Emission Modeling: Fires, Biogenics, and Sea Salt

Thomas Pierce, George Pouliot, William Benjey, Prakash Bhave, David Mobley, Robert Pinder, Alice Gilliland

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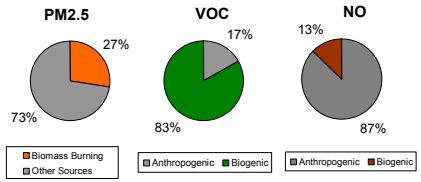
Model Development and Diagnostic Testing

Environmental Issue

Several expert panels (such as two National Academy of Sciences studies and the 2005 NARSTO assessment) have noted that emissions are at the cornerstone of air quality management. Despite their importance in multi-billion dollar environmental decisions, emission estimates continue to have numerous shortcomings. While EPA's Office of Air Quality Planning and Standards (OAQPS) bears the responsibility for building the National Emissions Inventory (NEI) for traditional anthropogenic sources (such as electrical generating units and mobile sources), many non-traditional emission categories (such as fires and biogenics) remain poorly characterized. Reducing the uncertainty in air quality model simulations justifies the need for research on the development and evaluation of improved emission algorithms for these non-traditional sources.

Importance of non-traditional sources of emissions



Source: EPA National Emission Trends, 2005 estimates

Research Objectives

- Improve the characterization of non-traditional emissions, particularly those modulated by meteorological conditions.
- Evaluate improved emissions characterizations in CMAQ.
- Share these improvements with the air quality modeling community.

Biomass Burning

Objective: Improve the biomass burning inventory by developing a cost-effective method to resolve fires on a temporal and spatial basis. Evaluate the performance of CMAQ with the improved emissions versus other biomass burning inventories.

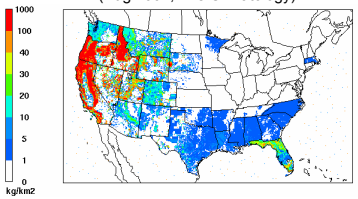
Fire Climatology: Based on an old OAQPS approach, in which emissions were averaged on a monthly and county basis as taken from a 7-year period. Average emissions distributed to forest lands in a county. All emissions placed in layer 1 for modeling.

2002 NEI: RPO/OAQPS-sponsored inventory based on detailed ground reports; cost nearly a million dollars to create.

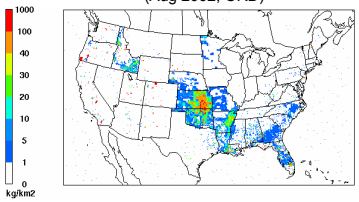
AMAD/ORD Method: Blend of ground-based information and MODIS satellite detections, produced at a fraction of cost.

Biomass Burning (continued)

PM2.5 biomass burning emissions
(Aug 2002, Fire Climatology)



PM2.5 biomass burning emissions
(Aug 2002, ORD)

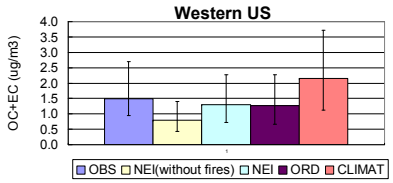


Increasing Specificity

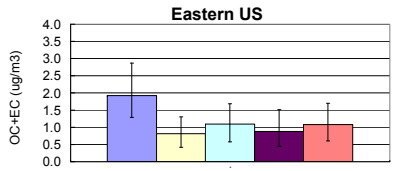
CMAQ Model Performance

Comparisons of total carbon measured at IMPROVE sites versus CMAQ simulations with various fire inventories show that fire-specific emissions (like those produced with the ORD/AMAD approach) can improve model performance. The medians are shown below, as well as the 25th and 75th percentiles from Aug 2002 for the eastern and western U.S.

Median TC (n=819) IMPROVE vs model



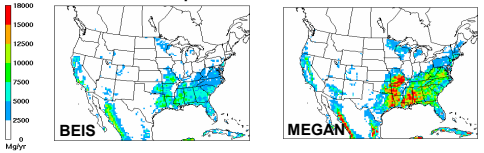
Median TC (n=481) IMPROVE vs model



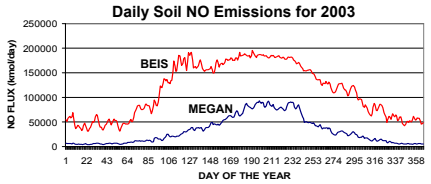
Biogenic Emission Models

- AMAD is the originator of the Biogenic Emissions Inventory System (BEIS) for estimating biogenic volatile organic compounds from vegetation and NO from soil.
- BEISv3.14 is the latest operational biogenic emissions module in CMAQ.
- We are collaborating with the National Center for Atmospheric Research on the development and application of the Model for Emissions of Gases and Aerosols from Nature (MEGAN).
- We are working to integrate the National Land Cover Database (NLCD) into MEGAN.

Annual Isoprene Emissions for 2003



Daily Soil NO Emissions for 2003

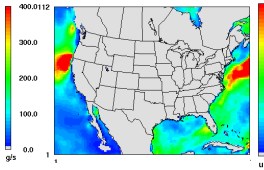


Modeling Sea-Salt Emissions

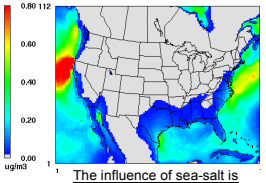
Until recently, the characterization of sea-salt emissions did not exist in regional air quality simulation models. We have constructed a saltwater and shoreline geographical coverage file to drive emissions from open water and breaking waves using available flux equations that vary as a function of wind speed. The equation of emission flux below is fitted to a bimodal form for CMAQ.

$$\frac{dF_{N-Open}}{dr_{80}} = 1.373 \cdot u_{10}^{3.41} \cdot r_{80}^{-A} \cdot \left(1 + 0.057 r_{80}^{3.45}\right) \cdot 10^{1.607 e^{-B^2}}$$

Sea salt emissions
(10 d avg, coarse mode)



Sea salt sulfate concentration
(10 d avg, coarse mode)



The influence of sea-salt is shown 100s of kms inland.

Conclusions

- Natural emissions from fires, biogenics, and sea salt are a significant part of the emissions budget, and they display large spatial and temporal variations that should be accounted for in regional-scale air quality models.
- AMAD has been a major contributor towards improving other aspects of emissions, including ammonia, fugitive dust, and the speciation of organics and particulate matter (SPECIATEv4).
- Incorporating more-advanced estimates of fires, biogenic, and sea-salt emissions appears to have improved CMAQ model performance.

Future Directions

- Continue to test, evaluate, and improve the integration of the MEGAN biogenic emission algorithms in the CMAQ modeling system.
- Introduce and evaluate an algorithm for estimating the production of nitric oxide from lightning.
- Incorporate and evaluate a windblown dust algorithm in the CMAQ model.

Impact

- Advances in emission modeling have improved the performance of the CMAQ modeling system for estimating ozone and fine particulates, helping to reduce the uncertainty in national air quality management decisions. This work has helped to better quantify emissions from "irreducible" sectors.
- The Biogenic Emissions Inventory System (BEIS) is used worldwide in air quality modeling, and it is serving as a basis for developing the MEGAN natural emissions model.
- The satellite-based methodology for estimating emissions from fires has been incorporated into the National Emissions Inventory (NEI).
- CMAQ uses scientifically-defensible methods and data for estimating emissions from fires, vegetation, saltwater, and soils.

Contributors/Collaborators

Cornell University: K. Zhang;
EPA/NRMRL: C. Geron;
EPA/OAQPS: Emissions Inventory & Assessment Group;
EPA/Region VI: D. Roy;
EPRI: E. Knipping;
NASA: A. Soja, K. Pickering;
NCAR: A. Guenther, C. Widenmeyer;
U.S. Forest Service: Fire Sciences Group.