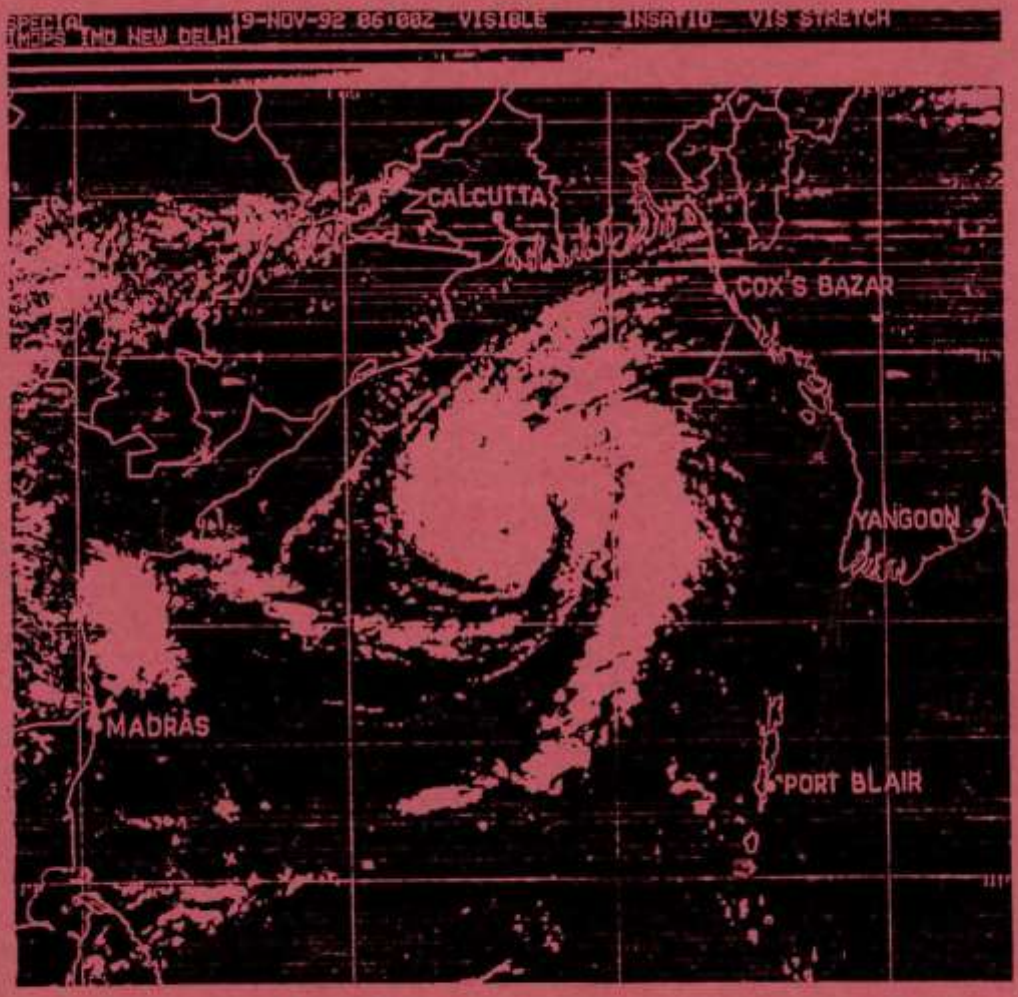
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES
(DEPRESSIONS AND TROPICAL CYCLONES)
OVER NORTH INDIAN OCEAN IN 1992



REGIONAL SPECIALIZED METEOROLOGICAL CENTRE (RSMC) -
TROPICAL CYCLONES, NEW DELHI

JANUARY 1993

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CYCLONIC DISTURBANCES (DEPRESSIONS AND TROPICAL CYCLONES) OVER THE NORTH INDIAN OCEAN (THE BAY OF BENGAL AND THE ARABIAN SEA) DURING 1992 - A REVIEW

INTRODUCTION

This report gives a review of cyclonic disturbances (depressions and tropical cyclones) formed in the North Indian Ocean (The Bay of Bengal and the Arabian Sea) during the year 1992. 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).

The year 1992 witnessed an active cyclone season. There were as many as 12 cyclonic disturbances (depressions and tropical cyclones) formed over the North Indian Ocean during the year. Out of these 8 formed over the Bay of Bengal and 4 over the Arabian Sea. Out of the 12 cyclonic disturbances 7 intensified into tropical cyclones and 5 of them were of depression category. With the formation of two cyclones and one depression over the Arabian Sea in 1992 the cyclonic activity in this region was much higher this year. The cyclonic activity in the Arabian Sea increased after a gap of 6 years. There was no cyclone over the Arabian Sea during the past 6 years. The above statistics of cyclonic disturbances over the Arabian Sea also includes a depression which emerged into the Arabian Sea as a remnant of the Bay of Bengal severe cyclonic storm after crossing the Indian coast near Tuticorin (43379) in Tamilnadu in the evening of November 13, 1992. However, these two weather systems are shown as a single cyclonic disturbance both in the text and the track given in this report. In the Bay of Bengal, out of the eight cyclonic disturbances five attained the cyclone intensity, two of which were of Pacific Origin. The remnants of typhoon "Angela" and "Forrest" after emerging in the Bay of Bengal re-intensified into cyclones, one during 3 - 7 November, and the other during 16 - 21 November, 1992 which attained the hurricane intensity.

The number of cyclonic disturbances forming during the pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-December) seasons this year were 1, 3 and 8 respectively. Out of the total seven cyclonic storms which formed over the North Indian Ocean during 1992, one each formed in the pre-monsoon and monsoon seasons and the remaining five in the post-monsoon season. Out of the five depressions, two formed in the monsoon season and the remaining three in the post-monsoon season.

In addition to these twelve cyclonic disturbances, a short-lived depression also formed on 1 December, 1992 over southeast Arabian Sea close to the equator which had a life span of only a few hours (less than a day).

Detailed accounts of all these cyclonic disturbances are given in the following paragraphs. The tracks of the cyclonic disturbances are given in Fig.1. Tables 1 to 7 give the best track positions at 6 hourly interval alongwith other meteorological information in respect of all the 7 cyclonic storms which formed during 1992.

2. DETAILED DESCRIPTION OF CYCLONIC DISTURBANCES

2.1 PRE-MONSOON SEASON

2.1.1 Bay of Bengal Cyclone of 16-19 May, 1992

A depression formed in the southeast Bay of Bengal in the morning of 16 May 1992 and was located near Lat. 11.0°N/Long. 88.0°E about 750 km east-south-east of Madras (43279). Moving initially in a north-westerly direction and then taking a northward track, it intensified into a cyclonic storm by the evening of the 17th. Thereafter, it moved north-eastward and was located near Lat. 15.0°N/Long. 88.5°E about 650 km east-south-east of Visakhapatnam (43150) in the 18th morning. Later, the cyclonic storm moved rapidly in a northeasterly direction and crossed Myanmar coast in the mid-day of 19 May 1992. The system attained its peak intensity of T3.0 (on Dvorak's Scale) with estimated maximum sustained surface wind of 45 kt. (83 kmph) just at the time of crossing the coast around 0600 UTC of 19 May. The system subsequently dissipated over the land on the same night. Fig. 2 shows the INSAT-1D cloud imagery (Visible) at 0600 UTC of 19 May, 1992.

As the cyclone remained far away from the Indian mainland, it did not cause any adverse weather over India. However, the northeastern States of India and its neighbouring areas experienced good rainfall activity during the dissipation stage of the cyclone.

2.2 MONSOON SEASON (June -September)

2.2.1 Arabian Sea Cyclone of 8-12 June 1992

A depression formed in the southwest Arabian Sea in the evening of 8 June 1992 near Lat. 11.5°N/Long. 60.0°E about 1750 km west of Kochi (43353). It remained practically stationary and intensified into a deep depression by 9th morning. Thereafter the weather system took a west-north-westerly course towards south Yemen coast, intensified further into a cyclonic storm and was located near Lat. 13.5°N/Long. 56.0°E about 1200 km east of Aden on the 11th. Continuing to move west-northwestwards, it rapidly weakened and dissipated over the sea area off south Yemen coast by the evening of 12 June 1992. The cyclone was tracked mainly with the help of INSAT-1D satellite cloud imageries over the high seas during its life period. Fig.3 shows the INSAT-1D cloud imagery (Visible) at 0800 UTC of 11 June 1992.

2.2.2 Bay of Bengal Deep Depression of 17-20 June 1992

A depression formed over the northwest Bay of Bengal near 19.0°N/88.0°E in the morning of 17 June 1992. It initially moved westwards, rapidly intensified into a deep depression by the same evening and was located about 100 km southeast of Paradip (42976) off Orissa coast. Subsequently the deep depression moved in a west-north-westerly direction and crossed north Orissa coast about 50 km north of Puri (43053) on the same night. After crossing the coast, it weakened into a depression and was centred over north Orissa by the morning of the 18th.

The depression moved further westwards over the land and dissipated by the evening of 20 June 1992. Under the influence of this weather system, the summer monsoon strengthened and the rainfall activity over the peninsular and central India increased considerably. The system attained its peak intensity of T2.0 with estimated maximum sustained surface wind of 30 kt. (57 kmph) just before crossing the coast on the 17th.

2.2.3 Bay of Bengal Deep Depression of 26 - 30 July 1992

A depression formed over the north Bay of Bengal near 20.0°N/88.0°E in the morning of 26 July 1992. It intensified into a deep depression by the mid-day of the 26th and was located about 85 km east-south-east of Chandbali (42973). Moving west-north-westward, the weather system crossed Orissa coast near Chandbali in the mid-night of 26-27 July 1992. It continued to move in the same direction through the central parts of India and finally dissipated by the evening of the 30th. Under the influence of this weather system, there was an increase in the monsoon activity over the central and north-western parts of India.

2.3 POST MONSOON SEASON (October - December)

2.3.1 Arabian Sea Cyclone of 1-3 October, 1992

A tropical depression formed over east-central Arabian Sea in the morning of 1 October 1992 near lat 16.0°N/Long. 67.0°E about 700 km southwest of Bombay (43003). The weather system moved slowly north-westwards, intensified into a cyclonic storm by the same evening and was centred near Lat. 17.5°N/Long. 62.5°E at a distance of 850 km west-south-west of Bombay. Thereafter the cyclone followed a westward track and attained the peak intensity of T3.0 (on Dvorak's Scale) over west-central Arabian Sea with associated maximum sustained surface

wind speed of 45 kt (83 kmph) in the morning of the 2nd. Moving further north-westward, it crossed the Saudi Arabia coast on 3 October, 1992.

As this cyclone moved away from the Indian coast, it did not affect the weather over the country. Fig.4 depicts the INSAT-2A cloud imagery at 0600 UTC of 1 October 1992.

2.3.2 Bay of Bengal Deep Depression of 7-12 October 1992

A depression formed in the central Bay of Bengal on 7 October 1992 near Lat. 14.0°N/Long. 85.5°E about 500 km east-south-east of Machilipatnam (43185). It rapidly intensified into a deep depression on the same night, moved west-north-westwards and was located near Lat. 15.0°N/Long. 82.5°E about 200 km southeast of Machilipatnam on 8th morning. Moving further in a northwesterly direction, the depression crossed Andhra Pradesh coast near Machilipatnam in the early hours of 9 October. Continuing to move in the same direction over land, it weakened by the same evening. Under the influence of this depression widespread rainfall with scattered heavy falls occurred over the coastal areas of Orissa, Andhra Pradesh and north Tamilnadu during 8-10 October 1992.

2.3.3 Bay of Bengal Cyclone of 20 - 22 October 1992

A depression formed over the north and adjoining central Bay of Bengal on 20 October 1992 near Lat. 19.0°N/Long. 89.0°E about 450 km south-south-east of Calcutta (42809). It moved slowly north-eastwards and intensified into a deep depression in the morning of the 21st and lay centred near Lat. 20.0°N/Long. 90.0°E about 400 km south-south-east of Calcutta. Moving further north-eastward it intensified into a cyclonic storm on the mid-day of the 21st and was located near Lat. 21.8°N/Long. 91.5°E about 100 km southwest of Cox's Bazar (41992). The cyclone attained its peak intensity of T2.5 on 21 October 1992. It crossed

Bangladesh coast in the early hours of 22 October, 1992. Subsequently it rapidly weakened over the land by the same evening. Fig.5 shows the INSAT-2A visible cloud imagery of the cyclone at 0600 UTC of 21 October 1992.

2.3.4 Bay of Bengal Cyclone of 3-6 November, 1992

The remnant of typhoon "Angela" emerged into the Bay of Bengal, moved westwards and developed into a depression over the central Bay of Bengal in the morning of 3 November, 1992 near Lat. 15.0°N/Long. 90.0°E, about 800 km east-south-east of Visakhapatnam (43150). The depression moved in a westerly direction and rapidly intensified into a cyclonic storm by the next morning. The cyclone remained practically stationary till the morning of 6 November when it was located near Lat. 16.5°N/Long. 85.0°E about 250 km southeast of Visakhapatnam. However, it rapidly weakened over the high seas by the mid-day of 7 November, 1992. Fig.6 shows the INSAT-2A visible cloud imagery at 0600 UTC of 5 November, 1992.

2.3.5 Bay of Bengal/Arabian Sea Severe Cyclonic Storm of 11-17 November, 1992

2.3.5.1 *The life history of the severe cyclone*

A depression formed over south Bay of Bengal in the morning of 11 November 1992 near Lat. 7.5°N/Long. 86.5°E about 800 km east-south-east of Nagapattinam (43347). It followed a steady westerly track and intensified into a cyclonic storm by the same evening and lay centred near Lat. 7.5°N/Long. 84.5°E about 500 km south-south-east of Nagapattinam on the 12th morning. After crossing Sri Lanka, it emerged into the Gulf of Mannar and was located near Lat. 7.5°N/Long. 79.0°E about 180 km south-south-east of Tuticorin (43379) on the 13th morning. Later it changed its course suddenly and moved north-westwards,

intensified into a severe cyclonic storm on the 13th afternoon and crossed south Tamilnadu coast (India) near Tuticorin on the same evening. It attained a peak intensity of T4.0 on the Dvorak's scale, with maximum sustained surface wind of speed 64 kt. (120 kmph) just before crossing the coast on the 13th evening. Moving further northwestwards, it weakened into a deep depression in the 14th morning and emerged into south-east Arabian Sea as a depression on the same evening. However, it intensified again into a deep depression on the 15th morning and moved northwards. It was located about 50 km southwest of Mangalore (43284) on the 16th and was close to the Karnataka coast near Honavar (43226) near Lat. 14.0°N/Long.74.5°E on the 17th morning. It crossed the Karnataka coast near Honavar on the afternoon of the 17th and rapidly weakened. Fig.7 shows the INSAT-2A visible cloud imagery at 0600 UTC of 13 November 1992.

2.3.5.2 *Monitoring and Tracking*

The cyclone was mainly tracked with the help of INSAT-1A cloud imageries and Ships' observations over the high seas. As the weather system approached the Indian main land, frequent surface and upper air meteorological observations from coastal stations in Sri Lanka and the Indian Peninsula were very useful in tracking the cyclone. After the cyclone crossed Sri Lanka and emerged into the Gulf of Mannar on the 13th morning, the observations of the Cyclone Detection Radar Station (CDR) at Karaikal (43346) alongwith other conventional meteorological observations of the coastal stations in Tamilnadu and Kerala continuously tracked and monitored the cyclone till it crossed the coast near Tuticorin (43379) in Tamilnadu on the evening of 13 November, 1992.

2.3.5.3 *Rainfall, Damages and Storm Surge*

Under the influence of this cyclone, widespread rains with scattered heavy to very heavy falls occurred over south Tamilnadu and Kerala during 13-15 November, 1992. Widespread rains with isolated heavy falls also occurred over Karnataka and Lakshadweep area from 16 to 18 November. Several stations in Tamilnadu and Kerala reported 15 cm or more of rain during the 24-hour period on 14 November 1992. An exceptionally heavy rainfall of 37 cm was recorded at Ambasamudram in Tamilnadu on this day.

The severe cyclonic storm caused extensive damage to the property in the coastal districts of Tamilnadu and Kerala. According to the press reports about 175 persons lost their lives and 160 people were reported missing in Tamilnadu and Kerala due to the cyclone. Heavy rains caused flash floods and landslides resulting in considerable damage to the standing crops and houses in Karnataka, Kerala and Tamilnadu.

Strong winds with speed ranging from 80 to 100 kmph were experienced in the areas close to the landfall point in Tamilnadu on 13 November. Storm surges of 1 to 1.5 metre height inundated the coastal belt of about 70 km long, upto 200 to 300 metre inland in Tamilnadu at the time of the cyclone's crossing the coast.

2.3.6 Bay of Bengal Severe Cyclonic Storm with a Core of Hurricane Winds of 16-21 November 1992

The tropical storm "Forrest" moving steadily in a westerly direction from the gulf of Thailand crossed the Malaysian peninsula and emerged into south Andaman Sea of the Bay of Bengal as a tropical depression and was centred near Lat 9.5°N/ Long. 96.0°E on16 November, 1992. Moving further westwards, it intensified into a cyclonic storm by the 17th morning and was located near Lat.

9.5°N/ Long. 91.5°E. Thereafter, the cyclone slowly moved in a northwesterly direction and at the same time intensified further. It attained the intensity of a severe cyclonic storm with a core of hurricane winds on the 18th morning when it was centred near Lat. 10.5°N/ Long. 89.5°E over the southeast Bay of Bengal. The hurricane continued to move in the northwesterly direction till the mid-day of the 18th but subsequently changed its course towards the north and later to the northeast. It attained a peak intensity of T5.5 (on the Dvorak's Scale) with maximum sustained surface wind of speed 102 kt. (189 kmph) in the morning of 19 November when it was centred near Lat 16.0°N/Long. 87.5°E. Moving further northeastwards, the hurricane rapidly weakened into a cyclone before crossing the Bangladesh - Myanmar coasts in the afternoon of 21 November 1992. Fig.8 shows the INSAT-2A visible cloud imagery at 0600 UTC of 19 November 1992.

The cyclone was tracked and monitored with the help of INSAT-2A cloud imageries, Ships' and other conventional meteorological observations from the time it emerged into the Bay of Bengal on the 16th morning till its dissipation over the land on 21 November 1992. The cyclone remained beyond the surveillance range of the coastal Cyclone Detection Radars in India during its life span. However, the Cyclone Detection Radar stations in Bangladesh, viz, Cox's Bazar (41992) and Khepupara (41984), tracked the cyclone from the morning of 20 November till it made landfall on the coast in the afternoon of the 21st.

2.3.7 Arabian Sea Deep Depression of 21-24 December 1992

This weather system originated as a depression in the Inter Tropical Convergence Zone (ITCZ) over the Arabian Sea and was centred near latitude 5.5°N/long. 68.0°E about 880 km west-south-west of Thiruvananthapuram (43371) on 21 December 1992. Moving in a westerly direction it rapidly intensified into a deep depression and lay centred near lat. 5.5°N, long. 65.5°E on the same

evening. Subsequently, it changed its course towards west-north-west and was centred near lat. 7.5°N/long. 55.5°E over southwest Arabian Sea. The deep depression continued to move west-north-westwards, weakened gradually into a depression and dissipated off Somali coast by the evening of 24 December 1992.

3. TRACK PREDICTION BY MODELLING

Various cyclone track prediction models, such as Climatology, Persistence, combination of Climatology and Persistence (CLIPER), Analogue and Statistical, are run as a routine at the RSMC New Delhi for predicting the tracks of the cyclonic disturbances in the North Indian Ocean. The model outputs from these techniques are compared and verified from the best fit tracks of these disturbances. At present the Analogue technique is used only for the track prediction of tropical cyclones whereas other techniques are utilised for all classes of cyclonic disturbances. The statistical model is not run in the operational mode. Table 8 gives the mean forecast errors in respect of the Bay of Bengal tropical cyclones using the Analogue and the CLIPER models for different time projections of 12, 24 and 36 hours. It may be noted from Table 8 that the Analogue model showed better skill in 24 and 36-hour forecasts than the CLIPER model. However, the 24 and 36-hr forecast errors from the Analogue model in respect of 16-21 November cyclone were relatively larger than those for other cyclones mainly due to the fact that this cyclone was a recurving storm.

4. DISTRIBUTION OF OTHER DYNAMICAL PARAMETERS IN THE CYCLONE FIELD

4.1 Vertical Wind Shear

Vertical shear of the zonal winds between 200 and 850 hPa over the North Indian Ocean region and adjoining areas were calculated in respect of the cyclones

and depressions. These values were computed by utilising the winds at 850 and 200 hPa from the land stations in India and at 5^{o} Lat./Long. grid point over the oceanic areas received at RSMC New Delhi from the European Centre for Medium Range Weather Forecast (ECMWF), U.K.

The analysed chart of the vertical wind shear values for 1200 UTC of 18 November 1992 is presented in Figure 9. It may be seen that the vertical wind shear was nearly zero over the storm centre on this day. To the north of the centre, there was strong anticyclonic vertical shear, whereas to the south, cyclonic shear was present. This pattern of vertical wind shear remained nearly similar on 19 November also when the cyclone attained its peak intensity. However, the anticyclonic shear to the north of the cyclone centre increased considerably on this day and exhibited large meridional gradient of the vertical shear, while the cyclonic shear to the south of the centre showed a significant decrease. The above pattern of vertical wind shear suggested the occurrence of large meridional temperature gradient over the region to the north of the centre than to the south during this period.

Similar patterns of vertical wind shear between 200 and 850 hPa were also observed in association with other cyclones of pre-monsoon and post-monsoon seasons of 1992.

The pattern of vertical wind shear in respect of the depressions during the southwest monsoon season (June-September) 1992 was observed to be significantly different from that of the pre-monsoon and post-monsoon cyclones. Strong easterly (negative) wind shear was present around the depression centres during the monsoon season, which inhibited their further intensification into cyclones.

4.2 VERGENCE, RELATIVE VORTICITY AND VERTICAL VELOCITY FIELDS

4.2.1 Vergence

The horizontal fields of vergence in respect of the Bay of Bengal hurricane of 16-21 November 1992 at 0000 UTC of 18 November for 850 and 200 hPa levels are presented in Fig.10 (a) and (b). It may be seen that large values of the low level convergence and high level divergence occurred in and around the cyclone centre on this day.

The vertical cross-sections of vergence along latitude 11.0°N and longitude 88.5°E over the Bay of Bengal on 18 November 1992 are presented in Fig. 11 (a) and (b). Maximum convergence occurred in the lower tropospheric levels close to the cyclone centre. In the upper levels, however, the maximum divergence occurred in the forward sector of the cyclone at about 3 to 4° latitude away to the north of the centre. Similar patterns of horizontal vergence were observed in association with the severe cyclonic storm of 11-17 November 1992.

In the case of depressions of the southwest monsoon season, the horizontal and vertical distribution of vergence showed maximum low level convergence occurring in the southwest sector of the depression at a distance of 200 to 300 km away from the centre, while divergence occurred close to the centre. This is a typical feature of the distribution of vergence observed in association with monsoon depressions.

4.2.2 Relative Vorticity

The relative vorticity distribution at 850 and 200 hPa levels at 0000 UTC of 18 November 1992 are shown in Fig. 12(a) and (b). Large values of cyclonic

(positive) vorticity occurred upto mid-tropospheric levels close to the centre of the cyclone. The positive vorticity progressively decreased upwards with height and finally changed to anticyclonic (negative) vorticity at 200 hPa. However, maximum negative relative vorticity was observed to occur in the forward sector of the cyclone.

The distribution of relative vorticity over the Bay of Bengal in respect of the severe cyclonic storm of 11-17 November 1992 also showed similar features. The positive vorticity in the lower and middle troposphere of this cyclone was nearly of the same magnitude as that of the hurricane of 16-21 November 1992. The negative relative vorticity at 200 hPa was however, of much smaller magnitude in this cyclone than that of the hurricane of 16-21 November 1992.

4.2.3 Vertical Velocity

The vertical velocity fields over the Bay of Bengal at 850 and 200 hPa at 0000 UTC of 18 November 1992 are shown in Fig. 13 (a) and (b). Maximum upward motion occurred close to the centre of the cyclone which coincided with the region of the maximum low level convergence and cyclonic vorticity. Maximum downward motion occurred at 200 hPa level at about 4 to 5^{o} away to the west of the cyclone centre. Similar features of vertical motion were observed in respect of the cyclone of 11-17 November, 1992 also.

Fig. 14(a) & (b) show the vertical cross-sections of vertical motion field along Latitude 11.0^{o}N and Longitude 88.5^{o}E over the Bay of Bengal at 0000 UTC of 18 November, 1992. Large upward motion occurred close to the cyclone centre, which attained its maximum value in the mid-tropospheric levels. Maximum downward motion however, occurred in the upper troposphere to the north of the centre.

In the case of the monsoon depressions, the vertical velocity was downward in the lower levels close to the depression centre, while maximum upward motion occurred at a distance of 300-400 km away to the southwest of the centre. It may be noted that the southwest sector of a monsoon depression is a region of maximum cloudiness and high rainfall.

5. DISSEMINATION OF WARNINGS

The cyclone warnings were disseminated to the general public, Central and State Government officials and other user organisations in India through high priority telegrams, T/P, Telephone and Telex. The electronic and print media were also used extensively for this purpose. Timely cyclone warnings issued to the public and the State Government Officials of Tamilnadu, Kerala and Karnataka in respect of the severe cyclone of 11-17 November 1992 helped to a large extent in minimising the loss of life and property in these coastal States. Cyclone warnings in different local languages were communicated directly to the coastal population likely to be affected by the cyclone through the satellite based communication system known as the Disaster Warning System (DWS). In India, this system has been in operation in the coastal areas of Tamilnadu and Andhra Pradesh since 1987 and has proved very dependable and effective in quick dissemination of cyclone warnings during all these years.

6. CO-OPERATION AMONG PANEL COUNTRIES

The Regional Specialized Meteorological Centre (RSMC), New Delhi issued frequent tropical cyclone advisories to all the WMO/ESCAP Panel countries in the region during the Cyclone Season of 1992. The RSMC New Delhi received observations of the coastal Cyclone Detection Radar (CDR) stations in Bangladesh

in respect of the cyclone of 16-19 May 1992 and the hurricane of 16-21 November, 1992 which were useful in tracking the systems. RSMC, New Delhi issued Tropical Weather Outlook for the North Indian Ocean daily at 0600 UTC as a routine to the member countries of the WMO/ESCAP Panel.

7. CONCLUDING REMARKS

In 1992, 12 cyclonic disturbances formed over the North Indian Ocean, out of which 8 formed in the Bay of Bengal and 4 in the Arabian Sea. The year witnessed above average cyclone activity both over the Arabian Sea and the Bay of Bengal particularly during the post-monsoon season. Although, there were as many as 7 cyclonic disturbances attaining the cyclone intensity this year, but only one cyclone of 11-17 November affected the weather over the Indian peninsula. Under the influence of this weather system, widespread heavy to very heavy rainfall occurred in the coastal districts of Tamilnadu and Kerala.

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TABLE 1: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF CYCLONIC STORM 16 MAY - 19 MAY, 1992

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of the outermost closed isobar (°Lat)
16th MAY	0000	09.5	89.0	1.0	1002	-	1004	2.0	4.0
	0600	11.5	87.5	1.5	1002	25	1006	4.0	4.0
	1200	12.0	87.0	1.5	1000	25	1004	4.0	4.0
	1800	12.5	87.0	1.5	1000	25	1004	4.0	4.0
17th MAY	0000	12.5	87.0	1.5	998	25	1002	4.0	5.0
	0600	14.0	87.0	2.0	996	30	1002	6.0	6.0
	1200	14.5	87.5	2.0	996	30	1002	6.0	6.0
	1800	14.5	88.0	2.0	996	30	1002	6.0	6.0
18th MAY	0000	14.5	88.0	2.0	994	30	1002	8.0	7.0
	0600	15.5	89.5	2.5	994	35	1004	10.0	8.0
	1200	16.5	91.0	2.5	992	35	1002	10.0	8.0
	1800	17.0	91.5	2.5	994	35	1004	10.0	8.0
19th MAY	0000	17.5	92.5	2.5	992	35	1002	10.0	8.0
	0600	19.0	94.0	-	994	35	1002	8.0	6.0
	1200	19.5	94.5	-	998	25	1002	4.0	4.0
	1800	20.0	95.0	-	1000	-	1002	2.0	4.0

TABLE 2: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF CYCLONIC STORM 8 JUNE - 12 JUNE, 1992

Date	Time (UTC)	Centre Lat. (^{o}N)	Centre Long. (^{o}E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of outermost closed isobar(^{o}Lat)
8th	0000	11.5	60.0	-	1002	-	1004	2.0	5.0
JUNE	0600	11.5	60.0	-	1002	-	1004	2.0	5.0
	1200	11.5	60.0	1.5	1000	25	1004	4.0	5.0
	1800	11.5	60.0	1.5	1000	25	1004	4.0	5.0
9th	0000	11.5	60.0	1.5	998	25	1002	4.0	5.0
JUNE	0600	12.0	60.0	1.5	998	30	1004	6.0	6.0
	1200	12.0	60.0	1.5	998	30	1004	6.0	6.0
	1800	12.0	60.0	1.5	998	30	1004	6.0	6.0
10th	0000	12.5	60.0	1.5	998	30	1004	6.0	6.0
JUNE	0600	12.5	59.5	2.0	998	30	1004	6.0	6.0
	1200	12.5	60.0	2.0	998	30	1004	6.0	6.0
	1800	13.0	59.0	2.0	998	30	1004	6.0	6.0
11th	0000	13.0	58.5	2.0	998	30	1004	6.0	6.0
JUNE	0600	13.0	57.0	2.5	996	35	1004	8.0	7.0
	1200	13.5	56.0	3.0	994	45	1004	10.0	8.0
	1800	13.5	55.5	3.0	994	45	1004	10.0	8.0
12th	0000	14.0	55.0	2.5	996	35	1004	8.0	7.0
JUNE	0600	14.0	53.0	1.5	1000	25	1004	4.0	5.0
	1200	14.0	52.5	1.5	1000	25-	1004	4.0	5.0
	1800	14.0	51.5	-	1002	-	1004	2.0	4.0

TABLE 3: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF CYCLONIC STORM 1 OCTOBER - 3 OCTOBER, 1992

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of outermost closed isobar(°Lat)
1st OCT	0000	16.0	67.0	1.5	1002	25	1006	4.0	5.0
	0600	17.0	66.0	2.0	1002	30	1008	6.0	6.0
	1200	17.5	65.0	2.5	998	35	1006	8.0	7.0
	1800	17.5	64.0	2.5	1000	35	1008	8.0	7.0
2nd OCT	0000	17.5	63.0	2.5	998	35	1006	8.0	7.0
	0600	17.5	62.0	3.0	998	45	1008	10.0	8.0
	1200	18.5	60.5	2.5	1000	35	1008	8.0	7.0
	1800	19.5	59.5	2.5	1002	35	1010	8.0	7.0
3rd OCT	0000	19.5	58.5	3.0	996	45	1006	10.0	8.0
	0600	20.0	56.5	-	1000	35	1008	8.0	6.0
	1200	20.5	56.0	-	1000	35	1008	8.0	6.0
	1800	20.5	55.0	-	1006	-	1008	2.0	5.0

TABLE 4: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF CYCLONIC STORM, 20 OCTOBER - 22 OCTOBER, 1992

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of outermost closed isobar(°Lat)
20th	0000	18.0	88.5	-	1004	-	1002	2.0	4.0
OCT	0600	18.5	89.0	-	1004	-	1006	2.0	4.0
	1200	19.0	89.0	1.5	1000	25	1004	4.0	5.0
	1800	19.5	89.0	1.5	1002	25	1006	4.0	5.0
21st	0000	19.5	89.5	2.0	1000	30	1006	6.0	6.0
OCT	0600	20.5	90.5	2.5	998	35	1006	8.0	8.0
	1200	21.0	91.5	2.5	996	35	1004	8.0	8.0
	1800	21.0	92.0	2.5	998	35	1006	8.0	7.0
22nd	0000	22.0	94.0	-	1000	25	1004	4.0	5.0
OCT	0600	22.5	94.5	-	1004	-	1006	2.0	4.0

TABLE 5: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF CYCLONIC STORM 3 NOVEMBER - 6 NOVEMBER, 1992

Date	Time (UTC)	Centre Lat. (^{O}N)	Centre Long. (^{O}E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of outermost closed isobar(^{O}Lat)
3rd	0000	15.0	90.0	-	1002	-	1004	2.0	4.0
NOV.	0600	15.0	90.0	2.0	1000	30	1006	6.0	5.0
	1200	15.5	89.5	2.0	998	30	1004	6.0	6.0
	1800	15.5	89.0	2.0	1000	30	1006	6.0	6.0
4th	0000	15.5	89.0	2.5	998	35	1006	8.0	7.0
NOV.	0600	15.5	87.5	2.5	998	35	1006	8.0	7.0
	1200	15.5	87.5	2.5	998	35	1006	8.0	7.0
	1800	15.5	87.5	2.5	1000	35	1008	8.0	8.0
5th	0000	16.0	86.5	3.0	998	45	1008	10.0	8.0
NOV.	0600	16.0	86.0	3.0	998	45	1008	10.0	8.0
	1200	16.0	86.0	3.0	996	45	1006	10.0	8.0
	1800	16.0	86.0	3.0	998	45	1008	10.0	8.0
6th	0000	16.5	85.5	3.0	1000	45	1010	10.0	8.0
NOV	0600	16.5	85.5	3.0	1000	45	1010	10.0	8.0
	1200	16.5	85.5	2.5	1000	35	1008	8.0	7.0
	1800	16.5	84.5	2.0	1002	30	1008	6.0	6.0
7th	0000	16.0	83.0	2.0	1004	30	1010	6.0	6.0
NOV.	0600	16.0	82.5	-	1008	-	1010	2.0	5.0

TABLE 6: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF SEVERE CYCLONIC STORM, 11 NOVEMBER - 17 NOVEMBER, 1992

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum surface pressure (hPa)	Minimum estimated wind (kt)	Maximum closed isobar (hPa)	Outermost ΔP (hPa)	Size of outermost closed isobar (°Lat)
11th NOV.	0000	7.5	86.5	-	1004	-	1006	2.0	4.0
	0600	7.5	85.5	2.0	1002	30	1008	6.0	5.0
	1200	7.5	84.5	3.0	998	45	1008	10.0	6.0
	1800	7.5	83.5	3.0	998	45	1008	10.0	7.0
12th NOV	0000	7.0	82.5	3.0	996	45	1008	12.0	8.0
	0600	7.0	81.5	2.5	1002	35	1010	8.0	8.0
	1200	7.5	80.0	2.5	1000	35	1008	8.0	8.0
	1800	7.5	79.5	2.5	998	35	1006	8.0	8.0
13th NOV	0000	7.5	79.0	2.5	1000	35	1008	8.0	8.0
	0600	8.0	78.5	3.5	994	55	1008	16.0	8.0
	1200	9.0	77.5	-	996	45	1006	10.0	8.0
	1800	9.5	77.5	-	1000	30	1006	6.0	6.0
14th NOV	0000	9.8	77.0	-	1000	30	1006	6.0	6.0
	0600	10.5	76.5	1.5	1002	25	1006	4.0	6.0
	1200	10.5	76.0	1.5	1002	25	1006	4.0	6.0
	1800	10.5	75.5	1.5	1004	25	1008	4.0	6.0
15th NOV	0000	10.5	75.0	1.5	1002	25	1006	4.0	6.0
	0600	11.0	74.5	2.0	1000	30	1006	6.0	6.0
	1200	11.5	74.5	2.0	1000	30	1006	6.0	6.0
	1800	12.0	74.5	-	1002	30	1008	6.0	6.0
16th NOV.	0000	12.5	74.5	-	1000	30	1006	6.0	6.0
	0600	12.5	74.5	-	1002	30	1006	6.0	6.0
	1200	13.5	74.5	-	1000	30	1006	6.0	6.0
	1800	13.5	74.5	-	1002	30	1008	6.0	6.0
17th NOV.	0000	14.0	74.5	-	1000	30	1006	6.0	6.0
	0600	14.5	74.5	-	1002	25	1006	4.0	5.0
	1200	15.0	75.0	-	1004	-	1006	2.0	4.0

TABLE 7: BEST TRACK POSITIONS ALONGWITH OTHER PARAMETERS OF SEVERE CYCLONIC STORM WITH A CORE OF HURRICANE WINDS, 16 NOVEMBER - 21 NOVEMBER, 1992

Date	Time (UTC)	Centre Lat. (°N)	Centre Long. (°E)	T.No.	Minimum surface pressure (hPa)	Maximum estimated wind (kt)	Outermost closed isobar (hPa)	ΔP (hPa)	Size of outermost closed isobar(°Lat)
16th NOV	0000	9.5	97.0	-	1006	-	1008	2.0	4.0
	0600	9.5	95.5	1.5	1004	25	1008	4.0	4.0
	1200	9.5	94.5	1.5	1002	25	1006	4.0	5.0
	1800	9.5	93.5	2.0	1000	30	1006	6.0	6.0
17th NOV	0000	9.5	92.0	2.5	1000	35	1008	8.0	7.0
	0600	9.5	90.5	3.0	996	45	1006	10.0	8.0
	1200	10.0	90.0	3.5	990	55	1006	16.0	10.0
	1800	10.5	89.5	4.0	986	65	1008	22.0	10.0
18th NOV	0000	11.0	88.5	4.5	978	77	1008	30.0	10.0
	0600	12.0	87.8	4.5	976	77	1006	30.0	10.0
	1200	13.5	87.5	4.5	974	77	1004	30.0	10.0
	1800	14.5	87.5	4.5	974	77	1004	30.0	10.0
19th NOV	0000	16.0	87.5	5.0	966	90	1006	40.0	10.0
	0600	16.5	87.5	5.5	952	102	1004	52.0	10.0
	1200	17.5	88.5	5.5	952	102	1004	52.0	10.0
	1800	18.0	88.5	5.5	954	102	1006	52.0	10.0
20th NOV	0000	18.5	89.0	5.5	954	102	1006	52.0	10.0
	0600	19.0	89.5	5.5	956	102	1008	52.0	10.0
	1200	19.5	90.0	5.0	968	90	1008	40.0	9.0
	1800	19.5	91.0	5.0	972	90	1012	40.0	9.0
21st NOV	0000	20.0	91.5	5.0	972	90	1012	40.0	8.0
	0600	20.0	92.5	3.0	1000	45	1010	10.0	7.0
	1200	20.5	93.5	-	1000	35	1008	8.0	6.0
	1800	21.0	94.0	-	1008	15	1010	2.0	4.0

TABLE 8: 12, 24 AND 36 HOUR FORECAST POSITION ERRORS FOR INDIVIDUAL TROPICAL CYCLONE OVER THE BAY OF BENGAL BASED ON ANALOGUE AND CLIPER FORECAST MODELS

Tropical Cyclones	ANALOGUE Forecast Errors (km)			CLIPER		
	12-hr	24-hr	36-hr	12-hr	24-hr	36-hr
16-19 May, 1992	115	160	-	127	241	496
20-22 October	235	-	-	146	343	465
3-6 November	85	147	118	99	172	252
11-16 November	130	157	180	100	170	187
16-21 November	97	239	398	97	225	377
Average Error	132	175	232	114	230	347

MEANING OF THE SYMBOLS USED IN FIGURES

	Sea level position of depression/cyclone (with wind speed up to 63 kt)
	Sea level position of severe cyclonic storm with a core of hurricane winds (wind speed 64 kt or more)
C	Convergence in vergence field
D	Divergence in vergence field
	Downward vertical velocity
	Upward vertical velocity
–	Anticyclonic relative vorticity
+	Cyclonic relative vorticity

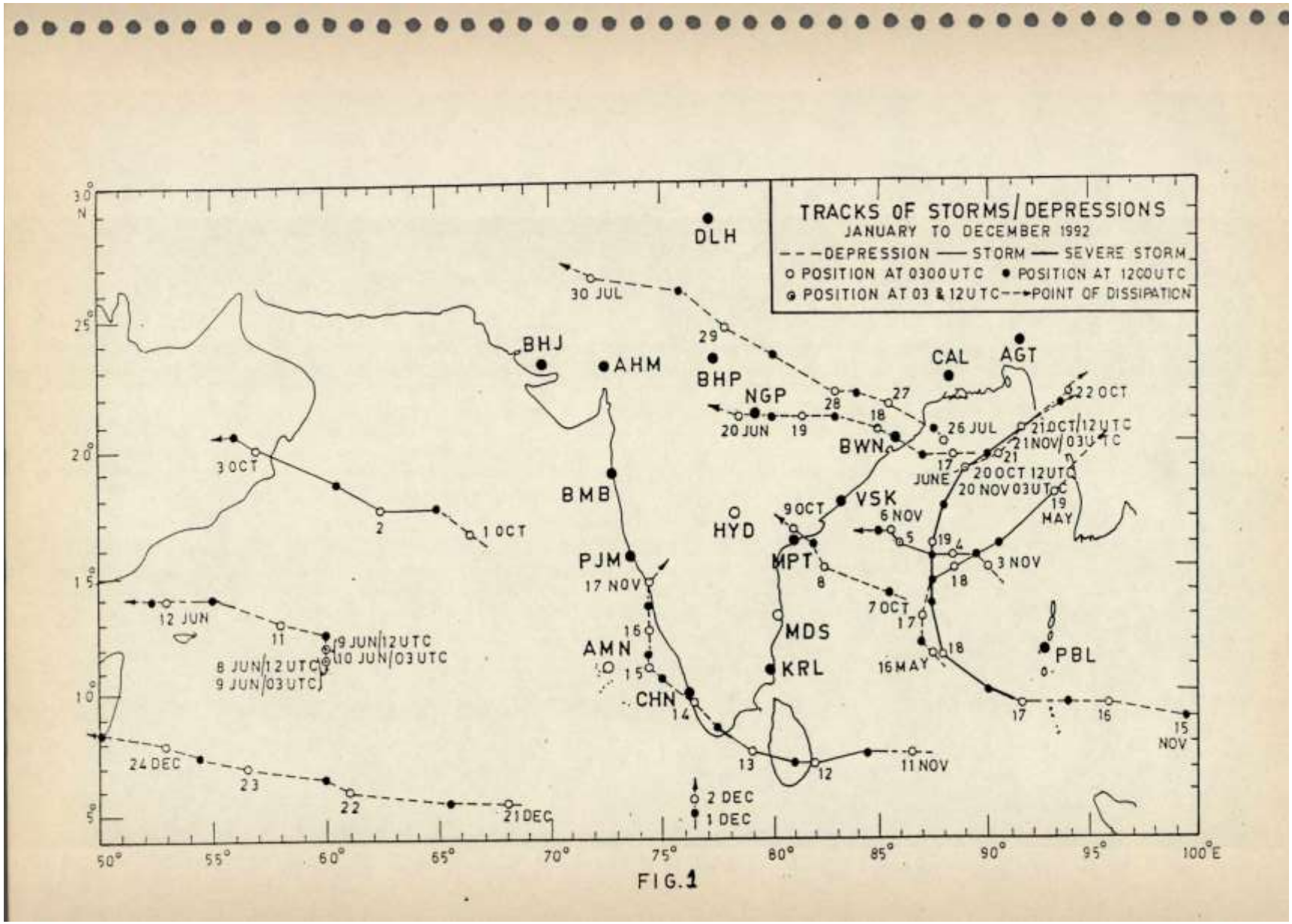

TRACKS OF STORMS/DEPRESSIONS
JANUARY TO DECEMBER 1992
---DEPRESSION —— STORM —— SEVERE STORM
o POSITION AT 0300 UTC • POSITION AT 1200 UTC
⊙ POSITION AT 03 & 12 UTC --→ POINT OF DISSIPATION
DLH
BHJ
AHM
BHP
NGP
CAL
AGT
BWN
BMB
HYD
VSK
PJM
MPT
MDS
KRL
AMN
CHN
PBL
30 JUL
29
27
28
18
20 JUN
19
26 JUL
22 OCT
21 OCT/12 UTC
21 NOV/03 UTC
17
21
JUNE
20 OCT 12 UTC
20 NOV 03 UTC
19
MAY
3 OCT
2
1 OCT
9 OCT
6 NOV
5
19
4
3 NOV
18
8
7 OCT
17
17 NOV
16
15
14
13
12
11 NOV
16 MAY
18
17
16
15
NOV
12 JUN
11
9 JUN/12 UTC
10 JUN/03 UTC
8 JUN/12 UTC
9 JUN/03 UTC
24 DEC
23
22
21 DEC
2 DEC
1 DEC
30° N
25°
20°
15°
10°
5°
50°
55°
60°
65°
70°
75°
80°
85°
90°
95°
100° E

FIG. 1

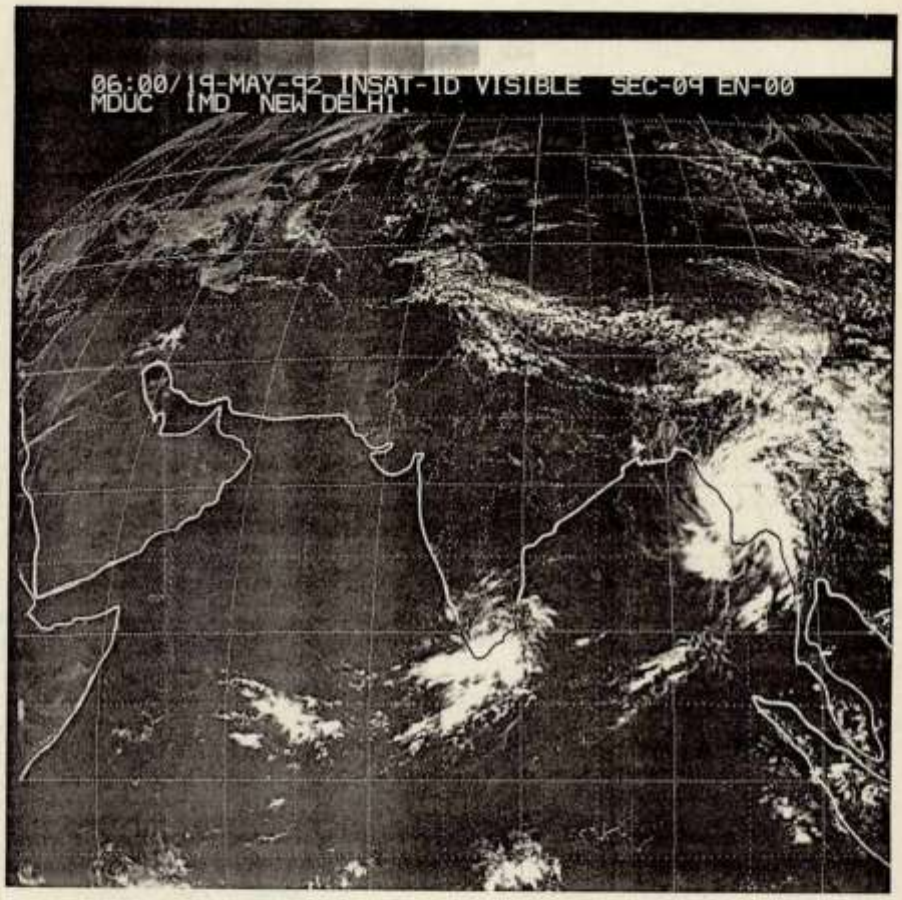


FIG. 2. INSAT-1D SATELLITE IMAGERY- 0600 UTC OF 19 MAY, 1992

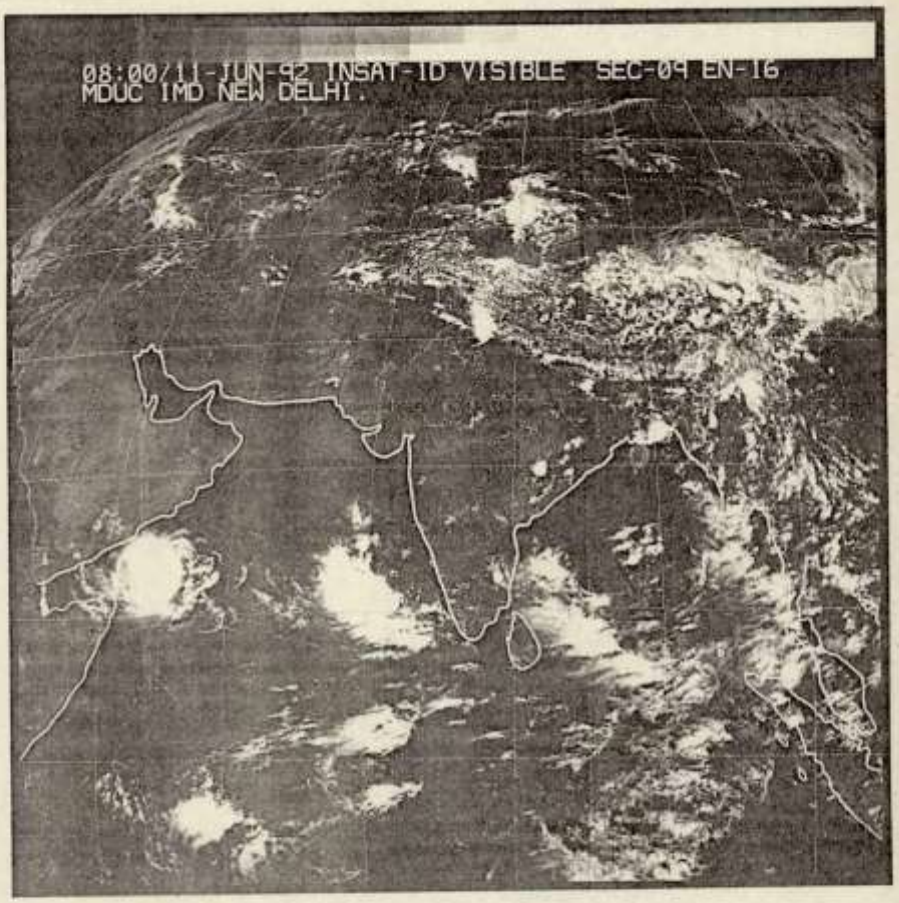


FIG. 3. INSAT-1D SATELLITE IMAGERY - 0800 UTC OF 11 JUN, 1992

FIG.4. INSAT-2A SATELLITE IMAGERY- 0600 UTC OF 1 OCT, 1992

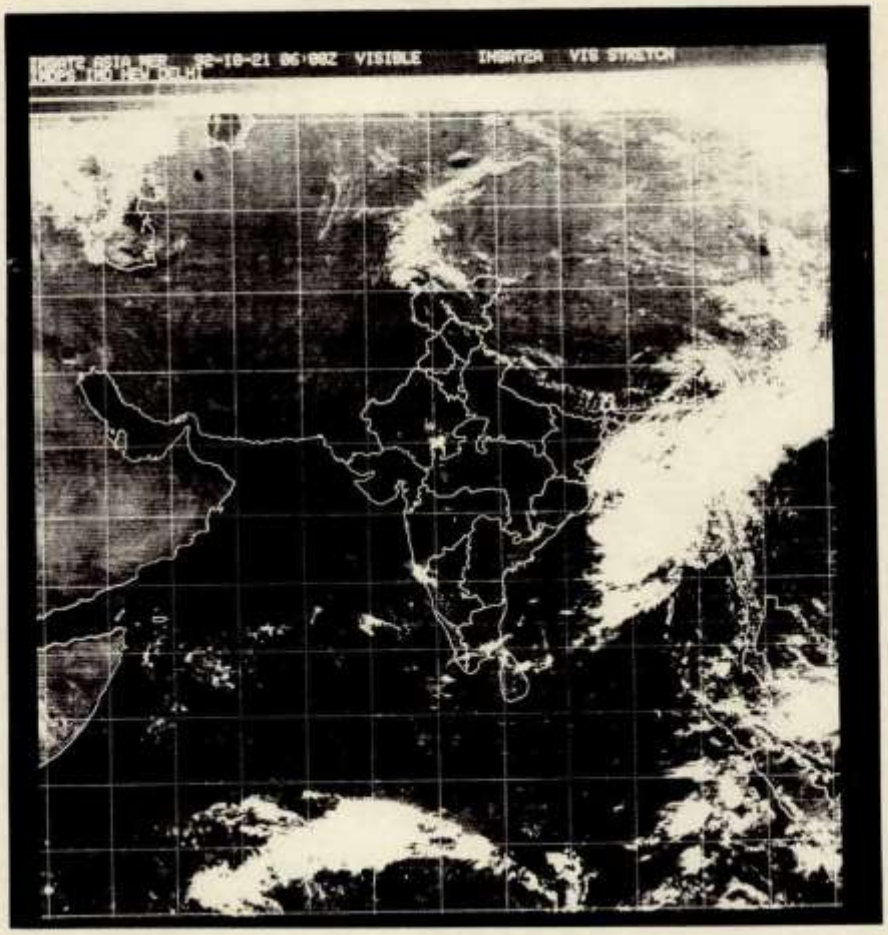


FIG.5 INSAT-2A SATELLITE IMAGERY-0600 UTC OF 21OCT, 1992

FIG. 6. INSAT-2A SATELLITE-IMAGERY 0900 UTC 5 NOV, 1992

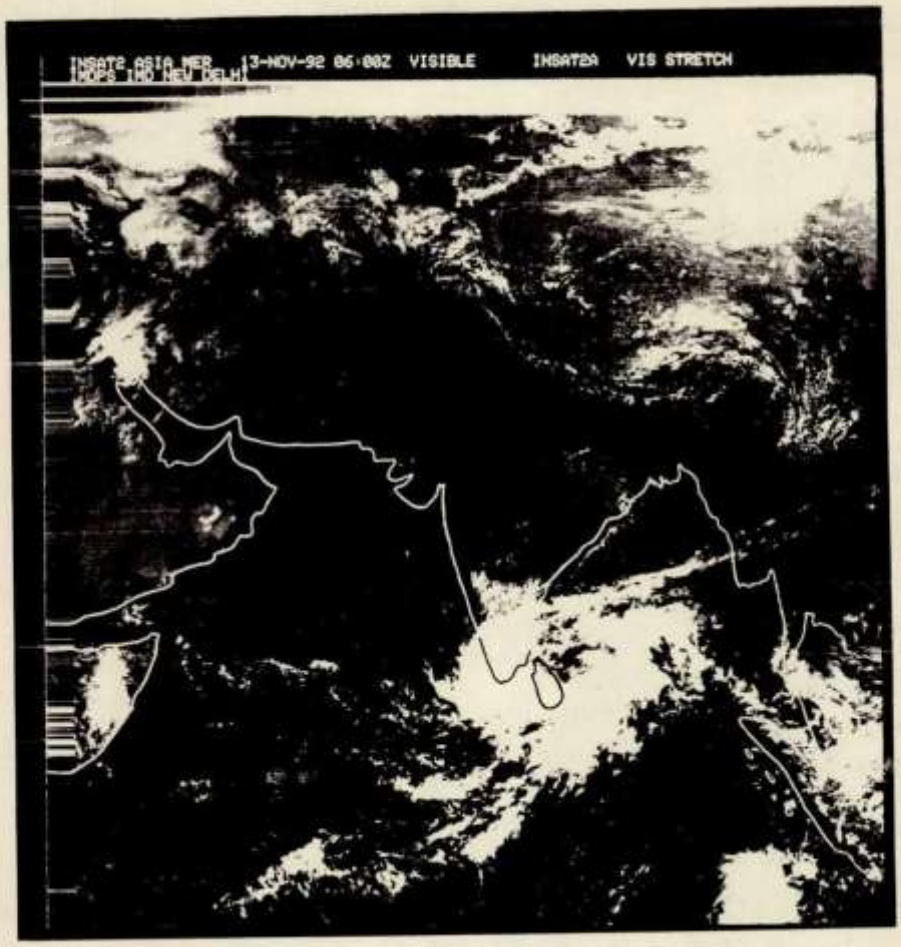


FIG.7 INSAT-2A SATELLITE IMAGERY - 0600 UTC OF 13 NOV, 1992

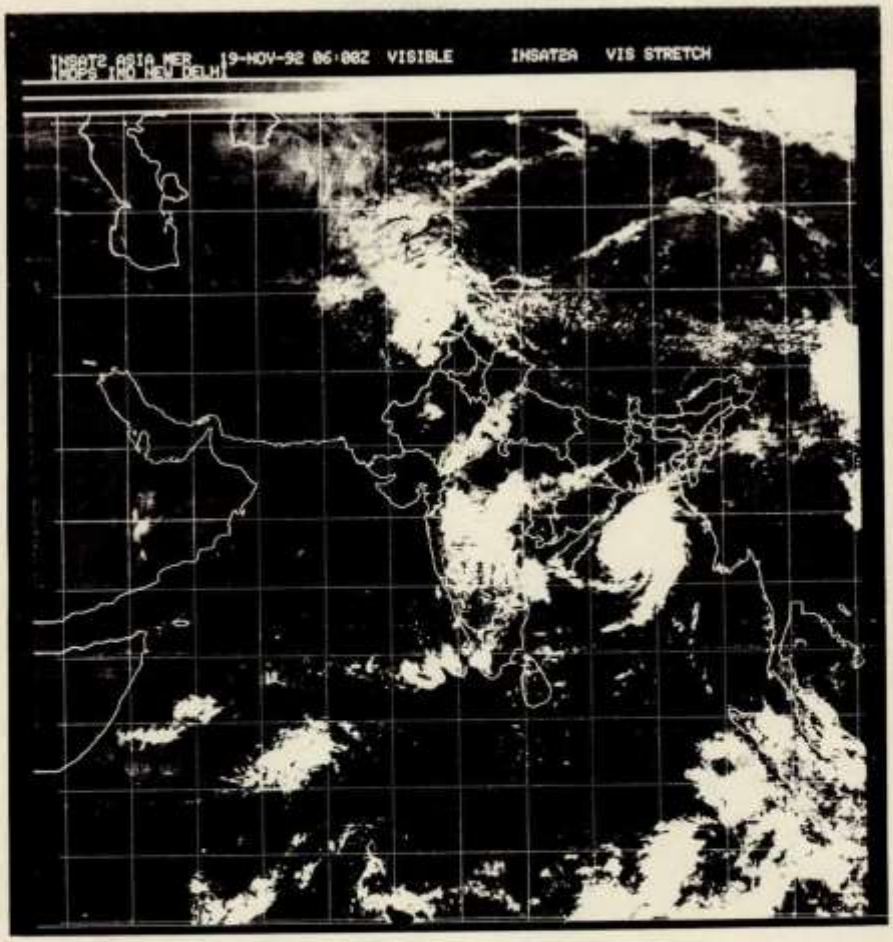


FIG. 8. INSAT-2A SATELLITE IMAGERY - 0600 UTC OF 19 NOV, 1992

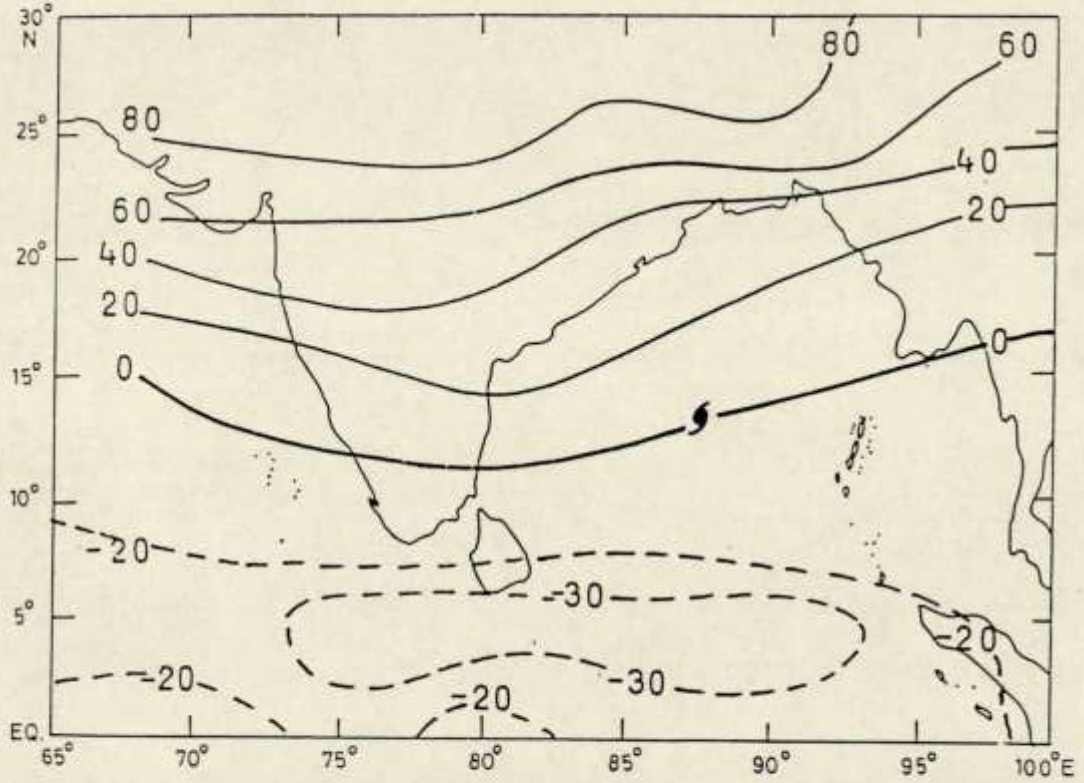


FIG. 9. VERTICAL SHEAR OF ZONAL WIND BETWEEN 850 AND 200 hPa AT 1200 UTC OF 18 NOVEMBER, 1992
(UNIT : Knot 650 hPa^{-1})

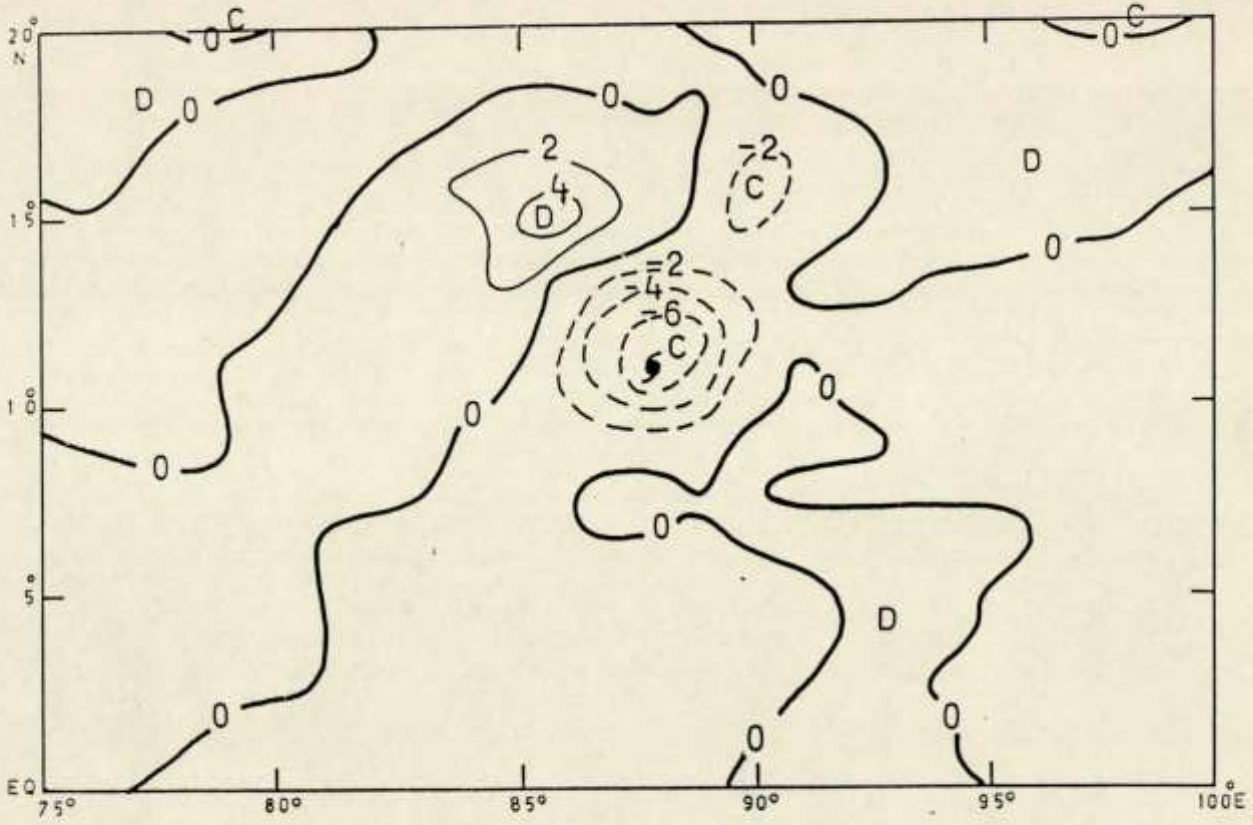


FIG.10(a). VERGENCE, 850hPa, 00 UTC OF 18.11.1992
(UNIT: 10^{-5} SEC^{-1})

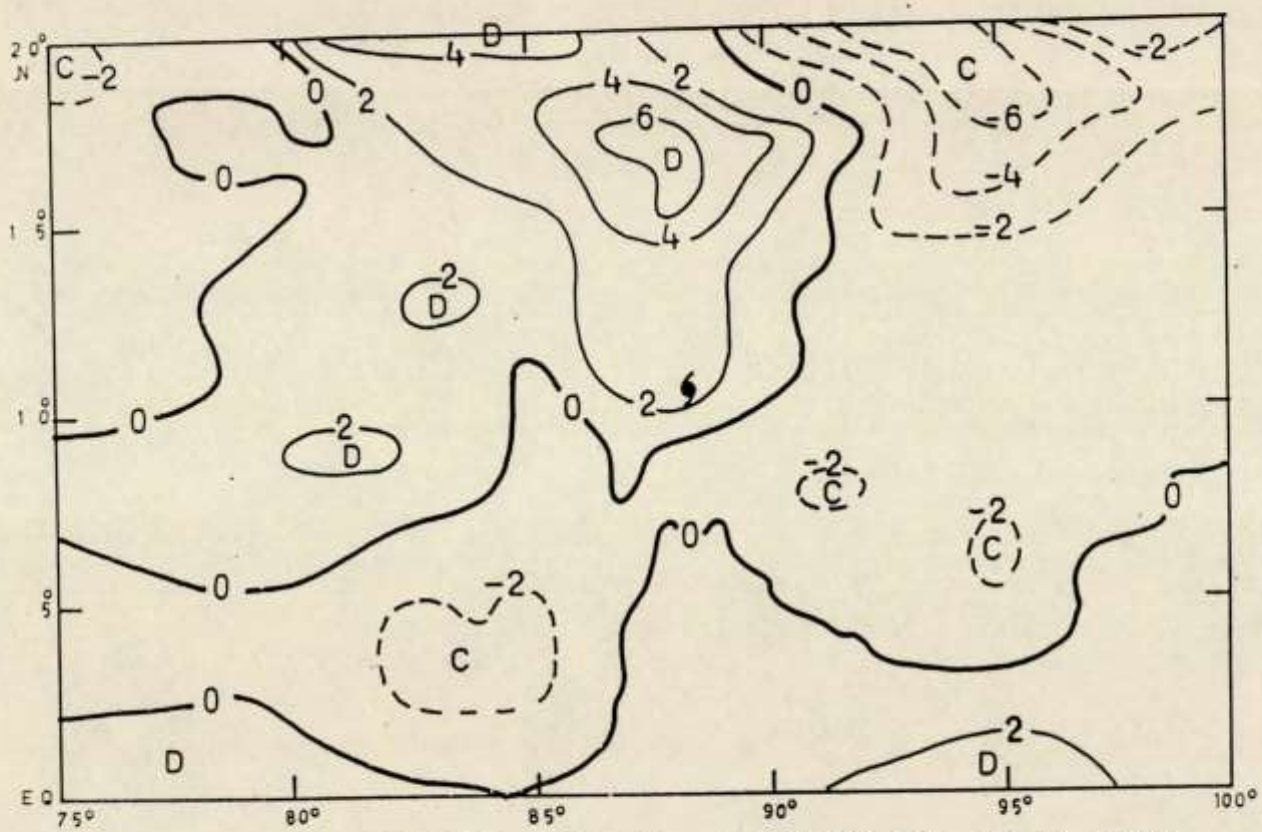


FIG. 10(b). VERGENCE, 200 hPa, 00 UTC OF 18.11.1992
(UNIT: 10^{-5} SEC^{-1})

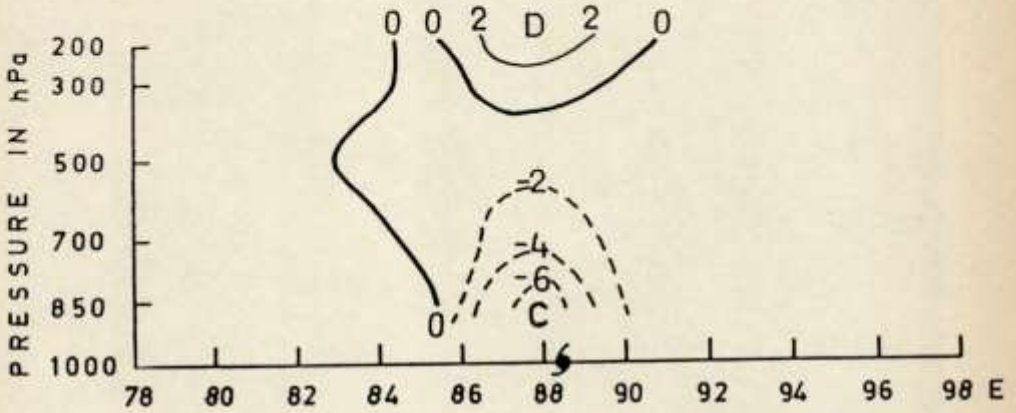


FIG.11(a).VERTICAL CROSS-SECTION OF VERGENCE OVER THE BAY OF BENGAL ALONG LAT 11.0° N ON 18·11·1992 (0 0 UTC)
(UNIT : 10^{-5} SEC^{-1})

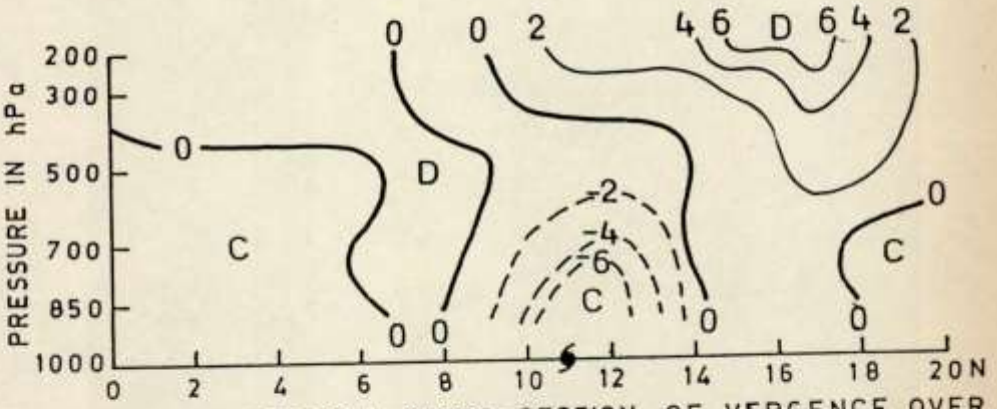


FIG. 11(b). VERTICAL CROSS-SECTION OF VERGENCE OVER THE BAY OF BENGAL ALONG LONG. 88·5° E ON 18.11.1992 (00 UTC)
(UNIT : 10^{-5} SEC^{-1})

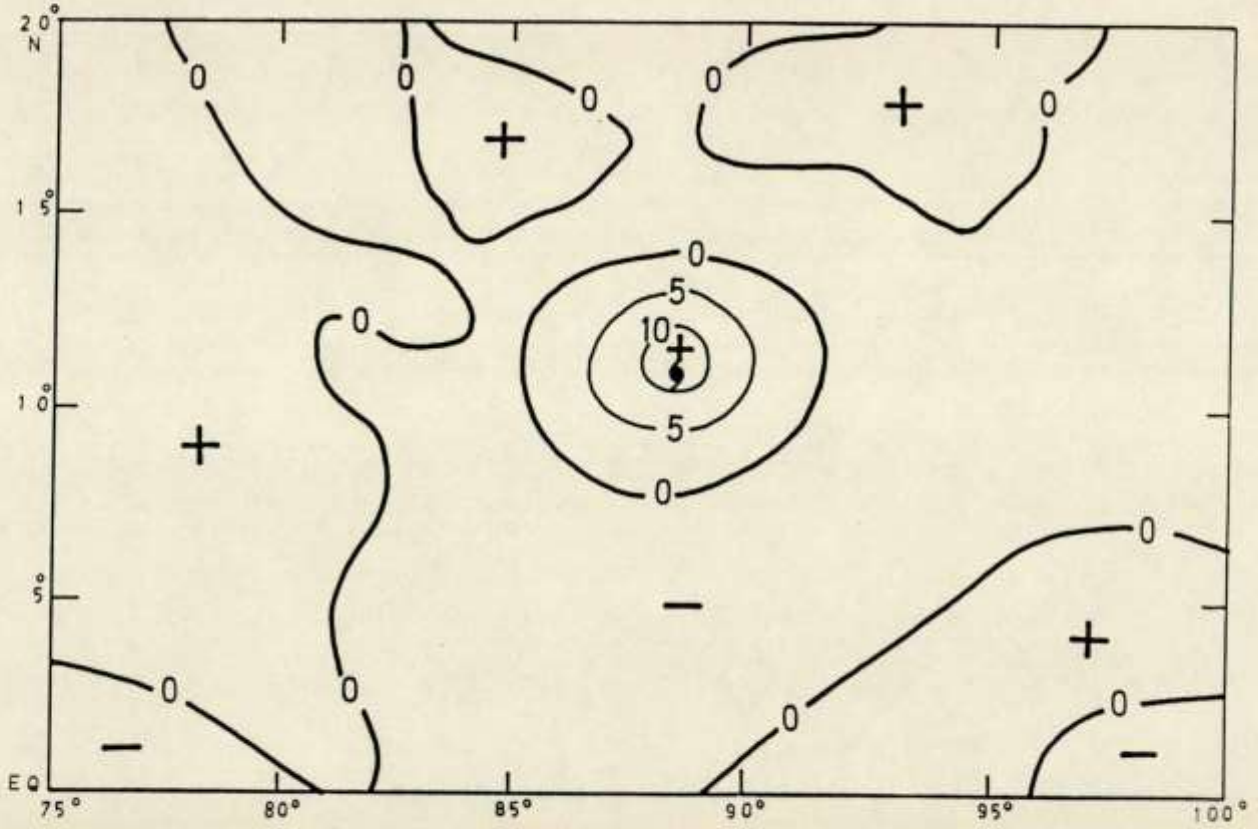


FIG. 12(a). RELATIVE VORTICITY, 850 hPa, 00 UTC OF 18.11.1992
(UNIT : 10^{-5} SEC^{-1})

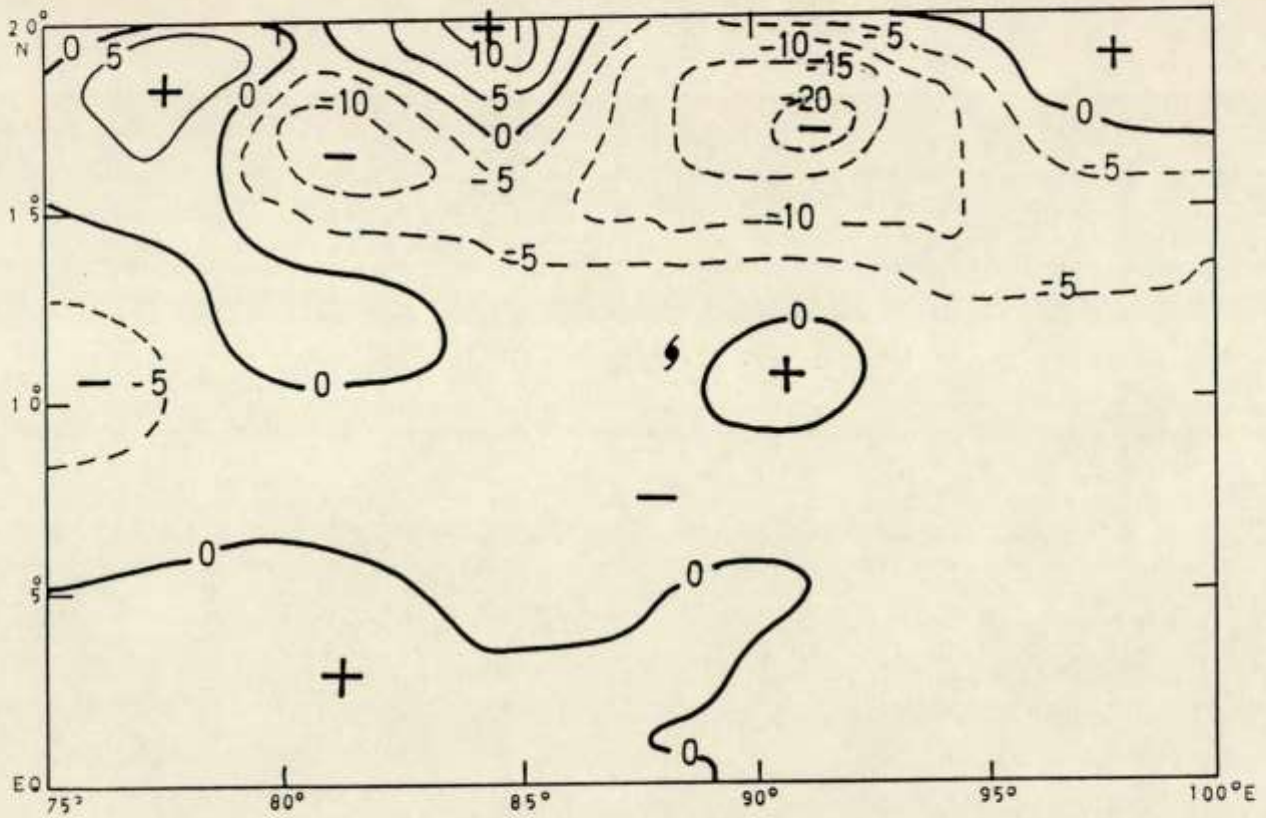


FIG.12(b). RELATIVE VORTICITY, 200 hPa, 00 UTC OF 18.11.1992
(UNIT: 10^{-5} SEC^{-1})

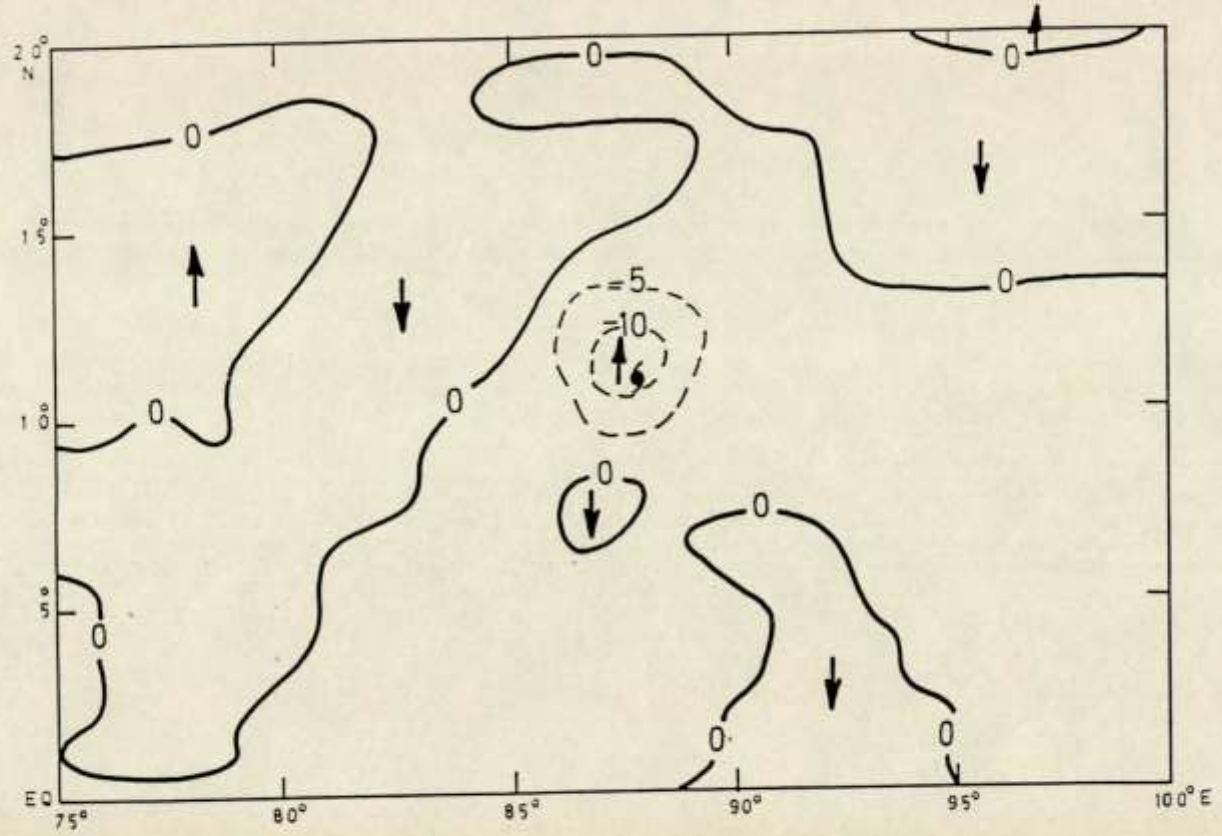


FIG.13(a). VERTICAL MOTION, 850 hPa, 00 UTC OF 18.11.1992
(UNIT : 10^{-3} hPa SEC^{-1})

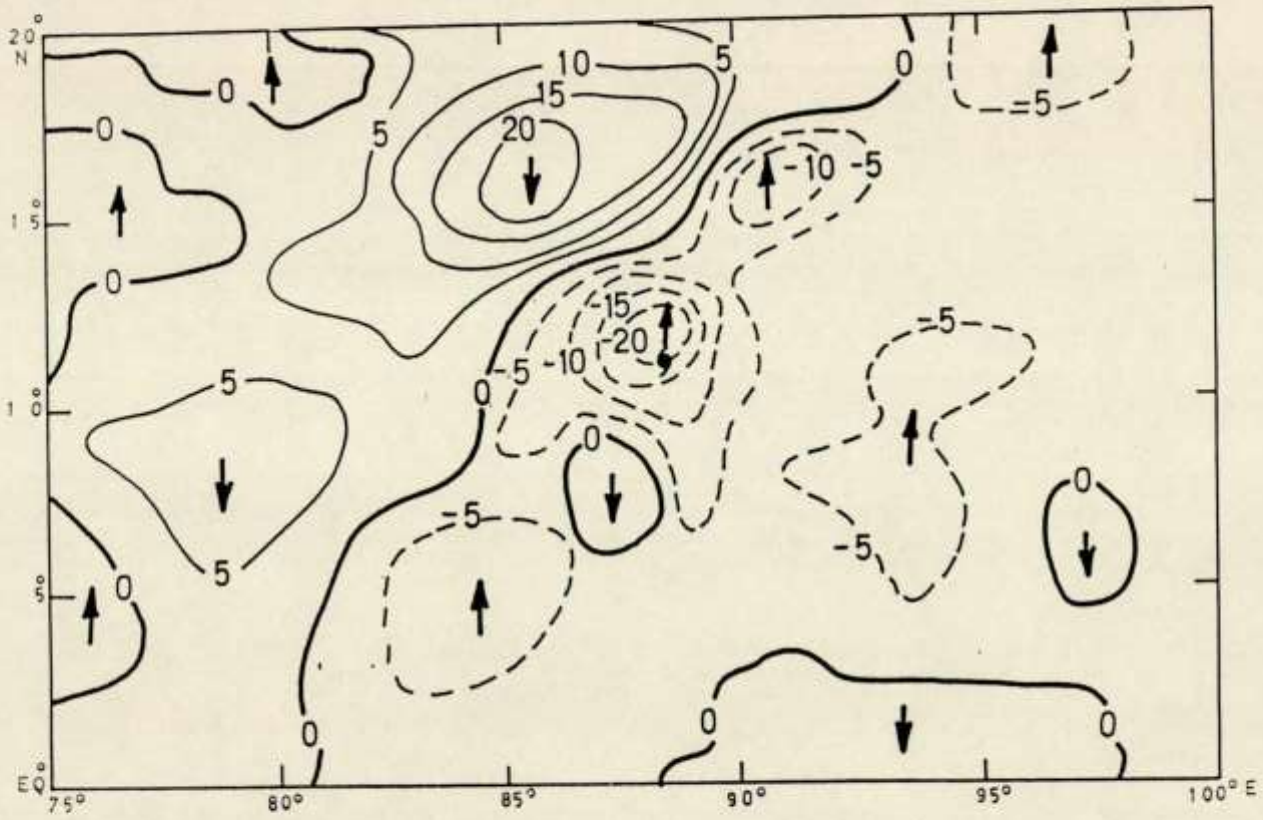


FIG.13(b).VERTICAL MOTION, 200 hPa, 00 UTC OF 18.11.1992
(UNIT : 10^{-3} hPa SEC^{-1})

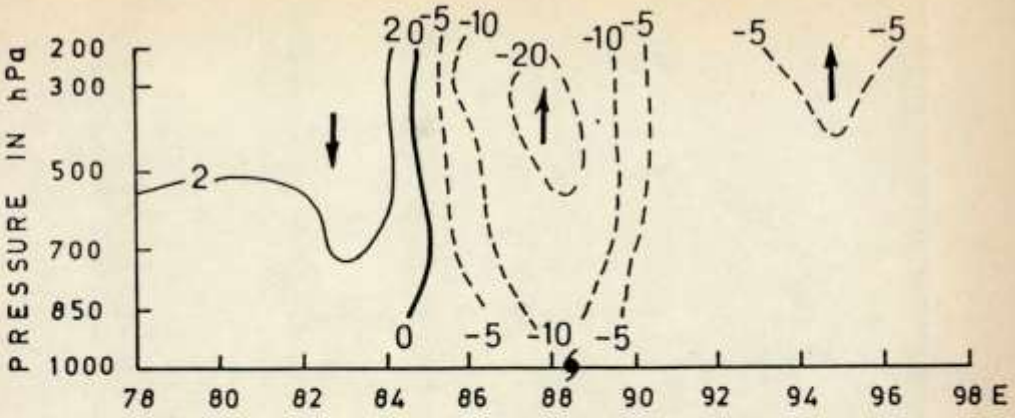


FIG.14(a) VERTICAL CROSS-SECTION OF VERTICAL VELOCITY OVER THE BAY OF BENGAL ALONG LAT. 11·0°N ON 18·11·1992 (00 UTC)
(UNIT : 10^{-3} hPa SEC^{-1})

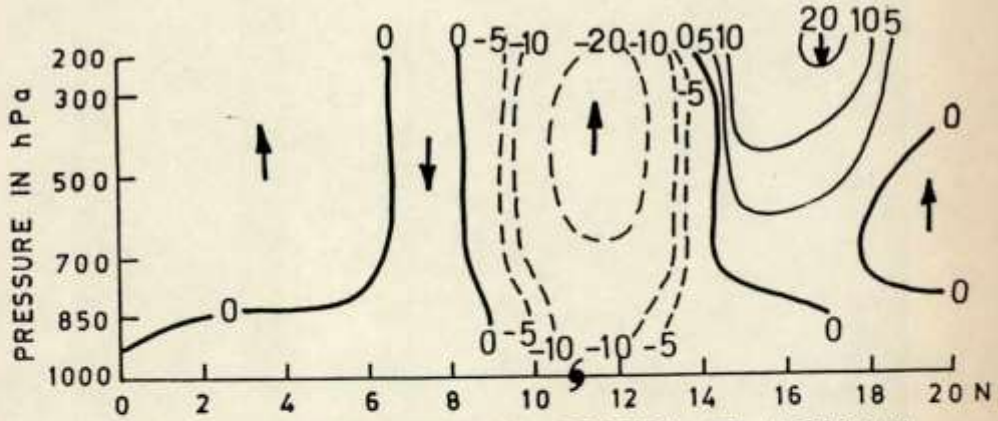
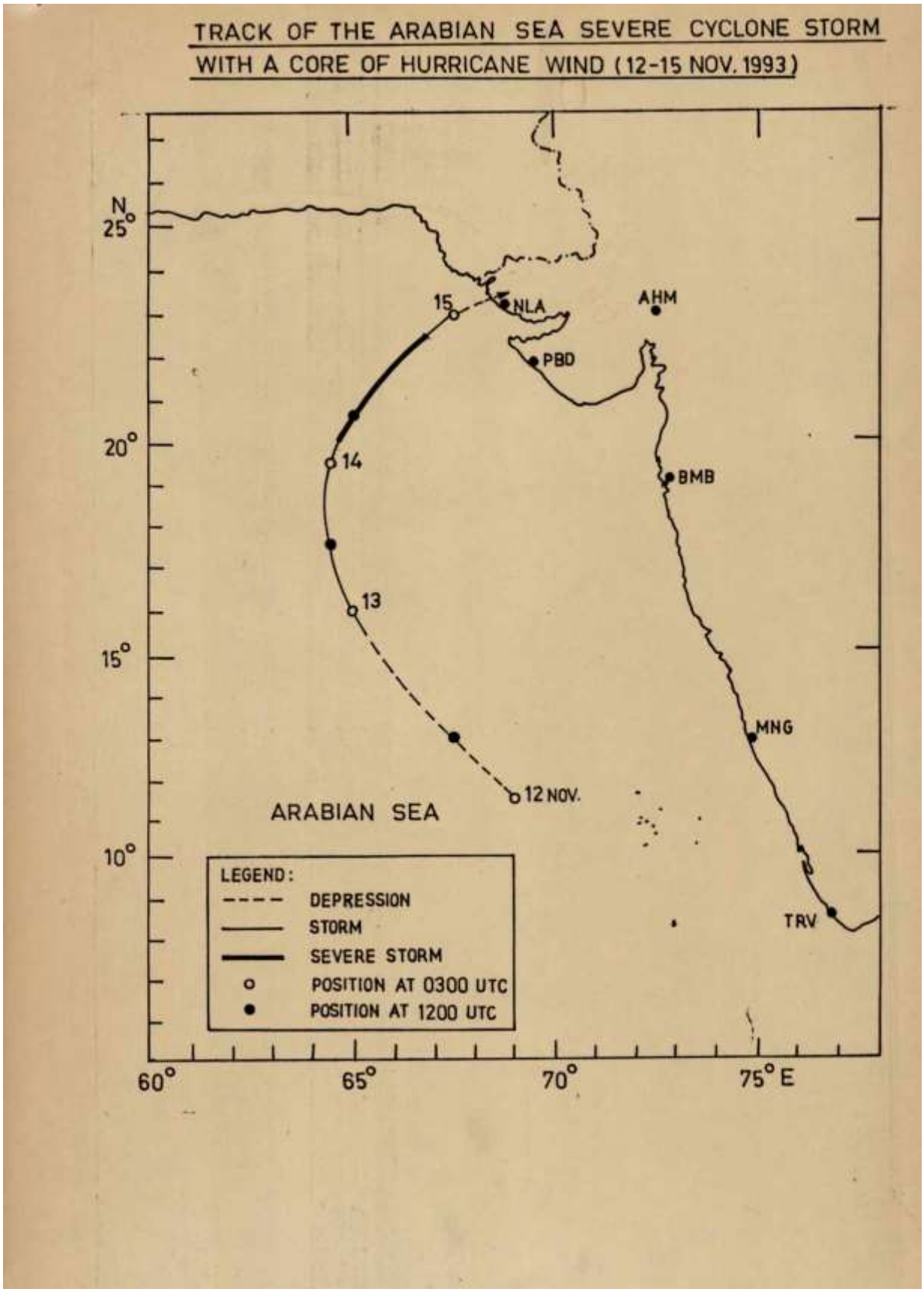
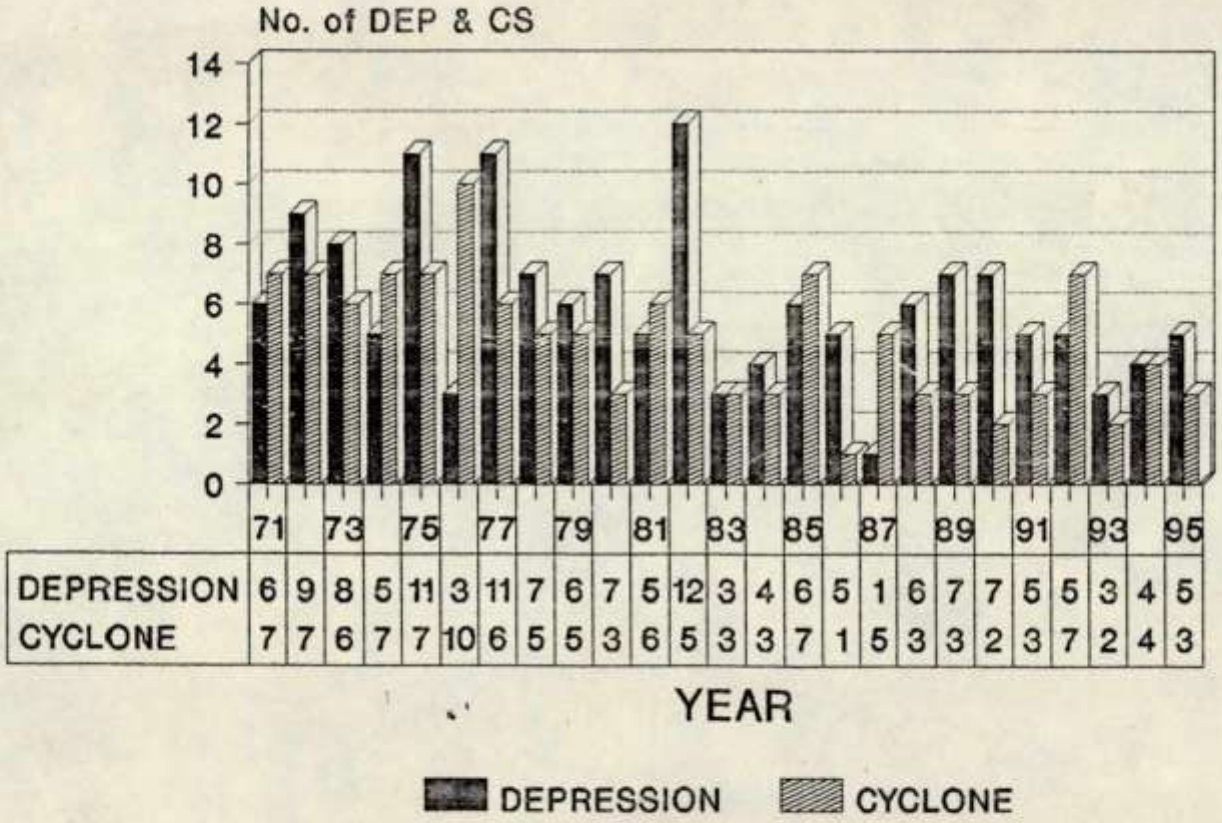


FIG.14(b). VERTICAL CROSS-SECTION OF VERTICAL VELOCITY OVER THE BAY OF BENGAL ALONG LONG. 88·5°E ON 18.11.1992 (00 UTC)
(UNIT : 10^{-3} hPa SEC^{-1})

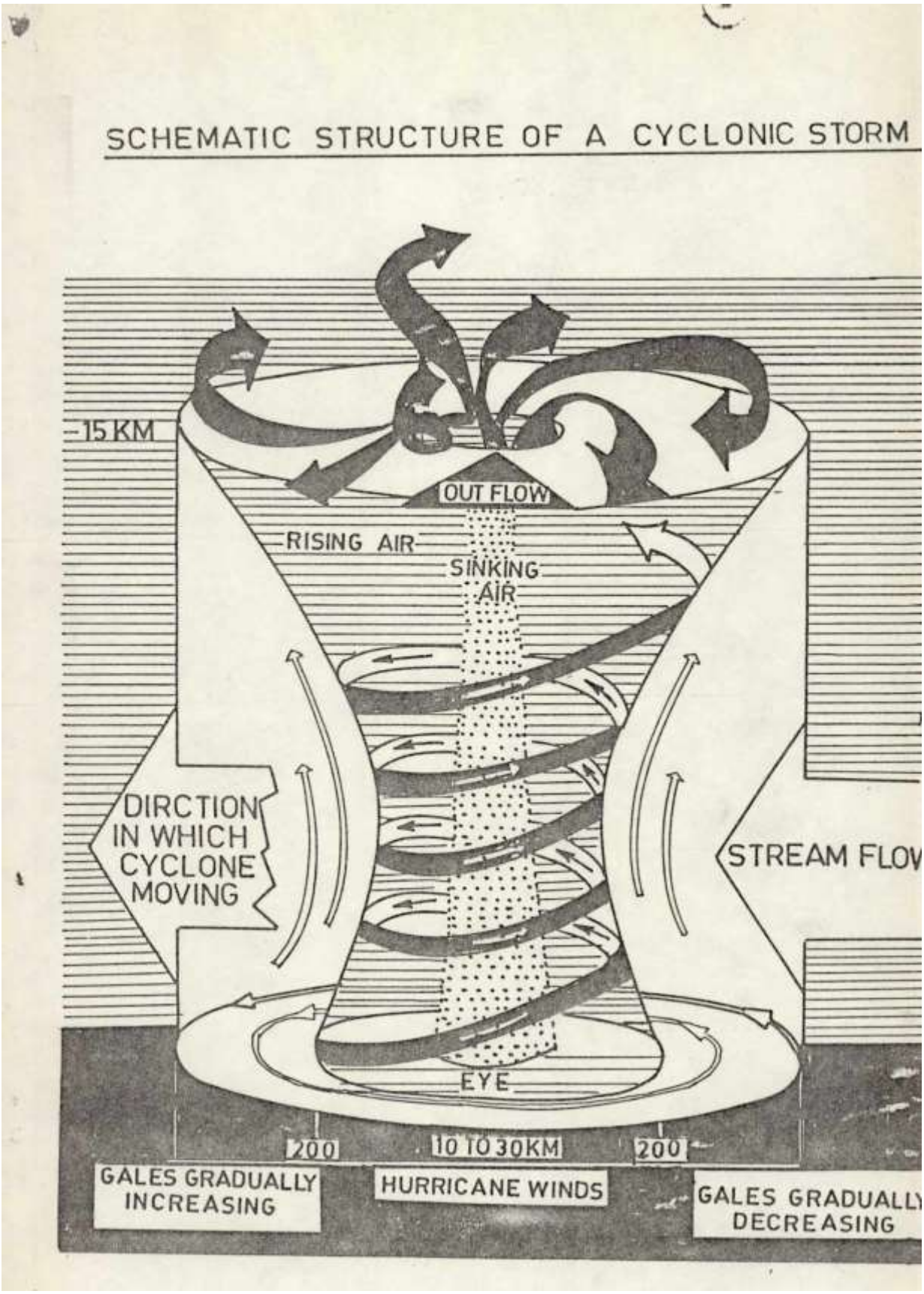

TRACK OF THE ARABIAN SEA SEVERE CYCLONE STORM
WITH A CORE OF HURRICANE WIND (12-15 NOV. 1993)
N
25°
20°
15°
10°
60°
65°
70°
75° E
15
NLA
AHM
PBD
14
BMB
13
MNG
12 NOV.
ARABIAN SEA
TRV
LEGEND:
DEPRESSION
STORM
SEVERE STORM
POSITION AT 0300 UTC
POSITION AT 1200 UTC

DISTURBANCES OVER NORTH INDIAN OCEAN
DEPRESSION & CYCLONE



	71	73	75	77	79	81	83	85	87	89	91	93	95
DEPRESSION	6 9	8 5	11 3	11 7	6 7	5 12	3 4	6 5	1 6	7 7	5 5	3 4	5
CYCLONE	7 7	6 7	7 10	6 5	5 3	6 5	3 3	7 1	5 3	3 2	3 7	2 4	3

PERIOD: 1971-1995


SCHEMATIC STRUCTURE OF A CYCLONIC STORM
15 KM
OUT FLOW
RISING AIR
SINKING AIR
DIRCTION IN WHICH CYCLONE MOVING
STREAM FLOW
EYE
200
10 TO 30 KM
200
GALES GRADUALLY INCREASING
HURRICANE WINDS
GALES GRADUALLY DECREASING