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Aila and it's unique features

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Abstract
Aila, a severe cyclonic storm, was an unique tropical cyclone for its specific features. Usually, the genesis of cyclones takes a considerable time and follows a curve track when approach towards land. But Aila was intensified rapidly and followed a straight path nearly northerly direction throughout its life period maintaining its intensity of cyclone even upto 15 hours after the landfall. It has coincided with the highest level of spring tide resulting enormous loss of life and properties of West Bengal and Bangladesh mainly in Sundarban Region which is a cyclone prone region for coastal location of Bay of Bengal.

Keywords: severe cyclonic storm, spring tide, embankmet breaching, overtopping**.**

Introduction

The tropical cyclones can produce extremely powerful winds and torrential rain**.** They are also able to produce high waves and damaging storm surge as much as super cyclonic storm. They develop over large bodies of warm water, and lose their strength if they move over land. This is why coastal regions receive significant damage from a tropical cyclone, while inland regions are relatively safe from receiving strong winds (Desai, 1983) [2]. Heavy rains, however, can produce significant flooding inland, and storm surges can produce extensive coastal flooding**.** The Sundarban Region of both India and Bangladesh is very much prone to such tropical cyclones and thus it plays a vital role in devastation made by the ***river*** embankment breaching. Aila is a severe cyclonic storm which plunged on the West Bengal and Bangladesh on 25th May 2009 and exerted an enormous effect on Sundarban caus***ing*** huge loss of lives and properties.

Materials and Methods

- The secondary information and maps are collected from Regional Meteorological Centre, Chennai**.** IMD e Atlas, 2009 is used to identify the tracks of Cyclonic Storms that had travelled over the Sundarban Region during the period from 1891 to 2007.
- Constant readings of tide level have been recorded at an interval of one hour by using permanent concrete Getty at Bhanderkhali Station ($22^0 19.024'$N & 88^0 $57.043'$E). Tidal levels are measured by tape with reference of fixed datum.
- The intensive field surveys are done to measure water velocity by digital Water Current Meter and wind velocity are measured by Digital Anemometer**.**
- The Co-incidence of Severe Cyclonic Storm and High Spring tide is identified with help of Gregorian-Lunar Calendar Conversion Table**.**

Result and Discussion

Occurrences and frequencies of tropical disturbances during 1891-2007

The climatic data available from Regional Meteorological Centre, Chennai, shows that during the period from 1891 to 2007, the North Indian Ocean experienced 1471 tropical disturbances of which 1148 disturbances were formed in Bay of Bengal accounting 78% of total disturbances (Table-***1***). 77% Depressions, 83% Cyclonic Storms and 75% of total Super Cyclonic Storms of North Indian Ocean were occurred in Bay of Bengal during that period. Sundarban being situated at north east of Bay of Bengal, receives almost all of the tropical disturbances occurred. These are deflected north and eastward into Sundarban being guided by south west monsoon. The coastal location of Sundarban attracts landfall of tropical disturbances. So, all tropical disturbances, which are formed just to the southern sea, may virtually affect the Sundarban irrespective of their cyclonic intensity (Das, 1965).

Table 1: Occurrences and frequencies of tropical disturbances (1891-2007)

Basin	Depression (D)	Cyclonic Storm(CS)	Severe Cyclonic Storm(SCS)	Total (D+CS+SCS)	Percentage
Bay of Bengal(BOB)	659	273	216	1148	78%
Arabian Sea(AS)	082	046	067	0195	13%
Land(L)	115	009	004	0128	09%
TOTAL	856	328	287	1471	100%

Surface air temperature anomaly data over the Sundarbans and adjacent parts of the Bay of Bengal (Fig.2) has been analysed by Hazra *et. al*. (2002) [3] and found an increasing trend in the yearly rise in temperature. This finding corroborates with the existing global warming phenomena. Temperature increase is found out to be 0.019^0 C per year. They have analysised available records of cyclones over the Bay of Bengal adjoining the Sundarbans which exhibits an increasing trend in the degree of their intensity while showing a decrease in the frequency of occurrence. This is a striking phenomenon in the perspective of warning trend which has a significant bearing on the extent of coastal flooding, erosion and saline water intrusion due to storm surges. The effect of the storm surge is likely to be more devastating in areas which were not earlier vulnerable (Hazra *et. al*. 2002) [3].

Table 2: Monthly distribution of severe cyclonic storm in NIO and BOB (1891-2007).

Months	J	F	M	A	M	J	Ju	A	S	O	N	D	Total	Percentage
North Indian Ocean	2	1	2	17	57	20	8	3	20	49	83	25	287	100%
Bay of Bengal	2	1	2	13	39	5	8	3	15	38	67	23	216	75%

It is evident from the table-2 that maximum concentration (75%) of Severe Cyclonic Storm (SCS) of North Indian Ocean is found in Bay of Bengal. Monthly distribution of occurrences of SCS shows that maximum number of Severe Cyclonic Storm of North Indian Ocean as well as Bay of Bengal occurs in November and May (Fig-1 & Fig-2). Pre and post monsoon seasons are crucial for developing Severe Cyclonic Storm. Around 50% Severe Cyclonic Storm (SCS) of North Indian Ocean and Bay of Bengal has occurred in November and May (Table-2). Therefore these two months are very much prone to formation of Severe Cyclonic Storm (SCS) as the occurrence of severe cyclonic storm is related to monsoon regime.

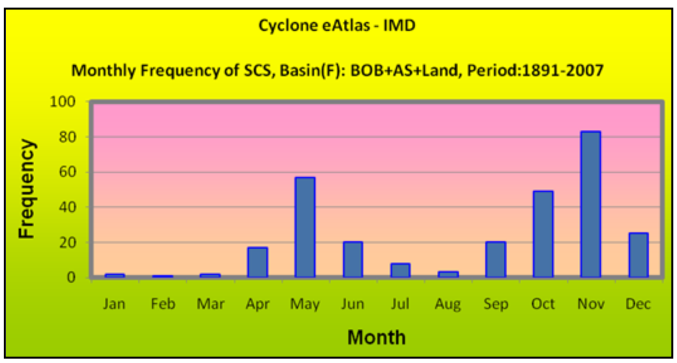

Fig 1: Monthly Frequency of Severe Cyclonic Storm in North Indian Ocean

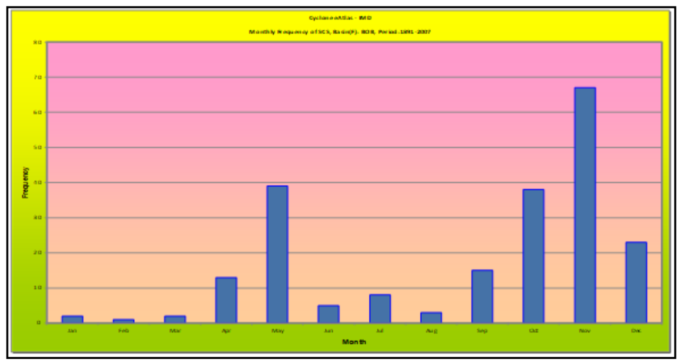

Fig 2: Monthly Frequency of Severe Cyclonic Storm in Bay of Bengal

Table 3: Seasonal distribution of severe cyclonic storm (SCS) in north Indian Ocean and Bay of Bengal (1891-2007).

Seasons	JF	MAM	JJAS	OND	Total	Percentage
North Indian Ocean	3	76	51	157	287	100%
Bay of Bengal	3	54	31	128	216	75%

The genesis of Aila

Southwest monsoon set*s* in over Andaman Sea and adjoining south Bay of Bengal on 20th May 2009. Under its influence, the southerly surge over the region increased. It resulted in increase in the horizontal pressure gradient and the north-south wind gradient over the region. Hence the lower level horizontal convergence and relative vorticity increased gradually over the southeast Bay of Bengal. It led to the development of the upper air cyclonic circulation extending up to mid tropospheric level on 21st May over the southeast Bay of Bengal and associated convective cloud clusters persisted over the region. Under the influence of the cyclonic circulation, a low pressure area formed over the southeast Bay of Bengal over 22nd May. It concentrated into a depression. The sea surface temperature (SST) was warmer (about 28^{O} C) over central and North Bay of Bengal, being 0.5 to 1^{O} C above normal. There was maximum lower level convergence to the south east of the system centre. Similarly, the upper level divergence and the lower level relative vorticity were higher around the system centre (IMD, 2009).

The special features of this storm are as follows-

1. Rapid intensification of Aila

Under the favourable conditions as discussed in the genesis above, the depression moved mainly in a northerly direction and intensified into a deep depression and lay centred at 08:30 hours IST of 24th near Lat. 18.0ºN/Long 88.5ºE (Fig-***3***.B). It further intensified into a cyclonic storm ‘Aila’ at 17:30 hours IST of 24th May and lay centred near Lat. 18.5ºN/Long 88.5ºE (Fig-***3***.C). It continued to move in northerly direction and intensified into a severe cyclonic storm at 11:30 hours IST of 25th May and lay centred over northwest Bay of Bengal near Lat. 21.5ºN/Long 88.0ºE close to Sagar Island (Fig-***3***.D).The system crossed West Bengal coast close to the east of Sagar Island between 13:30 to 14:30 hours IST as a severe cyclonic storm with wind speed of 100 to 110 km per hour (Fig- ***3***.E& ***3***.F). The lowest estimated central pressure was about 967 hPa at the time of landfall. After the landfall, the system continued to move in a northerly direction for long time**,** the***n*** gradually weakened into a cyclonic storm and lay centred at 20:30 hours IST of 25th May over Gangetic West Bengal, close to Kolkata. While it continued its northerly movement, it further weakened into a deep depression and lay centred at 08:30 hours IST of 26th May over Sub-Himalayan West Bengal & Sikkim, close to Malda. It weakened into a depression and lay centred at 11:30 hours IST of 26th May over the same region close to Bagdogra. It weakened and lay as a well-marked low pressure area over Sub-Himalayan West Bengal and neighborhood at 14:30 hours IST of 26th and became less marked on 27th May. The system could retain its intensity of cyclone for about 15 hrs after the landfall, as it lay close to the Bay of Bengal and lay centred over the Ganges deltaic region for quite some time, thus ascertaining the availability of moisture. However, the system gradually weakened due to interaction with land surface (IMD, 2009).

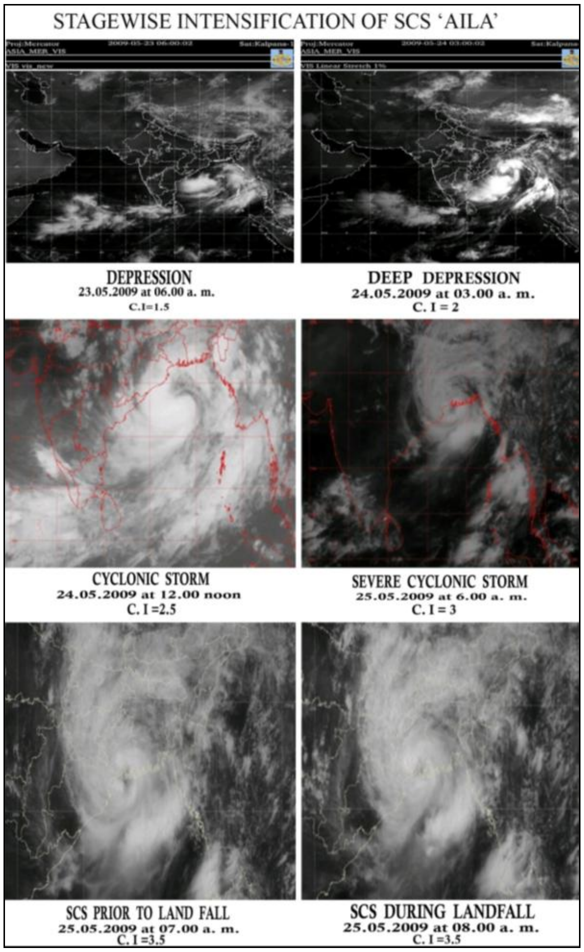

Fig 3: A-Depression, B-Deep Depression, C-Cyclonic Storm, D-Severe Cyclonic Storm E-SCS prior to Landfall, F- SCS during Landfall

2. Cyclone Track Analysis

2a. Tracks of Severe Cyclonic Storms (SCS)

It is mentioned earlier that 216 Super Cyclonic Storms has been formed in the Bay of Bengal between the periods from 1891 to 2007 but they have seldom followed a straight path and virtually followed deflected track. The tracks of seasonal severe cyclones are analysed to understand the nature of deflection. In this connection the cyclones originated and travelled through northern Bay of Bengal bounded by co-ordinates from 85º to 100º E and 10º – 35ºN are analyzed here under.

The tracks of the severe cyclonic storms that occurred in January to April are analyzed. It is evident that almost all the storms were originated between 10º – 15º N and deflected substantially towards north east (Fig-4A) those have not affected Indian Sundarban. It is clear that Indian Sundarban is free from severe cyclone during the period.

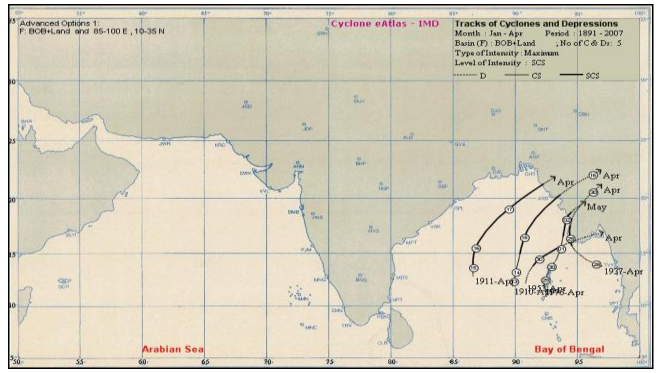

Fig 4A

Data available from Indian meteorological office and image prepared under cyclone e-atlas (IMD) shows that a huge number (31) of severe cyclones originated during May to June months are mostly deflected either towards right or left (Fig-4B). A considerable percentage of those severe cyclones passed over Sundarban only.

The cyclones generated during July to September over the span of generated data experienced mostly north westward deflection after being originated between 15º – 20ºN latitude. Only a few storms diverted towards north east (Fig -4C).

The cyclones generated in the month of October had also followed deflected track (Fig-4D) and no cyclones seldom took a northward straight course.

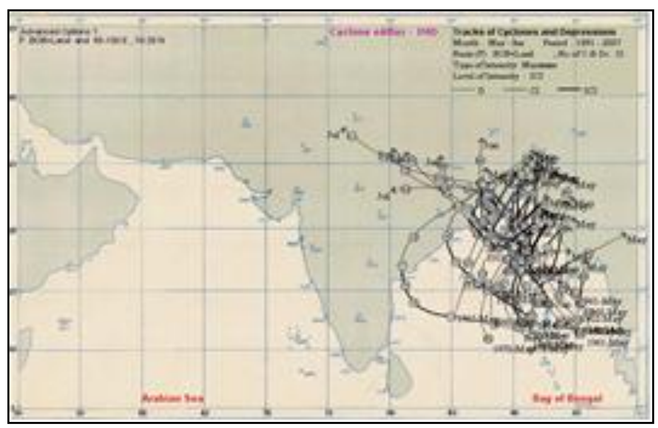

Fig 4B

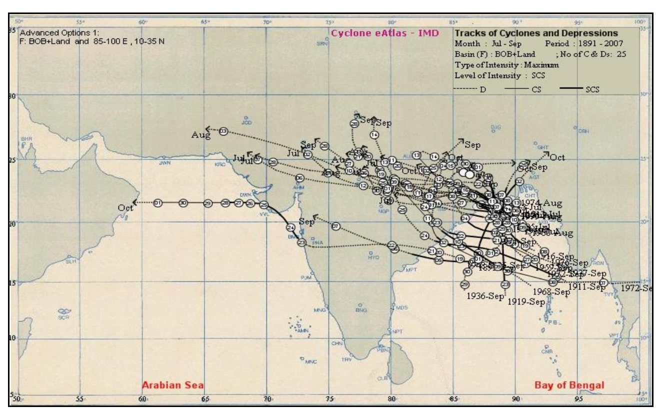

Fig 4C

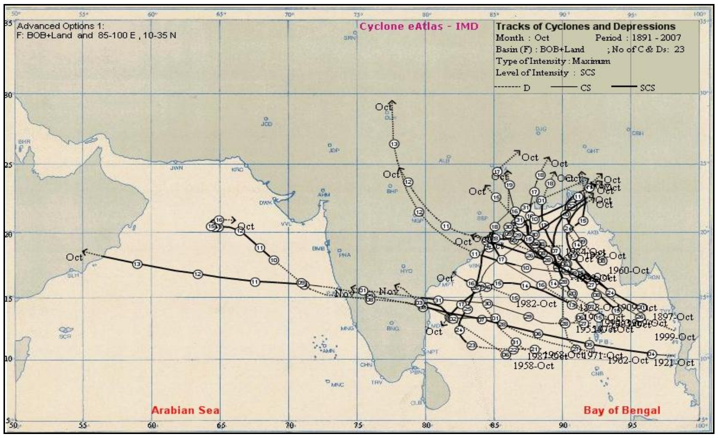

Fig 4D

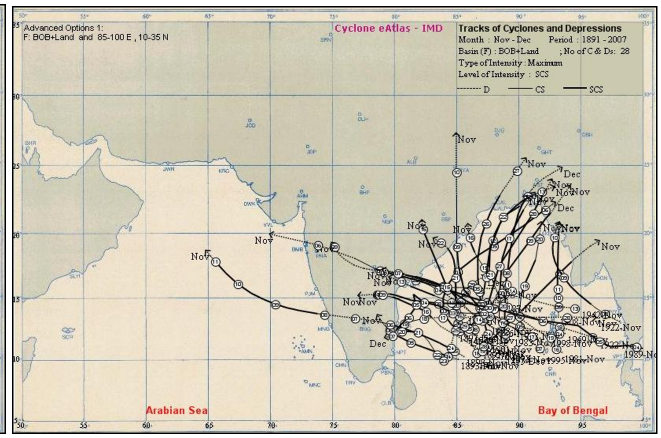

Fig 4E

The depression and other cyclonic storms generated during November and December showed varied tracks (Fig-4E). They seldom had a northward journey along the estuarine Sundarban. They have deflected either towards right or left. If severe cyclones move northward in a straight path it can push huge amount of water inward in form of storm surge. That may cause more devastation by ***river*** embankment breaching.

2B. Track of Aila and Relation between Estuaries and direction of Aila

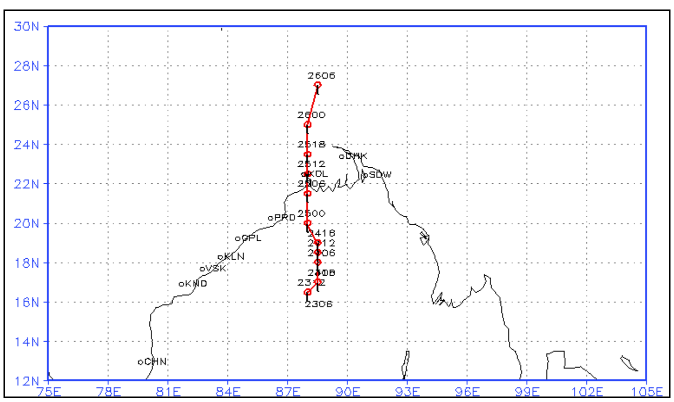

Fig 5: Track of Severe Cyclonic Storm 'AILA'

One of the greatest impacts in the coastal regions by the tropical cyclones is storm surges. Storm surges are generated by tropical cyclones by inverse barometric effect in the open ocean region. Surges are barotropic in nature, i.e. they are vertically homogeneous. They propagate towards the shore along with astronomical tides, which are also barotropic. While approaching the shore, they amplify due to the bottom topographic effects and attenuation and cause damages while striking the coast (Unnikrishnan, 2006). The System, Alia, has travelled about 11^{O} latitudinal span (from 16.5^{O}N to 27^{O}N) within a negligible (only 0.5^{O}) longitudinal difference (from88^{O}E to 88.5^{O}E) (Fig-5) having no curvature and that is how it hit the coastal zone as well as Sundarban in a straight way with amplified energy so that it was able to compel huge amount of tidal water to enter into the channels through the funnel shaped mouth of tidal rivers of gangetic system and resulted a tremendous storm surge and tidal bore through the tapering estuaries.

3. Co-incidences of Aila with Spring Tide

The Purely lunar calendars are based on the natural cycles of the Moon, which have months which attempt to synchronize with the lunar phases, and whose years (composed of months) have no close relation with the solar cycle (www.hko.gov.hk). It is revealed that 25 severe cyclonic storms have travelled over the region since 1891. The exact dates of travel of the severe cyclonic storms that have been passed over the study area are found out from the Cyclone e Atlas-IMD-2008(Table-4). The Gregorian Lunar Calendar Conversion tables are used to identify the lunar day of occurrences of severe cyclonic storm in the lunar month.

It is observed in the study area that the tidal fluctuation is related with the relative position of earth in relation to Moon and Sun and highest tidal amplitude and highest level of tidal water are found on the 2^{nd} and 17^{th} lunar day i.e. the day just after the New Moon and Full Moon Day. The potentiality of overtopping of water due to co-incidence of highest tidal water level and the additional force of storm surge due to landfall of severe cyclonic storms are assessed. The occurrence of SCS during spring tide is very crucial for river embankment breaching and overtopping and hence marked as very severe for potentiality of overtopping but the occurrence of SCS beyond the one or two days of spring tide are marked as safe.

Identification of the Co-incidence of Severe Cyclonic Storm and High Spring tide following New Moon Day or Full Moon Day with help of Gregorian-Lunar Calendar Conversion Table.

Table 4: Co-inciden*ce* of Severe Cyclonic Storm and High Spring Tide. Source: www.hko.gov.hk and IMD

Months : Jan - Dec		**Area of Formation(F) and Dissipation(Di)**		
Period : 1891 - 2007		Formation		Dissipation
Basin (F) : BOB		BOB and 85-95 E, 15-25 N		Land and 50-100 E, 5-35 N
Type of Intensity : Maximum		Direction of SCS		
Level of Intensity : SCS		Sea to Land:- Bangladesh and West Bengal Coast		
Date	Lunar Month	Lunar Day	Potentiality for Overtopping	Remarks
30.09.1895	Data Not Available	Data Not Available	Data Not Available	
26.06.1896	Data Not Available	Data Not Available	Data Not Available	
23.07.1913	6	20th	Safe	
30.07.1913	6	27th	Safe	
19.09.1916	8	22nd	Safe	
31.05.1927	5	1st	Severe	
23.05.1932	4	18th	Severe	
08.07.1935	6	8th	Safe	
26.09.1937	8	22nd	Safe	
30.06.1940	5	25th	Safe	
08.07.1940	6	4th	Severe	
06.07.1941	6	12th	Safe	
14.10.1942	9	5th	Safe	
29.05.1956	4	20th	Safe	
08.10.1960	8	18th	Severe	
08.10.1967	9	5th	Safe	
04.06.1971	8	18th	Severe	
28.09.1971	8	10th	Safe	
13.08.1974	6	26th	Safe	
08.09.1976	8	15th	Severe	
14.10.1983	9	9th	Safe	
22.05.1985	4	3rd	Severe	
23.05.1989	4	19th	Safe	
16.05.2004	3	28th	Safe	
25.05.2009	5	2nd	Very Severe	AILA

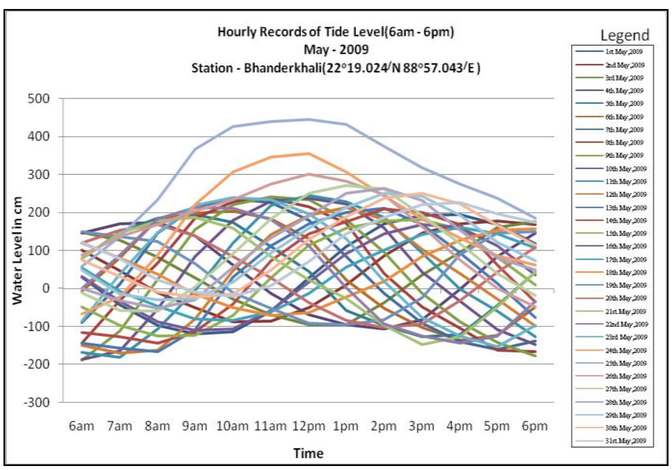

Fig 6: Tidal fluctuation during May, 2009

Thus it is revealed that Aila was too much severe for destruction of embankment and flood because of the fact that it was travelled over the region on 25th May, 2009 i.e 2nd day of lunar month (Table-4) when all the rivers of the region attained its highest tidal level (Fig-6) and tidal amplitude (Fig-7) and additional wind surge pushed water towards interior portion. The tidal wave surges were also abruptly raised due to huge influx of water through funnel shaped estuary of the river and closer and constricted channels in the interior portion had turned the tidal surges into bores. The estuarine mouth of Hooghly and it's numerous distributaries acquired a typical seaward facing funnel shaped pattern favoured to enter more water into the river system of Sundarban.

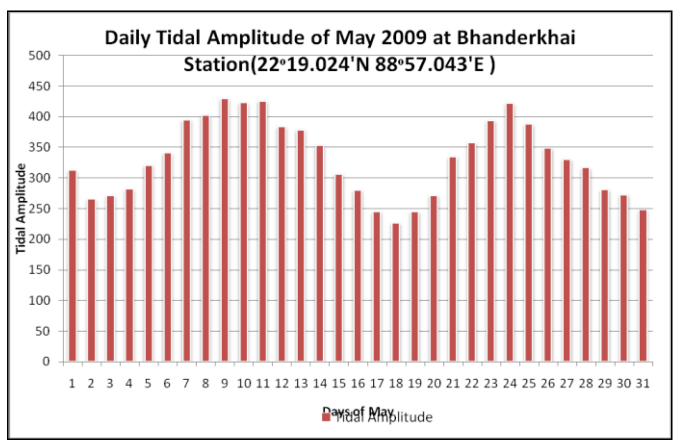

Fig 7: Daily Tidal Amplitude of a lunar month. (May, 2009)

Due to progressive shallowing of channels, the height of tidal bore became maximum 6.4 m and further inland this increased to 7.17 m. The analysis of available records of cyclones over the Bay of Bengal adjoining the Sundarban, exhibits an increasing trend in the degree of their intensity while showing a decrease in the frequency of occurrence. This is a striking phenomenon in the perspective of warming trend and has significant bearing on the extent of coastal flooding, erosion and saline water intrusion due to storm surges (Hazra *et. el*. 2002) [3]. The total length of river embankment of Indian Sundarban is 3500 km of which 767 km was entirely washed out by Aila (Kanjilal, 2011) [6]. The huge loss of human lives, livestock, properties and infrastructures were accounted both in India and Bangladesh.

Conclusion

The magnitude of destruction was much more greater than the other previous Severe Cyclonic storm because of it's unique features not only for its stright path but also for its co-incidence with highest tidal level in the rivers of Sundarban. So a planned preparedness for every spring tidal period during the advent and retreat of Monsoon specilly in the month of May and November is required for combatting such type of Storms.

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