Characteristics of New CMAQ Deposition Series of 2002 to 2011 for Critical Loads

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Characteristics of New CMAQ Deposition Series of 2002 to 2011 for Critical Loads

Improvements to WRF, CMAQ and Emissions

Wet Deposition Trends (Straight CMAQ Output vs Adjusted CMAQ)

Wet Deposition Errors

Dry Deposition Trends Compared to Wet Deposition

Dry Deposition Trends Compared to Air Concentrations

Air Concentration Trends

Summary

Comparisons are annual by year
Improvements to WRF, CMAQ, Emissions

- 12km CONUS
- Consistent CMAQ version 5.0.2
- Layer 1 at 19m instead of 38m (affects aerodynamic resistance)
- **Meteorology with improved convective parameterization**
- Meteorology recognizing wetlands in the Southeast
- Corrected land-sea mask from NLCD (coastal areas)
- **Bi-directional ammonia flux (includes use of EPIC fertilizer application)**
- Year specific agricultural NH$_3$ emissions (EPIC)
- Dynamic CAFO NH$_3$ emissions profile (thermodynamics-based)
- Mesophyll resistance change (affects NO$_2$ deposition)
- Year specific lightning NO$_x$ emissions of NO simulated (anchored to strike data)
- Land use updated to NLCD (2001 and 2006) (older USGS was 1992)
- Consistent basis for mobile source emissions (MOVES)
Wet Deposition Characterization

5 US Sub-regions of NADP Sites
Regional Averages of Annual Total Precipitation (cm)
Regional Averages of Annual Total Wet Deposition of NO₃ (kg/ha)

Note: CV RMSE = RMSE of CMAQ-obs errors based on a leave-one-out cross validation.
- Sites within 30 miles (48 km) of one another are dropped out together in the CV.
Regional Averages of Annual Total Wet Deposition of NH$_4$ (kg/ha)

- **Northeast**
- **Great Lakes**
- **Southeast**
- **West**
- **Pacific**

Note: CV RMSE = RMSE of CMAQ-obs errors based on a leave-one-out cross validation.
- Sites within 30 miles (48 km) of one another are dropped out together in the CV.
Wet Deposition: NADP, “Raw”, Adjusted CMAQ

SO₄

Regional Averages of Annual Total Wet Deposition of SO₄ (kg/ha)

Note: CV RMSE = RMSE of CMAQ-obs errors based on a leave-one-out cross validation.

• Sites within 30 miles (48 km) of one another are dropped out together in the CV.
Wet Deposition Smooth Bias Adjustment NO$_3$

Precip-Adj Model/Obs NO$_3$

2002

2003

2004

2005

2006

2007

2008

2009

2010

2011

[Colorbar with levels from 0.1 to 10]
Wet Deposition Smooth Bias Adjustment NH$_4$

Precip-Adj Model/Obs NH$_4$

2002

2003

2004

2005

2006

2007

2008

2009

2010

2011
Wet Deposition Smooth Bias Adjustment $SO_4$
## Wet Deposition Error

<table>
<thead>
<tr>
<th>Wet Deposition Cross Validation RMS Error</th>
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<tbody>
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<table>
<thead>
<tr>
<th></th>
<th>North East</th>
<th>Great Lakes</th>
<th>South East</th>
<th>West</th>
<th>Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet NO\textsubscript{3} (kg-N/ha)</td>
<td>0.68→0.23</td>
<td>0.45→0.23</td>
<td>0.45→0.33</td>
<td>0.45 – 0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>% Error</td>
<td>20%→14%</td>
<td>20%→14%</td>
<td>20%→14%</td>
<td>50%</td>
<td>75%</td>
</tr>
<tr>
<td>Wet NH\textsubscript{4} (kg-N/ha)</td>
<td>0.4</td>
<td>0.5 – 0.6</td>
<td>0.4 – 0.8</td>
<td>0.4</td>
<td>0.4 – 0.8</td>
</tr>
<tr>
<td>% Error</td>
<td>17%</td>
<td>14%</td>
<td>20% – 40%</td>
<td>33%</td>
<td>100%</td>
</tr>
<tr>
<td>Wet SO\textsubscript{4} (kg-S/ha)</td>
<td>1.3 → 0.67</td>
<td>0.67 – 1.0</td>
<td>1.0 → 0.67</td>
<td>0.33 – 0.5</td>
<td>0.3 – 0.5</td>
</tr>
<tr>
<td>% Error</td>
<td>20%</td>
<td>17%</td>
<td>20% → 25%</td>
<td>50%</td>
<td>60%</td>
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</tbody>
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Note: a→b denotes a trend; a—b denotes a range

Consistent error across eastern US
Larger error in west
Largest error in Pacific
Error at Individual NADP Sites
2010 Example

Wet Deposition
Final Bias-Adjusted Model/Observation

NO₃

NH₄

SO₄
Dry vs Wet Deposition Trends: Ox-N
(at NADP Sites)
Dry vs Wet Deposition Trends: Red-N (at NADP Sites)
Dry vs Wet Deposition Trends: Sulfur
(at NADP Sites)
5 US Sub-regions of CASTNET Sites
Dry vs Air Concentration Trends
Ox-N & TNO₃⁻N Dry to TNO₃ Air
(at CASTNET Sites)
Dry vs Air Concentration Trends
T-S & SO₂-S Dry to SO₂ Air
(at CASTNET Sites)
5 US Sub-regions of AMON Sites
Air Concentration Trends
NH$_3$ (AMON)

Northeast

Great Lakes

Southeast

West

Pacific

<table>
<thead>
<tr>
<th>Year</th>
<th>AMON Observation</th>
<th>CMAQ output</th>
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<tbody>
<tr>
<td>2002</td>
<td></td>
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<tr>
<td>2003</td>
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<td>2010</td>
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Air Concentration: 2011 Time Series
NH₃ (AMON)

CMAQv502_2011_Base NH₃ for AMON Site: OH02 in OH

CMAQv502_2011_Base NH₃ for AMON Site: CO13 in CO
Model performing fairly well at large scale, especially in eastern half of CONUS
  - Capturing the main trends well, except for 2002
Balance between wet and dry deposition improved, with better "raw" wet deposition (more confidence)
Still not getting the west very well.
  - Continues to need attention
Check western boundary condition inputs
Ammonia better than expected (pleased)
  - But still looking to improve performance (more sites help)
Future Directions

• Upcoming (CMAQ 5.1 released next fall)
  – Organic N estimates (oxidized portion)
  – Soil NO (new algorithm)
  – Nonvolatile nitrate enhancement
  – Updated BEIS biogenic emissions
  – Bi-directional formulation allowed for all species, with Mosaic (land-cover specific deposition) output option

• Farther in Future
  – Cloud impaction
  – Connection to throughfall and mosaic
  – Use hemispheric CMAQ for BC’s
Thanks

Total N

2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

units = kg·N/ha

max = 74.9
Extra Slides
Air Concentration Trends
$TNO_3$ (CASTNET)
Air Concentration Trends
$SO_2$ (CASTNET)
Wet Deposition
Final Bias-Adjusted Model/Observation
2008

NO3

NH4

SO4
Wet Deposition
Final Bias-Adjusted Model/Observation

2006
Air Concentration Trends

SO₄

Northeast

Great Lakes

Southeast

West

Pacific

CASTNet Observation

CMAQ output