Referee comments 1:

This paper focuses on two issues associated with application of a direct-detection Doppler lidar for measuring winds ahead of an aircraft to feed forward for gust load alleviation. First, it describes development of a design to maximize wind measurement precision, focusing on telescope, background filter, and detector specifications. It then utilizes an atmospheric model of molecular and aerosol backscatter to predict performance for three different laser transmitters. The second issue addressed is optimization of the angle of deviation for a lidar that utilizes a four-direction concept, assuming turbulence from a commonly employed turbulence model.

I find the paper quite well done and certainly worthy of publication. Although the two main issues could have been addressed separately, they fit together acceptably into a single article. The figures are appropriate and illustrate the main points and conclusions.

In reading the paper, I would have liked to have seen a bit more discussion of the QMZ interferometer and explanation of how the SNR lead to errors in wind speed. This is more of a personal preference – the paper is very well referenced and the Appendix provides the necessary details for estimating wind error from photon count. Perhaps a figure that illustrates how the output from the detectors changes as function of wind speed (or phase) would be tutorial and useful in illustrating the concept.

Although speckle noise is an important component in velocity measurement uncertainty estimate, there is very little discussion of the basis for speckle noise and which system and laser transmitter parameters affect it. For example, line 223 on page 8 says that "the speckle noise decreases because the backscattering is predominantly molecular, which is less coherent than particulate backscattering. I may have missed it, but I didn't see in the text or the appendix that discusses the speckle relative to the signal coherence and how this is incorporated into the simulation.

Figure 3 is quite informative and sums up the discussion on wind speed standard deviation nicely.

The angle optimization part of the study produces a nice and useful result. While reviewing the paper, I thought that thus problem had to have been addressed earlier in slider studies of wind energy, but I perused the literature a bit and didn't find it. Consequently, this result should be of significant interest to the community.

As with all simulation studies, this work begs for follow-up research to demonstrate the concept and validate the simulation. The authors should add some text at the end on anticipated future work and tell the reader how they intend to use the results of the study.

General answer; We would like to thank the referee 1 for showing a keen interest in our article and in particular for finding the paper "quite well done and certainly worthy of publication". 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.

Referee 1: In reading the paper, I would have liked to have seen a bit more discussion of the QMZ interferometer and explanation of how the SNR lead to errors in wind speed. This is more of a personal preference – the paper is very well referenced and the Appendix provides the necessary details for estimating wind error from photon count. Perhaps a figure that illustrates how the output from the detectors changes as function of wind speed (or phase) would be tutorial and useful in illustrating the concept.

Answer: We agree with the referee and we have done the following changes: (end 2nd paragraph section 2.1) "…which is then sampled and digitized into a computer. Figure 3 shows the evolution of the simulated signal at the output of the detectors, for the reference signal and the Rayleigh signal. Signal processing makes it possible to recover the phase of the interference…"

(see Figure 3 in the revised version)

The variation of SNR can leads to errors in wind speed estimation because wind speed estimation implies the ratio of the difference between signals from detectors to the sum of the signals. This means that, in the variance of the wind speed, the ratio of the variance of signals to the sum of signals will appear (see eq A15), which is homogeneous to the inverse of a SNR. This mean that when the SNR increases, the standard deviation decreases.

Referee 1: Although speckle noise is an important component in velocity measurement uncertainty estimate, there is very little discussion of the basis for speckle noise and which system and laser transmitter parameters affect it. For example, line 223 on page 8 says that "the speckle noise decreases because the backscattering is predominantly molecular, which is less coherent than particulate backscattering. I may have missed it, but I didn't see in the text or the appendix that discusses the speckle relative to the signal coherence and how this is incorporated into the simulation.

Answer: We agreed with the referee and added:

- After equation (A15) in appendix A, line 432: "N_m and N_p are the number of speckle patterns obtained for a given range gate, linked to the size of the laser beam over the scattering volume, and the number of temporal speckles, due to the coherence of the scattered light. The number of spatial pattern is $\left(\frac{\pi\theta_{div}r_{pup}}{2\lambda}\right)^2$ where θ_{div} is the half divergence of the laser beam and r_{pup} the radius of the telescope pupil. The number of temporal Speckle pattern is $\frac{2\delta z}{c\tau_{coh}}$ with δz the range gate and τ_{coh} the coherence length of the signal. The coherence length is inversely proportional to spectrum width. Therefore, as the spectrum of the Rayleigh signal is wider than that of the Mie signal due to a larger Boltzmann distribution, the number of time patterns will be higher for Rayleigh than for Mie."

- How it is incorporated into the simulation (section 2.3.4, line 222): ".... We considered that the laser has a full width at $1/e^2$ of 400 MHz, significantly less than the spectral broadening induced by the thermal movement of the molecules (6.3 GHz for a full width at $1/e^2$). For the Mie scattering, the coherence time is limited by the laser pulse duration, i.e. 10 ns. For the Rayleigh scattering, it is limited by spectral broadening due to thermal motion of the molecule, i.e. 0.63 ns for a broadening of 6.3 GHz at $1/e^2$. The simulations were conducted both on the ground and at 10 km altitude, approximately corresponding to the aircraft's cruising altitude, as the GLA must operate throughout the flight.

<u>Referee 1:</u> Figure 3 is quite informative and sums up the discussion on wind speed standard deviation nicely.

We appreciate the comments

<u>Referee 1:</u> The angle optimization part of the study produces a nice and useful result. While reviewing the paper, I thought that thus problem had to have been addressed earlier in slider studies of wind energy, but I perused the literature a bit and didn't find it. Consequently, this result should be of significant interest to the community.

We did not find either studies published previously where lidar addressing angle was optimized for 3D wind reconstruction. We appreciate very much the comment.

<u>Referee 1:</u> As with all simulation studies, this work begs for follow-up research to demonstrate the concept and validate the simulation. The authors should add some text at the end on anticipated future work and tell the reader how they intend to use the results of the study.

<u>Answer:</u> We propose to modify the conclusion as follow (line 379) : "…Additionally, this method demonstrates that the intuition of using a small lidar angle to maintain almost homogeneous wind field conditions between measurement points to minimize error on the vertical component is misleading. Indeed, the error between the projections on the lidar axes and those at the point of reconstruction, induced by turbulence, are amplified by the factor $\frac{1}{2\tan(\theta)}$ for small angle. In a future work, we plan to validate experimentally the improvement of the accuracy on the reconstructed 3D wind when increasing the addressing angle with an existing heterodyne wind lidar at ONERA. The lidar will be used to reconstruct the 3D wind along a central axis using four axis evenly distributed around this central axis. The reconstructed wind will be compared with the "true" wind measured with an independent local detector (anemometer); This comparison will be performed for several angles between the four beams and the central axis to validate this calculated improvement."