International Workshop on Air Quality Forecasting Research

Boulder, Colorado, USA, 2-3 December 2009

Workshop Report

Summary of Discussions

19 March 2010

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Background and Organization

The past decade has seen the explosive growth of emissions-based air quality (AQ) forecasting from a fledgling enterprise practiced by a few dedicated groups to a global network of daily AQ forecasts provided on local to global scales. These forecasts are used by health, environmental, and meteorological agencies in a host of air-quality related services. The provision of daily operational AQ forecasts, however, comes with unique challenges different from those faced by the weather forecasting or regulatory AQ modeling communities. Over time, a loosely knit group of practitioners has worked to address these scientific challenges, and their successes are evident in the improvements to forecast skill and the reliability of AQ forecasts over time.

The International Workshop on Air Quality Forecasting Research (IWAQFR) was established in response to the emerging need for a regular series of scientific meetings to promote the science required to support AQ forecasting around the globe. The Workshop, as envisioned by the Organizing Committee (Appendix A), had the primary goal of improving and extending AQ forecasts by:

1. Providing a venue for presentation of science issues and advancements related to AQ forecasting where practitioners could discuss current research and exchange ideas
2. Establishing and supporting a more formal community that would promote collaboration and cooperation among researchers whose primary focus is improving operational AQ forecasts.

The 2009 workshop held in Boulder, Colorado, USA was the inaugural workshop for what the Organizing Committee hopes will become an annual event. The US National Oceanic and Atmospheric Administration (NOAA) and the Meteorological Service of Environment Canada (EC) have agreed to sponsor the first two workshops in the US and Canada, respectively

The target audience of these workshops includes:

- Those directly involved in developing operational AQ forecast models;
- Those involved in research specifically targeted at supporting operational forecasts;
- Those working to improve predictive capabilities in areas of particular interest to AQ forecasting; and
- Operational users of AQ forecast models.

This first workshop included both oral and poster presentations organized around five themes:

1. Challenges in Particulate Matter Forecasting
2. Treating Intermittent Sources in Forecast Models
3. Air Quality and Weather Forecasts: Two-way Interactions
4. Post Processing of Air Quality Forecasts
5. Chemical Data Assimilation in Air Quality Forecasts.

The organizers were careful to allow ample time for discussion during the workshop. In particular, a discussion period was scheduled at the end of each session. Key points from the presentations and the discussion for each of the five themes are summarized below, including gaps in our understanding and recommendations for future research.

Theme 1: Challenges in Particulate Matter Forecasting
Chair: Jerome Fast (PNNL)

Forecasts of particulate matter (PM) mass still contain relatively large errors compared to operational forecasts of ozone. Air quality forecasters and research scientists report that persistence is usually a better 24-h forecast of PM concentrations than predictions made by 3-D mesoscale models. Errors in PM predictions can be attributed to many factors, including those associated with emissions, meteorology and the influence of aerosols on radiation and clouds, aerosol formation and transformation, and removal.

Rather than focusing on uncertainties in specific factors that influence predictions of PM, the workshop participants suggested that it is important to define classes of deficiencies in PM forecasts that need to be addressed. One such deficiency is the lack of an adequate understanding of the factors contributing to the diurnal evolution of PM that is needed to beat persistence forecasts. PM predictions will likely improve when uncertainties in meteorological forecasts are reduced. One, two, and multi-day simulations of PM have been shown to have similar errors, suggesting that synoptic-scale meteorology is not likely the dominant problem associated with poor PM forecasts. However, the diurnal variations in boundary layer properties have large uncertainties that likely contribute to errors in the dilution and transformation of PM near the surface. Small errors in predicted humidity and cloud fields can also have large effects on the simulated evolution of sulfate, a large fraction of PM mass over the eastern U.S. Air quality forecasters indicated that they need models that can reproduce the observed day-to-day trends in PM. If there are errors in PM concentrations, forecasters can usually account for known biases in the models. A second deficiency in PM predictions is that models fail to produce the seasonal variations in PM concentrations. Predicted PM mass during the summer is typically too low, presumably because secondary organic aerosol formation is insufficient in the models. But other factors likely contribute to this bias. A third deficiency is the inability of air quality models to account for intermittent sources of PM. Large fires can be observed in real time by satellites, and biomass burning emission estimates can then be derived and included in air quality model forecasts, but knowing how long current fires will continue into the future or where new fires will occur is extremely challenging. Since biomass burning can produce very high concentrations of PM, errors in representing these sources can have a profound effect on air quality forecasts.

Adequately evaluating PM forecasts from air quality models is an area that needs improvement. One must consider the totality of the model, including the meteorological, photochemical, and aerosol components, since the performance of an air quality model will be constrained by its weakest component. Operational monitoring network data have been frequently used to evaluate operational air quality predictions, but these data are available only at the surface and most stations are located near populated areas. In addition, PM concentration is the most reported quantity, with fewer stations measuring aerosol composition. Field campaign data provide more detailed information on PM properties both at the surface and aloft, but participants at the workshop suggested that more extensive concurrent measurements of meteorological, chemical, and particulate properties are needed during these field campaigns to fully evaluate air quality models. Additional long-term monitoring at "supersites" as well as profiles of aerosol quantities, such as those from lidars, are also needed to better evaluate models over seasonal time periods. Predicted aerosol number and size distribution are quantities that need to be assessed more frequently to determine the overall performance of air quality models; however, relatively few measurements of these quantities are routinely collected.

How complex air quality models are operated is another important issue that affects the performance of PM predictions. Some participants have noticed that different teams of researchers obtain substantially different predictions of PM, even though the same model is used. This situation can easily occur when community models, with their selection of options for parameterizations, are used. More detailed documentation of the emissions, domain configuration, and physical parameterizations employed is needed for the community to understand the best practices associated with PM forecasting.

Because of the large uncertainties in PM predictions that will require on-going research to reduce, air quality forecasters will likely benefit from ensemble modeling. Recent studies have shown that forecasts of both ozone and PM improve when they are based on the results of several models or model configurations. Some participants suggested that air quality forecasting should employ a probabilistic approach, rather than the current deterministic one. This would provide a range of likely PM concentration forecasts, rather than just one number. Other metrics than just PM concentrations, such as visibility, need to be implemented and tested more frequently.

Theme 2: Treating Intermittent Sources in Forecast Models
Chair: Stuart McKeen (NOAA)

Intermittent sources such as forest fires, dust outbreaks, volcanoes, stratospheric O_3 intrusions, accidental releases and industrial upsets can lead to extremely high concentrations of PM2.5, O_3, other criteria air pollutants or air toxics in populated regions. Incorporating intermittent sources within air quality forecast models presents unique logistical challenges in source identification, emission rate estimation, and inclusion within model forecast cycles. Ongoing efforts to include intermittent PM2.5 sources within air quality forecasts, primarily from wild fires and episodic dust emissions, were the focus of the oral and poster presentations within this section. These highly visible sources are the public's first-hand experience with air pollution meteorology, have immediate health consequences, and are key limitations to the accuracy of particulate matter forecasts. Since intermittent sources of PM2.5 and dust often occur well outside the domain of current air quality forecast models, their effects on regional pollution episodes can require special treatment of long-range transport through coupling with larger scale models.

Major limitations and research needs related to intermittent PM2.5 and dust sources fall under two broad categories: the timely identification of episodic events, and uncertainties in the forecast model treatment of associated physical processes. With regard to the latter, a fundamental limitation for both fire and dust sources relates directly to surface and land-use characterization. Emission parameterizations are highly dependent on variables such as the surface moisture and vegetative and soil types. These parameters are typically not well characterized in the global and regional models, and they are changing regionally, along with climate, through increased desertification, human encroachment, forest die back and vegetative succession.

Smoke from fires:
Retrievals from a suite of polar-orbiting and low-earth geostationary satellites are the primary means for detecting fire locations and plume transport over regional and global scales. Implementing these products within AQ forecasts has been demonstrated, as hot-spot locations from GOES satellites and the MODIS platform aboard the Terra and Aqua satellites now provide the basis for the U.S. NOAA/NWS operational smoke forecast system over North America [http://www.weather.gov/aq]. There is still a large gap between the actual satellite retrievals and their use in providing population exposure guidance or health alerts within air quality forecasts. Retrieval algorithms for the existing satellite platforms are the subject of ongoing research, and are only able to provide a limited amount of information needed for smoke emission estimates. Retrievals of hot spots are inherently limited in terms of cloud obscuration and estimating the area burn rates. The critical area burn rate parameter requires either local scale fire models or retrieval differences from previous unburned satellite scenes. Emission strengths, relative composition, and long-range transport are critically dependent on plume height, and also on the phase of combustion, whether it is flaming, crowning or smoldering. These aspects of fire emissions are outside the capabilities of satellite retrieval, and better suited

for local fire models. However, there are open questions about the scalability and application of local fire models within larger scale air quality models, given the self-induced dynamics and local topographic forcing of large forest fires relative to the regional or global scale model meteorological fields. Aerosol optical depth (AOD) retrievals are commonly used to track optical extinction from particulates, yielding column-integrated information on plume transport from fires. If the bulk of the smoke column is known to be within the planetary boundary layer (PBL), AOD can be used as a proxy for surface concentrations, given adequate additional meteorological information such as PBL height and humidity. Fire AOD retrievals from today's satellites are often limited by clouds and by a lack of quantitative uncertainty over high albedo surfaces. Advanced technology within the NASA sponsored GEO-CAPE (Geostationary Coastal and Air Pollution Events) satellite mission should significantly enhance current detection capabilities, and give limited vertical resolution of retrievals over Central and North America, though this mission is not scheduled for launch until at least 2014. Planned geosynchronous satellite deployments by the European and Japanese space agencies in the same time frame should ensure nearly complete coverage over the Northern Hemisphere. Ozone and aerosol lidars provide additional, independent observational platforms that can complement space-based measurements, particularly in terms of forecast and satellite verifcation studies.

Wind-blown dust:
Dust events from the regional to inter-continetal scale associated with desserts and arid crop lands are a significant contributor to high PM concentrations and a health concern for a major fraction of the Earth's population. Multispectral satellite retrievals are able to distinguish wind-blown dust events from other PM sources, but quantitative relationships to PM10 or PM2.5 concentrations are beyond the capabilites of current satellites, particularly near the Earth's surface. The physical processes associated with PM emissions from dust events are reasonably well understood from wind tunnel and other controlled experiments. Parameterizing these processes is routinely done within global and regional air quality models and local scale erosion models. The complication in accurately forecasting dust events arises from the highly nonlinear dependence of emissions on surface wind speed and soil properties such as moisture content and soil compaction. Highly accurate forecast wind fields and momentum profiles and detailed knowledge of surface properties are therefore a prerequisite to making adequate source emission estimates, and these are typically lacking over arable source regions. Over agricultural regions, knowledge of crop growth and decomposition, irrigation, and management activities such as tillage are also necessary considerations. In East Asia, where dust events and public alerts are common occurrences during certain times of the year, reliance is placed on an expanding international network of visibility estimates, surface monitors and tower measurements over desert source regions in Mongolia and China, along with surface monitors, lidar profilers and satellite images throughout the region to detect and provide an early warning system for dust events.

Theme 3: Air Quality and Weather Forecasts: Two-way Interactions

Chair: Véronique Bouchet

Report written by Jack Chen and Véronique Bouchet

The first generation of air quality models has been developed predominantly using a one-way approach, whereby meteorology is an integral part of determining the fate of atmospheric pollutants, but feedbacks of the pollution loading on meteorological variables, such as radiation or clouds, are not taken into account. An increasing number of studies document how the composition of the atmosphere, even close to the surface, can significantly influence its behavior on timescales varying from a few hours to years to centuries. A shift in the science community towards on-line meteorology/chemistry/air quality models is supporting the recent developments in this research area. The session reviewed different implementations of modeling feedbacks between meteorology and air quality and discussed the potential benefits and current limitations of considering two-way interactions in the context of air quality forecasting.

The WRF-Chem and Enviro-HIRLAM models follow an on-line approach, where transport schemes and integration time steps are fully consistent between the meteorology and chemistry variables that are handled within the same model. In addition, depending on their level of complexity, the available aerosol schemes are coupled to the radiation scheme or to both the radiation and cloud microphysics schemes, allowing the investigation of the two-way feedbacks between aerosols and meteorology. The WRF-CMAQ model retained an off-line approach, where the two-way communications between the air quality and the meteorological models, focused on the radiative feedbacks of the aerosol loading at this time, are handled via a coupler at a user-defined frequency. In that configuration, separate transport schemes and numerical time steps can be adopted for each model. At the global scale, the NEMS/GFS-GOCART weather forecast system currently has the option to include online aerosol parameterizations to account for direct radiative feedbacks from aerosols with an objective of improving global weather predictions and boundary conditions for regional air quality forecasts.

The studies primarily investigated the effects of air pollution levels (aerosols and selected gases) on the radiation balance and its subsequent effect on the planetary boundary layer and surface concentrations of ozone and its associated precursors. Generally, the dynamic representation of atmospheric aerosol loading can lead to a reduction in the shortwave radiation reaching the surface and a cooling of the surface, especially during strong PM events such as forest fires. In turn, the lower surface temperature can decrease the planetary boundary layer height, and consequently increase surface-level gas concentrations. Within and just above the boundary layer, on the other hand, absorption of radiation by aerosols originating from biomass burning leads to a warming. In addition, the WRF-Chem study illustrated the indirect effects of aerosol on cloud fraction, cloud water content and precipitation, with evidence of smaller droplet sizes when pollution interacts with cloud microphysics, leading to less precipitation except in some intense storm cells which are longer lasting. At the global scale, the NEMS/GFS-

GOCART study showed evidence that including aerosol feedback mechanisms can improve the forecast errors related to surface temperature and even, in some cases, the storm tracks. On a climate timescale, changes in the atmospheric general circulation were also noted.

In light of the recent advances in the investigation of two-way interactions in the context of air quality, weather and climate modeling, participants to the workshop identified the following gaps and recommendations with respect to the needs and potential benefits for weather and air quality for forecast operations:

- The majority of the current chemistry/weather coupled models focused their research on the radiative feedbacks from atmospheric aerosol and absorptions of selected gases. Feedbacks between the atmosphere and land surface as well as atmosphere-biosphere feedbacks are so far not well represented. Land surface processes interact dynamically with the atmosphere, and including this dynamic link can improve the representation of surface energy exchanges in addition to biogenic emissions, two factors which are important in weather and air quality forecasts (e.g., low soil moisture content can stress the vegetation and affect emissions and evapotranspiration; and transpiration rates from plants can change rapidly with atmosphere conditions).

- Timing is an important consideration in all forecast operations. This limitation needs to be finely balanced with the additional complexities inherent to chemistry/weather coupled models. Having to resort to a lower spatial resolution to accommodate the treatment of two-way interactions would likely be undesirable; hence, the gains in forecast accuracy for both air quality and weather with chemistry/weather coupled models would need to be assessed further. A longer-term study could be envisioned to provide more systematic evidence of the benefits of such an approach for forecasting.

- On-line models tend to lend themselves better to the study of two-way interactions and facilitate the interpretation of results and diagnosis of errors. They also offer a framework for stronger interactions between the meteorological and air quality communities. Although weather and air quality forecasts focus on different aspects of this issue (e.g., unstable vs. stable conditions; lower importance of planetary boundary layer height in weather forecasts compared to AQ forecasts), on-line coupled models may allow improvements to be achieved in both areas with more consistent parameterizations that better represent the state of the atmosphere. These developments would be facilitated by having a larger pool of inter-disciplinary experts from the university and research communities.

- It is important to ensure that aerosol formation and transport are modeled correctly in both space and time, as aerosol and some gases can have a significant effect in meteorological forecasts through radiative feedbacks. Uncertainties in aerosol science (secondary organics algorithms, emissions) may introduce additional errors and uncertainties to the weather and air quality forecasts in a coupled system. On the other hand, given the long residence time of dust in the upper atmosphere, chemistry/weather coupled models could provide a better forecasting capability for weather and air quality when it comes to long-range transport.

- Finally, chemistry/weather coupled models should also be considered for emissions control scenarios (State Implementation Plans - SIPs) and source/receptor studies. Despite the cost of modeling meteorology for simulations, the inclusion of feedbacks on meteorology may provide additional insights for policy studies.

Theme 4: Post Processing of Air Quality Forecasts

Chair: Mike Moran

The application of statistical post processing in weather forecasting dates back to the 1950s. More recently, ensembles of models have become another important post-processing tool for weather forecasting. This session on the post processing of AQ forecasts consisted of 13 oral and poster presentations, most of which were related to these same two approaches. Topics included (a) Model Output Statistics (MOS), bias correction techniques, and other model-measurement fusion techniques such as objective analysis that are applied to individual AQ model forecasts, (b) ensemble forecasts based on forecasts from either multiple AQ models or multiple versions of a single AQ model, and (c) the human-machine interface and forecaster expert judgment

As noted in the presentation by Antonopoulos et al., statistical post processing can (a) compensate for systematic model errors, (b) account for scales and phenomena not resolved by the meteorological and AQ models being used, (c) provide forecasts of quantities not directly predicted by AQ models (e.g., daily ozone maximum or an AQ index), (d) generate probabilistic forecasts (e.g., probability that an AQ threshold will be exceeded during a 24-hour period), and (e) provide a means to combine disparate sources of information such as gridded AQ model forecasts, meteorological and AQ station measurements, back-trajectory and satellite information, and so on. Note that if AQ measurements are used, their use occurs *after* a forecast model has been run, so that statistical post processing can be considered to be a complementary approach to data assimilation techniques.

Three presentations discussed MOS, which typically employs multiple linear regression. MOS is more than a bias-correction technique since it can consider a wider variety of predictors and predictands, but it also requires larger (longer) developmental data sets than many bias-correction techniques. All of these statistical post-processing techniques, however, are point-specific and are limited to measurement locations since their use depends on the availability of measurement data. Objective analysis is another approach to combine gridded model forecasts and measurement data, but it produces gridded results, that is, values at every location.

Ensemble forecasts, like single-model forecasts, also apply everywhere in the modeling domain. Different ways to calculate AQ ensembles were presented, from simple unweighted averaging to weighted-averaging approaches based on singular-value-decomposition, ridge-regression, and exponential-gradient methods. The weighted-averaging approaches, however, depend on the availability of network measurement data to calculate the weights. One presentation dealt with the blending of bias correction techniques with ensemble forecasts. It was also noted by several presenters that different approaches may be required for different objectives; for example, for minimizing forecast root-mean-square error vs. maximizing threshold detection skill.

The role that AQ model predictions play in the issuance of AQ forecasts to the public in North America and Europe was also discussed. There are a number of non-technical issues that are of concern. For example, many of the organizations responsible for issuing AQ forecasts to the public, particularly in the U.S., are separate from the organizations that provide AQ model forecasts and often have limited resources. AQ model forecasts are only one of a number of inputs considered by AQ forecasters in developing their forecasts and are viewed as numerical guidance of limited skill. In some cases, the timeliness of delivery of AQ model forecasts is an issue if a forecaster is to have sufficient time to examine and analyze model guidance before a forecast must be issued. Finally, forecasters must deal with AQ forecast models that are now evolving rapidly from year to year so that their performance and behavior are also changing.

Research and operational needs identified during the session included the following:

- Need for additional intercomparisons of different statistical post-processing techniques for different forecast objectives to identify both the most promising techniques and the advantages and disadvantages of different techniques.
- Need for more frequent intercomparisons of operational AQ models.
- Need to extend national AQ forecast model guidance to include (a) point-specific pollutant concentration forecasts based on statistical post processing of both model predictions and measured air pollutant concentrations and (b) air-parcel back trajectories from selected measurement locations based on the same meteorological fields used by the AQ model.
- Need to extend national AQ forecast guidance to include additional gridded forecast fields such as the major chemical components of total $PM_{2.5}$ mass (e.g., sulfate and nitrate mass).
- Need to develop operational ensembles based on either forecasts from different versions of one AQ forecast modeling system (i.e., single-model ensembles) or forecasts from multiple AQ forecast models (i.e., multi-model ensembles). The latter approach has already been employed in Europe by ECMWF under the GEMS and MACC projects (see http://gems.ecmwf.int/d/products/raq/ensemble/epsfields/plot_ensemble_o3/).
- Need to provide operational AQ forecasters with (a) more timely model forecasts, (b) longer forecasts (i.e., more than two days out), and (c) forecasts from more than one AQ model.

Theme 5: Chemical Data Assimilation in Air Quality Forecasts
Chair: Greg Carmichael (U. Iowa)

The session consisted of oral and poster presentations from scientists from North America and Europe engaged in data assimilation research. The presentations addressed many different aspects of data assimilation in support of air quality forecasting efforts. Topics covered included: 1) results from application and comparison of various chemical data assimilation methods applied to air quality forecasting, including OI (optimal interpolation), 3dVar and 4dVar, and ensemble-based; 2) the impact of satellite observations of meteorological and chemical parameters on air quality predictions; 3) new techniques in chemical data assimilation; and 4) assessment of the information content of different observing systems (including geostationary platforms) for use in air quality chemical assimilation systems.

Through these presentations and discussions it is clear that data assimilation in support of air quality forecasting is a growing area of application and research. Data assimilation capabilities in terms of air quality models with assimilation capabilities, approaches to assimilation and tools to support assimilation, and the number of centers and groups applying assimilation methods in "operational" settings are growing. In addition, the experience in applying data assimilation in air quality applications is growing and there is clear value in, and the need for, sharing this information with those engaged in assimilation, and more broadly within the community.

It is also clear that the field of chemical data assimilation is in its early stages of development with research along several fronts needed to advance the field. Furthermore, it is clear that air quality forecasting is of growing importance to science and society, and efforts to improve the assimilation capabilities will yield large benefits in terms of accelerating the quality of the forecasts. Research needs identified include those focused on enabling the following improvements:

- Further improvements in assimilation will benefit from improvements in the forward model in terms of reducing model biases, and these in turn require reductions in key uncertainties (e.g., emissions, better basic understanding of some processes such as the formation of secondary organic aerosols).

- Further development of assimilation methods designed specifically for chemical data assimilation is needed. This need recognizes that current efforts have been focused on applying methods designed for use in weather forecasting, and that air quality forecasting poses some different problems (for example, the strong role that emissions play in the air quality system). In addition, there is a need to develop further capabilities to perform assimilation in coupled meteorological and air quality systems to better facilitate the assimilation of meteorological and chemical data for the benefit of both air quality and meteorological forecasts.

- Further developments in the observing systems are needed to support air quality forecasting. There is a need to extend the observations available for air quality applications to include more information above the surface and to increase the spatial and temporal information. Increased efforts are needed to define the "value" of various observations in the context of their potential to improve air quality forecasts and to use this information in the design of future observing systems, including surface-based and satellite (e.g., geostationary)-based components. Data assimilation applications also place increased demands on these observing systems in terms of "real-time" data streams.

Appendix A
Organizing Committee

Véronique Bouchet (EC)
Greg Carmichael (University of Iowa)
Paula Davidson (NOAA)
Mike Howe (EC)
Jim Meagher (NOAA) - Chair
Craig Stroud (EC)

Workshop Coordinator:
Greg Frost (NOAA)

Appendix B
Workshop Agenda

Day 1 - December 2, 2009

Plenary Session: *Research Needs from the Practitioner's Perspective*
Chair: Jim Meagher (NOAA)
8:45 - 9:15 Véronique Bouchet (EC) - *Research Needs from the EC Perspective*
9:15 - 9:45 Paula Davidson (NOAA) - *Research Needs from the NOAA Perspective*
9:45 - 10:15 Adrian Simmons (ECMWF) - *Research Needs from the European Perspective*
10:15 - 10:20 Discussion

10:20 – 10:40 Break

10:40 – 12:00 Theme 1: *Challenges in PM Forecasting*
Chair: Jerome Fast (PNNL)
10:40 - 11:00 Alma Hodzic (NCAR) - *Can 3D Models Explain Observed Primary and Secondary, Fossil and non-Fossil Organic Aerosols?*
11:00 - 11:20 Ho-Chun Huang (SAIC, NOAA) - *The Impact of Transcontinental Transport on US Particulate Matter Prediction*
11:20 - 11:40 Mike Moran (EC) - *The PM Module in the New Canadian Operational AQ Forecast Model*
GEM MACH15: Current Status and Future Plans
11:40 - 12:00 Paul Makar (EC) - *High Resolution Simulations of Particle Sulfate Formation in Lake Breeze Fronts: Process Tracking and Implications for Forecasting*

12:00 – 13:00 Lunch

13:00 – 14:00 Theme 1: *Challenges in PM Forecasting – Continued*
13:00 - 13:20 Wanmin Gong (EC) - *Evaluating Cloud Processes in Particulate Matter Forecasting*
13:20 - 13:40 Jerome Fast (PNNL) - *How Do We Know that Aerosol Forecasts are Improving for the Right Reasons?*
13:40 - 14:00 Discussion

14:00 – 14:20 Break

14:20 – 16:00 Theme 2: *Treating Intermittent Sources in Forecast Models*
Chair: Stuart McKeen (NOAA)
14:20 - 14:40 Daewon Byun (NOAA) - *Improving Air Quality Forecasting through Incremental Reduction of Input Uncertainties*
14:40 - 15:00 Youngsin Chun (NIMR/Korea) - *Asian Dust Early Warning System in Korea*
15:00 - 15:20 Hermann Jakobs (U Cologne) - *Dust Storm Simulation with the Regional Air Quality Forecast Model EURAD*
15:20 - 15:40 David Lavoué (EC) - *Capacity for Forest Fire Forecasting in the Canadian Air Quality Model GEM-MACH*

Appendix B
Workshop Agenda

15:40 - 16:00 Discussion

16:00 – 18:30 Poster Session for all Themes

Day 2 - December 3, 2009

8:30 – 10:10 Theme 3: *Air Quality and Weather Forecasts: Two-way Interactions*
Chair: Véronique Bouchet (EC)
8:30 - 8:50 Georg Grell (NOAA) - *Impact of smoke from the ALASKA 2004 wildfires on radiation and cloud microphysics using WRF-Chem*
8:50 - 9:10 Rohit Mathur (EPA) - *The WRF-CMAQ Two-way Coupled Modeling System: Development, Testing, and Initial Applications*
9:10 - 9:30 Sarah Lu (NOAA) - *The NEMS/GFS-GOCART System: Overview, Status, and Preliminary Result*s
9:30 - 9:50 Alexander Baklanov (Danish Met Institute) - *Overview Of European Research In Online Coupled NWP & ACT Modeling With Two-Way Interaction*
9:50 - 10:10 Discussion

10:10 – 10:30 Break

10:30 – 11:50 Theme 4: *Post Processing of Air Quality Forecasts*
Chair: Mike Moran (EC)
10:30 - 10:50 Stavros Antonopoulos (EC) - *Forecasting O3, PM25 and NO2 three-hourly spot concentrations using an updatable MOS methodology*
10:50 - 11:10 Edouard Debry (INERIS/France) - *Using ensemble modeling to improve particulate matter forecasting in France*
11:10 - 11:30 Irina Djalalova (U Colorado, NOAA) - *Ensemble and bias-correction techniques for forecasting surface O3 and PM2.5 during the TEXAQS-II experiment of 2006*
11:30 - 11:50 Scott Jackson (EPA) - *Post Processing of Air Quality Forecasts for the AIRNow Forecaster Community*

11:50 – 12:50 Lunch, Photo

12:50 – 13:50 Theme 4: *Post Processing of Air Quality Forecasts – Continued*
12:50 - 13:10 Frederik Meleux (INERIS/France) - *Post-processing of the PREVAIR operational air quality system over Europe combining model outputs and observations*
13:10 - 13:30 William Ryan (Penn State U) - *Operational Use of Air Quality Numerical Forecast Model Guidance*
13:30 - 13:50 Discussion

13:50 – 14:10 Break

14:10 – 16:30 Theme 5: *Chemical Data Assimilation in AQ Forecasts*

Appendix B
Workshop Agenda

Chair: Greg Carmichael (U. Iowa)
14:10 - 14:30 Vincent-Henri Peuch (CNRM-GAME, Météo-France, CNRS) - *Chemical data assimilation for AQ prognoses over Europe in GEMS/MACC*
14:30 - 14:50 Adrian Sandu (Virginia Tech) - *Hybrid Methods for Chemical Data Assimilation*
14:50 - 15:10 Tianfeng Chai (STC, NOAA) - *Data assimilation and air quality forecasting using CMAQ*
15:10 - 15:30 Richard Ménard (EC) - *Coupled stratospheric chemistry-dynamics modeling and assimilation*
15:30 - 15:50 Mariusz Pagowski (Colorado State U, NOAA) - *Three-dimensional variational data assimilation of ozone and fine particulate matter observations: Some results using the Weather Research and Forecasting – Chemistry model and Gridpoint Statistical Interpolation*
15:50 - 16:10 R. Bradley Pierce (NOAA) - *Real-time Air Quality Modeling System aerosol and ozone assimilation and forecasting experiments during the NOAA ARCPAC field mission*
16:10 - 16:30 Discussion

16:30 – 17:00 Workshop Wrap-up
Speakers: Jim Meagher (NOAA), Véronique Bouchet (EC)

Appendix C
List of Posters

Theme 1 - Challenges in PM Forecasting

Ravan Ahmadov, (U Colorado, NOAA) - *The sensitivity of PM2.5 aerosol modeling in WRF-CHEM to chemical and meteorological parameterizations*

Youngsin Chun (NIMR/Korea) - *Asian Dust Aerosol Model Operated in Korea*

Colleen Farrell (EC) - *Sea Salt Flux Parameterization Sensitivity in the Chemical Transport Model AURAMS: The contribution of naturally occurring sea salt aerosol to fine particulate mass in Atlantic Canada*

Jeong Eun Kim (NIMR/Korea) - *Intensive Network of PM10 for Asian Dust Early Warning System in Korea*

Paul Makar (EC) - *High Resolution Simulations of Particle Sulfate Formation in Lake Breeze Fronts: Process Tracking and Implications for Forecasting*

Sylvain Ménard (EC) - *A new Canadian operational air quality forecast model: GEM-MACH15*

Steven Peckham (U Colorado, NOAA) - *Progress made towards including wildfires in real-time cloud resolving forecasts at NOAA/ESRL and examining its impact upon weather and air quality*

Craig Stroud (EC) - *Condensation of Gasoline Exhaust Organic Vapour onto Sulfate Aerosol: Flow Tube Studies and Regional Air Quality Modeling*

James Wilczak (NOAA) - *Meteorological Dependence of Surface PM2.5 During the TEXAQS II Field Program: A Comparison of AIRNow Observations with the NMM-CMAQ & WRF-Chem Models*

Jian Zeng (ERT, NOAA) - *Automatic Smoke Detection and Tracking Applied to GOES Observations*

Theme 2 - Treating Intermittent Sources in Forecast Models

Mary Barth (NCAR) - *Implementing Lightning-NOx for studies of Thunderstorms and Chemistry*

Serena Chung (Washington State U) - *Incorporating the Wind Erosion Prediction System (WEPS) for Windblown Dust into a Regional Air Quality Modeling System*

Masayuki Takigawa (AMEST/Japan) - *Comparison of the distribution of mineral dust calculated by WRF/Chem with the Mie scattering Lidar observations in East Asia*

Christine Wiedinmyer (NCAR) - *Estimating emissions and air quality impacts from fires*

Theme 3 - Air Quality and Weather Forecasts: Two-way Interactions

Wayne Angevine (U Colorado, NOAA) - *Improving boundary layer representation for air quality modeling: Stable, cloudy, and coastal boundary layers*

Evelyn Grell (U Colorado, NOAA) - *Comparisons of Off-line and On-line Air Quality Simulations in California's Central Valley*

Sara Michelson (U Colorado, NOAA) - *Evaluation of the Summertime Low-Level Winds Simulated by MM5 in the Central Valley of California*

Youhua Tang (SAIC, NOAA) - *Progress on NEMS/NMMB-AQ Development*

Theme 4 - Post Processing of Air Quality Forecasts

Appendix C
List of Posters

Hermann Jakobs (U Cologne) - *Chemical Weather Forecast for Europe and selected regions - Evaluation and Model Output Statistics*

Shobha Kondragunta (NOAA) - *Observed and Modeled Diurnal Variation in Tropospheric Nitrogen Dioxide*

Stuart McKeen (U Colorado, NOAA) - *Seven air quality forecasts and their ensemble: upper-air comparisons with ozone and aerosol lidar data during the TexAQS-2006 field study*

Vincent-Henri Peuch (CNRM-GAME, Météo-France, CNRS) - *Towards European-scale Air Quality operational services for GMES Atmosphere*

Jacques Rousseau (EC) - *Canadian new Air Quality Health Index, 2008 Evaluation*

Andrew Teakles (EC) - *Development of XM statistical tool for air quality forecasting*

Sarah Wong (EC) - *Air Quality Model Evaluation for Summer 2009 with Specific Focus on Aug 15-17th*

Theme 5 - Chemical Data Assimilation in AQ Forecasts

Greg Carmichael (U Iowa) - *Rapid Update of Emissions Using Chemical Data Assimilation*

Greg Carmichael (U Iowa) - *GURME – The WMO GAW Urban Research Meteorology And Environment Project*

Claire Granier (LATMOS/France, U Colorado, NOAA) - *An integrated forecasting system for global reactive gases in the troposphere and stratosphere – The GRG sub-project of MACC*

Richard Ménard (EC) - *Estimated error variances derived from assimilation residuals in observation space*

Gregory Osterman (JPL, Cal Tech) - *Impact of long range transport on surface air quality in the US: Recent insights from satellite assimilation*

Arastoo Pour-Biazar (U Alabama) - *Examining the utilization of satellite observations in improving air quality predictions*

Qiang Zhao (NOAA) - *Assimilation of Satellite Derived Aerosol Products to Improve PM2.5 Predictions*