NPS Meeting Report:

Enhanced Monitoring Data Workshop

Dec. 15, 1998, Park Headquarters, Shenandoah National Park
Meeting notes: John D. Ray

Meeting Overview

This meeting provided a forum for the presentation of results by researchers on the photochemical production and transport of ozone and its precursors that reach the park.

Project Description

Objectives

This year's meeting focused on the following objectives of the enhanced ozone monitoring program:

- To identify sources and source regions of ozone and key ozone precursors based on conserved tracers, meteorology, and transport models

- To determine the relative contributions to observed surface ozone levels within SNP of:
  - Locally produced versus transported ozone
  - Mobile versus stationary sources of ozone and key ozone precursors
  - NOX-limited versus VOC-limited production of ozone
  - Biogenic versus anthropogenic production of ozone

The purpose of this meeting was to provide an *overview of key findings* of the SNP's enhanced ozone monitoring project to an audience comprised of NPS, Virginia DEQ, EPA, and private corporation staff.

Researchers and instrumentation

List of instruments, project description, and researchers. {Handout: available on the web site at http://www.nature.nps.gov/ard/gas/enhanced.htm }

Overview of high ozone at Shenandoah NP

Ozone concentrations at the Big Meadows site are characterized by a seasonal cycle with the highest values in August and September. The diurnal cycle has a peak in late afternoon and a minimum overnight, however, the range is limited to between 40 to 100 ppb in a pattern that is typical of a high elevation site removed from local sources of air pollution. The lack of very low ozone values overnight indicates that ozone titration with fresh NO emissions and surface deposition are not dominant loss mechanisms. Based on the dominant winds from the northwest and ozone patterns, it is reasonable to view the Big Meadows ozone data as regionally representative.

Ozone events are typically broad periods of high ozone rather than sharp spikes. This is reflected in the 1-hr peak ozone values and the maximum daily 8-hr ozone concentrations. In 1998, there was one day with the maximum 1-hr ozone above 124 ppb and 22 days when the 8-hr daily maximum was above 84 ppb. The 1-hr daily maximum ozone can be used to predict the maximum 8-hr daily ozone for 1998: 8-hr O3 = 31.2 + 0.61*(1-hr O3) $R^2 = 0.64$. [Ray]

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Trends analysis

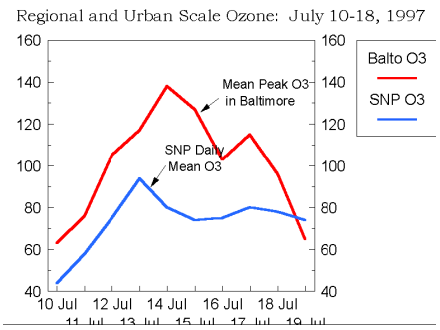
Linear regression analysis of a variety of ozone statistics for the period 1983 to 1997 gives linear models with poor R^2 values that are not statistically significant. The S.T. Rao (1997) trends analysis of park service ozone data removes seasonal and diurnal variance from the data and generates an estimate of long-term trends. For Big Meadows, the Rao analysis yielded an upward trend of 0.4% per year that was statistically significant. Analysis of the ozone data at Sawmill Run and Dickey Ridge through 1994 yielded decreasing ozone trends. These two sites are at lower elevation and have a shorter dataset. The net conclusion is that there is a small upward trend in ozone concentrations for Shenandoah NP. [Ray, Ryan, Doddridge, Hallock-Waters]

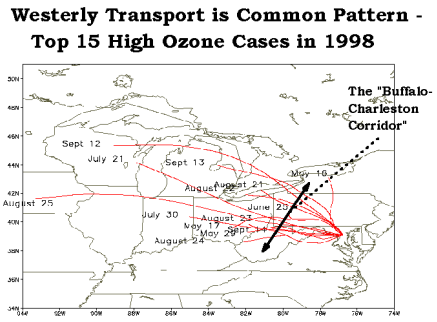
Ozone forecasting

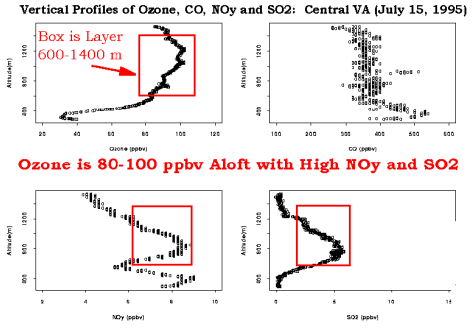
The peak ozone concentrations are forecast by UMd for the Washington DC and Baltimore metro areas each day during the summer season and broadcast through the news media. Although there are many factors considered in the forecast, the Shenandoah, Big Meadows ozone data is one factor used. The high ozone periods for the metro area usually relate to slow moving high-pressure areas and air masses that have transport from the west to northwest sector. The Big Meadows site sees this incoming regional air about 60% of the time and may even lead the high ozone periods in the metro areas by a day. Basically, when the incoming regional air has high ozone, locally produced ozone in the metro area is more likely to push the concentrations into the unhealthy zones. [Ryan] http://www.meto.umd.edu/~ryan/ozone_fcst.html

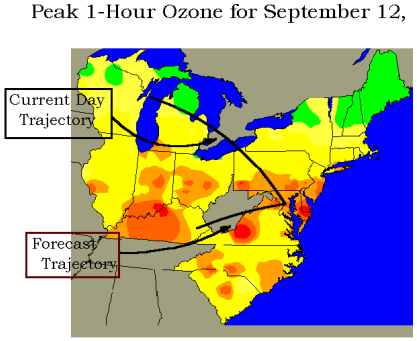
The ozone mapping available from the EPA AirNow web site (http://www.epa.gov/oar/oaqps/airnow/) can be used to better understand the spatial extent of high ozone episodes and to observe the regional incoming air when it has higher ozone. The Shenandoah data was being used to help generate the ozone maps for TV broadcasts in the metro area previously, but was not included in the Internet ozone mapping in 1998. Examination of a few of the episode days shows that the predictions for the rural areas of Virginia don't necessarily agree with the actual observed ozone concentrations at Shenandoah, Big Meadows. The addition of the new ESC datalogger will facilitate getting the Big Meadows data back into the ozone-mapping project. [Ryan]

Episode examples (Figure 1 a-d)









Ozone formation and transport

Characteristic cycles – regional site indicators

The NO/NOy ratio shows a seasonal cycle with a minimum in July (0.02) and a maximum in November (0.1). The NO represents the fresh emissions and what is being cycled from photochemistry while the NOy is the total reactive nitrogen. The very small ratios indicate that most of the nitrogen is in "aged" or oxidized nitrogen species. The cycle follows photochemical activity.

The NOx/NOy ratio was found to have higher values in July and Aug. than in Sept. and Nov. The NOx (defined as NO + NO_2) is the relatively "fresh" emissions portion of the total reactive nitrogen (NOy).

A diurnal cycle is observed for NO with concentration rising quickly after sunrise and peaking in late morning. Total nitrate and NOy were observed to have no diurnal cycle. A small portion of NOy (the NO_2) is photolyzed during the day to NO. The lack of NOy cycle indicates that local sources are not contributing significant amounts of reactive nitrogen.

CO shows no diurnal cycle that suggests transport to the site rather than local sources. The very small diurnal cycle of ozone suggests the same. The SO_2 tends to be slightly higher around sunrise and to have a seasonal cycle with a peak in winter and a minimum in summer. [Doddridge, Hallock-Waters]

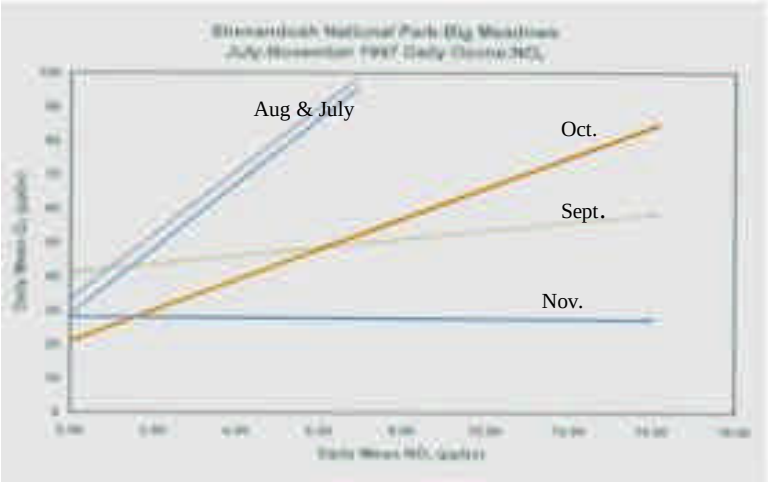


Figure 2: The production of ozone by nitrogen oxides changes with season. July and Aug. have high production and Nov. has a slight loss in ozone with increasing NOz (defined as NOy-NOx). The NOz variable represents the oxidation products from "aging" of the NOx emissions and are mostly HNO_3 and particulate NO_3.

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CO as a tracer

CO is emitted primarily by mobile sources, with the highest concentrations coming from urban areas. It is thus a tracer for urban pollutants since the atmospheric lifetime of CO is several months. At the BM site CO concentrations range from 80 ppb in really clean air to about 450 ppb in the "dirty" air. Carbon monoxide is frequently a co-pollutant with the shorter lived ozone precursors, NO_x and VOCs. Thus, CO is a useful tracer in ozone studies and the correlation between ozone and CO can be used as an indicator of ozone production or destruction. During summer a linear regression of CO with ozone have a positive slope (R= 0.61) while in winter there is a negative slope (R = -0.62). Thus, CO correlates to formation of ozone over losses, while in winter, losses exceed formation. Spring and Fall show signs of both positive and negative slopes. The seasonal cycles in slope and correlation coefficient have been observed before at remote sites in the Atlantic. [Doddridge, Hallock-Waters]

Trends indicators – CO, O3, SO2

Since starting CO measurements at BM in 1995, there appears to be a downward trend in CO. The trend is consistent with decreasing values from the 1988-89 measurements by UMd at SHEN. A comparison of the frequency distributions for each of the years shows a shift from a mean CO of 204 ppb in 1989 to a mean of 166 ppb in 1997. The decreasing CO trend is approximately 10 ppbv per year or about 16% per year. The EPA emission trends report has a similar value for urban emission decreases. CO is one of the regulators of the OH radical concentrations, thus less CO would mean more OH was available to oxidize other pollutants like hydrocarbons, SO2, or nitrogen oxides. The importance of this finding is still being considered, but it may be a factor in regional pollutant transport considerations. A manuscript has been prepared and is being submitted to a peer-reviewed journal. [Doddridge, Hallock-Waters]

A look at several years of SO2 data from BM shows an annual cycle and a decreasing trend. The sulfate and total sulfur need to be looked at from the dataset. [Ray]

Back trajectory info on high ozone

Work by U. of Va researchers showed where stratospheric ozone is transported to the troposphere by weather events. Individual events where ozone is enhanced by stratospheric inputs may be observable at the BM site. More often, the stratospheric ozone would mix to increase the overall regional ozone levels.

<10th percentile (cleanest days) **>90th percentile (dirtiest days)**

Figure 3 a,b: Ozone probability density plots for summer 1989-1994 (1100 & 15000 EST). Shading represents probability in increasing 10% increments up to the darkest regions near the receptor of >70%. (Ref: Owen Cooper, 1997.)

Back trajectory analysis has also been done for high ozone periods. The highest probability areas for high ozone air transported to BM is from the west (see graphic) in a region extending out to the Ohio Valley . Clean air is most likely to come from the south or the east and have origins over the Atlantic Ocean. [Cooper, Moody]

Implications of emission regions, SRI's, typical patterns

Emission sources for NOx, SO2, and VOC were summed into wind sector grids based on distance from the BM site. Combined with the wind roses and back trajectory information, a better view on likely source areas for ozone precursors can be obtained. Major power plants to the east and south of Shenandoah don't appear as discernable signals at BM. The Shenandoah site does not have the characteristic high SO2/NOy signals of relatively fresh power plant plumes that are seen at Great Smoky Mts. and Mammoth Cave NPs.

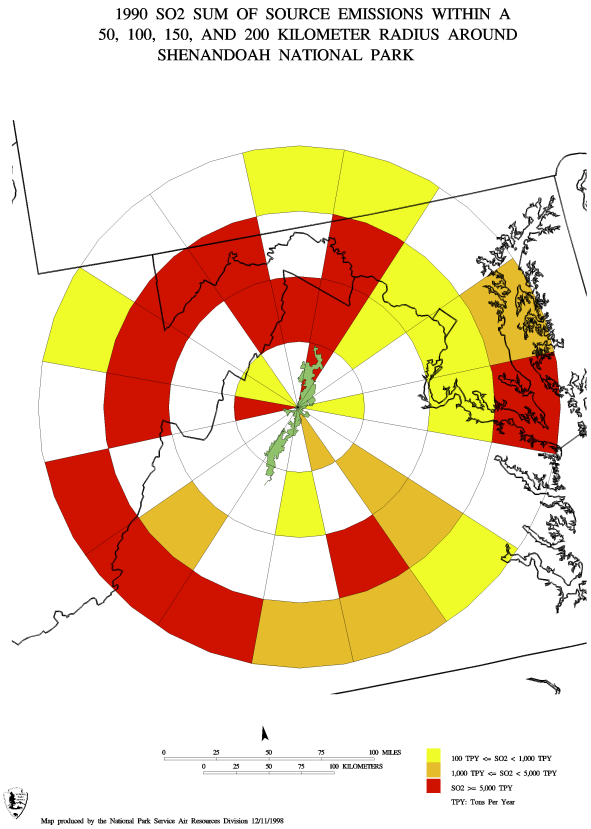


Figure 4: Sector analysis for SO2 emissions within 200 km of Shenandoah NP. Each ring is 50 km. Yellow is less than 1000 TPY; orange is 1000 to 5000 TPY; red is greater than 5000 TPY.

The concept of source areas of influence was explored a bit at the meeting: the significance is that each source has a very broad area of influence and that the overlap in SRI's complicates the picture enough that only the closest of sources are likely to be individually identified from the pollutant levels and tracer species. [Ray, Dotts]

Seasonal changes in limiting precursors

Some previous short-term work at Shenandoah had suggested that a seasonal change in the limiting ozone precursor occurred in the Fall. An examination of the $\Delta[O3]/\Delta[NOy - NOx]$ vs. time plots indicates a

dramatic reduction in the ratio near the end of August and going into September. The ratio relates the amount of ozone formation to the amount of reactive nitrogen oxidation. The switch from a ratio of 9.8 in mid-summer to –0.12 in November suggests a transition from NOx-limited to VOC-limited photochemcal production regime. This implies that NOx emission reductions upwind should reduce ozone formation during mid-summer, but will have a lesser effect in the Fall. [Doddridge, Hallock-Waters]

Using Speciated VOC to indicate source types

Basic characterizations at BM

Spatial differences within the park

VOC samples have been taken from several other sites than Big Meadows. A gradient in toluene is seen from higher concentrations in the north-end of the park to lower concentrations at Big Meadows. Other VOC species, that are generally of mobile-source origin, do not show this gradient.

Relation to other sites and expected values

Compared to other rural sites, the VOC values at Big Meadows are high for isopentane and toluene and lower than expected for isoprene. Based on limited data, the methanol appears to be high and an unusual mix of freon compounds is observed.

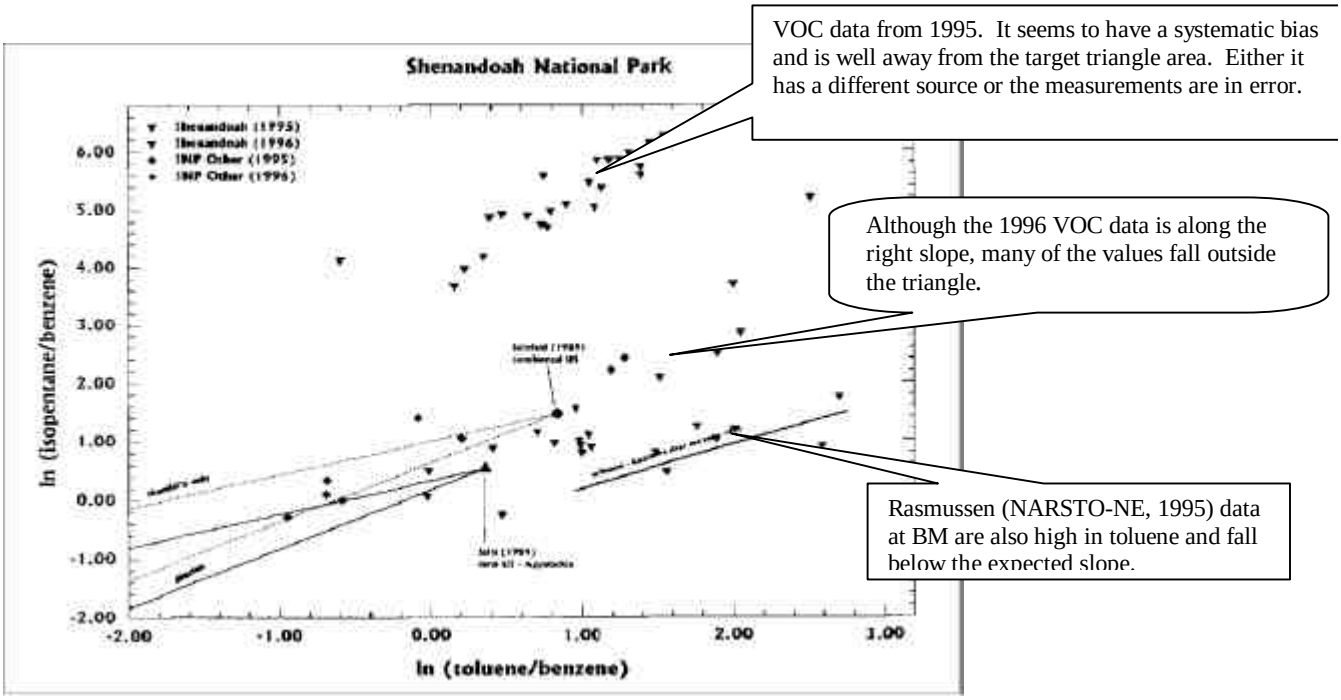


Figure 5: A plot that ratios more reactive to less-reactive compounds allows a wide range of concentrations to be presented on the same graph. The point labeled "Seinfeld, 1987" is an average concentration for a selection of urban areas. It should represent a near-source value and all samples down wind should fall within the lines labeled *chemistry only* and *dilution.* An alternative pivot point have been suggested for rural data, but it doesn't account for the observed values at Shenandoah any better than the Seinfeld data.

The 1995 VOC data appears to be systematically too high in isopentane, although the slope for the data points is about right. If the isopentane bias were lowered the toluene would still be too high. The 1996 and 1997 data do seem to have the isopentane bias removed. Samples taken at BM during the NARSTO-NE Intensive and analyzed by Rassmussen have even lower isopentane, but retain the higher than expected toluene.

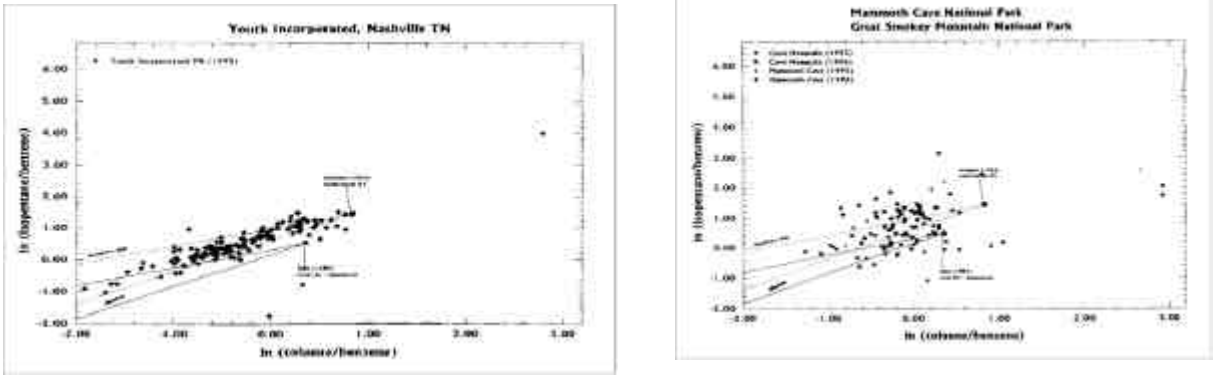


Figure 6 a,b: VOC ratio data from a suburban Nashville, TN site and a rural Mammoth Cave NP, KY site.

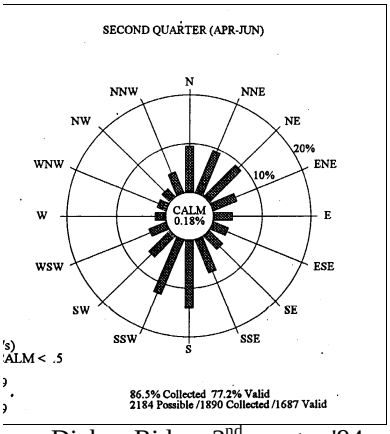
Just to show that this concept can work, plots for a site just outside Nashville (Youth Inc. site) and for Mammoth Cave are presented above. The Youth Inc data seems to fit the theory very nicely. Most of the data points can be explained by chemical reaction and dilution from the mostly mobile-source mixture of VOC expected from an urban area. The Mammoth Cave data is less conclusive and has many points outside the chemistry/dilution triangle.

The conclusion for the Shenandoah VOC data is that both isopentane and toluene have an alternate non-mobile source. Since increasing the sampling height reduced the isopentane bias, but not the toluene, two different sources are suggested with the isopentane source being more localized. The presence of high methanol and freon concentrations suggest additional non-mobile VOC sources. Plots of other VOC ratios may put the data closer to the expected chemistry/dilution triangle. [Zika, Farmer]

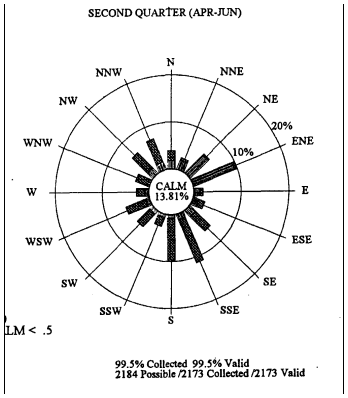
Cycles and environmental influences

Wind sector analysis

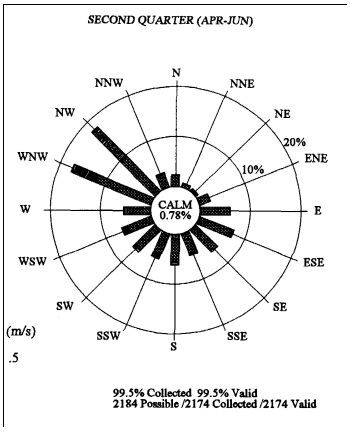
Wind roses show different wind patterns for the three principle sites where ozone has been measured in the park. Dominant flow to the BM site is from the northwest, NE and S for Dickey Ridge, and ESE and SSE for Sawmill Run. The lower elevation sites have more localized wind patterns than the BM site.



Dickey Ridge, 2nd quarter '94



Sawmill Run, 2nd quarter '94



Big Meadows, 2nd quarter '97

Figure 7 a,b,c: Sample wind roses for the three ozone monitoring sites in Shenandoah NP. Note that the Dickey Ridge and Sawmill Run sites were shut down in 1994.

EPA VOC emission inventory data (1990) has been plotted for a 200 km radius around the park and the emissions summed within wind sectors grids for 50 km distances. For the Big Meadows site, there are moderate emissions to the north and northwest. Sectors to the NNE, ENE, and SE with high emission grids at distances of greater than 100km have low incidences of winds from those directions. Back trajectory analysis would improve on this simple wind analysis. [Ray]

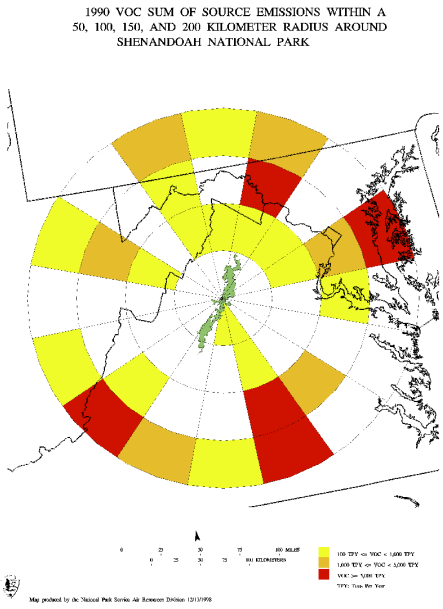


Figure 8: Sector analysis of VOC emissions within a 200 km radius of Shenandoah NP based on the 1990 EPA inventory.

Possible local area VOC sources are summarized in the table below for facilities in proximity to the park. The largest concentration of photochemically reactive VOC emissions is in the Front Royal/Winchester area just north of Shenandoah. There are also significant emissions from just west of Luray. Comparison

to the sector analysis figure puts the size of these sources in perspective. These facilities also release a number of ketones, alcohols, and ethers that could be photochemically active, but are not normally detected by using the canister sampling method. The VOCs emissions from Merck and DuPont (Waynesboro) do not include aromatics and are limited to mostly methanol (which the canister method does not routinely detect). The list below is consistent with the unusually high aromatics that are observed at Big Meadows and may be a partial explanation. The distribution and amounts are also consistent with the higher concentrations in the north that was observed by sampling at alternate locations. [Ray]

Table 1: Some estimated annual emissions from reporting sources. Based on HAPS list.

Facility	City	Direction from BM	Organic emission	Amount (tons/year)
O'Sullivan Corp	Winchester	N	Toluene	305.8
			Xylenes	95.0
			Ethylbenzene	17.1
Crown Cork & Seal	Winchester	N	Ethylbenzene	30.7
			Xylenes	144.4
			n-hexane	205.6
DuPont	Front Royal	N	Toluene	21.3
			Xylenes	26.7
			Ethylbenzene	0.27
			Styrene	0.42
Seaward Intl	Clear Brook	N	Toluene	90.3
	Winchester	N	Styrene	1.65
Merillat Industries	Mount Jackson	W	Toluene	131.9
			Xylenes	159.2
			Ethylbenzene	32.5
Ethan Allen	Bridgewater	SW	Toluene	27.0
Merck	Elkton	SW		--
DuPont	Waynesboro	SSW		--

Source: VA DEQ emissions inventory

Anthropogenic vs. biogenic

Based on observed VOC data over the last three years, VOCs from anthropogenic sources are the largest component of organic compounds at the three parks. Shenandoah has a lower biogenic percentage than the other two parks. [Kang, Aneja]

Table 2:

Park	Biogenics	Anthropogenics	Ratio B/A by ppbC	
Shenandoah	14	86	0.16	
Great Smoky Mountains	32	68	0.47	
Mammoth Cave	34	66	0.51	

Percentages by organic class

Shenandoah is lower in biogenics and higher in alkanes. The usually high isopentane concentrations account for the alkane class as higher than expected at Shenandoah. Isopentane typically comes from gasoline as vaporization or as combustion exhaust. [Kang, Aneja]

Table 3: Percentages of VOC by class in three National Parks

Park	Biogenics	Aromatics	Alkenes	Alkanes
Shenandoah	14	23	8	55
Great Smoky Mountains	32	27	9	32
Mammoth Cave	34	16	9	41

* ppbC units, as 3-year average of all valid samples

Isoprene to temperature relationship

Isoprene is emitted from vegetation mostly during the day in proportion to the temperature. The relationships for the three sites are listed below. The greater similarity for Shenandoah and Great Smoky Mountains is mostly because the mix of vegetation is more alike than for Mammoth Cave. Isoprene is the dominant biogenic VOC species and is very photochemically reactive to form ozone.

Table 4:

Park	Intercept	Slope	R^2 value
Shenandoah	-2.80	0.25	0.76
Great Smoky Mountains	-3.33	0.24	0.46
Mammoth Cave	-2.11	0.16	0.30
All 3 sites	-1.04	0.13	0.41

[Kang, Aneja]

Ozone formation potentials

Propylene equivalents

One method of estimating the ozone formation potential of organic compounds is to ratio the OH reaction rate to that of propylene for the observed concentration of each organic species. For Shenandoah, the propylene-equivalent is highest for isoprene (biogenic source), however, oxygenated organics are not routinely measured and may play a larger role than currently estimated. Propylene-equivalents will be recalculated for the three parks based on discussion at the meeting. [Kang, Aneja]

Comparison to other sites

Propylene-equivalent values were lower for Shenandoah than for Great Smoky Mountains and Mammoth Cave. This probably reflects the lower isoprene observed at Shenandoah more than other factors.

Estimating source types

CMB analysis of sources

A chemical mass balance technique was applied to the VOC data for the three parks. The assumption is that observed concentration for each compound is the sum of concentrations for each emission source. A matrix of 6 compounds and 6 sources can be solved to determine the contribution of each source. The compounds chosen where propane, butane, pentane, isopentane, benzene, and toluene. For Great Smoky Mountains and Mammoth Cave, mobile-source emissions accounted for greater than 50% of the

anthropogenic hydrocarbons observed. At Shenandoah, mobile-sources accounted for less than 15% and natural gas was identified as the dominant source. Unfortunately, the results are somewhat dependent on the selection of compounds chosen and selection of source types. The Shenandoah results might better be characterized as low mobile-source contributions and high non-mobile source(s). [Kang, Aneja]

Use of VOC ratios

The emissions of aromatic compounds from gasoline powered mobile-sources can be used to identify source categories and estimate the amount of "aging" by the VOC in the air parcel. For example, the xylene to toluene (X/T) ratio for automobile exhaust is 1.03, but gasoline vapor has an X/T ratio of only 0.57. As the more reactive xylenes are removed during aging the ratio gets smaller. Both the benzene/toluene (B/T) ratio and the X/T ratio at Shenandoah are out of line of mobile-source emissions and VOC aging. Local sources of xylenes and toluene that are non-mobile-sources are indicated. This is an unusual result; both Great Smoky Mountains and Mammoth Cave National Parks have B/T and X/T ratios that are consistent with moderately aged mobile-source emissions. [Ray, Zika]

Summarizing the uses and value of the BM data

Regional studies and ozone research

The Shenandoah ozone data and the continuous enhanced monitoring are being used by a variety of organizations and researchers including:

U. of Maryland researchers and ozone forecasters
NARTO-NE study of the ozone formation and transport
OTAG for back trajectory analysis, ozone mapping, wind sector analysis, and transport issues

Forecasting ozone episodes for the metro area

Shenandoah data is used to help estimate the daily peak ozone concentrations for the Baltimore-Washington DC metro area in the summer.

Indicator of regional air

Data from the Big Meadows site, because of its high elevation location and isolation from precursor sources, is generally a good indicator of regional air pollution levels.

Research on transport and formation

Polluted air that is transported to Big Meadows can be characterized by source types, the degree of photochemical aging, and amount of photochemical ozone production based on tracer species and O3 to NOz ratios.

Comparison to other monitoring and PAMS stations

There is a network of PAMS stations along the East coast that characterize upwind and downwind ozone and precusors for major urban centers. The rural character of the Big Meadows site represents further downwind transport from urban centers to the west and inflow air for the B-W metro area. Additional understanding of the ozone formation situation can be gained by using and comparing the Big Meadows data to the other PAMS stations.

Control strategy implications

The regional character of the formation and transport of ozone that reaches Shenandoah National Park requires a much better understanding of the processes and sources involved if reasonable control strategies are to be applied. Most ozone control strategies have been applied in urban areas without a solid understanding of the effects downwind in rural areas. The Big Meadows station provides data that can be used in a broader context to understand regional air pollution.

Implications for resource management, policy, and outreach

Shenandoah National Park clearly has air pollution problems from haze and high levels of ozone that are above the National Ambient Air Quality Standard for health effects and are high enough to have observable injury to vegetation. Visibility degradation in the park has reached levels that prevent visitor enjoyment of the scenic vistas. These are not problems that can be solved within the park or by the Park Service alone. Protection of natural resources, visitor health, and the valued scenic vistas requires an understanding of the extend of the problem to park resources, an understanding of the processes involved in air pollution reaching the park, and an outreach to inform the public and decision makers of the situation. A solid scientific foundation and an understanding of the effects on park resources is needed to participate in the national dialog on the best control strategies to be used.

What still needs to be done

The air pollution research at Big Meadows is just getting to a stage where results can be communicated in peer-reviewed publications, public reports, and in discussions with other agencies. Much more analysis and reporting is needed for the data already collected. Data collection needs to be continued and the manuscripts in preparation completed and submitted to peer-reviewed journals. Results from the research need to be reported in an expanded forum and funding for continued monitoring secured for beyond the 1999 ozone season.

Need for Rural Pollutant Monitoring

The importance of additional monitoring in rural areas for ozone and ozone precursors has been presented in a number of reports:

- OTAG Report (1997)
- NAPAP Report (1996)
- Ozone Effects Workshop (EPA, 1997)
- NARSTO Critical Reviews (in preparation)
- Rethinking the Ozone Problem in Urban and Regional Air Pollution (NRC, 1991)

This document is available on the NPS Internet AirWeb site at http://www.nature.nps.gov/ard/gas/enhanced.htm

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NPS Meeting Report:

Publications that use Shenandoah Monitoring Data

(1) Manuscripts that use the ozone and enhanced monitoring data from the Big Meadows station:

K.A. Hallock-Waters, B.G. Doddridge, R.R. Dickerson, Shane Spitzer, and John D. Ray, "Carbon Monoxide in the U.S. Mid-Atlantic Troposphere: Evidence of a decreasing trend, manuscript for submission *to Geophys. Res. Letters, 1998.*

Kang, D., V. P. Aneja, R. Zika, and J. D. Ray, "Non-methane Hydrocarbons in the Rural Southeast United States National Parks," draft manuscript for submission to *J. Air & Waste Manage. Assoc.*, 1999.

Stehr, J., R.R. Dickerson, K.A. Hallock-Waters, B.G. Doddridge, and D. Kirk, "Observations of NO_y, CO, and SO_2 and the Origin of Reactive Nitrogen in the Eastern United States," manuscript for submission *to J. Geophys. Union, Atmos.*, 1998.

(2) These are published articles that use the ozone and enhanced monitoring data from the Big Meadows station:

Cooper, Owen R., "An Ozone Climatology Study for Big Meadows, Shenandoah National Park, Virginia:1989-1994," Master of Science thesis, Dept. of Environmental Sciences, University of Virginia, May, 1997.

Kang, D., V. P. Aneja, R. Zika, and J. D. Ray, "Non-methane Hydrocarbons in the Rural Southeast United States," Proceedings of the AWMA Symposium "Measurement of Toxic and Related Air Pollutants," Sept. 1998.

Moy, L.A., R.R. Dickerson, and W.F. Ryan, Relationship Between Back Trajectories and Tropospheric Trace Gas Concentrations in Rural Virginia, *Atmos Environ***, 28**, 2789-2800 (1994).

Ryan, W.F., B.G. Doddridge, R.R. Dickerson, R.M. Morales, K. A. Hallock, P.T. Roberts, D.L. Blumenthal, J.A. Anderson, and K.L. Civerolo, Pollutant Transport During a Regional O3 Episode in the Mid-Atlantic States**,** *J. Air & Waste Manage***.** *Assoc.***, 48**, 786-797 (1998).

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NPS Meeting Report:

Doddridge, B. G., R. R. Dickerson, J. Z. Holland, J. N. Cooper, R. G. Wardell, and O. Poulida, Observations of tropospheric trace gases and meteorology in rural Virginia using an unattended monitoring system: Hurricane Hugo (1989), a case study, *J. Geophys. Res.*, **96**, 9341-9360 (91) [NPS] A

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Eder, B. K., J. M. Davis, and P. Bloomfield, A characterization of the spatiotemporal variability of non-urban ozone concentrations over the Eastern United States, *Atmos. Environ*., **27A**, 2645-2668 (93) [AIRS]

Jacob, D. J., L. W. Horowitz, J. W. Munger, B. G. Heikes, R. R. Dickerson, R. S. Artz, and W. C. Keene, Seasonal transition from NO_x- to hydrocarbon-limited conditions for ozone production over the eastern United States in September, *J. Geophys. Res*., **100**, 9315-9324 (95) [non-NPS data] A

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Lefohn, A. S., P. J. Edwards, and M. B. Adams, The characterization of ozone exposures in rural West Virginia and Virginia, *J. Air & Waste Manage. Assoc.*, **44**, 1276-1283 (94) [AIRS]

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Munger, J. W., D. J. Jacob, B. C. Daube, L. W. Horowitz, W. C. Keene, and B. G. Heikes, Formaldehyde, glyoxal, and methylglyoxal in air and cloudwater at a rural mountain site in central Virginia, *J. Geophys. Res.*, **100**, 9325-9333 (95) [non-NPS data] A

Poulida, O., R.R. Dickerson, B. G. Doddridge, J. Z. Holland, R. G. Wardell, and J. G. Watkins, Trace gas concentrations and meteorology in rural Virginia: 1. Ozone and carbon monoxide, *J. Geophys. Res.*, **96**, 22,461-22,475 (91) [NPS] A

Talbot, R. W., B. W. Mosher, B. G. Heikes, D. J. Jacob, J. W. Munger, B. C. Daube, W. C. Keene, J. R. Maben, and R. S. Artz, Carboxylic acids in the rural continental atmosphere over the eastern United States during the Shenandoah cloud and photochemistry experiment, *J. Geophys. Res*., **100**, 9335-9343 (95) [non-NPS data] A

Attachments:

1. Meeting agenda
2. Attendee list

NPS Meeting Report:

1. Meeting agenda

SHENANDOAH NATIONAL PARK
GASEOUS POLLUTANTS MONITORING & RESEARCH MEETING

9:30- 9:45 Welcome & Meeting Objectives	Doug Morris Christi Gordon
9:45-10:30 SNP SO2 & O3 Trends	John Ray
DC-Baltimore O3 Forecasting - Use of SNP Data, Findings & Applications	Bill Ryan
10:30-11:45 SNP Back Trajectory Modeling - Areas of Influence	Kristin Hallock-Waters, Owen Cooper
Related Current Topic (TBD)	Jenny Moody
11:45- 12:30 Delivered Lunch (TBD)	
12:30- 2:00 SNP CO, NOx, O3 Photochemistry & What It Tells Us About O3 Formation	Kristin Hallock-Waters, Bruce Doddridge
2:00- 3:00 VOC Sampling Methodologies SNP VOC Sampling Findings	Rod Zika
3:00- 3:15 Break	
3:15- 4:00 Regional Comparison of VOC & NOx Data for Shenandoah, Mammoth Cave & Great Smoky Mountains National Parks	Daiwen Kang, Viney Aneja,
4:00- 5:00 Discussion Are we getting the information we intended? Is the information responsive to resource management issues? How can the information be used to develop control strategies? How do managers interpret the information? What is the potential for Big Meadows as a PAMS site? What is the future of the enhanced ozone monitoring project?	Moderator: TBD
5:00 Adjourn - Drive Safely	

Tuesday, December 15, 1998 at Park Headquarters (Lower Level Training Room)

2. **Attendee list**

Name	**Representing**	**Email address**
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