Response to Referee Comment (RC1) on

Airborne wind lidar observations over the North Atlantic in 2016 for the pre-launch validation of the satellite mission Aeolus (https://doi.org/10.5194/amt-2018-19)

We appreciate the referee's very insightful and positive comments on our manuscript AMT-2018-19. Following the suggestions and questions, the following aspects will be elaborated more in detail in a revised version of the paper.

Comment #1:

The authors spend a substantial part of the paper on ground detection and zero wind calibration. Clearly, high quality calibration is crucial for the quality of the final product, the wind profile. Despite the proposed solution, calibration will still be challenging, also for a space borne instrument. Systematic errors due to imperfect differentiation between atmospheric and ground return signals will be hard to avoid. Is it true that the wind difference between adjacent bins (i.e. wind-shear) does not suffer from these systematic errors? In that case, rather than producing a wind profile, one could produce a profile of wind-shear for use in NWP, clearly at the expense of losing one bin, but without systematic errors from calibration issues. Can the authors please elaborate on this wind-shear option. Wind-shear profiling may also resolve the curtain issue discussed on page 14.

Response to Comment #1:

Concerning systematic wind errors a distinction has to be made between range-independent and range-dependent error sources. First, systematic errors are caused by inaccuracies in the aircraft attitude angles, e.g. by improper knowledge of the laser pointing, or by constant errors in the wind retrieval, e.g. introduced by uncertainties in the calibration parameters. The resulting wind bias is constant along the wind profile and can be reduced by applying Zero Wind Correction, provided that sufficient ground return signals are available and that the atmospheric contamination of the ground return signals is low. If the latter conditions are not fulfilled, producing a wind-shear profile at the expense of one range bin is certainly an option for eliminating this systematic error source in the analysis of the airborne observations. Similar systematic error sources, e.g. improper knowledge of pointing direction or satellite-induced LOS speed, exist for the satellite instrument producing a slowly varying bias along the orbit which will be not present in wind-shear profiles.

The second source of systematic wind errors which is specific to the airborne demonstrator is the imperfect transmit-receive co-alignment, as discussed on page 14. In contrast to the statement on page 14, the systematic error which varies from observation to observation and which manifests as vertical pattern in the Rayleigh wind curtain, is **not identical** for all the atmospheric range gates. It is **only correlated** among all the atmospheric range gates, but also range-dependent. The error is largest in the near-field and decreases with increasing distance from the instrument, i.e. towards the ground. Thus, the curtain issue discussed on page 14 would not be fully resolved by plotting the wind-shear profile instead of the wind profile.

For the satellite instrument, the situation is more complicated due to the much higher ground track velocity of about 7.2 km/s. The different travel times of laser pulses backscattered from different altitudes in combination with the angular movement of the satellite during the propagation period of the pulses leads to range-dependent incidence angles of the backscattered light on the Rayleigh (and Mie) spectrometers, and hence to a range-dependent bias in the wind speeds. This effect will be characterized at the beginning of the Aeolus mission and can be subsequently corrected. Consequently, wind-shear profiles will not eliminate these range-dependent bias sources, if they are not fully corrected.

In summary, it depends on the cause of the systematic error, if it can be eliminated with wind-shear profiles. A paragraph discussing the wind-shear aspect will be part of the revised manuscript.

Comment #2:

In section 4.1.4 the authors discuss the issue of comparing A2D Rayleigh winds and 2 micron lidar data. The fact that the 2 micron lidar does provide measurements between 9 and 10 km altitude suggests the presence of particles in this region and hence contamination of A2D Rayleigh winds. This explains part of the poorer statistics of A2D Rayleigh winds, as the authors correctly mention in section 4.1.5. Also, from Figure 9d, it appears that the range of wind speeds is largest in this area and thus largest wind variability. It may therefore be the most challenging region for wind measurements, where Mie winds have a relatively "easy job" further down in the troposphere. Considering, in addition, the height assignment error (unknown location and distribution of cloud and/or aerosols inside the bin) apparent for Mie winds in particular, the remark on page 15: "Mie wind is preferred due to the generally lower systematic and random error (see next sections)" may be too strong based on the presented results. Can the authors please comment on this? Also how these conclusions translate to Aeolus? Can you please comment?

Response to Comment #2:

Regarding the comparison of Rayleigh winds with data from the 2-µm DWL, it should be mentioned that the latter is very sensitive even to weak aerosol backscatter return, due to its coherent detection principle with small bandwidth. In addition, the deployment of a coherent DWL on an aircraft is favourable, because the atmospheric altitudes with low aerosol backscatter are located in near range gates, which do not suffer from the R^2-dependency of the signal and strong aerosol extinction (as it would be the case for ground-based coherent DWL). Thus, 2-µm DWL winds are even available for low scattering ratios (<1.1), where no significant aerosol-contamination of the A2D Rayleigh winds can be expected. But we agree with the referee, that the comparison of A2D Rayleigh winds with the 2-µm DWL is limited to atmospheric altitudes, where at least weak aerosol backscattering occurs.

Furthermore, with a view to the Aeolus mission, it is important to note that the strategy for vertical sampling differ between the A2D and the satellite instrument ALADIN. The latter will measure wind profiles from ground up to about 20-30 km altitude, so that the range gates covering the troposphere will generally be fewer and larger compared to the A2D where all the atmospheric range gates are available to sample the altitude range from ground up to about 9 km. For the flights discussed in the manuscript, the vertical sampling grid was chosen such that the wind-shear in the jet stream region could be determined with the highest possible resolution. Hence, the A2D vertical sampling was adapted to the expected wind variability (from short-range NWP forecasts) and science objectives of the flights, which will not be possible for Aeolus, where only a climatology-based approach for different vertical sampling schemes can be applied.

The height assignment error of the Mie channel, comprehensively discussed in (Sun et al., 2014), is thus less pronounced, as the bin height is only 300 m compared to 500 m or 1000 m which would be a typical bin size for the satellite instrument. According to (Sun et al., 2014), the wind error standard deviation grows linearly with increasing bin size. Apart from that, the Rayleigh channel of the A2D exhibits large systematic and random errors owing to the co-alignment issue which has only insignificant influence on the Mie winds. Hence, in terms of the airborne demonstrator, the Mie channel is characterized by higher accuracy and precision compared to the Rayleigh channel. For the satellite instrument, this difference in the performance of both channels is not expected, due to the coarser resolution in the troposphere and the absence of the co-alignment loop. In this sense, we agree with the referee's comment that the remark on page 15: "Mie wind is preferred due to the generally lower systematic and random error" is too strong. A more differentiated discussion of the Rayleigh and Mie wind errors considering the above arguments and how they translate to Aeolus will be included in the revised manuscript.

Minor comments:

Page 2: *Replace "as it will close the gaps in the wind data coverage" by "as it will contribute to close the gap in wind profile data coverage"*

Response: The sentence will be changed accordingly in the revised version.

Page 2, line 19: *"aircraft" => aircrafts*

Response: Aircraft is the correct English plural of aircraft.

Page 5, line 14: *Replace "from moving particles (cloud particles, aerosols, molecules)" by "from particles (cloud droplets, aerosols) and molecules with move with the ambient wind"*

Response: The sentence will be changed accordingly in the revised version.

Page 6: x_0, *Δx and k have not been clearly defined near equation 2. Please do.*

Response: The quantities will be clearly defined in the revised manuscript as follows: In Eq. (2), x_0 represents the Mie fringe centroid position at the frequency f_0 of the emitted laser pulse and is referred to as Mie centre. Δx is the shift of the Mie fringe centroid position with respect to the Mie centre and k denotes the proportionality factor between the Doppler frequency shift $\Delta f_{\text{Doppler}}$ and the resulting shift of the Mie fringe Δx, thus describing the sensitivity of the Mie channel.

Caption of Fig. 2: *"the respective transmitted intensities". Should "transmitted" here not be replaced by "received"?*

Response: The term "transmitted intensities" refers to the transmission of the light through the two sequential Fabry-Pérot interferometers and therefore appears appropriate from our point of view. For the sake of clarity, we will replace "transmitted intensities" by "intensities transmitted through the filters".

Caption of Fig. 4: *I do not understand the last sentence: "Orange bins are identified as ground bins and thus considered for the determination of the ground response function." Which orange bins? Please explain or correct.*

Response: In a previous version of the manuscript, the ground bins in Figure 4(c) and (d) were indicated in orange. The colour of the bins was changed to white without adapting the figure caption. The caption will be corrected accordingly in the revised version. Sorry for the inconvenience.