IMPROVED REDUCED NITROGEN DEPOSITION ESTIMATES IN THE UNITED STATES: SPATIAL VARIABILITY OF AMMONIA

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ABSTRACT: Over the past decade, reduced nitrogen (NHx) has become an important component of atmospheric nitrogen deposition due to increases in agricultural activities and reductions in oxidized sulfur and nitrogen emissions from the power sector and mobile sources. Reduced nitrogen is known to cause negative impacts on air quality (i.e. PM2.5 formation) and ecosystems (i.e. eutrophication, soil acidification), yet the fate and transport of reduced nitrogen from emissions sources is not well characterized in the United States. Ammonia is believed to be deposited locally around large emissions sources, but can be re-emitted back into the atmosphere or react with acidic gases to form NH_4^+ particulates, allowing for transport and deposition much further downwind. Ammonia also alternates between particulate (NH_4^+) and gas phases with differing atmospheric and meteorological conditions greatly affecting the fraction which is transported or deposited.

Here we perform a field study and statistical analysis to determine the distance at which variability between sites can be explained for use in inverse distance weighting approaches utilized in gridded map products. In this study, it was noted that monitoring sites within 20km of large animal feeding operations near Fort Collins, CO (Figure 1) are significantly impacted by emissions from the point sources and, therefore, do not represent a regional signal. We will continue to investigate the appropriateness of the current AMoN siting criteria for large animal operations to identify a distance that represents regional NH_3 concentrations.

BACKGROUND: To better characterize NH_3 concentrations on a national scale, NADP's AMoN began measuring bi-weekly NH_3 concentrations in 2007 and has grown to nearly 100 monitoring sites. Many of the sites that began measuring during the initial pilot study (2007) have shown an increasing trend in NH_3 concentrations, but little is known about how concentrations vary between site locations. Knowledge of the spatial variability is important as it is a key factor in measurement-model fusion approaches such as the NADP Total Deposition (TDEP) Science Committee's hybrid map product. The distances used for inverse distance weighting in the TDEP maps were determined using concentration grids from CMAQ in a variogram analysis for each pollutant. The variogram was fitted using an exponential covariance model[a]. Given the high spatial variability of NH_3 concentrations, an evaluation of these distances is needed.

A field experiment was conducted where ambient NH_3 was measured using the AMoN passive samplers at 17 sites located around the Fort Collins, CO AMoN site (CO13) and 9 sites around the University of Illinois Bondville monitoring station (IL11) (Figure 1). Samplers were deployed for 1-year resulting in ~10 sampling periods per location. The two different areas were selected based on varying land-use, source type, and the proximity of sampling locations to those sources. The Fort Collins area is heavily influenced by large confined animal feeding operations (CAFOs) to the east in Weld county and complex terrain to the west (Rocky Mountain National Park). Bondville is a relatively flat, agricultural landscape that is impacted by nearby fertilized crop fields. To estimate the variability in concentration at each site, a correlation analysis was performed for all site pairs for the 2 regions.

RESULTS: AMoN siting criteria was not considered when the supplemental sites were selected. Therefore, we were able to evaluate whether the siting criteria developed in 2010 would represent a regional NH_3 concentration. Figure 1 shows the CAFOs located in and around Weld county, CO. Results of the study indicate that variability between sites significantly increases within 20 km of a CAFO (Figure 2). The current AMoN siting criteria requires that a site is located greater than 500 m away from large animal operation facilities. ***We will continue to investigate the appropriateness of the siting criteria for large animal operations to determine a distance at which site should be identified as being source impacted due to proximity to a large CAFO. We will also recommend that the NADP adopt EPA's definition for large CAFOs (Table 1).***

TABLE 1. Suggested update to AMoN siting criteria with size thresholds for CAFO's

Animal Sector	Large CAFO	Animal Sector	Large CAFO
Cattle	1,000+	Swine (weighing over 55 lbs)	2,500+
Dairy Cattle	700+	Swine (weighing less than 55 lbs)	10,000+
Turkeys	55,000+	Horses	500+
Laying Hens/Broilers (liquid manure handling system)	30,000+	Sheep/Lambs	10,000+
Chickens Other Than Laying Hens (other than liquid manure handling system)	125,000+	Laying Hens (other than liquid manure handling system	82,000+

The second goal of the study was to determine the regional representativeness of AMoN sites to support the NADP's Total Deposition Science Committee's hybrid map products. The TDEP maps use a seasonal radius of influence for the interpolation method using estimates from CMAQ (ftp://ftp.epa.gov/castnet/tdep/Total_Deposition_Documentation_current.pdf). The latest version of the TDEP maps does not use AMoN to estimate NH_3 deposition as additional information on spatial variability such as that provided by this study was needed. Figure 2 shows the regression coefficient (r^2) versus distance (km) for each site pair. The Bondville region showed low variability between site pairs up to 115 km (distance between BD01 and BD09). The results from the Fort Collins region was more variable due to the influence from point sources (CAFOs) and complex terrain (elevation difference of more than 2000m between FC04 in the foothills and CO02 on the Niwot Ridge). In this study there were not enough sample periods in each season to estimate a seasonal radius of influence for the inverse distance weighting approach. If AMoN concentrations are utilized for inverse distance weighting, it's suggested that the site locations near large point sources (CAFOs) be treated separately. ***The variability is explained between sites at a distance of 45 km for sites not impacted by large confined animal feeding operations. There will be more uncertainty in the interpolated concentrations over complex terrain.***

In subsequent versions of TDEP, the measured NH_3 concentrations should be included in the bi-directional framework. Soil and vegetation chemistry, meteorology and canopy characteristics will be measured at select AMoN sites to determine how the bi-weekly concentrations may be used to drive the bi-directional flux box model. Results from the spatial variability study and the site characterization pilot will provide the TDEP community with improved estimates of net NH_3 flux in the next version of the maps.

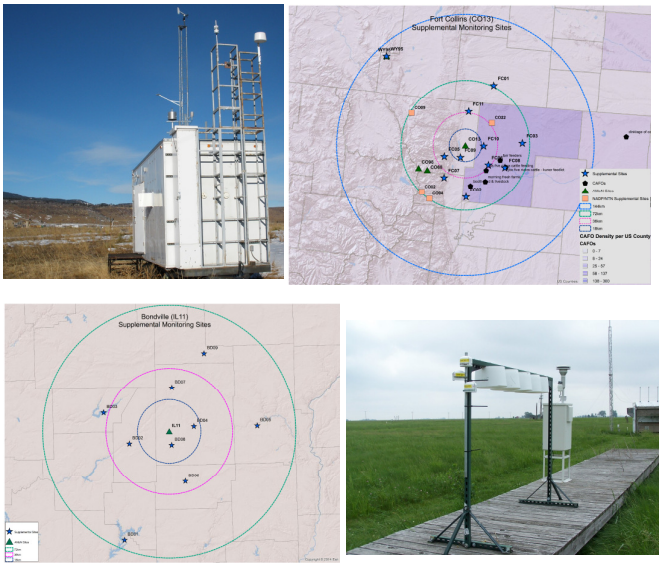

Figure 1: Supplemental monitoring sites located around the Fort Collins, CO (CO13) and Bondville, IL (IL11) AMoN sites. Circles show distances (radius) in km around the AMoN sites. Large confined animal feeding operations (CAFOs) are shown on the Fort Collins map with black pentagons. Several of the Fort Collins supplemental monitoring sites were co-located with existing NTN or AMoN sites. These sites are represented by pink squares or green triangles, respectively. Complex terrain (high elevation) is represented on the Fort Collins map.

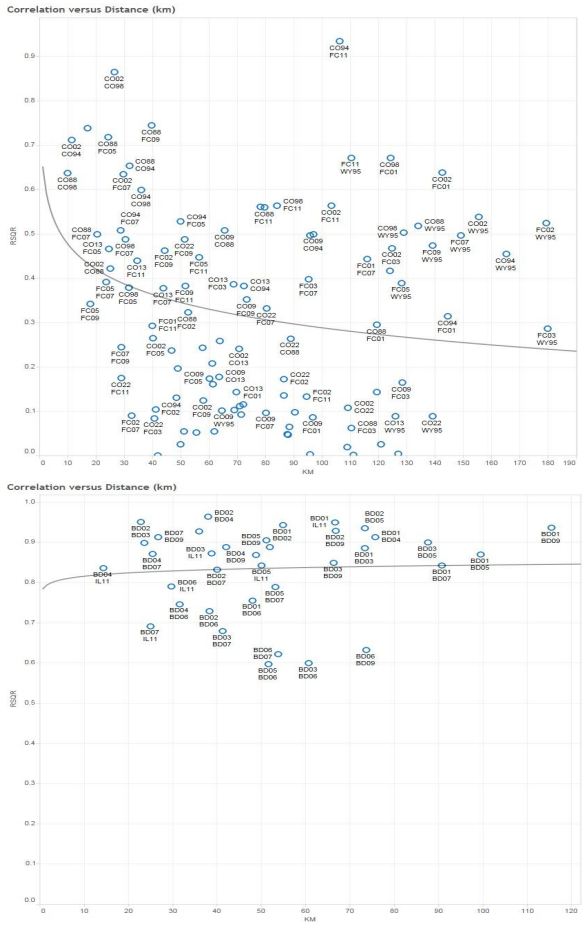

FIGURE 2: Correlation analysis from Fort Collins region (top) and Bondville region (bottom). Plots show the r^2 versus distance for each site pair. Concentrations were consistent with AMoN annual average concentrations as measured by the network.

ACKNOWLEDGEMENTS: We would like to thank all the site operators that participated in this study including Derek Day, Doug Gucker, Jennifer Morse, Ryan Lotkeff, Mark Lindquist, Justin Scharton, Jane Tollett, Sybil Anderson, and Cara Kesler

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