Preliminary OTC Modeling Results in Support of SIPs

MARAMA SIP Coordination Workshop
Baltimore, MD
September 28, 2010
Participants in this Effort

- NJDEP/ORC
- UMD/MDE
- NYSDEC
- MARAMA
- OTC
Overview

• Status of Ozone NAAQS

• 2010 Ozone Season Update

• Current OTC SIP Modeling Performance
  – Meteorology
  – Screening Modeling
Ozone NAAQS

• In 2008
  – Prior 8-hour average $O_3$ NAAQS was 0.08 ppm.
    • Has not yet been revoked, but also not implemented.
    • Form remains the same as the 1997 NAAQS of 0.05 ppm.
  – Primary 8-hour average $O_3$ NAAQS is 0.075 ppm.
  – 3 year average of 4$^{th}$ maximum (Design Value).
  – Secondary NAAQS equal to Primary (0.075 ppm).

• In 2010
  – Primary $O_3$ NAAQS -range of 0.060 to 0.070 ppm for 8-hr average.
  – Secondary NAAQS, a seasonal average in 7-15 ppm-hours.
  – Both to be finalized soon.
<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2007-09</th>
<th>2008-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th HIGH average</td>
<td>80.9</td>
<td>75.4</td>
<td>67.2</td>
<td>74.2</td>
<td>74.1</td>
<td>71.9</td>
</tr>
<tr>
<td>% of sites &gt;59 ppb</td>
<td>98.9%</td>
<td>96.7%</td>
<td>91.8%</td>
<td>92.9%</td>
<td>97.8%</td>
<td>95.6%</td>
</tr>
<tr>
<td>% of sites &gt;64 ppb</td>
<td>96.7%</td>
<td>90.7%</td>
<td>74.2%</td>
<td>87.9%</td>
<td>94.0%</td>
<td>89.6%</td>
</tr>
<tr>
<td>% of sites &gt;69 ppb</td>
<td>95.6%</td>
<td>81.3%</td>
<td>30.8%</td>
<td>79.1%</td>
<td>82.4%</td>
<td>71.4%</td>
</tr>
<tr>
<td>% of sites &gt;75 NAAQS</td>
<td>76.9%</td>
<td>51.1%</td>
<td>4.4%</td>
<td>45.1%</td>
<td>44.5%</td>
<td>29.7%</td>
</tr>
<tr>
<td>% of sites &gt;84 NAAQS</td>
<td>30.8%</td>
<td>9.3%</td>
<td>0.0%</td>
<td>9.9%</td>
<td>1.1%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

Notes:
- Represents only monitoring sites in existence from 2007 – 2010.
- 2010 data is preliminary up to September 6.
• Weather Research and Forecasting (WRF) model.

• Technical reports available from the OTC:
  – Sensitivity testing of WRF physics parameterizations for meteorological modeling and protocol in support of Regional SIP air quality modeling in the OTR.
  – Assessment of 2007 WRF meteorological modeling in support of regional air quality modeling in the OTR.
Design Approach & Conclusions

- Collaborative process with other RPOs, with assistance from University of Maryland College Park
- Participant States were GA, IA, MD, NC, NY, and VA.
- Setup benchmark and sensitivity simulations to develop a common configuration.
- Simulated WRF meteorological fields were found to be acceptable, based on performance metrics for surface-level temperature, wind speed and direction, water vapor, precipitation, radar wind profilers, cloud cover, and planetary boundary layer height (PBL).
WRF Sensitivity Comparison

• Goal: To determine a suitable configuration for annual simulation

• Selection:
  – Planetary Boundary Layer (PBL) Schemes:
    • ACM2, MYJ, YSU, and modified Blackadar
  – Microphysics: WSM5 and WSM6
  – Land Surface: NOAH and PX
  – Time Periods: Summer and Winter Periods

• Comparison Analysis:
  - Techniques Development Laboratory (TDL) data – wind speed (with/without calms), temperature and humidity from National Weather Service (NWS)
  - Clean Air Status and Trends Network (CASTNet) data – wind speed and temperature
  - Wind profiler data from NWS
  - Satellite cloud cover data from UMD
  - Precipitation data from NWS
### Selected Configuration

#### 2007 OTC WRF Annual Modeling

**WRF version 3.1**
- North American Mesoscale model (NAM) analyses fields as input to 36 km, and 12 km domains in a 2-way nested mode
- OBSGRID for enhance nudging with observed data
- Model runs were at five and half days block with 12 hours overlap

**Model Options**
- WSM6 microphysics
- RRTM long and shortwave radiation
- Pleim-Xiu land-surface and surface layer models
- Modified-Blackadar planetary boundary layer (PBL) scheme
- Kain-Fritsch cumulus parameterization
- Applied analysis nudging for winds above and below PBL
- Applied analysis nudging for temperature and moisture above PBL only
WRF Modeling Domains

• The figure shows the following:
  – WRF Modeling domains at 36 and 12 km,
  – the 12 km Air Quality Modeling domain is shaded,
  – and the MANE-VU domain shown in blue.
WRF Simulation Assessment TDL Data – Monthly Statistics

- **Wind Speed:**
  - WRF over-predicted (positive bias) in winter months, and negative bias in summer months. The normalized bias is higher in summer due to observed low wind speeds.

- **Temperature:**
  - WRF predictions exhibit positive bias in winter and negative bias in summer.

- **Humidity:**
  - WRF overestimated observed humidity.

- **Overall:**
  - WRF Performance is in-line with acceptable range of bias reported for meteorological modeling systems.
Aug. 2007 Wind Speed Comparison

- Comparison of WRF and TDL daily Wind Speed and bias for August 2007 over 12 km entire domain and MANEVU Region.
Humidity

- Comparison of WRF and TDL daily humidity and bias for August 2007 over the 12 km entire domain and MANEVU Region
CASTNet Data

• Wind Speed: WRF over predicted wind speed compared to measured by CASTNet.

• Temperature: WRF predicted higher temperatures than those measured by CASTNet.

• Note: Unlike NWS-TDL, CASTNet data were not used in the FDDA (four dimensional data assimilation) or nudging process.

• Also, CASTNet measurements are at rural stations.
Wind Profiler Data

- Five sites:
  - Beltsville, MD (BLTMD),
  - Rutgers, NJ (RUTNJ),
  - Stowe, MA (STWMA),
  - Charlotte, NC (CHANC),
  - Raleigh, NC (RALNC)

- Qualitative comparison of the measured vertical profile of wind speed with WRF predictions.

MDE Beltsville Site
Beltsville and WRF Comparison

Beltsville RWP Data

WRF Data
Rutgers and WRF Comparison

Rutgers RWP Data

WRF Data

RUTNJ Profiler Date: 20070803

RUTNJ-2007215 - Wind Speed
Stowe and WRF Comparison

Stowe RWP Data

WRF Data
BLUE: Wind Profiler
RED: WRF
Stowe RWP & WRF Vertical Profiles

BLUE: Wind Profiler
RED: WRF
Observed and WRF Cloud Fraction Comparison

• Using GOES-12 satellite observations derived cloud fraction from UMD’s Surface Radiation Budget (SRB).

• Cloud fraction estimates are made on an hourly basis at 0.5° resolution for an area bounded by 70-125 °W longitude and 25 – 50 °N latitude.

• MCIP processed cloud fraction using WRF output.
Cloud Fraction Comparison

- Comparison of cloud fraction based on observed (SRB) and WRF predicted (MCIP) for August 2\textsuperscript{nd}, 2007 at 1700

General agreement in pattern over the domain
Comparison of cloud fraction based on observed (SRB) and WRF predicted (MCIP) for August 3rd, 2007 at 1700

General agreement in pattern over the domain
Planetary Boundary Layer (PBL) Height Comparison

- Lidar-based observed PBL height at CCNY

- WRF-based PBL height at CCNY grid and maximum value of 9 by 9 grid surrounding CCNY grid

- The maximum of the 9 by 9 grid is found to be closer to Lidar-based observed PBL height
Lidar and WRF PNL Comparison

- Comparison of PBL heights from Lidar and WRF at the CCNY grid during 2007.
- Data are from 1000 to 1300 hours (EST) with 1 to 1 line and best fit
Precipitation

- Obtained NCEP gridded stage 4 precipitation data from measurements.

- Compared against WRF estimate on a monthly accumulation basis.

- Overall WRF performed fairly well over non-summer months, in terms of amount and pattern.

- Over the months of April through September, WRF over-predicted precipitation amounts, except for August for which the model is found to under-predict the precipitation because of passage of Hurricane Dean in late August.
Precipitation Comparison

- Based on measured (Stage-4) and predicted (WRF) for January 2007
Precipitation Comparison

- Based on measured (Stage-4) and predicted (WRF) for August 2007
2007 WRF Summary & Conclusions

• WRF simulations showed good comparison with NWS-TDL surface-based measurements.

• WRF simulations showed similarly good comparison with CASTNet data.

• WRF captured the cloud coverage pattern when compared with satellite-based data.

• WRF simulated the nocturnal low level jet (NLLJ) and compares well with wind profiler data.

• WRF based estimates of Planetary Boundary Layer (PBL) heights compared well with Lidar-based PBL heights at New York City location.

• WRF simulated precipitation patterns are found to match well with measurements.
Time Series Comparison

- Modeled vs. Monitored 8-hour ozone, OTR States.

- Timing of the episodes are generally captured, but the magnitude tends to be over estimated.

![Time Series Comparison Diagram](image-url)
## Daily Maximum 8-hour Ozone

<table>
<thead>
<tr>
<th>Region</th>
<th>Data Pairs</th>
<th>Mean Observed</th>
<th>Mean Model</th>
<th>Mean Bias (ppb)</th>
<th>Mean Error (ppb)</th>
<th>Normalized Mean Bias (Percent)</th>
<th>Normalized Mean Error (Percent)</th>
<th>Root Mean Square Error (ppb)</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain-wide</td>
<td>115,712</td>
<td>49.7</td>
<td>51.9</td>
<td>2.2</td>
<td>9.5</td>
<td>4.4</td>
<td>19.2</td>
<td>12.4</td>
<td>0.7</td>
</tr>
<tr>
<td>OTC States</td>
<td>39,320</td>
<td>47.6</td>
<td>52.7</td>
<td>5.0</td>
<td>10.3</td>
<td>10.6</td>
<td>21.5</td>
<td>13.4</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Model performance is within the range of previous studies
Diurnal Box plot of all OTR NO$_x$ AQS Monitors
Mean Bias of 6am-9am Average NOx Concentrations
Modeled minus Observed

units = ppbV
coverage limit = 75%
Caveats

- These screening runs use proxy emissions through interpolated inventories for many sectors and regions.

- Simplified “MOVES-like” adjustment to MOBILE6 emissions have not been fully tested.

- Use of “time invariant clean” boundary conditions.

- Screening simulations are based on simplified across-the-board emission reduction approaches.
• 2007 Meteorology (WRF) simulation appears to have captured the episode and non-episode periods over the modeling domain as evidenced from observed and predicted ozone pattern

• Ozone levels are somewhat overestimated during episodes over the OTC states – One potential cause could be impact from increased mobile source NO$_x$ from the adoption of MOVES-like mobile source emissions
Contact: Michael Woodman with any questions

email address: mwoodman@mde.state.md.us

• Participants in this effort included the following:
  – NJDEP/ORC
  – UMD/MDE
  – NYSDEC
  – MARAMA
  – OTC