Trends in Agricultural Ammonia Emissions and Ammonium Concentrations in Precipitation over the Southeast and Midwest United States

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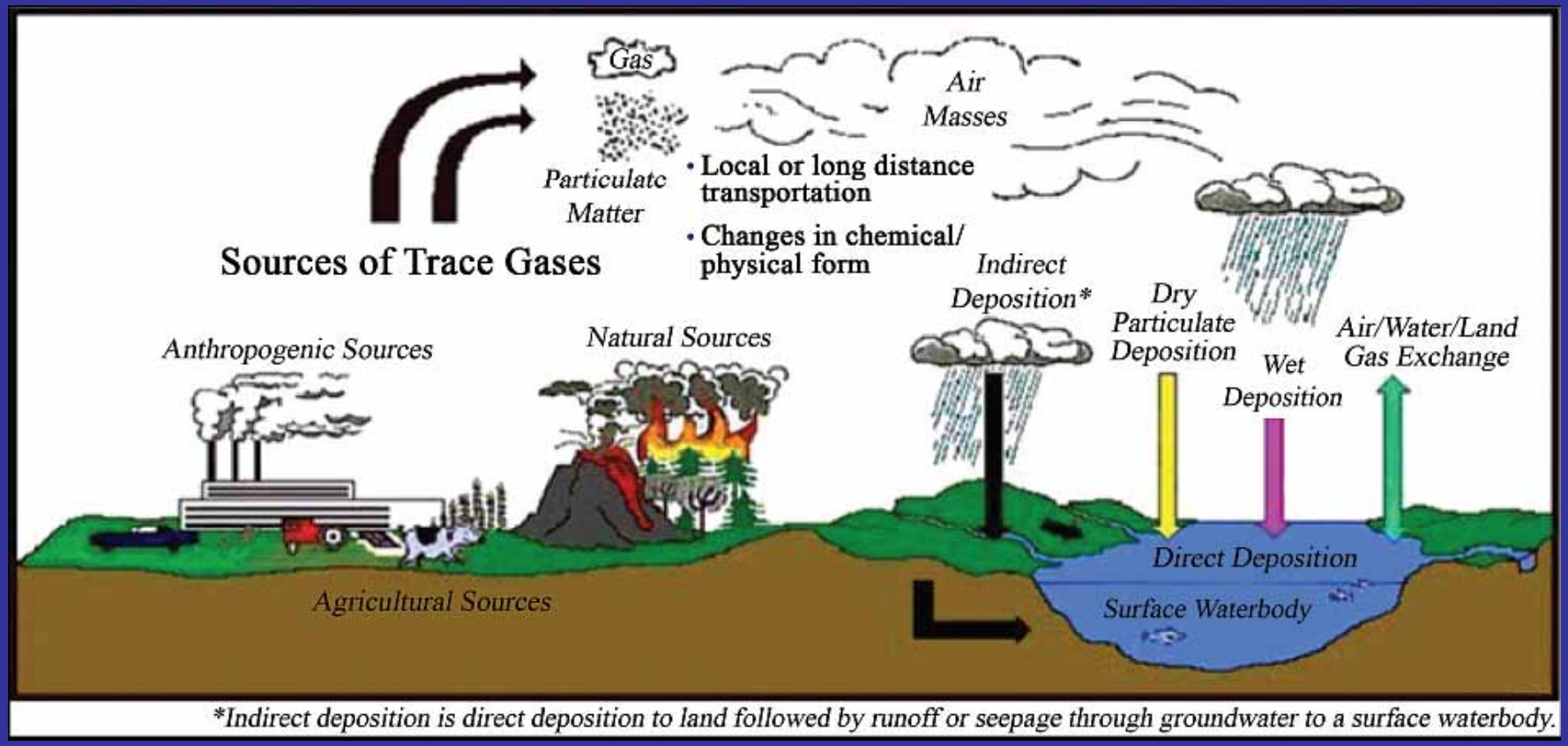
http://www.meas.ncsu.edu/airquality

ESF-FWF Conference in Partnership with LFUI
Reduced Nitrogen in Ecology and the Environment
Oetz Valley, Austria, 14-18 October 2006

Emission, Transport, Transformation, and Deposition of Trace Gases



Source: Aneja et al., 2006, Eos

U.S. Agricultural 2004 Revenues

- Confined Animal Feeding Operations (CAFOs)

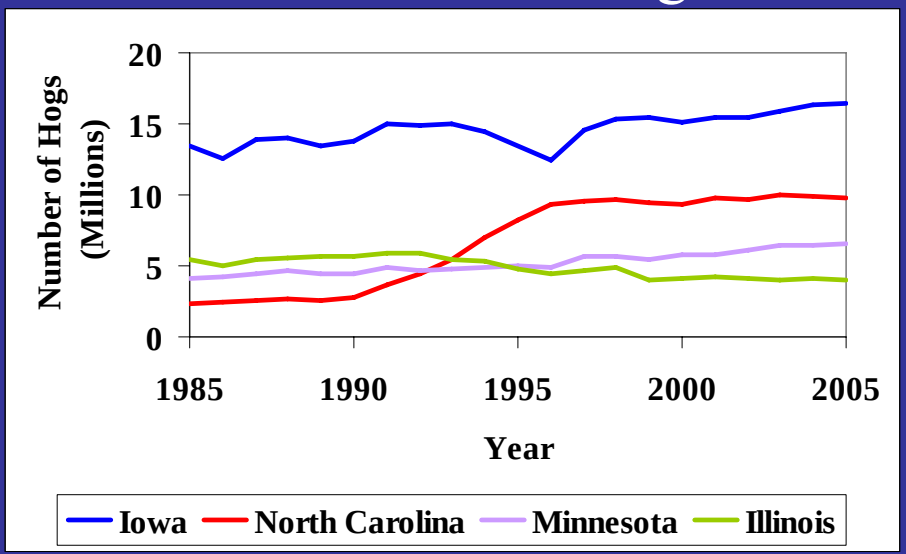
  Cattle, hog, poultry, and dairy operations: ~$120 billion

- Crop production: ~$116 billion

Source: http://www.ers.usda.gov

National Hog Farming Trends

States with most hogs



Changes in Production Facilities

1992	2005
Hog Population	
58.2 million	61.3 million
Animals in Facilities > 2000 Head	
29%	79%

National Research Council, 2002

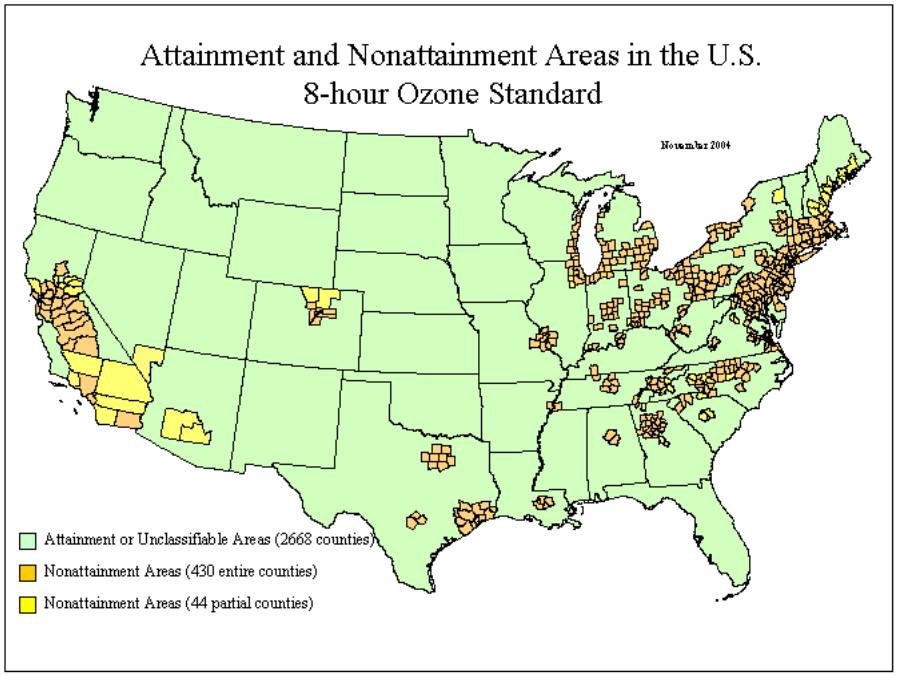
Report "The Scientific Basis for Estimating Emissions from Animal Feeding Operations"

- **"The stakes in this issue are large. More and more livestock are raised for at least part of their lives in AFO's in response to economic factors that encourage further concentration. The impacts on the air in surrounding areas have grown to a point where further actions to mitigate them appear likely."**

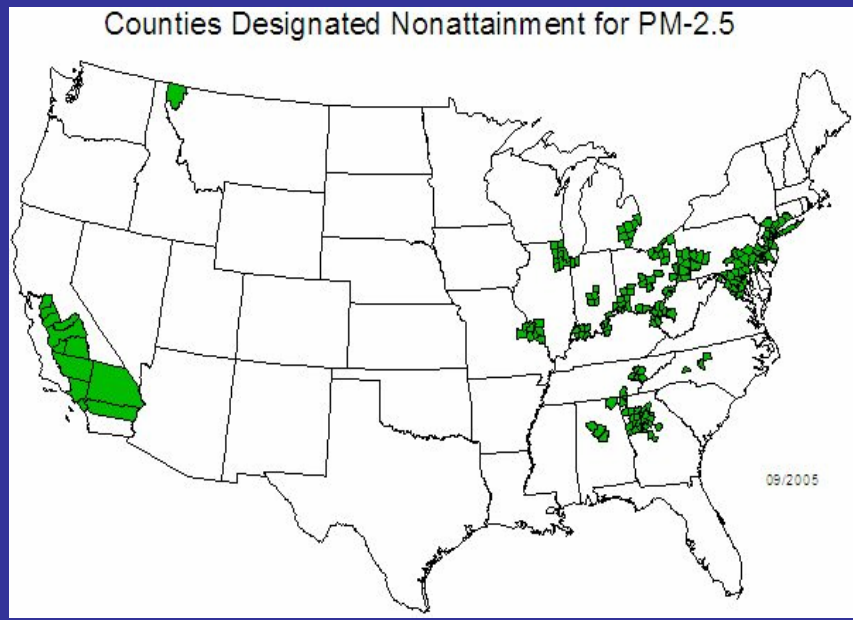
"EPA may use information from this project in determining how it will approach regulating both air and water quality impacts of AFOs. Substantial emissions of nitrogen (N), sulfate (S), carbon (C), particulate matter (PM), and other substances from AFOs do occur and cannot be ignored."

Nonattainment Areas in 2005

Areas exceeding O_3 Standard

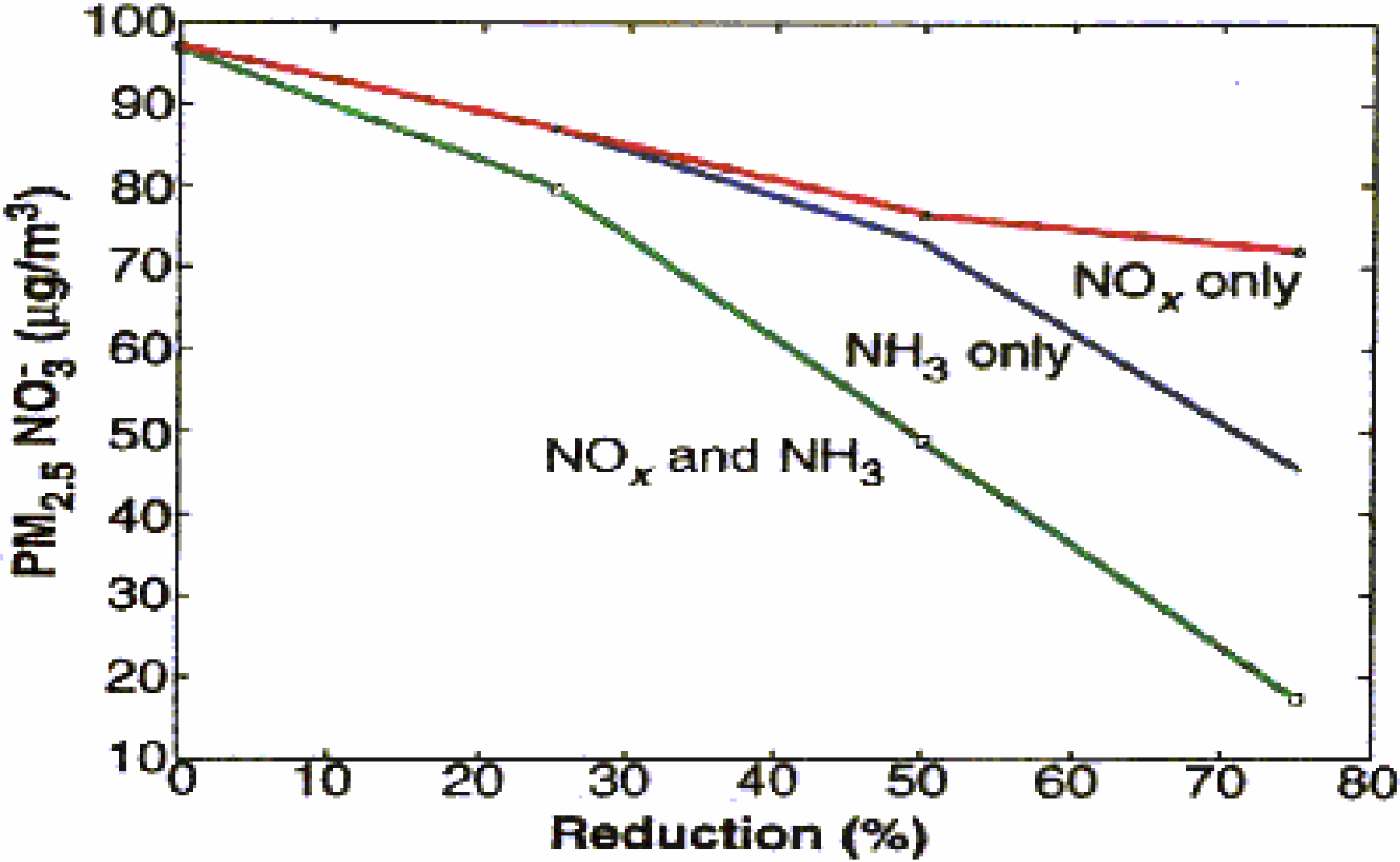


Areas exceeding $PM_{2.5}$ Standard



(Source: EPA Green Book, 2005)

($PM_{2.5}$: Particulate Matter with an aerodynamic diameter of up to 2.5 μm)



Peak 1-hour average $PM_{2.5}$ nitrate levels achieved at Riverside, California, on 28 August, 1987 as dependent on the degree of emissions reduction from the base conditions of the episode.

(Source: Meng, Dabdub, and Seinfeld, SCIENCE, 1997)

Objectives

- Develop county level agricultural ammonia estimates and analyze spatial distributions for comparisons between Midwest and Southeast United States

- Study correlation between NH_3 emissions and NH_4 ion concentrations in precipitation over the period of 1989-2004

- Does precipitation chemistry provide a regulatory/policy framework for the environment?
  - Hog moratorium in North Carolina as a case study

Impacts of Enhanced Ammonia on the Environment

- Particulate matter (PM) formation
- Visibility degradation
- Nitrogen enrichment and eutrophication in aquatic ecosystems
- Impact on crop and forest production
- Impact on ground water quality
- Odors and odorants
- Changes in rainfall chemistry

GLOBAL SOURCES OF TROPOSPHERIC AMMONIA

1.	Fossil Fuel Combustion	2 Tg N/Yr
2.	Soil-Biogenic Emissions	
	Cultivated Land	10 Tg N/Yr
	Undisturbed Soils	10 Tg N/Yr
3.	Domestic Animal Waste	32 Tg N/Yr
4.	Human Excretion	4 Tg N/Yr
5.	Biomass Burning	5 Tg N/Yr
6.	Seas and Oceans	13 Tg N/Yr
	Total Global Ammonia Emissions	~75 Tg N/Yr

Volcanic emissions ?

(Source: Schlesinger & Hartley, 1992)

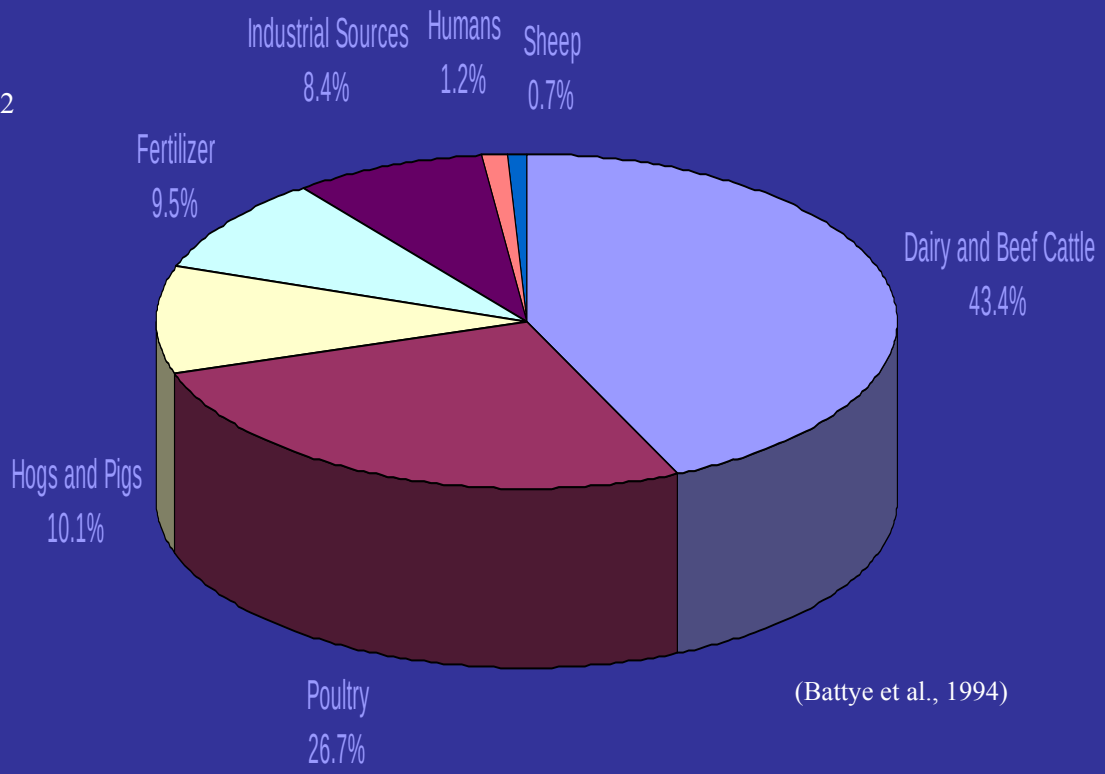
Sources of NH_3 in the U.S.

- Microbial breakdown of urea and uric acid in animal excreta

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

- Natural emissions from soil and vegetation
- Minor Sources

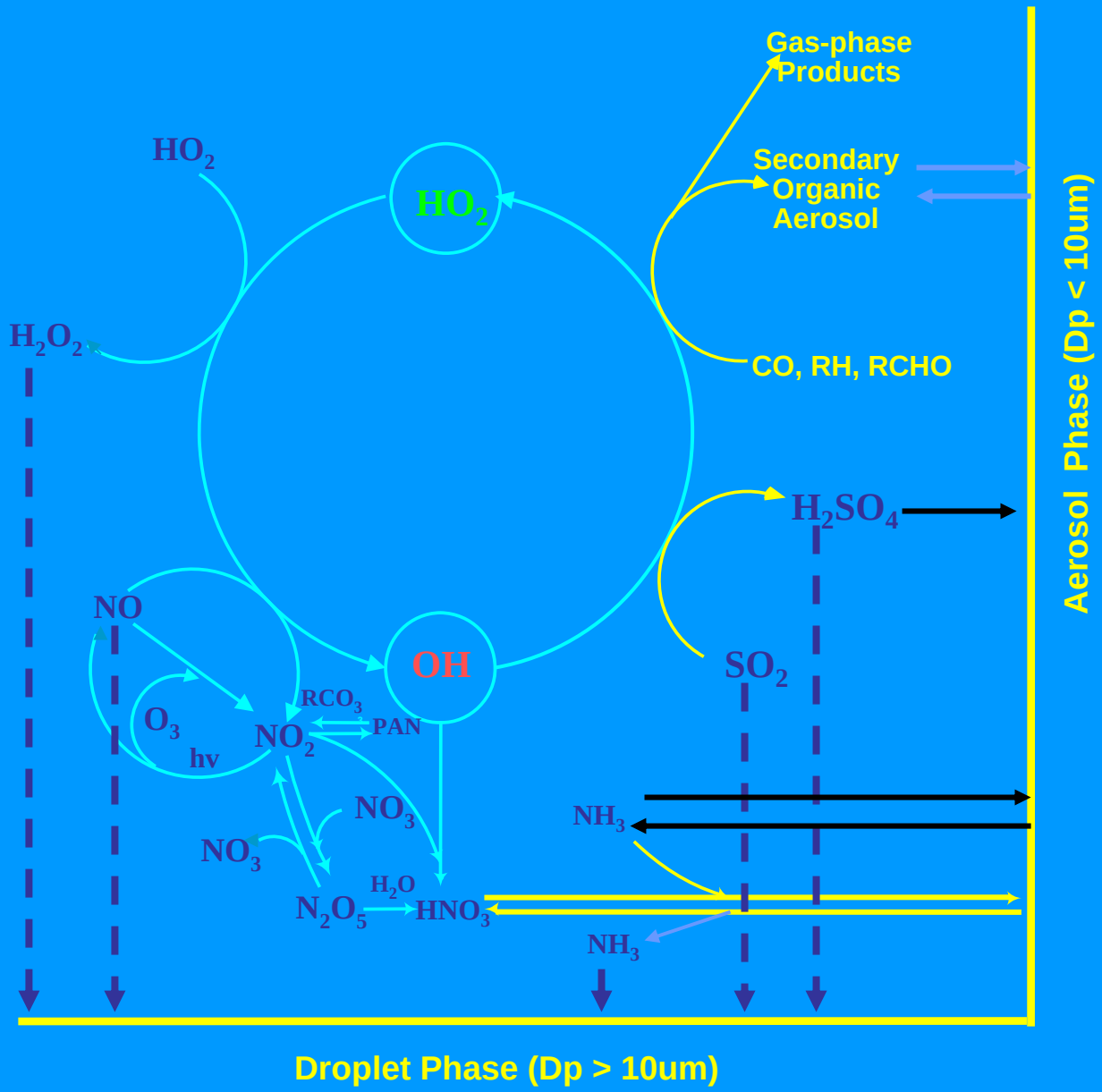
  Traffic
  coal combustion
  human perspiration and excretion
  biomass burning
  industrial processes



(Battye et al., 1994)

Total = 5.26 Tg N-NH_3

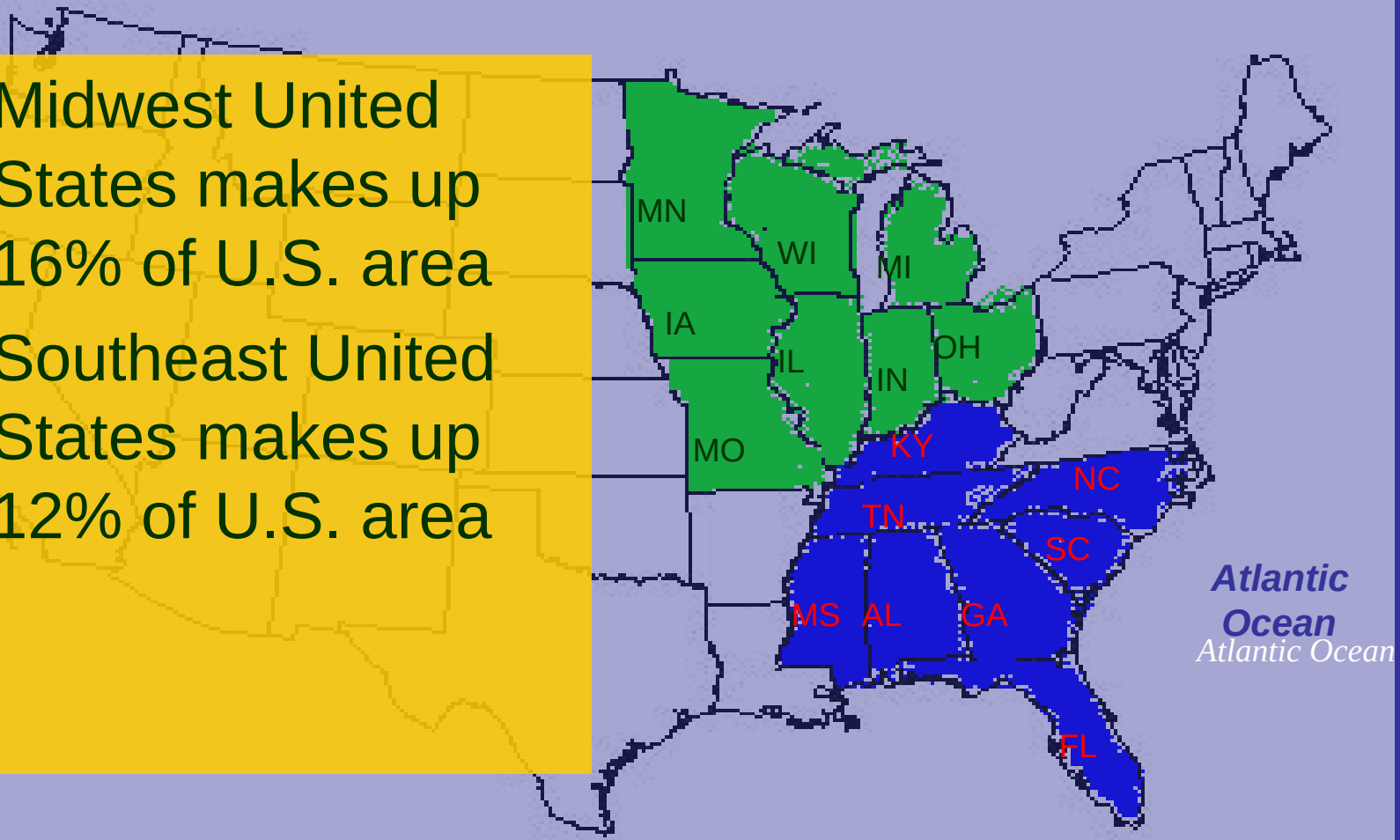
Gas-To-Particle Conversion Processes



Chemical coupling in the atmospheric gas, particle, and droplet phases (Meng, et al., 1997).

Southeast and Midwest United States

- Midwest United States makes up 16% of U.S. area
- Southeast United States makes up 12% of U.S. area



Data Used
(Southeast and Midwest United States)

- 2002 USDA Census of Agriculture
  - County-level animal activities inventories
- National Atmospheric Deposition Program/National Trends Network (NADP/NTN)
  - Ammonium ion concentrations in precipitation
  - 59 sites
- Hybrid Single-Particle LaGrangian Integrated Trajectory (HYSPLIT) Model
  - Back-trajectories for source-receptor relationship

Estimating Agricultural NH_3 Emissions

Emission Rate (kg NH_3 $year^{-1}$) =

Activity Data (animal population) * Emission Factor (kg NH_3 $animal^{-1}$ $year^{-1}$)

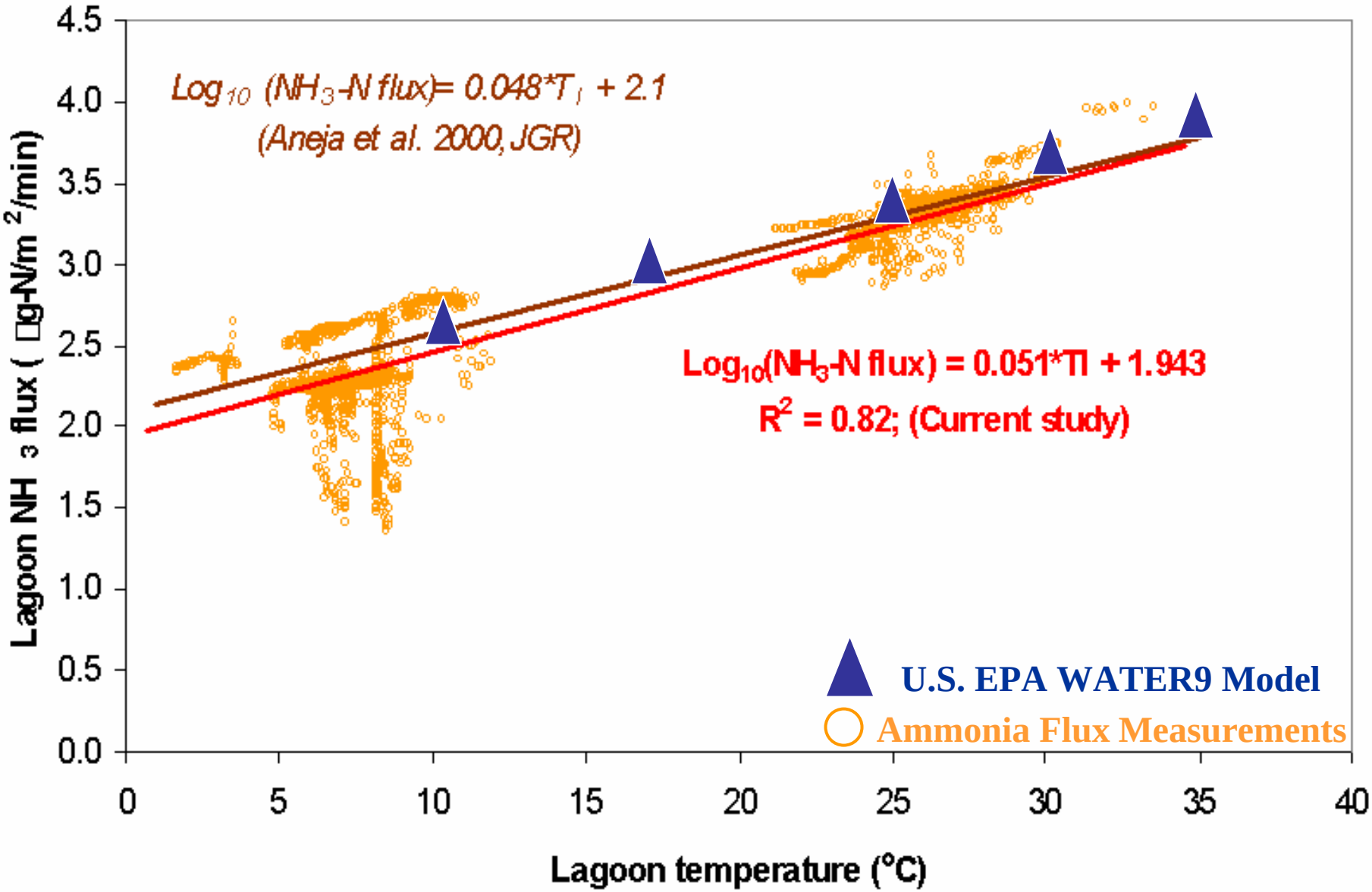
- Activity Data: U.S. Census of Agriculture for 2002 at county-level
  - **Beef and Dairy Cattle**
  - **Hogs and Pigs**
  - **Chickens**
  - **Broilers**
  - **Turkeys**
  - **Horses**
  - **Sheep**
  - **Fertilizer Application (AAPFCO)**

Ammonia Emissions Factors for Agricultural Operations

Source	Emissions Factor
	(kg NH3 animal-1 year -1)
Beef Cattle	10.2
Dairy Cattle	28.04
Horses	8
Hogs and Pigs	
Sows	16.43
Fattening Pigs	6.39
Sheep	1.34
Broilers	0.28
Chicken	
Laying Hens	0.37
Pullets 13-20 weeks old	0.269
Pullets <13 weeks old	0.17
Turkeys	0.858

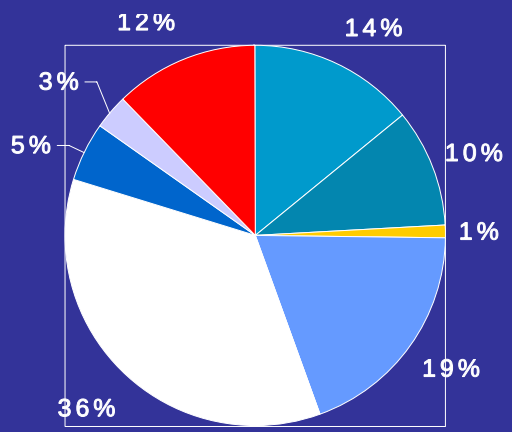
Source: Aneja, V.P., D.R. Nelson, P.A. Roelle, J.T. Walker, and W. Battye, Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. *J. Geophys. Res., 108*(D4), 4152, doi:10.1029/2002JD002271, 2003.

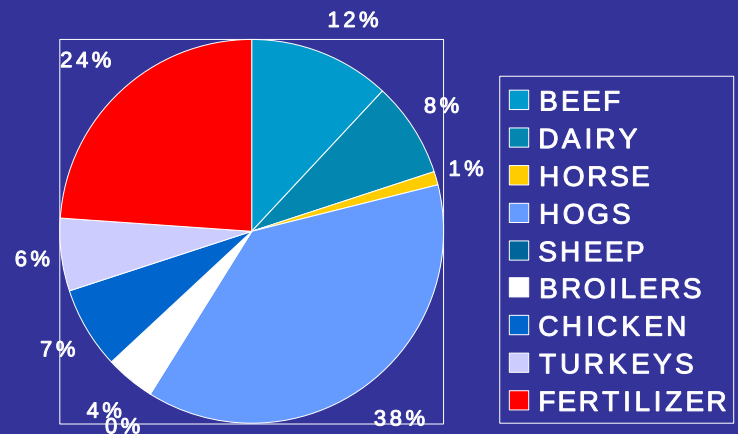
Comparison of Ammonia Flux vs Lagoon Temperature



Ammonia Emissions in the Southeast and Midwest United States

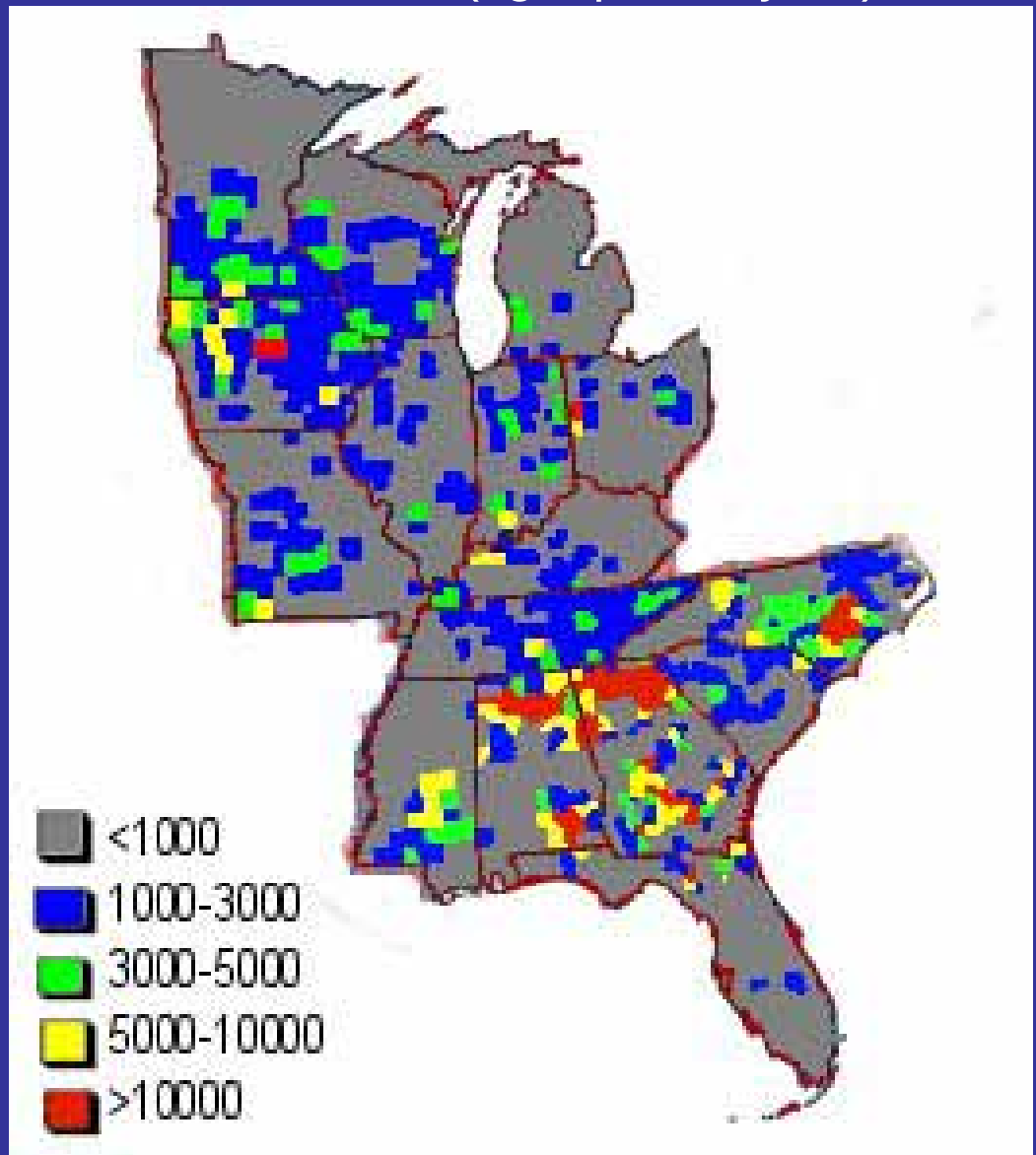
Source	Total Emissions in Southeast (kTon)	Total Emissions in Midwest (kTon)
Beef Cattle	65.1	67.1
Dairy Cattle	45.1	49.1
Horses	6.5	5.7
Hogs	220.0	91.0
Sheep	1.3	1.6
Broilers	17.9	168.0
Chickens	40.1	26.3
Turkeys	35.1	16.5
Fertilizer	70.1	107.5
TOTAL	491.2	532.8



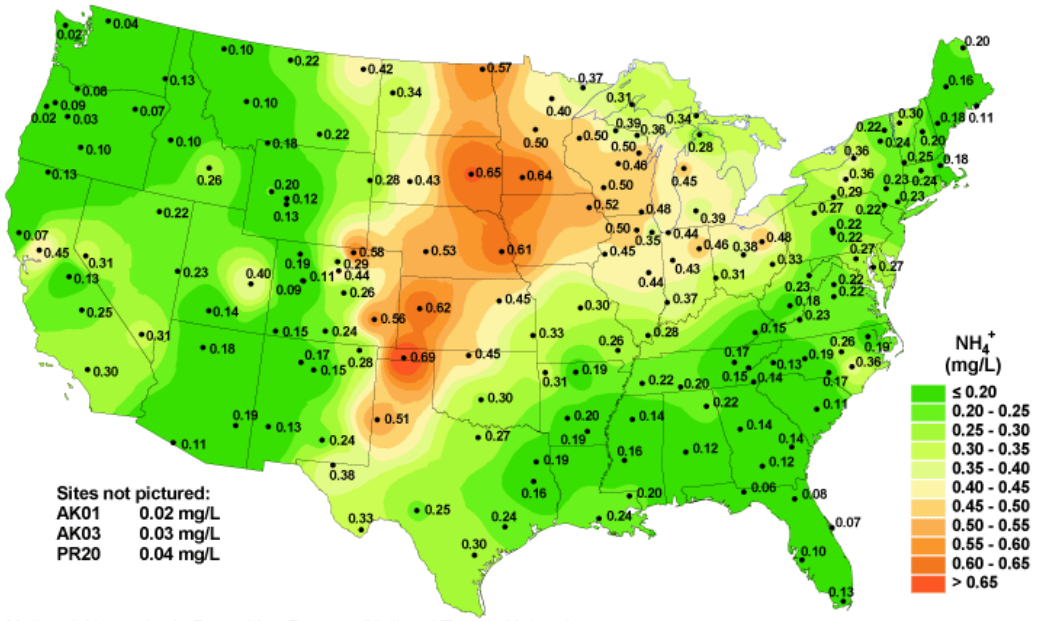


Spatial Distribution of Agricultural Ammonia Emissions

(kg/sq. mile/ year)

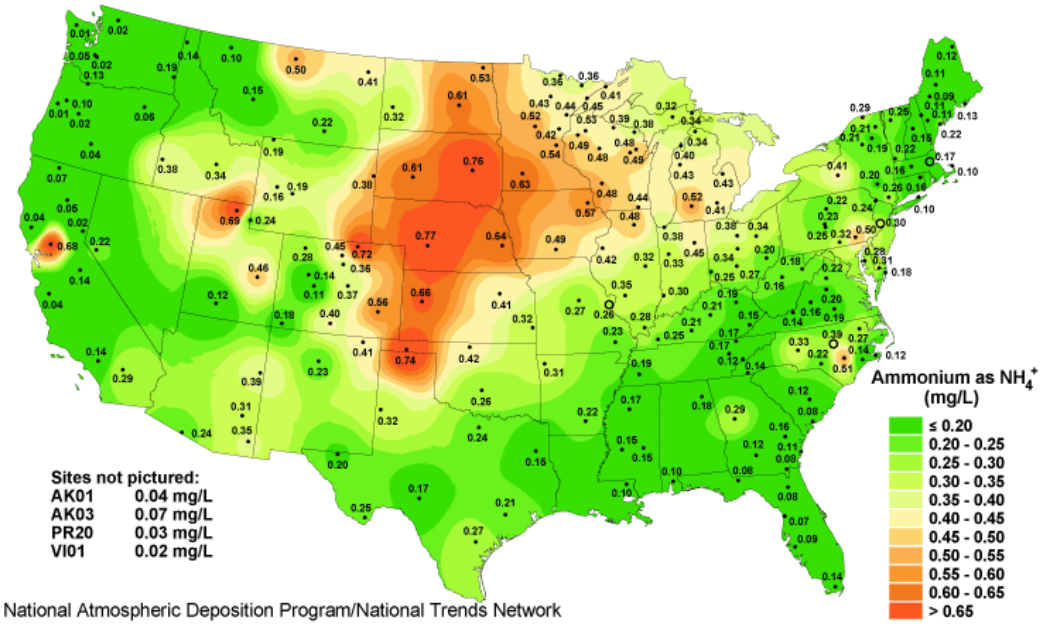


Ammonium ion concentration, 1994



National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

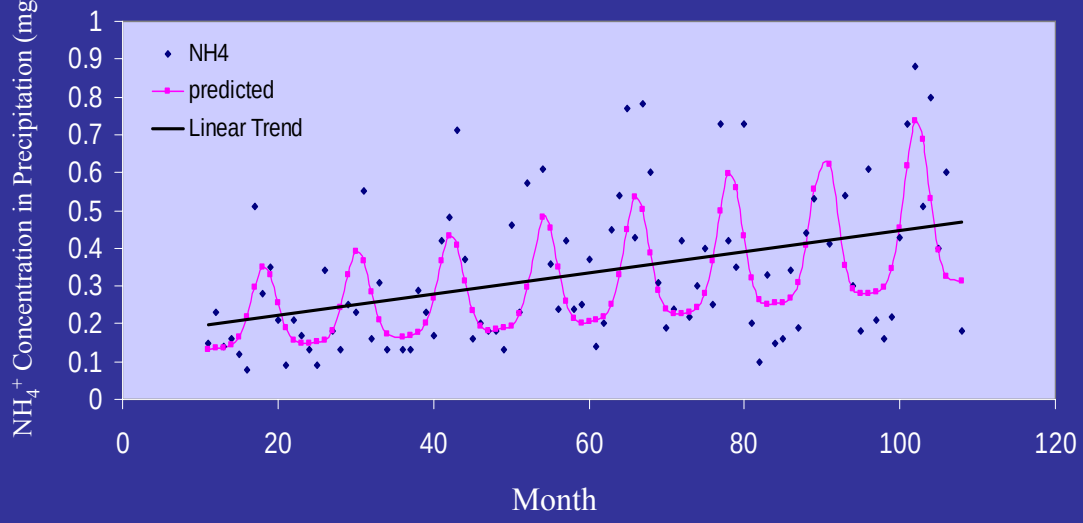
Ammonium ion concentration, 2004



National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Trends in NH_4^+ Concentration in Precipitation

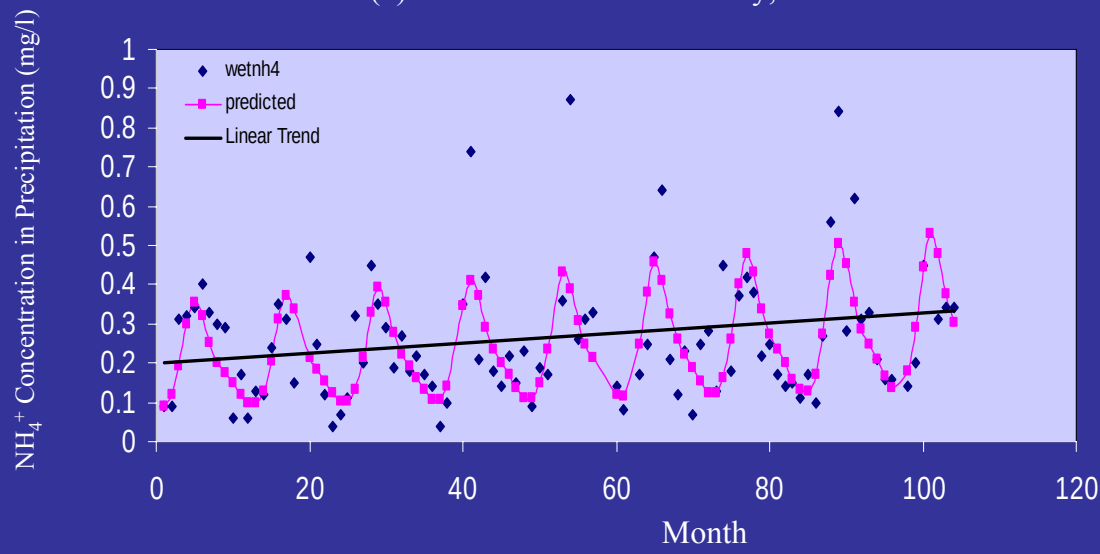
(a) Site NC35 Sampson County, NC



• Mean NH_4^+ concentration in precipitation rose from 0.2 mg/l in 1990 to 0.48 mg/l in 1998

• Mean NH_4^+ concentration in precipitation rose from 0.2 mg/l in 1990 to 0.35 mg/l in 1998

(b) Site KY35 Rowan County, KY

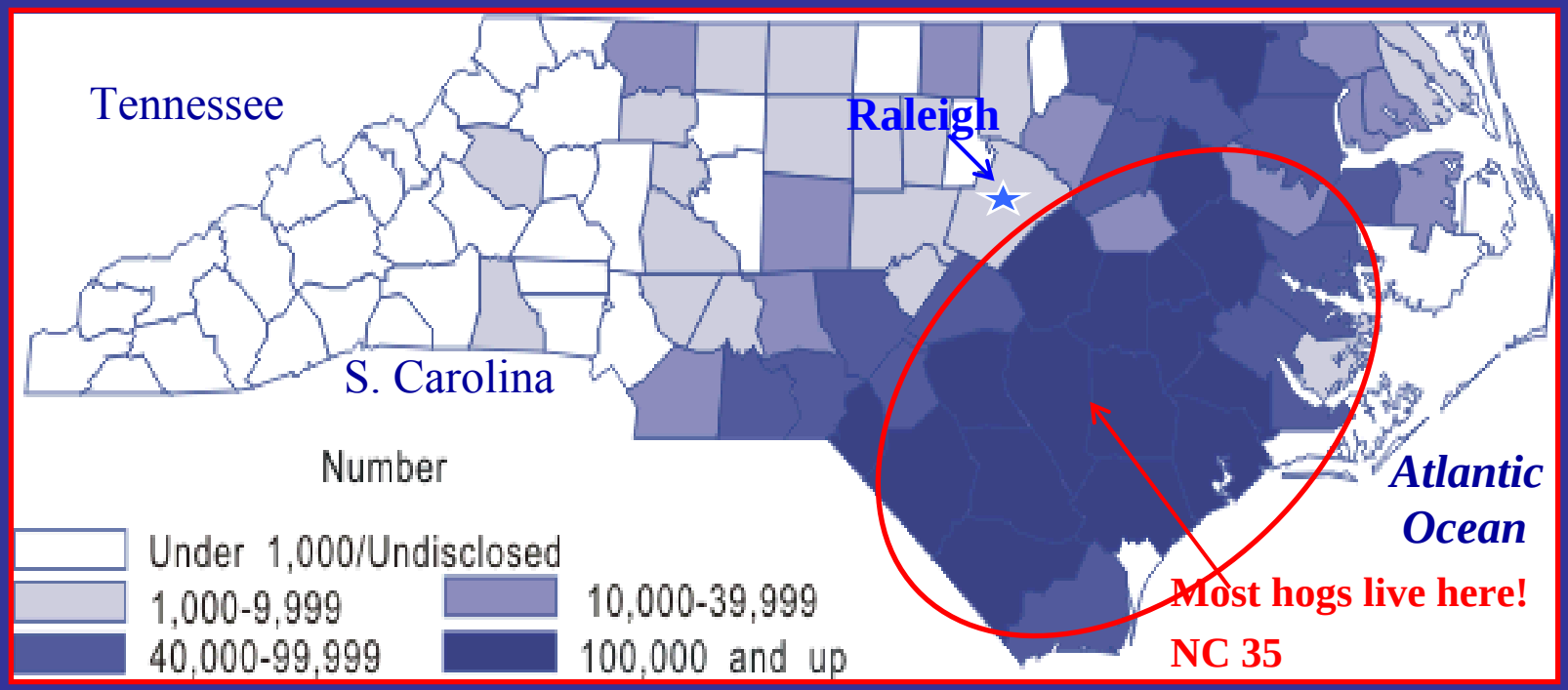


Ammonium Ion Concentrations

- R-square values for correlation between NH_3 emissions and NH_4^+ concentrations in precipitation
  - Midwest: 0.531
  - Southeast: 0.384
- Differences attributed to meteorological conditions, long range transport and more uniform conditions over the Midwest

Growth in North Carolina Hog Population

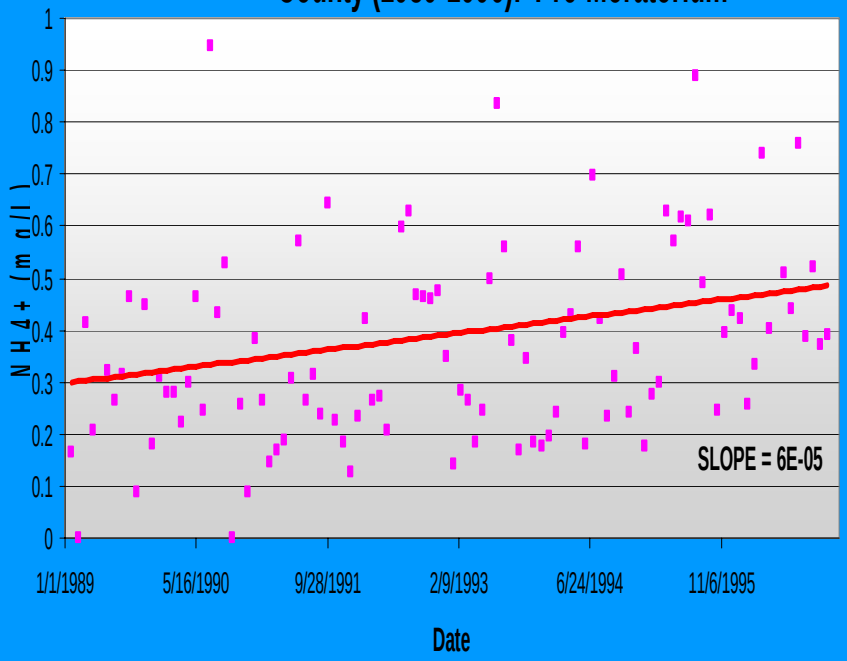
2003 North Carolina Swine Population Distribution



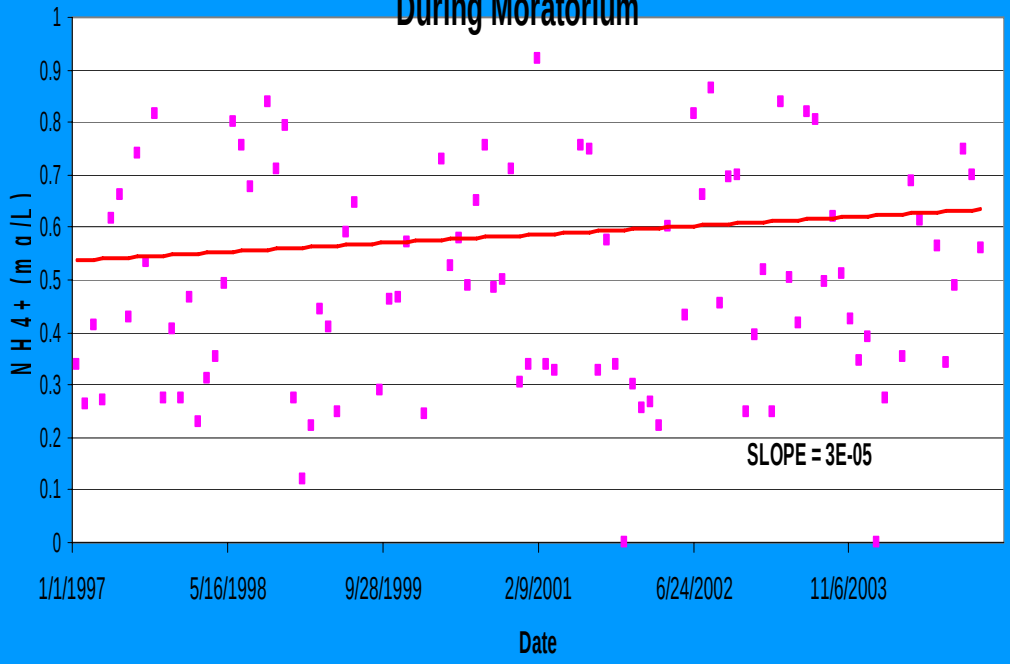
Source: http://www.ncagr.com/stats/cnty_est/ctyhogyv.htm

Trends in Ammonium Concentrations Before/After Moratorium

4-week Averaged NH4+ wet deposition concentrations at high ammonia emission North Carolina NADP site: NC 35 Sampson County (1989-1996): Pre-Moratorium



4-week Averaged NH4+ wet deposition concentrations at high ammonia emission North Carolina NADP sites (1997-2004): During Moratorium



Trends in Ammonium Concentrations Before/After Moratorium

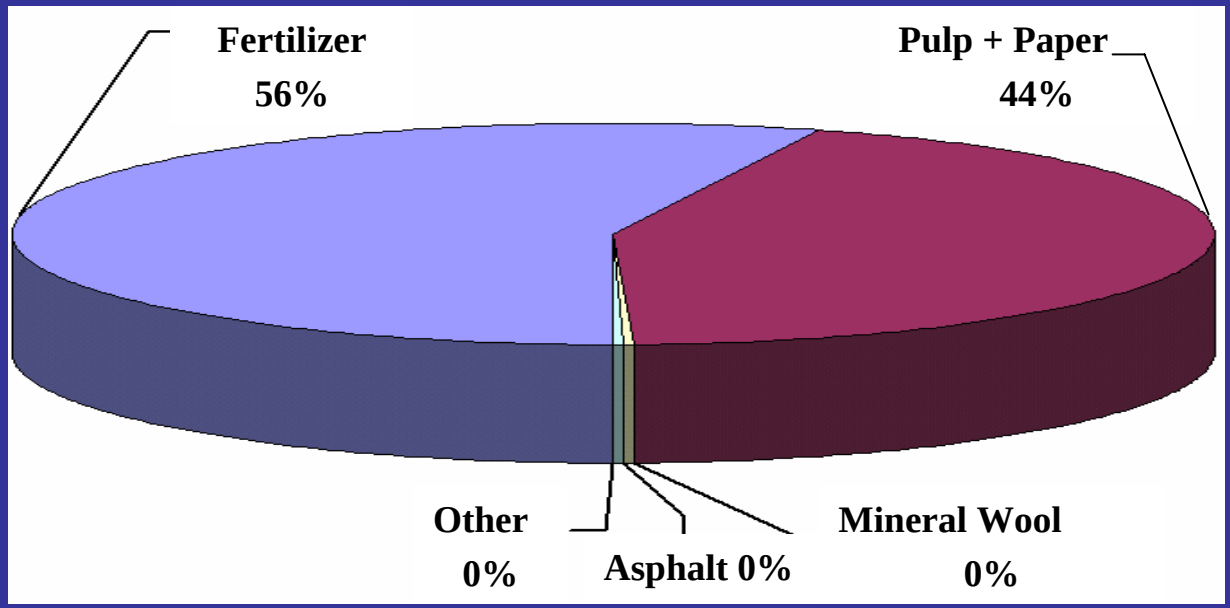
- Over Sampson County (NC 35), annual rate of increase in NH_4^+ ion concentration in precipitation dropped from 9% to 4% per year
  - in the heart of the high hog density region

Conclusions

- A county-level NH_3 emissions inventory (high resolution) for agricultural sources was developed for the Southeast United States
- Three regions of elevated NH_3 emissions were identified in the Southeast United States
  - Area I – Eastern North Carolina
  - Area II – Northeast Georgia
  - Area III – North-Central Alabama
- Two regions of elevated NH_3 emissions were identified in the Midwest United States
  - Area I – Central Iowa
  - Area II – Western Ohio
- Results of wet NH_4^+ concentration in precipitation regression revealed that ammonia emissions are statistically significant
- An increasing trend in NH_4^+ concentration in precipitation was found at NADP sites NC35 and IA23
- Spatial distribution of NH_4^+ concentrations in precipitation agreed well with the spatial distribution of estimated NH_3 emissions
- Ammonia emission signature reflects the moratorium in hog production as seen in the precipitation chemistry

North Carolina

2002 H_2S Emissions Inventory



Total = 11.9 Million lb (6000 tons) H_2S yr^{-1}

What about Animal Feeding Operations???

No data available due to poor data quality

U.S. EPA estimates ~40 Million lb (20,000 tons) H_2S yr^{-1} in N.C. based on Midwest farm emission factors (*unpublished data*)

Source: http://daq.state.nc.us/toxics/studies/H2S

Global Non-Industrial Sources of Sulfur in the Atmosphere (Gmol yr^{-1})*

Source	Hydrogen sulfide	Dimethyl sulfide	Carbon Disulfide	Carbonyl Sulfide
Oceans	< 9	500-1300	2.4-9.5	2.7-7.8
Coastal Wetlands	0.2-30	0.2-18	0.2-1.2	2.3-7.8
Soils and Plants	2-56	3-24	0.4	-
Volcanoes	16-47	-	0.2-2.4	0.1-1.5
Biomass burning	-	-	-	0.7-4.3
Other	-	-	-	4.5-14.8**
SUMS	18-133	503-1342	3.3-14.1	10.4-37.1

**Reaction of OH• with carbon disulfide and dimethyl sulfide

*1 Gmol-S = ~7,000,000 lb-S

What about Animal Feeding Operations???

No data available due to poor data quality

Source: Warneck (2000)

Workshop on Agricultural Air Quality: State of the Science

June 5-8, 2006

Why a Workshop Now?

Emissions of nitrogen, sulfur, and volatile organic compounds, and particulate matter from animal and crop agriculture have become a serious political and environmental problem. Compliance with increasingly stringent federal and state air pollution regulations poses both economic and technical challenges to agricultural operations. It is time to address these needs!

Call for Papers

Abstract Deadline October 14, 2005

Oral and poster presentations that update current and emerging knowledge about agricultural air quality science and policy, as well as innovative ideas, processes, and programs by which to optimize agricultural management in crop and animal food production and environmental protection.

Workshop Goals

- Assess the state of science
- Enhance our knowledge
- Foster multidisciplinary communication
- Recommend changes and improvements in tools and practices

Registration Information

The Bolger Conference Center is a complete meeting, housing, and dining facility. Registration will open in November, 2005. Look for early bird and student discount registration rates.

"Maximizing the benefits and reducing the detrimental effects of agricultural production requires us to transcend scientific disciplines and political boundaries. This task challenges the creativity of natural and social scientists, economists, engineers, business leaders, and policy makers."

Bolger Conference Center, in Potomac Maryland, near Washington DC, USA

Agricultural Air Quality Topical Areas

- Air Emissions
- Best Management Practices
- Biomass Burning
- International Perspectives
- Monitoring and Measurements
- Modeling
- Terrestrial Ecosystems
- Science Policy: Changing Global Agendas
- Public Policy and Air Quality Standards
- Ecosystems and Economics
- Commodity in Environmental Trade
- Industry Perspectives

Travel and Awards

Student Awards: A competition and cash award (5 awards) will be presented for the best student paper/posters.

Travel Support: Limited funds are available to facilitate attendance of junior faculty, junior scientists, agricultural extension specialists, post-doctoral fellows, and graduate students based at U.S. institutions presenting papers at the Workshop.

Important Dates

- Abstract Submission Deadline, Oct. 14, 2005
- Notification of Abstract Acceptance, Nov. 15, 2005
- Workshop Registration, Opens Nov., 2005
- 10-15 Page Conference Proceedings Paper, Deadline Jan. 16, 2006
- Workshop, June 5-8, 2006
- Journal Manuscript Submission, June 30, 2006

Workshop Organizers

Steering Committee members: Viney P. Aneja (Chair), William H. Schlesinger (co-Chair), Greg Jennings, Dev Niyogi, Wendell Gilliam, Clifford Duke, Raymond Knighton.

International Executive Scientific Advisory Committee of experts in agricultural air quality science and policy. The Committee includes 19 members from 11 countries.

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Workshop Products

- Peer reviewed proceedings
- Papers published in peer reviewed journals
- Congressional briefings and activities to share the Workshop results
- Workshop summary submitted to the Proceedings of the National Academy of Sciences

Acknowledgements

- Conference Organizers
- NC Animal and Poultry Waste Management Center
- USDA-NRI Grant # 2003-05360
- NCSU Air Quality Research Group