Response to Reviewer #3

We thank the reviewer for helpful comments. Our responses to the reviewer's specific comments are listed below. The reviewer's concerns are in bold italicized font and our responses are in regular font. The page numbers and line numbers given in our responses below are in reference to the revised version of the manuscript.

General comments: The paper describe the development of the stratospheric aerosol data set GloSSAC V2.0 and changes made since the last release of V1.1. The methodology of the data set construction and rational is clearly described. The paper is well written, and the results are presented and discussed with sufficent details. I recommend for publication subject to the following changes.

Major comment: I find the authors choice of conforming rather than excluding data that exhibit very large biases (> 50 %) somewhat concerning. Mainly because some of these data may be affected by clouds. Kar et al. (2019) reported large differences with SAGE III/ISS below 20 km, which can be explained in part by subvisible cirrus cloud scattering artifacts that may appear to within several kilometers above the tropopause. In addition, the authors failed to explain the advantage of using the newly released CALIOP standard products instead of version 4.0 Level 1 data used in GloSSAC V1.0. Do they believe that their approach produces better product than what was used in V1.0 and V1.1?

When we have started our efforts to incorporate CALIOP data in to GloSSAC v 2.0 by using version 4.0, level 1 data as it was used in GloSSAC 1.0 and 1.1, the official CALIPSO stratospheric aerosol product was released. The release of CALIPSO standard stratospheric aerosol product was followed by a paper that was published (Kar et al., 2019). After the release of the official CALIOP stratospheric aerosol product, it was appropriate for us to use the standard stratospheric product from CALIPSO team instead of using version 4.0 level 1.0 data. To some extent we had no choice but to use the CALIPSO data as it is a priority for the data set to be gap free. The old technique used a fixed extinction to backscatter ratio that created what we believe have biases in the lower stratosphere. The new approach seems to minimize this issue. We do agree with the reviewer that there is large bias in CALIOP data, sometime exceeding 50% when compared to other data products. This was the reason we decided to use the conformance process based on the extinction to backscatter ratio as shown in Figure 9. As you can see from Figure 9a that the extinction to backscatter ratio decreases to even less than 30 sr as noted in the manuscript. By using these values, we believe the bias in the lower stratosphere has been reduced to a greater extent although not completely bias free. We also note that CALIOP data is used only when other extinction measurements (OSIRIS or SAGE III/ISS) are not available which occurs mostly at higher latitudes. Attached is a figure that shows the percent difference between the standard CALIOP product and the bias corrected CALIOP extinction (after conformance process) for 201711. It is evident from this figure that the conformance process help reduce the bias in the data particularly in the lower stratosphere where the percent difference (STANDARD-CORRECTED/CORRECTED)*100) exceeds 80% indicating the conformed CALIOP extinctions values have been reduced significantly. We do agree that this will not completely remove the bias in the lower stratosphere but it clearly helped reduce the bias in the lower stratosphere in particular.

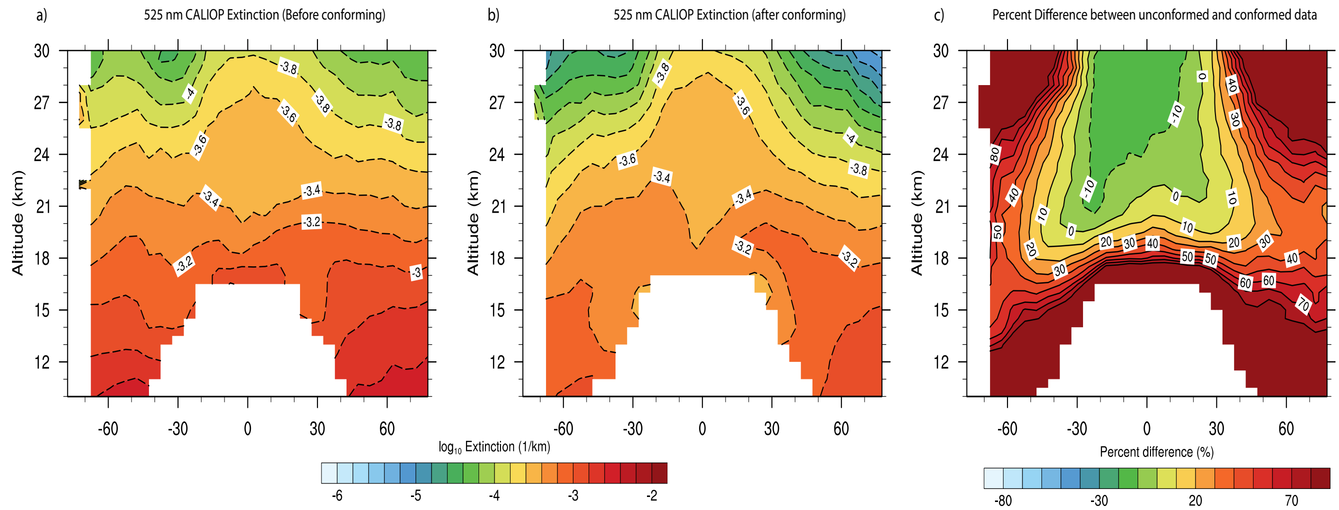

Figure 1: CALIOP extinction coefficient and percent difference for 201711. (a) Standard CALIOP extinction coefficient (CS) at 525 from the standard CALIOP data product, (b) CALIOP data after conformance (CC), following method described in manuscript, and (c) Percent difference computed as (CS-CC/CC)*100. The standard CALIOP extinction is available at 532 nm and is converted to 525 nm using a constant Angstrom exponent of 2.33 in (a).

General comments:

Table 1: Some of the volcanic eruptions listed in table 1 did not reach the stratosphere and thus are not relevant to this dataset. The table should be modified to include only volcanic eruption that are evident in GloSSAC dataset.

We have now revised Table 1 to extend the record back to 1979 as one of the reviewers suggested to include the entire record of GloSSAC. We also label these in Figure 15, 16 , and 18.

Figure 1: the figure is identical to figure 1 published earlier by (Thomason et al., 2018), which shows SAGE III/ISS as a future instrument. I suggest either updating the figure or simply just cite the figure in (Thomason et al., 2018).

We have revised this figure and made necessary changes so that the figure now shows SAGE III/ISS as current instrument.

Page 3, first paragraph: The authors need to add a brief statement justifying the change and summarizing the differences between the new CALIOP products and the

one used in V1.1.

We have added a brief statement toward the end of the paragraph and it now reads: " While we use the standard CALIPSO stratospheric aerosol product, enhanced levels of aerosol extinction in the lower stratosphere are consistently noted in the entire dataset after comparing against OSIRIS and SAGE III/ISS. We, therefore decided to use a conformance process which is described below that helps reduce the bias in the lower stratosphere and also at higher latitudes."

Page 8 L6: ?OSIRIS extinction is also routinely produced at 525 nm, : : :? should be replaced by ?OSIRIS extinction can be produced at 525 nm, : : :? or something like that. The original text implies that it is part of the official V7.0 release.

The sentence is revised and now reads as " In addition to 750 nm, OSIRIS extinction can be calculated at 525 nm...."

Page 8 L10: ?Since the SAGE III/ISS instruments operates in a manner virtually identical to SAGE II? ?virtually identical? should be replaced by ?similar? since the two instruments have different designs and age. Toward the end of its life, SAGE II was an aging instrument that operated on reduced duty cycle as compared to the newly refurbished SAGE III/ISS instrument.

The sentence now reads as "Since the SAGE III/ISS instruments operates in a manner similar to SAGE II, the expectation is that there would be minimal bias between these instruments at least at the strongest aerosol measurement wavelengths at 525 and 1020 nm."

Page 8, L15: ?SAGE II and SAGE III/ISS are relatively unbiased with each other? this not accurate since both (Thomason et al., 2010) and (Damadeo et al., 2013) reported 10 % bias between SAGE II and SAGE III Meteor, which is supposed to be identical to SAGE III/ISS. The differences between SAGE II and III should be acknowledged and discussed in this section.

We now add another footnote about the bias between SAGE II and SAGE III meteor which now reads as "While the differences between SAGE II and SAGE III meteor aerosol extinction coefficient are relatively smaller, some previous studies (Thomason et al., 2010; Damadeo et al., 2013) reported a small bias between SAGE II (v 7.0) and SAGE III (v 4.0) meteor that are within ± 10% for measurement wavelengths of 525 and 1020 nm for the altitudes between 7 and 25 km."

Page 8, footnote 1: ?While the OSIRIS instrument performance has remained unchanged over time,? This not exactly accurate. According to Bourassa et al. (2018) and Rieger et al. (2019), OSIRIS had a small drift that resulted in a pointing error and a correction was applied to V7.0. Please modify the text accordingly.

Yes. We changed the footnote to "While the OSIRIS instrument performance has relatively remained unchanged over time, the scattering angle has slowly drifted, and the fraction of ascending/descending node measurements has changed. These factors may affect overall data quality."

Page 9, L23: I suggest changing ?Angstrom exponent? (where appropriate) to something like ?pseudo Angstrom exponent? to eliminate any confusion regarding its physical meaning.

Done.

Figure 7: Can you add the year to the volcanic eruption label?

Done.

Section 3.1: The paragraph describing the choice between using the standard CALIOP stratospheric backscatter or the alternative product is confusing and difficult to follow, especially when the authors conclude that ?it ultimately does not matter a great deal whether we use the standard CALIOP stratospheric backscatter product or the alternative product described above?. If that is the case, why not use the standard product and eliminate the confusion? Also, the CALIPSO section in supplementary materials implies that the standard products were used.

Sorry about the confusion. We initially thought of using the standard particulate backscatter product. We later realized that the particulate backscatter in the Level 3 data file is retrieved using a lidar ratio 50 Sr. So, if we use the retrieved particulate backscatter for computing scale factor (SF) which is based OSIRIS extinction to CALIPSO backscatter ratio, we are in fact using a SF (which is similar to a lidar ratio) on a product that was already retrieved using a constant lidar ratio of 50. We, therefore used an alternate method that does not use any fixed value for lidar ratio.

We have computed a percent difference between the standard retrieved backscatter coefficient and the backscatter coefficient computed using the alternate method (inferred backscatter). The Figure 2a below, shows the percent difference computed between retrieved and inferred backscatter for March 2007. At altitudes above 18 km, the percent difference is below $\pm 10\%$, while the percent difference increases to about $\pm 30\%$ near below 15 km. While there is increased difference below 18 km, it does not really matter much as we scale those differences away in the conformance process by using OSIRIS extinction to CALIOP backscatter, defined as scale factor (SF) in the manuscript. We then computed the ratio of 525 nm OSIRIS extinction to 532 nm CALIOP backscatter coefficient using both the retrieved and the inferred CALIOP backscatter. Figure 2b,c show the ratio of OSIRIS extinction to retrieved and inferred CALIOP backscatter coefficient respectively for March 2007. There are differences between the two methods particularly below 18 km, where they match with the increased percent difference shown in Figure 2a. While the SF computed using retrieved CALIOP backscatter shows values below 30 sr below 18 km (Figure 2b), the SF using inferred CALIOP backscatter shows a higher SF which is around 40 sr (Figure 2c). Generally, below 18 km the retrieved backscatter coefficient is larger than inferred backscatter coefficient. However, these differences are scaled away in the conformance process where we use OSIRIS extinction to CALIOP backscatter ratios (SF) as they are evident from Figure 2b,c.

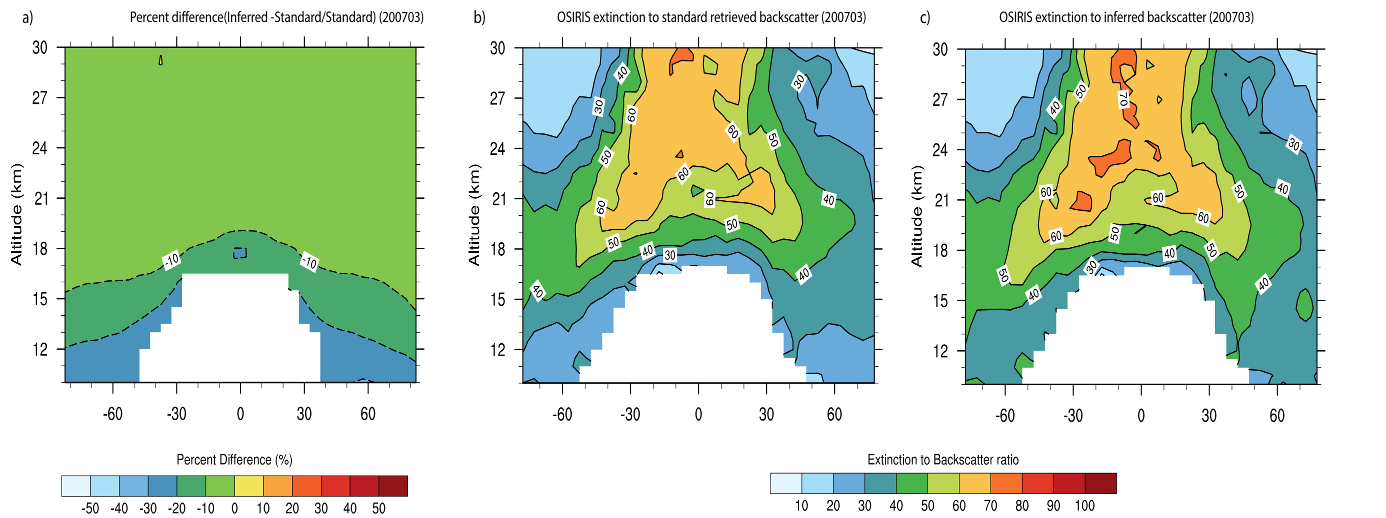

Figure 2: Percent difference and extinction to backscatter ratios for 200703. (a) percent difference between standard retrieved and inferred CALIOP backscatter coefficient computed as (Inferred-Standard/Standard)*100, (b) 525 nm OSIRIS extinction to retrieved 532 nm CALIOP backscatter and (c) 525 nm OSIRIS extinction to inferred 532 nm CALIOP backscatter.

Page 11, L29-30: ?except at higher altitude at polar latitudes where it is possible that the impact of the polar vortex plays a role in producing SFs less than 10 sr? I find it difficult to believe that the effect of PSC can cause this small ratio at altitudes between 25 ? 30 km, and the statement is pure speculation. Unless the authors can show that this low ratio takes place during the winter season and low temperature, which are ideal for PSCs formation, I suggest deleting it.

We have now revised the sentence.

Page 12, L11: The authors claim that the difference between CALIOP and SAGE III/ISS is now below 20 %, when in fact figure 8d clearly shows the differences are mostly 30 and 40 %. Please revise the text accordingly.

It is now revised and reads as :"Similarly, the difference between the scaled CALIOP stratospheric extinction and SAGE III/ISS is now mostly below 30% except near the tropical lower stratosphere and polar high altitudes, whereas the the difference between standard CALIOP stratospheric extinction coefficient and SAGE III/ISS is also often more than 50%."

Figure 10 and 12: Can you change the y-axis to linear scale instead of log. The log

scale makes it difficult to see the differences between different measurements.

We tried changing it to linear scale but looked crowded. But, we changed ”markers” to ”lines” which we hope is now clearer in the revised figure.

Figure 6 and 11: Can you modify the color scale to -1 to 5.

Done.

Page 13 second paragraph: The authors use angstrom exponents to infer 1020 nm, similar to the method used to derive 520 nm. Can they comment on any potential use the two wavelengths in climate models, which will most likely use it to infer particle size information?

This has already been mentioned in the summary section (last point) that reads :

”While the inferred 1020 nm extinction in GloSSAC v2.0 for the post-SAGEII era (2005-2018) is improved compared to v1.0, there are limitations with the inferred 1020 nm extinction. We note that deducing size information using 525 10 and 1020 nm extinction ratio for the period between August 2005 and June 2017 may still be an issue with single wavelength measurement from either OSIRIS or CALIOP, particularly during and following a volcanic event, despite some improvement in the inferred 1020 nm extinction. While this is clearly a limitation, we are not able to address changes in extinction ratio for volcanic events in v2.0 where the data set is based on only one wavelength. As a result, it is likely that GloSSAC extinction for small volcanic events during the OSIRIS/CALIOP period will be biased high 15 to an unknown extent. Further study into this period may result in changes in a future version of GloSSAC. Since June 2017, multi-wavelength extinction coefficient data became available from SAGE III/ISS, giving us an opportunity to compare/validate OSIRIS/CALIOP data particularly during and following such events.”

Figure 13, 14 and 15: Can you modify the color scale to properly show the volcanic enhancements. Also, can you remove the labels as they are distracting and interfere with the figure.

We have now modified the color scale which we hope now show any volcanic enhancements. We have removed the labels too.

Section 5: It?s difficult to follow the arguments regarding figure 15 because of the color scale, which doesn?t show the author?s argument. Please modify the color scale accordingly.

Done.

Figure 16: Again, can you adjust the color scale to show the smaller volcanic eruptions? In addition, remove the labels and add a symbol or a label denoting the

location and time of each volcano.

Done. This figure has been moved and used in Figure 15 instead, as this figure now shows SAOD for the entire GloSSAC record. We have now used labels for volcanic eruptions at the respective latitude and time of the year.

Figure 17: Can you comment on the lack of seasonality in CALIOP data in the southern and northern hemisphere compared to other data set?

Unfortunately, we are not able to comment on this now as the CALIOP data set does not have it for reasons we cannot account for.

Section 6 Conclusions and future work: There is no mention of any addition of new data sets when figure 1 implies that SCIAMACHY and OMPS will be added in the future.

We have added a sentence toward the end of the manuscript that reads as:

"There are additional datasets that are available for stratospheric aerosol extinction coefficients. We plan to evaluate and use these datasets, including SCanning Imaging Absorption spectrometer for Atmospheric CartograpHY (SCIAMACHY) and Ozone Mapping Profiler Suite (OMPS)."

Supplementary materials, Figure 1: The figure needs further explanation, what year, SAGE II or III/ISS? The text implies both datasets without explaining the methodology to combine it. What wavelength? 750 nm converted to 525? How?

While our intent to use this figure was to show relative percent difference with respect to the monthly climatology of angstrom exponent, we realize that it may not be a statistically correct approach as there are not enough data points in each grid for computing standard deviation. We, therefore removed this figure from supplementary.

References

Damadeo, R. P., Zawodny, J. M., Thomason, L. W., and Iyer, N.: SAGE version 7.0 algorithm: application to SAGE II, Atmos. Meas. Tech., 6, 3539–3561, https://doi.org/10.5194/amt-6-3539-2013, 2013.

Kar, J., Lee, K.-P., Vaughan, M. A., Tackett, J. L., Trepte, C. R., Winker, D. M., Lucker, P. L., and Getzewich, B. J.: CALIPSO level 3 stratospheric aerosol profile product: version 1.00 algorithm description and initial assessment, Atmospheric Measurement Techniques, 12, 6173–6191, https://doi.org/10.5194/amt-12-6173-2019, URL `https://www.atmos-meas-tech.net/12/6173/2019/`, 2019.

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