Atmos. Meas. Tech. Discuss., 4, C2915–C2926, 2012
www.atmos-meas-tech-discuss.net/4/C2915/2012/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Tracking of urban aerosols using combined lidar-based remote sensing and ground-based measurements" *by* T.-Y. He et al.

T.-Y. He et al.

tingyao.he@ung.si

Received and published: 18 March 2012

The authors wish to thank the reviewer for extensive and valuable comments and suggestions, which were very helpful for improving the manuscript.

Comment#1 "One minor criticism is that, although the assumptions made at each step are correctly described, the uncertainties that are introduced are not necessarily carried through to the final stage. Firstly, it is not made clear whether the surface point-based in-situ measurements of PM10 are being compared to lidar extinction values from a point 200m directly above the in-situ measurements, or from a path-integrated value of lidar extinction. This distinction is important for understanding Fig. 8 (see next point).

Secondly, the uncertainty stated in the lidar extinction is for the path-integrated value, not for an extinction value at a single point. The uncertainty in extinction at a single point will be much higher, and, given the variability in backscatter shown in the lidar PPI sector scans, there is also potential for the lidar ratio (the relationship between lidar backscatter and extinction) to also vary.

Comparing the lidar-derived extinction coefficients to the PM10 concentration is certainly valid, but the error bars are probably wider than those shown in Fig. 8. and, if it is true that this figure is comparing in-situ point measurements to path-integrated values, then it may not be surprising that the correlation coefficient is not that high, since Fig. 5 shows how variable the aerosol emission appears to be.

For the scientific community (and for potential operational monitoring), an assessment of the uncertainties in the retrieval is crucial. Overall, this manuscript is appropriate for publication, providing the authors address the issue of the uncertainty in their retrieval, and whether they are comparing point sources of PM10 measurements to point-based or path-integrated values of lidar extinction."

Response: In the analysis presented in Sec. 4.4 of the original manuscript we correlate the extinction coefficient at the elevation 200m averaged over the entire scanning area (with point sources excluded) to the ground-based point measurement. The correlation was found to be about 0.6.

We performed further analysis by constraining the scanning area to a circle with a radius $R \leq 300$m directly above the ground-based measurement site, and in this case, the resulting correlation is much higher, around 0.84 (see the attached Fig. 1). In the attached Fig. 2, we show both the localized extinction data (same as in Fig. 1) and the unconstrained values (red points represent those above the correlation line for the localized extinction and green those below). Detailed investigation of the conditions for the apparently non-correlated values with lower extinction (green) revealed they all represent measurements at times where the traffic was low (the measured NOx values were low). The correlation coefficients of the red and the green subset of the whole dataset (over the entire scanning area) to the PM10 concentration were found to be 0.72 and 0.86, respectively.

From this we can conclude that the ground-based PM10 measurements are best correlated to the averaged extinction of the whole scanning area when the traffic is low. When the traffic is high, then the PM10 measurements are dominated by vehicle exhausts from the vicinity of the measuring site and do not represent the averaged extinction of the whole scanning area so well any more, but the correlation to the localized extinction from an area with a circle with a radius R$\leq$300m directly above the ground-based measurement site, remains high.

The errors in the attached Fig. 1 and Fig. 2, as well as Fig. 8 in the original manuscript were obtained according to Eq. 2 using the slope method, where the parameters of the slope were obtained by fitting (see Fig. 4 in the original manuscript). The manuscript has been modified and additional explanations were added accordingly.

Comment#2 “p 6388 line 19. The introduction could expanded slightly, to include some of the many advances made in the scientific understanding alluded to in the opening line. Please also include a few references to recent research on the radiative and microphysical impact of particulate matter in the atmosphere; for example, the impact on clouds!”

Response: As suggested by the reviewer, the introduction was expanded in the modified manuscript. We added the sentence "Because of their absorbing and scattering properties, the presence of aerosol particles can directly and indirectly affect Earth’s radiation budget, as well as influences on cloud properties through a variety of different physical mechanisms (Li, 1998; Andreae et al., 2004; Che et al., 2005; IPCC, 2007)." The following references were added:

1. Li, Z.: Influence of absorbing aerosols on the inference of solar surface radiation budget and cloud absorption, J. Climate, 11, 5-17, 1998.

2. Andreae, M. O., Rosenfeld, D., Artaxo, P., Costa, A. A., Frank, G. P., Longo, K. M., and Silva-Dias, M. A. F.: Smoking Rain Clouds over the Amazon, Science, 303, 1337-1342, 2004.

3. Che, H. Z., Shi, G. Y., Zhang, X. Y., Arimoto, R., Zhao, J. Q., Xu, L., Wang, B., and Chen, Z. H.: Analysis of 40 years of solar radiation data from China, 1961-2000, Geophys. Res. Lett., 32, L06803, doi:10.1029/2004GL022322, 2005.

4. Intergovernmental Panel on Climate Change (IPCC): Climate Change 2007: in: The Scientific Basis, edited by: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., and Miller H. L., Cambridge Univ. Press, New York, USA, 2007.

Comment#3 “p 6389 line 10. Update references! Again, there is a huge amount of recent research on the use of lidars in this area.”

Response: As suggested by the reviewer, we updated the references regarding lidar techniques. We also mentioned satellite lidar for the study of aerosols and clouds. The following references were added:

1. Ansmann, A., Wandinger, U., Riebesell, M., Weitkamp, C., and Michaelis, W.: Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic backscatter lidar, Appl. Optics, 31, 7113-7131, 1992.

2. Bosenberg, J., et al.: EARLINET project: A European Aerosol Research Lidar Network, Max-Planck Institute (MPI), Final Report, 348, 1-250, 2003.

3. Muller, D., Ansmann, A., Mattis, I., Tesche, M., Wandinger, U., Althausen, D., and Pisani, G.: Aerosol-type-dependent lidar-ratio observed with Raman lidar, J. Geophys. Res., 112, D16202, doi:10.1029/2006JD008292, 2007.

4. Hair, J. W., Hostetler, C. A., Cook, A. L., Harper, D. B., Ferrare, R. A., Mack, T. L., Welch, W., Izquierdo, L. R., and Hovis, F. E.: Airborne High Spectral Resolution Lidar for profiling aerosol optical properties, Appl. Optics, 47, 6734-6752, 2008.

5. Winker, D. M., Hunt, W. H., and McGill, M. J.: Initial performance assessment of CALIOP, Geophys. Res. Lett., 34, L19803, doi:10.1029/2007GL030135, 2007.

6. Winker, D. M., Vaughan, M. A., Omar, A., Hu, Y., Powell, K. A., Liu, Z., Hunt, W. H., and Young, S. A.: Overview of the CALIPSO mission and CALIOP data processing algorithms, J. Atmos. Ocean. Tech., 26, 2310-2323, doi:10.1175/2009JTECHA1281, 2009.

7. Winker, D. M., Pelon, J., Coakley Jr., J. A., Ackerman, S. A., Charlson, R. J., Colarco, P. R., Flamant, P., Fu, Q., Hoff, R., Kittaka, C., Kubar, T. L., LeTreut, H., McCormick, M. P., Megie, G., Poole, L., Powell, K., Trepte, C., Vaughan, M. A., and Wielicki, B. A.: The CALIPSO Mission: A Global 3D View of Aerosols and Clouds, B. Am. Meteorol. Soc., 91, 1211-1229, 2010.

Comment#4 “p 6389 line 15. As an example, traditional micro-pulse lidars do provide high temporal resolution if required, certainly higher than the temporal resolution discussed here (150 shots gives a temporal resolution of 15 seconds per line-of-sight-profile). I agree that they have not yet been routinely used for scanning purposes though.”

Response: We changed the corresponding sentence into "Traditional micro pulse lidars (Spinhirne, 1993) are inexpensive and reliable, however, they do not provide scanning capability which is needed for the acquisition of two dimensional aerosol information."

Comment#5 “In section 2.1 you should complete the details of the lidar setup. For instance, where is full overlap of the laser beam and telescope achieved? Figure 4 suggests that full overlap does not occur until about 700-800 m. Is any attempt made to apply an overlap correction for data closer to the lidar? Or is this regarded as a blind

AMTD

4, C2915–C2926, 2012

zone for the instrument?”

Response: We included more details regarding the lidar setup and its “blind zone” in the modified manuscript. As implied in Fig. 4 of the original manuscript, the “blind zone” of our lidar system is around 700 m because of its bi-axial design. We fully agree with the reviewer that the overlap correction would provide close range data and improve the performance of the lidar, however, the exact value of the overlap factor for our lidar is not known, so the overlap correction was not performed in the present study and the return signal in the first few hundred meters was discarded.

Comment#6 “p 6392 equation 1. The character C is what is commonly used in the literature to represent the lidar system constant. This avoids any potential conflict with some authors choice of k for the lidar ratio (although S is preferred for the lidar ratio when in units of sr).”

Response: As proposed, we changed "k" into "C".

Comment#7 “p 6392 line 17. The range resolution is no longer really 3.75 m after such a smoothing. p 6392 line 22. What is the resolution of the Cartesian 2-D grid that the data is interpolated to?”

Response: The resolution of the Cartesian 2D grid is 5 m (the detectable range of 5 km was divided into 1000 pixels). The manuscript was modified to explain this.

Comment#8 “p 6393 equation 2. P_{bg} is not defined.”

Response: P_{bg} represents the background noise. Its definition was added in the modified manuscript.

Comment#9 “An additional assumption is that the lidar ratio is constant over the entire profile path (fig 4). Is this likely if you have localized point sources, and/or gradients in relative humidity (for RHIs)? I understand that it is difficult to account for the variability in the lidar ratio along an individual profile, but this should still be discussed as a potentially significant source of error, even in those cases which do not appear to show such

AMTD

4, C2915–C2926, 2012

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

variability. This would manifest itself as uncertainties in the derived lidar extinction."

Response: We fully agree with the reviewer that the variable lidar ratio could be a potential source of uncertainty of the extinction. Nevertheless, we expect a relatively constant lidar ratio when averaging over the entire horizontal scanning area at a specific height, with the exclusion of the traces with distinct point sources (apparently non-linear data). We understand that even in the remaining profiles the lidar ratio may not be constant and we mentioned this as a possible significant source of uncertainties in the modified manuscript.

Comment#10 "p 6398 line 21. Why necessarily constrain to zero, if other scatterers could be responsible for the residual (for example PM2.5 only), and you have no measurements above the surface to discern whether there has been particle growth?"

Response: We constrained the extinction to zero when PM10 concentration is zero on the basis of the assumption that aerosols with diameters up to 10 micrometers are the main scatterers (2.5 micrometer size particles are included in PM10). We also performed unconstrained linear fit for correlation plot in the attached Fig. 1 and the result is shown in the attached Fig. 3. For the constrained fit, the fitted line is described as $y_{\text{constrained}}$ = (0.002$\pm$0.00007)x and for the unconstrained fit as $y_{\text{unconstrained}}$ = (0.0022$\pm$0.0004)x+(-0.004$\pm$0.012), both fits yield the same correlation coefficient of 0.84. The constant term in the unconstrained fit is consistent with zero. We explain this in the modified manuscript.

Comments on technical and typographical corrections

p 6388 line 7. Suggest that you modify sentence to "Based on the data we collected.."

Response: We changed "Based on the collected data ..." into "Based on the data we collected ..."

p 3688 line 10. Suggest that it is probably safer to say "..., which are associated with the presence of point sources.."

AMTD

4, C2915–C2926, 2012

Interactive Comment

Response: We changed "..., which were found to be due to the presence of point sources.." into "..., which are associated with the presence of point sources.."

p 6391 line 12. Suggest that you modify sentence to “In this study, only the infrared channel was used, to minimize the amount of molecular scattering relative to particulate scattering”

Response: We changed "In this study only the infrared channel was used to minimize the amount of molecular scattering compared to scattering on particles." into "In this study, only the infrared channel was used, to minimize the amount of molecular scattering relative to particulate scattering."

p 6391 line 24. Suggest that you modify sentence to “a busy road”

Response: We changed "frequented road" into "busy road"

p 6397 line 3. Suggest that you modify sentence to “result in the appearance of prominent ..”

Response: We changed "..result in the appearance prominent.." into "..result in the appearance of prominent.."

p 6397 line 9-10. Suggest that you modify sentence to “In addition to the exhaust emissions, road dust picked up and injected into the boundary layer by vehicles may also be responsible for the concentration increase.”

Response: We changed "In addition to the exhaust emissions, an amount of road dust was pick-up and injected into the troposphere by vehicles may also be responsible for the concentration increase." into "In addition to the exhaust emissions, road dust picked up and injected into the boundary layer by vehicles may also be responsible for the concentration increase."

p 6397 line 15. “heating season”? Do you mean the “winter season”?

Response: We changed "heating season" into "winter season"

AMTD

4, C2915–C2926, 2012

Interactive Comment

Figs. 2 and 5. There is no mention of what is actually being plotted in these figures. There are no units for the colour scale axis. I assume this is just lidar signal and the units should be AU (arbitrary units), is it linear or logarithmic? Has the signal been range corrected?

Response: Fig. 2 and Fig 5 present the logarithm of the range-corrected lidar signal and the color code is in arbitrary units. We have added the units to the plots and the description of the plotted variables to the captions.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 6387, 2011.

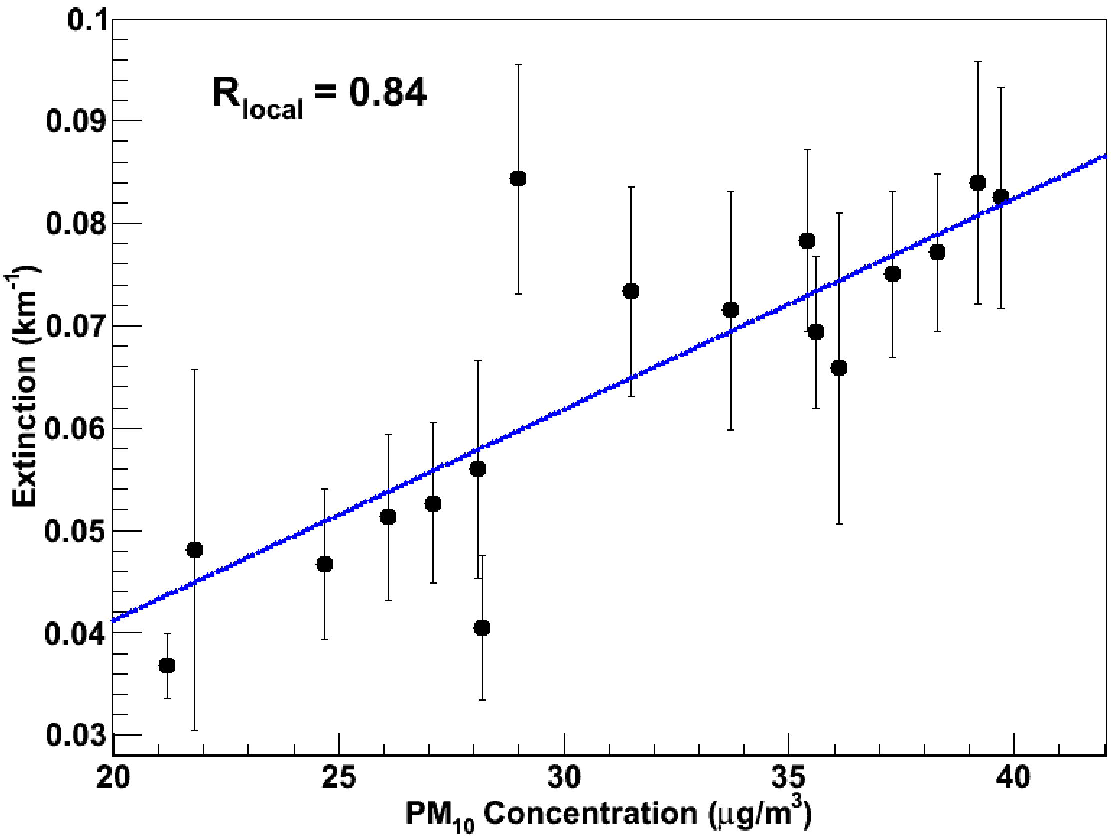

Fig. 1. The correlation between the lidar derived extinction and PM10 concentration. The extinction was obtained from a localized area with a radius R≤300 m directly above the PM10 measuring site.

AMTD
4, C2915–C2926, 2012

Interactive Comment

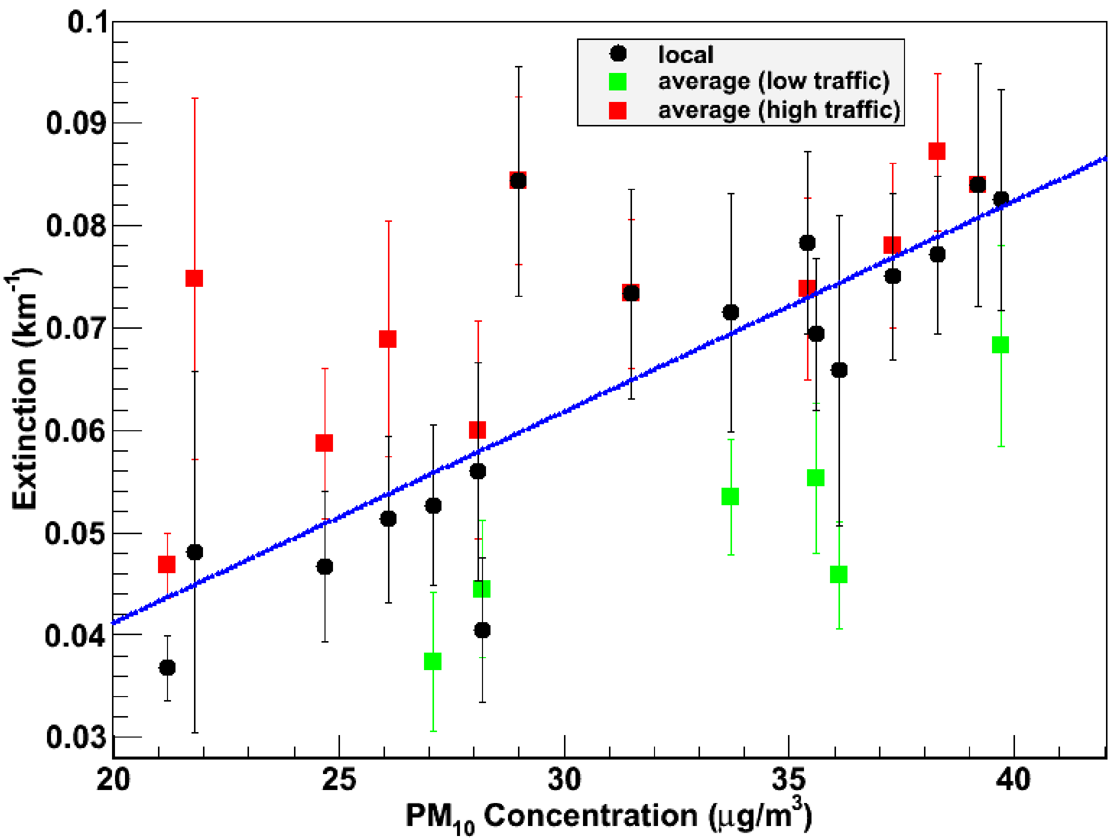

Fig. 2. Red points (correlation 0.72) represent the extinction values averaged over the entire scanning area for periods of high traffic and green points (correlation 0.86) for periods of low traffic.

AMTD

4, C2915–C2926, 2012

Interactive Comment

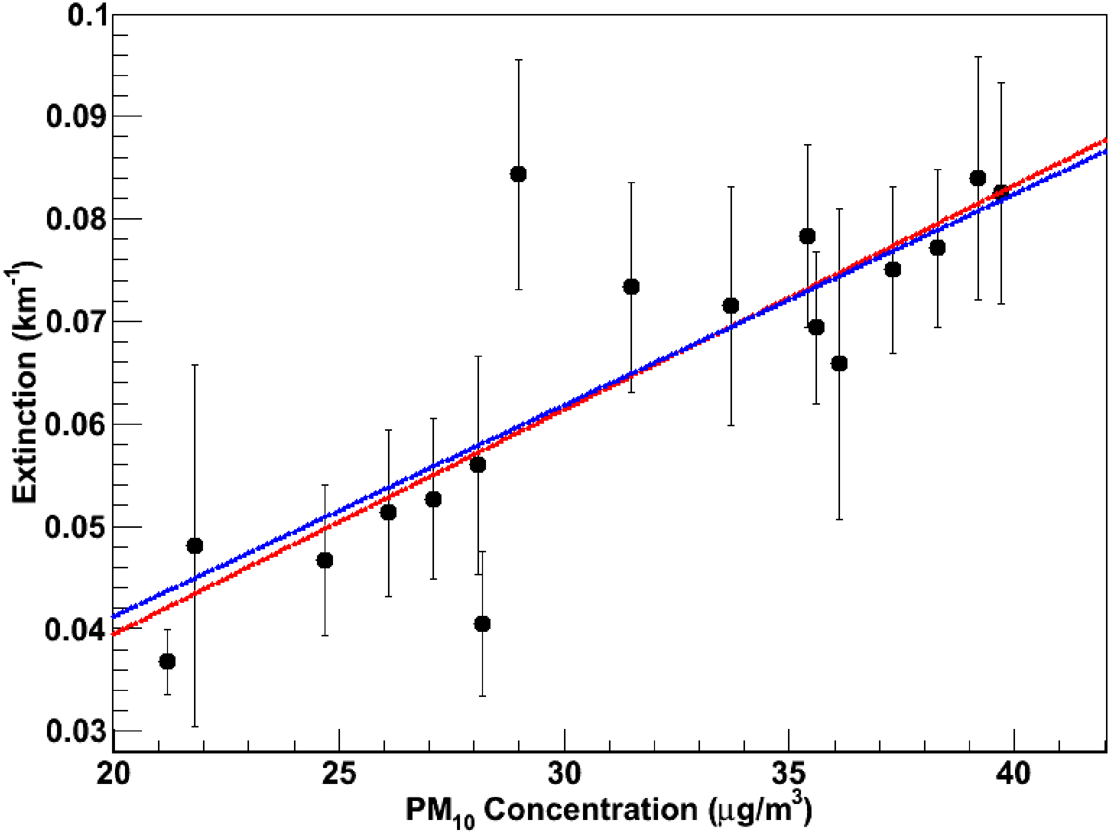

Fig. 3. In both constrained and unconstrained cases the correlation between the PM10 concentration and the extinction was found to be 0.84. The constant term in the unconstrained fit is consistent with zero.

AMTD

4, C2915–C2926, 2012

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper