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Atmospheric Measurement Techniques Discussions

Interactive comment on "Performance of NO, NO_2 low cost sensors and three calibration approaches within a real world application" *by* Alessandro Bigi et al.

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The introduction suggests that improved control of regulatory monitoring networks has resulted in "...occasionally more efficient..." measurements. This is subjective, inflammatory and untrue, at least in the EU, where significant improvements in data quality over the last 30 years are directly attributable to improvements in regulation and QA/QC. Increased spatial density of measurements is not a requirement of the Directive, assessment of maximum exposure is. This needs to be reconsidered.

The sentence was not meant to raise gratuitous disagreement and we recognize that

is potentially misleading. We rephrased it as the following "The costs associated to these monitoring sites lead to a reconfiguration of regulatory air quality networks across Europe over the last decade, resulting in improved but still spatially sparse regulatory air quality networks over the continent." (page 2 in the enclosed latexdiff manuscript).

The behaviour of the sensors to rapid transients in meteorology needs to be considered. It is well known (Alphasense technical guidance, for example) that the EC sensors they supply are extremely sensitive to rapid changes in RH, which can change the processing required to produce concentration datasets. This does not appear to have been specifically considered in the paper.

Transients in meteorology were not included in the models employed in this study. Transient changes in relative humidity were shown to have an impact on the measurements of EC sensors (Alphasense Application Note 110, Mueller et al. 2017, Pang et al., 2017). The EC sensors used in our study were operated in ambient conditions with changing relative humidity and temperature. It is possible that a dedicated formulation of transient humidity effects in the models would have led to slightly better results. Nevertheless, we prefer to let the models unchanged. Humidity transients and their effect are now mentioned in the enclosed latexdiff manuscript (page 9).

Additionally, while the B43F has been specifically designed with a screen to minimise the effect of ozone interference, there's little data available to confirm that this is effective long term. Were any tests conducted after the campaign to assess the effectiveness of the screen after 8 months in use?

No lab tests have been performed. In fact, the sensors are still deployed in the field, so their behavior on the longer-term will be evaluated in future work. Lab and field tests of the predecessor sensor model B42F (also equipped with an ozone screen) showed that this screen worked well and the capacity was as stated by the manufacturer. We therefore do not think that changes in the effectiveness of the ozone screen has a relevant influence on the temporal development of the data quality of the sensors.

Long term drift of the sensors before application of training is an important question. There's very little data available, or recommendations from manufacturers about sensor shelf life or maximum number of hours a sensor should be used. Some of this seems to be apparent in e.g. Figure 8?

We agree that the maximum number of hours a sensor can be operated is useful information. Electrochemical sensors may exhibit a zero drift as well as a change in sensitivity over time (e.g. Alphasense specifications). We used the daily residuals as a proxy for the overall drift of the instrument and we highlighted the occurrence of a drift in daily residuals in the original manuscript (line 18, page 10 original manuscript and Figure 8 original manuscript). We found that the sensors are not stable over time. Maximum operation time depends on the accuracy requirements of an application, the operation conditions a sensor encounters and the options for improving sensor measurements while the sensor is employed in the field. Based on this study, we cannot indicate numbers having a general validity, although we reported the performance from the devices used (page 11 enclosed latexdiff manuscript).

It was not obvious to me what frequency the electrode outputs were interrogated for the creation of 1 minute, 10 minute and hourly data. Could this be reported?

EC sensors of this sensor unit sample every 20 seconds. Three such values are averaged by the sensor unit to form a 1 minute value. These 1 minute values are transmitted to a central database every 180 minutes. Further averaging to 10 minute and hourly values is performed based on the values in the database. This information is now included in the enclosed latexdiff manuscript (page 4).

Was there any laboratory testing of the sensors (apart from the manufacturing data provided by the supplier)?

Laboratory testing for this class of sensor units had been performed previously to this study using the predecessor sensor type (B42F). Main results of these tests were presented in Mueller et al. (2017).

I assume in equations (1), (2) etc, where you define the models to calculate concentrations, that the factors are unique to each sensor? E.g in equation (1), do the variables beta0 to beta5, plus epsilon have different values in both the NO and NO2 equations?

Yes, for all equations the parameters were estimated specifically for each gas and each sensor unit, using the calibration dataset collected in Haerkingen from April 2017 through July 2017.

In section 2.1 you talk about the use of a small blower to bring sample air to the sensors. Do you measure the flow of air at all times? The effective diffusion length of the EC sensors will be affected by this flow of air, if it fluctuates, you may well see changes in performance characteristics.

The blower is operated for 7 seconds every 20 seconds. Air flow is not measured.

In section 3.1, third paragraph, you start a sentence "Whether this shortage in generalisation occurred over a spatial scale or not...", but it doesn't end as a proper sentence.

In the revised manuscript the sentence was reworded accordingly: "The SU performance at LAU and ZUE (paragraph 3.2) allows the evaluation of the effect of relocation of the sensors on the data quality, since the two sites are representing urban air pollution situations that are different from the site where the collocated measurements have been performed (HAE), see Table S1 and Figures S1, S2 and S3)." (page 10, line 2 in the enclosed latexdiff manuscript).

The Uncertainty plots for Figure 9 are illuminating. The Directive requirement is to report measurement uncertainty "in the region of the Limit Value", so for NO2 this would be at 21ppb (annual LV) and 104.6ppb (hourly LV), using the calculation methodologies described in EN14211:2012 It would be very interesting to overlay the measurement uncertainties for the reference methods used in

Switzerland on top of Figure 9 for comparison. I'm sure Christoph will be able to provide this!

Expanded uncertainty for reference NO2 are available from the 2016 Technical Report for the Swiss Federal Network of Air Pollution Monitoring (EMPA, 2016). These data are included in the text, in Figure 11 of the enclosed latexdiff manuscript and Figure S26 of the revised Supplementary Information (not enclosed).

References:

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EMPA: Technical report for the national monitoring network of atmospheric pollutants (NABEL), 2016 (in German), Tech. rep., EMPA, 2016

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2018-26/amt-2018-26-AC2-supplement.pdf

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