Chapter 8
CASTNET Methodology for Modeling Dry and Total Deposition

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Abstract Gaseous and particulate pollutants are deposited to the environment through dry, wet, and occult atmospheric processes. The US Environmental Protection Agency (USEPA), in conjunction with the National Park Service (NPS), the Bureau of Land Management (BLM), and other partners, has established the Clean Air Status and Trends Network (CASTNET) to provide estimates of the dry deposition component of total deposition of sulfur and inorganic nitrogen across the United States. CASTNET began operation in 1991 and currently features 90 active sites with many partners including multiple federal agencies, tribal, state, and local entities, and educational institutions. Most CASTNET locations are rural and intended as long term monitoring sites. Previously, CASTNET used an inferential method to estimate dry deposition by combining measured pollutant concentrations and modeled deposition velocities. Until recently, deposition velocities were modeled using the NOAA/USEPA Multi-layer Model (MLM), which incorporated meteorological measurements and information on the vegetative cover within 1 km of each site. These values were combined with wet deposition values provided by the National Atmospheric Deposition Program's National Trends Network (NADP/NTN) to obtain total deposition. Recent changes to the methodology have improved data completeness.

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8.1 Introduction

In 2011, CASTNET adopted a data substitution method developed by Bowker et al. [1] to allow for the estimation of deposition velocities in the absence of meteorological inputs whether due to invalid data or lack of monitoring. This results in nearly 100 % data completeness for dry deposition estimates at CASTNET sites. Also, the Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data set was utilized to improve the resolution of wet deposition estimates, particularly in high elevation areas. Using this method, CASTNET and NADP data show that total deposition of sulfur and nitrogen have decreased by approximately 47 % and 26 %, respectively, over the past 15 years.

The current methodology is part of a transition from the inferential method to a hybrid model that will incorporate deposition velocities produced using the Community Multiscale Air Quality (CMAQ) model with concentrations collected by CASTNET. The resulting dry deposition data set will have dramatically improved spatial resolution and will permit increased use of CASTNET data for applications such as analyzing critical loads throughout the United States.

8.2 Estimating Dry Deposition

Dry deposition processes are modeled as resistances to deposition. CASTNET's original network design was based on the assumption that dry deposition or flux could be estimated as the linear product of measured pollutant concentration (C) and modeled deposition velocity (V_d). V_d is influenced by meteorological conditions, vegetation, and atmospheric and plant chemistry. The deposition velocity values for each site are calculated for each hour of each year using the MLM [3, 4]. The data used as inputs include meteorological measurements with an estimation of the vegetative species and associated characteristics including leaf-out timing and leaf area index (LAI).

In 2010, EPA discontinued meteorological measurements at all but four of the EPA-sponsored CASTNET sites. NPS- and BLM-sponsored sites continue to measure these parameters. The loss of this source of inputs for the MLM plus the need to improve V_d data completeness resulted in the development of a method by EPA [1] to substitute historical average hourly V_d values for missing MLM simulations. The substitution method was applied to the historical CASTNET database and used for dry deposition estimates beginning in 2012.

Historically, modeled V_d values have been about 70 % complete for a given year. Bowker evaluated the new approach, which captures the site-specific diurnal and seasonal patterns in modeled V_d values, by calculating the differences created by replacing missing V_d values with the substituted data and calculating the percent error (%E) and percent difference (%D) between the original data and substituted data for 5,000 pairs of annual V_d values.

Both measures of bias were found to be site dependent. The %E increased generally with the percentage of missing data for the 11 sites selected for evaluation. The %D showed both positive and negative average percent differences across the range of percent missing data. For a particular year at any given site, the annual mean V_d resulting from substitution was either higher or lower than the true mean and, consequently, showed little bias. The results indicated that the average percent difference was relatively small (less than ±5 %).

8.3 Using PRISM to Estimate Wet Deposition for CASTNET Sites

NADP/NTN operates wet deposition samplers to measure concentrations of pollutants in precipitation and to calculate the deposition rate of air pollutants removed by precipitation. NADP/NTN operates more than 250 monitoring sites across the United States. Historically, wet deposition values were obtained from a grid of concentration and precipitation estimates derived from available NADP/NTN sites by using an inverse distance weighting (IDW) algorithm. Despite the equivalent precipitation and wet deposition values at NADP/NTN sites, this IDW approach produces interpolation errors, especially in regions with variable terrain and low geographic site density.

In 2011, the Parameter-elevation Relationships on Independent Slopes Model (PRISM) model [2] was selected by CASTNET and NADP as a source of precipitation data because it provides more accurate estimates of annual precipitation values in areas with complex terrain. The model was developed by the PRISM Climate Group at Oregon State University (OSU). PRISM uses point precipitation measurements, a digital elevation model (DEM), and other geographic data to estimate annual, monthly, and event-based precipitation data on a 4 km grid resolution.

Unlike statistical models such as IDW or kriging, PRISM is not a system of equations but a coordinated set of rules, decisions, and calculations designed to emulate the decision-making process a climatologist uses when creating a map of climatic data. The PRISM gridded data are adjusted to the precipitation measurements collected by NADP. Concentration in precipitation maps are then produced for the PRISM grid. The concentration values are multiplied by the precipitation rates to obtain gridded wet deposition fluxes. Gridded wet deposition fluxes are then interpolated to CASTNET monitoring locations [6].

The PRISM results indicate a significant improvement over the IDW estimates. Figure 8.1 presents scatter plots that show NADP/NTN measured precipitation rates compared to estimated IDW values and measured NADP/NTN rates compared to estimated PRISM values in the right diagram. In Fig. 8.1, the MARPD calculated using a bootstrapping method for PRISM and NADP/NTN precipitation data is 2.5 % versus an MARPD of 39 % between IDW-derived grid and NADP/NTN precipitation values.

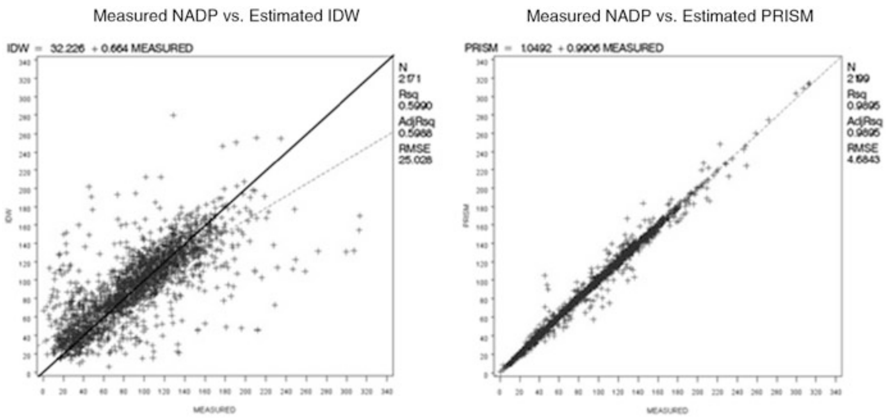

Fig. 8.1 Comparison of NADP precipitation measurements with IDW estimates and PRISM estimates for 1999–2009 (Source: EPA Clean Air Markets Division)

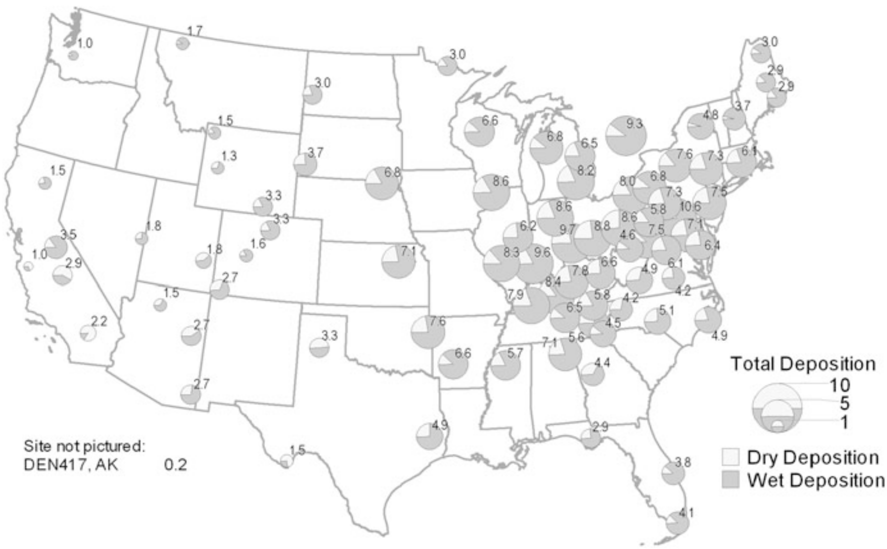

Fig. 8.2 Total inorganic nitrogen deposition (kg/ha/year) for 2011

8.4 Estimates of Total Deposition

The MLM/Bowker approach was used to estimate dry deposition fluxes for 2011 for all CASTNET sites. These were combined with PRISM-adjusted wet deposition rates from NADP. Figure 8.2 presents a map of N deposition using this method. The estimates updated using the Bowker approach and incorporating PRISM-adjusted NADP data indicate that total deposition of sulfur and nitrogen has declined by approximately 47 % and 26 %, respectively, over the past 15 years.

8.5 Summary

CASTNET and NADP/NTN data are used to produce estimates of total sulfur and inorganic nitrogen deposition. In 2011, both CASTNET and NADP began using revised procedures that produced improved total deposition estimates. As a next step for estimating dry deposition, CASTNET will transition from the inferential method to a hybrid model that will incorporate deposition velocities and concentration surfaces produced using the Community Multiscale Air Quality (CMAQ) model with concentrations measured by CASTNET [5]. The new method will include modeled species that are not measured at CASTNET sites. The resulting deposition data set will realize improved spatial resolution and will permit increased use of CASTNET data for applications such as analyzing critical loads.

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