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A cyclonic storm as seen from enhanced AVHRR satellite imagery

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सार–ध्रुव परिक्रमी उपग्रहों की शृंखला टी० आई० आर० ओ० एस०–एन० में एक उन्नत अति उच्चविभेदन विकिरणमापी लगा है । इससे पृथ्वी की मेघाछन्नता के अतिउच्च विभेदनी छायाचित्र (उप-उपग्रह बिन्दु पर 1.1 कि० मी०) प्राप्त किये जा सकते हैं । इन संकेतों को प्राप्त करने के लिए फरवरी 1981 में नई दिल्ली में भारत मौसम विज्ञान विभाग में भू-उपस्कर लगाए गए । इस शोध पत्र में सितम्बर 1981 में बंगाल की खाड़ी में आए चक्रवाती झंझा के अतिसूक्ष्म पहलुओं के अध्ययन का प्रयास किया गया है।

इस अध्ययन से पता चला है कि मौसम प्रणाली की तीव्रता और केन्द्र बिन्दु के ठीक ठीक निर्धारण में आयनिक उपग्रह छायाचित्र काफी उपयोगी हैं । प्रणाली के उत्तरपूर्व में गहन कपासी वर्षी मेघों के क्षेत्र का बनना यह संकेत देता है कि यह प्रणाली बाद में उत्तर पूर्व दिशा की ओर गमन करेगी ।

ABSTRACT. An Advanced Very High Resolution Radiometer (AVHRR) sensor has been provided in the TIROS-N series of polar orbiting satellites. With this, very high resolution pictures (1.1 km at the sub-satellite point) can be obtained of the earth's cloud cover. A suitable ground equipment to receive these signals has been set up in the Meteorological Department at New Delhi in February 1981. An attempt has been made in this paper to study the finer aspects of a cyclonic storm which developed in the Bay of Bengal in September 1981.

This study reveals the great utility of enhanced satellite pictures in correctly estimating the centre and intensity of weather systems. The formation of an area of intense *Cb* clouds to the northeast of the system suggests that the system will subsequently move in a northeasterly direction.

1. Introduction

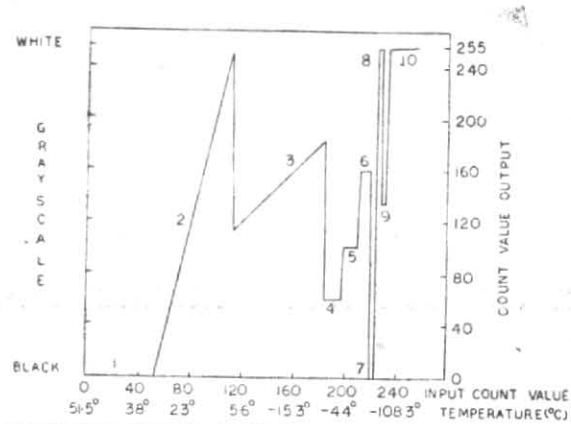
The TIROS-N series of polar orbiting satellite are provided with an Advanced Very High Resolution Radiometer (AVHRR). This transmits very high resolution pictures of earth's cloud cover, the resolution being 1.1 km. at the sub-satellite point. This radiometer has five channels which measure energy in the visible, near infra-red, water vapour and thermal infra-red regions.

A suitable ground equipment to receive the signals transmitted by the AVHRR has been set up in the Headquarters Office of the Meteorological Department at New Delhi in February 1981 and useful pictures are being received from May 1981.

The NOAA-6 and NOAA-7 satellites belonging to the TIROS-N series are at present circling the globe transmitting AVHRR data. An attempt has been made in this paper to study the finer aspects of a cyclonic storm which developed in the Bay of Bengal in the end of September 1981 with the help of the pictures obtained with this equipment using enhancement techniques. A somewhat similar study about the structural and cloud organisation changes duraing the Saurashtra cyclone of 6-12 November 1978 was made by Narayanan & Rao (1981).

2. Brief history of the system

A well marked low pressure area was seen in east central Bay of Bengal on the morning of 24 September 1981. This system intensified into a depression on the evening of 24th. It further intensified into a cyclonic storm on 25th morning and crossed Orissa coast near Puri on 26th morning. After crossing coast, the cyclonic storm



SEGMENT NO.	TEMPERATURE (°C)	INPUT COUNT	OUTPUT COUNT	REMARKS
1	51·5 TO 33·6	0-52	0	NO SIGNIFICANT INFORMATION
2	33·3 TO 9·3	53-112	5-250	LOW CLOUDS
3	8·9 TO -30·3	113-183	113-183	CIRRUS OUTFLOW PATTERN
4	-31·1 TO -41·3	184-197	60	DARK GRAY
5	-42·2 TO -53·6	198-210	101	MEDIUM GRAY
6	-54·7 TO -64	211-219	160	LIGHT GRAY
7	-65·3 TO -69·5	220-223	0	BLACK
8	-71·0 TO -75·7	224-227	255	WHITE
9	-77·4 TO -83·0	228-231	135	TOP MEDIUM
10	-85·0 TO -110·0	232-255	255	WHITE

Fig. 1. Enhancement curve for the cyclonic storm

weakened into a deep depression. From 28 September the depression moved in a NEly direction and broke up over the Western Himalayas by 29th morning.

3. Source of data

Polar orbiting US satellites NOAA-6 and NOAA-7 are presently circling the earth. With this we can get four pictures a day. Both these satellites transmit AVHRR (Advanced Very High Resolution Radiometer) data at 1.1 km resolution. Visible and infrared pictures used in this study have been taken from NOAA-6 and NOAA-7 day time AVHRR data. An attempt has been made to use infrared data to determine the temperature (and indirectly the height) of the coldest cloud top using an enhancement technique.

4. Description of the enhancement curve used for the study of cyclonic storms

Enhancement of infrared satellite data is used to bring out clearly the temperature distribution in clouds by assigning different shades of grey to different temperature ranges. The enhancement curve used in this study for finding the finer aspects of the cloud features associated with a cyclonic storm is shown in Fig. 1. As can be seen from the graph, this enhancement changes the grey shades of input radiance values corresponding to the temperatures from 33.7 deg. C to —110.2 deg. C into 10 segments. The low clouds in the temperature range 33.7 deg. C to 9.3 deg. C are enhanced in the second segment and the output shade changes from black corresponding to 33.7 deg. C to white corresponding to 9.3 deg. C. In the third segment medium to high clouds are enhanced while from 4th onwards it is completely high clouds. As the wall clouds extend to very great heights, it is reasonable to assume that they will be beyond 200 mb heights, where the average temperature is about —55 deg. C. Narayanan & Rao (1981) have taken 255 deg. K (—18 deg. C) as defining the CDO cloud boundary. It is, however, felt that this is too high a temperature representing medium cloud level to define the CDO. As CDO is the dense overcast mass of clouds forming part of the comma head, its temperature will be much colder than —18 deg. C

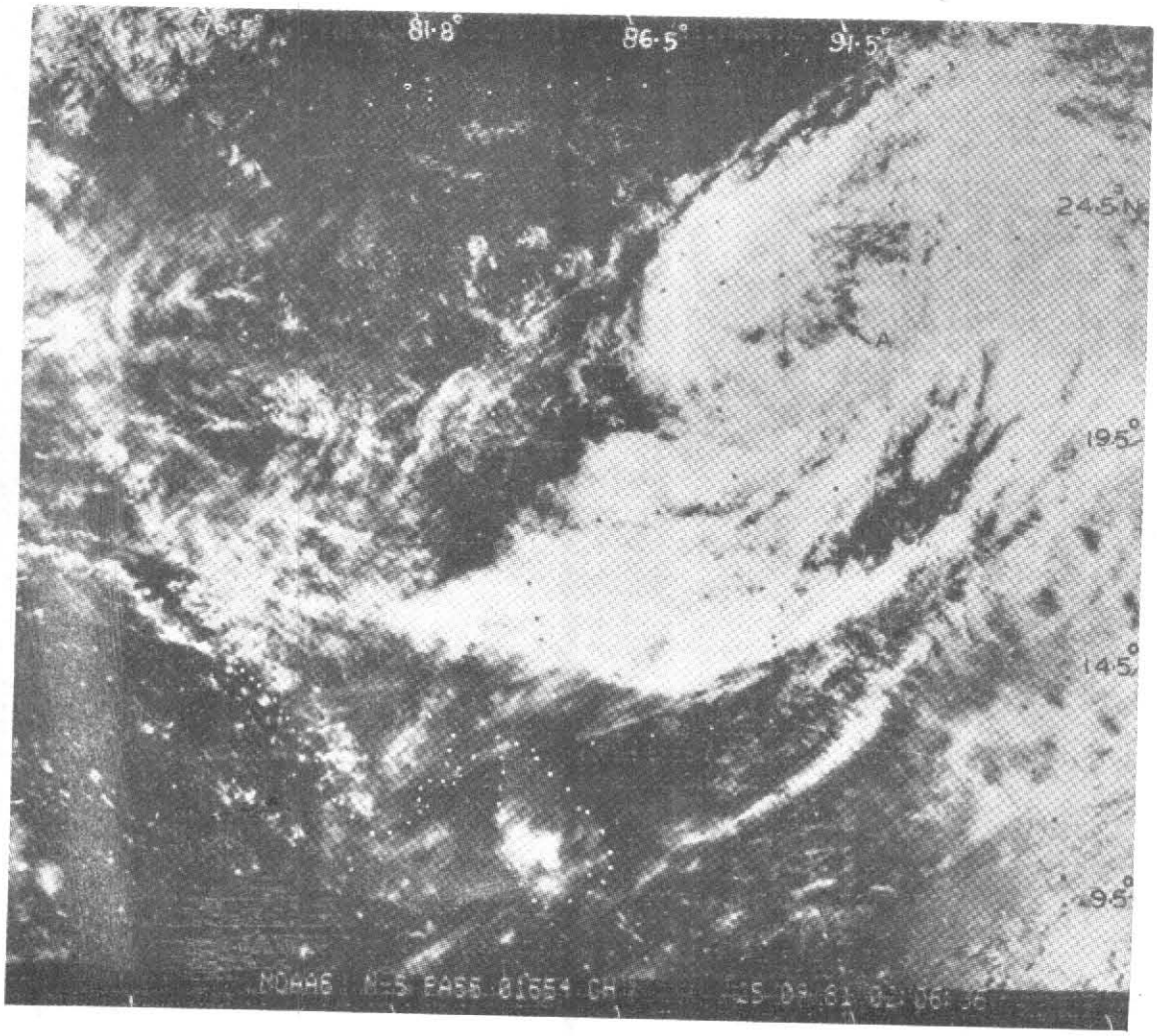


Fig. 2. NOAA-6 visible imagery of 25 September 1981, time 07-00-26 IST

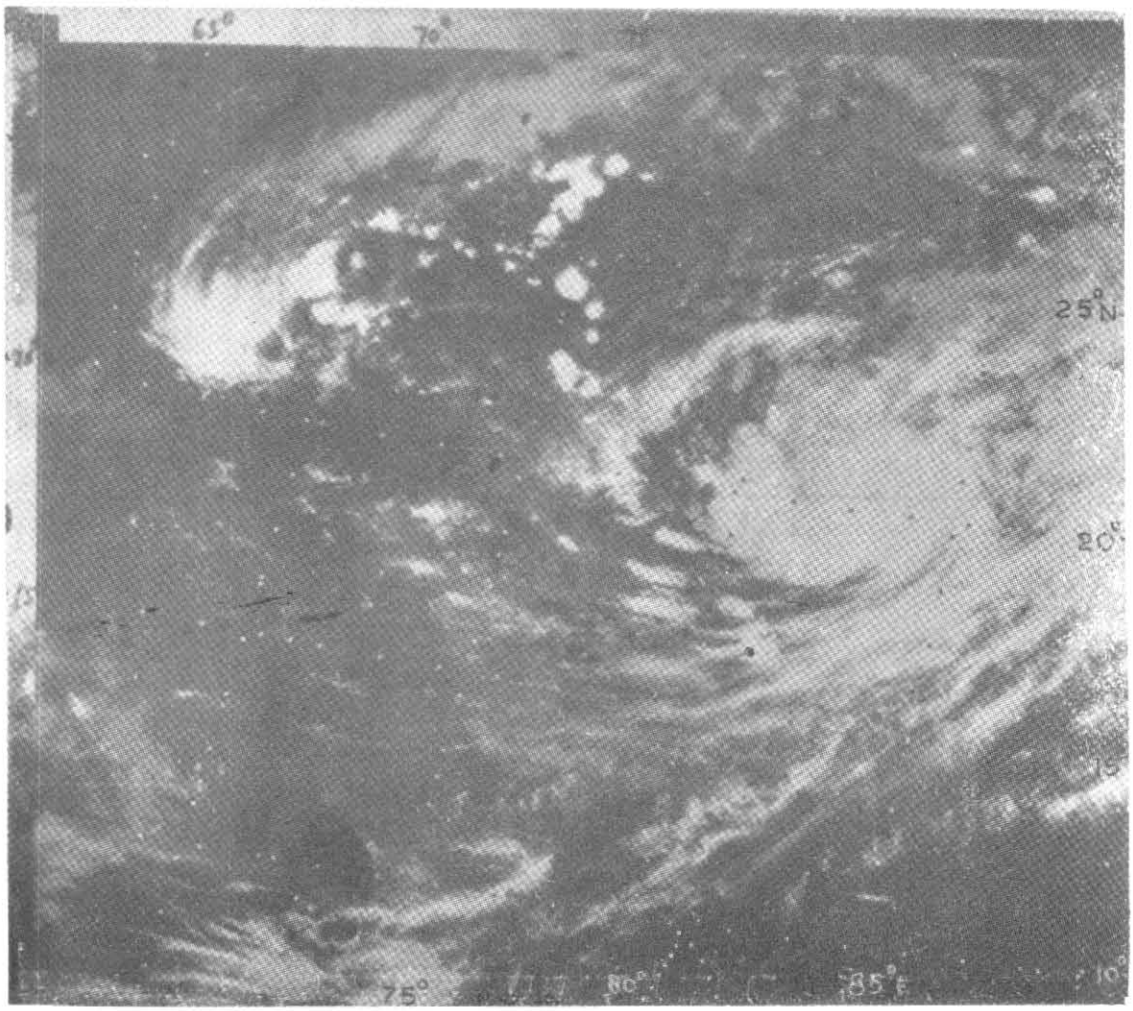


Fig. 3. NOAA-7 visible imagery of 26 September 1981, time 14:36:51 IST

Fig. 4. NOAA-7 infrared (enhanced) imagery of 26 September 1981, time 14-36-51 IST

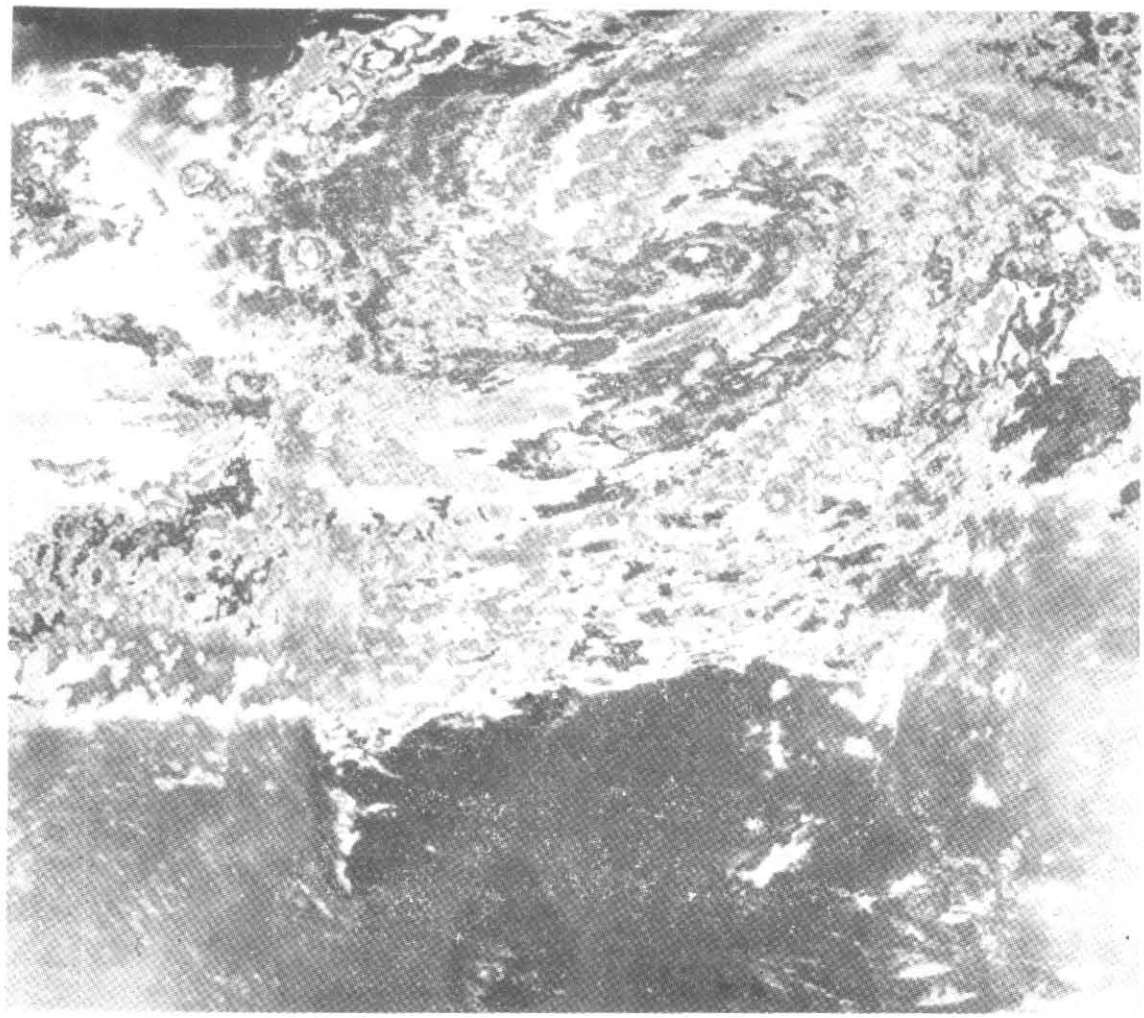


Fig. 5. NOAA-7 infrared (enhanced) imagery of 27 September 1981, time 14-25 IST

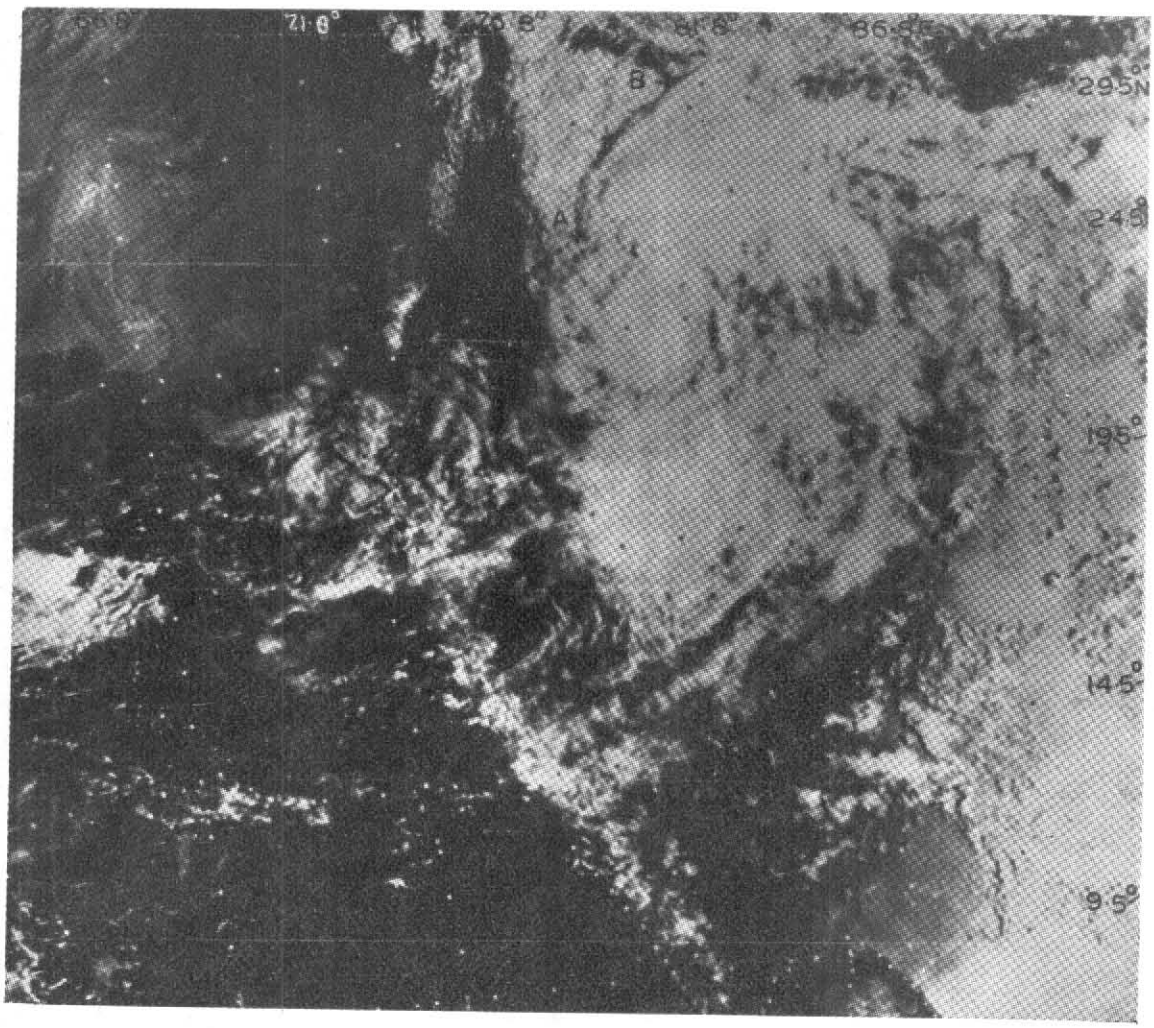


Fig. 6. NOAA-6 visible imagery of 28 September 1981, time 08-07-55 IST

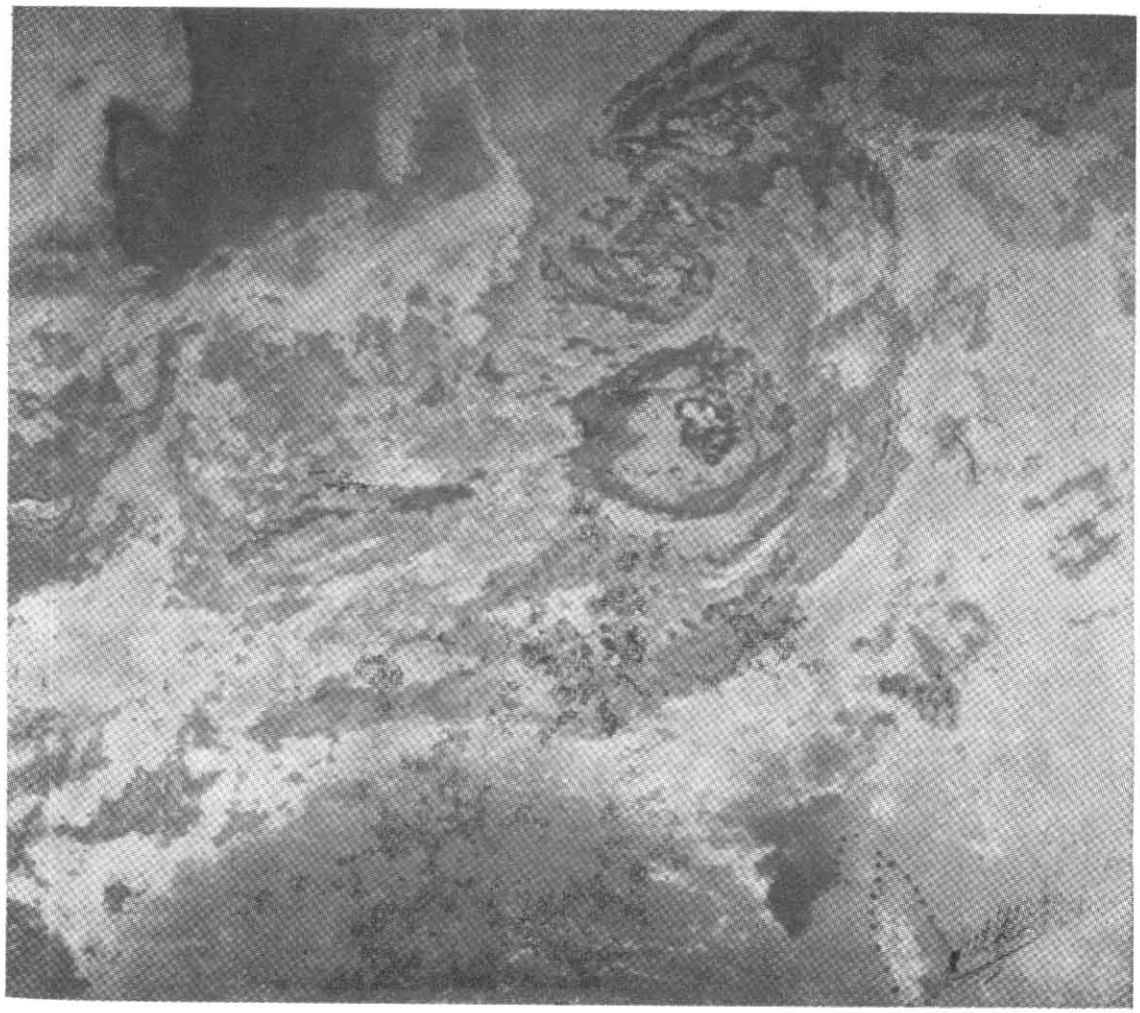


Fig. 7. NOAA-5 infrared (enhanced) imagery of 28 September 1981, time 08-07-55 IST

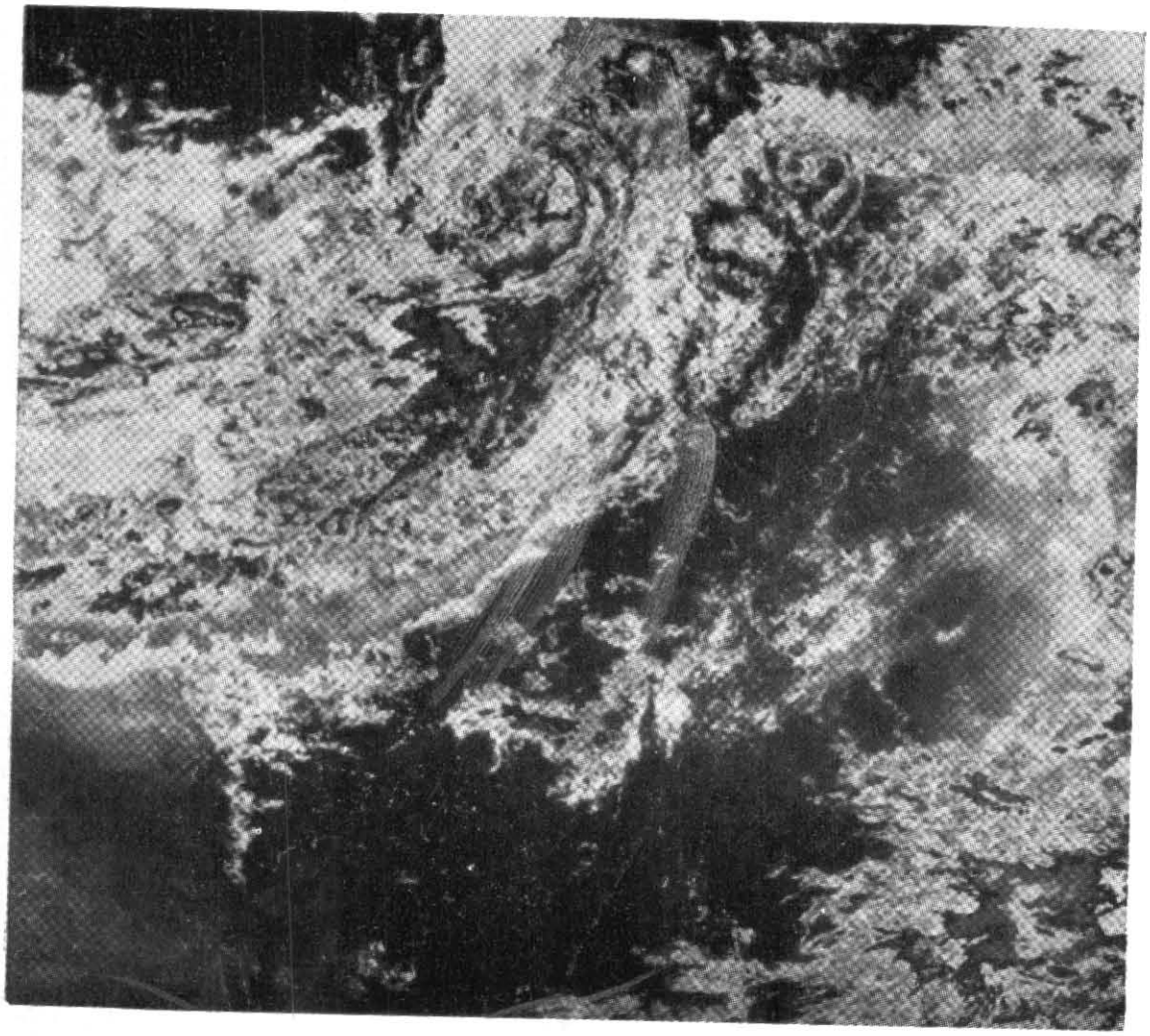


Fig. 8. NOAA-7 infrared (enhanced) imagery of 28 September 1981, time 08-07-55 IST

and hence the temperature of —65 deg. C and lower representing the cirrus level and above will adequately represent the CDO. Thus the seventh segment and above corresponding to a temperature — 65 deg. C and lower may be expected to represent the wall clouds. Consequently area bounded by the black shade represents the wall clouds of the cyclone.

5. Day to day changes in cloud features associated with the cyclonic storm

Visible satellite imagery on the morning of 25 September 1981 (Fig. 2) shows the initial organisation of a developing cyclone. The cloud mass at the centre has not yet organised but *Cb* cells are seen all around the centre. The centre is at A in the cloudless region near 18.0 deg. N, 88.5 deg. E giving the false appearance of a banding type of eye. According to Dvorak's classification (Dvorak 1975) the cloud configuration can be assigned T-number 2. This depression has concentrated into a cyclonic storm on 26th morning as seen from NOAA-6 satellite cloud imagery. A central dense overcast (CDO) is clearly seen and the centre of the cyclonic storm is within the CDO. The afternoon infrared cloud imagery (Fig. 3) shows the CDO is somewhat elongated and the centre is within the CDO. Fig. 4 shows the enhanced IR imagery taken on the afternoon from NOAA-7 corresponding to the unenhanced infrared picture seen in Fig. 3. The enhanced picture (Fig. 4) shows the coldest cloud top is in the right hand corner of the CDO and the coldest temperature is less than —77 deg. C (top medium). However, the cloud top is not very well organised and circular. Some cloud bands are clearly seen around the main system. West of the main cyclonic centre, there is a fairly large area in NE Arabian Sea off Gujarat coast having large cumulonimbus clouds, tops reaching beyond —77 deg. C. A long train of medium and low clouds emanates from this huge convective mass towards NE indicating the presence of a low level trough.

The enhanced features associated with the afternoon picture of 27 Sept 1981 can be seen in Fig. 5. Curved convective bands are clearly seen converging towards centre. Though the banding is better organised on this day than on 26th, the lowest cloud top temperature is colder and more extensive on 26th than on 27th as seen by the area covered by the white and top medium shades on these 2 days. Thus by the cloud top temperatures, we can conclude that the system was weaker on 27th than on 26th. This is also borne out by the synoptic features, namely the lowest isobar on 26th being 997 mb, whereas it is 998 mb on 27th, the 24 hour pressure drop on 26th was 11.4 mb while it was 9.0 mb on 27th.

Three large cumulonimbus cells can be seen embedded in the low level trought to the west and northwest of the deep depression aligned in a SW to NE direction. The tops of these *Cb* cells are quite cold, extending beyond — 77 deg. C. These are probably the outcome of the huge *Cb* area seen on the previous day of Gujarat coast.

Visible satellite imagery of NOAA-6 on 28 September 1981 (Fig. 6) shows that the circulation associated with the deep depression is centred near 24.5 deg. N, 78.5 deg. E. To the south of the main system a large bright dense circular could mass is also present. This represents an area of intense convection as seen from the enhanced AVHRR picture of NOAA-6 (Fig. 7) whereas by seeing the visible picture alone, it can be mistaken for cyclonic circulation. The low level trough to the west of the deep depression is no more visible on 28th morning except as a belt of low clouds. Another significant feature brought out in the visible picture of this day (Fig. 6) is a dark shadow line (AB) representing the shadow of the thick multilayer clouds to the right on the low level clouds to the left, fitting with the Sun's position.

The infrared cloud imagery of the afternoon is shown in Fig. 8 This enhanced picture does clearly indicate that the banding feature has greatly weakened, though the coldest cloud temperature is extending beyond —77.0 deg. C as suggested by top medium shade at the centre. This is probably due to the merger of the western disturbance cloud with that of the depression.

Another noteworthy feature is the presence of an intense thunderstorm area to the NE of the system. This suggests the recurvature of the system towards NE. The deep depression actually recurved and moved NEwards from 28 Sept 1981. Thus the presence of such intense convective clouds can give the clue for recurvature. Mishra and Singh (1977) have also observed the formation of active convective band in the direction ahead of a cyclone.

6. Conclusion

This study reveals the great utility of enhanced satellite pictures in correctly estimating the centre and intensity of systems just as Narayanan & Rao have felt about the utility of CTT (Cloud Top Temperature) maps. The system in our study was a marginal cyclone with no *'Eye'* seen. The Central Dense Overcast (CDO) was seen only on one day, *viz.*, 26th in the visible picture. The formation of an area of intense *Cb* clouds to the NE of the system on 28th appears to suggest that the system will later recurve northeastwards which it actually did. As observed by Narayanan & Rao no progressive shift of the deep convective zones was noticed in this case when the system was decreasing in intensity.

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