B. Witschas 13.02.2020

The valuable comments given by the anonymous Referee #1 (received on 27 January 2020, shown in black) are highly appreciated. The corresponding answers of the authors and the respective changes in the manuscript are given below in blue color.

Interactive comment on "First validation of Aeolus wind observations by airborne Doppler Wind Lidar measurements" by B. Witschas et al. (Author response)

The manuscript by Witschas et al. provides first results on the evaluation of the spaceborne ALADIN wind lidar by comparing its measurements with those collected by an airborne coherent wind lidar. The comparison shows the results of two different validation campaigns and discusses the different possible sources for the observed differences. The paper is well organized and provides very valuable information for the lidar and atmospheric science communities. I recommend publishing on AMT after the following minor concerns are addressed:

1) My main concern is related with the technique used to retrieve the 2um lidar data. If I understand the procedure correctly, a sliding window on the LOS measurements is applied to increase the spatial coverage of the retrieval. I expect this sliding window (floating window in the paper) filter to introduce a spatial shift in the data which might lead to an increase in the systematic error. A difference plot between the two retrievals shown in Fig. 2 (one scan vs five scans) might help to show the effect of this sliding window filter. For future evaluations, it might be worth using the ALADIN retrieval grid to group all the 2um lidar LOS measurement and retrieve 2um data natively on the ALADIN grid. It might be even possible to retrieve directly HLOS winds using the MFAS algorithm instead of retrieving first 3D winds and projecting them after into the ALADIN HLOS.
Thanks a lot for this comment. As discussed on page 7, we use the MFAS algorithm in order to retrieve the wind vector from the raw data. The sliding window is thus not applied to single LOS wind speeds, but to the corresponding spectra of single LOS measurements. After accumulating the spectra, an FFT is performed in order to retrieve the wind. Using this procedure, it is not expected that a sliding window will introduce a "spatial shift" but rather smear out strong gradients. However, as the horizontal resolution of the Aeolus data (90 km for Rayleigh-clear winds) is more than twice of the sliding window size (~ 42 km), this effect is considered to be negligible.

In order to verify this hypothesis, the wind speed difference of 1-scan and 5-scan measurements from all AVATARE flights is analyzed for all common data points. This leads to the histogram shown in the figure below, which is also added to the paper manuscript. It can be seen that the systematic error of the wind speed difference is only **0.04 m/s**, which is negligible for Aeolus comparisons and which demonstrates that the sliding window does not introduce a distinct systematic error to the wind data.

Furthermore, the standard deviation of the wind speed difference is determined to be **1.24 m/s**. By assuming that both data sets (1-scan and 5-scan) contribute equally, the random error of 2-µm wind speed observations can be estimated to be **0.88 m/s**, which is in line with previous comparisons to dropsonde measurements as shown in section 4.3.

Still, for future evaluations it will be investigated if a spectral accumulation on Aeolus grid level will further improve our analysis or rather further increase the data coverage.

The manuscript was changed as follows (section 4.2):

In order to prove this hypothesis, the wind speeds retrieved by means of one scanner revolution ($v_{2\mu m_{1\text{-scan}}}$) and five scanner revolutions ($v_{2\mu m_{5\text{-scans}}}$) are analyzed. In particular, the difference of both data sets for all common data points of all flights flown during the AVATARE campaign (see also table 1) and the corresponding mean and standard deviation (STD) is calculated. An histogram of the wind speed difference is shown in Fig. 3. All together, more than 40000 data data points contribute to this analysis.

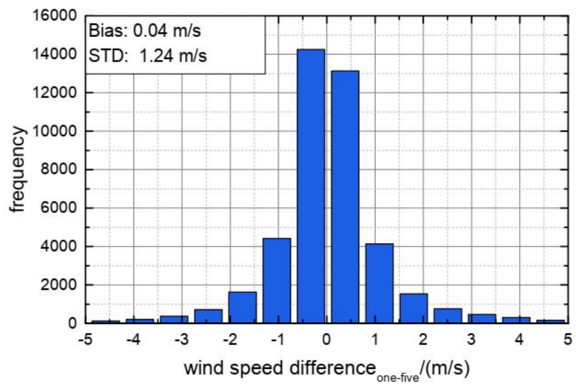


Figure 3. Histogram of the difference of wind speeds derived from 2-μm DWL data by means of one scanner revolution and five scanner revolutions (one minus five) for all flights performed during the AVATARE campaign (see also table 1). The mean and the standard deviation (STD) of the data are indicated by the inset.

It can be seen that the systematic error of the wind speed difference is 0.04 m/s and thus negligible for the comparison to Aeolus data. The random error (standard deviation) is determined to be 1.24 m/s. Assuming that both data sets contribute equally, the random error of 2-μm DWL wind speeds can be estimated to be $\sigma_{2\mu m} = (\sigma_{\text{difference}}/2)^{1/2} = 0.88$ m/s, which is in line with previous comparisons to dropsonde measurements as shown in section 4.3, table 2.

Considering that, it is decided to use the 2-μm DWL data retrieved by means of the modified MFAS algorithm using five scanner resolutions (horizontal) and five range gates (vertical) for comparison to Aeolus observations as it increases the number of available data points significantly without introducing a distinct systemic error. For all flight legs performed during WindVal III and AVATARE, 56% more data is available when applying the five-scanner-revolution average, keeping all the other parameters constant.

2) The authors use a threshold (8 m/s for Rayleigh and 4 m/s for Mie retrievals) based on the error reported in the L2B files to leave out from the evaluation some of the ALADIN retrievals. Do you know if during the assimilation of the ALADIN data by ECMWF similar filtering criteria are used? If that is the case, it would be good to use the same criteria for this study.

Yes, similar error thresholds using the estimated L2B errors are used by ECMWF before Aeolus data is used during the assimilation process (Rennie, M., L. Isaksen (2019): Guidance for Aeolus NWP Impact Experiments during the period September 2018 to November 2019, internal document available for registered Aeolus Cal/Val teams).

3) Although I expect the vertical component of the wind to have a small effect in the evaluation (considering the long spatial averaging), it might be worth mentioning it and maybe show an example of the retrieved 2um vertical component as a proof.

In general, all underflights performed during WindVal III and AVATARE were performed under conditions where larger vertical wind speeds, as for instance induced by mountain waves, can be excluded. This can also be seen by the vertical wind speed measurements from the 2-µm DWL, as exemplarily shown for the first flight of the WindVal III campaign (*Figure 2*). It can be seen that the vertical wind speeds are measured to lie between ± 0.5 m/s and are more or less varying randomly. Thus, the impact on the retrieved Aeolus winds is expected to be negligible.

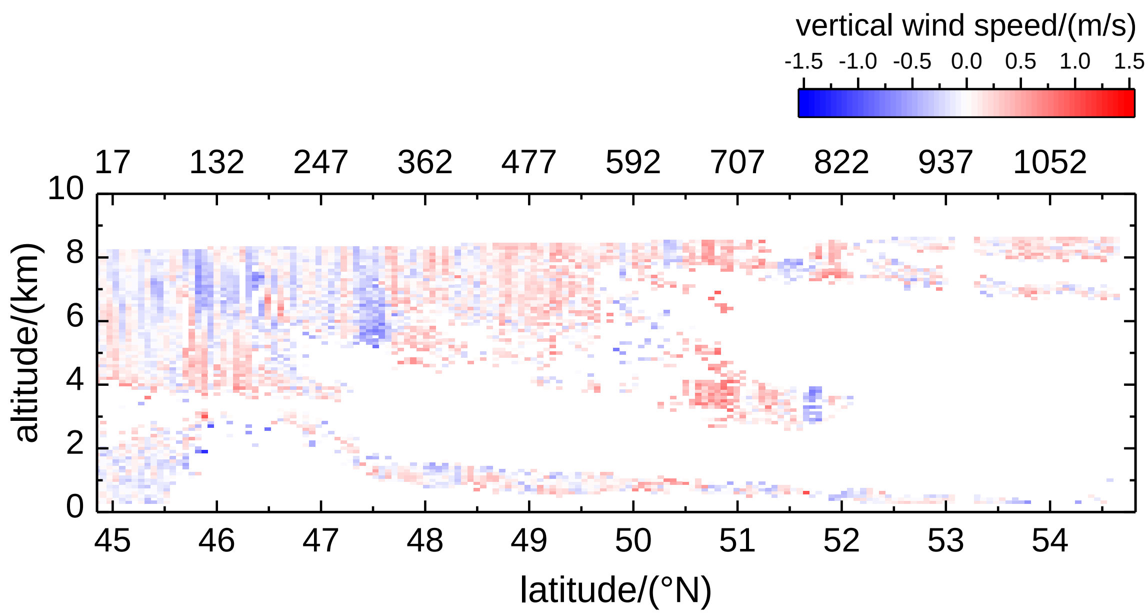


Figure 2. Vertical wind speed retrieved from 2-µm DWL data by means of the MFAS algorithm for one scanner revolution during the first ever Aeolus underflight performed on 17 November 2018 during the WindVal III campaign (corresponding horizontal wind speed is shown in Figure 1). White colors indicate areas with no valid wind measurements due to aerosol-poor atmospheric conditions and a corresponding insufficient SNR.

During the most recent Aeolus validation campaign AVATARI performed from Iceland in September/October 2019, one particular research flight was performed over Greenland with predicted excitation of gravity waves. This flight is addressed to the investigation of the impact of larger vertical winds on the Aeolus wind product. The first analysis reveal vertical wind speeds of up to 2 m/s. The impact on the Aeolus winds is still under investigation. As the horizontal wavelength of these mountain waves is of the order of 10 km, the impact on Aeolus winds is still expected to be small as they average out for an Aeolus observation.

The manuscript was changed as follows (end of section 6.2):

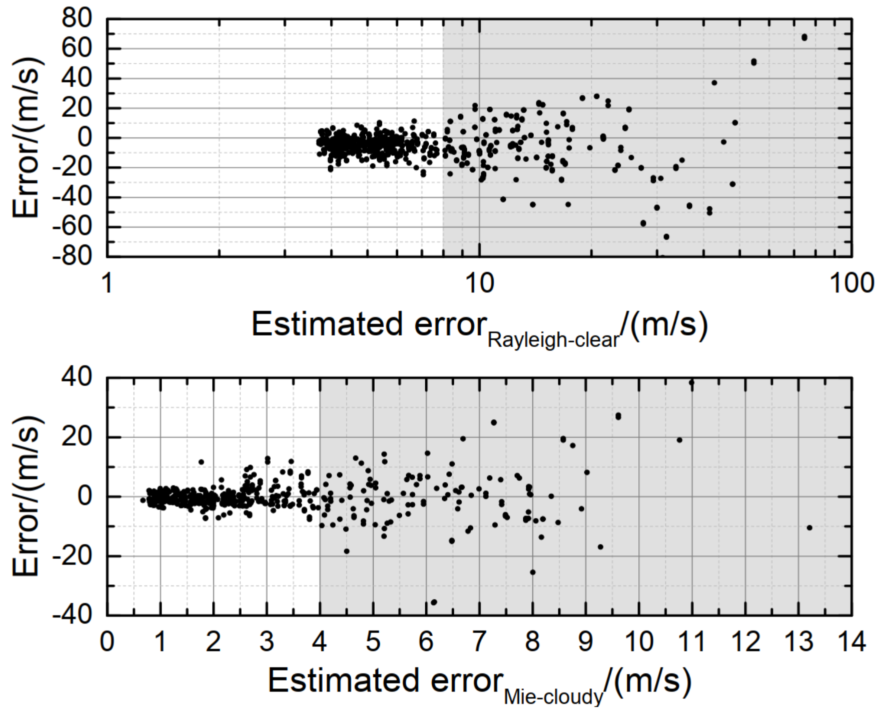
It is worth mentioning that all flight during WindVal III and AVATARE were performed under conditions where larger vertical wind speeds, as for instance induced by mountain waves, can be excluded. The vertical winds measured by the 2-μm DWL confirm that the vertical wind speeds rarely exceed 0.5 m/s. Thus, the vertical wind speed can be excluded as distinct contributer to the Aeolus random error.

Specific comments:

1) Fig. 4: The Y axis scale could be reduced to -40/40.

As the random error of Rayleigh-clear winds exceed +/- 40 m/s, only the scale of the Mie-cloudy error was adapted, as shown in the Figure below.

The figure is also adapted in the revised manuscript.



2) Pag. 9, line 203: should be ‘assess’ instead of ‘asses’

Thanks a lot for this hint → corrected.