Siting Monitors for use in Land Use Regression Modelling

Matthew Adams, University of Toronto Mississauga

Land use regression (LUR) modelling associates measured pollution levels to land cover characteristics for spatial interpolation. LUR is commonly applied in the domain of air pollution and less commonly for noise, soil and water pollution. Model outputs can be applied to estimate human or environmental exposure. The model's predictor variables include land use attributes, such as land cover and transportation network characteristics that are calculated within spatial buffers of the monitoring locations. LUR models can be used to predict values at unobserved locations.

The application of spatial interpolation attempts to ensure that data are not extrapolated beyond the bounds of the observed values. However, our research identifies that without guaranteeing monitoring data be collected in all land use classes and conditions, it is possible with LUR to actually be extrapolating data and still be within the 2-dimensional spatial boundaries of the monitoring locations. This potential extrapolation occurs because the interpolation is based on a multi-dimensional space that sits upon the 2-D plane, which creates a new set of boundaries for the interpolation.

In this paper, we define and demonstrate the potential problem of ensuring LUR models interpolate within both the 2-D spatial domain and the multi-dimensional space that is applied in LUR modelling. We then demonstrate a solution to this problem in a simulated dataset and in an empirical dataset. First, we identify all possible monitoring locations. Second, the objective function is defined with the goal of selecting monitoring locations to maximize the variation across land use conditions. A heuristic search technique is applied to identify good potential solutions. The location of monitors is identified using an ensemble of potential optimum solutions.

Additional Authors:

Piloting the use of air monitoring in STEM internships to develop models for regional dissemination

Leslie Allsopp, University of North Texas Health Science Center School of Public Health

A consortium of community partners, municipalities, and universities in North Texas are working to bring spatiotemporally refined air monitoring to our region. The consortium is in communication with five K-12 school districts and the community college system to support student and community engagement with the initiative while promoting STEM, health, and environmental science. To build capacity and introduce educational applications of lower cost air monitors, two, 120 hour internships will be held during the summer of 2018. One internship will focus on environmental health and engineering including: 1) building hand held particle monitors, 2) calibrating hand-held monitors with estimates of uncertainty, 3) completing a preliminary assessment of ambient and indoor air quality. The second internship will focus on data visualization and communication including: 1) identifying challenges and opportunities in dissemination and communication of environmental data, 2) coding to design data visualizations for communication of particle data, 3) proposing a health initiative that utilizes

applications built during the internship. Both internships will focus on the connection between human health and the built environment and interpretation of environmental data. The internships will serve to pilot the use of spatiotemporally refined air monitoring in project-based STEM, to build capacity for dissemination to K-12 and community college partners across the region.

Additional Authors:

Miniaturizing particle sizing instruments for planned atmospheric studies: The Caltech-ADI Scanning Electrical Mobility Spectrometer

Stavros Amanatidis, California Institute of Technology

In this study, we present the Caltech-ADI Scanning Electrical Mobility Spectrometer (SEMS), a highly portable particle sizer designed primarily for planned atmospheric studies. The instrument combines a novel, compact, radial-flow Differential Mobility Analyzer (DMA) developed at Caltech, and a self-sustaining, motion-tolerant, water-based condensation particle counter (WCPC) designed by Aerosol Dynamics Inc. The system operates at low flowrates (0.6â€“1.2 L/min, and 0.3 L/min for sheath and aerosol flows, respectively), and provides particle sizing in the 10â€“500 nm range with resolving power on the order of 2â€“4; these operating parameters are sufficient to attain the precision and counting statistics required for atmospheric measurements.

The low flows in this instrument reduce the volume, weight, pumping, and power requirements (<5kg, <50W) below those of traditional SMPS systems. Here, we present the key design features of the classifier that enable size distributions to be measured in as little as 10s in order to enable good spatial resolution in Unmanned Aerial Vehicle (UAV) measurements of atmospheric aerosol properties. To demonstrate the viability of the low flow rate measurements and fast scans, we compare the Caltech-ADI SEMS to a benchtop Scanning Mobility Particle Sizer (SMPS) in measuring ambient aerosol particle size distributions.

Additional Authors:

Performance evaluation of low-cost sensors for the benzene and other Volatile Organic Compound in ambient air within the Key VOCs project.

Maurizio Barbiere, Joint Research Centre

Among other objectives, the Key-VOC project aimed at validating new sensor-based measurement systems in support of the air monitoring networks and the European Union regulations. This project was focused on the evaluation of sensors for volatile organic compounds (VOCs) and in particular BTEX (Benzene, Toluene, Ethylbenzene and Xylene). Different technologies were tested: a simple Metal Oxide (MOx) and a multi Metal Oxide (MOx) semiconductor gas sensor operated in Temperature Operation Cycle (TCO); a PID and a PID coupled with a miniaturized-Gas Chromatography (mini-GC) and electrochemical sensors. Final goal of the project was to assess if the currently available technology was able to meet the data quality objective (30% of uncertainty at 1.54ppb, the European limit value), for indicative measurement. All sensors were linear with a high scattering and a low precision. The MOx, the

electrochemical, the MOx-TCO and the mini-GC showed a Limit Of Detection (LOD) under 50ppb, while the others were measuring above 100 ppb. The PID sensors, the mini-GC and the MOx showed to be affected by a long-term drift. During the laboratory phase organic and inorganic interferences, humidity and temperature influence were checked. Laboratory test showed that current sensor technology is not able to accurately and selectively measure benzene at ambient levels. At low ppb levels only the mini-GC was found to be linear. One of the MOx revealed a strong interference with CO that more likely was measured rather than benzene. Conversely during the field tests the mini-GC, was giving satisfying benzene measurements and correct values up to 4 months with a relative expanded uncertainty of less than 10% at 1.4 ppb.

Additional Authors:

Testing low-cost sensors by means of passive samplers

Damian Bikiel, UBA-FCEyN / INQUIMAE-CONICET

Increased availability of low-cost sensors is becoming a reality in most part of the world. Better and less expensive instruments are starting to be deployed and tested in order to complement monitoring sites. The need to perform field calibrations for low cost sensors is a recurrent conclusion in literature. One of the questions that arise then is, how to perform field calibrations when, in the best of the cases, only a few of monitoring sites exists in a particular city.

For long time, environmental agencies and other organization has been relied in the use of passive samplers to monitor pollutants in a larger scale. This classic technique is a very robust and inexpensive strategy to map averaged concentrations. Depending on the design of the sampler, the averaged values can range from hours to months. In addition, this kind of techniques has been tested against reference methods, being a suitable proxy to test low-cost sensors.

Flanked by a highway and the La Plata River, the University of Buenos Aires Campus present spatial gradients of NO2. In this work, we present a pilot study in the Campus, with two fundamental objectives: 1) to assess the capability of our passive diffusion tubes to obtain weekly temporal series of NO2 and spatial patterns close to hundreds of meters; 2) To assess the performance of low-cost sensors of NO2 against the passive samplers.

Additional Authors:

Identifying the impact of a stone quarry on exposure to respirable particles

David Broday, Technion

The adverse health effects of inhaled particulate matter (PM) are a global concern. Estimation of the exposure to respirable particles is a challenge due to the sparsity of observation locations and the low accuracy of models at high enough spatial resolutions. The city of Elad, Israel, is situated less than 1 km from the Migdal Tzedek stone quarry and public concerns were raised regarding the impact of the quarry's particle emissions on the air quality in town. As there is no air quality monitoring (AQM) station in Elad, we describe here an analysis of a year-long campaign of monitoring the particle number

concentration (PNC) in a few locations in the city and its vicinity, using a network of low cost optical particle counters (OPCs). We first examined the OPCsâ€™ accuracy, precision and coherency, and assessed their capability to detect the quarry's impact on the PNC in the city. Using the PNC time series from five devices, PM10 and PM2.5 concentrations from a nearby AQM station, and meteorological data, we could confidently conclude that the quarry's impact on air quality in the city is probably very small relative to the background PNC in the study area. Our long term field measurements demonstrate methodologies that can be used to render data coming from non-standard particle sensors useful while also showing some shortcomings of using such devices. The basic trade-off is between highly accurate data from one central unit and data that comes from lower quality instruments but at a unit cost that enables deployment of multiple devices that can observe at high temporal resolution.

Additional Authors:

In-situ calibration of wireless distributed environmental sensor network (WDESN)

David Broday, Technion

Low-cost air quality sensors offer highly resolved spatiotemporal measurements that can be used for air quality management and exposure estimation but require frequent calibration to provide reliable data. Specifically, even after laboratory calibration such sensors might not report correct values when they are deployed in the field due to interference with other pollutants, as a result of sensitivity to varying environmental conditions, and due to sensor aging and drift. Field calibration has been suggested as a means for overcoming these limitations, with the common strategy involving periodical collocations of the sensor units at an air quality monitoring station. However, the inconvenience and complexity involved in relocating numerous sensor nodes back and forth, and the loss of field data during the repeated calibration periods make this strategy inefficient. Here, we examined an alternative approach, node-to-node (N2N) calibration, where only one sensor in each chain is directly calibrated against the reference measurements whereas the rest of the sensors are calibrated sequentially one against the other while they are deployed. The calibration can be performed multiple times as a routine procedure. This procedure minimizes the total number of sensor relocations and enables calibration while simultaneously collecting data. We studied the propagation of the N2N chain calibration error analytically, computationally and experimentally. The in-situ N2N calibration was found to be generic and applicable for different pollutants, sensing technologies, sensor platforms, chain lengths, and sensor order within the chain. Based on our limited data, we show that chain calibration of three nodes, each calibrated for a week, propagates calibration error that is similar to those found in direct field calibration. Hence, N2N calibration seems to be suitable for calibration of distributed sensor networks.

Additional Authors:

Variations in Wintertime PM Among Communities in Sacramento Measured with a Combination of Traditional and Low-Cost Sensor Methods

Steven Brown, Sonoma Technology Inc

To understand how wood smoke contributions and PM concentrations varied across Sacramento, and between environmental justice (EJ) and non-EJ communities, we conducted measurements during winter 2016/2017 of PM with low cost AirBeam sensors at 15 locations, of hourly PM with beta attenuation monitors (BAMs) and 24 hour PM via filter measurements at two locations. Before and after the main study period, AirBeam sensors were collocated with a BAM and a filter PM instrument to determine correction factors for the sensors. In addition, the AirBeam sensors were collocated with a BAM and a filter PM instrument at two locations throughout the study to assess whether there was drift in the sensor measurements and to determine the comparability of PM measurements among the sensors, BAM, and filter instrument.

The 20 AirBeam sensors had extremely high precision during the pre- and post-study collocations, with AirBeam-to-AirBeam correlation coefficients (r2) greater than 0.95. AirBeams also had very high precision with very little drift at the two locations with collocated AirBeams throughout the study. Since each AirBeam had a consistent PM concentration response relative to the other collocated AirBeams, we developed an AirBeam-specific calibration based on the collocated data, and used the calibrated AirBeam data to assess with high confidence how PM varied across communities. We also determined the extent to which AirBeam data can be corrected to BAM or 24-hr filter measurements using meteorological data.

Additional Authors:

Integration of Sensor and Regulatory Air Monitoring Data through Concentration Interpolation and Hot Spot Analysis

Bowan Call, Utah Division of Air Quality

Inexpensive air quality sensors have come to coexist with regulatory air monitoring instruments in the state of Utah, but their various data remain largely isolated. While sensors and monitors have vastly different accuracy and calibration standards, both produce pollutant concentration data that may fill gaps in our understanding of poor air quality persistence throughout Utah. Particulate matter less than 2.5 microns in diameter (PM2.5) concentration data was collected from a suite of regulatory monitors and PurpleAir sensors in 24-hour averages over 3 month periods during the winter seasons of 2015 to 2018. Concentration values were then interpolated between all monitors and sensors, generating a

"heat map" of high PM2.5 concentrations in Utah. This heat map was then compared to photochemical modeling output of emissions in Utah in order to identify potential problem areas that were not represented in our air monitoring network plan. Finally, the heat map was subjected to hot spot analysis by the Getis-Ord Gi* method. PM2.5 concentration values were examined in the context of their neighboring PM2.5 concentration values to identify statistically significant spatial clusters. The result of

this work is a collection of maps that visualize historical PM2.5 concentration values in Utah while providing a roadmap for future air monitoring network development.

Additional Authors:

A PM2.5 Swiss Army Knife for R

Jonathan Callahan, Mazama Science

The 2017 wildfire season brought extended periods of heavy smoke to west coast urban areas that have little experience with wildfire smoke. These events in Seattle, Portland and San Francisco generated a huge demand for real-time information on air quality, particularly PM2.5 levels associated with smoke. One of the most popular sites providing this data was the website hosted by the US Forest Service AirFire group: https:monitoring.airfire.org.

This presentation will look under the hood of this site and discuss the data model and the PWFSLSmoke R package that allow us to:

1) ingest, quality control and harmonize data from multiple providers

2) work in UTC or local timezones and apply ephemerides calculations to generate time-of-day plots

3) apply various algorithms for spatial clustering or temporal smoothing

4) generate static and interactive data visualizations

5) create reproducible, public facing plots and reports

6) build scientifically rigorous, intuitively usable and operationally robust web sites

Version 1.0 of the PWFSLSmoke R package has been released on CRAN while the current development is available on Github. The AirFire group maintains a publicly accessible data archive of harmonized datasets extending back 10 years. Real-time, up-to-the-hour datasets are also available. For anyone using R, working with PM2.5 monitoring data has gotten a whole lot easier.

Additional Authors:

Application of Visualization tools for Air Sensor Data Collected in Southern California

Shea Caspersen, US EPA, Region 9

The evolution of data V-A-I (Visualization, Analytics, & Informatics), or what has collectively become known as data science is driving the environmental sector toward ‘big data’ to find answers to environmental problems and discover new methods for making data-driven decisions. Changes in the way that we interface with the data, slicing and dicing complex arrays of information, are alone revolutionizing how data is being used to understand and protect human health and the environment. With the onset of air sensor technologies, more environmental data can be collected at higher time

resolutions giving rise to 'big data' and a need for tools to easily process and visualize the data. This presentation will highlight some of EPA's visualization tools using air sensor data, specifically fine particulate matter and ozone, collected from January to April 2017 in Southern California.

Additional Authors:

Field testing a low-cost passive aerosol sampler for long-term measurement of PM2.5

Maria Castillo, Boston University School of Public Health

As part of the NASA Health and Air Quality Applied Sciences Team (HAQAST), this study was designed to field test the University of North Carolina Passive Aerosol Sampler (UNC PAS), for measuring long-term concentrations of PM2.5. Starting in summer 2017 and continuing for one year in Boston, New York City, and San Francisco, we collected sequential 4-week and 12-week integrated samples at eight sites where sampling for PM using conventional, high-cost sensors also took place.

Samplers consist of a standard scanning electron microscopy (SEM) stub placed under a fine mesh screen of 1.5 cm in diameter. Collection of airborne particulate occurs primarily through gravitationally settling, diffusion and inertia. Samplers are sent to RJLee Group laboratory for analysis by computer-controlled SEM with an advance analytical tool for particle characterization (IntelliSEM) and for further manual analysis of PM2.5 composition.

Initial laboratory results indicate that the numbers of collected particles were suitable for good particle statistics. Particle concentrations, in general, are low, which suggests that longer sampling periods can be considered. Initial comparison with FRM/FEM data indicates that PM2.5 concentrations may be underestimated, which suggests that a significant fraction of PM2.5 consists of volatile species. Quantitative analyses comparing the UNC PAS data with co-located standard devices will be reported.

Additional Authors:
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Long-Term Assessment of CO2 Sensors Marketed for Demand Controlled Ventilation Systems

Wanyu Chan, Lawrence Berkeley National Laboratory

We evaluated accuracy of seven CO2 sensors for two years in three spaces (general office, conference room, and classroom) by comparing measured concentrations with a high-accuracy reference instrument (EGM-4, PPSystems). The seven CO2 sensor models from five manufacturers (AirTest, BAPI, Gas Sensing Solutions, Telaire, and Vaisala) used different technologies: single-beam single-wavelength, single-beam dual-wavelength, with or without auto-baseline calibration (ABC) algorithm, different IR sources (incandescent bulb, MEMS emitter, LED). One-minute data were recorded from a replicate of

three CO2 sensors of each model. Accuracy of the reference instrument was checked using standard gas monthly throughout the study period. Compared with prior study (LBNL Report 3279E) that found absolute values of error was about 15% on average among CO2 sensors already in used in occupied buildings, this study found lower absolute values of error (average = 7%). For some CO2 sensors, larger measurement errors were observed in classroom which had higher and more variable CO2 concentrations. Both zero offset error and gain error (slope not equal to 1) contributed to measurement errors. During the two-year evaluation period, only a limited set of CO2 sensors showed systematic changes in response over time. There is a need to check CO2 sensors shortly after they are installed, instead of assuming that all new sensors are reliable because they are newly calibrated by the manufacturer.

Additional Authors:

Evaluation Platform for Performance Inspection on PM2.5 Analyzers and Sensors in Taiwan

Chia-Wei Chang, ITRI, Taiwan

PM2.5 analyzers/sensors have been extensively utilized as prompt monitors by researchers and citizens. However, data quality of commercially available analyzers/sensors varies considerably. To systematically evaluate the performance of PM2.5 analyzers/sensors, Taiwan EPA cooperates with ITRI (Industrial Technology Research Institute) in development of a PM2.5 analyzers/sensors evaluation platform. Two environmental circumstances are provided in the evaluation platform, one is conducted in an outdoor atmosphere (field test) and the other is under well-controlled conditions (wind speed, temperature, relative humidity and PM2.5 concentration) in the laboratory. The traceability in terms of mass concentration for data collected by PM2.5 analyzers/sensors is achieved through comparison with USEPA FRM (Federal Reference Method).

At 25 Â°C 80 RH% in the laboratory test, a condition similar to common weather in Taiwan, we found that the slope of linear regression of some analyzers/sensors could be higher than 2 while the slope is around 1 in field test. Further, using KCl as PM2.5 source, accuracy could be different while humidity increases. It indicates that the chemical compositions of PM2.5 and humidity interference are the major causes of the performance of analyzers/sensors. With this platform, we anticipate that we could improve not only the data quality control of PM2.5 analyzers/sensors but also the air quality monitoring network in Taiwan.

Additional Authors:

Undergraduate education using wearable sensors to train citizen scientists and increase air quality awareness

L.-W. Antony Chen, University of Nevada, Las Vegas - Department of Environmental and Occupational Health

The air quality regulatory framework in the U.S. has been focused on improving urban-scale air quality. Air quality measurement is considered highly technical and seldom covered in the K-14 public health curriculum. The shift of air quality monitoring towards microscale and personal exposure assessment in recent years and the development of compact, inexpensive air quality sensors challenges the public health instructors to integrate the new information into their courses. This study illustrates such an attempt with the objectives to 1) teach students the link between exposure and personal behaviors and 2) equip students with the measurement principle including QA/QC so they can interpret the data correctly. In a 3-week period, lower-level college students with non-science major were introduced to air quality concept, principle of air sensors for PM2.5 and PM10, QA/QC, and data management. They were tasked to wear the sensors for 48 hours to monitor personal exposure, and link that to their activities in different microenvironments through a detailed activity log and survey. They learned to explain differences between data acquired from the sensor and nearby stationary air quality stations. This program may be adapted to more classes at different levels to train future citizen scientists. Data from the initial student groups in Las Vegas also showed that most PM2.5 exposure resulted from indoor sources, which are highly underestimated by the ambient monitoring networks.

Additional Authors:

A Multi-Scale Framework for Community-Level Air Quality Analysis in California

Yanju Chen, California Air Resources Board

While California has seen significant improvements in air quality, some communities are still exposed to higher levels than others. It is therefore important to understand community-scale air quality and implement mitigation measures in the most impacted communities. As a complement to the regional regulatory air monitoring network, new technologies have become available to study ambient air quality, including fine-scale satellite retrieval, saturation monitoring with low-cost instruments, and mobile measurement.

In this study, we describe and demonstrate a multi-scale measurement and analysis framework that utilizes all approaches to characterize local-level air pollutant concentrations for communities in California, and identify and quantify source emissions contributing to these concentrations. Regional-scale (1km – 10km) air pollutant concentrations are derived from satellite retrieval and regional air monitoring, and served as bases to select communities with disproportionate exposures. Both saturation and mobile monitoring are then deployed to screen concentration hotspots at the neighborhood scale (10 m – 1 km) in selected communities. As a complement to each other, they provide both temporal and spatial coverage of community air quality. Source emissions contributing to the hotspots are identified and quantified with follow-up measurements using multi-species research-grade analyzers, source apportionment analyses, and mass balance emission estimates.

Additional Authors:

Serial dilution of inverted flame source as calibration approach for black carbon monitors

Steven Chillrud, Lamont-Doherty Earth Observatory of Columbia University

Columbia University and AethLabs are developing and evaluating a modular array of air monitors for use in personal and residential settings including the MA series of real-time microAeth monitors that measure spatial and temporal variations of black carbon, UV-active particulate matter from sources such as environmental tobacco smoke, wood smoke or incense, particle reactive PAHs, relative humidity and temperature. Tri-axial accelerometer and GPS chips are integrated into the monitors allowing determinations of location, wearing compliance and activity related parameters.

Critical to use of real-time air monitors is the ability to calibrate them and test them for specificity and sensitivity under different mixtures and conditions. Traditionally, for black carbon monitors, calibrations have been done through comparison to a master sensor in a lab or comparison to different methods. In our presentation, we will present our design for and experience in developing a calibration chamber utilizing serial dilution of an inverted flame soot source that obtains concentrations relevant to human exposure. We will also demonstrate its use to test sensor response to known mixtures of UV-active sources (e.g. cigarette smoke or wood smoke) and soot.

Additional Authors:

Field Performance Evaluation of Four Low-Cost Particulate Matter Sensors

Andrea Clements, U.S. EPA

Low-cost (<$2500) particulate matter (PM) sensors are appealing to many stakeholders including professional researchers, community groups, and citizen scientists. Although the low-cost, compact size, and portability of air quality sensors makes these devices attractive for community level monitoring and for citizen science applications, detailed performance evaluations are needed to better understand the data quality. In recent years, the U.S. Environmental Protection Agency (EPA) has conducted a number of evaluations on low-cost air quality sensors with full results published on the Air Sensor Toolbox for Citizen Scientists, Researchers and Developers (www.epa.gov/air-sensor-toolbox). This work presents results from the evaluation of four PM sensors â€“ TES 5322 Air Quality Monitor, Plantower PMS 7003, PurpleAir PA-II-SD, and Aeroqual Portable Particulate Monitor PM10/PM2.5. Each sensor was deployed in triplicate for a period of at least 30 days between October 2017 and March 2018 at the Ambient Air Innovation Research Site (AIRS) test platform on EPAâ€™s campus in Research Triangle Park, NC. Sensors were collocated with nearby meteorological and Federal Equivalent Method (FEM) instruments, and data were compared to evaluate the sensor performance. Results include comparison to FEM measurements (accuracy, bias, reproducibility), examination of environmental variables (e.g.

temperature, relative humidity) that influence performance, and observations about the ease-of-use and reliability of each sensor.

Although this abstract was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Additional Authors:

DustyACorn - Bringing air quality science to pre-schoolers

Guy Coulson, National Institute of Water and Atmospheric Research

The â€œDusty Air Cornerâ€ (DustyACorn) is an interactive learning device for pre-schoolers that enables them to explore different properties of the air and how some of our day-to-day activities impact on the quality of the air. This device was developed in collaboration with early childhood teachers who wanted to bring air quality science to their students.

The DustyACorn is divided in two parts, the sensor box and the display. The sensor box is a next generation PACMAN (https://www.niwa.co.nz/atmosphere/research-projects/pacman) tailored to focus on measuring CO2, PM2.5, temperature, relative humidity and distance. This modified PACMAN device communicates with a single board computer (Raspberry Pi v3) that turns its readings into a web page that is displayed on the attached TV. Th system lets the teacher choose different visualisations of the measurements for directed and exploratory learning.

We will present the process we followed to develop the DustyACorn and the feedback we received from the students and teachers as well as our future plans for this device.

All the details of the project, firmware, software and hardware design files will be released as an open source package under an MIT license (https://github.com/niwa/dusty-acorn)

Additional Authors:

Using Air Sensors to Build Capacity to Measure Air Pollution Mitigation Strategies at Schools: A Case Study at Brookfield Elementary School, Oakland, CA

Kenneth Davidson, US EPA

Research indicates that noise and vegetative barriers, separately or in combination, can reduce downwind air pollutant concentrations near busy roads. EPA and its project partners are participating in an ongoing effort to measure the spatial patterns of traffic-related gas- and particle-phase pollutants consistent with traffic activity both with and without a vegetation barrier at Brookfield Elementary School in Oakland, CA. Brookfield is directly adjacent to a busy goods movement corridor (I-880); a noise barrier currently separates the school from the highway shoulder. EPA collected initial air quality samples at the school before vegetation was planted on the downwind side of the sound wall in early

2017 using a combination of low-cost mobile and fixed sensors to establish on-site conditions. In the projectâ€™s second phase, EPA is developing low-cost BC and NOx mobile and fixed sensor packages that will be deployed at the school by teachers, staff and students to learn more about exposure to near-road pollutants including how newly planted vegetation affects their air quality over time. Prior to deployment, EPA is developing a hands-on training for teachers and staff on how to operate the sensors and evaluate the data. EPA is also developing educational materials to accompany the sensor deployment. The lessons learned at Brookfield will be transferable as a case-study to other schools/communities interested in air quality education and research.

Additional Authors:

Performance of Two Sensor-Based Methods for Measuring Formaldehyde and NO2 in New California Homes

William Delp, Lawrence Berkeley National Laboratory

Healthy Efficient New Gas Homes (2016-2018) field study measured indoor air quality in 74 new California homes. We compared performance of two sensor-based methods for measuring formaldehyde (GrayWolf Monitor FM-801) and NO2 (Aeroqual Series 500) with passive samples. The FM-801 uses a colormetric sensor element to measure formaldehyde concentration at 30-minute time-interval. The Aeroqual uses gas sensitive electrochemical technology to detect NO2 at 30-second time-interval. FM-801 and Aeroqual gathered one-week of data from each home in a main indoor area, and also in the master bedroom for formaldehyde. One-week average formaldehyde and NO2 were measured concurrently using SKC UMEx and Ogawa passive samplers. Passive samples showed lower formaldehyde concentrations (median = 23.4 ppb) than prior study of new California homes from ten years ago (median = 29.5 ppb; CEC Report 500-2009-085). We observed reasonable agreement between FM-801 and passive formaldehyde samplers (R2 = 0.45 for main indoor area, and 0.73 for master bedroom) after censoring low values measured by FM-801 (<20 ppb). NO2 measured passively indoors showed low concentrations (median = 3.8 ppb). The Aeroqual monitors were calibrated using standard gas each time prior to field use, but significant baseline offset remained. Sensor-based NO2 was useful at identifying indoor emissions (e.g., gas cooking), but may not give reliable weeklong averages without further adjustments even with frequent calibration.

Additional Authors:

Design and Evaluation of Fixed and Mobile Sensor-based systems for collection of local Air Quality Data

Parikshit deshmukh, Jacobs Technology

Design and Evaluation of Fixed and Mobile Sensor-based systems for collection of local Air Quality Data

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Abstract: Air pollution from mobile sources has been identified by numerous organizations as a public health concern. With increasing traffic on major interstates, an increasing number of people are at risk of exposures to high levels of near-road air pollution. Fixed and mobile air quality sensors offer advantages to assessing these impacts. Studies demonstrate the value of using high-quality mobile monitoring and low-cost, sensor-based technologies in evaluating air quality in near-road environments.

With this increasing concern about human exposure and related adverse health effects near roads, the ability of the public to collect air quality data using sensor-based systems is of increasing desire and importance. With this in mind, we have developed user-friendly packages for use by the general public in evaluating air quality in their communities. This presentation describes the use and evaluation of black carbon and NO2 sensors to measure near-road mitigation effects of roadside vegetation in the San Francisco Bay area, including quality assurance results with the Near-Road Monitoring Station at Laney College in Oakland. This presentation also describes the development and use of a stationary Solar-Powered Air Quality (S-PAQ) sampling platform for fixed-site data collection and a mobile Portable Air Quality System (PAQS) sampling platform for mobile data collection by the public.

Key words: Urban environments, Low cost sensors, Mobile monitoring, Air pollution, Traffic

Additional Authors:

U.S. EPA's AirNow International Air Sensor Applications and Initiatives in Accra, Ghana

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Air pollution harms millions of people around the world and takes a toll on our ecosystem. Many African cities lack the capacity and cost-effective means to measure and characterize ambient air quality in support of critical air quality objectives, which includes setting ambient air quality standards and future implementation of the United Nations Environment Assemblyâ€™s air quality decision.

Under the Africa Megacities Partnership initiative, the Ghana Environmental Protection Agency, the United States Environmental Protection Agency (U.S. EPA), and the World Bank are working together to deploy and operate a low-cost particulate matter (PM) air sensor network in Ghanaâ€™s capital city of Accra for up to a year. In addition, the project will explore the feasibility of using the U.S. EPAâ€™s AirNow International data management system for sensor data processing and management that can be applied to other cities worldwide. Two traditional, regulatory-grade air monitoring instruments will be deployed by the World Bank, which will provide an opportunity to collocate sensors for data quality assessment and sensor calibration methods development.

During this presentation, we will discuss the challenges and lessons learned during the planning phase and implementation of this sensor and data management project. We will also talk about initial sensor

performance metrics under Accraâ€™s unique air quality and weather conditions, spatial PM concentrations based on sensor data, and future plans.

Additional Authors:

Demonstrating the uptake and excretion of air pollutants in real time using ambient air sensors to measure inhaled and exhaled concentrations.

Albert Donnay, Donnay Detoxicology LLC

One way to make air pollution exposures â€œrealâ€ to people who may not consider themselves at risk is to show them how much of the air pollutants they inhale are absorbed in their body and how much less they exhale as a resultâ€”unless they already have a higher level in their tissues from some prior exogenous or endogenous exposure, in which case they will be exhaling even higher levels than they are inhaling.

The same types of portable analyzers that professionals and the public are currently using to measure levels of toxic gases and particulates in ambient inhaled air also can be used to measure levels of the same air pollutants as they are being exhaled. The method is based on the simple physiological principle that the exhaled alveolar concentration of any gas equals the inhaled concentration minus the balance absorbed into blood and tissues. A positive difference between exhaled and inhaled levelsâ€”what Dr. Michael Phillips of Menssana first coined â€œthe alveolar gradientâ€â€”indicates net excretion while a negative gradient indicates net absorption.

In the case of particulates, the concentrations exhaled from various sections of the airway can be distinguished from the mouth down to the lower lung, while breath-holding methods can now distinguish the average levels of free gases diffusing from the nose, mouth, lungs, arteries, veins, and the average of all tissues.

Among the gases whose exhaled levels can be measured in this manner are carbon monoxide, hydrogen sulfide, hydrogen, and nitric oxide, all of which may be either transiently or chronically elevated in breath from endogenous and/or exogenous sources. Breath testing devices for each have long been sold in many countries for clinical use (e.g. NO to monitor asthma) and some also for consumer use (H2S to monitor halitosis).

But none of these are also designed to measure these gases in air except for calibration; most specify only one breath-holding time if any; and they are commonly more expensive than professional air quality instruments that can measure gases in exhaled breath just as accurately as air. Conversely, none of the devices currently sold to monitor indoor or outdoor air pollution are designed to monitor exhaled breath, but they are more robust and easier to adapt for alternative uses.

Unfortunately, the most abundant air pollutant that we inhale continuously and also produce endogenouslyâ€”carbon dioxideâ€”cannot be easily measured in breath using air quality instruments or vice versa. Its concentration in air is two orders of magnitude lower (only 400 ppm compared to around 40,000) and few portable devices span this range.

Most other gases show a much smaller difference between inhaled and exhaled levels so both can be detected on typical air quality scales. For gas analyzers that work via diffusion, they need only be small enough to be fit inside a disposable plastic bag. Those fitted with a sampling pump and a probe or dedicated port can draw exhaled air directly from a sample bag. The only type of air quality monitoring devices that are not suited for measuring exhaled breath are those that need more than 100ml of sample; that need some type of sample preparation; or that may be adversely affected by high levels of humidity or alcohol, although the former could be filtered and the latter screened first with a breath alcohol analyzer.

This [poster/presentation] reviews how breath testing with air quality instruments can be used to estimate the levels of air pollutants people absorb from any exposure into their lungs, blood and tissues, as well as monitor how long these levels take to decline. Breath tests can show how the absorption of any exposure from lungs to blood increases with breath-holding time unless there is already a higher level in blood, in which case no further absorption occurs and a higher level is exhaled.

They also can be used to: quantify the degree to which arterial, venous and the average tissue levels of any gas are decreased by hyperventilation, hyper-oxygenation, partial rebreathing or other methods; calculate gas half-lives in these compartments; and measure the extent to which venous blood gas levels rebound after any interventions are stopped, which depends on whether a higher level remains in any tissues.

It works both with gases and particulates to which humans are only exposed exogenously as well as those that we also produce endogenously. When needed, radio-labeled isotopes can be used in controlled gas exposures to monitor distribution of the gas and labeled breakdown products throughout the body as well as their excretion over time via breath and other pathways, such as in urine and stool, and over longer time frames in hair and nails.

Other potential applications that remain to be explored include monitoring how exhaled levels of gases change around the clockâ€”several like CO are known to exhibit regular diurnal variationâ€”as well as during the menstrual cycle and pregnancy. This might be able to identify women at risk for complications such as hyperemesis gravidarum and post-partum depression, as well as fetuses at risk for premature birth or other adverse outcomes.

That showing people the levels of toxic gases they exhale can impact their behavior is well documented in the peer-reviewed literature on breath alcohol testing programs designed to discourage driving after drinking and breath CO testing programs designed to help people quit smoking, especially pregnant women. No special expertise or qualifications are needed to measure exhaled breath with portable instruments, although both body position and exhalation rate should both be kept constant. One drawback is that exhaled gas levels are not immediately reproducible, as they tend to decline steadily with each repeat unless spaced at least a few minutes apart. For this reason, it is recommended to start with measurements that require the least breath holding time and shortest exhalation (sampling nose and mouth) before moving on to the other measurements that require larger end-tidal exhalations.

Examples will be presented from the CO literature and from the authorâ€™s experience as a consulting toxicologist.

Additional Authors:

CommunityAQ: Utilizing Emerging Technologies to Gain Community Participation in Air Monitoring

Jessa Ellenburg, 2B Technologies

2B Technologiesâ€™ CommunityAQ program is reimagining the future of air pollution monitoring by making public participation not only possible, but a primary focus. CommunityAQ utilizes complimentary instrumentation, mobile and stationary, to spark public interest in data collection and analysis. Since schools are the central gathering point of communities, CommunityAQ deployments often focus on schools. K-University students initially utilize the mobile portion of the program with the Personal Air Monitor (PAM) and AQTreks to make mobile air pollution measurements inside and outside their schools and communities. The PAM measures CO, CO2, particulate matter (PM10, PM2.5, PM1.0), temperature, pressure and relative humidity. In the app, students view real-time data on maps and graphs, the relative health of the air being measured, and data from the nearest government monitoring stations for comparison. Trek data are automatically uploaded for discussion and analysis. After evaluating air pollution levels around their schools and communities, students make recommendations for the location of a stationary monitor, called the Community Air Monitor (CAM). The CAM is a PAM plus an FEM ozone monitor. The CAM includes signage with a QR code for an app download where people are able to view real-time data from the CAM and other CAMs in the area. With CommunityAQ, air pollution monitoring no longer occurs in isolation; it is done with community collaboration.

Additional Authors:

Remote sensing data analytics accommodating multi-source characterization in a complex petrochemical/chemical industrial area

Yael Etzion, Atmosfir Optics

An automation of open path FTIR was developed as a high-end remote sensing solution for real-time analysis of VOC emissions, including characterization of their non-point sources based on USEPA methods OTM-10. The implemented algorithm automatically provides a single source location when a significant gradient is measured along the a â€œfence-lineâ€ open path. The emission source location estimate is updated per measurement cycle (2-5 minutes). The scope of this study was to generalize the automated location estimation, for a multi-source problem, accounting for cases where the measured concentrations along the fence-line result from leaks in different locations in a monitored site that may occur simultaneously or intermittently. Multi-source location based on cluster analysis is demonstrated for different sites and different emissions, e.g., n-Alkanes mixtures and Ammonia. This approach can better serve realistic scenarios and root cause analysis in industrial complexes with several proximate emission sources of the same compound.

Additional Authors:

Quartz Crystal Microbalance Gas Sensors Prepared by Laser Deposition

Premysl Fitl, University of Chemistry and Technology in Prague

Focused Laser beam is a widely used for deposition, localized annealing and patterning of various materials (eg. metals, oxides, organic substances). Our work is focused to possibilities of usage of continuous wave (CW) lasers for local deposition and patterning of black metal and organic semiconductors on the QCM sensor substrates. Our method is based on laser direct write to sensing layer on the active electrode and laser induced forward transfer of sensing material to sensing substrates. For our test we used QCM substrates based on circular (d=8.65 mm) quartz AT cuts with chrome + gold electrode with base working frequency at 10.880 MHz. As the sensing layer we used black aluminium, Iron and Zinc Phthalocyanine. The direct write/ deposition apparatus includes micro CNC machine (minimal step adjustable to 300 nm) equipped with the semiconductor laser (lambda = 405 nm, power of 10 - 50 mW, spot size 6 microns) in CW mode and focusing optics. Deposition process was held in an inert gas (Argon, Nitrogen) at atmospheric pressure. Morphology and microstructure of modified and deposited layers were studied by optical, electron microscopy and AFM. Chemical composition of deposited Phthalocyanines was studied by FTIR and compared with the source substances. It was proved that chemical structure of all chosen substances is not affected by this deposition technique. Employing our technique we are able to achieve precise and reproducible laser transfer of organic semiconductors to the target sensor substrate with lateral resolution of 14 microns. Our sensors were tested for detection of NOx, VOCs and the results shown significant improvement of sensitivity caused by enhanced surface morphology.

Additional Authors:

Aiding smoke forecasting & providing better information to help the public reduce their exposure.

Javier Fernandez, CEO & Cofounder, Kunak Technologies SL

Wildlife Fire Sensor Challenge, coordinated by EPA, seeked a field-ready prototype system capable of measuring constituents of smoke, including particulates, carbon monoxide, ozone, and carbon dioxide, over the wide range of levels expected during wildland fires. The desired Measurements were: PM2.5, CO, CO2, O3. Kunak participated in the Challenge with 2 units of Kunak AIR, that were tested by EPA in March 2018. Results show excellent accuracy for PM2.5 (R2:0,95) -CO (R2:0,98) -O3 (R2:0,98)

Additional Authors:

Learning from a dense network of PM2.5 measurements in the San Francisco Bay Area

Helen Fitzmaurice, University of California Berkeley

Large numbers of observations offer the promise of dramatic changes to our understanding of the interaction of air quality with public health and of specific guidance to policy makers about the efficacy of the choices the make. With more than 50 sensor nodes spaced at approximately 2km, the Berkeley Atmospheric CO2 Observation Network (BEACO2N) aims to observe atmospheric gases and aerosol and to learn about emissions and exposure with an unprecedented level of detail in space and time. Each node in the network is equipped with low-cost instruments measuring PM2.5, CO, NO, NO2, O3, and CO2. The aerosol measurements are made using a Shinyei PPD42NS optical particle counter. Here we describe observations of PM2.5 using the network that characterize short and long-term variability and provide insight into the processes controlling aerosol in the region. We compare these observations to simulations using the WRF-Chem chemical transport model with a high spatial and temporal resolution emissions inventory (1km x 1km, hour of week). Similarities and differences provide insight into opportunities for improvement of the model and of our understanding of aerosol.

Additional Authors:

Arduino and Raspberry PI Based Air Quality Sensor for the City of Manila

Maria Cecilia Galvez, De La Salle University

Low cost air quality sensors are becoming popular in monitoring Urban Air quality because of the cost of conventional air quality monitoring stations. Air quality has been a problem especially in the city of Manila. The government through its Environmental Monitoring Bureau has been doing lots of efforts to increase the number of Air Quality Monitoring Stations. However, the number is not yet enough to completely assessed the air quality in Manila. An Arduino and Raspberry PI based air quality monitoring device was developed that may help with this problem on cutting the cost to a very affordable price, making the data accessible to everyone. The device is designed to measure criteria pollutants such Particulate matter, Carbon Dioxide, Carbon Monoxide, Nitrogen Dioxide, Sulfur Dioxide, and Ozone. It is portable and a powerbank or a 5V DC adaptor can be use to provide the 5V DC voltage needed by the device. The measured variables of the developed device were compared with a commercial particle counter and gas sensor. Measurement was conducted along a busy intersection and along a major in Manila. Temporal and Diurnal variation was also analyzed when the developed device starts collecting data for pm10, pm2.5, Carbon monoxide, Carbon Dioxide, Nitrogen Dioxide this parameter will also be correlated with Temperature and Humidity. Data is stored in an SD card but the device has a capability of sending data to a web server and displayed on a dedicated website.

Additional Authors:

Characterisation and Enhancement of low-cost aerosol sensors for use in air pollution monitoring in diverse environments.

Stefan Gillott, King's College London

Background: Current techniques to measure atmospheric particulate matter (PM) use large and expensive instruments that require significant resources while still unable to detect the spatial heterogeneity of PM in urban environments. Miniaturised detection methods have the potential to reduce costs and increase portability while providing real time measurements. However, laboratory and field evaluations of low-cost optical particle counters (OPC) show significant artefacts from meteorological variables such as relative humidity (RH) and physicochemical variables such as chemical composition and size distribution.

Methods: This project will assess a variety of low-cost OPCâ€™s against reference instrumentation in a range of ambient (roadside; urban background) and indoor (dwelling; office; extreme work) environments while measuring the mass of PM10 and PM2.5. This will provide a full characterisation and enhancement of the OPCâ€™s response to PM due to the diversity of physical and chemical properties of PM in these environments. Algorithm development and exploration into machine learning techniques will aim to improve OPC performance.

Results: To date, measurements were made at a heavily trafficked kerbside location in Central London using the Alphasense OPC-N2. Mass was overestimated on several occasions when RH was high. However, a direct association with high humidity was not observed and the chemical composition likely had a significant impact on the OPCâ€™s mass results.

Additional Authors:

Particle-bound Polycyclic Aromatic Hydrocarbons (PPAHs) as indicators of Toxicity potential of particles

Anubha Goel, indian institute of technology kanpur, india

This study assessed exposure by the roadside to highly toxic particle-bound polycyclic aromatic hydrocarbons (PPAHs) that are known to adsorb preferentially on fine particles dp< 1 Âµm. PAHs are a result of incomplete combustion of fuels or lack of oxygen during fuel combustion which generates high molecular weight PAHs. Typically, 70to90% of total PAHs are adsorbed on particles with dp< 0.2 Î¼m and relatively a little are found in the accumulation mode and on coarse particles at ambient temperatures (Nikolaou et al. 1984Respiratory particles play a vital role as media to absorb PAHs on their surface area and transport them into human lungs.). It clearly shows that particulate matter and PAHs have a great impact on urban populations (CvetkoviÄ‡ et al., 2015). A study has reported that human exposure to PPAHs is equivalent to the smoking of a few cigarettes every day (Sideman and Seigmann, 1997).

Real-time air measurements were conducted in the month of May 2015 in Kanpur at a busy roadside location (outside IIT Kanpur Main Gate). Diffusion-charging (DC) continuous monitor (Ecochem Analytics, USA) was used to measure total active surface (TAS) in mm2/m3 of air for particles of nanometric size (up to1000 nm or PM1). Photoelectric-charging (PC) continuous monitor (Ecochem Analytics, USA)

measured total PPAHs. High concentrations of PM10, PM2.5 and PM1, determined through OPC, were observed at IG (PM10: 700 - 800 Âµg/m3) owing primarily to nature and high density of traffic. The Multiple Path Dosimetry model (MPPD-V3.04) applied on the average particulate mass to obtain regional inhaled dose of PM in human respiratory tract reveals the highest deposition fraction for PM1 in the innermost region of lungs. Mass of nanoparticle-bound PAHs (PC/DC ratio) at IG (4.08 ng/mm2) suggests that ambient air has great 'toxicity potentialâ€™. The relation between airborne particle distribution and absorbed PAHs needs to be examined to better understand the impact of particle inhalation on human health. Results suggest that toxicity of airborne particles at regions with high fuel or biomass burning can be assessed and used as a public information tool.

Additional Authors:
Jason Gu, Sensevre

An Off-Centric Impactor to Reduce Particle Bounce Off: Its Design and Development

Tarun Gupta, Indian Institute of Technology Kanpur

Air sampling is important for monitoring and source apportionment of air pollutants. Inertial impactors are simple and useful devices for size specific collection of aerosols. Particle bounce off is a problem in impaction based air sampling, perturbs collection efficiency and promotes errors in scientific research. This problem is non-predictable and increases with longer sampling period and pollution level. This study presents the design and development of a novel inertial impactor to reduce particle bounce off. This design includes an off-centric impaction nozzle and is rotated to a certain angle after a certain time interval to provide fresh impaction surface. By simple means of load distribution, the total particle loading is distributed to multiple points and thus reducing the chance of particle overloading and exhaustion of single point impaction substrate which eventually results in particle bounce-off. The new design has been compared with a conventional PM impactor by co-located sampling for 4 h. After 4 h of sampling, both the impaction plates were compared. For the new design, the total load generated from non-targeted particles formed four distinct points on the impaction surface which are much smaller in size compared to the single impaction point for the conventional impactor. The solution is generic and can be applied to any inertial impactor to achieve less particle bounce off.

Additional Authors:

A variable head PM1/PM2.5 medium flow (175 LPM) sampler to enable quick sample collection

Tarun Gupta, Indian Institute of Technology Kanpur

In line with the goal of accurate measurement of ambient PM, at places which suffer mostly due to indiscriminate advancement of industries coupled with poor urban planning this study was carried out. The impactor operates at a flow rate of 175 LPM and consists of two different circular acceleration nozzles designed for PM2.5 (particle aerodynamic diameter < 2.5 Âµm) and PM1 (particle aerodynamic

diameter < 1 Âµm), either of them could be used one at a time as per the requirement. High vacuum grade silicone grease is used as an impaction substrate. Lab experiments were performed using a poly-disperse dolomite powder as test aerosol. The nozzle configurations selected were such that the first one provides a 50% cut-point at 2.50 Âµm (aerodynamic diameter) with a pressure drop of 0.35 kPa while the second one produces a 50% cut-point at 1.06 Âµm (aerodynamic diameter) with a pressure drop of 1.07 kPa. Particle losses through the nozzle were low for particle diameter up to 5.0 Âµm. Particle bounce off and re-entrainment losses were found to be insignificant. Owing to its medium flow rate, it has an advantage of collecting appreciable quantity of particles in a relatively smaller time frame as compared to other low flow rate samplers. A 47 mm filter was used for PM collection. Thus, it enables near realistic comparison with data captured by real-time instruments.

Additional Authors:

Use of low-cost sensors in a polluted environment: Addressing challenges and lessons learned over the course of three years of field measurements (2015-2018) in Delhi, India

David Hagan, MIT

The past several years has seen the emergence of many commercial devices for low-cost sensing (LCS) to measure particulate matter (PM) and gaseous species for the monitoring of indoor and outdoor air quality. Although our understanding of their operation and our ability to quantify their error and performance has improved substantially over this period of time, a number of major concerns still exist. These include the effect of relative humidity, temperature, and cross-sensitivities for gas sensors; and relative humidity, composition, morphology, and perturbations in the particle size distribution for optical particle counters. Here we describe the deployment of several low-cost multi-pollutant air quality sensors in Delhi, India between 2015-2018, discussing in detail the operational and technical challenges faced unique to low-cost sensors. We observe extreme conditions across a number of different vectors including large temperature swings, periods of sustained high relative humidity, high concentrations of gaseous species including CO, NOx, O3, and SO2, and extremely high fine particulate loadings (sometimes exceeding 1 mg/m3). While such high concentrations may appear on the surface to make analytical measurements using LCS easier, a number of additional challenges present themselves. We discuss in detail the operational and analytical challenges faced and how we improved and optimized our instrument design for a harsh environment over the course of several years.

Additional Authors:

Linking Low-Cost Particle Sensor Measurements to Regulatory Monitoring

Walter Ham, CA Air Resources Board

Low-cost particle sensors have the potential to collect high spatial and temporal measurements that can be used to better understand air pollution trends at a local scale. However, the data quality from these sensors may be unknown which presents a challenge for properly interpreting and utilizing their data.

There is a need to better understand the performance of sensors by characterizing their real-world accuracy and precision. In this study, we investigate the performance of Purple Air-II sensors by co-locating these sensors with Beta Attenuation Monitors at multiple field sites. All sensors will undergo an initial co-location at a single regulatory site before being deployed at field sites equipped with at least one Beta Attenuation Monitor. Data management and data validation will also be discussed. Data from this field campaign will be used to generate adjustment algorithms in an effort to improve the quality of data from air sensors and better understand how sensor data can be used to supplement regulatory air monitoring data.

Additional Authors:

Evaluation of PM2.5 and CO sensors for wildfire smoke identification

Dan Jaffe, University of Washington

Wildfires generate significant emissions of PM and CO. However as these emissions mix and dilute with other pollutants in an urban area, it can be challenging to identify and quantify the sources of each. We have shown previously (Laing et al 2017) that the PM/CO enhancement ratio can be used to identify smoke in urban areas. However many urban monitoring stations do not measure CO. For this project we want to see if lower cost sensors could provide adequate accuracy and precision to distinguish different source types in an urban area based on the PM/CO enhancement ratio. For PM we have tested multiple sensors including the Dylos, Purple Air and the Vaisala AQT 420. While all show some response to PM, the responses can vary greatly making some of these more reliable than others. For CO, we have evaluated the Cairclip sensor and found good precision for this sensor down to below 100 ppb. However to use the data quantitatively requires careful comparison against a known reference standard. In summer of 2018 we will test combinations of these sensors to look at their ability to get PM/CO enhancement ratios and use these to evaluate their suitability for distinguishing source types, including wildfires and residential wood smoke.

Additional Authors:

Childrenâ€™s Personal and Microenvironmental Exposures to PM2.5 and Ozone in Shanghai, China

Karoline Johnson, Duke University

Air pollution exposure has been linked to various adverse health outcomes especially in children and people with asthma. In order to formulate cost-effective exposure reduction strategies, it is necessary to quantify contributions from specific microenvironments where people spend their time. During spring of 2017, 43 asthmatic children were recruited for a study in suburban Shanghai. These children carried personal exposure packages containing PM2.5 and ozone sensors for two 48-hour periods. During one period, the children received air filtration in their bedroom and during the other period they used a placebo filtration device. The children or their caregiver also filled out time activity diaries indicating their location and activity in one-hour intervals during these two 48-hour periods. The locations were divided into 6 microenvironments: outdoor, childâ€™s bedroom, other rooms at home, classroom,

bus/car/taxi/railway, and walk/bike. The average pollutant concentrations in each microenvironment are calculated by matching the one-hour personal monitoring pollutant data with the time activity data. In addition, by combining the concentration and time activity data we can find the microenvironment with the largest contribution to personal exposure. The children spent the most time on average in their bedroom (47%) followed by their classroom (22%) and other rooms at home (22%). Preliminary results suggest that on average, bedroom air filtration did reduce personal exposure and indoor levels of PM2.5. Additional analysis is ongoing. Results from this study will help identify the most important microenvironment to target in order to reduce childrenâ€™s personal exposure to air pollution.

Additional Authors:

Measuring Air Pollution with a small Unmanned Aerial Vehicle (sUAV)

Ajith Kaduwela, CARB

We have mounted an air sensor package (originally developed at the Albany High School in California and later improved at the University of California at Davis) on a small Unmanned Aerial Vehicle (sUAV – DJI s1000+ octocopter) and made vertical flights to measure the temperature structure and the particulate loadings of the early-morning atmosphere. The sensor package consists of a BMP280 chip (barometric pressure, relative humidity, and temperature) and a PMS7003 sensor (PM size cuts of 0.3, 0.5, 1.0, 1.5, 2.5, and 10 µm and PM1, PM2.5, and PM10 mass) controlled by a Raspberry Pi Version 3 B+. The temperature measurement of BMP280 is a “board temperature” used to correct pressure and humidity measurements and prone to heating of the board by the sunlight during the field measurements. Therefore, we have also added a thermocouple to the sensor package for fast ambient temperature measurements. During the presentation, we will present the measured early morning vertical temperature structure and particulate matter loading of the atmosphere for a clean and a wild-fire-impacted day. We will also compare the ambient temperature measurements made using the BMP280 and the thermocouple.

Additional Authors:
Roberto Hurtado1, Longji Yin2, Russell Evangelista1, Daniel Andenmatten1, Peng Wei1, Amal Kaduwela3, Anthony Wexler1,4, and Zhaodan Kong1,4

Quartz-Enhanced Photoacoustic Spectroscopy for Environmental Trace Gas Sensing with WSNs

Markus Knoll, Institute of Electronic Sensor Systems, Graz University of Technology

To increase the spatial resolution of air pollution measurements, sensor nodes, usually combined with wireless sensor networks (WSN), are equipped with low-cost air quality sensors.

Among the pollutants of highest interest is nitrogen dioxide (NO2). The detection of NO2 in WSNs is commonly done by electrochemical sensors, which are cheap but lack long-term stability and suffer from cross-sensitivity. Our first principle approach for sensing NO2 is based on quartz-enhanced photoacoustic spectroscopy (QEPAS) to overcome these drawbacks. Modulated light is absorbed by the

analyte, which results in the production of a sound wave. The sound wave is amplified by a quartz tuning fork (QTF), which results in a measurable current.

Our experiments show promising results without the need of an additional micro-resonator. This makes corrections due to temperature and pressure changes easier. Allan variance analysis showed a noise equivalent concentration (NEC) as low as 20 ppb for 30 sec. averaging time, satisfying international health and safety standards requirements.

The reported NEC is achieved with a low-cost laser diode, a commercial laser driver and data acquisition system. Additionally, results using a miniaturized sensor consisting of a homemade low-cost and small footprint laser driver and lock-in amplifier will be presented.

Due to the sensor principle, the sensor could be easily extended to sense all regulatory relevant pollutants, by adding other wavelength light sources.

Additional Authors:

Mapping Occupational Hazards with a Multi-Hazard Monitor Network in a Heavy-Vehicle Manufacturing Facility

Kirsten Koehler, JHSPH

Sensors have an important, emerging role in environmental health. Due to their small size, low power demands and interoperability, low-cost sensors can be deployed in collections that are spatially distributed in the environment, known as sensor or monitor networks. We have developed and deployed 40 multi-hazard monitors, constructed with low-cost sensors for particulate matter, carbon monoxide, oxidative gases and noise in a wireless network in a heavy-vehicle manufacturing facility. Here, we report on the temporospatial measurements from the monitor network, precision of network measurements, and accuracy of network measurements with respect to field reference instruments after approximately 5 months of continuous deployment. During production periods, 1-hr mean hazard levels across all monitors for PM, CO, oxidative gases and noise ranged from 0.4-0.6 mg/m3, 2-10 ppm, 50-150 ppb, and 78-83 dBA respectively. We examined the influence of major manufacturing processes on the spatial variability of hazards by grouping monitors by the processes that surrounded them. We assessed the accuracy of monitors in the network by conducting side-by-side measurements with field reference instruments and observed the median percent bias for each hazard equal to -17.8%, -0.9%, -25% and 0.3%, for PM, CO, oxidative gases and noise respectively.

Additional Authors:

Creating a network of low-cost, field-deployable PM sensors to characterize regional dust emissivity

Katheryn Kolesar, Air Sciences Inc.

Inland regions of the western United States are particularly vulnerable to high concentrations of particulate matter (PM, both PM less than 10 Âµm, PM10, and PM less than 2.5 Âµm, PM2.5) from windblown dust emissions. In desert ecosystems, windblown dust (PM) emissions may be highly localized (e.g. dry lakebeds) but are more often characterized by relatively low emissions and concentrations over large areas. Since PM10 and PM2.5 are hazardous to human health, an accurate, low-cost PM sensor would be an invaluable tool for monitoring PM concentrations over large land areas and identifying local sources for targeted mitigation. The purpose of the current study is to assess the use of low-cost field-deployable PM sensors for creating a high-density network of PM measurements that can be used to determine surface emissivity in real-time. Results from field tests will be discussed along with method development.

Additional Authors:

Methodology development for routine evaluation of atmospheric data quality aboard a mobile platform

Brian LaFranchi, Aclima Inc.

Advances in lower cost air pollutant sensing technology have enabled opportunities to deploy large scale networks of mobile sensing platforms with the potential to provide information about exposure and emissions at hyper-local spatial scales, capturing unexpected features that are the least straightforward to predict. Data of sufficient quality is necessary to have confidence in the precision of value of these features. Dynamic and rapidly changing pollutant concentrations and atmospheric conditions experienced onboard mobile platforms results in an additional layer of variables that needs to be taken into account when assessing data quality for mobile applications. The Aclima mobile laboratories, a fleet of 4 regularly deployed Google StreetView cars outfitted with reference grade instruments and our low-cost sensor nodes, offers a proven platform to address key questions surrounding sensor performance in a moving vehicle. In addition to being an active data collection platform, this fleet has been utilized as a ground truthing source for Aclimaâ€™s sensor-based device development and is a central operational piece in our broader QA/QC strategy. In this presentation, we will discuss our standard operating procedures for QA/QC of the reference grade instruments in the mobile labs and assessing the unique aspects of uncertainty quantification of these measurements aboard a mobile platform.

Additional Authors:

Citizen Monitoring Documents Toxic Air Pollution in Puerto Rico

Denny Larson, Community Science Institute

Residents of the community of Tallaboa-Encarnacion have reason to suspect that the air they breathe is impacted by emissions from industrial sources including petrochemical facilities, Central Costa Sur (a 1090 MW power plant that burns a combination of natural gas and bunker fuel oil), the Penuelas Valley Landfill, and Highway 2, which is frequented by trucks servicing the landfill and local industries. An inspection report of the Puerto Rico Environmental Quality Board dated 22 June 2015 observed fugitive emissions from the Penuelas Valley Landfill that exceed emission standards. Central Costa Sur is located

approximately 4.25 kilometers west of the community of Tallaboa-Encarnacion; the Penuelas Valley Landfill is located approximately 2 kilometers north of the community; Highway 2 runs just southwest of the community and is separated by less than 100 meters from homes on Calle 1. Community members trained by the Community Science Institute in 2016 collected over 30 air samples of gases and particulate matter to document the problem. Many of the samples were above federal standards and other health based levels.

Additional Authors:

Applications of Low-Cost Sensors for Youth Education in Arizona

Tami Lavezzo, Sonoma Technology, Inc., 1450 N. McDowell Blvd, Petaluma, CA 94954

Low-cost sensors are being used by the public to measure air quality. Individuals can make a significant impact within their communities by collecting and crowdsourcing credible local air quality data. But understanding sensor applications can be challenging, because sensors range widely in quality and some air quality knowledge is needed to ensure successful deployment.

The emerging technologies surrounding air quality sensors are creating new educational opportunities. Sonoma Technology developed the Kids Making Sense (KMS) program that blends traditional curriculum in chemistry, physics, and computer science with hands-on projects to teach students about air pollution and empower them to drive positive change in their communities. Classroom activities and lectures prepare students for a hands-on project with air sensors. Data collected by students are crowdsourced on a website to aid guided discussions and data interpretation. KMS workshops have taken place in middle and high schools across the U.S., Taiwan, and Thailand.

The MCAQD in Arizona is leading a roll-out of KMS to County classrooms and has tailored the curriculum to meet the needs of their teachers. We will discuss KMS in Maricopa County schools, and how the program unites science, technology, engineering, and mathematics (STEM) education with environmental education and a field measurement system using small sensors. We will also talk about the status of the project and some lessons learned.

Additional Authors:

Decision support of satellite remote sensing data for PM2.5 air quality in California

Hyung Joo Lee, California Air Resources Board

Satellite remote sensing has become increasingly important to government agencies to support decision-making processes for improving air quality. The California Air Resources Board (CARB) is currently using satellite data to fill spatial gaps in air quality information derived from ground-level monitoring networks. Air quality prediction modeling with satellite data is particularly significant for its capacity to capture air pollution hotspots located between ground monitors. These hotspots are not likely to be captured by a popular prediction model, such as land use regression, alone. Furthermore, satellite-based modeling is independent of emission inventory data, enabling the model to be useful to identify unknown source emissions. In this study, we estimate ambient PM2.5 concentrations using satellite data, land use parameters, and local meteorology in a statistical model at the spatial resolution of 1 km in California, for the year 2016. The PM2.5 estimates are then applied to (1) PM2.5 hotspot analysis and (2) Environmental Justice (EJ) analysis. As a screening tool, the satellite-based PM2.5 estimates show potential PM2.5 hotspots that are not currently captured by CARBâ€™s air monitoring network. These PM2.5 hotspots can be investigated further through ground resources. With respect to PM2.5 disparity between disadvantaged (i.e., EJ) and advantaged (i.e., non-EJ) communities, we quantify statewide and regional PM2.5 disparity, and examine source emissions associated with the PM2.5 disparity.

Additional Authors:

Associations of respiratory responses with traffic air pollution for asthmatic children attending a roadside school

Wen-Whai Li, University fo Texas at El Paso

A cohort of school children (age 6-12 years) diagnosed with asthma was recruited to participate in a repeated respiratory health outcome measurement study at a roadside elementary school in El Paso, TX. Concurrent continuous monitoring of traffic-related air pollutants of PM2.5, PM10, NO2, and ozone were conducted on the school premise immediately adjacent to an interstate highway. Respiratory health monitoring was performed twice a week by measuring childrenâ€™s exhaled nitric oxide (eNO) levels and pulmonary lung function in terms of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) while asthma symptoms and control questionnaires were administered simultaneously.

We examined longitudinal associations between respiratory health responses and air pollution metrics using generalized linear mixed effect models. We assumed the subject-specific random intercept and included additional control for the repeated measures of the outcome data using a first-order autoregressive covariance structure. Subject-specific factors (race, BMI, caretaker education, etc.) were also considered as potential covariates in secondary analyses including interaction terms of pollutantÃ—factor. The eNO FVC, and FEV1 showed weak, but consistent associations with pollutant concentrations. Significant associations were observed between the 72-hr ozone and increased eNO. All statistical analyses were performed using R version 3.2.2.

Additional Authors:

Data Quality Control System—the Key of Sensor Application in Air Quality Monitoring

Yi Li, Sunset CES Inc

Low-cost air quality sensors have attracted increasing attention in recent years due to their advantages over conventional methods. However, they also face many challenges regarding data quality issues. To mitigate such issues and build a robust sensor-based system, a four-stage calibration quality control system was implemented.

During standard material calibration, each individual sensor is screened for quality assurance by testing its response to known concentrations of standard gases. Then, the selected sensors are assembled into “sensor node” and put in a control chamber to perform simulated environmental calibration. Standard gases and PM are injected into the chamber simultaneously to simulate a wide range of ambient conditions by controlling temperature and humidity. Machine learning and neural-networking algorithms are applied to characterize sensor response. Next, the sensor nodes are installed outdoor with a Federal Reference Method (FEM) monitor in close vicinity to conduct combined supervision calibration. Since the real ambient atmosphere is more complicated than the controlled chamber, the

FEM data is used to train the algorithms for improved sensor response. In regions without FEM nearby, the transfer calibration is conducted using mobile or portable equipment.

The result shows that (1) after standard material and simulated environmental calibration, the correlation between sensors and FEM increased from 0.4-0.6 to over 0.95; (2) after adaptive learning through combined supervision and/or transfer calibration, the correlation improved from 0.6-0.75 to over 0.85. Over 10,000 sensor nodes calibrated through this calibration system have been successfully deployed in more than 80 cities across China.

Additional Authors:

Performance evaluation and community applications of low-cost sensors for particulate matter

Hai-Ying Liu, Department of Environmental Impacts and Sustainability, Norwegian Institute for Air Research

This study reports on the performance of laser-based low-cost sensors for measuring particulate matter (PM) and their use in communities-based applications in Germany and Norway, under the EU H2020 project hackAIR. Five SDS011 PM sensors were collocated at official air quality monitoring stations in Oslo, Norway, three in a dense traffic area (Kirkeveien, Oslo, Norway) and two in a calm-traffic area (Sofiebergeparken, Oslo, Norway), respectively. In addition, more than 200 SDS011 PM sensors were operating in different sites both in Norway and Germany by local community members. Measurements were focused on PM10 and PM2.5. The performance evaluation showed that the SDS011 PM sensors provided a consistent measurement response to measurements of the reference monitoring stations, with R2 value higher than 0.70. By help of data calibration, the R2 value increased from 0.71 to 0.84, using only the internal sensor data without creating external dependencies. By applying a Random Forest algorithm with features such as meteorological observations recorded around the sensors, the R2 value increased from 0.71 to above 0.9. The SDS011 sensor data from the citizen science sites were merged with other data sources such as air quality models, allowing for detailed high-resolution mapping of urban air quality. This study is one of few studies that provides important information on data quality from low-cost PM sensor technologies by using sensor data collected directly by citizens. The performance assessment results indicate that the SDS011 has a great potential for implementation in larger quantities under the real world conditions.

Additional Authors:

Assessing the Perfomance of a Low Cost Ambient Air Quality Sensor Network in Cambridge, UK

Geoff Ma, University of Cambridge

Low cost sensor systems are increasingly being seen as valuable tools in measuring ambient air quality. The cost benefit allows these sensor systems to be deployed as high density networks within urban

environment; providing the significant advantage of increased spacial resolution in comparison to traditional, significantly more costly reference stations.

As the technology has developed, increasing numbers of multiple low cost air quality sensor systems have entered the commercial market. One example of such a sensor system is the AQMesh `Pod' developed by Environmental Instruments[1]. AQMesh Pods are complete sensor systems, containing Alphasense B4 sensors for measuring gaseous species at ambient levels and a proprietary device measuring airborne particle mass. The devices typically measure: NO_2, NO, O_3, CO, CO_2, PM_1, $PM_{2.5}$ and PM_{10}.

In this poster we will present an overview of the `out of the box' performance from a deployment of 20 AQMesh `Pods' within Cambridge, UK, between June 2016 and July 2017. One of the pods was co-located with a reference station, equipped with 2 BAM-1020[2] (Beta Attenuation) monitors for $PM_{2.5}$ and PM_{10} and a M200E[3] chemiluminescent instrument for NO_x. A further eight pods were located across a development area (the Addenbrooke's Hospital Site to the South of the City) and each was co-located with NO_2 Palmes diffusion tubes. An atmospheric dispersion model (ADMS) provided by Cambridge Environmental Research Consultants generated model data at the locations of each pod deployment.

We will present examples of the measurements obtained, interpretation of aspects of the measurements, and comparisons of the AQMesh pod data with data from the co-located reference instrument, the co-located diffusion tubes and the ADMS model.

Additional Authors:

Open Science Hardware

Juan Maestre, University of Texas at Austin

Over the last decade the â€˜do-it-yourselfâ€™ movement has experienced incredible growth, centered primarily around the creation of open source solutions to many technologies historically inaccessible to the public, like the instrumentation for air pollution monitoring. The ability to use, study, replicate, and improve scientific instrumentation is central for experimental science, and plays a crucial role in public life, research and action. Currently, these activities are largely restricted by proprietary instrumentation, thus being unavailable to be fully inspected, evaluated, or customized.

In this work, we present the Global Open Science Hardware Roadmap (http://openhardware.science/global-open-science-hardware-roadmap/), a collaborative effort of 100+ people from different backgrounds and countries working on or with Open Science Hardware (OScH). The roadmap aims at describing and analyzing what is required to realize the vision of OScH being ubiquitous by 2025 by laying out the challenges and opportunities and recommending concrete actions. These actions include: 1) creating support structures; 2) preparing guidelines for hardware designers, funders, users and newcomers on key aspects of OScH development such as quality control and standards compliance, licensing, documentation best-practices, social and ethical aspects of scientific

[1] https://www.env-inst.com
[2] https://metone.com/air-quality-particulate-measurement/regulatory/bam-1020
[3] https://www3.epa.gov/ttnamti1/files/ambient/pm25/spec/M200EUNOySOP.pdf

production; 3) creating a common research agenda to involve the members of the OScH community in the task of elaborating an assessment framework for OScH projects; 4) feeding the results of collaborative research into a common pool of open educational resources; and 5) creating mentorship programs and support networks to increase diversity in OScH community. The Global Open Science Hardware Roadmap document also describes how the OScH community can: i) learn about itself, the context in which it currently operates, and the ways in which OScH impacts society; ii) support each other and forge partnerships to create the conditions under which OScH can flourish; and iii) grow with respect to local differences, increasing the diversity, scale and impact of the OScH community.

The OScH community have developed and is developing numerous open hardware initiatives for air monitoring but much more needs to be done to enable communities to monitor the air they breathe. The roadmap is highly relevant to the air monitoring stakeholders as it aims at making more available â€˜historically inaccessibleâ€™ tools for assessing air quality.

Additional Authors:

Comparison and evaluation of PM2.5 measured in an urban setting using a low-cost optical particle counter and a Federal Equivalent Method Beta Attenuation Monitor

Brian Magi, University of North Carolina at Charlotte

In this study, we evaluate the results of a multi-season field evaluation of a low-cost optical particle counting sensor (Purple Air PA-II) that reports mass concentration of particulate matter with diameter less than 2.5 microns (PM2.5). PA-II is part of a relatively large and growing network of microelectronic (internet-of-things) sensors. We assessed PA-II PM2.5 data collected in the urban air space over Charlotte, North Carolina, from March 2017 through March 2018. The PA-II was co-located with a Federal Equivalent Method Beta Attenuation Monitor (BAM 1022) that is used to monitor PM2.5 for compliance assessment in the Charlotte area, and is maintained by the Mecklenburg County air quality staff. Weather data from a co-located weather station were used to evaluate the role of temperature and relative humidity (RH) on the comparison. Overall, the PA-II PM2.5 measurements are biased high by 45% compared to the BAM 1022 PM2.5. The bias increases linearly from 4% at low RH to over 60% at high RH, but temperature did not notably affect the PA-II PM2.5 measurements. We developed an RH-based correction for PA PM2.5 that reduces the overall bias from 45% to 6%, and mean absolute error from 5.3 to 2.6 micrograms per cubic meter. With this critical correction, our work substantially improves PA-II data and suggests that PA-II may be suitable for air quality, health, and urban aerosol research.

Additional Authors:

Comparison of Three Consumer-Grade Air Quality Monitors Using Different Particles

Gedi Mainelis, Rutgers University

This project compared Foobot, AirVisual Node, and Particulate Matter-Dust Sensor (Libelium Tech.) against DustTrak DRX when measuring particulate matter and against IAQ Monitor (both TSI Inc.) for CO2, humidity, and temperature. Measurements with polystyrene latex (PSL) beads (diameter of 0.72 um and 2.00 um) and Arizona road dust were carried out in CH technologiesâ€™ test chamber; nanosilver particles were used in Rutgers Universityâ€™s Controlled Exposure Facility; particles from cooking event were measured in a home. CO2, humidity, and temperature were measured simultaneously.

For particulate matter measurements, the Pearson correlation coefficients between Libelium, Airvisual, and DRX were always higher than 0.85, while this value for Foobot dropped to 0.72. Most linear correlations were statistically significant with p-values < 0.01. For temperature and humidity measurements, the Pearson correlation coefficients between Foobot, Airvisual and IAQ monitor were higher than 0.92 (p-value <0.01), and the R-squares were higher than 0.84 for linear regressions with IAQ monitor. For CO2 measurements, the Pearson correlation coefficient between Airvisual and IAQ monitor were higher than 0.99 (P-value<0.01), while Foobot and IAQ Monitor had correlation coefficients of 0.56 or even lower. The data show that consumer-grade devices are reliable in some cases; however, testing in different conditions is needed before using them in field studies. This research was funded by NSF grant AGS-1645786.

Additional Authors:

Application of Consumer-grade Air Quality Sensors to Investigate Outdoor Factors Affecting Indoor Air Quality

Gedi Mainelis, Rutgers University

The proliferation of inexpensive consumer-grade air quality sensors offers new opportunities to investigate factors affecting exposures to air pollutants, including exposures indoors.

We investigated the effect of heatwaves on indoor air quality, specifically in vulnerable populations. We recruited 24 seniors residing in three different buildings in Elizabeth, NJ, to participate in a study. We deployed AirVisual air quality sensors (IQAir North America) in their apartments to monitor indoor and outdoor air pollution levels, air temperature, relative humidity, and CO2. Another set of sensors monitored air conditioner (AC) use, window operation, and ozone. The study was performed in summer of 2017.

We found that air pollution levels indoors were affected not only by outdoor pollutant levels and outdoor temperatures but also by building conditions and individual behaviors of seniors, including smoking, use of windows, and their financial ability to use AC. For example, in non-smoking apartments, average PM2.5 levels were 15 Âµg/m3, while in smoking apartments, those levels approached 100 Âµg/m3.

Our experience demonstrated the utility and usability of consumer-grade air quality sensors to study factors affecting indoor air pollution. At the same time, data suggest that long-term adaptation and resilience to climate change could beneï¬t from an integrated resident-to-building-to-neighborhood evaluation. This research was funded by NSF grant AGSâ€1645786.

Additional Authors:

Performance testing of next-generation air sensors during wildfires

Anna Mebust, EPA Region 9

Recent increases in the frequency and severity of wildfires have led to increased smoke exposure in communities within western states. The current approach to wildfire smoke risk communication is often limited by the relative sparsity of existing regulatory monitoring networks in rural locations where wildfire smoke impacts are more often experienced. Air sensors may be able to fill spatial and temporal gaps in the existing monitoring network and better inform the public â€“ and sensitive populations in particular â€“ about their air quality and smoke exposure risk during wildfires. However, it is critical to understand how emerging air sensor technologies perform in these settings to ensure appropriate communication about potential exposure to the public. This poster will discuss preliminary results from an EPA research project to deploy next-generation PM2.5 air sensors during a wildland fire event and evaluate sensor performance and accuracy under smoky conditions. This project also aims to address questions related to the results of the performance evaluation, such as how to incorporate sensor data into the existing framework for wildfire air quality monitoring and how to communicate results from these sensor datasets to the public, schools, health officials, and others.

Additional Authors:

Exploring Efficient Mapping Approaches with the Google Street View Mobile Monitoring Dataset

Kyle Messier, University of Texas at Austin

Approaches to minimize the resources required to successfully map an urban areaâ€™s air quality may help improve the scalability of the mobile monitoring approach. This study utilized two Google Street View cars with fast-response instruments to collect ~ 3.6 million measurements of nitric oxide (NO) and black carbon (BC) measurements in Oakland, CA over 2 y. Multiple strategies to efficiently map spatial air quality patterns were explored. First, a data-only mapping approach where the number of repeated visits to each road was minimized. Second, we combine our data with a land use regression-kriging (LUR-K) model to predict at unobserved locations, and consider sampling schemes where only a subset of a cityâ€™s roads or repeat visits are measured. Lastly, we simulate sensor performance degradation scenarios including sampling frequency, averaging time, Gaussian noise, and serially correlated errors. Data-only mapping can have surprisingly modest data requirements and surpass LUR-K in approximating long-term trends within 6-8 drive days. LUR-K models can produce valid predictions of air quality quickly and when it is not possible to sample air quality on every road. The simulations demonstrate that an air quality mapping approach with repeated observations can be surprisingly robust to these common types of measurement degradation.

Additional Authors:

Rapid Trace Detection of Formaldehyde using Chemical Sensors Based on Organic Nanofibers

Angela Mitcham, Vaporsense

Formaldehyde is considered especially harmful as an indoor air pollutant since most of the population spends 80% of their time indoors where the concentration can be up to 10 times higher than outside. Organic nanofiber sensors can monitor for common trace air toxics, such as formaldehyde. Vaporsens has developed and evaluated an array of nanofiber sensors to detect formaldehyde down to the sub parts per billion range in varied temperature and humidity conditions and. diverse environments. The limit of detection was demonstrated to be 1 ppb, which greatly exceeds safety standards for exposure in both indoor and outdoor environments. These sensors demonstrate essentially no cross reactivity with ethanol, and other common interferents that hinder effectiveness of other sensor technologies. Real time, selective, trace detection of formaldehyde and other air toxics is possible with organic nanofiber chemical sensors. The sensors were placed at a National Air Toxics Trends Station in Bountiful, Utah (part of a study by the U.S. Environmental Protection Agency) and monitored formaldehyde in a complex, outdoor environment. The sensors showed strong correlation to formaldehyde quantified by the accepted method (liquid chromatography-mass spectrometry).

Additional Authors:

Low-cost Sensor Array Devices as a Method for Reliable Assessment of Exposure to Traffic-related Air Pollution

Natalia Mykhaylova, University of Toronto

The exposure to air pollutant mixtures is a well-known risk factor for inducing and increasing the severity of diseases. For real-time detection and monitoring of pollutant exposure, sensor arrays are an optimum choice because of versatility and aptitude for tracking composite multi-pollutant exposure. While many low-cost air pollution monitoring devices have been proposed, several underexplored opportunities remain, including sensor-derived pollution indices, source analysis and exposure assessment.

A thorough investigation of different low-cost commercial gas and particulate matter sensors from 5 manufacturers has been conducted and best-performing sensors were identified. A device for monitoring air quality has been developed and tested. Each device consists of an array of commercially available metal oxide semiconductor for monitoring NOx and O3, CO, CO2 and optical sensors for monitoring PM2.5. Level of pollutant exposure has been characterized at different locations in Toronto over 3 different campaigns between 2013 and 2016. These deployments allowed long-term sensor performance to be evaluated under different meteorological conditions as well as different ranges of pollutant concentrations.

Analysis of a large range of gas sensors revealed several key challenges, including high intra-sensor variability, interference from temperature and nonlinearity. Air quality health index estimation from sensor readings was successfully demonstrated. Three aspects of device reproducibility were evaluated: drift over time, impact of interferences and impact of site-specific mixtures. Three categories of approaches for improving sensor accuracy and reproducibility were tested: nonlinear calibration models, variable transformations and training data selection. Model reproducibility, ability to adjust for multiple combinations of interferences and ability to resolve sites was improved when devices were calibrated at multiple sites. Analysis showed that both short-term and long-term temporal patterns could be resolved and compared at different sites. Background subtraction helped further emphasize the differences and rank sites in terms traffic-related pollution.

Additional Authors:

Overcoming Environmental Variability

Elizabeth Noth, University of California, Berkeley

One of the most challenging aspects of exposure assessment for epidemiology studies is collection of spatially and temporally refined data. As reliability and accuracy of new air pollution sensors improve, we address how best to use them in exposure assessment for epidemiology. For very short term or small epidemiology studies one can take advantage of the cheap, portable nature of sensors to collect personal data. However, for annual exposures, sensor data may be inputs to air pollution models. The

recent use of sensors on mobile platforms is a potential solution to the challenge of adequate spatial coverage in field sampling. How much time is needed at a given location to meaningfully characterize the pollution concentrations? To simulate mobile monitoring, we compared the measured 24-hour annual mean black carbon concentration during 2016 to annual means calculated by 5, 10, and 24 hours of sampling. The BC was measured with an Aethalometer (AE33, Magee Scientific). In 10,000 sets of 5 random hours, only 17% of the sets fall within 10% of the true annual mean; 34% fall within 20%, and 50% fall within 30%. For sets of 10 random hours, the corresponding values are 24%, 46%, and 65%; and for 24 hours are 36%, 65%, and 84%. The acceptable uncertainty is dependent on the scientific purpose and requirements of the investigation. Next steps are to evaluate stratified random sampling (within days and seasons) and to repeat the simulations with NO2 and PAH data collection.

Additional Authors:

Air Pollution Hyperlocal Mapping Using Fleet Vehicles

Aileen Nowlan, Environmental Defense Fund

Background: Studies indicate that air pollution can vary by 5 to 8 times within a city block. Hotspots are identified when air pollution is measured in 30 m segments. Granularity enabled new research that indicates that air pollution has more severe health consequences. While the need for collecting hyperlocal air pollution insights is clear, further innovation is needed to develop scalable solutions.

Objective: We quantify the number of fleet vehicles required to measure hyperlocal air pollution in sample North American cities by repeated driving on their regular routes over 3 or 6 months. We describe several factors that make fleets conducive to becoming an air pollution sensing platform. With this new assessment, we give direction to technology innovators, fleets and others as they design instruments and methodologies.

Methods: Aggregate, anonymous statistical analysis of a data set of over 1 million drive histories collected by Geotab telematics units.

Results: In one city, the top 50 fleet vehicles covered almost 80% of the entire city in 6 months. In five cities with under a million residents, the top fleet covers 60% â€“ 80% of the city with just 30 vehicles, and 50% or more with just 10 vehicles.

Conclusions: Hyperlocal air pollution mapping can be accomplished with a modest number of fleet vehicles, and instruments and operations should be designed to meet that challenge.

Additional Authors:

Advancing Direct Reading and Sensor Technologies for Occupational Safety and Health: The NIOSH right sensors used right initiative for safety, health, well-being, and productivity

Justin Patts, NIOSH

The Air Sensors International Conference provides a robust forum to engage major issues surrounding the selection, calibration, use, interpretation, and limitations of direct reading sensors for occupational health. Questions include: Do these methods accurately measure what they are supposed to be measuring? How can they be adequately calibrated and validated to enable hazard-informed exposure assessment and exposure-informed hazard assessment? When are they limited to use for screening and when can they provide accurate characterizations of specific hazards, exposures, and resulting risks? Given the dramatically increasing volume, velocity, and variety of sensor data, how can those data be feasibly analyzed and interpreted? To advance its capabilities and partnerships to anticipate and recognize hazards, evaluate exposures, and control and confirm protection of workers from all hazards, the National Institute for Occupational Safety and Health has established the NIOSH Center for Direct Reading and Sensor Technologies. The Center uses a â€œright sensors used rightâ€ approach to 1) develop guidance pertinent to direct reading methods and sensors such as validation and performance characteristics, 2) develop training protocols, 3) establish partnerships to collaborate in the Centerâ€™s activities, and 4) foster a national sensor research agenda to understand, communicate, and manage risks to worker safety, health, well-being, and productivity in a timely and cost-effective manner.

Additional Authors:

Evaluation and Use of Sensors for Monitoring Smoke Impacts of Wildfires and Prescribed Burns

Charles Pearson, California Air Resources Board/Incident Air Monitoring

In California, wildfires and prescribed fire projects used for purposes of forest management are increasing in frequency, magnitude and duration. These events produce significant amounts of particulate air pollution impacting both the health and prosperity of local communities. The California Air Resources Board (CARB), along with local air quality management districts, have begun to examine using new sensor technologies to more effectively measure air quality during these episodes. To understand how the devices can complement and benefit existing monitoring platforms, CARB conducted a study comparing a limited number of sensors to other conventional and non-conventional particulate monitoring instruments in both field and smoke chamber environments to determine their suitability for these purposes. The presentation will include results of the instrument evaluation and deployment of sensors in advance of 2018 fire season.

Additional Authors:

Essential Research Questions and Progress in the Use of Unmanned Aerial Vehicles with Miniaturized Sensors for Atmospheric Environment Monitoring

Zhong-Ren Peng, Center for Intelligent Transportation Systems and Unmanned Aerial Systems Application, State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China

Additional Authors:

Internet of Things (IoT) for Air Environment Monitoring: A study

Poonam Prasad, CSIR-National Environmental Engineering Research Institute

ABSTRACT:

Internet of Things (IoT) is emerging as a very popular branch in Information Communication and Technology (ICT). It is estimated that by 2020, 50 billion devices would be connected to internet. IoT in future would connect all gadgets, human beings and everything in the surrounding on a single network and all living and non-living things could communicate and exchange information. IoT is transforming each and everything into an intelligent virtual device. This paper focuses on evolution, history, architecture, features, technologies, protocols and applications of IoT especially on environmental domain. The objective of this paper is to observe the trend and future scope of IoT in environmental domain targeting air quality monitoring which is a major concern these days. Moreover, there are several new research & development activities going on environmental IoT as the analytical monitoring methods are time consuming and require technical trained manpower.

KEYWORDS: Internet of Things, Environment, IoT Protocols, Sensors, network

Additional Authors:

Estimating PM2.5 from Photographs using Physics-based Modeling and Machine Learning

Batsal Pudasaini, Clarkson University

Accurate determination of the impacts of aerosol particles on human health is made challenging by the lack of high-resolution air quality data. Globally, PM2.5 monitoring sites are limited in number, as they require extensive manpower and equipment to operate. This research takes a physics-based approach in estimating PM2.5 by analyzing photographs from different locations. An image captured by a camera is impacted by the presence of aerosol particles because of a combination of light scattering and extinction by particles between the camera and the objects during image capture. We develop a governing equation that relates camera signal to the properties of aerosol, the incident light, and the image being captured. From inversion of this integral equation, we establish an expression for turbidity and estimate PM2.5 from these measurements. Analyzing 3-years of images captured from a camera at a fixed location (downtown Chicago), we calculate turbidity and compare the values against PM2.5

values estimated from nearby EPA monitoring sites. Our calculated turbidity values are seen to have a statistically significant positive linear correlation to the estimated PM2.5 values. Combining information from meteorological conditions to the turbidity values is seen to create a further improved model to estimate PM2.5. We will present our theoretical approach and the details of our prediction capabilities of PM2.5 in our presentation.

Additional Authors:

Low-cost sensor network to improve air quality management capability: a case study in Jining, China

Xiaohui Qiao, Tsinghua University

Severe fine particulate matter (PM2.5) pollution along with higher mortality risk raised unprecedented public awareness in China. To realize Chinese governmentâ€™s urgent vision of improving air quality, more refined actions are needed. However, the spatial resolution of current air quality monitoring system is not enough to support that. The emergence of low-cost, compact PM sensors enables measurement at high spatial resolution that can provide new opportunities to couple with the existing monitoring system and to improve air quality management capability. We established a monitoring network with 161 packaged low-cost sensor platforms in Jining, a city in eastern China, to couple with its 8 regular air quality monitoring stations. Geographic information analysis was performed to integrate the sensor network with administrative units and population distributions. The sensor network helps the government at township level to design and implement air quality management strategies. Based on the network, ranking among township can be established and be used to motivate and to guide air pollution control at the township level.

Through laboratory and field evaluation of current available PM2.5 sensors, the PM sensor from Oneair was selected and integrated into a platform together with other sensors for gaseous species. Depending on the availability, either utility power or solar panel was used to power the platform. Data measured by the platform (including the GPS information and meteorology parameters) are transferred to the main database server through the GPRS wireless network. In this talk, data from Nov. 2016 to Feb. 2017 were taken as an example. Through comparisons with standard stations and adjacent platforms, we conclude that the network was running in good condition and the data quality are good. Based these data, air quality was assessed at the township level by ranking them from three perspectives, i.e., ambient PM2.5 concentration, population-weighted PM2.5 concentration, and PM2.5 concentrations of all the platforms. Population-weighted PM2.5 helps to take exposure into consideration. The rank among all the platforms helps to find out potential emission sources. With the help of this network, effective control measures were designed and implemented which lead to significant improvement in Jiningâ€™s air quality.

Additional Authors:

An Automated Microenvironmental Aerosol Sampler (AMAS) For Location/Activity Exposure Assessment

Casey Quinn, Colorado State University

Existing methods for assessing time-integrated personal exposure to pollutants are cumbersome and relatively expensive, especially for individual microenvironments. To address these limitations, we developed an automated microenvironmental aerosol sampler (AMAS). The AMAS was derived from the Ultrasonic Personal Aerosol Sampler (UPAS), and was designed to be small (slightly larger than a smartphone) and light enough (300 g) to be worn by school-aged children. The AMAS features a four-channel flow manifold that is used to sample particulate matter from microenvironments (i.e., home, school, transit) through individual PM2.5 cyclones onto separate 15 mm filters. An algorithm is used to detect pre-determined microenvironments using on-board sensor data (GPS, light intensity, temperature, motion). The AMAS was validated through a pilot study and is currently still in use in an on-going study in Fresno, CA. The samples collected to date were analyzed for black carbon (BC) and oxidative potential (OP). The median home exposures for BC and OP were 238% and 108% greater than in school and 145% and 79% than in the â€˜otherâ€™ microenvironment. During a 48-hr period with high mean ambient BC concentrations (1.4 Âµg m-3), mean(one standard deviation) home BC exposure was 1.7(0.8) Âµg and demonstrates exposure variability between participants (n=8). These results indicate that the AMAS is a feasible approach for resolving personal exposure to PM2.5 BC and OP within distinct microenvironments.

Additional Authors:

Assessment of Air Pollutant Spatial Trends in PeÃuelas, Puerto Rico Using Low-Cost Air Quality Sensors

Stephen Reece, ORISE Participant hosted by US EPA

A citizen science led effort conducted between October 2016â€“February 2017 collected real-time measurements of the particulate matter size fraction 2.5 micron (PM2.5), total volatile organic compounds (tVOCs), and nitrogen dioxide (NO2) across eight locations in the south area of Puerto Rico (Tallaboa-EncarnaciÃ³n, PeÃ±uelas) with little historical data on pollutant spatial variability. Pollutant concentrations were measured at 5-minute intervals using the EPA developed Citizen Science Air Monitor (CSAM), a package of low-cost (<$2,500) original equipment manufacturer (OEM) sensors. In addition to the CSAMs, meteorological parameters (wind speed, wind directions, temperature, relative humidity) were obtained from four collocated Vantage Vue weather stations.

The 1-hour averaged concentrations for the PM2.5, tVOC, and NO2 sensors ranged between 0.3-136.2 Âµg/m3, 0.9-1220.2 ppb, and 0.9-50.6 ppb, respectfully. Evaluation of the weather stations indicated winds were active (wind speeds â‰¥2 mph) between 17%-51% of the deployment, predominantly from the east-southeast direction. Initial comparisons of 1-hour averaged pollutant concentrations and meteorological parameters observed pollutant concentrations change with local wind directions indicating unique micro-environments across locations. Supplemental analysis will use wind-based

receptor models and local 5-minute weather data from Weather Underground to calculate local back-trajectories to assess the impact of local sources.

Additional Authors:

Impact of Home Remediation on Respiratory Symptoms

AJ Salkoski, Alaska Native Tribal Health Consortium

Adverse indoor air quality (IAQ) and inadequate housing can contribute to lower respiratory tract infections (LRTIs) and lung conditions in children. Rural Alaska Native children experience high rates of LRTIs and chronic lung conditions. 63 homes in 8 communities were enrolled; 60 homes completed the study. Home remediation included ventilation improvements, woodstove replacement, and/or new diesel-fired furnaces. VOCs and PM2.5 concentrations were significantly associated with # persons in the house and wood use as primary heat source; PM2.5 was associated with smoking. VOCs, primary wood heat and PM2.5 were associated with increased respiratory symptoms.

Additional Authors:

Data fusion techniques for mapping urban air quality using low-cost sensor networks

Philipp Schneider, NILU â€“ Norwegian Institute for Air Research

The technology of low-cost sensors for air pollution is developing rapidly. Many initiatives worldwide are deploying networks of such sensors. The observations provided by such sensors are improving, yet they are still often prone to high uncertainties, making a direct use of their data challenging. However, merging data from such networks with other data sources such as air quality models can add value to the observations and allows for detailed high-resolution mapping of urban air quality. We present a novel approach for combining observations from low-cost air quality sensors with model data, allowing near-real-time, high-resolution maps of urban air quality. The approach is based on geostatistical data fusion and combines observations with model data in a mathematically objective way, thus adding value to both the observations and the model. Using data from sensor networks deployed in the city of Oslo, Norway, we present the algorithm and examples of resulting urban air quality maps. We demonstrate that the method produces spatially realistic hourly concentration fields, and is able to reproduce typical diurnal cycles. We also show validation results indicating that the method is capable of reproducing the city-wide averaged official NO2 concentration with R2 values of around 0.9. Overall the technique is a robust way of extracting useful information from uncertain sensor data using a time-invariant model dataset and the knowledge contained within an entire sensor network.

Additional Authors:

Quality Control for Networks of Low-Cost Air Pollution Sensors

Edmund Seto, University of Washington

Low-cost air pollution sensors may be used in large numbers for epidemiologic studies to improve exposure assessment. A challenge of using this technology in research is identifying broken sensors in a timely fashion in order to limit bad data. We developed quality control (QC) procedures for a network of over 75 monitors deployed across multiple cities in the US. Each monitor contains 16 sensors and transmits particulate matter, gas (NO2, NO, O3, CO) and environmental condition data to a server every 5 minutes. We used the open source statistical software R to produce automated and reproducible reports summarizing sensor performance with statistical measures and graphics. We flagged sensors for measures such as data completeness, departure from typical pollutant levels or typical daily variation and correlation of values both across duplicate sensors within a monitor and across monitors in nearby geographic locations. A major challenge was distilling information from this large network of sensors into summaries that were concise and useable to the field staff who maintain the network. Our approach was to create multiple navigation panes, several levels of QC flagging and a report organization that highlighted the highest priority issues (based on weighted QC criteria flags), to allow staff to efficiently identify quality issues. Our work may benefit other research groups managing large networks that depend upon quality data for health effect studies.

Additional Authors:

Use of Low-cost Air Pollution Sensors in an Air Pollution Cohort Study

Lianne Sheppard, University of Washington

Incorporating modern air pollution sensor technology into epidemiologic cohort studies is appealing because of its low cost, allowing much better spatial representation of pollution exposure. Exposure sampling design can also leverage emerging understanding from measurement error correction methods that the monitoring network design should be spatially compatible with the locations where the health study participants live. However, research has not yet been conducted to determine whether these low-cost sensor data are reliable, accurate, and consistent enough to use for epidemiological study exposure assessment. Our scientific goal is to estimate individual-level long-term average exposures to PM2.5 and oxides of nitrogen for inference about the effects of air pollution on brain health. To accomplish this we are developing new spatio-temporal pollution predictions based on recently collected low-cost sensor data combined with existing ambient monitoring data. I will discuss the necessary quality control criteria for using the low-cost sensor data in a spatio-temporal prediction model, including calibration of these measurements to federal reference measurements. I will present the improvement in the performance of the spatio-temporal predictions from adding the low-cost sensor data and discuss the implications of these results for improving inference from epidemiologic cohort studies such as the Adult Changes in Thought Air Pollution study.

Additional Authors:

Remote sensing data analytics accommodating petrochemical/chemical industrial fence-line monitoring challenges

Gilad Shpitzer, Atmosfir Optics

New regulations were recently introduced to enforce better detection and control of fugitive emissions from petrochemical and chemical industries, therefore robust solutions for sensitive real-time and spatial monitoring are required. An automation of open path FTIR was developed as a high-end remote sensing solution for multicomponent analysis of VOC emissions and for characterization of non-point emission sources, based on USEPA methods TO-16 and OTM-10. An innovative spectral averaging algorithm was developed and implemented to form a dynamic background spectrum and reduce measurement noises. The current research evaluated different spectral averaging time-spans for short term-high concentration vs long term- low concentration events. The different time spans for averaging were simultaneously implemented in an ongoing automatic monitoring of two different sites during 2016-2018. Overall the algorithm was found to improve the measurement sensitivity by a factor of 5 â€“ 10 as related to the time-spans. Spectral averaging over narrow time-spans showed efficacy for real-time detection of short-term acute events, e.g., Benzene emissions due to human errors and equipment failures, that are not accounted in annual reported data. It also enabled spatial and temporal characterization of the emission to assist a root cause analysis in order to reduce the overall annual emission rate. Data sets from the monitored sites will be presented to demonstrate the drawn conclusions.

Additional Authors:

Small Air Quality Sensor Applications to Improve Community Engagement in Western Canada

James Sievwright, Environment and Climate Change Canada

Environment and Climate Change Canada recognizes the value of small, inexpensive air quality sensors and their potential for improving community engagement around air quality issues. Western and northern Canada remains a challenge for air quality monitoring due to the number of small, remote communitiesâ€”particularly first nations communitiesâ€”at risk for forest fire smoke impacts in a diverse range of terrains and climates. This work describes preliminary efforts and results from a pilot project to assess the applicability of small air quality sensors to improve community engagement and their potential role in providing air quality information and tools to decision makers in small communities.

Additional Authors:

Consumer Indoor Air Quality Monitors Performance for Residential Sources of Fine Particle

Brett Singer, Lawrence Berkeley National Lab

In this study, we generated particles from typical residential sources in a 120 m3 laboratory and measured time-concentration profiles using seven consumer monitors (2-3 units each), two research monitors (Thermo pDR-1500, MetOne BT-645), a Grimm Mini Wide-Range Aerosol Spectrometer (GRM), and a Tapered Element Oscillating Microbalance with Filter Dynamic Measurement System (FDMS), which is a federal equivalent method (FEM) for PM2.5. Sources included recreational combustion (candles, cigarettes, incense), cooking activities, an unfiltered ultrasonic humidifier, and dust. FDMS measurements along with filter samples and known or estimated densities were used to adjust the GRM to obtain time-resolved PM2.5 mass concentrations. Data from the research monitors and four of the consumer monitors â€“ AirBeam, AirVisual, Foobot, Purple Air â€“ were time-correlated and within a factor of two of the estimated mass concentrations for most sources. All seven of the consumer and both research monitors substantially under-reported or missed events for which the emitted mass was comprised of particles smaller than 0.3 Î¼m diameter. But the VOC sensors on two of the consumer monitors responded to the sources that produced only the sub-0.3 Î¼m particles.

Additional Authors:

Deployment of low-cost PM sensors in the highly polluted urban environment in Nepal: Field performance of the Alphasense PM sensor

Ashish Singh, Institute for Advanced Sustainability Studies (IASS)

Regulatory air quality monitoring infrastructure in many cities or town in Nepal is still a distant goal and often superseded by the priorities for other public infrastructure needs. The recent improvement in low-cost sensors (LCS) have shown that such sensors can provide indicative air quality information for indoor to outdoor. With in-situ calibration, quantitative air quality measurements are also possible.

This paper looks at the performance of low-cost particulate matter (PM) sensors to determine the suitability of LCS use in the Kathmandu Valley, a highly polluted region with strong seasonable variability in emission sources. The sensor evaluation primarily focused on the Alphasense OPC-N2. 15 identical units were packaged into fully weatherproof systems with an independent power supply (via DC-solar charging) and data logging capabilities. To our knowledge, this is the first field performance evaluation of Alphasense OPC-N2 optical particle counter in Nepal. In addition, a preliminary evaluation for SDS011 and Plantower PM sensors will also be presented. The evaluation will address design and fabrication issues, in addition to sensor validation with a reference PM sensor. The sensor validation steps include comparison with co-located TSI SMPS and OPS particle number size distribution and gravimetric reference instruments to aid in determining a representative aerosol density distribution. The role of environmental factors such as humidity and emission sources will be discussed. Post-calibration deployment results (in PM mass/number, temperature and humidity) in 15 locations in the Kathmandu Valley from May 2017-May 2018 will be shown.

Additional Authors:

Approaches to Sensor Calibration

Levi Stanton, Sonoma Technology, Inc.

Thousands of small air quality sensors are deployed throughout the world, yet data assimilation between different devices is complicated by the dozens of different approaches to reconciling sensor data with measurements from regulatory-grade instrumentation. The range of approaches includes chamber testing, collocation, and the development and implementation of complex machine learning techniques. Some collocation methods are designed to be implemented in a â€œfirmwareâ€ approach, where sensor performance is characterized and used for calibration until future collocation is performed. Other attempts have been made to permanently collocate several sensors with a regulatory monitor and apply the calibration factor determined from that collocation to an entire network of sensors. Some models adjust raw sensor measurements for temperature and/or humidity influences, while others also attempt to adjust measurements based on local emission information and the proximity of the sensor to potential sources. In situ attempts, which do not require the sensor to be physically moved, have been based on statistical models, a mobile sensor deemed the â€œgolden sensor,â€ or collocation with regulatory grade instrumentation built into a mobile platform. This work explores the results of the different methods for reconciling small sensor data with measurements from regulatory-grade instrumentation, how the methods could be used in tandem, and the future of air sensor network reconciliation.

Additional Authors:

Field Experience from 6 Months Operation of a Supplementary Air Quality Sensor Network in Helsinki, Finland

Jari Suikkola, Vaisala

Traditionally, air quality is measured at reference stations that are equipped with separate high-quality instruments for every desired parameter. However, these stations come at high cost and require a large container and hence they are distributed sparsely. During recent years, there has been a growing interest in supplementary air quality networks that consist of lower cost sensors that can be distributed more densely, thus improving the spatial resolution of the air quality measurements.

In 2017 several Finnish companies, research institutes and authorities started Helsinki Metropolitan Air Quality Testbed (HAQT) project. In the project, a supplementary air quality network consisting of 15 compact sensors and 3 fine particle analyzers was established in the Helsinki Metropolitan area. The sensors were installed to locations not covered by the reference measurement sites to provide complementary information on air quality, and to support air quality modelling.

We report the operational experience from the first 6 months of operating the network of 15 compact sensors, such as maintenance, equipment uptime, data quality and stability as well as correlation studies with reference analyzers. During an evaluation period before distributing the sensors in the network, the coefficients of determination R2 for the 15 sensors ranged between 0.70 and 0.90 for NO2, 0.68 and 0.90 for CO, and 0.50 and 0.94 for PM10 against reference instruments in a test site.

Additional Authors:

Impact of high pollution episodes on the indoor air quality in schools and its implications on health-based air quality index

Li SUN, City University of Hong Kong

Since 2014, Air Quality Health Index (AQHI) has been used in Hong Kong to inform public a short-term health risk of air pollution and assist the public to take precautionary measures. AQHI are reported hourly by Air Quality Monitoring Stations on a scale of 1 to 10 and 10+. When it reaches to 8 or above, citizens are advised to reduce or avoid outdoor activities. Whether the indoor environment could still be a haven is unconfirmed. Students, as one of the vulnerable populations, spend one third to half of their days in schools, where indoor AQ could be easily affected by outdoor AQ. Their exposure in schools is under our concern because poor indoor AQ may have influence both on health and learning outcomes. Extraordinary AQHI was reported during 12th to 17th Sept 2017 in Hong Kong. In this study, customs-designed sensor units were placed in 5 schools of Hong Kong covering the above-mentioned period, measuring indoor and outdoor air pollutant concentrations simultaneously, including NO2, O3 and PM. Corresponding indoor AQHI were generated based on the same calculation method for ambient AQHI. Outdoor air pollutant concentration of each investigated school showed similar variation trend with closest AQMS but different concentration levels, which was mainly due to the local natures of each school. When the outdoor AQHI was high on weekends, the indoor AQHI was also high when air conditioning was not used. Other times, indoor AQHI was not found out of the limit. However, it is still possible that the indoor AQHI could also be severe when outdoor air quality is poor. Further actions should be taken from schools and parents to protect vulnerable students from serious air pollution.

Additional Authors:

Low cost air monitors: their role, best practices and lessons learned from the field

Ken Szutu, Citizen Air Monitoring Network

Often people question the usefulness of low cost monitors. We are going to share with you our experiences from the Citizen Air Monitoring Network – A citizen initiated and funded network using 25 PurpleAir monitors around Vallejo, California.

We will discuss what motivated us to start this network; what we see as lacking from the current system; where we are now and where we want to be in the future.

We will compare our low cost monitor with the EPA official monitor and show you the differences.

We will talk about how we use them in daily life; how they help us and what the limitations are. We will also cover support services to make them more useful to wider communities.

Additional Authors:

Portable Dilution Sampling Equipment for Climate-Relevant Emission Source Characterization

Ryan Thompson, Mountain Air Engineering

Solid fuel combustion sources can be difficult to characterize due to high particle emissions, large emission fluctuations, and remote locations. The Ratnoze dilution sampler was developed to meet current needs in climateâ€“relevant emission characterization. The Ratnoze is a portable sampling kit (sensor box, probe, dilution system, and accessories) that measures a suite of climate-relevant species. The sensor box includes filter holders for PM2.5 gravimetric and composition analysis, real-time particle optical scattering and absorption sensors, and gas sensors for carbon dioxide, carbon monoxide, sulfur dioxide, hydrogen sulfide, nitrogen oxides, and hydrocarbons.

The Ratnoze equipment can be used to determine emission factors, emission rates, emission patterns, and combustion diagnostics for a wide range of combustion sources (cookstoves, heating stoves, boilers, kilns, and vehicles) and a wide range of fuels (biomass, coal, liquid and gas). The equipment has been used to characterize emissions of several types of brick kilns in India, Nepal, and Colombia that burn coal, wood, industrial fuel waste, and agricultural residue.

Additional Authors:

Combining an Array of Low Cost Sensors and Pattern Recognition Techniques to Attribute VOCs to Local Sources

Jacob Thorson, University of Colorado Boulder

Determining the source(s) of pollutants is one of the most challenging parts of studying air quality within a community, especially in complex urban environments. Current techniques for attributing air toxics and other VOCs to their sources rely on using wind data or measuring tracer gases. This work uses an array of low-cost sensors to quantify the contribution of different sources to the measured VOC concentrations without speciating the component gases.

Data were collected using our air quality platforms that included a total of 15 unique, commercially available, low-cost gas sensors. The sensor arrays included metal oxide, electrochemical, nondispersive infrared, and photoionization detector sensors. Additionally, different models of each type of sensor were included to take advantage of differences in their target gases and cross-sensitivities. The sensor arrays were exposed to mixtures that included commercial fuels, other hydrocarbons, and non-VOC gases that were selected to approximate mixtures produced by common VOC sources including gas stations, highways, and natural gas transmission lines. We will share the results of several statistical models and compare their success at quantifying and classifying complex pollution mixtures. When

combined with local wind data, this classification could provide another strong indicator of local sources of measured VOCs.

Additional Authors:

Compact air quality sensor measurements in an urban street canyon during a street dust season

Hilkka Timonen, Finnish Meteorological Institute

In Finland, annual street dust episodes occurring during the spring time exposes citizens to high concentrations of PM10. Additionally, high NO2 levels have been previously observed in street canyons, especially during inversion episodes, which also deteriorate air quality. To combat these sources of adverse health effects, compact aerosol sensors have been proposed to assess the spatial and temporal variability of traffic related pollutants; PM10, NO2 and CO.

Two commercial air quality sensors (Vaisala AQT420) were used simultaneously with the reference instruments at an air quality measurement site located in a busy street canyon (MÃ¤kelÃ¤nkatu 50, 28,000 vehicles per workday) in Helsinki, Finland. For the mass concentration of PM10, the performance of the AQT420 sensor was evaluated against Tapered Element Oscillating Microbalance (TEOM 1405) reference monitor. In addition, Aerodynamic Particle Sizer (APS 3321) was used to analyze aerosol size distribution data. The Horiba APMA-360CE and Environnement CO12M instruments were used to evaluate NO2 and CO concentrations measured withthe AQT420, respectively. The results showed fairly good correlation in raw data comparisons and thus signified the utility of sensor type measurements which, under right circumstances, can be used to measure targeted pollution parameters in adequate detail.

This study was funded and by the Regional innovations and experimentations funds AIKO, governed by the Helsinki Regional Council (project HAQT, AIKO014).

Additional Authors:

Chemiresistive sensors for real-time NOx monitoring

David Tomecek, University of Chemistry and Technology, Prague

Phthalocyanine materials are well known for their high affinity to NO2. This affinity makes them promising candidates for the fabrication of sensitive layers devoted to detect presence of this pollutant at low ppb concentrations in air. However, it is also this affinity which limits the speed of a sensor recovery process which results in a long period of the measurement (typ. 15 min for a single measurement) and elevated temperatures (typ. 150 â€“ 200 Â°C) that shorten sensor lifetimes.

This contribution presents a robust, repeatable and low-cost method that allows to shrink the length of the measurement cycle to 2 min at only mildly elevated temperatures (50 â€“ 100 Â°C) preserving sensitivity and a low detection limit. The method is based on short NO2 exposition and short illumination of the sensitive layer by intensive UV-VIS light. Small doses of NO2 let the sensor operate in

kinetic regime excluding the long-lasting processes such as NO2 diffusion in layer volume and particularly itâ€™s diffusion out of the material during the recovery period. The recovery period is further shortened by the application of light which, at certain conditions, significantly increases the rate of NO2 desorption without the disruption of several other equilibria (especially O2 and H2O adsorbates) that co-determine the value of sensor electrical resistance.

The response was found to be a linear function of NO2 concentration in the range from 0 to 900 ppb. The detection limit was calculated as 20 ppb.

Additional Authors:

Low Cost particle sensing (for kids)

AJ uppal, Los Altos High School

When the air we breathe is polluted it impacts our immediate health and also has long-term effects causing asthma, heart disease, diabetes and even cancer. Unicef recently reported that over 300 million kids breathe highly toxic air. Ideally everyone should know the quality of the approx. 3000 gallons of air they breathe every day. While there have been many attempts at air monitoring for ordinary citizens, one of the main challenges is making sense of the data, calibrating measurements so that they relate to data from standard instruments. Other challenges are cost and portability, can everyone aspire to have a low cost personal air monitor below $100 ?

The PICKLEÂ is a personal calibrated air pollution monitor using photoelectric sensors, cloud services for time-series and calibration and Techshop laser cutting. TheÂ PICKLEÂ is built on open software and hardware and is not one fixed design. I will demonstrate different versions of theÂ PICKLEÂ using a variety of sensors with different air flows and sensitivities. The enclosure is designed around laser cut acrylic at the TechShop and each monitor can be assembled and disassembled in minutes. From this session, participants will get the outline to build their own personal air pollution monitor, understand the challenges of calibration and the fun of connecting the monitor to the cloud.

I will need table top space to lay out several of the PICKLE air pollution monitors, an internet connection to show the cloud analytics, and an AV projector for the slides.

This topic was also presented by the author at the Youth For Environment and Sustainability Conference in 2017 at BAAQMD while the author was an intern at BAAQMD. The author won a fellowship at the SolidCon event in SF in 2015 and was showing early prototypes of the PICKLE there.

The author is a high school senior (graduating) and has had a personal journey in pollution and particle sensing. His website and blog are at indiaairquality.com

Additional Authors:

A cost effective ambient air quality monitoring system for evaluation urban air quality

Monika Vadali, MN Pollution control agency

Effective urban air quality management requires robust and accurate ambient air quality data; however, equipment cost and siting are frequently barriers to this task. To meet this challenge, the Minnesota Pollution Control Agency (MPCA) has begun a two year project to help evaluate relatively inexpensive air quality sensors and explore how air quality differs across urban neighborhoods. The project at full implementation will operate a network of 250 air quality monitoring sensors measuring fine particles, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. The monitors will be placed across all zip codes in Minneapolis and St Paul, Minnesota. The monitors used for this investigation are the AQMESH monitors, which contain 5 sensors each. Initial monitor deployment began with 50 units collocated at the Anoka-Blaine MPCA continuous air monitoring site for calibration. Collocation data revealed an R2 of greater than 0.70 for NO, NO2, O3, CO, PM2.5 and PM10, when compared with EPA reference data for that site. The same 50 sensors were deployed to 7 MPCA monitoring sites in Minneapolis and St Paul during the Summer of 2018. All 50 monitoring locations were expected to be operational as of Summer, 2018. Sensor performance, current data and implications for Environmental Justice and environmental sustainability will be discussed.

Additional Authors:

Photographic paper: an integrated measure for community study of industrially produced corrosive gases?

Lourdes Vera, Northeastern University - BOSTON, MA

17.6 million americans live within a mile of an unconventional oil or gas well, 15 to 20% of those wells could emit hydrogen sulfide (H2S), a neurotoxic and corrosive gas. However, there are no federal monitoring requirements for H2S emissions during extraction. Working with communities in Texas and Saskatchewan and in Bostonâ€™s Municipal Sewage Treatment Plant we validated photographic paper as a low-cost, integrated measure for community exposure to sulfuric corrosive gases including H2S. The silver in photo-paper tarnishes with exposure to corrosive gases, causing the color to darken. At the sewage treatment plant, we compared levels of silver on the photo-paper to Purafil Corrosion Coupons, an industry standard reference method that also measures corrosion with silver. We found a statistically significant positive correlation between the photo-paper and corrosion coupons. Fieldwork with communities in Texas and Saskatchewan demonstrates that photo-paper, costing a few cents per sample, can map corrosive gases. We found multiple homes where corrosion severity exceeded that of uninhabitable areas of the sewage treatment plant. We describe how comparison of community results to exposure benchmarks, such as sewage treatment plants, can improve the advocacy relevance of citizen science data by illustrating how community exposures compare to locations that are already regulated due to similar hazards.

Additional Authors:

IMPLEMENTATION OF LOW-COST AIR QUALITY SENSORS FOR URBAN MEASUREMENTS ON STATIONARY AND MOBILE PLATFORMS

Guillermo Villena, Institute for Advanced Sustainability Studies (IASS-Potsdam)

Air pollution is linked to about nine million premature deaths worldwide in 2015 according to the last Lancet commission report. The classical view of urban air pollution monitoring is based on well-established and expensive reference methods installed in scarce and static monitoring stations. The use of small sensors as a complementary tool for air quality monitoring could give us high spatial density and temporal resolution relevant for city scale measurements and more information related to air pollution exposure of the population. This potential is however associated with challenges, such as interferences and the impact of environmental influences that require significant evaluation and calibration of the sensors to ensure data quality.

In summer 2017, in the framework of the BMBF project â€œUrban Climate Under Changeâ€, a field campaign was carried out in Berlin, Germany where NO2, O3 and particulates were measured using low-cost air quality sensors (prototype Zephyrs). The sensors were implemented over the course of a number of months to measure the vertical distribution of pollutants in a street canyon, as well as more limited implementation for mobile measurements. The results of these deployments, as well as the calibration and performance of these sensors will be discussed.

Additional Authors:

Nanocomposite Gas Chemiresistors Based on Poly-Ionic Liquid With Nanocarbons

Jan Vlcek, University of Chemistry and Technology, Prague, Czech Republic

Polymeric ionic liquids (PILs) are the new class of materials with unique features for sensor devices. PILs exhibit ion conductivity and they can be effectively used as chemiresistors device, in which resistance depends mainly on mobility of ions. Gas analyte permeating into PILs can affect this ion mobility by filling of their free space and also direct chemical interaction with ionic species. We found that addition of nanocarbons into the PILs can also improve selectivity and sensitivity.

In this contribution we present gas sensing by nanocomposites consists of PILs matrix (Tetrabutylphosphonium sulfopropylacrylate as a copolymer) and dispersed nanocarbons - fullerenes C60, C70 and onion-like carbon nanospheres. We also demonstrate the effect of phosphonium ion size by Tetrabutylphosphonium and Tributyloctylphosphonium. We describe synthesis process from dispersing of nanocarbons in PILs precursors to photopolymerization. Nanocomposites in form of thin films are polymerized on glass sensor substrate with a pair of gold sputtered electrodes. Sensor behavior was measured as impedance changes (in range of 1 mHz - 1 MHz) to selected gas analytes (alcohol vapors, NOx, CO2) in concentration of 10 ppm in synthetic air. Material behaviour was fitted by Randles-circuit and sensitivity is then determined from the Warburg impedance as an ion mobility change. We present characterization of prepared nanocomposites by SEM, Raman, UV-VIS and impedance spectroscopy.

Additional Authors:

Robust and Low Cost Drag Sphere Anemometer

Christopher Wallis, UC Davis Air Quality Research Center

Wind speed and direction information is a valuable addition to a variety of air pollution monitoring systems. When combined with time-resolved pollution data, wind data aids researchers in determining aerosol sources and paths. A wide variety of speed and direction sensors based on propeller or cup anemometers, wind vanes, or ultrasonic sensors are available to researchers. However, scientific-grade instruments of this type typically demand a high price, making deployment to sampling networks a costly proposition. Additionally, instrument robustness is an issue, as meteorological equipment is regularly subjected to a wide variety of environments including rain, snow, ice, and extreme heat. Anemometers and vanes with moving parts or delicate components may require maintenance when in continuous use, or be otherwise susceptible to harsh environmental conditions.

We have developed a low-cost, robust device, with no moving parts, for measuring wind speed and direction by revisiting the concept of a Drag Sphere Anemometer. In short, a spherical float is held in the air and wind drag acts upon the sphere. The sphere is connected to an instrumented base via a rod. Force on the sphere is transmitted to the base, where it is translated into component vectors using load cells. A microcontroller reads the load cells, handles data collection, and is capable of interacting with other devices such as air pollution samplers via serial communication.

We will present data comparing our prototype to established commercial wind sensors in outdoor environments.

Additional Authors:

Performance Evaluation of an Integrated Multifunctional Sensors-Device in Taiwan

Wen-Cheng Wang, Research Center for Environmental Changes, Academia Sinica, Taiwan

Low-cost sensors develops rapidly recently. In our work, we evaluated the operation performance of a sensor package, called AS-LUNG, short for Academia Sinica-Lung (the organ affected by air pollutants). AS-LUNG includes sensors for PM2.5 (Plantower 3003), CO2, temperature and relative humidity (RH%). Real-time data can be transmitted through optional WIFI or GSM system and be stored in the back-up SD-card. AS-LUNG-outdoor (the outdoor version) equipped with multiple power supply systems (a solar panel and municipal electric systems). Water-proof housing protects sensors from harsh weathers.

PM2.5 and CO2 readings of AS-LUNG-outdoor were compared to the observations of GRIMM and TSI7545 side-by-side in laboratory and filed. For laboratory evaluation, operation conditions of the chamber range from 1-472 ug/m3 (18.1-34.9 Â°C and 56.3-97.4%). In the field, a 72-hour-monitoring

was conducted under the conditions of 3.9-30.1 ug/m3, 25.9-40.9 Â°C and 43.4-93.8% . The averagely 1-min PM2.5 from AS-LUNG-outdoor was on average 2.33 times higher than GRIMM in the laboratory test (R2=0.80-0.98) and 2.01 times higher in the field test (R2=0.68-0.97). For CO2 evaluation, 1-hr mean concentration from AS-LUNG was 1.12 times higher than TSI7545 (R2=0.75-0.91).

AS-LUNG can measure high-resolution data. These results are good for research as long as systematic correction was conducted based on inter-comparison relationships of readings from sensors and sophisticated instruments. Our results indicate that these low-cost devices can be widely used to fill the data gap of air quality.

Additional Authors:

Microsensor Smoke Detection for Spacecraft Fire Safety

John Watson, Desert Research Institute

Fire is among the most catastrophic threats to manned spacecraft. Therefore, early detection of smoke is of the essence but in-use spacecraft smoke detectors have not been optimized for detecting space smoke, which is different from that on the ground due to different fuels and different combustion and particle formation/transformation processes. Consequently, these detectors have lower sensitivity and higher false alarm rates in space.

This study characterized smoke from combustion of spacecraft-relevant materials with an aim to improve space fire detection. Two spacecraft-relevant materials, cotton weave and Poly(methyl methacrylate), were burned in a laboratory chamber with smoldering and flaming combustion. Carbon monoxide (CO) concentrations were measured with a federal reference method (FRM) and with an electrochemical microsensor, and carbon dioxide (CO2) concentrations were measured with a nondispersive infrared (NDIR) microsensor. Modified combustion efficiency was calculated based on CO and CO2 concentrations. Particle concentrations were measured with two ionizing smoke detectors, three low-cost light-scattering particle sensors, and a DustTrak DRX monitor. Particle size distributions were measured with a scanning mobility particle sizer (SMPS) and an optical particle spectrometer (OPS). In addition, particle light absorption coefficients were measured with a three-wavelength photoacoustic soot spectrometer (PASS-3) and a seven-wavelength Aethalometer (AE-31). The time series of CO, CO2, and particle concentrations, size distributions, and wavelength-dependent light absorption provide insights into optimizing smoke detectors for space applications, as will be discussed.

Additional Authors:

A cost-effective data correction approach for low-cost air sensor network data quality assurance

Peng Wei, City University of Hong Kong

Recent developments in low cost sensing technology provide new opportunities for air monitoring in remote areas where there is only limited reference air monitoring infrastructure. Compared to conventional stationary monitoring systems, low-cost sensor-based systems are advantageous because

of their inherent flexible deployment as a means to improve spatial coverage at high temporal resolution. Yet, data quality remains an issue with sensor usage; in contrast with the high performance in the laboratory, limiting the application in atmospheric measurements. Sensor performances may be affected by changing conditions or sensor instability in the field. One common and effective means to achieve good performance is to conduct one or more co-location comparison of sensors with reference monitors. But collection and co located operations includes potentially a considerable loss of data presents the tradeoff between the costs of these actions and improved data quality.

In this work, 8 sensor nodes were deployed in an urban area for 6 months in a typical polluted Chinese city and with 1 node nearby the air quality measurement station (AQMS). We examined different electrochemical sensorsâ€™ (NO2, CO and O3) performance over this period and characterized two basic aspects (sensitivity and baseline stability) separately using the data collected in the field. The sensors were compared with AQMS data regularly and the impacts of environment parameters were evaluated over collocated period. The weight of each factor on the sensor response were also evaluated. The nature of sensor sensitivity variation was evaluated by subtracting the corrected baseline sensor response. While for baseline, the interference with the effects of the ambient environment was detected by applying the rolling calibration approach. Finally, a cost-effective approach was set up based on one sensor node in the long-run and applied to the other sensor nodes. The sensors nodes performance of the networks also demonstrated great potentials for increasing measurement density in areas especially for polluted and/or remote regions with little support of reference monitoring infrastructure.

Additional Authors:

Testing and calibration of air quality sensors in the Netherlands: some lessons learned

Ernie Weijers, National Institure for Public Health and the Environment

Testing and calibration of air quality sensors in the Netherlands: some lessons learned

At RIVM field studies are performed with different types of sensors (NO2/PM). These are mostly located at urban sites and near residential housing. The data analysis revealed that NO2 sensors can be successfully calibrated when being compared to reference measurements. The calibration algorithms derived for the individual sensors are based on multilinear regression. These are applied real-time and use data of meteorology and ozone from measurements or hourly maps (based on modelling and measurements).

It was observed that the sensitivity of (some) sensors significantly changes with time. To detect and correct this, two strategies were examined. The simplest method is to re-calibrate each sensor after a specific period (2-3 months) in the field. A more complex method is based on the assumption that the variation in NO2 during the night over areas is low. This effect allows an adjustment of the individual sensor readings (with data from nearby reference measurements or interpolation).

The presentation summarizes the main conclusions of this work and ends with a future perspective.

Additional Authors:

A Low Cost System for Detecting Fog Events and Triggering an Active Fog Water Collector

Peter Weiss-Penzias, University of California, Santa Cruz

Determining the chemical composition of fog water is important because it reveals processes taking place in the lowest levels of the atmosphere, where there is concern about the transport of pollutants from point and areal sources. This presentation describes a simple, low-cost system for activating a standard active fog water collector (Caltech Active Strand Cloudwater Collector, CASCC). This system detected the onset of early-morning wet deposition due to the advection of marine stratus clouds in Santa Cruz, CA. This system uses an optical rain sensor (ORS), a standard passive fog collector (SFC), a relative humidity sensor, and an internet-connected Raspberry Pi microcomputer to view the sensor output in real-time and log their data, and to control the operation of the doors and fan of the CASCC. All components (not including the CASCC) cost around $700 to obtain and build. It was shown that this new technique triggered the CASCC on and off during the same fog events as those detected by a visibility monitor.

Additional Authors:

Data from Low cost sensors must be handled with care

Dane Westerdahl, Hong Kong University of Science and Technology

â€œThe sensors were calibrated by the factory prior to use .â€ This statement is seen in many of papers sent for review. It is a sign that there will problems.

Care must be taken to establish the performance of sensors before they are used in studies. Conventional monitors have well established calibration protocols and known performance characteristics, but are not practical for use in many community, personal or indoor monitoring studies. Low cost sensors offer promise to gather such data and often report mass concentration data directly or through servers of vendors. However, the validity of these data must to be questioned. The user must understand factors that impact the systems they select and deploy and the nature of data that are reported.

Suggested practices for calibration and post sampling data correction will be discussed. These will be based on data collected in extensive field observations performed in Hong Kong and greater China. Laboratory calibration findings will be shown. Sample data from field observations made with sensor system including PM as well as Ozone, NO, NO2 will be included. Uncorrected field data will be shown and followed with the results of post processing. Key factors and knowledge gained from these efforts will be shared including what manufacturer calibrations mean as well as how key environmental factorsâ€”humidity, temperature, co-present pollutants may challenge low cost sensors.

Additional Authors:

Investigating Electronic Noses: How Do Individual Sensor Characteristics Affect the Performance of Sensor Arrays?

Edward Wolfrum, National Renewable Energy Laboratory

The basic concept of an â€œelectronic noseâ€ is well-understood: when an array of individual sensors responds to a given stimulus, the aggregated responses of the individual sensors that comprise the array can provide information that is unavailable when the responses of the sensors are considered individually[1,2]. In this sense an electronic nose is greater than the sum of its parts.

We have designed and built electronic noses for sensing volatile organic compounds (VOCs) in air which consist of arrays of low-cost, non-specific heated metal oxide sensors, and have demonstrated that aggregating the responses of the individual sensors that comprise the array permits the identification and quantification of different volatile organic compounds (VOCs) at sub-ppm concentrations in air[3]. There was enough natural variability in the performance of nominally â€œidenticalâ€ sensors to provide the multivariate leverage required for the array to act as an electronic nose.

What is not well-understood is how the performance of the individual sensors in a sensor array affects the overall performance of the array. How â€œgoodâ€ do the individual sensors have to be, and what happens if you have too many â€œbadâ€ sensors in the array. To answer these general questions, I will discuss two specific questions â€“

â€¢ How many sensors are necessary for an effective electronic nose?

â€¢ How does the performance of individual sensors influence the overall array performance?

All the data and programs used for this presentation will be made publicly available prior to the presentation.

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Additional Authors:

A study of low cost VOC and PM Sensors

Sai Yamanoor, DesignAbly

As DIY enthusiasts and citizen scientists, we are interested in indoor quality using inexpensive sensors. There has been a rise in the sensors sold in the DIY space. These include the CCS811, SGP 30, BME680 and the PMS5003 sensors. We conducted an experiment to understand the performance of different under identical conditions and understand the differences between the sensors. We would like to share our findings at the conference.

Additional Authors:

Mapping air quality using big data: Accounting for uncertainty

eunhye yoo, Department of Geography, University at Buffalo, The State University of New York (SUNY)

Recent advancements in sensing technology enable investigators and communities to collect air quality measurements at a time and location of interest. The low-cost and real time sensing capability of mobile sensors increase spatial and temporal resolution and data availability, although the accuracy of measurements often need improvement. Similarly, computer simulation models, such as community multiscale air quality models (CMAQ) provide information on air quality with exhaustive spatial coverage, whereas these data are not directly compatible to ground air quality measurements. We investigated the impact of spatially and temporally correlated multiple data sets, available at different spatial and temporal resolutions with varying levels of uncertainty, on predictions. We also assessed the effects of design for mobile sensing network. To illustrate our point, we assessed the contribution of each data source on the quality of reconstructed the PM2.5 concentration surface at a fine scale using a realistically simulation example. The three data sets --- 24-hr PM2.5 measurements from four fixed monitoring stations, CMAQ modelled values at 12 km resolution, and mobile sensor measurements --- in Erie and Niagara counties in New York States, US, for 60 days. We used Fixed Rank Kriging as a spatiotemporal predictor to account for mismatched spatial and temporal resolutions among data sources, and adaptive geostatistical designs for identifying optimal sampling locations.

Additional Authors:

Personal Exposures to Emissions from Lawn and Garden Equipment

Qunfang Zhang, California Air Resources Board

To quantify personal exposures to air pollutants and noise from lawn and garden equipment, personal exposures to particles, black carbon (BC), carbon monoxide (CO), formaldehyde and noise were measured for new lawn and garden devices. Tested devices included 18 gasoline-powered and 5 electric devices, and covered six categories - chain saws, hedge trimmers, leaf blowers, string trimmers, push lawn mowers, and riding lawn mowers. Extremely high, short-term exposures to air pollutants and noise were observed for the gasoline-powered devices. Average exposures for the gasoline-powered devices

were about 1.2 to 70 times higher than those for the electric devices. Such differences were statistically significant for ultrafine particles, BC, CO, and noise. For PM2.5 and PM10, the differences between gasoline-powered and electric devices were much smaller, due to large particle resuspension from mechanical movement. Moreover, some of these short-term exposures exceeded the levels of the 24-hr national ambient air quality standard (AAQS) and California AAQS for PM2.5 and PM10, respectively. Formaldehyde emissions were observed in gasoline-powered devices, with exposures ranging from 2.3 to 22.7 ppb, including one sample exceeding the level of the California Office of Environmental Health Hazard Assessmentâ€™s 8-hour Reference Exposure Level. Therefore, moving towards zero-emission technologies may help reduce usersâ€™ exposures to harmful air pollutants from lawn and garden equipment.

Additional Authors:

Field evaluation of low-cost particulate matter sensors in high and low concentration environments

Tongshu Zheng, Duke University

Low-cost particulate matter (PM) sensors are promising tools for supplementing existing air quality monitoring networks but their performance under field conditions is not well understood. Three field campaigns were made in both low (Durham and RTP, NC) and high (Kanpur, India) concentration environments to characterize how variability in ambient PM2.5 levels, reference monitor types (Durham and Kanpur: MetOne E-BAM; RTP: Teledyne T640 and ThermoScientific SHARP), and meteorological factors can affect the performance of Plantower PMS3003 sensorsâ€™ PM2.5 measurements at various integration times. Errors after calibration by univariate linear models were generally lower in Kanpur than Durham, indicating that PMS3003 performance improved as ambient PM2.5 increased. The precision of reference analyzers is critical in performance evaluation and beta-attenuation-based monitors (E-BAM and SHARP) may not be ideal for testing PM sensors at low concentrations, as underscored by the less dramatic error reduction over averaging times in RTP against optical-based T640 (1 h 27% to 24 h 9%) than in Durham against E-BAM (201% to 15%), and higher T640â€“PMS3003s correlations (R2 â‰¥ 0.63) than SHARPâ€“PMS3003s (R2 â‰¥ 0.25). A major RH influence was found in RTP due to the relatively high precision of the T640 that can explain up to ~30% of the variance in 1 min to 6 h measurements. The PMS3003s can measure PM2.5 within ~10% of ambient values after RH corrections using empirical nonlinear equations.

Additional Authors:

Review of real-time air pollution data in United States and their potential applications in environmental health tracking at CDC

Ying Zhou, National Center for Environmental Health (NCEH), Centers for Disease Control and Prevention (CDC)

CDCâ€™s National Environmental Public Health Tracking Network (Tracking Network) provides integrated health and environmental data to inform public health actions. Current data on the network are historical and typically updated annually. While historical data can inform actions regarding chronic exposure or acute exposures that occurred in the past, real-time data are needed to mitigate potential exposure as it happens. The objective of this study is to review existing real-time air pollution data and evaluate the feasibility of integrating them into the Tracking Network. A combination of Google searches and prior knowledge were used to find real-time air pollution data. Google searches included â€œreal-time air quality dataâ€ and its variations. Each relevant site was reviewed for further details. As of April 2018, we identified 26 websites providing real-time air pollution data in 19 states in United States. Monitors deployed by local government or communities provided inputs to these websites. In addition, there were 5 websites reporting real-time Air Quality Index or pollutant concentrations at the national level. 3 of the websites used observations from air quality monitors; the other 2 further applied interpolation/air quality modeling techniques to air quality monitoring result. To determine inclusion in the Tracking network, we are currently assessing data quality, coverage, reliability and how to combine these data with existing Tracking data to further add value.

Additional Authors:

Evaluation of Air Pollution Regulations in Maryland: an argument for air sensor data from an impacted community

Len Zuza, Community of Communities, affiliated with the Maryland Environmental Health Network

Most federal and state regulations for monitoring air pollution track regional levels, instead of densities in neighborhoods near point-sources of pollution. This absence of fenceline monitoring means that most communities near high-emitting facilities cannot track or react to spikes in toxic pollution to which they may be exposed. Identifying the absence or inadequacies of regulations for monitoring pollution in such communities can provide evidence of the need for air sensing systems to determine whether pollution levels in nearby neighborhoods are higher than health-based standards. Sensor data make a stronger case for accurate, timely monitoring of toxic pollution levels, than residentsâ€™ complaints about strong odors or multi-colored â€œsmokeâ€ from a nearby facility. This paper evaluated regulations for monitoring and reporting on toxic pollution from Dominion Energyâ€™s liquefaction facility at Cove Point, MD. We determined that there are no regulations that require useful real-time reporting on hazardous and toxic pollution levels in nearby neighborhoods. Our main recommendation is to set up a timely, transparent air monitoring system. This kind of analysis can serve as a model for requiring sensor-based data to monitor air pollution in neighborhoods close to high-volume sources of emissions,

and provide information that reinforces pressure on state and local officials to protect constituents by monitoring air pollution or improving regulations to reduce it.

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