The Visibility Information Exchange Web System (VIEWS)

http://views.cira.colostate.edu

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The Visibility Information Exchange Web System (VIEWS) is a website and database system designed to provide easy access to a wide variety of air quality data through an integrated suite of visualization and analysis tools. VIEWS began as a collaborative effort funded by EPA, between the five Regional Planning Organizations (RPOs) responsible for analyses to support regional haze planning by each of the 50 states and the National Park Service Visibility Program at CIRA to help states, tribes, federal land managers, researchers, and planners evaluate air quality and visibility in federally-protected ecosystems according to the stringent requirements of the EPA's Regional Haze Rule and the National Ambient Air Quality Standards. As a result of its early success and growing inventory of data and tools, VIEWS began to attract a wider audience in the years following its debut, and its original focus on regional haze has since been expanded to include climate change, health effects, emissions control strategies, and general environmental impacts.

Figure 1: The VIEWS home page provides a guided tour of features, information on recent data updates, local weather news, maps of visibility and weather webcam locations, and local air quality news.

VIEWS provides access to over five dozen different air quality datasets, including data from the EPA's Air Quality System (AQS), the Clean Air Status and Trends Network (CASTNet), the National Atmospheric Deposition Program

(NADP), AIRNow, and the National Emissions Inventory. VIEWS is also the primary dissemination point for data from the Interagency Monitoring of Protected Visual Environments (IMPROVE), a national monitoring initiative designated by the EPA as the official source of data for use in calculating visibility impairment from fine particulate matter in federal Class I Areas in accordance with the Regional Haze Rule and the Clean Air Act. The VIEWS team is also starting to incorporate results from a variety of air quality and meteorological models, as well as data and images from several NASA satellites. A primary goal of VIEWS is to bring together ground-based observations, modeling results, emissions inventories, and satellite data into a single, integrated system so that they can be compared and analyzed side-by-side in order to give the user a more comprehensive understanding and "one atmosphere" view of air quality.

VIEWS employs an advanced data acquisition and import system to consolidate air quality data from a variety of sources into a single, highly-optimized data warehouse. Ground-based measurements from dozens of monitoring networks, air quality modeling results, and detailed emissions inventories are imported and updated on a regular basis using a systematic data model and carefully standardized metadata. The names, codes, units, and flags used in the source datasets are carefully mapped to a unified protocol, and native formats and organizations are transformed into a common, normalized database schema. This design enables users to explore, merge, and analyze datasets of widely-varying origin in a consistent manner using a single set of tools and web services. This degree of integration allows decision-makers to analyze diverse datasets side-by-side and focus on high-level planning strategies without having to contend with the details of data management and manipulation.

At present, VIEWS has over 1500 registered users from over 100 different countries and 500 different organizations, including scientists, students, researchers, planners, and stakeholders. In 2008, the VIEWS website averaged around 1200 unique visitors per day and had a yearly total of 2,343,012 individual page views from around 85,000 unique IP addresses, a volume of traffic that has been steadily increasing every year since the first launch of the system in late 2002. While the majority of visits come from users in the United States, an increasing number are coming from other countries, and the development team has received several inquiries about the possibility of adding international air quality data to the VIEWS database.

In 2006, VIEWS was selected by the Western Regional Air Partnership (WRAP), the largest RPO administered by the Western Governors' Association and the National Tribal Environmental Council, to serve as the infrastructure for the WRAP's Technical Support System (TSS). The TSS is an extended suite of analysis and planning tools designed to help planners develop long term emissions control strategies for achieving natural visibility conditions in Class I Areas by 2064. The TSS was designed upon the foundational database and software framework developed for VIEWS, and leverages this infrastructure to provide a unique decision support system for Western states and tribes that are seeking to develop emissions control strategies and track the effectiveness of those strategies over time. The TSS also consolidates the data resources of the WRAP's Emissions Data Management System (EDMS), Fire Emissions Tracking System (FETS), Regional Modeling Center (RMC), and Causes of Haze Assessment project. The integrated systems approach that has been used to design the framework of the VIEWS/TSS allows developers to leverage and add value to these additional significant investments in data, expertise, and information technology.

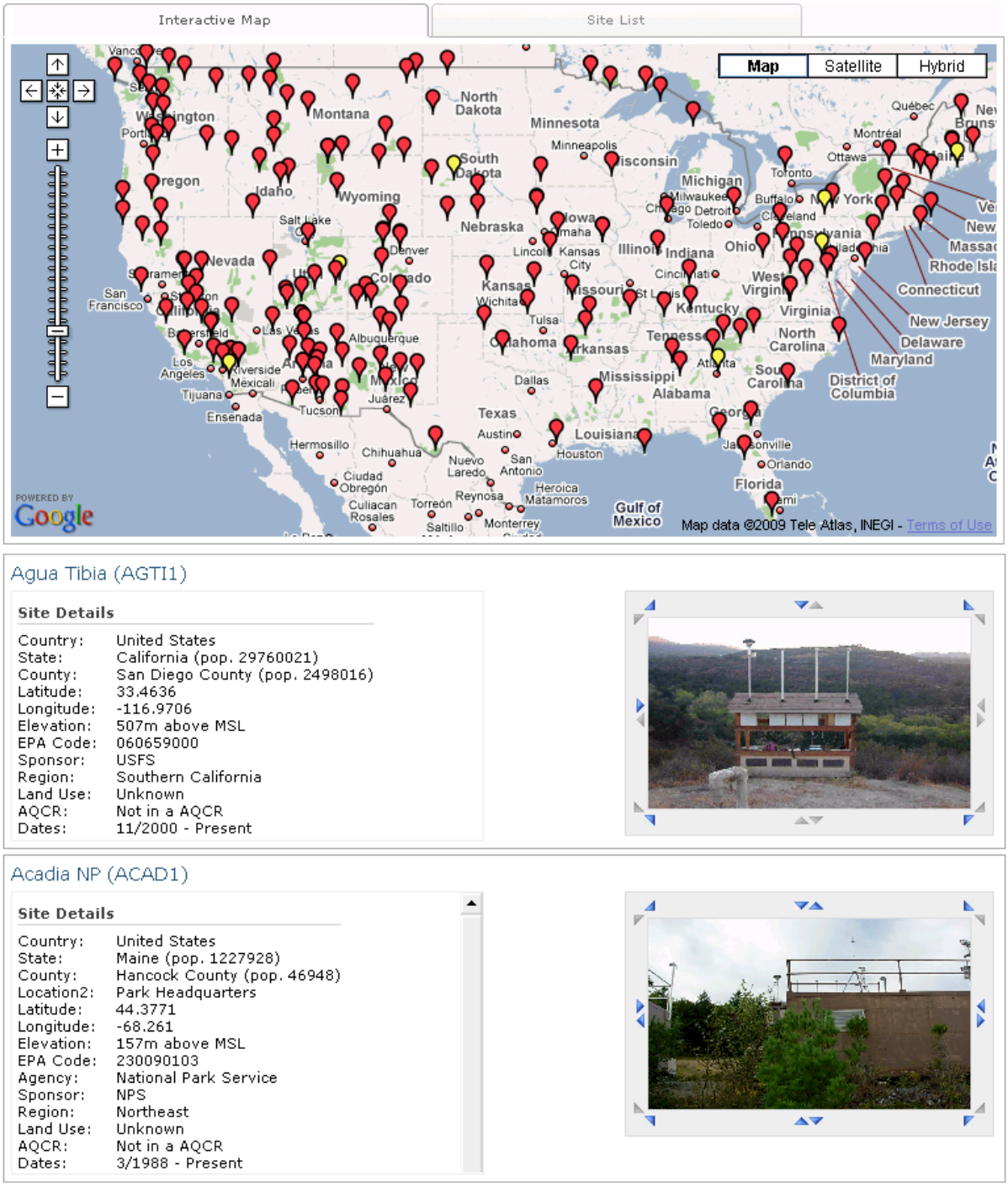

Figure 2: The VIEWS site browser uses Google Maps to allow users to select and view metadata details about data collection locations.

The WRAP has been instrumental to the continued development VIEWS, both from a funding and planning standpoint. As the largest of the RPOs, the WRAP represents a history of almost 20 years of collaboration on the technical aspects of western air quality issues, and has established valuable precedents for air quality planning and tracking that have often been facilitated by its ongoing investment in VIEWS/TSS. This investment, bolstered by the participation and in-kind support of states, tribes, and federal agencies, has been instrumental in establishing a broad basis for developing a regional understanding of air quality issues related to environmental health, ecological and aesthetic protection of our natural areas, and beginning to evaluate the air quality impacts of climate change and adaptation. The VIEWS team plans to continue working with the WRAP to evolve the

VIEWS/TSS into an enterprise-level decision support system that can serve the air quality analysis and planning needs of air quality researchers worldwide.

VIEWS/TSS users are typically asking questions of "What pollutants are impacting a given area?" and "Where are these pollutants coming from?" States are further mandated to answer the question of "What can be done to reduce these impacts?", because the Regional Haze Rule requires states and tribes to develop implementation plans for reducing emissions and demonstrating reasonable progress towards doing so, and these plans must provide for an improvement during the 20% worst visibility days while also ensuring no degradation during the 20% best visibility days. To accomplish this, users must identify the pollutants impacting a given area, quantify their amounts, and determine the sources of anthropogenic emissions that contribute to this pollution on both the "best" and the "worst" visibility days in the area. They must then determine available control measures for each source and evaluate these measures on the basis of costs, time, energy and environmental impacts, and the remaining life of the source. Planners then employ these analyses to make decisions about what controls to implement, to estimate projected improvements, and to track their progress in reaching these goals. The resulting decisions have obvious ecological impacts, but can also have important political and economic impacts in the sense that deciding which sources to control is a significant issue for such an aesthetic standard, and the process of controlling emissions and tracking progress costs money and takes time.

This rather complex decision-making process requires an array of analytical tools and a multiplicity of data. Historically, planners had to assemble this data from a wide variety of segregated sources, reorganize and reformat it, and then employ an inconsistent and heterogeneous collection of tools to examine and analyze it. With VIEWS/TSS, planners can now use a single, standardized database and an integrated suite of tools to access all the resources they need and answer the questions, perform the analyses, and make the decisions required for the development and acceptance of their state and tribal implementation plans.

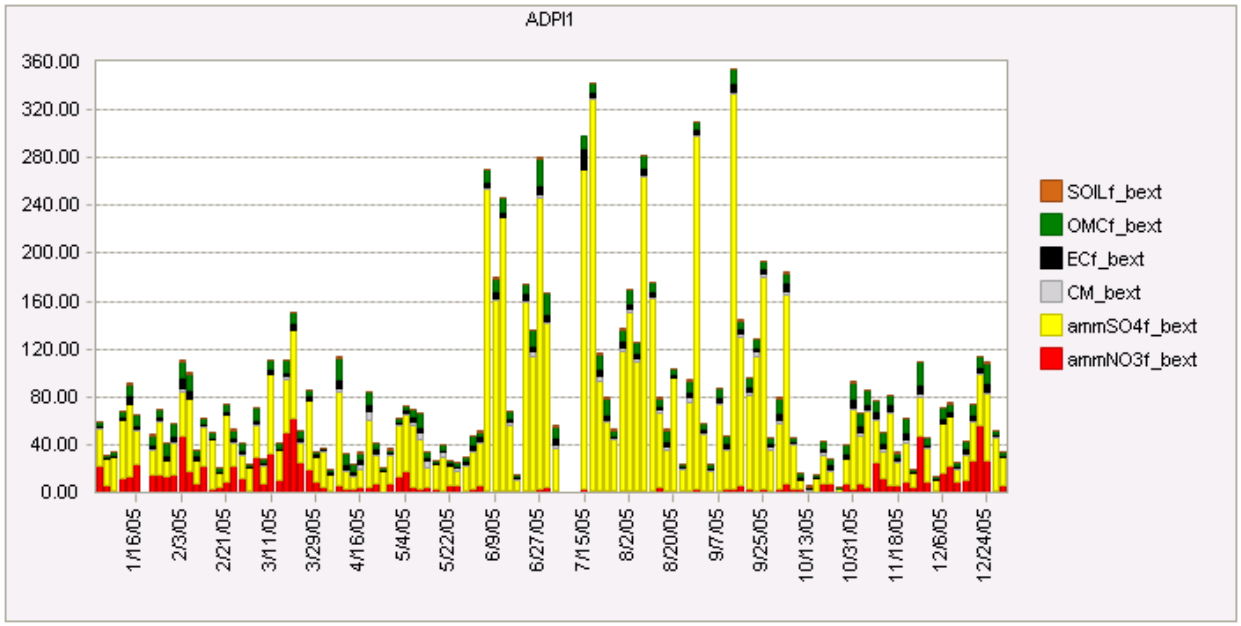

Figure 3: An integrated suite of interactive visualization and analysis tools provide quick exploration of patterns and trends in the data.

To further enhance the value of VIEWS for the purposes of air quality decision support, the team collaborated in 2007 with the Institute for the Environment at the University of North Carolina, Chapel Hill to submit a NASA ROSES proposal to incorporate satellite data into VIEWS/TSS. The proposal was awarded, and work began at CIRA in mid-2008 to seamlessly integrate a wide variety of NASA satellite data into VIEWS. It is hoped that the satellite data, through their extensive temporal frequency and geographic coverage, will yield important insights into the temporal evolution and the three-dimensional distribution of atmospheric aerosols. In addition, air quality modeling specialists at UNC are using the satellite data to enhance the inputs and boundary conditions of the

Community Multi-scale Air Quality Modeling System (CMAQ). Once the model has been appropriately augmented with the satellite data, the results will be added to the raw data already in VIEWS to provide a unique comparison between the original model results and those that have been augmented with the satellite data, an effort that is expected to improve the predictive capabilities of the air quality models and significantly increase understanding of both the observed and simulated systems as changes in anthropogenic and natural emissions occur over time. The availability of both the raw and model-integrated satellite data will complement the existing inventory of ground-based, modeled, and emissions data in VIEWS to provide end users with a uniquely comprehensive collection of air quality data that can be visualized and compared using an integrated set of tools.

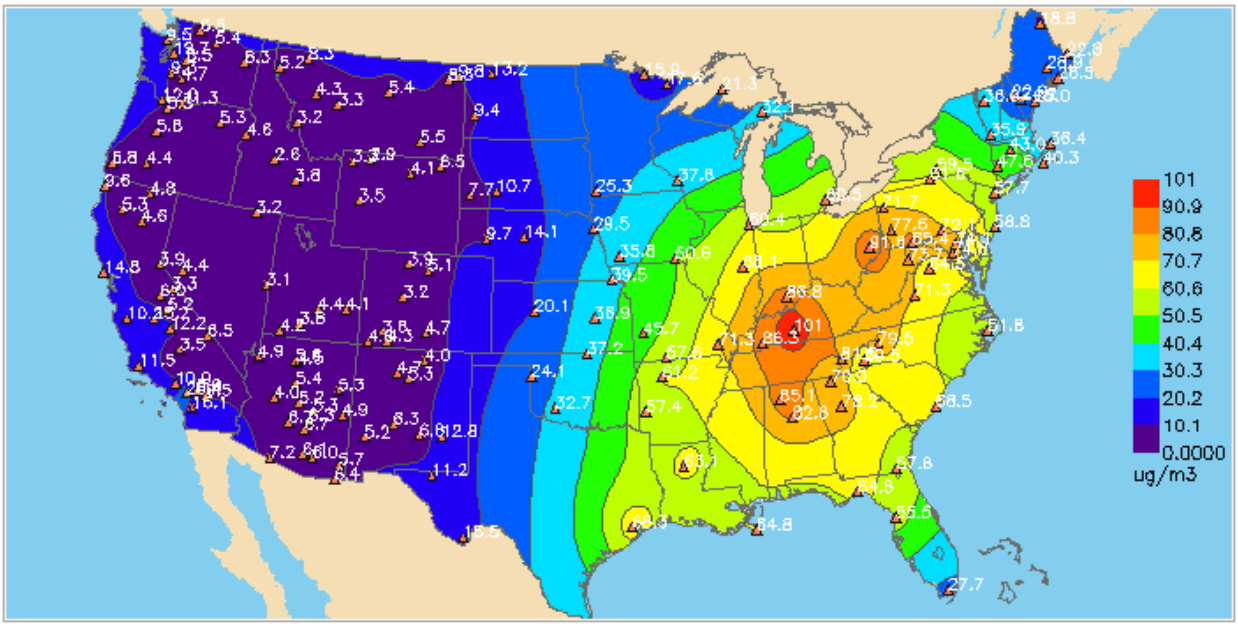

Figure 4: A variety of mapping tools can be used to view the geospatial distribution of the data.

The VIEWS team also won a proposal in 2008 to incorporate results from the Navy Aerosol Analysis and Prediction System (NAAPS) in collaboration with the U.S. Naval Research Laboratory (NRL). NAAPS, with data assimilation of NASA Earth Sciences data, produces accurate and timely quantitative forecasts and analyses of the distributions of dust and smoke that originate outside the U.S. The VIEWS team will work with NRL to add NAAPS data to VIEWS in order to provide better quantification of the influx and impact of international aerosol plumes. The use of these data will result in more thorough identification of exceptional events, long range transport of aerosols, and better estimates of the impact of these sources on U.S. air quality. And because the transport of international aerosol plumes to the U.S. is a complicated, three-dimensional process, the combination of NAAPS data with the satellite aerosol optical depth data being added to VIEWS as part of the 2007 ROSES project will provide a unique opportunity to study the long range transport of aerosols and may also help yield improvements to air quality model inputs and boundary conditions.

From the outset, a primary goal of the VIEWS development team has been to create a foundational software architecture that can be leveraged and extended easily by both the VIEWS team and outside developers that are implementing air quality decision support systems. To facilitate this “interoperability”, an emphasis has been placed upon designing VIEWS with a Service-Oriented Architecture (SOA), a design principle that separates functionality into distinct units, or services, which are provided over the Internet for users to combine and reuse in the development of their own applications. At present, many of the data retrieval mechanisms of VIEWS already make use of these services internally, and VIEWS developers are working to finalize these services so that they can be made directly available to other developers over standard Internet protocols. When complete, this collection of services will be offered to end users and other developers through an application programming interface that will allow the creation of “mashups” using VIEWS data and services.

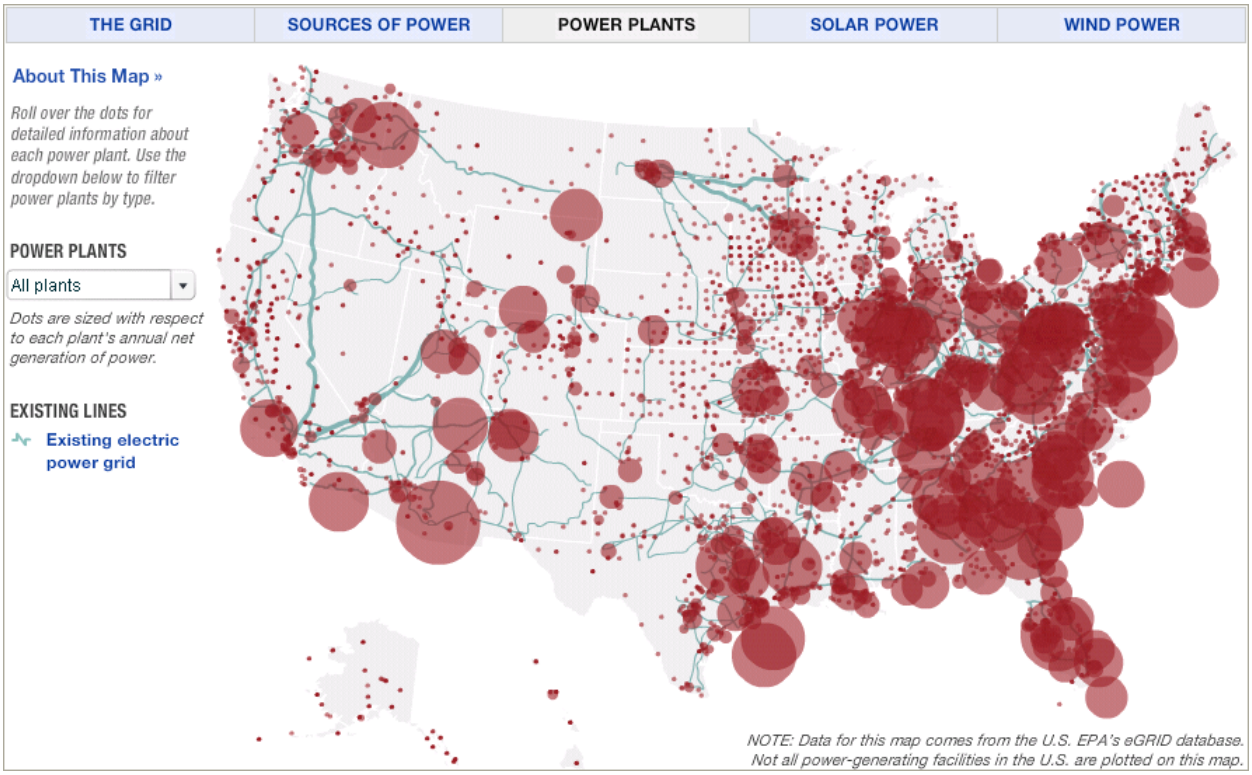

Figure 5: The locations of known emissions sources and power generation facilities are shown on a map using data from the EPA's eGRID database.

A critical component of this effort is collaboration with developers of other air quality systems to establish flexible and comprehensive metadata standards. To facilitate this, the VIEWS team has been participating in the development of the Global Earth Observation System of Systems (GEOSS), a long term project of the Group on Earth Observations (GEO) to collect and disseminate improved data, information, and models to stakeholders and decision makers. In 2008, VIEWS was selected to participate in the GEOSS Architectural Implementation Pilot as a "persistent operational exemplar" of a decision support system that is developing services that support the GEOSS Societal Benefit Areas (SBAs) using a consistent architecture and suite of standardized data exchange protocols. VIEWS will participate as an air quality data node in the proposed "system of systems", and will help facilitate the development of data exchange and interoperability standards to be utilized in the project.

The VIEWS team also participated in the EPA Data Summit held at Research Triangle Park, NC. The purpose of the summit was 1) to convene organizations and individuals with key roles in retrieving, storing, disseminating, and analyzing air quality data in order to learn about and explore efficient means of leveraging the numerous individual efforts underway; 2) to examine the mechanisms and potential opportunities for "interoperability" between existing systems, 3) to assist EPA/OAQPS in honing its role in the larger air quality data community; and 4) to begin to establish a community-wide strategy for responding to user defined needs. Subsequently, the EPA provided funding to help VIEWS become more of a multiple-pollutant data system and expand its scope beyond regional haze issues. Multiple datasets were considered, such as Ozone, CO, SO2, NH3, etc, and it was eventually decided that the incorporation of AQS Ozone data would be the optimal pilot project by which to begin this effort. The VIEWS team has imported the hourly EPA Ozone data into the integrated database and will be working with the EPA to design and develop tools for exploring, visualizing, and analyzing the data.

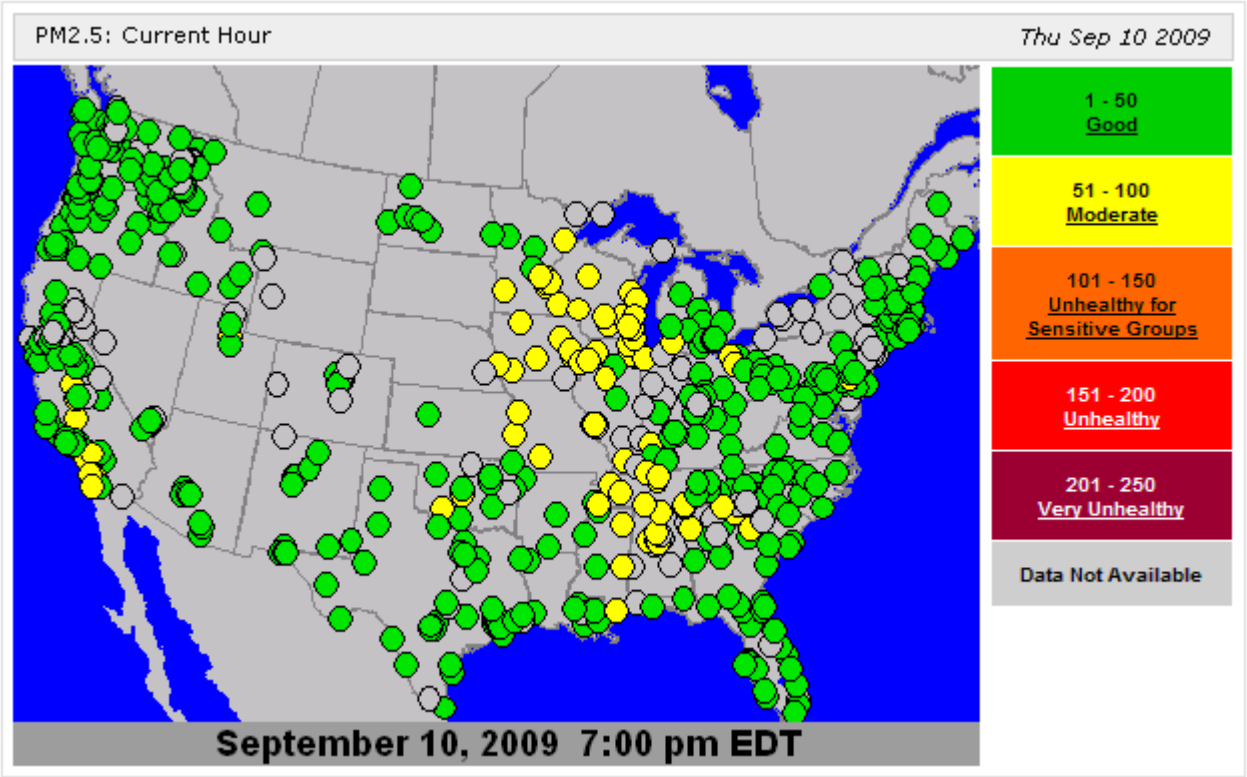

Figure 6: Air Quality Index (AQI) maps from AIRNow.gov are made available in a dynamic tool that allows quick date range selection and display customization.

In conjunction with these collaborations, the VIEWS team has been working over the past two years to develop an updated version of the website that will be initially launched in the fall of 2009 and further enhanced with additional incremental releases over the following year. The new website incorporates a variety of new technologies and techniques, and is deployed upon newly upgraded hardware. The update introduces a new "look and feel" to the site and will offer several new features, including a user forum, a new database query wizard, dynamic contour maps, air quality index maps, and daily images from NASA's Terra, Aqua, Aura, and CALIPSO satellites. Various new tools also make use of Google maps for the display of monitoring site locations and geospatial datasets, and a searchable "Dataset Index" allows the user to more easily explore the complete inventory of the integrated database and search for data by keyword. Photographs of monitoring site locations are available for some networks, and visibility and weather webcams are also offered. Raw data can be downloaded as files or visualized through dynamic charts, graphs, and maps. The VIEWS website is publicly accessible and does not require a username and password, but users are encouraged to register for an account so that they can take advantage of certain personalization features and help build an online community of air quality data specialists and consumers.

The VIEWS development team consists of principal investigator Shawn McClure, a software engineer who developed the database and software infrastructure on which VIEWS is built, developer Dr. John Huddleston, a retired federal employee and registered professional engineer who holds a PhD in Geophysics from Colorado State University, and researcher Dr. Duli Chand, a scientist from the University of Washington in Seattle who holds a PhD in Atmospheric Trace Gases and did his post doctorate at the Max Planck Institute for Chemistry in Mainz, Germany. Providing administrative leadership from the WRAP and the Western Governors' Association is Tom Moore, and providing scientific guidance from the National Park Service is Dr. Bret Schichtel. In addition, Helene Bennett of CIRA contributes invaluable administrative and operational support on a daily basis, and Dr. Bill Malm of the National Park Service has also contributed instrumental scientific guidance and support. The VIEWS team is committed to making the system as useful and relevant as possible to the evolving needs of air quality researchers worldwide, so visitors to the website are encouraged to provide comments, suggestions, and requests for additional new data and functionality.