Low-cost sensors for CO_2 monitoring: calibration, characterization and assessment

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The Swiss project Carbosense proposes a uniquely dense CO_2 low power sensor network combined with atmospheric transport models. It relies on three levels of CO_2 measurements: (i) 300 nodes of battery-powered CO_2 low-cost diffusive NDIR sensors (SenseAir LP8), (ii) 30 temperature stabilized, mains-powered NDIR sensors with active sampling and zero-air connection (SenseAir HPP [1]), and (iii) high-precision laser spectrometers (Picarro G1301/G2401, CRDS) as reference instruments. The sensors will be distributed nationwide, mainly at Swisscom radio transmitter locations and at MeteoSwiss meteorological stations. All LP8 and HPP data is transmitted as 10 minute averages through Swisscom's new Low Power Network (LPN).

Over 300 LP8 CO_2 sensors have been integrated with relative humidity and temperature measurements and with LoRaWAN communication [2]. All sensors were characterized with respect to carbon dioxide (350 – 1000 ppm), temperature (-5 to 50 °C) and pressure (770 – 1010 hPa). A calibration model was developed based on the Beer-Lambert law, and relating the raw signal of the IR detector to the true CO_2 mixing ratio, determined by CRDS, and referenced to the NOAA scale.

The impact of temperature and pressure variations on the IR detector signal is modelled by including polynomial correction terms in the calibration model. Largest IR signal changes are related to temperature variations. Pressure effects are slightly higher than expected for an ideal gas due to factors such as absorption line characteristics and sensor design [3]. Relative humidity becomes a critical issue above ca. 95%, likely because of local condensation.

Before network deployment, all 300 sensors were placed next to a Picarro instrument for several weeks. To account for a wide range of operating conditions, these deployments took place at the rural site Dübendorf (432 m a.s.l.) and the mountain site Rigi (1031 m a.s.l.).

Two HPP sensors were also characterized with respect to pressure (770 to 1010 hPa) and CO_2 (450 to 900 ppm) and operated in the field next to a reference instrument for several months. Pressure, correction was based on measurements of integrated sensors, and zero drift was measured by pumping CO_2 free air into the instrument at regular intervals.

This paper presents findings obtained from the extensive CO_2 sensor data set. These include the accuracy of the LP8 and HPP sensors, variability in performance between sensors, long-term sensor behaviour, power consumption and reliability of the data transmission. Furthermore, we discuss operational aspects such as deployment strategies, quality assurance, model based drift correction and assessment of the long-term data quality.

References

[1] Hummelgard, C. et al., Low-cost NDIR based sensor platform for sub-ppm gas detection (2015) Urban Climate, 14, pp. 342-350.

[2] https://www.lora-alliance.org/

[3] Gaynullin, B. et al., A practical solution for accurate studies of NDIR gas sensor pressure dependence. Lab test bench, software and calculation algorithm (2017) Proceedings of IEEE Sensors, art. no. 7808828.