Reply to Anonymous Referee # 1 Comment on 'Measurement report: Vehicle-based and In Situ Multi-lidar Observational Study on the Effect of Meteorological Elements on the Three-dimensional Distribution of Particles in the Western Guangdong–Hong Kong–Macao Greater Bay Area'

comments:

The measurement report 'Vehicle-based and In Situ Multi-lidar Observational Study on the Effect of Meteorological Elements on the Three-dimensional Distribution of Particles in the Western Guangdong–Hong Kong–Macao Greater Bay Area' focuses on the analysis of data collected by different lidar systems which were mounted on a vehicle during several day-time research tours in the western Guangdong–Hong Kong–Macao Greater Bay Area in China. This dataset is complemented by ground based lidar measurements during night-time at the Haizhu Lake research base. The goal of the study is to characterize the typical vertical distributions of aerosols over the research area.

I consider such a measurement campaign as an important contribution to the understanding of pollution in Chinese metropolitan regions. However, the determination of three different types of vertical aerosol distributions from just three night-time lidar measurements in one specific month of the year seems to be cherry-picking and inadequate. For a possible publication in ACP I wished for a longer measurement period and an in-depth analysis of the observations which may fortify the stated hypotheses in this manuscript. In my opinion, the current manuscript is more like a data-paper or paper of first observations which may be published elsewhere in more appropriate journals like for example ESSD.

In addition to that I found much room for improvement when reading through the manuscript, i.e. in the description of the employed methods, in the presentation of the analyzed data, the interpretation of the collected data as well as in the discussion of the results. Unfortunately, some parts of the manuscript were also hard to review because of poor English language.

I strongly encourage the authors to thoroughly revise the submitted manuscript with regard to these points for a possible resubmission. I also encourage the authors to involve a native speaker for proofreading before resubmitting.

This is why I tried to do my best in outlining the specific points that motivated my decision and that should be considered when revising the paper.

Reply:

We would like to thank you for the careful review of our manuscript. We have thoroughly revised the manuscript based on all your comments and suggestions. We sincerely appreciate your comments on language errors. We are currently revising the manuscript and checked carefully to avoid typos.

One of your main points was that the determination of three different types of vertical aerosol distributions from three night-time lidar measurements in one specific month of the year seems to be inadequate. We feel sorry that our description of the experiment was not sufficient enough, which caused your misunderstanding. We conducted vehicle-based lidar observation experiments from September 10 to October 8, 2019, and from August 29 to October 27, 2020. During 89 days of continuous observation, and we found that most of the aerosol vertical distributions are consistent with these three distribution types. Due to space limitations, we only selected the three most representative processes for analysis. Details about the measurement has also been added to the manuscript.

General comments:

comments:

As lidar is an active remote sensing technique and not an in-situ measurement technique, the phrase 'in-situ' in the manuscript/title is misleading.

Reply:

We have replaced 'in-situ' with 'fixed-location'. At the same time, we apologize for the misleading. All lidar data used in this manuscript are derived from vehicle-based lidars, including data of fixed-location observations and mobile observations.

comments:

The abstract should be written in present tense

Reply:

We have rewritten the abstract into the present tense.

comments:

The instrument platform has to be better described. In the current form of the manuscript the reader has no idea of the setup and the vehicle that was used. What type of car did you use? How have the instruments been mounted onto the car? How fast did the vehicle go? I guess you did not drive the vehicle with constant speed, but you had to adapt the speed of the vehicle to the traffic condition.

Reply:

Thank you for your suggestion! We have added information about the instrument platform. The car we used was a modified 7-seater Mercedes-Benz sport utility vehicle. Three lidars were fixed to the rear of the car by steel bars to ensure their stability. In order to avoid the impact of frequent changes in speed and vehicle bumps on the observation, the routes were basically flat highways, and the driving speed was controlled within 80 km/h.

comments:

The measurements of the research trips are only described on a half-page. I wished for an in-depth description and discussion of the collected data. What was the motivation for the chosen route that

you drove along? How long does it take to drive the 320 km? Why did you only go during daytime? When did you start with the measurement-circle? In the morning hours? I can imagine that it makes a difference if you start measuring in the morning hours compared to starting in the afternoon hours.

Reply:

Thank you for your suggestion! We have added more information about our measurements. The reason for choosing this route is that it covers the major urban agglomerations in the western part of the Guangdong-Hong Kong-Macao Greater Bay Area, which contains a large number of aerosol anthropogenic emission sources. It is representative for studying the regional distribution of particles in this area. We conducted mobile observations once a day, from August 29 to September 4, 2020. The set off time was at 10:00 and a single measurement-circle was completed at around 16:00. Due to the surface heating, convection in the boundary layer develops vigorously during daytime, which allows the aerosol to mix well in the boundary layer and form a more homogeneous distribution vertically. Therefore, it is more suitable to conduct mobile observations during the daytime to study the horizontal distribution of particles in the GBA area. Meanwhile, according to our observations, aerosols are more likely to have different types of vertical distribution nocturnally, which motivated us to continuously conduct fixed-location observations at night on days that we made a mobile observation in the daytime. Details of our observations were shown in the table below.

Time	Observation
Sept. 10 – Oct. 8, 2019	Fixed-location observation
Aug. 29 – Sept. 4, 2020, in the daytime	Mobile observation
Aug. 29 – Sept. 4, 2020, at night	Fixed-location observation
Sept. 5 – Oct. 27, 2020	Fixed-location observation

comments:

Even though you added the links to the webpages of the respective lidar systems, I wished for a more detailed introduction of the used instruments as well as of the instrument setup on the vehicle. What are the measurement uncertainties? What are the limitations of the instruments? How did the setup on the vehicle look like?

Reply:

We are currently collecting relevant information from manufacturers. We have previously compared simultaneous observations from two meteorological observation towers in Beijing and Shenzhen with the lidar system. The results show that observations of this lidar system was highly accurate and suitable for studying. We have also used this lidar system in our previous research and have shown them to be reliable (He et al., 2021a; He et al., 2021b). The setup on the vehicle was shown in the figure below.

He, Y., Xu, X., Gu, Z., Chen, X., Li, Y., and Fan, S.: Vertical distribution characteristics of aerosol particles over the Guanzhong Plain, Atmospheric Environment, 255, 118444, https://doi.org/10.1016/j.atmosenv.2021.118444, 2021a.

He, Y., Wang, H., Wang, H., Xu, X., Li, Y., & Fan, S.: Meteorology and topographic influences on nocturnal ozone increase during the summertime over Shaoguan, China, Atmospheric Environment, 256, 118459, https://doi.org/10.1016/j.atmosenv.2021.118459, 2021b.

comments:

Have the ground-based lidar observations at Haizhu Lake Research Base been conducted with the same instruments that were also mounted onto the vehicle? Why don't you show time-height lidar plots from data collected on the vehicle? Why was some of the data collected in September 2019 and some of the data collected in September 2020? What was the motivation to choose only the month of September?

Reply:

We have added more information about the equipment. All our fixed-location observations and mobile observations were done using the same vehicle-based lidar system. During fixed-location observations, the car was parked in the observation field and connected to a stable power source. As we pay more attention to the horizontal distribution of aerosols during the mobile observations, and also limited by space, we did not show time-height lidar plots. We conducted lidar observation experiments from September 10 to October 8, 2019, and from August 29 to October 27, 2020. The reason for choosing these two months is that September and October are the periods when the wet season changes to the dry season in the GBA area. Therefore, changes in meteorological elements have a significant impact on the three-dimensional distribution of particles.

comments:

Although this paper is a measurement report, it's vague to define three types of aerosol distributions from single observations in autumn. Would long-term lidar measurements at the Haizhu Lake Research Base be available to conduct a statistical analysis of the typical aerosol layering over different seasons of the year in the region? This would substantiate your hypotheses.

Reply:

Thank you for your suggestion! The Haizhu Lake Research Base is located in the centre of the metropolis Guangzhou, so it is representative for studying the distribution of urban aerosols. Unfortunately, there is only ground observation equipment in the base. This motivated us to park the car in the base and conducted a total of 89 days of fixed-location observation. During 89 days of continuous observation, we found that most of the aerosol vertical distributions are consistent with these three distribution types. Due to space limitations, we only selected the three most representative processes for analyzing the three distribution types. Statistical analysis was conducted when studying the extinction coefficient at different wind speeds in 3.3.1, using the fix-location observation data of 89 days.

comments:

Could you also discuss the possible impact of the topography on your measurements? The research area seems to be a basin surrounded by a quite hilly/mountainous region.

Reply:

That is a very good suggestion. The research area is on the Pearl River Delta Plain. The area is bordered by the Nanling Mountains in the north. The obstruction of mountains makes the GBA area less susceptible to long-distance transport of pollutants from other areas. The transport of pollutants mainly occurs between cities in the research area. We have added this content to the manuscript.

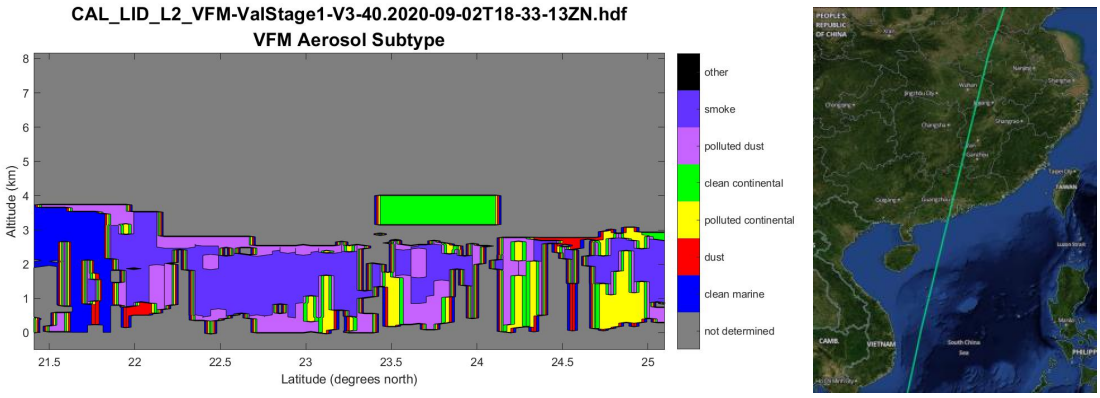
comments:

You could go into more detail with analyzing the lidar data. What aerosol types do you observe? Could it be possible that marine sea salt contributes to the observed aerosol layers as you have observed a southerly component of the wind speed at low altitudes (especially during Type 1).

Reply:

Thank you for your suggestion! We used micro pulse lidar for aerosols observation. The obtained extinction coefficient generally reflects the strength of light absorption by the total aerosol in the air. It cannot distinguish the type of different aerosols. In this study, we are more concerned about the anthropogenic particulate matter in the metropolis, therefore sea salt aerosols are not in our focus. Fortunately, the CALIPSO satellite passed just a few hours before Type 1 over the observation area, so we also plotted the corresponding VFM aerosol subtype data from the CALIPSO satellite inversion, and the results show that there is a low level of sea salt aerosols in our region of interest.

However, in future studies we will also consider adding equipment for measuring aerosol components.



Nearly all figures and their captions have to be revised, as many things remain unclear to the reader (for details see below).

Specific comments:

comments:

Figure 1: For a better comparison and to condense the information shown you could use wind barbs and plot them in Figure 4.

Reply:

Thank you for your suggestion. We couldn't agree more. We are currently revising the images based on this suggestion.

comments:

Formula 1: Please motivate why you have chosen a fixed value of S = 50 sr for the conversion to the extinction coefficient.

Reply:

S = 50 sr was the default value given by the manufacturer. This value was consistent with prior work in the GBA area (Li et al., 2020).

Li, Y., Wang, B., Lee, S. Y., Zhang, Z., Wang, Y., and Dong, W.: Micro-Pulse Lidar Cruising Measurements in Northern South China Sea, Remote Sensing, 12(10), 1695, https://doi.org/10.3390/rs12101695, 2020.

comments:

What is k representing in formula (2). What depolarization ratio are you exactly measuring? According to the formula it is the volume linear depolarization ratio.

Reply:

Thank you for your suggestion! k is the depolarization calibration constant, which is the ratio of the gains of the parallel and perpendicular channels (Dai et al., 2018). This content has been added to the manuscript.

Dai, G., Wu, S., and Song, X.: Depolarization ratio profiles calibration and observations of aerosol and cloud in the Tibetan Plateau based on polarization Raman lidar, Remote Sensing, 10(3), 378, https://doi.org/10.3390/rs10030378, 2018.

comments:

Line 192: '…wind direction over the observation points…' I don't understand what points you mean. Which instrument was used for the measurements? Please clarify.

Reply:

This should be 'location' rather than 'points'. We are sorry that we have made a mistake in our wording and have caused you to misunderstand. The instrument used for this measurement is the Doppler wind profile lidar.

comments:

Line 195: How exactly can low wind speeds at low altitudes act as a disincentive for regional transport at higher altitudes? Please explain in more detail.

Reply:

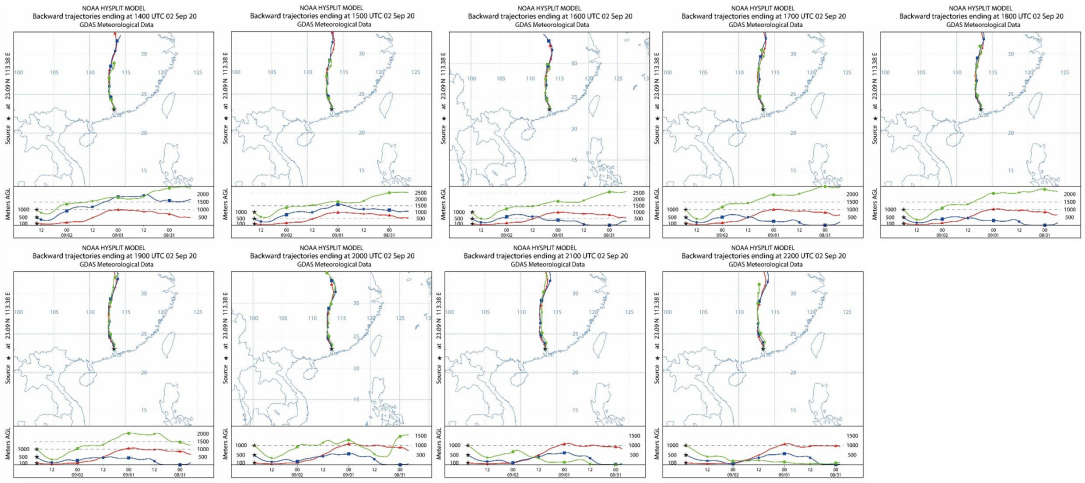
We would like to express that low wind speeds near the surface favour the accumulation of locally generated particles and that low wind speeds at higher altitudes (500-1000 m) are not conducive to the transport of particles from surrounding areas over the observation location. We have revised the manuscript to avoid confusion.

comments:

Line 208: Why did you choose 22 LT as starting time for your trajectory calculations? From the shown wind measurements, you already see that later in the night the wind (at 540 m) shifts to the South. I could imagine that a starting point later in the night would show a completely different result.

Reply:

We have calculated every time of the process. The results of HYSPLIT calculation are shown in the figure below. HYSPLIT model calculations based on reanalysis data yielded that the trajectory came from the north at all times of the process. Due to space constraints, we have selected only one representative figure. This also shows that the use of remote sensing instruments such as Doppler wind lidar could capture changes that are not included in the reanalysis data.



comments:

Line 226: Aerosol is always suspended in the air, also when it's located near surface. Please correct.

Reply:

Thank you for your suggestion! We have corrected this incorrect wording.

comments:

Line 234: I don't understand this sentence. What 'unconverted primary particulate matter' are you meaning? Sea salt? Depolarization predominantly depends on the shape of the particles.

Reply:

In this context we refer to primary pollutant emissions from anthropogenic sources near the surface, including industrial emissions, traffic emissions, etc. We have revised the manuscript to avoid confusion. According to existing studies, particle depolarization ratio from lidar is an indicator of non-spherical particles and is sensitive to the fraction of non-spherical particles and their size (Burton et al., 2015). If aerosol particles are small in size, they often show a spherical character when observing them with a micro pulse lidar, and the value of the depolarization ratio of the aerosol is small.

Burton, S. P., Hair, J. W., Kahnert, M., Ferrare, R. A., Hostetler, C. A., Cook, A. L., Harper, D. B., Berkoff, T. A., Seaman, S. T., Collins, J. E., Fenn, M. A., and Rogers, R. R.: Observations of the spectral dependence of linear particle depolarization ratio of aerosols using NASA Langley airborne High Spectral Resolution Lidar, Atmos. Chem. Phys., 15, 13453–13473, https://doi.org/10.5194/acp-15-13453-2015, 2015.

comments:

Chapter 'Conclusion' is rather a summary than a conclusion.

Reply:

Thank you very much for your advice! We have rewritten the chapter to condense our findings.

comments:

Line 384: I guess that according to the ACP-Guidelines data should be made freely available in an online repository.

Reply:

Yes, we will make the data public.

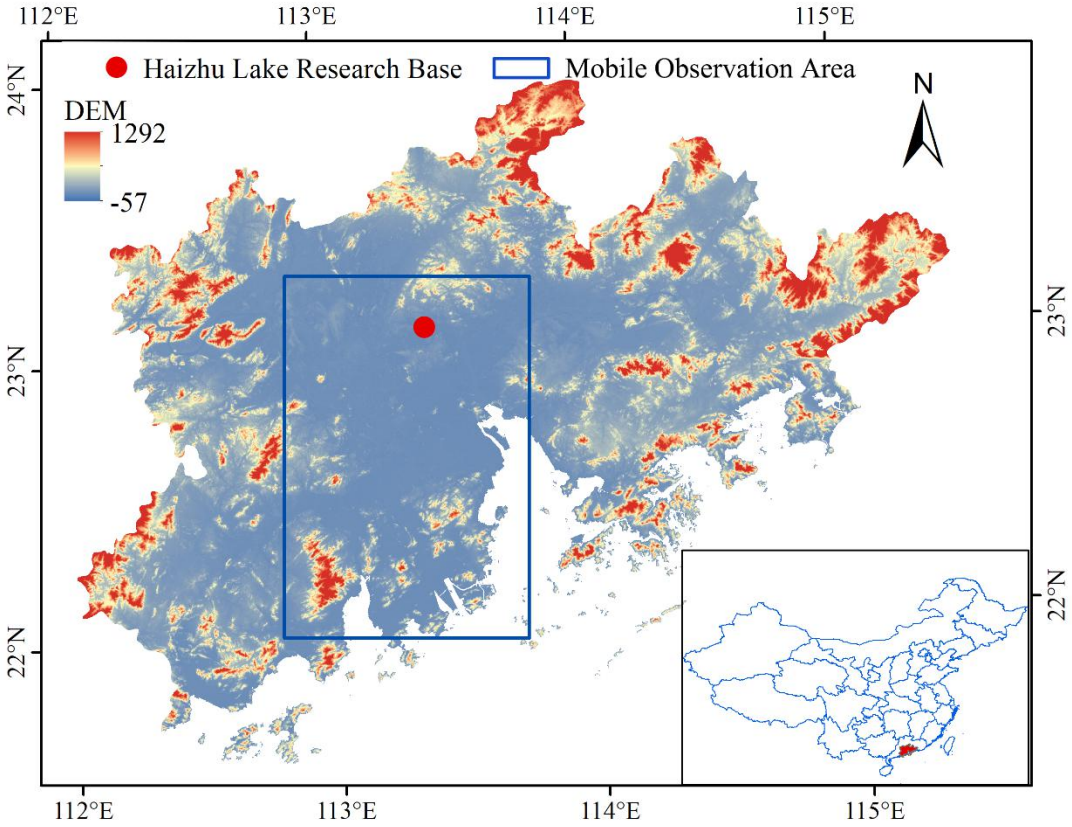
Specific comments to shown figures:

comments:

Figure 1: Y-Axis – a sequential colormap instead of a diverging colormap would fit better? Where did you take the underlying Altitude data from? It's not clear to the reader. The resolution seems to be quite coarse.

Reply:

Thank you very much for your suggestion! The altitude data we used before has a resolution of 0.033 degrees. We have used data with higher resolution for the plots, as well as a sequential colormap.



comments:

Figure 2: Please label the colorbar and axes and add information at what wavelength AOD has

been measured. Are the AOD-measurements averaged over time? Why do you only show vertically integrated point-measurements and no continuous and height-resolved measurements?

Reply:
Thank you very much for your suggestion! We are currently modifying the figure following your suggestion. The AOD measurements are averaged over a short period of time. As in this chapter we focus on the horizontal distribution of particles in the GBA area, we use AOD figure for our discussion.

comments:
Figure 3: Please label the shown axes and clarify from which model the wind field has been retrieved. Could you indicate the research area in these plots? This would make it easier for the reader to compare Figure 2 to Figure 3.

Reply:
Thank you very much for your suggestion! We are currently modifying the figure following your suggestion.

comments:
Figure 4: Is the figure showing lidar measurements? Or is the data collected form a model? What is the y-axis showing? Depolarization ratio at 532 nm?

Reply:
This figure shows lidar measurements. Y-axis refer to the altitude above instrument. Extinction coefficient and depolarization ratio at 532 nm are shown in figure (a) and (b) respectively.

comments:
Figure 5: Clarify meaning of Y-axis? Altitude above sea level or above instrument? Why does it only show 4 h of data and not 8 h like the lidar data in Figure 4?

Reply:
Y-axis refers to the altitude above instrument. Due to equipment failure, the Doppler wind profile lidar was not able to capture data after 03:00, so we only show data before 02:33.

comments:
Figure 7: Please use SI-units: Kelvin instead of degrees Celsius and clarify meaning of Y-axis. Altitude above sea level or above vehicle? Please indicate the measurement uncertainty of the Raman-Temperature measurements.

Reply:
Thank you very much for your suggestion! Y-axis refer to the altitude above instrument. We are currently modifying the figure and adding information following your suggestion.

comments:

Figure 8: Same suggestions as for Figure 4.

Reply:

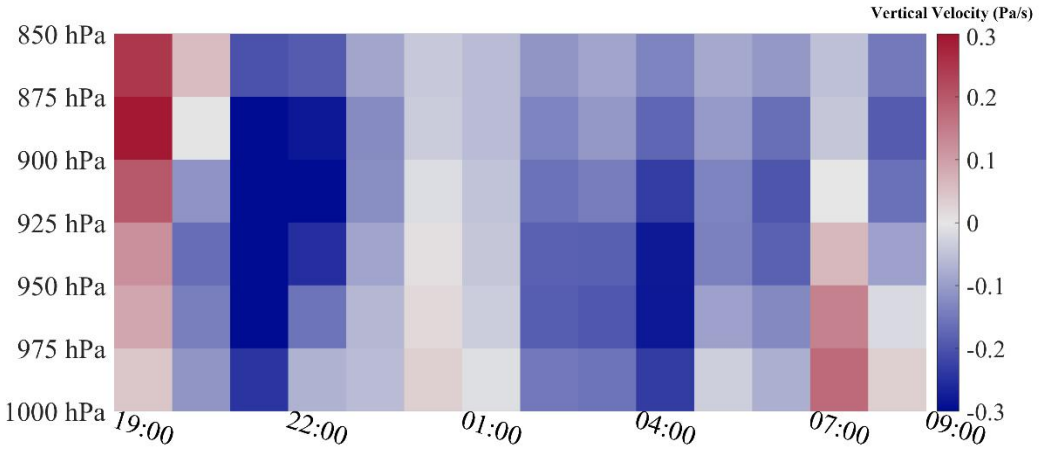
This figure also shows lidar measurements. Y-axis refer to the altitude above instrument. Extinction coefficient and depolarization ratio at 532 nm are shown in figure (a) and (b) respectively.

comments:

Figure 10: What is going on between 19 pm LT and 19:30 pm LT? Please modify the range of the colorbar to resolve the magnitude of the apparent updraft.

Reply:

Thanks to your correction, we have adjusted the plotting method and the result is shown below. We can see that the area was controlled by downdrafts until 20:00, after 20:00 it changes to updrafts.



comments:

Figure 11: Same suggestions as for Figure 4. Where are these periodic oscillations in the first half of the night in the lidar signals coming from? Is this a natural phenomenon or a measurement-artefact?

Reply:

This figure also shows lidar measurements. Y-axis refer to the altitude above instrument. We consider these periodic oscillations as a measurement-artefact rather than a natural phenomenon.

comments:

Figure 12: Same suggestions as for Figure 5.

Reply:

Y-axis refer to the altitude above instrument. We have added the information in caption.

comments:

Figure 14: Same suggestions as for Figure 7.

Reply:
Thank you very much for your suggestion! Y-axis also refer to the altitude above instrument. We are currently modifying the figure and adding information following your suggestion.

comments:
Figure 15: From where has the wind speed data been taken? Please clarify in caption.

Reply:
Thank you for your suggestion! Wind speed data was obtained from fixed-location observations at Haizhu Lake Research Base using the Doppler wind profile lidar. We have added the information in caption.