551.515.2 (267.64)

COMPARISON OF TWO SUPER CYCLONIC STORMS OVER THE BAY OF BENGAL (*i*) 14-20 NOVEMBER 1977, (*ii*) 25-31 OCTOBER 1999

1. Super Cyclonic Storm over the Bay of Bengal, 14-20 November 1977 (henceforth called as SC 1) and Super Cyclonic Storm over the Bay of Bengal, 25-31 October 1999 (henceforth called as SC 2) were two of the intense cyclones to hit Indian coast during the last 124 years. Maximum intensity as estimated by NOAA Satellite Imagery on Dvorak's scale in respect of SC 1 was T 7.0 (140 kts) and that given by INSAT Imagery in respect of SC 2 was also T 7.0 (140 kts). Both the cyclones caused unprecedented devastation, heavy loss of property and a death toll of about 10,000 each in Andhra Pradesh & Orissa. To study these two storms in greater details, some special features like formation & movement of storm, maximum wind, lowest central pressure, Satellite observations, radar observations, field of relative

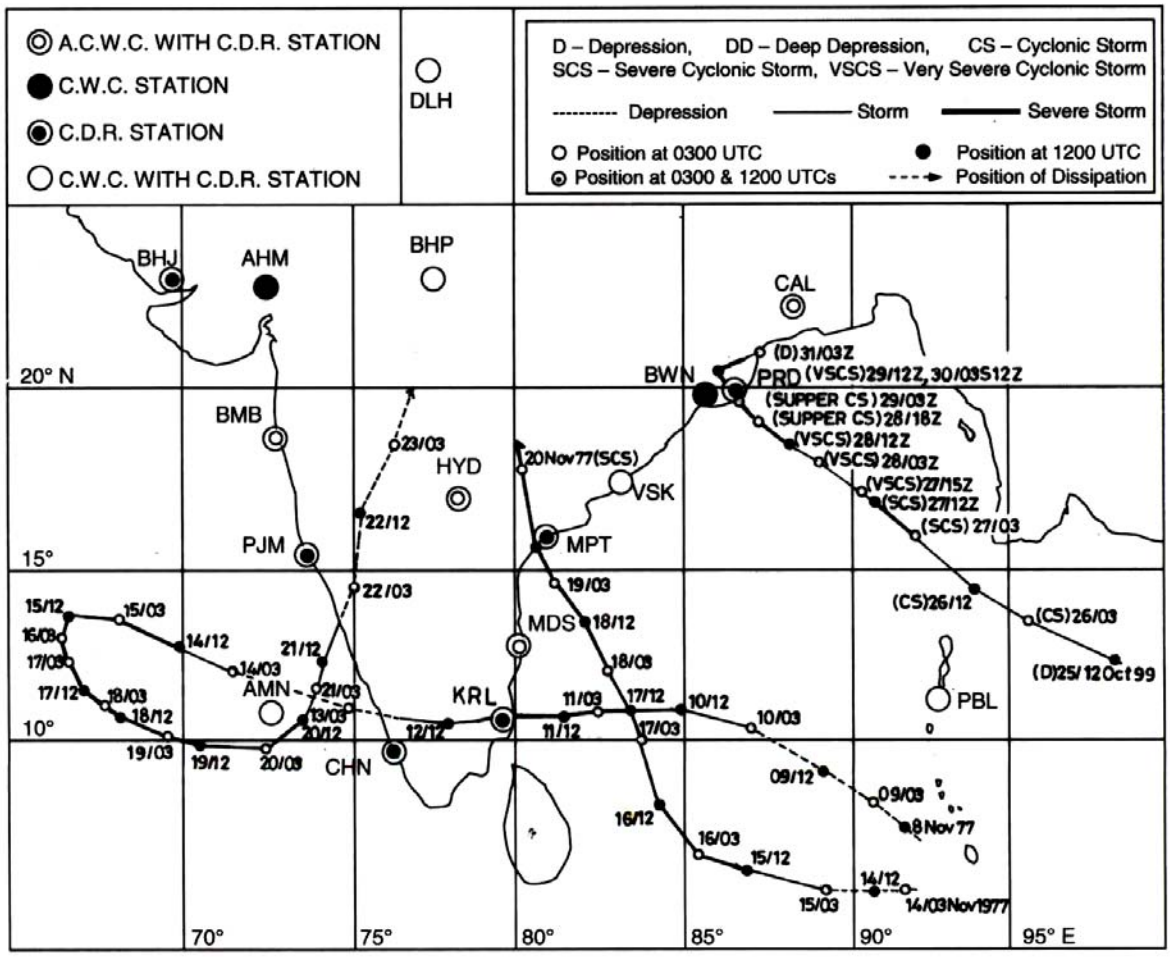

Fig. 1. Storm Tracks. Super cyclonic storm 14 – 20 November 1977, Arabian sea severe cyclonic storm 8 – 23 November 1977, Super cyclonic storm 25 – 31 October 1999

TABLE 1

Intense cyclonic storms which crossed the Indian coast in the last 30 years (1970 - 2000)

S. No.	System	Date	T Number	Landfall
1	Bay Severe Cyclonic Storm (H)	14 - 20 Nov 1977	T 7.0	Nizamapatnam (Andhra Pradesh)
2	Arabian Sea Severe Cyclonic Storm (H)	5 - 13 Nov 1978	T 6.0	Okha (Gujarat)
3	Bay Severe Cyclonic Storm (H)	17 - 24 Nov 1978	T 6.0	Kilakkarai (Tamil Nadu)
4	Bay Severe Cyclonic Storm (H)	5 - 13 May 1979	T - 6.0	Ongole (Andhra Pradesh)
5	Bay Severe Cyclonic Storm (H)	1 - 5 May 1982	T - 6.5	Arakan coast
6	Bay Severe Cyclonic Storm (H)	9 - 14 Nov 1984	T 6.0	Sriharikota (Andhra Pradesh)
7	Bay Severe Cyclonic Storm (H)	23 - 30 Nov 1988	T - 6.0	West Bengal
8	Bay Severe Cyclonic Storm (H)	1 - 9 Nov 1989	T - 6.5	Kavali (Andhra Pradesh)
9	Bay Severe Cyclonic Storm (H)	4 - 11 May 1990	T 6.5	Machilipatnam (Andhra Pradesh)
10	Bay Severe Cyclonic Storm (H)	24 - 30 Apr 1991	T - 6.5	Bangladesh
11	Bay Super Cyclonic Storm	25 - 31 Oct 1999	T - 7.0	Paradip (Orissa)
12	Bay Very Severe Cyclonic Storm	26 - 30 Nov 2000	T - 6.0	Cuddalore (Tamil Nadu)

Note:- Out of above 12 cyclones, 11 formed over the Bay of Bengal and only one formed over the Arabian Sea

TABLE 2

Brief history of Super Cyclone 1, 14 to 20 November 1977

Date	Time (UTC)	Intensity of system	Position		T. No. given by satellite	Estimated wind speed (knots)	Nearest observation	Remarks
			Lat. (°N)	Long. (°E)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
14 Nov 1977	0300	Deep depression	6.0	92.0	1.5	30	Car Nicobar - Wind - Easterly 35, at 0000 UTC at 0.9 km a.s.l.	A low pressure area moved westwards across Malaysia and south Andaman Sea into extreme southeast Bay and concentrated into a deep depression
15 Nov 1977	0300	Cyclonic storm	6.0	90.0	2.5	35	SHIP ELTP - close to centre. Pressure - 995 hPa at 0120 UTC	–
15 Nov 1977	1200	Severe cyclonic storm	6.5	87	4.0	65	–	–
16 Nov 1977	0300	Severe cyclonic storm with core of hurricane winds	7.0	85.5	5.0	90	Ship ATJZ (150 km west of the centre) Wind - northerly 40 knots at 0000 UTC	–
16 Nov 1977	1200	do	8.°	84.5	–	–	–	System changed its westward movement towards north. This appears to be the result of interaction with another severe cyclone in Arabian Sea (Track given in Fig.1) which also started changing its course abruptly from practically westerly direction to a southerly direction. Two storms detoured cyclonically around each other where the SC - 1, moving northwestwards and the Arabian Sea storm moving southeastwards upto 19th
17 Nov 1977	0300	do	10.0	84.0	–	–	SHIP Jagatswamini (ATFY 10.8° N / 83.8° E) at 0500 UTC. Wind - NNE / 60 knots	–

TABLE 2 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
17 Nov 1977	1200	Severe Cyclonic Storm with core of hurricane winds	11.0	83.5	–	–	Ship Jagatswamini ATFY 10.7 ° N / 84.1 ° E. Wind, SSW / 90 knots. Pressure - 947.9 hPa uncorrected	Ship Jagatswamini went right in 'Eye' of the storm. Maximum wind reported by the ship was 104 knots at 1030 UTC and minimum pressure recorded at the centre was 941 hPa uncorrected
18 Nov 1977	0300	Severe Cyclonic Storm with core of hurricane winds	12.5	83.0	7.0	140	–	–
18 Nov 1977	1200	Severe Cyclonic Storm with core of hurricane winds	13.5	82.0	7.0	140	–	–
19 Nov 1977	0300	Severe Cyclonic Storm with core of hurricane winds	14.5	81.5	7.0	140	–	–
19 Nov 1977	1200	Severe Cyclonic Storm with core of hurricane winds	Crossed coast near Nizamapattinam	–	7.0	140	Ongole - Max. wind 55 knots. Masulipattinam - 65 knots, Gannavaram - Max. wind 75 knots, Lowest pressure recorded by Ongole, Masulipatnam, Gannavaram were 992, 987 and 972 hPa respectively	Storm centre passed about 60 kms east of Ongole and 50 kms west of Masulipatnam between 0900 and 1400 UTC and was very close to Gannavaram and 1700 UTC. Storm retained its severe intensity with core of hurricane winds over land upto Gannavaram
20 Nov 1977	1200	Low pressure area	Eastern parts of Telangana	–	–	–	–	–

vorticity, cyclonic outflow, vertical extention, storm surge, rainfall & damage caused are discussed and compared here. Table 1 gives the cyclonic storms during 1970-2000 which crossed the Indian coast & had intensity given by satellite on Dvorak's scale as T ≥ 6 (≥ 115 kts). Table 1 also shows the period of cyclones of intensity T ≥ 6 and place of landfall. Out of 10 cyclones 9 crossed the east coast of India, 1 crossed Gujarat coast, 1 crossed Arakan coast & 1 cyclone crossed Bangla Desh coast. Out of 9 cyclones, which crossed east coast, 5 cyclones crossed Andhra coast, 2 cyclones crossed Tamil Nadu coast & 1 cyclone each crossed Orissa coast and West Bengal coast. It is seen that Andhra coast is most vulnerable for most intense cyclonic storm of T ≥ 6.0 (115 kts). Satellite observations helped us to estimate the intensity of the cyclonic storms in an objective way. These estimates were also verified with wind & pressure observations in the vicinity or storm centre. The devastation caused by SC 1 & SC 2 was unprecedented and their intensities are comparable. Information on

TABLE 3

Brief history of Super Cyclone 2, 25 - 31 October 1999

Date	Time (UTC)	Intensity of system	Position		T. No. given by satellite	Estimated wind speed (knots)	Nearest observation	Remarks
			Lat. (°N)	Long. (°E)				
24 Oct 1999	1200	Well marked low pressure area	Gulf of Siam and neighbourhood		1.0	25	–	–
25 Oct 1999	1200	Depression	12.5	98.0	1.5	25	–	–
26 Oct 1999	0300	Cyclonic storm	13.5	95.5	2.5	35	–	–
26 Oct 1999	1200	Cyclonic storm	14.5	94.0	2.5	35	–	–
27 Oct 1999	0300	Severe cyclonic storm	16.0	92.0	3.5	55	–	–
27 Oct 1999	1500	Very severe cyclonic storm	17.2	90.3	4.0		65	–
28 Oct 1999	0300	Very severe cyclonic storm	18.0	89.0	4.5	77	–	–
28 Oct 1999	1200	Very severe cyclonic storm	18.5	88.0	6.0	115	–	–
28 Oct 1999	1800	Super cyclonic storm	19.3	87.2	6.5	127	–	–
29 Oct 1999	0300	Super cyclonic storm	19.9	86.7	7.0	140	Paradip – Lowest pressure 980.9 hPa at 0200 UTC. Max wind – 80 knots. Puri – estimated Max. wind 95 knots at 0700 UTC	Crossed Orissa coast near Paradip between 0400 and 0530 UTC
29 Oct 1999	1200	Very severe cyclonic storm	20.5	86.0	–	–	–	–
30 Oct 1999	0300	Cyclonic storm	20.5	86.0	–	–	–	–
31 Oct 1999	0300	Depression	21.0	87.0	–	–	–	Moving in a southeasterly direction it again entered into the sea and weakened as a well marked low pressure area over northwest Bay and adjoining parts of north Orissa - West Bengal coasts on 31 evening

damage caused was collected from the State Government officials of Andhra Pradesh & Orissa. This was also verified from the reports of touring officers, who obtain this first hand information after visiting the affected area immediately after the cyclone.

2.1. The track of SC 1, 14-20 November, 1977 is given in Fig. 1. The brief history of the storm is given in Table 2. Above information has been collected from Pant *et al.* 1980.

2.2. Track of SC 2 is given in Fig. 1. Brief history of this storm is given in Table 3. Above information has been collected from Thapliyal *et al*., 2000.

3. Various aspects of the above two most intense cyclones are compared and given in Table 4. These aspects include the parameters like (*i*) Formation & Movement (*ii*) Lowest central pressure (*iii*) Maximum wind (*iv*) Satellite observations (*v*) Radar observations

TABLE 4

Comparison of Super Cyclone 1, 14-20 November 1977 and Super Cyclone 2, 25-31 October 1999

S. No	Parameters	Super Cyclone 1, 14 - 20 November 1977	Super Cyclone 2, 25 - 31 October 1999
(1)	(2)	(3)	(4)
1.	Formation & movement of cyclonic storm		
	Formation	6° N, 92° E	12.5° / 98° E
	Direction of movement	(*i*) Initially westerly & then changed to northwesterly. Interacted with system in Arabian Sea. Storm retained its intensity of severe cyclonic storm (core hurricane winds) over land upto Gannavaram and (*ii*) Ridge at 200 hPa was north of the system	(*i*) Northwesterly movement. After crossing land, it remained as a cyclonic storm for 2 days and (*ii*) System was in the "Col" region. As a result the system remained stationary without appreciable movement
	Duration	5½ days sea travel as cyclonic storm	4 days sea travel as cyclonic storm
2.	Lowest central pressure	*Recorded* : 941 hPa (uncorrected) at 1200 UTC of 17th by ship Jagatswamini at the centre of storm. Pressure depth 65 hPa *Estimated by satellite* : 912 hPa on 18th & 19th & pressure depth of 98 hPa	*Recorded* : 980.9 hPa at 290200 UTC at Paradip. *By satellite* : 912 hPa from 1800 UTC of 28th to 0600 UTC of 29th *Pressure depth* : 98 hPa
3.	Maximum winds	Estimated 140 kts (252 kmph). Ongole 55 kts, Machilipatnam 65 kts & Gannavaram 75 kts on 19th November	Estimated 140 kts (252 kmph). Paradip 80 kts on 29th 0200 UTC, later wind instrument went out of order. Puri estimated a maximum wind of 95 kts on 0700 UTC of 29
4.	Satellite observations		
(*i*)	Maximum Intensity on Dvorak's scale	T - 7.0 (140 kts) attained on 18th and maintained it on 19th as given by NOAA. JTWC Guam estimated maximum wind 115 kts on 18 on basis of Satellite pictures	Reassessed (140 kts) T - 7.0 from 1800 UTC of 28th to 0300 UTC of 29th. It was the highest T No. reported by INSAT
(*ii*)	Eye	Diameter 30 kms, eye was clear and distinct	Eye was seen. Diameter was not reported
(*iii*)	Duration of highest T classification	24 hours	9 hours
5.	Radar observation		
(*i*)	Eye	CDR Madras showed diameter of eye about 60 kms	CDR Paradip reported "eye" from 0800 UTC of 28th to 0200 UTC of 29th
		Jagatswamini reported diameter of eye on radar as 30 km	Diameter of eye was reported as 30 - 39 kms at 1100 UTC to 1700 UTC on 28 October 1999
(*ii*)	(RMR) Radius of maximum reflectivity	Not known	10 kms
(*iii*)	Eye wall	Was seen from 0350 to 0800 UTC of 18th November 1977	Not seen
6.	Relative Vorticity (By Bellamy's Grid Method)	Average relative vorticity at (surface) 1200 UTC of 19 November 1977 at time of landfall was 12.33×10^{-5} sec^{-1} over the storm field. However relative vorticity over the area over the following triangles was as given below : (*i*) Nellore, Machilipatnam and Kurnool = 28.71×10^{-5} sec^{-1} (*ii*) Ongole, Khammam and Kakinada = 8.02×10^{-5} sec^{-1} (*iii*) Gannavaram, Bhadrachalam and Vishakhapatnam = 0.27×10^{-5} sec^{-1}	Average relative vorticity at surface at 0300 UTC of 29 October 1999 (landfall was at 0430 UTC of 29 October 1999) was 5.78×10^{-5} sec^{-1} over the storm field. However relative vorticity over the area over the following triangles was as given below. (*i*) Puri, Sandheads and Balasore = 29.31×10^{-5} sec^{-1} (*ii*) Calcutta, Jharsuguda & Bhubaneswar = -1.46×10^{-5} sec^{-1}. (*iii*) Calcutta, Jharsuguda and Paradip = -11.96×10^{-5} sec^{-1}

TABLE 4 (*Contd*.)

(1)	(2)	(3)	(4)
7.	Cyclonic outflow	Cyclonic outflow was seen at 200 hPa on 19th November 1200 UTC *i.e.* at time of landfall	No cyclonic outflow was observed
8.	Vertical extention	200 hPa	400 hPa
9.	Storm surge	Tidal wave of height about 5 metres above mean sea level affected Divi, Eduramondi and Eletidibba islands at estuary of river Krishna and main coast south of Machilipatnam. Tidal waves extended inland upto 12 kms. in Divi island the western portion was not affected.. High tide at Kakinada was 1.44 above datum level (0.57 above mean sea level) at 1607 hrs UTC and low tide was 0.89 above datum level (0.02 m above mean sea level) at 2211 UTC. Thus contribution to tidal waves from the astronomical tide was very small and major contribution was from storm surge	Storm surge of 9 metres above astronomical tide at Paradip from 0630 hrs UTC to 1600 hrs UTC on 29 Oct 1999. Tidal inundation upto was 35 kms from the coast. Astronomical Tide at Paradip was 2.45 meters at 0522 hrs UTC of 29th. Thus contribution to tidal waves from astronomical tide was less and major contribution was from storm surge
10.	Rainfall	Rainfall on 20th Nov 1977 (in cm) Repalle 48, Bapatla 45, Palnad 45, Guntur 40, Madhira 33, Tenali 24, Tuni 22, Yellavaram 22 and Kothagudam 21	Rainfall on 30th Oct 1999 (in cm) Paradip 53, Bhubaneswar 43, Anantpur 40, Puri 18, Akhuapada 36, Balasore 21, Jenapur 26 and Naraj 21. Rainfall on 31st Oct 1999 (in cm) Anantpur 30, Bhubaneswar 10, Akhupada 17 and Puri 12
11.	Damage	Prakasam, Guntur, Krishna, East & west Godavari districts of coastal Andhra Pradesh were affected. Road & rail traffic telecommunication & power supply was dislocated. People killed 10,000. Herds of cattle lost 27,000. People killed in Divi Taluka alone = 8,000. Damage to crops and other property = 350 crores of rupees	12 districts in Orissa state *viz.*, Jagatsinghpur, Cuttack, Kendrapara, Puri, Jajpur, Bhadrak, Khurdo, Denkanal, Balasore, Keonjhar, Mayurbhanj, Nayangarh where complete breakdown of essential services were reported. Erasma & Kujang blocks of Jagatsinghpur district were worst affected. Population affected : 129.22 Lakh. Villages affected: 14643. Blocks affected : 97. Crop area affected : 18.42 Lakh Ha. Houses affected : 16.49 Lakh. Loss of life : 9887. (Jagatsinghpur - 8119, Cuttack - 471, Kendrapara - 469, Puri - 301, Jajpur 188, Bhadrak - 98, Khurda - 91, Dhenkanal - 55, Balasore - 51, Kenjhar - 31, Mayurbhanj - 10, Nayangarh - 3). Persons injured : 2507. Lives stock perished : 4.44 Lakh Fishing boats lost : 9085 and Fishing nets lost : 22143

(*vi*) Field of relative vorticity (*vii*) Cyclonic outflow (*viii*) Vertical extension (*ix*) Storm surge (*x*) Rainfall and (*xi*) Damage. It is seen that both the systems had comparable intensities and caused comparable loss of life and damage to property. But they differed in many respects in some of the characteristic features as discussed below.

4.1. SC 1 formed at lower latitude than the SC 2. SC 1 moved initially in westerly direction & then in a northwesterly direction, because of the interaction with the storm in Arabian Sea. SC 2 moved generally in northwesterly direction & remained stationary as a cyclonic storm for 2 days after crossing the coast. The system was in the Col region just at the time of crossing the coast. SC 1 had a Sea travel of 5½ days (132 hrs). SC 2, had a Sea travel of 4 days (96 hrs).

4.2. Estimated lowest central pressure was (912 hPa) in both the storms. This is the historical record of lowest central pressure over the Indian Seas. The recorded lowest central pressure in SC 1 was 941 hPa (by ship Jagatswamini) and 980.9 hPa (by Paradip) in SC 2.

4.3. (*i*) Estimate maximum wind by Satellite was 140 kts in both cyclones. The recorded maximum wind in SC 1, by Gannavaram observatory was 75 kts. However, Puri observatory estimated maximum wind as 95 kts in SC 2 on the basis of anemograph. (*ii*) Both the storms reported T 7.0 (140 kts) on Dvorak's scale. In case of SC 1 NOAA satellite gave T classification on Dvorak's scale and in case of SC 2 INSAT gave T classification on Dvorak's scale. Duration of highest T No. was for 24 hrs in SC 1 & for 9 hrs in SC 2. (*iii*) Diameter of eye was 60 km in SC 1 & 30 - 39 km in SC 2. In case of SC 1 Double

eye wall was seen for about 4 hrs where as it was not seen in SC 2. Because of double eye wall horizontal extension of SC 1 was more & intense. (*iv*) Average surface relative vorticity during SC 1 was 12.33×10^{-5} S^{-1} & 5.78×10^{-5} S^{-1} in SC 2. (*v*) Cyclonic outflow at 200 hPa was seen during SC 1. It was not seen during SC 2. (*vi*) Vertical extension was upto 200 hPa in SC 1 & upto 400 hPa in SC 2.

4.4. Rainfall amounts were comparable in both cyclones. As SC 2 was stationary near Bhubaneshwar for 2 days, the rainfall occurred for 2 days. In SC 1 rainfall occurred for 1 day. In case of SC 1, heavy rainfall belt extended as far as 300 - 400 km to the east of track while to the west it rapidly decreased & hardly extended 100 kms. But in SC 2 rainfall was heavy to the east & west of track also.

4.5. Storm Surge height was 9 m in SC 2 & 5 m in SC 1. Tidal inundation was 35 km inside from coast in SC 2 & 12 km inside from the coast in SC 1.

4.6. Damage caused by the two systems was comparable & were equally severe. SC 1 caused 10,000 death toll (8,000 in Divi Taluka alone) and damage to crops & other properly estimated to be 350 crores of rupees in coastal Andhra Pradesh (Prakasam, Guntur, Krishna, East & West Godavari districts) SC 2 caused severe damage in 12 districts of Orissa state. Loss of life was 9887, [Jagatsinghpur district alone - 8119].

5. Both the systems had comparable intensities & caused comparable loss of life & damage to property. But they differed in many respects in some of the characteristic features discussed above.

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