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Introduction to a Special Issue of *JA&WMA* on NOAA's 7th International Workshop on Air Quality Forecasting Research (IWAQFR)

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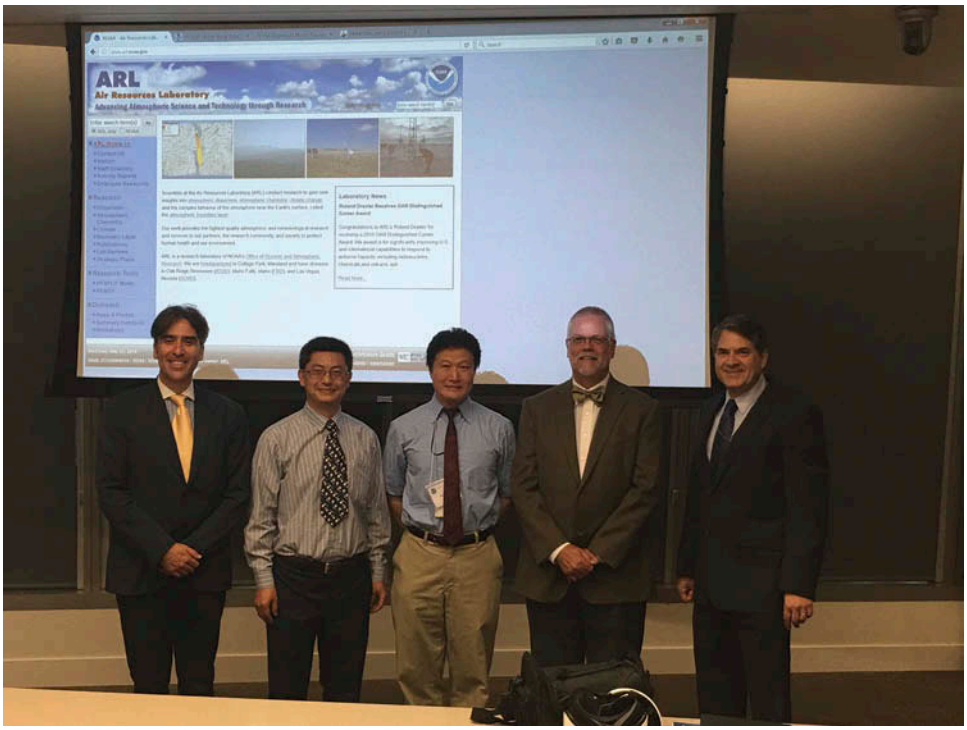

Operational air quality forecasts have unique challenges and specialized needs that are not typically addressed by either the traditional weather forecasting community or the air quality modeling community. In response, a regularly scheduled series of scientific meetings, the International Workshop on Air Quality Forecasting Research (IWAQFR), was established in 2009 to specifically focus on promoting and improving the science required to support operational air quality forecasting around the globe. IWAQFR was designed to foster interactive communication between researchers and practitioners of operational air quality forecasts, to provide a forum for discussion of recent advances in air quality forecasting research and current operational forecasting challenges, and to establish a more formal community promoting collaboration between researchers and forecasters.

The NOAA Air Resources Laboratory (ARL) provides research support to NOAA's National Air Quality Forecasting Capability (NAQFC), which makes operational ozone and fine particulate matter forecasts for the United States via the U.S. National Weather Service (NWS). From September 1-3, 2015, ARL was honored to host the 7th IWAQFR in College Park, MD. As with previous conferences in this series, the 7th workshop provided stimulating and useful communication of recent research and operational advances with participation of over 100 scientists, including 20 international participants from Asia, Australia, Canada, Europe, and South America. The conference was composed of seven oral sessions and a general poster session focused on several themes: (1) operational air quality forecasting: progress and challenges, (2) emissions forecasting, (3) model data assimilation, (4) evaluation and post-

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processing of model results, (5) megacities, (6) interactions of meteorological and air quality prediction, and (7) forecasting and communicating impacts. Further information concerning the workshop and many of the talks and posters can be found at: http://www.arl.noaa.gov/IWAQFR_home2015.php.

The conference opened with a statement from ARL Director Dr. Steven Fine welcoming the group and reinforcing the purpose of the program to meet the scientific and technical challenges associated with air quality science to protect citizens of the United States as well as globally. Dr. Fine reported that the primary current focus of NAQFC is the improvement of the fine particulate matter (PM) concentration forecast product. Dr. Fine cited studies by U.S. Environmental Protection Agency (EPA) and the wider epidemiological community that recognized PM as the EPA criteria pollutant most detrimental to human health. The often observed strong spatial gradients and relatively short atmospheric lifetime of PM highlights the need for fine resolution modeling of the emission, transport, formation and removal processes which control PM surface concentrations. The location of urban cores along coastal regions compounds the difficulties of PM forecasting due to the added complexity generated via the land-water interface. Dr. Fine's introduction was followed by four keynote speeches.

Dr. Mitch Goldberg, Joint Polar Satellite System (JPSS) Program Scientist of the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) spoke of the emerging capabilities of environmental observing satellites (EOS) to assist in air quality forecasting programs. Dr. Goldberg discussed the schedule associated with the launch of the NOAA series of JPSS satellites, ensuring data availability and product support out to 2038. The JPSS program partners with other international polar orbiting satellite programs, including the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Space Agency (ESA), and the Japan Aerospace eXploration Agency (JAXA), to further improve global characterization of the dynamics and composition of the atmosphere. Studies using the Suomi National Polar-orbiting Partnership (S-NPP) satellite—the first of the JPSS series—have been performed to provide improved satellite-based measurements for wild fire hot-spot detection and fire radiative power quantification. The JPSS visible infrared imager, infrared sounder, and ozone instruments have been successfully used for air quality applications. Drought indices, sea-surface temperature, and a wide array of surface characteristics and atmospheric composition can be determined with improved accuracy to describe the states of the planet's atmosphere and climate. Utilization of information from current and future geostationary satellites will improve the temporal scale of observations at the regional scale. Dr. Goldberg also noted the capability to measure ocean color from JPSS platforms to track algal blooms and associated emissions of reactive trace gases (e.g., isoprene and dimethylsulfide) and organic aerosols.

Dr. Veronique Bouchet, Acting Director of the Canadian Meteorological Centre for National Operations of Environment Canada (EC), reported that EC has been forecasting air quality in Canada for the past 15 years. Improvements to the Canadian system during this period include the ability to forecast multiple criteria pollutants including ozone and PM and the ability to generate increasingly finer spatially resolved forecasts. A research version of the system was tested last summer to forecast in real-time air quality for the Pan Am 2015 games in Toronto. The prototype system relied on a nested grid with an innermost domain of 2.5 km horizontal resolution and successfully captured the Lake Ontario–land interface. Dr. Bouchet also serves as the Chair of the WMO Global Atmosphere Watch (GAW) Urban Research Meteorology and Environment Project and provided an overview of the European Center's Monitoring Atmospheric Composition and Climate (MACC) and the Copernicus Program that produced a multi-year reanalysis record of atmospheric composition.

Professor Bill Ryan of Pennsylvania State University addressed the need to maximize societal welfare by identifying the potential benefits resulting from accurate air quality forecasts. Having been a veteran air quality forecaster for the Philadelphia and Baltimore regions for over two decades, Mr. Ryan possesses a large repository of experience and knowledge concerning the highly localized meteorological features of the region, which often permits improvements to the official NOAA forecasts. However, with the large decline in emissions due to enforcements and regulations that have taken place since passage of the 1990 Clean Air Act Amendments, Mr. Ryan noted that the statistical approaches he had been using over the past decade no longer produce forecasts as accurate as he typically was able to achieve in the 1990s concerning surface ozone concentrations. Mr. Ryan stated that the NOAA fine particulate model forecast has become an even more indispensable tool due to the often strong concentration gradients observed relative to tropospheric ozone. Mr. Ryan outlined his daily routine used in the production of early afternoon air quality forecasts, always made in consultation with the NOAA numerical forecast guidance. The reliability of the official forecast was

addressed in his presentation. As a side note, because of a minor publishing issue, Mr. Ryan's conference paper was not included here with the other meeting publications. In his paper, detailed changes in operational air quality forecasting over the past decade were identified, and prospects for future improvements were outlined. Mr. Ryan's paper may be found here: Ryan, W.F. The air quality forecast rote: Recent changes and future challenges; *J. Air & Waste Manage. Assoc*. **2016**, *66* (6), 576-596; DOI:10.1080/10962247.2016.1151469.

Dr. William Lapenta, Director of the NWS National Centers for Environmental Prediction (NCEP), gave a high level overview of the history of numerical weather forecasting. The phenomenal advance of weather and climate forecasting was noted for a range of applications as well as resulting important societal impacts. He highlighted Space Weather and Cyclone Genesis Forecasts as new applications made possible through huge advances in computational sciences. He identified the integration of all relevant earth systems in a model-interoperable and holistic manner as the key emerging challenge for the immediate future. For example, hydrological forecasting simulation should be structured to communicate with atmospheric, ocean, air quality, and land-surface simulations in real time to detect surges in storm run-off. Dr. Lapenta provided news concerning the national program being developed across federal and private institutions designed to address the interface challenges associated with multiple model communications. Dr. Lapenta encouraged the air quality scientists to participate as a member of the team developing forecasting models that work within the next generation of comprehensive global and earth systems.

Dr. Ivanka Stajner of the NOAA NWS highlighted the challenges of air quality forecasting that remain as epidemiologists continue to recommend the reduction of ambient ozone and particulate standards to lower concentrations. A presentation from Dr. Marin Cope of Australia demonstrated the strength of ensemble forecasts for providing a probabilistic concept of the occurrence of events, especially those of an intermittent nature such as from wildfires and dust storms. Dr. Limseok Kim of the Republic of Korea also noted the improvements promised from ensemble forecasts, noting that Korea had recently begun officially forecasting particulate matter for particles smaller than 10 μm in diameter. International cooperation was strongly endorsed as critical to accelerate improvements in air quality forecasting. Drs. Julia Zaitseva and Radenko Pavlovic of Environment Canada, Pablo Saide of Chile, and Gufran Beig and Sunil Peshin of India described their respective national programs and their dependence on international cooperation concerning sharing of emissions data from neighboring countries and an understanding of regional scale atmospheric phenomena. The first day of oral presentations concluded with a session on emissions forecasting, where progress is being made through the utilization of the rapidly increasing availability of real time satellite data to provide rapid refreshing of emission projections and the use of inverse modeling techniques to improve emissions estimates. The day concluded with an evening poster session where 29 posters were presented highlighting a wide variety of topics in air quality forecasting research.

The second day of the workshop emphasized data assimilation and highlighted chemical reanalysis and emission inverse modeling techniques for high impact air quality events. A session on evaluation and post-processing techniques identified the pros and cons of bias correction schemes and the general evaluation approaches performed in different parts of the world. A final session recognized the emergence of larger and more numerous mega-cities around the world. Dr. Yongtao Hu brought attention to the situation in China, highlighting the dire particulate pollution in China during the winter of 2013 and the drastic and partially successful steps taken to mitigate the situation. The construction of an air quality monitoring network in China has contributed significantly to gradually improving conditions.

A town hall meeting was held during the evening of the second day to announce the official release of a prototype marine isoprene emissions product developed through collaboration of satellite, research, and operational programs across NOAA. Isoprene, emitted by trees, grass and phytoplankton, is a reactive biogenic hydrocarbon that is important for the formation of tropospheric ozone and secondary organic aerosols. Built upon the pioneering work found in several isoprene emission algorithms, ARL collaborated with the NESDIS Ocean Color Team and George Mason University to use the ocean color retrievals from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the NOAA Suomi-NPP satellite to derive a marine isoprene emissions product. This work, funded by the NOAA JPSS Proving Ground and Risk Reduction Program, seeks to support air quality forecasting operations, as well as to improve climate models and Earth System models, all of which currently use predefined values to represent ocean-atmosphere exchange. The isoprene emissions product is presently undergoing testing, with the hope of eventually moving the product into operational use within NOAA.

On the final day of the workshop, discussion of the interaction of meteorology and air quality prediction

recalled remarks from Dr. Lapenta's keynote address noting that all earth phenomena are linked. Two-way feedbacks link meteorological and air quality simulations in a variety of ways. Consequently, a key issue of discussion during this workshop concerned efforts to exploit the emerging science allowing for two-way feedback between atmospheric composition and meteorological and climate forcing. The session on "Interactions of Meteorological and Air Quality Prediction" was dedicated to an effort to better understand forecasting perspectives associated with integrated multiple time and space scales of interlinked atmospheric phenomena. Six talks and two posters were presented. Dr. Rohit Mathur of the U.S. EPA led off the session by analyzing the impact on pollutant prediction by varying the frequency of data exchange between a meteorological driver and a regional air chemistry transport/transformation model. It was shown that with 4 km horizontal grid spacing and "off-line" hourly data exchange, the impact of inlining air chemistry was noticeable for time scales less than 12 hours and negligible beyond that. Direct radiative forcing effects were also analyzed across several seasons and regions around the Northern Hemisphere. Drs. Stu McKeen and Georg Grell of NOAA introduced a new aerosol-influenced convective parameterization scheme to account for the indirect forcing of aerosols on meteorology. They showed that inlining air chemistry within the meteorological drivers is potentially feasible but must be optimized with the intent of meeting operational time constraints.

IWAQFR 2015 concluded with a session concerning forecasting and communication impacts. A highlight of the session was a presentation by Joel Dreessen of the Maryland Department of the Environment, outlining the steps required during a forecaster's busy day to produce a good forecast for a case study when Canadian fires produced a plume impacting air quality in the Mid-Atlantic region. The conference adjourned with a summary discussion with renewed emphases concerning the need to acquire temporally- and spatially- relevant satellite-based data and to develop comprehensive high-resolution chemical models and ensemble modeling systems. Health impact and epidemiology studies and longer lead-time air quality forecasts require additional attention to address current limitations in atmospheric aerosol science. The workshop shed new light on the importance and feasibility of the integration of air quality and meteorological modeling systems as they are interacting in multiple ways with one another, thus highlighting the benefit of interoperable coupling of the respective models. Overall, the meeting re-emphasized that global cooperation is critical to understand past and current air quality conditions and to improve forecast capabilities for future states of the atmosphere. Meeting materials for IWAQFR 2015 are available at http://www.arl.noaa.gov/IWAQFR_home2015.php.