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Cyclones and depressions over the north Indian Ocean during 2010*

1. Introduction

During 2010, in all 7 intense low pressure systems [excluding the Cyclonic Storm Bandu (19 - 23 May) over the Arabian Sea, which formed to the west of Long. 55° E, thereby not influencing the weather over the Indian region] formed over the Indian seas. These include two Very Severe Cyclonic Storms (Phet & Giri), two Severe Cyclonic Storms (Laila & Jal); one Deep Depression and two Depressions. Out of these 7 systems, the Very Severe Cyclonic Storm (Phet) and the Severe Cyclonic Storm (Laila) occurred during the pre-monsoon season and the Very Severe Cyclonic Storm (Giri), the Severe Cyclonic Storm (Jal), two Deep Depressions and one Depression occurred during the post-monsoon season. All the low pressure systems formed over the Bay of Bengal except Phet, which formed over the Arabian Sea. No intense low pressure system formed during the southwest Monsoon season.

The Severe Cyclonic Storm (Laila) over the Bay of Bengal crossed Andhra Pradesh coast near Bapatla. The very Severe Cyclonic Storm (Phet) over the Arabian Sea crossed Oman coast; re-emerged into northwest Arabian Sea and then it crossed Pakistan coast, close to south of Karachi as a Depression.

The Very Severe Cyclonic Storm (Giri) over the Bay of Bengal struck Myanmar coast and crossed near Sittwe. The Severe Cyclonic Storm (Jal) over the Bay of Bengal crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai.

All the three Depressions formed over the Bay of Bengal during the post-monsoon season. As stated earlier, southwest Monsoon season 2010 was devoid of any Depressions and this is the second such year in the recorded history, after the year 2002, during which no low pressure area concentrated into Depression during southwest monsoon season.

The track/intensity of these systems is given in Fig. 1. A brief history and monthly distribution are given in Tables 1 & 2. The relevant ship and buoy observations are given in Table 3. Detailed season wise descriptions of these systems are given below.

2. Disturbances formed during the winter season (January and February)

No intense system formed during the season.

3. Disturbances formed during the pre-monsoon Season (March to May)

3.1. *Severe Cyclonic Storm (Laila) over the Bay of Bengal (17-21 May 2010)*

3.1.1. *Life cycle*

A low pressure area formed over the southeast Bay of Bengal and neighbourhood in the evening of 16. It concentrated into a Depression at 0600 UTC of 17 and lay centered near Lat. 10.5° N / Long. 88.5° E, about 930 kms eastsoutheast of Chennai. It moved northeastwards and intensified into a Deep Depression and lay centered at 1200 UTC, near Lat. 11.0° N / Long. 88.0 º E. Moving in a westnorthwesterly direction, the system further intensified into a Cyclonic Storm (Laila) and lay centered at 0000 UTC of 18, near Lat. 11.5° N / Long. 86.5° E, about 700 kms southeast of Chennai. Thereafter, it moved in a northwesterly direction and at 0300 UTC it lay centered near Lat. 12.0° N / Long. 85.5° E; at 1200 UTC of 18 near Lat. 13.0° N / Long. 83.5° E and near Lat. 13.5° N / Long. 82.0° E at 0300 UTC of 19. The system further intensified into a Severe Cyclonic Storm and lay centered near Lat. 13.5° N / Long. 81.5° E at 0600 UTC of 19. Remaining practically stationary, the system lay near Lat. 14.0° N / Long. 81.5° E at 1200 UTC. Moving in northwesterly direction, it lay near Lat. 15.5° N / Long. 80.5° E at 0300 UTC of 20. The Severe Cyclonic Storm crossed south Andhra Pradesh coast near Bapatla between 1100 & 1200 UTC on 20 and weakened into a Cyclonic Storm at 1200 UTC close to Bapatla (Lat. 16.0° N / Long. 80.5° E). Remaining stationary for some time, it re-curved northnortheastwards and further weakened into a Deep Depression and lay centered over north coastal Andhra Pradesh, about 50 kms north of Machilipatnam (Lat. 16.5° N / Long. 81.0° E) at 0300 UTC of 21. Continuing its northnortheastward movement, it weakened into a Depression and lay centered at 0600 UTC over coastal Andhra Pradesh, about 100 kms west of Kakinada (Lat. 17.0° N / Long. 81.5° E). Thereafter, it rapidly weakened into a low pressure area in the evening of 21 over north coastal Andhra Pradesh and adjoining Telangana.

3.1.2. *Satellite cloud features and other observations*

The system was tracked initially with the help of satellite cloud imageries from 1200 UTC of 16; then by hourly DWR observations; hourly coastal observations and AWS observations of Andhra Pradesh. The maximum

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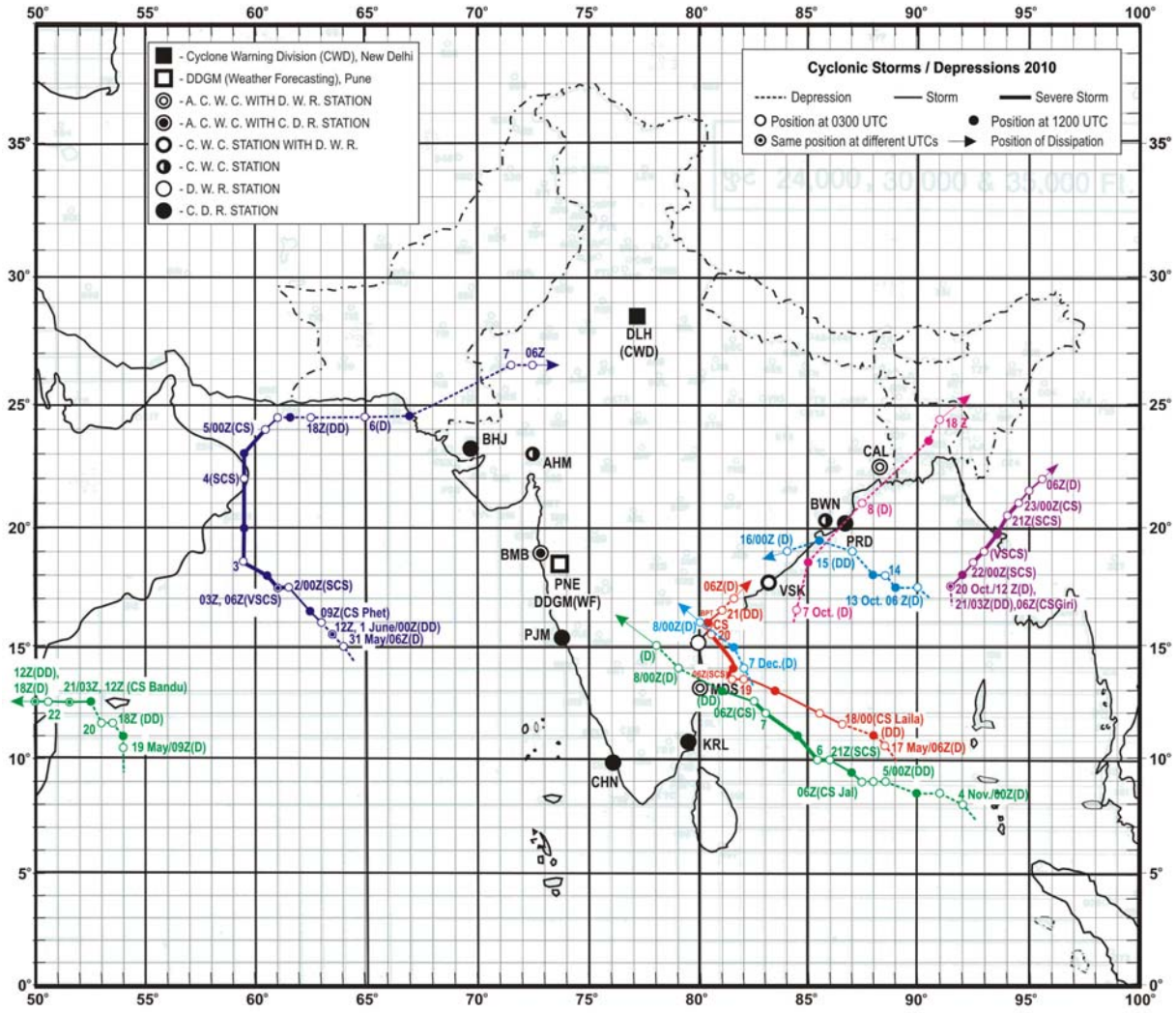

Fig. 1. Tracks of cyclonic storms/depressions - 2010

intensity of T 3.5 was reported from 0500 UTC to 2000 UTC of 19 (Fig. 2). It crossed the coast at 0500 UTC of 20 May with intensity T 3.0 and the center was at 15.7° N/80.1° E. The structure of the system was curved band except for one or two cases when it was observed of Central Dense Overcast (CDO) type.

DWR Chennai : The vortex was first noticed in RADAR scope around 0700 UTC of 18. Spiraling line echoes with EYE could be seen from 1300 UTC of 18 to 0700 UTC of 19. Initially the system moved fairly fast (16 kmph westwards) but eventually slowed down (09 kmph) after gaining northerly component in its motion. Varying features (closed, circular. Elliptical, ill-defined etc.) of EYE of the cyclone were seen during the course of the system within the RADAR range. System's centre was closest to the RADAR (130 km) during 0600-0900 UTC of 19.

Maximum radial velocity recorded during the course of the system was around 48 mps at the height of 1 to 2 kms above ground level during the period 0600 to 0900 UTC of 19.

3.1.3. *Other features observed*

The lowest Estimated Central Pressure (ECP) was 986 hPa. The maximum estimated mean wind speed was 55 kts. The system moved initially in northwesterly direction and then recurved into northeasterly direction and crossed Andhra Pradesh coast near Bapatla (16.0° N / 80.5° E) between 1100-1200 UTC.

TABLE 1

Brief Summary of cyclonic storms and depressions over the Indian seas and neighbourhood during 2010

S. No.	Category	Life period	Place / Time of landfall	Lowest Estimated central pressure (hPa)	Max. wind (Estimated/ observed) (kts)	Highest "T" No.
1.	Severe Cyclonic Storm (Laila)	17 - 21 May	Andhra Pradesh coast near Bapatla between 1100 & 1200 UTC of 20	986	55	3.5
1a.	Cyclonic Storm (Bandu)	19 - 23 May	Dissipated over Gulf of Aden	994	40	2.5
2.	Very Severe Cyclonic Storm (Phet)	31 May - 7 Jun	crossed Oman coast Near Lat. 21.5° N between 00 & 02 UTC on 4 and Pakistan coast close to Karachi between 1230 and 1330 UTC on 6	964	85	4.5
3.	Depression	7 - 8 Oct	crossed West Bengal-Bangladesh coasts near Long. 88.5º E between 0500 & 0600 UTC of 8	996	25	1.5
4.	Deep Depression	13 - 16 Oct	crossed Orissa coast, close to Gopalpur between 1500 & 1600 UTC of 15	995	30	2.0
5.	Very Severe Cyclonic Storm (Giri).	20 - 23 Oct	crossed Myanmar coast about 70 kms eastsoutheast of Sittwe (Myanmar) around 1400 UTC of 22	950	105	5.5
6	Severe Cyclonic Storm (Jal)	4 - 8 Nov	crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai around 1600 UTC of 7	988	60	3.5
7.	Depression	7 - 8 Dec	crossed south Andhra Pradesh coast near Bapatla around 2000 UTC of 7	1000	25	1.5

TABLE 2

Storms / depressions statistics 2010

Name of the system	Winter	Pre-monsoon			Monsoon				Post-monsoon			
	Jan - Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Over Bay of Bengal												
Depressions/Deep Depressions	-	-	-	-	-	-	-	-	2	-	1	3
Cyclonic Storms	-	-	-	-	-	-	-	-	-		-	-
Severe Cyclonic Storms	-	-	-	1	-	-	-	-	-	1	-	2
Very Severe Cyclonic Storms	-	-	-	-	-	-	-	-	1	-	-	1
Super Cyclonic Storms	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-
Land Depression												
Deep Depressions	-	-	-	-	-	-	-	-	-	-	-	-
Over Arabian Sea												
Depressions/Deep Depressions	-	-	-	-	-	-	-	-	-	-	-	-
Cyclonic Storms	-	-	-	-	-	-	-	-	-	-	-	-
Severe Cyclonic Storms	-	-	-	-	-	-	-	-	-	-	-	-
Very Severe Cyclonic Storms	-	-	-	1	-	-	-	-	-	-	-	1
Super Cyclonic Storms	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	2	-	-	-	-	3	1	1	7

TABLE 3

Crucial Ship/buoy observations during the storm/depression periods 2010

Call Sign	Date/Time (UTC)	Position of the Ship		Wind		Pressure
		Lat. (° N)	Long. (° E)	Dir. (Deg.)	Speed (kts)	PPPP (hPa)
(A) Severe Cyclonic Storm (Laila) over the Bay of Bengal (17-21 May 2010)						
9WCX9	18/1200	11.8	85.9	255	25	1001.0
(B) Very Severe Cyclonic Storm (Phet) over the Arabian Sea (31 May – 7 June 2010)						
DDZG2	31 May/1200	13.9	65.7	250	30	1002.6
A8UN3	31 May/1200	15.5	65.6	170	25	1002.0
MZFC9	31 May/1200	18.0	65.4	90	20	-
VRKZ8	31 May/1200	11.8	85.9	255	25	1001.0
DBUQ	2 Jun/0000	11.7	63.4	250	35	1005.4
DBUQ	2 Jun/1200	13.0	60.1	210	35	1005.0
DBUQ	3 Jun/0000	14.1	57.5	210	40	1004.0
ZNQO3	3 Jun/1200	17.5	63.7	180	35	1006.4
A8UE5	4 Jun/0000	23.8	60.7	090	30	1003.0
MCCN6	4 Jun/0000	23.9	63.1	120	20	1006.1
ZNQO3	4 Jun/0000	17.1	59.6	180	30	1004.2
(C) Depression over the Bay of Bengal (7- 8 October 2010)						
AUCT	7 Oct/0000	12.0	82.0	270	25	997.8
(D) Deep Depression over the Bay of Bengal (13–16 October 2010)						
ATTU	14 Oct/0000	17.0	92.0	230	20	997.5
VVKT	14 Oct/1200	19.0	88.0	000	25	997.0
ONEU	15 Oct/0000	18.0	83.0	270	20	997.0
(E) Severe Cyclonic Storm (Jal) over the Bay of Bengal (4–8 November 2010)						
DIIN	4 Nov/0000	6.0	89.0	340	10	1008.5
MYMX5	4 Nov/0000	6.0	94.0	240	15	1007.0
VRYO2	4 Nov/1200	6.0	88.0	270	10	1007.0
MYMX5	4 Nov/1200	6.0	91.0	250	5	1005.1
DGOJ	5 Nov/0000	2.5	89.5	270	25	1005.5
9KKS	5 Nov/0000	4.5	79.0	330	25	1009.5
MYMX5	5 Nov/1200	6.0	84.5	270	5	1004.9
MQYA3	5 Nov/1200	14.0	87.5	070	20	1008.0
DPAK	6 Nov/0000	5.0	85.0	270	30	1009.8
VRCP2	6 Nov/1200	5.5	87.0	230	25	1006.0
A8SC4	7 Nov/0000	6.0	86.5	240	30	1008.8
VRCP2	7 Nov/0000	6.5	89.5	240	15	1008.0
AUCT	8 Nov/0000	5.0	85.0	270	30	1009.8

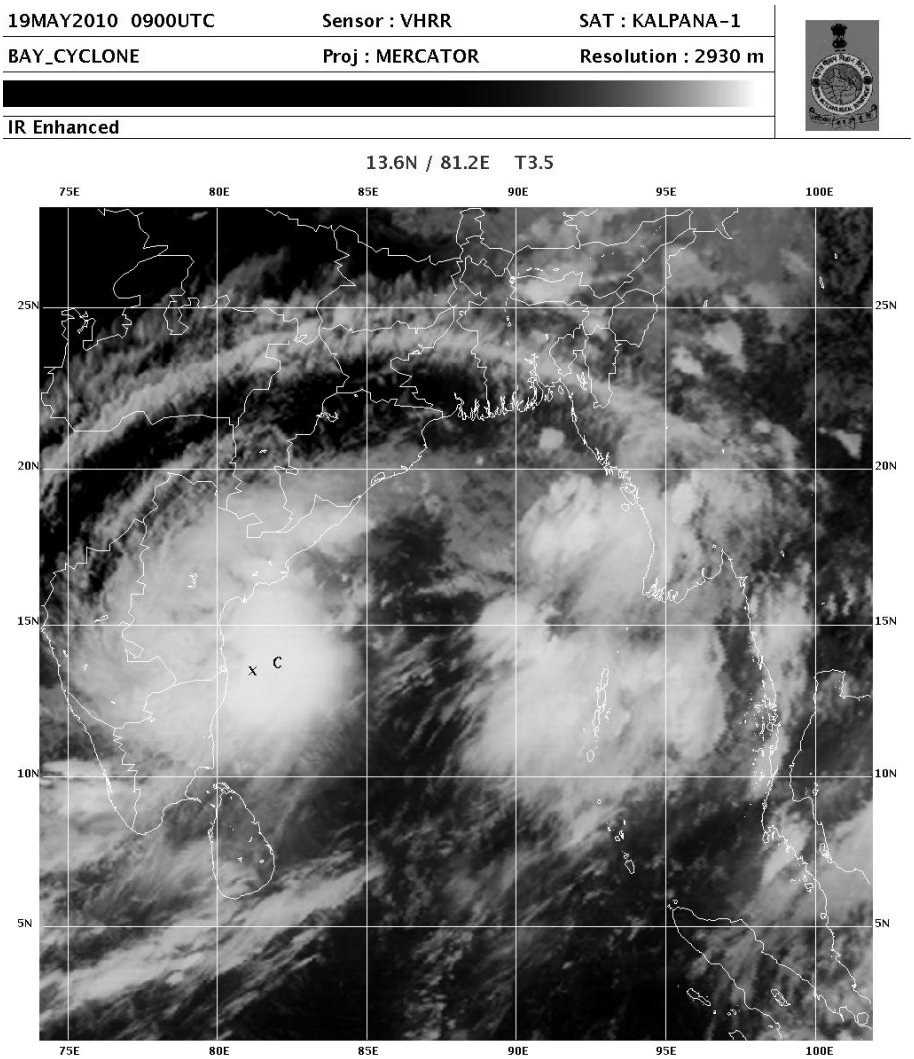

Fig. 2. Satellite imagery of severe cyclonic storm (Laila) at 0900 UTC of 19 May (T3.5)

Post Cyclone survey report

Landfall : The Severe Cyclonic Storm appears to have entered the land through the mouth of Nallamada drain (15.8° N / 80.6° E) at Suryalanka coast which is about 12 kms southsoutheast of Bapatla and travelled about 4 to 5 kms over land. It then re-curved in a northnortheasterly direction near Karlapalem village and Satyavathipetha. During its course of recurvature, it remained stationary for 4 to 5 hours.

Wind : As per the report, the maximum estimated wind speed was 55 to 65 kts. Observations of Suryalanka Air force station show that the maximum surface wind speed was 53 kts at 0000 UTC of 19. As per the local people and fishermen's version, the wind speed at the time of landfall was 125 to 150 kmph; whereas the forecast wind at the time of landfall at 0900 UTC of 20 was 100-110 kmph gusting to 120 kmph.

Tidal Waves: As per the fishermen's report; at Vadarevu (Prakasam district), height of tidal waves was 6 to 7 meters; at Suryalanka it was 5 to 6 meters and 5 meters at Kothapatnam (Prakasam district). The forecast of the height of tides was 9-14 meters.

Storm Surge: Storm Surge of 2 to 3 meters was observed at Suryalanka (Guntur district) coast and 3 to 4 meters at Vadarevu (Prakasam district) coast (forecast storm surge was 1.5 to 3 meters).

Pressure: The lowest mean sea level pressure of 992.8 hPa was recorded at 0900 UTC of 20 at Bapatla.

3.1.4. *Weather and damage caused*

As per press reports, heavy rains and floods took a toll of 23 people in Andhra Pradesh and Thousands of acres of crops suffered heavy damage in Ongole, Nellore, Guntur, East Godavari and Krishna districts. Many people were rendered homeless. Road and rail traffic was disrupted due to heavy rains and floods in coastal districts of Andhra Pradesh. Hundreds of houses were either fully or partially damaged.

No damage was reported from Tamil Nadu.

Heavy rains occurred at isolated places in Orissa from 21 to 24 May.

Some significant amounts of rainfall (in cms) are:

Andhra Pradesh

20 May : Kothapatnam 35, N. G. Padu 34, Ongole 32, Maddipadu 26, Tangutur 22, Chimakurthy 20, S. Konda 19, Zarugumalli & Narsapur 18 each, Tanuku 15, J. Pangalur 13, Kandukur, Bhimavaram, Machilipatnam & Inkollu, 12 each, Chinaganjam, Kondepi, Avanigadda, Kaikalur, Kakinada, Ulavapadu & Vetapalem, 11 each, Bapatla, Chirala, Korisapadu, Koderu, Kavali, Tadepalligudem & Repalle 10 each, Nagram, Addanki, S. N. Padu & Bhattiprolu 9 each, Parchur, Karamchedu, Yaddanapudi, Gudlur, Darsi, Tallur, Gudivada, Nakirekallu, Kollurru, Karlapalem & Guntur 8 each, Mudalavur, Anakapalli, Elamanchili, S. Magalur, Ponnalur, Pedanandipadu, Chilkavuripet, Amarthalur & Tuni 7 each.

21 May : Addanki 52, Maadipadu 28, Chimakurthy, Nurendla & S. N Padu 27 each, Tallur & Kothapatnam 26 each, Vinulonda 25, Savalyapuram 23, Bollapalli 20, Machavaram 19, Rompicherla, Tadepalle & Darsi 18 each, Nakirekkallu, N. G. Padu & Ipur 17 each, Kondepi 16, Mangalagiri, Korisapadu, Zarugumalli & Kurichedu, 15 each, Mundlamur, Ongole, Tangutur & S. Konda 14 each, Visakhapatnam, Elamanchili, Piduguralla, Bhimunipatnam, Bellamkonda & Duggirala 13 each, Pidugupalla, Kandukur, J. Pangulur, Vijaywada, Kandukur & Donakonda 12 each, Karempudi, Ballikurava, Vinjamur, Vijayanagaram, Ulavapadu, Pedakakani & Rajupalem 11 each, Chebrolu, Thollur, Podili, Narsipatnam, Waltair, Anakapalli, Dachepalli, Podili & Nadendla 10 each, Chilkavuripet, Amaravathi, Pedakurapadu, Atchampet, Krosur, Srungavarapu Kota, Chipurupalli, Chodavaram, Bhimadole, Polavaram, Tiruvuru, V.V Palem, K.K Mitla, Tenali & Amarthalur 9 each, Tadikona, Nandigama, Pathapatnam, Chintalapudi, Guntur, Ranasthalam, Yaddanapudi, S. Magalur, Maripudi, Tenali & Nagram 8 each, Amalapuram, Sattenapalli, Paderu, Prathipadu, Sompeta, Kalingapatnam, Inkollu, Sattenapalli, Vetticharukur, Narasaraopet, Drugi, Ponnur, Vemuruand & Tuni 7 each.

22 May : Tiruvuru 25, Nuzvid 15, Palasa 11, Ichapuram, Chintalapudi & Salur 10 each, Sompeta 9, Mandasa & Tekkali 7 each.

Tamil Nadu

19 May : Thozudur 9, Chennai 8, Tiruvarur, Musiri 7.

20 May : Ponneri 17, Cholavaram 13, Chennai, Thamaraipakkam 11, Tiruvallur & Poondi 9 each, Poonamally, Chembarambakkam, Tiruttani & Arakonam 7 each.

Orissa

21 May : Parlakhemundi 9.

22 May : Gopalpur 10, Berhampur 9, Chatrapur 8, Purushottampur & Krishnaprasad 7 each.

23 May : Athagarh 13, Dhenkanal 10, Tikabali 8, Rajkishorenagar 7.

24 May : Jaipur 9, Nilgiri 8.

3.1a. *Cyclonic Storm (Bandu) over the Arabian Sea (19–23 May 2010)*

The cyclonic storm formed west of Long. 55.0° E and dissipated over Gulf of Aden. As the system did not

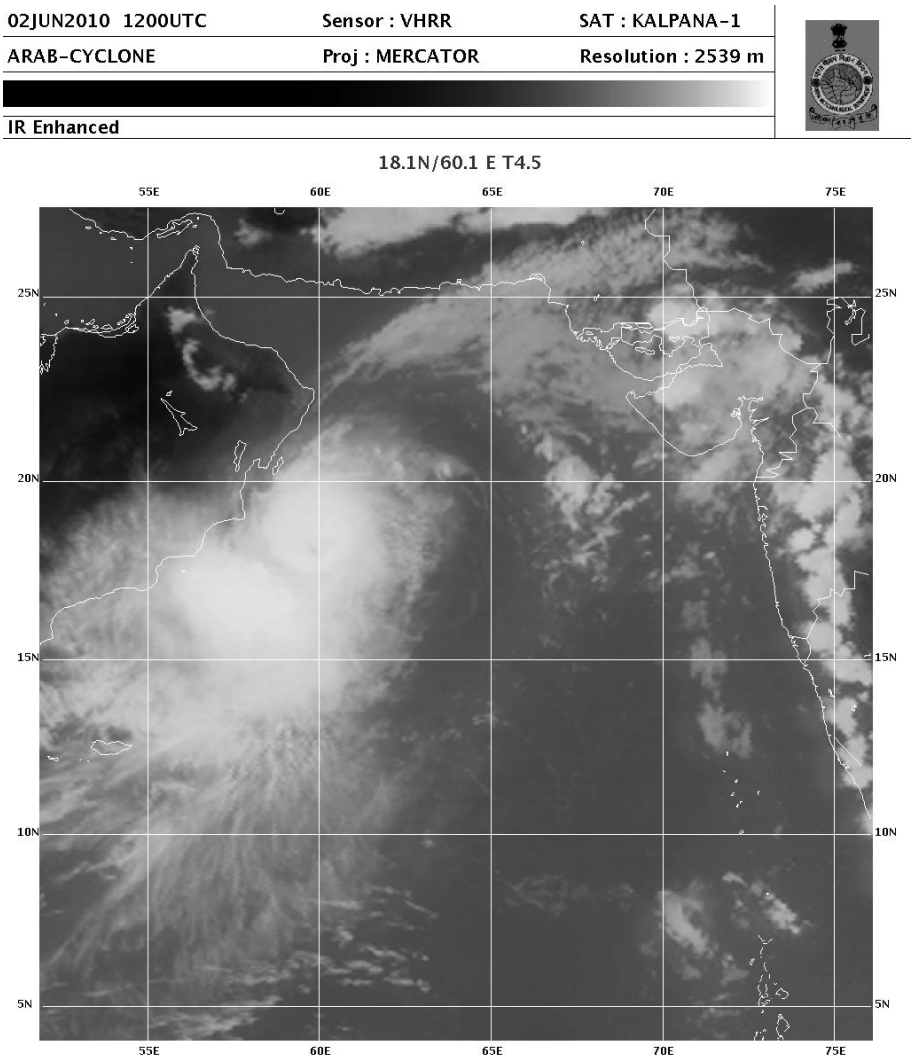

Fig. 3. Satellite imagery of very severe cyclonic storm (Phet) at 1200 UTC of 2 June (T4.5)

influence the weather over the Indian Region either directly or indirectly, the description of the system is not included in this article. However, the track is included in Fig. 1 as the area comes under RSMC responsibility.

3.2. *Very Severe Cyclonic Storm (Phet) over the Arabian Sea (31 May - 7 June 2010)*

3.2.1. *Life cycle*

Under the influence of an upper air cyclonic circulation over the southeast Arabian Sea, a low pressure area formed over the east central and adjoining west central Arabian Sea on 31 morning. It rapidly concentrated into a Depression and lay centered at 0600 UTC of 31 May near Lat. 15.0° N / Long. 64.0° E and at 1200 UTC near Lat. 15.5° N / Long. 63.5° E. It remained practically stationary upto 0300 UTC of 1 June and in the mean time, intensified into a Deep Depression at 0000 UTC. Then it moved northwestwards and further intensified into a Cyclonic Storm (Phet) and lay centered at 0900 UTC of 1 June, near Lat. 16.0° N / Long. 63.0° E. Continuing the northwestward movement, it lay centered near Lat. 16.5° N / Long. 62.5° E at 1200 UTC. Subsequently, it intensified into a Severe Cyclonic Storm and lay centered at 0000 UTC of 2 June near Lat. 17.5° N/ Long. 61.5° E. Moving slightly westwards, it lay centered at 0300 UTC of 2 June near Lat. 17.5° N / Long. 61.0° E. Remaining practically stationary, it further intensified into a Very Severe Cyclonic Storm at 0600 UTC of 2. It

moved further northwestwards and lay centered near Lat. 18.0° N / Long. 60.5° E at 1200 UTC of 2 June; lay centered near Lat. 18.5° N / Long. 59.5° E at 0300 UTC of 3 and near Lat. 20.0° N / Long. 59.5° E at 1200 UTC. Moving further northwards, it crossed Oman coast near Lat. 21.5° N between 0000 & 0200 UTC of 4 June; weakened into a Severe Cyclonic Storm and lay centered at 0300 UTC of 4 over coastal Oman near Lat. 22.0° N / Long. 59.5° E. Continuing the northward movement, it emerged into the northwest Arabian Sea and lay centered at 1200 UTC of 4 near Lat. 23.0° N / Long. 59.5° E. It further weakened into a Cyclonic Storm and lay centered at 0000 UTC of 5 near Lat. 24.0° N / Long. 60.5° E. Re-curving northeastwards, it lay centered at 0300 UTC of 5 near Lat. 24.5° N / Long. 61.0° E and at 1200 UTC near Lat. 24.5° N / Long. 61.5° E. Moving further eastwards, it weakened into a Deep Depression and lay centered at 1800 UTC of 5 near Lat. 24.5° N / Long. 62.5° E. It further weakened into a Depression at 0300 UTC of 6, near Lat. 24.5° N / Long. 65.0° E and lay centred at 1200 UTC near Lat. 24.5° N / Long. 67.0° E. Moving eastnortheastwards, it crossed Pakistan coast close to south of Karachi (near Lat. 24.7° N and Long 67.2° E) between 1230 & 1330 UTC of 6 and lay centred at 1500 UTC near Lat. 25.0° N / Long. 68.0° E (about 220 kms northnortwest of Naliya). Further moving eastnortheastwards, it lay centered at 0300 UTC of 7 over west Rajasthan, close to Barmer (Lat. 26.5° N / Lat., 71.5° E) and at 0600 UTC of 7 near Lat. 26.5° N / Long. 72.5° E. It weakened into a well marked low pressure area over east Rajasthan and adjoining northwest Madhya Pradesh in the evening of 7 and became less marked on 8th morning. However, the associated upper air cyclonic circulation extending upto lower tropospheric levels lay over west Uttar Pradesh and neighbourhood on 8 and became less marked on 9.

3.2.2. *Satellite cloud features and other observations*

The system was tracked mainly with the help of satellite cloud imageries from 1200 UTC of 30 May to 1200 UTC of 6 June. The maximum intensity of T. No. 4.5 (Fig. 3) was reported from 0800 UTC to 2200 UTC of 2 June.

The intensity of the system was T No. 1.5 reported from 0600 UTC of 31 May. At 0000 UTC of 1 June, the intensity increased to T 2.0. At 0600 UTC of 1 June, the signs of rapid intensification were observed. Again its intensity increased to T 2.5 at 0900 UTC of 1 June with center as Lat. 16.3° N / Long. 62.7° E. Its rapid intensification continued and at 1800 UTC its intensity raised to T 3.0 with center as Lat. 17.0° N / Long. 61.8° E. The intensity of the vortex increased to T 3.5 at 2300 UTC, when its EYE was visible. The EYE continued to be visible until 2300 UTC of 2 June and was clearer from 0500 UTC of 2 June, when the system attained the intensity of T 4.0. The system had its first landfall between 0000 & 0200 UTC of 4 June and second between 1230 & 1330 UTC of 6 June.

3.2.3. *Other features observed*

The lowest Estimated Central Pressure (ECP) was 964 hPa. The maximum estimated mean wind speed was 85 kts. The system moved initially in a northwesterly and then northerly direction before crossing Oman coast as Very Severe Cyclonic Storm in the early morning of 4 June. It then re-curved into northeasterly direction and further moved in an easterly direction and crossed Pakistan coast as a Depression close to south of Karachi. It moved again in a northeasterly direction across Rajasthan, causing heavy rainfall over the region.

3.2.4. *Weather and damage caused*

The system was a Depression when it entered the Indian region. It weakened rapidly and hence no damage was reported. However, fairly widespread rainfall with heavy falls at isolated places occurred over west Rajasthan on 7 June.

Some chief amounts of rainfall are:

West Rajasthan

7 June : Jaisalmer 11, Phalodi 9.

4. Disturbances formed during the monsoon season (June to September)

No intense low pressure system (reaching a stage of depression and above) formed during the season.

5. Disturbances formed during the post-monsoon season (October to December)

5.1. *Depression over the Bay of Bengal (7- 8 October 2010)*

5.1.1. *Life cycle*

A low pressure area formed over the east central Bay of Bengal and neighbourhood on 4. It moved over to the west central Bay of Bengal off Andhra coast on 6 and concentrated into a Depression at 0300 UTC of 7 and lay centered near Lat. 16.5° N / Long. 84.5° E, about 180 kms southeast of Visakhapatnam. It moved northnortheast-wards and lay centered near Lat. 18.5° N / Long. 85.0° E

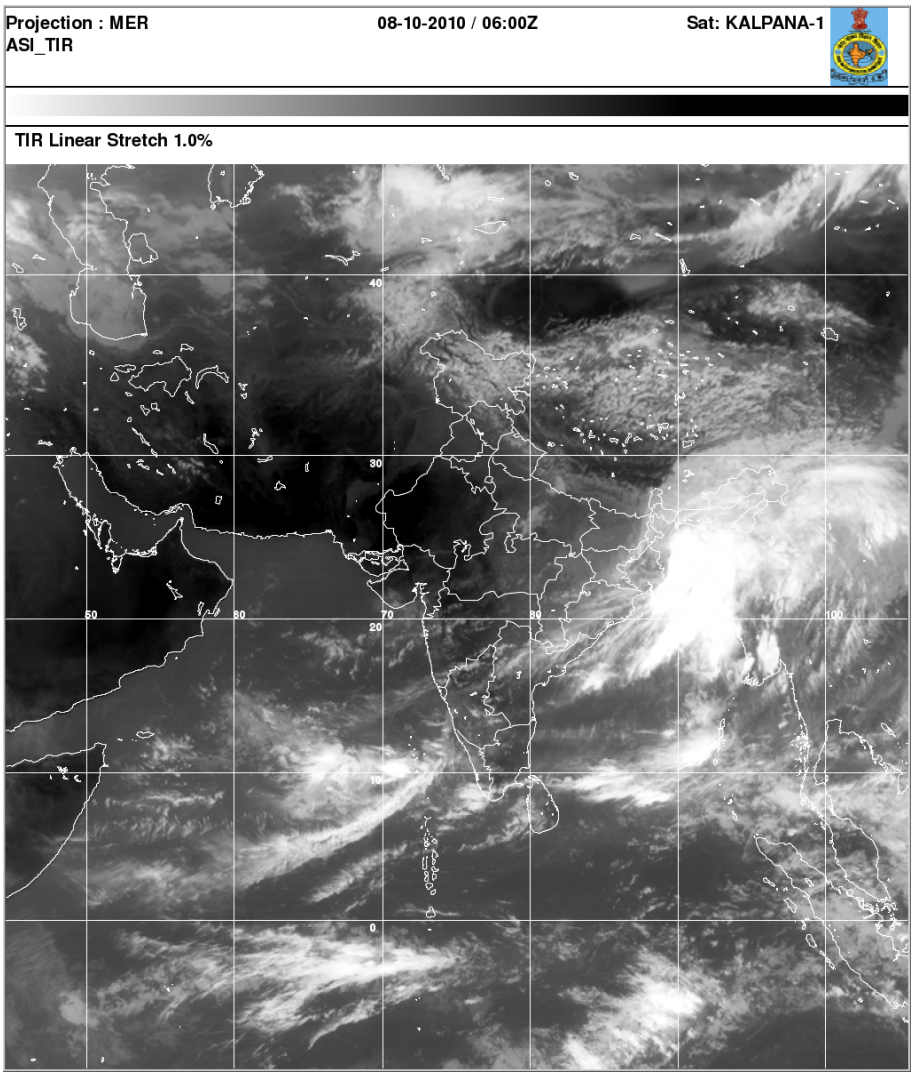

Fig. 4. Satellite imagery of depression (7-8 October) at 0600 UTC of 8 October 2010

at 1200 UTC, about 100 kms southsoutheast of Gopalpur. Thereafter, it moved in a northeasterly direction and at 0300 UTC of 8 it lay centered near Lat. 21.0° N / Long. 87.5° E, about 90 kms south of Digha. It moved northeastwards and crossed West Bengal-Bangladesh coasts near Long. 88.5º E between 0500 & 0600 UTC and lay centred at 1200 UTC over Bangladesh, close to Dhaka (Lat. 23.5° N / Long. 90.5° E). The system weakened into a low pressure area over Nagaland-Manipur-Mizoram-Tripura and neighbourhood in the early morning of 9, which subsequently moved over to Arunachal Pradesh and neighbourhood and became less marked in the morning hours of 9.

5.1.2. *Satellite cloud features and other observations*

The system was tracked initially with the help of satellite cloud imageries. The maximum intensity of T No. 1.5 was reported from 0300 UTC of 7 to 0500 UTC of 8. As per the satellite report, the depression crossed the coast around 0600 UTC of 8 October (Fig. 4).

CDR Paradip : Though the system was tracked by CDR Paradip, no CYREP was issued. Hourly RADAR observations were taken and reported from 0700 UTC of 7 to 0600 UTC of 8.

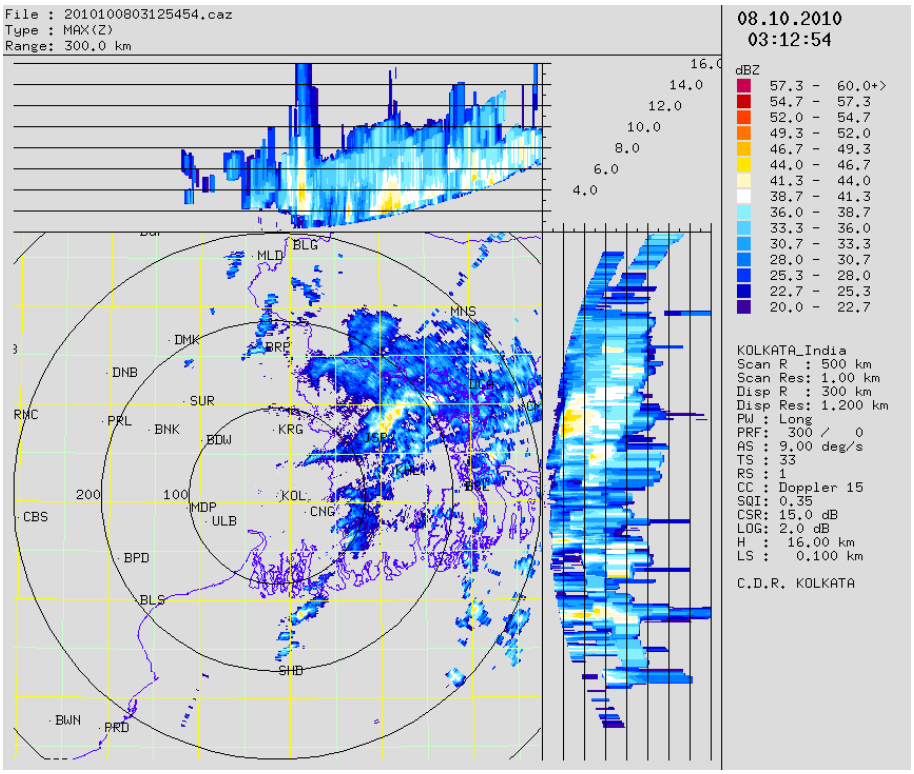

Fig. 5. Reflectivity imagery of depression 08 Oct 2010 at 0300 UTC

DWR Kolkata : DWR Kolkata tracked the system since 0000 UTC of 7 at every 15 minutes interval. The initial echoes of the system (WML) were observed in the form of scattered clouds at about 200-300 kms southsouthwest of Kolkata. The Amount of convective clouds increased in the subsequent observations. Moderate type of clouds were observed with reflectivity about 40 dBz with vertical extension from 6 to 8 kms towards southsouthwesterly and southerly direction of Kolkata at 1900 UTC of 7. The system moved in a northeasterly direction and moderate convective clouds of reflectivity about 42 dBZ with vertical extension upto 12 kms were observed over Kolkata from 2200 UTC of 7 to 0000 UTC of 8. It was observed from subsequent DWR pictures from 0100 UTC of 8 onwards that, the system was moving towards Jessore (Bangladesh) at 0300 UTC of 8 (Fig. 5).

Maximum wind observed

The maximum radial wind as observed from PPI (V) was in the range of 22 to 26 mps at a height of 0.5 km above ground level at 2100 UTC of 7 at a distance of 140 kms south/southsouthwest from DWR. The maximum horizontal wind estimated from DWR product VVP_2 is 20 knots at height 6 kms within 50 kms of Kolkata.

5.1.3. *Other features observed*

The lowest Estimated Central Pressure (ECP) was 996 hPa. The maximum estimated mean wind speed was 25 kts. The lowest mean sea level pressure of 998.6 hPa was recorded at Barisal (41950, Bangladesh) at 1200 UTC of 8. The system moved initially in a northnortheasterly direction and then in a northeasterly direction and crossed West Bengal-Bangladesh coasts near Long. 88.5° E of 8.

5.1.4. *Weather and damage caused*

The system did not cause much damage in India. However, tidal waves wreaked havoc in east Midnapore district and 850 families were shifted to safer places. Under the influence of this system, monsoon was active or vigorous in Orissa, Gangetic West Bengal, Assam & Meghalaya and Nagaland-Manipur-Mizoram-Tripura. Heavy rainfall occurred at isolated places in interior Orissa on 6 and 7 and extremely heavy rain with heavy to

very heavy falls at isolated places occurred in coastal Orissa on 8.

Some significant amounts of rainfall (in cm) are:

Orissa

7 Oct : Kendrapada 9, Rajkanika 8, Soro, Chandbali & Bhadrak 7 each.

8 Oct : Paradip 25, Pattamundai 15, Kakatpur 15, Chandbali, Kendrapara & Bhadrak 14 each, Rajkanika 11, Balasore & Puri 10 each, Athgarh & Soro 9 each, Mundali 8, Nimapara 7.

Gangetic West Bengal

8 Oct : Canning Town 8, Diamond Harbour & Durgachak 7 each.

Assam & Meghalaya

8 Oct : Barapani 46, Cherrapunji 22.

9 Oct : Cherrapunji 30, Silchar 14, Shillong 4, Dholai & Williamnagar 9 each, Lumding, Barapani, Gharmura & Amraghat 8 each, Kherunighat & Jorhat 7 each.

Nagaland-Manipur-Mizoram-Tripura

8 Oct : Sonamura 15, Belonia 14, Sabroom, Udaipur 11.

9 Oct : Agartala 18, Kailashahar 12, Imphal 10.

5.2. *Deep Depression over the Bay of Bengal (13–16 October 2010)*

5.2.1. *Life cycle*

A low pressure area formed over the east central Bay of Bengal and neighbourhood on 12. It became well marked over there on 13 morning and subsequently concentrated into a Depression at 0600 UTC near Lat. 17.5° N / Long. 90.0° E, about 550 kms southeast of Gopalpur. Moving westwards, it lay centered at 1200 UTC of 13 near Lat. 17.5° N / Long. 89.0° E. Subsequently moving northwestwards, it lay centred near Lat. 18.0° N / Long. 88.5° E, about 430 kms southeast of Gopalpur at 0300 UTC and near Lat. 18.0° N / Long. 88.0° E at 1200 UTC of 14. Further, it moved northwestwards and intensified into a Deep Depression and lay at 0300 UTC of 15 over northwest Bay of Bengal centred near Lat. 19.0° N / Long. 87.0° E, about 220 kms eastsoutheast of Gopalpur. Moving westwards, it lay centred at 1200 UTC over northwest Bay of Bengal, close to Orissa coast near Lat. 19.5° N / Long. 85.5° E, about 50 kms southsouthwest of Puri. It moved westwards and crossed Orissa coast near Gopalpur between 1500 & 1600 UTC of 15. It continued to move in a westerly direction and weakened into a Depression and lay centred at 0000 UTC of 16 over south Orissa and adjoining areas of Chhatisgarh and north Andhra Pradesh, about 50 kms west of Gopalpur (Lat. 19.0° N / Long. 84.0° E). Continuing the westerly course, it weakned into a well marked low pressure area over south Orissa and adjoining Chhatisgarh & north Andhra Pradesh on 16 morning. On 17 morning, it lay over south Chhatisgarh and adjoining Vidarbha and Telangana and over Telangana and neighbourhood in the evening. It continued to move in a near westerly direction as low pressure area and moved across Vidarbha, Marathwada and Madhya Maharashtra and finally became less marked on 20 over the east central Arabian Sea off Maharashtra coast.

5.2.2. *Satellite cloud features and other observations*

The system was tracked initially with the help of satellite cloud imageries. From 0700 UTC of 14 onwards, it was also tracked by CDR Paradip. Hourly coastal observations and AWS observations of Andhra Pradesh were also recorded after 0000 of 13. The maximum intensity of T. No. 2.0 was reported from 0300 to 1800 UTC of 15. As per satellite observations, the system crossed south Orissa coast around 1800 UTC of 15 and lay over land with centre near Lat. 19.0° N / Long. 84.7° E.

5.2.3. *Other features observed*

The Estimated lowest Central Pressure (ECP) was 995.0 hPa at 1200 UTC of 15. The estimated maximum wind speed was 30 kts during the period 0300 UTC to 2300 UTC of 15. The system moved in a northwesterly direction throughout its course and crossed Orissa coast near Gopalpur between 1500 & 1600 UTC of 15. As per the hourly observations from Orissa, Gopalpur recorded the lowest pressure of 994.6 hPa (wind 340°/10 kts) at 1000 UTC of 15; which is very close to the estimated central pressure. Puri reported maximum wind speed of 25 kts from 1600 UTC to 1800 UTC of 15.

5.2.4. *Weather and damage caused*

No damage was reported in Orissa and Andhra Pradesh. Heavy to very heavy rainfall occurred at isolated

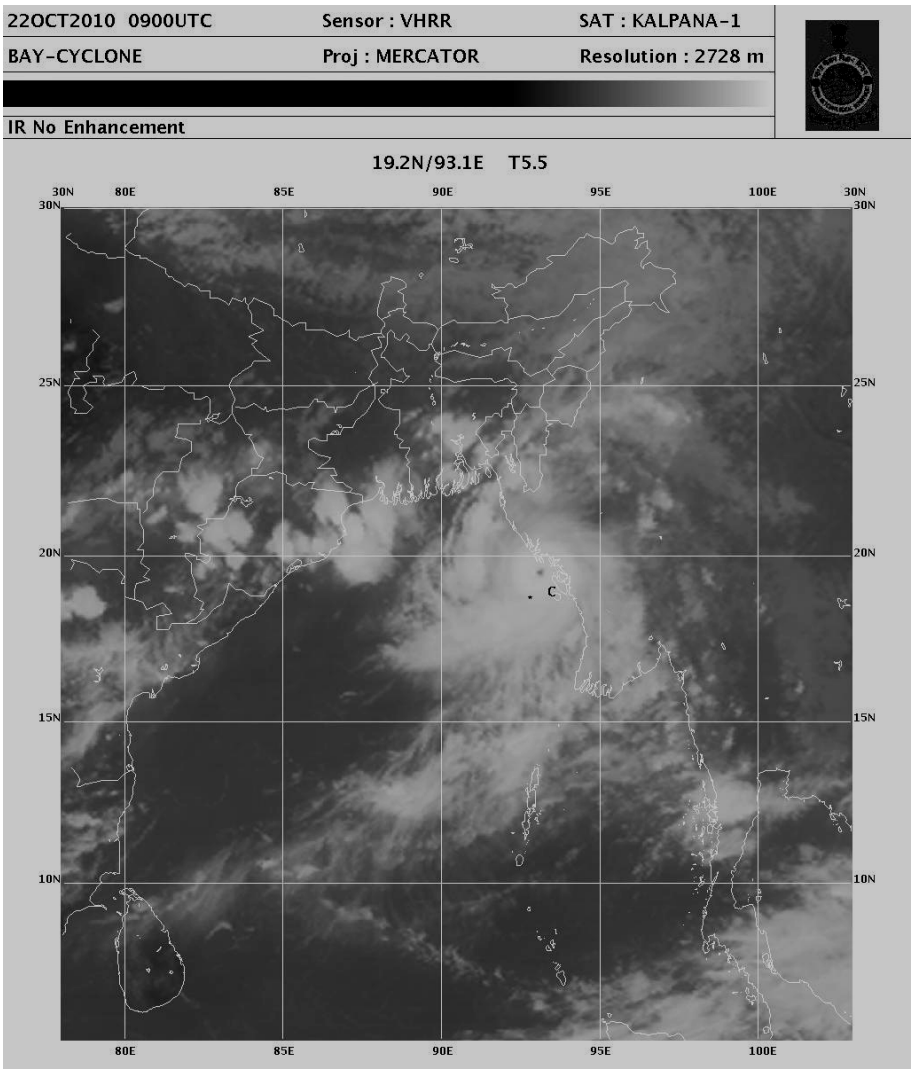

Fig. 6. Satellite imagery of very severe cyclonic storm (Giri) over the Bay of Bengal (20-23 October 2010) at 0900 UTC of 22 October (T5.5)

places over coastal Orissa on 15 and 16. Heavy rainfall occurred at isolated places in Andhra Pradesh on 15.

Some significant amounts of rainfall (in cm) are:

Gangetic West Bengal

15 Oct : Basirhat 11, Uluberia 8.

Orissa

15 Oct : Paradeep 14, Pattamundai 9, Pipili, Bhadrak, Kendrapara, Rajkanika & Khandapara 8 each, Nimapara, Mahendragarh & Alipingal 7 each.

16 Oct : Kosagumda 24, Junagarh & Umarkote 15 each, Jaipatna 14, R. Udaigiri 13, Soro 12, Parlakhemundi & Nawarangpur 11 each, Kalinga & Jeypore 9 each, Bhawanipatna & Daringibadi 8 each, Rayagada & Koraput 7 each.

Andhra Pradesh

15 Oct : Palasa 8.

Chhatisgarh

16 Oct : Jagdalpur 11, Narayanpur & Kondagaon 8 each.

5.3. *Very Severe Cyclonic Storm (Giri) over the Bay of Bengal (20-23 October 2010)*

5.3.1. *Life cycle*

A low pressure area formed over east central Bay of Bengal and neighbourhood on 19. It concentrated into a Depression at 1200 UTC of 20 and lay centred near Lat. 17.5° N / Long. 91.5° E, about 550 kms southeast of Digha. Remaining practically stationary, it intensified into a Deep Depression at 0300 UTC of 21 and further into a Cyclonic Storm (Giri) at 0600 UTC. It then moved northeastwards and lay centred at 1200 UTC near Lat. 18.0° N / Long. 92.0° E, about 600 kms southeast of Digha. Continuing the northeasterly movement, it further intensified into a Severe Cyclonic Storm at 0000 UTC of 22 and lay over east central and adjoining northeast Bay of Bengal centred near Lat. 18.5° N / Long. 92.5° E. It further intensified into a Very Severe Cyclonic Storm and lay at 0300 UTC 22 over northeast Bay of Bengal centred near Lat. 19.0° N / Long. 93.0° E. Further, it moved north-northeastwards and lay centred at 1200 UTC centered near Lat. 19.8° N / Long. 93.5° E, close to Myanmar coast, about 100 kms southeast of Sittwe (Myanmar). Taking a northerly course, it crossed Myanmar coast about 70 kms eastsoutheast of Sittwe (Myanmar) around 1400 UTC of 22 and lay at 1500 UTC over coastal areas of Myanmar centred near Lat. 20.0° N / Long. 93.5° E, about 70 kms eastsoutheast of Sittwe (Myanamar). Further, it moved northeastwards and weakened into a Severe Cyclonic Storm at 2100 UTC and lay centered near Lat. 20.5° N / Long. 94.0° E. Weakening further into a Cyclonic Storm, it lay centered at 0000 UTC of 23 near Lat. 21.0° N / Long. 94.5° E. It continued to move in a northeasterly direction and lay centred at 0300 UTC of 23 near Lat. 21.5° N / Long. 95.0° E, about 70 kms southsouthwest of Monywa (Myanmar). It weakened into a Depression and lay centered near Lat. 22.0° N / Long. 95.5° E at 0600 UTC of 23. It lay as well marked low pressure area over central parts of Myanmar in the evening of 23 and became less marked thereafter.

5.3.2. *Satellite cloud features and other observations*

The system was tracked with the help of satellite cloud imageries from 0600 UTC of 20 to 1400 UTC of 22 October. The maximum intensity of T. No. 5.5 was reported from 0900 UTC of 20 till it crossed Myanmar coast.

At 0900 UTC of 22, the cloud pattern indicated sharp improvement in organization and convection around the vortex centre and also decrease in diameter of EYE, which is indicative of explosive intensification. Thus, Very Severe Cyclonic Storm (Giri) gained its maximum intensity with centre near Lat. 19.2° N / Long. 93.1° E and T 5.5 at 0900 UTC of 22 (Fig. 6).

5.3.3. *Other features observed*

The Estimated Lowest Central Pressure (ECP) was 950 hPa from 0900 UTC till the system crossed Myanmar coast. The estimated maximum wind speed was 105 kts.

5.3.4. *Weather and damage caused*

As the system moved away from the east coast of India, it did not affect the weather over India.

5.4. *Severe Cyclonic Storm (Jal) over the Bay of Bengal (4-8 November 2010)*

5.4.1. *Life cycle*

A low pressure system emerged into the Andaman Sea from the east and lay as a low pressure area over the south Andaman Sea and neighbourhood in the evening of 2. It lay as a well marked low pressure area over the same region in the morning of 3. It concentrated into a Depression and lay over the southeast Bay of Bengal and neighbourhood centred near Lat. 8.0° N / Long. 92.0° E at 0000 UTC of 4. It moved westnorthwestwards and lay at 0300 UTC centred near Lat. 8.5° N / Long. 91.0° E and moving westwards, it lay centered at 1200 UTC near Lat. 8.5° N / Long 90.0° E. Further moving westnorthwestwards, it concentrated into a Deep Depression at 0000 UTC of 5 and lay centered near Lat. 9.0° N / Long. 88.5° E and at 0300 UTC, it lay centred near Lat. 9.0° N / Long. 88.0° E. Moving in a northwesterly direction, it further intensified into a Cyclonic Storm (Jal) at 0600 UTC of 5 and lay centered near Lat. 9.0° N / Long. 87.5° E and 1200 UTC of near Lat. 9.5° N / Long. 87.0° E. Taking a westnorthwesterly course, it further intensified into a Severe Cyclonic Storm at 2100 UTC of 5 and lay centred near Lat. 10.0° N / Long. 86.0° E. It moved slightly westwards and lay centred near Lat. 10.0° N / Long. 85.5° E at 0300 UTC of 6. It then moved northwestwards and lay centered at 1200 UTC near Lat. 11.0° N / Long. 84.5° E. It continued to move in the same direction and lay over the southwest Bay of Bengal at 0300 UTC of 7 centered near Lat. 12.0° N / Long. 83.0° E. It weakened into a Cyclonic Storm and lay centred near Lat. 12.5° N / Long. 82.5° E at 0600 UTC and further weakened into a Deep Depression at 1200

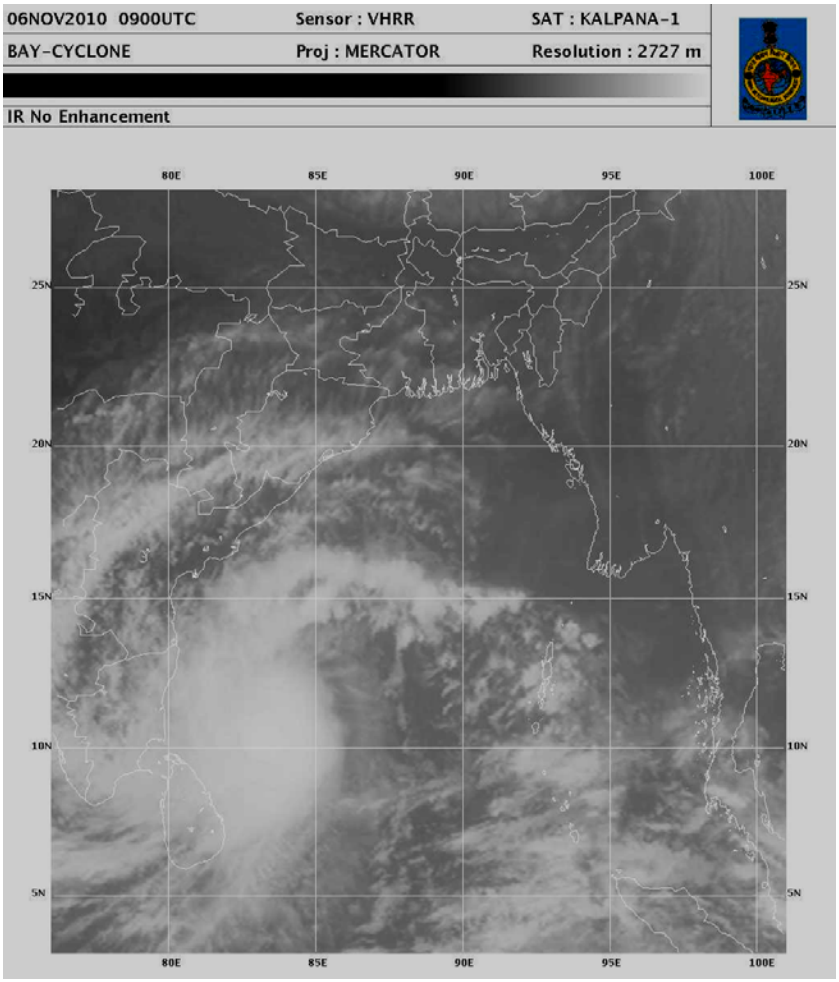

Fig. 7. Satellite imagery of severe cyclonic storm (Jal) over the Bay of Bengal (4-8 November 2010) at 0900 UTC of 6 November (T3.5)

UTC of 7 and lay centered near Lat. 13.0° N / Long. 81.0° E. Continuing its northwestwards movement, it crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai near Lat. 13.3° N / Long. 80.2° E around 1600 UTC of 7 and lay over coastal areas of north Tamil Nadu-south Andhra Pradesh, centred near Lat. 13.5° N/ Long. 80.0° E (about 60 kms northwest of Chennai) at 1800 UTC. It moved westnorthwestwards and weakened into a Depression and lay at 0000 UTC of 8 over Rayalaseema and neighbourhood centred near Lat. 14.0° N / Long. 79.0° E. Moving northwestwards, it lay at 0300 UTC of 8 over Rayalaseema, centred about 50 kms northeast of Anantpur (Lat. 15.0° N / Long. 78.0° E). Moving slightly westwards, it further weakened into a well marked low pressure area over Rayalaseema and adjoining south interior Karnataka by 0600 UTC and over interior Karnataka and adjoining south Madhya Maharashtra in the evening of 8. On 9 morning, it lay over the east central Arabian Sea off south Maharashtra-Goa coasts and over the east central Arabian Sea off Maharashtra coast in the evening. It lay over the northeast Arabian Sea off Gujarat coast in the morning of 10.

5.4.2. *Satellite cloud features and other observations*

The system was tracked by Satellite from 0600 UTC of 2 November till the landfall. The maximum intensity of T 3.5 (Fig. 7) was reported from 2100 UTC of 5 to 0500 UTC of 7.

DWR SHAR : The RADAR operation recorded hourly observation and transmitted to HQ offices and to

user agencies from 0300 UTC of 6. It was observed that the Cyclonic Storm started moving towards the coast in a westnorthwesterly direction. The structure/Eye of the Cyclone was not so well defined as the RADAR echoes did not depict the required properties of a cyclone eye. The cloud heights were about 5 to 6 kms; the reflectivity in the wall cloud region was about 35-45 dBz maximum. General maximum velocities recorded are about 20-23 mps.

The vortex of the cyclonic storm was close to SHAR at 1554 and 1654 UTC (Fig. 8).

The likely cloud center locations of the system are presented below along with related description.

7 Nov 2010 Time(UTC)	*Azimuth In deg.*	*Range (kms)*	*Lat. °N*	*Long. °E*	*Remarks*
0000	140	200	12.44	81.49	Estimated from the wall cloud region.
0053	140	180	12.57	81.41	Do
0153	140	150	12.67	81.12	Do
0254	140	150	12.67	81.12	Do
0355	-	-	-	-	Centre not well defined.
0455	-	-	-	-	Do
0554	140	110	13.06	80.85	Estimated from Wall cloud region.
0656	-	-	-	-	Centre seems to dissipated.
0801	135	110	13.04	80.91	Spiral Bands visible.
0859	135	110	13.01	80.83	Spiral bands getting dissipated
0957	-	-	-	-	Inner last band cloud over SHAR.
1054	-	-	-	-	All Spiral bands appeared to have crossed the SHAR coast.
1200/1300	-	-	-	-	System appears to be weakened.
1400	130	090	13.22	80.84	Spiral bands re-appeared.
1455	120	060	13.43	80.66	Do
1554	100	050	13.44	80.63	Centre close to SHAR.
1654	100	025	13.57	80.43	Do
1755	-	-	-	-	Vortex of the System appears to be over SHAR.

DWR Chennai : The system was tracked from 0400 to 1800 UTC of 7. The vertical wind shear had detrimental effect on weakening the system at sea level. The centre of mass of dense convection area crossed north Cuddalore by about 0600 UTC of 7. Surface wind speed associated with the weak vortex was not more than 25 kts at any time. No bulletin was issued as the intensity of the system as seen by the RADAR had been very weak and deformed.

5.4.3. *Other features observed*

The Estimated lowest Central Pressure (ECP) was 988 hPa. The estimated maximum wind speed was 60 kts. As per DWR Chennai and DWR SHAR reports, the system started weakening from 0300 UTC of 7 while continuing its northwesterly track and crossed the coast as Deep Depression north of Chennai, close to SHAR around 1800 UTC.

The newly deployed BD07_OMNI buoy (located at Lat. 08.0° N / Long. 88.5° E) recorded maximum wind speed of 16 mps on 5 around 2000 UTC.

5.4.4. *Weather and damage caused*

Eleven people died in Andhra Pradesh. Hundreds of houses were damaged and crops over about 15,000 hectares were destroyed. A loss of about 83 crores was estimated.

Five persons lost their lives in Tamil Nadu. About 100 pucca / kutcha houses were either fully or partially damaged. Many boats were damaged and some were also missing due to floods. Rail, road and air transports were affected due to heavy rains. Sea water inundated low lying areas.

Very heavy to heavy rainfall occurred on 8 & 9 in Andhra Pradesh with extremely heavy falls at isolated places on 8.

Some significant amounts of rainfall (in cm) are:

Tamil Nadu

8 Nov : Gingee 16, Panruti 15, Ambur 13, Vaniyambadi 12, Tiruvannamalai & Alangayam 11 each, Tindivanam, Villupuram & Puducherry 10 each, Cuddalore, Vanur & Thali 9 each, Chengalpattu, Polur & Krishnagiri 8 each, Dharmapuri, Palacode, Tirukoilur, Vandavasi, Arakonam, Gudiyatham, Sholinghur, Tirupattur & Vellore 7 each.

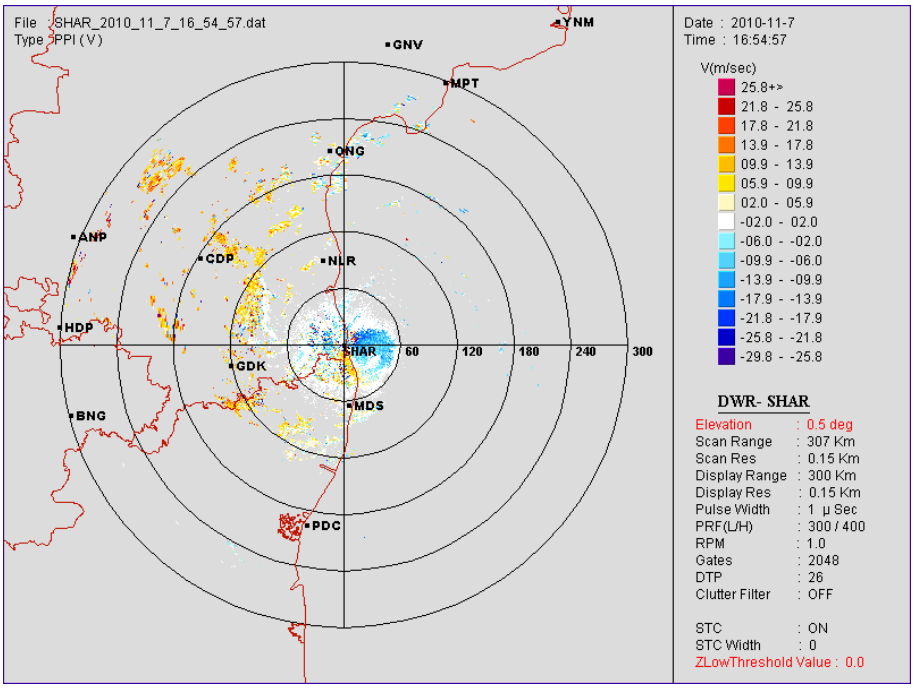

Fig. 8. Radial velocity recorded by DWR SHAR when the vortex was close by

Andhra Pradesh

8 Nov : Palasa 27, Sompeta 14, Ichhapuram 12, Kalingapatnam 10, Tekkali 9, Bheemunipatnam 8, Nellore, Anakapalli, Mandasa, Kandukur & Sullurpet 7 each.

9 Nov : Ichhapuram 9, Bobbili 7.

5.5. *Depression over the Bay of Bengal (7-8 December 2010)*

5.5.1. *Life cycle*

A trough of low at sea level lay over the southeast Bay of Bengal and adjoining south Andaman Sea on 2 and over the southwest Bay of Bengal off Tamil Nadu-Sri Lanka coasts on 3. It organized into a low pressure area over the southwest Bay of Bengal on 4 and persisted there on 5. It became well marked over the same region on 6, subsequently concentrated into a Depression and lay centered at 0300 UTC of 7 over the southwest and adjoining west central Bay of Bengal, near Lat. 14.0° N / Long. 82.0° E (about 230 kms southeast of Kavali). Moving northnorthwestwards, it lay centred at 1200 UTC of 7, near Lat. 15.0° N / Long. 81.5° E (about 150 km eastsoutheast of Ongole). Then it moved northwestwards and crossed Andhra Pradesh coast near Bapatla around 2000 UTC of 7 and lay centred at 0000 UTC of 8, about 50 kms northwest of Bapatla (Lat. 16.0° N / Long. 80.0° E). Subsequently, it weakened into a well marked low pressure area and lay over coastal Andhra Pradesh and neighbourhood in the morning of 8.

5.5.2. *Satellite and RADAR observations*

As per the satellite observations, the system continued to move in northwesterly direction; weakened into a low level circulation at 0000 UTC of 8 and crossed coast at 0300 UTC of the same day centered near Lat. 16.5° N / Long. 80.5° E. The maximum intensity of T 1.5 was reported from 0300 UTC of 7 to 2300 UTC of 8 (Fig. 9).

5.5.3. *Other features observed*

The Estimated Lowest Central Pressure (ECP) was 1000 hPa. The estimated maximum wind speed was

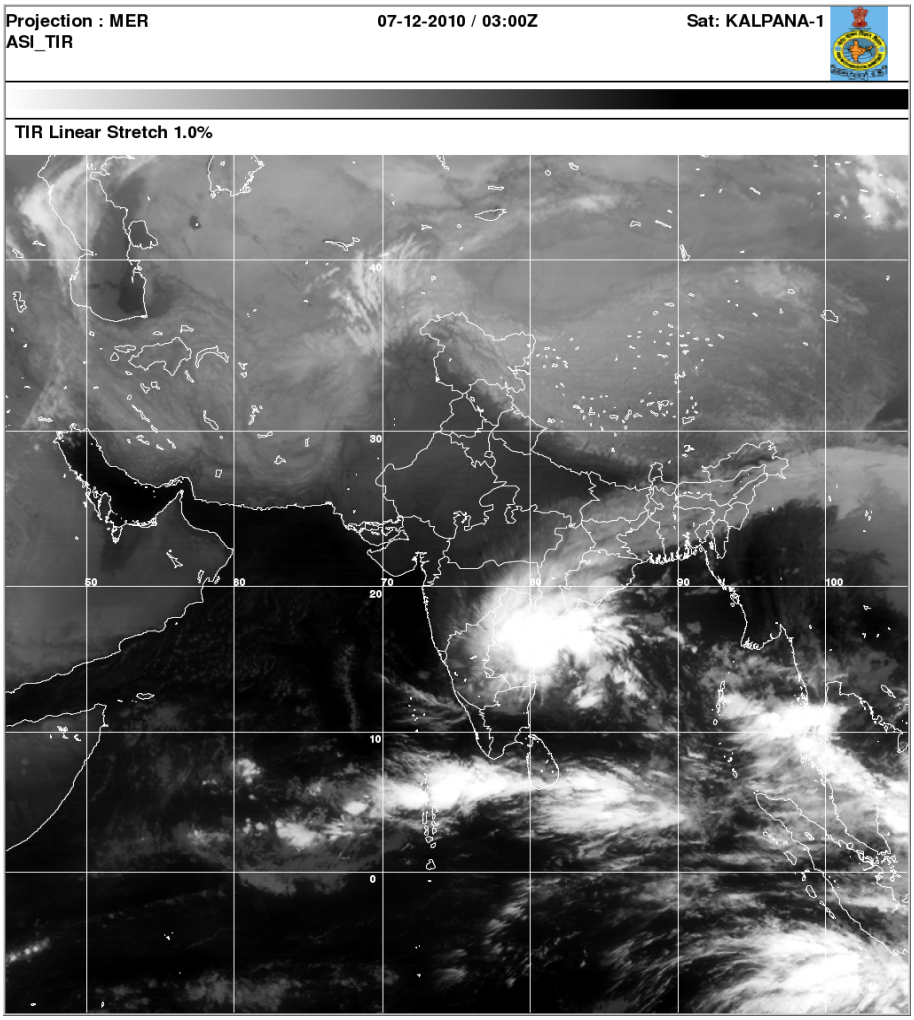

Fig. 9. Satellite imagery of depression over the Bay of Bengal (7–8 December 2010) at 0300 UTC of 7 December (T1.5)

25 kts. The system moved in a northnorthwesterly direction and crossed Andhra Pradesh coast near Bapatla in the early hours of 8.

5.5.4. *Weather and damage caused*

Heavy rains claimed 2 lives in Andhra Pradesh. As the Depression did not cross Tamil Nadu coast, there was no serious loss of life and property. However, when it was located over west central Bay of Bengal off south Andhra Pradesh coast; Tamil Nadu received bountiful rainfall almost in all the districts of Tamil Nadu with heavy rainfall over Kanyakumari district in which 4500 huts were damaged and about thousand acres of Paddy field were submerged.

Northeast monsoon was vigorous in Andhra Pradesh from 6 to 8. Widespread rainfall activity with heavy to very heavy falls at isolated places occurred over coastal Andhra Pradesh on 7 & 8. Heavy to very heavy rainfall also occurred over Tamil Nadu from 6 to 8.

Some chief amounts of rainfall are:

Tamil Nadu

6 Dec : Mahabalipuram 13, Anna University 11, Chennai AP 10, Cheyyur, Chengalpet & Ponneri 9 each.

7 Dec : Ponneri, Poonamally & Mahabalipuram 7 each.

8 Dec : Kuzhithurai 24, Boothapandi & Pechiparai 17 each, Tiruchendur 15, Radhapuram 10, Thuckalay 9, Nanguneri 7.

Andhra Pradesh

7 Dec : Bapatla & Narsapur 10 each, Repalle & Sullurpet 9 each, Tada 8, Sattenapalli, Kailaur, Machilipatnam, Nuzvid, Gudur & Bhimavaram 7 each.

8 Dec : Ranasthalam 14, Tekkali & Cheepurpalli 13 each, Kakinada, Kalingapatnam & Araku Valley 12 each, Macherla, Udayagiri, Vinjamur, Cumbum, Visakhapatnam & Salur 11 each, Amalapuram, Peddapuram, Patapatnam, Elamanchili, Srungavarapukota, Terlam & Vizinagaram 10 each.