Supplementary Material

Performance of microAethalometers: Real-world Field Intercomparisons from Multiple Mobile Measurement Campaigns in Different Atmospheric Environments

Honey Dawn C. Alas1*, Thomas Müller1, Kay Weinhold1, Sascha Pfeifer1, Kristina Glojek2, Asta Gregorič3,4, Griša Močnik3,5, Luka Drinovec3,5, Francesca Costabile6, Martina Ristorini7, and Alfred Wiedensohler1

1 Leibniz Institute for Tropospheric Research, Leipzig, Germany
2 Department of Geography, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia
3 Center for Atmospheric Research, University of Nova Gorica, Ajdovščina, Slovenia
4 Aerosol d.o.o., Kamniška 39 A, 1000 Ljubljana, Slovenia
5 Condensed Matter Physics Department, J. Stefan Institute, Ljubljana, Slovenia
6 Institute of Atmospheric Science and Climate, National Research Council, Rome, Italy
7 Department of Bioscience and Territory, University of Molise, Pesche, Italy

Table S1. Descriptive summary of the instruments used in this study.

| Instrument | Platform | Operating principle | Light source wavelength | Time resolution |
|------------|----------|---------------------|-------------------------|-----------------|
| AE51       | Mobile   | Attenuation of light by particle loaded filter | 880 nm | 10 s |
| MA200      | Mobile   | Attenuation of light by particle loaded filter | 375 nm, 470 nm, 528 nm, 625 nm, 880 nm | 10 s |
| MAAP       | Fixed    | Absorption of light by particle loaded filter. Multiangle absorption photometers allows for the use of the radiative transfer scheme to remove scattering effects | 637 nm | 60 s |
| AE33       | Fixed    | Attenuation of light by particle loaded filter | 370, 470, 520, 590, 660, 880 and 950 nm | 60 s |
Table S2. Summary of the IC periods for each route.

| IC locations | # of IC periods | Total IC period in minutes | # of filter changes |
|--------------|-----------------|----------------------------|---------------------|
| **Manila campaign** | | | |
| Katipunan Route (urban street) | 32 | 222 | 77 |
| (urban background) | 73 | 128 | |
| Taft Route | 86 | 383 | 34 |
| **Rome campaign** | | | |
| Rome city route | 41 | 1116 | 77 |
| **Loški Potok campaign** | | | |
| Village route (rural village) | 102 | 2287 | 107 |
| (rural background) | 107 | 1166 | |
Table S3. Regression results for all AE51 correlations

| Instrument | Study Area | IC Location | FLE Correction | Time of IC | Duration of IC | R² | Slope | Time base | N (no. of IC points) |
|------------|------------|-------------|----------------|------------|----------------|----|-------|-----------|---------------------|
| S5 vs S6   | Rome       | No          |                |            |                | 0.821 | 0.952 ± 0.003 | 10s                   | 38909               |
|            | Loski Potok| No          |                |            |                | 0.972 | 1.003 ± 0.001 | 10s                   | 27521               |
| S5 vs Reference | Manila |            |                |            |                | 0.367 | 0.879 ± 0.031 | 60s                   | 1420                |
|            | Rome       | No          |                |            |                | 0.985 | 1.017 ± 0.005 | 60s                   | 772                 |
|            | Loski Potok| No          |                |            |                | 0.985 | 0.808 ± 0.003 | 60s                   | 1390                |
| S6 vs Reference | Manila |            |                |            |                | 0.982 | 1.013 ± 0.004 | 60s                   | 1157                |
|            | Rome       | No          |                |            |                | 0.973 | 0.841 ± 0.003 | 60s                   | 3006                |
|            | Loski Potok| No          |                |            |                | 0.965 | 0.876 ± 0.005 | 60s                   | 2888                |
| AE51 vs Reference | Loski Potok | Rural background |            |            |                | 0.962 | 0.876 ± 0.005 | 60s                   | 2888                |
|            | Rome       | Urban background |            |            |                | 0.983 | 1.015 ± 0.003 | 60s                   | 1929                |
|            | Manila     | Urban background |            |            |                | 0.845 | 0.871 ± 0.013 | 60s                   | 815                 |
|            |            | Urban street |                |            |                | 0.545 | 1.55 ± 0.095  | 60s                   | 222                 |
|            |            | Urban street canyon |            |            |                | 0.318 | 0.746 ± 0.056 | 60s                   | 383                 |
| S5 vs Reference | Loski Potok | Rural background | No          |            |                | 0.965 | 0.876 ± 0.008 | 60s                   | 475                 |
|            |            |            | yes           |            |                | 0.962 | 0.916 ± 0.008 | 60s                   | 475                 |
|            | Rural village | No          |                |            |                | 0.986 | 0.806 ± 0.003 | 60s                   | 915                 |
|            |            | yes          |                |            |                | 0.999 | 0.951 ± 0.003 | 60s                   | 915                 |
| S6 vs Reference | Rural background | No          |                |            |                | 0.96 | 0.876 ± 0.006 | 60s                   | 1033                |
|            |            | yes          |                |            |                | 0.959 | 0.934 ± 0.006 | 60s                   | 1033                |
|            | Rural village | No          |                |            |                | 0.973 | 0.840 ± 0.003 | 60s                   | 1973                |
|            |            | yes          |                |            |                | 0.979 | 0.962 ± 0.003 | 60s                   | 1973                |

Table S3 continued.
| Instrument       | Study Area     | IC Location            | FLE Correction | Time of IC | Duration of IC | R²          | Slope          | Time base | N (no. of IC points) |
|------------------|----------------|------------------------|----------------|------------|----------------|-------------|----------------|------------|---------------------|
| AE51 vs Reference| Manila         | Urban background       | No             | NN         | 0.726          | 0.905 ± 0.031 | 60s           | 325        |                     |
|                  |                | Urban street           | No             |            | 0.409          | 1.518 ± 0.179 | 60s           | 105        |                     |
|                  |                | Urban street canyon    | No             |            | 0.389          | 0.841 ± 0.078  | 60s           | 184        |                     |
|                  |                | Urban background       | No             | PM         | 0.888          | 0.862 ± 0.014  | 60s           | 490        |                     |
|                  |                | Urban street           | No             |            | 0.709          | 1.573 ± 0.093  | 60s           | 117        |                     |
|                  |                | Urban street canyon    | No             |            | 0.249          | 0.647 ± 0.081  | 60s           | 199        |                     |
| Rome             | Urban background| No                     | AM             |            | 0.988          | 1.022 ± 0.005  | 60s           | 718        |                     |
|                  |                | No                     | NN             |            | 0.939          | 0.941 ± 0.009  | 60s           | 747        |                     |
|                  |                | No                     | PM             |            | 0.975          | 1.006 ± 0.009  | 60s           | 464        |                     |
| Loski Potok      | Rural background| Yes                    | AM             |            | 0.939          | 0.917 ± 0.010  | 60s           | 607        |                     |
|                  | Rural Village  | Yes                    |                 |            | 0.978          | 0.926 ± 0.004  | 60s           | 1202       |                     |
|                  | Rural background| Yes                   | NN             |            | 0.978          | 0.894 ± 0.007  | 60s           | 353        |                     |
|                  | Rural Village  | Yes                    |                 |            | 0.972          | 0.917 ± 0.006  | 60s           | 692        |                     |
|                  | Rural background| Yes                   | PM             |            | 0.954          | 0.975 ± 0.009  | 60s           | 549        |                     |
|                  | Rural Village  | Yes                    |                 |            | 0.989          | 0.976 ± 0.004  | 60s           | 994        |                     |
| S5 vs Reference  | No             | < 5 minutes            | 0.845          | 0.871 ± 0.013 | 60s           | 815         |                |            |                     |
|                  | Yes            | 10 minutes             | 0.962          | 0.916 ± 0.008 | 60s           | 475         |                |            |                     |
|                  | Yes            | 20 minutes             | 0.991          | 0.951 ± 0.003 | 60s           | 915         |                |            |                     |
|                  | No             | 30 minutes             | 0.985          | 1.017 ± 0.005 | 60s           | 772         |                |            |                     |
| S6 vs Reference  | No             | < 5 minutes            | NA             | NA         | NA             | NA          |                |            | NA                  |
|                  | Yes            | 10 minutes             | 0.959          | 0.934 ± 0.006 | 60s           | 1033        |                |            |                     |
|                  | Yes            | 20 minutes             | 0.979          | 0.962 ± 0.003 | 60s           | 1973        |                |            |                     |
|                  | No             | 30 minutes             | 0.982          | 1.013 ± 0.004 | 60s           | 1157        |                |            |                     |
| Instrument               | IC Location      | FLE Correction | Wavelength | R²     | Slope          | Time base | N(no. of IC points) |
|-------------------------|------------------|----------------|------------|--------|----------------|-----------|--------------------|
| MA200 75 vs 69          |                  | UV             | 0.876      | 1.083 ± 0.002 | 10s         | 27474                |
|                         |                  | Blue           | 0.574      | 1.121 ± 0.004 | 10s         |
|                         |                  | Green          | 0.917      | 1.059 ± 0.002 | 10s         |
|                         |                  | Red            | 0.929      | 1.051 ± 0.002 | 10s         |
|                         |                  | IR             | 0.935      | 1.034 ± 0.002 | 10s         |
| MA200_75 vs AE51_S5     |                  | IR             | 0.917      | 0.965 ± 0.002 | 10s         | 30236                |
| MA200_69 vs AE51_S6     |                  | IR             | 0.911      | 1.019 ± 0.001 | 10s         | 63495                |
| MA200_69 vs Reference   | Rural background | no             | UV         | 0.887  | 0.681 ± 0.008 | 60s       | 930                |
|                         | Rural background | yes            | UV         | 0.900  | 0.995 ± 0.001 | 60s       |
|                         | Rural village    | no             | UV         | 0.798  | 0.369 ± 0.005 | 60s       | 1825               |
|                         | Rural village    | yes            | UV         | 0.935  | 0.854 ± 0.008 | 60s       |
| Instrument                  | IC Location      | FLE Correction | Wavelength | R²   | Slope ± 0.008 | Time base | N(no. of IC) |
|-----------------------------|------------------|----------------|------------|------|---------------|-----------|--------------|
| MA200_75 vs Reference      | Rural background | no             | UV         | 0.947| 0.742 ± 0.008 | 60s       | 445          |
|                             |                  |                | Blue       | 0.957| 0.814 ± 0.008 | 60s       |              |
|                             |                  |                | Green      | 0.961| 0.881 ± 0.008 | 60s       |              |
|                             |                  |                | Red        | 0.963| 1.014 ± 0.010 | 60s       |              |
|                             |                  |                | IR         | 0.965| 1.013 ± 0.009 | 60s       |              |
|                             | Rural background | yes            | UV         | 0.941| 1.087 ± 0.013 | 60s       |              |
|                             |                  |                | Blue       | 0.957| 1.022 ± 0.010 | 60s       |              |
|                             |                  |                | Green      | 0.962| 1.044 ± 0.010 | 60s       |              |
|                             |                  |                | Red        | 0.964| 1.117 ± 0.010 | 60s       |              |
|                             |                  |                | IR         | 0.964| 1.076 ± 0.010 | 60s       |              |
|                             | Rural village    | no             | UV         | 0.828| 0.289 ± 0.005 | 60s       | 843          |
|                             |                  |                | Blue       | 0.876| 0.401 ± 0.005 | 60s       |              |
|                             |                  |                | Green      | 0.899| 0.471 ± 0.006 | 60s       |              |
|                             |                  |                | Red        | 0.925| 0.625 ± 0.006 | 60s       |              |
|                             |                  |                | IR         | 0.957| 0.743 ± 0.006 | 60s       |              |
|                             | Rural village    | yes            | UV         | 0.936| 0.782 ± 0.007 | 60s       |              |
|                             |                  |                | Blue       | 0.956| 0.821 ± 0.006 | 60s       |              |
|                             |                  |                | Green      | 0.963| 0.851 ± 0.006 | 60s       |              |
|                             |                  |                | Red        | 0.968| 0.924 ± 0.006 | 60s       |              |
|                             |                  |                | IR         | 0.978| 0.971 ± 0.006 | 60s       |              |
Assessment of FLE in Manila and Rome datasets

Here, the details of the BC(ATN) approach performed to assess the FLE for the Manila and Rome datasets are presented. For the other two approaches, the information is provided in the Methods section of the main manuscript. They require the same data preparation as below.

For the BC(ATN), the 1-s raw data from the AE51 was compiled and given IDs pertaining to each mobile measurement period (1 completion of the route = 1 “run”). As ATN should start at 0 when the new filter is inserted at the start of each run, we deducted the initial value for each run (ATN at t=0, ATN0) from the ATN values during the measurements: the corrected ATN (ATNcorr) was calculated as the difference between the ATN measured at the next point in time (ATNt=1) and ATN0. ATN does not start at 0 when the filter is inserted due to ununiform illumination of the sample and reference spots in the filter photometers. Then, the BC mass concentrations were binned according to ATNcorr with intervals of 1 ATN. The BC mass concentration (with mean and median concentration per bin) was then plotted as a function of the ATNcorr. To detect the loading effect, a linear fit of both the mean and median values of the BC mass concentrations was performed over whole ATN range. Another experiment was to fit the mean and median values over only a specific ATN range. Drinovec et al. (2015) did not include the lowest and largest ATN values in the fitting due to low frequency of BC measurements at those values. In this study, we fitted the BC(ATN) plots only for BC values below the 95th percentile of the ATN. If the fit featured a negative slope, and BC is decreasing with increasing ATN, we interpreted this as the presence of the loading effect, that is the dependence of BC on ATN rather than just on the change of ATN in time. Normally, the loading parameter to correct the AE51 raw concentrations can be derived from the slope and intercept of the regression line.
**Results of the FLE on AE51 data from Manila and Rome campaigns**

In this section, the loading effect on the AE51 measurements from the Manila and Rome campaign was investigated following three approaches presented in the manuscript. The prerequisites for applying the filter loading effect correction using a loading parameter derived from a single period of analysis are having sufficient measurement data points and homogenous sources of particles.

For the BC(ATN) approach, again, the whole datasets (not just the data points during the intercomparison (IC) period) were used for a complete loading effect assessment. The results are shown in Figure S1. The blue and red dots represent the median and mean eBC mass concentration per ATN bin, respectively, while the error bars represent the standard deviation.

To detect if there is a loading effect, a linear fit was performed over the whole ATN range and the ratio of the slope and the intercept represents the loading parameter $k$. If the slope of the fit is negative and its absolute value is greater than 0, then there is a loading effect.

However, Fig. S1 shows a positive slope which could be a statistical artifact (Drinovec et al., 2015).

![Figure S1](image.png)

*Figure S1* Binned raw measurements from the AE51 plotted against the attenuation (ATN) for a) Katipunan Route, b) Taft route, and c) Rome city route. Data were taken from the raw AE51 measurements (1-s resolution) from all the runs performed in each location (see Table S2), wherein a new filter was used for each run. The duration of a run is 1 hour for the Katipunan and Taft Route, and 2.5 hours for the Rome route. The blue and red dots represent the median and mean eBC mass concentration per bin, respectively, with the error bars as standard deviation. The solid lines are the linear fit for each statistic. The whole ATN range was used for linear fitting.
Hence, to determine an appropriate range of ATN for fitting, the frequency distribution of the number of measurements per ATN bin was plotted and are shown in Figure S2. From here, the ATN range for fitting was adjusted to include only everything below the 95th percentile of the ATN as the frequency of the measurement decreases towards higher ATN.

The BC(ATN) was plotted again, this time fitting within the range of ATN reflecting 0-95th percentile of the data (Figure S3). For the Taft and Rome routes, the slopes are still positive. Refitting with ATN range down to < 85th percentile still resulted to positive slopes (not shown). For the Katipunan route, fitting the median values for an ATN range covering up to 95th and up to 85th percentile of the data gave negative slopes which could indicate a loading effect. However, from these plots, it can be observed that the dependency of BC on ATN seem to be affected by the route itself.
Figure S3 Same as Fig. S1 but this time the fit was only done on the data below the 95th percentile.

This indicates that there are clearly different sources throughout the route, which means probably different aerosol compositions. According to Drinovec et al., 2015, when the frequency distribution is not unimodal, this is indicative of different periods or in this case “area types” which could mean different source compositions and should be analyzed separately. However, as can be observed from Fig. S2, the number of measurements per ATN bin are not enough to derive loading parameters that are dependent on specific parts of the route.

The results of the deviation (ATN) approach are shown in Fig. S4. Figures on the left panel are AE51/Ref ratios vs AE51_ATN and on the right panels are AE51-Ref vs. AE51_ATN. The plots for the Katipunan dataset show inconclusive results with negative slope for the ratio vs ATN and positive for the difference vs ATN. The Taft dataset, on the other hand, show negative slopes for both, indicating a possible FLE. However, it must be noted that the number of datapoints used for this analysis is quite low (222 for Katipunan, and 383 for Taft) with the IC periods of less than 5 minutes each. This is evident in the figures with ratios much greater than 1 and large differences. As mentioned in the manuscript, the IC periods occurred in the middle
of a run, hence, this analysis do not cover a uniform dataset over the whole ATN range. Deriving a loading parameter from this analysis would also be misleading as we do not expect that the loading parameter in one point in space would be representative of the rest of the route in inhomogeneous atmospheres. The loading parameter depends on the whole collected sample on the spot.

Figure S4 Scatter plots of the deviation between the AES1 and reference instruments expressed in ratios (left panels) and differences (right panels) for (a and b) the Katipunan (n = 222), (c and d) Taft (n = 383), and (e and f) Rome (n = 1116) datasets.
As a last attempt, a fixed $k$ value of 0.005 was used to correct the Manila and Rome datasets (as was done for the Loški Potok AE51 data). This value represents the loading effect of a diesel exhaust dominated atmosphere as well as from fresh ambient wood burning (Drinovec et al., 2017). The corrected eBC was then plotted against the uncorrected eBC and is show in Fig. S5. This shows that the correction did not change the eBC measurements substantially (6%, 8%, and 3% overall differences between corrected and uncorrected measurements for the Katipunan, Taft, and Rome routes, respectively). As a result, no filter-loading effect correction was applied on the Manila and Rome datasets. As for the Manila dataset, the discrepancy between the mobile AE51 and the reference instrument is due to the high variabilities of different factors (wind, sources, etc.) characteristic of an urban area.

![Figure S5 Correlation between the uncorrected and corrected (k = 0.005) eBC mass concentrations for the AE51 measurements along the a) Katipunan route, b) Taft route, and c) Rome route. The color of the dots represents the ATN. The red dashed line represents the 1:1 line, while the solid blue line represents the linear fit.]

References

Drinovec, L., Gregorič, A., Zotter, P., Wolf, R., Bruns, E.A., Prévôt, A.S.H., Petit, J.-E., Favez, O., Sciare, J., Arnold, I.J., Chakrabarty, R.K., Moosmüller, H., Filep, A. and Močnik, G. (2017). The filter-loading effect by ambient aerosols in filter absorption photometers depends on the coating of the sampled particles. Atmos. Meas. Tech. 10: 1043-1059, https://doi.org/10.5194/amt-8-1965-2015.

Drinovec, L., Močnik, G., Zotter, P., Prévôt, A.S.H., Ruckstuhl, C., Coz, E., Rupakheti, M., Sciare, J., Müller, T., Wiedensohler, A. and Hansen, A.D.A. (2015). The "dual-spot" aethalometer: An improved measurement of aerosol black carbon with real-time loading compensation. Atmos. Meas. Tech. 8: 1965-1979, https://doi.org/10.5194/amt-10-1043-2017.