Response to reviewer #2

General Remarks

This paper describes 11 years of lidar data at 30N in eastern China and compares the measurements to several satellite and other lidar records. The period includes several volcano and wild fire events.

The primary difficulty with the paper is in the variable altitude intervals used in the sAOD comparisons. First it is not clear why the Wuhan data above 25 km are not used for the sAOD calculation, while all other sites extend their sAOD calculations to 30 km or above. Second there is often a lot of stratosphere and aerosol below 17 km where the Wuhan calculations begin, particularly in the winter months, yet this region also seems to be ignored. Why is that when other records extend to the tropopause or 1 km above the tropopause? The impact of ignoring these differences on the sAOD comparisons is not even mentioned, yet it may contribute significantly to the differences which are observed.

Response: We appreciate the reviewer's thoughtful review and constructive comments. We use the meteorological data from the Global Data Assimilation System (GDAS1) for aerosol retrieval, which can only reach up to 25 km altitude. Now, by using U.S. Standard Atmosphere (1976) above 25 km, we have updated the retrieved aerosol properties to 30 km, which is considered the upper limit for sAOD calculation.

In addition, we have used tropopause+1 km as the lower limit for sAOD calculation in the revised manuscript. As a result, the sAOD values integrated from tropopause+1 km to 30 km have been updated in Fig. 3 and we have also added the statements below '**Same as Trickl et al. (2024), we use 1 km above tropopause as the lower limit for sAOD calculation to avoid the influence of tropospheric aerosols and to incorporate the stratospheric aerosols as much as possible. Therefore, the stratospheric aerosol optical depth (sAOD) is calculated by integrating the aerosol extinction coefficient from 1 km above tropopause to 30 km to minimize disturbances from the troposphere and ensure a sufficient signal-to-noise ratio (SNR).**' (please see lines 103-107).

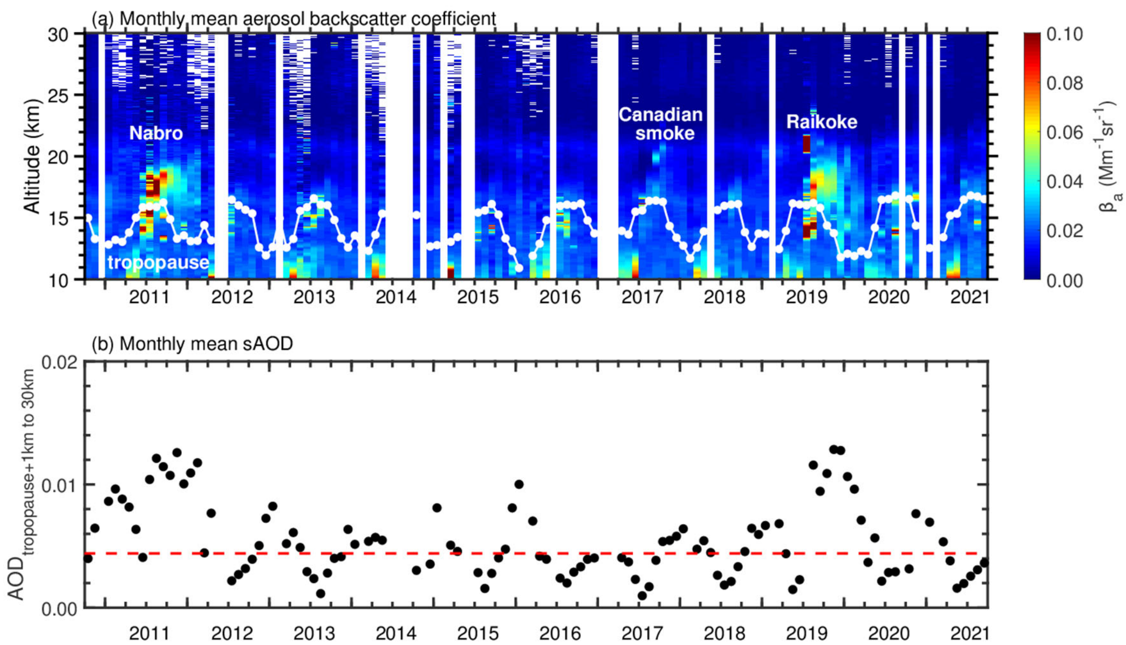

Figure 3. (a) Time-height contour plots of the aerosol backscatter coefficient measured by 532-nm polarization lidar over Wuhan during 2010-2021; the white curve represents the monthly mean tropopause from CALIOP (October 2010 to July 2020) and OMPS (August 2020 to September 2021). (b) The evolution of monthly mean 532-nm sAOD from 1 km above tropopause to 30 km derived from polarization lidar observation (black curve) at Wuhan. The red dashed line represents the background sAOD of 0.0038.

<u>Specific Comments</u>

Here are additional detailed comments to address.

Figure 1. The labels on some lidar sites may be misleading. Are both the Hampton and Sao Jose dos Campos sites still making measurements? If not then indicate the time frame of measurement availability.

Response: The observation periods at Hampton and Sao Jose dos Campos sites have been modified. Sakai et al. (2016) and Hofer et al. (2024) mentioned that the lidar system at Lauder station is working continuously; thus, we mark it as 'since 1992' in Fig. 1.

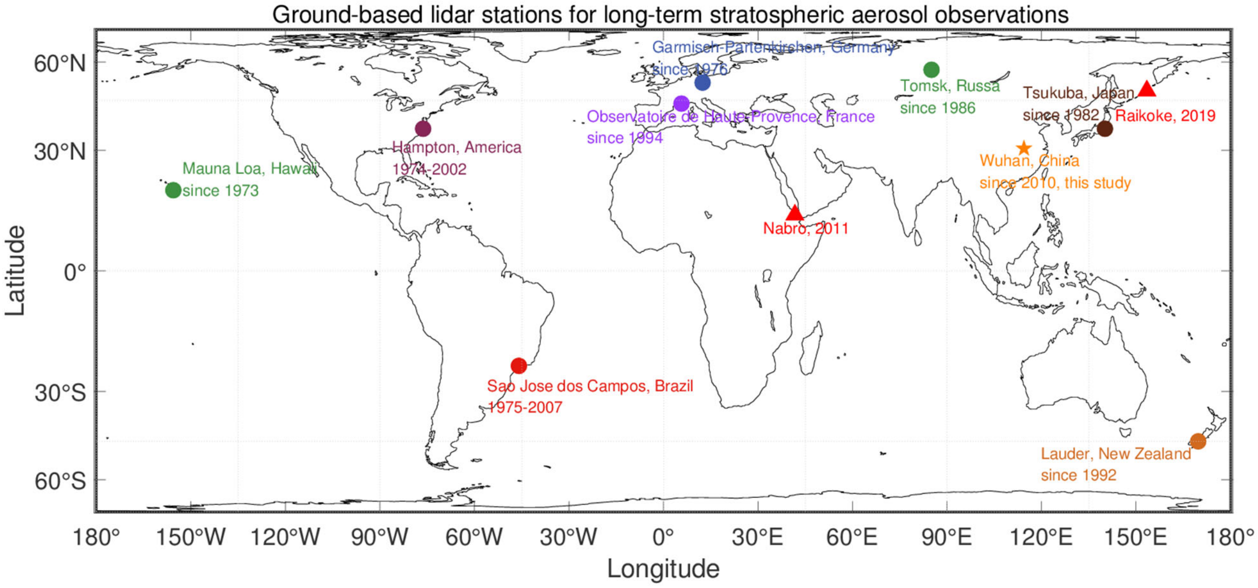

Figure 1. The locations of ground-based lidar sites with long-term stratospheric aerosol observations (solid dots) and two main volcanic eruptions, i.e., Nabro 2011 and Raikoke 2019 (solid triangles), as reported by Kremser et al. (2016), Hofer et al. (2024), and Trickl et al. (2024).

Reference:

Hofer, J., Seifert, P., Liley, J. B., Radenz, M., Uchino, O., Morino, I., Sakai, T., Nagai, T., and Ansmann, A.: Aerosol-related effects on the occurrence of heterogeneous ice formation over Lauder, New Zealand/Aotearoa, Atmos. Chem. Phys., 24, 1265–1280, https://doi.org/10.5194/acp-24-1265-2024, 2024.

Kremser, S., Thomason, L. W., von Hobe, M., Hermann, M., Deshler, T., Timmreck, C., Toohey, M., Stenke, A., Schwarz, J. P., Weigel, R., Fueglistaler, S., Prata, F. J., Vernier, J., Schlager, H., Barnes, J. E., Antuña-Marrero, J., Fairlie, D., Palm, M., Mahieu, E., Notholt, J., Rex, M., Bingen, C., Vanhellemont, F., Bourassa, A., Plane, J. M. C., Klocke, D., Carn, S. A., Clarisse, L., Trickl, T., Neely, R., James, A. D., Rieger, L., Wilson, J. C., and Meland, B.: Stratospheric aerosol—Observations, processes, and impact on climate, Rev. Geophys., 54, 278–335. https://doi.org/10.1002/2015RG000511, 2016.

Trickl, T., Vogelmann, H., Fromm, M. D., Jäger, H., Perfahl, M., and Steinbrecht, W.: Measurement report: Violent biomass burning and volcanic eruptions – a new period of elevated stratospheric aerosol over central Europe (2017 to 2023) in a long series of observations, Atmos. Chem. Phys., 24(3), 1997–2021. https://doi.org/10.5194/acp-24-1997-2024, 2024.

166-167. The explanation for the source of the sulfur for the stratospheric aerosol layer isn't correct. While tropospheric SO2 plays a, still unquantifiable role, H2S does not get to the stratosphere. The primary source of stratospheric sulfur is OCS. See any of the review papers on stratospheric aerosol e.g. Kremser et al., 2016 or the SPARC Assessment of Stratospheric Aerosol Properties (Thomason and Peter).

Response: The "H_2S" has been modified to "OCS (carbonyl sulfide)".

Fig. 3 and discussion on sAOD. The authors need to discuss and perhaps quantify the fraction of sAOD ignored during the winter by limiting their integration to 17-25 km. In the winter there is up to 4 to 5 km of the atmosphere ignored in this formulation as the tropopause descends in winter.

Response: Considering the reviewer's comments, we have recalculated the sAOD by setting a lower limit of troposphere+1km. Accordingly, the sAOD values have been updated in the revised manuscript.

Table 3 suffers from similar problems. All the mid latitude lidars save Haute Provence calculate AOD by integrating from near the tropopause to > 30 km. The Mauna Loa lidar is integrated from 17 km, but this is a tropical site and the tropopause varies little from 17 km throughout the year. Without having similar altitude integral it is unclear what the value is in comparing sAODs. Also, the sAODs are not just one number. What is reported, the mean, median, is there a standard deviation, …?

Response: We have changed the lower limit of sAOD calculation from 17 km altitude to 1 km above the tropopause. The former aerosol retrievals were based on the meteorological data from the Global Data Assimilation System (GDAS1), which can only reach up to 25 km altitude. We have updated the aerosol retrievals to 30 km, by using the U.S. Standard Atmosphere (1976) above 25 km altitude. Therefore, we have recalculated the sAOD by integrating the aerosol extinction coefficient from 1 km above the tropopause to 30 km.

We have added/modified the related statements as follows "**The mean background sAOD (1 km above tropopause to 30 km) over Wuhan was 0.0044 (±0.0019), as obtained from January 2013 to August 2017.** " (please see lines 204-206).

Fig. 9 Is there a mistake in the abscissa label? Should it be $Mm^{-1}sr^{-1}$ as in all the other plots? What does the shading represent? If the standard deviation then wouldn't it be much larger? Notice in the previous plots the backscatter coefficient exceeds values of 1 $Mm^{-1}sr^{-1}$ in a number of cases.

Response: Thank you very much for pointing out the mistake. The unit of the abscissa label in Fig. 9 has been modified to '$Mm^{-1}sr^{-1}$'. The shadings have been modified to show the standard deviations; we have added the related statements in the caption of Fig. 9. Although the backscatter coefficient of CCC in the Raikoke event (2019) exceeded 1 $Mm^{-1}sr^{-1}$, it was only an occasional case with a relatively short duration compared to the entire period generating the statistical results.

Fig. 10 The altitude interval over which these calculations were made should be mentioned. The quantities in the box and whisker plots should be defined in the caption. What is the box, the center line, …?

Response: The caption of Fig. 10 has been modified to "**Monthly mean sAOD integrated from 1 km above tropopause to 30 km in the cold half-year (October-next March) and warm half-year (April-September). For each box, the center lines represent the median value, and the bottom and top edges of the box represent the 25th and 75th percentiles, respectively. The whiskers were set to be 1.5.**"

359 …60 W/m^2 for BC …

Response: The "and" has been modified to "for".

363 How are sAOD_OC and sAOD_BC determined from the lidar data?

Response: The contribution of OC or BC cannot be directly distinguished by polarization lidar without the assumption. The ratio of OC and BC and the conversion factor were provided by Koch et al. (2001) and Hanson et al., (2005), the related statements have been given in section 3.5 "**As estimated by Hanson et al. (2005), the conversion factors from AOD to RF are -13 $W \cdot m^{-2}$ for OC and 60 $W \cdot m^{-2}$ for BC. As a result, the contribution of sAOD to RF can be divided into three parts: background sAOD ($sAOD_{background}$), OC sAOD ($sAOD_{OC}$) and BC sAOD ($sAOD_{BC}$). The RF during the smoke injection period can be calculated as follows:**

$$\mathbf{RF_{smoke} = sAOD_{background} \times (-25) + sAOD_{OC} \times (-13) + sAOD_{BC} \times 60}$$

(please see lines 376-380).