Answers to reviewer 2

We thank reviewer 2 for sharing insights with the comments. Below follows our answers. Text of the reviewer in black and the authors in blue.

Review of manuscript Five satellite sensor study of the rapid decline of wildfire smoke in the stratosphere (acp-2021-1015) by Martinsson et al.

Summary

This manuscript utilizes data from five satellite sensors to document the lifetime of the August 2017 Pacific Norwest pyroCb event and suggest photolysis as the mechanism responsible for the rapid aerosol mass decrease observed by satellite observations. Aerosol extinction measurements by CALIPSO-CALIOP, S-NPP OMPS Limb Profiler, and ISS-SAGE III are used in the analysis.

The paper is suitable for publication in ACP after the authors address the minor issues discussed below.

General Comments

Most of the manuscript is dedicated to the analysis of CALIOP's level1b data. No specific reason is given as to why the authors decided not to use the standard CALIOP level2 products but to develop their own interpretation of CALIOP measured backscattered radiances.

1. We started to use CALIOP level 1B ten years ago. With support by a scientist from NASA we extended his studies of volcanism using CALIOP to also include the aerosol load in the LMS (Andersson et al., 2015; Nature Communications 6:7692, DOI: 10.1038/ncomms8692).

It should be emphasized that CALIOP's main advantage over SAGE III and LP observations is the availability of nighttime observations that, unlike SAGE III and LP, allowed for aerosol measurements during polar night. The usefulness of CALIOP's nighttime observational capability clearly comes across in this work where 29 out of 32 analyzed CALIOP profiles were nighttime observations.

2. We are not sure that we understand this comment. Compared with the limb-oriented methods we find the main advantages of CALIOP to be orders of magnitude shorter path through the smoke layers which is important to avoid event termination, and distinct signal along the laser path that can be utilized for the purpose of correcting the signal for attenuation. To that we can add extremely high vertical resolution.

The OMPS-LP - CALIOP AOD comparison yields no meaningful information on the accuracy of either measurement because of their implicit dependence on assumed aerosol properties.

3. In Fig. 2a we estimate the lidar ratio until day 22 after the fire, reaching the average 48.9 sr (95% confidence interval: 47.6 – 50.3 sr). Since that result does not deviate significantly from the typical stratospheric background (50 sr), we use 50 sr except for the densest layers (the first days after the fire) where any deviation in the fitted lidar ratio strongly affects the estimated scattering. After day 22 the smoke layers are too thin for the method to estimate the lidar ratio. We agree that the OMPS-LP results are based on standardized assumptions on the optical properties of the aerosol. The good agreement of OMPS-LP with CALIOP stems from that the estimated lidar ratio happens to be close to that of the typical stratospheric background aerosol.

Although photolytic destruction is a reasonable aerosol removal mechanism, the authors should address other possible mechanisms such gravitational settling. It could be argued that the initial massive injection included a variety of aerosol types and sizes some of which would have been removed by gravitational settling on time scales similar to that of photolysis.

4. We do consider gravitational settling in the manuscript, as well as several other explanations, but it could be a good idea to make our text more explicit. To further clarify we have added some text relating settling velocity to the extratropical downward transport large-scale circulation in the first paragraph of the Discussion section.

Specific Comments

A key step in the retrieval of aerosol properties from lidar observations is the selection of the lidar ratio. The choice of lidar ratio involves specific assumptions on the polydispersion particle size distribution, particle shape and complex refractive index. Although, not explicitly stated in the manuscript, one can assume that the authors considered the implicit lidar ratio assumptions (and the associated aerosol model) in the standard CALIOP level 2 product (Omar et al., 2009) to be inadequate for the interpretation of CALIOP observations in the presence of stratospheric carbonaceous aerosols and, therefore, decided to carry out their own inversion of CALIOP's Level 1b data making use of an improved aerosol model. A brief description of both the standard and adopted aerosol properties should be presented along with the rationale leading to the re-interpretation of CALIOP level1b data.

5. In part we have addressed this comment in answers 1 and 3 above. Here we would like to add that we did not chose a lidar ratio, instead we computed the lidar ratio in an iterative fitting procedure.

The authors discuss the evolution of the lidar, color and depolarization ratios in detail. Although the technical definitions of these terms are well known to the lidar community, the manuscript fails to connect the variability of those parameters with the variability on the actual microphysical and optical properties of the aerosol layer of great interest to readers beyond the lidar the community. A discussion of results in terms of practically meaningful aerosol properties will enhance the science value of this contribution.

6. We agree. We have added explanations in section 3.1 and 3.4.

The manuscript includes several statements on assumed numerical values of parameters without any references. No doubt most lidar experts are familiar with those values, but references may be important for the at large aerosol community. Please provide references and/or a rationale for the quoted numerical values in the statements below

Line 135. ….When the depolarization ratio is less than 0.05 the data is considered background and the lidar ratio is set to 50 sr.

7. OK, we added a reference to Vernier et al. (2009).

Line 137. Ice-clouds were removed in the lowest 3 km of the stratosphere by identifying them in stratospheric layers where the backscattering was high (attenuated backscattering larger than 0.0025 km-1 sr-1).

8. We have added a sentence that explains that we need to avoid statistical influence on cloud detection.

Line 138-139 Data in these layers were classified as probable clouds if their δv was higher than 0.20, or smoke if δv was between 0.05-0.20..

9. We have reformulated and clarified in the manuscript.

Line 164 …..very dense with layer AODs exceeding 1.

Detailed observations of the rapid evolution of the stratospheric AOD during the first two weeks following the onset of the pyroCb were carried out by the DSCOVR-EPIC mapper and AERONET ground-based observations (Torres et al., 2020). Both measurements reported stratospheric AOD's significantly larger than 1.0.

10. Thank you, this is a good suggestion. We have added text with reference to Torres et al., (2020).

Line 333. The UV aerosol index is available from a variety of UV-capable sensors on several platforms (Aura-OMI, SNPP-OMPS, DSCOVR-EPIC, S5P-TROPOMI). It should be pointed out that, when data on height of absorbing aerosol layers is available, the UVAI information content can be quantified in terms of the physically meaningful aerosol optical depth (AOD) and single scattering albedo (SSA) parameters. DSCOVR-EPIC near UV observations (Torres et al., 2020) were used to quantitatively (380 nm AOD and SSA) describe the 2017 Pacific Norwest pyroCb-triggered stratospheric aerosol layer on the first week following the injection using CALIPSO-provided aerosol layer height information.

11. Thank you, we have added that information in section 2.5.

Line 382. An objective evaluation of the accuracy of OMPS-LP -CALIOP measured aerosol extinction should be done using SAGE III as standard reference. Unlike CALIOP and OMPS LP aerosol extinction, SAGE III solar occultation observations require no aerosol model assumptions whatsoever. Although SAGE III measurements are spatially and temporally sparse, just a few collocations would be sufficient to assess the accuracy of the reported aerosol extinction products.

12. At first this suggestion has some appeal. However, in practice it is very difficult to compare SAGE III/ISS to the other two instruments. The reason is that the results of the two limb-oriented instruments report results in the tangent point, which is only one point in the line of sight. Since the lines of sight differ between the two instruments the results differ (Bourassa et al., 2019; JGR-Atmospheres, doi.org/10.1029/2019JD030607). Problem of not observing the same aerosol also affects a comparison with CALIOP. To overcome this obstacle a large amount of data from SAGE III/ISS would be needed to produce averages like those we formed for CALIOP and OMPS-LP. However, that is not possible because SAGE III/ISS produces such a small amount of data and is carried in a sub-optimal orbit for such a purpose, which we point out in the manuscript. See also our answer 3 concerning accuracy of the CALIOP results presented here.