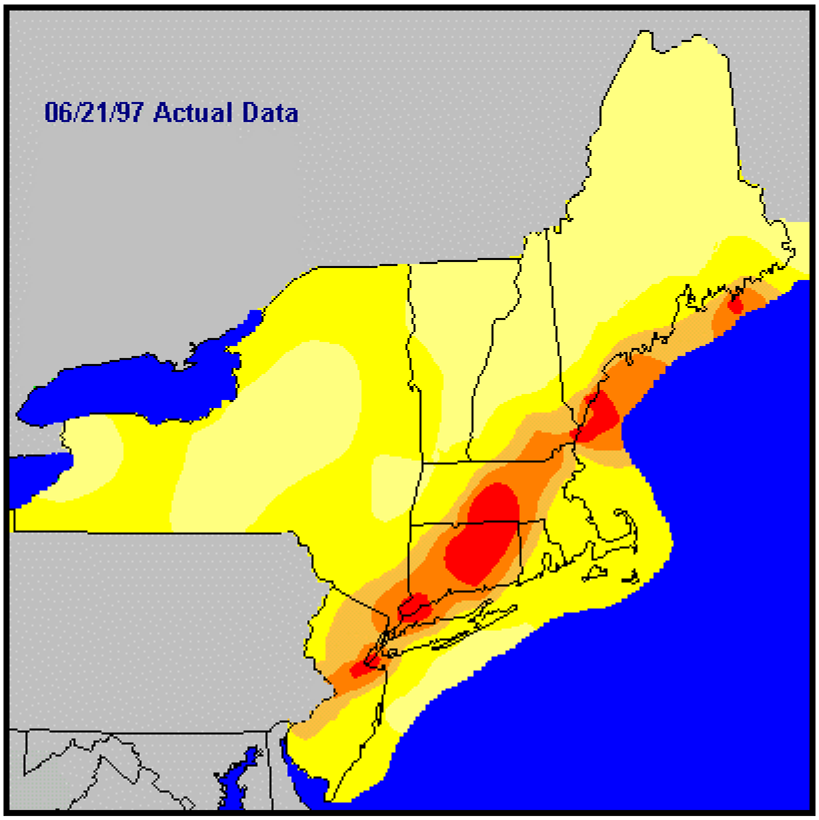
# 1997 Summer Ozone Season in the NESCAUM Region




**Northeast States for Coordinated Air Use Management**

**June 1998**

# Northeast States for Coordinated Air Use Management

The Northeast States for Coordinated Air Use Management (NESCAUM) is a non-profit organization whose purpose is to exchange technical information and promote cooperation among the air quality agencies of its eight member states.



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**Northeast States for Coordinated Air Use Management**

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# 1997 Summer Ozone Season in the NESCAUM Region

## Summary

This report presents information regarding ozone levels that occurred in the northeastern United States during the summer of 1997.

The report's **BACKGROUND** section provides a brief overview of the formation of ozone, its health impacts, and the extent of ozone nonattainment in the Northeast. It also describes the sources of ozone precursor pollutants, existing control options for these sources, ozone transport in the Northeast, and the efforts of the Ozone Transport Assessment Group's (OTAG) Air Quality Analysis Workgroup.

In order to make the summer 1997 ozone experience more meaningful to the reader, the **HISTORICAL CONTEXT** section presents ozone precursor emission trends from 1991 through 1996. It explains the role of monitoring in the Northeast States for Coordinated Air Use Management (NESCAUM) region and assesses the region's ozone trends. The larger OTAG experience is described briefly and the NESCAUM region's ozone trends are discussed further by comparing 1991 with 1992 and 1995 with 1996.

Finally, the **1997 OZONE SEASON** is presented, first according to the recorded exceedances, then as the respective four episodes that occurred in June and July. This section also summarizes the 1997 ozone experience on a state-by-state basis for the NESCAUM states.

## Introduction

Northeast States for Coordinated Air Use Management (NESCAUM) is an organization serving the state air quality divisions of the six New England states, New York and New Jersey. In recognition of the common air quality challenges and goals shared by the eight member states, NESCAUM aids in assessing the scope of air quality challenges, and identifying solutions at both the technical and policy levels. To that end, this document provides a summary of the air quality experienced across the NESCAUM states during the ozone season of 1997.

Of further relevance for appreciating the implications of recent air quality is the revision of the health-based National Ambient Air Quality Standard (NAAQS) for ozone by the U.S. Environmental Protection Agency (EPA). In July 1997, EPA revised the ozone standard from a one-hour concentration of 0.12 parts per million (ppm) to a 0.08 ppm level averaged over eight hours. The 0.12 ppm one-hour standard still remains in effect for an area until it experiences three consecutive years during which the one-hour standard is not violated.

### *Ozone Basics*

The presence of ozone at two different levels in the atmosphere has different impacts upon the health and welfare of people and their environment. Stratospheric (upper level) ozone is beneficial due to its ability to filter out harmful ultraviolet rays. Tropospheric (ground level) ozone is harmful to people, vegetation and many man-made materials due to a variety of destructive effects.

Ozone is not emitted directly into the air, but rather is formed as a result of the combination of high temperatures and sunlight in the presence of "precursor pollutants" – oxides of nitrogen (NOx) and volatile organic compounds (VOCs). The precursor pollutants are emitted by a wide range of both natural (e.g., trees) and human-related (e.g., stationary, area and mobile) sources. Human-related NOx emissions are typically the product of fossil fuel combustion. Human-related VOC emissions are usually the result of evaporation of solvents and gasoline.

### *Adverse Effects of Ozone*

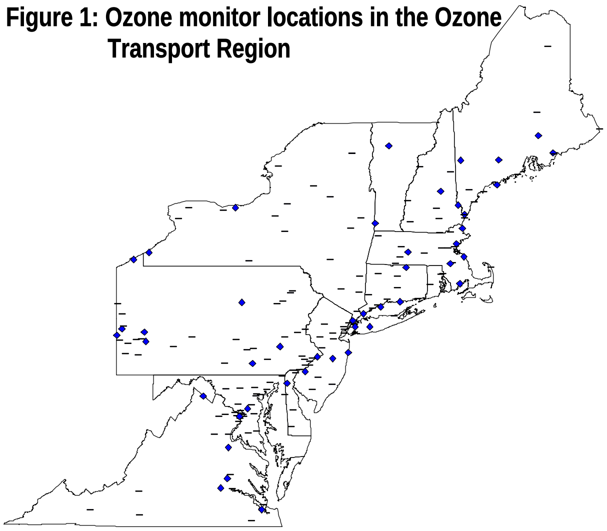
Ground-level ozone has been shown to cause health problems by damaging lung tissue, reducing lung function, and aggravating existing asthmatic conditions. Particularly at risk are those with pre-existing respiratory illnesses, and otherwise healthy children and adults who are very active, either at work or at play, during times of high ozone levels. Ozone also adversely affects the ability of plants and trees to produce and store nutrients, causing 1-2 billion dollars of damage annually to crops.[1]

[1] EPA, "National Air Quality and Emissions Trends Report," 1995.

### *Ozone Nonattainment*

Ozone monitors located within each state measure a state's ambient ozone levels. Ozone monitor locations in the Northeast are shown in Figure 1.

Figure 1: Ozone monitor locations in the Ozone Transport Region



An air quality standard has three specifications: 1) a type of measurement, 2) an ambient threshold level, and 3) an allowable exceedance rate. The revised ozone standard specifies the use of an eight-hour average as the type of measurement, 0.08 parts per million (ppm) as the threshold level, and requires that the three year average of the fourth-highest annual daily ozone maximum eight-hour concentration be below 0.085 ppm.[2] When an area violates the federal ozone standard, it is considered to be "out of attainment," and is required to implement pollution reduction measures in order to achieve attainment.

On July 16, 1997, President Clinton approved the adoption of a more stringent ozone health standard, replacing the one-hour averaging time with a longer exposure time of eight hours. EPA believes that the one-hour ozone standard of 0.12 ppm does not adequately protect public health. EPA considers the longer averaging time of eight hours and the lower ozone concentration of 0.08 ppm to be more appropriate for protecting public health given general human outdoor activity (outdoor occupations, exercise, and general child recreation). In a preliminary effort to identify which areas might be affected by the new standard, EPA analyzed the historical ozone monitoring record.

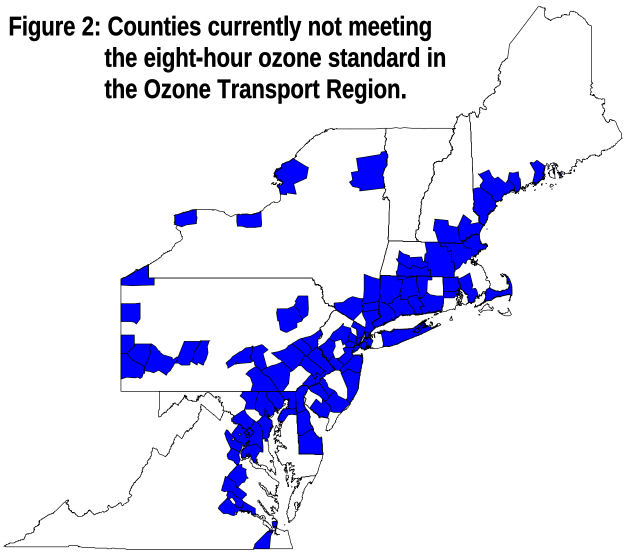
In a preliminary effort to identify which areas might be affected by the new standard, EPA analyzed historical ozone monitoring data and published a list of counties that did not meet the eight-hour ozone criteria in the period from 1993-1995. Figure 2 displays the counties contained within that list (shaded blue) that are located in the Ozone Transport Region. Note that at this time, EPA has only considered the counties which have monitors located within their boundaries. EPA has not extrapolated beyond these counties to include counties currently without ozone monitors. Official ozone nonattainment designations based on the new eight-hour standard will not be done until 2000.

[2] USEPA truncates ozone values between 0.0800 and 0.0849 ppm to 0.08 ppm. Therefore, an exceedance does not occur until the eight-hour ozone average reaches 0.0850 ppm or greater.

### ***Sources of Ozone Precursor Pollutants***

Meteorological conditions (such as temperature, cloud coverage, and wind motion) and the relative levels of NOx and VOCs present in the atmosphere influence ozone formation. The levels of ozone-forming gases in the atmosphere can be estimated as a function of anthropogenic (human-related) and biogenic (natural) activity. Biogenic NOx emissions are relatively small compared to human-related NOx emissions. In contrast, biogenic VOCs can make up the majority of state-wide VOC emissions with human-related VOC emissions being a relatively larger portion of urban area emissions. Agricultural practices (e.g. fertilizer applications) and the lifecycles of vegetation dictate biogenic activity, while economic activity and the general economic well-being of an area heavily influence anthropogenic pollution.

**Figure 2: Counties currently not meeting the eight-hour ozone standard in the Ozone Transport Region.**



Within each state, a state agency that is charged with protecting the environment maintains records on emissions from all anthropogenic sources of both NOx and VOCs, as shown in Table 1. These inventories are used to guide the development of pollution control strategies for areas that are in nonattainment with the federal ozone standard.

Major source categories of anthropogenic emissions are stationary, area, mobile, and nonroad sources. In 1995, contributions of anthropogenic NOx emissions within the Ozone Transport Region (OTR) were, on average, 29% stationary, 10% area, 48% mobile and 13% nonroad.[3] Total NOx emissions in the OTR were 3,350,000 tons. In 1995, VOC emissions were, on average, 14% stationary, 47% area, 29% mobile and 10% nonroad in the OTR, totaling 4,300,000 annual tons.[4]

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[3] The Ozone Transport Region includes Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and a portion of northern Virginia.

[4] "Emission Trends Viewer CD, 1985-1995, Version 1," US Environmental Protection Agency, September 1996.

**Table 1: 1995 Ozone Precursor Emissions in the NESCAUM Region (tons per summer day)[5]**

| State | NOx Emissions | VOC Emissions |
|---|---|---|
| Connecticut | 923 | 1,386 |
| Maine | 532 | 664 |
| Massachusetts | 1,856 | 2,096 |
| New Hampshire | 482 | 453 |
| New Jersey | 3,042 | 2,908 |
| New York | 4,226 | 5,504 |
| Rhode Island | 201 | 401 |
| Vermont | 157 | 220 |

### *NOx and VOC Emission Controls*

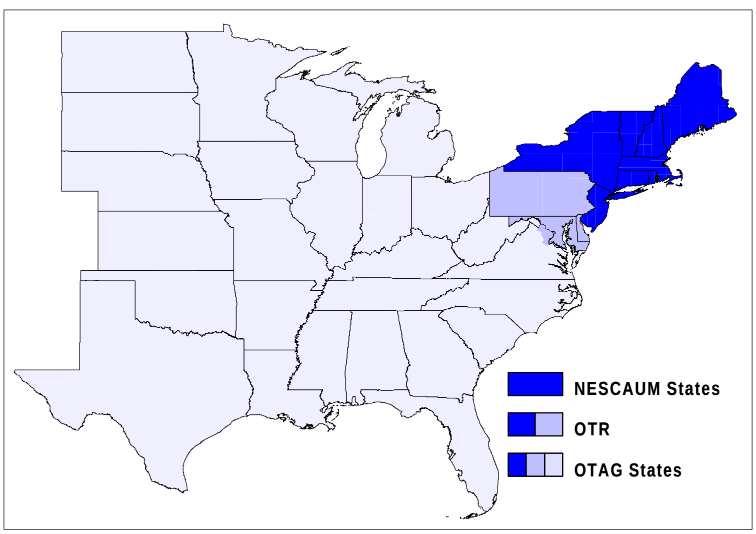
Especially since 1990, NESCAUM states have implemented an array of emission control measures for anthropogenic emissions of both NOx and VOCs to aid in achieving the ozone standard. These measures have included: new source review emission offset requirements, reasonably available control technology (RACT) for stationary sources of both NOx and VOCs, inspection and maintenance programs for light-duty vehicles, stage II gasoline vapor recovery at fueling stations, reformulated gasoline, the OTC NOx Budget Program for large stationary sources, and other measures.

### *The Northeast Airshed and Ozone Transport*

The formation of NESCAUM as an organization in 1967 and its continued existence today is because the air quality agencies of the six New England states, New York and New Jersey recognize that air quality is a regional concern. As illustrated daily by weather forecasts, the region's air quality is affected by a common meteorology.

In the 1990 Clean Air Act Amendments, the extent of this interrelated air quality was formally extended to include 12 northeastern states and the District of Columbia, which form the Ozone Transport Region. A legal entity called the Ozone Transport Commission (OTC) was established to create regional approaches in controlling ozone transport. This action acknowledged that individual states do not always have the ability to adequately affect their respective air quality levels – intrastate regulation of emission sources is not always sufficient. Sometimes air with unhealthy ozone levels is transported into a state, for which even aggressive emission controls within the state are unable to adequately compensate.

**Figure 3: NESCAUM, OTAG and Ozone Transport (OTR) Regions.[1]**




More recently, in 1995, EPA provided for the formation of the Ozone Transport Assessment Group (OTAG) composed of 37 eastern states and the District of Columbia. This action recognized that the effects of transported ozone have implications for air quality across a broader geographic expanse than the Ozone Transport Region. During its two-year review of ozone transport, the OTAG process led to the formation of a variety of workgroups, each

[5] OTAG Emission Inventory Workgroup Report, 1996.

charged with exploring different technical aspects of the ozone challenge facing the OTAG region. As a result, extensive empirical and analytical information was generated, providing the basis for OTAG's recommendations to EPA on regional ozone control measures.

### *OTAG's Air Quality Analysis Workgroup Monitored Air Quality as an Indication of Ozone Transport*

The stated goals of the OTAG Air Quality Analysis (AQA) Workgroup were to:

> *[I]dentify, characterize, compare, and assess observational data and studies, including but not limited to air quality trends analyses, overflight data, and meteorological studies for the purpose of evaluating the effects of the transport of ozone and its precursors on ozone nonattainment in the eastern United States.*[6]

To aid in this endeavor, forward and backward trajectory analyses of air masses were conducted for the summers between 1989 and 1995 in the eastern United States. These analyses were used to identify regional scale transport, directions, speeds, and pollutant transport pathways during high and low ozone conditions.

The results of these long-term, trajectory-based studies indicate that the central Midwest is an important source region for regional-scale transport of moderately high ozone levels to surrounding receptor areas in many directions. Regional transport results in elevated background concentrations in the receptor areas that, when combined with local emissions, can contribute to exceedances of the ozone standard.[7]

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[6] OTAG Executive Report, 1997. Page 21.

[7] Climatology of Ozone Synoptic Scale Transport in the Eastern U. S., 1997 (available at http://capita.wustl.edu/otag/).

## Historical Context

***Ozone Precursor Emission Trends: 1985 – 1995***

**Figure 4a: Ozone Transport Region VOC emission trends, 1985–1995.**[8]

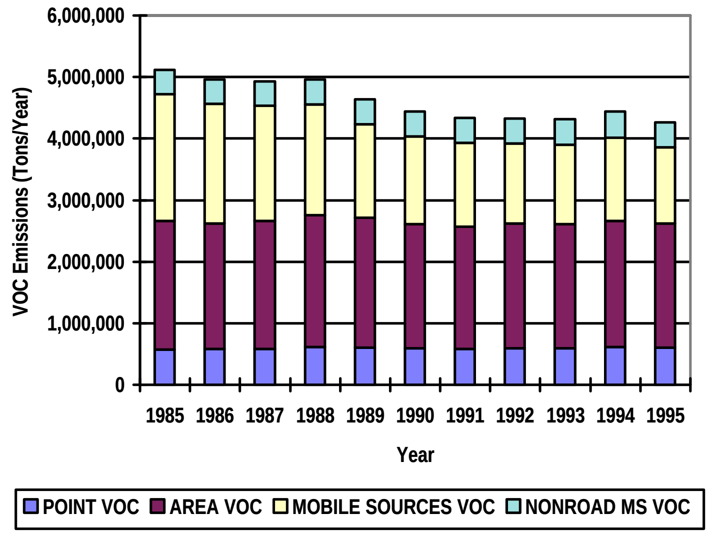
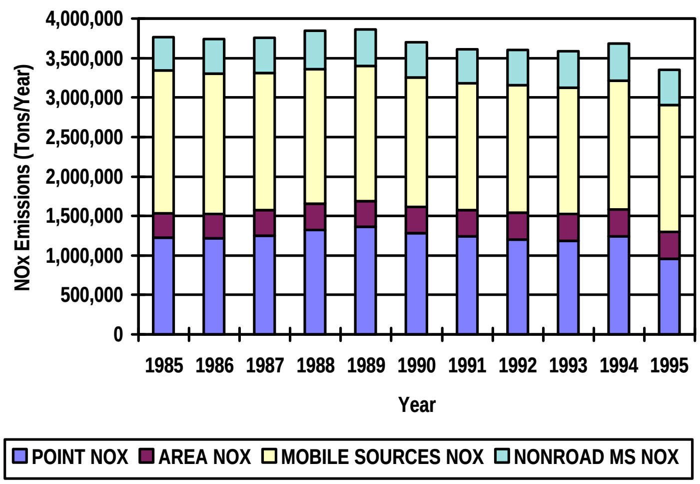



**Figure 4b: Ozone Transport Region NOx emission trends, 1985–1995.**[9]




Emission levels of ozone precursor pollutants over a recent time period are useful for better understanding the implications of 1997's ozone readings: whether air quality is improving, declining or remaining constant. Information across a larger geographic region is also useful for evaluating trends in ozone levels.

It is important to note that the ability to assess historic trends in ozone levels is constrained somewhat by changes in monitoring activity from year to year, including the number of monitors available, their location and the quality of their measurements. For example, data from monitors are only used if the monitor achieves a minimum of a 75% "data capture rate" – the implication being that evaluation of less than 75% of the possible data is too incomplete to allow for valid results. Similarly, in many cases, monitors are "co-located" at a single site. If ozone measurements from the two monitors are inconsistent, both sets of data are rejected. Therefore, it is possible for a state to have data from a different number of monitors

[8] National Air Pollutant Emission Trends Viewer (NET), 1985-1995, GPO Number 055-000-00559 -1.
[9] Ibid.

from one year to the next.

Another complication in determining historic ozone trends is the year-to-year variability of weather patterns. The frequency of meteorological conditions favorable for ozone formation and transport can greatly fluctuate from one year to the next, so that historic trends can be masked by the variability of weather.

Levels of ozone precursor emissions in the Ozone Transport Region (OTR) have been on the decline since 1985, according to emissions data collected by USEPA, even though the economy has grown substantially (Figures 4a and 4b). Nationally, VOC emissions were reduced by 11% and NOx emissions were reduced by 5% between 1985–1995. The OTR has made more significant VOC and NOx reductions than the nation overall due to stricter emissions requirements. Total OTR VOC emissions dropped by 17% and total NOx emissions were down by 11% during the same ten-year period.

### *Monitoring in the NESCAUM Region*

In 1997, the NESCAUM states had a total of 103 official ozone air monitors in the region, as shown in Table 2. It should be noted from Figure 1 that there are many more monitoring locations concentrated in the heavily populated coastal region from southern New Jersey to southern Maine. These monitors are augmented by several "special purpose" monitors that are operated by EPA (as opposed to state environmental departments) for observational purposes. These special purpose monitors are not used to determine an area's nonattainment status. An additional 84 monitors exist in the OTR outside of the NESCAUM region (Delaware, D.C., Maryland, Pennsylvania and northern Virginia).

**Table 2: Number of ozone monitors in the NESCAUM region during 1997.**[10]

| State | Number of Monitors |
|---|---|
| Connecticut | 12 |
| Maine | 11 |
| Massachusetts | 16 |
| New Hampshire | 12 |
| New Jersey | 15 |
| New York | 31 |
| Rhode Island | 4 |
| Vermont | 2 |

### *Assessing Ozone Trends*

Determination of the severity of the ozone problem from year to year is not an easy task. In order to facilitate the analysis of an ozone season, several types of data are considered in an attempt to characterize the year. Monitoring data are collected by location and date, which helps determine where and when violations of the ozone standard have occurred. Finally, once ozone levels have been established, the meteorological record can be used to further analyze how the ozone was formed and the general direction from which it (and its precursors) came.

The following sections will describe the characteristic ozone problems faced by the NESCAUM region and how this problem varies from year to year. Later in the document, an overview of the 1997 ozone season in the NESCAUM region will be presented.

[10] Source: US EPA AIRS Executive database.

### *OTAG Episodes: Transport Characteristics*

Work undertaken during the OTAG process by the Air Quality Analysis Workgroup led to the following findings:[11]

> Ozone transport occurs in the OTAG region on local, sub-regional, and regional scales. Local transport, in the 30-150 mile range, likely contributes most to ozone nonattainment. Sub-regional transport occurs over the 100-300 mile range, and regional transport can occur over the 300-500 mile range, often including significant transport aloft at night. In general, the longer the transport distance, the lower the ozone impact, although this may vary from case to case.
>
> The eight-hour ozone standard will result in significantly more nonattainment areas across the OTAG region, located closer together. This will make ozone transport more critical with respect to nonattainment than it is under the one-hour standard.
>
> The perceived contribution of ozone transport is strongly dependent on how the ozone “problem” is defined. Local emissions are more important with respect to peak one-hour concentrations than with respect to lower concentration thresholds and concentrations assessed over longer averaging times (eight-hour or seasonal averages), where larger areas and longer distance scales become increasingly important.
>
> The central portion of the OTAG domain is unique with respect to ozone and ozone transport. It persistently has elevated ozone levels producing an "ozone pool." Transport in any direction from this region has been implicated in the high ozone levels of neighboring areas.
>
> High ozone levels in the southern portion of the OTAG domain are typically associated with stagnant transport conditions resulting in shorter transport scales than on average. In contrast, high ozone levels in the northern portion of the OTAG region are more typically associated with higher speed and persistent (i.e., nearly unidirectional) transport conditions from inside the OTAG region.

### *NESCAUM Regional Ozone Trends*

In general, within the NESCAUM region, ozone levels tend to be lowest in northern and inland areas and highest in the southern and coastal areas. The pattern of higher concentrations of ozone tends to be correlated with meteorological trends and areas of higher population (which in turn correspond to higher anthropogenic emissions). Pockets of ozone, however, do occasionally appear in the northern, rural areas of the NESCAUM region, mainly due to changes in the region's meteorology and regional ozone transport.

The region's air quality is strongly affected by emissions along the coast in the Metropolitan Statistical Areas (MSA) of Philadelphia, New York City and Boston (Philadelphia is technically not in the NESCAUM region, but is part of a multi-state MSA shared with New Jersey). These large metropolitan areas are the largest contributors of emissions to the region; therefore, any areas directly downwind of these MSAs receive high levels of exported air pollutants. In addition, on severe ozone days in the Northeast, air entering into the Northeast from the Ohio River Valley often

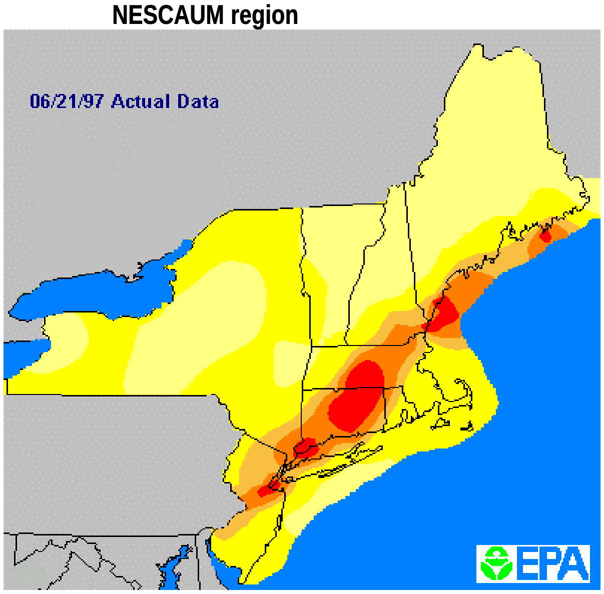
[11] OTAG Executive Report, 1997.

already contains ozone levels greater than 80 parts per billion (ppb),[12] further exacerbating the ozone problem in the Northeast.

During the summer, winds often blow diagonally across the NESCAUM region from the southwest to the northeast, therefore downwind is defined as any areas to the northeast of these MSAs. Coincidentally, these MSA's are roughly aligned in a diagonal from the southwestern to the northeastern corners of the NESCAUM region along the same direction as the wind flow. Moving outside the NESCAUM region, the additional metropolitan areas of Baltimore, Washington, DC and Richmond, VA extend further to the south and west, creating an alignment of pollution sources along the same direction of wind flow. An air mass coming into the NESCAUM region from the southwest and across the Philadelphia area will generally travel over the New York City area and then move on over the Boston area. Each time an air mass moves from one metropolitan area to another, it can be expected to increase its load of air pollution. Given the proximity of Philadelphia to the New York City metropolitan area, it comes as no surprise that the areas bordering the Long Island Sound (Connecticut and Long Island) tend to record some of the highest ozone levels in the region. The coastal portion of southern Maine is also susceptible, although not to the same extent.[13] Figure 5 contains a depiction of the ozone levels that occurred on June 21, 1997, and it serves as a good illustration of the southwest to northeast ozone pattern experienced in the NESCAUM region.

The northern portions of the NESCAUM region do not experience ozone exceedances with nearly the frequency of the region's southern tier. The northern area benefits from two major factors. First, the northern NESCAUM regions (northern portions of Maine, New Hampshire, New York and Vermont) have a significantly lower population than their southern counterparts, and therefore contain fewer sources of anthropogenic air pollutants. Second, the general flow of air in the NESCAUM region does not typically put these areas directly downwind of the high emission areas along the Mid-Atlantic coast. These two factors combined help keep levels of ozone in these regions down throughout the summer, although shifts in meteorology can adversely affect the region. A shift in wind direction can cause ozone exceedances along more northerly tracks (up the Hudson River or Connecticut River Valleys) if urban pollution plumes are directed as such.

**Figure 5: Characteristic direction of transport within the NESCAUM region**

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[12] 80 ppb is equivalent to 0.08 ppm.

[13] Downwind areas are more susceptible to ozone exceedances due to the secondary nature of ozone. Recall that ozone is not directly emitted by air pollution sources, but rather is a result of complex chemical reactions that occur in the atmosphere when NOx and VOCs mix. This complex chemical reaction takes time to evolve; therefore, NOx and VOCs are carried by wind to locations farther away from their sources before ozone formation is complete.

Although these general patterns in ozone formation are helpful in understanding how and where ozone occurs in the Northeast, it must be stressed that summer weather patterns can vary between different years. Differences in summer weather patterns can dramatically change the characteristics of any particular ozone season. As stated earlier, meteorology is an important component in ozone production, not merely wind strength and direction but also a variety of other factors, such as air temperature, humidity and cloud cover. Changes in any of these factors will affect ozone production.

The nature of ozone production in the atmosphere is highly complex and difficult to describe without delving into the technical aspects of photochemical reactions and atmospheric chemistry, which is beyond the scope of this report. Therefore, as the goal of this report is to describe the 1997 ozone year in a manner that is easily comprehended, the 1997 ozone year will be compared to ozone concentrations measured during other recent summers. The comparison will look at measured ozone concentrations, the geographic extent of ozone episodes, and the historical trends in summer temperatures and precipitation. A portion of these historical ozone data is presented in Tables 3 and 4. The tables display one-hour and eight-hour ozone related information, respectively, from which comparisons will be made.

In order to generally characterize the 1997 ozone year, some semblance of a baseline for comparison must be made, therefore historical ozone data from 1991 through 1997 have been compiled as a means to illustrate the variation which occurs from one ozone season to the next. Two distinct sets of years in the period from 1991 to 1997 will be used as an illustrative example of the variation associated with ozone formation from year to year. The years, 1991/1992 and 1995/1996, were chosen because they represent two distinct sets of ozone season variation, 1991 and 1995 are among the more severe ozone seasons during the 1991–1997 period, and 1992 and 1996 are two of the less severe ozone seasons in the same time frame. Coincidentally, these more/less severe ozone year pairs fall on contiguous years, which emphasizes the annual variability associated with ambient ozone levels. The ultimate goal of presenting these comparisons is to establish a point of reference to which the 1997 ozone year can be compared.

**Table 3: Historical one-hour ozone nonattainment statistics in the NESCAUM Region.**

| Year | Number of sites exceeding the 1 hour standard | Number of exceedance days in the NESCAUM region | Max. 1 hour value (ppb) | Date | Location | Max number of monitors exceeding the 1 Hr NAAQS in a single day | Date |
|---|---|---|---|---|---|---|---|
| 1991 | 63 | 39 | 217 | 8/30/91 | Babylon, NY | 34 | 7/19/91 |
| 1992 | 31 | 13 | 173 | 5/24/92 | Brigantine Wldlfe Rfg., NJ | 18 | 5/23/92 |
| 1993 | 38 | 28 | 200 | 7/8/93 | Babylon, NY | 13 | 7/7/93 |
| 1994 | 42 | 18 | 187 | 6/18/94 | Stratford, CT | 16 | 7/13/94 |
| 1995 | 55 | 20 | 175 | 7/14/95 | Madison, CT | 25 | 7/14/95 |
| 1996 | 18 | 11 | 148 | 7/18/96 | Groton, CT | 5 | 7/7/96 |
| 1997 | 44 | 19 | 187 | 7/15/97 | Stratford, CT | 23 | 7/15/97 |

**Table 4: Calculated eight-hour ozone nonattainment statistics in the NESCAUM Region.**

| Year | Number of sites exceeding the 8 hour standard | Number of exceedance days in the NESCAUM region | Highest 4th Max. 8 hour value (ppb) | Date | Location | Maximum number of monitors exceeding the standard in a single day | Date | Maximum 8 hour value (ppb) | Date |
|---|---|---|---|---|---|---|---|---|---|
| 1991 | 86 | 81 | 125 | 8/1/91 | Madison, CT | 85 | 6/28/91 | 152 | 6/28/91 |
| 1992 | 58 | 44 | 111 | 6/29/92 | Rider College, NJ | 86 | 5/23/92 | 130 | 8/24/92 |
| 1993 | 53 | 70 | 110 | 7/09/93 | Stratford, CT | 52 | 6/25/93 | 151 | 7/08/93 |
| 1994 | 53 | 52 | 108 | 7/13/94 | Greenwich, CT | 43 | 8/04/94 | 135 | 6/18/94 |
| 1995 | 73 | 51 | 117 | 6/20/95 | Colliers Mills, NJ | 75 | 8/01/95 | 147 | 7/14/95 |
| 1996 | 39 | 41 | 97 | 7/17/96 | Westport, CT | 31 | 8/06/96 | 120 | 7/18/96 |
| 1997 | 60 | 38 | 117 | 7/15/97 | Ancora State Hosp., NJ | 47 | 6/21/97 | 153 | 7/15/97 |

### *1991 vs. 1992*

In terms of the number of one-hour exceedances, 1991 appears to be the single worst ozone year in the NESCAUM region during the seven-year period from 1991 to 1997. During 1991, 63 monitoring sites in the NESCAUM region recorded exceedances of the one-hour standard, and exceedances were recorded at a minimum of one monitor on 39 separate days. The maximum one-hour ozone concentration was 217 parts per billion (ppb), recorded in Babylon, NY on Long Island. During the same summer of 1991, 86 monitoring sites recorded ozone concentrations in excess of those set by the recently adopted eight-hour ozone standard.[14] Ozone monitors measured eight-hour concentrations above 85 ppb on 81 separate days in the NESCAUM region. The highest eight-hour ozone concentration measured in the region during 1991 was 152 ppb at Madison, CT. This value is significant because it represents an average ozone concentration above the EPA designated one-hour standard that was sustained for at least eight hours.

In comparison, during the following year, 1992, 31 monitoring sites exceeded EPA's one-hour ozone standard on thirteen days. The regional maximum one-hour concentration of 173 ppb occurred at the Brigantine Wildlife Refuge in southern New Jersey. In 1992, the eight-hour standard was exceeded at 58 monitoring sites on 44 days, with a maximum value of 130 ppb measured at Rider College in New Jersey.[15]

Ozone exceedances seemed to occur indiscriminately throughout the NESCAUM region in 1991 with great frequency. In 1992, however, portions of the NESCAUM region north of the New York City MSA recorded much lower concentrations of ozone than the norm. Examination of the meteorological record reveal significant differences between the summers of 1991 and 1992 which help explain the stark differences between their corresponding ozone concentrations.

Based on rankings of summers from 1895 to 1997 in terms of warm temperatures and arid conditions, the northeastern United States[16] experienced conditions less favorable for ozone production during the summer of 1992 (i.e., the region experienced relatively cool damp weather).[17] The 1992 summer is ranked as the 101$^{st}$ warmest and the 88$^{th}$ driest year respectively (with the rank of 1 representing the respectively warmest and driest years in this time period). As a comparison, 1991 is ranked as the 17$^{th}$ warmest and the 31$^{st}$ driest summer in this historical context. It should be reiterated that temperature and precipitation are not a guarantee of more active ozone production,

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[14] The number of monitors exceeding 85 ppb averaged over eight hours should not be taken as an indication of the potential nonattainment status for a particular region. Nonattainment status for the eight-hour standard will be determined by the three year average of the 4$^{th}$ highest annual eight-hour ozone concentration measured from 1997-1999.

[15] Data originally extracted from EPA's Aerometric Information Retrieval System (AIRS). Data compiled by R.B. Hussar, et al. for use as a Voyager 3.1 file. Voyager 3.1 was developed by the Lantern Corporation, 63 Ridgemoor Drive, St. Louis, MO 63105, (314) 725-6125. Data files are available at the following internet address: *http://capita.wustl.edu/otag/Data/DataInterest.HTML*.

[16] Only in this circumstance will the northeastern United States be defined as the following states: CT, DE, MD, ME, MA, NH, NJ, NY, PA, RI, VT. Elsewhere in the report, Northeast is defined either as the Ozone Transport Region or the NESCAUM states.

[17] Historical temperature and precipitation data were analyzed by Desmond Bailey, meteorologist with the National Oceanic and Atmospheric Administration and the USEPA Office of Air Quality Planning and Standards. Data were extracted from the 103 year (1895–1997) drought database maintained by the National Climatic Data Center (NCDC).

however, it has been observed that ozone production is more likely to occur on hot, dry days than cooler, damp ones.

### *1995 vs. 1996*

The singular qualities that each ozone season possesses make it difficult to determine exactly how to rank one ozone season relative to another in terms of severity. Although it is difficult to rank the 1995 ozone season, 1995 was, qualitatively one of the three worst years in the 1991 to 1997 period. This year can be characterized with 55 monitoring sites exceeding the one-hour ozone standard. The one-hour ozone standard was exceeded at a minimum of one site throughout the NESCAUM region on 20 separate days. The maximum ozone concentration (175 ppb) was recorded at Madison, CT on July 14. In terms of eight-hour exceedances, 73 monitoring sites exceeded the eight-hour standard, and exceedances were seen on a total of 51 days, with a maximum eight-hour concentration of 148 ppb in Colliers Mills, NJ.

In contrast to this, the following year, 1996 experienced the least severe ozone season in the seven year span. While the record shows that in 1995, seven of the eight NESCAUM states (the exception is Vermont) recorded at least one exceedance of the one-hour standard, only four of the eight NESCAUM states (CT, MA, NJ and NY) exceeded the one-hour ozone standard in 1996.

In 1996, 18 sites exceeded the one-hour ozone standard, and exceedances were seen on 11 separate days. The maximum ozone reading was 148 ppb, recorded in Groton, CT. The eight-hour ozone standard was exceeded at 39 sites, and on 41 separate days, with a maximum value of 120 ppb recorded in Groton, CT on the same day as the one-hour maximum, July 18, 1996.

The meteorological record of 1995 strongly supports the observation that temperature and precipitation are factors in ozone production. In the 103 year span from 1895 to 1997, 1995 proved to be one of the hottest and driest summers in the Northeast. 1995 was the 3$^{rd}$ hottest and 2$^{nd}$ driest year in this time period. By comparison, 1996 was the 50$^{th}$ hottest and the 89$^{th}$ driest year. Once again hot, dry weather is associated with ozone production whereas cool damp weather is associated with much lower concentrations and fewer events.

The ozone values recorded during the summers of 1995 and 1996 reveal the complications associated with predicting ozone concentrations. According to the National Climatic Data Center drought database, the summer of 1995 experienced temperatures and precipitation (or lack thereof) which favored ozone production more than any other year in the 1991–1997 period. If ambient ozone production were only a function of temperature and precipitation, it would be expected that 1995 would have more severe ozone episodes than almost any other year in this period. Recall from the 1991/1992 analysis, the 1991 summer was ranked the 17$^{th}$ warmest and 31$^{st}$ driest during the 103 year period between 1895–1997. On the other hand, 1995 was the 3$^{rd}$ hottest and 2$^{nd}$ driest year during the same 103 year span. While 1991 was, on average, milder than 1995, the NESCAUM region experienced more severe ozone episodes in 1991 than 1995. This indicates that there are other factors contributing to ozone production. These factors probably include a reduction in NOx and VOC emissions in the Northeast from 1991 to 1995 as well as differences in other weather variables besides temperature and precipitation, such as wind speed and direction. Table 5 summarizes the ozone exceedances experienced over these years.

**Table 5: Ozone monitoring site statistics – 1991 vs. 1992, 1995 vs. 1996.**

| Monitor Recordings | 1991 | 1992 | | 1995 | 1996 |
|---|---|---|---|---|---|
| # sites Exceeding the 1 Hour NAAQS | 63 | 31 | | 55 | 18 |
| # days in which at least one site in the NESCAUM region exceeded the 1 hr NAAQS | 39 | 13 | | 20 | 11 |
| 1 Hour Maximum Ozone Concentration | 217 | 173 | | 175 | 148 |
| Maximum # sites exceeding the 1 hr NAAQS in a single day | 34 | 18 | | 25 | 5 |
| # sites exceeding the 8 hr NAAQS | 86 | 58 | | 73 | 39 |
| # days in which at least one site in the NESCAUM region exceeded the 8 hr NAAQS | 92 | 44 | | 51 | 41 |
| Maximum 8 Hour Ozone Concentration | 152 | 130 | | 148 | 120 |
| Maximum # sites exceeding 8 hr NAAQS in a single day | 85 | 86 | | 75 | 31 |
| Rank over 103 period from 1895 to 1997 for warm temperature (1 = hottest) | 17 | 101 | | 3 | 20 |
| Rank over 103 period from 1895 to 1997 for aridness (1 = driest) | 31 | 88 | | 2 | 89 |

## The 1997 Ozone Season

As stated previously, ranking ozone seasons is difficult due to the complex factors that shape each year. One can at least order the years informally, and on a qualitative basis, as shown in Figure 6. The relative rankings reflect the extent of ozone exceedances seen throughout the NESCAUM region, but do not attempt to rank seasons according to meteorological conditions or changes in precursor emissions. The year of 1991 had the highest ozone pollution, whereas the ozone problem in 1996 was at a somewhat lower level. Within this range, the year of 1997 falls in as slightly worse than average. This simplistic ranking should not be taken at face value without also considering the circumstances that shaped the 1997 ozone season. Examination of the actual ozone exceedances in various portions of the NESCAUM region will provide a better appreciation for 1997 ozone levels and why they occurred.

**Figure 6: Ranking of years in terms of the degree of ozone pollution, 1991-1997.**


### *Ozone Exceedances*

When compared to past years, the 1997 NESCAUM ozone season was average, if not slightly worse. Depending on geographic location, however, areas may have experienced relatively less polluted air and no exceedances of the ozone standard. This is because the NESCAUM region experienced some very disparate meteorological conditions in 1997 that had a strong effect on ozone production throughout the region. For the northern NESCAUM states, the 1997 ozone season was relatively mild, which is not unusual, except that this "clean" region included areas that usually tend to exceed the ozone standard more frequently (predominantly Massachusetts).

In contrast to these relatively less polluted northern states, the southern NESCAUM states, and all the Mid-Atlantic United States in general, recorded an extensive ozone air quality problem throughout the summer. The NESCAUM region had 19 one-hour ozone exceedance days[18] during the 1997 summer, and the Ozone Transport Region had a total of 23 exceedance days. Over the course of the summer, 42 monitors in the region exceeded the 120 ppb one-hour ozone standard 105 times (i.e., many monitors recorded exceedances on multiple days).

**Table 6: 1997 summary of NESCAUM State one-hour ozone exceedances.[19]**

| | CT | MA | ME | NH | NJ | NY | RI |
|---|---|---|---|---|---|---|---|
| **No. of exceedance days** | 12 | 4 | 3 | 3 | 10 | 8 | 1 |
| **No. of sites w/exceedances** | 11 | 3 | 7 | 3 | 10 | 7 | 1 |
| **Maximum state ppb** | 187 | 151 | 154 | 156 | 176 | 175 | 149 |
| **Date of max. ppb** | 7/15 | 6/ 21 | 6/30 | 6/30 | 7/15 | 7/16 | 7/15 |
| **Location of max. ppb** | Stratford | Ware | Cape Elizabeth/ Kennebunkport | Rye | Colliers Mills | New York City | Kent County |

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18 An exceedance day is defined as any day within which at least one monitor exceeds the ozone NAAQS.

19 USEPA AIRS database. Vermont is not included in the table because none of its monitors recorded a one-hour exceedance of the ozone NAAQS in 1997.

Although the ozone season technically lasts from April to September, all of the 1997 episodes occurred during the months of June, July and August. The 1997 ozone data indicate that the highest values reported in the NESCAUM region occurred primarily in Connecticut, New York and New Jersey. The most extensive episode occurred from July 12 to July 17. It was during this episode that the Northeast experienced its worst ozone days and some of its highest one-hour levels. In Connecticut on July 15, the monitor at Stratford reached 187 ppb and the Groton monitor recorded a level of 183 ppb. On that same day, the monitor at Colliers Mills, New Jersey measured 176 ppb. On the following day, a monitor in New York City (Susan Wagner) saw an ozone level of 175 ppb. Table 6 contains a summary of the exceedances of the one-hour ozone standard measured in the NESCAUM region during 1997.

While the coastal Mid-Atlantic and New England regions experienced a worse than average ozone season, the north/northwestern portion of NESCAUM experienced a very mild summer to which low ozone concentrations can be attributed. The presence of cool and sometimes damp weather systems descending from Canada over northern New York, Vermont, New Hampshire and Maine helped keep at bay the air masses which were conducive to ozone formation in the coastal regions. Thus any stagnant, ozone laden air mass approaching from the southwest could not penetrate into the northern, interior NESCAUM region.

The one example of such "blocking" weather patterns occurred during the July 12–17 episode. The mid-July episode was responsible for producing high ozone levels in the Mid-Atlantic and southern New England states. As will be chronicled in the following section, a cold front descended over New England from the northeast at the peak of this episode, preventing warmer air from penetrating much farther north than Connecticut. More details on this and other episodes can be found in the next section.

## The 1997 Ozone Season: Ozone Episodes

Of particular interest are the episodic nature of ozone exceedances, the extent to which they are linked over time, and the meteorology that transports the high ozone concentrations across large regions. To effectively track the transport nature of these episodes, it is necessary to have a basic understanding of meteorology to see how the specific weather systems participate in the production and transport of ozone. For example, precursor pollutants (NOx and VOCs) require warm temperatures (80°+F) and sunshine to create ozone, therefore weather conditions involving overcast skies or rain would inhibit ozone production, as would cool temperatures. Thus, meteorology plays a very important role in the ozone production cycle, as much so as the actual emissions of NOx and VOCs that are responsible for ozone formation. A precursory lesson in general meteorology is given in the following discussion before presenting a detailed analysis of ozone episodes during the summer of 1997.

A given area can be affected by ozone via two very different and separate mechanisms involving locally generated ozone and transported ozone. Locally generated ozone can occur on very hot sunny days when the air is very still and emissions of NOx and VOCs are not blown away from the area. The hot, sunny weather combined with sufficient levels of NOx and VOCs provide good conditions for ozone production. Local formation of ozone, however, is not the only way a region may experience poor air quality. Areas within the NESCAUM region often see their highest ozone levels under less stagnant conditions when ozone and its precursors can be transported long distances.

Transported ozone occurs under very different conditions than local stagnation. Transport is highly dependent on atmospheric pressure. Meteorologists commonly refer to "high" and "low" pressure when presenting the weather. High-pressure systems are generally associated with clear skies, and, most importantly from a transport perspective, clockwise motion of winds around the center of the high. In contrast, low-pressure systems have winds that move in a counter clockwise direction around the center. A hurricane is an example of a very intense low-pressure system.

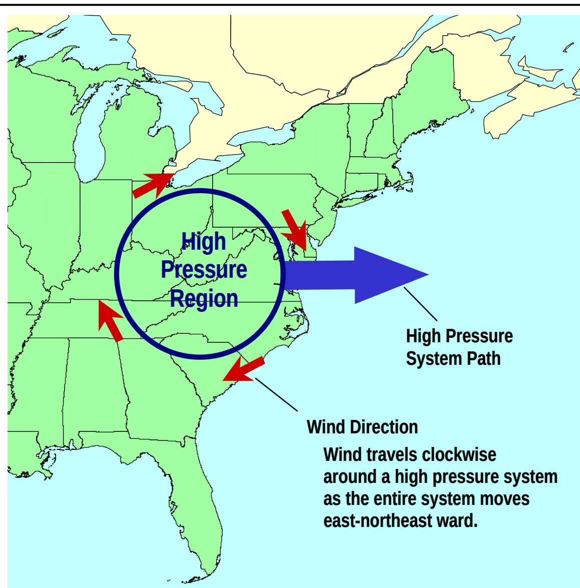


**Figure 7: Common meteorology affecting the NESCAUM region.**

During the summer, high pressure systems with clockwise rotating winds will sometimes cross the Midwest and exit out over the Atlantic Ocean from the Mid-Atlantic states. As the system begins to cross the Mid-Atlantic coastline, winds north of the system come out of the west, bringing transported ozone and its precursors into the Northeast from the Midwest. As the system continues to move east across the Mid-Atlantic states, the winds shift to out of the southwest along the trailing edge of high pressure zone (see Figure 7). Now, ozone and precursors to the southwest of the NESCAUM region are brought into the area. Under the transport scenario, NOx, VOCs and ozone are funneled from one region of the country (i.e., the Midwest or Southeast) into another (the Northeast). Although pollutants are generally drawn from the Midwest and the Southeast into the Northeast, the reverse typically does not occur under weather conditions conducive for ozone formation.

Although this informal tutelage of ozone meteorology is extremely simplistic, it will be useful in understanding the detailed descriptions of the meteorology associated with the 1997 ozone episodes in the NESCAUM region that follow.

The ozone episodes that occurred in the Ozone Transport Region (OTR) during the summer of 1997 being considered in this report are:[20]

| | |
|---|---|
| June 20-25 | Episode 1 |
| June 29-July 1 | Episode 2 |
| July 12-17 | Episode 3 |
| July 26-28 | Episode 4 |

For each episode, surface weather conditions and ozone concentrations will be discussed as well as upper air meteorology. Because ozone concentrations may be affected by the depth of the well-mixed boundary layer (the atmospheric layer directly above the earth's surface) and local or regional transport of ozone and its precursors, the upper air patterns are often of great interest. The upper air information reported here is generally at three levels in the atmosphere that are determined by atmospheric pressure: 850, 500 and 200 millibar (mb). Lower pressure corresponds to higher altitudes above the earth's surface. The three levels given here are the so-called "mandatory" levels that are reported by all weather balloons and are archived and analyzed by the National Weather Service. The 850 mb level is approximately 1500-1600 m above sea level. It is of interest in air quality studies because it is typically near the top of the mid-afternoon well-mixed layer. In addition, wind flow at this level is generally "geostrophic," or unaffected by surface friction, allowing for better quality trajectory analyses.[21] The 500 mb level is typically 5-6 km above the surface and is approximately the middle of the troposphere. Larger scale weather patterns, including troughs (areas of lower than normal pressure) and ridges (areas of higher than normal pressure), can be easily analyzed at this level. The 200 mb level is the level of the jet stream.

### *Episode 1: June 20-25*

*Summary*: This episode was characterized by two high ozone phases (June 20–21 and June 24–25), each terminated by frontal passages (June 22–23 and June 26–27). The upper air pattern was similar to most high ozone cases in this region with a ridge in the upper atmosphere covering the eastern US. For both high ozone phases, a frontal zone stalled south of the region and then moved rapidly northward as a warm front. Ozone levels were highest in the immediate wake of the warm frontal passage, with highest concentrations in the mid-Atlantic on the first day (June 20 and

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20 NESCAUM thanks Dr. William Ryan, University of Maryland, for providing meteorological descriptions of the 1997 ozone episodes.

21 Sea breeze along coast lines may also be a local surface feature not necessarily reproduced in air mass trajectories at higher altitudes.

June 24) and then spreading to New York and New England on the succeeding day as the front moved northward (June 21 and June 25).

*Details:* The first two weeks of June were very cool and wet across the eastern US, following upon a cool and wet spring. On June 18, just prior to the onset of this event, a cold front approached the Northeast from the west with a secondary low pressure system along the frontal boundary in southern Indiana. Above the surface at 850 mb, a trough, or area of lower pressure, in the Tennessee Valley drove strong SW winds in the Ozone Transport Region. Temperatures at this level were 12-17$^{o}$ C, which is slightly above average. At the jet stream level (200 mb), a weak trough was located over Michigan with a jet streak, or region of enhanced winds, over the northern Appalachians.

On the morning of June 19, the cold front was located near a line stretching from Baltimore, Maryland through Millville in southern New Jersey, Providence, Rhode Island, and Boston, Massachusetts. A squall line, with substantial thunderstorm activity, lay just ahead of the front. The trough at 850 mb that brought strong winds on June 18 had weakened and lay along the coastal plain. Temperatures at 850 mb were cooler than the previous day – 12-15$^{o}$ C in the mid-Atlantic and 10-13$^{o}$ C in western New York and Pennsylvania.

While ozone concentrations were low on June 19 – peak one-hour concentrations in the Baltimore region reached only 80 ppb – conditions were ripe for increased ozone on the following day as a strong ridge built to the west.

On June 20 at 1200 UTC (Universal Coordinated Time, formerly Greenwich Mean Time, which in this case is four hours ahead of Eastern Daylight Time), the front was stationary just south of a line from Washington, DC to Wallop's Island in the southern end of the Delmarva Peninsula. To the west of Washington, the front retreated northward as a warm front into western Pennsylvania.

The key feature driving high ozone concentrations this day was the rapid northward movement of the front. By 2100 UTC, the warm front was on a line from Buffalo, New York to Cape Cod. At 850 mb, a ridge built along the coast. Temperatures were still cool (9-12$^{o}$ C) in New England but strong warm air advection occurred to the west and south with Washington, DC, Pittsburgh, and Buffalo warming to 15-16$^{o}$ C. Winds were W and WSW 10-20 kts along the western boundary of Ozone Transport Region. The upper air pattern this day was characteristic of high ozone episodes in the mid-Atlantic.

A rapidly northward moving warm front, usually formed from the remnants of a pre-existing cold front that crossed the region 24-48 hours prior, often leads to high ozone in the mid-Atlantic. The movement of air – moving southward after cold frontal passage, then flowing northward with the warm front – and very stable conditions, as warm air above the frontal zone rides up over relatively cooler air, leads to high ozone concentrations. In addition to the stable conditions in the Northeast, 48-hour back trajectories from the Baltimore area for June 20 at upper levels of the atmosphere show transport from the west (Figure 8).[22]

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[22] All trajectories in this report were generated from the 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.

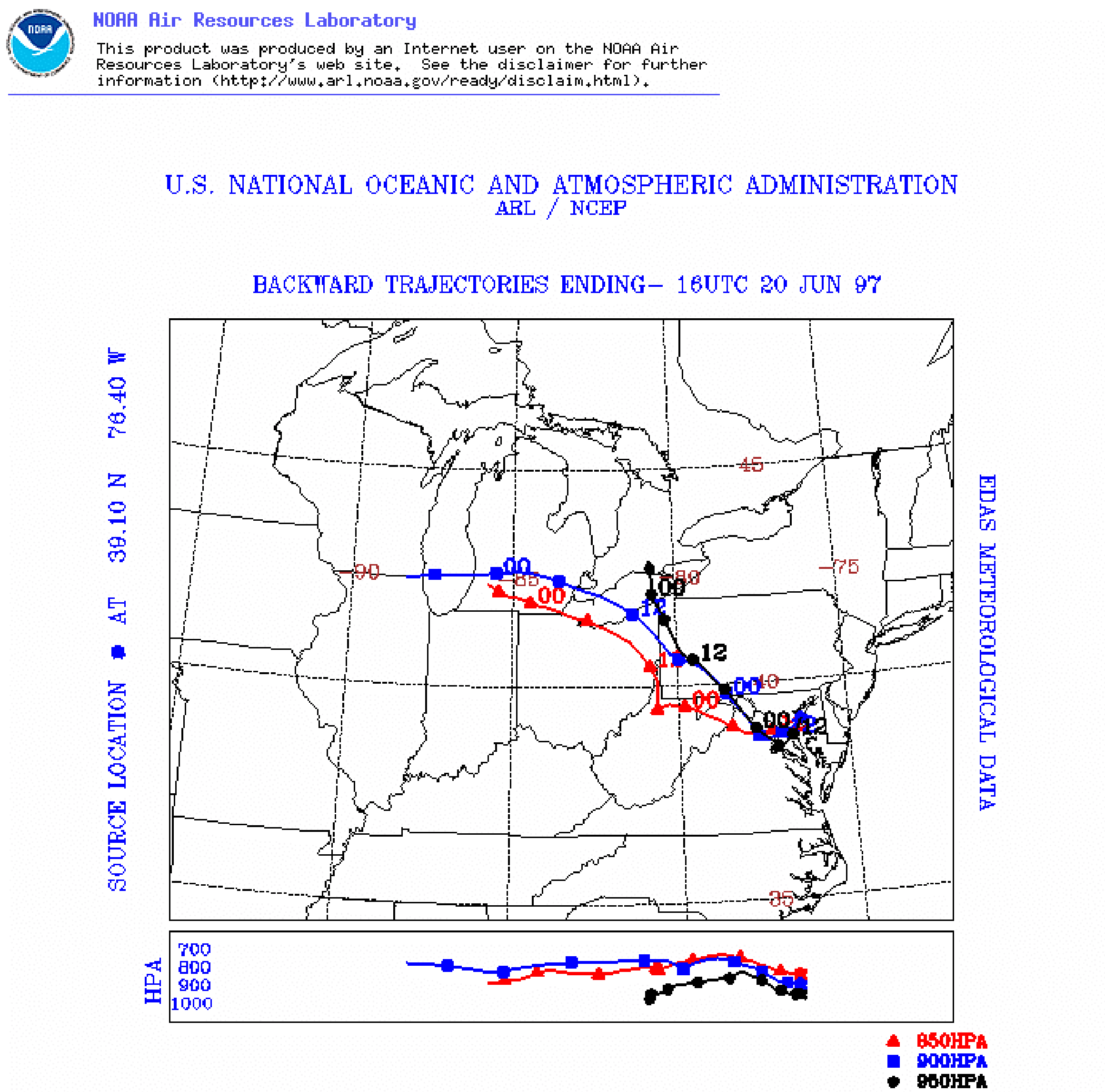



**Figure 8: 48-hour back trajectories from the Baltimore area at three levels of the atmosphere (850 HPa, 900 HPa, and 950 HPa). Trajectories end on June 20, 1997 at 16 UTC (12 EDT) in the Baltimore area.**

This direction of transport was similar to those seen in the highest ozone cases in 1995 and 1996 (Figure 9).

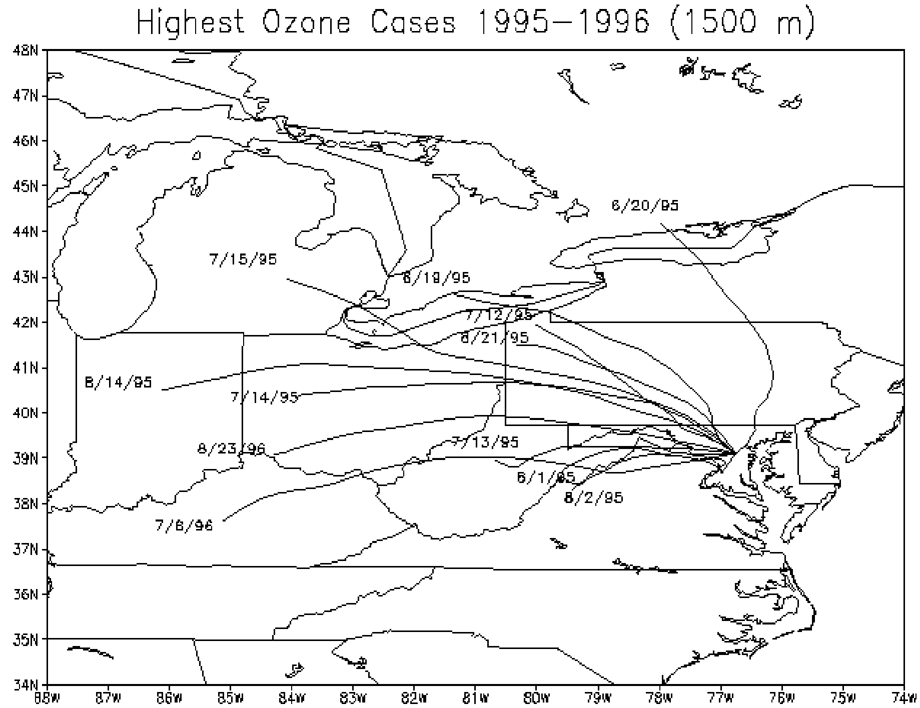



**Figure 9: Back trajectories from the Baltimore, MD area during the highest ozone cases from 1995–1996.**

Ozone exceedances were reported throughout the region south of the warm front including Delaware, Pennsylvania, New Jersey, and Maryland. On the following day (June 21), the warm front continued to move rapidly northward and reached into central Maine.

Ozone exceedances on June 21 were widespread along the Ozone Transport Region from Maine to Maryland. One-hour exceedances in the NESCAUM region are shown in Figure 10.

At 850 mb, a high pressure ridge was well-established along the coast with temperatures increasing rapidly in New England from 9-12° C on June 20 to 15-17° C on June 21. Winds at this level were fairly strong from the WSW at 15-20 kts. Forty-eight hour back trajectories at 500 m (950 HPa), 1000 m (850 HPa) and 1500 m (800 HPa) above the surface for central Connecticut are shown in Figure 11.

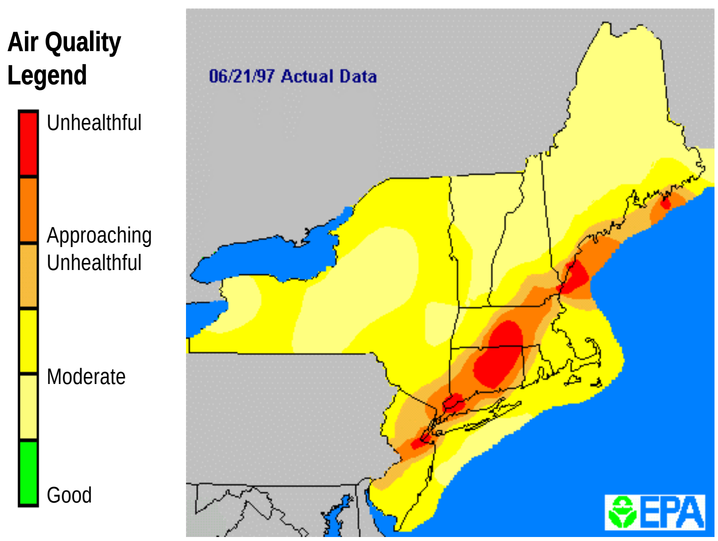



**Figure 10: Pattern of one-hour ozone exceedances (indicated by red shading) on June 21, 1997 in the NESCAUM region.**

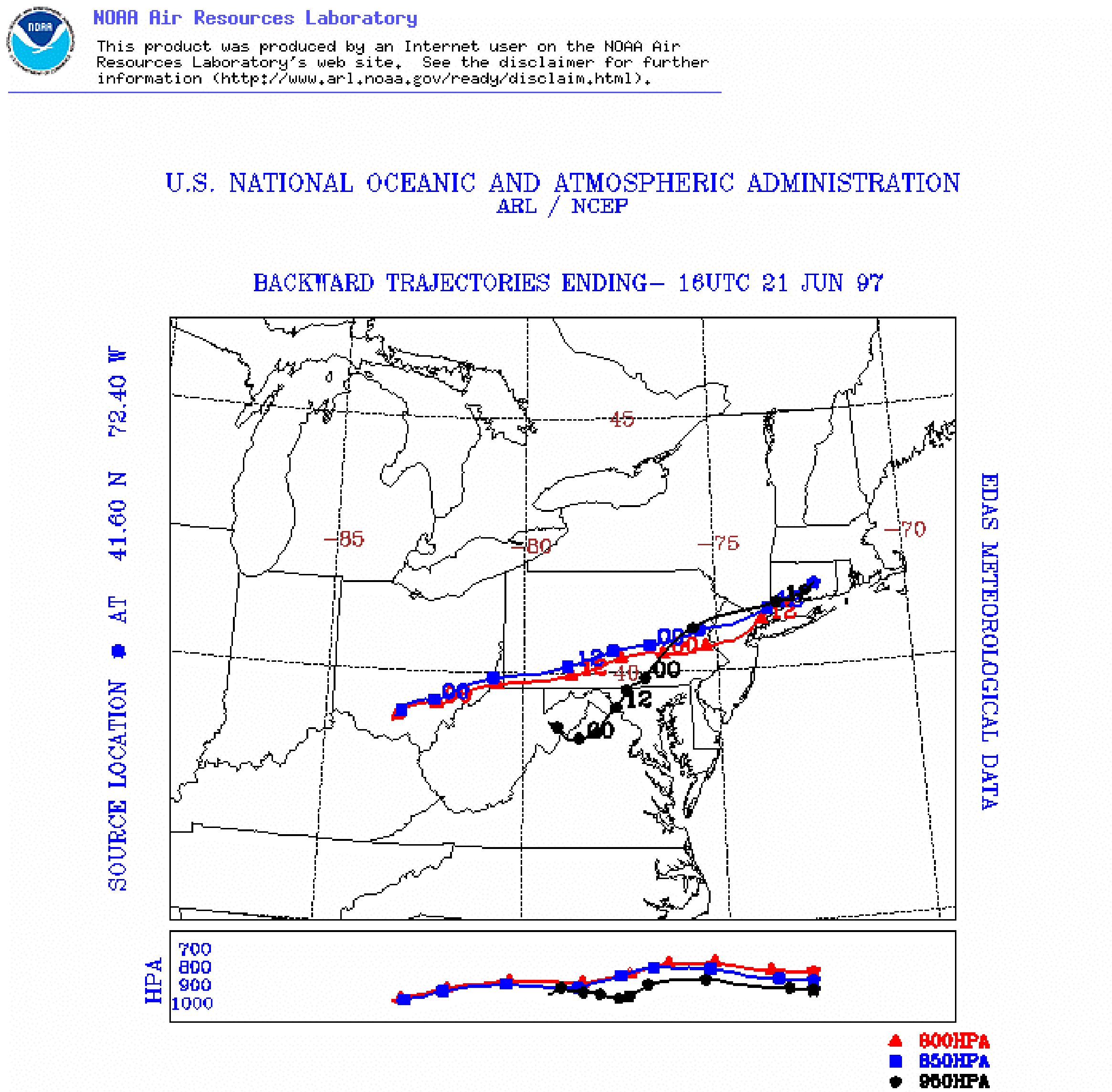



**Figure 11: 48-hour back trajectories from central Connecticut ending at 16 UTC on June 21, 1997 at three levels of the atmosphere (800 HPa, 850 HPa, and 950 HPa).**

By 1200 UTC on June 22, a cold front in the Midwest had moved rapidly eastward to a line from central New York to Pittsburgh and southern Ohio with a trough just ahead of the front. By 2100 UTC, the cold front was located on a line from Boston to Baltimore with significant convective activity occurring along the pre-frontal trough. This convection effectively ended the first stage of this high ozone episode for most of the Ozone Transport Region with only Connecticut reporting one-hour ozone exceedances.

By the morning of June 23, the front was well offshore and as far south as North Carolina. Following this quick frontal passage, the weather conditions reset to a situation similar to June 19–20. The western end of the front became stationary across western North Carolina and eastern Kentucky and, with strong high pressure to south, its remnants were driven northeastward as a warm front over the next 48 hours.

On June 24, a surface high pressure center was located in Virginia with a warm front again in western New York and Pennsylvania. Ozone exceedances were reported from New Jersey southward with many Maryland monitors above the one-hour ozone standard. The back trajectories for June 24 (Figure 12) showed a very similar track as June 20 (Figure 8).

As occurred on June 20-21, the strongest one-hour exceedances spread north into New York and New England the following day. At 850 mb on June 24, a broad east-west ridge built over the mid-Atlantic with its center on the Virginia–North Carolina border. Temperatures were 16-17$^{o}$C in the mid-Atlantic but significantly cooler (10-12$^{o}$C) in New England. Winds were W and NW with speeds of 10-20 kts.

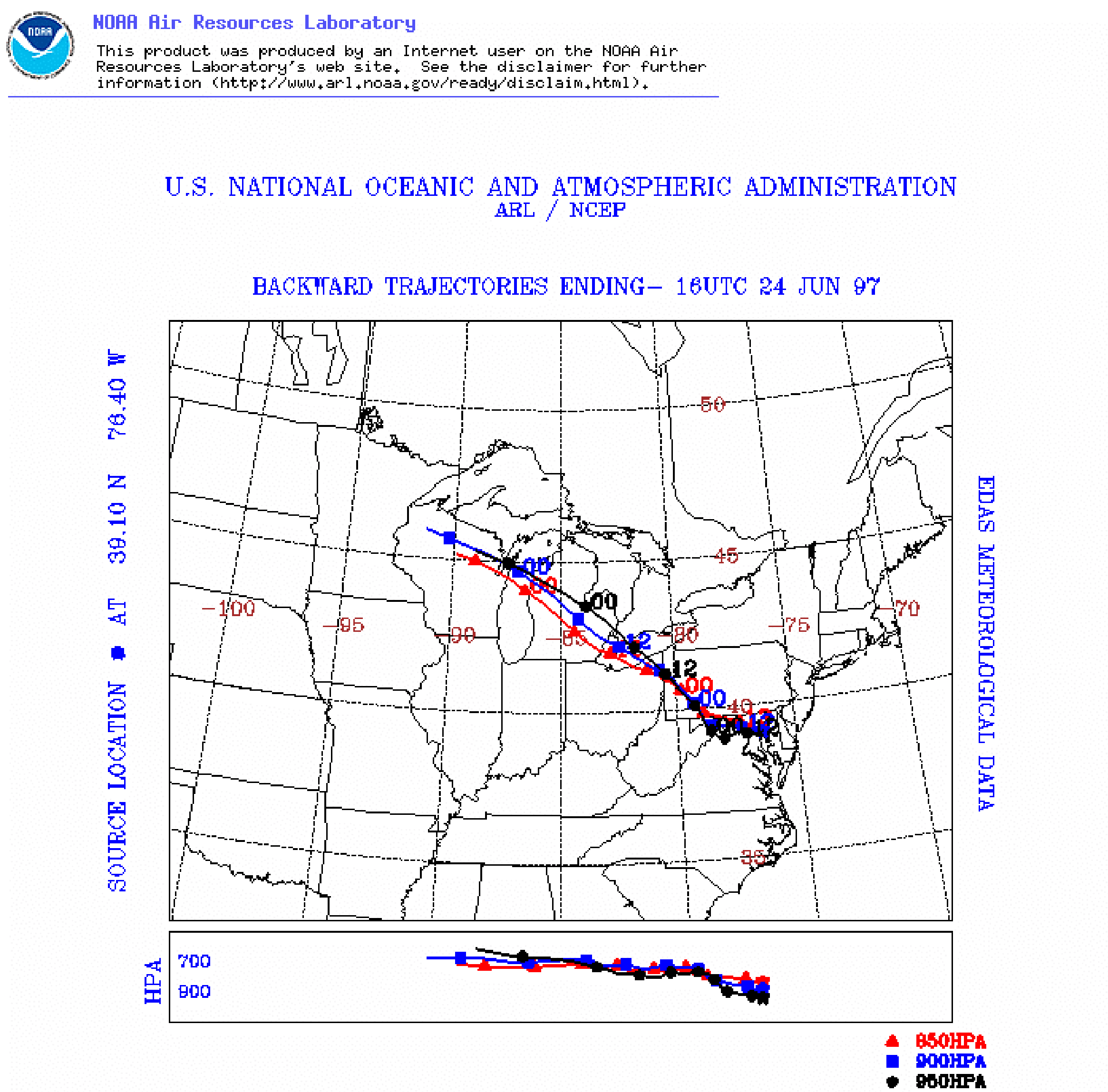



**Figure 12: 48-hour back trajectories from the Baltimore area ending at 16 UTC on June 24, 1997 at three levels of the atmosphere (850 HPa, 900 HPa, and 950 HPa).**

On the following day (June 25), the warm front that was located on a line across central New York to New York City at 1200 UTC moved northward to Boston–southern New Hampshire line by 1800 UTC.

At 850 mb, warm air moved north into New York and Connecticut (17$^{o}$ C) though it was still cool in eastern New England. This pattern was similar in many respects to the June 20-21 period. Seventy-two hour back trajectories for June 25, 1997 are given in Figure 13 for central Connecticut. In the Baltimore–Washington region, however, a strong pulse of winds at mid-day kept concentrations just below the one-hour ozone standard though exceedances were reported in Delaware, Massachusetts, New Jersey, and New York.

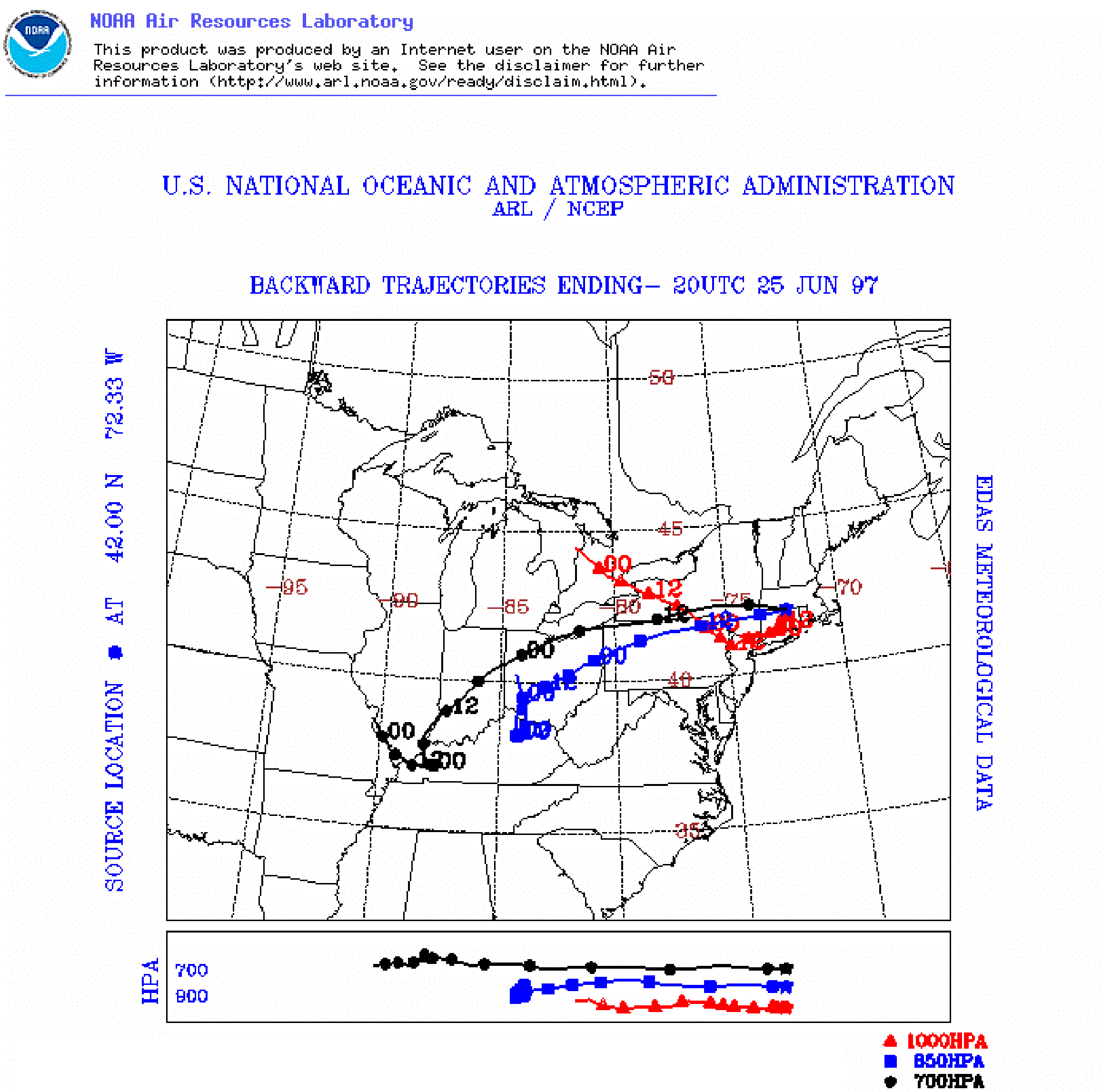



**Figure 13: 72-hour back trajectories from central Connecticut ending at 20 UTC on June 25, 1997 at three levels above the surface – 10 m (1000 HPa), 1000 m (850 HPa), and 3000 m (700 HPa).**

The pattern of one-hour ozone exceedances in the NESCAUM region is shown in Figure 14. The next trough of lower pressure that would end this episode advanced into the upper Great Lakes.

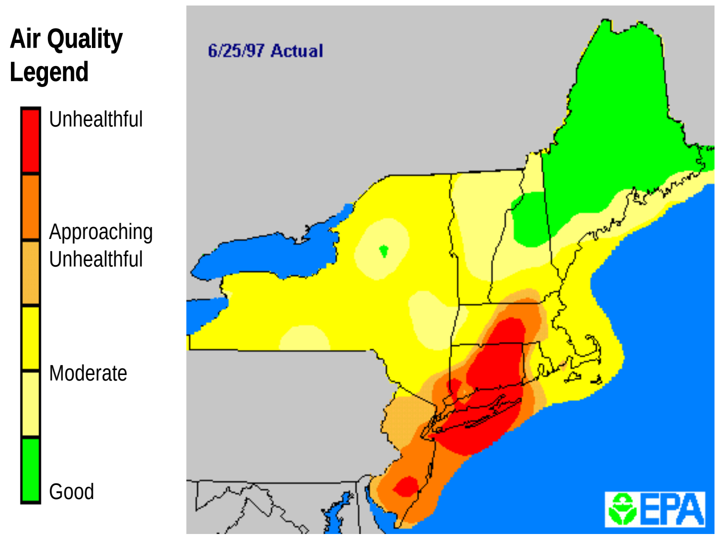



**Figure 14: Pattern of one-hour ozone exceedances (indicated by red shading) on June 25, 1997 in the NESCAUM region.**

On June 26, a trough at 850 mb crossed eastern Canada with several short wave disturbances affecting New England. At 850 mb, temperatures of 19-20$^{o}$ C were reported along the coast with north winds of 20 kts. Cooler air (15-16$^{o}$ C) was observed along the western boundary of the Ozone Transport Region. Significant convection occurred in the very warm and moist atmosphere that kept ozone below the one-hour ozone standard.

### *Episode 2: June 29-July 1*

*Summary:* This episode was unusual in that it affected much of New England but had a relatively smaller impact on the mid-Atlantic. One-hour exceedances were reported in Connecticut, New Jersey and New York on June 29. On the following day (June 30), the area of exceedances moved north into Maine, New Hampshire and Connecticut and continued into Massachusetts, New Hampshire and Maine on July 1. The driving force behind the exceedances was a compact high pressure system that drifted over New England bringing clear skies and stable conditions to the region. A low pressure system off the Carolinas (later Tropical Depression #1) brought maritime air, cooler temperatures, and clouds into the mid-Atlantic.

*Details:* At the jet stream level (200 mb), the ridge that was in place during Episode 1 re-established over the eastern United States with the main branch of the jet stream and associated storm track well north into Canada. This upper air pattern, with a broad ridge over the eastern United States, provided for higher than average ozone concentrations. The cold front that ended Episode 1 dropped as far south as the North Carolina–South Carolina border by June 27. High pressure behind the front was centered over Ohio on June 27 and moved into eastern Pennsylvania by June 28 as the cold front stalled in South Carolina.

On the morning of June 29, surface high pressure was centered over the Delmarva Peninsula, with a weak low off the coast of South Carolina along the old frontal boundary. At 850 mb, the center of high pressure was over Connecticut. Although temperatures at this level were only 13-16$^{o}$C, conditions were stable immediately beneath the upper level high. Ozone exceedances were reported in Connecticut, New York and New Jersey on this day.

On June 30, the low off the South Carolina coast moved slowly east with a coastal trough forming to its north along the mid-Atlantic coast. Large diffuse surface high pressure was located along the Interstate 95 corridor and east. At 850 mb, the center of the high dropped southward so that winds north of New York City were westerly with a more easterly component to the south of New York.

Temperatures at 850 mb warmed in New England (13-15$^{o}$C) but remained cooler (12-13$^{o}$C) in the mid-Atlantic as a consequence of more easterly flow off the ocean. Significant cloud cover developed by afternoon in Pennsylvania and Maryland and to the west, but the region from New York to the east and north remained cloud free beneath the rather compact high pressure center.

On the following day (July 1), the low pressure off the South Carolina coast became Tropical Depression (TD) #1. Winds were variable at 850 mb over the Ozone Transport Region with the warmest air advecting over the top of the ridge into Maine (15-17$^{o}$C) but cooler air (13$^{o}$C) to the south. The large area of cloud cover previously seen on June 30 now extended from the eastern border of New York to the south and west. The only clear area was northern New England and this was where the ozone exceedances occurred (Figure 15). As high pressure moved east, ozone concentrations fell throughout the Ozone Transport Region.

Forty-eight hour back trajectories from southern Maine (Figure 16) overlap the observed pattern of high ozone seen in Figure 15.[23] The back trajectories are chosen to end later in the day (20 UTC) to better coincide with observed peak ozone values occurring later in the day along the Maine coast.

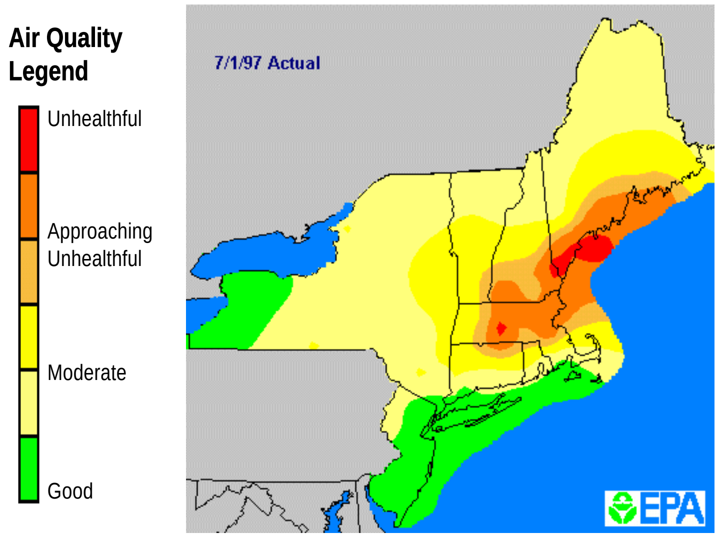



**Figure 15: Pattern of one-hour ozone exceedances (indicated by red shading) on July 1, 1997 in the NESCAUM region.**

[23] Some caution should be used, however, in viewing back trajectories at coastal locations due to sea breeze effects that may not be reproduced in the calculated air trajectories.

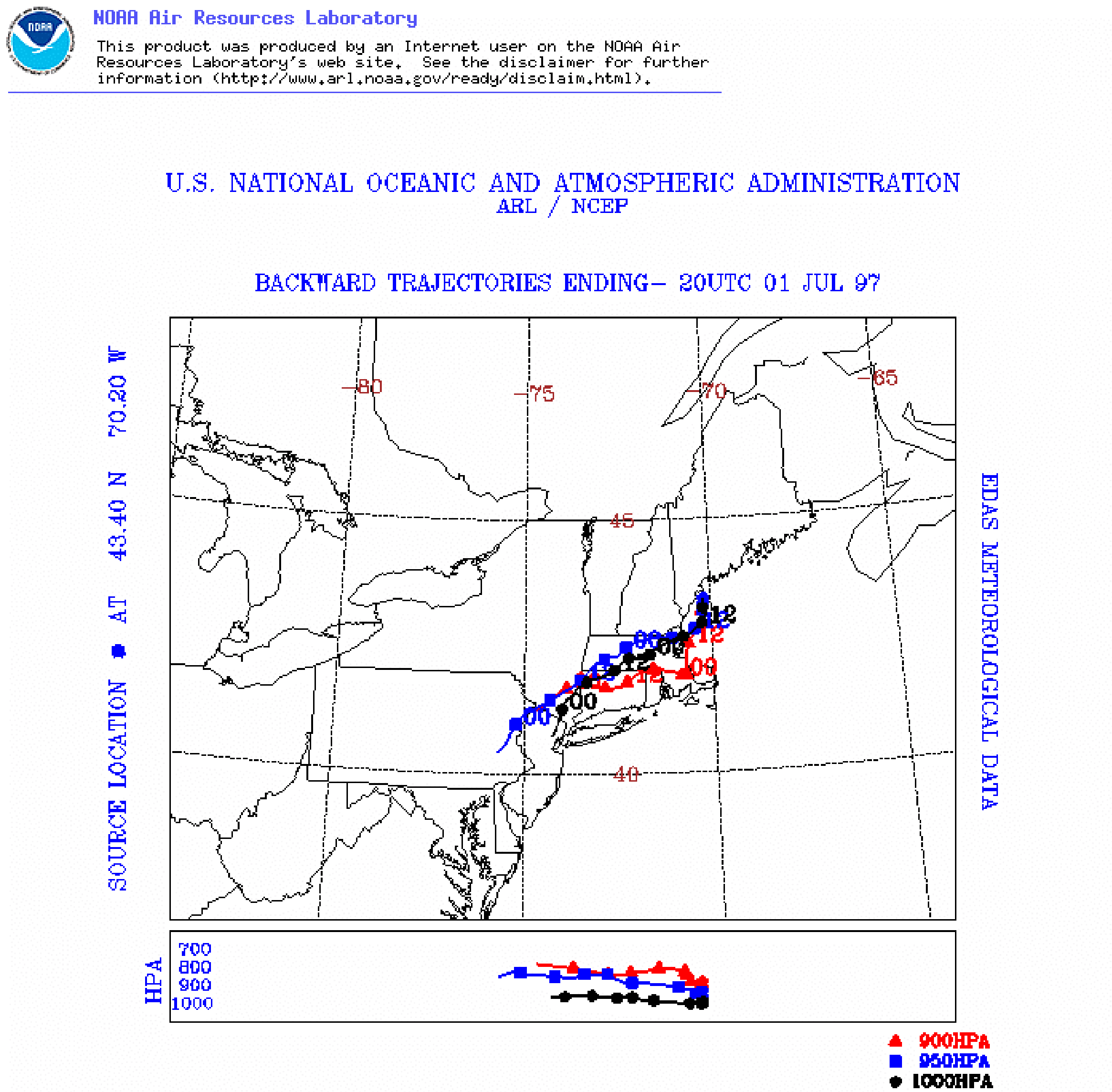



**Figure 16: 48-hour back trajectories from southern Maine ending at 20 UTC on July 1, 1997 at three levels above the surface – 10 m (1000 HPa), 1000 m (950 HPa), and 1500 m (900 HPa).**

### *Episode 3: July 12-17*

*Summary:* The most severe ozone episode of 1997 occurred during the period July 12-17, 1997. This episode was slightly stronger, locally and regionally, than the July, 1995 episode and rivaled the historic 1988 cases. The weather pattern associated with this episode was of the "classic" type and very similar to the July, 1995 episode.

*Details:* Ozone concentrations increased rapidly in the mid-Atlantic on July 12 as a strong upper air ridge moved into position west of the region. This pattern was quite similar to July 1995. While extreme ozone concentrations are due to the coincidence of a number of factors, at various time and length scales, the presence of a strong large-scale (synoptic) ridge to the west of the Ozone Transport Region typically signals the beginning of a multi-day period of unusually high ozone. Day-to-day variations in peak ozone, and the size and extent of exceedances of the ozone standard, are dependent on other, smaller scale, effects.

The region downstream (east) of an upper air ridge axis is characterized by downward motion (subsidence) resulting in decreased vertical motion, limited cloud cover and a tendency for stronger than normal low-level inversions. In addition, surface high pressure is usually centered slightly east of the position of the upper air ridge placing it more or less over the mid-Atlantic region. Surface high pressure centered overhead means weak winds and limited horizontal ventilation. All these factors are conducive to high concentrations of ozone. In addition, wind flow above the surface is west or northwest in this pattern, which results in transport from heavily industrialized regions west of the Ozone Transport Region.

At the beginning of the July 12–17, 1997 episode, a ridge moved into position west of the region, and ozone exceedances were reported on July 12 in Pennsylvania and Maryland and spread into New York and New Jersey on July 13. Region-wide exceedances (from Virginia to Connecticut) were reported on July 14-15. One-hour ozone exceedances in the NESCAUM region are shown in Figures 17 and 18.

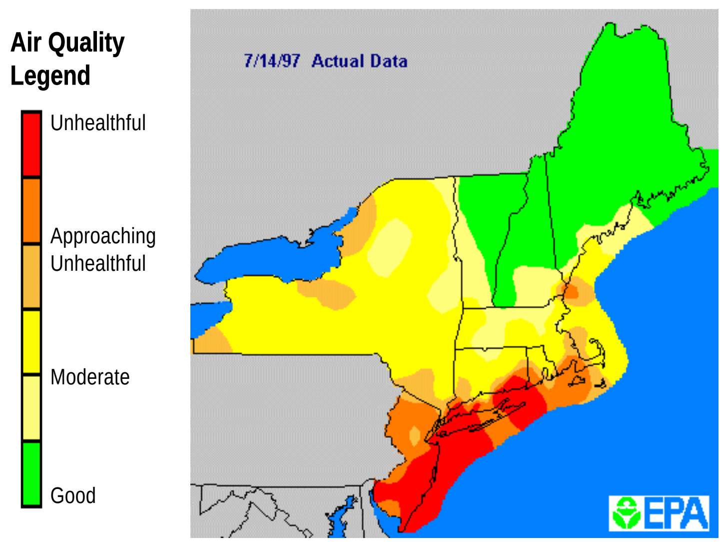



**Figure 17: Pattern of one-hour ozone exceedances (indicated by red shading) on July 14, 1997 in the NESCAUM region.**

A “back door” cold front kept New England cool and cloudy and prevented ozone exceedances from spreading north of Connecticut and Rhode Island. The term “back door” refers to motion of a front from a northeasterly to southwesterly direction in contrast to the more typical flow of weather fronts from west to east.

Ozone concentrations dropped significantly (though still >125 ppb in the mid-Atlantic) on July 16 and then rebounded on July 17 before tapering off again on July 18. The decrease on July 16 was due to a very weak and decaying frontal zone crossing the region early on July 16.

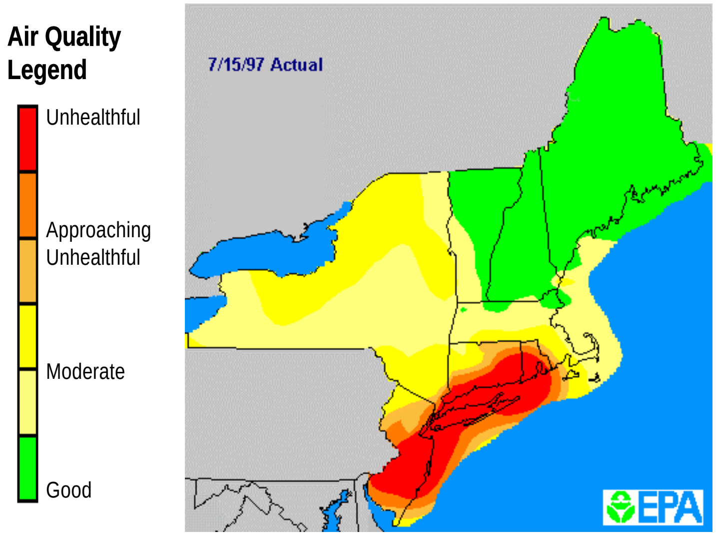



**Figure 18: Pattern of one-hour ozone exceedances (indicated by red shading) on July 15, 1997 in the NESCAUM region.**

Previous research on ozone episodes in 1995 and 1996 show that certain paths of air parcels are associated with strong regional ozone episodes (see Figure 9). During this 1997 episode, very similar trajectories were observed in the mid-Atlantic (Figure 19).

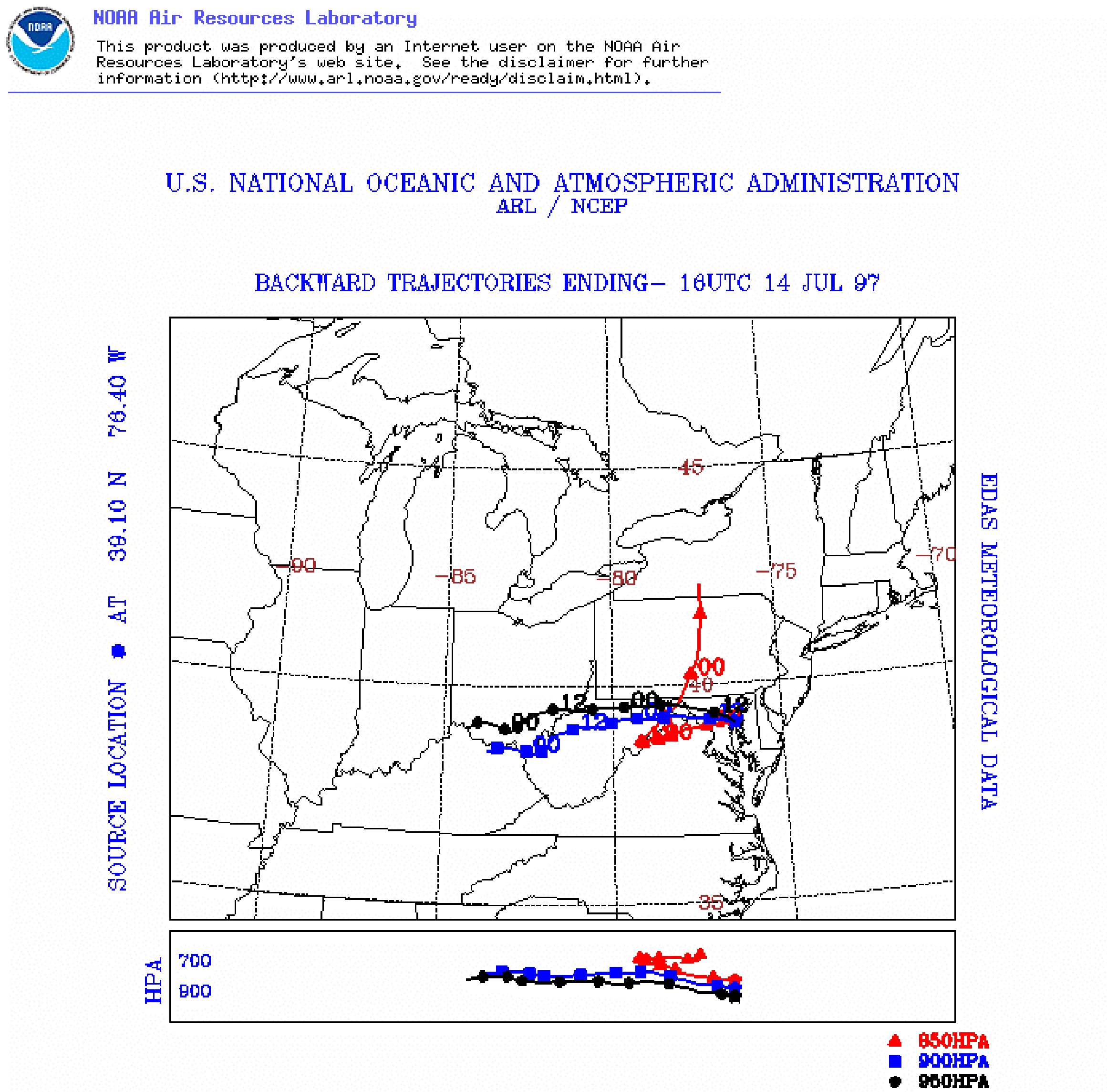



**Figure 19: 48-hour back trajectories from the Baltimore area ending at 16 UTC on July 14, 1997 at three levels of the atmosphere (850 HPa, 900 HPa, and 950 HPa).**

Of particular interest during this episode was the shift to more westerly transport on July 14 as the event became extreme and regional in nature. Preliminary observations from aircraft flown as part of the NARSTO-Northeast research program showed ozone concentrations aloft at mid-day on July 13 in excess of 100 ppb along the western boundary of the Ozone Transport Region. In addition, haze, which was reported by pilots west of the Ozone Transport Region on July 13, became widespread in the Baltimore-Washington Corridor before dawn on July 14. The coincidence of high ozone with high sulfur dioxide concentrations during extreme regional events was observed at a remote rural site at Shenandoah National Park in western Virginia during the July 1995 episode and was again observed during the July 1997 episode. Forty-eight hour back trajectories from Shenandoah National Park on July 13 indicate that air flow was from the Ohio River Valley where many power plants emitting sulfur dioxide and NOx are located (Figure 20).

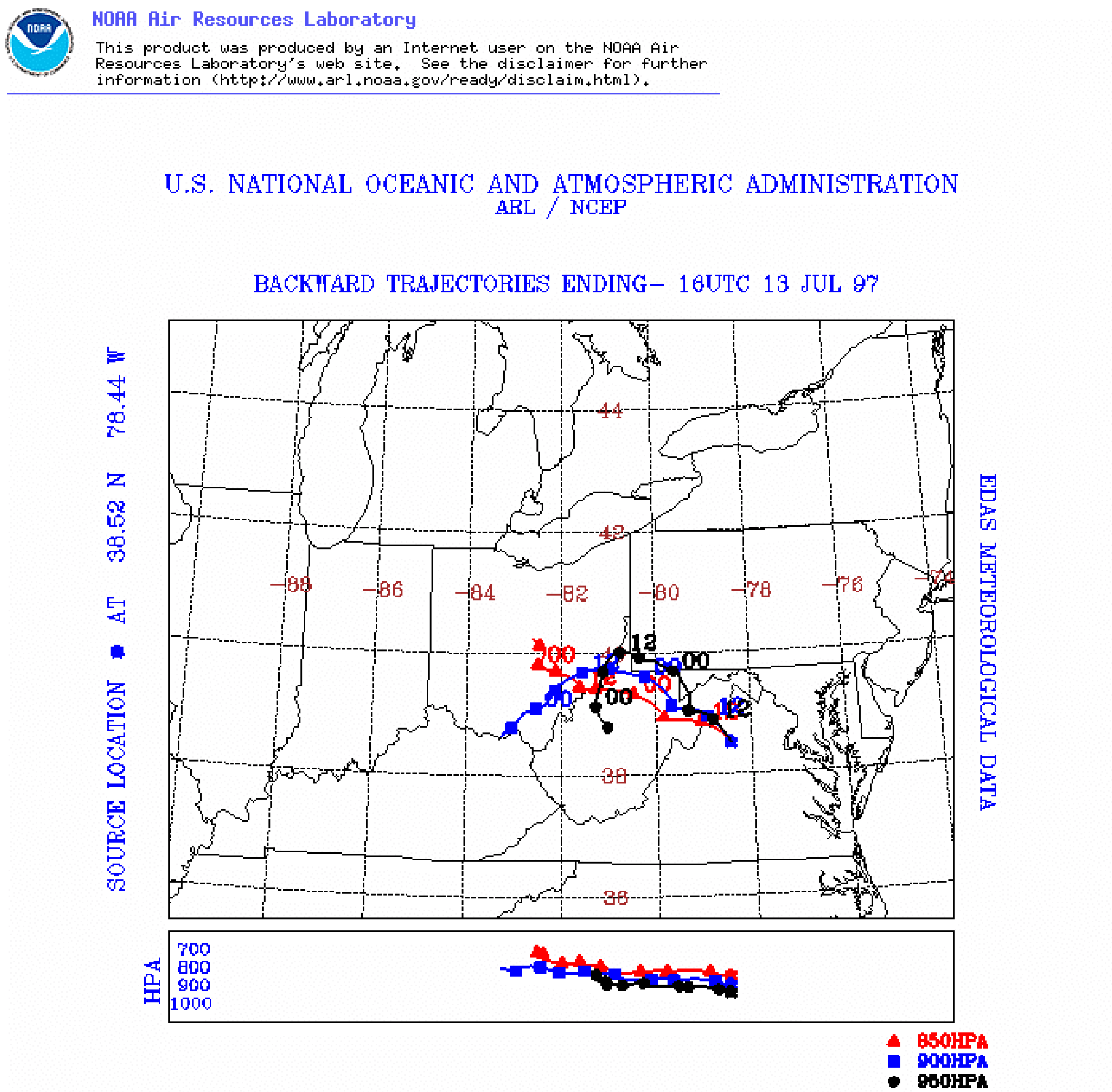



**Figure 20:** **48-hour back trajectories from Shenandoah National Park, VA ending at 16 UTC on July 13, 1997 at three levels of the atmosphere (850 HPa, 900 HPa, and 950 HPa).**

### ***Episode 4: July 26-28***

*Summary:* The final ozone episode of July 1997 was relatively weak with only scattered exceedances in Connecticut and the mid-Atlantic.

*Details:* A cold front crossed the northeastern US and became stationary over Virginia on July 23. Weak waves moved west to east along this front on July 23, until the remnants of Hurricane Danny piled into it on July 24. By early on July 25, the center of re-invigorated Hurricane Danny was south of Nantucket and the frontal zone previously stalled in Virginia moved south to the Carolinas.

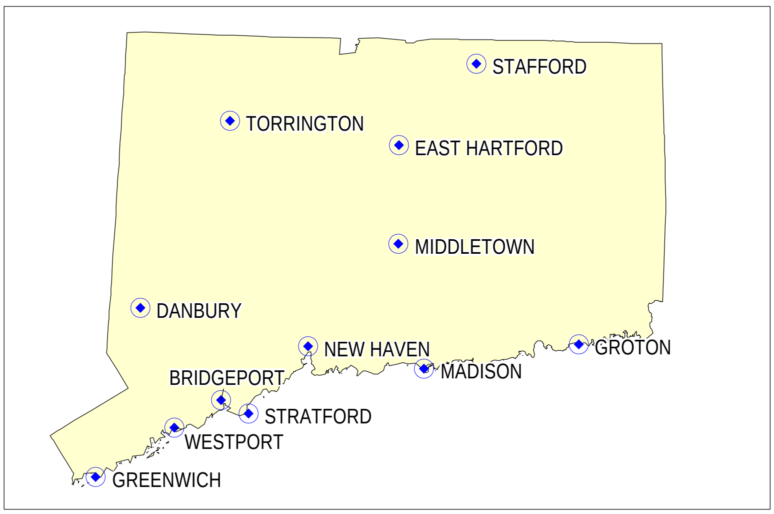
In wake of Danny's passage, large, diffuse surface high pressure built up over West Virginia and remained in place through the remainder of episode. Aloft, a wide ridge stretched from the Rockies to the Appalachians. The eastern end of the upper air ridge moved over the mid-Atlantic by July 26 and remained in place through July 27.

On July 28, a cold front associated with a rapidly advancing Canadian trough moved to Lake Erie and then across the region over the following days. Later on July 28, substantial convection formed well ahead of the cold front with thunderstorms across New Jersey, Maryland, West Virginia and northern Virginia. Ozone exceedances on the final day of the episode were relegated to the regions well east of the pre-frontal convection (Delaware and Virginia).

### *The 1997 Ozone Season: State Focus*

There has been a significant emphasis on how ozone affects the NESCAUM region as a whole, but it is also important to note how individual states are affected by ozone. Although states are relatively small when compared to the entire NESCAUM area, the Ozone Transport Region, or the OTAG states, they still have unique patterns that tend to repeat from year to year, again, depending on the meteorological conditions of a particular summer. In the state analyses, the strong southwest to northeast transport component remains apparent. This phenomenon greatly affects an individual state's ozone levels from year to year.

### *Connecticut*




Of all of the NESCAUM states, Connecticut recorded the most frequent and highest ozone exceedances. Connecticut experienced 12 exceedance days and had a maximum one-hour ozone concentration of 187 ppb at Stratford on July 15, 1997. When compared to states in the Ozone Transport Region, Connecticut was surpassed in number of exceedance days by only one other state, Maryland, which totaled 14 exceedance days. Furthermore, 11 of Connecticut's 12 ozone monitoring sites recorded at least one exceedance of the one-hour ozone standard during 1997, the majority of them recording multiple exceedances over the course of the summer.

Connecticut also recorded multiple exceedances of the eight-hour ozone standard. In fact, during the summer of 1997, all of Connecticut's monitoring sites recorded eight-hour ozone concentrations exceeding 85 ppb for the 4$^{th}$ highest eight-hour average. Additionally, when averaging 4$^{th}$ maximum eight-hour ozone concentrations over the three-year period from 1995 to 1997, only the Bridgeport and New Haven monitors have a three year running average lower than 85 ppb.

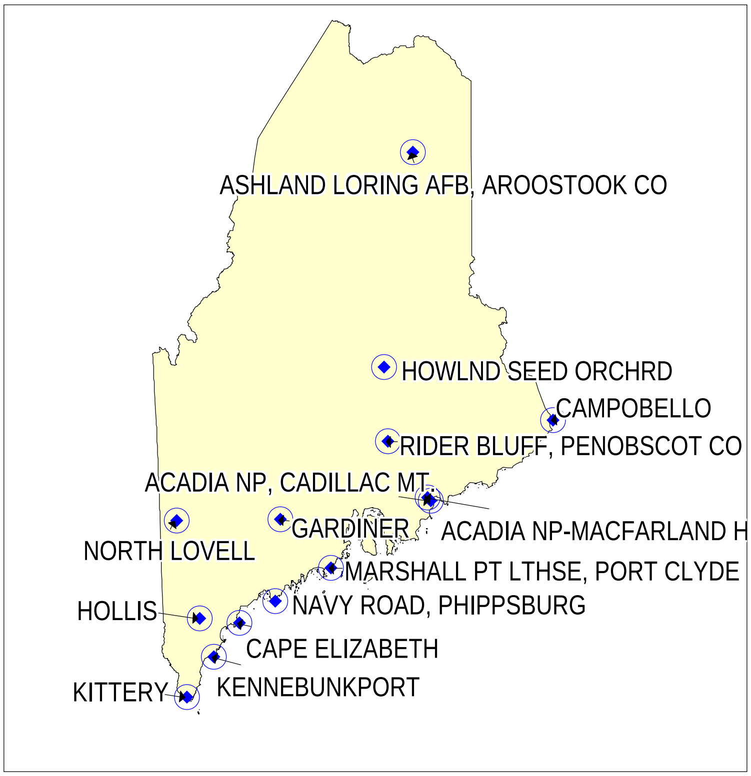
An examination of the 1991–1997 ozone record reveals that Connecticut monitoring sites regularly record the highest ozone levels of all of the NESCAUM states. Averaging the maximum one-hour ozone values measured over the past seven years results in a Connecticut value of 172 ppb. This is higher than similar averages for both New York (166 ppb) and New Jersey (161 ppb).

**Table 7: Monitoring sites which have recorded Connecticut maximum 1 hour and 8 hour ozone levels from 1991-1997.**

| Year | Location of 1 hour max. | Location of highest 8 hour 4th max |
|---|---|---|
| 1991 | Madison | Madison |
| 1992 | Danbury | Middletown |
| 1993 | Stratford | Stratford |
| 1994 | Stratford | Greenwich |
| 1995 | Madison | Madison |
| 1996 | Groton | Westport |
| 1997 | Stratford | Westport |

The 1997 ozone data indicate that all of Connecticut is susceptible to poor air quality due to ozone. Table 7 contains a listing of monitoring sites that recorded maximum ozone levels in Connecticut from 1991-1997. It is interesting to note that maximum eight-hour ozone exceedances were much more prevalent near the New York City area than one-hour maximum concentrations.

## *Maine*




The coastal portions of southern Maine tend to exceed the ozone standard quite a bit more frequently than their northern coastal and inland counterparts. The 1997 ozone season in Maine was no exception. During 1997, exceedances occurred along coastal Maine as far north as Acadia National Park, yet no exceedances of the ozone standard were recorded at Roosevelt Campobello International Park, 60 miles to the northeast. Three exceedance days occurred in Maine at seven of its 14 ozone monitoring sites during 1997. Table 8 lists the sites that exceeded the ozone standard during 1997.

Six sites in Maine – Acadia National Park (Cadillac Mountain), Cape Elizabeth, Kennebunkport, Kittery, Phippsburg, and Port Clyde – had 4$^{th}$ highest eight-hour annual averages above 85 ppb. These five sites are along Maine's coast. The maximum 4$^{th}$ highest eight-hour ozone value was recorded at Cape Elizabeth. Over the three-year period from 1995 to 1997, the running average of the 4$^{th}$ highest annual eight-hour ozone average is above 85 ppb at Cape Elizabeth, Kennebunkport, Phippsburg, and Port Clyde. The data from Cadillac Mountain do not cover the entire three-year period, so are inconclusive.

**Table 8: Ozone exceedances recorded in Maine during 1997**

| Date | Site | Ozone Concentration |
|---|---|---|
| June 21, 1997 | Acadia, Nat. Park | 126 ppb |
| | Kennebunkport | 125 ppb |
| June 30, 1997 | Cape Elizabeth | 154 ppb |
| | Kennebunkport | 154 ppb |
| | Phippsburg | 143 ppb |
| | Port Clyde | 134 ppb |
| | Kittery | 132 ppb |
| July 1, 1997 | Cape Elizabeth | 130 ppb |
| | Hollis | 125 ppb |
| | Phippsburg | 125 ppb |

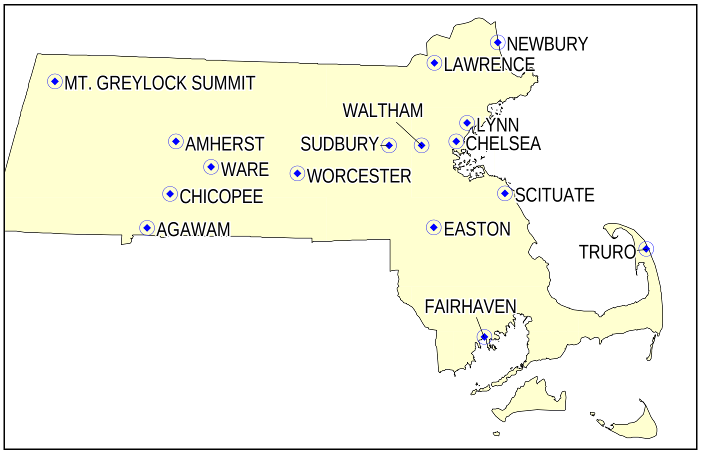
Looking at Maine's 1991–1997 ozone record (Table 9), the sites that regularly recorded the state's highest one- and eight-hour exceedances were Kennebunkport, Cape Elizabeth and Phippsburg. These three sites are among Maine's most southerly coastal monitoring sites.

This trend of southern, coastal exceedances in Maine should be no surprise. This portion of the state is the closest to the major metropolitan areas in the NESCAUM region, and is directly along the transport route that extends from Washington, DC, along the Interstate 95 corridor through Baltimore, Philadelphia, New York City and Boston. Maine is the most northeastern point of the United States, and is the furthest downwind of all the NESCAUM states. Therefore it receives the brunt of any transported pollutants that follow this route, and sites along Maine's southern border are exposed to these pollutants in the highest concentrations. Emissions from all along the Northeast Corridor, including local emissions in Maine, will have a significant effect on Maine's air quality.

**Table 9: Monitoring sites that have recorded Maine maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997.**

| Year | Location of 1 hour max. | Location of highest 8 hour 4th max |
|---|---|---|
| 1991 | Kennebunkport | Kennebunkport |
| 1992 | Kennebunkport | Kennebunkport |
| 1993 | Kennebunkport | Kennebunkport |
| 1994 | Cape Elizabeth/ Phippsburg | Kennebunkport |
| 1995 | Phippsburg | Kennebunkport |
| 1996 | none | Phippsburg |
| 1997 | Cape Elizabeth/ Kennebunkport | Cape Elizabeth |

### *Massachusetts*




During the 1997 ozone season, Massachusetts recorded four exceedance days. The series of Canadian frontal systems responsible for preventing interstate transport and production of ozone in the north/northwestern portions of the NESCAUM region throughout the summer of 1997 sometimes descended as far south as the Massachusetts/Connecticut border, which helped minimize ozone production in the Bay State. One-hour exceedances were recorded at three of the 17 ozone monitoring sites located throughout the state: Chicopee, Fairhaven and Ware. The monitoring site at Ware recorded the 1997 maximum Massachusetts one-hour ozone concentration of 151 ppb on June 21.

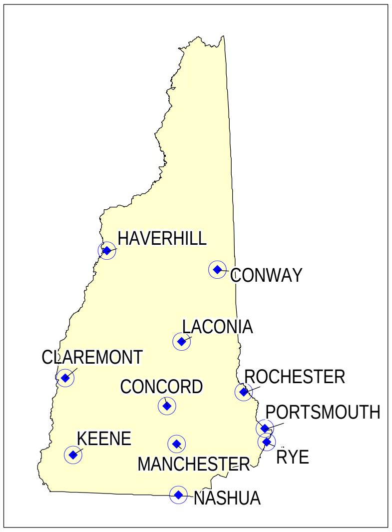
Eleven out of 16 monitoring sites in Massachusetts recorded a 4$^{th}$ maximum eight-hour ozone level above 85 ppb during the 1997 ozone season. These sites were Agawam, Chicopee, Easton, Fairhaven, Lynn, Newbury, Sudbury, Truro, Waltham, Ware, and Worcester. The three-year average (1995-1997) of the 4$^{th}$ highest eight-hour ozone level was above 85 ppb at the same sites except for Easton. (The Easton monitor does not have a complete set of data over the three-year period.)

Table 10 lists sites that have recorded Massachusetts' maximum ozone concentrations in the past seven years (both one and eight hour). Fairhaven and Ware have recorded maximum values the most frequently of these sites, probably due to their down-wind relationship to Metropolitan New York City.

**Table 10: Monitoring sites that have recorded Massachusetts' maximum 1-hour and 8-hour exceedance ozone levels from 1991-1997.**

| Year | Location of 1 hour max. | Location of highest 8 hour 4$^{th}$ max |
|---|---|---|
| 1991 | Truro | Ware |
| 1992 | Worcester | Ware |
| 1993 | Agawam | Agawam |
| 1994 | Ware | Easton |
| 1995 | Fairhaven | Fairhaven |
| 1996 | Fairhaven | Truro |
| 1997 | Ware | Ware |

### *New Hampshire*




Three of New Hampshire's 11 ozone monitoring sites exceeded the one-hour ozone standard in 1997 (Table11). These were Rye, Rochester and Portsmouth. Similar to Maine, the ozone exceedances occurred on or near the coastal portion of the state. Northern portions were safeguarded by cooler air masses that originated in Canada.

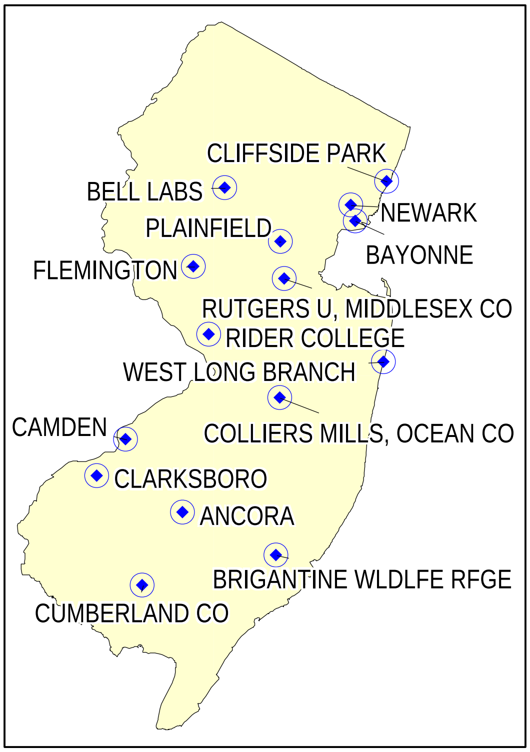
The Rye, New Hampshire site recorded the state's 1997 maximum one-hour value of 156 ppb on June 30. The Rye monitor is also the most common location of the State's eight-hour ozone exceedances. This is most likely due to its position on the Atlantic Coast just north of Boston. Emissions originating from Boston, combined with a sea breeze, carry pollutants directly to the New Hampshire and Maine coasts.

During the 1997 ozone season, three of New Hampshire's 11 sites had 4$^{th}$ highest eight-hour ozone averages above 85 ppb (Table 11). These were Nashua, Portsmouth, and Rye, all located in the southeastern part of the state. Averaged over 1995 to 1997, only Nashua and Rye had 4$^{th}$ highest eight-hour averages over 85 ppb.

**Table 11: Monitoring sites that have recorded New Hampshire maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997.**

| Year | Location of highest 1 hour exceedance | Location of highest 8 hour 4$^{th}$ max. |
|---|---|---|
| 1991 | Rye | Rye |
| 1992 | none | Nashua |
| 1993 | Nashua | Rye |
| 1994 | Rye/ Portsmouth | Rye |
| 1995 | Rye | Rye |
| 1996 | none | Rye |
| 1997 | Rye | Rye |

### *New Jersey*




New Jersey, centrally located in the megalopolis which extends from Washington, DC to Boston, MA, exceeded the ozone standard on multiple days at multiple sites throughout the state. Ten one-hour ozone exceedance days were recorded in New Jersey. The maximum one-hour ozone value recorded in New Jersey was 176 ppb, measured on July 15, 1997 at the Colliers Mills monitoring site.

New Jersey recorded $4^{th}$ highest eight-hour ozone levels above 85 ppb at all 15 of its monitoring locations during the 1997 ozone season. The maximum $4^{th}$ highest eight-hour concentration was recorded at the Ancora site in southern New Jersey. Averaged over the 1995-1997 period, all New Jersey sites except Plainfield have three-year $4^{th}$ highest average ozone levels above 85 ppb.

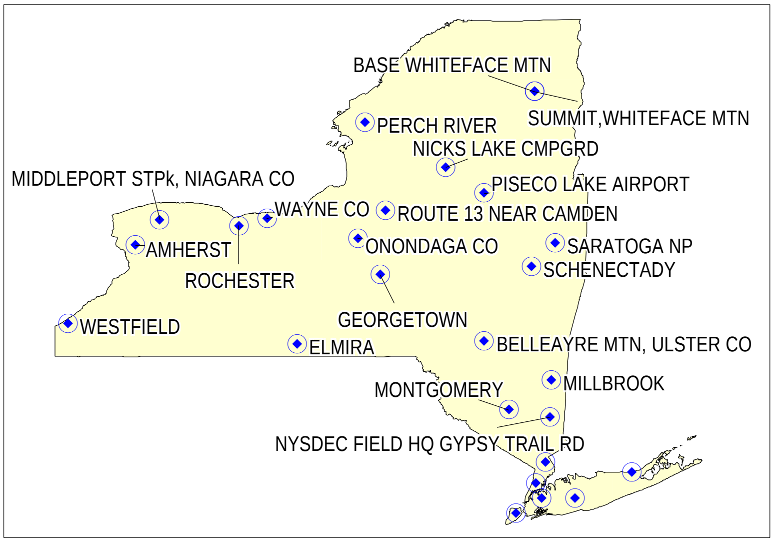
New Jersey, sandwiched between the Philadelphia and Baltimore MSAs to the south and the NYC MSA to the north, has a variety of factors influencing its ozone concentrations. Although New Jersey's primary region of industrial development is in the northern portion of the state, one-hour ozone exceedances in the north are relatively less common compared to the middle and southern portions of the state. This would implicate a direct influence of the Philadelphia and Baltimore metropolitan areas on the state's air quality, and follows the same reasoning for the poor air quality in Connecticut and Maine. Pollutants are transported into New Jersey, i.e., from the southwest (from Philadelphia and Baltimore) to the northeast (central and southern New Jersey), just as northern New Jersey pollutants are similarly transported to the northeast (into New York and Connecticut).

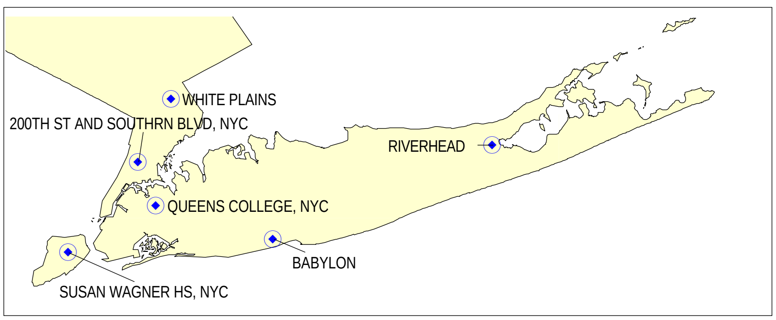
Table 12 contains a listing of sites where maximum ozone was recorded annually in New Jersey. Note the number of central and southern New Jersey sites impacted by both one and eight hour ozone.

**Table 12: Monitoring sites that have recorded New Jersey maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997.**

| Year | Location of 1 hour max. | Location of highest 8 hour $4^{th}$ max |
|---|---|---|
| 1991 | Bayonne | Rider College |
| 1992 | Brigantine Wldlfe Rfg. | Rider College |
| 1993 | West Long Branch | Ancora |
| 1994 | Rider College | Rider College |
| 1995 | Colliers Mills | Colliers Mills |
| 1996 | Camden | Ancora |
| 1997 | Colliers Mills | Ancora |

### *New York*




Upstate New York experienced weather similar to northwestern New England, in that no exceedances of the one-hour ozone standard were recorded in that portion of the state. However, downstate New York, which includes the metropolitan New York City region, experienced more ozone exceedances than usual in 1997. Eight exceedance days were recorded in New York at seven monitoring sites, all in the New York City metropolitan area. Once again, this portion of New York is coastal in nature and it lies south of the "boundary" which segregates the northern portion from the southern portions of New York State.

Sixteen of New York's 31 ozone monitoring sites had 4$^{th}$ highest eight-hour ozone levels above 85 ppb during the 1997 ozone season. The bulk of eight-hour ozone exceedances occurred in the extended New York City region, but high levels were also recorded in the Buffalo and Rochester areas. Averaged over the three-year period of 1995 to 1997, thirteen New York sites had 4$^{th}$ highest eight-hour ozone averages above 85 ppb.

Table 13 contains a listing of maximum one-hour and eight-hour exceedances of the ozone standard in New York over the past seven years. Notice that the bulk of one-hour ozone exceedances occurred in areas outside of New York City. This is due to the secondary nature of ozone. By the time VOCs and NOx react to form ozone, they are generally already blown out of the New York City area.

Not shown in Table 13 are high ozone levels observed at New York's high elevation sites. These sites, the top of the World Trade Center in New York City (an altitude of 1,500 feet) and Whiteface Mountain's summit (an altitude of 4,850 feet) in the Adirondacks, have measured state maximum ozone values at one point or another during the 1991–1997 time period. The World Trade Center is especially noteworthy because of the frequency with which it records values higher than any other site in the state. This can be attributed to the transport of ozone aloft. Ozone builds up at ground level during the daytime. At night, as stable layers form in the atmosphere, the ozone is “captured” aloft and separated from the ground, insulating it from destruction at the surface. The aloft ozone is able to migrate along strong wind currents at night, thus the higher concentrations recorded at high elevation sites. During the following day, the stable layers in the atmosphere break down as the sun warms the earth's surface, and the ozone aloft mixes back down to the ground.

**Table 13: Monitoring sites that have recorded New York State maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997.**

| Year | Location of 1 hr max. | Location of highest 8 hour 4th max. |
|---|---|---|
| 1991 | Babylon | Queens College, NYC |
| 1992 | White Plains | Babylon |
| 1993 | Babylon | Millbrook |
| 1994 | Albany | Susan Wagner H.S., NYC |
| 1995 | Babylon | Babylon |
| 1996 | Montgomery | Montgomery |
| 1997 | Susan Wagner H.S., NYC | Susan Wagner H.S., NYC |

## *Rhode Island*

One exceedance day of the one-hour ozone standard was recorded at one of Rhode Island's four monitoring sites during 1997. A maximum value of 149 ppb was recorded at the Alton Jones Campus in Kent County on July 15, 1997. As shown in Table 14, the Alton Jones monitor consistently records Rhode Island's highest one-hour and 4th highest eight-hour ozone levels.

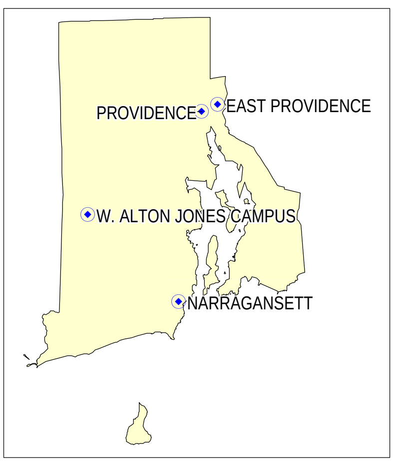



**Table 14: Monitoring sites that have recorded Rhode Island maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997.**

| Year | Location of 1 hr exceed. | Location of highest 8 hr 4th max. |
|---|---|---|
| 1991 | Alton Jones | Alton Jones |
| 1992 | Alton Jones | Alton Jones |
| 1993 | Alton Jones | Alton Jones |
| 1994 | Alton Jones | Alton Jones |
| 1995 | Alton Jones | Alton Jones |
| 1996 | None | Alton Jones |
| 1997 | Alton Jones | Alton Jones |

The monitors at Alton Jones and Providence both had 4th highest eight-hour ozone averages above 85 ppb during the summer of 1997. The monitor at East Providence had a 4th high just below 85 ppb, and the site at Narragansett started in mid-July, so it did not have a complete set of data for the 1997 ozone season.

### *Vermont*


Vermont's two ozone monitoring sites recorded no exceedances of the one-hour ozone standard during 1997, nor did either monitor have a 4$^{th}$ highest eight-hour average over 85 ppb (Table 15). Some related information, however, provides insight into the effects that meteorology has on ozone production in Vermont, and the NESCAUM region as a whole. Vermont's sites are located almost diametrically north and south within the state. The town of Bennington hosts the southern Vermont monitoring site and the town of Underhill the northern site. Following the general trend of the NESCAUM region, Bennington, the southern site, recorded significantly higher concentrations of ozone when compared to its northern counterpart, Underhill. The four highest one-hour ozone values recorded at Bennington range from 87 ppb to 106 ppb, whereas the maximum ozone value recorded at Underhill was 86 ppb (Table 16). This difference in concentration can be attributed, in part, to the same series of air masses that prevented excessive ozone from forming or being transported into northwestern portions of the NESCAUM region.

**Table 15: Monitoring sites which have recorded Vermont maximum 1 hour and 8 hour exceedance ozone levels from 1991-1997**

| Year | Location of 1 hour exceed. | Location of highest 8 hour 4$^{th}$ max. over 85 ppb |
|---|---|---|
| 1991 | Bennington | Bennington |
| 1992 | None | Underhill |
| 1993 | None | None |
| 1994 | None | None |
| 1995 | None | None |
| 1996 | None | None |
| 1997 | None | None |

**Table 16: Four highest one-hour ozone concentrations monitored values at the Vermont sites**

| Bennington | Date | Underhill | Date |
|---|---|---|---|
| 106 ppb | 6/30/97 | 86 ppb | 8/10/97 |
| 105 ppb | 8/10/97 | 81 ppb | 8/11/97 |
| 89 ppb | 6/12/97 | 77 ppb | 6/30/97 |
| 88 ppb | 7/17/97 | 77 ppb | 7/1/97 |

## Conclusion

The 1997 summer ozone season in the NESCAUM region was not atypical relative to previous summers. High ozone periods occurred (mainly in June and July), including a "classic-type" ozone episode covering a large part of the Northeast during July 12-17, 1997. Northern New England was spared from the brunt of this episode due to the presence of a cold front blocking more conducive ozone conditions from entering out of the southwest. Over the period from 1991-1997, the summer of 1997 fell roughly in the middle of the range in terms of overall ozone severity for the NESCAUM region.

With the recently promulgated eight-hour ozone standard, more places in the Northeast exceeded the new ozone standard than the older one-hour standard. Eight-hour ozone exceedances also occurred on more days than one-hour exceedances. This is not an indication of worsening air quality in the Northeast, rather it demonstrates that a larger part of the Northeast's population experiences poor air quality than was encompassed by the older, less protective one-hour ozone standard.

The periods of high ozone experienced in the Northeast during the summer of 1997 were characterized by both local influences and long-range transport. Pollution sources in the metropolitan areas within the Northeast Corridor align along the predominate southwest to northeast wind flow direction during high ozone events. The chain of urban areas can have an additive effect on ozone experienced in places farther downwind. In addition, the paths of air parcels arriving in the Northeast on the days leading up to high ozone episodes often come from the Ohio River Valley. Within this upwind area are large power plants and other pollution sources emitting tons of pollutants that contribute to regional ozone levels transported into the Northeast. As in past years, the summer of 1997 saw air masses with elevated levels of ozone entering from the west prior to some of the Northeast's highest ozone days.

Despite continuing periods of poor air quality, progress continues to be made towards achieving healthful air. Reductions in the amounts of ozone-forming pollutants have been accomplished over the years, particularly in the Northeast. With the implementation of a more protective eight-hour ozone standard, future progress will continue to be made as long as the NESCAUM states and states throughout the eastern United States pursue a joint effort to preserve and protect our shared natural resource – the air we breathe.