

**Mid-Course Review for 1-Hour Ozone in
the Lake Michigan Region:
Technical Support Document (Draft)**

Lake Michigan Air Directors Consortium

October 26, 2004

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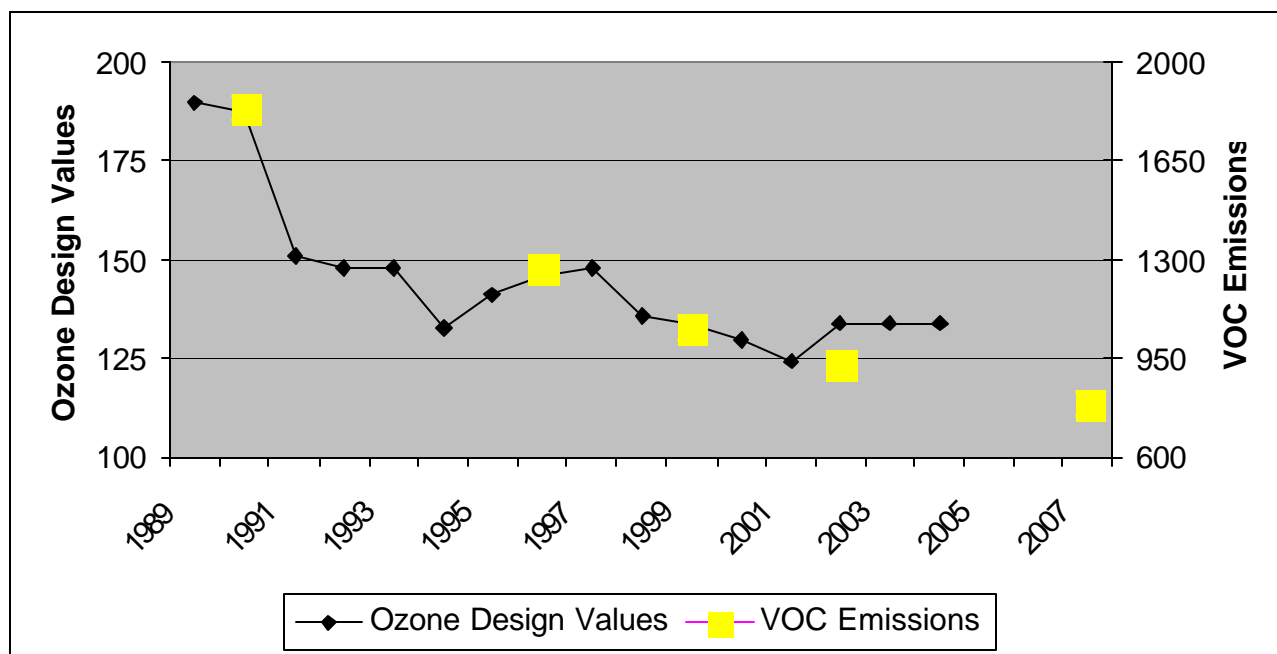
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Executive Summary

Ozone air quality has improved considerably over the past 15 years in the Lake Michigan area. In particular:

- 1-hour ozone design values have declined from 190 ppb to 134 ppb – see figure below (note: the 1-hour ozone standard is 0.12 ppm or 125 ppb),
- the number of monitoring sites in violation of the 1-hour standard have declined from 30 to 4, and
- the number of days above the standard from over 30 to just a few.

The figure below shows that the improvement in ozone air quality is consistent with the reduction in local VOC emissions due to motor vehicle control programs, including inspection and maintenance, and reformulated gasoline; area source control programs, and stationary source controls. Further progress is expected to come from reductions in regional NO_x emissions (e.g., USEPA's NO_x SIP Call and Wisconsin's NO_x rule).



Note: design value for three most recent 3-year periods are driven by 4th high values from 2002

This report reviews the ozone (and ozone precursor) data for the Lake Michigan region and demonstrates that the States are “on track” toward attaining the 1-hour ozone standard.

Section 1 Introduction

This document presents the mid-course review for 1-hour ozone for the States of Illinois, Indiana, and Wisconsin. The purpose of this review is to assess whether the states are "on track" toward attaining the 1-hour National Ambient Air Quality Standard (NAAQS) for ozone in the Lake Michigan area. A mid-course review was required by USEPA as part of their approval of the ozone SIPs for these states (66 FR 56744, 66 FR 56904, 66 FR 56931). This document was prepared in accordance with USEPA guidance ("Mid-Course Review Guidance for the 1-Hour Ozone Nonattainment Areas that Rely on Weight-of-Evidence for Attainment Demonstration", March 28, 2002)¹.

The mid-course review relies on trends in ambient air quality (both ozone and ozone precursors) and emissions data for the 3-year period used for the original nonattainment designations (1987-1989) through the most recent 3-year period (2002-2004). Examination of the changes in ozone air quality over time provides information on progress toward attainment and the relative effectiveness of control programs.

The key findings of this document are as follows:

- Since 1981, trends in 1-hour peaks are generally downward. In recent years, however, these trends are flatter. Trends in 8-hour peaks are similar to those for 1-hour peaks, with some indication of increasing trends in recent years
- The improvement in ozone air quality is consistent with the reduction in local VOC emissions due to motor vehicle control programs, including inspection and maintenance, and reformulated gasoline; area source control programs, and stationary source controls. Further progress is expected to come from reductions in regional NO_x emissions (e.g., USEPA's NO_x SIP Call and Wisconsin's NO_x rule).

These findings demonstrate that 1-hour ozone air quality levels in the Lake Michigan area have improved since the original nonattainment designations and combined with expected future emissions reductions, show that the region is on track to meet the 1-hour standard by the statutory attainment date of 2007.

¹ The attainment demonstration for the Lake Michigan region was based on a photochemical modeling analysis, not a weight-of-evidence determination. USEPA has indicated that its mid-course review guidance is applicable to areas with attainment demonstrations based on modeling, as well as weight-of-evidence.

Section 2 Basic Ozone Parameter Trends

A few simple parameters are presented here to characterize the change in ozone air quality over time in the Lake Michigan area: number of 1-hour exceedance days, number of monitored violations, and 1-hour design values. These metrics are used to assess attainment of the 1-hour NAAQS².

Number of Exceedance Days: The figure below shows the number of exceedance days and the number of exceedance site days (top), the number of hot days and the number of cooling degree days (bottom)³.

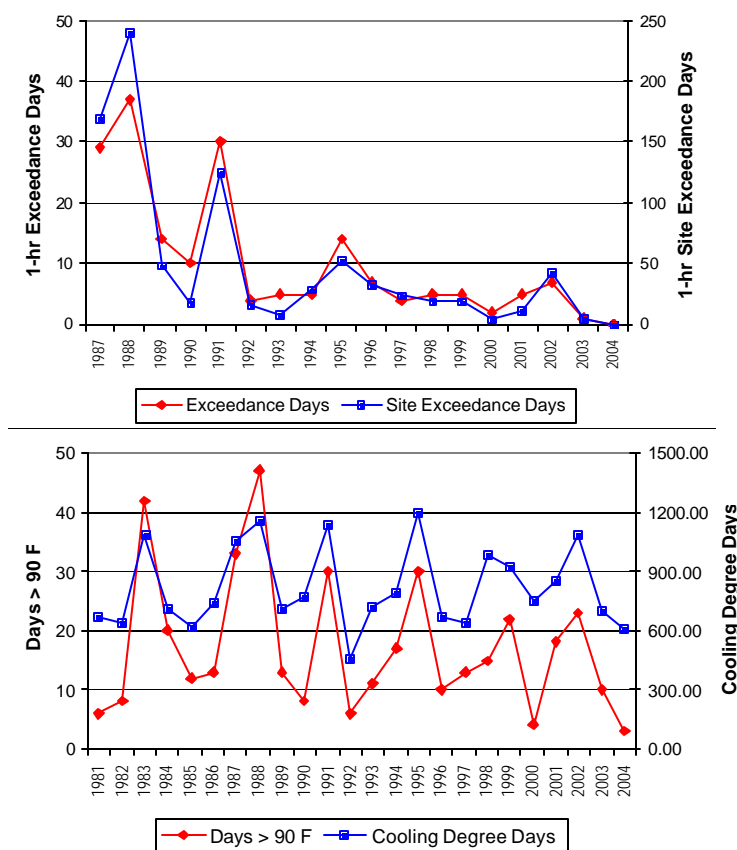


Figure 1. 1-Hour Ozone and Weather Statistics (Lake Michigan Area)

² The ozone NAAQS is attained when the number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.0, averaged over a 3-year period. An alternative means of judging attainment is to take the 4th highest daily 1-hour value over a 3-year period (i.e., the design value). An exceedance is defined as a peak daily 1-hour ozone concentration equal to or greater than 0.12 ppm (125 ppb) and a violation is defined as a design value equal to or greater than 0.12 ppm (125 ppb).

³ A hot day is defined as a day with the maximum daily temperature equal to or greater than 90°F, as measured at Chicago-O'Hare Airport. A cooling degree day is defined as the difference between the average daily temperature and 65°F, as measured at Chicago-O'Hare Airport.

These figures show:

- Ozone is strongly influenced by meteorology. The number of exceedance days (and site exceedance days) is generally higher during the hotter summers. In comparison to prior hot summers (e.g., 1988), there were substantially fewer exceedance days (and site exceedance days) during recent hot summer (e.g., 2002).
- The ratio of exceedance days to hot days has changed dramatically. During most years in the 1980's, there were more exceedance days than hot days; whereas during most years in the 1990's and 2000's there were more hot days than exceedance days.

Number of Monitored Violations: Table 1 presents the number of exceedances at each monitoring site since 1981. (Note, many of these monitors operated for the past 10 years or so, and only a few operated for the entire 24-year period.) Based on this information, the number of monitors in violation of the 1-hour ozone NAAQS for each 3-year period is as follows:

| <i>3-Year Period</i> | <i>Sites in Violation</i> |
|----------------------|---------------------------|
| 1981 – 1983 | 22 |
| 1982 – 1984 | 25 |
| 1983 – 1985 | 25 |
| 1984 – 1986 | 17 |
| 1985 – 1987 | 26 |
| 1986 – 1988 | 28 |
| 1987 – 1989 | 30 |
| 1988 – 1990 | 21 |
| 1989 – 1991 | 13 |
| 1990 – 1992 | 10 |
| 1991 – 1993 | 8 |
| 1992 – 1994 | 1 |
| 1993 – 1995 | 5 |
| 1994 – 1996 | 11 |
| 1995 – 1997 | 12 |
| 1996 – 1998 | 8 |
| 1997 – 1999 | 6 |
| 1998 – 2000 | 2 |
| 1999 - 2001 | 0 |
| 2000 – 2002 | 4 |
| 2001 – 2003 | 4 |
| 2002 – 2004 | 4 |

These results demonstrate the decrease in the number of monitors in violation of the 1-hour NAAQS.

Table 1. Number of Actual 1-Hour Exceedances

| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| ILLINOIS | | | | | | | | | | | | | | | | | | | | | | | | |
| Zion | | | | | | | | | | | | | | | | 2 | 1 | | | | | 3 | | |
| Waukegan | 4 | | 5 | 4 | 3 | | 7 | 11 | 2 | | | | | | | | | | | | | 1 | | |
| Libertyville | 2 | 1 | 4 | 1 | 1 | | 3 | 2 | | | | | | | | | | | | | | | | |
| Deerfield | 2 | | 3 | 1 | 2 | | 3 | 2 | | | | | | | | | | | | | | | | |
| Northbrook | | | | | | | | | | | | | | | | | | | | | | | | |
| Cary | 1 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | |
| Elgin | | | | | | | | | | | | | | | | | | | | | | | | |
| Des Plaines | | | 2 | 2 | | | | | | | | | | | | 1 | | | | | | | | |
| Evanston | 2 | 1 | 6 | 4 | 4 | | 6 | 16 | | | | | | | 2 | | | 1 | | | | | | |
| Chi-Truman | | | | | | | | | | | | | | | | | | | | | | | | |
| Chi-Taft | | | | | 1 | 1 | 5 | 1 | | | | | | | | | | | | | | | | |
| Univ of Chi | | | | | | | | | | | | | | | 2 | | | | | | | | | |
| Chi-SE Police | | | | | | | | | | | | | | | 2 | | | | | | | | | |
| MuseumSI | | | | | | | | | | | | | | | | | | | | | | | | |
| Chi-84th St | | | 4 | 1 | | | | | | | | | | | | | | | | | | | | |
| Chi-SWFP | | | | | | | 4 | 7 | | | | | | | 2 | | 1 | | | | | | | |
| Chi-Jardine | | | | | | | | | | | | | | | 2 | | | | | | | 1 | | |
| Chi-Edgewater | | | | | | | 4 | 5 | | | | | | | | | | | | | | | | |
| Chi-CTA | | | | | | | | | | | | | | | | | | | | | | | | |
| ChiSearsTower | | | | | | | | | | | | | | | | | | | | | | | | |
| Alsip | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Calumet City | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Cicero | | | 4 | 1 | | | 2 | 2 | | | | | | | | | | | | | | | | |
| S.Lockport | | 1 | 3 | | | | | | | | | | | | | | | | | | | | | |
| Lisle | | | | | | | | | | | | | | | | | | | | | | | | |
| Lemont | | | | | | | | | | | | | | | | | | | | | | | | |
| Braidwood | | | | | | | | | | | | | | | | | | | | | | | | |

| INDIANA | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Laporte | | | | | | | | | | | | | | | | | 1 | | 1 | | | 2 | | |
| Michigan Cty | | | | | | | | | | | | | | | 6 | 3 | 1 | | 1 | | 1 | 5 | | |
| Hammond | 3 | 1 | 5 | 4 | 1 | 2 | 1 | 5 | | | | | | | 1 | 1 | | | | | | 1 | | |
| Ogden Dunes | | | | 3 | 1 | 3 | 4 | 10 | | | | | | | 1 | 1 | | 1 | 1 | | | 3 | | |
| Gary-IITRI | | | 5 | 5 | | | | | | | | | | | | | | | | | | 2 | | |
| Lowell | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Natl Lakeshore | | | | 4 | | 1 | 5 | 6 | | | | | | | | | | 1 | 1 | | | 1 | | |
| Potato Creek | | | | | | | | | | | | | | | | | | | | | | | | |
| South Bend | | | | | | | | | | | | | | | | | | | | | | | | |
| Granger | | | | | | | | | | | | | | | | | | | | 1 | | 2 | | |
| Bristol | | | | | | | | | | | | | | | | | | | | | | | | |
| Valparaiso | | | 6 | 3 | | | | | | | | | | | | | | | | | | | | |
| Liberty School | 1 | 2 | 1 | 1 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| MICHIGAN | | | | | | | | | | | | | | | | | | | | | | | | |
| Frankfort | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| Scottville | | | | | | | | | | | | | | | 3 | 2 | | | 1 | 1 | 1 | | | |
| Muskegon | 2 | 1 | 6 | 1 | 3 | 4 | 8 | 12 | 5 | 8 | 5 | 1 | 1 | 1 | 4 | 1 | | | 1 | 1 | | 2 | | |
| Holland | | | | | | | | | | 1 | 3 | | | | 4 | 1 | | | 1 | 1 | | 1 | | |
| Jenison | | | | | | | | | | | | | | | 2 | 1 | | | | | | | | |
| Grand Rapids | | 1 | 2 | 1 | 1 | | 3 | 7 | 3 | 1 | 2 | | | | 1 | 2 | | | | | | | | |
| Parnell/Evans | | | | | | | | 4 | 1 | | | | | | 1 | 2 | | | | | | | | |
| Coloma | | | | | | | | | | | | | | | 1 | 2 | | 2 | 1 | | 1 | | | |
| Cassopolis | | | | | | | | | | | | | | | | | | | | | | 2 | | |
| Kalamazoo | | | | | | | | | | | | | | | | | | | | | | | | |
| Traverse City | | | | | | | | | | | | | | | | | | | | | | | | |
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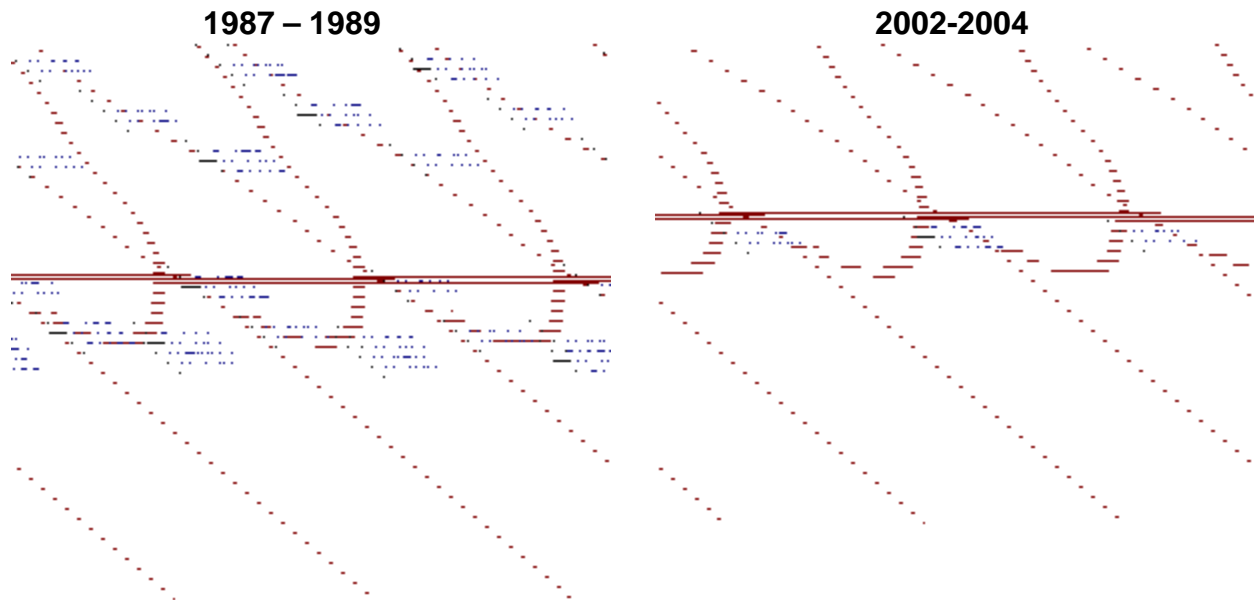
| WISCONSIN | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Chiwaukee | | | | | | | | 18 | 4 | | 10 | 2 | 2 | 1 | 4 | 2 | 1 | 2 | 2 | | 2 | 4 | | |
| Kenosha | 7 | | 6 | 4 | 3 | 1 | 8 | 17 | 3 | | 1 | 1 | | 1 | | | 1 | | | | | 4 | | |
| Lake Geneva | | | | | | | | 3 | 1 | | 1 | | | | | | | | | | | | | |
| Racine | | | | | | | | | | | 4 | 1 | | 1 | 2 | 2 | 1 | 1 | | | | 4 | | |
| S.Milw | | | | | 2 | | 7 | 9 | 2 | 1 | 3 | | | 1 | 2 | | 2 | | 1 | | 1 | | | |
| Milw-Alverno | | | | | | | 4 | 1 | 1 | 1 | 2 | | | 1 | 1 | | | | | | | | | |
| UWM-N | 8 | 2 | 10 | 4 | 4 | 5 | 8 | 14 | 6 | | 6 | | | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | | |
| Milw-SE Hdqs | | | | | | | | | | | | | | | | | | | | | | | | |
| Milw-App.Ave | 2 | | 3 | 1 | 2 | | 4 | 2 | | | 1 | | | | 1 | | | | | | | | | |
| Bayside | | | | 3 | 1 | 2 | 9 | 14 | 5 | 2 | 10 | | | 3 | 2 | 1 | 1 | 2 | 1 | | 1 | 1 | | |
| Waukesha | 2 | 4 | 3 | 1 | 1 | 2 | 6 | 1 | 2 | | 0 | | | | | | | | | | | | | |
| Grafton | 4 | 1 | 9 | 2 | 2 | 2 | 6 | 11 | 4 | 1 | 3 | | | 1 | | | 2 | 1 | 1 | | 1 | | | |
| Slinger | | | | | | | 4 | | | | | | | | 1 | | | | | | | | | |
| Harrington Beach | | | | | | | | | | | | | | 1 | 2 | 1 | 3 | 2 | 1 | | 1 | | 1 | |
| Sheboygan | | 2 | 11 | 6 | | | 11 | 15 | 1 | | 6 | | | 1 | 1 | | 2 | 2 | 2 | | 1 | | 1 | |
| Manitowoc | | | | 6 | 2 | | 11 | 13 | 1 | 2 | 5 | | | 2 | 1 | 2 | 2 | 1 | 1 | | | | 1 | |
| Kewaunee | | | | | | | 5 | 9 | | | 2 | | | 1 | 0 | | 1 | | | | | | 1 | |
| Newport Beach | | | | | | | | | | 3 | 4 | | | 2 | 1 | 1 | 2 | | | | 1 | | 1 | |
| Milton | | | | | | | | | | | | | | | | | | | | | | | | |
| Beloit | | | | | | | | | | | | | | | | | | | | | | | | |
| Collins | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | |
| Green Bay | | | | | | | | | | | | | | | | | | | | | | | | |
| Jefferson | | | | | | | | | | | | | | | | | | | | | | | | |
| Mayville | | | | | | | | | | | | | | | | | | | | | | | | |
| Columbus | | | | | | | | | | | | | | | | | | | | | | | | |
| Appleton | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Oshkosh | | | | | | | | | | | | | | | | | | | | | | | | |
| Fond du Lac | | | | | | | | | | | | | | | | | | | | | | | | |

(Note: not all sites were in operation during the full period of 1981 – 2004.)

Design Values: Figure 2 shows the design values for sites in violation of the standard for 1987-1989 (i.e., the 3-year period used to establish the original 1-hour nonattainment classifications) and for 2002-2004. Based on this figure (and Table 1), it is apparent that:

- The spatial extent of ozone violations has decreased considerably over the past 15 years, from 30 sites in violation in the late 1980's to only 4 for the most recent 3-year period.
- The magnitude of peak ozone design value has decreased considerably over the past 10 years, from 0.190 ppm in the late 1980's to 0.134 ppm for the most recent 3-year period.

Figure 2. 1-Hour Ozone Design Values (≥ 0.12 ppm)



Section 3

Statistical Ozone Trends Analysis

Given the strong effect of meteorology on ambient ozone levels (as noted above), the year-to-year variations in meteorology can make it difficult to assess trends in ozone air quality. Four approaches were considered to adjust ozone trends for meteorological influences:

CART: "CART Analysis of Historic Ozone Episodes", D. Kenski (LADCO), January 2004

Rao-Zurbenko: "Long-Term Temperature-Adjusted Trends, Peak Daily Ozone, Lake Michigan Region, 1980 – 2003", Wisconsin DNR, February 2004

Cox-Chu: "Trends in Daily Maximum 1 -Hour Ozone in Urban Areas (1990-2002)", 2004

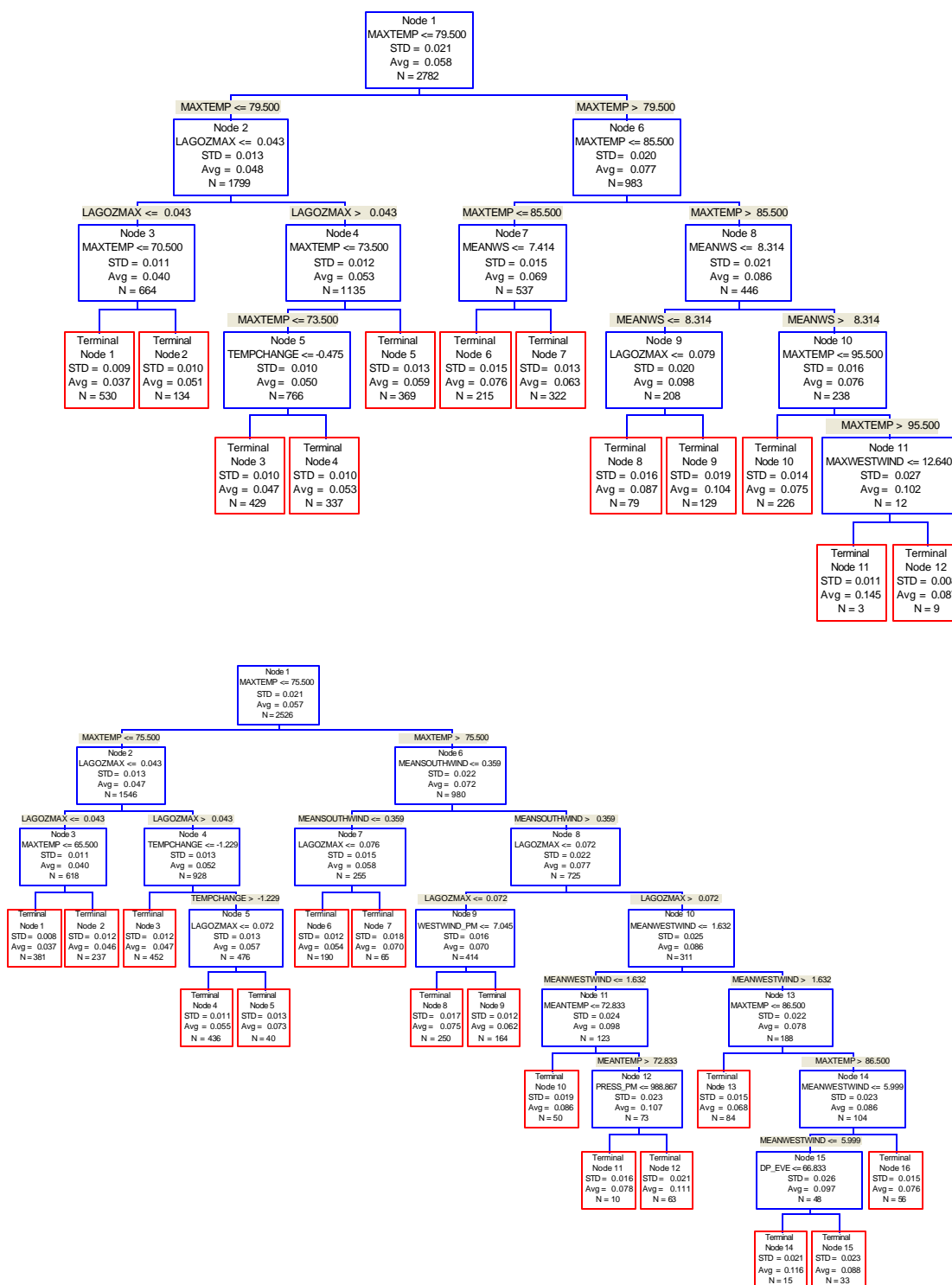
Time Series Analysis: "Ambient Ozone Air Quality Trends for the Lake Michigan Region, 1980-2003", Michael Rizzo and Peter Scheff, USEPA, Region V, April 2004

Each analysis is addressed separately below. Collectively, these analyses show downward trends in 1-hour ozone levels since the late 1980s, but somewhat flatter trends in recent years. 8-hour trends, on the other hand, show less change, and in some cases, indicate increases in recent years.

CART: Classification and Regression Tree (CART) analysis is a statistical technique used to partition data sets into similar groups. While the relationships between ozone and meteorological variables are well understood in a general sense, CART offers the ability to quantify the unique relationship among those variables at a specific geographic location. Regression trees were calculated for eight Midwestern cities for ozone, including Chicago and Milwaukee. The meteorological variables tested in the model included surface and aloft wind direction (converted to north/south and east/west components), wind speed, relative humidity, temperature, dewpoint, pressure, mixing height, solar radiation, and cloud cover. Ozone data were examined from 1990-2002. CART-identified ozone episodes are compared to assess meteorological variability over the 13-year period and its impact on ozone trends.

The regression trees for Chicago and Milwaukee are shown in Figure 3. In both cities, maximum daily temperature was the most important variable for categorizing ozone. Each box represents meteorologically similar days.

Figure 3. Regression Trees for Chicago (top) and Milwaukee (bottom)



The plot below shows the distribution of ozone concentrations within each group of meteorologically similar days for Chicago.⁴ The higher ozone groups include Groups 6, 8, 9, 10, 11, and 12 (see figure below). Groups 11 and 12, however, include only 3 and 9 days, respectively, which are not enough samples to produce any valid statistical findings. Thus, a trends analysis was only conducted for the other four high ozone groups.

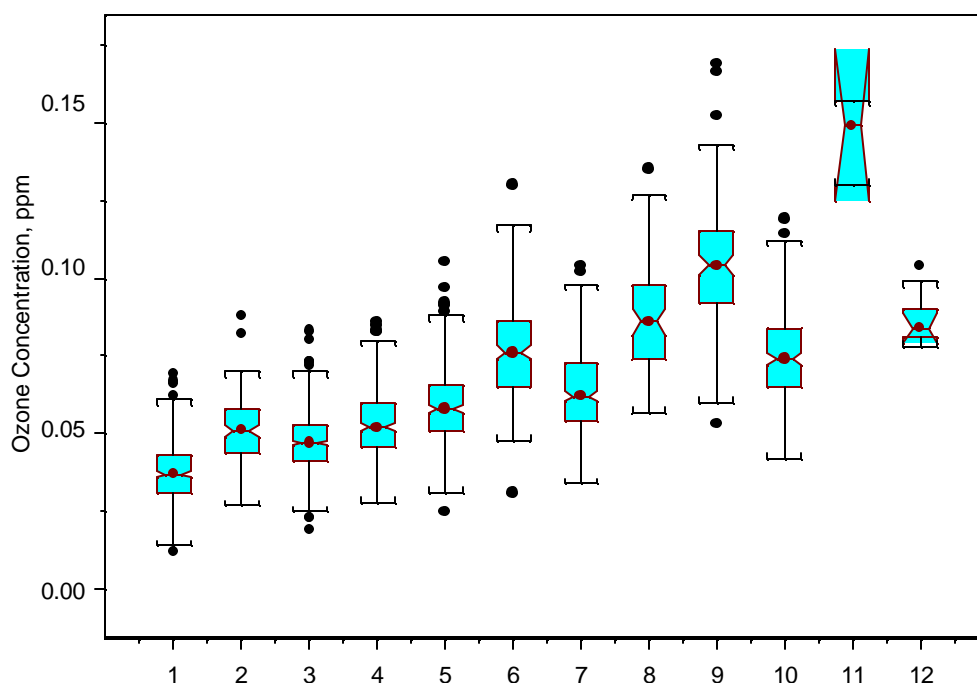
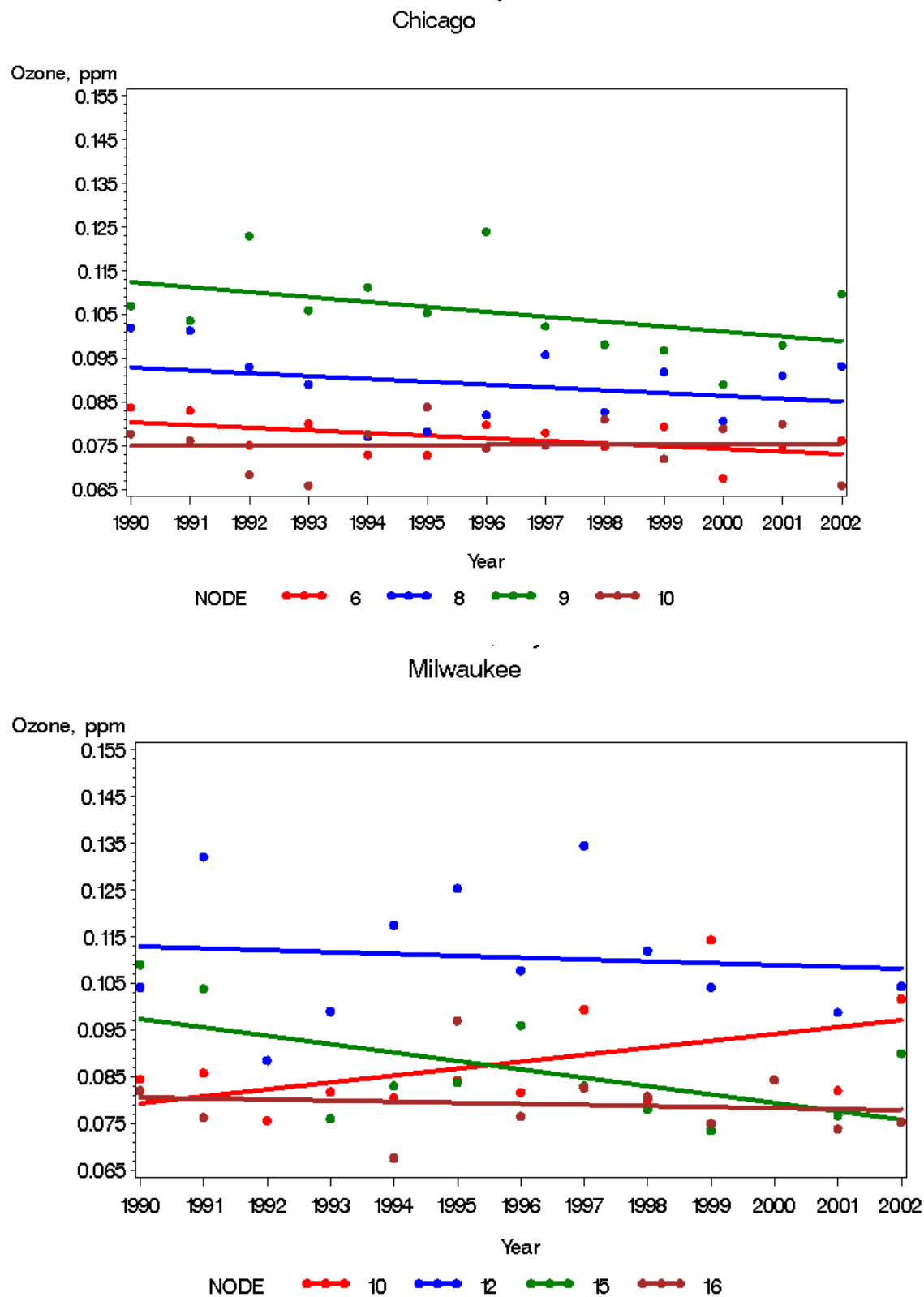


Figure 4. Distribution of Ozone Concentrations by Group of Meteorologically Similar Days for Chicago

Trends over the 1990-2002 period were examined within groups. Examining concentration changes by group minimizes the influence of meteorology and reveals trends in ozone response to emission control programs. The trends by group for Chicago and Milwaukee are shown in Figure 5. The results for Chicago show a clear downward trend, especially for Group 9 (average ozone = 104 ppb, 129 samples). The results for Milwaukee also show a downward trend for several high ozone groups, in particular Group 15 (average ozone = 88 ppb, 33 samples).

⁴ In these plots, the middle of the box (for a given year) reflects the 50th percentile value and the top (bottom) of the box reflects the 75th (25th) percentile values. The top (bottom) of the whiskers extend 1.5 times the top (bottom) portion of the box. The other data points, which appear as dots above and below the whiskers, represent outliers.

Figure 5. Ozone Trends by Group of Meteorologically Similar Days for Chicago (top) and Milwaukee (bottom)



Rao-Zurbenko: This method, which was developed by Professors S.T. Rao and I. Zurbenko at the State University of New York at Albany, attempts to filter-out or moderate the influence of meteorology on ambient ozone levels, using surface temperature as a surrogate for all meteorological variables that affect ozone. By filtering-out most of the influence due to the synoptic (several days, “short-term”) and seasonal (annual) weather fluctuations that yield varying ozone levels, the remaining portion of the ozone spectra can hypothetically be called the “baseline” or “long-term” component of the ozone time series. This long-term ozone is assumed to be attributed mostly to local anthropogenic influences. Linear regression techniques and moving average filters can help identify quasi-linear trends and rates of change in the long-term baseline ozone time series.

The method was applied to data from 11 long-term sampling stations (see Figure 6) for the period 1980 – 2003: IL – Evanston; IN – Hammond; MI – Grand Rapids and Muskegon; WI – Kenosha, Racine, Milwaukee, Grafton, Slinger, Madison, and Waukesha.

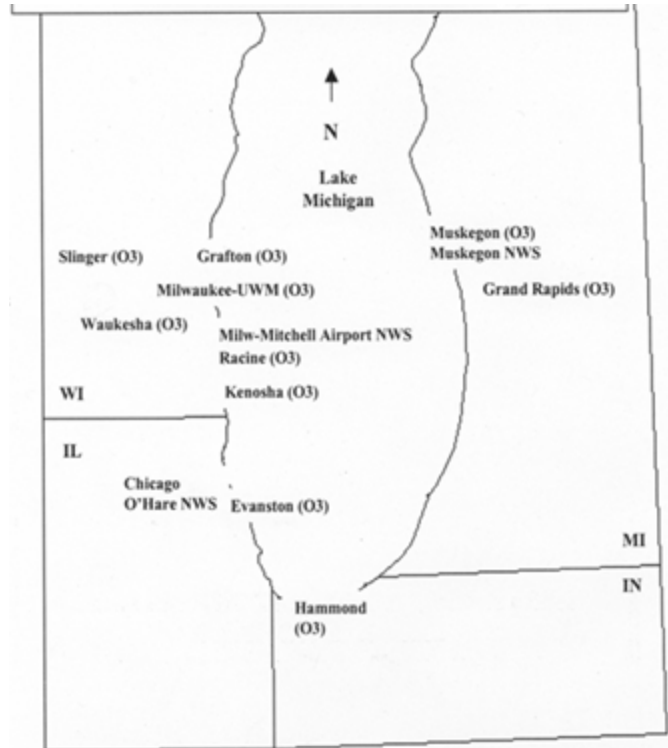


Figure 6. Sites Used in Rao-Zurbenko Analysis

A summary of calculated annual average percentage changes for 1-hour and 8-hour ozone is presented in Figure 7. Statistically significant decreasing trends were found for the two urban sites: Evanston, IL (-0.24% for 1-hour and -0.55% for 8-hour) and UW-Milwaukee, WI (-0.33% for 1-hour). This suggests that the implemented control programs have been successful in “shaving the peaks” in the short-term (1-hour) ozone levels.

Statistically significant increasing trends were found for three sites: Kenosha, WI (+0.42% for 1-hour and +0.69% for 8-hour), Racine, WI (+0.28% for 8-hour), and Madison, WI (+0.34% for 1-hour and +0.20% for 8-hour). The trends for the other sites were not statistically significant.

The increasing trends for Kenosha and Racine are surprising, and not consistent with the calculated trends for the nearby urban areas. This discrepancy may be a result of certain shortcomings with the Rao-Zurbenko method (e.g., does not completely normalizing for maximum temperature impacts during hot summers, or does not deal with lake breezes, which affect the location of high ozone in the region).

Temperature-Adjusted Annual Ave. % Change
Site-Peak Daily 1-Hr & 8-Hr Ozone
11 Sites in the Vicinity of L. Michigan
15 April - 15 Oct^(a) 1980-2003
Employing the Rao-Zurbenko Method

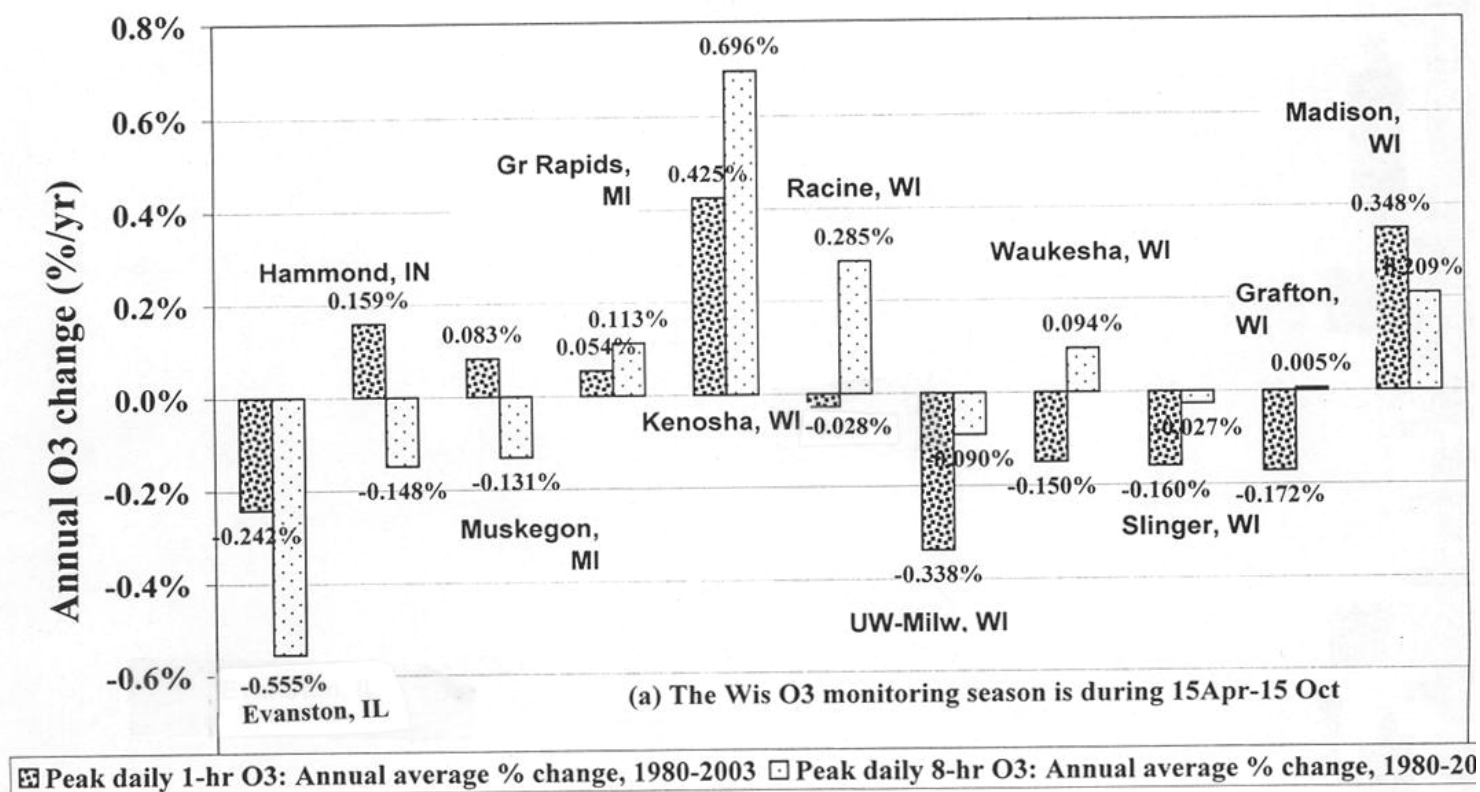


Figure 7. Rao-Zurbenko Trends for 11 Sites in the Lake Michigan Region

Cox-Chu: This method uses a statistical model to “remove” the annual effect of meteorology on ozone and allows for a non-linear trend over a multi-year period. This approach consists of applying a generalized linear model to relate daily peak ozone levels to four meteorological variables (i.e., daily peak 1-hour temperature, midday average relative humidity, morning and afternoon wind speed and wind direction, and morning mixing heights). Exploratory analyses show that daily peak 1-hour ozone is a non-linear function of Julian day, relative humidity, and the long-term trend.

Example results are shown in Figure 8 for Chicago for the period 1981-2000. The top two panels show the results with and without meteorological co-variates. The bottom two panels show the same comparison, except that the trend component has been smoothed. Data values represented on the y-axis are logarithmic (-0.2 to +0.2) and centered on 0. Changes across years can be interpreted in a fractional or relative sense. For example, a change on the y-axis from 0.2 to 0.1 represents approximately a 10 percent improvement in ozone levels between two corresponding years.

Figure 9 shows the “smoothed, meteorologically adjusted” trends for Chicago and Milwaukee for the periods 1981-2000 and 1990-2002. The 1981-2000 plots for both cities show that ozone levels experienced a steady downward trend over this period. The 1990-2002 plots show a “flatter” trend in ozone levels over the past 10 years.

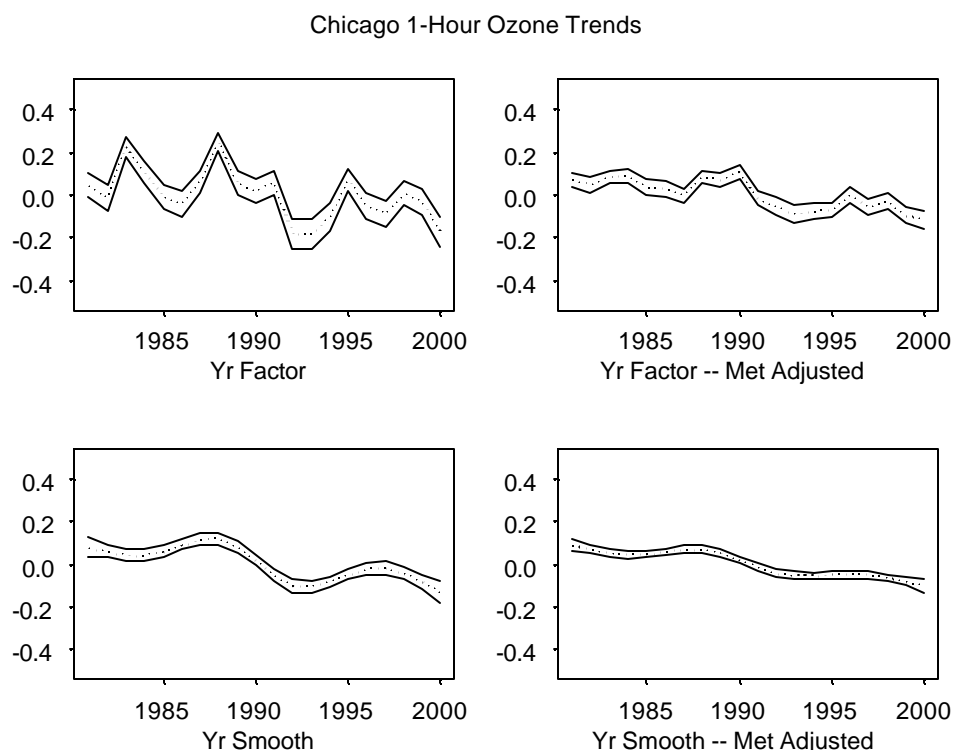
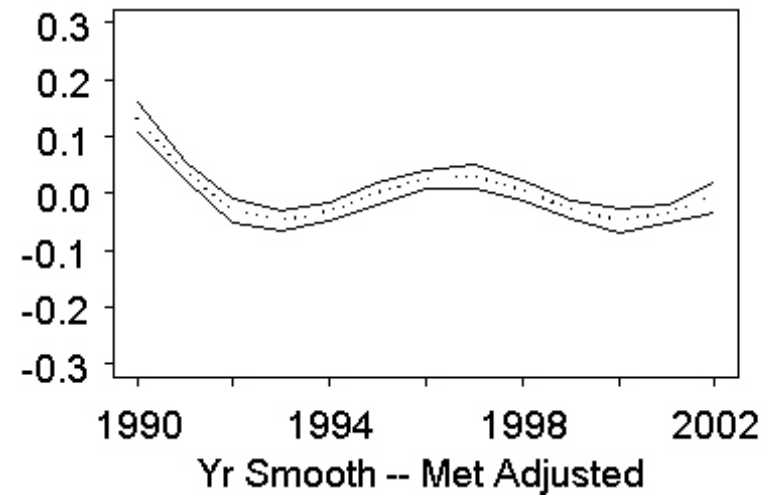
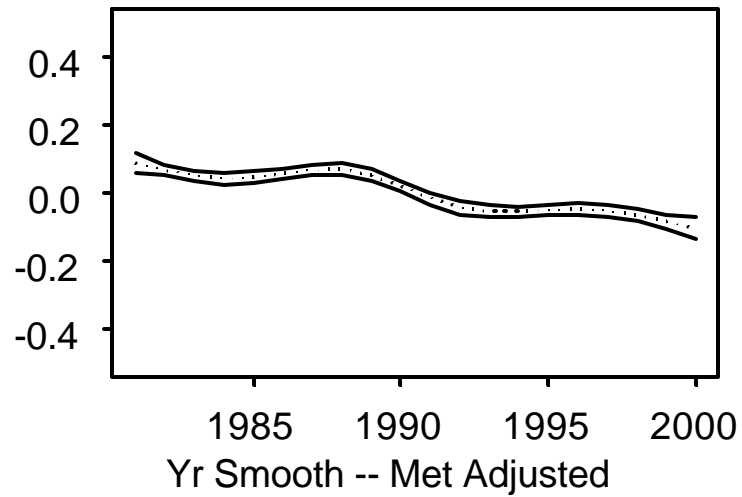


Figure 8. Cox-Chu Trends for Chicago (1981 – 2000)

1981 – 2000

1990 – 2002

Chicago



Milwaukee

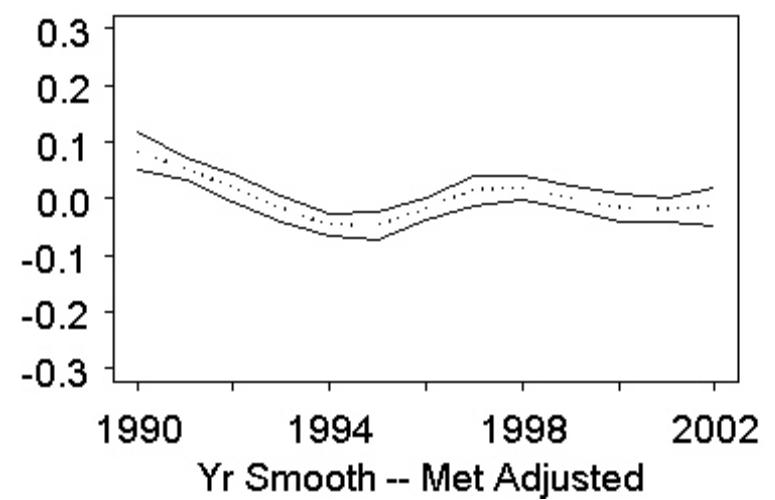
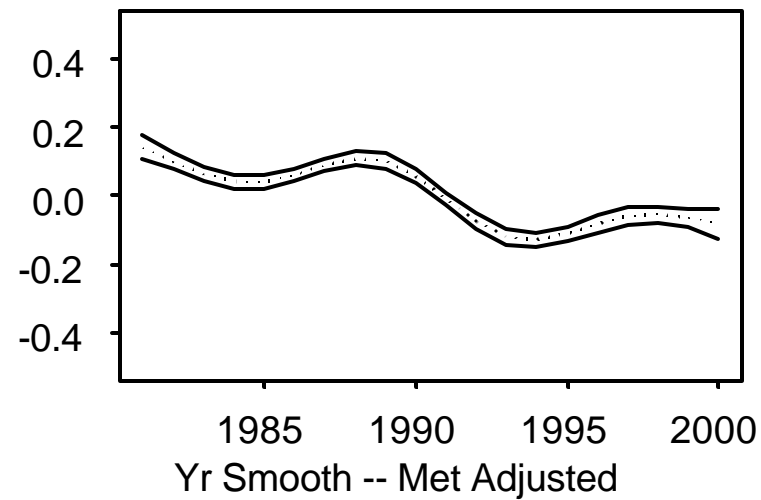


Figure 9. Cox-Chu Trends for Chicago and Milwaukee

Time Series Analysis:

Ozone data from eleven sites within the Lake Michigan Region and two sites from downstate Illinois (see Figure 10) were analyzed for trends utilizing time series techniques for the period 1980 to 2003. The time series analysis calculates trends while taking into account meteorological variability, without altering the data through smoothing or other data processing techniques. In addition, with the inclusion of the wind direction score, this approach adjusts for the effect transport has on ozone at individual sites. This is important for sites where year-to-year differences in transport may affect the trend.

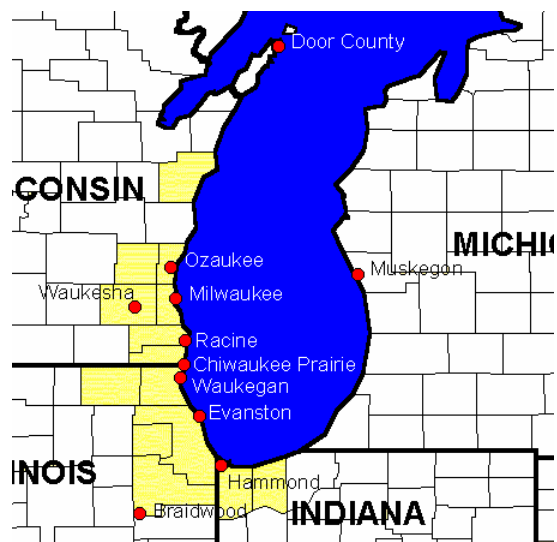


Fig 10. Sites Used in Time Series Analysis

The 1-hour and 8-hour trends are presented in Table 2. As can be seen, over the past 20 years, both 1-hour and 8-hour ozone concentrations have been reduced significantly at sites around Lake Michigan. The 1-hour results for the last 20 years show statistically significant trends at 8 of the 13 sites, all of which were downward. The 8-hour results for the last 20 years show statistically significant trends at 9 sites, 5 downward and 4 upward. The decreasing trend sites are generally located in the Chicago and Milwaukee urban areas, and the increasing trend sites are located farther downwind.

For the last 10 years, however, statistically significant 1-hour and 8-hour trends occurred at only 4 sites, all of which were upward. The difference in trends between the full 20-year period and the more recent 10-year period suggests that the progress made by previous federal and state control programs were generally successful in lowering 1-hour ozone levels, but may be losing their effectiveness in recent years, suggesting the need to develop new control programs to reduce 8-hour ozone concentrations.

It should also be noted that incoming (transported) ozone levels (as represented by the trends at the Braidwood, IL and Waukesha, WI sites) have been relatively steady and, in recent years, may even be increasing. This suggests that transport of ozone into the region is still a major concern and will need to be reduced for the region to come into attainment. As discussed in Section 5, regional NO_x emissions are expected to reduce regional ozone levels.

Table 2. Time Series Trends for 1-Hour and 8-Hour Ozone

| Site | Averaging Time | Last 20 Years | | | Last 10 years | | |
|----------------------------------|-----------------------|----------------------|---------------|--------------------|----------------------|---------------|--------------------|
| | | Trend | 95% CI | Sig. at 95% | Trend | 95% CI | Sig. at 95% |
| Chiwaukee Prairie 1988 - 2003 | 1 hour | -1.02% | +/- 0.41% | Yes | -0.22% | +/- 0.74% | No |
| | 8 hour | -0.65% | +/- 0.39% | Yes | 0.39% | +/- 0.65% | No |
| Door County 1989 - 2003 | 1 hour | 0.26% | +/- 0.44% | No | 0.33% | +/- 0.69% | No |
| | 8 hour | 0.32% | +/- 0.46% | No | 0.34% | +/- 0.72% | No |
| Effingham 1982 - 2002 | 1 hour | -0.72% | +/- 0.20% | Yes | -0.31% | +/- 0.57% | No |
| | 8 hour | -0.64% | +/- 0.23% | Yes | -0.04% | +/- 0.67% | No |
| Evanston 1980 - 2003 | 1 hour | -0.51% | +/- 0.21% | Yes | 0.14% | +/- 0.67% | No |
| | 8 hour | -0.47% | +/- 0.24% | Yes | 0.36% | +/- 0.75% | No |
| Grafton 1980 - 2003 | 1 hour | 0.08% | +/- 0.26% | No | 0.28% | +/- 0.76% | No |
| | 8 hour | 0.53% | +/- 0.29% | Yes | 0.56% | +/- 0.71% | No |
| Milwaukee 1980 - 2003 | 1 hour | -0.54% | +/- 0.26% | Yes | 0.99% | +/- 0.95% | Yes |
| | 8 hour | -0.37% | +/- 0.33% | Yes | 1.76% | +/- 1.36% | Yes |
| Muskegon 1980 - 2003 | 1 hour | -0.26% | +/- 0.24% | Yes | -0.57% | +/- 0.63% | No |
| | 8 hour | 0.42% | +/- 0.34% | Yes | -0.56% | +/- 0.67% | No |
| Racine 1980 - 2003 | 1 hour | -0.50% | +/- 0.21% | Yes | 0.64% | +/- 0.60% | Yes |
| | 8 hour | -0.25% | +/- 0.22% | Yes | 0.93% | +/- 0.63% | Yes |
| Springfield 1981 - 2003 | 1 hour | -0.32% | +/- 0.20% | Yes | -0.38% | +/- 0.55% | No |
| | 8 hour | -0.20% | +/- 0.24% | No | -0.20% | +/- 0.63% | No |
| Waukegan 1980 - 2003 | 1 hour | 0.15% | +/- 0.24% | No | 0.17% | +/- 0.71% | No |
| | 8 hour | 0.38% | +/- 0.26% | Yes | 0.41% | +/- 0.77% | No |
| Waukesha 1980 - 2003 | 1 hour | -0.26% | +/- 0.25% | Yes | 1.53% | +/- 0.77% | Yes |
| | 8 hour | 0.09% | +/- 0.29% | No | 1.63% | +/- 0.72% | Yes |
| Hammond 1980-2003 | 1 hour | 0.15% | +/- 0.36% | No | -0.10% | +/- 0.62% | No |
| | 8 hour | 0.52% | +/- 0.38% | Yes | 0.41% | +/- 0.70% | No |
| Braidwood 1987-2002 | 1 hour | -0.18% | +/- 0.42% | No | 2.00% | +/- 0.78% | Yes |
| | 8 hour | 0.21% | +/- 0.54% | No | 2.45% | +/- 0.94% | Yes |

Section 4 Ozone Precursor Trends

Ozone precursor data are available from the Lake Michigan States' regional Photochemical Assessment Monitoring Stations (PAMS). The regional PAMS network was proposed in a letter dated August 12, 1993, letter from the State Air Directors to USEPA. On February 16, 1994, USEPA approved the regional network. Data collection began during the mid-1990s. A map of the PAMS sites in the region is provided in Figure 11.

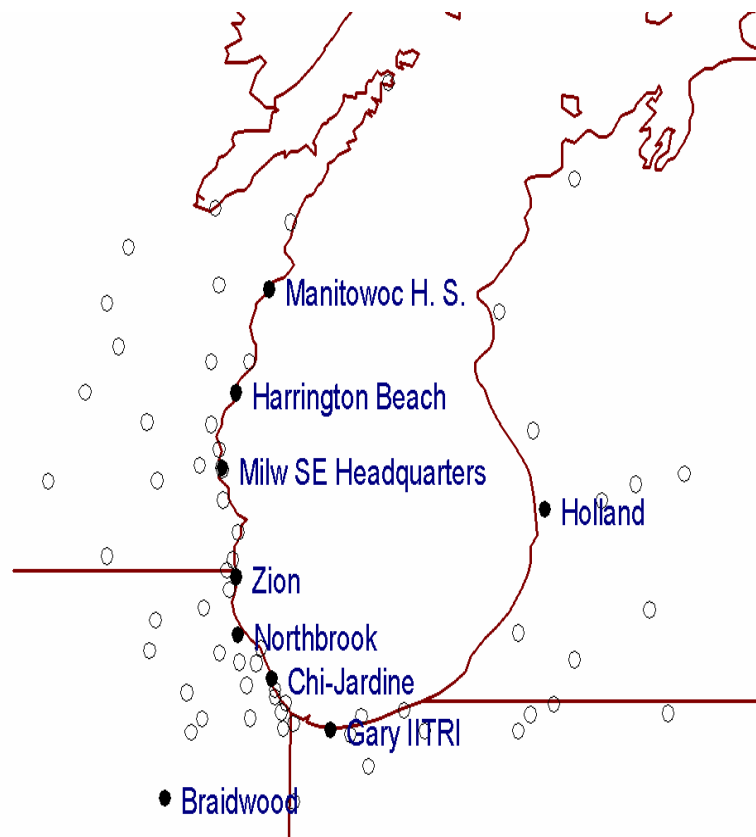


Figure 11. PAMS Monitoring Stations in the Lake Michigan Area

Objectives of the PAMS program include identifying trends in ozone and ozone precursor concentrations, and assessing the effectiveness of ozone control programs. An initial trends analysis with these data was performed by the Wisconsin Department of Natural Resources ("Trends Analysis Ozone Precursor Air Quality Measurements, PAMS Sites, Lake Michigan Region, 1987-2003", April 2004). Several key findings from this report should be noted:

TNMOC

The longest record of total nonmethane organic carbon (TNMOC) data exist for Milwaukee. Discrete (canister) sampling began in the late 1980s and continued until 2000 at the University of Wisconsin-Milwaukee (UWM) site. In 1999, continuous (gas chromatograph [GC]) sampling began at the WDNR Southeast Headquarters, which is located about 3 miles from the UWM site.

The almost 15 years of 6 – 9 am canister data from UWM are presented in the box-whisker plot below⁵. As can be seen, median TNMOC levels (50th percentiles) at this site show a steady and substantial decline since the late 1980s.

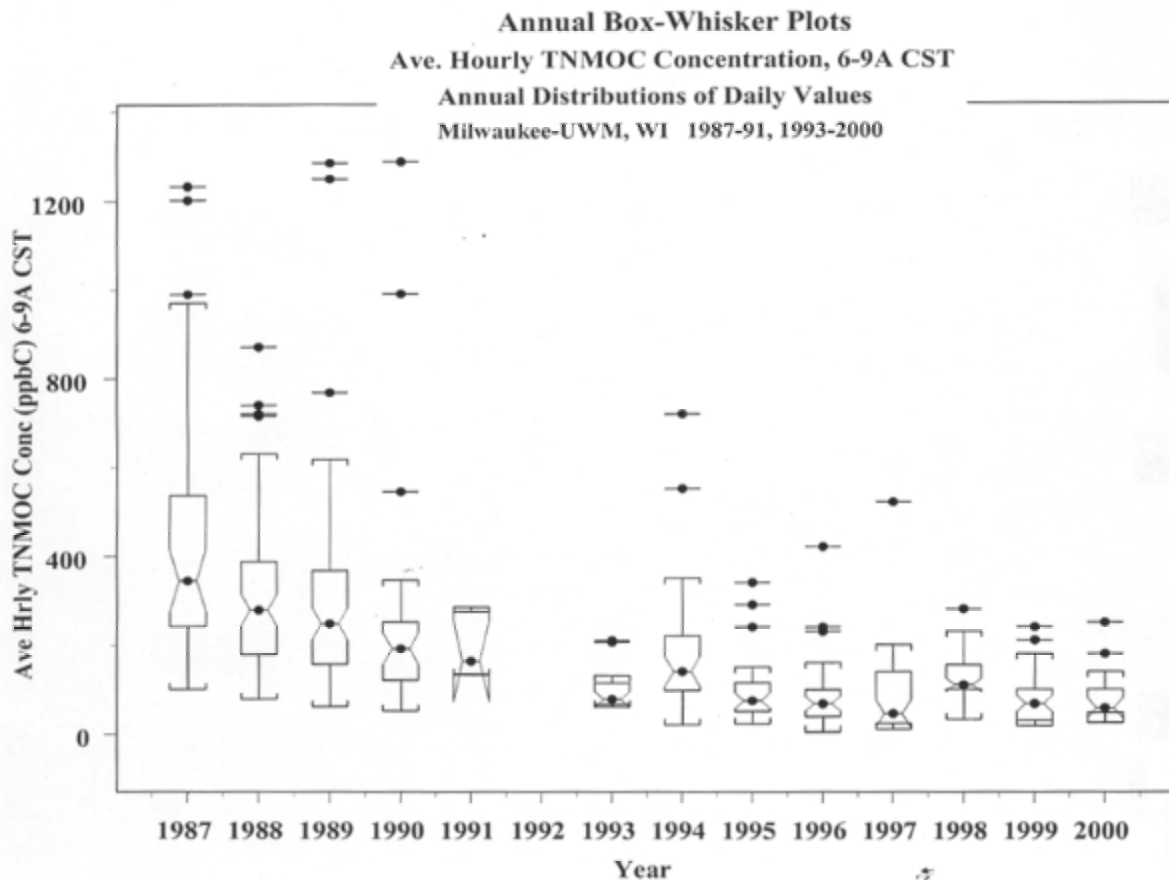


Figure 12. Trends in TNMOC Concentrations (Canister) in Milwaukee

The more recent continuous data in Milwaukee also show a decline since 1999, as seen in the box-whisker and time series plots in Figure 13.

⁵ In these plots, the middle of the box (for a given year) reflects the 50th percentile value and the top (bottom) of the box reflects the 75th (25th) percentile values. The top (bottom) of the whiskers extend 1.5 times the top (bottom) portion of the box.

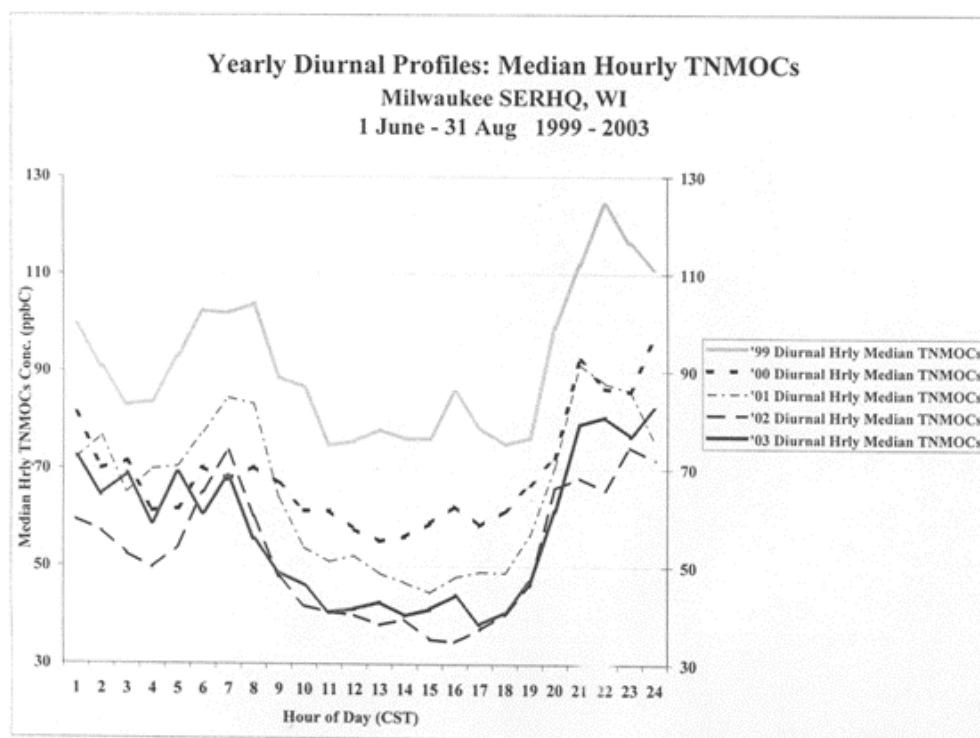
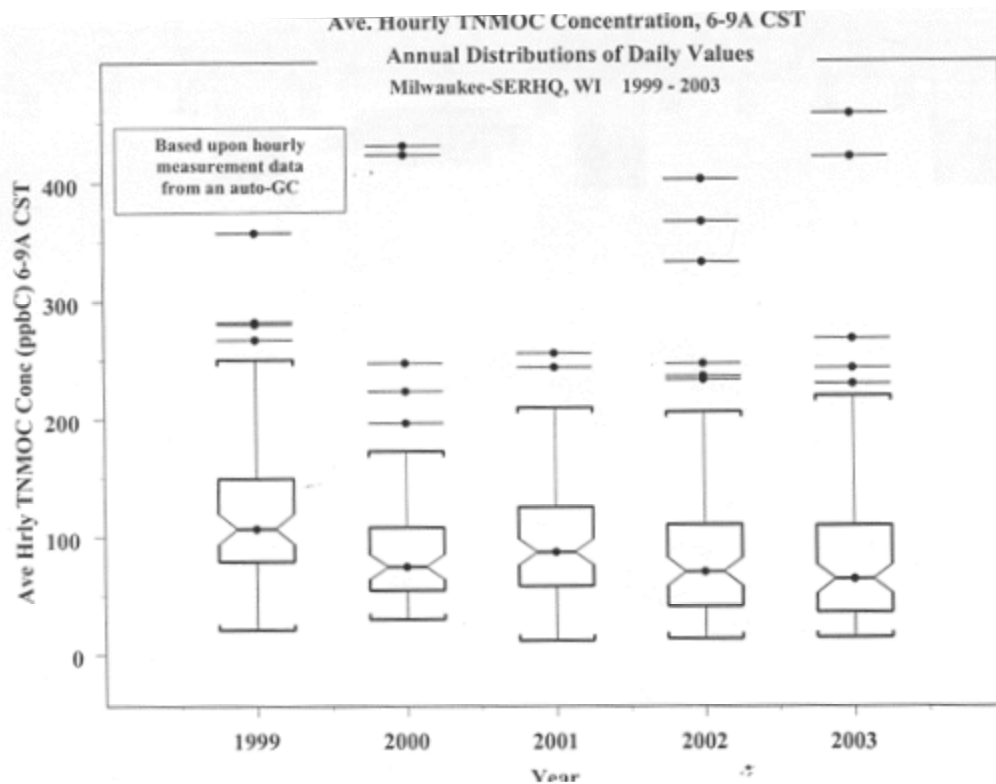


Figure 13. Trends in TNMOC Concentrations (GC) (top) and Diurnal Profiles by Year (bottom) in Milwaukee

Data from the PAMS site downwind of Milwaukee (i.e., Harrington Beach) also show declines in TNMOC levels between 1994 and 1995, and between 1999 and 2000 (see figure below). These decreases coincide with the implementation of the RFG program – Phase I in 1995 and Phase II in 2000, which targeted a number of VOC species, including benzene, which showed similar decreases (see figure below).

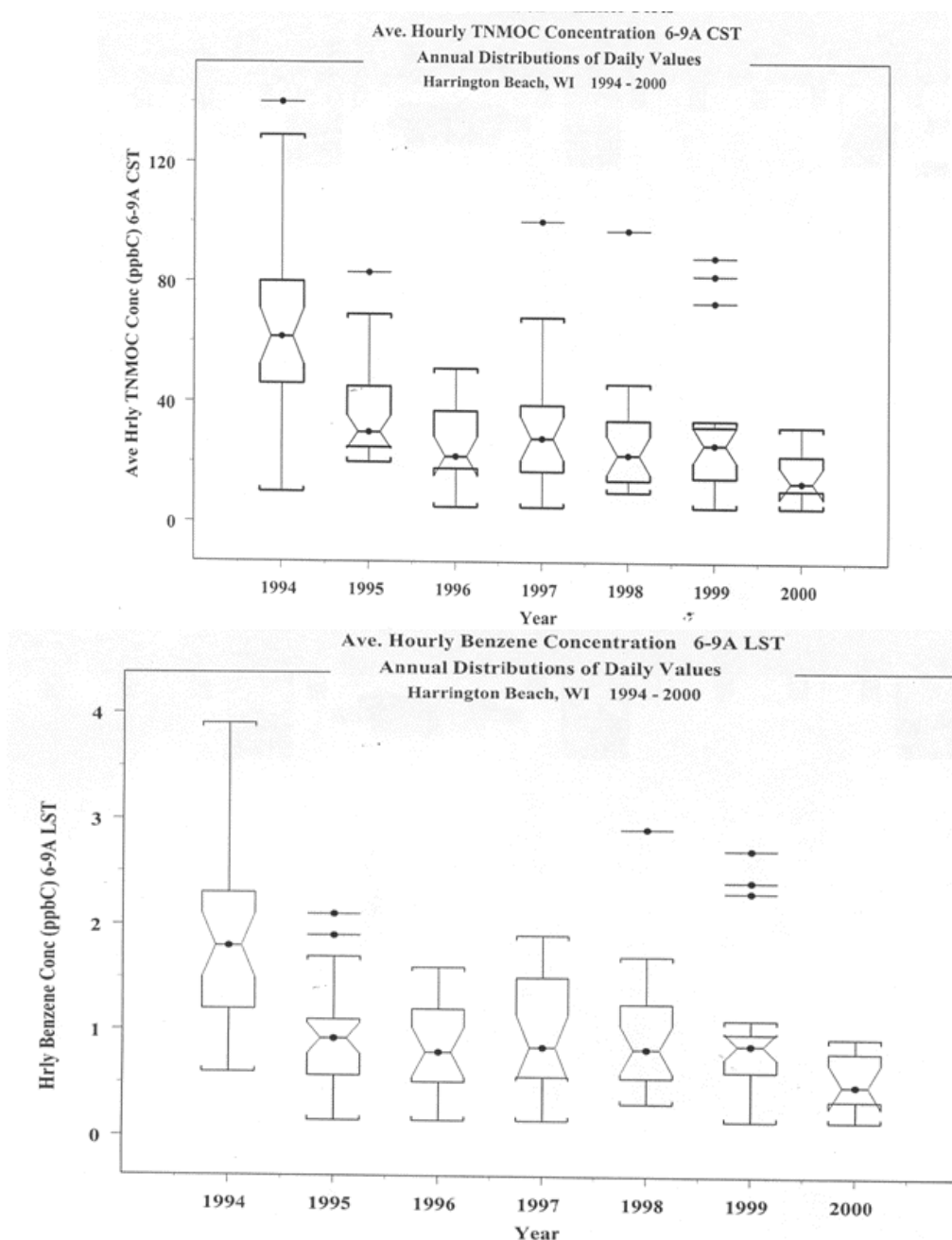


Figure 14. Trends in TNMOC (top) and benzene (bottom) Concentrations in Harrington Beach, Wisconsin

TNMOC concentrations are also available for Chicago from the late 1980's (e.g., the 1989 median TNMOC value was 764 ppbC⁶). Because these data were collected at different locations (e.g., 1986 – Illinois State Office Building, 1987 – 160 N. LaSalle Street, and 1989 – CTA site in the Chicago Loop), they are not directly comparable to the data from the current PAMS site (Jardine), which are shown in the figure below. Qualitatively, however, it appears that NMOC levels have declined considerably in Chicago.

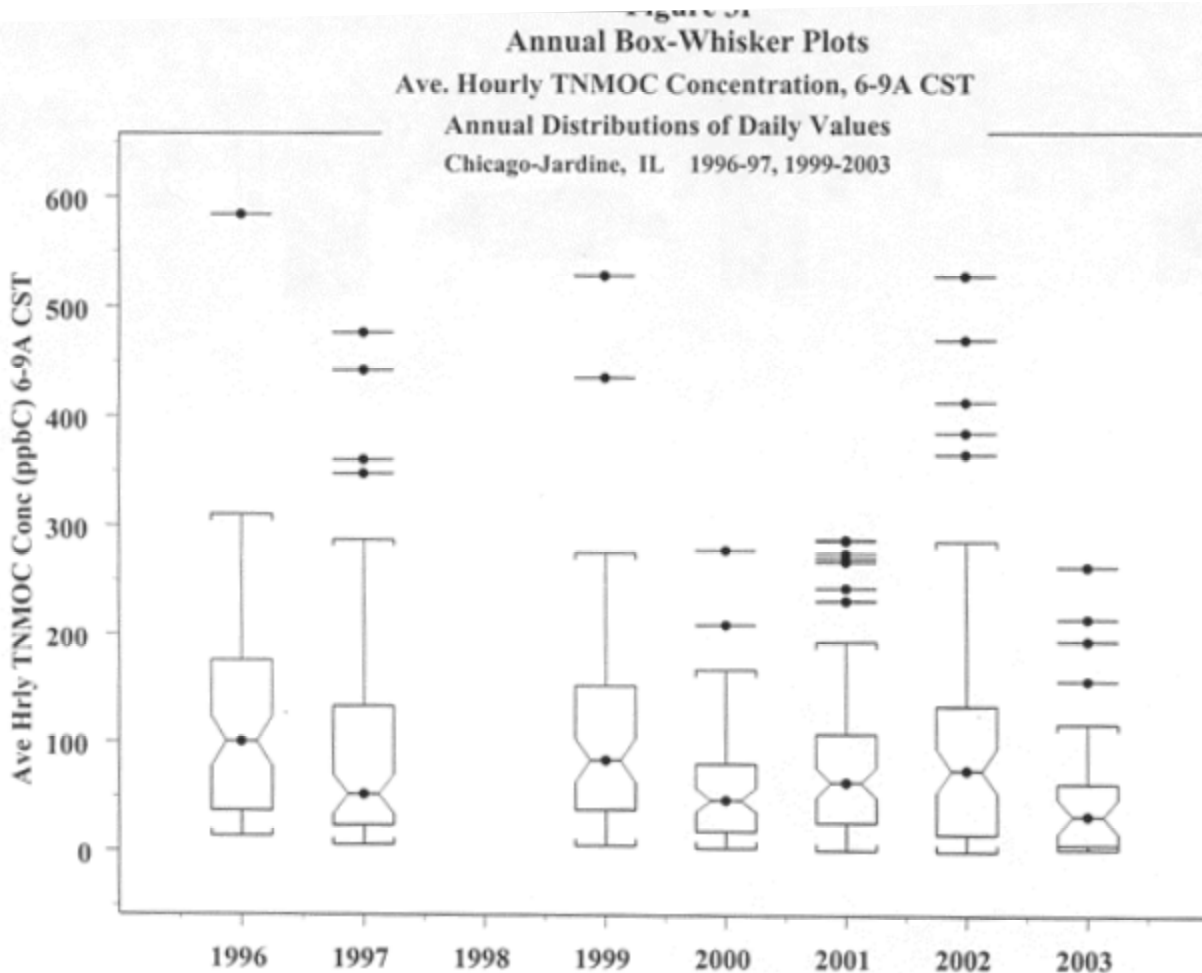


Figure 15. Trends in TNMOC Concentrations in Chicago

⁶ "1989 Nonmethane Organic Compound Program and Three-Hour Air Toxics Monitoring Program", EPA-450/4-9-011, May 1990

TNMOC data for the Gary, Indiana site show relatively steady median TNMOC concentrations over time. Also, compared to the Chicago and Milwaukee sites, there are more extreme, high values at the Gary site, indicating the effect of a local source (i.e., the USX-Gary Works plant, which is located less than 1 km to the north).

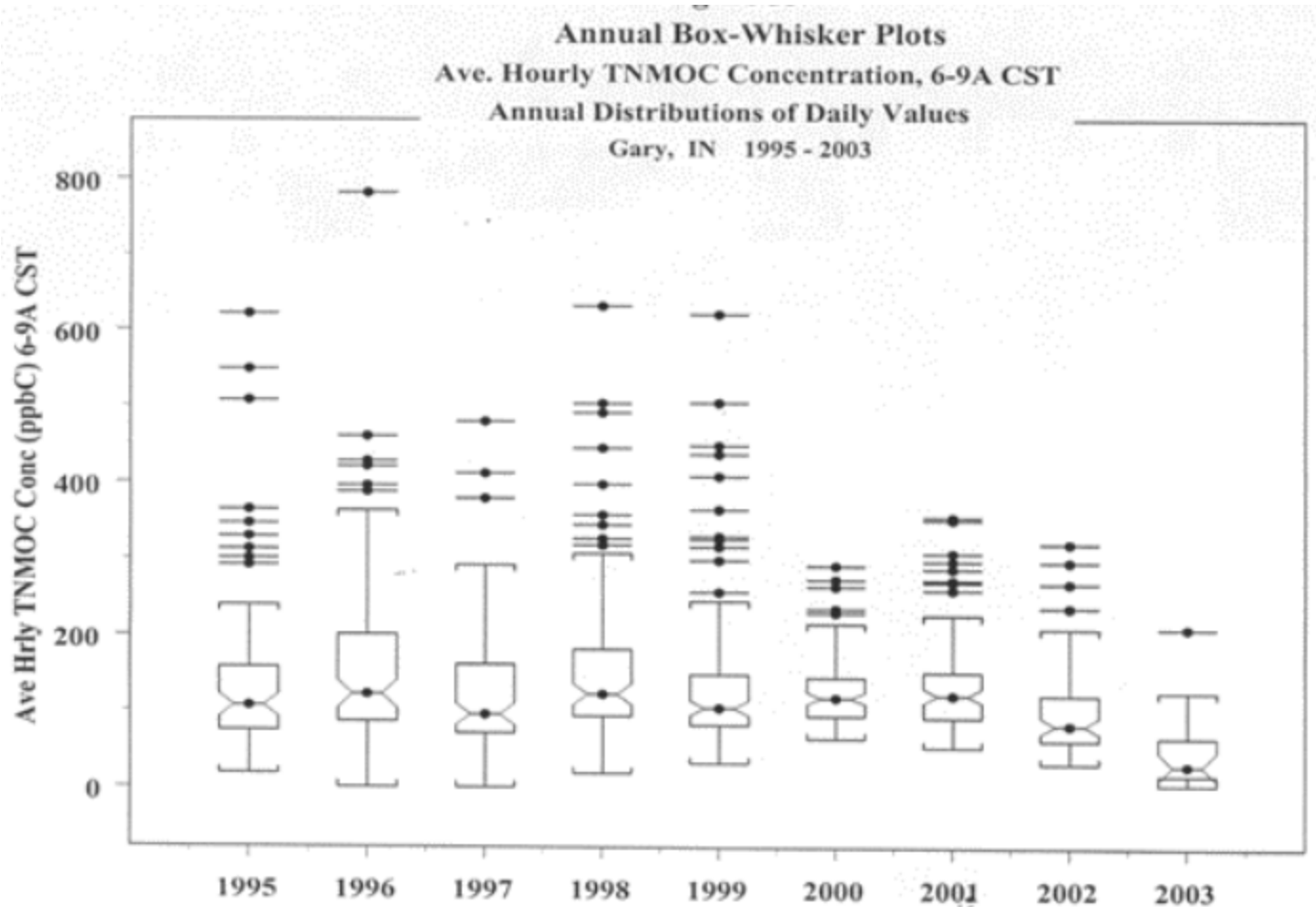


Figure 16. Trends in TNMOC Concentrations in Gary

NO_x

Unlike TNMOC, there was little (if any) trend in the early morning (6-9 am) NO_x levels since the late 1980s. The early morning NO_x concentrations at the Milwaukee-UWM site are shown in the figure below. The NO_x data for the other PAMS sites in the Lake Michigan States display a similar lack of trends for NO_x (see Figure 18). This is not unexpected given that most of the existing ozone control programs in the region focused on VOC emissions (see discussion in following section).

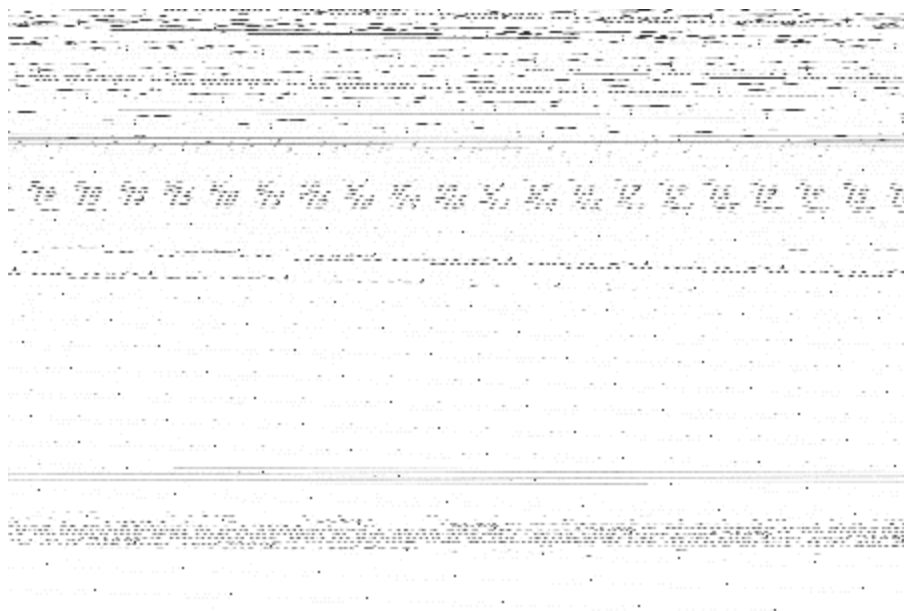
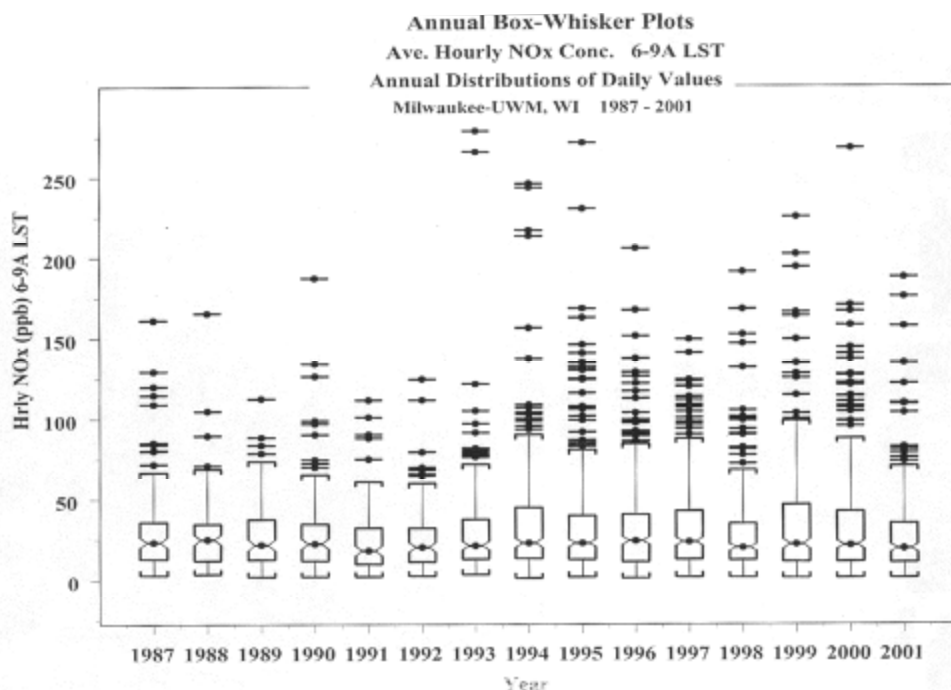


Figure 17. Trends in NO_x Concentrations (top) and Diurnal Profiles by Year (bottom) in Milwaukee

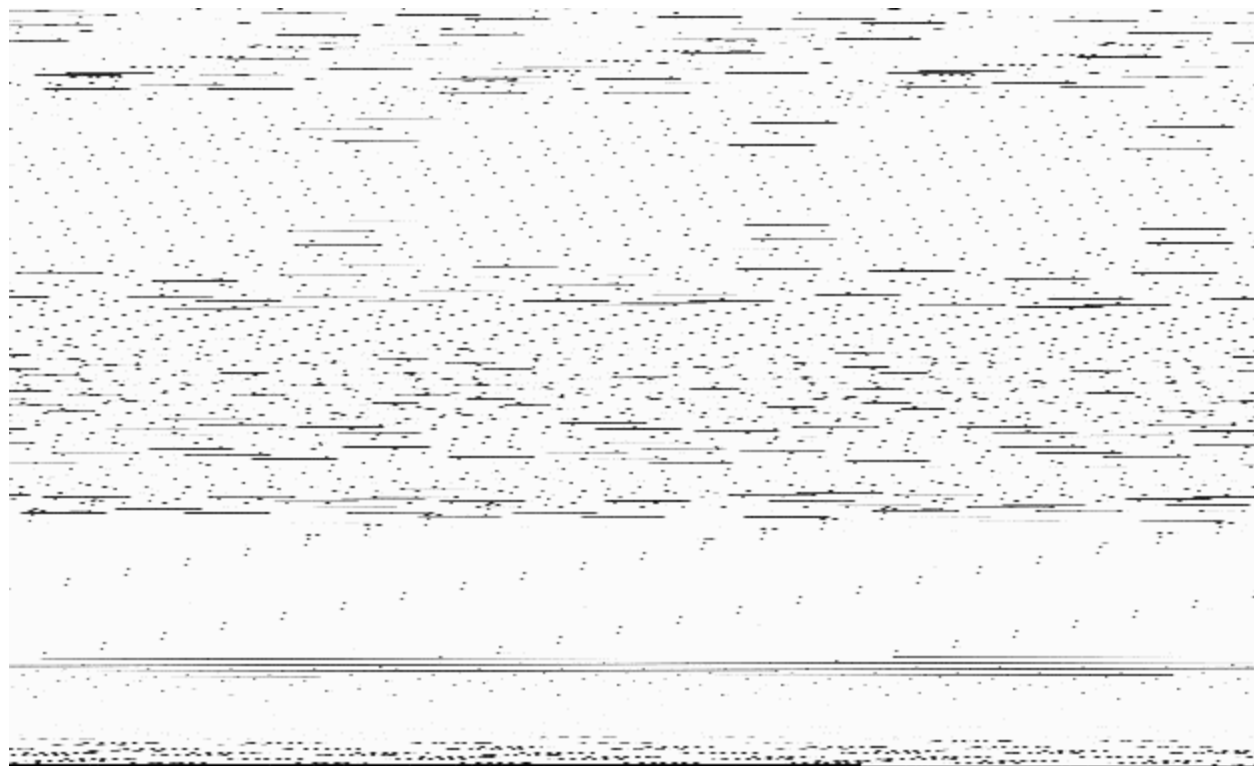
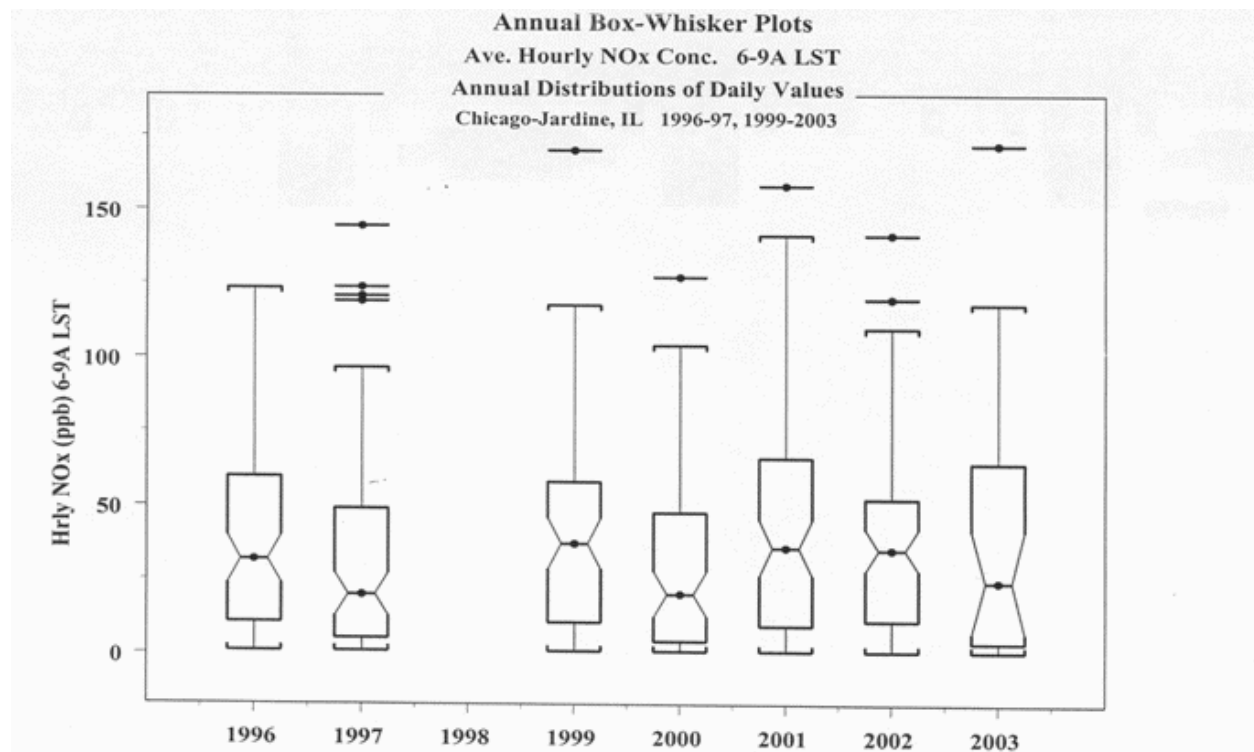


Figure 18. Trends in NO_x Concentrations in Chicago (top) and Gary (bottom)

In summary, this initial trends analysis shows an apparent decrease over time in VOC concentrations (and certain individual species), but little change in NO_x concentrations. Limitations with this analysis include: (1) there are occasionally large gaps in the data bases at individual sites, (2) meteorological influences on pollutant levels are not addressed. The lack of any strong trends, despite the implementation of several emission control programs may be due to several factors, including the lack of a long-term record of quality measurements, compensating factors, such as increases in activity levels, and the effect of meteorological conditions. Continuation of the PAMS ozone precursor measurements is necessary to support future trends analyses.

Section 5 Emissions Trends

A summary of ozone precursor emissions was prepared based on the periodic inventories prepared by the States of Illinois, Indiana, and Wisconsin:

Years: 1990, 1993 (not available), 1996, 1999, and 2002

Pollutants: VOC and NOx

Sources: Point, Area (anthropogenic), On-road, and Off-road

Area: Severe nonattainment counties in Illinois (Cook, DuPage, Kane, Lake, McHenry, and Will); Indiana (Lake and Porter); and Wisconsin (Kenosha, Milwaukee, Ozaukee, Racine)

The total VOC and NOx emissions are presented in the figure below. As can be seen, local VOC emissions have decreased significantly over the past decade. Local NOx emissions, on the other hand, have remained fairly steady.

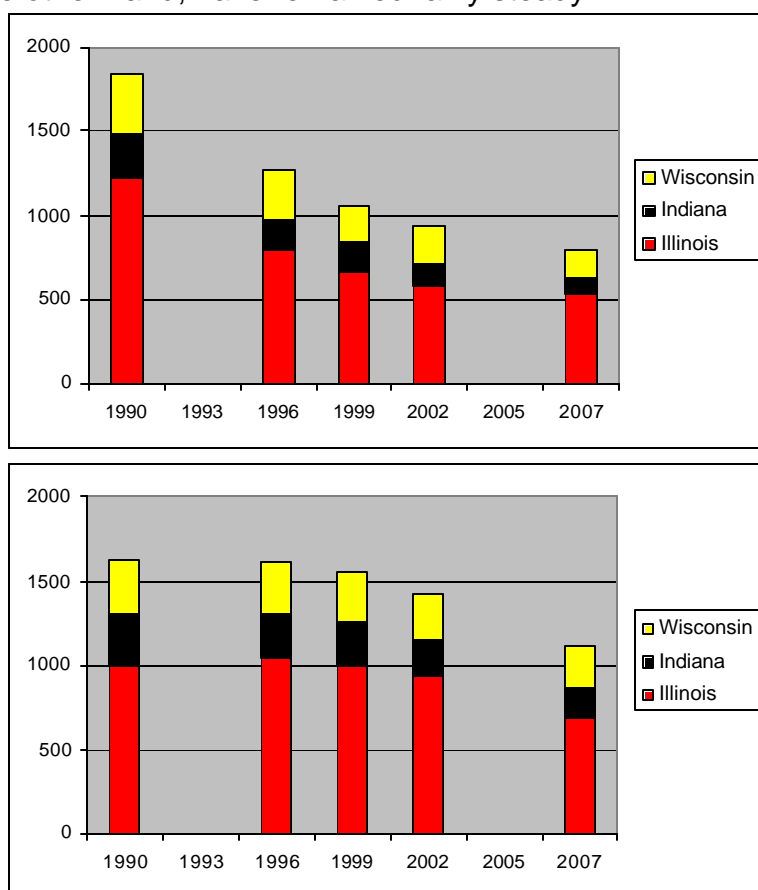


Figure 19. Trends in VOC (top) and NOx (bottom) Emissions for Severe Nonattainment Counties in Lake Michigan Area (Note: emissions units are tons per day)

The States' 1-hour ozone attainment demonstration consists of local VOC emission reductions in the urban nonattainment areas, plus regional NO_x emission reductions (see "Technical Support Document, Midwest Subregional Modeling: 1-Hour Attainment Demonstration for Lake Michigan Area", September 18, 2000). The VOC and NO_x emissions (for the nonattainment area) in the modeled attainment demonstration are shown in the figure above as the 2007 levels.

Regional reductions in NO_x emission from power plants are required pursuant to USEPA's NO_x SIP Call (63 FR 57356)⁷ and Wisconsin's NO_x Rule⁸, and from on-road and nonroad sources pursuant to USEPA's Tier 2/low sulfur gasoline, heavy-duty highway, and clean air nonroad diesel rules. The figure below shows the actual annual NO_x emissions from power plants in Illinois, Indiana, and Wisconsin for 1990, 1993, 1996, 1999, and 2002, as well as the emissions in the modeled attainment demonstration for 2007. As can be seen, regional NO_x emissions from these sources are expected to decrease by 2007. These emission reductions, along with those from on-road and nonroad sources, are expected to reduce transported ozone levels coming into the Lake Michigan area.

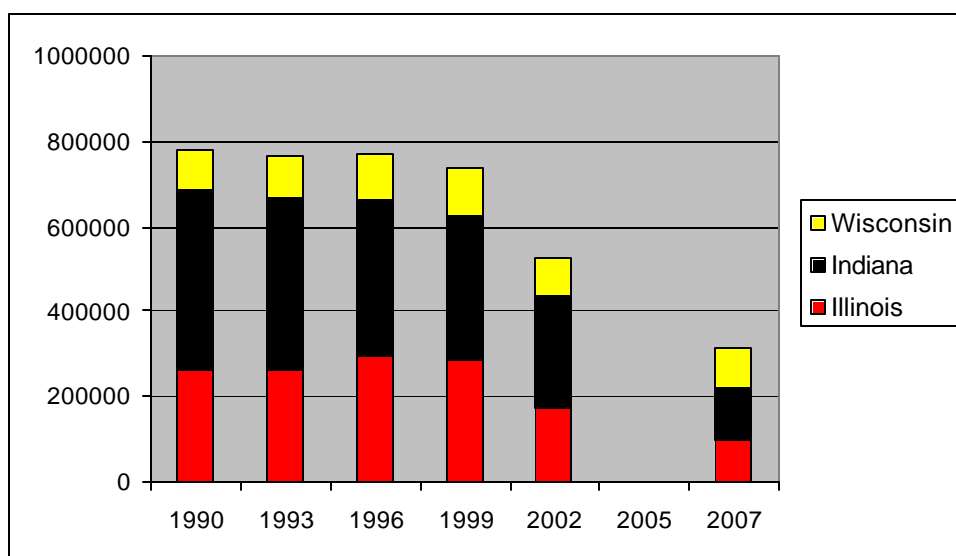


Figure 20. Trends in Statewide NO_x Emissions for Illinois, Indiana, and Wisconsin
(Note: emissions units are tons per year)

⁷ In 1998, EPA finalized a rule (known as the NO_x SIP Call) requiring 22 States and the District of Columbia to submit State implementation plans that address the regional transport of ground-level ozone. This rule requires reductions in summertime emissions of NO_x by May 2004 in the affected states. By improving air quality and reducing emissions of nitrogen oxides (a precursor to ozone formation known as NO_x), the actions directed by these plans will decrease the transport of ozone across State boundaries in the eastern half of the United States.

⁸ The State of Wisconsin, which is not subject to the NO_x SIP Call, adopted State Rule NR428 to addresses stationary source NO_x emissions for eight southeastern counties. It requires NO_x controls for larger existing sources and established emission standards for new sources. The program is expected to achieve a 30 TPD NO_x reduction by 2003 and a 55 TPD day reduction by 2007.

Section 6 Results from Other Studies

Additional information on trends in the Lake Michigan area is available from other studies. A summary of the findings from these studies is provided below:

“VOC and NO_x Limitation of Ozone Formation at Monitoring Sites in Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin, 1998-2002”, Charles Blanchard and Shelley Tannenbaum, Envair, February 24, 2004

This report analyses ambient measurements of ozone and ozone precursors for states in the Midwest to characterize where and when ozone formation is limited by VOC or NO_x. One key finding from this report is that peak ozone levels have declined over time, as seen in the plot below (i.e., lower values for 1998-2002 period compared to 1992-1997 period).

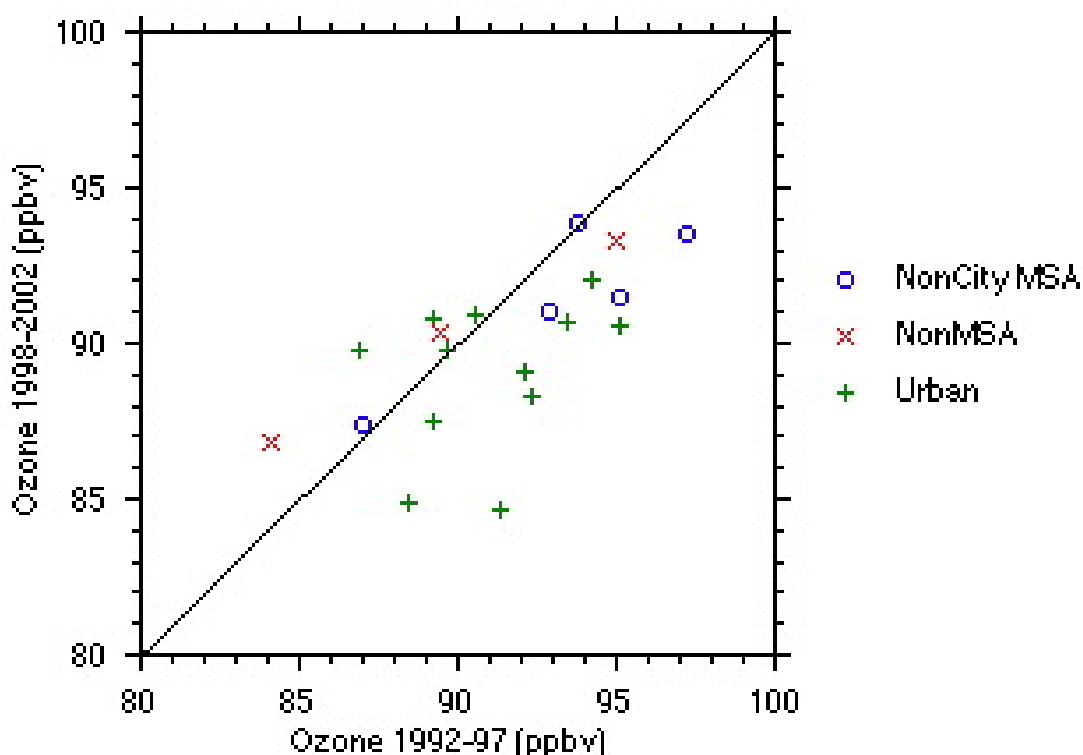


Figure 21. Comparison of 1998-2002 v. 1992-1997 statistics for ozone days > 80 ppb

“Data Analysis for a Better Understanding of the Weekday/Weekend Ozone and PM Differences”, prepared for the Coordinating Research Council by Atmospheric and Environmental Research, Inc., June 2001

This analysis was performed to examine the weekly cycle of ozone and particulate matter concentrations in three cities: Atlanta, Chicago, and Philadelphia. Data for two

5-year periods were considered: 1986-1990 and 1995-1999. The Chicago results are summarized in Table 3. The study found that the mean daily peak ozone values were greater on Saturday and Sunday compared to weekdays for both 5-year periods (by about 5 – 10 ppb), and that the mean daily peak values for 1995 –1999 are less than those for 1986-1990.

Table 3. Statistics of mean daily max one-hour average ozone concentrations by day of week in Chicago for 1995-1999 (top) and 1986-1990 (bottom)

| Site ID | Maximum (ppm) | Day of maximum | Minimum (ppm) | Day of minimum | Max minus min (ppm) | Stat. significance |
|------------|---------------|----------------|---------------|----------------|---------------------|--------------------|
| 1703100014 | 0.0508 | Sundav | 0.0419 | Wednesday | 0.0088 | 5% |
| 1703100324 | 0.0552 | Sunday | 0.0483 | Wednesday | 0.0069 | 5% |
| 1703100504 | 0.0499 | Sundav | 0.0424 | Tuesday | 0.0075 | 5% |
| 1703100634 | 0.0432 | Sundav | 0.0326 | Tuesday | 0.0106 | 5% |
| 1703100644 | 0.0502 | Sunday | 0.0423 | Wednesday | 0.0079 | 5% |
| 1703100724 | 0.0553 | Sundav | 0.0499 | Wednesday | 0.0054 | 5% |
| 1703110034 | 0.0487 | Sunday | 0.0396 | Wednesday | 0.0090 | 5% |
| 1703116014 | 0.0491 | Sundav | 0.0437 | Tuesday | 0.0053 | 5% |
| 1703140024 | 0.0482 | Sundav | 0.0391 | Tuesday | 0.0091 | 5% |
| 1703140064 | 0.0517 | Sunday | 0.0434 | Tuesday | 0.0083 | 5% |
| 1703170024 | 0.0559 | Sundav | 0.0496 | Tuesday | 0.0063 | 5% |
| 1703180034 | 0.0464 | Sunday | 0.0390 | Wednesday | 0.0074 | 5% |
| 1704360014 | 0.0504 | Sundav | 0.0424 | Wednesday | 0.0080 | 5% |
| 1709700014 | 0.0500 | Sundav | 0.0437 | Wednesday | 0.0063 | 5% |
| 1709710024 | 0.0530 | Sunday | 0.0471 | Tuesday | 0.0059 | 5% |
| 1709710074 | 0.0549 | Sundav | 0.0500 | Tuesday | 0.0049 | 5% |
| 1709730014 | 0.0495 | Sunday | 0.0433 | Tuesday | 0.0062 | 5% |
| 1719710114 | 0.0547 | Sundav | 0.0509 | Tuesday | 0.0038 | 5% |

| Site ID | Maximum (ppm) | Day of maximum | Minimum (ppm) | Day of minimum | Max minus min (ppm) | Stat. significance |
|------------|---------------|----------------|---------------|----------------|---------------------|--------------------|
| 1703100014 | 0.0606 | Sundav | 0.0508 | Friday | 0.0097 | 5% |
| 1703100324 | 0.0564 | Sunday | 0.0499 | Friday | 0.0065 | 5% |
| 1703100374 | 0.0507 | Saturday | 0.0444 | Tuesday | 0.0063 | 5% |
| 1703100504 | 0.0487 | Sundav | 0.0408 | Tuesday | 0.0079 | 5% |
| 1703100644 | 0.0591 | Sunday | 0.0491 | Tuesday | 0.0099 | 10% |
| 1703110024 | 0.0514 | Sundav | 0.0458 | Thursday | 0.0056 | insignificant |
| 1703110034 | 0.0548 | Saturday | 0.0464 | Friday | 0.0084 | 5% |
| 1703116014 | 0.0557 | Saturday | 0.0484 | Friday | 0.0074 | 5% |
| 1703140024 | 0.0529 | Sundav | 0.0457 | Tuesday | 0.0072 | 5% |
| 1703140034 | 0.0547 | Saturday | 0.0471 | Friday | 0.0076 | 5% |
| 1703170024 | 0.0592 | Saturday | 0.0545 | Tuesday | 0.0047 | 10% |
| 1704360014 | 0.0520 | Saturday | 0.0443 | Friday | 0.0077 | 5% |
| 1709700014 | 0.0544 | Saturday | 0.0478 | Friday | 0.0066 | 5% |
| 1709710024 | 0.0567 | Saturday | 0.0504 | Friday | 0.0063 | 5% |
| 1709730014 | 0.0540 | Saturday | 0.0480 | Friday | 0.0060 | 5% |
| 1808910164 | 0.0485 | Sundav | 0.0434 | Wednesday | 0.0050 | 5% |
| 1808920084 | 0.0585 | Thursday | 0.0550 | Tuesday | 0.0035 | insignificant |
| 1812700244 | 0.0638 | Thursday | 0.0595 | Friday | 0.0043 | insignificant |

Fiore, A.M., Jacob, D.J., Logan, J.A., Yin, J. H., 1998, “Long-term trends in ground level ozone over the contiguous United States, 1980 – 1995”, *Journal of Geophysical Research*, 103 (D1), 1471 – 1480

Based on an examination of nationwide trends in median and 90th percentile ozone concentrations for the period 1980 – 1995, this study found that trends were insignificant over most of the continental U.S., with decreasing trends clustered in a few metropolitan areas, including Chicago.

Lin, C. C.Y., Jacob, D.J. and Fiore, A.M., 2001, “Trends in exceedances of the ozone air quality standard in the continental United States, 1980 – 1998”, *Atmospheric Environment*, 35 (2001), 3217 – 3228

Based on an examination of nationwide trends in the number of exceedance days of the 1-hour and 8-hour ozone NAAQS for the period 1980 – 1998, this study found that:

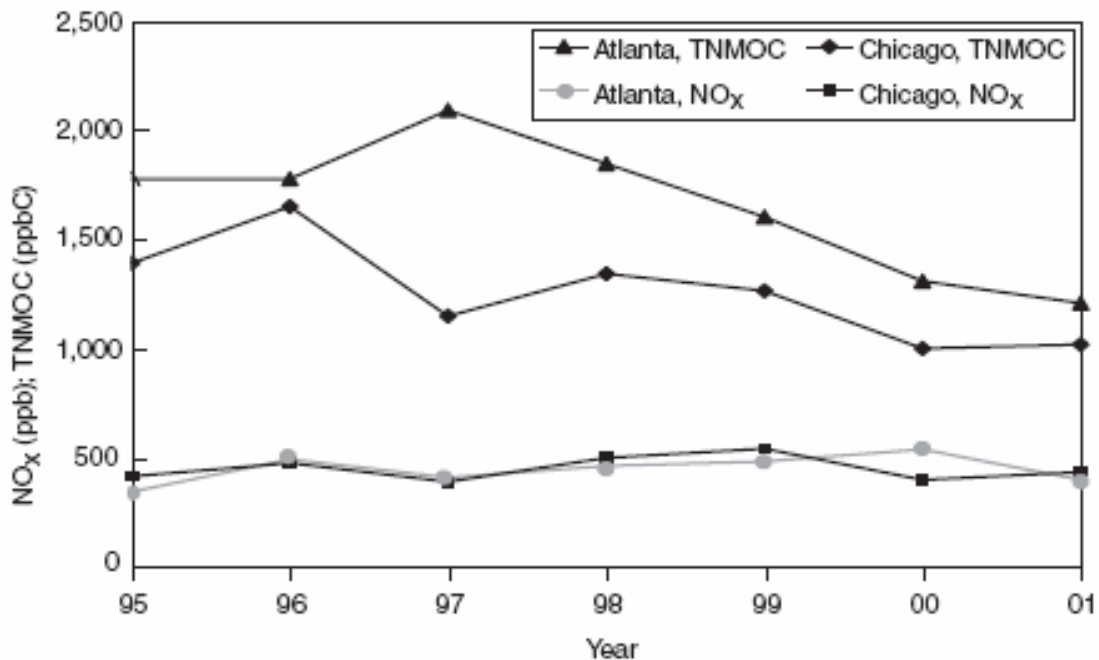
- downward trends occurred in several areas, including “the western back of Lake Michigan”;
- binning the data by temperature to remove the effect of interannual variability in weather revealed stronger and more significant trends;
- downward trends for the 1-hour NAAQS are greater and more significant than those for the 8-hour NAAQS, but there is a close correspondence between both standards in regions where significant downward trends were found (which suggests that controls enacted to improve 1-hour ozone levels were also effective in improving 8-hour ozone levels); and
- except for the southwest, quadrants of the U.S. experienced significant downward trends in ozone exceedances over the 19-year period, although mostly over the 1980s (i.e., there was little change during the 1990s).

USEPA, 2003, “National Air Quality and Emissions Trends Report, 2003 Special Studies Edition”, EPA 454/R-03-005, September 2003

This document, which is USEPA’s 28th annual report documenting air pollution trends in the United States, highlights USEPA’s most recent assessment of the nation’s air quality. It features information for the criteria pollutants and hazardous air pollutants, as well as relevant ambient air quality information for visibility impairment and acid rain. Findings of relevance for the Lake Michigan ozone situation include:

- Trends in summer weekday ozone precursor concentrations for Chicago (see figure below) indicate a decline in TNMOC concentrations (composite

trend of -7.8 ppb/year), but little change in NO_x concentrations (composite trend of +0.3 ppb/year).



- Air quality trend statistics for Chicago show a slight decrease in ozone concentrations (composite trend of -1.2 ppb/year), with 7 sites showing a decreasing trend.

USEPA, 2004, "The Ozone Report: Measuring Progress Through 2003", EPA 454/K-04-001, April 2004

This document, which summarizes USEPA's latest analyses of ozone data for the United States, shows that in 2003 nationwide ozone levels were the lowest since 1980. EPA concludes in the report that improvements in 2003 air quality are largely attributable to favorable weather conditions and continued reductions in emission of NO_x and VOCs. The agency further notes that the overall downward trend in ozone levels is slowing and that, despite improvements in air quality, in 2003 more than 100 million people in 209 counties still lived in communities with poor air quality for ozone based on EPA's 8-hour ozone standard. Many of the areas with unhealthful air quality are highly populated areas of the Northeast, Mid-Atlantic, Midwest and California. EPA states in the report that although improvements in air quality have been made, ozone continues to be a pervasive air pollution problem, and existing control measures are not expected to achieve attainment of the 8-hour standard in every county even as late as 2015.

Section 7 Summary

The change in ozone air quality over time provides information on progress toward attainment and the relative effectiveness of control programs. The trends in local ozone concentrations (including basic ozone metrics, such as the number of exceedance days and the design values, and statistical analyses which account for the year-to-year variation in meteorology), local ozone precursor concentrations, and incoming (background) ozone concentrations were considered here.

The key findings of this document are as follows:

- Since 1981, trends in 1-hour peaks are generally downward. In recent years, however, these trends are flatter. Trends in 8-hour peaks are similar to those for 1-hour peaks, with some indication of increasing trends in recent years
- The improvement in ozone air quality is consistent with the reduction in local VOC emissions due to motor vehicle control programs, including inspection and maintenance, and reformulated gasoline; area source control programs, and stationary source controls. Further progress is expected to come from reductions in regional NO_x emissions (e.g., USEPA's NO_x SIP Call and Wisconsin's NO_x rule).

These findings demonstrate that 1-hour ozone air quality levels in the Lake Michigan area have improved since the original nonattainment designations and combined with expected future emissions reductions, show that the region is on track to meet the 1-hour standard by the statutory attainment date of 2007.

With respect to compliance with the 8-hour standard, the flatter (and, in some cases, increasing) trends since the late 1980s suggest the need for new control programs to reduce 8-hour ozone concentrations. It is expected that the planned regional reductions in power plant, on-road, and nonroad NO_x emissions will help lower 8-hour ozone concentrations. Preliminary air quality analyses, however, suggest that these reductions will not be enough to meet the 8-hour standard. The LADCO States are currently working together to develop regional control plans to meet the 8-hour standard.

Finally, it should be noted that trends analyses should be performed in future years to assess compliance with the 1-hour ozone standard and progress toward attainment of the 8-hour standard. To this end, important data needs include ozone data from the regional ozone monitors and ozone precursor data from the regional PAMS network.