



Impact of Physics Parameterization Schemes in the Simulation of tropical cyclone Phailin using the Advanced Mesoscale Weather Research and Forecasting Model

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Abstract: The Severe Cyclonic Storm phailin developed from a low pressure system that formed under the influence of an upper-air cyclonic circulation in the Andaman Sea and intensified into a Severe Cyclonic Storm and crossed Odisha coast near Gopalpur on 12 October, 2013. The model domain consists of one coarse and two nested domains. The resolution of the coarse domain is 45 km while the two nested domains have resolutions of 15 km and 5 km, respectively. The model simulated for 72 hrs starting from 0012UTC, 10 October, 2013 to 0012UTC, 13 October, 2013. The track and intensity of simulated cyclone are compared with best track estimates provided by the Indian Meteorological Department (IMD) data. Simulations are performed using four convective cumulus parameterization schemes, namely, KF (Kain-Fritsch), BMJ (Betts-Miller-Janjic), GD (Grell-Devenyi), and GRE (Grell-3D ensemble scheme) and in combination with different microphysics parameterization schemes, namely, Kessler Scheme, Lin et al. Scheme, WSM-3 scheme, WSM-5 scheme and Thompson Schemes. The main purpose of the present study is to find out the influence of the microphysics and the cumulus parameterization schemes on the track simulation of tropical cyclones phailin over Bay of Bengal. The planetary boundary layer (PBL) scheme is kept fixed to Yonsei University Scheme (YSU) throughout the simulation. The Betts-Miller-Janjic (BMJ) cumulus physics scheme in combination with Kain-Fritsch (new Eta) micro physics scheme gives the best track which closely matches with the IMD track.

Keywords: Tropical Cyclone, microphysics, parameterization, cyclone track, intensity

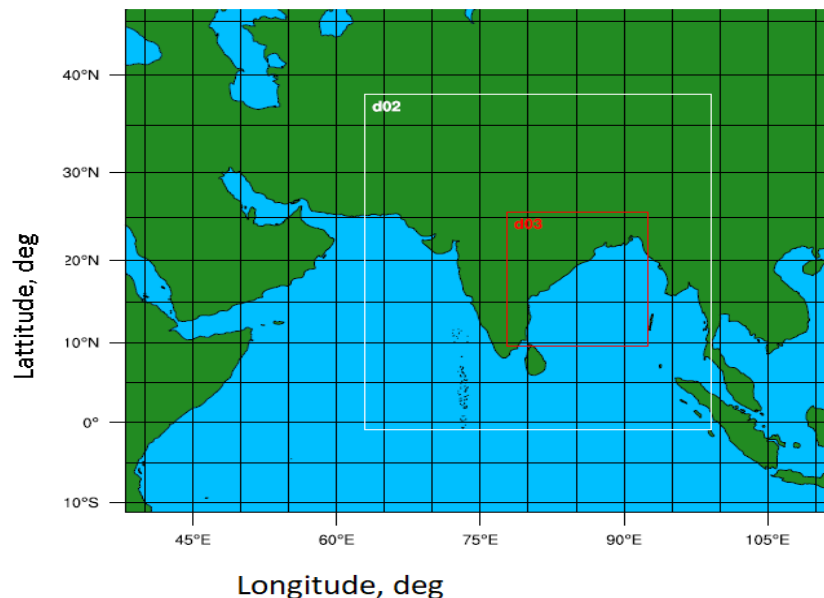
I. Introduction

The numerical weather prediction (NWP) and dynamical statistical models provided good guidance with respect to tropical cyclone genesis, track and intensity. The India Meteorological Department (IMD) and the Joint Typhoon Warning Centre (JTWC), predicted the cyclone genesis, cyclone intensity, track, location and time of landfall in advance. It is considered to be very important to examine the synoptic features of cyclone with different microphysics schemes using Advanced Research Weather Research and Forecasting (ARW-WRF, hereafter WRF) mesoscale model developed at National Center for Atmospheric Research (NCAR). WRF provides better forecast skill and superior performance in generating fine-scale atmospheric structures (Otkin et al. 2005; Pattanayak and Mohanty 2008).

II. Data and Methodology

The Numerical Weather Prediction (NWP) model used in cyclone simulation is the Advanced Research WRF (ARW) v 3.6.1 mesoscale model developed by NCAR. NWP is a method of weather forecasting that uses governing equations, different numerical methods, parameterization schemes, different domains and Initial and boundary conditions. The WRF model is acknowledged as one of the best performing models for cyclone prediction [6][8][9] & [11]. The MODIS based terrain topographical data have been used for domain1, domain2 and domain3 in the WRF Preprocessing system (WPS). The Initial and boundary conditions are obtained from the UCAR & NCAR Research Data Archive <http://rda.ucar.edu/datasets/ds083.2/index.html#sfol-wl-/data/ds083.2?g=2>. These NCEP FNL (Final) Operational Global Analysis data are on 1-degree by 1-degree grids prepared operationally every six hours. For all the three TC simulations the model output is generated for every six hours were taken into consideration for track position.

Figure. 1 The model domains used for the prediction of phailin cyclone with horizontal resolution of 45 km, 15km (d02) and 5 km (d03)



The WPS domain configuration shown in the Fig.1 is generated using NCL (NCAR Command Language). The WRF Model dynamics and domain details are listed in Table.1 and the micro physics and cumulus physics parameterization schemes used in the present simulation to investigate the track of the tropical cyclones were listed in Table-2.

Tabel I WRF Model dynamics and domain details

Model Dynamics	
Equation	Non-hydrostatic
Time integration scheme	Runge-Kutta scheme (Third order)
Horizontal grid type	Arakawa-C grid
Domain Details	
Map projection	Mercator projection
Central point of the domain	75°E, 20°N
No. of domains	3
No. of vertical layers	27
Horizontal grid distance	45 km , 15 km & 5 km for domain 1, 2 & 3 respectively
Time step	180 sec, 30 sec & 10 sec for domain 1, 2 & 3 respectively
No. of grid points	173 (EW), 148 (SN) in domain-1
	253 (EW), 295 (SN) in domain-2
	310 (EW), 355 (SN) in domain-3
Data	NCEP Final Analysis (FNL) data

Tabel II List of MP and CP used in WRF simulations

Model Microphysics schemes		
1	Kessler scheme	KS
2	Lin <i>et al.</i> scheme	LIN
3	WRF Single Moment 3-class simple ice scheme	WSM3
4	WRF Single Moment 5-class scheme	WSM5
5	Thompson graupel scheme 2 moment	THOM2
Model Cumulus physics schemes		
1	Kain-Fritsch(new Eta) scheme	KF
2	Betts-Miller-Janjic scheme	BMJ
3	Grell-Devenyi ensemble scheme	GD
4	Grell-3D ensemble scheme	GRE
Planetary Boundary Layer (PBL)scheme		
1	Yonsei University Scheme	YSU

III. Results and Discussions

The Simulations for the Phailin cyclone were carried out in order to determine the best track of phailin cyclone. Results from the inner most domains have been used for the analysis. The Yonsei-University (YSU) planetary boundary layer (PBL) scheme is kept fixed for all the simulations. The simulated track of Phailin cyclone with different microphysics and cumulus physics parameterization schemes plotted. Grid Analysis and Display System (GrADS) used for the visualization of the wrf output. The wrf model output and the IMD observed track were compared concurrently. Track error is calculated using Haver-Sine formula. The track error for Phailin TC for different CP and MP are also plotted.

$$a = \sin^2\left(\frac{\Delta\phi}{2}\right) + \cos\phi * \cos\phi * \sin^2\left(\frac{\Delta\lambda}{2}\right) \quad (1)$$

$$c = 2 * \tan^{-1}\left(\frac{\sqrt{a}}{\sqrt{(1-a)}}\right) \quad (2)$$

$$D = R * c \quad (3)$$

$$\Delta\phi = \phi_{JTC} - \phi_{wrf} \quad (4)$$

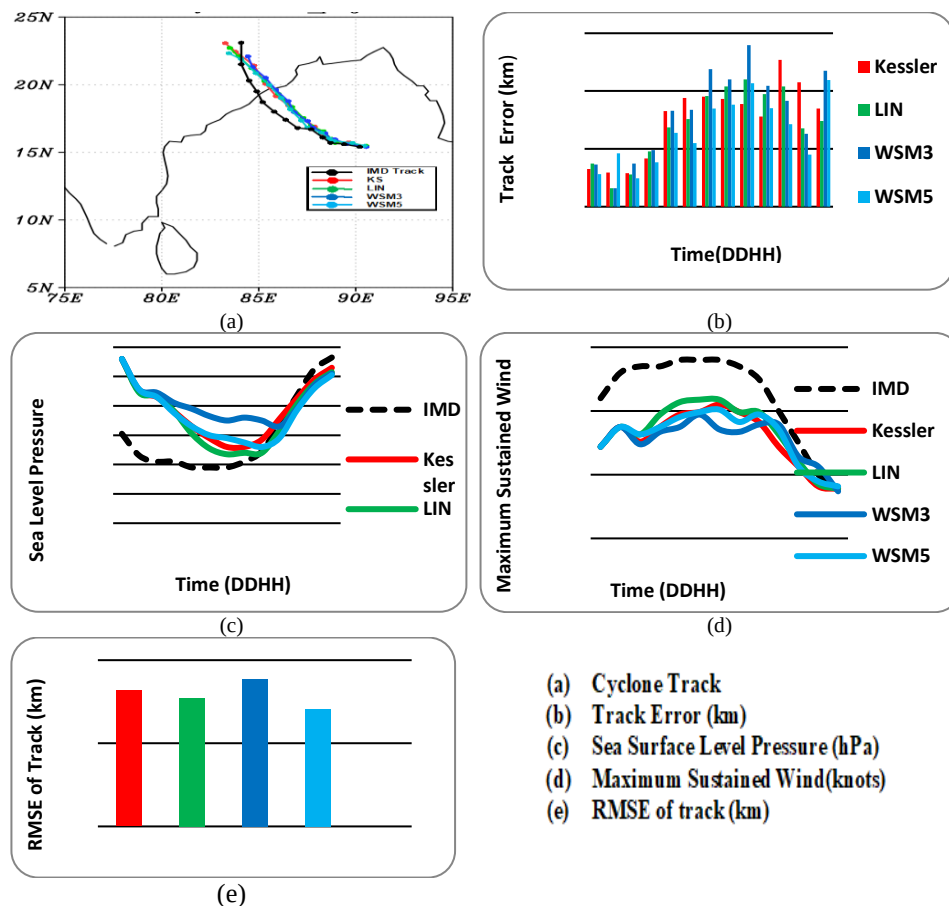
$$\Delta\lambda = \lambda_{JTC} - \lambda_{wrf} \quad (5)$$

Where D is Track error, ϕ is latitude, λ is longitude, R is earth's radius (mean radius = 6,371km) and the angles are in radians.

IV. Phailin Cyclone Simulations

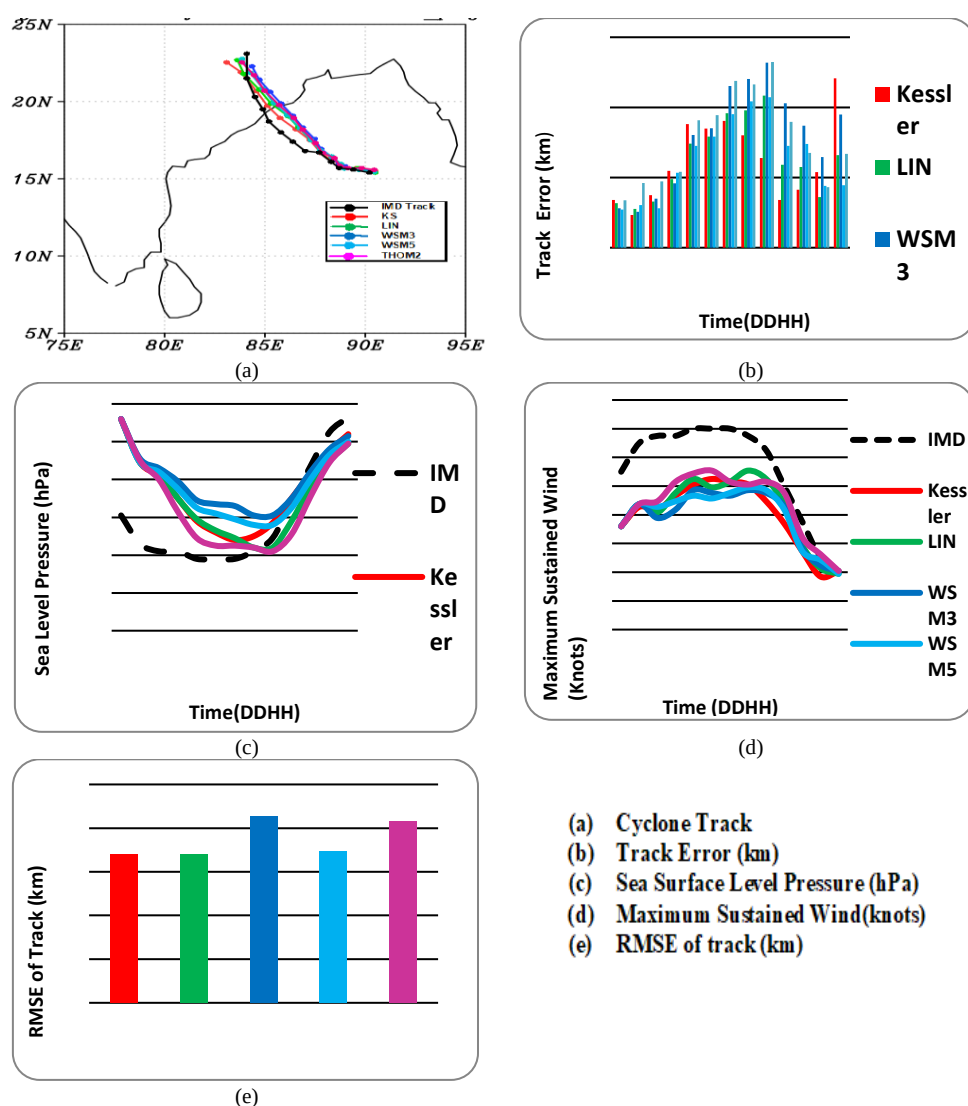
Phailin TC Simulations were initiated on 10th October 2013, 0012 UTC with lateral boundary condition and were carried up to 13 October 2013, 1200 UTC. The model was run up to 72 hr. Phailin cyclone simulations for no-cu physics (cu=0) scheme with different micro physics schemes plotted in Figure.2. The Yonsei-University (YSU) planetary boundary layer (PBL) scheme is kept fixed for all the simulations [2][3][5].

Figure2. Phailin cyclone 72 hr simulations for no-cu physics (cu=0) scheme with different micro physics schemes and 2013/10/10: 12 hr UST initial conditions



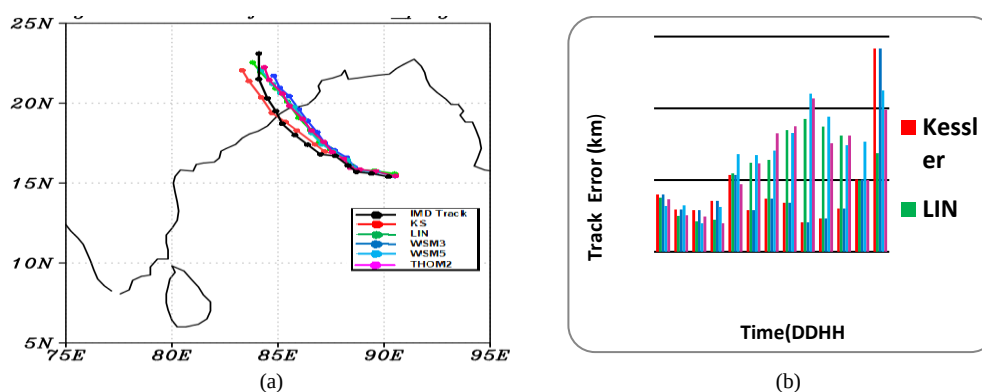
Phailin cyclone simulations for KF cu physics scheme with different micro physics schemes plotted in Figure.3.

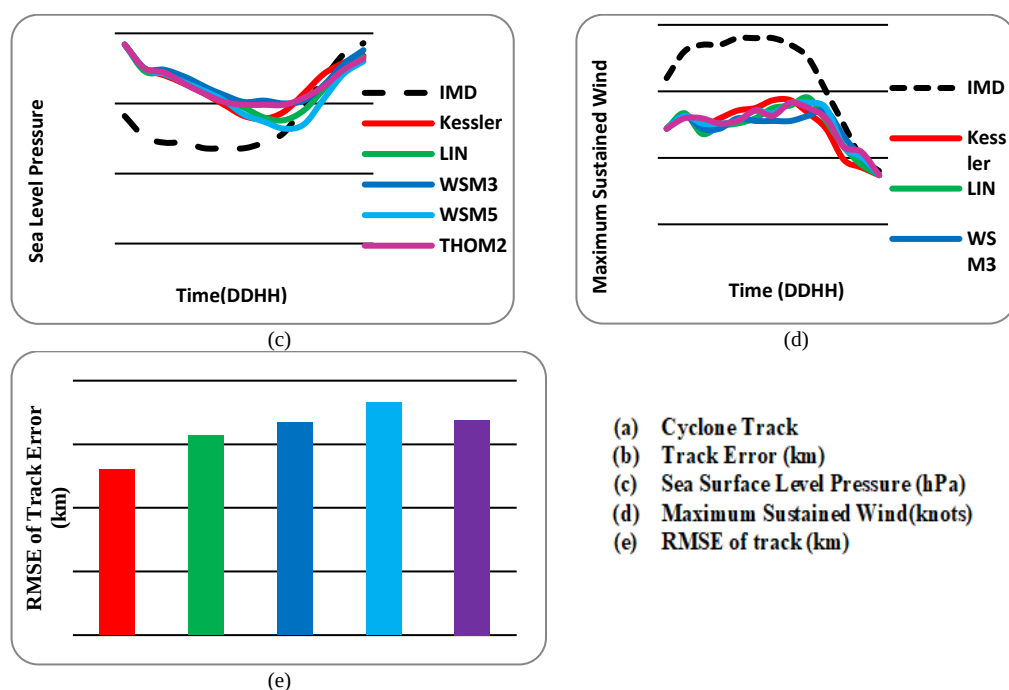
Figure 3. Phailin cyclone 72 hr simulations for KF cu physics scheme with different micro physics schemes and 2013/10/10: 12 hr UST initial conditions



Phailin cyclone simulations for BMJ cu physics scheme with different micro physics schemes plotted in Figure.4.

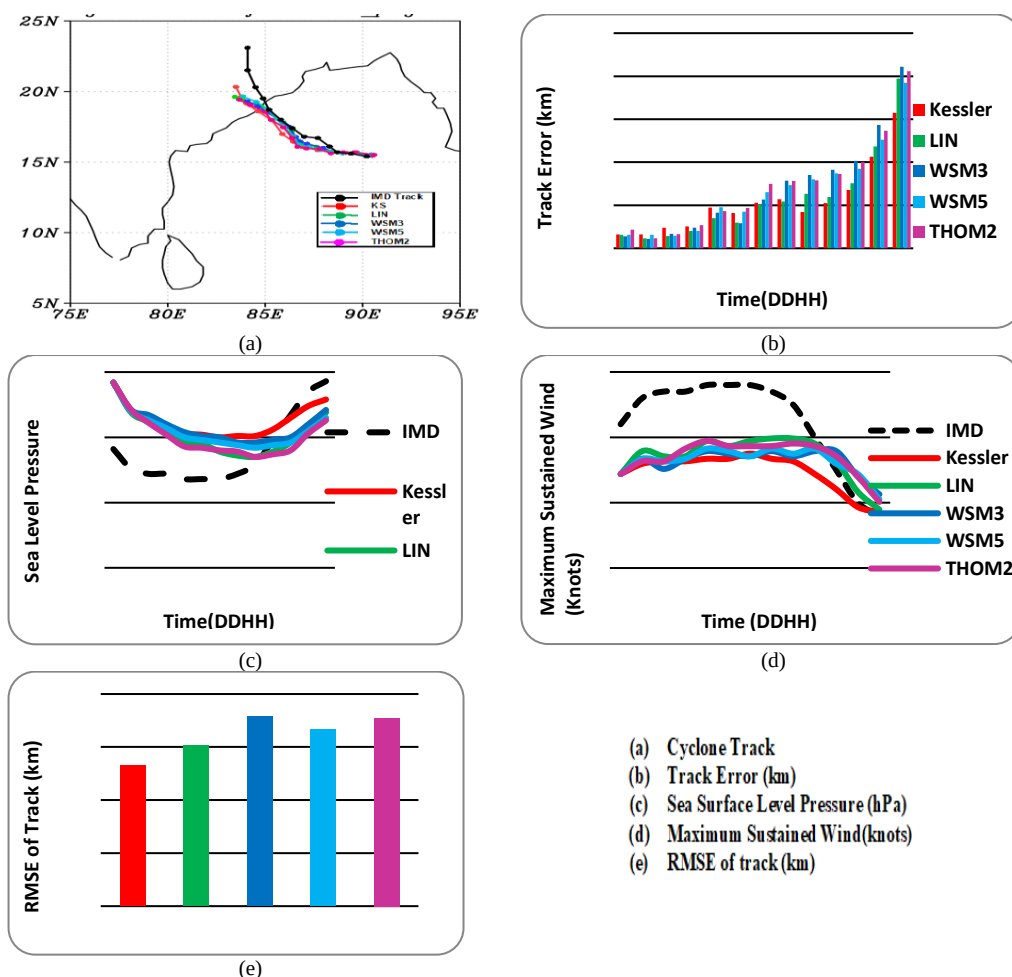
Figure 4. Phailin cyclone 72 hr simulations for BMJ cu physics scheme with different micro physics schemes and 2013/10/10: 12 hr UST initial conditions



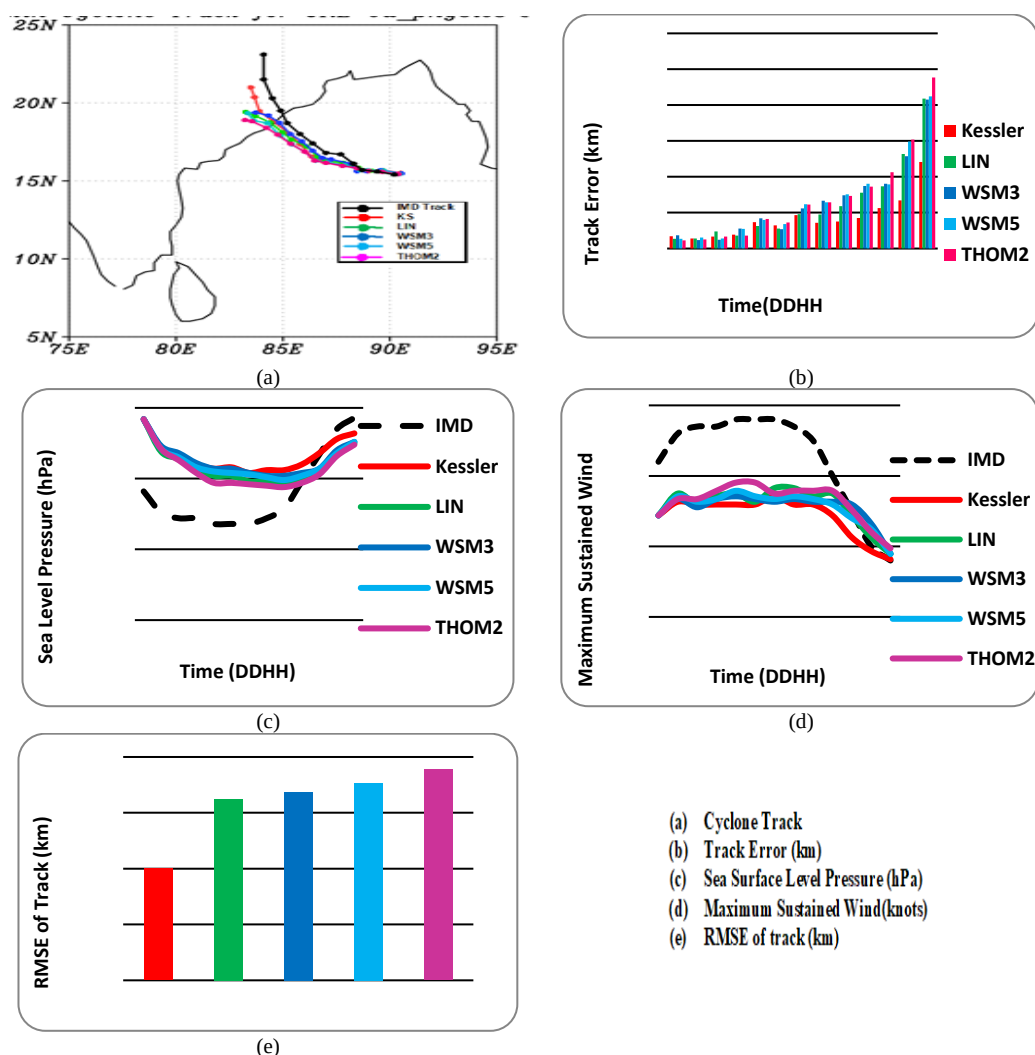


Phailin cyclone simulations for GD cu physics scheme with different micro physics schemes plotted in Figure.5.

Figure 5. Phailin cyclone 72 hr simulations for GD cu physics scheme with different micro physics schemes and 2013/10/10: 12 hr UST initial conditions



Phailin cyclone simulations for GRE cu physics scheme with different micro physics schemes plotted in Figure.6.
Figure 6. Phailin cyclone 72 hr simulations for GRE cu physics scheme with different micro physics schemes and 2013/10/10: 12 hr UST initial conditions



All the schemes well simulated the initial position of the storm and the RMSE of track error is minimum 52.102(km) for BMJ cu physics and KS micro physics schemes and RMSE of track error is maximum 188.8291(km) for GRE cu physics and THOM2 micro physics schemes.

V. Conclusions

In this paper, Phailin cyclone developed over the coast of Bay of Bengal simulated using WRF numerical Weather Prediction model and presented the best possible combination of microphysics and cumulus physics. All the schemes well simulated the initial position of the storm and all the schemes under estimated the minimum sea level pressure (slp) and Maximum sustained wind speed (MSW). For Phailin TC simulations cumulus physics scheme Betts-Miller-Janjic (BMJ) in combination Kessler microphysics parameterization schemes gives out the minimum RMSE of about 52km and Thoms2 microphysics scheme in combination with GRE cumulus scheme gives out the maximum RMSE of about 189 km. The microphysics Betts-Miller-Janjic scheme (BMJ) in combination with Kain-Fritsch (new Eta) scheme gives the best track which closely matches with the IMD track. The track error for this combination is minimum of all the other combinations.

VI. References

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