Air Quality Data When You Need It

Incorporating Satellite Data Updates into AirNow

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An overview describing recent updates to the U.S. Environmental Protection Agency's AirNow system, integrating the use of fused air quality data products that will ultimately allow decision-makers and the public to make informed choices to protect health and better understand their local air quality.

Air pollution is a major health issue, contributing to heart and lung diseases and premature death. One of the most harmful pollutants is fine particulate matter ($PM_{2.5}$), which contributes to between 47,787 to 131,000 premature deaths in the United States annually.[1,2] $PM_{2.5}$ primarily comes from combustion sources, including vehicles, industries, power plants, and fires. One primary source of particulate pollution is smoke from fires (including wildland fires and agricultural burning), with estimated contributions ranging from 25–43% of total U.S. $PM_{2.5}$ emissions.[3–5]

In many ways, air quality has improved since the passage of the U.S. Clean Air Act.[6] However, in the western United States, the wildfire season has lengthened in recent years, with the maximum annual wildfire incidence in 2020 of more than 80,000 wildfires, eight times greater than the incidence in 2001.[7] This trend has caused periods of poor air quality to worsen in fire-prone areas.[8] Though these major wildfires often originate in the western United States, the smoke plumes can stretch across the continent, as visualized by the true-color satellite image in Figure 1, and are linked to numerous health impacts.[9] To improve the accessibility of health-relevant smoke information, our collaborative team has updated a popular tool to make pollution information more localized and timely to the public.

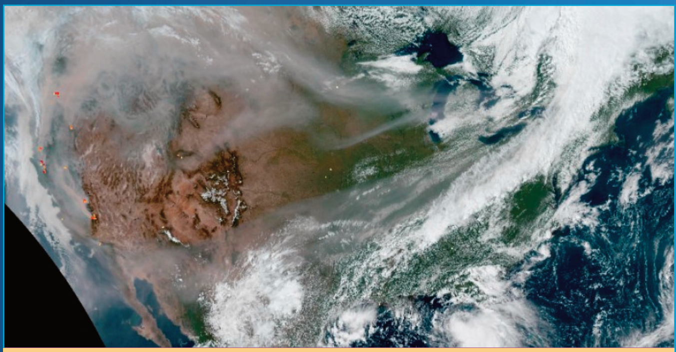

Figure 1. Visualization of wildfire smoke (gray) spreading over the contiguous United States from September 13, 2020, based on the true-color image of Geostationary Operational Environmental Satellites (GOES) East.
Note: Red dots indicate fire locations, as detected by GOES-East.

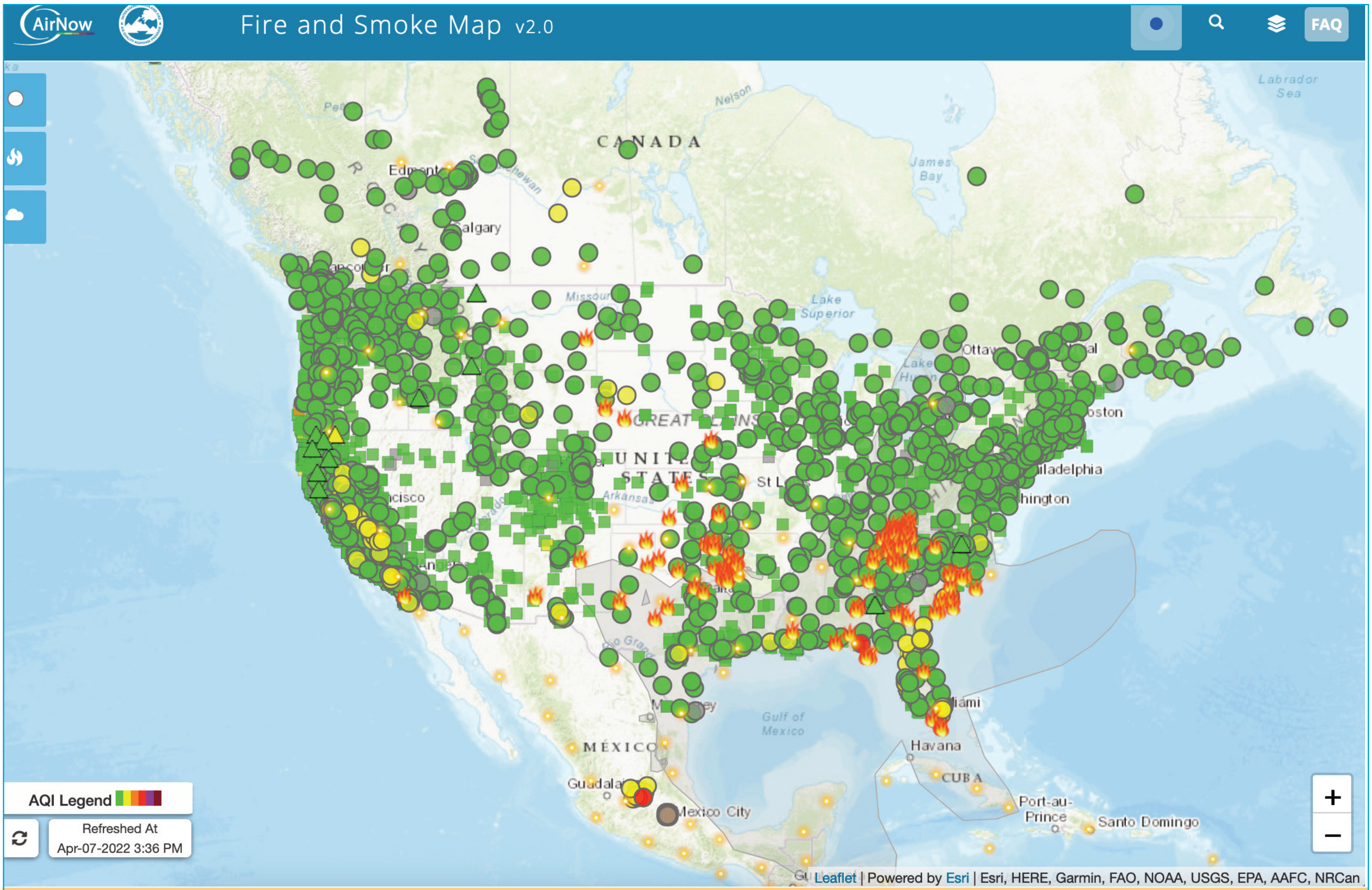

Figure 2. Screenshot of archived data from April 7, 2022, from the Environmental Protection Agency (EPA) AirNow website Fire and Smoke Map, showing $PM_{2.5}$ monitors in circles and estimated $PM_{2.5}$ contours.
Note: Colors indicate the scale on the Air Quality Index (AQI), with green representing good air quality of AQI 0–50, yellow representing moderate pollution (51–100), orange representing a range unhealthy for sensitive groups (101–150), red representing a level unhealthy for the general public (150–200), and ranges above 200 are represented by purple. The gray shaded area in the Southeast United States represents a smoke plume.

The AirNow System

Accurate and timely air quality information is critical to public health. Among the most widely used public-facing sources of information in the U.S. is the Environmental Protection Agency's (EPA) AirNow system (**https://www.airnow.gov/**). AirNow provides easy-to-understand, local air quality information across the United States and filtering for selected locations worldwide. Users can search by city, state, or postal ZIP code via the website or phone app to find their local U.S. Air Quality Index (AQI). This index runs from 0–500, where higher levels indicate greater ambient air pollution concentration (see Figure 2). The values are divided into six categories, to quickly indicate the relative level of concern, particularly for sensitive groups. In 2021, 85% of the total AirNow pageviews (59.6 million) occurred during the four most active fire months (July 1–October 31), with more than 1.5 million page views on a single day.

This long-standing EPA project has benefited from numerous improvements and upgrades over the years. Primarily, AirNow relies on ground-based monitors, with recent additions including data from low-cost sensors and satellite-detected fire locations" (Fig. 2). Also shown in Fig 2 are shaded areas ("smoke polygons") which are satellite-model derived areas representing areas of likely smoke. These smoke plumes are generated by the National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System that uses all available satellites to generate daily smoke maps by human analysts.

For AirNow, ground-based continuous monitors provide the highest accuracy in local regions, but there are a limited number of monitors, which can be expensive to build and maintain. For example, on July 15, 2021, there were 1,079 sites that reported data to AirNow; of those, 738 used Federal Reference or Equivalent Methods in the United States. Ground-based monitoring can be further supplemented with low-cost sensors. The less expensive PurpleAir sensor's data have recently been incorporated into AirNow, though the data requires corrections for biases and detection of potentially malfunctioning sensors.[10,11] To fill the data gap in air quality monitoring networks, EPA has investigated the use of satellite data to complement ground-based monitors, including through the National Aeronautics and Space Administration NASA-funded AirNow Satellite Data Processing project.[12,13] Satellites can improve spatial coverage, especially useful where ground-based monitors and sensors may be less dense. Satellite observations also provide a unique bird's-eye view of entire continental regions, which can help monitor pollution transport from region to region, specifically during air quality events such as fires and dust storms.

The HAQAST Project

In the new project funded by the NASA Health and Air Quality Applied Science Team (HAQAST), AirNow is again being expanded, this time with geostationary satellite data, which will improve spatial and temporal coverage. The Tiger Team project is a collaborative effort led by NASA HAQAST with EPA and NOAA. This project incorporates data from NOAA's Geostationary Operational Environmental Satellites (GOES), specifically the GOES-East (GOES-16) and GOES-West (GOES-17/18) satellites, which are located at the equator and more closely observe eastern and western United States, respectively. These new generation GOES satellites provide observations of atmospheric aerosols with an interval of 5 minutes to 10 minutes, which is not possible with the traditional and more well-known sensors in low Earth orbits. Examples of a merged GOES data product can be seen in Figure 3, where the map is colored based on EPA AQI. This project is assessing within-day variability in $PM_{2.5}$ through leveraging data from both GOES satellites.

Data Gaps in Alaska

Additionally, the HAQAST project will address challenges related to Alaska, the largest state in the United States. Alaska has fewer ground-based monitors than the lower 48, and lacks geostationary satellite monitoring, yet smoke from wildfires is a major public health and air quality issue. To address this, data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensors onboard the Terra and Aqua satellites, along with Visible Infrared Imaging Radiometer Suite (VIIRS) instruments onboard the Suomi National Polar-orbiting Partnership (SNPP) and NOAA-20 satellites will be used to help fill data gaps in Alaska.

Data Fusion Challenges

Incorporating new data for this major update requires ongoing work to correct biases and validate the data provided by NOAA. The HAQAST collaborative team is using an hourly $PM_{2.5}$ product developed by NOAA,[14] ingesting into the AirNow system only after validation and bias correction. The Tiger Team members are currently testing and validating the data to ensure accurate data fusion that improves the AirNow product. Satellites do not directly measure ground-level PM concentrations, but rather aerosol optical depth

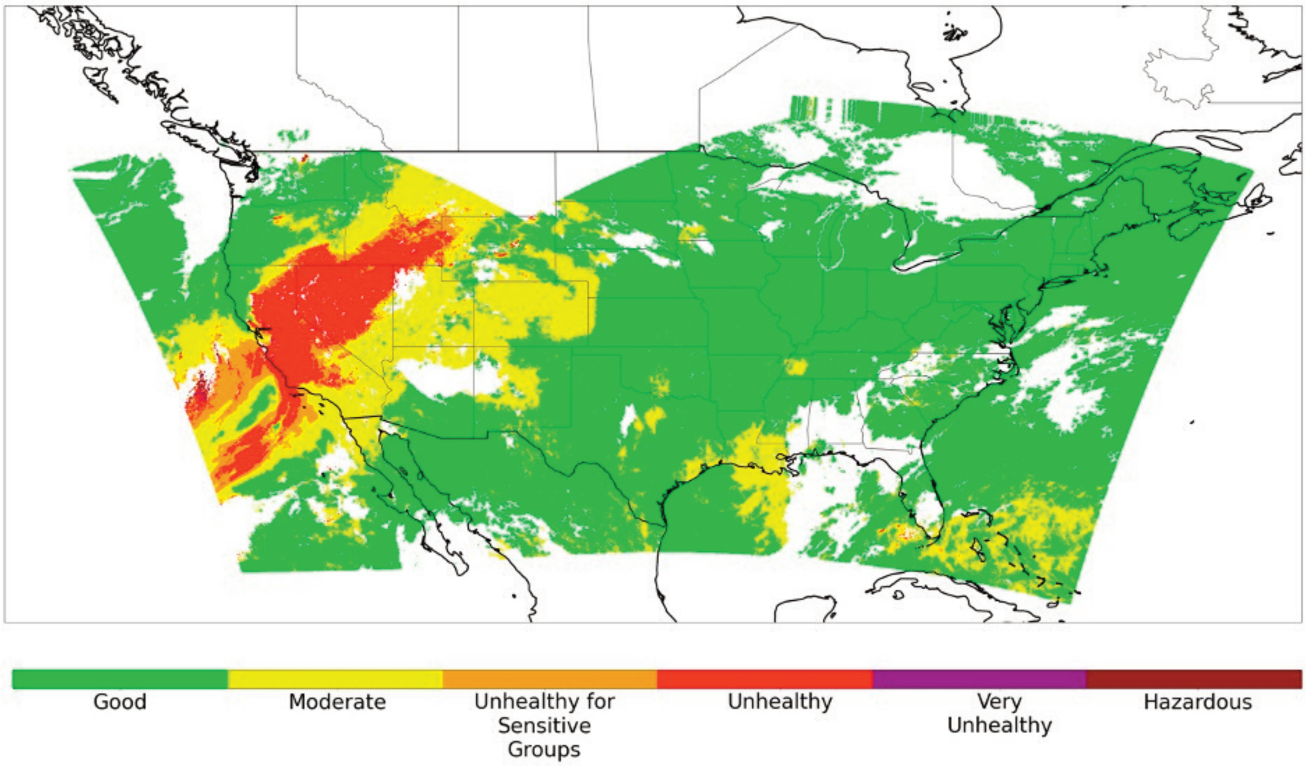

Figure 3. A map showing GOES (East and West combined) $PM_{2.5}$ data from August 20, 2020, over the continental United States.
Note:The map is colored using EPA's AQI. The unhealthy AQI values over part of the western United States are associated with wildfires.

(AOD). AOD is essentially a measure of how much light is attenuated through a column of air by airborne particles. With higher PM concentrations, just as you can see haze and dust looking up in the sky, satellites can measure the haziness looking down on the Earth. As with most satellite data, some uncertainties are inherent in the data because the measurements are from space, looking down over a column of air. This is in contrast to a direct nose-level measurement on the ground, which can be corrected with various algorithms.

Additional challenges include ensuring accurate measurements during times of high concentration of $PM_{2.5}$ due to limited data to train the model and limitations on the satellite's ability to collect data during the daytime and without clouds. Initial data validation efforts demonstrate encouraging performance of GOES $PM_{2.5}$ compared to EPA measurements under a moderate level of concentration (e.g., < 150 μg/m-3), whereas biases increase in very high loading (i.e., during smoke and dust transport). Areas like Alaska, with limited monitoring, also present certain challenges for data fusion. As the project moves forward, the team will work with stakeholders to ensure the data on AirNow is easy to use, accessible, and understandable.

A major innovation in this work is the ability to provide $PM_{2.5}$ data across the United States on an hourly and daily scale in near-real time. While historical datasets are extremely valuable for assessing long-term trends and studying health impacts, quickly updated information is especially useful for public communication of ongoing air quality risks. By improving both the local accuracy and timeliness of the information, people can make the most informed decisions to manage their risk. By using a new statistical, machine learning approach, the $PM_{2.5}$ satellite data can be incorporated into AirNow, bias-corrected, and processed faster than ever before.[14,15] These advances in the field in the past two decades have moved the prospect of using satellite data in air quality monitoring from a theoretical possibility used on a case-by-case basis[16] to a tool, as commonly used as weather forecasting.

Moving Forward

The vision for the future of AirNow is using fused data products to increase fine-scale local air quality capability. Ultimately, this will allow decision-makers and the public to make informed choices to protect health and better understand their local air quality. Anyone interested in using AirNow and newly developed capabilities is invited to get involved with the NASA HAQAST Tiger Team by reaching out to the Tiger Team lead Pawan Gupta (**pawan.gupta@nasa.gov**) or HAQAST Outreach Coordinator Jenny Bratburd (**bratburd@wisc.edu**) to learn more about the updates and provide feedback. **em**

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