Responses to the Reviewer 2 comments

(comments in black, responses in red)

General comments:

The manuscript demonstrates a rigorous comparative analysis of three DWLs under different atmospheric conditions and integrates novel ML techniques to address data anomalies and gaps. The findings on PBLH-dependent lidar performance have direct implications for urban air quality studies and wind energy applications, where boundary layer dynamics are paramount. The proposed IF-RF pipeline offers a scalable solution for operational lidar networks, particularly in polluted regions with high aerosol variability. By evaluating lidar performance against radiosonde and satellite datasets, the study provides actionable insights into the interplay between aerosol dynamics, boundary layer processes, and instrument accuracy. While the work is methodologically robust, several areas require refinement to enhance clarity, statistical rigor, and physical interpretability. I consider this manuscript adequate for publication in Atmospheric Measurement Techniques once my comments are addressed.

Dear Reviewer,

We extend our sincere gratitude for your thorough and insightful review of our manuscript, "Comparison of the Performance between Three Doppler wind Lidars and a Novel Wind Speed Correction Algorithm." Your expertise has been invaluable, particularly regarding: the scarcity of wind field data in the PBLH layer, impacts of aerosol hygroscopic growth and cloud microphysics on radar signal attenuation, temporal resolution limitations of ERA5 reanalysis data, the influence of aerosol concentration on radar performance and so on. After the revision the logic structure and scientific statement has been significantly improved. We have carefully addressed each point raised—revising sections for precision, enhancing methodological explanations, clarifying details where needed. The manuscript has been significantly improved as a direct result of your meticulous review.

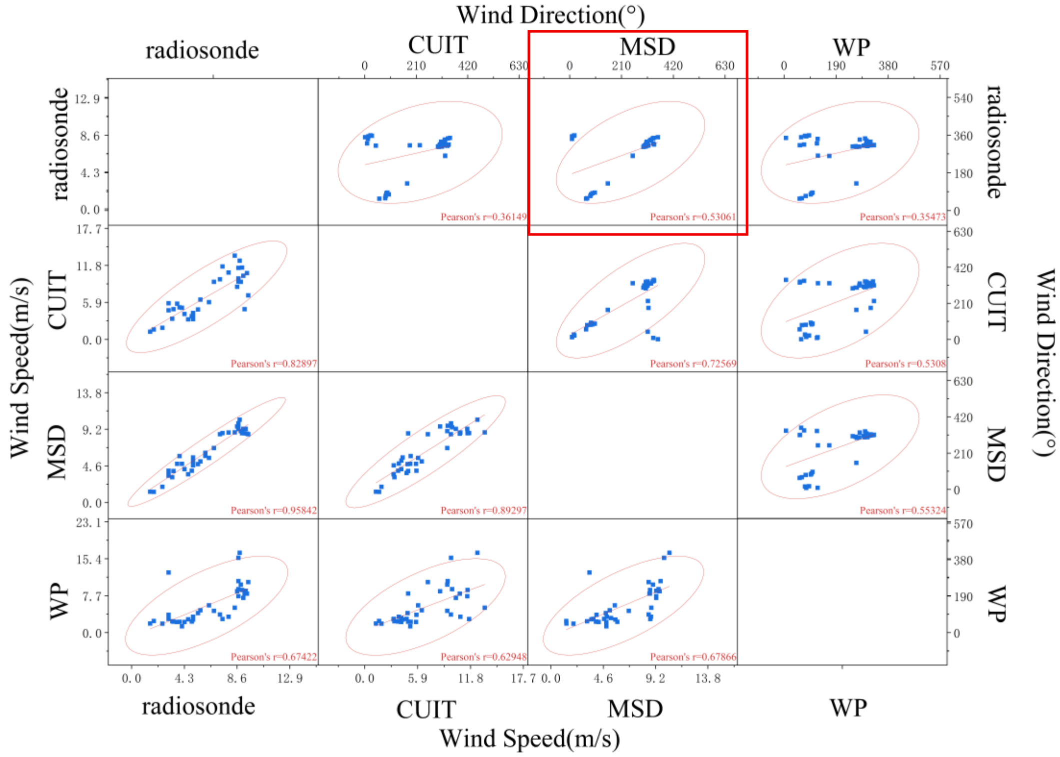
The following are the detailed responses:

Major comments:

1.The manuscript should explicitly acknowledge the significant disparity in sample sizes across the analyzed PBLH strata, particularly the notably small sample (N = 41) within the 1500–1750 m stratum. This limited representation inherently reflects the rarity of PBLH events in the study region, as discussed in Section 3.3 ('PBLH’s impact on Doppler wind Lidars'). Consequently, any statistical interpretations or conclusions drawn specifically from this stratum require considerable caution and should be clearly qualified. We recommend discussing the limited statistical power and the inherent challenge of capturing sufficient events.

Reply: In section "3.3 PBLH’s impact on Doppler wind Lidars," line L280 state that within the PBLH range of 1500–1750 m, the Lidar data samples are relatively few (N=41). However, for the MSD Lidar, wind speed was unaffected and even showed a high correlation (0.96); it was the particularly poor performance in wind direction (0.53) that stood out.

The following figure shows the correlation analysis of wind speed and directions between radiosonde and three Lidars at the PBLH of 1500-1750 m. The selected part shows that the wind direction correlation coefficient between radiosonde and MSD is 0.53. Although there is less data at this range, it can be seen that the strong correlation of wind speed, while the weak correlation of wind direction due to the large deviation.



Yamartinoz proposed [1] that even when wind speed errors are small, wind direction errors can be significant, especially under low wind speeds or strong turbulence conditions. Wind direction is more sensitive than wind speed to localized, instantaneous small-scale turbulent disturbances or slight variations in airflow direction. A brief shift in airflow or a vortex can significantly alter instantaneous wind direction measurements but may have a smaller impact on average wind speed. Within the high PBLH layer (near the boundary layer top), turbulent intermittency, entrainment processes, and residual layer influences are typically stronger, potentially leading to more unstable airflow direction.

The 1500–1750 m range represents a relatively high boundary layer height, which may correspond to a thicker aerosol layer with potentially more heterogeneous vertical structure (multi-layered, concentration gradients, particle properties). If these aerosol populations carry slightly different local wind information (e.g., due to slight wind shear) or if low aerosol concentration reduces the signal-to-noise ratio, the synthesized wind direction vector will contain greater uncertainty.

Lothon, M. et al.[2] demonstrated that complex turbulent structures and aerosol distributions, which complicate wind field (especially direction) measurements, are typically present at the boundary layer top (high PBLH regions).

We will revise the text in the manuscript to: "However, its wind direction correlation notably decreased to 0.53 within the 1500–1750 m PBLH range, likely attributable to enhanced aerosol-layer complexity at elevated mixing heights and the small samples in this range (N = 41). Although the sample size within this PBLH is relatively less, wind speed was unaffected; only the poor performance in wind direction was particularly prominent. This may be due to complex turbulent structures and aerosol distributions leading to wind direction instability."

2.The study links PBLH and CBH to DWL performance but does not address how cloud microphysical properties (e.g., hydrometeor phase, particle size distributions, liquid/ice water content) modulate signal attenuation. High humidity under coupled PBLH-CBH conditions likely promotes hygroscopic growth, altering aerosol scattering properties. This microphysical-aerosol interaction mechanism is especially critical to consider in complex, polluted urban environments like Beijing, where aerosol loading and composition are highly variable and can profoundly influence lidar performance. We strongly recommend the authors discuss this potential mechanism and its implications for their findings, or explicitly acknowledge this limitation for future work.

Reply: The coupling ratio between cloud and PBLH reaches to 90% under high PBLH conditions. Such regimes feature elevated relative humidity, intensified turbulent mixing, and complex aerosol stratification – all exacerbating lidar signal interference. We acknowledge that the current lidar performance evaluation (particularly in high PBLH-CBH coupled regimes) may be subject to potential interference from aerosol-cloud microphysical interactions. Under high PBLH-CBH coupling (e.g., PBLH > 1000 m and CBH < 1000 m), elevated cloud liquid water content and aerosol hygroscopic growth may interfere with wind vector retrieval accuracy by altering backscattering profiles. Notably, during our summer campaign in Beijing, cloud bases were typically elevated, resulting in infrequent occurrences of PBLH > CBH conditions. This observational constraint limited our ability to systematically investigate hygroscopic growth processes under strong PBLH-CBH coupling scenarios.

3.Ambiguity in High-Aerosol Performance: The assertion that peak lidar accuracy occurs at PM2.5=35-50 μg/m³ (L3) contradicts conventional lidar attenuation models. The conclusion that higher PM2.5 concentrations (35-50 μg/m³) enhance lidar performance (e.g., Sec. 3.2, Fig. 5) merits further discussion. Given that dense aerosol layers are known to cause signal attenuation (reducing penetration depth and SNR), the observed performance improvement under polluted conditions (L3) appears paradoxical. We recommend expanding the physical interpretation to address how attenuation effects were overcome in this study.

(a) Lidar fundamentals: High aerosol loads increase attenuation, degrading SNR.

Reply:

While aerosols are crucial scattering targets for coherent Doppler lidar, their excessive concentration leads to substantial signal attenuation, a well-documented phenomenon. China's ambient air quality standards categorize conditions based on $PM_{2.5}$ levels as follows:

Air quality grade	$PM_{2.5}$ levels
Excellent	0–35 μg/m³
Good	35–75 μg/m³
Light Pollution	75–115 μg/m³
Moderate Pollution	115–150 μg/m³
Heavy Pollution	150–250 μg/m³
Severe Pollution	⩾250 μg/m³

Wu et al. [3]mentioned that by combining MODIS satellite data with ground observations, the relationship between $PM_{2.5}$ concentration and aerosol optical thickness (AOD) was quantified, and it was pointed out that the inversion error of lidar increased under high $PM_{2.5}$ concentration. When $PM_{2.5}$ > 100 μg/m³, AOD > 0.8, and the attenuation rate of the radar signal increases by more than 40%.

Our study, conducted during the summer months (June-August) in Beijing—a period characterized by naturally lower aerosol burdens—stratified data into three levels for methodological clarity:

L1: PM2.5 = 0–15 μg/m³
L2: PM2.5 = 15–35 μg/m³
L3: PM2.5 = 35–50 μg/m³
Notably, our results show enhanced lidar performance sensitivity at the L3 level (35–50 μg/m³). This aligns with the concentration threshold where aerosol scattering optimizes the signal-to-noise ratio before triggering severe attenuation. We recognize that the original manuscript's phrasing was potentially ambiguous. To prevent misinterpretation, we will revise the manuscript to explicitly state: " The observed performance improvement at L3 concentrations reflects that the Lidar requires a certain amount of aerosol backscattering rather than implying superior functionality under polluted conditions."

4.It is necessary to discuss the limitations of the temporal resolution of ERA5 reanalyzed data. Analyzing ERA5 data's accuracy is not as precise as the radiosonde, please discuss the issue of time resolution.
Reply: The time resolution of the PBLH and CBH of the ERA5 reanalysis data is one hour. During the research period of this paper, the radiosonde balloon was released at 7:15 a.m. and 7:15 p.m. every day. The three Lidars matched the time and altitude through the sliding window method, and the data of ERA5 also matched exactly.

Minor comments:
1.Pay attention to the use of plural, like DWLs and DWL···
Reply: We will carefully examine these statements to confirm all the expressions of plural.
2.Line 12, Units must be written exponentially (e.g. W m–2).
Reply: According to the "Figures & tables" section in the submission requirements on the official website, we have revised it to exponentially units (m s-1) in the manuscript.
3.Line 75-77, please add references.
Reply: We have added references [4] to the manuscript.
4.Line 77-78, please check whether the reference is correct.
Reply: we have revised it to "Siying et al. examined the seasonal variation in Aeolus satellite detection performance in China by combining ERA5 and radiosonde data, concluding that the satellite's performance is influenced by seasonal factors (Siying et al., 2021)".
5.Line 92, Coordinates need a degree sign and a space when naming the direction (e.g. 30° N).
Reply: We have modified the direction in the manuscript, in accordance with the submission requirements on the official website. (e.g. 39.80° N)
6.Line 96, Common abbreviations to be applied: hour as h (not hr), kilometre as km, metre as m.
Reply: According to the "Figures & tables" section in the submission requirements on the official website, we have revised it to "h", "km", "m".
7.Line 145, what is the IF
Reply: We have revised the manuscript to "The isolation forest (IF) model…"
8.Results and discussions should be 3, and. 1.3.1 Isolation tree should be 2.2.1···.
Reply: We didn't carefully check the subheadings. We have modified "1.3.1 Isolation tree" to "2.2.1 Isolation tree ". and "1.3.2 Anomaly Detection" has been modified to "2.2.2 Anomaly Detection ".
9.Line 317, what is ROC?
Reply: We have revised the manuscript to "the comparison of the Receiver Operating Characteristic

(ROC) curves…".

10.Line 339, what is AUC?

Reply: We have revised the manuscript L318 to "The Area Under the Curve (AUC) metrics…".

11.Line 382, ranges need an endash and no spaces between start and end (e.g. 1–10, Jan–Feb).

Reply: In the requirements for manuscript submission, ranges need an endash and no spaces between start and end (e.g. 1–10, Jan–Feb). We will examine the full text and make corrections.

12.Avoids accusatory language (e.g., "contradicts" → "appears counter to," "warrants deeper analysis")

Reply: We will carefully examine these statements to confirm all the expressions.

13.Line 419, "RF-based correction of CUIT enhanced R^2 from 0.42 to 0.65" → "RF correction significantly enhanced R^2 from 0.42 to 0.65".

Reply: L419: The statement "RF-based correction of CUIT enhanced R^2 from 0.42 to 0.65" has been revised to "RF correction significantly enhanced R^2 from 0.42 to 0.65".

14.Simplify conclusions and avoid redundant expressions.

Reply: We will carefully examine the manuscript to avoid redundant expressions and make the article more coherent.

References:

1. YAMARTINO, *A COMPARISON OF SEVERAL SINGLE-PASS ESTIMATORS OF THE STANDARD-DEVIATION OF WIND DIRECTION.* JOURNAL OF CLIMATE AND APPLIED METEOROLOGY, 1984. **23**(9).
2. Lothon, *Doppler Lidar Measurements of Vertical Velocity Spectra in the Convective Planetary Boundary Layer.* BOUNDARY-LAYER METEOROLOGY, 2009. **132**(2).
3. Wu, J., et al., *VIIRS-based remote sensing estimation of ground-level PM2.5 concentrations in Beijing–Tianjin–Hebei: A spatiotemporal statistical model.* Remote Sensing of Environment, 2016. **184**: p. 316-328.
4. Guo, J., et al., *Technical note: First comparison of wind observations from ESA's satellite mission Aeolus and ground-based radar wind profiler network of China.* Atmospheric Chemistry and Physics, 2021. **21**(4): p. 2945-2958.