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Comparative study on wind characteristic parameters of typhoons in offshore and coastal areas of China

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SUMMARY:
Although the near-surface wind characteristics of typhoons have been studied by plenty of observational studies in the inland and open sea areas, the research on the variation law of the near-surface wind characteristics during typhoon landfall is still lacking. This study investigates the variation law and impact factors of three wind characteristic parameters for landing typhoons in offshore and onshore areas of China. The near-surface wind profile data were obtained from 15 typhoons that made landfall on the southeast coast of China during 2009–2020. The results show that the variations of wind characteristic parameters with wind speed in the sea-land transition area are different from those in the inland and open sea areas for landing typhoons. With the increase of the distance from the coastline, the variation law of the wind characteristic parameter gradually transforms from that of the open sea into that of the inland. For onshore wind over land, a new piecewise function of the drag coefficient (C_d) is proposed to better describe the variation of C_d with wind speed in the sea-land transition area. For onshore wind over the sea, the variation of C_d with wind speed shows a double-peak change, which is mainly because the water depth changes the dependence of C_d on wind speed.

Keywords: typhoon, wind characteristics, drag coefficient

1. INTRODUCTION

China suffers disasters induced by landing typhoons more frequently than anywhere else in the world (Duan et al., 2019). In the fields of wind engineering, meteorology and energy, it is of great importance to understand the wind characteristics of landing typhoons near the surface. Commonly, the best way to characterize the near-surface wind field is through in situ observation. However, although the near-surface wind characteristics of typhoons have been studied by plenty of observational studies in offshore (Giammanco et al., 2013; Li et al., 2019; Powell et al., 2003; Zhao et al., 2015) and onshore (Fang et al., 2018; He et al., 2020; Song et al., 2016) areas, the research on the variation law of the near-surface wind characteristics during typhoon landfall is still lacking. This study aims to explore the variation law and impact factors of the near-surface wind characteristic for landing typhoons. Specifically, a comparative study on wind characteristic parameters of typhoons in both offshore and onshore areas is carried out by using the near-surface wind profile data of 15 typhoons that made landfall on the southeast coast of China.

2. TYPHOON OBSERVATIONS AND DATA

In this study, the near-surface wind profile data of 15 typhoons that made landfall on the southeast coast of China during 2009–2020 were collected. Figure 1 shows geographical locations of 17 observation points and best-track positions and intensities of 15 landfalling typhoons. Inspection of Fig. 1 also suggests that all typhoons made landfall on the southeast coast of China, and then died out in the inland.

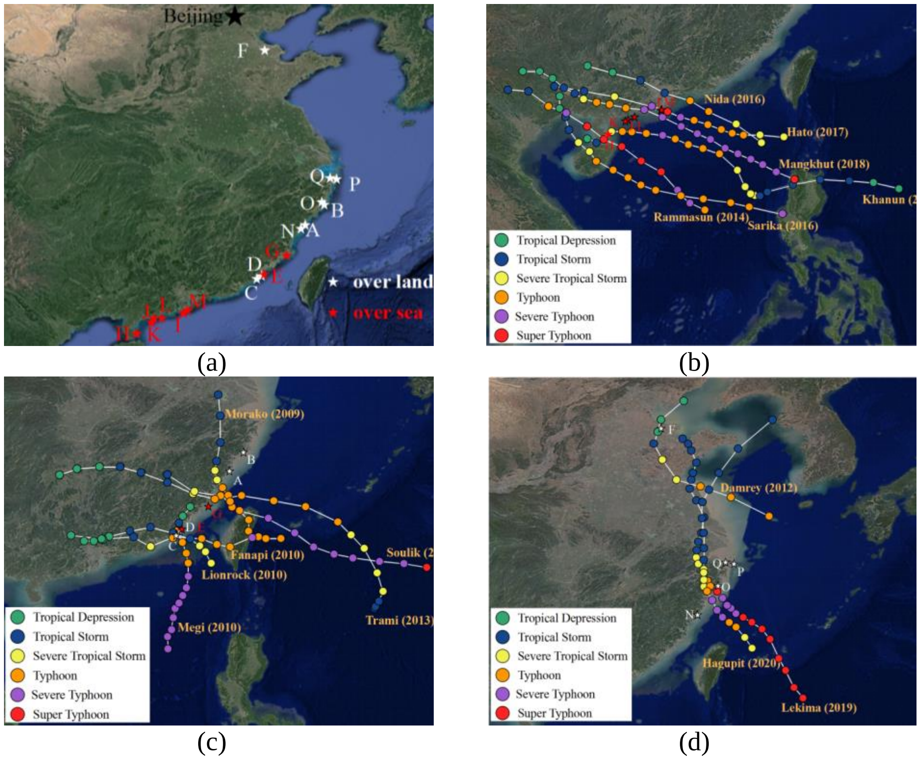

Figure 1. (a) Geographical locations of 17 observation points and (b, c, d) best-track positions and intensities of 15 landfalling typhoons.

3. METHOD

3.1. Logarithmic law

According to the Monin-Obukhov similarity theory, the logarithmic law wind profile model can be expressed as follows:

$$U(Z)=\frac{U_*}{\kappa}\left[\ln\frac{Z}{Z_0}-\Psi\left(\frac{Z}{L}\right)\right], \quad (1)$$

where $U(Z)$ is the mean wind speed at the height of Z, U_* is the friction velocity, κ is the von-Kármán constant which is taken as 0.4 herein, Z is the height from the surface, Z_0 is the aerodynamic roughness length, Ψ is a function of stability parameter Z/L, and L is the Monin-Obukhov length. Under the influence of typhoons, the atmospheric is considered to be near-neutral stratified that makes $L = \infty$ and $\Psi = 0$, then Eq. (1) can be simplified as:

$$U(Z) = \frac{U_*}{\kappa} \ln \frac{Z}{Z_0} \tag{2}$$

3.2. Calculation of wind characteristic parameters

The calculation of Z_0 and U_* are accomplished simultaneously by least-square fitting of the logarithmic law wind profile in neutral stratification (Eq, (2)). After obtaining the value of U_*, the drag coefficient is introduced by the calculation of momentum flux or stress (τ) using bulk transfer method:

$$\tau = \rho U_*^2 = \rho C_d U(10)^2 \tag{3}$$

where ρ is air density, C_d is the drag coefficient, and $U(10)$ is the mean wind speed at 10 m in neutral stratification. Then, the drag coefficient can be obtained by:

$$C_d = \left(\frac{U_*}{U(10)} \right)^2 \tag{4}$$

4. RESULTS

Figure 2 shows variations of three wind characteristic parameters (Z_0, U_*, C_d) with 10-m wind speed over the sea and over land.

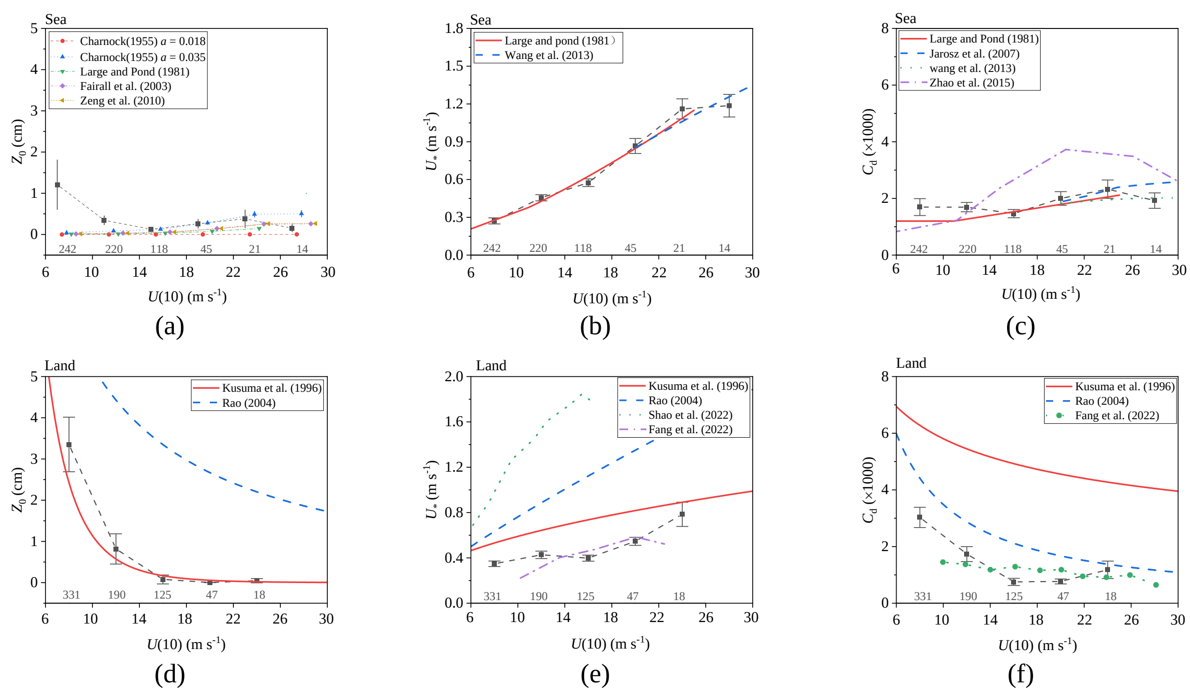

Figure 2. Variations of (a, d) roughness length (Z_0), (b, e) friction velocity (U_*) and (c, f) drag coefficient (C_d) with 10-m wind speed (a, b, c) over the sea and (d, e, f) over land. The black square represents the average value and the values between two whisker ends represent the 95% confidence interval.

5. CONCLUSIONS

This study investigates the variation law and impact factors of three wind characteristic parameters (Z_0, U_*, C_d) for landing typhoons in offshore and onshore areas of China. The near-surface wind profile data were obtained from 15 typhoons that made landfall on the southeast coast of China during 2009–2020.

The most important finding of this study is that the variations of wind characteristic parameters with wind speed in the sea-land transition area are different from those in the inland and open sea areas for landing typhoons. With the increase of the distance from the coastline, the variation law of each wind characteristic parameter gradually transforms from that of the open sea into that of the inland.

For onshore wind over land, C_d firstly decreases from 4.22×10^{-3} to 1.31×10^{-3} and then remains stable with the increase of wind speed. In order to better describe the variation of C_d with wind speed in the sea-land transition area, a new piecewise function of C_d is proposed for landing typhoons. For onshore wind over the sea, the variation of C_d with wind speed shows a double-peak change, which is mainly because the water depth changes the dependence of C_d on wind speed. The two prevailing wind directions at M point result in two water depths and two critical wind speed at which C_d peaks.

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