Appendix 2

Ambient Monitored Data

Introduction

This Appendix discusses ozone and ozone precursor monitored data and demonstrates the impact of transported pollutants on Pennsylvania.

Part I. Monitoring Results and Transport

Pennsylvania maintains a substantial ground level monitoring network that measures a number of air pollutants including ozone. (See Figure 2A)

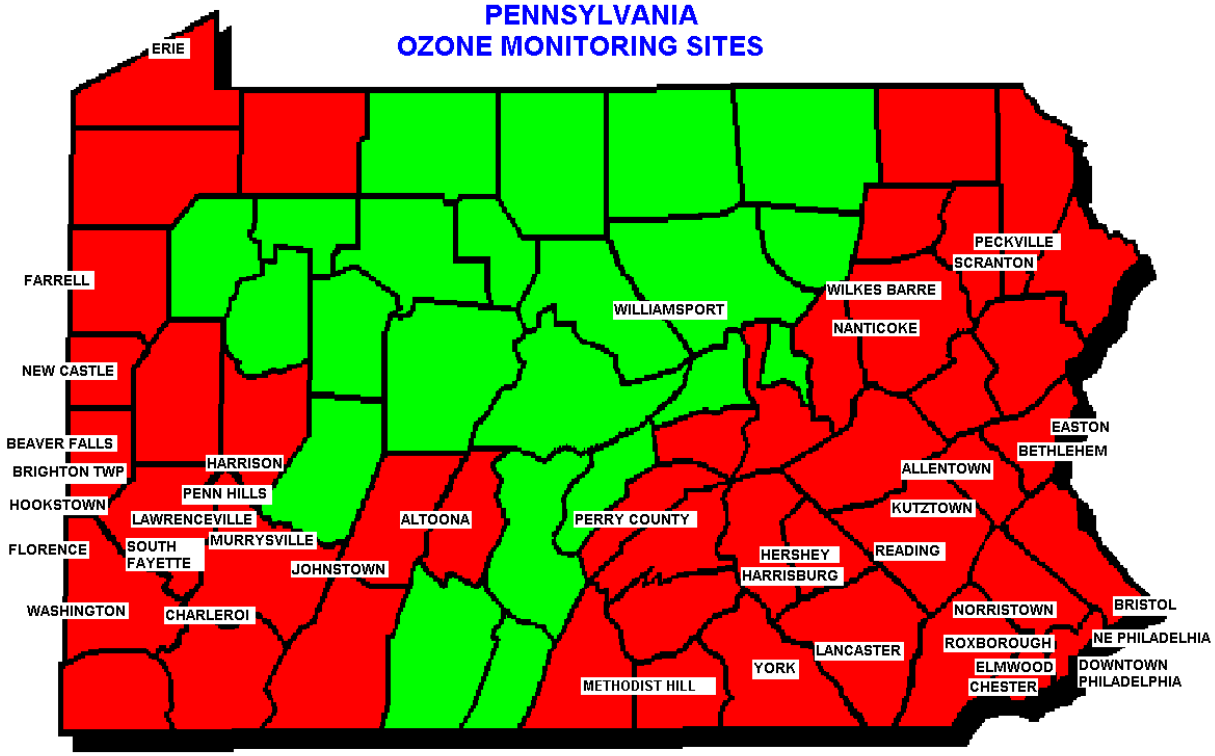


Figure 2A

Ozone concentrations entering Western Pennsylvania are in excess of 100 ppb when compared to the federal one hour standard of 120 ppb (See Figure 2B). The Hookstown and Florence monitors are of particular importance as they are located outside of any urbanized area, and are upwind of Pittsburgh. Hookstown is located within 1 mile of the Ohio border and Florence is located within 5 miles of the Ohio border. Thus, they represent a pure measurement of incoming ozone levels.

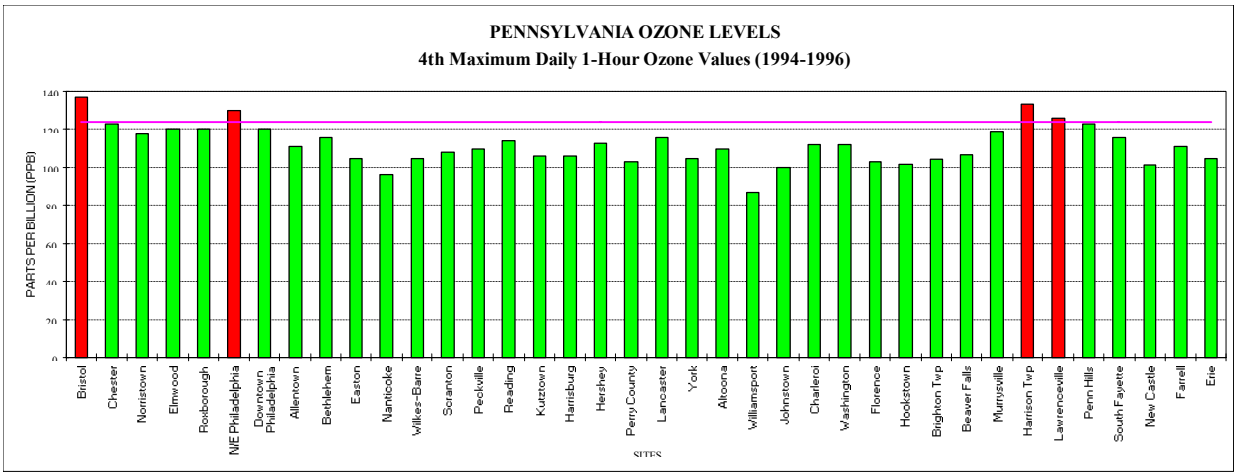


Figure 2B

When these and other border monitors are compared to the new federal ozone standard, concentrations entering Pennsylvania actually violate that new standard (See Figure 2C). This Figure shows the Florence and Hookstown monitors reporting ozone readings of above 85 ppb compared to the new ozone standard of 80 ppb.

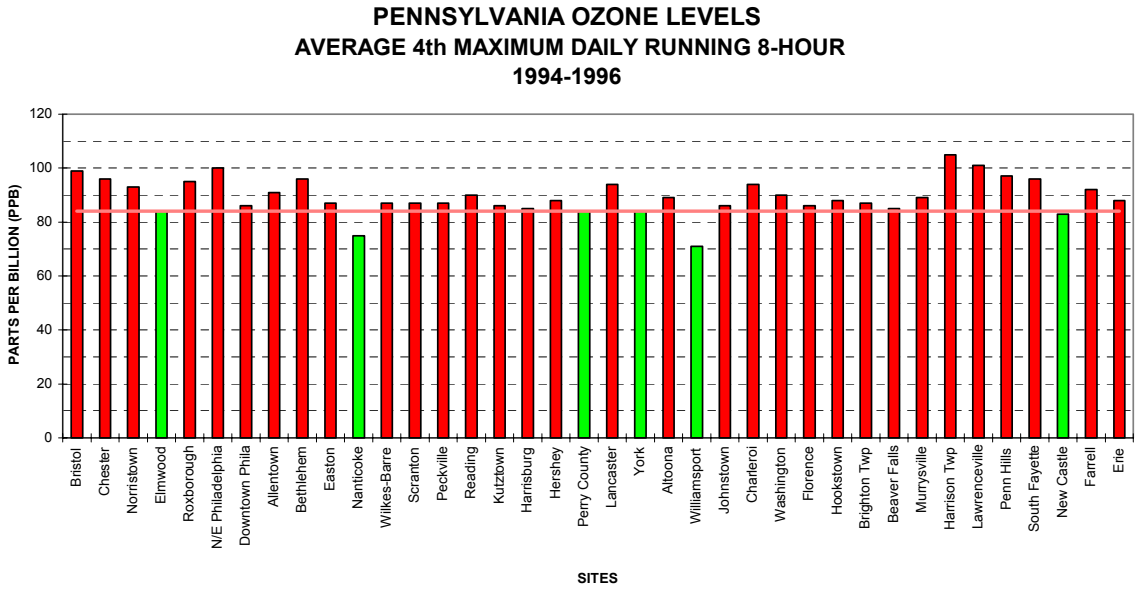


Figure 2C

A separate analysis was also done for ground level monitoring data at Pennsylvania's southern border near the south boundary of the Ozone Transport Region. This analysis demonstrates that on the days where exceedances are recorded in sites upwind of the Philadelphia urban area there is a significant mass of ozone being transported across the southern border of Pennsylvania. (See section B. Monitored Ozone Data in Southeastern Pennsylvania)

Monitored Ozone Data in Southwestern Pennsylvania

As the figures above demonstrate, ground level ozone concentrations entering Western Pennsylvania, as determined by the Hookstown and Florence monitors are in excess of 100 ppb on high ozone days. All the ground level monitoring data analyzed for this report is available through either the EPA's Aerometric Inventory Retrieval System (AIRS) or from the Commonwealth of Pennsylvania Air Monitoring System (COPAMS).

Upper air data collected from a NARSTO aircraft flying along the western border of Pennsylvania, during an episode day demonstrates high ozone levels aloft. This data is presented in part II.

An additional analysis was completed on ozone concentrations brought in the Pittsburgh area during the 1995 exceedances. Back trajectories were calculated using the National Oceanic and Atmospheric Administration's (NOAA) HYSPLIT model on eight ozone exceedance days. Air masses associated with these elevated ozone levels passed over a variety of states including: Michigan, Ohio, Illinois, Missouri, West Virginia, Indiana and Virginia. (See Part III. Pittsburgh 1995 Back Trajectory)

Monitored Ozone Data in Southeastern Pennsylvania

In Southeastern Pennsylvania ozone, wind speed and wind direction data from the following sites were analyzed:

Bristol (FDR School)
Chester (Front and Norris Sts.)
Lancaster East (Lincoln School)
Norristown (Armory)
York East (Davis School)

On seven separate days in the summer of 1995 ozone values exceeded the one hour standard of 120 ppb. The highest recorded reading was for the Bristol monitor which reached 162 ppb (35% over the standard) on July 15, 1995.

The Southern Oxidant Study identified that episodes with significant transport are characterized by high ozone levels that occur several hours after the period of peak solar radiation. This confirms the model observation that plumes of pollutants can exist many miles downwind of it's source and pollutant levels within those plumes remain at higher levels for a longer period of time. The study [i] further identified two types of plumes, the broader plumes that create high background concentrations, but not necessarily exceedances, and source plumes that can be imbedded within the urban plumes causing peak values.

Overall average winds, for the monitors studied, are out of the south (192°) at a speed of 9 miles per hour (mph). To identify these broader plumes, data was analyzed for days where the ozone monitors showed a reading of at least 80 ppb at 4:00 p.m. or later. The winds at those monitors were recorded for the period between 11:00 a.m., by which time the synoptic winds should have developed, and 8:00 p.m., since 90% of the high ozone readings occur before that time. The result was that average winds for this period were out of the southwest (220°) at 11 miles per hour.

In this wind direction, the monitor sites are a maximum of approximately 25 miles from Pennsylvania's southern border. This would mean that the mass of air containing elevated ozone

levels over the monitors was likely well south of the Pennsylvania border during the period of peak solar radiation and ozone formation.

Because of the complexity of emissions within an urban plume, data for monitors upwind or representative of upwind conditions of the Philadelphia urban center were selected. On the exceedence days in 1995, this eliminated the monitor at Bristol from the analysis. Of the upwind monitor sites in 1995, the following data were recorded.

Date	Monitor	Time	Max. Ozone Level (ppb)	Wind Speed (mph)	Wind Direction
6/19/95	Norristown	6:00pm	125	15	253°
6/19/95	Chester	5:00pm	133	15	253°
8/2/95	Lancaster	3:00pm	125	12	208°
8/21/95	Chester	5:00pm	126	14	256°

Of the monitor sites upwind of the Philadelphia metropolitan area, the earliest exceedence occurred at 3:00 p.m., and all other daily maximum levels during exceedances occurred after 4:00 p.m. This strongly suggests that exceedances at these monitors are in part due to elevated background levels that have been transported across the southern border of Pennsylvania.

Philadelphia back trajectories were reconstructed for 11 exceedance episodes in 1996, 1995, and 1993 using NOAA's HYSPLIT trajectory model. Thirty-three back trajectories were calculated using HYSPLIT. These trajectories represented the path of air parcels from three different elevations over Philadelphia during the 24 hours prior to an exceedance. Origins of the back trajectories were grouped according to whether they originated inside or outside the Ozone Transport Region (OTR), and according to state. Over half of the back trajectories originated outside the OTR (58%). A number of the back trajectories originated in Midwest states such as Ohio and Michigan. This analyses shows that pollution from outside the OTR enters Philadelphia during ozone exceedance episodes. (See Part IV. Philadelphia Trajectory)

Part II. Aerial Measurements of Ozone Data

An analysis was performed to specifically look at days when aircraft flights were used to monitor ozone values aloft during high ozone days in Western Pennsylvania. Measurements of 90 ppb and higher were recorded along the Western Pennsylvania border during early morning hours while winds were from the west. On these days, monitored values flying along the Western Pennsylvania border showed levels that were 85 % higher than the average for the region on July days and 56 %of the highest recorded exceedance day.

Sources of Data

1. Monitors at the following locations:
   - Beaver Falls (Eighth and River)
   - Hookstown
   - Florence
   - Brighton Township
   - Washington (McCarrell St)
   - Charleroi
   - Murrysville

2. North American Research Strategy for Tropospheric Ozone-Northeast (NARSTO-NE) conducted intensive monitoring during the summer of 1995 when ozone exceedances occurred. This included measurements from the 7/31/95 NARSTO-NE flight (Aztec N6670Y). This consisted of a morning flight that flew along the Pennsylvania border from approximately 8 a.m. to 11 a.m. and an afternoon flight that flew along the border from noon until 3 p.m.

3. Meteorological data from a site at Holbrook.

Introduction

The analysis focuses on the 7/31/95 episode day because of the availability of data from the NARSTO-NE flights along the western border of Pennsylvania (Figure 1). The ozone exceedances recorded that day are summarized in the following table.

Table 1. Excedences in western PA (7/31/95)

Monitor Site	Time	Ozone (ppb)
Murrysville	3:00pm	127
Penn Hills	4:00pm	139
Lawrenceville	4:00pm	126
Harrison Twp	5:00pm	147

The flight consisted of take-off and landing sections, sections in traverse mode where the altitude was between 750 and 900 meters and sections in spiral mode where the altitude varied from 250 to 1,500 meters or from 500 to 2,000 meters with little variation in latitude. The data collected included ozone, NO, NOx, altitude, position, temperature and dew point temperature.

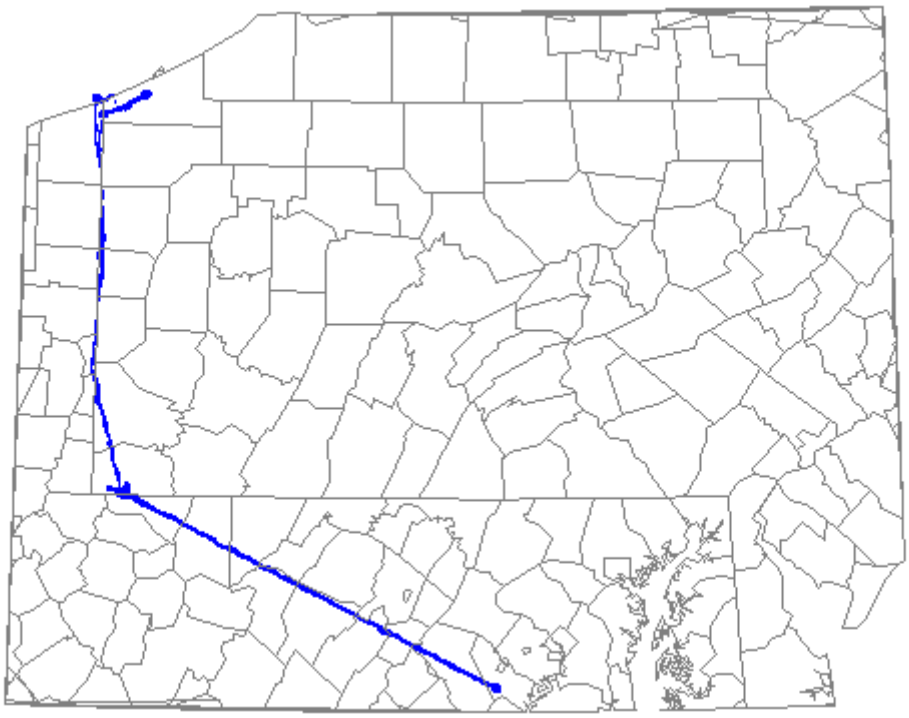


Figure 1. NARSTO flight path (7/31/95)

Analysis

Determination of Background levels of Ozone

To establish typical background levels during the period of time the NARSTO-NE plane was in operation, the ozone levels at the Pittsburgh area monitors recorded from 8 a.m. to 3 p.m. during July 1995 were averaged. This resulted in a mean ozone level of 44 ppb, which corresponds to the OTAG estimates of 30-50 ppb[ii].

Analysis of NARSTO Flight Data

The recorded levels of ozone were averaged for the duration of the morning and afternoon flights. This resulted in means of 77 and 93 ppb respectively. The levels of ozone, NO and NOx were then plotted for the duration of the flight (figures 2 and 3). These plots show that while the majority of ozone values fall in the same range, there are several irregularities in the observed levels. To arrive at a reasonable estimate of ozone concentrations at the border, it is necessary to limit the analyzed data to only meaningful data points.

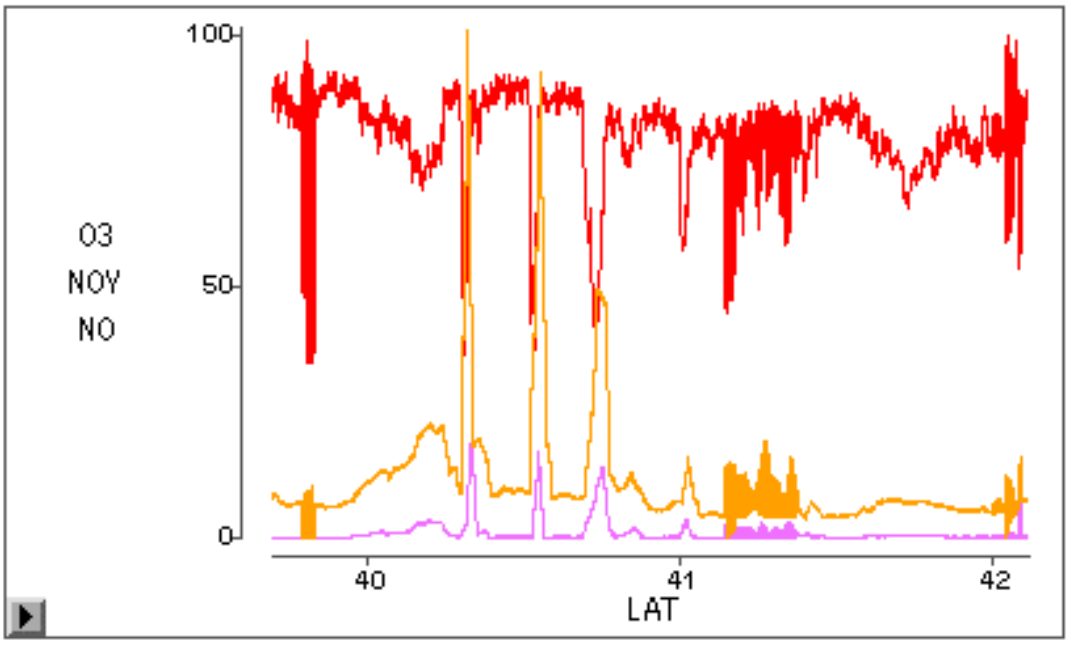


Figure 2. Pollutant levels recorded during the am flight.

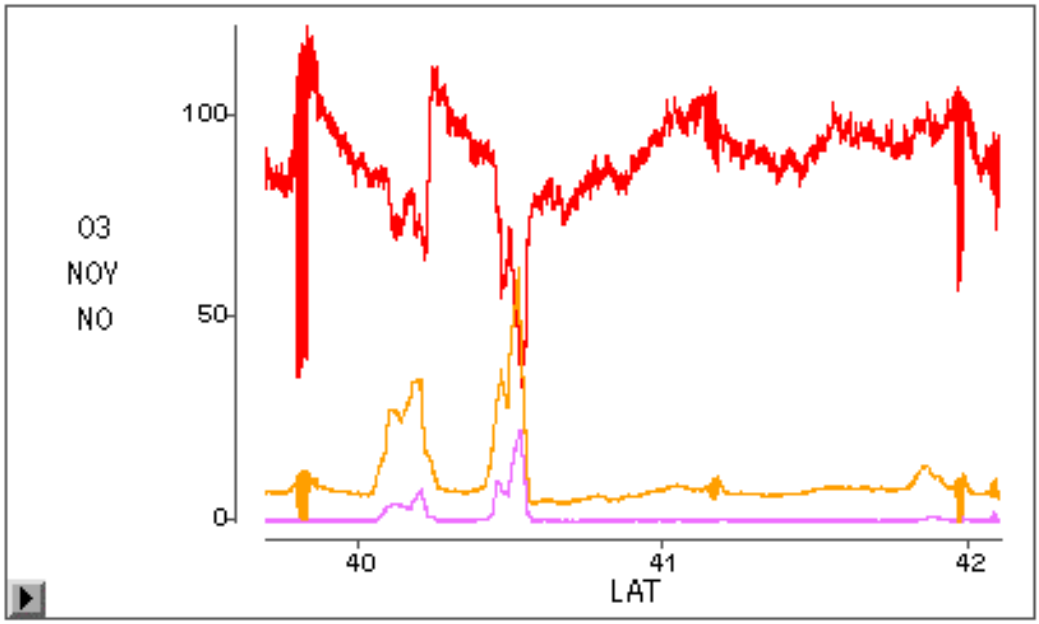


Figure 3. Pollutant levels recorded during the pm flight

Adjustments to the Data

The following data points were considered inappropriate for this analysis:

1. Data not collected along the Pennsylvania Border.
2. Data collected during take-offs, landings and while the aircraft was flying spirals.
3. Data collected where ozone levels were reduced because of scavenging from NOx plumes.

This was accomplished by first removing data that was collected at a latitude less than 39°42' N which is the approximate southern border of Pennsylvania.

When the aircraft was in other than traverse mode, variations in monitored ozone level could be attributed to changes in the vertical profile of concentrations when the aircraft flew above the mixing height. While the aircraft was below the mixing height, more data points would be logged for a given latitude which would artificially "weight" certain values higher than others. Both these possibilities were eliminated by only utilizing data that were logged in traverse mode.

Scavenging from NOx plumes occurs when NO and ozone react together ($NO + O3 \rightarrow NO2 + O2$). As expected, the observed data supports this assumption. In figures 5 and 6, it can clearly be seen that large increases in NO levels are paired with proportional decreases in ozone levels. Although this creates lower ozone values at the border, it is not reasonable to consider this a benefit to the air quality in Pennsylvania because, as modeling shows, these NOx plumes will likely contribute to higher ozone levels in areas downwind. To account for this effect, ozone readings were not used that were collected during the highest 10% of NO readings (levels above 2.8 ppb in the morning and 1.04 ppb in the afternoon.)

After application of these adjustments, the ozone data was again averaged for the morning and afternoon flights. This results in a morning average of 81.7 and an afternoon average of 92.7 ppb.

Meteorological Data

For the period of time from 8 a.m. to 3 p.m. on July 31, 1995, the average winds recorded at Holbrook from ground-level to 1,500 meters were 5.3 mph out of the southwest (235°). At an angle of 235° the sites that recorded exceedances on July 31 are approximately 40 miles from the Pennsylvania border. Based on the wind data from Holbrook it would take approximately 7.5 hours for the mass of ozone at the border to reach the monitors. Or, in other words, the air mass over the border at 7:30 a.m. to 9:30 a.m. was over the monitors at the time of the exceedances.

Summary

The ozone levels monitored during the morning flight are a reasonable estimate of the emissions contribution from transport across the Pennsylvania border. These levels were 85% higher than the average for the region on July days and 56% of the highest recorded exceedence that day.

Part III. Pittsburgh 1995 Back Trajectories

Background ozone concentrations entering Pittsburgh during 1995 exceedances were estimated using a combination of back trajectories and AIRS data. Back trajectories from NOAA's HYSPLIT model determined air mass locations 24 hour prior to an exceedance in Pittsburgh. Three trajectories representing three elevations were generated for each exceedance day. Ozone concentrations in the areas upwind of Pittsburgh, as determined by HYSPLIT, from the AIRS database determined a background ozone concentration. Incoming background ozone concentrations determined by this method ranged from 80-106 ppb. These concentrations are well above the background concentrations (30-50 ppb) established by OTAG's Air Quality Analysis workgroup (Final Report) and show upwind regions can contribute background ozone concentrations that are at least two thirds of the current one hour ozone standard.

Introduction

Background ozone concentrations were estimated for Pittsburgh using 1995 back trajectories. The Pittsburgh region recorded 17 exceedances of the health-based ozone standard during 1995. Exceedances were grouped into five exceedance episodes that occurred over a total of nine days. Table 2 summarizes the 1995 Pittsburgh exceedances.

Table 2.

Station	Date	Ozone (ppb)	Hour of Max
Murrysville	6/19	130	17
Lawrenceville	6/19	137	17
Penn Hills	6/19	129	18
Harrison	7/13	127	14
Harrison	7/14	129	15
Harrison	7/15	138	12
Penn Hills	7/15	133	12
Lawrenceville	7/15	125	12
Harrison	7/31	147	17
Lawrenceville	7/31	126	16
Murrysville	7/31	127	16
Penn Hills	7/31	139	16
Harrison	8/1	138	15
Harrison	8/2	131	17
Lawrenceville	8/2	140	17
Harrison	8/15	133	14
Murrysville	8/26	125	17

Background Ozone Concentration Determination

Background ozone concentrations for Pittsburgh's 1995 exceedances were determined by locating upwind (source) regions on the days prior to measured exceedances. Source region ozone concentrations (from AIRS) were then used as a background concentration for Pittsburgh on the exceedance days.

One method used to determine source regions involved using Pittsburgh's actual surface and 850 mb level winds (winds at approximately 5000 ft). Exceedance episode wind speeds and wind directions were determined for the Pittsburgh region. Back trajectories for the previous 24 hours were then calculated using this information. The 850 mb winds had to be included in this analysis to account for daytime vertical mixing within the lower levels of the atmosphere (mixed layer). Vertical mixing and aloft ozone transport are recognized as important features in many air-quality analyses (OTAG, NESCAUM). In fact, ozone transport aloft is more important than surface transport in the Pittsburgh region. Pittsburgh's sharp topography generates many local-scale features in the surface winds.

Upwind regions were also determined using the HYSPLIT trajectory model. The HYSPLIT model was developed by NOAA to construct forward and backward trajectories from a given location. HYSPLIT has archive data which was used to determine Pittsburgh's source regions during the 1995 exceedances. HYSPLIT uses output from the Nested Grid Model (NGM), a three dimensional weather forecast model, to back-track air parcels from a given point.

Establishing "Background" Ozone Concentrations

Results from DEP's analysis of actual wind data for each of Pittsburgh's 1995 exceedances are summarized below. Information for each episode includes maximum ozone concentrations for the Pittsburgh region and surface and 850 mb trajectories determined from the actual wind fields. Trajectories determined from the actual surface and 850 mb wind fields are compared with the HYSPLIT back trajectories to determine consistency. Background ozone concentrations for Pittsburgh were estimated from the HYSPLIT determined source region's ozone concentrations (from AIRS).

Pittsburgh Episode Analysis Summary

Episode 1: June 19, 1995:

Surface Winds (5pm)

Regional Avg: West, 0-3mph

850mb Winds (8am)

Pitt: North, 10kts

Wind Fields Suggested Ozone Transport:

Surface: Ozone Transport from Pittsburgh to the east

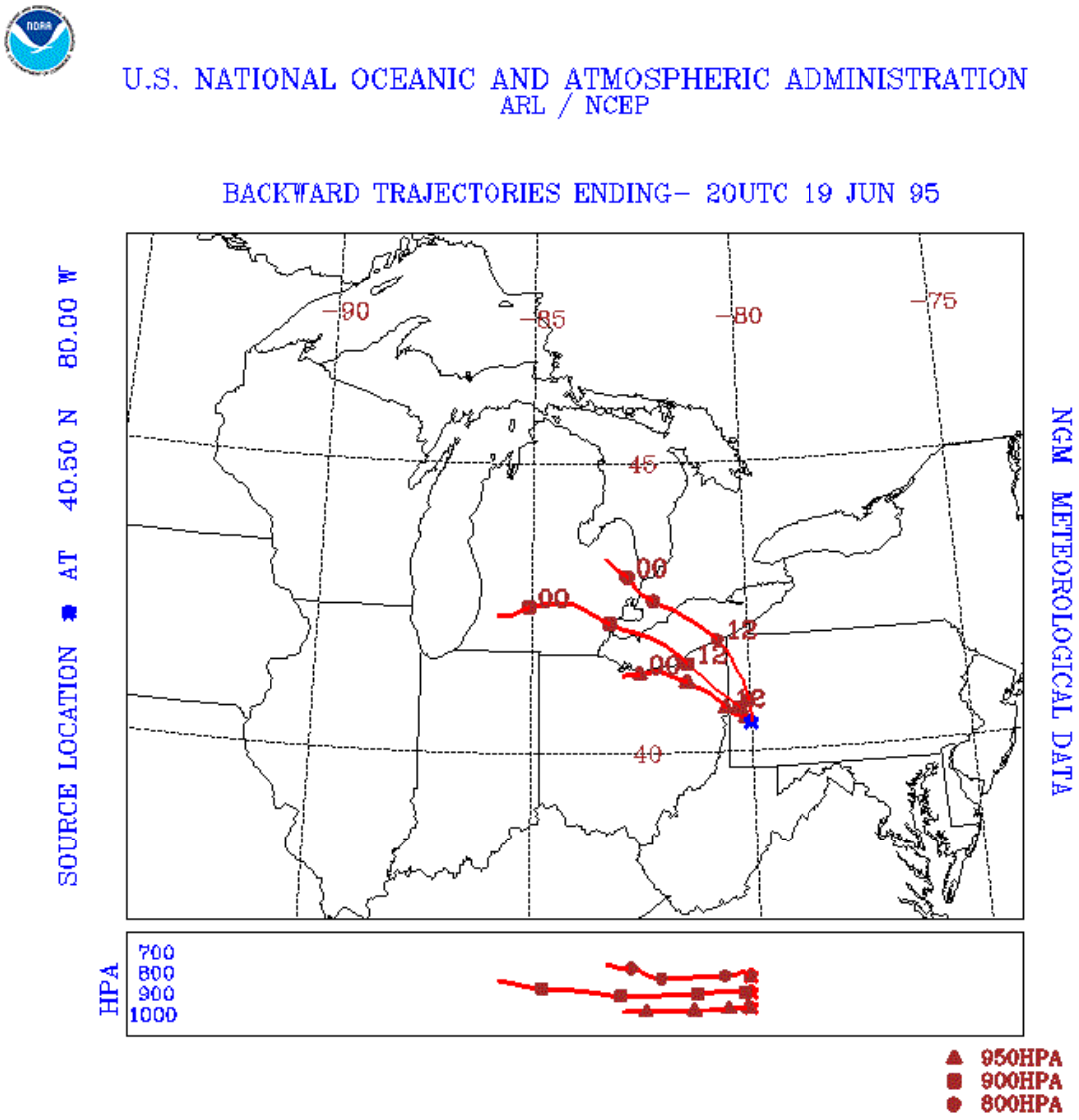
850mb: Ozone Transport from Chicago & Midwest, to Pittsburgh, to WV

Regional Maximum Ozone Levels (6-19-95)

COPAMS	Conc. (ppb)	Hour
BEAV	106	17
CHAR	110	18
HOOK	98	15
FLOR	MSG	--
MURR	**130**	17
NEWC	123	17
WASH	111	19

ALLEGHENY COUNTY	Conc. (ppb)	Hour
HARR	118	13, 17
LAWR	**137**	17
PENN	**129**	17
SFAY	117	16

HYSPLIT back trajectories for June 19, 1995, are plotted below. Three levels were chosen as start points for the back trajectory analysis. They were 50 m, 750 m, and 1500 m. The 50 m level was chosen to backtrack the surface air mass. The 750 m level was chosen to backtrack the mixed layer in which potential ozone transport occurred. This level is also roughly the same height as the NARSTO-NE flights along the PA-OH border (see Appendix 2 Part II). The 1500 m level was chosen to backtrack the 850 mb air mass. This also allowed for verification of the back trajectories developed from the 850 mb wind fields. The 1500 m level represented the upper limit of the mixed layer in which ozone could be transported. A key to the chart can be found on page 2-25.



Results from HYSPLIT corresponded well to the trajectories determined from the actual surface and 850 mb level winds. The HYSPLIT results demonstrated that the 750 m air mass started over western Michigan on June 18, 1995. Ozone measurements from Grand Rapids and Holland indicate ozone concentrations were 80 ppb and 99 ppb respectively. This demonstrates that background ozone concentrations over Pittsburgh on June 19, 1997, were between 80-99

ppb. This is approximately twice natural background levels determined by OTAG's Surface Analysis Workgroup, and represents about 58-72% of the maximum one-hour concentration measured at Lawrenceville.

Episode 2: July 13-15, 1995

	July 13	July 14	July 15
Surface Winds (3pm)	SW, 2-5mph	SW, 2-5mph	W, 1-4mph
850mb Winds	NW, 10kts	NW, 30kts	NNW, 25 kts

Wind Field Suggested Ozone Transport:

Surface: Ozone transport from Pittsburgh to the northeast

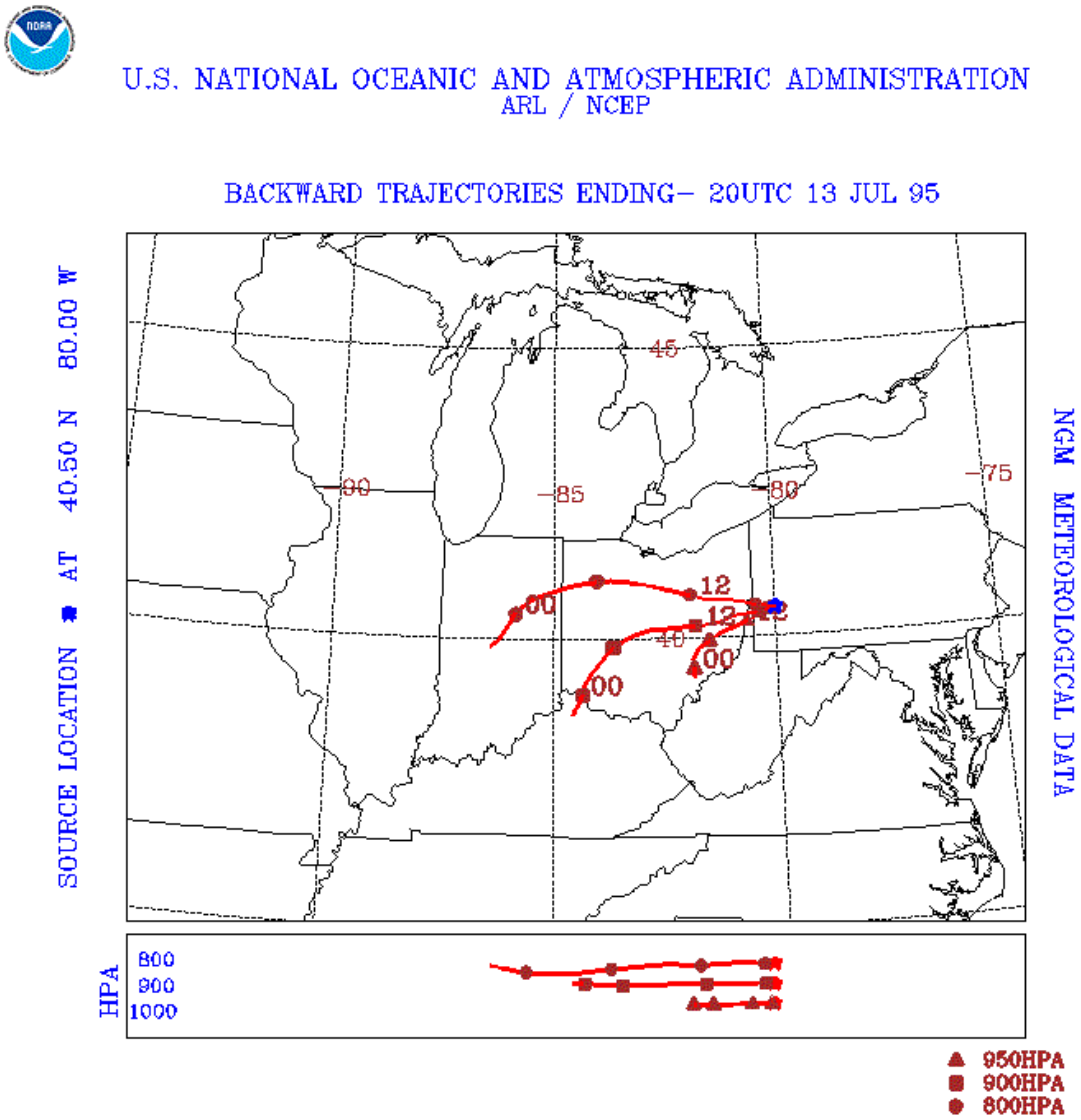
850mb: Ozone transport from Midwest, Chicago, Detroit, to Pittsburgh, to DC, VA

Regional Maximum Ozone Levels

COPAMS	7-13 (Hour)	7-14 (Hour)	7-15 (Hour)
BEAV	98 (17)	82 (16)	92 (16)
CHAR	89 (16)	112 (19)	98 (14)
HOOK	100 (16)	95 (21)	105 (14)
FLOR	89 (14)	91 (20)	99 (13)
MURR	92 (15)	96 (16,17)	118 (16)
NEWC	81 (20)	83 (15)	83 (14,15)
WASH	97 (16)	82 (20)	MSG
ALLEGHENY COUNTY			
HARR	**127 (14)**	**129 (15)**	**138 (12)**
LAWR	108 (17)	105 (16)	**125 (12)**
PENN	102 (13)	114 (16)	**133 (12)**
SFAY	102 (16)	89 (15)	106 (15)

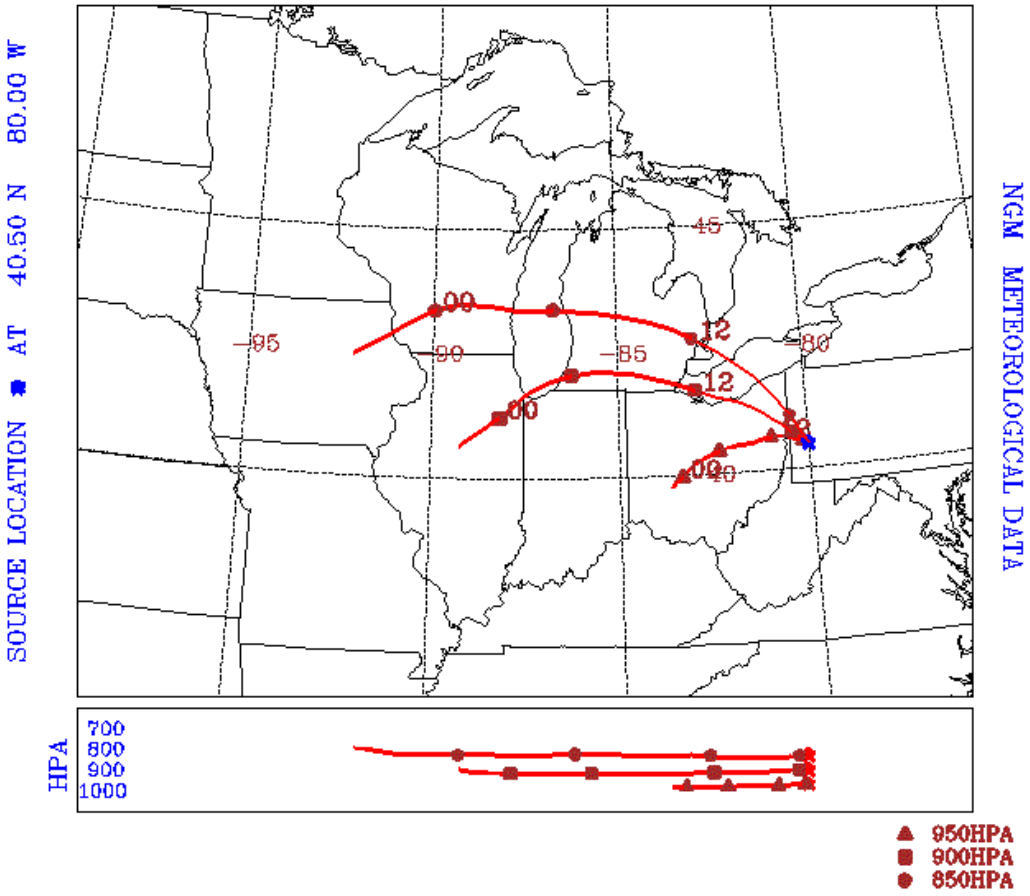
HYSPLIT back trajectories for each day of this episode are included below. Upwind areas determined from the 750 m level back trajectories indicated Pittsburgh's source regions shifted throughout the episode. Pittsburgh's source region on July 12, 1995, appeared to be Cincinnati, Ohio. Background ozone concentrations for Pittsburgh on July 13, 1995, are 90-106 ppb based on July 12, 1995, concentrations near Cincinnati. This is approximately 71-83% of the maximum ozone concentration observed at Harrison on July 13, 1995. On July 14, 1995, Pittsburgh's source region, according to the 750 m back trajectory, appeared to be Peoria, Illinois. Late morning ozone concentrations near Peoria peaked at 92 ppb. This result shows Pittsburgh's July 14, 1995, background ozone was 92 ppb, or 71% of the maximum ozone concentration recorded at Harrison. Pittsburgh's source area for July 15, 1995, remained in Central and West-Central Illinois according to the 750 m back trajectories. July 14, 1995, surface ozone concentrations in that area were unusually low (54-77 ppb). Upon further

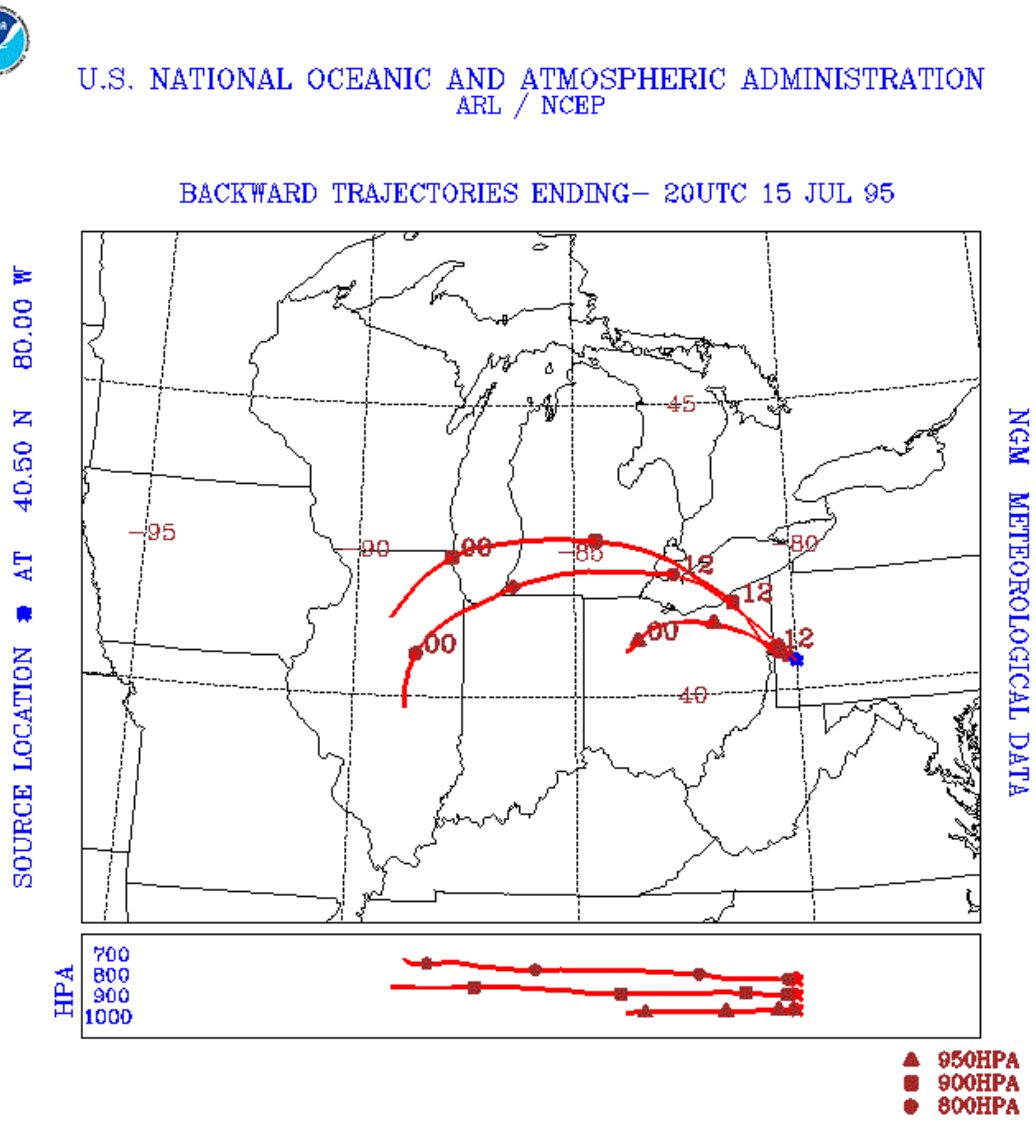
examination, the analysis shows that the air mass over Pittsburgh on July 15, 1995, from St. Louis, Missouri. On July 13, 1995, ozone levels around St. Louis exceeded the standard (134 ppb downwind in Illinois). Forward trajectories placed the 750 m air mass that was over St. Louis on July 13, 1995, was over extreme Northeastern Indiana on July 14, 1995. No ozone monitors were located in this area. There was, however, one monitor just across the border in Michigan: Cassopolis. Its maximum ozone reading for July 14, 1995, was 150 ppb. This result shows that elevated ozone concentrations drifted northeast from St. Louis to the Michigan/Indiana border on July 14, 1995, before moving southwest into Pittsburgh causing exceedances on July 15, 1995. Forty-eight hour back trajectories starting over Pittsburgh on July 15, 1995, indicated the 750 m's source region was near St. Louis on July 13, 1995 (exceedance date).



U.S. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ARL / NCEP

BACKWARD TRAJECTORIES ENDING- 20UTC 14 JUL 95





Episode 3: July 31 to August 2, 1995

	7-31	8-1	8-2
Surface Winds (5pm)	W, 1-3mph	W, 1-3mph	NW, 1-2mph
850mb Winds (8am)	SW, 5kts	W, 10kts	W, 10kts

Wind Field Suggested Ozone Transport:

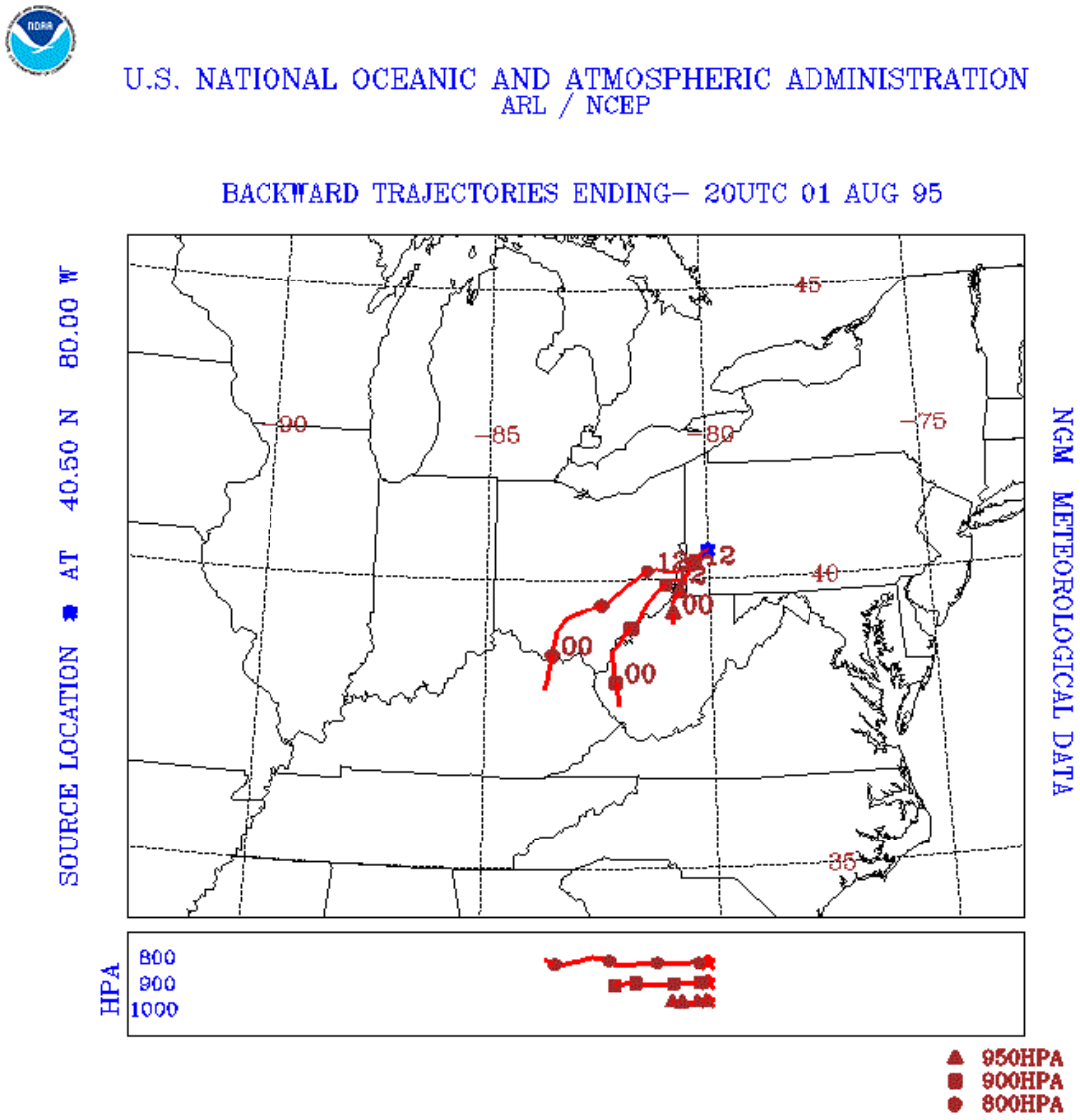
Surface: Ozone transport from Pittsburgh to east

850mb: Ozone transport from Ohio River Valley, to Pittsburgh, to VA & DC, eastern PA

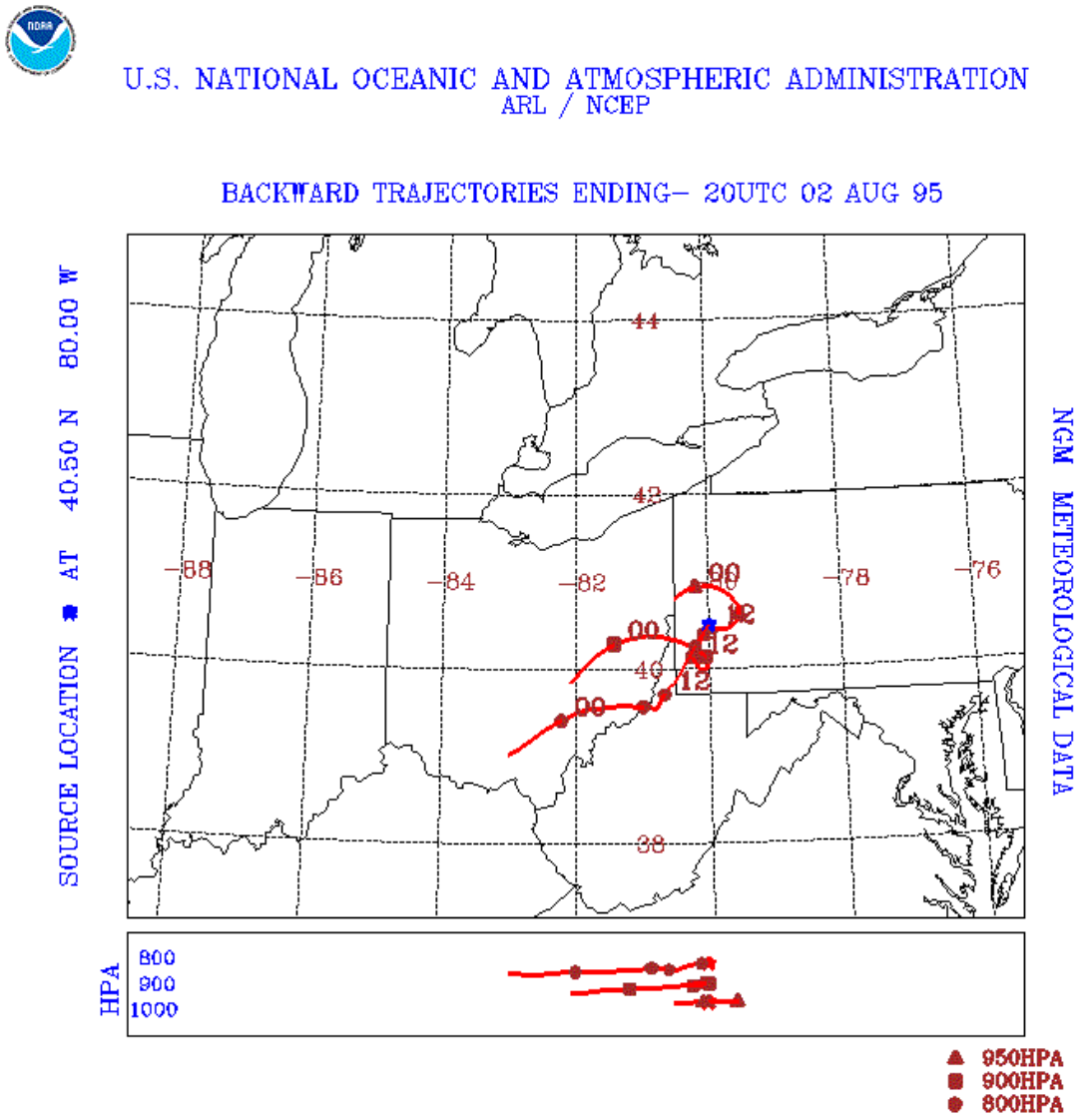
Regional Maximum Ozone Levels

COPAMS	7-31 (Hour)	8-1 (Hour)	8-2 (Hour)
BEAV	92 (17)	95 (15)	90 (19)
CHAR	109 (15,18)	105 (18)	100 (15)
HOOK	76 (15)	84 (13)	88 (16)
FLOR	104 (17)	103 (16)	89 (16)
MURR	**127 (16)**	106 (16)	108 (16)
NEWC	97 (18)	74 (19)	72 (19)
WASH	92 (17)	104 (18)	82 (17)
ALLEGHENY COUNTY			
HARR	**147 (17)**	**138 (15)**	**131 (17)**
LAWR	**126 (16)**	100 (18)	**140 (17)**
PENN	**139 (16)**	108 (13,14)	123 (17)
SFAY	106 (17,18)	95 (16,17)	102 (14)

The HYSPLIT 750 m back trajectory indicated source regions for this episode were in Ohio and the Ohio River Valley. This result was similar to trajectories reconstructed from the 850 mb wind data. Pittsburgh's source area for August 1, 1995, was located in West Virginia, near its border with Kentucky. July 31, 1995, ozone concentrations in this area were approximately 90-100 ppb. This demonstrates that Pittsburgh's August 1, 1995, background ozone concentration was about 65-72% of the maximum ozone concentration measured at Harrison.



HYSPLIT 750m back trajectories for August 2, 1995, (below) show that Pittsburgh's source area was located in the east-central portion of Ohio. Ozone concentrations in this area ranged from 97-101 ppb on August 1, 1995. This shows that background ozone concentrations over Pittsburgh on August 2, 1995, were about 69-72% of the maximum ozone concentration measured at Lawrenceville.



Episode 4: August 15, 1995

Surface Winds (2pm)

Directions site dependent, 1-3mph

850mb Winds (8am)

West, 5kts

Wind Field Suggested Ozone Transport:

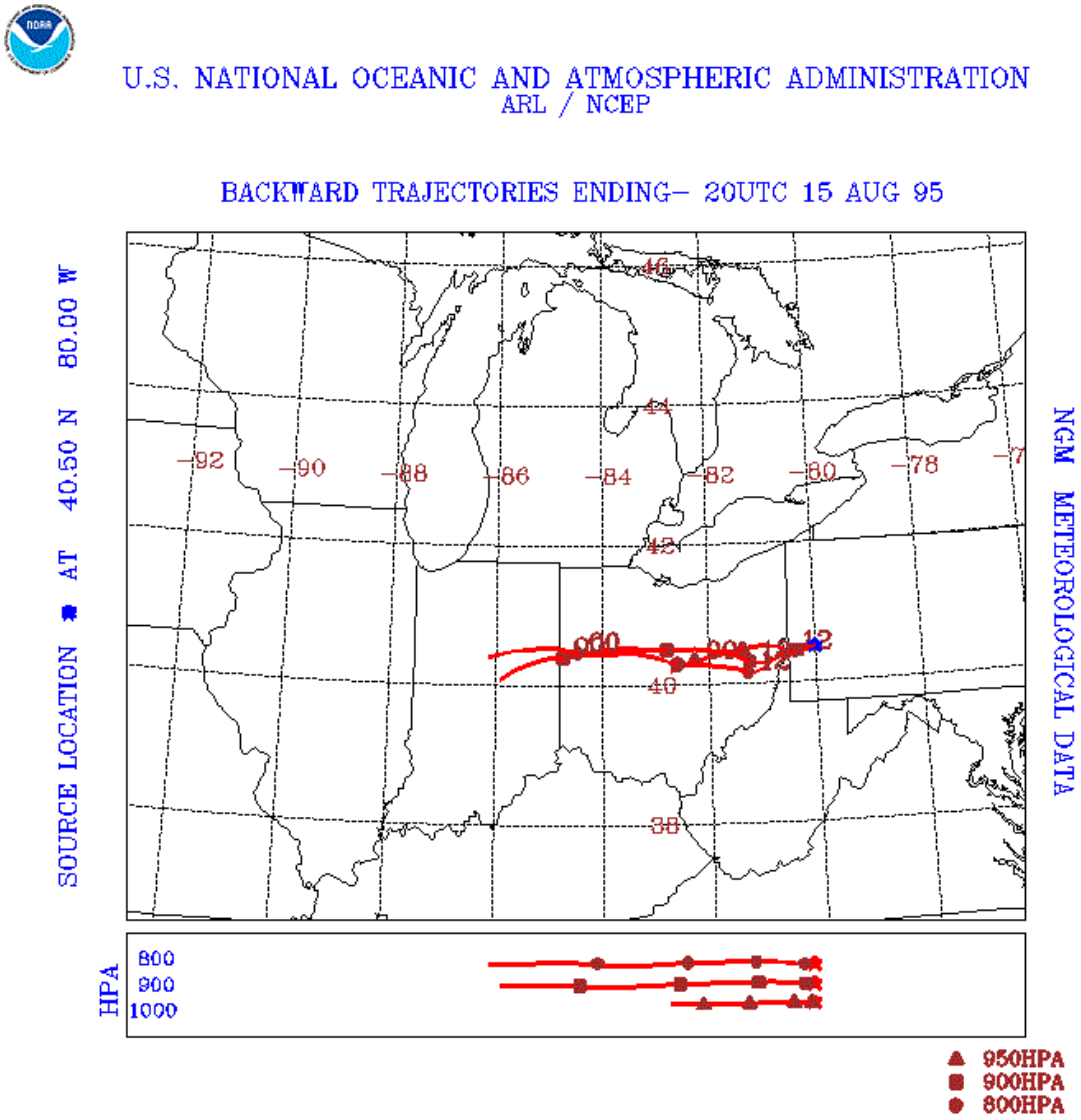
Surface: From Pittsburgh to the east or northeast

850mb: From Midwest to WV

Regional Maximum Ozone Levels (8-15-95)

COPAMS	Conc. (ppb)	Hour
BEAV	72	15
CHAR	102	19
FLOR	85	16
MURR	96	16
NEWC	54	13
WASH	84	19
ALLEGHENY COUNTY		
HARR	**133**	15
LAWR	101	14
PENN	112	15
SFAY	89	14

HYSPLIT 750 m back trajectories for August 14, 1995, suggested Pittsburgh's source region was the Indianapolis area, which was similar to the 850 mb trajectory. August 14, 1995, ozone concentrations in this region were 74-80 ppb. This shows Pittsburgh's August 15, 1995, background ozone were about 56-60% of the maximum ozone concentration measured at Harrison. Note regional ozone concentrations listed above are close to the ozone concentrations measured in Indianapolis the day before.



Episode 5: August 26, 1995

Surface Winds (6pm)

Regional Average: North, 1-3mph

850mb Winds

Missing on 8-26-95, Northeast, 10kts at 8am on 8/25/95

Wind Field Suggested Ozone Transport:

Surface: From Pittsburgh to the south

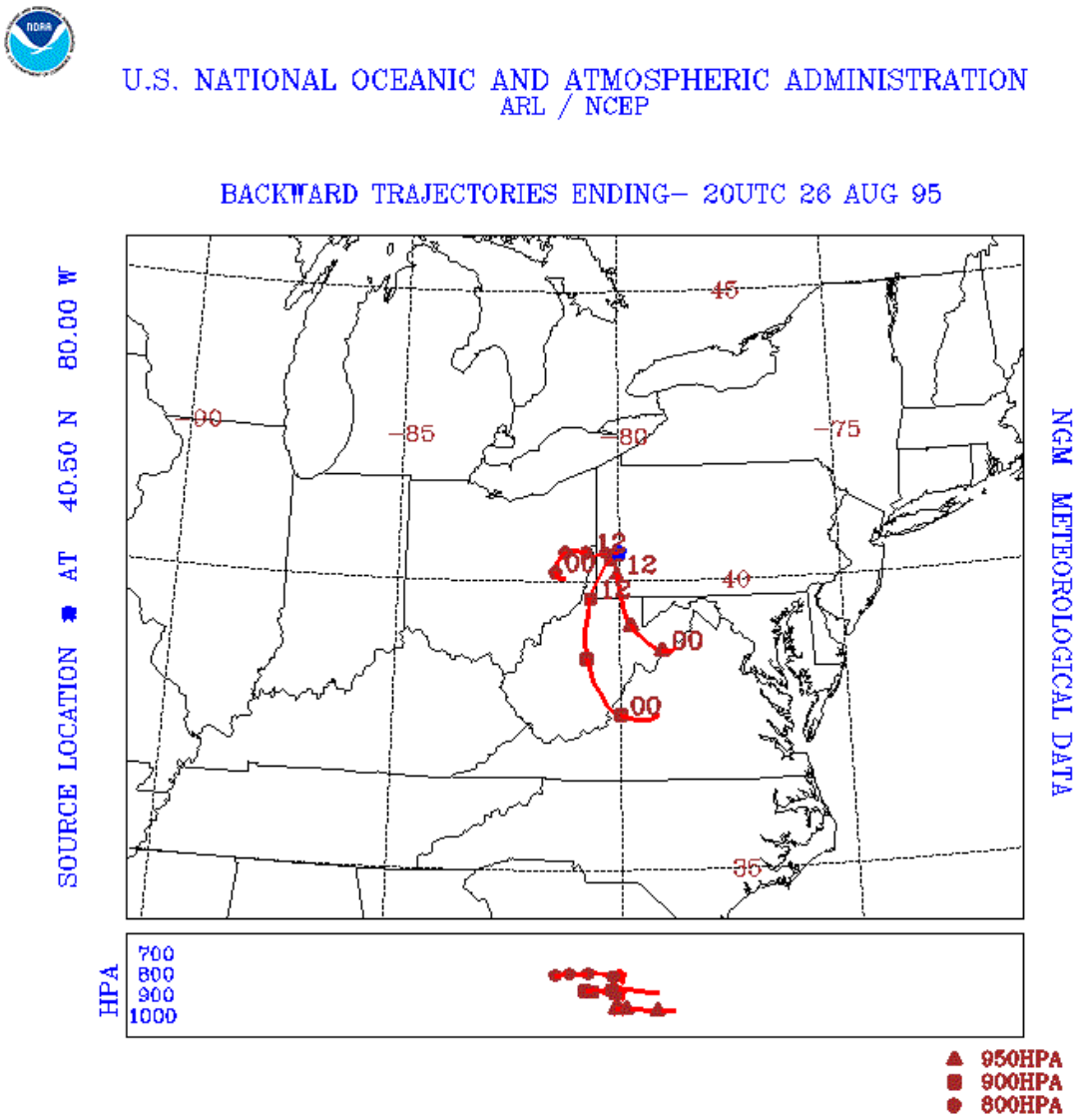
850mb: Unknown

Regional Maximum Ozone Levels (8-26-95)

COPAMS	Conc. (ppb)	Hour
BEAV	97	17, 18
CHAR	94	14
FLOR	98	17
HOOK	63	15
MURR	**125**	18
WASH	94	18

ALLEGHENY COUNTY	Conc. (ppb)	Hour
HARR	109	15
LAWR	124	17
PENN	119	16, 17
SFAY	116	17

HYSPLIT 750 m back trajectories for August 26, 1995 indicate Pittsburgh's source area was located in central Virginia. The 850 mb data was not collected during this episode. Late day ozone concentrations in West Virginia were used to estimate ozone concentrations in the source region since there were no monitors in this part of Virginia. Late-day ozone concentrations in West Virginia (along the Virginia border) were approximately 85 ppb. This demonstrates backgound concentrations over Pittsburgh on August 26, 1995, were about 68% of the maximum ozone concentration recorded at Murrysville.



Station Key

Station Identifier	Station Name	County
BADE	Baden	Beaver
BEAV	Beaver Falls	Beaver
CHAR	Charleroi	Washington
FARR	Farrell	Mercer
FLOR	Florence	Washington
HOOK	Hookstown	Beaver
MURR	Murrysville	Westmoreland
WASH	Washington	Washington
HARR	Harrison	Allegheny
LAWR	Lawrenceville	Allegheny
PENN	Penn Hills	Allegheny
SFAY	South Fayette	Allegheny

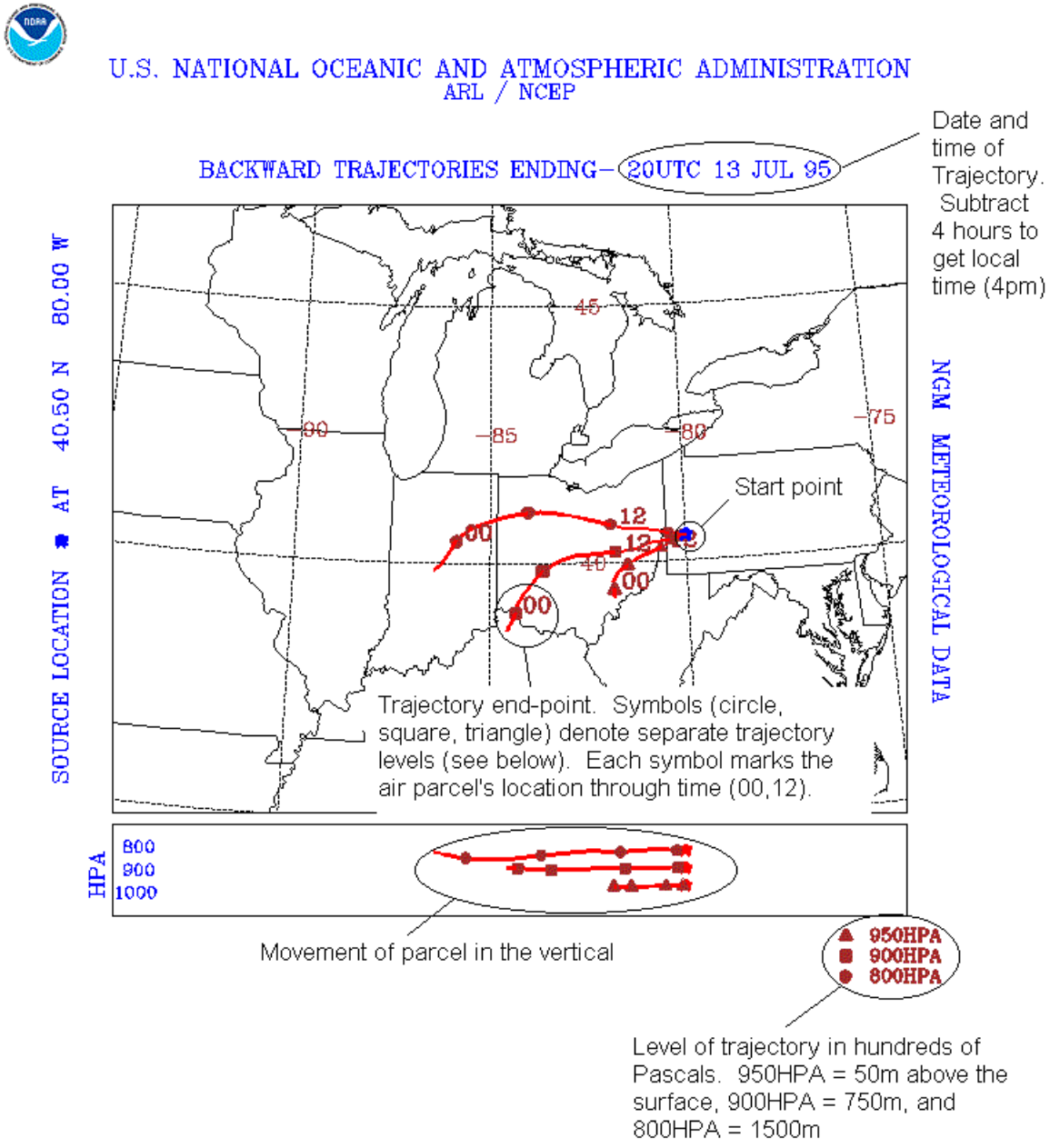
Summary

Background ozone concentrations over Pittsburgh during the 1995 exceedances were estimated using back trajectories calculated by HYSPLIT. HYSPLIT is a trajectory model developed and supported by NOAA. The model calculates trajectories using wind data from various three-dimensional weather forecast models. Background ozone concentrations were determined by identifying Pittsburgh's upwind source region, then using AIRS to determine the source region's ozone concentration (usually the day prior to a Pittsburgh exceedance). This assumed ozone was transported from the source region identified by HYSPLIT to Pittsburgh. Transport was assumed to occur at approximately 750 m.

The table below summarizes background ozone concentrations for Pittsburgh's 1995 exceedances based on the data reviewed by the Department.

Exceedance Date	Max Concentration (ppb)	Incoming Background (ppb)	% of Max Concentration	Source Region
6/19/95	137	80-99	58-72	Western MI
7/13/95	127	90-106	71-83	Cincinnati, OH Area
7/14/95	129	92	71	Peoria, IL Area
7/15/95	138	150ppb (?)	109 (?)	St. Louis, MO (?)
8/1/95	138	90-100	69-72	Western West Virginia
8/2/95	140	97-101	69-72	Central Ohio
8/15/97	133	74-80	56-60	Indianapolis, IN
8/26/95	125	85	68	Central Virginia

HYSPLIT4 (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model, 1997. Web address: http://www.arl.noaa.gov/ready/hysplit4.html, NOAA Air Resources Laboratory, Silver Spring, MD.


U.S. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ARL / NCEP
BACKWARD TRAJECTORIES ENDING– 20UTC 13 JUL 95
Date and time of Trajectory. Subtract 4 hours to get local time (4pm)
SOURCE LOCATION ● AT 40.50 N 80.00 W
NGM METEOROLOGICAL DATA
45
90
85
80
75
Start point
12
00
12
00
00
Trajectory end-point. Symbols (circle, square, triangle) denote separate trajectory levels (see below). Each symbol marks the air parcel's location through time (00,12).
HPA
800
900
1000
Movement of parcel in the vertical
950HPA
900HPA
800HPA
Level of trajectory in hundreds of Pascals. 950HPA = 50m above the surface, 900HPA = 750m, and 800HPA = 1500m

Part IV. Philadelphia Trajectory Summary

Introduction

Back trajectories during Philadelphia ozone exceedance episodes were calculated using NOAA's HYSPLIT trajectory model [1]. Trajectories for 11 exceedance episodes in 1993, 1995 and 1996 were calculated.

Each episode day had three back trajectories calculated for it: one for three different elevations over Philadelphia. The three elevations represented the lower portion of the mixed layer (50 m), the middle portion of the mixed layer (750 m), and the upper portion of the mixed layer (1500 m). Back trajectories started at 3 p.m. (19UTC) local time, and went back 24 hours to the air parcel's previous afternoon's position.

This particular time was chosen for two reasons. First, 3 p.m. is approximately the time of maximum vertical mixing (maximum mixed layer height). Second, 3 p.m. is also the approximate time of maximum afternoon ozone concentration. HYSPLIT back trajectories determined areas upwind of Philadelphia prior to exceedance dates. While the exact contribution these designated upwind areas may have had on Philadelphia's exceedances can not be determined solely based on these trajectories, the trajectories can determine areas that could have influenced Philadelphia on exceedance days.

Back Trajectory Results

Thirty-three individual back trajectories were calculated over Philadelphia for 11 ozone exceedances in 1993, 1995 and 1996. These exceedance days represent a small portion of the total number of exceedance days for Philadelphia. Back trajectories were calculated with NOAA's HYSPLIT model. HYSPLIT calculated trajectories based on atmospheric model wind fields. The trajectories discussed here were calculated using Nested Grid Model (NGM) data.

The back trajectories calculated by HYSPLIT show the path of a particular air parcel during the previous 24 hours. Back trajectories for three elevations (50 m, 750 m, 1500 m) show where each air parcel was 24 hours prior to a Philadelphia exceedance. Back trajectories are to show upwind regions that affected ozone concentrations in Philadelphia on exceedance dates.

Back trajectory origins are summarized in two tables below. The first table divides trajectory origins according to whether they originated inside or outside the Ozone Transport Region (OTR). The second table summarizes back trajectory origins by state. Exceedances are listed by date. Maximum ozone concentrations for the Pennsylvania monitoring sites are also listed. Each exceedance date has three back trajectories calculated for it: one for each of the three different elevations discussed above.

Both tables show that a large number of the back trajectories calculated for Philadelphia originated outside of the OTR, 58% outside the OTR vs. 42% inside the OTR. There were also a number of trajectories that originated from regions in the Midwest, particularly Michigan. These results indicate that pollution from areas well outside the OTR reach Philadelphia.

Table of 24-Hour Back Trajectory Origins (OTR vs. non-OTR)

YEAR	DATE	MAX O3	OTR	NON-OTR
1996	7-7	139	3/3	0/3
	7-8	130	0/3	3/3
	8-6	126	3/3	0/3
1995	6-19	140	1/3	2/3
	7-14	137	0/3	3/3
	7-15	162	0/3	3/3
	7/25	126	0/3	3/3
	8/1	127	2/3	1/3
	8/21	126	1/3	2/3
1993	8-2	127	1/3	2/3
	8-27	129	3/3	0/3
TOTALS			**14/33**	**19/33**
			42%	**58%**

Table of 24-Hour Back Trajectory Origins (By State)

YEAR	DATE	MAX O3	PA	MD	VA	MI	WV	OH	KY	IN	OTHER
1996	7-7	139	2/3	1/3							
	7-8	130			1/3		1/3		1/3		
	8-6	126	2/3	1/3							
1995	6-19	140	1/3			2/3					
	7/14	137			1/3	1/3		1/3			
	7/15	162				1/3		1/3		1/3	
	7/25	126			1/3		1/3				1/3
	8/1	127		2/3	1/3						
	8-21	127	1/3								2/3
1993	8-2	127			2/3				1/3		
	8/27	129	1/3	2/3							
Total			**7/33**	**6/33**	**6/33**	**4/33**	**2/33**	**2/33**	**2/33**	**1/33**	**3/33**
			22%	**18%**	**18%**	**12%**	**6%**	**6%**	**6%**	**3%**	**9%**

Reference

[1] HYSPLIT4 (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model, 1997. Web address: http://www.arl.noaa.gov/ready/hysplit4.html, NOAA Air Resources Laboratory, Silver Spring, MD.

i. Chameides, W. L., Cowling, E.B. 1995. Policy-Relevant Findings in Ozone Pollution Research. Southern Oxidants Study, pp 68-69.
ii. OTAG Air Quality Analysis Workgroup Summary Report. Available from: http://capita.wustl.edu/otag/