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Interactive comment on "Development and validation of a CCD-laser aerosol detective system for measuring the ambient aerosol phase function" *by* Yuxuan Bian et al.

Anonymous Referee #1

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General Comments:

This paper describes a newly developed CCD and laser-based detection system for measuring aerosol phase function.

Overall, this instrument has some advantages, such as a very simple setup and design. I believe that, if the efficacy can be shown, the idea for this instrument is a significant advance and falls under the scope of AMT.

However, I feel that there are some outstanding questions that need to be addressed before the paper can be published. These are listed below in the specific comments.

I believe that if these questions are addressed, then the paper may be publishable.

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However, the following questions are crucial to the measurement and the authors may need to perform more measurements to ensure the efficacy of the instrument.

In general, the English in the paper is relatively unclear and needs to be edited.

Specific Comments:

1) What is the polarization state of the laser relative to the plane of scattering?

Although the authors do not specifically address this, I suspect that they have taken this detail into consideration. The point of my comment is that the phase function of the aerosol depends on the incoming polarization of the laser relative to the plane of scattering. The laser polarization can be oriented perpendicular to, parallel to, or somewhere in between these two positions. In order to compare the measurements to Mie theory, the polarization state must be included in the Mie calculation. This is not mentioned in the paper.

The scattered light will also be polarized and this needs to be addressed as well. For example, the detectors may detect different polarizations of light slightly differently. A flat-field calibration across the CCDs is also needed to verify that different angles of incident light to the detector are measured with equal sensitivity.

2) How can the authors be sure that they are not detecting scattered light from multiple points along the laser into their CCD detectors? Although this is mentioned in the text, it is not clear that this is true.

In Figure 1, the authors show the setup, including scattering angle into the detector. But the aerosol is not constrained in any way along the path of the laser. Therefore, light scattering from a particle near the laser and from a particle at a different point along the laser beam could strike the detector at the same location.

It would be highly useful to show some raw data from the two CCD detectors for one measurement to show the relationship between the two and how the data is spliced together. At what scattering angles do the two CCD measurements overlap?

How do the authors determine the scattering angle that corresponds to each pixel position on the CCD? Is there some sort of measurement of a known scatterer that could be used to calibrate the angle, such as PSL or ammonium sulfate?

In general, it would be a good idea to perform the measurement with a known compound to better determine the efficacy of the instrument.

3) More detail is needed regarding many aspects of the study. There needs to be more information regarding how the Mie calculations were performed. What was the refractive index used? Were the size distributions from the SMPS? 4) The instrument will measure scattered sunlight when used during daylight hours. Using a 532 nm filter in front of the cameras will block much of the scattered sunlight, but the sunlight near 532 nm will be scattered by the particles and will reach the detector. Was there any attempt to block the sun from reaching the particles? For example, could a dark curtain or sampling box be used? 5) Fluctuating temperature in the ambient measurement will likely cause fluctuations in the laser alignment during the measurements. Also, temperature fluctuations could affect the CCD efficiencies. Were the CCD cameras electronically cooled or was the temperature stabilized in any way? 6) The authors claim that a significant portion of the particles measured were biomass burning particles. These particles could absorb a significant fraction of light. Was the absorption considered in the Mie calculations or was only scattering considered? 7) Ambient gases, such as nitrogen dioxide and ozone could absorb a significant fraction of light. It would be useful on Page 4, Line 20, for example, to discuss more detail in the assumption that the transmittance of the laser is 1. 8) The entire discussion of the retrieval algorithm is not clear (Section 2.2.2). More detail is needed. Please describe exactly how the retrieval algorithm works. Why is the retrieval needed? You are measuring the phase function, correct? Why would you need to retrieve it? 9) Error bars (uncertainties) of the measured phase functions are needed to better understand the overlap between the models and measurements (in Figure 4, for example).

Technical Corrections:

In general, there are not enough citations to the literature in the introduction. For example, Bohren and Huffman should be cited for Mie theory. The IPCC report should be cited for the first sentence (Page 1, Line 20). There are more field measurements that used an integrating nephelometer. Overall, more citations are needed.

Throughout the paper, “figure” should be capitalized as “Figure 1”.

N0 and T are both used as symbols for transform coefficient (Page 4, Lines 6 and 19). How are these different?

Page 1, Line 24 should read “The aerosol phase function. . .”.

Page 2, Line 5 should read “A plane mirror was placed at that point and reflected the scattering signals. . .”

Page 2, Line 7: Is “linearity” correct? If so, please explain.

Page 2, Line 28. “mainly” is not needed. More information is needed about the laser. The make, model, etc. is needed.

Page 3, Line 20 should read “The CCD-LADS system covers an area 12 m long and 1 m wide.”

Page 3, Line 21. How is the background noise measured? It would be useful to show a plot of the signals measured during the daytime and nighttime. Also, why is the noise so much higher in the daytime? See the comment above regarding the filters above. I suspect that you have a large portion of ambient light being scattered by the particles. Depending on the angle of the sun, this could affect the ambient measurements.

Page 4, Lines 8-13. More detail is needed about the linear weighting and the data processing in general.

Page. 4, Line 30. The authors state that the hemispheric backscattering is half of the full scattering. This is true for Rayleigh scattering, but it depends on the polarization of the light. Bohren and Huffman, or a Rayleigh scattering calculation needs to be cited

here.

Page 5, Lines 1-9. This section is very confusing. Was a separate measurement of the air molecule scattering measured by an integrating nephelometer during this study? More detail is needed. What is meant by “the percentage of air scattering”, for example? See the comment above.

Page 6, Line 13. What is the external/core-shell ratio of 1:1? What does this mean? 1:1 core and shell ratio by volume?

Page 6, Line 23. The explanation that the scattering abilities of aerosol particles and gas molecules match better in the back scatter than the forward scatter is not clear. In the phase function, the Rayleigh and Mie scattering generally match in the forward and reverse directions (0 and 180 degrees).

Page 6, Line 25 and Figure 4. Biomass burning aerosol is not shown on the graph. Also, this needs a reference for the discussion about biomass burning size, absorption, etc.

Page 7, Line 2. The authors state that the difference “Is not obvious”, but there is clearly a difference between the Mie model and the measurement in Figure 5. This is not clear.

Page 7, Line 13. Why was the instrument limited to 30-160 degrees because of the ambient conditions?

Page 7, Line 16. It is more correct to say that the particles will exhibit hygroscopic growth rather than “grow up”. Also in Line 18, why was the data collected at RH > 70% eliminated? How was 70% RH chosen? Many particles exhibit water uptake at lower relative humidities. Biomass burning aerosol is highly hygroscopic and shows continuous growth. 70% seems to be arbitrarily chosen.

Page 7, Line 18. It is better to say “eliminated” than “kicked off”.

Page 7, Line 26. What is meant by better stability? Was the data less noisy? This is not clear.

Page 8, Line 18. What is meant by “steadier”?

Figure 3: The data shown here was not collected by the CCD-LADS instrument that is the focus of this paper. Why is this data shown? Was it used in the Mie calculation to compare to the CCD-LADS measurements?

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