Answers to the Reviewer#1

We thank the anonymous reviewer #1 for the detailed review. Including the suggestions made has significantly enhanced the paper. In the following you will find our response to the reviewer directly marked in red.

Anonymous Referee #1

Received and published: 29 May 2019

This manuscript provides an analysis of a set of laboratory experiments comparing the recently developed CAPS PMssa instrument, which measures aerosol extinction and absorption (from which is derived single-scatter albedo) using cavity phase-shift and integrating sphere techniques, respectively. Because this instrument can determine SSA through from a single sample, and bypasses the need for relatively uncertain ab- sorption measurements using filter media, it has the potential to be extremely valuable. The aerosol direct effect remains a large uncertainty in the Earth's radiative balance, and this instrument, if accurate and widely used, has the potential to help reduce this uncertainty. The topic is entirely within the scope of AMT and there should be many readers interested in the subject. The experiments described in the manuscript appear to be well conducted and have produced high quality data.

Regrettably, there are some significant issues with the manuscript, two especially, that will require a major revision. These two issues are:

1) There is no error analysis of the techniques being compared. Instead, variance in the measurements is used as surrogate for uncertainty. The authors need to directly and independently determine the uncertainty in the phase-shift extinction measurement and the uncertainty in the scattering measurement, and propagate these uncertainties through to the final SSA product. This uncertainty analysis must include consideration of both potential biases (which might include determination of pressure and temperature in the instrument, for example) and random uncertainties (which might include noise in the measurement that requires averaging). As it currently stands with this manuscript, if I were to purchase two of the CAPS PMssa instruments and compare them and find that they disagree by 5% in extinction and/or scattering, I would not know if this is within expectations or would indicate a problem with one of the instruments. A complete uncertainty analysis needs to be applied to all the instrument combinations used. In Table 6, it is not at all clear where these "uncertainties" come from; they appear to be either the scatter in the data (plotted in Fig. 12) or else the difference between the mean values of the data and the "expected" values of the calibration aerosols. Because the SSA of the calibration aerosols is not truly known, there is no absolute standard provided against which to evaluate the different approaches to measuring SSA, so a fundamental uncertainty propagation is needed.

This paper does NOT address in any explicit way, nor was it designed to address, the question of the absolute uncertainties of these techniques. It was designed to address the question of how well they correlate. Thus, the results are given in correlation coefficients (slope and intercept) and their statistical uncertainties

We have added Section 2.3 (new) summarizing the measurement uncertainties reported by the different instrument paper. In particular the uncertainty of the CAPS PMssa was described in detail by Onasch et al. (2013). We have added a passage to the manuscript referencing the detailed error analysis by Onash et al. more pronounced. Temperature and pressure variabilities as potential biases are part of the used measurement error and minimized by regular taking baseline measurements.

2) The linear regressions which provide the bases for the evaluated values appear to have some sort of error. Examining Fig. 4, the fitted line shown on the scatterplot lies below all of the datapoints. Using Table A1, I plotted the data shown in Fig. 4 and performed a linear regression. I got a slope of ~1.08 and the fitted line passed directly through the data. This compares with the "all" fit shown in Table 3 of the manuscript, which gives a slope of 0.97. I tried a two-sided regression, a one-sided regression, and one-sided regression forced through zero intercept. All gave slopes >1.06. Inspecting the other scatterplots in the manuscript (e.g. Figs. 8, Fig. 11 for absorptions <70 Mm-1), the fitted slopes do not seem to go through the data. Unless I've made an error, it appears that the values appearing in all the tables are suspect because of this fitting issue. Thank you for including all the data in the supplemental material tables, which makes finding an apparent problem like this easier.

The line shown in the linear regression was misplaced. The line is actually just a 1-1 line to help readers to evaluate the results in comparison to a perfect correlation (1-1). We have replaced the figures and added the information to the figure caption.

In addition to these two principal issues, there are some smaller items that need addressing.

a) The table captions all need to be more precise. For example, Table 3 might have a caption of, "Linear regression parameters slope (m), intercept (b) and their standard deviations and the linear regression coefficient R2."

We have added your suggestion to the captions.

b) I was trying to understand for quite some time how the column labeled "SSA" in Table 3 was calculated before realizing that it is simply an estimate of the SSA for the aerosol type being generated. It might be clearer to move the SSA column to the second column of the table and label it "estimated SSA".

We have added your suggestion to the table.

c) The figures all need to use a heavier line width and larger, denser font. It is quite hard to read the labels and identify the symbols and lines.

We have improved the figures resolution. But a final version (more readable) of each figure will depend on the layout specified by the AMT. Therefore, we will wait until the final version of the article is given (format wise) to optimize the figures sizes and resolutions.

d) The descriptions in the tables and figures of "PSAP-Neph" is confusing; it suggests that you are subtracting the scattering data from the absorption data. I suggest you use PSAP+Neph for Table 1 and Fig. 4, and "PSAP & Neph" for Table 6.

We have added your suggestion

e) Figs. 5 and 9 are not needed since the data appear in tables already.

It is a visual results representation, which we believe is important to many readers.

f) Fig. 12 should also show the SSA determined for the ammonium sulfate aerosol; this would give a good idea of the scatter about a known, non-absorbing compound.

We have added the AS Data to Figure 14 (new)

g) The title includes "Field Deployment". There is no field deployment of the instrument described in this manuscript, just laboratory tests.

Good point! The field deployment was excluded from this article, thus the title has been modified.

h) Lines 93 to 97, the description of the roles of MFC#1 and #2 in regulating make-up air appear to be switched with MFC#3 and #4 in Fig. 1.

Right. It is corrected (lines 96-97) now.

i) Section 2, please describe the truncation angles for the various instruments and typical magnitudes of the correction factors. The uncertainty in these correction factors need to be part of the total uncertainty analysis and error propagation.

There are many studies about the truncation angles and corrections for the proven technologies (most important and used ones are referred in the article). For the SSA Monitor the information has been added to section 2 (lines 196-204) in the description of the instrument, since it is what is being evaluated in this article. For the other instruments, we included the uncertainty section 2-3 citing the relevant literature in a pronounced part.

j) Please use 2-sided (orthogonal distance) regression when performing the linear regressions. There are uncertainties in both x and y dimensions that should be accounted for. Please weight the regressions by the uncertainty in the measurements.

All uncertainties (standard deviations) are presented for both x and y. Sometimes the values are so small that they are smaller than the data point marker.

k) The figure captions (e.g., Fig. 3: "Time series of the measurements by the extinction channel" do not adequately describe the contents of the figures, which in this case shows results from 3 different instruments/combinations, not just the extinction channel of the CAPS PMssa. The same for the other time plots.

We have updated the captions.

There is a lot of good information from some carefully performed and important lab- oratory studies in the manuscript. I encourage the authors to address the concerns indicated above and submit a revised manuscript that more fundamentally addresses uncertainties and that uses accurately determined regression slopes using properly weighted 2-sided linear regressions.