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NORTH CAROLINA'S INTEGRATED AIR QUALITY AND METEOROLOGICAL MONITORING NETWORKS

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1. INTRODUCTION

The North Carolina Division of Air Quality (NCDAQ) developed the NC Air Awareness program in the spring of 1997. The key components of the program include: (1) educational outreach, media exposure, and a citizen awareness campaign, and (2) the production of a daily air quality forecast. Initially, the program provided air quality forecasts in the Charlotte metropolitan area based on the Federal 1-hour National Ambient Air Quality Standard (NAAQS) for ozone. The program transitioned to air quality forecasts based on the 8-hour ozone NAAQS in 1998, and the program has now expanded to include five metropolitan areas in North Carolina. During this five-year period, NCDAQ has identified and established a unique air quality and meteorological monitoring infrastructure that is fundamental to a credible air quality forecasting program.

While air quality forecasting is similar to weather forecasting, atmospheric data requirements for air quality forecasting extend beyond the normally reported meteorological information. Monitoring and analyzing atmospheric chemical constituents in real time as well as assessing detailed characteristics of the planetary boundary layer (PBL) are essential steps in producing the next day's air quality forecasts. The density and spatial distribution of air quality and meteorological monitoring sites are important to the identification and comprehension of varying pollutant concentrations across North Carolina's diverse geographic landscapes.

2. AIR QUALITY MONITORING

The Ambient Monitoring Section of NCDAQ, along with other air quality agencies in North Carolina, has developed a robust ozone monitoring network of 46 ozone monitors (Figure 1). Federal mandates require a minimum number of ozone monitors in urban areas based on population. North Carolina's monitoring network goes beyond those requirements by strategically placing additional monitors in areas downwind of urban centers and at rural background locations. With approximately one monitor per 2500 km^2, this is one of the densest statewide ozone monitoring networks in the nation.

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The robust ozone monitoring network reveals real-time ozone concentration gradients across North Carolina. This detailed spatial distribution of ozone increases the forecaster's ability to relate observed air quality to meso-scale meteorological features (Seaman and Michelson 1998) specific to each of the forecast regions. The enhanced dataset improves the air quality analysis that is fundamental in determining the next day's air quality forecast.

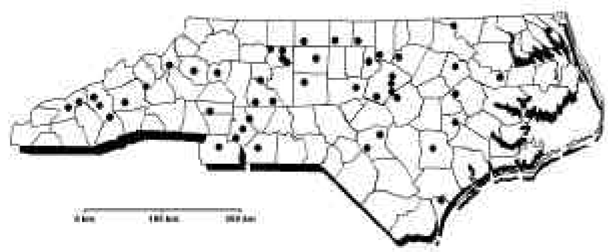

Fig. 1. North Carolina's Ozone Monitoring Network.

Regional background and transport are equally important factors to consider in developing the air quality forecast. Conventional surface-based ozone monitoring does not adequately resolve these factors because of several issues including the titration of ozone within the shallow nocturnal boundary layer (NBL) (Hogrefe et al. 2000). NCDAQ installed four ozone monitors on a 600 m television tower at the surface, at 76 m, at 128 m, and at 433 m to monitor ozone above the NBL and in the residual layer during the overnight period. The observed vertical distribution of ozone concentrations furthers the forecaster's understanding of the regional contribution to the current ozone situation (Zhang et al. 1998).

All of the monitored air quality data are collected hourly and reported to a centralized database at NCDAQ headquarters in Raleigh. NCDAQ then forwards the hourly ozone dataset to the United States Environmental Protection Agency (US EPA 2002) where the data are used to create animated graphics of spatial ozone concentrations across the nation for its AIRNow mapping program. NCDAQ forecasters are also able to communicate directly with the ozone monitors to assess minute-to-minute behaviors of ozone concentrations. This is particularly interesting at the television tower to observe the evolution of the convectively mixing boundary layer.

3. METEOROLOGICAL MONITORING

NCDAQ benefits from an expansive network of standard surface meteorological observations from Federal Aviation Administration and NC Department of Transportation ASOS and AWOS sites. Additionally, North Carolina State University's Agricultural Weather Network (AgNet) augments the standard dataset with additional information (Figure 2). The AgNet, operated by the State Climate Office of North Carolina (SCO 2002), includes 25 sites statewide with standard temperature, dewpoint, pressure, winds, and rainfall; however, AgNet adds solar radiation, soil moisture, and soil temperature, and at some sites an additional 10 m temperature. This additional data are critical in determining surface fluxes important to the PBL, and thus pollutant, behavior.

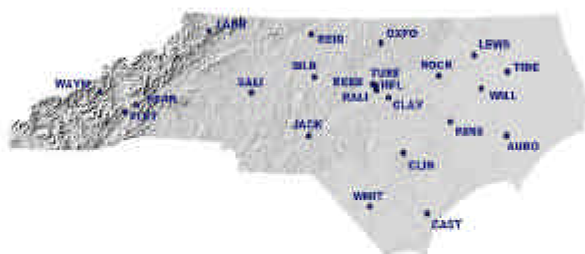

Fig. 2. North Carolina State University's AgNet.

The western and mountainous third of North Carolina is a particularly data-sparse region with only a few ASOS/AWOS airport sites in the mountain valleys. NCDAQ installed three high-elevation meteorological observation sites approximately at 1300 m, at 1600 m, and at 2000 m above mean sea level to augment the existing valley sites. The high-elevation locations are generally not affected by valley flows and micro-scale meteorological phenomena common in the mountain valleys. The National Park Service, the Eastern Band of the Cherokee Indians, and the United States Forest Service also maintain several meteorological and air quality monitoring sites in and around the Great Smoky Mountains National Park, including two "web cam" sites that report nephelometer-derived visual range.

Working with the State Climate Office, NCDAQ is facilitating the integration of all known quality surface meteorological observing sites in the state into the North Carolina Environment and Climate Observing Network or ECO-Net. This database integration collects and displays the data from federal, state, and local government sites as well as from the university and other non-standard sites that adhere to NWS observing standards.

NCDAQ also owns and operates two 915 MHz boundary layer radar profilers with radio acoustic sounding systems (RASS), one at Charlotte/Douglas International Airport (KCLT) and one southeast of Raleigh. The Raleigh profiler site is about 8 km from the television tower-mounted ozone monitors and is collocated with one of the surface ozone monitoring sites. The boundary layer radar profilers are configured to sample winds at 60 m resolution up to 3000 m and at 100 m resolution up to 5500 m, but atmospheric conditions determine the maximum height of each profile. The winds are continuously sampled and averaged into 30-minute observations. The RASS samples a vertical profile of virtual temperature every half hour up to 2000 m, but the RASS profiles only average about 1000 m in height.

The boundary layer radar profiler data is useful in determining the vertical structure of winds and the depth of the PBL. The RASS data are important in identifying low-level inversions. The proximity of the television tower-mounted ozone monitors to the Raleigh profiler and RASS provide a comparison of vertical structure of the PBL to the local vertical pollutant distribution.

4. FUTURE PLANS

The capabilities of the air quality forecasting community will continue to grow as air quality and meteorological observing networks are enhanced throughout the United States. As haze and fine particulate monitoring receive more emphasis, NCDAQ will exploit the additional continuous and speciated $PM_{2.5}$ monitoring and local meteorological monitoring. These datasets will provide greater spatial resolution and will potentially reveal relationships between $PM_{2.5}$ and the weather conditions affecting the visibility. In addition, future efforts should be directed toward developing more tall-tower air quality monitoring sites, a nationwide boundary layer radar profiler network, or a tethersonde network to overcome the lack of atmospheric chemistry data from above the surface. Another emerging technology is LIDAR remote sensing of pollutants and meteorology in the boundary layer (Philbrick et al. 2002). It is a promising but currently expensive and manpower intensive technology.

5. REFERENCES

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