CALL FOR ABSTRACTS

Submit your work and present at the most comprehensive conference on environmental science, technology and regulation

Gateway to Innovation

Technical and political challenges often require innovative solutions. California is a global leader in environmental and energy technology and policy, making San Francisco the ideal place for scientists, practitioners, and companies from around the world to share ideas and develop solutions for current and future environmental issues. From June 29 - July 2, 2020, the Air & Waste Management Association (A&WMA) will bring the world’s leading environmental experts and practitioners to San Francisco to spark new environmental initiatives embracing innovation and the vision to address and develop new approaches and effective solutions to addressing climate change, sustainability, new contaminants of concern, and other environmental issues while accommodating growth.

A&WMA’s Annual Conference is recognized as the premier international conference for the latest information on air, climate change, environmental management, resource conservation, and waste with 300+ platform and poster presentations, 35+ panels, and up to 11 concurrent tracks each day.

Abstracts for platform presentations, posters, and panels due November 18. Authors of accepted abstracts may use several submission formats, including full manuscript, extended abstract, PowerPoint presentation with content review, and posters. All submissions must follow A&WMA format guidelines. All presenters are required to register and pay to attend. Accepted platform/poster/panel presentations at the conference that meet A&WMA submission guidelines will be published in an online proceedings. Young Professionals (YPs) who submit a full manuscript or extended abstract will be eligible for YP paper awards. See A&WMA’s website for more details.

Abstracts are solicited to cover one of the topics listed below or another relevant environmental area.

- 2020 Mini Symposium—Embracing Innovation
- Air Emissions - Stationary/Mobile Sources, Inventory, Modeling, Measurements, Monitoring, Control Technologies
- Air Quality, Visibility, Data QA/QC
- Bioenergy, Biofuels, Biogas, Landfills
- Brownfield Redevelopment
- Climate Change - Science, Policy, Regulation, Impacts, Food Security, Mitigation & Adaptation
- Environmental Program Administration—Policy, Regulation & Implementation, Permitting, Public Participation, Odor Issues, EPA Priorities
- Emerging contaminants of concern
- Federal, Public Sectors, and Tribal Issues
- Health, Safety and Environmental Effects and Exposure
- Oil & Gas, Power Generation, Heavy Industry and General Manufacturing
- Nanotechnology
- Regulatory and Legal Issues
- Sustainability, Resource Conservation, Circular Economy, Green Infrastructure
- Transportation and Land Use
- Indoor Air, Vapor Intrusion
- Waste Treatment, Processing & Waste-to-Energy, Landfills, Site Remediation

Find the complete Call for Abstracts and submit online at www.awma.org/ACE2020.

San Francisco, California’s City by the Bay, offers an intellectual and stimulating venue with its rich history of innovation and growth. Share ideas, present your work, and make key connections to advance the profession.
Citizen Science in Environmental Applications
by Prakash Doraiswamy

The involvement of citizens in data collection and evaluation as part of research studies has been gaining traction in the environmental field in recent years. This type of collaborative effort among citizens and professional scientists is referred to as citizen science, community engagement, or community science. Part of the drive for increased citizen involvement includes the availability of accessible tools and increased personal awareness and interest in environmental issues in surrounding areas. This month *EM* highlights example environmental research studies where citizen science is an important component.
We made it to November! I, for one, am ready for some time at home after earning some fairly serious frequent flyer miles this past month. October was a busy month for the Association and our Sections and Chapters. Not only was I able to join colleagues and provide an Association welcome to registrants at this year’s IT3 Conference (https://www.awma.org/it3), I also found my way up to Montana for the Pacific Northwest International Section (PNWIS) Conference and down to Tallahassee, FL, for the Annual Florida Section Meeting. If you’re counting, that’s over 7,500 air miles in one month devoted to catching up with our members and conference attendees. There were many other Association events this past month as well, including the Freight and Environment Ports of Entry Conference (https://www.awma.org/ports), and annual conferences in the Louisiana, West Coast, and Ontario Sections. We also hosted several webinars on a variety of topics. (Find the latest list of A&WMA webinars online at https://www.awma.org/webinars.) All of these events, whether putting together a specialty conference program, a Section or Chapter meeting, or a webinar, are driven both by the hard work of our A&WMA staff and our army of Association volunteers. Many thanks to each and every one of you for your hard work and commitment to the Association!

Speaking of making use of a small army of resources, this month’s EM issue focuses on the topic of citizen science. There is no doubt that the collective resources of researchers, engineers, and concerned citizens can increase the overall value and reach of any research or monitoring application. In a recent A&WMA webinar, the City of Denver talked about the work they’ve done with local citizens, employing smart sensors throughout the city in response to the Bloomberg Mayor’s Challenge (https://www.mayorschallenge.bloomberg.org/). At the Air Quality Measurement Methods and Technology Conference back in April, I heard sensor deployment and source measurement companies talk about software applications they were developing to work with citizen air monitors to help triangulate sources of leaks or odor concerns (check out the conference proceedings for sale in the Online Store at https://www.awma.org/store_product.asp?prodid=264). And on the golf course just the other month, I got into a highly technical conversation with non-environmental industry friends about climate adaptation and mitigation, recycling initiatives, and waste management. With the increased availability of low-cost sensors, ease of modern monitoring techniques, and an increased citizen awareness on environmental issues, citizen science has advanced very quickly.

According to the U.S. Environmental Protection Agency (EPA), the agency utilizes citizen science in three primary ways: filling data gaps, leveraging resources, and building meaningful relationships. They support these initiatives by increasing knowledge through citizen science projects, supporting external grants, and developing resources for community work. (Read more about EPA’s citizen science program on their website at https://www.epa.gov/citizen-science/basic-information-about-citizen-science-0.) I’m curious as to how you tackle the issue of citizen science in your day-to-day world. What types of partnerships have your companies developed with citizen advisory boards? What type of initiatives does your regulatory agency offer to promote collaboration and increase citizen science participation? If you have a unique program that you think our members could benefit from or that could be employed in another community, state, or region, please let me or one of our Board members know. With a mission to assist in the professional development and critical environmental decision-making of our members and a core purpose of improving environmental knowledge and decisions through a neutral forum, the Association is well suited to help promote and engage with citizen science programs so that we can drive further environmental education and participation in all of our communities.
Citizen Science in Environmental Applications

This month’s issue highlights examples of environmental research studies where citizen science is an important component.
The involvement of citizens in data collection and evaluation as part of research studies has been gaining traction in the environmental field in recent years. This type of collaborative effort among citizens and professional scientists is referred to as citizen science, community engagement, or community science. Part of the drive for increased citizen involvement includes the availability of accessible tools and increased personal awareness and interest in environmental issues in surrounding areas.

In this issue, we have three articles presenting examples of environmental research studies employing citizen science, and the approaches deployed by those studies. All three articles showcase studies funded by the National Aeronautics and Space Administration (NASA) as part of their Citizen Science for Earth Systems Program (CSESP; https://earthdata.nasa.gov/esds/competitive-programs/csesp), while the first article also includes a study funded by the U.S. Environmental Protection Agency (EPA).

In the first article by Karmann Mills et al., the authors describe the case studies from two research efforts—one funded by NASA and the other by EPA—that engage citizens to measure and understand surface-level fine particle (PM$_{2.5}$) concentrations using low-cost sensors and/or personal exposure monitors. The article summarizes the key lessons learned from these two research efforts and recommendations to improve citizen scientist engagement.

Next, Casey Quinn, Bonne Ford, and John Volckens describe a study that engages citizens in the measurement of PM$_{2.5}$ and aerosol optical depth using sensors and a mobile application. The article discusses the development of the mobile application and how it simplifies the process of data collection for citizens.

In the final article by Tamlin M. Pavelsky et al., the authors present an interesting study on how citizens help track water resources. Specifically, this article discusses how citizens

Citizen Science

Citizen science allows the public to take part in the scientific process, including formulating research questions; collecting, analyzing, and making conclusions about data; or developing new technologies and applications. Anyone can be a citizen scientist; the best part about citizen science is that it can take place anywhere, even in your own backyard!

Looking to get involved? Here are some useful resources.

CitizenScience.gov (https://www.citizenscience.gov) is an official government website designed to accelerate the use of crowdsourcing and citizen science across the U.S. government.

Explore NASA's Citizen Science Projects (https://science.nasa.gov/citizenscience) to learn more about NASA's efforts and how you can be involved in a wide range of projects.

Citizen Science for Environmental Protection (https://www.epa.gov/citizen-science) is where you can learn more about the U.S. Environmental Protection Agency's (EPA) work in citizen science and environmental citizen science projects and how you can get involved.

Read about the science behind U.S. Forest Service Citizen Science Projects (https://www.fs.fed.us/working-with-us/citizen-science) and the experiences of volunteers. Find projects by state and theme. Learn what tasks are involved and how to join a project near you.

The Citizen Science Association (https://www.citizenscience.org) "unites expertise from educators, scientists, data managers, and others to power citizen science". With over 5,000 members and over 1,000 projects, The Citizen Science Association helps speed innovation by sharing insights across disciplines.

The Citizen Science Alliance (https://www.citizensciencealliance.org) is "a collaboration of scientists, software developers, and educators who collectively develop, manage, and utilize web-based citizen science projects".

Check out Zooiverse (https://www.zooniverse.org/), one of the most popular platforms that enables citizen participation in a variety of cross-disciplinary projects.
scientists work with the research team to collect lake water level data, and in conjunction with satellite data on lake area, help estimate and track lake water volume over time.

All three articles demonstrate how recent developments in sensor technology better enable the involvement of citizen scientists in research efforts. Evident from these studies is the importance of communicating and connecting with citizen scientists for successful data collection and their continued engagement. In addition, these case studies demonstrate a key point: the ability to scale up data collection exponentially by expanding citizen scientist involvement and using standardized approaches. With proper engagement, training, and communication, citizen science may prove to be a valuable component of a research study and enable sustainable, large data collection efforts on an ongoing basis. If designed well, such an approach may benefit both the researchers (i.e., scale of study, sustainable data collection, significant spatial coverage) and the citizens (i.e., community participation, personal environmental awareness). We thank the authors for their contributions to this issue.

Prakash Doraiswamy is Principal Air Quality Scientist with RTI International. He currently serves as Vice Chair of the JA&WMA Editorial Review Board and is a member of EM’s Editorial Advisory Committee. E-mail: pdoraiswamy@rti.org.
Empowering Citizen Scientists to Fill the Gaps in Air Quality Monitoring


A look at two federally funded citizen science research projects that collect air quality measurements for assessing impacts and exposure.
Citizen science, sometimes called community science, partners professional scientists with local citizens to enhance public participation and collaboration in research with an aim of increasing scientific knowledge. Through these partnerships, data are often collected by citizen scientists to address real-world problems that impact their local community. A review of the literature indicates a growing acceptance of citizen science by the scientific community in performing research.\textsuperscript{1-2} For some research areas, this growth is enabled by emerging technological innovations with low-cost, field-deployable analytical devices and cloud-based platforms designed to ingest and display collected data. Citizen science collaborations along with technological innovations are leading to data collection on spatiotemporal scales that would otherwise be impossible or impractical.\textsuperscript{3-6}

Federal agencies, like the National Aeronautics and Space Administration (NASA) and the U.S. Environmental Protection Agency (EPA), use citizen science to better engage the community. In this article, we present examples of research projects funded by these agencies to expand air quality monitoring data, increase its usage, and to improve awareness of air quality and air pollution exposure in a community. Funded by NASA and EPA, we are working with citizen scientists on two projects, implementing citizen science programs that collect air quality measurements for assessing air quality impacts and personal exposure:

1. Low-cost sensor network to relate surface data to satellite observations (funded by NASA). The NASA Citizen Science Project (http://aqcitizenscience.rti.org) works with citizen scientists to deploy a network of low-cost sensors that measure fine particulate matter (PM\textsubscript{2.5}) at their residences and businesses. These PM\textsubscript{2.5} data are compared with satellite aerosol optical depth (AOD) observations in order to assess and improve the ability of satellites to monitor the spatial gradients at the surface.


**Citizen Science Case Studies and Lessons Learned**

**NASA Citizen Science Project**

The goal of this project is to increase the value of NASA Earth Science products for monitoring PM\textsubscript{2.5} near the Earth’s surface. Surface PM\textsubscript{2.5} is a known health hazard and is an EPA criteria pollutant. PM\textsubscript{2.5} can be estimated from satellite-derived data, but uncertainties are large, especially at the local scale. A spatially-dense network of surface monitors is needed to model, validate, and improve estimates of surface
The low-cost sensor deployed in this study is popular, with a large number already deployed around the world, and with data publicly available online. The advantage of such widespread deployment and open data framework is the availability of data at spatial and temporal scales not feasible by regulatory monitoring networks or citizen science projects with closed or limited data access. Among the sensors tested, this sensor showed good performance and met our criteria regarding ease of deployment, data transfer, and minimum maintenance burden. The performance of low-cost sensors is often subject to biases, which need to be properly communicated through citizen scientist education and outreach for proper data interpretation. Nevertheless, widespread deployments of such sensors generate data at high spatial and temporal resolution that enable researchers to ask and answer specific research questions. For example, our study found that these sensors were useful in understanding the local spatial gradients during the California wildfires and in building a model relating satellite-based estimates to surface measurements.

Citizen scientists who hosted air quality monitors and surrounding communities were invited to attend an in-person workshop. This workshop provided training on the sensor (installation, setup and monitoring), its data, satellite data utility, and potential applications of these data for their own use as well as the scientific community. The response of the citizen science sensor hosts varied, ranging from volunteers who were passive and rarely looked at the data to volunteers who were data enthusiasts, interested in using data for personal or school projects. We realized that such a mix of citizen scientists was needed to maximize our research objective of having sensors in multiple grids, while also interacting with data periodically. Requiring both active interaction with data and

![Figure 1](https://www.purpleair.com/map)
sensor hosting did not always yield promising results. Regardless, when presented with opportunities, people wanted to learn more about air quality, and wanted to engage with the project.

The low-cost sensor deployed by citizen scientists in this study offered minimum burden, one of our criteria for sensor selection. While the easy-to-use sensor reduced the burden on citizen scientists and increased data completeness, the lack of required interaction between host and sensor device raised the risk of disengagement by citizen scientists. We have chosen several avenues of communication to mitigate disengagement, including regular blogs, emails, and example lessons depicting the utility of these sensor data. Such sensors are deployed by citizens throughout the world. Our research has identified the need for better education of such data and the need for a data framework that provides citizen scientists with the ability to view and analyze long term sensor data and use data with appropriate quality measures.

**EPA EJ Citizen Science Project**

This study focuses on air quality in the communities of Gloveville and Elyria-Swansea in northeast Denver, CO. These communities are classified as environmental justice communities because of their proximity to a Superfund site, high-density highways, refineries, and industry. People living in these communities typically have lower socio-economic status and are largely of Latino descent. This study involves Gloveville and Elyria-Swansea community members during multiple monitoring campaigns, as well as a community advocacy group, a local chapter of a professional health society, and city developers. These groups work together with research institutes and state and city representatives to collect ambient data across 12 community sites and personal monitoring data from 20 households in the community.

This study uses the MicroPEM exposure monitor. The air sensors produce a rich dataset that can be used to assess spatio-temporal variabilities of air quality and exposures to air pollution within the local community. However, there are limitations to citizen scientists effectively using the air quality and exposure data to address the community air quality issues. Technical ability is needed to obtain, validate, and summarize data. Yet, most citizen scientists do not have the technical background and the required skills to process and understand such data.

For instance, specific technical skills involve processing raw sensor data, and then performing quality assurance to produce a useful and defensible dataset. Additional knowledge and analysis are needed to connect the air quality data with lifestyle factors and other factors that are associated with high exposure conditions. Finally, interpretation of such data and analyses must be followed by individual and/or policy solutions. Therefore, the main goal of this project is to support skill development of citizens to participate more fully in the collection and utilization of data to inform changes.

Our stakeholders participate in focus groups to evaluate different data output formats for their effectiveness in air quality...
and health messaging that would support informed decision making and action. The data output formats were adapted from graphics and tables commonly used to communicate the air quality data such as EPA’s Air Quality Index (https://airnow.gov/index.cfm?action=aqibasics.aqi). The focus group results indicate that commonly used air quality messaging did not address issues of particular interest to this community because descriptions that explained the degree of exposures and potential health effects were confusing. These issues ultimately hindered citizens’ ability to identify and implement action steps to lower the air pollution exposure. Overall, results to date suggest that traditional approaches for displaying air quality data and messaging for follow-on actions are inadequate and confusing to permit informed decision-making and the use of exposure reduction strategies for environmental justice communities.

Recommendations
Citizen science research benefits from citizen interest at many levels. There are citizens interested in hosting sensors and contributing to the data stream, citizens focused on the data analysis, citizens interested in evaluating the results and impacts on health, and there are also citizens interested in making decisions. In some cases, one person may be interested in all facets, but generally most individuals have only one or two areas of interest. All are important. For all levels of citizen science involvement, many avenues of education should be offered, including training in the terminology of that scientific field, data analysis guides, open access modeling algorithms, online communities with professional scientists for questions and troubleshooting, and design of data outputs for communication with individuals and communities.

Regardless of the project research area, an indicator of sustainable citizen science program success is the degree of interaction between volunteers and professional scientists. This conclusion is grounded in the aspects of data quality, ongoing volunteer recruitment, training, management, and, ultimately, credibility with scientific and regulatory communities. Programs that involve a high level of collaboration between professional researchers and citizen scientists are better able to achieve the desired scientific and/or public policy outcomes. Additionally, the programs will be able to deliver authentic learning experiences to a diverse set of stakeholders. An evaluation of participant outcomes in an ecology project found that one of the most important factors associated with an increase in scientific knowledge among citizen scientists was their interaction with researchers.

The EPA project case study shows the example of close involvement with multi-level stakeholders who are aware of and have been affected by the chronic air quality and health disparity issues in their community. Stakeholders, including citizen scientists and professional researchers from research institutes and state and city environmental health...
departments have formed a consortium. This motivated group wanted to know how industrial facilities and traffic sources in their neighborhood affect their air quality and to compare local air quality with the state monitoring data. Through the EPA project, this consortium functions as community advisory committee and participates in various tasks involving air sensor data to address the air quality questions and identify the best approaches for the citizen science framework.

**Conclusion**

As the research community continues air quality research alongside citizen scientists, we must seek to understand the balance of study need and the citizen scientist interest level. Engagement of citizen scientists is vital, and bandwidth must be allowed for education materials and training delivery, as well as consistent communications. The application of citizen science in the field of air quality appears to be rapidly increasing due to availability of low-cost sensors. The accuracy of the sensor data and potential post adjustment is an area of ongoing research. Better education of citizen scientists on potential sensor differences, interpretation, and the need for good data quality, along with awareness of availability and application of satellites for air quality monitoring, will contribute to improved datasets. With enhanced upfront planning during study design on data quality and improved outreach and education, citizen scientists will be better able to contribute to developing air quality and exposure datasets that may be useful for future policy development. **em**

---

**Acknowledgment:** The NASA Citizen Science Project is funded by the National Aeronautics and Space Administration under the Citizen Science for Earth Systems Program (CSESP) through cooperative agreement No. 80NSSC18M0101 to RTI International. The EPA EJ Citizen Science Project has been supported by a grant from the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) program through agreement No. 836187 to RTI International.

**Disclaimer:** The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of NASA or EPA. It has not been formally reviewed by the funding agencies. Mention of commercial products does not imply endorsement by the funding agencies.

---

**References**


A look at how the market nexus of air quality monitoring and low-cost sensor technologies has created opportunities to enlist, empower, and motivate a new generation of citizen scientists for air quality.
Air pollution exerts a tremendous health and economic burden both domestically and abroad. Nearly all regulatory standards for air quality require some level of monitoring to enforce compliance; however, regulatory monitors are expensive to install and maintain. Thus, dense monitoring networks are rare and global coverage tends to be sparse. The market for alternatives to traditional “reference-grade” monitors is growing rapidly, as local governments, communities, and individuals seek more temporally and spatially resolved information on local air quality, without significant cost.

To meet this need, a wave of low-cost sensor technologies has recently emerged on the market. Such technologies provide access to air quality data for stakeholders outside the realms of regulatory monitoring or academic research. While the performance and reliability of low-cost pollutant sensors remains a topic of scientific research and debate, there is a growing consensus that such technologies do have utility. For example, studies have demonstrated that the best-performing sensors on the market can distinguish “good” from “poor” air quality conditions (albeit with reduced accuracy). The emergence of these sensor technologies has also enabled new forms of advocacy and research through crowdsourced data collection and citizen science.

Access to low-cost sensor technologies, however, creates challenges associated with collecting, interpreting, and communicating the results of data assimilated by untrained or non-technical personnel. There is also a need to ensure data quality, as a growing body of research suggests that these sensors require frequent calibration and/or correction using various forms of environmental or metadata. Thus, while the sensors themselves are low cost, they are often deployed with additional instrumentation and/or sophisticated computational algorithms. These requirements, in addition to the complexity of the sensors themselves, pose a “barrier to entry” for non-experts. One way to make these technologies more accessible to non-experts is by providing better user interfaces. Here, we discuss the use of software applications for mobile devices as a means to lower such barriers.

Our research group at Colorado State University has developed several low-cost air quality instruments over the past decade. The original goal was to create small, wearable instruments that could estimate personal exposure to fine particulate air pollution. For example, the Ultrasonic Personal Aerosol Sampler consists of an integrated micro pump, cyclone inlet, filter, and mass-flow system used for the determination of particulate matter mass or chemical concentration. Future iterations modified the technology for outdoor use and to include a variety of low-cost sensors. However, as the use model for this technology expanded (e.g., epidemiological research, exposure science, community-based monitoring, and citizen science), so did instrument complexity. Thus, we looked to develop a smartphone application that allowed users to interface with the instrument in a more simplified, streamlined fashion (e.g., for instrument programming, sample collection, data visualization, and data transfer).

Recognize those who are making a difference
A&WMA honors outstanding individuals and companies contributing to the environmental industry in various ways.
Nominate someone from your network who deserves recognition.

2020 Awards Deadline: November 22
- Frank A. Chambers Excellence in Air Pollution Control Award
- S. Smith Griswold Outstanding Air Pollution Control Official Award
- Charles W. Gruber Association Leadership Award
- Richard Beatty Mellon Environmental Stewardship Award
- Richard C. Scherr Award of Industrial Environmental Excellence
- Richard I. Stessel Waste Management Award
- Lyman A. Riperton Environmental Educator Award
- Exceptional Education Contributor Award
- Fellow A&WMA Membership
- Honorary A&WMA Membership
- Outstanding Young Professional Award

Go to www.awma.org/honors for descriptions and criteria.
Why Use Mobile Applications?
Mobile phones are a near-ubiquitous resource with five billion users worldwide. Over half of these users (and up to 80% in the United States) have a smartphone—a form of technology that is firmly embedded in our cultural fabric. Smartphones provide individuals with a portable, interactive computer capable of wireless data communications. Many application developers leverage a smartphone’s Bluetooth functionality to communicate with external hardware (e.g., personal health monitors, home appliances, etc.). Thus, the smartphone has become one of the most common interfaces for cyber-physical systems.

The use of mobile applications to support environmental monitoring is not new (e.g., aircasting.org and globe.gov). However, our aim was to create a mobile application that allows a user to interface with a relatively complex air quality instrument (i.e., one that records and presents data on pollutants, GPS location, weather variables, operational parameters, and other metadata). After consulting with the iPhone design team at Apple, we structured our application to mimic the “phone settings screen” common to iOS and Android devices. This motif lets users interact with the instrument in nearly the same fashion as they would when changing their phone settings (e.g., power management and connectivity). A version of this “research app” is shown in Figure 1.

A Mobile Application for Citizen Science
The development of our mobile application evolved from the need to streamline instrument setup for sample and data collection. The software allows a user to connect to an instrument via Bluetooth, set sample parameters (e.g., flow rate, sample duration, sample, and filter cartridge identification), and wirelessly transfer data between the instrument and a smartphone. Under this paradigm, we soon realized that even minimally trained users could operate the instrument. This realization gave rise to a citizen-science project: Citizen-Enabled Aerosol Measurements for Satellites (CEAMS; csu-ceams.com).

The CEAMS network is a campaign to monitor fine particulate matter (PM$_{2.5}$) and aerosol optical depth (AOD) simultaneously using low-cost sensor technologies. Satellite-derived estimates of surface-level PM$_{2.5}$ are currently used to estimate the health and climate impacts of fine particle air pollution; however, these estimates are uncertain due to a lack of information about the ratio of surface-level PM$_{2.5}$ to AOD arising from the scarcity of co-located PM$_{2.5}$ and AOD measurements. Thus, the CEAMS project seeks to crowdsource PM$_{2.5}$ and AOD monitoring by deploying a low-cost instrument at unprecedented scale (i.e., hundreds of stations).

To achieve this scale, we needed a tool that could be used by research staff and citizen scientists without substantial training. Thus, we designed our mobile application to have both an administrative mode—where research staff are able to access all instrument parameters—and a citizen scientist mode—where users see only a streamlined version that guides them through the process to set up a sample and acquire data (see Figure 2). The mobile application is available for iOS and Android phones, so citizen scientists can download it directly to their own smartphone or tablet.

Over time, our mobile application evolved to incorporate features that improved sample collection, which contributes to the overall success of the campaign. For example, we reduced the amount of data entry required by users by leveraging the phone’s camera in conjunction with Quick Response codes (QR codes, machine-readable information labels) that can be scanned to set sample identification data (sample name, number). We also simplified data transfer: Initially, users had to pull data manually from a secure digital...
The mobile application, however, provides additional options: the application can receive data files wirelessly from the instrument and either store the data on the mobile phone to send to a central server at a later time (e.g., when Wi-Fi is available), or the application can configure the instrument to directly send data files to a central server over Wi-Fi (i.e., without downloading the files to the mobile phone).

Simplifying data transfer gives researchers and users access to data sooner and helps ensure that data files are not lost. These features have made it possible for a citizen scientist to set up our instruments to take complex measurements (i.e., optical and gravimetric PM$_{2.5}$, AOD at multiple wavelengths; see Figure 3) in a matter of minutes. The only additional interactions that users have with the instrument are powering it on, changing a filter, and charging the instrument at the end of the week.

A key part to the success of the mobile application was that we allow users to provide feedback. For example, it was suggested that we needed larger fonts and more simple terminology. Users also wanted confirmation messages (e.g., “Congratulations! You have successfully started a sample!” or “Battery is low, please recharge before proceeding”), which was not something that we had originally considered.

As we look to expand CEAMS, we anticipate adding new functionality that further enhances the user experience. For example, the ability of the phone to “talk” to the instrument could enable the development of an adaptive troubleshooting guide. Our instruments monitor and collect dozens of instrument performance variables; however, if an instrument malfunctions, there are no instructions within the mobile application to aid troubleshooting. Users are provided a manual, but they would prefer “on demand” troubleshooting that leverages these real-time sensor data. This is especially important as our instruments are often deployed in remote locations. Eventually, we anticipate the ability for users to run diagnostic tests directly from their mobile device, so that instrument downtime is minimized in the field.
Conclusion
Mobile applications can support air quality monitoring with low-cost instruments. Our smartphone-based application provides both researchers and citizen-scientists with an easy, intuitive means to interface with a complex scientific instrument. This interface has the advantage of retaining instrument complexity while also affording flexibility for various use modes. The ability of smartphones and mobile application software to lower the “entry barriers” for scientific measurements further suggests that the low-cost sensor revolution is here to stay.

References

In Next Month’s Issue…

Winter Time Air Quality
Severe air pollution episodes occur in the United States and other parts of the world in wintertime when meteorological inversions trap emissions of particles and other pollutants near their sources. In addition, wintertime inversions can lead to elevated secondary particulate matter and ozone concentrations under certain conditions. The sources, meteorology, and formation pathways for wintertime pollution differ from those that lead to high summertime pollution. The December issue of *EM* will review contemporary wintertime air quality challenges.
Monitoring the World’s Lakes:
Progress from Citizen Science and Remote Sensing

by Tamlin M. Pavelsky, Sheikh Ghafoor, Faisal Hossain, Grant M. Parkins, Sarah K. Yelton, Sarina B. Little, Simon N. Topp, Megan Rodgers, and Xiao Yang

A sneak-peak at NASA’s Lake Observations by Citizen Scientists and Satellites (LOCSS) project to help measure changes in lake water levels
Although lakes are important for our water supply, the ecosystem services they provide, and their role in local and regional water cycles, there is still a lot we don’t know about them. Water storage is not measured in most lakes in the United States and around the world, which makes it difficult to manage these important natural resources. NASA has funded a new initiative, the Lake Observations by Citizen Scientists and Satellites (LOCSS) project (http://locss.org), that extracts lake area from satellite data and works with citizen scientists to collect lake water level data. Together, these measurements allow us to measure change in volume. These data can help us address science and management questions now, and they will be used in the future to help validate a lake-focused satellite mission that NASA will launch in 2021.

Worldwide, there are something like six million lakes larger than one hectare, but almost none of them are regularly monitored. As a result, we know surprisingly little about them. Simple questions about the quantity of water they store, how that varies in time, and the quality of the water in them are answered mostly by inference. This lack of information is unfortunate because lakes are such useful sentinels of the water cycle. As integrators of all hydrologic processes in their catchments, knowing how lakes vary can help us understand the nature of hydrologic and ecological processes more generally. These processes are well-monitored in some parts of economically developed countries but are poorly measured globally.

Accordingly, scientists and engineers are looking to two solutions at opposite ends of the technological spectrum. Satellites can be used to remotely infer variations in lake water quantity, but the algorithms used to extract information from satellite data can be complex and sometimes unreliable. Meanwhile, collaboration with citizen scientists offers local observations and knowledge, but without the potential for fully global coverage. Combining these two approaches offers the exciting prospect of global satellite measurements validated against widespread local observations made by citizen scientists.

This combined approach is particularly promising in the context of the upcoming Surface Water and Ocean Topography (SWOT) Satellite Mission (http://swot.jpl.nasa.gov), a joint project of NASA and CNES, the French space agency. SWOT, a Ka-band interferometric radar satellite specifically designed to simultaneously measure variations in inundation extent and water level in lakes, rivers, and oceans worldwide, is scheduled to launch in September, 2021. By observing lake height and inundation extent simultaneously, SWOT will allow measurement of variations in storage volume for lakes as small as 250 m x 250 m worldwide (with a goal of one hectare).

The novel SWOT measurements require considerable on-the-ground validation before they are likely to be trusted by end users. While water level in some lakes and most large
reservoirs is professionally monitored, this is largely not true for smaller lakes. To address this limitation and develop a robust validation network for SWOT, NASA has initiated the LOCSS project. The project involves installing staff gauges in lakes (see Figure 1), often in partnership with local management agencies, and asking citizen scientists to send in measurements of lake height via text message, web page, data sheet, or other methods.

The LOCSS project, funded by the NASA Citizen Science for Earth Systems Program, began in 2017 with a prototype phase focused on 12 North Carolina lakes. Since that time, the project has expanded to 62 lakes in Washington, Illinois, and Massachusetts in the United States, as well as France and Bangladesh, with plans for more lakes in new locales in the coming two years. Almost 1,000 (993) citizen scientists have submitted over 4,000 total measurements of lake height (see Figure 2). Scientists have assessed the accuracy of these measurements against comparable measurements from several hundred automated pressure transducers and found a mean absolute error of 1.1 cm, only slightly higher than the 0.8 cm uncertainty associated with the transducer measurements.

LOCSS is certainly not the first project to work with citizen scientists to measure variations in lake height. For example, there are excellent programs in Minnesota and Wisconsin, the latter of which was developed in collaboration with the CrowdHydrology project. However, we believe that LOCSS is the first such project to focus specifically on links with satellite missions.

At present, researchers are combining measurements of lake height by citizen scientists with measurements of lake area from the Landsat 8 satellite to calculate variations in lake volume. Landsat 8 has an orbit repeat time of 16 days, and regular reminders are sent out to newsletter subscribers to measure heights on overpass days. Measurements are received within +/-1 day of a satellite overpass more than 70% of the time.

This success suggests to us that, after the SWOT launch, we will likely be able to count on regular measurements by citizen scientists in many of our validation lakes. This reliability will be particularly important during a three month phase at the beginning of the SWOT mission, the so-called fast sampling phase, when we will observe only a small fraction of the Earth on a daily basis (see Figure 3). During the bulk of the mission, SWOT will observe each lake, on average, approximately every 11 days. During the fast sampling phase, we hope to work with citizen scientists to collect as many measurements as possible. These measurements will be used to evaluate SWOT’s accuracy and assess its suitability for science and engineering objectives.

Even before SWOT’s launch, LOCSS is achieving a range of goals in science, monitoring, and community engagement. Most of the more than 60 lakes had no prior monitoring, and because all of the data is available in real time on the LOCSS website, managers and other stakeholders can use the data for any purpose they choose. Many have been enthusiastic collaborators.

For example, Dan Grigas of the DuPage County Forest Preserve District, one of our collaborators in Illinois, wrote: “We chose to work with the LOCSS team because it is important for us to try to widen our understanding of how our environments change over time. This includes how changes in climate patterns in both the near-term and long-term can affect freshwater ecology. This program also allows for and relies on citizen scientists to participate, which strengthens the relationships among government agencies, the people they serve, and the environments that we all treasure.”

![Figure 1. A LOCSS gauge in Walupt Lake, WA.](image1)

![Figure 2. Key summary metrics regarding data collected for by the LOCSS project by citizen scientists.](image2)
Scientists are also using data from the LOCSS project to better understand the primary drivers of lake water levels and water storage variations—are they primarily driven by regional climate, local physiography (e.g., bedrock geology), or human management? In Bangladesh, for example, LOCSS data have revealed contrasting water level dynamics for the seasonally inundated water bodies (locally known as haors) as a function of size. The smaller ones (e.g., the 3.7-km² Dekhar haor) seem to be experiencing withdrawals for neighboring water applications. Meanwhile, the larger haors (e.g., the 63-km² Korchar haor) maintain steady water levels as the monsoon rain arrives, suggesting that the larger water bodies are most likely being maintained for aquaculture. This type of information, not previously available to managers, allows for improved understanding and management of water resources. Ultimately, everyone’s goal—researchers, lake managers, citizen scientists—is to better understand our lakes here in the United States and around the world.

References
EPA Proposes to Rollback Regulation of Methane Emissions

On August 28, 2019, EPA proposed to amend the Obama-era NSPS from 2012 and 2016 pertaining to methane emissions from the oil and gas industry. The proposed amendments came more than two years after a 2017 legal defeat suffered by the agency, when it attempted to delay implementation of the 2016 NSPS in an early environmental deregulatory effort by the Trump Administration.

EPA’s proposed amendments could narrow the number of sources that are subject to the NSPS by removing transmission and storage sources from the source category. In so doing, the agency suggests that it erred in 2012 and 2016 under President Obama when the source category was expanded to include transmission and storage sources. The primary proposal also seeks to rescind limits on methane emissions from the production and processing segments, while retaining limits on the emission of volatile organic compounds (VOCs) from those...
EPA Administrator Andrew Wheeler stated that regulation of methane emissions via the NSPS were “unnecessary and duplicative regulatory burdens”. The Administration sees limits on methane emissions as unnecessary given that “methane is valuable, and the (oil and gas) industry has an incentive to minimize leaks and maximize its use”. The agency also sees regulation of existing sources under the NSPS as unnecessary based on the assumption that some existing sources will “modify” (subjecting themselves to NSPS for new or modified sources), while many other existing sources will cease to operate over time as they shut down due to obsolescence.

Interestingly, this same logic was applied to the “grandfathering” of existing coal-fired power plants (and other large sources of air pollution) when the 1970 CAA was being drafted. At the time, industry lobbyists convinced legislators that “old” power plants did not warrant regulation as “existing sources,” since they would shortly reach their end of life to be replaced by new plants that would be subject to regulations as “new sources” requiring state-of-the-art air pollution control equipment. These plants ultimately became known as “vampire power plants” (a nod to the supposedly difficult task of killing a vampire), as the electric utility industry found ways to extend the useful life of many of these plants well into the 21st century and to the present day.

Along with its proposed amendments to the regulation of methane emissions from the oil and gas industry under NSPS, EPA is simultaneously seeking comment on a possible reversal of the agency’s own longstanding interpretation of the process for establishing NSPS under Section 111 of the CAA. Section 111(b)(1) at 42 U.S.C. §7411(b)(1) requires the EPA Administrator to establish standards of performance for new sources (an NSPS) following a determination that a source category causes or contributes significantly to air pollution which may endanger public health or welfare. Historically, the agency has interpreted Section 111(b)(1) to require only a single significant contribution finding (SCF) for unspcciated air contaminant emissions from the entire source category. This single SCF has then been followed by standards of performance establishing pollutant-specific emission limits without regard for whether emissions of a specific pollutant (in isolation) “significantly contribute” to air pollution which may endanger public health or welfare.

EPA’s request for comments on alternative interpretations of its legal authority under Section 111(b)(1) suggests that the provision may be more appropriately read to require a pollutant-specific SCF for each individual air pollutant the agency seeks to regulate under an NSPS for a given source category. Using the oil and gas NSPS as an example, EPA suggests that its 2016 NSPS regulating methane emissions should have been preceded by a methane-specific SCF showing that methane emissions from the oil and gas industry contribute significantly to air pollution which may endanger public health or welfare.

If the agency ultimately changes its interpretation and application of Section 111(b)(1), EPA under future administrations will be faced with additional procedural hurdles before promulgating an NSPS. These may include additional qualitative or quantitative criteria, which could include reliance upon historical trends and future projections. For example, EPA suggests that it may consider a projected rapid decline in emissions (perhaps due to market conditions or other forces) even in the absence of new rulemakings as a justification for not making an SCF and establishing NSPS. To some extent, EPA has already applied such logic in its current proposal to eliminate methane emission limits for existing sources.

As the Trump Administration and EPA move closer to finalizing a revised version of their “Safer Affordable Fuel-Efficient Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks” (SAFE Rule), several automakers—comprising more than 30% of the market share of all cars and light-duty trucks sold in the United—have sided with California in the state’s long-running battle with the Administration over fuel economy standards. In July 2019, BMW, Ford, Honda, and Volkswagen all announced that they had reached an agreement with California to voluntarily comply with stricter fuel economy rules. Mercedes-Benz also intends to comply according to recent news reports.

While the agreed-upon rules are expected to be slightly less ambitious than the target set during the Obama Administration that Trump is seeking to replace, the standards are more stringent than those proposed in the SAFE Rule (i.e., 37 miles per gallon by 2026). With the increasing likelihood that other automakers will join in voluntarily complying with California’s standards, the Administration and the state are on a collision course over California’s authority to adopt standards more stringent than federal standards.

Voluntary adoption of stricter standards by automakers would effectively render the less stringent SAFE Rule standards moot throughout a significant portion of the country in light of the fact that 12 other states and the District of Columbia typically follow California’s more stringent standards. To avoid this outcome, the Administration is expected to seek to strip the state of its ability to establish more stringent fuel economy standards.

As to the automakers, the U.S. Department of Justice launched an investigation in early September into whether the agreement reached by BMW, Ford, Honda, and Volkswagen violated federal antitrust laws. While there is seemingly nothing the Administration can do to stop automakers from voluntarily making more fuel efficient vehicles (short of a “fuel efficient vehicle tax”), the government could use antitrust laws to prevent automakers from joining together to do so.
The November 1999 issue of EM tackled the combustible subject of wildfire, a problem that remains a serious concern two decades later. Fire is a natural component of most forest ecosystems. But how does it affect ambient air quality and visibility? And how should fire be managed to keep air pollution at acceptable levels?

These and other questions were addressed in the article, *Where There’s Fire, There’s Smoke*, by Douglas G. Fox, et al. The authors summarized data from the IMPROVE network of air quality monitoring sites associated with the U.S. Class I areas, illustrating that organic carbon is a significant contributor to impaired visibility at U.S. national parks and wilderness areas. Although not the only source, forest and agricultural fire emissions contribute to organic carbon levels and should be considered in efforts to reduce regional haze.

*Quoting from the article:* “Fire is a force that influences the development of virtually all natural ecosystems. Because humans value elements of these ecosystems, and, increasingly, build permanent homes within them, fire has and will continue to be ‘managed’ in such ecosystems.”

Elsewhere in this issue, two articles take more of an international focus. In the first article, *Environmental Regulations and Developments in Singapore*, Shekar Viswanathan described how in just three decades Singapore grew from a Third World nation to one with the highest standard of living in the world. The country’s rapid industrial expansion created a need for greater environmental regulation and control. The author highlighted Singapore’s response with a series of successful environmental programs.

*Quoting from the article:* “Despite urbanization and limited space, large tracts of land continue to be committed for conservation of the natural environment. The government plays a facilitating role in the promotion of environmental technology, which requires that the government identify and encourage companies to switch to or develop environment-friendly substitutes and adopt innovative technologies to minimize pollution.”

In another article, *Environmental Preservation: An Insight into the Indian Scene*, Viswanathan and coauthor K.S. Narayanaswamy documented India’s approach toward environmental protection, noting how the nation was taking important steps to improve its environmental status.

*Quoting from the article:* “Indian environmental laws and the parameters outlined in them are comparable to those of any other country. The formation of state and central pollution control boards and the establishment of analytical laboratories and public awareness programs are marginally improving the situation. … The judiciary is also playing a vital role in creating much-needed awareness on the degrading environment. Many landmark judgments in the environmental field have helped regulatory agencies in formulating additional notifications and rules.”

**EM Archive**

Access to A&WMA’s complete EM back issues archive through 2013 is available online at [www.awma.org/empastissues](http://www.awma.org/empastissues). If you are searching for a particular issue or article from our pre-2013 archived back catalog, please send a request e-mail to lbucher@awma.org.
Staff and Contributors

A&WMA Headquarters
Stephanie M. Glyphis
Executive Director
Air & Waste Management Association
Koppers Building
436 Seventh Ave., Ste. 2100
Pittsburgh, PA 15219
1-412-232-3444; 412-232-3450 (fax)
em@awma.org
www.awma.org

Advertising
Jeff Schurman
1-412-904-6003
jschurman@awma.org

Editorial
Lisa Bucher
Managing Editor
1-412-904-6023
lbucher@awma.org

Editorial Advisory Committee
Teresa Raine, Chair
ERM
Term Ends: 2022

Bryan Comer, Vice Chair
International Council on Clean Transportation
Term Ends: 2020

Leiran Biton
U.S. Environmental Protection Agency
Term Ends: 2022

Gary Bramble, P.E.
Retired
Term Ends: 2021

James Cascione
SABIC Innovative Plastics
Term Ends: 2022

Prakash Doraiswamy, Ph.D.
RTI International
Term Ends: 2022

Ali Farnoud
Ramboll Environ
Term Ends: 2020

Steven P. Fryninger, Ph.D.
James Madison University
Term Ends: 2021

Keith Gaydosh
Affinity Consultants
Term Ends: 2021

Jennifer K. Kelley
General Electric
Term Ends: 2020

John D. Kinsman
Edison Electric Institute
Term Ends: 2022

Mingming Lu
University of Cincinnati
Term Ends: 2022

David H. Minott, QEP, CCM
Arc5 Environmental Consulting
Term Ends: 2020

Brooke A. Myer
Indiana Department of Environmental Management
Term Ends: 2022

Brian Noel, P.E.
Trinity Consultants
Term Ends: 2020

Golam Sarwar
U.S. Environmental Protection Agency
Term Ends: 2022

Melanie L. Sattler
University of Texas at Arlington
Term Ends: 2022

Anthony J. Schroeder, CCM, CM
Trinity Consultants
Term Ends: 2022

Justin Walters
Southern Company Services
Term Ends: 2022

Susan S.G. Wierman
Johns Hopkins University
Term Ends: 2021
Check Out *EM* via the A&WMA App!

*Read EM on the go, wherever, whenever.*

The A&WMA App is available to all A&WMA members for FREE download for use on all Apple, Windows, and Android mobile devices. Remember, interactive content, such as video, audio, animations, hyperlinks, pop-up windows, and slideshows, are only available via the App.