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Exploration of Nitrogen Total Deposition Budget Uncertainty at the Regional Scale

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NADP Annual Scientific Symposium
October 25-28, 2011
Providence, RI

Exploration of Nitrogen Total Deposition Budget Uncertainty at the Regional Scale

- We desire accurate deposition estimates for:
    - Nitrogen budget studies (nitrogen cascade)
    - Ecosystem impact studies
    - Secondary standards development and implementation
    - Critical loads studies
- We need models to fill in for sparse data and missing species
- We can evaluate wet deposition estimates with data and processed precipitation fields
- Dry deposition is more problematic due to the lack of data
    - With the resistance analog of dry deposition there are several pathways to be parameterized
    - Bi-directional ammonia adds another layer of complexity

The Dry Deposition Sensitivity Study

- We examined several source of uncertainty in the CMAQ parameterizations of dry deposition through sensitivity studies on a June 2006 time period
  - Stomatal resistance is constrained to be consistent with meteorological evapotranspiration. A key specie with an important stomatal component, NH_3, is treated as part of the bi-directional uncertainty
  - Deposition uncertainties investigated include cuticular, mesophyll and aerodynamic resistances and bi-directional emission potential.
    - PAN's were most affected by cuticular resistance uncertainties
    - NO and NO_2 were most affected by mesophyll resistance uncertainties
    - All (especially HNO_3) are affected by aerodynamic resistance uncertainties
    - NH_3 and NH_4^+ are most affected by emissions potential (Γ) uncertainties

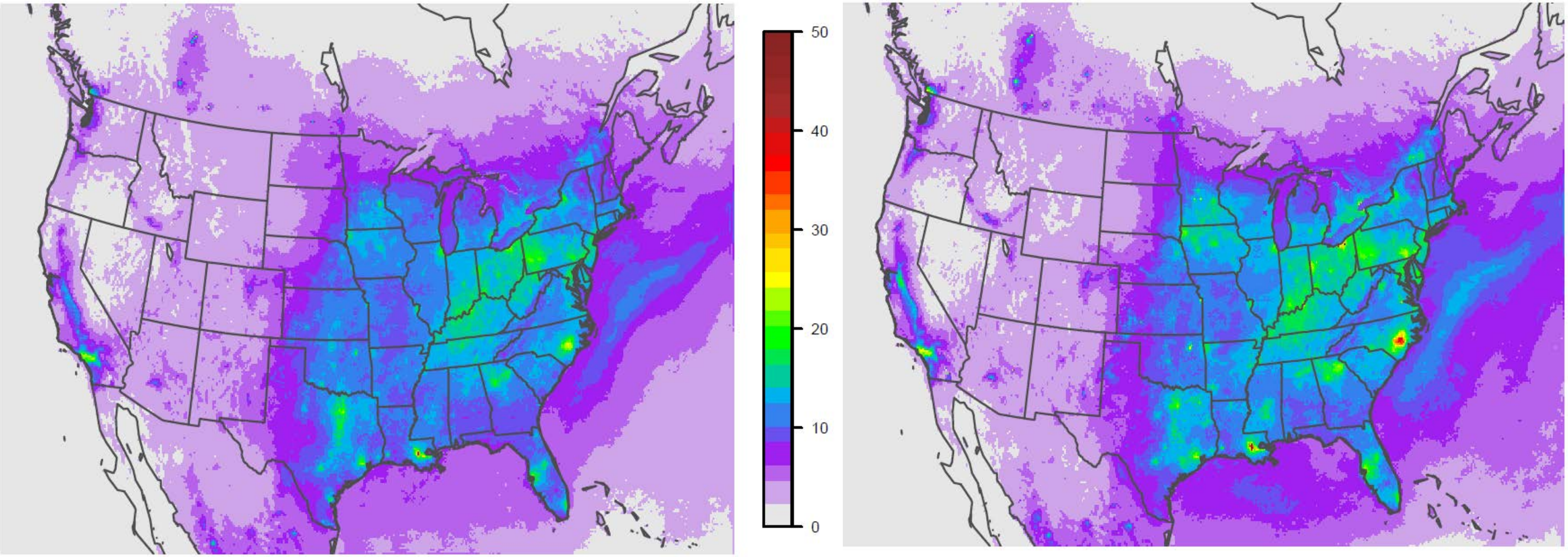
Continental Deposition Patterns

2002: Bi-Directional CMAQ

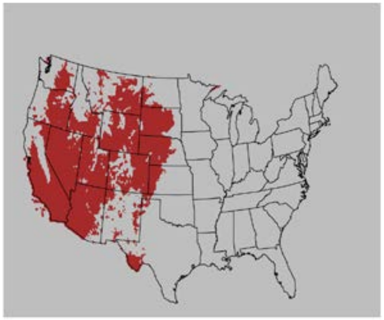
BIDI: 2002 Deposition Total (kg/ha)

2002 Unidirectional CMAQ

Base: 2002 Deposition Total (kg/ha)



Dry cells
Precip < 60 cm
Median = 43 cm



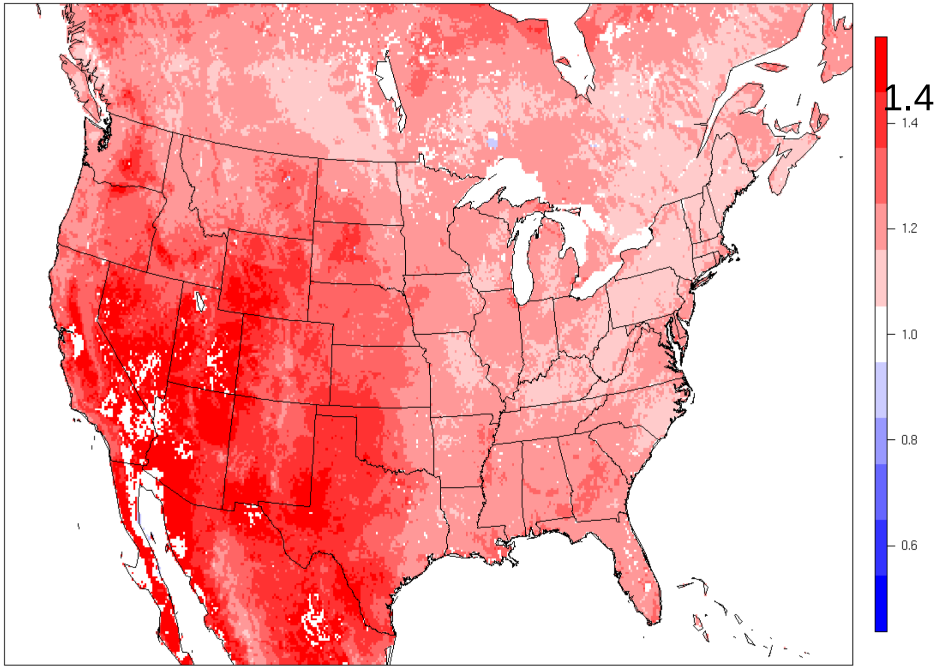
Wet cells
Precip > 90 cm
Median = 130 cm

Continental Deposition Budgets
2002 Annual (10^6 kg)

	Unidirectional CMAQ			Bi-Directional CMAQ	
Oxidized-N Total	3,927.4	63.0%		3,917.3	66.1%
WD Ox-N Total	1,666.9	26.7%		1,580.9	26.7%
DD Ox-N Total	2,260.5	36.3%		2,336.4	39.4%
NOx	216.3	3.5%		216.2	3.7%
HNO3	1,439.7	23.1%		1,513.5	25.5%
NO3$^-$	125.1	2.0%		119.0	2.0%
PAN’s	218.4	3.5%		223.3	3.8%
Ox-Organic-N	176.0	2.8%		178.2	3.0%
Other	85.1	1.4%		86.2	1.5%
Reduced-N Total	2,305.5	37.0%		2,009.9	33.9%
WD Red-N Total	1,195.0	19.2%		1,357.6	22.9%
DD Red-N Total	1,110.5	17.8%		652.3	11.0%
NH3	1,001.4	16.1%		547.6	9.2%
NH4$^+$	109.1	1.8%		104.6	1.8%
TOTAL N Deposition	6,232.9	100.0%		5,927.2	100.0%

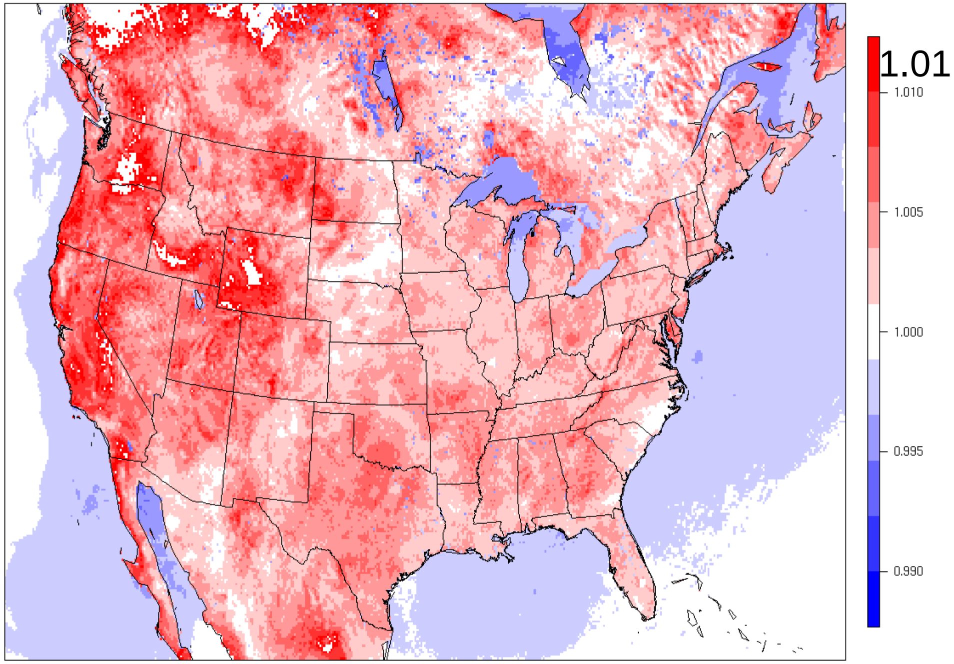
Cuticular Resistance Sensitivity June 2006: 50% Increase (unidirectional CMAQ)

Base/Sensitivity: PANT+ORGN



Base/alpha_pan_m50 Deposition PAN+ORGN

Base/Sensitivity: Total (wet+dry) Ox-N



Base/alpha_pan_m50 Deposition TD_OXN_TOT

ORGN = oxidized organic nitrates, such as alkyl nitrates: (CB05 NTR)

Cuticular Sensitivity: June 2006 (unidirectional CMAQ)

PAN + Oxidized Organic N Sensitivity
50% Increase in Cuticular Resistance

Continental US		Absolute change (10^3 kg)	Relative change
Sensitivity	PAN’s + Organic Ox-N	2,244.6	18.2%
Competing oxidized Species	Dry Total Nitrate	-542.4	-0.34%
	Wet Total Nitrate	-392.9	-0.24%
	Other Oxidized N	-22.1	-0.09%
	Total Oxidized N	1,287.3	0.36%
	Total Reduced N	13.1	0.005%
Resultant Change	Total N Deposition	1,300.1	0.20%

Overall change is not large, less than 0.5%; PAN’s are not a large part of budget. The chemical interactions among the oxidized nitrogen species, due to photo-chemistry, rebalanced the species, with the total decrease being just 58% as large as the original PAN’s+Organic Ox-N decrease.

Chemistry can offset changes in the overall removal, nearly cutting response in half.

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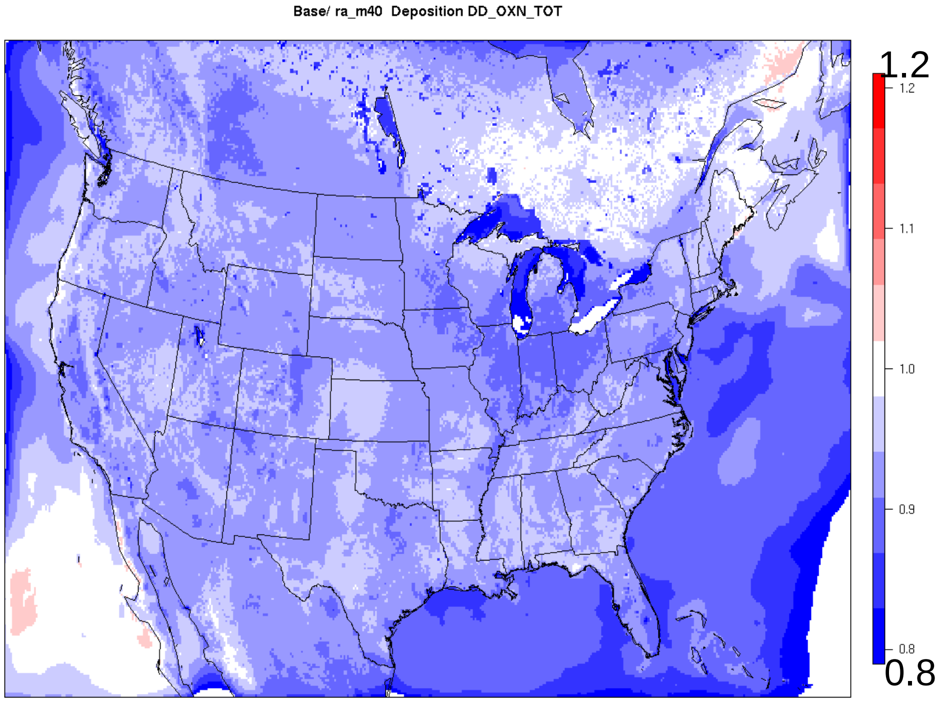
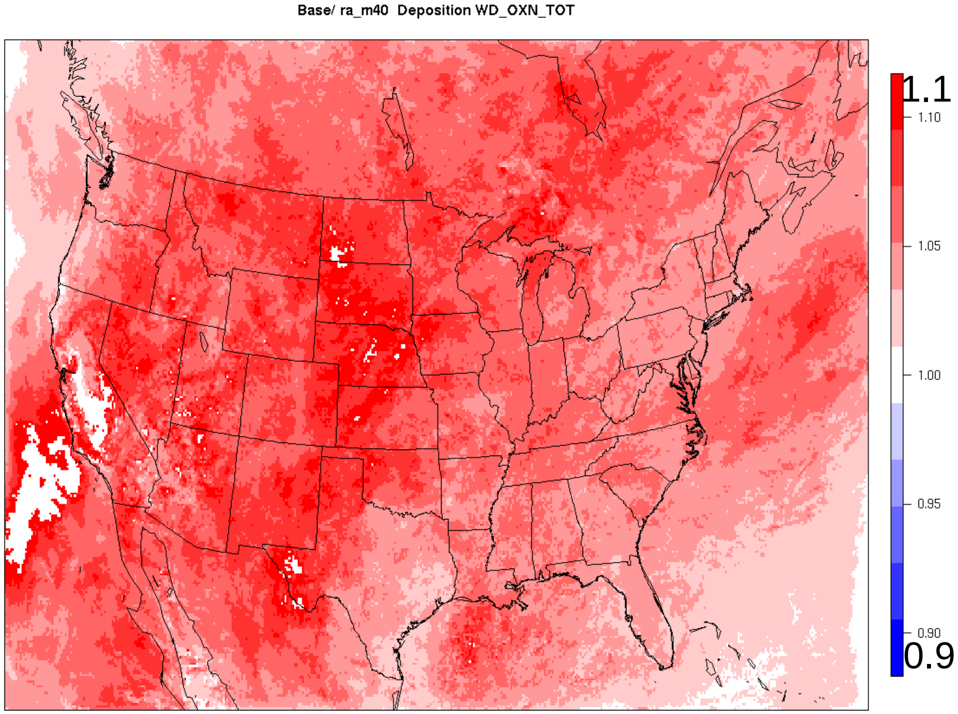
Aerodynamic Resistance Sensitivity June 2006: Decrease by 40% (unidirectional CMAQ)

Base/Sensitivity: Dry Ox-N Dep

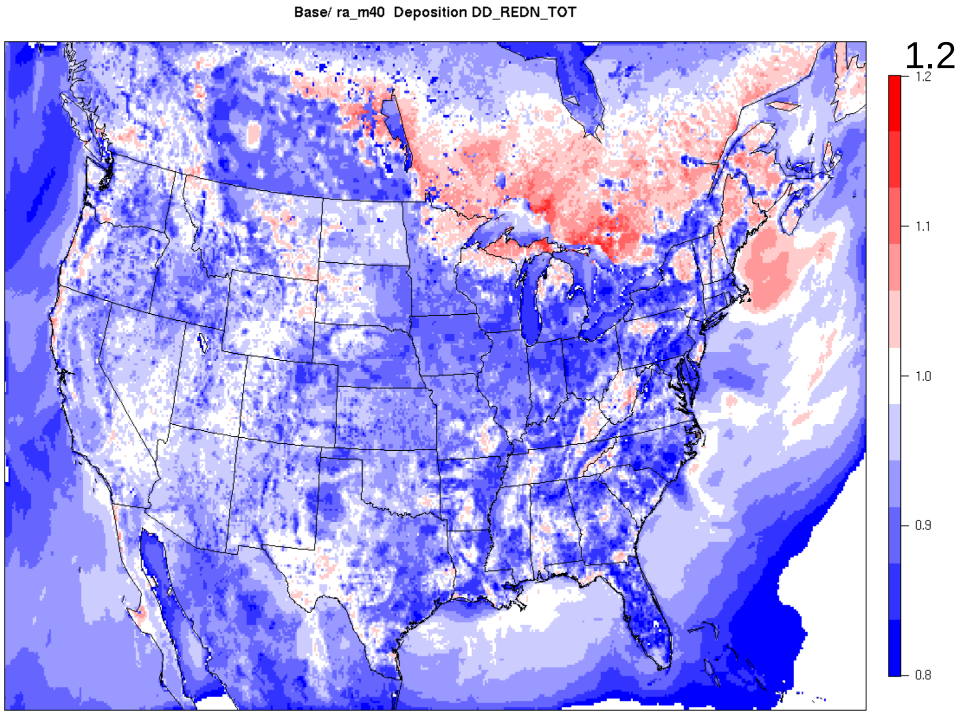


Base/Sensitivity: Wet Ox-N Dep

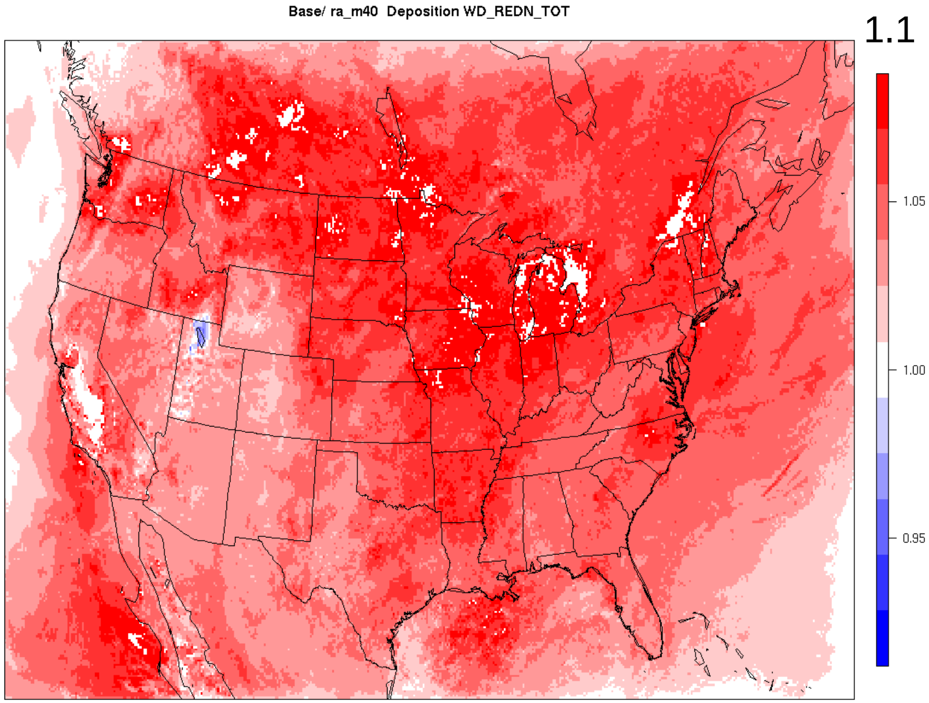


Aerodynamic Resistance Sensitivity June 2006: Decrease by 40% (unidirectional CMAQ)

Base/Sensitivity: Dry Red-N Dep

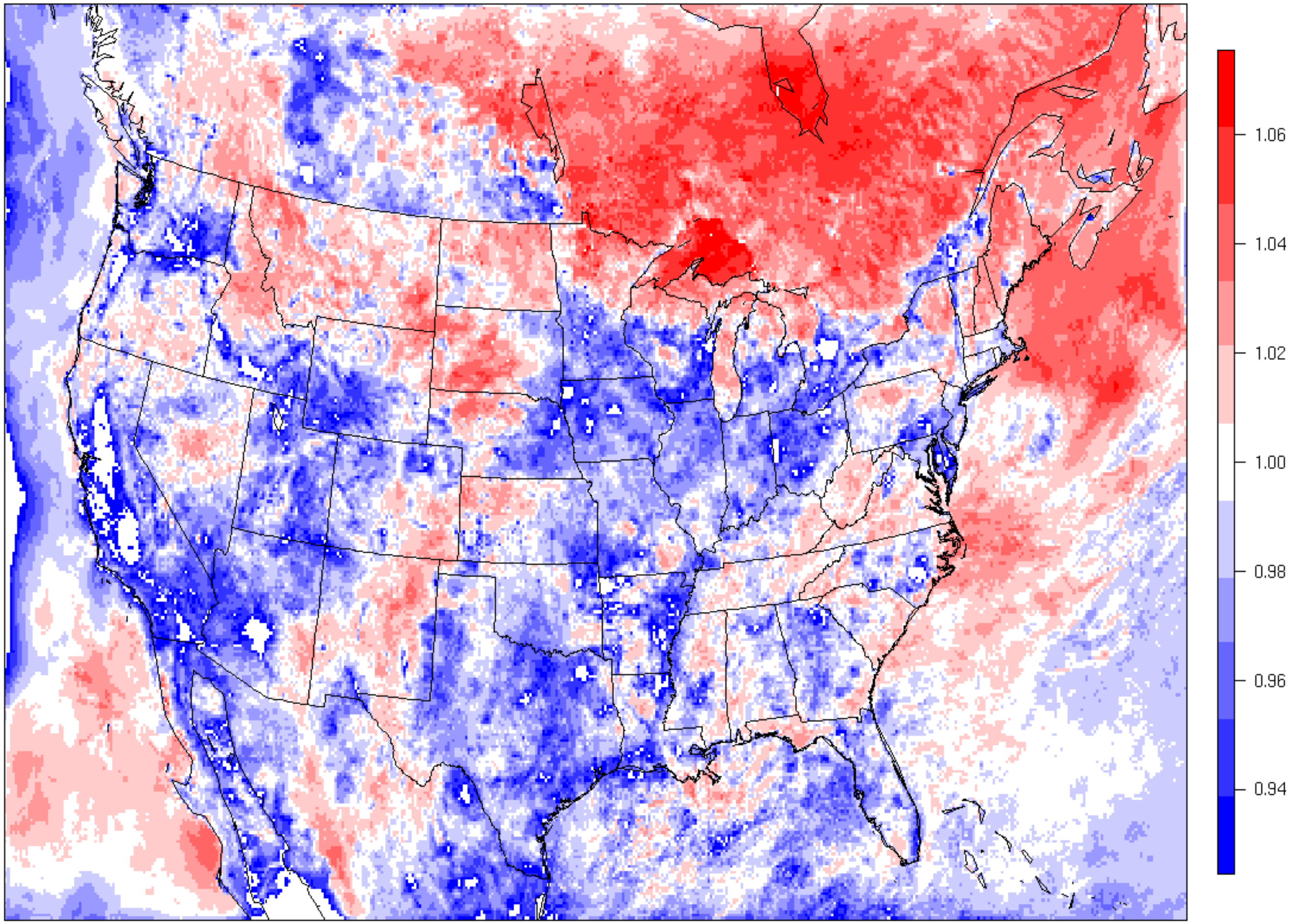


Base/Sensitivity: Wet Red-N Dep



Aerodynamic Resistance Sensitivity June 2006: Decrease by 40% (unidirectional CMAQ)

Base/Sensitivity: Total (wet+dry & Red-N+Ox-N) N



Aerodynamic Resistance Sensitivity June 2006: Decrease by 40% (unidirectional CMAQ)

Aerodynamic Sensitivity: 40% Decrease in Resistance			
	Continental U.S. Domain Species	Absolute Change (10^3 kg)	Relative Change
Sensitivity Species	Dry Oxidized-N Total Nitrate	-13,280.2	-8.3%
	Dry Oxidized-N Other	-2,011.6	-5.8%
	Dry Reduced-N	-13,982.4	-10.5%
	Dry Deposition Total Change	-29,274.2	-8.9%
Competing Species	Wet Oxidized-N Total Nitrate	9,489.7	5.9%
	Wet Oxidized-N Other	14.6	.43%
	Wet Reduced-N	8,067.3	5.5%
	Wet Deposition Total Change	17,571.6	5.6%
Resultant	Total N Deposition Change	-11,702.6	-1.8%

The overall change is not large, around 2% due to rebalancing of pathways. In this case the dry and wet deposition removal pathways move in opposite directions with the wet deposition offsetting 60% of the dry deposition change.

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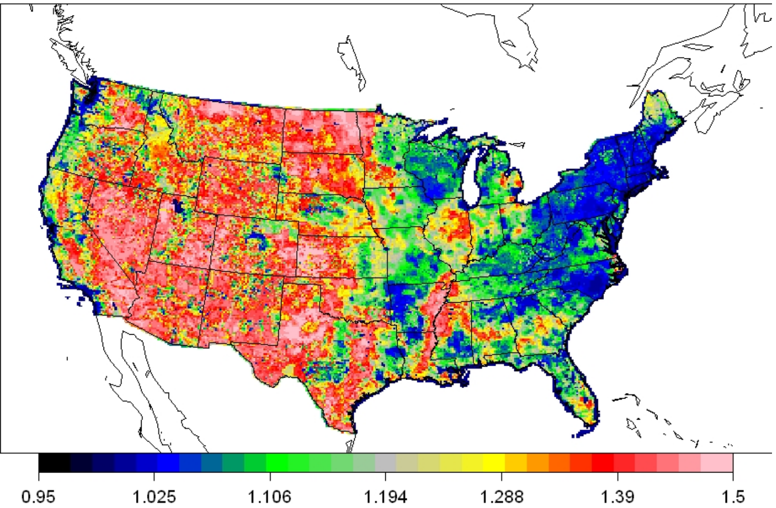
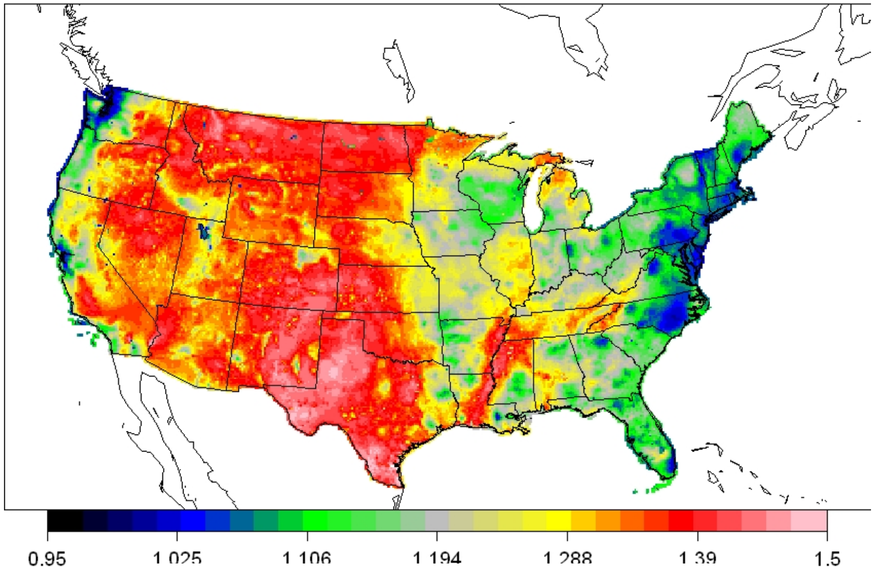
Bi-Directional Air-Surface Exchange
June 2006: Sensitivity to 150% Soil Gamma

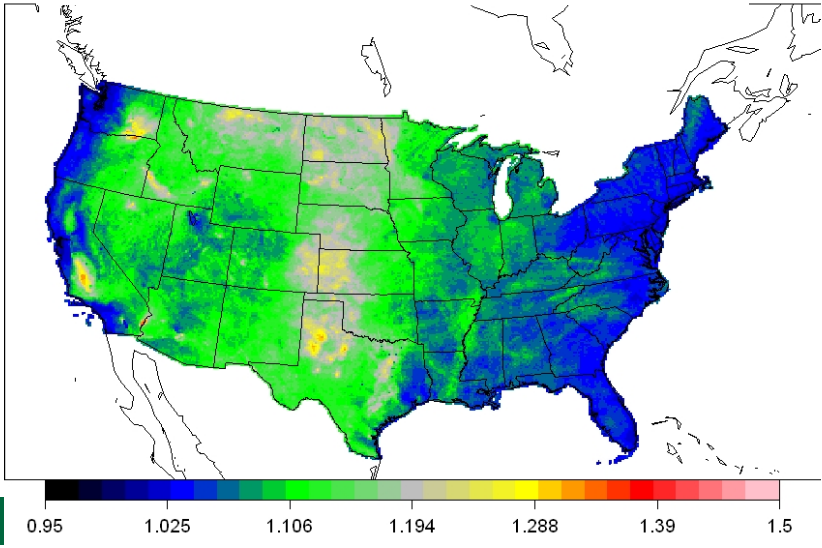
Sens/Base: NH_3 Emissions



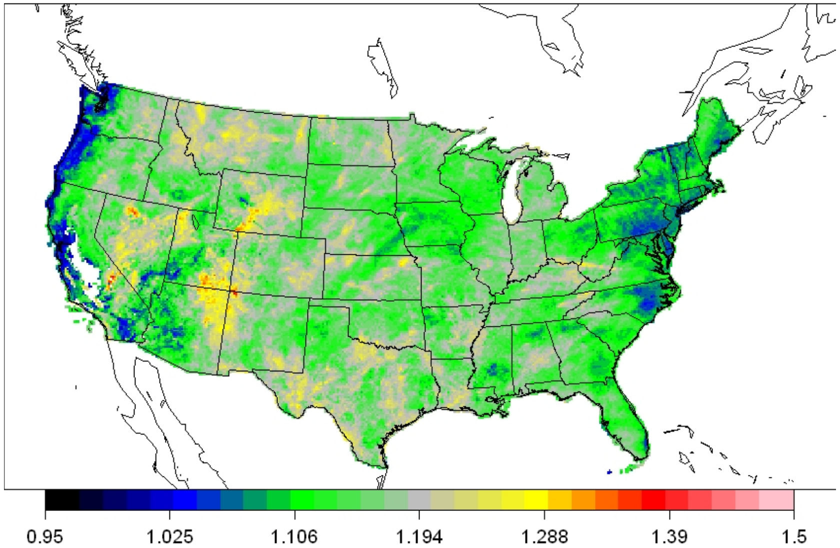
Sens/Base: Red-N Dry Deposition



Sens/Base: Total Ox-N+Red-N Dep



Sens/Base: Red-N Wet Deposition



Bi-Directional Air-Surface Exchange June 2006: Sensitivity to Soil Gamma

Gamma Soil Sensitivity

Relative Change for 150% Increase in Gamma Soil

	Fertilizer Emiss.	Total NH3 Emiss.	NH3 Air Conc.	NH4+ Air Conc.	Red-N Dry Dep	Red-N Wet Dep	Red-N Total Dep	Total N Deposition
CONUS	49%	28%	28%	2.6%	30%	15%	20%	10%
Wet Domain	48%	20%	21%	2.5%	24%	14%	17%	7.4%
Dry Domain	49%	36%	35%	2.2%	34%	17%	26%	14%

Change in NH_3 emissions dominates the nitrogen deposition response, up to a 26% response of reduced-N deposition, 14% response in N deposition.

Dry NH_X deposition follows the NH_3 emissions change.

Wet NH_X deposition lags in its response to the NH_3 emissions change (half as large).

The result is a change in the amount of the budget transported off the continent

Working with soil Γ's is a new, flexible way to work with fertilizer emissions uncertainty

Summary

- Unidirectional dry deposition parameterizations are not a major source of uncertainty regarding continental-scale nitrogen budgets (< 5%)
- Bi-Directional parameterization uncertainties do lead to budget uncertainties (order of 20-25%) due to impact on NH_3 emissions
- Uncertainty analyses need to be conducted with the full chemical transport model, not stand-alone deposition models or simple models, to best represent the dynamic interactions of the system
- These sensitivities can provide insights into the types of measurements that can help reduce the uncertainties, such as establishing representative gammas
- Emissions errors are a dominant issue related to local, regional and continental scale deposition budgets and they need to be addressed
- We want to eliminate missing pathways for removal, such as cloud impaction as these can be as large as other sources of error
- Subgrid issues involving concentrations and deposition are still important to address relative to providing deposition estimates for critical loads