Future Directions and the Importance of Scale in Estimating Atmospheric Nitrogen Loading to the Next Generation Chesapeake Bay Model

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Motivation

• Atmospheric nitrogen deposition contributes to surface water eutrophication and biodiversity loss

• Air quality models typically have a base resolution on the order of 1-36 km
  • Simulations at finer resolution are problematic due to bulk atmospheric physics parameterizations

• The next generation of distributed watershed models have a resolution in the tens of meters
  • Can we leverage sub-grid scale data to better match atmospheric loading to watershed models?
CMAQ v5.3

Deposition Updates

- Option to output land use specific deposition
  - Deposition fluxes estimated for each land use type
  - Land use based aggregation to the grid cell (NLCD or MODIS)
- More comprehensive parameterization of organic nitrogen chemistry and deposition
- Correction to coarse aerosol dry deposition
Wet Deposition Updates

- Annual 2016 model simulation
- CMAQ v5.3.1 precipitation was biased low compared to NADP/NTN observations in the summer months when deposition is usually the highest
- Model improvements due to updates to coarse aerosol treatment

<table>
<thead>
<tr>
<th>Species</th>
<th>CMAQ v5.2.1 NMB</th>
<th>CMAQ v5.3.1 NMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃ Wet Deposition</td>
<td>-14.8%</td>
<td>-9.1%</td>
</tr>
<tr>
<td>NHₓ Wet Deposition</td>
<td>-50.0%</td>
<td>-43.7%</td>
</tr>
<tr>
<td>SO₄ Wet Deposition</td>
<td>-28.5%</td>
<td>-22.4%</td>
</tr>
<tr>
<td>Precipitation</td>
<td>5.0%</td>
<td>-9.6%</td>
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</tbody>
</table>
Planned simulations

• Dry deposition by land use planned for 2002-2017
  • CMAQ v5.3.2 simulations
  • MODIS 250 m base resolution
  • 12 km grid resolution
• Air Quality Modelling Evaluation International Initiative (AQMEII) Phase 4
  • Dry deposition intercomparison project (primarily for ozone) including simulations for 2010 and 2016 as well as box model comparisons with field data
  • CMAQ v5.3 deposition will be well evaluated
• Potential 1990 simulation being scoped
How can we leverage sub-grid cell data?
Disaggregating flux estimates

• Grid cell flux

\[ Flux_{\text{Grid}} = \sum_{LU} Frac_{LU,\text{Grid}} Flux_{LU,\text{Grid}} \]

• Land use fraction

\[ Frac_{LU,\text{grid}} = \frac{\sum_i LU_{i,30\text{m}}}{\text{Area}_{\text{Grid}}} \]

• Disaggregated Flux

\[ Flux_{\text{Gri}} = \sum_{LU} \left( \frac{\sum_i Flux_{LU,\text{Grid}} LU_{i,30\text{m}}}{\text{Area}_{\text{Grid}}} \right) \]
Disaggregating Flux Estimates

- Developed an R script to disaggregate land use specific flux data
- Confirmed that the mass of the 30m disaggregated flux is equivalent to the 12 km grid cell flux
- 30 m fluxes estimated for CMAQ 5.3 July 2014 simulations at a 12 and 4 km resolution over the Chesapeake Bay Watershed
  - ~10 hours of processing time on one core for an annual simulation
  - Viable for production runs
  - Not exactly an exact comparison
    - 4 km used CMAQ v5.3 beta and 12km used CMAQ v5.3.1
Disaggregating flux estimates 12km
Disaggregating flux estimates 4km
12 km versus 4 km fluxes
12 km versus 4 km fluxes
Summary Part 1

- The land use specific fluxes can differ from grid cell fluxes by a factor of two
  - Forested land use types have the largest deposition fluxes
  - Highest deposition rates are where forested landscapes are collocated with high emission sources
- Deposition hot spots are focused around NH$_3$ emission sources
  - Higher levels of deposition are not seen in the I-95 corridor (a large NOx source)
  - NO$_x$ deposits relatively slowly
  - HNO$_3$ deposits quickly but is a secondary pollutant (formed downwind from sources)
- 12 km and 4 km simulations resulted in remarkably similar deposition totals over the domain
  - 4 km domain had more variability in deposition
Summary Part 2

• Improvements in modeled wet deposition when compared to NADP observations
  • Despite larger precipitation biases in the more recent WRF simulations used for the comparison
• Land use specific fluxes can be disaggregated and still maintain the model mass balance
  • Code has been developed to do this disaggregation
• Increased model spatial resolution primarily impacts reduced nitrogen deposition near ammonia emission sources and wet deposition
• Disaggregated 12 km model data captures much of the spatial variability of the 4 km simulations
COVID 19 and Air Quality

• NO$_2$ OMI and TROPOMI columns 10-12% lower in the US
  • Approximately 28% lower over major Northeastern Cities
• This change in emissions is likely to have an impact on atmospheric N deposition
• How do we translate the observational data into model emissions?
• Similar reductions not seen in PM$_{2.5}$

Bauwens et al. 2020 GRL DOI:10.1029/2020GL087978
COVID 19 and Emissions Modeling

- Where will emissions be reduced
  - Decrease in mobility has been documented
  - Other sectors?
- Likely to impact NO\textsubscript{2} emissions and HNO\textsubscript{3} deposition primarily
- Data is still coming in and being collected
  - Some will be delayed

2020 National Emissions Inventory

• National Emissions Inventories (NEI) are compiled every three years currently
  • 2020 is an NEI year
• Will not be a good base year due to COVID 19 and emission anomalies
• Emission activity data will be arriving late
  • Due to workplace disruptions from COVID 19
  • Typically about 2 years to compile data and estimate emissions for a public release
• Will be collaborating with a COVID modeling team