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Array of Things: Evaluating a network of low-cost air quality sensors

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The Array of Things (AoT) is a collaborative effort among leading scientists, universities, local government, and communities in Chicago to collect real-time data on the city's environment, infrastructure, and activity for research and public use. The AoT is an urban-scale "instrument" that will enable the City, urban planners, residents, and researchers to monitor and examine Chicago's environment, infrastructure and activity, including detecting trends and changes over time. Ultimately, the goal is to measure the city in sufficient detail to provide data to help engineers, scientists, policymakers and residents work together to make Chicago and other cities healthier, more livable and more efficient. A key component of an AoT node is the air quality board (ChemSense) with surface chemistry sensors that measure carbon monoxide, hydrogen sulphide, nitrogen dioxide, ozone and sulfur dioxide. These measurements will link human activities (for example, traffic counts) with human health and are therefore critical for achieving the AoT goal. But low-cost sensors have many limitations compared to instruments that use Federal Reference Methods (FRM) to measure air pollutants. Ultimately, the AoT air quality data will be assessed holistically, but the first step is to compare AoT results to FRM measurements.

The chemical sensors are calibrated by the manufacturer and shipped for installation in the AOT module. To test the performance of these sensors after placing them in an AOT node, a collocation experiment was designed. We are currently conducting this study to evaluate the performance of these low-cost gas sensors with reference grade systems operated by the EPA. The collocation site is operated by Cook County on behalf of the US EPA for air quality standards conformance in the county. There are three gases measured by Chemsense that are also monitored by the EPA instruments: ozone, NO2 and SO2. The SO2 levels measured at the site are relatively low and often below the detection limit of the Chemsense SO2 sensor. As a result, we have focused our attention on understanding ozone and NO2. There is considerable cross sensitivity between the ozone and NO2 sensors. Three types of error were considered: random, systematic and spikes for evaluation with the reference instruments. For NO2 and ozone, the random error is larger than the reference sensor, but the results are encouraging ($r2 > 0.65$). There was some systematic error in the zero (residual from Chemsense compared to EPA data) that might be related to either sensor drift or temperature, but the level was relatively low and should be amenable to analysis with spatial techniques across the Array. We are continuing the analysis of spikes in the NO2 signal that were not detected by the EPA reference sensor and were not related to temperature or absolute humidity. Overall, the results are very encouraging and demonstrate that the Chemsense boards produce data that can be applied to city-wide urban air quality science questions.