

## ***Interactive comment on “Year-round stratospheric aerosol backscatter ratios calculated from lidar measurements above Northern Norway” by Arvid Brand et al.***

**Arvid Brand et al.**

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(Author responses are in blue. In the tracked changes version deleted sequences are marked red. New text is marked in blue.) General Comment: We want to thank the three reviewers for the detailed reviews with many useful ideas and suggestions which, we think, have significantly increased the quality of the manuscript. We have rewritten a substantial portion of the manuscript. We restructured the outline of the manuscript. Section 2, formerly named “ALOMAR RMR Lidar” is now called “Instrument and Method” with subsections 2.1 “Processing of the raw data”, 2.2 “Calculation

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of backscatter ratios” and 2.3 “Identification of the stratospheric aerosol layer”. Section 3, formerly named “Methodology” is now named “Calculating the backscatter ratio under daytime conditions”. Section 4 contains the results of the paper. A “Summary and Conclusion” can be found in section 5. The nomenclature for the calculation of the backscatter ratio and the color ratio was changed. Therefore, sections 2.2 and 3 have been completely rewritten. The figures have been updated to account for the new symbols.

In the paper, “Year-round stratospheric aerosol backscatter ratios calculated from lidar measurements above Northern Norway”, the authors present a multiyear stratospheric sulfate aerosol (SSA) dataset from lidar observations at the ALOMAR research station. This paper provides valuable insight into lidar-measured SSA over the Arctic, and the study is appropriate for AMT, however I have a few major concerns with the paper in its current form. These include the overall writing quality of the manuscript and lack of important details of the study. Thus, I recommend a major revision. The authors should address the major and minor comments outlined below for the revised manuscript.

1. Writing quality of manuscript: Many grammatical errors and misspellings are found throughout the text, and acronyms need to be defined. The paper should be thoroughly proofread.

The paper has been reworked completely to improve the writing quality.

2.Lack of study details: There are several instances in the manuscript that I believe need additional information, as follows:

- a. Page 4, Lines 7-10: Please add more description of ECMWF (e.g., spatial resolution). Why ECMWF? Are there other options? What are the uncertainties associated with the parameters from ECMWF?

The section has been rewritten. We have selected the ECMWF model as it provides density and ozone data with a time resolution of 1 hour for the location of ALOMAR. We have briefly discussed the use of ozone values from another model

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in the manuscript (Page5, line 16).

When you state “converted to a 5 min and 150 m grid”, converted from what? Also, add more details on how the Rayleigh and ozone corrections are done.

We interpolate the model data and the lidar data to a grid with a 5 minute time and 150 m vertical spacing. A special bullet point “Gridding of lidar data” has been added to section 2.1

- b. Sensitivity studies: Please comment on the choices made, and any sensitivity studies completed for normalization altitudes (Page 5, Line 11), wavelengths for elastic/inelastic signals (Page 5, Lines 22-23), and lower limit of data availability (Page 7, Lines 13-14).

Normalization altitude: The approach was to use the highest possible altitude range as limited by the signal to noise ratio of the Raman backscattered light. This can be seen in Fig 2c: The Signal  $S_{387}$  becomes exceedingly noisy at about 40 km, thus we used a range below. First, we used a range of 30-34 km (as suggested by previous publications) but the results showed, that the upper boundary of the aerosol layer was found above 30 km in many cases. Thus we have lifted the normalization altitude. We have improved section 2.2 accordingly.

Wavelengths: All elastic/inelastic wavelength combinations have been analyzed and lead to proper results. We focused on  $R^{1064}/387$  because of lowest effects due to Ozone extinction and highest backscatter ratios. This is now discussed in the revised manuscript.

Lower limit of data availability: We have improved the section 4 accordingly.

- c. Equation 1 (Page 3): Where is this from (reference), or how was it determined?

The equation has been corrected. We have added a reference in the manuscript (Kovalev et al, 2004, “Elastic Lidar: Theory, Practice, and Analysis Methods”, Page 138).

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- d. Page 6 (Section 4): Please add more discussion/explanation for this section, and the importance/purpose of each figure (Figures 4 through 7). For example, why are you showing  $R_{355}/387$  for Figure 5 instead of R at other wavelengths?

The section has been reworked completely. The correction is presented in more detail.

Also, please state why a correction is needed for  $CR_{1064}/355$ .

The correction is now explained in detail in the discussion of equations 8 to 11.

- e. Page 7 (Figures 9 and 10): Explain how these figures were created (e.g., averaging), as was included in the figure captions.

We have updated the manuscript accordingly: We first calculated hourly averaged backscatter ratios smoothed in altitude with a running mean of 1.1 km. Then we calculated the average for the two telescopes. Finally the mean of the hourly profiles is calculated for each month.

3. Conclusions: I believe this entire section needs to be re-worked. Please address the following:

- Re-define all acronyms.
- I recommend not referencing figures in this section.
- Please do not state results that have not been already discussed earlier in the paper. For example, the uncertainties stated in Line 10 of Page 8. This belongs in the Results section.
- As mentioned above there are grammatical errors in this section.
- The narrative does not flow well (including ending with a lone sentence), so I recommend re-writing the entire section.

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- f. I suggest including bullets or something similar to summarize the main findings of the study.

The section has been reworked completely to account for all the comments.

Minor comments: 1. Page 1, Lines 1-12: Please add a few sentences to the abstract describing the primary results of the study.

Done. Abstract has been reworked

2. Page 1, Line 5: Define ALOMAR.

Done

3. Page 1, Line 15: Define SSA. All acronyms should be defined at their first use in the paper.

Done

4. Introduction section: State the location and dates of the study.

Done

5. Page 2, Lines 31-33: lidar measurements of what? R and CR? Explain the parameters of interest. Also, add more motivation as to why this study is important. What is being accomplished/what is the general purpose of this paper?

6. Page 3, Line 5: Add the elevation of the ALOMAR station.

Done

7. Pages 3 and 4 (Section 2): I suggest not using dashes when listing the processing steps. Bullets may work better.

Done

8. Page 4, Line 14: How was this relative uncertainty computed? Please add an explanation to the text.

This section was rephrased to provide the explanation in the manuscript.

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9. Page 6, Lines 1-2: The layers are also not associated with PSCs because of the PSC screening metrics described on Page 5, correct?

Correct. We added this information now in the manuscript.

10. Page 7, Line 20: Rephrase "The first picture".

Done

11. Page 7, Line 31: Significantly lower altitudes? Are you comparing 12-18 km to 12-22 km? If so, this sentence does not make sense. This paragraph is confusing, so I recommend revising it.

The paragraph was split, because 2 different effects are discussed. The altitude ranges were not meant to be discussed together. This was made clearer.

12. Page 8, Lines 1-4: How do these findings compare with other studies?

We have included a brief comparison to previous studies in section 4.

13. Figure 2: Add labels, like a-d, to the plots, and refer to them in the caption. How was the altitude range of the stratospheric aerosol layer determined? Also, as a general comment, mention whether the altitudes are referenced to above ground level (AGL) or above mean sea level (AMSL). This should be stated in the text of the paper as well.

We added labels and used them in caption. The altitude range of the aerosol layer in this figure is 15 to 34 km and indicates the altitude range between a high tropopause and the lower boundary of the normalization altitude. All altitudes are referenced to AMSL. This is now stated in the revised manuscript.

14. Figure 4: For the x-axis, I suggest not using a slash symbol (/) here, as this could be confusing. Maybe use "or" instead. Also, the colored shaded areas representing the measurement uncertainties are very difficult to see.

We now use "or" as suggested. The uncertainties are pretty small and therefore hard to see. However they become visible above about 28 km.

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15. Figure 5: Please mention in the caption what the shaded area in blue and black vertical line at  $R_{355/387} = 1$  represent.

The figure has been reworked to make the discussion clearer. We have changed the line color of the black vertical line to gray as this line is just drawn for reference.

16. Figure 8 caption: I suggest re-wording "Time of available data".

Changed to "Available data in hours".

17. Figures 1-10: I suggest making the text larger for both the axes and color bars.

Done. All figures have been reworked.