# Author Responses to Referee 2

We would like to thank both reviewers for their significant time spent reading the manuscript and for their constructive comments for improving it. We have made very careful revisions to address all these comments. In the following paragraphs, the **bolded** words represent the reviewers' original comments and the unbolded text represents our answers.

## Referee 2:

**1 General Remarks**

**The authors give a comprehensive description of their approach for retrieving aerosol backscatter profiles from the return signals of an atmospheric lidar operating in the UV near 290 nm. Their aerosol results in the UV are compared with HSRL lidar measurements of aerosol at 532 nm. Generally good agreement is found. Uncertainties of the retrieved aerosol properties in the UV are also estimated. They usually exceed 50% over a wide range of altitudes.**

**I agree with reviewer 1 that comparison to Aeronet optical depth data would be a good addition to the paper. I also agree with reviewer 1 that a few more cautionary remarks on the variation of extinction to backscatter ratio and aerosol wavelength dependences between aerosol types should be added. However, in many cases the stated large uncertainties probably cover a good fraction of these changes between aerosol types.**

**Overall I think this is a solid paper, well suited to the scope of AMT. I recommend publication with only a few minor revisions.**

We thank the reviewer for the positive comments and good suggestions. We have added a paragraph on $RO_3QET$ data evaluation using collocated AERONET data at 340 nm (Lines 213-237) to address both reviewers' suggestion. The AERONET data provide a very nice evaluation of the ozone lidar data and the assumed lidar ratio. (Please refer to the answers to Reviewer 1 for more details.) The references for AERONET have been also added.

**2 Suggestions**

1. **line 33: "weighing" or "weighting"?**

We meant "weighing", so we keep it unchanged.

2. **lines 35/36: I suggest to add the Browell et al. 1985 reference here as well. Ed Browell really pioneered operational airborne UV-lidar measurements of tropospheric ozone in the 1980s.**

We agree and we have added Browell et al. 1985 in the citation list here.

3. **lines 32 to 42: Here, and in several other places of the paper (e.g. lines 256 to 262), I suggest to add more cautionary sentences on the general problem of aerosol interference on DIAL ozone measurements (Browell et al. 1985, but also Steinbrecht and Carswell, JGR, 1994). Especially the differential backscatter term can cause large problems for narrow aerosol layers (errors exceeding 10s of percents). Investigations of aerosol effects on ozone, of the order of a few percent, are very desirable, but substantial caution is required.**

We have cited Steinbrecht and Carswell (1994) in the 1st paragraph.

4. **lines 48/49: there is ozone absorption at 532 nm, which is not necessarily negligible. Add statement.**

We have replaced "negligible" with "much smaller than".

5. **lines 55 to 62: Maybe the authors should move this to the beginning of the paragraph, and even extend it? Important lidar facts are: Because of the strong wavelength dependence of molecular Rayleigh scattering ($\lambda^{-4}$), and the weaker wavelength dependence of aerosol scattering ~$\lambda^{-1.5}$, aerosol is measured best by lidars at 532 and 1064 nm (NdYAG) or 694 nm (Ruby). Nevertheless, the authors' UV lidar also measures aerosol, and aerosol interference on the ozone measurement needs to be looked at. Fortunately, because of the large increase of ozone extinction from 320 nm to 250 nm (2 orders of magnitude), aerosol interference at your wavelengths (around 290 nm) is a factor of 5 to 20 smaller than, e.g., for a stratospheric ozone DIAL (around 310 nm) for the same amount of aerosol.**

We have made change to say: "Lasers used for aerosol lidars are preferred in the visible and infrared bands, typically 532 and 1064 nm for Nd:YAG laser or 694 nm for Ruby laser (Russell et al., 1979),…".

We agree with the reviewer on the aerosol interference in the ozone DIAL retrieval approximately proportional to $\Delta\lambda/(\lambda\Delta\alpha_{O3})$. The aerosol interference in DIAL is pretty complicated and is worth another paper to discuss. Since the major purpose of this article is to discuss aerosol retrieval and its uncertainty, we decide not to add more discussion on the aerosol interference in DIAL retrieval. But, this is certainly an important motivation to do aerosol retrieval. So, in the Introduction, we say "Vertical aerosol profiles are of high interest not only because they are needed for aerosol correction in ozone lidar retrievals (Steinbrecht and Carswell, 1994), …". In the Conclusions, we write "Aerosol correction for ozone lidar retrievals will be described in a subsequent paper."

6. **line 154: "owning" -> "owing"?**

We have made the correction as per the suggestion.

7. **line 186: Why is the extinction wavelength exponent (1.49) different from the backscatter wavelength exponent (1.34). Is that because the constant lidar ratio (S = 55) is only used for the UV lidar, whereas the HSRL actually measures extinction? The authors might want to clarify that. I also wonder how meaningful this entire extinction comparison then is, because the UV lidar really only measures backscatter, and extinction is largely assumed.**

Yes. The extinction wavelength exponent is different from the backscatter exponent because the lidar ratio (*S*) is wavelength dependent. After an extensive literature review, we assumed S=60 sr at 299 nm and the resulting extinction retrievals agree well with the AERONET observations at 340 nm (we have added this description in the AERONET-DIAL comparison). The *S*=55 sr assumption for the HSRL at 532 nm is taken from Reid et al. 2017, who derived this value by comparing HSRL data (532 nm) with collocated AERONET observations at 500 nm. To clarify this, we have added "the calculated Ångström exponent is different from the backscatter-related wavelength exponent because of the wavelength dependence of *S*."

Yes, as the reviewer pointed out, the elastic lidar directly measures backscatter so that the extinction retrieval has larger uncertainty than backscatter retrieval. However, we still believe the extinction retrieval is meaningful because "In practice, aerosol extinction is a more meaningful parameter and more relevant for several applications than backscatter" (Lines 203), such as AOD calculations to compare with satellite data.

8. **lines 225 to 236: In Fig. 2, the UV lidar measured backscatter above 6 km during daytime clearly is too high (lighter blue colors). The authors state that they are not looking at these altitudes. However, I am wondering if the systematic high bias above 5 km in Fig. 4, has something to with the daytime high bias above 6 km in Fig. 2? Have the authors considered that? A few additional sentences might be good.**

We agree that the large positive differences above 5 km can be due to strong solar background during daytime. We have added the following explanation:

“These positive biases can be caused by two reasons. First, the $RO_3QET$ derived aerosol extinction above 5 km is obviously larger than that from HSRL during daytime due to the solar background impact, which is especially strong in the summer. The relative differences are even worse in clean (compared to turbid) regiosn during the daytime because of the small number division effect mentioned earlier. It can be seen from Figure 3 that $RO_3QET$ nighttime retrievals above 5 km and daytime retrievals below 5 km are relatively good due to either lower solar background or larger lidar signal resulting in better SNR.”

**9. Figure 3: Maybe a logarithmic plot (both axes) would be better here? A lot of the data points are close to the lower left corner (0,0).**

We have accepted the reviewer’s suggestion and changed the linear scale to log scale for Figure 3 (currently Figure 4). There are about 80,000 points in that figure, with a large number being very small values. So, the log scale is better to show how the points are scattered relative to the regression line.