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A note on wind-finding with weather radar

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ABSTRACT. A method of estimating upper winds under adverse weather conditions, by radar observations on the movement of clouds containing precipitable water content, is described. The utility and limitations of the method are discussed.

1. Introduction

The idea of estimating upper winds by means of weather radar observations on clouds, is not new. Such studies have been conducted by Hiser and Bigler (1953), Ligda and Mayhew (1954) and it has been suggested that from "a careful calculation of the velocity of individual echoes" details of wind-motion over an area can be obtained (Battan 1959). Indian subcontinent, situated as it is in the monsoon regime, offers definite scope for such an application of the weather radar.

During the monsoon season the pilot balloon observations of upper winds are meagre and in any case not available above 1000—2000 ft in regions where strong monsoon conditions prevail. Even under moderate monsoon conditions, the passage over the station, of low clouds or a shower prevents balloon ascents. In such adverse weather, the radar however can see the movement of showers and clouds over the area around the station.

The Dependant Meteorological Office at Agartala airport has no Rawin facility but takes three Pibal ascents at 0001, 1200 and 1800 GMT daily. Most of the aircraft movement being concentrated around early morning and midday, the failure of either or both of 1800 GMT and 0001 GMT (of the next day) pibal ascents can be a severe handicap to the weather forecaster; more so, if he draws a blank from the nearby pibal stations as well.

A weather radar has been in operation at Agartala airport since January 1962 and has the following characteristics—wavelength 3·2 cm, peak power 18 KW, effective range 120 nautical miles, 3-degree pencil beam and a PPI display; azimuth scanning is done by the scanner at 15±3 RPM and upto elevation angles of +15 degrees. The elevation angle can be set to an accuracy of 1/5th of a degree by a special enlarged scale fitted to the elevation control. During the monsoon season the effective range of the set is considerably less but still the precipitation cells can be observed upto at least 60 nautical miles around Agartala. These generally move towards the station from some southerly direction between 130—230 degrees depending upon the synoptic situation. An attempt was made by the author to streamline a method of estimating winds in the lower troposphere with the aid of weather radar—as a standby to the pibal method—and the results are detailed in this note.

2. Details of the method

Briefly the method consists of measuring the drift or bodily movement of the cloud under observation during a known interval, thus arriving at an estimate of the wind direction and speed. This necessitates (*a*) two observations on the same cloud at a suitable time interval, say ten minutes, and (*b*) scanning in quick succession the different layers of the cloud corresponding to the mean heights at which the winds are required.

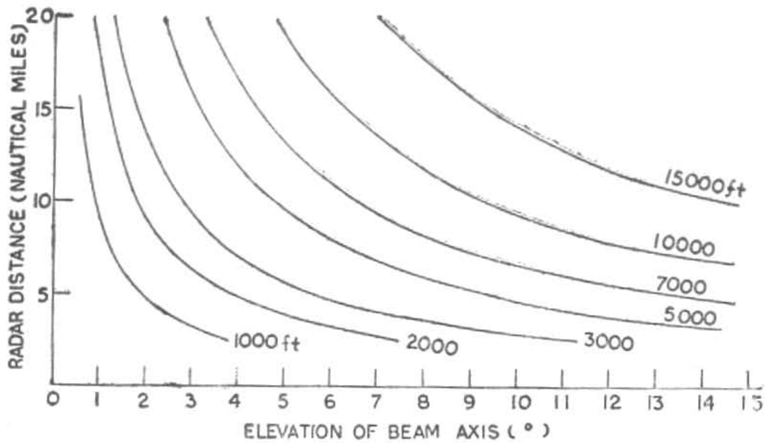

Fig. 1. Elevation of radar-beam axis *vs* radar distance from site, for scanning the cloud at constant height

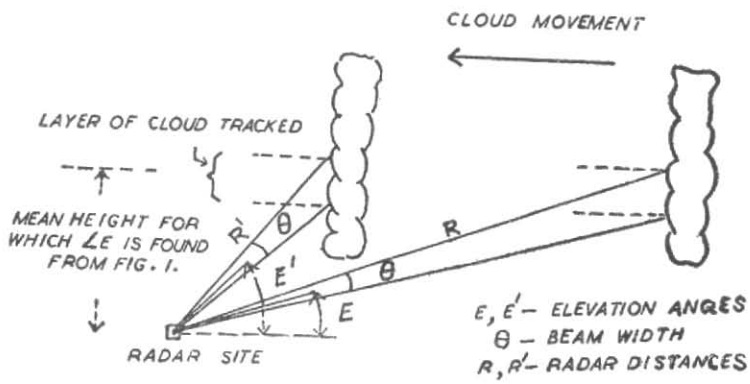

Fig. 2. Schematic drawing to illustrate the change of elevation angles and scanned layer thickness with the movement of the cloud

Once a cloud with definite identifying features at a known distance has been selected, the elevation angles at which the different layers have to be scanned as mentioned above are obtainable from a graph (Fig. 1). This elevation will have to be changed suitably to scan the same layer of cloud during the second set of observations as it might have drifted to a different distance in the meanwhile (*see* Fig. 2). This angle also is read from the same graph. The echoes returned by different layers of the cloud are copied with glass marking pencils on plastic overlays having azimuth markings on their periphery and properly oriented with reference to the screen of the PPI. The two positions of the echo returned by a particular layer during the two sets of observations are marked on the same overlay. During the trials described here, the interest centred around a few heights used for operational purposes and the observations were copied on only two plastic overlays and a suitable colour scheme.

The distance between the two positions of the identifiable features such as a well

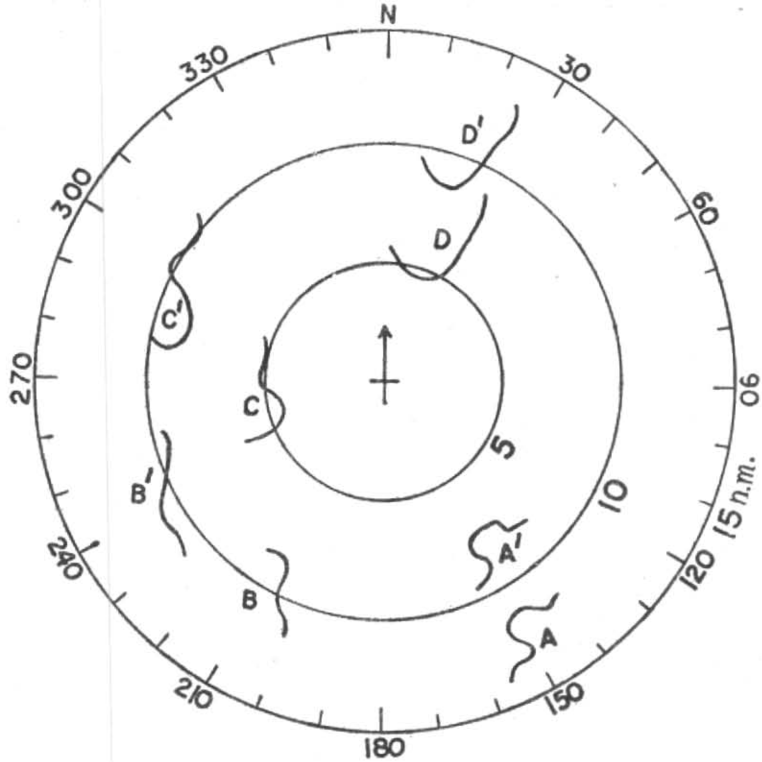

Fig. 3. Typical cloud echoes as seen on the radar PPI

(Only the nearer edges of echoes are shown. A′, B′, C′ and D′ refer to the positions of the respective clouds at the end of an interval)

defined corner or edge of the cloud-echo selected for observation, is measured on the plastic overlay and gives the drift of the cloud in nautical miles during the interval, at that level. Hence the windspeed at the mean height of the cloud layer is determined. Then the plastic overlay is superposed on a base with a set of parallel lines one of which passes through the centre of the overlay. The overlay is rotated around its centre so that the reference features of the echo in its two positions are lined up along the same base line (or an imaginary line parallel to one of the base lines). The azimuth reading corresponding to the base line passing through its centre gives the direction of drift of the cloud layer. Hence the wind direction is determined.

Fig. 3 shows some typical cloud layer echoes in the first and second observations (only the nearer edges are shown). Wind-direction determination is illustrated for one height only in Fig. 4 which shows the movement of two cloud layers near the station with their direction of movement lined up along the base lines; the reference features of the cloud echoes during the first and second observations are suitably labelled as a, a′, b, b′ etc.

Only those clouds at 5—15 n. miles make good targets for the above methods for reasons advanced in the discussion. The nearer edge of the cloud was invariably chosen as the reference edge, for obvious reasons. Two or three clouds could be tracked simultaneously during the same

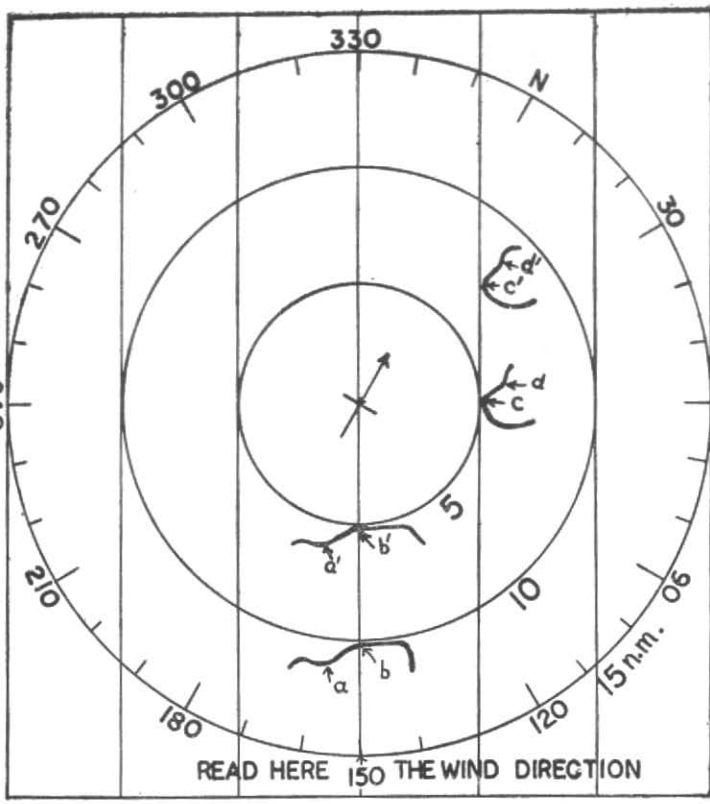

Fig. 4. Illustration of the method of determination of wind direction from the observations on the overlay

period under favourable conditions and the results averaged, to get a more accurate estimate of the windspeed and direction. With some practice the whole process took only 20—30 minutes depending upon the time interval between the two sets of observations.

3. Discussion of results

The observations as described above were conducted for a fortnight during August 1962. Table 1 is a comparison, level for level, of the 1200 GMT pibal winds and the winds obtained by cloud tracking as described above within two hours of the synoptic hour, *i.e.*, 1200 GMT; where the pibal winds were not available due to failure of, or limited ascent, the winds interpolated from the upper air streamline chart of 1200 GMT have been taken for comparison. Such values are marked with asterisks, to differentiate them from the actuals. On a few days there were no suitable clouds for observation near the station. The dates missing in the series tabulated, are thus accounted for. The observations could not be continued for a longer period due to major breakdown of the equipment towards the end of the monsoon.

It is seen from Table 1 that the winds obtained by tracking radar echoes of clouds do not differ very much from the pibal winds (or in their absence, the winds interpolated from the general windfield in the region) on days when the upper winds were fairly strong whereas there is considerable

TABLE 1

Comparison of upper winds obtained by the pibal observation (PIB) and by tracking cloud-echoes with radar (RCE)

Date (August 1962)	Height			
	3000 ft	5000 ft	7000 ft	10000 ft
	PIB / RCE	PIB / RCE	PIB / RCE	PIB / RCE
14	170/25 k 160/25	160/30 k 160/25	160/30 k 150/28	— —
16	190/22 185/25	210/21 185/25	220/29 185/25	*200/20 k 190/20
17	200/28 210/20	210/29 210/25	*220/20 210/18	*220/20 210/18
18	230/26 215/25	240/26 220/25	— —	— —
20	210/20 220/15	*240/12 220/15	*240/12 230/15	*260/12 240/15
22	190/16 180/15	180/15 180/15	160/15 170/15	160/18 170/15
23	170/17 180/15	160/15 180/15	160/16 170/15	— —
24	170/16 200/03	200/05 calm	170/11 (echo diffuse)	160/19
25	170/06 200/03	150/07 180/03	130/08 160/05	090/14 —
27	220/12 205/12	210/13 205/12	*210/12 205/11	*200/12 205/11
28	*200/10 190/09	*200/10 190/09	*210/10 195/07	*200/12 195/07
29	210/19 220/16	220/13 220/14	220/12 230/14	210/13 200/10
30	230/08 220/10	240/06 230/10	250108 230/10	— —

*Interpolated values

TABLE 2

Vertical depths (in ft) of a cloud covered at different distances (in n. miles) with a pencil beam of width θ

θ	R (nautical miles)				
	5	10	15	20	25
3 deg.	1590	3180	4770	6360	7950
1 deg.	530	1080	1590	2120	2650

discrepancy between the two, on days when the winds were weak, *i. e.*, 7 knots or less.

With reference to the movement of thunderstorms cells as depicted on radar (screen), Battan (1959) defines two components of movement of a cell; one of 'translation' and the other by 'propagation'; the first one being due to the drift with the wind at that level and the second one being due to new development or dissipation — and hence a change of outline of the radar echo. In general, he adds that in a strong windfield, translation effects would dominate and with light winds propagation can be the determining factor. If this reasoning could be applied to the cumuliform clouds of the monsoon season in this area, the discrepancy between pibal winds and 'radar-echo winds' on days when the upper winds were weak, *i.e.*, 24th, 25th and 30th can be attributed to inaccuracies in delineating identifiable features or the absence of the same, which themselves might have been due to considerable propagation effects of the cloud cell during the long intervals required in such cases for a measurable drift to occur, sometimes as much as 20 to 30 minutes.

The cloud echo as seen on the PPI screen is the integrated effect of the signals returned by scatterers in a volume of the clouds scanned by the radar, *i.e.*, the vertical depth of the layer is involved among other factors. This vertical depth depends upon the radar beamwidth and the distance of the cloud. Table 2 gives the vertical depths of the cloud layer covered by a three-degree and one-degree pencil beams respectively for various radar distances from the radar site. It is seen from the table that in order to be able to scan a reasonably thin layer of the cloud with a radar of any beamwidth, only those clouds very near the station are to be chosen for tracking. If they are too near, the scanning angles (elevation) become inconveniently large even for moderate heights. In the case of the radar at Agartala such limitations led to the choice of clouds lying between 5 and 10 n. miles when upper winds upto 7000 ft were required and those lying between 7 and 15 n. miles when winds upto 12,000—15,000 ft were required. The upper wind estimates thus obtained are, therefore, mean winds in a vertical layer of about 2400 ft deep for relatively low levels and about 3200 ft deep for relatively higher levels. It is relevant to mention here that the winds computed from pibal ascents are mean winds in a vertical layer 300-ft thick at the lower levels and 1000-ft thick at higher levels. As seen from Table 2, thinner slices of the cloud can be scanned with a one-degree pencil beam and hence greater accuracy should be possible with Raytheon or Japanese radars in use in the India Meteorological Department.

4. Conclusion

When wind data are not otherwise available, the method of inferring winds from the movement of weather radar echoes may be used as a quick standby during adverse weather conditions, for the guidance of the forecaster dealing with local forecasts, for aviation and other purposes. The data obtained by an observing station in a weak wind-field should, however, be used with caution.

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