Linking CMAQ to Watershed/Estuarine Models

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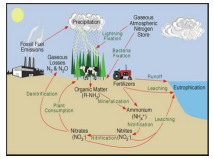
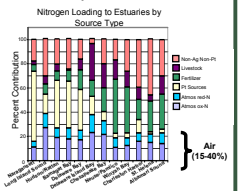
Linking Air Quality and Ecosystem Health

Environmental Issue

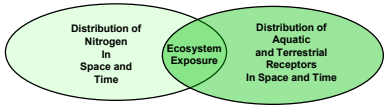
Estimation of ecosystem exposure to air pollutants

Pollutant loadings to water bodies consist of point sources of effluent (e.g. sewage treatment plants) and non-point sources that are diffused across the landscape (e.g. agriculture). Atmospheric wet and dry deposition can be important non-point source contributors to total pollutant loadings to water bodies, leading to harmful effects on ecosystems.





- Atmospheric deposition of reactive nitrogen can be an important source of unintended fertilization, leading to eutrophication in coastal ecosystems.
- Acidification, caused primarily by atmospheric deposition of sulfur and reactive nitrogen, drives a number of adverse effects in aquatic and terrestrial ecosystems.



For exposure to occur, the stressor and the receptor must come together at the same time and place. Emerging exposure issues focus on land cover changes driven by population, policy (e.g., biofuels) and climate change.

AMAD research is improving exposure estimates through….

- Improved characterization of pollutant distribution on eco-relevant spatial and temporal scales.
- Improved characterization of estuarine and terrestrial vegetation, i.e. receptors in space and time.
- Implementation of effective approaches to estimate ecological exposure to atmospheric stressors that reflect receptor response to drivers of landscape change.

Research Objectives

- Develop modeling approaches to address multiple ecological stressors and receptors across multiple scales.
- Develop approaches that determine whether regulatory programs are protective of sensitive biological systems.
- Link air quality simulations to the broad assessment of regulatory program effectiveness (i.e. critical loads).
- Provide more relevant estimates of atmospheric loading to regional or local communities and government agencies.

Modeling Approach

Improved estimates of nitrogen deposition

Spatially and temporally explicit estimates of nitrogen deposition are needed for ecological exposure studies. Monitoring data alone cannot provide the needed information because

- Monitors are relatively sparse and may not represent surrounding ecosystems of interest. Spatial interpolation over these large distances may mis-represent important atmospheric chemistry processes.
- Monitored data do not support prospective analyses.
- Not all critical species/forms needed to construct complete chemical budgets are measured.

Previous ecological assessments used CMAQ results which were based on a fixed, archived set of atmospheric transport cases to drive CMAQ air quality modeling simulations at the 36 km grid scale. The CMAQ transport case outputs were then combined via a weighted average to create clima-tological seasonal and annual average deposition estimates for nitrogen and sulfur across the United States. More recent studies utilize monthly, seasonal, and annual CMAQ estimates for a specific year modeled at a 12 km grid scale, which is a more relevant scale for ecological assessments.

The Watershed Deposition Tool (WDT) allocates gridded CMAQ deposition estimates to polygons providing an easy-to-use means of mapping CMAQ outputs to the watersheds used in TMDL (Total Maximum Daily Load) and related nonpoint-source water quality analyses.

Improved spatial distribution of terrestrial receptors

Dry deposition velocity varies with underlying vegetation type due to differences in leaf area index, canopy height, and plant characteristics such as minimum stomatal resistance. The current CMAQ release relies on the 1992 National Land Cover Dataset to identify the location of land cover types.

USGS 2001 NLCD and 2001 to 2006 NOAA coastal lands (C-CAP) databases provide higher resolution information. These data can now be used as input to meteorological and CMAQ studies, which will provide better estimates of deposition.

Improved estimates of ecosystem exposure

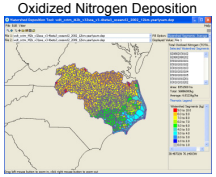
In the past, deposition estimates from CMAQ were based on average grid cell characteristics of the underlying land cover. Ecological applications need information regarding the amount of deposition to the individual land cover categories. An additional option was added to CMAQ to allow calculation and output of land cover specific deposition velocities.

Results and Discussion

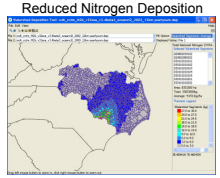
The Watershed Deposition Tool (WDT)

The Models-3 I/O API format of CMAQ output files is not easily imported into standard spatial analysis tools. The WDT remaps data from the CMAQ grids to the spatial delineations of watersheds so that the data can be used for analyses that are needed for TMDL and other non-point source watershed analyses, such as examining the relative contributions of wet and dry deposition, and the relative contributions of oxidized and reduced nitrogen species to total nitrogen deposition.

Oxidized Nitrogen Deposition



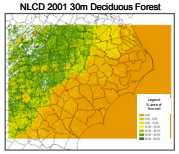
Reduced Nitrogen Deposition



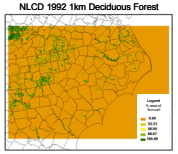
More detailed vegetation-type location

Raster image file processing programs now compute modeling domain gridded land use information based on input image data of 2001 USGS NLCD and 2001 to 2006 NOAA coastal lands (C-CAP). The figures below illustrate our improved ability to identify the location and extent of deciduous forest cover areas in North Carolina over current information. Colors indicate the percentage of each 1km rectangular grid containing deciduous trees.

NLCD 2001 30m Deciduous Forest

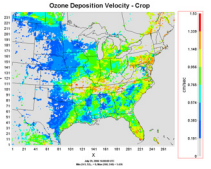


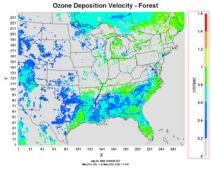
NLCD 1992 1km Deciduous Forest



Land cover-specific deposition estimates

Some dry deposition velocity components are calculated within the meteorological model and only the grid-average value is carried forward to CMAQ. The mosaic approach disaggregates these grid-average values within CMAQ to allow output of deposition estimates for each land cover type within a grid in a manner consistent with meteorological model flux calculations. These land cover-specific deposition estimates are an important input to ecological exposure assessments. The figures below illustrate deposition velocity dependence on vegetation type.





Conclusions

- More complete air quality/ecosystem temporal and spatial linkage is needed to improve exposure estimates.
- AMAD is advancing the modeling science as well as building the tools and databases needed to facilitate this linkage.
- Further work is needed to implement, test and evaluate the models, databases, and tools
- On-going interaction with clients and cross-laboratory collaboration ensures research outputs will support management decisions leading to more positive ecosystem health and service outcomes.

Future Directions

- Develop methods to improve mass consistency across linked air, watershed and estuarine models through consistent landscape and precipitation inputs (collaboration with ERD).
- Develop a fertilizer application data base to support nitrogen bi-directional flux process modeling and landscape change scenarios.
- Update terrestrial vegetation species distribution and merge with NLCD 2001 and C-CAP imagery to improve deposition and biogenic emission modeling.
- Expand linkage approach to other chemicals of interest, e.g., mercury.
- Bring WDT into the Visualization Environment for Rich Data Interpretation (VERDI) to enhance its capabilities.

Impact

- CMAQ data are being used by local, state and regional modelers in conjunction with the WDT to support numerous water quality and ecological assessments including those being done to support regulations associated with TMDLs and critical loads. Applications include the following:
  - Chesapeake Bay
  - Susquehanna River Basin
  - Narragansett Bay
  - Shenandoah National Park
- ORD's Ecological Services Research Program (ESRP) is planning to use CMAQ data as part of its National Nitrogen and Future Midwestern Landscapes (FML) themes.

Contributors/Collaborators

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