Indian J. Met. Hydrol. Geophys. (1977), 28, 1, 97-102

551.577: 551.551.508.85

Study on the estimate of precipitation with the help of S-band at radar Calcutta

A. C. DE, P. BHATTACHARYYA and S. K. GHOSH

Regional Meteorological Centre, Calcutta

(*Received 5 April 1975*)

ABSTRACT. An attempt has been made to study the amount of rainfall associated with the severe cyclonic storm of 14-16 August 1974 with the help of the S-band radar installed at Calcutta. The first two modes of the gray scale, *viz*,. gray and white shades were utilised in this study. It has been found that these modes correspond fairly well with the rates of rainfall recorded at the self recording raingauge stations and rainfall reported by ordinary raingauge stations within a radius of 200 km around Calcutta. Isogram analysis of the rates of rainfall at a particular time has also been made and the results compare fairly well with the radar photographs at the corresponding time.

1. Introduction

The cyclone warning radar at Calcutta is operated mainly for tracking of Bay storms with the range of the radar, *i.e.*, 500 km around Calcutta. The severe cyclonic storm of 14-15 August 1974 was successfully tracked from the stage of its initial formation in the Bay till it weakened into a depression over land. The radar detected the "eye" of the cyclonic storm not only over the head Bay of Bengal before the storm crossed the coast but also for more than 12 hours after the storm crossed the coast near Contai in the district of Midnapore, West Bengal.

A large number of photographs of radarscope presentations were taken. It is worthwhile to mention that photographs were taken in different modes including the 'gray' mode. An attempt has been made to get an idea of the estimation of rainfall intensity from the available radar data. The result of the study is presented in this short communication.

2. Discription of the radar

The meteorological radar type RC-32 E manufactured by M/S Mitsubishi Electric Corporation, Japan operates on 10 cm wave band with a nominal peak output power of 500 kw and has got a maximum range of 500 km. The parabolical antenna of about 2° beam width of the radar is placed on the top of New Secretariat building at Calcutta at a height of about 66 m above ground level, *i.e.*, 70 m above mean sea level. The radar can be operated both on long (4 μs for the entire range and on short (1 μs upto a range of 200 km) pulse widths.

One mode of iso-echo contour facility of the radar is 'gray' scale contour presentation on the PPI scope. This device process the raw radar video. The echo signals are first smoothed or partially integrated by a simple resistance-capacitance filter circuit with time constant of 5 times of the radar pulse duration (*i.e.*, 20 μs in the case of long pulse radiation of 4 μs duration). The advantage of such smoothing are that the resultant signal is more nearly representative of average received power, a term appearing in the radar reflectivity relation and also for better delineation of gray level brightness contours. The selection of 5 times pulse duration smoothing is, however, arbitrary as averaging for longer duration would mean further degradation in range resolution. The processed video produces a 5 band intensity contour display of 10 db step each. The steps are 1st gray, 1st white, black, 2nd gray and 2nd white in the increasing order of rates of precipitation. In the present case only the first two shades, *i.e.*, first gray and first white were selected. These two shades were clearly observed on the radarscope in association with the cyclonic storm of 14-15 August 1974 and were utilised for the purpose of estimation of rainfall over the affected area and the neighbourhood.

3. Data used

3.1. *Radar data* — The radar photographs on gray modes during the entire period when the

TABLE 1 (a)

Comparison of radar photograph with rate of rainfall collected from S. R. raingauge charts

Date (Aug 1974)	Time (IST)	Radar photographs (Gray scale) (mm/hr)	Rainfall (mm/hr)	Radar photographs (Gray scale) (mm/hr)	Rainfall (mm/hr)	Radar photographs (Gray scale) (mm/hr)	Rainfall (mm/hr)
		Midnapore (265°/105 km)		**Saugor Island (200°/112 km)**		**Datan (242°/140 km)**	
14	1714	B (>1·8)	5·0	G (upto 2·0)	1·5	B (>3·0)	6·0
14	1819	N	0·0	B (>2·0)	5·4	G (upto 3·0)	0·0
14	2218	B (>1·8)	5·0	B (Do.)	4·0	G (Do.)	Tr
14	2304	G (upto 1·8)	0·1	B (Do.)	4·8	B (>3·0)	2·5
15	0008	G (Do.)	0·5	—	—	G (upto 3·0)	0·3
15	0208	N	0·0	E	Tr	N	0·0
15	0311	G (upto 1·8)	1·5	E	Tr	B (>3·0)	0·0
15	0408	G (Do.)	1·0	E	Tr	G (upto 3·0)	4·0
15	0458	B (>1·8)	16·7	—	—	B (>3·0)	28·0
15	0714	B (Do.)	13·0	G (upto 2·0)	0·7	B (Do.)	15·0
15	0913	B (Do.)	9·0	G (Do.)	1·6	B(Do.)	10·0
15	1021	B (Do.)	21·0	B (>2·0)	5·0	N	0·0
15	1734	B (Do.)	12·0	N	Tr	B (>3·0)	2·5
15	0458	B (Do.)	40·0	B (>2·0)	40·0	—	—
15	0008	—	—	B (Do.)	6·0	—	—
		Baripada (250°/185 km)		**Kharagpur (260°/108 km)**		**Jamshedpur (275°/225 km)**	
14	1714	N	0·0	B (>1·9)	15·0	N	0·0
14	1819	B (>4·2)	8·0	N	0·0	N	0·0
14	2218	N	0·0	B (>1·9)	5·0	N	0·0
14	2304	G (upto 4·2)	Tr	G (upto 1·9)	Tr	N	0·0
14	2216	—	—	B (>1·9)	5·0	N	0·0
15	0008	B (>4·2)	2·0	—	—	—	—
15	0100	—	—	N	0·0	N	0·0
15	0208	G (upto 4·2)	0·7	G (upto 1·9)	3·0	N	Tr
15	0311	N	0·0	B (>1·9)	—	N	0·0
15	0408	G (upto 4·2)	1·5	G (upto 1·9)	2·0	N	0·0
15	0458	G (Do.)	2·0	—	—	—	—
15	0714	G (Do.)	3·0	B (>1·9)	15·0	G (upto 6·5)	Tr
15	0913	B (>4·2)	8·0	B (Do.)	15·0	N	Tr
15	1021	G (upto 4·2)	0·5	B (Do.)	32·0	N	Tr
15	1734	B (>4·2)	6·0	B (Do.)	6·0	G (upto 6·5)	3·0
15	1823	—	—	G (upto 1·9)	2·0	G (Do.)	6·0
		Purulia (28°/223 km)		**Luchipur (12°/170 km**		**Panagarh (317°/140 km)**	
14	1714	N	0·0	N	0·0	N	0.0
14	1819	N	0·0	—	—	N	0·0
14	2216	N	0·0	—	—	—	—
14	2304	N	0·0	—	—	N	0·0
15	0100	N	0·0	N	0·0	N	0·0
15	0714	G (upto 6·5)	0·6	—	—	G (upto 4·0)	1·2
15	1021	N	0·0	N	0·0	N	Tr
15	1734	G (upto 6·5)	3·0	N	0·0	B (>4·0)	4·3
15	1823	G (Do.)	1·0	N	0·0	N	Tr
15	0408	—	—	—	0·0	N	Tr
15	0913	—	—	N	0·0	G (upto 4·0)	Tr
		Sriniketan (335°/145 km)					
14	1714	—	—				
14	1819	—	—				
14	2216	N	0·0				
14	2304	—	—				
15	0100	—	—				
15	0714	G (upto 3·2)	1·0				
15	1021	N	0·0				
15	1734	G (upto 3·2)	Tr				
15	1823	N	0·0				
15	0408	N	Tr				
15	0913	G (upto 3·2)	Tr				

N—No echo, G—Gray, B—Bright, E—Eye of the storm

TABLE 1 (b)

Comparison of radar photograph with rainfall data collected from hourly surface observations

Date (Aug 1974)	Time (GMT)	Radar photograph (gray scale) (mm/hr)	Rainfall (mm/hr)	Radar photograph (Gray scale) (mm/hr)	Rainfall (mm/hr)
		Sandheads (190°/170 km)		Contai (220°/100 km)	
14	1714	G (upto 4·0)	0·0	N	*
14	1819	G (Do.)	0·0	G (upto 1·6)	*
14	2218	N	0·0	G (Do.)	*
14	2304	N	0·0	N	*
15	0100	N	0·0	B (>1·6)	**
15	0208	N	0·0	B (Do.)	**
15	0408	G (upto 4·0)	*	B (Do.)	**
15	0714	N	0·0	G (upto 1·6)	0·0
15	0913	N	0·0	G (Do.)	*
15	1021	N	0·0	B (>1·6)	**
15	1734	—	—	B (Do.)	**

N—No echo, G—Gray, B—Bright, E—Eye of the storm, *Slight rain, **Moderate continuous rain.

'eye' of the cyclonic storm was visible have been selected for the study. While making the above selections the fact that a number of raingauge stations are located in the southern, western and northern sectors of the storm within a range of 200 km from Calcutta were kept in mind. In other words, those radar photographs were selected which showed gray and white bands over the raingauge stations in the sectors stated above. A few radar photographs taken on the gray scale are shown in Fig. 1.

3.2. *Self recording raingauge data* — The rainfall data of self recording raingauge stations within a radius of 200 km from Calcutta during the period 14-15 August 1974 have been utilised in the study. However, Jamshedpur and Purulia which are also S.R. raingauge stations but located slightly beyond 200 km from Calcutta have been included in the study.

3.3. *Ordinary raingauge data* — Since the network of self recording raingauge within a range of 200 km from Calcutta is not fully adequate and evenly distributed for a close comparative study, the rainfall data of a few ordinary raingauge stations within the same radius were collected and analysed. Fig. 2 shows the network of ordinary and self recording raingauges. The track of the cyclone has been superimposed on this field area map.

4. Anaylsis of the data

The radar photographs taken at different times and the rates of precipitation as calculated from the records of the self recording raingauges at the corresponding time are shown in Table 1 (a). Table 1(b) shows radar data against corresponding hourly rainfall as recorded by the observer.

5. Discussion

It may be mentioned that the radar observations were taken primarily for locating the centre and for closely tracking the cyclonic storm which skirted the coastal districts of West Bengal before finally crossing near Contai in the district of Midnapore. During the later period of the life history of the storm, it was observed that the system remained active for a considerable period on sea and over land even after crossing the coast.

For the purpose of quantitative estimation of the rates of rainfall, the radar is calibrated assuming the generally accepted reflectivity relation, $Z=200\ R^{1.6}$ where Z is radar reflectivity factor, and R is the rate of rainfall. In the present study this relation has been accepted to be valid for estimation of rainfall.

Photographs in Figs. 1 (a-c) show two modes of gray, scales, *i.e.*, gray and white. The rate of rainfall corresponding to gray shade is 1-4 mm/hr and for the white shade it is above 4 mm/hr calibrated for peak power output of 500 kw and with 'range' and 'gas' corrections applied to the received signals with the help of a specially built-in circuit.

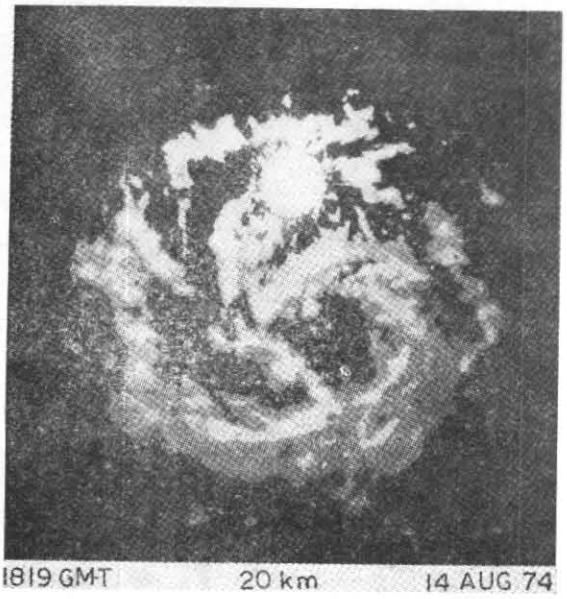

Fig. 1 (a)

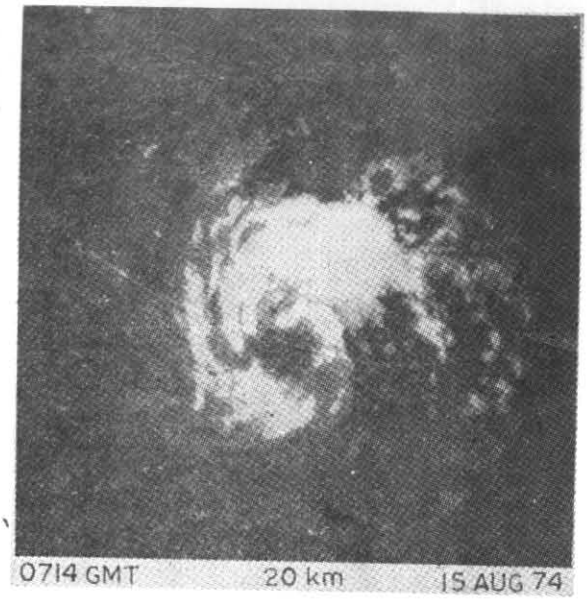

Fig. 1 (b)

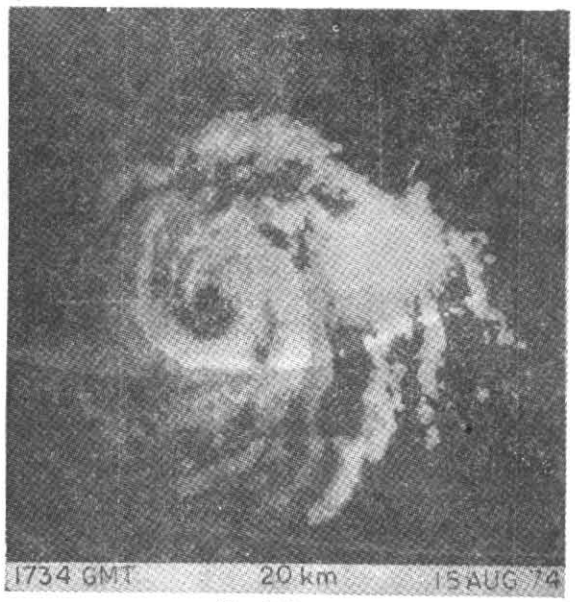

Fig. 1(c)

Figs. 1 (a-c). PPI presentations in (gray mode) of the of the Cyclone Warning Radar at Calcutta

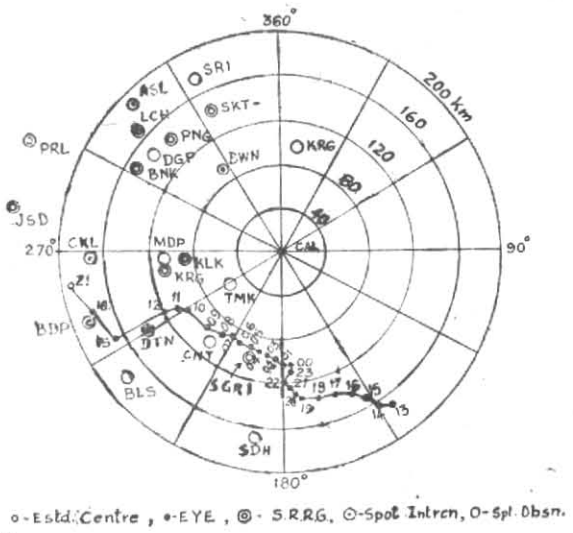

Fig. 2. Field area surveyed together with network of O.R.G. and S.R.R.G. stations and the track of the cyclone

In the photographs analysed for the present study, however, the range and gas corrections circuit was not made 'on' and peak power output was measured to be 350 kw. A correction is, therefore, necessary to account for these factors. Table 2 shows the different corrections and the corrected values of rate of rainfall arrived in gray and white modes in respect of individual stations.

Thus in the photographs of present study the rate of rainfall may vary from station to station even if they appear with same mode in the gray scale. It may be seen from Tables 1 (a) and (b) that the radar photographs agree fairly well with the rates of precipitation recorded by self recording raingauges and ordinary raingauges and also generally agree with the reported observations.

TABLE 2

Different magnitudes of corrections necessary to be applied to arrive at corrected rainfall rate from radar photographs in respect of individual stations

Station	Azimuthl/ distance (deg./km)	Correction (in db) due to		Total correction (db)	Corrected values of rainfall rate in gray scale (mm/hr)	
		Change in output power (rated– actual) (db)	Gas and range in respect of the station (db)		G upto	B more than
Midnapore	265/105	+2	—7·4	—5·4	1·8	1·8
Saugar Island	200/112	+2	—6·9	—4·9	2·0	2·0
Datan	242/140	+2	—4·3	—2·3	3·0	3·0
Baripada	250/185	+2	—1·0	+1·0	4·2	4·2
Kharagpore	260/108	+2	—7·2	—5·2	1·9	1·9
Luchipore	312/170	+2	—2·0	0·0	4·0	4·0
Panagarh	317/140	+2	—4·3	—2·3	3·0	3·0
Sriniketan	335/145	+2	—3·9	—1·9	3·2	3·2
Sandheads	190/170	+2	—2·0	0·0	4·0	4·0
Contai	220/100	+2	—8·0	—6·0	1·6	1·6
Jamshedpore	275/225	+2	+2·0	+4·0	6·5	6·5
Purulia	280/223	+2	+2·0	+4·0	6·5	6·5

Keeping in mind the limitations regarding the paucity of the number of raingauges within a radius of 200 km around the radar site, an attempt has been made to compare the radar photographs with available rainfall data. Fig. 3 (a) shows an enlarged sketch of the radar photograph taken at 0714 GMT of 15 August 1974. Two modes (gray and white) are clearly depicted in the figure. Fig. 3 (b) shows an analysis of the rate of precipitation at the corresponding time. As the radar photograph itself could not be modified in Fig. 3 (a) for range and gas attenuation corrections, necessary corrections have been applied in respect of rate of rainfall for individual stations in Fig. 3 (b). The rate of rainfall in Fig. 3 (b) thus is apparent and not actual and is shown only for the purpose of comparison with Fig. 3 (a).

An isogram of rainfall rate indicating precipitation rate of 4.0 mm/hr together with a line showing demarcation of region with rain and without rain (0.0) have been drawn. From a comparison of Figs. 3 (a) and 3 (b) it may be seen that the analysis agrees with the actual radar contouring. There are, however, smaller areas of different shades in the radar photographs which could not be demarcated in the analysis due to insufficient number of reports and/or as the photograph was not corrected for range and gas attenuation. For the purpose of micrometeorological analysis of this type a large number of rainfall reporting stations are necessary.

Inspite of the above limitations. the result of the present analysis is quite encouraging. It is seen that the radar reflectivity relation assumed gives a fair estimate of the precipitation rate over our region for precipitation associated with tropical cyclonic storm particularly for short period estimation of rainfall amounts over the affected region. This broad basis can be further utilised for flashing flood potential of particular storm over selected regions through further and precise contouring. It is proposed to undertake further detailed studies on these lines in respect of different weather situations during different seasons so as to find a suitable correlation between the rate of precipitation and the radar reflectivity relation assumed in the calibration of the radar for the quantitative estimation of the rate of rainfall.

6. Concluding remarks

The result of the study may be summarised as below :

(*i*) This study is the first attempt in this country to interpret the rainfall distribution associated with a cyclonic storm with the help of 10 cm radar.

(*ii*) The selected radar photographs were interpreted in terms of rate of precipitation from a network of self recording and ordinary raingauge stations within a radius of 200 km around Calcutta.

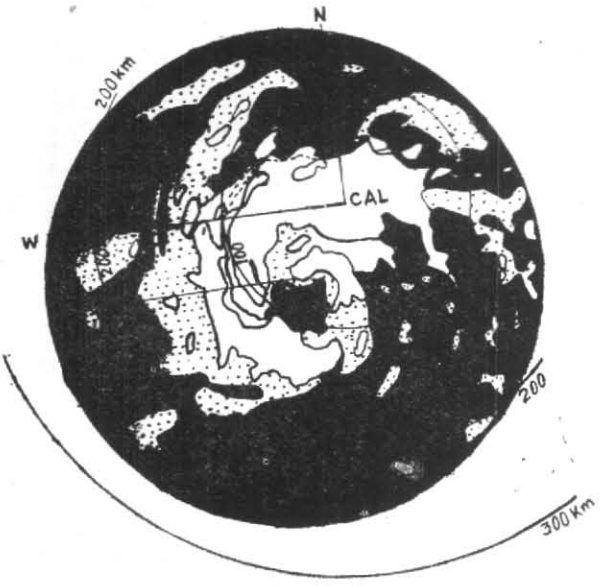

Fig. 3 (a). A sketch of radar photograph taken at 0714 GMT of 15 Aug 1974 indicating two modes (Gray and white) of gray scale

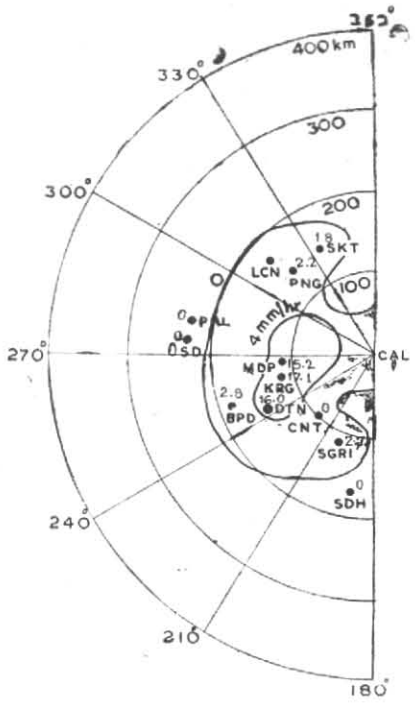

Fig. 3 (b). Analysis of rate of precipitation (0714 GMT of 15 Aug 1974). An isolyet indicating precipitation rate of 4mm /hr together with a line showing demarcation of region with rain and without rain (0·0 isoline) have been drawn.

(*iii*) It has been found that the first two modes of the gray scale, *viz.*, gray and white modes, for which study has been made, correspond fairly well with the expected values of rates of precipitation.

(*iv*) In spite of the limitations of the study mentioned elsewhere in this communication, it is seen that the result of the study is quite encouraging for estimating the rates of precipitation on different areas on the basis of different modes of gray scale presentations on the radarscope. It is proposed to undertake extensive study on gray scale as well as other techniques for estimation and comparison of precipitation rates associated with weather situations in different seasons.

(*v*) It has been found that the radar photographs agree fairly well with the analysis of isogram of rainfall rate though some minor details could not be studied due to insufficient number of rainfall reporting stations.

(*vi*) The above study has got a significance for quantitative estimation of flood potentials of different rain storms.