Replies to comments by Referee 1

Comments, replies, *„changes in the manuscript“*

The manuscript describes a method to derive the backscatter coefficient of stratospheric aerosol from a novel frequency scanning lidar system. It is of great interest for the scientific community to resolve with high vertical and temporal resolution even low amounts of stratospheric aerosol. They compared their results to passive satellite observations and found a reasonable agreement considering the uncertainties of the spaceborne instruments. The manuscript is well written and structured and fits into the scope of AMT. I would recommend publication after minor revisions.

We appreciate the careful review of our manuscript and the many constructive suggestions you provided. Together with the co-authors, we have carefully considered all of your comments and revised the manuscript accordingly by incorporating the proposed changes and additional clarifications wherever appropriate. We hope that these revisions have improved the quality and clarity of the manuscript.

Main comments:

You derive independently profiles of the Mie and Rayleigh signal similar to the HSRL method. The pure molecular signal would allow you to derive the extinction coefficient from your observations additionally to the backscatter coefficient. It would be a great achievement to deliver the extinction coefficient as well, because (1) you could better compare it to the extinction coefficient derived from the passive satellite observations without the assumption of a lidar ratio and (2) you could derive the lidar ratio of the stratospheric aerosol from FSL. Have you tried to derive the extinction coefficient? If possible, you could add it (as a “cherry on the cake”) to the paper, if not, you could discuss why it is not possible to get the extinction coefficient.

Thank you for this valuable comment. Although the spectral information provided by the FSL technique has the potential to enable extinction retrievals analogous to HSRL approaches, the current implementation is limited to the retrieval of aerosol backscatter coefficients. The retrieval of atmospheric transmission required for an independent extinction retrieval has not yet been implemented. Consequently, extinction coefficients can currently only be estimated by assuming a lidar ratio, analogous to conventional elastic backscatter lidar retrievals. Since such an approach relies on an a priori assumption rather than the spectral information provided by the FSL technique, it would not provide additional information beyond the current retrieval. The implementation of an independent extinction retrieval is therefore planned as a future extension of the FSL retrieval.

The following text was added to the publication (chapter 2.2.2): “*The current implementation of the FSL retrieval is limited to aerosol backscatter coefficients. Although extinction could be estimated by assuming a lidar ratio, as in conventional elastic backscatter lidar retrievals, an* *independent extinction retrieval analogous to HSRL is not yet implemented and is planned for a future extension of the method."*

It is good that you prove the consistency of your backscatter coefficients with independent observations by OMPS and SAGE-III. I would consider a comparison to ATLID as well. You state, that the wavelength conversion from 355 to 770 nm hampered the comparison. However, the comparison to OMPS and SAGE also required a number of additional steps and assumptions. If you once have to assume a particle size distribution (PSD), you could easily calculate the backscatter Angstrom exponent from 355 to 770 nm for sulfate aerosol and use ATLID for comparison. Wavelength dependent signal attenuation in the stratosphere is, e.g., discussed in Kar et al., AMT 2026. There is no direct overpass of EarthCARE for your 4 selected comparison cases, but for the September 2024 case, the orbits 1503D or 1510B might be considered.

Apart from the reason mentioned in the paper, we had originally omitted it because it was only suitable for a single measurement, and under background conditions above around 20 km, it is often not possible to derive a meaningful profile. But you are right, a comparison with a spaceborne lidar is of course also interesting and does not require a more complicated conversion than for the other satellite instruments. Using a SAGE PSD, we have now calculated a profile of the expected 770/355 nm ratio of backscattering cross sections. The averaged backscatter coefficient at 770 nm from ATLID measurements within a 350 km radius around Kühlungsborn, derived from the orbit 1510B, is now included in Fig. 4. Sections 2.3 and 3.2 and the appendix have been supplemented with information on the methodology.

Minor comments:

In the introduction the usage of ground-based and spaceborne lidar systems for stratospheric aerosol observations is underrepresented. There are plenty of studies using these lidar systems for the study of stratospheric aerosol. There are studies focusing on volcanic eruptions or wildfire smoke injections as well as long-term monitoring of stratospheric aerosol conditions. The FSL method provides another great opportunity to study stratospheric aerosol additional to the already existing ones.

Thanks for this suggestion. Along with the comments from Reviewer 2, we have added a paragraph regarding spaceborne lidars to the Introduction, and also referenced studies on wildfire smoke injections and the long-term monitoring of stratospheric aerosol conditions.

You use the spectral scanning capability of your laser to derive the spectrum in the receiver. This technique is needed for retrieving the wind speed. There are other (simpler) approaches which use scanning capabilities in the receiver to separate the Rayleigh and Mie signal for the purpose of aerosol retrievals. Please include a short discussion in Sect. 2.1.

We did add a clarification in the first sentence of the abstract, highlighting the universal nature of the instrument. Since the instrument is designed for simultaneous measurements of wind, temperature and aerosols doing Doppler-Mie, Doppler-Rayleigh and Doppler-resonance measurements, a simpler approach could be used for pure measurements of aerosols, but would be insufficient for wind, temperature and resonance measurements. We have added a short discussion to Sec 2.1.

Two short questions about your system: What is the height of full overlap? And is it operated continuously or manually?

The height of the overlap is 20 km. The measurements used for this paper were carried out in manual mode. Since 2025, it has been possible to operate the VAHCOLI system in continuous mode.

Could you indicate the time of sunset and sunrise in Fig. 3 to underline the good performance during daytime?

Done. The vertical solid orange lines denote sunset (16:05 UT, 7 February 2023) and sunrise (06:47 UT, 8 February 2023), respectively.

Technical corrections

L102 The ATLID aerosol retrieval is described in Donovan et al., AMT 2024.

The reference has been added.

Fig 2 caption "APD1 on 28 February"

Done.

L228 ATLID is not a Doppler lidar, but a HSRL

The error has been corrected.

L423 "These …" please provide a noun from the previous sentence to which "these" corresponds to be unambiguous here.

Done.