Responses to ***Dr. Huang's Comments***

Manuscript Number: nhess-2019-375

Title of Paper: Estimation of Tropical Cyclone Wind Hazards in Coastal Regions of China

Journal: Natural Hazards and Earth System Sciences (NHESS)

Dear Dr. Huang

We would like to thank you for your careful and thorough reading of our manuscript and for the thoughtful comments and constructive suggestions. Your comments are of great help to improve the quality of this manuscript. We agree with all your comments and we have revised the manuscript accordingly. We are already crafting a revised version of the paper.

1. Comment: *This manuscript estimates the tropical cyclone wind hazards in southeastern coastal region of China. Two typhoon wind field parameters, i.e. radius to maximum winds $R_{max,s}$ and shape parameter of radial pressure profile B_s are identified using JMA best track dataset coupled with a boundary layer wind field model. TC wind hazard curves in terms of design wind speed versus return periods for major coastal cities of China are developed. The topic of this study is in-line with the journal of "Natural Hazards and Earth System Sciences (NHESS)". Generally, the paper is a well-organized study and worth to be published. The obtained results will be valuable to the researchers and engineers in this field.*

Response: We really appreciate your positive feedback. We agree with all your comments and we have revised the manuscript accordingly.

2. Comment: *The major concern is the use of the wind-driven $R_{max,s}$ and B_s. The results in Figs. 11 and 13 show that B_s and $R_{max,s}$ have a positive correlation which is inconsistent with the findings by Vickery et al. (2008). And few values of B_s are higher than 2.5 which fall outside the range of 0.5~2.5 suggested by Vickery et al. (2000). Please explain.*

Vickery, P. J., Skerlj, P. F., Steckley, A. C., and Twisdale, L. A.: Hurricane Wind Field Model for Use in Hurricane Simulations, Journal of Structural Engineering, 126, 1203-1221, 2000.

*Vickery, P. J. and Wadhera, D.: Statistical Models of Holland Pressure Profile Parameter and Radius to Maximum Winds of Hurricanes from Flight-Level Pressure and H*Wind Data, Journal of Applied Meteorology and Climatology, 47, 2497-2517, 2008.*

Response: Thanks for your comment. Regarding the value difference of B_s identified in this study, similar response replied to Anonymous Referee #1 was present as follow:

The difference is mainly attributed to the use of different wind field models and data sources. As listed in Table 1, the pressure and wind speed data sources were commonly employed to extract the R_{max} and B using different fitting models.

Table 1 Use of data source and fitting model for R_{max} and B

Data source	Fitting model	Reference
Surface pressure	Holland pressure model	Holland, 1980; Zhao et al., 2013; Fang et al., 2018b
Surface wind speed	Gradient and boundary layer wind models	Vickery et al., 2008; Fang et al., 2019; Zhao et al., 2020
Upper level pressure	Convert to surface pressure	Vickery et al., 2000, 2008
Upper level wind speed	Gradient wind model	Vickery et al., 2000

Holland pressure model:

$$P_{rs} = P_{cs} + \Delta P_s \cdot \exp\left[-\left(\frac{R_{max,s}}{r}\right)^{B_s}\right] \quad (1)$$

in which subscripts s and r denote surface values at the radius of r, P_{rs}= surface air pressure at radius of r from the typhoon's axis (hPa), P_{cs} = central pressure (hPa), $\Delta P_s = P_{ns} - P_{cs}$ is the central pressure difference (hPa).

Gradient wind model:

$$V_g = \frac{V_{T\theta} - fr}{2} + \sqrt{\left(\frac{V_{T\theta} - fr}{2}\right)^2 + \frac{r}{\rho_g}\frac{\partial P_g}{\partial r}} \quad (2)$$

in which $V_{T\theta} = -V_T \cdot sin(\theta - \theta_T)$, V_T is the translation speed (m/s), θ_T and θ are the translation direction and the direction of interest (counterclockwise positive from the east, °), f is the Coriolis force, ρ_g (kg/m^3) and P_g (hPa) are the air density and pressure at gradient layer.

The pressure data (direct surface observations or converted from upper-level observations) can be directly applied to Eq. (1) to obtain $R_{max,s}$ and B_s, which is considered as the most physically reasonable method. Vickery et al. (2000, 2008) utilized the surface pressures converted from flight-level reconnaissance data to optimally obtain a pair of $R_{max,s}$ and B_s for each traverse observation through the storm. Fang et al. (2018b) fitted the surface pressure data of landing typhoons observed by distributed meteorological stations in the mainland of China. However, when this equation is applied to model the wind speed field (assume $P_{rs} = P_g$) using Eq. (2) as used by most wind field models (Vickery et al., 2008), some inconsistencies could be introduced since the pressure distribution at free atmosphere is somewhat different from that at the surface. This can be approved from the results obtained by Willoughby et al (2004) and Vickery et al. (2000). Vickery et al. (2000) found that estimated B from upper-level wind speed data using Eqs. (1)~(2) were about 20%~30% higher than that estimated from surface pressures. That means if Eq. (1) is estimated from the surface pressures, it cannot be directly applied to Eq. (2) due to the height-resolving characteristics of air density and pressures. And Eq. (2) is actually an approximate formula by neglecting the radial and vertical wind components. Moreover, even the pressure observation-based $R_{max,s}$ and B_s were employed in the present wind field model, some inevitable errors on the estimations of wind speed would be introduced due to the simplification and linearization of the Navier-Stokes equations as discussed by Kepert and

Wang (2001).

The other method is the use of wind speed observations. Vickery et al. (2008) used a boundary layer model to match the H* Wind surface wind field. The Holland pressure model, say Eq. (1) was also directly applied to Eq. (2) for calculating the gradient wind speed before converting to surface level. In fact, if Holland pressure model is considered to be valid at gradient level and substituted into Eq. (2), it is acceptable and self-consistent. That means R_{max} and B are estimated from gradient wind. And real wind field at gradient or surface level can be well captured although the real pressure field has a large deviation from Holland's model. The only problem is how to predetermine a gradient height since it is a variable and generally believed to increase from the storm center to peripheral area.

Comparatively, the wind field model adopted in present study uses the surface level say 10 m above the ground as a standard height. The surface pressure was converted to gradient layer using a height-resolving pressure model (Fang et al., 2018a):

$$P_{rz} = \left\{P_{cs} + \Delta P_s \cdot exp\left[-\left(\frac{R_{max,s}}{r}\right)^{B_s}\right]\right\} \cdot \left(1 - \frac{gkz}{R_d \theta_v}\right)^{\frac{1}{k}} \quad (3)$$

Then, an analytical boundary layer wind field model was utilized to calculate the surface wind speed (Fang et al., 2018a). The maximum gradient wind speed is considered to be positively correlated with the central pressure difference and B_s. To fit a specific real wind speed, a higher value of B_s is required due to the decrease of central pressure difference from the surface to gradient layer when compared to no consideration of height-resolving characteristics of pressure field. Moreover, the analytical boundary layer model disregards some nonlinear terms and neglects the non-axisymmetric effects (Fang et al., 2018a), a larger B_s is usually fitted to compensate for the deficiency of the model.

It is noteworthy that the surface pressures modeled by Eq. (1) using the fitting pair of $R_{max,s}$ and B_s in this study could have a remarkable difference from the real pressures, but the modeled wind field is forced to match the observations as closely as possible to increase the accuracy of wind hazards estimation. More details regarding the extraction of $R_{max,s}$ and B_s used in this study have been discussed in another study and in review (Zhao et al., 2020).

Explanations were also added in the revised manuscript in Lines 219-224 as:

"It is noteworthy that the fitted values of B_s are slightly higher than traditional results, i.e. Vickery et al. (2000b, 2008) while $R_{max,s}$ are almost unchanged. This is mainly attributed to the use of surface wind data and an analytical wind field model in this study (Fang et al., 2018a, 2019b). To fit a specific real wind speed, a higher value of B_s is required due to the decrease of central pressure difference from the surface to gradient layer when compared to no consideration of height-resolving characteristics of pressure field. Moreover, the analytical boundary layer model disregards some nonlinear terms and neglects the non-axisymmetric effects (Fang et al., 2018a), a larger B_s is usually fitted to compensate for the deficiency of the model."

The correlation between B_s and $R_{max,s}$ is positive in this study while negative correlation was found by Vickery et al. (2008). This could attribute to the difference of TC structure in Western Pacific and Atlantic Ocean. The difference of best track dataset as well as the use of different fitting methods could also be responsible for this difference. Polamuri (2019) also found a positive correlation between B_s and $R_{max,s}$ when JMA best track dataset was utilized.

Reference

Holland, G. J.: An analytic model of the wind and pressure profiles in hurricanes, Monthly Weather Review, 108, 1212-1218, 1980.

Fang, G., Zhao, L., Cao, S., Ge, Y., and Pang W.: A novel analytical model for wind field simulation under typhoon boundary layer considering multi-field correlation and height-dependency, Journal of Wind Engineering and Industrial Aerodynamics, 175, 77-89, 2018a.

Fang G, Zhao L, Song L, et al. Reconstruction of radial parametric pressure field near ground surface of landing typhoons in Northwest Pacific Ocean[J]. Journal of Wind Engineering and Industrial Aerodynamics, 2018b, 183:223-234.

Fang, G., Pang, W., Zhao, L., Cao, S., and Ge, Y.: Towards a refined estimation of typhoon wind hazards: Parametric modelling and upstream terrain effects, The 15th International Conference on Wind Engineering, Beijing, China; September 1-6, 2019b.

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Vickery P J , Wadhera D . Statistical Models of Holland Pressure Profile Parameter and Radius to Maximum Winds of Hurricanes from Flight-Level Pressure and H*Wind Data[J]. Journal of Applied Meteorology and Climatology, 2008, 47(10):2497-2517.

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Zhao L., Fang G. S., Pang W., Rawal P., Cao S. Y., and Ge Y. J.. Toward a refined estimation of typhoon wind hazards: Parametric modeling and upstream terrain effects, Journal of Wind Engineering & Industrial Aerodynamics, 2020. (in review).

3. Comment: *The titles of section 2.1 and 2.2 are identical. Please check.*

Response: Thanks for your comment. Section 2.2 should be "Statistical correlations". The correction has been made.

4. Comment: *Line 409, "...show satisfactory agreement with…", consider use "...show a satisfactory agreement with…" or "...are in satisfactory agreement with…".*

Response: Thanks for your careful reading. The correction has been made.

5. Comment: *A similar study performed by Wu and Huang (2019) is suggested to be compared and discussed. Wu F., and Huang G.: Refined Empirical Model of Typhoon Wind Field and Its Application in China, Journal of Structural Engineering, 145(11): 04019122, 2019.*

Response: Thanks for your recommendation. Authors have carefully read the suggested paper. It provides us with a lot of information to further understand the typhoon hazard in coastal regions of China. They have also been added to our reference. It was also compared with present and other studies in Lines 368 and 408.

"…A similar trend can also be observed from the differences between Li and Hong (2016), Chen and Duan (2017), Wu and Hung (2019) and the codes…"

"…The wind speeds predicted by Wu and Huang (2019) are similar to those estimated by Li and Hong (2016) which mainly attributes to the use of the same best track dataset as well as R_{max} and B models…"