AIRNow AIR QUALITY NOTIFICATION AND FORECASTING SYSTEM.

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1. INTRODUCTION

Like many countries around the world, the United States (U.S.) experiences air pollution problems. The two major pollutants of concern are ground-level ozone and particulate matter ($PM_{2.5}$ and PM_{10}—also called particle pollution). While ozone is mostly a summertime problem, particle pollution can occur throughout the year. The U.S. National Ambient Air Quality Standard (NAAQS) for ozone is a daily 8-hr average of 85 parts per billon (ppb). The standard for $PM_{2.5}$ is a 24-hr average concentration of 65 µg/m^3 and an annual standard of 15 µg/m^3.

Ground-level ozone can be harmful to human health and plant life and is created by emissions from man-made and natural sources. PM is a complex mixture of solid and liquid particles that vary in size and composition, and remain suspended in the air. Over the past decade, several health effects studies have shown an association between exposure to PM and increases in daily mortality and symptoms of certain illnesses (HEI, 2002; Dockery and Pope, 1994; Schwartz, 1994).

Historically, air quality data collected by local, Tribal, State, and federal air quality agencies in the U.S. have been quality-controlled and calibrated and sent to the U.S. Environmental Protection Agency (EPA) approximately three to six months after data collection. While this decentralized collection program is adequate for regulatory purposes and for evaluating long-term trends, real-time data and forecasts were not widely available to decision makers, the public, and the media prior to EPA's AIRNow program.

AIRNow consists of a centralized Data Management Center (DMC) that receives real-time ozone and particle pollution data from more than 115 U.S. and Canadian agencies as well as air quality forecasts from over 300 U.S. cities. AIRNow also maintains an informational web site (www.epa.gov/airnow) where the principal products are posted: ozone and $PM_{2.5}$ maps and city air quality forecasts. Current air quality is shown with point and contour maps that are animated with color-coded pollutant concentrations according to the EPA's Air Quality Index (AQI). The animated point and contour maps, much like radar images showing precipitation, display the hourly formation and movement of particle pollution and ozone.

This paper provides an overview of the components of the AIRNow notification and forecasting program. This includes how the DMC coordinates with over 115 air quality agencies that supply hourly air quality data and issue air quality forecasts; develops software and database systems to quality-control and process the data; and distributes this air quality information to the public and media. Many of the AIRNow systems and methods could be applied to air quality issues in other countries, including China.

2. BACKGROUND

Because ground-level ozone is regional in nature and the public wants and needs to be informed of its possible health effects, EPA developed the AIRNow program in 1998 to provide easy and timely access to national air quality information. AIRNow emerged from EPA's Environmental Monitoring for Public Access and Community Tracking (EMPACT) initiative to provide time-relevant, environmental information to the public. Initially, the program focused on ground-level ozone because it was the most common—and the most understood, as well as monitored—air pollution problem. The AIRNow program was created to address the lack of real-time data and to link air quality pollutant concentrations to health-based cautionary messages utilizing the AQI (U.S. Environmental Protection Agency, 1999, 2000).

The AQI, established by the EPA under the Clean Air Act, is a color-coded, nationally uniform index for reporting air quality data to the public. It provides a simple, consistent system to report levels of air pollutants. It also links health impacts to air pollutant concentrations and provides the public with easy-to-understand information about air quality so that citizens can determine their own levels of health concern. The AQI converts a measured pollutant concentration to a number on a scale of 0 to 500, as shown in Table 1. The AQI value generally corresponds to the NAAQS established for pollutants addressed by the Clean Air Act. An AQI above 100 indicates that the air could be unhealthy to certain individuals.

Providing educational materials and training about the health effects of air quality is just as critical as providing the real-time data and forecasts. The EPA has developed numerous brochures about the AQI (EPA, 2000), ozone health effects (EPA, 1999a,b), and the differences between ground-level and stratospheric ozone (EPA, 1997a), as well as guidance on how to provide AQI forecasts to the public (EPA, 1999c). This information helps the media and the public understand the relationship between air quality and health so that forecasts and real-time data can be used to make health-based decisions.

Table 1. Air Quality Index numbers, categories, and concentration cut points for ozone, $PM_{2.5}$, and PM_{10}.

AQI	AQI Category	AQI Color	O_3 (ppb) (8hr)	(1hr)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
0 -50	Good	Green	0 – 64	–	0 – 15	0 – 54
51-100	Moderate	Yellow	65 – 84	–	16 – 40	55 – 154
101-150	Unhealthy for Sensitive Groups	Orange	85 – 104	125 – 164	41 – 65	155 – 254
151-200	Unhealthy	Red	105 – 124	165 – 204	66 – 150	255 – 354
201-300	Very Unhealthy	Purple	125 – 374	205 – 404	151 – 250	355 – 424
301+	Hazardous	Maroon	–	405 – 604	251 – 500	425 – 604

3. DATA FLOW IN THE AIRNOW SYSTEM

The flow of data through the AIRNow system and the resulting products are shown schematically in Figure 1. Each hour, the data flow starts at over 1300 ozone and nearly 400 $PM_{2.5}$ monitoring sites covering 46 states, the District of Columbia, and Canada. More than 115 State, Tribal, local, and federal air quality agencies then collect the data and submit the data via file transfer protocol (FTP) to the DMC. Once at the DMC, software loads the ozone and particle pollution data into an Oracle relational database. Data undergo automated quality control (QC) checks to ensure that erroneous data are not used in the ozone or $PM_{2.5}$ maps. The QC checks include maximum and minimum thresholds, rate of change, and other more advanced checks to detect inconsistencies with surrounding sites and monitors reporting a constant value. All QC criteria and thresholds are set for each monitor, pollutant, and hour. Next, air quality data are converted to the AQI. At 30 minutes past every hour, local, regional, and national animated ozone and $PM_{2.5}$ maps are generated. These maps are transferred to the EPA's AIRNow web site, media outlets, and ultimately to the public. Figure 2 shows an example of the local, regional, and national ozone and PM maps available on the AIRNow web site.

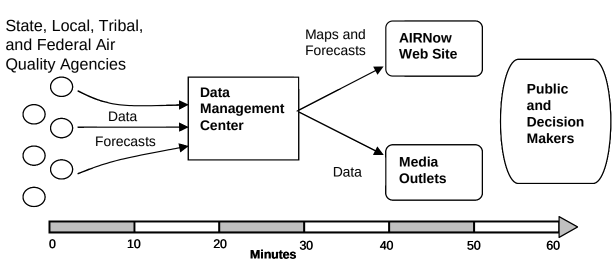

Figure 1. Schematic showing the data flow and resulting product distribution to the public.

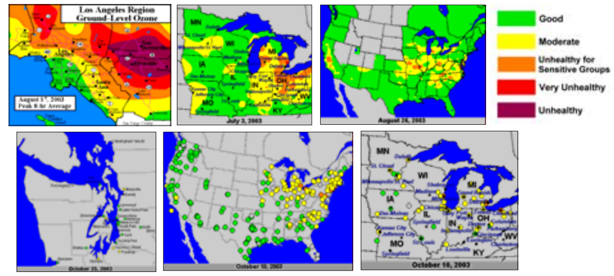

Figure 2. Local, regional, and national maximum daily ozone and $PM_{2.5}$ AQI maps.

4. AIR QUALITY FORECASTING

Reporting current real-time air quality information via maps of the AQI is a very useful tool. However, AQI forecasting provides the ultimate guidance for health protection as it allows individuals to plan and make lifestyle changes that may reduce their exposure on poor air quality days. Air quality forecasting depends not only on weather prediction, but also on prediction of how the weather affects emissions, chemical reactions, and pollutant transport. It also relies on an understanding of the spatial-temporal patterns of biogenic and anthropogenic emissions.

Ozone forecasting has been occurring in the U.S. since the early 1990s, and forecasting skill and accuracy are constantly improving. Recently, air quality agencies have begun forecasting particles. Air quality forecasts are issued for ozone and particles by local meteorologists for over 300 cities across the U.S. as part of the AIRNow program, as shown in Figure 3. Most forecasters submit their forecasts to AIRNow daily by early afternoon. Forecasters use a variety of tools and techniques to predict daily peak air quality values (Dye et al., 2000; Ryan, 1994; Comrie, 1997).

To create a daily ozone forecast, meteorologists with experience in air quality forecasting use several tools as guidance. One of them is the criteria method which utilizes specific threshold values (criteria) of meteorological or air quality variables to forecast ozone concentrations. For example, hot temperatures are often associated with high ozone concentrations; thus, future high ozone concentrations can be expected when hot temperatures are predicted. Another tool, statistical regression equations, was developed to describe the relationship between ozone concentrations and other predictor variables (for example, temperatures and wind speeds). Other air quality forecasting techniques include Classification and Regression Tree (CART), intuition, and climatology.

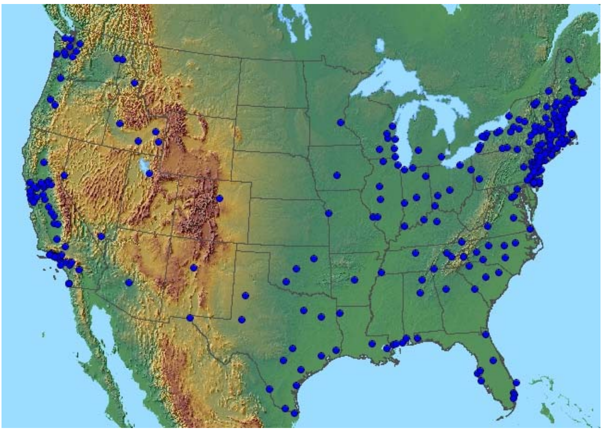

Figure 3. AIRNow Forecast Cities.

Recently, EPA recognized the need to start forecasting $PM_{2.5}$. EPA developed a series of forecasting tools to aid State and local forecasters in predicting $PM_{2.5}$. These tools consist of phenomenological tables and statistical methods. In addition, EPA developed regional workshops and a $PM_{2.5}$ forecasting guidance document (U.S. Environmental Protection Agency, 2003c). The statistical forecasting tools were developed using CART analysis. CARTs are decision trees derived by systematically splitting historical peak pollutant concentration data into two groups based on a single value of a selected predictor variable. For air quality forecasting, a decision tree can be used to predict future pollutant concentrations based on the values of forecasted weather variables. Figure 4 shows an example decision tree for Columbus, Ohio.

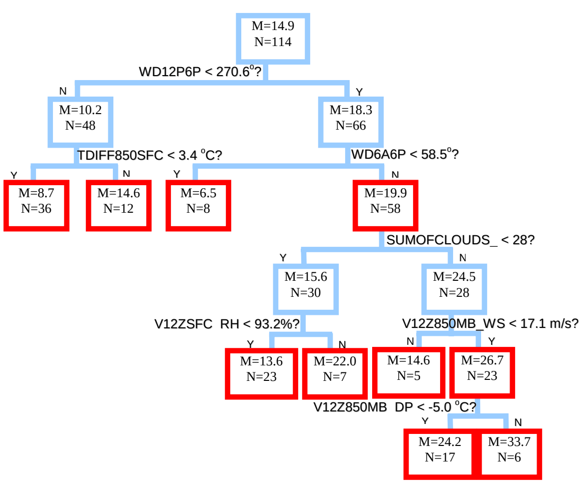

Figure 4. CART for predicting 24-hr average $PM_{2.5}$ concentrations in Columbus, Ohio. Variables include wind direction, cloud cover, north-south component of the wind, and vertical temperature difference. "Y" and "N" indicate which branch of the tree to proceed down given the condition. In the boxes, M = 24-hr average $PM_{2.5}$ concentration in the node, and N = number of cases in the node. The correlation (r^2) for this decision tree is 0.72.

EPA also developed phenomenological tables relating weather conditions and expected particle pollution levels. These tables incorporate forecasts of important weather features to estimate future air quality conditions.

EPA forecasted air quality for the 2002 Winter Olympics in Salt Lake City, Utah. This region has strong temperature inversions during the winter, which can trap particle pollution near the surface. The goal of this project was to develop and implement $PM_{2.5}$ forecasting techniques for Salt Lake City. EPA developed statistical forecasting tools to predict $PM_{2.5}$ concentrations for the current- and next-day periods. Forecasting was performed during a 45-day period around the Olympic Games. These forecasts were used by the Utah Department of Environmental Quality to help plan their media and outreach strategies during the Olympics, especially to anticipate days with poor air quality. Several media sources used the $PM_{2.5}$ forecasts. *USA Today* newspaper published air quality forecasts several times on the weather page as shown in Figure 5.

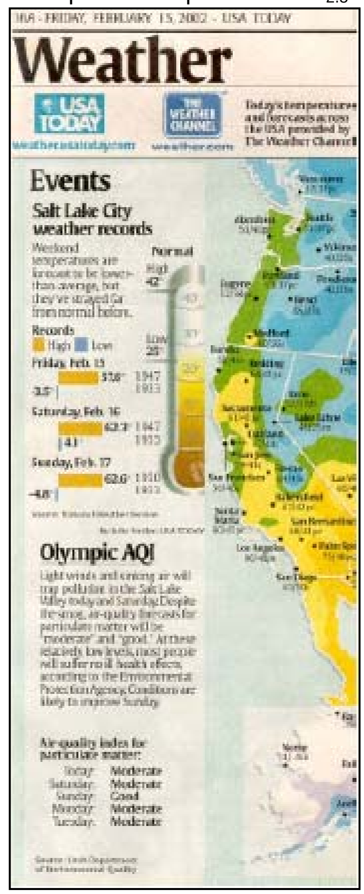

Figure 5. *USA Today* article on air quality forecast during the 2002 Winter Olympics published on February 15, 2002.

The U.S. air quality forecasting community ranges from very experienced forecasters to individuals with modest meteorological and air quality experience and knowledge. The AIRNow program is actively training new and existing air quality forecasters in prediction methods and techniques (U.S. EPA, 2003; Dye et al., 2003). In addition, new forecasting guidance, generally considered to be methods, tools, and models that provide predictions, are being created by the National Oceanic and Atmospheric Administration and the private sector to help local forecasters produce improved air quality forecasts.

5. PUBLIC AND MEDIA NOTIFICATION

AIRNow is the public's focal point for accessing current air quality conditions and forecasts for the U.S. and Canada. Effective communication of air quality information to the public requires distributing this information to media outlets via Internet content providers and commercial weather service providers (WSPs) for television weathercasts and newspapers.

On the Internet, the AIRNow web site (www.epa.gov/airnow) provides easy access to real-time local, regional, and national air quality maps, displays air quality forecasts, and offers suggestions about what individuals can do to improve air quality. These maps and forecasts are also available on several commercial web sites, for example, www.weather.com and www.weatherunderground.com as shown in Figure 6. Decision makers can use the information to convey messages to the public, alert the public to possible health impacts, encourage voluntary emission reduction actions, and implement public outreach and education programs. Numerous local programs use AIRNow's ozone maps directly as part of their local outreach programs. One example is the "Spare The Air" program (www.sparetheair.com) in Sacramento, California.

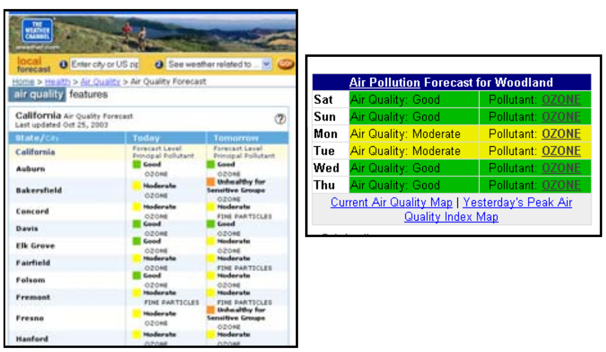

Figure 6. Air quality forecasts from the AIRNow project used on Weather.com and Weatherunderground.com.

To reach television audiences, the AIRNow program works with commercial WSPs who supply television stations (and other media outlets) with graphics and weather data, thereby enabling air quality information to reach millions of people. For example, air quality forecasts have been routinely featured on television on the Cable News Network's (CNN) weathercasts as shown in Figure 7. Additionally, *USA Today* publishes AQI forecasts for 36 major U.S. cities, Monday through Friday, as shown in Figure 8. The AIRNow program also provides educational stories to news media to help explain current important weather and air quality phenomena.

Figure 7. Air quality forecasts and ozone maps from the AIRNow project used on CNN.

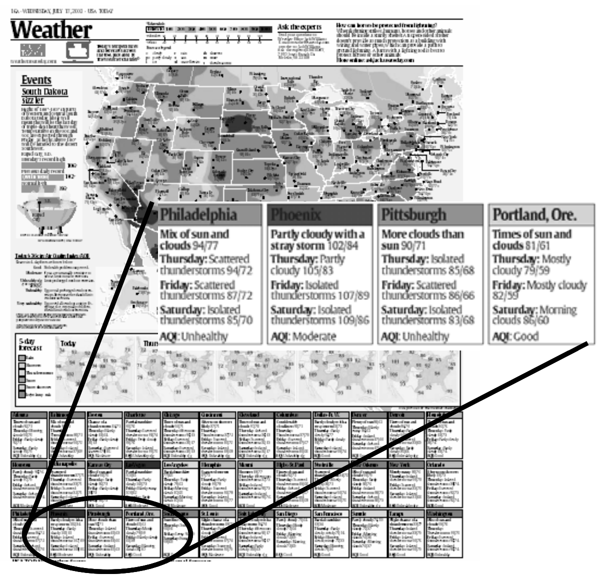

Figure 8. An example of a *USA Today* Weather Page. The AQI forecasts are printed below the weather forecasts for 36 U.S. Cities.

The distribution of air quality information to media outlets accomplishes the ultimate goal of the AIRNow program: to provide air quality forecasts and real-time air quality information in a visual, easy-to-understand format to decision makers and the public.

6. LESSONS LEARNED AND FUTURE PLANS

A number of important lessons have been learned in setting up and operating the AIRNow system:

- Working with the voluntary stakeholder community of over 115 State, Tribal, local, and federal air quality agencies requires an effective way to communicate and resolve problems. The AIRNow program has developed e-mail systems and Internet-based news pages and conducts conference calls to keep the stakeholder community informed. Keeping the stakeholder community satisfied with existing and new tools for AIRNow is critical to ensuring long-term participation.

- Running the DMC around the clock requires a robust and redundant infrastructure (Internet, web servers, and communications) and a diverse team of personnel with operational and development skills. Although AIRNow is an automated system, it requires human oversight to ensure the quality and consistency of its operations and data products.
- Ensuring data quality is critical for this real-time system. Extensive QC procedures involve five QC checks for each data value. These checks rely on site-specific and hour-specific QC criteria that require manual adjustments by DMC operators.

The AIRNow program is continually expanding. Continuous PM monitors are still being deployed across the U.S. and Canada, and more particle pollution data are being sent to the AIRNow program. As more particle pollution data become available, new QC procedures will be implemented so that reliable data can be readily distributed to decision makers as well as the public. In addition, the flexibility of the program means that more criteria pollutant data can be accommodated. The AIRNow program is also seeking to expand coverage nationally as well as abroad to include the remaining states and other countries.

7. CONCLUSIONS

The AIRNow program was developed to make air quality-related products available to as many people as possible and to protect public health. Decision makers can now readily access real-time, dependable air quality data and subsequently take appropriate precautionary measures to alert the public and protect their health. As air pollution is a problem without boundaries and affects millions of people in the U.S. and around the world, a real-time air quality system similar to AIRNow can be applicable and beneficial to other countries.

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