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Quantile mapping based calibration for Particulate Matter Low-Cost Sensors

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Idea and concept

- Development and calibration of a low-cost particulate matter sensor ensemble (Fig.1 and Fig. 2) with respect to a reference device for use in mobile applications
- calibration performed using regression analysis and quantile mapping

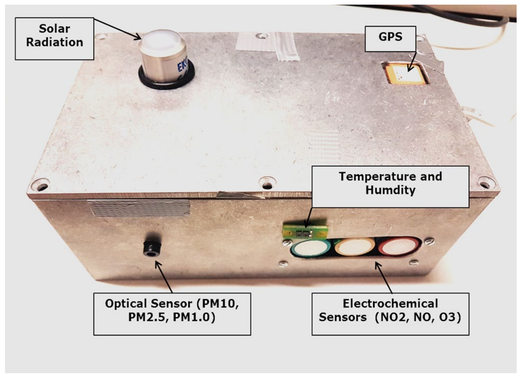

Fig. 1:URBMOBI 3.0 device for mobile air quality and meteorology with sensors for fine dust (OPC-N2), gases (NO2, NO, and O3), air temperature, and humidity (SHT35), and global radiation (EKO ML-01); Photo: Janani Venkatraman Jagatha.

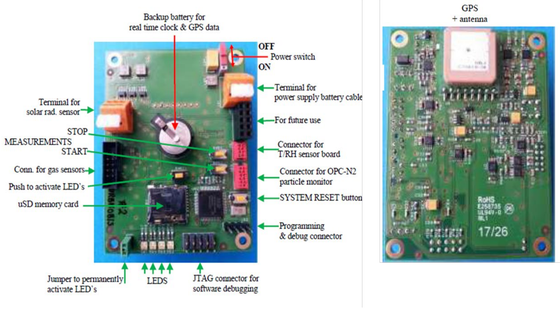

Fig. 2: Printed circuit board (PCB), bottom-side (left) and top-side (right), of the URBMOBI 3.0 sensor-box. Photo: Evert Nieuwkoop.

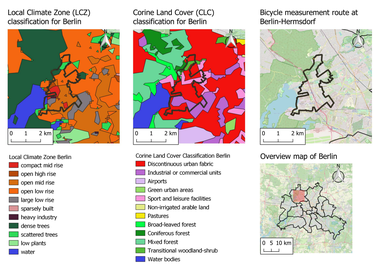

Fig. 3: Measurement route at Berlin-Hermsdorf across different local climate zones and land use classes.

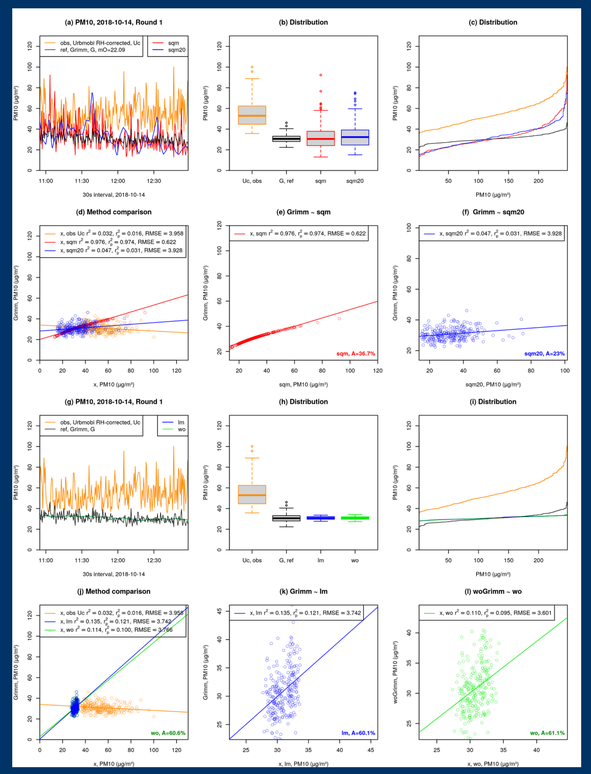

Fig. 6: Factsheet for PM10 calibration of URBMOBI 3.0 with GRIMM 1.109 as the reference; an example of a measurement round at Berlin-Hermsdorf. The UBRMOBI 3.0 data obtained after calibration using the quantile mapping method has an accuracy of 36.7% in this example

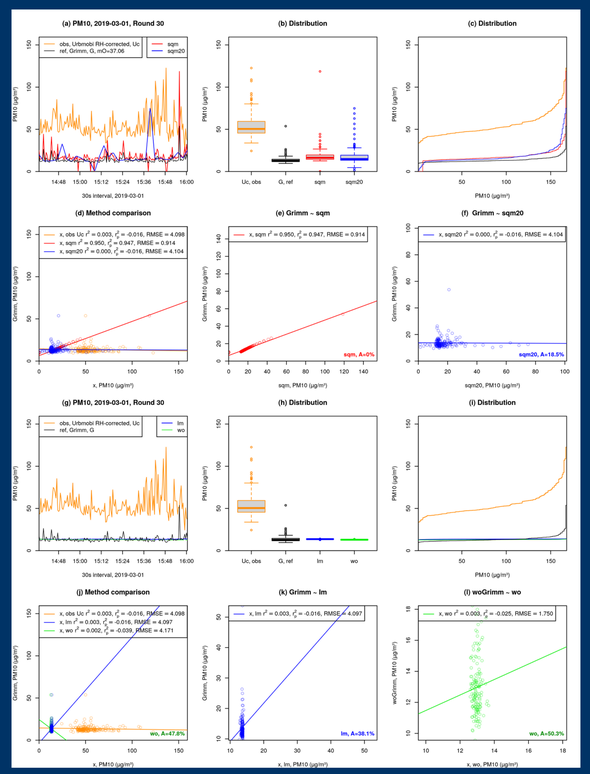

Fig. 7: Factsheet for PM10 calibration of URBMOBI 3.0 with GRIMM 1.109 as the reference; an example of a measurement round at Berlin-Hermsdorf. The UBRMOBI 3.0 data obtained after calibration using the quantile mapping method has an accuracy of 0% in this example

Key takeaways:

- Sensors perform well under stationary conditions (Fig. 4). However, laboratory or co-location experiments alone might be insufficient to determine the accuracy of measured values and the reliability and characteristics of the sensors
- it is important to not only assess mobile data with respect to its statistics but also to check the time series in order to account for possible impacts of spatial characteristics
- Predicted R-square provides a better estimate of the performance when it comes to low-cost-sensors since R-square tends to over fit
- Quantile mapping is significantly better than all other correction models for all three pollutants, PM10, PM2.5 and PM1 (Fig. 5)
- Although quantile mapping seems to be a good option for calibrating LCS on a mobile platform, it does not work similarly for all the measurement rounds (Fig. 6 and Fig. 7).

Publication

Venkatraman Jagatha, J.; Klausnitzer, A.; Chacón-Mateos, M.; Laquai, B.; Nieuwkoop, E.; van der Mark, P.; Vogt, U.; Schneider, C. (2021) Calibration Method for Particulate Matter Low-Cost Sensors Used in Ambient Air Quality Monitoring and Research. Sensors 2021, 21, 3960. https://doi.org/10.3390/s21123960

Methods

- calibration of sensor ensemble in a stationary setup under laboratory (using particle dispenser) and field conditions
- calibration of sensor ensemble in a mobile setup using a bicycle on a predetermined route across various local-climate-zones and land-use-classes (Fig. 3).
- Quantile mapping using 20% of the data to calibrate 80% of the data.
- Relative humidity correction based on Köhler's theory

Results

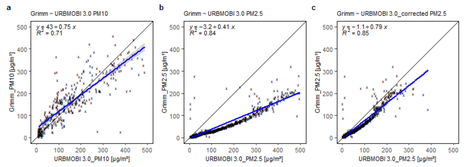

Fig. 4: Results of the calibration tests recorded by the URBMOBI 3.0 and the reference instrument (Grimm 1.108) inside the particle generator with a time integral of 6 s; (a) PM10 scatter plot between Grimm 1.108 raw data and URBMOBI 3.0; (b) PM2.5 scatter plot between Grimm 1.108 and URBMOBI 3.0 raw data; (c) PM2.5 scatter plot between Grimm 1.108 raw data and URBMOBI 3.0 data corrected using the compensation function.

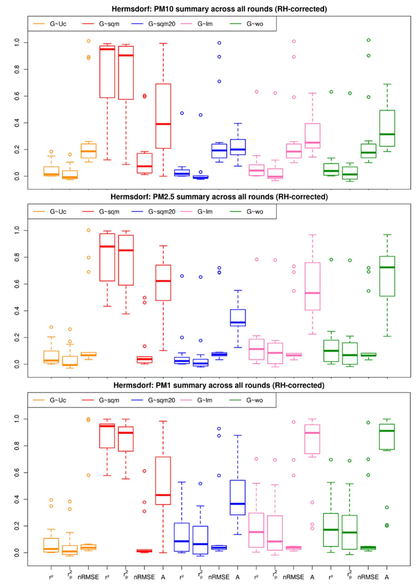

Fig. 5: Summary of different correction methods, namely coefficients of determination (r^2), the predicted coefficient of determination (r2p), and the normalized mean square of deviation (nRMSE) for RH corrected PM10, PM2.5 and PM1, for the measurement campaign in Berlin-Hermsdorf. The Accuracy (A) is also provided for the correlations between the Grimm 1.109 and URMBOBI 3.0 raw data (G~Uc), Grimm 1.109 and URBMOBI 3.0 corrected data using quantile method with 100% data (G~sqm), Grimm 1.109 vs. URBMOBI 3.0 corrected using quantile ethod with 20% data (G~sqm20), Grimm vs. URBMOBI 3.0 corrected with linear regression (G~lm), and Grimm 1.109 and URBMOBI 3.0 with all outliers removed (G~wo).