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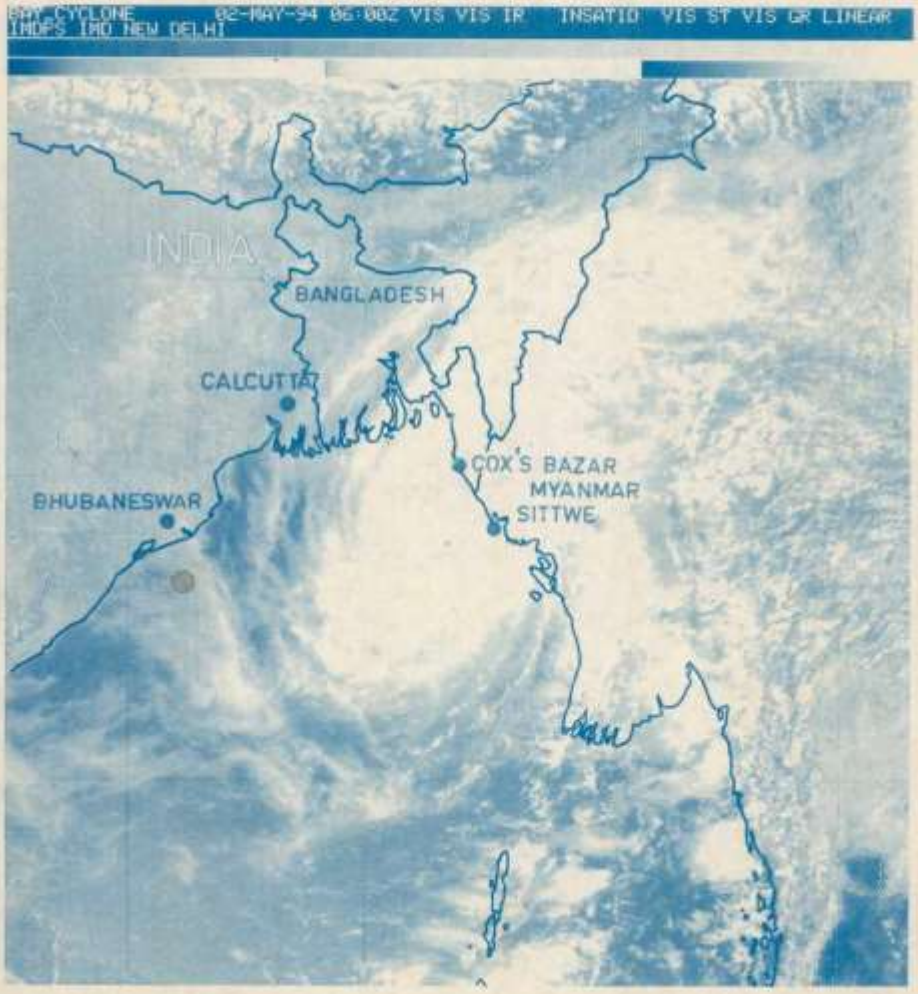
INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 1994



RSMC-TROPICAL-CYCLONES, NEW DELHI
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Introduction

This report consists of a review of the cyclonic disturbances and their associated features, that formed in the North India Ocean (The Bay of Bengal and the Arabian sea) during the year 1994. The classifications of cyclonic disturbances followed in the report are given below:

	Weather System	Maximum Sustain Surface Wind speed
1.	Low	Wind speed less than *17 kt* *(<31 kmph)*
2.	Depression	Wind speed between *17 kt* and *27 kt.* *(between 31 and 49 kmph)*
3.	Deep Depression	Wind speed between *28 kt* and *33 kt.* *(between 50 and 61 kmph).*
4.	Cyclonic Storm	Wind speed between *34 kt* and *47 kt.* *(between 62 and 88 kmph).*
5.	Severe Cyclonic Storm	Wind speed between *48 kt* and *63 kt.* *(between 89 and 117 kmph)*
6.	Severe Cyclonic Storm with a core of hurricane winds.	Wind speed *64 kt* or more *(118 kmph or more)*

The term 'cyclone' used at times in the text, is to indicate all the three categories of cyclonic disturbances given above under S.N. (4) to (6).

Following are the important features of cyclonic disturbances in the North Indian Ocean during 1994:

(a) This year, there were eight cyclonic disturbances against the normal frequency of 15 per year. Six out of the eight disturbances formed over the Bay of Bengal and the two over the Arabian Sea. Only four of these systems intensified to cyclone.

(b) A depression formed over Bay of Bengal in the month of March after a gap of 55 years.

(c) A system that formed over the Bay of Bengal towards the end of April, attained hurricane intensity, recurved toward north-east and finally crossed Bangladesh-Myanmar coast near the border of two countries.

(d) A system that formed over the East Arabian Sea at the leading edge of southwest monsoon current attaining its peak intensity of severe cyclonic storm weakened near Oman coast after recurving towards west.

(e) A cyclonic disturbance which formed near latitude 10 deg. N in the Arabian Sea, moved west-south-westward, attained hurricane intensity and finally crossed north Somalia coast. There was no such parallel case in the recorded history.

(f) The systems which affected the Indian coast in 1994 formed close to the coast and had a short life of 48 to 72 hours.

(g) The 'eye of' a cyclonic storm passed over 'Madras' a major city of India. There was no record so far during this century when the eye of a cyclone passed through a mega city like Madras.

The first system formed over the southeast Bay of Bengal on 21 March and attained the intensity of depression. It moved northward and weakened over east central Bay of Bengal by 24 March. The second system formed over southeast Bay of Bengal on 29 April and moving in a northerly to northeasterly direction, intensified into severe cyclonic storm with a core of hurricane winds. It crossed Bangladesh-Myanmar coast near 'Technaf'(41998) in the afternoon of 2 May. The third system formed in the Arabian Sea on 5 June at the leading edge of southwest monsoon current. It moved initially northwest and then westward. It intensified into a severe cyclonic storm by the afternoon of 7 June. Moving in a westerly direction upto 9 June, it weakened near Saudia Arabia coast on the morning of 10 June. This system strengthened the activity of southwest monsoon over southern parts of Indian peninsula.

The fourth & fifth cyclonic disturbances attained the intensity of deep-depression only. The fourth system formed on the morning of 17 August over the northwest Bay of Bengal and crossed Orissa coast during the early morning of 18 August. The fifth system formed over West Central Bay of Bengal on 4 October and crossed Andhra Pradesh coast by the morning of 5 October. The sixth cyclonic disturbance of the year formed on 29 October and intensified into severe cyclonic storm in the evening of 30 October and crossed north Tamilnadu coast near Madras city on the morning of 31 October. It weakened gradually over south Andhra Pradesh by 2nd November. The storm caused death of 304 persons in Tamilnadu & Andhra Pradesh. Large damages to crops and houses were also reported from these States.

The seventh disturbance was a depression which formed over the southwest Bay of Bengal on the morning of 4 November and crossed north Tamilnadu coast near Karaikal by midnight of same day. It caused widespread rainfall with scattered heavy falls over south Tamilnadu on 5 November. The last system formed as depression over the southeast Arabian Sea on 15 November. It initialy moved westward and then west-south-westwards. The system intensified into a severe cyclonic storm with a core of hurricane winds on the morning of 19 November and finally crossed over north Somalia coast as a severe cyclonic storm on the morning of 20 November. This is a unique case of a cyclone crossing north Somalia coast.

Table 1A gives the monthly distribution of cyclonic disturbances over the north Indian Ocean. It may be seen from the table that the number of the systems in the pre-monsoon (March- May), monsoon (June-September) and post monsoon (October- December) seasons of this year were 2,2 and 4 respectively. Only one depression formed in the monsoon season against the normal frequency of six per year.

Table 1B gives the duration of each type of cyclonic disturbance alongwith the duration of peak intensity, place and date of crossing the coast, loss of lives, peak storm surge etc. Identification numbers are given to the systems of cyclone intensity only in accordance with the para 2.3 of the TCP-21. Table 2 to 9 give the best track position at 00,03,06,12 and 18 UTC alongwith the other meteorological parameters for all the systems in the Bay of Bengal and the Arabian Sea.

Detailed account of all the systems are given in the following paragraphs. The tracks of these systems are shown in Fig 1. The locations of various stations referred to in this report are shown in Fig 2.

2. Detailed description of cyclonic disturbances

2.1 Pre-monsoon Season (March-May)

During the pre-monsoon season, two disturbances formed over the Bay of Bengal one depression in the month of March and the other a severe cyclonic storm towards the end of April. The formation of a depression in the month of March 1994 occurred after a gap of 55 years, the last one was

observed in 1938. This is the second depression during the past 100 years in March. The frequency of a depression or cyclonic storm during March in the Bay of Bengal is 0.4% (5 out of 1231) which is second lowest frequency; lowest being in the month of February. March is generally depression free month for the Indian Seas.

Towards the end of April 1994 a severe cyclonic storm formed in the Bay of Bengal and moved initially northward and then recurved north-eastward towards Bangladesh/Myanmar coast by the evening of 2nd May 1994. Though cyclone crossing Bangladesh coast even in April or beginning of May is not unusual but these are low probability event.

2.1.1 Bay of Bengal Depression (21-24 March 1994)

A well marked low pressure area formed over the southeast Bay of Bengal at 0300 UTC of 21 March 1994 with estimated center near 8.0 deg.N and 92.0 deg.E. By the same evening some organization of clouds as seen in the satellite picture indicated the formation of a depression and its intensity at that time was estimated as T-1.5 on Dvorak's scale with center near lat. 9.5 deg.N and long. 91.0 deg.E. The depression moved almost in a northerly direction without any intensification and by the evening of 24 March, weakened into a low pressure over the east central Bay of Bengal. This system sustained itself for 72 hours without any intensity change and did not affect any coastal area as it weakened over the sea.

2.1.2 Bay of Bengal Severe Cyclonic Storm with a core of Hurricane Winds from 29 April-2 May 1994 (BOB 9401 0429)

2.1.2.1 Life history of the cyclone

The INSAT-2B imagery of 00 UTC of 28 April 94, indicated an intense organised convective cloud cluster over the Andman Sea and adjoining southeast Bay of Bengal suggesting a broad scale low level circulation. Subsequently, from 0900 UTC satellite cloud imagery (Fig. 3) further development and better organisation of clouds could be seen and the system was classified as low pressure area near Lat.7.5 deg.N/Long. 94.0 deg.E. By the morning (00 UTC) of 29 April, further organisation of cloud system indicated the formation of a depression over the southeast Bay of Bengal with its centre located near latitude 8.5 deg.N/long. 92.0 deg.E and at 0300 UTC near Lat. 9.0 deg.N/Long. 91.5 deg.E as a deep depression. It

moved in a north-north- westerly direction and by 1200 UTC intensified into a cyclonic storm near Lat.10.0 deg.N/Long. 91.0 deg.E. Continuing to move in a north-north-westerly direction with slow intensification, it was located at 0300 UTC of April 30 near Lat.11.0 deg.N/Long. 90.5 deg.E with estimated central pressure 994 hPa. By the evening it recurved towards north and acquired the intensity of a severe cyclonic storm with its centre near Lat. 12.0 deg.N/Long. 90.5 deg.E at 1200 UTC with estimated central pressure of 988 hPa. It continued its northerly movement and intensified further into a severe cyclonic storm with a core of hurricane winds by 0900 UTC of 1st May 94 with its center at 1200 UTC near Lat. 16.0 deg.N/Long. 90.4 deg.E. Thereafter the system recurved northeastward, with continuous intensification and was located at 020300 UTC near Lat.19.0 deg.N/Long. and 91.4 deg.E. By the mid-night (1700 UTC) of 2nd May, it crossed Bangladesh-Myanmar Coast near Technaf. The system attained the peak intensity of T-6.0 on Dvorak's scale equivalent to the associated maximum sustained surface wind of 115 kts (213 kmph) at 0700 UTC of 2 May and crossed the coast with same intensity.

2.1.2.2 Monitoring and Tracking

As the cyclone was beyond the range of Cyclone Detection Radar (CDRs) located over the east coast of India, it was tracked and monitored continuously with the help of INSAT-2B cloud imageries and from 1st May onward by the CDRs located at Cox's Bazar (41992) and Khepupara (41984) in Bangladesh.

Hourly INSAT-2B cloud imageries provided continuous indication about the organisation of clouds, ongoing slow intensification of the system into cyclonic storm. Curved convective cloud bands were clearly seen developing and contracting around the center of the system. A well defined system with center near Lat. 9.3 deg.N/Long 91.3 deg.E was observed in the satellite cloud imagery of 0600 UTC of 29 April. Subsequently, the associated bands became more tight and eye appeared in the central area of the central dense overcast (CDO) by the evening of 29 April. The system further intensified and the features suggested the intensification to T-3.5 at 0800 UTC of 30 April. The associated CDO pattern continued to evolve and the imagery of 0600 UTC of May 1 (Fig.4) showed the full development of an eye. Warming of eye was noticed in the evening of May 1 and it continued upto May 2.

The radar observations recorded at Khepupara and Cox's Bazar were very useful in fixing the center of the system on May 2. The radar track of the cyclone is given in Fig. 5. The diameter of the eye was reported as 30 km.

2.1.2.3 Movement

The system was initially located in the southwest sector of the upper air anticyclone at 200 hPa and accordingly it moved in a north-westerly direction under the influence of southeasterly flow in the upper levels. The sub-tropical ridge line at 200 hPa passed along Lat.11.0 deg. N over the Bay of Bengal on these days. Slowly the system moved into western portion of the upper air anticyclone at 200 hPa and accordingly it recurved towards north on May 1. The ridge line at this time shifted north and was passing along Lat.12.0 deg.N over the Bay of Bengal. Gradually, the system came under the influence of southwesterly flow at 200 hPa and ridge line also moved northward upto Lat. 15.0 deg.N on 2 May. This pattern caused the system to move in a north-north-easterly direction. Therefore, it appears that the movement of this system was governed by the position of upper air anticyclone at 200 hPa.

2.1.2.4 Meteorological Features and Weather Caused

2.1.2.4.1 Pressure

The cyclone attained a peak intensity of T 6.0 on Dvork's scale at 0700 UTC of May 2. Considering the peripheral closed isobar of 1006 hPa, the estimated lowest central pressure corresponding to the peak intensity works out to be 940 hPa. The lowest pressure of 971.9 hPa was recorded by the station Technaf (41998) on 1200 UTC of May 2. As the system crossed about 30 km north of Technaf the pressure gradient between Technaf and center of the system was quite high, i.e., 1 hPa per km.

2.1.2.4.2 Winds

Although a good number of ships' observation were available during the life period of this cyclone, they were beyond the field of cyclone. As such, no significant wind observations were available from the cyclone field. However, when the cyclone approached the coast, Cox'Bazar (41992) reported strong wind 023 deg/43 kt at 1200 UTC and 340/75 kt at 1500 UTC of May 2. At 1800 UTC, station Kutubdia (41989) in Bangladesh reported strong

wind of NE/55 Kts. As per the available reports from Bangladesh Meteorological Department(BMD) station Technaf (41998) recorded a maximum wind of SE/150kt at 12 UTC of May 2. The wind speed appears to be on a higher side in comparison to the estimated Maximum wind of 115 kt.

2.1.2.4.3 Rainfall

Based on the available rainfall reports received from Bangladesh, heavy to very heavy rainfall occurred over southeastern parts of Bangladesh on 3 and 4 May. The chief amounts of rainfall recorded on May 3 are Technaf-19 cm, Cox's Bazar-18 cm.

2.1.2.4.4 Damages

On account of strong winds and torrential rains in the coastal areas of southeast Bangladesh and adjoining parts of Myanmar, extensive damage to the crops, houses, livestock and other property have been reported from these areas. The loss of life was limited to 188 due to the timely and adequate cyclone warnings issued by Bangladesh Met. Department. The particulars of some other damages, as per the reports available from BMD are given below:

1. Affected people 4,16,000
2. Damaged houses 45,000
3. Loss of livestock 7,890
4. Loss of crop 21,167 acres.

Reports on storm surge caused by the system in the region were not readily available.

2.2 Southwest Monsoon (June-September)

During this period a severe cyclonic storm formed over the Arabian sea on 5 June. Moving initially northwestward, it recurved to Oman coast and weakened before crossing the coast by 10 June 1994. A second system formed as depression in the Bay of Bengal on 17 August, 1994 and crossed Orissa coast on the morning of next day.

2.2.1 Arabian sea severe cyclonic storm 5 - 9 June 1994 (ARB 9402 0605)

2.2.1.1 Life history of the cyclone

A well marked low pressure area formed off Maharashtra-Goa coast at 1200 UTC of 5 June 94 near Lat.15.5 deg.N/Long. 73.0 deg.E. At this time Goa recorded the lowest pressure of 991.4 hPa and southwesterly wind of 15 kt at 12 UTC of 5 June. It concentrated into a depression by 1800 UTC and deep depression by 03 UTC of 6 June with centre near Lat.17.5 deg. N/Long. 71.5 deg. E. At this time Ratnagiri reported westsouthwest wind of 40 kt. By the same evening it intensified further into a cyclonic storm and was located at 1200 UTC near Lat.18.0 deg.N/Long.70.5 deg. E.

By 7 June the cyclonic storm intensified into a severe cyclonic storm with its centre at 0900 UTC near Lat.19.5 deg.N/Long. 64.5 deg.E and at 1200 UTC near Lat. 19.5 deg.N/Long. 64.0 deg.E. Moving in a westerly direction it weakened into a cyclonic storm and was centered at 0300 UTC of 8 June near Lat. 19.5 deg.N/Long. 61.5 deg.E. It weakened further into a deep depression at 1200 UTC with its centre near Lat. 19.5 deg N/Long.61.0 deg.E. By 03 UTC of June 9, it became depression near Lat. 19.5 deg.N/Long. 59.5 deg. E and dissipated finally near Oman coast by the evening of June 9.

2.2.1.2 Monitoring and Tracking

In the initial stage, when the system was in the depression stage off south Maharashtra-Goa coast, the tracking was done with the help of INSAT-2B cloud imageries, coastal radar, conventional coastal synoptic observations and ship observations. At 0300 UTC of 6 June radar observations from CDR Bombay showed scattered intense clouding in the west and southwest sector from 270-180 deg. At 0600 UTC spiral bands were observed at about 220 km westnorthwest of Bombay. As the cyclone moved westward, away from the coast further radar observations did not show any organized spiral bands due to limitation on its range of detection. Only broken convective clouds at a distance of 100-200 km with little organisation were seen. Some vital ship observations and ONGC Rig observations also helped in tracking the system till 7 June. Thereafter the system was monitored mainly with the help of INSAT-2B cloud imageries.

2.2.1.3 Movement

This system formed over the Arabian Sea near 17 deg.N during the onset phase of the southwest monsoon. At this time the wind flow at higher levels over this area is normally from easterly direction and the ridge line at 200 hPa passes roughly along 25 deg.N. The movement of this cyclone was influenced by the upper level easterlies at 300 and 200 hPa. Since, at this stage the system was embedded in deep easterlies prevailing in the southern portion of the sub-tropical anticyclone between 300-200 hPa, it changed its course from northwesterly to westerly direction.

2.2.1.4 Meteorological Features and Weather Caused

2.2.1.4.1 Wind

The system attained its peak intensity of T-3.5 on Dvorak's scale at 0900 UTC of 7 June when it was centered near Lat.19.5 deg.N/Long.64.5 deg.E. The associated estimated maximum sustained surface wind for this intensity is 55 kt (102 kmph). Ships' observations in the periphery of the system reported southeasterly to easterly winds of 25 to 35 kts.

2.2.1.4.2 Pressure

The lowest central pressure corresponding to the peak intensity T-3.5 at 0900 UTC of June 7 was estimated as 980 hPa considering the pressure drop corresponding to highest T-No. and the value of outer closed isobar of the cyclone.

2.2.1.4.3 Rainfall

Under the influence of this cyclone, the southwest monsoon strengthened along the west coast of India. Heavy to very heavy falls were recorded by several stations in coastal Karnataka and southrn parts of Konkan & Goa.

2.2.1.4.4 Damages

The system formed at the leading edge of the southwest monsoon current of the Arabian Sea resulting in increased rainfall activity along the western ghats. As the cyclone moved, subsequently futher away from the Indian coast, it did not cause any damage. However, under its influence

squally winds of the order 50-60 kmph were reported along and off Maharashtra and Gujrat coast, during 6 to 8 June.

2.2.2 Bay of Bengal deep-depression. 17-21 August 94

A depression formed over the north west Bay of Bengal at 0300 UTC of 17 August near Lat.20.5 deg.N/Long.88.5 deg.E (close to Sandheads). It intensified into a deep-depression by the same evening and was located close to Orissa coast at 1200 UTC near Lat.20.5 deg.N/Long.87.5 deg.E. Moving in a westerly direction, it crossed Orissa coast near Chandbali in the early morning of 18 August and weakened into a depression over Orissa by the same morning. Maintaining its intensity, the depression moved in a westnorthwesterly direction till the afternoon of August, 20 when it was located near Jodhpur (42339) in Rajasthan. Thereafter, it weakened gradually over southern parts of Pakistan.

The disturbance formed in situ over the north Bay of Bengal on 17 August. Satellite imageries of 0300 UTC and 1200 UTC of 17 August showed dense curved clouds off Orissa coast. The clouds were mainly in the southern sector of the system.

Under the influence of this depression, southwest monsoon strengthened along the west coast and central parts of India. Widespread rainfall with isolated heavy to very heavy falls occurred over western ghats and central India.

2.3 Post-monsoon Season (Oct-Dec)

During this season, two systems formed over the Bay of Bengal in October and one each formed in the Bay of Bengal and Arabian sea in November. A deep depression formed over west central Bay of Bengal during the first week of October and crossed south Andhra Pradesh coast. Thereafter it recurved towards northeast and weakened gradually. The second system formed over the Bay of Bengal towards the end of October and intensified into severe cyclonic storm. It crossed Tamilnadu coast on October 31. The third system formed as depression over the Bay of Bengal during the first week of November and crossed Tamilnadu Coast near 'Karaikal'. The fourth one formed in the Arabian sea during the middle of November and crossed north Somalia coast as severe cyclonic storm on November 20.

2.3.1 Deep Depression (4-7 Oct. 1994)

A well marked low pressure area formed over west central Bay of Bengal on the morning of 4 October and concentrated into a depression by the same evening. It intensified into a deep depression by 1800 UTC with center near Lat 16.0 deg.N/Long 81.5 deg.E (about 100 km ESE of Machilipatnam). Moving in a west-north-westerly direction it crossed south Andhra Pradesh coast near Machilipatnam in the morning (around 0200 UTC) of 5 October. At 0300 UTC, it was located inland near Lat 16.5 deg. N/Long 80.5 deg. E. Moving northwestward, it weakened into a depression and by the morning of 6 October and recurved first towards north and then towards northeast. Its position at 1200 UTC of 6 October was close to Nizamabad and at 0300 UTC of 7 October near Adilabad. Thereafter, it weakened into a well marked low near Gondia (Lat.21.7 deg.N/Long.80.2 deg.E) in Vidarbha region of Madhya Pradesh. Later moving in a northeasterly direction it finally dissipated over northeast India by October 10.

The system acquired the maximum intensity of T-2.0 on the Dvork's scale on the evening of 4 October and crossed Andhra Pradesh coast by the morning of 5 October without any further intensification. It had a narrow core of 3 degree in diameter.

2.3.1.1 Meteorological features

As the system was well within the range of cyclone detection Radar at Machilipatnam, three hourly observations were taken from 1800 UTC of 3 Oct to 0300 UTC of 5 October and hourly observations thereafter upto 0900 UTC of 5 October. Though the spiral bands were first seen in the radar observation of 0300 UTC of 5 October, the center of the system could be fixed (low confidence) only from 0400 UTC to 0600 UTC of October 5. It had comma type open eye at 0600 UTC of 5 October as seen by radar (Fig.6). Since the system moved inland by 0300 UTC of 5 October, part of the eyewall was discernable. It appears that the system was in developing phase, but due to its proximity to the land, it could not attain the stage of a cyclone.

Gale winds speed reaching 39 kt were recorded at Machilipatnam and 40 kt at Gannavaram at 0500 UTC of 5 October. However, these winds speed were for a very short duration. The 24 hour pressure change 12.1 hPa

and 14.7 hPa were recorded at 0000 UTc of 5 October at Machilipatnam and Gannavaram (in Andhra Pradesh) respectively. The important feature of this deep depression is its rapid intensification near the coast.

During its movement towasrds Assam after landfall this disturbance caused widespread rain with scattered heavy to very heavy rain over north Tamilnadu, Andhra Pradesh, Orissa, Gangetic West Bengal and north eastern states between 5-10 October. Squally surface winds of the order of 30 kt gusting to 40 kt prevailed along and off coastal Andhra Pradesh from the evening of 4 to the morning of 5 October. The reported number of deaths due to floods caused by heavy rain was 38, severe damages to the crops and houses were also reported from south Andhra Pradesh.

2.3.2 Bay of Bengal Severe cyclonic storm 29-31 October 1994 (BOB 9403 1029)

The first cyclone of the post monsoon season formed over the southwest Bay of Bengal on 29 October and crossed north Tamilnadu coast by the morning of 31 October. The significant feature of the system is that the eye of the cyclone passed through the city of Madras (43279).

2.3.2.1 Life history of the cyclone

A low pressure area formed over the southwest Bay of Bengal on the evening of 28 October 1994. It concentrated into a depression by the next morning and was located at 0300 UTC of 29 October near Lat.9.5 deg.N/Long.85.0 deg.E. Later in the evening (1200 UTC), it intensified into a deep depression with center near Lat.10.5 deg.N/Long.84.5 deg.E. Moving in a north-westerly direction, it intensified further into a cyclonic storm at 0300 UTC of 30 October with its centre near Lat.12.0 deg.N/Long.82.0 deg.E. Thereafter it moved slowly in a north-westerly direction and further intensified into a severe cyclonic storm. Its position at 1200 UTC of 30 October was fixed near Lat.12.3 deg.N/Long.81.0 deg.E with the help of cyclone detection radar observation at Madras. It crossed north Tamilnadu coast near Madras between 0100 and 0200 UTC of 31 October 1994. At 0300 UTC it was centered near Lat.13.2 deg.N/Long.80.0 deg.E as severe cyclonic storm. Continuing to move in a north-westerly direction after landfall it weakened into a cyclonic storm and was located at 0600 UTC near Tirupathi. Later in the evening (1200 UTC), it weakened into a deep

depression with center near Lat. 14.0 deg.N/Long. 78.5 deg.E. Moving further in a north-westerly direction, it weakened into a low pressure area over south Andhra Pradesh by the morning of 1 November.

2.3.2.2 Monitoring and Tracking

The system was kept under constant surveillance of coastal radars at Madras and Karaikal from its genesis on 29 October to its dissipation over south Andhra Pradesh on November 1. The system was tracked with the help of conventional synoptic observations, hourly special observations, cyclone detection radars (CDRs) and satellites. CDR Madras and Karaikal recorded important characteristics of the system such as structure of spiral bands, position and shape of the eye etc.

Observations of CDR Madras indicated well defined spiral band from 0500 UTC of October 30 onward. Formation of well defined eye was noted in the observation of 1300 UTC of October 30 (Fig. 7a). The centres of the cyclone were fixed with a fair confidence and accuracy. The radar fixes of the eye of the cyclone at 2300 UTC of 30 October (Fig. 7b), 0000 UTC and 0100 UTC of 31 October clearly indicated that the system passed over the city of Madras. CDR Madras reported eye of the system upto 0550 UTC.

2.3.2.3 Movement

The depression formed over southwest Bay of Bengal on 29 October and was located about 400 km away from the Tamilnadu coast. The upper level flow at 200 hPa indicated that the system was embedded in the easterlies and was located in the southwest sector of the upper air anticyclone. The system was steered west- north-westward by the upper air flow. Later its movement changed to north-westerly direction as it came under the influence of south westend edge of the upper tropospheric anticyclone.

2.3.2.4 Meteorological Features and Weather Caused

2.3.2.4.1 Pressure

The peak intensity of the system was T-3.5 at 1200 UTC of 30 October when it was located about 100 km south-east of Madras. The corresponding pressure drop is 16 hPa. Considering the values of outer closed isobar, the central pressure was estimated as 988 hPa which is well supported

by the lowest recorded pressure of 989.3 hPa at 2140 UTC of October 30 by the Meenambakkam Observatory, Madras, as indicated in microbarogram of October 30 (Fig. 8). The other characteristic feature of the pressure curve is the small variation in the values of pressure between 2130 UTC to 2330 UTC. This supports that the eye of the system passed over Madras during this period.

2.3.2.4.2 Wind

The maximum sustained surface wind corresponding to peak intensity of T-3.5 is 55 kt. Madras Anemograph recorded the maximum sustained wind of 80 km per hour (43 kt) between 2030 UTC and 2100 UTC of October 30. The associated peak gust during this period was 132 kmph from northerly direction at 2050 UTC. During the passage of the eye, the calm winds were recorded at Madras observatory between 2130 to 2330 UTC of October 30. Thereafter between 2350 to 0050 UTC, the maximum sustained winds of the order 35 kt with peak wind speed of 49 kt (90 kmph) from south-westerly direction were recorded. Also, the observatory at Tambaram near Madras recorded a peak wind speed of 62.5 kt (116 kmph) from north-north-westerly direction at 2115 UTC of October 30.

2.3.2.4.3 Rainfall

The cyclone caused very heavy rainfall in north Tamilnadu and south coastal Andhra Pradesh. Rainfall of the order of 10 cm to 36 cm were recorded at several stations in the above region. The highest rainfall in 24 hours associated with this cyclone was 36 cm recorded at Gudluru in south Andhra Pradesh on November 1. One of the flooded areas of south Andhra Pradesh is shown in Fig.9. Isohyetal maps of rainfall recorded on October 31 and November 1 are given in Fig. 10(a) and 10(b).

2.3.2.4.4 Tidal wave

Post cyclone survey report estimates the occurrence of tidal waves of the order of 1 to 2 metres high along Tamilnadu- South Andhra Pradesh coast. Inundation due to sea water was seen upto 5 km.

2.3.2.4.5 Damages

Due to torrential rains and gale winds 235 and 69 persons died in Andhra Pradesh and Tamilnadu respectively. Widespread damages to crops, house structures and roads were reported from these areas. The estimated total loss was reported to be approximately Rs. 300 crores in Andhra Pradesh

and Rs. 61 crores in Tamilnadu. Timely and adequate preparedness and mitigation measures taken by the civil administration authorities on the basis of cyclone warnings issued by the India Meteorological Department, restricted the loss of life and property to a minimum extent. A few damage photographs are shown in Fig.11.

2.3.3 Bay of Bengal Depression 4-5 November 1994

A well marked low-pressure area formed over the south-west Bay of Bengal at 0000 UTC of 4 November 1994 near Lat. 9.0 deg.N/Long. 84.0 deg.E. By 0300 UTC of same day it concentrated into a depression near Lat. 9.5 deg.N/long 83.5 deg.E. Moving in a north-westerly direction, it crossed north Tamilnadu coast near Karaikal by the mid-night (1800 UTC) of the same day and weakened into a low pressure area over north Tamilnadu by the morning of November 5.

The depression formed very close to the coast and had a life period of 18 hours only. Under its influence, widespread rainfall with scattered heavy to very heavy falls occurred over Tamilnadu.

2.3.4 Arabian Sea Severe Cyclonic Storm with a core of Hurricane Winds of 15-20 November, 1994 (ARB 9404 1116)

This is a unique case of cyclone in the history of cyclones during the past 100 years when a cyclone formed in mid November over the South Arabian sea intensified into a severe cyclonic storm with a core of hurricane winds, moved in a west-south- westerly direction and crossed north Somalia coast as a severe cyclonic storm.

2.3.4.1 Life history of the cyclone

A low pressure area formed over the southeast Arabian sea and adjoining areas at 1800 UTC of 14 November, 1994 near Lat.10.0 deg.N/Long.66.0 deg.E. It concentrated into a depression by the next day (15 Nov.) with its center at 0300 UTC near Lat. 9.0 deg.N/Long. 65.5 deg.E. This position was fixed after considering the ship observations in the field. The depression remained practically stationary upto 1200 UTC without any further intensification. Thereafter it moved west-north-westward and intensified into deep depression (T-2.0) with center at 0300 UTC of 16 November near Lat. 9.5 deg.N/Long. 64.0 deg.E. Later, the satellite imagery of 1030 UTC of 16 November (Fig.12) indicated further organisation with a curved band

coiling almost in three quadrants around the centre. As such it was classified as a cyclonic storm (T-2.5) at 1200 UTC of 16 November when its center was near Lat 9.5 deg.N/Long 64.0 deg.E. Moving in a west-south-westerly direction it was located at 0300 UTC of 17 November near Lat.9.0 deg. N/Long.63.0 deg.E and at 1200 UTC of 18 November near Lat 8.0 deg.N/Long.57.0 deg.E. Thereafter, the storm remained stationary and intensified continuously and attained the intensity of severe cyclonic storm at 1800 UTC and hurricane intensity at 0300 UTC of 19 November (Fig.13) when it was centered near Lat 8.0 deg.N/Long. 54.0 deg.E. Moving in a westerly direction towards the coast of north Somalia, it weakened into severe cyclonic storm by 1200 UTC with location near Lat 8.0 deg.N/Long.51.0 deg.E just before crossing the coast of north Somalia in the early morning of November 20. The speed of the cyclone after 18 November was about 14 kt which was unusual for the system moving along such a low latitude (Table 10).

2.3.4.2 Monitoring and Tracking

As the system was far away from the Indian coast, it was tracked and monitored mainly with the help of INSAT-2B cloud imageries and available ship observations in the field.

2.3.4.3 Movement

The system formed over the southeast Arabian Sea near Lat. 9.0 deg.N/Long. 65.5 deg.E on 15 November and moved in west to west-south-westerly direction. The system was located on the southern side of upper tropospheric anticyclone. The distance between ridge line and center of the system was about 400 km. The wind flow pattern in this region was from east to east-north-easterly direction. It intensified at a low latitude of 8.0 deg.N on 19 November and moved in a westerly direction under the steering current from easterly direction at 200 hPa. The cyclone had fast movement in the westely direction after 18 November.

2.3.4.4 Meteorological Features and Weather Caused

2.3.4.4.1 Pressure

The system attained the peak intensity of T-4.0 on Dvork's scale at 0300 UTC of 19 November. The central pressure of the cyclone, by

considering the peripherial pressure at that time, was estimated to be 984 hPa.

2.3.4.4.2 Winds

The estimated maximum sustained surface wind corresponding to the highest intensity of T-4.0 is 65 kts or 120 kmph. The system weakened slightly before crossing the coast. According the the press reports the city of Basasso in north Somalia coast experienced winds of 104 kmph.

2.3.4.4.3 Rainfall

No rainfall report is available, but it appears from the Satellite cloudiness that it might have caused significant rainfall in the northern parts of Somalia.

2.3.4.4.3 Damages

As the system hit the sparsely populated region of north Somalia, the death toll reported to be 30 only.

3. Dynamical aspects

3.1 Vertical shear

It is known that the development of a disturbance is favored when the vertical wind shear is small over the disturbance. In order to see the contribution of this parameter for the development of cyclonic disturbances in the north Indian Ocean in 1994, vertical shear of the zonal winds between 200 and 850 hPa were computed in the case of each cyclone. Computations were made by utilizing the winds at 850 and 200 hPa from the land stations and 5 deg. Lat/Long grid point forecast winds available over the ocean areas from the European Center for Medium Range Weather Forecast (ECMWF), U.K.

The analysis of the vertical wind shear charts for the cyclones of 1994 shows the prevelance of minimum vertical wind shear over the area of disturbance. The shear charts for the cases of Bay of Bengal Cyclones in April and October 1994 are shown in Fig. 14(a) and 14(b) respectively.

2 Track Prediction Models

Storm track prediction is made operationally by RSMC New Delhi by utilising several models based on climatology, persistence and the combination of climatology and persistence (CLIPER). These models were run for all the cyclonic disturbances (depression onward). The track prediction was also made based on Analogue Techniques. Such forecasts were made for cyclonic disturbances of tropical storm intensity and above. Mean forecast position errors on the basis of climatology, persistence and CLIPER models for cyclones are given in Table 11. Mean forecast position errors for the cyclones based on Analogue are given in Table 12. The forecast skill relative to CLIPER model for cyclones is given in Table 13.

The forecast skill relative to CLIPER model is expressed as percentage and calculated by using the formula given below :

$$\text{FORECAST SKILL} = \frac{\text{CLIPER (PE)} - \text{OM (PE)}}{\text{CLIPER (PE)}} \times 100$$

CLIPER (PE) = Position errors based on CLIPER Model, OM (PE) = Position errors based on other models such persistence, climatology, Analogue etc.

The data reveals the following facts:

a. In general forecast errors were more with time.

b. The forecast positions based on CLIPER model were better than the other models. Forecasts based on climatology were better in the case of those systems which did not recurve.

c. This year, the forecast positions based on Analogue model were poor in comparison to 1993 may be due to less number of analogues available for the storms of 1994.

3.3. The Limited Area Forecast model of RSMC, New Delhi.

The limited area forecast model adapted from Florida State University U.S.A. is also being run by R.S.M.C. New Delhi on an experimental basis. The details of the models are given in R.S.M.C. report of 1994.

3.3.1. Results from Model for cyclones - 1994

The model could only be run for the two out of four cyclones of 1994 due to the non availability of necessary data input for the model. The first one was the Bay of Bengal severe cyclonic storm with a core of hurricane winds which formed on 29 April and crossed Bangladesh coast on 2 May. The other cyclone was the Bay of Bengal severe cyclonic storm of 29 - 31 October which crossed Indian coast near Madras (Tamilnadu) on 31 October.

Initial and predicted vorticity fields of 850 hPa for the cyclone of April - May 94 are given in Fig. 15(a) to (d) and Fig 16(a) to (d) respectively. Similarly, Fig.17(a) and (b) and Fig.18(a) and (b) shows the initial and predicted vorticity fields at 850 hPa for the cyclone of October 94. 850 hPa vorticity centre has been taken as the centre of cyclone for forecast.

The 24 hour forecast position errors on 1st, 2nd, 3rd and 4th day were 110, 120, 430 and 205 Kms respectively in the case of April - May cyclone. In the case of October cyclone 24 hours forecast errors for 1st and 2nd day were 60 and 220 Kms respectively. Results show slower than actual movements with a poleward bias in many forecast. The forecast skill of this model relative to CLIPER is -22 percent for the recurving cyclone of April 94 and +20 percent for the westward moving cyclone of October 94. Fig. 19 shows comparative forecast skill relative to CLIPER for all the models.

4. Dissemination of Warnings

Cyclone warnings were issued and disseminated to the general public, central and state government officials and other user organizations in India through high priority telegrams, T/P, Telephone and Telex. The electronic and print media were also used extensively for this purpose. Particularly, timely cyclone warnings issued to the public and the State governments of Tamilnadu, and Andhra Pradesh in connection with the severe cyclone of 21-31 October 1994 were helpful in minimising the loss of life and public property to a great extent. Cyclone warnings in different local languages were communicated directly by India Meteorological Department (IMD)'s Cyclone Warning Centres to the affected coastal populations through the satellite based communication system known as the Disaster Warning System (DWS).

5. Cooperation among Panel Countries

As in the previous years, Tropical Cyclone advisories were issued by the Regional Specialized Meteorological Center (RSMC) New Delhi to all the member countries of WMO/ESCAP Panel on Tropical Cyclones during the cyclone period at the six hourly interval. Besides this, Tropical Weather Outlooks for the north Indian Ocean were issued daily at 0600 UTC as a routine to the member countries of the Panel.

Cloud Motion Vectors based on 0000 UTC and 1200 UTC observations are regularly disseminated over GTS for the area covering the Bay of Bengal, the Arabian Sea and the Indian Ocean upto 30°S. 0000 UTC IR full frame satellite picture is transmitted on Radio Facsimile for international use.

Bangladesh Meteorological Department has provided some valuable information, upper wind data and radar observations from the coastal cyclone detection radars (CDR) in connection with the cyclone of 29 April to May 2, 1994 which were very useful in finalising the track and the intensity of the system at the time of crossing the Bangladesh coast on May 2.

6. Concluding Remarks

The year of 1994 witnessed the formation of eight cyclonic disturbances over north Indian Ocean. Out of which six formed in the Bay of Bengal and two in the Arabian Sea. Like last year, 1994 also had experienced below average cyclonic activity over the north Indian Ocean. There was only one depression during the south-west monsoon season against the normal frequency of 5 to 6.

Out of the four cyclones, one in the Bay of Bengal (29-31 October) crossed a mega city in India (Madras) on the east coast which was a rare event. Another cyclone which formed in the Arabian Sea intensified into a severe cyclonic storm with a core of hurricane winds at a very low latitude (along 8°N) and crossed Somalia coast as a severe cyclonic storm. There is no case of cyclone crossing Somalia coast in the history of cyclones in the North Indian Ocean.

TABLES

TABLE 1A

Monthly distribution of cyclonic disturbances (Depressions and Cyclones) over North Indian Ocean (the Bay of Bengal and the Arabian Sea) during 1994

Bay of Bengal

System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Depression	-	-	1	-	-	-	1	-	1	1	-		4
Cyclonic storm	-	-	-	-	-	-	-	-	-	-	-		0
Severe cyclonic storm	-	-	-	-	-	-	-	-	1	-	-		1
Severe cyclonic storm with a core of hurricane winds	-	-	1	-	-	-	-	-	-	-	-		1

Arabian Sea

Depression	-	-	-	-	-	-	-	-	-	-	-		0
Cyclonic storm	-	-	-	-	-	-	-	-	-	-	-		0
Severe cyclonic storm	-	-	-	-	1	-	-	-	-	-	-		1
Severe cyclonic storm with a core of hurricane winds	-	-	-	-	-	-	-	-	-	1	-		1
Total (North Indian Ocean)	-	-	1	1	-	1	-	1	-	2	2	0	8

TABLE 1B

S.No.	Cyclonic Disturbance	Peak Intensity T.No.	MSSW (Kt)	Duration Time(UTC) /Date	Place and time of crossing the coast	Loss of human life	Peak storm surge height (m)
1.	Bay of Bengal Depression 21-24 March, 1994	1.5	25	12 UTC/21 March to 06 UTC/ 24 March.	Weakened over north Andaman Sea on 24 March.	-	-
2.	Bay of Bengal Severe Cyclonic Storm with a core of hurricane winds 29 April-2 May, 1994 (BOB 9401 0429)	6.0	115	00 UTC/29 April to 17 UTC/2 May	Crossed near'Technaf' in Bangladesh around the mid-night of May 2,1994	188	N/A
3.	Arabian sea Severe Cyclonic Storm 5-9 June. 1994 (ARB 9402 0605)	3.5	55	18 UTC/5 June to 06 UTC/9 June	Weakened near Kuria Muria coast on the evening of June 9.	Nil	Nil
4.	Bay of Bengal Deep Depression 17-20 August, 1994	2.0	30	03 UTC/17 Aug. to 12 UTC/20 Aug.	Crossed near Chandbali around early morning of Aug. 18.	Nil	Nil
5.	Bay of Bengal Deep Depression 4-7 October, 1994	2.0	30	12 UTC/4 Oct. to 12 UTC/7 Oct.	Crossed near Machili-patnam on the morning fo 5 Oct.	38	Nil
6.	Bay of Bengal Severe Cyclonic Storm 29-31 Oct. 1994 (BOB 9403 1029)	3.5	55	03 UTC/29 Oct. to 18 UTC/31 Oct.	Crossed over Madras in the morning of 31 Oct.	Andhra Pradesh-235 Tamilnadu-69	0.5 to 1m
7.	Bay of Bengal Depression 4-5 Nov., 1994	1.5	25	03 UTC/4 Nov. to 18 UTC/4 Nov.	Crossed near Karaikal on the night of 4 Nov.	Nil	Nil
8.	Arabian Sea Severe Cyclonic Storm with a core of hurricane winds 15-20 November, 1994 (ARB 9404 1115)	4.0	65	03 UTC/15 Nov. to 12 UTC/20 Nov.	Crossed north Somalia coast on the early morning of Nov. 20.	30	N/A

TABLE - 2

Best track positions alongwith other parameters for Bay of Bengal Depression of 21-24 March, 1994

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
March									
21	0300	8.0	92.0	1.0	1006	15	1008	2	3
	0600	8.5	91.5	1.0	1006	15	1008	2	3
	1200	9.5	91.0	1.5	1004	25	1008	4	4
	1800	10.5	90.5	1.5	1004	25	1008	4	4
22	0000	11.0	90.3	1.5	1004	25	1008	4	4
	0300	11.5	90.0	1.5	1004	25	1008	4	4
	0600	12.0	90.2	1.5	1004	25	1008	4	4
	1200	12.5	90.5	1.5	1004	25	1008	4	4
	1800	13.0	90.5	1.5	1004	25	1008	4	4
23	0000	13.5	91.0	1.5	1004	25	1008	4	4
	0300	13.5	91.0	1.5	1004	25	1008	4	4
	0600	13.8	91.2	1.5	1004	25	1008	4	4
	1200	14.0	91.5	1.5	1004	25	1008	4	4
	1800	14.0	91.5	1.5	1004	25	1008	4	3
24	0000	14.0	92.0	1.5	1004	25	1008	3	3
	0300	14.0	92.0	1.5	1004	25	1008	3	3
	0600	14.0	92.0	1.5	1004	25	1008	3	3
	1200	14.0	92.0	1.5	1006	15	1008	2	2

TABLE - 3

Best track positions alongwith other parameters for Bay of Bengal severe cyclonic storm with a core of hurricane winds of 29 April to 2 May, 1994. *(BOB 9401 0429)*

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Apr.									
29	0000	8.5	92.0	1.5	1002	25	1006	4	4 x 3
	0300	9.0	91.5	2.0	1001	30	1006	5	4 x 3
	0600	9.3	91.3	2.0	1001	30	1006	5	4 x 4
	1200	10.0	91.0	2.5	998	35	1006	8	5 x 4
	1800	10.4	90.7	3.0	994	45	1004	10	5 x 5
Apr.									
30	0000	10.8	90.6	3.0	994	45	1004	10	5 x 5
	0300	11.0	90.5	3.0	994	45	1004	10	5 x 5
	0600	11.5	90.4	3.0	994	45	1004	10	5 x 5
	1200	12.0	90.5	3.5	988	55	1004	16	5 x 5
	1800	13.0	90.2	3.5	988	55	1004	16	5 x 5
May									
1	0000	13.5	90.1	3.5	986	60	1004	18	6 x 5
	0300	14.0	90.0	3.5	986	60	1004	18	6 x 5
	0600	15.0	90.1	3.5	986	60	1004	18	6 x 6
	1200	16.0	90.4	4.5	972	77	1004	32	6 x 6
	1800	17.0	90.5	5.0	962	90	1004	42	6 x 6
May									
2	0000	18.5	91.2	5.5	952	102	1004	52	7 x 6
	0300	19.0	91.4	5.5	952	102	1006	54	6 x 6
	0600	19.5	91.5	5.5	948	102	1006	58	6 x 5
	1200	20.6	92.0	6.0	940	115	1006	66	6 x 5
	1700	21.5	92.5	crossed coast					

Crossed Bangladesh - Myanmar coast around midnight.

TABLE - 4

Best track positions alongwith other parameters for Arabian Sea severe cyclonic storm of 5-9 June, 1994 (ARB 9402 0605)

Date	Time (UTC)	Centre Lat. (^{o}N)	Centre Long. (^{o}E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (^{o}Lat.XLong.)
June									
5	1200	15.5	73.0	1.0	994	15	996	2	3 x 3
	1800	16.0	72.5	1.5	992	25	996	4	3 x 3
6	0000	16.5	72.0	1.5	992	25	996	4	3 x 3
	0300	17.5	71.5	2.0	991	30	996	5	3 x 3
	0600	17.5	71.5	2,0	990	30	996	6	3 x 3
	1200	18.0	70.5	2.5	988	35	996	8	4 x 4
	1800	19.0	69.0	2.5	988	35	996	8	4 x 4
7	0000	19.5	67.4	2.5	988	35	996	8	5 x 5
	0300	19.5	66.5	2.5	988	35	996	8	5 x 5
	0600	19.5	65.0	3.0	986	45	996	10	6 x 6
	1200	19.5	64.0	3.5	980	55	996	16	6 x 6
	1800	19.5	63.0	3.0	984	45	996	12	6 x 6
8	0000	19.5	62.0	2.5	988	35	996	8	5 x 5
	0300	19.5	61.5	2.5	988	35	996	8	4 x 4
	0600	19.5	61.5	2.5	988	35	996	8	4 x 4
	1200	19.5	61.0	2.0	990	30	996	6	4 x 4
	1800	19.5	60.5	2.0	990	30	996	6	3 x 3
9	0000	19.5	60.0	1.5	990	25	994	4	3 x 3
	0300	19.5	59.5	1.5	990	25	994	4	3 x 3
	0600	20.0	59.0	1.5	990	25	994	4	3 x 2
	1200	20.0	58.5	1.0	992	15	994	2	2 x 2

Weakened near north Oman coast.

TABLE - 5

Best track positions alongwith other parameters for Bay of Bengal Deep Depression of 17-20 August, 1994

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Aug. 17	0300	20.5	88.5	1.5	992	25	996	4	3 x 2
	0600	20.5	88.5	1.5	992	25	996	4	3 x 3
	1200	20.5	87.5	2.0	992	30	996	5	4 x 3
	1800	20.5	86.5		988	30	Over land		
Aug. 18	0000	20.5	86.0	2.0	-	30	"		
	0300	21.0	85.0	2.0	-	25	"		
	0600	21.2	84.0	1.5	-	25	"		
	1200	21.5	82.5	1.5	-	25	"		
	1800	22.0	82.0	1.5	-	25	"		
Aug. 19	0000	22.5	81.0	1.5	-	25	"		
	0300	23.0	80.0	1.5	-	25	"		
	0600	24.0	78.0	1.5	-	25	"		
	1200	25.0	77.5	1.5	-	25	"		
	1800	25.0	76.0	1.5	-	25	"		
Aug. 20	0000	25.5	75.0	1.5	-	25	"		
	0300	25.5	75.0	1.5	-	25	"		
	0600	25.5	74.5	1.5	-	25	"		
	1200	26.0	74.0	1.5	-	25	"		
	1800	Weakened into low pressure area							

TABLE - 6

Best track positions alongwith other parameters for Bay of Bengal Deep Depression of 4-7 October, 1994

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Oct.									
4	0300	14.0	83.5	1.0	1006	15	1008	2	3 x 2
	0600	14.5	83.0	1.0	1003	15	1006	3	3 x 2
	1200	15.5	82.0	1.5	1000	25	1004	4	3 x 3
	1800	16.0	81.5	2.0	1000	25	1004	4	4 x 3
Oct.									
5	0000	16.5	80.5	2.0	998	30	1004	6	4 x 4
	0300	16.5	80.5	2.0	998	30	1004	6	4 x 4
	0600	17.0	80.0	2.0	1000	25	1004	4	4 x 4
	1200	17.0	80.0	2.0	1000	25	1004	4	4 x 4
	1800	17.0	79.0	2.0	Over land				
Oct.									
6	0000	17.0	79.0	2.0	"				
	0300	17.5	78.5	1.5	"				
	0600	18.0	78.0	1.5	"				
	1200	18.0	78.0	1.5	"				
	1800	19.0	78.0	1.5	"				
Oct.									
7	0000	19.5	78.5	1.5	"				
	0300	19.5	78.5	1.5	"				
	0600	20.0	79.0	1.5	"				
	1200	20.5	79.5	1.5	"				
	1800	Weakened into low pressure area.							

TABLE - 7

Best track positions alongwith other parameters for Bay of Bengal severe cyclonic storm of 29-31 October, 1994. *(BOB 9403 1029)*

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Oct.									
29	0300	9.5	85.0	1.5	1006	25	1010	4	4 x 3
	0600	10.0	84.5	1.5	1004	25	1008	4	4 x 3
	1200	10.5	84.5	2.0	1003	30	1008	5	4 x 3
	1800	11.0	84.0	2.0	1005	30	1010	5	4 x 4
Oct.									
30	0000	11.5	83.0	2.0	1004	30	1010	6	4 x 4
	0300	12.0	82.0	2.5	1002	35	1010	8	4 x 4
	0600	12.2	81.5	3.0	1000	45	1010	10	4 x 4
	1200	12.3	81.0	3.5	992	55	1008	16	4 x 4
	1800	12.7	80.5	3.5	990	60	1008	18	4 x 4
Oct.									
31	0000	13.0	80.3	3.5	988	60	1008	20	5 x 4
	0300	13.2	80.0	-	Over land	55	-	-	
	0600	13.6	79.5	-	"	35	-	-	
	1200	14.0	78.5	-	"	30	-	-	
	1800	14.5	78.0	Weakened into a low pressure area.					

TABLE - 8

Best track positions alongwith other parameters for Bay of Bengal Depression of 4-5 November, 1994

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Nov. 4	0000	9.5	83.5	1.0	1008	15	1010	2	3 x 2
	0300	9.5	83.5	1.5	1007	25	1010	3	3 x 3
	0600	9.5	82.5	1.5	1006	25	1010	4	4 x 3
	1200	10.0	80.5	1.5	1006	25	1010	4	4 x 3
	1800	10.5	79.5	1.5	1006	25	1010	4	3 x 2
Nov. 5	0000	Weakened into a low pressure area over land							

TABLE - 9

Best track positions alongwith other parameters for Arabian Sea severe cyclonic storm with a core of hurricane winds of 15-20 November, 1994. *(ARB 9404 1115)*

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum Surface Pressure (hPa)	Maximum Estimated Sustained Surface Wind(kts)	Outermost Closed Isobar(hPa)	ΔP (hPa)	Diameter Size of the Outermost Closed Isobar (°Lat.XLong.)
Nov.									
15	0000	10.0	66.0	1.0	1006	15	1008	2	2 x 2
	0300	9.0	65.5	1.5	1004	25	1008	4	3 x 2
	0600	9.0	65.5	1.5	1006	25	1010	4	3 x 2
	1200	9.0	65.5	1.5	1006	25	1010	4	3 x 2
	1800	9.2	65.0	1.5	1006	25	1010	4	3 x 2
Nov.									
16	0000	9.5	64.5	1.5	1006	25	1010	4	3 x 2
	0300	9.5	64.0	2.0	1004	30	1010	6	3 x 2
	0600	9.5	64.0	2.0	1002	30	1008	6	3 x 3
	1200	9.5	64.0	2.5	1000	35	1008	8	3 x 3
	1800	9.5	64.0	2.5	998	40	1006	8	4 x 3
Nov.									
17	0000	9.5	63.5	2.5	998	40	1006	8	4 x 3
	0300	9.0	63.0	2.5	998	40	1006	8	4 x 3
	0600	9.0	62.0	2.5	998	35	1006	8	4 x 3
	1200	8.5	61.0	2.5	998	35	1006	8	4 x 3
	1800	8.0	60.5	2.5	998	35	1006	8	4 x 3
Nov.									
18	0000	8.0	60.0	2.5	998	40	1006	8	4 x 4
	0300	8.0	60.0	2.5	998	40	1006	8	4 x 4
	0600	8.0	58.0	2.5	998	40	1006	8	4 x 4
	1200	8.0	57.0	2.5	998	40	1006	8	4 x 4
	1800	8.0	57.0	3.5	990	55	1006	16	5 x 4
Nov.									
19	0000	8.0	54.5	3.5	990	55	1006	16	5 x 4
	0300	8.0	54.0	4.0	984	65	1006	22	5 x 4
	0600	8.0	53.0	4.0	984	65	1006	22	5 x 4
	1200	8.0	51.0	3.5	990	55	1006	16	5 x 4
	1800	8.0	50.5	3.0	994	45	1006	12	4 x 4
Nov.									
20	0000	8.0	50.0	2.5	996	35	1004	8	3 x 3
	0300	8.0	49.5	-	over land.	35			

TABLE -10

12 Hourly Intensity and Speed of Severe Cyclones in 1994

Period of cyclone / Time (hour)		0	12	24	36	48	60	72	84	96	108	120
29 April-2 May 1994	T. No.	1.0	2.5	3.0	3.5	3.5	4.5	5.5	6.0	-	-	-
	Speed (In Kts)	--	5	6	9	15	13	6	11	-	-	-
5-9 June 1994	T.No.	1.0	1.5	2.5	2.5	3.5	2.5	2.0	2.0	-	-	-
	Speed (In Kts)	--	--	11	17	10	5	5	7	-	-	-
29-31 October 1994	T.No.	1.0	2.0	3.5	3.5	2.0	-	-	-	-	-	-
	Speed (In Kts)	--	9	11	7	5	-	-	-	-	-	-
15-20 November 1994	T.No.	1.0	1.5	2.0	2.5	2.5	2.5	2.5	4.0	3.5	2.5	-
	Speed (In Kts)	--	--	0	3	13	7	15	13	16	5	-

TABLE - 11

Forecast position errors for tropical cyclones in the Bay of Bengal and the Arabian Sea in 1994 based on Climatology, Persistence and CLIPER models.

Tropical Cyclone	12 hour			24 hour			36 hour			48 hour		
	A	B	C	A	B	C	A	B	C	A	B	C
29 Apr-2 May,1994	92	70	69	186	157	176	265	338	291	343	480	394
5 - 9 Jun., 1994	239	141	181	487	355	388	691	563	561	828	718	679
29-31 Oct., 1994	68	107	85	127	243	175	66	239	160	59	553	302
15-20 Nov., 1994	103	186	117	201	359	278	283	479	375	392	606	483
Average for 1994	125	126	113	250	279	254	326	405	311	405	589	465
Average for 1993	150	120	127	304	193	228	423	342	314	659	534	487

A- Climatology
B- Persistence
C- CLIPER

TABLE - 12

Forecast position errors for individual tropical cyclones over the Bay of Bengal and the Arabian Sea in 1994 based on Analogue and CLIPER Forecast Models

Tropical cyclones	ANALOGUE				CLIPER			
	Forecast Errors (km)							
	12-hr	24-hr	36-hr	48-hr	12-hr	24-hr	36-hr	48-hr
29 Apr-2 May,1994	75	157	230	220	69	176	291	394
5 - 9 Jun.,1994	80	105	155	200	181	388	561	679
29 - 31 Oct.,1994	184	270	300	415	85	175	160	302
15 - 20 Nov.,1994	278	320	540	670	117	278	375	483
Average Error for 1994	152	213	306	363	113	254	311	465
Average Error for 1993	121	183	222	-	127	253	314	-

TABLE - 13

Forecast skill (%) of Other Model with respect to CLIPER for tropical cyclones in the Bay of Bengal and the Arabian Sea in 1994

Tropical cyclones	Cliper Vs Persistence				CLIPER Vs Climatology				CLIPER Vs Analogue			
	12hr	24hr	36hr	48hr	12hr	24hr	36hr	48hr	12hr	24hr	36hr	48hr
29 Apr-2 May 1994	-01	+11	-16	-21	-33	-06	-09	+13	-09	+11	+21	+44
5 - 9 Jun. 1994	+22	+09	00	-06	-32	-25	-33	-21	+56	+73	+74	+71
29 - 31 Oct. 1994	-26	-39	-49	-83	+20	+27	+59	+80	-117	-54	-87	-37
15 - 20 Nov.1994	-59	-29	-27	-25	+12	+28	+25	+19	-131	-15	-44	-39
Average Error	-16	-17	-23	-34	-08	+06	+10	+23	-50	+04	-07	+10

Positive skill indicates Other Model (OM) forecast is better than CLIPER.
Negative skill indicates the CLIPER forecast is better than OM forecast.

FIGURES

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Fig.15(a): Initial vorticity field at 850 hPa for 29 April 94 00 UTC, 30 April
to (d): 94 00 UTC,1 May 94 00 UTC and 2 May 94 UTC respectively.

Fig.16(a) Predicted vorticity field at 850 hPa for 29 April 94 00 UTC, 30
to (d): April 94 00 UTC, 1 May 94 00 UTC and 2 May 00 UTC respectively.

Fig.17(a) Initial vorticity field at 850 hPa for 29 Oct 94 and 30 Oct 94.
& (b):

Fig.18(a) Predicted vorticity field at 850 hPa for 29 Oct 94 and 30 Oct 94
&(b):

Fig.19: Forecast skill relative to CLIPER and other models

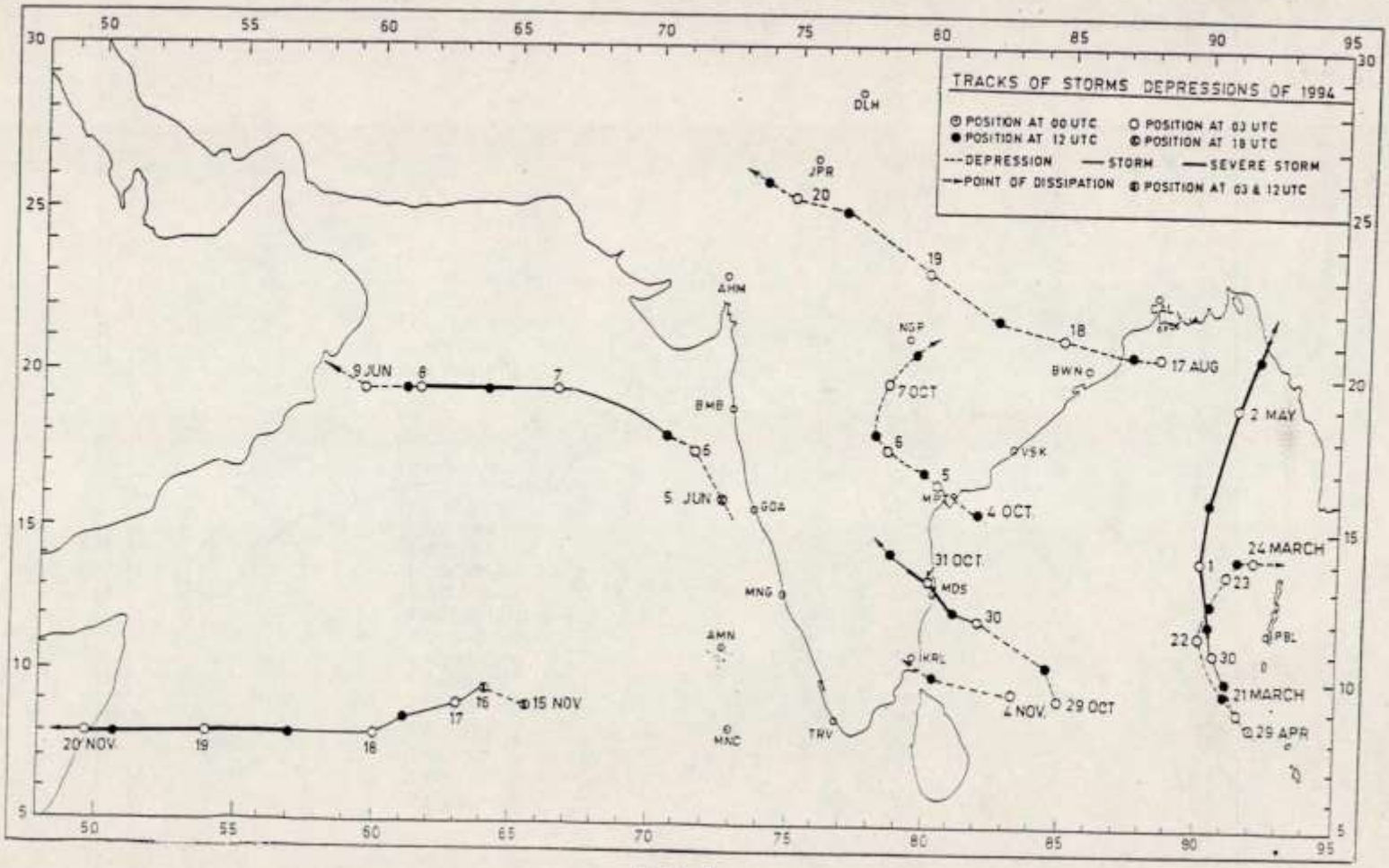

TRACKS OF STORMS DEPRESSIONS OF 1994
POSITION AT 00 UTC
POSITION AT 12 UTC
POSITION AT 03 UTC
POSITION AT 18 UTC
DEPRESSION
STORM
SEVERE STORM
POINT OF DISSIPATION
POSITION AT 03 & 12 UTC
DLH
JPR
AHM
BMB
GOA
MNG
AMN
MNC
TRV
NGP
BWN
VSK
MDS
KRL
PBL
9 JUN
5 JUN
7 OCT
4 OCT
31 OCT
4 NOV
29 OCT
17 AUG
2 MAY
24 MARCH
21 MARCH
29 APR
15 NOV
20 NOV

FIG. 1.

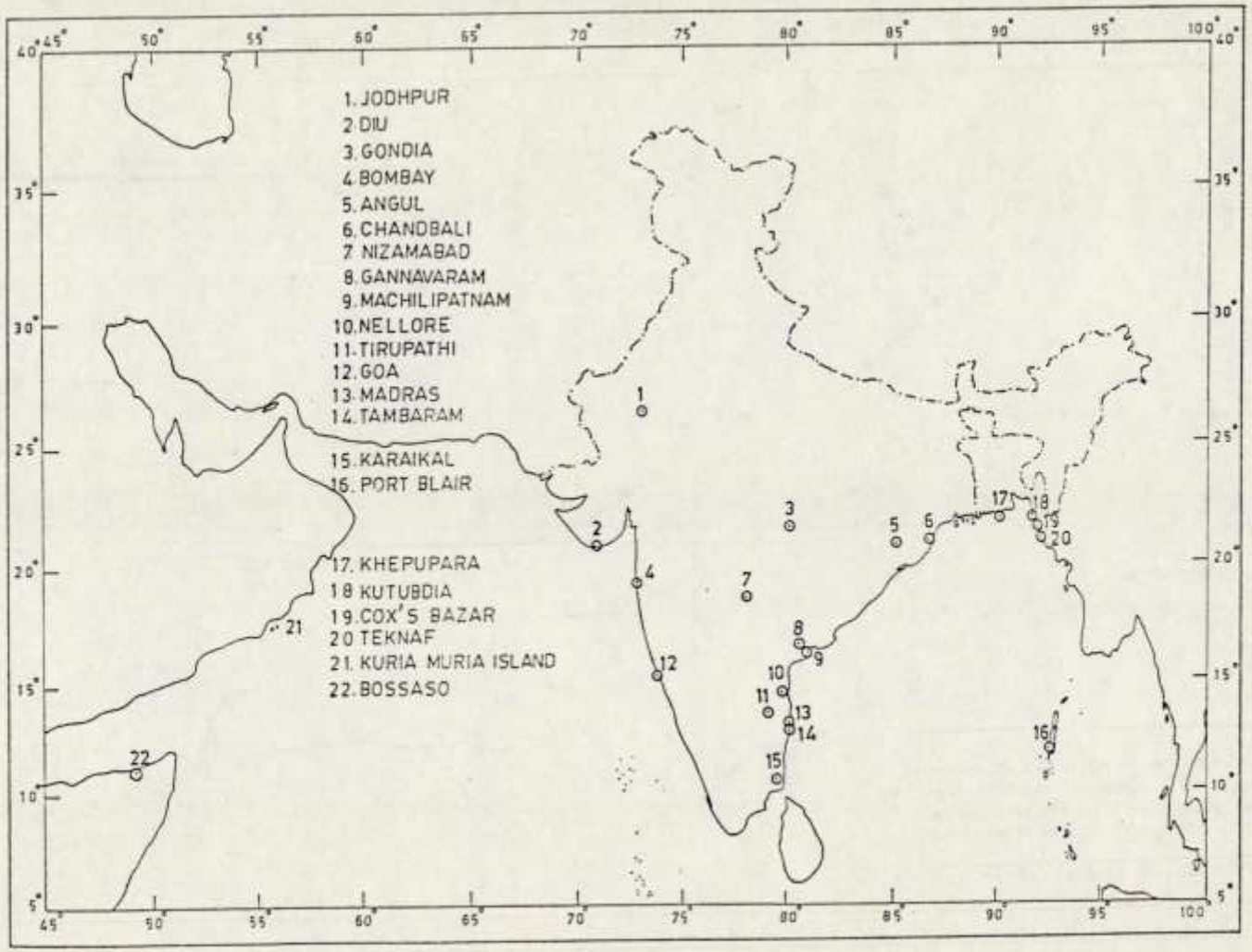

1. JODHPUR
2 DIU
3. GONDIA
4 BOMBAY
5. ANGUL
6. CHANDBALI
7. NIZAMABAD
8. GANNAVARAM
9. MACHILIPATNAM
10. NELLORE
11. TIRUPATHI
12. GOA
13. MADRAS
14. TAMBARAM
15. KARAIKAL
16. PORT BLAIR
17. KHEPUPARA
18 KUTUBDIA
19. COX'S BAZAR
20 TEKNAF
21. KURIA MURIA ISLAND
22. BOSSASO

FIG. 2.

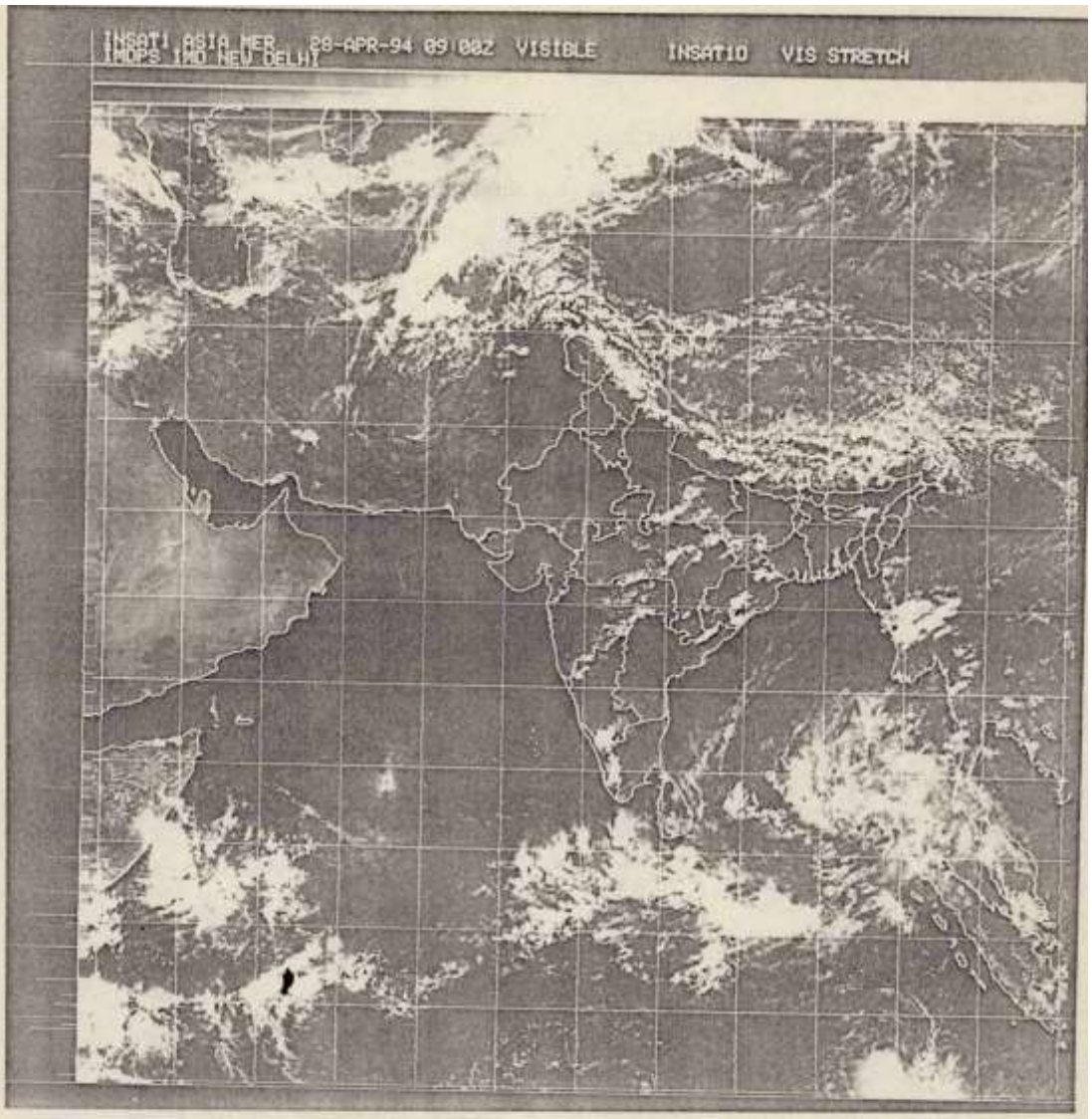

INSATI ASIA MER 28-APR-94 09:00Z VISIBLE INSAT1D VIS STRETCH
IMDPS IMD NEW DELHI

FIG 3.

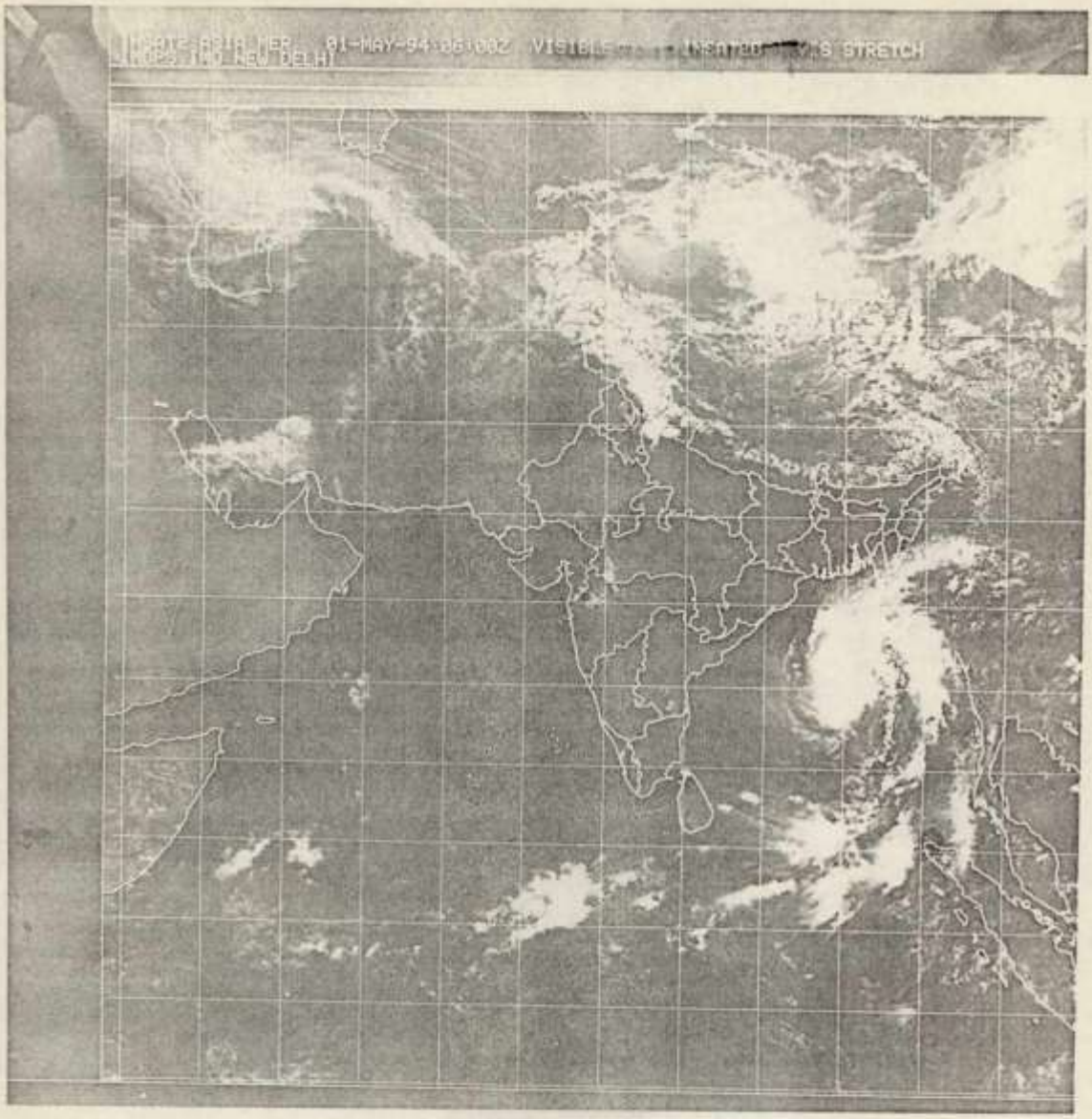


FIG. 4

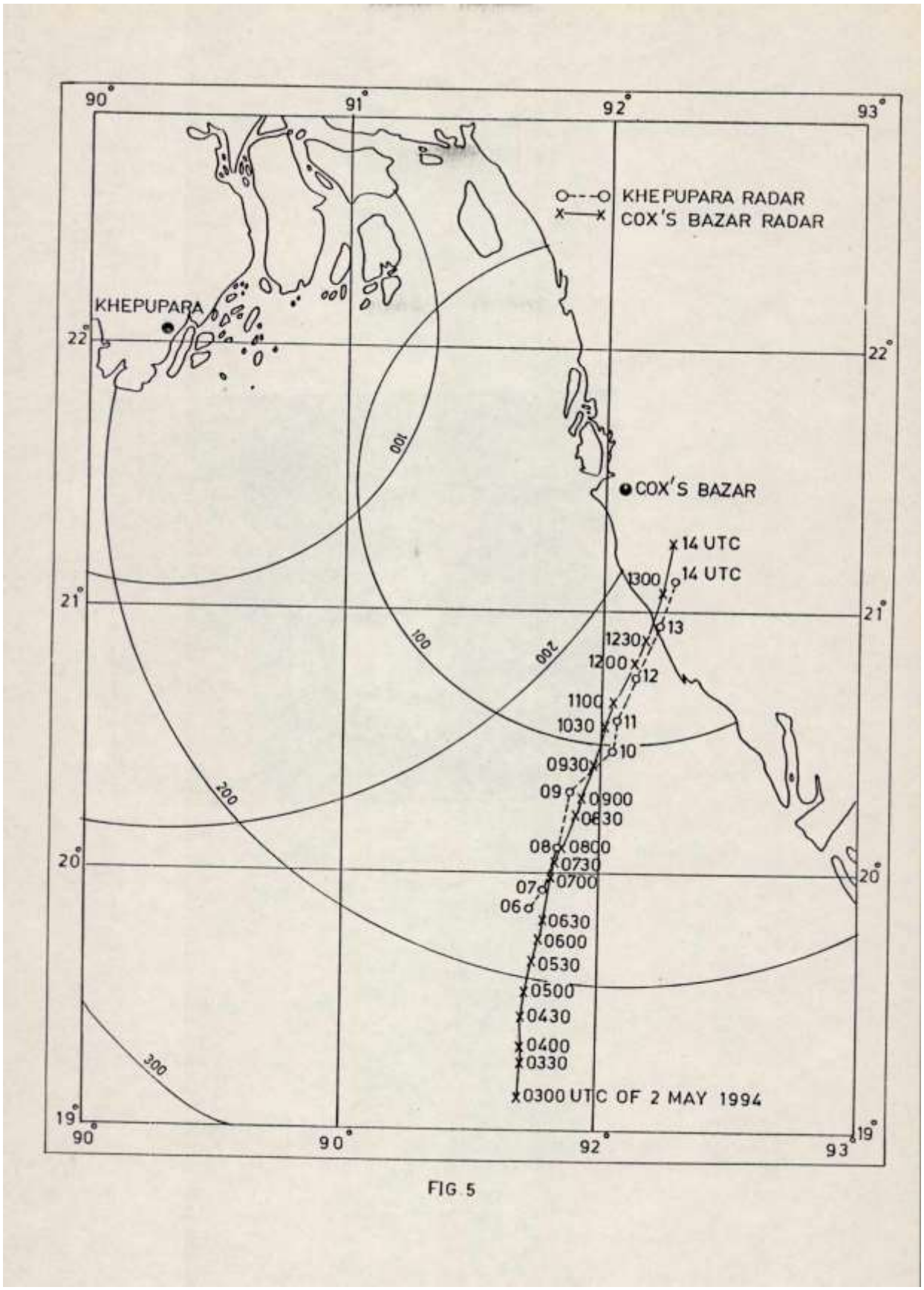

90°
91°
92°
93°
22°
21°
20°
19°
KHEPUPARA RADAR
COX'S BAZAR RADAR
KHEPUPARA
COX'S BAZAR
100
200
300
14 UTC
14 UTC
1300
13
1230
1200
12
1100
1030
11
10
0930
09
0900
0830
08
0800
0730
0700
07
06
0630
0600
0530
0500
0430
0400
0330
0300 UTC OF 2 MAY 1994

FIG 5

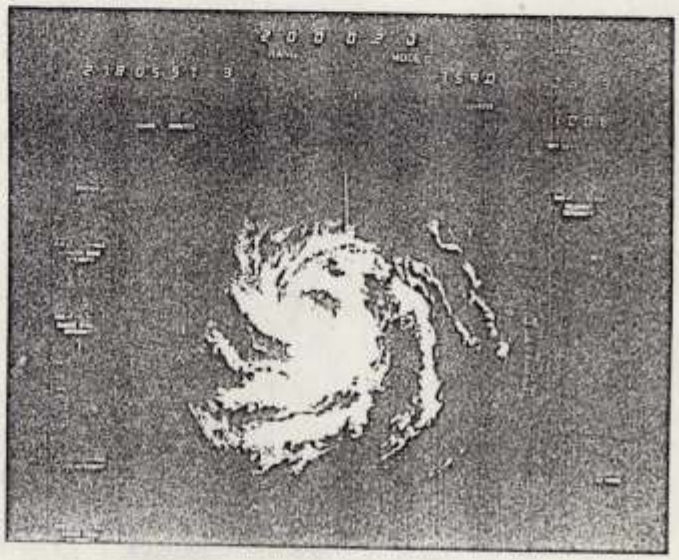


FIG. 6.

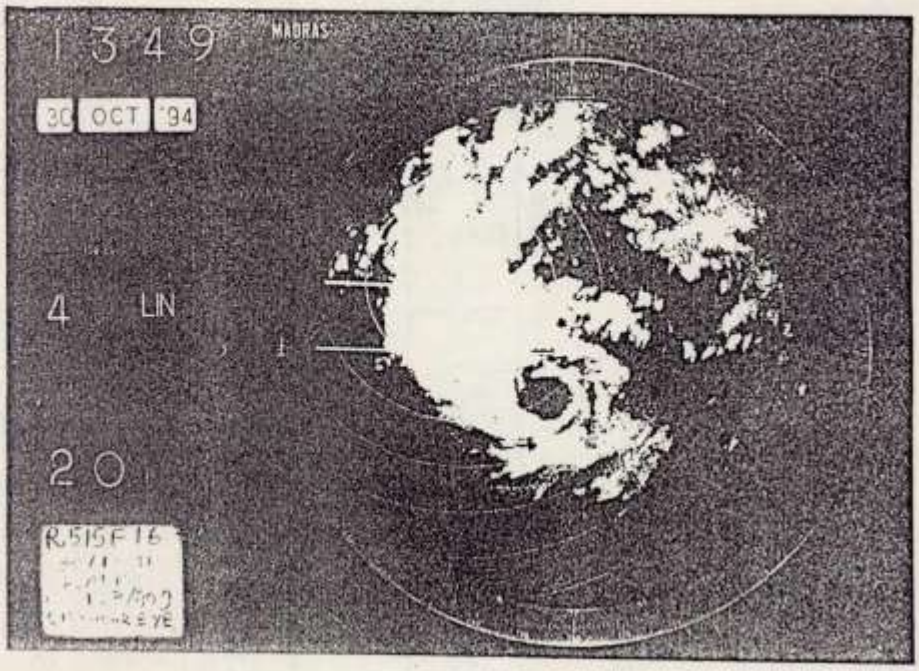


FIG. 7(a)

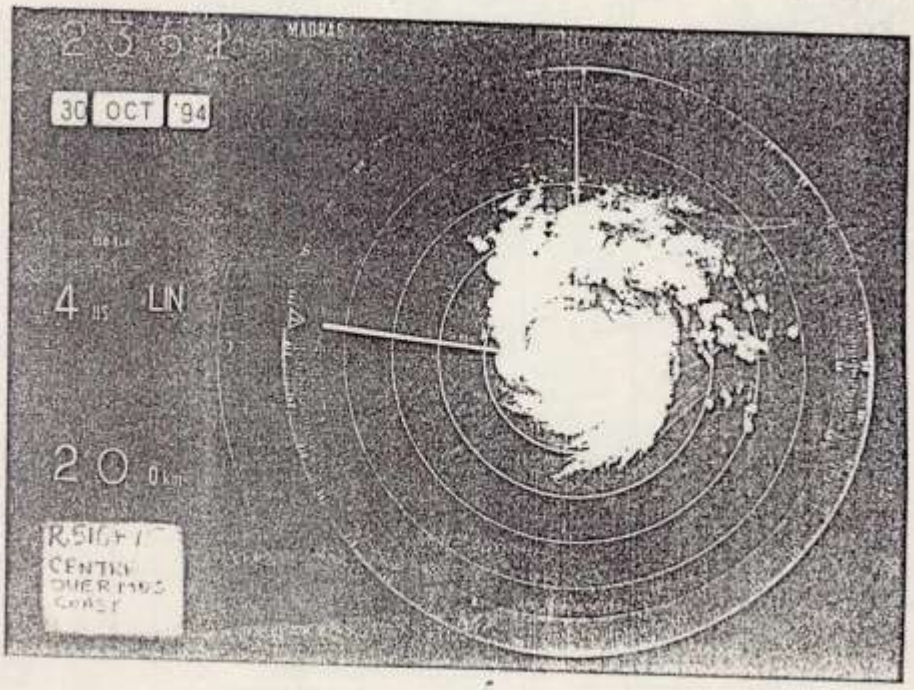


FIG. 7(b)

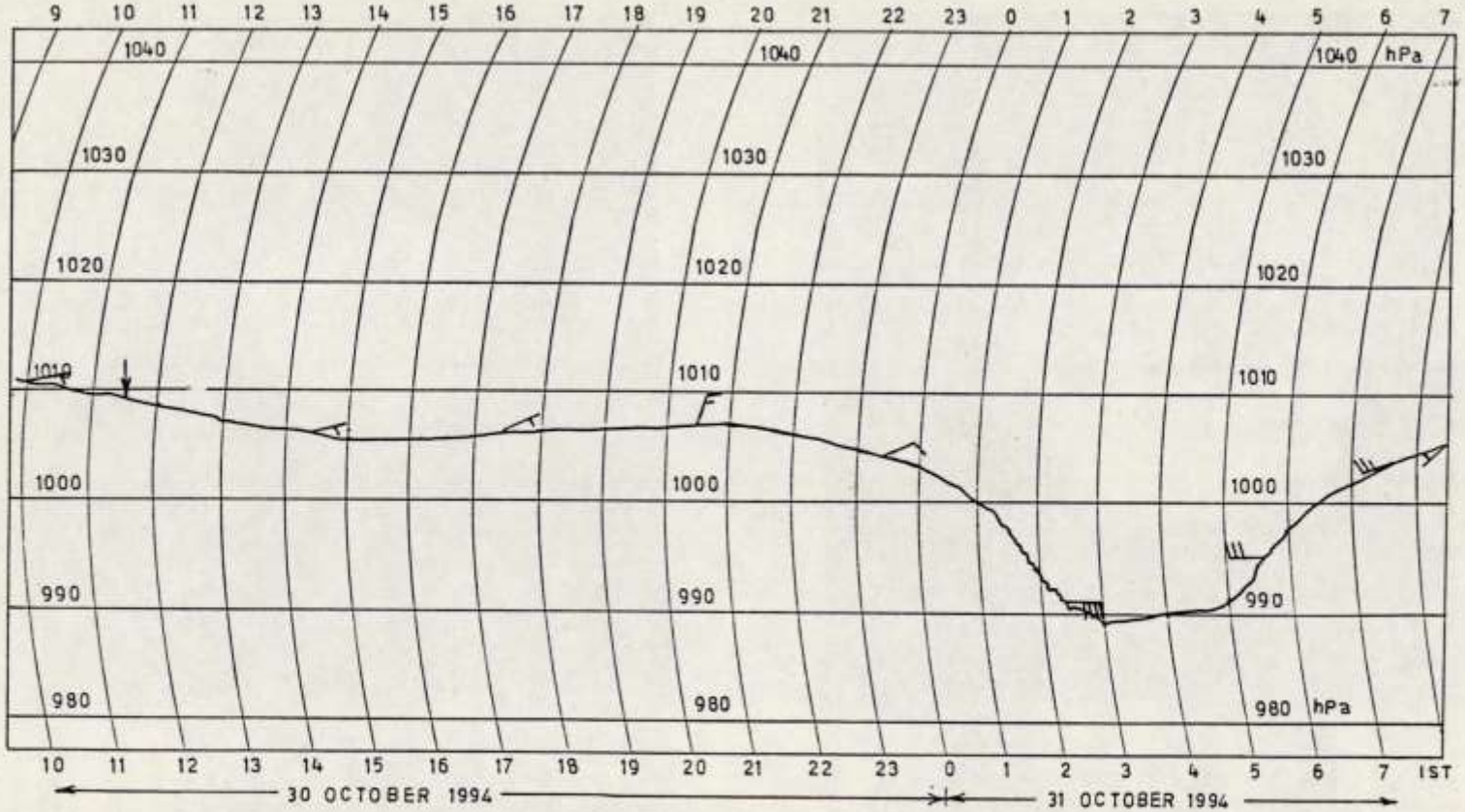

9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 IST
1040
1030
1020
1010
1000
990
980
hPa
10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 IST
30 OCTOBER 1994
31 OCTOBER 1994

FIG. 8.

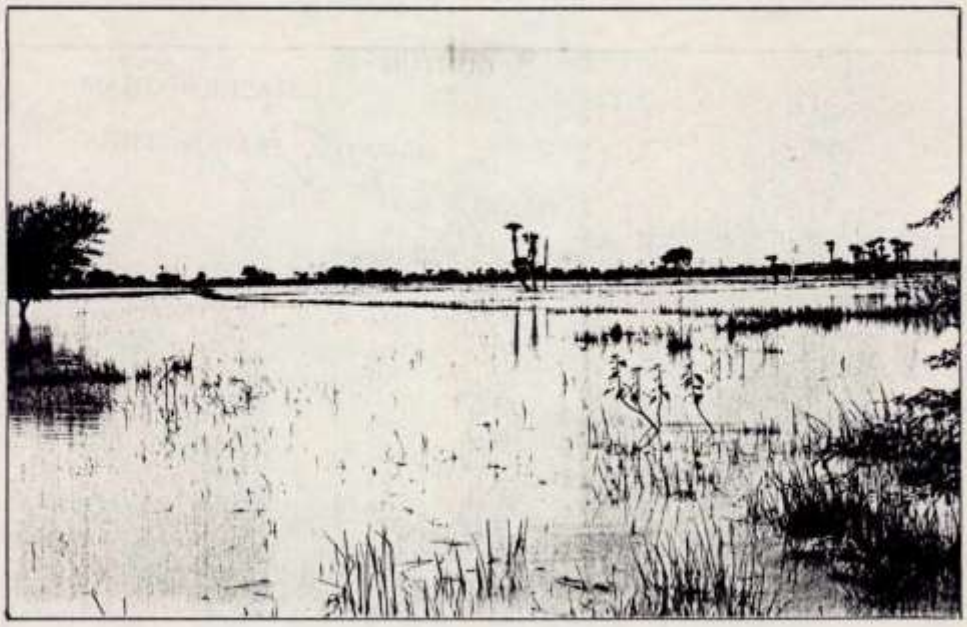


FIG . 9.

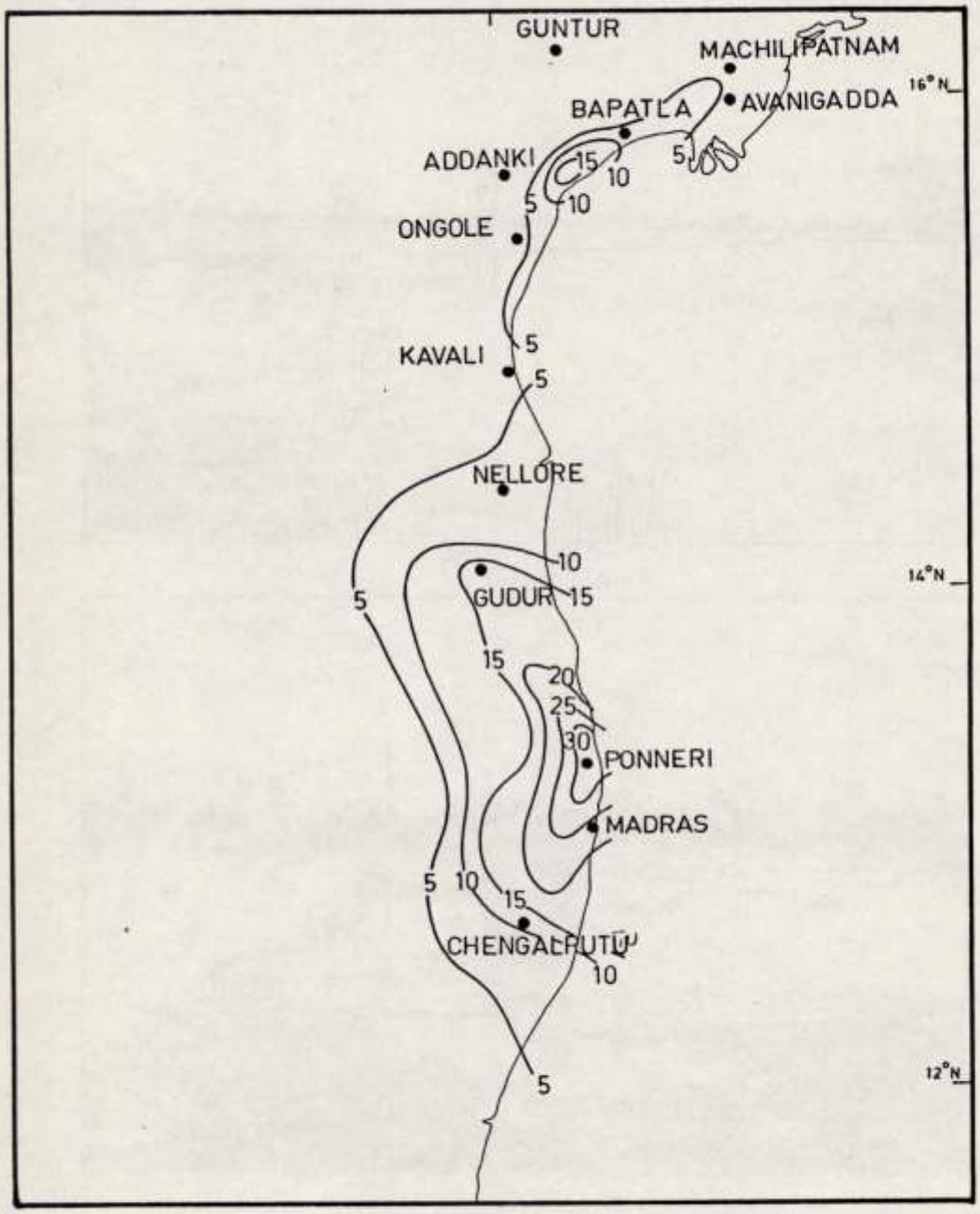

GUNTUR
MACHILIPATNAM
AVANIGADDA
16°N
BAPATLA
ADDANKI
ONGOLE
KAVALI
NELLORE
14°N
GUDUR
PONNERI
MADRAS
CHENGALPUTU
12°N
5
10
15
20
25
30

FIG. 10 (a)

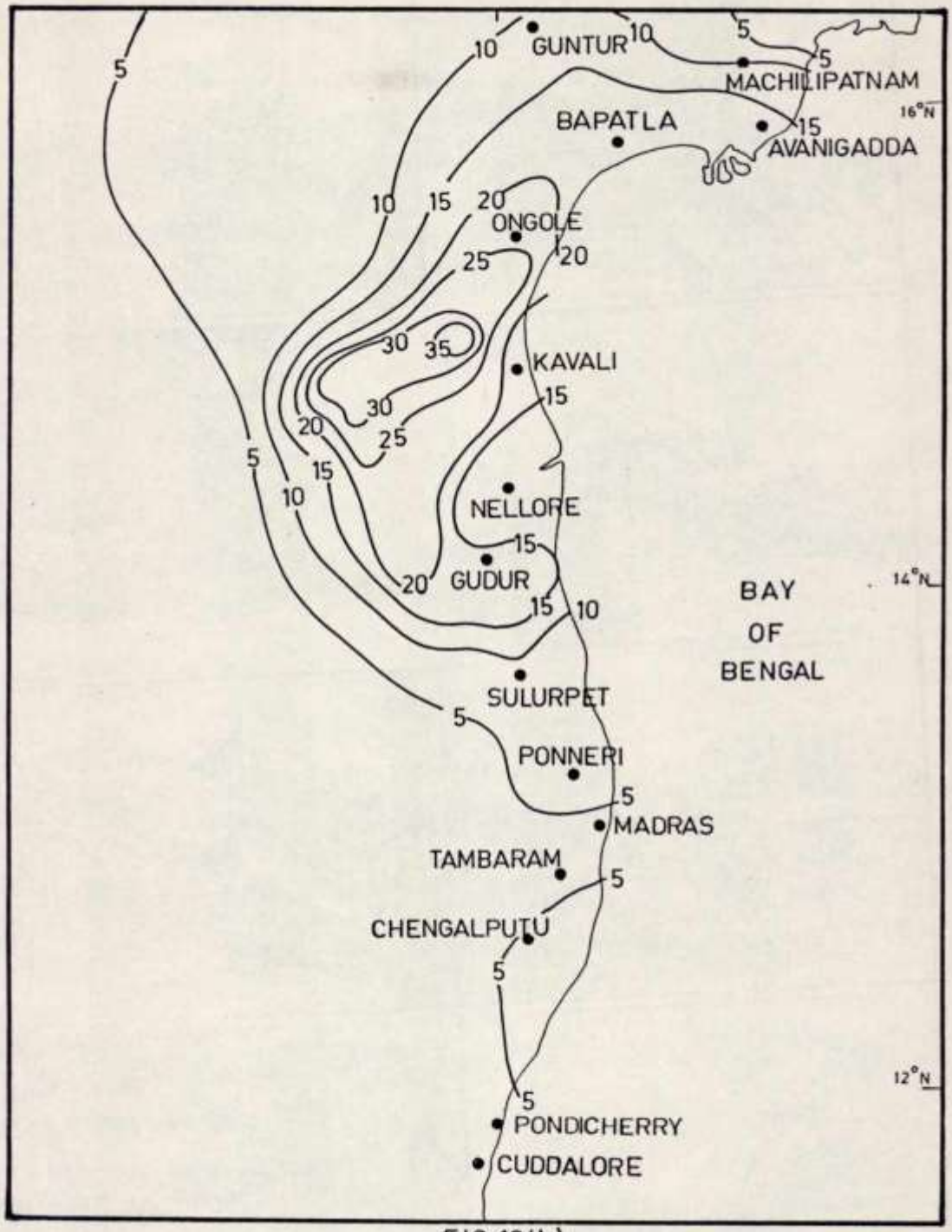

GUNTUR
MACHILIPATNAM
BAPATLA
AVANIGADDA
ONGOLE
KAVALI
NELLORE
GUDUR
SULURPET
PONNERI
MADRAS
TAMBARAM
CHENGALPUTU
PONDICHERRY
CUDDALORE
BAY
OF
BENGAL
16°N
14°N
12°N
5
10
15
20
25
30
35

FIG. 10(b)

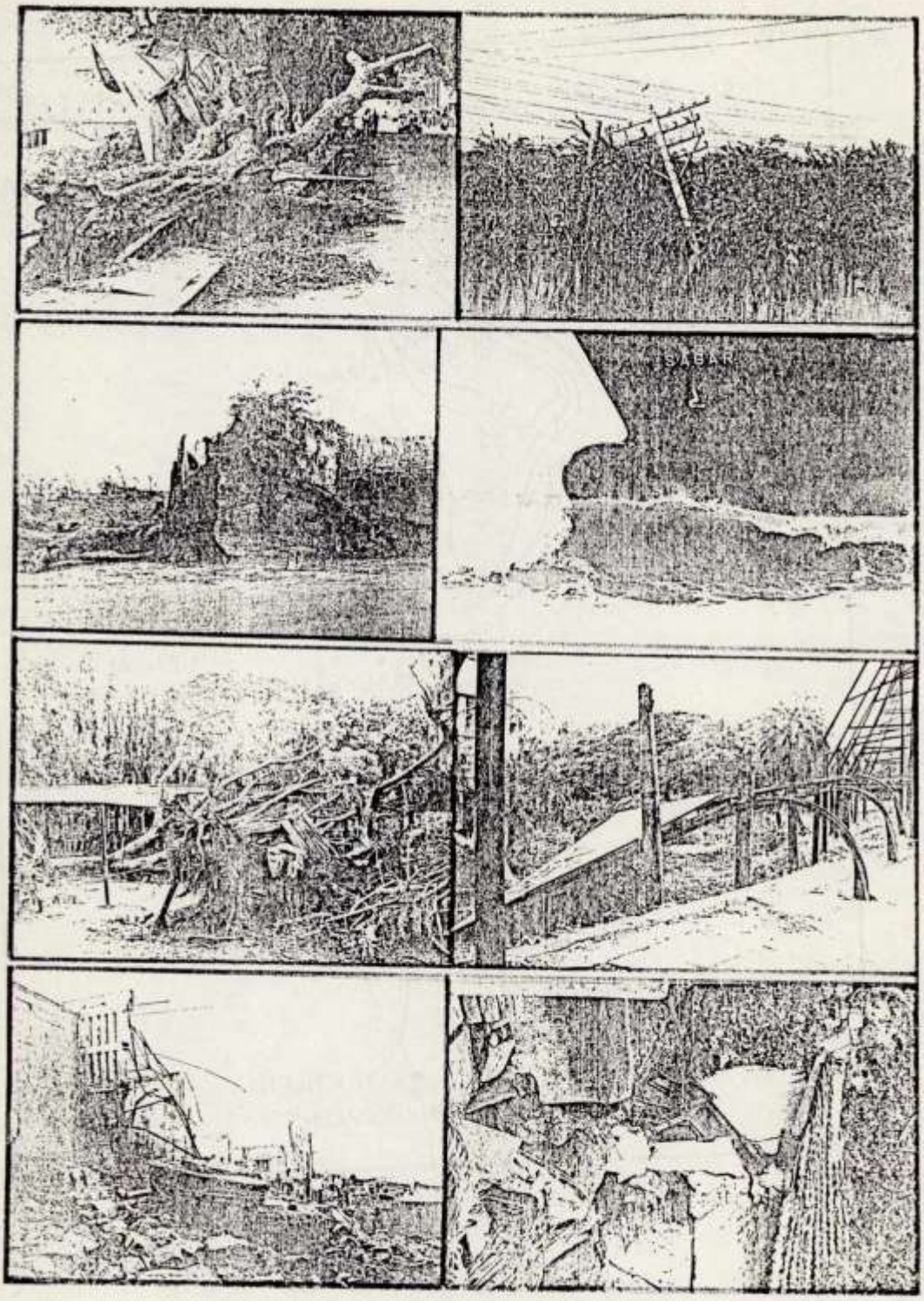


FIG. 11

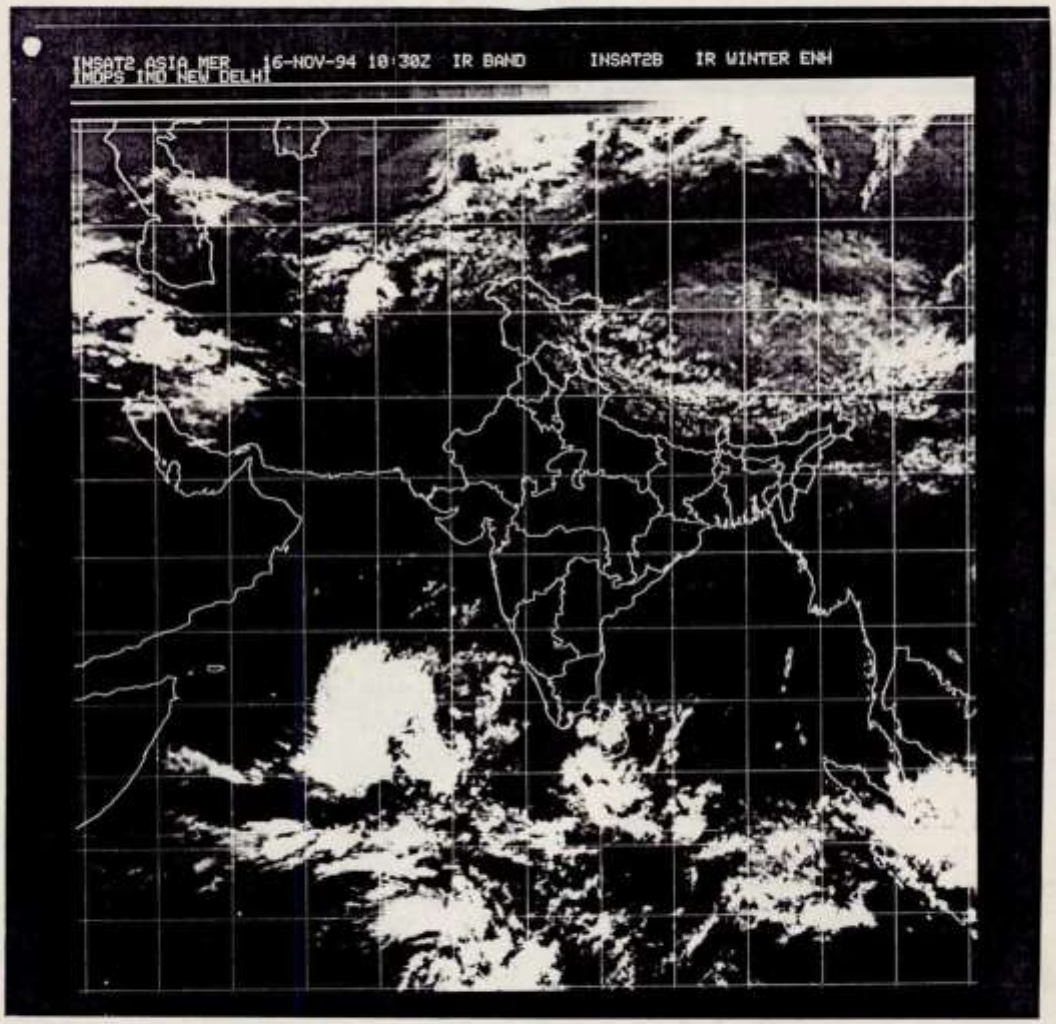
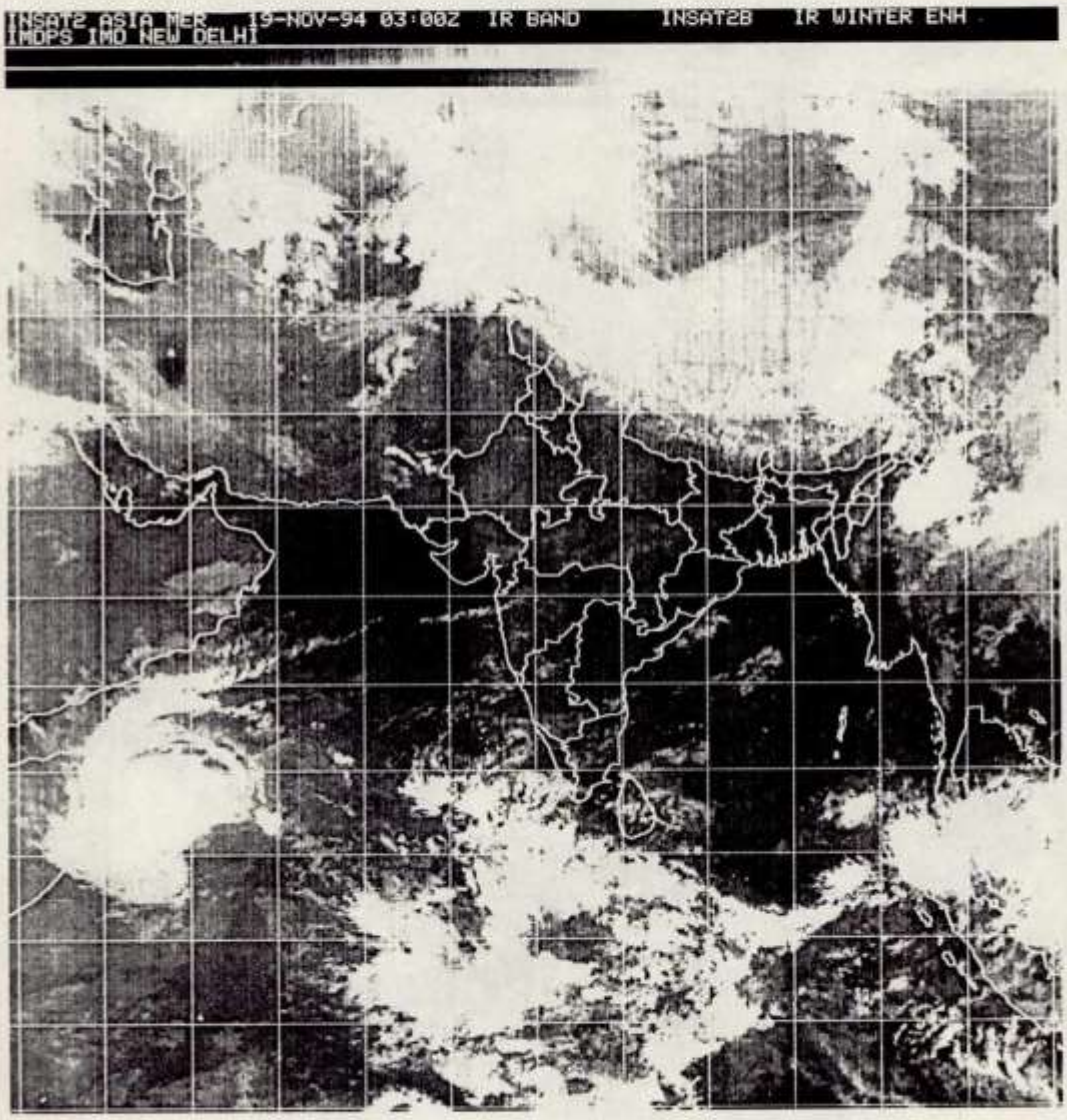

INSAT2 ASIA MER 16-NOV-94 10:30Z IR BAND INSAT2B IR WINTER ENH
IMDPS IND NEW DELHI

FIG. 12.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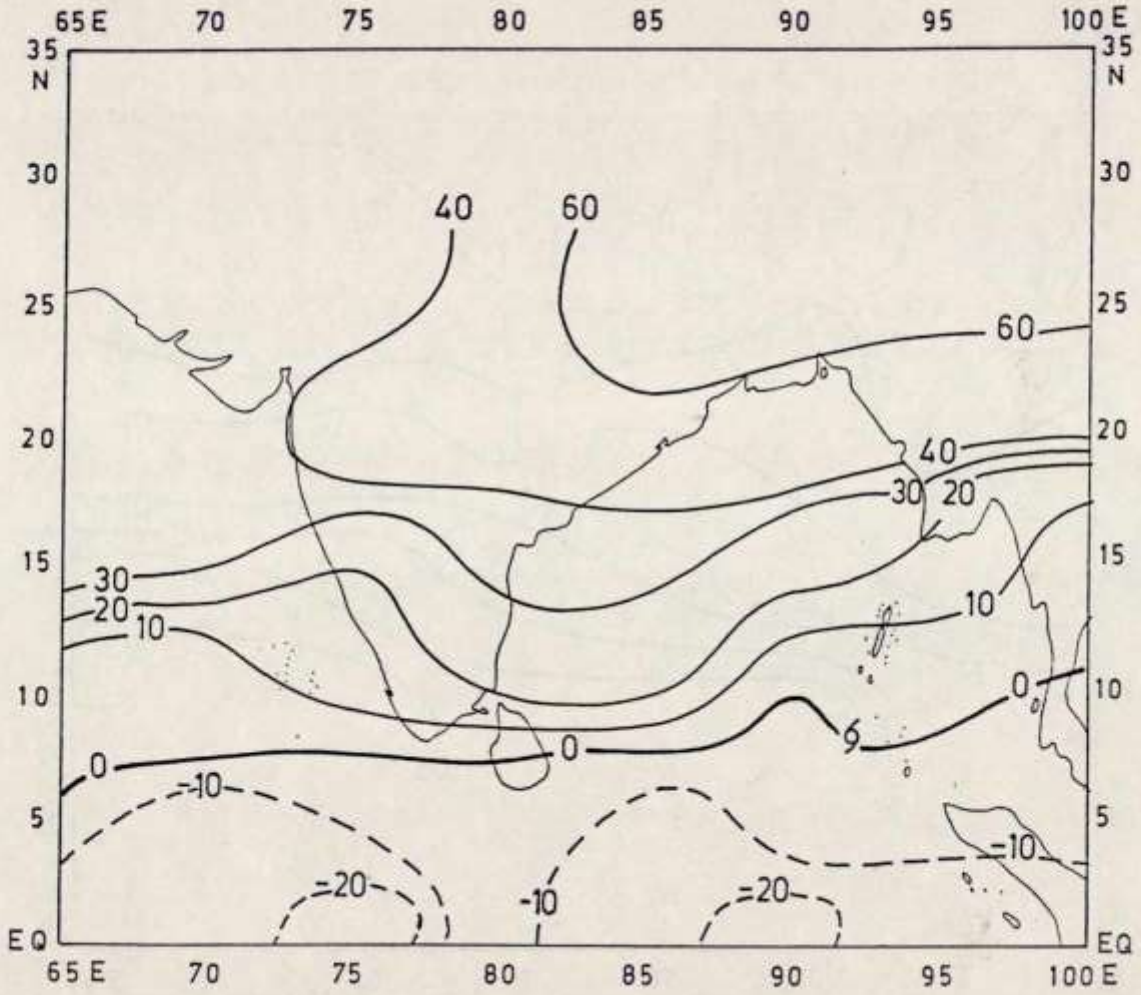
IMDPS IMD NEW DELHI

FIG.13.


65 E
70
75
80
85
90
95
100 E
35 N
30
25
20
15
10
5
EQ
40
60
60
40
30
20
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0
6
0
-10
-10
-20
-10
-20
-10

FIG 14.(a).

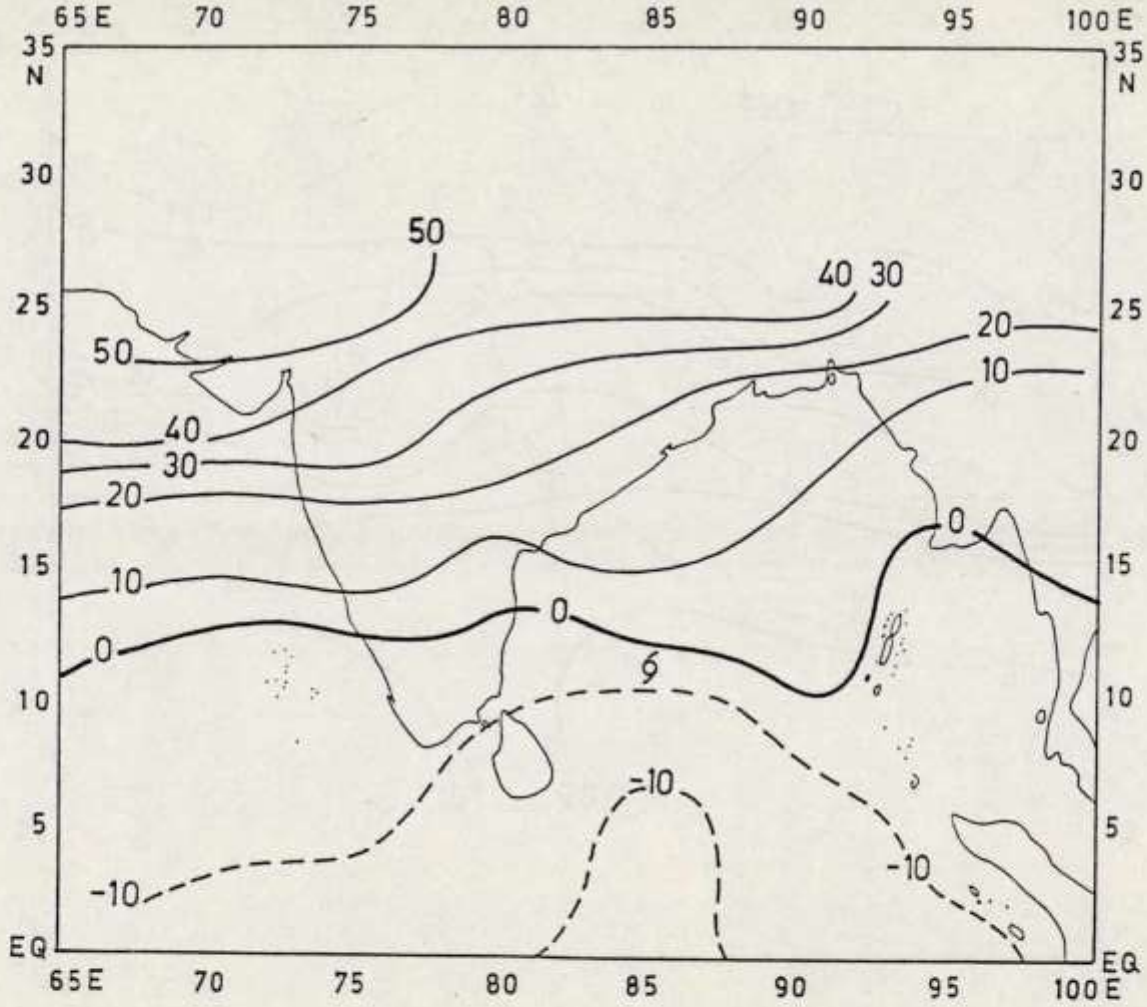


FIG 14.(b).

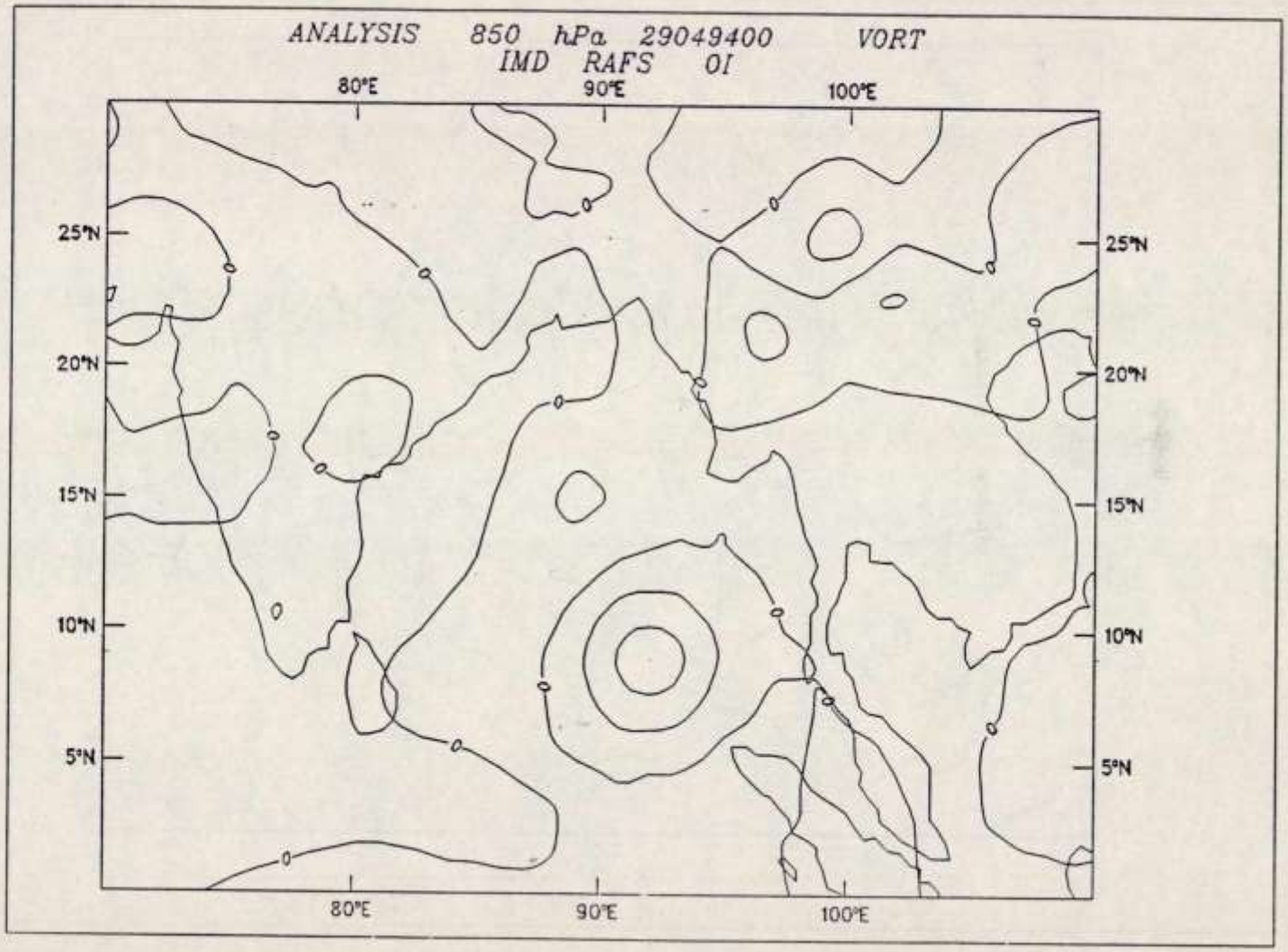
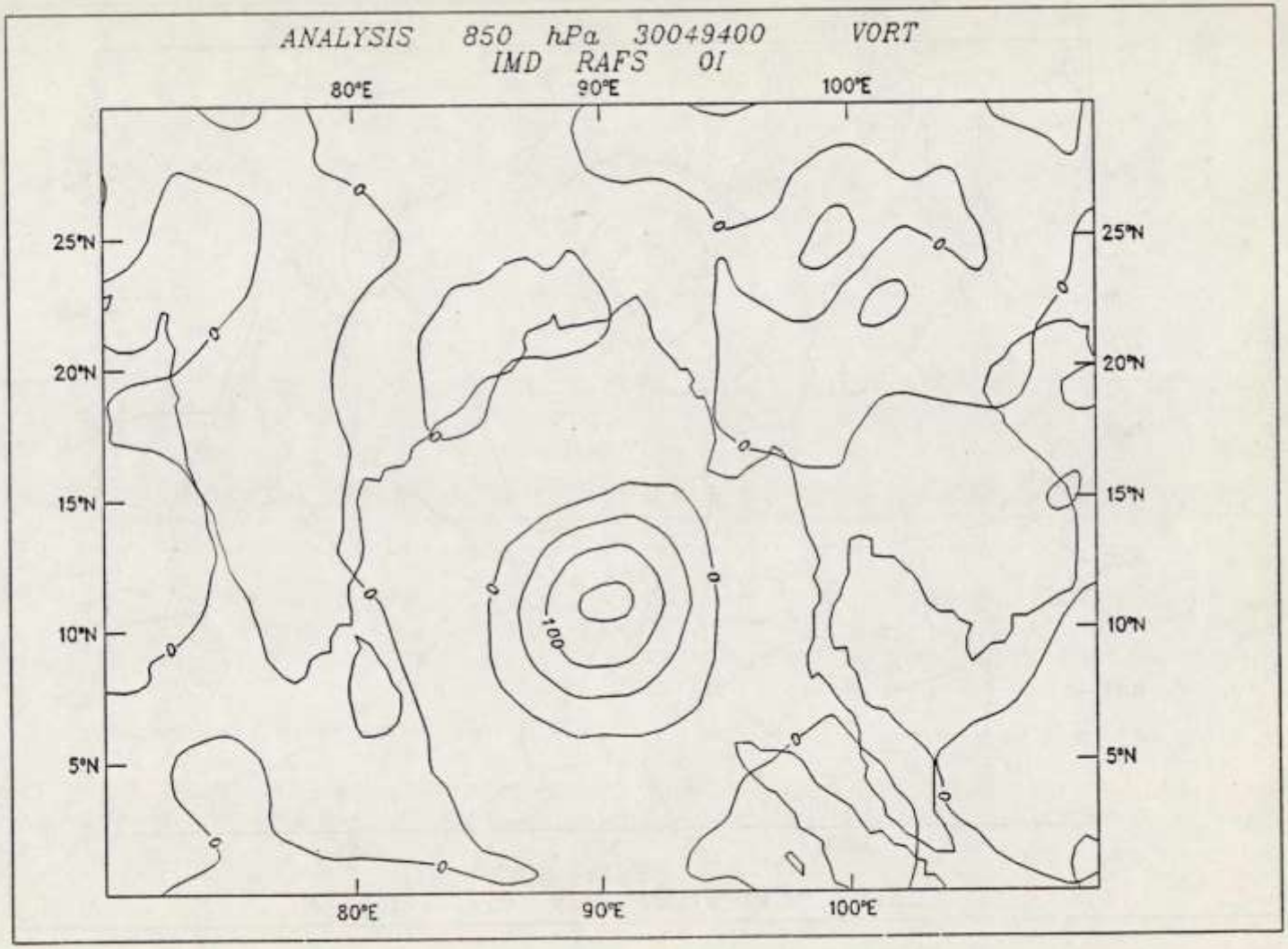

ANALYSIS 850 hPa 29049400 VORT
IMD RAFS OI
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N

FIG. 15(a)


ANALYSIS 850 hPa 30049400 VORT
IMD RAFS OI
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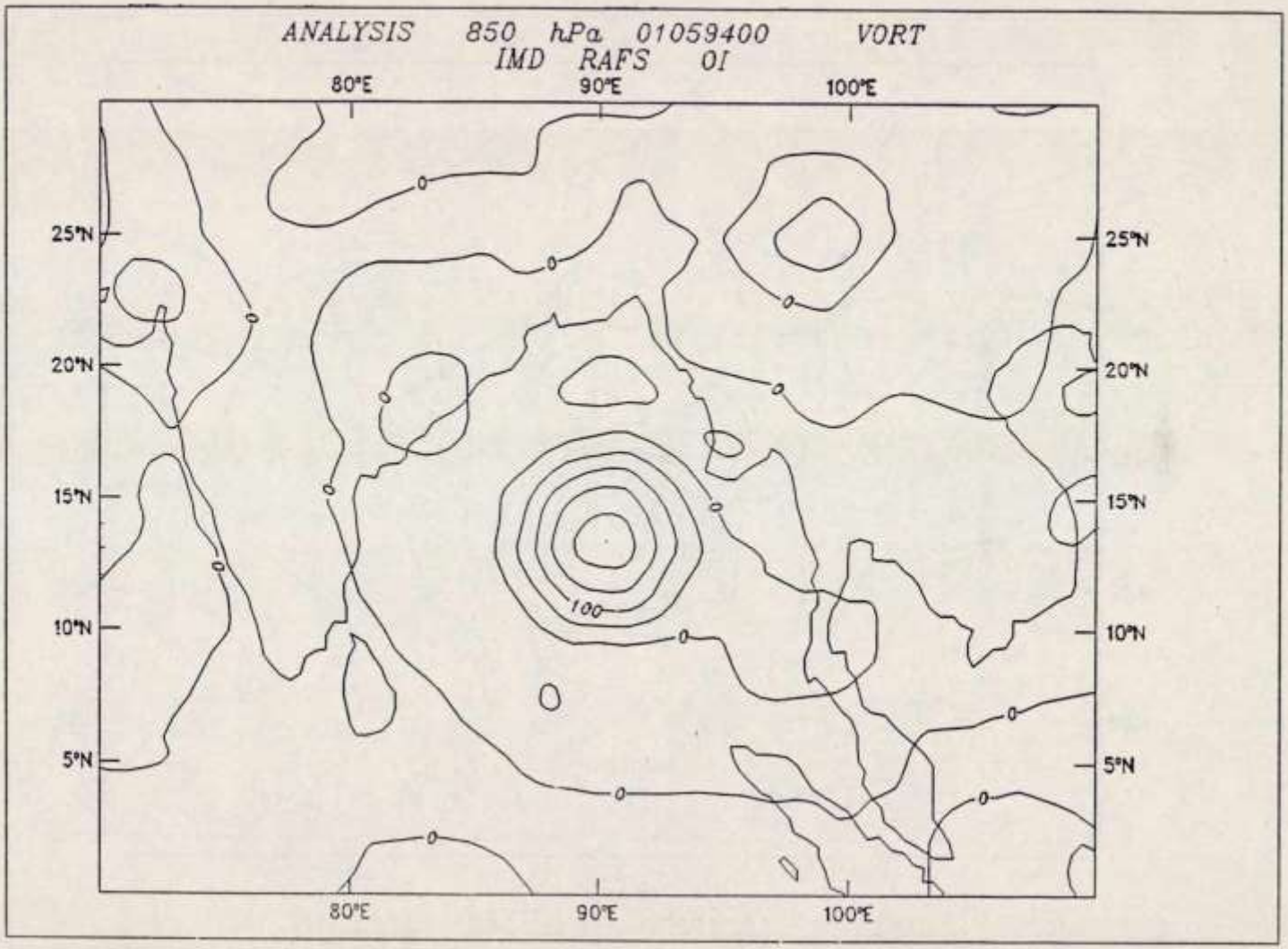
90°E
100°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 15 (b)


ANALYSIS 850 hPa 01059400 VORT
IMD RAFS OI
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90°E
100°E
25°N
20°N
15°N
10°N
5°N
100
0

FIG. 15(c)

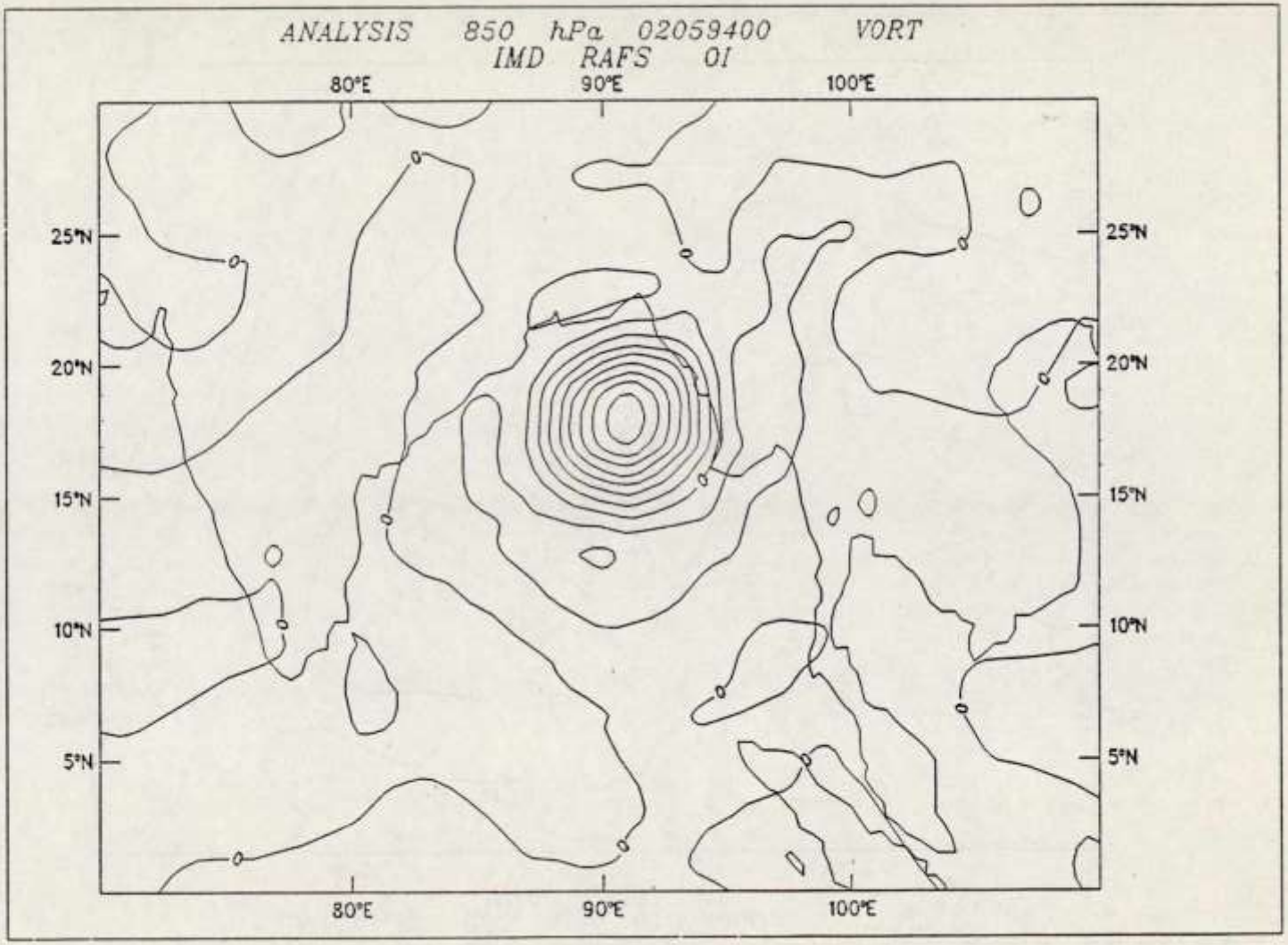

ANALYSIS 850 hPa 02059400 VORT
IMD RAFS 01
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N

FIG. 15(d)

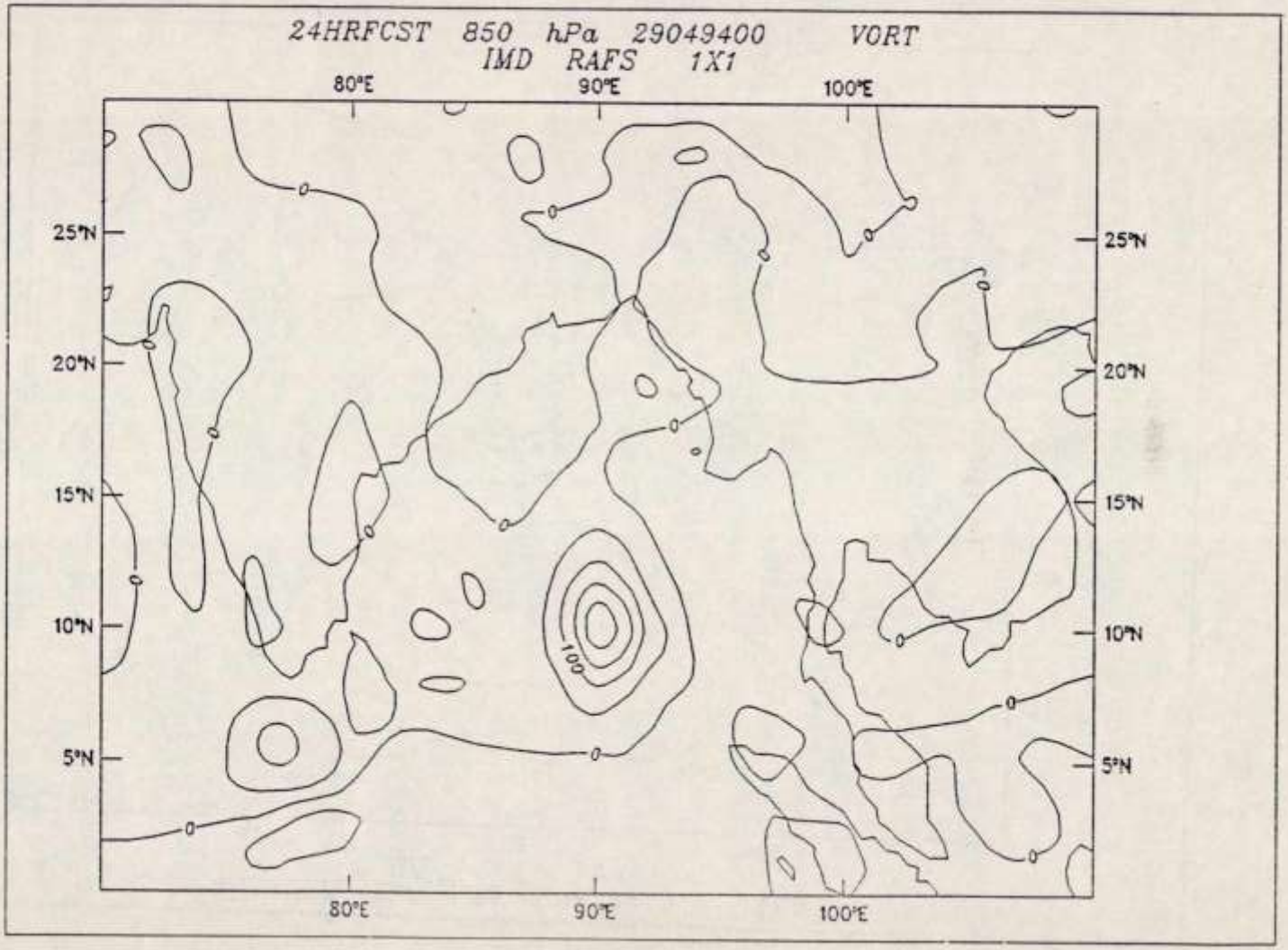

24HRFCST 850 hPa 29049400 VORT
IMD RAFS 1X1
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 16(a)

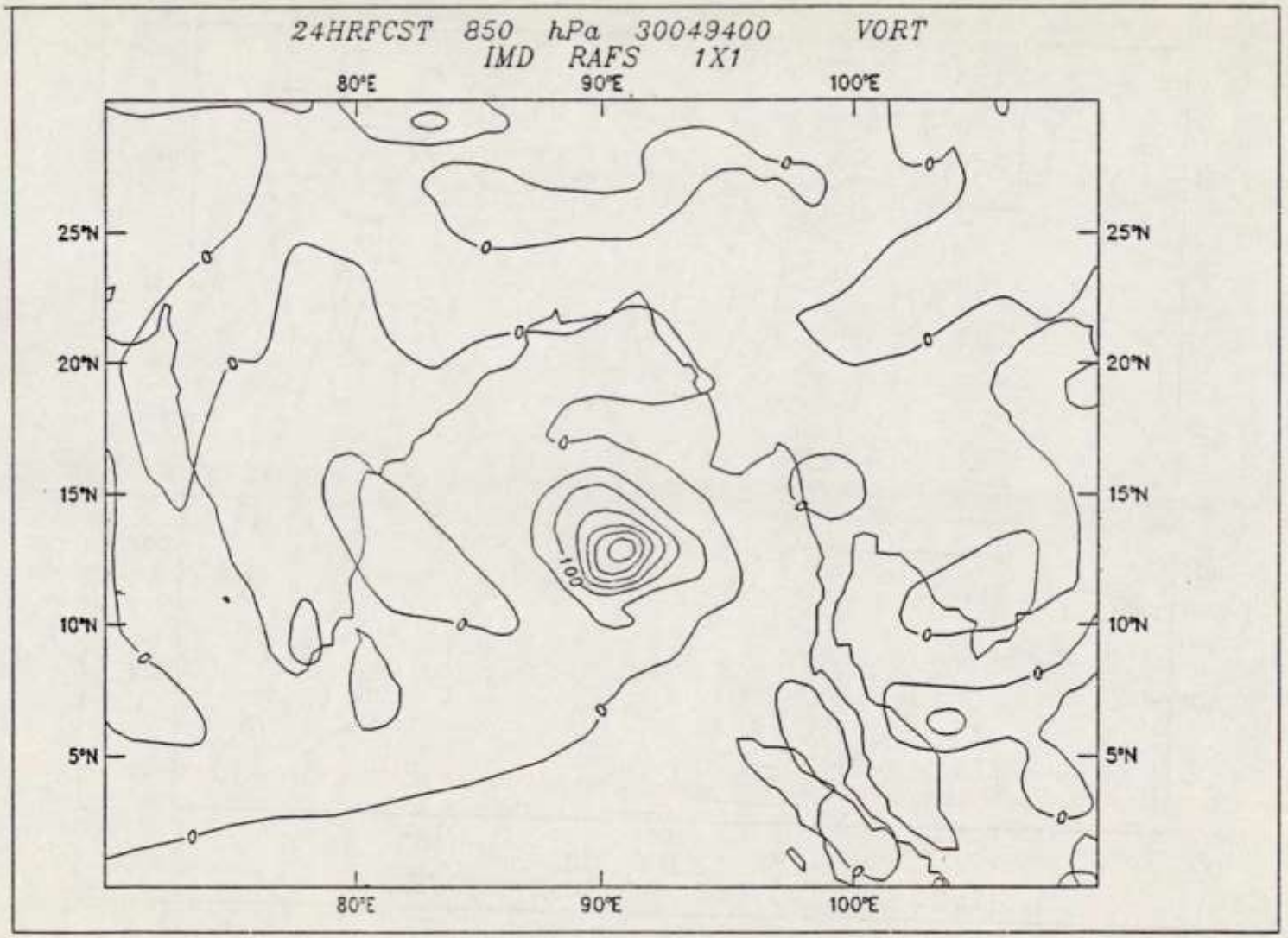

24HRFCST 850 hPa 30049400 VORT
IMD RAFS 1X1
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 16(b)

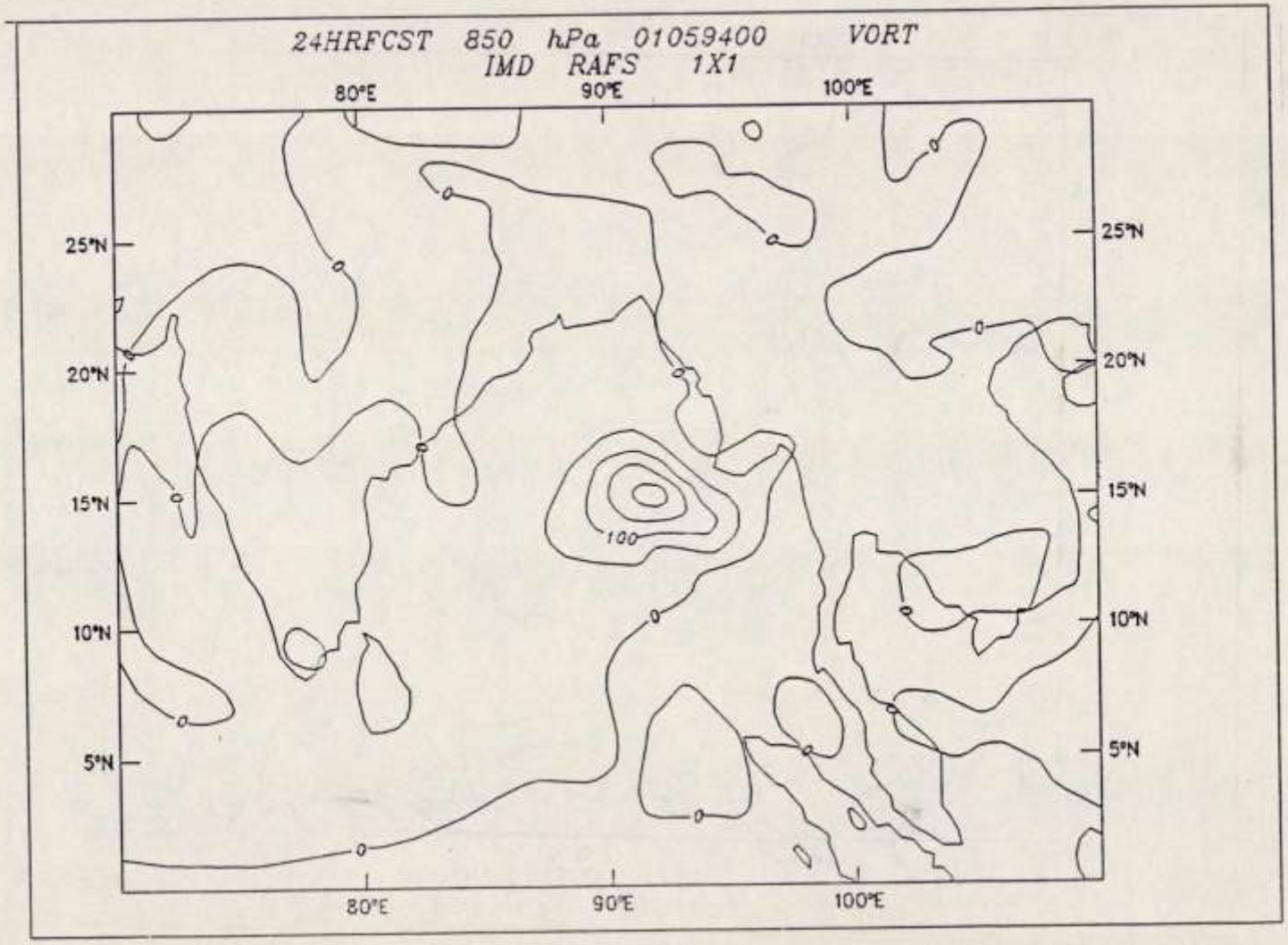

24HRFCST 850 hPa 01059400 VORT
IMD RAFS 1X1
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 16 (C)

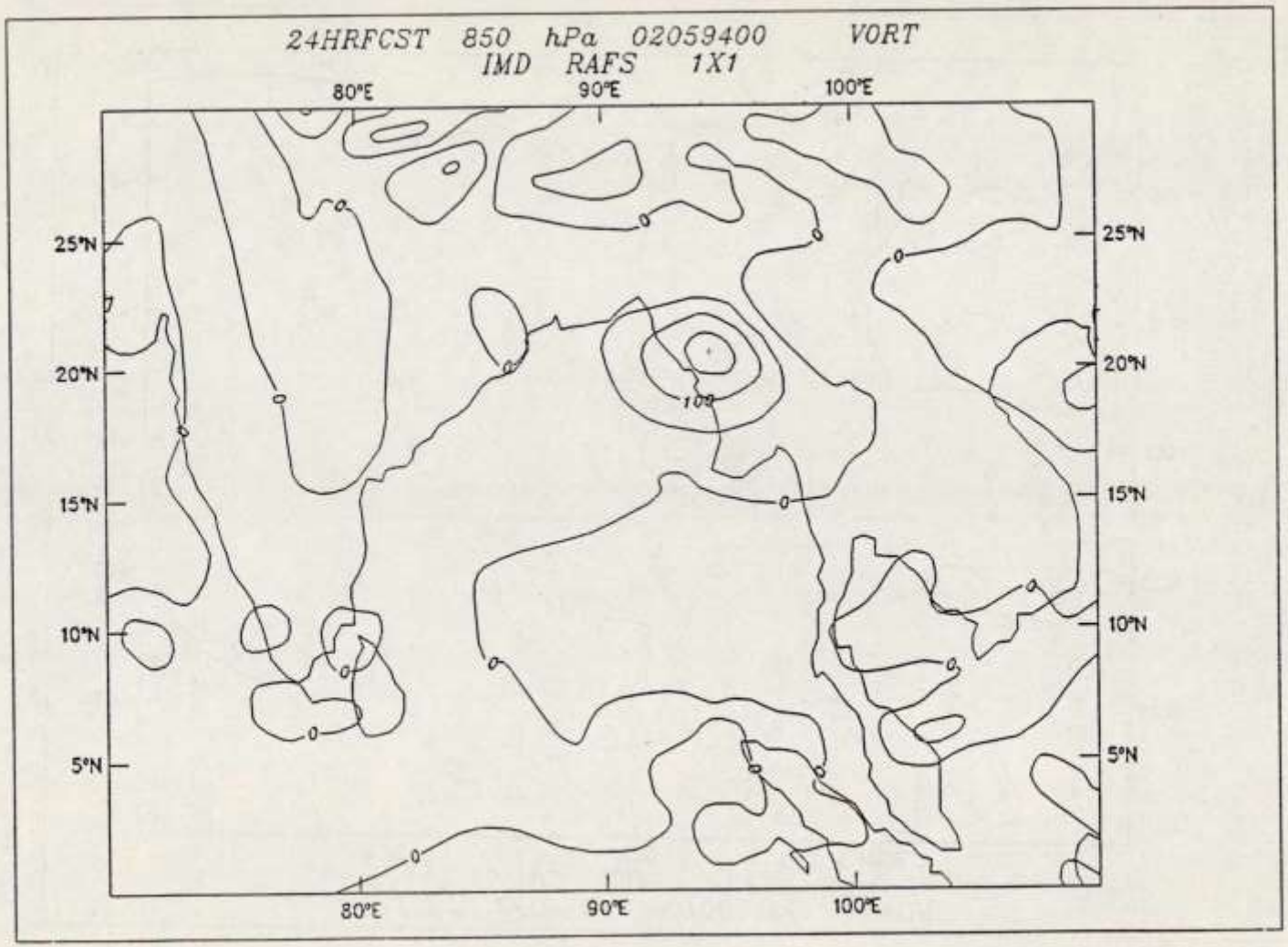

24HRFCST 850 hPa 02059400 VORT
IMD RAFS 1X1
80°E
90°E
100°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 16 (d)

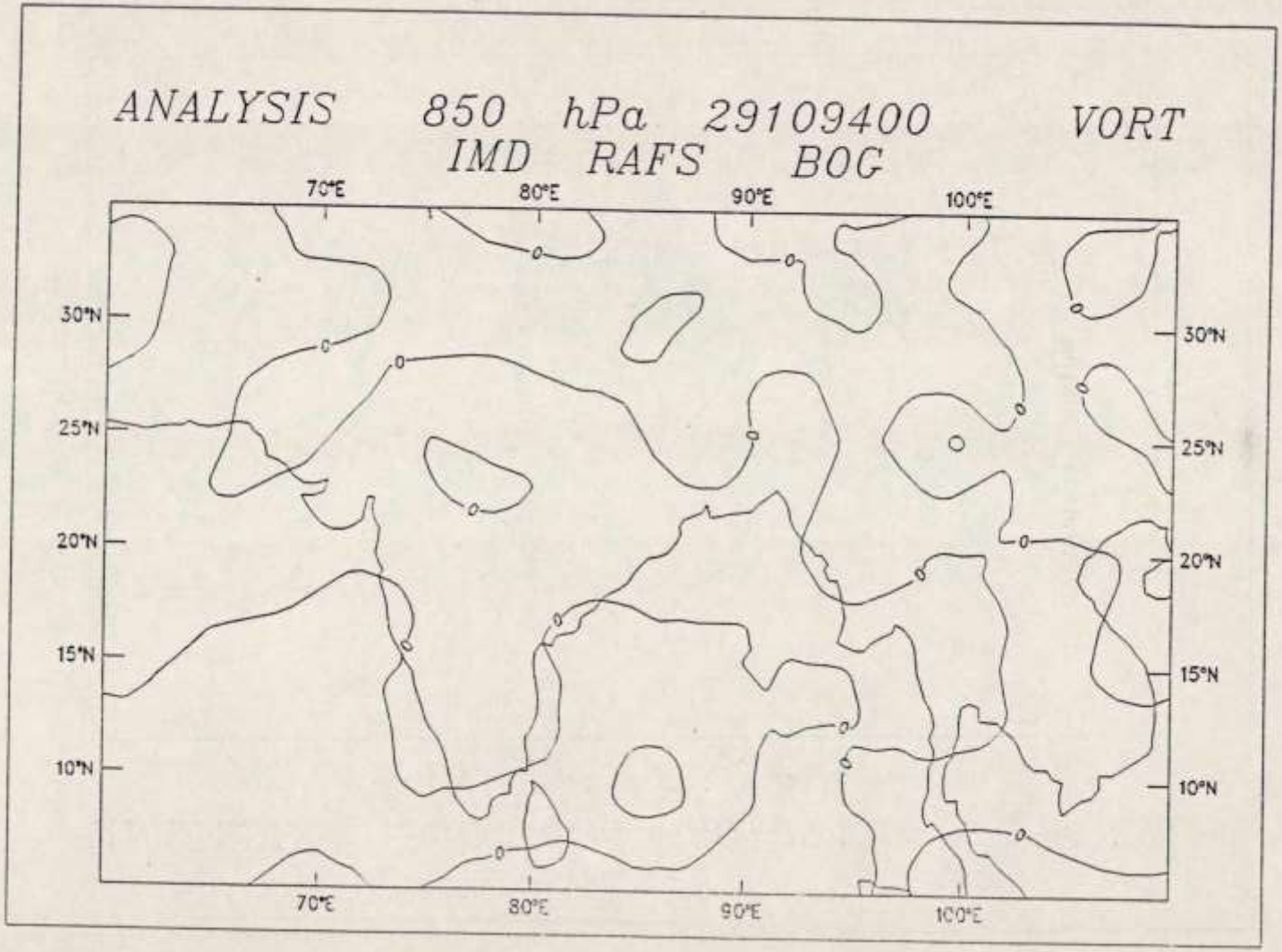

ANALYSIS 850 hPa 29109400 VORT
IMD RAFS BOG
70°E
80°E
90°E
100°E
30°N
25°N
20°N
15°N
10°N

FIG. 17(a)

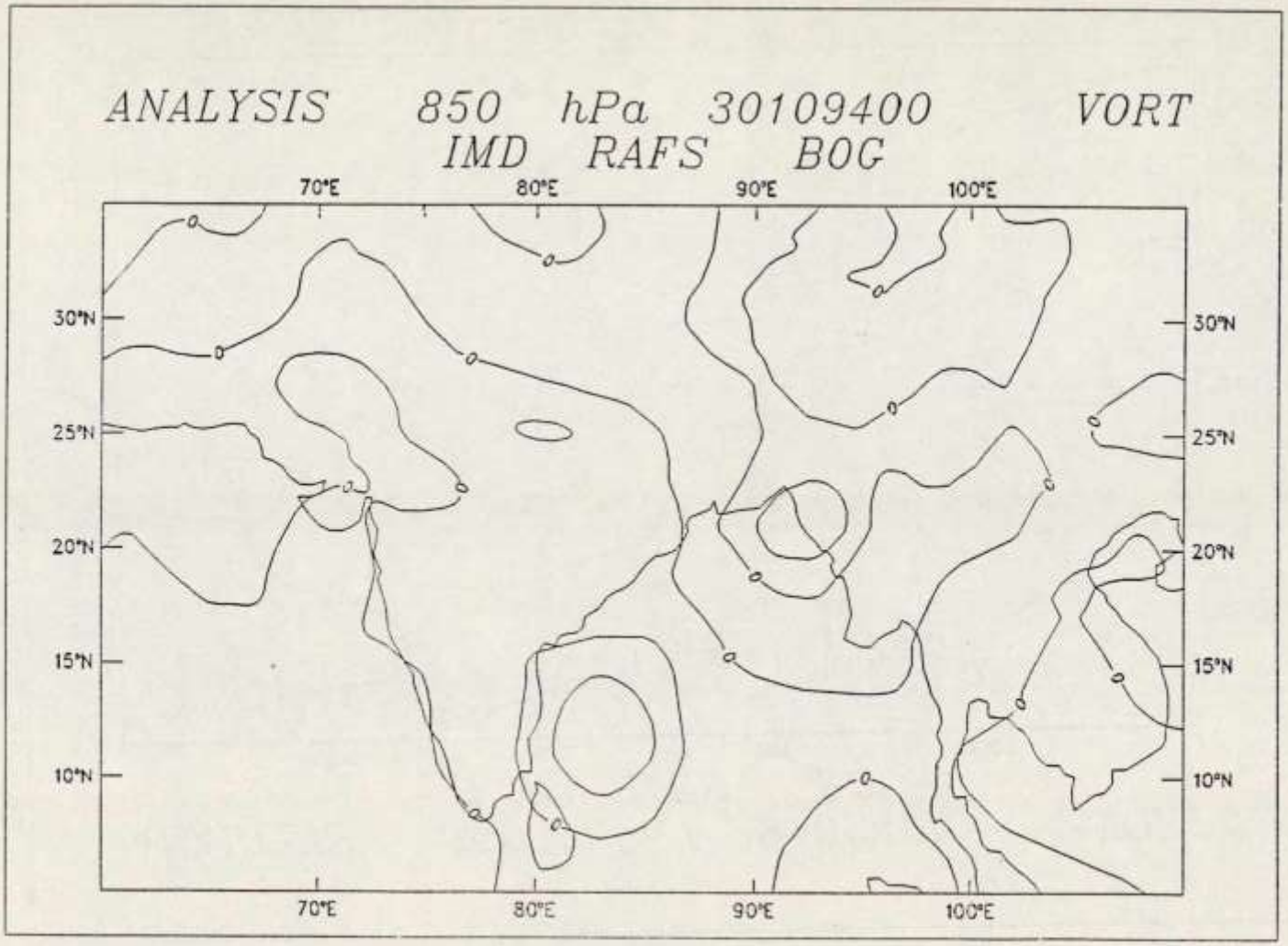

ANALYSIS 850 hPa 30109400 VORT
IMD RAFS BOG
70°E
80°E
90°E
100°E
30°N
25°N
20°N
15°N
10°N

FIG. 17(b)

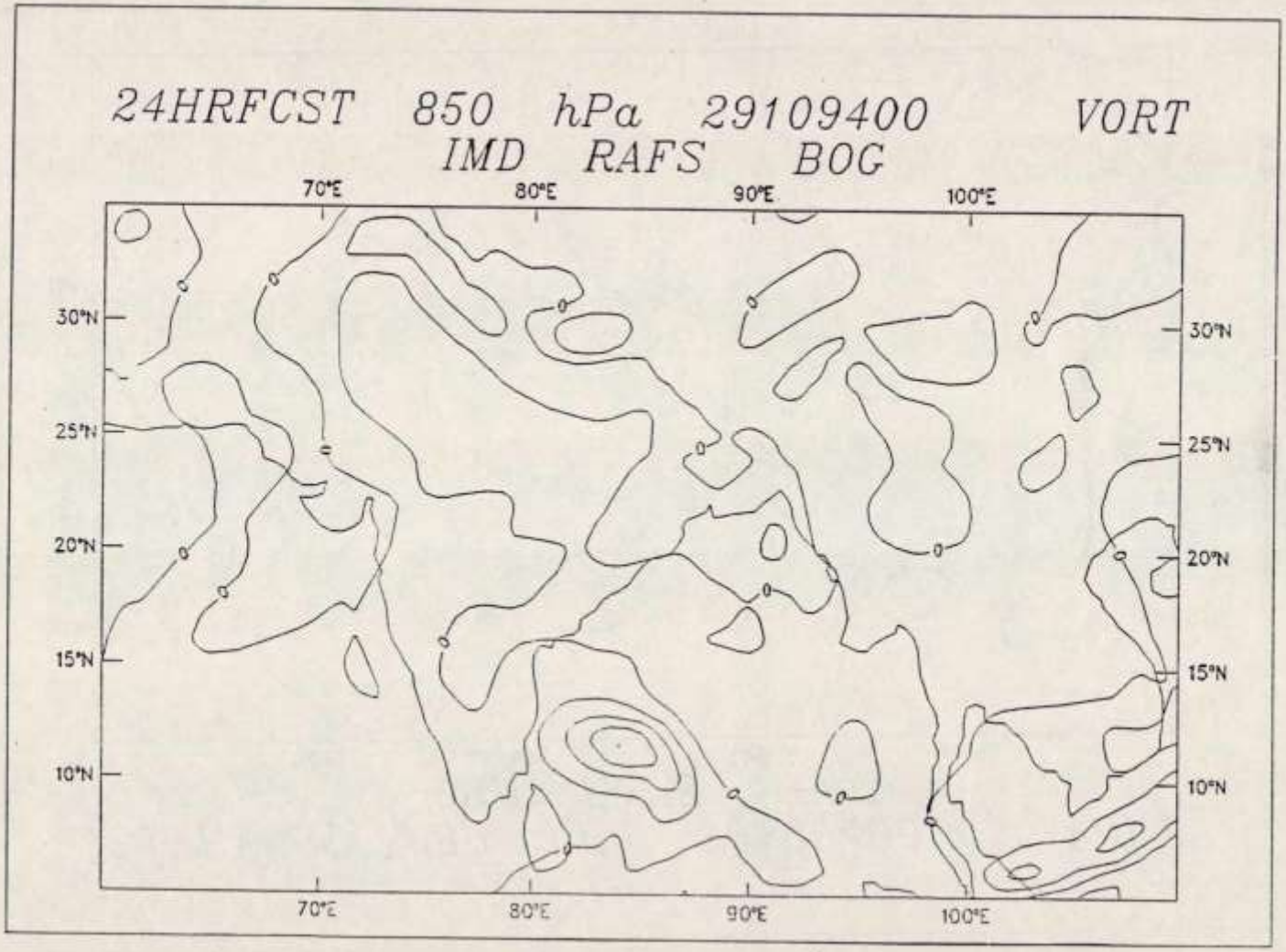

24HRFCST 850 hPa 29109400 VORT
IMD RAFS BOG
70°E
80°E
90°E
100°E
30°N
25°N
20°N
15°N
10°N

FIG. 18(a)

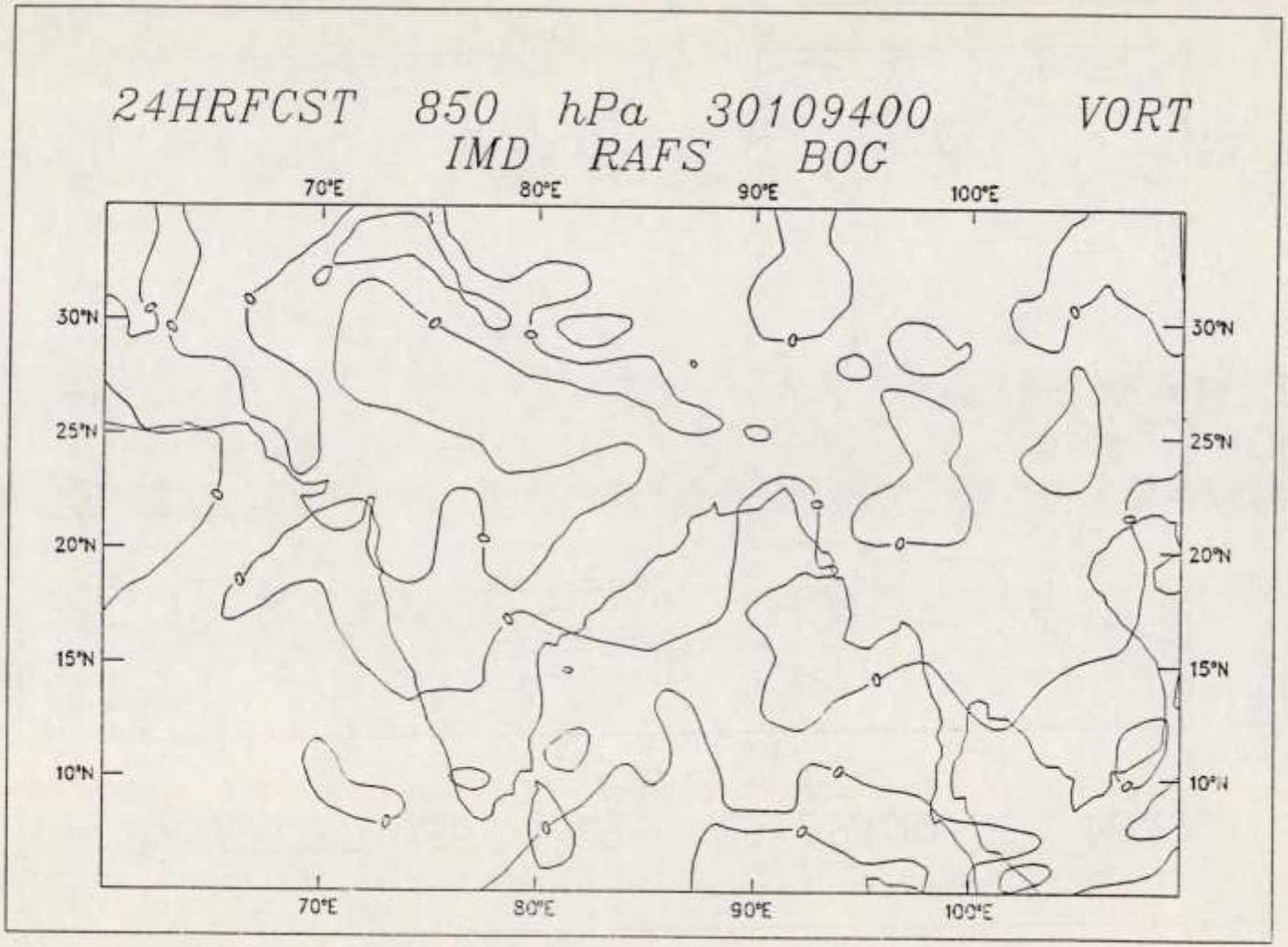
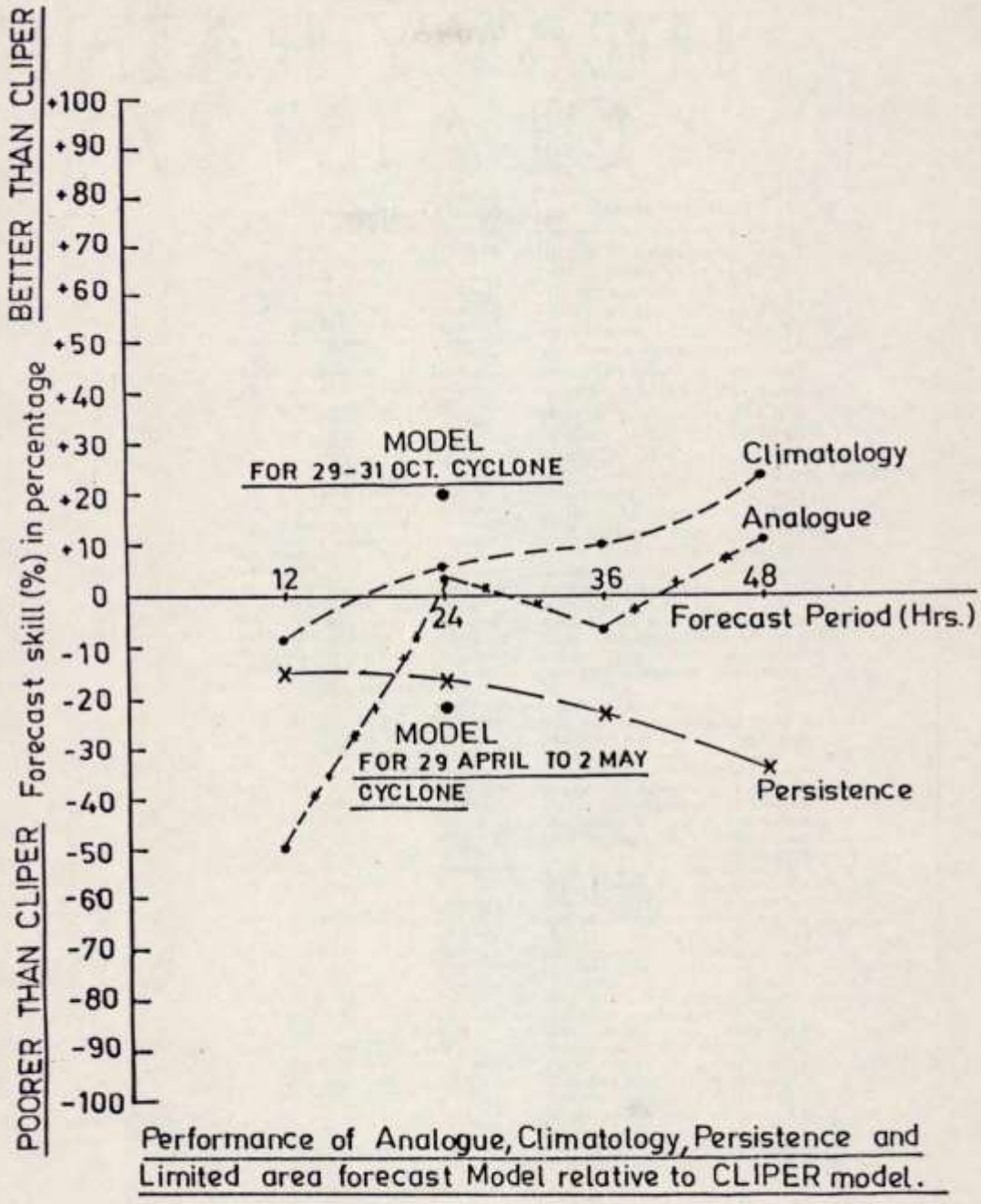

24HRFCST 850 hPa 30109400 VORT
IMD RAFS BOG
70°E
80°E
90°E
100°E
30°N
25°N
20°N
15°N
10°N

FIG. 18 (b)



Performance of Analogue, Climatology, Persistence and Limited area forecast Model relative to CLIPER model.

FIG. 19.

Reservoirs full, rivers in spate

HEAVY RAINS CLAIM 27

From Our Bureau

Hyderabad, Oct 6: At least 27 people were killed in the incessant rains that lashed many parts of the State, according to information reaching the State headquarters here on Thursday evening. Besides, six people died in two house collapses in the city. Official reports, however, put the death roll throughout the State, including the city, during the last three days at 17.

While the unexpected and incessant rains helped to wet the parched lands and filled dried-up reservoirs, it also left behind a trail of death and destruction in many parts of the State, which till three days ago was reeling under severe drought conditions.

The Additional Commissioner (Relief), Mr A Bhaskar Prasad, said that five children were washed away in flash floods at Kamalapuram in Cuddapah district on Wednesday, three persons, including two women, died in the city, five people were killed in Kurnool district and four deaths were reported from Krishna district.

However, according to information reaching here, besides the five deaths from Cuddapah, eight deaths were reported in Kurnool district, five in Mahbubnagar, seven in Krishna, two in Visakhapatnam. Six people died in two house collapses in the city.

Giving details of the Cuddapah incident, Mr Prasad said eight children, while on their way to school to appear for the examinations, were crossing the Penna river's Pageruvanka canal on a tullock cart. However, when they were halfway, a sudden gush of water seems to have washed them away. Three of the children survived, but five were drowned. Their bodies were recovered and handed over to their family members.

Mr Bhaskar Prasad said two minor irrigation tanks and the Kurnool Cuddapah canal breached at Santajuttur in Kurnool district and the river waters entered about five villages. The villagers were evacuated to a relief camp.

In Nandyal town, water entered low lying areas and people were shifted to a relief camp set up in a school.

No crop, except for sugarcane at Vuyyuru in Krishna district, was damaged, he said.

Communications were disrupted in some parts of Kurnool district. There was no information on the damage to crops and property so far, but relief assistance would be provided to the victims as and when information was received.

He said the widespread rains filled all the minor irrigation tanks, solving water problem in districts like Mahbubnagar and Cuddapah. Barring the damage, the benefit was substantial and farmers could take up short duration crops if they could not make it in the kharif.

He also stated that the State Government had released Rs 3 crores for inputs for crops in nine districts as relief so that crops could be raised for the next two months.

Mr Prasad said six crest gates of the Srisailam project were opened and two lakh cusecs of water was released on Thursday morning after the water level reached its full capacity of 885 feet.

The addl. collector was in touch with the collectors. He said water level in the Krishna river at Nagarjunasagar was 590 ft as against its full capacity of 590 ft.

The water supply to the twin cities, too, would improve substantially as the catchment areas for the Himayatsagar, Gandipet, Manjira and Singur were receiving heavy rains.

DECCAN CHRONICLE
7 October 1994

30 killed in cyclone

MOGADISHU: At least 30 people were killed and hundreds more injured in a cyclone that whirled through northern Somalia for 19 hours, an official of the faction controlling the area said on Sunday. Mr Yusuf Omar Azihari, Information Secretary of the Somali Salvation Democratic Front, told journalists here that the storm tore through Bosasso, a city of 300,000 on the Gulf of Aden. The storm, accompanied by winds speeding at up to 104 kmph hit the coast from the Gulf on Saturday and moved into the sparsely-populated interior, Mr Azihari said.

PRESS REPOR

(c) THE HINDU - 1st Nov. 94.

Cyclonic storm leaves 26 dead in Tamil Nadu

From Our Staff Reporter

MADRAS, Oct. 31.

The cyclonic storm which swept across the city and neighbouring districts on Sunday night left 26 persons dead — 15 in Madras and 11 in the districts — uprooted more than 1500 trees and severely disrupted transport services.

The Chief Secretary, Mr. N. Haribhaskar, said that 3000 persons were evacuated to safer places in Madras. The Chief Minister, Ms. Jayalalithaa, who returned here from Tuticorin in the afternoon, deputed ministers to supervise relief operations.

The cyclone crossed the coast near the city around 7 a.m. with wind speeds touching 100 km and moved about 50 km north. It was likely to move in a northwesterly direction and weaken gradually, the weather office said.

An empty general cargo ship, "Sagar," lying in anchorage off the Madras port was tossed by the cyclone winds and it ran aground near Thiruvottiyur after snapping its anchor. Distress calls were received by the port from at least two other drifting vessels. A fire broke out at the harbour as incendiary chemicals in unclaimed cargo containers reacted with water and ignited.

Air services suffered delays as the morning flights left over two hours behind schedule.

Many of the huge trees in the metropolis fell victim to the fury of the cyclone winds and were uprooted. Traffic had to be diverted at several points as the fallen trees were cleared. Suburban electric trains were not run for the major part of the day. Power supply was also switched off in the small hours of Monday in many parts of the city.

Several long distance trains scheduled to leave from Madras Central were cancelled or run on truncated routes. The departure of evening trains for the city were rescheduled for past midnight.

It is after several years that a cyclonic storm has crossed the coast close to the city. Normally, the cyclones approaching the State's coast get deflected further north or down south of Madras.

National Herald

2nd Nov. 94.

45 killed as cyclone batters AP

HYDERABAD, Nov 1 (UNI) — At least 45 people were killed today in the wake of a cyclonic storm as heavy rain battered the southern coastal districts of Andhra Pradesh, leaving a trail of destruction.

Thirty-nine people — including 13 women and 11 children, were drowned early today whe a private tourist bus fell into a rivulet while negotiating a causeway near Gudur in Nellore district.

The bus from Palacole in West Godavari district was carrying a 73-member marriage party to the temple town of Tirumala.

While 34 passengers were rescued five were still "missing", Nellore district police superintendent S.V. Ramana Murthy told UNI over trunk telephone.

In the adjoining Prakasham district, two children and a woman were killed near Kandukur when a building collapsed, burying their thatched hut. Two others were admitted to a hospital with injuries.

Relief commissioner T.K. Dewan told reporters here that the Ongole-Madras national highway was closed as it was heavily breached at a number of places.

TRAINS CANCELLED: South-Central Railway authorities have cancelled today's Kakinada-Madras Circar Express and Hyderabad-Madras Express following incessant rains in South Andhra following the cyclonic storm which crossed the Madras Coast yesterday.

All Express trains which left Madras were running late by about two to six hours.

MADRAS: The toll the severe cyclonic storm that battered the city and other parts of Tamil Nadu yesterday rose to 30 with four more deaths reported.

Official sources said a 40-year-old woman and her 19-year-old son were killed in a wall collapse a. Pattabhiram in Chengalpattu-MGR (East) district last night.

CONCRETE HOUSE IN ZAMMALAPALAM IN ANDHRA PRADESH (INDIA) SEVERELY DAMAGED BY THE BAY OF BENGAL SEVERE CYCLONE OF 29-31 OCTOBER, 1994