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Performance of WRF-ARW Model on the Track and Intensity Prediction of VSCS Hudhud over BoB System

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Abstract—*Performance of WRF model was examined for Track and Intensity prediction of Very Severe Cyclonic Storm (VSCS) Hudhud (7^{th}– 14^{th} October, 2014).*
The analysis and forecast field of IMD- GFS was utilized for the initial and lateral boundary condition.
Results demonstrated that WRF- ARW provided adept forecast of cyclone characteristics. Using obtained products, the track could be predicted three to four days earlier with maximum average track error less than 350 km (72^{nd} hour forecast lead time). Apex value of average intensity error was less than 25 knots and 17 hPa (both 48^{th} hour forecast lead time) for Maximum Sustained Wind (MSW) and Minimum Sea Level Pressure (MSLP) respectively. Approximate error in landfall time was three to four hours.

1. INTRODUCTION

Tropical cyclone (TC) play a major role in driving global and regional water cycle by enhancing low level convergence that supply the free troposphere with an upward flux of unstable air, which in turn brings moisture from the oceans to land [1].

TC unleash its highest potential as it makes landfall in coastal belt. Violent winds, torrential rains torrential rains and storm surge are the three major causes of destruction. Though fewer tropical cyclones occur in the north Indian Ocean (NIO) compared to the other basins, the shallow depth of the Bay of Bengal and the low flat coastal terrain produce much larger storm surge and take a very heavy toll of life. Bay of Bengal has experienced more than 75% of total TC's causing human deaths of 5000 or more in last 300 years [2]. India and Bangladesh have a coastline of 8000 km, which is very prone to very severe cyclone formation.

As TCs cannot be tamed to reduce their adverse effect, early and accurate prediction plays an important aspect in disaster management of cyclones. In the recent years mesoscale models are extensively used for simulation of genesis, intensification and movement of tropical cyclones. Das et al. (2008) made a comparative study on performance of various mesoscale models over Indian region and recommended ensemble approach instead of relying on single model [3]. Also sensitivity experiments have been conducted with Weather Forecasting Model (WRF) model in capturing the track and intensity of super cyclone 'Gonu' over Arabian Sea and very severe cyclonic storm (VSCS) 'Sidr' over Bay of Bengal [4].

In the present study VSCS 'Hudhud' is simulated using WRF model. Prime objective is to investigate the performance skill of WRF model for track and intensity prediction in day 1 to day 3 time scale. Skill score have been evaluated and compared with verifying analyses. A brief description of experimental setup and data used is described in section 2. Section 3 contains information about the synoptic situation of relevant cyclone. Results are discussed in section 4 and conclusions in section 5.

2. MODEL DESCRIPTION

In this study, version 3.6.1 of WRF-ARW is used. WRF is well-documented, and is widely used throughout the community, making it a good model for performing meteorological experiments. In this experiment two way WRF-ARW nesting is used for five set of experiment covering entire life-span of VSCS Hudhud (7^{th} – 14^{th} October 2014). The horizontal resolution of the parent domain is set at 27 km and for nested domain 9 km is set with 28 vertical levels. The model is integrated with 90 seconds time steps for the 72 hours simulation. Microphysics used is mp_physics = 3; WRF single moment 3-class scheme with ice and snow process suitable for mesoscale grid size. The cumulus parameterization (cu_physics) was taken as 2; Betts-Miller-Janjic scheme. Rest of the other schemes were taken as by default. GFS gridded data is taken for WRF initialization i.e. 00 UTC of 7 October 2014, 00 UTC of 8 October 2014, 00 UTC of 9 October 2014, 00 UTC of 10 October 2014 and 00 UTC of 11 October 2014.

3. SYSTEM DESCRIPTION

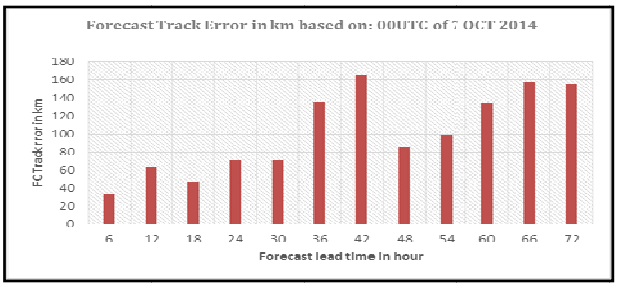
A low pressure system that formed over North Andaman Sea on 6th October 2014 intensified into depression in the morning of 7th October. It moved west-northwestwards where it intensified into a Cyclonic Storm (CS) in the morning of 8th October and crossed Andaman Islands close to Long Island between 0830 and 0930 hours IST of 8th October Further it emerged into Southeast Bay of Bengal and continued to move west-northwestwards. Intensification into a Severe Cyclonic Storm (SCS) happened in the morning of 9th October and further into a Very Severe Cyclonic Storm (VSCS) in the afternoon of 10th October. Moving northwestwards it reached to its maximum intensity in the early morning of 12th with a maximum sustained wind speed (MSW) of 180 kmph over the West Central Bay of Bengal off Andhra Pradesh coast. It crossed north Andhra Pradesh coast over Visakhapatnam (VSK) between 1200 and 1300 hours IST of 12th October with the same wind speed. After landfall, it continued to move northwestwards for some time and weakened gradually into SCS in the evening and further into a CS in the same midnight. It then, weakened further into a Deep Depression in the early morning of 13th and weakened into a depression in the evening of 13th. Thereafter, it moved nearly northward and weakened into a well-marked low pressure area over East Uttar Pradesh and neighborhood in the evening of 14th October 2014 [5].

4. RESULTS AND DISCUSSION

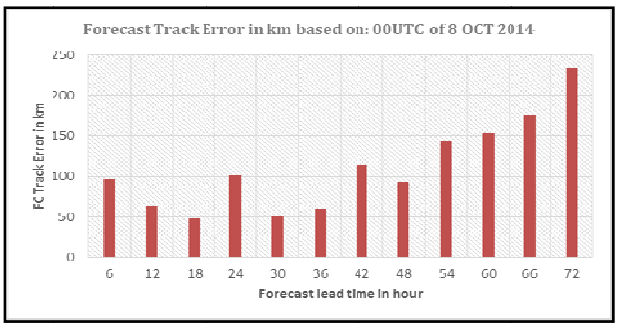
The prime impact of mesoscale WRF simulation of VSCS Hudhud is mainly based on track and intensity prediction of the storm inculcated during lifespan of the cyclone. The model simulated tracks are compared with India Meteorological Department (IMD) best- fit track dataset. The vector displacement error in model simulated track is calculated and discussed. The model simulated intensity in terms of MSLP and MSW is also compared with observed best fit values.

4.1 Track Forecast

The post event simulation corresponding track errors of VSCS 'Hudhud' using WRF model in two way nested at 27 km – 9km resolution starting from initial conditions 7 October 2014 at 00 UTC is shown in Fig. 1. The model 12 hourly direct positional errors are calculated as the geographical distance between the observed and forecast point.



(a)



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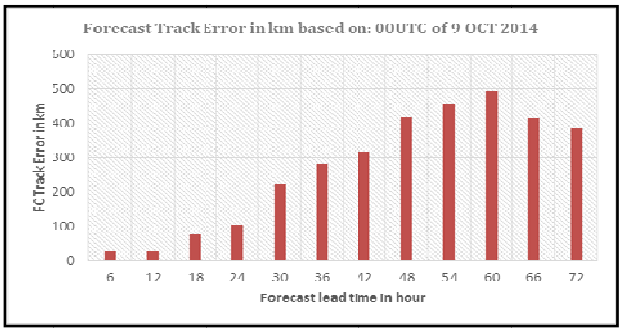

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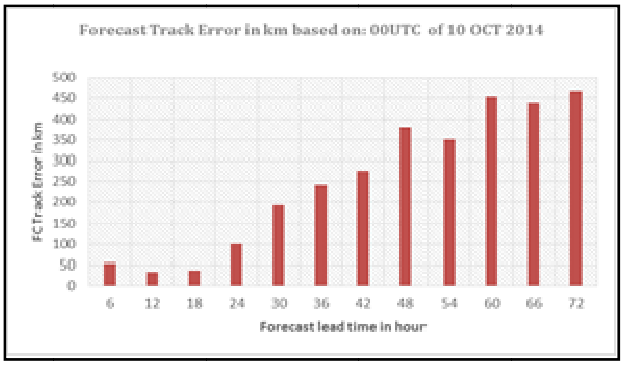


(d)

Fig. 1: Track Error based on initial condition of (a) 00 UTC of 07 October 2014 (b) 00 UTC of 08 October 2014 (c) 00 UTC of 09 October 2014 (d) 00 UTC of 10 October 2014

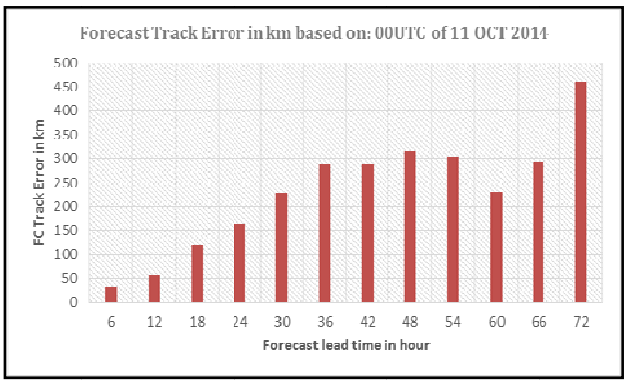
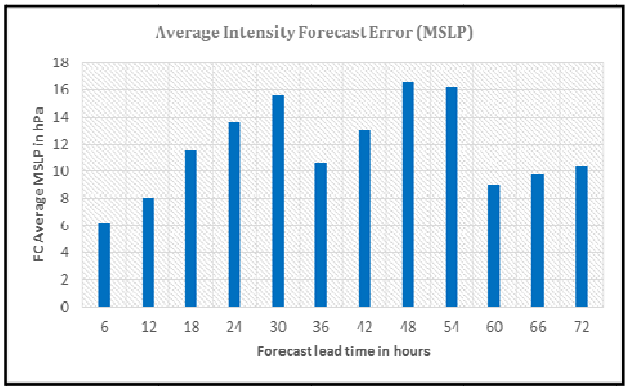


Fig. 2: Track Error in km based on initial condition of 00 UTC of 11 October 2014

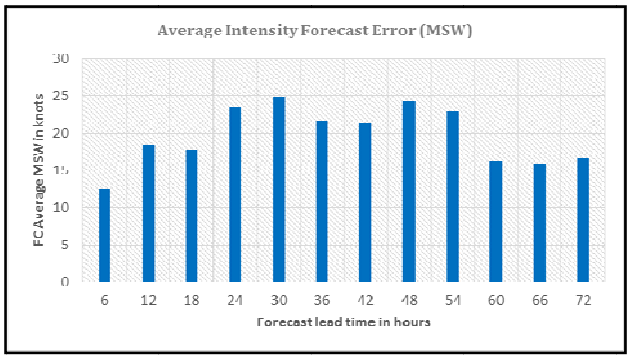
The initial 6 hourly forecast errors found from WRF model runs is shown in Fig. 1. Track error for 48th hour for all initial conditions is 87 km from 7 Oct 2014 at 00 UTC, 92 km from 8 Oct 2014 at 00 UTC, 417 km for 9 Oct 2014 at 00 UTC, 380 km for 10 Oct 2014 at 00 UTC and 317 km for 11 Oct 2014 at 00 UTC.

4.2 Intensity Forecast

Time evolution of average intensity error (simulated and observed) in terms of MSLP and MSW is shown in Fig. 3. The average intensity error is obtained by comparing the forecast with the observed then mean is plotted against 6 hourly forecast lead time.



(a)



(b)

Fig. 3: Average intensity forecast error (a) based on Minimum Sea Level Pressure (MSLP) (b) based on Maximum Sustained Wind (MSW)

5. CONCLUSION

In the study, a double nested WRF- ARW model is used to investigate the impact of various initial condition. The paper assesses the skill of WRF model for the prediction of track and intensity of VSCS Hudhud formed over Bay of Bengal. Results thus obtained reflects a relative high degree of error in forecast obtained by initial condition of 00 UTC of 9 October 2014. Average track error was found maximum for 72nd hour on time series having approximate value of 340 km.

In terms of prediction of intensity, WRF model was quite skillful as apex value of average intensity error was less than 25 knots and 17 hPa (both 48th hour forecast lead time) for Maximum Sustained Wind (MSW) and Minimum Sea Level Pressure (MSLP) respectively.

6. ACKNOWLEDGEMENT

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