

## Decaying characteristics of severe cyclonic storms after landfall over east coast of India

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**सार** – प्रचंड उष्णकटिबंधीय चक्रवातों से बहुत अधिक संख्या में जान और माल की तबाही के साथ-साथ खेती बाड़ी को भी भारी मात्रा में नुकसान होता है। चक्रवात के स्थल भाग में प्रवेश के उपरांत मुख्य रूप से नुकसान इसकी तीव्र हवाओं के कारण होता है। इस शोध-पत्र में 1990 से 2003 तक की अवधि के दौरान चक्रवात के स्थल भाग में प्रवेश के उपरांत भूभाग को प्रभावित करने वाले उष्णकटिबंधीय चक्रवातों की तीव्र वायु की गति के धीमे पड़ने की प्रकृति का अध्ययन करने का प्रयास किया गया है। इससे यह पता चला है कि चक्रवात के भूभाग में प्रवेश के पश्चात् तीव्र वायु की गति में तीव्रता से कमी आई है। प्रचंड चक्रवात के स्थल भाग से टकराने के पश्चात् 6 से 9 घंटे के भीतर प्रचंड चक्रवात तुफानी चक्रवात में परिवर्तित हो जाता है जबकि बहुत अधिक प्रचंड चक्रवाती तुफान स्थल भाग से टकराने के पश्चात् 6 घंटे में प्रचंड चक्रवात तुफान और 15 घंटे में घटकर चक्रवात तुफान में बदल जाते हैं। बहुत अधिक प्रचंड चक्रवात के धीमे पड़ने की औसत गति पहले के 6 घंटों में 0.46 और बाद के अगले 6 घंटों में 0.59 पाई गई है।

**ABSTRACT.** Severe tropical cyclones are responsible for large casualties and considerable damage to property and agricultural crop. After the landfall, the main damages from cyclones are due to strong wind. An attempt has been made in this paper to study the nature of decay of wind speed of tropical cyclones after landfall for the period 1990-2003. It is found that the maximum wind speed decreased exponentially after landfall. A severe cyclonic storm decay to cyclonic storm within 6 to 9 hours after landfall where as very severe cyclonic storm decay to severe cyclonic storm within 6 hours and to cyclonic storm within 15 hours after the landfall. The mean decay rate is found to be 0.46 for the first 6 hours and 0.59 for the subsequent 6 hours.

**Key words** – Decay curve, Decay rate, Reduction factor.

### 1. Introduction

East coast of India is frequently affected by tropical cyclones. During the period 1891-2003, 88 severe storms crossed east coast of India (Fig. 1). Tropical cyclones are among the most destructive of all natural disaster and capable of annihilating coastal towns and killing hundreds of thousands of people. A recent example is the Orissa super cyclone of October 1999, the maximum wind speed was 140 knots just before landfall, causing huge damage to property and loss of about 10,000 people lives. Development process of this super cyclone was described by Kalsi *et al.* (2002). A historical records of most devastating cyclonic storms, which formed in the Bay of Bengal and made landfall on the east coast of India have been listed in IMD publication (October 2002). The damage produced by winds associated with tropical cyclones is extensive and it covers areas occasionally greater than those of heavy rains and storm surges which are generally localized in nature. The knowledge of decay of tropical cyclones after landfall is essential for coastal zone planning and development.

To cover the devastating impacts of the cyclone on the inland areas, a fourth stage of warning on the 'post landfall scenario' has been introduced recently by India Meteorological Department in the operational cyclone warning procedure. This warning commences about 12 hours before landfall and continues till such time as the cyclone force winds are expected to prevail in the interior areas. A study on the decay features of storms will be useful in issuance of inland wind forecast.

Applying the technique of Kaplan and DeMaria (1995), Kalsi *et al.* (2003) investigated decaying nature of the Orissa super cyclone. The study warranted further investigation with more number of cyclone cases. Towards this direction, in this paper an attempt has been made to study the decaying characteristic of land falling severe cyclonic storms over the east coast of India.

The damage potential of various stages of tropical systems as used in convention by India Meteorological

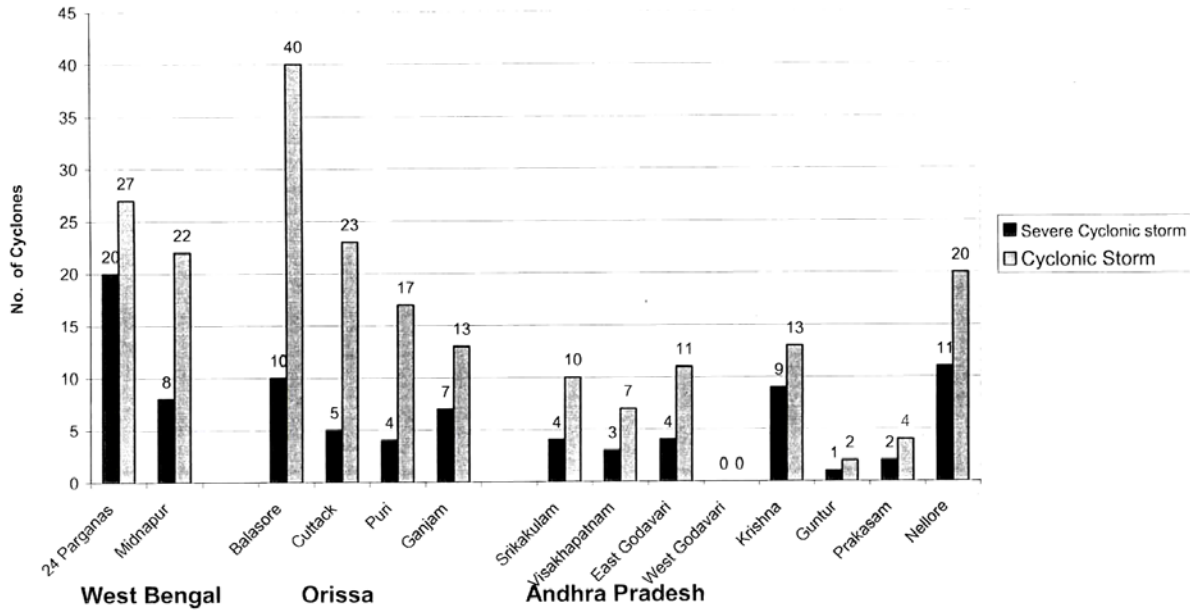


Fig. 1. Number of cyclonic storms which crossed the districts of eastern coast of India during 1891-2003

TABLE 1

System category and expected damage

System category	Damage expected
Deep depression (28-33 kts)	Minor damage to loose and unsecured structures.
Cyclonic storm (34-47 kts)	Damage to thatched huts. Breaking of tree branches causing minor damage to power and communication lines.
Severe cyclonic storm (48-63 kts)	Extensive damage to thatched roofs and huts. Minor damage to power and communication lines due to uprooting of large avenue trees. Flooding of escape routes.
Very severe cyclonic storm (64-90 kts)	Extensive damage to kutcha houses. Partial disruption of power and communication lines. Minor disruption of road and rail traffic. Potential threat from flying debris. Flooding of escape routes.
Very severe cyclonic storm (91-119kts)	Extensive damage to kutcha houses. Some damage to old buildings. Large-scale disruption of power and communication storm lines. Disruption of rail and road traffic due to extensive flooding. Potential threat from flying debris
Super cyclone or more (120 kts)	Extensive structural damage to residential and industrial buildings. Total disruption of communication and power supply. Extensive damage to bridges causing large-scale disruption of rail and road traffic. Large-scale flooding and inundation of sea water. Air full of flying debris.

Department is given in Table 1. It is observed that when the storm reaches below the stage of the cyclonic storm the damage potential is considerably reduced and is minimal when it reaches the stage of depression.

2. Data source

For present study, we consider five cases of Severe cyclonic storm and four cases of very severe cyclonic

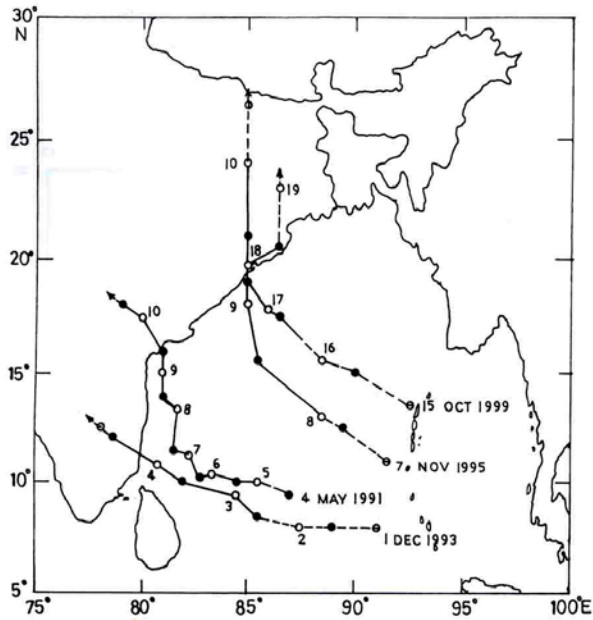


Fig. 2. Tracks of very severe cyclonic storms which cross east coast of India during 1990-2003

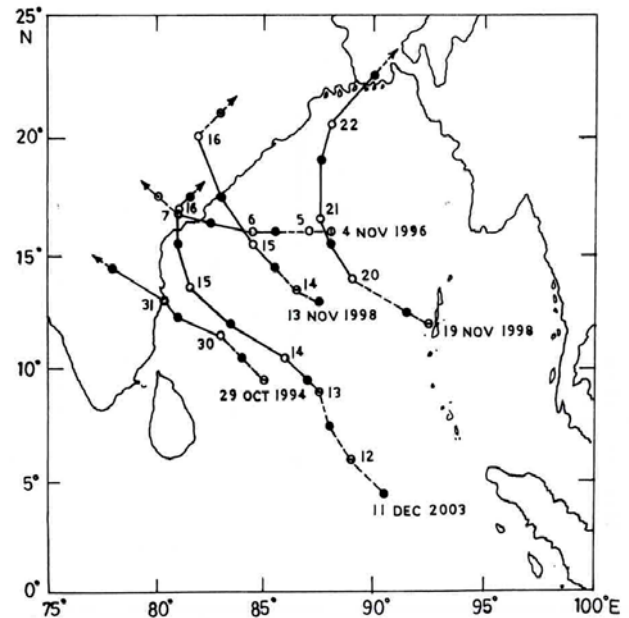


Fig. 3. Tracks of severe cyclonic storms which cross east coast of India during 1990-2003

TABLE 2

Maximum surface sustained wind after the landfall and subsequent 6 hour interval after the landfall

Date	Cyclone category	Maximum surface sustained winds in kts						
		Landfall time $V_0$	06 hours $V_6$	12 hours $V_{12}$	18 hours $V_{18}$	24 hours $V_{24}$	30 hours $V_{30}$	36 hours $V_{36}$
29-31 Oct 1994	SCS	60	33	28	17	-	-	-
5-7 Nov 1996	SCS	60	42	28	21	17	-	-
19-23 Nov 1998	SCS	55	30	27	25	25	-	-
13-16 Nov 1998	SCS	60	42	36	27	25	-	-
11-16 Dec 2003	SCS	55	35	25	25	23	-	-
4-9 May 1990	VSCS	90	58	35	23	17	-	-
1-4 Dec 1993	VSCS	77	38	19	15	-	-	-
7-10 Nov 1995	VSCS	77	45	40	35	30	25	20
15-19 Oct 1999	VSCS	90	55	45	30	30	25	-

storm which formed over the Bay of Bengal during the period 1990-2003. The storm tracks of these systems are given in Fig. 2 & Fig. 3 respectively. Data, such as

estimated maximum sustained surface wind speed, cyclone track and other synoptic information used in the study are based on the Annual Reports of the Regional

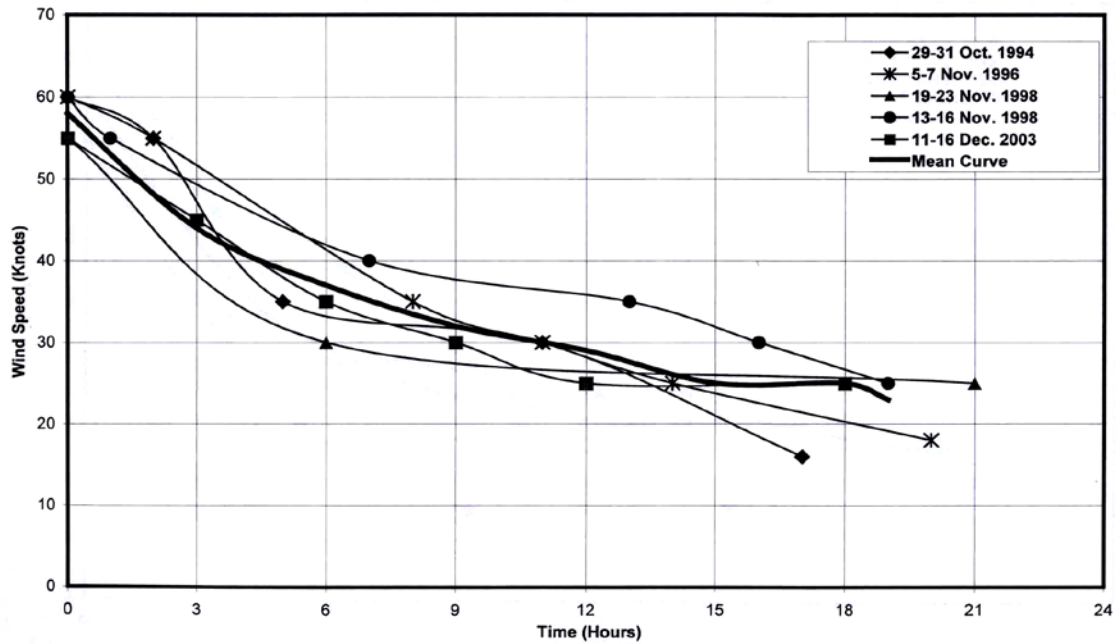


Fig. 4. Decay of maximum wind speed with mean decay curve of a severe cyclonic storms, cross east coast of India during 1990-2003

TABLE 3

The decay constant and reduction factor (Decay rates) of severe cyclonic Storm after landfall

Severe cyclonic storm	Decay constant		Decay rate	
	Decay constant initial 6 hours (a <sub>1</sub> ) (hr <sup>-1</sup> )	Decay constant subsequent 12 hours (a <sub>2</sub> ) (hr <sup>-1</sup> )	Decay rate initial 6 hours R <sub>1</sub>	Decay rate subsequent 6 hours R <sub>2</sub>
29-31 Oct 1994	0.18	0.05	0.35	0.73
5-7 Nov 1996	0.10	0.17	0.56	0.35
13-16 Nov 1998	0.18	0.04	0.34	0.78
19-23 Nov 1998	0.09	0.08	0.58	0.63
11-16 Dec 2003	0.13	0.07	0.47	0.67
Mean	0.14	0.08	0.46	0.63

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### 3. The decay parameters

Following Kaplan and DeMaria (1995), the Maximum Sustained Surface Wind Speed (MSSW) after the landfall at time *t* is written as:

$$V_t = V_b + (V_o - V_b) \exp(-at) \tag{1}$$

where *a* is termed as decay constant, *V<sub>o</sub>* is the maximum sustained surface wind speed at the time of

landfall, *V<sub>t</sub>* is the wind speed at the time *t* after the landfall and *V<sub>b</sub>* is the background wind speed. Background wind speed is simply the maximum wind speed that a tropical cyclone can maintain while over land under ideal condition, as suggested by Kaplan and DeMaria (1995).

MSSW decreases abruptly as the landing storm crosses the coastline and rapid decrease in the wind speed occurs during the early hours after the landfall. Because of this consideration Kaplan and DeMaria (1995), introduced a reduction factor *R* as a multiplier to the landfall intensity (*V<sub>o</sub>*). The optimal value of *R* obtained by them is 0.9. Very recently, Roy Bhowmik *et al.* (2005) applied the basic decay model in slightly different way than in the

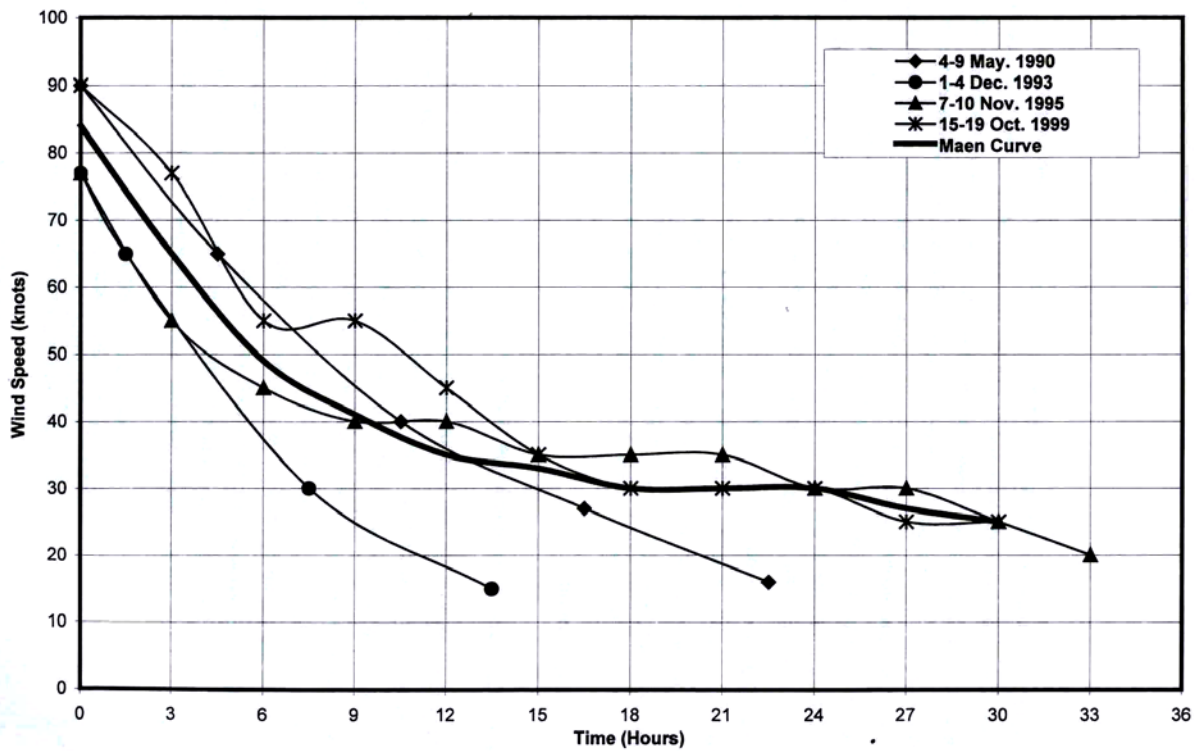


Fig. 5. Decay of maximum wind speed with mean decay curve of a very severe cyclonic storms, cross east coast of India during 1990-2003

TABLE 4

The Decay constant and reduction factor (Decay rates) of very severe cyclonic storm after landfall

Severe cyclonic storm	Decay constant		Decay rate	
	Decay constant initial 6 hours ( $a_1$ ) ( $hr^{-1}$ )	Decay constant subsequent 12 hours ( $a_2$ ) ( $hr^{-1}$ )	Decay rate initial 6 hours $R_1$	Decay rate subsequent 6 hours $R_2$
4-9 May 1990	0.10	0.15	0.56	0.41
1-4 Dec 1993	0.20	0.15	0.30	0.41
7-10 Nov 1995	0.13	0.04	0.47	0.80
15-19 Oct 1999	0.11	0.09	0.52	0.58
Mean	0.14	0.11	0.46	0.55

version of Kaplan and DeMaria (1995). They did not apply reduction factor, but instead, allow the decay constant to be determined at each time interval. They introduced current reduction factor (decay rates)  $R_1$  and  $R_2$  respectively for the first six hours and subsequent six hours after the landfall.  $R_1$  and  $R_2$  are defined as :

$$R_1 = \exp(-a_1 * 6.0) \tag{2}$$

$$\text{and } R_2 = \exp(-a_2 * 6.0) \tag{3}$$

Where,

$$a_1 = [\ln\{(V_0 - V_b)/(V_6 - V_b)\}]/6 \tag{4}$$

$$a_2 = [\ln\{V_6 - V_b)/(V_{18} - V_b)\}]/12 \tag{5}$$

$V_6$  and  $V_{18}$  are respectively MSSW at 6 hours and 18 hours after the landfall.

#### 4. Results and discussion

The maximum sustained wind speed at 6 hours intervals after the landfall for the cyclonic storms considered in this study are shown in Table 2. The corresponding decay curves for severe cyclonic storms (SCS) and very severe cyclonic storms (VSCS) are presented in Fig. 4 and Fig. 5 respectively. In case of the four very severe cyclonic storm it is observed that there is a wide variation in the decay time upto depression. For the two systems it remained intense upto 30 hours where as in one case it became depression within 9 hours.

The inland wind speed decreases in due to loss of oceanic heat source, decrease moisture supply and increased surface roughness over land which the cyclone encounters immediately after landfall. Another important synoptic situation which causes major variation in the life time is the wind shear in the middle and lower level. It is observed from Fig. 4 that SCS generally decays to a cyclonic storm within 6 to 9 hours and that to a depression within 15 hours to 18 hours after the landfall.

Decay rates ( $R_1$ ,  $R_2$ ) compared for five Severe Cyclonic Storms are shown in Table 3. The average decay rate for first 6 hours comes to 0.46 and for the subsequent 6 hours it becomes 0.63.

In case of the VSCS there is a wide variation in the decay patterns (Fig. 5). Two systems attained the stage of depression after 27 hours, whereas another dissipated within 9 hours. All the four systems decayed to SCS within 6 hours and to CS within 15 hours of the landfall.

For the systems which crossed south Andhra – north Tamilnadu coast, dissipation was rapid than those which crossed the north Andhra – south Orissa coast as in the former case the system encountered strong upper air easterlies causing rapid decay due to large shear.

The average decay rate of VSCS for the first 6 hours comes to 0.46 and for subsequent 6 hours it becomes 0.55. These values are comparable to those to

severe cyclonic storm. The average decay rate for combined SCS and VSCS cases become 0.46 and 0.59 for the first 6 hours and subsequent 6 hours respectively.

#### 5. Concluding remarks

Severe tropical cyclones are responsible for large casualties and considerable damage to property and agricultural crop. The present study shows that a tropical cyclone which crosses the east coast as severe cyclonic storm decays to a cyclonic storm within 6 to 9 hours and that to a depression within 15 to 18 hours. Similarly a very severe cyclonic storm decays to severe cyclonic storm within 6 hours and to Cyclonic Storm within 15 hours.

The mean decay rate for 6 hours and subsequent 6 hours of a severe cyclonic storm and very severe cyclonic storm are comparable. The mean decay rate comes to 0.46 for first 6 hours and 0.59 for the subsequent 6 hours.

The findings of this study appear to be useful in operational forecasting for post landfall scenario.

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