We thank referee #2 for the comments and suggestions. A point-to-point response is presented below. The author responses are in blue while the referee comments are in black. All line references are to the submitted revised copy.

General impression:

The paper deals with the aerosol products retrieved from SAGEIII/ISS observations. The material is worthwhile to be published in ACP/AMT. The focus is on wildfire smoke observations. This seems to be the new aspect here and main motivation for the manuscript. The history of the development of techniques to analyze spaceborne multiwavelength aerosol extinction observations (with SAGE and other instruments) is long and must be better reviewed in the introduction to clearly state what are the new aspects presented in this paper. The highlight of the manuscript is the comparison with balloon borne in situ observations of stratospheric aerosols (of smoke). This should be better emphasized in the introduction."

The introduction has been revised to include a more thorough review of previous works regarding techniques of analyzing spaceborne multiwavelength aerosol extinction measurements, with detailed responses to the referee's comments included below. Validation efforts of stratospheric smoke aerosol retrievals with coincident in situ measurements are better emphasized.

Detailed comments:

#1. "The used and carefully analyzed stratospheric in situ aerosol observations are provided by the balloon team of the University of Wyoming. Why is there no acknowledgement statement? Furthermore, I would find it well justified if one or two members of this group would be even co-authors. Section 5 (comparison of SAGEII/ISS products with Wyoming balloon observations) is clearly the strongest (unique) part of the manuscript."

Acknowledgement has been revised to acknowledge the balloon observations hosted at University of Wyoming (new lines: 782–783). We have reached out to the data providers to ensure their work is properly cited and acknowledged.

We also acknowledge the B^2SAP team and SAGE III/ISS project team (new lines: 783–787).

#2. "Lines 33-39: To my opinion, the European contribution to wildfire smoke research is poorly represented. This is not acceptable for a European reviewer. Especially the contributions of the EARLINET lidar teams need to be mentioned. Besides Khaykin et al. and Hu et al. (in the references) further essential lidar publications are: Haarig et al., ACP, 2018, Baars et al., 2019, Ohneiser et al., ACP, 2022. Ozone depletion related to wildfire smoke events was more pronounced in the polar regions than at midlatitudes. The potential impact of ozone depletion by wildfire smoke was described and summarized by Ansmann et al., ACP, 2022, and mentioned already in the papers of Ohneiser, ACP, 2021 and 2022."

We thank referee #2 for pointing out these important contributions from the European research community. We have revised the manuscript to add a new sentence on smoke impacts in polar regions (lines 39–41) and further cite these studies (see responses #3, #4, #5, #13, #16, #17, #18, #19 below).

#3. "The paper of Baars et al., ACP, 2019 shows Canadian smoke distributions and aerosol properties over Europe (including November 2017) and should be used when discussing the SAGEII and balloon observations performed in November 2017. To that time the aged wildfire smoke was homogeneously distributed over the northern mid latitudes so that comparisons can be carried out."

Added content and reference to the manuscript by Baars et al., 2019 in new lines: 30–32, 34–37, 72–75, 429–430, 454–456, 500–501, and 685–686 with respect to measurements made of stratospheric smoke from the 2017 PNE outbreak.

#4. "Lines 34-61: Here one should add the long-term studies of Ohneiser et al., ACP, 2022 (Australian smoke) and Baars et al., ACP, 2019 (Canadian smoke)."

New lines 30–32 includes an added reference to Baars et al., ACP, 2019. New lines 34–37, 39–41, and 72–75 are added to address stratospheric smoke lifetime and transport and unique aerosol properties, and also polar stratospheric chemical impacts, including the listed 2 papers.

#5. "Lines 62-66: In the papers of Haarig et al., 2018, Ohneiser et al., ACP 2021, and especially in Ansmann et al., ACP, 2021 (on wildfire smoke) you will find particle size distributions of wildfire smoke showing a very pronounced accumulation mode. There is obviously no bi-modal size distribution with separate fine mode and coarse mode. That should be included in the discussion, later on. Could be mentioned already here."

This comment is addressed in the introduction with new lines 34–37 and added reference in new lines 72–75 of the revised manuscript. We make note of and add that the aerosol size distributions and large particle mode carry the majority of the aerosol mass for wildfire smoke in the revised results (new lines 443–445) and discussion (new lines 592–593). Haarig et al., 2018, Ohneiser et al., 2021, and Ansmann et al., 2021 all show a strong increase in the accumulation mode of the volume distributions. A bimodal distribution is more apparent in the AERONET sun photometer inversion products detailing a fine and coarse mode in these examples. Lidar inversion products do have a smaller fine mode of $d_p \leq 400$ nm, while the majority of the aerosol mass is with the larger, accumulation mode aerosols.

#6. “Line 68: ‘well suited’ is not appropriate, to my opinion! When using just forward modelling you need so many assumptions and these assumptions are significant uncertainty sources….. Because of the potentially high uncertainties, I like the very convincing Section 5 (comparison with balloon observations).”

We have incorporated your comment and reworked the statement in new lines 90–92 to say “..well suited to solar occultation measurements with high signal to noise ratio and no a priori assumptions of the size distribution..”.

#7. “Line 80: After the paragraph line 68 -79, one could provide a short review, i.e., provide a history of the methodology applied to SAGE observations to obtain aerosol products! Who was the first (reference), what were big steps forward (references), what is now your new contribution?”

We have revised the introduction to address this comment, new lines 104–117 provide a review on the historical and operational SAGE and SAGE III aerosol products. The contributions of this work are formally introduced in the introduction in new lines 119–129.

#8 “Line 81-89: I would appreciate if Sect. 5 is here better introduced. For me, it is the best section of the manuscript.”

New lines 132–134 now include additional introduction describing section 5 with “Validation of SAGE III/ISS retrieved aerosol size distributions and aerosol properties against in situ measurements made following pyroCb events (the 2017 PNE event and 2020 North American pyroCb events) is presented in Sect 5.”.

#9. “Section 2.2, lines 110-118: The Wyoming ballon team did a great job. Are all these balloon profiles in Figs. 11-17 simply in the mentioned data base? No specific preparation of balloon aerosol profile products for this manuscript was necessary? If the Wyoming team had to process their data, guided by your wishes, they should be co-authors!”

Aerosol products from balloon launches in figures 11-17 are produced using data from the University of Wyoming data archive (Deshler et al., 2023) and processed by the authors here. Description of the use of sulfate and smoke aerosol refractive indices to describe in situ and satellite data is added in new lines 424–425. Clarifying statement for use of the OPC full resolution and size distribution products are added to sect. 2.2 in new lines: 170–171 and 171–173, respectively. The choice of data product is clarified in captions for figures 12a and 17 in new lines: 459–462, and 550–554.

#10. “Section 3, lines 128-177: The description of the methodology is given in this section. In Figures 11-15, so many different data analysis scenarios are shown (in Figure 11, eight different scenarios), but a clear description of all of these 8 different aerosol products is not given. It took me a long time to make me again familiar with the different scenarios. If possible, please create a small Table with all the different scenarios shown in Figure 11-17, maybe, name of the scenario and then the key information on contrasting input parameters, for example, different refractive index characteristics….”

Table 1 is added in new lines: 214–215 to list aerosol refractive indices used in this work. New lines 424–425 include additional clarification on data scenarios before presenting figures 11-15 with “Satellite and in situ data of sulfate or smoke aerosol external mixtures use the refractive indices in Table 1.” Figure captions for figs. 11 and 15 are updated to clarify scenarios in new lines: 441–442, 514–515, with “SAGEIII/ISS sulfate and smoke aerosol data are calculated from the retrieved aerosol size distributions.”.

#11. Line 141: ‘m’ is not explicitly introduced.”

Complex refractive index (m) is now introduced in new lines 188–189.

#12. “Lines 351-357: In the AERONET data base, the smoke shows a monomodal size distribution (Ansmann et al., ACP, 2021). And this (fresh or aged) accumulation mode belongs to the fine mode. Here, in this manuscript this mode belongs obviously to the coarse mode. Confusing!”

Lines 351–357 in the original manuscript have been edited in lines 410–413 in the revised manuscript to state ‘large particle mode’ in reference to the secondary mode. A brief clarifying statement regarding use of fine and coarse mode in this manuscript is added in line 183–184.

#13. “One should include the smoke products that were presented in the papers of Haarig et al., ACP, 2018 and of Baars et al., ACP, 2019 in the discussions in Section 5. Volume concentrations (Baars shows a table with input parameters, smoke particle density of 0.9 g/cm3) and effective radius can be compared.”

In response to comments #2–#5, reference to the lidar retrieval measurements from Haarig et al., 2018 and Baars et al., 2019 are now included in section 5. New lines 443–445 reference Haarig et al., 2018 measures of aerosol diameter in the fresh smoke plume following the PNE, with “SAGE III/ISS and WLPC display increases in aerosol effective diameters to 300–700 nm in the lower stratosphere below 20 km (Fig. 12a), in agreement with EARLINET lidar retrieved aerosol effective diameters of 640 ± 200 nm in smoke layers intercepted above Leipzig, Germany in August (Haarig et al., 2018).”.

New lines 454–456 reference Baars et al., 2019 work on the aerosol mass enhancement following the PNE, and long stratospheric lifetimes and decay of the aerosol mass enhancement as measured from Polly stations, with “PollyNET (NETwork of POrtabLe Lidar sYstems) stratospheric aerosol mass measurements of the diluted smoke layers agree well with the coincident SAGE III/ISS and WLPC observations, similarly describing the enhanced aerosol mass following the PNE over background stratospheric conditions (Baars et al., 2019).”. Further reference to Baars et al., 2019 observations over the aerosol lifetime subject to the dominant microphysical processes diluting concentrations are added as reference in new lines 685–686.

#14. “Figure 14 can only be understood at the screen. Dark colors are used in the case of three size distribution. Hard to find out which color belongs to which profile. Please use different line styles (dotted, dash, solid, thick and thin lines) as well as clearly distinguishable dark and bright colors.

#15. Almost the same in Figure 17: Please make use of thick and thin line styles.”

Addressing comment #14 and #15, Figures 14 and 17 (new lines: 487, 549) include new styling and coloring for the retrieved number distributions. Supplement figure 2 now also uses the new styles.

#16. “Line 524: This is new for me that the wild fire smoke size distribution consists of two modes. This means, there are two sources of smoke particles! But in case of pyroCB there is definitely only one source. The AERONET sunphotometer-derived size distributions and the lidar-derived size distributions do not corroborate your hypothesis. You assume a bi-modal size distribution. Ok! But that does not automatically mean, that the two modes really exist.”

We agree with referee #2 that fresh smoke emitted into the air is generally monomodal. In this study we assume bimodal distributions in the smoke mixture based on recent measurements. This does not mean the fresh emissions near the sources are inherently bimodal. New lines 592–593 are added which include reference to lidar retrievals of fresh pyroCb smoke in the stratosphere which are generally monomodal, with new lines 593–594 edited to clarify smoke aerosol distribution being monomodal in observations of fresh smoke. New lines 594–597 are edited to describe how microphysical processing leads to broader distributions in aged plumes.

#17. “Lines 589-591: According to Ohneiser et al, ACP, 2021 (MOSAiC observations) and Ansmann et al, JGR, 2024 (doi: 10.1029/2022JD038080), there was not only the Raikoke event, there were also strong Siberian wild fires, feeding the UTLS height range with aerosol.”

This statement is relevant for not only 2019, but on an annual basis for strong wildfire and frequent pyroCb occurrences in the hemisphere. New lines 657–658 are added, with “Intense wildfires in the boreal region can also loft wildfire smoke into the UTLS (Ohneiser et al., 2021; Ansmann et al., 2024; Khaykin et al., 2025).”.

#18. “Lines 606-607: Also Baars et al., ACP, 2019 documents this long lasting stratospheric smoke event.”

Included in new lines 30–32, 34–37, 72–75, 429–430, 454–456, 500–501, and 685–686 in reference to measurements made of stratospheric smoke from the 2017 PNE outbreak and characterization of the aerosol properties and lifetimes.

#19. "Line 611: There was not only aging and sedimentation, also lofting has an impact on the vertical distribution of smoke particles."

New lines 684–685 are added to preclude aging and sedimentation with spatial and vertical movement: "Transport and self-lofting of smoke aerosols spatially redistribute and increase the height of the smoke layers in the northern hemisphere stratosphere (Torres et al., 2020; Yu et al., 2019).".
New lines 657–658 are simultaneously added to address aerosol self-lofting and its influence on UTLS aerosol concentrations in the northern hemisphere in response to comment #17.

#20. "Figure 18: What about the large values measured in the second half of 2020 and in 2021 by LOPC? Are these values trustworthy?"

LOPC utilizes high resolution sampling of aerosol layers with more than 50 channels spanning 0.3–10 um. This results in much larger aerosol concentrations as the volumetric samples and number of size bins are increased over previous OPC instruments. Without a fitted lognormal distribution, the binned concentration data increases the overall aerosol volume in a layer compared to previous OPC instrument versions. The LOPC values are also larger due to the selected altitude range (10-30 km) which includes tropospheric samples over the selected period and are not necessarily the main focus area for these OPC instruments. The values displayed here are elevated due to the higher resolution sampling but also inclusion of upper tropospheric values into the column average.

#21. "Line 657: …display two modes within the accumulation mode … A mode is a mode, and does not consist of two modes."

New lines 732–733 are revised to remove 'within the accumulation mode'. The same change is made in lines 22–23.

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