EVALUATION OF 2009 ALTERNATIVE EMISSION REDUCTIONS FOR NORTHEAST OHIO

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1.0 Overview

Results of this project showed that selected monitors in the Northeast Ohio 8-county region will remain in moderate non-attainment of the 8-hour ozone standards for the future year 2010, the year set by the USEPA for attainment demonstration for moderate non-attainment regions. An earlier modeling analysis by the Lake Michigan Air Directors Consortium (LADCO) of the future year 2009 emissions, developed from its 2002 emissions inventory, showed that this region will be in non-attainment despite the imposition of control strategies and a decline of economic activity in the project region. The Northeast Ohio Areawide Coordinating Agency (NOACA) believes that the growth factors projected by LADCO in some source categories for this earlier run may have been overestimated for the Northeast Ohio region. On the basis of consultations with NOACA and the Ohio EPA, the Air Quality Center of Ohio University was commissioned to complete two tasks: 1) evaluate projected emissions for 2009 for the project area and 2) conduct photochemical modeling to evaluate the impact of the modified projected emissions on air quality.

2.0 Evaluation of Projected Emissions

Researchers identified emissions source growth factors that may have resulted in an overestimation of the projected change from 2002 to 2009 in Northeast Ohio. More locally precise growth factors were identified and substituted for these.

The member states of LADCO, the Midwest Regional Planning Organizations (RPO), revised the point, area, mobile source inventories, and the growth and control factors for future year modeling. LADCO updated emission growth factors. These amended and less optimistic emissions growth factors, called Base K emissions, were lower than the previous growth rates for the Northeast Ohio region (Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties).

Ohio University obtained the 2002 and 2009 Base K emissions from LADCO. Estimates of the non-electrical generating unit (non-EGU) point, area, and agricultural future projections are usually made using USEPA's model, the Economic Growth Analysis System (EGAS). In this case, Ohio University researchers based some of the projected source categories for 2009 on the 2002 Base K data using the "new approximations" stated below. The modified 2009 emissions inventory was compared to LADCO's original 2009 emissions inventory to determine any significant differences between the two. The comparison of the 2009 emission projections, if appreciably lower, would indicate that LADCO may have overestimated growth factors in the Base K emissions for Northeast Ohio.

Ohio University researchers based new approximations of future emissions projections on the following:

- Linear trends in the reduction of Title V Non-EGU Point Sources
- Linear trends in the decline of aircraft emissions
- Economic indicators such as employment and population growth in Northeastern Ohio

The results of this preliminary analysis were used to develop a list of alternative realistic assumptions for the future 2009 base-case emissions inventory for Northeast Ohio based on the current emissions reduction trends in the case of Title V sources and the percent change in the economic indicators for some categories of area sources.

2.1 Title V Sources

Major stationary sources of air pollutants are subject to Title V of the federal Clean Air Act. Title V requires major stationary sources of air pollution and a limited group of non-major sources to obtain operating permits that assure compliance with all applicable federal air pollution control requirements. A major source is defined as a source that has the potential to emit the following amounts:

- 100 tons or more per year of any pollutant
- 25 tons or more per year of either reactive organic compounds or nitrogen oxides
- 10 tons or more per year of a single hazardous air pollutant (HAP)
- 25 tons or more per year of a combination of HAPs

A Title V operating permit provides a means of implementing federal maximum achievable control technologies (MACT) standards and acid rain requirements.

2.1a. Data Analysis of Title V Sources

The Ohio EPA provided Ohio University with a list of Title V sources for the years 2002, 2003, and 2004. The source categories consisted of major electrical power generating unit (EGU) and non- EGU point sources. EGU stationary sources are the largest nitrogen oxide (NO_x) emitters in Northeast Ohio. The USEPA uses the Integrated Planning Model (IPM) to analyze the projected impact of environmental policies on the electric power sector (EGU sources) in the contiguous United States. Therefore, this analysis consisted of an assessment of emission trends only for non-EGU point sources in Northeastern Ohio. The results were used to calculate approximate projected emissions of non-EGU point sources for the future base case of 2009.

2.1b. Methodology

The non-EGU point sources were broadly classified in different source categories based on their source classification codes (SCCs). To accomplish this task, different reporting facilities with similar SCCs were combined for each year. Then the SCCs of the entire group were matched with the list of corresponding SCCs from USEPA's website at http://www.epa.gov/ttn/chief/codes/.

The emissions from these sources were the calculated daily NO_x and volatile organic compound (VOC) rates, estimated as follows:

Daily emissions (pounds per day) *= Emissions (tons per year) x seasonal adjustment factor x the daily factor*

> *where the seasonal adjustment factor is June–August % / 25% and the daily factor = 1 / (number of days/week) /(number of weeks per year)*

<u>2.1c Results and Discussion</u>

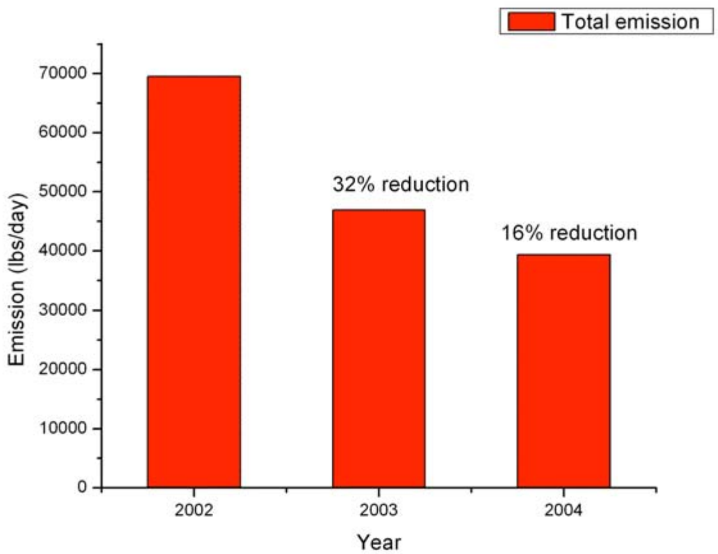

Figure 1. Total NO_x emissions

Figure 1 depicts the total NO_x emissions from Northeast Ohio non-EGU sources for 2002, 2003, and 2004. This figure depicts a 32% decrease of emissions from 2002 to 2003 and a further 16% reduction in emissions from 2003 to 2004. The shut-down of one external combustion boiler source caused the large decline from 2002 to 2003. After consultations with the NOACA and the Ohio EPA, project researchers assumed that, since the linear trend in reductions of NO_x emissions was approximately 25% from 2002 to 2004, this trend would flatten out in future years as a result of Northeast Ohio's stagnant economy. A similar assumption was made for the decline of VOC emissions from non-EGU Title V sources. Therefore, the NO_x and VOC emissions from these source categories were reduced by 25% (as a result of real data from 2002 to 2004) and a flat growth assumption was used to grow the emissions from 2004 to 2009.

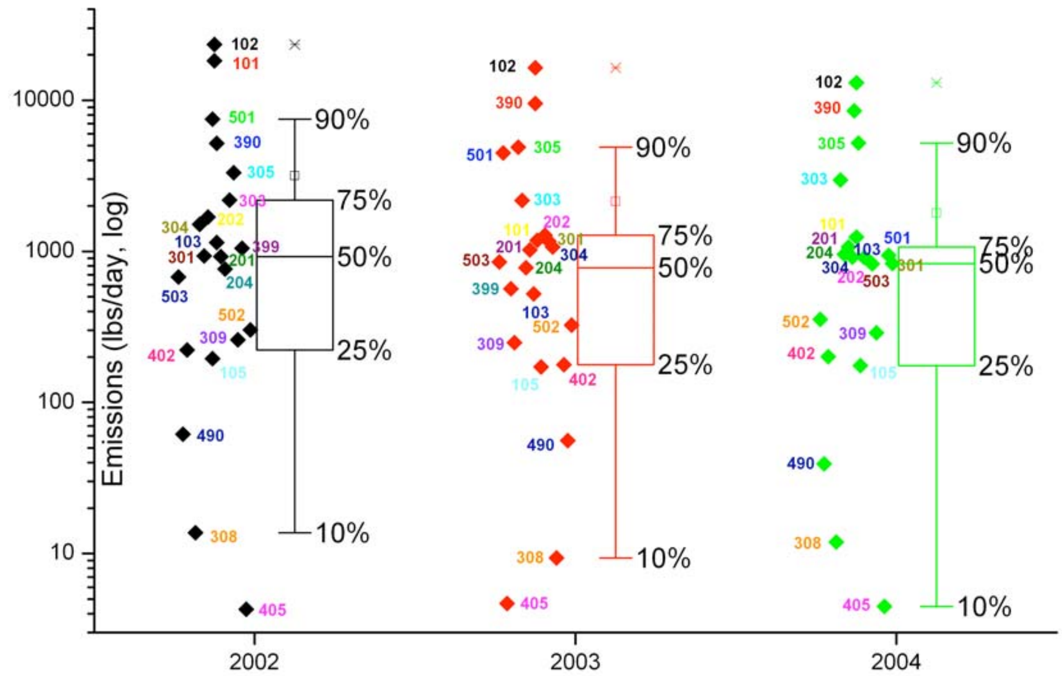

Figure 2. NO_x emissions of non-EGUs for 2002, 2003, and 2004

Figure 2 depicts a box-whiskers plot of NO_x emissions (lbs per day) of non-EGUs for the years 2002, 2003, and 2004. The left-hand dots indicate data distribution and the right box-whiskers indicate maximum, 90th, 75th, 50th, 25th, 10th, mean, and minimum A more detailed analysis of the Title V sources revealed that the largest contribution to the decline in emissions have come from the sources in the 90th percentile range (those sources contributing *n lbs/day* to 10,000 lbs/day), which are the high emitters, and in the 50–75th percentile range (those source contributing 1,000 to *n lbs/day*), which are the medium emitters. Hence, medium emitters also play an important role in determining potential control strategies because there is a downward decline in the medium percentile range.

2.2. Mobile Sources

Mobile source emissions were not modified for this analysis since they are computed by a separate transportation model that takes into account locally precise transportation demand factors.

2.3. Area Sources

The area source categories represent individual sources that are numerous yet small in magnitude and which are not classified as point, mobile, or biogenic sources. These area sources are grouped so they can be estimated collectively using one methodology. They consist of area "other" source emissions, area "mar" sources (marine vessels, aircrafts, and railroads), and area non-road emissions.

2.3a. Alternative Growth Assumptions

The following changes were made to area source categories in the 2002 Base K emission inventory to grow to 2009 emissions:

Area sources "other" emissions. These were not changed since economic indicators could not be used as surrogates.

Area sources " mar" (marine vessels, aircraft, and railroad) emissions. Emissions from marine vessels and railroads have not been modified since current trends were not available. A 28% reduction was applied to 2002 Base-K aircraft emissions based on current trends of fleet changeover from older stage-two engines to newer stage-three engines (NOACA). The relative contribution of emissions generated by aircraft is approximately 3% in the project sector. Emissions from marine vessels were the chief contributors in this category (approximately 70%) followed by emissions from railroads (approximately 27 %). The marine vessels' contributions are still under study by NOACA and LADCO.

Area sources "non-road" such as agricultural, commercial, and residential emissions. Researchers did not modify emissions from the agricultural category.

Commercial sources. In the case of commercial categories such as construction equipment, employment trends were used as a surrogate. A 25% reduction was applied in this category. NOACA challenged this assumption – a reduction is not logical. A redistribution of the emissions to follow population trends was more realistic.

Residential non-road mobile emissions. Researchers applied county-based population growth estimates for residential non-road mobile emissions such as lawn mowers.

2.4. Emission Reduction Methodology

In the case of emissions projections from 2002 Base-K emissions to 2009, researchers used the following methods:

1) **Selective reduction strategies for low point sources and area non-road sources such as aircraft**

   E2009new = E2009original – (E2009original x %contribution of source emissions x %area occupied by each county in each grid cell) + (1 + % reduction) x E2002 x %contribution of source emissions x %area occupied by each county in each grid cell

2) **Selective growth of emissions from 2002 to 2009 based on county-based population surrogates (varying from –3% in Cuyahoga County to 11% in Portage County to increments of 13% in all other counties**)

E2009new = E2009original – (E2009original x %contribution of source emissions x %area occupied by each county in each grid cell) + (1 + % growth in population) x E2002 x %contribution of source emissions x %area occupied by each county in each grid cell

2.5. Results and Discussion (Emissions Analysis)

In this section; the results of the emissions reduction evaluation are distributed across the Northeast Ohio region in terms of twelve-kilometer square grids, which constitute the template for photochemical modeling of regional NO_x and VOC emissions. Results of the VOC emissions reduction evaluation are shown in Figures 3 to 5

In Figure 3, LADCO emissions reductions between 2002 and 2009 are shown for each grid. As an example, 22% emissions reduction means that emissions are decreased by 22% between 2002 and 2009.

In Figure 4, NOACA/OU percentage emissions reductions between 2002 and 2009 are shown for each grid.

Figure 5 depicts the difference between LADCO-projected reductions and NOACA/OU-projected reductions. A negative value indicates that the projected NOACA/OU emissions reduction will be more than the LADCO emissions decrease between 2002 and 2009. Hence, NOACA/OU growth projections, where shown as negative grid numbers, resulted in more substantial reductions of emissions than the growth projections applied by LADCO.

Comparable results of the NO_x emissions reduction evaluation for Northeast Ohio are shown in Figures 6 to 8.

Table 1 is an example of how each grid cell percentage was calculated for regional reduction.

Table 2 shows the regional reductions for VOCs and NO_x, summarizing statistical differences between the LADCO and NOACA/OU results. As depicted in Figure 5, some of the grid cells experienced an increase in NO_x and VOC emissions as compared to the LADCO analysis. This was mainly due to the population and economic projections for the region. Again, negative grid percentages show that the NOACA/OU projections resulted in lower emissions projected for 2009. Table 2 shows the number of grid cells that experienced a positive and negative difference and the maximum and minimum differences (positive and negative). Overall, for the Northeast Ohio region, this project illustrates that the NOACA/OU projected VOC emissions for 2009 are 0.93% less than the LADCO 2009 projected emissions, and the projected NOx emission are 0.02% less than the LADCO 2009 projected emissions, indicating that the growth assumptions applied by NOACA/OU would produce fewer emissions than the LADCO growth assumptions.

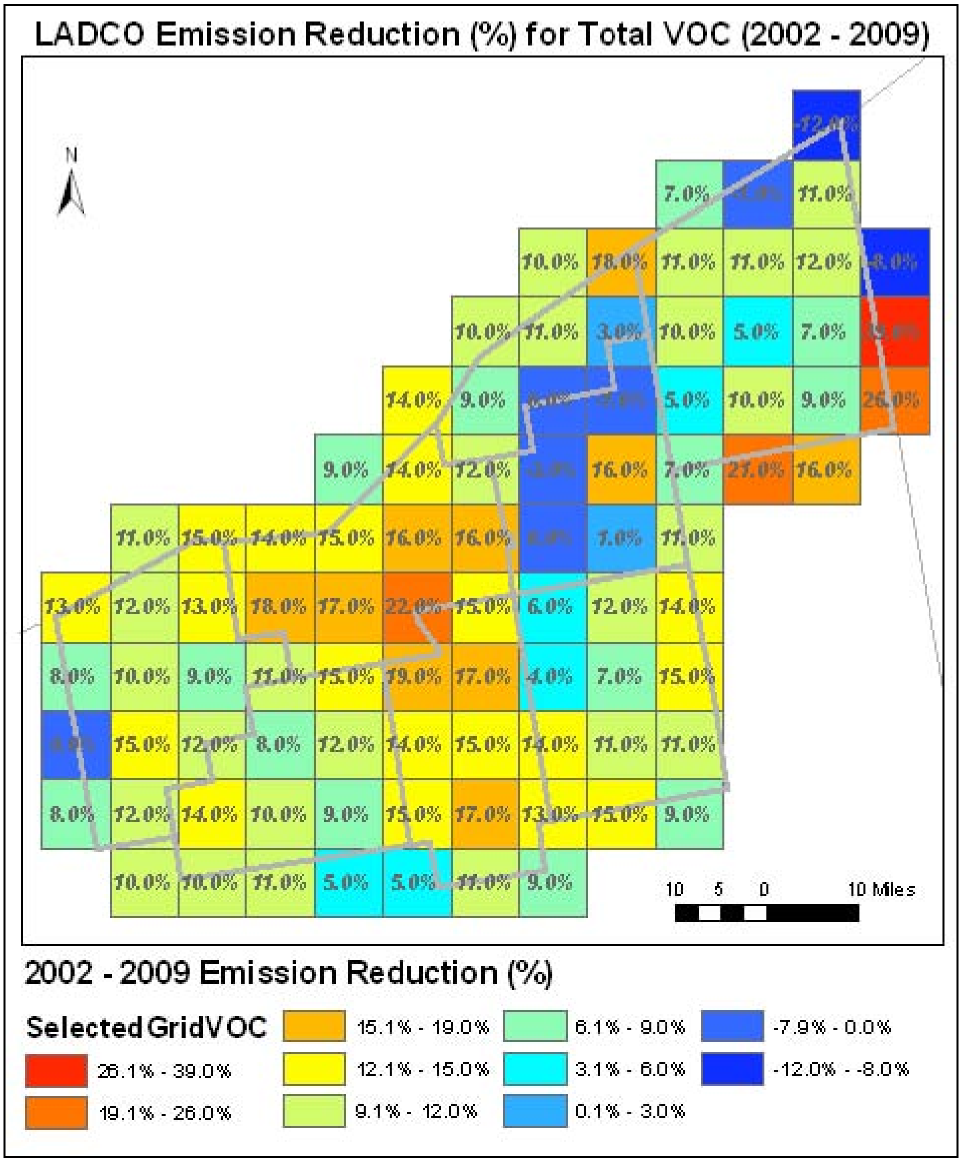

Figure 3. LADCO emissions reduction (%) for total VOC (2002–2009).

(A 22% reduction means emissions are decreased by 22% between 2002 and 2009 emissions in 2002 – emissions in 2009 / emissions in 2002 x 100.)

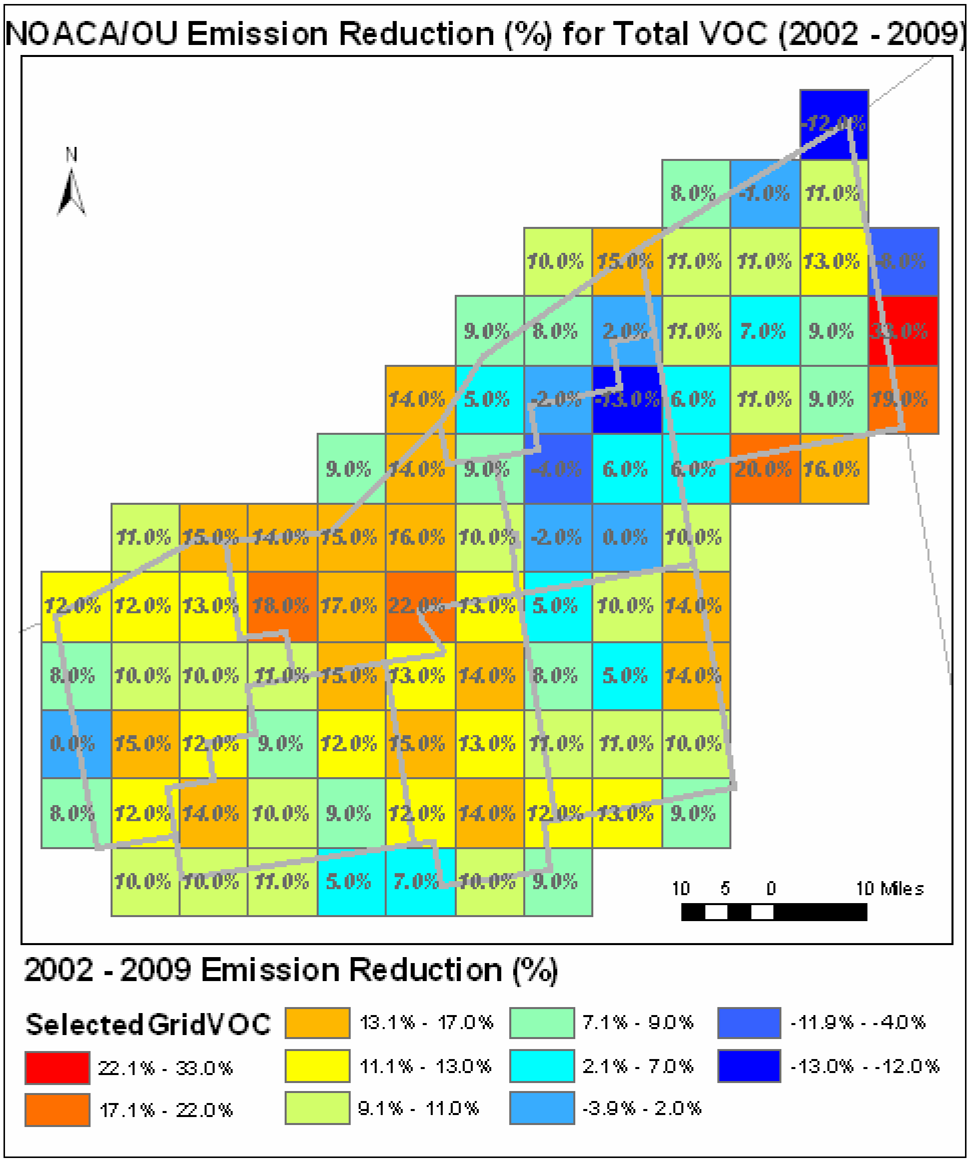

Figure 4. NOACA/OU emissions reduction (%) for total VOC (2002–2009).

(A 22% reduction means the emissions are decreased by 22% between 2002 and 2009 emissions in 2002 -–emissions in 2009 / emissions in 2002 x 100.)

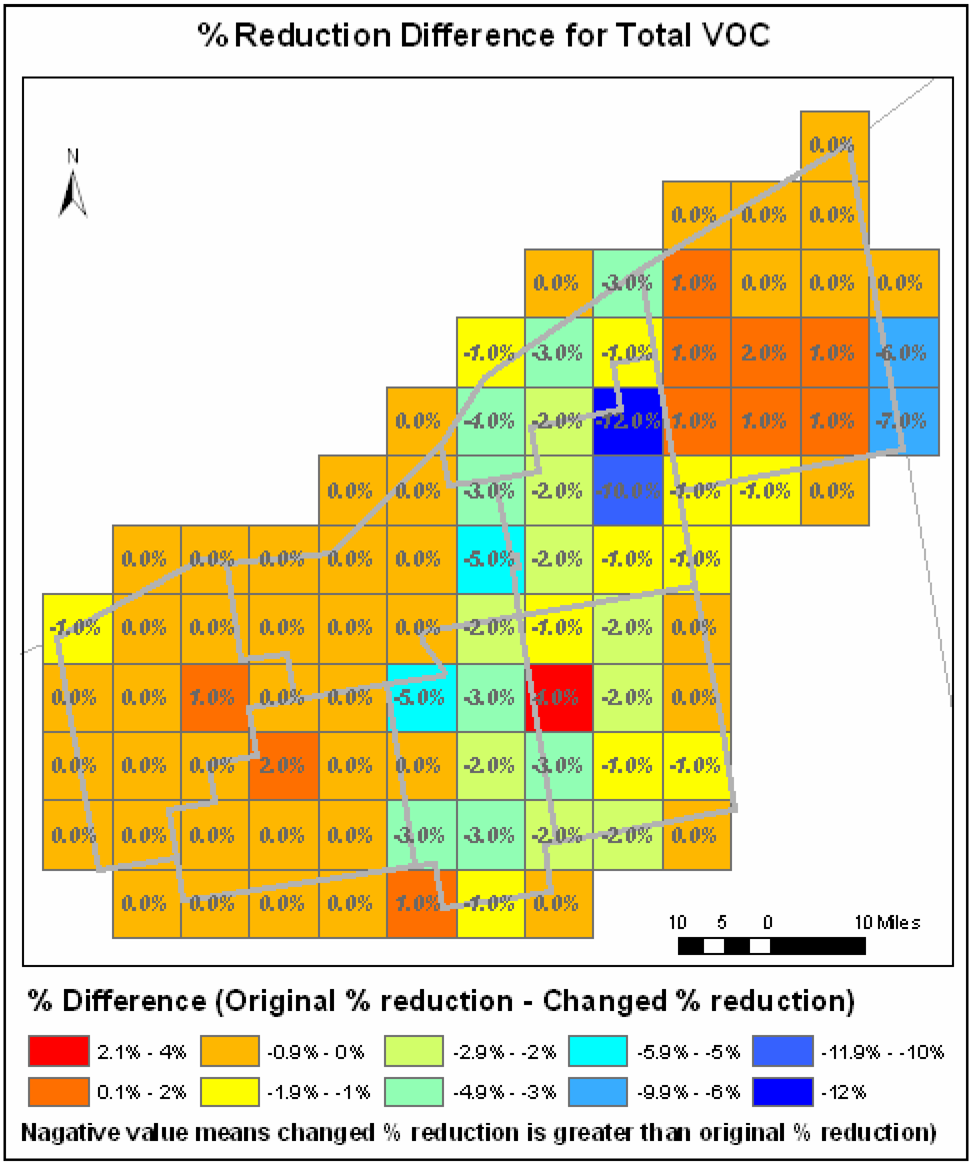

Figure 5. Percentage reduction difference (%) (LADCO reduction vs. NOACA/OU reduction) for total VOC (2002-2009).

Negative value means that the NOACA/OU emissions reduction is greater than LADCO emissions reduction. Table 1 is an example.

Table 1. Example of LADCO vs. NOACA/OU Emissions Reduction (2002–2009)

	2002	2009	Reduction	% Reduction
LADCO	120 t/day	110 t/day	**10** t/day	(120-110)/120 = 9 %
NOACA/OU	120 t/day	100 t/day	**20** t/day	(120-100)/120 = 16 %
% Difference				–7 %

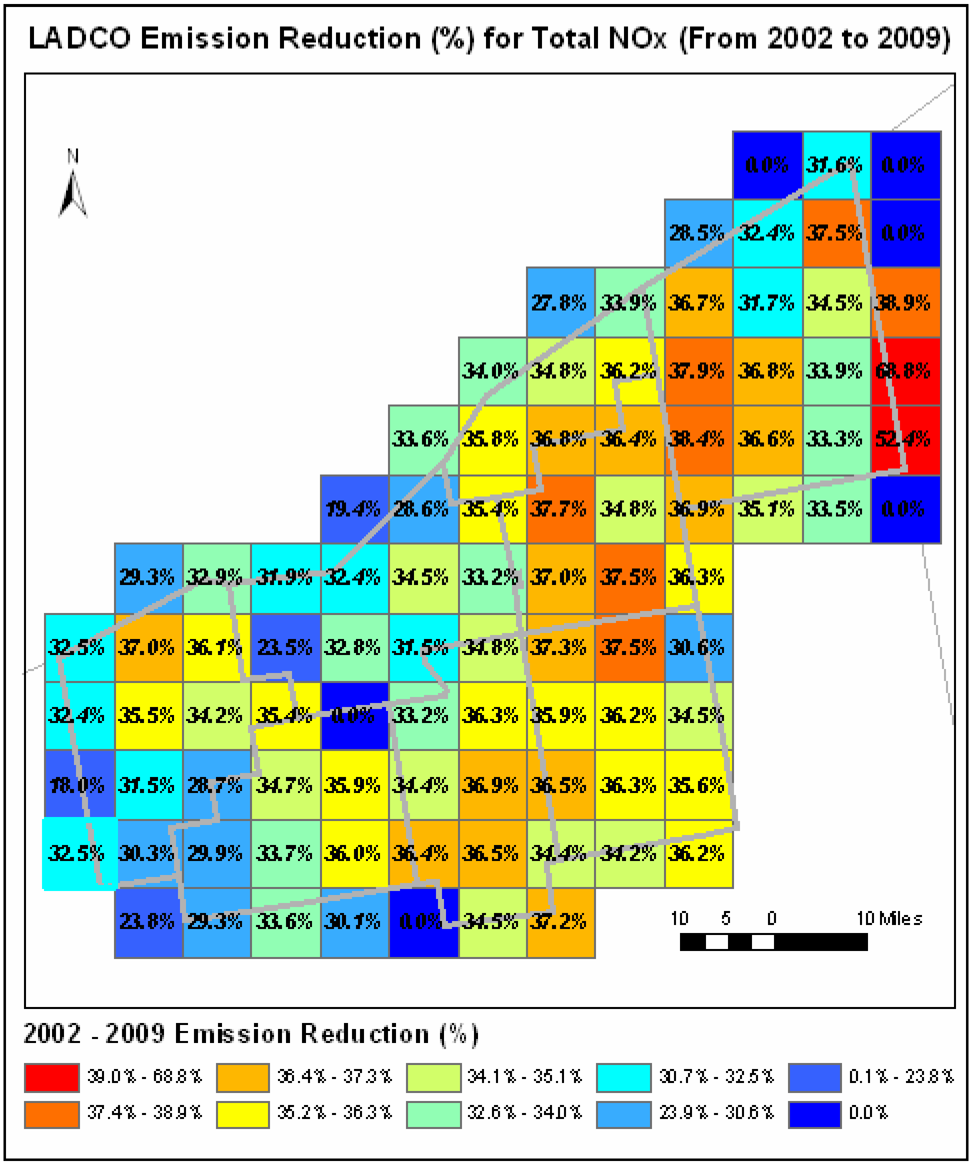

Figure 6. LADCO emissions reduction (%) for total NO_x (2002–2009).

(A 22% reduction means emissions are decreased by 22% between 2002 and 2009 emissions in 2002 – emissions in 2009) / emissions in 2002 x 100.)

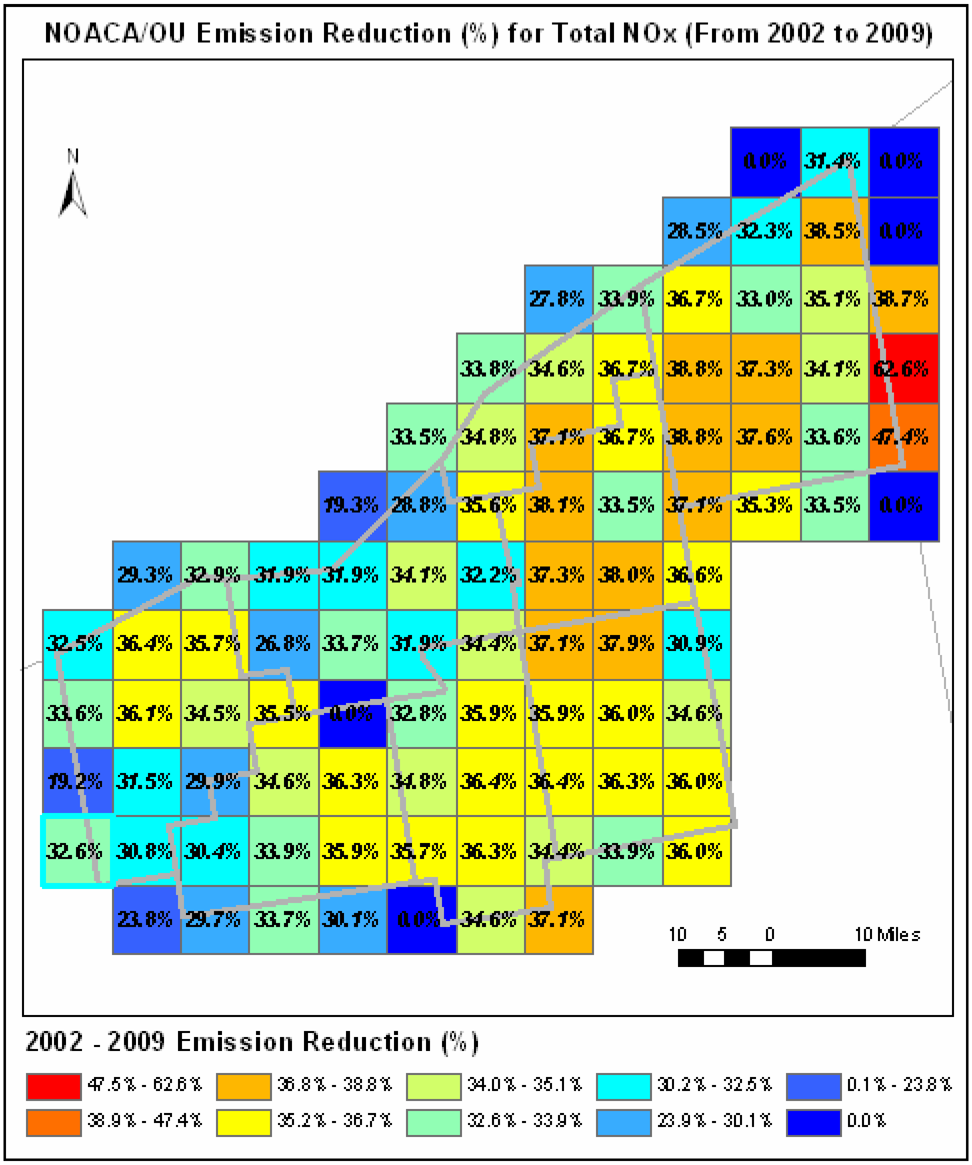

Figure 7. NOACA/OU emissions reduction (%) for total NO_x (2002–2009).

(A 22% reduction means emissions are decreased by 22% between 2002 and 2009 emissions in 2002 – emission in 2009) / emissions in 2002 x 100.)

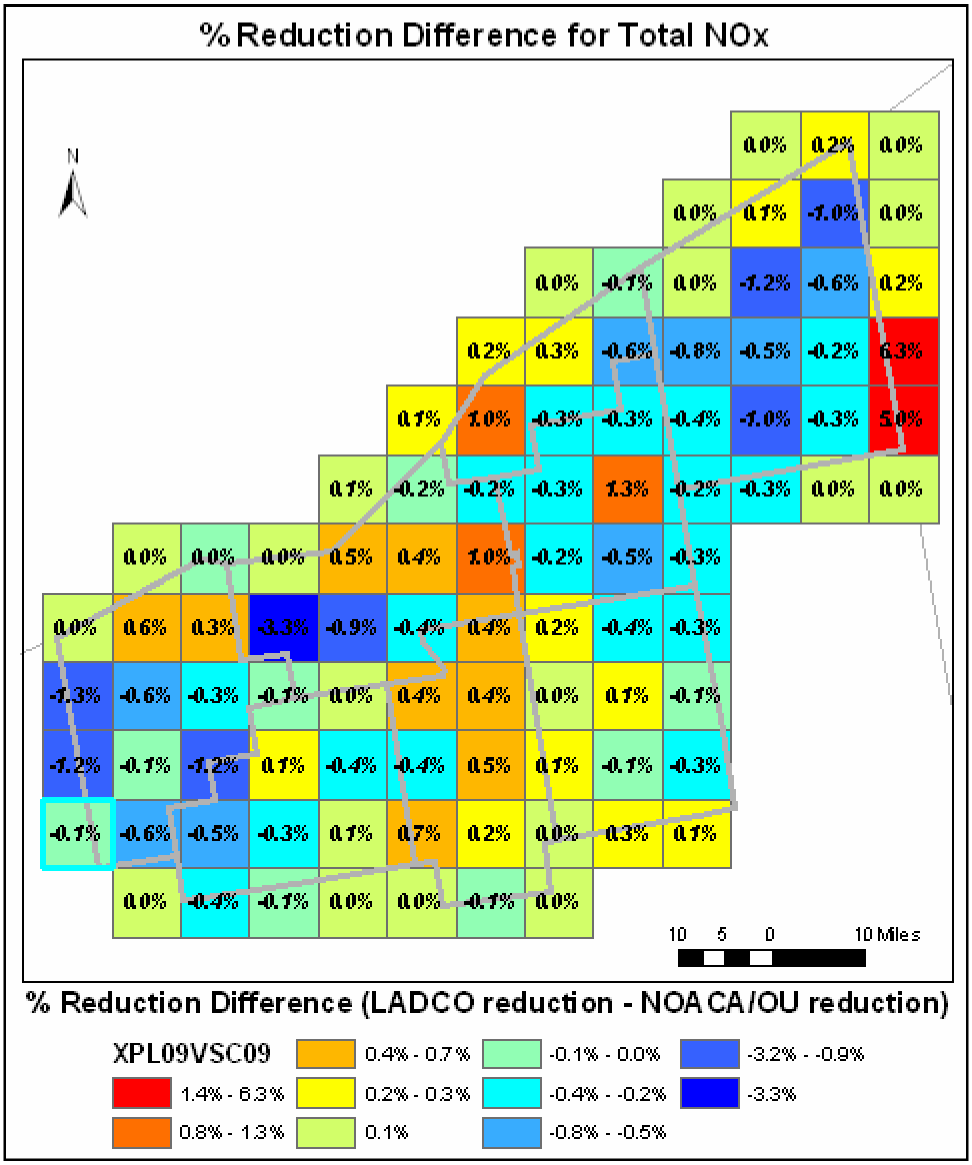

Figure 8. Percentage reduction difference (%) (LADCO emissions reduction vs. NOACA/OU emissions reduction) for total NO_x (2002–2009).

A negative value means that NOACA/OU emissions reduction is greater than LADCO emissions reduction. See example in Table 1 on page 9.

As shown in Figures 5 and 8, the plots of differences in both VOC and NO_x across the Northeast non-attainment area appear to indicate that modeling of the NOACA/OU alternative 2009 base case would be significantly different from the LADCO 2009 projected base case. While it appears that the absolute difference in tons may not be as much as was expected, the redistribution of emissions alone warrants further investigation.

Table 2. Summary of Emissions Reduction Difference for Total VOC and Total NO_x for Total VOC and Total NO_x for Each Grid Cell in the Model Domain.

	Total VOC	Total NO_x
No. of cells with +	11	38
No. of cells with -	34	52
Max	4.0 %	6.27 %
Min	–12.0 %	–3.3 %
Sum	–83 %	–1.87 %
Average	–0.93 %	–0.02 %

In Table 2, a negative difference means that the NOACA/OU emission projections were lower than those of LADCO. Again, negative grid percentages show that the NOACA/OU projections resulted in lower emissions projected for 2009. Therefore, this project illustrates that the NOACA/OU projected VOC emissions for 2009 are 0.93% less than the LADCO 2009 projected emissions, and the projected NOx emissions are 0.02% less than the LADCO 2009 projected emissions, indicating that the growth assumptions applied by NOACA/OU would produce fewer emissions than the LADCO growth assumptions.

3.0 Photochemical Grid Modeling Using CAMx

3.1 Model Description

The photochemical model used in this study was the Comprehensive Air Quality Model with Extensions (CAMx), Version 4.3, a three-dimensional photochemical grid-based model with extensions. The non-hydrostatic Penn State/NCAR Mesoscale model (MM5), Version 3 (Grell et al., 1994) provided the meteorological inputs to the photochemical model. The Emissions Modeling System (EMS) (LADCO, 1999) was used for processing the emissions. The model simulations were performed for the summer months of 2002 (June 5 to August 31) in a nested mode with a horizontal grid cell dimension of 36 km in a coarse domain and a 12 km fine grid covering Northeast Ohio (Figure 9). The vertical structure in the model consisted of 14 layers from the surface up through 4 km.

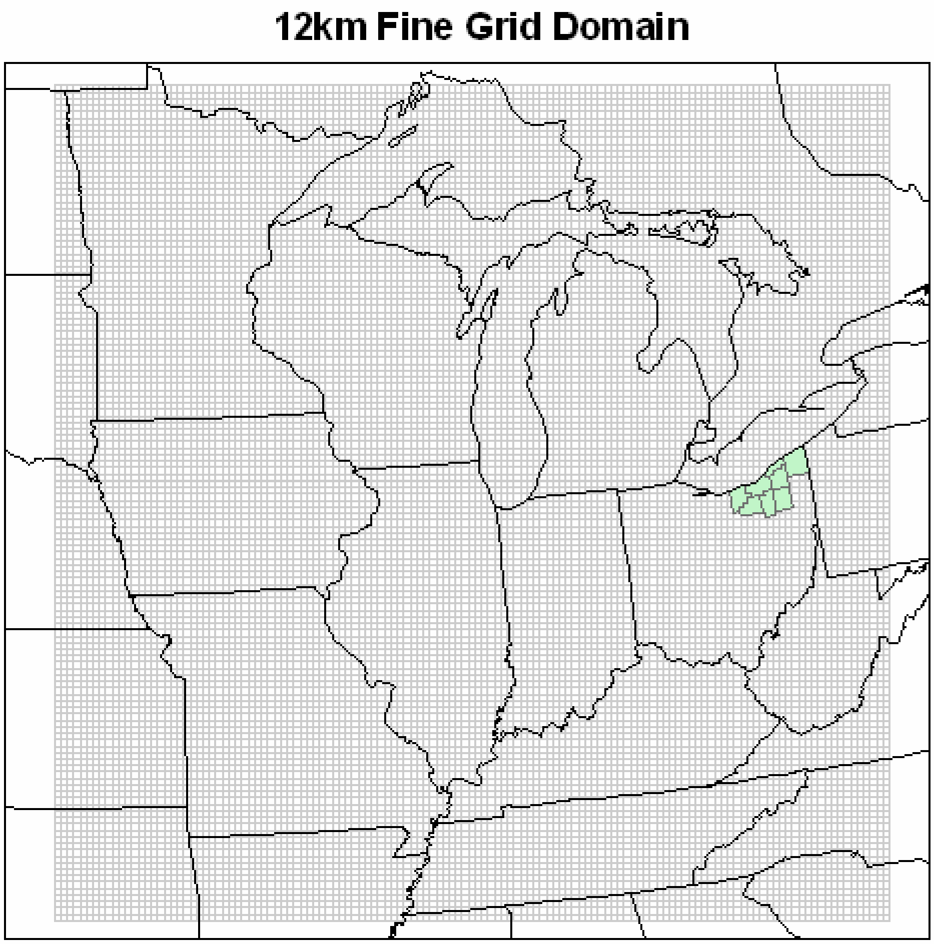

Figure 9. 12km fine grid domain for CAMx modeling.

3.2 Methodology

Researchers used the USEPA modeling guidance (USEPA, Nov. 2005) for the attainment demonstration.

- CAMx was applied with the emission inventory (EI) process based on the assumptions in Section 2.3a. CAMx was run for 87 days (June 5 through August 31). Figure 11 summarizes the results of the model run with comparison to LADCO's model runs for the same period. The CAMx outputs were post-processed for daily maximum 8-hour ozone calculations. In addition, researchers conducted the daily maximum 8-hour ozone calculations from the data received from the Geauga monitor.

- Several Excel macro files were utilized to take maximum values from the 3x3 grids (Figure 10) of "nearby grids of the monitor" and to calculate relative reduction factors (RRFs).

- The RRFs were calculated with the 2002 and 2009 LADCO model run and the 2009 OU-EI-modified runs for each day.

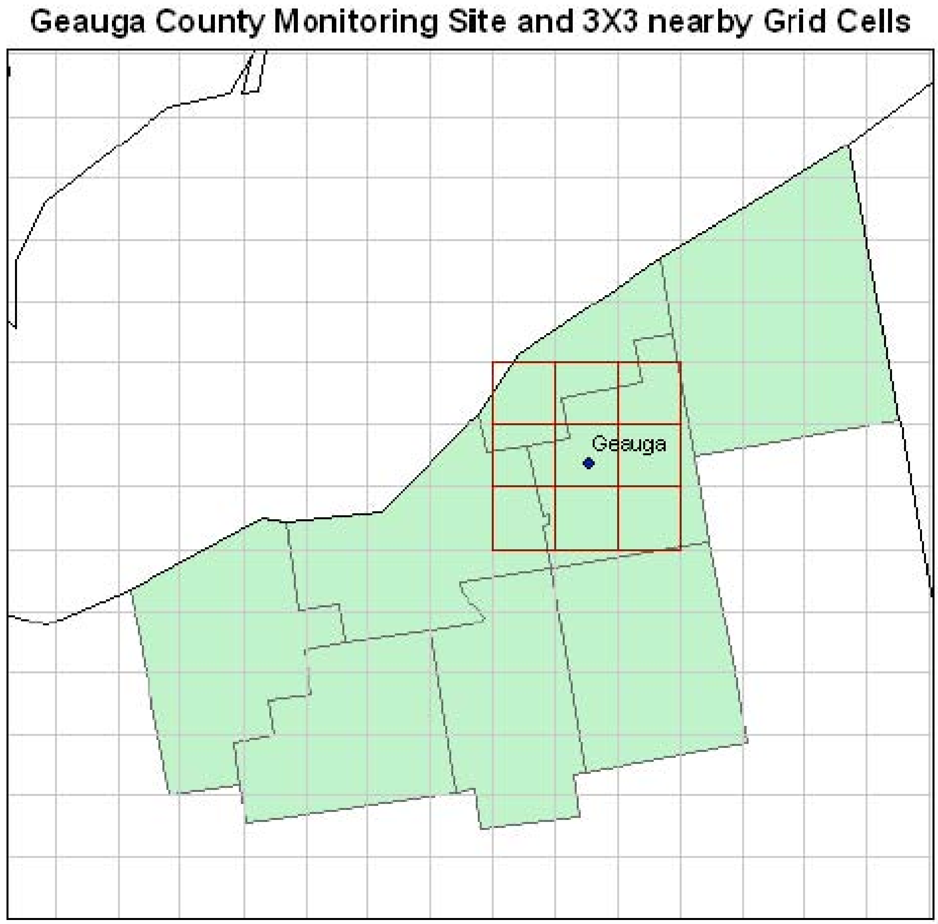

Figure 10. 3x3 Grids

3.3 Results and Discussion (Photochemical Model Runs)

OU researchers calculated the relative reduction factors for the Geauga county monitoring site with a design value above 85 ppb. The RRFs for the future base case and the alternative emissions reduction are listed in Figure 11. The RRFs are defined as the ratio of the maximum daily 8-hour average ozone level for the future case to the average of the base case over the entire simulation.

For the base-case model simulations, days on which the maximum 8-hour average ozone level was less than 70 ppb were not included in the calculation (USEPA 1999). The researchers calculated the mean RRF values of the 87 RRF values and applied the mean RRF values of LADCO's 2009 and OU's 2009 projections to the design value of 99.0 ppb (2000 to 2004) for the Geauga monitor. The LADCO 2009 design value (Round 3 modeling results) was 89.6 ppb and the OU design value was 88.2 ppb, a 1.4 ppb difference. Figure 11 depicts the ozone design value difference between LADCO 2009 and the OU 2009 alternative emissions reduction.

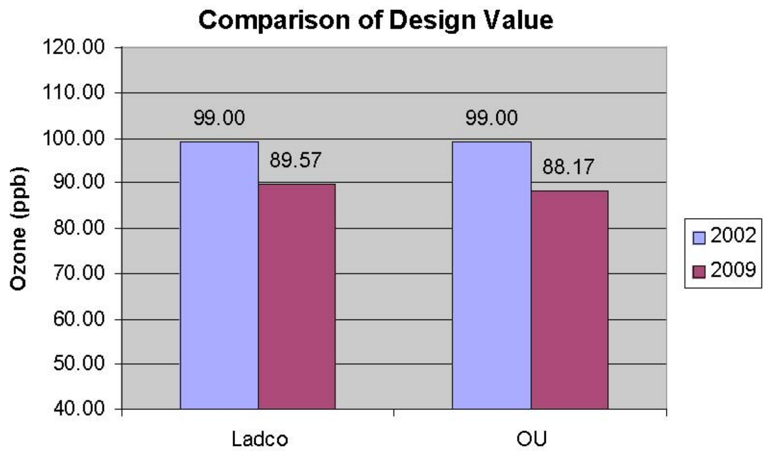

Figure 11. Ozone design value difference between LADCO 2009 and OU 2009.

4.0 Future Work

As this analysis demonstrates, for the State Implementation Plan (SIP) demonstration of attainment purposes, there may be value in substituting locally accurate growth factors for emissions sources in Northeast Ohio to facilitate future emissions inventory work on the behalf of the Ohio EPA.

Table 3. Daily Maximum 8-hour Ozone, Relative Reduction Factors, and Design Values for 2009: Geauga County

Julian	Date	2002	2009	2009ch	2009_LADCO_rrf	2009_OU_rrf
161	10-Jun-02	101.3583	92.58766	92.6596	0.913468951	0.914178711
171	20-Jun-02	90.64149	79.91012	79.91061	0.881606425	0.881611831
172	21-Jun-02	101.6202	93.32188	93.25425	0.918339858	0.91767434
173	22-Jun-02	109.4895	95.9657	95.9463	0.876483133	0.876305947
174	23-Jun-02	98.28075	84.87499	84.6889	0.863597297	0.861703843
175	24-Jun-02	100.3797	91.41162	91.34177	0.91065843	0.909962572
176	25-Jun-02	93.6455	87.46911	87.4231	0.934044989	0.933553668
181	30-Jun-02	95.59836	82.66085	82.35019	0.864668076	0.861418439
182	01-Jul-02	103.3307	93.45644	93.42434	0.90444021	0.904129557
185	04-Jul-02	85.25371	78.14639	78.18088	0.916633305	0.917037863
195	14-Jul-02	86.61142	75.75658	75.47301	0.874671954	0.871397906
198	17-Jul-02	90.67758	82.20552	82.15161	0.906569408	0.905974884
203	22-Jul-02	92.77339	85.75636	85.71733	0.924363764	0.923943062
207	26-Jul-02	96.36614	87.63634	87.61736	0.909410089	0.909213132
213	01-Aug-02	98.56635	90.25701	87.859	0.915698004	0.891369113
216	04-Aug-02	93.7504	86.12392	85.68114	0.918651227	0.913928261
223	11-Aug-02	90.15467	77.81388	69.05608	0.863115355	0.76597341
224	12-Aug-02	86.0311	88.53455	80.65033	1.029099361	0.937455525
225	13-Aug-02	86.10134	74.4422	71.04831	0.86458817	0.825170781
				2002 DV:	99	99
				mean rrfs:	0.904742527	0.890631729
				2009 DV:	89.56951014	88.17254114
				LADCO-OU:	1.396969007	