

Interactive comment on “Design and performance of a three-wavelength LED-based total scatter and backscatter integrating nephelometer” by T. Müller et al.

T. Müller et al.

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Reply to D. Baumgardner (referee #1)

Comment: The reader is left somewhat puzzled, however, and perhaps a bit unsettled, with the backscatter comparisons where the regression coefficients for the Aurora versus TSI go from a slope of 0.93 to 1.11 as the wavelengths change from blue to red. This in turn leads to large differences in the backscatter derived angstrom coefficients. Given the importance of backscatter in understanding radiative fluxes, it would be beneficial to understand these differences. The truncation errors normally

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have the largest impact on the forward scattered light, especially with larger sizes, so I wonder if the differences are more related to how the backscatter measurement is implemented in the two systems. Could the authors at least venture a hypothesis as to why these differences exist?

Reply: The authors do not think the difference in the design of the backscatter is responsible for the differences. The method used in both cases is actually quite similar with a shutter blocking the light from the light source. The distance of the shutter from the light source is the only major difference with the fact that the shutter is continuously moving in one case and not in the other. Differences in the design of the backscatter would affect all wavelengths similarly. Larger differences might be explained by the comparable low signal noise ratios of the backscattering raw signals. For atmospheric aerosol the backscattering intensities are lower by about an order of magnitude than intensities for total scattering. After subtraction of a temporal variable background signal from wall scattering and electronics the errors in backscattering can be relatively large compared to the errors of total scattering. In Heintzenberg et al. (2006) it was shown that differences between Mie-calculated and measured scattering and back scattering signals are largest for the red wavelength. In contrast to this manuscript, the backscattering in Heintzenberg et al (2006) seems to fit better than the total scattering for the red wavelength. In summary, the red channel of nephelometers might suffer from the lower signal to noise ratio, what leads to the much higher errors in total as well as in backscattering. The authors will comment on why they think that not the construction of the backscatter shutter but the signal to noise ratio might cause higher differences in the red channels.

Comment: I think it would be very beneficial to include a table that lists the specifications for both instrument, including things like physical dimensions, weight and power consumption, along with the noise levels (determined over the same averaging times, please) and truncation angles.

Reply: The authors will include a table with specifications and performance (noise

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level etc.) in the revised manuscript. The authors think that general information such as power consumption and dimensions are not necessary in such a paper where the focus is mainly comparing the scientific performance.

Comment: Page 6, Line 15 Does this sentence mean that the LED was introduced for the first time in an Ecotech instrument? Radiance Research has used an LED for a long time in their nephelometer.

Reply: Ecotech instruments are the first nephelometers with LED light sources. The Radiance Research nephelometer uses a flash-lamp as a light source.

Comment: Page 9, Line 11 "The illumination functions agreed well" Between total and back?

Reply: The illumination functions for total scattering agree well with the previous published studies in Anderson et al. (1996). Illumination function for backward scattering was not measured in Mueller et al. (2009). We will clarify this point in the revised version.

Comment: Page 9, Line 18 I think that it is very important to put in the summary the emphasis that there is currently no method to verify truncation angles. I would list this as a recommendation for future development as the correction factors are dependent on knowing these angles.

Reply: We will add the recommendation in the revised version.

Comment: Page 9, Line 20 Are the parameterizations based upon the Figure 2? If so, state this explicitly.

Reply: Yes, they are, we will explicitly state it.

Comment: Are beta 1 and beta 2 for total scattering the same as for backscatter? I don't understand the max and min function. Please clarify.

Reply: Yes, Beta1 & beta2 are the same. They are responsible of the shape of the

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backscatter light illumination curve after the shadowing effect of the shutter has diminished. There is actually a mistake in the equation. It should be as shown in Fig1 at the end of this document.

Comment: Page 10, Line 25. The noise levels are determined with 5 minute averaging for the TSI and only one minute for the Aurora and yet the Aurora S/N is lower than the TSI. This is a very important point but the same averaging time need to be used or the S/N needs to be adjusted to compare the two.

Reply We agree to the reviewer. We will report both noise levels using a 1 minute average.

Comment: Page 13, Line 5. The differences in the backscatter is quite large even though the correlation is high. Some discussion is needed to try and explain and why the relationship changes with wavelength.

Reply: To start with, the backscatter is in general noisier than the total scattering as it is written in page 4845, line 5. In addition, the red scattering has a greater noise than the other wavelength. We think that differences for the red channel are higher because of the lower signal to noise ratio, especially for backscattering. The authors will discuss the problems with the red backscattering-channel in the revised manuscript.

Comment: page 14, Line 7 Are these size distributions simulated or measured? Are these just examples? Please clarify a bit more in this section what you are trying to do. My understanding is that the simulations are necessary to calculate correction factors but it took me a while to understand the point of this exercise, i.e. estimating the imaginary component, etc.

Reply: These particle size distributions are the measured distributions during the ambient measurement period. The referee is right, the goal of this section was to calculate the index of refraction of the particles which we measured. The real part was estimated from Wex et al (2002) to be 1.53, what is a reasonable value for particles in an urban

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area. The imaginary part of refractive is much more variable. Thus the imaginary part was determined by an iterative algorithm. The median value of the time series of the imaginary part of refractive index was 0.048 and the 95th and 5th percentiles were 0.082 and 0.023, respectively. That way, we do not have to assume an index of refraction to calculate the correction factor. This will be clarified in the revised version.

Comment: Page 16, Line 4 The scatter plots in Figure 8 are not very insightful and fitting a curve to data with such poor correlation is not very meaningful. Perhaps plotting the angstrom coefficients against one another with the markers color coded by median volume diameter would offer a better perspective of when the coefficients agree or not.

Reply: The authors found that Figure 8 was the best way to support this finding. The correlation (r^2) between the ratios and the median volume diameter is poor. The important point of Figure 8 is that the fitted line is a function of the median volume diameter. The Authors will add the errors of the fit parameters to show that the slope significantly deviates from zero. For example, the fit parameters and errors of $Y = A + B * X$ are $A = 1.1038 \pm 0.00717$ and $B = -0.6722 \pm 0.02226$ for Figure 8 a).

Comment: There is no discussion of the potential impact of light reflection from the walls of the sample chamber. I understand that these are black but there is always some reflection. Is that a factor?

Reply The wall reflection is a bias to the scattering signal. The wall reflectance might vary with time due to increasing contamination of the walls with particles. The wall reflection is taken into account during calibration and during normal measurements by continuously measuring the scattering signal with particle free air (zero measurements). The authors will discuss the importance of zero measurements in the revised manuscript.

Minor corrections

Page 5, Line 2 know -> known

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Page 4, Line 1 instruments -> instrument

Page 4, Line 15 scattering -> light scattering

Page 7, Line 9 what -> which

Page 8, Line 10 angels -> angles

Page 9, Line 14 Beside -> besides

Page 9, Line 21 sin -> sine

Page 10, Line 10 what -> which

Page 12, Line 23 with -> within

Page 14, Line 1 what -> which

Reply:

The revised manuscript will be corrected.

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 4835, 2010.

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$$Z_{ts}(\theta) = \begin{cases} 0 & 0^\circ \leq \theta \leq \alpha_1 \\ \beta_1 \cdot \sin(\theta)^{\beta_2} & \alpha_1 < \theta < \alpha_2 \\ 0 & \alpha_2 \leq \theta \leq 180^\circ \end{cases} \quad \text{"1"}$$

and

$$Z_{bs}(\theta) = \begin{cases} 0 & 0^\circ \leq \theta \leq \alpha_1 \\ \max \left(0, \beta_1 \cdot \sin(\theta)^{\beta_2} \cdot \min \left(\frac{\theta - \gamma_1}{\gamma_2} \right) \right) & \alpha_1 < \theta < \alpha_2 \\ 0 & \alpha_2 \leq \theta \leq 180^\circ \end{cases}$$

Fig. 1.