Response to reviewer:

We greatly appreciate the reviewer's recognition of the value and significance of the present study, as well as the very valuable comments on the paper. We have addressed the comments carefully as detailed below. The original comments are in black italic and our replies in black normal font, we also put the revised paragraph in blue after each reply to show the changes.

Suggestions for major revisions / questions:

1.Lines 67 to 100: While the main conclusion is correct, the authors avoid extracting uncertainty numbers for the measured wind states from the references.

Response: We appreciate the reviewer's insightful comment. To address the concern regarding uncertainty quantification, we have revised Section 1 (Introduction) to explicitly incorporate uncertainty metrics from cited references, as detailed below:

"UAVs are often employed to measure wind characteristics both directly and indirectly. Indirect measurement methods involve utilizing pre-installed sensors on the UAV (Elston et al., 2015), in conjunction with specialized flight patterns and wind retrieval algorithm (Bonin et al., 2013; Rautenberg et al., 2018; Gonzalez-Rocha et al., 2019) to achieve wind speed measurement. While these methods offer advantages of operational simplicity and cost-effectiveness, their core principle relies on inversely estimating wind speed through dynamic parameters such as thrust, attitude angles, and flight velocity (Crowe et al., 2020; Donnell et al., 2018; Sikkel et al., 2016; Simma et al., 2020). However, their accuracy is critically dependent on both the measurement precision of inertial measurement unit (IMU) and the computational reliability of inversion algorithms. Specifically, inherent noise interference in IMU sensors (e.g., gyroscope's angular rates can be severely affected by external disturbances up to 0.5 °/s) (Hoang et al., 2021; Neumann and Bartholmai, 2015), combined with uncertainties in parameter configuration within inversion algorithms (the root mean squared errors (RMSE) of wind speed estimation is 1-1.4) (Bonin et al., 2013), can lead to significant deviations in wind speed estimations. Furthermore, these methods typically assume constant aerodynamic parameters for UAVs, an assumption that often fails to hold in practical complex wind field environments (Bonin et al., 2013).

In contrast, direct measurement methods entail installing additional wind sensors on the UAV to obtain real-time wind information in the field. Porous probes (Soddell et al., 2004; Spiess et al., 2007), pitot tubes (Niedzielski et al., 2017; Langelaan et al., 2011), and anemometers (Rogers and Finn, 2013; Nolan et al., 2018) are commonly used sensors. Sonic anemometers are a more prevalent choice for rotorcraft UAVs, capable of measuring wind speed by detecting changes in the speed of sound travel between different sensors (Thielicke et al., 2021). Recent experiments have demonstrated that under highly turbulent conditions, UAV equipped with properly installed sonic anemometers in wind tunnels can achieve wind speed measurements with RMSE ranging from 4.3% to 15.5% compared to bistatic lidar (Thielicke et al., 2020). Due to the increasing use of rotorcraft UAVs for wind measurements, sonic anemometers are recognized as one of the most promising methods in terms of measurement accuracy and precision.

Sonic anemometers have been mounted onto rotary-wing UAVs for measuring wind speed to varying degrees of success. Typically, an anemometer is mounted at a position along the central axis above the UAV, with data adjusted for the additional wind speed signals induced by UAV motion and attitude changes. Nevertheless, the strong airflow perturbations caused by the rotating propellers can distort real wind flow patterns and significantly affect the accuracy of wind measurements (De Divitiis, 2003). However, these distortions were not considered in the adjustment algorithms. To address this issue, researchers have developed several new correction methods. The first method involves mounting the anemometer along the central axis high above the UAV where the rotor wash effects are believed to be limited on the wind speed measurement (Shimura et al., 2018; Barbieri et al., 2019). Johansen concluded that anemometers at about 40 to 45 mm above the multi-rotor plane of small UAV the flow influences from rotors are negligible (Johansen et al., 2015). However, it may not be suitable for hexacopters and octocopters due to the high position required, which may raise safety and flight control concerns. The second method involves new corrections based on experiments in an indoor area to measure wind velocity signal bias caused by the rotors during flight and then subtracting the bias (Palomaki et al., 2017). Palomaki et al. (2017) quantified rotor-induced wind speed errors as 0.5 m/s compared to tower-mounted anemometers and subtracted these errors from the directly measured wind speed values in subsequent analyses (Palomaki et al., 2017). However, this method is limited by the size of the indoor area, inadequate for full simulations of real UAV rotor speed and attitude changes during flight, and insufficient for the development of a comprehensive correction scheme. Additionally, it does not take into account the detailed coupling of true winds with propeller downwash. The third method is similar to the second except the use of wind tunnels to establish a more accurate relationship between increased air speed and UAV motion or attitude parameters (Thielicke et al., 2021; Neumann and Bartholmai, 2015). While effective in determining numerical relationships, the method is limited by the high cost of wind tunnel experiments (Dao et al., 2023), and more importantly, by the additional errors introduced by reflected airflows from the wind tunnel walls and ground (Haleem, 2021; Pettersson and Rizzi, 2008), as well as the same issues of full simulations of real UAV rotor speed and attitude changes during flight."

2.Lines 135ff: The reviewer does not understand, why a matrix of ground-speed and wind-speed variations was used, instead of varying the airspeed? In other word: How is the groundspeed feed into the simulation?

Response: We sincerely apologize for any confusion caused to the reviewers due to insufficient clarity in our original presentation. Regarding the wind speed parameter issue raised by the reviewer, please allow us to provide supplementary clarification:

During the initial design phase of the program, we adopted multi-parameter combinations of wind speed, wind direction, and ground speed to construct simulation scenarios. In the actual implementation of simulations, we converted wind speed and ground speed into airspeed through vector synthesis for simulation calculations. This dual parametrization approach was primarily employed to ensure comprehensive coverage of the flight envelope in our simulation scenarios.

To enhance the clarity of presentation, we have added the following content in Section 2.2 (Lines 180-181) of the revised manuscript:

"It should be noted that the numerical simulations were conducted by converting wind speed and ground speed into airspeed through vector synthesis."

3.Line 193, fig. 2, resp. ch. 2.4: The computational domain is described in detail, but I miss a reasoning for the chosen parameters.

Response: We thank the reviewer for prompting us to clarify the rationale behind the setup of the computational domain.

In the revised manuscript, we have added the following explanation in blue text in Section 2.4 (Lines 213-215) to clarify the rationale for parameter selection:

"The simulation parameters primarily include the computational domain and mesh, fluid and environmental properties, as well as the rotating region. During the CFD flow simulations of the UAV using Solidworks, the computational domain dimensions (3.3 × 3.3 × 3.3 m^3) were determined by prioritizing the analysis of flow field distribution around the anemometer while balancing computational costs."

4.Line 382ff, ch. 3.5: The flight tests are not described adequately in quality and quantity. Thus the data basis of the uncertainty numbers given in line 399 – 401 is not clear. A link to the quite nice fig. 6 and 7 and the uncertainties is missing.

Response: We sincerely appreciate the reviewer's constructive feedback. We would like to respectfully inquire whether Fig. 6 and 7 you referenced might actually correspond to Fig. 9 and 10. This is because Fig. 9 and 10 present the flight test data, whereas Fig. 6 and 7 focus on illustrating the algorithm construction process. If this is the case, to clarify the experimental design and strengthen the connection between flight tests, uncertainty quantification, and Fig. 9-10 (corresponding to Fig. 11-12 in the revised manuscript), we have made the following revisions in Lines 445-466 of Section 3.5 of the revised manuscript:

"A comparative experiment was designed to verify the effectiveness of the correction algorithm described in Eq. (23). The experiment primarily compares three different wind data: the first is the three-dimensional wind vector corrected only for UAV motion and attitude compensation (Eq. (19) and denoted as $\mathbf{V_O}$), the second includes additional corrections for UAV rotor interference, along with motion and attitude compensation (Eq. (23) and denoted as $\mathbf{V_R}$), and the third is the three-dimensional wind directly measured by the meteorological tower (denoted as $\mathbf{V_T}$). The comparison experiment was conducted with the UAV flying wind-boxes around the 80-meter meteorological tower within the Experimental Base of the Beijing Key Laboratory of Cloud, Precipitation and Atmospheric Water Resources. The meteorological tower was equipped with three-dimensional ultrasonic anemometers positioned at heights of 30, 50, and 70 m, with one anemometer in the north and one in the south (see Fig. 10). Experiments were conducted during the daytime on July 19, 2022, with neutral atmospheric stability to minimize thermal boundary layer effects on vertical wind variability.

The UAV flew around the tower in a box flight path at a horizontal distance of about 10 m away from the tower, at all three heights. During these flights, the UAV maintained a commanded horizontal speed of approximately 5 m/s, a value selected as a compromise between achieving sufficient spatial sampling resolution and maintaining stable flight attitude control. A total of 30 independent wind-box flights were conducted, with each altitude (30, 50 m and 70 m) sampled 10 times. Each flight lasted approximately 13 minutes, generating over 800 valid data points per altitude. Given the potential interference from near-surface vegetation on the 30-meter anemometer on the tower, wind velocities acquired by the UAV at 50 and 70 m heights during steady flight intervals were analyzed herein. Using a 3σ threshold of the mean value of the entire dataset to exclude data outliers caused by sudden gusts or UAV maneuvers (such as turning), retaining data during steady UAV flight periods."

Suggestion for minor revisions:

5.Line 249ff, fig. 3 to 5: I suggest a uniform scaling for the color bar.

Response: We sincerely appreciate the reviewer's valuable suggestion regarding color bar consistency. We fully acknowledge the importance of maintaining consistency in visualization for effective comparison across figures.

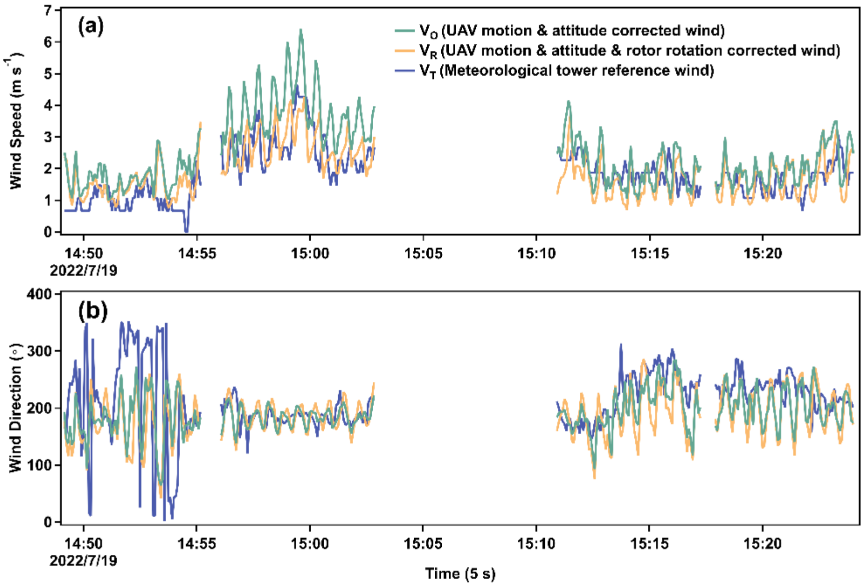
We initially implemented uniform scaling (0-18 m/s) for Fig. 3-5 during revision. However, upon closer examination, we observed that the larger simulated airflow velocities in Fig. 3 and 5 fell within the yellow-green spectrum, making it challenging to visually distinguish subtle velocity variations critical to understanding rotor-induced airflow patterns.

After careful consideration, we opted to optimize the color bar ranges individually for each figure to enhance contrast in regions of scientific interest and maintain resolution of velocity gradients across different flight scenarios.

We would be happy to implement alternative visualization strategies if the reviewer feels this approach could be improved.

6.Fig. 9: Instead of V0, VR, VT better write a full word description into the legend.

Response: We would like to express our sincere gratitude to the reviewer's valuable suggestion. In the revised manuscript, we have added a complete description of the legend in Figure 11 (corresponding to Figure 9 in the original manuscript), as detailed below:


(a)
VO (UAV motion & attitude corrected wind)
VR (UAV motion & attitude & rotor rotation corrected wind)
VT (Meteorological tower reference wind)
Wind Speed (m s-1)
0
1
2
3
4
5
6
7
14:50
2022/7/19
14:55
15:00
15:05
15:10
15:15
15:20
(b)
Wind Direction (°)
0
100
200
300
400
14:50
2022/7/19
14:55
15:00
15:05
15:10
15:15
15:20
Time (5 s)