

Author Response to Comments on "A new method for measuring optical scattering properties of atmospherically relevant dusts using the Cloud Aerosol Spectrometer Polarization (CASPOL) instrument" by A. Glen and S.D. Brooks.
ACPD 12, C7802-C7805, 2012

Reviewer's Comments:

This paper describes the operation and calibration of a new instrument, the cloud and aerosol spectrometer with polarization detection (CASPOL). The instrument is shown to be capable of detecting differences in scattering properties of different dust components, proving its potential to classify dust particles in atmospheric measurements.

However, no atmospheric measurements are presented; only laboratory measurements are shown. Because the paper focuses exclusively on instrument performance, I don't feel that it is appropriate for publication in ACP, which focuses on "studies investigating the Earth's atmosphere and the underlying chemical and physical processes". It is much more suitable for Atmospheric Measurement Techniques, which covers "the development, intercomparison and validation of measurement instruments and techniques of data processing and information retrieval for gases, aerosols, and clouds." Thus my recommendation is to reject the paper. Although the paper is a fine contribution, it should have been steered to AMT in the initial submission stage. Let's reserve ACP for the actual science, not the techniques.

In general the paper is well written, clear, and reasonably concise. I have only a few substantive comment (other than that it should be submitted to AMT rather than ACP).

Authors' Response:

Clearly, the Reviewer has completely missed the fact that this manuscript has been submitted to a "Special Issue jointly organized between Atmospheric Measurement Techniques Discussions and Atmospheric Chemistry and Physics Discussions" and not to ACPD.

Since the reviewer states that the manuscript is suitable for AMT, we assume that if he/she were aware of the special issue specifically on "Light depolarization by atmospheric particles: theory and measurements" to which this was submitted, he/she would have reviewed it positively.

We would also like to note that the laboratory measurements presented go well beyond mere calibration. Optical properties of 13 varieties of atmospherically relevant dusts, including several collected field samples are reported. Thus this manuscript, while providing all the details of a new and unique single particle technique, also includes measurements never reported in the literature, making this an ideal type of paper for the special issue at hand.

Reviewer's Comments:

1) Lack of quantitative evaluation of particle shape in Section 3.4. High resolution SEM images were taken of the different aerosol types. The qualitative conclusion is drawn that, "the SEM images of each dust . . . do not yield any distinctive similarities for dust types allocated to the same groupings indicating

that shape and size are not the only determining factors in the optical scattering properties." This needs to be expanded upon. Scattering is dependent upon shape (morphology), size, refractive index, and homogeneity. It is very surprising that there is no consistent relationship between the measured polarization and scattering intensity and these particle parameters. Have the authors attempted to classify particles in the SEM images by fractal dimension, aspect ratio, or other quantitative parameters? There are image analysis packages available (e.g., for Matlab and IDL) that can perform automatic, objective classification. Simply saying (in the Summary) "no clear correlation between single particle characteristics and their optical properties were (sic) determined" is not adequate. The "characteristics" of single particles are the only things that can explain their optical properties!

Authors' Response:

The authors agree that the characteristics of the single particles are what causes the change in optical properties, however as stated in the manuscript this is not a function of one variable alone. The conclusions in Section 3.4 made within the manuscript state "Based on the SEM images of each dust (not shown) the images do not yield any distinctive similarities for dust types allocated to the same groupings indicating that shape and size are not the only determining factors in the optical scattering properties." The authors stand by this claim and have attached a table of the aspect ratio for the dust types used in this study, with minimum, maximum and average aspect ratios analyzed using ImageJ software. As the table shows there is no clear or consistent relationship between particle shape and the particle grouping. By the Reviewers own admission, there are several additional factors other than size and shape which influence the optical scattering by a particle, including refractive index and composition. The relationship between these particle characteristics and the optical properties are very complex, so attempting to identify a consistent relationship between the measured scattering intensities and any one individual particle parameter is unlikely.

Table C1. Aspect Ratios of the dusts used in this study.

	Aspect Ratio		
	Min	Max	Mean
Arizona Test Dust	1.20	1.81	1.49
Hematite	1.02	3.82	2.36
Kaolinite	1.14	1.77	1.55
Gypsum	1.94	2.58	2.35
Quartz	1.11	2.45	1.92
Red New Mexico	1.08	2.00	1.50
Red Saudi Arabia	1.54	2.54	2.02
White Quartz	1.45	1.88	1.71
White Sands	1.05	2.26	1.86
Magnetite	1.14	2.52	1.83
Montmorillonite	1.22	1.78	1.58
Yellow Saudi Arabia	1.30	1.74	1.48
Zeolite	1.18	1.29	1.23

Reviewer's Comments:

2) Polarization ratios exceeding 1. Figure 9 and Section 3.5 describe polarization ratios exceeding 1. Yet Eqn. 1 describes the polarization ratio as the ratio of polarized backscatter intensity to total backscatter intensity. This ratio should never exceed one.

Please explain how this can be.

Authors' Response:

This question has been addressed in the comment revisions AC C7954 posted on the 11 October 2012.

Reviewer's Comments:

3) Section 3.7 describes theoretical calculations of backward scattering cross sections for various compounds to show the sensitivity of backscattering to refractive index. However, this calculation cannot be replicated because the necessary refractive indices are not given. Please do so.

Authors' Response:

First the authors would like to direct the Reviewer to Table 1 in the manuscript in which the known real components of the refractive index are shown, with source references. Since the submission of this

manuscript the complex components of refractive indices have been added for the known dust types. Additionally, the authors would like to note that the theoretical calculations of the backward scattering cross sections shown in the manuscript were based on the optical measurements made by the CASPOL during these experiments. In particular the scattered intensity of light in the backward direction for a particular size and dust type. The theoretical backward Mie response was also needed for the calculation of scattering cross section, and was calculated for each dust type to take into account the particular refractive index of that dust. The use of the Mie response for each of the dusts inherently includes the refractive index for those dust types, so actually using the refractive index in the back scattering cross section calculation is unnecessary. The methodology described in Section 3.7 can then be followed to estimate the backward scattering cross section for 2.5 μm particles of the three representative dusts. The development of backscattering cross sections allows for the comparison of data collected in situ to instruments with increased spatial resolution such as lidar.

Reviewer's Comments:

4) Figure 6 is unnecessarily a color figure. Many of us are colorblind and simply can't read this graph. Histograms would be clearer, although they would take a bit more space. If you must use color, the "yellow hot" is a better scale to use in Figs 9-11 for most colorblind readers than is than the "rainbow" scale.

Authors' Response:

An unfortunate aspect of the data analysis we employ here is that it does rely heavily on color, so the authors apologize for any inconvenience this may have caused. However, the authors believe the use of color for Figure 6 is necessary as it provides the most simplistic view of the data across all dust types. The analysis of this data was completed using IDL, which does not have a "yellow hot" color scale. Instead a "blue gradient" was used as it seems the most appropriate for suffers of red/green color blindness, deuteranopia or protanopia. The authors attempted to create their own "yellow hot" color table from scratch, which resulted in a lack of clear data representation. In addition Figures 9 - 11 were also reprocessed for your convenience with the improved color scale and are attached below.

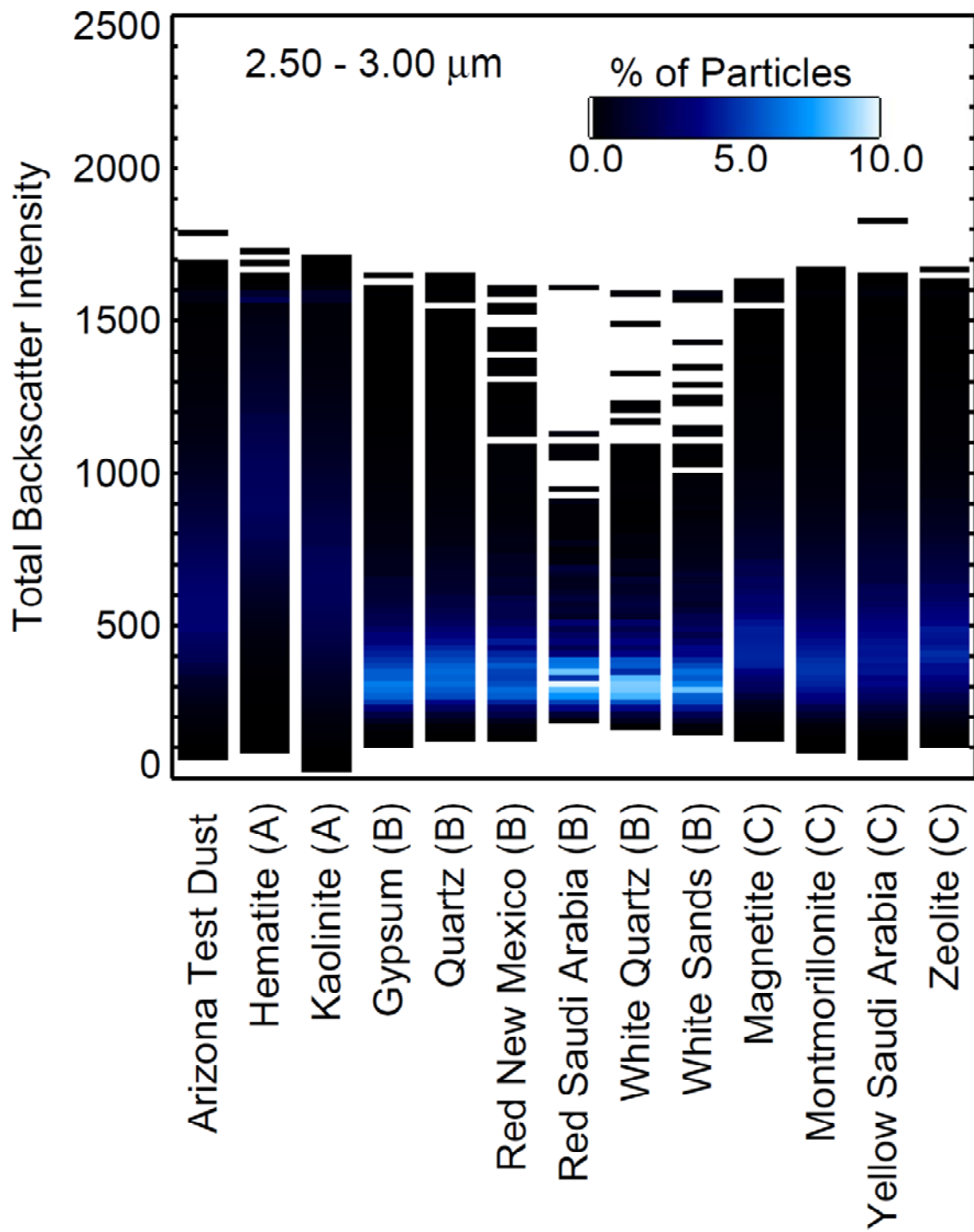


Fig. 6. For the 2.5 μm to 3.0 μm CASPOL channel only, the percentages of particles which have a given total backscatter intensity are shown, for each dust type.

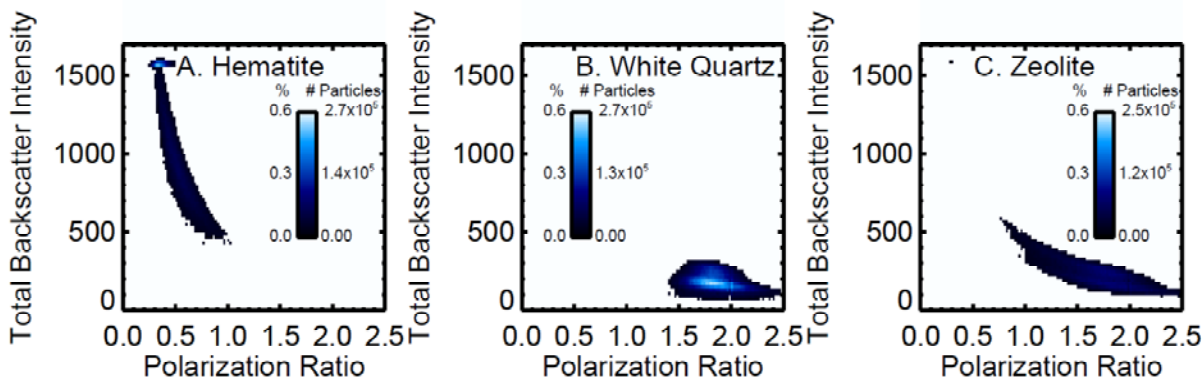


Fig. 9. The total backscatter intensity vs. polarization ratio for representative members of the optical scattering Groups A (hematite), B (white quartz) and C (zeolite) are shown.

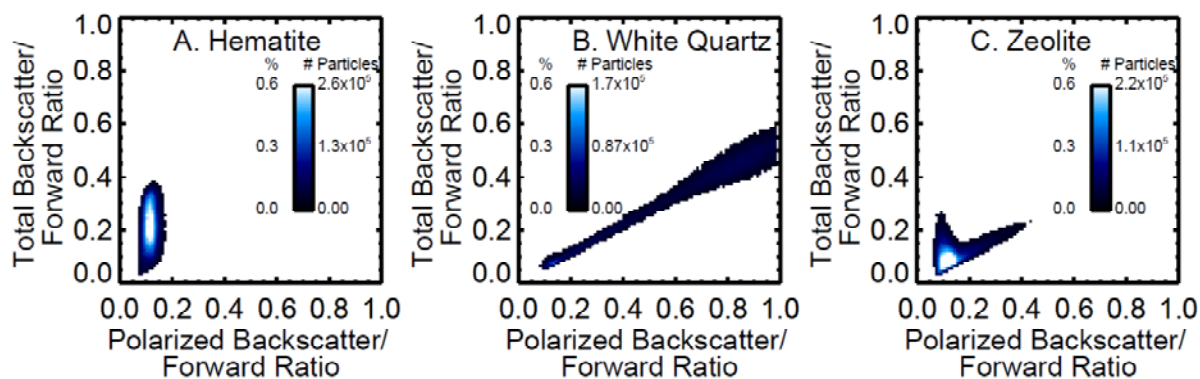


Fig. 10. Polarized backscatter to forward scatter ratio vs. the total backscatter to forward scatter ratio for representative members of the optical scattering Groups A (hematite), B (white quartz) and C (zeolite) are shown.

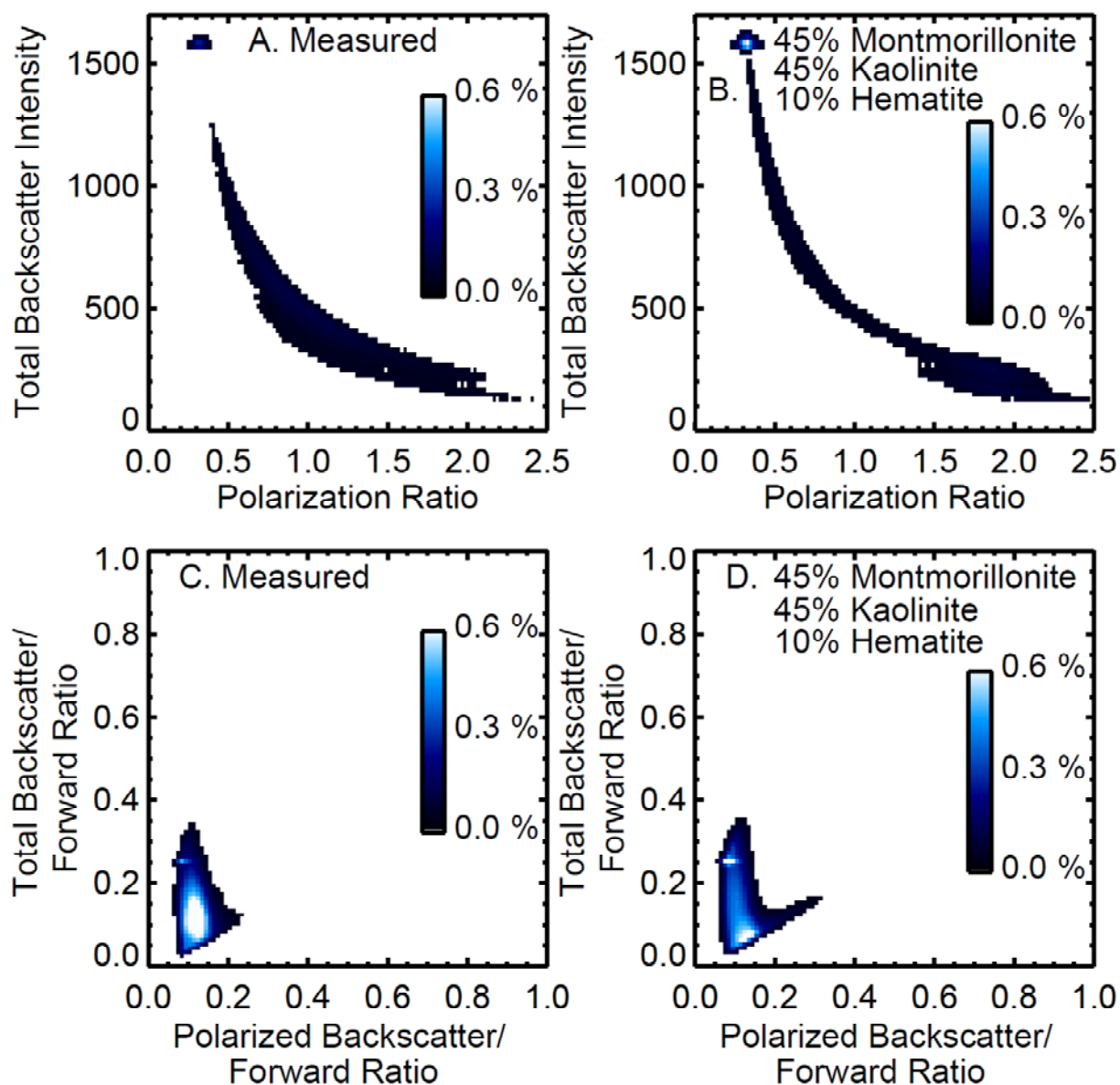


Fig. 11. The optical signature of measured Arizona test dust sample and the composite signature generated using montmorillonite, kaolinite and hematite data are shown in (A) and (B), respectively.

Technical corrections:

Reviewer's Comments:

a) The DMT web site describes the CAS as the "cloud AND aerosol spectrometer".

Authors' Response:

The instrument we used for this experiment was a prototype which DMT have designated as the "Cloud Aerosol Spectrometer - Polarization Option (CAS-POL)" in their manual DOC-0167 Rev A. As we used this manual as a reference for the name of the instrument, the authors termed the instrument the "Cloud Aerosol Spectrometer Polarization, (CASPOL)". There is no "AND" between the words cloud - aerosol.

Reviewer's Comments:

b) p. 22419 line 18. Change "variable" to "variability".

Authors' Response:

Completed.

Reviewer's Comments:

c) p. 22420 line 9. PSL equivalent optical diameter? Water equivalent? Olive oil equivalent? Please define since optical diameter is dependent upon refractive index.

Authors' Response:

The manuscript has been corrected to clearly state that we used the water equivalent optical diameter. The equivalent optical diameter of a particle is the diameter given to a particle that scatters the same amount of light as the particle being measured by the instrument.

Reviewer's Comments:

d) Section 2.1. Was olive oil or oleic acid used? Is the refractive index of "olive oil" well known (e.g., for Section 3.7)?

Authors' Response:

Olive oil was used for the calibration as mention on page 22421 line 8. The refractive index for olive oil is known, a value of 1.46 was taken from Yunus et al. (2009) and is now indicated in the manuscript.

Reviewer's Comments:

e) p. 22421 line 20. Add a comma between "isopropanol" and "leaving".

Authors' Response:

Completed.

Reviewer's Comments:

f) p. 22421 line 24. Change to "Near-monodisperse"

Authors' Response:

Completed.

Reviewer's Comments:

g) p. 22422 line 8. What does "specially designed" mean?

Authors' Response:

The term "specially designed" is in reference to the precision engineered rotating scraper that is used to load a toothed conveyor belt with a dust sample at a constant rate as part of the Topas Solid Aerosol Generator (SAG), a commercially available instrument. It was not in reference to the Topas being a "specially designed" instrument for this work.

Reviewer's Comments:

h) p. 22423 line 3. Please describe the composition of the Arizona test dust.

Authors' Response:

Arizona test dust is a well known commercially available dust. The composition of which is stated in the manuscript in Section 3.6. But now a description is included in Section 2.2 which discusses the measurements of the optical scattering signatures of atmospheric dust particles. We have included the following statement: "The last commercially available sample, Arizona test dust, is a well characterized multi-component specimen primarily composed of three components, montmorillonite, kaolinite and hematite."

Reviewer's Comments:

i) p. 22424 Sect. 3.1. Add a reference for the undersizing of large particles by the VOAG.

Authors' Response:

The submitted manuscript read "At particle diameters larger than 13 μm there is some deviation between the CASPOL and the VOAG. This may be due to a combination of factors. At relatively large particle sizes, the VOAG tends to produce undersized particles. This may be due to the increase in the surface stress of the droplet at larger volumes which causes a deformation of a particle from spherical to non-spherical and subsequently induces breakup."

The manuscript now reads "At particle diameters larger than 13 μm there is some deviation between the CASPOL and the VOAG. This may be due to a combination of factors. At relatively large particle sizes, the VOAG has been known to miss-size particles, with actual particle size not being accurately predicted by theory (Peters et al., 2008). This may be due to the increase in the surface stress of the droplet at larger volumes which causes a deformation of a particle from spherical to non-spherical and subsequently induces breakup."

Reviewer's Comments:

j) p. 22425 line 1. Is this change in polarization ratio, interpreted as a change in aspect ratio, consistent with the SEM images? Please quantify.

Authors' Response:

See above discussion on this issue.

Reviewer's Comments:

k) p. 22425 line 7. Remove the sentence, "To improve the categorization, additional data processing was employed."

Authors' Response:

The authors believe that this sentence states the direction in which the paper develops. As the lines before this state "Based on these raw data, the thirteen dust samples were sorted into three groups with only one outlier. Groups A through C aptly describe the characteristics of all dust types except Arizona test dust which is further discussed below". At this point the authors bring in the questioned statement to indicate their intention to improve these categories by further developing analysis methods.

Reviewer's Comments:

l) p. 22429 line 4. Change to "based ON the".

Authors' Response:

Completed.

Reviewer's Comments:

m) p. 22430 line 16. "calculation of the measurements"?

Authors' Response:

Rephrased to "the calculation of the backward scattering cross section of particles based on the size resolved measurements."

Reviewer's Comments:

n) Baumgardner et al., 2012 (in prep) is not citable at this stage.

Authors' Response:

This reference has already been removed from the manuscript after comments made by the previous reviewer. Please see AC C7954: 'Response to Reviewer Comments' dated 11 October 2012.

References:

Peters, T. M., Riss, A. L., Holm, R. L., Singh, M., and Vanderpool, R. W.: Design and evaluation of an inlet conditioner to dry particles for real-time particle sizers, *Journal of Environmental Monitoring*, 10, 541-551, 2008.

Yunus, W. M. M., Fen, Y. W., and Yee, L. M.: Refractive Index and Fourier Transform Infrared Spectra of Virgin Coconut Oil and Virgin Olive Oil, *American Journal of Applied Sciences*, 6, 328-331, 10.3844/ajassp.2009.328.331, 2009.