Integrated Science Assessment for Oxides of Nitrogen and Sulfur – Environmental Criteria

2nd External Review Draft

Presentation to the

Clean Air Scientific Advisory Committee

National Center for Environmental Assessment
US EPA Office of Research and Development

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Framework for Causal Determinations

- A two-step approach is used to judge the scientific evidence about relevant exposures to criteria pollutants and risks to the environment
  - The first step is to determine causality
    - Sufficient to infer a causal relationship
    - Sufficient to infer a likely causal relationship (i.e., more likely than not)
    - Suggestive but not sufficient to infer a causal relationship
    - Inadequate to infer the presence or absence of a causal relationship
    - Suggestive of no causal relationship
  - The second step is further characterization of the ecological response (e.g., the concentration-response relationship, deposition loads and exposure time periods at which effects are observed)

General Revisions

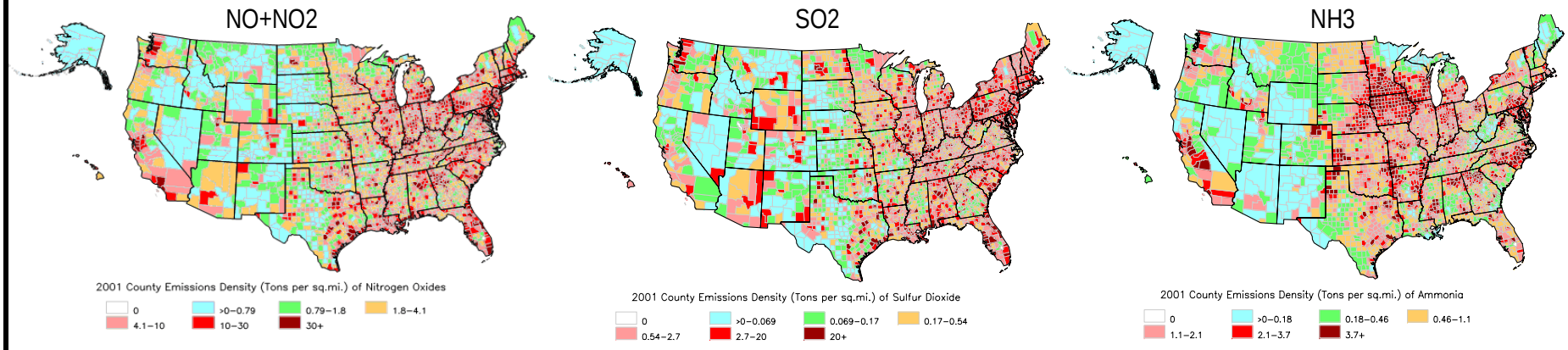
Applied causal framework

New sections to summarize the main conclusions

- Executive Summary
- Key Findings

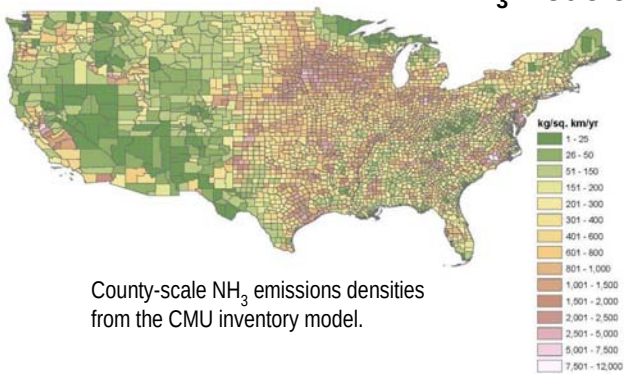
Reduced redundancy

Chapter 2 Major Revisions: Emissions

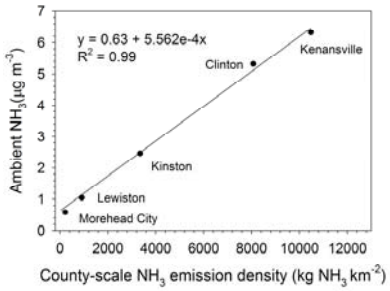


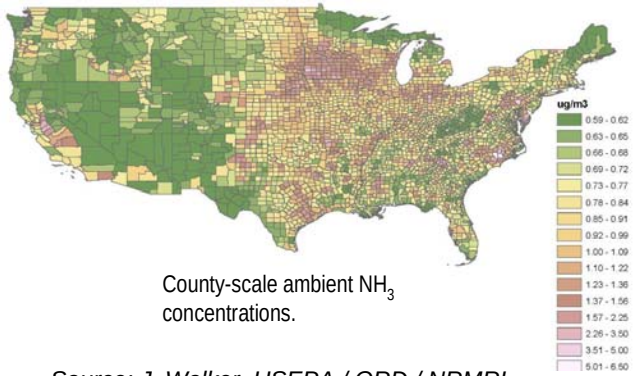
Source: U.S. EPA NEI (2006)

NH_3 Modeled Emissions and Ambient Concentrations



County-scale NH_3 emissions densities from the CMU inventory model.



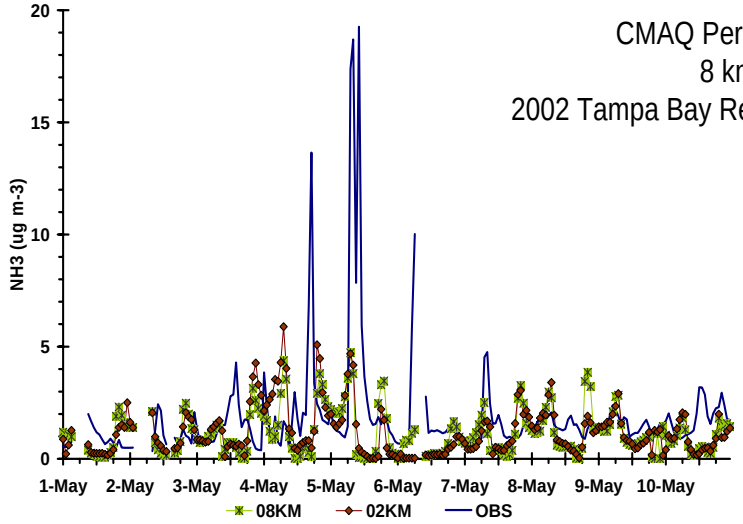


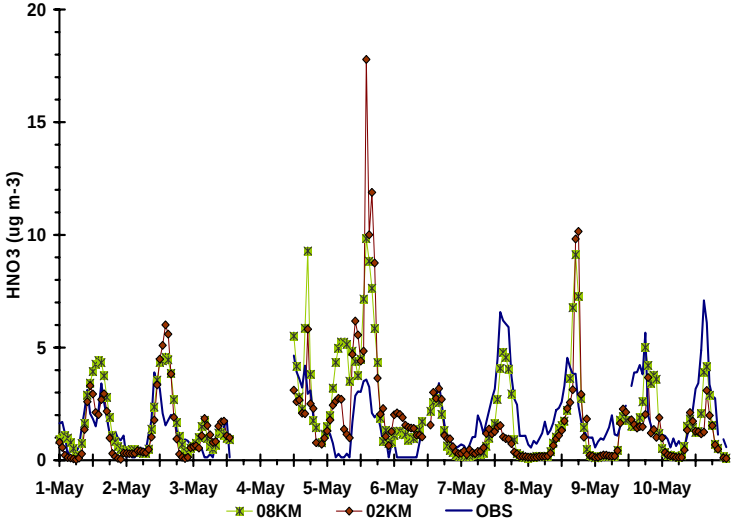
County-scale ambient NH_3 concentrations.

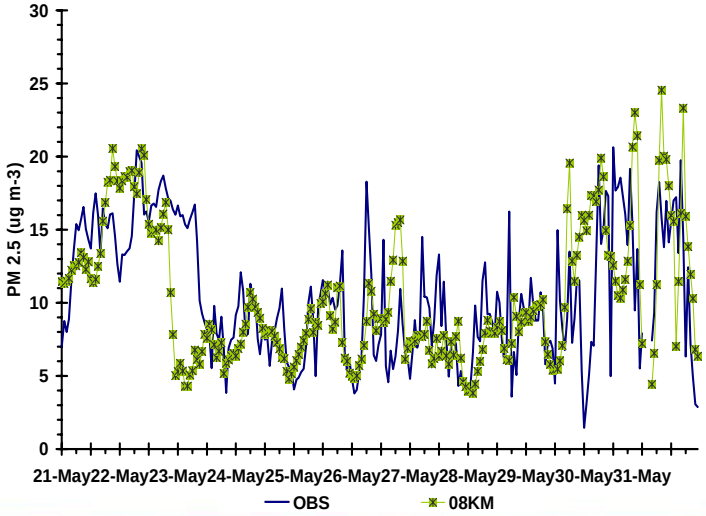
Source: J. Walker, USEPA / ORD / NRMRL

Chapter 2 Major Revisions: Air Quality Model Components & Testing

CMAQ Performance for Selected Relevant Ambient Species
8 km and 2 km CMAQ-UCD Solutions against
2002 Tampa Bay Regional Atmospheric Chemistry Experiment (BRACE) Data

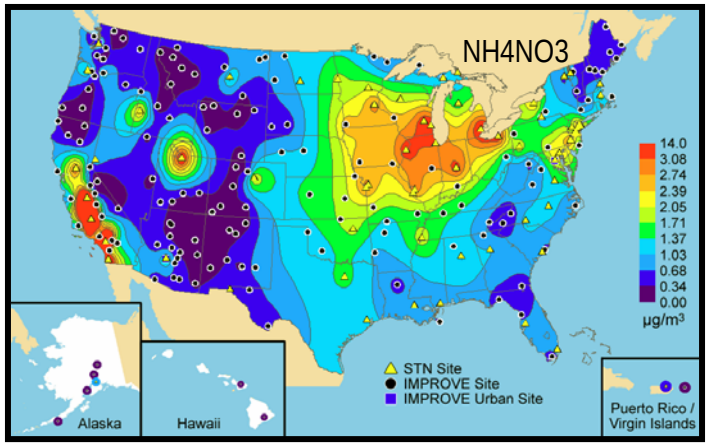


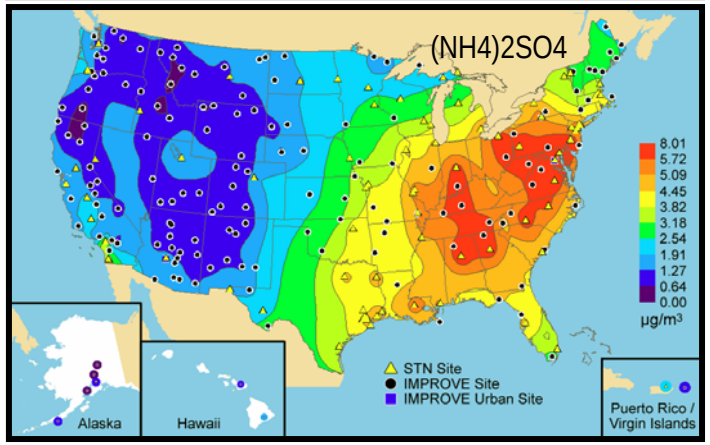




Chapter 2 Major Revisions: Deposition

IMPROVE and CSN (labeled STN) monitored mean concentrations, 2000 -- 2004





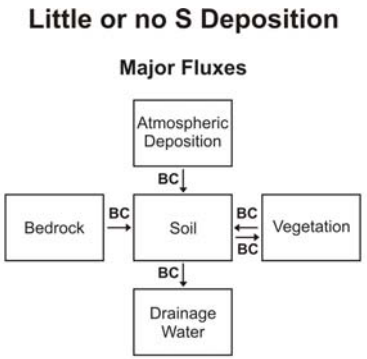
Regional Changes in Air Quality and Deposition for S and N, 1989—1991 vs. 2003--2005

Measurement	Unit	Region	Average 1989–1991	Average 2003–2005	Percent Change
Wet Sulfate Deposition	kg/ha	Mid-Atlantic	27	20	-24
		Midwest	23	16	-32
		Northeast	23	14	-36
		Southeast	18	15	-19
Wet Sulfate Concentration	mg/L	Mid-Atlantic	2.4	1.6	-33
		Midwest	2.3	1.6	-30
		Northeast	1.9	1.1	-40
		Southeast	1.3	1.1	-21
Ambient Sulfur Dioxide Concentration	µg/m³	Mid-Atlantic	13	8.4	-34
		Midwest	10	5.8	-44
		Northeast	6.8	3.1	-54
		Southeast	5.2	3.4	-35
Ambient Sulfate Concentration	µg/m³	Mid-Atlantic	6.4	4.5	-30
		Midwest	5.6	3.8	-33
		Northeast	3.9	2.5	-36
		Southeast	5.4	4.1	-24
Wet Inorganic Nitrogen Deposition	kg/ha	Mid-Atlantic	5.9	5.5	-8
		Midwest	6.0	5.5	-8
		Northeast	5.3	4.1	-23
		Southeast	4.3	4.4	+2
Wet Nitrate Concentration	mg/L	Mid-Atlantic	1.5	1.0	-29
		Midwest	1.4	1.2	-14
		Northeast	1.3	0.9	-33
		Southeast	0.8	0.7	-9
Ambient Nitrate Concentration	µg/m³	Mid-Atlantic	0.9	1.0	+5
		Midwest	2.1	1.8	-14
		Northeast	0.4	0.5	+20
		Southeast	0.6	0.7	+17
Total Ambient Nitrate Concentration (Nitrate + Nitric acid)	µg/m³	Mid-Atlantic	3.5	3.0	-14
		Midwest	4.0	3.5	-12
		Northeast	2.0	1.7	-13
		Southeast	2.2	2.1	-5

Source: U.S. EPA CAMD CASTNET and NADP / NTN.

Revisions to Chapter 3: Acidification

- New conceptual diagram (Figure 3-1) of major ionic fluxes associated with sulfur-driven acidification of drainage water
- New section discussing the quantification of acidification in aquatic ecosystems
- Expanded the discussion of *Health, Vigor, and Reproduction of Tree Species in Forests* to include interactions between acidification and plant disease (e.g., dogwood anthracnose)



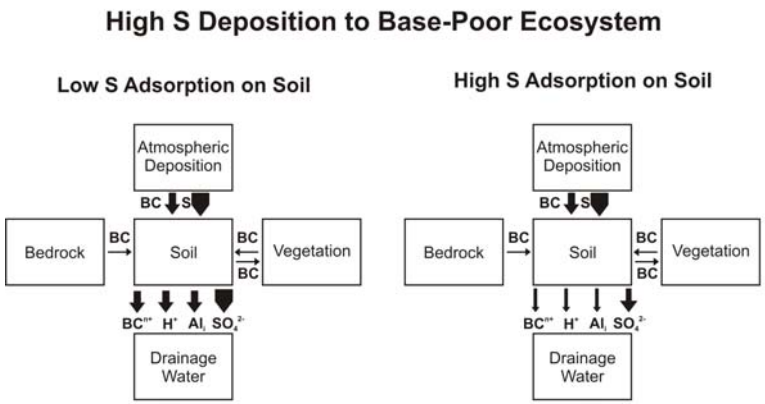
Simplified Description

Base cation supply to soil from deposition and weathering is stable.

Base cation losses to soil water and surface water are replaced by the external supply from weathering and BC deposition.

Base cation uptake into vegetation is recycled.

Inorganic monomeric Al is not mobilized to drainage water.



Simplified Description

Increased S deposition is often accompanied by increased base cation deposition.

Sulfate leaches through soil to drainage water if it is not adsorbed to soil.

Sulfate flux is partially neutralized by flux of BC and Al from soil to drainage water.

Over time, soils can become depleted of BC, and drainage water enriched in Al and H^+, both of which can be toxic to plant roots and aquatic biota.

Revisions to Chapter 3: Nitrogen Enrichment

New section on primary productivity and C budget

- Primary productivity
  - In terrestrial ecosystems, N deposition can increase plant growth rates and change carbon allocation patterns, which may lead to increased susceptibility to severe fires, drought and windthrow
  - Most freshwater, coastal and estuarine ecosystems are N limited, N deposition has been shown to cause eutrophication
- Carbon budgets
  - A meta-analysis conducted by the EPA indicated
    - N addition (10 to 562 kg N/ha/yr) has no significant effect on net ecosystem CO_2 exchange of non-forest ecosystems
    - N addition (25 to 200 kg N/ha/yr) increased ecosystem carbon content (sum of carbon content of vegetation, forest floor and soil) of forest ecosystems

Revisions to Chapter 3: Nitrogen enrichment

New section on N_2O and CH_4 flux from ecosystems

- A meta-analysis conducted by the EPA indicated that N addition increased N_2O emission, reduced CH_4 uptake and increased CH_4 emission

	N_2O fluxes		CH_4 fluxes	
	terrestrial	**wetland**	**terrestrial**	**wetland**
# observations	80	19	41	17
N forms	NH_4^+, NO_3^-, NH_4NO_3, urea	NH_4^+, NO_3^-, NH_4NO_3, urea	NH_4^+, NO_3^-, NH_4NO_3, urea	NH_4^+, NO_3^-, NH_4NO_3, urea
N addition rates	10 to 562 kg N $ha^{-1}yr^{-1}$	15.4 to 300 kg N $ha^{-1}yr^{-1}$	10 to 560 kg N $ha^{-1}yr^{-1}$	30 to 240 kg N $ha^{-1}yr^{-1}$
Responses	Increased N_2O emission by *234%* [95% CI: 171% to 312%].	increased N_2O emission by *207 %* [95% CI: 64% to 418%].	reduced CH_4 uptake by -39% [95% CI: -25% to -50%]	increased CH_4 emission by 109% [95% CI: 56% to 182%] from the source wetlands, but had no impact on CH_4 uptake from the sink wetlands

Revisions to Chapter 3: Nitrogen Enrichment

- Reorganization and expanded discussion on species richness, composition and biodiversity
- New section on U.S and European empirical critical loads and other quantified relationships between deposition load and ecological effects
  - N critical loads for ecosystems found in Europe (Table 3-24)
  - Summary of dose-response curve for N deposition and ecological responses (Table 3-25)
  - Summary of deposition levels and corresponding ecological effects focused on U.S. ecosystems (Table 4 - 4)
- New case study on the San Bernardino Mountains
- New section on ecosystem services affected by N deposition

Revisions to Chapter 3: Phytotoxic effects of gas-phase NO_x & SO_x

- Added new section on the direct effects of nitric acid to vegetation
  - Some evidence that current levels of nitric acid vapor could have caused a decline of sensitive lichens in southern CA
- Included additional recent studies on the direct effects of SO_2 on vegetation
- Brought forward key studies from the 1993 AQCD on NO_2 effects on plants and included additional recent studies

Key Conclusions

At current deposition levels, the available evidence is *sufficient to infer a causal relationship* between

- Acidifying deposition and effects on
  - (1) biogeochemistry in terrestrial and aquatic ecosystems
  - (2) biota in terrestrial and aquatic ecosystems
- Nitrogen deposition and effects on
  - (1) biogeochemical cycling of N and C in terrestrial, wetland, freshwater aquatic, and coastal marine ecosystems
  - (2) biogenic flux of CH_4 and N_2O in terrestrial and wetland ecosystems
  - (3) species richness, species composition, and biodiversity in terrestrial, wetlands freshwater aquatic and coastal marine ecosystems
- Sulfur deposition and effects on mercury methylation