Center for Technology in Government

# Air Quality Data Use, Issues, and Value in Colorado

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# Executive Summary

This case describes the air quality conditions and related programs and issues centered in the area around Denver, Colorado, including an urban corridor from Ft. Collins in the north to Pueblo in the south and is part of a larger study to assess the potential benefits of enhancing air quality monitoring data from ground sensor networks with data gathered by satellites.

## COLORADO AIR QUALITY CHARACTERISTICS AND DATA

Colorado presents complex topography and meteorology, and extreme variations in population density, urban-rural character, and economic activity that all make the state vulnerable to a variety of air quality (AQ) issues. Today, ozone is the primary air pollution problem. The Denver Metro area has been out of attainment of the National Ambient Air Quality Standards for ozone since 2007. Vehicle usage, coal-fired power plants, and oil and gas drilling are large contributors to ground-level ozone, especially in the heavily populated areas along the Front Range urban corridor. A corrective State Implementation Plan (SIP) is in place to address the non-attainment areas. Extensive oil and gas exploration in other parts of the state are emerging as additional contributors to air pollution. In addition, unique topography and weather patterns bring additional air quality problems in the form of particulates from smoke and blowing dust, as well as high levels of winter ozone in the large, high mountain valley known as the Uintah Basin.

**Colorado presents complex topography and meteorology, and extreme variations in population density, urban-rural character, and economic activity that all make the state vulnerable to a variety of air quality (AQ) issues. Today, ozone is the primary air pollution problem.**

The State of Colorado operates AQ monitors at 57 locations around the state. Additional monitors are operated by federal government installations and some local governments. Most of these report data to AirNow, the national repository of near real time air quality information for public information and research users, others monitor local conditions only. State government meteorologists prepare daily air pollution forecasts that are communicated to the public via websites, news outlets, community organizations, and social media. Other government and community groups use AQ data for a variety of purposes including permitting, inspections, complaint investigations, preparation and execution of state implementation plans to address non-attainment areas, and environmental and public health outreach and education.

## GAPS AND WEAKNESS IN EXISTING MONITORING DATA

Existing air quality data are extensive, but incomplete and imperfect. Interviewees discussed the following gaps and weaknesses that affect their work:

- **Gaps in the monitoring network.** The most obvious and important gap in existing AQ data is a consequence of the monitoring network itself: large portions of Colorado are long distances from the ground-based monitors in the regulatory network.
- **Interpolation of ground monitor data to describe larger geographic areas.** AirNow uses mathematical interpolation of the ground sensor readings to estimate pollution concentrations in surrounding areas. For some areas of the state this is a reasonably good way to fill the data gap. However, long distances and, more importantly, extreme changes in terrain make these estimates unreliable for local use in many places.
- **Inconsistent terminology in public health messages.** Public health messages often use different terms to convey information about the same

conditions. The choice of “action day,” “advisory,” or “alert” generally reflects either the language of legacy programs or local choices about the content of public health messages rather than real differences in air quality conditions.

- **Rising expectations but lack of resources for more data coverage and public health messaging.** The availability and promotion of public air quality information has stimulated rising expectations and demand for accurate localized data, simultaneously creating potential credibility problems when the state cannot meet the demand due to limited staffing, funding, and gaps in network coverage.
- **Missed opportunities for use of AQ data by state regulators.** The data gaps and difficult-to-use formats of existing AQ monitoring data prevent potential use by non-scientists for a variety of governmental responsibilities.

## POTENTIAL VALUE OF SATELLITE-ENHANCED DATA

Satellite data and related products that record particulate pollution in a 4 km grid are becoming available for regular use. If fully applied to air quality responsibilities, this new data resource could potentially deliver the following benefits:

- **Fill gaps in the ground sensor network.** Both satellite data products could fill coverage gaps in the existing network to support routine forecasts and advisories to the public.
- **Support design and deployment of the monitoring network.** While satellite data can help the state optimize the future placement of monitors in the ground sensor network by providing more information about parts of the state currently fall in the gaps.
- **Support state-level AQ programs and longer range planning and priority setting.** Satellite data could assist in documenting exceptional events, developing and promoting active adoption of state implementation plans, setting priorities, and providing broader context for state-level regulation and enforcement activities.
- **Improve understanding of micro scale environments.** The rather unique geographic and topographic characteristics of the state create many different air quality situations that can be better understood with good quality, detailed satellite data.
- **Enhance forecasting, daily advisories, and public awareness.** While the satellite data are not part of the regulatory network and cannot be used to demonstrate compliance with the NAAQS, it would be valuable to refine daily pollution forecasts because it provides a different kind and granularity of information.

## STAKEHOLDER RECOMMENDATIONS FOR FURTHER DEVELOPING SATELLITE DATA PRODUCTS

Interviewees represented different stakeholder groups and consequently offered different kinds of recommendations regarding the future development and use of satellite data and fused data products. Some focus on the regulatory environment and the need for precise data to demonstrate attainment and progress toward attainment of the NAAQS. Some reflect scientific and technical viewpoints about how more or different data can inform analysis, forecasting, planning, policy making, or enforcement. Others address public health and education concerns about how scientific information and health messages can best be communicated to the lay public.

- Compare satellite data to monitor data to verify and improve quality and credibility.

- Invest in technologies that allow data from ground sensors and from satellite sensing to be gathered, compared and fused for the same time periods.
- Support research in satellite sensing technologies that permit measurement of other pollutants, especially ozone.
- Design different kinds of products to meet the needs and capabilities of different users.
- Provide training and technical support to both scientific and administrative users of ground sensor data, satellite data and fusion products
- Provide satellite imagery and data separately from a fused ASDP product

**This case is part of a larger study to assess the potential** benefits of enhancing air quality monitoring data from ground sensor networks with data gathered by satellites. The study considers this question from the community-level view through three case studies in Denver, Atlanta, and Kansas City. This case begins with an overview of US air quality policy and regulatory programs and the companion AirNow Program for public outreach. In the subsequent sections we describe the air quality conditions, issues, and stakeholders in the Denver-area case. We summarize current uses of air quality data as well as its benefits, gaps, and weaknesses. We conclude with a discussion of ways that satellite-sensed data can expand the uses and enhance the socio-economic value of this kind of information.

## NATIONAL AIR QUALITY MONITORING AND AIRNOW

The Clean Air Act, last amended in 1990, requires EPA to set standards for six criteria pollutants that make up the National Ambient Air Quality Standards (NAAQS): carbon monoxide, nitrogen dioxide, ozone, particle pollution, sulfur dioxide, and lead. All are considered harmful to public health and the environment. The NAAQS sets two kinds of standards:

- Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly.
- Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

This study is concerned with two criteria pollutants: ozone and fine particulate matter with a diameter less than 2.5 microns (called PM2.5). NAAQS for ozone is 0.075 parts per million (ppm) by volume (measured as an 8-hour average), and for PM2.5 the standard is 35 micrograms per cubic meter of air (µg/m3) for the 24-hour, and 12 µg/m3 for the annual average[i].

**The Clean Air Act, last amended in 1990, requires EPA to set standards for six criteria pollutants that make up the National Ambient Air Quality Standards (NAAQS): carbon monoxide, nitrogen dioxide, ozone, particle pollution, sulfur dioxide, and lead. All are considered harmful to public health and the environment.**

State-operated networks of more than 2000 monitors located throughout the United States measure ozone and fine particle pollution. These networks were established as part of the implementation of the Clean Air Act and are in place for the primary purposes of determining compliance with the NAAQS and for informing both state and national level assessments and policy decisions related to air quality improvement. States perform extensive quality checks on these data and report data quarterly to EPA to be used to assess compliance with, or "attainment" of, the NAAQS.

The EPA operates the AirNow program to provide Air Quality Index (AQI) information to the public and the media in real-time. Data from the monitoring networks flow directly from the monitors to AirNow. As the national repository of real-time air quality data and forecasts for the United States, AirNow simplifies air quality reporting to the general public by combining concentrations of five criteria pollutants (all except lead) into a single index available to the public every day. The AQI is divided into six categories associated with different levels of threat to human health (see Appendix 4). For example, an AQI of 50 or less indicates "good" air quality and is indicated by the color green in maps


or scales. An AQI of 151-200 is labeled "unhealthy" and indicated by orange. Each level beyond "good" includes recommendations for reducing exposure.

The AirNow program obtains its data from the same state-operated monitoring networks used for regulatory compliance with the NAAQS. The regulatory data go through a painstaking and time-consuming quality assurance process and are reported to EPA by the states every quarter. However, while accuracy is the most critical feature of the data for compliance purposes, timeliness is equally important for the purposes of AirNow. Consequently, the AirNow program applies a less extensive quality control process (dealing with missing data, grossly out of range readings, etc.) in order to provide hourly updates on ozone and PM2.5. These hourly reports support daily pollution forecasts to the media and other stakeholders and are intended to be timely enough to influence individual behavior. For example, declaration of community-level action or awareness days based on air quality forecasts trigger voluntary programs, such as carpooling, to reduce pollution and improve local air quality. The same forecasts coupled with public health messages help individuals, especially those with high sensitivity to pollution such as asthmatics or young children, avoid or limit their exposure.

AirNow also maintains an informational website (http://airnow.gov, left) where near real-time ozone and particulate matter maps and city air quality forecasts are posted for public access. In addition, the AirNow program offers a password-protected website, called AIRNow-Tech, which allows the organizations that contribute data to have direct access to the full national database for research, analysis, and planning. States use this same daily data, either through AirNow-Tech or directly from their own EPA-approved monitoring networks, for similar but more localized forecasting, analysis, and public reporting.

## EXISTING SENSOR NETWORKS

The ground sensors and the data they collect about ambient air-quality are governed by federal regulations in 40 CFR Part 58[ii]. These regulations establish data standards such as timeliness and validation as well as requirements for the scientific precision of the instruments that collect the data, and specifications for quality assurance processes to assure data quality. Monitoring stations in the networks may house single or multiple sensors specialized for measuring different pollutants. The networks are designed and operated by the states (and some tribal and local agencies and federal installations) with the advice and approval of EPA.

The placement of sensors in the state monitoring networks follows a set of complex design criteria that specify detailed factors for each type of pollutant, with special consideration for measuring exposure in large population centers. The federal regulations further require an annual monitoring network plan and periodic network assessment to continually consider updates that respond to changing conditions[iii]. Subject to public comment and EPA approval, states may move, add, or decommission monitoring stations or sensors in response to changing needs.

Monitoring networks that meet these extensive regulatory requirements, however, do not necessarily provide full geographic coverage due to the expense of designing, installing, and maintaining monitors of exacting scientific quality. Rough estimates of the cost are around $100,000 to deploy a monitoring station, and about $50,000 per year to maintain one, although the costs can vary widely according to the specific pollutant(s) to be measured, the complexity of the monitoring station, its distance from the home base of the organization that maintains it, and other factors. As a result, sensors are deployed as strategically as possible and their actual readings are used to demonstrate compliance with the NAAQS.  When reported to AirNow, however, the monitoring data are interpolated using complex algorithms to estimate conditions in surrounding geographic areas in order to provide forecasts for most communities. In some areas, however, no reasonable estimates are possible due to distance, topography, and other factors, so AirNow does not report conditions for these areas.

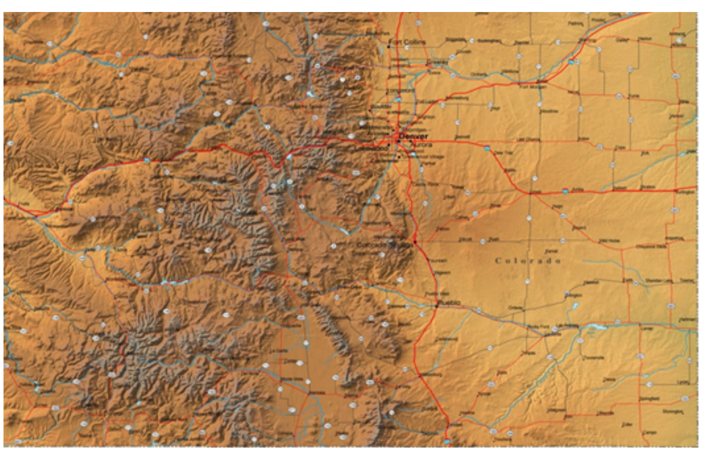
The AirNow Satellite Data Processor (ASDP)[iv] system is currently under development to partially compensate for these gaps in the ground sensor network for fine particles, which enables the blending or fusing of surface PM2.5 measurements and satellite-estimated PM2.5 concentrations, providing additional spatial air quality information to AirNow in areas without existing surface monitoring networks. The ASDP system, while currently working only with satellite estimated PM2.5, is building the capability necessary to implement a wider range of remote sensing capabilities for additional pollutants. At present, data are available from two daily satellite passes over the US at mid-morning and early afternoon. The satellites gather data within a 4 km grid for all areas in the US where atmospheric and other conditions allow. Dense cloud cover, snow cover, and desert landscapes prevent the satellites from taking readings in those conditions.

# Community Context

**This case presents a summary of air quality conditions** and related programs and issues centered in the area around Denver, Colorado. However, because air quality conditions are affected by natural processes, layers of government policies, and human and organizational activity, the case is not limited to the Denver Metro Area. The case also includes information reflecting three larger contexts: the state of Colorado, EPA Region 8, and the Western US. Interviewees for this case represented EPA Region 8; several units of the Air Pollution Control Division of the Colorado Department of Public Health and Environment (CDPHE) (including public information, field services, monitoring, modeling, and air quality forecasts), and the Regional Air Quality Council (RAQC), all in Denver, and the El Paso County Public Health Department and the Pike's Peak Area Council of Governments in Colorado Springs.

## Physical and Socioeconomic Characteristics of the Region

The Denver Metro area is located near the center of Colorado along the Front Range of the Rocky Mountains. Colorado is part of EPA Region 8, headquartered in Denver, covering the plains and mountain areas that include Montana, North and South Dakota, Utah, Wyoming, and 27 Tribal Nations. As shown in the map below, the eastern half of the state lies in the Great Plains, while the western half lies in mountainous terrain. The major population concentration runs in an urban corridor from north to south along the Front Range from Ft. Collins in the north, through Denver and Colorado Springs to Pueblo in the south.



Source: Colorado Topography Map (State-Maps.org)

The Uintah Basin in the northwest contains high mountain valleys that connect Utah and Colorado in a shared air shed that is increasingly characterized by unusual episodes of elevated wintertime ozone. From the west, weather patterns bring smoke from frequent, sometimes massive, wildfires in Arizona, New Mexico, and other states.

The seven-county Denver Metro region is home to more than half of Colorado's 5.1 million residents. The Front Range urban corridor represents a large service-based economy while farms and ranches dot the eastern half of the state. A rapidly growing oil and gas industry comprises both exploration and drilling in several parts of the state. At the same time, the state is noted for outdoor life with extensive hiking, skiing, and resort areas. In short, Colorado presents complex topography and meteorology, and extreme variations in population density, urban-rural character, and economic activity.

## History of Air Quality in the State and Region

The meteorology, topography, and geography of Colorado make the state vulnerable to a variety of air quality issues. In 1970s and 80s, the most frequent air quality issues occurred in winter when many rural regions were in nonattainment for particulate matter and Front Range urban centers were in non-attainment for carbon monoxide. Until the mid-1980s, carbon monoxide pollution was so severe in Colorado that levels sometimes surpassed those in the Los Angeles basin. However, these problems were solved partly by regulating residential burning activities and implementing rules for wood stoves and fireplace modifications, and partly by paving dirt roads in and around small ski resort towns to reduce wintertime particulate matter. At the same time, nationwide improvements in vehicle and fuel technology led to a dramatic reduction in carbon monoxide levels.

Today, ozone is the primary air pollution problem in Colorado. Vehicle usage, coal-fired power plants, and oil and gas drilling are large contributors to ground-level ozone, especially in the heavily populated areas along the Front Range urban corridor. Significant variation in Colorado's topography and the local industry mean that highest ozone source areas are not unified across the state. In the Northern Front Range, Western Slope, Uintah Basin, and the Four Corners Region (where Colorado, Utah, Arizona and New Mexico meet), emissions from oil and gas production are a significant new source. In recent years, a new ozone problem has been identified in atypical locations and times of year. Ozone is typically a summertime problem, created from precursor pollutants generally associated with vehicle and industrial emissions (NOx and VOCs) reacting in the presence of high temperatures and sunlight. In recent years, however, wintertime ozone pollution is frequently observed in high mountain valleys of the Uintah Basin where temperature inversions trap stagnant air to create ozone in high concentrations even in very sparsely populated areas. Colorado shares this problem with Utah where the situation is more frequent and severe.

Particulate matter is also an issue in Colorado and the Rocky Mountain region. Occasional high levels of particle pollution are associated with drilling, construction, and transportation in dry land areas. Colorado is also prone to dust storms and wildfires, which are significant sources of PM10 and PM2.5, respectively. Burning also contribute to PM2.5 levels mainly from permitted residential burning of scrub and large but regulated prescribed burns of dry land conducted to prevent wild fires in Colorado and the other western states.

In 1990, Colorado adopted a state-level aesthetic visibility standard to address frequent occurrences of smoke and haze that may not present health risks but affect quality of life. The standard is not based on EPA regulations but was developed in response to strong public, business, and government concerns regarding the Denver Metro area's episodic haze problem known locally as the "brown cloud[v]."

## CURRENT AIR QUALITY ATTAINMENT ISSUES

Ozone pollution is presently the largest contributor to air quality problems in Colorado and the Rocky Mountain West. During the mid-to-late 1990s Colorado dropped out of compliance with the national ozone standard. This occurred partly because the air quality standard for ozone became stricter, dropping from 80 parts per billion (ppb) to 75 ppb between 1997 and 2008. Unable to find methods to stay in compliance with these lower thresholds, the fastest growing and most populous part of the state around Denver has been in non-attainment since 2007. Nine counties in the Denver metropolitan area and the Northern Front Range (including portions of two counties that contain Fort Collins and Greeley) are in nonattainment with the current national ozone standards. At present, a new ozone standard is being considered by EPA that would set the threshold in the range of 60-70 ppb for an 8-hour average from the current standard of 75 ppb. If this lower figure is adopted, more areas of the state will likely be in nonattainment[vi].

Colorado is currently in attainment for the PM2.5 standard although periodic exceedances occur mainly due to severe stagnation episodes and wild fires. However, because PM2.5 at any level is a public health consideration, Colorado maintains an active public information program to alert residents to high concentrations.

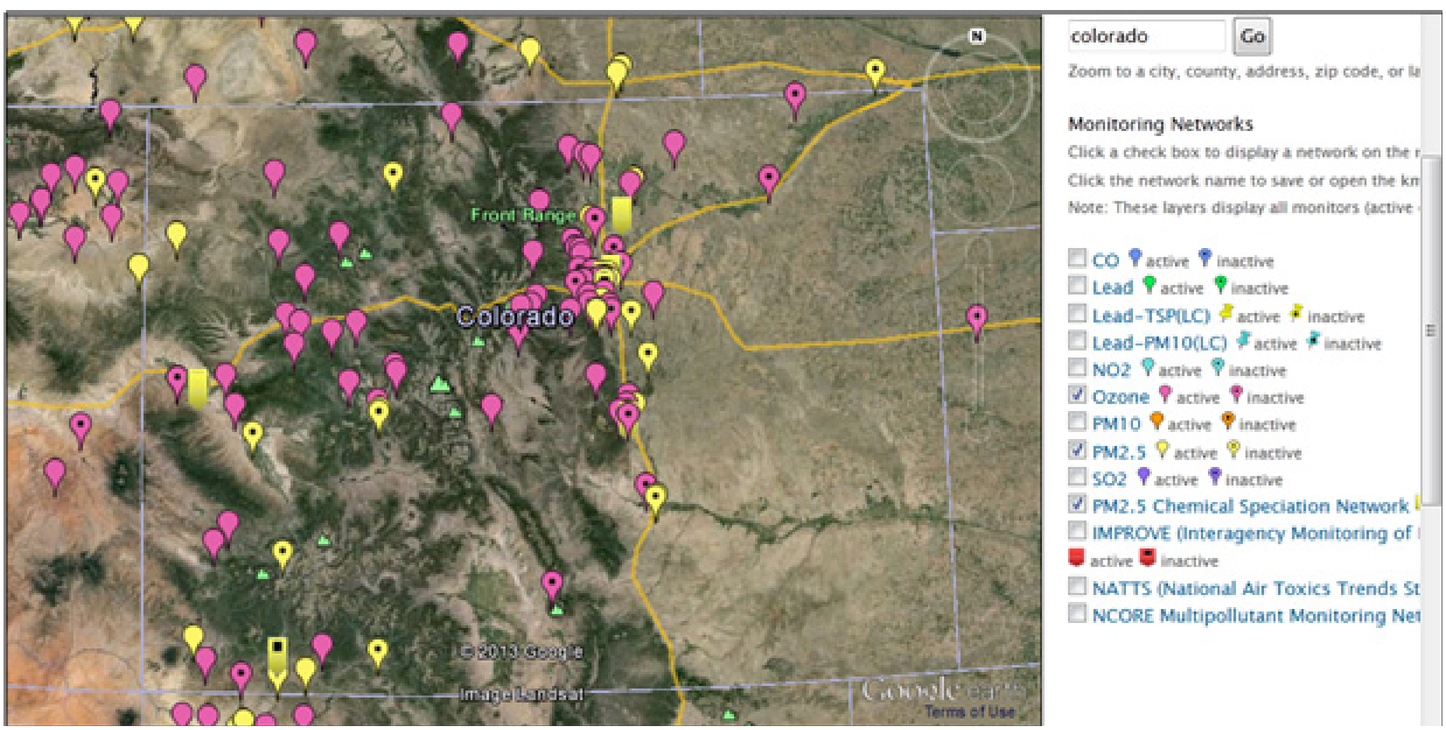
When a state is in non-attainment of any part of the NAAQS, it is required to work with a wide range of stakeholders to develop a State Implementation Plan (SIP) that identifies and monitors specific actions to come into compliance. For the Denver-Boulder metro area and portions of the Front-Range, this responsibility lies with the Regional Air Quality Council, an air quality planning agency created by the Governor in 1989, to address non-attainment issues in the Denver Metro area. The RAQC's primary responsibility is to develop pollutant-specific SIPs for compliance with federal air quality standards, prepare emissions budgets and submit the proposed SIP and proposed implementing regulations to the Colorado Air Quality Control Commission for adoption. CDPHE assumes this role for other areas in the State and provides technical and policy analyses for the RAQC when it is preparing a SIP.

## COLORADO AQ MONITORING NETWORK AND OTHER AQ DATA SOURCES

The State of Colorado has been monitoring air quality statewide since the mid-1960s. Today, the Air Pollution Control Division of the Colorado Department of Public Health and Environment (CDPHE) operates monitors at 57 locations. Monitoring stations measure the criteria pollutants in the NAAQS to document attainment or non-attainment of the standards for each pollutant. Particulate monitors, including PM10 and PM2.5, and ozone monitors are the most abundant and widespread types, but monitors are also in place to measure the other pollutants in NAAQS. Carbon monoxide (CO) monitors are in place to comply with EPA requirements to monitor CO for 20 years after a period of non-attainment ending in the mid-1990s, although CO has not been a pollutant of concern for many years in Colorado or the rest of the United States. The Technical Services Program (TSP) of CDPHE installs and maintains the sensors in the network. Newer sensors, which are generally located in dense population areas, are continuously updated, but a large number of sensors are filter-based and either TSP or their contractors must visit each week to change the filters and calibrate the devices. Often this work involves a considerable amount of travel from place to place and is therefore quite expensive.

Additional regulatory-quality monitors are operated by federal government installations such as the Bureau of Land Management. Colorado operates additional monitors to track changing conditions in areas where air quality concerns are emerging such as near the City of Rifle in Garfield County, and some local governments also operate monitors to track local conditions but these are not part of the regulatory network and do not report readings to EPA. However, many of these sensors do feed into the AirNow.

The map below shows the locations of Ozone and PM2.5 monitoring stations around the state. Stations are concentrated along the Front Range/urban corridor where air quality and human exposure to pollutants is of most concern.



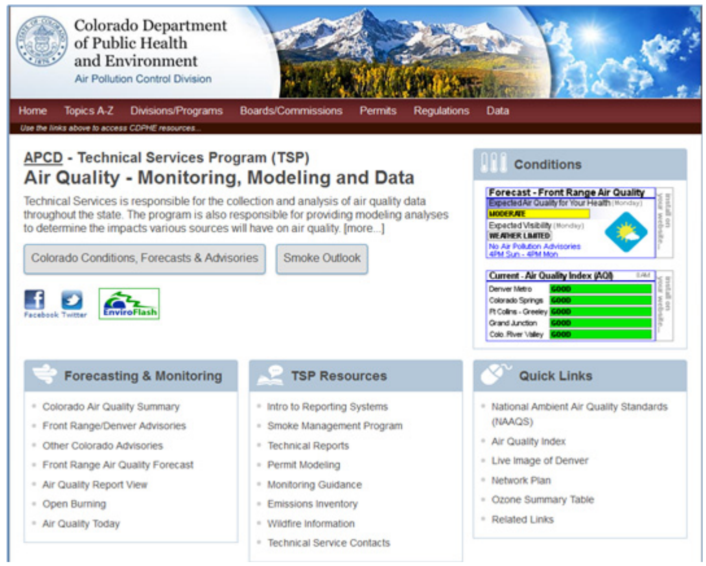

**Source: EPA AirData Website**

The continuous feed monitors transmit data hourly after it has been subjected to initial validation. However, only those monitors that meet regulatory standards are used to report to EPA. After initial hourly validation, these data also go through an extensive cycle of nightly, quarterly, and semi-annual audits to ensure accuracy before being exported to EPA for compliance purposes. Conversely, the data reported to AirNow is subjected to a much less rigorous validation process and includes some sources that may not meet the EPA instrumentation requirements. As a result, inaccurate data are sometimes reported to AirNow. When the validation process uncovers an error, the AirNow data are corrected to improve the information provided to the public.

## USERS AND USES OF AQ DATA

During the interviews in Denver with staff from the respective federal, state, and local air quality responsible agencies and the Regional Air Quality Council and Pikes Peak Area Council of Governments we learned about the different users and uses of existing air quality data and other sources of information. Right, is a summary of those users and uses.

The EPA Regional Office uses both AirNow and AirNow-Tech to monitor conditions in the six state region. Staff use AirNow-Tech to evaluate, summarize and report the previous day's air quality to the EPA management chain and they work with states in the region to interpret and use the data transmitted to AirNow. Detailed knowledge of the region provides critical context for understanding the data – for example, knowing the topography of a certain area makes it possible to accept or dismiss area interpolations that may be mathematically correct, but are logically false. Of particular current concern is the winter ozone problem in the Uintah Basin where EPA is supporting scientific studies to better understand the situation by "daily pulling the data from those eight monitors out of AirNow Tech and sending an update to the science team while the aircraft was there to see where the residual ozone warning was sitting so they could plan their flights for the day."



Source: CDPHE APCD Air Quality Monitoring Website (CDPHE APCD 1)

While the EPA Region 8 staff use AirNow and AirNow-Tech regularly, Colorado's state and local agencies vary considerably in their adoption and use of AirNow products.

The Air Pollution Control Division (APCD) at the Colorado Department of Public Health and Environment (CDPHE) is charged with monitoring air quality levels, enforcing codes, responding to complaints, and communicating this data to the public. The Technical Services Program (TSP) within CDPHE uses the monitoring data to report, model and forecast air quality statewide. These analyses are used to issue action day forecasts or advisories, and they form the basis of messages to web products and the air quality Listserv that the office maintains.

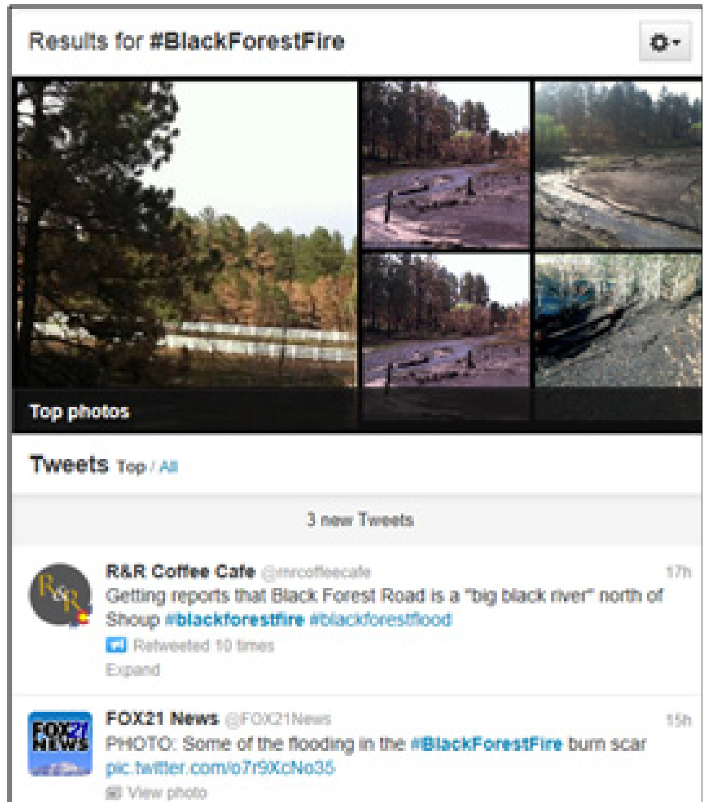
In addition to the reports from the monitoring stations, a variety of other data sources are used by state forecasters for daily pollution forecasts, health alerts, and exceptional events like forest fires and dust storms. CDPHE meteorologists also conduct dispersion modeling for the State to use in its implementation plans and permitting activities. If patterns of data indicate new issues or emerging problems, the analysts may recommend changes in the


Source: CDPHE APCD Twitter Feed (CDPHE APCD 3) and Facebook Page (CDPHE APCD 2).

monitoring network. Data sources for forecasting and other analysis include computer weather models, AirNow Tech, and a number of satellite products that include NASA's MODIS Terra and Aqua satellite imagery, GOES imagery, AIRS (Atmospheric Infrared Sounder) data CO data to track smoke plumes, OMI and GOME trace gas products and the GOES Aerosol/Smoke Product (GASP) from the National Oceanic and Atmospheric Administration (NOAA).

While CDPHE updates AirNow daily and uses AirNow tools, it prefers to direct people to its own website as the primary source of public information about air quality in Colorado. In addition to standard AQI and advisory information, the website contains a wealth of additional AQ resources regarding monitoring, network design, smoke outlook, and links to related material.

In addition to AirNow and its own website, the Air Pollution Control Division communicates to the public through the local media, an air quality telephone hotline that updates a recorded message twice daily, Facebook and Twitter accounts, and ad-hoc outreach programs. The Division issues an advisory or action day when a region is nearing or is forecasted to exceed EPA standards, or because it is expected to exceed the State visibility standard. These messages also include information regarding the voluntary and prohibited actions associated with it. For visibility days and action days prompted by particulate levels, the message is focused on the regulatory requirements, or prohibited actions, imposed on the community. When an action day is prompted by ozone, the message focuses on voluntary actions to protect human health and reduce precursor emissions.


Source. El Paso County Public Health Twitter Feed (EPCPH 2) and Black Forest Fire Twitter Trend (EPCPH 1).

The CDPHE Field Services Unit (FSU) in the Stationary Sources Program within the Air Pollution Control Division inspects stationary sources to ensure they are compliant with EPA standards and state regulations, carries out enforcement actions, responds to complaints, and issues general open burn permits. The FSU relies mainly on the permits and locally maintained records to perform these functions and rarely uses AQ monitoring data.

El Paso County Public Health Department Environmental Health Division is primarily responsible for ozone monitoring programs for El Paso County. Historically, the El Paso County Public Health Department had a robust air quality program. In the past, the department issued permits, responded to complaints, inspected small-source generators, and monitored sites. Severe budget cuts in 2008 eliminated El Paso County's air quality program, thereby returning responsibility for these services to the State of Colorado. By 2011, the State contracted with the El Paso County Health Department to again provide these services locally. Current work also includes issuing residential burn permits and working with construction sites to mitigate dust and other environmental impacts.

The El Paso County Health Department does not access AirNow directly. Instead, it uses data from the state's ozone, carbon monoxide, PM2.5 and PM10 monitors. When El Paso County Health Department is either alerted by the State or notices the levels (typically the ozone level) near the EPA limit, it alerts the public. The prompt to alert the public is the result of a particular air quality measurement (i.e. ozone or particulate levels); however, the actual public message refers to air quality generally. The Department works with local media and posts to Facebook and Twitter, to alert the public and provide public health and mitigation recommendations.

The Regional Air Quality Council (RAQC) has two main missions: to develop and oversee the State Implementation Plans (SIPs) related to non-attainment of the NAAQS, and to maintain a public education and outreach program about air pollution aimed at reducing emissions and improving public awareness of environmental and health risks. While its responsibility for SIPs is concentrated in the Denver Metro area, the RAQC reaches a larger area of the state for education and outreach using both traditional and new media.

In order to develop the SIPs, the RAQC evaluates the effectiveness and cost-efficiency of a variety of air quality initiatives with input from state and local government, the private sector, community stakeholder groups, and private citizens. The RAQC works with the CDPHE Air Pollution Control Division to develop the technical basis of the plan, including emission inventories and air quality modeling, and takes the lead in identifying and analyzing potential control measures. In consultation with the Denver Regional Council of Governments and others, the RAQC develops proposed emission budgets for purposes of transportation conformity with air quality regulations and goals[vii].

The RAQC depends on CDPHE for all its data and began using AirNow data four or five years ago. Ozone and PM2.5 data from CDPHE is posted to the RAQC website daily, generally before it has either been quality checked or reported to the EPA. The RAQC also uses the aggregate data to develop action plans to bring a community into compliance with the NAAQS. The data is used to provide real-time alerts and recommends mitigation and public health behaviors to the public via radio, television, and social media.

The RAQC's outreach and education program, Ozone Aware, has two purposes (http://raqc.org/programs/more/ozone_aware). First to raise awareness about ground level ozone pollution in the Metro area, and second to motivate behavior change among residents to help reduce it. For example, in 2013 the RAQC is cooperating with local television station KMGH to have their lead meteorologist serve as the program's ambassador. The program also includes some Spanish stations as well as NPR and PBS and commercials on radio stations to report total traffic drive time updates so people in their cars will hear about ozone days. The program also includes a social media push that offers an online calculator or air quality impact tool where people can log on and report actions such as "I didn't drive into work today." "I worked from home." "I mowed my lawn after 5:00 PM" to earn ozone reduction ratings and calculate associated cost and vehicle mile savings. Local meteorologists are also going into schools with a target of reaching 500 students a week with ozone awareness messages.


Source: OzoneAware Website (RAQC 3).

The Pikes Peak Area Council of Governments (PPACG) includes three counties and twelve cities in the area around Colorado Springs. Several different types of monitors are in place in this region (for ozone, carbon monoxide, and PM2.5 and PM10 monitors). PPACG uses the air quality data from these monitors as reported on the CDPHE website to track conditions in the region, produce reports, and conduct public outreach and education. They do not use the data contained on the AirNow website because when a user clicks on Colorado Springs on the website, it pulls up information for Denver. PPACG would like to do more education and outreach but previous funding for this work is no longer available. Since the area is generally in attainment, the Environmental Planning Manager spends about thirty percent of his time on air quality issues noting, "Generally it's a concern among the residents, but as far as the state and federal efforts go, because we're in attainment, there is not as much emphasis or certainly money, that's being sent to our area. Denver gets most of it, you know, because they're still in non-attainment for the old ozone standard."

## GAPS AND WEAKNESS IN EXISTING AQ MONITORING DATA

### *Gaps in the monitoring network*

The most obvious and important gap in existing AQ data is a consequence of the monitoring network itself: large portions of Colorado are long distances from the ground-based monitors in the regulatory network. While the state is consistently evaluating the coverage and effectiveness of its network and the need for additional monitors, the Colorado network remains predominantly Denver- or at least Front Range-focused with the majority of monitors located in larger population centers and in those areas with historic attainment issues.

Interviewees noted consistently that gaps and weaknesses in monitoring data have less to do with the data itself but more reflects the size and density of the overall state network. Although monitors are placed for maximum compliance with EPA's design criteria, they still leave large parts of the state with only estimates of pollution measures or in some areas no data at all. For example, El Paso County shares a media market with neighboring Pueblo, but there are no monitors in or near Pueblo so all media messages it receives reflect the measurements taken in El Paso County (mainly in Colorado Springs) which is more urban and has a different mix of industries. Another consequence of the data gap occurs in the development of the SIPs where the lack of monitoring stations in the more rural areas of the non-attainment region means stakeholders in those communities are unaware or unconvinced that activities in their vicinity contribute to non-attainment or could contribute to remediation.

Theses gaps limit the state's overall ability to provide timely and accurate air quality information to some areas but it is neither economically nor politically feasible to place enough monitoring stations throughout the state to eliminate them. This results in unaddressed public health and quality of life issues and inadequate information to fully understand both current conditions and longer-term trends.

### *Interpolation of ground monitor data to describe larger geographic areas*

AirNow uses mathematical interpolation of the ground sensor readings to estimate pollution concentrations in surrounding areas. For some areas of the state this is a reasonably good way to fill the data gap. However, long distances and, more importantly, extreme changes in terrain make these estimates unreliable for local use in many places. An EPA Region 8 air quality expert illustrated this with AirNow maps explaining how the interpolated data in part of the Uintah Basin represented "bleeding" of the monitor reading into area where knowledge of the local conditions and topography indicated they were clearly false. He noted that the data gap problem is unlikely to be filled with more ground monitors because of the expense of deployment, operation, and maintenance. However, under the right atmospheric conditions, good quality satellite data could substitute for interpolation in some areas to provide more accurate localized readings and forecasts.

### *Inconsistent terminology in public health messages*

The terminology used for public health messages is sometimes inconsistent and confusing. While EPA uses the term "action days" to indicate that conditions warrant actions to be taken to protect individual health, Colorado and some localities may use the term "advisory" or "alert" for essentially the same conditions. These different terms generally reflect either legacy programs or local choices about the language of public health messages rather than real differences in air quality conditions.

While experts understand the cause of these language differences, they are problematic for several reasons: first they are confusing to the public as their meanings are not clearly different from a resident's point of view. Second, different parts of the state can receive different messages for similar pollution problems. Third, some local governments and community groups operate their own monitors that may not have the same precision as the regulatory monitors, thus prompting messages that can raise local public health concerns but that are not comparable from place to place or among different monitoring systems. CDPHE is planning to review these issues and to make recommendations for changes in terminology that will address these problems.

### *Rising expectations but lack of resources for more data coverage and public health messaging*

Ironically, the availability and promotion of public air quality information has also stimulated rising expectations and created the potential for credibility problems. Local governments and regional associations rarely use AQ data directly. Instead they rely on the experts at CDPHE to gather and analyze the reports from the monitors, to prepare forecasts, and to issue alerts when needed. Some localities would prefer to operate their own monitors or to have the state add them to the statewide network, but these are both unlikely to happen for reasons of reliability and compatibility in the first instance, and cost in the second.

From a public information perspective, the problem is more one of credibility. After having encouraged people to become aware of AQ issues, the challenges of reporting AQ conditions in a way that makes sense to lay people immersed in very specific local situations remains a major challenge. For example, one interviewee told us, "the Colorado website says "good" air quality [for a local area] but [a caller says] they can't see their neighbor's house because of so much smoke. The problem is that [the website is] reporting a 24 hour average" while the caller is looking at the situation right now. The state agency is considering a new algorithm that would help reduce these discrepancies in the future.

In addition, federal government funding is no longer available for environmental health outreach or education programs. In recent years, EPA funding for public education and outreach has been cut so that "we rely on word of mouth and media and recently have started to get into social media and are posting our advisories on our Facebook page and tweeting about them" so we have more control over the content and timing of the messages. Some funding is available through the Federal Highway Administration Congestion Mitigation and Air Quality Improvement Program (CMAQ) the but it cannot be used to advise about human health effects. The RAQC and PPACG can apply for grants which help to some degree, but most interviewees agreed the job of public health communication is difficult and the resources are inadequate to the task.

### *Missed opportunities for use of AQ data by state regulators*

The data gaps and difficult-to-use formats of existing AQ monitoring data prevent potential use by professional field staff to better understand the context of specific complaints for investigations. When investigating a public complaint near a refinery, for instance, the field inspector might check meteorological data for wind direction to try to determine if wind direction matches with what the complainant thinks is the source of the pollution, although according to one supervisor, “the majority of field inspectors following up on a complaint “do not take much information other than who, what, when, where, and why.” For the hundreds of routine facility inspections conducted annually they rely mainly on immediate on-site observation of compliance with the provisions of state-issued permits and the records each facility is required to maintain. Although existing sources of AQ data might provide useful historical or other context, they are seldom consulted.

One field supervisor noted that the available AQ monitoring data are not easy to use or understand and that some education about the variety of data sources, analyses, uses, and limitations would be necessary for them to take advantage of it in their daily work. “We might have the data we already would need or want but just knowing how to use it, how to access it, how to make it useful for us [is a barrier]. . . I’m sure there’s a ton of information there and if it was displayed a little bit differently it might tell us a completely different story and then we could use it in a much different way. So I think a lot of that stuff probably exists, we just don’t even know how to make it helpful.”

# Potential Value of Satellite-Enhanced Data

**During each interview we presented examples of the** satellite and satellite-enhanced AirNow products produced by the STI team developing the ADSP. Each example focused on the greater Denver metro region and was drawn from past dates selected by STI to highlight different daily conditions and the capabilities and limitations of the ASDP. We asked the interviewees to consider how they might use these products in light of their intimate knowledge of the case study region and to suggest the value of these products in their jobs or for the stakeholders they serve. The rest of this section describes the main benefits identified.

## FILLING GAPS IN THE GROUND SENSOR NETWORK

A consistent theme across all of the interviews was that satellite data could be used by local and state governments to supplement the existing ground-based network. Interviewees agreed that both the satellite data and the fused product could fill coverage gaps in the existing network to support routine forecasts and advisories to the public.

Gaps in the monitoring network are addressed as far as possible by AirNow by estimating or extrapolating air quality measurements from sensors at the monitoring sites to areas farther away. However, as described in the previous discussion of gaps and weaknesses, distance from the monitor and topographic and meteorological conditions can make these estimates inaccurate. In these instances, the satellite data could supplement the monitoring data. The accuracy of the satellite measurements is affected by local conditions such as cloud cover, so this supplementation would not always be possible, but in many instances the satellite data could add considerable granularity by providing direct local measurements for forecasting and public information purposes. An expert at the EPA Regional Office summarized it this way:

> *"Contextual knowledge of a region's topography and geography is crucial to understanding where the satellite data could be the most useful. One thing I think is always a problem in this area as far as forecasting is with the terrain. We know there's big differences as far as transport of pollutants and ozone, especially. . . Particulates are going to stack up somewhat as well and the algorithms in AirNow, may not always handle that and it may just extrapolate thinking it's just going to go out and it doesn't. . . .It just smears it out and that probably is not a reality so the satellite and the fusion may help resolve some of those issues."*

## SUPPORTING DESIGN AND DEPLOYMENT OF THE REGULATORY MONITORING NETWORK

Due to a combination of economic, geographic, and political factors, Colorado cannot place ground sensors in all the places needed to provide complete coverage. However, the state constantly evaluates its network against current and emerging air quality conditions in an effort to optimize the network they do have. They occasionally place monitors in new locations, sometimes as part of the regulatory network and sometimes as exploratory efforts to understand better the conditions in a certain location. The state does use other air quality information such as "non-state" and "non-reference" monitors[viii] to help identify some of these areas, but the satellite products could be an important additional information source especially in those areas without ground monitoring of any kind. The interviewees agreed that satellite data could help identify those areas in the state where the expensive investment in an additional monitor could provide the greatest value.

Staff in the CDPHE APCD Technical Services Program – those responsible for the network design and the quality of the data– described how satellite data could help them determine where new monitors could be located. According to one expert, "We can't monitor everywhere in the state and we don't have the resources to look everywhere in the state to see if there's an issue especially as conditions change over time." However, "sources come, sources go . . . there may be hot spots that we miss and satellites could pick up on that type of situation." For example, oil and gas exploration in Eastern Colorado is a growing air quality concern. One local government expert noted that satellite data might provide an early warning of local impact by identifying emerging air quality issues early and helping the state determine whether ground monitors should be placed in the area.

### SUPPORTING STATE-LEVEL AQ PROGRAMS AND LONGER RANGE PLANNING AND PRIORITY SETTING

Satellite data cannot not be used to demonstrate attainment of the NAAQS, but it could be valuable in making a case for an “exceptional event” exemption. Because satellite data are not limited to the location of the monitors, or even to the boundaries of the state, it might assist CDPHE to compile the extensive data necessary to show that it would have been in compliance during a certain period except for naturally occurring uncontrollable conditions (such as heavy prolonged smoke from distant wildfires) that pushed the monitor readings above the threshold level for attainment.

A RAQC official described possible state-level benefits related to preparation and adoption of State Implementation Plans for areas out of attainment with the NAAQS. He described how having place-specific data in “almost real time” would be useful in convincing residents and business interests located some distance from monitoring stations that activities and conditions in their locales do contribute to air quality problems in the area and that they could take actions to help mitigate them.

The state APCD Field Services Unit identified ways to use this data to support permitting and enforcement activities as well as for investigating air quality complaints. While the field services staff we interviewed said they rarely use air quality monitoring data in their day to day work, they recognized that satellite data could provide a broader context for their work allowing them to look at various regions retrospectively to identify patterns or “hot spots” of air quality concerns that could then be used to prioritize inspections.

In addition, field staff typically use inspectors’ observations onsite to make a compliance determination or initiate an enforcement action, but they could also potentially use the satellite data to identify historical correlations between air quality conditions and specific complaints. “So, if they [the complainants] are saying on every Saturday they’re doing something at a quarry or a facility where they’re creating a bunch of particulate emission, to be able to see that and verify that, maybe we could use it as credible evidence.”

### IMPROVING UNDERSTANDING OF MICRO SCALE ENVIRONMENTS

Another potential value of the satellite data pertains to the rather unique geographic and topographic characteristics of the state. Through a combination of varying elevations, mountains, valleys, and population distributions, Colorado has several different “micro scale environments” that it make it difficult for ground-based air quality monitors to provide the range of coverage that would be possible in flatter, more uniform terrain. These features can result in inaccurate air quality designations for areas that are not close to the monitor itself. Satellite data might be used to supplement the ground monitors in these areas.

Western Colorado is particularly susceptible to these micro scale variations. According to one state interviewee, satellite data “could really come into play in the Grand Junction area. . . It’s a tight valley; kind of dead ends just to the east of Grand Junction in the Colorado River and topographically you’ve got a higher area coming down through it. Grand Junction can get severe inversions going on at times and very localized, it’s below the tops of the mesas, which are at about 10,000 feet from the mesa tops. You’re up on them clear as a bell [but] down in Grand Junction you’re seeing high NAAQS PM2.5 and how micro scale environments like that can get resolved by the satellites.”

These micro scale environments, especially when combined with smoke, can affect the air quality of populations living at high elevations. According to one local health official “Just because you're out east and the ground monitors do not show unhealthy air quality doesn't mean you're safe. Well, in this case, when you look just at the satellite data, it does show the higher you're going up in elevation it's worse. That's probably due to the smoke. You look right here… well, that satellite reading is lower [near Colorado College]. But in here [in the higher elevation near the Ute Pass], it's higher. That makes sense."

## ENHANCING FORECASTING, DAILY ADVISORIES, AND PUBLIC AWARENESS

While the satellite data are not part of the regulatory network and cannot be used to demonstrate compliance with the NAAQS, it would be valuable to refine daily pollution forecasts because it provides a different kind and granularity of information. For example, dust storms, local wildfires, and smoke from distant wildfires often occur in sparsely monitored areas of the state. While state forecasters are often aware of and communicate the potential air quality threats from these events, interviewees stated that the satellite data could increase their confidence in the coverage, accuracy, and timeliness of the information they provide.

The lead air quality forecaster at CDPHE stated that, "Smoke from fires is an issue and that's clearly one that a PM2.5 satellite product could help us with when issuing Wildfire Smoke Health Advisories for anywhere in the state where we have surface smoke . . . Usually if visibility due to smoke is less than five miles there is some indication that 2.5 is high enough to be a health hazard." Therefore, in areas without sufficient ground monitors, "a satellite PM2.5 product could add value to any visibility data" by providing greater confidence in the decision to issue a public health message or the areas to include in its coverage.

# Stakeholder Recommendations

## for satellite data products

**Interviewees represented different stakeholder** groups and consequently offered different kinds of recommendations regarding the future development and use of satellite data and fused data products. A clear tension exists between the desire for more information that is useful but not of regulatory quality and the desire for accuracy and consistency across data sources to demonstrate compliance and avoid unwarranted actions or mixed messages to the public, businesses, or local communities. Some of the recommendations therefore focus on the regulatory environment and the need for precise data to demonstrate attainment and progress toward attainment of the NAAQS. Others reflect scientific and technical viewpoints about how more or different data can inform analysis, forecasting, planning, policy making, or enforcement. A third set addresses public health and education concerns about how scientific information and health "messages" can best be communicated to the lay public.

***Compare satellite data to monitor data to verify and improve quality and credibility.***

Satellite data would be a new source for most users of AQ information. As such, its quality and reliability need to be assured. One way to do this would be to periodically compare time-matched ground sensor readings on clear days to satellite readings on the same days in the small grid area surrounding each sensor. If the readings are substantially the same, the two sources could be considered equivalent quality for many purposes and satellite readings in areas more distant from the sensors could be considered valid. Another approach would be to test satellite readings in remote areas against readings from good quality mobile ground sensors in the same locations. A third would be to substitute satellite readings for a subset of ground sensor readings and compare the combined results to the results from the full set of ground sensors. All of these would help to establish the validity of satellite data and document its limitations relative to both sensor readings and interpolated results.

***Invest in technologies that allow data from ground sensors and from satellite sensing to be gathered, compared and fused for the same time periods.***

Nearly all interviewees noted that the potential benefits of satellite data and especially of a fused product, depend on finding a way to synchronize the data from the ground and satellite sources. One interviewee explained that "we don't have any data out here to validate the fusion product. From two passes of MODIS, we suspect that the fusion product's better than interpolating the monitors, but without data anytime except those two passes… we don't really know if it's better or worse. It's probably better, just because it has knowledge that the mapping algorithm can't have. But it [is trying to incorporate] knowledge of two time[s] of day [into] a 24-hour product." Ideally, the readings from both sources would be recorded frequently so that information could be compared, fused, or adjusted using measurements from both sources taken at the same time of day. Investments in geosynchronous satellites or other technologies that collect data throughout a 24-hour period seemed far preferable to algorithms that attempt to compensate mathematically for missing data and widely different time frames.

***Support research in satellite sensing technologies that permit measurement of other pollutants, especially ozone.***

Interviewees could see the definite benefits of satellite data for filling in the gaps and improving the granularity of PM2.5 data gathered in the sensor network, but they also agreed that PM2.5 is less problematic than ozone as an environmental pollutant and health hazard. Better data are need regarding ozone for two reasons. First, Colorado is generally in attainment with the PM2.5 standard but has a history along the Front Range of non-attainment for ozone. Second, PM2.5 is often accompanied by visible dust, smoke or haze as well as eye and respiratory irritation that cause people to take reasonable precautions on their own, while ozone is invisible and more insidious as a health risk.

***Design different kinds of products to meet the needs and capabilities of different users.***

Because of its complexity and limitations, most interviewees were cautious about making the satellite data directly available to the public because interpretation demands more than a lay person's knowledge and appreciation for the data and what it represents. However, investment in a well-designed, - tested and -explained fusion product might be a solution to the obvious gaps in the public version of AirNow. One said, "I think we all agree it's incredibly important to be transparent and give the public the information but if you're not helping to interpret that information, I'm not sure what the value is." Given resource constraints for public outreach and education, this kind of assistance will most likely need to be built into the product itself.

There was strong agreement that satellite data and data products could enhance the work of various kinds of experts for forecasting, permitting, compliance reviews and other functions. However, as noted below, different kinds of experts will need different kinds of products or different sorts of technical assistance to use the data effectively. One interviewee added that agency experts need to be encouraged to use a consistent set of data sources in compatible ways because their work and their constituencies overlap. "I would see the most value of these products if my health department, the state health department, and our other nearby health departments were all using the same information and were on the same page. I would hate for one person to be doing satellite, one doing AirNow."

***Provide training and technical support to both scientific and administrative users of ground sensor data, satellite data and fusion products***

Data users need information and training about the nature and limitations of the satellite data in order to make informed judgments about whether and how to use it. For example, a forecaster from CDPHE wanted to have a detailed explanation of how the two data sets are fused to create ASDP products before he could decide about its use in forecasting or modeling. A standard description of this process would help a technical user understand how the fusion is done and whether the result would be relevant or useful in any given application. Administrative users suggested webinars or other training programs to introduce them to the range of AQ data available, its pros and cons, and suggestions about how it can be applied to support different responsibilities.

***Provide satellite imagery and data separately from a fused ASDP product***

The fused product has potential value as an eventual replacement or point of comparison for current AirNow products. However, simpler approaches, such as making better use of satellite photo imagery, are available now and would be very useful. According to one interviewee "we're already letting the eye and the nose be the first line of defense here and I'm not sure this [data fusion] would replace that kind of common sense advisory. . . [just the satellite imagery of smoke is] pretty informative" and its location relative to the ground could be validated with a phone call. Others noted that looking at the separate map representations of the satellite data and the AirNow data was more helpful than looking at the fused product because they could readily see the difference in the readings and interpret their implications. In its current form, the fused product not only masks differences in granularity and time scale, it also makes certain standard assumptions about which data source is more reliable—assumptions that may not be appropriate in all circumstances. In other words, "the mismatch can tell more of a story" than the fusion.

# Appendix 1

## List of Interviewees

**Environmental Protection Agency, Region 8**

- Richard Payton, Air Quality Monitoring

**Colorado Department of Public Health and Environment**

- Marley Bain, Unit Supervisor, Field Services
- Paul Carr, Unit Supervisor, Field Services
- Christopher Dann, Public Information Officer, Air Pollution Control Division
- Greg Harshfield, Gaseous Monitoring Supervisor, Technical Services
- Patrick McGraw, Particulate Monitoring Supervisor, Technical Services
- Shannon McMillan, Field Services Program Manager, Field Services
- Gordon Pierce, Technical Services Program Manager, Technical Services
- Patrick Reddy, Senior Air Quality Meteorologist

**Regional Air Quality Council (RAQC)**

- Meg Alderton, Communications Manager
- Gerald Dilley, Air Quality Engineer

**El Paso County Public Health**

- Tom Gonzales, Director, Environmental Health Division

**Pikes Peak Area Council of Governments**

- Richard Muzzy, Environmental Planning Manager

# APPENDIX 2

## LIST OF ACRONYMS

**Items Pertaining to Air Quality Science, EPA, NASA, and National Policies**

**ASDP:** AirNow Satellite Data Processor

**40 CFR Part 58:** Ambient Air Quality Surveillance Siting Criteria for Open Path Analyzers

**CMAQ: Congestion Mitigation and Air Quality Improvement Program**

**CO:** Carbon Monoxide

**GASP:** Geometric Autonomous Shuttle

**GOES:** Geostationary Operational Environmental Satellite

**MODIS:** Moderate Resolution Spectroradiometer

**NOx:** generic term for mono-nitrogen oxides, NO and NO2

**OAPQS:** EPA Office of Air Quality Planning and Standards

**PIO:** Public Information Officer

**QA:** Quality Assurance

**SIP:** State Implementation Plan

**VOC:** Volatile Organic Compounds

**Colorado-specific items**

**APCD:** Colorado Air Pollution Control Division

**AQCC:** Colorado Air Quality Control Commission

**BLM:** Bureau of Land Management

**CDPHE:** Colorado Department of Public Health and Environment

**PPACG:** Pikes Peak Area Council of Governments

**RAQC:** Regional Air Quality Council of Denver

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# Appendix 4

## National Ambient Air Quality Standards (NAAQS)

The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards (40 CFR part 50) for pollutants considered harmful to public health and the environment. The Act identifies two types of standards. Primary standards provide public health protection, including protecting the health of “sensitive” populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. EPA has set NAAQS for six “criteria” pollutants listed below. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air (µg/m3). The standards shown in the table below are effective October 2011.

| Pollutant<br>[final rule cite] | | Primary/ Secondary | Averaging Time | Level | Form |
|---|---|---|---|---|---|
| Carbon Monoxide<br>[76 FR 54294, Aug 31, 2011] | | primary | 8-hour | 9 ppm | Not to be exceeded more than once per year |
| | | | 1-hour | 35 ppm | |
| Lead<br>[73 FR 66964, Nov 12, 2008] | | primary and secondary | Rolling 3 month average | 0.15 µg/m3 (1) | Not to be exceeded |
| Nitrogen Dioxide<br>[75 FR 6474, Feb 9, 2010]<br>[61 FR 52852, Oct 8, 1996] | | primary | 1-hour | 100 ppb | 98th percentile, averaged over 3 years |
| | | primary and secondary | Annual | 53 ppb (2) | Annual Mean |
| Ozone<br>[73 FR 16436, Mar 27, 2008] | | primary and secondary | 8-hour | 0.075 ppm (3) | Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years |
| Particle Pollution<br>Dec 14, 2012 | PM2.5 | primary | Annual | 12 µg/m3 | annual mean, averaged over 3 years |
| | | secondary | Annual | 15 µg/m3 | annual mean, averaged over 3 years |
| | | primary and | 24-hour | 35 µg/m3 | 98th percentile, averaged over 3 years |
| | PM10 | primary and secondary | 24-hour | 150 µg/m3 | Not to be exceeded more than once per year on average over 3 years |
| Sulfur Dioxide<br>[75 FR 35520, Jun 22, 2010]<br>[38 FR 25678, Sept 14, 1973] | | primary | 1-hour | 75 ppb (4) | 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years |
| | | secondary | 3-hour | 0.5 ppm | Not to be exceeded more than once per year |

(1) Final rule signed October 15, 2008. The 1978 lead standard (1.5 μg/m3 as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

(2) The official level of the annual NO2 standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

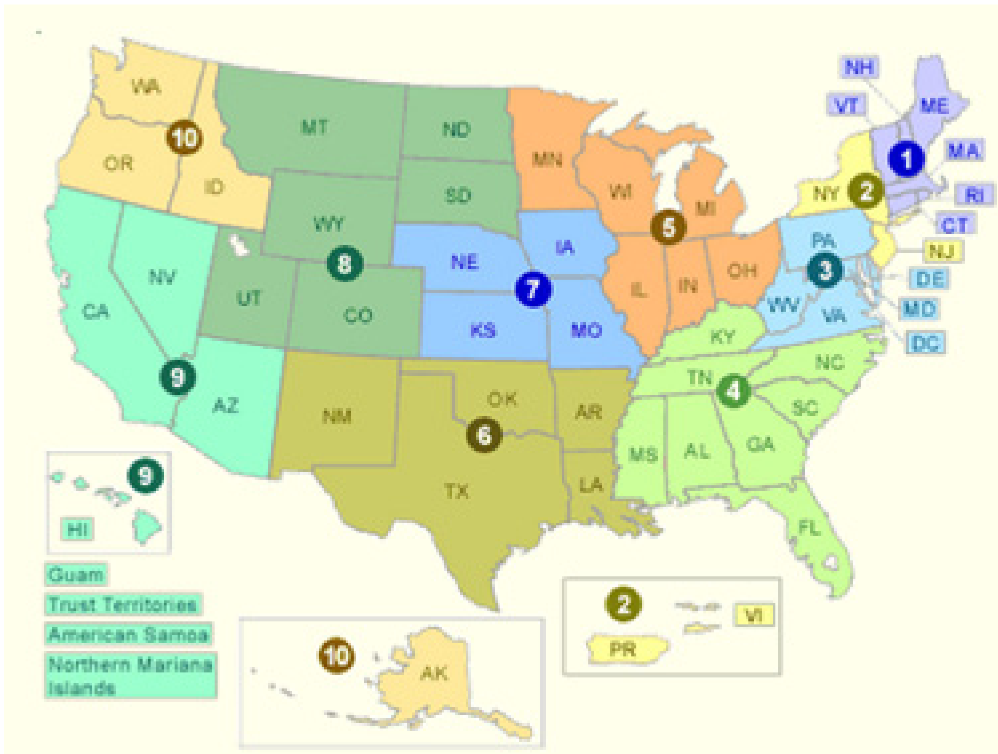
(3) Final rule signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years) and related implementation rules remain in place. In 1997, EPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per year) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The 1-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to 1.

(4) Final rule signed June 2, 2010. The 1971 annual and 24-hour SO2 standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

# Appendix 5

## Case Study Methodology

This study, funded by NASA and in partnership with EPA and Sonoma Technology, Inc., addresses the ways in which current AirNow source data and data products contribute to socioeconomic benefits today and how satellite-enhanced data might contribute to different or greater benefits in the future.




To understand the potential benefits of adding satellite data to AirNow, we put that data in a larger context including the flow of air quality monitoring data among different stakeholders. Within the regulatory process that requires compliance with the NAAQS established under the Clean Air Act, data are collected hourly but organized and reported quarterly to the US Environmental Protection Agency by the air quality agency in each state. States that do not meet the air quality standard are required to develop and implement action plans to come into compliance. Most of the improvement in air quality in the U.S. can be attributed to the adoption and enforcement of these standards which have influenced both public policy and private enterprises. AirNow uses essentially the same data for non-regulatory purposes, but use this data in near-real time, before extensive quality assurance has been performed. State air quality agencies use AirNow data to forecast air quality conditions for the next day and to inform the public and the media about potentially unhealthy conditions so they can take action to reduce pollution and protect human health.

Most research on the benefits of air quality regulation and information rest on complex mathematical models or surveys that cover extensive regions of the US or the entire country. By contrast, this study attempts to understand the value of monitoring data from a community-level view through three case studies: Denver, Atlanta, and Kansas City located respectively in EPA Regions 4, 7 and 8.

Using these communities as a focus, we take localized contexts into consideration to address the following questions:

- Who are stakeholders in air quality information in the case study area? What are their needs and capabilities?
- Who uses AirNow source data and data products now and how do they use it?
- What techniques or strategies seem to have the most positive effect on public awareness and behavior? What evidence is available on these effects?

- What gaps or weaknesses in current data reduce its usability and usefulness for different kinds of users?
- To what extent could NASA satellite data ameliorate these problems or provide for new or expanded uses?
- What other activities, information, or capabilities would enhance the usability and usefulness of AirNow data for informing and educating the public about air quality and its effects on health and quality of life and for furthering the goals of the Clean Air Act?

We organize the analysis according to a public value framework that assesses the impact of existing AirNow source data and data products along several dimensions including economic, social, strategic, quality of life, stewardship, and mission impacts.

The case studies involved 23 face-to-face and three telephone interviews with responsible officials and leaders in these communities representing EPA, state agencies, local public health authorities, regional planning and outreach organizations, university researchers, and relevant others. Interviews were transcribed and coded to identify factors associated with each of the research questions and the various indicators of public value. The study data also include regulatory documents, news media, local and state websites and reports, and a previous research studies in these three sites.

# Endnotes

[i]The full NAAQS is found at http://www.epa.gov/air/criteria.html and in the Appendix.

[ii]For more information about 40 CFR Part 58 see http://www.gpo.gov/fdsys/pkg/CFR-2002-title40-vol5/pdf/CFR-2002-title40-vol5-part58.pdf.

[iii]See Ambient Air Monitoring Network Assessment Guidance. Prepared by STI 2007, pp. 2-1 – 2-3.

[iv]The AirNow Satellite Data Processor Website is located at http://asdp.airnowtech.org/

[v]In the 1980s, public surveys identified the brown cloud as a top concern in the eyes of the general public and local leaders began to perceive it as an obstacle to restoring economic health to the metropolitan area. Then Governor Romer commissioned a study and based on the results, called for the creation of the visibility standard. For more information see http://www.albany.edu/cpr/stewart/Papers/T0210-ElyDenverVisStandard-1991cap.pdf

[vi]For more information on the Denver region's ozone chronology see http://www.colorado.gov/cs/Satellite/CDPHE-AP/CBON/1251594875735.

[vii]For more information on RACQ's role in State Implementation plans see http://raqc.org/programs/more/state_implementation_plans/.

[viii]"Non-state" monitors refers to federal agency monitors such as Forestry Service or other monitors owned and maintained by local governments or communities. "Non-reference" monitors refer to those monitors not certified by EPA for providing regulatory quality data.

## THE CENTER FOR TECHNOLOGY IN GOVERNMENT

The mission of the Center for Technology in Government (CTG) at the University at Albany/SUNY is to foster public sector innovation, enhance capability, generate public value, and support good governance.  We carry out this mission through applied research, knowledge sharing, and collaborative problem solving at the intersection of policy, management, and technology.

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