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Performance of NO/NO_2 low cost sensors and of three calibration algorithms within a long-term real-world application

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Networks of low cost sensors provide a promising answer to the rising demand for air quality spatial information in urban areas. However these devices still face problems of calibration (Spinelle et al., 2013), stability (Fonollosa et al., 2016), cross-sensitivity (Mead et al., 2013) and low reproducibility (Rai et al., 2017), with calibration being one of the major unsolved issues and urging for more research (Lewis et al., 2016). A common calibration approach is the field co-location next to a regulatory instrument, which however introduces uncertainty in the generalisability of this type of models, because of the limited and site-specific range in environmental conditions during the calibration period. This holds even more true when the subsequent measurements are performed at a different site, a realistic occurrence which lacks of in-depth investigations in the literature.

Four sensor units (SUs) using low cost electrochemical sensors (EC) were tested. The exercise mimicked a realistic application of these instruments and consisted in field-calibrating the units at a rural reference site for 3 months, and subsequently deploying them for 4 months at two distant urban reference sites, in Switzerland. This relocation procedure possibly involved additional errors due to the differences in pollution levels, in emissions and in environmental conditions between the calibration and the deployment site/period.

Within this framework the performance at the relocation sites of three state-of-the-art algorithms were tested: Multivariate Linear Regression (MLR), Support Vector Regression (SVR) and Random Forest (RF). Each unit hosted 2 EC sensors for each monitored pollutants (NO and NO_2), resulting in several possible combinations of regressors. For all three algorithms the model using all 4 EC sensors performed best and was used throughout the analysis.

For each SU and for each algorithm, the performance and its variation over time was estimated according to several goodness-of-fit metrics. RF and SVR outperformed MLR, with a mean RMSE of ~5.0 ppb (4.0 ppb) and a mean R^2 of 0.90 (0.83) for NO (NO_2).

The influence of each algorithm on the estimate and on the selectivity of each SU was compared by the means of its partial plots: these showed a linear response by each EC towards its target gas, along with a minor contribution by the non-target EC sensor (e.g. by NO sensor to NO_2 estimate), indicating problems with selectivity either by the algorithm or by the EC itself. RMSE trend was steady in time, with variations between 0.5 – 2.0 ppb. Drift was largest for MLR (up to 15 ppb) and as low as 1 ppb for some RF instances. The resolution achieved by the devices was estimated using two different procedures, providing comparable outcomes: best results obtained by one SU using RF indicate a resolution of ~15 ppb for both NO and NO_2, with an uncertainty of 25%.

References

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