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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.

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We are grateful to the reviewer for very useful comments to improve the manuscript. According with the advice, our answer is given below.

Comment#1 "Section 1: the description of lidar technique for aerosol study is not up to date. Authors should at least mention that there is a satellite with lidar on board specifically designed for aerosol and clouds study. In addition, it is well known that ground-based lidar measurements for aerosol study are today the state-of-the-art measurements for aerosol optical properties characterization. What authors reported instead is

not updated and too much focused on air quality/boundary layer. A short introduction of lidar for aerosol (in general) would be appropriate."

Response: As suggested by the reviewer, we expanded the introduction to include a short introduction on satellite lidar for the study of aerosols and clouds. We updated the references for the lidar techniques and presented lidar measurements of aerosol optical properties in general. We added the following references:

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

2. 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.

3. 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.

4. 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.

5. 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.

6. 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#2 "Section 4: Four examples of lidar applications are reported. For each one of these cases, results are not well commented. Even if AMT is more focused on technical and methodological topics, something should be added. In particular, 4.1: lines 23-25, how large is it the uncertainty for the extinction in this case? Here authors could quantify this uncertainty and avoid to anticipate results of section 4.4."

Response: As suggested by the reviewer, we provided more detailed explanations for the four cases presented in section 4 in the modified manuscript. In the case of section 4.1, the total relative uncertainty for the extinction was estimated to be less than 0.21 (see section 3) and the lines 23-25 have been modified into "The described turbulent atmospheric conditions due to changing structure of the lower troposphere were the main source of the horizontal aerosol extinction coefficient, as relative errors of the retrieved values increased from about 0.1 to about 0.15 (Fig. 7)". Please also see the attached Fig. 1.

Comment#3 "4.2: what happened on 24 May? There is any difference between these 2 days? (Figure 7 would suggest this)"

Response: The extinction values in Fig. 7 represent averaged horizontal aerosol extinction over the entire scanning area with the exclusion of the traces with distinct point sources (apparently non-linear data). For each scan, less than 10% of the traces were excluded from the average. The differences between 24 and 25 in Fig. 7 are only due to different weather conditions (presence / absence of low clouds, different wind conditions). Regarding horizontal scans on the 24 (Monday) and 25 (Tuesday), they revealed the same point sources A,B,C,D (of course at different times and not all of them on both days). We clarified this in the modified manuscript.

Comment#4 "4.3: what about the peak in NOx in the evening? The plateau in PM10 is reported as a maximum in the abstract."

Response: The presence of NOx local peak in the evening can be regarded as a regular event in Nova Gorica from long-baseline environmental monitoring data and can be related to human activities. As the ground-based measurements were performed

near a busy road, which is also close to the largest shopping center in this region, emissions from vehicles could result in elevated NOx concentration and are expected to be correlated to the working hours. The concentration decreases after 22:00 after the closure of the stores. We have clarified this in the modified manuscript and also changed the corresponding sentence in the abstract into "... and a plateau after around 17:00 Central European Time."

Comment#5 "Authors should better explain difference between Fig. 6 and 7. It is probably true that aerosol extinction measurements performed at 200m above the ground have in some sense more inertia and therefore reaction time is longer. But what about the sudden decrease on 14:30? (13:30 for 25 May) And what can authors tell about the second maximum observed on 25 May around 16 CET?"

Response: For the decrease that happened at 14:30 CET on May 24 and 13:30 CET on May 25, the possible explanations are provided in section 4.3: "In such a case, we expect the aerosol extinction decrease to be due, at least in part, to the increased water evaporation from hygroscopic aerosols (e.g. Lewandowski et al., 2010) during the daily temperature maximum (Fig. 3c). Another reason for the decrease could be that in this period the convection was the strongest. The resulting mixing of air-masses and the increase of the boundary layer height would decrease aerosol concentrations in the entire Nova Gorica basin, including at the lidar scanning height."

Regarding the second maximum observed on 25 May around 16:00 CET, it coincides with the decrease of the wind speed (Fig. 3a) and simultaneous decrease of the solar radiation. As a result, lower troposphere was relatively stable and the concentration of the accumulated aerosols in the basin-like terrain configuration increased. We have clarified this point in the modified manuscript.

Comment#6 "Surprisingly it seems to reflect NOx measurements more than PM10 ones. In addition, uncertainty on extinction on 24 and 25 May seems to be almost equal and not affected by the large uncertainty mentioned for 25 May on section 4.2."

Response: Actually, temporal evolution of lidar derived aerosol extinction coefficients better reflects the behavior of PM10 than NOx. It may be misleading to the reader that Figs. 6 and 7 are not drawn with the same time scale, therefore, we have attached Fig. 2 with the lidar measurement interval marks. We have replaced Fig. 6 in the manuscript with Fig. 2 in the attachment and modified the caption accordingly.

Section 4.2 deals with the identification of point sources, while the average horizontal aerosol extinction of the whole scanning area (with traces manifesting point sources excluded, see answer to comment#3) is being discussed in Sec. 3 and 4.1. The increase of the extinction coefficient uncertainty was found to be correlated to wind change (see answer to comment#3 and the attached Fig. 1).

Comment#7 "4.4: Are all points available reported in fig 8? There is a difference if 24 and 25 May cases are treated separately? The correlation of 0.64 is not so good. On the other hand, it cannot be good because of different temporal behavior observed in fig. 7 and 6. This would mean that actually lidar extinction measurements are not useful for the PM10 investigation, unless lidar measurements could be used for identifying special cases in which measurements at the ground level cannot be considered representative of a larger (in 2d space) area. For example, Figure 8 would suggest that a good correlation is observed for almost all values apart from 3-4 values with low extinction (in the graph points below the solid line). Authors could better investigate this point, even if of course 2 case studies are not enough for developing a method or providing assessed results."

Response: We thank the reviewer for his observation.

In the analysis presented in Sec. 4.4, which relates the extinction coefficient at the elevation 200 m averaged over the entire scanning area (with point sources excluded) to the ground-based point measurement the data for 24 and 25 May were treated separately and similar correlation values of about 0.6 were found for each day.

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 even for the entire 24-25 May data set (see the attached Fig. 3). In the attached Fig. 4, we show both the localized extinction data (same as in Fig. 3) 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). Both the red and the green subset of the whole dataset (over the entire scanning area) are separately highly correlated (with correlation coefficients 0.72 and 0.86, respectively) to the PM10 concentration, while the correlation fades when disregarding traffic conditions. We clarified this in the modified manuscript.

Additional minor comments: Page 6388 line 9: investigate ... an evidence? Please check the syntax of the phrase

Response: The sentence has been changed into "..., we investigated the flow dynamics and the aerosol concentrations within the lower troposphere and showed an evidence for daily aerosol cycles."

Page 6388 line 11: point or Punctual?

Response: The sentence now reads "... which are associated with the presence of point sources".

Page 6393 line 4: lidar ratio is not defined

Response: The expression has been changed into "... the extinction-to-backscatter ratio (so-called lidar ratio)."

Page 6394 line 26: maybe investigated is more suitable than performed.

Response: As proposed, we changed "performed" into "investigated".

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

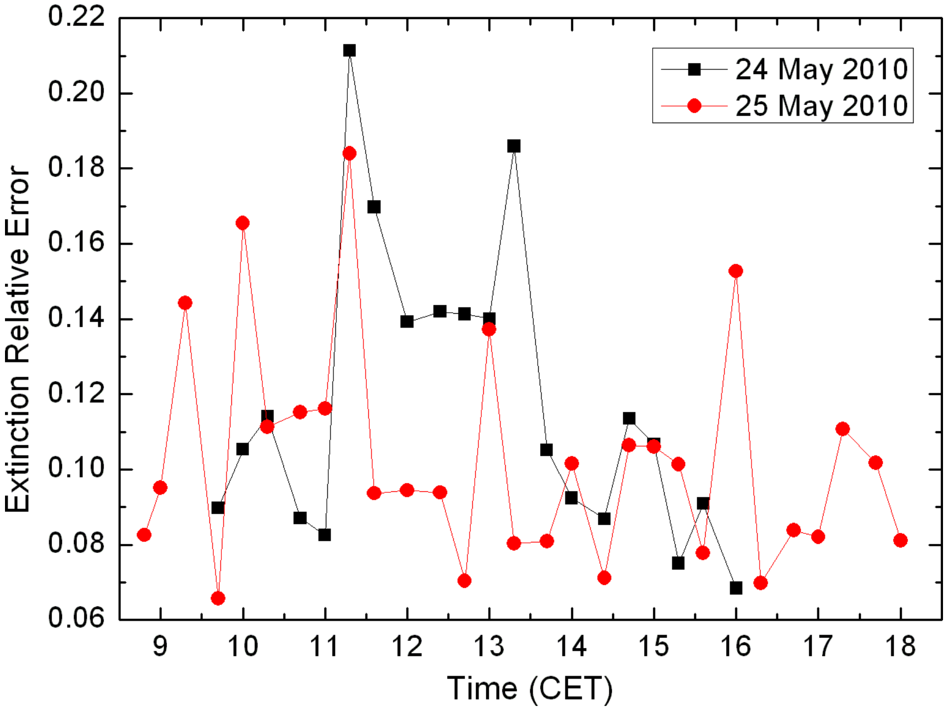

Fig. 1. Temporal evolution of relative errors of atmospheric extinction (averaged over the entire scanning area) 200m above the ground.

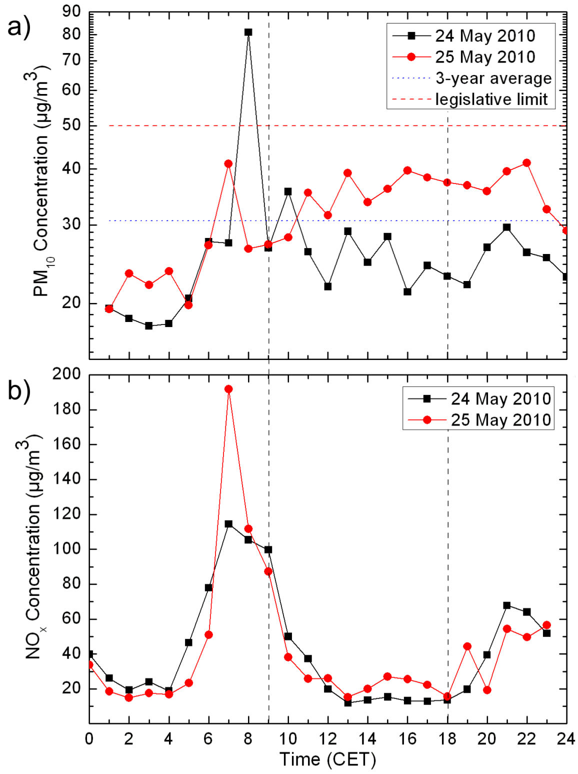

Fig. 2. Temporal evolution of PM10 and NOx concentrations. The intervals when lidar measurements are available are marked with vertical dashed lines.

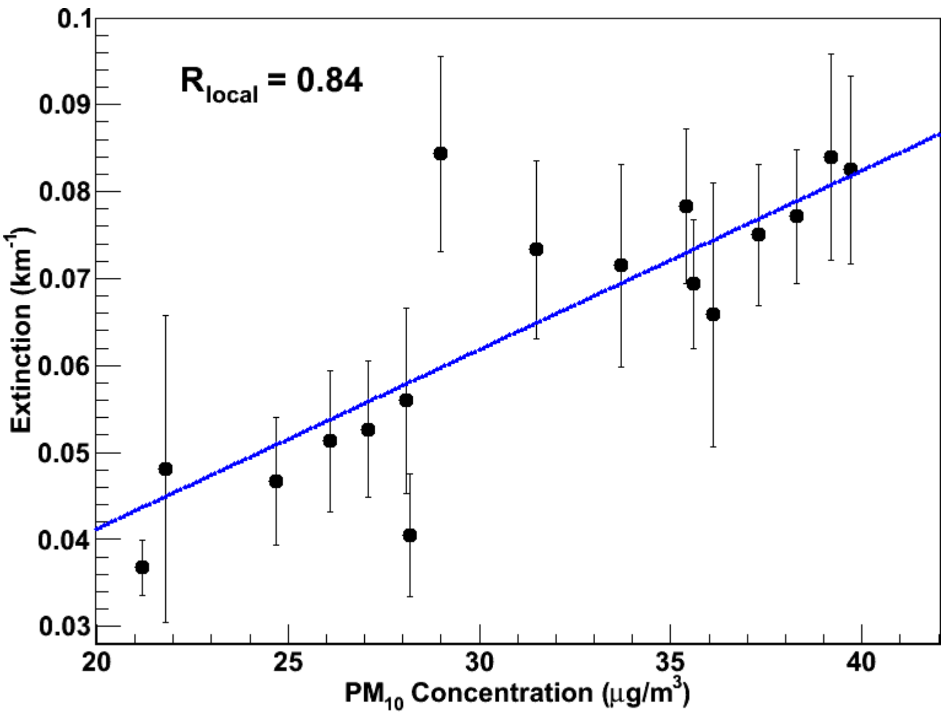

Fig. 3. The correlation between the lidar derived extinction and PM10 concentration. The extinction was obtained from a localized area with a radius R≤300m directly above the PM10 measuring site.

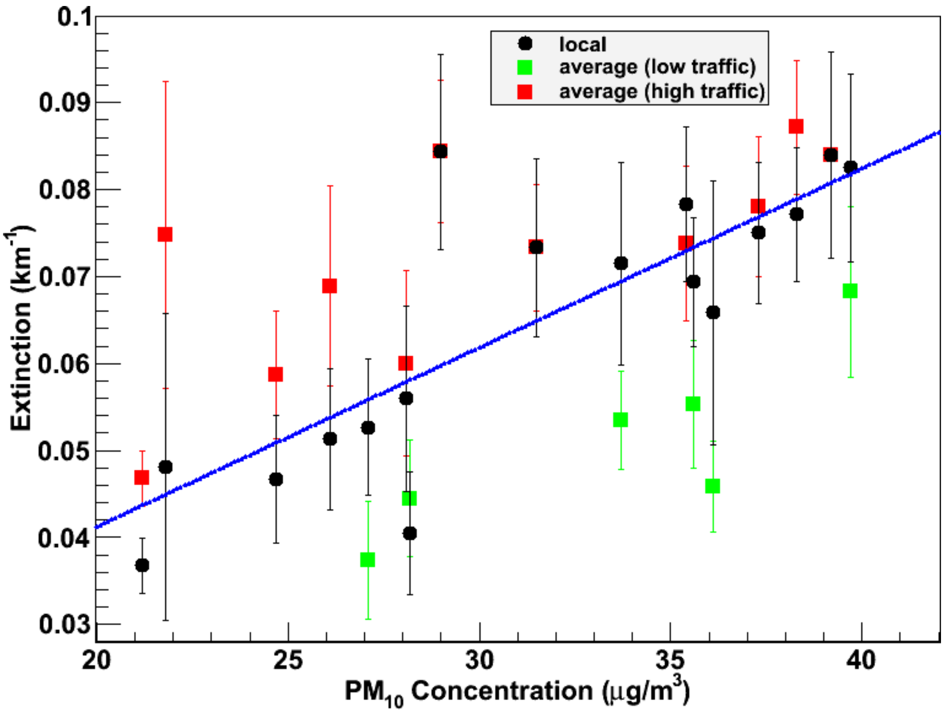

Fig. 4. Red points (correlation 0.72) represent the extinction values averaged over the entire scanning area for periods of high traffic and green points (correlation 0.86) for periods of low traffic.