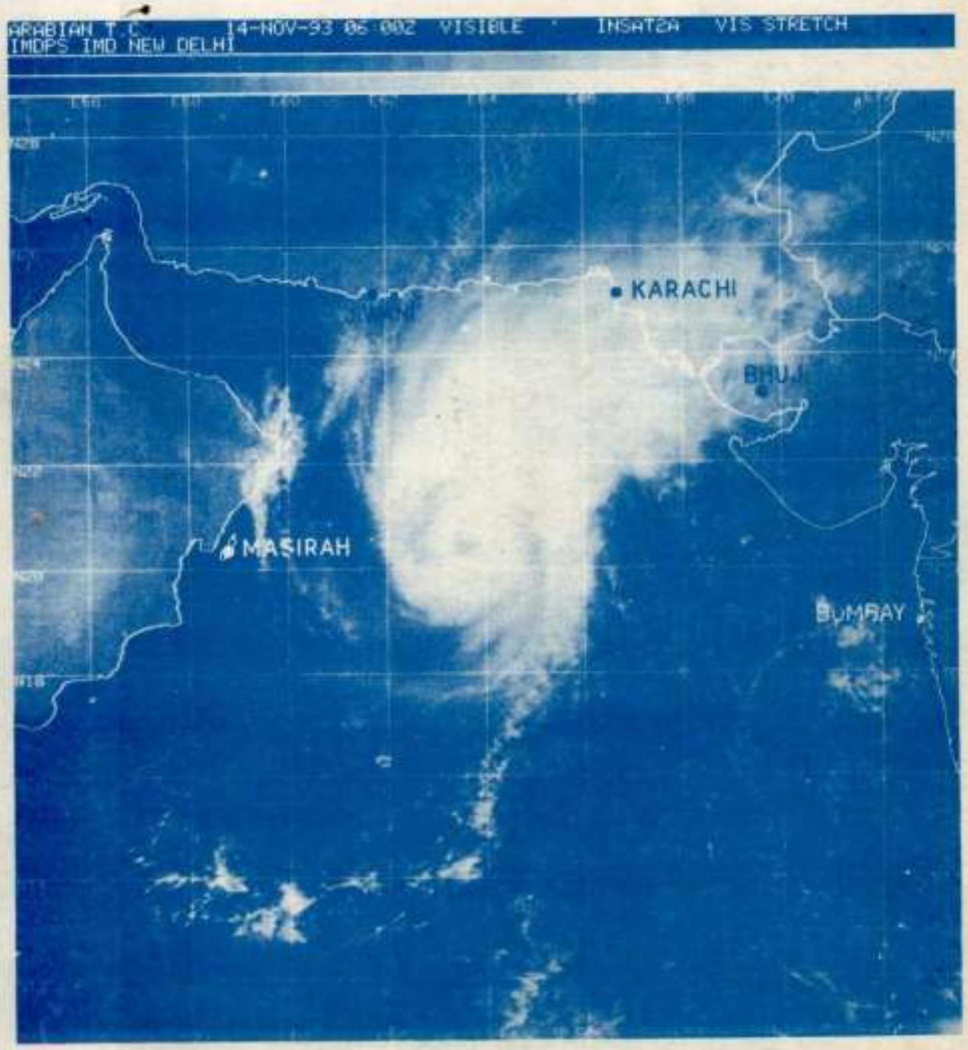
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 1993



RSMC-TROPICAL CYCLONES, NEW DELHI
JANUARY 1994

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Introduction

This report gives a review of cyclonic disturbances (depressions and tropical storms) formed in the North Indian Ocean (The Bay of Bengal and the Arabian Sea) during the year 1993. The definitions of the cyclonic disturbances as given in the WMO Tropical Cyclone Operational Plan for the North Indian Ocean (TCP-21) are given in Annex I.

1993 was a year of below normal cyclone activity over the North Indian Ocean region. There were only five cyclonic disturbances over the region during this year as against the normal frequency of 15 disturbances. This has been a rare event during the past 102 years (1891-1992), which has surpassed the past record of minimum frequency of 7 cyclonic disturbances in 1984.

Out of the five cyclonic disturbances during 1993, two intensified into severe cyclonic storms with a core of hurricane winds (hereafter called cyclone with hurricane intensity), one each in the Bay of Bengal and the Arabian Sea. Out of the remaining three, two intensified into deep depressions while the third one remained as depression only. Two of these systems formed in the Bay of Bengal whereas the third one formed in the Commorin area of the Arabian Sea west of Sri Lanka.

Table-1A gives the monthly distribution of cyclonic disturbances over the North Indian Ocean. It may be seen from this table that this year there was no cyclonic activity in the winter and the pre-monsoon seasons . The frequencies of cyclonic disturbances during the southwest monsoon (June-September) and post-monsoon (October/December) seasons this year were 1 and 4 respectively. Both the cyclones of hurricane intensity (one in the Arabian Sea and the other in the Bay of Bengal) formed in the post-monsoon season. Out of the three depressions, one formed in the monsoon season while the other two formed in the post-monsoon season.

Table-1B gives the life period of each cyclonic disturbance along with duration of peak intensity, place and time of crossing the coast, loss of lives as reported in the press, peak storm surge if any 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 TABLE-6 give the best track positions at 00, 03, 06, 12 and 18 UTC along with other meteorological parameters in respect of all the five cyclonic disturbances.

Detailed accounts of all the cyclonic disturbances are given in the following paragraphs. The tracks of these cyclonic disturbances 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)

As stated earlier, there was no cyclonic disturbance during the pre-monsoon season this year. This is the 8th occasion during the past 103 years (1891-1993) when no cyclonic disturbance formed over the North Indian Ocean during both the winter (January-February) and pre-monsoon seasons (March-May). The earlier such years were 1912, 1913, 1915, 1981, 1983, 1984 and 1988.

2.2 Southwest Monsoon Season (June-September)

There was only one cyclonic disturbance (a deep depression) during monsoon season this year. This is the only year during the last 103 years (1891-1993) when only one cyclonic distrubance formed over the North Indian Ocean in the monsoon season. Nevertheless, there were as many as 14 low pressure areas forming over the Bay of Bengal, Arabian sea and the land areas during this season, which gave copious rainfall over different parts of the country.The country as a whole received 100% of the long term average rainfall of the southwest monsoon season this year.This clearly suggests that the fequency of monsoon depressions does not possess good correlation with the total performance of the monsoon over the country.

2.2.1 Bay of Bengal Deep Depression of 17-19 June 1993

A depression formed over north Bay of Bengal near lat. 21.5 deg. N/ long.87.5 deg. E about 150 km southwest of Calcutta (42807) in the morning of 17 June, 1993. Moving in a northeasterly direction it crossed the Indo-Bangladesh coast by mid-day of the same day and was centred near lat. 22.5 deg.N/long.88.5 deg.E over Bangaldesh by the same evening. Subsequently it moved towards north-north-east and intensified slowly into a deep depression by the morning of 18th when it was located near Jessore (41936) in Bangladesh. The system then moved in a northeasterly direction, weakened into a depression by the morning of 19th and was located near lat. 25.5 deg. N/long.91.5 deg. E about 100 km south of Guwahati(42410). Thereafter, the depression took a northerly track and dissipated gradually over Assam & Meghalaya in India by the same evening.

The system attained its peak intensity in the evening of 18 June with maximum sustained surface wind speed of 30 kt (56 kmph) and minimum surface pressure of 988 hPa.

Under the influence of this system southwest monsoon advanced into Bihar. Widespread rains with heavy to very heavy falls occurred in the north-eastern states of the country, causing extensive floods over these states.

Fig.3 depicts 0300 UTC INSAT-2A visible cloud imagery of 18 June, 1993 when the system was in a deep-depression stage over Bangladesh.

2.3 Post monsoon season (October-December)

During the post-monsoon season of 1993 four cyclonic disturbances formed over the North Indian Ocean. As stated earlier two of these disturbances intensified into severe cyclonic storm with a core of hurricane winds one each in the Arabian Sea and the Bay of Bengal. Remaining two were of depression intensity, one in the Commorin area of the Arabian Sea and the other in the Bay of Bengal. Detailed descriptions of these disturbances are given in the following paragraphs.

2.3.1 Arabian Sea depression of 8-9 November 1993.

This depression developed near lat 6.5 deg.N/long 78.5 deg.E at 0300 UTC of November 8,1993 from a pre-existing low pressure area which emanated from the active I.T.C.Z. region. Moving northwards with the same intensity, it lay centred near lat. 7.0 deg.N/long.78.5 deg.E over the Commorin area of the southeast Arabian Sea by the same evening. It continued to move in a northerly direction with a relatively faster speed and crossed the southern coast of India near Tuticorin (43379) during early morning hours of 9th. The system was located near lat. 9.0 deg.N/long.78.5 deg. E on 9th morning. Over the land while maintaining the same intensity, it moved westwards and lay centred near lat. 9.0 deg.N/long.77.5 deg.E on the same evening. During its westward journey the system weakened and emerged as a low pressure area into the southeast Arabian Sea by the morning of November 10, 1993.

The system reached at its peak intensity in the evening of November 9, 1993 with the maximum sustained surface winds of 25 kt (46 kmph) and minimum surface pressure of 998 hPa.

Under its influence, widespread northeast monsoon rains with heavy to very hevy falls occurred in the southern states of the country. Some loss of human lives was also reported due to landslides in some parts of these *states. Fig. 4 shows the INSAT-2A visible cloud imagery of 0300 UTC of 9 November 1993 when the depression was near Tuticorin (43379) over the land.*

2.3.2 Arabian Sea Severe Cyclonic Storm with a core of hurricane wind 12-15 November, 1993 (ARB 9301 1113)

2.3.2.1 The life history of the Cyclone

The remnant of the depression of 08-09 November 1993, moved west-north-west wards and developed into a depression in the east Arabian sea near latitude 14.0 deg. N,long 67.5 deg. E by the evening of November 12,1993. Moving initially in a northwesterly direction it intensified into cyclonic storm centred near lat. 16.0 deg. N/long. 65.0 deg.E by 13th morning. Thereafter, the cyclonic storm changed its track from northwesterly to northerly direction and was centred near lat.17.5 deg.N/long.64.5 deg.E at 1200 UTC of the same day. The system moved in the same direction and intensified further into a severe cyclonic storm by the morning of 14th with its centre near lat.20.0 deg.N/long.64.5 deg.E. Moving slowly further northwards, it rapidly intensified into a severe cyclonic storm with a core of hurricane winds and lay centred near lat. 20.5 deg.N/long. 64.5 deg.E about 550 km west-south-west of Porbandar (42830) by the same evening.

The system then moved in a north-north-easterly direction with relatively higher speed and weakened into a severe cyclonic storm with its centre located about 300 km west-south-west of Naliya (42631) by the mid-night of 14-15 November. The severe cyclone weakened further into a cyclonic storm and recurved tpwards northeast and was located near lat.23.5 deg.N/long.67.5 deg.E on 15th morning. Thereafter, the cyclonic storm remained practically stationary and weakened into a deep-depression by the same evening. The system further weakened into a well marked low pressure area over northeast Arabian Sea off Gujarat-Sind coast by the morning of November 16, 1993. The hurricane attained its peak intensity of T-4.0 with estimated maximum sustained surface wind of 65 kt (120 kmph) on Dvorak's Scale on the afternoon of 14th. Fig.5 is the visible INSAT-2A cloud imagery at 0900 UTC of 14 November.

2.3.2.2 Monitoring and Tracking

The cyclone was tracked and monitored mainly through the INSAT-2A cloud imageries. The system remained beyond the surveillance range of the Cyclone Detection Radars on the west coast of India till 00 UTC of 15 November, 1993. From this time onwards 3 hourly/hourly observations from CDR Bhuj (42634), along with the special hourly surface observations from the coastal stations of Gujarat and ships observations were available.

From the evening of November 12, 1993 when the system was in the depressiona stage over the southeast Arabian Sea the tracking of the system was done mainly with the help of INSAT-2A cloud imageries and ships observations. The cloud organisation observed through the satellite imageries and a few ships' observations in the depression field indicated ongoing slow intensification of the system into a cyclonic storm by the morning of 13th, thereafter hourly observations from INSAT-2A together with a few ship observations from the cyclone field were available. The cyclone changed its track from northwesterly to northerly and intensified into a severe cyclonic storm by 0300 UTC of 14th. These changes were clearly monitored by INSAT-2A and supported by the observations from two ships, viz., ELJA9 and P3BK5 which were located at a distance of 200 km south-south-east and north-north-west of the storm's centre and each reported winds of the order of 50kt (93 kmph). After the system had intensified into a severe cyclonic storm with a core of hurricane winds around 1200 UTC of 14th and recurved from northerly to north-north-easterly direction, in addition to INSAT observations, special hourly surface observations from the coastal stations of Gujarat and Saurashtra in India and a few surface observations from Pakistan and ship observations from the storm's field were also available. These observations were found very useful in further tracking of the system over north Arabian Sea. By 0000 UTC of 15th the system came within the detection range of CDR Bhuj and hourly observations from the same were available thereafter. The hurricane weakened rapidly into a severe cyclonic storm by 2100 UTC of 14th and then into a cyclonic storm by 0300 UTC of 15th. From 0300 UTC onwards, INSAT imageries indicated rapid disorganisation of the cloud pattern. The clouding associated with the system seemed to be sheared off by the upper tropospheric strong westerlies prevailing over the region. Most of the clouding and associated convection moved inland indicating as if the system had already crossed the coast. This was a unique situation because neither the available wind observations nor the surface pressure distributions were supporting this change. At this time the wind observations reported by the ships located over north Arabian Sea were found to be very useful. These observations not only helped in keeping the centre of the system over the sea area but also in maintaining its intensity as a deep depression till the morning of 16th after which the system weakened into a well marked low pressure area off Gujarat-Sind coast over the northeast Arabian Sea.

2.3.2.3. Movement

The hurricane of 12-15 November followed more or less the climatological parabolic track over the Arabian Sea. The movement of the cyclone from its formative stage on 12 November till its dissipation over *the northeast Arabian Sea on 16th was apparently influenced by the upper level winds prevailing over the Arabian sea in association with the upper tropospheric sub-tropical high pressure cell at 200 hPa.*

Initially the system was located in the southern periphery of the subtropical high pressure cell with the ridge line running in an east west direction along lat. 18.0 deg.N over the Arabian sea. The ridge line continued to remain along the same position till the morning of 13 November 1993 (Fig. 6). The system appeared to have got steered north-westwards by the southeasterly winds of 35-40 kt (65 kmph-74 kmph) prevailing over the region.

By the evening of 13 November, the cyclone moved to the western boundary of the 200 hPa subtropical high pressure cell (Fig. 7) and at the same time the 200 hPa ridge line had shifted northward to latitude 20.0 deg. N. The cyclone came under the influence of upper tropospheric southerly winds prevailing over the region and therefore got slowly steered northwards.

Thereafter, the 200 hPa ridge line shifted southward and lay along lat 18.0 deg.N over the Arabian sea on 14th morning (Fig. 8). Further movement of the cyclone was influenced by the southwesterlies prevailing over the cyclone centre at 200 hPa. By the evening of 14th the subtropical ridge at 200 hPa continued to remain at the same latitude (18.0 deg. N). The cyclone showed relatively fast movement towards northeast (Fig. 9).

2.3.2.4 *Meteorological Features (Pressure, Winds, Rainfall, Damages, Tidal waves/storm surges)*

2.3.2.4.1 Pressure

The cyclone attained its peak intiensity of T-4.0 on Dvorak's scale in the evening of 14 November when it was located about 500 km away to the southwest of Naliya on the Indian Coast. This peak intensity of the cyclone corresponds to a pressure drop of 21 hPa as per the empirical relationship between the satellite classification of the cyclone intensity (T-number), the maximum sustained surface wind (MSSW) and the pressure drop (Δp). Taking the ambient surface pressure as 1008 hPa the central pressure of the cyclone at the time of its peak intensity on 14th evening works out to be 987 hPa.

On 15th morning (00UTC),two ships namely ELJA9 and P3BK5 located about 575 km south-west and 350 km south-south-east of cyclone's centre reported surface pressure of 1006.8 hPa and 1005.5 hPa. The central pressure of the cyclone around this time was estimated as 998 hPa. The sea level analysis of 00 UTC of this date shows highly asymmetric *surface pressure distribution in the cyclone field with isobars oriented in a north-south direction (Fig.10). The average pressure gradient to the south of the cyclone's centre was as weak as 1.5 hPa per 100 Km whereas to the north, it was of the order of 10 hPa per 100 Km.*

2.3.2.4.2 Winds

The estimated maximum sustained surface wind associated with the cyclone on 14th evening comes out to be 65 kt (120 kmph) corresponding to its peak intensity of T-4.0. This was supported by the observations of the ship P3BK5 located at a distance of 200 km to the north-north-west of the cyclone centre at 0600 UTC of the same day which reported a surface wind of NE/50 kt (92 kmph). Another ship ELJA which was located about 180 km to the south- south-west of cyclone centre reported SW/25 kt (46 kmph) at 1200 UTC of the 14th.

After the hurricane weakened into a severe cyclonic storm over the northeast Arabian Sea, the ships with call signs ELJA9 and P3BK5 located respectively at a distance of 575 km to the southwest and 350 km to the southsoutheast of cyclone centre at 0000 UTC of 15th November reported winds of 30 kt (56 kmph) from northnortheast and 35 kt (65 kmph) from south-south-west respectively. All these winds agreed well with the estimated winds of the cyclone.

2.3.2.4.3 Rainfall

The system caused fairly widespread rains over Saurashtra & Kutch in India with highest rainfall of 17 cm reported by Bhuj during 0300 UTC of 15 and 0300 UTC of 16 November.

2.3.2.4.4 Damages

There was no loss of life or damage to property on the Indian territory as the system had weakened significantly over the sea itself.

2.3.2.4.5 Tide waves/Storm surges

The system did not generate any surge as it weakened over the sea.

2.3.3 Bay of Bengal Cyclonic Storm with a core of hurricane winds 1-4 December (BOB 9302 1202)

2.3.3.1 The life history of the cyclone

It developed initially as a tropical depression over the southeast Bay of Bengal near lat. 8.0 deg.N long. 89.0 deg. E in the evening of 1 December 1993. Moving westwards, it concentrated into a deep-depression *by 2nd morning near lat. 8.0 deg.N long.87.0 deg.E. It then moved in a westnorthwesterly direction and rapidly intensified into a cyclonic storm by the same evening with its centre near lat. 9.5 deg.N long. 85.5 deg.E. The system intensified into a severe cyclonic storm on 3rd morning when it was located near lat.9.5 deg.N/long.83.5 deg.E, about 400 km east-south-east of Nagapattinam (43347) over the southwest Bay and further into a severe cyclonic storm with a core of hurricane winds by the same evening when it was centred near lat. 10.0 deg.N long. 82.0 deg.E. The system maintained the same intensity till it crossed Tamilnadu coast near Karaikal (43346) between 0400 and 0500 UTC of 4 December. It weakened into a cyclonic storm over land by the same afternoon and around 0900 UTC it was located 50 km north of Tiruchirapalli (43344). It further weakened into a deep depression centred near Salem (43325) by 4th evening and moved in a northwesterly direction till its dissipation over south Karnataka by the morning of 5 December 1993. Fig. 11 shows INSAT-2A (visible) cloud imagery at 0500 UTC of December 4, 1993.*

2.3.3.2 Monitoring and Tracking

The hurricane was continuously tracked and monitored with the help of INSAT-2A cloud imageries, Cyclone Detection Radars at Madras and Karaikal located on the east coast of India besides the conventional meteorological observations and the ship observations.

The observations from the ships VWWK and VWTT located at a distance of 150 Km to the west-north-west and 400Km to the northwest of the cyclone centre reporting northerly 45 kt (84 kmph) and 25 kt (46 kmph) respectively at 0600 UTC of 3 December were very useful in assesssing the cyclone's intensity and position. The Cyclone Detection Radar (CDR) station, Karaikal reported circular open eye of diameter of 60 Km in most of their observations on the 3rd. Centres reported by the CDR, Karaikal were by and large in good agreement with those reported by the INSAT-2A. By 1700 UTC of 3 December the severe cyclonic storm was located at a distance of 230 Km east-south-east of Nagapattinam. It then came under the surveillance range of CDR, Madras (43279) also. Further monitoring was done with the help of both the CDRs besides INSAT-2A and other observational tools.Both the CDRs reported open eye of diameter ranging between 60-90 Km with good confidence. The width of the eyewall on the western side was 35-40 km till 0500 UTC of 4th. The eyewall remained open on the eastern side during the entire life period of the system.Fig.12 is the radar photograph of the cyclone at 2255 UTC of 3 December,1993.

2.3.3.3. Movement

Throughout its life period from the depression stage to its intensification into a hurricane, the system was located in the upper tropospheric easterlies prevailing north of its centre. As a result, the system followed a nearly westward track.

On the evening of 2 December, 1993 the subtropical ridge line at 200 hPa was located along lat. 13.0 deg.N. The centre of the cyclonic storm around this time was nearly 4 deg. lat. south of this ridge line (Fig.13). The southeasterly winds at the southwestern end of the subtropical high pressure cell at 1200 UTC of 2 December 1993 were of the order of 35 to 40 kt (65 to 74 kmph). By the evening of 3 December, the ridge-line at 200 hPa moved northward and lay along lat. 15.0 deg.N , whereas the cyclonic storm was located about 5.0 deg. latitude south of it (Fig. 14). The ridge line at 200 hPa continued to lay along the same latitude (15.0 deg. N) till 00 UTC of 4 December when the severe cyclonic storm with a core of hurricane wind was about to cross the coast. Subsequently, the south-easterly winds at 200 hPa changed to south-south-easterlies. Perhaps,as a result of this the cyclone moved north-westwards after crossing the coast.

2.3.3.4. Meteorological Features (Pressure, Winds, Rainfall, Damages, Tidal waves/Storm surges)

2.3.3.4.1 Pressure

The cyclone attained its peak intensity of T-5.0 in the forenoon of 4 December at 0400 UTC just before crossing the coast. The estimated lowest central pressure corresponding to this peak intensity (T 5.0) comes out to be 968 hPa. At 0300 UTC of the same day the hurricane's centre was located 30 km northeast of CDR Karaikal and at that time the meteorological observatory at Karaikal reported the lowest surface pressure of 974 hPa with a 24 hour pressure fall of 34.6 hPa which was quite consistent with the estimated lowest central pressure in the system.

2.3.3.4.2 Winds

As the system developed into a severe cyclonic storm, a good number of observations from the ships and coastal stations were available especially from 3rd evening onwards. The meteorological observations from Srilanka, east coast of India and the ships VWTT and VWWK reporting maximum surface winds of 45 kt (84 kmph) and 25 kt (46 kmph) respectively on the 3rd forenoon agreed well with the estimated maximum sustained surface winds of 55 kt (102 kmph) in the core of the cyclone corresponding to its intensity of T-3.5 at that time.

From the evening of 3 December, the wind over the coastal stations of India progressively strengthened with its veering from northwesterly to *northeasterly direction especially at Karaikal. The station reported northerly 60-75 kt winds gusting to 95 kt around 0230 UTC and southwesterly 70-90 kt with peak gust reaching upto 107 kt around 0400 UTC of 4th as recorded by the High Wind Speed Recorder (HWSR) installed at Karaikal before and after the crossing of storm. There were relatively weak winds during the passage of the eye of the storm close to the station. Fig.15 shows the hourly variation in the surface pressure and winds at Karaikal before and after the crossing of the cyclone near Karaikal based on autographic records of the station. As the average radius of the eyewall reported by the radar was approximately 30 km, it may be reasonable to assume that eyewall had actually passed over the station. CDR, Karaikal observations also confirmed passage of eyewall through the station around the time when peak value of wind was observed. The estimated maximum sustained surface wind corresponding to the peak intensity of T-5.0 works out to be around 90kt (167 kmph) which agrees well with the observed value.*

The cyclone provided an excellent testing ground for the newly installed German made HWSR at Karaikal. Ordinary anemometers could have hardly survived such a strong wind force associated with the cyclone of hurricane intensity. The fact that the HWSR was able to withstand the peak gust of 107 kt offers good prospects for recording high wind speeds associated with severe cyclonic storms forming in the Indian seas. Two similar recorders have already been installed at Paradip and Visakhapatnam and another one is likely to be installed soon at Machilipatnam on the east coast of India. This would greatly help in improving high wind speed data base in this region.

2.3.3.4.3 Rainfall

Under the influence of this cyclone, heavy to very heavy rainfall occurred in Tamilnadu, Pondicherry and Kerala on 3rd, Tamilnadu, Andhra Pradesh and Karnataka on 4th and Tamilnadu, and Andhra Pradesh on 5 December, 1993. Fig.16 gives the cumulative rainfall distribution over southern parts of Indian peninsula associated with the cyclone for the period of 4-6 December,1993.

2.3.3.4.4 Damages

On account of torrential rains in coastal areas of Tamilnadu, extensive damage to property and standing crops and some loss of life have been reported from these areas. As per the media reports, the maximum loss of life was limited to less than 100 in Tamilnadu and Pondicherry on account of timely and adequate preparedness and mitigation measures taken by the civil administration authorities on the basis of advance cyclone warnings issued from the India Meteorological

Department. However, total loss of property and damage to standing crops could be around 700 crores. The cyclone affected a total population of about 4.5 lakh in the coastal areas of Tamilnadu& Pondicherry besides the evacuation of about 40,000 people living in the low lying areas to safer places. Copies of a few newspaper cuttings reporting damage and loss of lives due to the cyclone are appended in the Annex II.

For each devastating cyclone, the India Meteorological Department conducts a post cyclone survey of the cyclone affected areas so as to assess the severity of the system and also to get first hand information about the receipt and response of the cyclone warnings issued by the Department to the public and the State government officials engaged in the disaster management work. For the present cyclone, IMD survey team led by a Meteorologist made an extensive survey of the cyclone affected areas in Tamilnadu and Pondicherry. As per the survey report, districts of Nagapattinam, Quaid-E-Milleth, Karaikal administration, some parts of Thanjavur, South Arcot Vallalar, South Arcot Ramaswamy Padaiyachi, Salem and Tiruchirapalli were the worst affected districts of Tamilnadu State. Gale force winds, torrential rains and inundation of sea water lashed the coastal areas near the landfall point.

The survey also revealed that the cyclone warnings issued by the IMD were timely and adequate which were widely appreciated both by the public and state government officials.

2.3.3.4.5 Tidal wave/Storm Surge

As per the report of post cyclone survey, the peak storm surge of 3 to 4 metre above astronomical tide level occurred along the coastal stretch of 50 to 60 km north of the track with sea water inundation reaching upto 22 km. inland.

2.3.4 Bay of Bengal Deep-Depression 19-20 December 1993

The remnant of typhoon Manny emerged as an upper air cyclonic circulation over south Andaman Sea on the morning of 16 December. It became a low pressure area by the mid-day of 18th. The low pressure area moved westnorthwestwards and concentrated into a depression over the southwest Bay of Bengal near lat. 8.5 deg N log. 83.5 deg. E about 450 km southeast of Nagapattinam on 19th morning. It then moved northwestwards and intensified into a deep depression by the same evening with its centre near lat. 9.5 deg.N long. 82.0 deg.E i.e. 350 km southeast of Nagapattinam. The system weakened into a depression by 20th morning with its centre about 50 km east of Nagapattinam. The system finally dissipated over the sea off North Tamilnadu coast by the evening of 20

December 1993. Fig 17 is INSAT-2A cloud imagery (Infrared) at 1200 UTC of 19 Dec.1993.

Under the influence of this system, heavy rainfall occurred at a few places in Tamilnadu and Pondicherry during the period 19-21 December 1993.

3. Dynamical aspects

3.1 Vertical wind shear

Vertical shear of zonal winds between 200 and 850 hPa over the North Indian Ocean and adjoining areas were computed in respect of cyclones and depressions which formed this year. These values were computed by utilizing the winds at 850 and 200 hPa from the land stations and 5 deg. lat/long grid point forecast winds available over ocean areas from the European Centre for Medium Range Weather Forecast (ECMWF) U.K.

Vertical wind shear values at 12 UTC of 13-15 November for the Arabian Sea cyclone and at 12 UTC of 2-4 December for the Bay of Bengal cyclone are analysed and presented in Fig.18 (a) to (c) and Fig.19(a) to (c). It is evident from these figures that for both the hurricanes the vertical wind shear around the centre of the system was nearly zero on the first day of their development as cyclone.

Vertical wind shear values around the centre of Arabian Sea cyclone became progressively positive during its movement in a north-north-easterly direction. On the other hand the vertical wind shear arround the Bay of Bengal hurricane remained nearly zero throughout its life period as cyclone.

3.2 Track prediction models

The Analogue model is being run operationally by the RSMC,New Delhi for cyclonic disturbances of tropical storm intensity and above. Three simple techniques viz., Climatology, Persistence and CLIPER are run for all the cyclonic disturbances (Depression onwards).

Table 7 gives the mean forecast errors from Analogue and CLIPER models in respect of two cyclones of 1993. In Table 8, mean forecast errors for all the cyclonic disturbances using Climatology, Persistence and CLIPER models are listed.

It may be seen from these tables that 24 and 36 hour forecast errors for 12-15 November cyclone were large compared to those for the *cyclone of 01-04 December. This may be perhaps due to the fact that the Arabian sea cyclone was of recurving type.*

From Table 7 it is evident that the mean 12 hour forecast error for the two cyclones by Analogue model is quite comparable with that by CLIPER model whereas for 24 hour and 36 hour forecast periods, Analogue technique showed better skill compared to CLIPER.

In order to assess the performance of a track prediction model the world-wide practice is to take the forecast errors from CLIPER as standard (or neutral) and compare the relative performance of different models with respect to it. Fig. 20 shows the performance of Analogue, Climatology and Persistence models relative to CLIPER using figures of average forecast errors given in Tables 7 & 8. It may be seen that barring Analogue model both Climatology and Persistence performed poorer than CLIPER.

3.3 The Limited Area Forecast Model of RSMC, New Delhi and description of its products

A limited area forecast model adapted from Florida State University, USA is being run by the RSMC, New Delhi on an experimental basis. Details of the model are given in the following paragraphs:

3.3.1 The model

(a) Input data

The grid point fields for running the forecast model are prepared from the conventional and nonconventional data received through GTS. The input data used for analysis consist of the surface SYNOP/SHIP, upper air TEMP/PILOT, SATEM, SATOB and AIREP. The pseudo observations in the cyclone field, generated by a empirical scheme, are added to the input data file.

(b) Analysis procedure

The objective analysis is carried out by a three dimensional multivariate optimum interpolation procedure. The variables analysed are the geopotential, u and v components of wind and specific humidity. Temperature field is derived from the geopotential field hydrostatically. Analysis is carried out on 12 sigma surface 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.07, 0.05 in the vertical and on $1^{\circ} \times 1^{\circ}$ horizontal lat./long. grid. The sigma fields are post processed to the pressure surface for display and archival. The first guess fields for carrying out the analysis are prepared from the 24th forecast produced by a global model run by the

National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi.

(c) **Forecast model**

The forecast model is a semi-implicit semi-Lagrangian multilayer primitive equation model cast in sigma coordinate system and staggered Arakawa C-grid in the horizontal. The present version of the model has a horizontal resolution of $1^{\circ}X1^{\circ}$ lat./long. (domain 91x51) in the horizontal and 10 equi-spaced sigma levels (1.0 to 0.1) in the vertical. Time-dependent boundary conditions obtained from the NCMRWF are used. The following physical processes are included:

Large scale condensation, shallow moist convection, Deep cumulus convection, Surface fluxes, Vertical diffusion, Short-wave radiation, Long-wave radiation, surface energy balance and orography.

3.3.2 Procedure for generating synthetic vortex

The approach followed in the present scheme is to generate pseudo observations from the known empirical structure of tropical cyclones. First, surface pressure field is constructed at dense enough grid. Surface winds are obtained from the surface pressure using the gradient wind relationship. Upper winds are obtained from the surface winds with the aid of composite vertical wind shear factors. Appropriate inflow and outflow angles are added to the computed winds to ensure proper convergence in the lower levels and divergence in the upper levels. Humidity field is prescribed as a near saturation value within the field of the vortex. The later two steps have been introduced in the improved version of the scheme to ensure a proper spin up of the vortex during the course of integration of the forecast model. In the current version of the scheme we provide only the bogus wind observations and leave it to the initialization process to generate its own mass field. Brief details of the scheme are outlined in the following paragraphs.

3.3.2.1 Surface pressure field

The empirical model developed by Holland (1980) is used to prescribe the surface pressure field in the cyclone. The relationship is given by:

$$Pr = Pc + (Pe-Pc)\ EXP(-a/r^{b})$$

Where Pr is the surface pressure at radius r, Pe is the environmental pressure, Pc is the central pressure, and a and b are *empirical constants. The constants a and b are related to the radius of maximum wind (RMW) by the following equation:*

$$RMW = (a)^{1/b}$$

The constants a and b have to be determined empirically and may differ from region to region. Application of the above model for deriving the surface pressure distribution is dependent upon the availability of the following parameters:

i) central pressure
ii) radius of maximum wind
iii) value of constant 'b'

The central pressure is estimated with the help of pressure drop corresponding to the satellite T-Number classification of the storm and the pressure value of the outermost closed isobar. The radius of maximum wind may be estimated from the radius of the eye as available from the radar report if already in the range of a coastal Cyclone Detection Radar station or from the satellite imagery if the storm is out in the sea. RMW of 30 km has been assumed here in all cases. The value of constant b varies between 1.0 and 2.5 and needs be determined for each cyclone empirically. In the present case it is taken as 1.5. Pressure data are generated upto 400 km radius, on a grid of 50 km spacing.

3.3.2.2 Surface winds

After the surface pressure distribution is defined, the surface winds are derived using the gradient wind relation. A correction for storm motion is applied. In the absence of friction an expression for wind speed V inside the cyclone field can be obtained in the form:

$$V = -\alpha + (\alpha^2 + r/\rho\ \delta p/\delta r)^{1/2}$$

where

$2\alpha = fr - Vc \sin\theta$

f = *Coriolis parameter*

r = *radial distance*

Vc = *storm speed*

θ = *azimuthal angle measured clockwise from direction of motion (taken as 0^o.)*

The above expression is obtained from the gradient wind equation expressing balance of forces in the absence of friction (Basu and Ghosh, 1986).

$$1/r.\ \delta p/\delta r - fV - V^2/r + V.Vc \sin\theta/r = 0$$

3.3.2.3 Upper winds

The upper winds are derived from the surface winds by assuming an ad-hoc vertical wind shear which decreases the strength of the vortex with increasing height. Values of vertical wind shear factors are taken as proposed by Andersson and Hollingsworth (1988).

Composite vertical wind shear factors

Level	Surface	850	700	500	400	300
	1.0	0.9	0.8	0.7	0.65	0.35

The above factors are based on the rawinsonde composites constructed by McBride (1986). The composites indicate a wind speed varying very slowly with height upto 400 hPa with a rapid decrease above. The factors would vary from case to case and depend upon thermal stability and stage of development of the system.

An inflow angle is added in the lower levels varying from 30 deg. at the surface becoming zero at 500 hPa. The computed winds are reversed at 250 and 200 hPa, same constant factor as at 300 hPa is applied, and an outflow angle of 20 deg. is added. This procedure is followed in order to ensure a proper low level convergence and an upper level divergence in the vortex field as mentioned earlier.

3.3.3 Description of results from RSMC, New Delhi model for cyclones of 1993

The model was run for the two severe cyclonic storms with a core of hurricane winds of November and December 1993. The Arabian Sea cyclone of 12-15 November was a northward moving recurving system whereas the Bay of Bengal cyclone of 1-4 December moved in a west-north-westwards direction. Fig. 21 (a) & (b) show the best fit tracks and the 24 hour predicted positions of storm's centre at 850 hPa from the model for the above two cyclones. These figures clearly show that the movement of tropical cyclones as predicted by the model was reasonably good. An important fact that emerges from the predicted track of the Arabian Sea cyclone is that the forecasts of the changes in direction of movement from northwesterly to northerly and then northerly to northeasterly are brought out well by the model. The performance of the model in this case (Arabian Sea cyclone) was far superior than the Analogue, CLIPER or any other dynamical model. The mean 24-hr forecast error from this model was of the order of 100 km only for the Arabian Sea cyclone. In the case of the Bay of Bengal cyclone of December 1993, the performance of the model was comparable with

Analogue and CLIPER. Nevertheless, the model appears to have a bias towards slower than actual movements and also a poleward bias in many cases of forecast.

Fig. 22(a) to (c) and 23(a) to (c) are the initial and predicted 850 hPa vorticity fields for the Arabian Sea cyclone of November 1993. It may be seen that the intensity changes are predicted well by the model particularly based on the initial conditions at 00 UTC of 13 and 14 November which showed intensification on 14 and weakening on 15 November. 850 and 500 hPa wind field analysis and 24 hour forecast based on initial condition of 14 November also show weakening of the wind field on 15th morning [Fig. 24 (a) & (b) and 25 (a) & (b)]. As a matter of fact the severe cyclonic storm rapidly weakened into a cyclonic storm by the morning of 15th. Similar conclusion can be drawn from 500 hPa analysis and predicted vorticity fields for the same cyclone (Fig. 26 (a) to (c) and 27 (a) to (c)).

For the Bay of Bengal cyclone of December 1993, the 850 hPa analysis and 24 hour forecast field of winds are shown in Fig. 28(a) to (d) and 29(a) to (d). Similarly, initial and predicted fields of vorticity at 850 hPa are depicted in Fig.30(a) to (d) and 31(a) to (d). It is evident from these figures that while the intensification of the system has been clearly brought out by the model as observed during 1-4 December, the rate of intensification predicted by the model was slightly higher than the observed. Moreover, the vorticity fields predicted by the model based on initial condition of 3rd and 4th were slightly asymmetric compared to the observed ones. Similar conclusion can be drawn from the 500 hPa analysis and forecast vorticity fields of the cyclone [Fig.32 (a) to (d) and 33(a) to (d)].

4. Salient features of 1993 hurricanes

Both the hurricanes were of moderate size with average diameter of circulation field of about 1000 km towards the later parts of their lives. The rate of increase of intensity (in terms of T number) was more than normal for both the cyclones as shown in Fig. 34. The intensity rate was, however, higher in the case of Bay of Bengal cyclone compared to that for the Arabian Sea cyclone.

An interesting aspect of this year's cyclones was that while the Arabian Sea hurricane weakened significantly on 15 November morning and subsequently dissipated over the sea off Indo-Pakistan coast, the Bay of Bengal cyclone intensified into a hurricane before crossing the coast. Such kinds of sudden structural changes pose great difficulties to the cyclone forecaster who is otherwise providing reasonably accurate forecast and warning against the adverse weather conditions.

Yet another interesting aspect of the Arabian Sea cyclone was that subsequent to the weakening of the system into a cyclonic storm on 15th morning the cloud field associated with the system as observed by INSAT-2A appeared to have moved inland indicating as if the system has already crossed the coast. On the other hand, the pressure and wind fields did not respond to this change.

The characteristics of eye and eyewall reported by the Cyclone Detection Radar, Karaikal for the cyclone of December 1993 were also quite interesting. The CDR, Karaikal reported open eye in the cyclone right from the time the cyclone came within its detection range till it weakened over land. For the cyclone of hurricane intensity this is somewhat rare if not unusual. The cyclone gave an excellent opportunity for the recently installed High Wind Speed Recorder (HWSR) at Karaikal to record hurricane winds. The recorder has been able to withstand the highest peak of the gust of 107 kt as seen from the autographic chart attached with the recroder. Fortunately, other instruments such as barograph, radar system etc worked well during such an adverse situation.

5. Dissemination of Warnings.

Cyclone warnings were issued and disseminated to the general public, central and state Government officials and other user organisations in India through high priority telegrammes, T/P, Telephone, Telex and Telefax. The electronic and print media were also used extensively for this purpose. Hourly cyclone warnings were issued to public and State Governments of Gujarat, Tamilnadu, Andhra Pradesh and the Union teritory of Pondicherry in connection with the Cyclones of 12 -16 November and 1 - 4 December, 1993. Cyclone warnings in different local languages were communicated directly to the coastal population in Tamilnadu and Pondicherry through satellite based Disaster Warning System (DWS) located at different locations on the east coast of India. Existing network of DWS receivers on the east coast of India is being expanded to other coastal areas of the country.

6. Co-operation among Panel Countries

The Regional Specialized Meteorological Centre (RSMC) New Delhi issues frequent Tropical Cyclone Advisories to all the WMO/ESCAP Panel countries in the region during the tropical cyclone periods. Tropical Weather Outlook for the North Indian Ocean is issued daily at 0600 UTC as a routine to the member countries of the WMO/ESCAP Panel.

7. Concluding Remarks

In 1993, there were only five cyclonic disturbances over the North Indian Ocean out of which three formed in the Bay of Bengal and two in the Arabian Sea. 1993 was a year of less than average cyclone activity over the region especially during SW- monsoon season in which only one monsoon depression formed. Nevertheless, the SW monsoon season rains were normal over the country mainly due to the fact that there were as many as 14 low pressure areas formed during this season. Out of the two cyclonic disturbances originated in the Arabian Sea, during post monsoon season one attained the intensity of hurricane. There were three cyclonic disturbances over the Bay of Bengal this year. While one of them reached upto hurricane stage the other two intensified upto deep-depression stage.

The interesting aspects of this year's disturbances were that two out of five disturbances (12-15 Nov. and 19-20 Dec.) dissipated over the sea itself without crossing the coast. On the other hand the cyclone of 1-4 December intensified into a hurricane before crossing the coast. Similarly, the depression of 17-19 June intensified after moving over land.

***

TABLES

TABLE 1A

Monthly occurrence of Depressions and Cyclones over North Indian Ocean (the Bay of Bengal and the Arabian Sea) during 1993

System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bay of Bengal													
Depression	-	-	-	-	-	1	-	-	-	-	-	1	2
Cyclonic storm	-	-	-	-	-	-	-	-	-	-	-	-	0
Severe cyclonic storm	-	-	-	-	-	-	-	-	-	-	-	-	0
Severe cyclonic storm with a core of hurricane winds	-	-	-	-	-	-	-	-	-	-	-	1	1
Arabian Sea													
Depression	-	-	-	-	-	-	-	-	-	-	1	-	1
Cyclonic storm	-	-	-	-	-	-	-	-	-	-	-	-	0
Severe cyclonic storm	-	-	-	-	-	-	-	-	-	-	-	-	0
Severe cyclonic storm with a core of hurricane winds	-	-	-	-	-	-	-	-	-	-	1	-	1
Total (North Indian Ocean)	-	-	-	-	-	1	-	-	-	-	2	2	5

TABLE 1B

S.No.	Cyclonic Disturbance	Peak T.No.	Intensity 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 Deep Depression 17-19 June, 1993	-	30	00-18/18 Jun	Indo-Bangladesh border around 0900 UTC of 17 June	Nil	Nil
2.	Arabian Sea/Indian Sea Depression 8-9 November,1993	1.5	25	03 UTC of 8 Nov. - 18 UTC of 9 Nov.	Near Tuticorin (Tamilnadu) on 9th morning	35	Nil
3.	Arabian Sea Severe cyclonic storm with a core of hurricane winds 12-15 Nov., 1993 (ARB 9301 1113)	4.0	65	09-21/14 Nov.	Dissipated off Gujarat-Sind coast on 16th early morning.	Nil	Nil
4.	Bay of Bengal Severe cyclonic storm with a core of hurricane winds 1-4 Nov., 1993 (BOB 9302 1202)	5.0	90	04-06/4 Dec	30 km north of Karaikal (Tamilnadu) on 4th forenoon.	100	3-4
5.	Bay of Bengal Deep Depression 19-20 Dec., 1993	1.5	30	09-21/19 Dec.	Dissipated off Tamil-nadu coast near Nagapattinam on 20th mid-day around 09 UTC.	Nil	Nil

TABLE 2

Best track positions alongwith other parameters for Arabian Sea severe cyclonic storm with a core of hurricane winds of 12-15 November, 1993. *(ARB 9301 1113)*

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. X Long.)
Nov. 12	0000	11.0	69.5	1.0	1006	15	1008	2	5
	0300	11.5	69.0	1.5	1004	25	1008	4	6
	0600	12.0	68.5	1.5	1004	25	1008	4	6
	1200	14.0	67.5	2.0	1002	30	1008	6	7
	1800	14.0	66.5	2.0	1002	30	1008	6	7
Nov. 13	0000	15.0	65.5	2.5	1000	35	1008	8	8
	0300	16.0	65.0	3.0	1000	45	1010	10	8
	0600	16.5	64.5	3.0	1000	45	1010	10	10
	1200	17.5	64.5	3.0	998	45	1008	10	10
	1800	18.5	64.5	3.0	1000	45	1010	10	10
Nov. 14	0000	19.5	64.5	3.0	1000	45	1010	10	10
	0300	20.0	64.5	3.0	998	45	1008	10	10
	0600	20.0	64.5	3.5	992	55	1008	16	10
	1200	20.5	64.5	4.0	986	65	1008	22	10
	1800	21.5	65.5	4.0	988	65	1010	22	10
Nov. 15	0000	22.5	67.0	3.5	998	55	1012	14	8
	0300	23.5	67.5	3.0	1002	45	1012	10	8
	0600	23.5	67.5	-	1004	35	1012	8	7
	1200	23.5	67.5	-	1004	30	1010	6	6
	1800	23.5	67.5	-	1004	30	1010	6	5
Nov. 16	0000	23.5	67.5	-	1008	15	1010	2	5

TABLE 3

Best track positions alongwith other parameters for Arabian Sea Depression of 8-9 November, 1993

Date	Time (UTC)	Centre		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. X Long.)
		Lat. (°N)	Long. (°E)						
Nov. 8	0000	6.0	79.0	1.0	1002	-	1004	-	4
	0300	6.5	78.5	1.5	1000	25	1004	4	5
	0600	6.5	78.5	1.5	1000	25	1004	4	5
	1200	7.0	78.5	1.5	1000	25	1004	4	5
	1800	7.5	78.5	1.5	1002	25	1006	4	5
Nov. 9	0000	8.5	78.5	-	1000	25	1004	4	5
	0300	9.0	78.5	-	1000	25	1004	4	5
	0600	9.0	78.0	-	1000	25	1004	4	5
	1200	9.0	77.5	-	998	25	1002	4	5
	1800	9.0	77.0	-	1000	25	1004	4	5
Nov. 10	0000	9.5	76.0	-	1002	15	1004	2	5

TABLE 4

Best track positions alongwith other parameters for Arabian Sea severe cyclonic storm with a core of hurricane winds of 12-15 November, 1993. *(ARB 9301 1113)*

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. X Long.)
Nov. 12	0000	11.0	69.5	1.0	1006	15	1008	2	5
	0300	11.5	69.0	1.5	1004	25	1008	4	6
	0600	12.0	68.5	1.5	1004	25	1008	4	6
	1200	14.0	67.5	2.0	1002	30	1008	6	7
	1800	14.0	66.5	2.0	1002	30	1008	6	7
Nov. 13	0000	15.0	65.5	2.5	1000	35	1008	8	8
	0300	16.0	65.0	3.0	1000	45	1010	10	8
	0600	16.5	64.5	3.0	1000	45	1010	10	10
	1200	17.5	64.5	3.0	998	45	1008	10	10
	1800	18.5	64.5	3.0	1000	45	1010	10	10
Nov. 14	0000	19.5	64.5	3.0	1000	45	1010	10	10
	0300	20.0	64.5	3.0	998	45	1008	10	10
	0600	20.0	64.5	3.5	992	55	1008	16	10
	1200	20.5	64.5	4.0	986	65	1008	22	10
	1800	21.5	65.5	4.0	988	65	1010	22	10
Nov. 15	0000	22.5	67.0	3.5	998	55	1012	14	8
	0300	23.5	67.5	3.0	1002	45	1012	10	8
	0600	23.5	67.5	-	1004	35	1012	8	7
	1200	23.5	67.5	-	1004	30	1010	6	6
	1800	23.5	67.5	-	1004	30	1010	6	5
Nov. 16	0000	23.5	67.5	-	1008	15	1010	2	5

TABLE 5

Best track positions alongwith other parameters for Bay of Bengal severe cyclonic storm with a core of hurricane winds of 1 - 4, December, 1993. *(BOB 9302 1202)*

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. X Long.)
Dec. 1	0300	8.0	91.0	1.0	1004	15	1006	2	4
	0600	7.0	91.0	1.5	1002	25	1006	4	5
	1200	8.0	89.0	2.0	1000	30	1006	6	5
	1800	8.0	88.0	2.0	1002	30	1008	6	6
Dec 2	0000	8.0	87.5	2.0	1002	30	1008	6	6
	0300	8.0	87.0	2.0	1000	30	1006	6	6
	0600	8.5	86.5	2.5	1002	30	1008	6	6
	1200	9.0	85.5	3.0	996	45	1006	10	8
	1800	9.0	85.0	3.0	996	45	1006	10	8
Dec. 3	0000	9.5	84.5	3.0	994	45	1004	10	8
	0300	9.5	83.5	3.5	988	55	1004	16	8
	0600	9.5	83.0	3.5	988	55	1004	16	8
	1200	10.0	82.0	4.0	982	65	1004	22	8
	1800	10.5	81.5	4.0	982	65	1004	22	8
Dec. 4	0000	10.8	80.8	4.5	976	77	1006	30	8
	0300	11.0	80.0	4.5	976	77	1006	30	8
	0600	11.5	79.0	5.0	968	90	1008	40	8
	1200	12.0	78.5	-	998	30	1004	6	6
	1800	12.5	78.0	-	1002	15	1004	2	5

TABLE 6

Best track positions alongwith other parameters for Bay of Bengal Deep Depression of 19-20 December, 1993

Date	Time (UTC)	Centre		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. X Long.)
		Lat. (°N)	Long. (°E)						
Dec. 19	0000	8.5	83.5	1.5	1008	25	1012	4	5
	0300	8.5	83.5	1.5	1008	25	1012	4	5
	0600	9.0	82.5	1.5	1008	25	1012	4	5
	1200	9.5	82.0	1.5	1006	30	1012	6	5
	1800	10.0	81.0	1.5	1008	30	1014	6	5
Dec. 20	0000	10.5	80.5	1.5	1008	25	1012	4	5
	0300	11.0	80.5	1.5	1008	25	1012	4	5
	0600	11.0	80.5	1.5	1008	25	1012	4	5
	0900	11.0	80.5	1.5	1008	25	1012	4	4
	1200	11.0	80.0	1.0	1010	15	1012	2	4

TABLE 7

12, 24 and 36-hour forecast position errors for individual tropical cyclones over the Bay of Bengal and the Arabian Sea in 1993 based on Analogue and CLIPER Forecast Models

Tropical cyclones	ANALOGUE			CLIPER		
	Forecast Errors (km)					
	12-hr	24-hr	36-hr	12-hr	24-hr	36-hr
12-15 Nov.	124	230	260	155	311	144
1 - 4 Dec.	118	146	185	99	146	185
Average Error	121	183	222	127	253	314

TABLE 8

12, 24, 36 and 48 hours forecast position errors for tropical cyclones and depressions in the Bay of Bengal and the Arbian Sea in 1993 based on Climatology, Persistence and Cliper models.

Tropical Depression	12 hour A	12 hour B	12 hour C	24 hour A	24 hour B	24 hour C	36 hour A	36 hour B	36 hour C	48 hour A	48 hour B	48 hour C
17-19 June	105	105	97	258	233	228	380	217	267	452	65	175
8 - 9 Nov.	200	130	146	204	127	141	217	286	95	-	-	-
12-15 Nov.	200	114	155	416	250	311	585	418	444	960	770	710
1 - 4 Dec.	100	127	99	193	137	146	261	266	185	357	298	263
19-20 Dec.	90	00	55	70	120	30	-	-	-	-	-	-
Average	138	95	110	232	173	171	363	279	248	590	378	383

A- Climatology
B- Persistence
C- Cliper

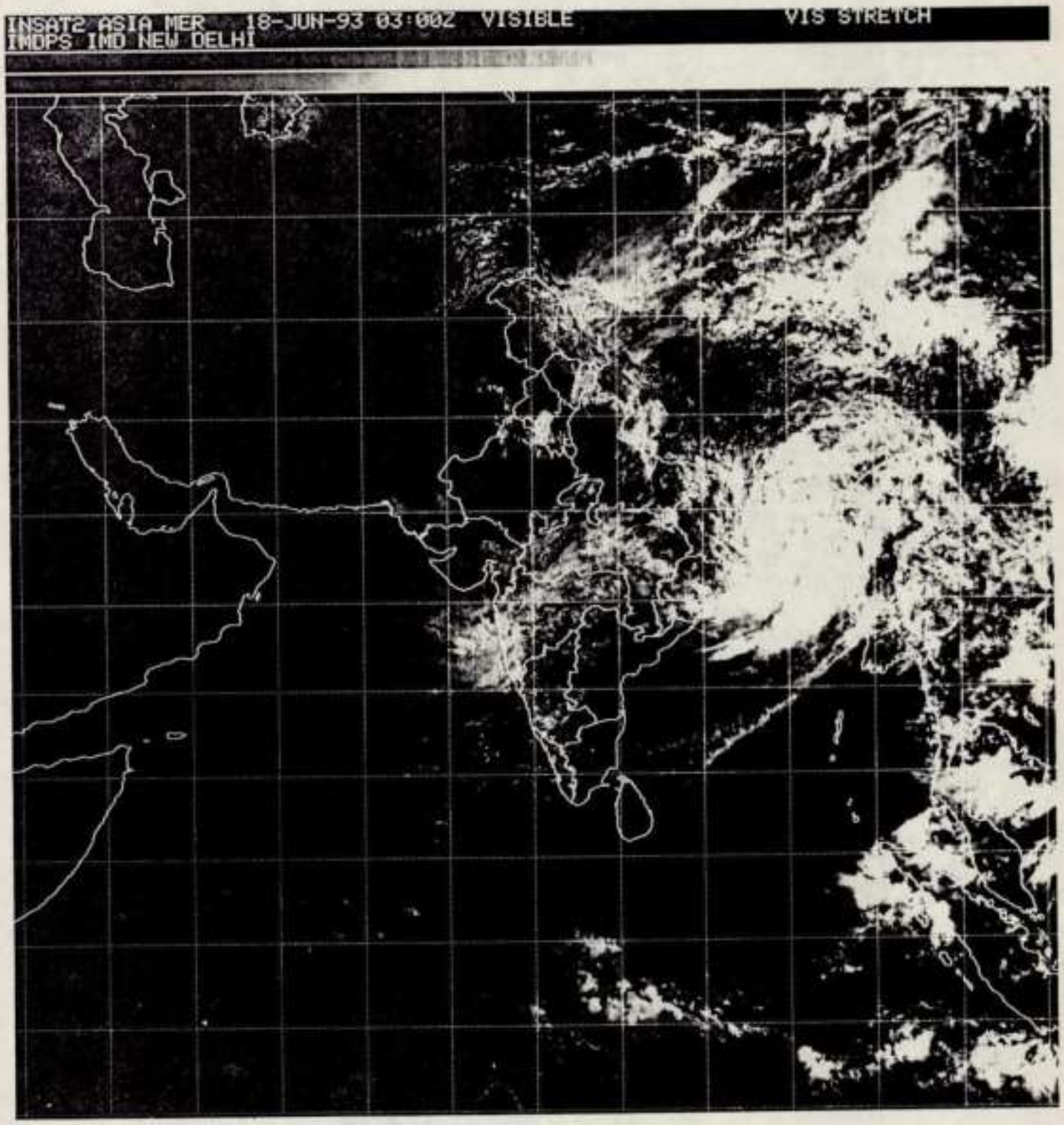
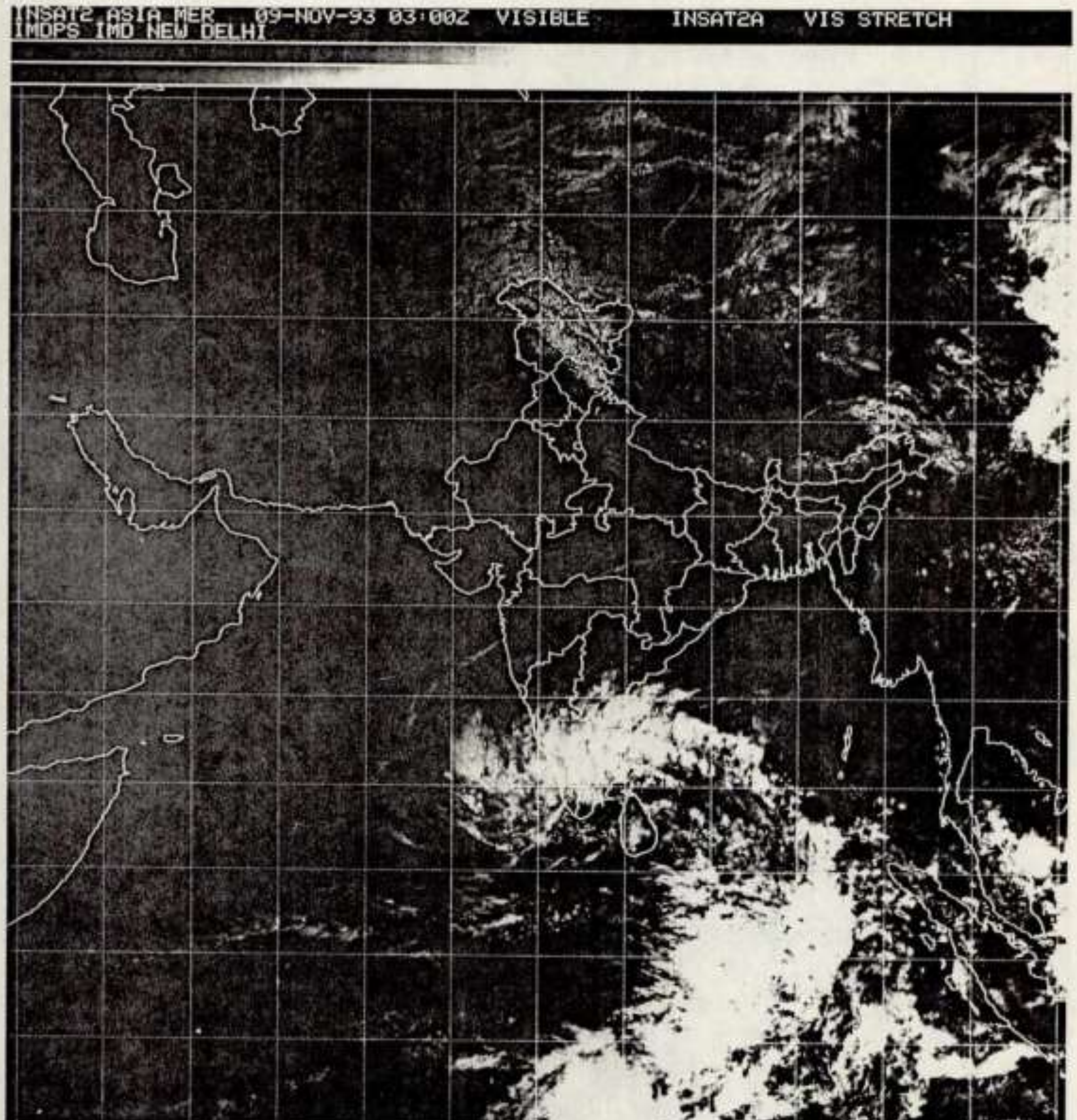

INSAT2 ASIA MER 18-JUN-93 03:00Z VISIBLE
VIS STRETCH
IMDPS IMD NEW DELHI

FIG. 3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IMDPS IMD NEW DELHI

FIG. 4


INSAT2 ASIA MER
IMOPS IMD NEW DELHI
14-NOV-93 09:00Z VISIBLE
INSAT2A VIS STRETCH

FIG. 5

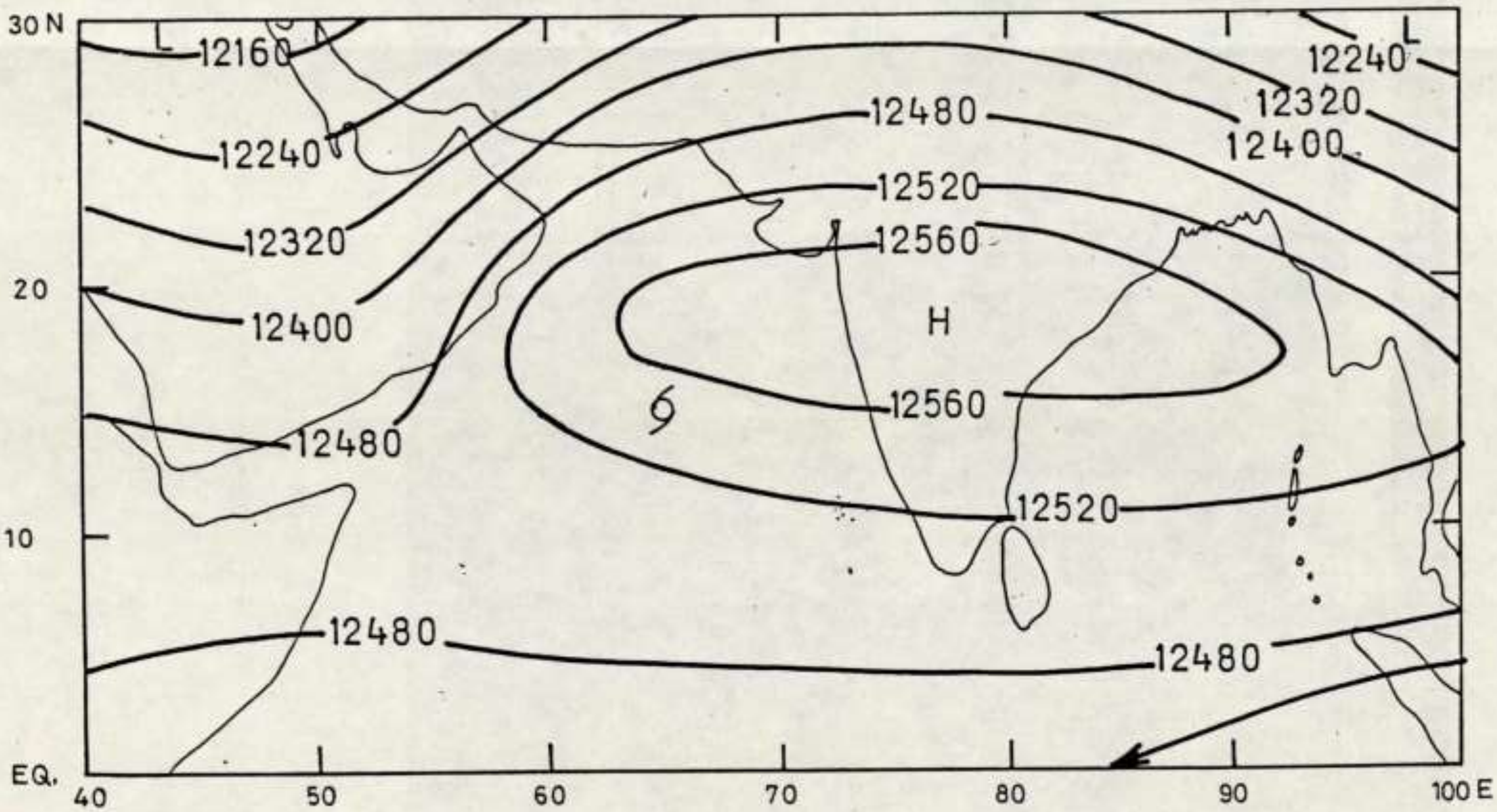


Fig. 6 . 200 hPa Analysis, 00 UTC of 13 November 1993

FIGURES & ANNEXES

LIST OF LEGENDS FOR THE FIGURES AND ANNEXES

ANNEXES

Annex.I: *Definition of cyclonic disturbances as per the WMO Tropical Cyclone Operational Plan for the North Indian Ocean (TCP-21).*

Annex.II: *Newspaper cuttings on Karaikal cyclone of December 1993.*

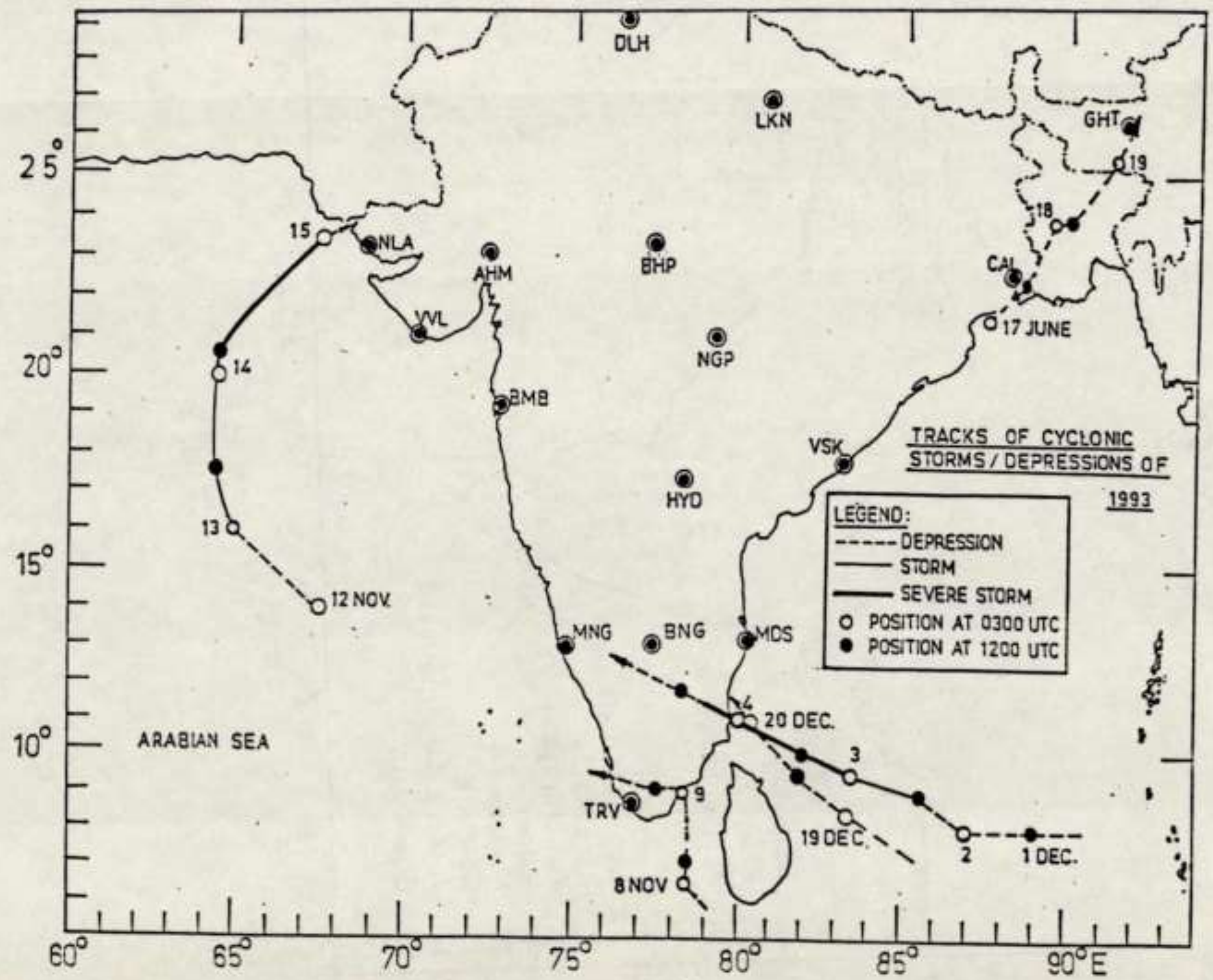
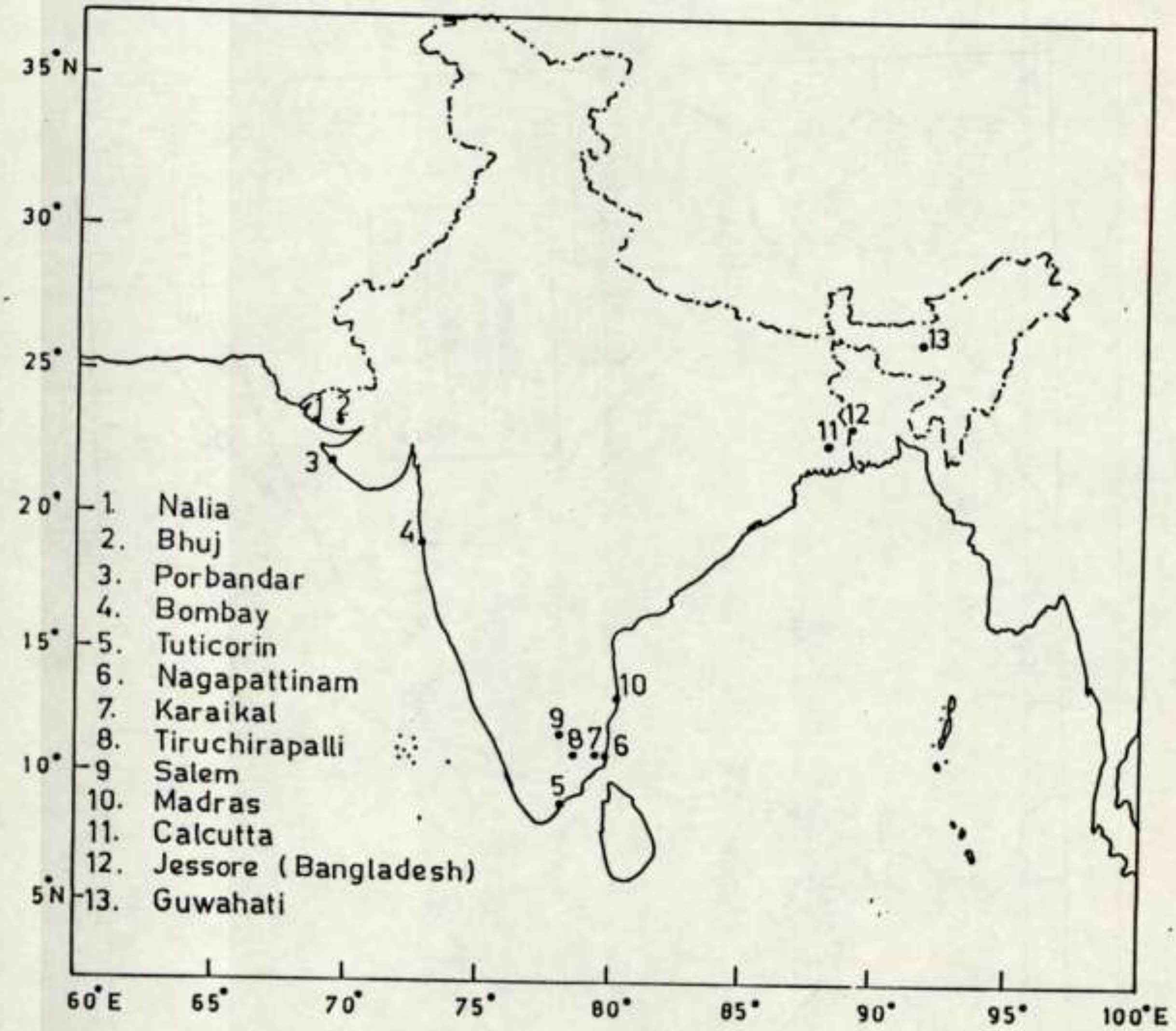

TRACKS OF CYCLONIC STORMS / DEPRESSIONS OF 1993
LEGEND:
DEPRESSION
STORM
SEVERE STORM
POSITION AT 0300 UTC
POSITION AT 1200 UTC
DLH
LKN
GHT
CAL
17 JUNE
18
19
NLA
AHM
BHP
NGP
VVL
BMB
VSK
HYD
MNG
BNG
MDS
TRV
ARABIAN SEA
12 NOV.
13
14
15
8 NOV
9
20 DEC.
19 DEC.
1 DEC.
2
3
4
25°
20°
15°
10°
60°
65°
70°
75°
80°
85°
90°E

FIG. 1



35°N
30°
25°
20°
15°
10°
5°N
60°E
65°
70°
75°
80°
85°
90°
95°
100°E
1. Nalia
2. Bhuj
3. Porbandar
4. Bombay
5. Tuticorin
6. Nagapattinam
7. Karaikal
8. Tiruchirapalli
9 Salem
10. Madras
11. Calcutta
12. Jessore (Bangladesh)
13. Guwahati

FIG. 2

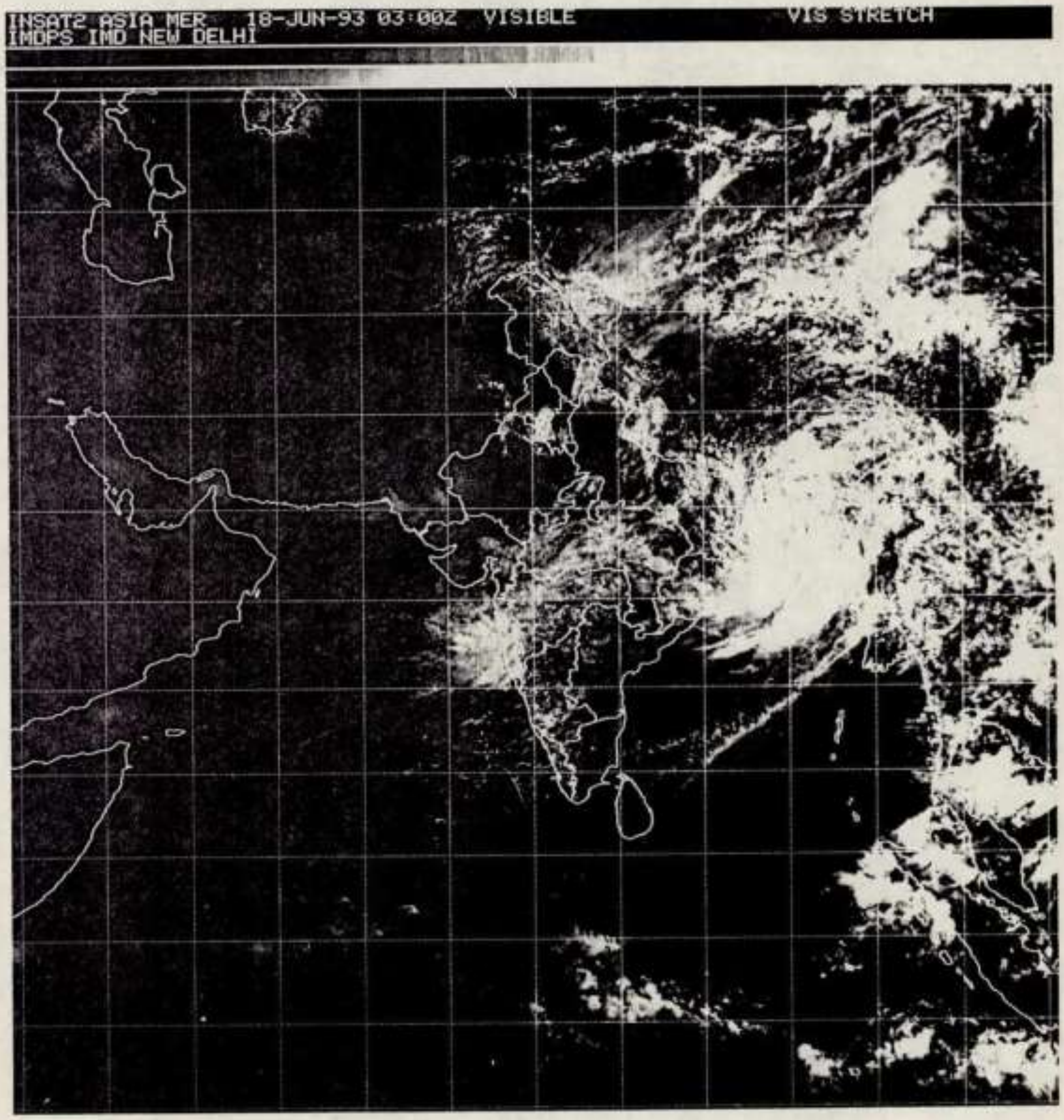

INSAT2 ASIA MER 18-JUN-93 03:00Z VISIBLE
IMDPS IMD NEW DELHI
VIS STRETCH

FIG. 3

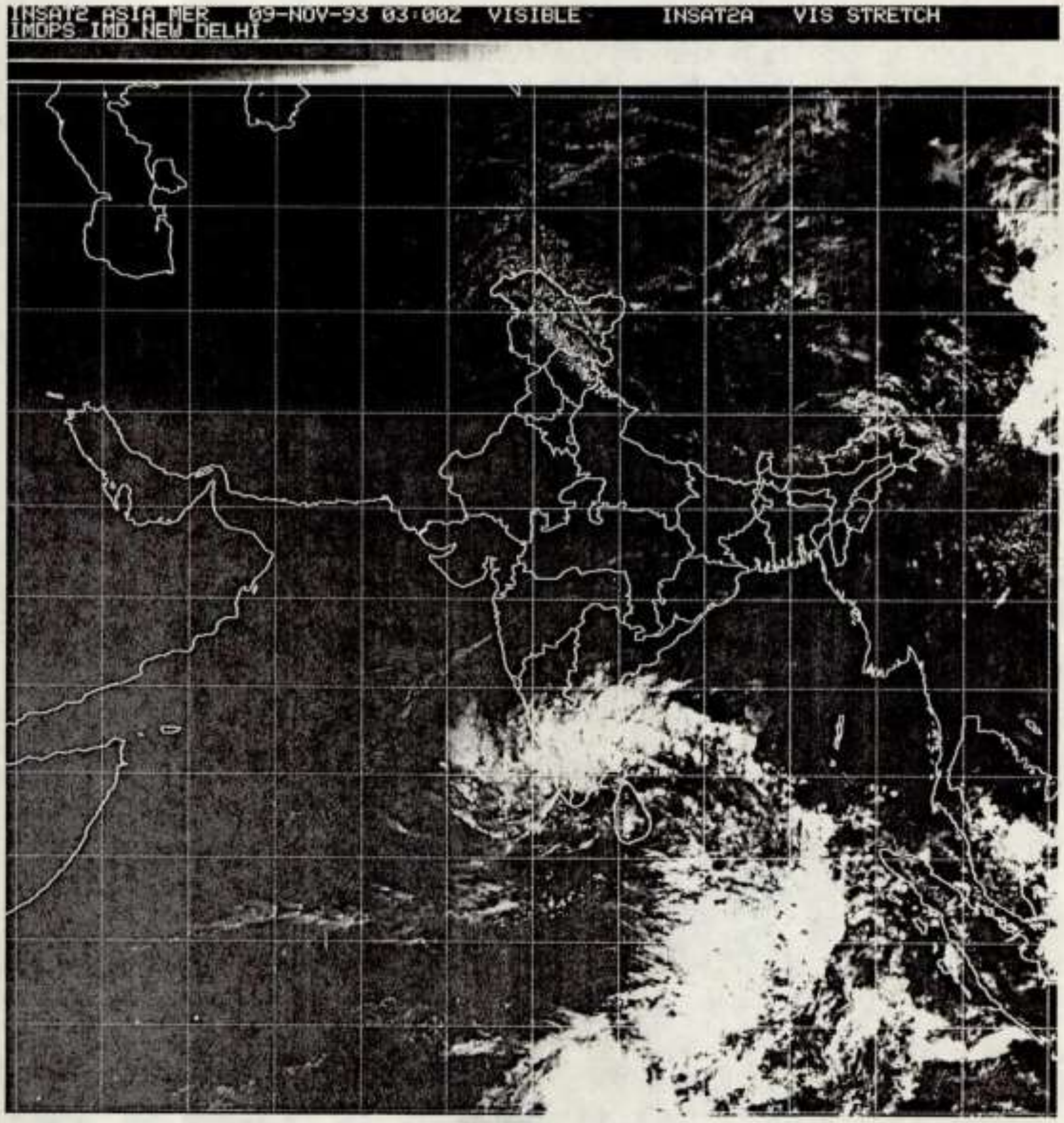

INSAT2 ASIA MER 09-NOV-93 03:00Z VISIBLE INSAT2A VIS STRETCH
IMDPS IMD NEW DELHI

FIG. 4


INSAT2 ASIA MER
IMOPS IMD NEW DELHI
14-NOV-93 09:00Z VISIBLE
INSAT2A VIS STRETCH

FIG. 5

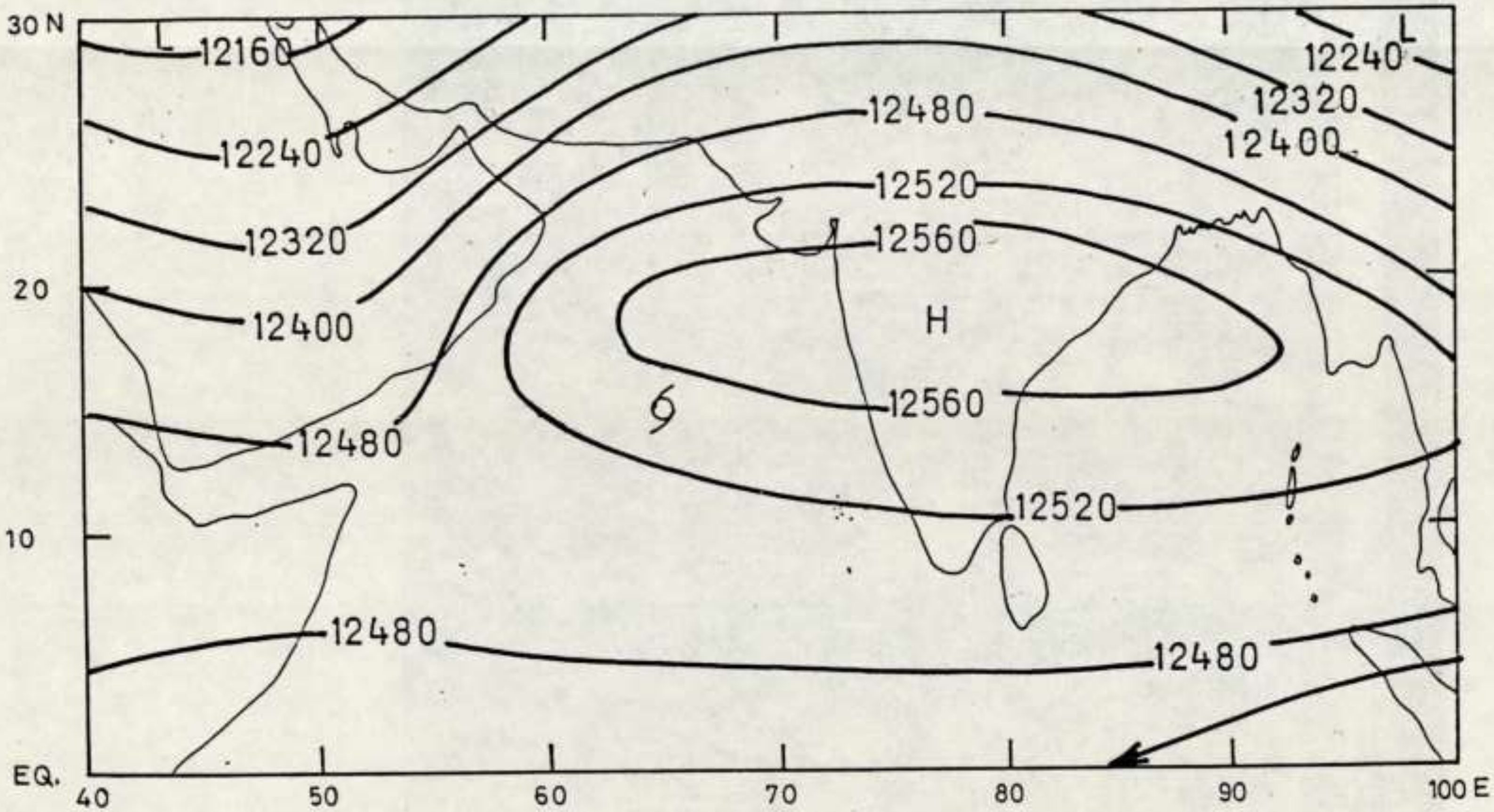


Fig. 6 . 200 hPa Analysis, 00 UTC of 13 November 1993

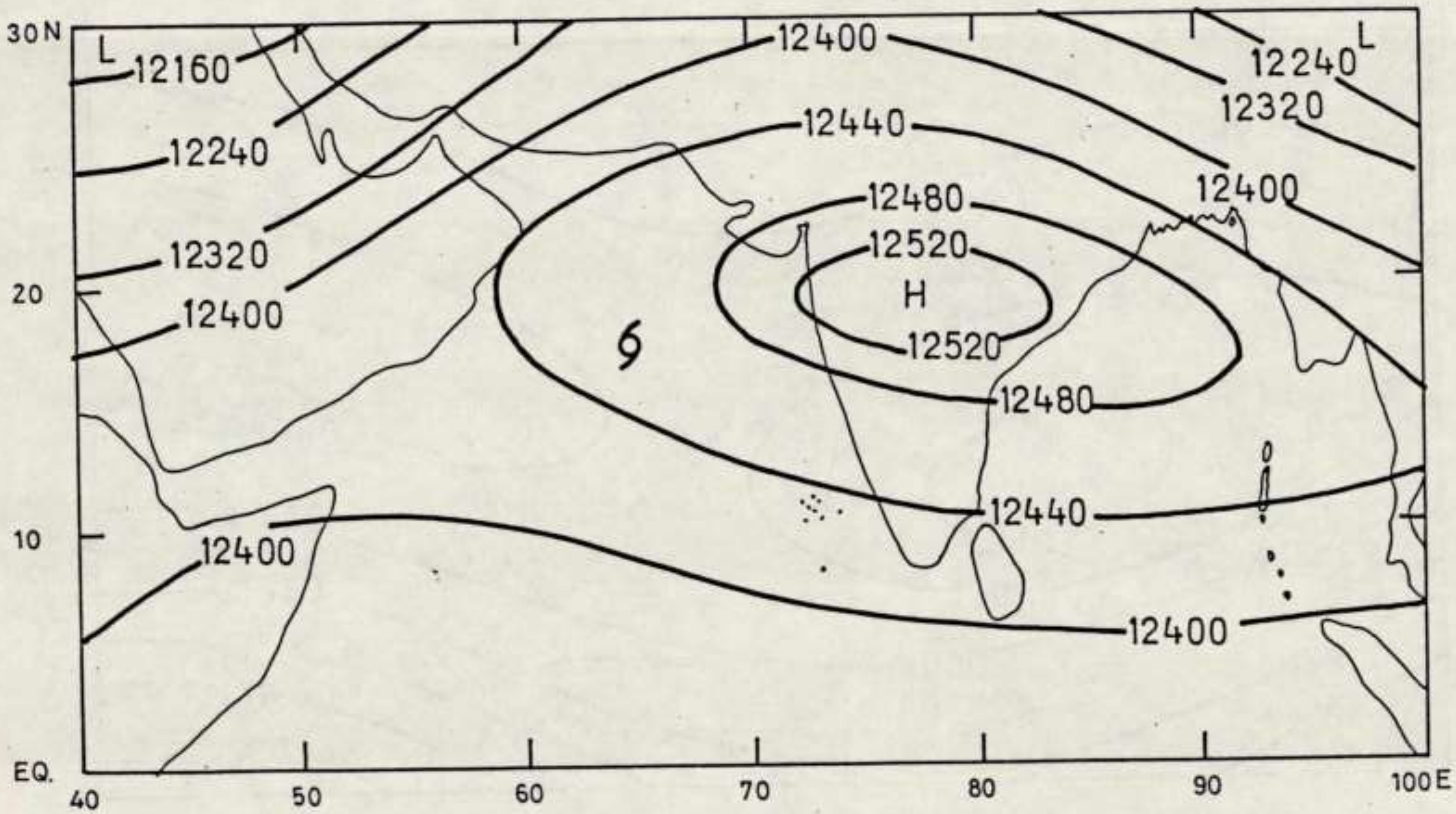


Fig.7 . 200 hPa Analysis, 12 UTC of 13 November 1993

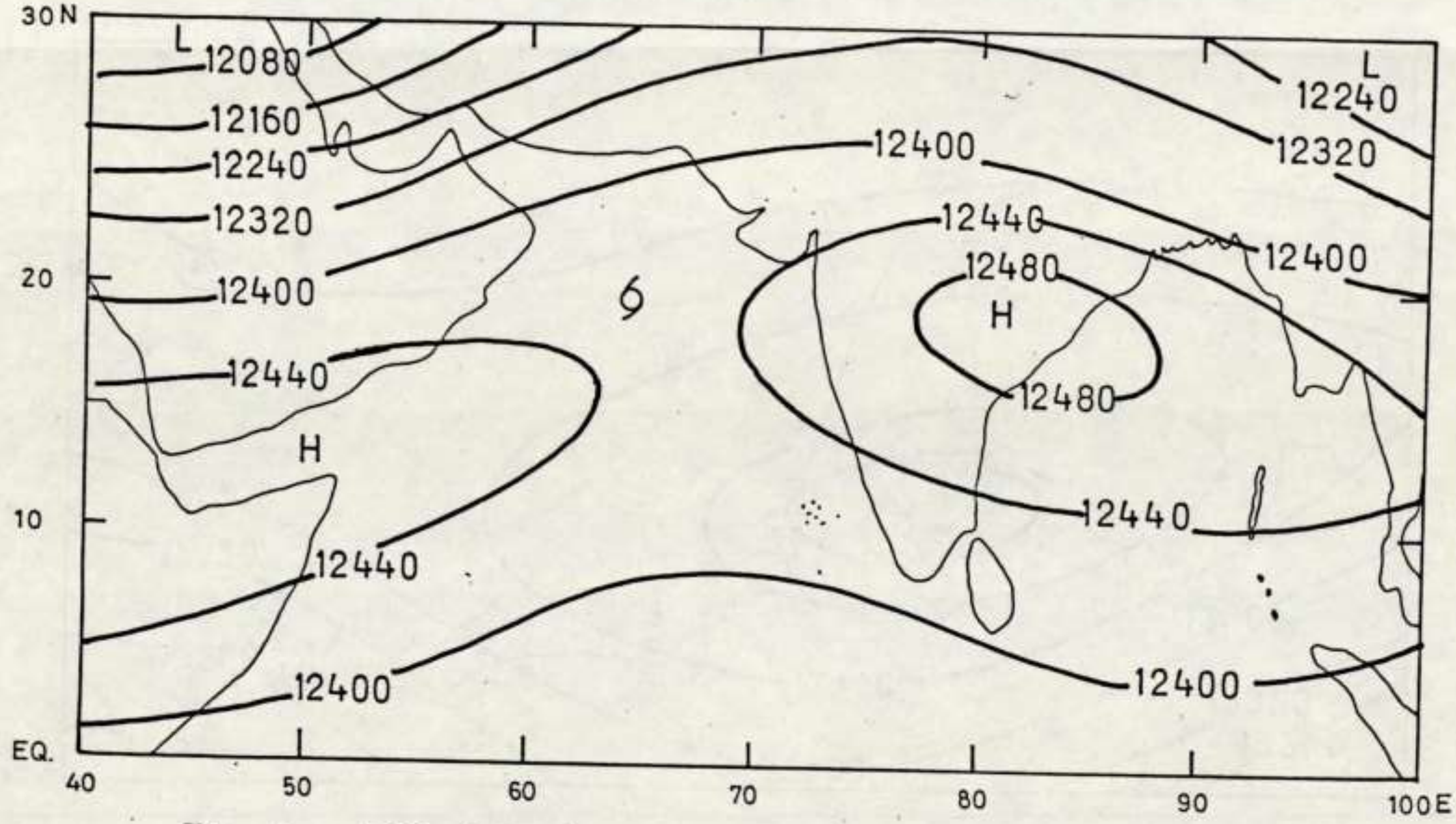


Fig. 8 . 200 hPa Analysis, 00 UTC of 14 November 1993

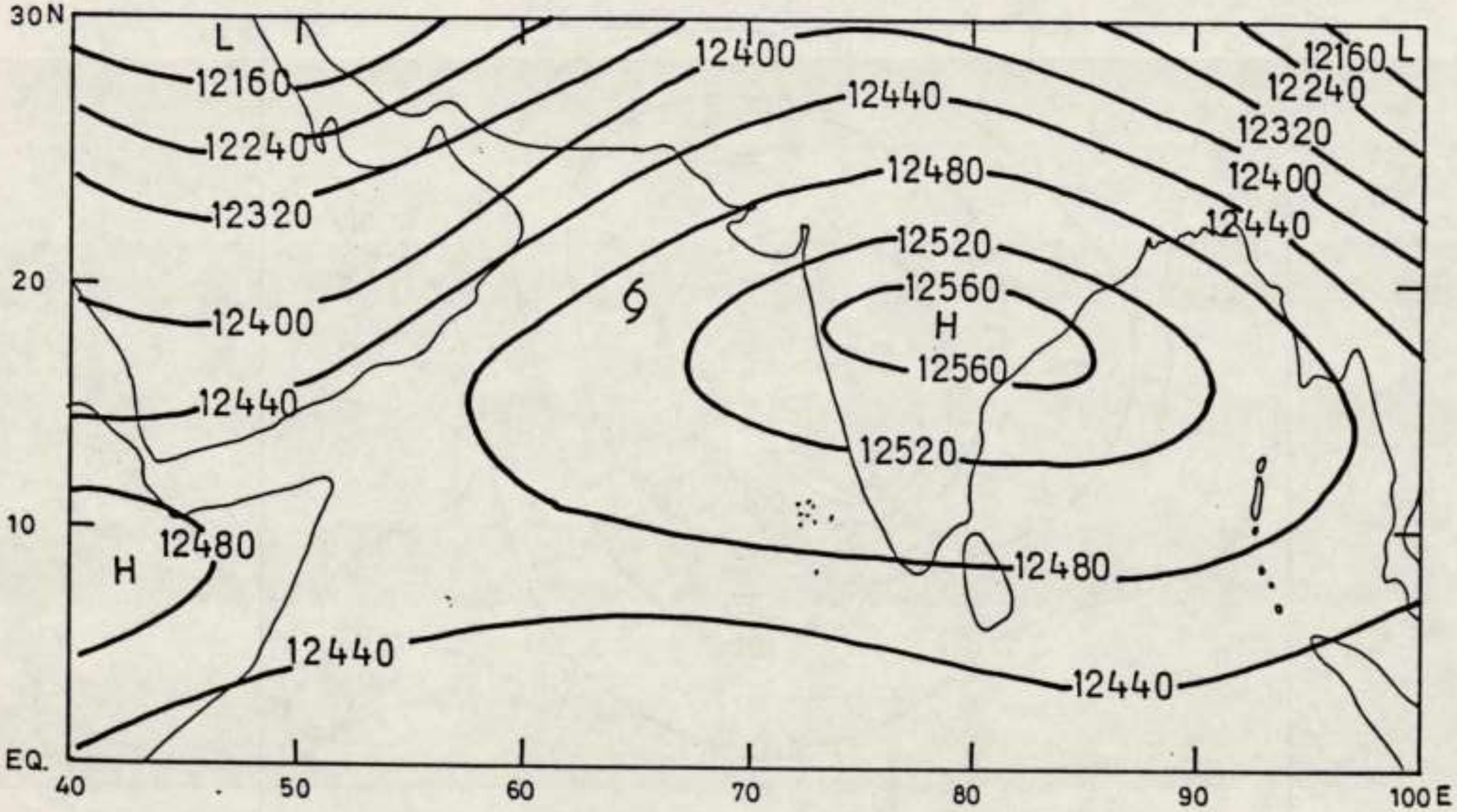


Fig. 9 . 200 hPa Analysis, 12 UTC of 14 November 1993

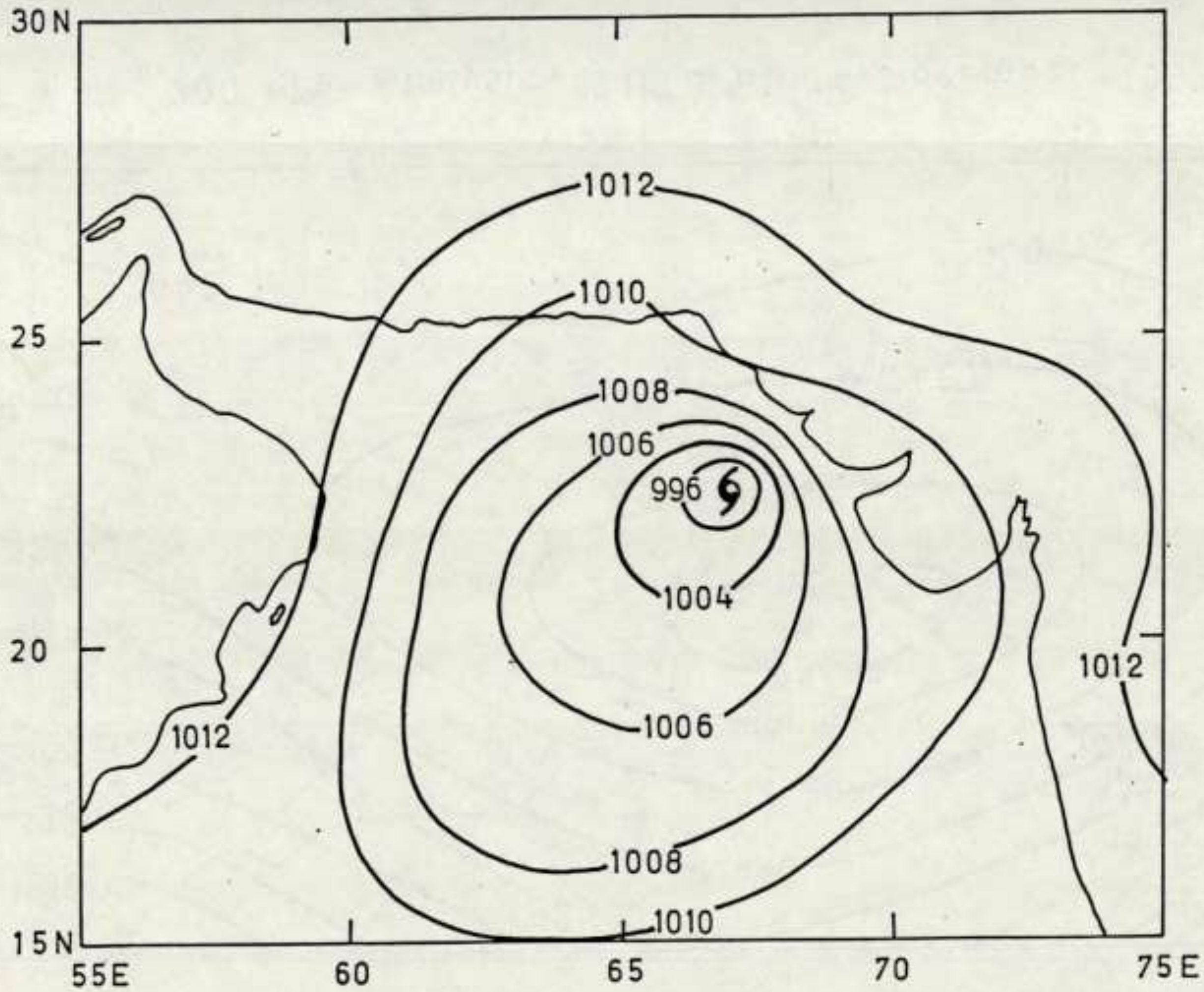


Fig. 10 . Sea Level Analysis 00 UTC of 15 November 1993

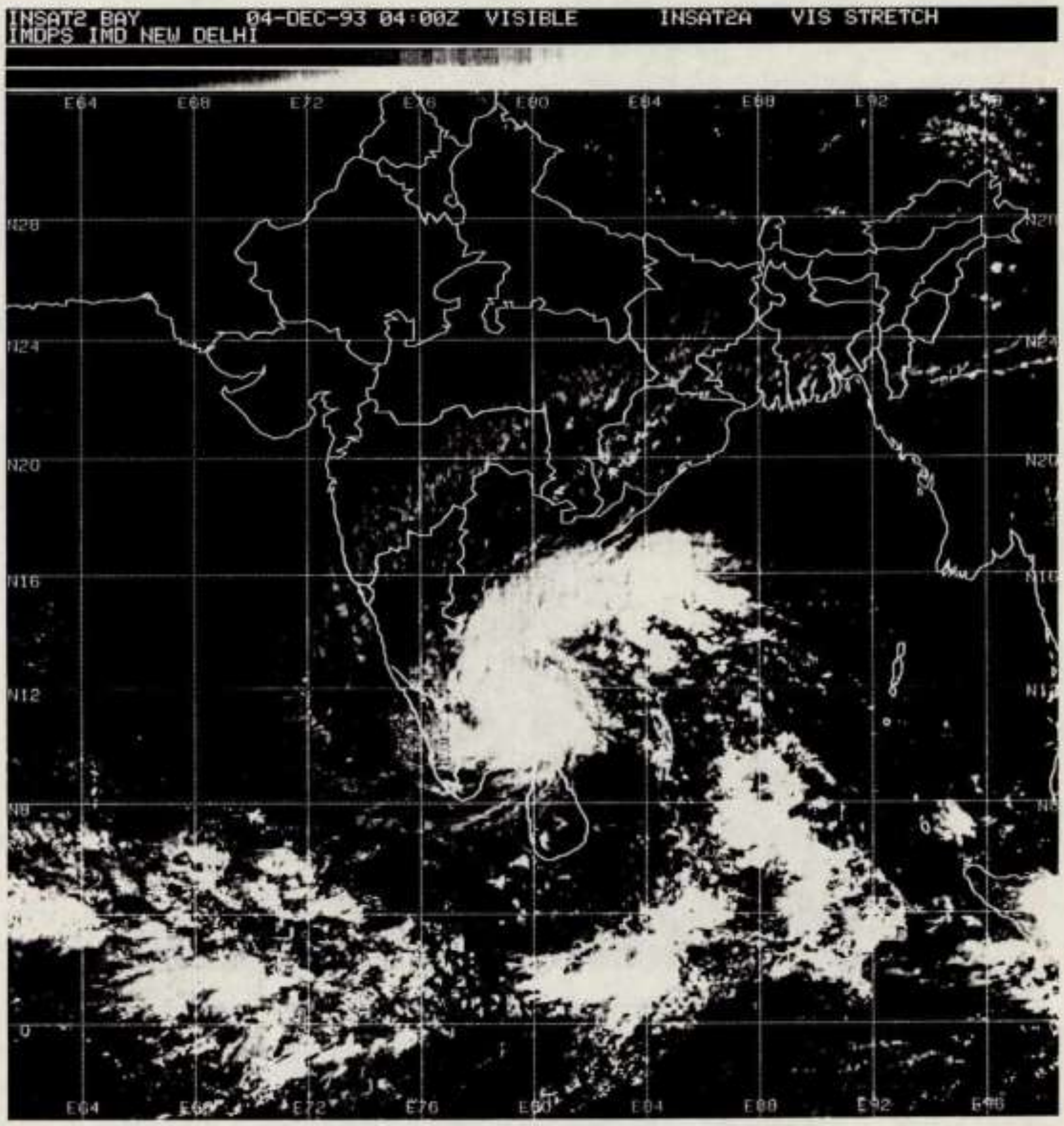

INSAT2 BAY 04-DEC-93 04:00Z VISIBLE INSAT2A VIS STRETCH
IMDPS IMD NEW DELHI
E64
E68
E72
E76
E80
E84
E88
E92
N28
N24
N20
N16
N12
N8
0

FIG. 11

FIG. 12

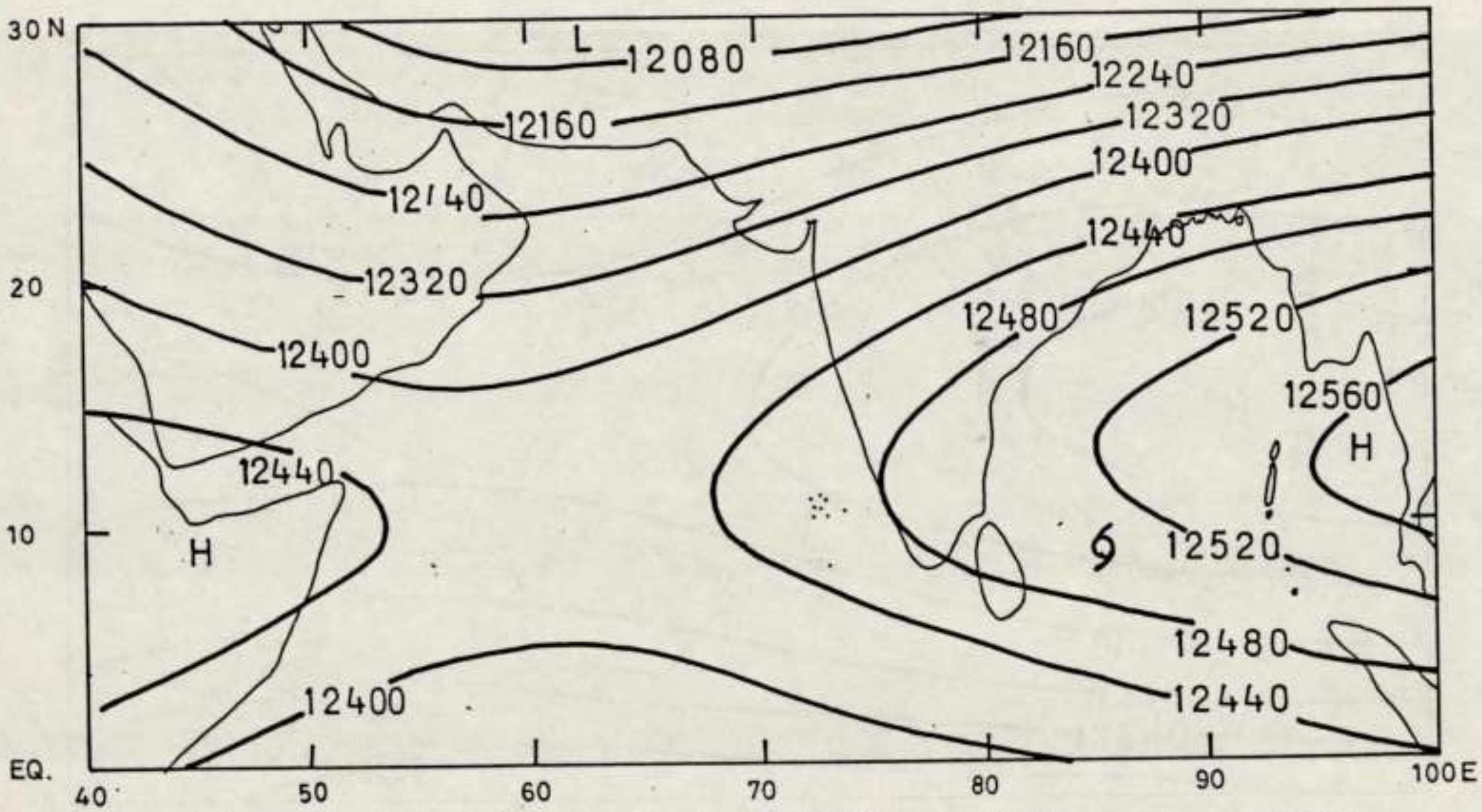


Fig.13 . 200 hPa Analysis, 12 UTC of 2 December 1993

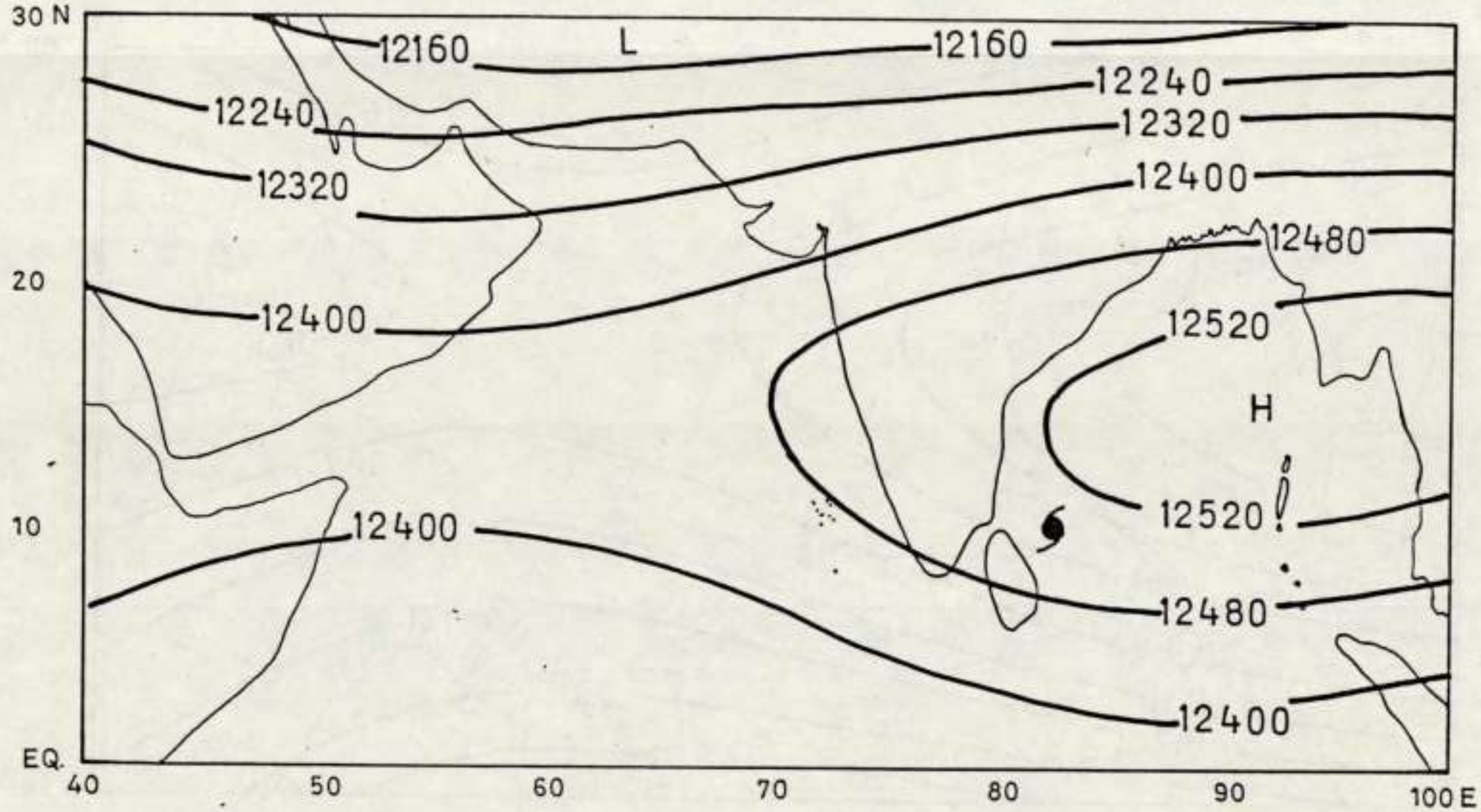


Fig.14 . 200 hPa Analysis 12 UTC of 3 December 1993

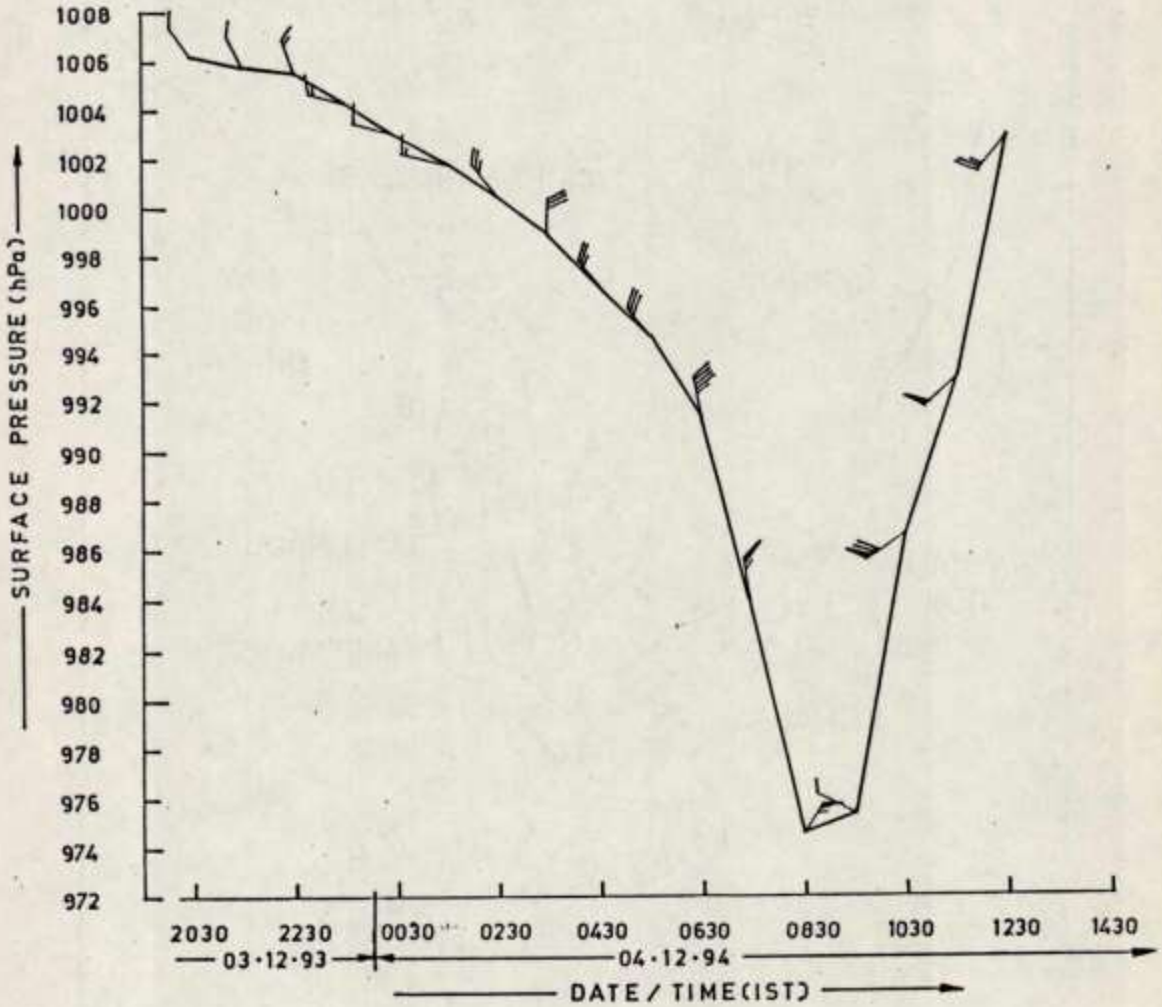

SURFACE PRESSURE (hPa)
1008
1006
1004
1002
1000
998
996
994
992
990
988
986
984
982
980
978
976
974
972
2030
2230
0030
0230
0430
0630
0830
1030
1230
1430
03·12·93
04·12·94
DATE / TIME(IST)

FIG. 15.

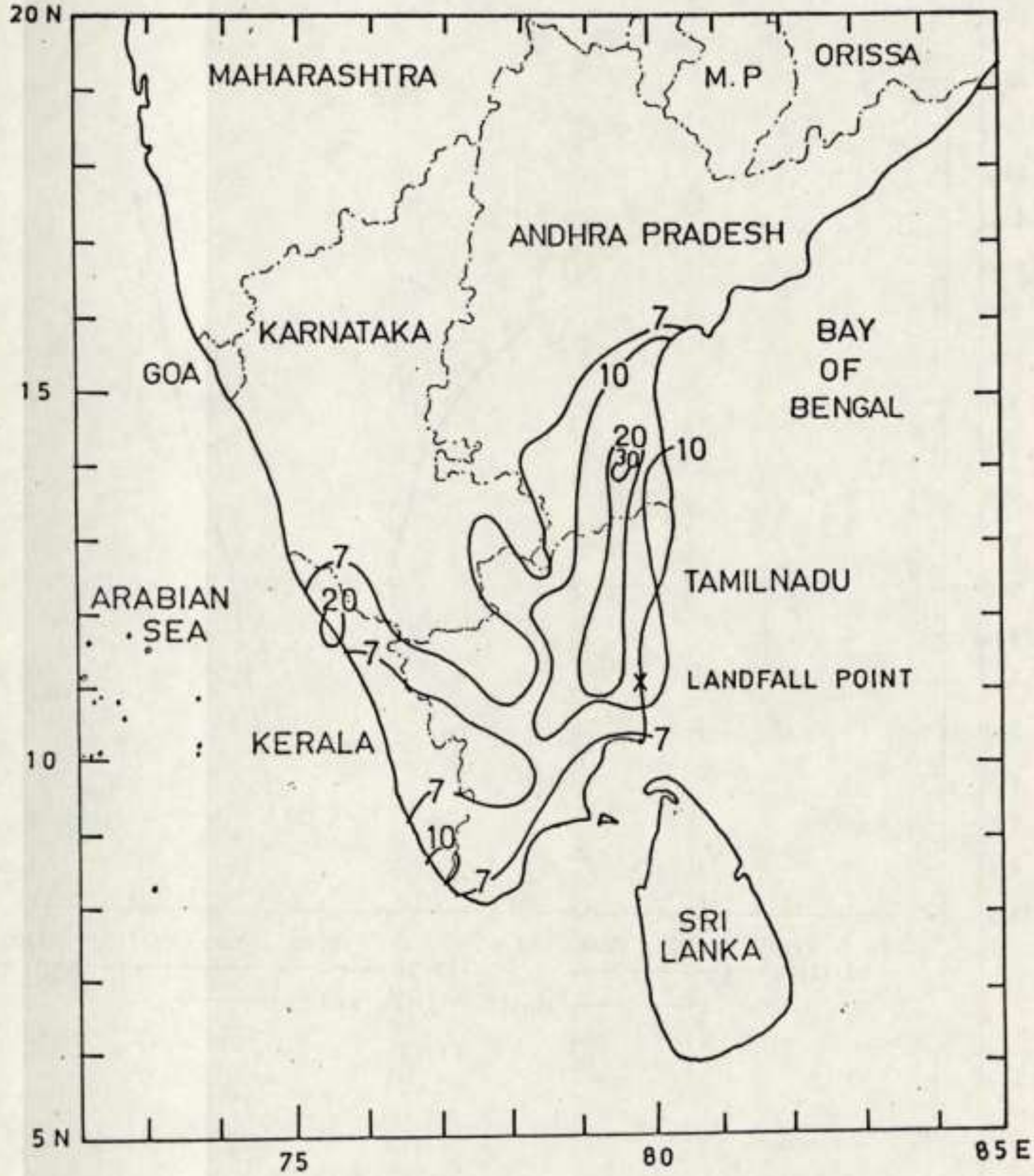


Fig. 16 . Cumulative Rainfall (cm) for the period from 4 to 6 December 1993.

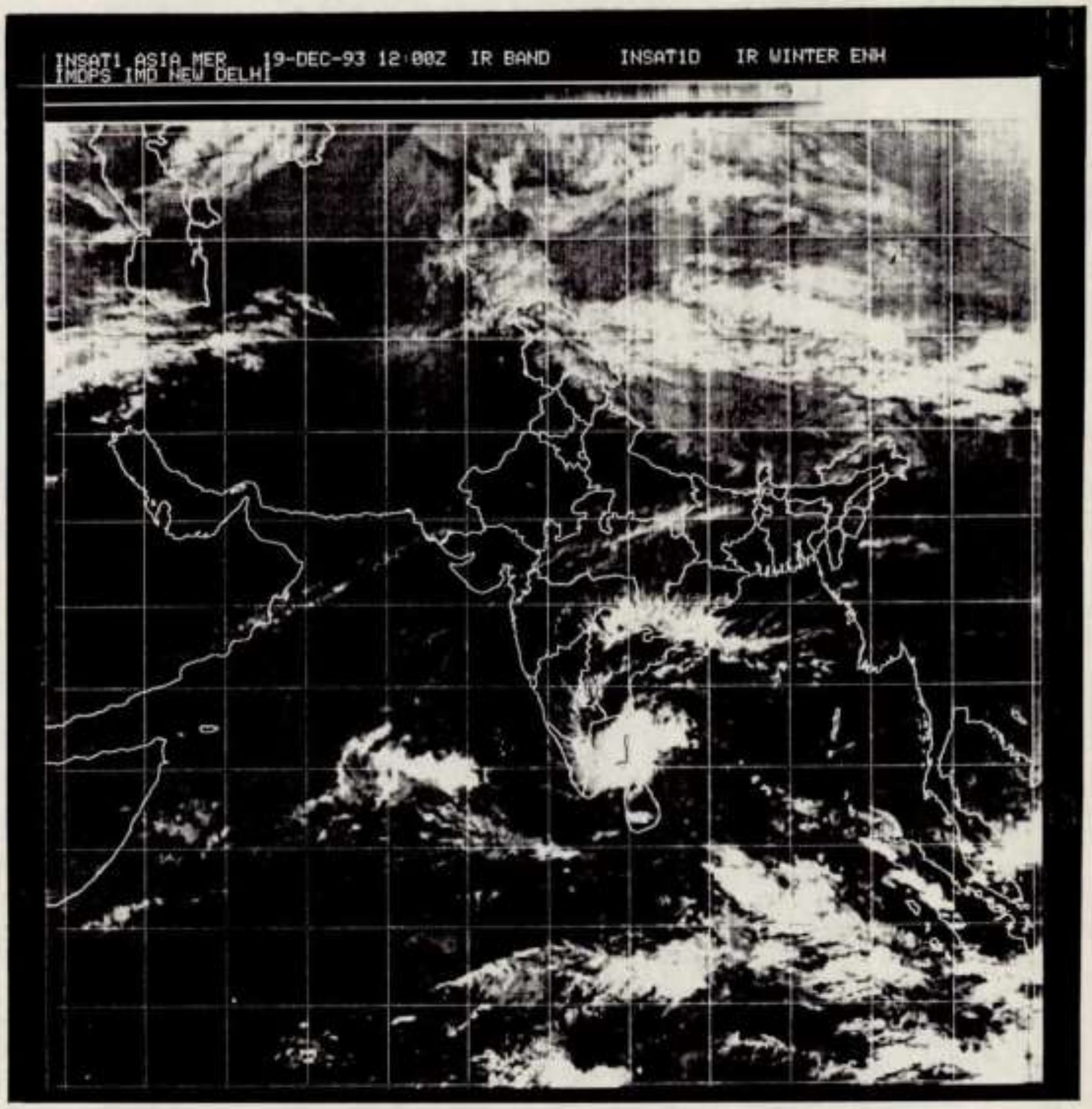

INSAT1 ASIA MER 19-DEC-93 12:00Z IR BAND INSAT1D IR WINTER ENH
IMDPS IMD NEW DELHI

FIG.17

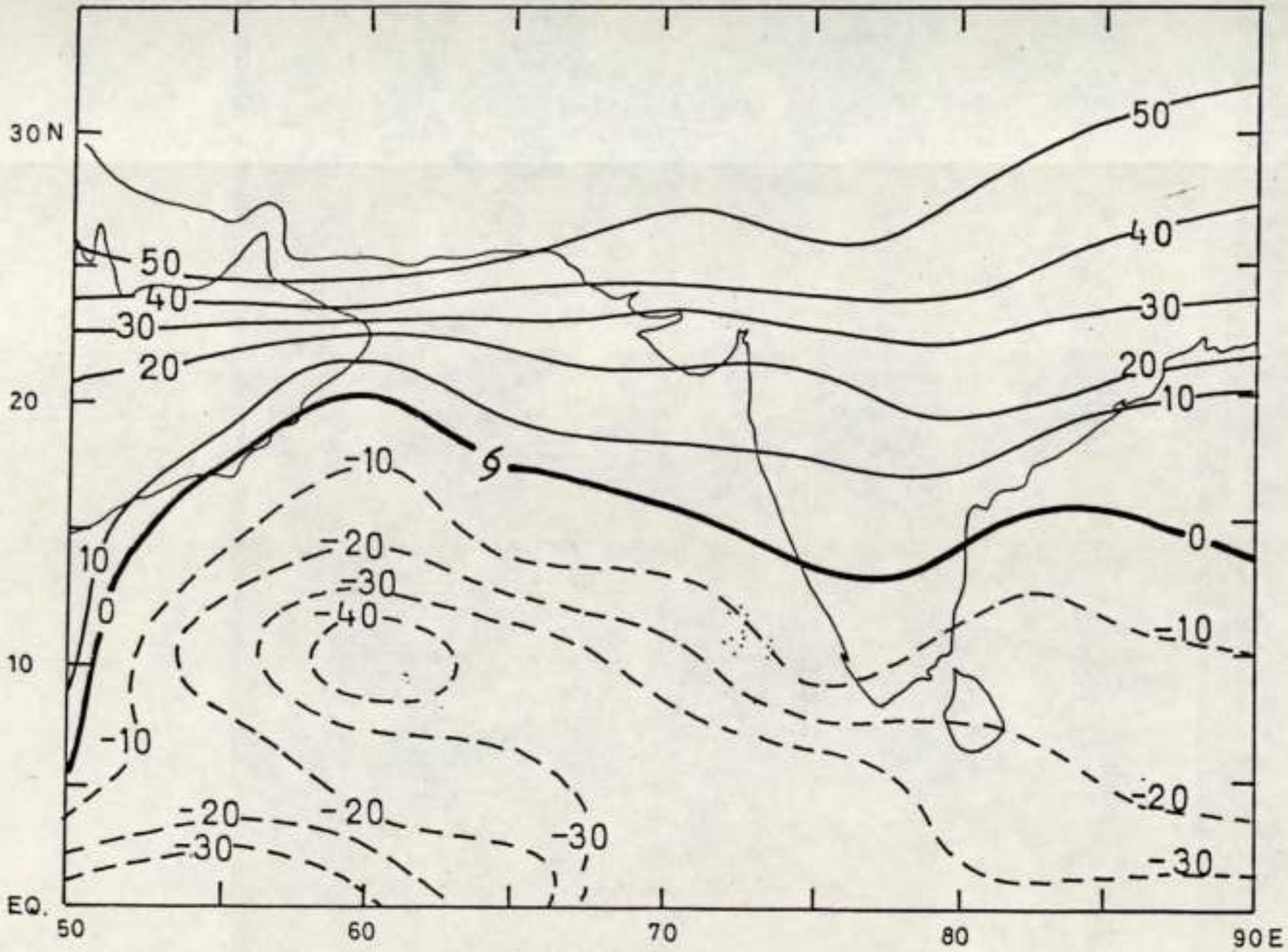


Fig.18(a). Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 13 November 1993 (Unit : Knot 650 hPa^{-1})

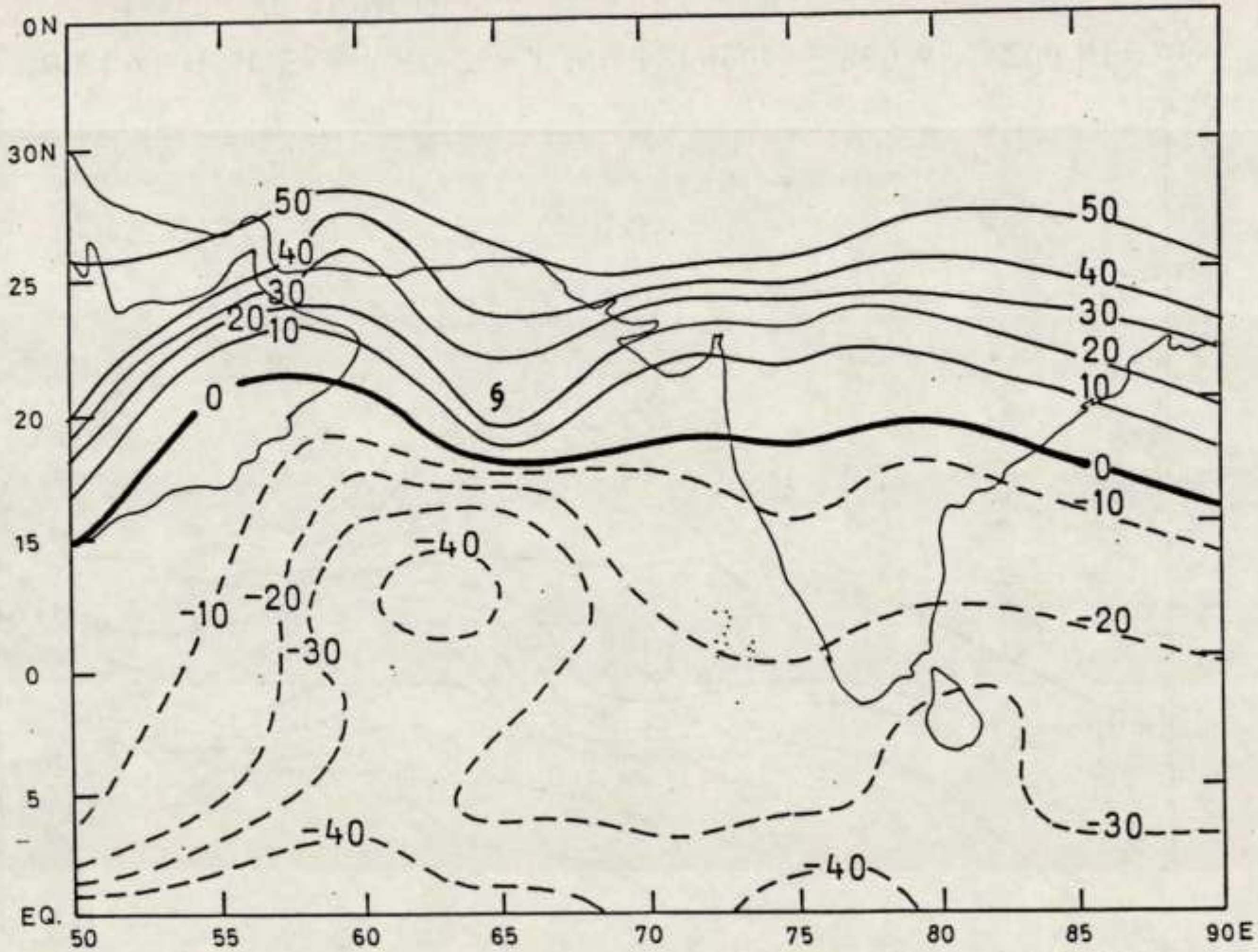


Fig.18(b) Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 14 November 1993 (Unit : Knot 650 hPa^{-1})

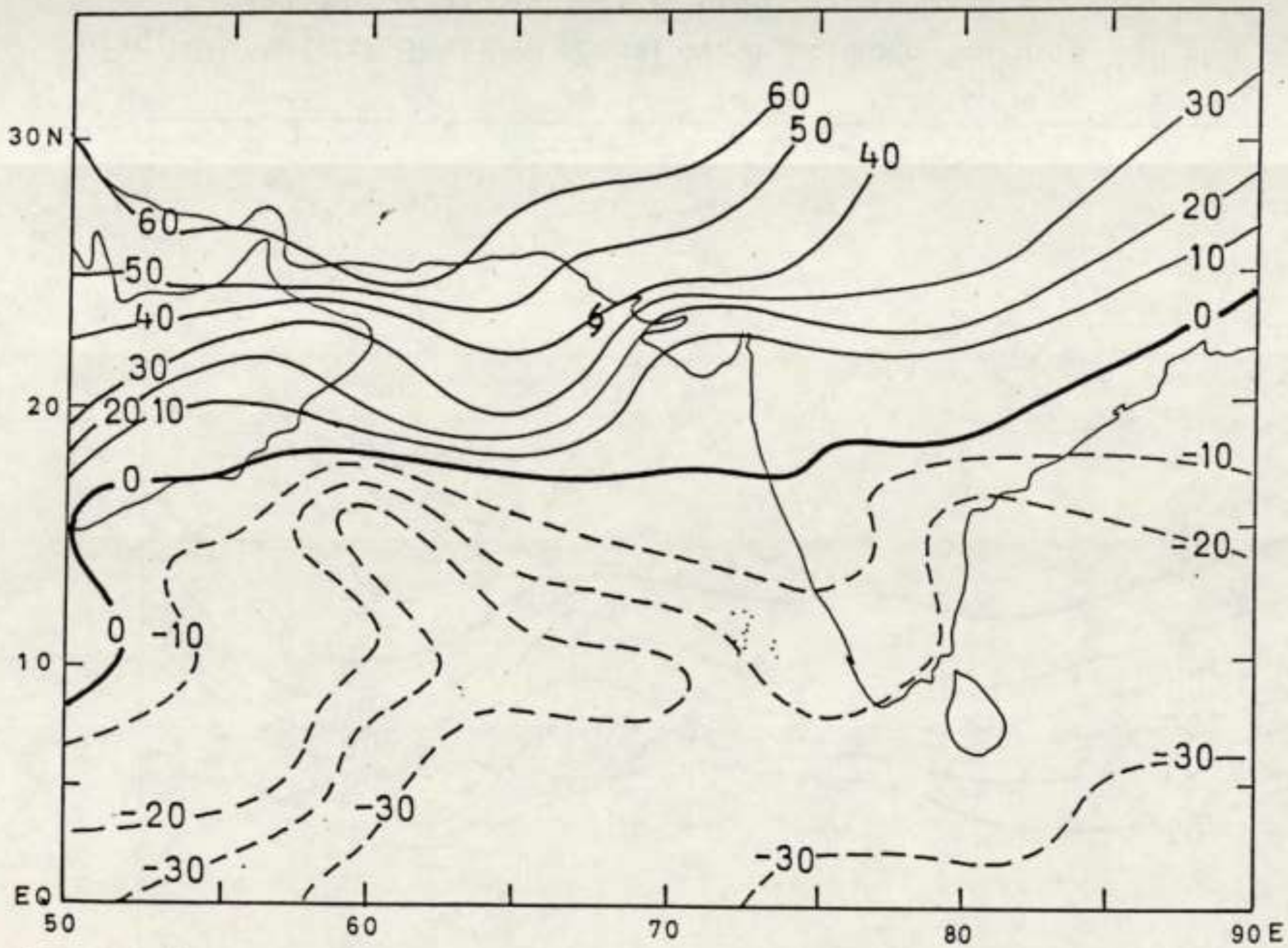


Fig.18(c). Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 15 November 1993 (Unit: Knot 650 hPa^{-1})

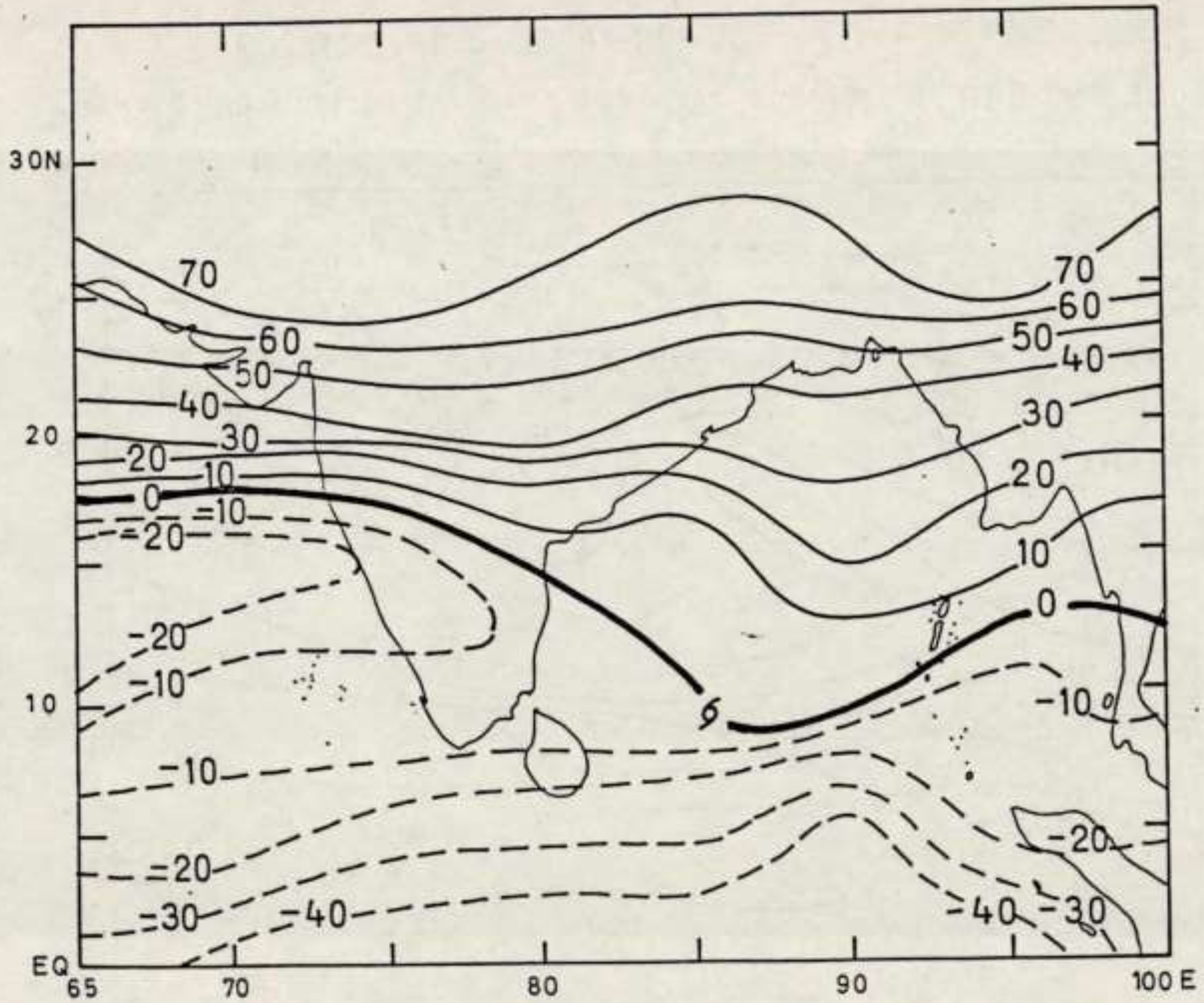


Fig. 19(a). Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 2 December 1993 (Unit: Knot 650 hPa^{-1})

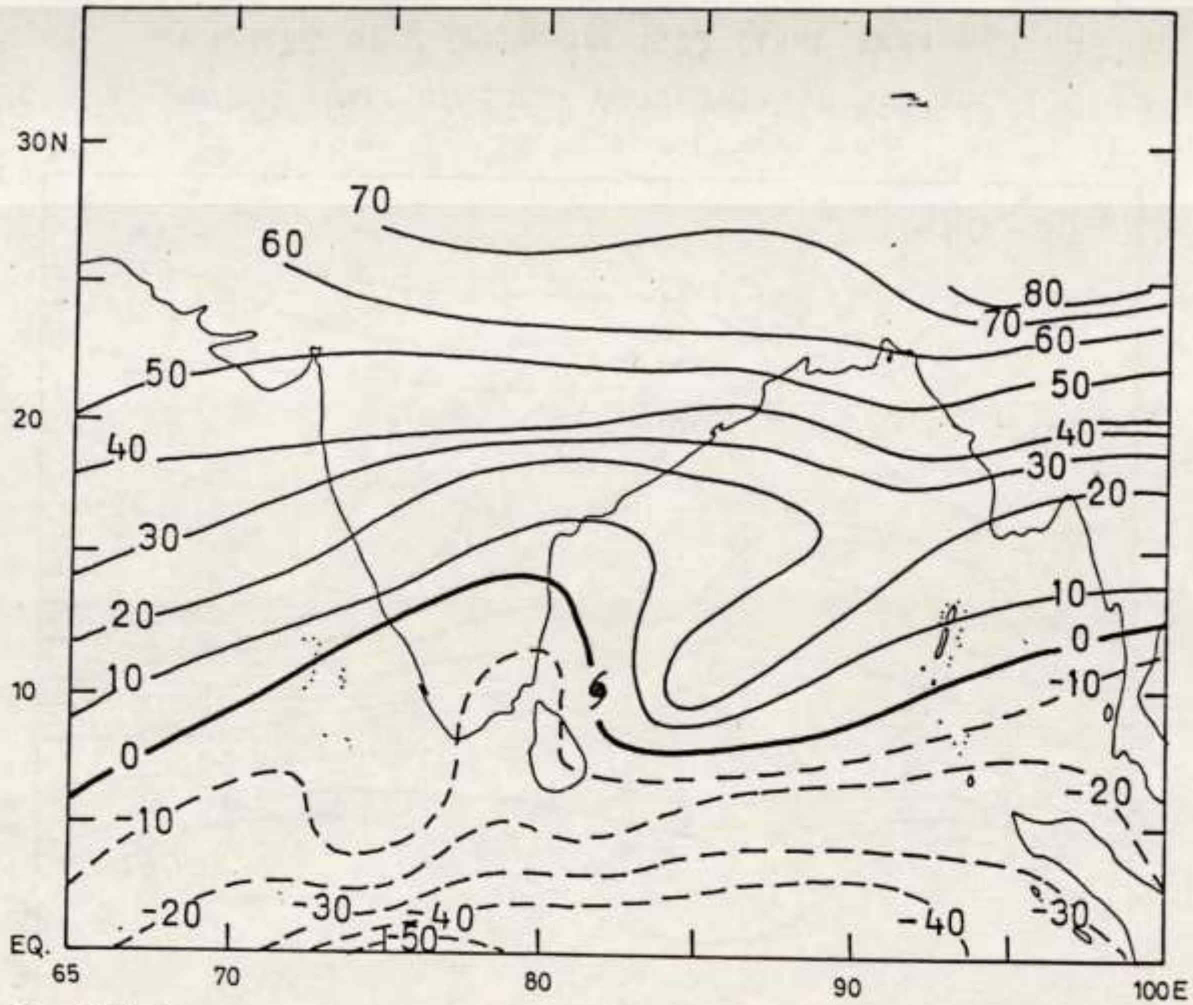


Fig.19(b). Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 3 December 1993 (Unit : Knot $650\,hPa^{-1}$)

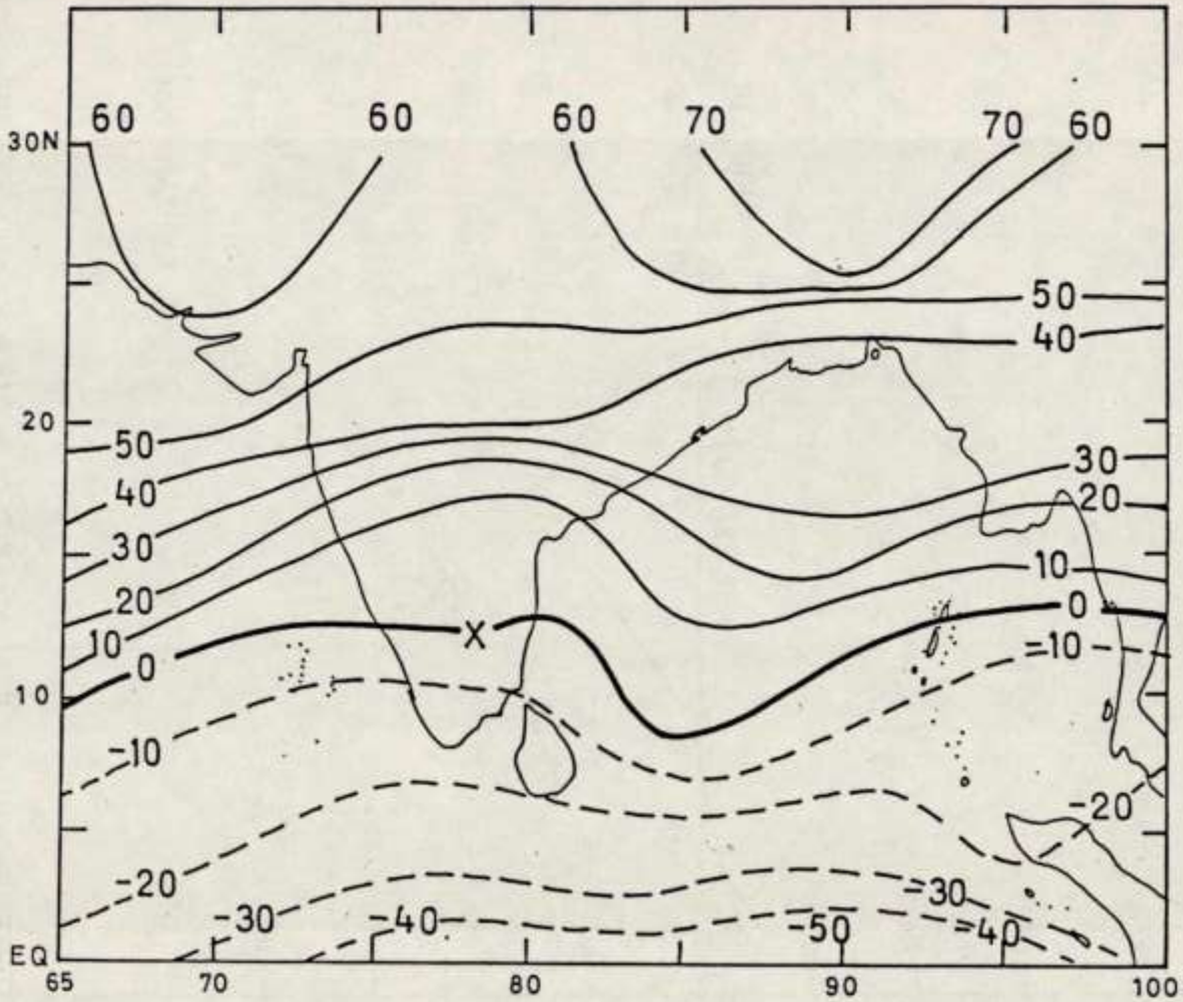


Fig.19(c).Vertical Shear of Zonal Wind between 850 and 200 hPa at 12 UTC of 4 December 1993 (Unit: Knot 650 hPa^{-1})

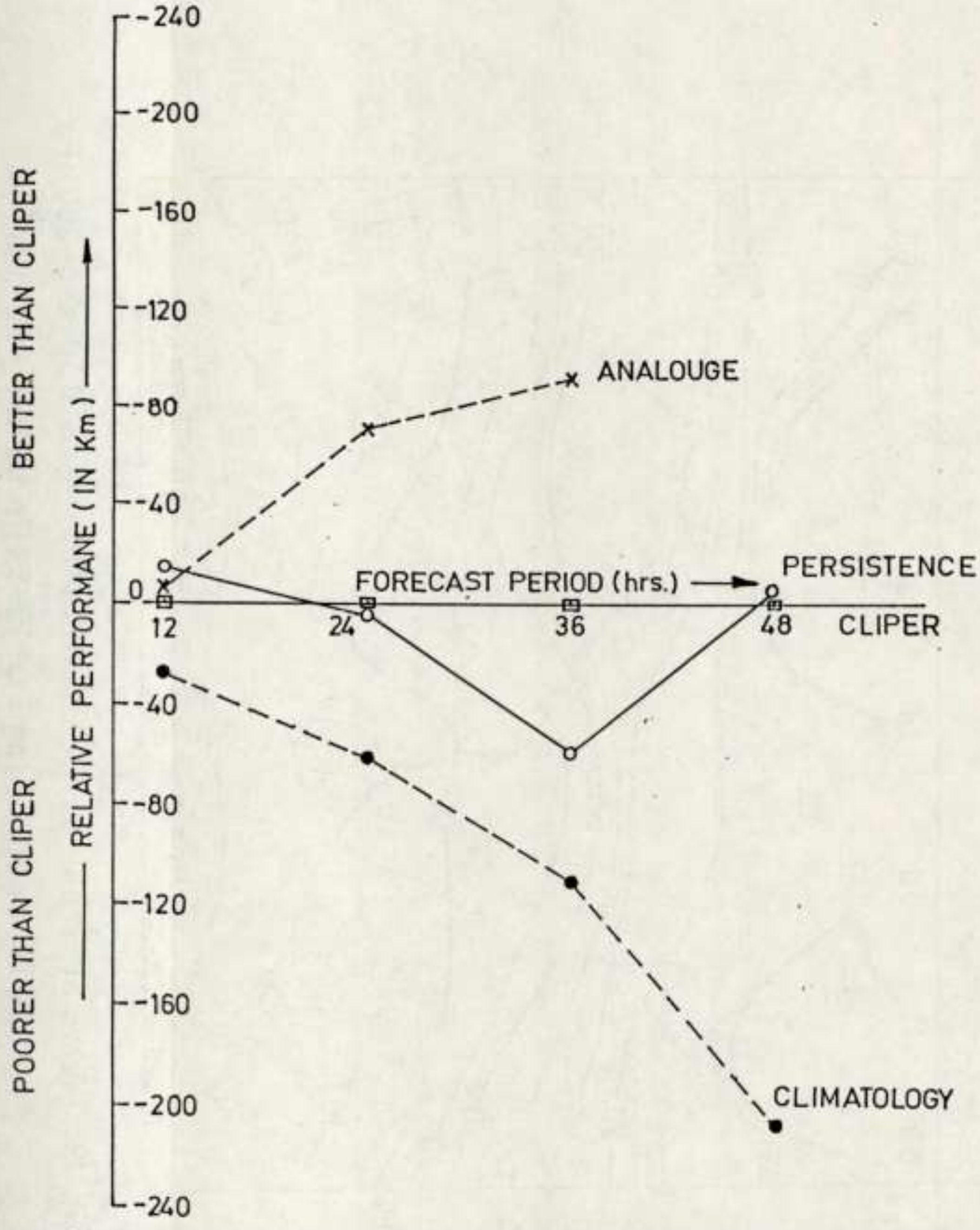


FIG.20. PERFORMANCE OF ANALOUGE CLIMATOLOGY AND PERSISTENCE MODELS RELATIVE TO CLIPER MODEL.

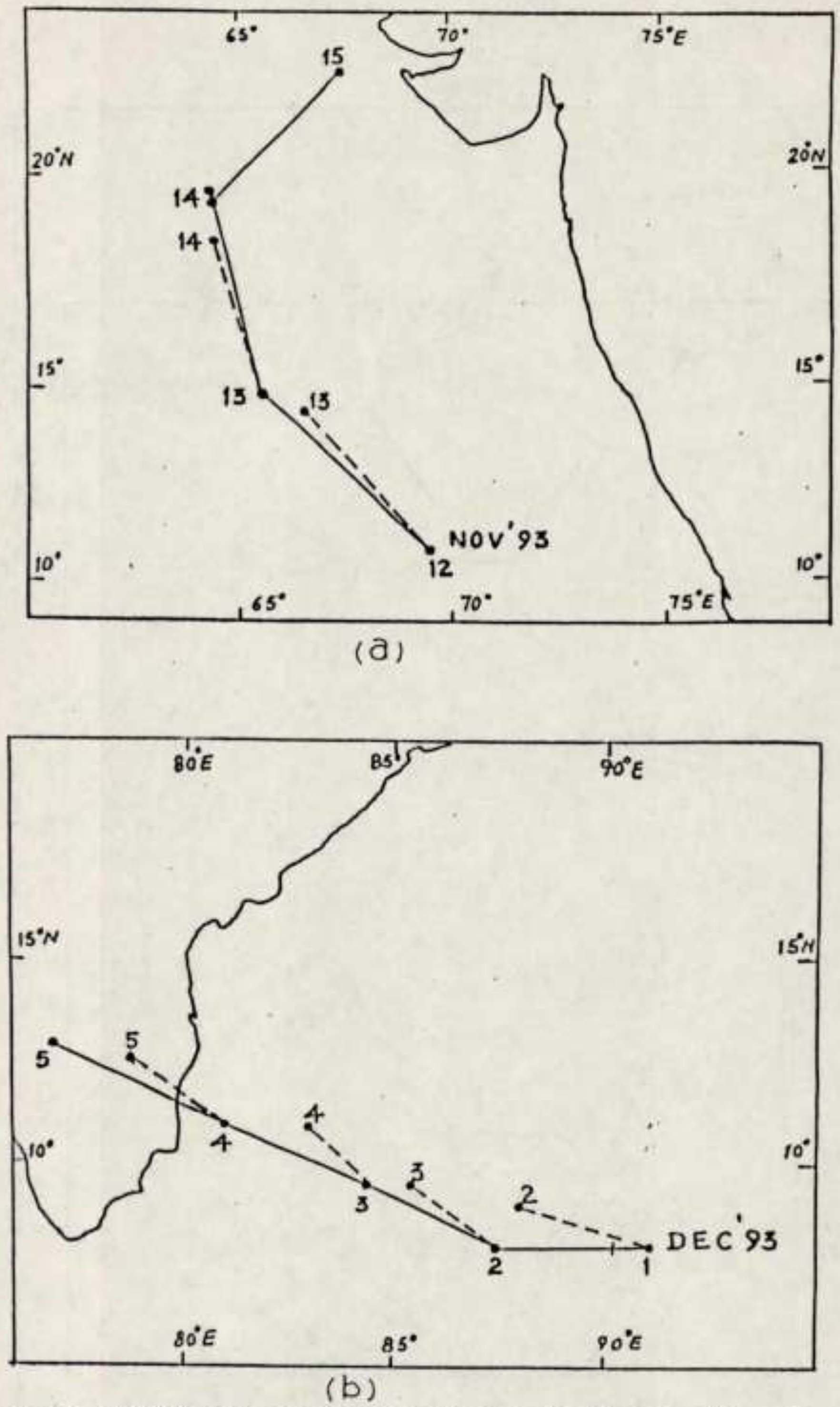


Fig. 21 : Tracks of cyclonic storms in the Arabian Sea, 12-15 Nov., 1993 and Bay of Bengal, 1-4 Dec., 1993.

●——● Actual
●- - -● Forecast

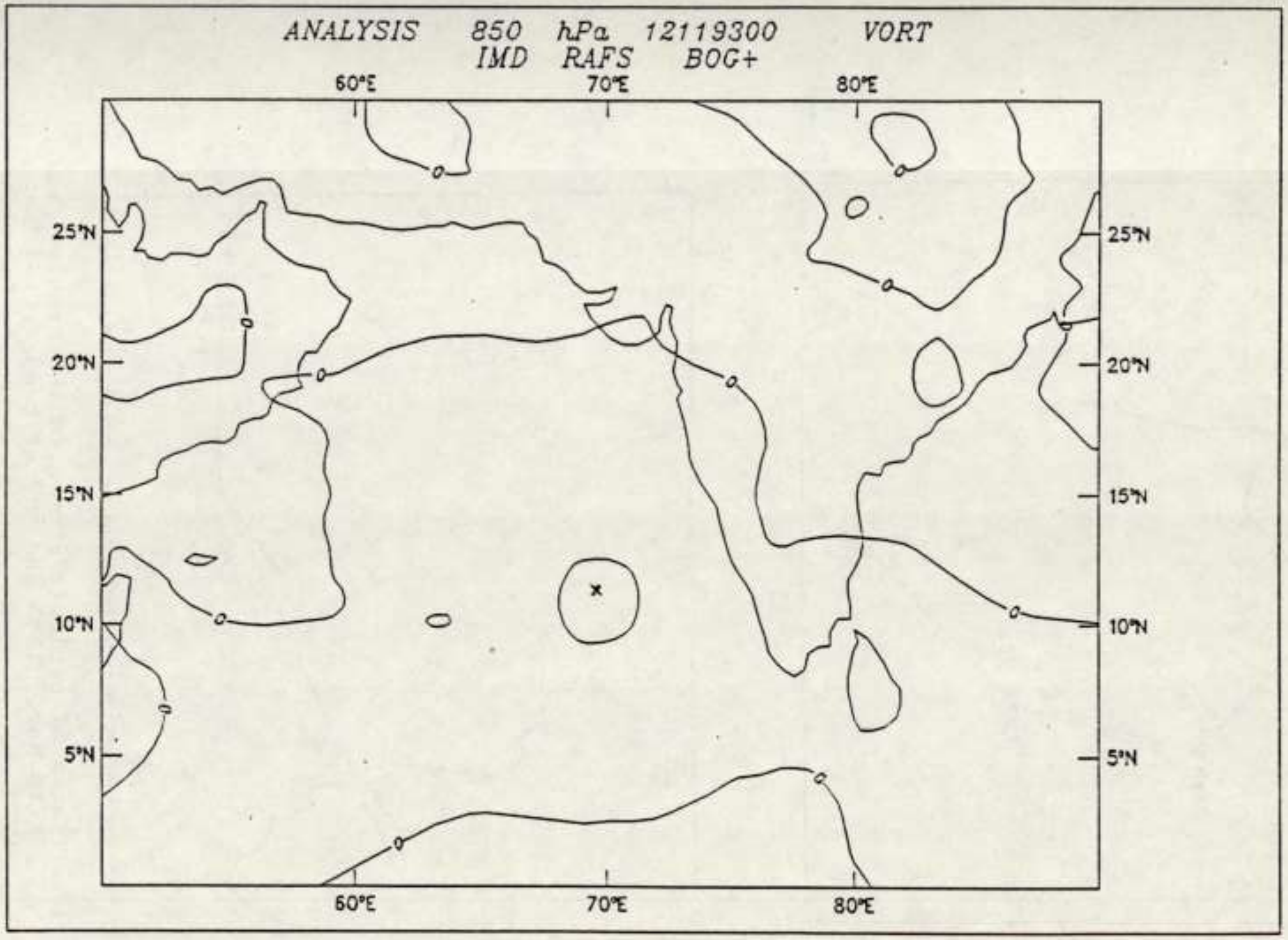

ANALYSIS 850 hPa 12119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
0
x

FIG. 22(a)

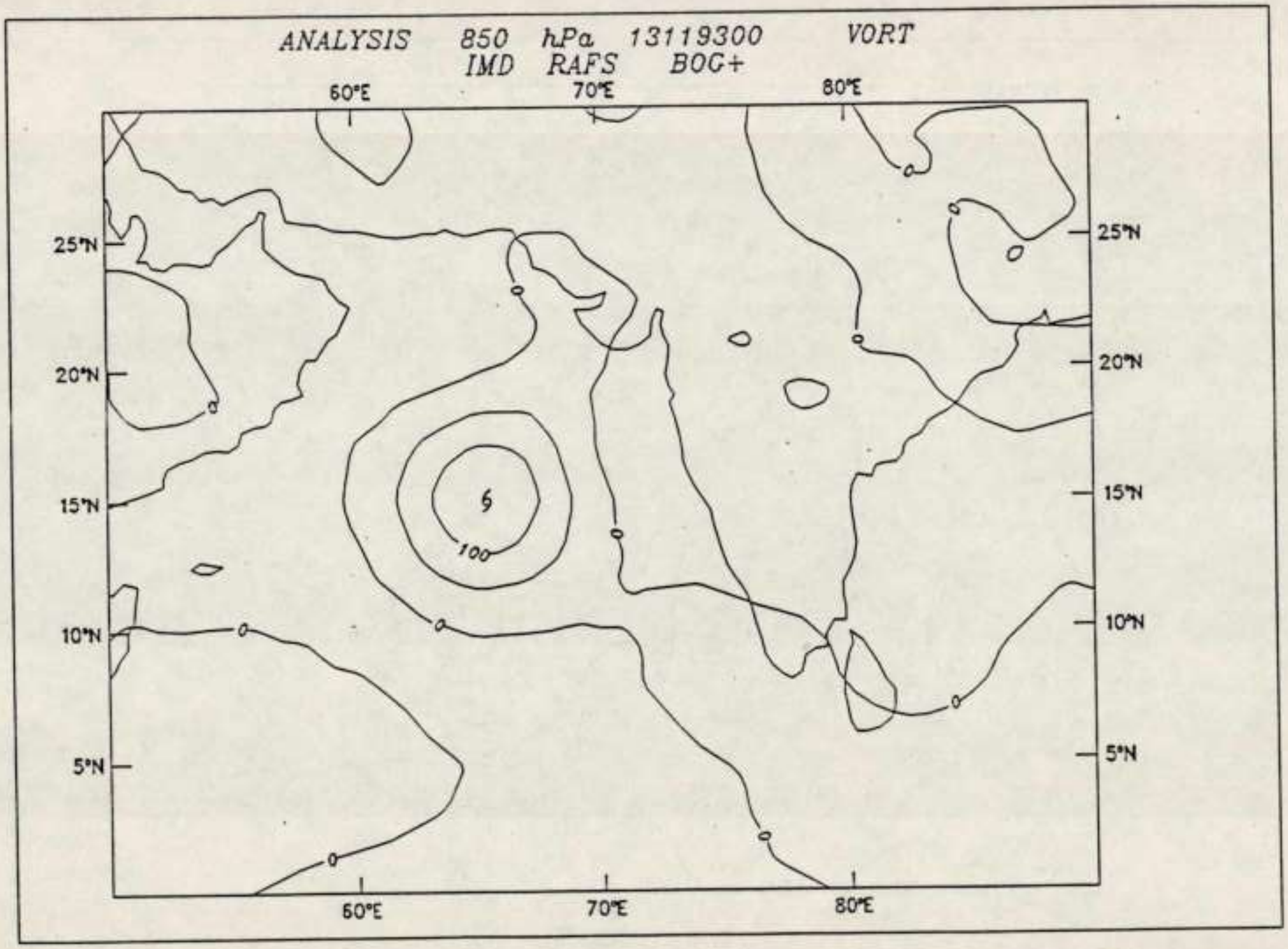

ANALYSIS 850 hPa 13119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
0
100

FIG. 22(b)

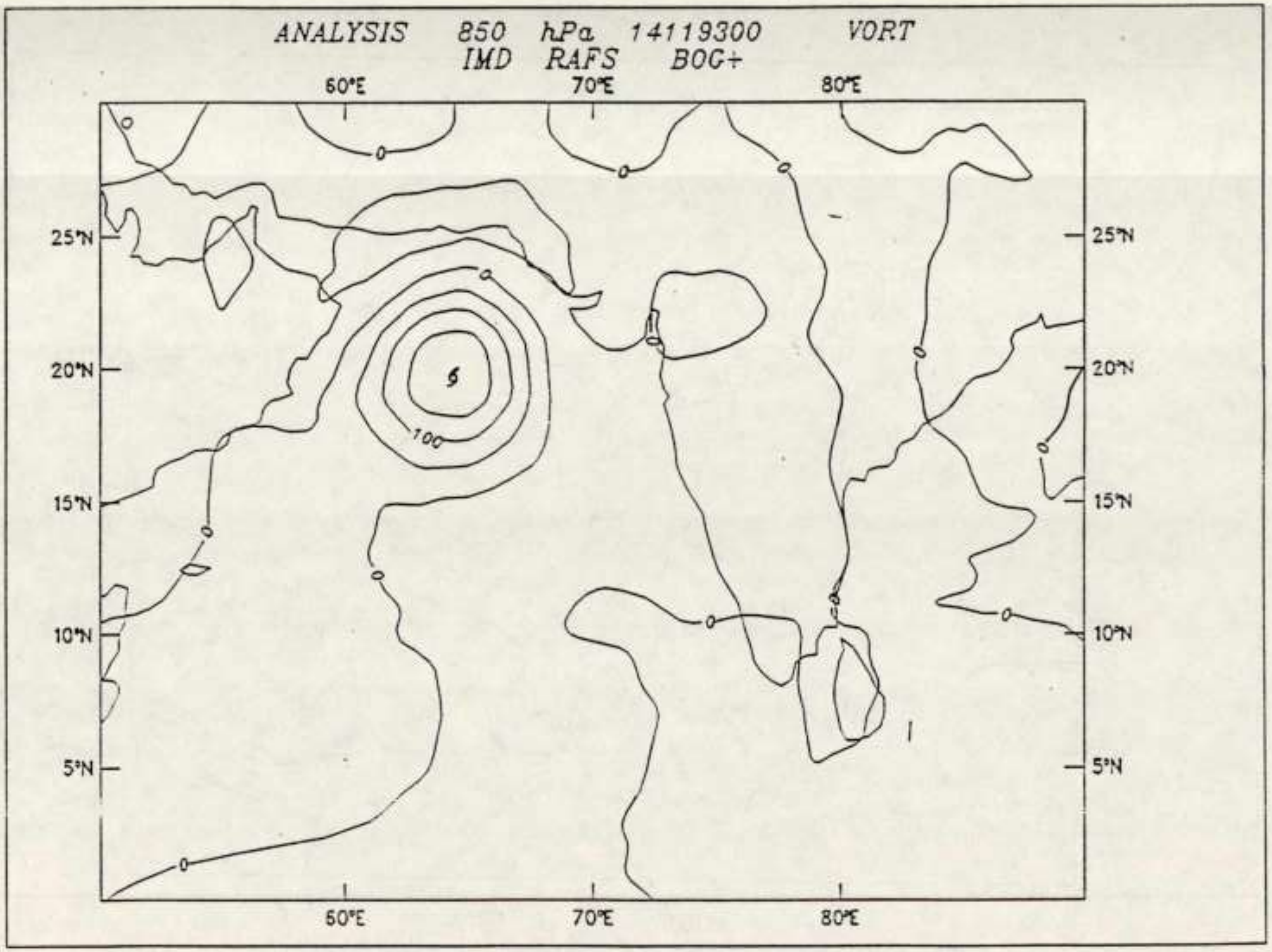

ANALYSIS 850 hPa 14119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 22 (c)

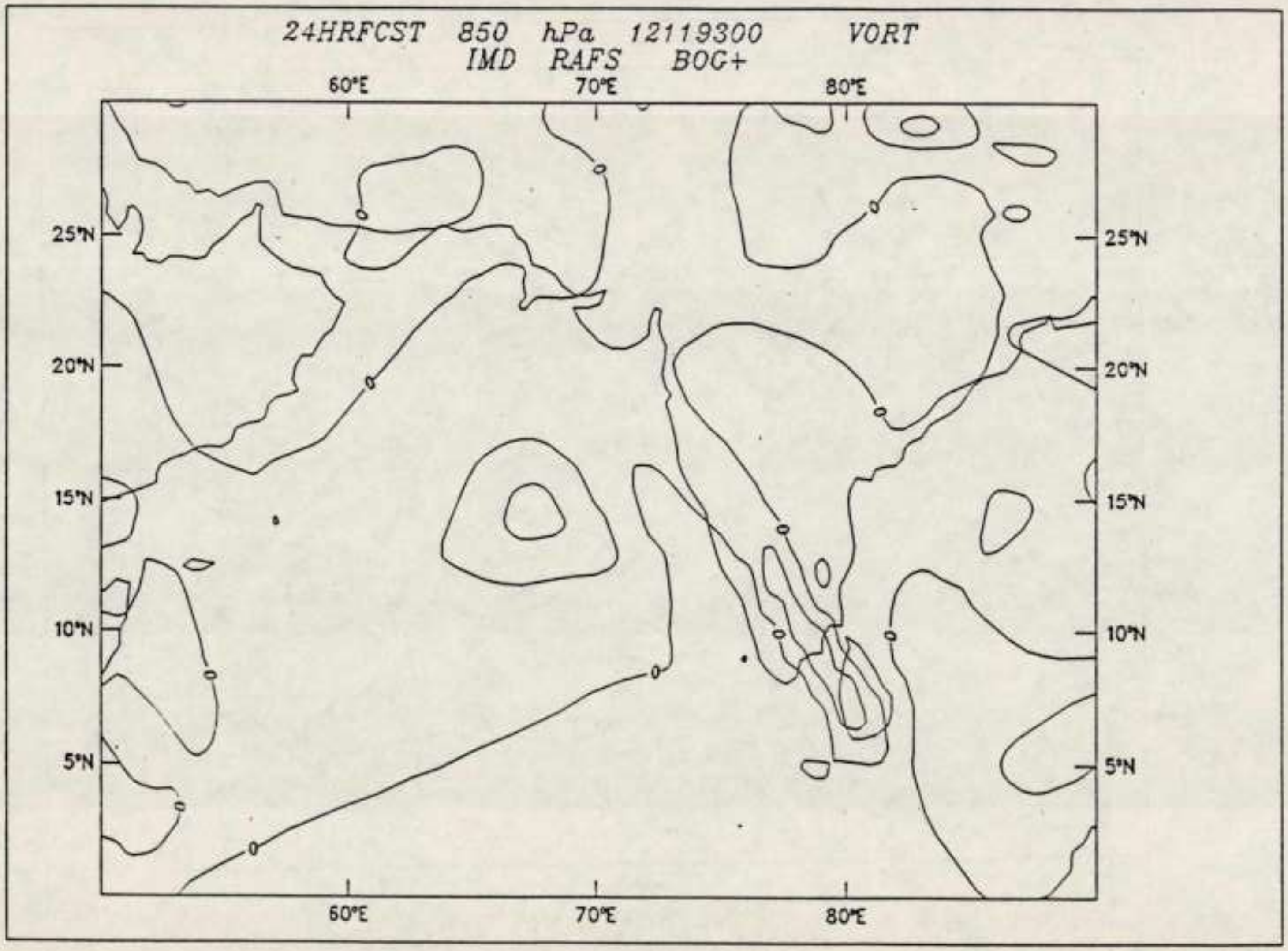

24HRFCST 850 hPa 12119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
0

FIG. 23 (a)

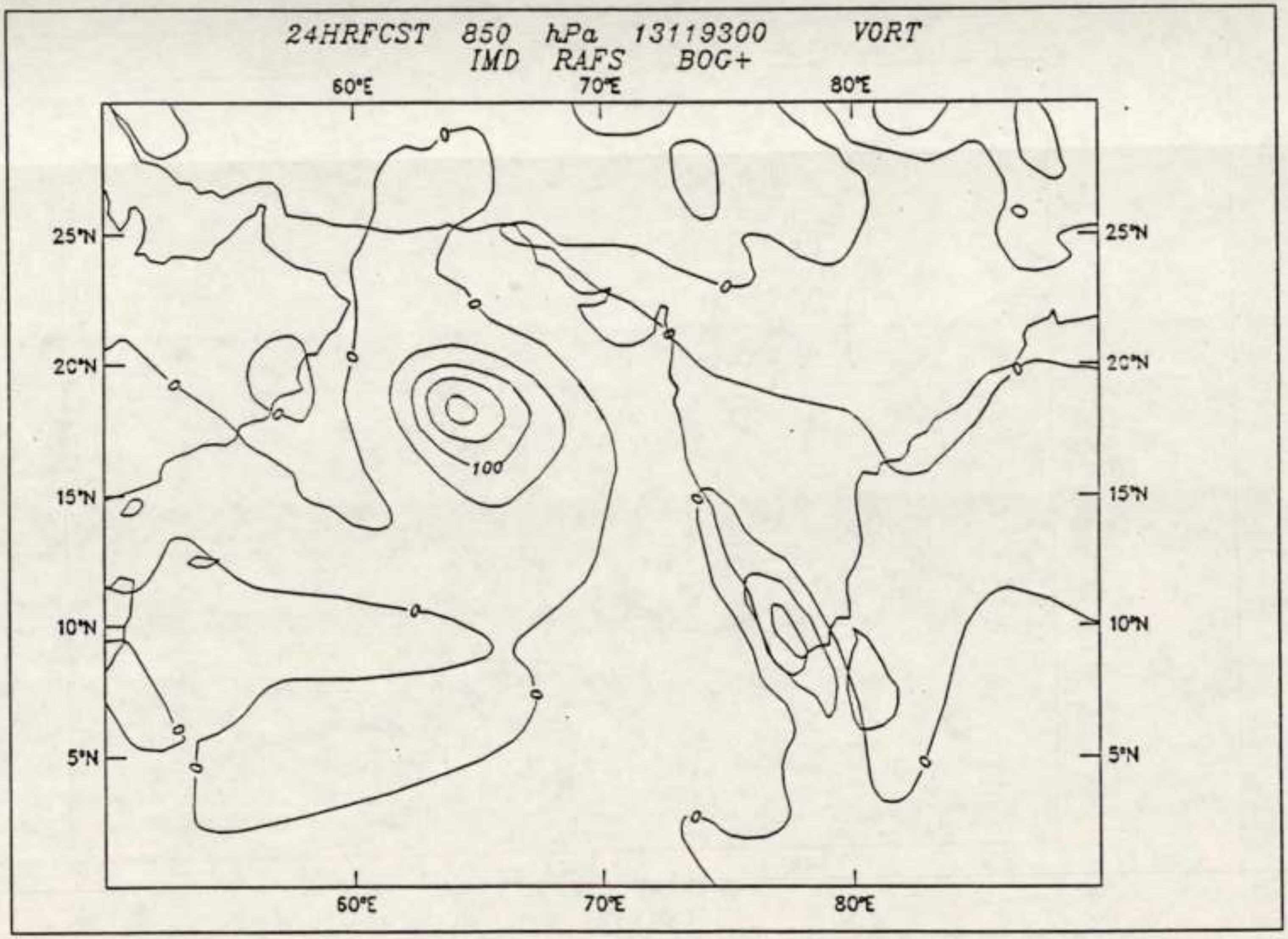

24HRFCST 850 hPa 13119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
100
0

FIG. 23(b)

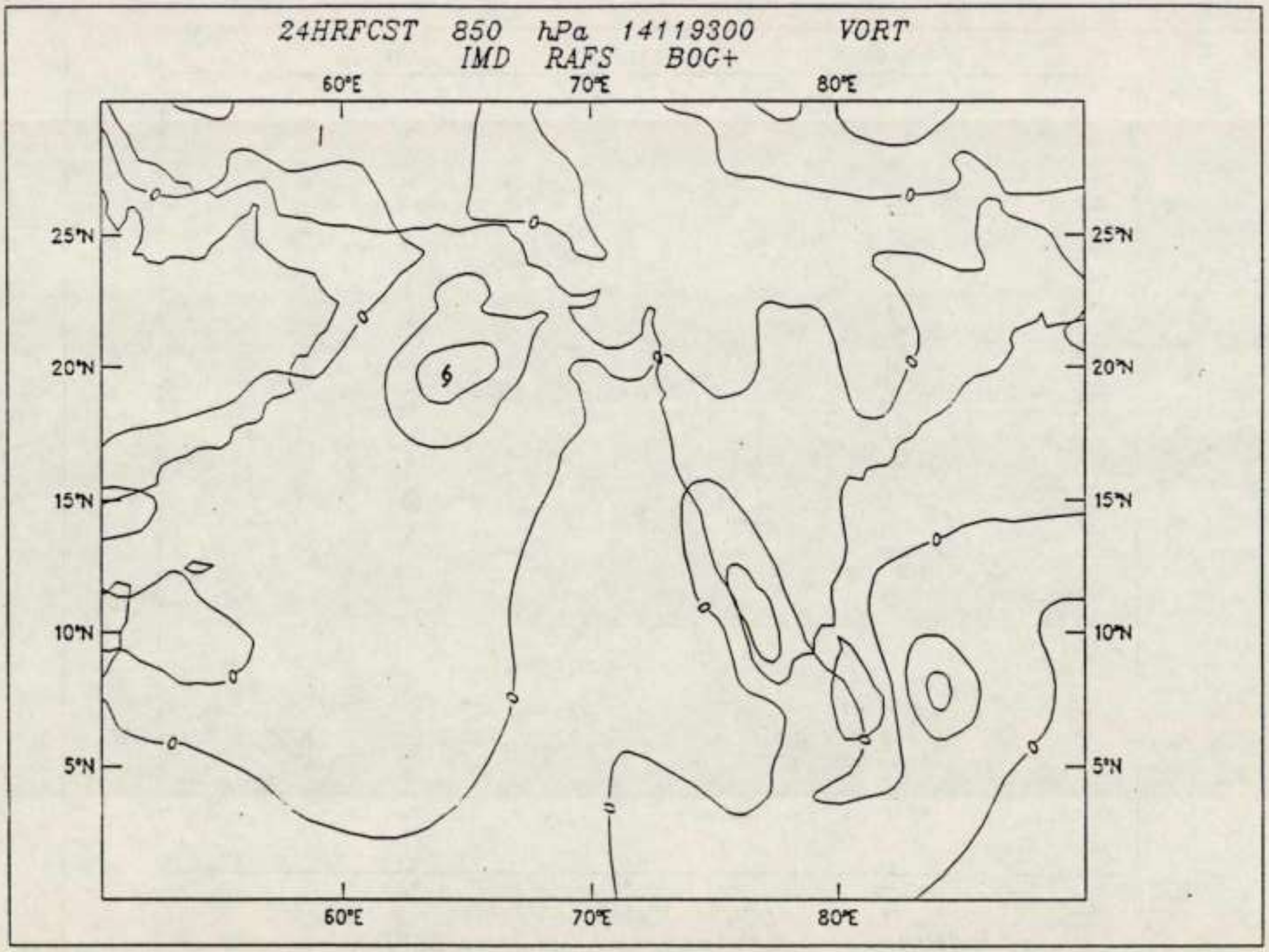

24HRFCST 850 hPa 14119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
6
0

FIG. 23 (c)

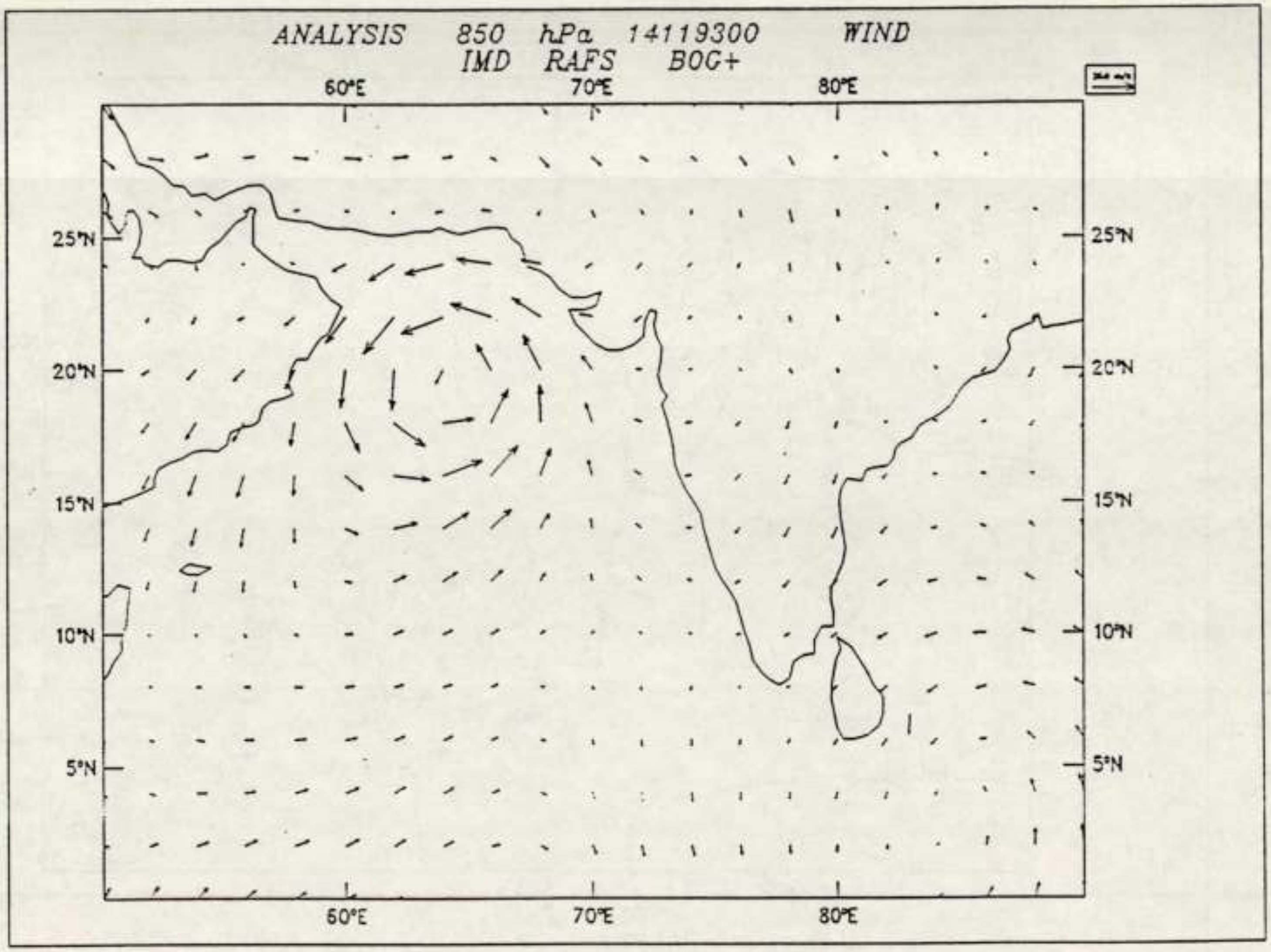

ANALYSIS 850 hPa 14119300 WIND
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 24 (a)

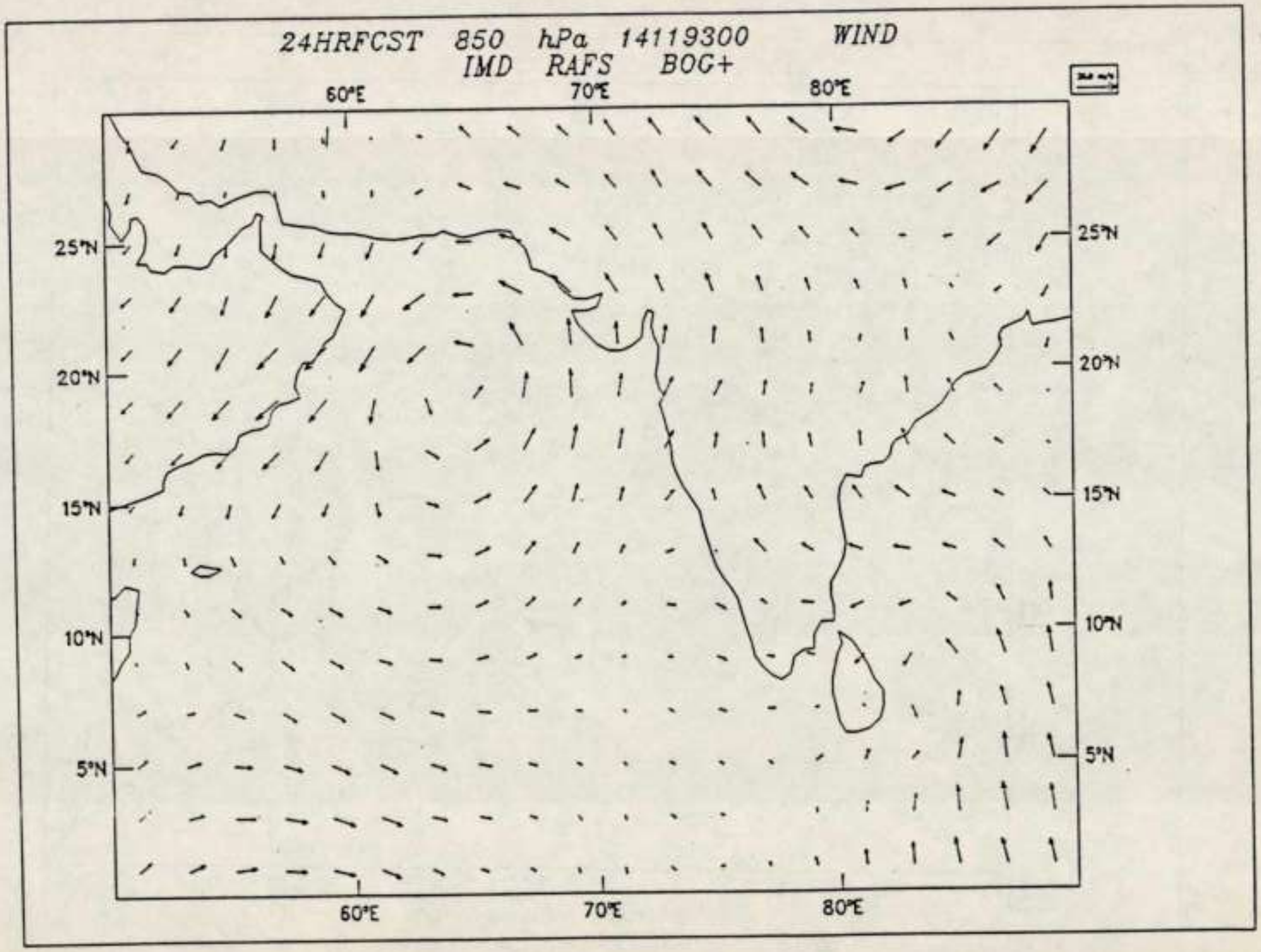

24HRFCST 850 hPa 14119300 WIND
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 24(b)

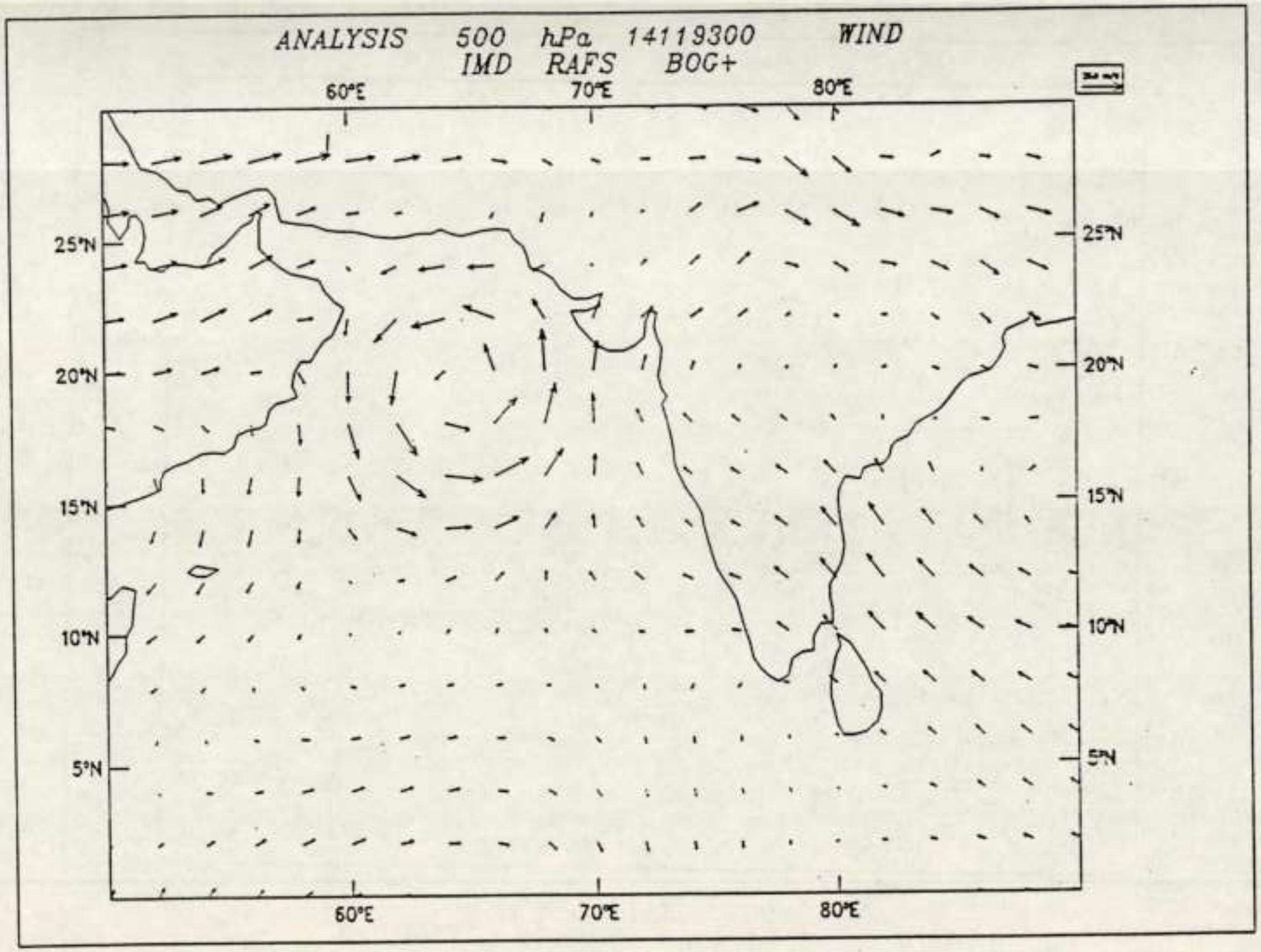

ANALYSIS 500 hPa 14119300 WIND
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 25 (a)

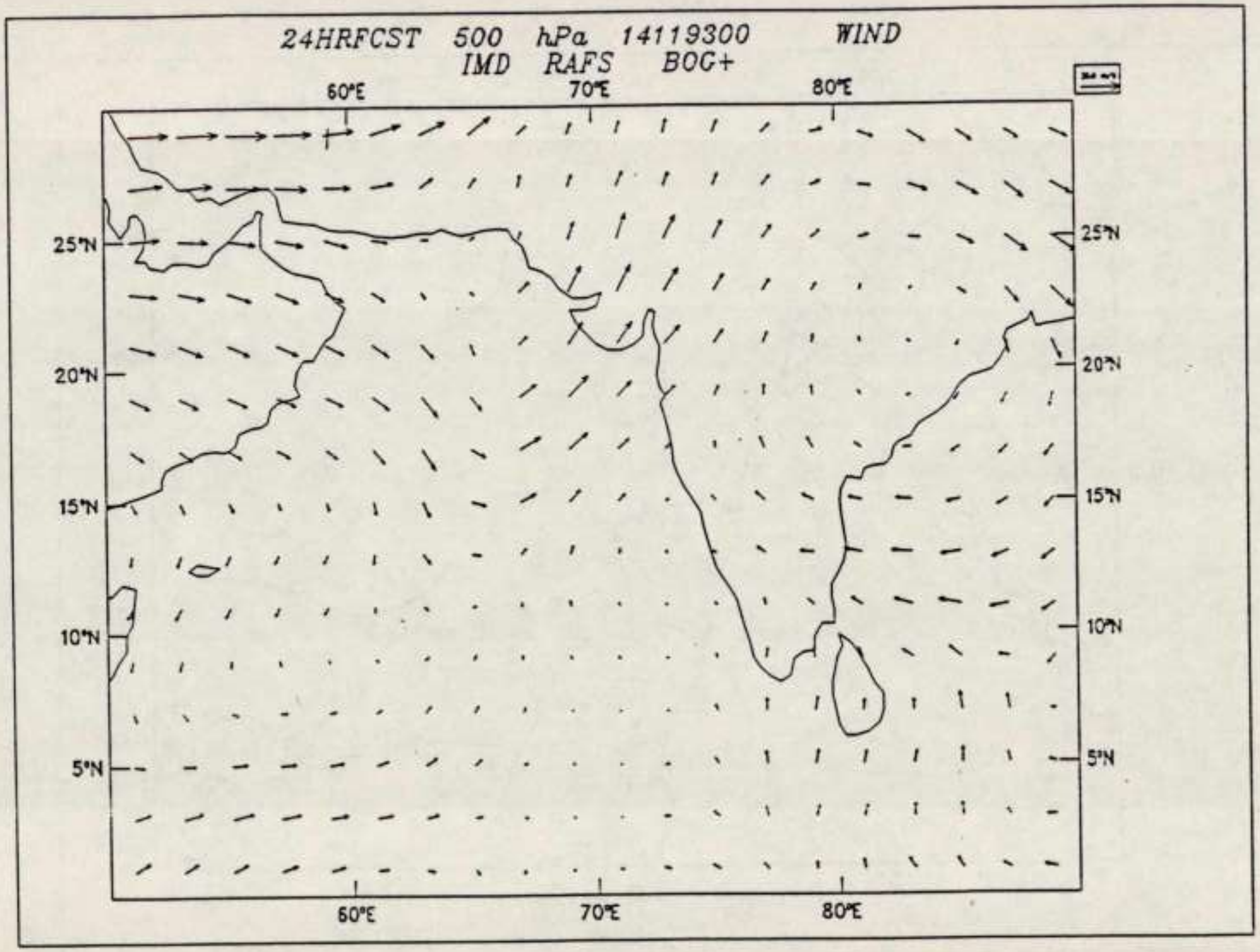

24HRFCST 500 hPa 14119300 WIND
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 25 (b)

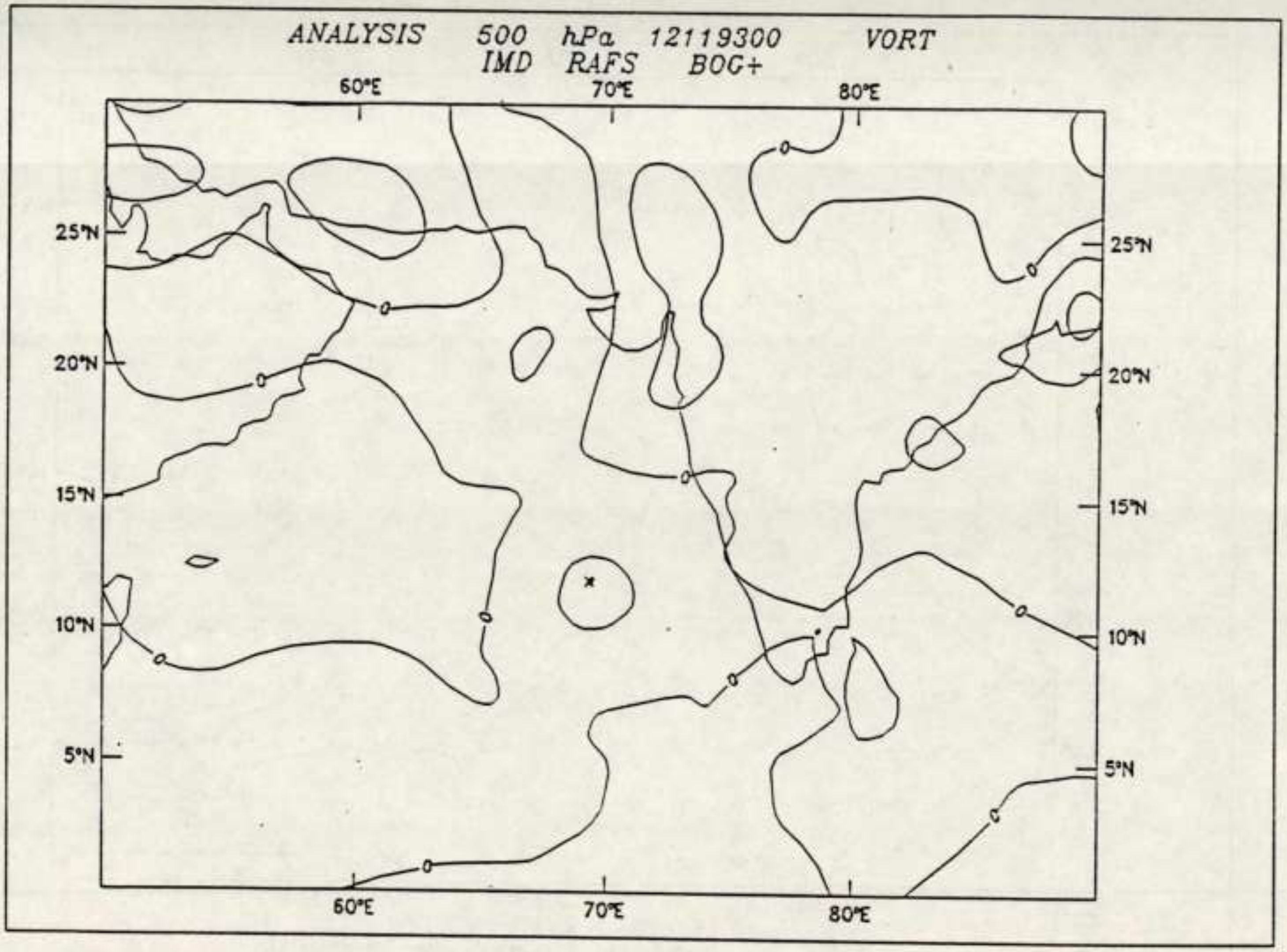

ANALYSIS 500 hPa 12119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 26 (a)

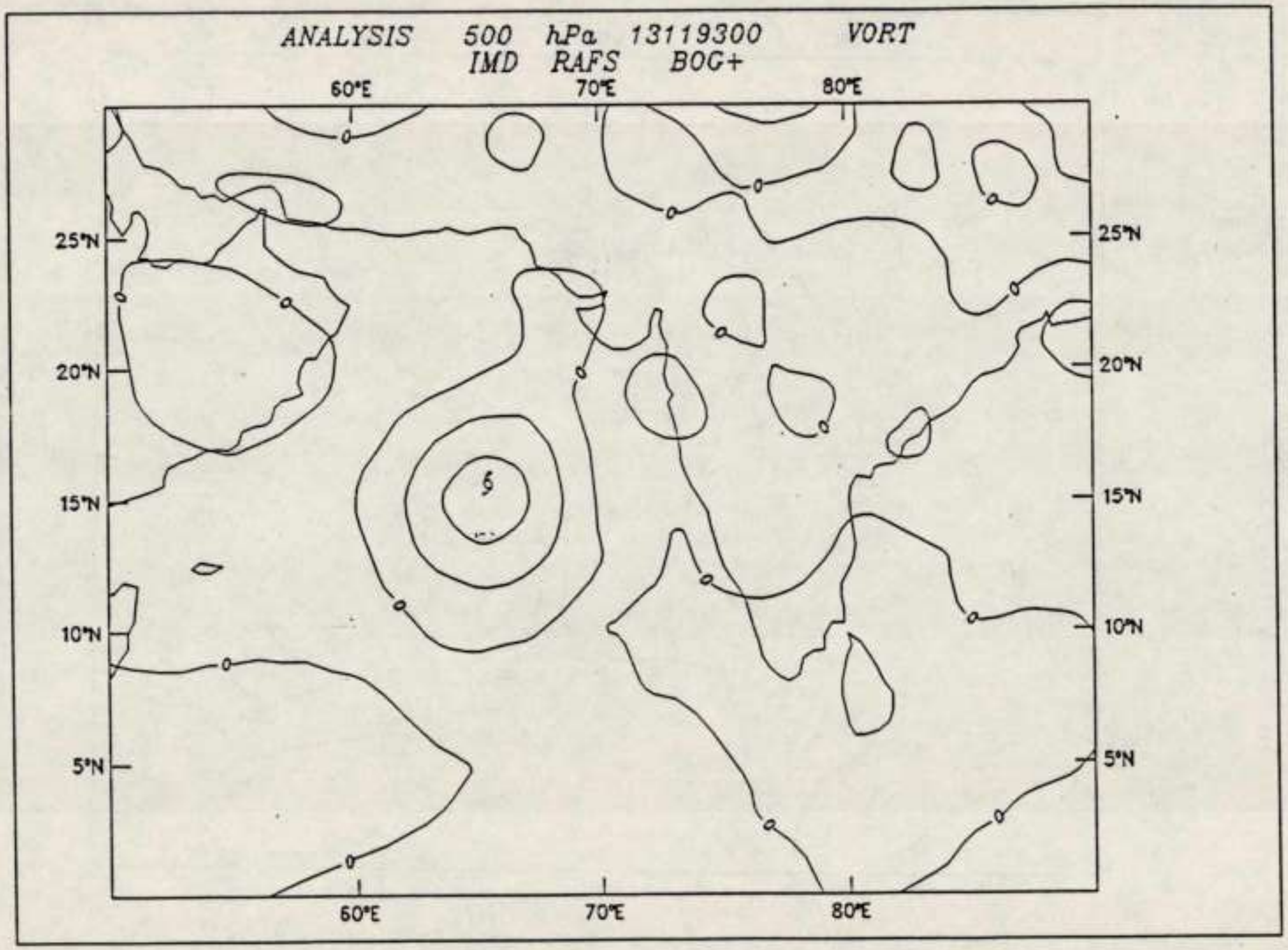
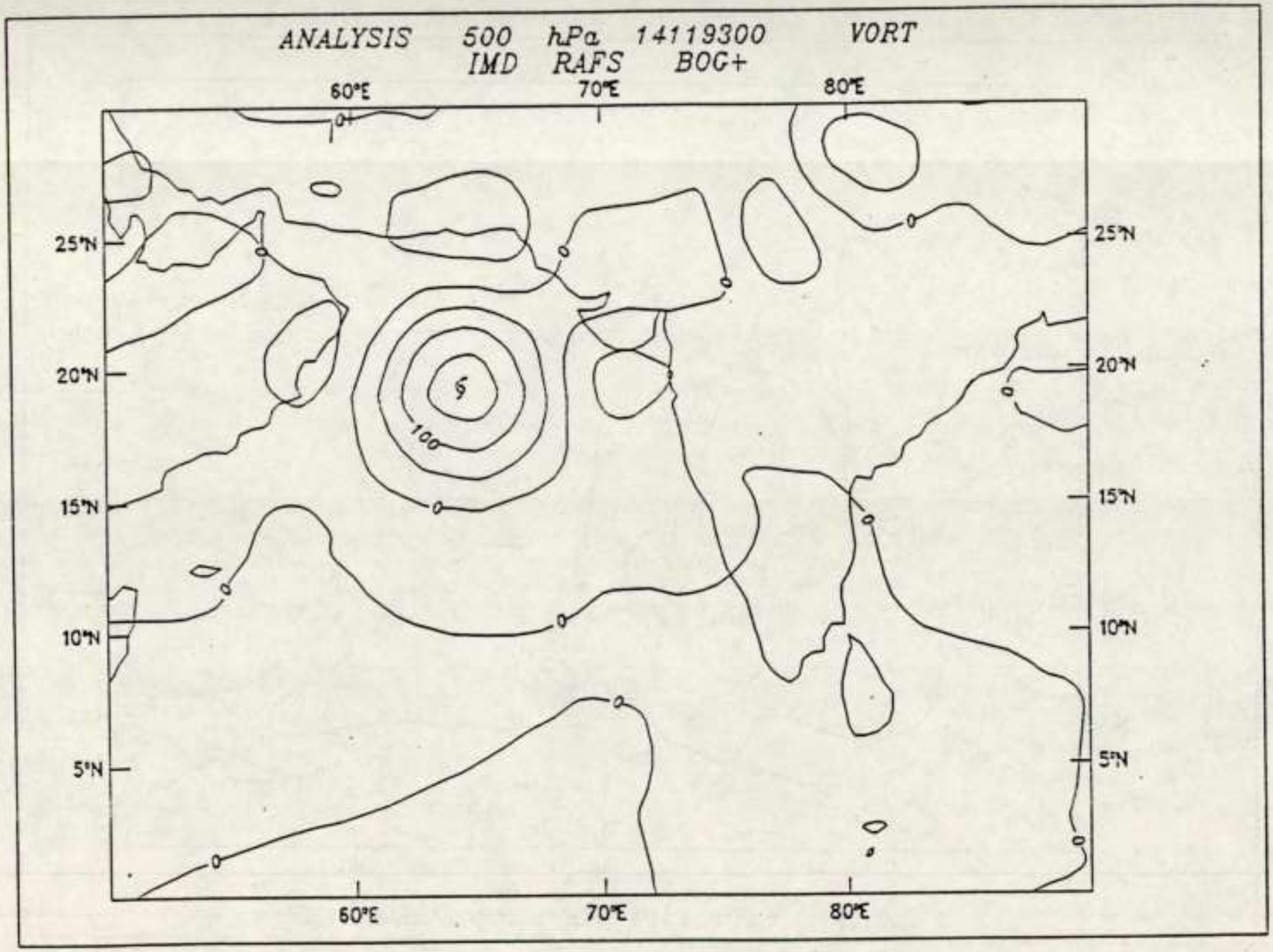

ANALYSIS 500 hPa 13119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
6

FIG. 26(b)



ANALYSIS 500 hPa 14119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
100
0

FIG. 26 (c)

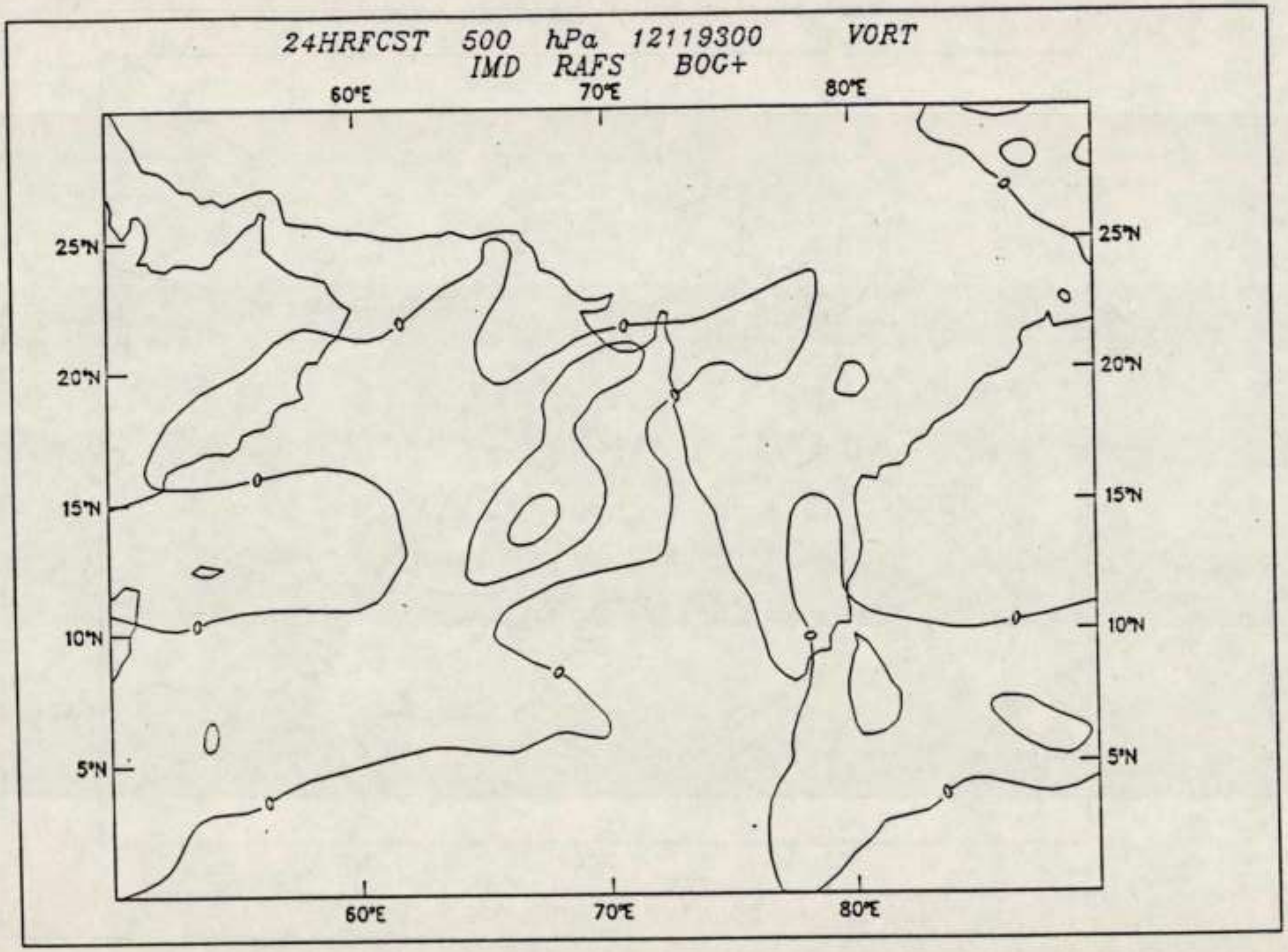

24HRFCST 500 hPa 12119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
0
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 27 (a)

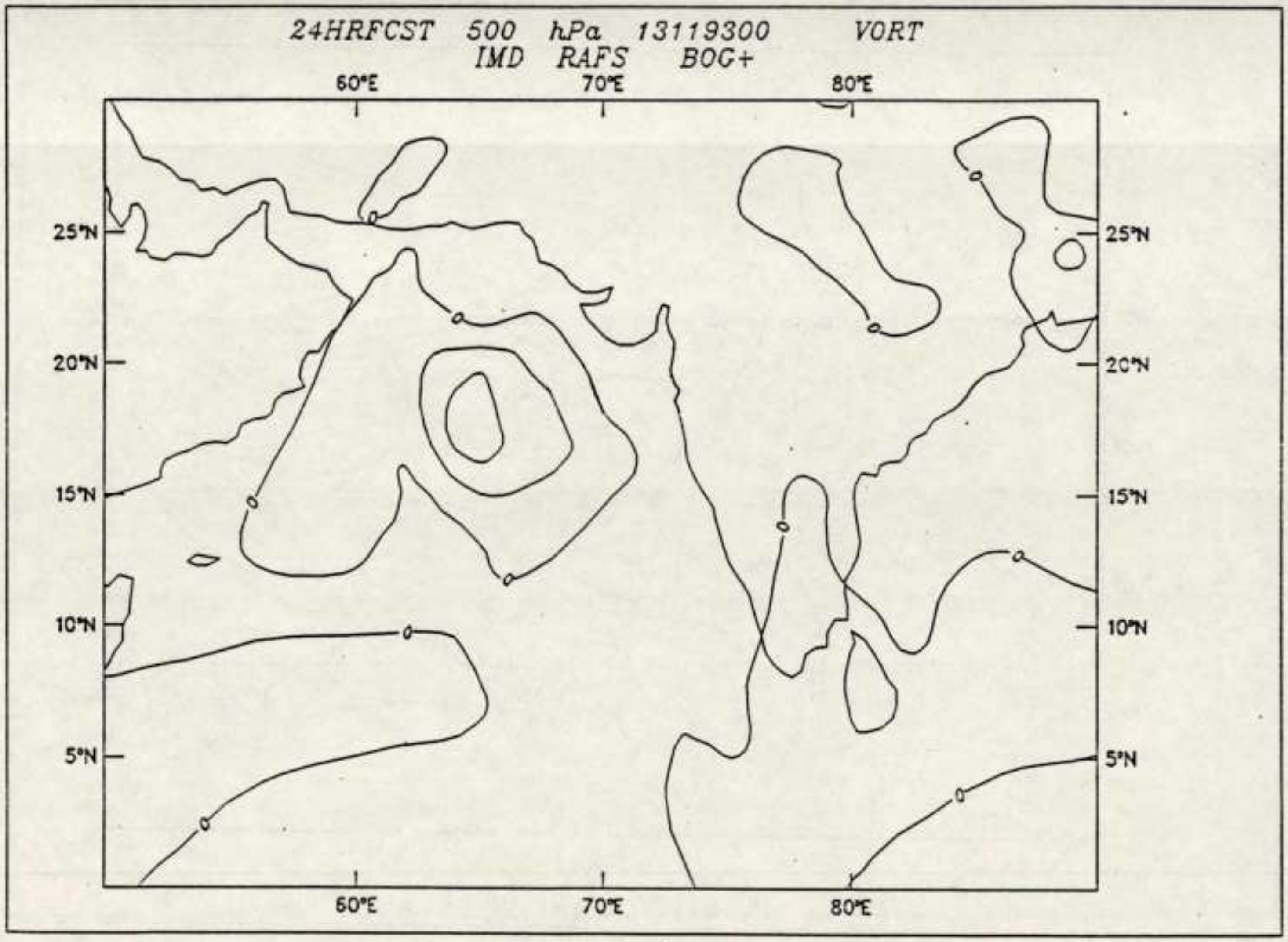

24HRFCST 500 hPa 13119300 VORT
IMD RAFS BOG+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N
0

FIG. 27(b)

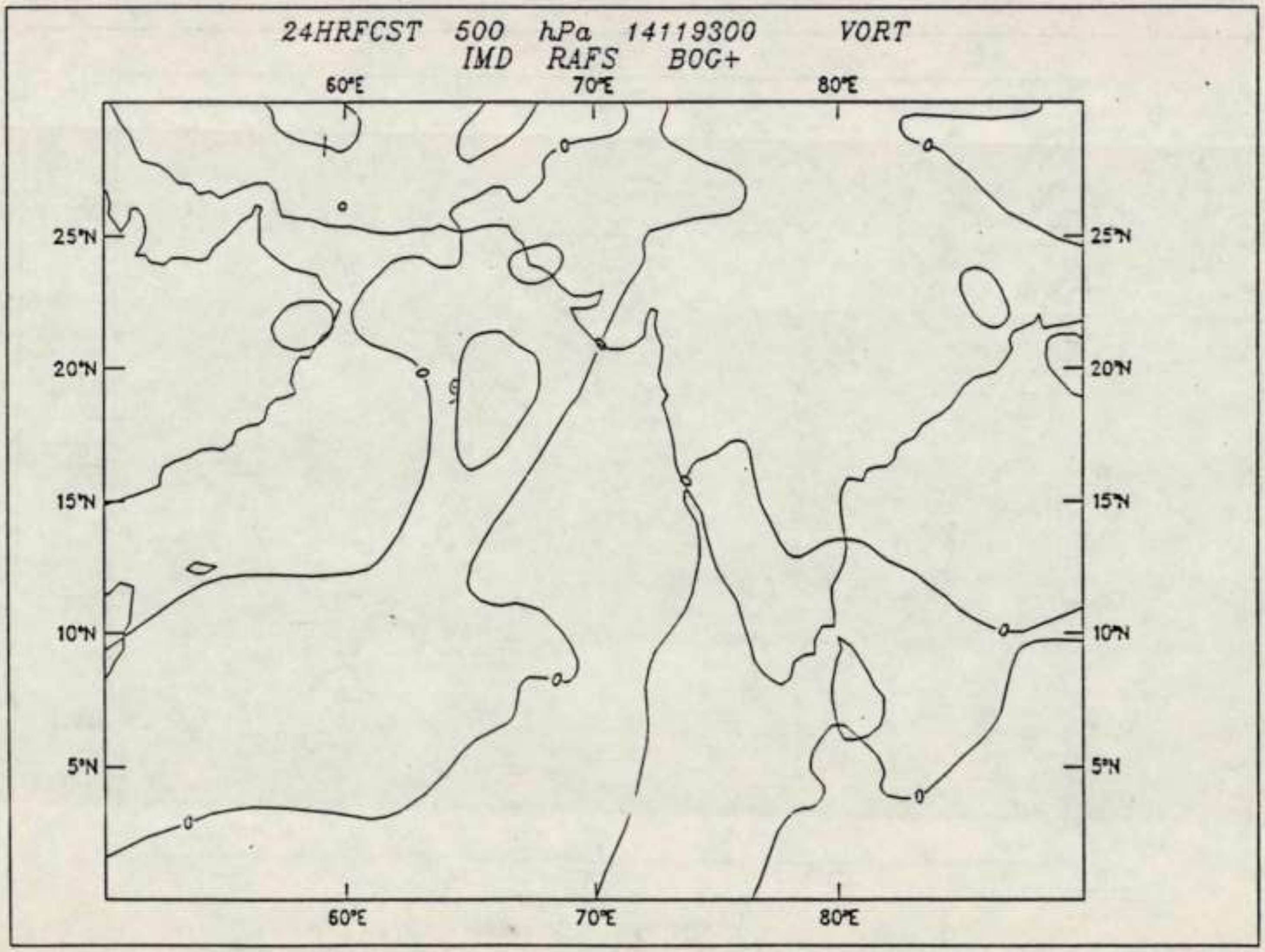

24HRFCST 500 hPa 14119300 VORT
IMD RAFS BOC+
60°E
70°E
80°E
25°N
20°N
15°N
10°N
5°N

FIG. 27(c)

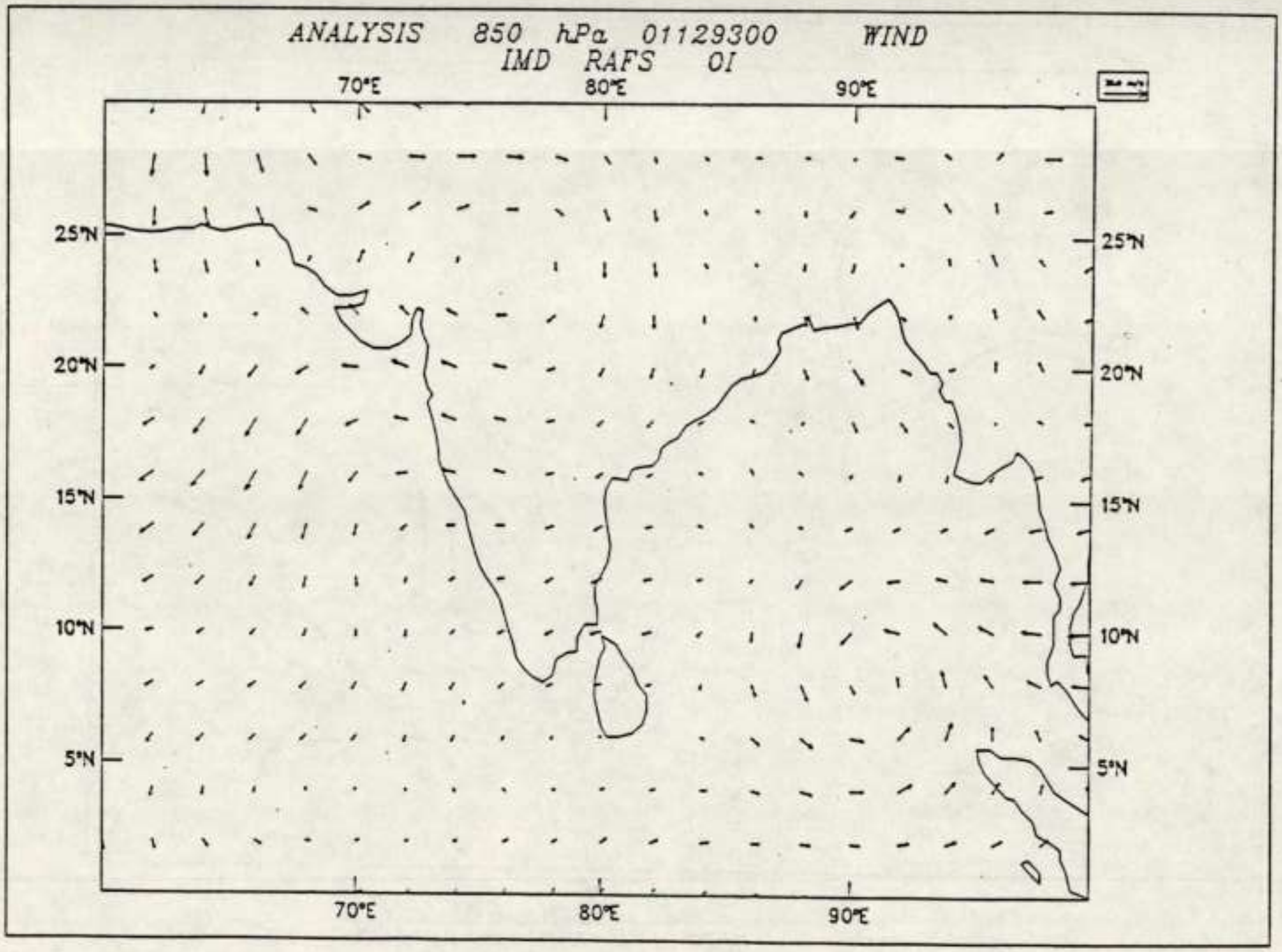

ANALYSIS 850 hPa 01129300 WIND
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 28(a)

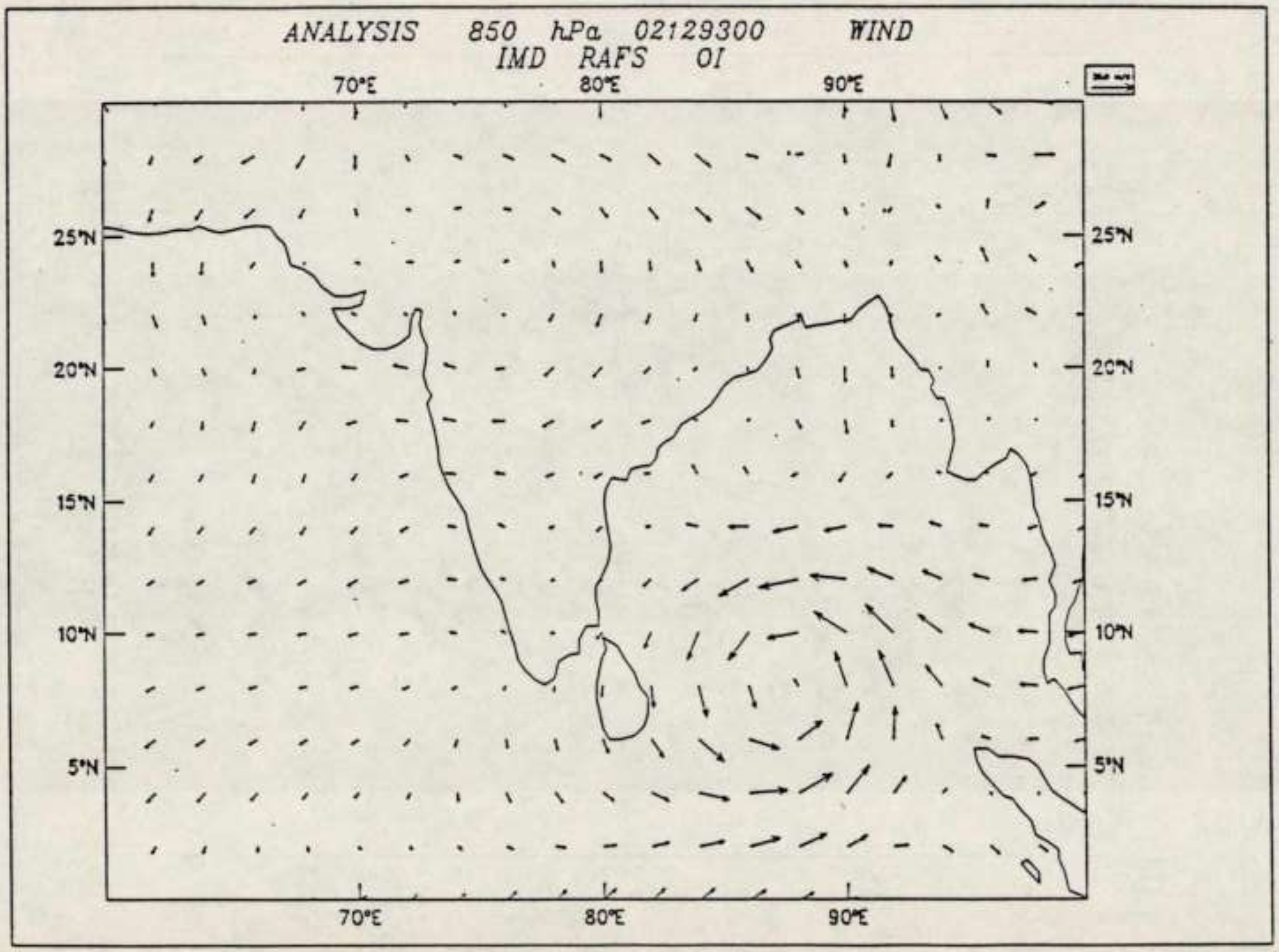

ANALYSIS 850 hPa 02129300 WIND
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 28(b)

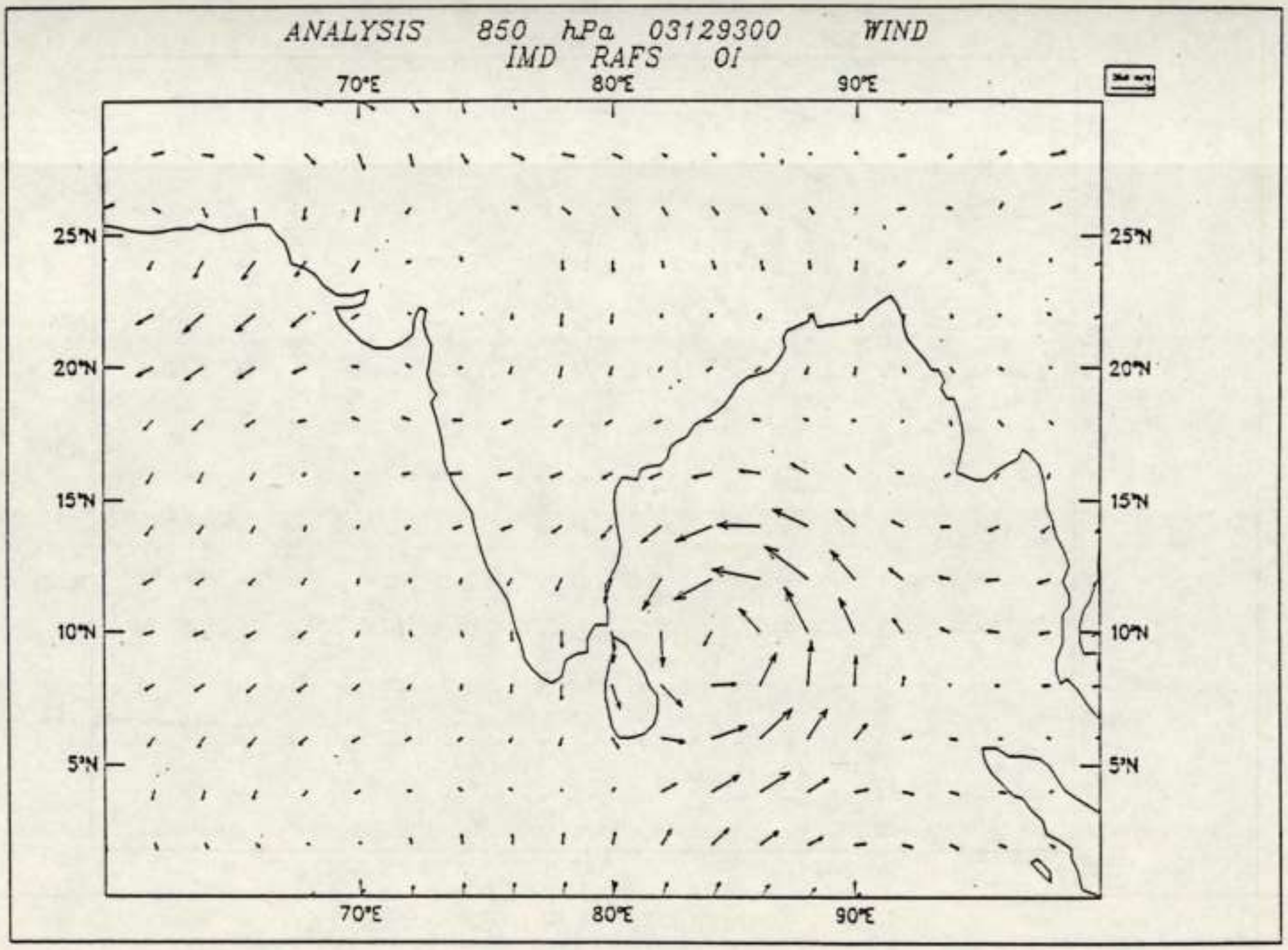

ANALYSIS 850 hPa 03129300 WIND
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 28(c)

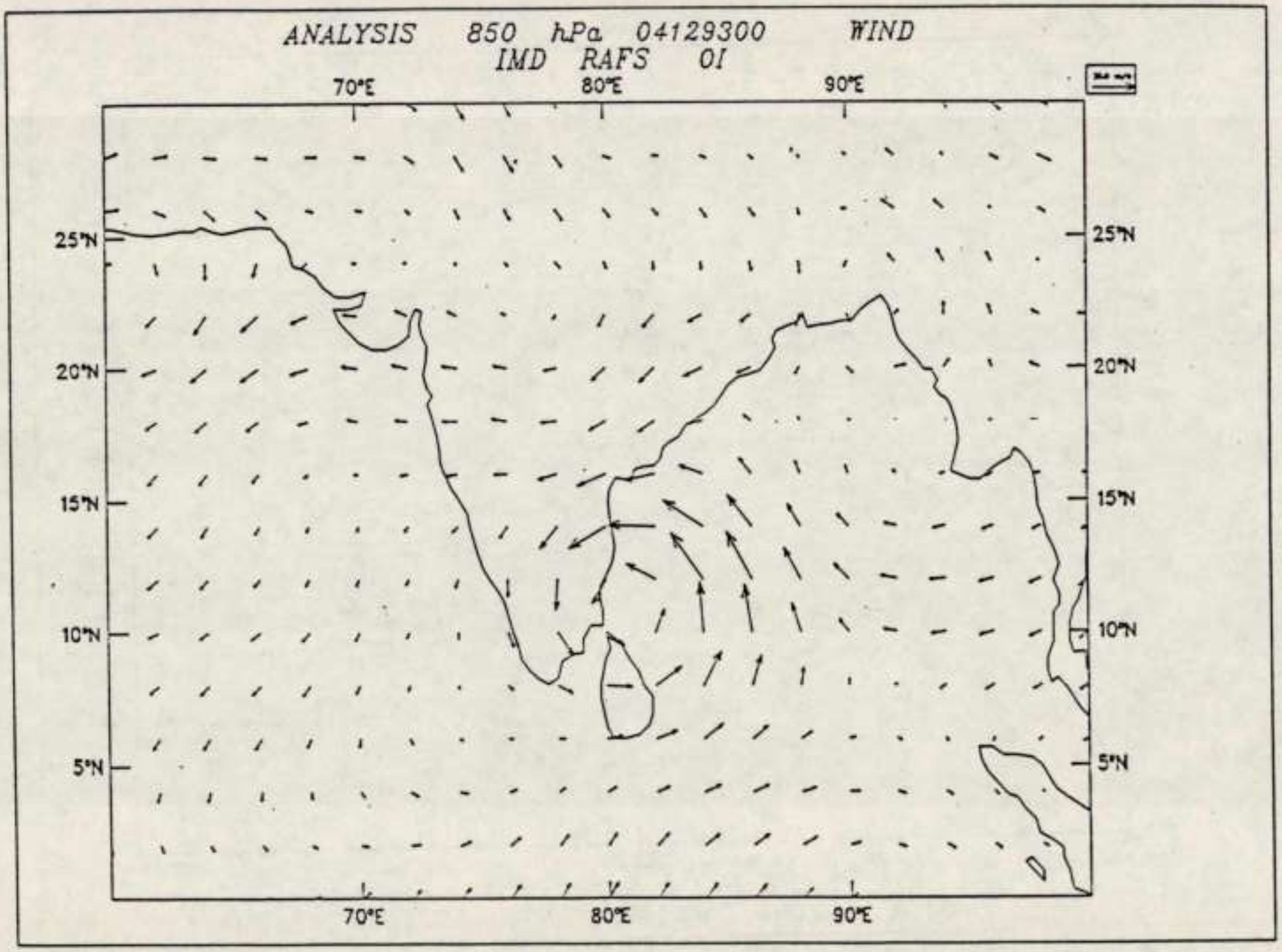

ANALYSIS 850 hPa 04129300 WIND
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 28 (d)

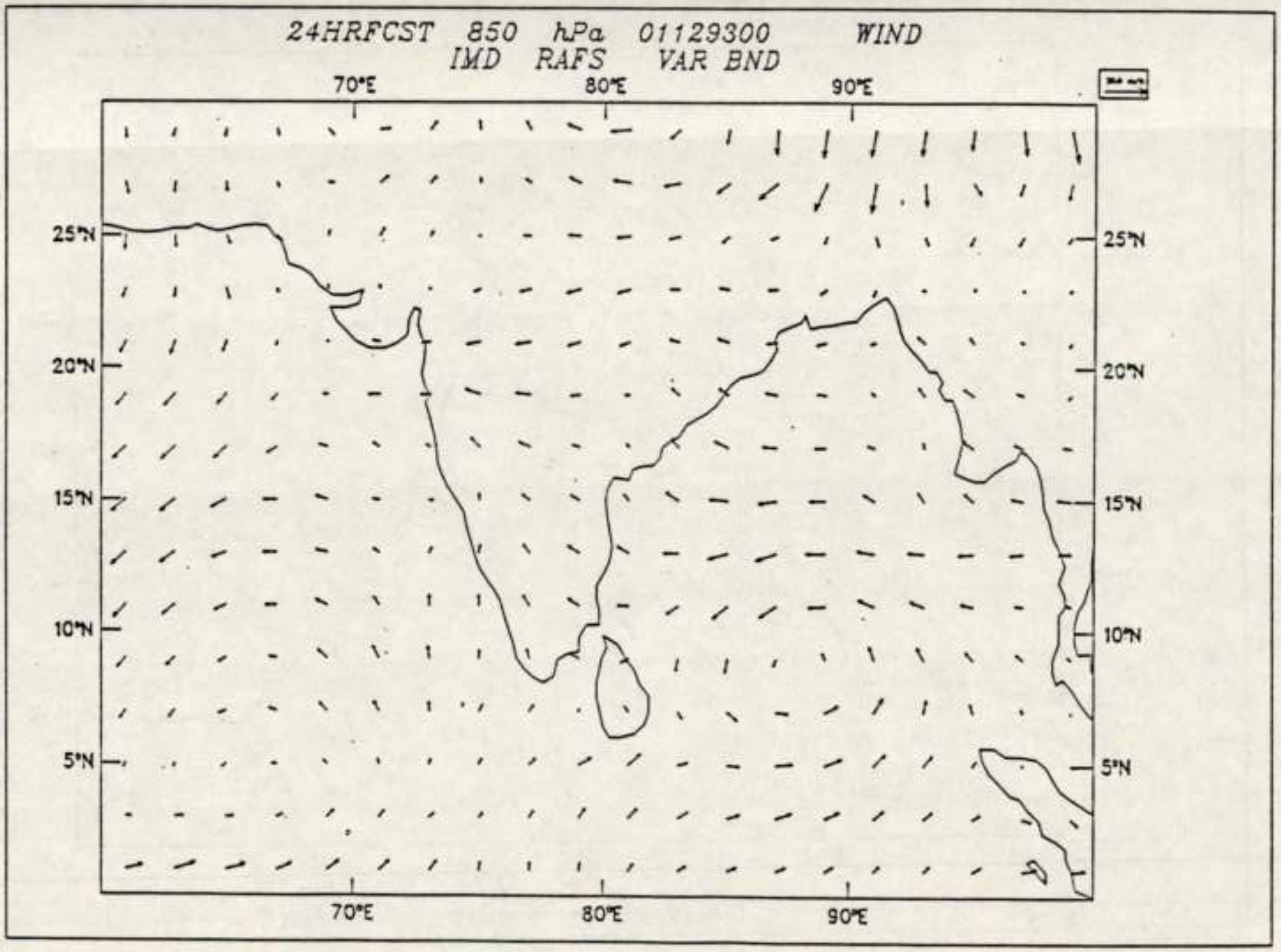

24HRFCST 850 hPa 01129300 WIND
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 29 (a)

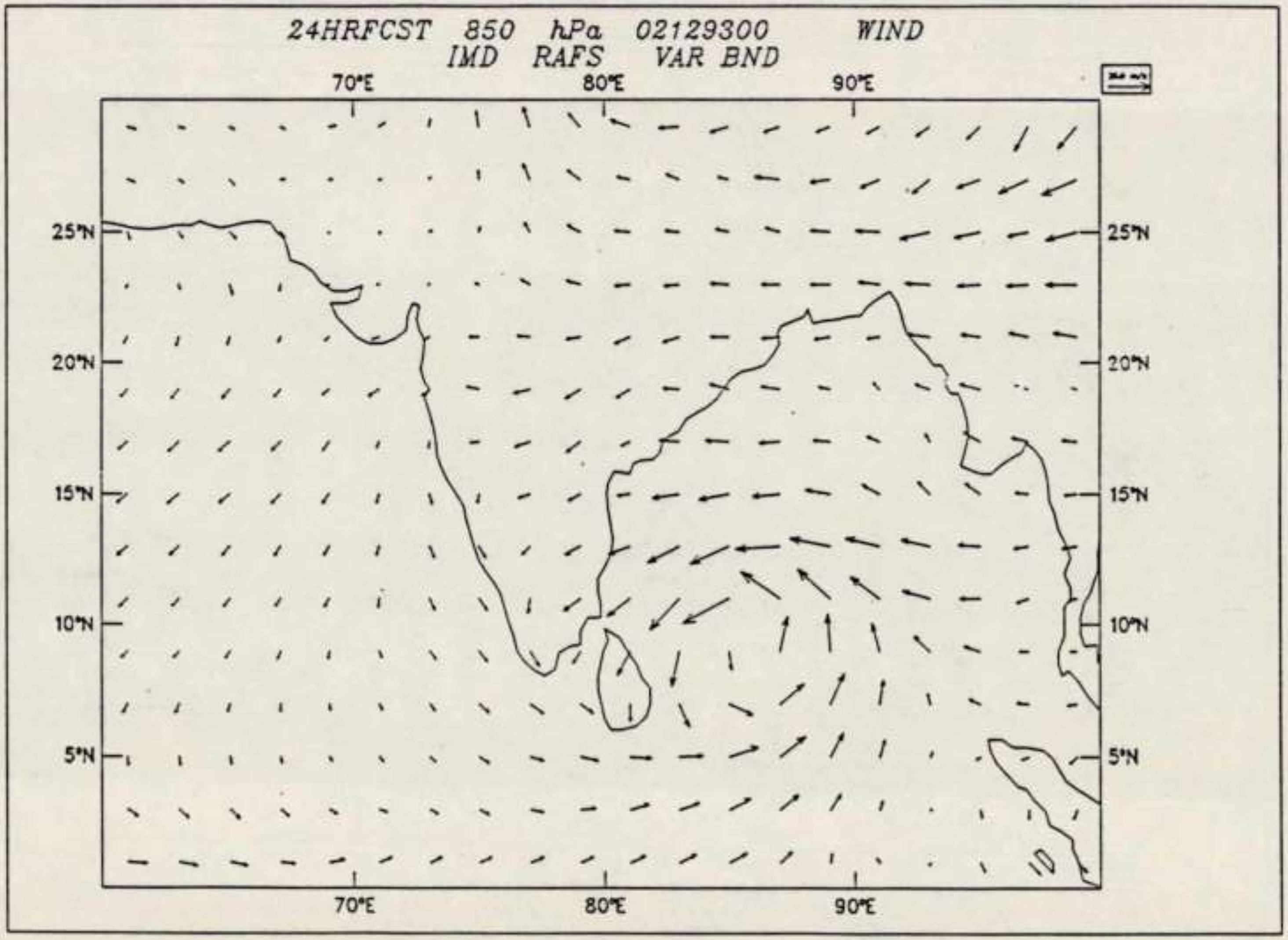

24HRFCST 850 hPa 02129300 WIND
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 29(b)

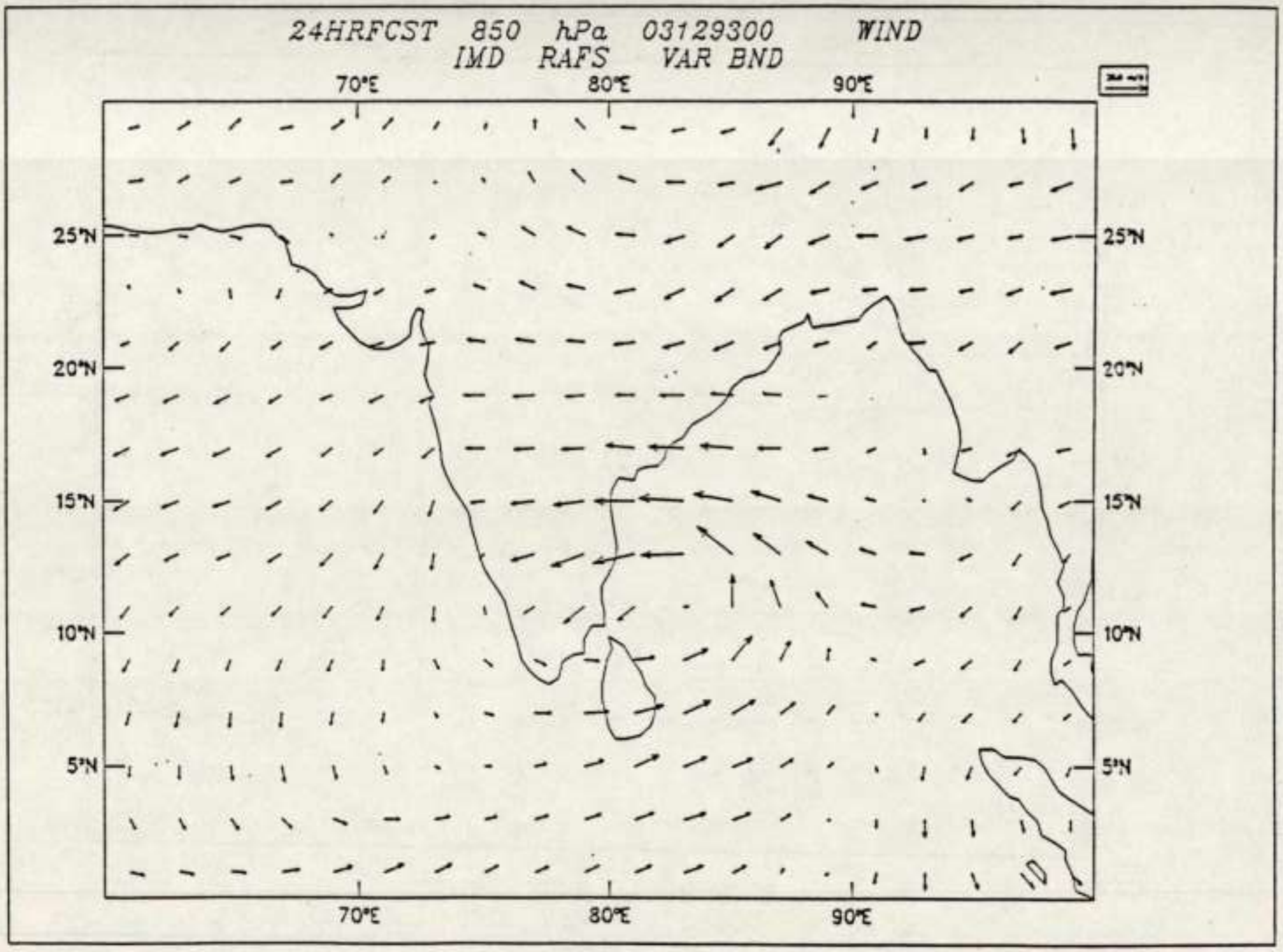
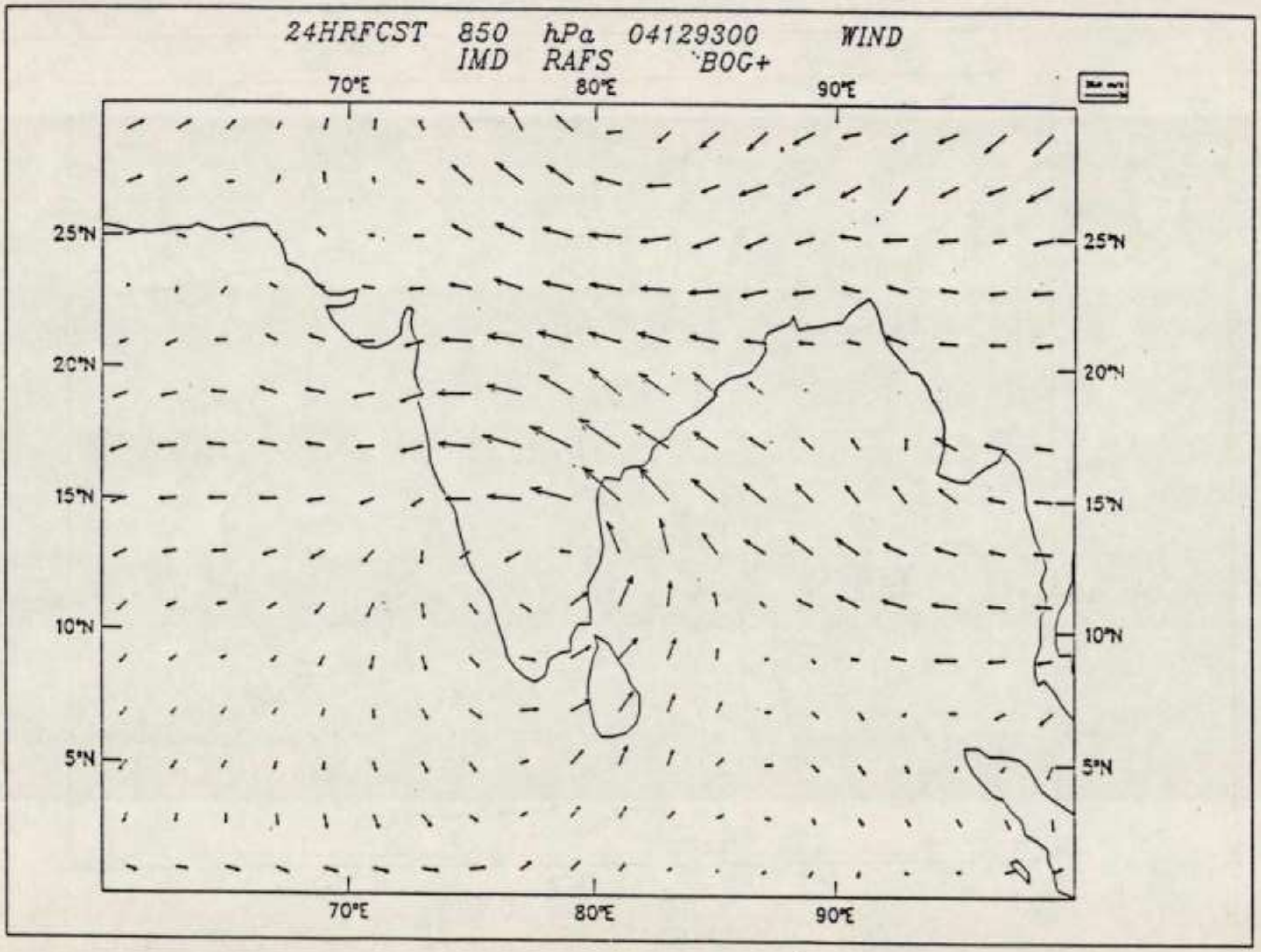

24HRFCST 850 hPa 03129300 WIND
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 29 (c)



24HRFCST 850 hPa 04129300 WIND
IMD RAFS BOG+
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 29 (d)

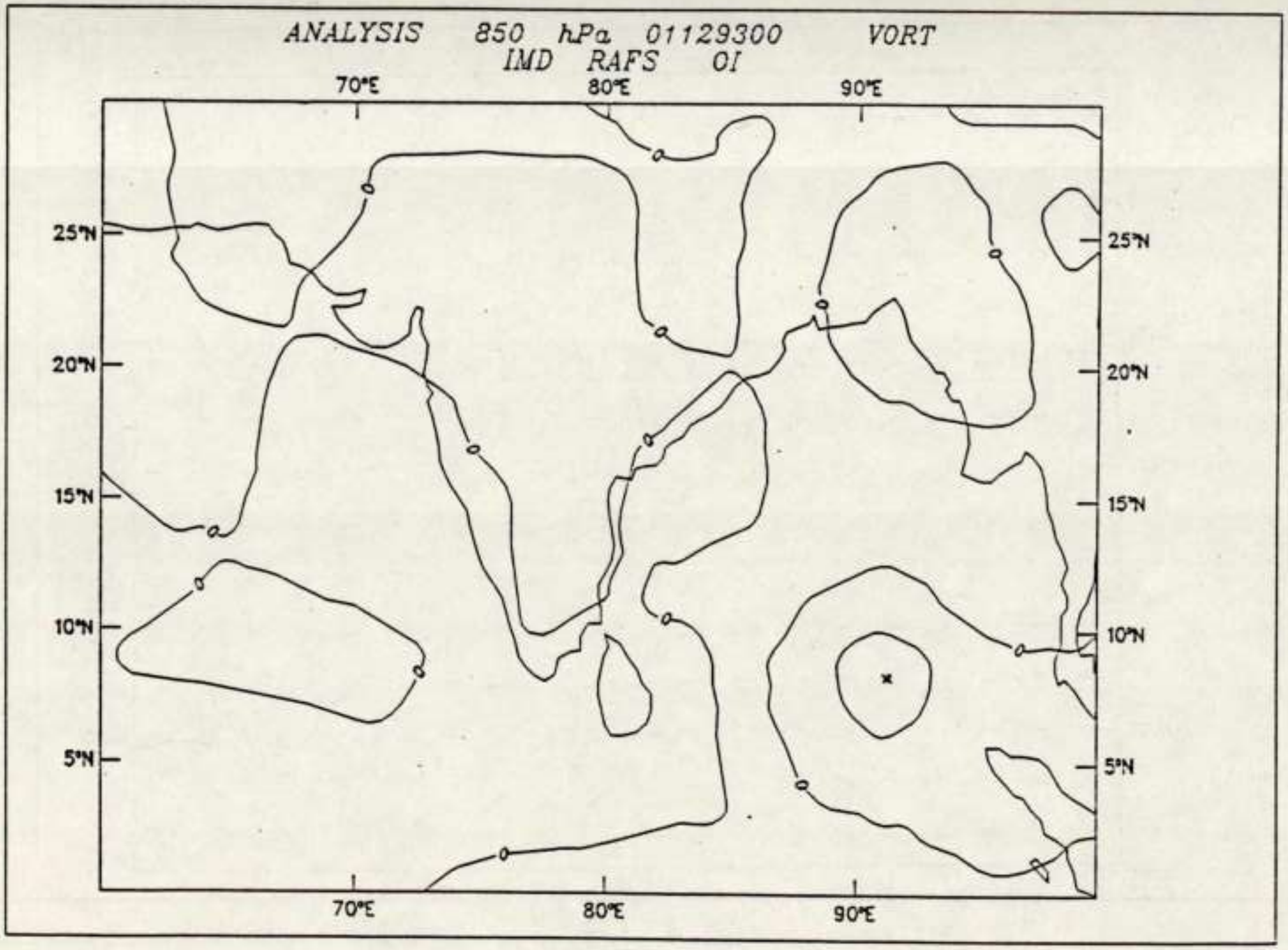
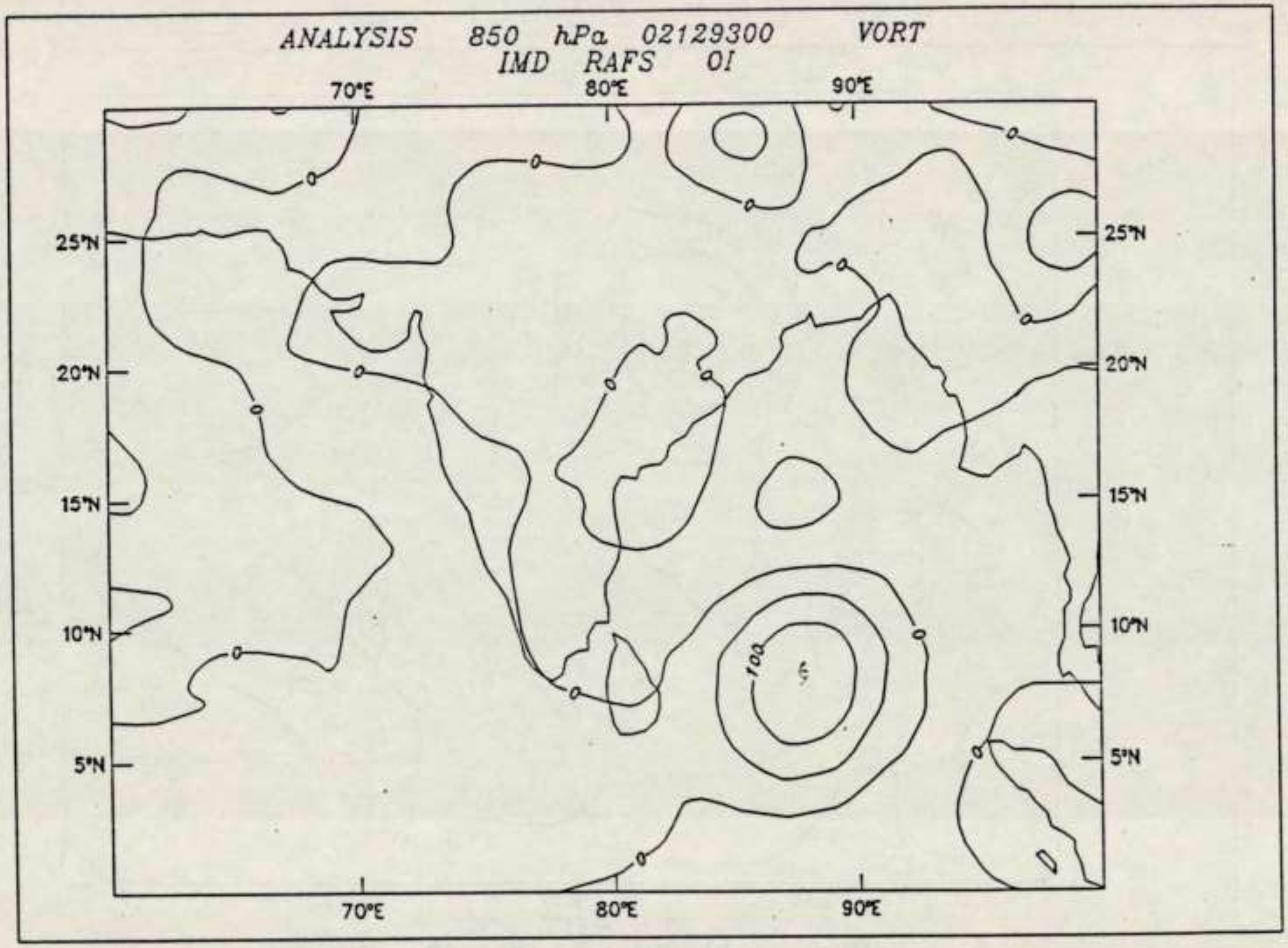

ANALYSIS 850 hPa 01129300 VORT
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
0
x

FIG. 30(a)



ANALYSIS 850 hPa 02129300 VORT
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
0
100

FIG. 30 (b)

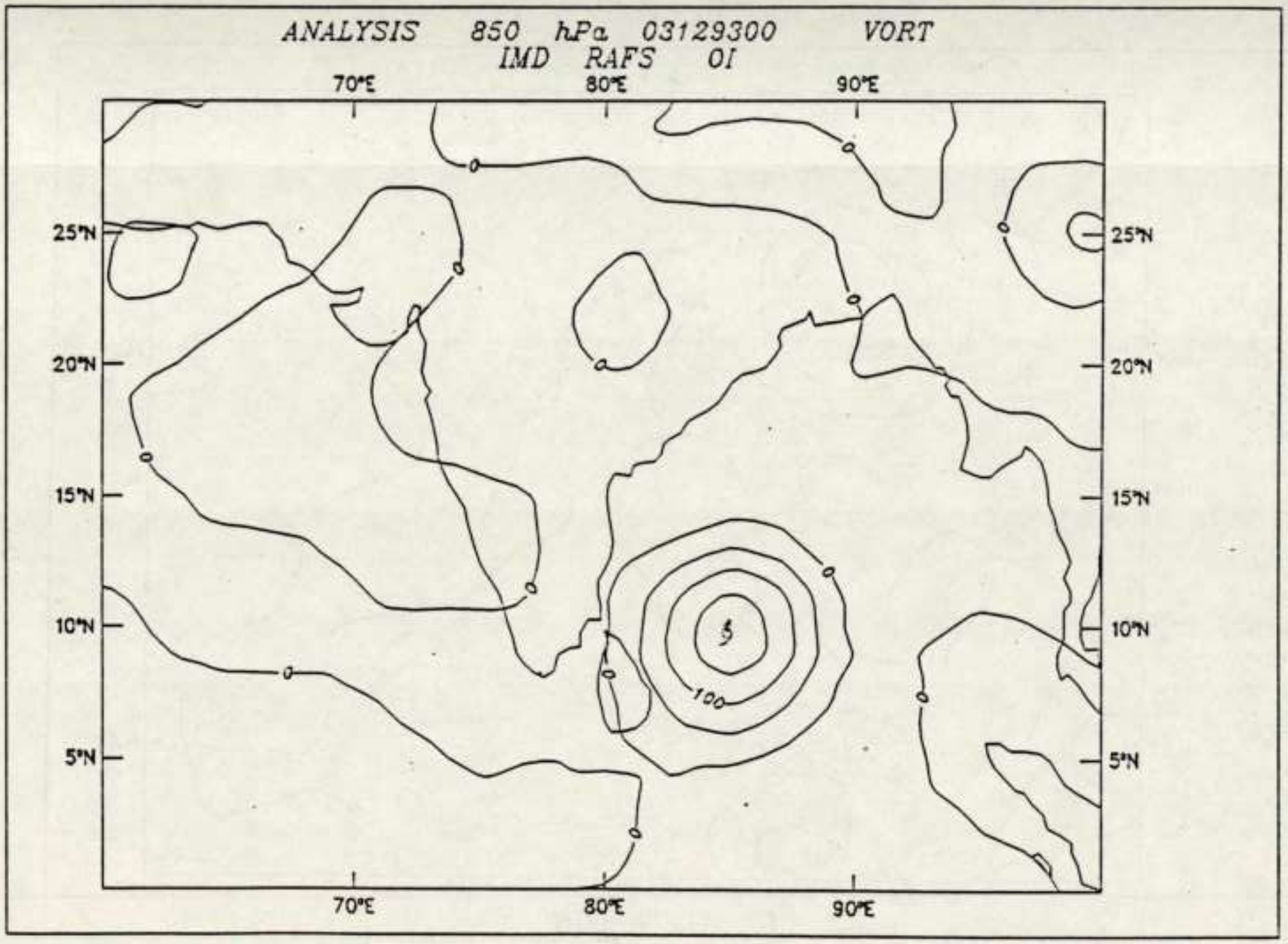

ANALYSIS 850 hPa 03129300 VORT
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 30 (c)

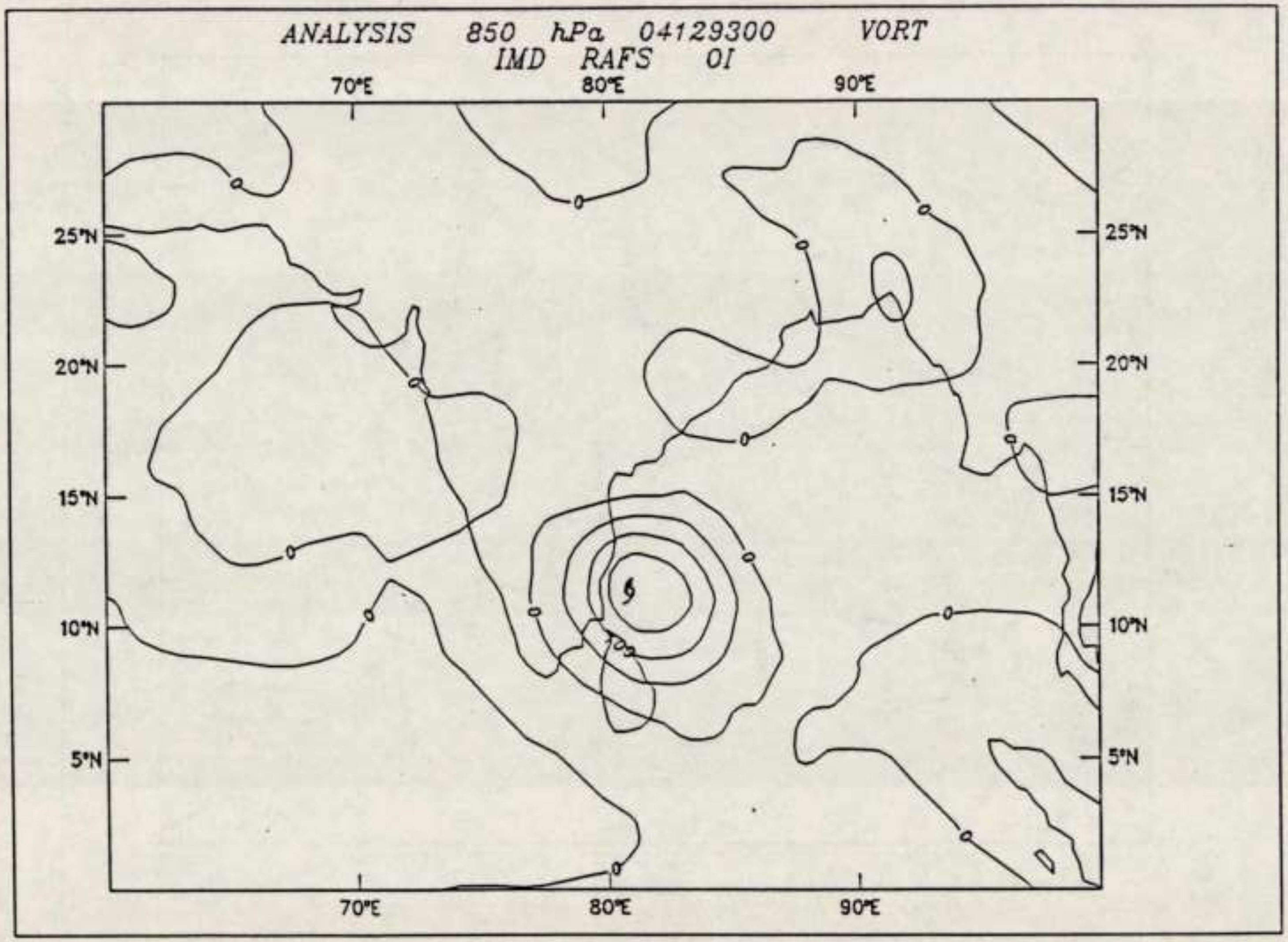

ANALYSIS 850 hPa 04129300 VORT
IMD RAFS OI
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
0
6

FIG. 30 (d)

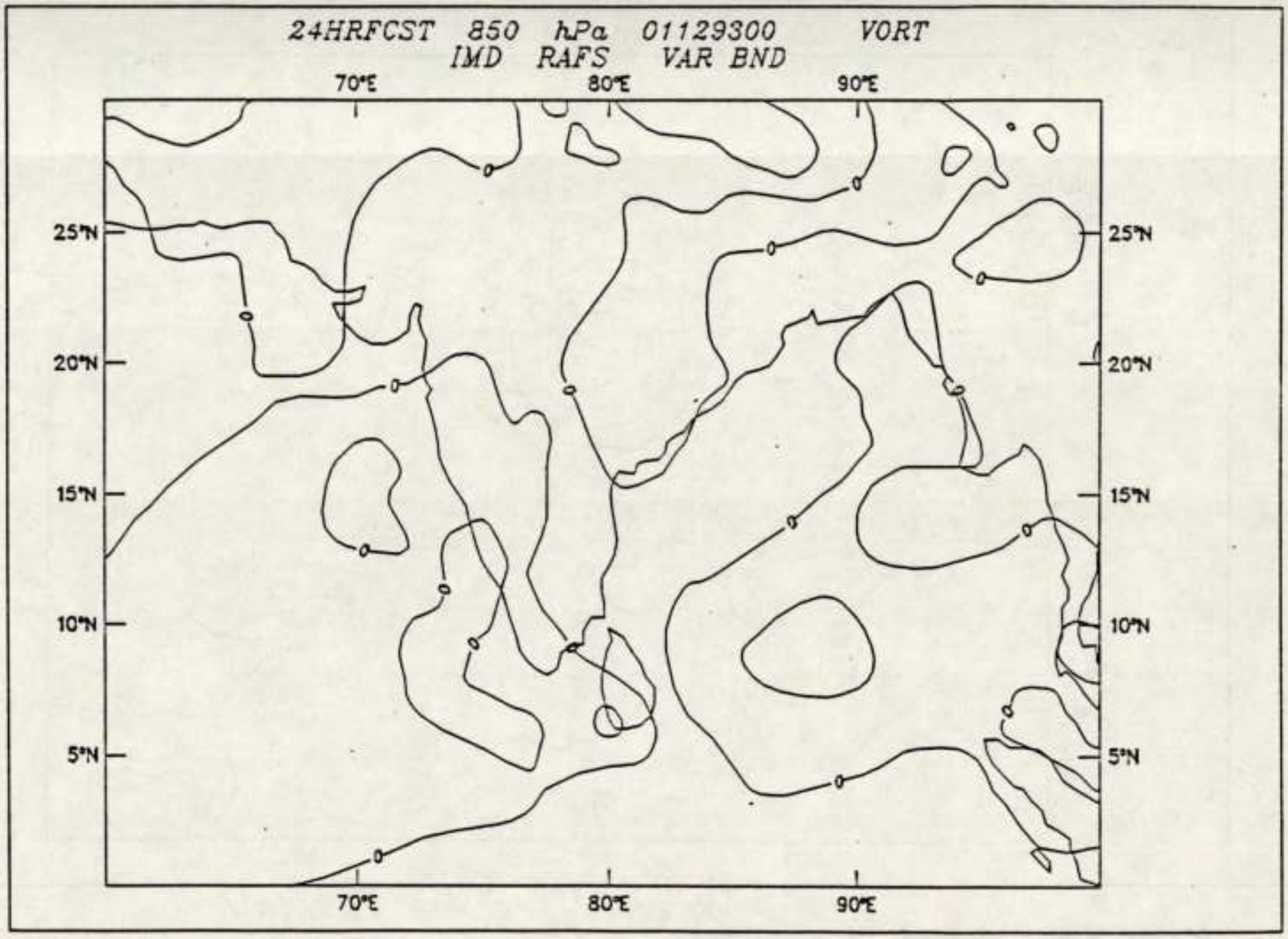
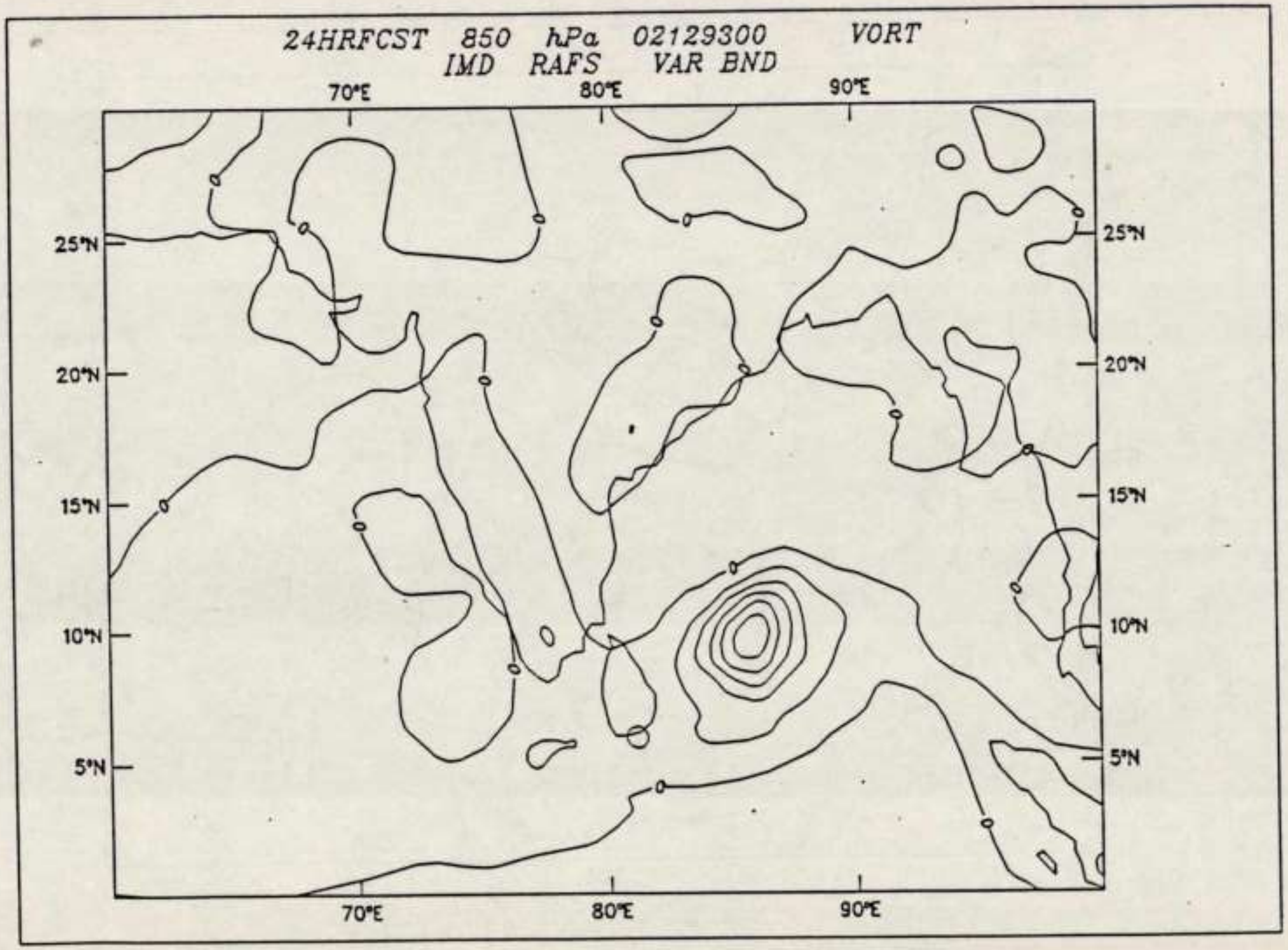

24HRFCST 850 hPa 01129300 VORT
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 31 (a)


24HRFCST 850 hPa 02129300 VORT
IMD RAFS VAR BND
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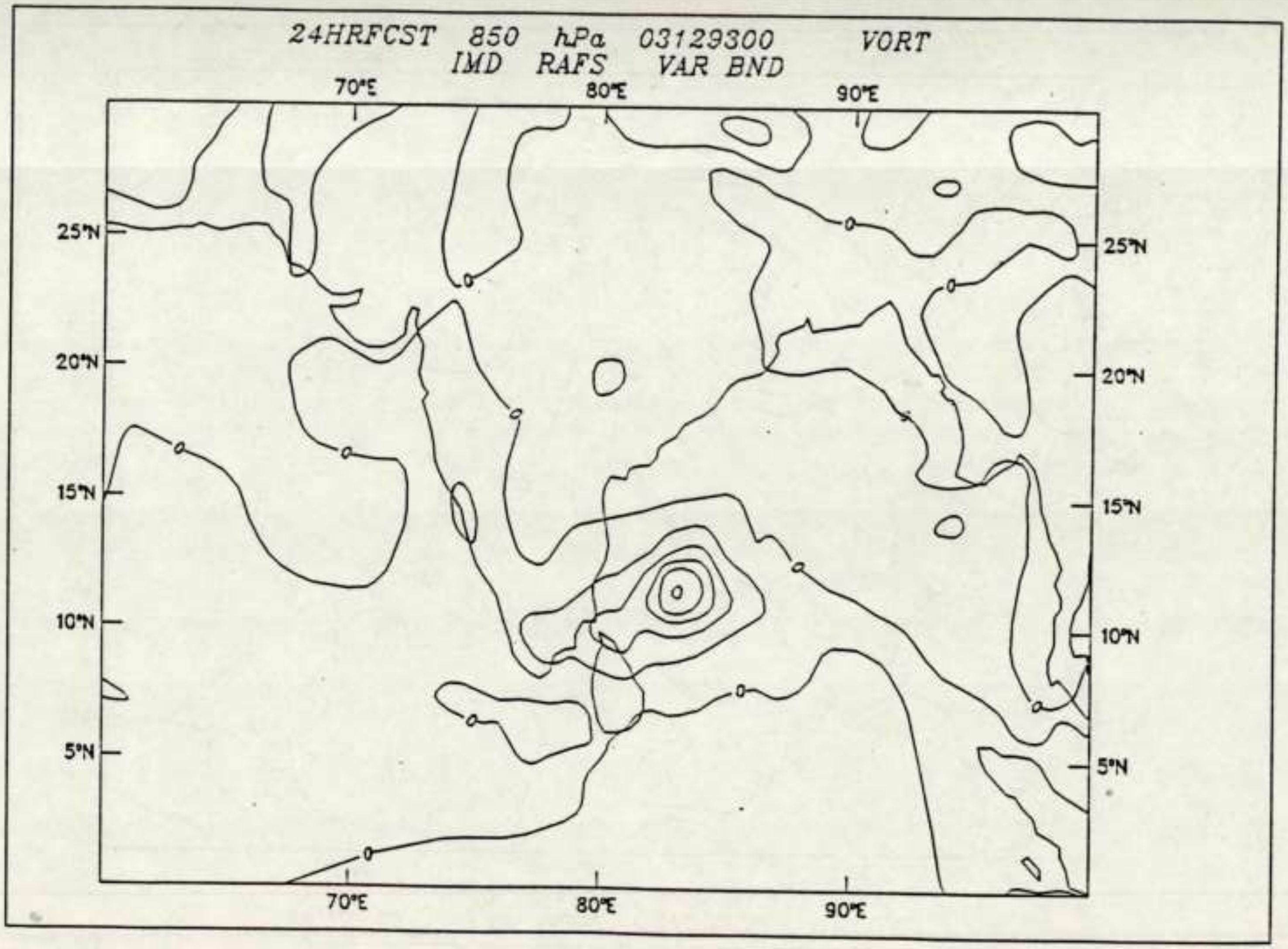
80°E
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 31(b)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IMD RAFS VAR BND
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90°E
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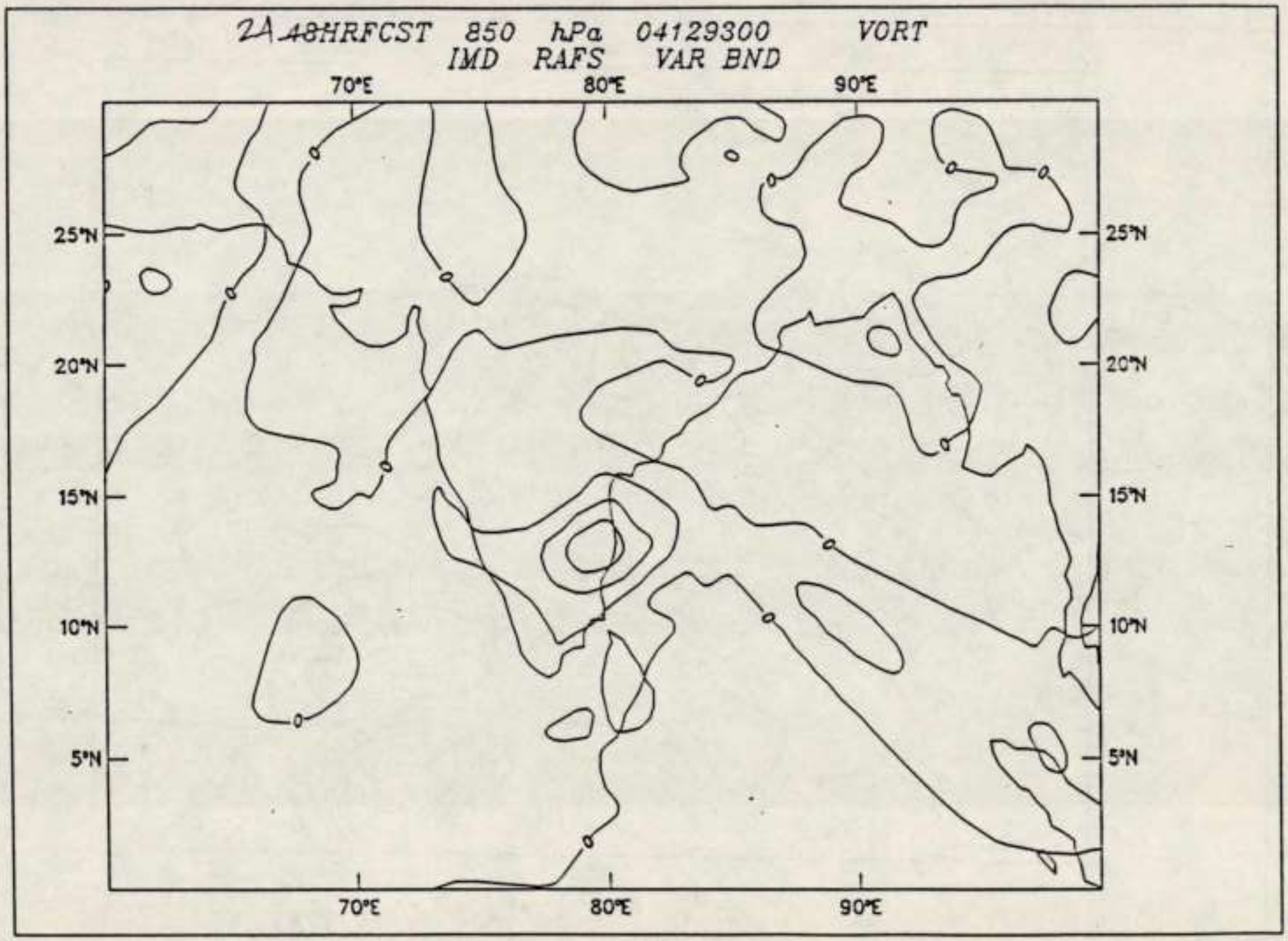
20°N
15°N
10°N
5°N

FIG. 31 (c)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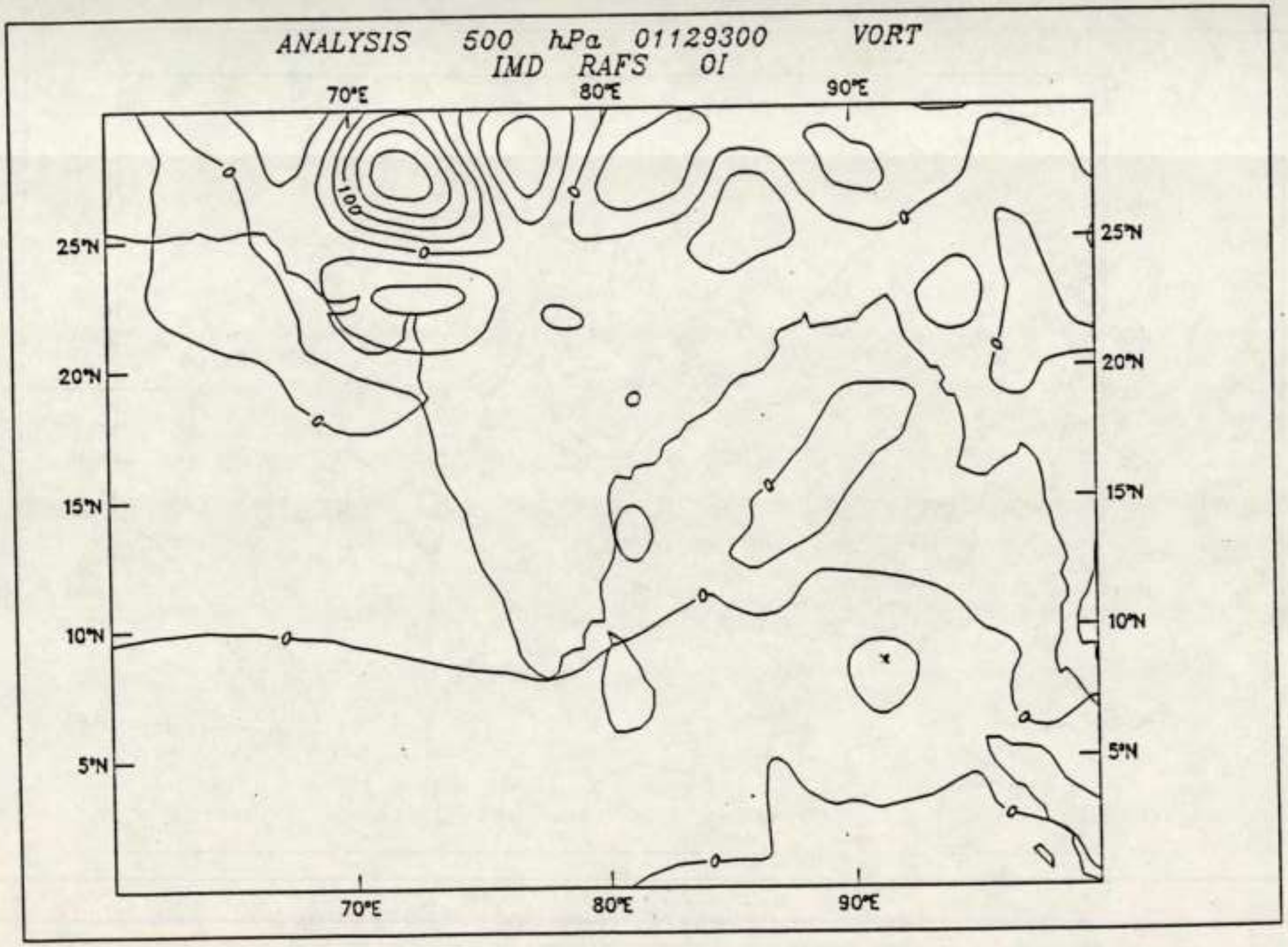
90°E
25°N
20°N
15°N
10°N
5°N

FIG. 31(d)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IMD RAFS OI
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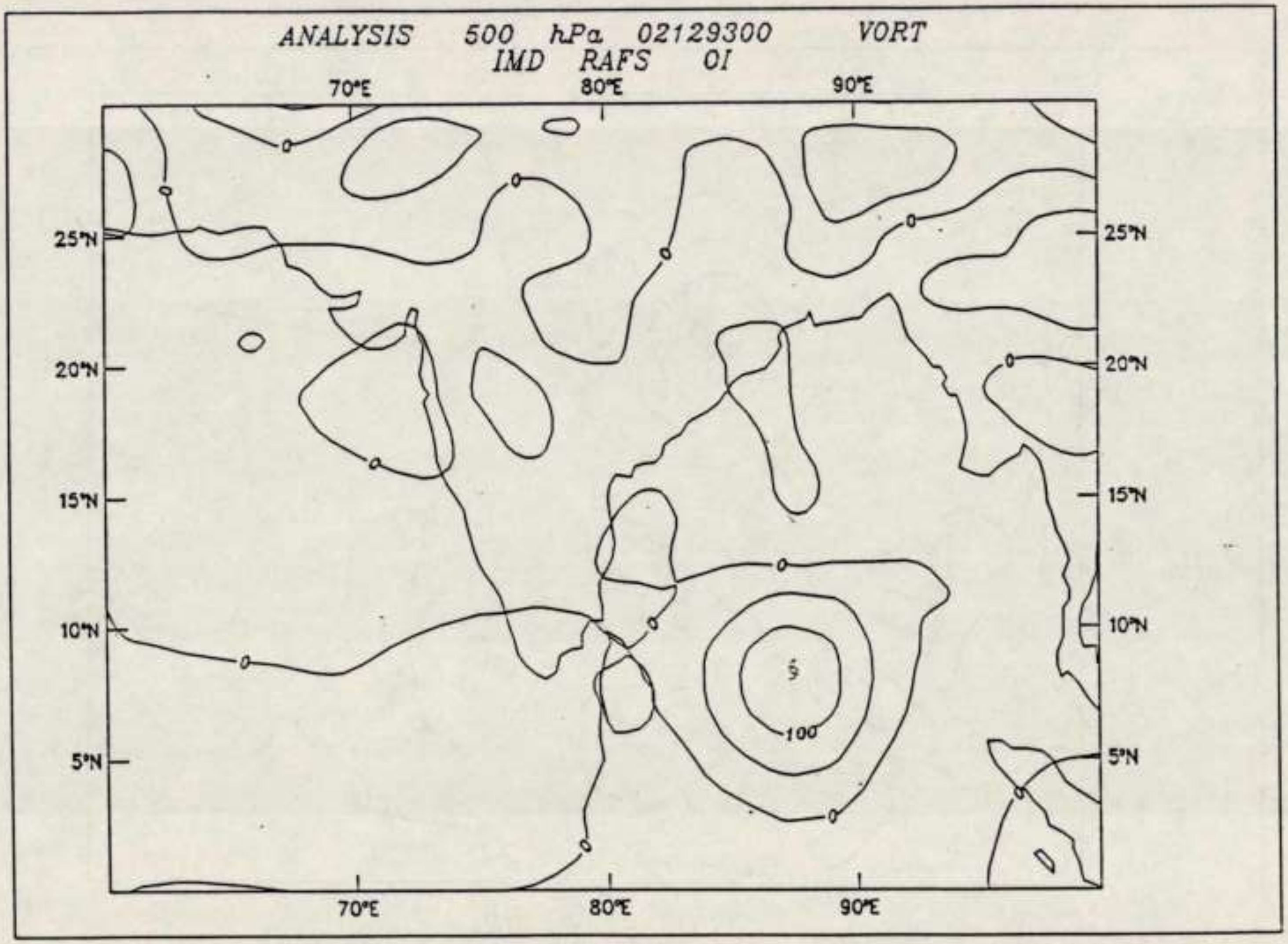
80°E
90°E
25°N
20°N
15°N
10°N
5°N
100
0

FIG. 32(a)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90°E
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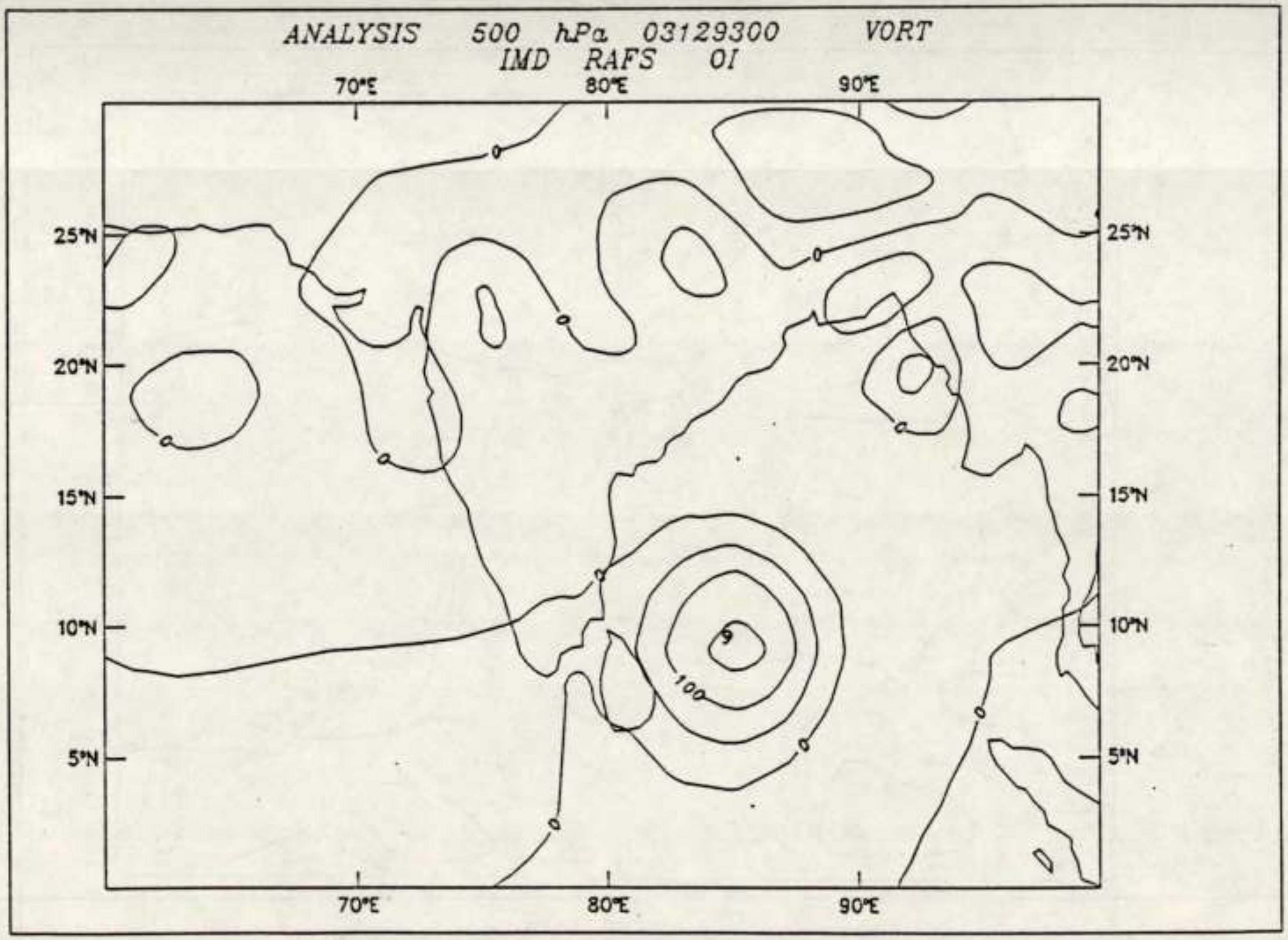
20°N
15°N
10°N
5°N
0
100

FIG. 32(b)



ANALYSIS 500 hPa 03129300 VORT
IMD RAFS OI
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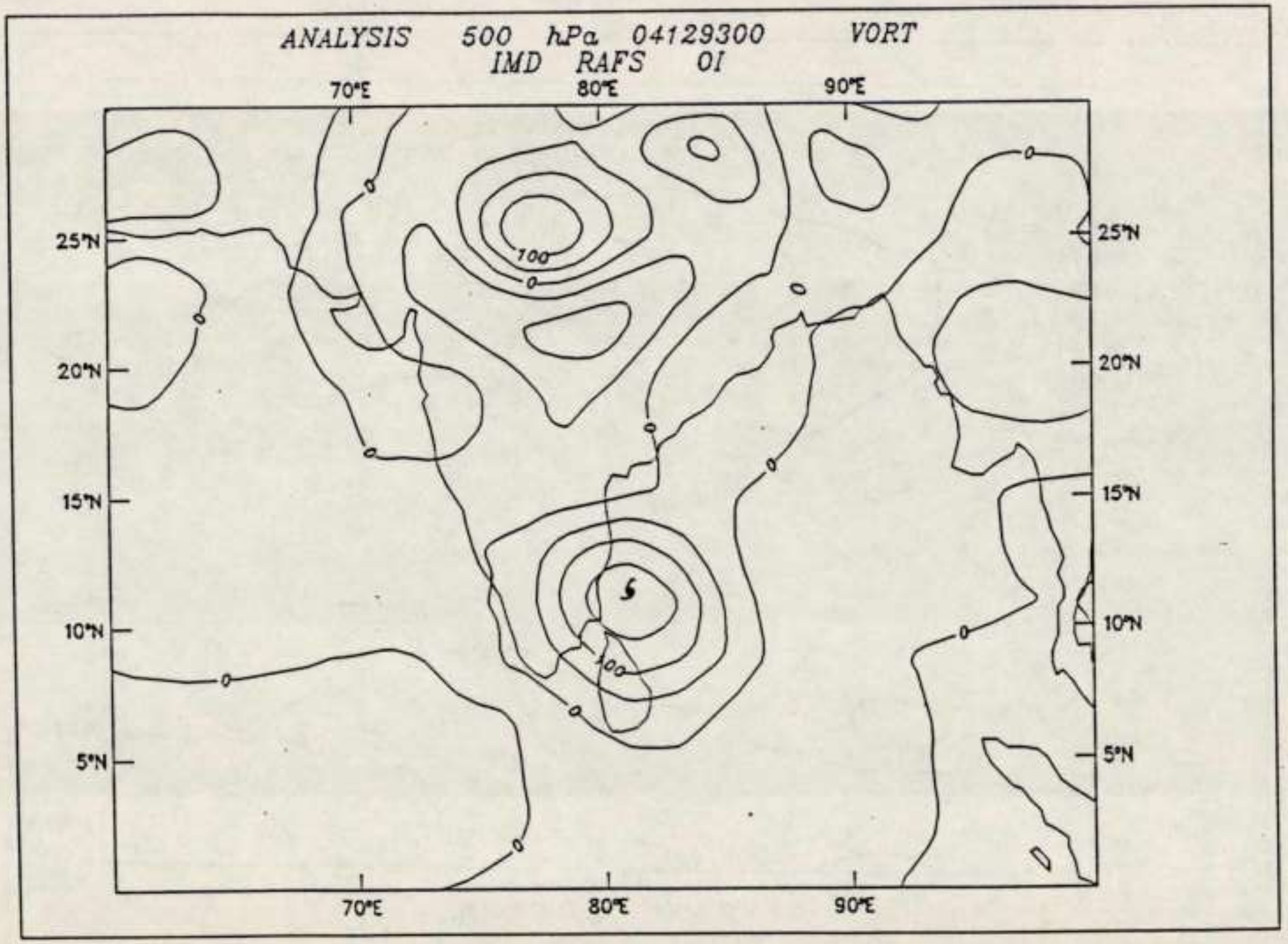
80°E
90°E
25°N
20°N
15°N
10°N
5°N
100

FIG. 32 (c)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IMD RAFS OI
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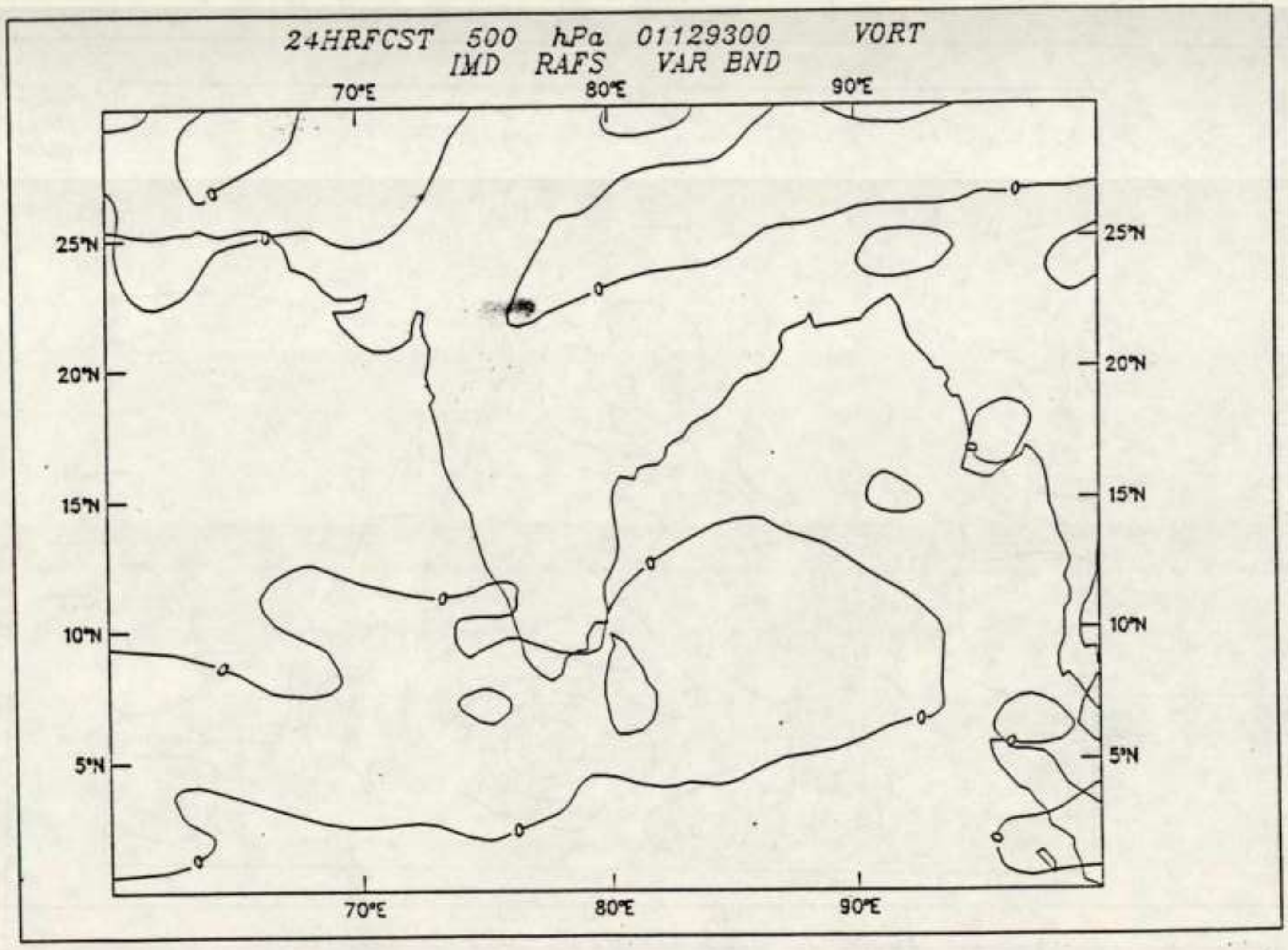
90°E
25°N
20°N
15°N
10°N
5°N
100
0

FIG. 32(d)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IMD RAFS VAR BND
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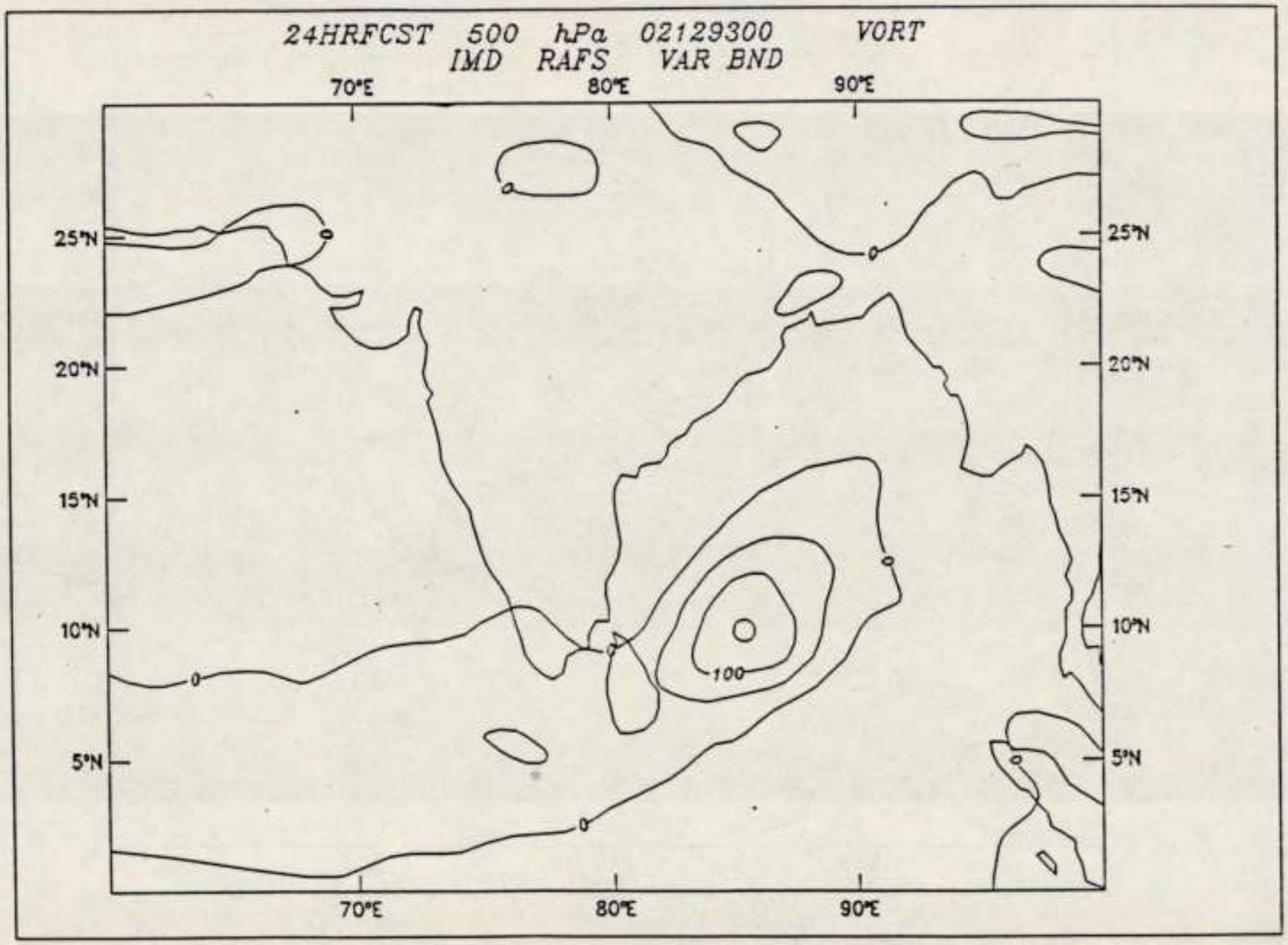
90°E
25°N
20°N
15°N
10°N
5°N
0

FIG.33(a)



24HRFCST 500 hPa 02129300 VORT
IMD RAFS VAR BND
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90°E
25°N
20°N
15°N
10°N
5°N
0
100

FIG. 33 (b)

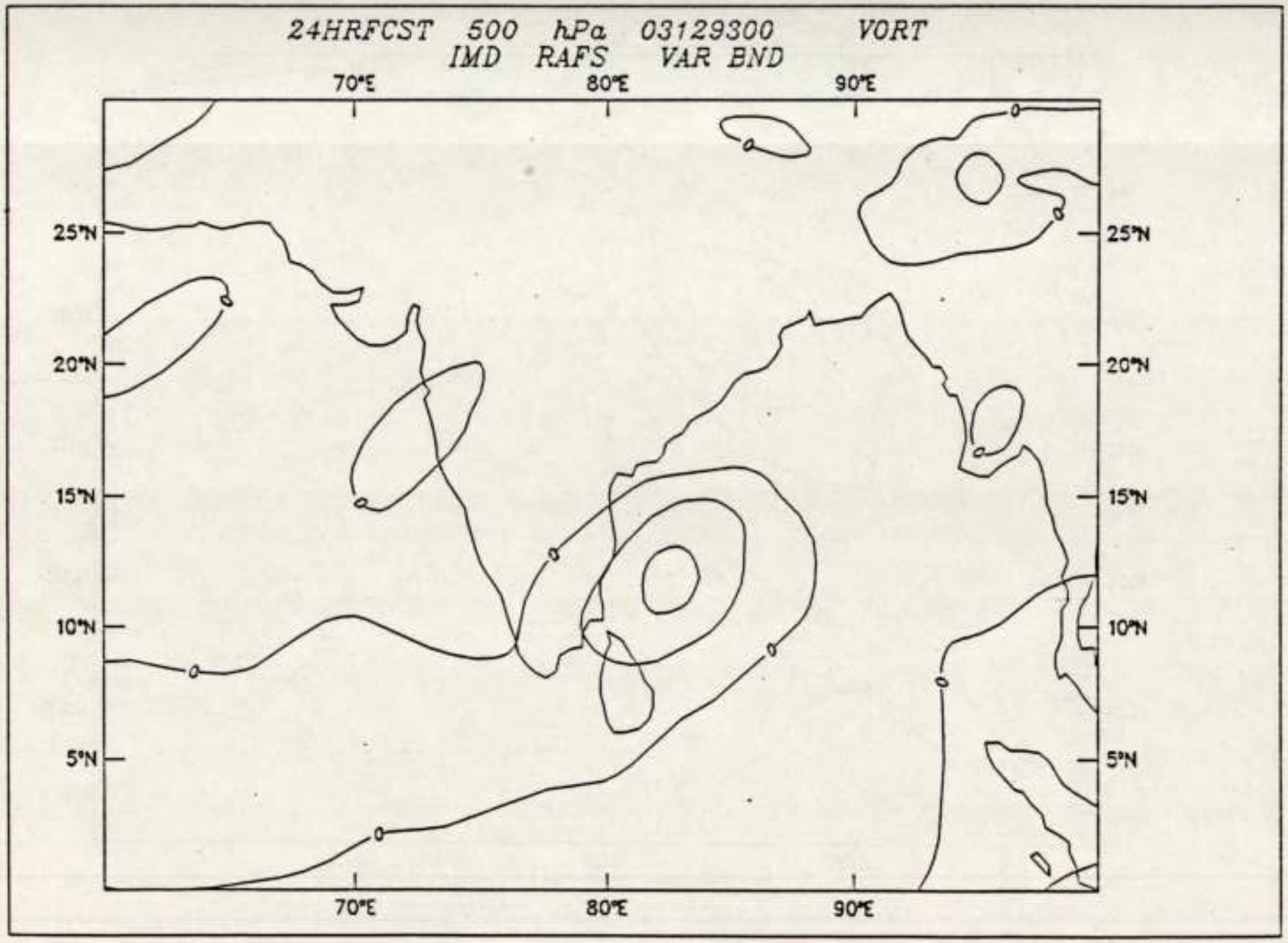
24HRFCST 500 hPa 03129300 VORT
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
0
0
0
0
0
0
0
0
0
0

FIG. 33 (c)

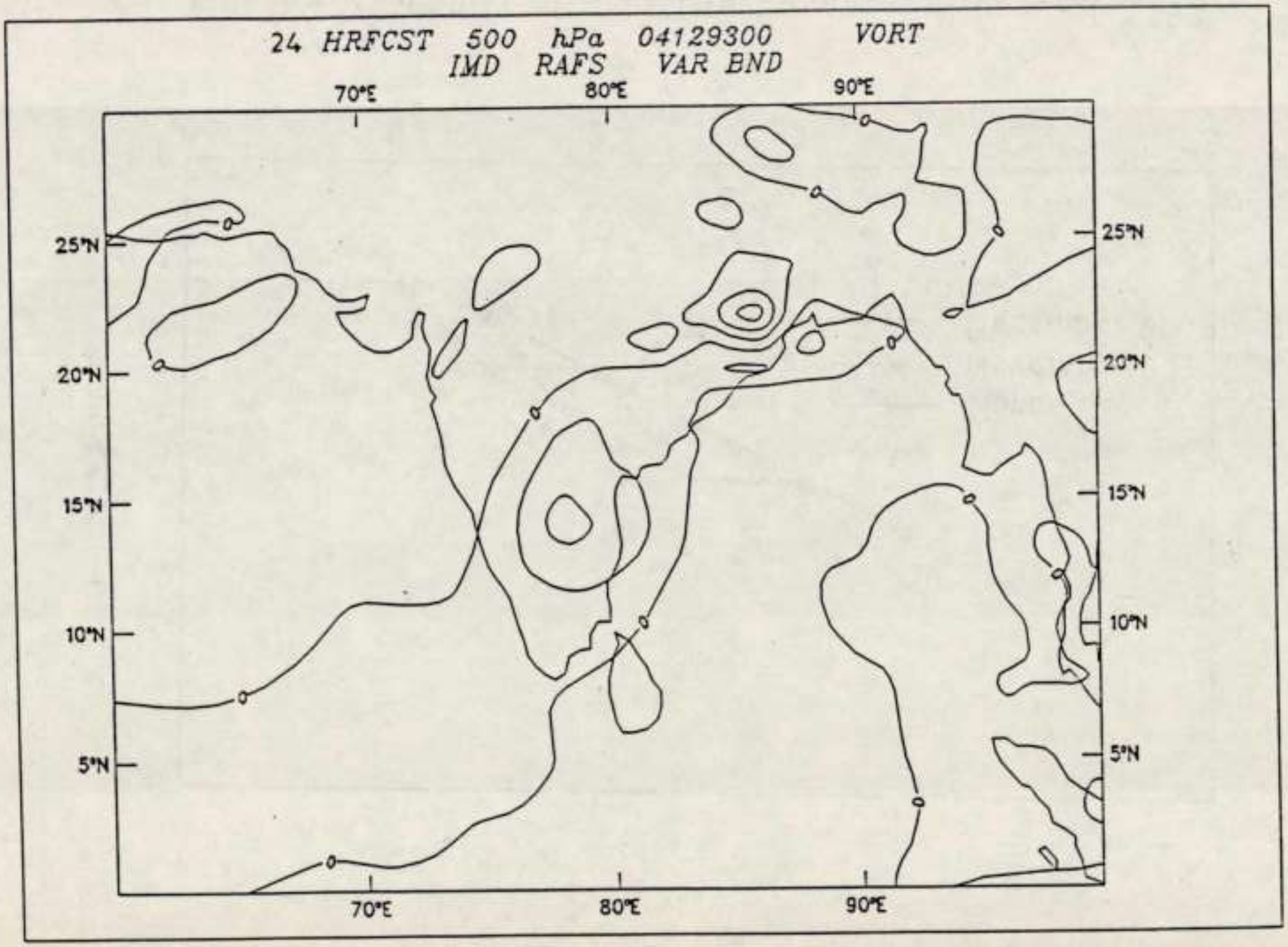
24 HRFCST 500 hPa 04129300 VORT
IMD RAFS VAR BND
70°E
80°E
90°E
25°N
20°N
15°N
10°N
5°N
0

FIG. 33(d)

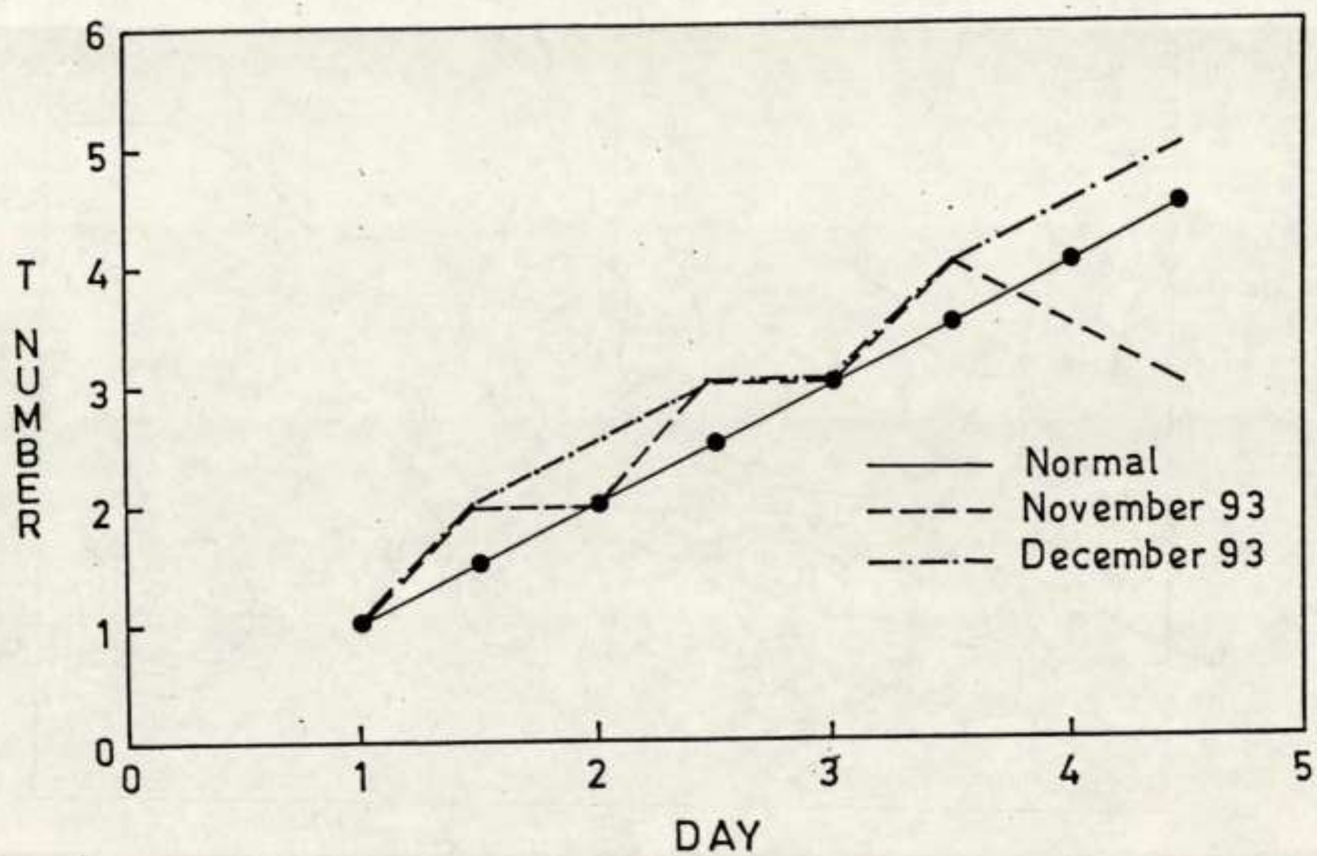

Fig. 34 . Intensity rate in the Severe Cyclones of 1993

Classification of Cyclonic Disturbances as per WMO Tropical Cyclone Operational Plan for North Indian Ocean

The definitions of the cyclonic disturbances as given in the WMO Tropical Cyclone Operational Plan for the North Indian Ocean region (TCP-21) are as follows:

	Weather System	Maximum sustained surface wind speed
1.	Low	Wind speed less than 17 kt (<31 kmph)
2.	Tropical Depression	Wind speed between 17 and 33 kt. (between 31 and 61 kmph)
3.	Cyclonic Storm	Wind speed between 34 and 47 kt. (between 62 and 88 kmph)
4.	Severe Cyclonic Storm	Wind speed between 48 and 63 kt. (between 89 and 117 kmph)
5.	Severe Cyclonic Storm with a core of hurricane winds.	Wind speed 64 kt or more (118 kmph or more)

In India, the cyclonic disturbances indicated under S.N.(2) above are classified into depression and deep depression with wind speed ranging from 17 to 27 kt (31-49 kmph) and 28 to 33 kt (50-61 kmph) respectively.

The terms, tropical storm, tropical cyclone or cyclone are used to indicate all the three categories of cyclonic disturbances given above under S.N. (3) to (5).

ANNEX II

INDIAN EXPRESS 6·12·93

Cyclone toll rises to 54

EXPRESS NEWS SERVICE

MADRAS - The toll in the cyclone that crossed the Karaikal coast on Saturday rose to 54 by Sunday night.

Nagapatinam-Quaid-e-Millath was the worst affected district with 19 deaths, nine being men and 10 women. South Arcot-Vallalar reported 7 deaths, Thanjavur 5, Tiruchi 5, Salem 8, Chengalpattu-MGR 3, Dharmapuri, Madras and Villupuram-Ramasamypadayachi 2 each, and Tiruvannamalai-Samburavaiyar district 1.

Over 45,000 people have been hit in the ravage caused by the cyclone in Karaikal and about 14,000 huts damaged. Most roads were damaged and communication and power links were cut in Pondicherry.

While the road blocks in the districts of Tamil Nadu including Tiruvarur, Koradacheri, Needamangalam were removed, efforts were on to clear the trunks of trees that have blocked the roads on the Mayiladuthurai-Nagapatinam route. Breaches occurred at a couple of points near Villupuram. The estimated loss due to road damage is Rs 6 crore. A number of houses and standing crops were also damaged.

A total of 39 road breaches were reported in the state. The break-up is: Saidapet in Chengalpattu-MGR district 2, South Arcot-Cudalore 12, Tiruvanamalai-Samburavayar 3, Puddukotai 1, Nagapatinam-QM 21.

The reports said 29 culverts were damaged, the break-up being: Chengalpattu-MGR 3, South Arcot 5, Villupuram-Ramasamypadayachi 2, Nagapatinam-QM 19.

Surface damage of roads was very extensive with the figure going up to 1,460. The break-up is Nagapatinam-QM 297, Thanjavur 210, Tiruchi 195, Pudukotai 141, Saidapet in Chengalpattu-MGR 145, Chengalpattu 95, South Arcot 125, Villupuram-Ramasamypadayachi 92, Tiruvanamalai-Samburavayar 85 and North Arcot-Ambedkar 75.

Tele-communication facility was restored in most districts except in Nagapatinam-QM, where power supply was yet to be restored.

Revenue Administration joint commissioner M Abdullah Sha, who is in charge of the operations, told *Indian Express* that but for the ham network, which has been installed at the Collectorates of Nagapatinam-QM, Thanjavur, Cuddalore and the Revenue Administration Joint Commissioner's office in Madras, timely action could not have been taken.

CYCLONE WEAKENS: The cyclone that crossed the Karaikal coast on Saturday at 11 a.m. emerged into the Arabian Sea and weakened into a deep depression on Saturday evening, Area Cyclone Warning director S.K.Subramanian said on Sunday.

Karaikal region cut off

EXPRESS NEWS SERVICE

PONDICHERRY - The cyclonic storm that crossed the Karaikal coast on Saturday has wrought extensive havoc to property and crops rendering nearly 13,000 homeless and submerging standing paddy crops in about 5,000 hectares.

Twenty-four hours after the depression hit the coast off Karaikal, an enclave of the Union Territory of Pondicherry in Nagapattinam district, the region remained cut off.

Telephone communication is yet to be restored and power supply was cut off for the past 24 hours.

Preliminary reports trickling in to the headquarters through police wireless spoke of tidal waves entering coastal hamlets like Thiruvettakudi, Vanjore and Vlahiyur on Saturday.

Nearly 40,000 people living in low-lying areas have been evacuated to safer places. The region which was reeling under rains for the past ten days bore the brunt of the cyclonic storm attack which accompanied by heavy downpour devastated paddy crops in about 5,000 hectares.

With roads virtually becoming unmotorable owing to rains, rescue and relief operations are slow in reaching the populace.

Chief Minister V.Vaithilingam, who had left for an on the spot assessment of the situation at around 8 a.m. on Sunday, could not reach Karaikal, lying about 160 km away from Pondicherry.

Local Administration Minister M Chandrakasu is camping in Karaikal and supervising the relief works. The administration had also rushed a team of revenue officials to assess the damage. But preliminary assessment has it that the destruction due to cyclone would have cost the Union Territory about Rs 5 to Rs.6 crore of property and crops.

Food packets distribution is going on the affected areas and the people were also being given five kg of rice and one litre of kerosene, according to Collector R.Narayana.

In the Pondicherry region, which had experienced heavy downpour on Saturday, about 1,400 huts were damaged and the administration is distributing food packets in the coastal areas.

INDIAN EXPRESS 6.12.93

Heavy damage to samba paddy in Thanjavur, Nagapattinam

EXPRESS NEWS SERVICE

THANJAVUR – Heavy loss to Samba paddy crops and house property was reported in Thanjavur and Nagapattinam Quaid-e-Milleth districts due to Saturday's cyclone. The death toll due to wall collapses had risen to 30 with two more deaths reported in these two districts on Saturday night and Sunday morning.

More than 1,000 trees fell on the roads alone and these trees were cut and removed paving way for normal bus traffic in many areas. The heavy rains on Saturday night and Sunday morning hampered the relief work. Kumbakonam recorded the highest rainfall of 235 millimetres followed by Vedaranyam 166 mm and Orathanadu 125 mm. Other places received below 100 mm rainfall.

In all, more than 300 hamlets (200 in Nagapattinam-QM district and 100 in Thanjavur district) were surrounded by flood waters in the Thiruthuraipoondi, Vedaranyam, Nagapattinam, Sirkazhi, Adirampattinam, Peravurani and Mannargudi areas. About 30,000 people were evacuated in Nagai district and 10,000 in Thanjavur district to safer places.

According to a rough estimate, the Samba paddy crop loss would be more than Rs.150 crore, house property about Rs. 50 crore and banana and coconut crops about Rs 20 crore, besides heavy loss to telecom and electricity network.

For the second consecutive day, the entire Thanjavur and Nagapattinam-QM districts are without power supply on Saturday and it is not known when these would be restored. Drinking water supply through pipe system was completely affected and hospitals could not treat the patients for want of power supply.

C.N. Ramdas, special commissioner for relief works, is visiting the cyclone affected areas, along with E. Venkatachalam, Thanjavur Collector, and S.Savarkar, Nagapattinam Collector, to assess the damage caused by the cyclone. All the fair price shops functioned on Sunday and the officials ensured supply of essential commodities like rice and kerosene to the affected people.

A top official told *Indian Express* that Samba paddy crop in about four lakh acres (three lakh acres in Nagai and one lakh acre in Thanjavur district) were completely affected and the loss would be more than Rs. 150 crore. About 50,000 houses had collapsed in these districts so far, he said.

Revenue Minister S.D. Somasundaram rushed to Nagapattinam on Sunday.

8 killed in Salem

SALEM – Eight persons, including three women and a two-year-old girl were killed in flash floods and wall collapses in different parts of Salem district on Sunday.

District Collector Braj Kishore Prasad said here on Sunday that four persons, including a woman, Singari, in Vepampoondi village, near Kamakapalayam in Thalaivasal block, were washed away in the flash floods in the Periar jungle stream on Sunday morning. The mishap occurred while they were trying to cross the stream.

In another incident, the body of an unidentified man was found near Mamanchi village in the same region on Sunday morning.

In Mettur, two women, Chinnammal and Sarasu, were killed on Sunday morning when the wall of their house collapsed.

In Namakkal, a woman fell into a well when the parapet of the well collapsed. She died instantaneously.

In Omalur taluk, a two-year-old girl, died on the spot on Sunday morning when the wall of her house collapsed on her.

The Mookaneri lake near Salem town is overflowing and the revenue and police officials are camping in the area. Police personnel have been posted at all the important bridges and traffic is being regularised.

The Collector said about 1,000 huts had been damaged in the rains and the families shifted to safer places. Of these, about 735 huts were on the banks of Vashista and the remaining in Salem.

The Chinnamasamudram tank in Attur taluk suffered minor damage when a tree fell over it, resulting in leakage to the tank. However, officials took immediate repair works and a major breach was avoided.

Traffic was affected on the Yercaud-Kottachedu Road owing to landslides and uprooting of trees on Saturday. However, traffic was restored on Sunday morning. A private bus skided into the berm near Semmedu, Kolli hills, which had also resulted in road blockade. The bus was retrieved and traffic restored, the Collector said.

Traffic on the Attur-Trichy Road was also affected owing to heavy flow of water in Swetha river.

The entire district received heavy rains for the second consecutive day on Sunday. Yercaud received a maximum rainfall of 124.2 mm in the 24 hours which ended at 8.30 am on Sunday. Omalur (91 mm), Attur (80 mm), Salem (46 mm) and Mettur (41 mm) received heavy rains.

The water level in the Mettur reservoir stood at 104.4 ft on Sunday morning. The inflow was 12,936 cusecs and the discharge was maintained at 320 cusecs. The Collector said the catchment areas had also received moderate rains and the inflow to the reservoir was expected to increase.

He said additional collectors S K Prabhakar and Atulya Misra were in charge of the entire district, which had been divided into two regions, and they were monitoring the situation. A special cell had been created in the Collectorate for this purpose.

The damage to agricultural crop, roads etc were being analysed and reports would be sent to the government for relief action, the Collector said.

In Erode: Widespread rains were reported throughout Periyar district on Saturday. Thalavadi recorded a maximum of 50 mm rainfall followed by Erode 37, Kodumudi 40, Perundurai 35, Bhavani 30, Gobi 36, Sathy 28, Kangeyam 31, Modakurai 18, Bhavanisagar 24 and Dharapuram 9 mm.

Death toll up in S.Arcot

CUDDALORE – The toll in Saturday's wall collapses caused by heavy rains in South Arcot Vallalar district has risen to nine, with the death of four more persons – two in Cuddalore and one each in Vriddhachalam and Thittakudi taluks, police sources said on Sunday. They were: Anjalai (23) of Cuddalore, Kandasamy of Thittakudi, Perumalthal of Vayalamur, near Pudachatram and Veeran of Vriddhachalam. Of the dead, Anjalai was crushed to death when a tree fell on the roof of her house.

Nearly 440 villages in South Arcot district were marooned due to floods caused by the heavy rains. While 12,825 huts were fully damaged, 17,375 were partly damaged. Nearly 25,000 persons were evacuated in the entire district to safer places. To provide assistance to the marooned people, 24 relief camps – 12 in Cuddalore, 11 in Chidambaram and one in Vriddhachalam – have been opened.

Except Cuddalore, rain water have inundated many areas in all taluks affecting road traffic. Many stretches of road near B.Muttu remained under waist-deep water. District Collector Prabhakar Rao visited flood-affected areas like Akkaraigori, Sonankuppam and Devanampattinam on Saturday. Food packets were distributed to 7,000 families. The Collector issued instructions for the distribution of extra rice and kerosene to the flood affected people.

Chidambaram taluk was the worst affected in the whole district. Paddy crop in 5,000 hectares, sugarcane in 7,000 hectares and plantain in 300 hectares had been badly damaged, according to Collector Rao. Eleven relief camps have been opened for rendering help to the affected people. Nearly 11,000 persons have been evacuated to safer places.

Telecommunication links had remained affected in many parts of the district for the second day on Sunday. In Cuddalore, power supply was restored only in the afternoon on Sunday.

About 20,300 huts in Chidambaram taluk and 10,000 huts in Thittakudi taluk had been damaged due to heavy rains and gale, according to reports reaching here.

Roadlinks between Kallakurichi and Vriddhachalam and between Vriddhachalam and Thittakudi and Ulundurpet have been badly damaged. Bus services remained affected in these sectors.

More than 400 huge trees had been uprooted between Thittakudi and Ramanatham. This will be cleared within three days, official sources said. Ten goats and two calves were killed in Chidambaram taluk in the recent rains.

THE HINDU 6.12.93

Storm leaves coastal dts. reeling

From Our Special Correspondent

THANJAVUR, Dec. 5.

The cyclonic storm which hit Nagapattinam and Karaikal regions in the east coast on Saturday, devastated infrastructure, uprooted thousands of coconut trees, affected standing samba, and [illegible] paddy crop and banana, besides rendering thousands homeless. The toll rose to 43, with Nagapattinam suffering the maximum.

Stretches of paddy fields in Thanjavur and Nagapattinam Quaid-e-Milluth districts look like a vast sheet of water, as drainage has become a problem due to high tide in the sea.

To aggravate the misery, most rivers including Mullaiyar and Gomuki and jungle streams are carrying heavy floods, eroding vast stretches of district roads and highways in their course. A large number of uprooted trees are lying on the road like sleeping giants hindering traffic.

The telecommunication and power system have been totally affected not only in the coastal districts which bore the brunt of the five-hour cyclonic storm, but also Vellore and Ramasamy Padayachiar districts. Except for pockets, all other areas in these districts have been plunged into darkness since yesterday.

For the second day today most parts of Thanjavur town were without power. Till the morning the entire stretch of Nagapattinam district was not accessible because of a large number of breaches in the link roads and also road blocks created by uprooted trees. During the drive from Madras to Thanjavur one could see several bent, twisted telephone and electric poles and snapped wires.

Though the initial estimate of damage to dwelling houses is put at anything between 20,000 to 30,000, a correct picture will be available only after all villages and hamlets become accessible.

Traffic hit: Traffic was worst hit not only in the arterial National Highway No.45 connecting Madras and Tiruchi but also on all roads leading to different places in Nagapattinam district.

On Saturday night vehicles including State Corporation buses were seen stranded near Sethiathope, Vriddhachalam and nearby places and the passengers spent a sleepless night. Credit should go to local villagers, who braving the drizzle throughout the night helped in removing the trees. And traffic on NH45 came to an abrupt halt as several huge tamarind trees got uprooted and fell across the road this morning. When traffic was resumed lorries and buses moved in convoys inching their way on.

The hardship to passengers could have been mitigated if only police personnel were present to regulate the traffic at least on arterial roads. They were conspicuous by their absence even on important traffic junctions.

What causes concern is the damage to standing paddy, banana and other crops in these districts. Even during the previous spell nearly 5,000 hectares of paddy crop was written off. The farmers who were hoping for a bumper samba paddy crop are keeping their fingers crossed.

Though relief operations are being carried out on a war footing, they are not without complaints. Nearly 30,000 families have been evacuated in the affected districts and they are being given food packets. Those who were rendered homeless have been accommodated in special centres.

Work is apace for restoring the affected roads in the districts, and skeletal traffic restored from the afternoon from Nagapattinam to different destinations. It is said that it would take at least three to four days to restore normalcy in regard to power supply. Same is the case with telephones also.

Tanks surplussing: According to information reaching here, most irrigation tanks in the cyclone hit districts are surplussing and it is feared that further showers will lead to breaches. The PWD authorities have arranged round the clock patrolling of banks of rivers, which are carrying heavy flood.

Though details are not available here, Poompuhar and nearby places in Nagapattinam district and Karaikal region are worst affected and the latter was not accessible by road till the afternoon.

The Tamil Nadu Chief Minister Ms. Jayalalitha is to visit flood hit districts by helicopter and also oversee relief operations by revenue authorities. Mr. S. D. Somasundaram, Revenue Minister, has been deputed to organise relief measures.

Even in the memorandum prepared on the recent havoc in Madurai and other districts including The Nilgiris, the State had hinted that it had spent more than the quantum of Rs. 39 crores allotted under the Calamity Relief Fund for the year and the massive repair work can be taken up in the cyclone damaged areas only if Central assistance was forthcoming, according to a Government source.

Road, rail traffic remain disrupted

MADRAS, Dec. 5.

Road and rail traffic from Madras to destinations in South Tamil Nadu remained disrupted today following a large number of breaches and blockades mainly in Thanjavur, Nagapattinam Quaid-E-Milleth and South Arcot districts.

A Southern Railway spokesperson said there was a large number of breaches in the Villupuram-Tiruchi section on the main and chord lines. Consequently, all trains from Madras Egmore were cancelled today, while Nellai Express from Tirunelveli, Quilon Mail from Kollam and Sethu Express from Rameswaram were terminated at Tiruchi and turned back.

According to TTC sources, the movement of express buses, which was stopped in many parts of the State last night, was resumed early this morning. Buses were plying to various destinations, except to Nagapattinam, Mayiladuthurai and neighbouring areas. It was not possible to maintain the schedules as once it got out of gear it took at least two days for normalcy to be restored.

Vehicles stranded: According to reports reaching here a large number of buses and other vehicles were stranded at several places such as Tindivanam, Villupuram and Tozhudur last night after the police stopped traffic in many areas as roads were flooded and blocked by fallen trees. The entire Thanjavur district was badly affected and the National Highway 45 suffered damage in many stretches beyond Tindivanam.

To make matters worse, the roads in the neighbourhood of Madras, which were damaged in floods in October, were also yet to be fully restored.

MASILAMANI TEMPLE IN TAMILNADU (INDIA) SEVERELY DAMAGED BY THE BAY OF BENGAL CYCLONE OF 2-4 DECEMBER, 1993.