Response to Referee Comment 1 on "*Rayleigh wind retrieval for the ALADIN airborne demonstrator of the Aeolus mission using simulated response calibration*"

We appreciate the referee's insightful and valuable comments on our manuscript AMT-2019-274, which helped to significantly improve the manuscript. We have revised the manuscript accordingly. A point-by-point response is also attached to this file.

Comments:

1. The paper shows how calibration curves for a direct-detection airborne Doppler lidar can be derived from the known pressure and temperature in the sensed atmospheric volume and a careful characterization of the transmission characteristics of the interferometers used in the receiver. The calibration procedure is a copy from what is done for AEOLUS. It is shown that the procedure can be applied as well to the airborne demonstrator of AEOLUS, and achieves a better accuracy with a reduced bias and equivalent standard deviation with collocated drop-sonde wind measurements as with a measured response curve that does not take specifically into account the pressure and temperature conditions.

   R: Thanks for your comment. It should be noted that the A2D SRRC procedure mentioned in this paper is not a pure "copy" from what is done for ALADIN. There are some significant differences, especially in the generation and update of the transmission characteristics of the FPIs of the Rayleigh receiver for the atmospheric channel. The specific differences are listed below:

   1. The transmission characteristics of FPIs for the atmospheric path are different from the transmission curves registered on the internal reference path during the instrument spectral registration because of the difference of the illumination of the beams in the atmospheric and the internal reference paths due to different divergence and incidence angles on FPIs (Reitebuch et al., 2009). **As for ALADIN**, the FPIs transmission curve in the atmospheric path is modelled by a convolution of an Airy function, which describes the transmission of a perfect FPI, and a defect function which is used to consider deviations from the perfect FPI. For ALADIN, a tilted top-hat function is used (Dabas and Huber, 2017), whereas a Gaussian defect function is used for the A2D. As opposed to ALADIN, where only the transmission curve in the internal reference path can be measured during instrument spectral registration, **the A2D** FPI transmission curves both in the internal reference path and in the atmospheric path were measured in previous campaigns, demonstrating slight deviations between both transmission paths due to the aforementioned reasons. Therefore, different combinations of FPI transmission functions derived from different campaigns can be used to derive different candidate SRRCs. After the comparison of candidate SRRCs with simultaneous MRRC, the most satisfactory combination is used for initial SRRC determination.

   2. **As for ALADIN**, the core idea of the updated spectral registration using the Airy and top-hat function is based on the comparison of the predicted one and an MRRC. The FPIs transmission characteristics cannot represent the actual sensitivity of the Rayleigh receiver at the atmospheric path until the difference of predicted and the measured responses coincide within a threshold limit. But for **A2D**, the optical path characteristic of the A2D Rayleigh channel is considered

carefully. Basically, the FPI center frequency is sensitive to the incidence angle of the light. It is a reasonable way to optimize the FPI transmission function by fine adjusting the center frequency of filter A or B for the atmospheric path. The Rayleigh spectrometer is composed of two FPIs which are sequentially coupled. Thus, the reflection of the directly illuminated FPI is directed to the second FPI. Any incidence angle change in front of the Rayleigh spectrometer will act similarly on both FPIs.

The related description has been added in **Sect 7 Page 20 Line 5-23.**

2. The practical significance of the method should be discussed. The paper suggests the transmission characteristics of the two FPs are very stable, except for a frequency shift caused by an incidence angle varying from one flight to the other. In Fig 10 or 13, the results are obtained with a frequency shift determined from data acquired during the same flight. Will the frequency shift be significantly modified during another flight? If yes, this should be stressed and a conclusion should be that response calibration should be done every flight.

   R: revised. Thank you for this comment. We will add a clarification to the manuscript.

   The derived frequency shift of 20 MHz can basically depend on the alignment of the atmospheric optical path. From the experience from the last 10 years it is known that this alignment is not randomly varying from flight to flight, but changes from campaign to campaign. As the telescope and optical receiver is coupled via free optical path (and not via a fibre), the mechanical integration of the A2D into the aircraft prior to each campaign leads to small variation in position and incidence angle on the spectrometers for each deployment. Thus, a valid response calibration can be used for the entire campaigns period. This is true for both, measured or rather simulated response calibrations. In order to monitor the atmospheric path alignment, the position of the spots generated on the ACCD detector behind each FPI is analyzed and serves as information on the alignment during the flight itself and among the flights during the campaigns period. It should be noted that the applied frequency shift is only 20 MHz, which is even less than the frequency separation of successive measurement points during a response calibration (25 MHz) and which corresponds to 1.8×10^{-3} of the FSR of the FPIs. The related description has been added to **Sect 5.3 Page 16 Line 17-26.**

3. The SRRC reduced the bias, but on the other hand lower the correlation coefficient with dropsonde vlos in Fig 10. This should be commented.

   R: revised. The comparison of the correlation coefficient has been added **in Sect 6 Page 17 line 8-21**: "The correlation coefficient, bias and standard deviation are also calculated and listed in Table 5. Fig. 10 (a) illustrates the comparison of the LOS wind velocity between dropsonde and A2D Rayleigh channel measurements, showing that the fit parameters slightly deviate from the ideal case. The correlation coefficient, bias and standard deviation of the A2D Rayleigh winds are 0.95, 0.23 m s^{-1} and 2.20 m s^{-1}, respectively, which is comparable to results in previous studies (Lux et al., 2018). The comparison of LOS wind velocity between dropsonde measurements and the results derived from SRRC without FPIs optimization is illustrated in Fig. 10 (b). The corresponding correlation coefficient, bias and standard deviation are determined to be 0.93, -3.32 m s^{-1} and 2.61 m s^{-1}, respectively. It can be seen that the underestimation of the LOS wind velocity from SRRC without the FPIs optimization is significant, demonstrating the necessity of the FPIs optimization before wind retrieval using

SRRC procedure. Figure 10 (c) shows the comparison of LOS wind velocity between dropsonde measurements and results derived from SRRC with FPIs optimization. The bias is 0.05 m s^{-1}, which is better than the results from A2D wind with MRRC, and the correlation coefficient and standard deviation are 0.94, 2.52 m s^{-1}, respectively, comparable to the results from A2D Rayleigh channel measurements, thus implying the feasibility and robustness of SRRC with FPIs optimization on A2D Rayleigh wind retrieval. From now on, only SRRC results with optimized FPI parameters will be discussed."

4. The paper mentions the presence of an internal reference channel without explaining exactly what it is. A simple graph showing the internal reference and the atmospheric path would improve the clarity of the paper.

   R: revised. Thanks for your suggestion, we didn't explain it clearly. The specific schematic of ALADIN Airborne Demonstrator (A2D) was shown in Fig. 1 in (Lux et al., 2018), which has been already referenced in the following added in **Sect 2, page 4, line 11-23** see below:

   "For each direct detection wind lidar system, the emitted laser frequency should be known to accurately derive the Doppler frequency shift. A zero Doppler shift reference determined by pointing to the zenith direction has been used to correct for the short-term frequency drift in previous studies (Souprayen et al., 1999b; Korb et al., 1992; Dou et al., 2014). But for the A2D, the internal reference path is specially used to measure the emitted laser frequency information. As shown in Fig. 1 in (Lux et al., 2018), a small portion of laser beam radiation is collected by an integrating sphere and coupled into a multi-mode fibre, then injected into the receiver via the front optics. The atmospheric backscattered signal is collected by a Cassegrain telescope and guided via free optical path propagation to the front optics and receiver successively. This path is called the atmospheric path. An electro-optic modulator is used to separate the atmospheric signal from the internal reference signal temporally in order to minimize the contamination of the internal reference signal with atmospheric signals and saturation of the detectors at short ranges (Reitebuch et al., 2009). Because of the different optical illumination of the internal path and atmospheric path resulting in different divergence and incidence angles on the FPIs, the response calibration curves for these two paths are slightly different. Note that ALADIN uses free path propagation rather than a fibre coupling unit for the internal reference path."

   The related descriptions of the internal reference path and atmospheric path are also updated:

   1. **In Sect 2.1, page 5, line 9-11**, "The ALADIN Rayleigh winds produced by the level 1B processor (Reitebuch et al., 2018) are based on a MRRC while the level 2B processor uses SRRC. Basically, MRRC includes two response calibration curves derived from internal reference path and atmospheric path, respectively."

   2. **In Sect 2.2, page 6, line 25-28**, "The A2D SRRC based on this simulation approach promises an improvement in terms of A2D wind speed errors due to the limitations of A2D MRRC. Similar to MRRC, SRRC also includes two response calibration curves derived from internal reference path and atmospheric path, respectively."

5. Page 2, line 9: in the CDL, the backscattered light captured by the telescope is mixed with a frequency shifted emitter laser. The frequency shift enables the measurement of positive and negative winds. It is not mentioned.
   R: revised. Please see **Sect 1, page 2, line 13-14:** "…, light, and the frequency shift introduced by an acoustic-optical modulator enables the measurement of positive and negative winds."

6. Equations 3 and 4: there integrals should be between -\infty and +\infty. In practice S_a has a limited width so the limits -FSR/2 +FSR/2 can be enough if FSR is much larger, but +-\infty is better.
   R: revised. Please see the updated **Equation 3 and 4 in Sect 3, page 7, line 22-24.**

$$I_{A,B,INT}(f_i) = \int_{-\infty}^{+\infty} T_{A,B,INT}(f) S_i(f_i - f) df$$

$$I_{A,B,ATM}(f_a) = \int_{-\infty}^{+\infty} T_{A,B,ATM}(f) S_a(f_a - f) df$$

7. Page 11, lines 13-20: it is suggested the atmospheric and internal characteristics of FP transmissions are solely due to plate defects. This is wrong. The main reason is the beam étendue is different in the two channels due to a diaphragm.
   R: revised. Thanks for your comment, yes, we didn't explain it correctly at this point. It has been revised as "the transmission characteristics of the FPIs for the atmospheric path are different from the transmission curves registered on the internal reference path during the instrument spectral registration because of slightly different illumination of the beams in the respective paths due to different divergence and incidence angles on FPIs (Reitebuch et al., 2009)." Please see **Sect 2.2, page 6, line 20-24**.

8. Page 12, lines 19-23: the authors should write what \eplison_R is. It is the difference between the SRRC and the MRRC. Ideally it should be randomly fluctuations about 0 with no offset not slope.
   R: revised. The definition of ε_R has been updated in the revised manuscript as "ε_R is defined as the difference between response from the respective SRRCs and the MRRC. Then, the linear fit of ε_R as function of $f^{'}$ is made, returning a slope and intercept based on Eqs. (18A) – (18B) in (Dabas and Huber, 2017). Ideally, if the result from the SRRC matches the measured one from MRRC, it should be randomly fluctuations about 0 with zero intercept and slope", please see **Sect 5.2, page 14, line 26-27 to page 15 line 1-2.**