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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Assimilation of Himawari-8 Imager Radiance Data with the WRF-3DVAR system for the prediction of Typhoon Soulder" *by* Dongmei Xu et al.

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Reply to reviewer 3

Overview: In this manuscript, the authors have tried to attempt to see the effect of data assimilation of AHI data for Typhoon Soudelor by using WRF-3DVAR. Perhaps, this data assimilation method has been widely used by many typhoon researchers, but this AHI data assimilation would be novel because Himawari-8 satellite provides more segmentalized bands compared to previous MTSAT series. I could see the effect of this AHI data assimilation, but the forecasting time is too short, which is close to nowcasting. Different initial locations may cause these track errors. Furthermore, the

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intensity forecasts from both experiments show the same tendency. It may indicate this AHI assimilation is not effective in improving inner-core structures yet. Actually, I could see longer period simulation results rather than 18-h simulations results to see definite improvement of AHI assimilation. Finally, as I suggest many specific comments and editorial comments, the authors seriously consider the English proofreading or carefully review this manuscript before publication. Therefore, since there are some corrections before publication, I would give a major revision opinion. Nevertheless, I think this paper approach is nice.

Specific comments Lines 119-123: The authors could make the section lists to show how this paper is comprised. ——— Reply: Thanks for your advice. A new paragraph is added as "Section 2 describes the observations and the data assimilation system. Introductions to the typhoon case and the experimental setup are provided in section 3. The detailed results in terms of the analyses and the forecasts are illustrated in section 4 before conclusions are summarized in section 5."

Lines 69-72 & 126-128: These sentences are repeated. ——— Reply: Agreed. Related sentences are deleted in section 1 and section 2.1. The sentence is also reorganized as "As the first new generational geostationary satellite, Himawari-8 plays a pioneering role for the geosynchronous imagers to be launched in US, China, Korea and Europe." from line 84 to 86. In the second part, we revised as "Himawari-8 satellite was launched by JMA to a geosynchronous orbit on 17 October 2014 and has begun its operational use since 7 July 2015 (Bessho et al., 2016)." from line 153 to 155.

Lines 147-151: I am not sure why the authors put the location of the focuses or purposes in this paragraph? I guess, if the authors put this to Introduction, it would be much clearer than now. ——— Reply: Thanks for the helpful advice. Following the reviewer's suggestion, these sentences are moved to the 6th paragraph in the introduction part (line 141 to 145).

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Lines 147-149: How can we understand that these three moisture channels are sensitive to those levels? Please provide some evidence. ——— Reply: Thanks. The evidence for the sensitive levels for three water vapor channels is provided as the weighing function in Fig. 1 in the revised manuscript (line 141 to 146). The sentence is revised as "Our study focuses mainly on assimilating the three water vapor channels (6.2, 6.9, and 7.3μm) since they are very sensitive to the humidity in the middle and upper troposphere and have a certain effect on the lower troposphere. Thus, a large amount of effective atmospheric information can be provided for AHI radiance data assimilation in the troposphere. The weighting functions for the three channels are provided in Fig. 1." in the manuscript.

Fig.1 Weighting function for Channel 8, 9, and 10.

Lines 190-200: About re-intensification of Soudelor, I guess, the authors reference JTWC best track data, because there is no such a pattern in JMA best track data. Please specify this information. ——— Reply: In this study, the best track data are provided by the China Meteorological Administration (Yu et al., 2007; Song et al., 2010). "Related information is added in section 3.1(line 215) and section 4.4 (line 407-408). Reference: Yu H, Hu C, Jiang L. 2007. Comparison of three tropical cyclone intensity datasets. Acta Meteorol. Sin. 21: 121–128. Song J-J, Wang Y, Wu L. 2010. Trend discrepancies among three best track data sets of western North Pacific tropical cyclones. J. Geophys. Res. 115: D12128, DOI: 10.1029/2009JD013058.

Line 200: what the Taiwan channel? Does that mean channel effect? I guess there are some papers discussing that. Please cite some references. ——— Reply: Thanks for the helpful advice. Taiwan channel means Taiwan Strait, which is a 180-kilometer (110 mi)-wide strait separating Taiwan and mainland China. To avoid misunderstanding, we replace Taiwan Channel with Taiwan Strait at line 227.

Lines 202-203: as mentioned in General comments, the authors should clarify the

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best track information. ——————————— Reply: Agreed. The best track data are provided by the China Meteorological Administration (Yu et al., 2007; Song et al., 2010). “Related information is added in section 3.1(line 215) and section 4.4 (line 407-408).

Section 3.1: Figure 2 needs to make the same period with Fig. 1, and the authors may highlight the specific period (color-shading) according to the purpose. ——————————— Reply: Agreed. Figure 2 is replotted from 0000 UTC 30 July 2015 to 0600 UTC 12 August 2015 and the specific period from 1800 UTC 1 August 2015 to 0000 UTC 3 August 2015.

Fig. 3 The time series of the minimum sea level pressure (solid line, unit: hPa) and the maximum surface wind (dash line, unit: m s-1) from 0000 UTC 30 July 2015 to 0600 UTC 12 August 2015.

Line 218: “We use Arakawa C grid in the horizon with a 5 km grid distance.” What is the Arakawa C-grid? I know this grid-structure, but people reading this paper without any background of the WRF model, may not understand this grid-type. If the authors want to use this, please clarify what it is or compare this with other grid-type kinds such as A, B, D, E types (should discuss momentum conservation and other kinds). ——————————— Reply: Agreed. Sentences are added to make it clear as “As is known, Arakawa A grid is "unstaggered" by evaluating all quantities at the same point on each grid cell. The "staggered" Arakawa B-grid separates the evaluation of the velocities at the grid center and masses at grid corners. Arakawa C grid further separates evaluation of vector quantities compared to the Arakawa B-grid.” (lin246-250)

Line 219: is this eta levels? Or sigma levels? And is this even vertical spacing? ——————————— Reply: Corrected. The eta levels are applied with coarser vertical spacing for the higher levels. The manuscript is revised as “Vertically, it has 41 eta levels using 10 hPa as its top with coarser vertical spacing for the higher levels.”

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(lin250-252) to make it clear.

Figure 4 appears earlier than Fig. 3; that is not critical, but its order should be sequential. Please rephrase the sentences or remove them. ——— Reply: Agreed. Thanks for pointing it out. The order of Figure 3 and Figure 4 is changed in the revised manuscript and related sentences are rephased.

Lines 224-225: are there references for the Dudia scheme? ——— — Reply: Thanks for the helpful advice. The sentence is revised as "The following parameterization schemes are used: WDM6 microphysics scheme (Lim et al., 2010), Grell Devenyi cumulus parameterization scheme (Grell et al., 2002), RRTM (Rapid Radiative Transfer Model) longwave radiation scheme (Mlawer et al., 1997), shortwave radiation scheme (Dudhia et al., 1989), and YSU boundary layer scheme (Hong et al., 2006) ." now from line 254 to 262. Besides, the reference is added as follows, Dudhia, J. Numerical Study of Convection Observed during the Winter Monsoon Experiment Using a Mesoscale Two-Dimensional Model, Journal of the Atmospheric Sciences, 46, 3077-3107, 1989.

Line 225: It is surprising that YSU PBL is Noh et al. 2003? By the way, the authors said WRFV3.9.1. About the above and this line, the authors should carefully look at the WRF website to cite more appropriate references for the parameterizations. ——— Reply: Thanks. We double checked the details for all the physics from WRF user guide and make corrections for the reference of YSU PBL as, Hong S.Y., Noh Y., Dudhia J. A New Vertical Diffusion Package with an Explicit Treatment of Entrainment Processes. Mon. Wea. Rev., 134, 2318-2341, 2006. Follow the reviewer's suggestion, all the references for the for the parameterizations are also checked. WDM6: Lim, K.-S. S., and Hong, S.-Y.: Development of an effective double-moment cloud microphysics scheme with prognostic cloud condensation nuclei (CCN) for weather and climate models. Mon. Wea. Rev., 138, 1587-1612, 2010. Grell Devenyi cumulus parameterization: Grell G.A., Dévényi D.: A generalized approach to parameterizing convection combining ensemble and data assimilation techniques,

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Geophys. Res. Let., 29, 587-590, 2002. The shortwave radiation scheme: Dudhia, J.: Numerical Study of Convection Observed during the Winter Monsoon Experiment Using a Mesoscale Two-Dimensional Model, Journal of the Atmospheric Sciences, 46, 3077-3107, 1989. The longwave radiation scheme: Mlawer E.J., Taubman S.J., Brown P.D., et al.: Radiative transfer for inhomogeneous atmospheres: RRTM, a validated correlated-k model for the longwave, Journal of Geophysical Research Atmospheres, 102: 16663-16682, 1997.

Sections 3.1 and 4.4 and Fig. 1: What the authors reference the best track data? In the body context and Fig. 1, there is no information on that. ———— Reply: Agreed. The best track data are provided by the China Meteorological Administration (Yu et al., 2007; Song et al., 2010). "Related information is added in section 3.1(line 215) and section 4.4 (line 407-408).

Section 4.2: I wonder that OMB and OBA indicate the observation (Himawari-8) – background (what background? Where it comes from? And how the authors calculate the brightness temperature of the analytic brightness temperature. Please clarify the methods of how to get the brightness temperature of the background and analytic one. Please put the title of each figure (band-8 micron unit). ———— Reply: The background for data assimilation is prepared as follows. Firstly, the initial condition and lateral boundary are obtained by the preprocessing module of WRF model with $0.5^\circ \times 0.5^\circ$ GFS reanalysis data. Then a 6-hour spin-up is conducted to provide as the background for the data assimilation purpose. The Community Radiative Transfer Model (CRTM; Liu and Weng, 2006) has been coupled within the WRFDA, which is applied as the observation operator for AHI radiance. The temperature and the humidity information from the model states are essential inputs for CRTM to calculate the simulated brightness temperature (the brightness temperature of the background and analysis). The simulation of the brightness temperature is conducted as one of the verification methods by comparing with the observed radiance. More explanation is added as "It should be pointed that even only parts of the AHI radiance data are

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applied after quality control in the data assimilation, the radiative transfer model is able to simulate the brightness temperature for all the pixels with the background and the analysis respectively for the verification purpose. The similar verification method is also applied in Yang et al., (2016)." (line 309-313). Reference: Yang, C., Liu, Z., Bresch, J., Rizvi, S. R. H, Huang, X.-Y., and Min, J. AMSR2 all-sky radiance assimilation and its impact on the analysis and forecast of Hurricane Sandy with a limited-area data assimilation system, Tellus A: Dynamic Meteorology and Oceanography, 68, 1,2016. Liu, Q., and F. Weng, 2006: Advanced doubling-adding method for radiative transfer in planetary atmosphere. J. Atmos. Sci., 63(12), 3459–3465. We also have put the title of each figure with the band information along with the micron unit for the related figures.

Lines 300-307: I understand the authors' purpose. But these sentences should be more clarified. Without any vertical profile, it could be mere speculation. Please provide the weighting functions of each band, and it could then be discussed. And, the authors mentioned "cloud", it would be water vapors. In other words, most people may think "cloud" as "just cloud". As you know, there are many species such as ice, overwater phase, water vapor, and so on. ———————————— Reply: Agreed. The authors have plotted the weighting function for each channel in Fig. 1. Thus, the manuscript is revised as "It can be inferred from Fig. 7a, c, and e that the magnitude in OMB of channel 10 is generally larger than that of channel 9, while that of the OMB in channel 8 is the smallest. This is because the detection height of channel 10 is lower than that of channel 8 and 9 seen from the weighting function (Fig. 1), indicating channel 10 is largely affected by the clouds."

Fig.1 Weighting function for Channel 8, 9, and 10.

Figure 8: I wonder whether this stdv is statistically significant or not? ———————————— Reply: Agreed. A significance test is conducted. A sentence is added as "The pairwise significance test is made between the OMA and OMB. Results show 95% confidence intervals in terms of the difference of the standard deviation using zero difference for the null hypothesis. A sentence is added as "Differences between

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the standard deviations of the OMB and OMA were statistically significant at the 95% level using zero difference for the null hypothesis."

Figure 9: I could see the improvement; however, why they fluctuate? ———— Reply: Fig. 9 shows the RMSEs of the simulated brightness temperature by the model before and after data assimilation against the observations. The background before the assimilation is the short-term forecast from the previous analysis. The increase of the RMSE in the fluctuation arise from the model error in the short-term forecast. To make it clear, a sentence is added as "The background before the assimilation is the short-term forecast from the previous analysis. The increase of the RMSE in the fluctuation arise from the model error in the 1 hour short-term forecast." (line377-380).

Lines 363-366: It would be better if the authors cite one reference, at least for this sentence. ———— Reply: Agreed. One reference is added to show the correlation between the water vapor environment and the typhoon intensity as follows, Kamineni, R., et al., 2003: Impact of High Resolution Water Vapor Cross-Sectional Data on Hurricane Forecasting, Geophysical Research Letters, 30, 38-1.

Figure 11a: The legend is wrong. Please revise that. I guess, the figure could be enlarged. ———— Reply: Thanks for the helpful advice. We replotted the tracks with colorful lines in the revised manuscript. The random drawings in the background is also removed. The labeling at left is also kept. The forecast from 0000 UTC 02 August 2015 is also added for the track in Figure 12a. The forecast ranges are extended from 18 hours to 48 hours. In addition, the mean track errors, maximum surface wind speed error, and the minimum sea level pressure error are also calculated in Figure 12b, and Figure 13.

Lines: 36-39: "The predictability of these TCs is limited because it entails complex multi-scale dynamic interactions. These interactions include environmental airflows, TC vortex interactions, atmosphere-ocean interactions, and the effects of mesoscale

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and micro-convective scale, together with microphysics and atmospheric radiation." Is your idea? Or someone said? Please cite some works for supporting this sentence. ——————————— Reply: Corrected. The following reference is added, which describes the complex multi-scale dynamic interactions for the TCs. Reference: Minamide, M., and F. Zhang, 2018: Assimilation of all-sky infrared radiances from himawari-8 and impacts of moisture and hydrometer initialization on convection-permitting tropical cyclone prediction. Mon. Wea. Rev., 146, 3241–3258.

Lines 241-243: Perhaps, this sentence accounts for data assimilation, in which the observations should be independent with each other. Do the authors think a 20-km resolution is appropriate to avoid the dependency between observations? If the authors say "right", please suggest any reference or results for that; for example, two normal distributions. ——————————— Reply: Agreed. It is proved that raw radiance observations thinned to a grid with 2–6 times of the model grid resolution are able to remove the potential error correlations between adjacent observations (Schwartz et al ., 2012; Xu et al ., 2015; Choi et al., 2017). Also, sensitivity experiments with 25 km, and 30 km thinning mesh are also conducted with similar results. Thus, the manuscript is revised as "It is proved that raw radiance observations thinned to a grid with 2–6 times of the model grid resolution are able to remove the potential error correlations between adjacent observations (Schwartz et al ., 2012; Xu et al ., 2015; Choi et al., 2017). Hence, 20 km is chosen to make thinning of AHI radiance data. Also, sensitivity experiments with 25 km, and 30 km thinning mesh are also conducted with similar results." to make it clear.

Editorial comments Over the whole manuscript: Please avoid to use many times "so" as the conjunction. Overall, the author should make the consistency of using the acronym and its order before the publication. For example, Lines 17-20: "The assimilation of AHI was implemented with the framework of the mesoscale numerical model WRF and its three dimensional variational assimilation system (3DVAR) for the analysis and prediction of typhoon "Soudelor" in the Pacific Typhoon season in 2015.". Perhaps,

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the authors should correct some words; “AHI” ! “AHI data”; spell “WRF” out; “typhoon Soudelor” ¡‘Typhoon Soudelor (2015)”. I guess the authors could use WRF-3DVAR “mesoscale numerical model weather research and forecasting three-dimensional variational assimilation system (WRF-3DVAR) or else. And please thoroughly see your wording to reduce mistyping or mistake since this paper goes forever after publication. ——— Reply: Thanks. We change “so” to other conjunctions at line 68, 73, 132, 158. Also, consistency is considered and we change the sentence from line 23 to 27. Other revisions can be found by tracks in detail.

Lines 20-21 and else somewhere: “AHI Imager data” “AHI data” since the authors already used this as the acronym above. Please correct this word in the manuscript. ——— Reply: Agreed. For an accurate expression, we use “AHI radiance data” in the whole manuscript.

Line 21: “. . .rapid intensify. . .” Do the authors mean “rapidly intensifying”? ——— Reply: Corrected. We revised it as “The effective assimilation of AHI radiance data in improving the forecast of the tropical cyclone during its rapid intensification has been realized.” at line 27-30.

Lines 20-22: This line gives me something awkward. Do you mean “the AHI data assimilation was effective to simulate rapidly intensifying TCs.”? ——— Reply: Corrected. This is what we mean. To avoid misunderstanding, the expression is changed to “The effective assimilation of AHI radiance data in improving the forecast of the tropical cyclone during its rapid intensification has been realized.” at line 27-30.

Line 26: forecast ! forecasts ——— Reply: Corrected. “forecast” is replaced with “forecasts”.

Line 35: Please use a general expression “quick intensification” ! “rapid intensification”; “exact forecast” ! “forecasts” ——— Reply: Thanks. The corresponding parts are corrected for the whole manuscript.

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Line 40: The authors do not use the “IC” acronym after this line. Please remove this. ——— Reply: Thanks. “IC” acronym is removed at line 49.

Line 42: “. . .relatively limited” ! “relatively insufficient compared to the land” or proper expression. ——— Reply: Corrected. “relatively insufficient compared to the land” is used at line 51-52.

Line 46: “. . . now can” ! “have adopted” ——— Reply: Thanks for pointing it out. “have adopted” is used at line 56.

Line 47: remove “directly” ——— Reply: Thanks. “directly” is removed.

Lines 50-51: “improve NWP technique” ! I am not sure the authors want to say “these data improve NWP technique”? what the authors mean NWP technique? Please suggest examples. ——— Reply: Thanks for the helpful advice. Here we want to express abundant satellite data are crucial to the improvement of NWP accuracy because most part of the earth is covered by ocean where conventional observations are scarce. To avoid misunderstanding, “improve NWP technique” is replaced by “improve the accuracy of the numerical model results” at line 61-62.

Line 52: “. . . contributions to forecast accuracy . . .” ! “contribution to improving the accuracy of the numerical model results”, The authors should rephrase this sentence. ——— Reply: Thanks. The sentence is rephrased at line 63-64.

Line 58: “Besides, compared to geostationary satellites, they have higher resolutions (Li et al., 2017; Shen et al., 2015; Xu et al., 2013).” ! “Besides, they have finer resolutions compared to geostationary satellites (Li et al., 2017; Shen et al., 2015; Xu et al., 2013). ——— Reply: Thanks for the helpful advice. The sentence is revised at line 69-72.

Line 61: “quickly” ! “rapidly” ——— Reply: Thanks. “quickly” is replaced with “rapidly” at line 74.

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Line 67: “supervising” ! “observing” ——— Reply: Thanks. “supervising” is replaced with “observing” at line 80.

Line 126: remove “(Japan Meteorological Agency)” ——— Reply: Corrected. “(Japan Meteorological Agency)” is removed at line 153.

Lines 135: “satellite” ! “satellite series” ——— Reply: Thanks for the helpful advice. This sentence is repeated and we delete it. From line 155 to 157.

Lines 190-191: The authors need to polish this sentence. ——— Reply: Thanks for the helpful advice. The sentence is revised as “From the record of the China Meteorological Administration (CMA), Typhoon Soudelor was the 13th typhoon in 2015 as the second strongest tropical cyclone in that year.” at line 215.

Line 193: “west by north” ! “north-westwards” ——— Reply: Thanks for the helpful advice. We use “north-westwards” instead of “west by north” at line 219.

Line 205: “its main body” ! “tropical disturbance” or “tropical depression” ——— Reply: Thanks. “its main body” is substitute with “the tropical depression” at line 231.

Line 220: “initial condition . . .” ! “The initial condition and . . .” ——— Reply: Thanks for pointing it out. “The initial condition and . . .” is used at line 252.

Line 238-239: Please remove unnecessary acronyms such as “Ps”, “RHs” which words are not used anymore. ——— Reply: Thanks. These unnecessary acronyms are removed at line 274-275.

Line 403: 2.6 m s-1 ——— Reply: Thanks for the helpful advice. “2.6 m s-1” is used at line 437.

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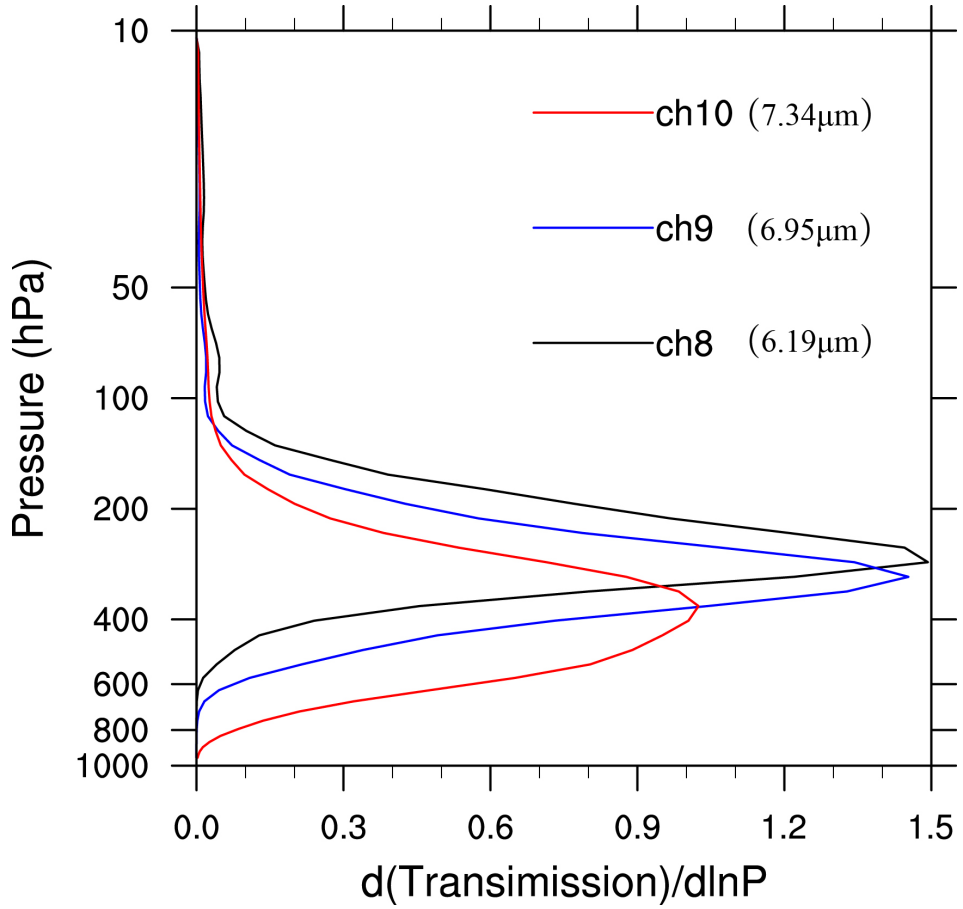

Fig. 1. Fig.1 Weighting function for Channel 8, 9, and 10.

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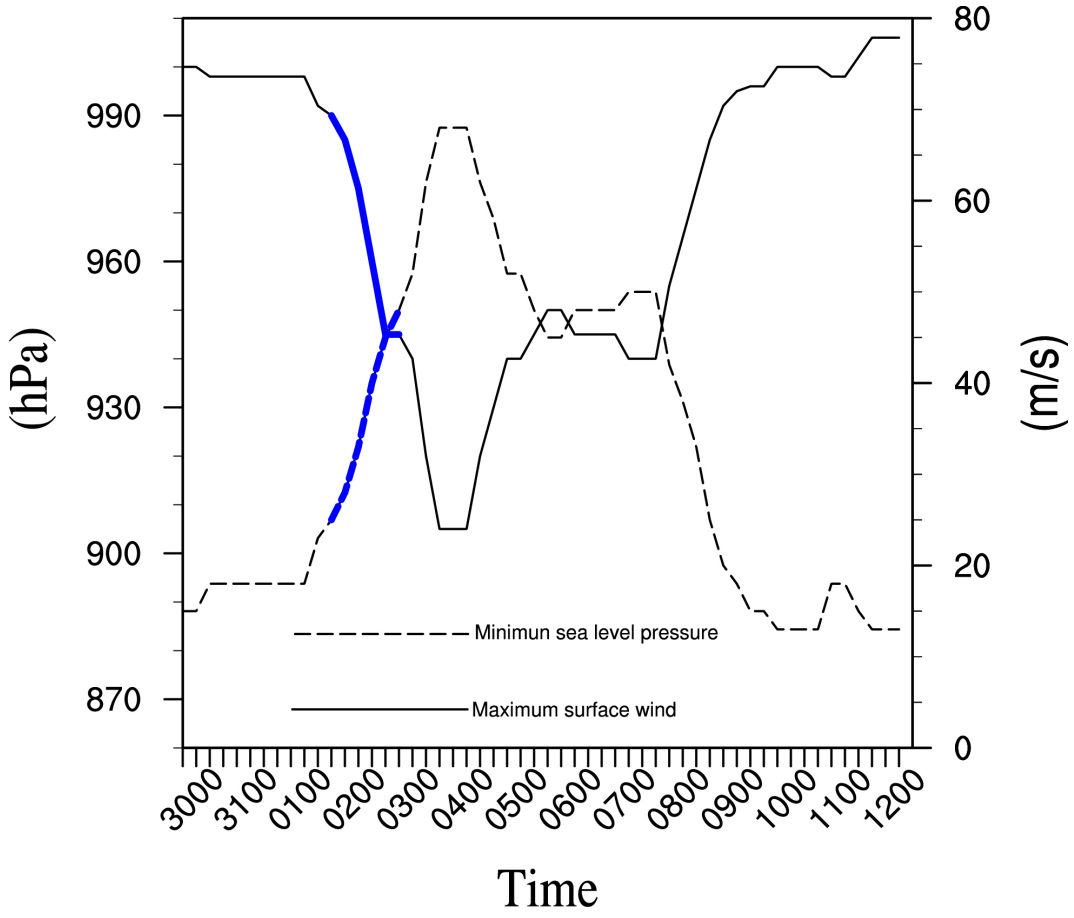

Fig. 2. Fig. 3 The time series of the minimum sea level pressure (solid line, unit: hPa) and the maximum surface wind (dash line, unit: m s-1) from 0000 UTC 30 July 2015 to 0600 UTC 12 August 2015.

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