IMPACT OF SATELLITE OBSERVED SST ON INTENSITY AND TRACK SIMULATION OF TROPICAL CYCLONE OVER VIET NAM EAST SEA: A CASE STUDY OF TYPHOON NALGAE (2011)

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Abstract: *Sea surface temperature (SST) is one of the most important thermal factors affecting typhoon. This paper was carried out to examine the impact of satellite observed SST on intensity and track simulation of tropical cyclone over Viet Nam East sea by using the Weather Research and Forecast (WRF) model. We have selected typhoon Nalgae (2011) for studying the SST impact. Three different sets of SSTs were used in this study: (1) SST from GFS analysis is provided for the initial condition and kept unchanged during the 72 hr simulation; (2) SST from Remote Sensing Systems (RESS) is used for the initial condition and kept unchanged during the 72 hr simulation; (3) SST from RESS is updated every 24 h for the initial and boundary conditions. The simulated results show that the using SST from satellite data for both only initial condition case and initial and boundary conditions case significantly improve the simulated intensity of typhoon due to improved simulation of latent heat and heat fluxes.*

Keywords: *Sea surface temperature, SST, typhoon, tropical cyclone, the Viet Nam East Sea*

1. Introduction

It has been recognized that the Sea Surface Temperature (SST) is one of the most important parameters which plays a significant role in the formation and intensification of tropical cyclone [12, 13]. Gray (1968, 1978) noted that the 26°C isotherm deepening to a depth to 60m from the surface is required for the formation of tropical cyclone. SST determines the amount of sensible and latent heat available to the tropical cyclone from the ocean, hence, it is indicative of the intensity of tropical cyclone [12].

Large number of studies [1,5-7,14, etc] found that the intensity of tropical cyclone increases rapidly when it passes through the warm water area due to increasing the sensible and latent heat flux. Shankar et al. (2007) showed that not only the magnitude of SST but also its gradient affects surface wind and convective activity, which affects the intensity of the tropical cyclone. Studies were also performed to investigate the influence of SST on the movement of tropical cyclone. Wu (2005) studied the effect of symmetric and asymmetric SST distributions on the centre of tropical cyclone on the movement of tropical cyclone. Accordingly, the asymmetric SST distribution over large areas affected the movement of tropical cyclone due to various surface friction and surface heat flux [2]. Recently, results from numerical weather prediction (NWP) model shown that the intensity and track of simulated tropical cyclones vary with the various SST due to the changed resolution of SST fields [11,17,4].

In operational NWP modelling applications, SST field is generally obtained from GFS analysis data of National Centers for Environmental Prediction (NCEP) with

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horizontal resolution of 0.5° x 0.5°. There is a need for alternative SST datasets, which can give more accurate representation of ocean boundary condition in the NWP model.

Nowadays, SST products are available from microwave (MW) and infrared (IR) sensors. One of these is the SST product from Remote Sensing Systems (RESS), Northern California, American. It is created from Tropical Rainfall Measuring Mission Microwave Imager (TMI), Advanced Microwave Scanning Radiometer (AMSR-E), Advanced Microwave Scanning Radiometer 2 (AMSR2), WindSat and the Moderate Resolution Imaging Spectroradiometer (MODIS) data. This SST data is the daily optimally interpolated product at 9 km x 9 km (MW_IR OI SST). Thus, it can be seen that MW_IR OI SST data is higher horizontal resolution than GFS SST data.

The objective of the present study is to investigate the impact of MW_IR OI SST on intensity and track simulation of tropical cyclones by using Weather Research and Forecast (WRF) model.

2. Data, experimental design and methodology

2.1. Data

The MW_IR OI SST is available at website: http://www. remss.com/.

The GFS analysis data of National Centres for Environmental Prediction available at 0.5° x 0.5° horizontal resolution and 6 hourly interval has been interpolated to the model grid for providing the initial and boundary conditions. This data is provided at website: ftp://nomads.ncdc.noaa.gov/GFS/analysis_only/.

In addition, tropical cyclone best track data (including tropical cyclone centre locations and intensities) from IBTrACS (International Best Track Archive for Climate Stewardship) data of National Oceanic and Atmospheric Administration (NOAA) and National Climatic Data Center (NCDC) has been used to verify the model simulated track and intensity from two different experiments. This data is available in the website: https://www.ncdc. noaa.gov/ibtracs/.

2.2. Experimental design

The mesoscale model used in this study is the WRF model version 3.6 with two nested domains. The first domain ranges from 0°N -31°N and 92°E-130°E with 135×158 grid points, horizontal resolution of 27 km. The second domain ranges from 5°N-25°N and 100°E-120°E with 259 × 250 grid points and horizontal resolution of 9 km (Fig. 1). The physics options of WRF model used the same for both domains, include the Kain–Fritch 2 cumulus parameterization scheme [10], Thompson microphysics scheme [16], Yonsei State University (YSU) [7] Planetary boundary layer scheme. Long-wave radiation and short-wave radiation are parameterized using RRTMG [8] scheme. Land surface are parameterized using the multi-layer Noah land surface model [3], and for Surface Layer, Revised MM5 Monin-Obukhov scheme [9] is used.

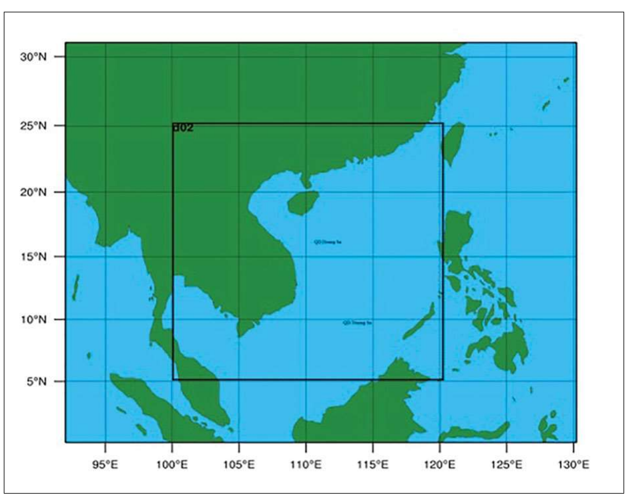

Figure. 1 The WRF model domains for cyclone simulation

Three experiments are carried out: (1) GFS SST is provided for the initial condition and kept unchanged during the 72 hr simulation (GFS); (2) MW_IR OI SST is used for the initial condition and kept unchanged during the 72 hr simulation (SSTVT); (3) MW_IR OI SST is updated every 24 h for the initial and boundary conditions (SSTUP).

2.2. General description of Typhoon Nalgae

Nalgae formed as a tropical depression over the Philippine Sea on September 27, 2011 and moved generally westwards. Within three days, it had strengthened into a severe typhoon. On October 1, Nalgae peaked intensity with an estimated maximum sustained wind of 175km/h, about 300 km northeast of Manila. Then it crossed Luzon and entered the Viet Nam East sea in the late afternoon. It moved west to west-north-westwards and weakened into a severe tropical storm on October 2. It weakened further into a tropical storm on 4 October and crossed the southern part of Hainan Island that afternoon and weakening into a tropical depression at night. Nalgae moved south-westwards across the southern part of the Gulf of Tonkin on October 5 and dissipated over the seas near Nghe An (Fig. 2). Due to the effect of Nalgae typhoon combined with cold front, the North East, North Central and Mid-Central regions had rainfall and heavy rainfall. The total rainfall of two days from October 4 to October 6 was commonly from 50 to 70mm, especially in the Nghe An - Ha Tinh areas, rainfall measured over 100mm.

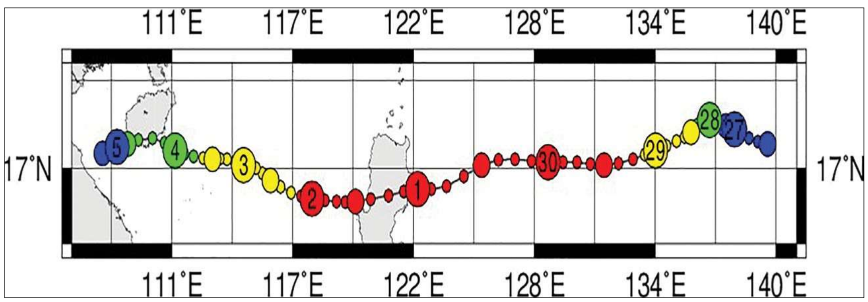

Figure. 2 Best track of Nalgae typhoon

(Source: http://agora.ex.nii.ac.jp/digital-typhoon/)

3. Results and discussion

The simulation of Nalgae typhoon for GFS, SSTVT and SSTUP cases were initialized at 00Z on October 2, 2011.

Figure 3 and 4 show the comparison of the GFS SST and the MW_IR OI SST valid for October 2, 2011. Accordingly, MW_IR OI SST shows colder than GFS SST of 1° to 2°K in the North-eastern part of Viet Nam East sea due to the effect of cold front. On October 3 and 4, MW_IR OI SST shows the effect of cold front on SST field is extended to the southern (Figure 5 and 6). On October 5, the effect of cold front on MW_IR OI SST tends to decrease (Figure 7).

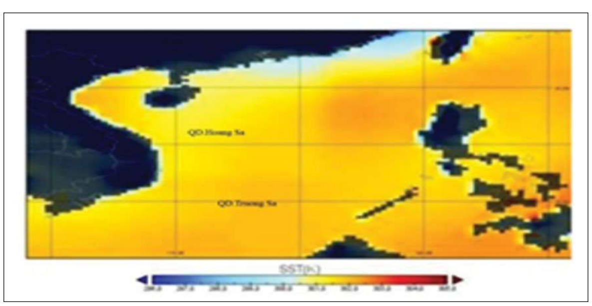

Figure. 3 SST from GFS valid for October 2, 2011

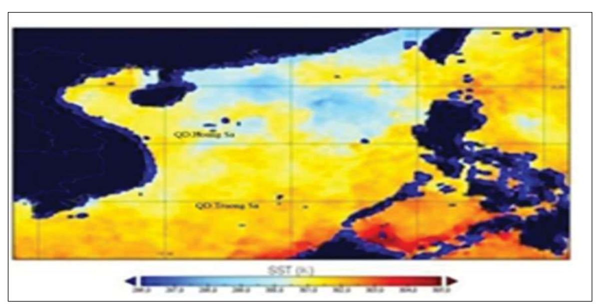

Figure. 4 SST from RESS valid for October 2, 2011

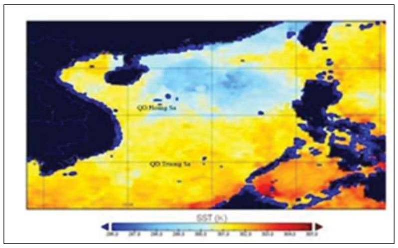

Figure 5. SST from RESS valid for October 3, 2011

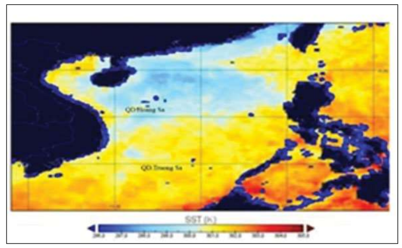

Figure 6. SST from RESS valid for October 4, 2011

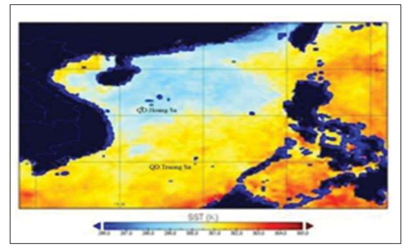

Figure 7. SST from RESS valid for October 5, 2011

Figure 8 shows that there is significant difference in the simulated latent heat fluxes between SSTVT and GFS cases. The 24 hr simulated latent heat flux in SSTVT relatively decreases in both area and magnitude when compared to GFS case. In the centre of Nalgae, the latent heat flux in SSTVT is smaller upto 400 Wm-2 than in GFS (Figure 8 a and d). For 48 and 72 hr, the difference in latent heat fluxes between GFS and SSTVT is relatively clear, especially in the southwestern part of the centre of Nalgae typhoon (Figure 8 b, c and e, f). The simulated latent heat fluxes is not much difference between SSTVT and SSTUP cases for 24 hr, 48 hr and 72 hr simulations (Figure 8 d, e, f and g, h, i).

During the 72 hr simulation, the simulated sensible heat fluxes in SSTVT is also relatively smaller when compared to GFS case and it is not much difference when compared to SSTUP case (Figure 9).

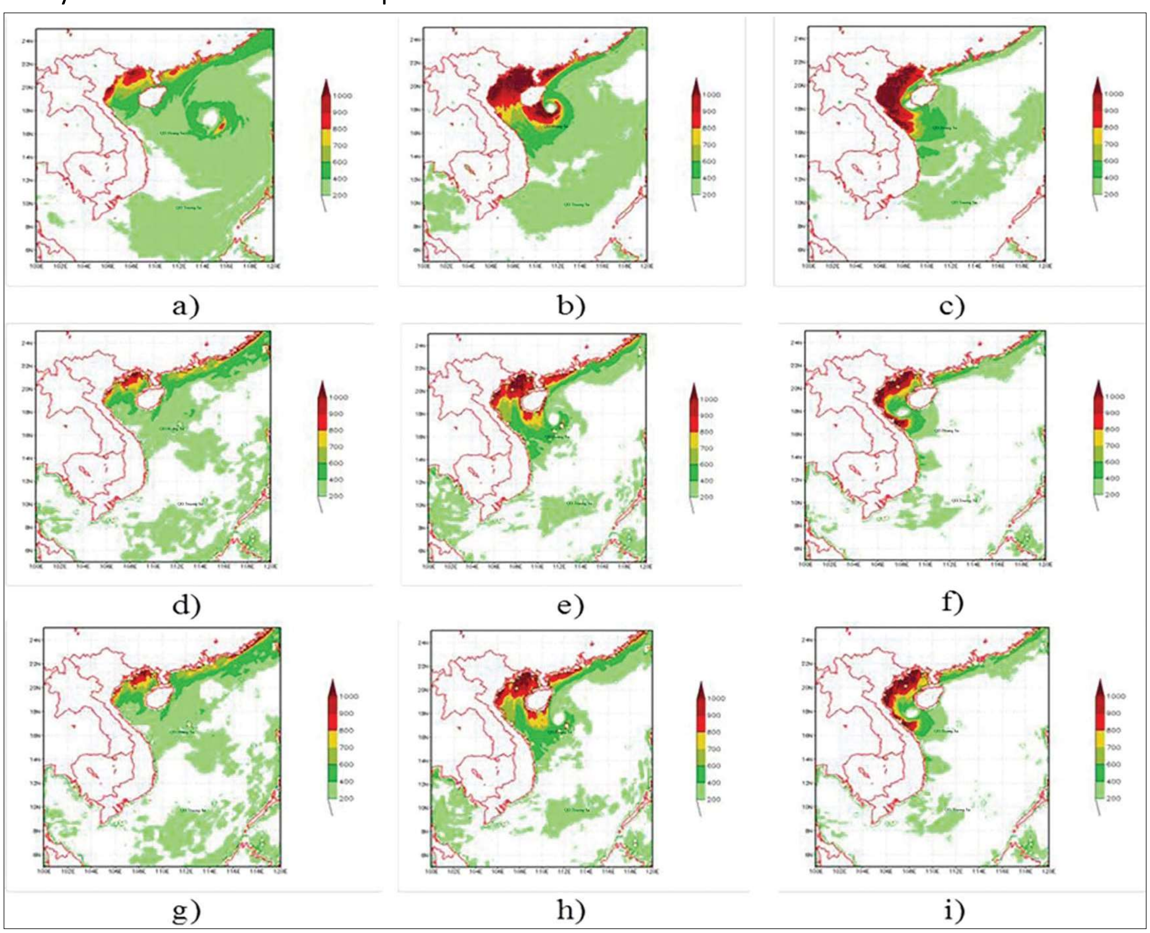

Figure 8. The simulated latent heat flux (Wm-2) after 24 hr (a, d, g), 48 hr (b, e, h) and 72 hr (c, f, i) from 00 Z on July 30, 2013 for: GFS (a,b,c) case; SSTVT (d, e, f) and SSTUP (g, h, i) case

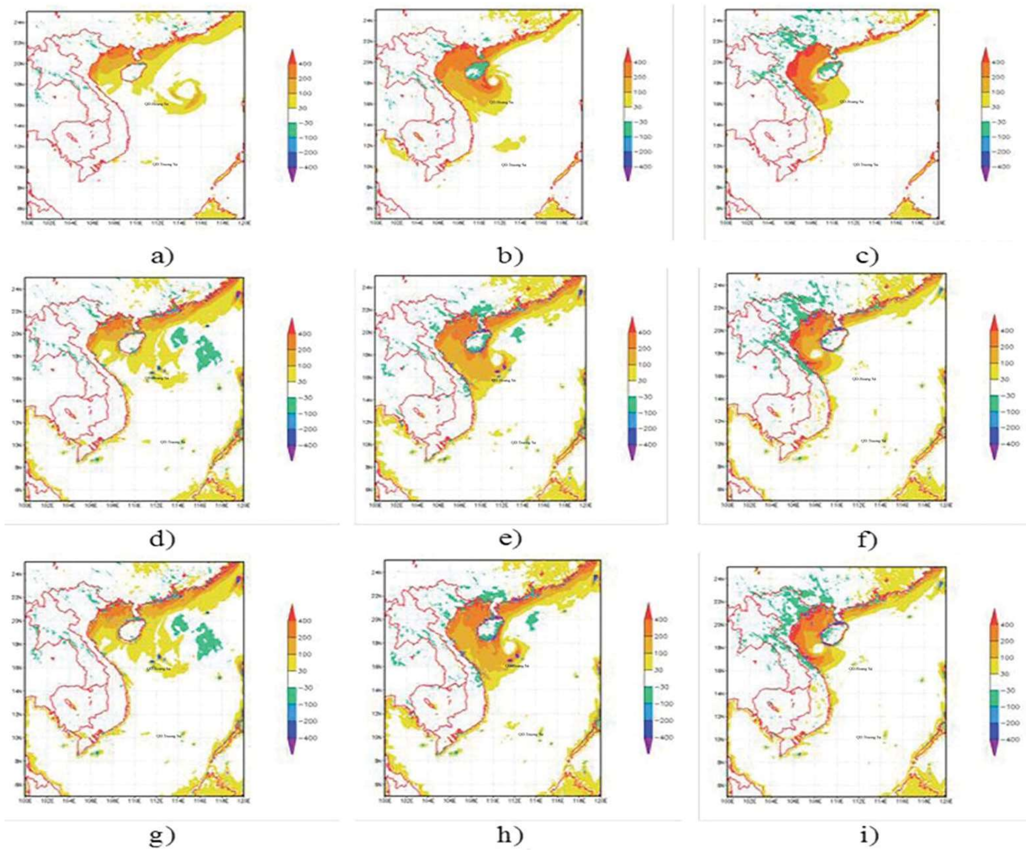

Figure 9. The simulated sensible heat flux (Wm-2) after 24 hr (a, d), 48 hr (b, e) and 72 hr (c, f) from 00 Z on July 30, 2013 for: GFS (a,b,c); SSTVT (d, e, f) and SSTUP (g, h, i) cases

Figure 10 shows the simulated sea level pressure and the wind velocity at 10 m after 24 hr (a, d, g), 48 hr (b, e, h) and 72 hr (c, f, i) from 00 Z on October 2, 2011 for GFS (a, b, c); SSTVT (d, e, f) and SSTUP (g, h, i) cases. The simulated sea level pressures and the wind velocities at 10 m for GFS demonstrate the intensity of Nalgae typhoon is strengthened from 24 hr to 48 hr simulations and significantly decreases at 72 hr simulation (Figures 10 a, b, c). On the Figures 10 d, e, f and g, h, i show the intensity of Nalgae typhoon slight increases from 24 hr to 48 hr simulations and significantly decreases at 72 hr simulation. Figure 10 also shows the simulated sea level pressures increases and the wind velocities at 10 m relatively decreases in both area and magnitude in SSTVT than in GFS. Location of the simulated typhoon centre in SSTVT is slightly shifted toward southwestern when compared to GFS during 72 hr simulation. The updating of the MW_IR OI SST data makes the cooling of the SST field at active area of the typhoon which leads to decreasing the latent heat flux and the sensible heat flux, therefore, decreases in the intensity and changes in the location of the simulated Nalgae typhoon compared to GFS. Figures 10 also shows there are not much difference in area of the simulated sea level pressures and the wind velocities at 10m between SSTVT and SSTUP cases. However, magnitude of the simulated sea level pressures and the wind velocities at 10 m in SSTVT is slightly smaller than in SSTUP in the North enter of typhoon for 48 hr and 72 hr simulation.

Figure 11 shows the time series of intensity a) Pmin; b) Vmax for Nalgae typhoon simulated from 00 Z on October 2, 2011 by GFS, SSTVT and SSTUP cases and observed by IBTrACS. The Pmin and Vmax are overestimated the IBTrACS observation for three cases, especially after 30 hr simulation. However, SSTVT and SSTUP show significant improvement in Pmin and Vmax simulation when compared to GFS. The Vmax in SSVT is difference upto 3m/s when compared to SSTUP case. However, the Pmin is not much difference between the SSTVT and SSTUP.

Figure 12 shows the observed IBTrACS best track and simulated tracks for Nalgae typhoon from 00 Z on October 2, 2011 by SSTVT and SSTUP. Accordingly, the simulated track for GFS shifts south-eastward when compared to Best Track. However, the simulated tracks for SSTVT and SSTUP cases slightly shift south-westward when compared to Best Track. The distance error in GFS is significant smaller than the SSTVT and SSTUP cases (Figure 13).

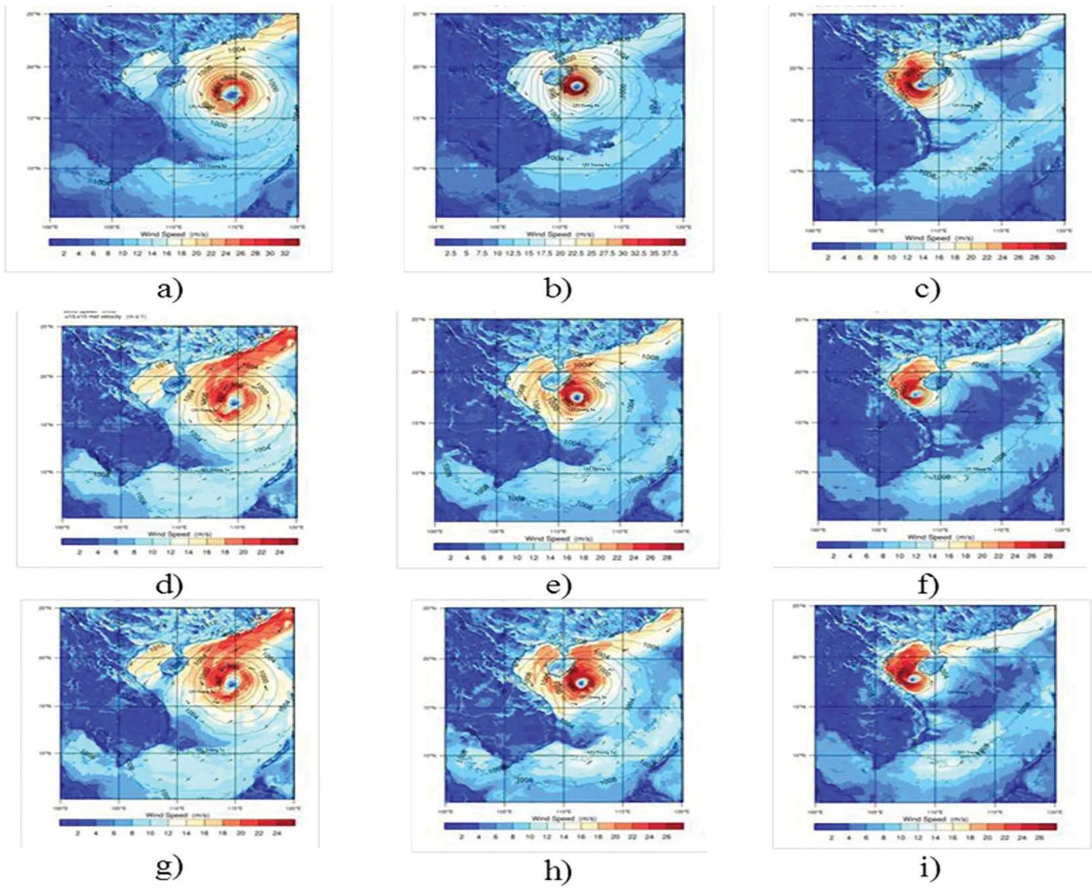

Figure 10. The simulated sea level pressure and the wind velocity at 10 m of Nalgae typhoon after 24 hr (a, d, g), 48 hr (b, e, h) and 72 hr (c, f, i) from 00 Z on October 2, 2011 for: GFS (a, b, c); SSTVT (d, e, f) and SSTUP (g, h, i) cases

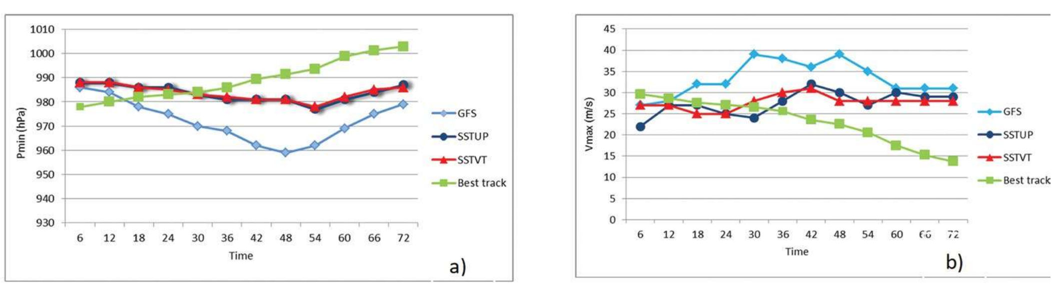

Figure 11. The time series of intensity: a) Pmin; b) Vmax for Nalgae typhoon simulated from 00 Z on October 2, 2011 by GFS, SSTVT and SSTUP cases and observed by IBTrACS (Best Track)

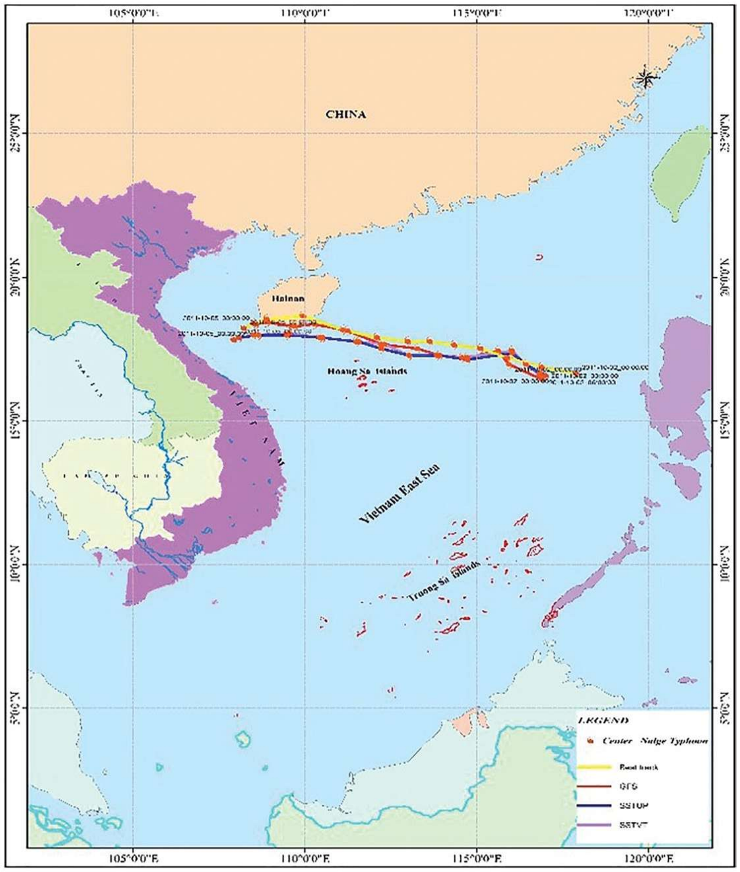

Figure 12. The simulated tracks for Nalgae typhoon from 00 Z on October 2, 2011 by GFS; SSTVT and SSTUP and the observed IBTrACS best track

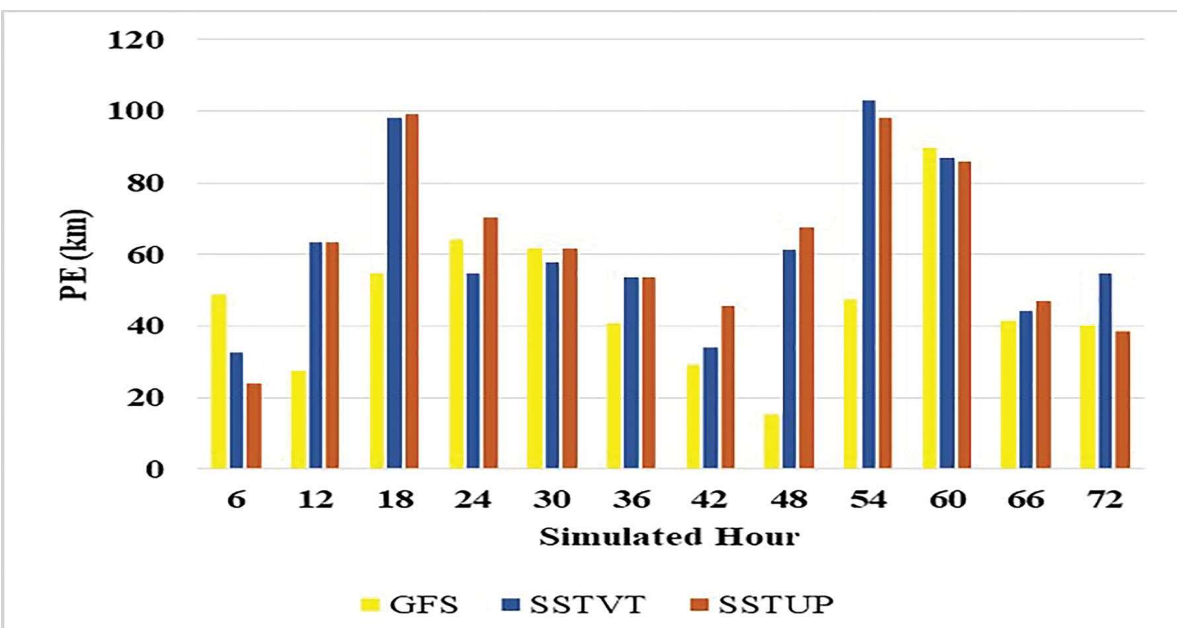

Figure 13. The distance errors (PE) for Nalgae typhoon simulated from October 2, 2011 by GFS; SSTVT and SSTUP cases

4. Conclusion

The present study investigated the effect of SST from satellite data with high resolution of space on intensity and track simulation of typhoon Nalgae (2011). The results demonstrate that the using of SST from satellite data with high horizontal resolution (9x9 km) for both only initial condition case and initial and boundary conditions case plays an important role to improve the 72 hr simulated intensity of typhoon due to improved simulation of latent heat and heat fluxes. The updating of SST for initial and boundary conditions case is not much difference when compared to only initial condition case. The results also show the using of SST from satellite data does not improve the simulated track of typhoon. The further research is required for more reasonable explanations.

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