Air & Waste Management Association

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THE MAGAZINE FOR ENVIRONMENTAL MANAGERS

SEPTEMBER 2014

Also in this issue:

DISCOVER-AQ

Advancing Strategies for Air Quality Observations in the Next Decade

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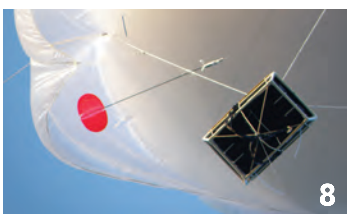
DISCOVER-AQ
Advancing Strategies for Air Quality Observations in the Next Decade

by James H. Crawford, NASA Langley Research Center; and Kenneth E. Pickering, NASA Goddard Space Flight Center

This month, *EM* focuses attention on the efforts of NASA's DISCOVER-AQ mission. As part of this mission, scientists collect pollutant measurements using aircraft, sondes, satellites, and ground-based instruments. These measurements are then used to better understand the processes governing near-surface pollution levels in various urban airsheds with the goal of improving our ability to accurately forecast and mitigate pollutant levels. **Page 4**



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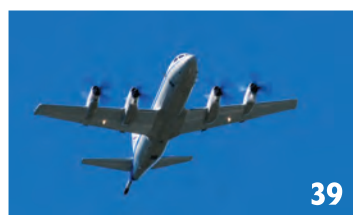

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Postcard from Long Beach

by Michael Miller
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I hope many of you reading this had the opportunity to attend this year's Annual Conference & Exhibition in Long Beach, CA. In my mind, it was an enormously successful meeting in terms of the level of energy and enthusiasm, networking, and the transfer of technical information. As you can imagine, as President, I spent the bulk of my time attending meetings of the various councils and committees that are the underpinning of both the Association and the conference itself. I also had the privilege to host the two keynote sessions and the annual business meeting, as well as participate in the annual honors and awards and student awards ceremonies. The one technical session I did have time to attend was the Critical Review, which I thought was very informative. Kudos to Critical Review Committee Chair, Gwen Eklund, and members of the Critical Review Committee, 2014 Critical Review author and presenter Tom Grahame, and the five invited discussants for a job well done.

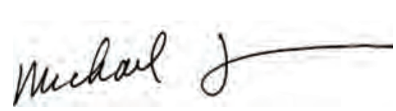
We were very privileged this year to hear four exceptional keynote addresses from Janet McCabe (U.S. Environmental Protection Agency), Dennis Arriola (Southern California Gas Company), Steven Shestag (The Boeing Company), and Barry Wallerstein (South Coast Air Quality Management District). Their remarks and the discussions that followed were first rate and illustrated the type of dialogue that can occur within an Association like ours that provides a neutral forum for all points of view. My sincere thanks go out to all of this year's keynote speakers for their willingness to participate and their highly valued remarks.

While visiting the various council and committee meetings, I reiterated the tenets of A&WMA's new Strategic Plan to obtain input and make sure that as many members as possible were on board. The feedback I received was invaluable and helped clarify some points. For example, the emphasis on engaging the industrial and regulatory community to a greater extent made others feel that we were neglecting them. That is certainly not the intent of the Strategic Plan. We value the diversity of our membership and want to continue growing all of the various constituencies that make up this Association.

I also had an opportunity to speak at the Committee for the Professional Development of Women Luncheon and was inspired by how well this group is networking and integrating new professional women into the Association.

The most satisfying parts of the week for me were the awards ceremonies. At the student awards ceremony, I was thrilled to see the excited faces of the students who had won awards or scholarships for their work on environmental issues, giving me enormous hope for the future. While at the honors and awards luncheon, the recipients inspired me and I began to think about how much effort these individuals have invested in the environmental profession and of the contributions they have made toward improving our lives.

With this message, I would personally like to thank the General Conference Chair, Glenn England, and members of the Long Beach Local Host Committee, A&WMA headquarters staff, sponsors, exhibitors, and everyone else who worked so diligently in making this year's Annual Conference & Exhibition a success.



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Connecting the Dots: Environmental Quality to Climate

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Mark your calendar for June 22-25, 2015!

Air & Waste Management Association

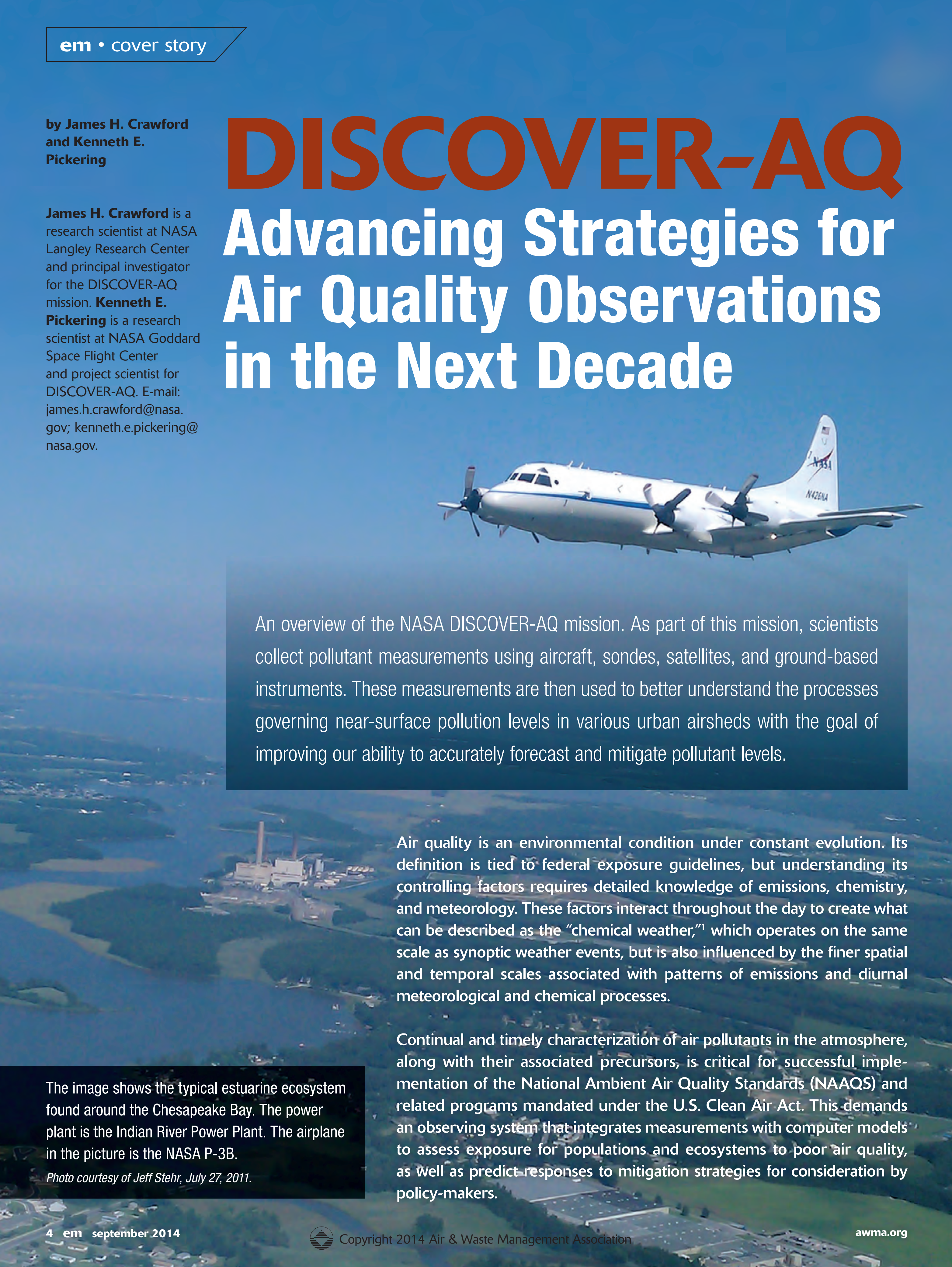
by James H. Crawford and Kenneth E. Pickering

James H. Crawford is a research scientist at NASA Langley Research Center and principal investigator for the DISCOVER-AQ mission. **Kenneth E. Pickering** is a research scientist at NASA Goddard Space Flight Center and project scientist for DISCOVER-AQ. E-mail: james.h.crawford@nasa.gov; kenneth.e.pickering@nasa.gov.

DISCOVER-AQ

Advancing Strategies for Air Quality Observations in the Next Decade

An overview of the NASA DISCOVER-AQ mission. As part of this mission, scientists collect pollutant measurements using aircraft, sondes, satellites, and ground-based instruments. These measurements are then used to better understand the processes governing near-surface pollution levels in various urban airsheds with the goal of improving our ability to accurately forecast and mitigate pollutant levels.



The image shows the typical estuarine ecosystem found around the Chesapeake Bay. The power plant is the Indian River Power Plant. The airplane in the picture is the NASA P-3B.

Photo courtesy of Jeff Stehr, July 27, 2011.

Air quality is an environmental condition under constant evolution. Its definition is tied to federal exposure guidelines, but understanding its controlling factors requires detailed knowledge of emissions, chemistry, and meteorology. These factors interact throughout the day to create what can be described as the "chemical weather,"[1] which operates on the same scale as synoptic weather events, but is also influenced by the finer spatial and temporal scales associated with patterns of emissions and diurnal meteorological and chemical processes.

Continual and timely characterization of air pollutants in the atmosphere, along with their associated precursors, is critical for successful implementation of the National Ambient Air Quality Standards (NAAQS) and related programs mandated under the U.S. Clean Air Act. This demands an observing system that integrates measurements with computer models to assess exposure for populations and ecosystems to poor air quality, as well as predict responses to mitigation strategies for consideration by policy-makers.

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THE INSTRUMENT

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PLUMES

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MiniMPL can provide a quantitative determination of the opacity of an emission plume remotely, during daytime or nighttime hours. Using precise measurements of plume opacity, MiniMPL can improve our understanding of pollution level and air quality for environmental monitoring and enforcement. Sigma Space is working as a contractor to support the US Environmental Protection Agency in developing the next generation plume monitoring kit, using Sigma's MiniMPL Sensor Suite. MiniMPL can also be used for monitoring dust concentration from open pit mining operations.

PLANETARY BOUNDARY LAYER

ACCURACY IN EMISSIONS ESTIMATES

Since aerosols accumulate in the Planetary Boundary Layer (PBL) – the layer of the atmosphere closest to the Earth's surface – MiniMPL is ideal for monitoring the daily rise and fall of the PBL. The PBL is the mixing bowl for greenhouse gases (GHGs) and other pollution, and the size of this bowl is essential to calculate emission inventories for climate change and air quality monitoring and policy.

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Over the decades, air quality agencies have largely relied on a combination of in-situ measurements, engineering calculations, and air quality models to provide the quality and quantity of data to characterize air quality in support of air quality management and policy decision-making activities. While satellites can now measure key pollutants (or surrogates) in the atmosphere, such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ammonia (NH_3), ozone (O_3), formaldehyde (HCHO), and a variety of aerosol optical properties, such as aerosol optical depth and extinction related to particulate matter (PM), methods are needed to characterize the satellite data so it can be used to derive a relevant air quality metric.

Air quality applications for using satellite data include:

- monitoring and trends;
- improved characterization of emissions;
- extreme event analyses;
- source attribution;
- lifetimes, transport, and distribution of pollutants; and
- radiative forcing of short-lived pollutants.

The current state of air quality monitoring in the United States is summarized in a recent report produced by the Air Quality Research Subcommittee of the Committee for Environment, Natural Resources, and Sustainability under the National Science and Technology Council.[2] Among the list of needs and opportunities identified in the report, two address the need for expanding observations to complement the capability of current ground-based monitoring networks.

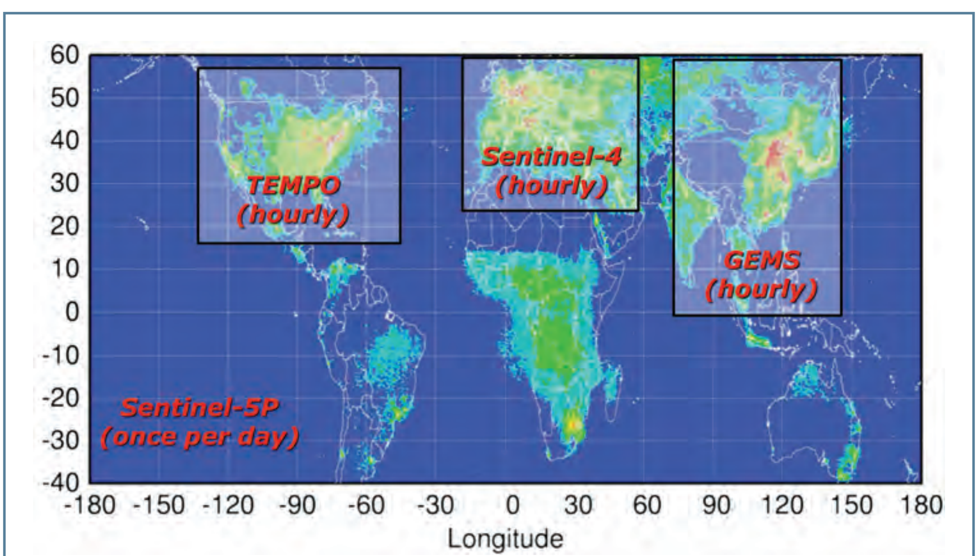
The first is the need for vertically-resolved observations of pollutants and their distribution in the lower atmosphere. Much of what happens at the surface is linked to conditions aloft, but there is limited information on how vertical mixing, boundary layer depth, and transport from upwind sources affect surface observations.

The second is satellite observations from geostationary orbit enabling observations many times per day at fine spatial scales across North America. Such observations would provide a more contiguous picture of air quality by filling the gaps between ground monitors and extending information beyond monitored areas.

Both of these needs are the focus of projects selected by NASA's Earth Venture Program promoting innovative Earth science research through targeted airborne field studies and satellite instruments. The first is a series of airborne field studies, called DISCOVER-AQ, and the other is a geostationary satellite instrument, called Tropospheric Emissions: Monitoring of Pollution (TEMPO).

TEMPO observations of gaseous pollution will include O_3 and its precursors (i.e., NO_2 and HCHO). Aerosol optical depth associated with fine particulate pollution will also be observed. The launch of TEMPO is planned for later this decade (est. 2019) when European and Asian partners also plan to launch geostationary air quality sensors, each observing their respective portion of the Northern Hemisphere (see Figure 1). In the meantime, DISCOVER-AQ has been busy collecting observations that will improve how these satellite observations will be interpreted and combined with ground observations

Figure 1. Global air quality monitoring constellation expected to become operational in the 2018–2020 timeframe.



Notes: Contributions include geostationary observations by NASA (TEMPO), European Space Agency (Sentinel-4), and Korean Aerospace Research Institute (GEMS). These hourly observations from geostationary orbit will be complemented by daily global coverage from low earth orbit by the European Sentinel-5P satellite. Satellite viewing areas are shown over a background image of the average global distribution of tropospheric NO_2, as seen from space.

DISCOVER-AQ

Deriving **I**nformation on **S**urface conditions from **CO**lumn and **VER**tically resolved observations relevant to **A**ir **Q**uality

to inform air quality models and provide decision-makers with better information on options for mitigating poor air quality.

This issue of *EM* reports on early outcomes from the DISCOVER-AQ series of field studies, the first of which was conducted in the Baltimore–Washington metropolitan area in July 2011. An overview of the observing strategy for this study sets the stage for a series of articles focused on what the DISCOVER-AQ observations are revealing about model capabilities, the spatial and temporal scales of pollution formation and transport, the influence of bay breeze circulations, challenges in connecting satellite observations to surface air quality, the impact of emission trends over the last decade, and how DISCOVER-AQ observations in other locations are revealing different challenges to air quality observations.

Following the Baltimore–Washington campaign, additional field deployments were conducted in California's San Joaquin Valley in January–February 2013 and in Houston, TX, in September 2013. DISCOVER-AQ will have just completed its final deployment in Colorado with the release of this issue of *EM*. Analysis of these observations will continue to inform strategies and put us in a position to take full advantage of geostationary satellite observations when they come online. **em**

Top: Inside the P-3B research aircraft, which contains 10 sets of instrumented racks.

NASA / Tom Tschida

Above, left: Scientist Stephanie Vay seated at the instrument rack containing the AVOCET instrument (left) and PDS display (right).

Above, right: AVOCET inlet, P-3B research aircraft.

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DISCOVER-AQ

Observations and Early Results

by James H. Crawford, Russell Dickerson, and Jennifer Hains

James H. Crawford is a research scientist at NASA Langley Research Center and principal investigator for the DISCOVER-AQ mission. **Russell Dickerson** is a professor in the Department of Atmospheric and Oceanic Sciences at the University of Maryland, College Park, and principal investigator for the Regional Atmospheric Measurement, Modeling, and Prediction Program (RAMMPP). **Jennifer Hains** is a research scientist at the Maryland Department of Environment's Air and Radiation Management Administration . E-mail: james.h.crawford@nasa.gov.

Insider observations and results from the Baltimore–Washington field studies.

The DISCOVER-AQ mission builds upon a long heritage of air quality field campaigns by employing a unique observational approach that is described by its acronym: **D**eriving **I**nformation on **S**urface conditions from **CO**lumn and **VER**tically resolved observations relevant to **A**ir **Q**uality. These words describe the multi-perspective observing strategy needed to enable future satellite observations from geostationary orbit to connect to surface monitoring networks and broadly extend information on air quality that will be useful for forecasting and assessment. This challenging task is complicated by several factors.

Firstly, satellites look down through the entire atmosphere, detecting not just what is at the surface, but everything in the atmospheric column. This includes large abundances in the stratosphere for ozone (O_3) and nitrogen dioxide (NO_2). This is less of a problem for aerosol optical depth (AOD) and formaldehyde (HCHO) column amounts, which are dominated by abundances in the lower atmosphere. Even in the troposphere, pollution plumes being transported at higher altitudes can complicate satellite interpretation. In the lowest portion of the atmosphere, the depth of mixing in the atmospheric boundary layer influences the dilution of emissions, the rate of formation for O_3 and secondary particles, and the ventilation and long-range transport of polluted air masses. Atmospheric humidity is another important factor, as water uptake influences particle size and light scattering properties. This affects AOD as observed from space but does not impact measurements of fine particulate dry mass ($PM_{2.5}$) measured at the surface.

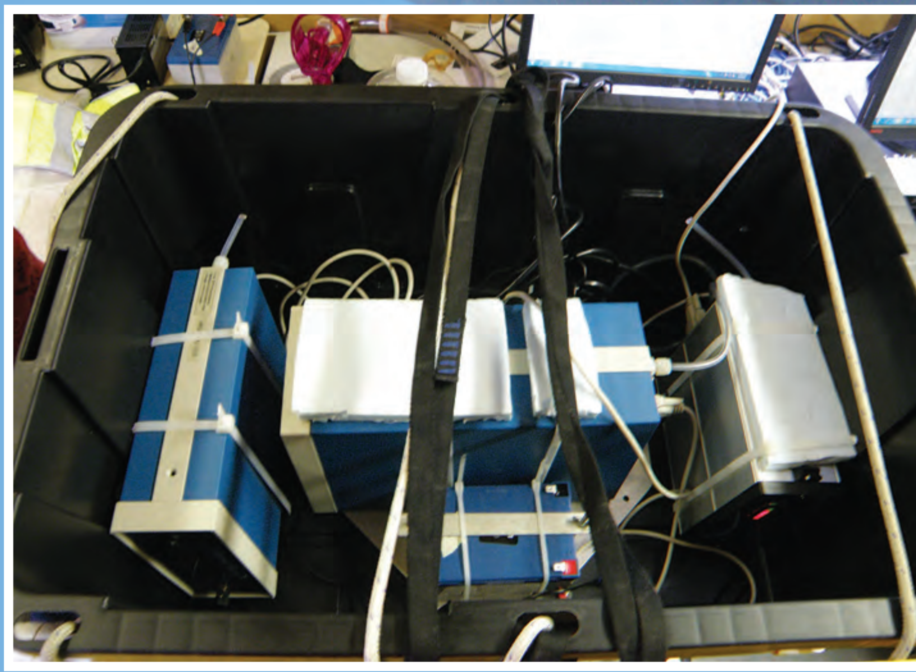
Addressing these problems requires a strategy that provides concurrent views of air quality that include surface, column-integrated, and vertically-resolved perspectives. DISCOVER-AQ accomplishes this by deploying multiple research aircraft and ground-based instruments to locations currently in violation of federal air quality standards. By partnering with state and local environmental agencies and university researchers, historical knowledge and experience can be used to tailor the observing strategy for each deployment location. Thus far, DISCOVER-AQ has conducted flights over the Baltimore–Washington area (July 2011), California's San Joaquin Valley (January–February 2013), Houston, TX (September 2013), and Denver, CO (July–August 2014).

Observational Strategy for the Baltimore–Washington Area

In DISCOVER-AQ's initial deployment to the Baltimore–Washington area, major local partners were the Maryland Department of Environment (MDE), the University of Maryland, College Park (UMD), Howard University (HU), and the University of Maryland, Baltimore County (UMBC). A full list of participants and partners is available online at http://discover-aq.larc.nasa.gov.

With guidance from MDE on the pattern and timing of air quality episodes in the region, the DISCOVER-AQ observing strategy was built around the existing monitoring network, as represented in Figure 1. The observing strategy included augmentation of ground sites with additional instrumentation and overflight by three research aircraft.

High above the network, a King Air twin-turboprop aircraft from NASA Langley Research Center flew at 8 km looking downward to simulate the satellite perspective. Since current satellites in low-earth orbit provide only a fleeting look at air quality once per day, this aircraft enabled an examination of how a satellite view would evolve throughout the day by executing numerous remote sensing transects over the ground sites. Column-integrated amounts of O_3, NO_2, and HCHO were provided by the Airborne Compact Atmospheric Mapper (ACAM),[1] while the High Spectral Resolution Lidar (HSRL)[2] provided vertically-resolved information on aerosol scattering and extinction, as well as other properties, such as depolarization, effective radius, single scattering albedo, and number concentration.



The final operational assembly of the tethersonde and air chemistry instrument box in flight.

Beneath the King Air flight pattern, the P-3B four-engine turboprop aircraft from NASA's Wallops Flight Facility conducted spiral ascents and descents over the ground monitoring sites. Onboard the P-3B, in-situ measurements of O_3, NO_2, HCHO, and PM provided the information on the vertical distribution of pollution needed to bridge the airborne remote-sensing to the surface measurements of air quality. The payload also included other measurements to provide context on pollution sources and chemical evolution of pollutants, including carbon monoxide (CO), methane (CH_4), carbon dioxide (CO_2), nonmethane hydrocarbons (NMHCs), reactive nitrogen species, and particle properties spanning number and size distributions, optical properties, and chemical composition.

During an 8-hr flight, there was sufficient time to profile three times over six ground sites at an

interval of about 2.5 hours. Profiles were generally from 300 m to 3.2 km, although profiles over Beltsville were limited to 1.7 km due to local air traffic patterns and were higher over Fairhill (4.8 km) to probe deeper into the free troposphere.

Collaborative flights by the UMD Cessna 402B twin piston engine aircraft were conducted upwind and downwind of the DISCOVER-AQ flight pattern (see Figure 1 inset). The value of these flights was also enhanced by their historical perspective, as the group had been flying similar sampling patterns for nearly 15 years prior. Observations for this platform included O_3, CO, NO_2, sulfur dioxide (SO_2), and aerosols (number, scattering, and absorption). During the field study, in-flight comparisons were conducted between the P-3B and Cessna observations.

At the surface, there were a number of critical augmentations to the existing monitoring network maintained by MDE. Sun-tracking remote sensors were placed at 12 sites to provide continuous column-integrated measurements of gaseous pollution (Pandora spectrometers) [3] and AOD (Aeronet sunphotometers).[4] Although not depicted in Figure 1, Aeronet also sponsored a Distributed Regional Aerosol Gridded Observation Network (DRAGON), resulting in a total of 44 Aeronet sunphotometers.

At selected locations, research-grade instrumentation was also placed alongside routine monitoring instruments. In some cases, this was to expand the measurement suite to enable identification of pollution sources. In other cases, it was to evaluate monitoring measurements against more robust

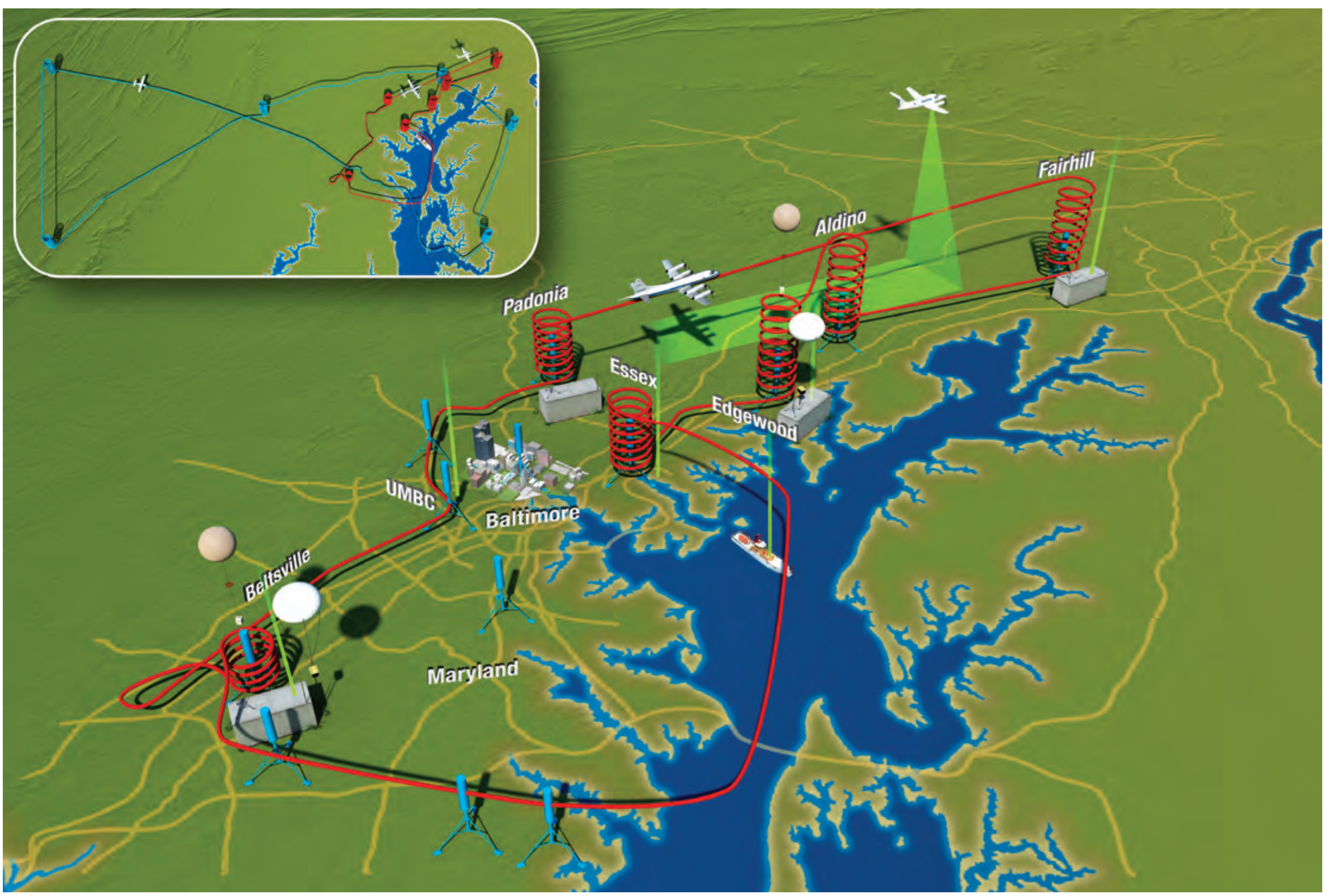
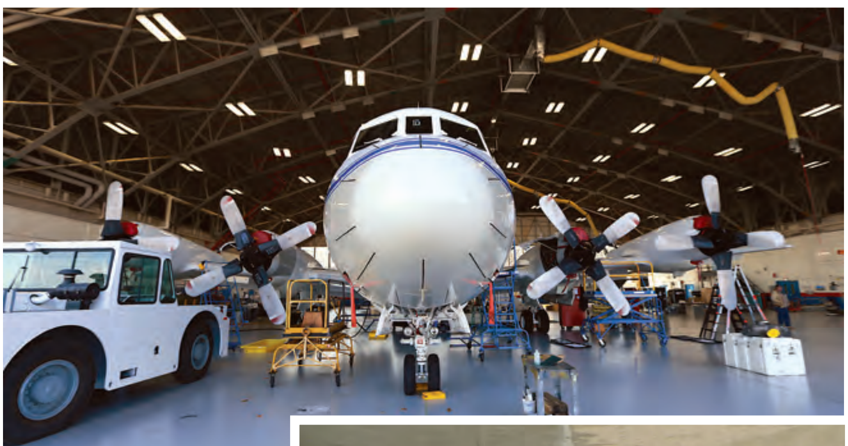
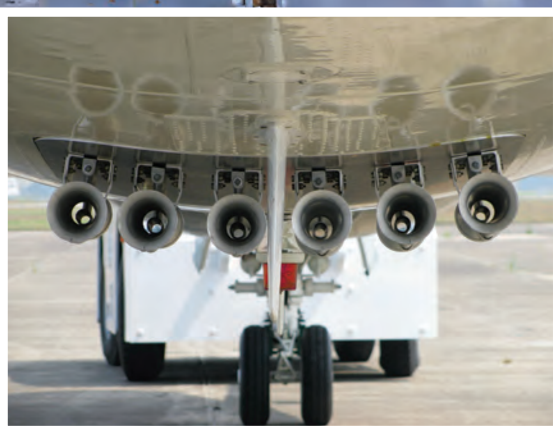


Figure 1. DISCOVER-AQ observing strategy employed during the Baltimore–Washington study.

Notes: The red line traces the P-3B flight path with recurring spirals over Maryland Department of Environment monitoring sites. This flight path was repeated three times on each flight day. Actual flight path for the higher flying King Air is not shown, but closely follows that of the P-3B. The inset view shows upwind and downwind sampling by the University of Maryland Cessna 402B. Tripod sensors represent locations of Pandora spectrometer and Aeronet sunphotometer pairs (30 additional Aeronet locations as part of the DRAGON network are not shown). Balloon pairs represent tethered balloon and ozonesonde operations. Trailers are shown at sites where additional in-situ measurements were added to a monitoring location. Lidar observations are shown as vertical traces in light green. The ship represents the cooperative CBODAQ research cruise.
Image courtesy of Timothy Marvel.





Top: HSRL integration on the B-200.

Middle: P-3B integration at Wallops.

Bottom, left: Downward-looking NO_2 photolysis radiometer.

Bottom, right: Instrument exhaust ports.

measurement techniques. For instance, the U.S. Environmental Protection Agency (EPA) provided NO_2 instruments with high specificity to compare with routine monitors, which are known to be susceptible to interferences from other reactive nitrogen species such as peroxyacetyl nitrate (PAN). Active remote sensing with aerosol lidars was provided by researchers at UMBC and a welcome, but unplanned, network of MicroPulse Lidars emerged as the result of four systems provided on loan from SigmaSpace Corp., enabling broad and continuous monitoring of the vertical distribution of aerosols across the domain.

With the P-3B aircraft limited to flight no lower than 1000 feet (330 m), tethered balloons provided an invaluable source of information on gradients between the surface and the lowest altitude sampled by the aircraft. These observations were implemented by HU at the Beltsville site and Millersville University at the Edgewood site. These sites also offered the most comprehensive surface measurements with augmentations by researchers from Penn State University. HU and Penn State researchers also launched ozonesondes from these locations, providing important information on the relative importance of surface pollution and upper atmospheric sources on O_3.

The observing system was rounded out by a ship-based collaboration called Chesapeake Bay Oceanographic campaign with DISCOVER-AQ (CBODAQ).[5] Sponsored by the oceanic working group for future geostationary observations of coastal ocean color, planned as part of the GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission, this ship acted as a temporary air quality monitoring site, providing observations over the adjacent waters of the Chesapeake Bay, an important unmonitored region downwind of the Baltimore–Washington area. Overflights of these ship-based observations also provided important information for the ocean color observations onboard as atmospheric aerosols, NO_2, and O_3 interfere with satellite observations of ocean color.

The scope of observations associated with DISCOVER-AQ has grown with subsequent deployments to California's San Joaquin Valley, Houston, TX, and Denver, CO. For instance, additional flexibility has been found in the use of mobile labs that include both remote-sensing and in-situ measurements that can be easily relocated or operated while moving between locations within the network. The use of missed approaches at small local airports has enabled airborne measurements much closer to the surface than the 1,000-ft limit. EPA has expanded its involvement to include near-road monitoring of NO_2, federal reference method evaluations, remote-sensing of boundary layer depth, and the evaluation of small air quality sensors commercially available for use by the public. Lidar remote-sensing has expanded to include O_3 in collaboration with NASA's Tropospheric Ozone Lidar Network (TOLNet). In Colorado, DISCOVER-AQ has been joined by the Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ), a jointly-funded collaboration between the National Science Foundation and Colorado's Department of Public Health and Environment. FRAPPÉ adds another major research aircraft, the NSF C-130, and additional surface-based observations to provide the largest collection of observations for the final DISCOVER-AQ deployment.

Benefits to Local Regulators

One of the added bonuses of DISCOVER-AQ has been the opportunity for collaborations between state regulatory air agencies and expert scientists from universities and federal laboratories. These collaborations have allowed state air managers to directly communicate with scientists on the air quality challenges they struggle with every day. This interaction between the two groups has helped ensure that the scientific findings address and help inform state air quality policy decisions. It has also provided the scientists with research opportunities that have direct impacts on air quality issues in their own backyard. DISCOVER-AQ laid the framework for a successful model for collaboration between state air quality managers and expert scientists in the future. This model is already being implemented successfully by the NASA Air Quality Applied Sciences Team (AQAST), as described in the February 2014 issue of EM. Cutting-edge scientific research based on DISCOVER-AQ has helped MDE with current policy issues, ranging from motor vehicle emissions inventories to pollution transport. Research associated with both of these issues will help inform future state air regulatory policy strategies.

Early Outcomes

During the July 2011 study period, DISCOVER-AQ conducted research flights on 14 days, encountering a wide range of air quality conditions. The choice of flight days was guided by a forecasting team using standard meteorological products, NOAA air quality model forecasts, and the

By partnering with state and local environmental agencies and university researchers, historical knowledge and experience can be used to tailor the observing strategy for each deployment location.

recommendations of local air quality forecasters. On 9 of these flights days, NAAQS violations for O_3 occurred at one or more of the six profiling sites, and while there were no violations for $PM_{2.5}$, daily average AOD values ranged from less than 0.1 to nearly 0.7. These flights resulted in 254 in-situ profiles (~40 per site), 47 in-situ transects following the I-95 traffic corridor at 1,000 feet, and 50 or more remote-sensing transects over the profile sites, the I-95 corridor, and the Chesapeake Bay. This rich dataset combined with the surface network observations provides a basis

Early Results from Baltimore–Washington

While there is still much analysis of the observations that lies ahead, early results from the first campaign include the following:

Goldberg et al.[6] verified model enhancements in O_3 over the Chesapeake Bay in comparison to adjacent land areas based on ship-based observations and nearby air quality sites. An exploration of the contributing factors revealed a combination of lower boundary layer heights, reduced cloud cover, and slower dry deposition rates over water contributed to this difference.

Anderson et al.[7] demonstrated that the Community Multi-scale Air Quality Model (CMAQ) tied to the updated National Emissions Inventory (NEI) matches CO observations for both in-situ and remotely-sensed satellite (MOPITT) data well, but the model substantially overestimates total reactive nitrogen (NO_y) concentrations. They attribute this to overestimated mobile source oxides of nitrogen (NO_x) emissions, which are not as well quantified as emissions from major point sources due to uncertainties in vehicle driving modes and various states of repair. Understanding the relative emissions from stationary and mobile sources is essential for directing control measures, while understanding the absolute emissions is essential for predicting the efficacy of those controls as the response of ozone to NO_x concentrations is highly nonlinear.

DISCOVER-AQ generated a rich data set from which ozone production efficiency (OPE) could be calculated for the Baltimore–Washington area. OPE indicates the number of O_3 molecules produced per NO_x molecule before it is lost to a sink or reservoir species such as HNO_3 or PAN. These data allowed He et al.[8] to show that high O_3 concentrations on hot days are, in part, a consequence of greater NO_x emissions due to greater demand for electric power. These results suggest that better control of peaking units may be an effective abatement strategy.

Ziemba et al.[9] verified an empirically-derived relationship between changes in aerosol extinction and aerosol growth due to humidification. Results indicated that 43% of ambient aerosol extinction could be attributed to this growth effect, an important factor in relating satellite measurements of ambient optical depth to dry $PM_{2.5}$ measurements.

Crumeyrolle et al.[10] performed a more complete analysis of the factors controlling the relationship between surface $PM_{2.5}$ and aerosol optical depth. In addition to humidification effects, the vertical distribution of aerosol was found to be the most important factor, especially accounting for aerosol above the boundary layer. This emphasizes the value of active remote sensors, such as lidars, for connecting satellite and surface-based observations.

Compton et al.[11] demonstrated a method for determining boundary layer depth from lidar and wind profiler observations using a covariance wavelet transform technique.

The importance of boundary layer depth to the relationship between column abundance and surface concentration was emphasized by several studies[12-14] and complex effects associated with sea breeze circulations were also highlighted.[15-17] Both topics are covered in more detail by other articles in this issue of *EM*.

Finally, DISCOVER-AQ data contributed to the information contained in an amicus brief to the U.S. Supreme Court regarding EPA's Cross-State Air Pollution Rule (CSAPR), which was recently upheld. Measurements of NO_2 made from aircraft during DISCOVER-AQ[18] and from satellite[19] demonstrated wide spread concentrations of NO_2 sufficient to catalyze the production of O_3 pollution over the eastern United States. This confirmation of the influence of mid-range transport played a role in shaping national policy regarding the transport of pollutants and their precursors across state lines.

for developing a statistical understanding of how the interpretation of satellite observations in the future can best complement regulatory monitoring networks and how the combined information from both can inform air quality models used to forecast air quality and test scenarios for mitigation. The data are also freely shared with partners and the interested public through an online public archive accessible through the project Web site (http://discover-aq.larc.nasa.gov).

Summary

The DISCOVER-AQ data have broad relevance across the spectrum of air quality research. The multi-perspective observations are useful for evaluating air quality models, developing better satellite retrievals, identifying gaps or errors in emissions inventories, and better understanding photochemical processes. The data also send a clear message that future geostationary satellite observations will provide invaluable information to complement ground based monitoring, but they will not replace or eliminate the need for ground-based monitoring methods. As the geostationary air quality era approaches, DISCOVER-AQ will help define the optimal combination of ground observations needed to make immediate use of satellite observations from NASA's Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument. **em**

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by K. Wyat Appel, Robert C. Gilliam, Jonathan E. Pleim, George A. Pouliot, David C. Wong, Christian Hogrefe, Shawn J. Roselle, and Rohit Mathur

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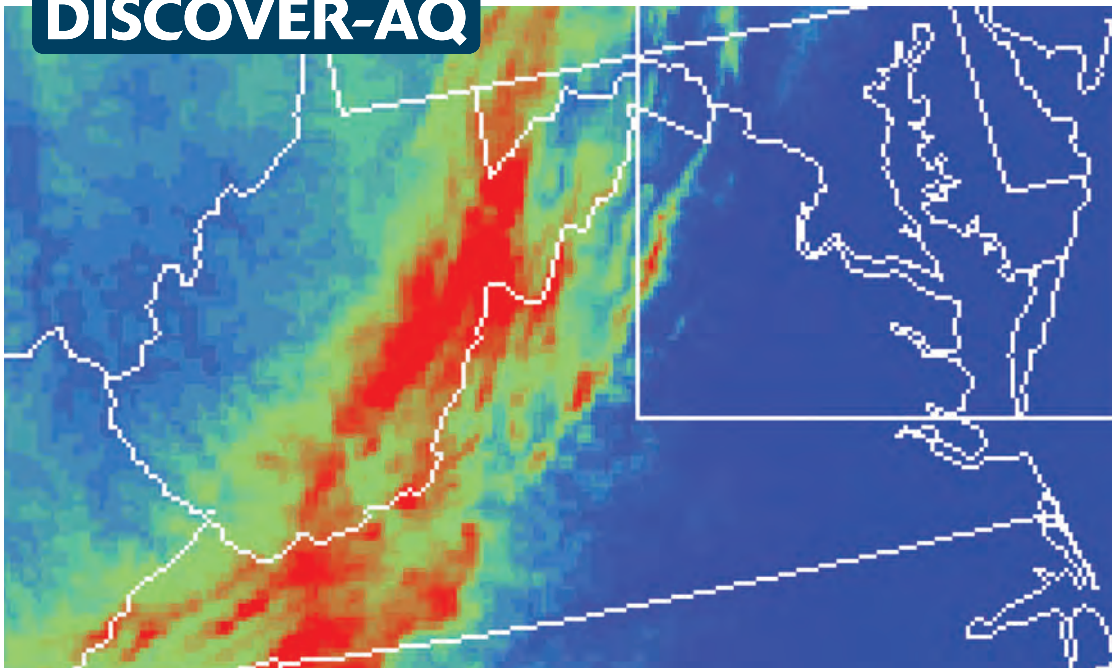
DISCOVER-AQ



Improvements to the WRF-CMAQ Modeling System for Fine-Scale Air Quality Simulations

A look at the model simulations performed across the continental United States using the coupled WRF-CMAQ modeling system, comparing them to measurements from the 2011 Baltimore–Washington DISCOVER-AQ campaign.

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Despite significant reductions in atmospheric pollutants such as ozone (O_3) and fine particulate matter ($PM_{2.5}$) over the past several decades, air pollution continues to pose a threat to the health of humans and sensitive ecosystems. A number of areas across the United States remain in violation of the National Ambient Air Quality Standards (NAAQS; http://www.epa.gov/airquality/greenbook). Numerical air quality modeling systems designed to simulate the emissions, transport and fate of atmospheric pollutants are a critical part of the regulatory process in designing abatement strategies to reduce these pollutants. Air quality models are also used to forecast next-day air quality conditions so as to allow citizens to modify their activities accordingly to avoid potential health issues (e.g., asthma attacks).

Eulerian air quality models, such as the Community Multiscale Air Quality (CMAQ) model,[1] discretize large simulation domains into smaller-sized grid cells to better represent spatial heterogeneities, with smaller-sized grid cells in theory providing a truer representation of fine-scale processes and near-field impacts. While utilizing larger-sized grid cells has the advantage of minimizing computation resources, it does have several disadvantages. Since Eulerian air quality models instantly dilute point emissions across the entire volume of the grid cell, decisions on grid resolution should be made with consideration of the spatial scale of the air quality problem, meteorology, and emissions being modeled, while also recognizing the increased computation resources required as grid cell size is decreased. The smaller the dimensions of the grid cells used, the more representative the model may be of the actual point source emissions. Additionally, meteorological fields (e.g., wind and temperature) are also likely to be better represented with smaller grid cells, particularly in areas with diverse and complex geography (e.g., coastal and mountainous regions).

The goals of this work were two-fold. First, to demonstrate the application and skill of the CMAQ modeling system, coupled with the Weather Research and Forecasting (WRF) meteorological model at fine-scales (i.e., 4 and 1 km).[2] Second, to evaluate the model results of the various simulations against a high-quality meteorological and air quality observation dataset. To meet these goals, model simulations were performed using 12-km, 4-km, and 1-km horizontal grid spacing (see Figure 1) over the continental United States (12-km domain), a portion of the eastern United States (4-km domain), and the Baltimore–Washington, DC, region (1-km domain). The results from the simulations were then compared to measurements from the 2011 Baltimore–Washington DISCOVER-AQ campaign (http://www.nasa.gov/mission_pages/discover-aq/index.html). Discussed here are several innovative modeling techniques and new data sets that were required to produce fine-scale WRF-CMAQ model simulations that performed at least as well as the coarser 12-km model simulation.

Iterative WRF Analysis for Fine-Scale Applications

For retrospective simulations, such as those described here, the WRF model[3] is typically run using four-dimensional data assimilation (FDDA), which requires gridded analyses of wind, temperature, and moisture to nudge the atmosphere above the planetary boundary layer (PBL). Also used are 2-m temperature and moisture analyses that are fused with surface observations to indirectly nudge soil moisture and temperature so that the ground-level WRF fields more closely track the observations.

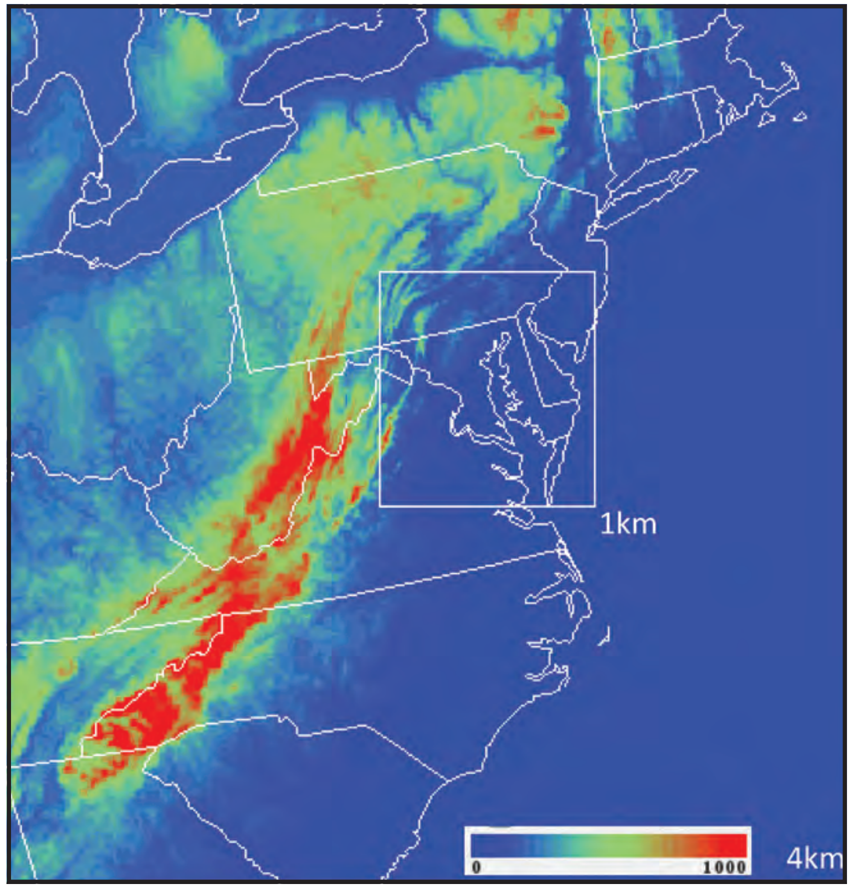


Figure 1. Depiction of the 4-km and 1-km WRF-CMAQ domains (terrain height shown in meters). The 12-km domain (not shown) covers the entire continental United States, including southern Canada and northern Mexico.

For this application, the readily available North American Model analysis product at 12-km horizontal grid spacing (NAM-12) was used for the initial WRF model applications for all three domains (12-km, 4-km, and 1-km). The 2-m analysis data are only used to adjust the soil temperature and moisture fields, so there is no need of direct nudging within the PBL. While the model performance for the 12-km simulation was consistent with results from comparable 12-km WRF simulations, the model performance for the initial 4-km and 1-km simulations was poor compared to that of the 12-km simulation. Since the coarse input data from the NAM-12 reanalysis product was inconsistent with the higher resolution geography, terrain, land use, and soil data used for the fine-scale WRF simulations, the soil moisture and temperature data assimilation scheme was less effective at reducing temperature and moisture errors.

To improve the near-surface analysis fields used to adjust soil temperature and moisture, an iterative

The smaller the dimensions of the grid cells used, the more representative the model may be of the actual point source emissions.

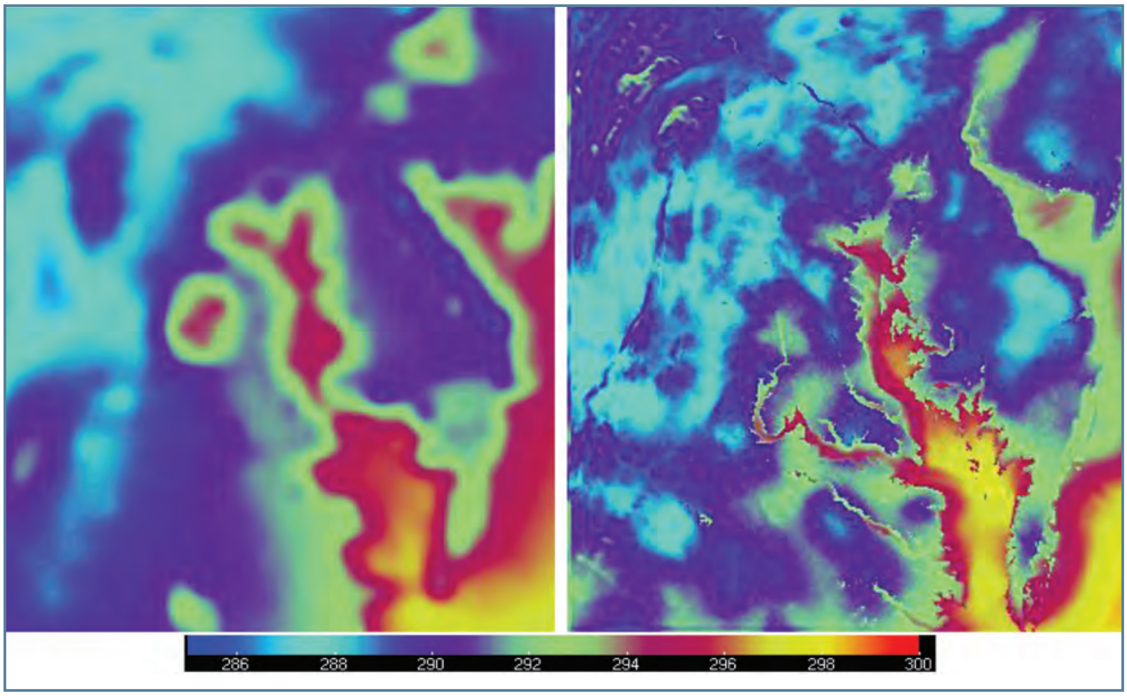


Figure 2. A 2-m temperature (K) analysis field for soil nudging using NAM 12-km background (left) and iterative 1-km WRF output as background (right).

process for running WRF at fine-scales was developed. Simply described, an initial 1-km or 4-km WRF simulation was performed using the coarse input data available from the NAM-12 as the analysis field. Once that run was complete, a second WRF simulation was performed using the output from the initial WRF simulation in place of the NAM-12 data used in the initial WRF simulation. These first guess fields were then fused with observations to correct for model bias.

Figure 2 presents the 2-m temperature analysis fields from the raw NAM-12 data and the 1-km iterative simulation. The analysis field based on the raw NAM-12 data is quite coarse with few discernable fine-scale topographic features (e.g., narrow mountain valleys and small tributaries of the Chesapeake Bay). Conversely, the 1-km iterative analysis field has a much more realistic representation of the gradients in temperature caused by the Chesapeake Bay and other topographic features (Figure 2). The 2-m temperature error is also greatly reduced in the iterative 1-km WRF simulations versus the non-iterative simulation (see Figure 3).

Improved Representation of Urban Environments

Urban landscapes present other challenges that standard WRF configurations do not resolve well. The numerous tall buildings disturb wind flow more than do natural landscapes, and radiation is trapped through multiple reflections between building walls. Additionally, urban areas have relatively high heat capacity due to abundant cement and asphalt that can make up the majority of the city landscape. Such surfaces require more radiative energy to warm early in the day as the sun rises, reach peak temperature later in the day, and cool slower in the evening than more natural surfaces found outside of cities (e.g., grasslands, forests, and agricultural fields). The net impact on the meteorology and air quality is slower buildup of ozone (O_3) in the morning due to slower entrainment from layers aloft and greater titration of O_3 by oxides of nitrogen (NO_x; i.e., NO + NO_2), which is less diluted in the more slowly deepening mixed layer. In the late afternoon and early evening, cooling and stabilizing occurs more slowly in the urban boundary layer, thereby increasing dilution of surface emitted pollutants such as NO_x and resulting in less titration and greater concentrations of O_3.

To address the deficiencies of standard WRF-CMAQ simulations in properly representing urban areas, a simple approach was applied which leverages very accurate and highly resolved impervious surface and canopy fraction data that are available from the National Land Cover Database (NLCD). In addition, the NLCD includes four urban classes for which surface characteristics can be differentially assigned.

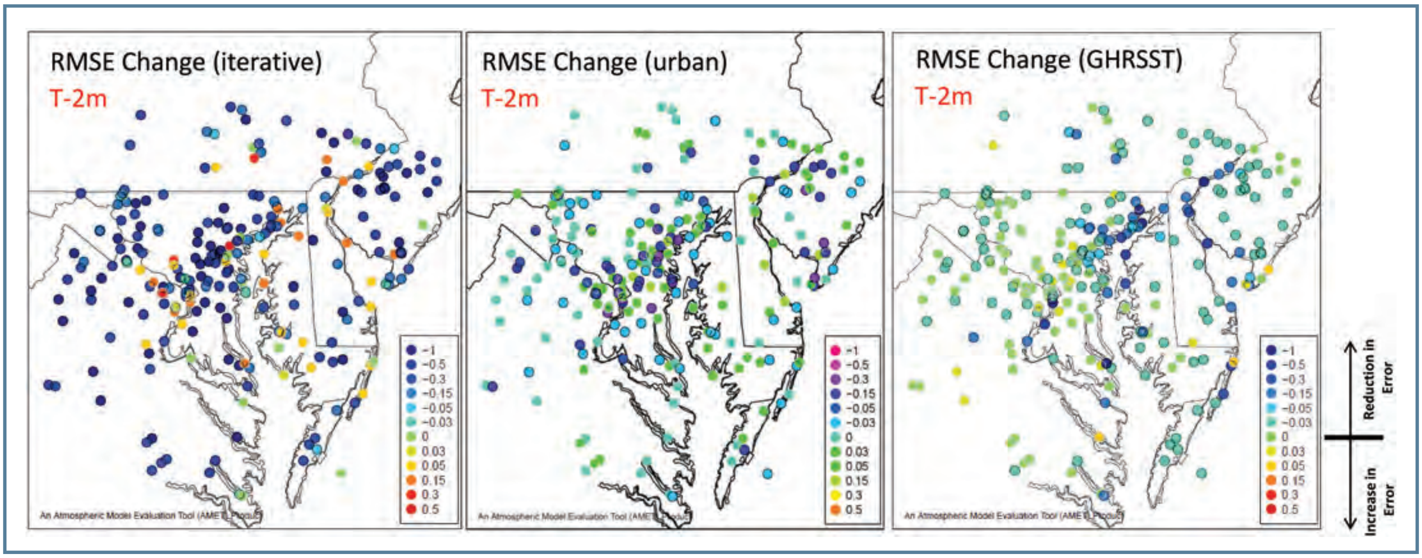


Figure 3. Change in 2-m temperature (K) error for the 1-km WRF simulation due to the iterative WRF processing (left), inclusion of impervious surface and urban canopy parameterizations (center), and inclusion of the GHR-SST data (right).

For example, in the three urban categories that represent high-, medium-, and low-density developed areas of cities from the urban core to the suburbs, surface roughness is increased to better account for the effects of structures and the albedo is decreased to account for the effects of radiation trapping within urban street canyons. Next, the impervious surface data are gridded to the WRF domain and the fraction of impervious surface in each model grid cell is used to adjust the volumetric heat capacity of the surface. Previously, the heat capacity was only based on fraction of vegetation versus natural ground surface. Now, the percent impervious surface is considered and the remainder is split between vegetation and bare ground to give a weighted value for the grid cell's surface heat capacity.

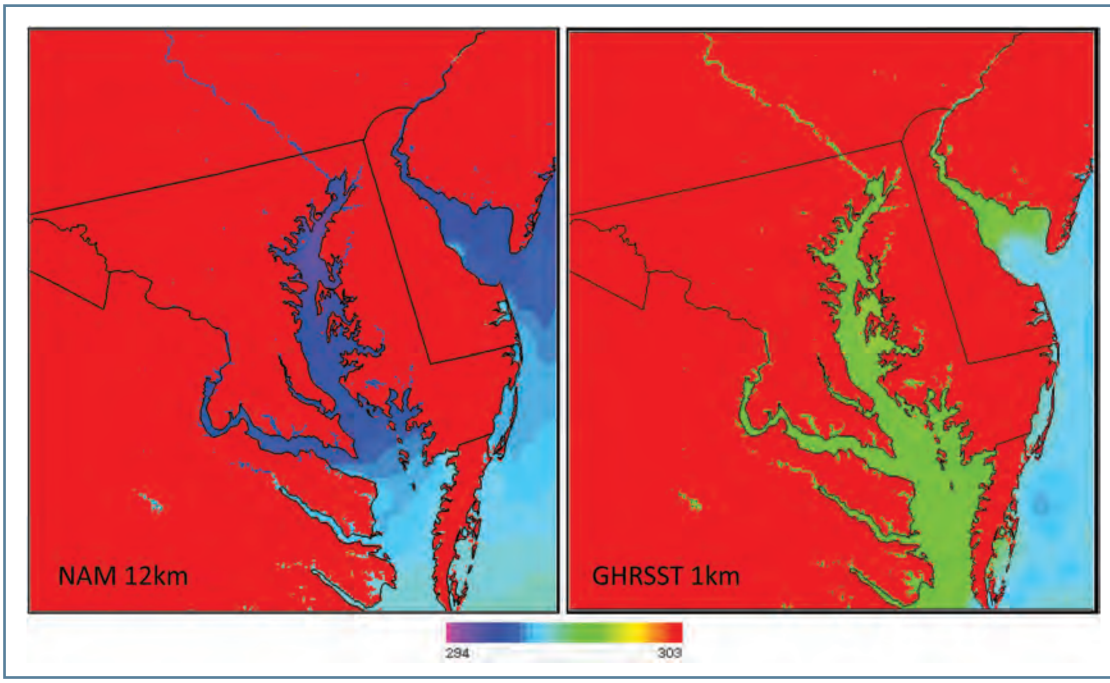
For the impervious fraction, the heat capacity was based on civil engineering estimates for asphalt and concrete with 15-cm thickness. Furthermore, since the urban land use categories do not give information about vegetation coverage, which is critically important to realistic partitioning of sensible and latent surface heat flux, the forest canopy fractional coverage is used along with the imperious fraction to constrain the forest and other vegetation fractions and better estimate the grid cell aggregate leaf area index (LAI). In future work, anthropogenic heating from traffic, residential heating and cooling, and commercial and industrial sources will be added. These effects will be particularly important during the winter in colder climates.

Figure 3 shows the change in 2-m temperature error (all hours) between the base WRF simulation and the WRF simulation with the changes to account for the effects of the urban environments. As expected, the largest reductions in error occur in the most highly urbanized areas, specifically in and around the Washington, DC, and Baltimore, MD, regions. The model typically cools these urban areas too quickly in the evening and overnight, but accounting for the increased heat capacity of the urban environments retains the heat longer resulting in a reduction of the overnight cool bias that is often present in the summer.

High-Resolution Sea-Surface Temperature Fields

The final change made to improve the fine-scale WRF simulation was an update to the sea-surface temperature (SST) data used.[4] For the 12-km WRF simulations, SST data were obtained from the NAM-12. However, it was evident in the 1-km WRF simulations that the relatively coarse NAM-12 SST data were not representing the temperature gradients across the Chesapeake Bay very well, often resulting in areas of erroneously cold surface temperatures (see Figure 4). To improve the simulated temperature in and around the bay, and consequently an improved representation of the land-bay breeze, a more detailed SST data set was needed. The Group for High-Resolution SST (GHR-SST; https://www.ghrsst.org/) product from the Advanced Very-High Resolution Radiometer (AVHRR) satellite provides twice daily composite SST measurements at 1-km grid spacing. When these data were used in place of the NAM-12 SST data, the representation of Chesapeake Bay and its many smaller inlets and tributaries was improved

Figure 4. Skin temperature (K) field using the NAM 12-km data (left) and the GHR-SST 1-km data (right).



significantly (Figure 4). A comparison of the 2-m temperature error between the WRF simulations using the NAM-12 SST data and the GHR-SST data show a significant reduction in the error in the WRF simulation using GHR-SST.

Application of WRF-CMAQ at 12-km, 4-km, and 1-km Resolutions

Table 1 presents summary statistics for July 2011 for the three grid resolutions for hourly O_3 and $PM_{2.5}$ for all sites in the 1-km domain. For O_3, the 1-km performed better than the 12-km and 4-km simulations in terms of correlation (*r*) and root mean square error (RMSE), normalized mean error (NME), and mean error (ME), but worse for normalized mean bias (NMB) and mean bias (MB). For $PM_{2.5}$, the opposite is the case, with the 1-km performing worse than the 12-km and 4-km simulations in terms of *r* and error, but having the best performance of the three simulation in terms of bias. It's not immediately apparent why the 1-km simulation has higher error for $PM_{2.5}$ than the 12-km and 4-km simulations, and additional analysis is needed to determine what changes may need to be made (e.g., emissions) to improve the 1-km performance for $PM_{2.5}$.

Figure 5 shows a comparison of O_3 and 10-m wind vectors for July 2 at 5:00 p.m. local time for all three domains. The representation of the bay breeze and sea breeze appears more realistic and better defined in the 4-km and 1-km simulations than the 12-km, in which it is difficult to identify the extent of the bay and sea breezes. The 4-km and 1-km simulations also tend to compare better with the observed O_3 mixing ratios (shown in the circles), particularly around the Washington, DC, and Baltimore, MD, regions. Additional analysis is needed

Table 1. Summary statistics for the 12-km, 4-km, and 1-km WRF-CMAQ model simulations.

Notes: All statistics are based on only the air quality monitoring sites that fall within the 1-km domain (12-km and 4-km domains are windowed to the 1-km).

DOMAIN	*r*	RMSE	NMB	MB	NME	ME
O_3						
1 km	0.76	14.6	-1.4	-0.61	26.6	11.1
4 km	0.74	15.3	-1.7	-0.7	27.7	11.6
12 km	0.74	15.7	0.1	0.03	28.2	11.8
$PM_{2.5}$						
1 km	0.22	18.6	-8.8	-1.46	58.5	9.73
4 km	0.38	11.1	-16.6	-2.76	47.7	7.94
12 km	0.41	10.6	-25.9	-4.36	48.2	8.1

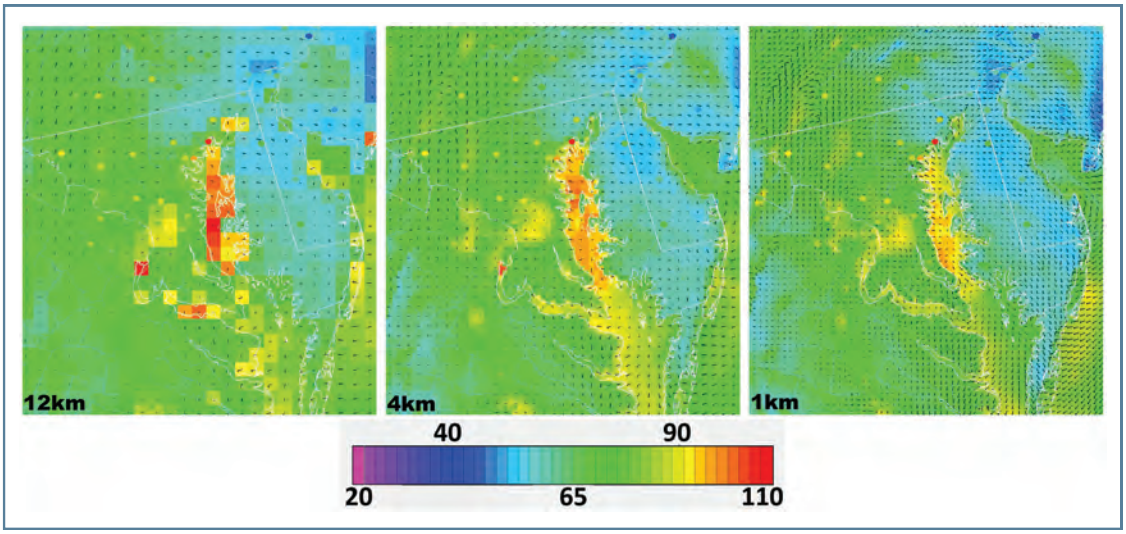


Figure 5. Ozone mixing ratio (shading; 20–110 ppb) and 10-m wind vectors for July 2, 2011, at 5:00 p.m. local time using 12-km (left), 4-km (center), and 1-km (right) horizontal grid spacing. The 12-km and 4-km results have been windowed to the 1-km domain.

to determine quantitatively how the representation of the bay and sea breezes compare between the different model resolutions for the entire month.

Overall, the model performance for the finer-scale simulations is somewhat better for O_3 and somewhat worse for $PM_{2.5}$ compared to the regional-scale simulation, demonstrating the successful application of the WRF-CMAQ modeling system at fine-scales. More analysis is needed to determine where and when the model performance of the finer-scale simulations improves upon the performance of the regional-scale simulation.

Summary

The WRF-CMAQ modeling system has been applied at 12-km, 4-km, and 1-km horizontal grid spacing to the 2011 Baltimore–Washington DISCOVER-AQ campaign. To improve the finer-scale WRF simulations several advances in the input processing and execution of the WRF model were made. First, an iterative processing technique was applied in which 1-km resolution WRF model output is recycled to serve as background for a much more accurate 1-km re-analysis that is then used for soil moisture and temperature data assimilation. Second, a high-resolution impervious surface, tree canopy, and land-use data were incorporated to improve the representation of the urban environment (e.g., buildings and pavement) and better represent the urban heat-island effect. Third, a high-resolution 1-km SST dataset was acquired to replace the coarse 12-km SST dataset that is typically used for regional-scale WRF applications. Together, these improvements to the WRF-CMAQ modeling system resulted in a dramatically improved 1-km simulation of meteorology compared to the initial 1-km simulation without these improvements.

Aggregate model performance metrics for hourly O_3 and $PM_{2.5}$ were generally similar between the three grid resolutions averaged across the entire month, with the 1-km simulation having slightly less error (but slightly more bias) for O_3 than the 12-km and 4-km simulations, while for $PM_{2.5}$ the 1-km had slightly less bias but greater error than the 12-km and 4-km simulations. Future work will include detailed comparisons of the model outputs with some high space and time-resolved measurements made during the DISCOVER-AQ campaign, such as ship measurements made over the Chesapeake Bay and extensive aircraft measurements taken over the Baltimore region. **em**

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DISCOVER-AQ

Chesapeake Bay Breeze

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Enhancement of Air Pollution Episodes and Boundary Layer Venting

by Ryan M. Stauffer, Christopher P. Loughner, and Anne M. Thompson

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A look at the important role the Chesapeake Bay breeze plays in local air pollution events in Maryland.

Sea, bay, or lake breeze circulations can contribute to poor air quality near coastal urban areas. At many worldwide coastal locations, sea breeze circulations are often present when surface ozone (O_3) levels are elevated.[1,2] In Houston, TX, for example, high surface O_3 episodes typically begin when the synoptic-scale winds transport pollutants offshore prior to the onset of a bay breeze.[3,4] As the bay breeze begins to develop, stagnant conditions ensue over the water as the winds begin to reverse direction. As the bay breeze intensifies, O_3 and O_3 precursors that built up

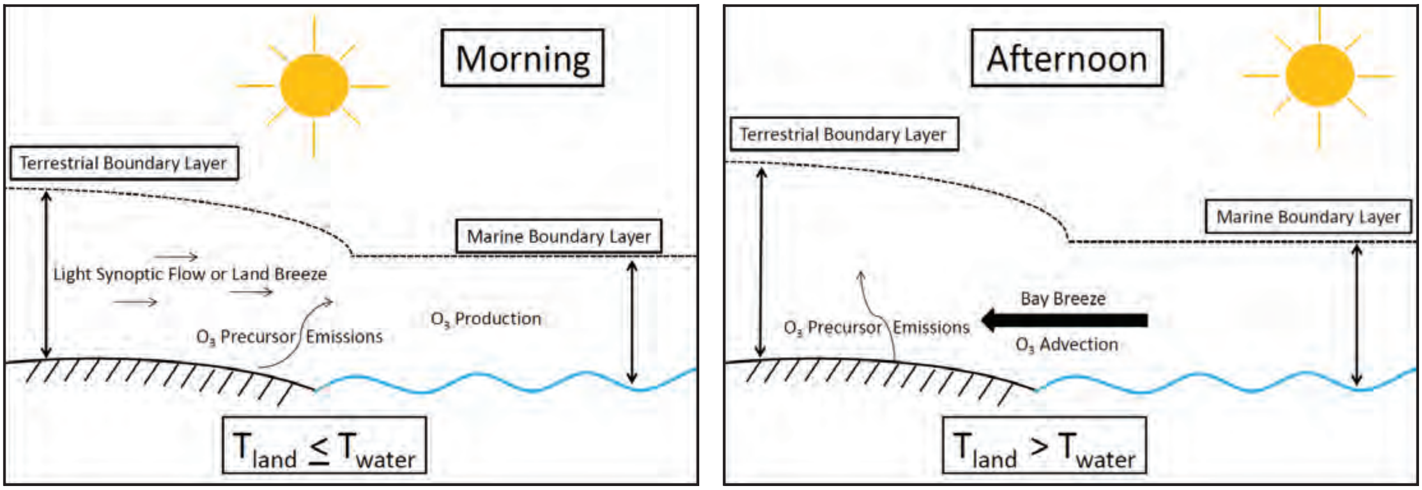

Figure 1. A conceptual model of conditions prior to and during a bay or sea breeze circulation. Ozone precursor emissions drift over the body of water, via large-scale synoptic winds, where O_3 is then produced by sunlight and photochemical reactions. Solar heating raises the temperature of the land above that of the water, and the bay or sea breeze is initiated, advecting high O_3 to coastal locations.

over the water are transported onshore (see Figure 1). In Maryland, the Chesapeake Bay breeze is the culprit for intensifying air pollution episodes.

The Chesapeake Bay breeze is responsible for elevated surface O_3 concentrations along the coastline of the bay. A Chesapeake Bay breeze case scenario for a poor air quality day found that: (1) prior to the development of the bay breeze, westerly winds allowed for pollutants from the Washington, DC, and Baltimore, MD, urban areas to be transported out over the surface waters of the Chesapeake Bay; (2) as the bay breeze began to form, stagnation developed over the bay, allowing pollutants to accumulate as the winds began to change to a southerly direction; and (3) once the bay breeze formed, southerly winds over the bay transported the high concentrations of surface pollutants that accumulated over the bay northward across the coastline.[5]

The bay breeze particularly enhances air pollution events at Edgewood, MD, which is on the northern coastline of the Chesapeake Bay, making it the most O_3-polluted site in Maryland and one of the monitoring stations with highest O_3 on the East Coast. In addition, it was found that once the Chesapeake Bay breeze circulation forms, surface pollutants are transported to the bay breeze convergence zone where they are lofted and then transported downwind, impacting surface air quality far from the emissions sources.[5]

Studies of the bay or sea breeze in other locations of the Mid-Atlantic States have found a growing influence of these circulations on local air quality.[6,7] Stauffer and Thompson,[7] examining 25 years of data, noted that a bay breeze is observed between 10–15% of days from May to September at Hampton, VA, and Baltimore, MD, making this a relatively frequent phenomenon that exacerbates air quality problems in the Mid-Atlantic. The difference between midday O_3 concentrations during bay breeze and non-bay breeze days was also found to be increasing from the mid-1980s to present. This suggests that as regional O_3 precursor emissions are continually reduced through environmental regulations, the bay or sea breeze will be a mechanism through which localized pollution events are magnified compared to the regional background air quality.

Observations and Modeling Results from DISCOVER-AQ

Modeling and observations from the 2011 DISCOVER-AQ field campaign (ground- and aircraft-based measurements) and the concurrent GeoCAPE-CBODAQ[8] field campaign (ship-based measurements) were utilized to build on our understanding of how bay breezes impact surface air quality and boundary layer venting. A comparison of ship observations and upwind monitoring sites noted that surface O_3 concentrations are usually higher over the water than upwind areas due to: (1) lower deposition rates over water; (2) ship emissions that mix with pollutants transported from over land becoming trapped in the shallow marine boundary layer; (3) higher photolysis rates due to the stable marine boundary layer inhibiting cloud development; and (4) a decrease in boundary layer venting due to the stable atmosphere over the water.[9]

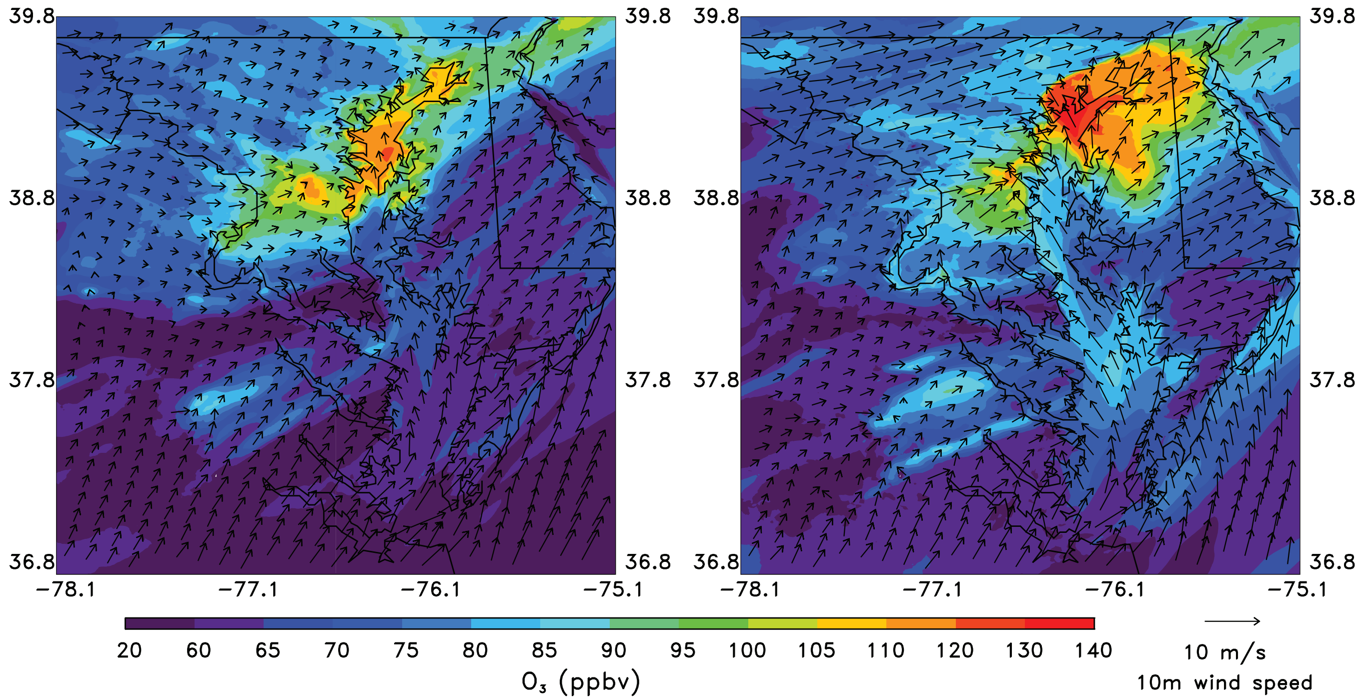

Figure 2. Community Multiscale Air Quality (CMAQ) model[10] simulated surface O_3 concentrations and 10-m wind velocity at 1500 UTC (left) and 1900 UTC (right) on July 22, 2011. The CMAQ simulation was run with a horizontal resolution of 1.33 km. Details on the model configuration described in Loughner et al. (2014).[12]

When a bay breeze begins to form, stagnation develops as the winds begin to change direction causing pollutants to accumulate, further amplifying O_3 and O_3 precursor concentrations over the bay. The accumulation is greatest when the synoptic-scale winds are westerly, transporting emissions from the Washington, DC, and Baltimore, MD, metropolitan areas over the bay. A large pool of O_3 and O_3 precursors over the water and an environment favorable for net O_3 production allows for high surface O_3 concentrations to develop as southerly winds associated with the bay breeze transport this plume onshore (see Figures 2[10] and 3[11]).

It was also found that O_3 concentrations observed at Edgewood, MD, peak in the evening hours on bay breeze days (Figure 3), about 3 hours later than non-bay breeze days.[11] Slower O_3 loss rates over water due to less deposition result in a later peak in O_3 concentrations over water than upwind areas.[9] This later peak is evident at Edgewood on bay breeze days when it is under the influence of transport from the bay.[11] In the case documented in Figure 3, the bay breeze frontal passage occurred at approximately 11:30 EST (vertical dashed line) as the wind direction veered to a southerly direction. Relatively cool, moist air from over the bay entered Edgewood with the dew point increasing by ~4 °C and the temperature plateauing at 34 °C after the bay breeze front passed. A pool of high O_3 concentrations that formed over the surface waters continued to move northward over Edgewood into the early evening (18:30 EST), leading to a maximum 8-hr average O_3 of 94 parts per billion by volume (ppbv), exceeding the air quality standard of 75 ppbv.

DISCOVER-AQ also provided insight into the role of bay breeze circulations on exporting pollution plumes out of the planetary boundary layer and into the free troposphere (see Figure 4).[12] When a bay breeze is present, air pollution converges at the bay breeze front (located near Padonia, MD, in the case shown in Figure 4), where it is lofted upward (depicted by the vertical arrows) and transported downwind aloft. The elevated pollution plume aloft was horizontally transported (depicted by horizontal arrow) by west-southwest winds over Edgewood, Aldino, and Fair Hill (areas with lower planetary boundary layer heights), resulting in the plume entering the free troposphere. Pollutants that are transported from the planetary boundary layer to the free troposphere gain longer lifetimes and are susceptible to long-range transport. These pollutants can then subside back into the planetary boundary layer impacting surface air quality far away from their emissions sources.

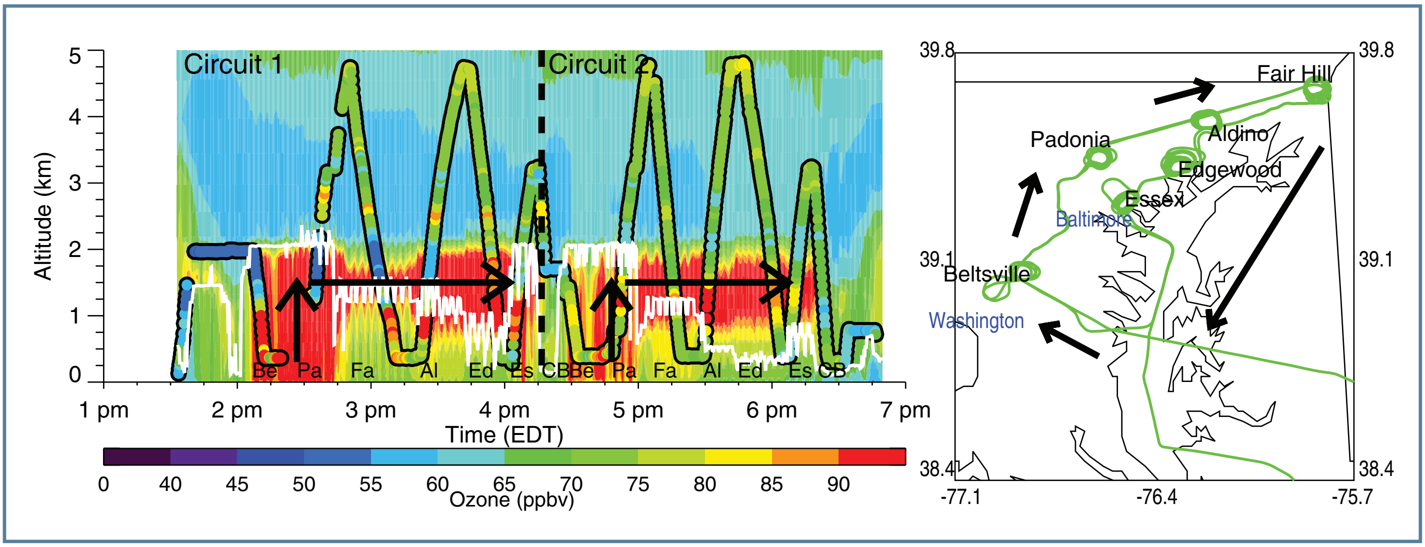

Figure 4. CMAQ simulated (background) and observed (overlay) O_3 concentrations along a flight track on July 11, 2011 (left). The white line shows the location of the top of the boundary layer as calculated by the Weather Research and Forecasting (WRF) model.[13] The black letters at the bottom of the figure, "Be", "Pa", "Fa", "Al", "Ed", "Es", and "CB" stand for the spiral locations Beltsville, Padonia, Fair Hill, Aldino, Edgewood, Essex (monitoring sites in Maryland), and the Chesapeake Bay, respectively. CMAQ results are from the 1.33 km horizontal resolution domain described in Loughner et al. (2014).[12] The flight track is shown on the right and consisted of two circuits.

Figure from Loughner et al. (2014)[12] ©American Meteorological Society. Used with permission.

Summary

Much like other locations susceptible to sea, bay, or lake breeze circulations, the Chesapeake Bay breeze plays an important role in local air pollution events in Maryland. The transport of emissions from the Baltimore–Washington metropolitan area, favorable O_3 production conditions over the bay waters, and subsequent transport of high O_3 via the bay breeze lead coastal locations, such as Edgewood, MD, to observe some of the worst air pollution in the region. The Chesapeake Bay breeze also lofts pollutants from the surface into the free troposphere at the convergence zone, allowing pollution to be transported farther downwind from source locations.

The bay breeze was shown to increase surface O_3 pollution in Maryland well above the regional

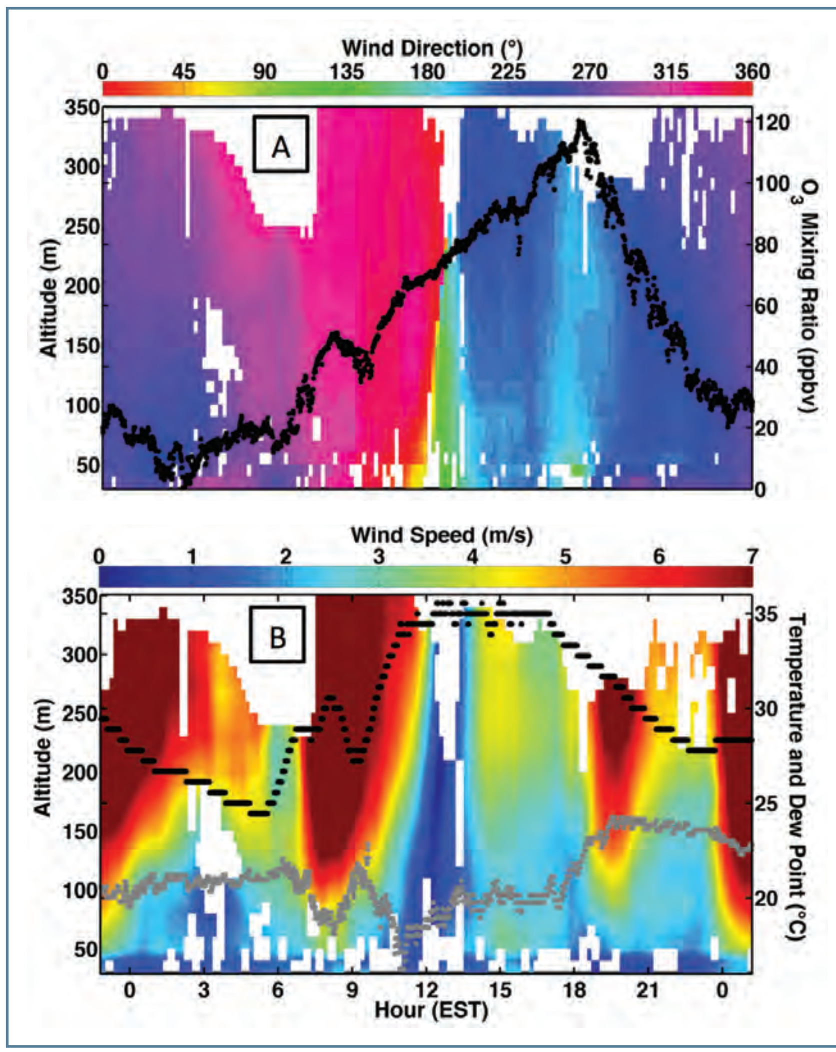

Figure 3. Impact of bay breeze as observed at Edgewood, MD, on July 23, 2011, on wind direction with height (a, colors); surface O_3 (a, black line); wind speed with height (b, colors); surface temperature (b, black dots); and dew point temperature (b, gray dots). *Figure from Stauffer et al. (2012)[11] published and used under permission of Creative Commons license 2.0 CC-BY.*

background. Even as O_3 precursors in the United States are reduced through emissions programs, the relatively frequent sea, bay, or lake breeze circulations will likely continue to create localized pollution events. Investigations of these small-scale phenomena and their effects on local air pollution elsewhere will continue as part of DISCOVER-AQ and related campaigns. **em**

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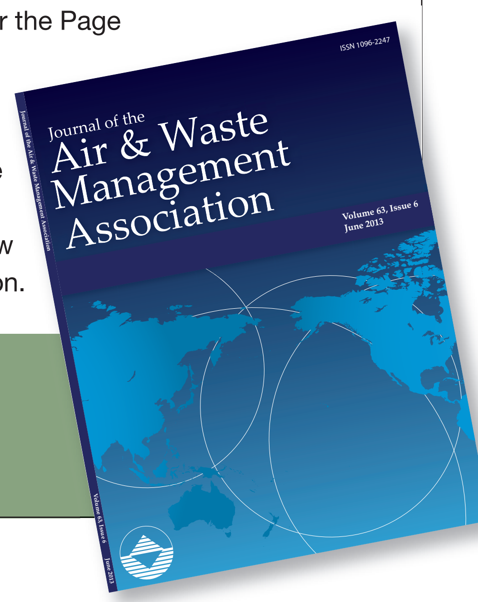

DISCOVER-AQ

Can Surface Air Quality Be Estimated from Satellite Observations of Trace Gases?

by Clare M. Flynn, Kenneth E. Pickering, James Szykman, Travis Knepp, Morgan Silverman, Russell Long, and Pius Lee

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Could the tropospheric trace gas column amounts observed by current low earth orbit and future geostationary satellites provide meaningful results for use by air quality agencies to help manage air quality? This article explores some key factors that influence the relationship between column amounts and surface mixing ratios for ozone and nitrogen dioxide, as observed during the 2011 DISCOVER-AQ mission over the Baltimore–Washington area.

Satellite observations of trace gas column abundances have contributed significantly to our understanding of atmospheric chemistry. The global coverage from low earth orbit (LEO) satellites, coupled with increasingly high spatial resolution, and fixed temporal resolution of observations from satellites has enabled many useful applications relevant to air quality management often not feasible by only surface observations.[1-6] Satellite observations also offer great potential for diagnosis of surface air quality, particularly in less urban regions, which

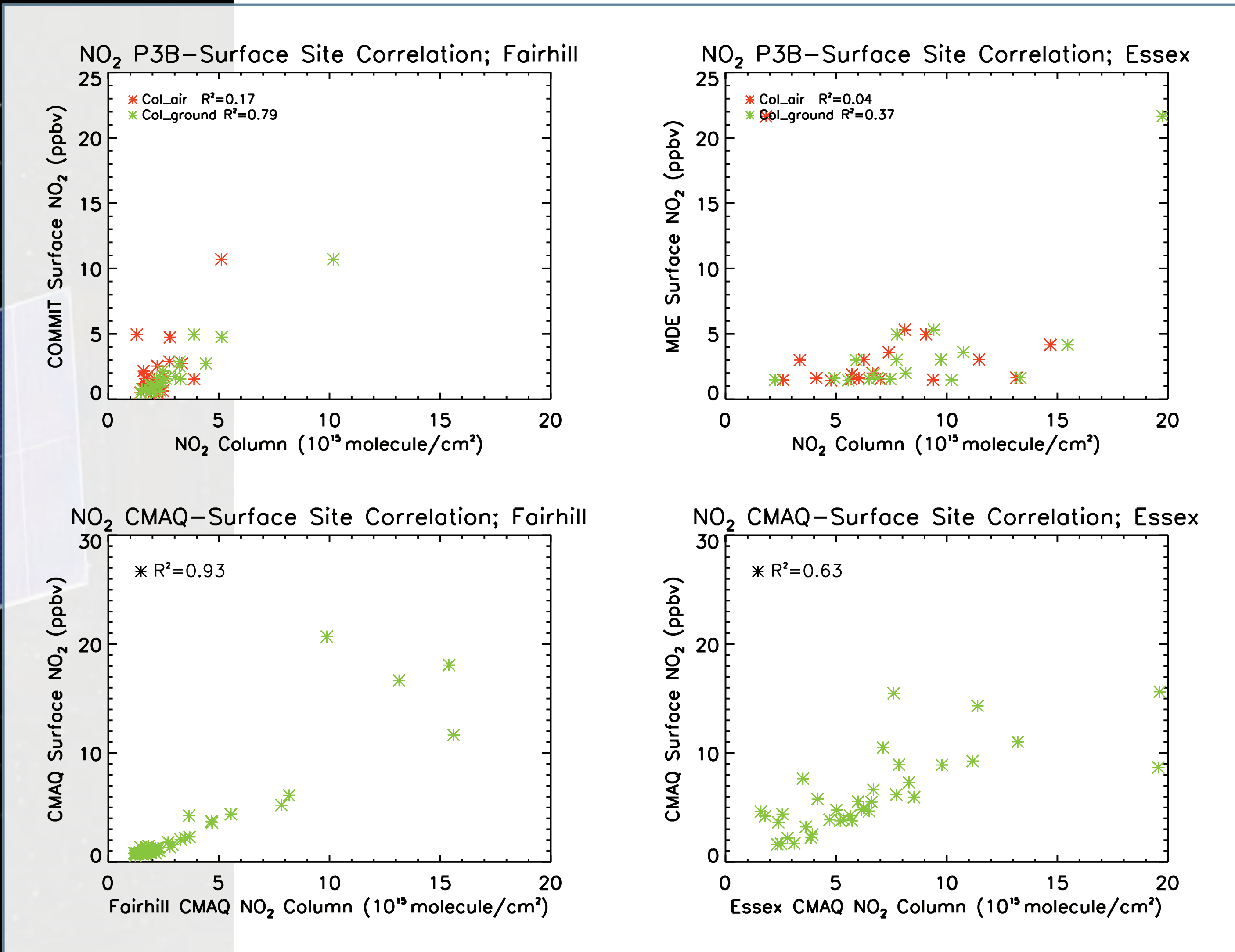

Figure 1. Example scatter plots of NO_2 column vs. surface NO_2 mixing ratio for Fair Hill and Essex during the Maryland deployment. Aircraft column amounts vs. observed surface in-situ measurements in the top row; CMAQ column amounts vs. CMAQ surface values in the bottom row. R^2 values displayed in the upper left corner of each plot.

often lack sufficient surface air quality monitors to properly characterize the spatial distribution of ozone (O_3) and nitrogen dioxide (NO_2).

However, several factors currently complicate the applicability of the satellite-observed column abundances for surface air quality assessments. These include the biases inherent in satellite retrievals, the method for separation of the stratospheric and tropospheric burdens, and reduced sensitivity of satellite instruments to the lower troposphere, where the greatest concentrations of many pollutants are found.[7] Furthermore, many current air quality satellite instruments are onboard LEO satellites, limiting the temporal coverage to one overpass per day at most sites. Because of these factors, it is uncertain how the column amounts observed by satellites are related to surface mixing ratios, a key measurement necessary for effective air quality management.[5-9]

For the Baltimore–Washington DISCOVER-AQ campaign in July 2011, we investigated the relationship between column amounts of trace gases computed from vertical integration of in-situ profiles conducted by the NASA P-3B over surface monitoring sites, and the associated mixing ratios measured at these surface sites. The P-3B spiraled vertically over these surface sites to obtain the profile data. We computed two different column amounts from these profiles: one called

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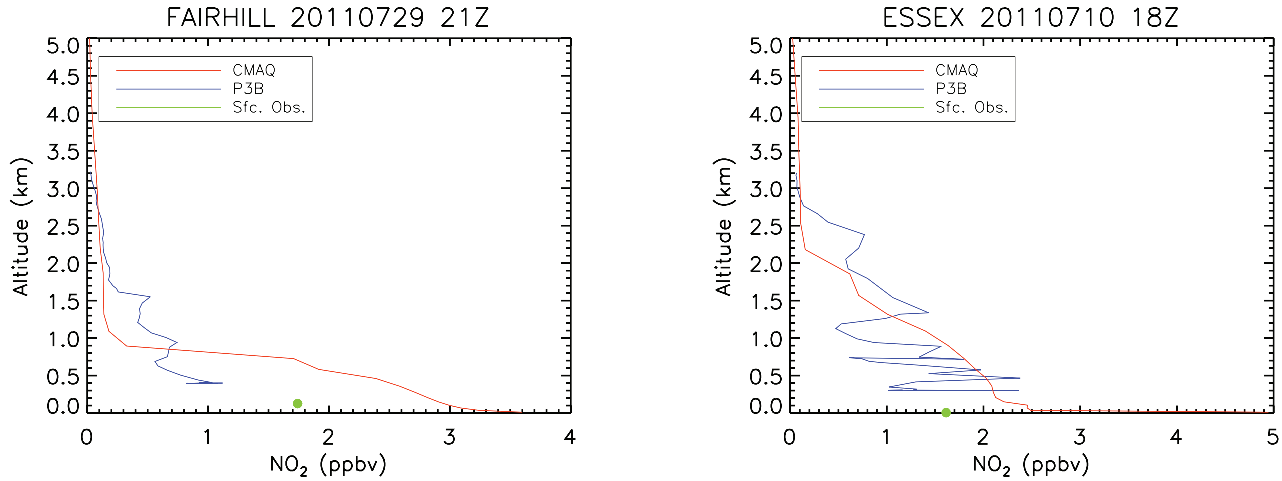

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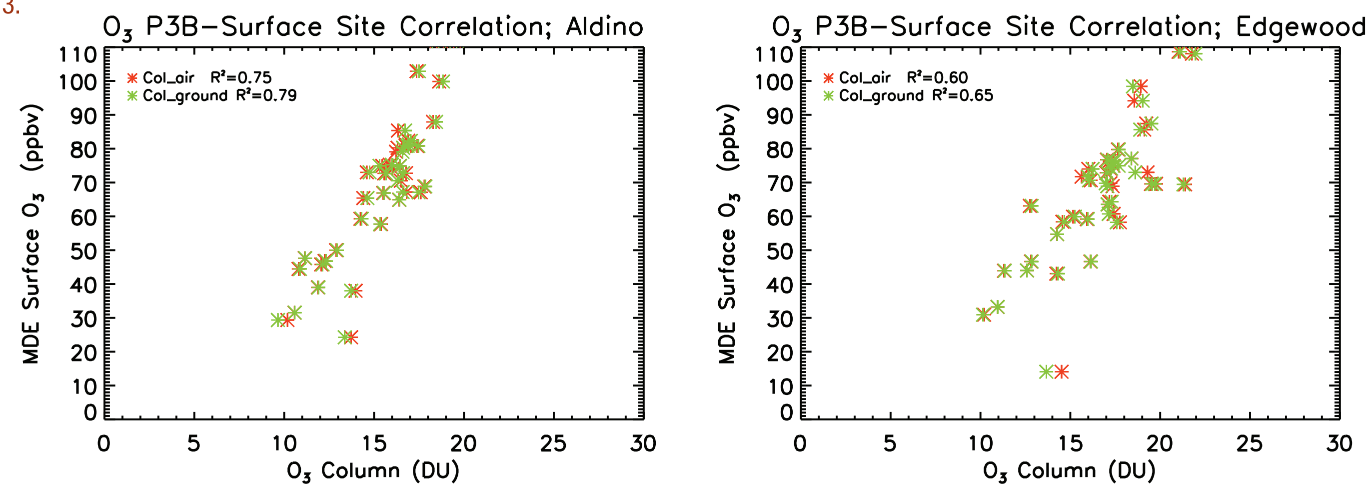

Figure 2. (top) Example profile plots for NO_2 for the Maryland deployment. Plots chosen represent the most typical behavior for both sites.

Figure 3. (bottom) Example scatter plots of O_3 column vs. surface O_3 mixing ratio for Aldino and Edgewood during the Maryland deployment. R^2 values displayed in the upper left corner of each plot.

"col_air," calculated using a constant mixing ratio as measured at the lowest flight altitude during the site spiral and extending this mixing ratio to the surface, and another called "col_ground," holding the surface measurement constant up to the lowest profile altitude, when a surface measurement was available. The column versus surface relationship was also examined using output from the Community Multiscale Air Quality (CMAQ) model.

Relationship between Column and Surface for O_3 and NO_2

The investigation of the column–surface relationship was initiated by an analysis of NO_2 data collected during the Maryland deployment, as well as longer-term data from the CAPABLE research site located at NASA Langley in Hampton, VA.[10] This work examined the correlation between the column amounts observed by the ground-based Pandora direct-sun UV/Vis spectrometer[11] and surface mixing ratio data. The Pandora columns served as a proxy for satellite measurements, and good agreement was obtained between these quantities. These columns were then transformed into average surface mixing ratios with the use of model-derived planetary boundary layer (PBL) heights; the correlation between observed and column-derived mixing ratios improved after use of the PBL height as a normalization factor.[10]

Building upon this work, an empirical simple linear regression model was developed to relate the observed column and surface mixing ratio data sets of O_3 and NO_2 for the Maryland deployment.[12] The computed (col_air and col_ground) column amount was used to predict the simultaneous surface mixing ratio, approximating how satellite data might be used to estimate surface

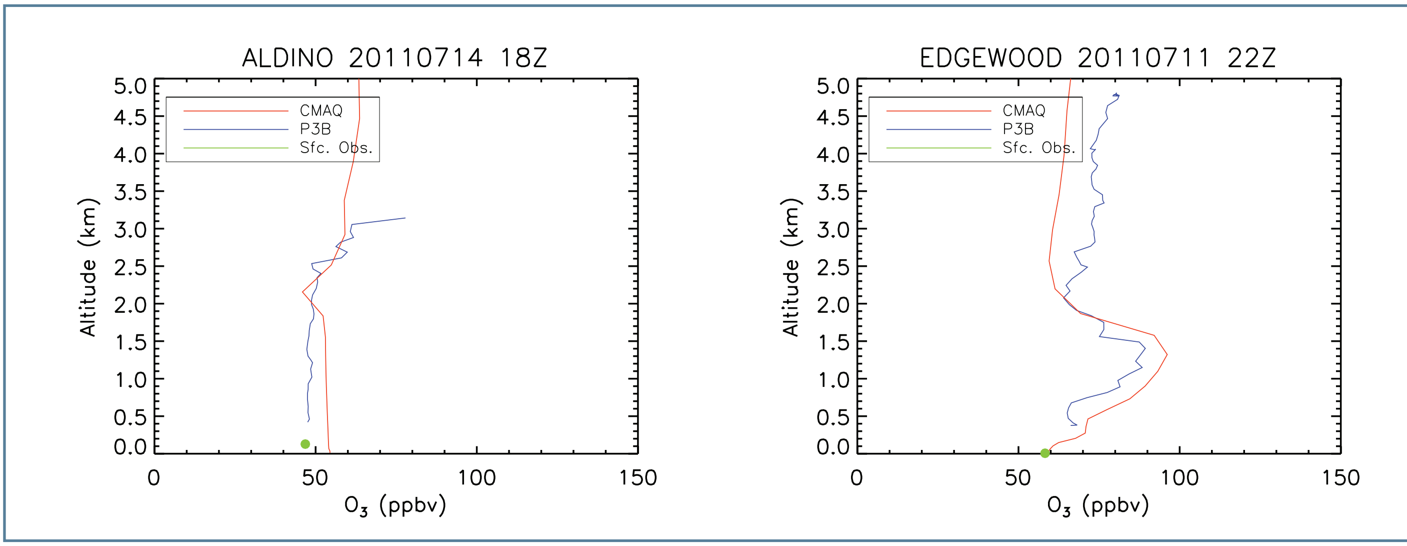

Figure 4. Example profile plots for O_3 for the Maryland deployment. Plots chosen represent the most typical behavior for both sites. July 11 was identified as a bay breeze day at Edgewood; the elevated O_3 reservoir in the upper PBL due to the bay breeze is apparent.

air quality. Both of the computed O_3 column amounts exhibited a high degree of correlation with the surface O_3 data (col_air: 0.58 <R^2 <0.83; col_ground: 0.63 <R^2 <0.88), while the NO_2 column versus surface correlation showed a strong dependence on the method used to compute the column (col_air: 0.02 <R^2 <0.18; col_ground 0.37 <R^2 <0.80). The col_ground correlations are likely larger than in reality, as this column computation assumed that the surface value was well mixed in the lowermost troposphere. The col_air correlation may underestimate the actual correlation.

However, the errors of the simple linear regressions relative to the observed values for NO_2 were typically larger than seen for O_3, while several of the assumptions of this regression model were violated. The strong connection between column and surface seen for O_3 (a secondary pollutant) is likely due to the frequent convective conditions in the lower troposphere that were encountered during this campaign and the regional nature of O_3 as a pollutant. Due to its short lifetime (a few hours), most NO_2 pollution is found near local emission sources of oxides of nitrogen (NO_x; NO + NO_2, which come into equilibrium within minutes of emission) and within the PBL, resulting in a much larger dependence on spatial scales,[13] thereby preventing the connection between column and surface from becoming as strong as seen for O_3.

The difference in correlations between col_air and col_ground for NO_2 shows the sensitivity to NO_2 concentrations in the lower 500 m of the atmosphere, an area void of NO_2 measurements during the site spirals. An additional factor impacting the level of correlations is the frequency of pollution plumes. Essex, located just downwind of Baltimore, demonstrated the poorest correlation (see Figure 1) due to the frequent presence of local plumes, while Fair Hill, the site farthest from large NO_x sources, demonstrated the greatest correlation. The aircraft profiles demonstrate the impact of these plumes on the connection between column and surface. In addition, the level of variability in the NO_2 profile across the lowest 2 km of the P-3B profiles appeared much greater than the level of variability in the O_3 profil data.

In essence, NO_2 did not exhibit a well mixed profile shape at any of the six sites. Fair Hill displayed the smoothest profile shape of all six sites. The NO_2 mixing ratio decreased from the bottom of the profile to the free troposphere with the fewest intrusions of pollution plumes. Essex displayed a large amount of structure within the PBL, interfering with the connection (see Figure 2). Edgewood, the site most often impacted by the bay breeze, demonstrated the poorest correlation for O_3, while Aldino, farther from the Chesapeake Bay, demonstrated high correlation (see Figure 3). Aldino typically displayed a well mixed profile, leading to the greater connection between the column and surface. The profiles for Edgewood were more complex. The profiles were typically well mixed except when impacted by the bay breeze; the bay breeze led to the formation of elevated reservoirs of O_3 (see Figure 4). The column-surface connection is thus influenced by local dynamics and pollution conditions.

Influence of Boundary Layer Mixing

During the Maryland deployment, addition of inverse PBL height as a second predictor to the regression analyses improved the statistical model relative to the original simple linear regression, while normalization of the NO_2 column amounts by PBL height improved the column–surface correlations. The PBL height data were derived from the P-3B potential temperature spiral data. These results are consistent with the previous findings,[10] which used model-estimated PBL heights. Neither analysis including PBL height improved the O_3 column-surface relationship, likely because O_3 is well mixed in the vertical and horizontal.

The degree to which the PBL height impacts the column-surface correlations was captured well in a set of spirals over Edgewood on July 5 (see Figure 5). The NO_2 profiles from early morning to early afternoon show that the lowest profile data seem to correspond well with the EPA surface NO_2, with the exception of the 7:30 a.m. profile, which likely was not low enough to obtain a measurement within the early morning PBL.

Comparison of CMAQ Model with Observations

A simulation of air quality with the CMAQ model was performed for the Maryland deployment at 12-km horizontal resolution. The correlations between the modeled O_3 column and surface values were similar to the observed correlations (i.e., not statistically different). The CMAQ NO_2 correlations ($0.39 < R^2 < 0.76$; Figure 1) were similar to the correlations for NO_2 col_ground, but were significantly larger than the correlations for NO_2 col_air at five of the six surface sites. As NO_2 is a short-lived precursor gas to O_3 with heterogeneous sources, these results indicate that CMAQ at the 12-km resolution does not adequately represent subgrid mixing, such that NO_2 is too well mixed in the horizontal and the vertical directions relative to the observations. After application of the PBL height as a normalization factor to the CMAQ O_3 and NO_2 columns, there were statistically significant increases in correlation between columns and surface mixing ratios. This result reinforces that vertical and horizontal mixing within CMAQ is too strong relative to the observations.

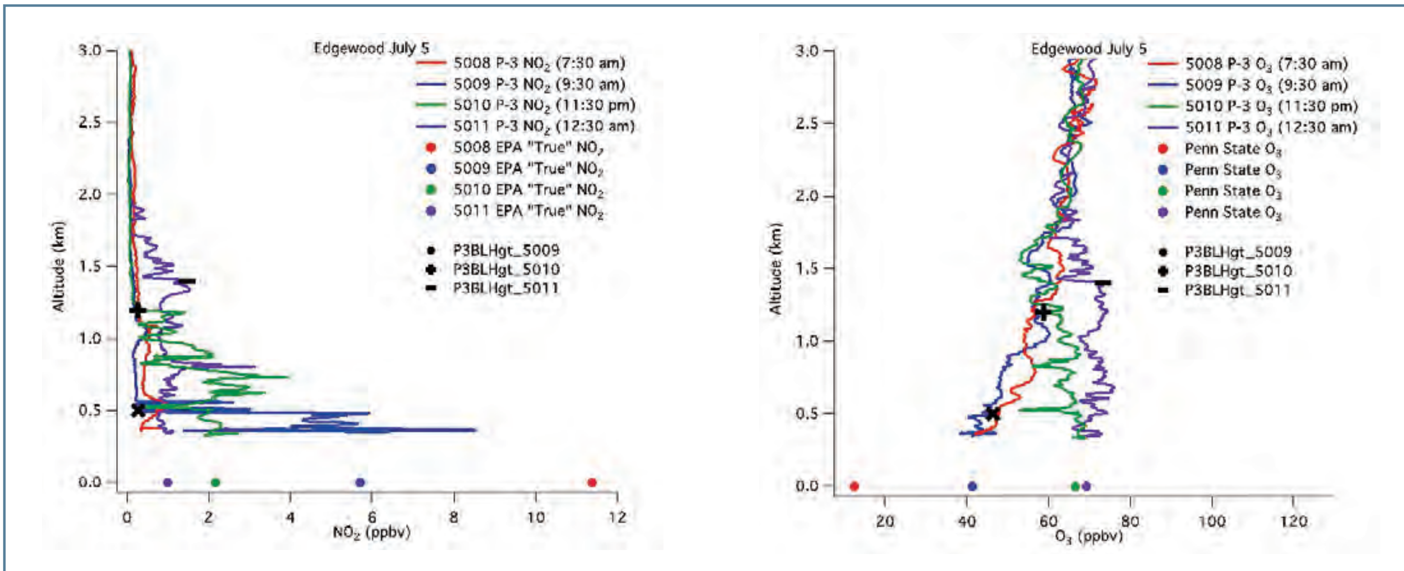

Figure 5. Profile plots for NO_2 and O_3 for the Maryland deployment at Edgewood for July 5, 2011. The NO_2 plot shows how the computed column amounts has a strong dependence on the level of NO_2 below the PBL height and the correspondence of the lowest profile measurement with the EPA NO_2. The O_3 plot shows how the O_3 profile well mixed in the vertical as compared to the NO_2 profiles. For both NO_2 and O_3, the early morning profiles did not correspond to the surface measurement.

Summary

The column–surface relationship for O_3 varies greatly among locations, time of year, and meteorological and air pollution conditions. However, under the conditions found in Maryland in summer, satellite-derived hourly lower tropospheric column O_3 observations, such as those expected from the future Tropospheric Emissions: Monitoring of Pollution (TEMPO) satellite, will be capable of well estimating surface O_3. These results suggest that the meaningfulness of satellite observations for surface air quality thus varies greatly with both the region and the prevailing meteorological regime. This relationship for NO_2 remains weaker, suggesting greater uncertainty in surface NO_2 estimation from satellite data and a need to also characterize the PBL height. Further, the CMAQ model overestimates mixing by turbulent eddies, causing a greater connection between column and surface than seen in the measurements. **em**

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DISCOVER-AQ

by Christopher P. Loughner, Bryan N. Duncan, and Jennifer Hains

The Benefit of Historical Air Pollution Emissions Reductions during Extreme Heat

An examination of the climate penalty factor phenomenon—as temperatures increase, air pollution worsens.

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Thermometer in the shade on the hottest day of the summer shows a 122 degree heat index during research hours.

Baltimore, Maryland

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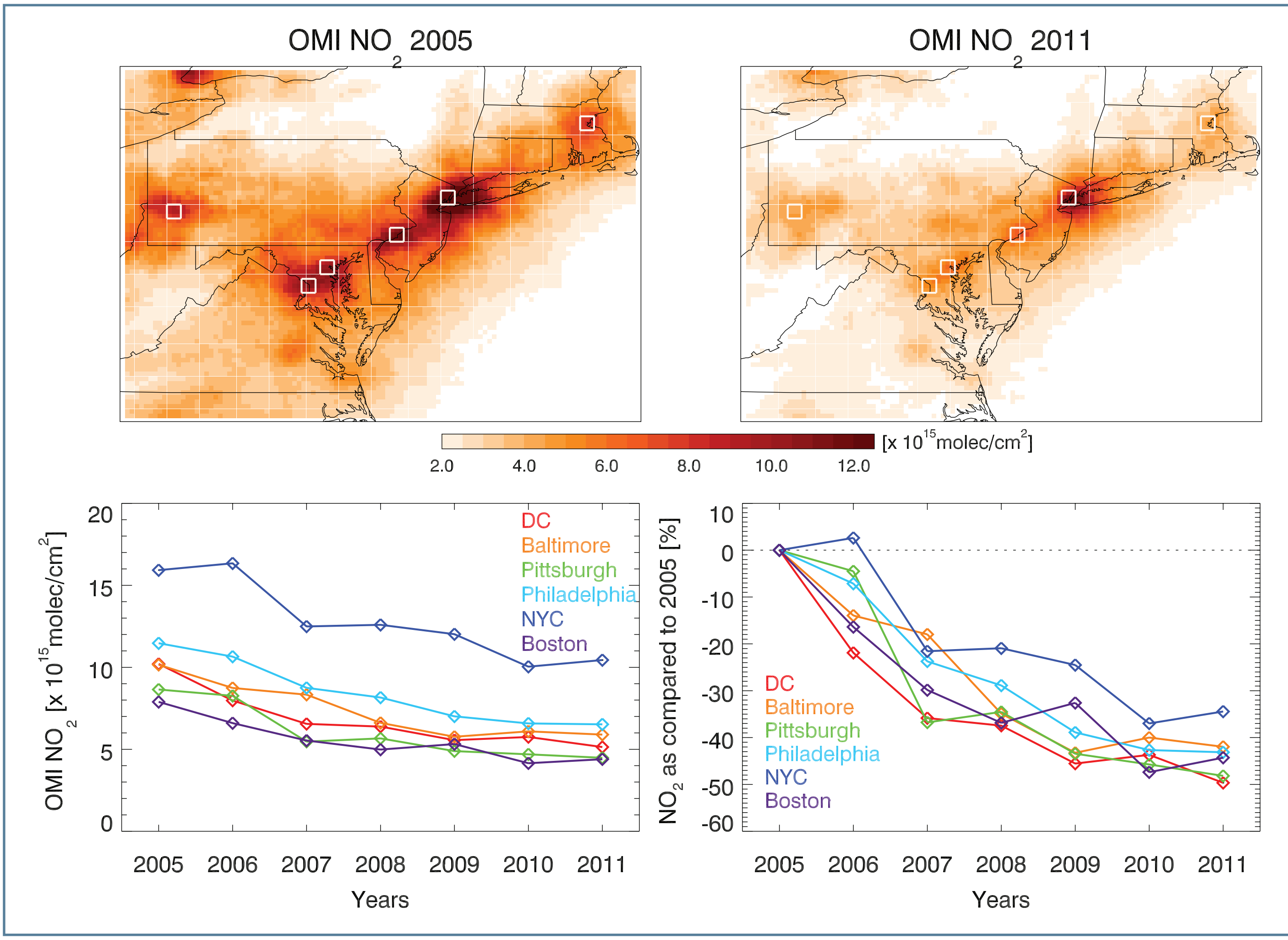

Figure 1. OMI annual average tropospheric NO_2 column throughout the Mid-Atlantic in 2005 (top left) and 2011 (top right), for select cities from 2005 to 2011 (bottom left), and percent change from 2005 for select cities (bottom right).

As air pollution emissions have been reduced in the United States over the past few decades, surface air quality has improved. However, future climate change is expected to dampen the benefit of emissions reductions. Air quality model results show air pollution worsens as temperatures increase,[1-4] and observations confirm a correlation of high temperature and events with high air pollution levels.[5-7] This phenomenon is termed the climate penalty factor.

Various meteorological, photochemical, and emissions processes describe the positive correlation between temperature and ozone (O_3).[8-10] Bloomer et al.[5] noted that the climate penalty factor is reduced as air pollution emissions decrease, and He et al.[10] determined that a third of the climate penalty factor is due to an increase in power plant emissions as a result of an increase in energy demand on hot summer days. Here, we examine the impact of historical air pollution emissions reductions on surface O_3 during unseasonably hot summer days, which are favorable for O_3 production and may become more typical due to climate change. This allows us to isolate the effects of emissions reductions from climate variability.

Hot, Hot, Hot in July

Maryland in July 2011, a historically hot month, is used as a backdrop for this study. The United States experienced extreme heat during July 2011, which coincided with the DISCOVER-AQ Maryland field campaign. Nationally, July 2011 was the fourth warmest July on record. The Baltimore–Washington metropolitan area experienced its hottest month in recorded history in July 2011, and the Baltimore–Washington International (BWI) airport recorded 24 days with temperatures at or above 90 °F during July 2011. The hot temperatures experienced in July 2011 may be more prevalent in the future under a globally warming world.

If emissions did not change since 2002, then half of the days in July 2011 would have been classified as O_3 exceedence days for much of the Mid-Atlantic.

The hot, stagnant weather conditions in July 2011 contributed to unhealthy air pollution levels. In Maryland, 14 code orange days (maximum 8-hr average O_3 >75 parts per billion by volume, ppbv) and three code red days (maximum 8-hr average O_3 >95 ppbv) were recorded. However, it could have been much worse without historical emissions reductions inside and outside Maryland.

Historical Emissions Reductions

Air pollution emissions regulations have been put in place with the goal of achieving attainment of healthy air, as defined by the U.S. Environmental Protection Agency's (EPA) National Ambient Air Quality Standards. In 1998, the nitrogen oxides (NO_x) State Implementation Plan (SIP) Call Rule was finalized to require 22 states and the District of Columbia to regulate NO_x emissions to mitigate O_3 transport. The NO_x SIP Call Rule was fully implemented by May 31, 2004, and included rules pertaining to the NO_x Budget Trading Program. Since then, additional court-orders and state regulations went into effect to further improve surface air quality. Nationwide, NO_x anthropogenic emissions have been reduced by 37% between 2002 and 2011 as reported by EPA's National Emissions Inventory (NEI).

Past emissions reductions have been detectable from space.[11] The Ozone Monitoring Instrument (OMI) onboard the NASA Aura satellite detects column integrated O_3, or the number of molecules of O_3 between the instrument and Earth's surface. However, it is difficult to discriminate the amount of the O_3 column that is at "nose level" as most of the column is in the stratosphere (e.g., "ozone layer") and ultraviolet (UV) wavelengths of light, which are used for detecting and measuring O_3, are strongly obscured by atmospheric scattering, which limits their ability to reach Earth's surface.

OMI also measures nitrogen dioxide (NO_2), an O_3 precursor. Column integrated NO_2 is typically reported in units of molecules per unit area of the Earth's surface. Decreases in NO_2 column content have been evident throughout the United States, including the Mid-Atlantic, as shown in Figure 1. For example, OMI detected tropospheric NO_2

column has decreased by about 40% over the Washington, DC, metropolitan area between 2005 and 2011. These reductions have occurred as air pollution emissions regulations have been adopted and implemented inside and outside Maryland, resulting in healthier air for everyone to breathe.

The benefits of regional reductions in air pollution emissions on surface O_3 concentrations are evident at ground monitoring stations. In order to isolate the influence of emissions from climate variability, we examine the number of O_3 exceedance days to high temperature days. Figure 2 depicts the number of days when the temperature reached 90 °F or higher at the BWI Airport and the number of days surface O_3 exceeded the current EPA standard (maximum 8-hr average O_3 >75 ppbv) at any monitoring site in Maryland for each year from 1980 to 2013. In 1980, Maryland experienced double the number of O_3 exccedance days based on the current standard (maximum 8-hr average O_3 >75 ppbv) than hot days (maximum temperature ≥90 °F). As numerous air pollution emissions reductions regulations took effect in the 2000s, the difference between the number of hot days and number of O_3 exceedance days decreased. In fact, Maryland experienced more hot days than O_3 exceedance days over the past five years, as shown in Figure 2 (2009–2013).

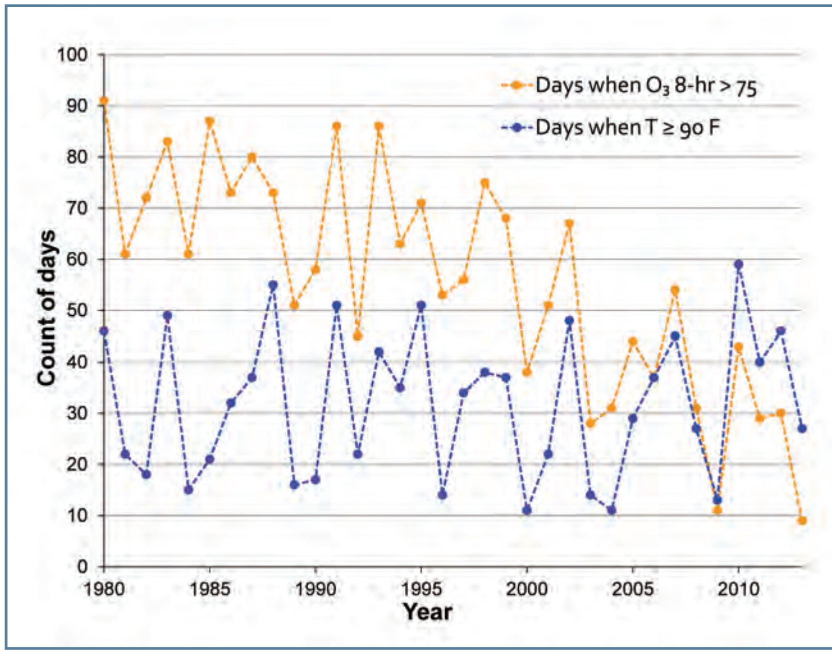

Figure 2. Number of days maximum 8-hr average O_3 exceeded the current EPA O_3 standard (>75 ppbv) from all monitored data collected in Maryland (orange) and the number of days daily maximum temperature reached 90 °F or above (blue) from 1980 to 2013.

CMAQ Model Simulation Results

To investigate the benefit of anthropogenic emissions reductions since the NO_x SIP call during a historically hot month (July 2011), the Community Multi-scale Air Quality (CMAQ) model[12] was run with emissions appropriate for 2002 and 2011. Both simulations use July 2011 meteorology, biogenic emissions, and lightning emissions, so the only difference in the two CMAQ simulations is the anthropogenic emissions inputs. This modeling approach removes the uncertainty in the role of climate variability impacting O_3 concentrations,

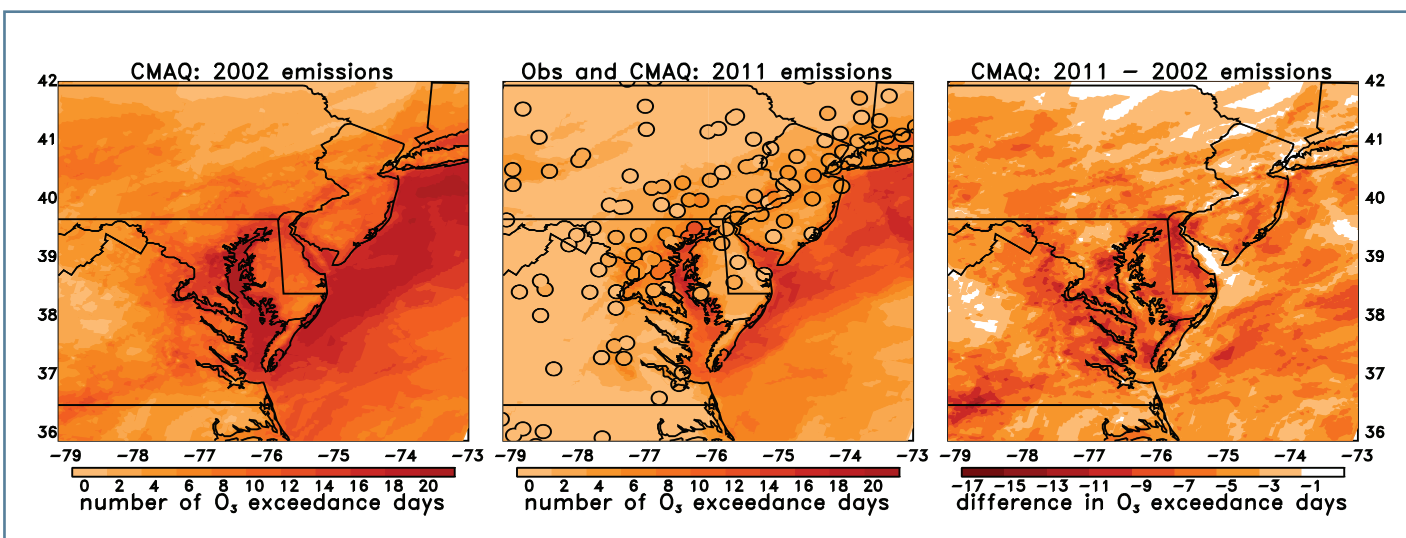

Figure 3. Number of O_3 exceedance days (>75 ppbv) for July 2011 from a CMAQ simulation using anthropogenic emissions appropriate for 2002 (left), a CMAQ simulation with anthropogenic emissions appropriate for 2011 with observations overlayed on-top (center), and the difference in number of O_3 exceedance days between the CMAQ simulations using 2011 and 2002 emissions (right).

so a comparison between the two model runs reveals only the benefit of the historical anthropogenic emissions changes (air pollution emissions regulations) on surface air quality.

Results presented here are from a 4-km domain covering the Mid-Atlantic that was nested down from 36- and 12-km domains. See Refs. 13–17 for details on the implementation and inputs used in the CMAQ simulation using anthropogenic emissions appropriate for 2011. CMAQ anthropogenic emissions inputs appropriate for 2002 were created by processing the EPA 2002 NEI with the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system.[18]

Results from the two CMAQ simulations, shown in Figure 3, indicate that if emissions did not change since 2002, then half of the days in July 2011 would have been classified as O_3 exceedence days for much of the Mid-Atlantic. Air pollution emissions reductions since 2002 likely prevented 3–11 O_3 exceedance days throughout Maryland during this historically hot month. Averaged over the entire month of July, simulated maximum 8-hr average O_3 with 2002 emissions is 3–9 ppbv higher than the simulation with 2011 emissions.

Summary

The benefit of recent regional emissions reductions regulations for meeting the O_3 standard is clear for the Mid-Atlantic. Emissions reductions between 2005 and 2011 reduced NO_x loading by approximately 40% in Maryland, as detected by the OMI. These regional emissions reductions have decreased the amount of O_3 exceedance days during hot, stagnant meteorological episodes (i.e., when O_3 production is favorable). The emissions reductions between 2002 and 2011 likely prevented 3–11 O_3 exceedance days throughout Maryland in July 2011, a month that experienced record breaking heat. The meteorological conditions Maryland experienced in 2011 may become typical under a globally warming world and should be considered when implementing future air quality plans. **em**

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DISCOVER-AQ

Air Quality Forecasting Guides Flight Plans

by Kenneth Pickering and Pius Lee

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Sampling a variety of air quality conditions with aircraft equipped with in-situ and remote-sensing instruments is aided through daily air quality forecasting.

Chemical forecasts to assist tropospheric composition research flight planning have benefitted air quality and atmospheric chemistry measurement campaigns over at least the last 15 years. Both global and regional chemical transport models have been employed in forecasting trace gas and aerosol conditions for field studies over the United States and in large international campaigns. Some of these past campaigns a decade or more ago covered large geographical areas and had considerably less forecasting capability due to the disadvantage of less computational power that limited the spatial resolution and chemical complexity of the forecast models, not permitting fine feature forecast guidance to be available for flight planning.[1,2]

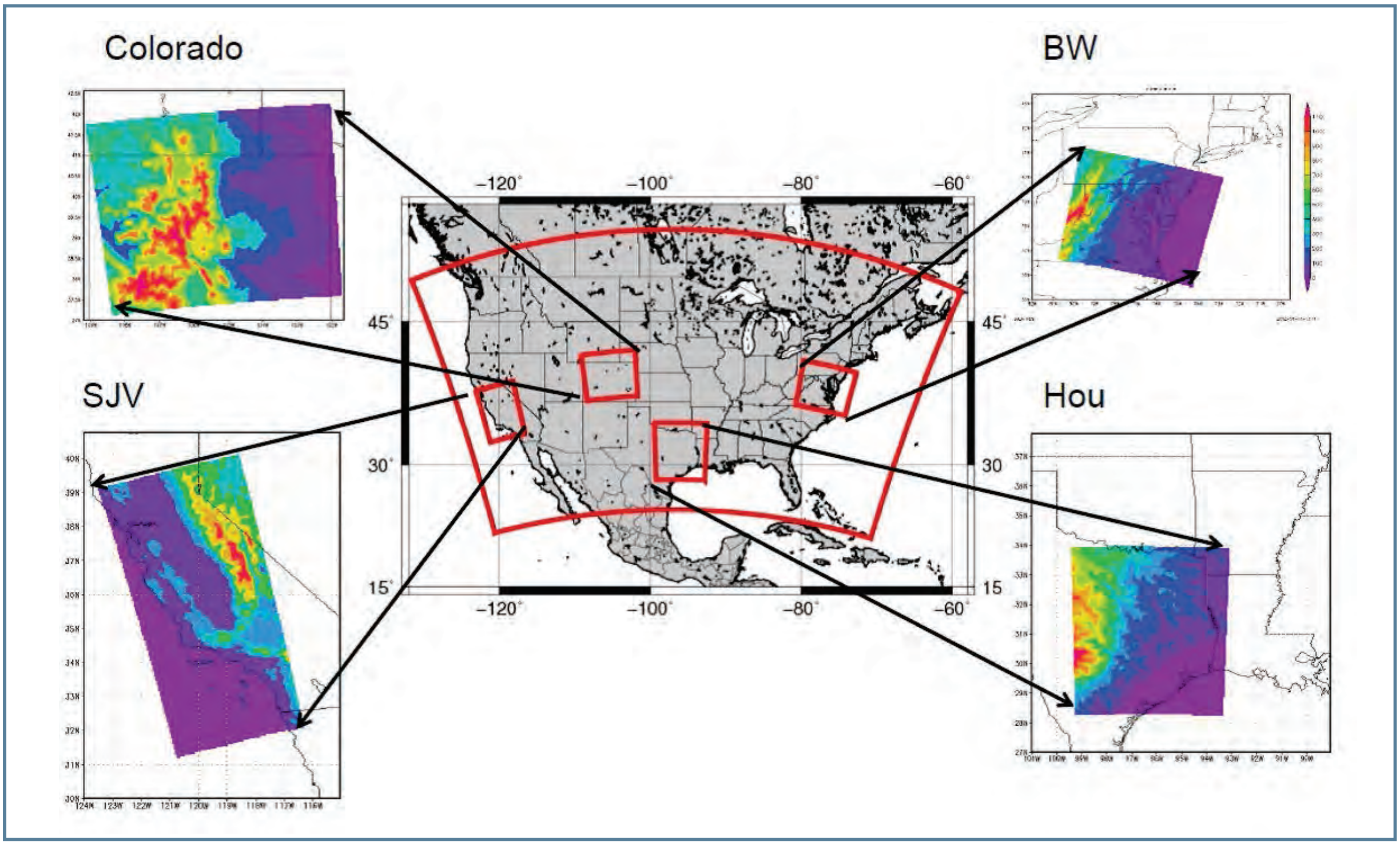

Figure 1. Domain configurations of NAQFC-β as a two-tiered nest for the past DISCOVER-AQ campaigns: (1) Baltimore-Washington (BW), (2) San Joaquin Valley (SJV), (3) Houston (HOU), and (4) Front Range.

DISCOVER-AQ was unique in that it provided a wealth of three-dimensional data for model evaluation, whereas most often only surface data are available to test models.

An ambitious series of multiple-platform coordinated measurement campaigns conducted between 2011 and 2014, called DISCOVER-AQ, was led by NASA to improve the interpretation of satellite observations to diagnose air quality conditions near the surface. The basic concept was to emulate remote-sensing of retrieval from a satellite by equipping very similar remote-sensing instruments in a high-altitude aircraft, such as NASA Langley's King Air. Surface air quality was recorded by ground-based air pollutant monitoring stations—typically 6–8 sites per campaign. A NASA P-3B aircraft was deployed to perform in-situ observations on lower tropospheric spiral profiles (which typically extended 0.3–3 km above the surface) over each ground station. Most of the time, the P-3B followed a standard flight plan performing the spirals over the several sites three times per day. In addition, low-level (~0.3 km) flight paths over major highway traffic corridors were included between spiral profile locations.

Air quality forecasting maximized the ability of DISCOVER-AQ to select flight days that would produce a wide variety of air quality conditions. However, the forecasts also significantly enhanced the flexibility of the campaign managers to make informed decisions to alter the P-3B flight plan on occasion to produce the best measurement variability and representativeness. Customarily, the second-day output from a forecast was used along with other factors in determining whether flights would be conducted on the following day. Early in the morning of the day of flight execution the planners consulted the same-day forecast from an early hour forecast cycle to determine if air quality conditions were expected to develop as earlier believed.

Model Requirements for Campaign-Support Forecasting

The National Air Quality Forecasting Capability β version (NAQFC-β) modeling system was one of the air quality forecasting systems assisting the DISCOVER-AQ campaigns (see Figure 1): Baltimore–Washington (BW) between July 1 and July 29, 2011; San Joaquin Valley (SJV), CA, between January 16 and February 6, 2013; Houston–Galveston (HG), TX, between September 4 and

September 26, 2013; and Front Range (FR), CO, between July 16 and August 10, 2014.

The NAQFC-*β* system is an off-line coupled atmospheric chemical concentration forecasting modeling system using the National Centers for Environmental Predictions (NCEP) North American Meso-scale non-hydrostatic Model (NAM)[3] with the U.S. Environmental Protection Agency (EPA) Community Multi-scale Air Quality (CMAQ) Model.[4,5] It solves the material continuity equation for the chemical constituents in the troposphere. At the lateral boundaries, a zero-flux divergence outflow condition is imposed.[5] Chemical lateral boundary conditions for inflow are adopted from a species mapping methodology introduced by Tang et al.,[1,2] which uses matching constituent correspondences between the CMAQ chemistry mechanisms with those in the Harvard University GEOS-Chem model.[6]

For the 12-km horizontal grid spacing parent domain, estimation of emission fluxes is similar to that in NAQFC-*β*.[7] For the 4-km horizontal grid spacing nested domain (as used in the FR campaign), the emission fluxes were estimated based on a separate set of surrogate flux intensity data using a finer spatial distribution than those used in NAQFC-*β*. We have chosen to use a hot-spot and smoke-plume detection product by the NOAA Hazard Mapping System (HMS), which blends multiple satellite retrievals and human analyst products to provide detection and hot-spot counts of wild fires over the continental United States. The HMS product is used to estimate the next day wild fire emissions.[8]

Evaluation of Forecasts using DISCOVER-AQ Data

DISCOVER-AQ was unique in that it provided a wealth of three-dimensional data for model evaluation, whereas most often only surface data are available to test models. Having observations in the vertical dimension allows assessment of vertical transport processes and evaluation of the ability of the model to simulate plumes of ozone (O_3) and precursors aloft. The NAQFC-*β* forecasts tended to have an overall high bias (9.7 parts per billion by volume, ppbv) for boundary-layer O_3 on the day of the forecast and a small low bias (-1.5 ppbv) for O_3 in the free troposphere over BW (see Figure 2), compared with the observations from the P-3B spirals on 14 flight days during July 2011.

While the forecast system predicted nitrogen dioxide (NO_2) very nearly correctly (less than 0.1 ppbv

Above: NASA P-3B aircraft performing a missed approach to obtain atmospheric chemistry data close to the surface.

Left: DISCOVER-AQ research plane arrives. Pilots Shane Dover, left, and Mike Singer are seen on the flight deck of the P-3B NASA research aircraft.

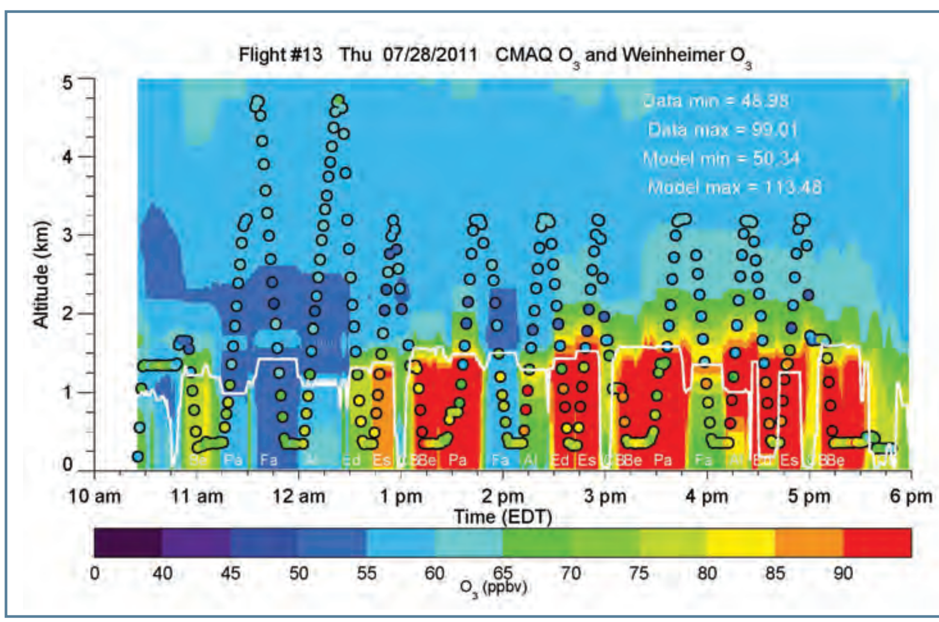

Figure 2. Curtain plot of model O_3 profiles (background colors) with superimposed 1-min average O_3 observations (dots) from the P-3B aircraft on July 28, 2011, during the BW DISCOVER-AQ campaign. White line indicates top of boundary layer.

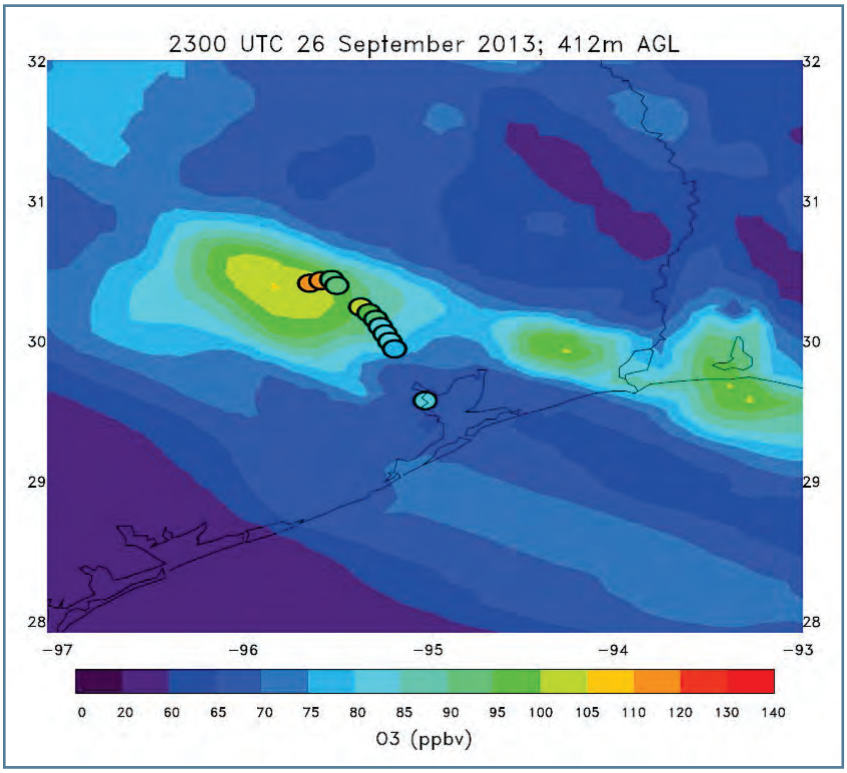

Figure 3. NAQFC-ß forecast of O_3 at ~400 m above ground level for 18:00 local time on September 26, 2013, over the Houston, TX, area with P-3B 1-min average observations (dots) superimposed along P-3B flight track.

bias in both boundary layer and free troposphere), it had a high bias for other forms of oxidized reactive nitrogen, such as the reservoir species peroxyacetyl nitrate (PAN) and alkyl nitrates, which have lifetimes longer than that of nitrogen oxides (NO_x), allowing them to be transported substantial distances. For example, the PAN high bias averaged 1.4 ppbv in the boundary layer over the 14 flights. On the other hand, formaldehyde, a product of volatile organic compound oxidation, had low bias (~1.2 ppbv) in the boundary layer.

A Houston campaign prescribed flight plan was altered to successfully locate the maximum O_3 in the Houston urban plume following the air quality forecast model guidance. Figure 3 displays the forecast O_3 at 1800 LT on September 26, 2013, showing the low-level O_3 plume being transported to the northwest of Houston with a maximum of ~105 ppbv. The P-3B located the maximum boundary layer O_3 (105–110 ppbv) in approximately the forecast location, thereby verifying the forecast.

Model Improvements

Assimilation of MODIS AOD

NAQFC-ß is run in a post-mission analysis mode to quantify the forecasting fidelity benefit for particulate matter (PM) when data assimilation of MODIS column-integrated aerosol optical depth (AOD) is included in the initialization adjustment step of each forecasting cycle. The assimilation of MODIS AOD requires estimation of the vertical distribution of the extinction coefficients due to the various chemical components and physical particle morphology of the aerosol.

Ideally, assimilated observations should represent data collected evenly in space and time and be void of instrument biases. For incorporation into a forecasting system, data availability must be assured. MODIS data are missing more than 50% of the time due to cloud coverage. Thus, surface readings of $PM_{2.5}$ measured by EPA's AirNow real-time surface monitors network are used to complement the MODIS AOD data. The AirNow network has about 1,000 active monitoring stations at any given hour are distributed rather unevenly across the continental United States. It is considered a data-rich surface observation network. The BW campaign showed an improvement of domain-wide mean bias for surface PM by 41% from -5.9 to -3.5 $\mu g/m^{-3}$ when MODIS AOD assimilation is employed (see http://acmg.seas.harvard.edu/presentations/aqast/jun2013/day1_pm_2/2_June4_3_15pm_PLee_chemical_reanaysis.pdf).

Improvement of Model Chemistry

As noted above, comparisons of the NAQFC-ß forecasts with DISCOVER-AQ observations brought to the forefront issues with the partitioning of reactive nitrogen species in CMAQ. The interconversion of different forms of oxidized nitrogen (NO_y) in air quality models has been a source of uncertainty for some time. Organic nitrate, in particular, has been difficult to represent in condensed chemical mechanisms because it encompasses a large class of compounds with widely varying chemical and physical properties. In the standard CB05 mechanism, all organic nitrates (NTR) are represented by one compound, with the characteristics of ethyl nitrate. Because ethyl nitrate does not react quickly, either with the hydroxyl radical, OH, or through photolysis, and it is not very soluble, NTR in CB05 has a long lifetime in the atmosphere, and releases NO_2 only very slowly, with little contribution to O_3 formation.

In reality, much of the organic nitrate is likely to have a more complex structure, which increases its solubility (faster removal) and its degradation (releasing NO_2 into the atmosphere, which can form O_3). EPA's Atmospheric Modeling and Analysis Division is currently testing updates to more appropriately represent the contribution of different forms of organic nitrate. Recent research has also highlighted several other areas where NO_y cycling might be updated in CB05. Taken as a whole, some of these updates will increase NO_2 and some will decrease NO_2, so the net effect on O_3 and NO_y is unknown, and is likely to be spatially and temporally variable.

Summary

NAQFC-*β* forecasts provided valuable guidance to enable sampling a variety of air quality conditions in the four DISCOVER-AQ field missions. Evaluation of the model forecasts using the DISCOVER-AQ observations provided useful information concerning model components that required improvement. **em**

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DISCOVER-AQ

Unique Perspectives

A brief look at the unique perspectives offered by the different

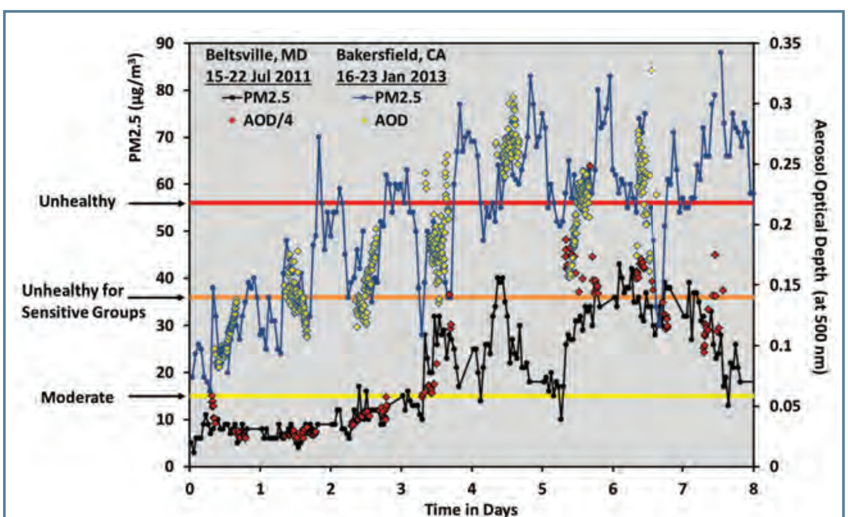
Beltsville, MD

Bakersfield, CA

By Suzanne Crumeyrolle

DISCOVER-AQ has been implemented as a series of four field studies in recognition of the differences in factors controlling air quality that exist between various locations and seasons. The Baltimore–Washington study in July 2011 was intended to focus on a region strongly affected by both upwind and local emissions, with ozone (O_3) events influenced by a mixture of sources, including power generation, transportation, and biogenic hydrocarbons.

Figure 1. Hourly surface and daytime 15-min AOD observations for an 8-day build-up of $PM_{2.5}$ over Beltsville, MD (summer) and Bakersfield, CA (winter).



Notes: Exposure levels for $PM_{2.5}$ are annotated by the colored lines; 24-hr average conditions above the orange line exceed the National Ambient Air Quality Standard; for AOD values, note that Beltsville observations are actually four times greater than shown.

Flights over California's San Joaquin Valley in January–February 2013 focused on observing how wintertime shallow boundary layer conditions and weak ventilation allow pollutants to accumulate near the surface as emissions from agriculture, livestock, wood burning, and transportation contribute to unhealthy levels of particulate matter (PM).

Houston, TX (September 2013), offered the opportunity to observe a complex environment due to both the unique and concentrated emissions associated with the petrochemical industry and coastal meteorology that can alternately alleviate or exacerbate poor air quality.

A final deployment plan to Denver, CO (July–August 2014), focused on a region of complex mountain flows and a mixture of emissions from urban activity, agriculture, and oil and gas exploration.

These differences present unique challenges to both air quality models and satellite remote sensing.

from the DISCOVER-AQ Deployments

DISCOVER-AQ field study deployments.

by James H. Crawford, Kenneth E. Pickering, Brent N. Holben, Andrew Weinheimer, Ryan Auvil, Nathan Trevino, and Mark Estes

James H. Crawford is a research scientist at NASA Langley Research Center and principal investigator for the NASA DISCOVER-AQ mission. **Kenneth E. Pickering** is a research scientist at NASA Goddard Space Flight Center and project scientist for DISCOVER-AQ. **Brent N. Holben** is a research scientist at NASA Goddard Space Flight Center and principal investigator for AERONET. **Andrew Weinheimer** is a research scientist in the Atmospheric Chemistry Division of the National Center for Atmospheric Research. **Ryan Auvil** is head of the Field Operations Section of the Maryland Department of Environment. **Nathan Trevino** is the supervising air quality instrument technician at the San Joaquin Valley Air Pollution Control District. **Mark Estes** is the senior air quality scientist at the Texas Commission on Environmental Quality. **James Crawford:** james.h.crawford@nasa.gov.

Houston, TX *By Scott Sandberg*

Denver, CO *By Ken Pickering*

Comparisons of data for $PM_{2.5}$ and O_3 from multiple DISCOVER-AQ study locations are presented here to highlight both the promise and the challenge of using satellite measurements to diagnose surface air quality.

Aerosol Optical Depth and $PM_{2.5}$

The first comparison examines relationships between in-situ $PM_{2.5}$ and remotely-sensed column aerosol optical depth (AOD) observed during summer in the Baltimore–Washington study and winter in the southern San Joaquin Valley. Hourly $PM_{2.5}$ data come from Beta Attenuation Monitors (BAMs) used by the Maryland Department of Environment in Beltsville, MD, and the San Joaquin Valley Air Pollution Control District in Bakersfield, CA.

Column AOD observations available during daylight hours at 15-min resolution are associated with co-located AERONET sunphotometers. For each location, an extended period of increasing $PM_{2.5}$ was selected for comparison. In both cases, surface $PM_{2.5}$ and column AOD show corresponding increases, however, the relative magnitudes of surface $PM_{2.5}$ versus AOD are vastly different. Notice, for instance, that AOD for Beltsville is divided by a factor of four in Figure 1. These differences can be attributed to several factors. The first and likely most important factor is the depth over which $PM_{2.5}$ is distributed. During the summertime period over Maryland, aircraft observations of aerosol scattering revealed that the layer of particle pollution typically reached from the surface up to 2 km. Conversely, during wintertime in California's Central Valley, the aircraft observed particle pollution to be consistently confined to the lowest 600 m above the ground, enabling very high surface $PM_{2.5}$ to be associated with modest values of AOD. Along with deeper mixing in the summer, warmer and wetter conditions contribute to higher AOD, as particles take on water, increasing in size, and scattering light more effectively.

A third factor is the difference in the composition of particle pollution in these two regions. Over Maryland, inorganic composition was dominated by sulfate in contrast to California where contributions from dust, smoke, and organic nitrates resulted in differences in particle optical properties (scattering vs. absorption), water uptake, and size distributions that impact aerosol scattering

DISCOVER-AQ observations are providing a critical testbed for evaluating the use of satellites to observe air quality.

and AOD. An important task in the ongoing analysis of DISCOVER-AQ observations is to quantify the contributions and relative importance of these factors in determining the relationship between $PM_{2.5}$ and AOD.

A Comparison of O_3 Episodes in Baltimore and Houston

Figure 2 offers a comparison of two O_3 episodes, one from the Baltimore–Washington study and the other as observed during flights over Houston, TX. For each case, O_3 profiles observed by the P-3B are shown for the day prior and the day of the episode. Profiles are colored to differentiate the three passes (morning, midday, and afternoon) over each of the monitoring sites.

While these examples are not presented as either representative or typical, they provide useful information on the challenges to remote-sensing of O_3 in the lower atmosphere by satellites. For context, these observations will be discussed in terms of the expected capabilities for future geostationary observations by the Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument expected to be operational before the end of this decade. TEMPO is expected to be sensitive to O_3 changes of 10 parts per billion by volume (ppbv) in the lower troposphere.

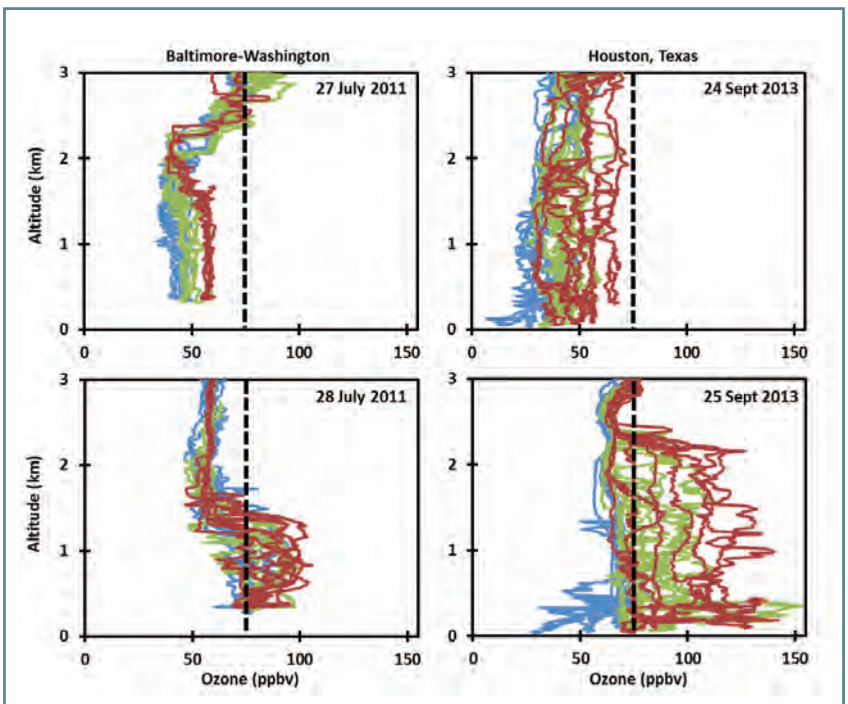


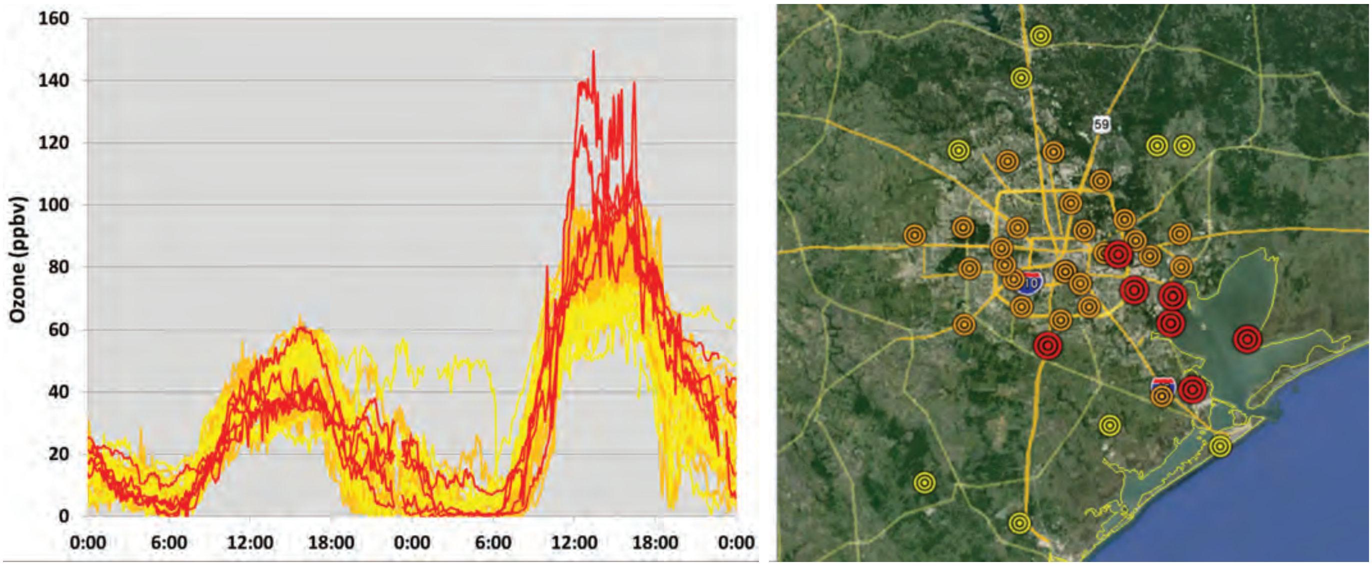
Figure 2. Ozone profiles observed from the P-3B aircraft on consecutive days for two episodes.

Notes: Profiles are colored blue, green, and red to indicate morning, midday, and afternoon profiles, respectively. The dashed vertical line indicates the National Ambient Air Quality Standard for O_3 of 75 ppbv for 8-hr average conditions.

Focusing first on the day-to-day difference in O_3, the average O_3 difference over Maryland from July 27–28 in the lowest kilometer was 30 ppbv; however, this number reduces to only 14 ppbv when considering the lowest 3 km. The presence of a stratospherically influenced layer just above the boundary layer on July 27 reduces the change in the O_3 column, effectively masking the increase in near-surface O_3. For Houston, the change in average O_3 from September 24–25 is 30 ppbv (40 ppbv below 1 km). Both of these differences would be visible to TEMPO, however, the need to understand the role of vertical structure is apparent, particularly in the Maryland case.

While day-to-day differences are important, the promise of hourly observations from TEMPO will revolutionize the application of satellite observations to air quality. From Figure 2, the in-situ profiles show clear evidence of temporal changes in O_3 related to photochemical production, even on the cleaner days. For the Maryland observations, the clean day shows more evidence for local O_3 production than the following episode day, which demonstrates numerous plumes, raising questions regarding the role of transport versus local chemical production that are beyond the scope of this article. For both days in Maryland, average O_3 changes across the day fall below the 10 ppbv sensitivity threshold for all sites. In stark contrast, large O_3 production rates are evident over Houston for both days. On the cleaner day, six of the eight profile sites experienced average O_3 increases of more than 10 ppbv and three sites saw changes in excess of 20 ppbv. This increased to seven sites on the day of the O_3 episode with three of the sites experiencing average O_3 increases of more than 30 ppbv.

For the Houston observations, spatial variability in O_3 is equally important. Figure 3 shows the time series for surface O_3 at 42 sites across the Houston area for the same period as shown in Figure 2. Data for these sites are colored based on their maximum 8-hr average O_3 over the two-day period. These time series demonstrate both an overall change in the regional O_3 level (see higher baseline values on September 25) and much greater spatial variability due to local O_3 production rates across the region.



The highest O_3 production rates were in proximity to emission sources associated with Houston's ship channel (see map). Higher nitrogen oxides (NO_x) emissions in this area are suggested in the time series data on September 24 with O_3 at sites colored in red trending below many of the orange and yellow sites and all but one red site showing O_3 to be fully titrated at night. These emissions along with favorable meteorological conditions on September 25 enabled much greater O_3 production in the ship channel area. When considered along with the profile data in Figure 2, these differences should be large enough to diagnose the spatial pattern of surface ozone increase across the region by the TEMPO satellite.

Summary

DISCOVER-AQ observations are providing a critical testbed for evaluating the use of satellites to observe air quality. By collecting observations with high temporal and spatial resolution across a range of clean and polluted conditions, as well as different seasons and locations, the relevant gradients in criteria pollutants and their remotely-sensed analogs are being defined and the value of additional information (e.g., boundary layer depth, humidity, aerosol hygroscopicity and composition, ozonesonde profiles) is being assessed. This information will help prioritize investments in additional ground observations most likely to improve the connection between satellites and regulatory monitoring networks. **em**

Figure 3. Surface O_3 across the Houston area on September 24–25, 2013.

Notes: The time series on the left shows O_3 at 5-min resolution for 42 sites; time series for each site is colored by the maximum 8-hr average value (yellow = below 75 ppbv; orange = 75–100 ppbv; red = above 100 ppbv); site locations are shown on the map to the right and are similarly colored.

Roman Sigaev/Hemera/Thinkstock

In the Next Issue...

Natural Gas

A summary of recent energy developments and forecasts for overall implications for air pollution and climate with an emphasis on natural gas use, as well as an update on the latest consensus on the net impact of coal vs. natural gas on climate.

Also look for...

- IT Insight
- YP Perspective

The Citizen Science Toolbox

A One-Stop Resource for Air Sensor Technology

by Amanda Kaufman, Ann Brown, Tim Barzyk, and Ron Williams

Amanda Kaufman is an ASPPH Fellow with the U.S. Environmental Protection Agency (EPA), Research Triangle Park, NC. **Ann Brown**, **Tim Barzyk**, and **Ron Williams** are all with EPA's Office of Research and Development, Research Triangle Park, NC. E-mail: williams.ronald@epa.gov.

A cache of resources is being developed by the U.S. Environmental Protection Agency (EPA) to help interested parties become familiar with, and appropriately use, low-cost air quality sensors. The development of the Citizen Science Toolbox is filling a vital niche in helping to advance environmental air quality monitoring for a wide variety of purposes.

The Growth of Low-Cost Sensor Applications

The air sensor technology market is exploding with new sensors in all kinds of forms. Developers are putting sensors in wristbands, headphones, and cell phone add-ons. Small, portable, and lower-cost measurement devices using sensors are coming on the market with a wide variety of potential uses to measure air quality in a neighborhood, school, or near sources of air pollution, such as highways and industrial facilities where air quality is a concern.[1] The benefits of advanced sensor technologies are many and offer the potential opportunity to transform how we monitor air quality. Such technology has the potential to enable citizen scientists to gather local air quality data to help them better understand the air in their community.

Demand for air sensor technology is growing from states, tribes, communities, citizens, and industry interested in using real-time monitoring in local settings. This includes the need for market survey information on availability of air sensor products and costs.[2] Possibly more important is the need for citizens and others to have practical information on sensor performance, data quality considerations for sensor users, and how individuals should interpret the data they collect. It is apparent that these latter factors have combined to either thwart citizens from collecting environmental data or have raised questions about the quality of the data obtained by citizens.

EPA is fostering development and implementation of air sensor technology on many fronts in an attempt to help overcome some of the aforementioned issues. Sharing information about such technology has been an important feature of EPA's effort. A series of air sensor technology workshops held by EPA has brought together developers, scientists, users, community groups, and other interested parties to discuss a wide variety of topics related to sensor development and use.[3] The most recent workshop, *EPA Air Sensors 2014: A New Frontier*, was held in June 2014. Summary information on the recent and earlier sensor workshops are available online at the conference Web site: https://sites.google.com/site/airsensors2014. (*Editor's Note:* See the January 2014 and August 2014 issues of *EM* for articles with a focus on air quality sensor technology.) In addition, EPA scientists have conducted laboratory evaluations on select ozone and nitrogen dioxide sensor technologies to provide sensor developers with information to improve performance of sensor products.[4]

The Citizen Science Toolbox

EPA is actively supporting citizen science projects and responding to community requests for information and guidance on sensor use.[5] The Citizen Science Toolbox is being developed specifically with resources and other tools in mind that can be used by citizens to learn more about air sensor technology at a practical level. The toolbox will provide guidance and instructions to citizens to allow them to effectively collect, analyze, interpret, and communicate air quality data.

Currently, the toolbox includes documents that describe the current market survey (i.e., availability of technologies to meet specific air quality monitoring needs); select sensor evaluation reports; and a sensor user guide. Future tools will include standard operating procedures on actual use of low-cost sensors; basic ideas for data analysis, interpretation, and communication; and other helpful information. EPA's Office of Research and Development is currently collaborating on a pilot effort involving one EPA regional office and a local community action group to develop a sensor package for use in the community. The goal of this pilot project is to determine the feasibility of such an effort for other regional offices to consider in their own collaborations with their local community action groups. The Citizen Science Toolbox has the potential to be a valuable resource for such collaborations. **em**

Inside the Toolbox

Images by Thinkstock Photo

Recent additions to the toolbox include the following research publications, which are available on EPA's Next Generation Air Measuring Web site: http://www.epa.gov/heasd/airsensortoolbox/index.html.

Mobile Sensors and Applications for Air Pollutants

This report identifies recent trends in mobile sensors and focuses on providing information for sensor developers and interested citizens on:

- Small, portable sensors, and some larger sensors that present opportunities for developing future mobile devices;
- Sensors in early stages of research and development, and some nearing deployment; and
- Commercial sensors incorporated into novel sensor systems.

Air Sensor Guidebook

This guide explores low-cost air sensor technologies, provides general guidelines on what to look for in obtaining a sensor, and examines important data quality features.

Sensor Evaluation Report

EPA scientists recently conducted performance trials of low-cost ozone and nitrogen dioxide air quality sensors to understand the current state of the science for such technologies. The sensors were evaluated in EPA laboratories using many of the performance criteria associated with Federal Reference Methods or Federal Equivalent Method evaluations that are used to support the National Ambient Air Quality Standards (NAAQS). The report summarizes the results of these trials.

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*QEPs and EPIs certifi d after June 30, 2014, will be acknowledged in the November 2014 edition of *IPEP Quarterly*.

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Wednesday, Oct. 1, 2014
Group Exam
New Orleans, LA

For details, visit IPEP at www.ipep.org.

YP Success

The Importance of Nurturing Mentor Communications

by Diana Kobus, IPEP
Executive Director

A fruitful mentoring relationship is probably the most valuable career resource that can be offered to young professionals (YPs). IPEP's YP-level certification is the Environmental Professional Intern (EPI), and I have often had conversations with EPIs on how to navigate employment searches and mentoring. It's important for YPs to understand just how rare the gift of true mentorship is—after all, when else in life does someone offer to assist you in developing your career path while asking nothing material in return? We are very lucky at IPEP to have many of our Qualified Environmental Professional (QEP) professionals available as mentors to our EPIs, and below are some tips for YPs on leveraging the gift of mentorship.

Be Professional and Respectful

This should go without saying, but in my experience, when YPs are nervous and in a hurry with a job search, it's easy to get off track in communications and conversations. When using e-mail, always take the time to use both a greeting and a closing, and be sure to include your contact information. Picking up the phone and having a conversation is ideal, but be considerate of your mentor's time by scheduling that call first and giving your mentor some general idea of what you would like to discuss. This will give your mentor the time and opportunity to think about how to best serve your needs. Most importantly, show your mentor that you recognize the value of a professional's time by being prepared. Do your research well ahead of the call, and demonstrate your familiarity with the subject matter, as well as your initiative. Remember that this is someone you want as an advocate in the marketplace, and who understands what you are going through in your current search.

Be Grateful

An e-mail to say thank you and follow up on the conversation is terrific in a pinch, but sending a thank you note through the mail in short order is a gesture that shows you are on top of the details and that you will go the extra mile. Immediately following up on any leads offered to you is also an essential way to show that you are grateful, and it is important to keep your mentor informed of your progress with those leads. Not only will you build your network through your mentor's network, you can show that you are organized, efficient, and have a good attitude—just the kind of employee a colleague may be looking to hire!

Continue to Nurture that Resource

Experienced professionals are in demand, and they are probably managing lots of people and/or projects, but on the flip side of that, they have a wealth of experience, especially when ethical concerns, professional disagreements, or employee treatment are at issue. If you take the time to keep in touch, to send a note on your progress, to inquire with your mentor regularly, you can steward that valuable resource so that it's there when you really need help. In times of turmoil or ethical crisis, I have seen that kind of feedback make all the difference in diffusing a charged situation. It is imperative in those instances to have open dialogue with someone you trust and admire. The balance and perspective that a true mentor can bring to your decision-making process, especially in those important moments, is something money simply cannot buy.

To learn more about IPEP's Mentor Program or the QEP or EPI certifications, please visit us online or contact me directly at ipepdirector@duq.edu. **em**

Improve Document Generation Efficiency with Revision and Version Control

by David Elam

David L. Elam, Jr., CIH, CMQ/OE, PMP, is a consultant with TRC Environmental Corp. E-mail: delam@trcsolutions.com.

Simple, consistent document control practices are central to quality management documentation and ultimately a project's success.

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The generation, revision, and archival of project documents are key responsibilities of environment, health, and safety (EH&S) project managers. In the interest of expediency, a project manager will often create a document and name the file with the document title (e.g., "Project X Sampling Plan.doc") and distribute it for review. Unless the project manager has provided clear instructions about how review comments should be submitted, it is likely that review comments will be returned in a range of formats. Some reviewers may use track changes features of the word processing or spreadsheet application and alter the file name to include their name. Other reviewers may begin editing the document without using the track changes feature and while they may rename the file, the original author must use document comparison tools to identify the edits. Still other reviewers might copy a few lines of edited text into the body of an email and return it to the original author. Although all of these approaches achieve the goal of soliciting feedback, the absence of a standardized process for revising and controlling documents is inefficient, makes it difficult to validate peer review, and could potentially result in the release of a final document that does not reflect all review comments.

Document control practices are central to quality management documentation, including the quality manual, standard operating procedures, work instructions, forms, and records. In fact, several applications exist for the control of quality system documentation and can be used for management of project documentation; however, many project managers will find that a simple file naming system, when consistently applied, will efficiently and inexpensively support their document control and peer review needs.

A simple example of version documentation and control using sequential numbers and relying on the track changes is presented in Table 1 (page 52). The use of sequential decimal numbers coupled with author identification information makes it easy to identify where the document is in the generation cycle. Once the document is ready for release, it is identified as 1.0. In the event that the 1.0 Version needs revision in the future, the revision cycle can be documented using 1.1, 1.2, and 1.3. Once that revision cycle is complete, the next version is identified as 2.0. Thus, any document in the review cycle will include a decimal value and the author's initials while any final version of the document will be designated with a "dot zero." Importantly, this process can be applied to text or spreadsheet documents.

Table 1. Document revision management using sequential numbers.

Task	Document Description	File Name
DLE authors base draft of Project X Sampling Plan	Base draft of Project X Sampling Plan authored by DLE	Project X Sampling Plan, v0, DLE.doc
DLE obtains comments from review team members AAA, BBB, and CCC	Review comments from AAA	Project X Sampling Plan, v0, AAA edits.doc
	Review comments from BBB	Project X Sampling Plan, v0, BBB edits.doc
	Review comments from CCC	Project X Sampling Plan, v0, CCC edits.doc
DLE revises the Project X Sampling Plan based on review team feedback	First revision of Project X Sampling Plan authored by DLE and incorporating the review comments of AAA, BBB, and CCC	Project X Sampling Plan, v0.1, DLE.doc
DLE obtains comments from review team members AAA, DDD, and EEE	Review comments from AAA	Project X Sampling Plan, v0.1, AAA edits.doc
	Review comments from DDD	Project X Sampling Plan, v0.1, DDD edits.doc
	Review comments from EEE	Project X Sampling Plan, v0.1, EEE edits.doc
DLE revises the Project X Sampling Plan based on review team feedback	Second revision of Project X Sampling Plan authored by DLE and incorporating the review comments of AAA, DDD, and EEE.	Project X Sampling Plan, v0.2, DLE.doc
DLE obtains review comments from FFF	Review comments from FFF	Project X Sampling Plan, v0.2, FFF edits.doc
DLE issues final draft reflecting the input of all reviewers	Final version of Project X Sampling Plan	Project X Sampling Plan, v1.0.doc

What about the case where the reviewer responds by e-mail that no changes to the document are required or notes minor comments in the text of the e-mail? This system easily accommodates those responses to document peer review. All the original author has to do is save the e-mail in the documentation folder using a file name that includes the version number and reviewer's initials.

Although the track changes feature of document generation applications is a powerful tool that supports efficient document review and revision, it is important to understand the options for using this feature. For example, it is possible that the document may contain track changes information that does not appear in certain document viewing options. Microsoft Word and Excel both incorporate an "Inspect Document" tool that allows the user to examine the document for comments, edits, or text that may be hidden from view. Using the "Inspect Document" feature will help secure the integrity of document review and revision process.

As EH&S project managers, we live in a world of documents that can easily become overwhelming unless rigorous efforts are undertaken to control document versions and revisions. Rigorous does not mean complicated though. In fact, a simple system that is easy to implement and understand is more likely to be used. Consider the time and effort your project team spends with document generation, review, and revision and develop and document a versioning process that makes sense for your work flow. You'll find that a structured process will enhance collaboration, improve efficiency, and improve document quality. **em**

CALL FOR ABSTRACTS

For the Air & Waste Managment Association's 108th Annual Conference & Exhibiton

The Air and Waste Management Association (A&WMA) is proud to announce that the 108th Annual Conference & Exhibition (ACE) will be held June 22–25, 2015, at the Raleigh Convention Center in Raleigh, North Carolina. The theme for the 2015 ACE is ***Connecting the Dots: Environmental Quality to Climate*** to consider the relationships between environmental quality and climate. The Conference's Critical Review will be on the "Interplay between Air Pollution and Climate." We are pleased to invite abstracts of original work on important and timely environmental issues reflecting the nexus of economic, social, scientific and political pressures shaping and forming international environmental policy and decision-making.

Raleigh, NC, is only a few minutes away from EPA's largest research facility and the home of EPA's Office of Air Quality Planning and Standards in Research Triangle Park. Mark your calendars for 3.5 days of professional growth and camaraderie with hundreds of the best minds in our profession.

Why You Should Present!

The conference is typically comprised of more than 400 platform and poster presentations and 40 panel sessions. With up to 50 technical sessions per day and as many as 12 concurrent sessions, it is recognized as the premier international conference of its kind providing the latest information on air and waste issues.

This is your opportunity to share your work at a technical conference, enhance the knowledge base of the industry, hear panel discussions of late breaking topics, and interact with an engaged audience of your peers, including: industry practitioners, consultants, regulators, students and researchers.

Original work documenting research, governmental, and industrial issues and solutions are especially desired. Papers consistent with our theme on environmental interactions such as the relationship between climate change and air quality, regulatory reforms, and new research and technology developments are encouraged. Additional areas and categories of interest are outlined in this Call for Abstracts by major topic areas and some example subtopics. The **abstract submission site** (accessed via http://ace2015.awma.org) has a more comprehensive subtopic list. A Mini-Symposium consistent with the conference theme will also be featured running throughout the conference (see below):

2015 Mini-Symposium – Regulatory Directions: Environmental Benefits, Societal Impacts, and Future Outlook

The 2015 Mini-Symposium will focus on U.S. regulatory policy in climate, air quality, and waste management. A&WMA invites proposals from the industrial, governmental, and environmental communities for a series of sequential paper and panel sessions. The Mini-Symposium will address the U.S. environmental regulatory framework, discuss realized environmental and climate benefits, examine compliance challenges faced by the regulated community and implementation challenges faced by regulators, scrutinize societal impacts including but not limited to economic, land use planning, and co-benefits or other consequences, and provide a forum for comments from the stakeholder industrial, governmental, and environmental communities.

A&WMA 2015 ACE Technical Program Timeline

November 3, 2014
Abstracts Due for Platform, Poster and Panel Presentations

December 2, 2014
Notification of Acceptance (Authors can start on manuscripts)

January 31, 2015
Notification of Presentation Format (Platform/Poster/Panel)

February 20, 2015
Draft Extended Abstracts / Manuscripts and Panel Summaries Due

April 3, 2015
Final Manuscripts Due (Incorporating review comments)

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- Student Platform Paper Award
- Student Poster Award

For more information and details related to eligibility criteria for these awards and requirements, please visit the conference website at http://ace2015.awma.org.

How to Submit an Abstract:

All abstracts must be submitted no later than November 3, 2014, using the abstract submission website. Detailed information, additional potential session topics, and a link to the abstract submittal site can be found at the conference website: http://ace2015.awma.org. All abstracts (**platform, poster and panel**) are peer reviewed and evaluated on the basis of: technical quality; relevance and significance to current environmental issues; and absence of commercialism.

Accepted submissions for the 2015 conference will be presented via platform or poster format. The program will include a poster-only session scheduled in a dedicated time slot, with no competing platform or panel sessions.

An extended abstract or full manuscript is required for each accepted platform or poster abstract, which will be published in the conference online proceedings, regardless of presentation format. Refer to the 2015 Technical Program Timeline for key dates and deadlines.

Submission Process

Step 1: Use AWMA's online submission site http://ace2015.awma.org, which will include information to guide you through the process. The listing of planned session topics along with general topic areas can be found at the online submission site to assist you with abstract submission.

Step 2: If you have been invited to submit an abstract in a specific area or for a specific session, check the solicitation box on the form, and be sure to select the name of your contact.

Step 3: Double check that your contact information is entered correctly; this is our only way of contacting you regarding your submission

A&WMA policy stipulates that all authors who attend the conference must register for the conference and pay the appropriate registration fees.

We hope to see you in Raleigh, NC for A&WMA's premier event, our 108th Annual Conference and Exhibition.

Sara Head, Technical Program Chair
Leo Stander, Technical Program Vice Chair

PROPOSED TOPICS FOR ABSTRACTS

Conference Theme, Local and Hot Topics

- Challenges Facing Air Quality Regulators and Industry
- Climate/Air Quality Interactions
- Greenhouse Gas PSD/BACT Issues
- Clean Power Initiatives
- Indoor Air Challenges
- IPCC Results and Climate Action Plans
- NAAQS Update – Revised Standards for Ozone and Particulate Matter
- Oil, Gas and Hydraulic Fracturing: Impacts and Implications of Exploration and Future Production
- Ozone and Long Range Transport
- Transport Rule

Air Quality Issues

Atmospheric Chemistry
- Atmospheric Chemistry and Deposition
- Atmospheric Secondary Pollutants
- Wintertime Ozone Issues

Atmospheric Modeling and Meteorology
- AERMOD Modeling/Case Studies
- Air Dispersion Modeling Issues and Guidance
- Photochemical Modeling Issues
- Source Apportionment

Control Technologies
- Air Pollution Control for Particulate Matter and Mercury
- Air Pollution Control – Acid Gases, NOx, and VOCs
- GHG/CO2 Control Technologies and Strategies

Emission Inventory and Data Application
- Air Emission Surveys
- Emission Factor Development
- PM2.5 Speciation in Emission Estimates – Measurements, Data Gaps, and Challenges

Measurement Technologies and Instrumentation
- Ambient Air Monitoring Methods and Study Results
- Next Generation of Air Monitoring Tools for Fugitive and Area Source Emissions
- Satellite Measurements for Environmental Monitoring

Particulate Matter
- Analysis of Ambient Particulate Matter Data and of Method Evaluation Results
- Carbonaceous Particulate Matter
- Fugitive Dust

Visibility and Radiative Transfer
- Topics in Visibility and Policy Implications
- Regional Haze State Implementation Plans
- Visibility Studies

Nanotechnology

- Developments in Nanoscale Science, Engineering and Policy
- Nanotechnology Research, Development and Applications
- Measurement, Analysis and Regulatory Developments

Environmental Management

Community Noise and Vibration
- Airport Environmental Design Tool 2B – A New Tool for Noise and Air Quality Analysis for Airports
- Mitigation Strategies for Noise Impacts from Industrial and Transportation Sources

Health Effects and Exposure
- Health and Environmental Effects – Toxics and HAPs
- Health Effects Due to Urban Air Pollution
- Toxic Air Pollutant Exposures

Odors
- Air and Odor Emissions from Animal Production
- What is an Odor? – How is it sampled, how is it measured?

On and Off Road Mobile Sources
- Measurement and Modeling of Near Road Air Quality
- Mobile Source Modeling – MOVES 2014
- Reducing Emissions from Rail Passenger Service
- Vehicle and Engine Emissions and Controls

Public Participation, Economics, and Partnering
- Real Time Air Quality Information and Citizen Science
- Challenges in Education, Training, and Outreach

Regulations, Legal Issues and Permitting
- Air Permit Compliance
- Air Toxics Regulations and Policies – Development and Implementation
- NSR/PSD Permitting
- Recent Court Rulings and Their Implications for Facilities
- Status of NSPS/NESHAP for Industrial Sectors
- International Regulatory Issues
- Visible Emissions Observation Training and Certification

Risk Assessment and EHS Management
- Environmental Management Systems
- Human Health Risk Assessment Studies
- Residual Risk and Technical Reviews
- Risk Communication

Transportation and Land Use
- ISIS Models
- Local/International Goods Movement
- Sustainable Transportation

Industrial, Government and Public Sectors

Chemical Petroleum
- Hot Topics in the Chemical and Refining Industries
- MACT Issues: Flares, Leaks, and Enforcement Priorities
- Emissions, Impacts, and Control Technologies Related to Oil and Gas Exploration and Production

Federal Facilities
- DoD Environmental Compliance Issues and Policies
- Strategic Sustainability Performance Planning at Federal Facilities and the Public Sector
- Compliance Information Management Challenges and Solutions

Indigenous Environmental Affairs
- Tribal Projects in Sustainability
- Tribal Minor NSR and Its Impact in Indian County

Industrial Furnaces and Boilers
- Implementation of Utility and Boiler MACTs

Mineral Extraction and Processing
- Issues in Mineral Extraction and Processing
- Issues in Mineral Exploration and Assessment

Power Generation and Renewable Energy
- Coal Ash Management and Disposal
- Energy Sources Development & Environmental Regulations
- Heat and Energy Recovery
- Renewable Energy

Sustainability, Climate Change, Resource Conservation and Waste Management

Climate Change Impacts and Adaption
- Climate Change Sustainability Challenges
- Methane/Waste Issues
- The Impact of Climate Change on Technology Selection for Air Pollution Treatment

Climate Change Policy, Strategy, and Regulations
- Corporate Climate Change Strategies
- Federal and State Methane Control Requirements
- Voluntary Climate Change Programs

Resource Conservation
- E-Waste Management
- Recycling and Diversion Programs
- Zero Waste Infrastructure and Systems, Economics, Funding, and Payback

Sustainability
- Sustainability Programs in the Waste and Energy Fields
- Sustainability Models to Engage Employees & Stakeholders
- Sustainability Reporting Standards

Waste Characterization and Site Remediation
- Managing Brownfield Agreements During Site Development
- Site Remediation
- Waste Characterization, Treatment and Beneficial Use
- U.S. Efforts to Adapt to International Hazardous Material Identification, Management and Reporting Standards

Waste Resource Recovery, Processing, and Bioenergy
- Anaerobic Digestion and Composting of Wastewater Sludges, Food Wastes, Agricultural Wastes and MSW
- Ash Management and Beneficial Reuse
- Bioenergy Technology, Biomass Combustion and Biofuels
- Lifecycle Impacts of Waste-to-Energy and Bioenergy, including GHG Emissions
- Municipal Waste and Wastewater Residuals Processing and Management
- Non-hazardous Waste Processing and Management – Industrial Liquids, Ash, and Manure
- Waste to Energy and Waste Conversion Technologies

JOURNAL

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Listed here are the papers appearing in the September 2014 issue of *EM*'s sister publication, the *Journal of the Air & Waste Management Association*. For more information, go to www.tandfonline.com/UAWM.

em • calendar of events

2014

SEPTEMBER

10–11 **Vapor Intrusion, Remediation, and Site Closure**
Philadelphia, PA; siteclosure.awma.org

10–12 **2014 A&WMA Southern Section Annual Meeting and Technical Conference** Montgomery, AL; www.ss-awma.org/annual.php

17 **A&WMA Central Texas Chapter Fall Symposium** Austin, TX; http://ice-texas.org/fall-2014-symposium

18 **A&WMA/AIChE Joint Webinar: Electricity and the Environment: Existing U.S. Coal-Fired Generation and Future Technologies**
2:00– 3:30 p.m. Eastern; www.awma.org

OCTOBER

13–15 **IT3: 33rd International Conference on Thermal Treatment Technologies and Hazardous Waste Combustors**
Baltimore, MD; it3.awma.org

21–22 North American Oil and Gas Conference Calgary, Alberta, Canada; oilandgas@awma.org

27–29 **2014 A&WMA Pacific Northwest International Section Annual Conference** Spokane, WA
www.pnwis.org/inlandnorthwest

28–29 **2014 A&WMA Louisiana Section Annual Conference**
Baton Rouge, LA; http://la-awma.org

29 Inter-Mountain Oil and Gas Environmental Conference
Denver, CO; www.awma.org

29–30 **2014 A&WMA Florida Section Conference**
Jacksonville, FL; http://floridasection.awma.org/conference.html

30 **2014 A&WMA Rocky Mountain States Section Technical Conference**
Devner, CO; www.awma-rmss.org

NOVEMBER

5–6 Great Lakes Oil and Gas Environmental Conference
Ann Arbor, MI; www.awma.org

Events sponsored and cosponsored by the Air & Waste Management Association (A&WMA) are highlighted in bold. For more information, call A&WMA Member Services at 1-800-270-3444 or visit the A&WMA Events Web site: www.awma.org/events.

To add your events to this calendar, send to: Calendar Listings, Air & Waste Management Association, One Gateway Center, 3rd Floor, 420 Fort Duquesne Blvd., Pittsburgh, PA 15222-1435. Calendar listings are published on a space-available basis and should be received by A&WMA's editorial offices at least three months in advance of publication.

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