Responses to ***Anonymous Referee #1' 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 Anonymous Referee #1,

We would like to thank you for your constructive comments to the manuscript. We agree with all your comments and we have revised the manuscript accordingly. We are already crafting a revised version of the paper. Please, find below the referees' comments repeated in italics and our responses inserted after each comment.

1. Comment: *The manuscript presents an interesting study on the estimation of tropical cyclone wind hazards. The topic falls in the scope of Natural Hazards and Earth System Sciences (NHESS). Generally, the paper is well written and organized. Some new findings different from suggestions in current specifications are highlighted and discussed. The presented research is of great importance to the wind-resistant design in coastal areas of China. The manuscript can be accepted for publication after minor revisions.*

Response: We really thanks for your careful review and valuable suggestions. We agree with all your comments and we have revised the manuscript accordingly.

2. Comment: *The values of the shape parameter of radial pressure profile in Fig. 11. Holland (1980) suggested that it should fall in the range [1.0, 2.5]. Vickery et al. (2000) suggested the range should be [0.5, 2.5]. There are a number of points larger than 2.5 in Fig. 11, which goes against our conventional cognition. Please give some essential explanations to clarify this point. i) Holland, G. J.: An analytic model of the wind and pressure profiles in hurricanes, Monthly Weather Review, 108, 1212-1218, 1980. ii) 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.*

Response: Thanks for your comment. 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):

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

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."

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.

Kepert J, Wang Y. The dynamics of boundary layer jets within the tropical cyclone core. Part II: Nonlinear enhancement. Journal of the atmospheric sciences, 2001, 58 (17), 2485-2501

Vickery P J, Skerlj P F, Steckley A C, et al. Hurricane Wind Field Model for Use in Hurricane Simulations[J]. Journal of Structural Engineering, 2000, 126(10):1203-1221.

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.

Willoughby H E , Rahn M E . Parametric Representation of the Primary Hurricane Vortex. Part Ⅰ: Observations and Evaluation of the Holland (1980) Model[J]. Monthly Weather Review, 2004, 132(12):p.3033-3048.

Zhao L , Lu A , Zhu L , et al. Radial pressure profile of typhoon field near ground surface observed by distributed meteorologic stations[J]. Journal of Wind Engineering and Industrial Aerodynamics, 2013, 122:105-112.

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: Fig. 11 can be improved to avoid some data points obscured by legend.

Response: Thanks for your careful reading and comments. Fig.11 has been replotted as follows.

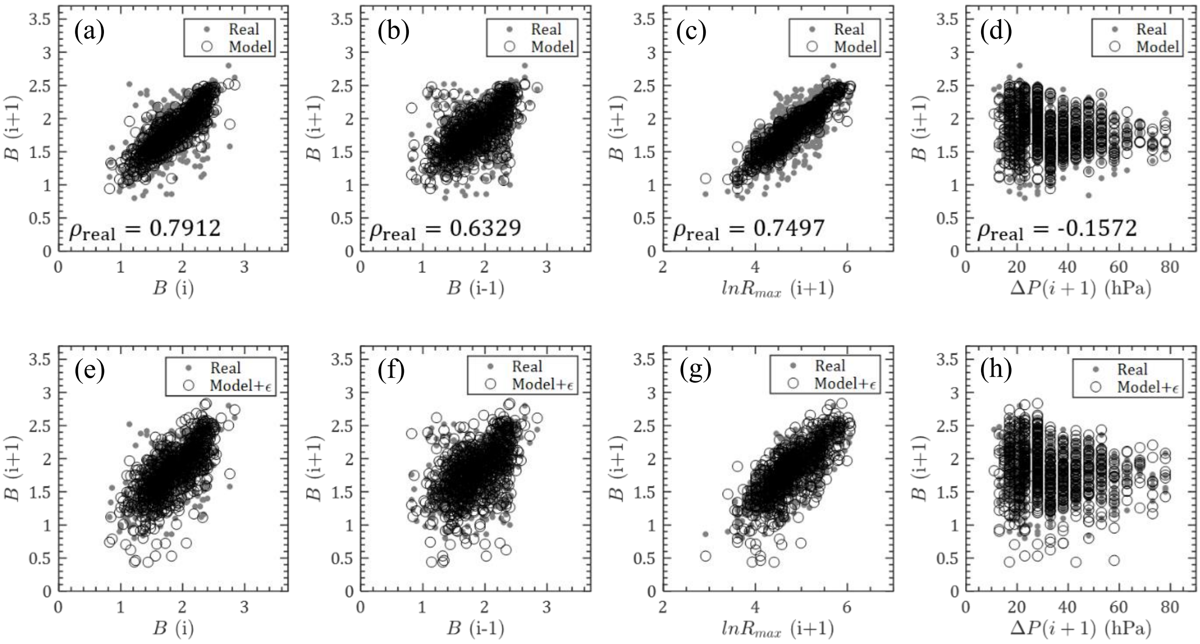

Figure 11: Comparison of B_s between model and real observations: (a~d) relations between $B_s(i)$, $B_s(i-1)$, $lnR_{max,s}(i+1)$, $\Delta P(i+1)$ and $B_s(i+1)$ without errors; (e~h) relations between $B_s(i)$, $B_s(i-1)$, $lnR_{max,s}(i+1)$, $\Delta P(i+1)$ and $B_s(i+1)$ with errors (ρ_{real} is the correlation coefficient for real observation data)

4. Comment: Lines 24, 37, 40, 416, 440: characterizing tropical cyclone as ’non-synoptic’ is questionable. Tropical cyclone is actually a non-frontal synoptic-scale cyclone as discussed by Vallis et al (2019). Vallis, M. B., Loredo-Souza, A. M., Ferreira, V., Nascimento E. L.: Classification and identification of synoptic and non-synoptic extreme wind events from surface observations in South America, Journal of Wind Engineering and Industrial Aerodynamics, 193, 2019, 103963.

Response: We really appreciate you for pointing out the misunderstanding of the concepts. We carefully examine the concept of synoptic scale winds and tropical cyclone. As explained by National Oceanic and Atmospheric Administration (NOAA) (https://www.nhc.noaa.gov/aboutgloss.shtml) "tropical cyclone is a warm-core non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined center". Vallis et al (2019) characterized the extreme wind events into synoptic, non-synoptic and tropical cyclone (TC) events. The word "synoptic" has been replaced by the "non-TC" in the revised manuscript.

5. Comment: Although this paper focuses on the characteristics of the mean components of tropical cyclones, some discussions on the fluctuation components (stationary or nonstationary) are suggested to be supplemented in the introduction part. The following references may do some help. i) Modelling of longitudinal evolutionary power spectral density of typhoon winds considering high-frequency subrange. Journal of Wind Engineering and Industrial Aerodynamics 2019, 193, 103957. ii) Reduced-Hermite bifoldinterpolation assisted schemes for the simulation of random wind field. Probabilistic Engineering Mechanics 2018, 53, 126-142.

Response: Thanks for your recommendation. Authors have carefully read suggested papers and found their great contributions to understand the fluctuating characteristics of TC winds. They provide us with a lot of information to further simulate the fluctuating components of TC winds in the future. They have also been added to our reference.

6. Comment: There are some typos in the manuscript, e.g., In line 124, "influnence" should be "influence"; In line 149, "modeling" was used while "modelling" was utilized in line 154. Please use a consistent form.

Response: Thanks for your careful reading and comments. The correction has been made. And similar typos have been carefully checked and revised.