4.9

MODEL EVALUATION AND SENSTIVITY OF THE MODELS-3/CMAQ AND CAMx MODELING SYSTEMS FOR THE JULY 1995 NARSTO-NORTHEAST EPISODE

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1. INTRODUCTION

The Coordinating Research Council (CRC) has sponsored the NARSTO-Northeast air quality modeling study. This study applied EPA's Models-3 Community Multiscale Air Quality (CMAQ) and the Comprehensive Air-quality Model with extensions (CAMx) modeling systems to the July 1995 NARSTO-Northeast ozone episode that occurred in the northeastern United States (US). During the summer of 1995, a field study was conducted in the northeastern US collecting enhanced surface and aloft meteorological and ambient air quality measurements under the direction of the North American Research Strategy for Tropospheric Ozone (NARSTO). The period of July 12-15, 1995 during the NARSTO-Northeast study experienced elevated ozone concentrations along the entire Northeast Corridor.

2.0 OVERVIEW OF APPROACH

The CRC NARSTO-Northeast study performed emissions modeling of the July 7-15,1995 episode using the 1995 version of the Emissions Modeling System (EMS-95) (Wilkinson, 1994). Photochemical modeling was performed using MM5 meteorological model output generated by Pennsylvania State University (PSU) with various levels of data assimilation (Seaman and Michelson, 1998) and the RAMS meteorological model output generated as part of the Ozone Transport Assessment Group (OTAG) study (OTAG, 1997). Particular emphasis was made to minimize any interpolation or averaging of the MM5 and RAMS meteorological output for input into the two photochemical models. Thus, the photochemical models were configured with the same horizontal grid structure and vertical layer interfaces as the meteorological models, a Lambert Conformal Projection (LCP) for MM5 and a Polarstereographic Projection (PSP) for RAMS. Up to three levels of grid nesting were utilized with grid resolutions of 36-km, 12-km, and 4-km. A model performance evaluation was conducted using the extensive NARSTO-Northeast database.

The purpose of the CRC NARSTO-Northeast modeling study was as follows:

- To use the information learned from the CRC NARSTO-Northeast data analysis study and;
- CRC PSU MM5 meteorological modeling of the NARSTO-Northeast July 1995 episode to support improved photochemical modeling of the Northeast U.S.;
- To apply multiple photochemical models using multiple meteorological models (MM5 and RAMS) with alternative options minimizing the amount of interpolation or averaging of the meteorological data;
- To perform a comprehensive model performance evaluation of photochemical models using the robust NARSTO-Northeast ambient database; and
- To investigate the sensitivity of photochemical models to a variety of model inputs and model formulations including:
  - Meteorological Model (MM5 and RAMS)
  - Level of Data Assimilation used in a Meteorological Model
  - VOC and/or NOx Emission Perturbations
  - Biogenic and Mobile Source Emissions
  - Grid Resolution
  - Advection Solver
  - Chemical Mechanism (SPARC and CB-IV)
  - Photochemical Model (CAMx and CMAQ)

3.0 MODEL PERFORMANCE EVALUATION

Model performance was evaluated for several photochemical model base case realizations including CAMx using MM5 with three different levels of data assimilation, CMAQ and CAMx using a 12-km and 4-km grid resolution, CAMx using two different chemistries (CB-IV and SAPRC97), and CAMx using meteorology from MM5 and RAMS. Although variations in model options caused subtle changes in model performance, there were three main model configurations that exhibited unique model performance attributes. Figure 1 displays time series of predicted and observed hourly ozone concentrations averaged across the NARSTO-Northeast analysis domain for three model configurations:

- CMAQ/MM5
- CAMx/MM5
- CAMx/RAMS

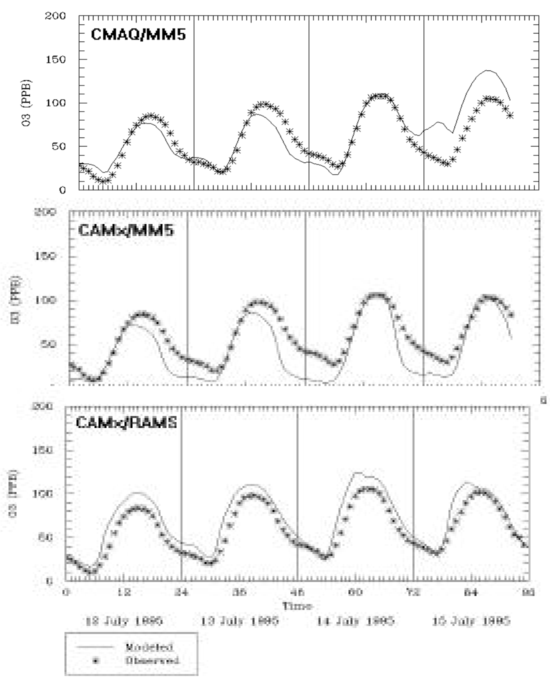

Figure 1. Time series of predicted and observed hourly ozone concentrations spatially averaged across sites in the NARSTO-Northeast region.

The basic ozone model performance attributes of the three models are summarized as follows:

- Both CAMx/MM5 and CMAQ/MM5 estimate the early morning rise in ozone concentrations reasonably well;
- CAMx/RAMS estimates the rise in ozone too early and too fast on all four days;
- CAMx/MM5 estimates the fall in the observed hourly ozone in the late afternoon too early and too fast;
- CAMx/RAMS and CMAQ/MM5 estimate the afternoon fall in ozone and nighttime ozone levels better than CAMx/MM5, with the exception of CMAQ/MM5 on the night of July 14;
- CAMx/RAMS overestimates the afternoon average ozone concentrations on all days and in all subregions; and
- CAMx/MM5 and CMAQ/MM5 estimate the average observed afternoon ozone concentrations slightly better than CAMx/RAMS, with the exception of CMAQ/MM5 on July 15 that exhibits a large ozone overprediction tendency.

4.0 MODEL SENSITIVITY TESTS

There were numerous sensitivity tests conducted with important findings that can not all be discussed here (see ENVIRON, 2002). Two important ones are as follows

4.1 Effects of Grid Resolution

The CMAQ and CAMx 12-km coarse grid and 4-km fine grid sensitivity tests using the MM5 meteorology were generally consistent on July 12-14, but not on July 15, 1995. Figures 2 and 3 display the, respectively, CMAQ and CAMx12-km and 4-km daily maximum ozone estimates on July 15, 1995. The key findings of the grid resolution sensitivity tests are as follows:

- On most days the CMAQ and CAMx 4-km modeling results are more like each other than their 12-km parent.
- On July 15, 1995, the 4-km MM5 simulation explicitly resolves convective downdrafts result in substantial differences in the CMAQ and CAMx results (Figures 2 and 3).
- The treatment of convective activity, grid resolution, and interface between meteorological and air quality models needs additional research.

4.2 Emission Reduction Sensitivity Tests

50% VOC and 50% NOx anthropogenic emissions reduction sensitivity tests were carried out using the CMAQ and CAMx models with the following findings:

- NOx controls result in widespread estimated ozone reductions across the Northeast in both

models except New York City (NYC) and occasionally other cities where ozone increases occur.
- VOC control mainly result in ozone reductions in NYC with little effects elsewhere.
- SAPRC97 chemistry is more VOC sensitive than the CB-IV.
- CMAQ is less VOC sensitive than CAMx.
- The addition of a 4-km grid increases the ozone increases due to the NOx control in NYC but has little effect elsewhere.

Ozone Design Value scaling was used to estimate future-year 1-hour ozone Design Values following EPA's draft 8-hour ozone guidance (EPA, 1999). The different model configurations produced arguably similar model performance and realizations of the July 1995 NARSTO-Northeast episode. However, they do produce different estimates of Ozone Design Values under the VOC/NOx emission reduction sensitivity runs. Thus using Design Value Scaling does not protect against a poor performing model or inadequate inputs (e.g., coarse grid spacing) providing misleading information.

5.0 CONCLUSIONS

The conclusions of the CRC NARSTO-Northeast study are summarized as follows (see ENVIRON, 2002 for details):

- The QSSA chemistry solver is inaccurate and slow and should not be used for air quality modeling.
- In most cases (see next point), the use of more four-dimensional data assimilation (FDDA) results in more representative meteorological fields.
- Care should be taken using strong observation nudging FDDA as it may introduce artifacts that destroy good meteorological features.
- The SAPRC97 chemistry is more reactive producing higher ozone, has slightly more VOC sensitivity than CB-IV chemistry, and produces larger NOx disbenefits.
- Ozone formation in CMAQ is less VOC sensitive and more NOx sensitive than CAMx when both models use the CB-IV chemical mechanism.
- The CMAQ horizontal diffusion coefficient parameterization that is inversely proportional to grid size masks the benefits of using higher resolution grids making the 4-km model estimates look similar to the 12-km model estimates.
- The use of the higher-resolution grid in CAMx increases the NOx disbenefits but has little effect on the ozone reductions outside of the Northeast Corridor urban areas.
- Meteorological modeling of convective activity is a particularly challenging task. What constitutes a good meteorological model simulation (e.g., correct placement of a squall line) may not necessarily be good for air quality modeling (e.g., incorrect placement of a down draft within the squall line).
- Although less sensitive than absolute ozone concentrations, the ozone Design Value scaling approach is still affected by model inputs and options.
- The use of different meteorological models (MM5 or RAMS) can result in different ozone responses to VOC and/or NOx controls.

6.0 REFERENCES

ENVIRON, 2002: Development, Application, and Evaluation of an Advanced Photochemical Air Toxics Modeling System: CRC A-42-2. June 30.

EPA, 1999: Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS." EPA-454/R-99-004, May 1999.

OTAG, 1997: Modeling Report - Version 1.1. February 12.

Seaman, N. and Michelson, 1998: Mesoscale meteorological structure of a high-ozone episode during the 1995 NARSTO-northeast study". *J. Appl. Meteor.* (submitted)

Wilkinson, J., 1994: Technical Formulation Document: SARMAP/LMOS Emissions Modeling System (EMS-95)." AG-90/TS26 & AG-90/TS27.

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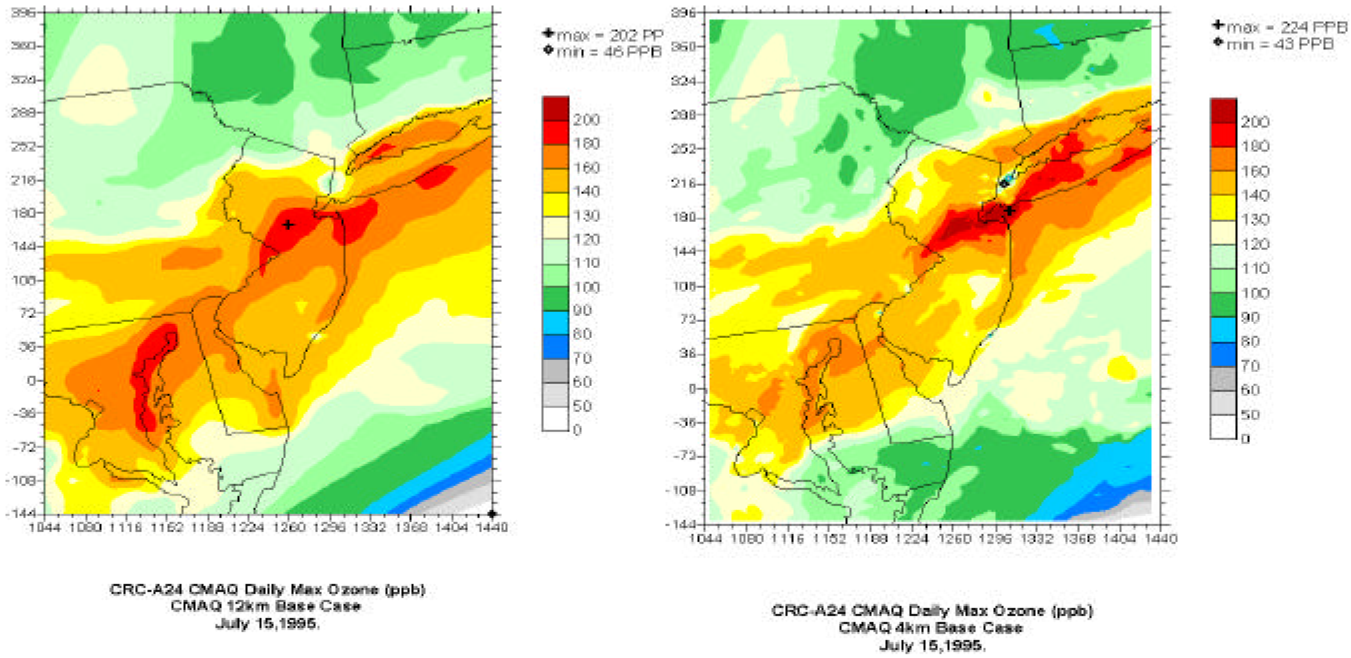

Figure 2. Daily maximum ozone concentrations (ppb) estimated by the CMAQ model or July 15, 1995 using a 12-km (left) and 4-km (right) grid resolution.

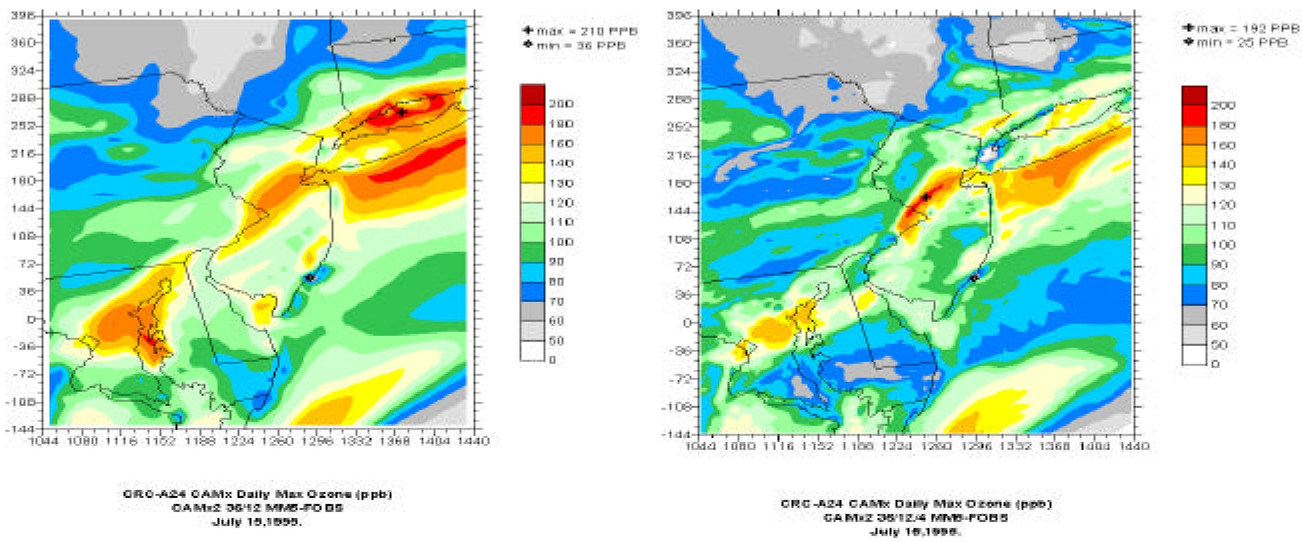

Figure 3. Daily maximum ozone concentration (ppb) estimated by the CAMx model on July 15, 1995 using a 12-km (left) and 4-km (right) grid.