General response: We would like to thank referee 3 for his interest in this article, and for the detailed corrections that he suggests to improve the paper's impact on the scientific community. We appreciate that referee 3 says "The manuscript is interesting approach to optimize performance on the lateral and vertical wind measurements of the UV airborne DWL". 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.

General comment

The authors assumed to be the measurement time of 0.1 sec, which corresponds to a range resolution of 25m for an aircraft speed of 250 m/sec. The target measurement range is 100 to 150 m. First concerning is the spatiotemporal and accuracy requirements of the wind measurement for the GLA. What is the response speed meeting the requirements? Please add explanation and references for the requirements.

Answer: The people within the project who specify the requirements have told us that the measurement should be made at a frequency of 10 Hz, about 100 m in front of the aircraft, with an accuracy of 1 m/s. We agree that this needs to be refined with full GLA simulations that take into account the true function of the lidar (and not simplify the lidar model) and study the effect of the lidar's spatial and temporal resolution in order to refine the requirements.

As far as control system response time is concerned, details specific to the GLA are beyond the scope of this article. What we do know is that, at present, the control system and actuators of current GLA systems do not have the time to react fully to turbulence. With lidar measurements at around 100 m and a repetition rate of 10 Hz, the time saving should be sufficient to significantly reduce the turbulence-induced load (see (Fournier et al., 2021)).

Second concern is the signal to noise ratio (SNR) at the focusing region at the lidar angles θ of 10 and 50 degrees. The backscatter coefficient at an altitude of 10 km is not shown in the manuscript. The size for the laser beam and receiver filed at the focusing plane is not shown. What is the SNR and the detectability required for the GLA?

Answer: The molecular backscattere coefficient hasbeen added in the article (see question no15). The size of the laser beam is precise line 181 of the revised version. For the receiver field, it is taken into account in the overlap function. Indeed, when this function is equal to one, the laser beam and the receiver field overlap.

For the GLA, the component of the 3D wind must be estimated with a precision of less than 1 m/s (3 sigma error), so a standard deviation of 0.3 m/s on the component. If we take the case the vertical wind component Vz, estimated with the measurement geometry of four axis as presented in the article, at 100 m in front of the aircraft, this lead to the condition of standard deviation on the projected wind speed σ_{lidar}< 0.12 m/s for an angle of 15° (see section 2.3.4) and σ_{lidar}< 0.35 m/s for 50° (present in the revised version). If know we assume that the different lidar component have been designed so that the wind speed measurement is shot noise limited for the considered range of estimation on the lidar axis, we have

$$\sigma_{lidar} = \frac{c\lambda_0}{4\pi D_0} \frac{\sqrt{2}}{SNR * M} \sqrt{1 - \frac{M^2}{4}}$$

If we named σ_{max} the maximum value of the std on projected wind speed, the condition is σ_{lidar}<σ_{max} and become on the SNR:

$$\frac{c\lambda_0}{4\pi D_0}\frac{\sqrt{2}}{\sigma_{max} \; * M}\sqrt{1-\frac{M^2}{4}} < SNR$$

$D_0 = 3\ cm$, M the contrast of interferences due to the width of the Rayleigh spectrum is equal to 0.68 at 10 km of altitude. So for σ_{max} = 0.12 m/s, the minimum SNR is 4600 and for σ_{max} = 0.35 m/s, the minimum SNR is 1580.

This is achieved with the three laser designs established in the article.

Regarding to the second concern, third concern is repetitiveness of the wind filed. The θ of 10 and 50 degrees have different volumes. When the laser beam and the receiver filed are focused, the reviewer thinks that the wind filed at the focusing volume will be no longer the repetitiveness around the plane. The refractive turbulence is strong in the UV.

Answer: Concerning the repetitiveness, it is taken into account in the simulation with the movement of the plane during the measurement time. This induces a displacement of the lidar axis along flight direction and the wind is integrated.

We are sorry but we are not sure to understand the sentence “When the laser beam and the receiver filed are focused, the reviewer thinks that the wind filed at the focusing volume will be no longer the repetitiveness around the plane”

For the effect of the refraction induce by turbulence, the effect should be minor since at short distance (100m -300 m), the correlation of the turbulence is good.

Specific Comments

1. Line 17: Introduction. Please add references regarding to aviation accident and safety.

Answer: We are not sure which part of the introduction the referee mentions, but we assume it relates to the sentence in line 30. We propose the following reference line 31 (see revised version) “In addition, it will limit aircraft vibrations, particularly the effects of air pockets that can30 hurt passengers (Kaplan et al., 2005).”

2. Lines 26-27: “100m- 200m ahead of the aircraft” is the spatial requirement. Please add explanation and reference related to spatial requirement.

Modification line 37: “100 m - 200 m ahead of the aircraft (In the case of the Airbus XRF1 (Fournier et al., 2021), the optimal distance ahead of the aircraft is 91 m, giving the control system enough time to react) ”

3. Lines 31 and 88: “abbreviation for Gust Load Alleviation” is shown again. Please remove “Gust Load Alleviation” if you use the abbreviation GLA.

Answer: it was corrected

4. Line 55: QMZ should be “Quadri Mach-Zehnder (QMZ)”.

Answer: it was corrected

5. Lines 62-63: “a factor √2 increase in statistical error” is not clear. Please add explanation regarding on the factor and the reference.

Answer: The factor appears when the number of channel of higher than 2 (for QMZ and fringe imaging technics). For the QMZ, It can be seen by the fact that 2 channel are required to determine the wind speed, those in phase opposition and localize near the maximum sensitivity of interference intensity with Doppler shift (see figure 3 in the revised version). So half of the collected photons are use to determine the wind speed, hence the √2 factor on SNR and so on the wind speed standard deviation

Modification line 62: "(at the cost of a factor √2 increase in statistical error due to the desensitization of the interferometer to the backscattering ratio (Bruneau, 2001, 2002), and do not require laser stabilization)"

6. Line 110: How much is the numerical aperture (NA) of multimode fiber assumed in the manuscript?

Answer: The NA of the multimode fiber is 0.22 (half aperture angle 12.7 °), that match with the telescope aperture of f/D=4 (half aperture angle 7.12° < 12.7)

Modification line 112: "…and to focus it into a multimode fiber with a numerical aperture of 0.22."

7. Line 156: What is "moy"?

Answer: It is "moyenne" for "average" in French, it was corrected by "av"

8. Line 162: "Maximum Likelihood Estimator (MLE)". Please add reference.

Answer: modification line 171 :" The Maximum Likelihood Estimator (MLE) (see paper of Cézard et al. (2009) for principle) was then employed…"

9. Line 165: "Cramer Rao's lower bound". Please add reference.

Answer: modification line 171 :" … the analytical formula closely matched Cramer Rao's lower bound (Cézard et al., 2009) as we obtain…"

10. Lines 168-169: The laser beam shown in Figure 2(a) should be convergent.

Answer: It was corrected

11. Lines 170-171: Please add explanation regarding on relation between F-number and the NA.

Answer: The noise factor take into account the noise added during the electronic amplification process (fluctuation of the number of electrons in the cascade produce in PMT and APD). According to Hamamatsu in his "PMT_HandBooK V4", the noise figure is define by the square of the ratio of SNR at the input to the SNR at the output. In our case, taking the photon noise on the detector, we have $SNR_{input} = \frac{N}{\sigma_i}$ with N the number of photon and $\sigma_i = \sqrt{N}$. At the input of the detector after the amplification, we have $SNR_{output} = \frac{G\eta N}{\sigma_o}$ with η the quantum efficiency and G the gain. So the noise factor will be $F = \left(\frac{SNR_{input}}{SNR_{output}}\right)^2 = \left(\frac{\sigma_o}{G\eta\sigma_i}\right)^2$. So the noise variance at the output of the detector produce by photon noise is ${\sigma_o}^2 = F(G\eta\sigma_i)^2 = F(G\eta)^2 N$. The square over η has been forgot in the first version

Modification line 189: "Taking the definition of the excess noise factor from (PMT Handbook), we have $F = \left(\frac{SNR_{input}}{SNR_{output}}\right)^2$ with $SNR_{input} = \frac{N}{\sigma_i}$ and $SNR_{output} = \frac{G\eta N}{\sigma_o}$. N represents the sum of backscattered photons obtained on the four detectors, G stands for the gain of the detector, and η signifies the quantum efficiency. The noise variance induced by the backscattered shot noise at the output of the detectors will be is $\sigma_o{}^2 = F(G\eta\sigma_i)^2 = F(G\eta)^2 N$. This noise must exceed the detection noise, leading to the condition $N >> \frac{4\sigma_{det}2}{F\,(G\eta)2}$, where σ2 det denotes the detection noise of a detector expressed in the number of electrons calculated for a range gate of 25 m. In order to meet the condition, we take $N > 10\frac{4\sigma_{det}2}{F\,(G\eta)2}$, with the right term corresponding to the equivalent number of photons produced by the detection noise. For the PIN, we found 1.1 × 108, for the APD 2.8 × 106 and for the PMT 2.9 × 10−5. Only the PMT ensures a low level of detection noise compared to the shot noise le"

12. Line 172: I don't understand M2<8. Please add explanation regarding on physical meanings of M2 and M2<8.

Answer: The M^2 (or M squared) is a parameter that define the laser beam quality. If we take the ideal case of a Gaussian beam, the half beam divergence is $\theta_0 = \arctan(\frac{\lambda}{\pi\omega_0})$ with λ the wavelength and ω_0 the beam waist. In practice, it is hard to reach the perfect Gaussian beam, that is traduced by an increase of the beam divergence relative to θ_0. The M^2 is then used to quantify the increased of the divergence and is M^2=θ/θ_0.

Modification line 180: "… where M^2, define as the ratio of the beam divergence angle to the beam divergence angle of the perfect Gaussian beam at the same wavelength, is considered lower than 8, value obtain for the commercial laser Merion C by Lumibird."

13. Line 190: What is "γ(r)2"? Please add explanation. Is "γ(r)2" correct?

Answer: it is the overlap function, the definition was added line 147

14. Lines 194, 236, and 240: "0," should be "0.".

Answer: it was corrected

15. Lines 199-200: The backscatter coefficient at an altitude of 10 km is not shown in the manuscript. Please add the backscatter coefficient.

Answer: modification line 217: "The backscatter coefficient for molecules is 7.2 × 10−6 m−1 sr−1 on the ground and 2.1 × 10−6 m−1 sr−1 at 10 km of altitude."

16. Line 200: "m-1.sr-1" should be "/m/sr".

Answer: I made a mistake in the format in which I wrote the units, AMT indicates that the unit in the denominator must be formatted with negative exponents. I correct it for all values with units

17. Line 203: Laser has a spectral width of <500 MHz. How long is the pulse width assumed? Is it possible to develop the laser system?

Answer: The pulse width is assumed to be 10 ns, I also made a mistake in the value, the laser have a full width at 1/e^2 of 400 MHz. The value taken here for laser parameters are the main one to realize the simulations. We prefer not to go into detail about the laser, as this is not the purpose of this article.

18. Line 204: Please add references regarding the spectral broadening of 3 GHz.

Answer: modification line 219 "… by the thermal movement of the molecules (6.3 GHz for a full width at 1/e2 (Bruneau and Pelon, 2003))"

19. Line 207: Figure 3 shows result of the relation between laser average power and pulse repetition frequency (Hz). Do you need to show the results at the laser average power of >10W operating at PRF of < 100 Hz. Is it feasible to develop the laser system in the term of the laser power density and laser-induced optical damage?

Answer: We agree that some of the laser parameters may lead to laser design that are not feasible in practice, for technological considerations as the one you mention. Maybe the range the laser parameters could be refined taking into account its technical considerations, but it is not the goal of the article to described all this, that could made the subject of other article.

20. Line 230: "repetition rate of 400 Hz and delivers 22.5 mJ of energy per pulse". In Figure 3, Merion C is "9W 40 kHz". Which is it correct?

Answer: It was a typos, corrected

21. Lines 225-240: Do three lasers have enough tolerance for the optical damage? Does each laser have enough tolerance for the optical damage?

Answer: For the Merion C, the optics of the emission telescope have been chosen so as not to be damaged by the high energy of each pulse emitted by the laser.

For the fiber laser, these designs are currently studied by laser team at ONERA, more details on this technology will be available soon

22. Figure 4: Please embed "high altitude" and "low altitude" int the Figures 4(a) and 4(b), respectively.

Answer: It was corrected

23. Line 270: "root mean square error". "root mean square error (RMS)" should be better.

Answer: It was corrected

24. Line 297: "root mean square error" should be removed.

Answer: It was corrected

25. Line 325: "Figure 5) displays the results.". ")" should be deleted. "results", how did you simulate? It is not clear. Please add explanation. Did you investigate the statistic difference between real wind component and retrieved wind component at two angles of 15 and 50 degree? Please add results and explanation.

Answer: It was corrected.

We indeed forgot to mention the parameters used to obtain the results. We propose the following modification line 342 : "For the simulation, the wind box was taken equal to 8 km×800 m×800 m, sample every 5 m in each directions.The turbulence length scale is taken equal to 762 m, value at 10 km, and the turbulence is 100 m2 s−2. We considered that the plane is moving at 250 m s−1, centered at y = 0 and z = 0, along x axis, and that the lidar is located in the nose of the aircraft. The model use for the lidar is simplify, considering only one measurement of the projected wind speed at a range z = d/ cos (θ), over a range gate of 25 m. The model of the lidar measurement noise is assumed to be Gaussian with the projected wind speed obtain on the range gate for the mean and a standard deviation corresponding to σ_{lidar}. For the simulation we take the one obtain for the Merion C. Figure 6 … "

The statistics difference between real wind component and retrieved wind component at two angles of 15 and 50 degree has not yet been studied in detail. Due to short time to answer the comments (I made mistakes in reading the comments and the comments of referee no3 has been discovered lately) we will not be able to perform simulations and give more results.

Refences

26. Line 445. What is the title? Which journal is the manuscript reviewed?

Answer: The title and journal have not yet been determined, as the document is currently under development.

27. Line 459. 2022 -> 2021.

Answer: It was corrected

Miscellaneous

28. The summary of specification parameters used in the simulations will be helpful for the readers. Please add the summary of the specification parameters.

Answer: Table that summurarize all parameters have been added in the appendix.