Path Forward for the Air Quality Model Evaluation International Initiative (AQMEII)

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The inhalation of air pollutants such as ozone and fine particles has been linked to adverse impacts on human health, and the atmospheric deposition of pollutants such as sulfates, nitrogen, and mercury has been linked to harmful effects on sensitive ecosystems. It is now well known that air pollution and climate change are interrelated. Given the local-to-global nature of atmospheric pollution, comprehensive air quality models are needed to better understand source-receptor relationships and to design meaningful and effective strategies to mitigate pollution problems. Both in North America and Europe, several models have been developed independently by different research groups during the last three decades. Some of these models are being widely used for designing emission control policies and forecasting air quality in both continents.

Unlike the global-scale climate modeling community, the regional-scale air quality modeling community has not benefitted from collaborative research efforts with participation of scientists from both continents for systematically assessing models' performance and for advancing the state-of-the-science in models. Recognizing this, the Air Quality Model Evaluation International Initiative (AQMEII) project was launched in 2009 by bringing together scientists from both sides of the Atlantic Ocean[1]. Several regional-scale numerical photochemical models have been exercised with a common emissions inventory for the year 2006 over North America and Europe. Several papers resulting from this collaborative effort have been accepted for publication in the AQMEII 2012 special issue of *Atmospheric Environment*[2]. Also, a large 4-D database of observations and model outputs, assembled by the European Commission Joint Research Centre for the AQMEII project, is now being made available to all scientists interested in developing innovative model evaluation techniques and for improving the science in regional-scale air quality models[3].

Having successfully completed the first phase of AQMEII, Phase 2 of AQMEII was discussed at the 2011 workshop in Chapel Hill, NC, USA to focus on the interactions of air quality and climate change. In Phase 2, coupled meteorology-atmospheric chemistry models would be applied for the two continents with a common emissions database to assess how well the current generation of coupled regional-scale air quality models can simulate the observed spatio-temporal variability in the optical and radiative characteristics of atmospheric aerosols and associated feedbacks among aerosols, radiation, clouds, and precipitation. The results from AQMEII Phase 2 would be useful to policy-makers for developing effective policies to deal with air pollution and climate change.

As mentioned above, the global-scale modeling community has long been involved in collaborative research efforts across continents. One such effort with direct relevance to AQMEII is the work of the Task Force on Hemispheric Transport of Air Pollution (HTAP)[4]. HTAP was formed in 2004 under the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP Convention) to develop a fuller understanding of the intercontinental transport of air pollution across the Northern Hemisphere, with respect to ozone, fine particles, acidification, eutrophication, heavy metals, and persistent organic pollutants. In response to this mandate, HTAP brought together scientists from North America, Asia and Europe to address questions such as:

- What is the observational evidence for intercontinental transport of O_3, PM, Hg, and POPs in the Northern Hemisphere?
- What are the key processes that drive these intercontinental flows?
- What do the current generation of models tell us about transboundary pollution and intercontinental source-receptor relationships?

In its first phase, HTAP assembled a large of team of scientists from Europe, Asia and North America to exercise approximately 30 global air quality models for the year 2001 fro estimating the contribution of pollutant fluxes from Asia to North America and Europe, and vice versa. In 2010, HTAP's mandate was renewed to i) examine the transport of air pollution, including ozone and its precursors and particulate matter and its components (including black carbon), across the Northern Hemisphere; ii) assess potential emission mitigation options available inside and outside the UNECE region; and iii) assess their impacts on regional and global air quality, public health, ecosystems, and near-term climate change in collaboration with other groups both inside and outside the Convention. In response to this mandate, HTAP is initiating its Phase 2 activities, which will focus on assessing the ability of current models to reproduce observations during the 2006-2010 period, estimating changes to transboundary fluxes under global emission control scenarios for

2030, and improving the estimation of the impacts of pollution transport on health, ecosystems, and climate. In addition, HTAP is interested in the influence of climate change on air quality, coordinating its work with various parallel activities (e.g. the IGAC/SPARC Atmospheric Chemistry and Climate Initiative.

CURRENT STATUS

Recognizing the value of continued collaboration and coordination of research among scientists in North America and Europe, a workshop was convened in Utrecht, The Netherlands in May 2012 to launch the Phase 2 activity of the AQMEII to apply coupled meteorology-chemistry regional models over Europe and North America to assess feedbacks among aerosols, clouds, and radiation as called for in Alapaty et al.[5] The model evaluation approaches suggested by Dennis et al.[6] can provide a common basis for evaluating regional-scale coupled models. The North American model domain covers the United States and southern part of Canada, while the European domain covers all countries in the European Union.

AQMEII will provide a set of time-varying gridded emissions (referred to as “standard” emissions) for each continent, focusing on the evaluation of the air quality and meteorological models. Standardized modeling outputs from each modeling group will be shared on the web-distributed ENSEMBLE system[7], facilitating statistical and ensemble analyses to be performed by each group. The observational data for several fields, based on surface monitoring networks and satellite observations over both continents, are being loaded into the ENSEMBLE system.

It is envisioned that annual simulations for 2006 and 2010 will be performed using several coupled or on-line regional-scale models. These two years are distinguished by different emissions brought about by the economic downturn as well as regulatory policies that have been implemented during these years. Model simulations for these two emission scenarios will help assess if the uncoupled vs. coupled models can reproduce the observed change in air quality over both continents.

PATH FORWARD

As the AQMEII community is continuing international collaboration on the evaluation of regional coupled (i.e., integrated meteorology-atmospheric chemistry) models’ ability to simulate the interactions of aerosols and radiation, the HTAP community is also organizing simulation experiments using a combination of global and regional models for the same years (2006 and 2010). This creates an opportunity for collaboration between the HTAP and AQMEII communities that will be beneficial for both modeling activities. Therefore, AQMEII and HTAP are working to integrate present-day continental-scale emission inventories developed for AQMEII into the global-scale emission inventories developed for HTAP. In addition, it is hoped that the output from global and hemispheric models can provide boundary conditions for the regional-scale models and that similar emission perturbation studies may be conducted at both scales. Finally, model evaluation activities will be coordinated between the two communities. Working together, these two modeling communities can identify the strengths and limitations in the current generation of uncoupled and coupled models.

AQMEII Phase 2, working with HTAP, will attempt to address the following policy-relevant questions:

- Do the current versions of coupled models accurately simulate aerosol-radiation feedback processes over North America and Europe?
- How sensitive are regional model predictions to the boundary conditions chosen?
- How important is scale interaction in air quality and climate change studies?
- Can global models learn from regional-scale models and vice versa?

The above research activities will not only enable us to better understand the current state-of-science in air quality modeling, but also help in rapidly advancing the science in regional models.

SUMMARY

In the relatively short time since its inception, AQMEII has emerged as a key forum for atmospheric modelers from North America and Europe to identify and address pressing science issues facing their respective communities. The initial task of performing an in-depth coordinated model intercomparison of uncoupled modeling systems has been completed successfully and, more importantly, has established the institutional and organizational framework for moving forward. In its current phase, AQMEII will address the question of how well regional-scale online coupled meteorology-chemistry modeling system can simulate air quality – climate interactions. To broaden this analysis, AQMEII is establishing collaborations with global-scale modeling activities such as HTAP to work on topics of mutual interest. Building upon its past and present work, AQMEII is well positioned to address emerging science issues facing the regional-scale modeling communities, such as the application of atmospheric models for human exposure and ecosystem impact assessments with emission controls under current and future climate scenarios. Regardless of the specific topic tackled under AQMEII, the cornerstone of this activity has been and will continue to be the critical evaluation of regional-scale air quality modeling systems, to help build confidence in their use for specific applications and to clearly communicate the strengths/limitations of these modeling systems when used for guiding policy decisions.

DISCLAIMER

Although this paper has been reviewed and approved for publication by the U.S. Environmental Protection Agency and the European Commission Joint Research Centre, it does not necessarily reflect their views and policies.

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REFERENCES

1. Rao, S.T., Galmarini, S., Puckett, K., 2011. Air quality model evaluation international initiative (AQMEII). Bulletin of the American Meteorological Society 92, 23-30. DOI:10.1175/2010BAMS3069.1
2. Galamrini, S., Rao, S.T., and Steyn, D.G., 2012a. Preface for the AQMEII special issue of Atmospheric Environment, in press.
3. Galmarini, S., and Rao, S.T., 2011.The AQMEII two-continent regional air quality model evaluation study, Atmospheric Environment. 45 (14), 2464.
4. UNECE, 2010. Hemispheric transport of air pollution, Part D: Answers to policy-relevant science questions, Air Pollution Studies No. 20.ISSN 1014-4625.
5. Alapaty, K. et al., 2012. New Directions: Understanding interactions of air quality and climate change at regional scales, Atmospheric Environment doi:10.1016/j.atmosenv.2011.12.016.
6. Dennis, R. et al., 2010. A framework for evaluating regional-scale numerical photochemical modeling systems. Environ Fluid Mech DOI 10.1007/s10652-009-9163-2
7. Galmarini, S., Bianconi, R., Appel, W., Solazzo, E., and et al., 2012. ENSEMBLE and AMET: two systems and approaches to a harmonised, simplified and efficient assistance to air quality model developments and evaluation. Atmospheric Environment doi:10.1016/j.atmosenv.2011.08.076