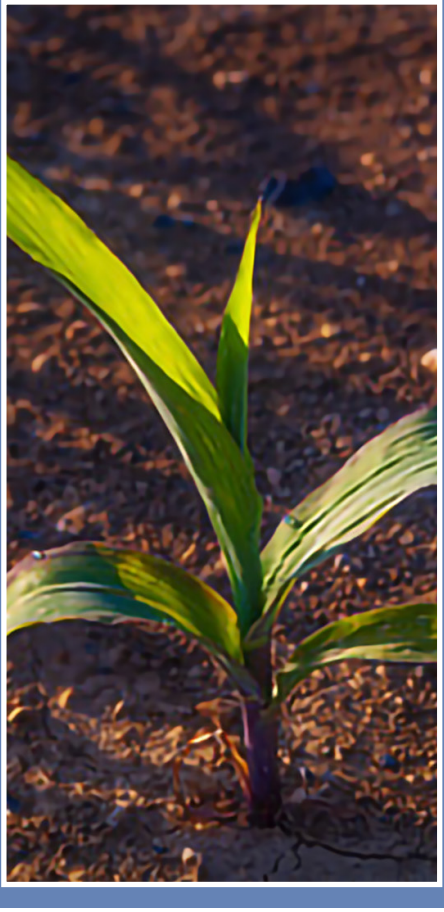
# Clear Air Status and Trends Network: Providing Air Quality Data to Rural Americans

## PROGRAM OVERVIEW

The Clean Air Status and Trends Network (CASTNET) is a **rural, multipollutant ambient air quality network** with sites specifically located away from large stationary emission sources (e.g., power plants, industry). Even though ninety-seven percent of the U.S. landmass – with a population over 65 million people – is considered rural, communities without CASTNET sites often rely on data from urban air quality monitors, which are influenced by local sources[1].

The network was established **to evaluate the need for and to assess the effectiveness of Clean Air Act emission reduction programs** by reporting spatial and temporal trends in air pollution and atmospheric deposition. One important use of CASTNET data is to **support the assessment of the primary and secondary National Ambient Air Quality Standards (NAAQS)**. The NAAQS are reviewed and set by the EPA Administrator at air levels that are protective of human health and the environment. To determine if an area meets the NAAQS, monitoring networks measure air quality and report data to EPA. With CASTNET's 35-year continuous record, the data are key to understanding air quality impacts to **human and environmental health**. Additionally, CASTNET data are used for assessing air pollution impacts to sensitive ecosystems and applications related to environmental assessments and permitting by land managers.

CASTNET is managed by the U.S. Environmental Protection Agency (EPA) and operated as a cross-agency partnership with Tribal, federal, state, and local agencies. While each partner agency may have an independent mission, every CASTNET site is operated following consistent, well-established methods. The CASTNET federal sponsors (EPA, National Park Service, and Bureau of Land Management) provide site infrastructure and equipment, training, quality assurance activities, and data to reduce the burden on network partners that operate the sites. Partners often provide in-kind services such as utilities or staff to collect weekly samples.



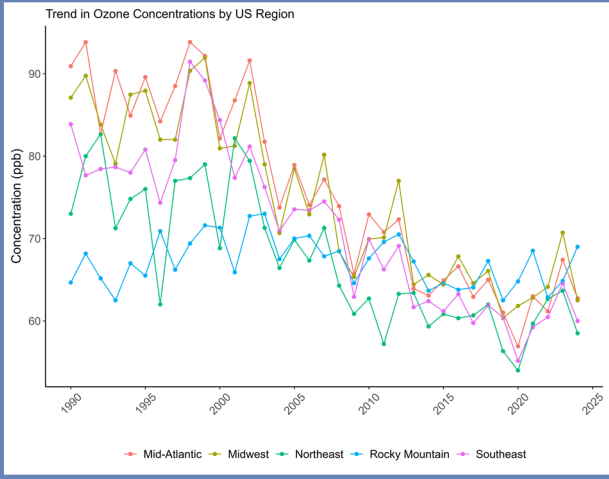



***Figure 1*** *The CASTNET program fills a critical role in federal, Tribal, state and local agencies' ability to establish and evaluate effective air pollution programs. When emission reduction programs are implemented, CASTNET and other air monitoring programs track progress in meeting air quality goals. Elevated levels of air pollution may cause negative health and environmental impacts (e.g., damage to crops, aquatic species). Left: CASTNET monitoring site at Haskell Indian Nations University. Middle: prolonged ozone exposure to crops can reduce yields and impact agricultural production. Top right: Measured ozone concentrations (shown as the annual mean of the 4th highest daily maximum 8-hour average) for several regions in the U.S. Bottom right: CASTNET was first established (over 30 years ago) to track air quality and atmospheric deposition due to changes in power sector emissions under Sections 401-416 (Title IV) of the Clean Air Act.*

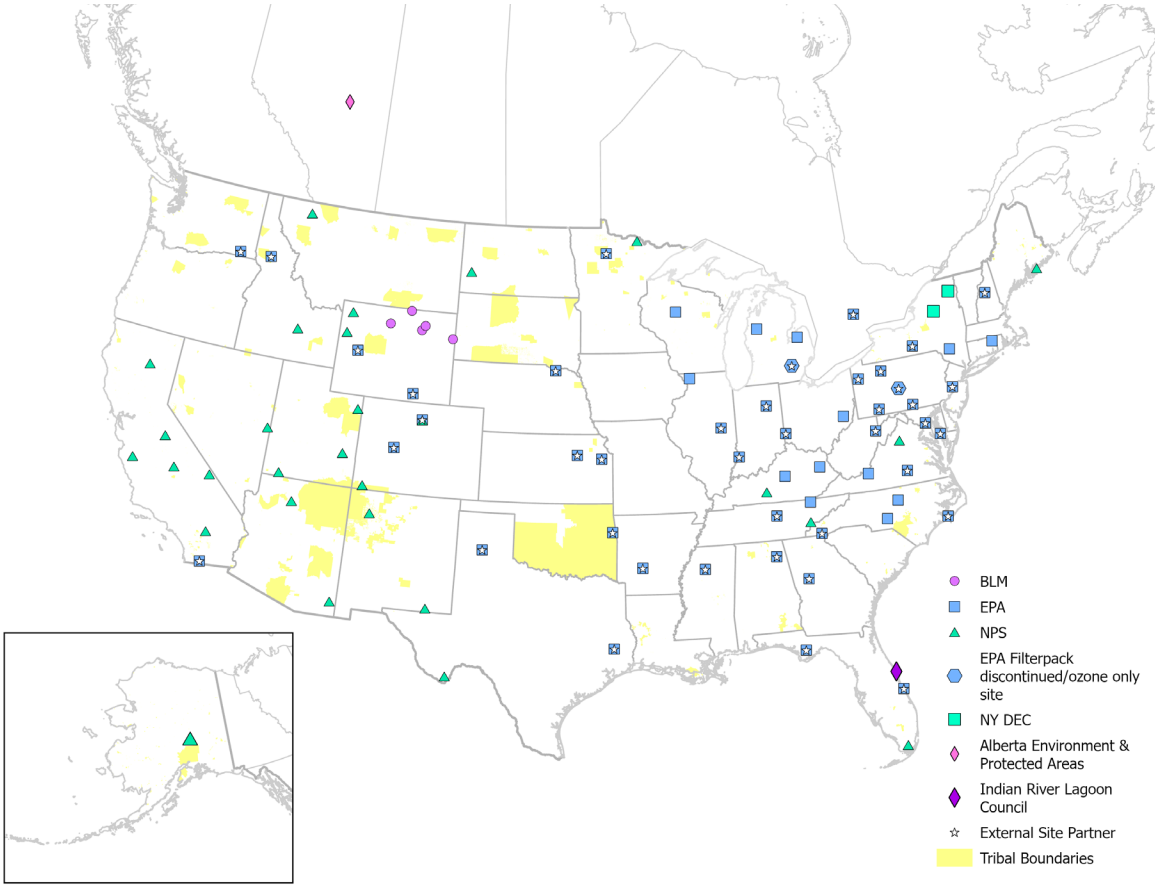



***Figure 2*** *Current CASTNET site locations (April 2025) with primary site sponsors. Tribal boundaries are shown on the map in yellow. External site partners include Tribes and other federal, state, or local agencies, universities, or NGOs that offer property, site support, or technical expertise.*

## MEASUREMENTS

CASTNET supports efforts to provide clean and healthy air for all Americans by measuring ozone and precursors of secondary aerosols ($PM_{2.5}$) (**Table 1**), which are associated with an increased risk of cardiovascular and other diseases. The public can access near-real time CASTNET ozone data through the AirNow[2] website, allowing populations to make decisions about health risks associated with outdoor activities during periods of poor air quality. In addition, CASTNET data help inform potential risks by supporting air quality forecasting, calculating the Air Quality Index (AQI), and evaluating regulatory actions. Data from rural CASTNET sites fill in important spatial gaps in Tribal and other federal (National Parks, Wilderness areas), state, and local air quality monitoring programs (**Figure 2**).

Most CASTNET sites are co-located with National Atmospheric Deposition Program (NADP) monitoring locations. The NADP collects data on chemistry in precipitation along with air concentrations of ammonia and other toxics (e.g., mercury). The NADP is a collaborative organization made up of sponsors from federal, Tribal, and state agencies, non-governmental organizations, universities, industry, and international agencies.[3] The NADP program is hosted at the University of Wisconsin-Madison/Wisconsin State Laboratory of Hygiene.

Air quality observations from CASTNET are combined with NADP's precipitation chemistry measurements ("wet deposition") and modeled values from EPA's Community Multiscale Air Quality (CMAQ) model to estimate total (wet + dry) atmospheric deposition and report on trends. This technique is referred to as measurement model fusion (MMF). CASTNET is the only network in the U.S. reporting dry and total deposition (See Atmospheric Deposition section).[4]

***Table 1*** *Summary of routine measurements collected at CASTNET and NADP monitoring sites. Networks with a * are managed by the NADP. Data from CASTNET, NTN and AMoN are used to create total deposition data and map products.*

| Network | Measurement Method | Pollutant(s) |
|---|---|---|
| **CASTNET** | Weekly Filter Pack | Particles ($SO_4^{2-}$, $NH_4^+$, $NO_3^-$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$); Gases ($HNO_3$) |
| | Continuous UV analyzer | $O_3$ |
| | Low-cost sensors | $PM_{2.5}$ Mass Concentrations |
| **National Trends Network (NTN) & PFAS Subnetwork (PFN)*** | Weekly precipitation collector & rain gage | $SO_4^{2-}$, $NH_4^+$, $NO_3^-$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, pH, 33 targeted PFAS, precipitation amount |
| **Ammonia Monitoring Network (AMoN)*** | Bi-weekly passive sampler | $NH_3$ |
| **Mercury Deposition Network (MDN)*** | Weekly precipitation collector & rain gage | Hg, precipitation amount |

***Atmospheric Deposition*** *represents air pollution that is deposited to the earth's surface and includes both dry and wet deposition. 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 by a process such as settling, impaction, or adsorption to the earth's surface. Dry deposition is estimated using measured atmospheric concentrations (CASTNET) with modeled deposition velocities (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 National Atmospheric Deposition Program's National Trends Network (NADP/NTN; Table 1). Measured pollutant concentrations in precipitation are combined with precipitation amounts.*

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

## EXPANDING MONITORING CAPACITY ACROSS RURAL AMERICA

EPA is implementing changes to modernize CASTNET. The changes will optimize the size of the network while investing in new measurements and expanding monitoring to fill key spatial gaps across the U.S. As part of the modernization effort, EPA has deployed low-cost sensors to provide real-time $PM_{2.5}$ data, a contributor to "soot" and a cause of negative health impacts. Additionally, the program is working to identify new cross-agency partnerships to fill key data gaps in the central U.S. (e.g., new Tribal or other federal agency-sponsored monitoring sites).

CASTNET is also a platform that contributes to 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, in collaboration with U.S. Forest Service, EPA is evaluating the relationships between measured air and precipitation concentrations to characterize how wildfire smoke has impacted air quality over time in the western U.S. The CASTNET program works closely with researchers to evaluate and implement new technologies to support network efficiencies.

## DATA AND 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.[5]

## OZONE

Ground-level ozone, often referred to as "smog," is measured at more than 80 rural CASTNET sites. 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. 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., reduce crop yields, slow growth in trees) and reduce ecosystem health. The U.S. health standard (primary NAAQS) for ozone is set at 0.070 ppm (or 70 ppb). Regulations to control $NO_x$ emissions from the power sector and mobile sources have resulted in significant reductions in ozone concentrations in the eastern U.S. (**Figure 3**), but events such as extreme heat and wildfires also impact attainment and air quality. Smaller reductions in ozone concentrations have been realized in the western U.S (not shown) due to topography, international pollution transport, and impacts from wildfires.

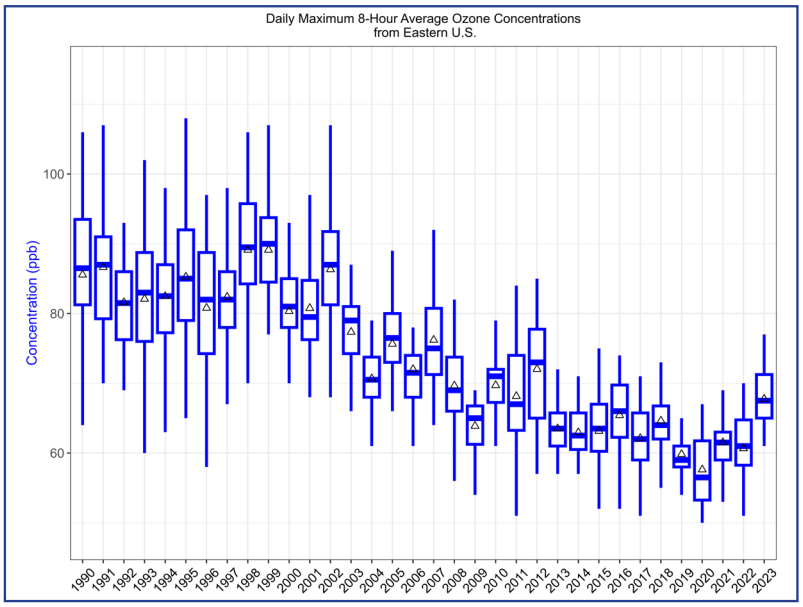



***Figure 3*** *Trend in daily maximum 8-hour average ozone concentrations from eastern CASTNET reference sites. Boxes extend from the 25th to 75th percentiles with median line. The whiskers extend to 1.5 interquartile range, and the mean is represented by a triangle. Dashed green line represents the level of the ozone NAAQS (70 ppb).*

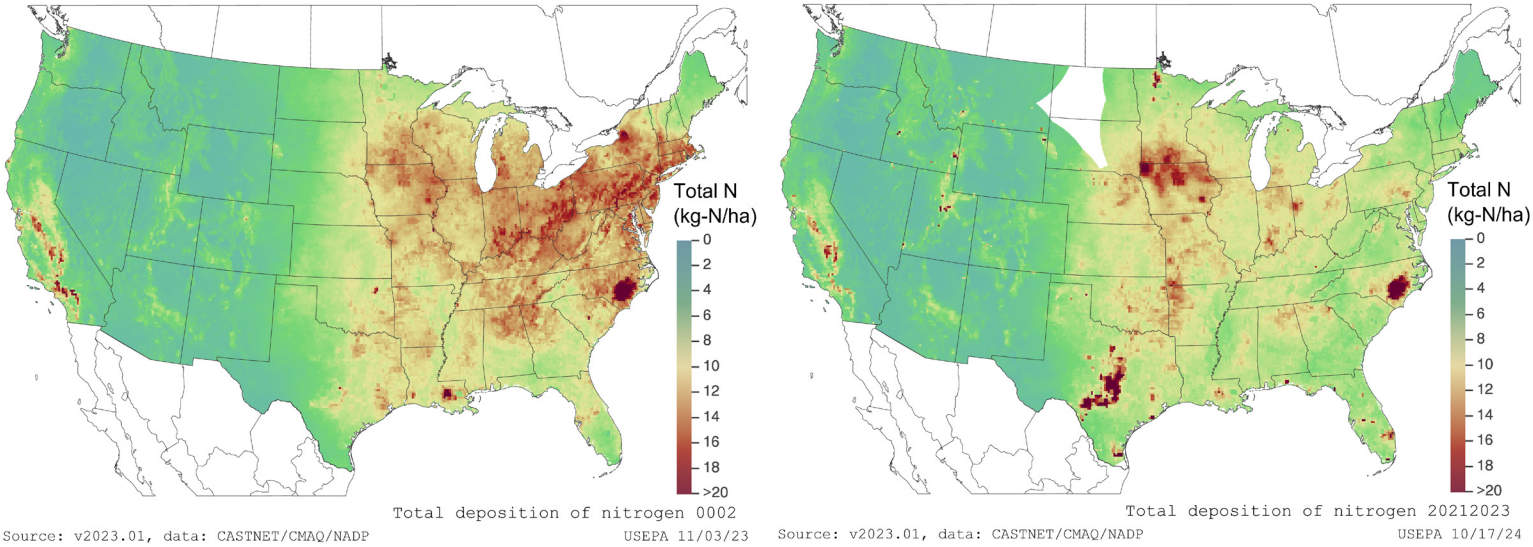



***Figure 4*** *Total deposition (wet + dry) of total (reduced + oxidized) nitrogen (kg-N ha-1) from 2000-2002 (left) and 2021-2023 (right)*

## ATMOSPHERIC DEPOSITION

Air pollution deposits (falls) to the ground via precipitation or as particles and gases. This process is known as atmospheric deposition. Excess atmospheric deposition can cause negative impacts on the environment, such as acid rain. Understanding the amount of deposition an ecosystem receives is important for characterizing whether the environment is healthy. Significant reductions in oxidized sulfur and nitrogen deposition have been realized in most regions throughout the U.S. **Figure 4** shows the changes in total nitrogen (oxidized + reduced) deposition between 2000-2002 and 2021-2023.

## CRITICAL LOADS: INFORMING LAND MANAGEMENT

CASTNET measurements help to assess whether air pollution levels are at or below a level that conserves America's natural resources and provides a clean environment. 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).[6] Excess nitrogen and sulfur deposition as a result of air pollution can negatively impact ecosystems and their natural resources. For example, both the deposition amount and whether it 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). **Figure 5** depicts whether deposition is above the critical load for herb species and sensitive tree species in Shenandoah National Park. These results indicate excess nitrogen is likely causing damage to herb species in some regions of the park while trees are generally protected. CASTNET measurements help EPA, other federal agencies, states, and tribes track air pollution and assess environmental conservation as emissions change from the energy, mobile source, and industrial sectors.

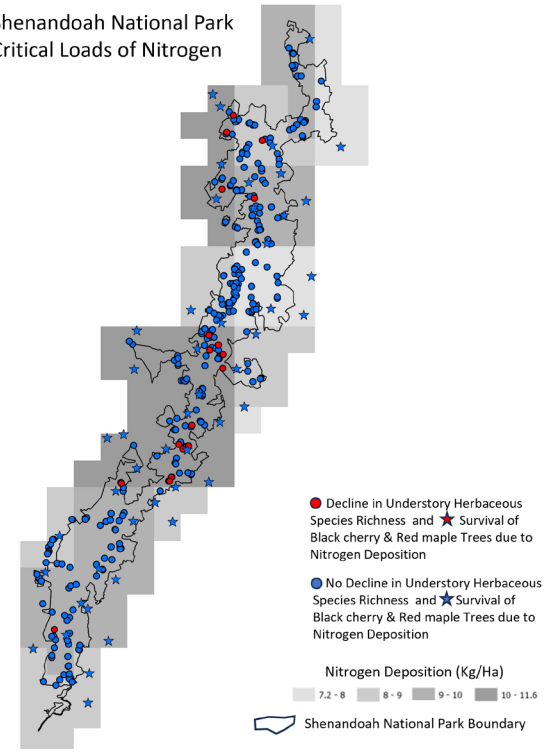



***Figure 5*** *Map showing critical load exceedances for herbaceous species, black cherry and red maple in Shenandoah National Park (VA). Total nitrogen deposition is calculated from CASTNET, NADP/NTN and modeled deposition.*

***Figure 6*** *Monitoring site near Gothic, CO (GTH161). Photo includes the CASTNET shelter and 10m tower. On the platform there is equipment to support the NADP/NTN site including a precipitation gage with a windshield and a NCON collector, and the NADP/AMoN shelter.*

## DATA AVAILABILITY

[1] US Census Bureau Urban and Rural Geographic Areas: County-level Urban and Rural Information for the 2020 Census https://www2.census.gov/geo/docs/reference/ua/2020_UA_COUNTY.xlsx

[2] Near-real time air quality data and forecasts can be found on the AirNow website, which includes data from CASTNET and other monitors. Users can also access the offical US Air Quality Index (AQI) https://www.airnow.gov/

[3] **The National Atmospheric Deposition Program (NADP)**: Overview of the NADP and data access https://nadp.slh.wisc.edu/

[4] **Measurement Model Fusion Method for Estimating Total Deposition (TDEP MMF)**: Method and TDEP data products https://nadp.slh.wisc.edu/committees/tdep/

[5] **CASTNET Data**: Ambient concentrations, dry and total deposition fluxes, and site information can be downloaded from the CASTNET website https://www.epa.gov/castnet

[6] **Additional information about critical loads can be found on the NADP Critical Loads of Atmospheric Deposition website** https://nadp.slh.wisc.edu/committees/clad/

### REFERENCES

Nilsson, J. (1988) Critical Loads for Sulphur and Ntrogen. In: Mathy P. (eds) Air Pollutaion and Ecosystems. Springer, Dordrecht. DOI: 10.1007/978-94-009-4003-1_11

CLRTAP (2004). Manual on methodolgies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends. Berlin; accessed on December 16, 2020 on web at umweltbundesamt.de