Mausam, (1980), 31, 4, 573-580

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The Andhra cyclone of 12 May 1979 : The radar meteorologist's point of view

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(*Received 25 January 1980*)

ABSTRACT. The severe cyclonic storm with a core of hurricane winds which struck the Andhra Pradesh coast on 12 May 1979, was tracked by radar from Madras over an unusually long range. The eye was seen at a range of 425 km which is a record for a radar on the Indian coasts. Even five days before landfall the radar gave indications of the likely northwesterly movement of the storm, a climatologically less probable direction. The extrapolation of the radar track also gave a good indication of point of landfall. These features facilitated timely warnings and effective precautionary measures.

When the storm came close to coast radar detection was not so satisfactory possibly because of subnormal radio propagation conditions. As seen from radar data the storm had a small well-formed eye which widened out as it approached the coast. However heights of cloud tops in the eyewall the maximum rainfall rate in the eyewall and the areal rainfall in the core area remained fairly constant during the period in which they could be observed, suggesting that the storm remained of constant intensity for about 24 hours before land-fall. The observed surface winds and pressures also support this conclusion. The left sector of the eyewall was better developed and associated with intense rainfall. The system can as a whole be classed as a mature cyclone of small extent.

1. Introduction

The severe cyclonic storm with a core of hurricane winds which struck the south Andhra coast in May 1979 caused extensive damage in the coastal districts. However, thanks to good coordination between meteorological warnings and the actions of local authorities, large numbers of people were evacuated in advance from coastal areas and many lives saved. The continuous tracking of the storm from an unusually long range by coastal radar from Madras was an important factor contributing to the issue of precise warnings more than 36 hours in advance. But the radar observation of this storm has also thrown up a number of questions the answers to which will be of great operational interest to radar meteorologists. These relate to the effective range of radar tracking, the prediction of track, the assessment of the extent and intensity of the storm, the precipitation distribution and structure of the storm. These aspects are examined mainly on the basis of radar data.

2. The history of the storm

This storm originated as a depression on the evening of 5 May 1979 at about 7 deg. N and 89 deg. E. It intensified into a severe cyclone by 12 GMT of 7th and moved westwards till the 8th. On the 9th morning when it was at 7 deg. N and 85.5 deg. E it started moving northnorthwestwards. From the evening of 10th when it was at 12.4 deg. N and 84.2 deg. E, the eye could be seen on Madras radar. It then started moving northwest. It is believed to have developed a core of hurricane winds by 11th morning. By 11th afternoon the movement became westerly. When it was close to coast on 12th morning it started moving northwards along the coast and crossed the coast near Ongole the same evening. The lowest known mean sea level pressure recorded at Ongole was 964 mb. The

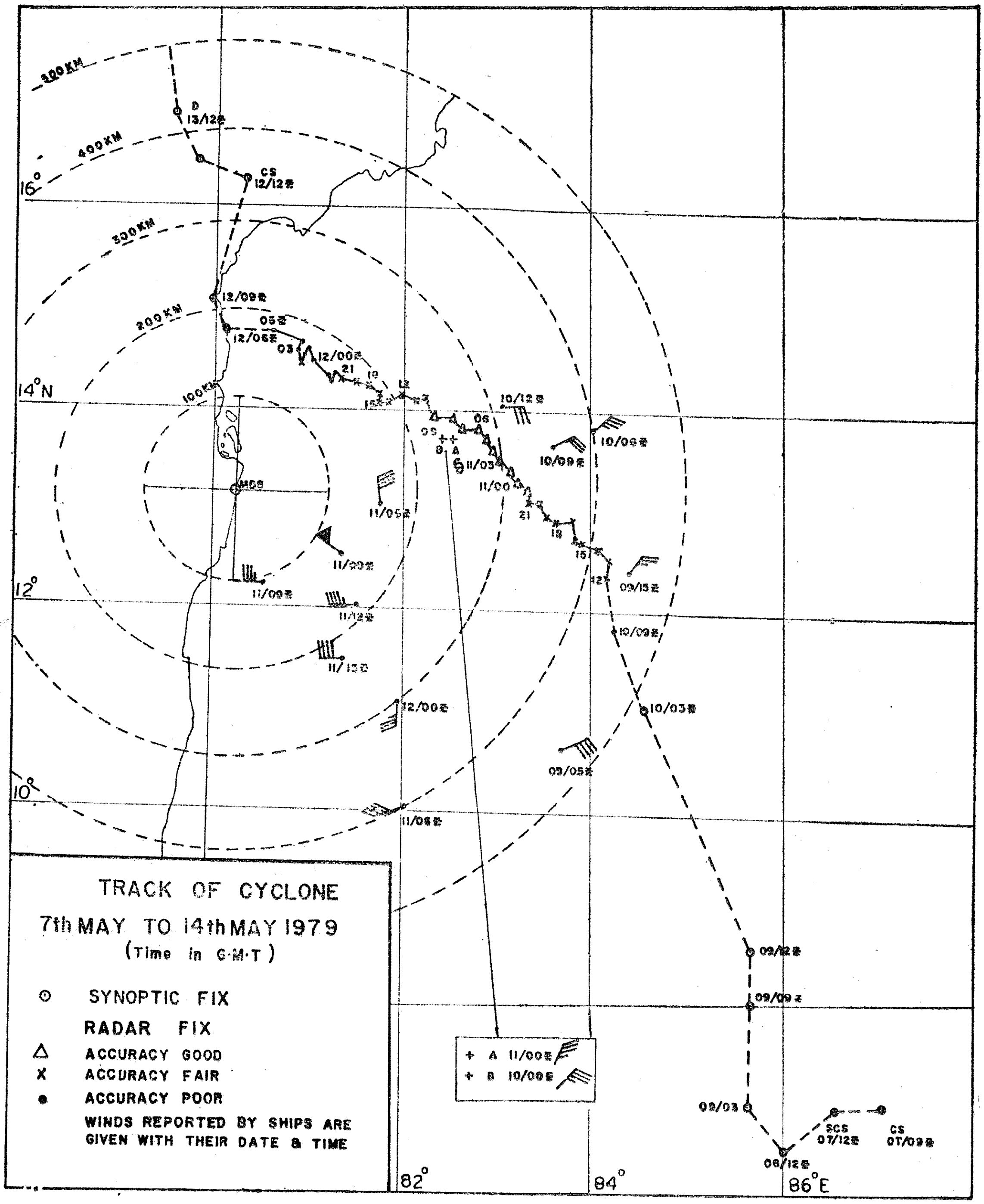


Fig. 1. Track of Andhra Cyclone of 7-14 May 1979

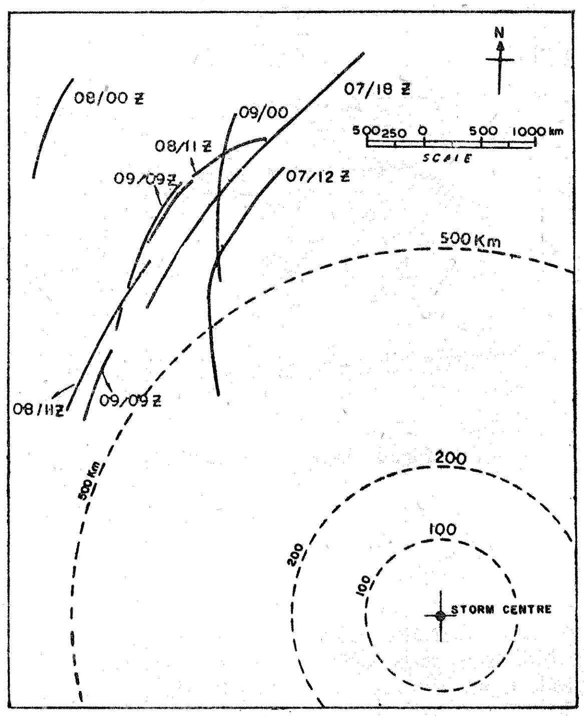


Fig. 2. Composite of pre-cyclone squall lines observed by Madras radar from 7-9 May 1979 — Andhra cyclone of May 1979

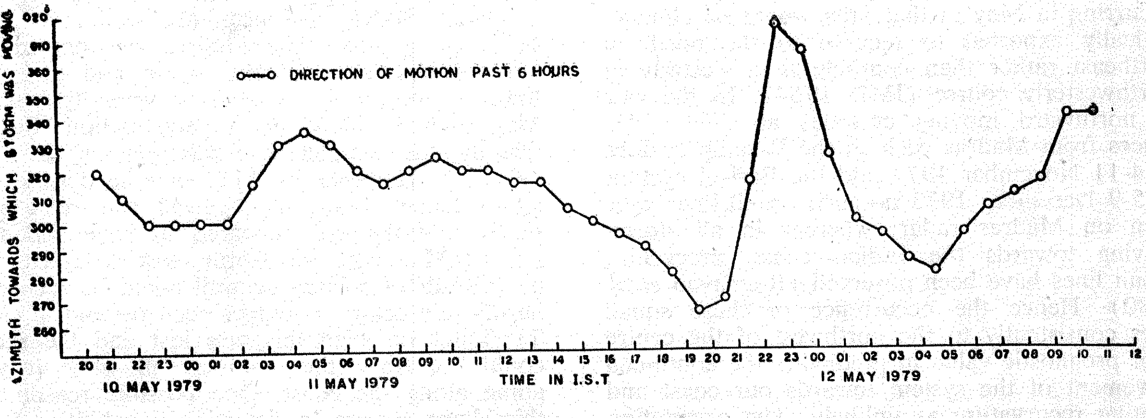


Fig. 3. Andhra cyclone of may 1979

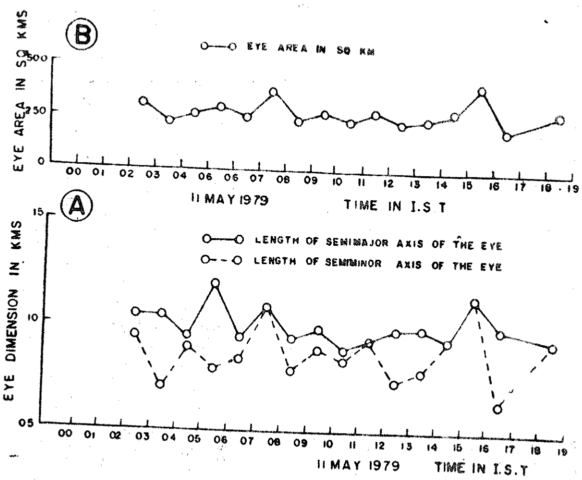


Fig. 4. Andhra cyclone of May 1979

recorded maximum sustained wind near the time of landfall was 65 kt but higher speeds upto 110 kt have been estimated from survey of damage. The track and the ships' winds on which the assessment of the system in its earlier stages was based are given in Fig. 1.

3. Radar determination of track

The first precyclone squall lines associated with the storm were seen on Madras radar from 7th evening onwards and continued upto 10th morning. In Fig. 2 these are drawn with reference to a fixed storm centre. The squall lines were about 500 km from the storm centre and were organised at various times in NE-SW, N-S and NNE-SSW orientations. The storm was at that time at about 7 deg. N, 86 deg. E. A storm occurring in May in that area would be climatologically expected to recurve to the north or northeast rather than continue in a westerly or northwesterly course (IMD 1964). In the case of northward moving cyclones at similar distances from Madras such as the Paradip cyclone of 4-11 November 1973 and the Barisol cyclone of 5-9 December 1973 no such squall lines were seen on Madras radar; whereas in all storms moving towards the Indian coast, precyclone squall lines have been observed (Raghavan *et al.* 1980). Hence the occurrence of these squall lines consistently to the northwest of the centre is of prognostic value in predicting the continued movement of the system towards our coast and treating recurvature as unlikely. The orientation of the squall lines is also an indication of movement in a roughly northwesterly direction.

Spiral rainbands associated with the storm were observed from the morning of the 10th. At 12 GMT of 10th a small part of the eyewall could be detected (Fig. 5). The centre position was thereby estimated to be 425 km from Madras. This is believed to be the longest range at which the eye of a storm in the Indian seas has been detected by coastal radar. The normal effective range at which the eye of a storm can be detected from a coastal radar is about 300 to 350 km (Raghavan *et al.* 1980). The unusually long range of detection of the eye in this case is readily explained by the presence of abnormal propagation conditions which are characteristic of the month of May especially in the evenings (Rajagopalan and Raghavan 1979). Extensive anomalous propagation both to the north and south of Madras had been observed from 7 to 10 May. At that time Madras was not in the field of circulation of this storm and therefore lower tropospheric conditions were typical of May and conducive to superrefraction. Subsequently, the complete eye was seen on the 11th (Fig. 6). However by 11th evening despite the storm being closer, the eyewall was seen only partly and the eye appeared to have widened. On 12 May with the storm close to coast, the nearer half of a large eyewall could be seen and hardly any echoes could be seen beyond it (Fig. 7). Later on even this was lost and the radar could not track the storm at all while it was going along the coast. One possible reason for this sharp change in detection capabilities from 10 to 12 May is that as the storm came closer the vertical humidity gradient in the lower

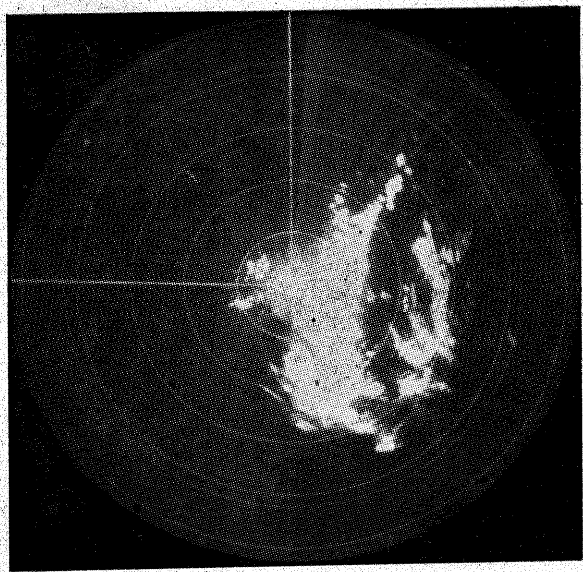


Fig. 5. Radar PPI photograph at 1729 IST of 10 May 1979 showing a part of the eyewall between 400 and 425 km. Range markers are at 100 km intervals

Fig. 6. Off centred PPI picture at 1225 IST of 11 May showing complete eye at a range of about 260 km. Markers are at 40 km intervals

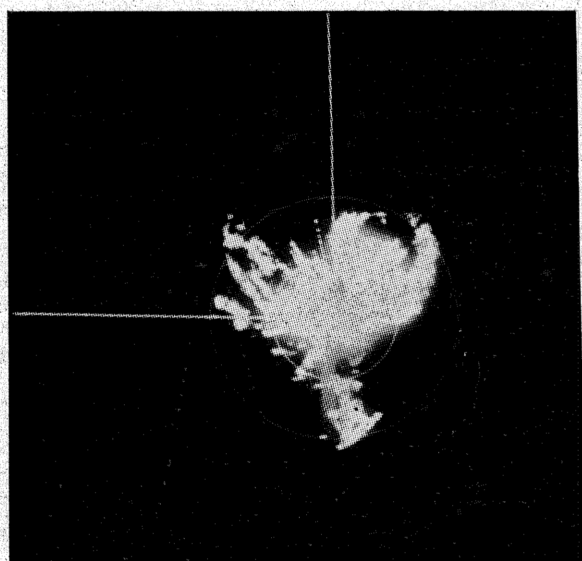
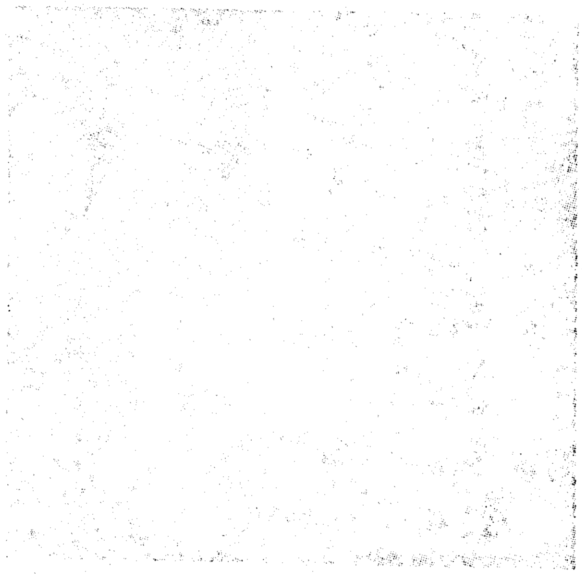
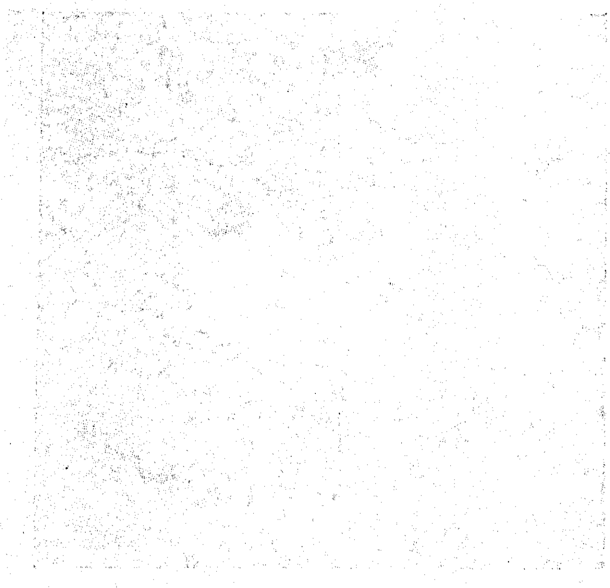
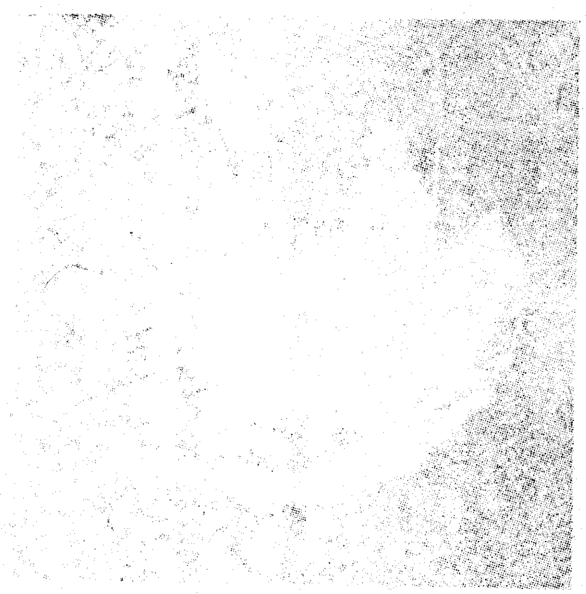


Fig. 7. At 0719 IST of 12 May an open eye is seen at a distance of 165 km with a few echoes beyond the eye. Markers at 100 km intervals







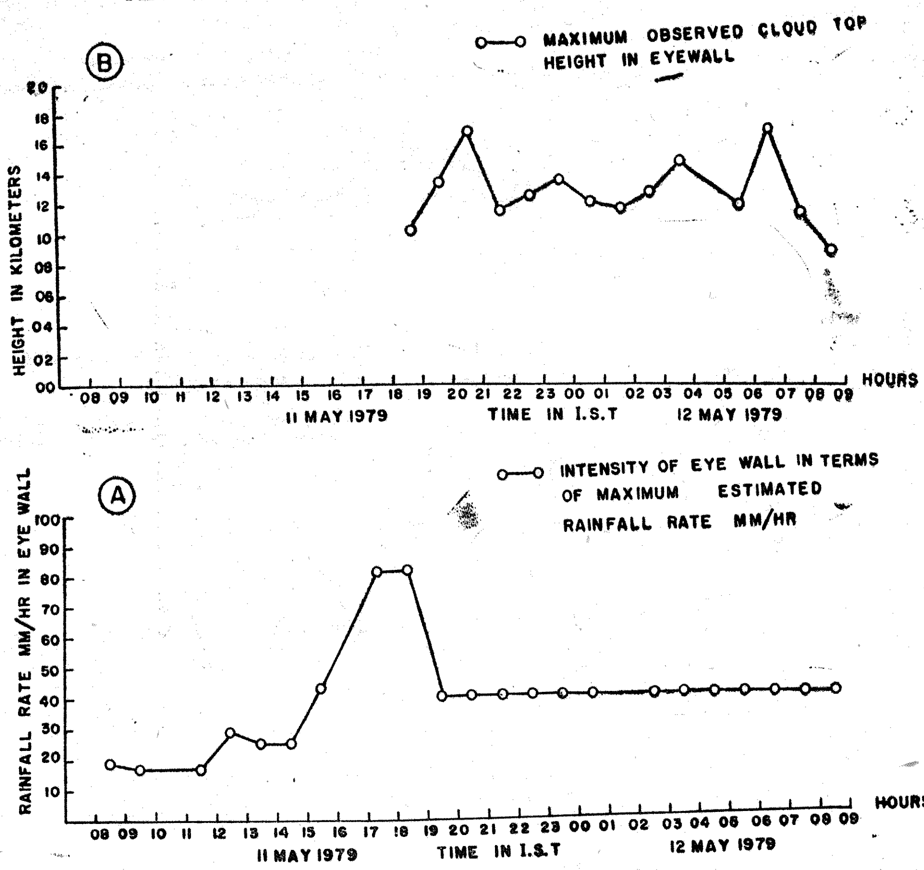


Fig. 8. Andhra cyclone of May 1979

TABLE 1

Date	Time (GMT)	Vertical lapse of refractivity: Surface to 950 mb $Ns\text{-}N_{950}$	Vertical lapse of refractivity: Surface to 900 mb $Ns\text{-}N_{900}$
10 May 79	12	60	110
11 May 79	00	65	125
11 May 79	14	52	92
12 May 79	00	21	66

troposphere near Madras was destroyed and subnormal propagation resulted. This can explain the range limitation of the radar on the 12th. To examine this further the refractivity (N) data for Madras based on radiosonde observations are shown in Table 1.

Although great reliance cannot be placed on radiosonde derived refractivity data (Rajagopalan and Raghavan 1979) the sharp fall in the gradient, supports the hypothesis that subnormal propagation occurred on 12th. However, if that were so, the apparent tops of the observed eyewall clouds should be expected to decrease from 11th to 12th. This is not found to be the case (Fig. 8). The observance of a few echoes beyond the eyewall on the 12th (Fig. 7) also is against the hypothesis of subnormal propagation. Echoes well beyond 200 km were also observed in directions other than that of the eyewall. It is known from experience that with a 10 cm radar there is no significant attenuation due to intervening precipitation. Hence it could be argued that the eyewall had actually opened out and that there was a reduction of storm intensity; but this seems unlikely as will be discussed in section 4. The tentative conclusion is that the apparent widening of the eyewall is due to subnormal radio propagation and should not be interpreted as a weakening of the system.

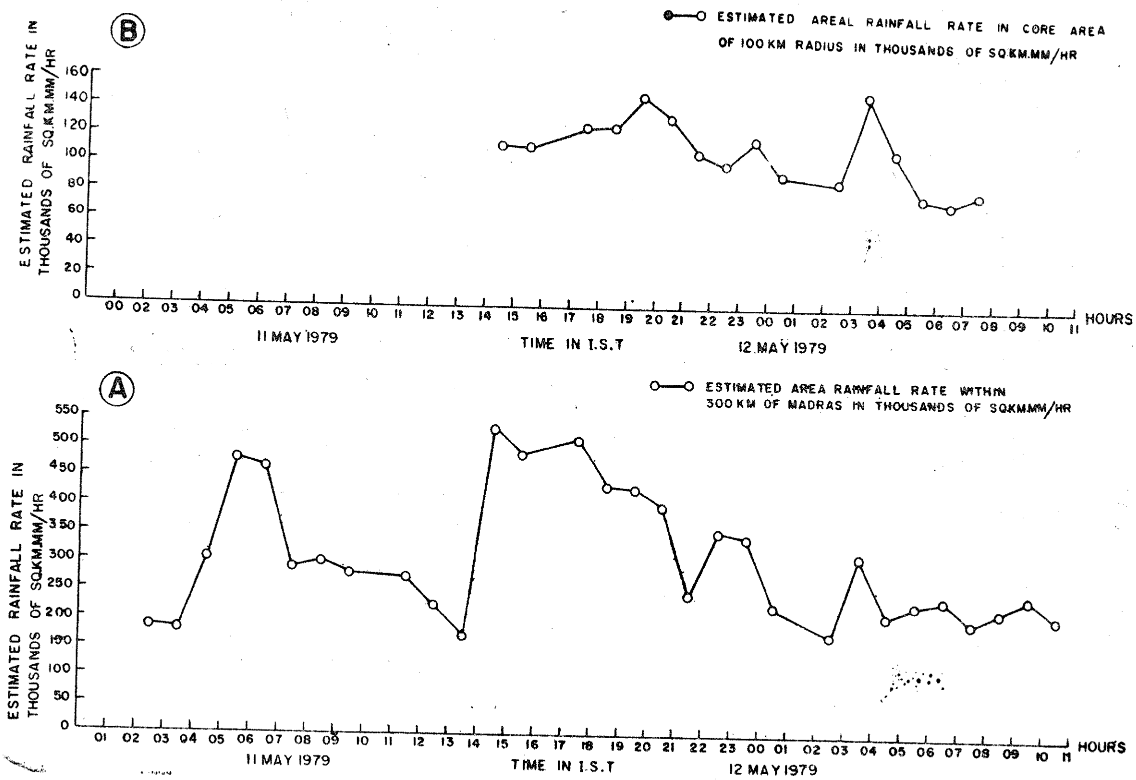


Fig. 9. Andhra cyclone of May 1979

As the eye was seen by radar over most of the period of tracking, the radar fixes could be considered accurate (within about 10 km) upto 09 GMT of 11th. Thereafter due to the aforesaid apparent widening of the eyewall the accuracy can be classified only as fair or poor (possible error 30 to 50 km). A linear extrapolation of the accurate track upto 06 GMT of 11th gives a 24-hour prediction of landfall near Ongole. This came true because subsequent changes of movement cancelled out. After 06 GMT of 11th the track became westnorthwesterly and an extrapolation would indicate landfall near Nellore. As it happened the storm turned northward when it approached the coast. The time variations in direction of movement based on the previous six hours of observation are indicated in Fig. 3. It is seen that the change in course towards north could have been recognised by the early morning of 12th.

4. Storm Intensity

As judged from surface winds reported by ships (Fig. 1) the storm was a severe one from 7th evening. During the period of radar tracking the eye was seen to be complete, nearly circular and of a diameter of about 20 km without much variation, upto 11th afternoon. The eye parameters are plotted in Fig. 4. The spiral rain bands observed on the 10th night were sparse and loose with large crossing angles. But by 11th morning the banding appeared more tight and crossing angles were less (about 10 deg.) near the centre. Therefore, it is probable that the storm had developed a core of hurricane winds by 11th morning. When the storm came over the coast the maximum recorded wind speed was 65 kt (at Nellore) and still higher speeds have been estimated from survey of damage. The lowest mean sea level pressure recorded at Ongole was 964 mb. Taking this to be the likely upper limit of the lowest surface pressure and the peripheral pressure to be 1004 mb the estimated maximum wind according to Fletcher's (1955) formula as modified by Natarajan and Ramamurthy (1975) comes to $13.6\sqrt{1004-964} = 86$ knots. Hence it appears that there was no significant change in intensity of the system between 11th and 12th. However the widening of the eye from 11th evening and the subsequent inability of the radar to see a closed eye could lead to an inference that the storm was weakening. But the heights of cloud tops in the eyewall (Fig. 8) do not show any reduction accompanying the opening out of the wall cloud. The maximum estimated rainfall rate in the eyewall also does not show any significant reduction (Fig. 8). Nor does the radar-estimated areal rainfall in the core area of 100 km radius around the storm centre (Fig. 9) show appreciable variation. The surface observational evidence is also against any conclusion that the storm could have weakened. Even if as seen from the eye structure the storm intensity has diminished, the winds associated with the system may take a further 24 hours to weaken (Dvorak 1972). Hence while it seems operationally useful to regard any reduction in eye diameter or increase in distinctness of the eye as a sign of intensification of a storm (Raghavan and Veeraraghavan 1979) the reverse inference involved in associating the widening out of the eye as weakening of the storm may not be reliable and may be operationally risky. The storm probably remained constant in intensity from the 11th to the 12th.

The approximate estimated areal rainfall in the entire radar echo within 300 km of Madras and that in the core area of 100 km radius are plotted in Fig. 9. As the calibration of the radar iso echo system on which these computations are based was not quite satisfactory during the period of the storm, the values in Fig. 9 may be taken only as rough order-of-magnitude estimates. The maximum areal rainfall rate is about 5.3×10^5 sq. km mm/hour in the entire echo and 1.5×10^5 sq. km mm/hour in the core area which are reasonable figures for a severe cyclone of small extent. The areal extent of the radar echo at its maximum was 7×10^4 km^2. The area of the total cloud cover seen by satellite (TIROS-N visible picture) on 11th afternoon was about 10 degrees across. Both of these are less than average. Hence we may conclude that the storm was a "mature cyclone of small extent" to use the words of Koteswaram and Gaspar (1956) who have surveyed a large number of Bay of Bengal cyclones.

5. Storm structure

As already mentioned the eye was a small one of diameter about 20 km. Throughout the 11th when the eyewall was clearly seen the southern part of the eyewall was most developed, *i.e.*, it had the greatest width and intensity. Allowing for beamwidth distortion which is significant in the case of a small eye (Raghavan and Veeraraghavan 1979) the maximum width of the eyewall in the southern sector was not more than 10 km. The radius of maximum winds may therefore be only about 25 to 30 km. This might have increased later as the diameter of the visible eyewall increased after 13 GMT of 11th (Fig. 4). It is not possible in this case to verify these figures from evidence of damage as the storm moved along the coast and consequently the damage was over an extensive area. The observation that the eyewall was better developed on the southern side, *i.e.*, the left sector of the storm agrees with the finding of Koteswaram and Gaspar (1956) and of Raghavan and Veeraraghavan (1979) that in *the core area* intense rainfall occurs preferentially in the left sector. However in the storm as a whole this may not be true. Though the radar was seeing more rainfall in the left sector this may be due to the proximity of that sector to the radar. In the case of November storms the above mentioned authors find extensive rainfall in the right sector. The analysis of rainfall data over land by Gupta and Subramanian (1969) in the Andhra cyclone of May 1969 shows that the rainfall in that storm extended over larger areas in the right sector than in the left sector. The observed distribution of rainfall in land areas in the present case suggests that this may be true for May storms in general. However this could not be verified from radar data as the right sector never came within the area of effective radar surveillance. Typical strong lines of convective cells or "streamers" in the right rear sector of the storm started appearing from 11th evening (Rockney 1956; Raghavan *et al.* 1980) and continued on the 12th. But these did not come over land and hence made no contribution to flood damage.

6. Conclusions

Analysis of the radar observed features of the Bay cyclonic storm of May 1979 supported by synoptic and satellite data, indicates that the storm was of severe intensity with a core of hurricane winds for about 24 hours before landfall. The storm was a mature one but of small extent. The core area was small and the most intense precipitation in the core area was in the left sector. There was an apparent widening of the eye which perhaps resulted from setting in of subnormal conditions of propagation following the initial abnormal propagation conditions favouring detection at an unusually long range. The radar gave the valuable indication of northwesterly movement of the storm even five days before landfall though this movement was climatologically less probable. Extrapolation of the radar track gave a good 24 hour forecast of point of landfall. Because of the unusually long range of tracking, precise warnings more than 36 hours before landfall were possible.

Acknowledgements

The authors wish to thank a number of colleagues at Cyclone Warning Radar, Madras and Area Cyclone Warning Centre, Madras for assistance in data collection and in useful discussions. It is a pleasure to acknowledge the assistance received from S/Shri M. S. Ranganathan, B. Ramakrishnan, A. Ramachandran, V. Ramaswami and V. R. Thiruvengadam in the computations, typing and preparation of photographs and diagrams.

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