Response to Anonymous Referee 1

Referee comments are indicated in *italic*, followed by our reply.

The paper presents a new background correction method for the HALO Photonics Streamline Doppler lidar, but it can also be applied to other Doppler lidar systems. The paper is a well structured and the algorithm description is presented in detail. My overall impression of the paper is good and it should be published in AMT if the authors take into account the following points:

We would like to thank the referee for the valuable comments, which have improved the manuscript.

Major issues:

- *The method is actually quite powerful and significantly lifts the performance of the Doppler lidar systems. It comes even close to the sensitivity of more powerful Raman lidar systems. In page 8 line 27 such collocated measurements with a Raman lidar are mentioned. It would be nice to a) show attenuated backscatter data of this Raman lidar system together with the improved signals in Fig. 8b. b) show profiles of att. backscatter of Raman and Doppler lidars to prove that there is no remaining trend with height in the corrected data. Such an analysis would give additional value to the paper and help the reader to perceive the performance of this post-processing algorithm.*

Thank you for the suggestion. We have added Raman lidar SNR and attenuated backscatter profiles as a new Fig. 9. Fig 9 includes also a comparison of Raman and Doppler lidar SNR profiles at 21 UTC. We have added a short description of the Raman system in Section 2 and modified text on page 8, line 26-27 as:

"These aerosol layers were also observed with a co-located multi-wavelength Raman lidar PollyXT (Baars et al., 2016; Engelman et al., 2016). A comparison of lidar 53 and the Raman lidar measurements at 1064 nm wavelength are presented in Fig. 9. Considering the wavelength difference, the agreement between the two systems is reasonably good."

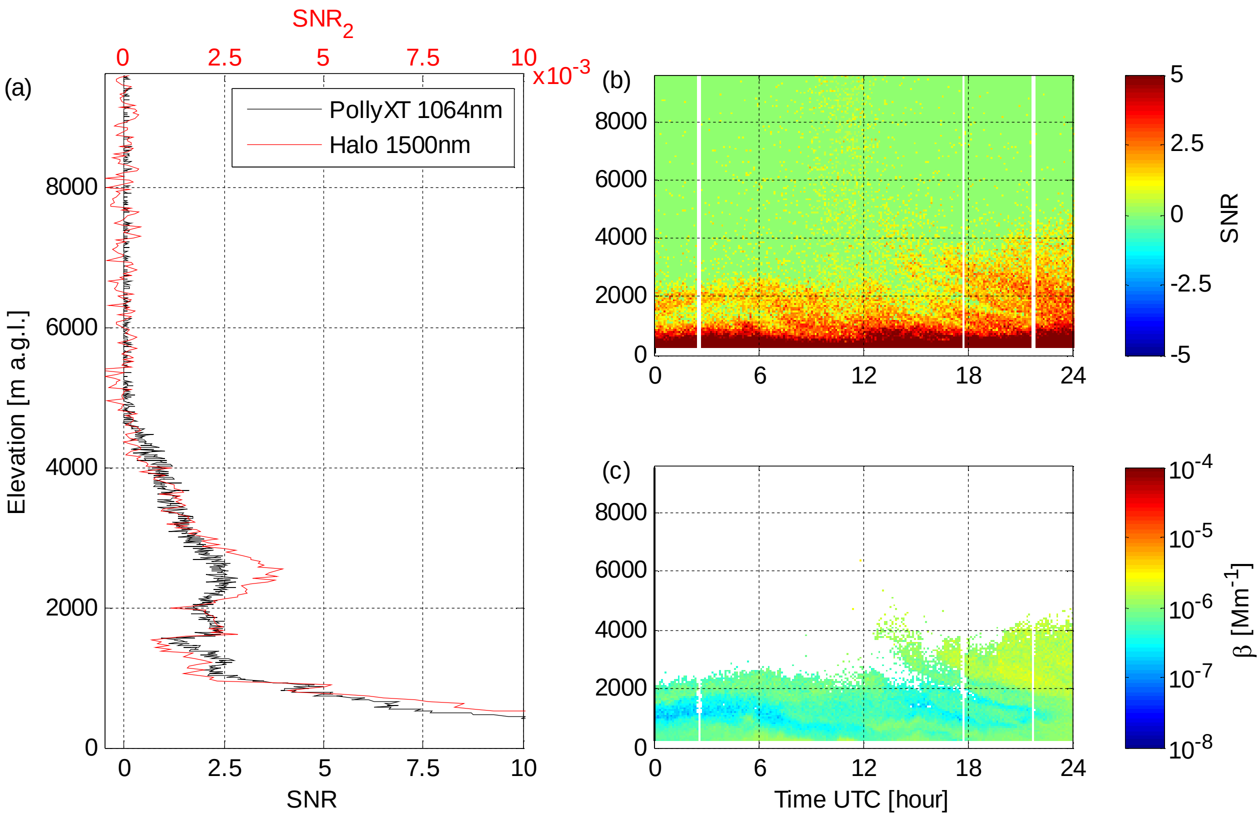

Figure 9: (a) Vertical profiles of SNR from PollyXT at 1064nm wavelength and SNR_2 from lidar 53 at Finokalia on 8 July 2014. Both profiles are obtained at 21 UTC; integration time of lidar 53 profile is 350s and integration time of PollyXT profile is 360s. (b) Time series of PollyXT SNR at 1064nm wavelength with 360s integration time at Finokalia on 8 July 2014. (c) Time series of PollyXT attenuated backscatter at 1064nm wavelength with 360s integration time at Finokalia on 8 July 2014.

- Such work should reflect back on the next versions of the lidar systems and/or the on-board processing software. The algorithm should even be included in the data acquisition itself. Please comment if there are any plans for that.

To our knowledge there are no plans to incorporate this algorithm in the on-board software at the moment. In our opinion this is not a severe limitation, as most (if not all) lidar systems require some post-processing for optimal data quality.

- Is the software available somewhere? It would be really useful to point to a repository of any kind.

A Matlab implementation of the algorithm presented here is available at https://github.com/manninenaj/HALO_lidar_toolbox. We have added a note on this in Conclusion and a reference to the toolbox in the references.

- Page 9 line 17: "With enhanced SNR, the instrumental contribution to radial velocity variance can be estimated with better accuracy". The method discussed in the paper is only applied to the SNR. How does improvement of radial velocity work in this context? Is the improvement maybe based on a better selection of radial velocity values? This is not fully clear, yet very interesting and should be demonstrated in the paper. Please provide plots of enhanced radial velocity together with Fig. 5, 7 or 8.

This method does not affect radial velocity values from the Doppler lidar, but only SNR.

As discussed in the manuscript on page 3, lines 17-20, instrumental uncertainty in radial velocity is a function of SNR (see also Fig. 3b). Variance calculated from a set of observed radial velocities will have contributions from both instrumental uncertainty and atmospheric turbulence. By improving the accuracy of SNR, this method enables more accurate determination of the instrumental contribution, which can be substantial under low signal conditions. This will result in more accurate retrieval of turbulent parameters when instrumental noise contribution is subtracted from the observed radial velocity variance.

We have tried to clarify this sentence as
"With enhanced SNR, the instrumental noise contribution to radial velocity variance can be estimated with better accuracy, which will improve the quality of turbulent parameter retrievals."

Minor issues:

- *Would temperature stabilization of the Stream Line / Stream Line Pro instruments help to reduce noise?*

Temperature stabilisation would help to ensure that the shape of Pamp is known well (c.f. Fig. 2b). However, temperature dependency of Pamp is a relatively small source of noise in the SNR, in the order of magnitude 10^{-5} x (SNR+1). We have added a note to this effect on page 5, line 23:

"For optimal data quality, additional temperature stabilisation could be applied to ensure that P_{amp} is always in the well-characterised temperature range."

- *The authors present an algorithm that is applied to the evaluated profiles of SNR. Would it make sense to apply it to the raw spectra.*

If SNR is calculated from the raw spectra, this algorithm will be needed to determine the actual noise floor. We have added a note to this effect in conclusions on page 9, line 16.

- *Concerning the alternation of the emitter of lidar 146: Is it a fault of the individual system or is it found for all systems?*

We have observed this behaviour on the two systems with the new, more sensitive amplifier that we have access to at the moment. We consider it likely that this alternation will be present in all systems with the XR-amplifier. This is easy to check from the saved background files by the lidar operator, though.

Technical issues:

- Table 1 could be condensed. Stream Line and Stream Line Pro seem to be identical and the only difference to the Stream Line XR seems to be pulse repetition rate and maximum range.

Table 1 has been condensed:

Table 1 Specifications for Halo Doppler lidars utilised in this study.

Lidar number and version	46, Stream Line
	53, Stream Line Pro
	146, Stream Line XR
Wavelength	1.5 μm
Pulse repetition rate	15 kHz (46 and 53) or
	10 kHz (146)
Nyquist velocity	20 m s^{-1}
Sampling frequency	50 MHz
Velocity resolution	0.038 m s^{-1}
Points per range gate	10
Range resolution	30 m
Maximum range	9600 m (46 and 53) or
	12000 m (146)
Pulse duration	0.2 μs
Lens diameter	8 cm
Lens divergence	33 μrad
Telescope	monostatic optic-fibre
	coupled

- Figure 2: Using red and black both in (a) and (c) is a bit confusing in this context. Please use alternative colors in (c).

We have changed the colors in Fig. 2c to blue and black:

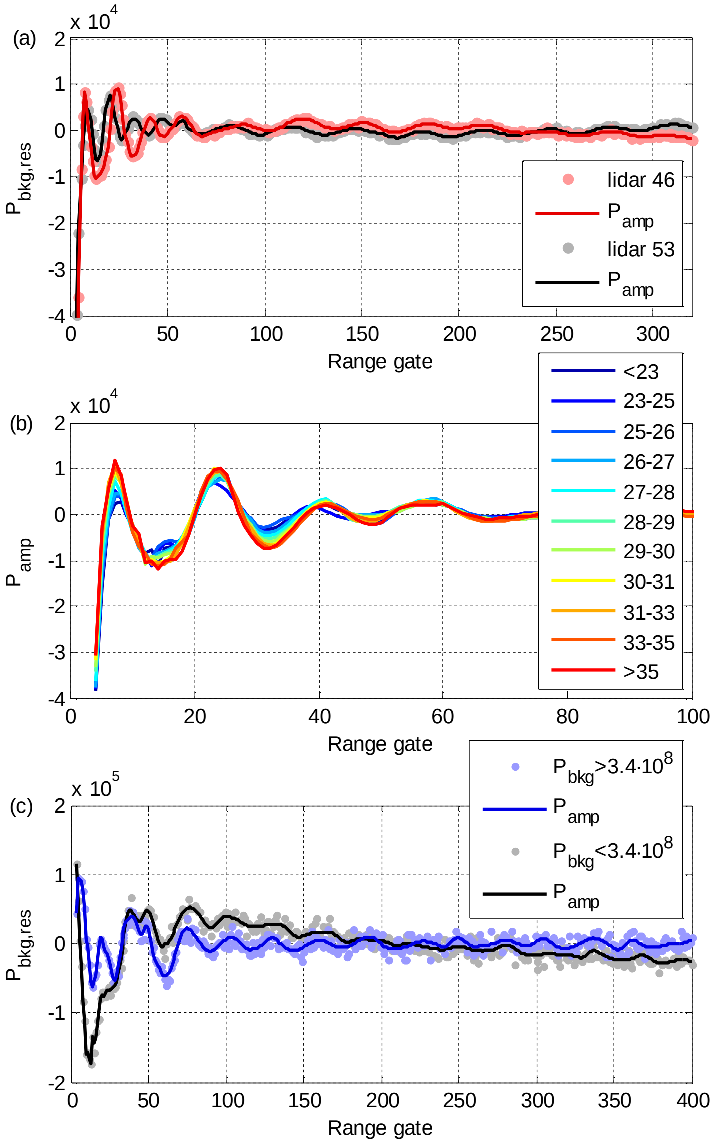

Figure 2: (a) Lidar 46 $P_{bkg,res}$ averaged from 20 August 2016 to 14 June 2017 (7193 background checks). Lidar 53 $P_{bkg,res}$ averaged from 1 January 2014 to 30 November 2015 (16802 background checks). P_{amp} is plotted for both systems. (b) First 100 range gates of lidar 46 P_{amp} calculated for different ranges of T. (c) Lidar 146 $P_{bkg,res}$ averaged from 12 January 2018 to 31 May 2018. $P_{bkg,res}$ is averaged separately for high P_{bkg} mode (1375 background checks) and for low P_{bkg} mode (1623 background checks). P_{amp} is plotted for both modes.