

The relationship between geopotential height and movement & landfall of tropical cyclone in the Bay of Bengal region

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सार – इस शोध पत्र में बंगाल की खाड़ी में उष्णकटिबंधीय चक्रवात की चाल और तट से टकराने के समय सापेक्षिक प्रभावों की जाँच करने के लिए सरल विधि का प्रयोग किया गया। चक्रवात के आने के समय पर विभिन्न क्षोभ मंडल स्तरों में भूविभव ऊँचाई का इनपुट के रूप में प्रयोग किया गया। इस अध्ययन के लिए मानसून से पूर्व और मानसूनोत्तर काल में बंगाल की खाड़ी में आए 5 उष्णकटिबंधीय चक्रवातों को चुना गया। इस अध्ययन के अर्तगत, चक्रवातों के आने वाली अवधि में तटीय स्थानों जैसे कोलकाता (दमदम), ढाका, अगरतला, भुवनेश्वर, विशाखापट्टनम, मसुलीपट्टनम, चैन्ने और कराईकल के रेडियो सौंदे और रेडियो विन्ड ऑकड़ों को इकट्ठा किया गया। प्रत्येक चक्रवात के लिए समय के विपरीत विभिन्न मानक स्तरों पर भूविभव ऊँचाई प्लॉट की गई। इस अध्ययन से पता चलता है कि चक्रवात इस स्थान के समीप आगे बढ़ता और उसे पार करता है तो उसकी भूविभव ऊँचाई मध्य उष्णकटिबंधीय स्तर से अपेक्षाकृत ढलवान में कमी आती है और उसके बाद उसके भूविभव ऊँचाई में वृद्धि होती है।

ABSTRACT. In this paper a simple relationship is employed to investigate relative impacts on the movement and landfall of tropical cyclone in the Bay of Bengal region when geopotential height of different troposphere levels is used as an input. Five tropical cyclone during pre-monsoon and post-monsoon season over the Bay of Bengal region has been selected for the study. The RS/RW data of coastal stations namely Kolkata (Dumdum), Dhaka, Agartala, Bhubaneswar, Visakhapatnam, Machlipatnam, Chennai and Karaikal has been collected for the period of the cyclones under study. The geopotential height of different standard levels has been plotted against the time for the stations for every cyclone. The study suggests that the cyclone moves towards and cross near the station having relatively steeper decrease in geopotential height upto mid tropical level followed by increased in geopotential height.

Key words – Tropical Cyclone, Geopotential Height, Movement and landfall.

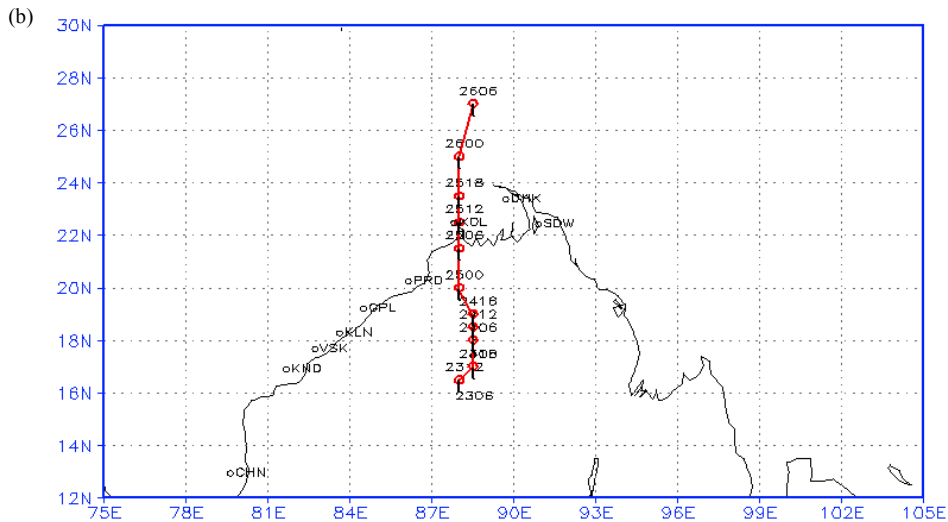
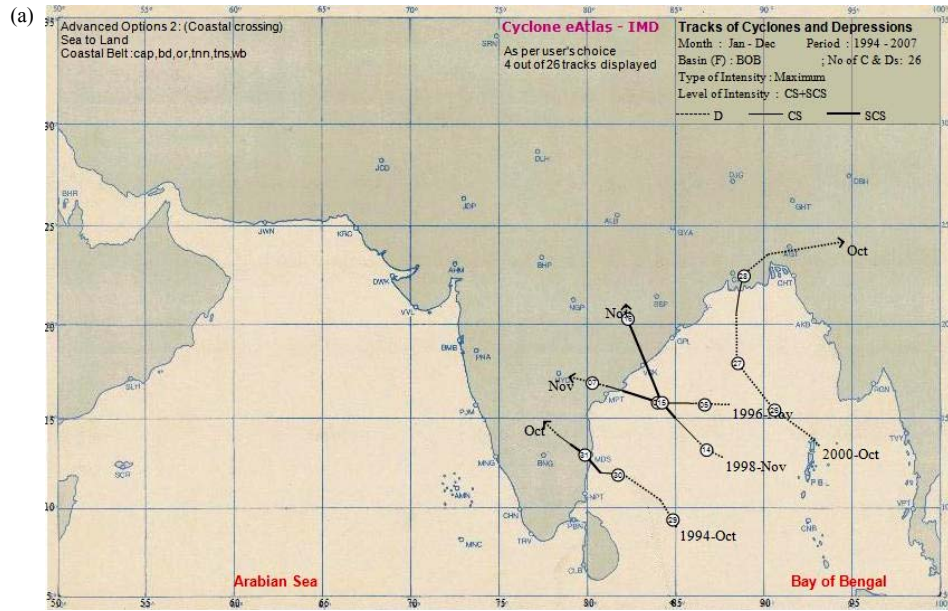
1. Introduction

Cyclonic storms (CS) are intense atmospheric vortices, which develop over warm tropical oceans causing enormous damage to life and property at the time of crossing the coast and subsequent movement over the land. The systems are maintained by the release of latent heat extracted from the under-lying sea. Most of these systems (87%) occur between 20° N and 20° S. Though only 7% of them form over north Indian Ocean, they are the most severe. East coast of India is frequently affected by tropical cyclones. During the period 1891-2003, about 112 severe cyclones crossed the east coast of India (IMD, Atlas of storm track 2002, RSMC-Reports)

Detailed tropical cyclone climatology of the North Indian Ocean (NIO) region has been studied by Mandal (1991). The three dimensional structure of a tropical cyclone has been extensively studied and documented by

Anthes (1982) and De & Joshi (1995). The surface pressure is lowest at the centre of the cyclone and increases outward. The wind speed reaches its maximum value at nearly 40-80 km from the centre beyond which it decreases. The central parts are warmer than the surroundings and the temperature anomaly could be more than 10° K at the upper troposphere. The tropical cyclone grows upto a height of 10-15 kms. Generally concentric isobars and gradient wind balance are assumed, to model a cyclone at the surface level. Intense cyclones frequently develop an eye, which is a cloud free region at the centre of the storm characterised by the presence of subsidence.

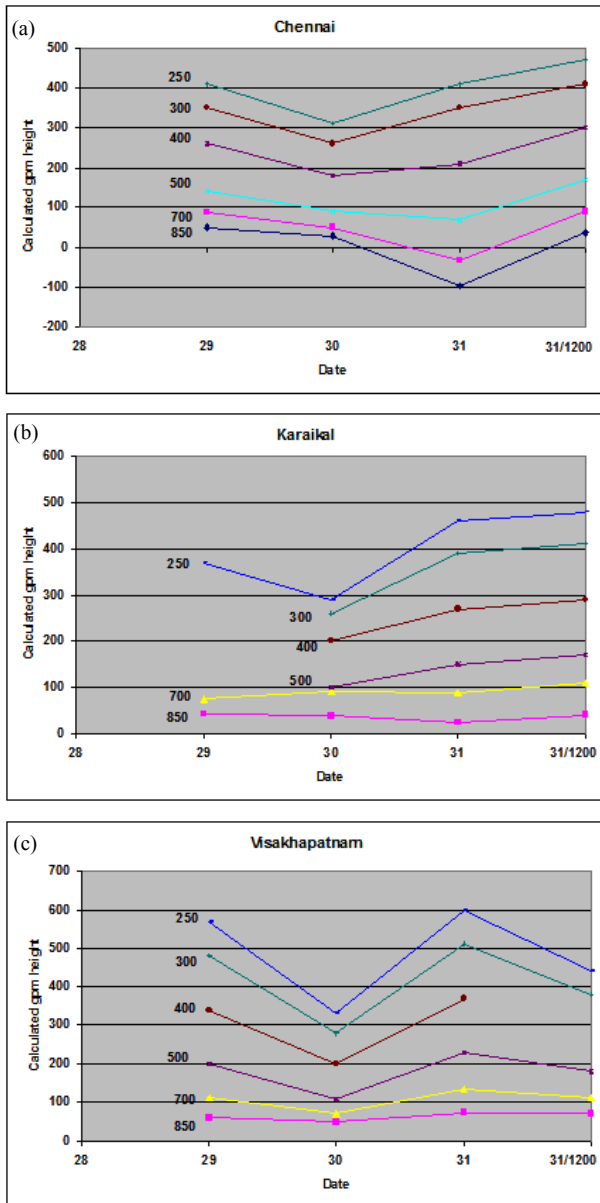
Many authors have studied tropical cyclone movement and intensity in details taking various parameters as an input. The consistency of INSAT OLR data based on a single radiometer and the methodology of extraction has been discussed in detail by Kelkar *et al.*, (1993), Rao and Kelkar (1989). Muthuchami and



Figs. 1(a&b). Track and movement of CS for the study

Sridharan (2008) have studied the intensification and movement of cyclonic storm in the Bay of Bengal during post monsoon season. They concluded that the orientation of isotherms of SST of Bay of Bengal influenced the direction of motion of tropical cyclone. They have found that during the years when the storms predominantly moving west/northwest the SST over the Bay of Bengal remained about 1.0° C warmer than the years when the storms predominantly moving in north/northeastward.

Muthuchami (2000) concluded that during post monsoon season in the Bay of Bengal cyclonic storms have a particular annual behavior in direction of motion in each year, *i.e.*, the storms in a year tend to move in a particular direction. Krishna Rao (1997) remarked that during the formative stage when the low level convergence zone is superimposed by upper level divergence it gets intensified. Holland (1983) has shown that the inclusion of vortex scale convergence changes the vorticity tendency



Figs. 2(a-c). Analysis of geopotential height for Chennai CS during 29-31 Oct 1994

propagation to a direction slightly poleward and westward.

In this paper an attempt has been made to investigate relative impacts on the movement and landfall of tropical cyclone in the Bay of Bengal region when geopotential height of different tropospheric levels is used as an input.

2. Data and methodology

The data for this study has been collected from 2008 IMD publications of Tracks of storms and depressions in

the Bay of Bengal and Arabian Sea, Regional Specialized Meteorological Centre (RSMC) report on cyclonic disturbances in the North Indian Ocean, Indian Daily Weather Report, Indian Weekly Weather reports for the period 1994-2009. Five tropical cyclone during pre monsoon and post monsoon season over the Bay of Bengal region has been selected for the study [Figs. 1(a&b)].

The RS/RW data of coastal station namely Kolkata (Dumdum), Bhubaneswar, Visakhapatnam, Machalipatnam, Chennai, Agartala, Dhaka and Karaikal have been collected from University of Wyoming (<http://weather.uwyo.edu/upperair/sounding.html>) for the period of the cyclones under study.

Geopotential height approximates the actual height of a pressure surface above mean sea-level. The work done in moving a unit mass from mean sea level to height *z* above sea level is defined as the geopotential of the level. Thus we have

$$\delta\phi = g\delta z \text{ and } \phi = \int_0^z g\delta z$$

where $\phi = 0$ at mean sea level.

For most of the meteorological calculations, the variation of gravity in the vertical is small and *g* is treated as constant. Hence

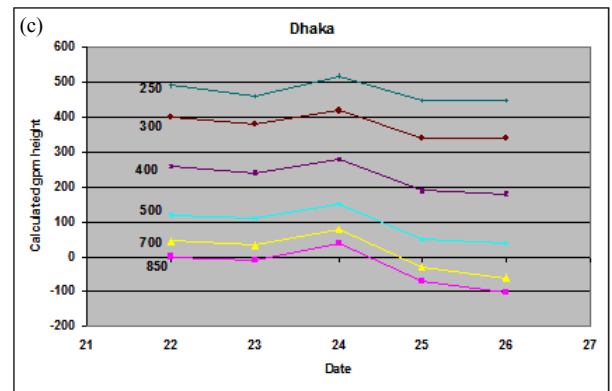
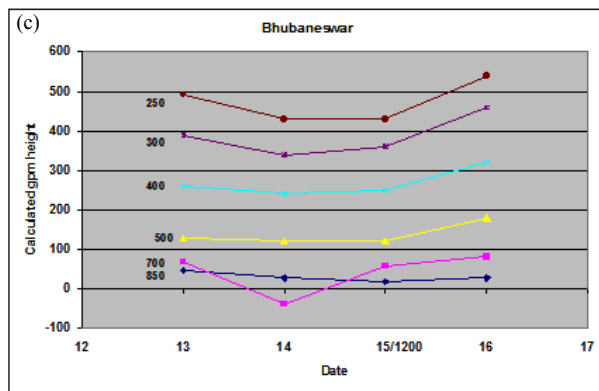
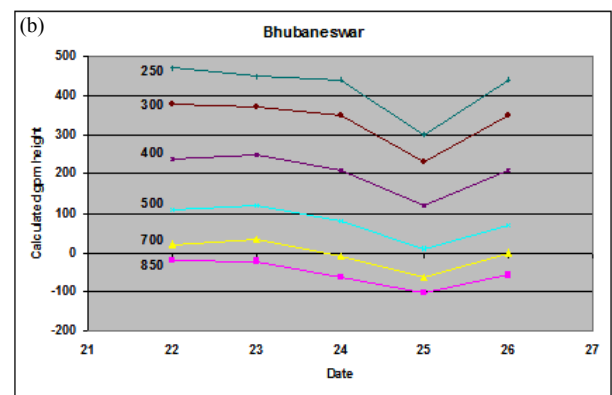
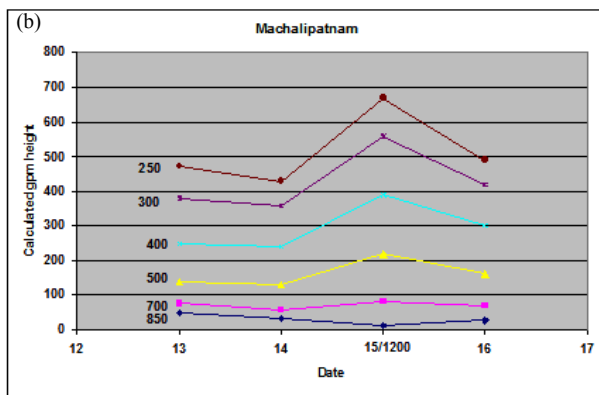
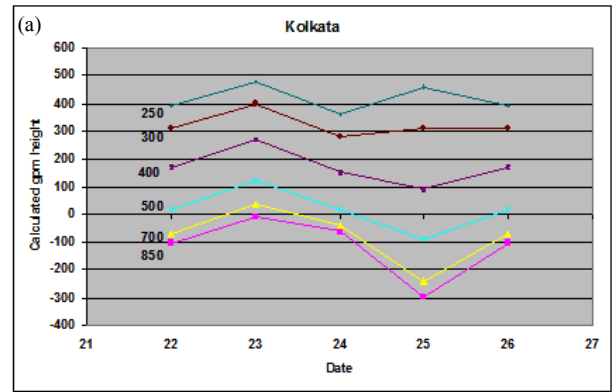
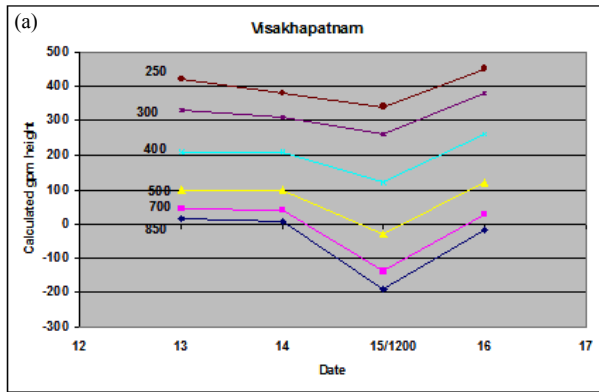
$$\phi = gz \text{ or } \phi_2 - \phi_1 = g(z_2 - z_1)$$

and surfaces of constant ϕ are called level surfaces.

The geopotential height anomalies of different standard levels have been plotted against the time for stations for every cyclone with the following criteria (actual value-normal value).

- 850 value = gpm height of 850-1450
- 700 value = gpm height of 700-3050
- 500 value = gpm height of 500-5700
- 400 value = gpm height of 400-7300
- 300 value = gpm height of 300-9300
- 250 value = gpm height of 250-10500

For each of the five cases of CS, data of three stations namely the station which has been hit by CS and two adjacent stations have been analysed and discussed.



Figs. 3(a-c). Analysis of geopotential height for Visakhapatnam VSCS during 14-16 Nov 1998

Figs. 4(a-c). Analysis of geopotential height for Kolkata SCS (AILA) during 22-26 May 2010

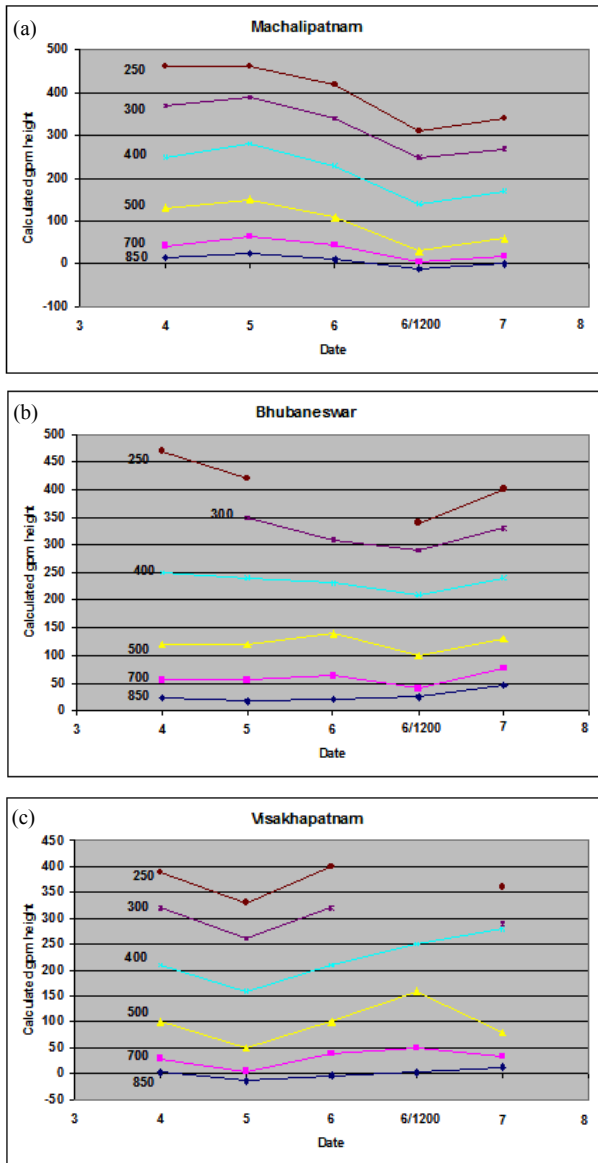
3. Discussions

Variation of GPM height for five cases of cyclonic storm has been discussed below.

3.1. Chennai CS during 29-31 Oct 1994

It crossed Tamilnadu coast and passed over Chennai between 0100 & 0200 UTC of 31st October 1994. In this

case the geopotential (GPM) height anomaly of three stations namely Chennai, Karaikal and Visakhapatnam (for the period 29/0000 UTC to 31/1200 UTC) have been plotted against time [Figs. 2 (a-c)]. From the figure it has been observed that Chennai shows a sharp fall of geopotential (GPM) height anomaly on 31st October (0000 UTC) in comparison with 30th October [Fig. 2(a)] upto mid tropospheric level (upto 500 hPa level) followed by rise in upper level whereas the adjacent stations Karaikal



Figs. 5(a-c). Analysis of geopotential height for Machalipatnam SCS during 4-7 Nov 1996

[Fig. 2(b)] show a slight fall in lower level (upto 700 hPa) followed by rise and Visakhapatnam [Fig. 2(c)] shows rise in calculated GPM height on 31st October (0000 UTC) in comparison with 30th October.

3.2. Visakhapatnam VSCS during 14-16 Nov 1998

It crossed north Andhra coast close to but south of Visakhapatnam in the evening of 15th Nov 1998. In this case the GPM height anomaly of three stations namely Visakhapatnam, Machalipatnam and Bhubaneswar (for the period 13/0000 UTC to 16/0000 UTC) has been

plotted against time [Figs. 3 (a-c)]. From the figure it have been observed that Visakhapatnam shows a very sharp fall of calculated GPM height on 15th November (1200 UTC) in comparison with 14th November [Fig. 3(a)] upto upper level whereas the adjacent stations Machalipatnam [Fig. 3(b)] show a slight fall at 850 level followed by rise and Bhubaneswar [Fig. 3(c)] also shows a slight fall at 850 level followed by rise.

3.3. Kolkata SCS (AILA) during 24-26 May 2009

It crossed West Bengal coast near Sagar Island between 1330 and 1430 hrs (IST) of 25th May 2009 [Fig. 1(b)]. In this case the GPM height anomaly of three stations namely Kolkata, Bhubaneswar and Dhaka (for the period 22/0000 UTC to 26/0000 UTC) have been plotted against time [Figs. 4 (a-c)]. From the figure it has been observed that Kolkata shows a very sharp fall of calculated GPM height on 25th May (0000 UTC) in comparison with 24th May [Fig. 4(a)] in lower level (upto 400 hPa level) followed by rise in upper level whereas the adjacent stations Bhubaneswar [Fig. 4(b)] also shows sharp fall upto 250 hPa level. Dhaka [Fig. 4(c)] also shows a sharp fall in calculated GPM height on 25th May (0000 UTC) in comparison with 24th May.

3.4. Machalipatnam SCS during 04-07 Nov 1996

It crossed Andhra coast close to Machalipatnam in the evening of 6th November 1996 and weakened rapidly on 7th November. In this case the GPM height of three stations namely Machalipatnam, Bhubaneswar and Visakhapatnam (for the period 04/0000 UTC to 07/0000 UTC) has been plotted against time [Figs. 5 (a-c)]. From the figure it has been observed that Machalipatnam shows a sharp fall of calculated GPM height on 6th November evening (1200 UTC) in comparison with 6th November morning (0000 UTC) [Fig. 5(a)] upto 250 hPa level whereas the adjacent stations Bhubaneswar [Fig. 5(b)] show a slight rise in lower level (upto 700 hPa) followed by fall and Visakhapatnam [Fig. 5(c)] shows a rise in calculated GPM height on 6th November evening (1200 UTC) in comparison with 6th November morning (0000 UTC).

A similar result has been found for the Kolkata CS (25-29 October 2000) that crossed near Sagar Islands between 0100 & 0300 UTC of 28th October 2000 when we have compared the GPM height anomaly of Kolkata, Bhubaneswar and Agartala.

4. Conclusion

(i) The study suggests that geopotential height anomaly at different level gives an indication of cyclone movement

and land fall when it reaches near the coast. The cyclone storm moves towards and crosses coast near the station having the steeper decrease in geo-potential height anomaly in lower level (upto mid tropospheric level) followed by increased in geo-potential height.

(ii) The result is consistent with the finding that Low Pressure Systems move along the steeper isallobaric gradient or in the direction where there is steepest change of pressure. After all the lower tropospheric GPM height reflect the surface pressure as well.

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