We have reproduced the referee's comments below in <u>black Times New Roman</u>. Our responses are given in <u>blue Tahoma</u>.

Calibration of lidar signals at 1064 nm from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite depends on the prior calibration of the primary 532 nm channel. The 1064 nm calibration procedure also requires knowledge of the ratio of stratospheric signal attenuations at 1064 nm and 532 nm. Since this ratio is not available a priori, it is typically assumed to be unity. This manuscript evaluates the impact of that assumption on the 1064 nm calibration using observations from the Stratospheric Aerosol and Gas Experiment (SAGE III) on the International Space Station (ISS) for the period 2017 onward, and the GLObal Space-based Stratospheric Aerosol Climatology (GloSSAC) to provide historical context during the SAGE II era (1984–2005). The study shows that the unity assumption introduces a potential bias in the computed 1064 nm calibration coefficients of less than 1–2% within the tropics under background stratospheric conditions, but recent biases can be as large as 5% when volcanic perturbations and/or pyro-cumulonimbus (pyroCb) injections dominate stratospheric aerosol loading. The manuscript further explores the implications of this bias on CALIOP's level-2 science retrievals by assessing the expected perturbations in cloud-aerosol discrimination (CAD) performance and quantifying the non-linear propagation of errors in CALIOP's 1064 nm extinction coefficients.

Overall, this evaluation and global characterization of spectral attenuation differences provide valuable guidance for potential corrections to CALIOP level 1 data products and for the development of data processing algorithms for future spaceborne elastic lidars operating at 1064 nm. This work represents an important contribution to space lidar data processing and should be published after minor revision.

My comments are all minor and provided in below:

Thank you for going through the paper carefully and for the helpful comments.

Section 2. Motivation: In this section, Equations (1) and (2) appear to provide the basis for transferring the calibration from 532 nm to 1064 nm. If so, the authors should state this explicitly and describe how the two-way transmittance ratio is determined in the CALIOP 1064-nm calibration.

We have reworded the first paragraph in the Motivation section to make it clear that we use equations (1) and (2) to accomplish the calibration transfer.

The two-way transmission ratio is not determined in the 1064 nm calibration algorithm, as the information to do so is not available at this stage. Instead, the ratio is assumed to be one. We state this both in the abstract (lines 13–14 in the discussion paper) and again in the Introduction (lines 47–50 in the discussion paper).

The authors could also briefly explain how the calibration cirrus cloud is selected. For example, is the presence of an overlying layer acceptable if it can be detected by CALIOP, or is only background aerosol in the stratosphere permitted when it is below CALIOP's detection limit?

We added the following description at the end of the paragraph following equation 2:

"To ensure robust estimates of f, the criteria for selecting 'calibration quality' clouds used in this calculation are

a) the cloud must be the uppermost layer within a profile averaged to a 5 km (15 shot) horizontal resolution;

b) cloud top altitude must lie below the local tropopause altitude;

c) the temperature at the cloud geometric midpoint must be less than –35 °C;

d) the layer integrated 532 nm volume depolarization ratio must lie between 0.30 and 0.55; and

e) the 532 nm layer integrated attenuated backscatter must lie be between 0.023 sr^{-1} and 0.038 sr^{-1}

Additional detail and the rationale for establishing these criteria are given in Vaughan et al., 2019."

1. Lines 75–77: The manuscript states: "While smoke plumes occur intermittently, the aerosol loading in the stratosphere is always present either as background or as volcanic ash or sulfate. Here we shall assess the potential bias from the stratospheric loading only." My question here relates to the previous comment: is a cirrus cloud beneath a smoke layer permitted as a calibration target, or is this only acceptable when the smoke layer is undetectable by CALIOP? It would be good to clarify this.

See criterion a) above. Figure 7 of Vaughan et al. (2019) shows a real-world example of a cirrus cloud lying below a strong plume of smoke from Australian Black Saturday fire. This cloud does not qualify as 'calibration quality' because it is not the uppermost layer detected in a 5 km averaged profile.

2. Fig. 8: use the same vertical span for all three panels.

Done.

3. Figure 9 presents a useful illustration of the possible impact of calibration error in the overlying cirrus cloud on the retrieval of the boundary layer aerosol. However, the illustration is based on an assumed cirrus cloud from another location in Figure 8. Would it be more straightforward to analyze the boundary aerosol layer directly beneath the cirrus cloud layer shown in Figure 8? If the aerosol layer directly beneath the cirrus cloud is not suitable for this illustration, the authors could explain the reason in the manuscript.

Actually, no. If anything, doing that would introduce some unquantifiable uncertainties into the comparison. The reason for using an aerosol layer that does not originally lie beneath a cirrus cloud is to compute an extinction retrieval that is unquestionably NOT perturbed by any assumptions (e.g., lidar ratios and multiple scattering factors) used to derive a solution in the overlying layer. Artificially inserting a cirrus cloud above allows us to meaningfully compare the unperturbed solution in the "aerosol only" case to the perturbed solution in the "aerosol with overlying cirrus" case.

4. Lines 281–283 state: "For multi-layer retrievals, the solution for any one layer requires that the attenuated backscatter coefficient in that layer be renormalized to account for the signal attenuation due to overlying layers." What happens if there is clear air between the two layers? In that case, would the solution renormalize the underlying layer to the clear air, such that the retrieval of the aerosol layer may not be impacted by the overlying cirrus cloud?

If the cloud and aerosol layer are separated by a region of "clear air", and if the SNR in the region is adequate, then yes, the renormalization of the aerosol will be based on a measured estimate of the two-way transmittance of the cloud (e.g., see the discussion of constrained solutions in Young and Vaughan, 2009). For CALIOP, this is never possible at 1064 nm simply because the SNR in clear air regions is abysmally low. But even at 532 nm, it's never true that "the retrieval of the aerosol layer may not be impacted by the overlying cirrus cloud", as cloud attenuation degrades the clear air SNR and hence introduces a somewhat different kind of renormalization error (e.g., see Young et al., 2013).

5. Lines 315–316 state: "The empirically derived estimate of γ'1064 is derived by integrating the 1064 nm attenuated backscatter profile between layer top and layer base." Why is γ'1064 referred to as empirically derived? Isn't γ'1064 simply defined as the integral of the 1064 nm attenuated backscatter profile between the layer top and base?

Yes, "empirically derived" γ'_{1064} estimates are calculated by integrating the 1064 nm attenuated backscatter signal between the top and base of a layer. We use the "empirically derived" modifier to (a) differentiate the source of the γ'_{1064} values from the model-derived values used for η_{1064} and S_{1064} and (b) draw a distinction between this numerical approximation of the integral and the value of γ'1064 that can be computed by applying Platt's equation to the model-derived parameters alone; i.e., $\gamma'_{1064} = (1 - \exp(2 \cdot \eta_{1064} \cdot \tau_{1064})) / (2 \cdot \eta_{1064} \cdot S_{1064})$.

References

Vaughan, M., A. Garnier, D. Josset, M. Avery, K.-P. Lee, Z. Liu, W. Hunt, J. Pelon, Y. Hu, S. Burton, J. Hair, J. Tackett, B. Getzewich, J. Kar, and S. Rodier, 2019: "CALIPSO Lidar Calibration at 1064 nm: Version 4 Algorithm", Atmos. Meas. Tech., 12, 51–82, https://doi.org/10.5194/amt-12-51-2019.

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