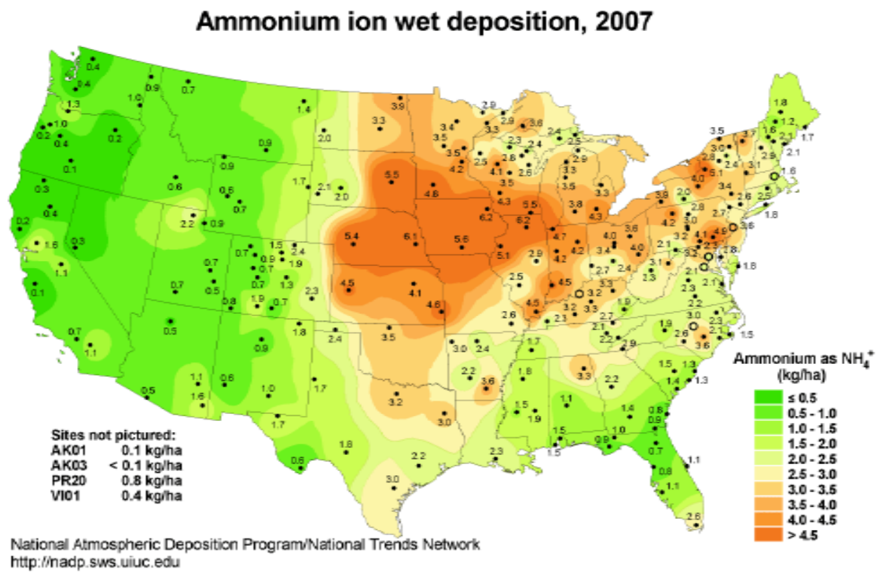
Report on the MANE-VU 2009 Science Meeting—Total Reactive Nitrogen: Regional Haze Impacts and Mitigation Options



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Mid-Atlantic / Northeast Visibility Union (MANE-VU)

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This technical report was prepared for use by the MANE-VU States and does not necessarily represent the position of the U.S. Environmental Protection Agency, MARAMA, MANE-VU, or OTC.

About MANE-VU

The Mid-Atlantic/Northeast Visibility Union (MANE-VU) was formed by the Mid-Atlantic and Northeastern states, tribes, and federal agencies to coordinate regional haze planning activities for the region. MANE-VU encourages a coordinated approach to meeting the requirements of EPA's regional haze rules and reducing visibility impairment in major national parks and wilderness areas in the Northeast and Mid-Atlantic region. MANE-VU provides technical assessments and assistance to its members, evaluates linkages to other regional air pollution issues, provides a forum for discussion, and encourages coordinated actions. MANE-VU also facilitates coordination with other regions.

About MARAMA

The Mid-Atlantic Regional Air Management Association, Inc. is a voluntary, non-profit association of ten state and local air pollution control agencies. MARAMA's mission is to strengthen the skills and capabilities of member agencies and to help them work together to prevent and reduce air pollution in the Mid-Atlantic Region. MARAMA provides cost-effective approaches to regional collaboration by pooling resources to develop and analyze data, share ideas, and train staff to implement common requirements.

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1. Introduction

The Mid-Atlantic/Northeast Visibility Union (MANE-VU) 2009 Science Meeting focused on the sources and effects of reactive nitrogen and mitigation options. Experts in monitoring, estimating emissions, modeling, and policy analysis provided perspectives on the issue. The 2009 Science Meeting was held July 28-29 in Baltimore, Maryland. A meeting agenda is appended at the end of this report, along with short biographical information about the speakers and a summary of meeting evaluations.

The purpose of the meeting was to increase understanding by state and local agency air quality managers in the region about:

- The source and fate of emissions of ammonia and other reactive nitrogen compounds (Nr);
- Impacts of Nr on air quality and the relationship of air quality to other environmental effects.
- Measurement technology to assess concentrations of Nr and emissions of Nr; and
- Potential control measures that may help reduce airborne Nr and deposition of Nr.

The agenda included fifteen presentations and a closing summary session. Topics began with a scientific framework and discussion of standards, progressed through ambient monitoring and emissions quantification, included data analysis and research, and provided information on control measures.

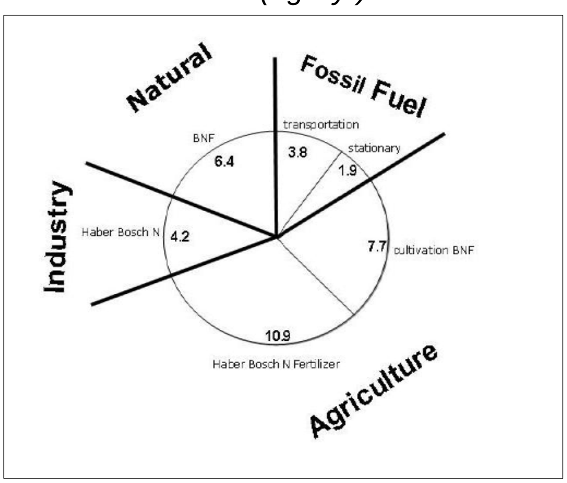
Meeting organization and support was provided by the Mid-Atlantic Regional Air Management Association (MARAMA), which prepared this meeting report. The speakers have reviewed the draft summary, which represents MARAMA's best efforts to accurately represent the information presented. Presentations from the meeting are posted on the MARAMA web site at www.marama.org.

2. Overview of Reactive Nitrogen in the Atmosphere, and Draft Overarching Recommendations of the EPA Integrated Nitrogen Committee

Professor Russell Dickerson (University of Maryland) set the stage for the meeting, providing a framework of the topics to be discussed with a background on chemistry and biological function of nitrogen in nature. While nitrogen exists naturally in 10 oxidative states ranging from +6 (NO_3) to -3 (NH_3), the majority is tied up in the atmosphere as N_2, which is unreactive in natural systems. N_2 only becomes biologically active when it is converted, or fixed, into either positive or negative oxidative states (reactive nitrogen). This is important because, while life requires it, nitrogen is toxic at relatively low concentrations. In nature, only a few plant types and lightning can fix nitrogen.

Nitrogen cycle: The natural nitrogen cycle has been perturbed by human efforts to fix nitrogen to enhance agricultural and industrial production, and today most reactive nitrogen is biogenic. The global N cycle is more perturbed than the global C cycle, and mankind dominates the global N cycle.

Sources of reactive nitrogen introduced into the US in 2002 (TgN/yr)



BNF = Biological Nitrogen Fixation
Haber Bosch = the nitrogen fixation process that produces ammonia for the production of fertilizer, munitions, etc.

Reactive nitrogen cascades through atmospheric, terrestrial, and aquatic environmental systems with multiple deleterious effects. The same nitrogen atom can cause multiple effects in the atmosphere, in terrestrial ecosystems, in fresh water and marine systems and on human health.

In the atmosphere, ammonia reacts with other chemicals to form particles that affect cloud physics. In addition, N_2O is a greenhouse gas, which is increasing rapidly in the atmosphere. It also is the main source of NO_x that depletes the stratospheric ozone layer.

Excess nitrogen in aquatic ecosystem leads to eutrophication of waters, which has resulted in significant disruption of the ecosystems of systems such as the Chesapeake Bay.

Efforts in the past to control reactive nitrogen have focused on transferring it from one medium to another; however the only true sink is denitrification back to the unreactive N_2. Denitrification occurs naturally in wetlands and other moist ecosystems but this natural process is much too slow to respond to the massive increase in fixed biogenic nitrogen caused by human activity.

Integrated Nitrogen Committee: The USEPA Science Advisory Board Integrated Nitrogen Committee (Jim Galloway, Chair) has drafted a report titled "Reactive Nitrogen in the United States; An Analysis of Inputs, Flows, Consequences, and Management Options". A draft of the report is available at: http://yosemite.epa.gov/sab/sabproduct.nsf/0/c83c30afa4656bea85256ea10047e1e1!OpenDocument&TableRow=2.2#2

Draft recommendations indicate that what is needed is an integrated approach where impacts on terrestrial and aquatic ecosystems, human health, and climate are considered together. Mechanisms for control may include command and control, taxes/price supports/subsidies, market based instruments, and voluntary programs. EPA should work with other agencies to manage the problem and conduct monitoring, modeling, and research. To accomplish this EPA should form a task force to help increase scientific understanding.

It is important to understand the nature of the nitrogen cascade and determine the most effective point to apply controls. NH_x controls are called for. Controlling N_2O, which is related to fertilizer, will be very difficult.

3. The Importance of Ammonia in Modeling Atmospheric Transport and Deposition of Air Pollution

Robin Dennis (EPA NERL) described the importance of ammonia in modeling atmospheric pollutant transport and deposition. Along with NOx and SOx emitted by fossil fuel combustion ammonia from agricultural production is one of the three main contributors to ambient $PM_{2.5}$. While NO_x and SO_x emissions are declining, ammonia emissions are increasing.

The major sinks of atmospheric ammonia are wet and dry deposition. Dry deposition of gas is much faster than deposition of particles

<u>Reaction with acidic gases and aerosols</u>: There are two major reactions of ammonia in the atmosphere that convert ammonia gas to ammonium particulate:

- Nitric acid (HNO_3) to ammonium nitrate (and back), and
- Ammonia neutralizes sulfuric acid to ammonium sulfate.

Ammonia affects the results of changes in emissions of other pollutants. Reductions in SO_2 emissions result in declines in sulfates (the second reaction above), but the remaining available ammonia then reacts with HNO_3 and nitrates increase (the first reaction). In the ozone season, if NO_x emissions are reduced, then nitrate and sulfate decline.[1] Higher concentrations of ammonia result in more particles (both reactions). Less ammonia means more dry deposition of nitric acid (which has a faster deposition rate). Biogenic VOC reductions increase both sulfate and nitrate concentrations.

The partitioning of ammonia, NO_x, and SO_x between gas and particle phases is affected by the relative concentration of each pollutant. The effect of reductions of any one pollutant on the ambient PM concentration depends on the concentrations of other pollutants. For example, when atmospheric ammonia concentrations are large compared to nitrate then reductions of ammonia emissions will not substantially reduce PM concentrations. However, in the Midwest, where ammonia emissions are largest, there are also large nitrate concentrations, and reductions of ammonia will reduce ambient PM concentrations.

[1] Gas phase production of sulfate is driven by OH and so depends on the level of OH. In rural settings most of the new OH comes from photolysis of ozone. In the ozone season rural ozone production is NO_x limited. So when NO_x is reduced, ozone will be reduced and the OH production will be reduced. This will reduce the formation of gas-phase sulfate and nitric acid.

Wet and Dry Deposition: Only about 10% of ammonia from animals deposits locally. The rest is transported, converted to ammonium associated with sulfate and nitrate, and later deposited. Regionally, wet deposition is greater than dry deposition, but where animal operations are large, dry can be much greater than wet. Reductions in NO_x and SO_2 emissions increase dry deposition and decrease wet deposition. In areas with agricultural operations, ammonia is a significant portion of the total nitrogen deposited.

Temporal distribution: Seasonal variation in ammonia emissions is related to application of fertilizer in the spring (major peak) and then also smaller peaks twice in later parts of the year. Inverse modeling has shown good agreement between observed and modeled monthly average ammonium concentration. However, for some months the model predicts higher extreme concentrations than are observed. Unless winter emissions are lower than other seasons, the model will over-estimate winter concentrations of nitrate.

Spatial distribution: The Mid-Atlantic and northeast have the highest measured wet deposition of sulfates. In general, the model predicts ammonia behavior better in the eastern United States than the west. Animal operations are a big factor in the spatial distribution of ammonia emissions. Uncertainty in emissions from this source contributes to modeled uncertainties.

Bi-directionality of Ammonia Emissions: Plants can both take up and emit ammonia to the air. After fertilization, plants tend to be net emitters of ammonia. Deposition tends to occur in the morning and emission tends to occur in the afternoon. EPA is incorporating this into CMAQ for future work. Bi-directional flux algorithms for different types of crops or natural vegetation are needed in order to implement the algorithms in the model. Adjustment of CMAQ to account for bi-directional plant ammonia flux increases the distance that ammonia is transported away from its source and may result in a 10% increase in PM concentrations in some areas.

Future needs: In general the current understanding of nitrogen movement and transformation processes in the atmosphere is reasonably good, but emissions and deposition are still very uncertain. Being able to compare monitored and modeled concentrations will help suggest areas where inventory improvements are needed. Routine monitoring of ammonia and other inorganics is needed to better understand the partitioning of NH_x, nitrates, and sulfates. Satellite data analysis would be helpful because of its large coverage.

4. Considerations on Combined NO_x-SO_x Secondary National Ambient Air Quality Standards

Professor Ted Russell (Georgia Institute of Technology) is a member of the Clean Air Science Advisory Committee (CASAC), which advises EPA on the scientific evidence concerning health and environmental effects of air pollution and recommends air quality standards. He reviewed CASAC's consideration of a combined NO_x and SO_x secondary ambient standard.

Secondary standards: In recognition of the close linkage between the potential ecological impacts of sulfur and nitrogen deposition, EPA separated the review of primary and secondary NAAQS standards for NO_x and SO_x and focused the secondary standard review on ecological endpoints considering both pollutants together. However, the original court-ordered deadlines limit what can be done in the current review of the secondary standard. Deadlines are: proposal by February 12, 2010, and complete by October 19, 2010. Given this timeline, pragmatically, EPA saw the options to be:

1. Retain the current secondary standards (same as primary),
2. Revise the standards to be same as the new primary standards, or
3. Revoke the secondary standards entirely.

Since the CASAC review, and letter to the Administrator noting that the lack of ample time to develop more scientifically appropriate secondary standards, the schedule has been changed that should allow an approach to be developed that would support more ecologically-protective standards.

Critical load approach: In future reviews EPA plans to set a secondary standard for NO_x and SO_x based on ecological endpoints. In October 2008 OAQPS presented a conceptual approach to a standard where Acid Neutralizing Capacity (ANC) is the indicator of biodiversity and fish health. Once the ANC goal is set, it is related to a deposition load, which is then related to an atmospheric concentration that would be the standard. Ultimately both aquatic and terrestrial ecological endpoints will be considered for both acidification and excess nutrient enrichment. This "critical load" approach recognizes that the combination of both Sulfur and Nitrogen increases acidity and shows that if you reduce both, you can get to an acceptable level sooner than if you focus only on one.

Aquatic areas in the Shenandoah Valley, the Potomac Estuary, and the New River estuary are under study in testing the new approach. The airshed studied may be 5 to 30 times larger than the watershed. There is an issue as to where the standard should be applied, as critical loads can vary dramatically between ecosystems.

5. Ammonia Monitoring Efforts Supported by EPA's Clean Air Markets Division and Office of Air Quality Planning and Standards

Melissa Rury (EPA CAMD) described EPA's efforts to expand ambient ammonia monitoring. Additional monitoring is needed because of increasing ambient ammonia concentrations with limited knowledge of trends, regional variability, seasonality, and deposition fluxes. Additional monitoring could be used to improve air quality and ecological models. Currently, NH_3 dry deposition fluxes are not measured by existing monitoring networks.

Existing monitoring networks, including CASTNET, NADP, and the Chemical Speciation Network (CSN) are currently collaborating to enhance our ability to assess NH_3 concentrations and deposition fluxes. CASTNET is a long-term rural network with 87 sites which provides data to assess gaseous and particle pollutant concentrations and dry deposition. NADP currently operates 3 precipitation networks, the National Trends Network (NTN), Mercury Deposition Network (MDN) and Atmospheric Integrated Research Monitoring Network (AIRMoN). NTN has measured long-term trends in acidic wet deposition since 1978. EPA's OAQPS is collaborating with CAMD and Colorado State University to develop a mini-parallel plate denuder system for measuring 24-hr ambient ammonia concentrations at CSN sites in urban areas.

NADP's Ammonia Monitoring Network, currently an NADP initiative, uses passive NH_3 samplers to collect ambient ammonia concentrations at select sites throughout the East and Midwestern US. AMoN is a collaborative effort between NADP, CAMD and other agencies. Three passive samplers, Radiello, ALPHA and Ogawa have been compared to annular denuder measurements in the field. Currently, triplicate Radiello samplers are deployed at several sites participating in the network which have been collecting 2-week samples for 2+ years. There are several advantages to using passive monitors such as low cost and no shelters, dataloggers, or computers are required, but there are also disadvantages such as samplers must be exposed for 1-2 weeks or longer. EPA would like others to join AMoN and will coordinate the shipment of samplers every two weeks, QA and post the data for participants.

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6. Data Needs and Measurement Methods for Ammonia and Reactive Nitrogen Species

George Allen (NESCAUM) began by observing that sampling intended to improve modeling must be shorter duration sampling than wet/dry deposition (for which 1 week samples are OK). The best would be 1-hr data. Twice daily (day/night) is good, and daily data is the minimum needed. Studies done to understand ammonia flux require sub-second time resolution.

No on-line ammonia measurement methods are practical, robust methods yielding high data quality. There are no routine measurements of total ammonium ion or the NH3 being collected anywhere. Monitoring agencies need input from modelers to decide what monitoring is needed.

Typical ammonia concentrations are as follows:

- Rural non agricultural areas: ~0.5 ppb
- Urban non-agricultural areas: ~2 ppb
- Intensive farming areas: 10 ppb is common, 20-50 have been measured.

Compared with the Midwest, the northeastern US has much smaller agricultural areas and as a result lower ammonia emissions. In MANE-VU the highest ammonia concentrations occur in Lancaster County (PA) which therefore also experiences elevated nitrate concentrations. In MANE-VU Class I areas, nitrate is low at all times, even in the winter.

Nitric acid (HNO_3) deposits immediately on surfaces in an indoor environment.

Therefore, personal exposure is not correlated to ambient concentrations. Surface nighttime concentrations of nitric acid approach zero.

The dominant daytime process forming nitric acid involves the hydroxyl radical:

$$OH + NO_2 \rightarrow HNO_3$$

There is currently no routine direct measurement method for OH.

7. Quantifying Emissions of Ammonia for Air Quality Analysis

Professor Viney Aneja (NC State University) spoke on sources of ammonia emissions, how emissions have changed over time, seasonal variation, the effect of emissions controls, and future challenges for developing emissions inventories.

Emissions sources: Global emissions estimates show that the largest emission sector is domestic animal waste, soil emissions are second, then emissions from seas and oceans. Biomass burning, human excretion, and fossil fuel combustions are relatively smaller. Japanese investigators have indicated there are emissions from volcanoes.

As elsewhere, agriculture is the largest US source of ammonia emissions. The NRC reported in 2002 that the emissions from animal feeding operations cannot be ignored. Agriculture is also an important part of the economy. In 2008 CAFO revenue was $143.1 billion, and crop receipts were $181.1 billion (due to growth in the ethanol industry).

Historic emission changes: The measured concentration of ammonium ion in rainfall has increased dramatically from 1997 to 2007 in the American Midwest, PA, and upstate NY. EPA air trends data indicates that since 1970 emissions of the criteria pollutants have declined, but emissions of ammonia have increased by 27%. On the other hand, in Europe, for the same time period, ammonia has decreased by 22%. EPA projections (2007) for future ammonia emissions suggest that swine and dairy cattle emissions will level off, but emissions from beef and poultry production will increase.

Estimating emissions: There are 4 main ways to estimate emissions: emissions factors, inverse modeling, process based modeling, and remote sensing. Emission factors are typically one number and are simple to use. However, they do not provide information about the variability of emissions diurnally or seasonally. Aneja, Battye, Roelle, and others have published emissions factors for various animals and crops that are lower than EPA's from 1994. US ammonia emissions for 2002 were estimated to be about 4 million tons.

Inverse modeling is documented in a 2006 *Atmospheric Environment* article by Gilliland et al. CMAQ is able to produce ammonia concentrations similar to those monitored.

Process based modeling means to measure physical and chemical parameters of the system and develop an emissions model for a specific process, corroborating the emissions model results with measurements. NRC recommended development of a process based model. Measurement-based emissions estimates for processes provide more complex information that can be used to reflect diurnal and seasonal variation. However, process models are not available for use today, while emissions factors are. The emission factor approach is easier to use than the process based approach, but it has more uncertainty. That is why we use emission factors now.

Remote sensing for ammonia and PM is in its infancy. There is no current sensor for ammonia from space. However, ammonia measurements from space-based platforms continue to be explored.

We need to understand the full cycle of emissions, transport, transformation, deposition, and re-emission—not just the initial emissions.

Studies of a hog farm in North Carolina have helped to quantify emissions. Sources of emissions from urine and feces include production houses, waste storage and treatment systems, land application, and emissions from soil and crops.

Currently, there is no standard method identified for emissions measurements (i.e., dynamic or static chambers, micrometeorological methods, etc.). Different investigators use different techniques. Accurate and consistent emissions measurement methods are needed to identify effective control strategies.

Temporal emission variation: Summer ammonia emissions are the highest. Winter emissions are lowest. Diurnally, emissions are higher in mid-day and lower at night. Finally, there is a relationship between lagoon temperature and lagoon ammonia flux. The US EPA WATER9 model gives good estimates of lagoon emissions.

Ammonia controls: The agricultural community relies mostly on best management practices to respond to environmental concerns. Manure additives can be used to reduce ammonia emissions. As the number of animals increase, it may be necessary to move beyond BMPs. For example, North Carolina's swine waste treatment system, which includes solid-liquid separation, nitrification/denitrification, and phosphorus removal (i.e., engineered solutions).

Future Challenges: We need a network to monitor emissions from agricultural sources. The current NADP numbers are uncertain due to the method used. It's difficult to say how much variation there is in emissions estimates, because even inverse modeling relies on uncertain data. We need to measure emissions to identify sources, and understand how ammonia reacts and is transported in the atmosphere.

European requirements limit the times of the year that manure can be applied as fertilizer. Their emissions estimates are no better than ours now.

Discussion/comments:

Russ Dickerson: Ammonia also contributes to the mass of ammonium sulfate in the summer. Ammonium nitrate is important in the winter.

Viney Aneja: There are BMPs that can be applied in the winter. Once you've done all that you can to minimize the emissions of ammonia by utilizing BMPs, then engineered solutions need to be explored.

Ray Knighton: To reduce emissions in the winter, omit the fall application of anhydrous ammonia fertilizer. There is no reason to apply at this time—Europeans have shown that fertilizer can be delayed until the spring.

8. Ammonia Emissions Estimation for Modeling—Current Practice

Julie McDill (MARAMA) noted that in 2003, the National Academy of Sciences recommended improving emissions estimation methods by defining the relationship between emissions and factors including climate, weather, and site characteristics, and using a process-based model that reflects a mass balance approach to characterizing emissions from various processes.

MANE-VU is currently using an emissions factor approach. Soil emissions are not included. Activity data is being updated to 2007 based on the latest Census of Agriculture. Emissions are prepared at the county level. Livestock emissions are estimated for a year, with monthly data for fertilizer application based on a 2007 database on fertilizer sales. Emissions factors were compiled by Carnegie Mellon and have not been changed.

Agricultural livestock emissions are based on an estimated number of animals, which is held constant throughout the year. Fertilizer emissions vary by season, but other emissions are constant.

Areas that need work: locations of large CAFOs, temporal profiles for more categories, information about housing conditions that affect emissions, differences due to climate. Factors that might relate to potential controls are not identified. Temporalization of evaporation from melting snow would be useful.

The CMU improved dairy model would be helpful to use. That model shows seasonal differences for housing and application of manure. We are hoping to be able to use this.

Ammonia emissions are projected to increase in the future.

9. Ammonia Emissions in the EPA's Emission Inventory

Roy Huntley (EPA OAQPS) explained that for the 2008 National Emissions Inventory, EPA is using an updated version of the CMU model. The 2007 census of agriculture activity data will be used. Emission factors that were updated for the 2002 inventory will be used unchanged in 2009.

The changes from 2002 to 2009 can be very substantial for particular states (both positive and negative). From 2002 to 2007 there was an increase in the number of poultry and swine nationally.

Beef, dairy, poultry, and swine are the largest sources of emissions. Dairy and poultry are most important in MANE-VU.

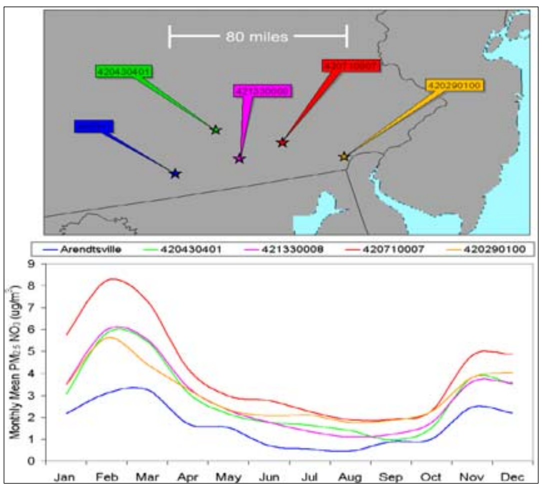
10. Characterization of the Winter Midwestern and Northeastern Particulate Nitrate Bulge

Rich Poirot (State of Vermont) provided an update on work originally reported by Marc Pitchford (NOAA), Bret Schichtel and William Malm (National Park Service), and Rich at the 2008 A&WMA Visibility Specialty Conference in Moab, UT. They analyzed patterns in the concentrations of nitrate and ammonia. Data sources included the rural IMPROVE and CASTNET networks and the urban CSN network.

The IMPROVE monitoring network with 157 sites nationwide by 2004 shows a very large maximum ammonia ambient concentrations in the agricultural Midwest. Higher levels are also evident in Central Pennsylvania-Baltimore-Washington. For the same areas the CASTNET network shows elevated wet deposition of nitrate. Trajectory analysis and emissions data point to ammonia sources in the Midwest as contributing to nitrate loadings.

For the 5 year period 2002-2006, combining IMPROVE data with CSN data shows high nitrate in the first quarter. In the second quarter sulfate was more important; in the third quarter sulfate dominated; by the fourth quarter organic carbon, sulfate, and nitrate were all important to total PM mass.

Monthly average PM2.5 nitrate (2002-2006) for five southeastern Pennsylvania monitoring sites



The above map shows 2002-2006 data from five monitoring sites in southeastern Pennsylvania. Monthly average PM2.5 nitrate shows a distinct seasonal pattern, with the highest levels in February and March.

Arendtsville, located in Adams County, PA is a very important site because PM speciation is measured at sites in counties east of there, including Lancaster County. The peak nitrate level is in February at all sites. Lancaster County is the highest site. Quite a few monitoring sites in and around the PA area of high ammonia emissions exceed the annual or 24-hour PM standards. Some of these exceedance days for which there are speciation data, are in winter, and some in summer. The winter exceedance days are dominated by nitrate. Summer days tend to be more dominated by sulfate.

Rob Pindar (EPA NERL) used modeling to estimate the seasonal effects of 50% reductions in SO_2, NO_x, or ammonia. In the summer season, a 50% reduction in SO_2 was the most effective. Reducing ammonia in the summer had little effect on summer fine particle concentrations. In the winter, on the other hand, the most efficient emission reduction in our region was ammonia. If there are controls to reduce winter-time ammonia emissions, this might be a good strategy for reducing winter PM concentrations.

The 2007 CASTNET annual report shows wet deposition is greater than dry. The dry deposition is missing a good portion of the species involved because the CASTNET data does not capture them. If you looked at total nitrogen, it would be 50-50 wet and dry. This points out the need for gaseous ammonia measurements.

11. The LADCO Winter Nitrate Study, January-March 2009

Donna Kenski (LADCO) commented that it is important not to assume monitoring results apply in too large a region. She described a study conducted in Milwaukee and Mayville, Wisconsin. Mayville is a rural site about 60 miles northwest of Milwaukee. The prevailing winds are from that direction.

LADCO conducted this study because at many sites in the Midwest, nitrate is much higher on high PM days than on the average day. The wanted to study urban excess in particulate nitrate, determine the relative effectiveness of reductions in ammonia and nitric acid concentrations on $PM_{2.5}$ concentrations, examine the role of meteorological conditions (does snow cover affect nitrate concentrations?), and examine diurnal variations. The intent was to evaluate the variability of the ammonium-nitrate-sulfate equilibrium during the winter.

The LADCO study focused on high time-resolution measurements of nitrogen species and gas precursors to particle nitrate. Eric Edgerton of ARA was their contractor. The State operated many measurement instruments at both sites, including hourly NO and NO_2 at Milwaukee and hourly SO_2 at Mayville. Both sites also had a 24-hr integrated denuder measurements every 3rd day that included H_2SO_4.

The project used NO_y monitors with various denuders and converters as well as high sensitivity SO_2 analyzers to measure nitric acid, ammonia, and sulfate. The monitors were based on existing equipment with modifications. ARA set up the instruments, which were operated by local agency staff, and ARA monitored the operation remotely.

The monitoring system was easy to use, but it can be noisy when the species concentrations change rapidly or when values are very high and measured constituents are a very small percent of the total.

At the time of this meeting, data was being delivered and analysis was just beginning. Mayville and Milwaukee particle nitrate concentrations were generally closely correlated, with some periods of difference. Nitrate and ammonium at Mayville were also similar.

EPRI and some private sector interests in Wisconsin volunteered to help pay for some data analysis. Data analysis plans include data validation, comparison of urban and rural concentrations, daytime and nighttime concentrations, box model simulations, comparisons to photochemical model results. The ISOROPIA thermodynamic model can help identify sensitivity to changes in ammonia or nitrate. Charles Blanchard has run that model for LADCO in the past.

Q&A
How will you study the impact of snow cover? Possibly by comparing times with and without snow cover and looking at snow conditions when spikes in ammonia occur.

Comment that there may be effects of temperature inversion induced by the snow.

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12. USDA Research Programs Related to Atmospheric Reactive Nitrogen

Ray Knighton (US Dept. of Agriculture) explained that only about 40% of the nitrogen applied as fertilizer gets taken up by plants. Only about 15% of the nitrogen fed to animals in grain stays in the animal; the other 85% leaves as waste products. Agricultural researchers are trying to increase the efficiency of the process.

Nitrous oxide (N_2O) and ammonia emissions are the focus of efforts to reduce nitrogen emissions to the atmosphere. N_2O is a greenhouse gas. Most N_2O emissions come from agricultural soil management; a smaller fraction comes from manure management. Ammonia emissions are principally from livestock.

Ammonium measurements from NADP (wet deposition) show that ammonium deposition was relatively constant from 1985 to 2004 in the Mid-Atlantic and

Northeast. The largest percentage increases were in the Southwest and North Central states. Overall in the US, ammonium deposition at most NADP sites was increasing. The USDA is concerned about this trend.

The Cooperative State Research and Extension Service (newly renamed the National Institute of Food and Agriculture) has three general mechanisms to support research: formula programs, competitive grants, and targeted programs. The Institute also enters into agreements with other agencies. Much of their funding supports faculty at land grant universities.

NADP is one such program started as a multi-state research project funded by USDA. It has grown such that other federal and state agencies now provide the majority of the support. The NADP program office is currently at the University of Illinois.

Research on the fate and transport of nitrogen, including process modeling has been supported by USDA. For example lidar has been used to study emissions from hog barns. Puffs of emissions seem to occur, with very high buoyancy.

There is a lot of data from agricultural research that can used to understand the fate of reactive nitrogen. Modeling and understanding the biogeochemical processes involved when fertilizer is applied is critical to properly managing nitrogen in agricultural systems.

In the last few years USDA has focused on policy, economic, and cultural barriers that are keeping producers from implementing beneficial practices. About 60% of USDA air quality grant funds are directed at integrating research with education and outreach to create more effective mitigation practices. It's important to engage farmers and producers to develop control technologies or mitigation practices that will work and that will be adopted by producers.

The USDA Agricultural Research Service also does in-house research. ARS is working to better quantify emissions, develop cost-effective controls, and better understand measurement and modeling. Since ARS research programs are intramural, they usually have a longer span than grant-funded projects.

One research result shows that if you reduce the crude protein content in the cows' diet, you can reduce ammonia emissions from the animal. Mixing in different amino acids is more effective and more expensive in reducing ammonia emissions and should be taken into consideration rather than just focusing on crude protein content.

Also within the Department of Agriculture, US Forest Service scientists have done a lot of work on passive ammonia monitoring and studying the deposition and transport of nitrogen.

Research has shown that tillage can reduce ammonia emissions from dairy slurry applied to land. Surface application of slurry causes the highest emissions; chisel plowing reduces emissions, discing emits even less, and plowing is better still. Unfortunately, these practices are not tracked in the emissions inventory.

Dr. Knighton identified several measurement gaps:

- New fast response and highly sensitive techniques for the measurement of ammonia/ammonium and nitrous oxide from plant and soil surfaces;
- Comparability of data from techniques being employed to measure ammonia/ammonium and nitrous oxide;
- Procedures to mitigate the impact of biological processes on the measurement of ammonium in precipitation;

- Better methods for evaluating field fluxes of nitrous oxide from fertilizers and land-applied agricultural wastes.

Modeling gaps:

- Numerical methods that accurately characterize the formation of ammonium-containing aerosols, including their size distribution and optical properties;
- Model representations to account for the complex atmosphere/surface exchange process involving ammonia and nitrous oxide; and
- Buoyant plume rise schemes appropriate to the dispersion of ammonia and aerosols from animal housing.

Research to address these gaps should involve both the USDA and other agencies, including EPA, NOAA, USGS, and the National Park Service.

The National Air Emission Monitoring Study began in 2006. Livestock producers have provided financial support, and EPA is coordinating the study. The data gathering phase is nearly complete. EPA will have 18 months to study the data. Purdue is the lead university.

USDA would like to be involved in cooperative field campaigns.

He expects USDA to sponsor a state of the science workshop in 2011. Dr. Aneja coordinated one for them in 2006. There will be an increased focus on nitrous oxide and methane, which are greenhouse gases.

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13. Managing Ammonia Emissions

Gary Saunders (State of North Carolina) discussed the North Carolina approach to managing ammonia emissions. NC has experienced rapid population growth. However, most of the state is rural outside the three major population centers. NC has a long history of agricultural operations, but the increase in animal agriculture is relatively recent. NC is known for swine farms but also vies with MN as the number one turkey producer.

Most hog farms in the state are large with more than half of the farms having over 1000 hogs. Just 610 farms account for 75% of all hog production. Farms with less than 100 animals are only 0.1% of total production. Hog farms are concentrated in ten counties in the eastern part of the state. However, three counties have 50% of the state production. NC has only two counties with monitored exceedances of the PM2.5 NAAQS.

State air and water quality rules apply to larger dairy, hog, and poultry farms with liquid animal waste management systems. Farm operators must take a class and become certified as operators of animal waste management systems, and farms must have a certified waste management plan, an odor management plan, and a water quality non-discharge permit. Regulated farms are inspected at least twice per year. Within the Department of Environment and Natural Resources, water and air quality staff are working with each other and trying to take a holistic approach to regulation and permitting.

Air quality regulation is focused on odor management. An agreement between the NC Attorney General's office and Smithfield Farms, Premium Standard Farms, and the independent Frontline Farmers group resulted in a study that identified 18 different technologies that could potentially be used as Environmentally Superior Technologies

(ESTs). Five of these technologies were designated as ESTs for new farms. Other technologies that can meet the control and reduction requirements can be used to meet the EST requirements for new and modified farms.

Ammonia is not directly regulated except for new and modified (expanded) hog farms. Existing farms are covered by odor management regulations. New farms must demonstrate 75% control of ammonia compared to existing hog farms. In 1997 a moratorium was placed on the construction of new manure lagoons. Farms that were rebuilt after the 1999 hurricane were not built with the ESTs but were built to "newer" standards for hog lagoons.

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14. Colorado MOU to Reduce the Impacts of Nitrogen on Class I Areas

John Vimont (National Park Service) detailed the Colorado Memorandum of Understanding to Reduce Impacts of Nitrogen on Class I Areas. The Rocky Mountain National Park (RMNP) has several air quality concerns, including: visibility, ozone, and nitrogen deposition. The RMNP Initiative began a process to address these concerns, with an initial focus on nitrogen deposition.
Rocky Mt National Park soils have excess nitrogen. Lakes at high elevation have shifted from a natural to a disturbed state, with changes in aquatic plant species. Current wet and dry deposition is about 4.0 kg/hectare/yr. The critical load goal is 1.5 kg/ha/yr of wet deposition. EPA and the Colorado Air Quality Control Commission endorsed this goal.

The process of developing a plan to implement the goal was fairly successful. The plan contains a list of possible best management practices (BMPs) to reduce ammonia emissions. There are no requirements. The legislature has not provided authorization to regulate agricultural sources. The plan includes voluntary reductions and identifies benefits from current programs. There is a commitment to include consideration of measures in the regional haze planning process. The hope is that ammonia emissions will remain constant through 2012 and that deposition will be reduced through controls on point and mobile sources required under other programs.

The park service is monitoring trends and doing attribution studies. The Rocky Mountain Atmospheric Nitrogen and Sulfur Study (ROMANS) was initiated in March 2009 to look at pollution source attribution in the Park. About two-thirds of deposition is wet deposition. East winds are associated with high concentrations. A wide variety of apportionment techniques were used. Chemical transport models (CTM) in combination with source apportionment modeling was helpful.

One conclusion from the study is that wildfires are associated with increases in ammonium. In spring and summer about 53-67% of nitrogen deposition was estimated to be due to in-state sources. The balance of nitrogen deposition was from a wide variety of regions.

Motor vehicle controls and other air quality efforts will reduce emissions of NOx. A glidepath going out to 2032 calls for reduction in deposition with an interim goal in 2012 of 2.7 kg/ha/yr. However, there hasn't been much change so far.

Ammonia is of concern because emissions have been increasing. Education and outreach to the agricultural community is planned, to show how producers can save money by implementation of voluntary measures.

15. Chesapeake Bay Foundation Nitrogen Footprint Calculator

Beth McGee (Chesapeake Bay Foundation) explained that the Calculator allows individuals to see the amount of nitrogen they contribute annually to the Bay and to evaluate ways reduce their nitrogen footprint. CBF works with institutions to reduce their footprint by a variety of measures, including driving less and create credits to offset or reduce pollution to the Bay. The Foundation promotes voluntary measures by unregulated entities. The Calculator is available on the internet at http://www.cbf.org/yourbayfootprint ,

16. Potential Use of Ammonia Reductions and Methane Capture from Livestock Operations as Emissions Offsets

Dallas Burtraw (Resources for the Future) reported on work by Jhia-Shyang Shih, himself, Karen Palmer, and Juha Siikamäki. The objective of the RFF study he described was to develop an integrated, farm-level process model to examine the full range of benefits and costs of controls for ammonia and methane emissions from dairy operations in order to evaluate the use of market-based policies to encourage adoption of methane and ammonia control technologies. Potential market mechanisms include:

- Particulate matter offset credits for ammonia control,
- Greenhouse gas offset credits for methane control. and
- Net metering policy for the sale of electricity generated from methane gas.

RFF developed an integrated assessment model and used it to characterize opportunities for a California farm. In this example, model elements and assumptions included:

- 65% ammonia reduction using a biofilter. (Simple calculations were used to account for avoided formation of PM2.5 as a result of ammonia reduction.)
- Methane reduction by anaerobic digestion systems for livestock manure. (In Europe, where waste is transported to centralized facilities, farm-based digesters are producing significant quantities of biogas)
- Electricity sale is allowed. (Selling electricity generated using biogass captured from manure.)
- CO_2 reduction was assumed to be worth $11 per ton (a conservative value).
- The retail price of electricity was assumed to be $0.11 /kWh.
- The net electrical metering rate was $0.06/kWh (a conservative value, because biogass is storable, and can be sold when marginal costs are higher).
- The value of a life used was about half of the value that used by EPA.

The net health benefits of ammonia control calculated by the model were substantial: for 400 cows, $11,910; for 500, $14,890; as compared with $29,770 for 1,000 cars. Methane control for a 1000 cow farm is about even in costs and benefits with 500 cars or more, and has a net benefit of $28,984. For all three strategies, the net benefits for a 500-cow farm would approach $30,000.

The problem is, that currently there is no institution to capture those benefits so that farmers could benefit as a result of making reductions. An emission reduction credit program would allow these benefits to be realized. If operaters were able to capture the benefits of the sale of electricity produced using biogass, then there would be a net benefit even for smaller farms.

What do we need from science and economics to develop new policies?

- A verifiable way to document emissions and reductions in emissions.
- Farm-level source-receptor coefficients.
- A better understanding of the greenhouse gas implications of different manure and livestock management approaches.
- Improved total cost estimates of control measures, including opportunity costs and transaction costs.
- More information on multi-farm digesters, which may be more economical.
- More information about impacts on water quality and odor.

What policy innovations are needed?

- Identify standard practices to allow incentive payments for additional controls.
- Inter-pollutant trading for emission reduction credits.
- Accounting for the ammonia and PM2.5 benefits of methane control.
- Offset markets for greenhouse gases.
- Unlimited time of day net metering for electricity from agricultural practices.

17. Key Points

The presentations and discussions at the meeting yielded a number of key points and recommendations for improvements in assessing the impacts of ammonia emissions in the region:

- Nitrogen atoms cascade from air to land and water through chemical reactions involving several reactive nitrogen compounds that affect human health and the environment.
- The largest source of ammonia emissions and the greatest need for improving ammonia emissions estimates relates to the agricultural sector—emissions from the whole farm and individual segments that are amenable to best management practices and controls to reduce emissions.
- Current emissions inventories need to do a better job of capturing the dynamic nature of emission. There are physical and biological reasons for seasonal variations and variations due to agricultural practices.
- Air quality agencies should work with the USDA in improving the emissions inventory.
- The NRC indicated the emission factor approach to calculating emissions should be replaced with a process model approach. This is complex and requires further work.
- The best current estimate of emissions may come from inverse modeling linking ambient monitoring data to model results; however, high concentration areas can be missed by gaps in the monitoring network
- We need an ammonia/ammonium monitoring network to address both urban and rural issues. NADP is providing data, but a more robust method would help validate models.

- We need models to help us understand the transport and transformation of ammonia emissions from ground level sources.
- Models are being improved to reflect that plants release ammonia to the air. This increases the distance ammonia is transported.
- Models show the dynamic relationship between airborne concentrations of fine particles and emissions of ammonia, sulfur dioxide, nitrogen dioxide, and VOC. The chemical interactions among these precursors can lead to increases in PM concentrations despite reductions in one or more precursors.
- Although ammonia emissions have increased in the US, ammonia emissions have been reduced in Europe through a variety of best management practices and emissions controls, including the timing of fertilizer application, the nature of animal feed, and manure management.
- We can do what Europe has done—the challenge is to not wait for better emissions data and measurements but to come up with new ideas on how to control emissions.

Appendix A – Agenda

MANE-VU 2009 Science Meeting
Total Reactive Nitrogen:
Regional Haze Impacts and Mitigation Options

Pier Five Hotel
Baltimore, MD 21202
July 28-29, 2009

Tuesday, July 28 Harbor Rooms D & E

9:30 am	**REGISTRATION**
10:00 am	**Welcome –** *Tad Aburn, MDE Air Director*
10:15 am	**Keynote Speaker: Overview of Reactive Nitrogen in the Atmosphere, and Draft Overarching Recommendations of the EPA Integrated Nitrogen Committee** *Russell Dickerson, University of Maryland*
11:15 am	**The Importance of Ammonia in Modeling Atmospheric Transport and Deposition of Air Pollution** *Robin Dennis, EPA NERL*
11:45 am	**LUNCH ON YOUR OWN**
1:00 pm	**Considerations on Combined NOx-SOx Secondary National Ambient Air Quality Standards** *Ted Russell, Georgia Institute of Technology*
1:45 pm	**Ammonia Monitoring Efforts Supported by EPA's Clean Air Markets Division (CAMD) and Office of Air Quality Planning and Standards (OAQPS)** *Melissa Rury, EPA Clean Air Markets Division*
2:15 pm	**Data Needs and Measurement Methods for Ammonia and Reactive Nitrogen Species: Atmospheric Nitrogen, from A to Z** *George Allen, NESCAUM*
2:45 pm	**BREAK**
3:15 pm	**Quantifying Emissions of Ammonia for Air Quality Analysis** *Viney Aneja, North Carolina State University*
4:00 pm	**Ammonia Emissions Estimation for Modeling—Current Practice** *Julie McDill, MARAMA*
4:30 pm	**EPA's 2008 Ammonia Inventory** *Roy Huntley, EPA OAQPS*
5:00 pm	**ADJOURN**

Wednesday, July 29, 2009   Harbor Rooms D & E

8:30 am **REGISTRATION AND COFFEE**

9:00 am **Characterization of the Winter Midwestern and Northeastern Particulate Nitrate Bulge**
Rich Poirot, Vermont DEC

9:30 am **The LADCO Winter Nitrate Study, January-March 2009**
Donna Kenski, LADCO

10:00 am **BREAK**

10:30 am **Federal Support for Research on Air Quality Impacts of Agriculture**
Raymond Knighton, USDA Cooperative State Research, Education & Extension Service

11:00 am **State of North Carolina Approach to Managing Ammonia Emissions**
Gary Saunders, North Carolina DENR

11:30 am **Colorado MOU to Reduce the Impacts of Nitrogen on Class I Areas**
John Vimont, National Park Service

12:00 noon **WORKING LUNCH – Harbor Club**
Speaker: Calculating Your Household's Nitrogen Footprint
Beth McGee, Chesapeake Bay Foundation

1:30 pm **Valuation and Policy Options, Including Consideration of the Potential Use of Ammonia Emissions Reductions as Emissions Offsets**
Dallas Burtraw, Resources for the Future

2:00 pm **Next Steps – Discussion of Options for the Region – Closing Comments**
Panel Discussion:
Susan Wierman, MARAMA - Moderator
Julie McDill, MARAMA
George Allen, NESCAUM
Raymond Knighton, USDA
Viney Aneja, NC State University
Rich Poirot, Vermont DEC
Russell Dickerson, U of Maryland

3:30 pm **ADJOURN**

APPENDIX B – Speaker Biographical Information

Allen, George*, NESCAUM.* George Allen is a Senior Scientist at NESCAUM involved with several aspects of the regional haze effort, coordination of the Monitoring and Assessment Committee, and support of the mobile source, public health, and air toxics programs.

Aneja, Viney*, North Carolina State University.* Viney Aneja is a Professor in the Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University. The U.S. Secretary of Agriculture appointed him as a member of the U.S. Agricultural Air Quality Task Force. He is a member of the US Environmental Protection Agency's Science Advisory Board Environmental Engineering Committee, and also a member of the US EPA's SAB Integrated Nitrogen Committee. He is a Member Representative of the University Corporation for Atmospheric Research, Boulder, CO. Dr. Aneja's industrial and academic research contributions have been extensively recognized. In 1998 the Air and Waste Management Association gave him its Frank A. Chambers Award, the Association's highest scientific honor; in 1999 he became a Fellow of the Association; in 2001 he received the Association's Lyman A. Ripperton Award for distinguished achievement as an educator. He is the recipient of the 2007 North Carolina Award in Science, the highest award a civilian can receive from the Governor of North Carolina. At North Carolina State University Dr. Aneja has developed one of the nation's leading agricultural air-quality research programs (http://www.meas.ncsu.edu/airquality). Much of his work has focused on the science needed to make important decisions on environmental policies in North Carolina and the nation. He has conducted research on natural and anthropogenic emissions of nitric oxide, ammonia, and sulfur compounds and demonstrated the important roles of these substances in ozone formation and gas-to-particle conversion. His research on atmospheric photochemical oxidants in the North Carolina mountains has clarified the role of long range transport of pollutants and impact of these compounds on the formation of acid rain and on the damage to trees at high elevation. His most recent research has concentrated on the critical issue of the contribution of animal feeding operations to air quality; quantifying the emissions, transformation, transport and fate of pollutants in the environment.

Burtraw, Dallas*, Resources for the Future*. Dallas Burtraw, Ph.D. is an economist. He joined RFF in 1989 and has been a Senior Fellow there since 1998. His research interests include the design of environmental regulation, the costs and benefits of environmental regulation, and the regulation and restructuring of the electricity industry.

Huntley, Roy*, EPA OAQPS.* Roy Huntley is an emissions inventory expert with the U.S. Environmental Protection Agency Office of Air Quality Planning and Standards in Research Triangle Park, North Carolina. He is a member of the Emission Factor and Inventory Group in OAQPS

Dickerson, Russell*, University of Maryland.* Russell Dickerson is a Professor and former Chair of the Department of Atmospheric and Oceanic Science at the University of Maryland at College Park. Prof. Dickerson's research focuses on the multidisciplinary areas of atmospheric chemistry and air pollution, specifically photochemistry and global biogeochemical cycles. His research group, composed of chemists and meteorologists, develops analytical instruments (for NO, NOx, NOy, NH_3, CO, SO_2, and aerosols), employs these instruments in the laboratory, field, and on ships and aircraft, and interprets the results in terms of photochemistry and atmospheric physics. They are studying the budget of tropospheric ozone both in the Baltimore-Washington area and on the large scale, the transport of trace gases in convective clouds, and the role of the atmosphere in the chemistry of the Chesapeake Bay. Observations are compared to calculations from computer models of clouds and chemistry. Prof. Dickerson was a member of the Center for Clouds, Chemistry and Climate. Aboard the NOAA Research Vessel Ronald H. Brown he and members of his group measured the gradient of atmospheric trace species across the equator in the Indian Ocean. He is also a member of the Earth System Science Interdisciplinary Center (ESSIC), which facilitates collaboration with NASA/GSCF and NOAA/ARL. Prof. Dickerson heads the Regional Atmospheric Measurement Modeling and Prediction Program (RAMMPP).

Dennis, Robin, *EPA NERL.* Robin Dennis, Ph.D. is a Senior Scientist with the U.S. Environmental Protection Agency's Office of Research and Development. He is a member of the Atmospheric Modeling and Analysis Division (AMAD) in the National Exposure Research Laboratory (NERL). A key interest of Dr. Dennis is environmental problem solving and bringing science to bear to inform and guide decision making. He was involved in setting the vision and conceptual development for EPA's third generation air quality modeling system and the resulting Community Multi-scale Air Quality Model (CMAQ), a community model. He has been engaged in the diagnostic evaluation of regional models. He is engaged in and directs the application of regional models for assessments, particularly involving cross-media modeling, linking air and water for coastal estuarine assessments, (e.g., for Chesapeake Bay) with attention to atmospheric deposition. More recently he has been engaged in linking air and fresh water/terrestrial ecosystems for critical loads assessments. He is the AMAD theme lead for ecosystem exposure modeling.

Kenski, Donna, *LADCO.* Donna Kenski, Ph.D., is the director of data analysis at Lake Michigan Air Directors Consortium (LADCO) in Rosemont, IL. Dr. Kenski's works closely with LADCO member states to develop supporting information for State Implementation Plans. Dr. Kenski's areas of expertise and research activities include source-receptor modeling and other observation-based models for source attribution of PM2.5 and haze; ensemble trajectory analysis; conceptual model development integrating ambient data with theoretical and laboratory observations; visual display of quantitative data; and development and field testing of advanced monitoring technologies. Dr. Kenski is an Adjunct Associate Professor at the University of Illinois at Chicago and a member of the EPA Clean Air Scientific Advisory Committee (CASAC), which provides independent advice to the EPA Administrator on the technical bases for EPA's national ambient air quality standards.

Knighton, Raymond, *USDA National Institute of Food and Agriculture.* Ray Knighton is the National Program Leader for Air Quality in the Natural Resources and Environment unit of the US Department of Agriculture's National Institute of Food and Agriculture. He provides national leadership for air quality research programs focused on emission data and the mitigation of greenhouse gases from agricultural production practices.

McDill, Julie, *MARAMA.* Julie McDill, P.E., has been the Senior Engineer at the Mid-Atlantic Regional Air Management Administration since January 2007. Ms. McDill has 20 years of experience in environmental engineering with an emphasis on air pollution planning, control, and regulation. Having worked as both a regulator and an industrial consultant, she understands the challenges faced by parties on both sides of the table. She has also been a researcher at laboratories in the U.S. and the

Netherlands. Her areas of technical expertise include air planning, permitting, air pollution control technology design and selection, air modeling, the air regulatory environment, engineering economics, and wastewater pretreatment technology design and selection. In addition, Ms. McDill is a Maryland State Certified Secondary Science teacher.

McGee, Beth, *Chesapeake Bay Foundation*. Beth McGee, Ph.D., is the Senior Water Quality Scientist with the Chesapeake Bay Foundation (CBF) – a non-profit environmental education and advocacy group dedicated to the protection and restoration of the Chesapeake Bay. She has been with CBF since 2003 as the lead on water quality science and policy issues. She has a B.A. in Biology from the University of Virginia, an M.S. in Ecology from the University of Delaware and a Ph.D. in Environmental Science from the University of Maryland. For more than 20 years, Beth has been very active in Chesapeake Bay water quality issues and has worked for a variety of state and federal agencies, including the U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and the Maryland Department of the Environment.

Poirot, Rich*, Vermont DEC.* Richard L. Poirot has worked as an environmental analyst in the Air Quality Planning section of the Vermont Department of Environmental Conservation since 1978. His responsibilities include developing the technical support for State Implementation Plans (SIPs) to ensure attainment and maintenance of Federal and State standards for ozone, particulate matter, and regional haze. Mr. Poirot has also developed interests in drawing inference on the nature of pollution sources from analysis of ambient measurement data, and in working in collaborative regional scientific of science/policy forums. For example, he is or has been a participant on Ambient Monitoring and Assessment Committee for the Northeast States for Coordinated Air Use Management, the Data Analysis workgroup for the Ozone Transport Assessment Group, the Science and Technical Support Workgroup for the Federal Advisory Committee Act (FACA) Subcommittee on Ozone, Particulate Matter and Regional Haze, the Monitoring and Data Analysis Workgroup for the Mid Atlantic/Northeast Visibility Union (MANE-VU), the EPA Clean Air Scientific Advisory Committee, the Steering Committee for the Interagency Monitoring of Protected Visual Environments, and the US/Canada (Air Quality Agreement) Subcommittee on Scientific Cooperation.

Russell, Armistead*, Georgia Institute of Technology.* Armistead G. Russell is the Georgia Power Distinguished Professor and Coordinator of Environmental Engineering at the Georgia Institute of Technology. Professor Russell arrived at Georgia Tech in 1996, from Carnegie Mellon University, and has expertise in air quality engineering, with particular emphasis in air quality modeling, air quality monitoring and analysis. He earned his M.S. and Ph.D. degrees in Mechanical Engineering at the California Institute of Technology in 1980 and 1985, conducting his research at Caltech's Environmental Quality Laboratory. His B.S. is from Washington State University (1979). Dr. Russell has been a member of a number of the National Research Council's committees, including chairing the Committee to Review EPA's Mobile Model, chairing the committee on Carbon Monoxide Episodes in Meteorological and Topographical Problem Areas, and serving on the committee on Tropospheric Ozone Formation and Measurement, the committee on ozone forming potential of reformulated fuels and the committee on Risk Assessment of Hazardous Air Pollutants. Recently, he served on two EPA SAB subcommittees: the CASAC subcommittee on the National Ambient Air Monitoring Strategy and the subcommittee on Air Quality Modeling Subcommittee of the Advisory Council on Clean Air Compliance Analysis. He was also a member of the EPA FACA

Subcommittee on Ozone, Particulate Matter and Regional Haze, the North American Research Strategy for Tropospheric Ozone, and California's Reactivity Science Advisory Committee. Previously he was on the Office of Science, Technology and Policy's Oxygenated Fuels Program Review and various National Research Council program reviews, and a committee to review a Canadian NRC program.

Rury, Melissa*, EPA Clean Air Markets Division.* Melissa Rury works in the Clean Air Markets Division at the U.S. Environmental Protection Agency in Washington, D.C. She has 3 years of experience working on CASTNET and has recently become involved in the NADP passive ammonia monitoring initiative. She completed her Masters Degree in 2006 at the University of Maryland, where she explored the use of particle size distribution data for distinguishing between local vs. distant and controlled vs. uncontrolled combustion sources.

Saunders, Gary*, North Carolina DENR.* Gary Saunders works for the North Carolina Department of Environment and Natural Resources as a Special Projects Engineer for the Air Quality Stationary Source Compliance Branch (SSCB), where he has worked for 11 years. Mr. Saunders has 30 years of experience conducting detailed inspections of major and complex sources and dealing with regulatory interpretation of rules and permit conditions. He was previously employed by engineering consulting firms conducting stack testing, inspection, and evaluations of facilities on behalf of the US EPA as part of their State Agency oversight role. He was part of the team of personnel that first developed the EPA Advanced Inspection Techniques courses and has been teaching courses on Inspection, Operation, Maintenance, Design, and Permitting of facilities for the past 30 years under various EPA training programs. He has also been involved in the development and presentation of specialty workshops on Kraft Pulp Mills, Cement Plants, Iron and Steel, Electrostatic Precipitators, and Fabric Filters. In addition, he has also been an instructor for the air issues component of EPA's Superfund Academy and taught specialty training courses on Superfund and RCRA issues.

Vimont, John*, National Park Service.* John Vimont works for the U.S. Department of the Interior as a Meteorologist with the National Park Service in Denver, Colorado.

APPENDIX C – Meeting Evaluation

MANE-VU Science Meeting on Total Reactive Nitrogen

Baltimore, MD
July 28-29, 2009

1. Please rate the meeting facilities and arrangements (circle one) *(18 responses)*

Poor 1	2	Average 3	4	Excellent 5	Average
-	-	-	*(11)*	*(7)*	*4.39*

Comments: The location of the meeting place was good; near public transportation was a plus.

2. Please circle the days of the meeting you attended: Tuesday, July 28……….18
Wednesday, July 29……17

3. Please rate the overall content of the sessions you attended.

	Poor 1	2	Average 3	4	Excellent 5	Average
Presentations	-	-	*(2)*	*(7)*	*(9)*	4.39
Handouts	-	-	*(5)*	*(9)*	*(4)*	3.94
Opportunities for Discussion	-	-	*(2)*	*(8)*	*(8)*	4.33
Opportunities for Networking & Exchange of Ideas	-	-	*(1)*	*(10)*	*(7)*	4.33

4. Which presentation made it most worth your while to attend this meeting and why? *(16 responses)*

- Ted Russell (5) – information of the possibility of combined NOx-SOx secondary NAAQS was very useful; liked the risk assessment component of the presentation
- Robin Dennis (4) – got some critical information on behavior of ammonia in CMAQ
- Russ Dickerson (4)
- Viney Aneja (3) – Provided an excellent overview of actual/current analysis of the environmental effects of the agricultural farming industry in NC
- Rich Poirot (3)
- Ray Knighton (2) – USDA research programs related to atmospheric Reactive Nitrogen – it was informative to hear about research being completed in the USA
- Roy Huntley
- Gary Saunders
- Dallas Burtraw
- Donna Kenski
- George Allen
- Together, the presentations provided helpful analysis of where to look and why – will we be doing harm before we do good?

5. Other things you liked about the meeting content: *(11 responses)*

- Good topic, pacing, mix of professionals and presenters
- Hearing USDA's perspective on nitrogen management
- Emission Inventory status
- The nitrogen footprint was good easing of the topic while bringing it home
- Provided a very good opportunity to learn how important the role of agriculture sector was in ammonia emissions and the various issues involved in its control, such as the interagency cooperation, need to talk to farmers for making any changes in their traditional farming practices, and other economic and political issues involved. Quality of the presentations
- Relevant to current collaborative effort within NCDENR

- Covered the full gamut of the issues from every aspect – measurements and strategies
- The opportunity to meet others such as the USDA person who might have data that can be used
- The discussions that followed many of the presentations. Nice blend of modeling and monitoring.
- Sharing of ideas. Getting to know what is occurring throughout the region in terms of ammonia research, development, and regulations. Some preliminary clarification of the difference between the two (CASTNET vs. CMAQ) monitoring systems.

Suggested improvements: *(3 responses)*

- A list of acronyms would be helpful
- A basic two-page primer on nitrogen chemistry would have been helpful for some, but, as was said, they may not read it ahead of time.
- I would have switched the first two presentations to later. Other presenters provided a better foundation.
- You could get speakers to have their presentations at least 24 hours in advance; you could send or post them. People could view on their computers or print in color or big. I think MIT does this, and NACAA. Got eye strain from not being able to see stuff either on screen or paper. Post conference posting is nice but not as useful.
- George Allen, NESCAUM – having a speaker tell us we were wasting our time was not useful- perhaps another speaker would have been more appropriate.

6. **What is the most important thing you learned at this meeting?** *(16 responses)*
   - Reductions in SOx & NOx mean ammonia is becoming more important. (3)
   - This is a difficult topic!
   - Importance of ammonia to air quality
   - Ammonia emissions are increasing in the US
   - Uncertainty/problems in ammonia/ammonium monitoring.
   - The problems, investigation and solutions of reactive nitrogen will have to be cross-agency like transportation is.
   - Diurnal Flux (Robin Dennis) doubles NHx transport distance
   - The extensive amount of work that has been performed to date by federal and state/local agencies to examine the affects of NH4/NO2 etc. on the environment
   - Upcoming changes in CMAQ – bi-directional
   - Relevant to current collaborative effort within NCDENR
   - Lancaster County may have unique PM attainment issues (post 1997 standards), requiring creative inventory, modeling, and control measures, interagency and governmental consultation – in light of lack of authority in air law to regulate agriculture. Affects Bay commitments too!
   - All was great
   - Science behind it all
   - What's being done in regards to Nitrogen and Ammonia
   - Monitoring NH3, NHx in the air
   - No good monitoring methodology
   - The impact of NH3 and Nitrogen emissions

7. **Did this meeting meet your expectations? (circle one)**

Not at all	No	Somewhat	Yes	Better than expected
		(1)	(14)	(3)

If not, please explain why:

- Would have appreciated a "policy level primer" – that is, nitrogen for dummies. I would have come for a 9:30am-10:30am session! I could not understand at least a third of this.

8. **What follow-up actions should MANE-VU staff pursue?** *(12 responses)*
   - Provide presentations and summary to the group (3)
   - Continue emissions inventory work
   - Follow-up issues on NH3 controls

- Send summary of panel recommendations to State Air Directors, especially the states who couldn't make it
- Participate in EPA discussions on NH3 monitoring regulations
- Emission Inventory improvements to the extent possible
- As part of the PM committee, help PA consider the Lancaster issue – affects haze in NJ too, according to Rich Poirot.
- Use the panel discussion as a starting point
- Email to all attendees notes from the panel discussion
- Look at the issues associated with inventory and monitoring
- Send out a meeting summary, with next steps included
- Give synopsis of EPA plans for ammonia regulations

9. Any other comments?

- This was a comprehensive, exceptional workshop.