United States
Environmental Protection
Agency

SCIENCE

United States Environmental Protection Agency

Adapting CMAQ Deposition Fields for Critical Loads Analyses

Robin L. Dennis

Kristen M. Foley

National Exposure Research Laboratory

Atmospheric Modeling and Analysis Division, US EPA

NADP 2009 Annual Meeting and Scientific Symposium

Saratoga Springs, NY

October 6-8, 2009

Adapting CMAQ Deposition Fields for Critical Loads Analyses

Need total deposition; data are sparse & incomplete
Can get total deposition from CMAQ model
But wet deposition considered to have too much error

Organization of Talk:

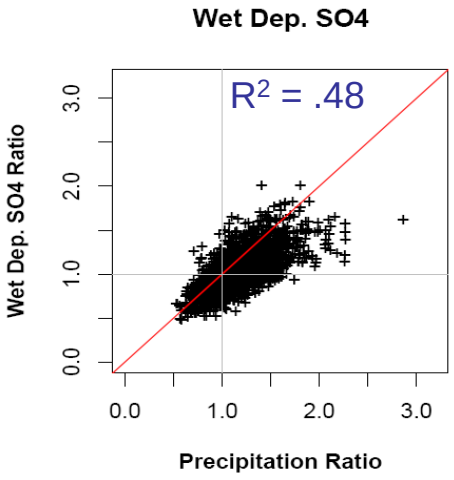
Outline approach to reduce CMAQ wet deposition error

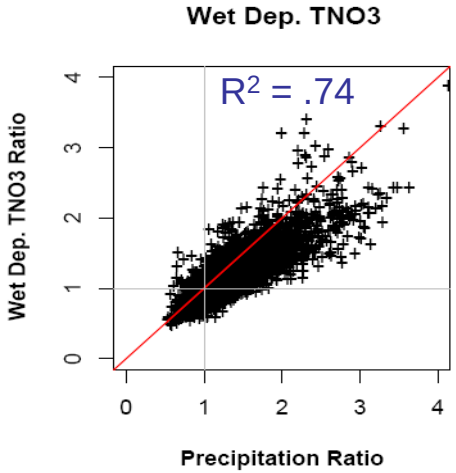
Walk through the analysis using 12km eastern domain

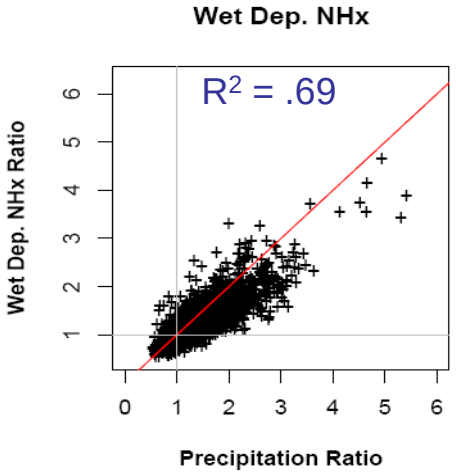
Characterized the final wet deposition results
What is our residual error?
What is its character?

Estimate error introduced into the dry deposition estimates

Thoughts on wet deposition biases

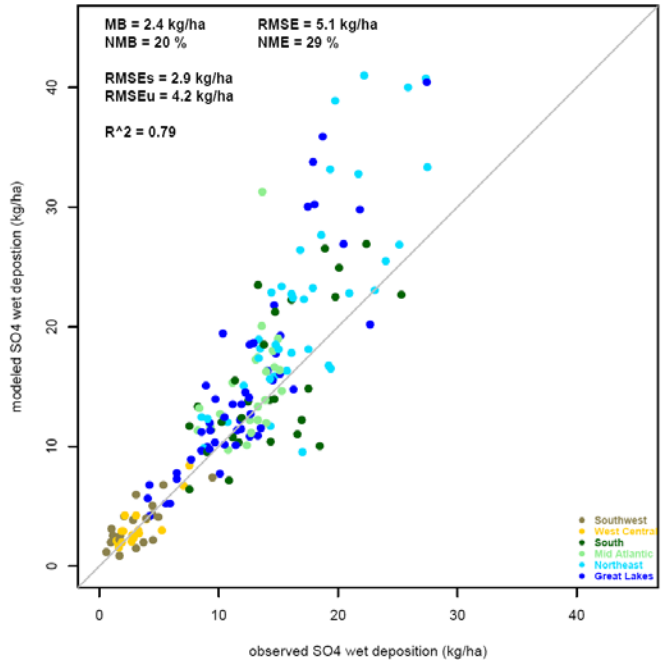




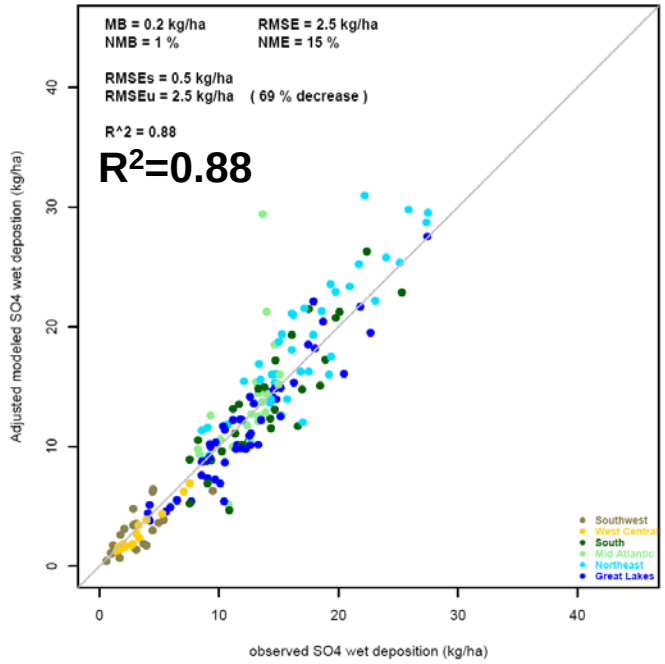


Wet Deposition And Precipitation In CMAQ Are Highly Correlated

Observed vs. CMAQ Wet Deposition SO_4



Observed vs. Precipitation Adjusted CMAQ Wet Deposition SO_4



Correcting CMAQ With Observed (NADP) Precipitation Looks Promising: 69% decrease In RMSEu

Procedure to Post-Process CMAQ Wet Deposition Estimates

1) Correct CMAQ Wet Deposition by Observed Precipitation

P_{obs}/P_{cmaq} * Wet Dep_{cmaq}

P_{obs} = gridded PRISM (Parameter-elevation Regressions on Independent Slopes Model)

(*Cannot use NADP – Inadequate spatial coverage*)

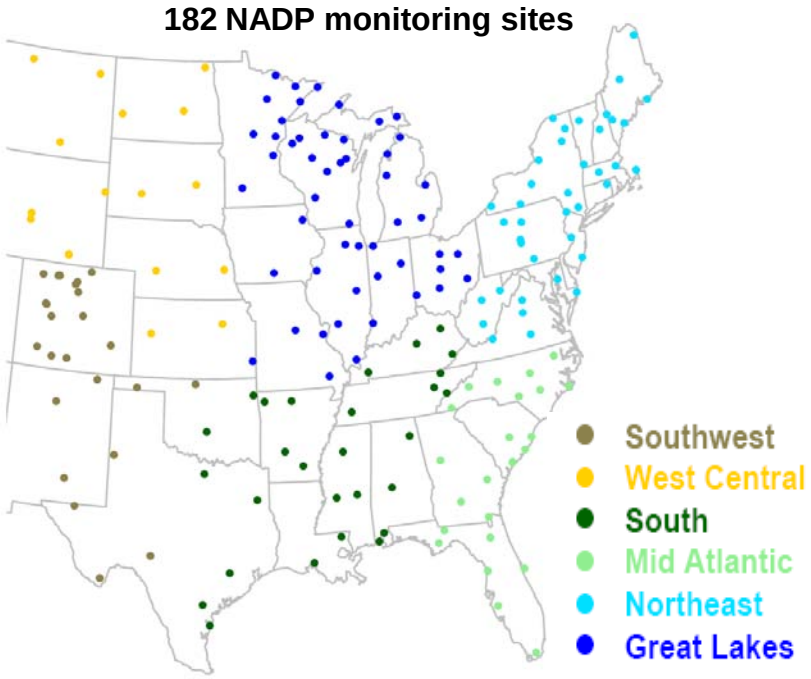
2) Perform Region-specific Bias Adjustment (If Necessary)

SO_4	NO_3	NH_4
Not Necessary	Yes	Yes

Separate Adjustment for East & West

No Adjustment for CA, OR, WA

(*Issue of orographic representativeness*)



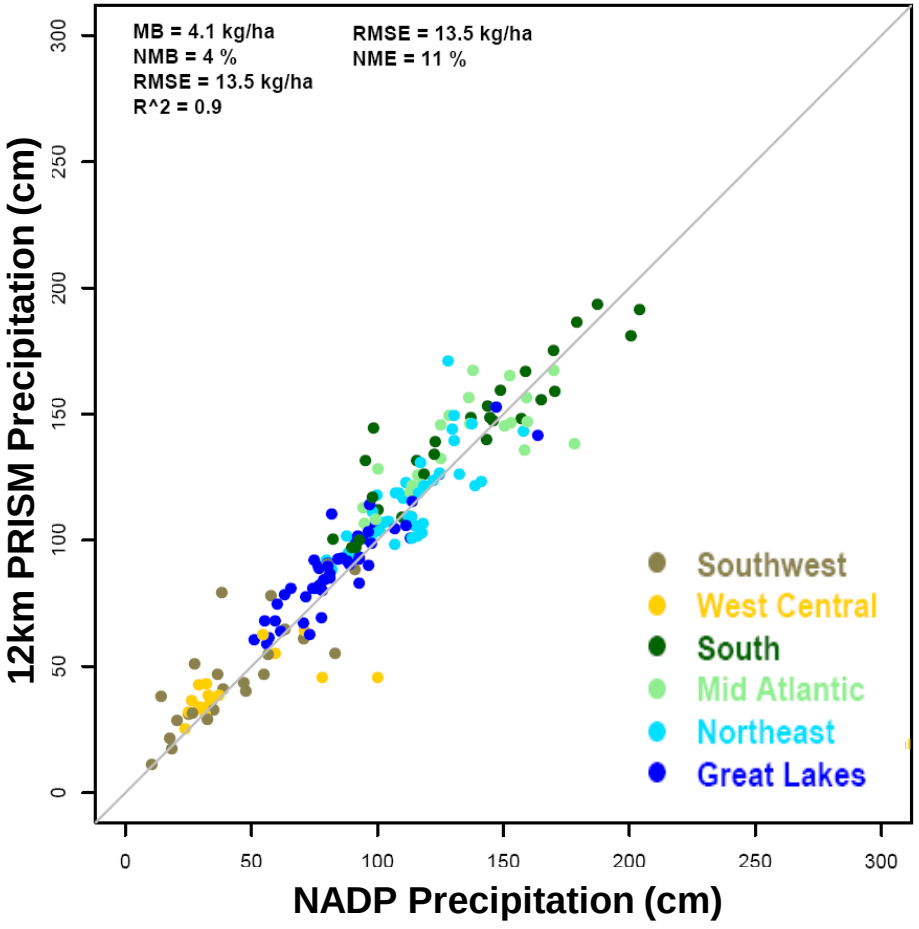
Color coding used for scatter plots

3) Add CMAQ Dry Deposition to Get Total

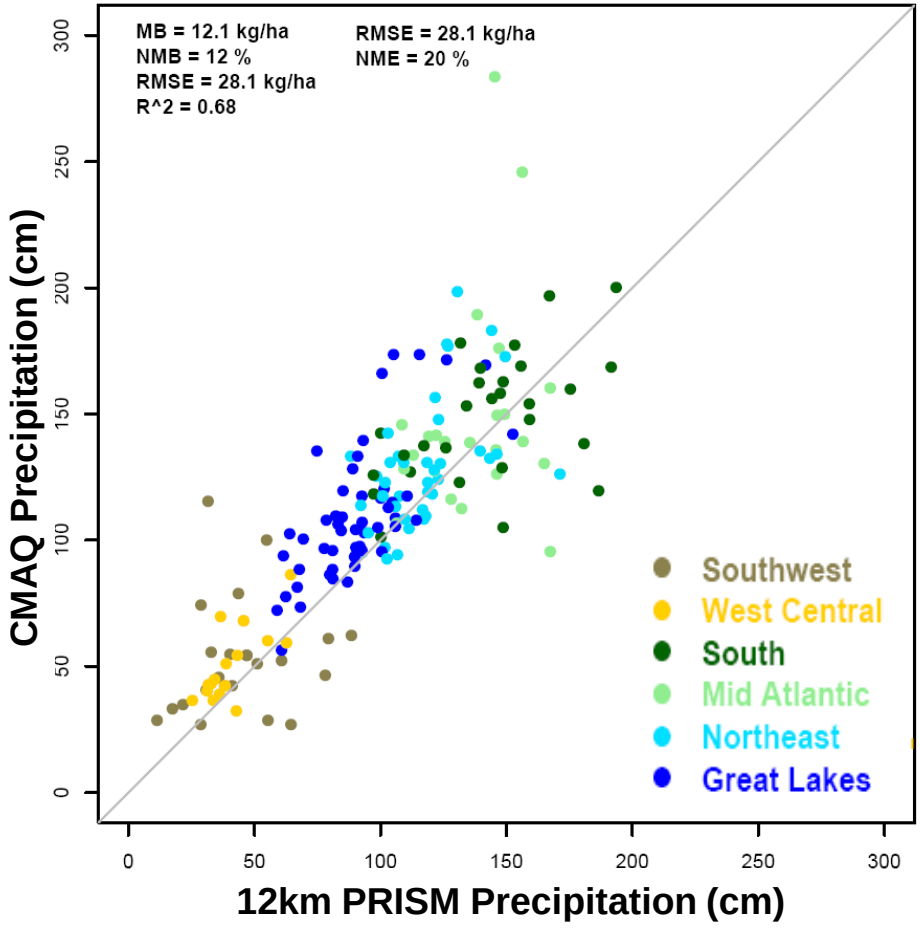
PRISM precipitation data is not in perfect agreement with NADP data, but pretty good

PRISM precipitation data has same degree of disagreement with CMAQ data as does NADP data

NADP Observed vs. 12km PRISM Precipitation



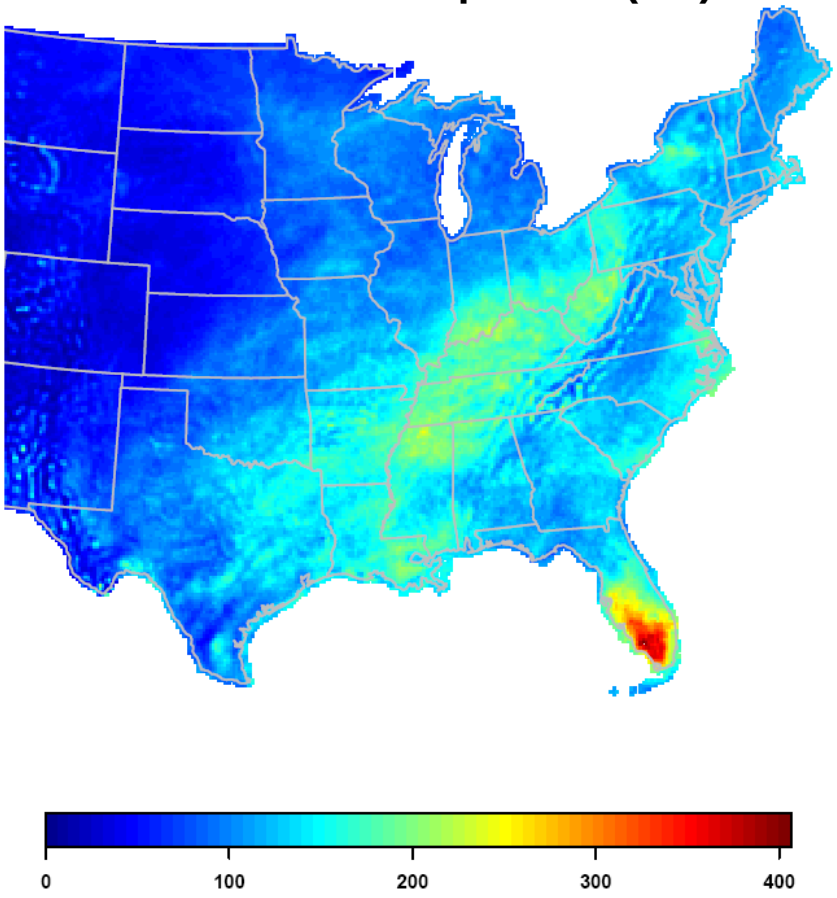
12km PRISM vs. 12km CMAQ Precipitation



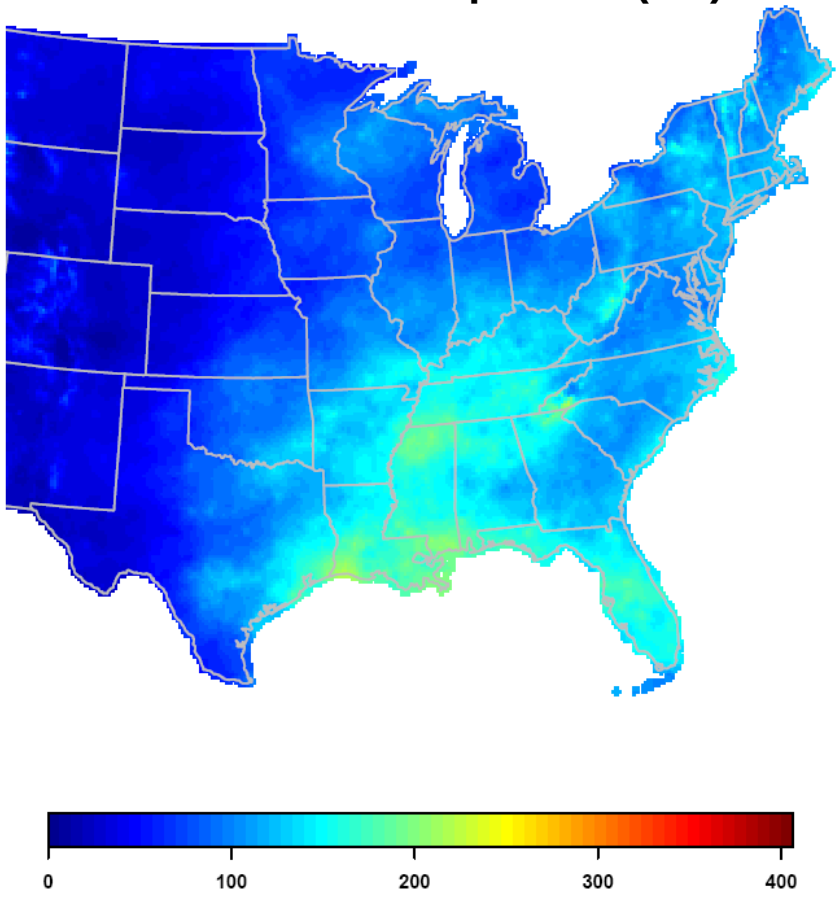
There are similarities and differences In the precipitation fields

United States Environmental Protection Agency

2002 12km CMAQ
Annual Total Precipitation (cm)



2002 12km PRISM
Annual Total Precipitation (cm)

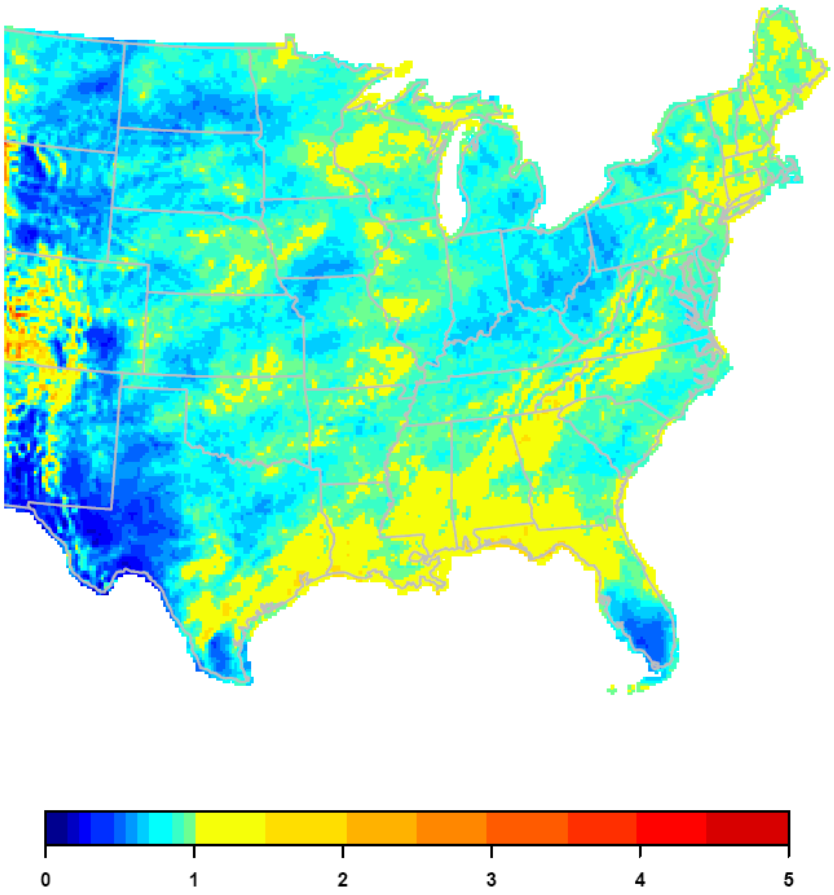


United States Environmental Protection Agency

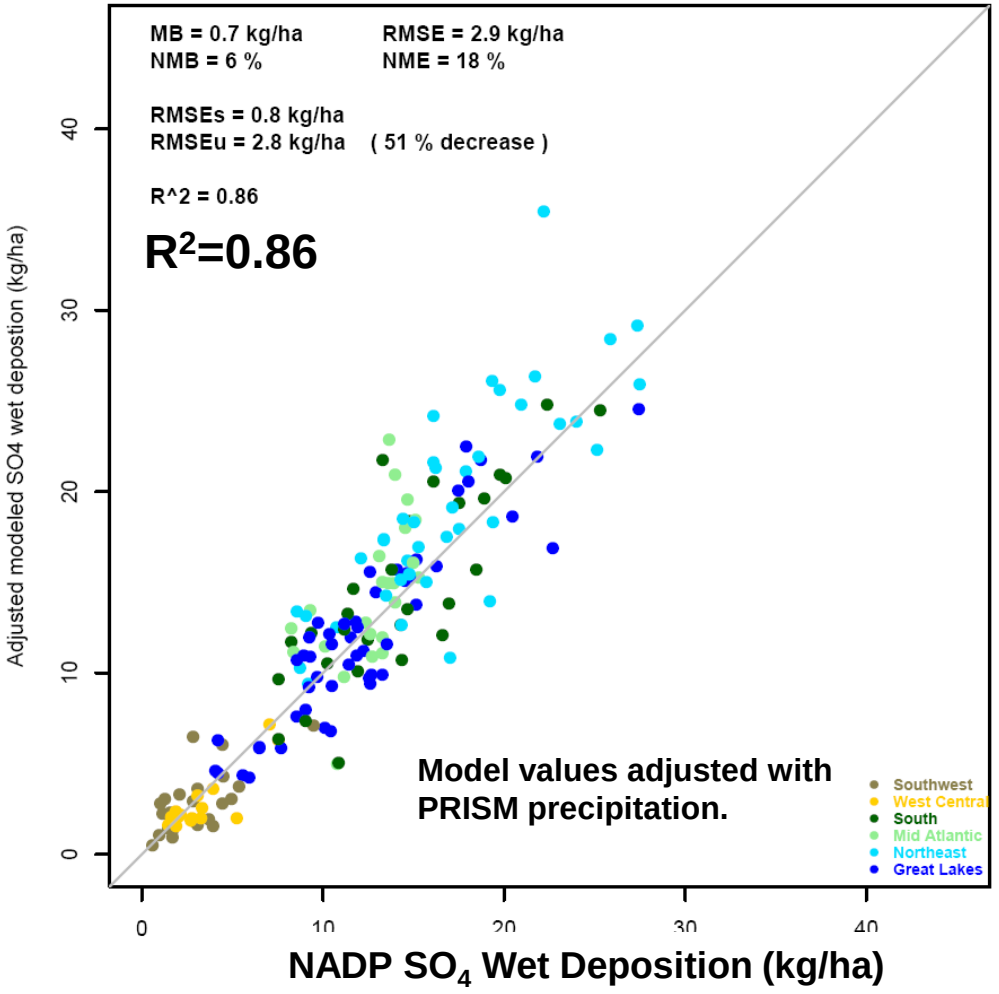
PRISM orographic enhancements are evident

CMAQ SO_4 dep. adjusted with PRISM precipitation improves almost as much as with NADP precipitation: (51% decrease in RMSEu)

Precipitation Ratio: PRISM/CMAQ



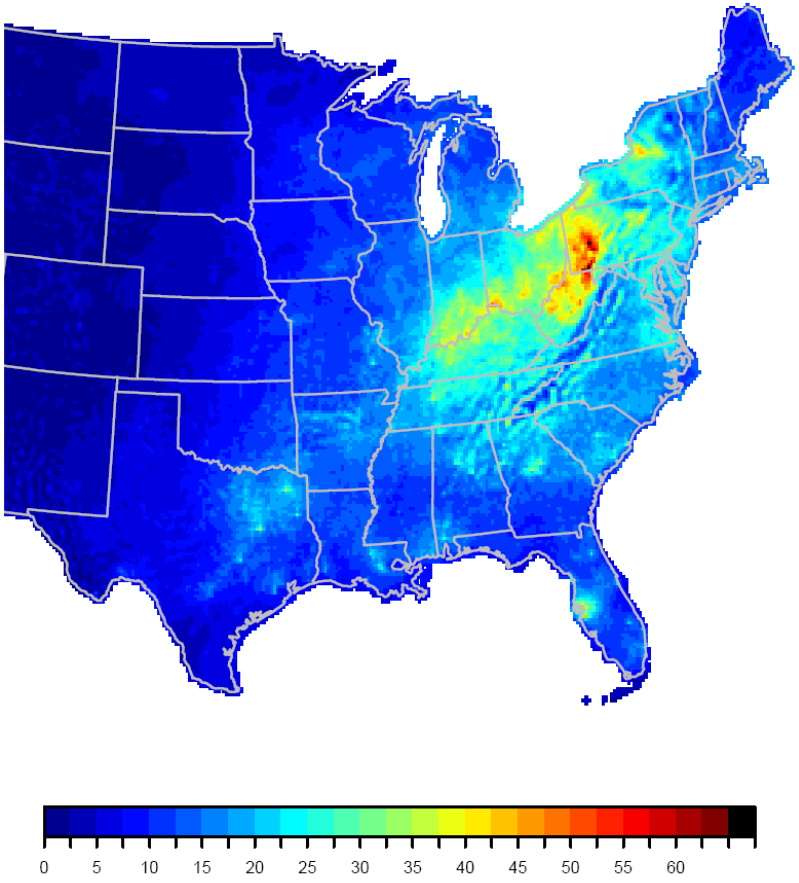
Observed vs. Adjusted CMAQ Wet Deposition SO_4



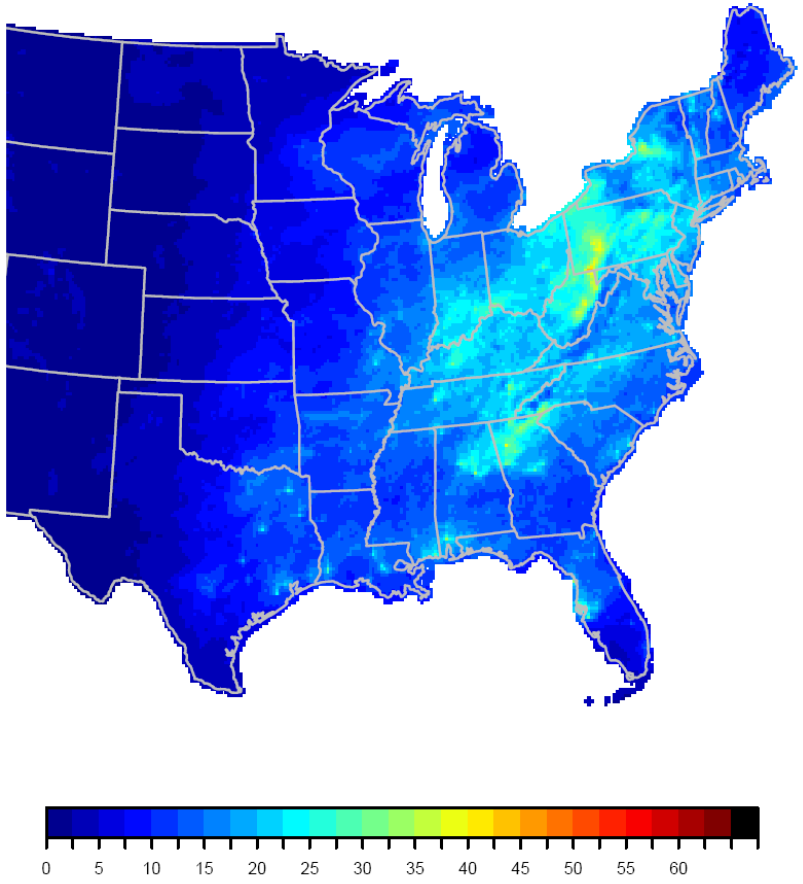
Resultant Wet Deposition Map for SO_4

United States Environmental Protection Agency

CMAQ Wet Deposition SO_4 (kg/ha) BEFORE



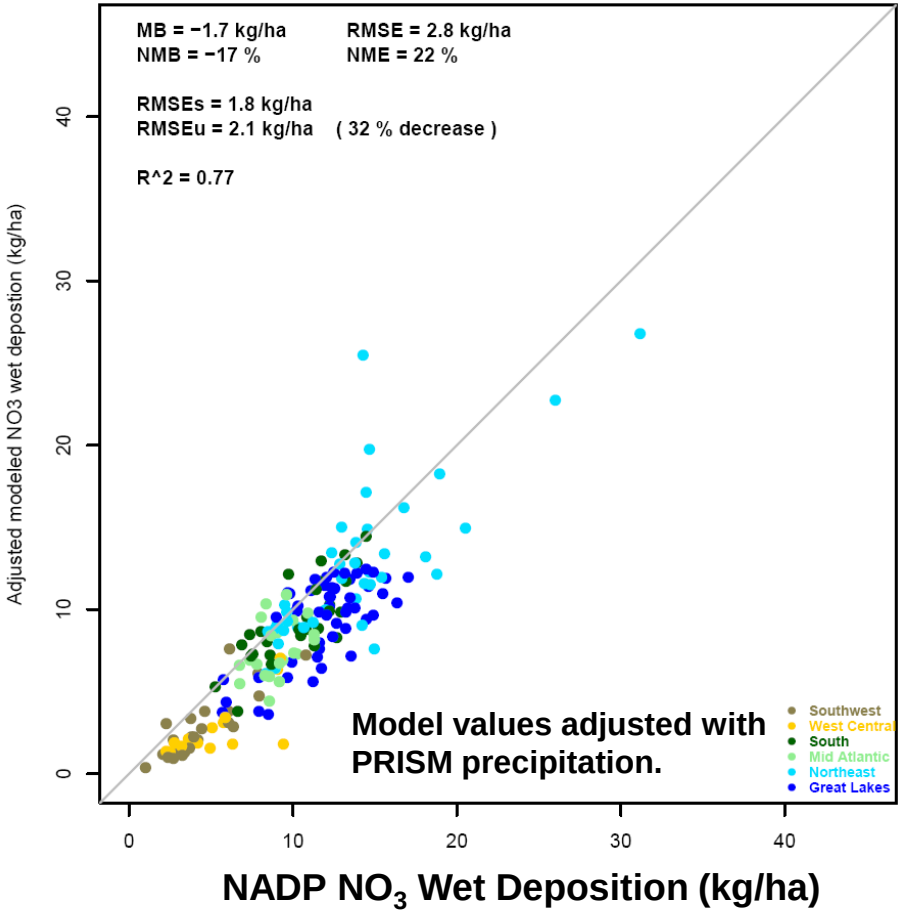
Adjusted CMAQ Wet Deposition SO_4 (kg/ha) AFTER / FINAL

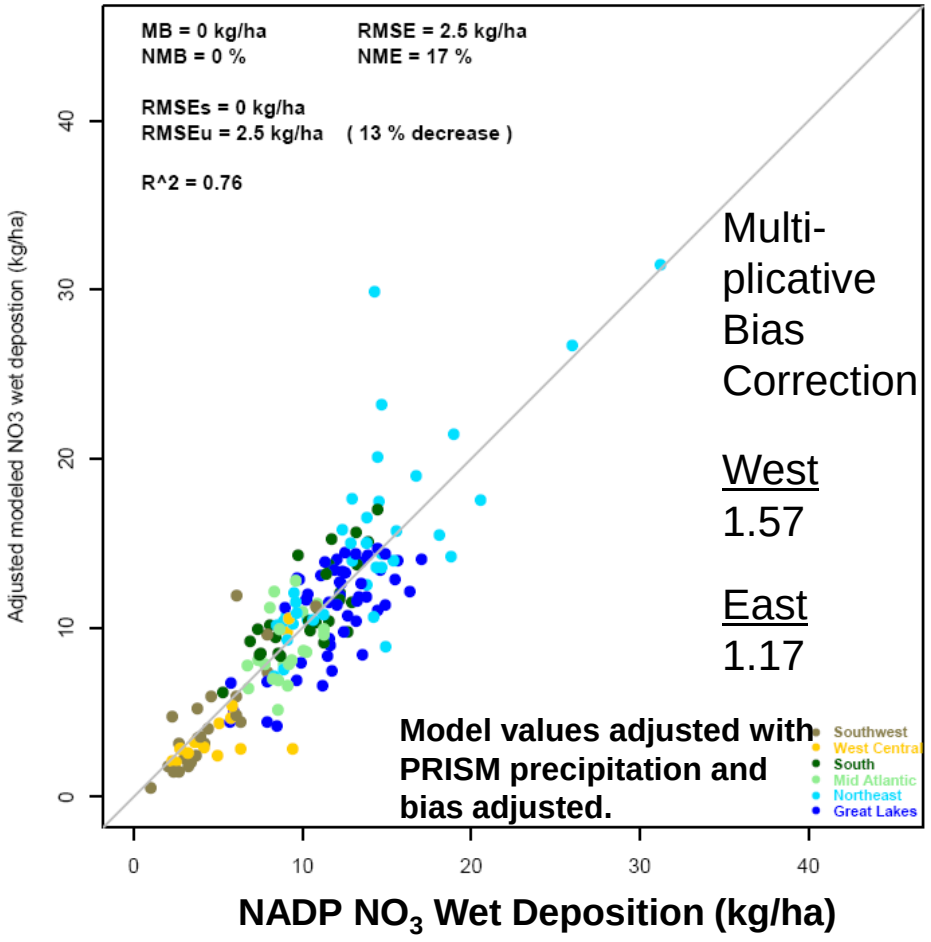


Model values adjusted with PRISM precipitation.

For NO_3 the Procedure Calls For Both A Precipitation and a Bias Adjustment

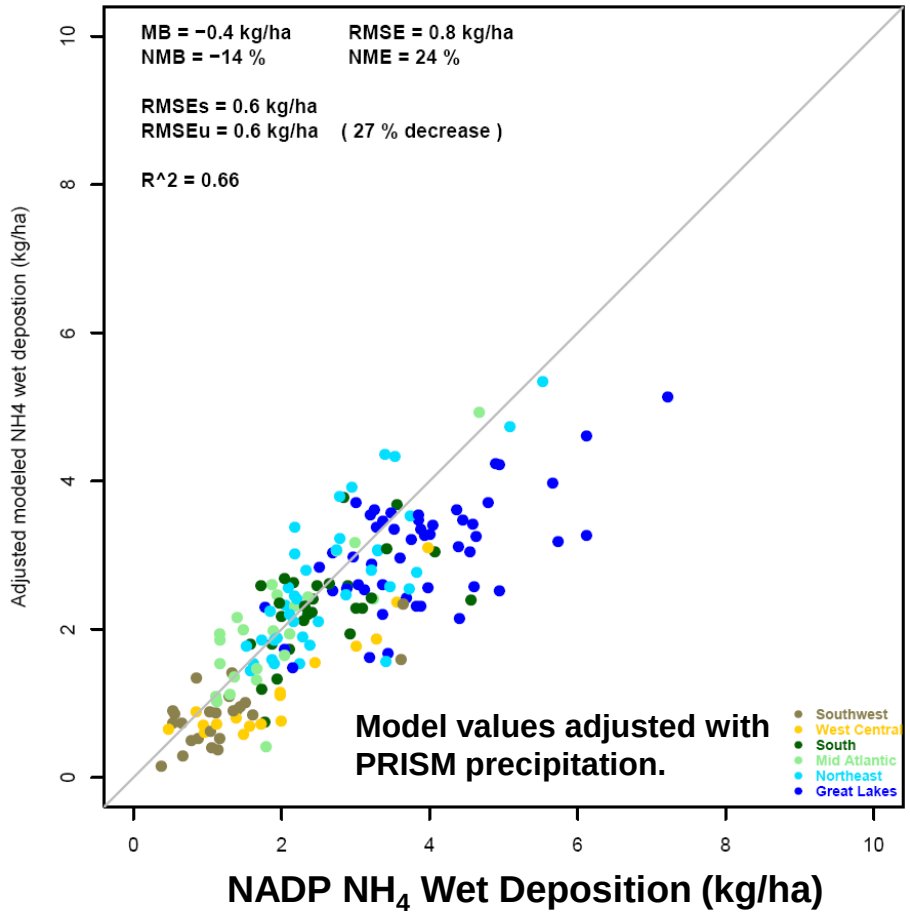
Observed vs. Adjusted CMAQ Wet Deposition NO_3

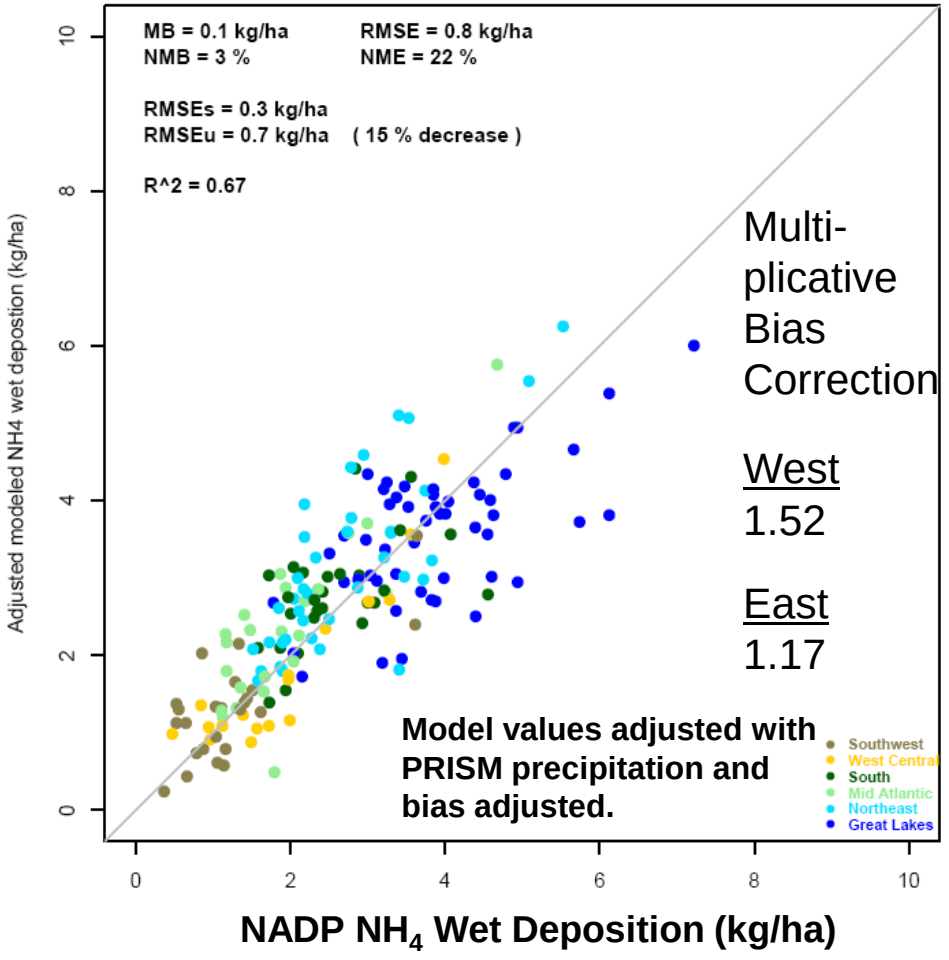




For NH_4 the Procedure Calls For Both A Precipitation and a Bias Adjustment

Observed vs. Adjusted CMAQ Wet Deposition NH_4

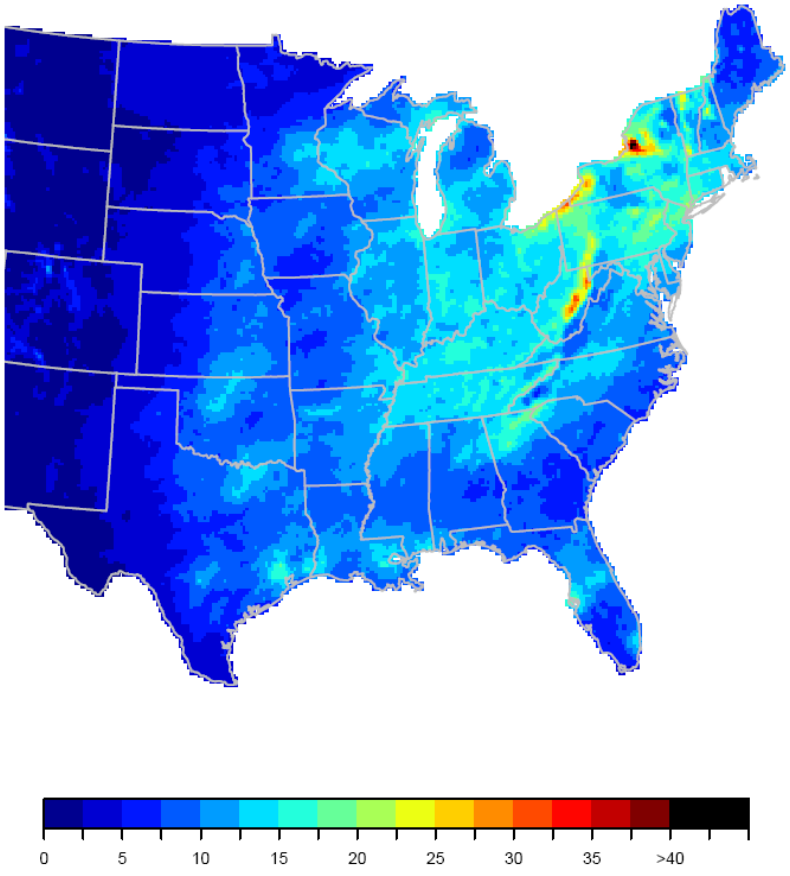




Resultant Wet Deposition Fields for NO_3 and NH_4

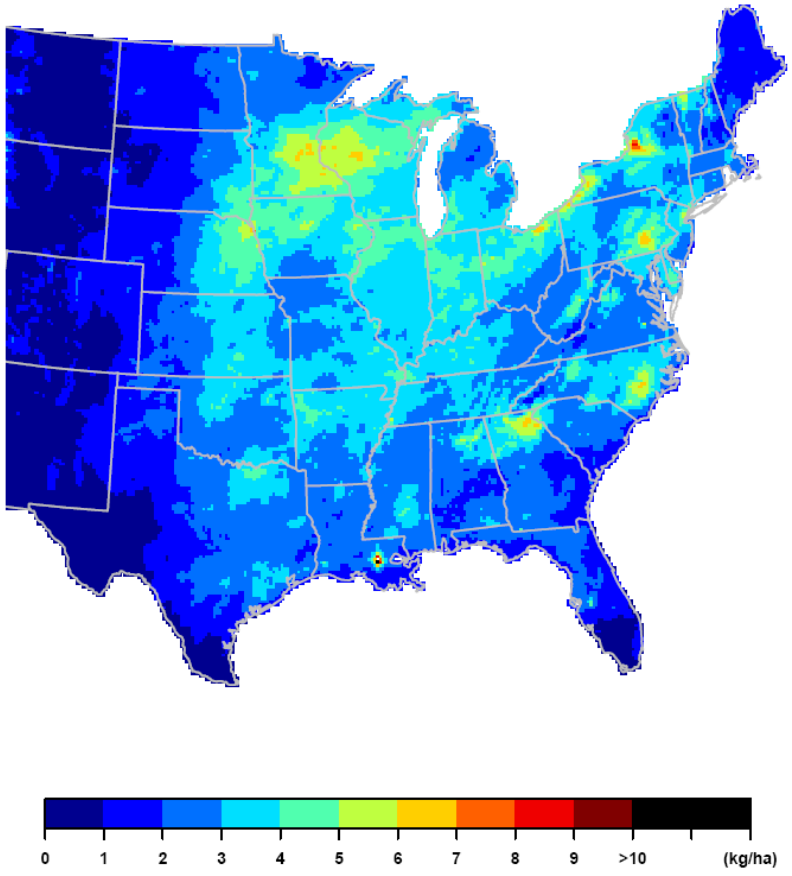
United States Environmental Protection Agency

Adjusted CMAQ Wet Deposition NO_3 (kg/ha)



Model values adjusted with PRISM precipitation and then bias adjusted.

Adjusted CMAQ Wet Deposition NH_4 (kg/ha)



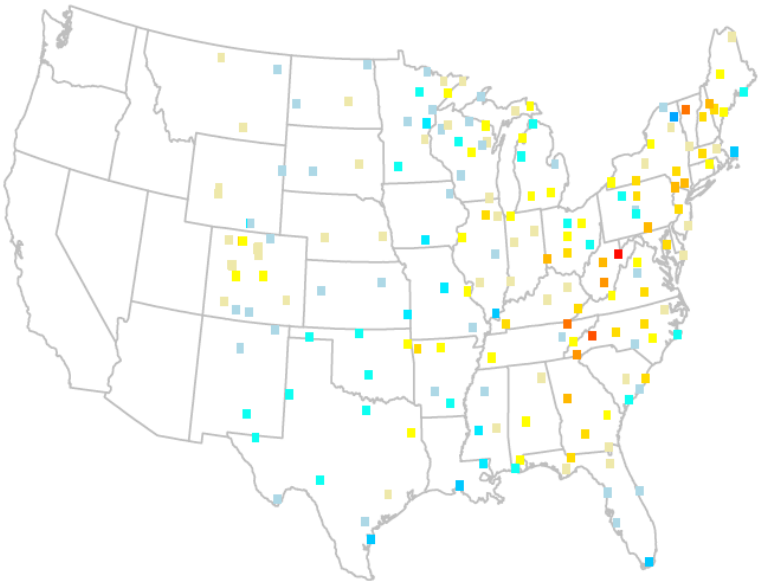
Model values adjusted with PRISM precipitation and then bias adjusted.

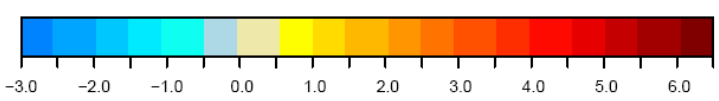
Absolute Error: CMAQ – Observed

Regionally Fairly Similar Except for Appalachian Mountains

Absolute Error in West Smaller Than In East

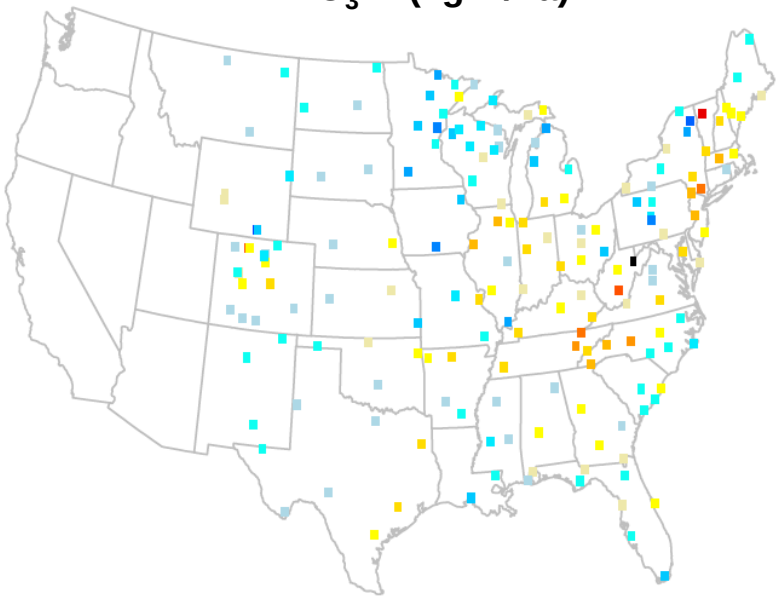
Adjusted CMAQ – Observed Wet Dep. SO_4-S (kg-S/ha)

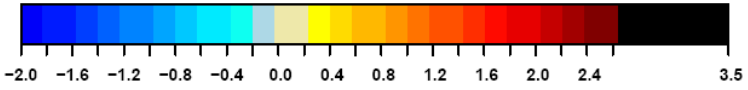




Model values adjusted with PRISM precipitation.

Adjusted CMAQ – Observed Wet Dep. NO_3-N (kg-N/ha)





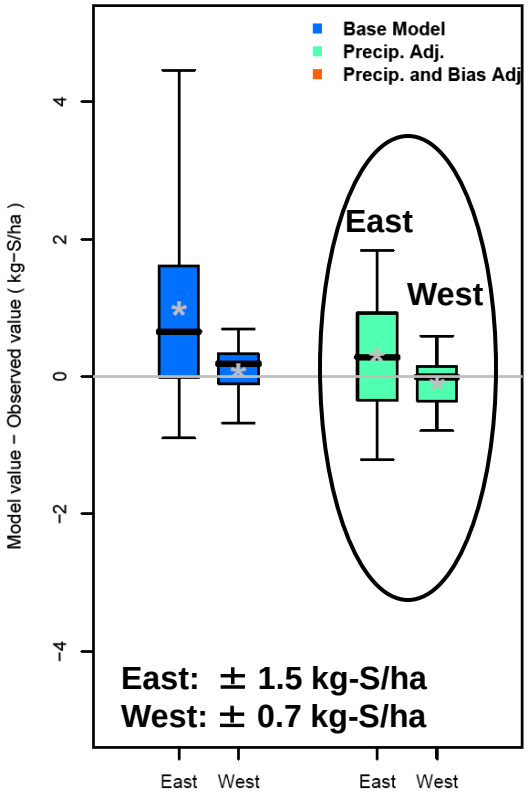
Model values adjusted with PRISM precipitation and bias adjusted.

Distribution of CMAQ Error: Modeled – Observed

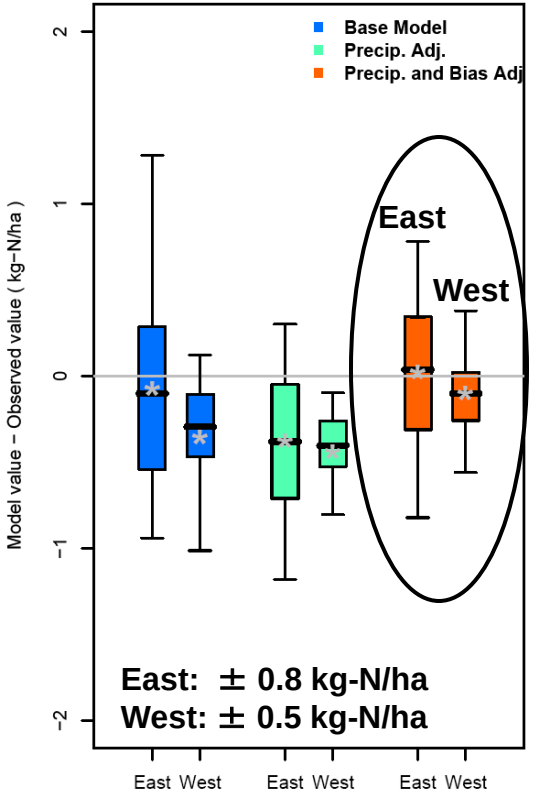
5^{th}-25^{th}-Median-75^{th}-95^{th}

United States Environmental Protection Agency

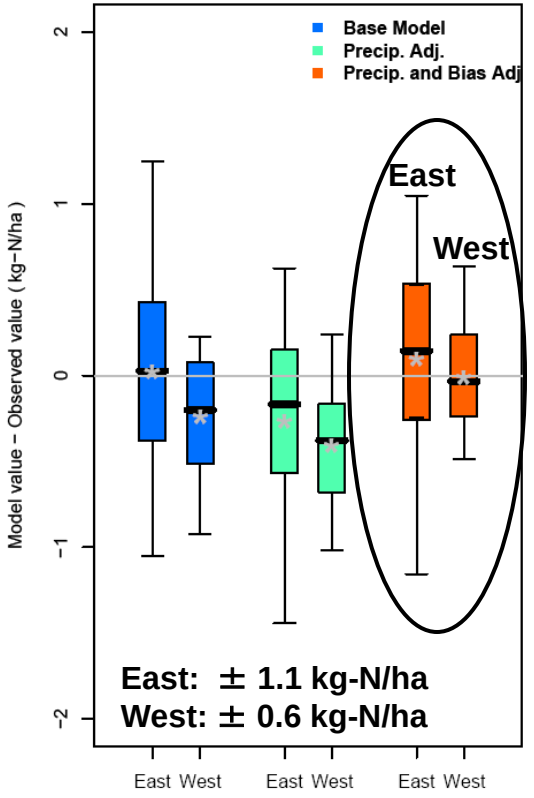
Wet Deposition SO_4-S



Wet Deposition NO_3-N



Wet Deposition NH_4-N



EAST: 141 NADP monitors
WEST: 41 NADP monitors

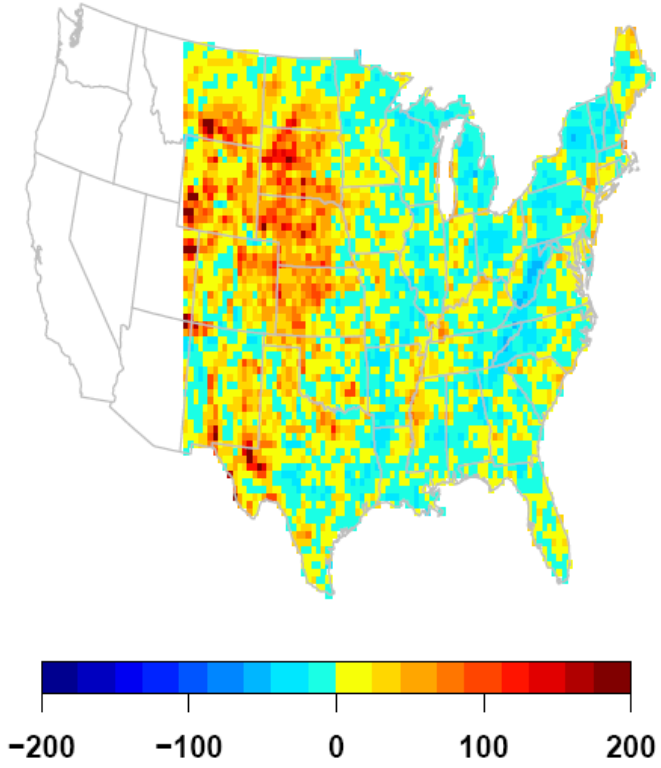
What Happens to Dry Deposition?

We expect the interaction between wet and dry deposition to be small

We performed a meteorological model sensitivity, changing the MM5 convective parameterization, thereby changing the precipitation prediction for summer 2002 and then reran CMAQ on the new meteorology to study change in deposition.

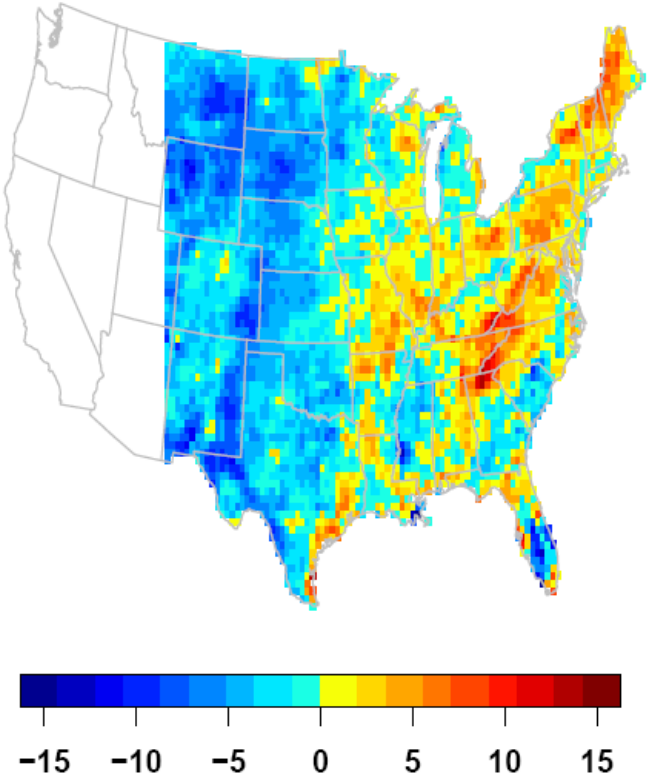
Wet Dep. TNO_3

(Model 1 − Model 2)/Model 2*100%



Dry Dep. HNO_3

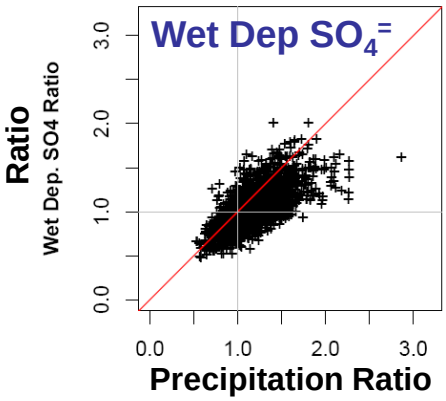
(Model 1 − Model 2)/Model 2*100%

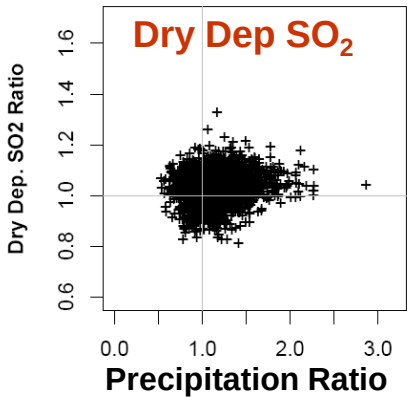


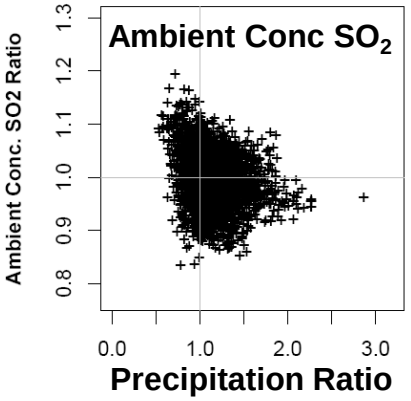
Note Order of Magnitude Change in Scale

There Is a Muted, Systematic Dry Deposition Response To the Change in Wet Deposition

Dry Deposition Response is small

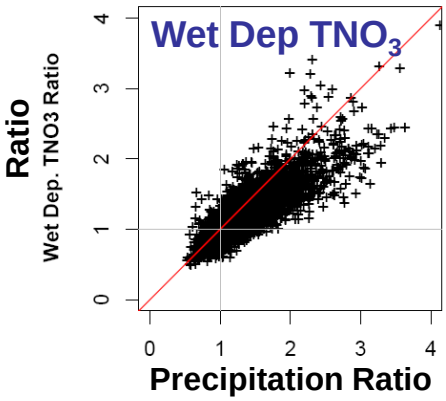


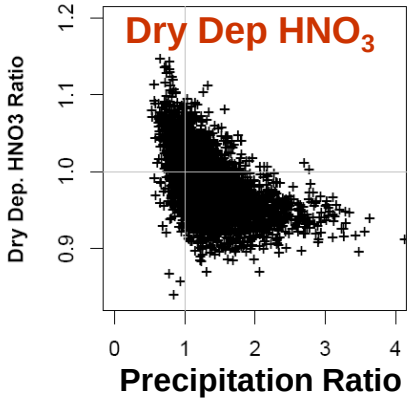


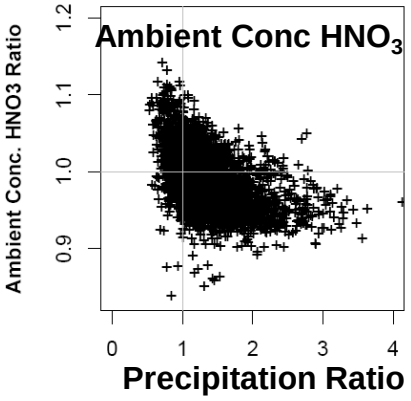


Dry Deposition SO_2

± 20%

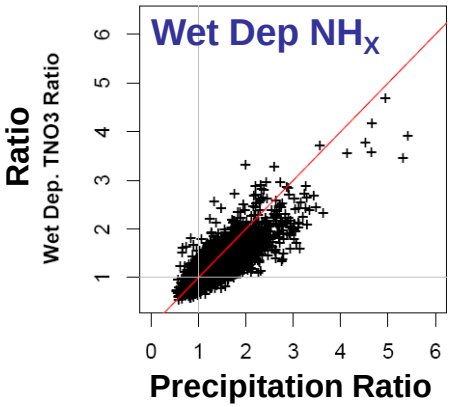


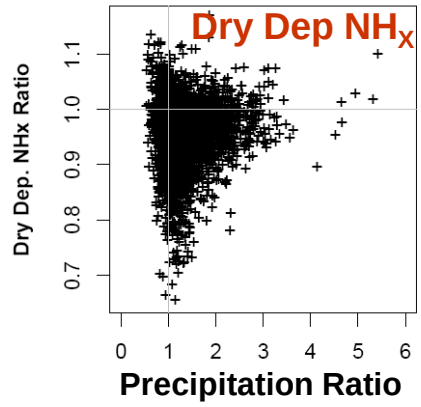


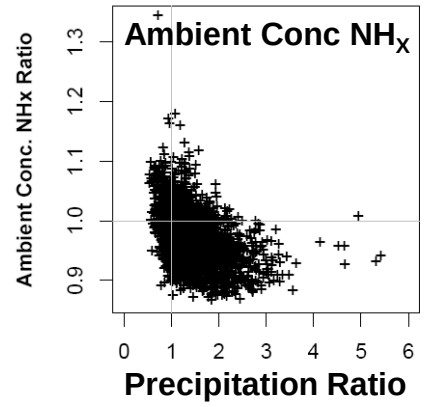


Dry Deposition HNO_3

± 12%







Dry Deposition NH_X

+ 10%
– 20%

We Need to Understand the Sources of Bias

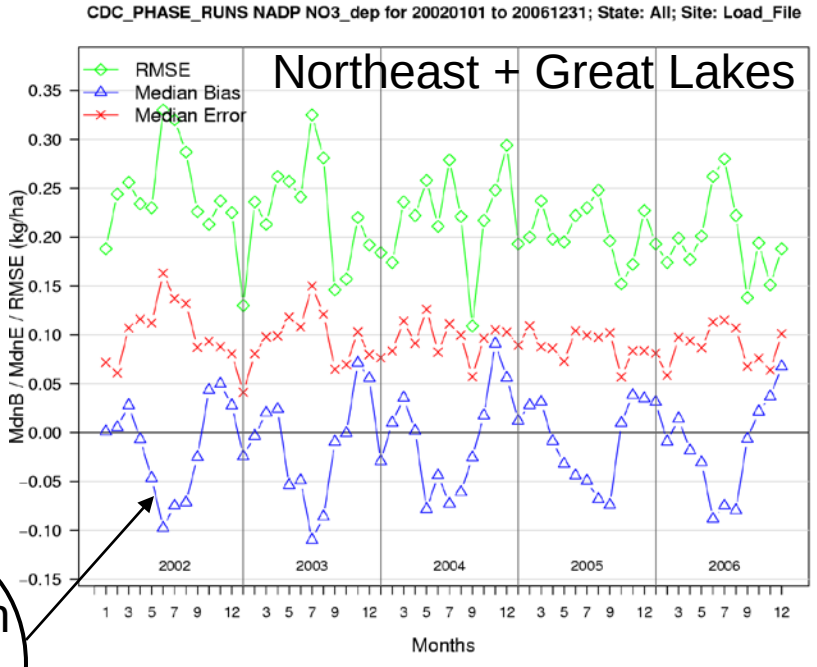
For Example

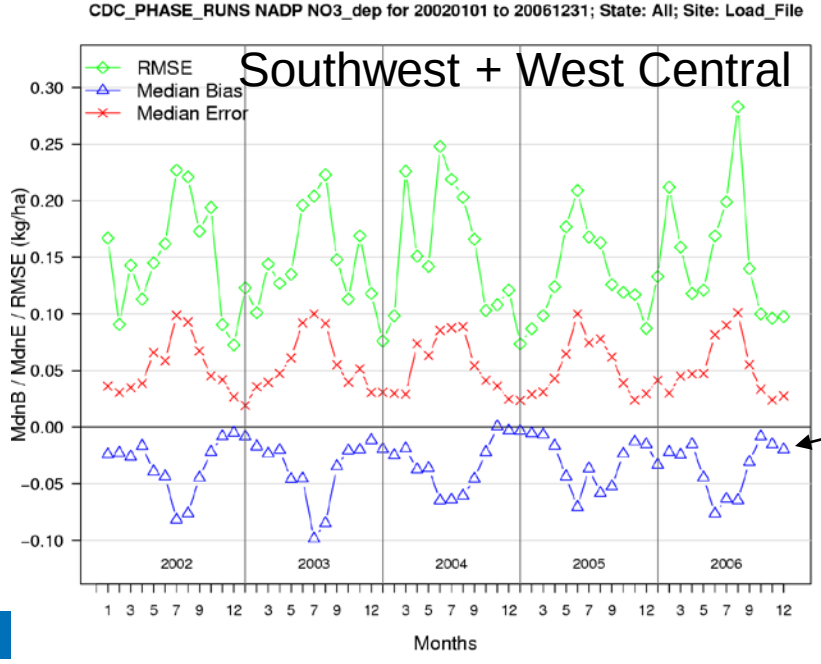
2002-2006 CMAQ NO_3 Wet Deposition vs. NADP NO_3 Wet shows a consistent under prediction bias in the summer.

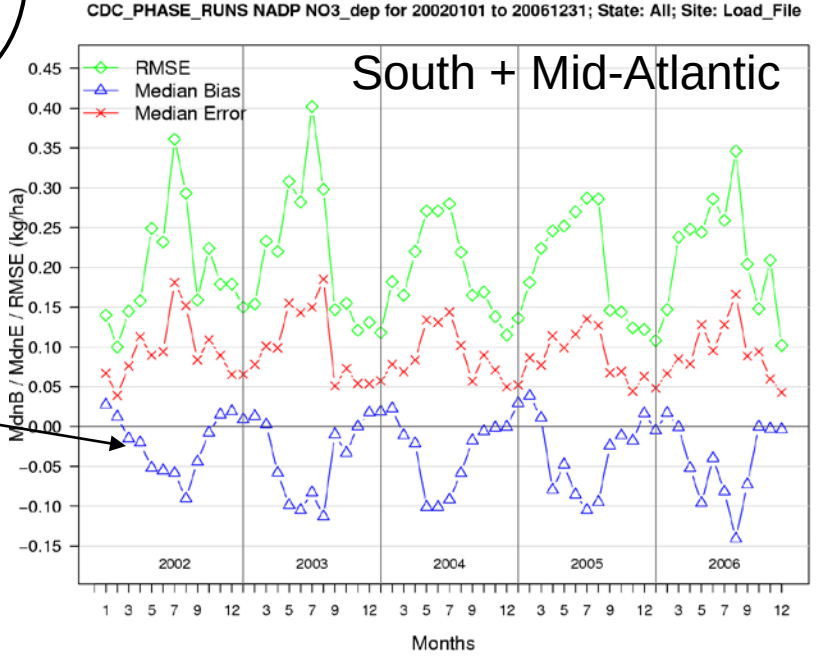
BUT, no under-prediction of TNO_3 at surface

We think a major source of this bias is missing lightning NO_X aloft in CMAQ

Median Bias







SUMMARY

- It is possible to post process CMAQ wet deposition with PRISM data to address precipitation error
  - Errors are reduced most for Sulfur and least for Reduced-Nitrogen
    - Errors can be quantified/estimated and hopefully are tolerable
    - Given the rather similar absolute error across subregions and the ability to allow for orographic corrections, the approach used here may be as good or better than data fusion
- The impact on dry deposition of the wet deposition post-processing is small and tolerable
- A bias correction is needed in addition to the precipitation adjustment for oxidized-N and reduced-N
    - The sources of bias need to be identified and treated
    - The sources of bias will determine how to project deposition into the future

United States Environmental Protection Agency

Acknowledgements

The collaboration with colleagues in AMAD:
Wyat Appel
Steve Howard

Data and Information from NADP

PRISM data