



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

Robin Dennis and Kristen Foley
Atmospheric Modeling and Analysis Division
NERL, EPA

2014 NADP Annual Meeting and Scientific Symposium
Indianapolis, Indiana
October 23, 2014



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



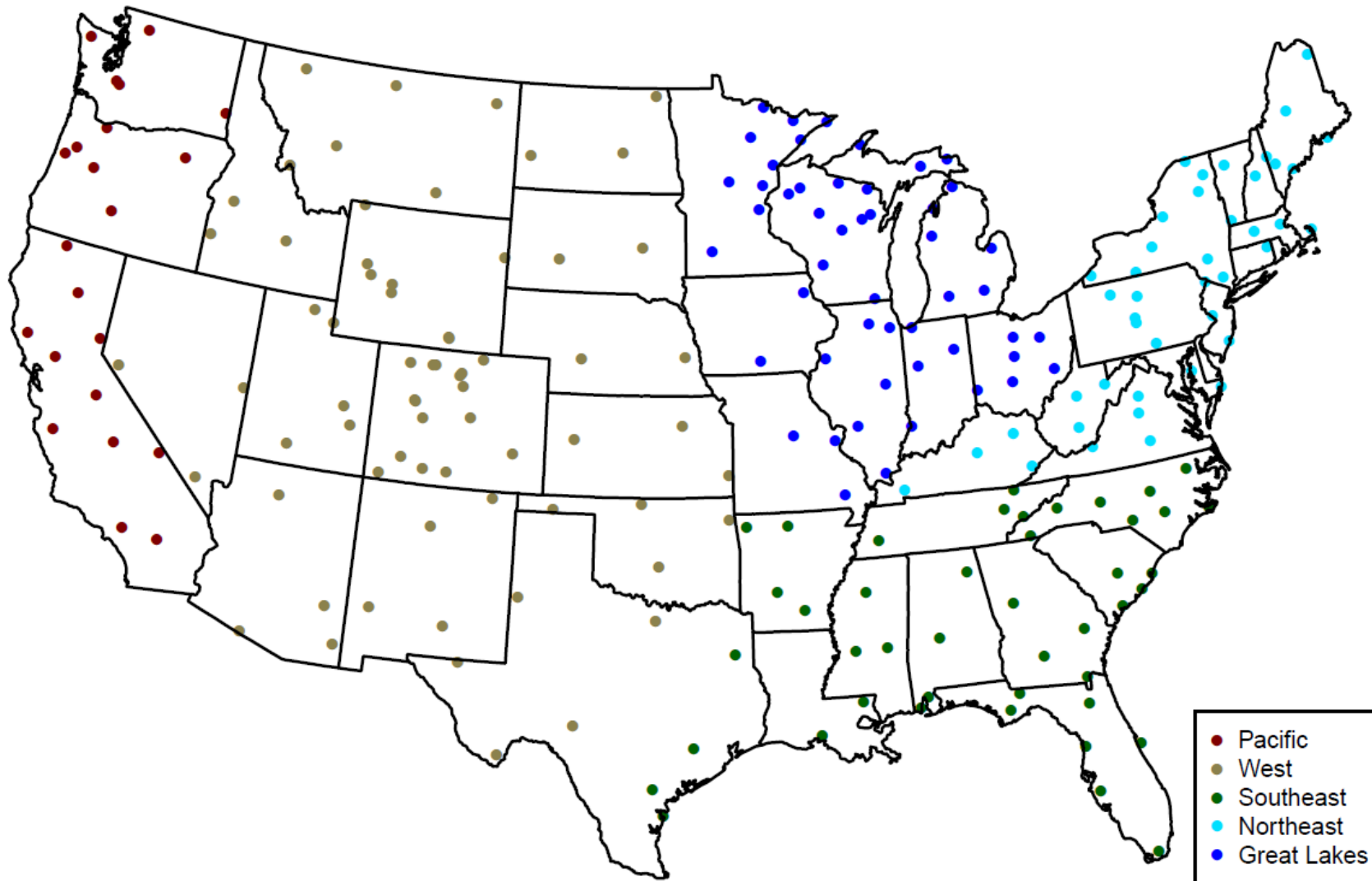
Improvements to WRF, CMAQ, Emissions

- 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 NH₃ emissions (EPIC)**
- **Dynamic CAFO NH₃ emissions profile (thermodynamics-based)**
- Mesophyll resistance change (affects NO₂ 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



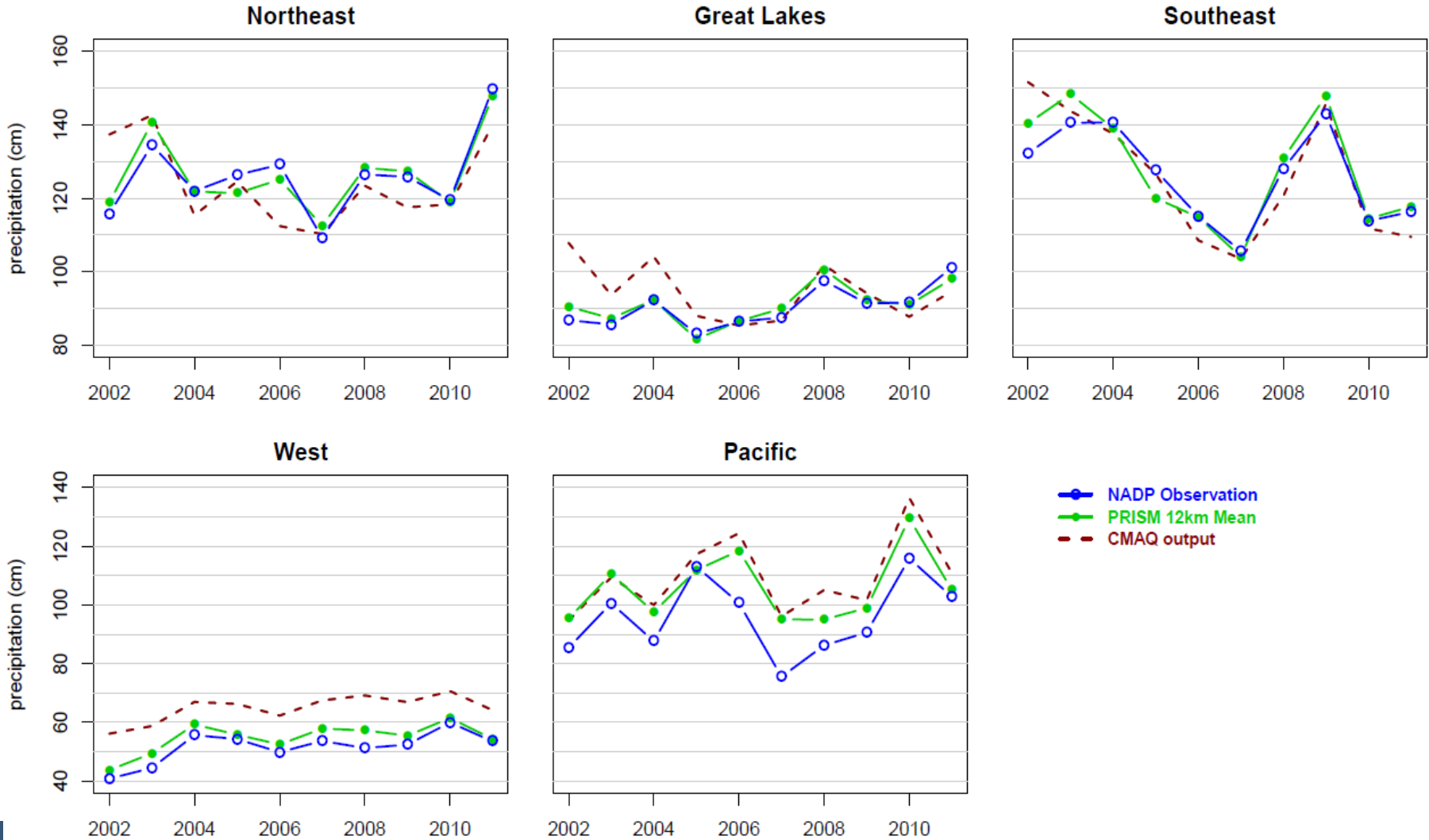
5 US Sub-regions of NADP Sites



Wet Deposition: WRF, PRISM, NADP Precipitation



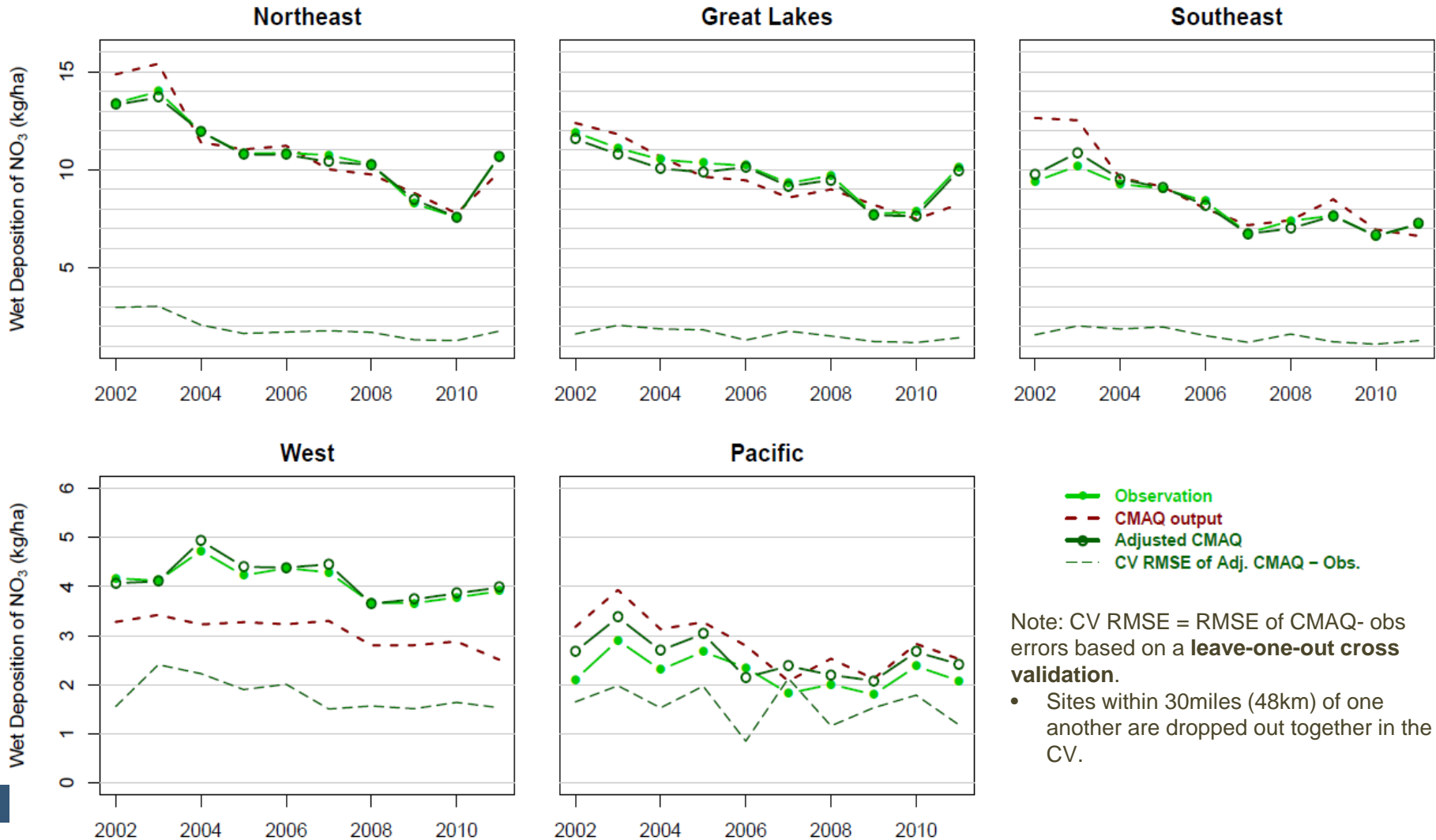
Regional Averages of Annual Total Precipitation (cm)



Wet Deposition: NADP, "Raw", Adjusted CMAQ NO₃



Regional Averages of Annual Total Wet Deposition of NO₃ (kg/ha)



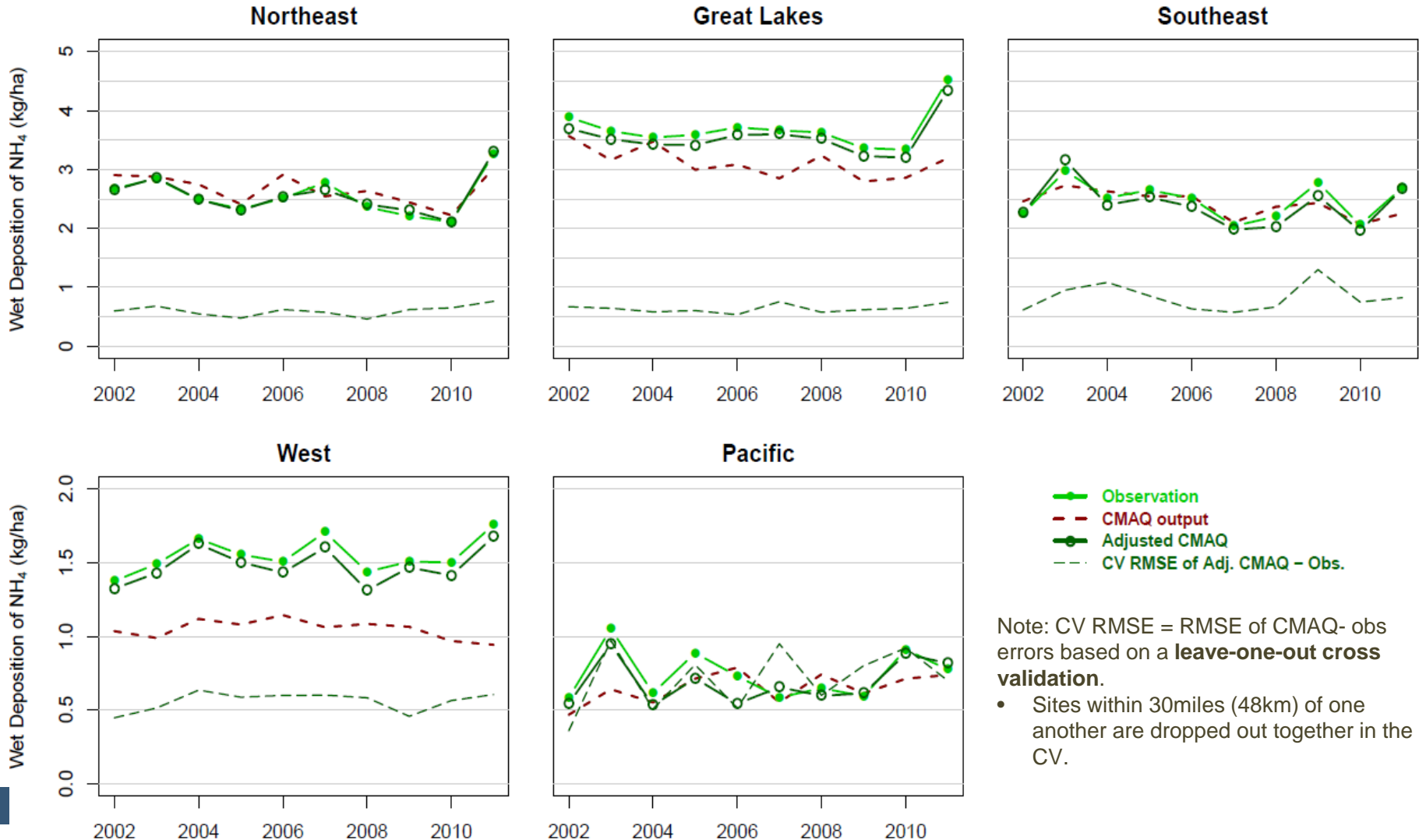
Note: CV RMSE = RMSE of CMAQ- obs errors based on a **leave-one-out cross validation**.

- Sites within 30miles (48km) of one another are dropped out together in the CV.

Wet Deposition: NADP, "Raw", Adjusted CMAQ NH₄



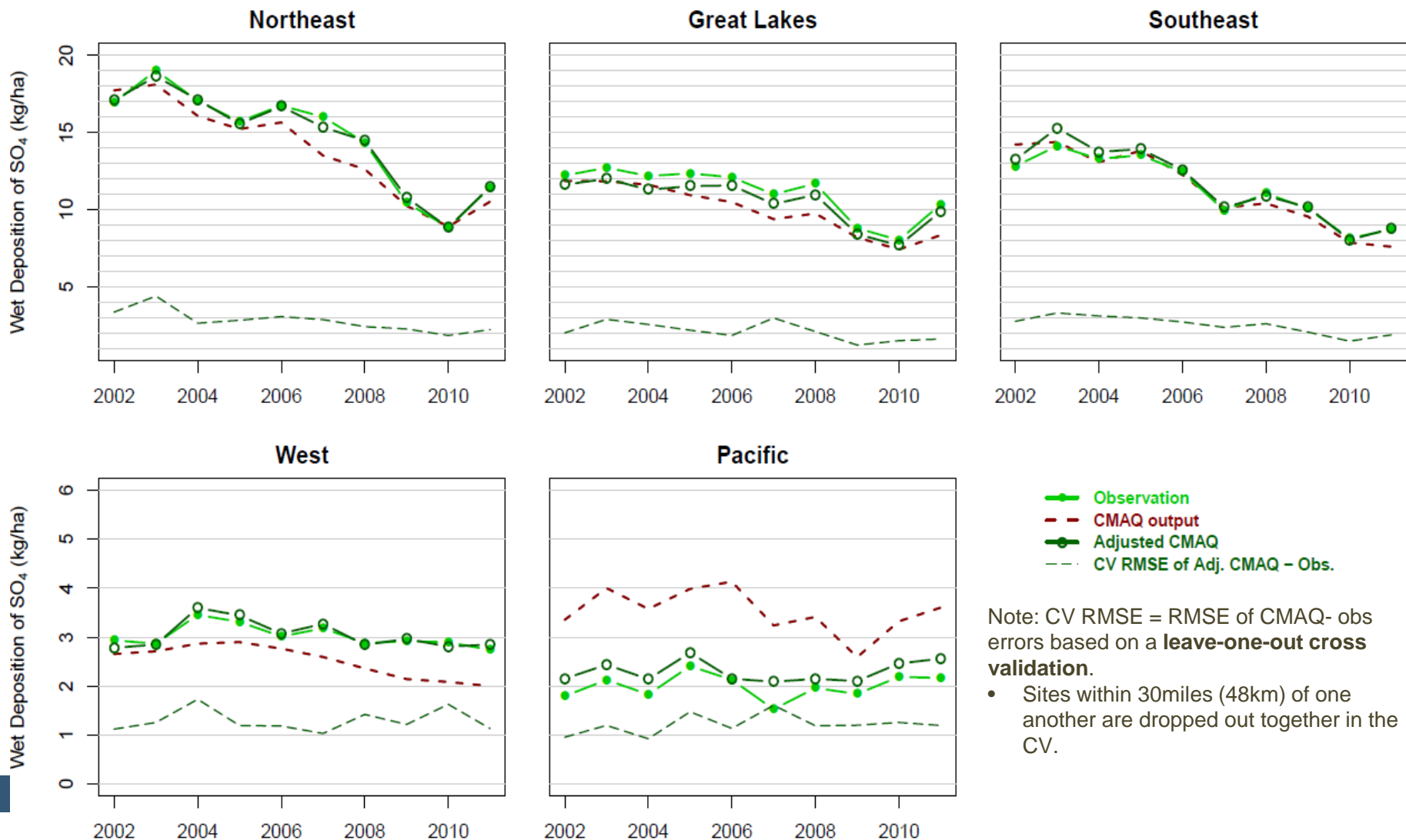
Regional Averages of Annual Total Wet Deposition of NH₄ (kg/ha)



Wet Deposition: NADP, "Raw", Adjusted CMAQ SO₄



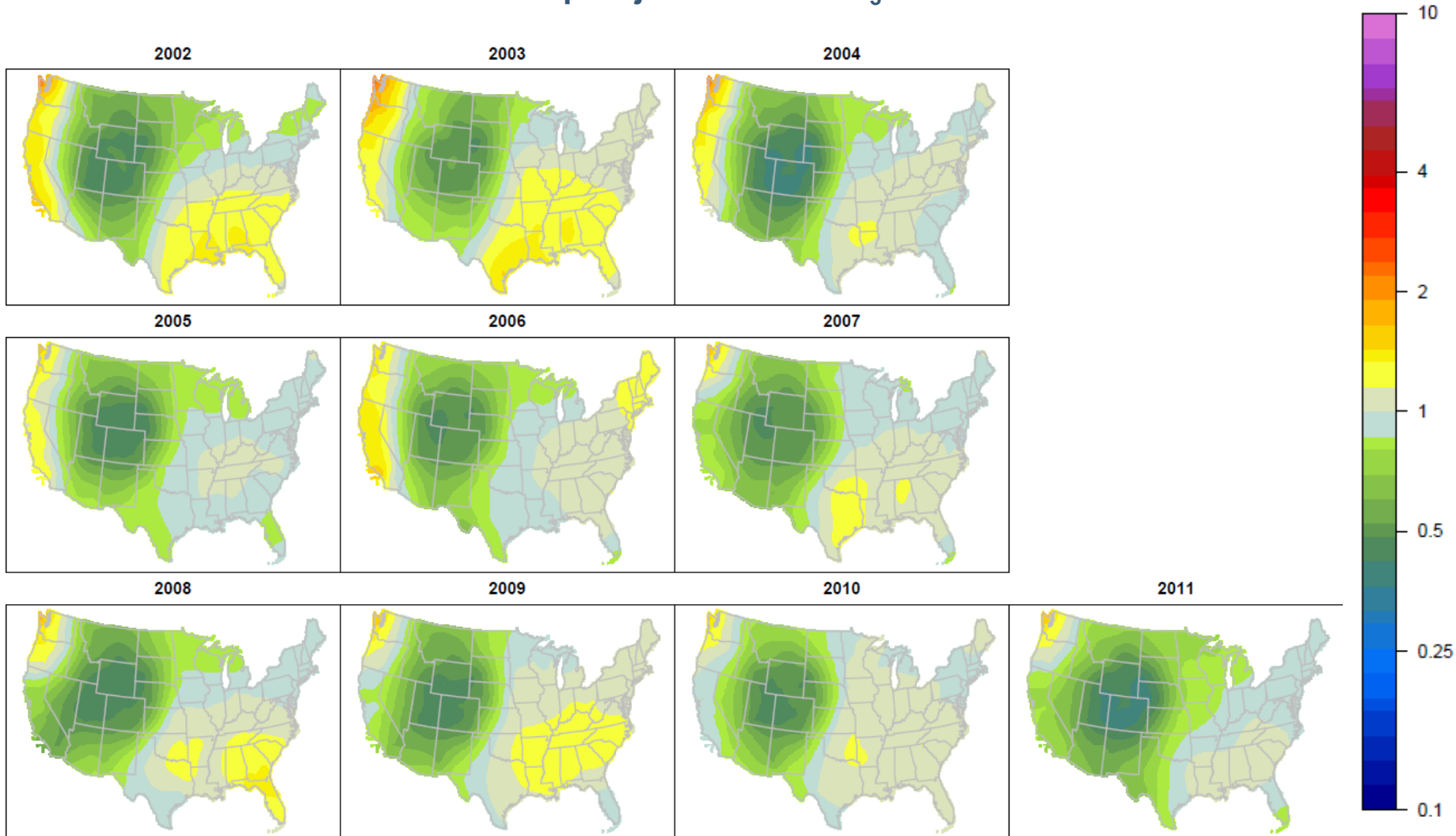
Regional Averages of Annual Total Wet Deposition of SO₄ (kg/ha)



Wet Deposition Smooth Bias Adjustment NO₃



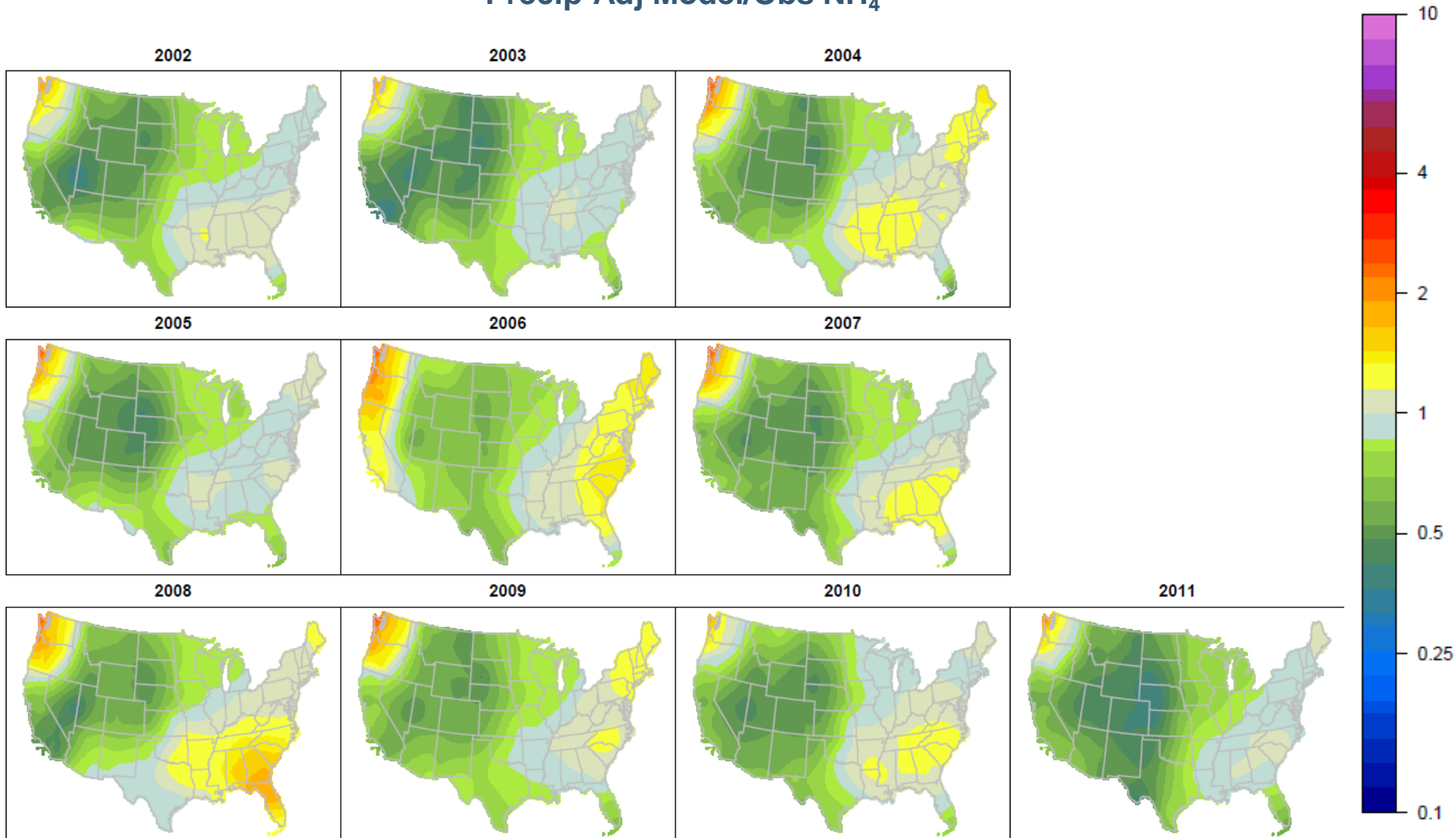
Precip-Adj Model/Obs NO₃



Wet Deposition Smooth Bias Adjustment NH₄



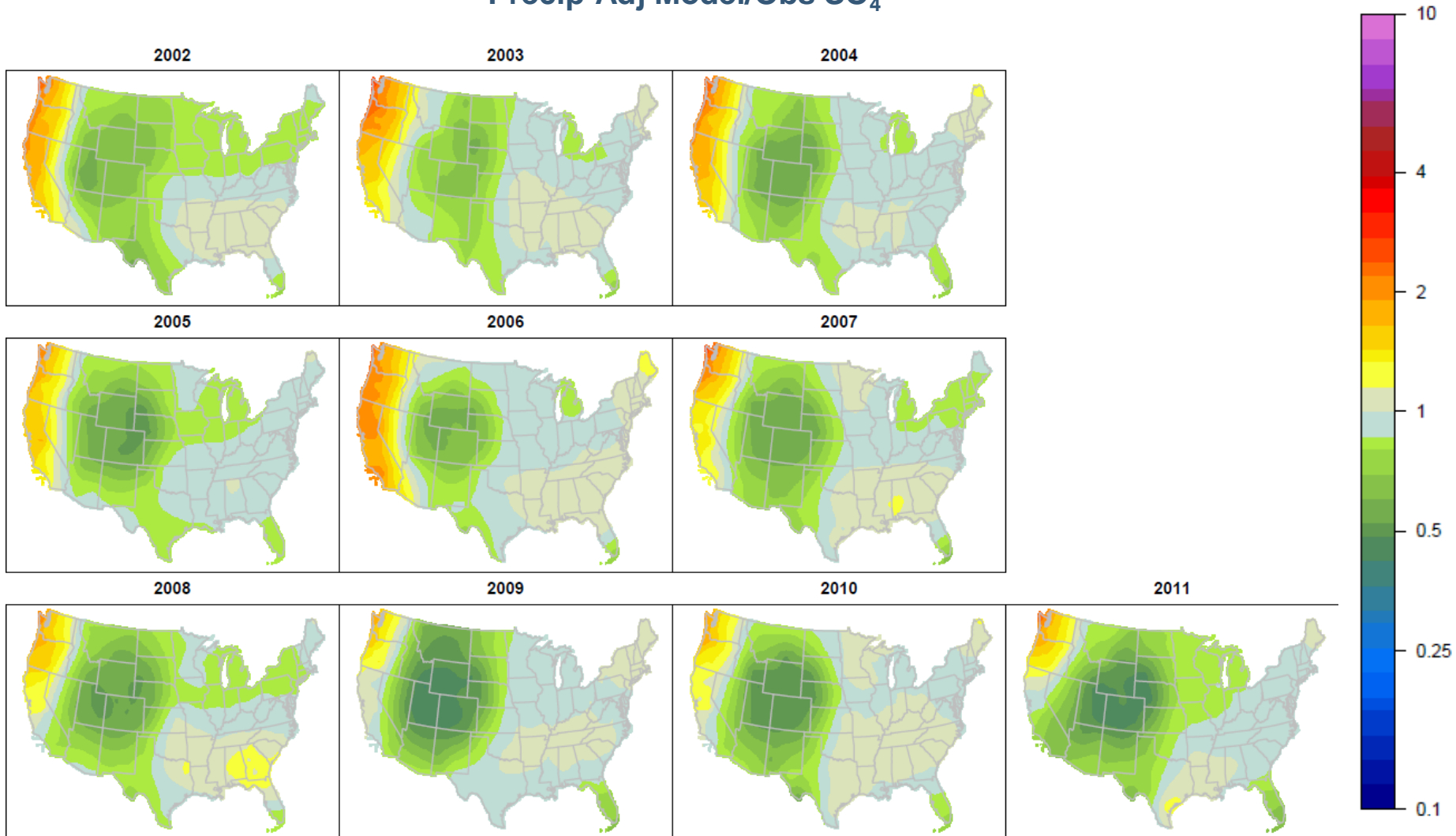
Precip-Adj Model/Obs NH₄



Wet Deposition Smooth Bias Adjustment SO₄



Precip-Adj Model/Obs SO₄



Wet Deposition Error

Wet Deposition Cross Validation RMS Error					
	North East	Great Lakes	South East	West	Pacific
Wet NO ₃ (kg-N/ha)	0.68→0.23	0.45→0.23	0.45→0.33	0.45 – 0.33	0.33
% Error	20%→14%	20%→14%	20%→14%	50%	75%
Wet NH ₄ (kg-N/ha)	0.4	0.5 – 0.6	0.4 – 0.8	0.4	0.4 – 0.8
% Error	17%	14%	20% -- 40%	33%	100%
Wet SO ₄ (kg-S/ha)	1.3 → 0.67	0.67 – 1.0	1.0 → 0.67	0.33 – 0.5	0.3 – 0.5
% Error	20%	17%	20% → 25%	50%	60%

Note: a→b denotes a trend;
a—b denotes a range

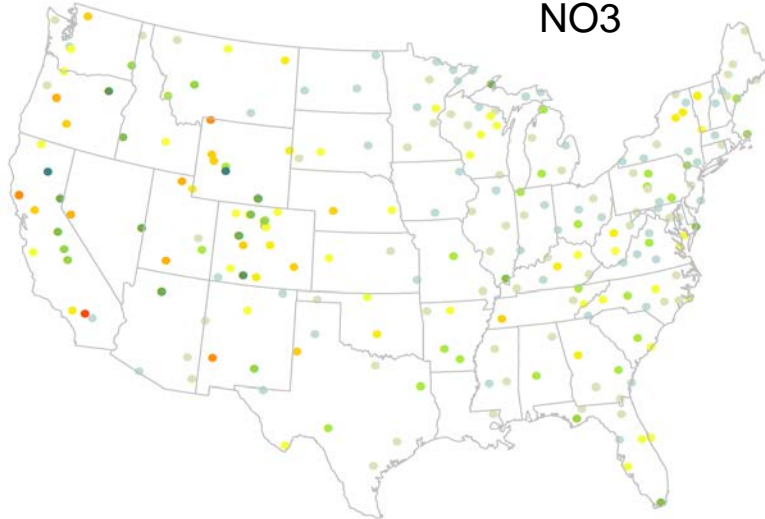
Consistent error across eastern US
Larger error in west
Largest error in Pacific

Error at Individual NADP Sites 2010 Example



PRISM Precip. and Bias Adjusted Model/Observed NO3 Wet Deposition (kg/ha)

NO3

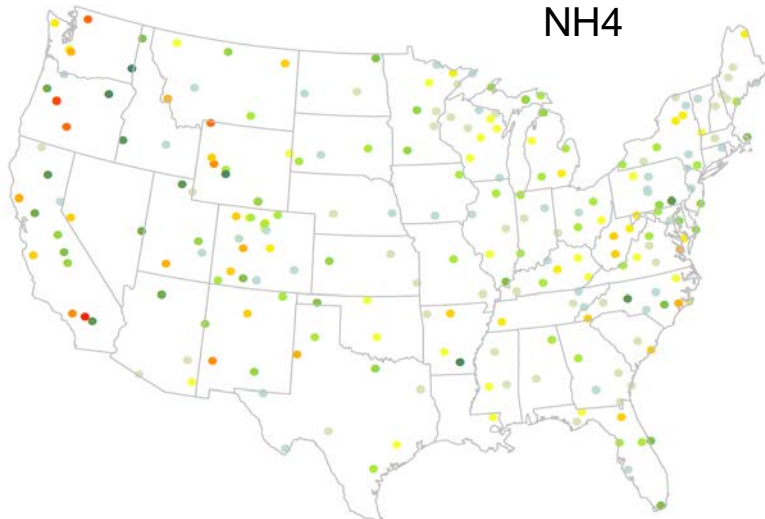


Wet Deposition
Final Bias-Adjusted Model/Observation

2010

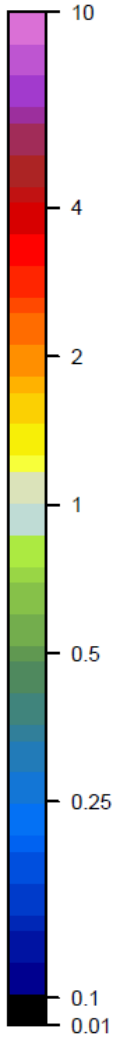
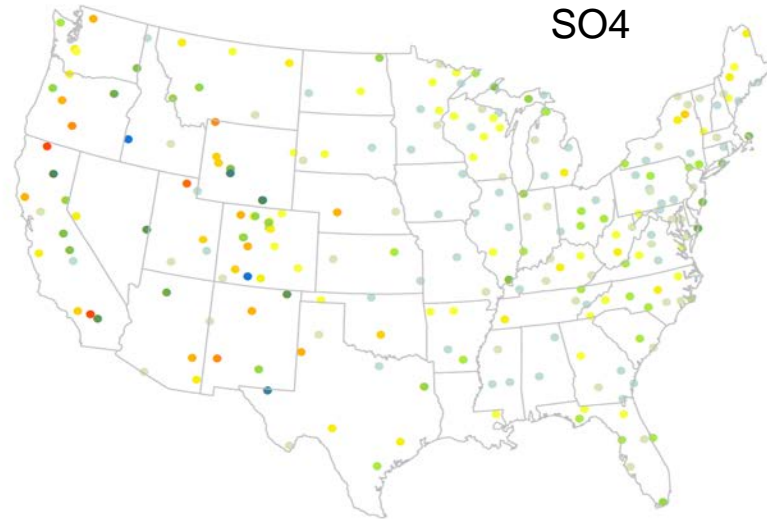
PRISM Precip. and Bias Adjusted Model/Observed NH4 Wet Deposition (kg/ha)

NH4



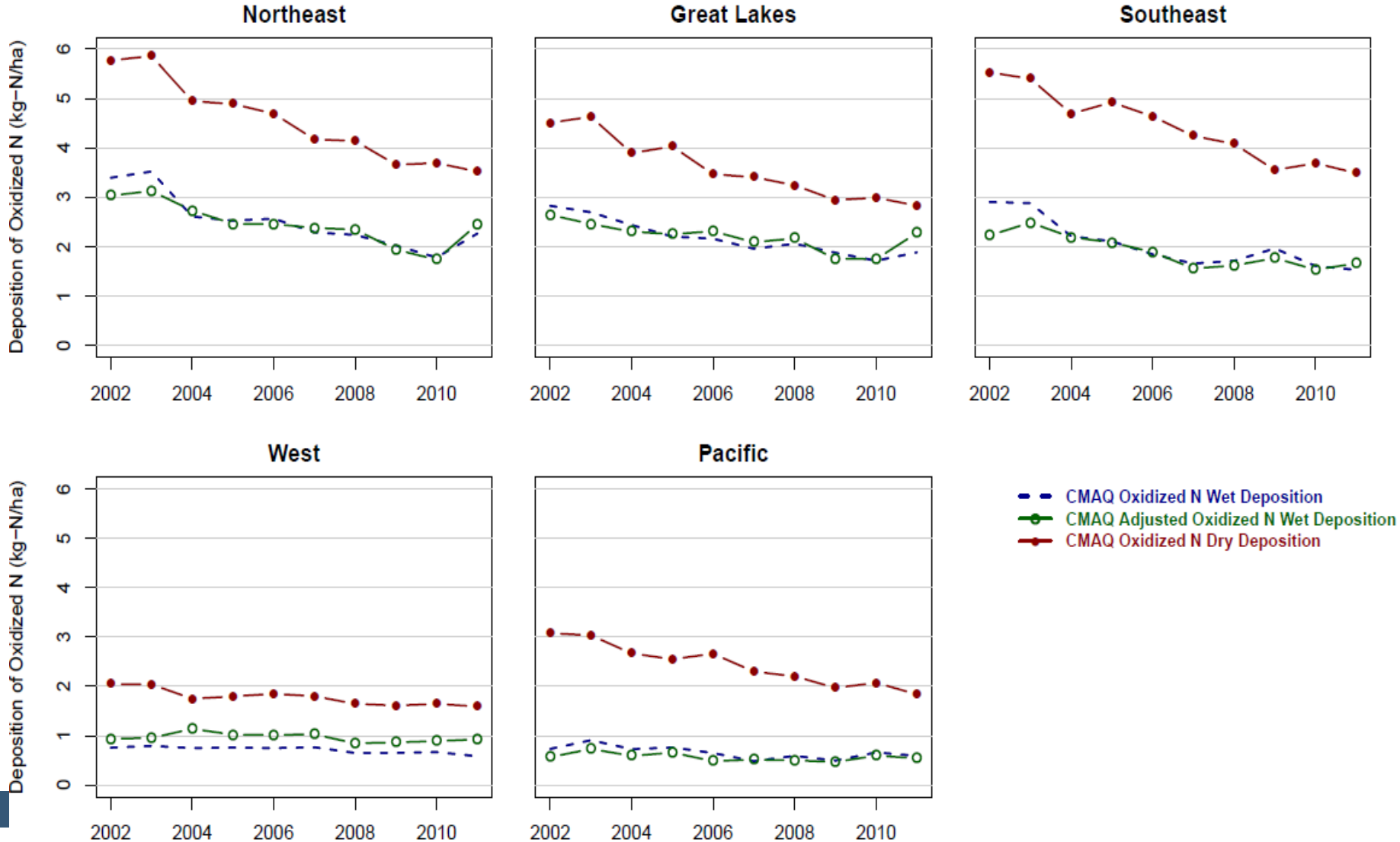
PRISM Precip. and Bias Adjusted Model/Observed SO4 Wet Deposition (kg/ha)

SO4



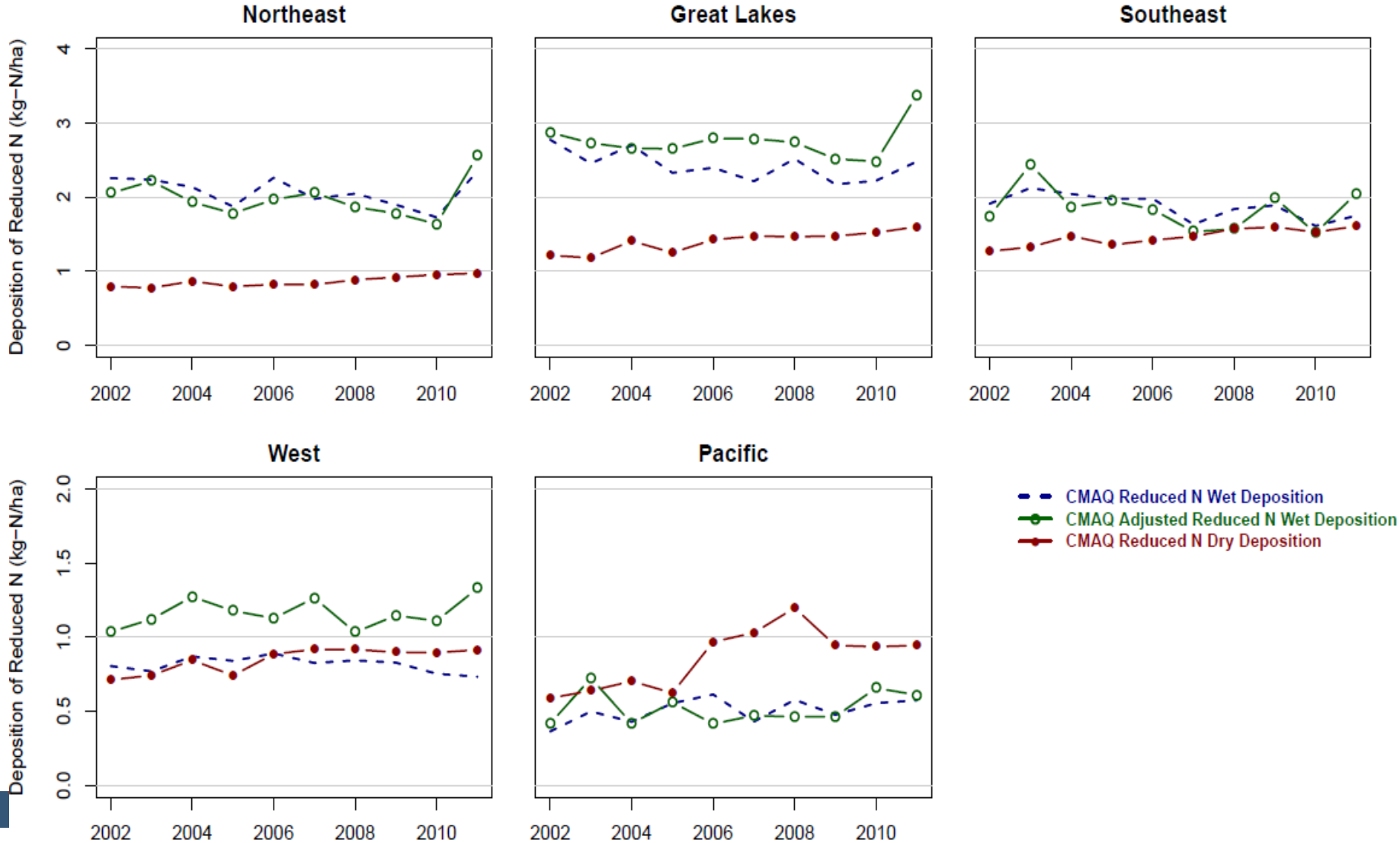
Dry vs Wet Deposition Trends: Ox-N

(at NADP Sites)



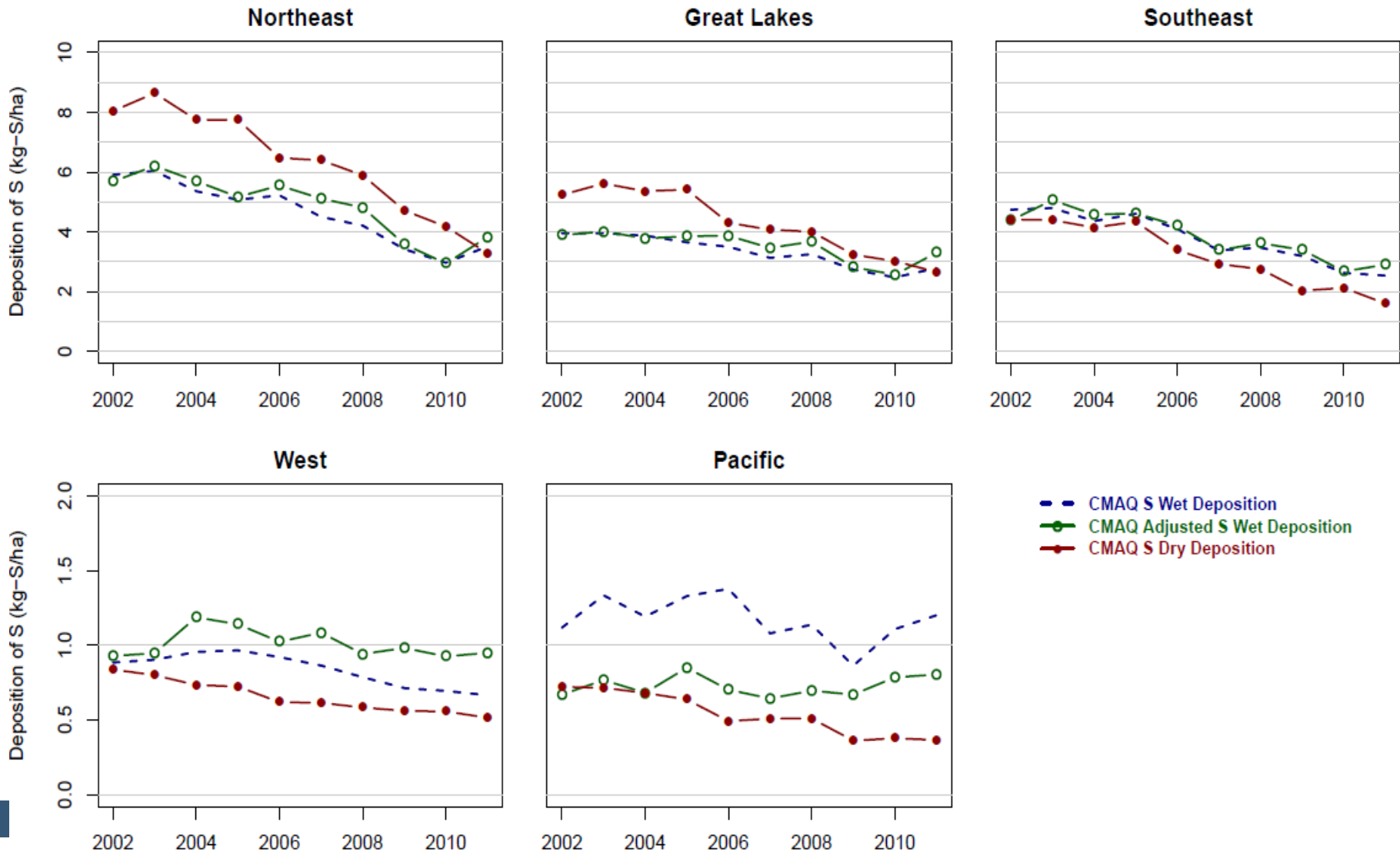
Dry vs Wet Deposition Trends: Red-N

(at NADP Sites)

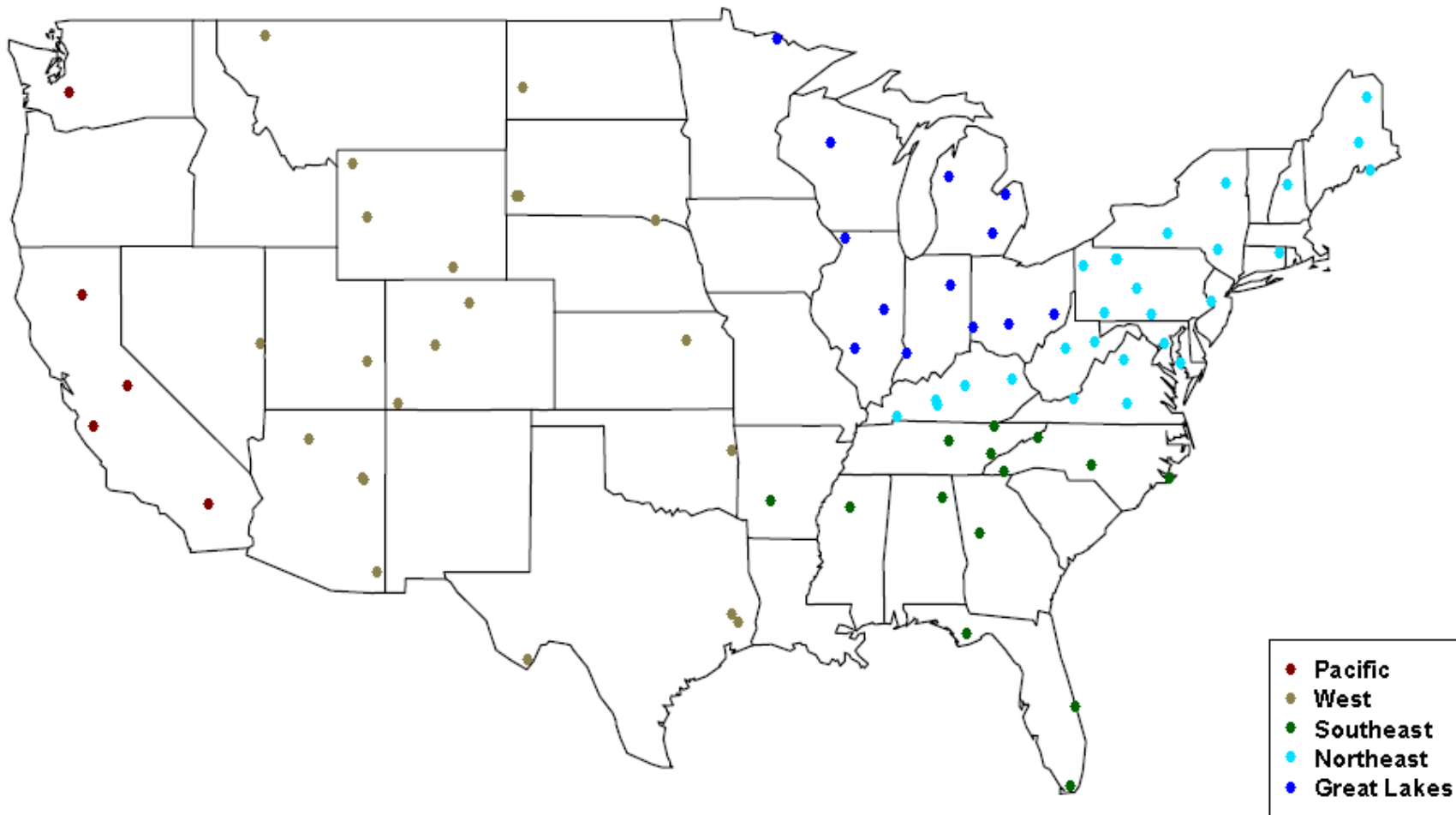


Dry vs Wet Deposition Trends: Sulfur

(at NADP Sites)



5 US Sub-regions of CASTNET Sites



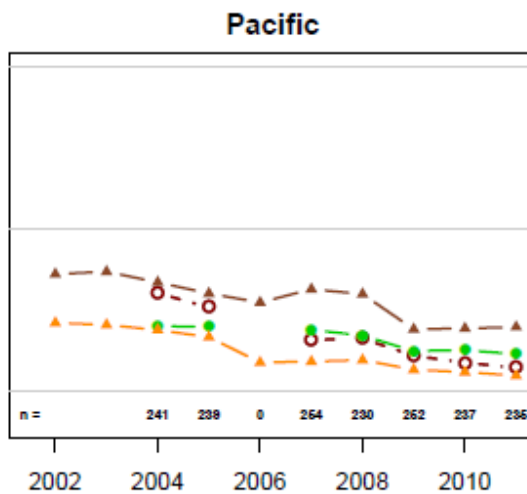
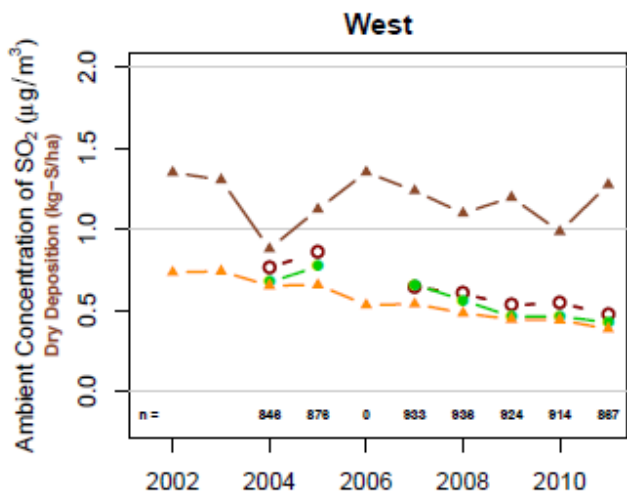
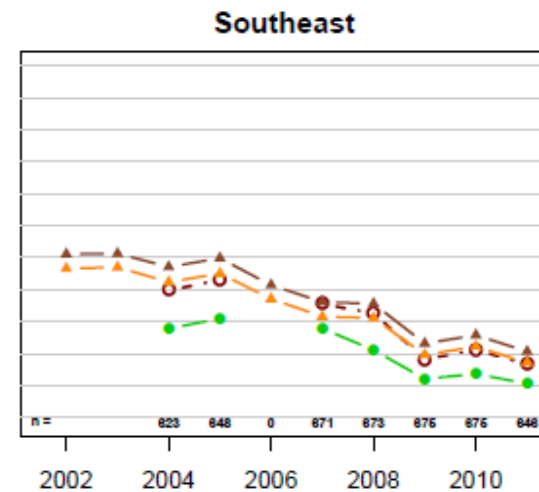
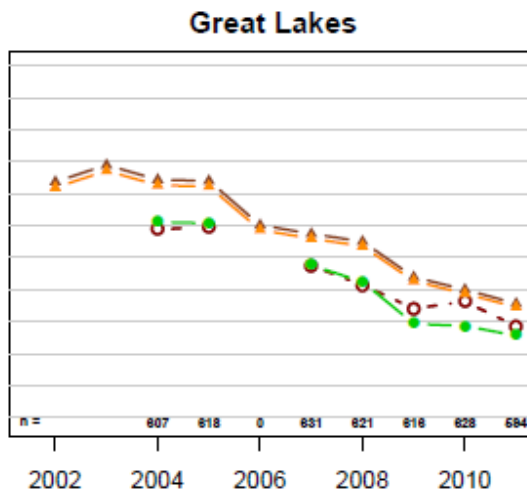
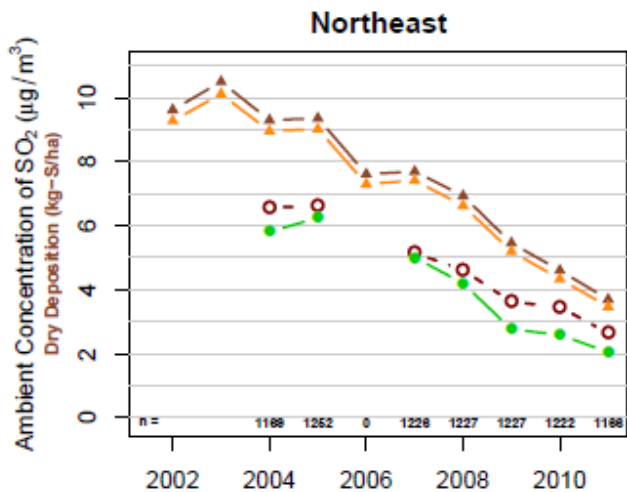
Dry vs Air Concentration Trends Ox-N & TNO₃-N Dry to TNO₃ Air (at CASTNET Sites)



Dry vs Air Concentration Trends

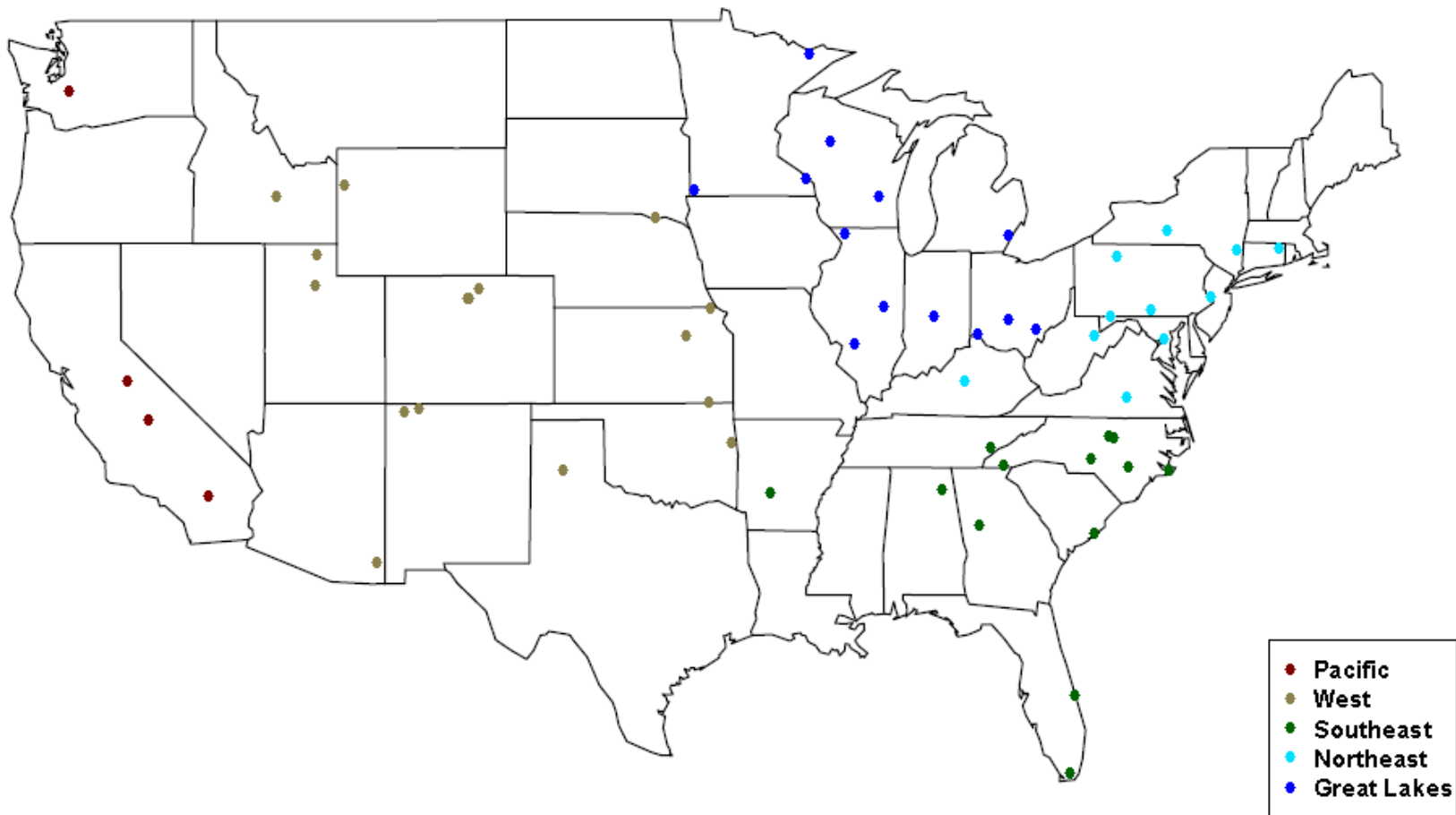
T-S & SO₂-S Dry to SO₂ Air

(at CASTNET Sites)



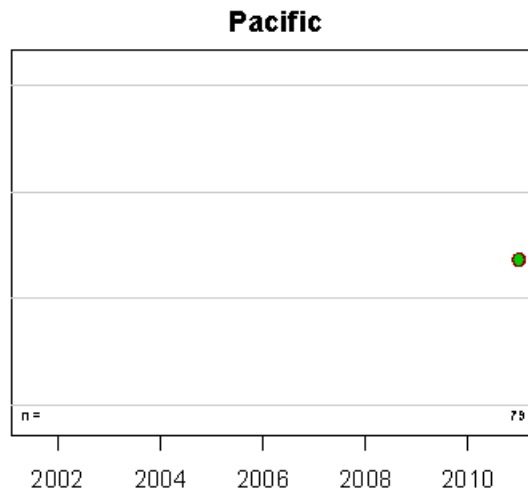
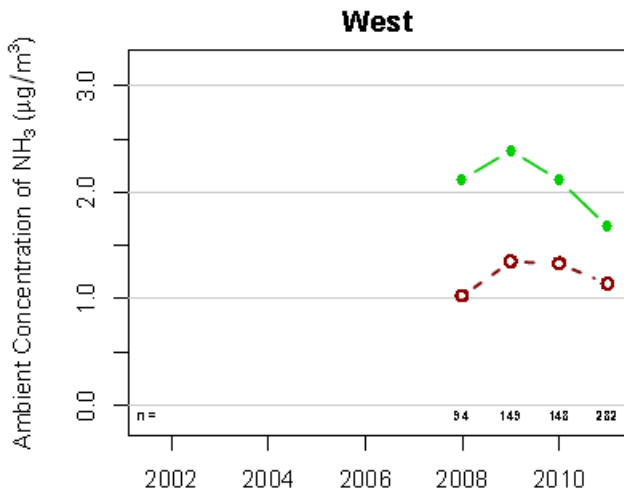
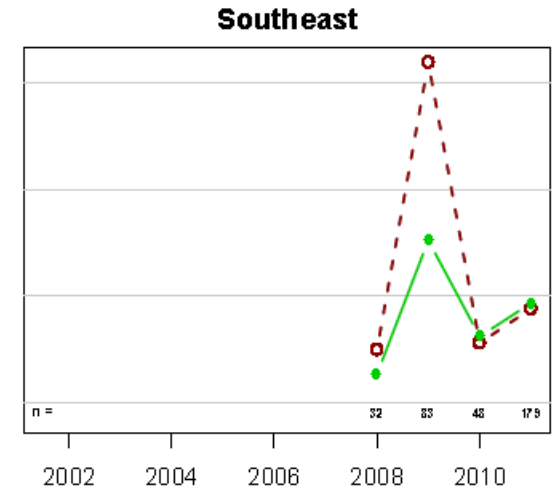
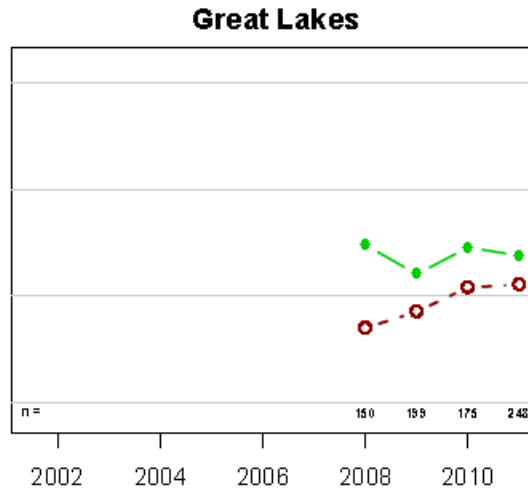
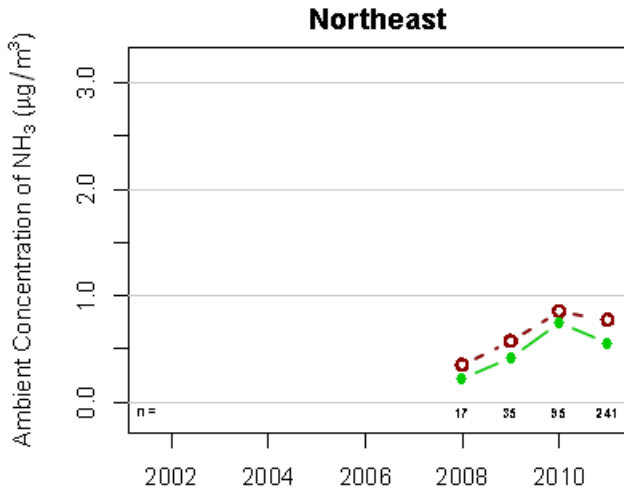
- CASTNet SO₂ Concentration
- CMAQ SO₂ Concentration
- ▲ CMAQ S Dry Deposition (kg-S/ha)
- ▲ CMAQ SO₂-S Dry Deposition (kg-S/ha)

5 US Sub-regions of AMON Sites



Air Concentration Trends

NH₃ (AMON)



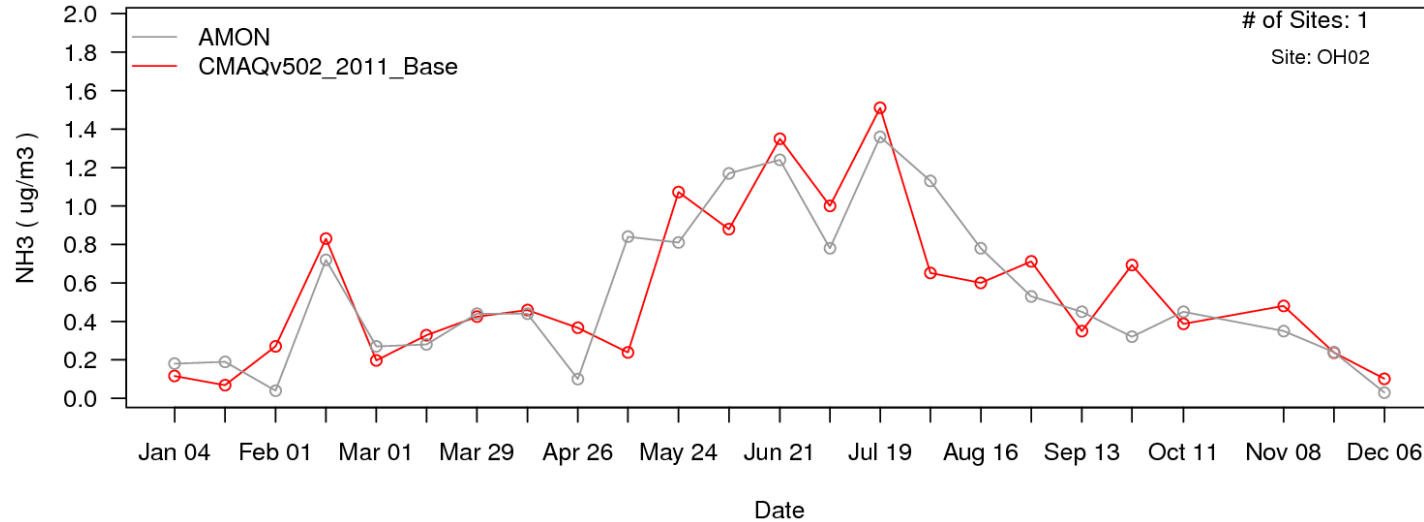
—●— AMON Observation
- -○- - CMAQ output

Air Concentration: 2011 Time Series

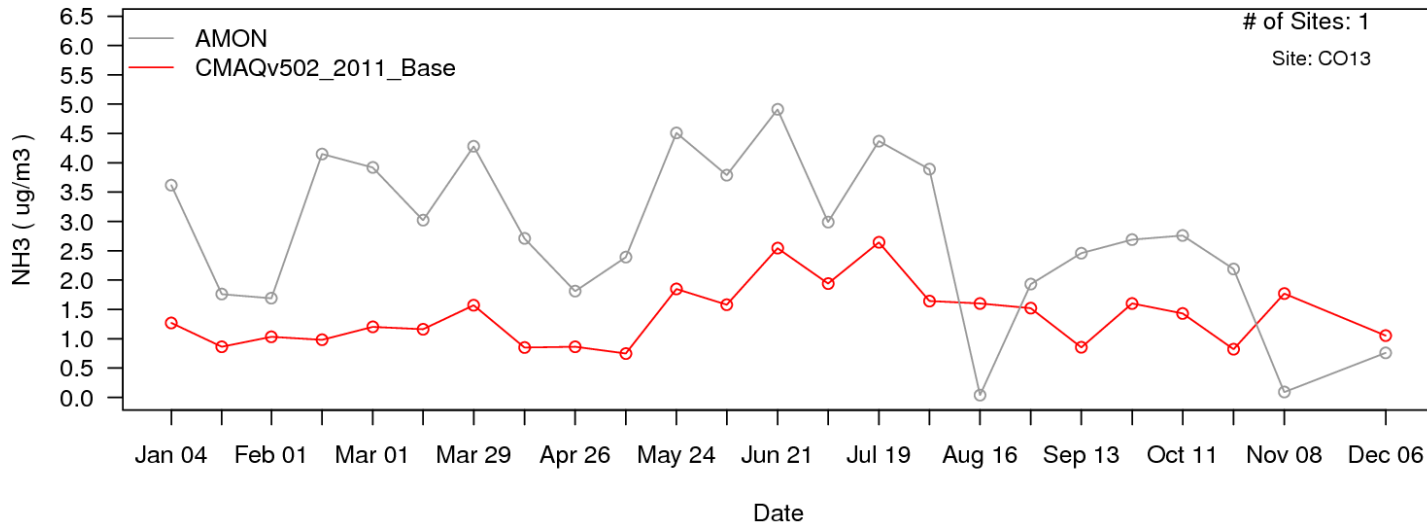
NH₃ (AMON)



CMAQv502_2011_Base NH3 for AMON Site: OH02 in OH



CMAQv502_2011_Base NH3 for AMON Site: CO13 in CO



Summary

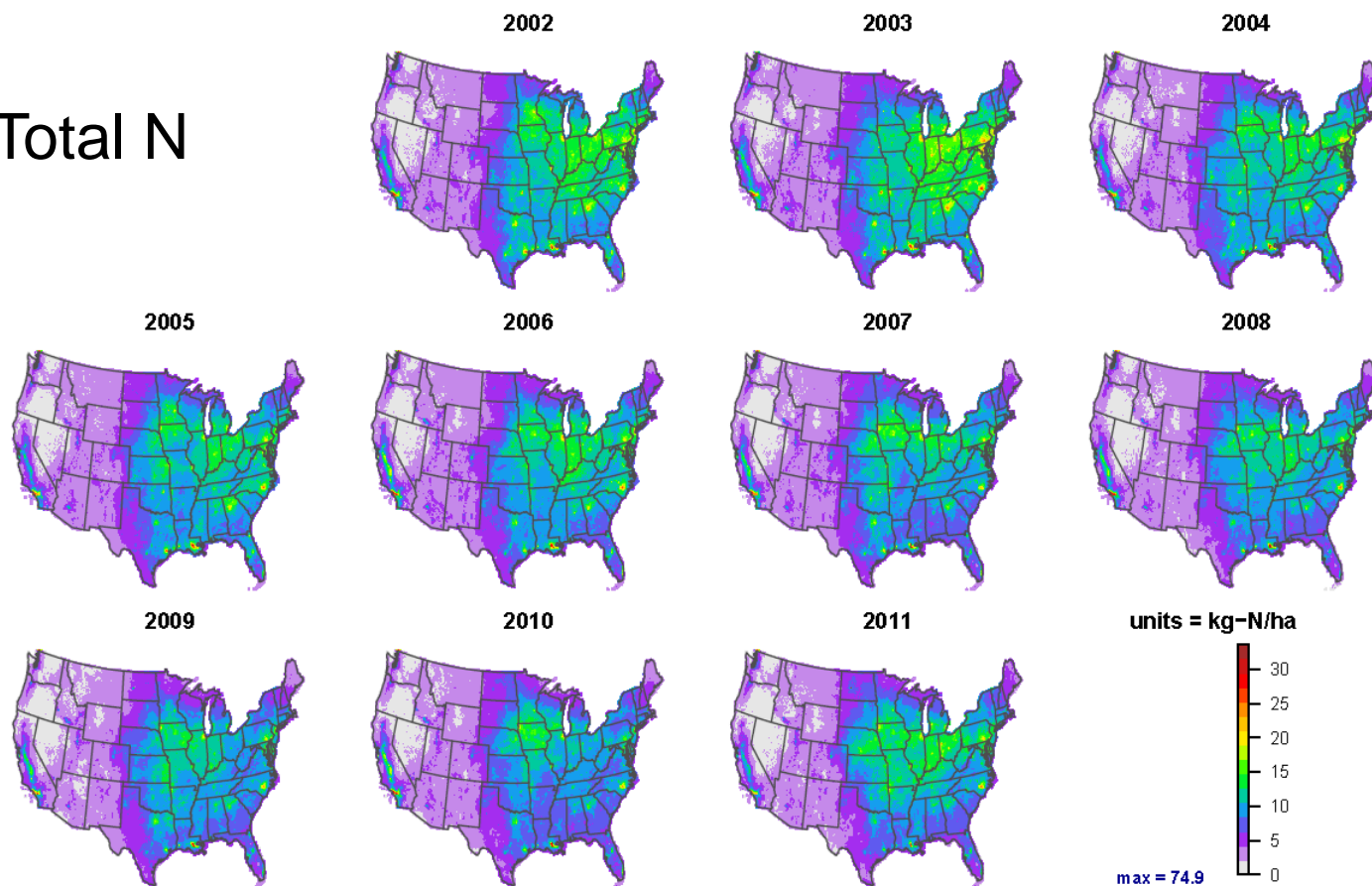
- Model performing fairly well at large scale, especially in eastern half of CONUS
 - Capturing the main trends well, except for 2002
- Balance between wet and dry deposition improved, with better “raw” wet deposition (more confidence)
- Still not getting the west very well.
 - Continues to need attention
- 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

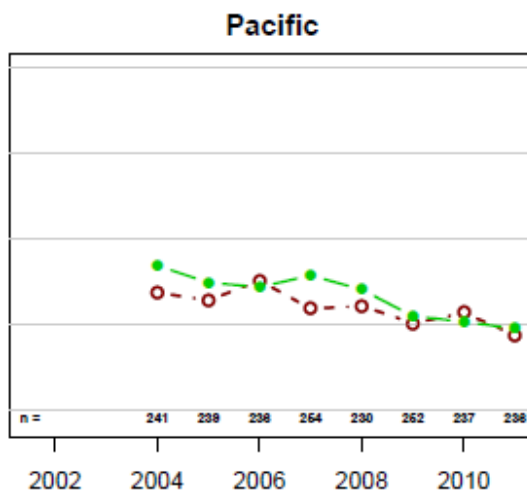
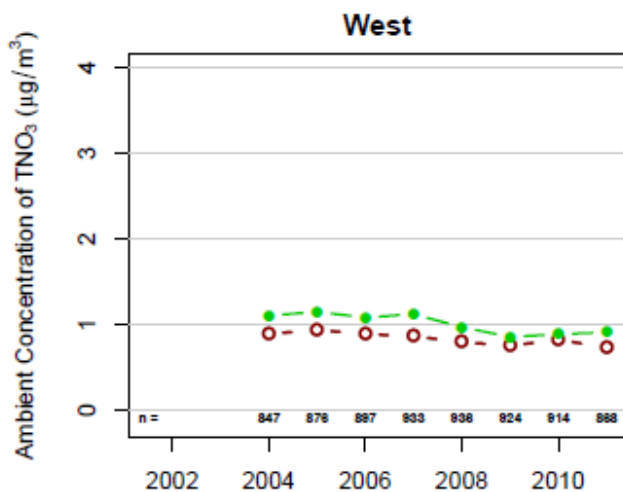
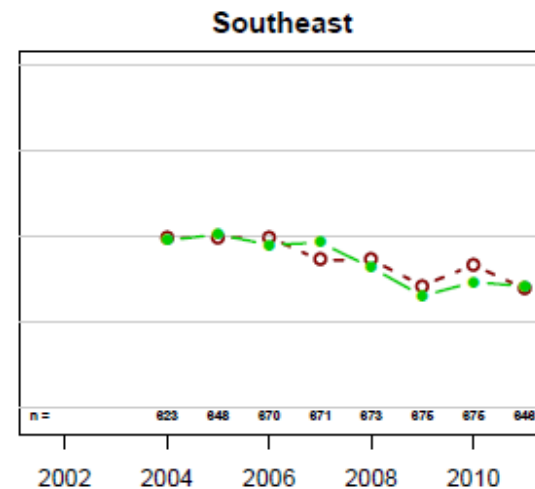
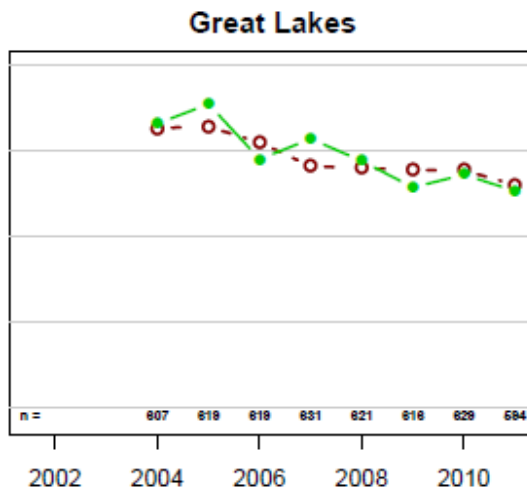
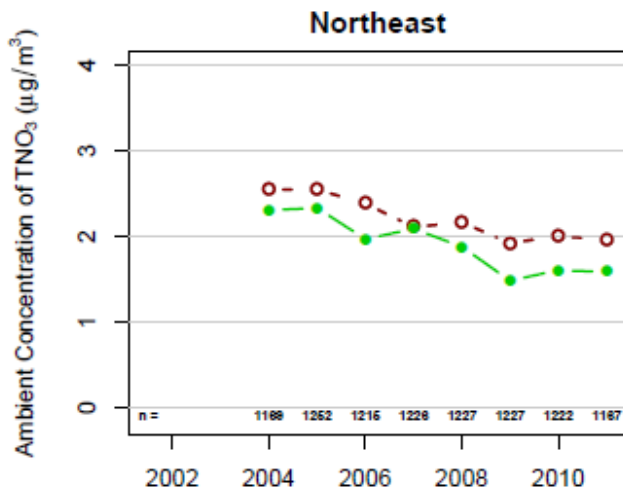




Extra Slides

Air Concentration Trends

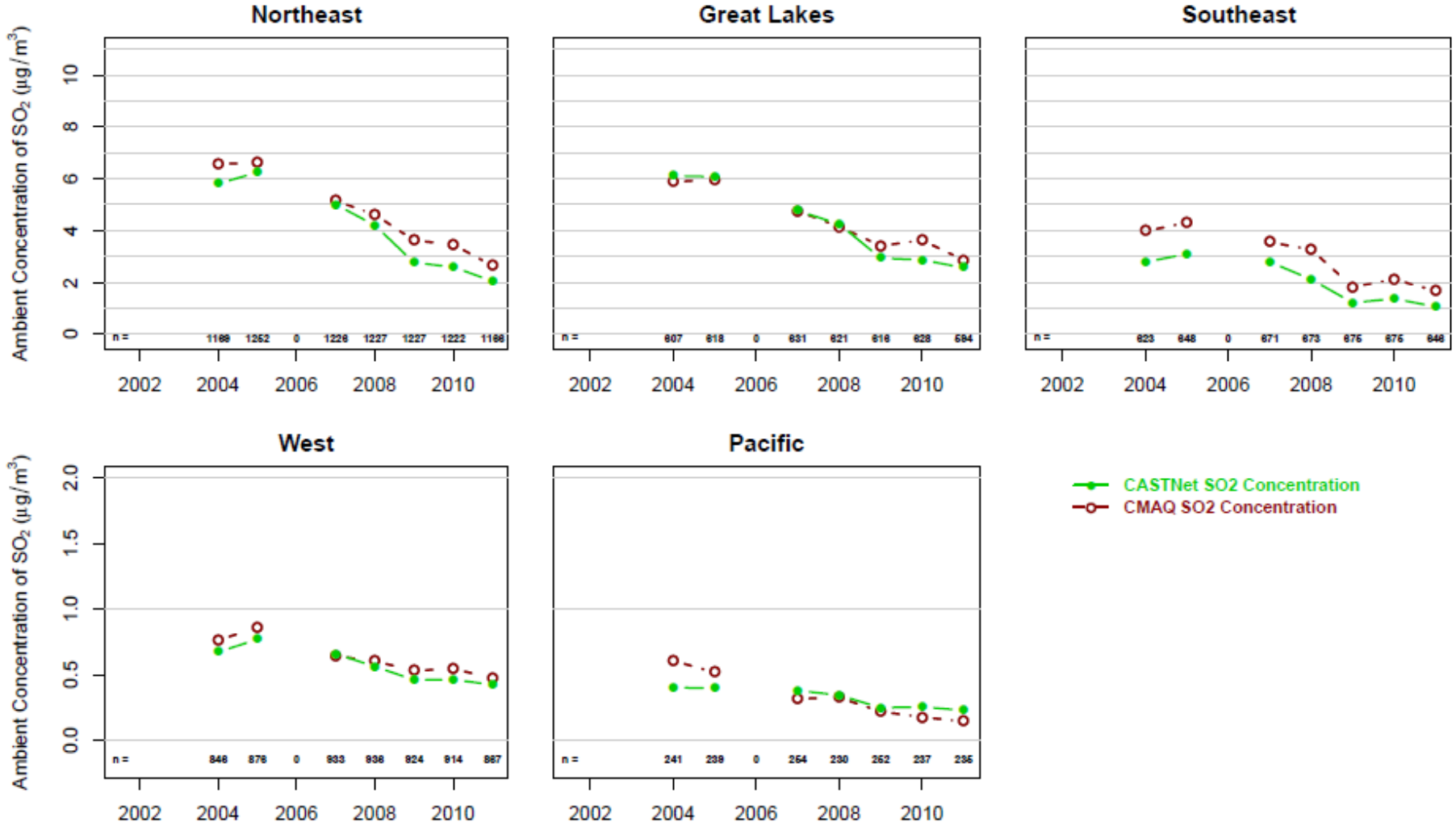
TNO₃ (CASTNET)



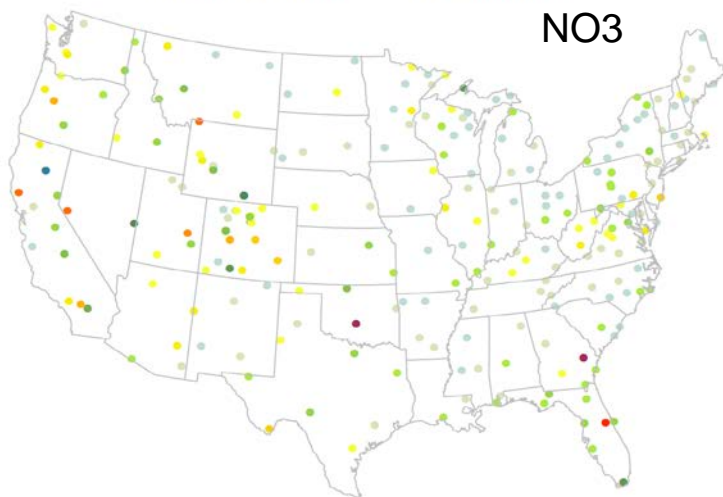
—●— CASTNet Observation
 -○- CMAQ output

Air Concentration Trends

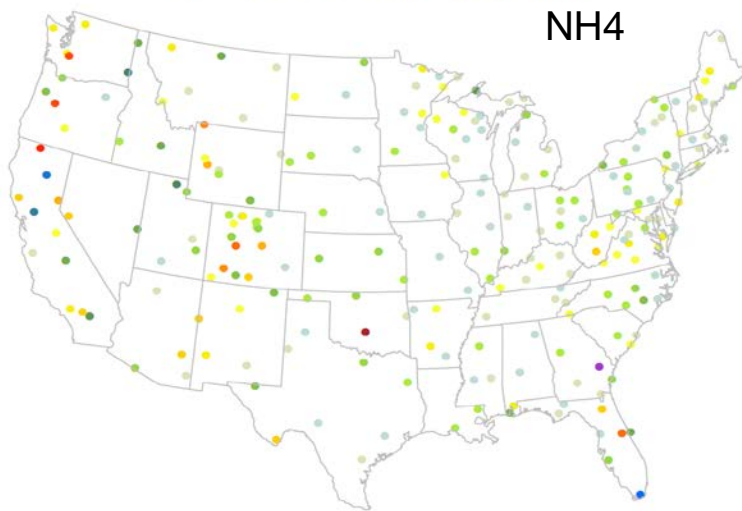
SO₂ (CASTNET)



PRISM Precip and Bias Adjusted Model/Observed NO3 Wet Deposition (kg/ha)

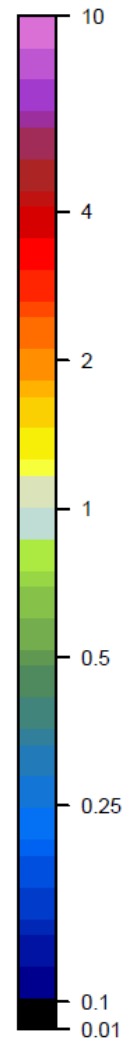
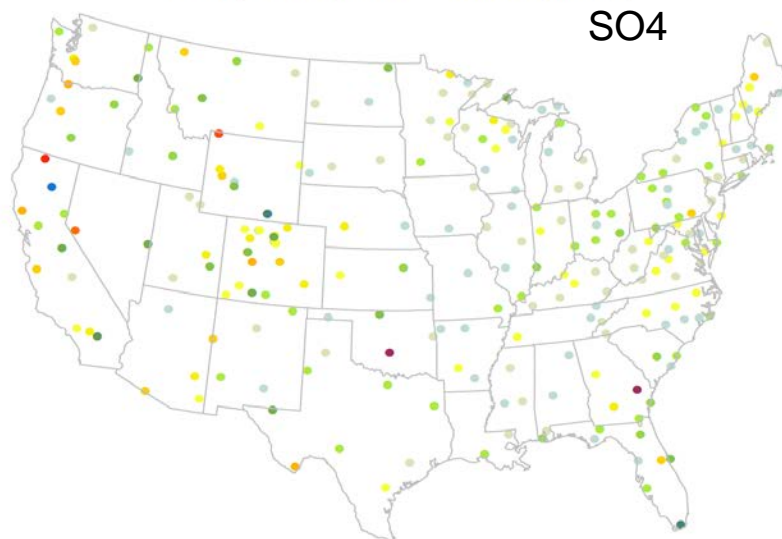


PRISM Precip. and Bias Adjusted Model/Observed NH4 Wet Deposition (kg/ha)



PRISM Precip. and Bias Adjusted Model/Observed SO4 Wet Deposition (kg/ha)

Wet Deposition Final Bias-Adjusted Model/Observation 2008



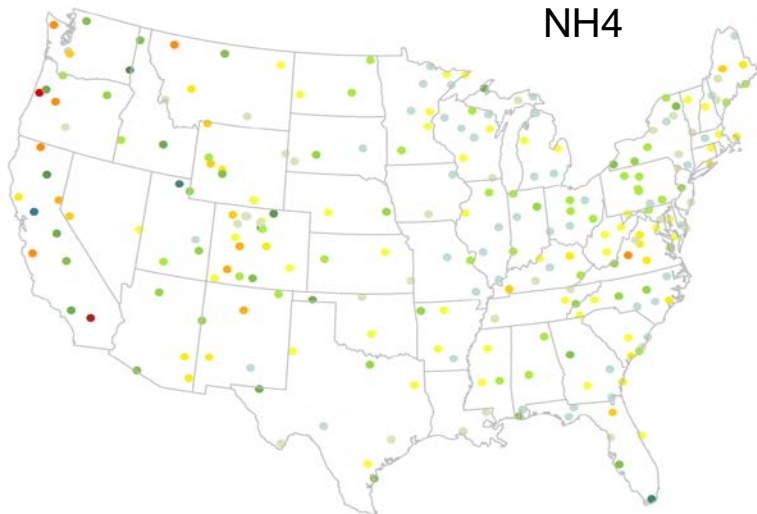
PRISM Precip and Bias Adjusted Model/Observed NO3 Wet Deposition (kg/ha)

NO3



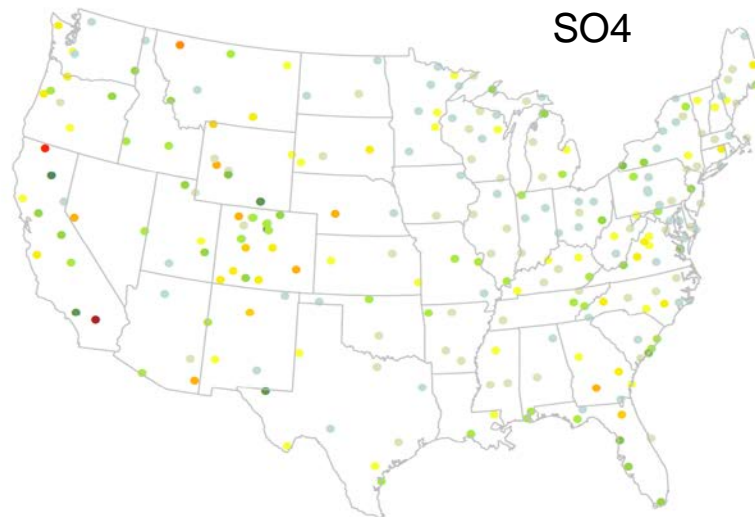
PRISM Precip. and Bias Adjusted Model/Observed NH4 Wet Deposition (kg/ha)

NH4



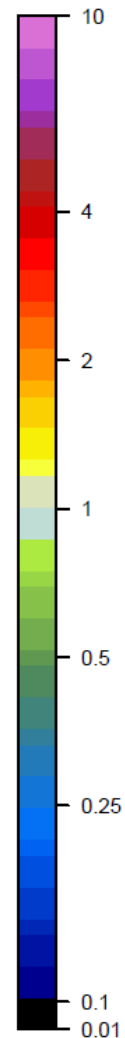
PRISM Precip. and Bias Adjusted Model/Observed SO4 Wet Deposition (kg/ha)

SO4



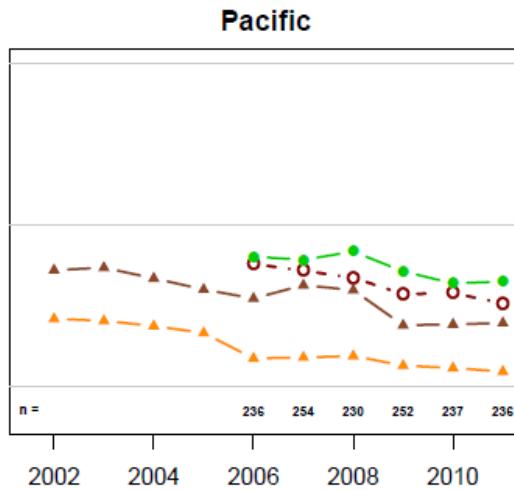
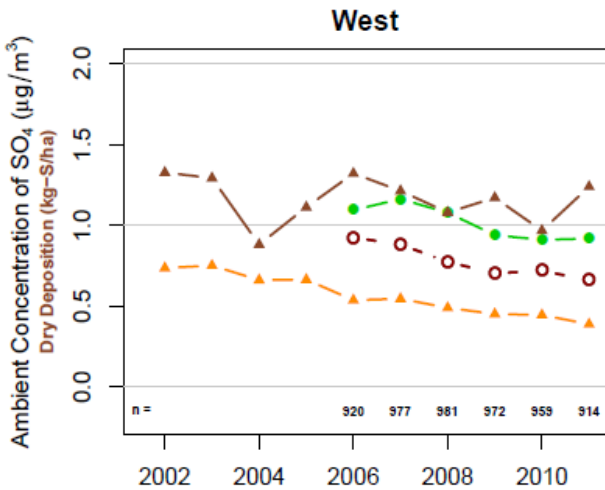
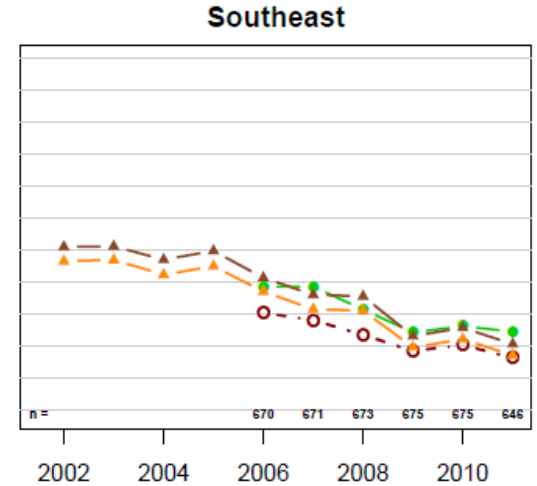
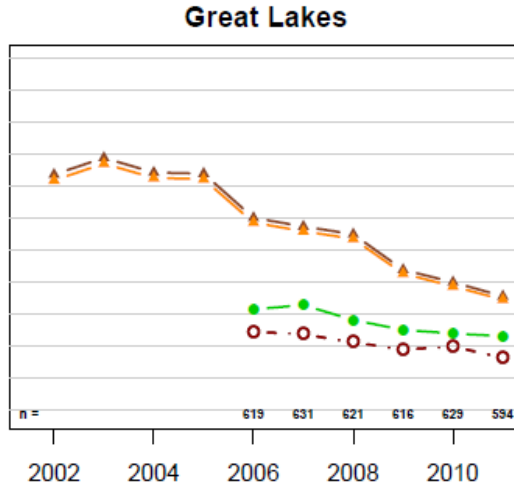
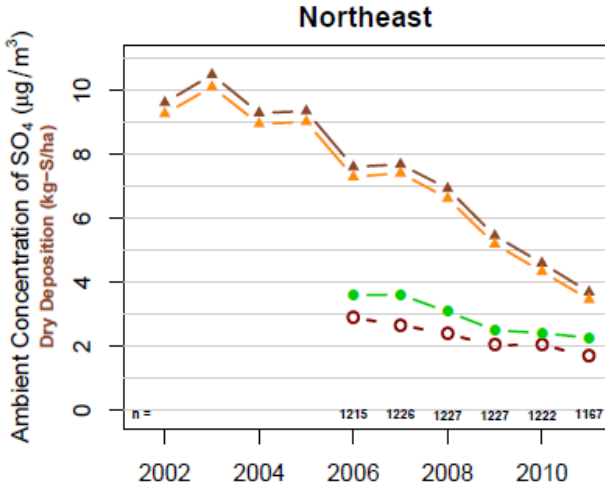
Wet Deposition
Final Bias-Adjusted Model/Observation

2006



Dry vs Air Concentration Trends

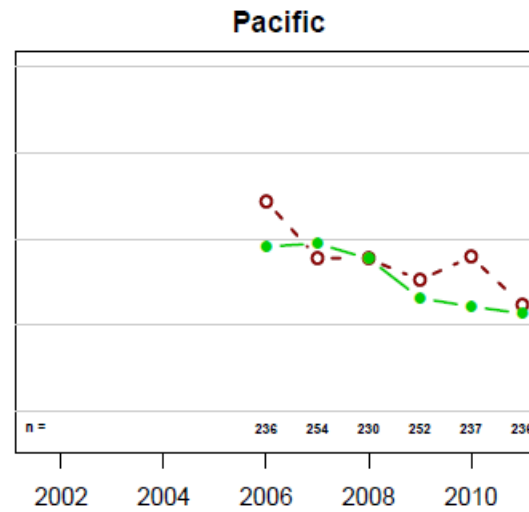
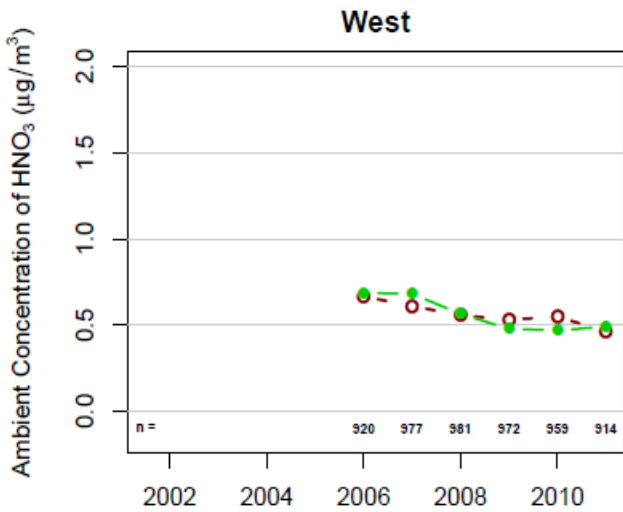
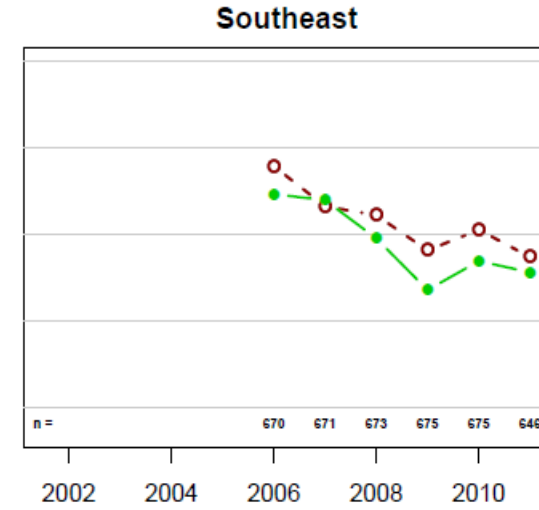
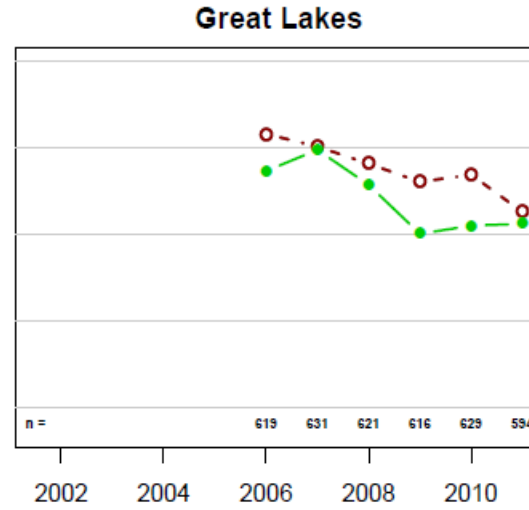
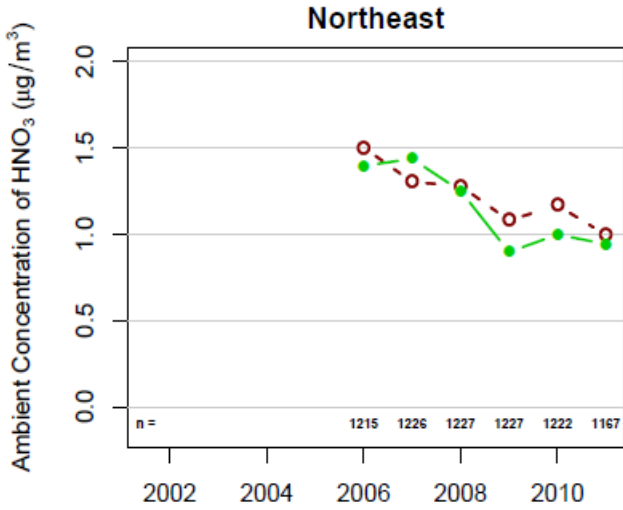
T-S & SO₂-S Dry to SO₄ Air



- CASTNet SO₄ Concentration
- CMAQ SO₄ Concentration
- ▲- CMAQ S Dry Deposition (kg-S/ha)
- ▲- CMAQ SO₂-S Dry Deposition (kg-S/ha)

Air Concentration Trends

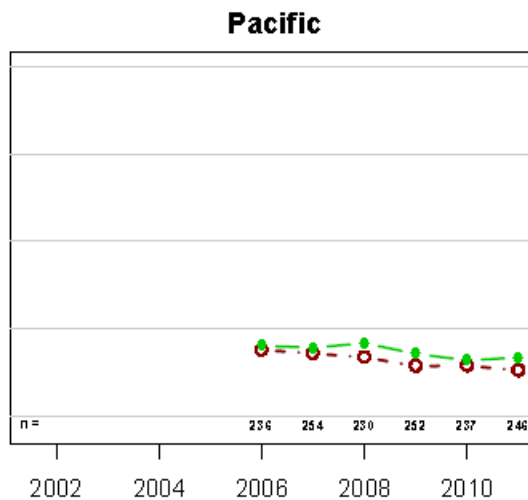
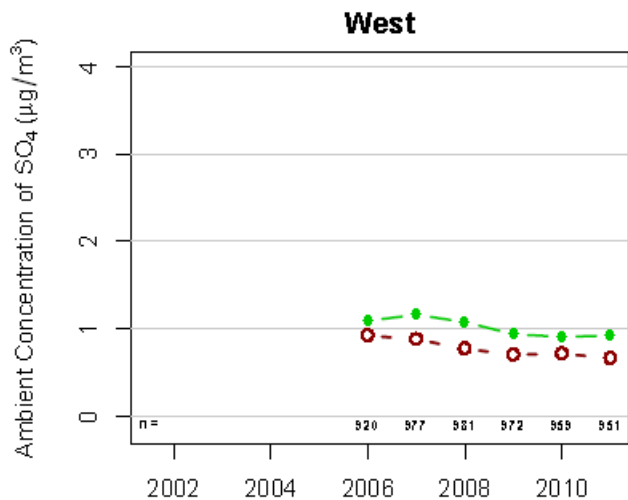
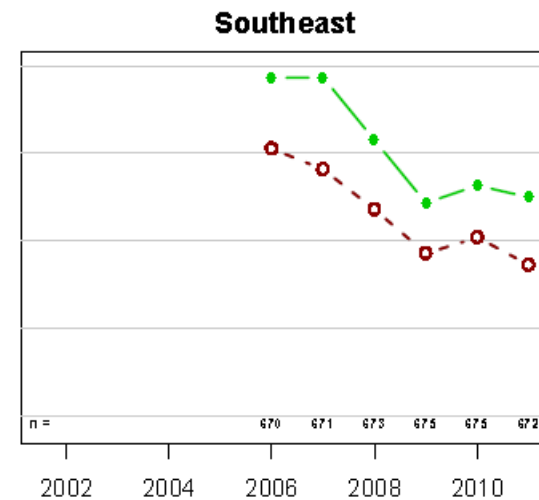
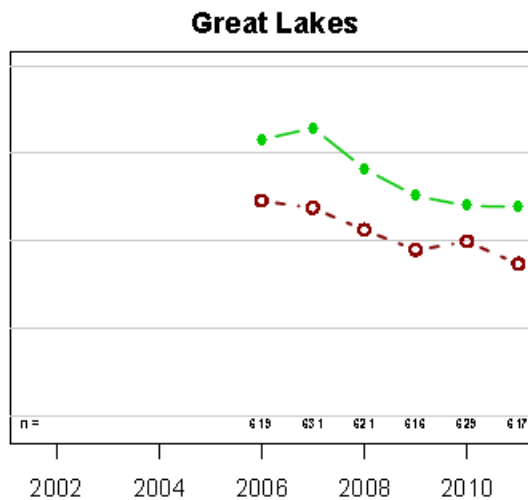
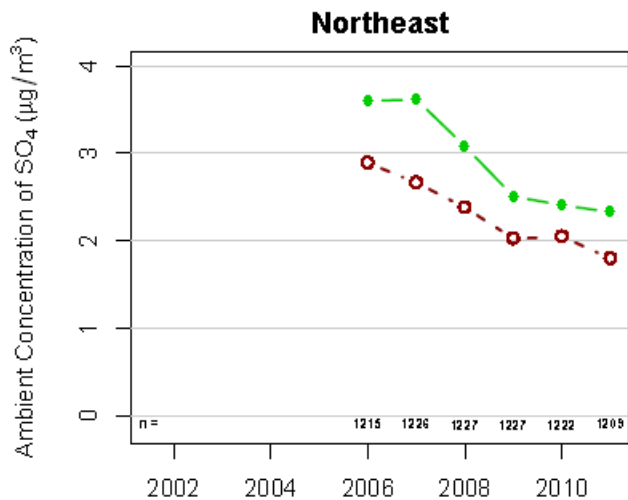
HNO₃



—●— CASTNet Observation
-○- CMAQ output

Air Concentration Trends

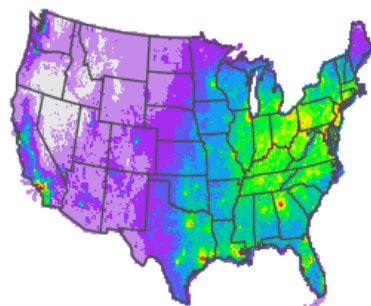
SO₄



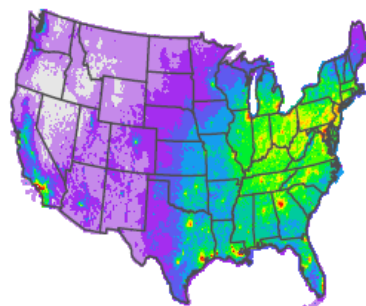
—●— CASTNet Observation
 -○- CMAQ output

Adjusted Total
Oxidized N

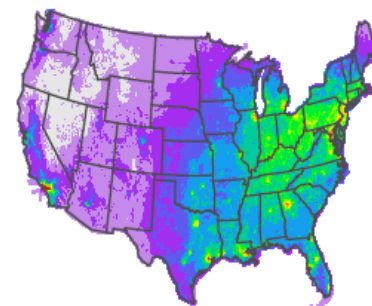
2002



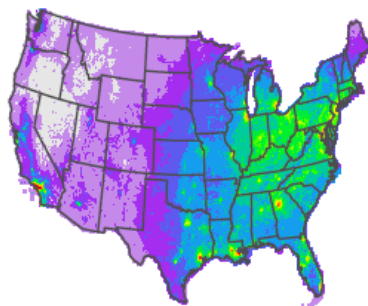
2003



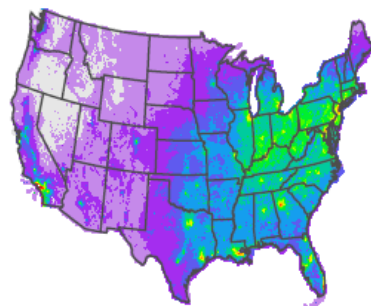
2004



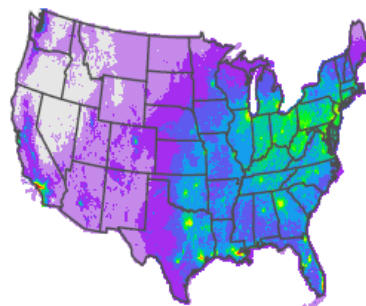
2005



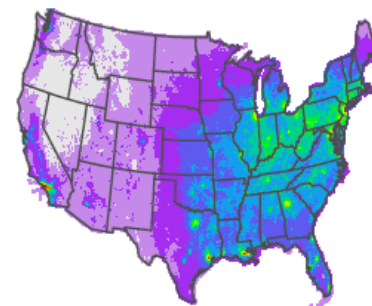
2006



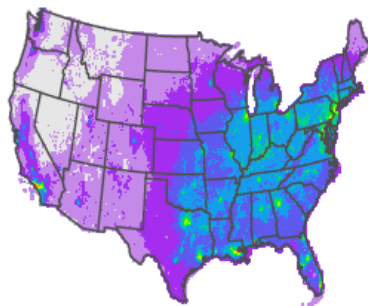
2007



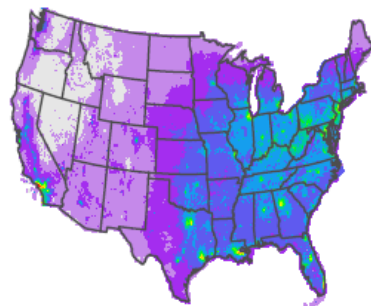
2008



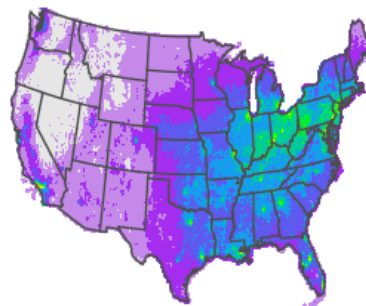
2009



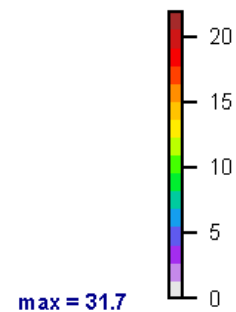
2010



2011

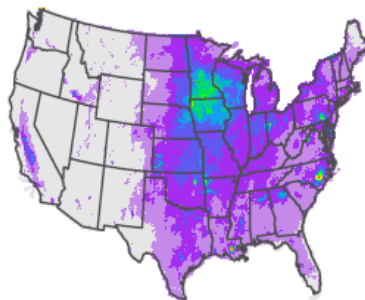


units = kg-N/ha

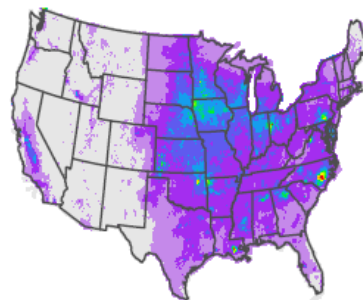


Adjusted Total
Reduced N

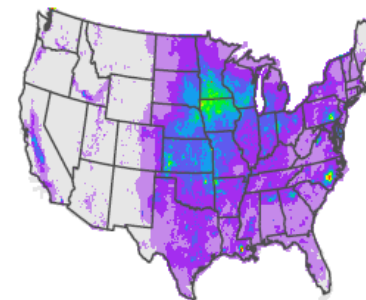
2002



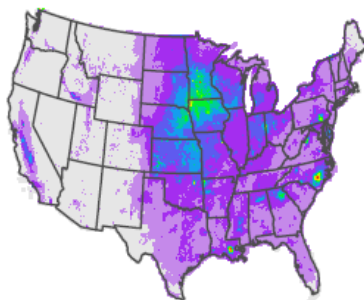
2003



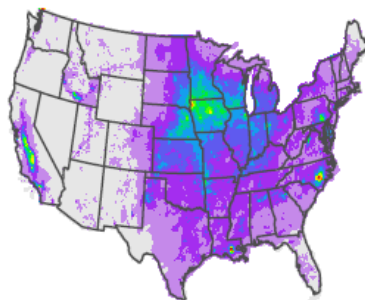
2004



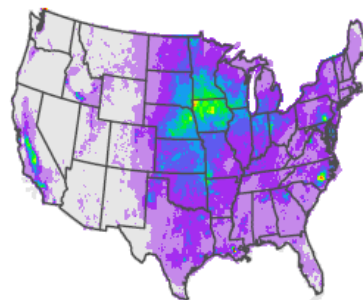
2005



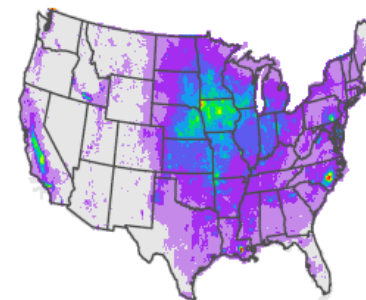
2006



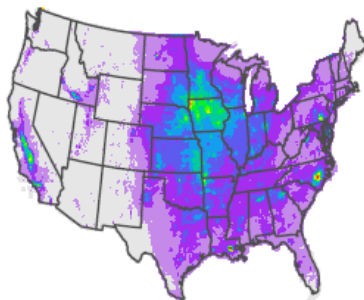
2007



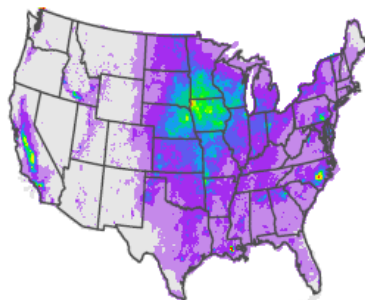
2008



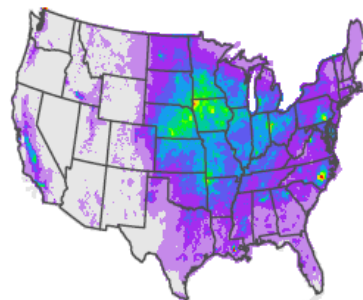
2009



2010



2011



units = kg-N/ha

