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Hot Weather Angels associated with High Level Temperature Inversions

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ABSTRACT. During the hot weather months (April to June), the CPS-9 radar installed at Safdarjung Airport, New Delhi, has been recording angel echoes having certain peculiar characteristics; the most important amongst them being the apparent association of the angel activity with an upper level temperature inversion or an isothermal layer between 6 to 11 km above ground. Examples of this type of angel activity, observed on seven different dates spread over a three-year period (1958 to 1960) are presented and their characteristics discussed in this paper. Their apparent association with high level temperature inversion is also explained.

1. Introduction

One CPS-9 radar (Specifications: X-band, 3·2 cm wavelength, 250 KW peak power, 0·5 and 5·0 microseconds pulse width, and 1 degree conical beam) has been in operation at Safdarjung Airport, New Delhi since September 1957. During this period, some angel echoes, with certain peculiar but interesting characteristics, have been recorded and are presented here.

2. Data

Figs. 1 to 7 show a set of radar echo photographs taken on the CPS-9 radar. All these photographs show the existence of 'blobby' or 'spotty' angels. The time of the year for these seven examples varies from the third week of April to the third week of June. These months can be classified as the hot weather months for north India.

Fig. 8 (a and b) shows the profiles of dry-bulb temperature and wind over New Delhi for these days and have been taken from the 00 GMT and 12 GMT radiosonde-rawin ascents for New Delhi.

3. Characteristics of the observed angels

A close and careful examination of Figs. 1 to 8 brings out the following characteristics of the observed angel activity—

(*i*) These were angels of a blobby or spotty nature.

(*ii*) These occurred during the hot weather months (late April to late June) only.

(*iii*) These occurred in the presence of isolation only and were never observed at nights.

(*iv*) The angel activity was more or less equally distributed upto about 25 miles all round the station; although at occasions, it is extended to about 50 miles. It was mainly limited to the first 5000 ft above ground level as revealed by the RHI photogrphs.

(*v*) The vertical wind profiles showed that shear was practically absent.

(*vi*) There were always some convective echo cells present in the neighbourhood thus characterising the unstable and turbulent nature of the lower atmosphere.

(*vii*) A very significant feature was the simultaneous occurrence of an upper level temperature inversion or an isothermal layer.

Table 1 gives heights of base of temperature inversion or isothermal layer (both for 00 GMT and 12 GMT radiosonde-rawin ascents) as well as the time of observation of the angel activity.

TABLE 1

Date	Height of base of temperature inversion or isothermal layer (km above ground)		Time of observation of angel activity
	00 GMT	12 GMT	(IST)
16-6-1958	..	5·94	1500—1630
17-6-1958	..	5·58	1500—1600
18-6-1958	6·31	..	0830—0900
17-4-1959	10·01	10·71	1300—1800
28-5-1960	6·03	5·73	1430—1530
13-6-1960	..	6·06	1430—1530
21-6-1960	7·06	8·24	1630—1700

It will be seen from Table 1 that there is no instance when this type of angel activity occurred without the simultaneous presence of an isothermal or inversion layer between 6 to 11 km above ground. On 18 June 1958, when angel activity was observed at about 0845 IST and not in the afternoon, it is significant to note that there was no inversion or even an isothermal layer in the evening sounding on that day. On other days when the angel activity was observed in the afternoons, there were temperature inversions present invariably in the afternoons. Thus the observed angel activity appeared to be associated with a high level temperature inversion at about 6 to 11 km above ground level.

4. Discussion

At a casual glance, the nature of these angels resembles that of the familiar angels of Harper (1957) and others which are unquestionably due to scattering of radar energy by birds and insects. But a little careful thought eliminates birds or insects as possible sources for these angels. Firstly, birds and insects are known not to fly at temperatures above 35° C. Secondly, the indicated angel source sizes of some hundreds of feet are not readily explained by birds or insects, in any case, not by birds or insects found over inland areas. Perhaps the only insect found over inland areas, flocks of which may give appreciable radar return, is locust. However, no locust swarms were reported over the area on these days. Thirdly, the concentration of birds or insects should tend to increase in the evenings whereas the angel activity was always found to decrease towards evening. Finally, the almost fixed position of these angels over an appreciable period completely eliminates the possibility of these echoes being due to scatter from birds etc.

A careful consideration of the seven characteristics of these angels as mentioned in Section 3 of this paper leads to the belief that these blobby angels were the result of turbulence in the lower atmosphere. It has been known since long that radar reflections in the lower atmosphere, referred to as angels, are the result of atmospheric turbulence which creates abrupt changes in the dielectric constant (Gordon 1949). In these cases, the turbulent atmosphere gave rise to numerous thermals or bubbles which were responsible for the widespread angel activity due to refraction of energy at the refractive index inhomogenities at the interface of the thermals or blobs set in the unstable turbulent atmosphere (Atlas 1959) and at a time when most of these thermals were still not sufficiently developed to reach the cloud formation stage. These thermals or blobs were naturally randomly distributed round the station and resulted in the observed angel activity.

The interesting point however is the simultaneous occurrence of the high level inversions associated with this angel activity. The question naturally arises: what has a high level temperature inversion to do with angels which are mainly a low level phenomena confined to about 5000 ft above ground. In this connection, it will be of interest to quote a significant paragraph from Byers (1959):

"..... in its slow movement downwards, the air heats at the rapid adiabatic rate due to compression. The air near the ground does not participate in the subsidence, because only the slightest degree of turbulence which is nearly always present at low levels, can completely counteract the slow sinking. The lower atmosphere then acts as a sort of shield against the subsidence and shows no appreciable temperature increase while above, the temperature at any level will slowly rise with the bringing down of potentially warmer air from greater heights. Between the shielding layer and the adiabatically heated air above, there will then be observed a temperature inversion. The greater the amount of turbulence or vertical convection in the shielding layer, the higher in the atmosphere will the inversion be found".

By a logical extension of the argument contained in the last sentence of the paragraph just quoted, it will be seen that a high level inversion signifies a greater degree of turbulence and vertical convection, thus justifying the existence of a large number of thermals in the area all round the station which finally resulted in the observed angel activity. Some of the stronger of these thermals naturally reached the cloud formation stage and finally, under favourable circumstances, grew enough to give strong convection cell type echoes observed in the neighbourhood.

5. Conclusion

Thus it is seen that the high level temperature inversion observed in the cases of angel activity presented in this paper, in fact, signifies the high degree of turbulence in the lower atmosphere. The turbulence in the lower atmosphere manifests itself in the form of randomly distributed, innumerable thermals or blobs which give rise to the observed angel activity. The present observations thus confirm the association of upper air temperature inversions with turbulence in the lower levels.

6. Acknowledgement

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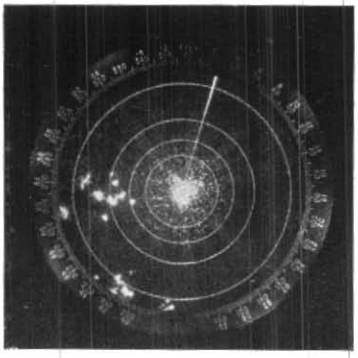
REFERENCES

Atlas, D.	1959	*J. atmos, terr. Phys.*, **15** (3/4).
Byers, H.	1959	*General Meteorology*, Mc-Graw Hill, p. 340.
Gordon, W. E.	1949	*Proc. Inst. Radio Engrs.*, **37** (1), p. 41.
Harper, W. G.	1957	*Nature*, **180**, p. 847.



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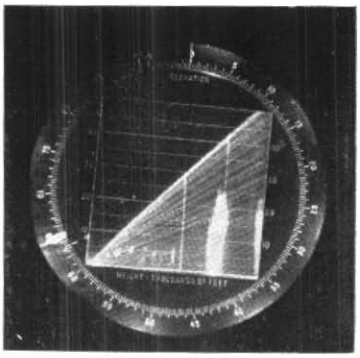

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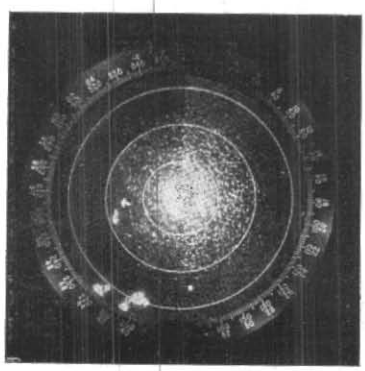
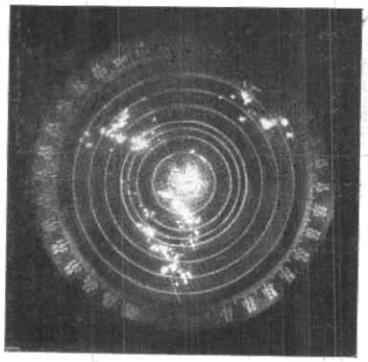


1610 75 2

Fig. 1. 16 June 1958



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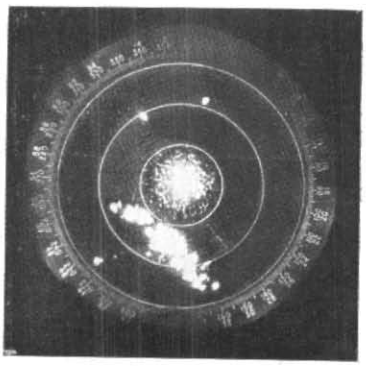
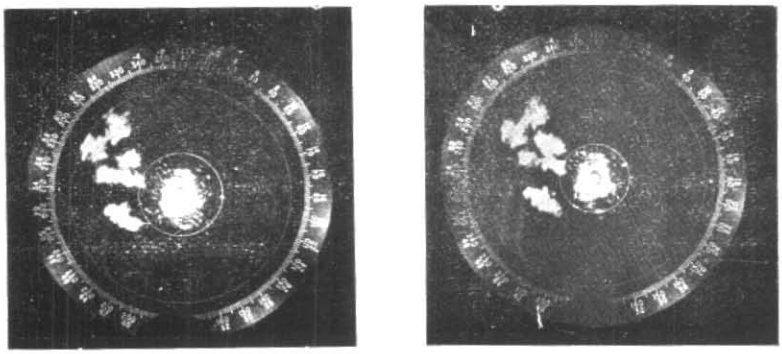


1523 75 5

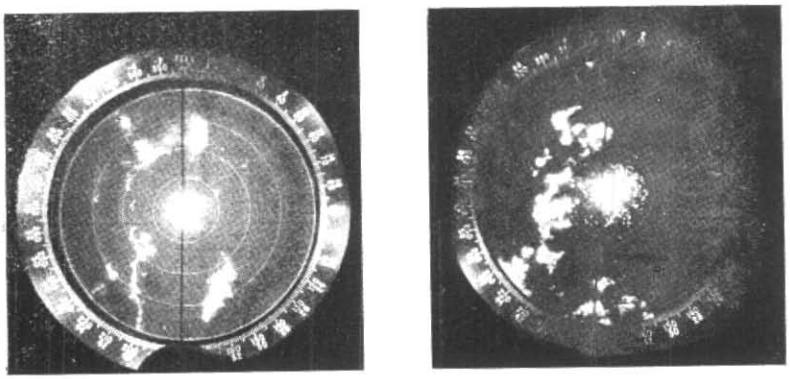
Fig. 2. 17 June 1958

The numbers from left denote time in IST, range in statute miles and elevation or azimuth in degrees



0845 25 5 0855 25 5

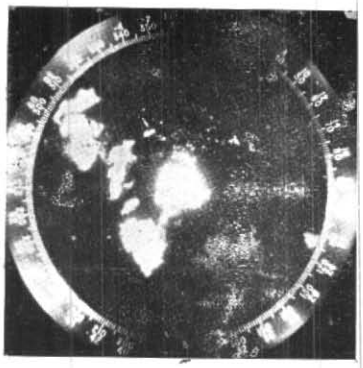
Fig. 3. 18 June 1958



1330 100 3 1730 75 2

Fig. 4. 17 April 1959

The numbers from left denote time in IST, range in statute miles and elevation or azimuth in degrees



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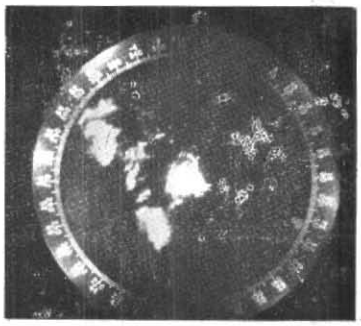

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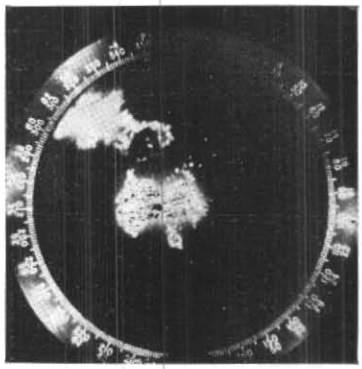
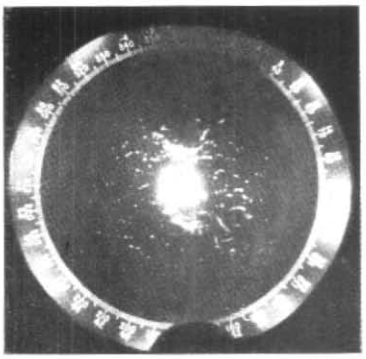


1517 25 5

Fig. 5. 28 May 1960

The numbers from left denote time in IST, range in statute miles and elevation or azimuth in degrees



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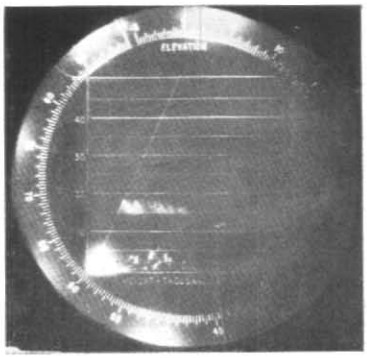
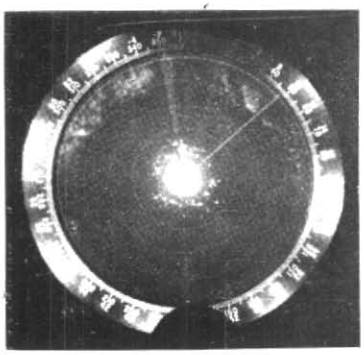
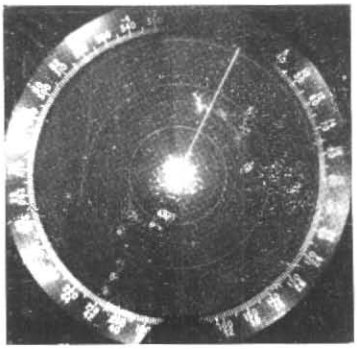


1502 25 341

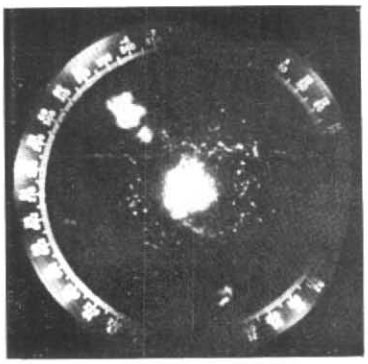


1455 25 10



1457 75 5

Fig. 6. 13 June 1960



1543 25 3

Fig. 7. 21 June 1960

The numbers from left denote time in IST, range in statute miles and elevation or azimuth in degree

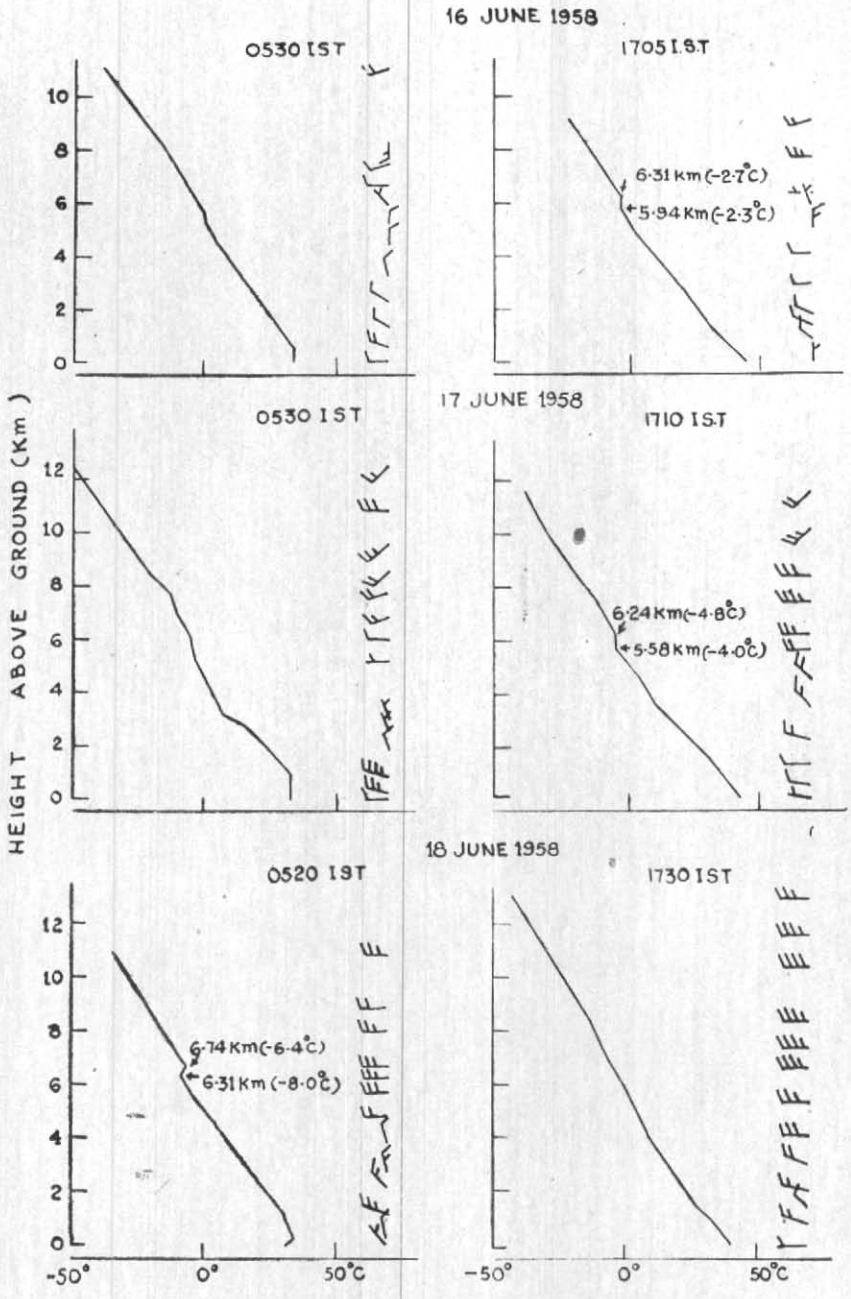


Fig. 8(a). Temperature profiles and winds at New Delhi on days of observed angel activity during 1958

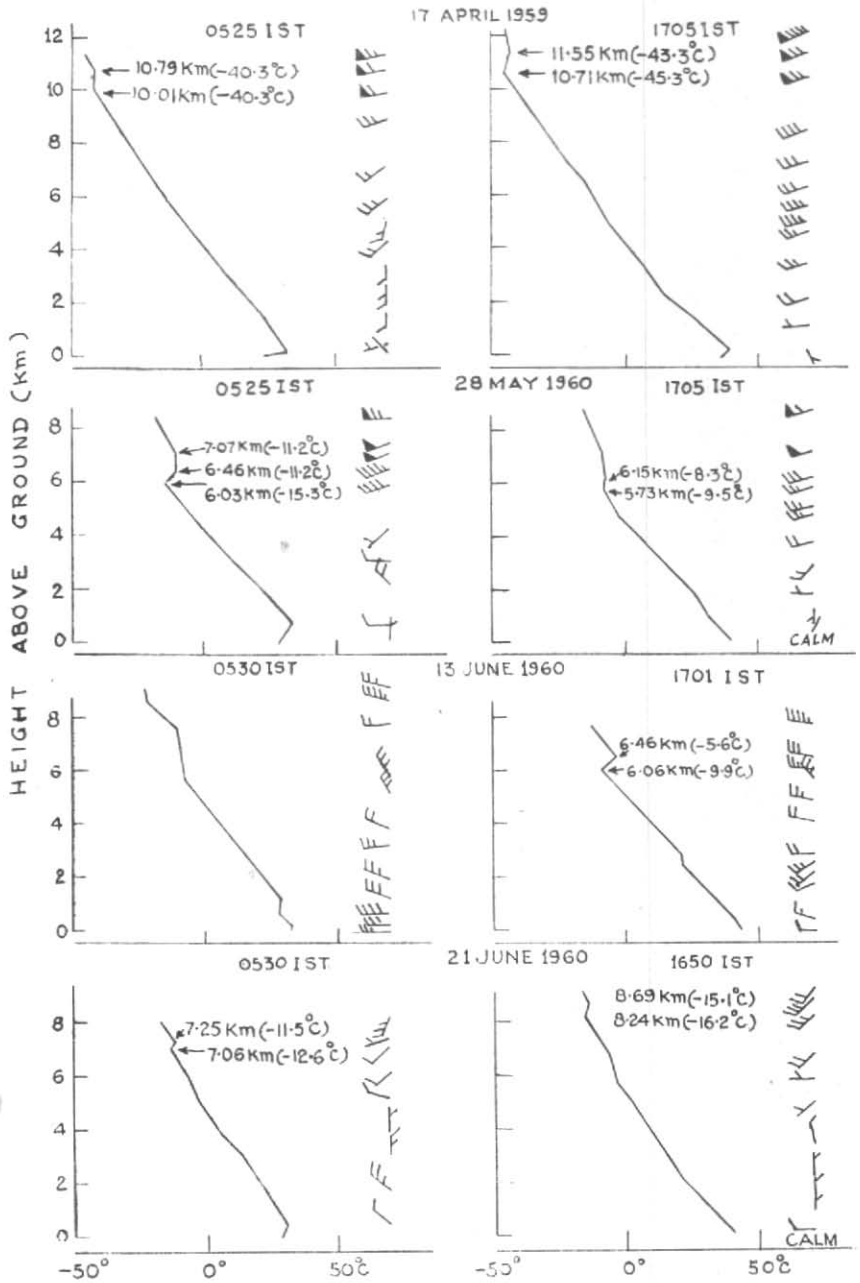


Fig. 8 (b), Temperature profiles and winds at New Delhi on days of observed angel activity during 1959-60