Atmospheric Measurement Techniques Discussion
Response to Referees' Science Review Comments – August 2019

"Cloud-Aerosol Transport System (CATS) 1064 nm Calibration and Validation" - Pauly, R., J.E. Yorks, D.L. Hlavka, M.J. McGill, V. Amiridis, S.P. Palm, S.D. Rodier, M.A. Vaughan, P. Selmer, A.W. Kupchock, H. Baars, A. Gialitaki

We received referee comments from two referees and one document with short comments from a member of the scientific community. Our responses to the comments of two of the referees of our submission: amt-2019-172: Pauly et al., "Cloud-Aerosol Transport System (CATS) 1064 nm Calibration and Validation" are below. The referees were very helpful in clarifying our explanation of the method, as well as the importance to future missions and CATS retrievals. We hope the editor will find our responses address the major and minor comments of the referees. Our response to the short comments from the member of the scientific community will be provided in a separate document. We believe the manuscript is clearer and more robust, and we look forward to the new step towards publication. Note that the referee comments appear in black while our responses appear in red.

Anonymous Referee #4 Comments

The paper describes an algorithm for calibrating and validation of CATS 1064nm backscatter coefficient. Overall, the work presented in this paper is very important because lidar observation at 1064 nm is needed together with 532 nm for characterizing particle size and other layered aerosol optical properties. The validation shows that the method appears to work well and gives an uncertainty of 20% when comparing
with other lidar observations from different platforms. I would recommend the paper be accepted after minor to moderate revisions to improve clarity and discuss its broader significance for the research community.

1) equations. the symbols in each equation should be well explained and with unit given (or otherwise mention unitless). This will help readers understand the equation better. For example, in equation 1, what is the unit of Ns, r, D, and E. In equation 2, what is the unit of R, beta or backscatter coefficient. The list goes on for all equations.
    a. The appropriate units have been added to the latest version of the manuscript throughout. You can see examples in the text corresponding to Equation 1 (page 3) and Equation 5 (page 5). Thank you for pointing out where they were missing.

2) equation 2. R is defined as aerosol scattering ratio. Should it be lidar ratio due to aerosol scattering? to separate it from aerosol single scattering albeit? How is it defined? Where does the equation (2) come from? If M is used to denote molecular, should A be added as a subscript for R because R is Aerosol scattering ratio? Again, description of unit and physics here will help to improve the clarity here.

   a. We have re-worked this section for clarity. We now provide a generic definition for the particulate scattering ratio (lines 31-34, page 4), which should prevent confusion about lidar ratio vs. particulate scattering ratio. We have also swapped Equations 2 and 3 so that it is more obvious how they relate. Finally, we more clearly label the variables as M to denote molecular and P to denote particulate.

3) paragraph before 2.2, what is the unit of calibration coefficient? what exactly is calibrated? from digital count to total attenuated backscatter coefficient? Table 2, the integrated attenuated backscatter has unit of sr-1? bur for CALIOP level-2 data, the same "total attenuated backscatter" has an unit of km-1sr-1. Given the terminologies can be used differently by different groups, it is important to define them from basic variables (e.g., extinction cross section, scattering phase function, etc) to avoid ambiguity.
   a. The units of the calibration coefficient are now provided on page 6, line 14 (and throughout the paper). More details about what this calibration coefficient is being applied to (the NRB profile) and the result (the ATB profile) are provided on lines 8-9 on page 6. The units of total attenuated backscatter (or attenuated total backscatter), which are $km^{-1}sr^{-1}$, are different than the integrated attenuated backscatter (sr^{-1}). In the equation for integrated attenuated backscatter, $\gamma' = \int_{top}^{base} \beta'(r)\, dr$, the differential range element dr has units of km, so the integrated quantity, γ', has units of sr^{-1}. These units are the same for both CATS and CALIOP.

4) conclusions. If the calibration has 20% uncertainty, does that also mean that the total aerosol optical depth derived from CATS will have an uncertainty of 20% at least? It is important to discuss the link between the calibration uncertainty and the level-2 product uncertainty.
   a. In general, yes, a calibration uncertainty of ±10-20% imposes a lower bound of ±10-20% on the uncertainty of the optical depth retrievals. We have added some brief text to the conclusion to express this relationship. However, the propagation of calibration errors in the solution of the lidar equation is both nonlinear and non-trivial, hence a more complete discussion of the link between calibration uncertainty and level 2 product uncertainties lies well beyond the scope of this paper. A complete mathematical description of calibration error propagation for elastic backscatter lidar measurements is given by Young et al., 2013 and Young et al., 2016.

5) finally, either in the introduction or conclusion, it is worthy to mention that lidar has been used to constrain smoke injection height (such asWang et al., 2013, Atmospheric Research , 122, 486-503) and understand relative distrubiton of smoke and dust particles

in the vertical (Yang et al., 2013, JGR, 118, 12,139-12,157) in the chemistry transport models.

a. References and discussion of these lidar applications were added to the introduction on page 2, lines 1-2.