B. Witschas   22.03.2020

The valuable comments given by the anonymous Referee #3 (received on 10 March 2020) are highly appreciated. The Referee comments are extracted from the supplement (black color) and the corresponding answers of the authors are given 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 presents unique near simultaneous and near common volume observations of an airborne lidar and of the ALADIN instrument onboard the Aeolus satellite. The manuscript is well written and mostly well organized. The manuscript is a result of an extensive and valuable effort and deserves publication after some minor modifications. I recommend re-organizing Section 5, as the formulas used to calculate the data in figure 3 is given after the discussion of figure 4. So swapping Figure 3 and 4 and rearranging the text will allow the reader to follow the thoughts in a less distracting way. In line with this the figures 3 and 7 will be easier to understand if the y-axis label is the symbol defined in Eq. 2 ($v_{diffHLOS}$). Further comments are given in the supplement.

The Referee comments are extracted from the supplement and answered in the following.

p. 1, abstract: Time resolution, altitude resolution altitude range?
The specifications of the respective Aeolus data products are described in detail in section 3.2. Still, for the sake of completeness and in order to better interpret the random error, the following numbers were added to the abstract (altitude range, vertical resolution and horizontal resolution for Mie and Rayleigh winds). The time resolution is contained in the spatial resolution information.

3.9 m/s (Rayleigh) and 2.0 m/s (Mie) for WindVal III, and 4.3 m/s (Rayleigh) and 2.0 m/s (Mie) for AVATARE, whereas the Aeolus observations used here were acquired in an altitude range up to 10 km and have mainly a vertical resolution of 1 km (Rayleigh) and 0.5 km to 1.0 km (Mie) and a horizontal resolution of 90 km (Rayleigh) and down to 10 km (Mie).

p. 6, section 4: "operating at " or "operated by"
adapted to be "operated by".

p. 7, section 4.2: vertical resolution of 0.5 km?
the value was adapted to be 0.25 km

p. 8, "sliding window" should be added
In all places of the text, it is added that the 5 revolution scan retrieval is based on a sliding window. However, the term "about" is skipped, as the sliding window is always five pixel large.

p. 8, Fig. 2: in Fig. 5 (a) it is written km asl. I guess "km asl." is also the unit for this plot.
The y-axes label was adapted to km asl. Additionally, the colors were adapted to HCL color bar.

p. 9, How does the 5 scan x 500 m sliding window and the averaging to the Aeolus grid affect (reduce) the random errors of the 2μm DWL given here?
A new section was added to the paper manuscript (based on the comments of Referee #1), comparing the common wind results of 1 and 5 scans. This comparison shows an equal random error for both

retrievals. Thus, it seems that the random error does not remarkably reduce as the wind results are not independent (sliding window) and as the representativity gets worse. On the other hand, this comparison shown that the 5 scan revolution winds are at least not "worse" than the 1-scan ones. A dropsonde comparison is so far not available for the 5-revolution retrieval in order to perform an independent verification of the respective errors. The section added to the manuscript reads as follows:

In order to prove this hypothesis, the wind speeds retrieved by means of one scanner revolution ($v_{2\mu m_{1-scan}}$) and five scanner revolutions ($v_{2\mu m_{5-scan}}$) are analyzed. In particular, the difference of both data sets for all common data points of all flights flown

200 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.
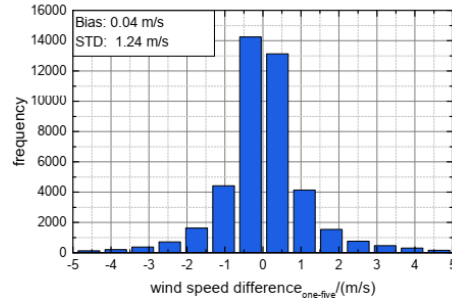

Figure 3. Histogram of the difference of wind speeds derived from 2-μm DWL data by means of one scanner revolution and five scanner revolutions (one minus five) for all flights performed during the AVATARE campaign (see also table 1). The mean and the standard deviation (STD) of the data are indicated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

205 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.

p. 10, table 2: 0.004 or <0.01
Value was changed to be <0.01 m/s

p.11, y-axes should be "v_diff_HLOS" instead of "error". Also in the text.
Changed for figure caption and in the text with additionally referring to the respective equation 2.

p.11, Fig.4: Is this for 17 November 2018 or for all data?
The graph shows all data points from WindVal III and AVATARE. The figure and the figure caption was modified accordingly.
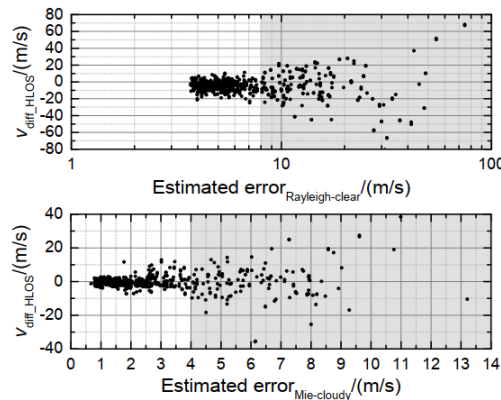
Figure 6. Wind speed difference of Aeolus HLOS winds and 2-μm DWL winds projected onto Aeolus viewing direction according to Eq. (2) depending on the estimated error given in the L2B product for Rayleigh winds (top) and Mie winds (bottom). Shown are all valid data points from WindVal III and AVATARE. Data points with an estimated error larger than 8 m/s (Rayleigh) or rather 4 m/s (Mie) are not considered as valid observations (gray areas).

p. 12, Fig. 5: The data shown in subfigure (a) is already plotted in Fig. 2. It would make the interpretation of Figure 5 easier if it is not repeated here.

The upper panel (a) was removed from the figure in order to avoid any confusion, and the caption was adapted accordingly. Furthermore, the color map was adapted to HCL colors:
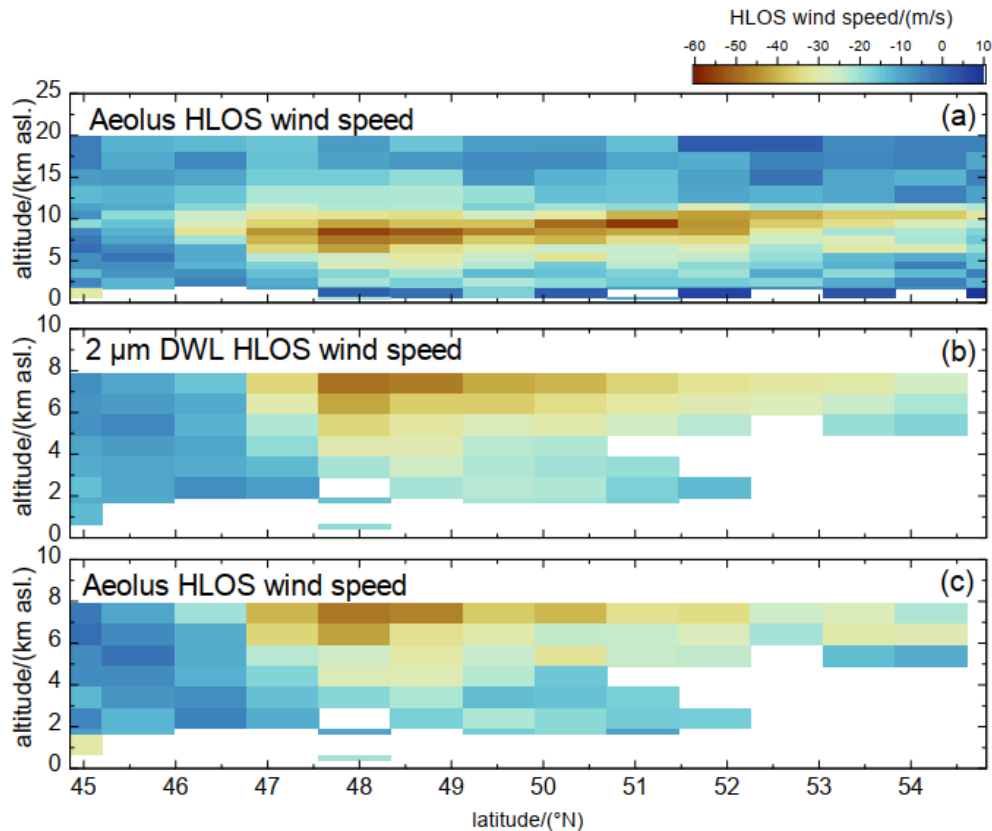
Figure 5. (a): Wind observations obtained during the first leg of the Aeolus underflight on 17 November 2018 between 45°N and 55°N (1146 km) in the framework of the WindVal III campaign. (a): Aeolus Rayleigh-clear winds with an estimated error of smaller than 8 m/s. (b): Corresponding 2-μm DWL observations averaged to the Aeolus grid and projected onto its viewing direction. (c): Aeolus Rayleigh-clear winds as shown in (a) in regions where 2-μm DWL data is available for comparison.

p. 12, Fig. 4 and Fig. 5: swap Figures 4 and 5 and re-arrange the corresponding discussion in the text

The figures were changed, and the text was adapted accordingly (see page 11 to page 14 in the new version of the manuscript). The content remained the same.

p. 13, Fig. 6: adapted color in label

done.

p. 14, Discussion: Does this increase the number of available data points or just diversifies their altitudes?

Actually it does both, it increases the number of available data points for comparison, by diversifying the altitudes due to smaller range gates in altitudes with airborne lidar measurements. The following sentence was added to the manuscript:

26 February 2019 (00:00 UTC) such that they follow the ground elevation which also increases the number of available data points due to smaller range gates in altitudes with airborne lidar measurements.

P. 15, Maybe add reference to Fig. 6 as a remainder.
Done

p. 17: Is there .a similar study (to Fig. 7) for Mie-cloudy winds? If yes and no correlations are found it would be worth mentioning here.
Currently, this study was performed for Rayleigh-clear winds only, as the number of available Mie-cloudy winds is not enough to perform a reasonable statistic. This is foreseen for the new campaigns data set of the AVATARI campaign (around Iceland and the North Atlantic), which provides more Mie-cloudy observations due to the modified Aeolus range gate setting applied during the campaign.

p. 18: Summary: It is stated three times in the manuscript that two wind lidars were onboard the Falcon aircraft. Only results from one lidar are shown. The reader wonders why. A short comment why only one lidar is used here may be useful.
The following paragraph was added for further clarification:

of Aeolus by means of collocated observations for the first time. In this paper, the systematic and random error of Aeolus wind observations is determined by means of the 2-μm DWL which acts as a reference system due to its low systematic and random error that comes along with the coherent measurement principle of the system (see also section 4.3). In particular, the

430 systematic error of 2-μm DWL observations is smaller 0.1 m/s and the random error is between 0.92 m/s and 1.5 m/s. Though this random error is noticeably smaller than the one of Aeolus, it is considered for the statistical comparison performed here. The Aeolus measurement principle, its calibration procedures and wind retrieval algorithms are addressed in the context of an intercomparison study between Aeolus and A2D wind observations from the WindVal III campaign (Lux et al., 2020).

p. 19, summary: The contribution by the 2µm DWL random error is not discussed here, probably because it is negligible. Please clarify.
Indeed, the 2µm-DWL random error contributes only marginally to the one of the scatter plot. Still, the random errors given for Aeolus were revised by considering a mean random error for 2-µm DWL observations of 1 m/s. The text was adapted accordingly.

6.2 Random error

The random error of the scatter plot σ_{sc} represented by the scaled median absolute deviation according to Eq. (4) and shown

395 in Fig. 7 is determined to be 4.0 m/s (Rayleigh) and 2.2 m/s (Mie) for the WindVal III data set, and 4.4 m/s (Rayleigh) and 2.2 m/s (Mie) for the AVATARE data set. As revealed in section 4.3, the random error σ_{DWL} of 2-μm DWL observations lies between 0.92 m/s and 1.50 m/s. By assuming independence between Aeolus and 2-μm DWL measurements the Aeolus random error σ_{Aeolus} can be calculated according to $\sigma_{Aeolus} = \sqrt{\sigma_{sc}^2 - \sigma_{DWL}^2}$, where σ_{DWL} is assumed to be 1 m/s here. With that, the random error of Aeolus HLOS winds is derived to be, 3.9 m/s (Rayleigh) and 2.0 m/s (Mie) for the WindVal III data set, and

400 4.3 m/s (Rayleigh) and 2.0 m/s (Mie) for the AVATARE data set. This demonstrates on the one hand, that the 2-μm DWL only contributes marginally to the random error, and that the random error of Rayleigh-clear winds is significantly larger than the 2.5 m/s required for Aeolus HLOS winds in altitudes between 2 km and 16 km (ESA, 2016; Kanitz et al., 2019; Reitebuch et al., 2019).