State of the Science FACT SHEET

Air Quality

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

Air pollution causes significant harm to human health, the economy, and ecosystems. The US spends tens of billions of dollars each year to reduce air pollution to protect public health and the environment. For over 50 years, industrial nations have reduced harmful air pollutants generated primarily by power plants, transportation, industry, and agriculture. Large improvements have occurred in US air quality over the last few decades. However, poor air quality still contributes to approximately 100,000 premature deaths each year from cardiovascular and respiratory diseases across the Nation. NOAA provides air quality predictions and critical research and observations that support alerts and the development of effective policies and strategies for air quality management.

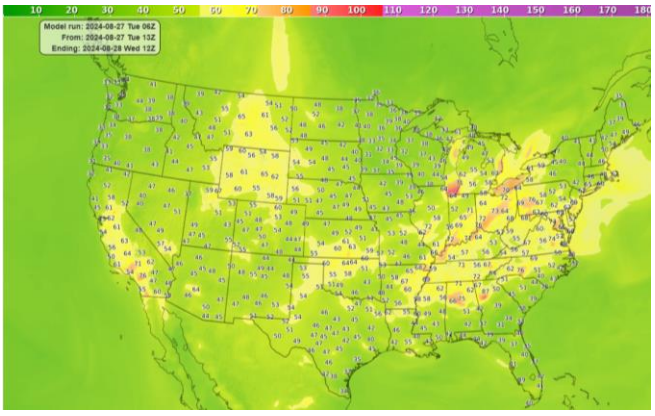
What is Air Quality?

Air quality is determined by the quantities and types of gaseous and particulate pollutants in the air we breathe. Pollutants are both directly emitted and formed by chemical reactions in the atmosphere. Critical pollutants affecting US air quality are:

Ground-level Ozone: A gas chemically created from precursor emissions, including nitrogen oxides, carbon monoxide, methane, and volatile organic compounds, that react in the presence of sunlight. Ground-level ozone is a major constituent of smog and has harmful effects on human health and ecosystems.

Fine particulate matter ($PM_{2.5}$): Small particles (with an effective diameter of 2.5 micrometers or less) emitted into the air (e.g., soot from combustion sources) or formed by chemical reactions of other gaseous pollutants such a sulfur, nitrogen, and organic compounds (e.g., from fossil fuel burning, volcanic eruptions, and wildland fires). Because health effects are associated primarily with small particles, $PM_{2.5}$ is a research and operational forecast focus of NOAA.

Other air pollutants: Compounds containing mercury, sulfur, or nitrogen, primarily emitted from fossil fuel combustion, can also be pollutants that impact human and environmental health. Additional sources of nitrogen-containing pollutants can originate from agricultural activities, such as fertilizer application and animal waste.

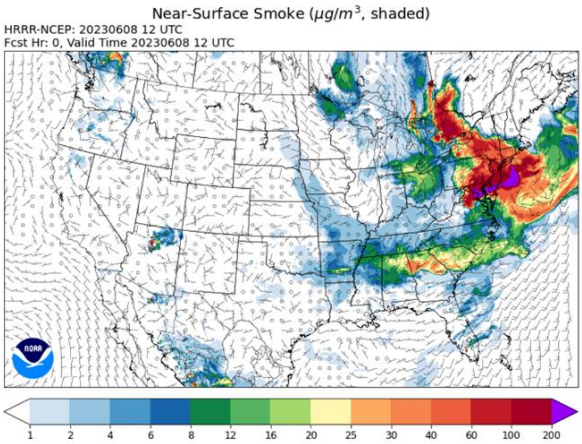


Ground-level ozone concentration (parts per billion) predicted by the NOAA/NWS Unified Forecast System Air Quality Model. The quantity shown is the highest 8-hour average in the 24 hours ending at 7 am EDT, August 28, 2024. [https://airquality.weather.gov]

How Does Poor Air Quality Affect the Nation?

Air pollution affects us through multiple pathways. People inhale pollutants. Crops and forests are also exposed to air pollution. Some air pollutants make their way into the aquatic and terrestrial food chains and ultimately into humans. Air pollutants have the following impacts:

- Ground-level ozone and $PM_{2.5}$ cause respiratory and cardiovascular problems. Almost 46% of US citizens live in areas with unhealthy levels of either ozone or $PM_{2.5}$, and studies have indicated that up to 50% of air-quality-related premature mortality results from pollution emitted far upwind. Particulate matter and smog reduce visibility, posing risks to aviation and highway safety and limiting vistas in national parks or other protected areas, thereby impacting tourism.
- Ground-level ozone damages crops and forests, causing billions of dollars in losses annually.
- Volatile organic compounds (VOCs) including methane are precursors for ozone formation and are emitted from motor vehicles, oil and gas extraction activities, volcanic eruptions, and wildfires, resulting in episodes of high summer and winter ozone production and increased climate forcing.
- Acidic and nitrogen-containing compounds deposit onto watersheds and move into lakes, rivers, and coastal waters. These compounds degrade water quality, ecosystem health, and reduce commercial and recreational use of these areas.
- Many air pollutants, including ground-level ozone and $PM_{2.5}$ contribute to, and are influenced by, climate change.



Smoke forecast by NOAA's operational HRRR-Smoke model during the severe air pollution event on the East Coast caused by smoke transport from wildfires in Canada, June 8, 2023. [https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/]

Improving Air Quality: What Are NOAA's Roles and the Benefits to the Nation?

Since understanding and predicting the behavior of the atmosphere is a primary part of NOAA's mission, its research and operations build the foundation needed by decision makers

to maintain and improve the Nation's air quality. In building this foundation, NOAA collaborates and interacts with other governmental agencies, academia and the private sector.

Role: Deliver operational air quality predictions to the public and air quality management agencies as the basis for health warnings and individual actions to limit exposure to poor air quality. Deliver both operational satellite-derived and hyper-local urban-scale particulate and trace gas products for air quality monitoring and forecasts. Improve the accuracy of air quality predictions through research and development.

Benefit: The public can adjust their daily activities to limit exposure to poor air quality, which contributes to approximately 100,000 premature deaths each year. People with access to air quality forecasts can reduce their exposure to pollutants as documented, for example, in reductions of hospital admissions for asthma.

Role: Provide decision makers with the scientific understanding of how physical and chemical atmospheric processes contribute to poor air quality.

Benefit: Federal and state agencies can develop and implement policies that are most effective in improving air quality. For example, studies focused on 2020/2021 measurements assessed how air pollution changed during the COVID-19 pandemic, when emissions from transportation and industrial sources were greatly curtailed during the initial lockdown. This information will help the regulatory agencies better anticipate the impacts that future emission controls will have on air quality.

Role: Quantify trends and variability in air quality and transport and deposition of pollutants.

Benefit: Air quality decision makers can use NOAA data and tools to assess whether policies and regulatory actions have achieved the desired outcome or if new approaches are needed to protect public health and the environment.

Role: Provide satellite observed fire hot spot locations and trace gas and particulate emissions based on satellite fire observations.

Benefit: These observational constraints can improve air quality predictions of ozone and $PM_{2.5}$ by regional and global models.

Role: Deliver modernized volcanic ash information and modernized science support for federal partners, as outlined in 43 USC §31k. National Volcano Early Warning and Monitoring System.

Benefit: USGS can make use of modernized NOAA data and tools to fully meet their congressional mandate for a modernized volcanic early warning and monitoring system. The public benefits from improved warnings and lead times related to volcanic events.

What Are the Priorities for NOAA Research?

NOAA's research on air pollution advances scientific understanding of the sources of pollutants and their transport and chemical transformations in the atmosphere, leading to more effective air quality management, better weather forecasts and the reduction of uncertainties in climate predictions.

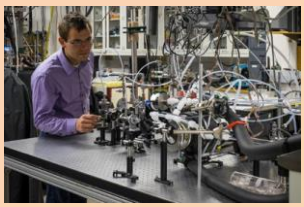
NOAA's research priorities include:

- Improving understanding of the processes that control $PM_{2.5}$ abundance and composition.
- Improving the accuracy of air quality predictions, especially for $PM_{2.5}$ and ozone, out to several days.
- Using observations to evaluate and improve the emissions inventories that are the foundation for air quality predictions.
- Improving near-real-time emissions products derived from satellite data, especially for intermittent emission sources, such as wildfires and dust storms.
- Helping guide the design of future satellite missions and improving air quality products from existing satellite sensors.
- Improving the understanding of regional and intercontinental transport of air pollution on US air quality.
- Improving predictions of inequitable impacts of poor air quality to human populations in underserved communities.
- Developing a comprehensive understanding of connections between air quality and climate and how these interactions affect future air quality and climate projections.
- Investigating the role of wildland fires on air quality, weather, and climate.
- Improving weather, sub-seasonal to seasonal, and climate model predictions by enhancing the representation of small particles in the atmosphere and their impacts on solar radiation, clouds, and precipitation.
- Development of probabilistic atmospheric composition guidance and exploration of use of Machine Learning technologies to provide forecasts more efficiently and quickly.

NOAA's Research and Development Capabilities

NOAA employs a comprehensive set of capabilities to advance understanding of air quality.

Laboratory investigations characterize and quantify fundamental properties of atmospheric composition and chemistry.



Observational studies use advanced instrumentation-deployed on the ground, on-board aircraft, ships, and satellites – to gather data on atmospheric composition and processes.

Air quality model improvements lead to more accurate and reliable predictions.

Participating NOAA Organizations

National Weather Service (NWS) / Environmental Modeling Center (EMC) – Develops and transitions regional air quality and global aerosol and atmospheric composition models into NWS operations to produce numerical forecast guidance aimed at protecting life and property. Collaborates with OAR labs, NESDIS, and the community to integrate research advancements in air quality modeling and new observations into NWS operations.
https://www.emc.ncep.noaa.gov/

Office of Oceanic and Atmospheric Research (OAR) / Air Resources Laboratory – Improves operational air quality

forecast models through emissions science, model updates, and improved representation of surface-atmosphere exchange processes; develops and uses advanced observation techniques and models. arl.noaa.gov

OAR/Global Systems Laboratory – Develops and improves regional and global prediction models for air quality, pollutant transport, fire weather, and the coupling between air quality and weather. gsl.noaa.gov

OAR/Chemical Science Laboratory – Investigates chemical processes that transform air pollutants, innovates emissions quantification and modeling approaches, and develops fast-response, compound-specific air quality sensors. csl.noaa.gov

OAR/Global Monitoring Laboratory – Conducts worldwide long-term monitoring of air pollutants. gml.noaa.gov

OAR/Geophysical Fluid Dynamics Laboratory – Advances understanding of the interactions and feedbacks between climate and atmospheric composition, provides comprehensive projections of future atmospheric composition and air quality, and investigates the influence of long-range transport and other background sources on US air quality. gfdl.noaa.gov

OAR/Pacific Marine Environmental Laboratory – Conducts research on particulate processes and their contribution to air quality in coastal areas. pmel.noaa.gov

OAR/Climate Program Office – Supports research on process-level understanding of the climate system through observation, modeling, analysis, and field studies to improve models and predictions. cpo.noaa.gov

OAR/Weather Program Office – Supports air quality research and forecasting for $PM_{2.5}$ and ozone predictions. wpo.noaa.gov

National Environmental Satellite, Data, and Information Service (NESDIS) / Center for Satellite Applications and Research (STAR) – Transitions satellite observations of air quality from scientific research and development into routine operations, and provides state-of-the-art data, products, and services to decision makers. star.nesdis.noaa.gov