ABSTRACT
Spatial interpolation of observed wet deposition values from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) is used to estimate past and current loads of acidic (S-N) and nutrient (N) deposition on sensitive ecosystems for critical loads studies. Due to siting criteria, such approaches can miss important emission sources and geographic features that impact deposition, e.g., orographic effects on precipitation amounts. The Community Multiscale Air Quality (CMAQ) model provides spatial fields of wet and dry deposition that explicitly account for emission sources across the United States as well as geographic features of the domain. However, errors in modeled precipitation (from MM5 or WRF) and in emission inputs can lead to significant bias and error in the wet deposition predictions compared to observed values. We present an approach to post-process the CMAQ model output to adjust for errors in precipitation using observation-based gridded precipitation data. Accounting for errors in modeled precipitation reveals bias in wet deposition predictions that were previously hidden due to compensating errors. We further correct the model output by applying a bias adjustment based on observed wet deposition values at the NADP/NTN sites. The final adjusted spatial fields of annual total wet deposition values (specifically $\text{SO}_4^{2-}, \text{NO}_3^-, \text{NH}_4^+$) have less bias and are more highly correlated with observed wet deposition values compared to the base model output.

SEASONAL PATTERNS IN WET DEPOSITION BIAS

- Underestimation in modeled precipitation in the NE tends to increase across the five year period and is greatest in Autumn months.
- Modeled – Observed seasonal total $\text{NH}_4^+$ wet deposition in the NE shows mostly overestimation with no strong seasonal trend.
- Precipitation-adjustment of $\text{NH}_4^+$ shows overestimation tends to increase over time, suggesting the emissions inventory is not capturing an observed decrease in $\text{NH}_3$ emissions as dairy and poultry farms close across the NE.
- In a second example (not shown here) precipitation-adjusted $\text{NH}_4^+$ wet deposition in the Great Lakes region reveals a large underestimation in Spring and Summer months. This is likely due to errors in emissions associated with fertilizer applications and the bi-directional exchange of $\text{NH}_4^+$ flux from soil and vegetation.

IMPROVED WET DEPOSITION FIELDS

The PRISM precipitation fields and the NTN-based multiplicative bias factors are used to adjust the CMAQ annual total wet deposition fields for 2002-2006. The final fields retain the emission sources and geographic features included in the CMAQ output and are consistent with the precipitation events characterized by the PRISM dataset, including orographic effects across the Appalachian and Rocky Mountains. These features cannot be captured by simple spatial interpolation of the observed wet deposition data due to the sparseness of the National Trends Network. The post-processing of the modeled wet deposition fields reduces the model error and increases the correlation between model predicted values and observed wet deposition for all three species.

Precipitation-adjusted fields are compared to modeled and observed wet deposition values at the NADP/NTN sites. Plots show median bias (dot) and interquartile range of model – observed bias by season.

PRISM PRECISION ADJUSTMENT
NADP/NTN observed precipitation does not provide the spatial coverage needed to adjust the entire CMAQ wet deposition field. The PRISM climate group at Oregon State University provides monthly and annual precipitation totals (4km x 4km grid) using point measurements and the Parameter-elevation Regressions on Independent Slopes Model (PRISM). The PRISM model was designed to handle orographic precipitation in complex terrain. In 2002, the MM5 modeled precipitation tends to be too high across most of the domain compared to the PRISM data.

REFERENCES

IMPLICATIONS AND FUTURE WORK
In the past, the ecological community has been reluctant to use CMAQ wet deposition predictions to assess critical loads because of large model biases. The post-processing approach described here has been well received as a method to address model performance concerns and to take advantage of the PRISM precipitation data, which are already widely used for critical loads analyses. Ongoing model development should address the existing model biases and errors in precipitation and wet deposition.

Future work includes using a seasonal precipitation adjustment, evaluating error in dry deposition predictions and reevaluating the $\text{NO}_3^-$ and $\text{NH}_4^+$ bias adjustments using new model simulations that include emissions of nitrogen oxides produced by lighting and bi-directional flux of ammmonia.

Spatial interpolation smooths the gradients in the wet deposition field and misses emissions sources due to the siting of the network monitors. For example in Lancaster County, PA the model shows elevated levels of $\text{NH}_4^+$ due to high levels of $\text{NH}_3$ emissions from poultry and chicken farms (red box). Since there was no monitor near these sites in 2002, this hot spot is missing in the interpolated field. A monitor was added in this region in 2003, confirming the model predictions for this county.