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MONITORING INTERSTATE POLLUTANT TRANSPORT FROM THE WESTERN MARYLAND PINEY RUN SITE: OBJECTIVES, DESIGN, AND DEMONSTRATION

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ABSTRACT

The Maryland Department of the Environment (MDE) Air Quality Monitoring and Planning Program deployed a new air monitoring site in 2004 to track the impact of interstate pollutant transport on air quality in Maryland. Currently Maryland does not meet the EPA National Ambient Air Quality Standards (NAAQS) for annual $PM_{2.5}$, 8-hour ozone, and 1-hour ozone. Consequently, the monitoring focus will be on $PM_{2.5}$, ozone, and their respective precursors and constituent species. Column monitoring of meteorology and air quality will also take place via remote sensing by a wind profiling radar system and via in-situ measurements by aircraft and balloons. The new site, called "Piney Run", will provide a continuous time series of highly time resolved data. The location is unique for measuring regional background pollutant loads because it is a high elevation, western boundary location in rural Maryland. Piney Run will also focus on haze-related measurements as part of the Rural Aerosol Intensive Network (RAIN) deployed in Spring 2004 by state agencies in the Mid-Atlantic/Northeast Visibility Union (MANE-VU) regional planning organization. In addition, the site is part of several national monitoring networks including the Interagency Monitoring of Protected Visual Environments (IMPROVE), the National Atmospheric Deposition Program (NADP), the National Trends Network (NTN), and the Mercury Deposition Network (MDN).

While recently proposed regulations from EPA, including the Clean Air Interstate Rule (CAIR) formerly known as the IAQR (Interstate Air Quality Rule), acknowledge the presence of interstate transport, equal implementation of emission control strategies across state boundaries remains an ambitious goal. Results from Piney Run will be used to address interstate transport and to develop future Maryland State Implementation Plans for ozone, $PM_{2.5}$, and regional haze.

INTRODUCTION

The Maryland Department of the Environment (MDE) Air Quality Monitoring and Planning Program operates an air monitoring network of 23 sites located across the state of Maryland. Past studies show strong evidence of westerly interstate transport into Maryland (Chen 2002; Ryan 1998; Stehr 2000; Taubman 2004a and 2004b). In Spring 2004, MDE deployed a new air monitoring site called "Piney Run" to monitor the impact of interstate pollutant transport on air quality in Maryland. Prior to the opening of Piney Run, the western-most monitor in Maryland was located in Hagerstown. MDE became interested in placing additional air monitoring instruments further west in an effort to better understand the upwind characteristics of air as it is transported into Maryland via the predominant wind direction from west to east. Located 10km northeast of Frostburg, Maryland at an elevation higher than most of its regional surroundings, Piney Run should be able to capture the regional characteristics of the air as it enters Maryland from the west and before it has traveled through the more industrialized and populated areas of central Maryland. The primary focus at Piney Run is to measure O_3, $PM_{2.5}$, and their respective precursors and constituent species. Column measurements of meteorology and air quality will also take place via remote sensing and in-situ measurements. Piney Run will provide continuous data with high temporal resolution from a unique location for measuring regional background pollutant loads. The site is distinct due to its high elevation and western boundary location in rural Maryland. Among Mid-Atlantic state-run monitoring sites, Piney Run is a novel site because it was established not only for measuring the Environmental Protection Agency (EPA) National Ambient Air Quality Standard (NAAQS) pollutants, but also to gain further understanding of regional air quality episodes and interstate pollutant transport.

Several universities and regional and state organizations are joining MDE at Piney Run with additional air quality monitors. The Mid-

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Atlantic/Northeast Visibility Union (MANE-VU) regional planning organization is sponsoring measurements for the Rural Aerosol Intensive Network (RAIN) (Allen 2004a and 2004b) including Interagency Monitoring of Protected Visual Environments (IMPROVE). The Appalachian Laboratory at the University of Maryland Center for Environmental Science (UMCES), the University of Maryland (UMD), and Howard University (HU), will all be contributing air quality measurements in support of MDE efforts. Finally, the Maryland Department of Natural Resources (DNR) has added Piney Run to several deposition networks including the National Atmospheric Deposition Program (NADP), the National Trends Network (NTN), and the Mercury Deposition Network (MDN).

Preliminary data from Piney Run look promising in terms of exhibiting the benefits of collecting data in a manner that is innovative for air quality monitoring in the Eastern United States. The data have already provided a demonstration of the benefit of measuring air quality in close proximity to states hosting major point sources. The onset of an air quality episode is observed in August 2004. The case shows the development of high $PM_{2.5}$, SO_4, and O_3 along the western boundary of Maryland. Another notable feature in August 2004 appears in Piney Run ozone data. The site location above the nocturnal boundary layer reveals a persistence of ozone values while sites below the nocturnal boundary layer experience sharp declines in concentration.

OBJECTIVES

In state and local air quality offices such as MDE, the focus has traditionally been on monitoring strictly for the EPA NAAQS for CO, NO_2, O_3, Pb, PM_{10}, $PM_{2.5}$, and SO_2. As a result, most of Maryland's air monitoring stations are sited to provide samples of ambient air near large metropolitan areas, medium sized cities, and along major transportation routes. While this approach effectively accomplishes the goal of monitoring ambient air, it has limited potential for learning about interstate transport of air pollution. MDE has been providing next-day air quality forecasts for the Mid-Atlantic for 8 years. When Maryland experiences its worst air quality episodes, there is inevitably an out-of-state component playing a critical role (Chen 2002; Ryan 1998; Stehr 2000; Taubman 2004a and 2004b). The recent development of EPA's AIRNOW mapping system along with the MODIS satellite imagery of aerosol optical depth (AOD) provide visual confirmation of the regional nature of the worst Mid-Atlantic air quality episodes.

Air pollution transported across political boundaries is important to state and local agencies not only because of public health concerns, but also because of the economic implications. When emission regulations are promulgated they can discourage growth and exchange of commerce. It promotes economic inequality if regulations are put in place within a state but the overall air quality does not improve because of an overwhelming influence from out of state. To reach an optimal balance of comparable emission controls among all states, the regional influence from out of state must be objectively understood.

The site objectives at Piney Run are formulated with a primary goal of addressing interstate transport. Data collected at both the surface and aloft will also serve an important role in model validation. Visibility and deposition studies are additional core foci for collaborative research of multiple co-located institutions. The objectives for Piney Run include the following:

1. Acquire "front-line" ambient air measurements for both analysis and forecasting. The term "front-line" is meant to indicate the first measurements of air transported into Maryland via the predominant westerly flow. Pollutant values at a high elevation on the western edge of Maryland signify the background regional pollutant load.
2. Provide estimates of regional background pollutant loads from a high elevation, rural location. Air quality forecasts rely heavily upon an accurate knowledge of the background regional pollutant load. The regional background combines with local emissions in the metropolitan areas to create the highest pollutant concentrations.
3. Provide information on the evolution of boundary layer mixing and boundary layer height during the diurnal cycle. Upper level winds and temperatures are beneficial to the goal of tracking long-range interstate transport. This is a critical component of model validation. Modeled wind fields coming across the Appalachian Mountains and into Maryland must be correct if chemical transport models are to accurately portray pollutant transport.
4. Acquire ground-truth data to complement western boundary aircraft flights.
5. Acquire data in the Mid-Atlantic high-elevation monitoring gap between Big Meadows, Virginia and Methodist Hill, Pennsylvania. Between these two sites there is a gap where no ambient high-elevation data are collected. A large part of this region is filled by West Virginia, but the panhandle of Maryland also extends into the region. Piney Run will fill the spatial gap in air monitoring.

As a participant in the RAIN program additional objectives are also required for Piney Run:

6. Acquire detailed $PM_{2.5}$ and visibility-related parameters.
7. Contrast "fresh" vs. "aged" secondary aerosol.
8. Collect highly time-resolved aerosol composition measurements.
9. Acquire sub-daily aerosol composition data to provide insight to regional aerosol generation,

source characterization, and factors that drive visibility.

The elevation of Piney Run is 781m (2,563ft). The site is on top of a local peak, among other peaks on the Allegheny Plateau in Garrett County, Maryland. Piney Run is located 10km NE of Frostburg, Maryland. Figure 1 shows a topographical map of the Piney Run site.

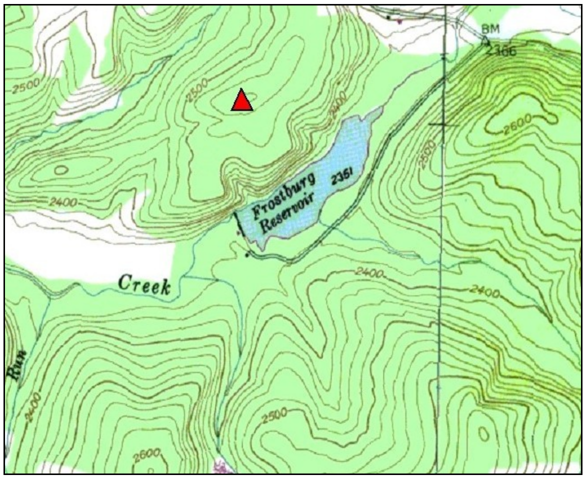

Figure 1: Topography of Piney Run Area and Site Location above Frostburg Reservoir

If the claim is to be made that measurements at Piney Run represent the regional background, then no local emissions should be impacting the site. A monitor placed high and to the west in Maryland should avoid local emission sources and capture pollutant concentrations transported into Maryland from other states. The three sources MDE investigated while searching for prospective western boundary monitoring sites included mobile sources, urban areas, and point sources. For mobile sources there are two major routes close to Piney Run. Both U.S. Route 40 and Interstate 68 lie to the south of Piney Run, at a distance of 2km (1.27mi) and 2.5km (1.55mi) respectively. According to Maryland State Highway Administration traffic counts, in 2001 these two major transportation routes received 4,500 and 20,000 average daily trips, respectively (MDOT 2002). To summarize urban area source contributions, Table 1 shows a list of cities within 180km (112mi) of Piney Run with a population of more than 23,000 (US Census 2000).

City, State	Distance	Direction	Population
Altoona, PA	127km (79mi)	NNE	49,523
Johnstown, PA	95km (59mi)	N	23,906
Pittsburgh, PA	153km (95mi)	NW	334,563
Wheeling, WV	177km (110mi)	WNW	31,419
Morgantown, WV	93km (58mi)	W	26,809

Table 1: Proximity of Cities (>23,000 population) to Piney Run

Every city listed in Table 1 lies outside of the Maryland state boundary. The third source of emissions to consider is point sources. Figure 2 shows the size and location of SO_2 point sources in the Eastern United States (EPA 1999).

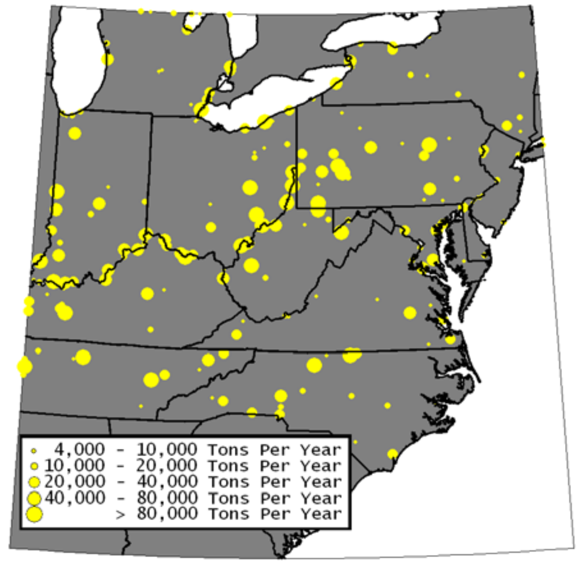

Figure 2: SO_2 Point Source Emissions

Few large SO_2 sources exist in Maryland, especially in the western half of the state. However, there are numerous large utility point sources just outside of the Western Maryland state boundary. Many of the largest sources in the Eastern United States are located along the Ohio and Monongahela River Valleys. Considering the proximity of Maryland to the large Ohio River Valley SO_2 sources, it is not surprising to see sulfate appearing as the dominant constituent in Maryland's $PM_{2.5}$ speciation measurements. Figure 3 displays seasonal $PM_{2.5}$ speciation at Fort Meade, Maryland for 2002.

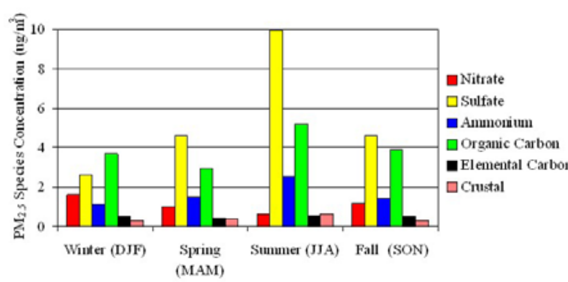

Figure 3: Fort Meade $PM_{2.5}$ Speciation for 2002

From quarter to quarter, sulfate is the most variable species. Sulfate is the largest percentage in most seasons, with winter being the exception when organic carbon makes up a larger magnitude than sulfate. During the winter, limited photochemistry and lower humidity reduce the formation of secondary $PM_{2.5}$, such as sulfate. Mixing is also suppressed during the winter, which lessens the influence of regional transport. The corollary occurs during the summer with extensive mixing, increased transport, and consequently a stronger regional influence on

Maryland. These mechanisms in part lead to the summer time sulfate maximum. One problem with monitoring speciation at Fort Meade and other sites within large metropolitan areas is the difficulty of separating out regional sources from local sources. By monitoring at the new Piney Run site where local sources are virtually nonexistent, MDE may conduct a more objective evaluation of interstate transport than was previously possible.

DESIGN

The Appalachian Laboratory of the University of Maryland Center for Environmental Science (UMCES) is assisting MDE in the operation of this multifaceted site. The measurement suite includes trace SO_2, trace CO, O_3, NO_y, NO, NO_2, continuous $PM_{2.5}$, and meteorology from a 10m tower, 20m tower, and an upper air boundary layer wind and temperature profiling system. Piney Run will also focus on haze-related measurements as part of the Rural Aerosol Intensive Network (RAIN) deployed in Spring 2004 by state agencies in the Mid-Atlantic/Northeast Visibility Union (MANE-VU). RAIN parameters include visibility from an automated CAMNET camera, continuous elemental, organic, and total carbon, continuous sulfate, IMPROVE aerosols, single wavelength scattering from a NGN-2 (wet) nephelometer, three wavelength scattering from a TSI nephelometer, and column O_3, H_2O_v, and aerosol optical depth (AOD) from a handheld MicroTops II unit. Additionally, the Maryland Department of Natural Resources (DNR) has added Piney Run to the National Atmospheric Deposition Program (NADP). Wet deposition of major cations and anions will be measured as part of the National Trends Network (NTN) and mercury as part of the Mercury Deposition Network (MDN). Ongoing collaborations with the University of Maryland Regional Atmospheric Measurement, Modeling, and Prediction Program (RAMMPP) will allow for overhead aircraft transects and corkscrew profiles from a nearby airport. The aircraft will compile aloft measurements of O_3, NO, NO_2, CO, SO_2, meteorology, aerosol absorption and scattering, particle counts, and aerosol size. Finally, collaborations with the Howard University Physics Department will allow for summertime launches of ozonesonde balloons with rawinsonde meteorology and GPS-derived wind speed and wind direction. Tables 2 through 5 describe the parameters being measured by MDE at Piney Run by category.

Instrument Type	Measurement Time Scale	Measurement Method(s)
$PM_{2.5}$ Mass	1 in 3 days	STN Filter Extraction
$PM_{2.5}$ Mass	Continuous	BAM (Beta Attenuation Monitor)

Table 2: $PM_{2.5}$ Mass Parameter

Instrument Type	Measurement Time Scale	Measurement Method(s)
EC, OC, TCM (Total Carbon Mass)	Semi-Continuous	Thermal Optical Reflectance
SO_4	Semi-Continuous	Fluorescence
SO_4, NO_3, EC, OC, TCM, NH_4, Crust	24-Hour	IMPROVE Filter Extraction
SO_4, NO_3, EC, OC, TCM, NH_4, Crust, Ions	24-Hour	STN Filter Extraction Ion Analysis HPLC
Trace Elements (Metals)	24-Hour	STN/IMPROVE Filter Extraction X-Ray Fluorescence

Table 3: $PM_{2.5}$ Speciation Parameters

Instrument Type	Measurement Time Scale	Measurement Method(s)
B_{scat}	Continuous	1λ Nephelometer Passive Photometric
B_{scat}	Continuous	3λ Nephelometer Passive Photometric
AOT, H_2O_v - Total Column	Snapshot	MicroTops II Passive Photometric
Visual Range Digital Images	Continuous	CAMNET Digital Camera

Table 4: Haze and Visibility Parameters

Instrument Type	Measurement Time Scale	Measurement Method(s)
Trace CO	Continuous	Non-Dispersive Infrared
Trace SO_2	Continuous	Fluorescence
NO_y, NO, NO_2, O_3	Continuous	Chemiluminescence
Upper Air Meteorology – WS, WD, Tv	Continuous	Microwave and Radiowave
Surface Meteorology – WS, WD, T, RH, P, Precipitation, Solar Radiation	Continuous	Various Methods

Table 5: Air Mass and Source Attribute Parameters

The visual range digital images show scene characteristics using an automated digital camera. The camera looks over a field of view that includes the air monitoring site and has a maximum visibility of 10's of miles. The images will be posted in real-time to the CAMNET website (www.hazecam.net). In order to incorporate the upper air wind profiler, substantial site improvements had to be made to accommodate the required elevation angles. Major clutter obstacles such as trees and towers should ideally be no more than 5º above the horizon on any side of a wind profiler (King 2003). In the Eastern United States relative humidity is generally high enough to allow for better radar signal return, so more flexibility is possible when considering elevation angles. Based on considerable experience of NOAA Environmental Technology Laboratory (ETL) profiler site operators (King 2003), 15º was used as a rule of thumb for siting elevation angles at Piney Run. Pointing the radar beams away from any clutter points that exceed the elevation angle criteria can create additional leeway. At Piney Run, the upper air profiler beams will be directed away from the 10m and 30m towers, which are sited in a line with each other and the wind profiler.

DEMONSTRATION

Initial measurement results from Piney Run have already provided a demonstration of the site's beneficial perspective. Monitors were brought online at Piney Run beginning April 4, 2004 with surface meteorology, ozone, and SO_2. IMPROVE followed on April 15, 2004 and NO_y began on June 23, 2004. The analysis shown here through various Piney Run time series begins with the commencement of $PM_{2.5}$ data collection with a Beta Attenuation Monitor (BAM) on July 29, 2004. Figure 4 shows that since monitoring commenced, the first instance of elevated $PM_{2.5}$ and sulfate at Piney Run occurred for several days at the beginning of August 2004. The increase of $PM_{2.5}$ and sulfate began August 1st and lasted through August 4th. Unfortunately, the Total Carbon (TC) instrument experienced some difficulty precisely during the period of interest on August 3rd and 4th.

Chief among Maryland's air quality concerns are ozone concentrations. The period described above turned out to be an ozone episode, which began to materialize on the western fringe of Maryland. The ozone concentrations culminated in NAAQS violations on August 4, 2004. Out of 15 ozone monitoring sites in Maryland, Fort Meade and PG Equestrian (both in Anne Arundel County, Maryland) exceeded the NAAQS of 85ppb for an 8-hour ozone average. An investigation of the ozone time series and the synoptic weather patterns reveals interesting relationships between Piney Run and the rest of the regional sites. Figure 5 is a map of regional ozone monitors.

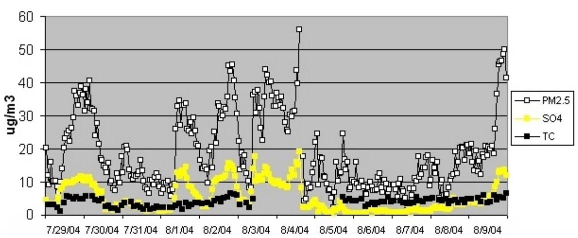

Figure 4: Piney Run $PM_{2.5}$, SO_4, TC for July 29 – August 9, 2004

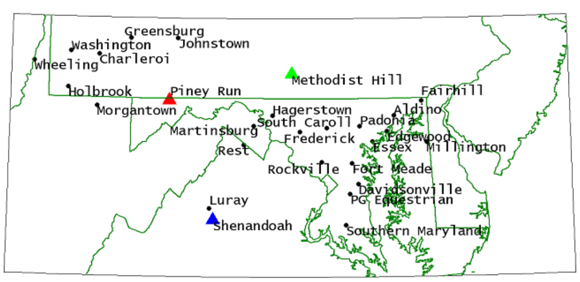

Figure 5: Map of Mid-Atlantic Ozone Monitoring Sites

The decision of which ozone monitors to include in Figure 5 was based on providing an all-inclusive comparison of sites, as opposed to choosing a limited and possibly biased number of sites. Sites chosen include all active ozone monitors in the state of Maryland and all ozone monitors that are closest to Piney Run in the three surrounding states (VA, WV, PA). Sites were added from the north of Piney Run up to the Pittsburgh Metropolitan Area and from the south of Piney Run down to Shenandoah National Park. The number of ozone monitors from the west of Piney Run was limited by the scarcity of West Virginia monitors, so all available monitors that were due west and located in West Virginia were included. From the east all monitors between Piney Run and Methodist Hill, Pennsylvania were included. Although the number of sites creates busy time series plots, an all-inclusive approach is favorable because it is unbiased. Utilizing a comprehensive approach also makes the conclusions more compelling. The three sites indicated by triangles are the regional high-elevation sites. Table 6 shows the marked difference between elevations of these three sites and all of the other sites in Figure 5.

Site	Elevation
▲ Piney Run, Maryland	781m
▲ Methodist Hill, Pennsylvania	630m
▲ Shenandoah National Park, Virginia	1,072m
All Other Sites in Figure 5	< 365m

Table 6: Elevation of Mid-Atlantic Ozone Monitoring Sites

Ozone time series from all of the regional sites mapped in Figure 5 are shown in Figure 6. The period of the time series is August 3rd through August 5th, 2004.

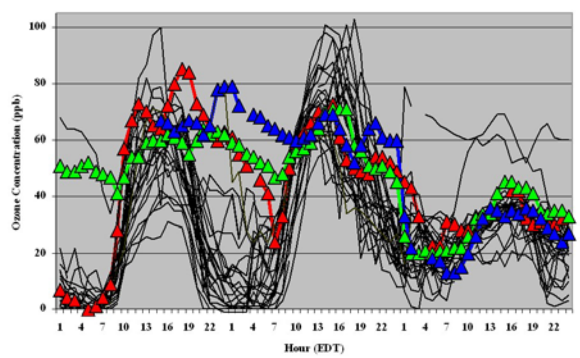

Figure 6: Mid-Atlantic Ozone for August 3-5, 2004

A feature of interest in Figure 6 is the 30ppb difference between Piney Run and the rest of the Maryland ozone monitors from 22 EDT on August 3rd to 1 AM EDT on August 4th. Two sites from Pennsylvania and one from West Virginia lie between 20-30ppb less than Piney Run during these same hours. While the rest of the Maryland monitors quickly decrease at sunset, Piney Run maintains high ozone concentrations. Several observations from Figure 6 are worth addressing:

1. Piney Run is the highest Maryland monitor on August 3rd. An unusual circumstance considering the remoteness of the site. Some of the other sites outside of Maryland, but near Piney Run show similar high concentrations. Unlike Piney

Run, those sites are at low elevations and they are in Pennsylvania and West Virginia.

2. During the night on August 3rd through the morning of August 4th, Piney Run ozone levels remain 30ppb higher than Maryland's low-elevation monitors, which all decrease quickly at sunset. The only other monitors to maintain high concentrations until 5 AM EDT are Methodist Hill and Shenandoah National Park. The mechanisms for ozone depletion at night include dry deposition and NO_x titration by NO. The high elevation monitor's position above the nocturnal boundary layer decouples those sites from the ozone-depleting mechanisms. Figure 7 is a diagram showing how Piney Run may frequently remain in the residual layer of the boundary layer.
3. During sunrise on August 4th, all of the Maryland ozone monitors show similar increasing slopes in ozone concentrations and they return to the 55ppb regional load that the high elevation monitors have maintained through the night. In this case Piney Run ozone does experience a sharp decline during the hours of 6-7 AM EDT but Methodist Hill and Shenandoah National Park do not decrease much. The clean air intrusion at Piney Run may have resulted from the expected rising slope of the ozone-poor nocturnal boundary layer. Because Piney Run is a peak upon a plateau, all of the layers depicted in Figure 7 may be higher in reality, thus exposing Piney Run to the stable layer prior to sunrise. Future work using the boundary layer profiling system at Piney Run should help to explain such variations of the boundary layer mixing heights.

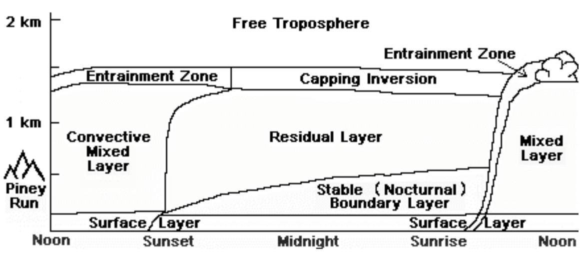

Figure 7: Boundary Layer Mixing Heights and The Residual Layer (after Stull, 1988)

Visible satellite imagery and surface analysis are shown in Figures 8 and 9 respectively. The figures were chosen for their specific time periods near the end of the episode. The persistence of weather allows these figures to accurately portray synoptic conditions on both August 3rd and August 4th.

Prior to the episode onset on August 3, 2004, most of the Maryland monitors enjoyed good air quality courtesy of Hurricane Alex (due east of Maryland and due south of Cape Cod, Massachusetts in Figures 8 and 9). Off the East Coast of the United States, the presence of Hurricane Alex and his cyclonic (counter clock-wise) rotation provides easterly clean maritime flow from the East. However, unlike the majority of Maryland's sites on August 3rd, Piney Run exhibits much higher ozone concentrations. This is a noteworthy feature considering the site's remote location and clean locale. As Hurricane Alex departed to latitudes further north, high pressure over the southeastern United States provided anticyclonic (clockwise) circulation, which enhanced westerly flow from the Ohio River Valley into Maryland. The primary influence in producing the westerly flow from the Ohio River Valley into Maryland is the cold front, seen as a stationary front in Figure 9, approaching from Lake Erie. The poor air quality first seen at Piney Run in Figure 4 moved eastward, ultimately producing violations of the 8-hour ozone NAAQS. An increase of pollutant concentrations ahead of frontal boundaries is a common occurrence in the Mid-Atlantic region (Ryan 1998).

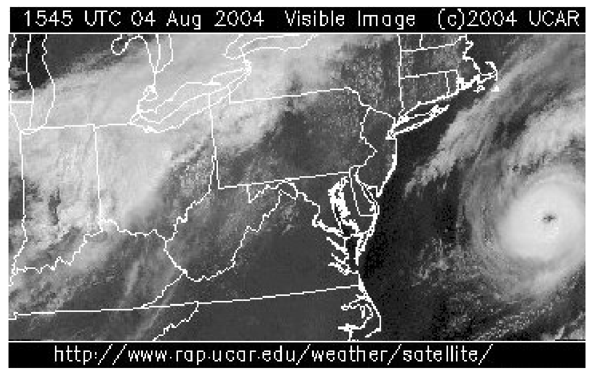

Figure 8: Visible Satellite Image August 4, 2004 15Z (11AM EDT)

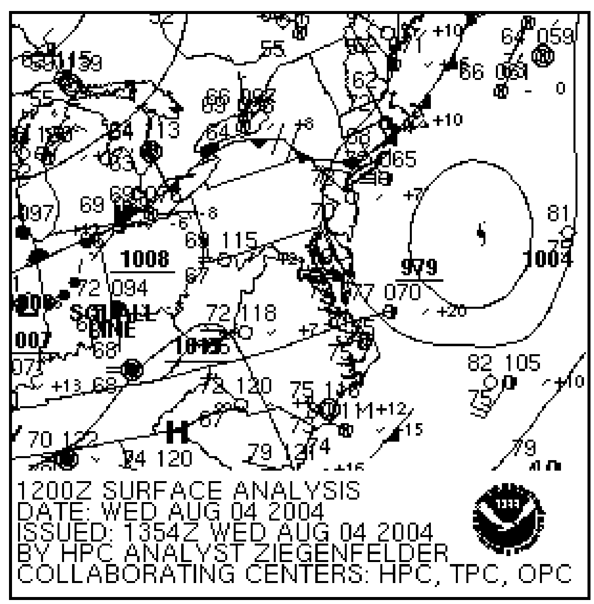

Figure 9: Surface Analysis August 4, 2004 12Z (8AM EDT)

The use of air parcel back-trajectories shows the difference in air mass origins for August 3rd and 4th. The back-trajectories of Figure 10 display a split of trajectory paths. Western Maryland experiences northwesterly 24-hour back-trajectory paths and

Eastern Maryland experiences easterly and re-circulating 24-hour back-trajectory paths. When Hurricane Alex moves northeast, Figure 11 reveals the shift of back-trajectories to the northwest. The cold front from over Lake Erie progresses towards Maryland and in concert with the high pressure over the Southeast United States creates strong northwesterly back-trajectory paths.

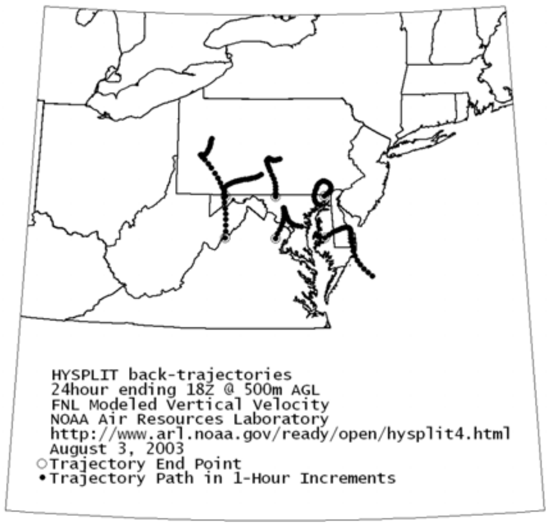

Figure 10: 24-Hour 500m Back-Trajectories Ending August 3, 2004 18Z (2PM EDT)

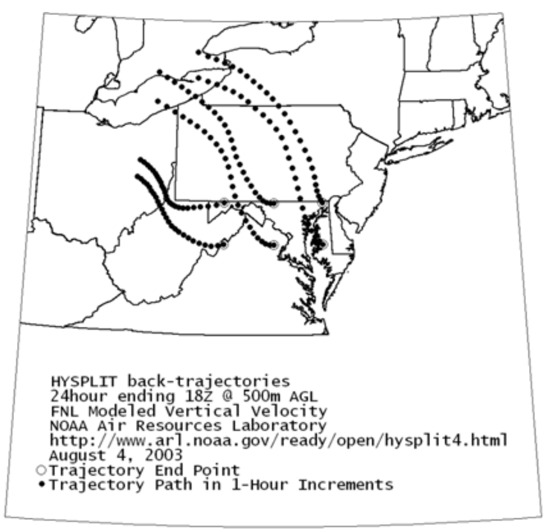

Figure 11: 24-Hour 500m Back-Trajectories Ending August 4, 2004 18Z (2PM EDT)

The August 4th Maryland ozone event was regional in nature, which is evident from the unified trajectories from beyond the state boundary and from the increase of ozone concentrations at all monitors during the morning hours. When the nocturnal boundary layer mixed with the residual layer during a 2-hour period from 7-9 EST, the slope of ozone increase was similar at all monitors. At the end of the episode a cold front crosses the area from the northwest, which causes a dramatic improvement in air quality conditions. Figure 4 shows the sharp decline in $PM_{2.5}$ and sulfate and Figure 6 shows the sharp decline in ozone.

CONCLUSIONS

While recently proposed regulations from EPA, including the Clean Air Interstate Rule (CAIR) (EPA 2004) formerly known as the IAQR (Interstate Air Quality Rule), acknowledge the presence of interstate transport, equal implementation of emission control strategies across state boundaries remains an ambitious goal. Results from Piney Run will be used to address interstate transport and to develop future Maryland State Implementation Plans for ozone, $PM_{2.5}$, and regional haze. The Piney Run air monitoring site is unique. It is an original endeavor for an air quality state regulatory agency to initiate, operate, and analyze data specifically to address the transport of interstate pollutants. Piney Run will supply several valuable products for future analysis:

1. Front-line indication of interstate transport from Maryland's western boundary.
2. Approximation of regional pollutant loads when the boundary layer is low enough for the site to sample from within the residual layer.
3. The diversity of the sampling suite supplies additional information on the characteristics of air pollutants crossing the state boundary into Maryland.
4. Availability of all data to the public domain.

The demonstration of preliminary data from Piney Run shows promising potential for air quality analyses. A sample of data from August 2004 showed Piney Run joining two other high-elevation monitors in the region, Methodist Hill, PA and Shenandoah National Park, VA, to reveal the regional background ozone concentration entering the western boundary of the Mid-Atlantic. While most surface ozone monitors in the region showed the usual decrease of ozone after sunset, the high elevation monitors continued to sample high ozone concentrations from their position above the nocturnal boundary layer. Such demonstrations of vertical and horizontal pollutant transport are invaluable for the preparation of MDE air quality regulations and for exhibiting the importance of equitable regional emission controls. Future work at Piney Run includes complete deployment of the monitoring suite listed in Tables 2-5, exploration of opportunities for on-site LIDAR and tethersonde measurements, and a plethora of analysis.

ACKNOWLEDGEMENTS

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