Clean Air Status and Trends Network
CASTNET

PROGRAM OVERVIEW

CASTNET is a multipollutant air quality network with rural monitoring sites located throughout the United States (U.S.) and Canada (**Figure 1**). The monitoring sites are generally located away from large stationary emission sources but are often in locations that capture air quality impacts from wildfires, dust events, agricultural facilities, and oil and gas extraction activities from regional to local scale. CASTNET is managed and operated by the U.S. Environmental Protection Agency (EPA) in cooperation with the National Park Service (NPS); Bureau of Land Management, Wyoming State Office (BLM); and Tribal, federal, state, and local agencies. The network was established in response to the 1990 Clean Air Act Amendments **to assess the effectiveness of emission reduction programs** by reporting trends in air pollution and deposition. Over the past three decades, CASTNET has evolved to adapt to changing Agency science data needs, upgraded to regulatory-grade ozone monitors, and added new measurements to address National Ambient Air Quality Standards (NAAQS) pollutant formation. Data from CASTNET also **support the assessment of the primary and secondary NAAQS** for ozone, nitrogen dioxide, sulfur dioxide and $PM_{2.5}$. With CASTNET's 35-year continuous record, the data are key to understanding **long-term air quality trends**. Additionally, CASTNET data are used for **assessing air pollution impacts to sensitive ecosystems** and **applications related to environmental assessments and permitting**.

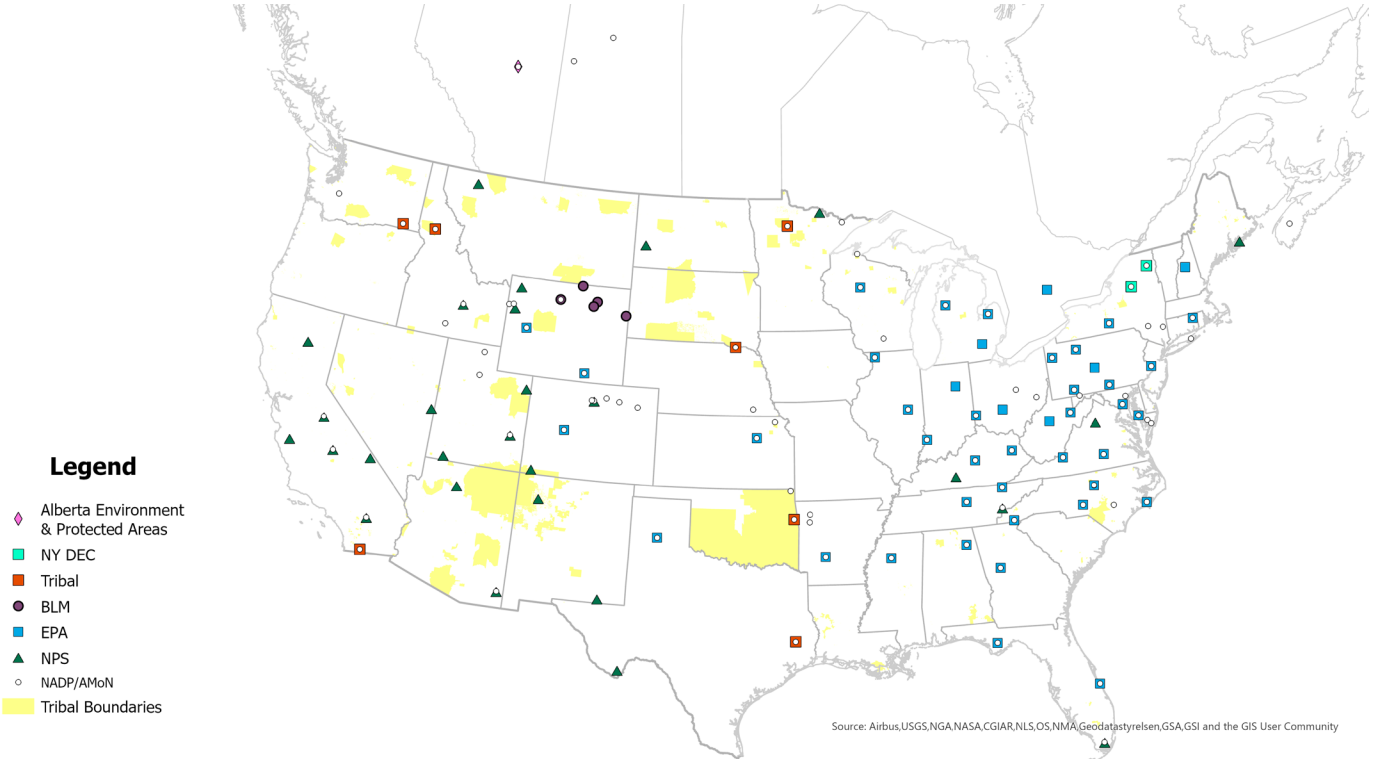

Figure 1 Current CASTNET site locations (May 2024) with primary site sponsors.

MEASUREMENTS

CASTNET https://www.epa.gov/castnet provides information on ozone and precursors of secondary aerosols ($PM_{2.5}$) (**Table 1**). The CASTNET measurements are valuable for understanding local conditions and regional pollution transport across political boundaries (state, Tribal, and international). CASTNET ozone data are reported near-real time to AirNow, allowing the public to quickly make decisions about health risks associated with outdoor activities in rural locations during periods of poor air quality. The ozone data are also reported to EPA's Air Quality System (AQS) to support NAAQS for ozone compliance activities. Data from CASTNET fill in spatial gaps in Tribal and other federal (National Parks, Wilderness areas), state, and local air quality monitoring programs.

Most CASTNET sites are co-located with National Atmospheric Deposition Program (NADP) monitoring locations. The NADP is a collaborative organization made up of sponsors from federal, Tribal, state agencies, non-governmental organizations, universities, industry, and international agencies. The NADP provides data on air concentrations of ammonia and other toxics (e.g., mercury) and precipitation chemistry.

Air quality observations from CASTNET are combined with precipitation chemistry measurements known as wet deposition from NADP and modeled values from EPA's Community Multiscale Air Quality (CMAQ) model to report on trends in total atmospheric deposition. This technique is referred to as measurement model fusion (MMF). CASTNET is the only network in the U.S. reporting dry and total deposition.

Atmospheric deposition *represents air pollution that is deposited to the earth's surface. It contributes to the loss of biodiversity, reductions in vegetation growth (e.g., crops, tree species), eutrophication, and acidification of ecosystems.*

Dry deposition *is the fraction of atmospheric pollution that is deposited to the earth's surface by settling, impaction, or adsorption. Dry deposition is estimated using measured atmospheric concentrations collected from CASTNET filter packs with modeled deposition velocity (i.e., the rate at which the gases and particles are deposited to the surface).*

Wet deposition *is the fraction of atmospheric pollution deposited to the earth's surface by precipitation, predominately as rain, snow, or cloud droplets. Wet deposition is measured by the NADP's National Trends Network (NADP/NTN;* ***Table 1****). Measured pollutant concentrations in precipitation are combined with precipitation amounts.*

Dry and wet deposition a*re summed to estimate the total deposition of pollutants (gases and particles) to the earth's surface.*

Network	Measurement Method	Pollutants	Number of Sites	Length of Record (years)
CASTNET	Weekly filter pack	Particles (SO_4^{2-}, NH_4^+, NO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-); Gases (SO^2, HNO_3)	81	37
	Continuous UV analyzer	O_3	77	37
NADP/NTN	Weekly Precipitation collector + rain gage	SO_4^{2-}, NH_4^+, NO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, pH, precipitation amount	246	46
NADP/AMoN	Bi-weekly passive sampler	NH_3	90	17

Table 1 Summary of routine measurements collected at CASTNET and NADP monitoring sites

EXPANDING MONITORING CAPACITY ACROSS RURAL AMERICA

CASTNET fills a unique gap in the nation's air quality monitoring program by providing air quality and environmental results in rural locations that often lack data, yet 97 percent of the U.S. landmass is considered rural and is home to more than 40 million people. The CASTNET program provides site infrastructure and equipment, training, quality assurance activities, and data to reduce the burden on network partners that help operate the sites. The network has designed a small-footprint monitoring site that enables communities to make decisions about daily activities based on air pollution health risks.

To address the evolving data needs of the Agency and its stakeholders, EPA requested a scientific review of the program by the EPA's Science Advisory Board (SAB). Based on the recommendations from the SAB report (EPA's SAB 2024), EPA is implementing changes that will optimize the size of the network while investing in new measurements and expanding monitoring to fill key spatial gaps in the U.S. as resources permit. EPA will deploy $PM_{2.5}$ sensors at CASTNET sites to expand the suite of measurements provided. The near real-time $PM_{2.5}$ measurements will be used to inform communities of potential health risks during poor air quality days due to anthropogenic pollution or events, such as wildfires, dust, etc. Additionally, the program will identify new partnerships and leverage resources to fill key data gaps in the central U.S. (e.g., new Tribal monitoring sites) to help inform policy decisions to address increasing levels of nitrogen and elevated springtime ozone concentrations in this region.

In addition to routine measurements, CASTNET has become a platform for addressing emerging contaminants of concern (e.g., per- and polyfluoroalkyl substances, perchlorate), evaluating wildfire and/or prescribed burn impacts on air quality, validation of satellite air quality measurements, and evaluation of air quality and deposition measurement methods. For example, EPA will evaluate the relationships between black carbon in precipitation and existing CASTNET and NTN measurements to characterize how biomass burning has impacted air quality over time in the western U.S.

CASTNET provides the backbone for many research activities that continue to advance atmospheric science. At the Duke Forest research site, EPA's Office of Research and Development operates a CASTNET site. The routine data are used to evaluate new measurement methods and improve deposition algorithms used in EPA's chemical transport models.

RESULTS

A brief snapshot of results provided by CASTNET is included in this section. Additional national maps and charts as well as trends from individual sites can be found on the CASTNET website.

OZONE

Ground-level ozone, often referred to as “smog,” is measured at more than 80 CASTNET sites. Ozone can cause negative health impacts, particularly for children, the elderly, and people with respiratory diseases such as asthma. Elevated ozone concentrations can also damage vegetation (e.g., crops, trees) and ecosystems. The 2015 NAAQS for ozone was set at 0.070 ppm (or 70 ppb) using the 3-year average of the fourth highest daily maximum 8-hour rolling average. Ozone is not directly emitted from sources but is formed in the atmosphere by NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Regulations to control NO_x emissions from the power sector and mobile sources have resulted in significant reductions in ozone concentrations in the eastern United States (**Figure 2**), but events such as extreme heat and higher frequency of wildfires will continue to slow progress towards areas meeting attainment. Smaller reductions in ozone concentrations have been realized in the western U.S (not shown) due to topography, international pollution transport, and other impacts.

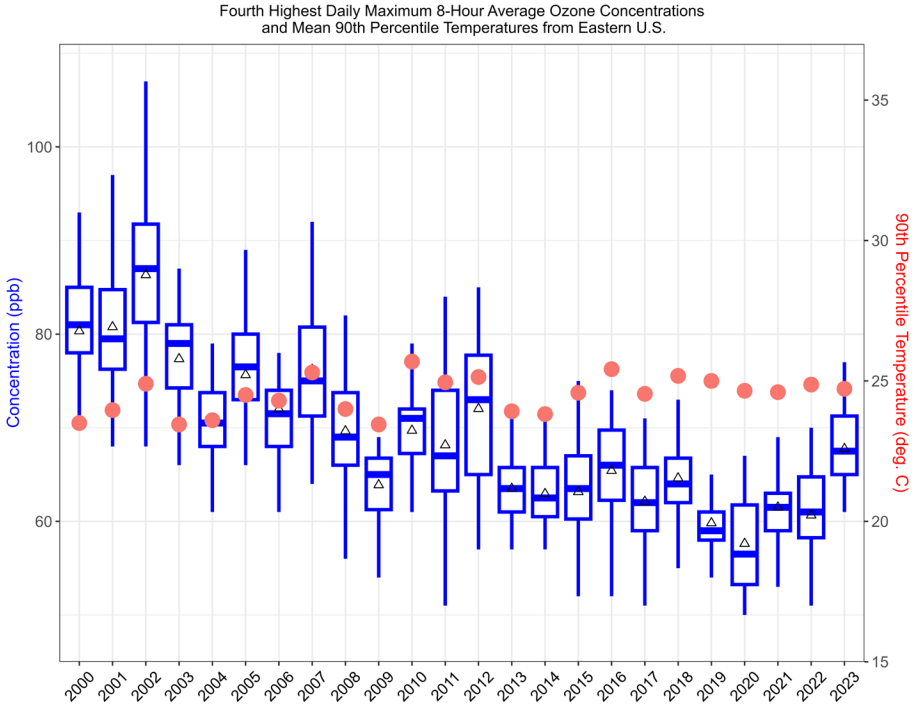

Figure 2 Trend in fourth highest daily maximum 8-hour ozone concentrations from eastern CASTNET reference sites. Boxes extend from the 25th to 75th percentiles with median line. The whiskers extend to 1.5 interquartile range, and the mean is represented by a triangle. The 90th percentile of hourly temperature from the eastern reference sites are displayed as red circles to show the relationship between high temperatures and ozone concentrations.

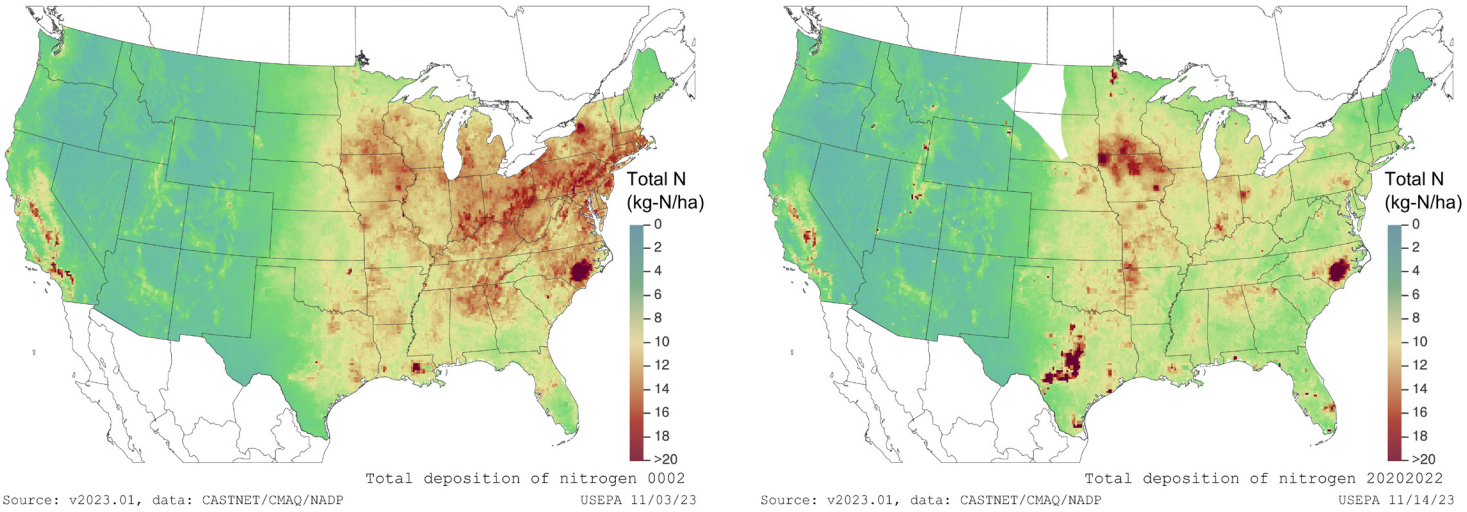

Figure 3 Total deposition of nitrogen (kg-N ha^{-1}) from 2000-2002 (left) and 2020-2022 (right)

ATMOSPHERIC DEPOSITION

The measurement model fusion process used to create dry and total deposition maps is described in Schwede and Lear (2014), and maps can be found on the NADP/TDep website. Significant reductions in oxidized sulfur and nitrogen deposition fluxes have been realized throughout the United States; however, increases in reduced nitrogen (NH_x) are persistent in areas impacted by agricultural activities. **Figure 3** shows the changes in total nitrogen (oxidized + reduced) deposition between 2000-2002 and 2020-2022.

CRITICAL LOADS: LAND MANAGEMENT AND PERMITTING

A “critical load” is the amount of air pollution that leads to harmful changes in an ecosystem, including changes in aquatic and terrestrial plant diversity, soil nutrient levels, or fish health (Nilsson, 1988; CLRTAP, 2004). Excess nitrogen and sulfur deposition can negatively impact ecosystems and the services they provide. The CASTNET data are critical for linking air quality to deposition, which is then used by land management and regulatory agencies to assess the environmental impacts

for permit applicants, forest planning, watershed assessments, and wilderness protection. For example, the baseline deposition and expected critical loads exceedances (i.e., where deposition is higher than the critical load) are evaluated during Environmental Impact Statements (EIS) and Environmental Assessments (EA) as required under the National Environmental Policy Act (NEPA). A primary purpose of this process is to aid in the protection and enhancement of air quality in national wilderness areas and other locations of scenic, recreational, historic, or natural value from new sources of air pollution. Total deposition (**Figure 3**) is compared to the critical load criterion to determine exceedances, where deposition is above the critical load and impacts are likely occurring. **Figure 4** depicts the critical load exceedances for herbaceous species and sensitive tree species in Shenandoah National Park. Excess nitrogen is likely causing damage to herbaceous species in some regions of the park. These species support wildlife habitats and carbon storage, prevent erosion, and help control pests. An important function of CASTNET is tracking how long term shifts in the energy sector, land use, and agricultural activities impact important air quality and ecosystem services.

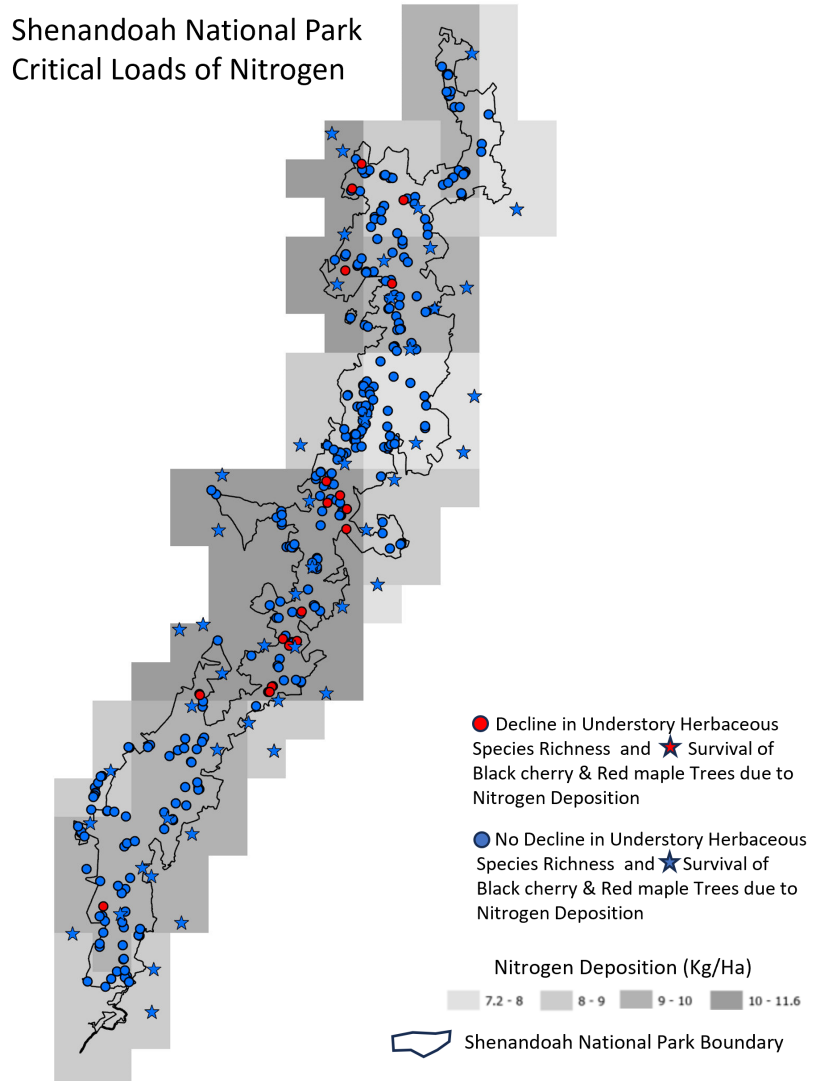

Figure 4 Map showing critical load exceedances for herbaceous species, black cherry and red maple in Shenandoah National Park (VA). Total nitrogen deposition is calculated from CASTNET, NADP/NTN and modeled deposition.

DATA AVAILABILITY

CASTNET Data: Ambient concentrations, dry and total deposition fluxes, and site information can be downloaded from the CASTNET website (https://www.epa.gov/castnet) under "Download Data."

NADP Data: NTN wet deposition data and AMoN ambient NH3 concentrations can be downloaded from the NADP website (https://nadp.slh.wisc.edu/)

TDep Hybrid Method Estimates: Data and maps produced using the hybrid method can be downloaded from the NADP TDep website (https://nadp.slh.wisc.edu/committees/tdep/).

AirNow: Provides near-real time air quality data and forecasts. AirNow reports air quality using the offical U.S. Air Quality Index (AQI). (https://www.airnow.gov/)

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