Answer: We would like to thank referee 2 for reading the article thoroughly, and for the detailed corrections that he suggests to improve the paper's impact on the scientific community. We appreciate that referee 2 says "The work is certainly of interest to readers working in the field of active remote sensing, and particularly to the wind lidar community", that he finds the article "well-structured" and that the "figures support the intriguing findings derived from the simulations". All his comments have been addressed in the following and the paper have been modified in this regard. We have also added small additional modifications throughout the paper to improve its quality. Please consider this revised manuscript for publication in AMT.

Please find bellow more detailed response to the referee 2:

Anonymous Referee : However, given the results reported in the paper, I am wondering a) to what extent the developed end-to-end simulator is applicable to other wind lidar instruments based on a QMZ (not necessarily for GLA), b) what the major limitations of the simulator are, c) what refinements of the simulator are planned in the future, and d) if (or when) experimental validation of the simulation results with the described instrument is foreseen. In my opinion, these four relevant questions are currently unaddressed and should be discussed in the conclusions section of the manuscript.

a) to what extent the developed end-to-end simulator is applicable to other wind lidar instruments based on a QMZ (not necessarily for GLA)

Answer:

a) Concerning the simulation of the atmosphere, the model can be extended to any simulation below 20 km of altitude as the molecular distribution is describes by the US standard atmosphere model. Concerning the Mie scattering, the difficulty is to model correctly the backscattering coefficient as it change with time/location/ altitude and so on. In our model we assumed beta = 8e-6 $m^{-1}.str^{-1}$ under 1 km of altitude and 0 above. This value is the median for the particle backscattering coeficient at 355 nm according to (Herbst, 2016). This could be refined.

   The code for the simulation of the telescope (calculation of the overlap function) can also be extended to other telescope configuration. For example, the study (Boulant et al., 2023) present the work we have done to modify the architecture for space based wind measurement.

   We also use the simulator to optimize an Aeolus-like lidar that use UV fiber laser and a QMZ interferometer as spectral analyzer. In conclusion, we propose to add line 365:

   "The simulations focused on GLA application, but the simulator can be applied to other QMZ lidar configuration performing wind measurement from space or in High altitude platform. In particular, we used previously this simulator to calculate lidar performances for wind measurement from space using the same architecture as Aeolus, but replacing the laser by a theoretical UV fiber laser and the two spectral analyzers of Aeolus by one QMZ interferometer (Boulant et al., 2023)."

   b) what the major limitations of the simulator are, c) what refinements of the simulator are planned in the future,

The major limitations of the simulator that will be refined latter are the following:

- We assume a transmission of the optics of 50% from the telescope to the QMZ entrance. This will need to be refined with experimental value.
- We assume a perfect interferometer with a contrast of 1. The imperfection of the optics and of the transmission/reflection may reduce the contrast. It may also lead to different transmission and contrast on each arm. This will be taken into account in future simulations with experimental values of transmissions and contrast.

d) if (or when) experimental validation of the simulation results with the described instrument is foreseen.

The instrument is currently under development and should be tested soon.

We have added this paragraph in conclusion, after the first paragraph :

The lidar is being assembled and the first validation will be performed soon. All the instrument characteristics (different noise levels, instrumental transmission and so on) will be performed and compared with simulation. In particular, the contrast of the different channel and the phase differences between channels of the QMZ will be measured and simulated to evaluate their effect on the lidar performances to refine the calculation of the performances of the system.

Specific comments:

1. **Given the multitude of system parameters discussed in the text, I strongly suggest to add a table that summarizes the specifications of the lidar instrument including both the given (or fixed) parameters, such as telescope diameter, primary mirror focal length, detector gain, as well as the derived optimized parameters such as focusing distances, solar filter bandwidth, laser pulse energy, pulse repetition frequency, etc.**

Answer: We agree with the referee and we have added the following table in appendix with a reference line 266 : "The main parameters that have been used in the simulation are sum up in table 1 and 2. The parameters in red correspond to the one that were optimized with simulations."

Reception Telescope	
Diameter	152.4 mm (6 in)
Focal length	609.6 mm (24 in)
Aperture	f/4
Secondary mirror diameter	38 mm
Focus distance	155 M
Fiber	
Core diameter	400 µm
Numerical aperture	0.22
Laser	

Beam size at emission	36 mm
M^2	< 8
Beam waist position	100 m
Spectral width ($1/e^2$)	400 MHz
Pulse duration	10 ns
Merion C	
Pulse energy	22.5 mJ
Pulse repetition frequency	400 Hz
Fiber Laser	
Pulse energy	250 µJ
Pulse repetition frequency	40 kHz
Hybrid fiber laser	
Pulse energy	750 µJ
Pulse repetition frequency	4 0 kHz
Solar filter	
Bandwidth	1 nm
Backgorund	
Solar Background	0.3 $W/m^2/str/nm$
Detector SiPIN S5971 Hamamatsu	
Quantum efficiency	0.5
Gain	1
Excess noise factor	1
Dark current	0.07 nA
Detector SiAPD S9075 Hamamatsu	
Quantum efficiency	0.5
Gain	5
Excess noise factor	1.57
Dark current	0.5 nA
Detector PMT R10721-210 Hamamatsu	
Quantum efficiency	0.43
Gain	2e6
Excess noise factor	1.3
Dark current	10 nA
Atmosphere	
Particle backscattering coefficient (< 1km)	8e-6 $m^{-1}.str^{-1}$
Measurement parameter	
Range gate	25 m
Measurement time	0.1 ms

2. **Line 71: The impact on micro-vibrations on the frequency of the Aeolus laser is discussed in a more recent publication (Lux et al., AMT, 14, 6305–6333, 2021). Please add this reference to the one already provided (Mondin et al., 2017).**

Answer: We agree with the referee that this publication is particularly interesting for our study as vibrations are a major concern. We have added this reference.

3. **Line 198: Why did the authors assume a solar filter bandwidth of 1 nm, although the spectral width of the Rayleigh signal considering Doppler shifts of +/- 100 m/s accounts for only 1 pm (line 186)? What is the actual limitation for the lower bound of the spectral bandwidth (transmission, price)?**

Answer: Yes the thinner the filter, the more expensive and the lower the transmission but the higher it suppress the background signal. Therefore, the choice of the solar filter is a tradeoff between background suppression transmission and price. In the simulation, we fixed the filter bandwidth to 1 nm because such filter is close to the limit of the technology. However, for each configuration, the filter thickness needs to be refined to determine the filter thickness that can be used for each laser parameter.

Section 2.3.3, last paragraph "… For a filter bandwidth of 1 nm, this results in a minimum laser energy per pulse E_{pmin} = ~~88~~ 298 µJ. This filter bandwidth is used for the rest of the simulation, as it is close to the limit of the technology in term of filter thickness."

Section 2.3.4, 1st paragraph "…simulations were performed by adjusting the average laser power and pulse repetition frequency to assess the error in the retrieved wind velocity. ~~We assumed a 1 nm solar filter with a transmission of 1 and~~ We neglected electrical noise by considering PMT detectors. At low altitudes …"

4. **Lines 233ff.: The maximum solar filter bandwidths of >10 nm, calculated for the three different laser sources, are much broader than what is typically used in such systems. I am not sure if these values are realistic. Given that 1 nm bandwidth corresponds to a minimum pulse energy of 88 µJ (line 195), the fiber laser parameters (PRF: 40 kHz, average power: 10 W hence pulse energy: 250 µJ) suggest a maximum bandwidth of 2.3 nm. For the hybrid fiber laser, the maximum bandwidth is then 6.8 nm. Please check the values given in the text.**

Answer: After verification, there were few mistakes with the numerical applications

- Section 2.3.3, last paragraph, the minimum energy for a 1 nm filter at 300m from lidar and 10 km of altitude is $E_{pmin} = 298\ \mu J$ (This is why on the right figure 3 the fiber laser is on the magenta zone). The difference with the referee value comes from the fact that we forget to write R the background radiance in B, this has been corrected
- Section 2.3.5, the maximum bandwidth for the fiber laser is 0.84 nm and for the hybrid fiber laser it is 2.5 nm. So for the fiber laser, the measure will be slightly affected by the solar background at 300m.

Correction in section 2.3.5 : "… We estimated that the maximum average power of 10 W can be achieved with current technology, it allows the use of a solar filter up to ~~11~~ 0.84 nm. Then the projected wind speed measurement at 300 m will be slightly affected by background noise. The results…"

"… We estimated that the maximum average power of 30 W can be reached, which allows the use of a solar filter up to ~~33~~ 2.5 nm. This results…"

Modification line 246 : "In this scenario, a wide bandwidth solar filter can be employed (typically » 1 nm is chosen) "

5. **Line 200: What is the influence of the particle backscattering on the QMZ interferometer output signals? I am wondering if the accuracy of the wind speed retrieval suffers from Mie contamination which is significant at lower altitudes.**

Answer: In presence of particle backscattering, the Speckle noise at the outputs of the QMZ will be more important if no precautions are taken (like mode scrambling in the fiber for example). I complete the appendix A2 to include the influence of the Mie scattering on the retrieved wind speed standard deviation, in response to the commentary of the first referee. However, for my simulation, I problably took a too low value for the particle backscattering, A more realistic value would be between 1.10^{-6} and 1.10^{-5} (VAUGHAN, J. 1995).

I will redo my simulation with a value of 8.10-6, the median of particle backscattering coefficient at 355 nm ((Herbst, 2016) with the value scaled from (VAUGHAN, J. 1995))

Section 2.3.4, line 211: « … At low altitudes (less than 1 km), we assumed a backscatter coefficient for particles of 8.10^{-6} m^{-1}.sr^{-1}. The simulations… »

Line 214 : "…This error corresponds to ~~0.27~~ 0.12 m/s on the projected wind speed standard deviation. The magenta…"

Section 2.3.5, line 235 : "... This configuration yields a standard deviation sigma_{lidar} of 0.07 m/s at low altitude and 0.17 m/s at high altitude. …"

Section 2.3.5, line 241 : "... The results for standard deviation sigma_{lidar} are 0.05 m/s at low altitude and 0.16 m/s at high altitude."

Section 2.3.5, line 245 : "... This results in a standard deviation sigma_{lidar} of 0.03 m/s at low altitude and 0.09 m/s at high altitude."

6. **Fig. 4: I suggest to mark the two scanning angles (15°, 51°) that are discussed in the text to better visualize the improvement in the RMSE.**

Answer: We agree with the referee and added on the figure on the left (high altitude) 1.36 m/s for 15° and 0.76 m/s for 51 °, and for the figure on the right (low altitude) 2.33 m/s for 15° and 1.22 m/s for 51°.

7. **Perhaps one could also add a 2D color plot, similar to those in Fig. 3, which depicts the RMSE vs. angle and altitude. This would illustrate the influence of scanning angle and altitude on the wind error in a more general manner with the two plots shown in Fig. 3a) and b) representing two intersection curves.**

Answer: It would indeed be interesting to plot this data, as the article does not deal with the influence of altitude on the optimum sweep angle. This is an issue that is currently under study, as we don't yet have a good model for the evolution of Von Karman turbulence parameters as a function of altitude. At present, we use the value defined by aeronautical standards. If we plot this with the current model, there will be no change compared to the figure 5 since the error induced by turbulence prevails.

8. **Can the authors please check the numbers in the parentheses in lines 295f.? I calculate a different value of 2r for $\theta = 15°$ when using the equation given in line 279: 2r = 54 m instead of 36 m.**

Answer: Yes it's a typo, I also find 54m after checking.

9. **Line 300: I think it would be helpful for the reader when referring the statement to the equation that contains the term $1/((2\sin(\theta))^2$. I suppose Eq. (3) is meant here.**

Answer: We agree with the referee and added

Line 300 : "… which can be amplified for small scanning angles due to the factor 1/(2\sin(\theta))^2 in Eq. (3) when retrieving the …"

10. **Line 328: Please mention the respective RMSE values obtained for the two angles in the text to quantify the improvement at the optimized scanning angle.**

Answer: We have changed line 331 to:

Line 331 : "…component recovered with an angle of 15°. The corresponding RMSE obtained for this run of the simulation are 12.9 m/s for an angle of 15° and 7.4 m/s for an angle of 50°. This illustrates …"

11. **Although the example shown in Fig. 5 is illustrative, I am missing information about its representativity for different turbulence scenarios. How does the RMSE at the two different angles vary for multiple runs of the simulation? How does it scale with the variance of turbulence σ^2?**

Answer:

Ancienne Answer: We do not study the variation of the RMSE with multiple runs of the simulation. This will be done in future work.

Concerning the evolution of RMSE with the variance of turbulence, it becomes rapidly proportional to the turbulence variance since the contribution of lidar measurement error becomes negligible and the different correlation and structure function are proportional to the turbulence variance.

12. **The three terms "scan angle", "scanning angle" and "lidar angle" are used synonymously in the text and should be harmonized to avoid confusion.**

Answer: corrected

Technical corrections:

1. **Lines 31, 88: The acronym GLA was already introduced in line 21 and can thus be used here.**

Answer: Corrected line 31 "… and the GLA system …"

Line 88 "… an aircraft for GLA applications,…"

2. **Line 109: Word missing: "… and to focus it into a multimode fiber".**

Answer: corrected Line 109 "… and to focus it …"

3. **Line 119: The acronym OPD was introduced before.**

Answer: corrected line 119 "… increases the OPD for horizontal…"

4. **Line 124: The symbol D_0 should be clarified.**

Answer: we added in line 124: "…, respectively, where D_0 is the OPD for output I_1"

5. **Line 139: Change (Liméry,2008) to Liméry (2018).**

Answer: It has been corrected

6. **Line 188: Correct to "This leads to:".**

Answer: It has been corrected

7. **Line 190: The symbol γ is not described in the text. Also, please check the equation for correctness.**

Answer: line 175 :"… resulting in an overlap function γ equal to 1 across…"

The equation has been check

8. **Fig. 3: The label of the right y-axis should read "Standard deviation on wind speed (m/s)".**

Answer: It has been corrected

9. **Fig. 3: The PRF in the label "Meron C" should be changed from 40 kHz to 400 Hz.**

Answer: It has been corrected

10. **Lines 237, 240: The commas have to be replaced by dots.**

Answer: It has been corrected

11. **Line 239: Correct to "can be reached".**

Answer: It has been corrected

12. **Caption of Fig. 4 can be shortened by writing "[…] for wind measurement at (a) high and (b) low altitude".**

Answer: It has been corrected

13. **Lines 255ff.: The formatting of the symbols in the text should be corrected, e.g. d, r and z should be printed in italics. Conversely, Eqs. (2)-(4), the terms "sin", "cos" and "tan" should be printed upright. This comment also applies to the Appendix sections where upright letters and italics are not used consistently.**

Answer: I hope everything has been corrected correctly.

14. **Line 275: Replace "that is homogeneous and isotropic" with "which is homogeneous and isotropic".**

Answer: It has been corrected

15. **Line 317: The symbol L_0 should be introduced.**

Answer: We replaced L_0 by l in line 320

16. **Line 325: Remove ")" after "Figure 5".**

Answer: It has been corrected

17. **Fig. 5a) Either remove the tick labels from the x-axis or add an axis description (x position in m?). Clarify "plan xOz" in the caption.**

Answer: It has been corrected

Figure 6: a) Sample of a wind simulation (norm of the wind vector, in the plan xOz where y = 0) and representation of the lidar measurements for the wind reconstruction ahead of a plane b) Evolution of the vertical wind component as a function of the position in the simulated wind volume. In black the actual wind component on the flight path, in red the wind component retrieved with an angle of 15°, in green with an angle of 50 °

Référence:

HERBST, Jonas. *Development and test of a UV lidar receiver for the measurement of wind velocities aiming at the near-range characterization of wake vortices and gusts in clear air*. 2019. PhD thesis. lmu.

VAUGHAN, J. M., BROWN, D. W., NASH, C., *et al.* Atlantic atmospheric aerosol studies: 2. Compendium of airborne backscatter measurements at 10.6 µm. *Journal of Geophysical Research: Atmospheres*, 1995, vol. 100, no D1, p. 1043-1065.