Overview of Particulate Matter (PM) Air Quality in the United States

Updated: August 25, 2025

1. Introduction

The purpose of this document is to maintain an up-to-date graphical summary of air quality information that supports the review of the National Ambient Air Quality Standards (NAAQS) for particulate matter (PM). In previous reviews of the PM NAAQS, this type of information has generally been included in atmospheric sections of the Integrated Science Assessment (ISA) and Policy Assessment (PA) for PM. This document provides summaries of the air quality emissions and monitoring data to be included in future PM NAAQS review supporting documents and will be updated at regular intervals as new data becomes available.

This document follows an organizational structure similar to that of the atmospheric sections of past PM NAAQS review supporting documents. The subsequent sections are as follows: 2. Atmospheric Chemistry; 3. Sources and Emissions of PM in Ambient Air; 4. Ambient Air Monitoring Requirements and Monitoring Networks; 5. Data Handling Conventions and Computations for Determining Whether the Standards are Met; and 6. PM Concentrations Measured at Ambient Air Monitoring Sites Across the U.S.

2. Atmospheric Chemistry

In ambient air, PM is a mixture of substances suspended as small liquid and/or solid particles. Particle size is an important consideration for PM, as distinct health and welfare effects have been linked with exposures to particles of different sizes. Particles in the atmosphere range in size from less than 0.01 to more than 10 micrometers (μm) in diameter. When describing PM, subscripts are used to denote the aerodynamic diameter[1] of the particle size range in micrometers (μm) of 50% cut points of sampling devices. The EPA defines $PM_{2.5}$, also referred to as fine particles, as particles with aerodynamic diameters generally less than or equal to 2.5 μm. The size range for $PM_{10-2.5}$, also referred to as coarse particles, includes those particles with aerodynamic diameters generally greater than 2.5 μm and less than or equal to 10 μm. PM_{10}, which is comprised of both fine and coarse fractions, includes those particles with aerodynamic diameters generally less than or equal to 10 μm. Figure 1 provides perspective on these particle size fractions. In addition, ultrafine particles (UFP) are often defined as particles with a diameter of less than 0.1 μm.

Atmospheric distributions of particle size generally exhibit three distinct modes ("nucleation mode", "accumulation mode", and "coarse mode") that roughly align with the PM size fractions defined above. Figure 2 below shows an example of the particle size distribution for each of these three modes. The nucleation mode is made up of freshly generated particles, formed either during combustion or by atmospheric reactions of precursor gases. The nucleation mode is especially prominent near sources like heavy traffic, industrial emissions, biomass burning, or cooking. While nucleation mode particles are only a minor contributor to overall ambient PM mass and surface area, they are the main contributors to ambient particle number. By number, most nucleation mode particles fall into the UFP size range, though some fraction of the nucleation mode number distribution can extend above 0.1 μm in diameter. Nucleation mode particles can grow rapidly through coagulation or uptake of gases by particle surfaces, giving rise to the accumulation mode. The accumulation mode is typically the predominant contributor to $PM_{2.5}$ mass and surface area, though only a minor contributor to particle number. $PM_{2.5}$ sampling methods measure most of the accumulation mode mass, although a small fraction of particles that make up the accumulation mode are greater than 2.5 μm in diameter. Coarse mode particles are formed by mechanical generation, and through processes like dust resuspension and sea spray formation. Most coarse mode mass is captured by $PM_{10-2.5}$ sampling, but small fractions of coarse mode mass can be smaller than 2.5 μm or greater than 10 μm in diameter.

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[1]Aerodynamic diameter is the size of a sphere of unit density (i.e., 1 g/cm^3) that has the same terminal settling velocity as the particle of interest.
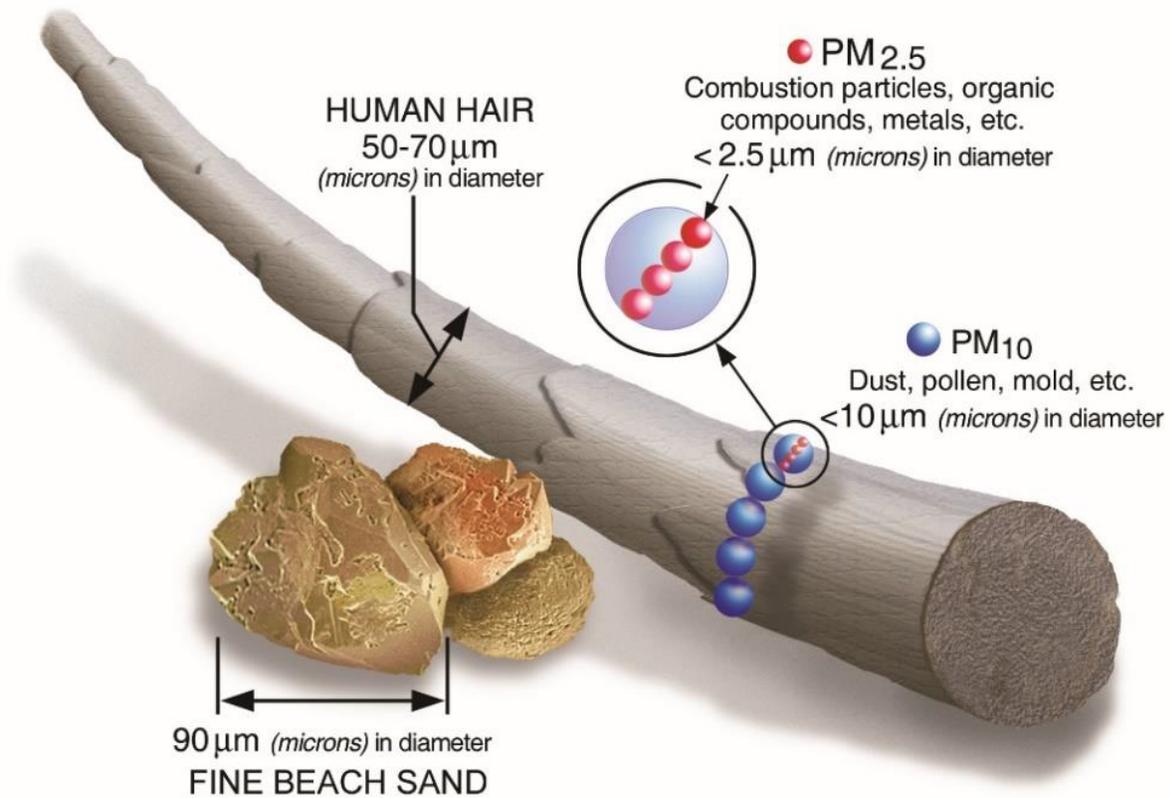
Figure 1. Comparisons of $PM_{2.5}$ and PM_{10} diameters to human hair and beach sand. Reproduced from Figure 2-1 of the 2020 PM PA.
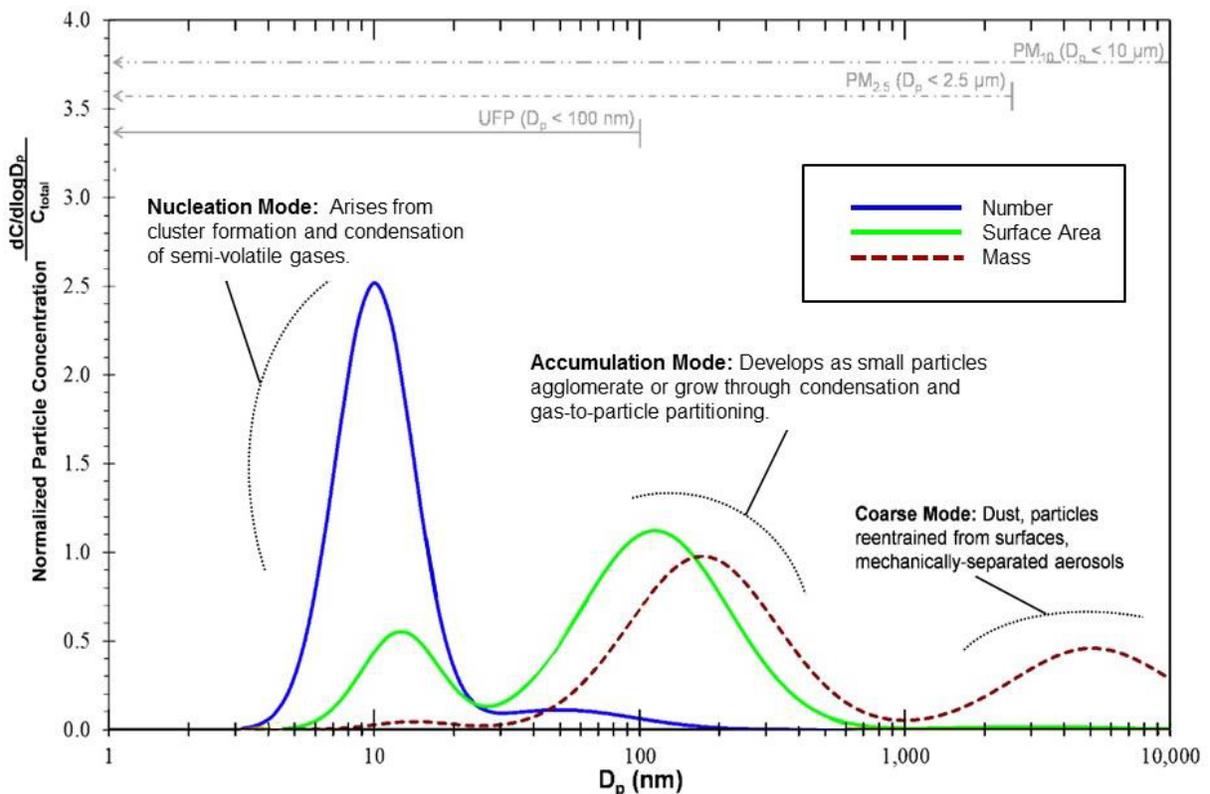

Figure 2. Comparison of particle size distribution by particle number, surface area, and mass. C_{total} = total particle concentration; D_p = particle diameter. Reproduced from Figure 2-1 of the 2019 PM ISA.

Most particles are found in the lower troposphere, where they can have residence times ranging from a few hours to weeks. Particles are removed from the atmosphere by wet deposition, such as when they are carried by rain or snow, or by dry deposition, such as gravitational settling or surface collision. Atmospheric lifetimes are generally longest for $PM_{2.5}$, which often remains in the atmosphere for days to weeks before being removed by wet or dry deposition. In contrast, atmospheric lifetimes for UFP and $PM_{10-2.5}$ are shorter. Within hours, UFP can undergo coagulation and condensation that lead to formation of larger particles in the accumulation mode, or can be removed from the atmosphere by evaporation, deposition, or reactions with other atmospheric components. $PM_{10-2.5}$ are also generally removed from the atmosphere within hours, through wet or dry deposition.

PM is composed of both primary and secondary components. Primary PM is derived from direct particle emissions from specific sources while secondary PM originates from gas-phase chemical compounds present in the atmosphere that have participated in new particle formation or condensed onto existing particles. Secondary PM, which accounts for a substantial fraction of $PM_{2.5}$ mass, forms through atmospheric photochemical oxidation reactions of both inorganic and organic gas-phase precursors such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), and ammonia (NH_3). Reactions leading to sulfate ($SO_4{}^{2-}$) production from SO_2, nitrate ($NO_3{}^{-}$) production from NO_X, and the gas-to-particle equilibrium between ammonia (NH_3) and ammonium ($NH_4{}^{+}$) are relatively well understood, while formation of secondary organic PM, often referred to as secondary organic aerosols (SOA), is less well resolved.

3. Sources and Emissions of PM

Both primary PM and the gas-phase compounds contributing to secondary PM formation are emitted from both anthropogenic and natural sources. Anthropogenic sources of PM include both stationary and mobile sources. Stationary sources include fuel combustion for electricity production and other purposes, industrial processes, agricultural activities, and road and building construction and demolition. Mobile sources of PM include diesel- and gasoline-powered highway vehicles and other engine-driven sources (e.g., ships, aircraft, and construction and agricultural equipment). Both stationary and mobile sources directly emit primary PM to ambient air, along with secondary PM precursors (e.g., SO_2, NO_X) that contribute to the secondary formation of PM in the atmosphere.

Natural sources of PM include dust from the wind erosion of natural surfaces, sea salt, wildfires, primary biological aerosol particles (PBAP) such as bacteria and pollen, oxidation of biogenic hydrocarbons such as isoprene and terpenes to produce SOA, and geogenic sources such as sulfate formed from volcanic emissions of SO_2. Natural emissions sources contributing to $PM_{2.5}$ concentrations can be interconnected with anthropogenic emissions through atmospheric chemistry, such as the modulation of biogenic SOA production by anthropogenic NO_X and SO_2 emissions.

Generally, the sources of PM for different size fractions vary. While $PM_{2.5}$ in ambient air is largely emitted directly by sources such as those described above or through secondary PM formation in the atmosphere, $PM_{10-2.5}$ is emitted almost entirely from primary sources (i.e., directly emitted) and is produced by surface abrasion or by suspension of sea spray or biological materials such as microorganisms, pollen, and plant and insect debris.

The major components of $PM_{2.5}$ mass include sulfate, nitrate, elemental or black carbon (EC or BC), organic carbon (OC), crustal materials, and sea salt. Some of these PM components are emitted directly to the air (e.g., EC/BC) while others are formed secondarily through reactions by gaseous precursors (e.g., sulfate, nitrate). Anthropogenic SO_2 and NO_X are the predominant precursor gases in the formation of secondary $PM_{2.5}$ sulfate and nitrate, and ammonia is the gas-phase precursor for $PM_{2.5}$ ammonium. Atmospheric oxidation of volatile organic compounds (VOCs), both anthropogenic and biogenic, is an important source of SOA, particularly in summer.

The National Emissions Inventory (NEI) is a comprehensive and detailed estimate of air emissions of criteria pollutants, precursors to criteria pollutants, and hazardous air pollutants from air emissions sources. The NEI is released every three years based primarily upon data provided by State, Local, and Tribal air agencies for sources in their jurisdictions and supplemented by data developed by the EPA. The NEI is built using the EPA's Emissions Inventory System (EIS) first to collect the data from State, Local, and Tribal air agencies and then to blend that data with other data sources.

Accuracy in an emissions inventory reflects the extent to which the inventory represents the actual emissions that occurred. Anthropogenic emissions of air pollutants result from a variety of sources such as power plants, industrial sources, motor vehicles and agriculture. The emissions from any individual source typically vary in both time and space. For the thousands of sources that make up the NEI, there is uncertainty in one or both of these factors. For some sources, such as power plants, direct emission measurements enable the emission factors derived from them to be more certain than sources without such direct measurements. However, it is not practically possible to directly monitor each of the emission sources individually and, therefore, emission inventories necessarily contain assumptions, interpolation and extrapolation from a limited set of sample data.

Figure 3 shows the main sources contributing to primary $PM_{2.5}$, primary PM_{10}, SO_2, and NO_X emissions in the U.S. Fires, which include wildfires, prescribed fires, and agricultural fires, contributed about 43% of primary $PM_{2.5}$ emissions

and 18% of primary PM_{10} emissions in 2020. Dust particles from roads, agriculture, and construction contributed 28% of primary $PM_{2.5}$ emissions and 68% of primary PM_{10} emissions, while most of the remaining primary PM emissions came from stationary fuel combustion (e.g., coal combustion for electricity), industrial and mobile sources. Regarding precursors to secondary PM formation, the main sources of SO_2 and NO_X are stationary fuel combustion (57% of total SO_2 emissions; 25% of total NO_X emissions), industrial processes (27% of total SO_2 emissions; 12% of total NO_X emissions) and mobile sources (1% of total SO_2 emissions; 45% of total NO_X emissions).
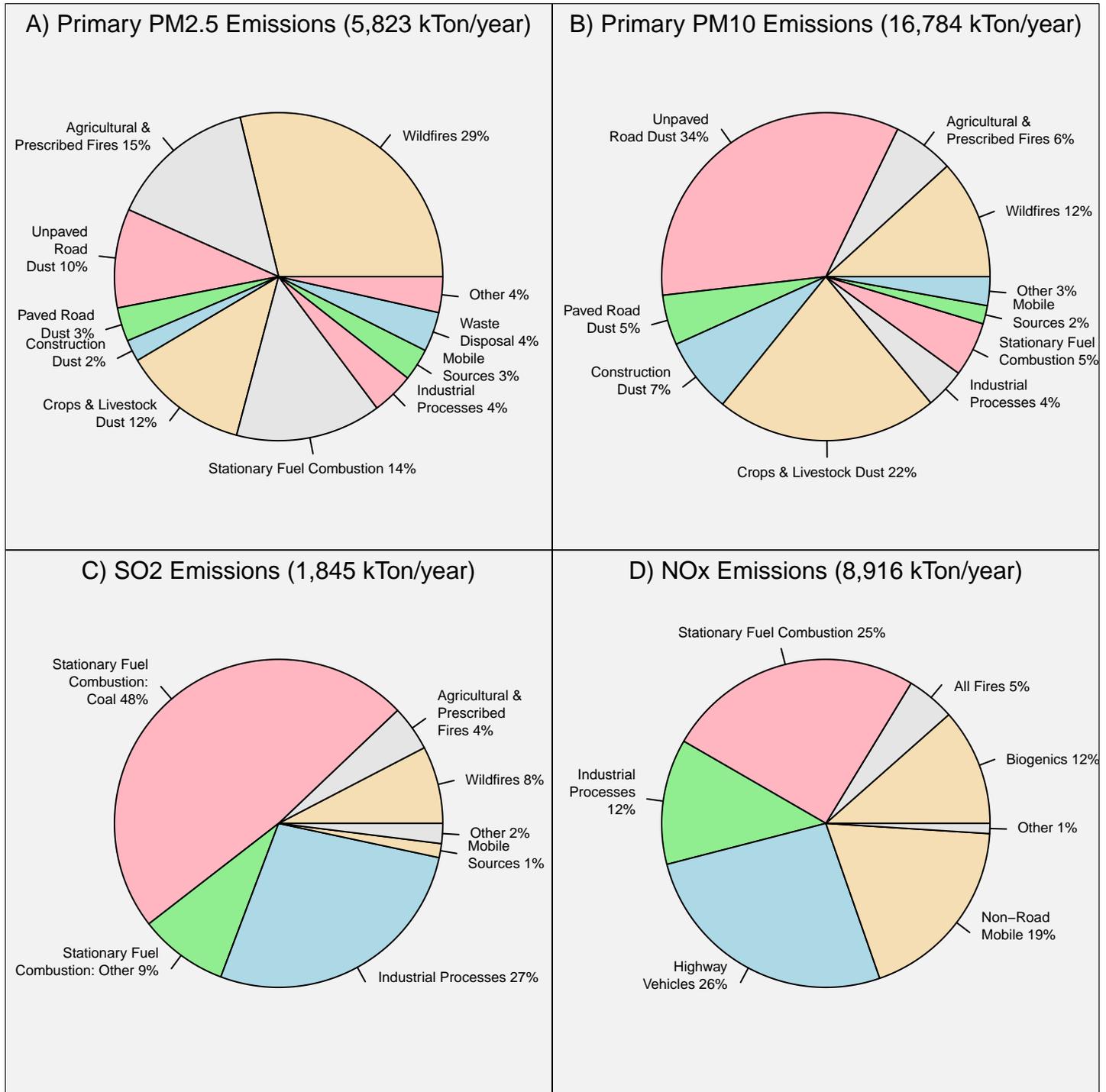

Figure 3: U.S. emissions for A) Primary $PM_{2.5}$; B) Primary PM_{10}; C) SO_2; and D) NO_X by sector. **Source:** 2020 NEI.

Figure 4 through Figure 7 show county-level estimates of U.S. emissions densities (in tons/year/mi^2) for primary $PM_{2.5}$, primary PM_{10}, SO_2, and NO_X emissions, respectively based on the 2020 NEI. Primary PM emissions tended to be highest near urban areas due to the larger number of industrial sources and vehicles, and near the center of the country due to dust from roads and agricultural sources. Parts of the northwest U.S. and California also experienced higher primary PM emissions due to wildfires in 2020. The highest SO_2 emissions tend to be located near large point sources such as coal-fired power plants or large industrial facilities, while the highest NO_X emissions tend to be located near urban areas and large point sources.
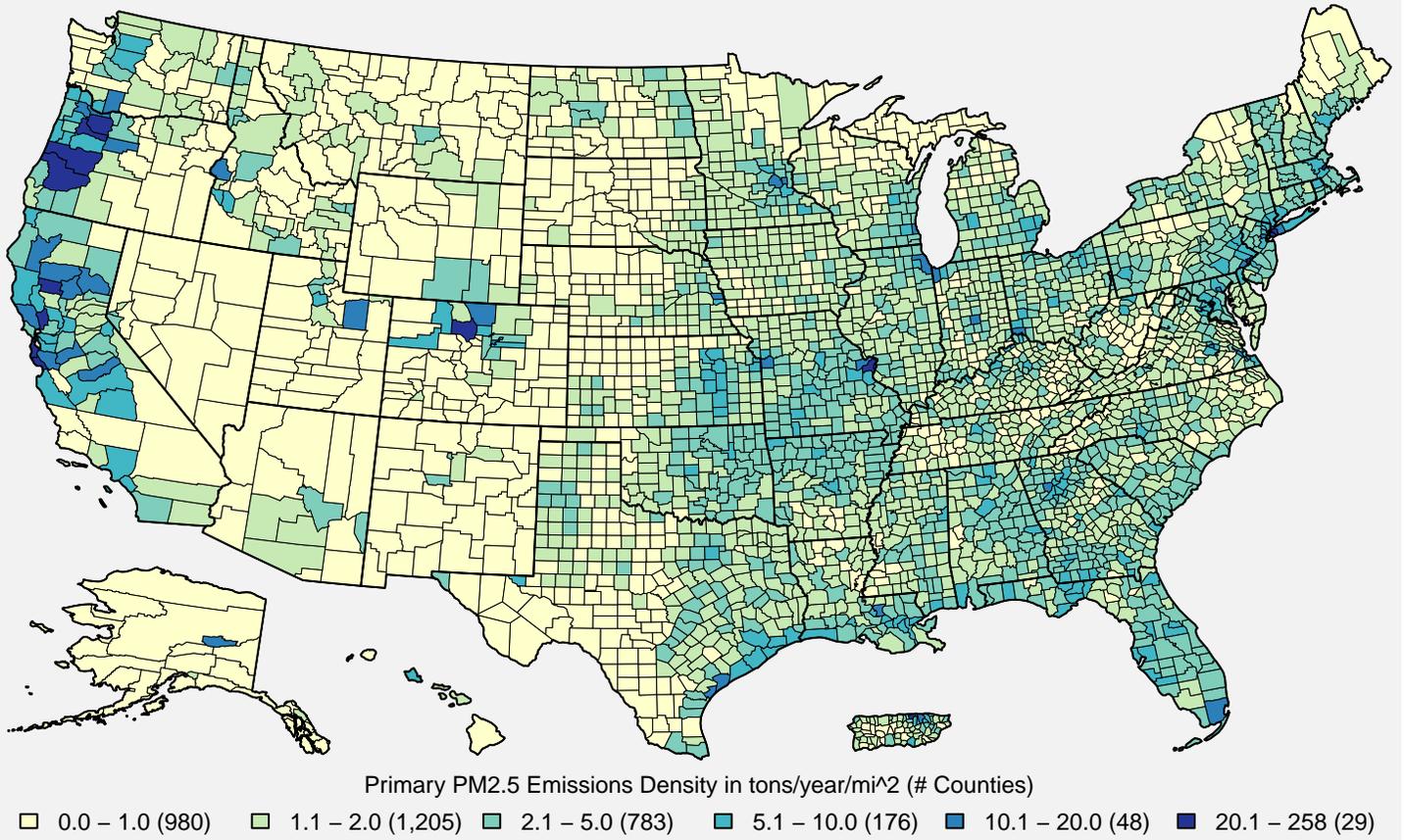
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Primary PM2.5 Emissions Density in tons/year/mi^2 (# Counties)

☐ 0.0 – 1.0 (980) ☐ 1.1 – 2.0 (1,205) ☐ 2.1 – 5.0 (783) ☐ 5.1 – 10.0 (176) ☐ 10.1 – 20.0 (48) ☐ 20.1 – 258 (29)

Figure 4. U.S. county-level primary $PM_{2.5}$ emissions density estimates in tons/year/mi^2. **Source:** 2020 NEI

Primary PM10 Emissions Density in tons/year/mi^2 (# Counties)

☐ 0 – 5 (1,636) ☐ 6 – 10 (1,083) ☐ 11 – 20 (366) ☐ 21 – 50 (108) ☐ 51 – 100 (20) ☐ 101 – 760 (8)
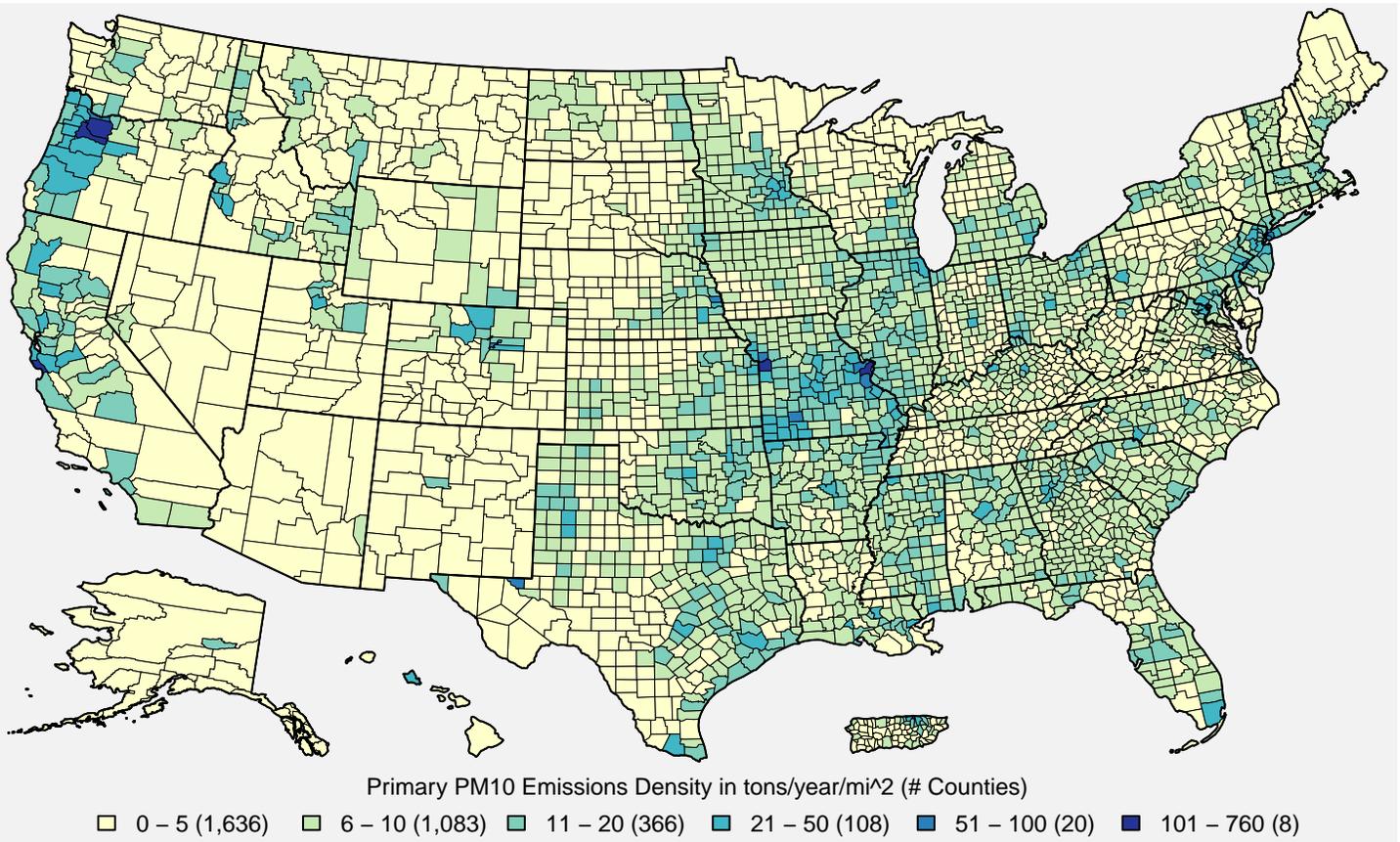
Figure 5. U.S. county-level primary PM_{10} emissions density estimates in tons/year/mi^2. **Source:** 2020 NEI

Sulfur Dioxide Emissions Density in tons/year/mi^2 (# Counties)

☐ 0.0 – 0.3 (2,397) ☐ 0.4 – 1.0 (421) ☐ 1.1 – 3.0 (222) ☐ 3.1 – 10.0 (111) ☐ 10.1 – 30.0 (54) ☐ 30.1 – 329 (16)
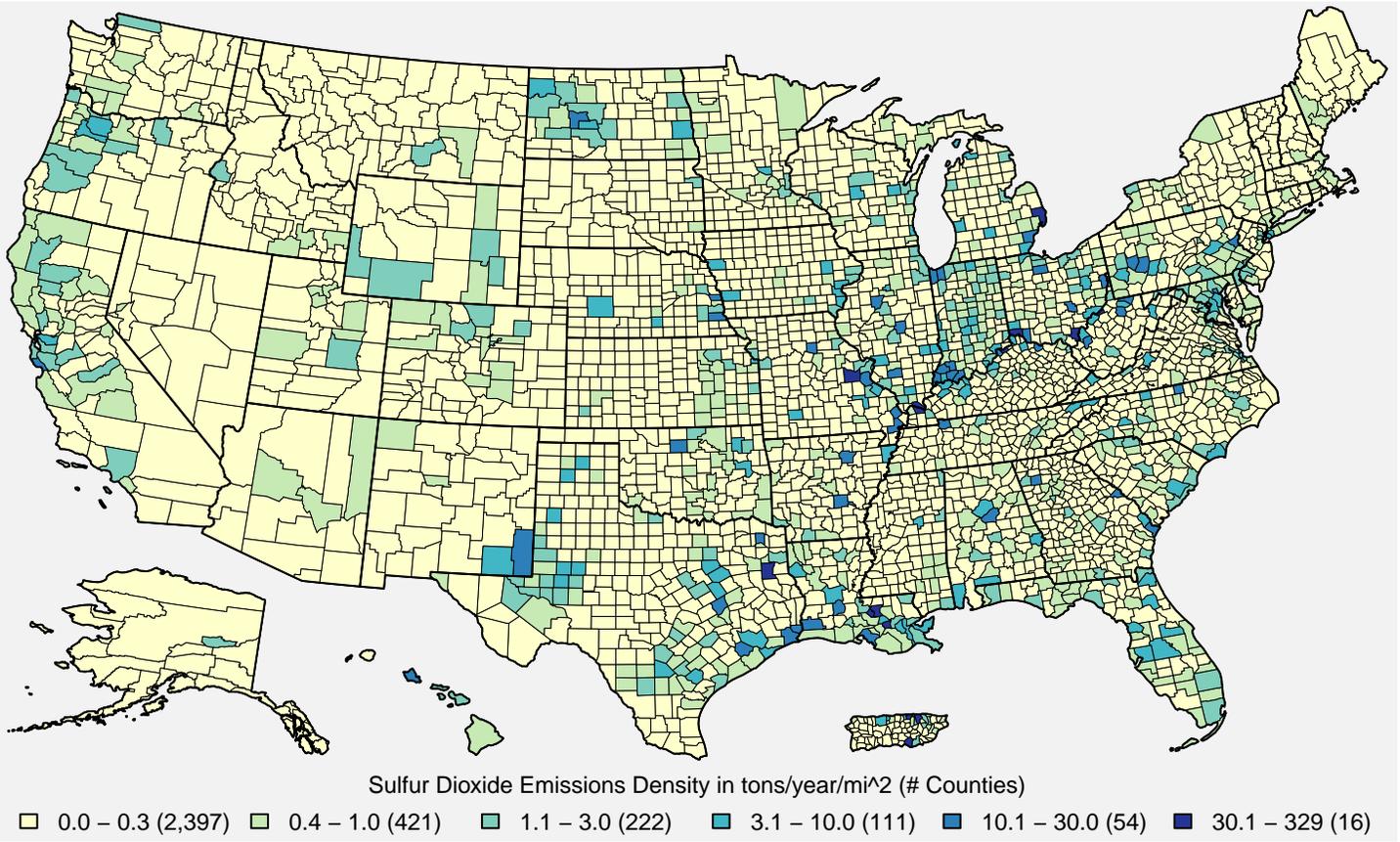
Figure 6. U.S. county-level SO_2 emissions density estimates in tons/year/mi^2. **Source:** 2020 NEI

Nitrogen Oxides Emissions Density in tons/year/mi^2 (# Counties)

☐ 0.0 – 2.0 (1,393) ☐ 2.1 – 5.0 (1,107) ☐ 5.1 – 10.0 (400) ☐ 10.1 – 20.0 (195) ☐ 20.1 – 50.0 (96) ☐ 50.1 – 648 (30)
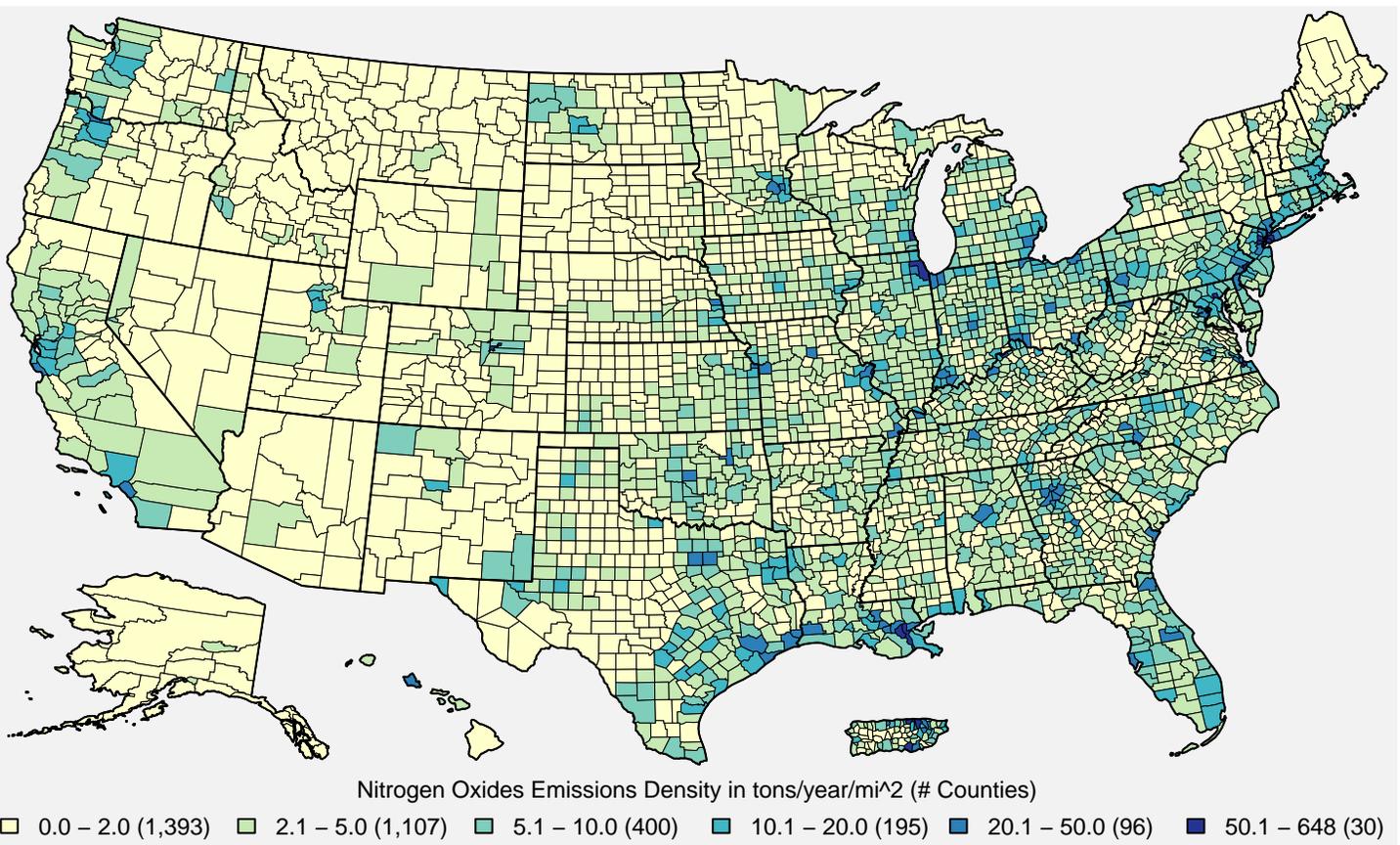
Figure 7. U.S. county-level NO_x emissions density estimates in tons/year/mi^2. **Source:** 2020 NEI

Figure 8 below shows the national trends in U.S. anthropogenic primary $PM_{2.5}$, primary PM_{10}, SO_2, and NO_X emissions from 2002 to 2024.[2] Primary $PM_{2.5}$ emissions reached a maximum of 5 million tons per year in 2005 and have decreased by 8% to 4.6 million tons per year in 2024. Similarly, direct PM_{10} emissions reached a maximum of 17 million tons per year in 2005 and have decreased by 8% to approximately 15.6 million tons per year in 2024. SO_2 emissions have decreased by 89% since 2002, while NO_X emissions have decreased by 73% since 2002. The large reductions in NO_X and SO_2 emissions are largely due to reductions in the electricity generation and transportation sectors resulting from EPA programs such as the Clean Air Interstate Rule and the Cross-State Air Pollution Rule for electric generating units, as well as the adoption of more stringent fuel economy standards and low sulfur diesel fuel standards for mobile sources.
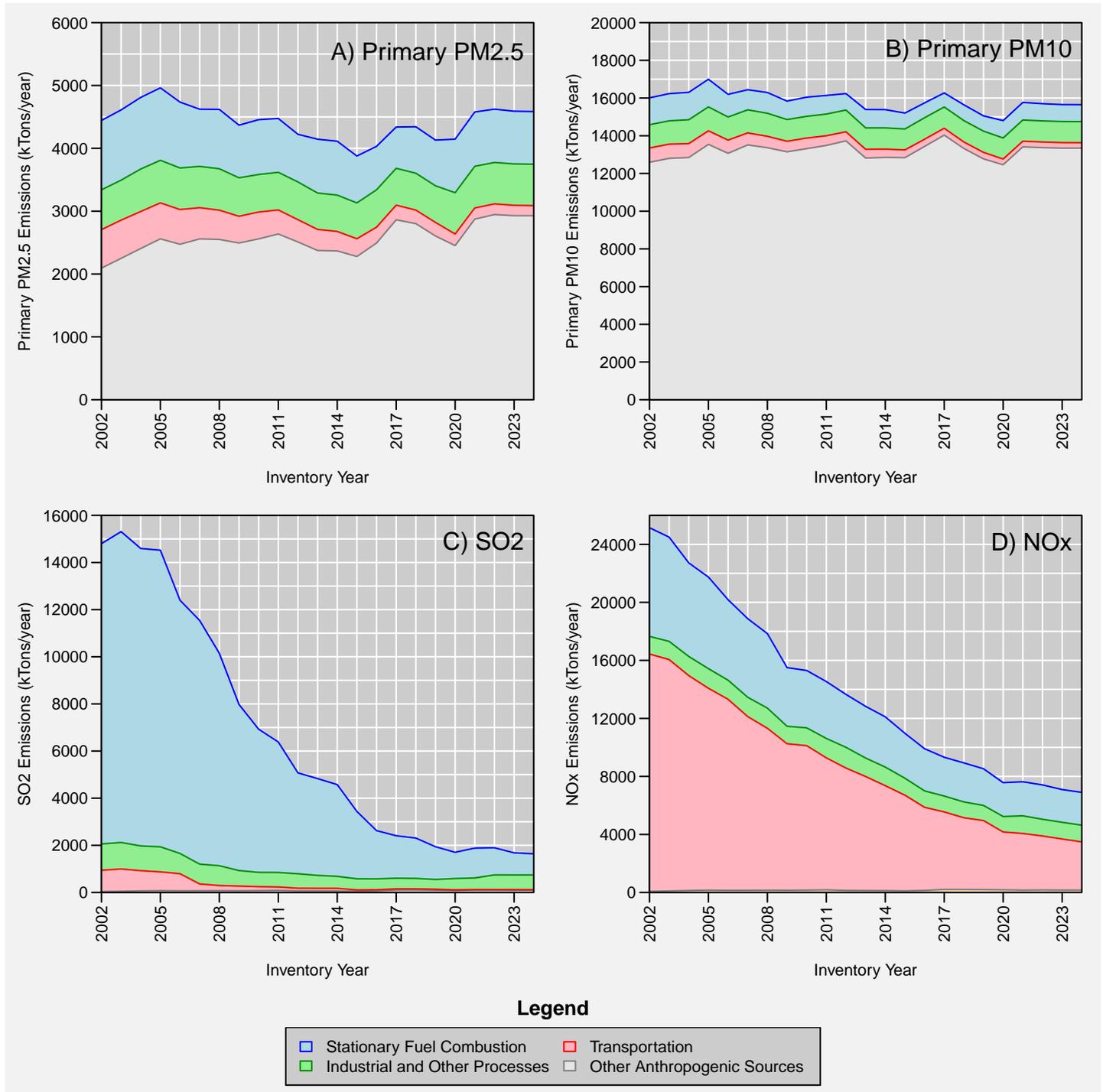

Figure 8. U.S. anthropogenic emissions trends for: A) Primary $PM_{2.5}$; B) Primary PM_{10}; C) SO_2; and D) NO_X. **Source:** EPA's Air Pollutant Emissions Trends Data

[2]Data for Figure 8 come from the EPA's Air Pollutant Emissions Trends Data. Note that emissions for some sectors are interpolated between inventory years, and the emissions for some sectors are held constant beyond the most recent inventory year (for details, see the "Development of Data" table in the national emissions trends data file. For the purposes of this document, wildfires are considered to be natural emissions and thus are not included in Figure 8.

4. Ambient Air Monitoring Requirements and Monitoring Networks

The EPA and its partners at State, Local, and Tribal monitoring agencies manage and operate the nation's ambient air monitoring networks. The EPA provides minimum monitoring requirements for PM and other pollutants in 40 CFR Part 58. Monitoring agencies carry out and perform ambient air monitoring in accordance with the EPA's requirements and guidance. Federal Reference Methods (FRMs) and Federal Equivalence Methods (FEMs) are monitoring methods that have been approved for use by States and other monitoring organizations to assess NAAQS compliance and implementation. The FRMs for measuring PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$ are specified in 40 CFR Part 50, Appendices J, L, and O, respectively, while performance requirements for the approval of FRM and FEMs are in 40 CFR Part 53.

The EPA and monitoring agencies manage and operate robust national monitoring networks for both PM_{10} and $PM_{2.5}$, as these are the two measurement programs directly supporting the PM NAAQS. PM_{10} measurements are based on gravimetric mass, while $PM_{2.5}$ measurements include gravimetric mass and chemical speciation. A smaller network of stations is operating and reporting data for $PM_{10-2.5}$ gravimetric mass and a few monitors are operated to support special projects, including pilot studies, for continuous speciation and particle count data.

The EPA first established NAAQS for PM in 1971 based on total suspended particulates, or TSP. The size of the TSP monitoring network peaked in the mid-1970s when over 4,300 TSP samplers were in operation. The TSP NAAQS was replaced by the PM_{10} NAAQS in 1987. TSP sampling remains in operation at a limited number of locations primarily to provide measurements for the Lead (Pb) NAAQS as well as for instances where a State may continue to have State standards for TSP. There were 122 monitoring sites reporting Pb TSP data to EPA during the 2022-2024 period.

To support the 1987 PM_{10} NAAQS, the EPA and its State and Local partners implemented the first size-selective PM monitoring network in 1990 with the establishment of a PM_{10} network consisting of mainly high-volume samplers. The PM_{10} monitoring network peaked in size in 1995 with 1,665 stations reporting data. There were 684 monitoring sites reporting PM_{10} data to EPA during the 2022-2024 period. Figure 9 shows the locations of these monitoring sites. Approximately 80% of these monitoring sites operate FEMs which report continuous PM_{10} data while the remaining sites operate FRMs which typically collect samples every day, every 3rd day, or every 6th day.[3]

To support the 1997 PM NAAQS, the first PM NAAQS with $PM_{2.5}$ as an indicator, the EPA and States implemented a $PM_{2.5}$ monitoring network consisting of ambient air monitoring sites with $PM_{2.5}$ mass and/or chemical speciation measurements. Network operation began in 1999 with nearly 1,000 monitoring stations operating FRMs to measure fine particle mass. The $PM_{2.5}$ monitoring program remains one of the largest ambient air monitoring programs in the U.S. There were 1,082 monitoring sites reporting $PM_{2.5}$ data to EPA during the 2022-2024 period. Figure 10 shows the locations of these monitoring sites. Approximately 89% of these monitoring sites operate FEMs which report continuous $PM_{2.5}$ data while the remaining sites operate FRMs which typically collect samples every day, every 3rd day, or every 6th day.[3]

To provide an assessment of data quality, monitoring agencies must perform quality assurance (QA) checks, such as flow checks and leak tests, to ensure the monitors are operating within performance specifications and meeting measurement quality objectives. Estimates of precision and bias for continuous PM monitors are determined through independent audits and collocated sampling against the federal reference method.[4] Ambient air quality data are reported to the EPA via the Air Quality System (AQS). Data are reported quarterly and must be submitted to AQS within 90 days after the end of each calendar quarter (i.e. Jan/Feb/Mar, Apr/May/Jun, Jul/Aug/Sep, Oct/Nov/Dec). Additionally, each monitoring agency is required to certify all FRM/FEM data that is submitted to AQS annually, taking into consideration any QA findings, and a data certification letter must be sent to the EPA Regional Administrator by May 1st of the following year.

The main network of monitors providing ambient data for use in implementation activities related to the NAAQS is the State and Local Air Monitoring Stations (SLAMS) network, which comprises about 86% of $PM_{2.5}$ monitoring sites and 76% of PM_{10} monitoring sites. Two important subsets of SLAMS sites are the National Core (NCore) multipollutant monitoring network and the near-road monitoring network. The NCore network was designed to collect consistent measurements of criteria pollutants for trends and NAAQS compliance purposes. NCore was fully operational as of 2011 and consists of approximately 60 urban monitoring stations and 20 rural monitoring stations. NCore sites are required to measure $PM_{2.5}$ using continuous and filter-based samplers, speciated $PM_{2.5}$, and $PM_{10-2.5}$. Each State is required to have at least one NCore station. $PM_{2.5}$ monitoring was required for near-road network sites as part of the 2012 PM NAAQS review and these sites monitors were phased into the network between 2015 and 2017. Near-road sites are required in each metropolitan statistical area (MSA) with a population of 1,000,000 or greater.

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[3]Some PM_{10} and $PM_{2.5}$ monitoring sites operate both FEM and FRM instruments.

[4]Quality assurance requirements for monitors used in evaluations of the NAAQS are provided in Appendix A to 40 CFR Part 58. Annual summary reports of precision and bias can be obtained for each monitoring site at the EPA's Air Data website.

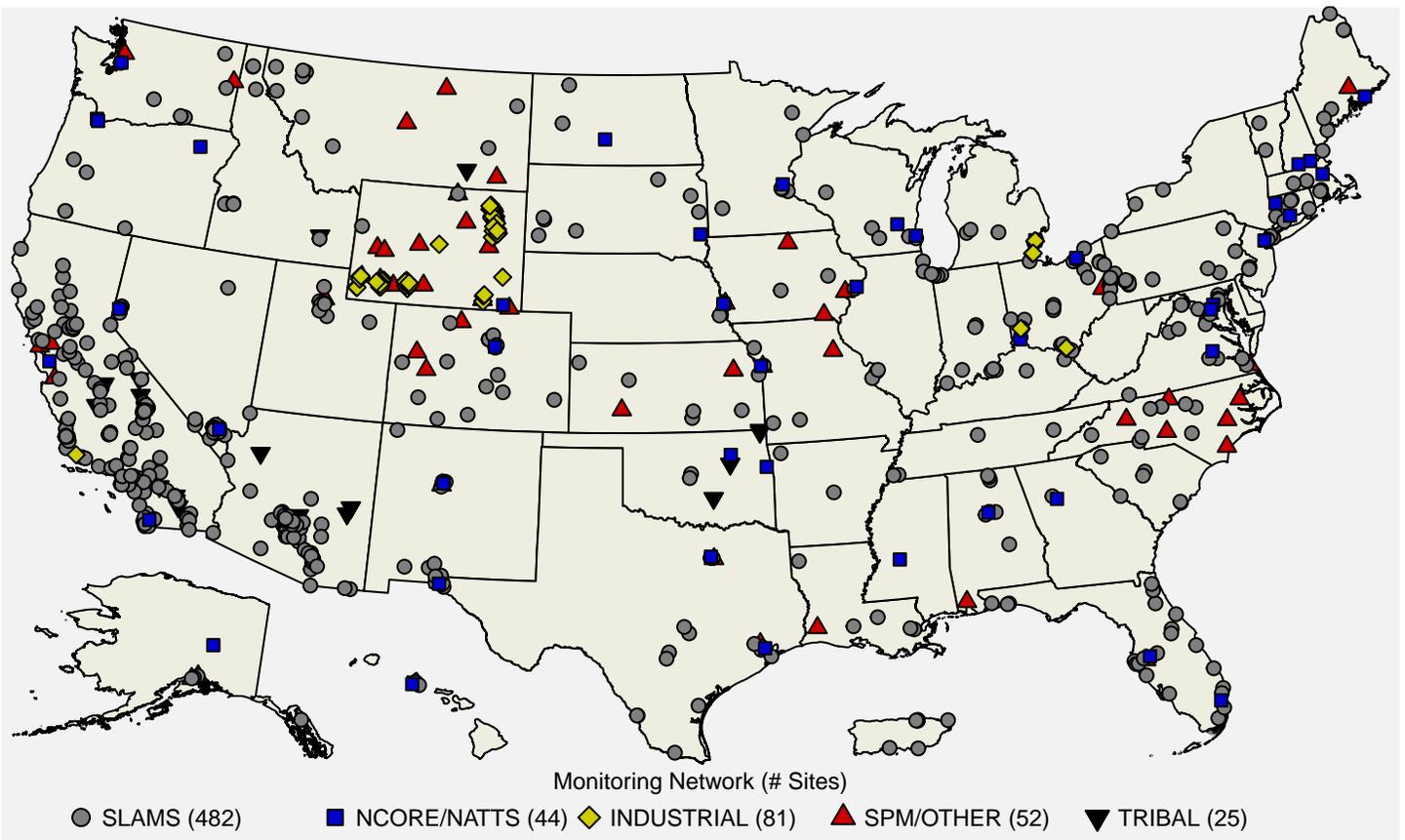**Figure 9:** Map of U.S. PM_{10} monitoring sites reporting data to the EPA during the 2022-2024 period. **Source:** AQS.
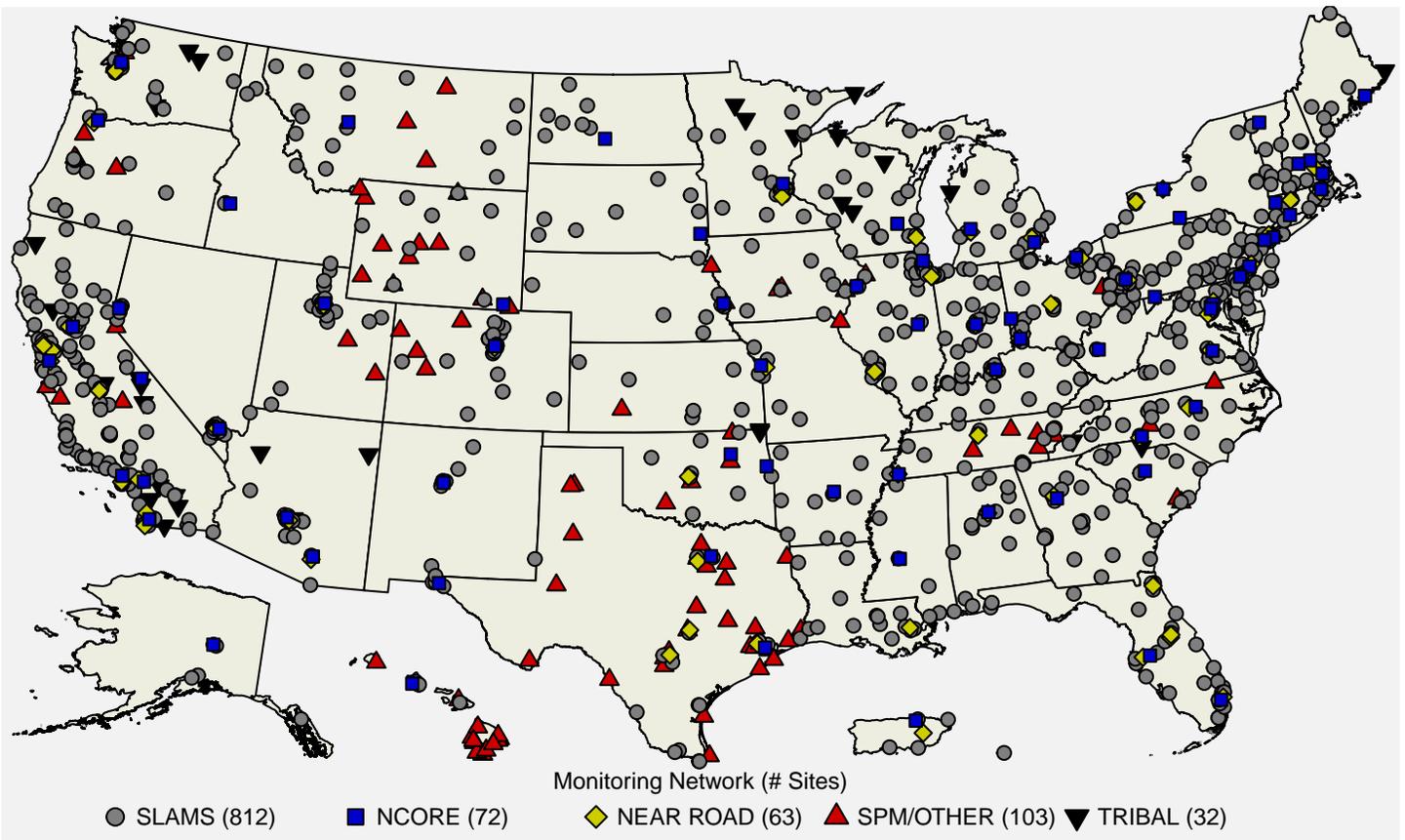

Figure 10: Map of U.S. $PM_{2.5}$ monitoring sites reporting data to the EPA during the 2022-2024 period. **Source:** AQS.

Due to the complex nature of fine particles, the EPA and States implemented the Chemical Speciation Network (CSN) to better understand the components of fine particle mass at selected locations across the country. The CSN was first piloted at 13 sites in 2000, and after the pilot phase, the program continued with deployment of the Speciation Trends Network (STN) later that year. The current CSN network consists of about 150 sites, of which about 50 are STN sites operating on a 1 in 3 day sampling schedule and about 100 are supplemental sites which typically operate on a 1 in 6 day sampling schedule. The locations of the CSN sites reporting data to the EPA during the 2022-2024 period are shown in Figure 11. CSN measurements are also collected at NCore stations, which are shown in Figure 10.

Specific components of fine particles are also measured through the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring program, which supports the Regional Haze Program and tracks changes in visibility in Federal Class I areas as well as many other rural and some urban areas. CSN and IMPROVE data can also be used to better understand visibility through calculation of light extinction using the IMPROVE algorithm[5] to support reviews of the secondary PM NAAQS. The locations of the IMPROVE sites reporting data to the EPA during the 2022-2024 period are shown in Figure 11.

As a result of the 2006 PM NAAQS review, the EPA promulgated a new FRM for the measurement of $PM_{10-2.5}$ mass in ambient air. Although the standard for coarse particles uses a PM_{10} indicator, a new FRM for $PM_{10-2.5}$ mass was developed to provide a basis for approving FEMs and to promote the gathering of scientific data to support future reviews of the PM NAAQS. $PM_{10-2.5}$ measurements are currently reported at NCore stations, IMPROVE monitoring stations, and at a few additional locations where State or Local agencies choose to operate a $PM_{10-2.5}$ monitoring method. There were 284 monitoring sites reporting $PM_{10-2.5}$ data to EPA during the 2022-2024 period. Figure 12 shows the locations of these monitoring sites. Additionally, some sites that operate both PM_{10} and $PM_{2.5}$ monitors also report $PM_{10-2.5}$ concentrations by taking the difference of the two measurements.
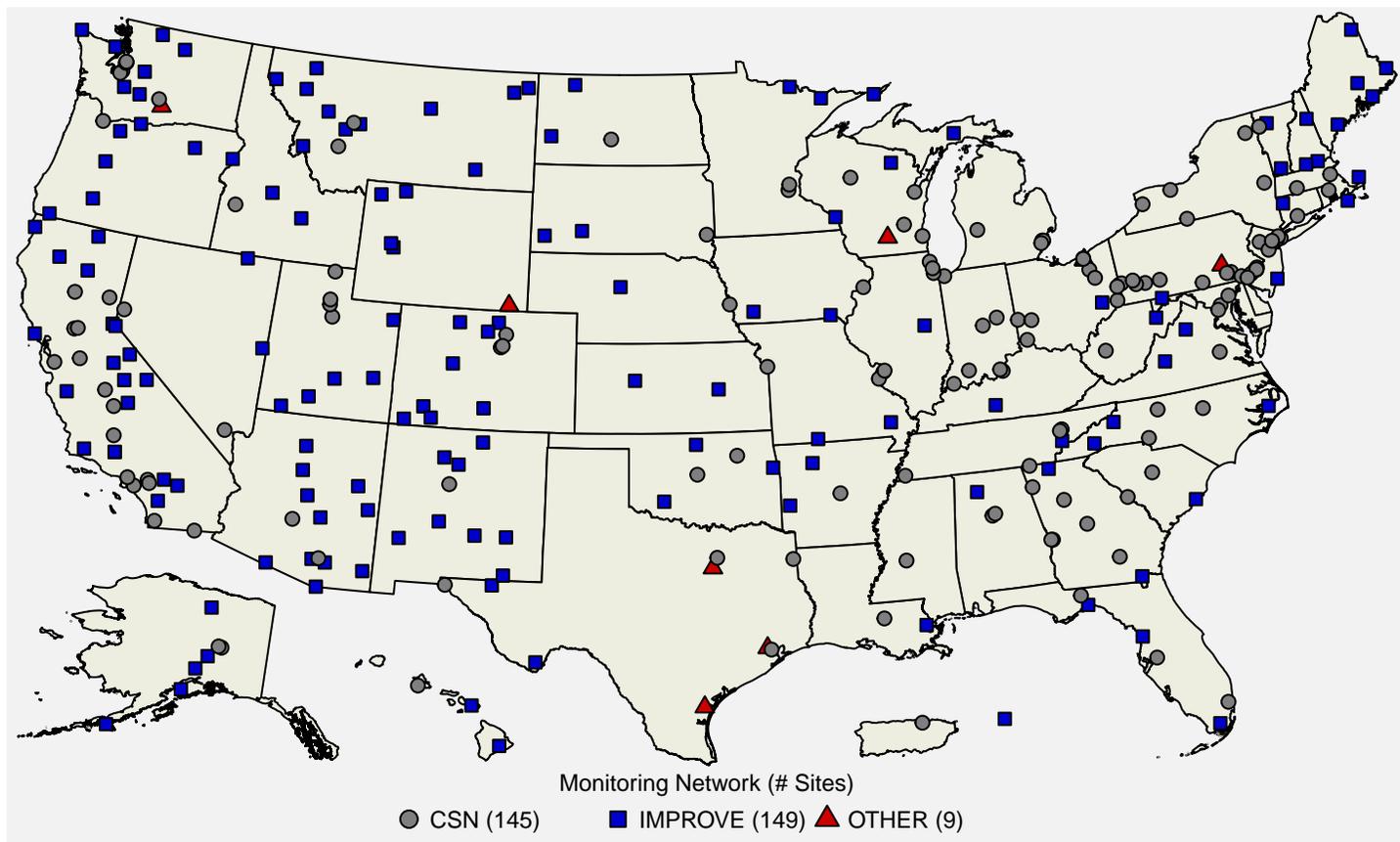
Figure 11: Map of U.S. $PM_{2.5}$ speciation monitoring sites reporting data to the EPA during the 2022-2024 period. **Source:** AQS.

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[5]The IMPROVE algorithm is an equation to estimate light extinction based on the measured concentration of several PM components and is used to track visibility progress in the Regional Haze Rule. More information about the IMPROVE algorithm is available at the IMPROVE website.
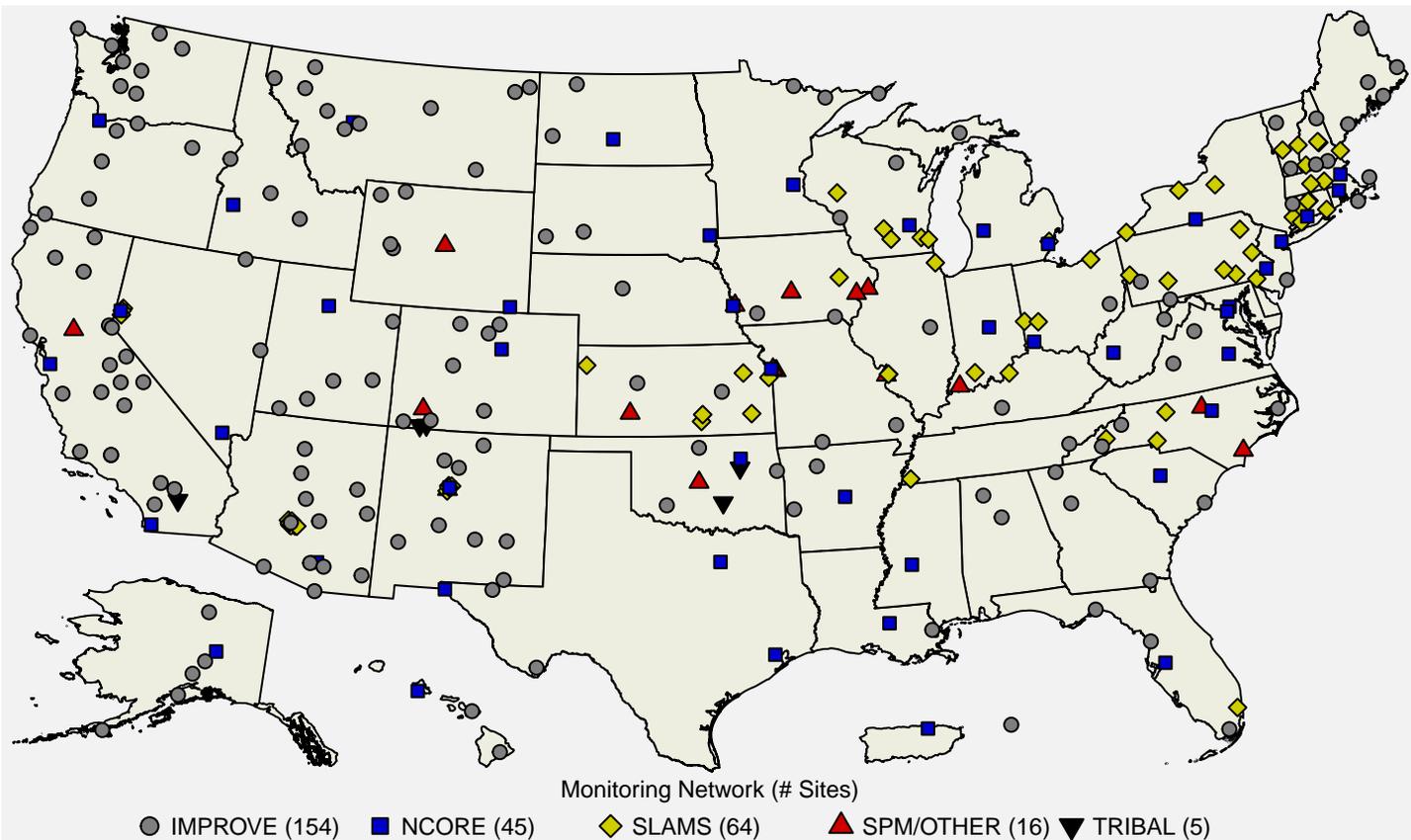
Figure 12: Map of U.S. $PM_{10\text{-}2.5}$ monitoring sites reporting data to the EPA during the 2022-2024 period. **Source:** AQS.

5. Data Handling Conventions and Computations for Determining Whether the Standards are Met

To assess whether a monitoring site or geographic area (usually a county or urban area) meets or exceeds a NAAQS, the monitoring data are analyzed consistent with the established regulatory requirements for the handling of monitoring data for the purposes of deriving a design value. A design value summarizes ambient air concentrations for an area in terms of the indicator, averaging time and form for a given standard such that its comparison to the level of the standard indicates whether the area meets or exceeds the standard. The procedures for calculating design values for the current PM NAAQS (established in 2024) are detailed in Appendix K to 40 CFR Part 50 for PM_{10} and in Appendix N to 40 CFR Part 50 for $PM_{2.5}$.

Daily 24-hour PM_{10} and $PM_{2.5}$ samples collected at an ambient air monitoring site using FRMs or FEMs, meeting all applicable requirements in 40 CFR Part 58, and reported to AQS in micrograms per meter cubed ($\mu g/m^3$) are used in design value calculations. All decimal digits are truncated (i.e., removed) from reported PM_{10} concentrations, and similarly, all digits after the first decimal place are truncated from reported $PM_{2.5}$ measurements. Monitored 24-hour PM_{10} and $PM_{2.5}$ concentrations flagged by the States as having been affected by an exceptional event, having been the subject of a demonstration submitted by the State, and having received concurrence from the appropriate EPA Regional Office, are excluded from design value calculations consistent with 40 CFR 50.14.[6]

If hourly samples are reported from a continuous PM_{10} or $PM_{2.5}$ monitor, 24-hour average concentrations will be calculated from the hourly data. Calculated 24-hour average PM_{10} and $PM_{2.5}$ concentrations are considered valid if hourly concentrations are available for at least 18 of the 24 hours in a given calendar day, or, if after substituting zero for the missing hourly concentrations, the resulting average is greater than the level of the 24-hour PM_{10} and $PM_{2.5}$ NAAQS, respectively. If multiple PM_{10} and/or $PM_{2.5}$ monitors are operating at a site, one PM_{10} monitor and one PM~2.5 monitor are designated as the primary monitors. Daily values from collocated monitors of the same measurement type are substituted on days where data is missing for the primary monitor(s) to create a site-level data record.

The number of exceedances of the PM_{10} NAAQS is determined for each calendar quarter over a 3-year period. The level of the PM_{10} NAAQS is 150 $\mu g/m^3$, but monitored concentrations are rounded to the nearest 10 $\mu g/m^3$ when compared to

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[6]A variety of resources and guidance documents related to identification and consideration of exceptional events in design value calculations are available at [https://www.epa.gov/air-quality-analysis/final-2016-exceptional-events-rule-supporting-guidance-documents-updated-faqs].

the NAAQS, so an exceedance occurs when measured concentrations are 155 $\mu g/m^3$ or greater. To correct for missing data, the observed number of exceedances in each calendar quarter is adjusted by dividing it by the data completeness rate during that quarter and rounded to the nearest hundredth, which is the expected number of exceedances for that quarter. This adjustment is performed regardless of sampling schedule, for example, a monitoring site that has an every 3rd day sampling schedule will have a minimum of 3 expected exceedances for each observed exceedance even if the data completeness rate is 100%. The annual number of expected exceedances is the sum of the expected exceedances over the four calendar quarters, and the design value is the average of the annual expected exceedances over three consecutive years, rounded to the nearest tenth. The PM_{10} NAAQS is met when the design value is less or equal to 1.0.

A PM_{10} design value meeting the NAAQS must meet minimum data completeness requirements in order to be considered valid. Specifically, a site must have reported concentrations for a minimum of 75% of the scheduled sampled days in each calendar quarter of the 3-year period in order to be considered valid. A PM_{10} design value greater than the NAAQS is always considered valid. Appendix K to 40 CFR Part 50 has additional language describing situations where a valid design value may be derived for a site which does not meet these minimum data completeness criteria.

For the annual $PM_{2.5}$ NAAQS, the 24-hour concentrations from the site-level data record are averaged over each calendar quarter for a consecutive 3-year period. The four quarterly averages are then averaged over each year to calculate an annual average, and finally the annual $PM_{2.5}$ design value is the average of the three annual average values, rounded to the nearest tenth. The annual $PM_{2.5}$ NAAQS are met when the design value is less than or equal to 9.0 $\mu g/m^3$. Annual $PM_{2.5}$ design values must have a minimum of 75% data completeness in each calendar quarter (according to the sampling schedule for the site) in order to be considered valid. In addition, for sites which fail to meet the 75% quarterly minimum data completeness, there are two data substitution tests in Appendix N to 40 CFR Part 50 by which an annual design value above or below the NAAQS, respectively, may be considered valid.

For the 24-hour $PM_{2.5}$ NAAQS, the 98th percentile of the 24-hour concentrations from the site-level data record is calculated for each of the three years. The 24-hour $PM_{2.5}$ design value is the average of the three 98th percentile values, rounded to the nearest integer. The 24-hour $PM_{2.5}$ NAAQS are met when the design value is less than or equal to 35 $\mu g/m^3$. Similar to the annual $PM_{2.5}$ design values, 24-hour $PM_{2.5}$ design values must have a minimum of 75% data completeness in each calendar quarter to be considered valid. In addition, a site with a design value meeting the NAAQS may also be considered valid if it is able to pass the 24-hour $PM_{2.5}$ NAAQS data substitution test in Appendix N to 40 CFR Part 50.

6. PM Concentrations Measured at Ambient Air Monitoring Sites Across the U.S.

Table 1 below presents summary statistics based on daily PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$ monitoring data reported to AQS for 2022 to 2024 for the full year and for each calendar quarter. There are two daily metrics for PM_{10} and $PM_{2.5}$: the daily 24-hour average (DA24) metric, which is available for both filter-based and continuous monitoring instruments, and the maximum daily 1-hour average (MDA1) metric, which is available only for continuous monitoring instruments. For $PM_{10-2.5}$, most of the measurements are filter-based, thus only the DA24 metric is shown. Table 2 presents summary statistics for the DA24 metric based on 2022-2024 PM_{10} and $PM_{2.5}$ monitoring data by type of site, including urban (CSN) versus rural (IMPROVE) sites located in the eastern U.S. versus western U.S., as well as near-road sites for $PM_{2.5}$.[7] Finally, Table 3 presents summary statistics for the same daily metrics based on 2022-2024 PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$ monitoring data for each NOAA Climate Region.[8]

Table 1 shows that PM concentrations are typically highest in the 3rd quarter (July-September), which coincides with the period of highest wildfire frequency in the western U.S. $PM_{2.5}$ concentrations tend to be lowest in the 2nd quarter (April-June), while PM_{10} and $PM_{10-2.5}$ concentrations tend to be lowest in the 1st quarter (January-March). MDA1 concentrations are typically 2-3 times higher than DA24 concentrations. Table 2 shows evidence of a sharper gradient between urban and rural PM concentrations in the western U.S. than in the eastern U.S, and that $PM_{2.5}$ concentrations measured at near-road sites are comparable to concentrations measured at urban sites located away from roads. Table 3 shows that PM_{10} concentrations are generally highest in the Southwest and West regions. The Northwest and West North Central regions have the lowest median PM_{10} concentrations, while the two easternmost regions (Northeast and Southeast) have the lowest peak PM_{10} concentrations. For $PM_{2.5}$ the median concentrations are comparable across the nine climate regions, while there is greater disparity in the peak concentrations, with the western regions generally having higher peak $PM_{2.5}$ concentrations than the eastern regions.

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[7]The MDA1 metric is not included in Table 2 because very few IMPROVE sites operate continuous PM_{10} and/or $PM_{2.5}$ instruments. $PM_{2.5}$ concentrations measured by the IMPROVE network are non-regulatory and thus may not meet all of the EPA's ambient air monitoring requirements in 40 CFR Part 58.

[8]For Table 3, monitoring sites in Alaska were assigned to the Northwest Region and monitoring sites in Hawaii were assigned to the West region.

Table 1. National distribution of PM concentrations in μg/m^3 by quarter based on monitoring data from 2022 to 2024.[9] **Source:** AQS.

pollutant	metric	quarter	N.sites	N.obs	mean	SD	min	p1	p5	p10	p25	p50	p75	p90	p95	p98	p99	max	max.site
PM10	DA24	all	877	622,874	20	26	-9	1	4	5	9	16	25	38	50	70	88	7681	060510011
PM10	DA24	1st quarter	863	153,785	16	20	-6	1	2	4	7	12	20	30	40	56	72	1343	060270025
PM10	DA24	2nd quarter	862	154,552	22	37	-9	2	4	6	11	17	26	39	51	71	93	7681	060510011
PM10	DA24	3rd quarter	863	157,307	23	19	-8	3	6	8	12	18	28	42	53	72	91	792	040213011
PM10	DA24	4th quarter	858	157,230	20	22	-6	1	3	5	9	15	25	41	54	75	93	2355	060510011
PM10	MDA1	all	575	509,012	57	182	-1	6	10	13	20	33	58	103	155	264	398	59603	060510011
PM10	MDA1	1st quarter	558	124,210	47	116	-1	5	8	11	17	28	48	85	127	218	329	10982	060270028
PM10	MDA1	2nd quarter	563	125,622	61	284	0	7	12	15	22	35	60	108	164	291	445	59603	060510011
PM10	MDA1	3rd quarter	562	128,167	63	158	0	9	14	17	24	36	62	111	167	294	450	15130	040217004
PM10	MDA1	4th quarter	563	131,013	55	118	0	6	9	12	19	32	60	108	158	252	364	10310	060270023
PM2.5	DA24	all	1,381	1,155,389	7.6	6.9	-7.2	0.5	1.7	2.5	4.0	6.3	9.4	13.4	16.9	22.8	28.8	833.8	250092006
PM2.5	DA24	1st quarter	1,352	286,173	7.0	5.2	-5.9	0.3	1.3	2.1	3.7	6.0	9.1	13.1	16.2	20.9	25.1	322.5	040239000
PM2.5	DA24	2nd quarter	1,356	287,646	7.4	7.8	-4.3	0.5	1.7	2.3	3.8	6.0	9.0	13.0	16.7	23.7	31.1	281.5	410170004
PM2.5	DA24	3rd quarter	1,353	291,623	8.3	7.8	-6.7	0.9	2.4	3.2	4.7	6.9	10.0	14.0	17.5	24.2	32.9	512.0	410330036
PM2.5	DA24	4th quarter	1,353	289,947	7.6	6.4	-7.2	0.4	1.6	2.4	4.0	6.3	9.5	13.7	17.3	22.8	27.9	833.8	250092006
PM2.5	MDA1	all	1,165	1,066,647	15.5	17.5	-4.0	2.7	4.4	5.7	8.0	12.0	18.0	26.5	35.1	51.7	70.0	1525.6	120050006
PM2.5	MDA1	1st quarter	1,125	262,820	15.4	14.8	-4.0	2.4	4.2	5.5	8.0	12.3	18.7	27.3	35.3	49.0	61.8	1075.5	120866002
PM2.5	MDA1	2nd quarter	1,136	264,705	14.6	17.8	-1.0	2.4	4.0	5.0	7.5	11.1	16.7	24.5	32.9	50.1	71.5	1041.0	380650002
PM2.5	MDA1	3rd quarter	1,138	268,712	16.0	20.7	-4.0	3.4	5.0	6.0	8.6	12.1	17.5	25.3	34.5	56.3	83.0	985.0	060932001
PM2.5	MDA1	4th quarter	1,141	270,410	16.0	15.9	-1.0	2.7	4.5	5.8	8.3	12.5	19.0	28.4	37.4	52.5	67.1	1525.6	120050006
PM10-2.5	DA24	all	283	156,794	9.4	13.4	-6.7	0.0	0.6	1.4	3.5	6.7	11.4	19.4	26.8	39.2	51.0	1539.1	060650500
PM10-2.5	DA24	1st quarter	279	39,310	7.6	11.0	-6.1	0.0	0.3	0.6	2.2	5.0	9.4	16.2	22.7	32.9	45.1	454.7	350010029
PM10-2.5	DA24	2nd quarter	278	39,773	10.5	17.8	-4.4	0.2	1.0	1.9	4.3	7.7	12.5	20.5	27.6	40.9	53.7	1539.1	060650500
PM10-2.5	DA24	3rd quarter	280	40,166	9.9	11.2	-6.7	0.6	1.7	2.6	4.8	7.5	11.7	18.9	25.7	36.2	46.8	885.7	060650500
PM10-2.5	DA24	4th quarter	278	37,545	9.7	12.2	-6.7	0.0	0.5	1.1	3.0	6.2	11.7	22.1	31.5	44.7	55.4	468.8	060650500

N.sites = number of sites; N.obs = number of observations; SD = standard deviation; min = minimum; p1, p5, p10, p25, p50, p90, p95, p98, p99 = 1st, 5th, 10th, 25th, 50th, 90th, 95th, 98th, 99th percentiles; max = maximum; max.site = AQS ID number for the monitoring site corresponding to the observation in the max column. 1st quarter = January/February/March; 2nd quarter = April/May/June; 3rd quarter = July/August/September; 4th quarter = October/November/December.

Table 2. National distribution of PM concentrations in μg/m^3 by type of site based on monitoring data from 2022 to 2024.[9] **Source:** AQS.

pollutant	metric	region	network	N.sites	N.obs	mean	SD	min	p1	p5	p10	p25	p50	p75	p90	p95	p98	p99	max	max.site
PM10	DA24	all	all	877	622,874	20	26	-9	1	4	5	9	16	25	38	50	70	88	7681	060510011
PM10	DA24	Eastern U.S.	CSN	67	55,898	19	12	-1	4	6	8	11	16	22	31	38	49	61	281	421010048
PM10	DA24	Eastern U.S.	IMPROVE	54	25,417	12	10	0	1	2	3	6	10	15	22	29	38	47	289	400319000
PM10	DA24	Western U.S.	CSN	35	29,881	26	21	-4	3	6	8	13	21	33	50	62	83	98	542	481410044
PM10	DA24	Western U.S.	IMPROVE	101	35,458	10	15	-1	0	1	1	3	6	12	22	31	46	59	1402	060893003
PM2.5	DA24	all	all	1,381	1,155,389	7.6	6.9	-7.2	0.5	1.7	2.5	4.0	6.3	9.4	13.4	16.9	22.8	28.8	833.8	250092006
PM2.5	DA24	Eastern U.S.	CSN	102	98,122	8.9	6.7	-2.9	1.6	3.0	3.8	5.3	7.7	10.9	14.9	18.3	23.6	29.0	235.4	420710012
PM2.5	DA24	Eastern U.S.	IMPROVE	54	33,978	6.4	5.7	-2.0	0.6	1.4	2.0	3.3	5.3	8.0	11.5	14.3	19.1	23.4	244.8	400319000
PM2.5	DA24	Western U.S.	CSN	43	45,072	8.8	8.2	-5.9	1.0	2.1	2.9	4.3	6.7	10.6	16.5	21.8	30.6	39.0	237.3	020900034
PM2.5	DA24	Western U.S.	IMPROVE	101	38,405	4.2	7.4	-3.0	0.1	0.4	0.7	1.4	2.8	5.0	8.3	11.7	18.2	25.1	794.9	060893003
PM2.5	DA24	all	Near Road	63	57,870	8.9	6.1	-1.0	1.8	3.1	3.8	5.4	7.6	10.8	14.9	18.3	24.1	29.5	240.8	421010075

N.sites = number of sites; N.obs = number of observations; SD = standard deviation; min = minimum; p1, p5, p10, p25, p50, p90, p95, p98, p99 = 1st, 5th, 10th, 25th, 50th, 90th, 95th, 98th, 99th percentiles; max = maximum; max.site = AQS ID number for the monitoring site corresponding to the observation in the max column.

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[9]Negative concentration values may appear in AQS datasets down to the negative of the lower detection limit (LDL) to allow for normal instrument variability at very low concentrations. Data that exceed the negative of the LDL is typically indicative of a malfunction or another issue that affects the data defensibility.

Table 3. National distribution of PM concentrations in μg/m^3 by climate region based on monitoring data from 2022 to 2024.[9] **Source:** AQS.

pollutant	metric	region	N.sites	N.obs	mean	SD	min	p1	p5	p10	p25	p50	p75	p90	p95	p98	p99	max	max.site
PM10	DA24	all	877	622,874	20	26	-9	1	4	5	9	16	25	38	50	70	88	7681	060510011
PM10	DA24	Central	75	47,602	20	15	0	3	6	8	12	17	25	36	46	61	74	266	295100093
PM10	DA24	East North Central	46	26,849	18	15	-3	2	4	6	9	15	22	33	43	56	68	700	261150951
PM10	DA24	Northeast	86	59,248	14	10	0	2	4	5	8	12	17	23	28	36	44	688	250251004
PM10	DA24	Northwest	55	29,053	15	26	-1	0	1	2	5	10	18	30	40	59	81	655	160050020
PM10	DA24	South	68	42,883	24	19	-6	4	7	9	14	20	29	41	53	74	93	599	201810003
PM10	DA24	Southeast	94	62,367	17	9	-8	3	6	8	11	15	20	27	33	42	51	262	120179000
PM10	DA24	Southwest	138	110,777	24	24	-1	1	4	6	11	19	31	46	60	85	109	896	350010029
PM10	DA24	West	182	140,241	25	42	-9	1	4	6	11	19	30	46	59	82	106	7681	060510011
PM10	DA24	West North Central	133	103,854	16	17	-4	0	2	4	7	12	20	33	45	63	80	988	560310805
PM10	MDA1	all	575	509,012	57	182	-1	6	10	13	20	33	58	103	155	264	398	59603	060510011
PM10	MDA1	Central	49	42,038	48	61	0	8	12	15	22	32	54	90	128	198	267	2239	290970003
PM10	MDA1	East North Central	24	21,232	39	43	0	6	10	12	18	27	44	75	107	160	211	1108	260810020
PM10	MDA1	Northeast	62	52,899	27	36	0	5	8	10	14	21	31	47	65	95	127	2868	250251004
PM10	MDA1	Northwest	27	20,507	45	66	0	5	8	11	17	28	48	84	126	211	304	1985	160050015
PM10	MDA1	South	44	36,798	53	85	0	9	14	17	24	35	55	93	141	240	348	4054	481410044
PM10	MDA1	Southeast	69	55,045	35	31	2	9	13	15	20	27	39	60	82	121	155	1394	120866002
PM10	MDA1	Southwest	102	96,235	86	205	0	8	13	17	28	48	85	158	248	445	691	15130	040217004
PM10	MDA1	West	140	130,973	70	298	0	7	12	16	25	41	70	119	175	309	502	59603	060510011
PM10	MDA1	West North Central	58	53,285	45	68	-1	4	7	10	15	26	48	91	140	235	317	2470	560010800
PM2.5	DA24	all	1,381	1,155,389	7.6	6.9	-7.2	0.5	1.7	2.5	4.0	6.3	9.4	13.4	16.9	22.8	28.8	833.8	250092006
PM2.5	DA24	Central	171	138,336	8.7	6.3	-7.2	1.8	3.0	3.8	5.3	7.5	10.5	14.2	17.3	22.2	27.2	214.0	171132003
PM2.5	DA24	East North Central	96	84,492	8.1	7.1	-3.6	0.5	2.0	2.8	4.3	6.7	9.9	14.2	18.0	24.1	30.4	195.7	551110007
PM2.5	DA24	Northeast	196	175,297	7.3	6.9	-2.9	0.8	2.0	2.7	4.1	6.1	8.9	12.5	15.3	20.0	25.2	833.8	250092006
PM2.5	DA24	Northwest	164	141,284	6.7	9.7	-2.7	0.3	1.2	1.8	2.9	4.5	7.5	12.9	17.8	26.7	38.0	512.0	410330036
PM2.5	DA24	South	131	109,446	9.1	5.6	-2.7	1.6	3.1	4.0	5.7	8.0	11.2	15.2	18.6	24.1	29.3	244.8	400319000
PM2.5	DA24	Southeast	195	165,226	8.2	4.7	-3.2	1.5	3.0	3.8	5.3	7.3	9.8	13.2	15.9	20.2	24.3	197.0	120179000
PM2.5	DA24	Southwest	122	90,931	6.3	5.4	-4.3	0.3	1.3	2.0	3.3	5.1	7.7	11.4	15.1	21.2	26.5	322.5	040239000
PM2.5	DA24	West	220	182,118	7.3	7.1	-6.7	0.2	1.3	2.0	3.5	5.7	9.3	13.8	17.7	24.5	30.5	794.9	060893003
PM2.5	DA24	West North Central	86	68,259	5.9	7.3	-4.1	-0.5	0.6	1.2	2.4	4.3	7.1	11.5	15.9	24.1	33.2	236.6	380650002
PM2.5	MDA1	all	1,165	1,066,647	15.5	17.5	-4.0	2.7	4.4	5.7	8.0	12.0	18.0	26.5	35.1	51.7	70.0	1525.6	120050006
PM2.5	MDA1	Central	140	122,349	15.9	13.4	-0.9	4.0	5.7	6.8	9.3	13.1	18.5	26.0	33.2	47.0	62.4	742.0	390170022
PM2.5	MDA1	East North Central	82	78,486	14.9	16.5	-2.0	2.4	4.0	5.1	7.8	11.9	17.3	25.1	32.6	48.0	68.0	859.0	270834210
PM2.5	MDA1	Northeast	176	167,083	13.4	14.4	0.0	2.8	4.3	5.3	7.5	10.9	15.7	22.1	27.9	38.9	53.0	865.0	250092006
PM2.5	MDA1	Northwest	144	132,820	15.2	24.1	-1.0	1.8	3.0	4.0	6.0	10.0	17.0	28.7	40.0	63.0	92.0	899.8	410170004
PM2.5	MDA1	South	111	100,130	18.1	17.0	0.0	4.5	6.6	8.0	10.9	15.0	20.9	29.4	38.0	53.1	71.4	993.2	480290677
PM2.5	MDA1	Southeast	167	151,828	15.3	13.0	0.0	4.2	6.0	7.1	9.4	13.0	17.8	24.6	31.3	44.8	58.3	1525.6	120050006
PM2.5	MDA1	Southwest	87	78,487	15.6	18.9	-1.0	2.1	4.1	5.3	7.6	11.4	17.8	28.2	38.9	57.3	77.8	1069.0	040130019
PM2.5	MDA1	West	189	171,921	16.6	19.2	-4.0	3.0	4.9	6.0	8.0	12.2	19.0	30.0	40.4	58.0	75.0	985.0	060932001
PM2.5	MDA1	West North Central	69	63,543	14.5	18.7	-1.0	2.3	4.0	5.0	7.0	10.4	16.9	26.1	35.6	53.9	74.4	1041.0	380650002
PM10-2.5	DA24	all	283	156,794	9.4	13.4	-6.7	0.0	0.6	1.4	3.5	6.7	11.4	19.4	26.8	39.2	51.0	1539.1	060650500
PM10-2.5	DA24	Central	21	13,525	9.4	8.1	-4.4	0.5	1.8	2.8	4.8	7.5	11.4	17.5	23.6	34.1	42.7	110.0	390350060
PM10-2.5	DA24	East North Central	23	14,114	8.5	7.6	-5.3	0.3	1.0	2.0	3.9	6.6	10.7	16.9	22.2	30.6	38.5	103.2	191130040
PM10-2.5	DA24	Northeast	48	31,699	6.3	4.3	-4.0	0.4	1.3	2.0	3.5	5.6	8.0	11.0	13.6	17.5	20.9	78.3	250250042
PM10-2.5	DA24	Northwest	25	8,099	3.2	5.0	-6.7	0.0	0.1	0.2	0.6	1.7	3.8	7.3	11.1	18.0	25.5	97.2	160010010
PM10-2.5	DA24	South	28	18,211	14.5	14.7	-6.7	0.8	2.6	3.9	6.7	10.9	17.8	27.8	36.8	53.4	67.2	435.3	481410044
PM10-2.5	DA24	Southeast	27	16,028	7.2	5.2	-2.2	0.4	1.4	2.3	4.0	6.4	9.0	12.2	15.1	20.5	25.3	109.9	120573002
PM10-2.5	DA24	Southwest	51	27,577	12.7	15.6	-2.8	0.1	0.7	1.4	3.7	8.6	16.7	27.7	37.5	52.9	67.1	666.3	350010029
PM10-2.5	DA24	West	34	16,340	12.4	27.3	-4.4	0.0	0.5	1.1	3.5	8.6	14.7	24.6	33.9	50.9	67.7	1539.1	060650500
PM10-2.5	DA24	West North Central	26	11,201	6.4	8.5	-4.2	-1.0	0.0	0.3	1.2	3.7	8.5	15.8	22.2	30.8	37.9	227.5	460990009

N.sites = number of sites; N.obs = number of observations; SD = standard deviation; min = minimum; p1, p5, p10, p25, p50, p90, p95, p98, p99 = 1st, 5th, 10th, 25th, 50th, 90th, 95th, 98th, 99th percentiles; max = maximum; max.site = AQS ID number for the monitoring site corresponding to the observation in the max column. Central = Illinois, Indiana, Kentucky, Missouri, Ohio, Tennessee, West Virginia; East North Central = Iowa, Minnesota, Michigan, Wisconsin; Northeast = Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont; Northwest = Alaska, Idaho, Oregon, Washington; South = Arkansas, Kansas, Louisiana, Mississippi, Oklahoma, Texas; Southeast = Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia; Southwest = Arizona, Colorado, New Mexico, Utah; West = California, Hawaii, Nevada; West North Central = Montana, Nebraska, North Dakota, South Dakota, Wyoming.

Figure 13 and Figure 14 show maps of the annual and 24-hour $PM_{2.5}$ design values, respectively, at U.S. ambient air monitoring sites based on monitoring data from the 2022-2024 period. Approximately one-sixth of the current $PM_{2.5}$ sites had valid design values exceeding the annual $PM_{2.5}$ NAAQS, which was recently revised in 2024 to a level of 9.0 $\mu g/m^3$. Additionally, there were 24 sites with design values exceeding the 24-hour $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$ in 2022-2024. The highest annual $PM_{2.5}$ design values are located in the San Joaquin Valley of California, while the highest 24-hour $PM_{2.5}$ design value occurred at a site in Oakridge, Oregon.

The PM_{10} NAAQS is unique in that the form of the standard is expressed in terms of expected exceedances rather than a concentration-based value. Alternatively, a "design concentration" can be used to show PM_{10} concentrations that would be expected at each site based on the averaging time and form of the NAAQS. The design concentration for PM_{10} is determined using a table lookup procedure.[10] For example, for a PM_{10} monitor with 3 years of complete daily sampling data, the design concentration is the 4th highest 24-hour average concentration measured during the 3-year period. Figure 15 shows a map of the PM_{10} design concentrations based on monitoring data from the 2022-2024 period. The overall pattern appears similar to the 24-hour $PM_{2.5}$ design values in Figure 14, with generally lower design concentrations in the eastern U.S. and higher concentrations in parts of the western U.S. One notable difference is the presence of several sites with high PM_{10} design concentrations in the central U.S., which is likely due to higher emissions of coarse particles in those regions. This is corroborated by Figure 16, which shows the average annual $PM_{10-2.5}$ concentrations measured at U.S. monitoring sites during the 2022-2024 period.
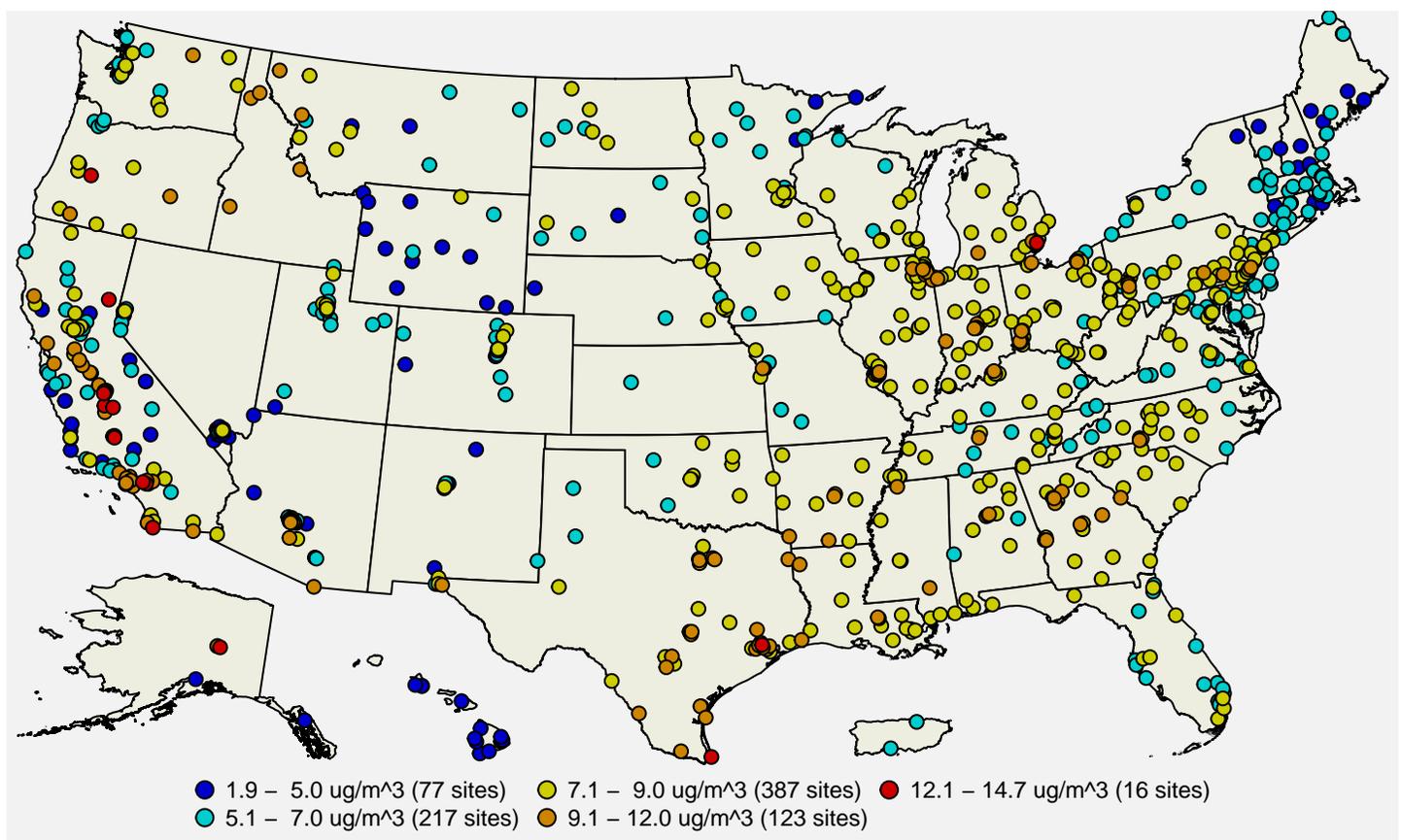

Figure 13: Annual $PM_{2.5}$ design values in $\mu g/m^3$ for the 2022-2024 period. **Source:** AQS.

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[10]The table lookup procedure is documented in Section 6.3 of the 1987 EPA guidance document *PM_{10} SIP Development Guideline*.
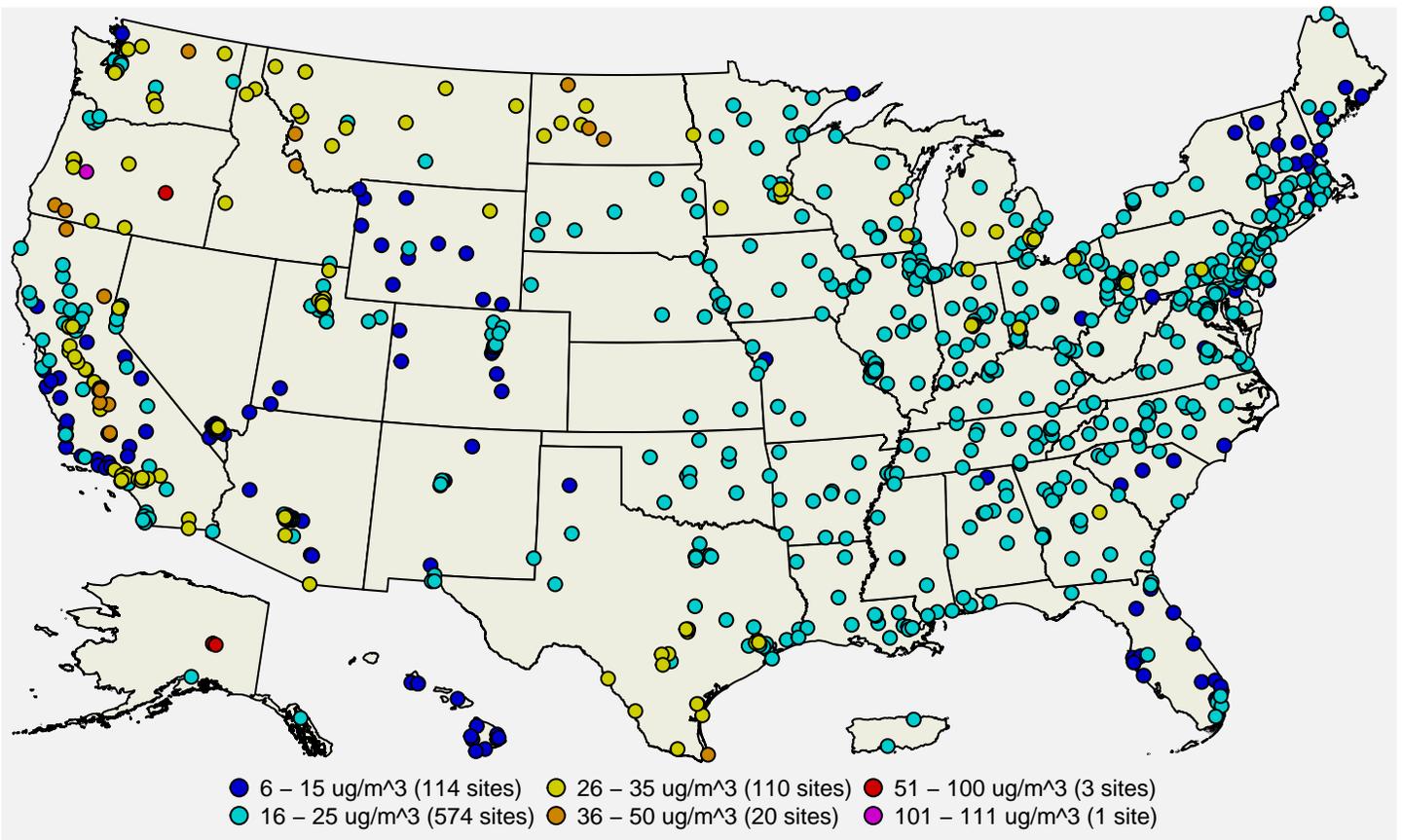
Figure 14: 24-hour $PM_{2.5}$ design values in $\mu g/m^3$ for the 2022-2024 period. **Source:** AQS.
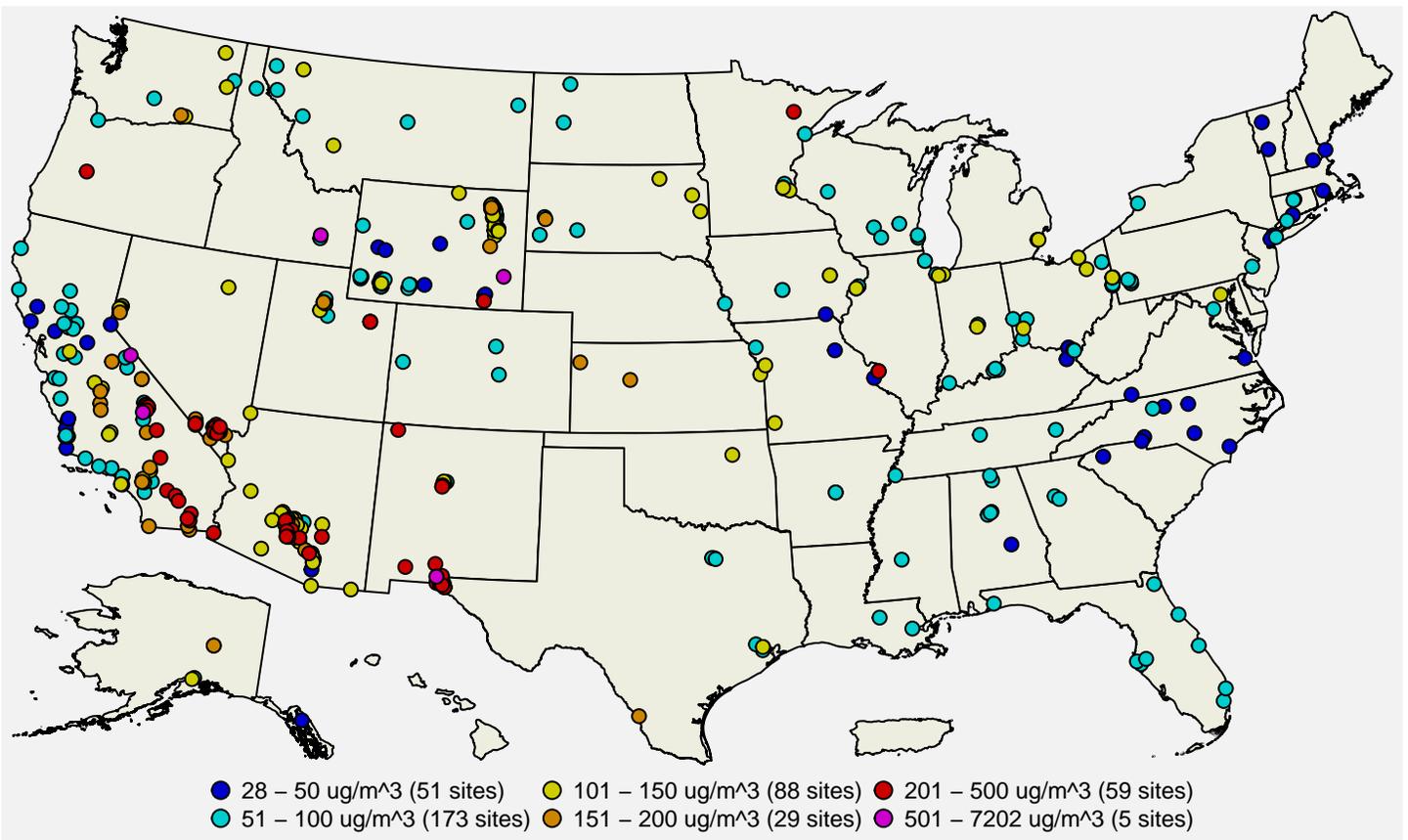

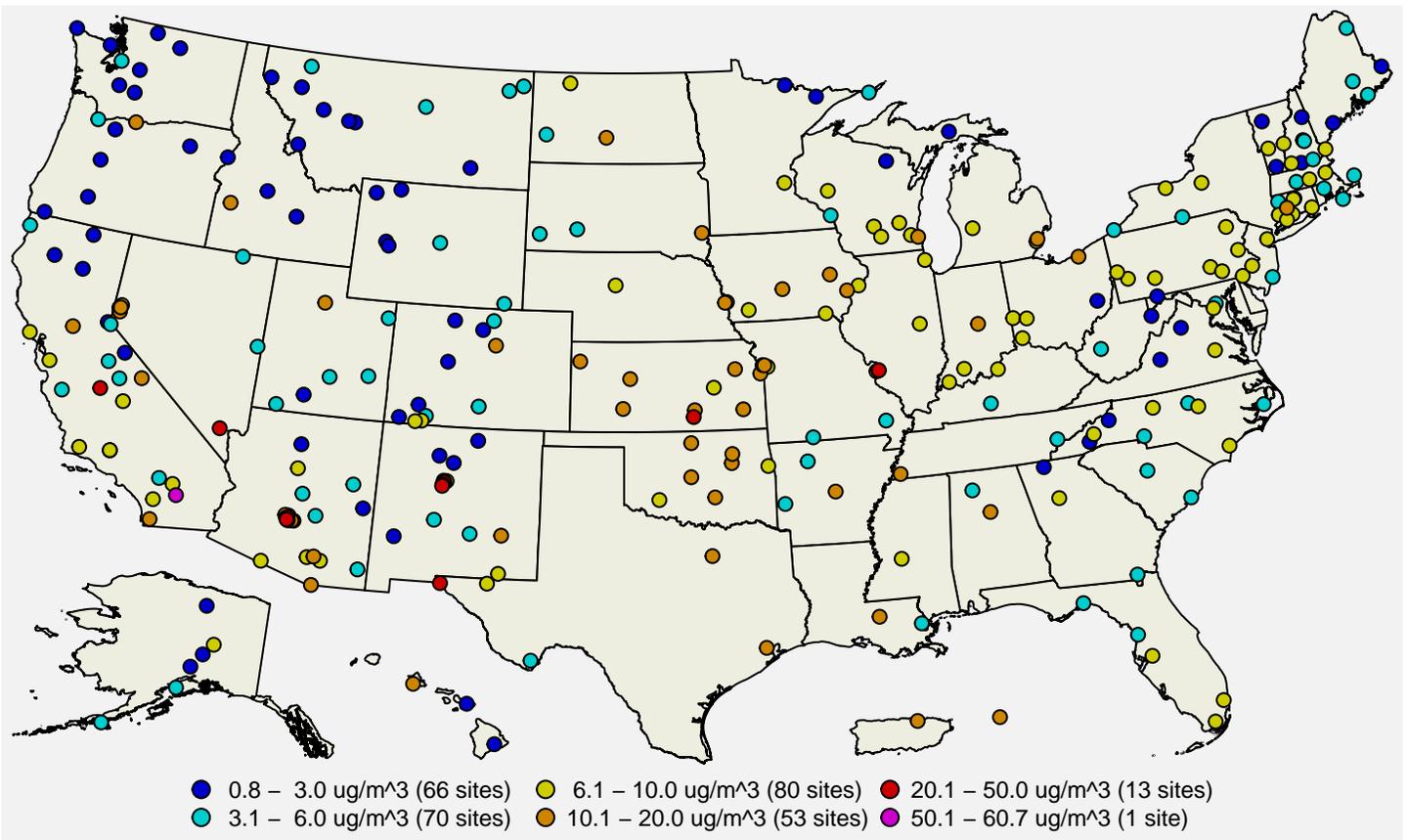**Figure 15:** 24-hour PM_{10} design concentrations in $\mu g/m^3$ for the 2022-2024 period. **Source:** AQS.

Figure 16: Average annual PM$_{10\text{-}2.5}$ concentrations in μg/m^3 for the 2022-2024 period. **Source:** AQS.

Figure 17 and Figure 18 show site-level trends in the annual and 24-hour PM$_{2.5}$ design values, respectively, for sites having valid design values in at least 18 of the 23 3-year periods from 2000-2002 through 2022-2024. The trends were computed using the Thiel-Sen estimator, and tests for significance (p-value < 0.05) were computed using the Mann-Kendall test. From this figure it is apparent that most of the U.S. has experienced significant decreasing trends in both the annual and 24-hour PM$_{2.5}$ design values over the past two decades, especially in the eastern U.S., where regional control programs such as the Clean Air Interstate Rule (CAIR) and the Cross-State Air Pollution Rule (CSAPR) have enabled large reductions in NO$_X$ and SO$_2$ emissions, which led to long-term reductions in secondary PM$_{2.5}$ components. There has been less progress in the western U.S., where most controls to-date have focused on local reductions, and emissions from wildfires in recent years have caused increases in PM$_{2.5}$ concentrations in some areas.

Figure 19 shows site-level trends in the 24-hour PM$_{10}$ design concentrations for sites having valid design values in at least 19 of the 25 3-year periods from 1998-2000 through 2022-2024, while Figure 20 shows site-level trends in annual average PM$_{10\text{-}2.5}$ concentrations for sites having data for at least 15 of the 20 years from 2005 to 2024. The trends in the 24-hour PM$_{10}$ design concentrations are much more variable than those for PM$_{2.5}$. While trends in the eastern U.S. are decreasing in most locations, there is no clear pattern in the western U.S., with sites even in close proximity sometimes having trends in opposite directions. Nationally, over half of the sites had no significant trend. The reason for this is apparent from Figure 20, which shows no clear trend the annual average PM$_{10\text{-}2.5}$ concentrations at the vast majority of U.S. monitoring sites.
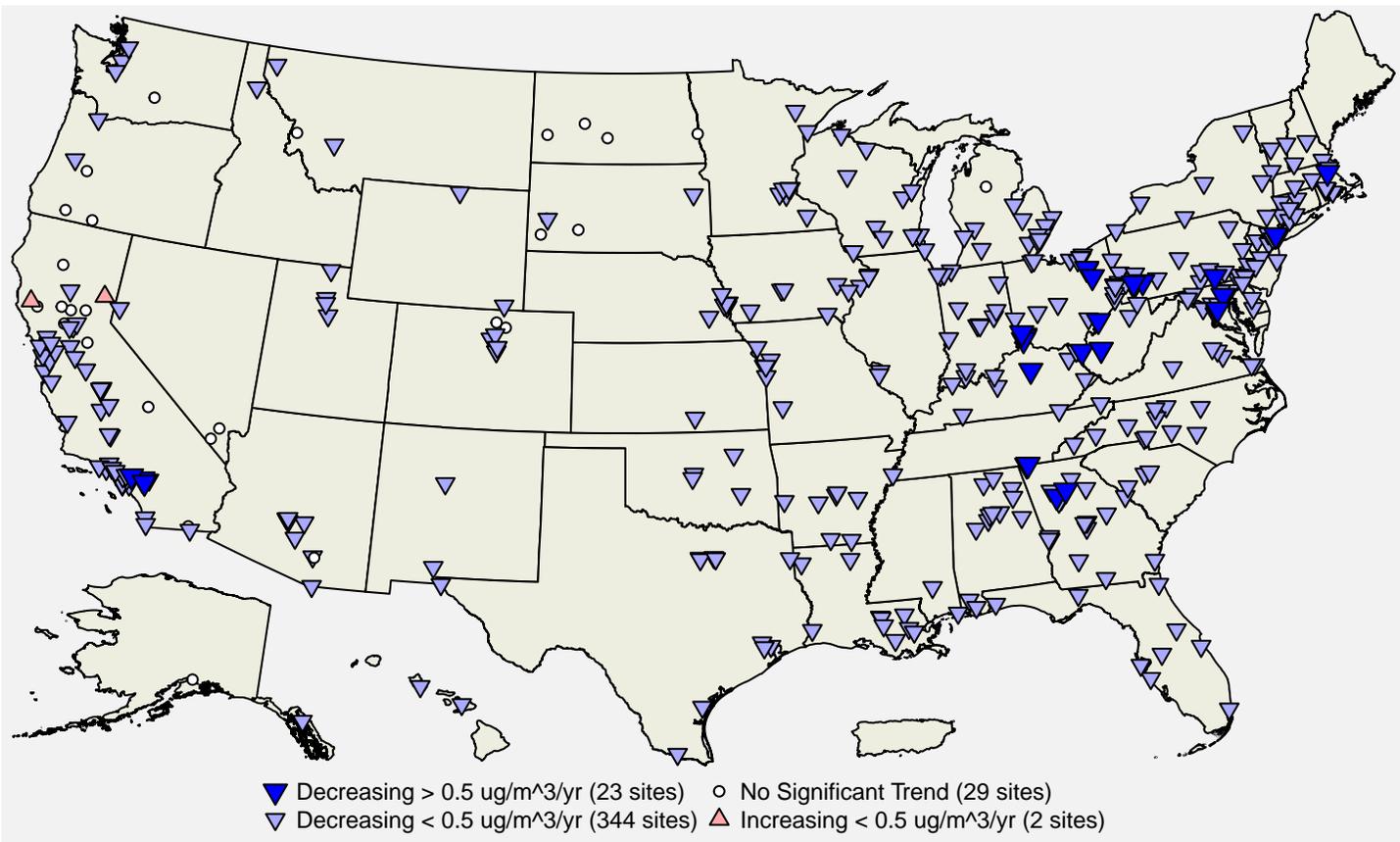
Figure 17: Site-level trends in annual PM$_{2.5}$ design values based on data from 2002 through 2024. **Source:** AQS, trends computed using R statistical software.
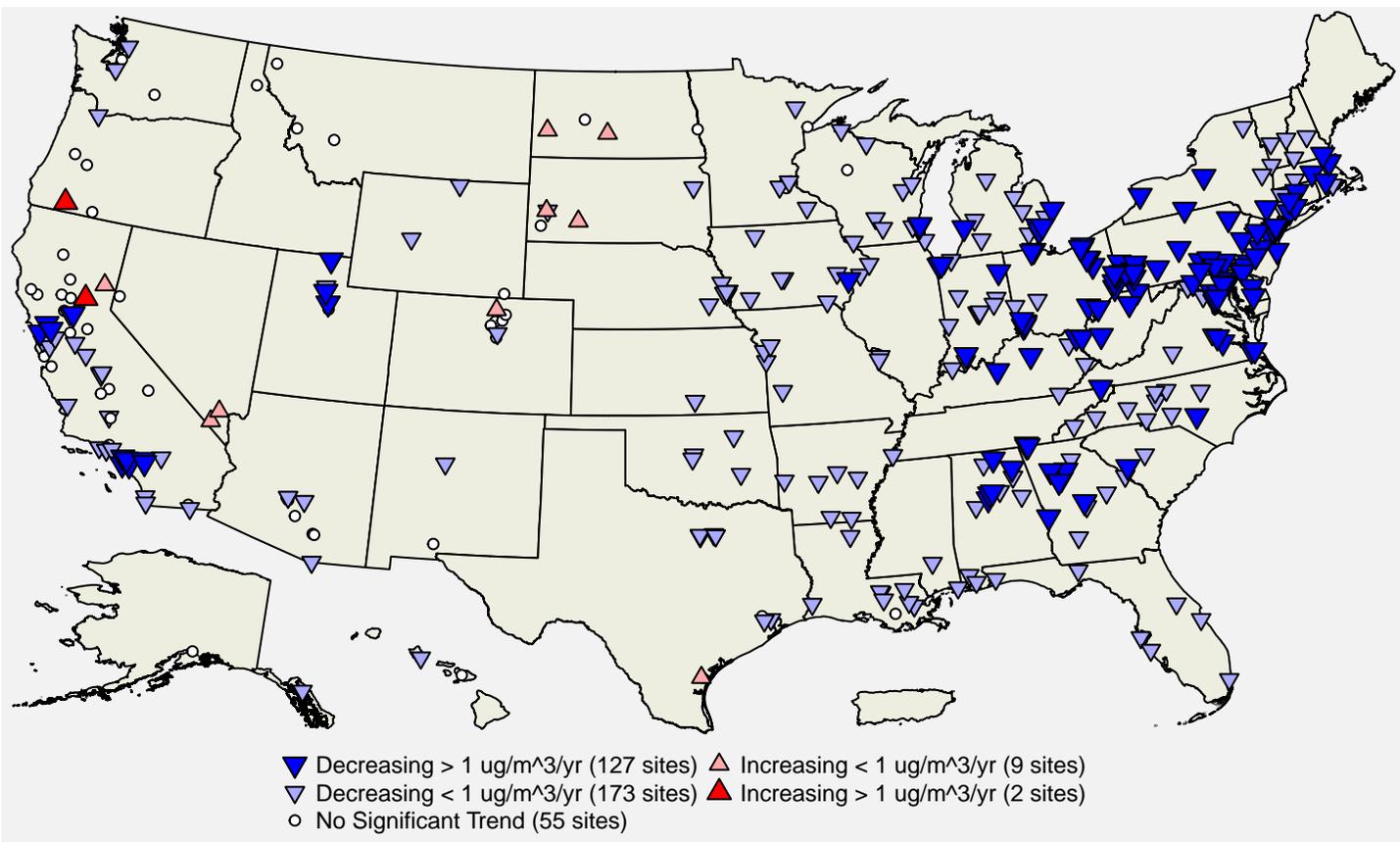

Figure 18: Site-level trends in 24-hour PM$_{2.5}$ design values based on data from 2002 through 2024. **Source:** AQS, trends computed using R statistical software.
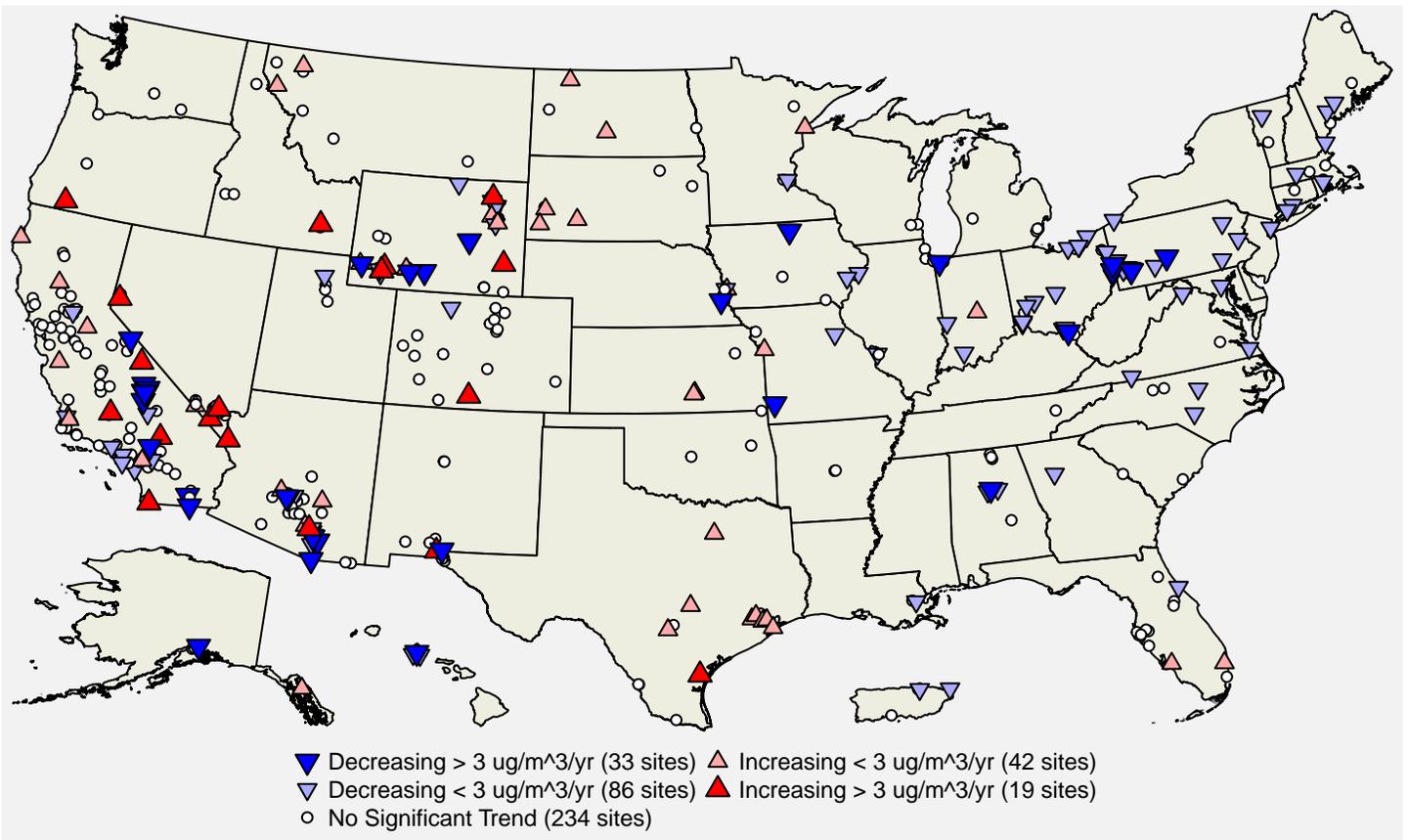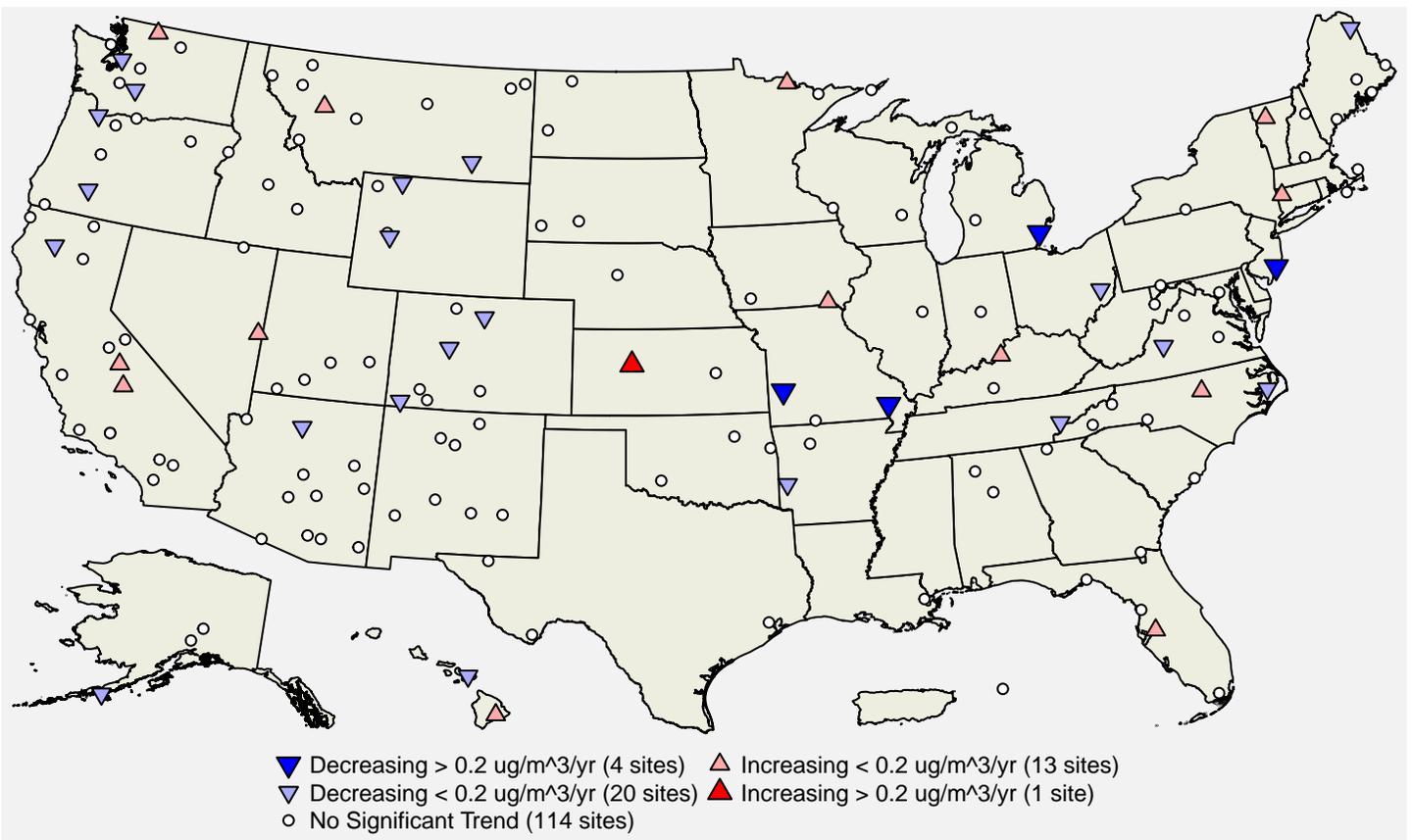
Figure 19: Site-level trends in 24-hour PM_{10} design concentrations based on data from 2000 through 2024. **Source:** AQS, trends computed using R statistical software.

Figure 20: Site-level trends in annual average $PM_{10\text{-}2.5}$ concentrations based on data from 2005 through 2024. **Source:** AQS, trends computed using R statistical software.

Figure 21 shows the national trends in the annual and 24-hour $PM_{2.5}$ design values based on the 398 sites in Figure 17 and the 366 sites in Figure 18, respectively. The U.S. median annual $PM_{2.5}$ design value decreased by 42% from 13.6 $\mu g/m^3$ in 2002 to 7.9 $\mu g/m^3$ in 2024, while the U.S. median 24-hour $PM_{2.5}$ design value decreased by 44% from 36 $\mu g/m^3$ in 2002 to 20 $\mu g/m^3$ in 2024.

Both the annual and 24-hour $PM_{2.5}$ design values exhibited steady decreases from 2002 to 2016. In recent years, the median annual $PM_{2.5}$ design value has remained relatively constant at about 8 $\mu g/m^3$ while the 10th and 90th percentile trends have also remained relatively flat at about 6 $\mu g/m^3$ and 10 $\mu g/m^3$, respectively. The 10th percentile and median of the 24-hour $PM_{2.5}$ design values, which are based on the annual 98th percentile, have also remained relatively constant at about 15 $\mu g/m^3$ and 20 $\mu g/m^3$, respectively, since 2016. However, the 90th percentile of the 24-hour $PM_{2.5}$ design values has fluctuated substantially in the past 8 years largely as a result of increased wildfire activity.

Figure 22 shows the national trend in the 24-hour PM_{10} design concentrations based on the 414 sites in Figure 19. The national median of the 24-hour PM_{10} design concentrations has remained relatively constant over the past two decades, though there has been an increase of about 15 $\mu g/m^3$ since 2016. The 90th percentile 24-hour PM_{10} design concentration has been highly variable, most likely as a result of year-to-year fluctuations in weather conditions and wildfire emissions.
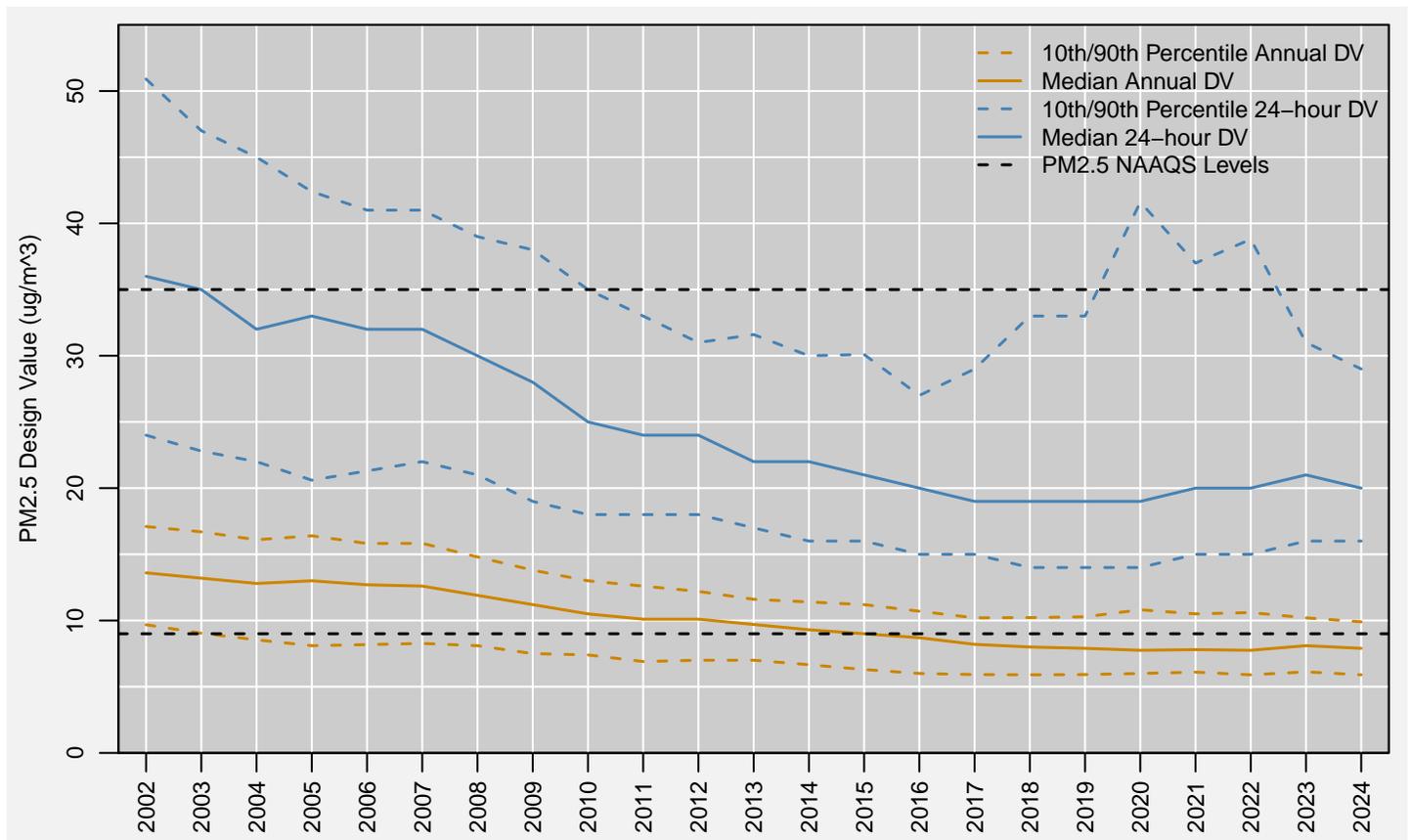

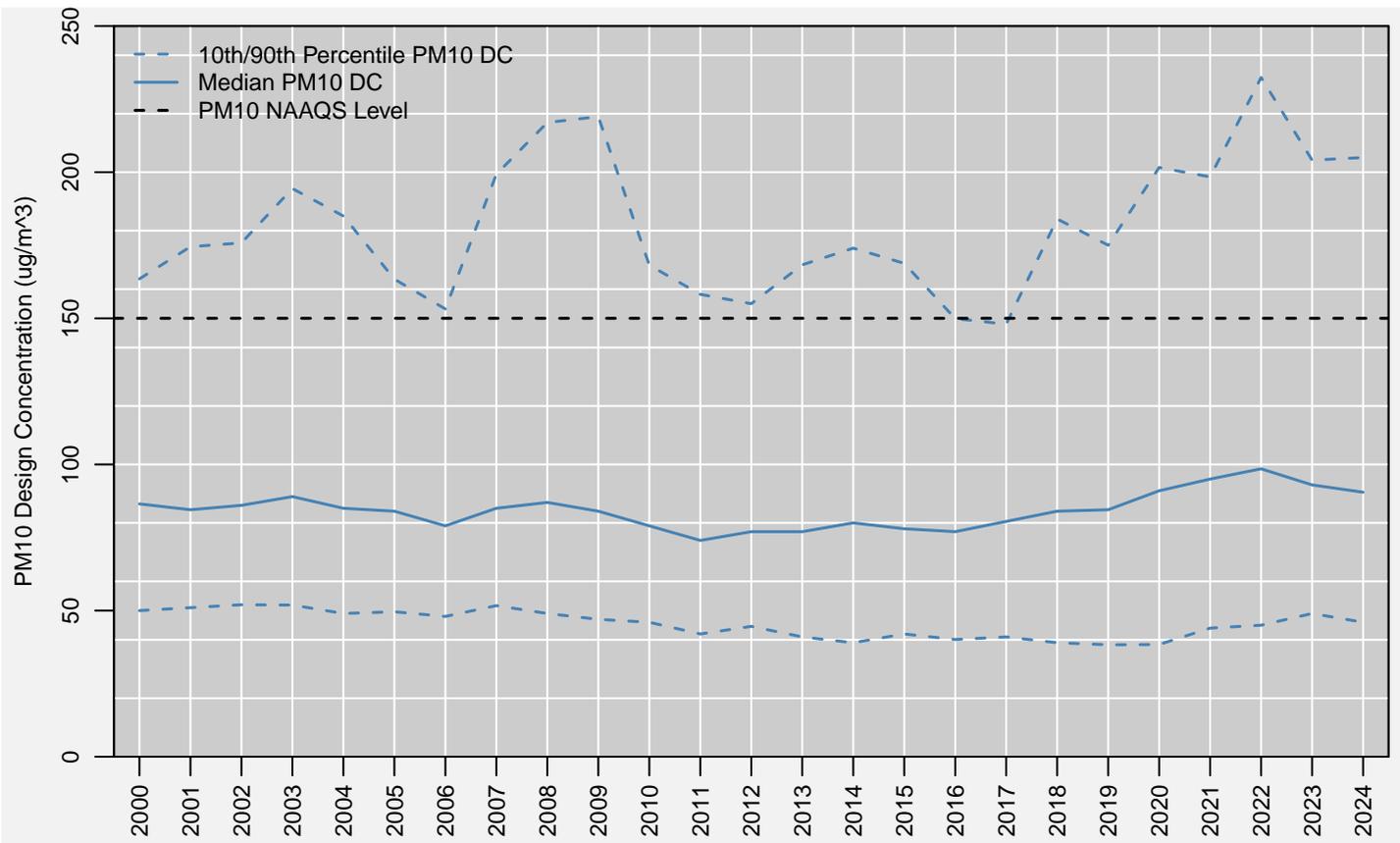**Figure 21:** National trend in $PM_{2.5}$ design values in $\mu g/m^3$, 2002 to 2024. **Source:** AQS.

Figure 22: National trend in 24-hour PM_{10} design concentrations in $\mu g/m^3$, 2000 to 2024. **Source:** AQS.

Figure 23 shows the national distribution of the annual average $PM_{2.5}$ concentrations along with the number of $PM_{2.5}$ monitoring sites reporting data in each year, while Figure 24 shows the national distribution of the annual 98th percentile 24-hour $PM_{2.5}$ concentrations reported in each year from 2000 to 2024 along with the number of $PM_{2.5}$ monitoring sites reporting data in each year.[11] The median of the annual average $PM_{2.5}$ concentrations decreased by 47%, from 13.1 $\mu g/m^3$ in 2000 to 6.9 $\mu g/m^3$ in 2024. Similarly, the median of the annual 98th percentile 24-hour $PM_{2.5}$ concentrations decreased by 48%, from 32.2 $\mu g/m^3$ in 2000 to 16.9 $\mu g/m^3$ in 2024. Both the annual average and 98th percentile 24-hour $PM_{2.5}$ concentrations decreased steadily from the early 2000s until 2016, and have fluctuated in recent years, especially in the upper tail of the distribution. These fluctuations are largely due to large-scale wildfire events that have occurred in recent years. The size of the $PM_{2.5}$ monitoring network increased rapidly following the establishment of a $PM_{2.5}$ NAAQS in 1997, and has been relatively stable at around 1,000 sites since 2000.[12]

Figure 25 shows the national distribution of the annual 2nd highest 24-hour PM_{10} concentrations reported in each year from 1990 to 2024 along with the number of PM_{10} monitoring sites reporting data in each year.[13] The median of the annual 2nd highest 24-hour PM_{10} concentration increased by 2%, from 61 $\mu g/m^3$ in 1990 to 62 $\mu g/m^3$ in 2024. Note, however, that many sites in the western U.S. were influenced by smoke from wildfires in 2020 and 2021, many sites in the eastern U.S. were impacted by Canadian wildfire smoke in 2023, and the median concentration in 2019 was only 49 $\mu g/m^3$. The PM_{10} monitoring network grew in size from its inception in the mid-1980's to a maximum size of around 1,600 sites in the mid-1990's. Following the establishment of a $PM_{2.5}$ NAAQS in 1997 along with new requirements for $PM_{2.5}$ monitoring, many PM_{10} sites were discontinued in 1998 and 1999. Over the past two decades, the PM_{10} monitoring network has slowly decreased in size over time as priorities have shifted toward $PM_{2.5}$ monitoring, and the geographic distribution of the PM_{10} network has shifted toward the western U.S., where higher concentrations are often measured due to the prevalence of wildfires and dust storms.

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[11]For this analysis, the annual average and 98th percentile 24-hour $PM_{2.5}$ concentrations were retrieved from AQS for all U.S. sites for years that had at least 75% annual data completeness.

[12]Some agencies are late in reporting and certifying their data in AQS, resulting in an apparent decrease in the number of sites in 2024 in Figures 23 through 25. It is expected that the number of sites with complete data in 2024 will increase in future versions of this document.

[13]For this analysis, the annual 2nd highest 24-hour PM_{10} concentrations were retrieved from AQS for all U.S. sites for years that had at least 50% annual data completeness.
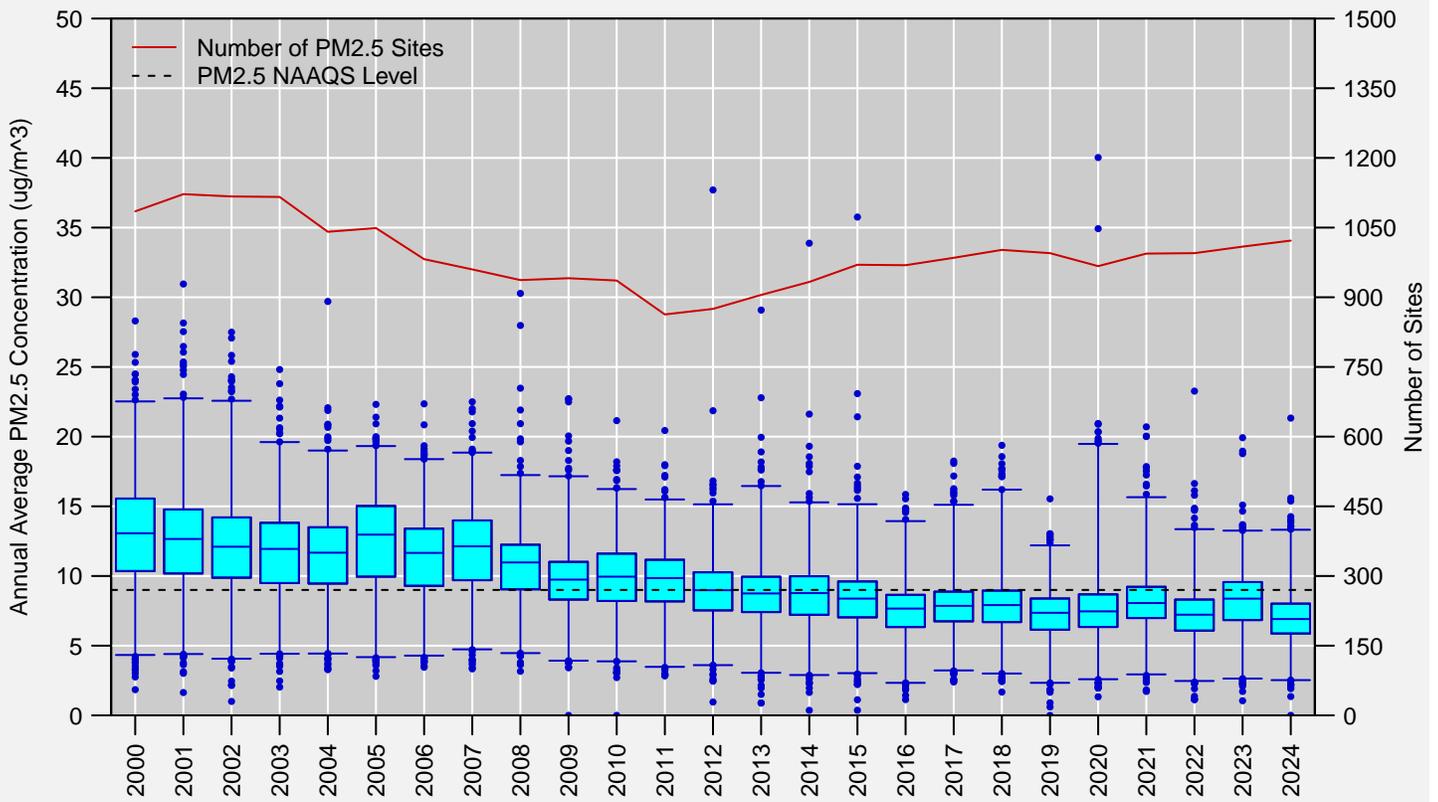
Figure 23: Distribution of annual average PM$_{2.5}$ concentrations measured at U.S. monitoring sites, 2000 to 2024. Boxes represent the median and interquartile range, whiskers extend to the 1st and 99th percentiles, and values outside this range are shown as circles. The red line shows the number of PM$_{2.5}$ monitoring sites reporting data to EPA in each year. **Source:** AQS.

Figure 24: Distribution of annual 98th percentile 24-hour PM$_{2.5}$ concentrations measured at U.S. monitoring sites, 2000 to 2024. Boxes represent the median and interquartile range, whiskers extend to the 1st and 99th percentiles, and values outside this range are shown as circles. The red line shows the number of PM$_{2.5}$ monitoring sites reporting data to EPA in each year. **Source:** AQS.
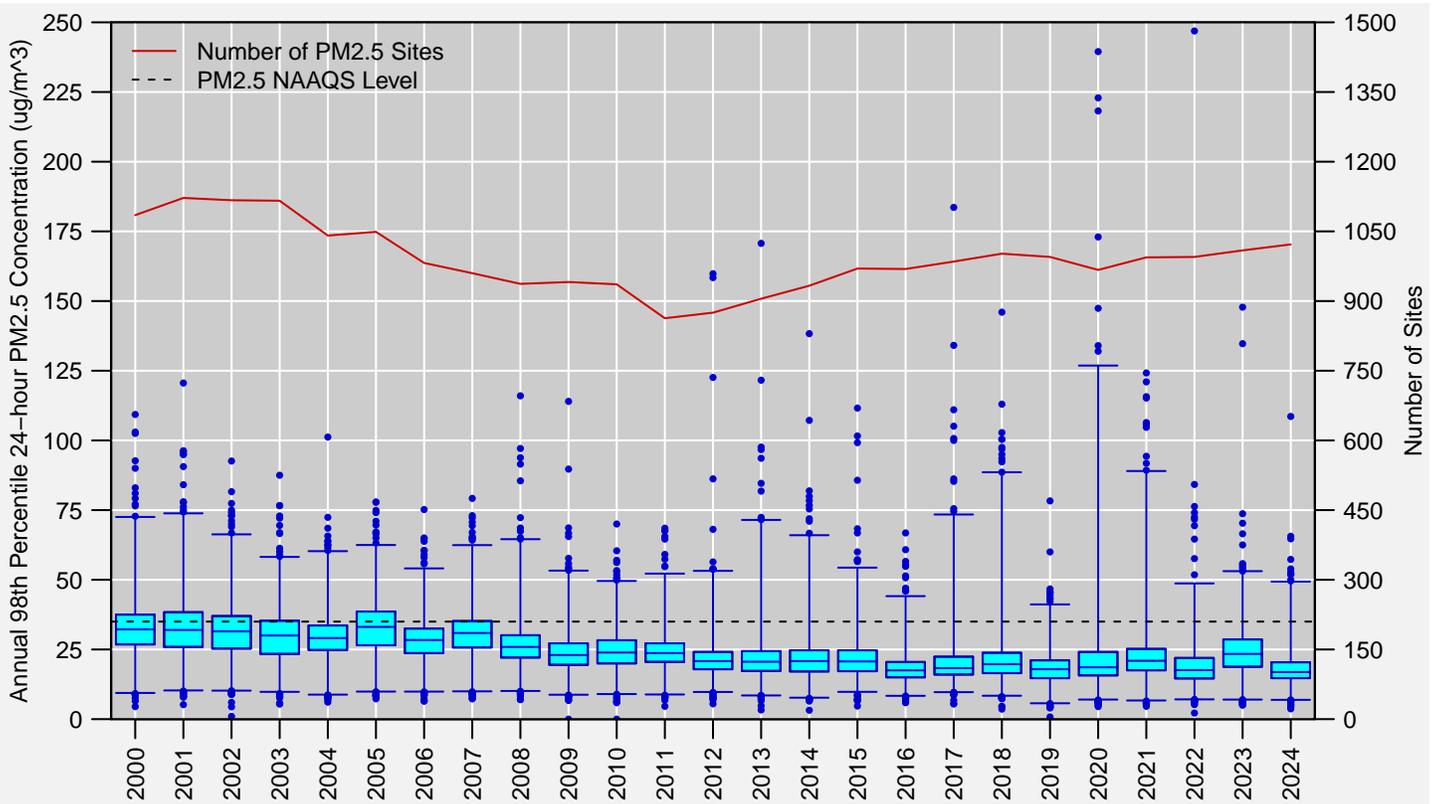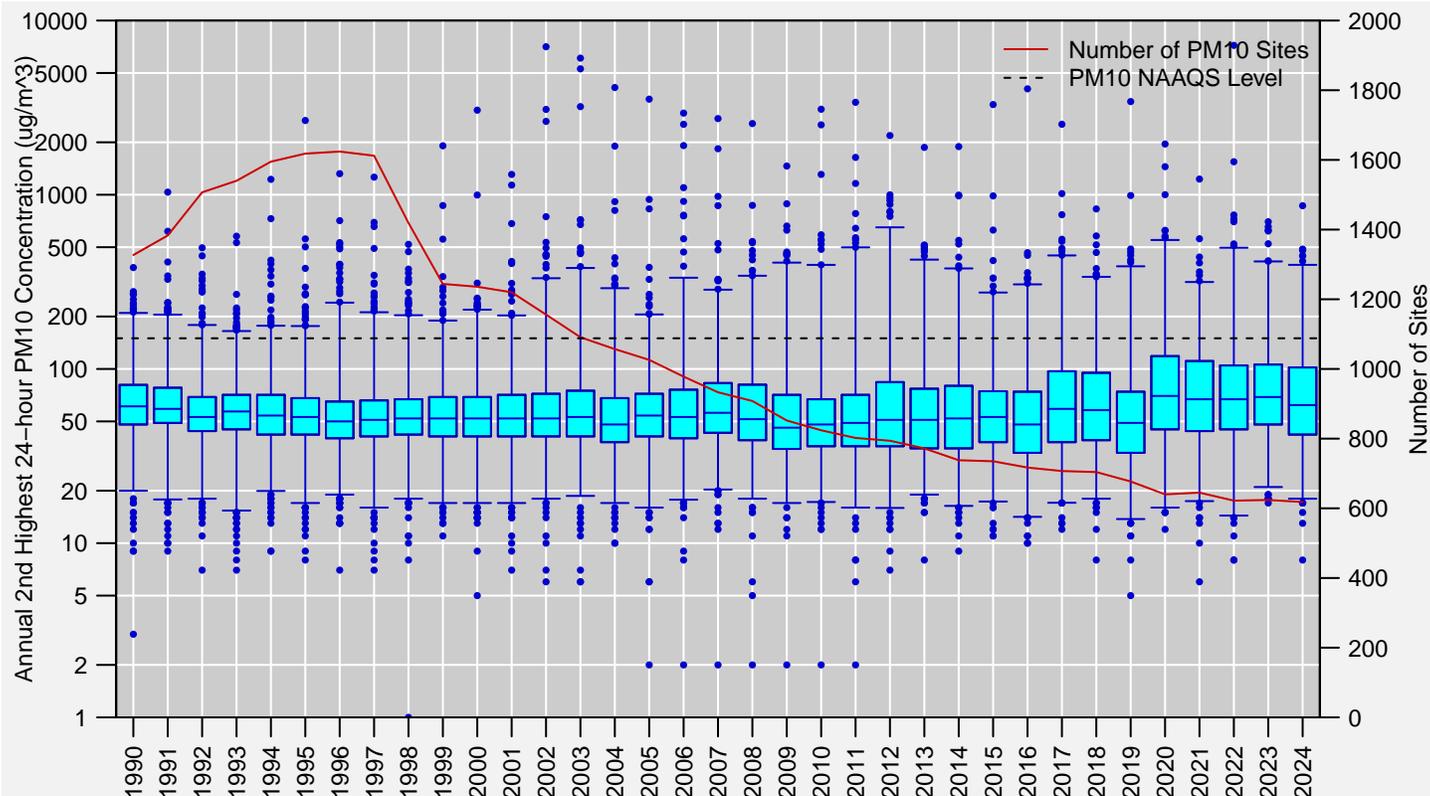
Figure 25: Distribution of annual 2nd highest 24-hour PM_{10} concentrations measured at U.S. monitoring sites, 1990 to 2024. Boxes represent the median and interquartile range, whiskers extend to the 1st and 99th percentiles, and values outside this range are shown as circles. The red line shows the number of PM_{10} monitoring sites reporting data to EPA in each year. **Source:** AQS.

    Table 4 presents summary statistics based on daily measurements of $PM_{2.5}$ species reported to AQS from 2022 to 2024. Sulfate and nitrate have opposite seasonal patterns, with sulfate typically having the highest concentrations during the summer months and nitrate typically having the highest concentrations during the winter months. EC has a relatively small contribution to total $PM_{2.5}$ mass and little seasonal pattern, while OC is the largest contributor to total $PM_{2.5}$ mass and has the highest concentrations during the summer, which is also peak wildfire season in the western U.S. On average, crustal material has roughly the same contribution to total $PM_{2.5}$ mass as sulfate and nitrate, with the highest concentrations occurring in the spring and summer months. Finally, sea salt is the smallest contributor to total $PM_{2.5}$ mass with very low concentrations typically measured away from coastal areas.

    Figure 26 shows a map with pie charts showing the major $PM_{2.5}$ species as a fraction of total $PM_{2.5}$ mass as measured at selected NCore, CSN, and IMPROVE sites during the 2022 to 2024 period. The six species shown are sulfate (SO_4), nitrate (NO_3), elemental carbon (EC), organic carbon (OC), crustal material, and sea salt. The pie charts are located at each monitoring site on the map. This figure portrays several aspects of regional variability in $PM_{2.5}$, for example, large portions of total $PM_{2.5}$ mass can be attributed to sulfate in the Appalachian region, nitrate in the upper Midwest, OC in the Pacific Northwest, crustal material in the southwest, and sea salt in coastal areas.

    Figure 27 shows the average concentrations for four $PM_{2.5}$ components (sulfate, nitrate, EC, and OC) based on data collected during the 2022 to 2024 period. From this figure it is apparent that sulfate concentrations are highest in the Ohio River valley and along the Gulf of Mexico, while nitrate concentrations are highest in the upper Midwest, along the northeast urban corridor, and in parts of California. EC concentrations tend to be higher near urban areas, especially those with large industrial sources, while OC tends to be more concentrated in rural areas, with impacts from prescribed burns, wildfires, and residential wood smoke.

    Figure 28 shows trends in annual average concentrations for sulfate, nitrate, EC, and OC based on sites that collected data for at least 15 out of 19 years from 2006 to 2024.[14] Broad national reductions in SO_2 emissions have resulted in significant reductions in sulfate concentrations nationally and especially in the eastern U.S. Similarly, reductions in NO_X emissions have resulted in significant decreasing trends in nitrate concentrations in most of the U.S., especially in areas where nitrate concentrations were historically highest. EC and OC concentrations were more variable, with most sites showing no clear trend.

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[14]Although $PM_{2.5}$ speciation monitoring has been conducted since 2000, the trends in Figure 28 begin in 2006 to avoid excluding CSN sites, which experienced a change in EC and OC sampling methods between 2007 and 2010.

Table 4. National distribution of PM$_{2.5}$ species concentrations in $\mu g/m^3$ by quarter based on monitoring data from 2022 to 2024.[9] **Source:** AQS.

species	quarter	N.sites	N.obs	mean	SD	min	p1	p5	p10	p25	p50	p75	p90	p95	p98	p99	max	max.site
SO4	all	301	85,907	0.65	0.60	-0.03	0.03	0.09	0.14	0.27	0.51	0.86	1.30	1.63	2.16	2.66	26.39	530530029
SO4	1st quarter	299	21,563	0.57	0.58	-0.01	0.02	0.06	0.10	0.20	0.43	0.77	1.16	1.49	2.05	2.60	22.24	020900035
SO4	2nd quarter	297	21,481	0.73	0.61	-0.03	0.06	0.14	0.20	0.34	0.57	0.95	1.41	1.77	2.37	2.96	13.31	483550034
SO4	3rd quarter	297	21,778	0.77	0.66	-0.01	0.08	0.18	0.24	0.37	0.62	1.01	1.45	1.78	2.27	2.75	26.39	530530029
SO4	4th quarter	295	21,085	0.52	0.47	-0.02	0.02	0.07	0.11	0.20	0.40	0.70	1.06	1.33	1.76	2.19	9.11	020900034
NO3	all	298	85,545	0.57	1.09	-0.04	0.01	0.02	0.04	0.09	0.23	0.56	1.40	2.28	3.69	5.03	35.93	490050007
NO3	1st quarter	296	21,460	0.90	1.41	-0.02	0.00	0.02	0.04	0.12	0.41	1.11	2.37	3.47	5.05	6.53	35.93	490050007
NO3	2nd quarter	294	21,392	0.39	0.60	-0.02	0.01	0.04	0.06	0.11	0.23	0.44	0.82	1.28	2.09	2.92	12.84	060371103
NO3	3rd quarter	295	21,694	0.26	0.40	-0.04	0.01	0.03	0.04	0.08	0.15	0.28	0.52	0.80	1.35	1.85	11.12	060712002
NO3	4th quarter	293	20,999	0.72	1.43	-0.02	0.01	0.02	0.03	0.08	0.26	0.77	1.85	2.86	4.52	6.46	29.32	060658001
EC	all	289	82,694	0.36	0.57	-0.01	0.00	0.02	0.03	0.08	0.20	0.45	0.86	1.23	1.80	2.33	43.76	040059000
EC	1st quarter	286	20,649	0.35	0.53	0.00	0.00	0.01	0.02	0.06	0.17	0.45	0.89	1.28	1.88	2.50	10.83	020900035
EC	2nd quarter	285	20,577	0.31	0.47	-0.01	0.00	0.02	0.03	0.07	0.17	0.38	0.72	1.02	1.46	1.92	22.07	460710001
EC	3rd quarter	286	21,039	0.36	0.49	-0.01	0.00	0.03	0.05	0.11	0.23	0.46	0.78	1.07	1.49	1.89	28.55	060893003
EC	4th quarter	282	20,289	0.43	0.74	-0.01	0.00	0.02	0.03	0.08	0.21	0.54	1.06	1.52	2.14	2.74	43.76	040059000
OC	all	289	82,904	1.47	2.91	-0.14	0.02	0.11	0.19	0.44	0.96	1.82	2.98	4.02	5.97	8.49	428.15	060893003
OC	1st quarter	287	20,752	1.04	1.48	-0.09	0.01	0.07	0.12	0.26	0.64	1.34	2.32	3.15	4.71	5.97	50.74	040239000
OC	2nd quarter	285	20,625	1.46	2.46	-0.14	0.04	0.14	0.23	0.45	0.92	1.73	2.85	3.85	6.11	9.26	52.49	020680003
OC	3rd quarter	286	21,085	1.99	3.22	-0.08	0.08	0.30	0.45	0.80	1.42	2.31	3.53	4.79	7.86	12.50	224.97	060893003
OC	4th quarter	282	20,324	1.39	3.85	-0.06	0.02	0.10	0.17	0.39	0.86	1.74	2.96	3.98	5.56	7.40	428.15	060893003
Crustal	all	302	84,730	0.65	1.13	-0.12	0.00	0.02	0.05	0.14	0.34	0.73	1.44	2.23	3.65	5.07	67.13	421255001
Crustal	1st quarter	300	21,228	0.41	0.75	-0.12	-0.00	0.01	0.03	0.09	0.22	0.45	0.89	1.34	2.21	3.10	21.65	350059000
Crustal	2nd quarter	298	21,085	0.92	1.47	-0.09	0.02	0.07	0.12	0.25	0.52	1.02	1.98	3.04	4.80	6.55	67.13	421255001
Crustal	3rd quarter	297	21,417	0.78	1.25	-0.12	0.01	0.04	0.09	0.21	0.44	0.89	1.68	2.51	4.20	6.00	40.47	060290014
Crustal	4th quarter	296	20,982	0.50	0.80	-0.11	-0.00	0.02	0.03	0.10	0.25	0.57	1.17	1.83	2.91	3.80	16.94	780200001
Sea_Salt	all	302	86,633	0.18	0.50	-0.02	0.00	0.00	0.01	0.01	0.04	0.14	0.42	0.79	1.51	2.20	38.97	040239000
Sea_Salt	1st quarter	300	21,681	0.21	0.54	-0.01	0.00	0.00	0.01	0.02	0.06	0.20	0.51	0.90	1.63	2.37	38.97	040239000
Sea_Salt	2nd quarter	298	21,596	0.20	0.53	-0.00	0.00	0.00	0.01	0.02	0.05	0.14	0.45	0.89	1.67	2.39	12.22	550790010
Sea_Salt	3rd quarter	298	21,923	0.14	0.49	-0.02	0.00	0.00	0.01	0.01	0.03	0.09	0.28	0.59	1.23	1.97	21.78	120573002
Sea_Salt	4th quarter	296	21,433	0.17	0.44	-0.00	0.00	0.00	0.00	0.01	0.04	0.15	0.41	0.75	1.44	2.10	15.03	371190041

N.sites = number of sites; N.obs = number of observations; SD = standard deviation; min = minimum; p1, p5, p10, p25, p50, p90, p95, p98, p99 = 1st, 5th, 10th, 25th, 50th, 90th, 95th, 98th, 99th percentiles; max = maximum; max.site = AQS ID number for the monitoring site corresponding to the observation in the max column. 1st quarter = January/February/March; 2nd quarter = April/May/June; 3rd quarter = July/August/September; 4th quarter = October/November/December.
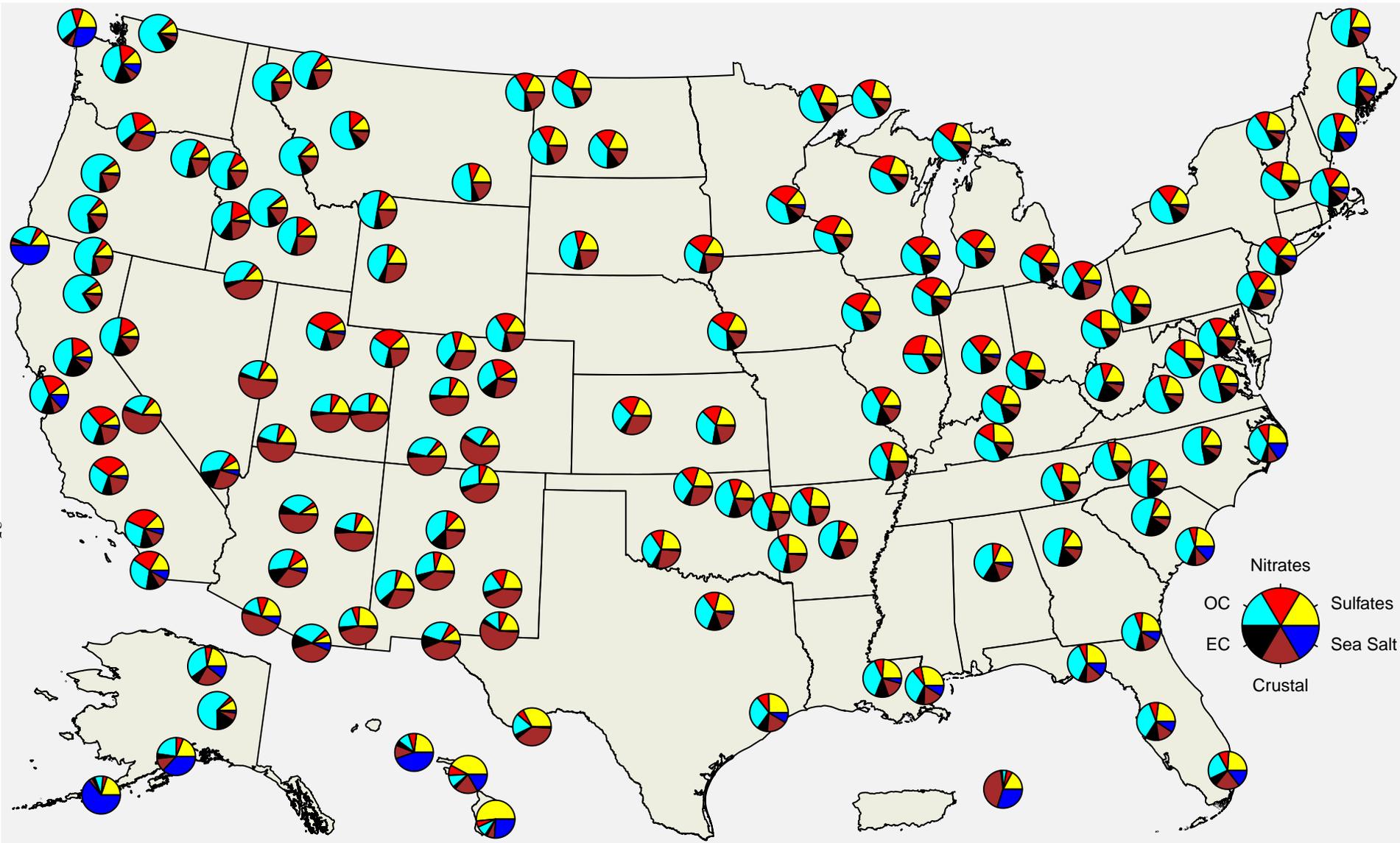
Figure 26: Map showing pie charts of PM$_{2.5}$ component species at selected U.S. monitoring sites based on 2022-2024 data. **Source:** AQS.
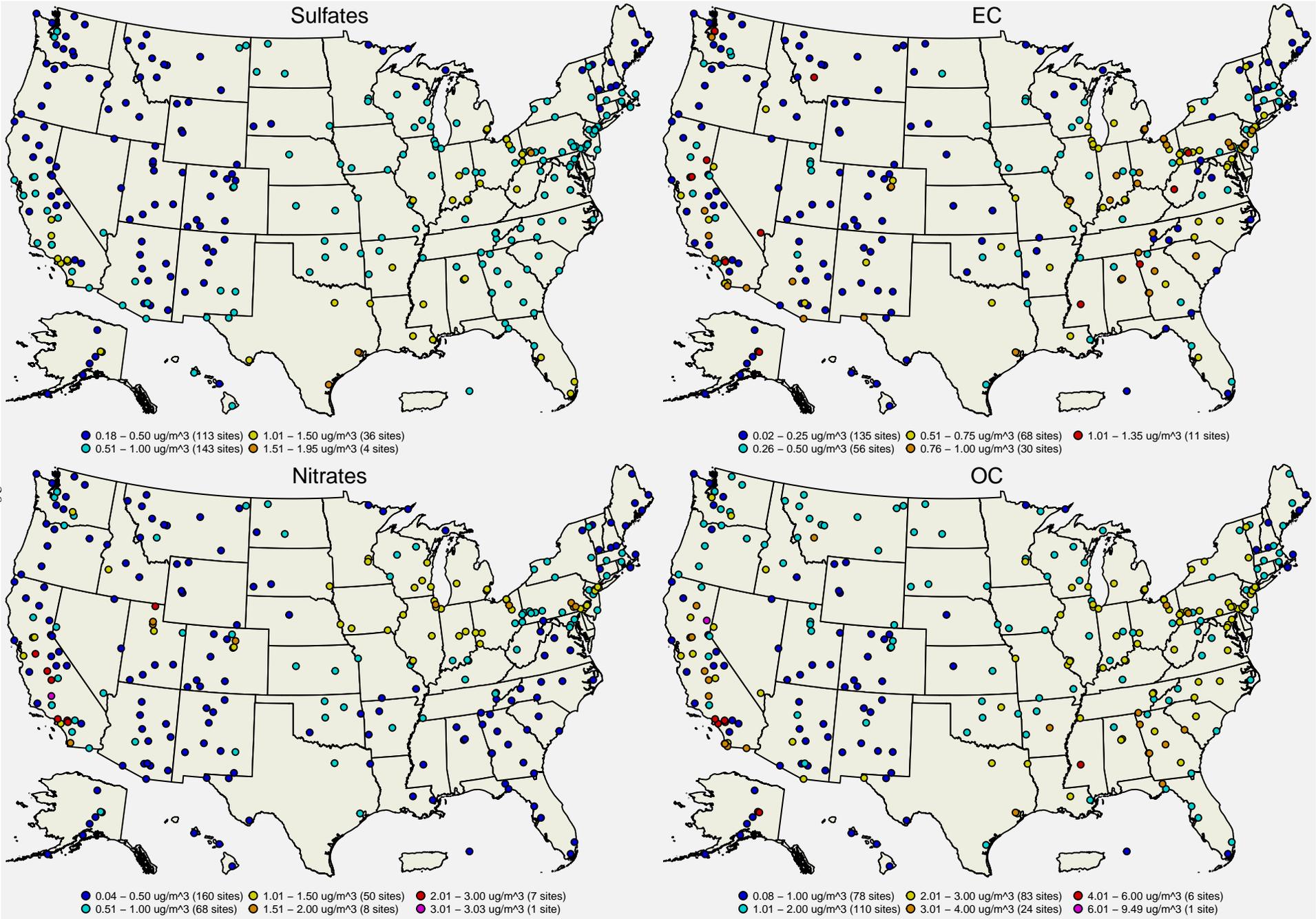
Figure 27: Average concentrations for sulfate (top left), nitrate (bottom left), elemental carbon (top right), and organic carbon (bottom right) at U.S. monitoring sites based on 2022-2024 data. **Source:** AQS.
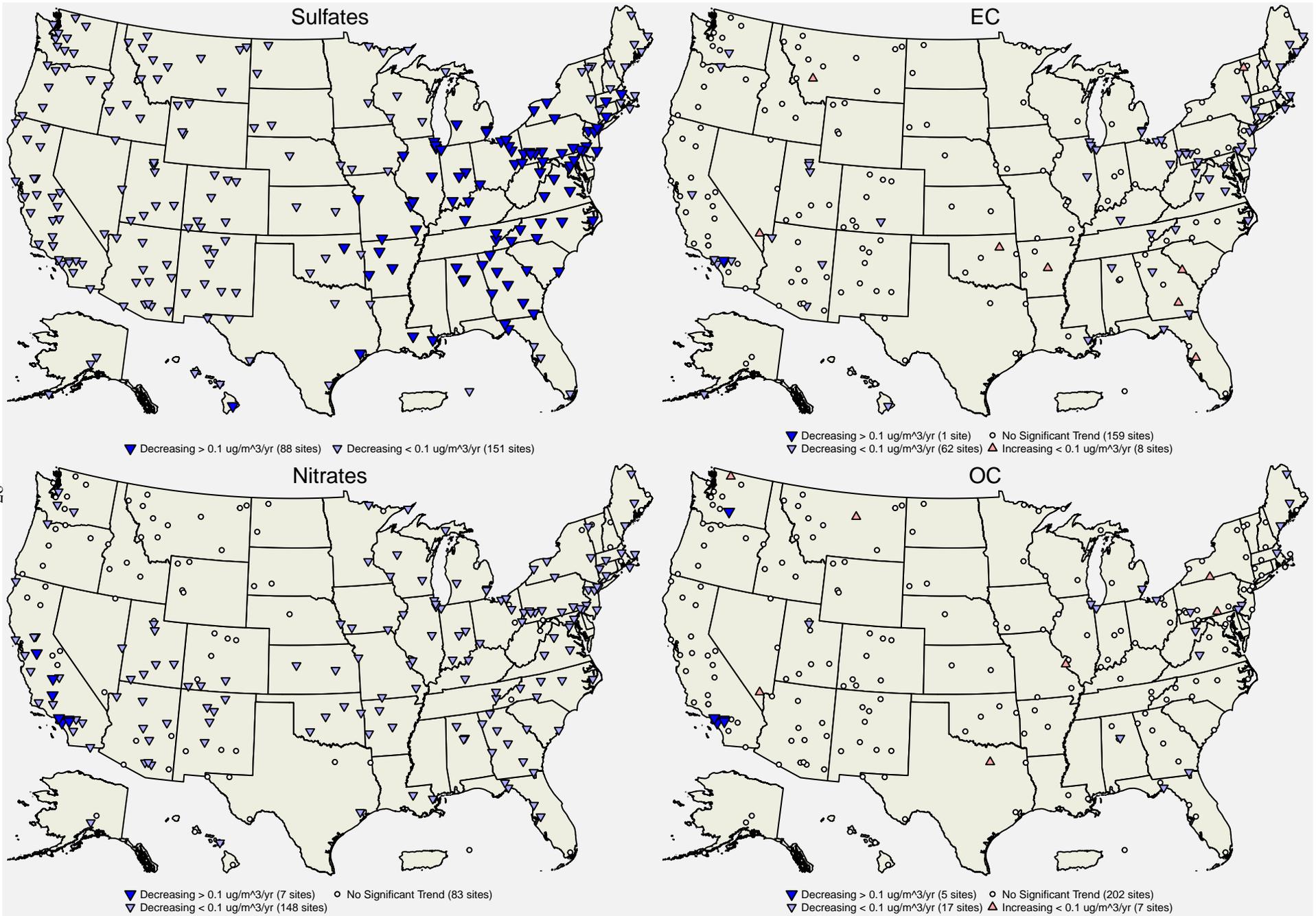
Figure 28: Site-level trends in annual average concentrations for sulfate (top left), nitrate (bottom left), elemental carbon (top right), and organic carbon (bottom right) based on data from 2006 through 2024. **Source:** AQS, trends computed using R statistical software.

References

U.S. EPA. Integrated Science Assessment for Particulate Matter (Final Report, December 2019). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-19/188, 2019.

U.S. EPA. Policy Assessment for the Review of the PM NAAQS (Final Report, January 2020). U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA-452/R-20-002, 2020.

Additional Resources

- Particulate Matter (PM) Pollution

- Particulate Matter (PM) Air Quality Standards

- National Emissions Inventory (NEI)

- Ambient Monitoring Technology Information Center (AMTIC)

- Air Quality Design Values

- National Air Quality: Status and Trends of Key Air Pollutants

- Air Data: Air Quality Data Collected at Outdoor Monitors Across the U.S.