels between 100—50 mb	8	7	6	3	3	4	13	9	9	6	10	9	87
No. of flights terminating between 100 and 50 mb with blur	0	2	4	1	2	0	7	3	1	3	7	0	30

of the fabric. The mean pressure value of the displacement due to the blur may give an indication of the severity of the turbulence and the quality of the balloon fabric. Table 2 gives the mean monthly pressure at which the flight terminated and the mean pressure value of the displacement of the recording pen due to the turbulence. Though the number of observations over Poona—Hyderabad is comparatively smaller, it can generally be concluded that the region of turbulence in the stratosphere is about 30 mb (*i.e.*, nearly 23 km) with another region of turbulence just below the tropopause between 70 and 90 mb (between 17 and 18 km).

It is interesting to note that the level of occurrence of turbulence in the stratosphere, as observed from the records of the Dines meteorographs, *viz.*, about 23 km agrees very nearly with the observation of Arnold (1954). The region of turbulence between 17 and 18 km observed in the above analysis agrees also fairly closely with those made from the rate of rotation of the fan in the records of the F-type radiosonde of the India Meteorological Department (Venkiteshwaran and Huddar 1958). It is observed from these radiosonde records, that there is a region of turbulence between 15–17 km just below the region of lowest temperature in the tropopause.

If we assume that the mean pressure value of the displacement due to the blur indicates roughly the depth of turbulent layer, then it is observed that the thickness of this layer

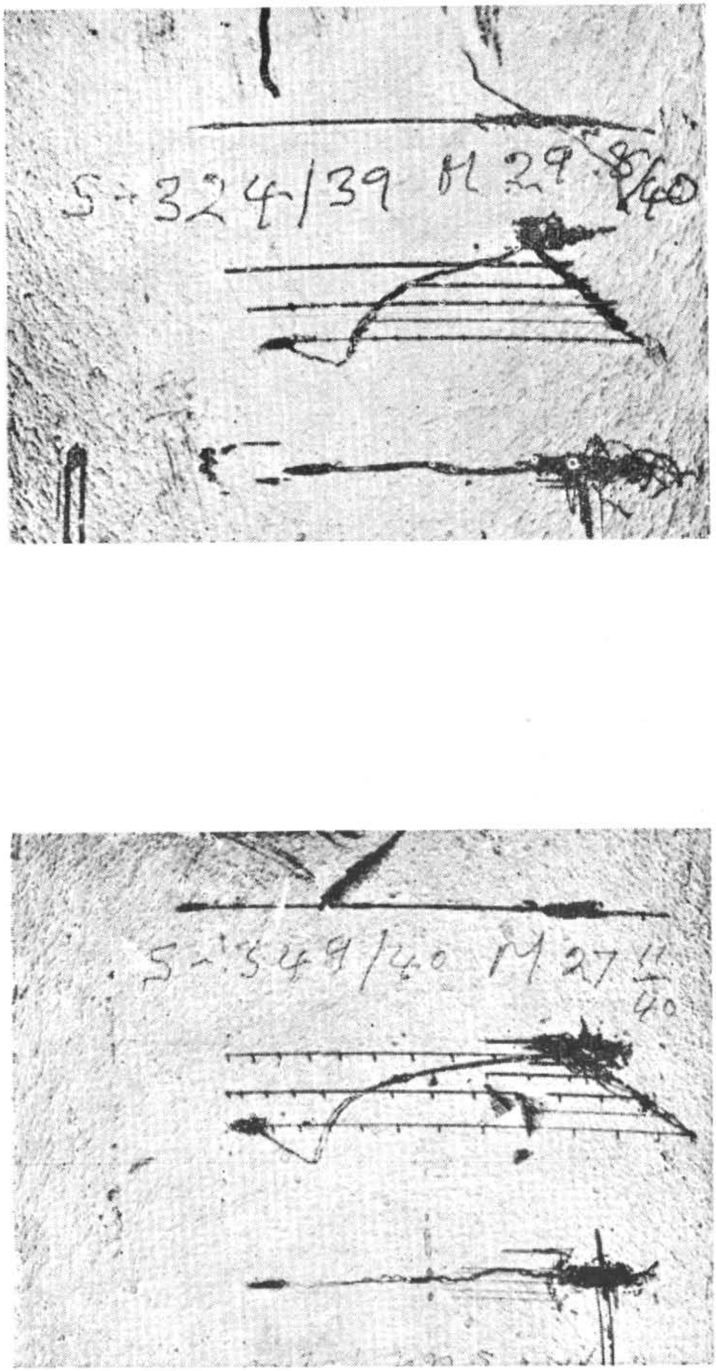

Fig. 1

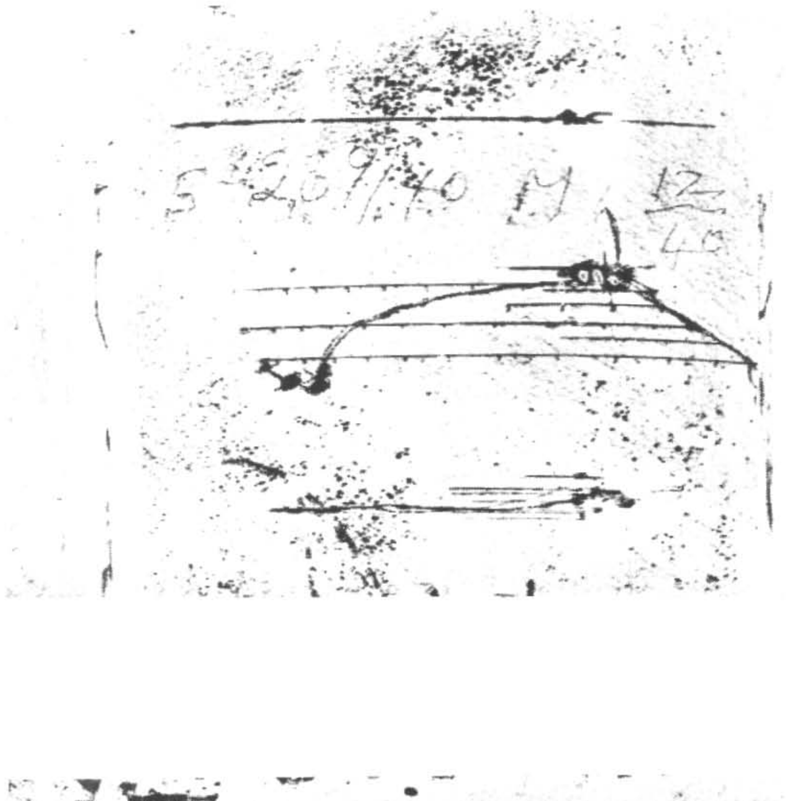

Fig. 2

TABLE 2

Mean pressure at which end blur occurs in different months and the mean displacement due to blur

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
						(*a*) MADRAS—BANGALORE (<50 mb)							
No. of occasions with blur	8	4	1	1	4	5	1	3	1	6	6	6	46
Mean pressure at termination of flight	30	33	23	39	28	30	45	42	46	34	34	34	24
Mean pressure value of displacement due to blur	17	18	10	15	9	19	10	12	20	21	25	16	16
						(100-50 mb)							
No. of occasions with blur	0	2	4	4	2	0	7	3	1	3	7	0	35
Mean pressure at termination of flight	..	68	69	53	64	..	86	61	93	73	56	..	69
Mean pressure value of displacement due to blur	..	20	24	13	17	..	11	13	20	20	19	..	17
						(*b*) POONA—HYDERABAD (<50 mb)							
No. of occasions with blur	0	0	1	1	0	1	0	0	0	1	7	5	16
Mean pressure at termination of flight	..	..	41	36	..	30	..	..	..	44	23	23	27
Mean pressure value of displacement due to blur	..	..	10	25	..	20	..	..	..	5	10	13	12
						(100-50 mb)							
No. of occasions with blur	1	2	0	0	0	0	0	0	0	3	0	0	6
Mean pressure at termination of flight	75	90	..	..	..	..	..	..	..	91	..	..	88
Mean pressure value of displacement due to blur	15	27	..	..	..	..	..	..	..	8	..	..	15

in the stratosphere is between 1–2 km. It is nearly of the same order just below the tropopause also. The thickness of the highest layer just below the tropopause observed on the Dines meteorograph records agrees with the value observed from the records of the F-type radiosonde (Venkiteshwaran and Huddar 1958).

There may be a doubt whether the blur was caused due to turbulence or whether the impact of the balloon fabric from the bursting balloon may as well have caused the blur just as the impact with the ground at the end of the descent is seen as a blur at the other end of the trace. The arguments against the latter suggestion are as follows—

(1) During the balloon ascent the Dines meteorograph is mounted inside a cylindrical aluminium cover of about three inches diameter, and this is fixed in the centre of a bamboo cage. When the balloon bursts crosswise frames of the bamboo cage will prevent bigger pieces of its fabric falling on the instrument.

(2) The meteorograph is fixed inside the aluminium cover with brass wires drawn diametrically across the cylinder from a number of points both at the top and bottom. This will prevent even small pieces falling and hitting the aneroid which is low for the end of the cylindrical cover.

It has been noticed that the blur occurs on all the recording pens of the meteorograph. If balloon pieces were the cause, there would have been occasions when at least one of the pens is unaffected, which has not been observed.

(3) The nature of the blur shows that it is not due to the impact of any piece of the balloon fabric, since it is associated with a very large number of motions of the pen in the trace in a definite layer of the atmosphere. Fig. 2 shows the photograph of records in which there are blurs both in the stratosphere and just below the stratosphere separated by regions of clear record. This shows definitely that the blur is not due to impact of the balloon at burst.

(4) Moreover, the balloon is at a height of about 50 ft above the instrument. Even if the balloon bursts to pieces, the free ones will be carried away by the wind and may not, therefore, fall on the instrument. Even if any part is remaining on the string, the air will exert a greater drag on it than on the instrument.

Considering the above factors the assumption that the blur is only due to turbulence in the atmosphere seems to be justifiable.

REFERENCES

Arnold, A.	1954	*Bull. Amer. met. Soc.*, 5, 8, pp. 377-378.
Sinha, K. L.	1954	*Weather*, 9, 1, pp. 1-8.
Venkiteshwaran, S. P. and Huddar, B. B.	1958	*Indian J. Met. Geophys.*, 9, 4, pp. 400-401.