Title
Diagnostic and Mechanistic Evaluations of MM5-CMAQv4.6 for the Summer 2000 Central California Ozone Study

Permalink
https://escholarship.org/uc/item/6jq8c8q1

Authors
Jin, Ling
Brown, N.J.
Tonse, S.
et al.

Publication Date
2007-10-01
Diagnostic and Mechanistic Evaluations of MM5-CMAQv4.6 for the Summer 2000 Central California Ozone Study

Ling Jin1, N. J. Brown1, S. Tonse1, R. A. Harley2, JV Bae2, S. A. Michelso2, and J. Wilczak2

1. Atmospheric Science Department, Lawrence Berkeley National Laboratory
2. Department of Civil and Environmental Engineering, University of California
3. Regional Weather and Climate Applications Division NOAA/Environmental Technology Laboratory
Contact Jinl@lbl.gov, 510-486-5407

1. Abstract
Past evaluations of Community Multiscale Air Quality (CMAQ) modeling system have focused on the eastern United States and applications of it are usually conducted for high ozone episodes that last for a few days. In our work, we seek more comprehensive model evaluation by applying MM5-CMAQ to simulating ozone formation for an entire summer season contained in the 2000 Central California Ozone Study. Ozone air pollution problems are severe in the central California region and air districts are out of compliance with the 8-hour ozone standard. In this study, we apply CMAQ (version 4.6) to a 15-day period that contains a high ozone episode in the middle 5 days as well as relative low ozone days before and after that. Model parameters and inputs are set to reflect actual conditions of the modeling domain. We apply a variety of evaluation and diagnostic methods to assess model performance across a range of days and locations, with significant spatial and temporal variations in air quality. Effects of meteorological data assimilation are evaluated. We perform sensitivity analyses with the brute force method and Direct Decoupled method (DDM) to diagnose causes for discrepancies between observations and model predictions.

2. Air Quality in Central California

- Topography and meteorology give rise to large pollutant loadings. San Francisco Bay forms a gap in the coastal range that allows wind to blow pollutants into valley from other regions.
- Region is seriously out of attainment with previous and current ozone standards.
- Potential to get worse because it is one of the fastest growing areas with increased human activity and land use changes (urbanization).

3. CMAQ Modeling System

- 5-day ozone episode: Jul 29th – Aug 2nd, 2000
- 15-day period: Jul 24th – Aug 8th, 2000
- SARMAP domain: 4 km by 4 km grid, 27 layers (~17 km).
- CMAQ4.6 EBI solver and SAPRC99 chemical mechanism
- Adjusted parameters:
  - Ozone dry deposition velocity over the ocean is set to 0.04 cm/s
  - Minimum eddy diffusivity is set to 0.1 m/s

4. Model Simulation and Evaluation

4.1 Temporal Trend in Model Performance

- Model correctly predicts higher ozone in the 5-day episode (Figure 3), but underpredicts peaks.
- Model produces reasonable ozone spatial trend (Figure 4).
- Lower on coastal and mountain areas and higher in the Central Valley and SFB.

4.2 Spatial Trend in Model Performance

- Model produces reasonable ozone spatial trend (Figure 4).
- Lower on coastal and mountain areas and higher in the Central Valley and SFB.

4.3 Ozone Production Efficiency

- Model overpredicts ozone along the western coastal areas. Biases are generally larger near the boundaries.
- Four dimensional wind nudging produces most noticeable improvements on Aug 1st, where ozone biases are also reduced by a factor of two.

4.4 Sensitivity Analysis

- SF Bay area is sensitive to both anthropogenic and biogenic emission sources, as well as boundary Ozone, while Fresno is more sensitive to anthropogenic emissions.
- Boundary Ozone significantly affects all the nearby areas.

5. Conclusions

CMAQ performance in central California region does not differ significantly between high and low ozone periods, except for the SF Bay area. Model tends to over predict ozone along the coastal areas. Wind nudging improves chemical transport processes and results in more accurate localization of ozone plumes. Modeled and observed ozone production efficiencies are similar when transport errors are reduced by wind nudging. The Bay area is highly sensitive to uncertainties in all the emission sources as well as boundary conditions, which suggests great challenges on correct simulating ozone concentrations in this area.

Table 1 Evaluation and Diagnostic Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor Diagram</td>
<td>Describe how well patterns in modeled and observed values match each other</td>
</tr>
<tr>
<td>RMSE, Gross Error</td>
<td>Average sign in model prediction errors</td>
</tr>
<tr>
<td>Spatial Krigging</td>
<td>Magnitude of model prediction errors</td>
</tr>
<tr>
<td>Ozone Production Efficiency</td>
<td>Spatial variation in model performance</td>
</tr>
<tr>
<td>Sensitivity Analysis</td>
<td>Identify the influential parameters that affect model performances</td>
</tr>
</tbody>
</table>

Table 2 Summary statistics for three 5-day periods

<table>
<thead>
<tr>
<th></th>
<th>Normalized Bias</th>
<th>Normalized Gross Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1h Peak O₃</td>
<td>-10% -7% -4%</td>
<td>17% 20% 18%</td>
</tr>
<tr>
<td>8h Peak O₃</td>
<td>-15% -12% -11%</td>
<td>17% 17% 18%</td>
</tr>
<tr>
<td>Daytime NOₓ</td>
<td>0% -4% 3% 57% 60% 64%</td>
<td></td>
</tr>
<tr>
<td>Nighttime O₃</td>
<td>8% 10% 8% 19% 29% 22%</td>
<td></td>
</tr>
</tbody>
</table>

This work has been supported by: U.S. Department of Energy, California Energy Commission, and California Air Resource Board, UC TSB&TP Student Fellowship.