Draft Final

AIR QUALITY MODELING ANALYSIS FOR THE DENVER EARLY ACTION OZONE COMPACT:

2007 Base Case, Control Strategy and Sensitivity Analysis Modeling

Prepared for:

Mr. Gerald Dilley

Denver Regional Air Quality Council
1445 Market Street, # 260
Denver, CO 80202

Prepared by:

Ralph E. Morris
Gerard Mansell
Edward Tai

ENVIRON International Corporation, Inc.,
101 Rowland Way, Suite 220
Novato, CA 94945-5010

Dennis E. McNally
T. W. Tesche

Alpine Geophysics, LLC
3479 Reeves Drive
Ft. Wright, KY 41017

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1. INTRODUCTION

This report describes future-year (2007) Base Case, control strategy and sensitivity modeling carried out as part of the Denver-Northern Front Range 8-hour ozone Early Action Compact Study (Denver EAC Study). The procedures used in the Denver EAC photochemical modeling are described in detail in the modeling protocol (Tesche et al., 2003a) and the 2002 Base Case modeling and model performance evaluation is described in Morris et al. (2003).

BACKGROUND

As described in the ozone modeling protocol (Tesche et al., 2003a), the goal of the Denver EAC 8-hr Ozone Study is to conduct a comprehensive photochemical modeling study for the Denver-Northern Front Range Region (DNFRR) that can be used as the technical basis for 8-hr ozone SIP development. The modeling study, guided by the protocol, is specifically designed to identify the processes responsible for 8-hr ozone exceedances in the region and to develop realistic emissions reduction strategies for their control. Major objectives of the Denver EAC study include:

- Prepare an Ozone Modeling Protocol (Tesche et al., 2003a), consistent with EPA requirements, that provides direction to the 8-hr ozone modeling of the Denver-Northern Front Range. Collaborate with the CDPHE in the identification and justification of one or more 8-hr ozone modeling episodes for the Denver study;

- Construct dynamically and thermodynamically consistent MM5 meteorological inputs at appropriate grid scales for direct input to the emissions and photochemical models (McNally, Tesche and Morris, 2003);

- Produce the model-ready base-year and future-year emissions inventories suitable for input to the CAMx model and perform additional quality assurance (QA) of the emissions data sets beyond that conducted by the CDPHE (Mansell and Dinh, 2003a,b);

- Develop photochemical model base case modeling inputs for the selected modeling episode(s) and carry out base case model performance testing, diagnostic analysis, and pertinent sensitivity studies, including a check on mass consistency (Morris and Mansell, 2003; Morris et al., 2003);

- Evaluate the photochemical model's performance for the selected episode(s) (Morris et al., 2003) and compare the results with EPA's performance objectives in their draft 8-hour ozone modeling guidance (EPA, 1999);

- Perform future-year (2007) Base Case and control scenario simulations to estimate ozone levels in the Denver region under different local control regimes (this document);

- Perform additional future-year (2007) emissions reduction sensitivity analysis to better understand the relative effectiveness of local VOC versus NOx controls for reducing elevated 8-hour ozone concentrations in the DMA (this document);

- Develop suitable "weight of evidence" analyses supporting the ozone attainment demonstration, consistent with EPA guidance and assist the RAQC and CDPHE in developing the technical information to support the documentation required for the Denver 8-hr ozone Early Action Compact protocol;

- Provide for a thorough and efficient transfer of modeling codes, data sets, and related information to other stakeholders in the process including the EPA Region VIII and the CDPHE; and

- Set up the full suite of models and databases developed in this study on CDPHE computers and provide on-site training in the use of the modeling system(s).

A photochemical modeling domain that covered the southwestern US using grid resolutions of 36, 12, 4 and 1.33 km was set up with the higher resolution grids (4 and 1.33 km) focused on the Denver Metropolitan Area (DMA). Figure 1-1 displays the grid nesting configuration used for the photochemical and emissions modeling. Meteorological modeling domains were slightly larger than used for the photochemical and emissions modeling and also included a large-scale 108 km grid covering North America. The MM5 meteorological, EPS2x emissions and CAMx photochemical models were selected for the Denver 8-hour ozone EAC modeling (Tesche et al., 2003a).

2002 BASE CASE MODELING

The 2002 Base Case modeling, diagnostic sensitivity tests and model performance evaluation is described by Morris and co-workers (2003). The CAMx ozone model performance for the June 25 – July 1, 2002 (June 2002 episode) and July 18-21, 2002 (July 2002 episode) episodes was evaluated and the performance metrics compared against EPA's performance goals (EPA, 1999). The CAMx June 2002 ozone model performance met EPA's performance goals. The performance for the July 2002 episode was not as good. Thus, additional analysis focused on the June 2002 episode results. In addition, the ozone performance using the 4 km and 1.33 km grid over the DMA region was very similar. Thus, given the time constraints of the study and the computational requirements of using the 1.33 km grid, the study proceeded with the future year (2007) modeling using the 36/12/4 km grid structure and the June 2002 episode.

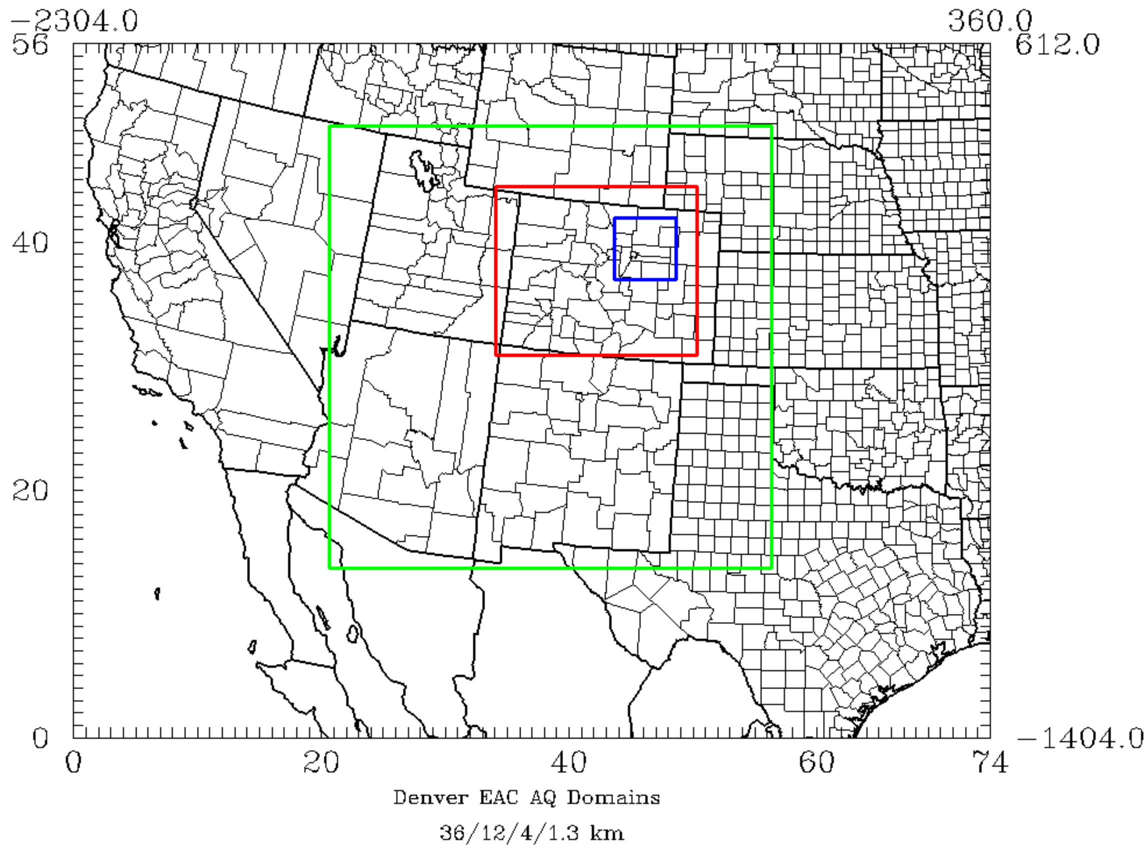


Figure 1-1. Denver EAC air quality 36 km (outer), 12 km (green), 4 km (red) and 1.33 km (blue) modeling domains.

2007 EMISSION SCENARIOS

The development of the 2002 Base Case emissions inventory is described by Morris and Dinh (2003a,b). The 2007 Base Case emissions development is described in Mansell and Dinh (2003c). Table 1-1 below summarizes the changes in VOC and NOx emissions between the 2002 Base Case and 2007 Base Case emissions scenarios in the 7 county Denver Metropolitan Area (DMA; i.e., Adams, Arapahoe, Broomfield, Boulder, Denver, Douglas and Jefferson Counties) plus Weld County. The projection of emissions from 2002 to 2007 results in increases in VOC emissions from point and area sources (~10 tpd each) and more substantial reductions in VOC emissions from non-road (-21 tpd) and on-road (-37 tpd) mobile sources. Thus, overall anthropogenic VOC emissions in the DMA+Weld Counties are projected to decrease by approximately 38 tpd (-7%). It should be noted, however, that the level of summer time biogenic VOC emissions in the DMA+Weld Counties is estimated to be comparable to the level of anthropogenic VOC emissions so that the net reduction in total VOC emissions from 2002 to 2007 Base Case conditions is closer to –3% to –4%. There are slight increases in NOx emissions in point and area sources going from 2002 to 2007 (2 tpd each). And slight reductions in non-road NOx emissions (-5 tpd) and more substantial reductions in on-road mobile NOx emissions (38 tpd). Thus, overall the projection of emissions from 2002 to 2007 is estimated to reduce anthropogenic NOx by 38 tpd (-10%). Note that biogenic NOx emissions are only approximately 10% of the anthropogenic NOx emissions in the DMA+Weld Counties so the reduction in total NOx emissions across the DMA+Weld Counties going from 2002 to 2007 is a little under 10%.

Table 1-1. 2002 Base Case and 2007 Base Case VOC and NOx emissions in tons per day (tpd) in the DMA plus Weld County region (typical summer weekday and county-specific emissions).

	VOC Emissions (tpd)			NOx Emissions (tpd)		
Category	**2002**	**2007**	**(%)**	**2002**	**2007**	**(%)**
Point	192	203	+5.8%	105	107	+1.9%
Area	95	104	+9.5%	26	28	+7.8%
Non-Road	75	54	-28.1%	88	83	-6.2%
On-Road	139	102	-26.2%	144	107	-25.6%
Total	501	463	-7.4%	363	325	-10.3%

2007 Emission Control Strategies

Four 2007 emission control scenarios were analyzed as follows:

2007 RVP Control Strategy (cntl1): Use of an 8.1 psi RVP gasoline fuel in on-road mobile sources in the DMA with a 1 psi waiver for ethanol fuels that are assume to have a 40% market penetration.

2007 Flash VOC Emissions Control (cntl2): 37.5% emissions reduction of VOC emissions from Flash emissions generated by oil and gas production.

2007 RICE Emissions Control (cntl3): Emissions controls on Reciprocating Internal Combustion Engines (RICE) of greater than 250 HP.

<u>2007 Three Control Strategies (cntl4)</u>: Combined RVP, Flash and RICE control measures.

Tables 1-2, 1-3 and 1-4 display the, respectively, VOC, NOx and CO emissions for the 2007 Base Case and four 2007 control strategies and the differences in emissions for the four 2007 control strategies from the 2007 Base Case by anthropogenic emissions source category.

The 2007 RVP (8.1 psi) control scenario is estimated to reduced anthropogenic emissions in the DMA+Weld area by –1.6% (-9 tpd) for a reduction in total (anthropogenic and biogenic) VOC emissions of < -1%. The RVP scenario has almost no effect on NOx emissions and reduces anthropogenic CO emissions by –3.5%. These emission reductions are from on-road mobile sources so occur primarily in the DMA.

The 2007 Flash control scenario reduces anthropogenic VOC emission in the DMA+Weld region by –10% (53 tpd) for a reduction in total VOC emissions of approximately –5%. The Flash control scenario has no effect on NOx and CO emissions. These VOC emission reductions come from Weld County to the northeast of the DMA.

The 2007 RICE emissions control scenario results in a –3% reduction in anthropogenic NOx emissions in the DMA+Weld region. A vast majority (~80%) of these emission reductions occur in Weld County to the northeast of the DMA.

The 2007 Three Control Measure control scenario combines the emission reduction effects of the RVP, Flash and RICE emission control measures. Note that since these control measures each control a different source category then the effects of the controls are additive and there were no effects of control measure overlap.

Table 1-2. Summary of anthropogenic VOC emissions (tons per day) in DMA plus Weld County for the 2007 Base Case and four 2007 control scenarios day-specific for Tuesday June 25, 2002 and grid cell representations of counties with on-road mobile being entire link-based network.

VOC	2007Base	2007 RVP		2007 Flash		2007 RICE		2007 All	
Category	(tpd)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)
Points	208	208	0.0%	155	-25.4	205	-1.7%	152	-27.1%
Area	102	102	0.0%	102	0.0%	102	0.0%	102	0.0%
Off-Road	57	57	0.0%	57	0.0%	57	0.0%	57	0.0%
On-Road	152	144	-5.5%	152	0.0%	152	0.0%	144	-5.5%
Total	**520**	**511**	**-1.6**	**467**	**-10.2**	**516**	**-0.7%**	**455**	**-12.4**

Table 1-3. Summary of anthropogenic NOx emissions (tons per day) in DMA plus Weld County for the 2007 Base Case and four 2007 control scenarios day-specific for Tuesday June 25, 2002 and grid cell representations of counties with on-road mobile being entire link-based network.

NOx	2007Base	2007 RVP		2007 Flash		2007 RICE		2007 All	
Category	(tpd)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)
Points	103	103	0.0%	103	0.0%	91	-11.9%	91	-11.9
Area	6	6	0.0%	6	0.0%	6	0.0%	6	0.0%
Non-Road	111	111	0.0%	111	0.0%	111	0.0%	111	0.0%
On-Road	176	176	-0.4%	176	0.0%	176	0.0%	176	-0.4%
Total	**396**	**396**	**-0.2%**	**396**	**0.0%**	**384**	**-3.0%**	**384**	**-3.2%**

Table 1-4. Summary of anthropogenic CO emissions (tons per day) in DMA plus Weld County for the 2007 Base Case and four 2007 control scenarios day-specific for Tuesday June 25, 2002 and grid cell representations of counties with on-road mobile being entire link-based network..

CO	2007Base	2007 RVP		2007 Flash		2007 RICE		2007 All	
Category	(tpd)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)	(tpd)	(%)
Points	41	41	0.0%	41	0.0%	30	-26.2%	30	-26.2%
Area	2	2	0.0%	2	0.0%	2	0.0%	2	0.0%
Off-Road	1312	1312	0.0%	1312	0.0%	1312	0.0%	1312	0.0%
On-Road	1284	1193	-7.1%	1284	0.0%	1284	0.0%	1193	-7.1%
Total	**2639**	**2547**	**-3.5%**	**2639**	**0.0%**	**2628**	**-0.4%**	**2537**	**-3.9%**

2007 Emission Reduction Sensitivity Scenarios

Three additional emission reductions sensitivity scenarios were run to better understand the relationship of controlling anthropogenic VOC versus NOx emissions in the DMA+Weld Counties. The emission reduction sensitivity scenarios performed across-the-board 20% reductions in anthropogenic VOC, NOx and combined VOC and NOx emissions. These across-the-board anthropogenic emission reductions were performed starting with the 2007 Three Control Strategy (cntl4) emissions strategy:

> 20% NOx Control (cntl5): 20% reduction in all anthropogenic NOx emissions from the 2007 Three Control Strategy level in the DMA+Weld Counties.
>
> 20% VOC Control (cntl6): 20% reduction in all anthropogenic VOC emissions from the 2007 Three Control Strategy level in the DMA+Weld Counties.
>
> 20% VOC&NOx Control (cntl7): 20% reduction in all anthropogenic NOx and VOC emissions from the 2007 Three Control Strategy level in the DMA+Weld Counties.

2. 2007 BASE CASE AND CONTROL STRATEGY MODELING RESULTS

The results for the 2007 Base Case and four 2007 control strategies are discussed below.

2007 BASE CASE

Appendices A and B display the daily maximum 8-hour ozone concentrations in the DMA and surrounding area for the, respectively 2002 and 2007 Base Case simulations. Note that in these and other Appendices results are presented for just June 27 through July 1, 2002 since those are the days that are used in projecting attainment of the 8-hour ozone standard. Appendix C displays differences in daily maximum 8-hour ozone concentrations between the 2002 and 2007 Base Case simulations. The spatial distribution and magnitudes of the estimated 8-hour ozone concentrations for the 2002 Base Case and 2007 Base Case simulations are quite similar. Figure 2-1 displays the 2002 Base Case and the differences between 2002 and 2007 Base Case estimated daily maximum 8-hour ozone concentrations on July 1, 2001. Results for the rest of the June 2002 episode are provided in Appendices A-C. The changes in emissions from the 2002 Base Case to the 2007 Base Case conditions results in ozone increases in the central DMA (primarily Denver County) and ozone reductions outside of the central DMA. On July 1, 2002, the magnitude of the maximum 8-hour ozone increase in downtown Denver (+4 ppb) is comparable to the maximum ozone decrease to the southwest of downtown Denver (-4 ppb). Results for other episode days are similar (see Appendix C).

It is important to note that the locations of ozone increases due to the changes in 2002 and 2007 Base Case emissions are areas with relatively lower (< 70 ppb) 8-hour ozone concentrations. Also important is the fact that the areas of highest ozone reductions due to the changes in emissions from 2002 to 2007 are the areas of highest estimated 8-hour ozone concentrations in the 2002 Base Case. The ozone increases due to changes in emissions from 2002 to 2007 in central DMA is due to the local NOx emissions reductions (see Table 1-2). In downtown Denver ozone formation is expected to be more VOC sensitive so that reducing NOx emissions increases ozone due to: (1) a reduction in the ozone titration reaction with NO (NO + O3 → NO2 + O2) so that less ozone is scavenged by the primary emitted NO in the NOx control case; and (2) reduction in the NOx inhibition effect where the NOx controls reduces the amount of NO2 available to react with the hydroxyl radical (NO2 + OH → HNO3) thereby result in more radicals being available to form ozone in the NOx control case. The disbenefits of NOx control are expected to occur in most large urban areas. In fact, recent studies on the effects of weekday versus weekend day ozone concentrations have observed this phenomena in the Los Angeles area (e.g., Lawson, 2003) as well as in Denver (Reddy, 2002).

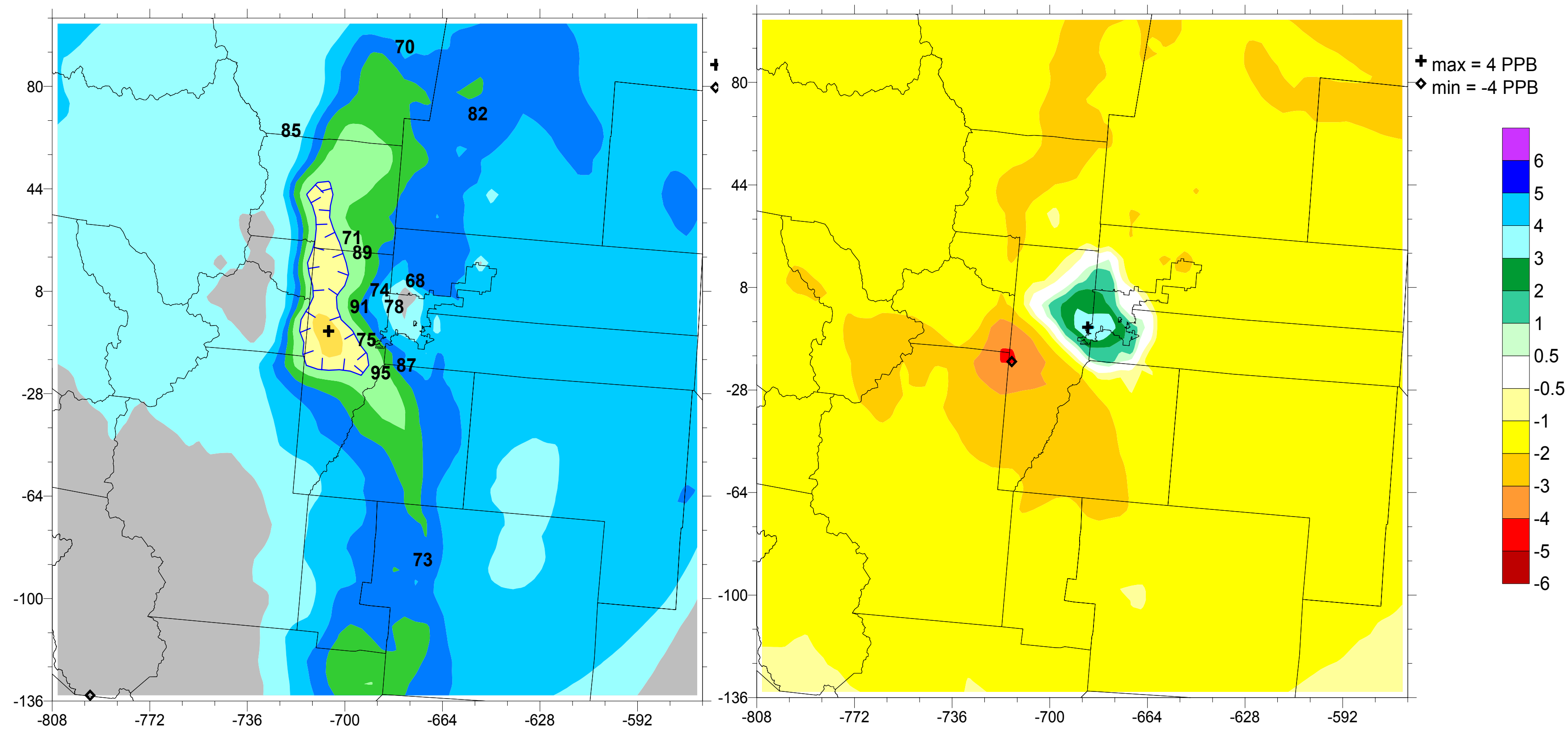


Figure 2-1. Daily maximum 8-hour ozone concentrations (ppb) for the 2002 Base Case (left) and differences in daily maximum 8-hour ozone concentrations between the 2002 Base Case and 2007 Base Case (right, 2007-2002) on July 1, 2002.

2007 CONTROL STRATEGIES

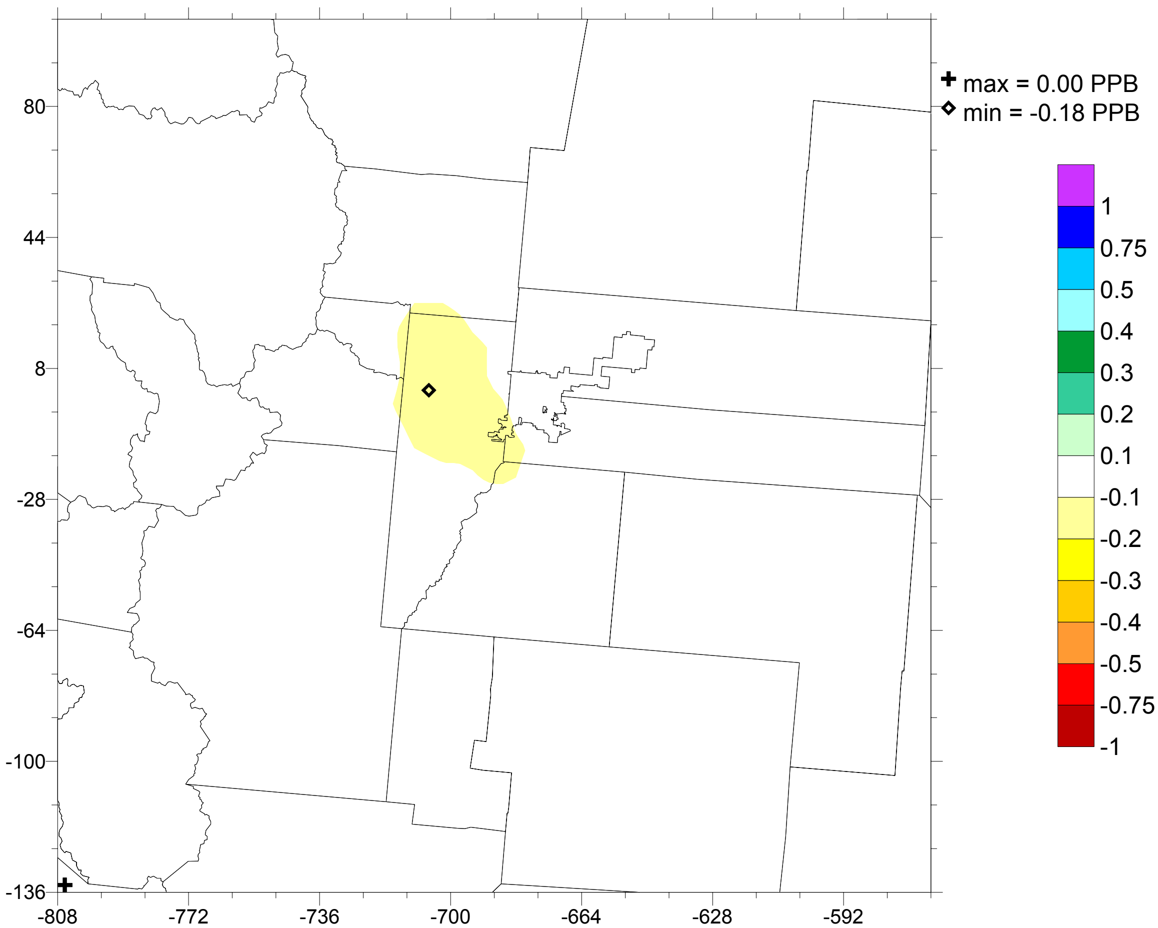
Difference plots of daily maximum 8-hour ozone concentrations between the 2007 control scenarios and the 2007 Base Case for the RVP, Flash, RICE and Three Control Strategy emission scenarios are shown in, respectively, Appendices D, E, F and G. Difference plots for July 1, 2002 and each of the 2007 control scenarios are reproduced in Figures 2-2 through 2-5.

The 2007 RVP control strategy results in reductions (-0.1 to –0.2 ppb) in 8-hour ozone concentrations immediately downwind of the central DMA (Figure 2-2 and Appendix D). Although small, these ozone reductions occur where elevated 8-hour ozone concentrations occur in the 2007 Base Case simulation (see Appendices B and D).

The 2007 Flash emissions control scenario results in larger ozone reductions than the RVP control scenario (as high as –0.77 ppb). However, the largest ozone reductions tend to occur in Weld County away from the areas of elevated ozone concentrations in the 2007 Base Case (see Appendices B and E). Some ozone reductions due to the Flash VOC emissions controls do occur downwind in areas of higher estimated ozone concentrations on some days, such as at Rocky Flats North on July 1, 2002 as shown in Figure 2-3. However, whether the Flash VOC emissions results in ozone reductions at DMA monitors varies day-to-day. As seen in Appendix E, the Flash VOC emissions do not affect ozone in the DMA region on June 27 and 29 as they appear to be advected away from the DMA.

The 2007 RICE emissions control scenario results in areas of ozone increases and decreases (Figure 2-4 and Appendix F). The areas of ozone increases are highly localized and occur at the locations of the RICE units, which is primarily in Weld County. The ozone reductions are more widespread with a maximum reduction of –0.7 ppb.

The 2007 Three Control Strategy combines the effects of the RVP, Flash and RICE controls (Figure 2-5 and Appendix G). The maximum ozone reduction when all three control measures are applied is –1.2 ppb.



CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Control Strategy #1 - 2007 Base Case

Figure 2-2. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 RVP (cntl1) control scenario and the 2007 Base Case on July 1, 2002.

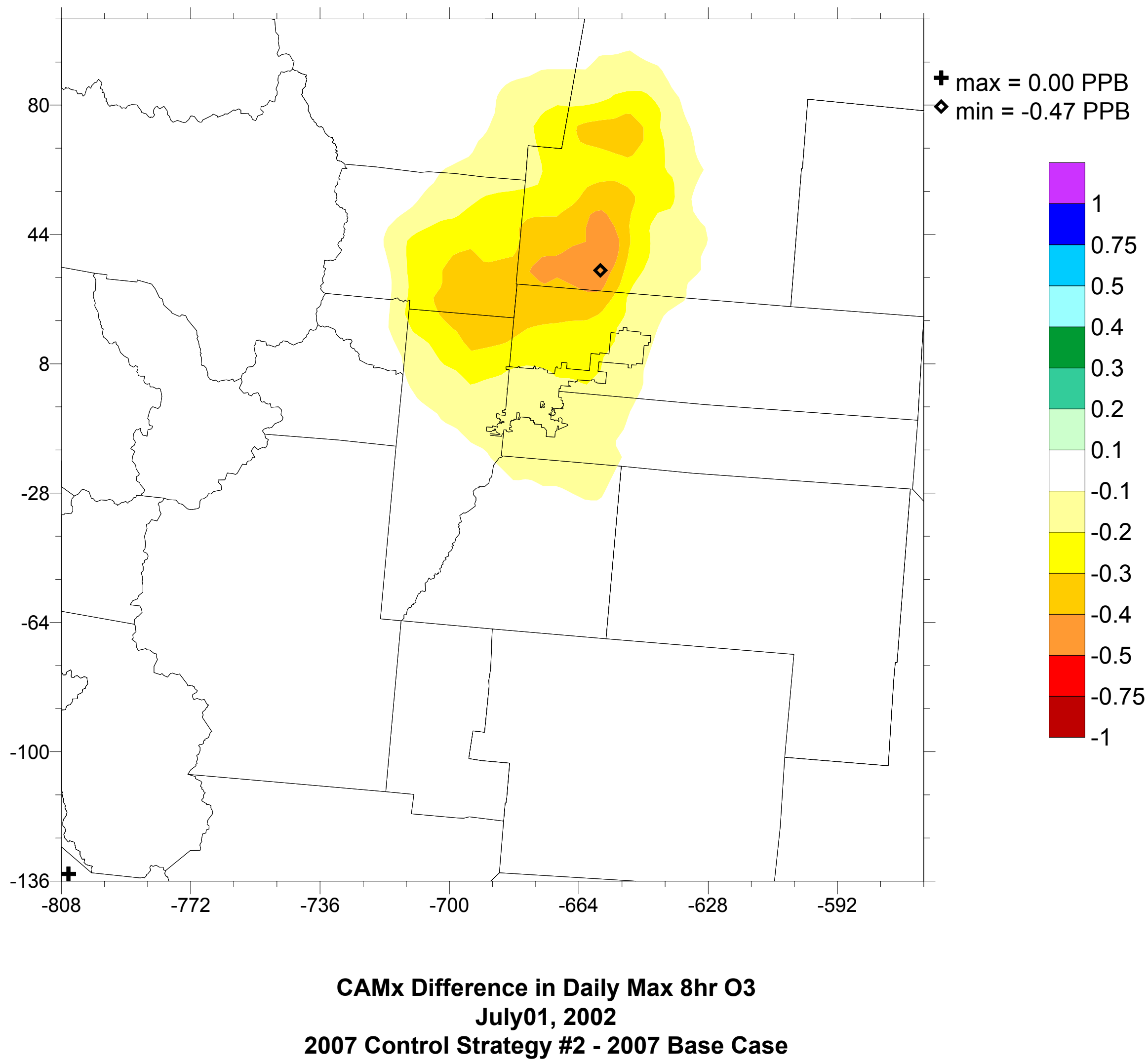
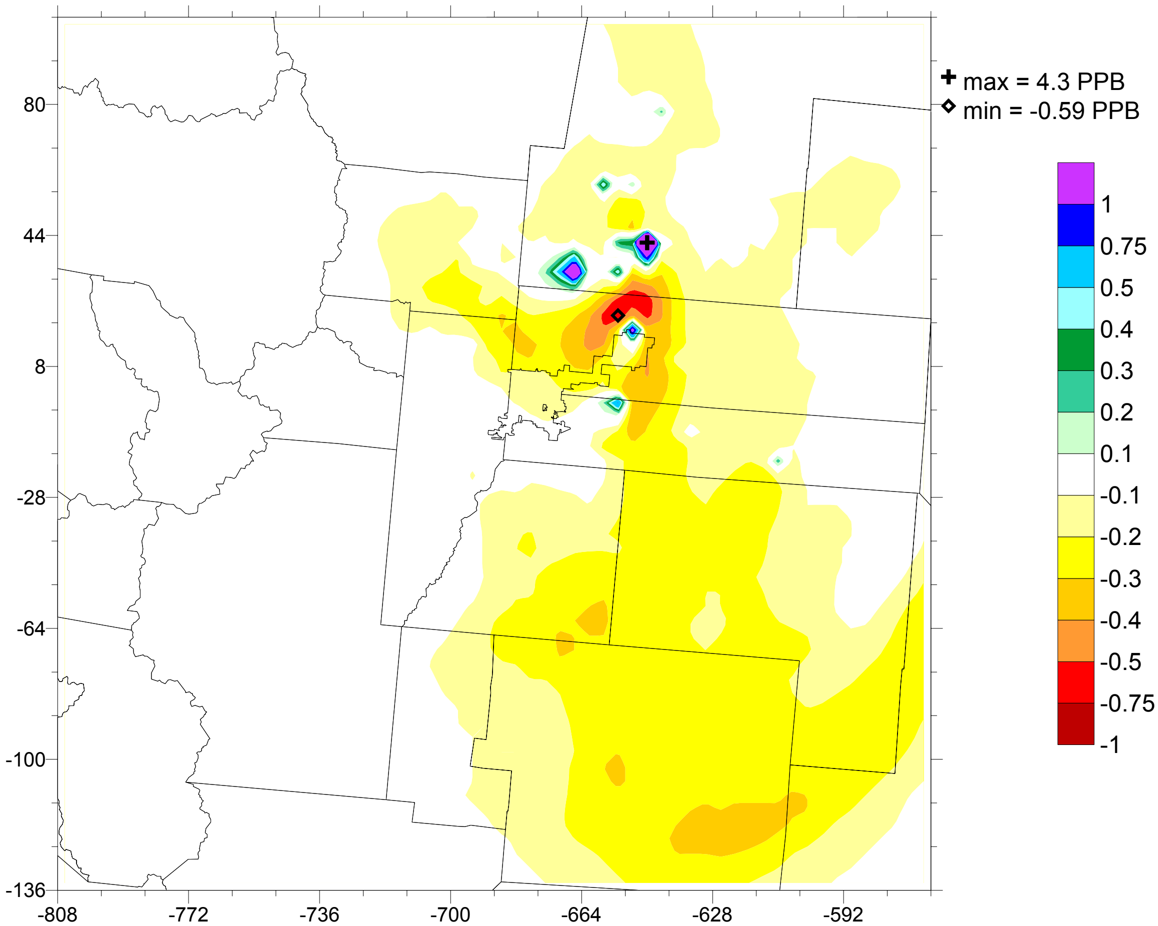
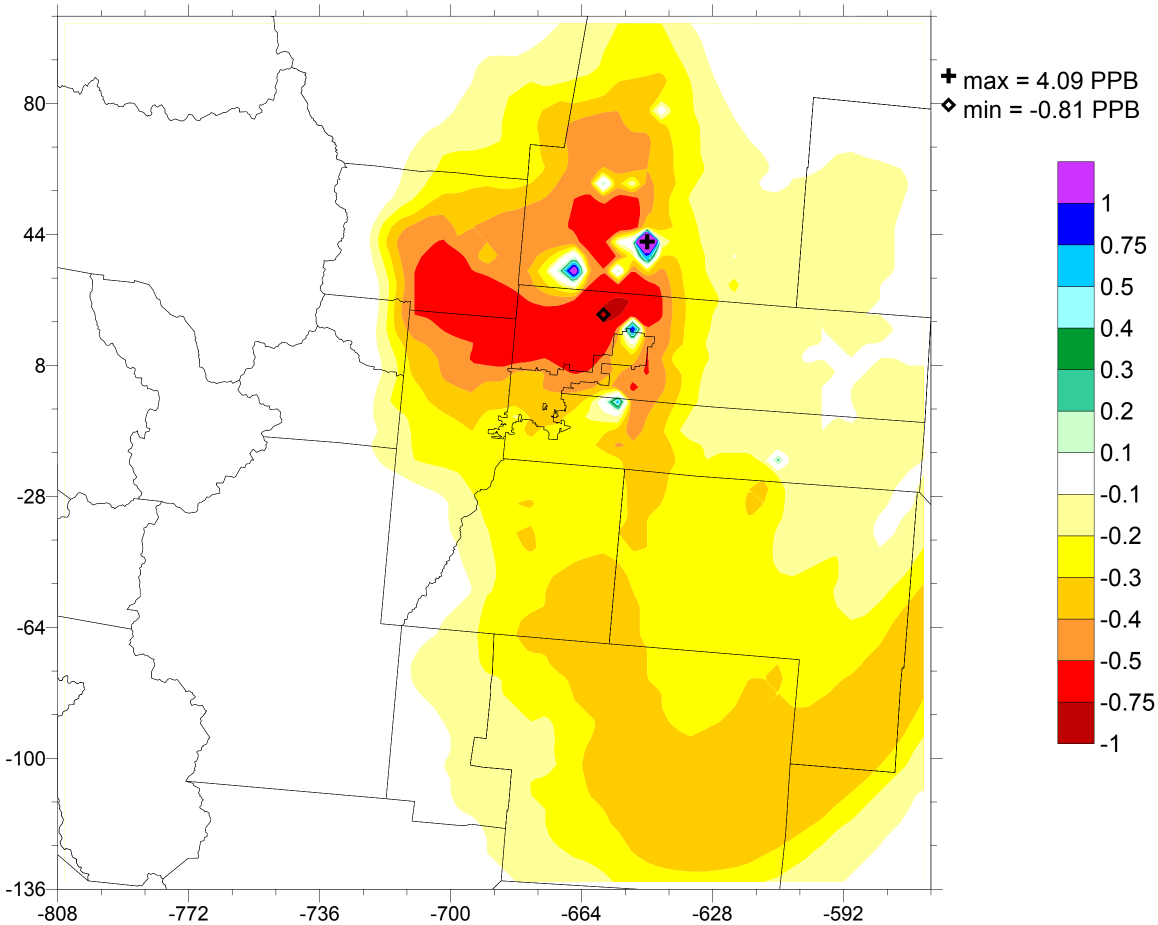


Figure 2-3. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 Flash (cntl2) control scenario and the 2007 Base Case on July 1, 2002.



CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Control Strategy #3 - 2007 Base Case

Figure 2-4. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 RICE (cntl3) control scenario and the 2007 Base Case on July 1, 2002.



CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case

Figure 2-5. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 Three Control Strategy (cntl4) control scenario and the 2007 Base Case on July 1, 2002.

PROJECTED 2007 8-HOUR OZONE DESIGN VALUES

The EPA draft guidance for 8-hour ozone modeling has specific procedures for using the modeling results in a relative fashion to scale the observed 8-hour ozone Design Values to project future-year 8-hour ozone Design Values for comparisons with the standard (EPA, 1999). These procedures were used to estimate 2007 8-hour ozone Design Values under the various 2007 emission scenarios.

The procedures for projecting future-year 8-hour ozone Design Values starts with the current-year observed 8-hour ozone Design Values, for which the observed values from the 2001-2003 3-year period were utilized.

The 2002 Base Case and 2007 emission scenario modeling results are used in a relative fashion to scale the observed 8-hour ozone Design Values. This is done through a model estimative Relative Reduction Factor (RRF) that is the ratio of the estimated 8-hour ozone concentrations from the 2007 emission scenario to the 2002 Base Case emissions scenario. The RRF is used to scale the current year Design Value (DVC) to estimate the future-year 8-hour ozone Design Value (DVF):

$$DVF = DVC \times RRF$$

The RRF is defined as the ratio of the average of the maximum 8-hour ozone concentrations near each monitor for the 2007 emissions scenario to the 2002 Base Case. Near the monitor is defined by an array of 9 x 9 grid cells centered on the monitor for the 4 km grid cell resolution case of the Denver application (EPA, 1999). With two exceptions (define below), EPA's draft 8-hour modeling guidance is followed to estimate the future-year 8-hour ozone Design Values for the 2007 emission scenarios.

Table 2-1 lists the current year observed and projected 2007 8-hour ozone Design Values for the 2007 emission scenarios. There are three ozone monitors in the Denver area that are currently (2001-2003) violating the 8-hour ozone standard of 84 ppb: Rocky Flats (87 ppb); NREL (85 ppb); and Chatfield (85 ppb). Under all of the 2007 emission scenarios the NREL and Chatfield monitors are estimated to come into compliance with the 8-hour ozone standard. However, the Rocky Flats monitor is projected to still violate the 8-hour ozone standard (i.e., projected 8-hour ozone Design Value of 84.5 ppb or higher) for the 2007 Base Case (86.2 ppb), RVP (86.1 ppb), Flash (86.1 ppb), RICE (86.2 ppb) and all three control measures combined (85.9 ppb).

The projection of emissions from the 2002 Base Case to the 2007 Base Case conditions results in the largest reduction in the projected 8-hour ozone Design Value at Rocky Flats (-0.8 ppb), with each additional control strategy (RVP, Flash and RICE) resulting in approximately another –0.1 ppb reduction each so that the projected Design Value for the 2007 Three Control Strategy is 85.9 ppb. It should be noted that EPA's draft 8-hour ozone modeling guidance recommends rounding the final projected 8-hour ozone Design Values, however we are retaining their precision to the nearest tenth of a ppb in order to see the effects of the different strategies.

Table 2-1. Current year (2001-2003) observed and 2007 projected 8-hour ozone Design Values (ppb) at ozone monitors in the Denver area.

Ozone Monitor	Observed 2001-03	2007	2007 Control Scenarios			
		Base	RVP	Flash	RICE	3 Cntrl
Weld County	81	79.0	78.9	78.6	78.9	78.5
Rocky Mtn. NP	81	79.3	79.3	79.2	79.2	78.9
Rocky Flats	87	86.2	86.1	86.1	86.2	85.9
NREL	85	84.2	84.1	84.1	84.1	83.9
Arvada	76	75.4	75.3	75.3	75.4	75.2
Welby	66	66.1	66.0	66.0	66.1	65.8
S. Boulder	77	76.3	76.2	76.2	76.3	76.0
Carriage	76	74.6	74.5	74.5	74.6	74.4
Highland	81	79.6	79.5	79.5	79.5	79.3
Chatfield Res.	85	83.2	83.1	83.1	83.1	82.9

Table 2-2 displays the details in projecting the 2007 8-hour ozone Design Values for the 2007 Three Control Strategy emissions scenario. For each day the estimated maximum 8-hour ozone near (within a 9 x 9 array of 4 km cells centered over the monitor) each monitor is extracted for the 2002 Base Case and 2007 Three Control Strategy. These daily maximum 8-hour ozone concentrations are averaged for all days in which the 2002 Base Case estimate is 70 ppb or greater (highlighted cells in Table 2-2). The RRF is then taken as the ratio of the averages across the 2007 Three Control Strategy to the 2002 Base Case. Finally, the 2007 Three Control Strategy projected 8-hour ozone Design Value is given as the product of the 2001-2003 observed Design Value times the RRF. For example, for the Rocky Flats monitor the 2001-2003 observed 8-hour ozone Design Value is 87 ppb and the 2007 Three Control strategy RRF is 0.988 resulting in a projected Design Value of 85.9 (=0.988 x 87).

Even though there are 7 episode days in the June 2002 episode, the projected Design Values are based on only one (Weld County monitor) to four (Rocky Flats monitor) days because some of the early days are screened out because the 2002 Base Case estimated ozone value is < 70 ppb.

Also note there are two deviations from EPA's draft guidance in this calculation approach. In EPA's guidance they propose that the average values across the different days for the 2002 and 2007 emission scenarios be rounded to the nearest ppb prior to calculating the RFF. However, this doesn't make sense as precision is lost and it will calculate step function RRFs, which is illogical. Also, EPA's guidance recommends rounding the RRFs to two significant figures to the right of the decimal place, whereas we use three. Again we believe this is an unnecessary loss of precision, however in this case it doesn't really make any difference.

Table 2-2. Details of 8-hour ozone Design Values projections for the 2007 Three Control Strategy (Cntl4) emissions scenario.

Site	2001-03 Obs DV	Jun 25	Jun 26	Jun 27	Jun 28	Jun 29	Jun 30	Jul 1	# Days	
				2002 Modeled 8-Hr Ozone (ppb)						
Weld County	81	61.0	57.2	65.2	60.6	69.4	66.9	**70.9**	1	
Rocky Mtn. NP	81	63.1	64.3	67.4	62.0	**71.4**	**76.0**	**79.1**	3	
Rocky Flats	87	62.8	62.7	**70.9**	62.1	**70.5**	**73.8**	**84.5**	4	
NREL	85	60.4	64.6	**70.9**	64.9	63.1	**73.8**	**87.2**	3	
Arvada	76	59.8	60.0	**70.8**	63.1	69.1	**71.8**	**85.1**	3	
Welby	66	56.6	55.2	62.6	66.5	**70.0**	66.2	**72.7**	2	
S. Boulder	77	63.0	62.8	**70.9**	63.0	**70.9**	**74.1**	**84.5**	4	
Carriage	76	58.4	62.3	68.8	67.9	66.6	**71.9**	**83.8**	2	
Highland	81	57.4	66.3	62.7	**73.0**	69.7	**71.9**	**81.6**	3	
Chatfield Res.	85	57.9	66.5	63.4	**73.0**	69.7	**71.9**	**85.9**	3	
	2001-03 Obs DV			**2007 Cntl4 Modeled 8-Hr Ozone (ppb)**					**RRF**	**2007 DV**
Weld County	81	59.9	56.3	64.3	59.5	67.9	65.5	68.7	0.969	78.5
Rocky Mtn. NP	81	62.8	62.8	66.0	61.0	70.1	74.2	76.5	0.974	78.9
Rocky Flats	87	63.1	61.7	70.5	61.3	69.6	73.4	82.6	0.988	85.9
NREL	85	60.3	65.4	70.5	65.4	62.5	73.4	85.0	0.987	83.9
Arvada	76	60.0	60.8	70.5	62.3	68.1	70.9	83.8	0.989	75.2
Welby	66	55.9	54.6	64.3	65.2	69.1	67.6	73.2	0.997	65.8
S. Boulder	77	63.3	61.9	70.5	62.1	70.1	73.4	82.6	0.987	76.0
Carriage	76	59.0	64.1	69.3	68.3	65.9	70.4	81.9	0.979	74.4
Highland	81	57.0	66.7	63.2	71.0	67.5	70.4	80.5	0.980	79.3
Chatfield Res.	85	57.9	66.7	61.6	71.0	67.5	70.4	83.8	0.976	82.9

3. 2007 EMISSION REDUCTION SENSITIVITY TESTS

The results from the three 20% emission reduction sensitivity tests are discussed in this section. Starting with the 2007 Three Control strategy (RVP, Flash and RICE control measures) emissions scenario, three additional emission reduction sensitivity simulations were performed that performed a 20% across-the-board reduction in anthropogenic emissions in the 8 county DMA+Weld region for VOC alone, NOx alone and combined VOC and NOx emissions.

Table 3-1 displays the projected 2007 8-hour ozone Design Values for each monitor in the Denver area and the 2007 Base Case and 2007 Three Control Strategy emissions scenarios and the three emission reduction sensitivity tests. Figure 3-1 through 3-3 displays the differences in daily maximum 8-hour ozone concentrations between the 2007 Three Control Strategy and the, respectively 20% VOC, 20% NOx and combined 20% VOC and NOx emission reductions sensitivity tests.

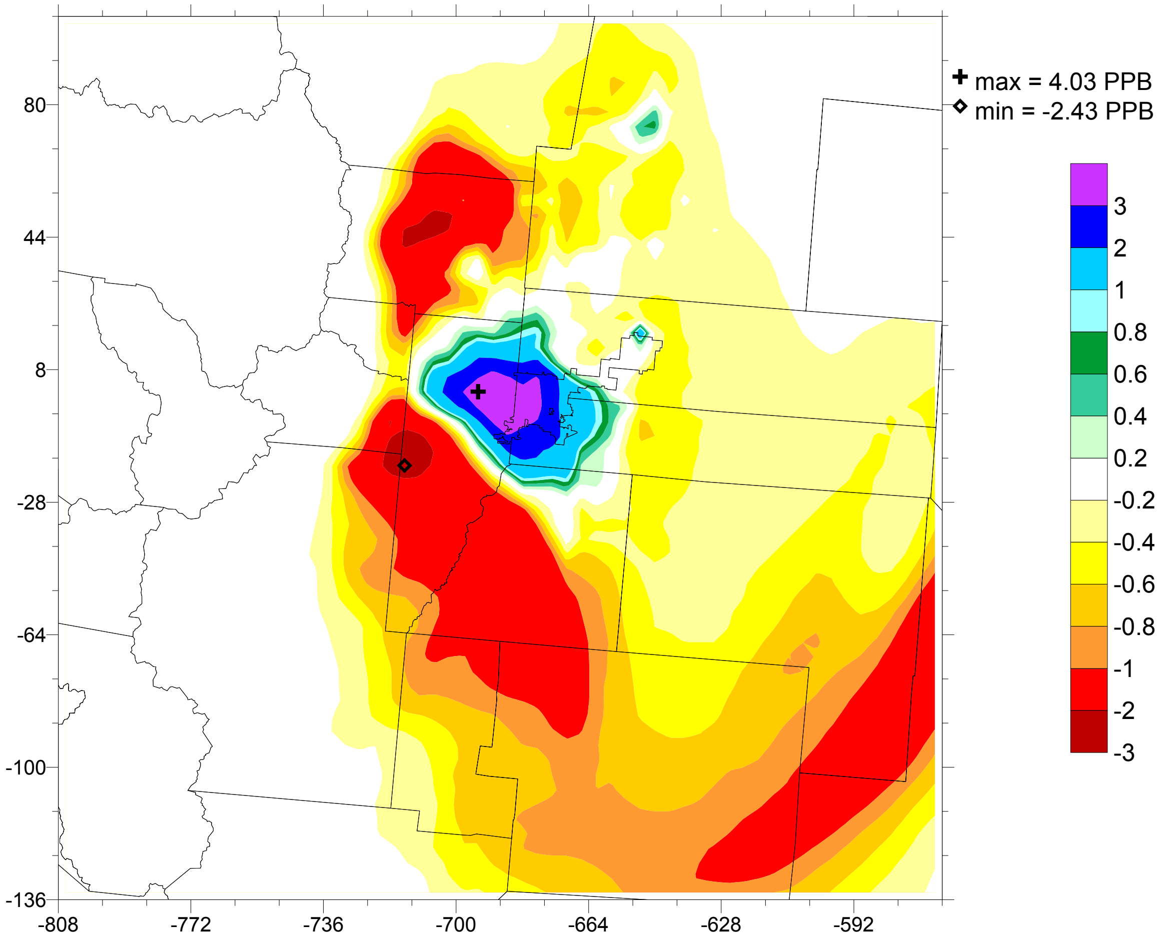
The effects of the 20% anthropogenic NOx control in the 8 county DMA+Weld region are to increase the projected 2007 8-hour ozone Design Values at the ozone monitors in and near the central Denver area and decreases at ozone monitors further away from downtown Denver (e.g., Rocky Mountain National Park). As seen in Appendix H, and Figure 3-1 for July 1, 2002, the increase in the ozone Design Values are due to NOx disbenefits in the central Denver area due to the NOx controls. These NOx disbenefits can be advected downwind from the central DMA, for example impacting the Rocky Flats monitors on June 27 and 30 (Appendix H). The 20% NOx control results in ozone reductions further way from the central DMA area. It is interesting to note that most of the ozone increases due to the NOx controls are in areas of relatively lower (< 70 ppb) ozone, whereas in most of the areas of the highest 8-hour ozone concentrations the NOx controls result in ozone reductions (compare Appendix B with Appendix H). At the key Rocky Flats monitor, the additional 20% NOx control on top of the 2007 Three Control strategy more than undoes the benefits of the three control measures as the 8-hour ozone Design Value is projected to increase from 85.9 ppb in the 2007 Three Control Strategy to 86.4 ppb in the 2007 20% NOx reduction sensitivity test, which compares with 86.2 ppb for the 2007 Base Case simulation.

The 20% VOC emissions reduction sensitivity results in reductions in ozone concentrations (Appendix I and Figure 3-2) and correspondingly reductions in the projected 8-hour ozone Design Values. At the Rocky Flats monitor the additional 20% VOC emission reduction is estimated to reduce the 8-hour ozone Design value from 85.9 ppb in the 2007 Three Control Strategy to 85.0 ppb in the 20% VOC control. With the exception of the Rocky Mountain National Park monitor, local VOC control is more effective at reducing the 8-hour ozone Design Values in the Denver area than local NOx control.

Combining the 20% NOx and 20% VOC control results in projected 8-hour ozone Design Values that is greater than the 20% VOC control alone scenario at all monitors, except Rocky Mountain National Park. At the Rocky Flats monitors the combined VOC/NOx control sensitivity simulations results in an estimate 8-hour ozone Design Value of 85.4 ppb.

Table 3-1. Current year (2001-2003) observed and 2007 projected 8-hour ozone Design Values (ppb) at ozone monitors in the Denver area for the 20% VOC/NOx emission reduction sensitivity tests.

Ozone Monitor	Observed 2001-03		2007 Control Scenarios			
		2007 Base	Three Cntrl	20% NOx	20% VOC	20% Both
Weld County	81	79.0	78.5	78.3	78.0	77.8
Rocky Mtn.	81	79.3	78.9	77.6	78.5	77.2
Rocky Flats	87	86.2	85.9	86.4	85.0	85.4
NREL	85	84.2	83.9	84.4	83.0	83.4
Arvada	76	75.4	75.2	75.5	74.3	74.7
Welby	66	66.1	65.8	67.2	64.8	66.2
S. Boulder	77	76.3	76.0	76.2	75.2	75.5
Carriage	76	74.6	74.4	74.7	73.7	73.8
Highland	81	79.6	79.3	78.8	78.7	78.2
Chatfield	85	83.2	82.9	82.3	82.2	81.6



CAMx Difference in Daily Max 8hr O3
July01, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area

Figure 3-1. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 20% NOx control sensitivity test and the 2007 Three Control Strategy (2007 20% NOx – 2007 Three Control).

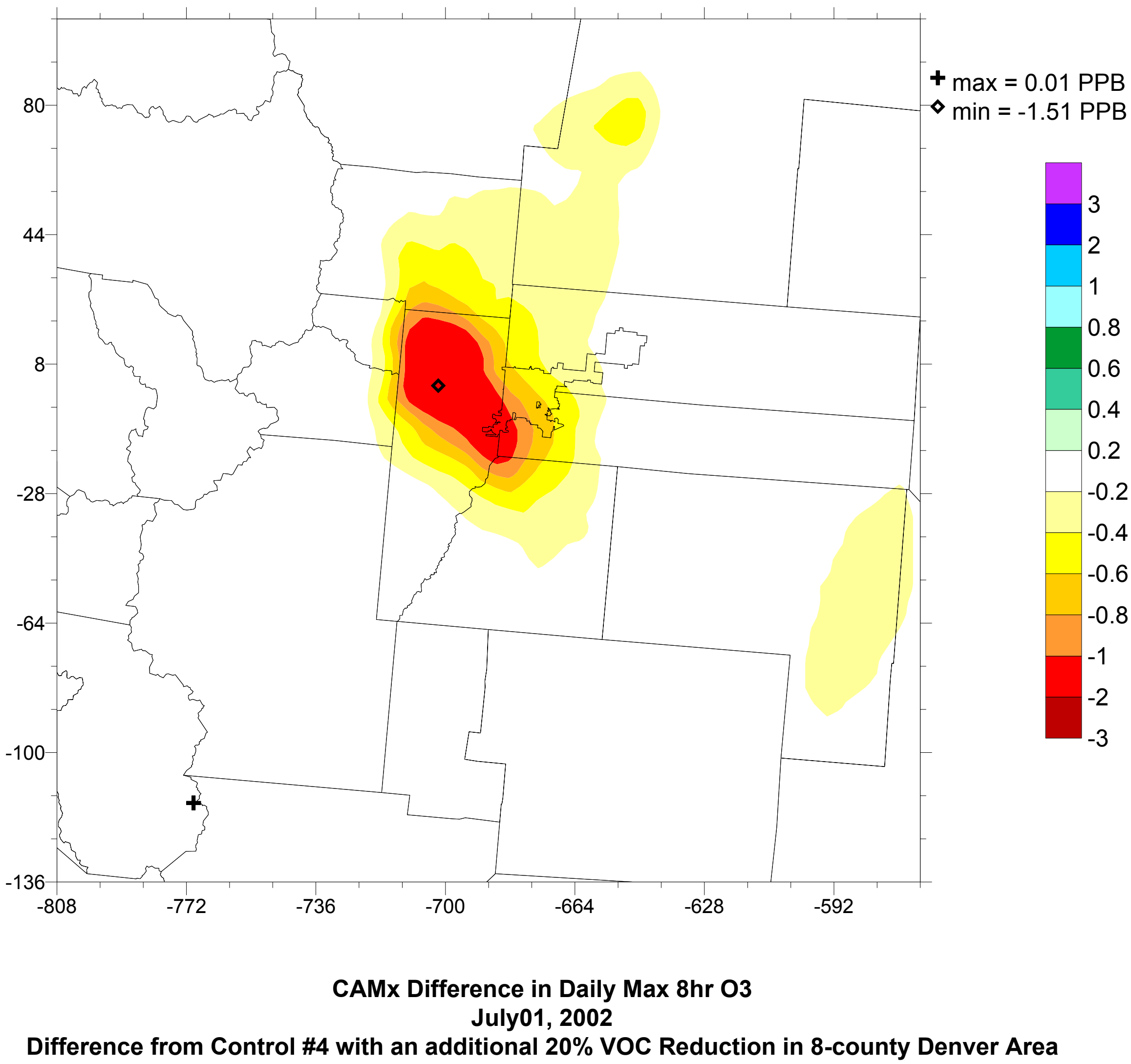
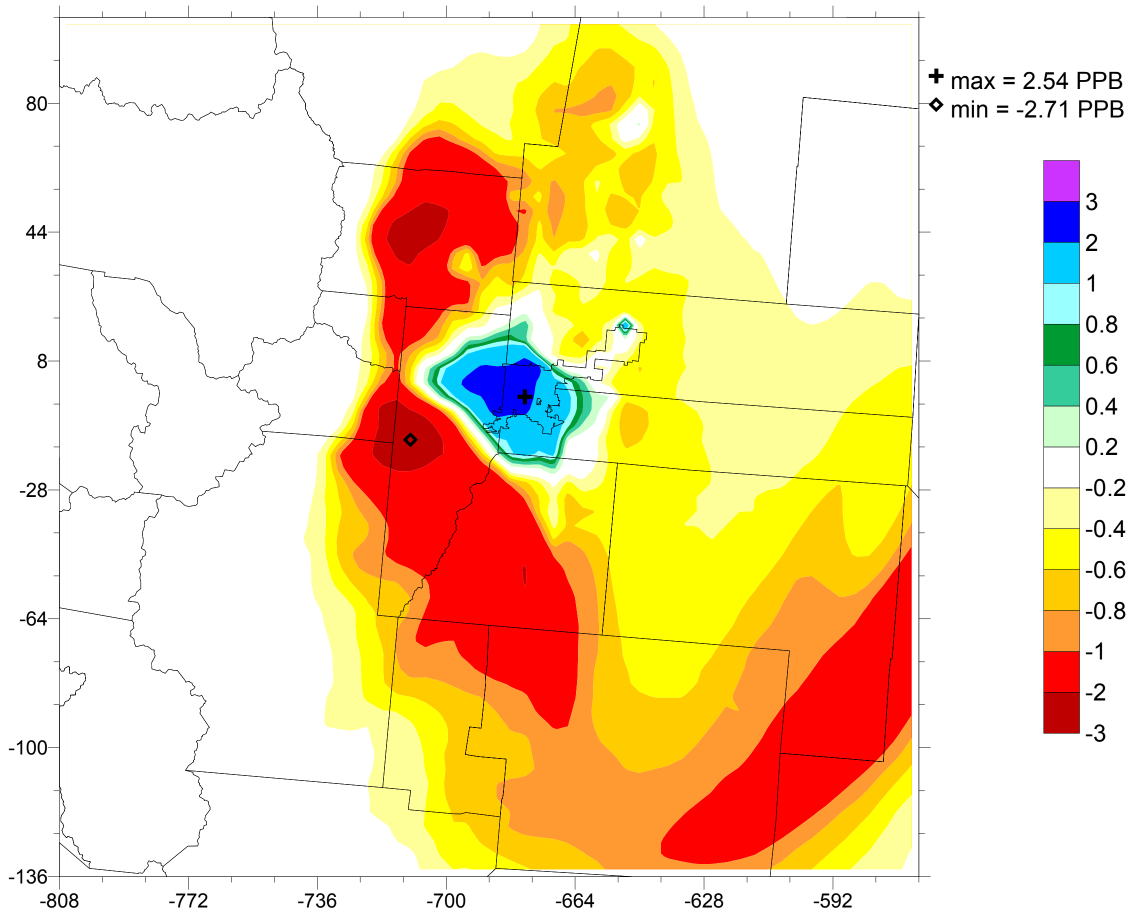


Figure 3-2. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 20% VOC control sensitivity test and the 2007 Three Control Strategy (2007 20% VOC – 2007 Three Control).



CAMx Difference in Daily Max 8hr O3
July01, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area

Figure 3-3. Differences in daily maximum 8-hour ozone concentrations (ppb) between the 2007 20% NOx and VOC control sensitivity test and the 2007 Three Control Strategy (2007 20% NOx&VOC – 2007 Three Control).

4. ANALYSIS OF RESULTS

Table 4-1 analyzes the 8-hour ozone Design Value calculations at the Rocky Flats monitor in more detail for the VOC/NOx emission reduction sensitivity tests. The model estimated 8-hour ozone Design Values appear to be very "stiff" in response to changes in emissions, that is the changes in emissions; result in little changes in the projected 8-hour ozone Design Values. One contributing factor to this stiffness is that on several of the days used in the Design Value scaling (i.e., June 27-30) the model estimated ozone in the 2002 Base Case is approximately 70 ppb and the 2001-2003 observed Design Value is 87 ppb. Thus the modeling results have less leverage in reducing ozone than the observed Design Value because a larger component of the ozone in the model is due to background than the observed Design Value. If the modeling results for just the highest estimated ozone day of July 1, 2002 were used in the Design Value scaling, then the projected 8-hour ozone Design Value at the Rocky Flats monitor would be as follows:

- 85.0 ppb for the 2007 Three Control Strategy;
- 85.9 ppb for the 2007 20% NOx Control;
- 83.8 ppb for the 2007 20% VOC Control; and
- 84.7 ppb for the 2007 20% NOx and VOC control.

Table 4-1. Data used in the 8-hour ozone Design Value projection at Rocky Flats for the 2007 Base Case, 2007 Three Control Strategy and 2007 emissions reductions sensitivity tests (2001-2003 observed 8-hour ozone Design Value = 87 ppb).

	Jun25	Jun26	Jun27	Jun28	Jun29	Jun30	Jul1	RRF	DV
2002 Base	62.8	62.7	70.9	62.1	70.5	73.8	84.5	1.000	87.0
2007 3 Cntl	63.1	61.7	70.5	61.3	69.6	73.4	82.6	0.9879	85.9
07 20% NOx	65.9	62.9	70.9	61.2	69.2	74.1	83.5	0.9934	86.4
07 20% VOC	61.9	61.2	69.7	60.9	68.9	72.6	81.4	0.9767	85.0
07 20% Both	64.7	61.8	70.1	60.8	68.4	73.4	82.3	0.9817	85.4

The reasons why the air quality modeling results are "stiff" are two-fold:

1. Although the model achieves the < 20% performance goal, it is underestimating some of the peak observed 8-hour ozone concentrations during some days; and
2. The observed 8-hour ozone Design Values are being driven by the observed values during the highly ozone conducive conditions that occurred during the summer of 2003 which the 2002 meteorological episode under-represents.

Fortunately EPA's modeling guidance has provisions for dealing with these sort of situations through the Weight of Evidence (WOE) attainment demonstration approach. EPA has several recommended modeling and data analysis activities for a WOE attainment demonstration in their guidance (EPA, 1999). Additional analysis that could be considered to address the two issues above would be to project 8-hour ozone Design Values using just the July 1, 2002 day in which the estimated 8-hour ozone concentrations (85 ppb) is close to both the Design Value (87 ppb) and observed value on this day (89 ppb). Another WOE activity would be to use the observed 2000-2002 observed ozone Design Values in the analysis to account for the fact that the unusual highly conducive ozone formation conditions of 2003 are not being used.

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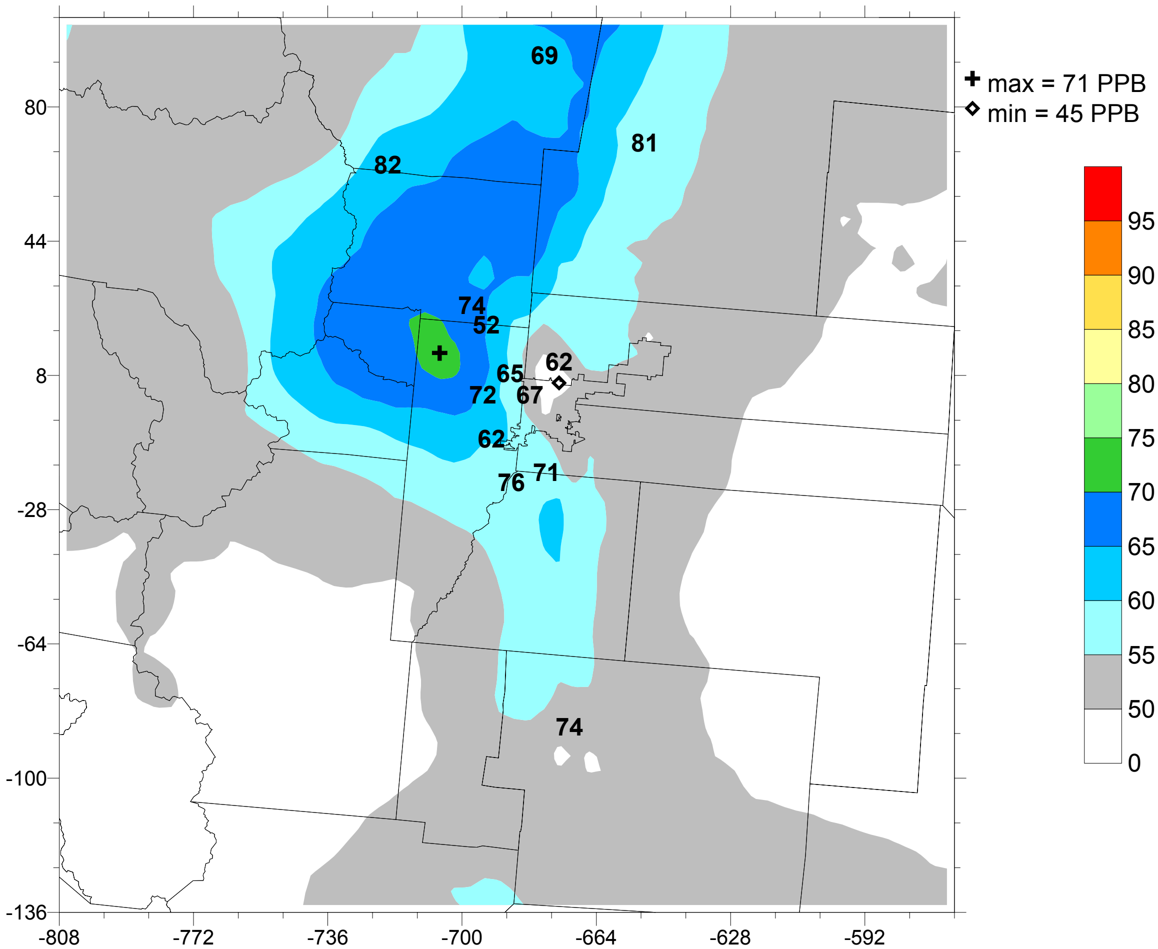
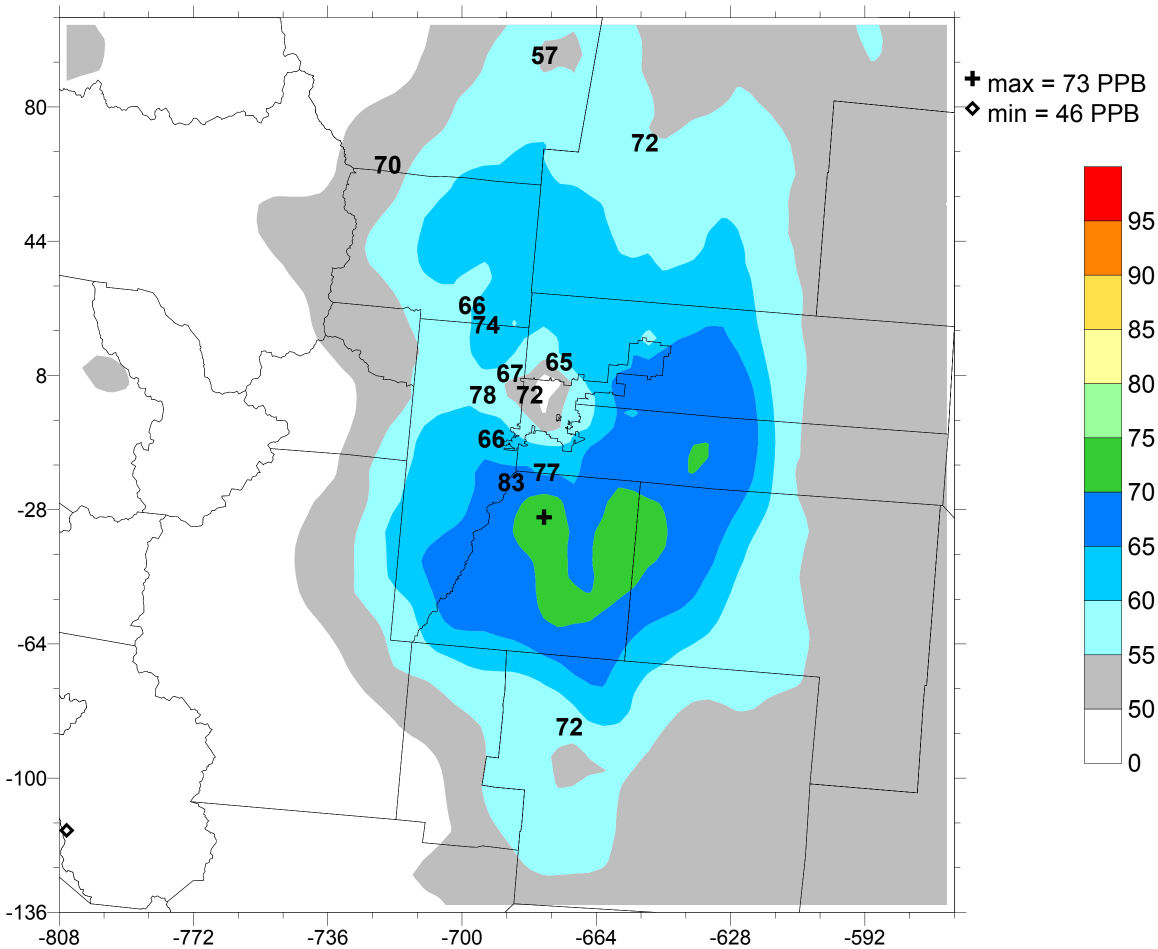
Appendix A

Estimated and Observed Daily Maximum 8-Hour
Ozone Concentrations (ppb) for the 36/12/4 km Run11a
2002 Base Case CAMx Simulation
(With Updated Northern VOC BCs and Wildfires)

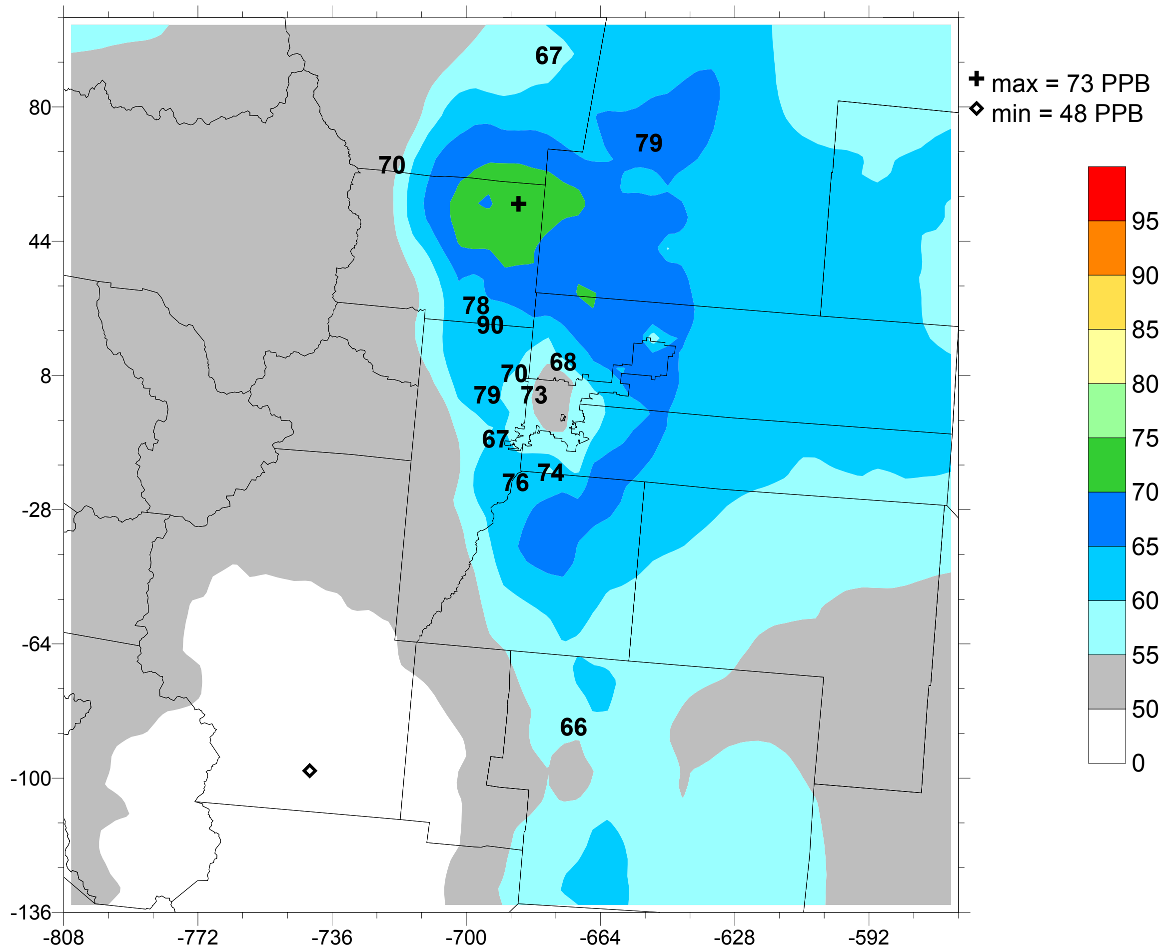
June 27 – July 1, 2002



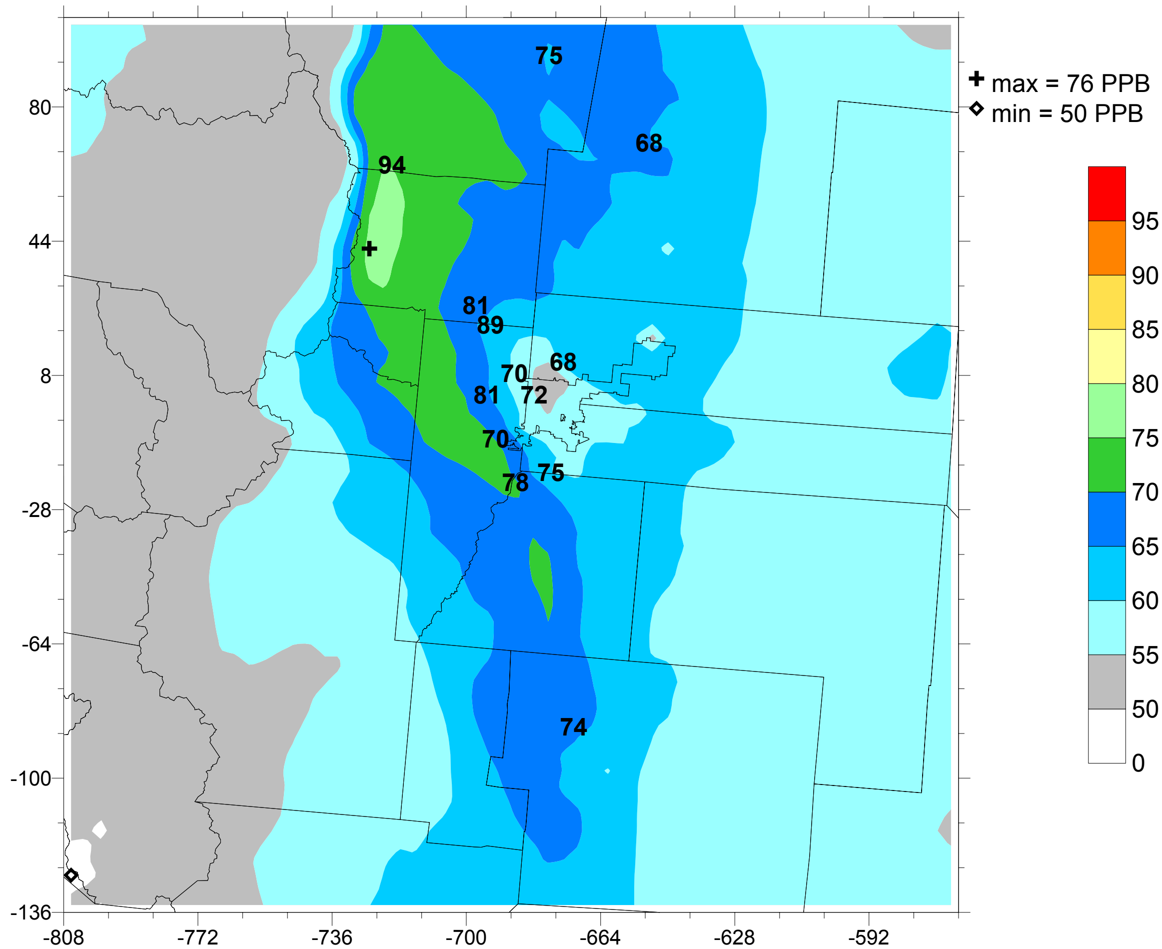
CAMx Daily Maximum 8hr O3
June27, 2002
36/12/4 Denver 2002 Base Case run11a



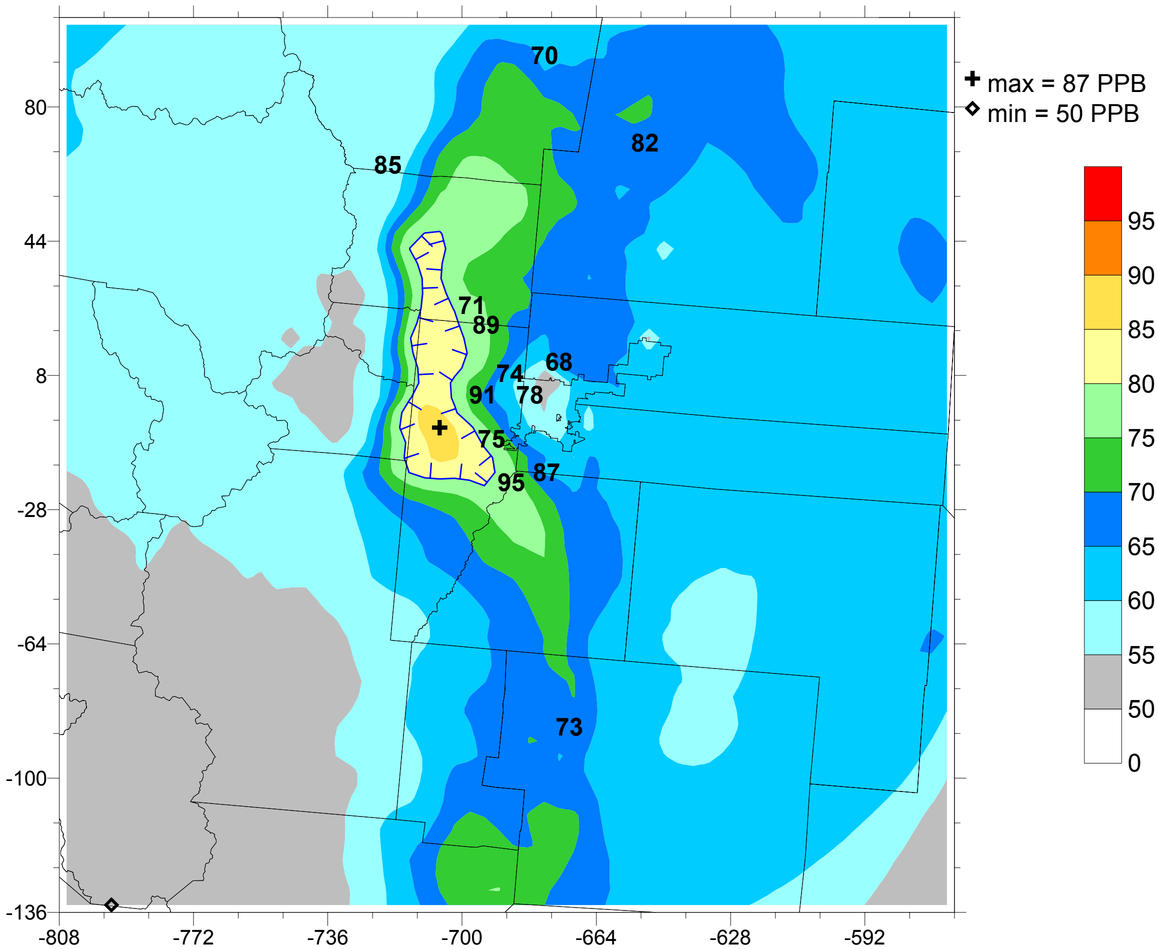
CAMx Daily Maximum 8hr O3
June28, 2002
36/12/4 Denver 2002 Base Case run11a



CAMx Daily Maximum 8hr O3
June29, 2002
36/12/4 Denver 2002 Base Case run11a



CAMx Daily Maximum 8hr O3
June30, 2002
36/12/4 Denver 2002 Base Case run11a

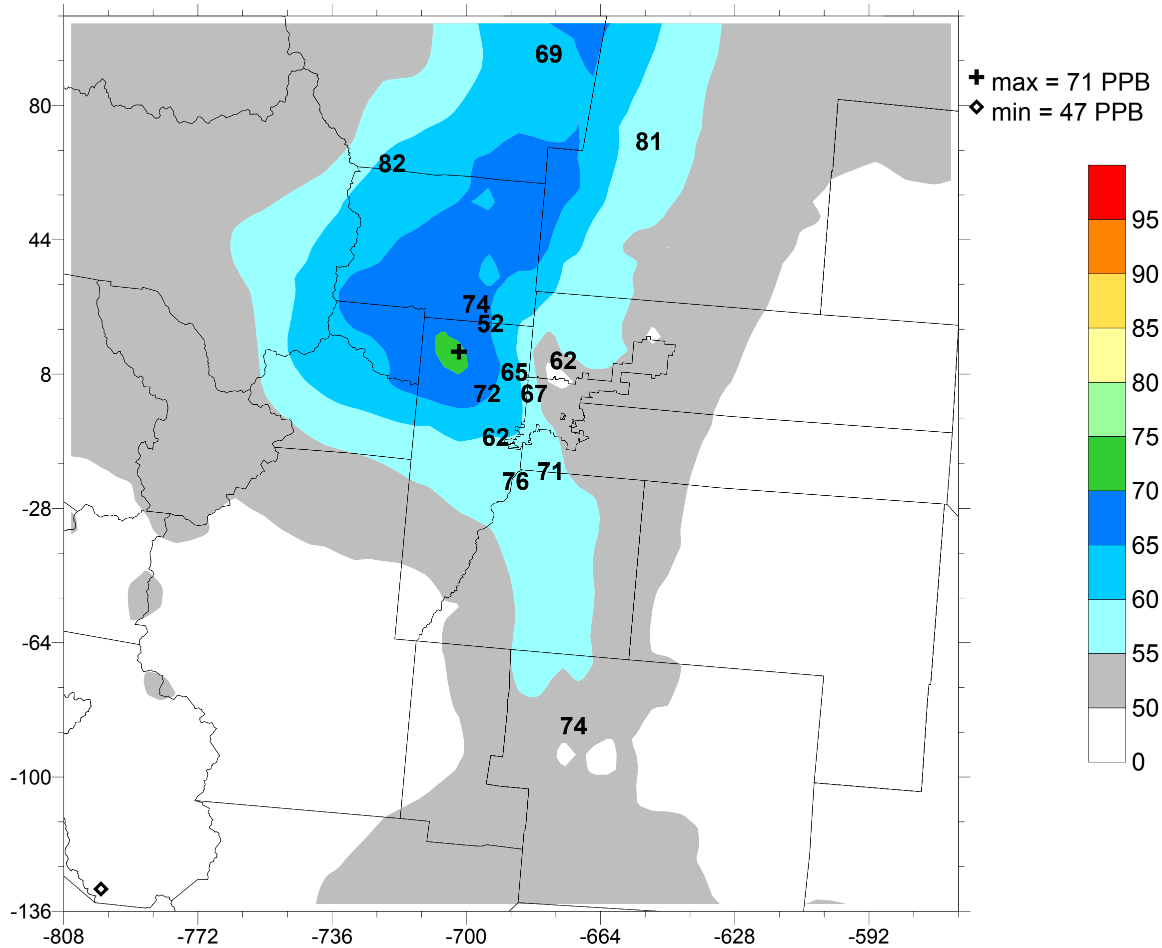


CAMx Daily Maximum 8hr O3
July01, 2002
36/12/4 Denver 2002 Base Case run11a

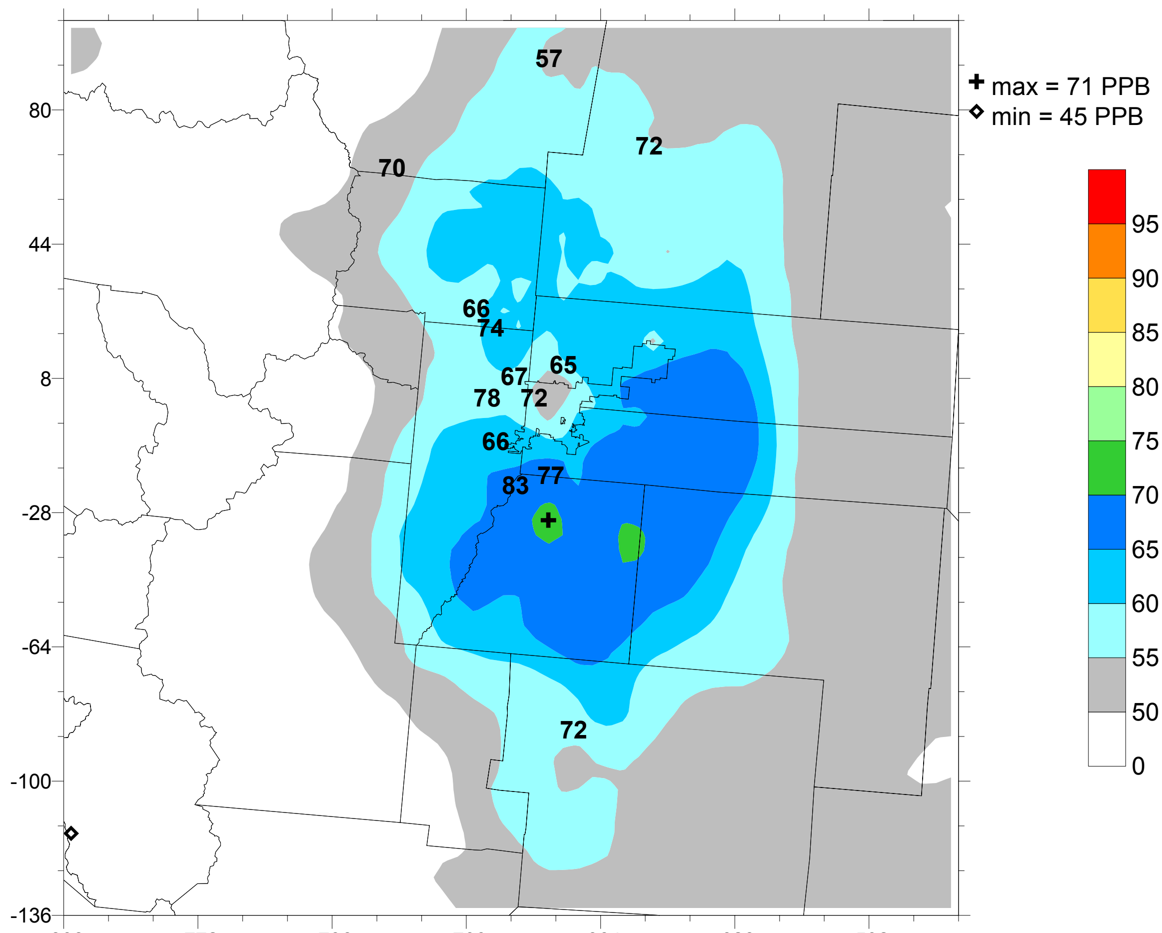
Appendix B

Estimated Daily Maximum 8-Hour
Ozone Concentrations (ppb) for the 36/12/4 km Run0711a
2007 Base Case CAMx Simulation

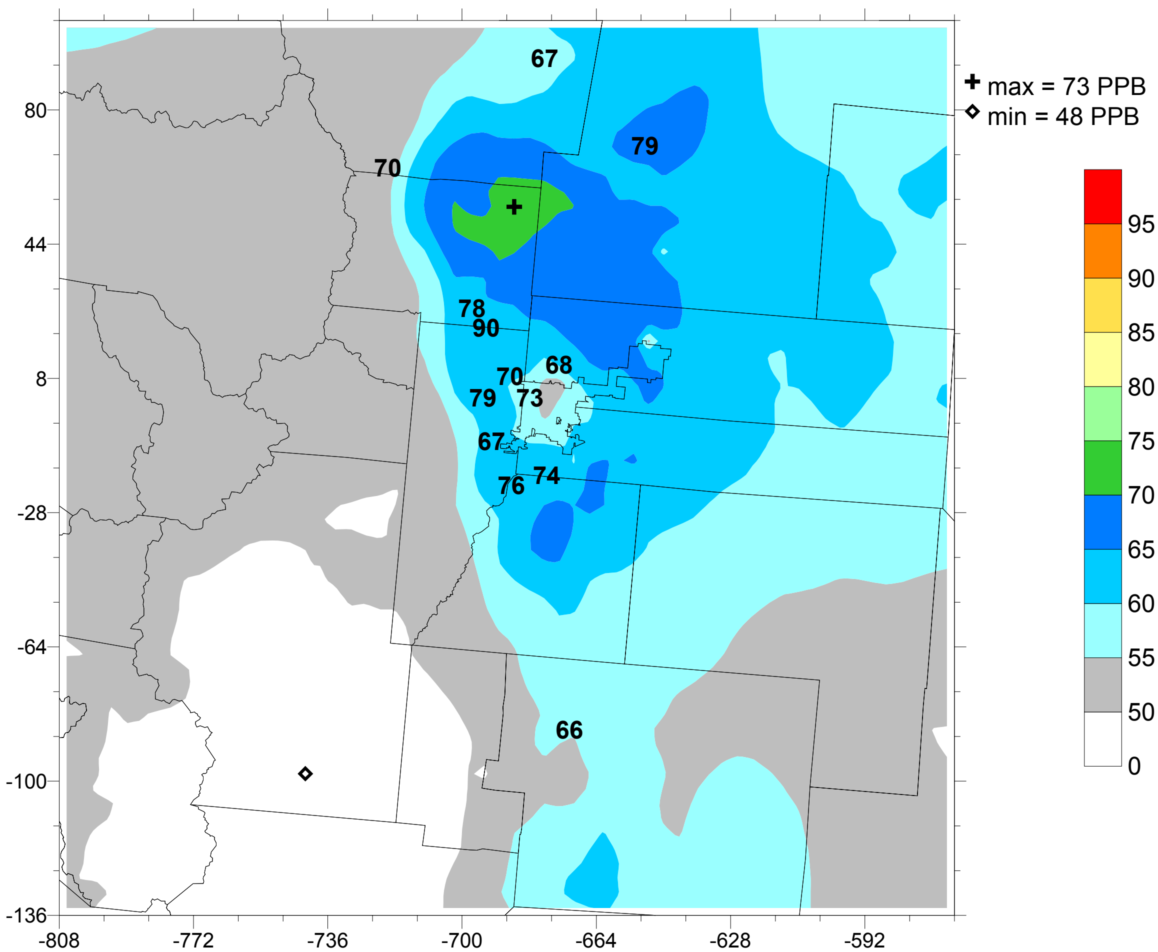
June 27 – July 1, 2002



CAMx Daily Maximum 8hr O3
June27, 2002
36/12/4 Denver Base Case for 2007:run11a



CAMx Daily Maximum 8hr O3
June28, 2002
36/12/4 Denver Base Case for 2007:run11a



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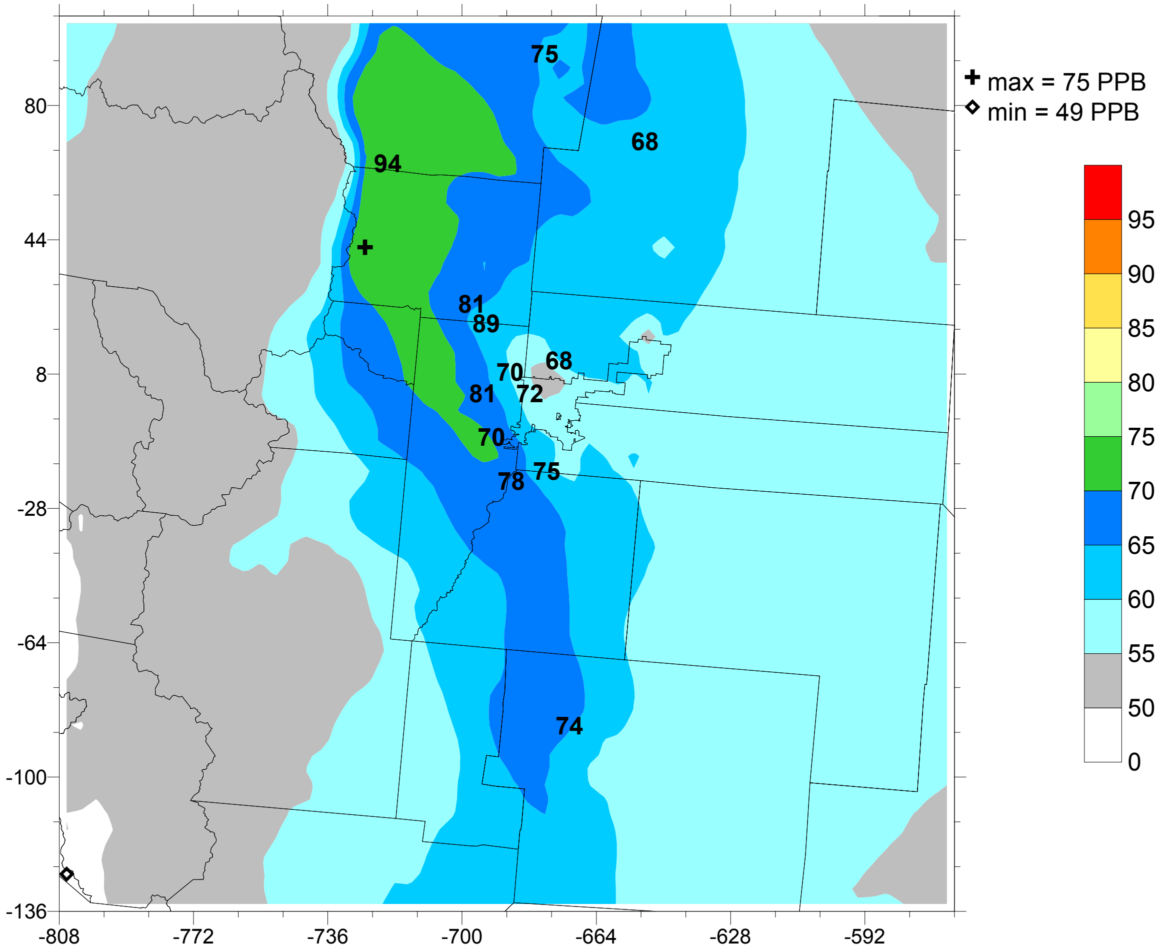
June29, 2002
36/12/4 Denver Base Case for 2007:run11a



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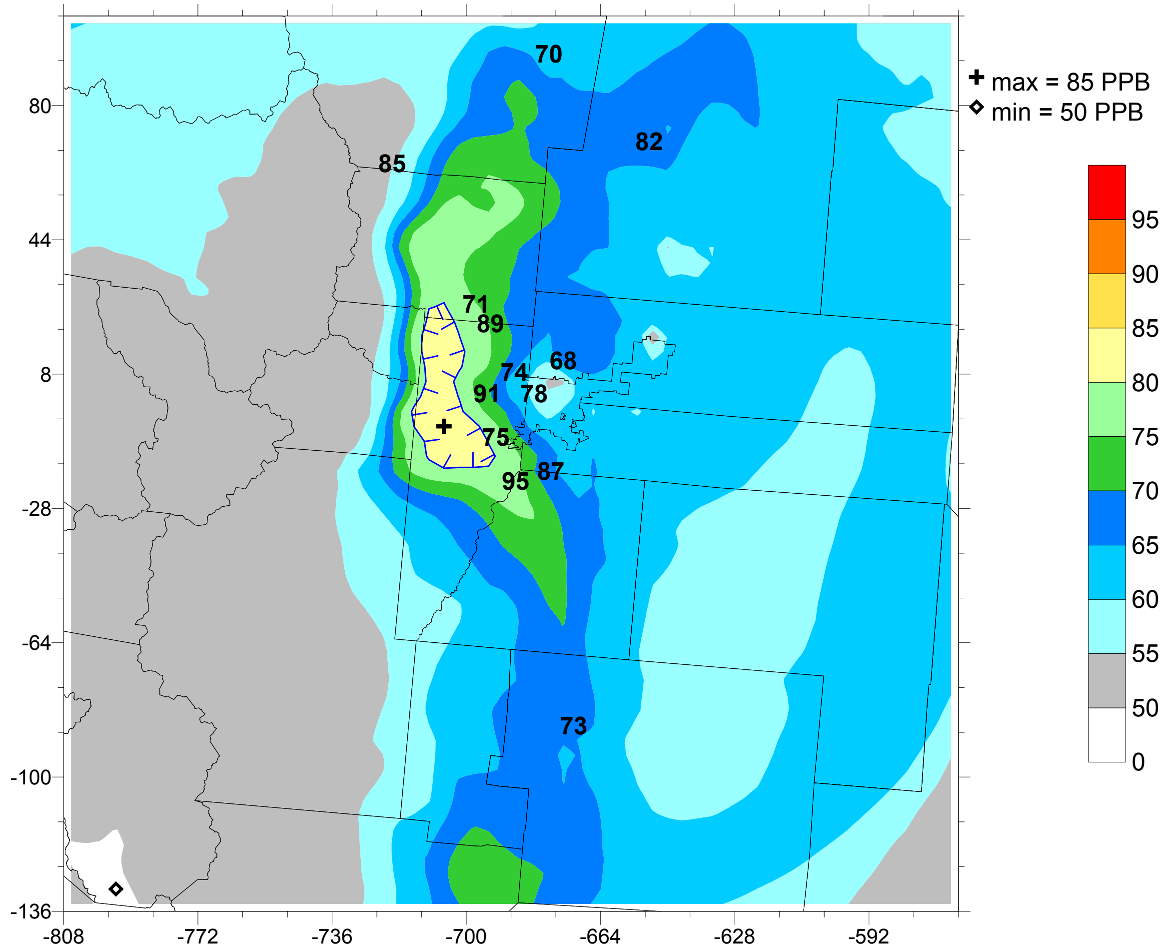
June30, 2002
36/12/4 Denver Base Case for 2007:run11a

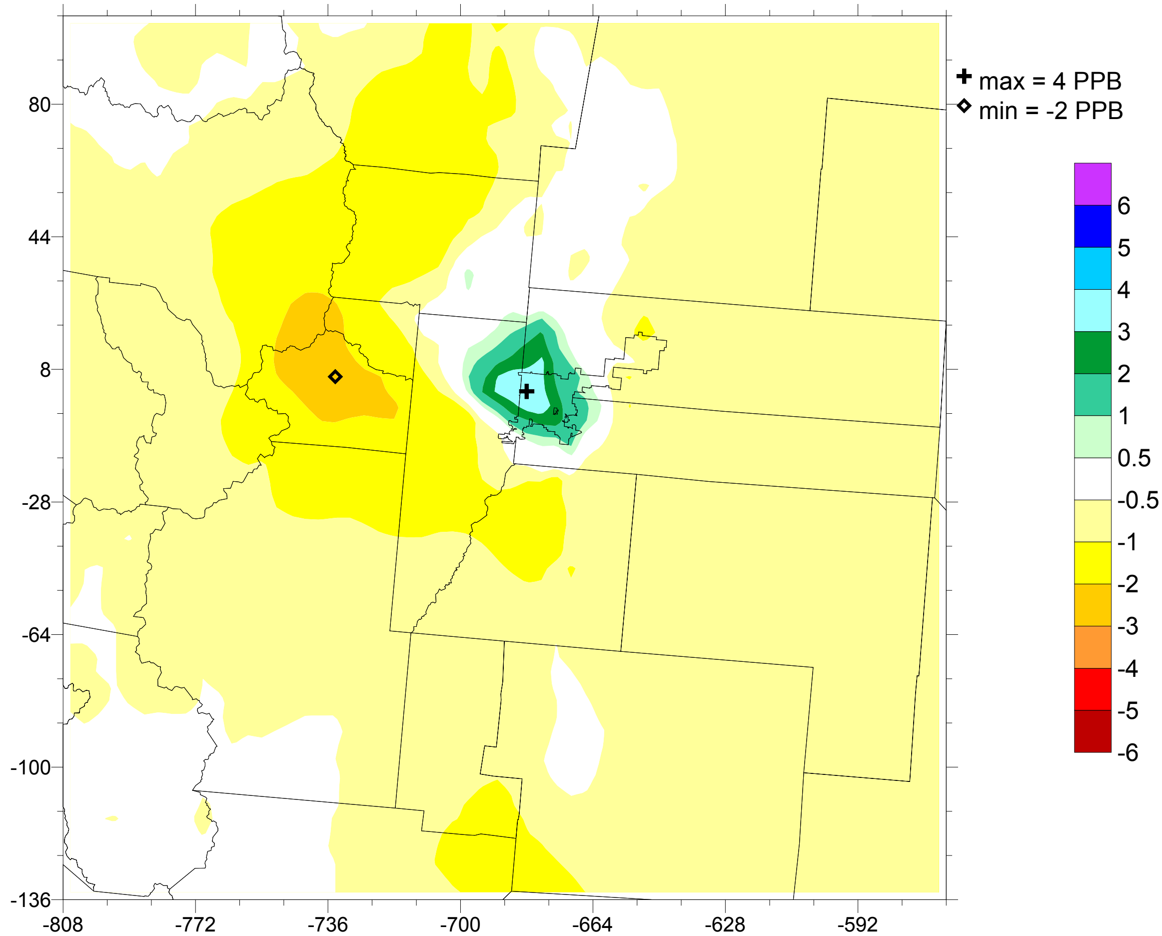


CAMx Daily Maximum 8hr O3
July01, 2002
36/12/4 Denver Base Case for 2007:run11a

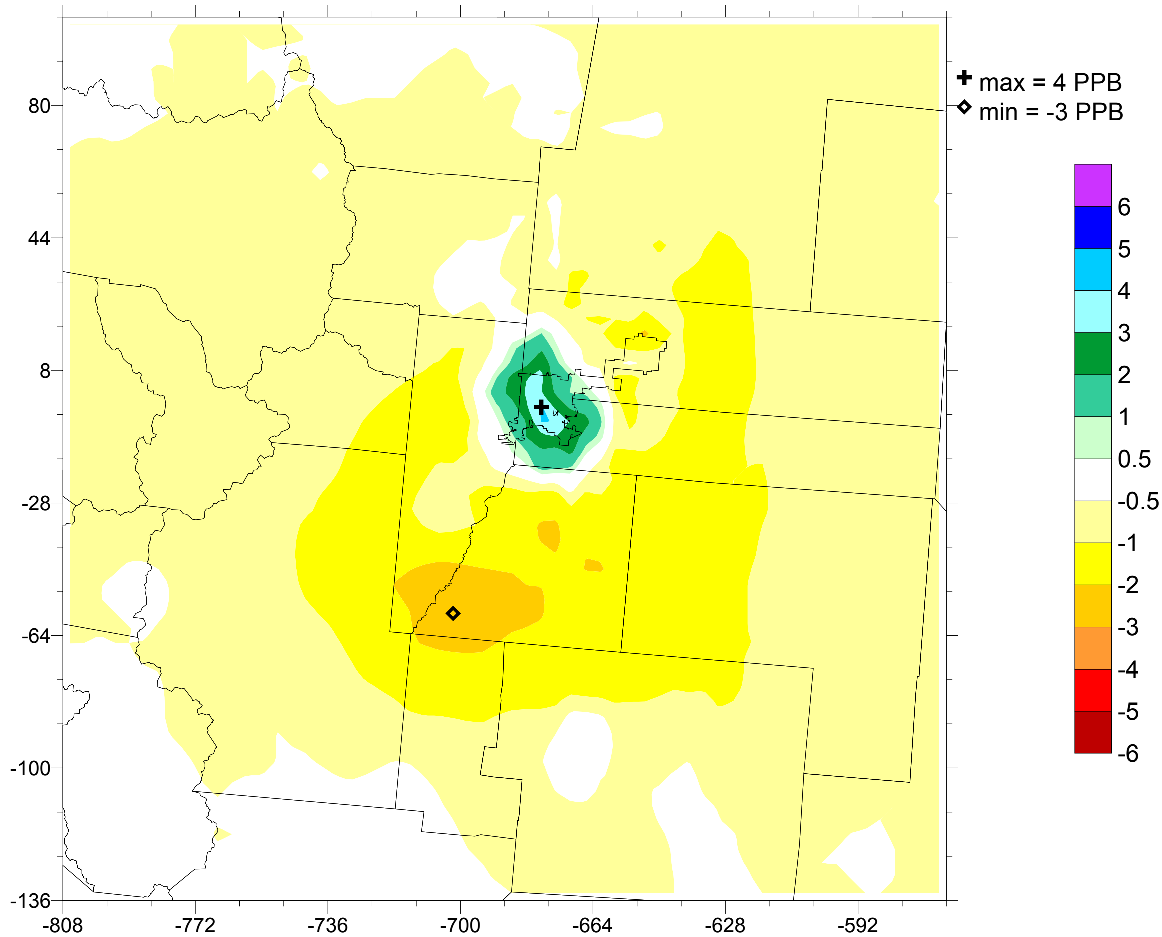
Appendix C

Estimated Differences in Daily Maximum 8-Hour
Ozone Concentrations (ppb) for the 36/12/4 km Run0711a vs. Run11a
2007 Base Case – 2002 Base Case

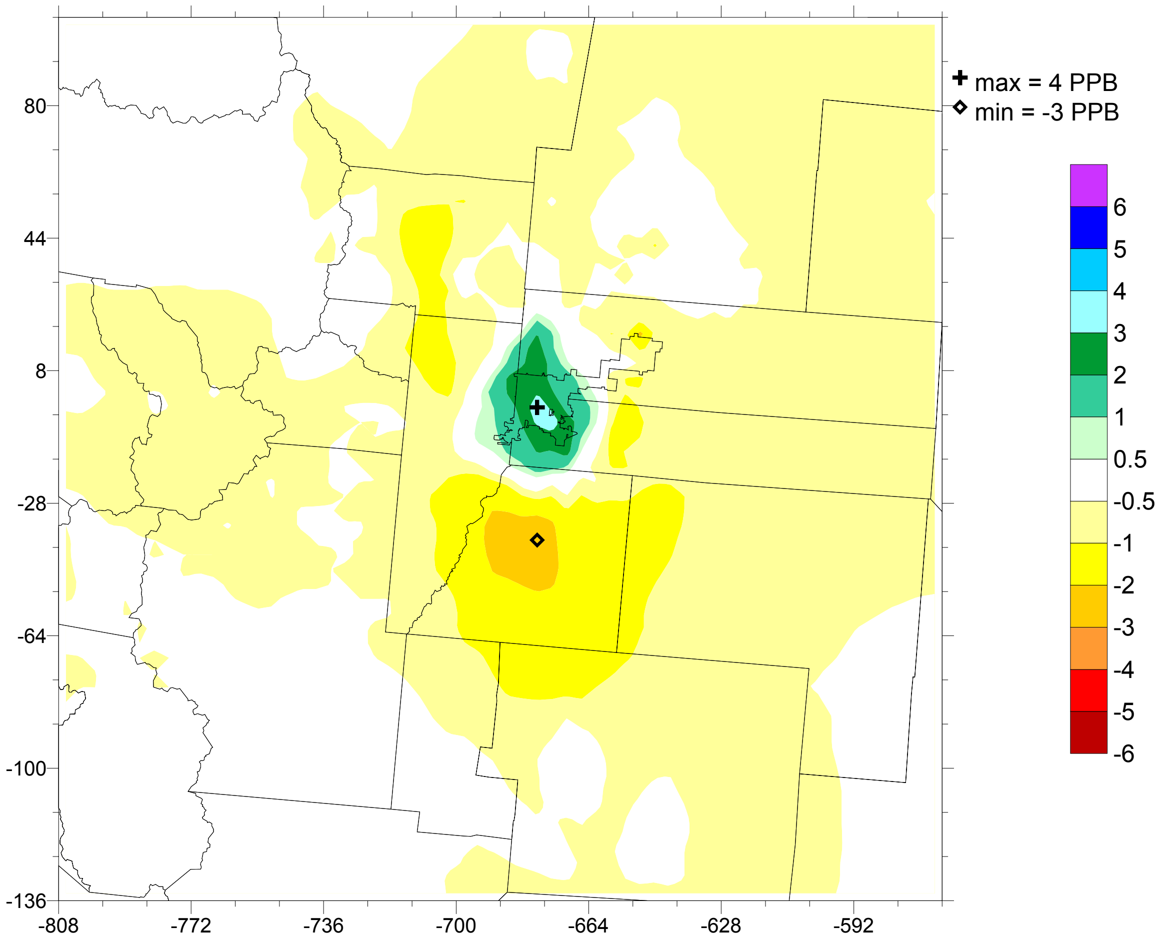
June 27 – July 1, 2002



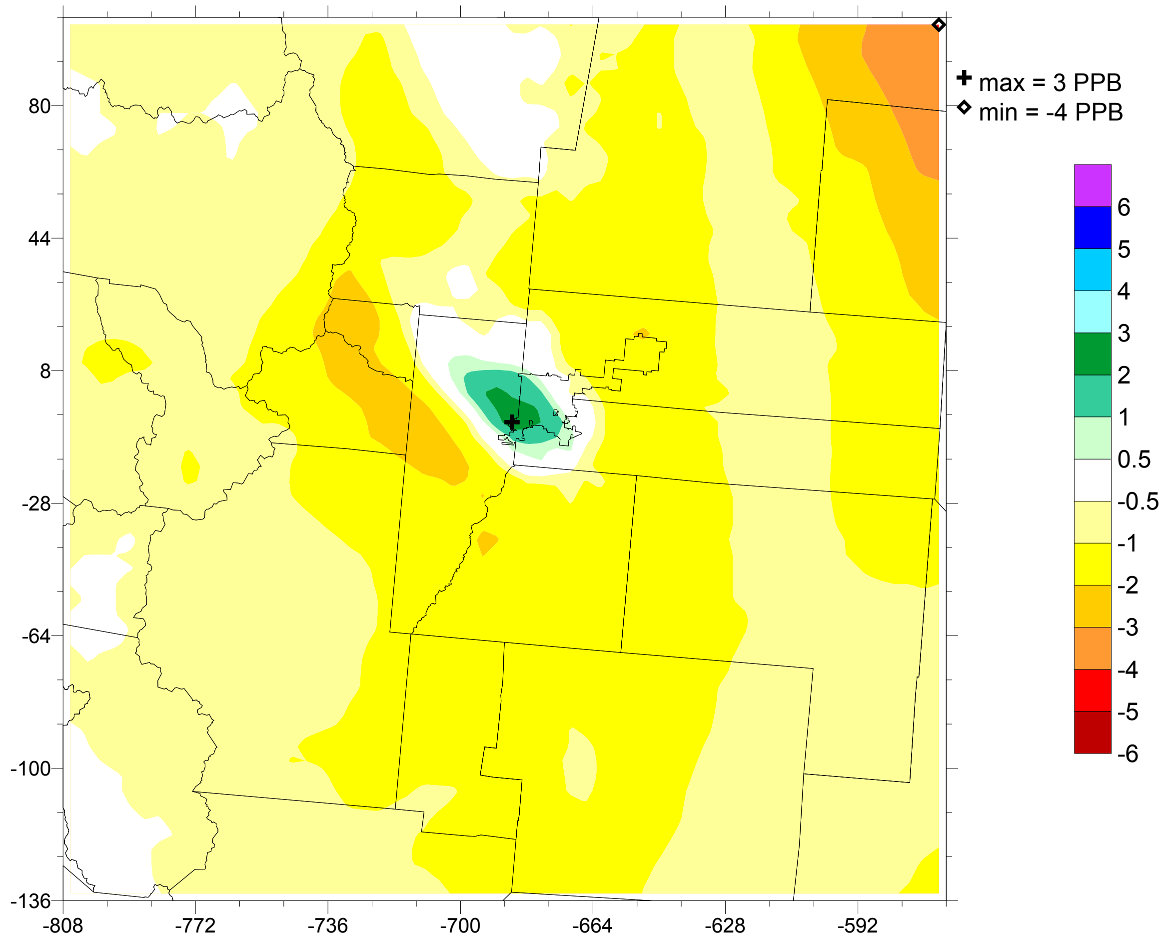
CAMx Difference in Daily Max 8hr O3
June27, 2002
2007 Base Case - 2002 Base Case



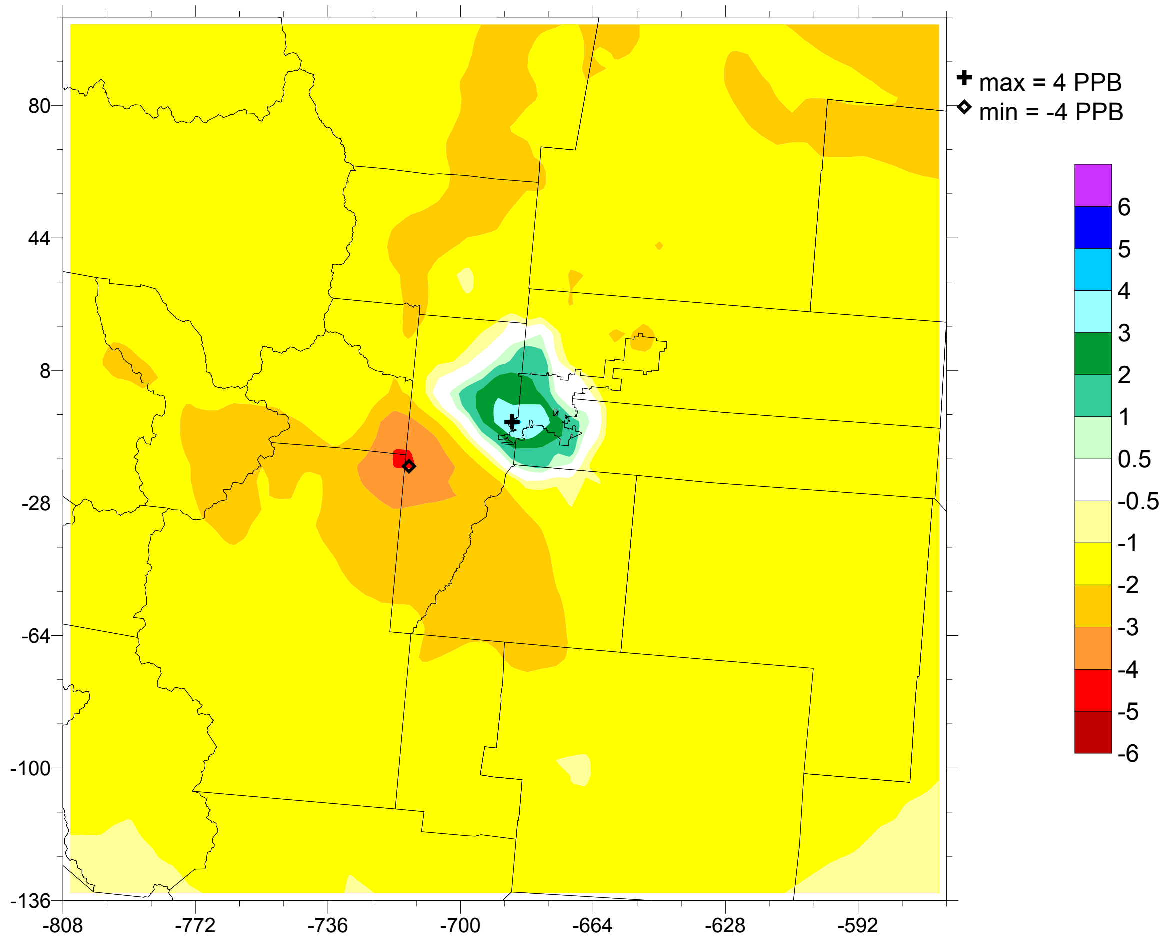
CAMx Difference in Daily Max 8hr O3
June28, 2002
2007 Base Case - 2002 Base Case



CAMx Difference in Daily Max 8hr O3
June29, 2002
2007 Base Case - 2002 Base Case



CAMx Difference in Daily Max 8hr O3
June30, 2002
2007 Base Case - 2002 Base Case

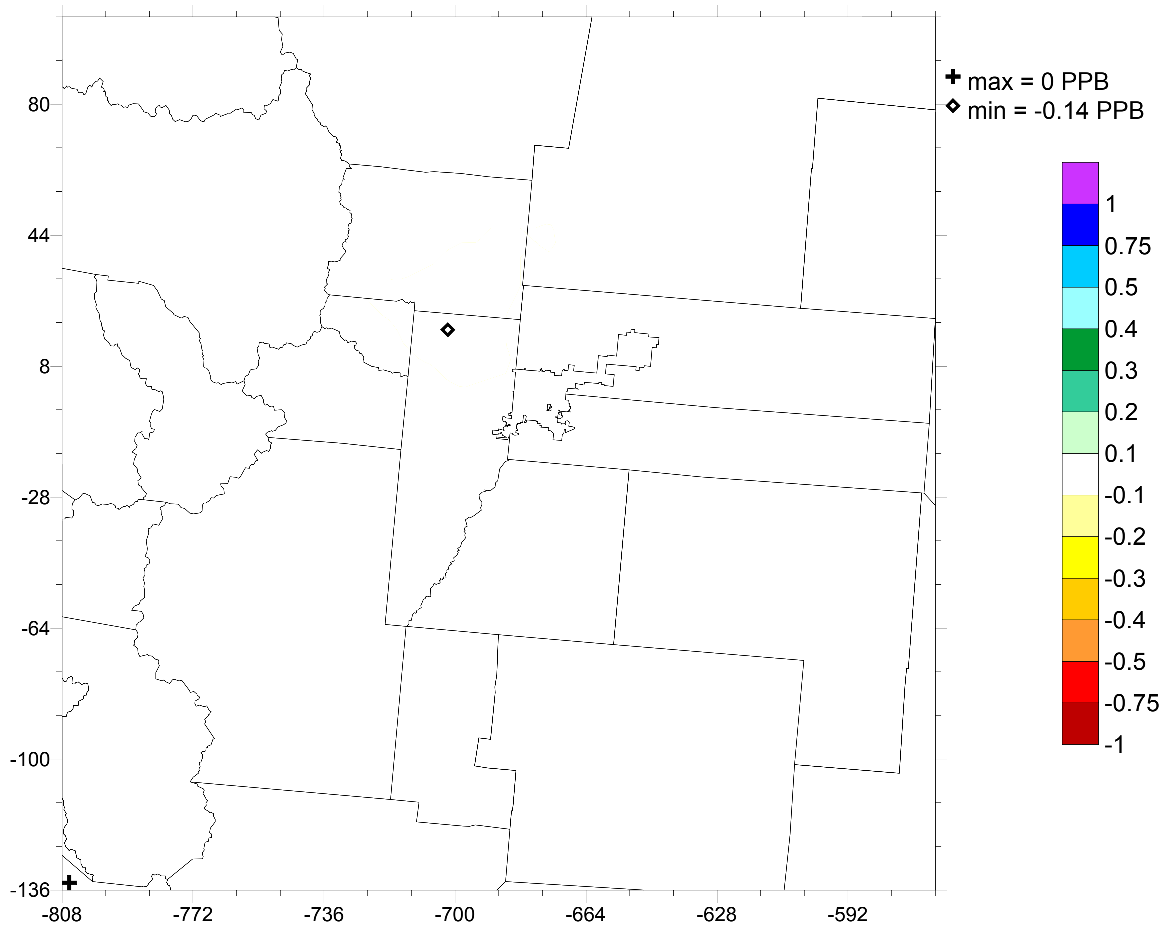


CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Base Case - 2002 Base Case

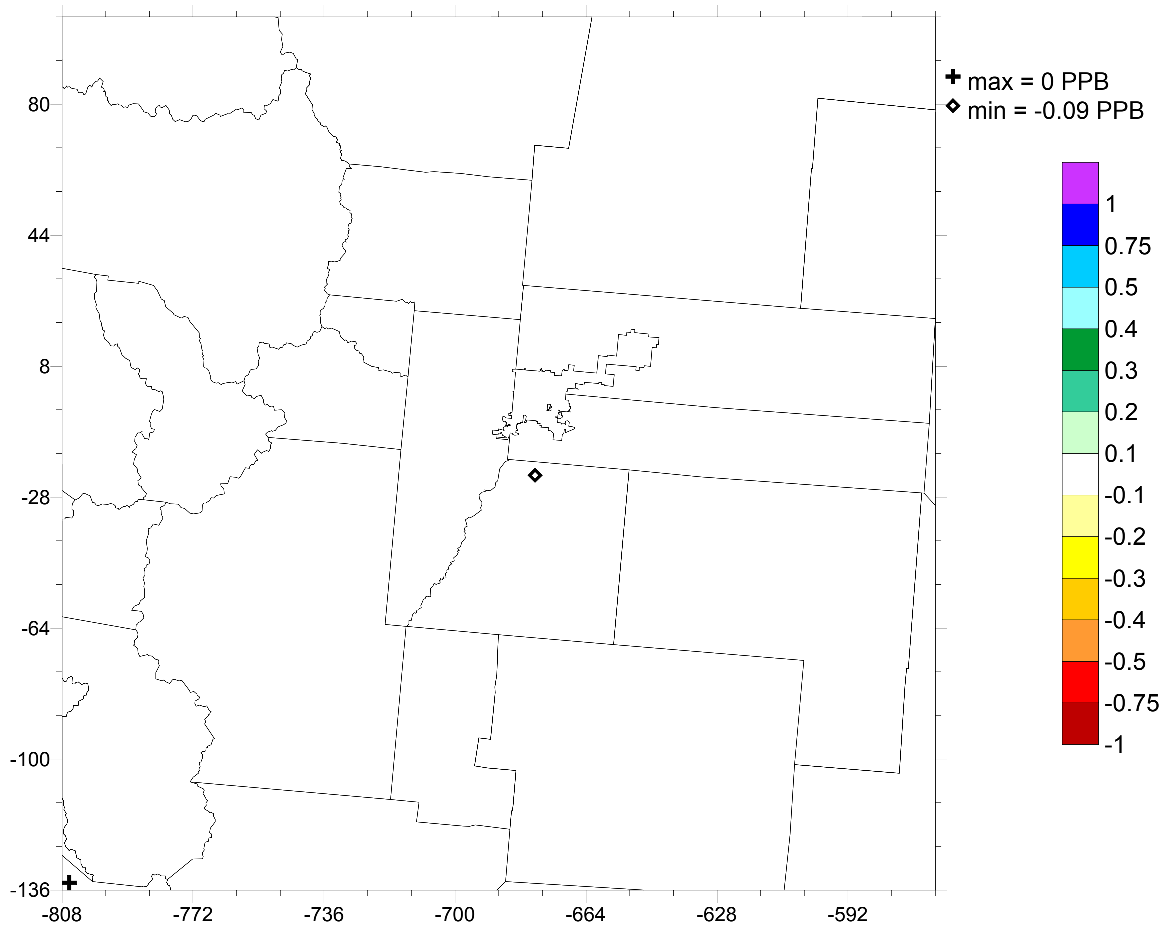
Appendix D

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl1 vs. 07Run11a
2007 RVP Control – 2007 Base Case

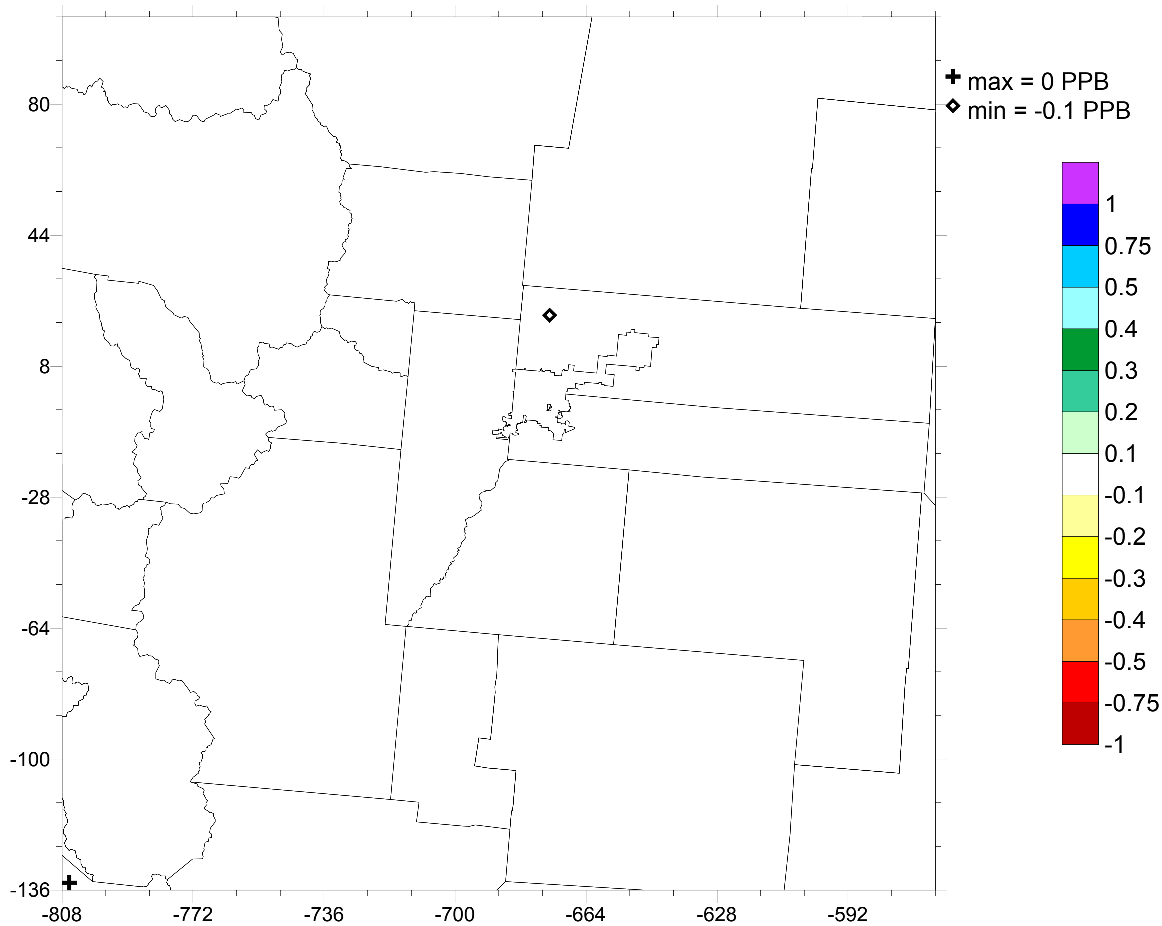
June 27 – July 1, 2002



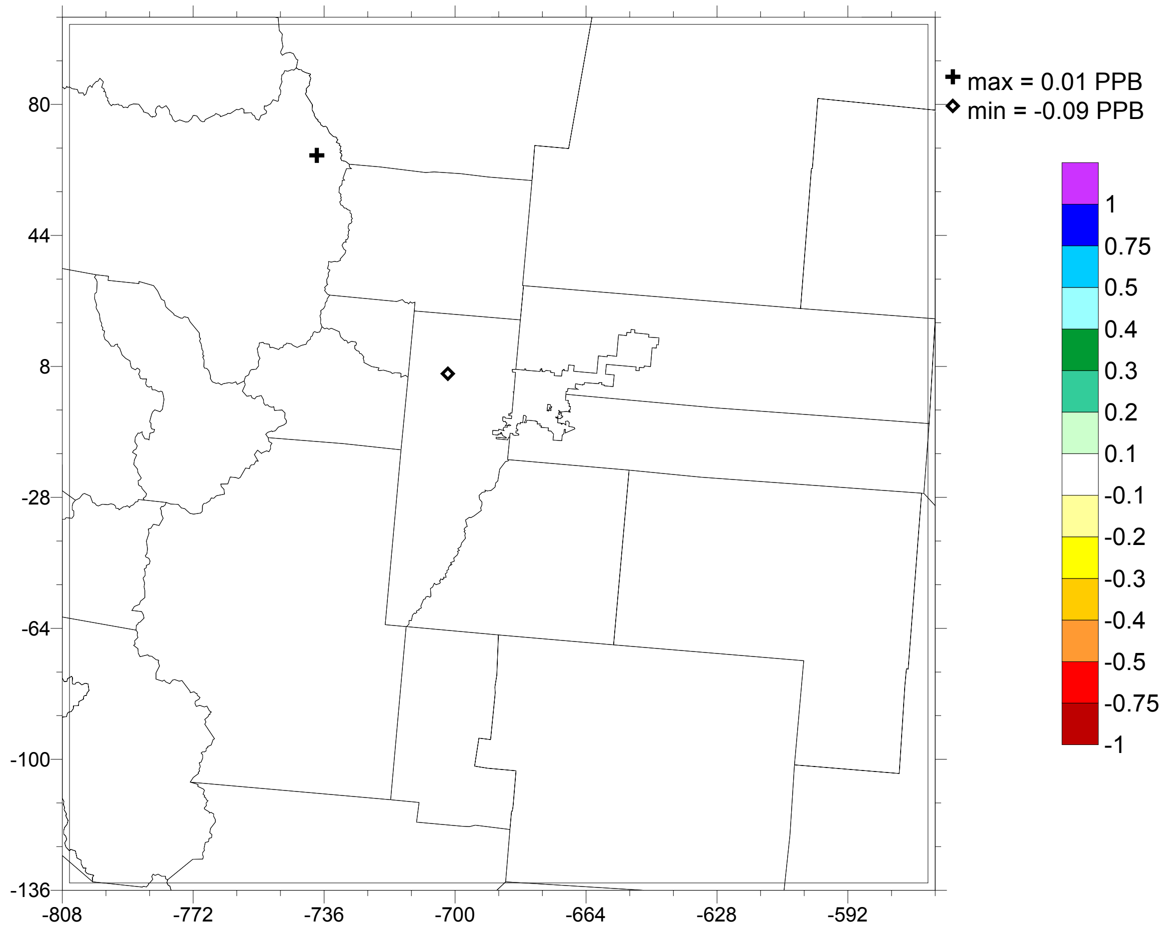
CAMx Difference in Daily Max 8hr O3
June27, 2002
2007 Control Strategy #1 - 2007 Base Case



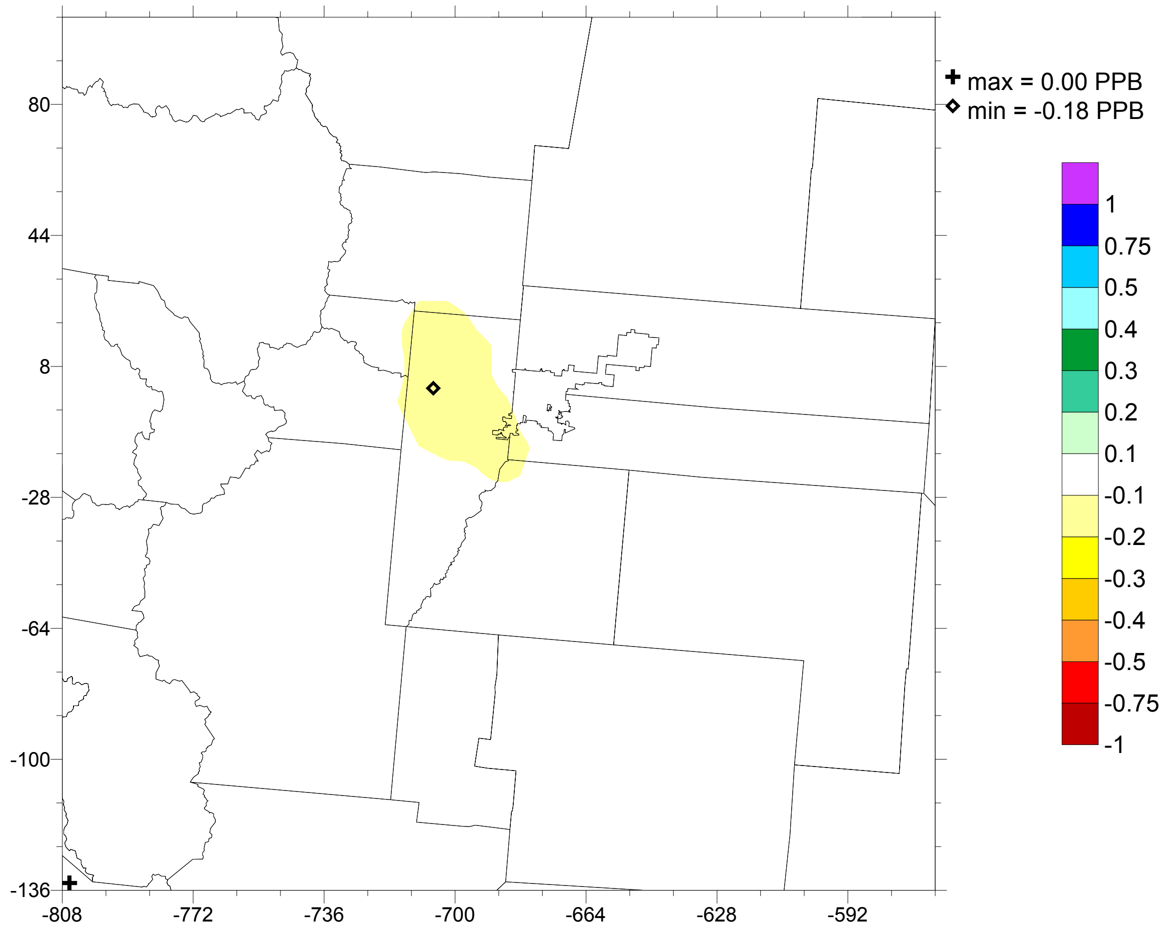
CAMx Difference in Daily Max 8hr O3
June28, 2002
2007 Control Strategy #1 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June29, 2002
2007 Control Strategy #1 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June30, 2002
2007 Control Strategy #1 - 2007 Base Case

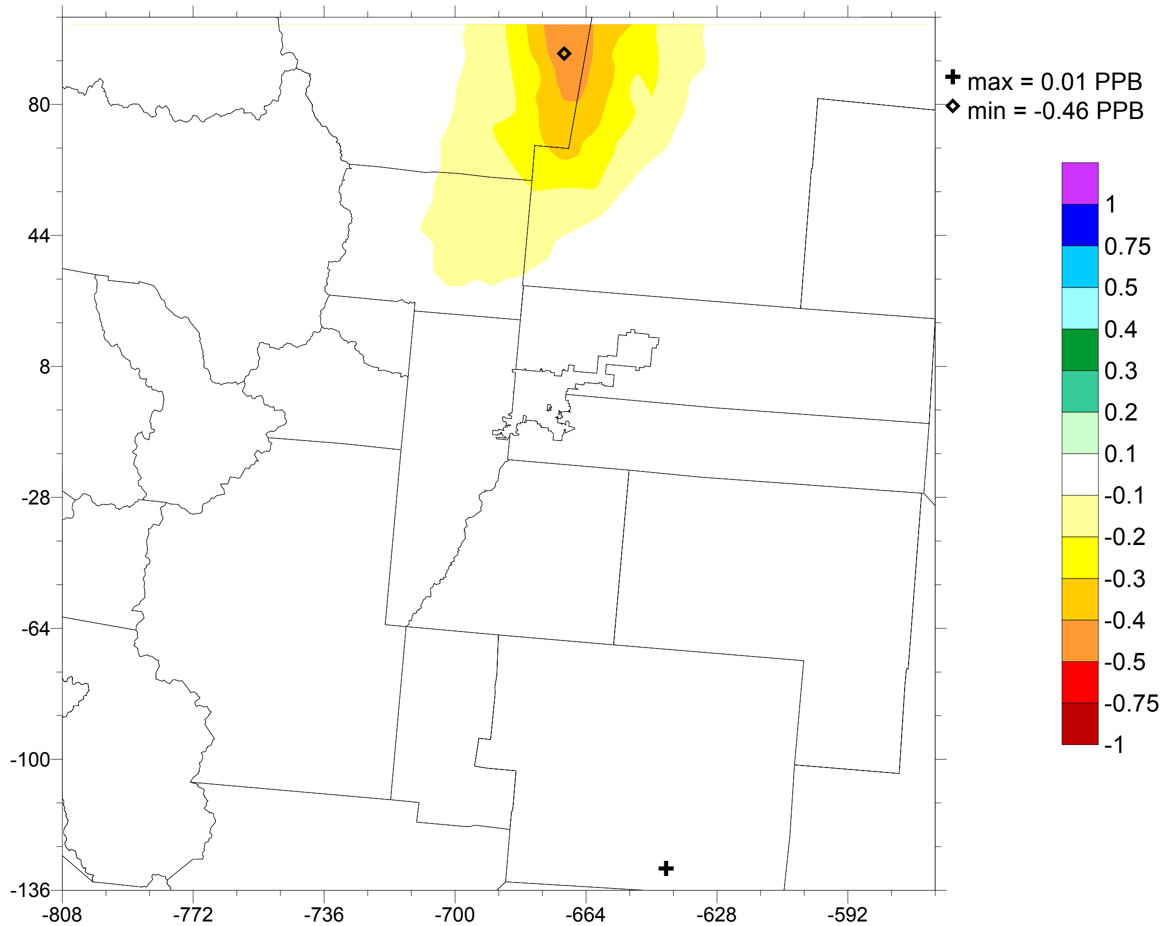


CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Control Strategy #1 - 2007 Base Case

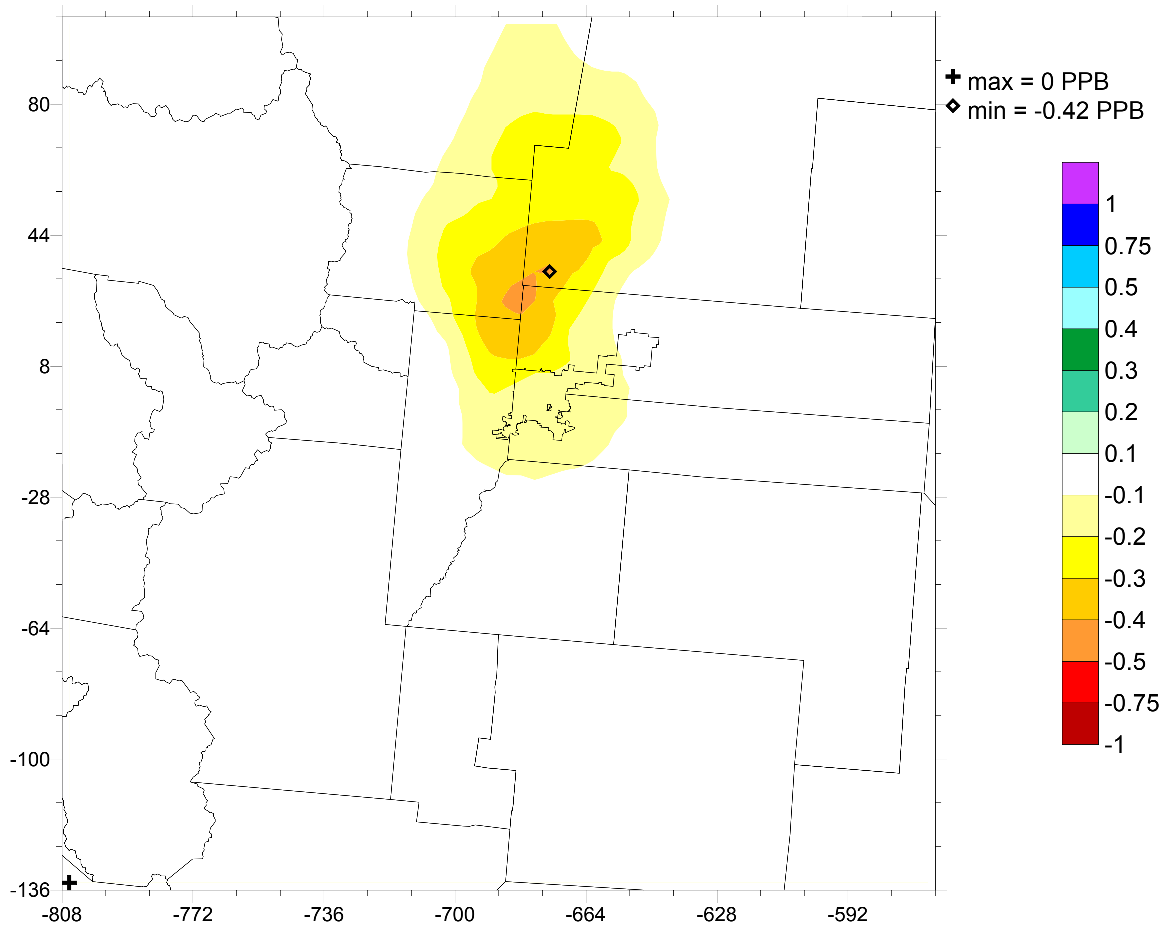
Appendix E

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl2 vs. 07Run11a
2007 Flash Control – 2007 Base Case

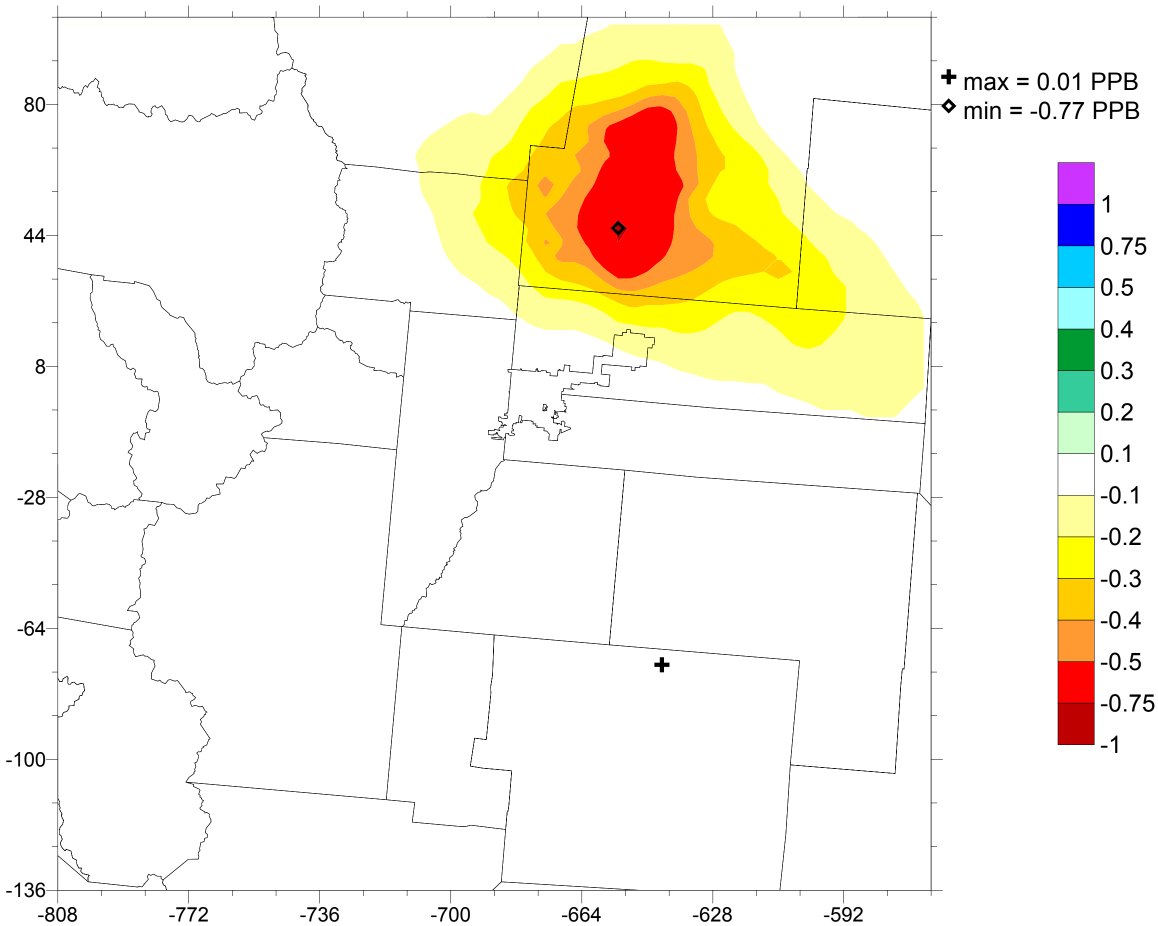
June 27 – July 1, 2002



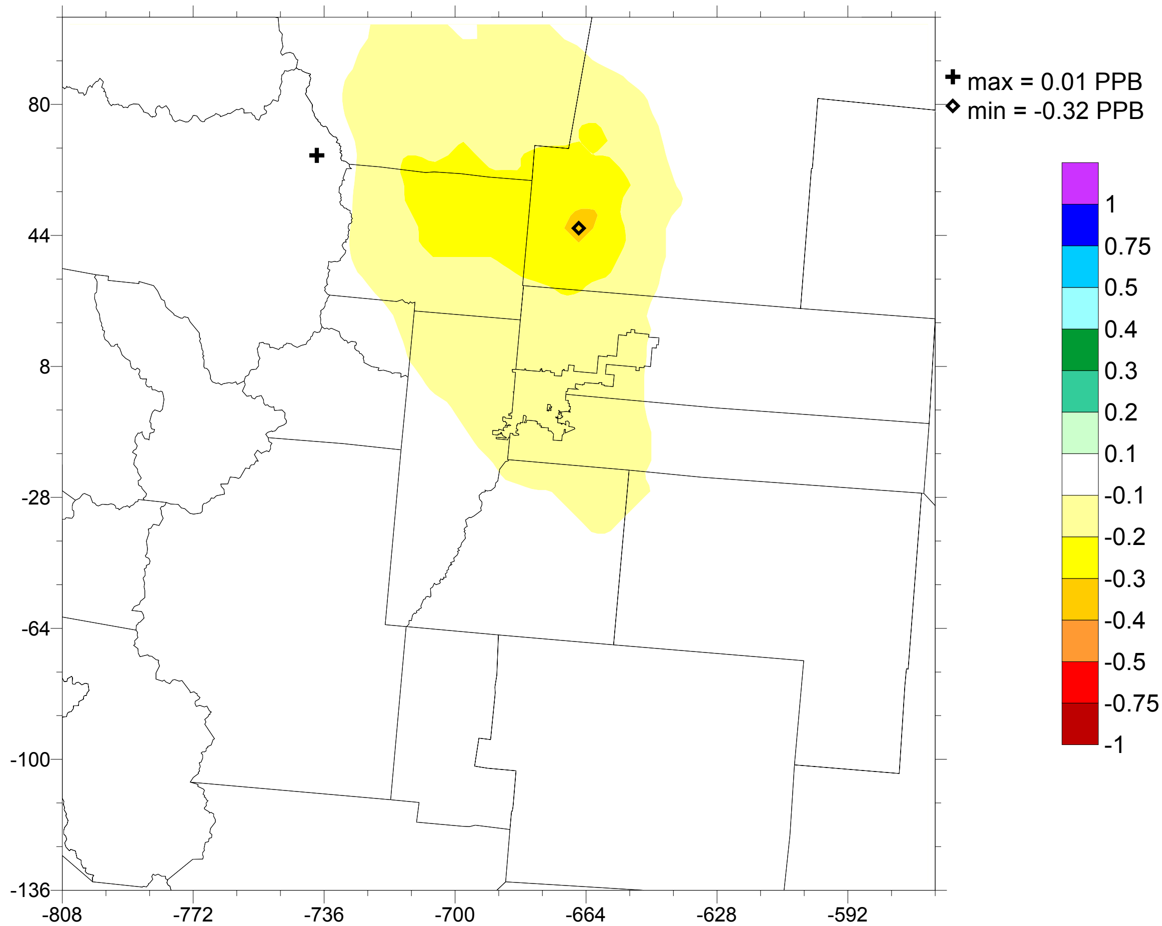
CAMx Difference in Daily Max 8hr O3
June27, 2002
2007 Control Strategy #2 - 2007 Base Case



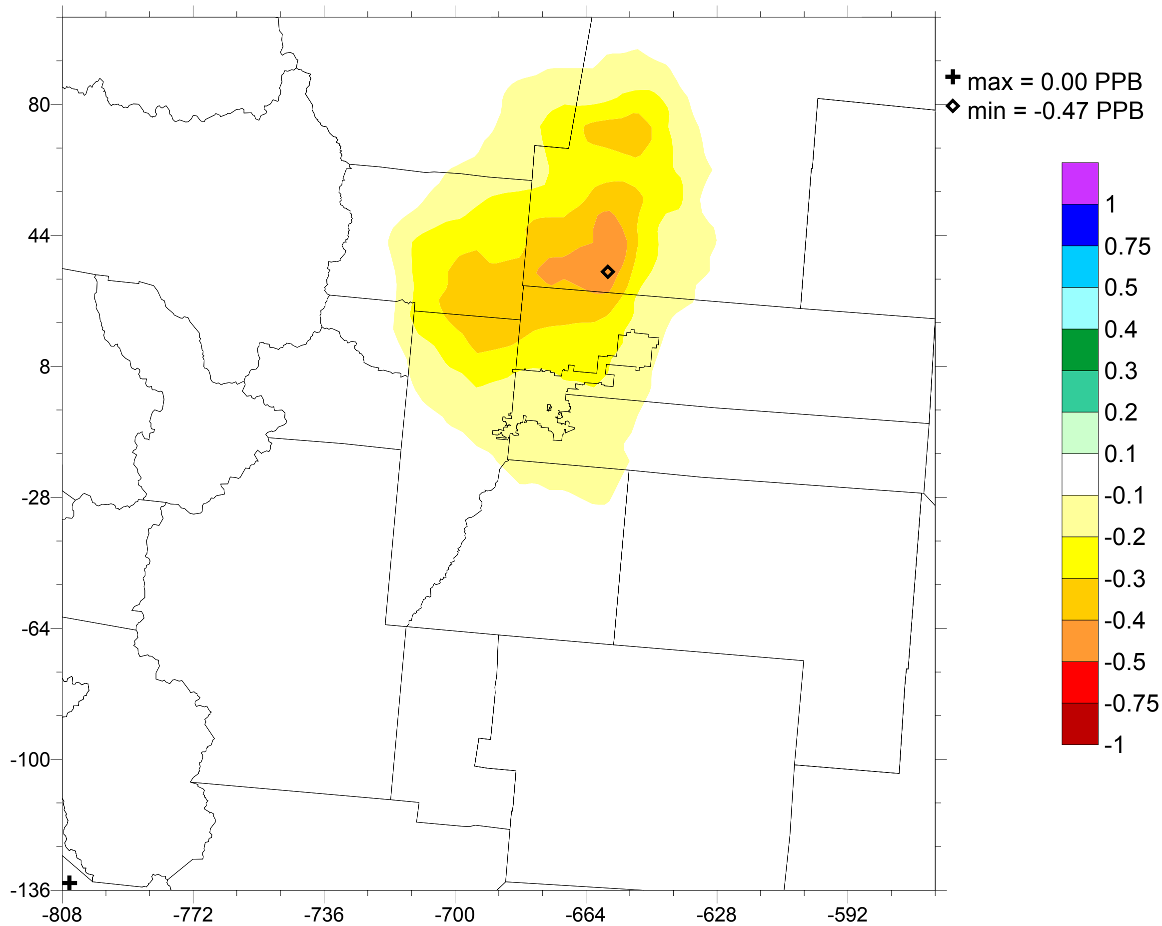
CAMx Difference in Daily Max 8hr O3
June28, 2002
2007 Control Strategy #2 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June29, 2002
2007 Control Strategy #2 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June30, 2002
2007 Control Strategy #2 - 2007 Base Case

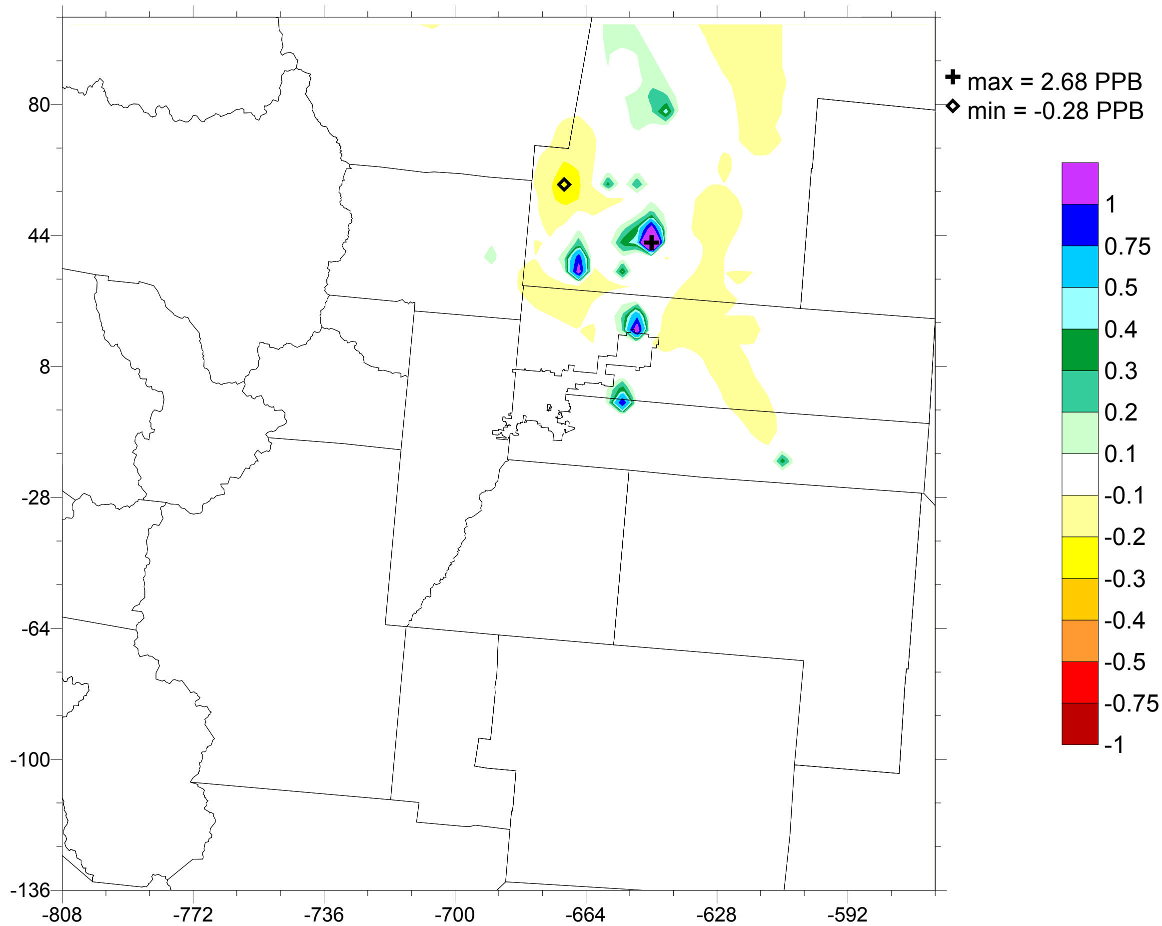


CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Control Strategy #2 - 2007 Base Case

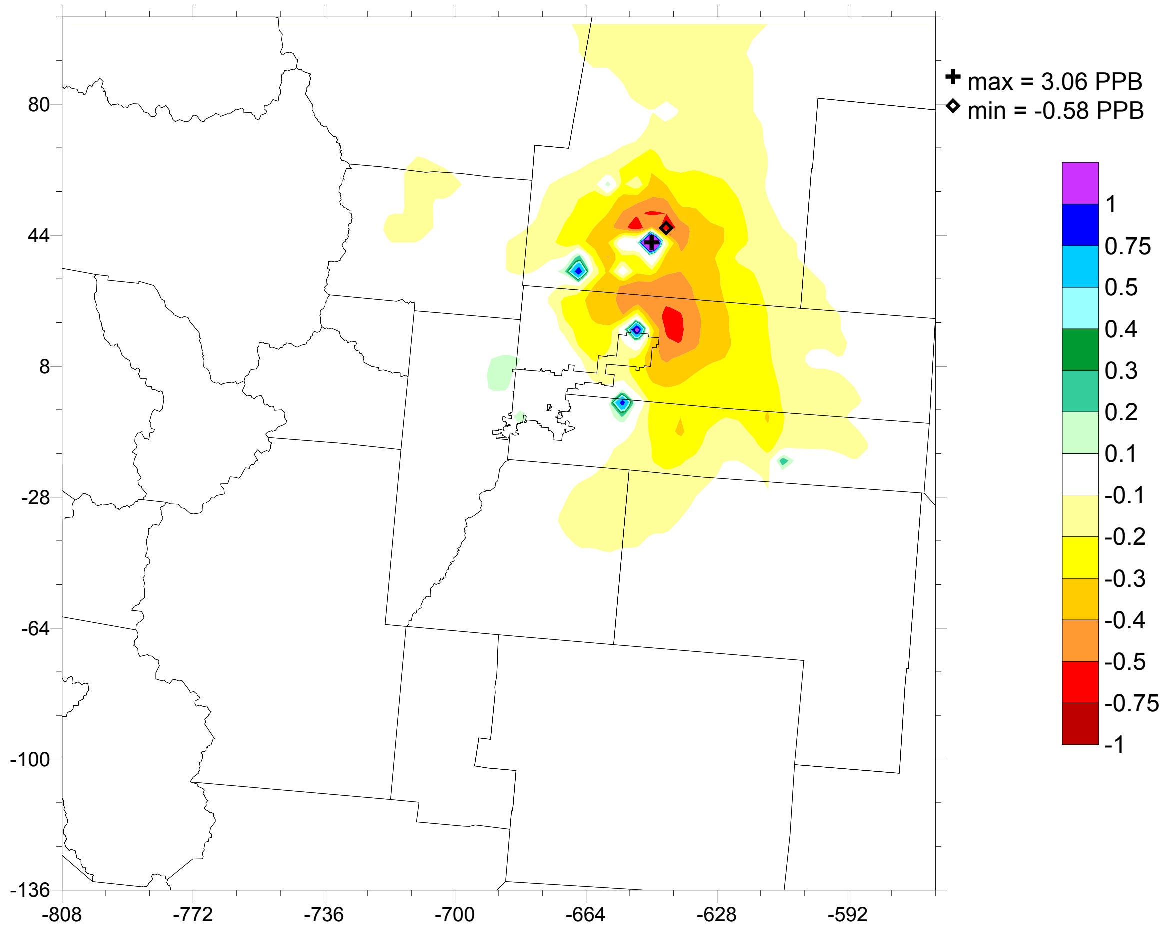
Appendix F

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl3 vs. 07Run11a
2007 RICE Control – 2007 Base Case

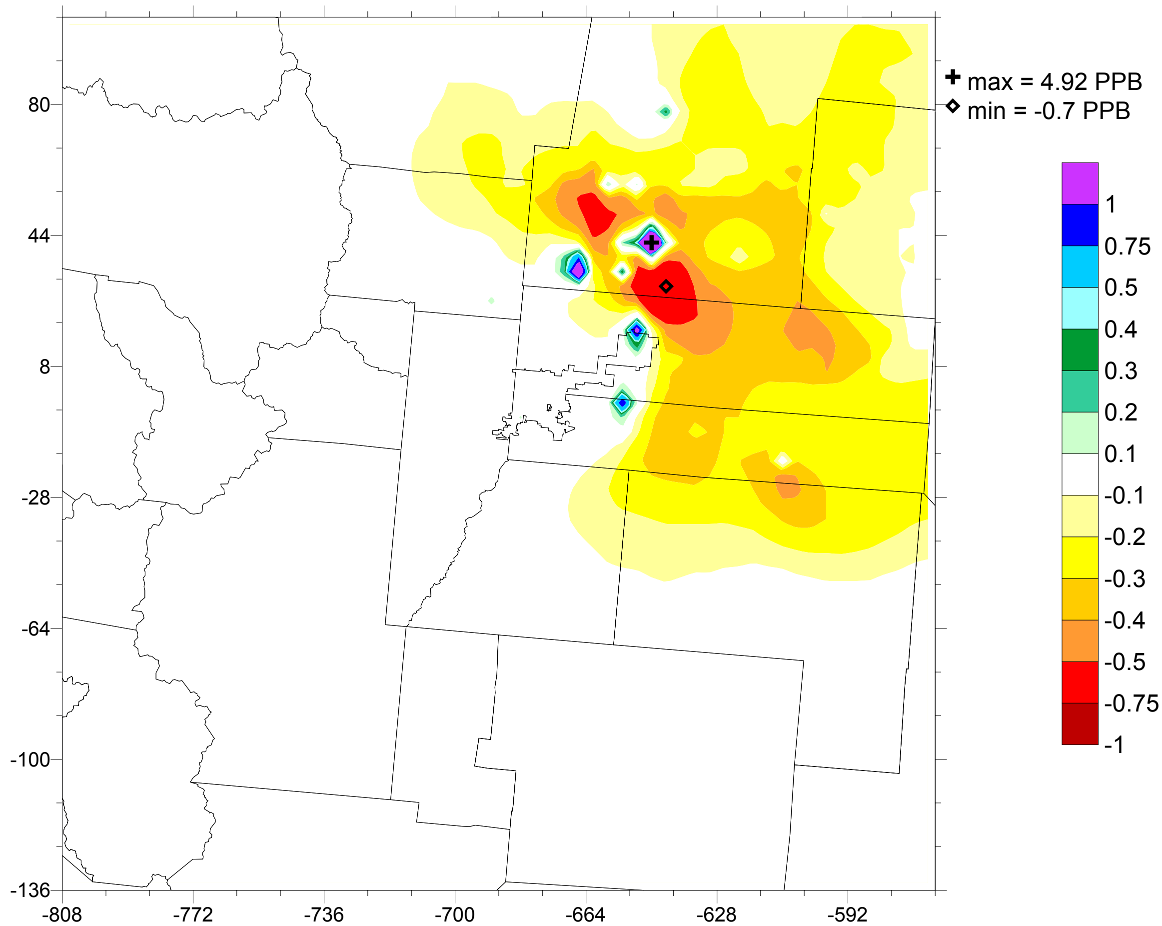
June 27 – July 1, 2002



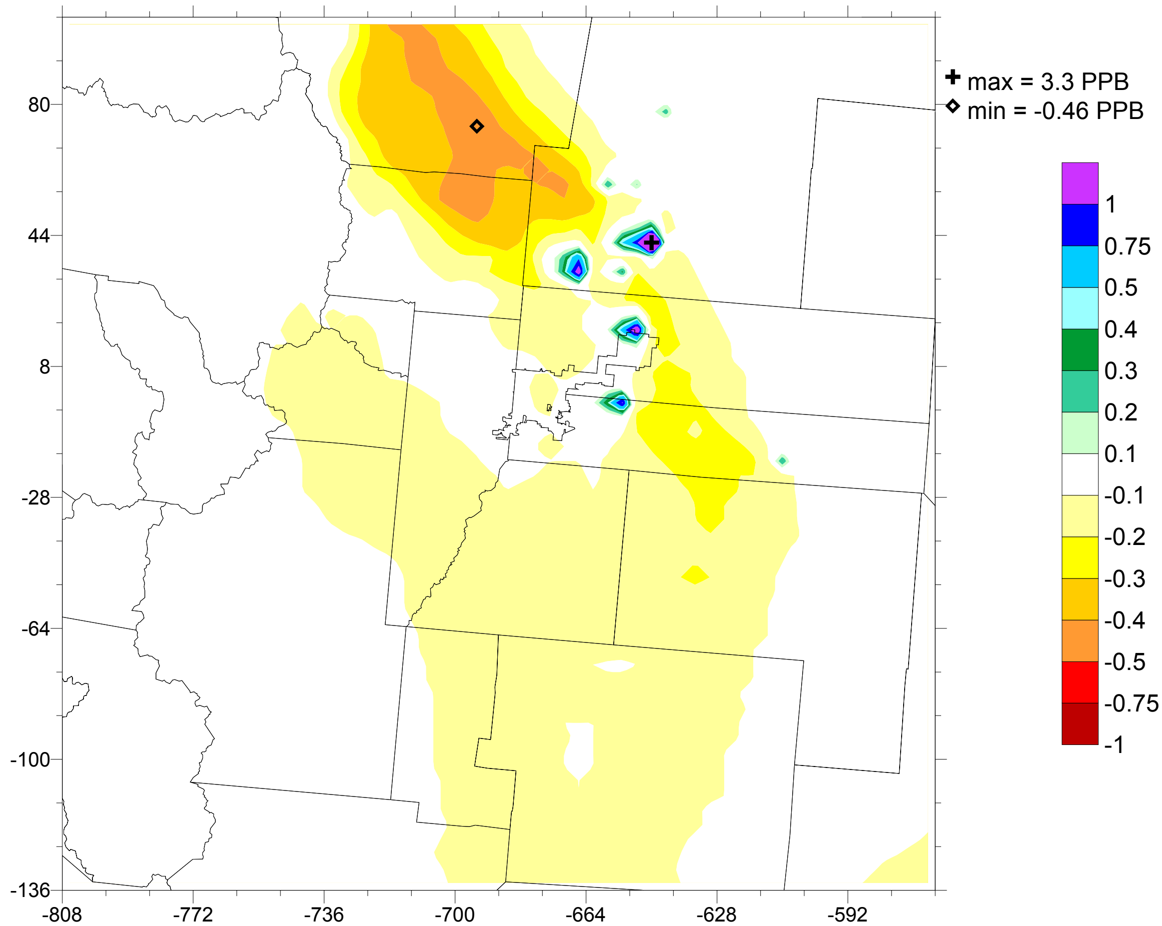
CAMx Difference in Daily Max 8hr O3
June27, 2002
2007 Control Strategy #3 - 2007 Base Case



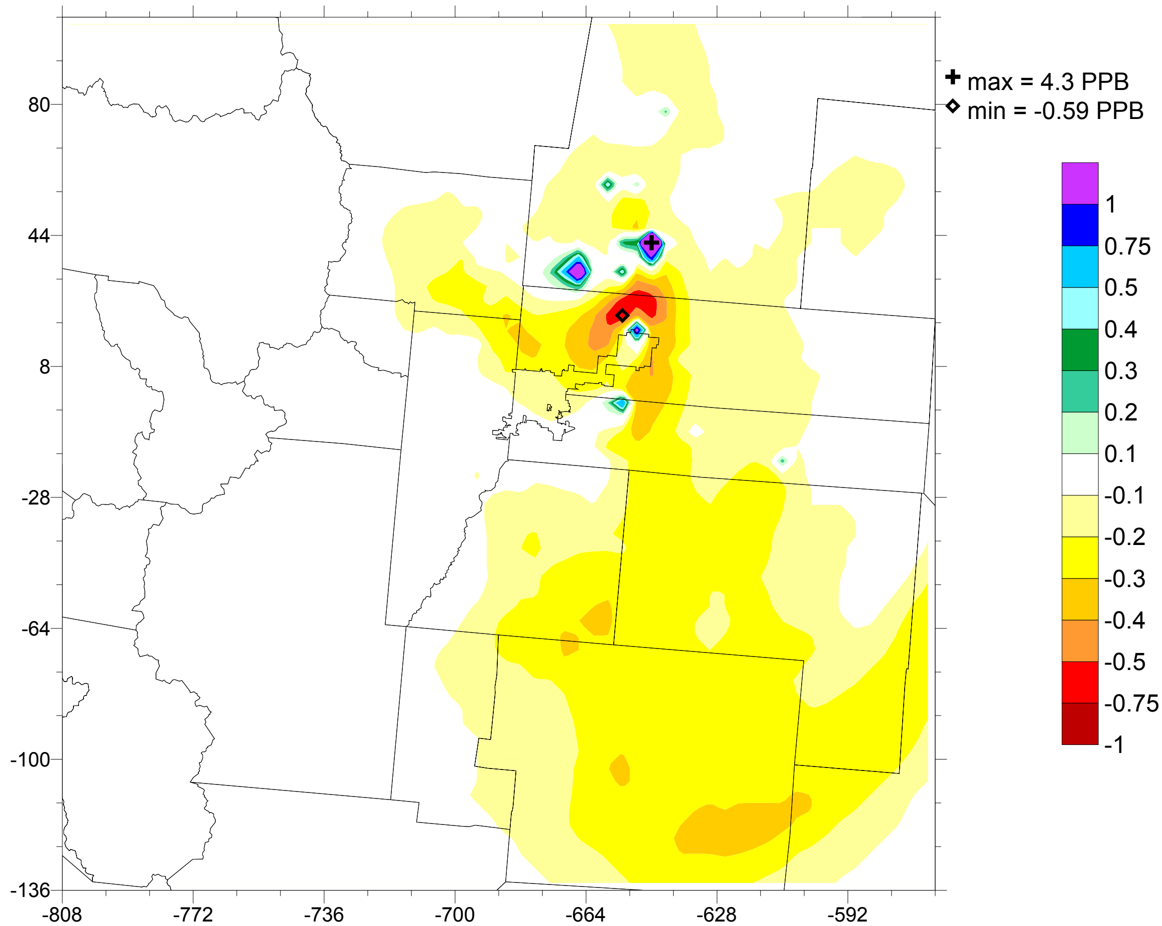
CAMx Difference in Daily Max 8hr O3
June28, 2002
2007 Control Strategy #3 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June29, 2002
2007 Control Strategy #3 - 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June30, 2002
2007 Control Strategy #3 - 2007 Base Case

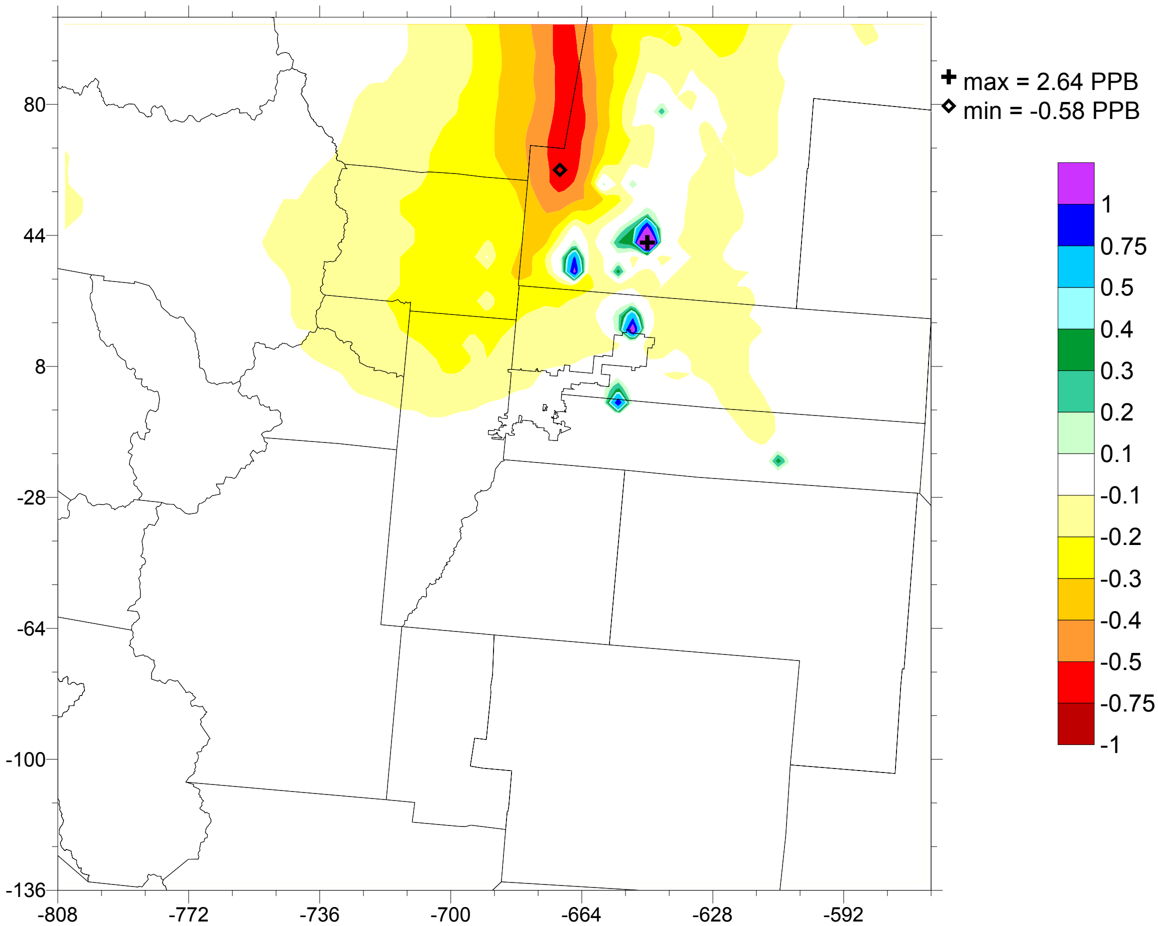


CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 Control Strategy #3 - 2007 Base Case

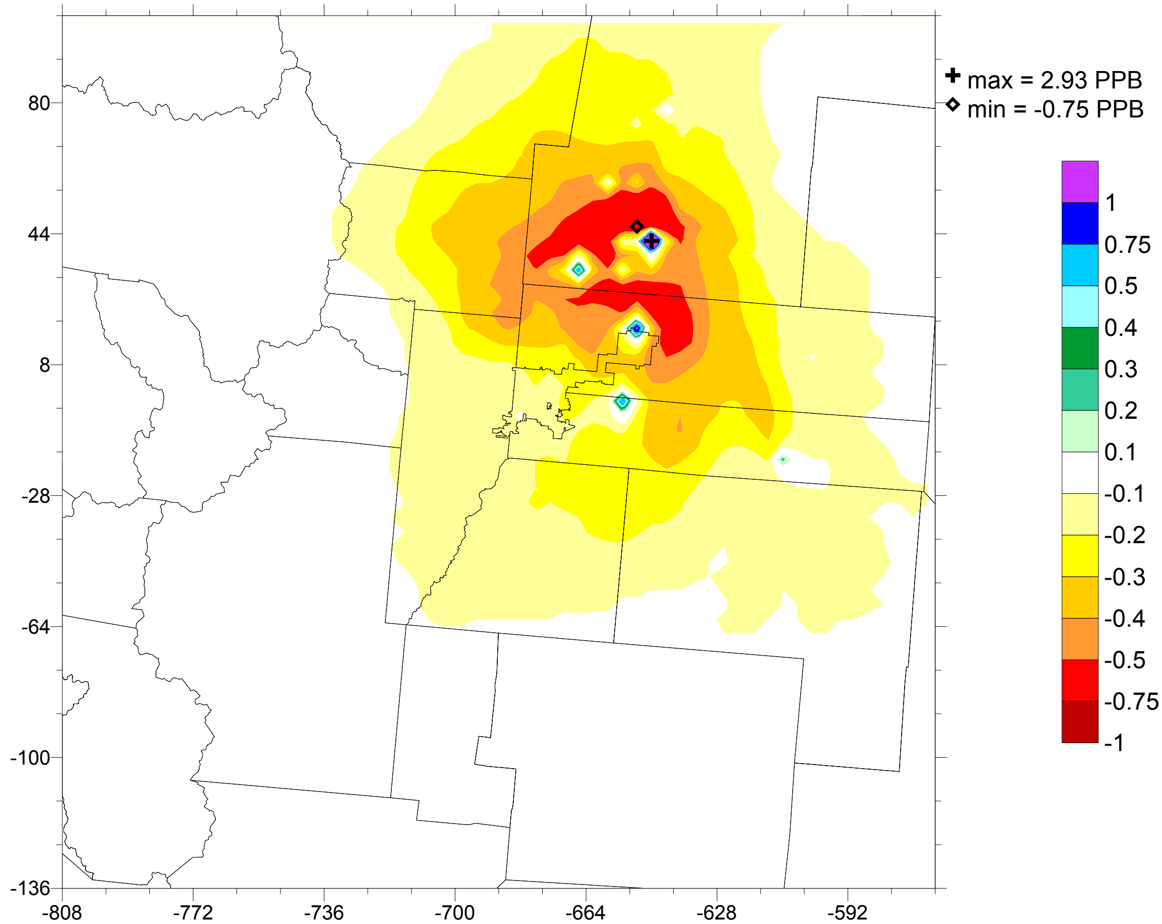
Appendix G

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl4 vs. 07Run11a
2007 RVP, Flash and RICE Control – 2007 Base Case

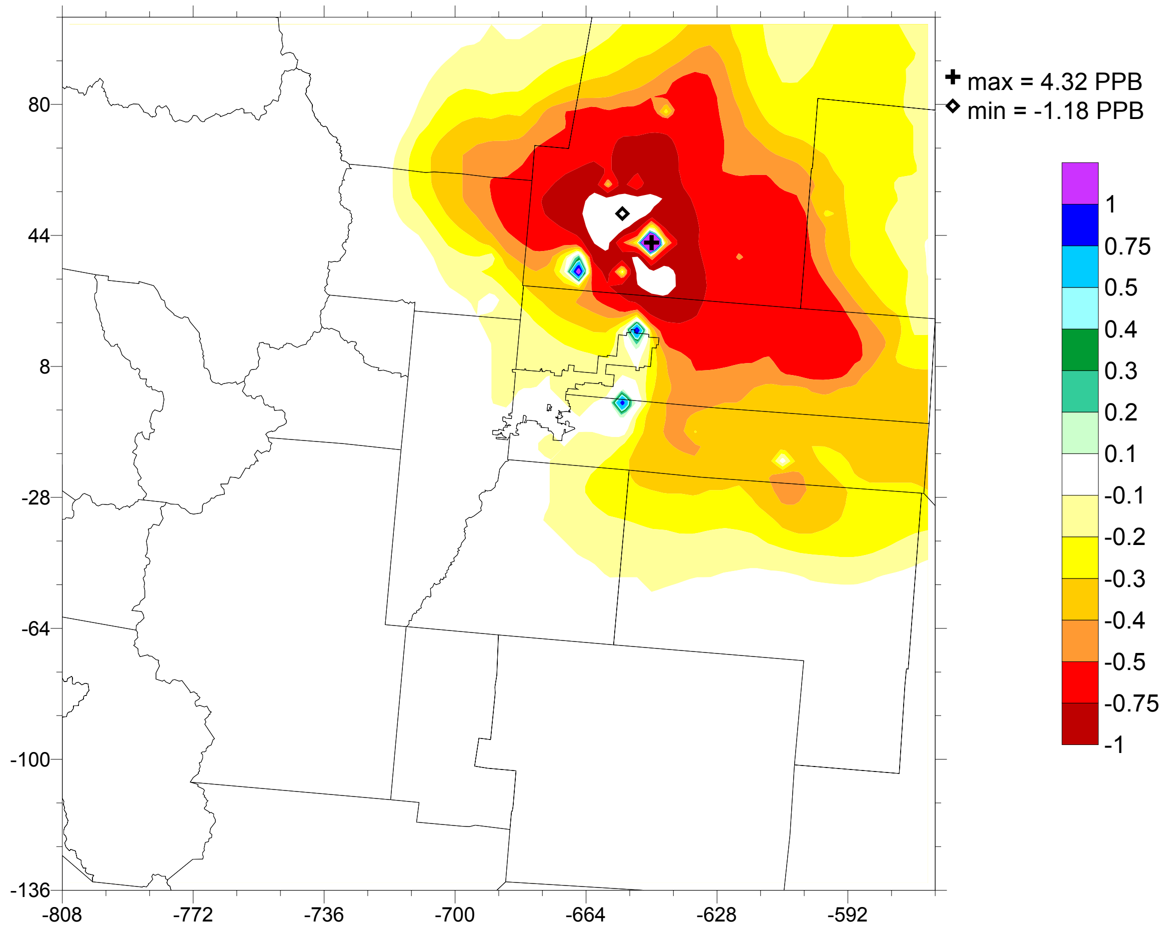
June 27 – July 1, 2002



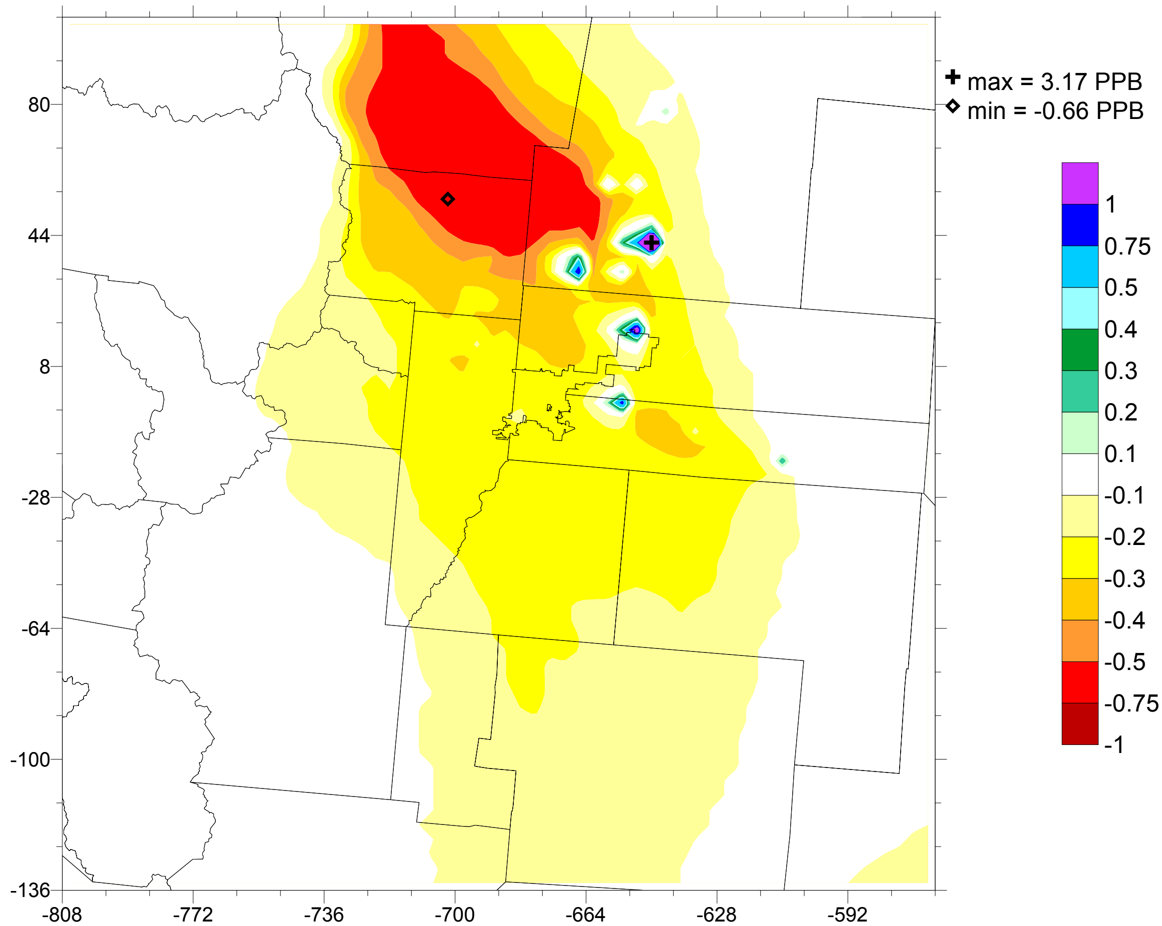
CAMx Difference in Daily Max 8hr O3
June27, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case



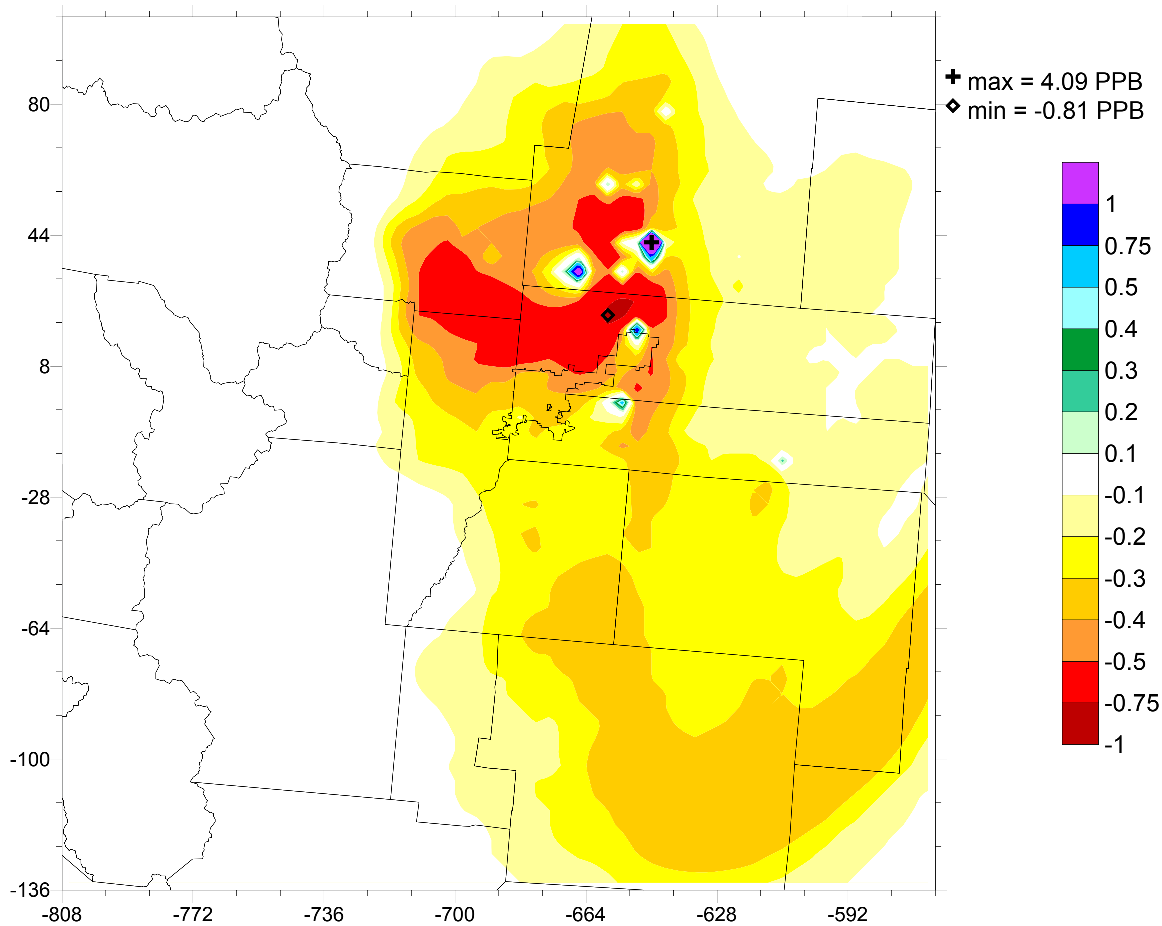
CAMx Difference in Daily Max 8hr O3
June28, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June29, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case



CAMx Difference in Daily Max 8hr O3
June30, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case

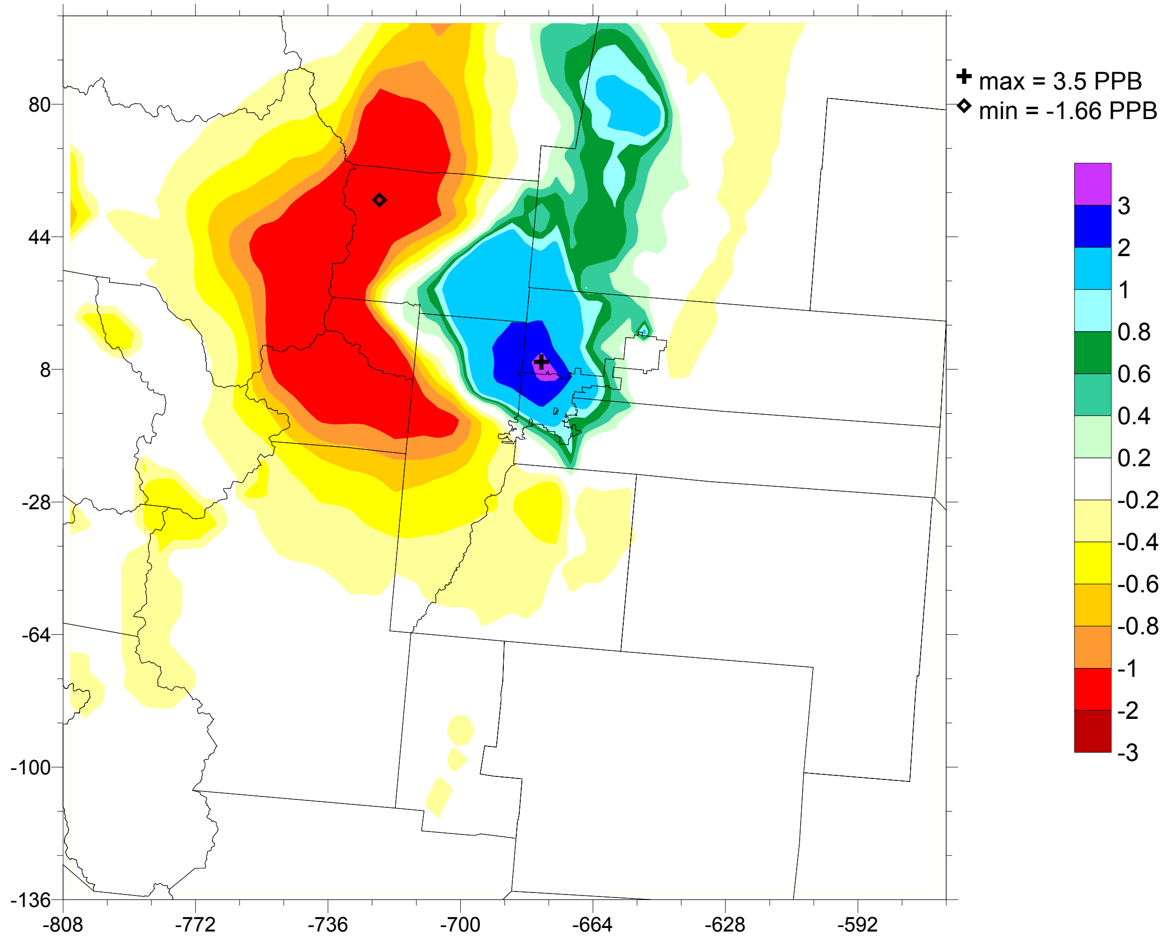


CAMx Difference in Daily Max 8hr O3
July01, 2002
2007 with All Controls (Strategy #4)- 2007 Base Case

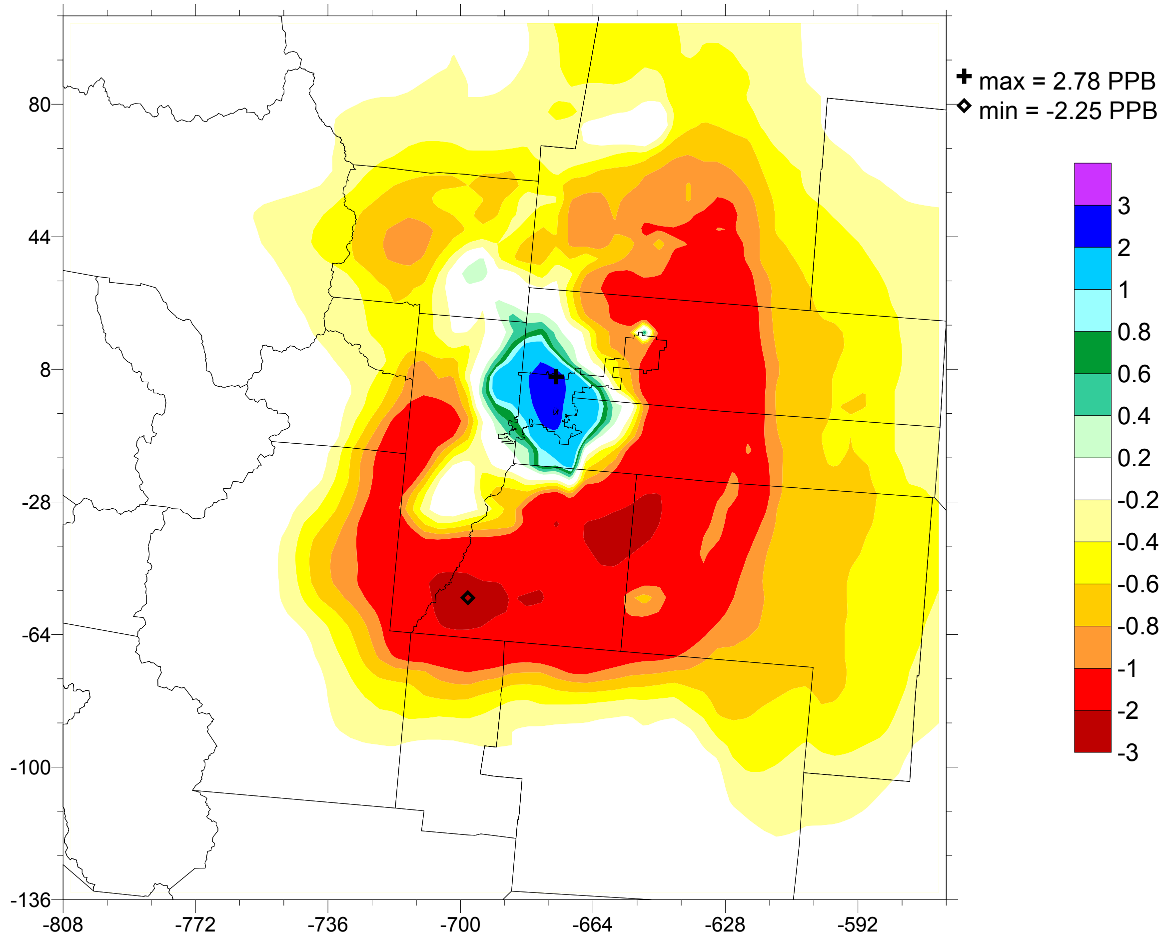
Appendix H

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl5 vs. 07Run11a-cntl4
2007 20% NOx Control in DMA+Weld – 2007 Base Case

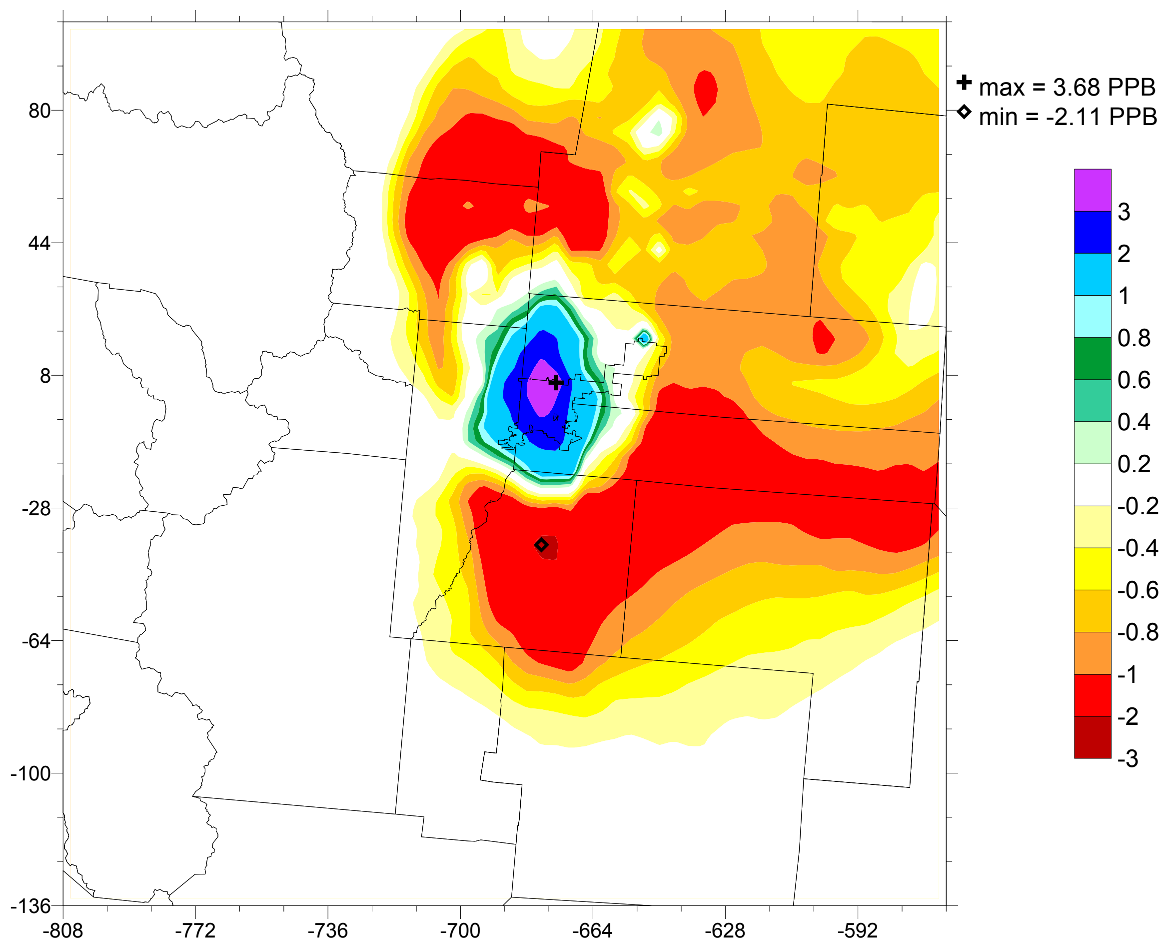
June 27 – July 1, 2002



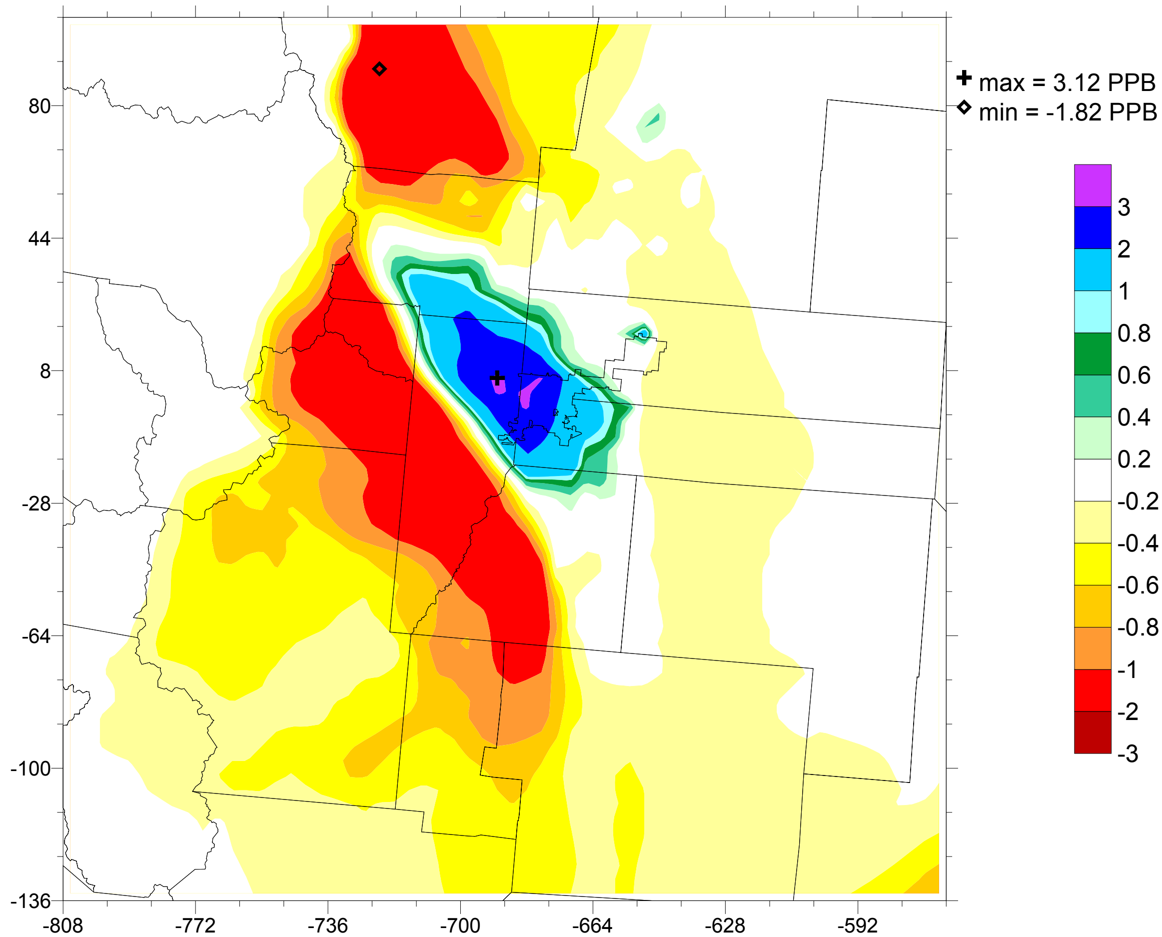
CAMx Difference in Daily Max 8hr O3
June27, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area



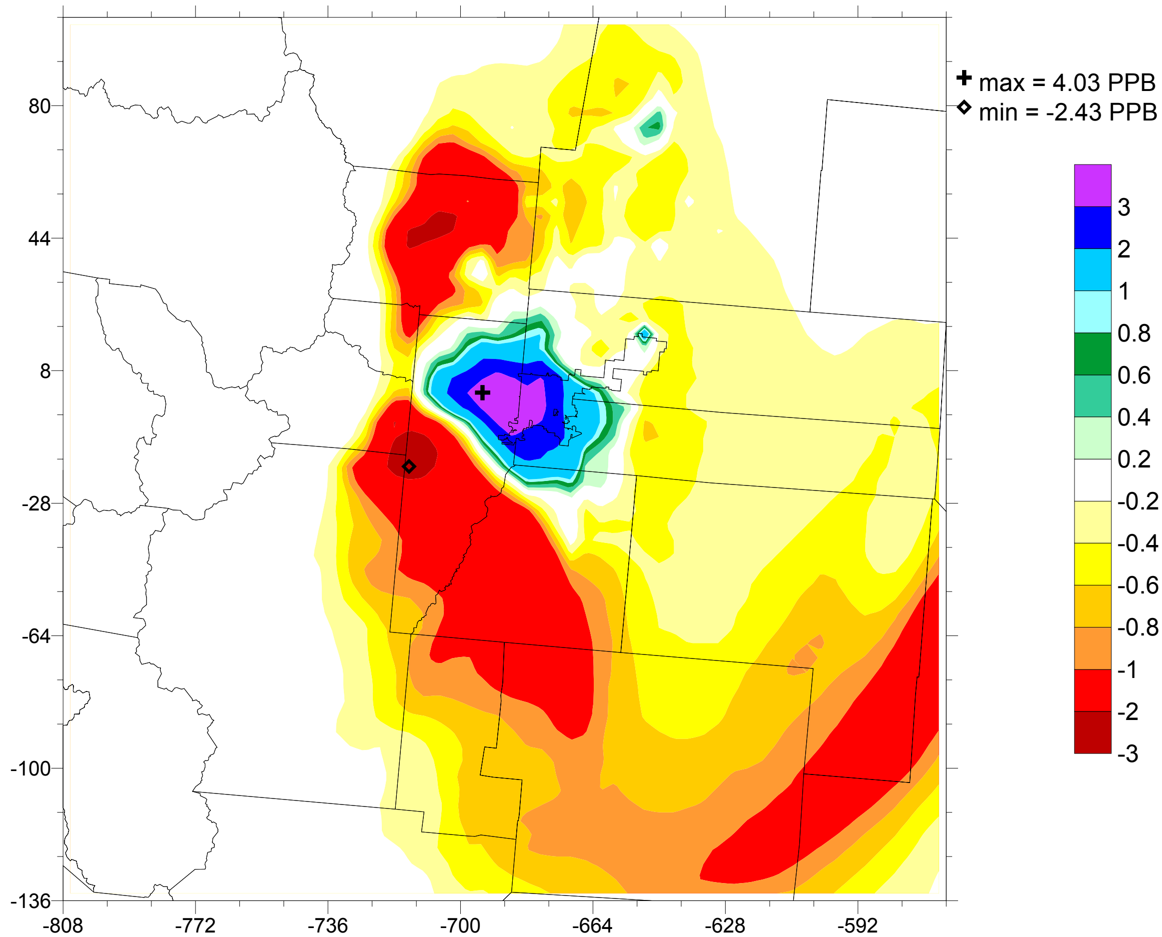
CAMx Difference in Daily Max 8hr O3
June28, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June29, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June30, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area

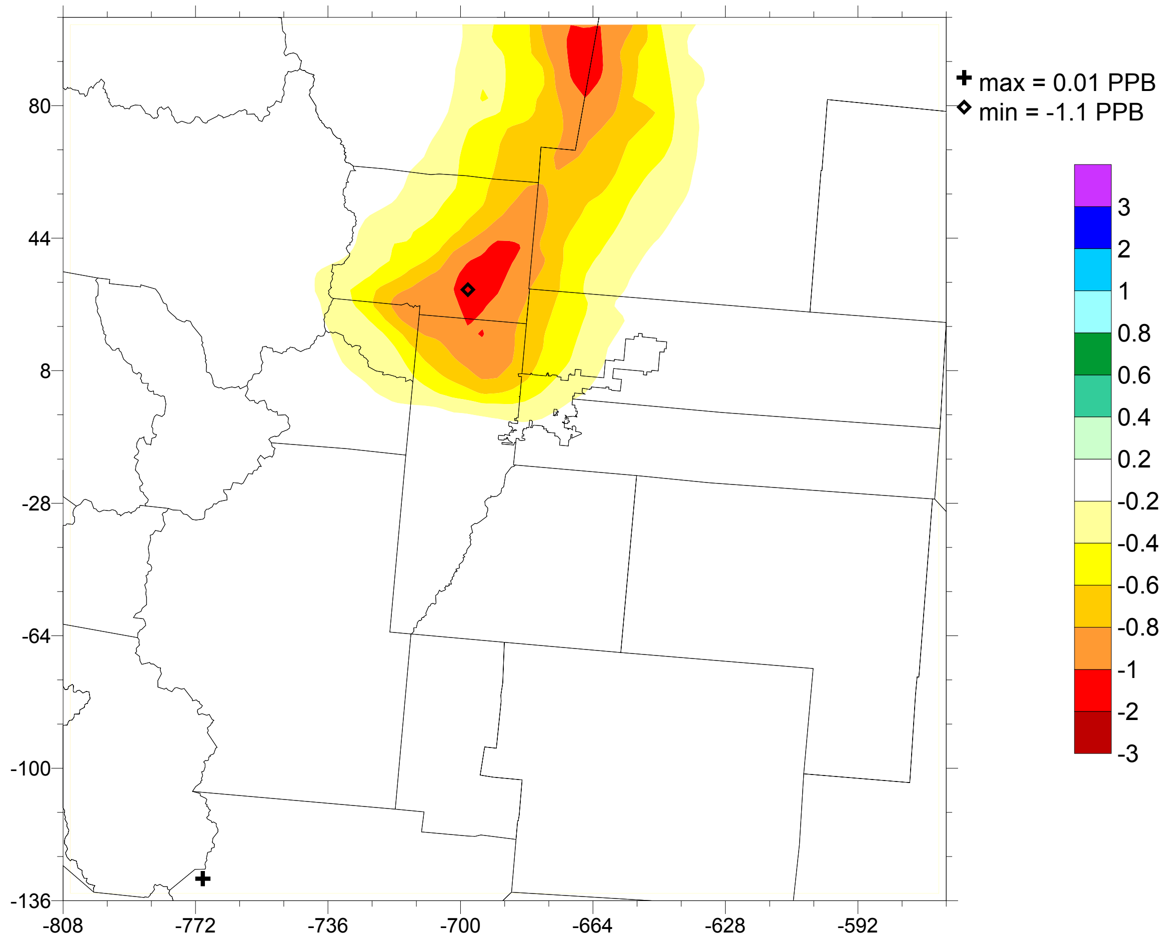


CAMx Difference in Daily Max 8hr O3
July01, 2002
Difference from Control #4 with an additional 20% NOx Reduction in 8-county Denver Area

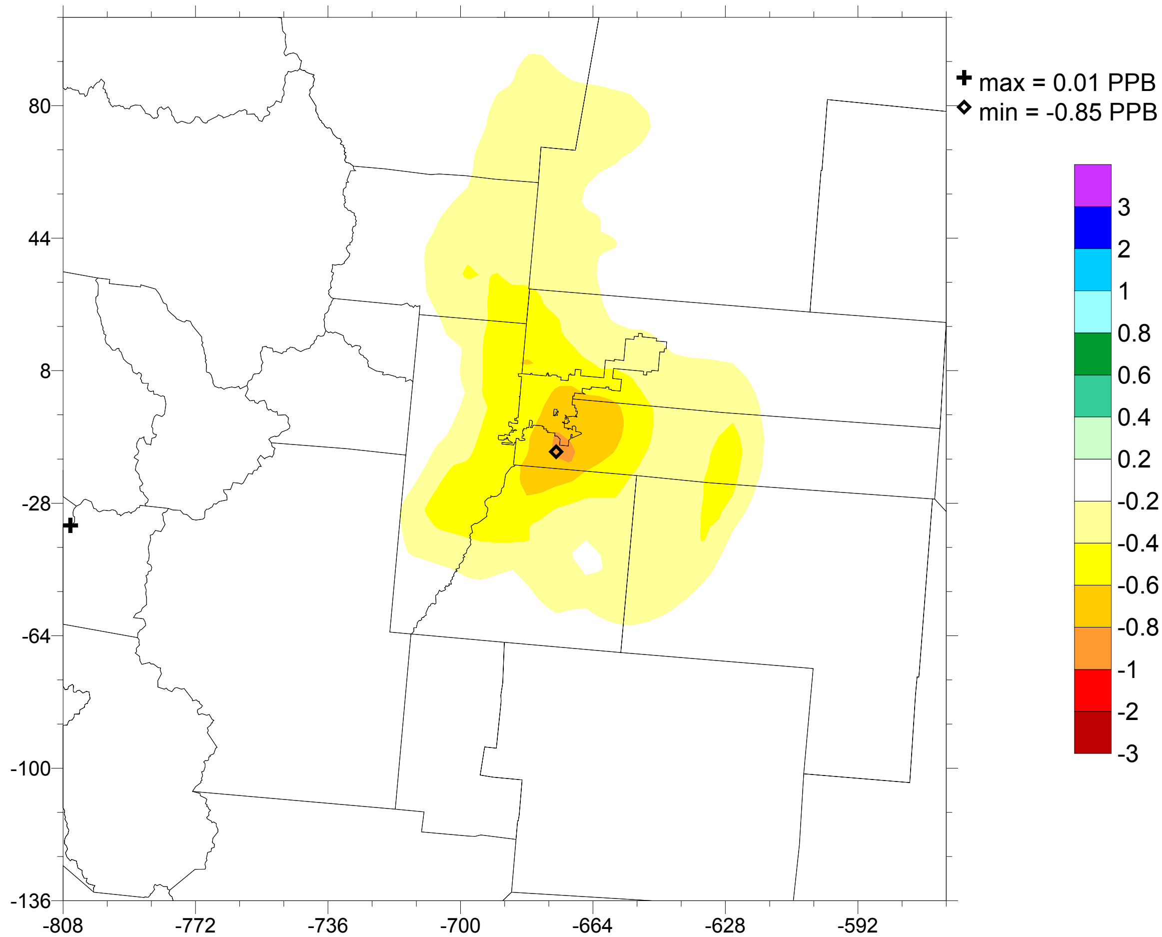
Appendix I

Estimated Differences in Daily Maximum 8-Hour Ozone Concentrations (ppb) for the 36/12/4 km Run0711a-cntl6 vs. 07Run11a-cntl4 2007 20% VOC Control in DMA+Weld – 2007 Base Case

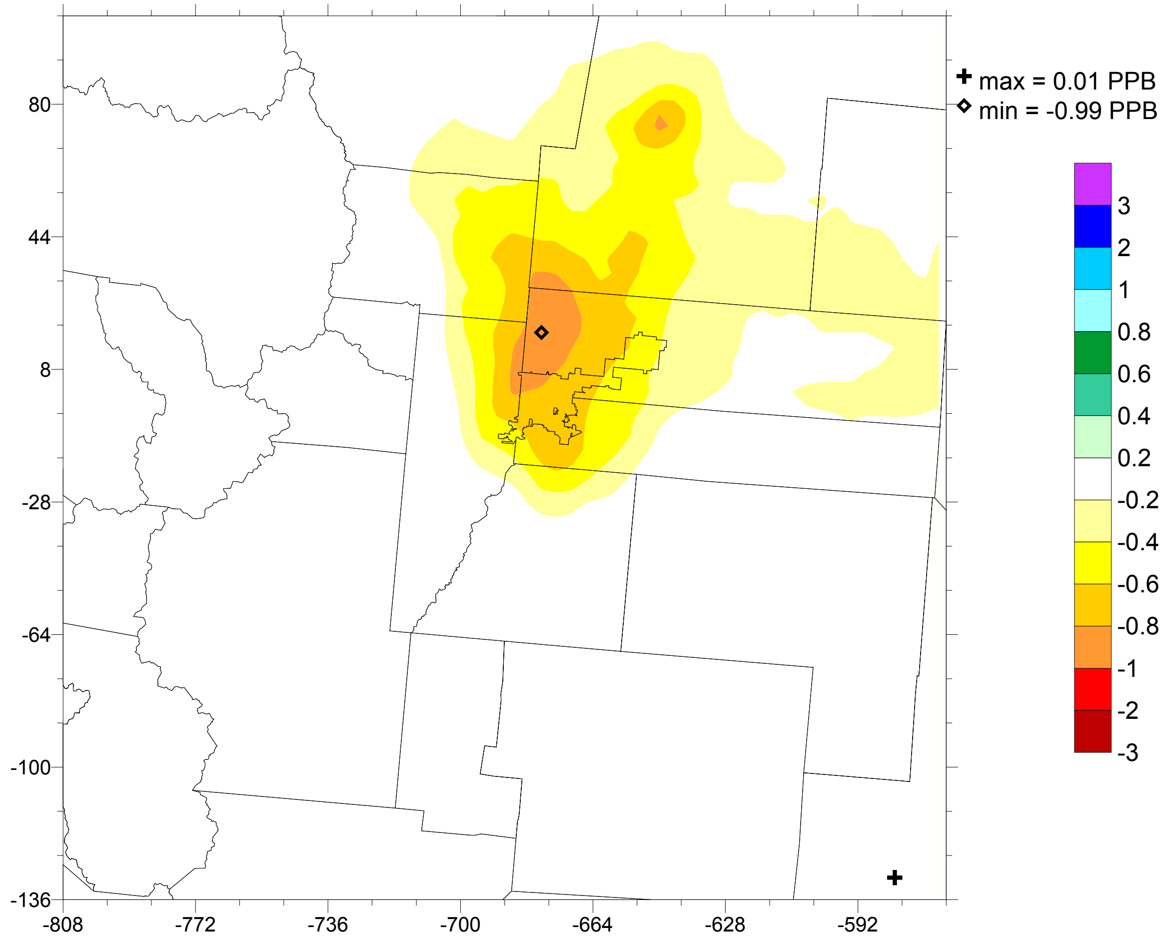
June 27 – July 1, 2002



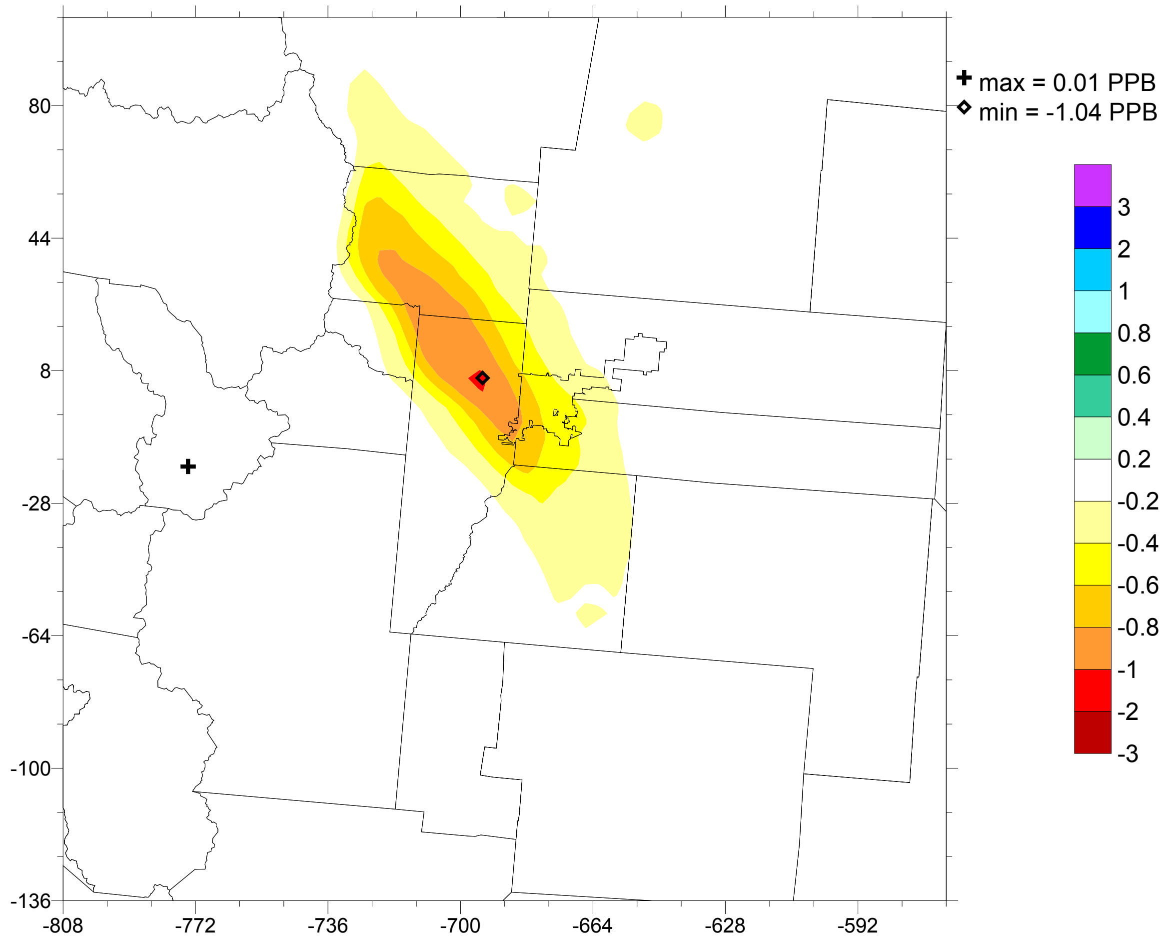
CAMx Difference in Daily Max 8hr O3
June27, 2002
Difference from Control #4 with an additional 20% VOC Reduction in 8-county Denver Area



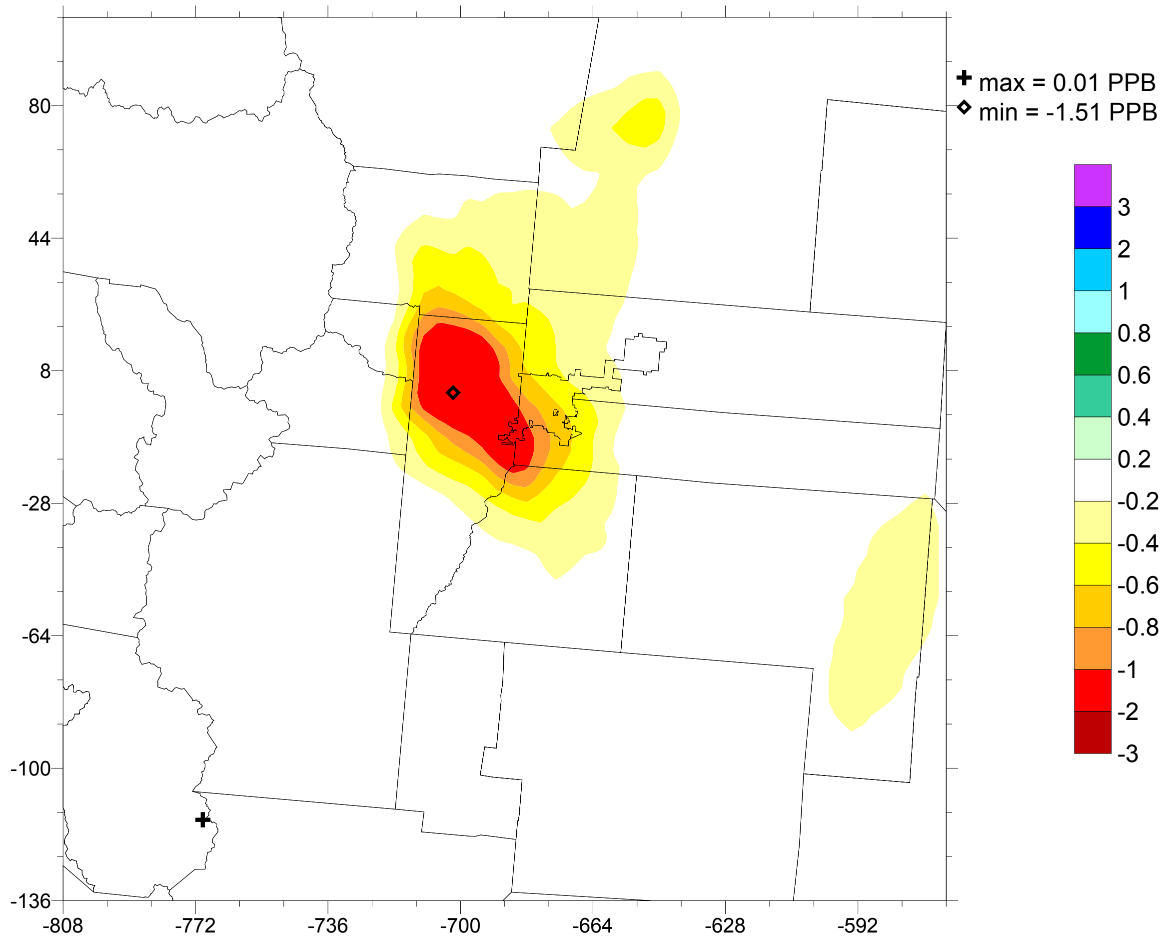
CAMx Difference in Daily Max 8hr O3
June28, 2002
Difference from Control #4 with an additional 20% VOC Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June29, 2002
Difference from Control #4 with an additional 20% VOC Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June30, 2002
Difference from Control #4 with an additional 20% VOC Reduction in 8-county Denver Area

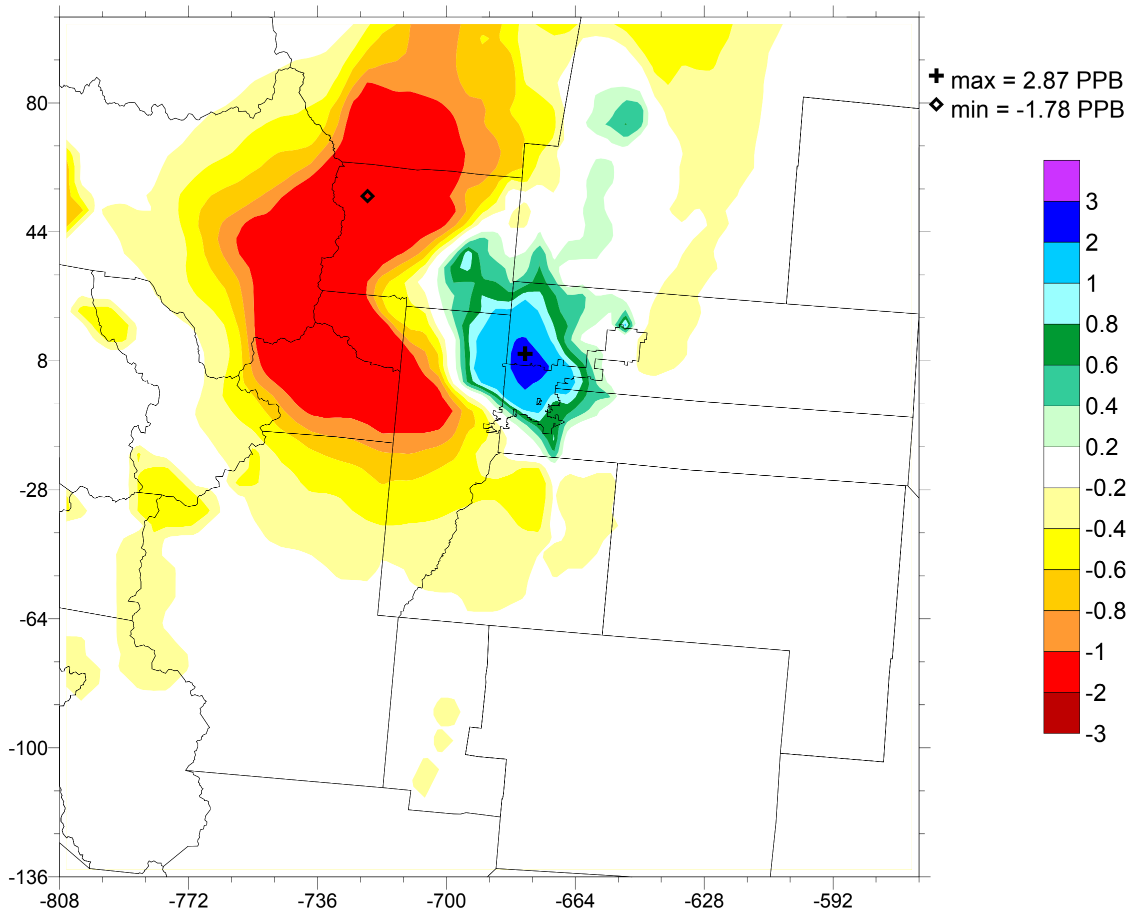


CAMx Difference in Daily Max 8hr O3
July01, 2002
Difference from Control #4 with an additional 20% VOC Reduction in 8-county Denver Area

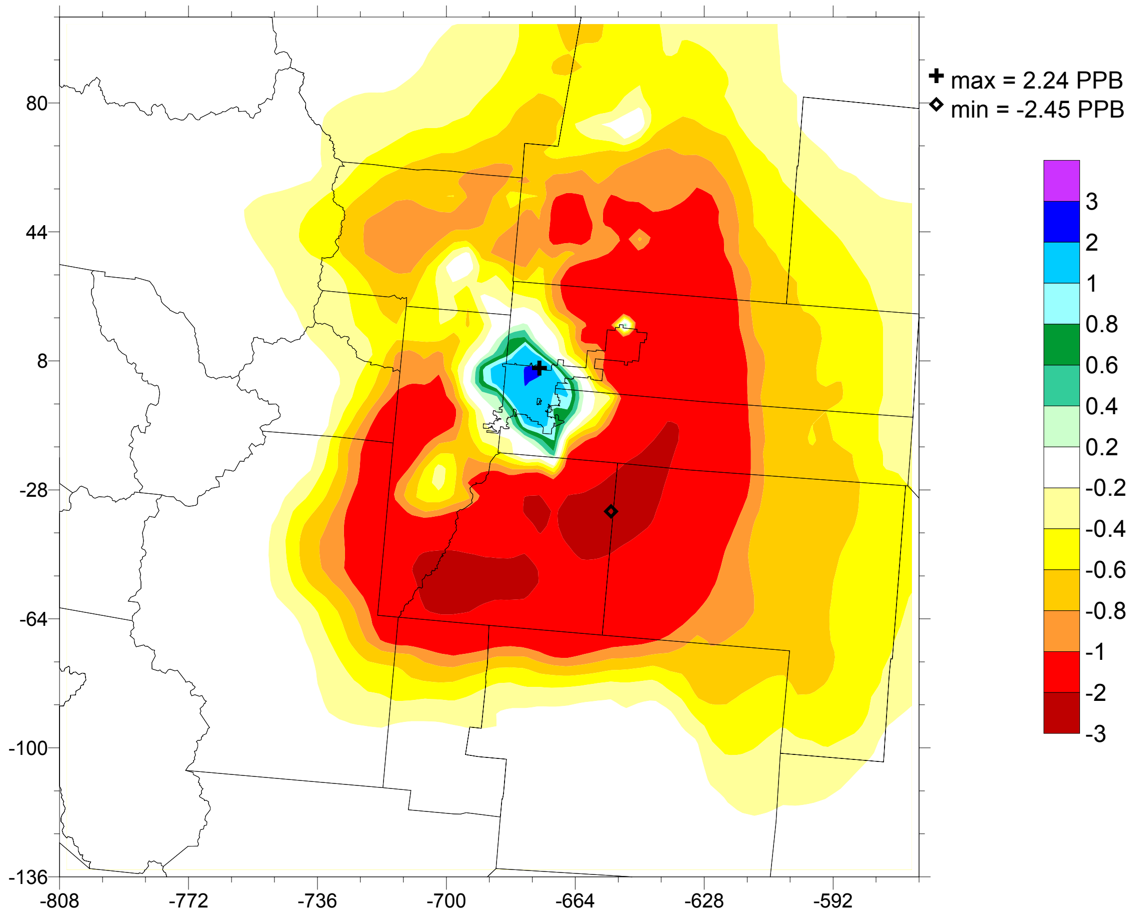
Appendix J

Estimated Differences in Daily Maximum 8-Hour Ozone
Concentrations (ppb) for the 36/12/4 km Run0711a-cntl6 vs. 07Run11a-cntl4
2007 20% NOx & VOC Control in DMA+Weld – 2007 Base Case

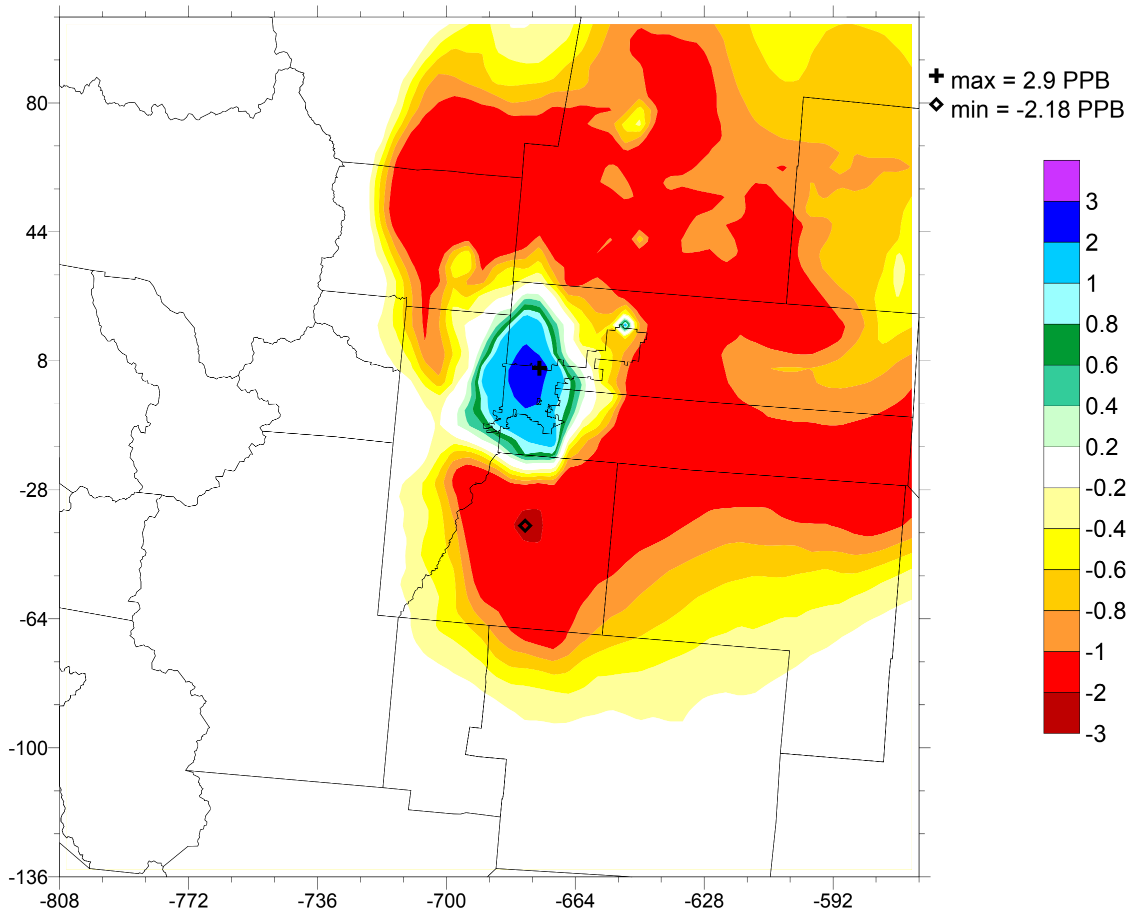
June 27 – July 1, 2002



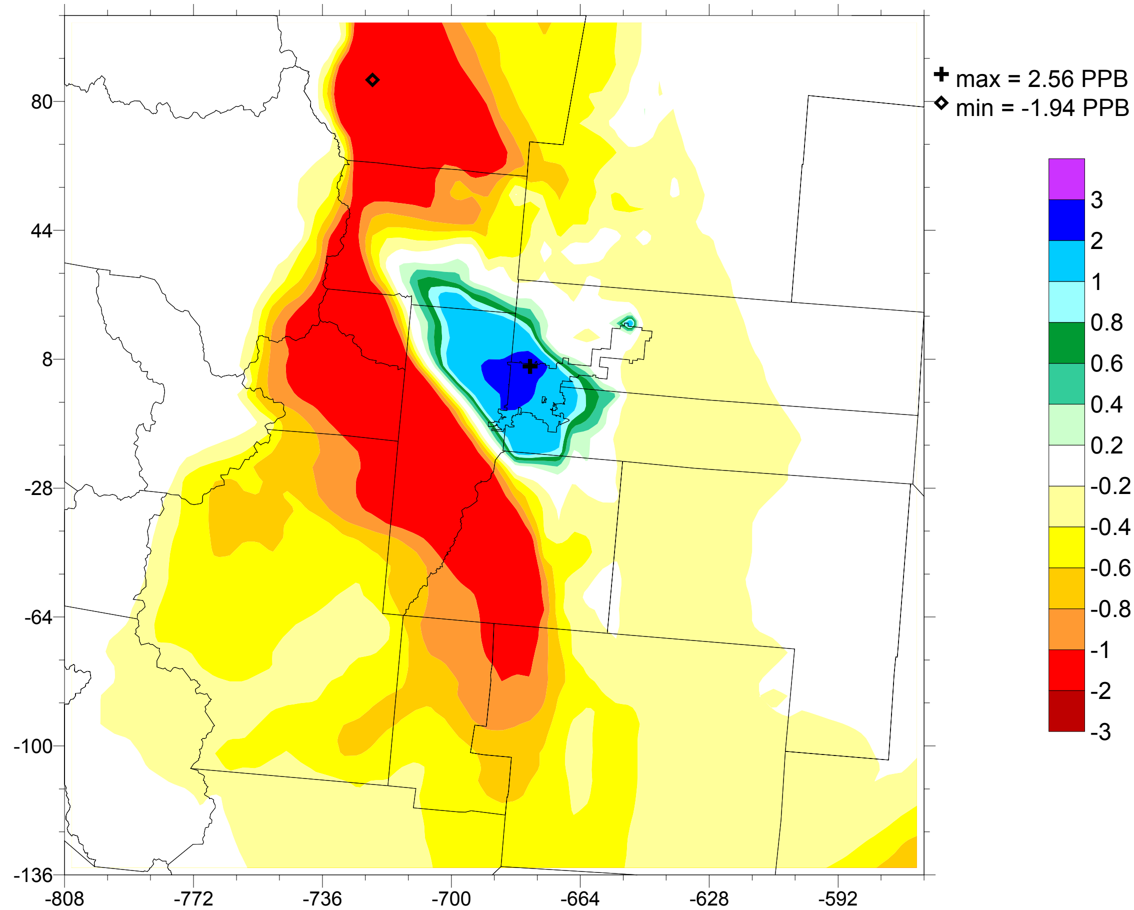
CAMx Difference in Daily Max 8hr O3
June27, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area



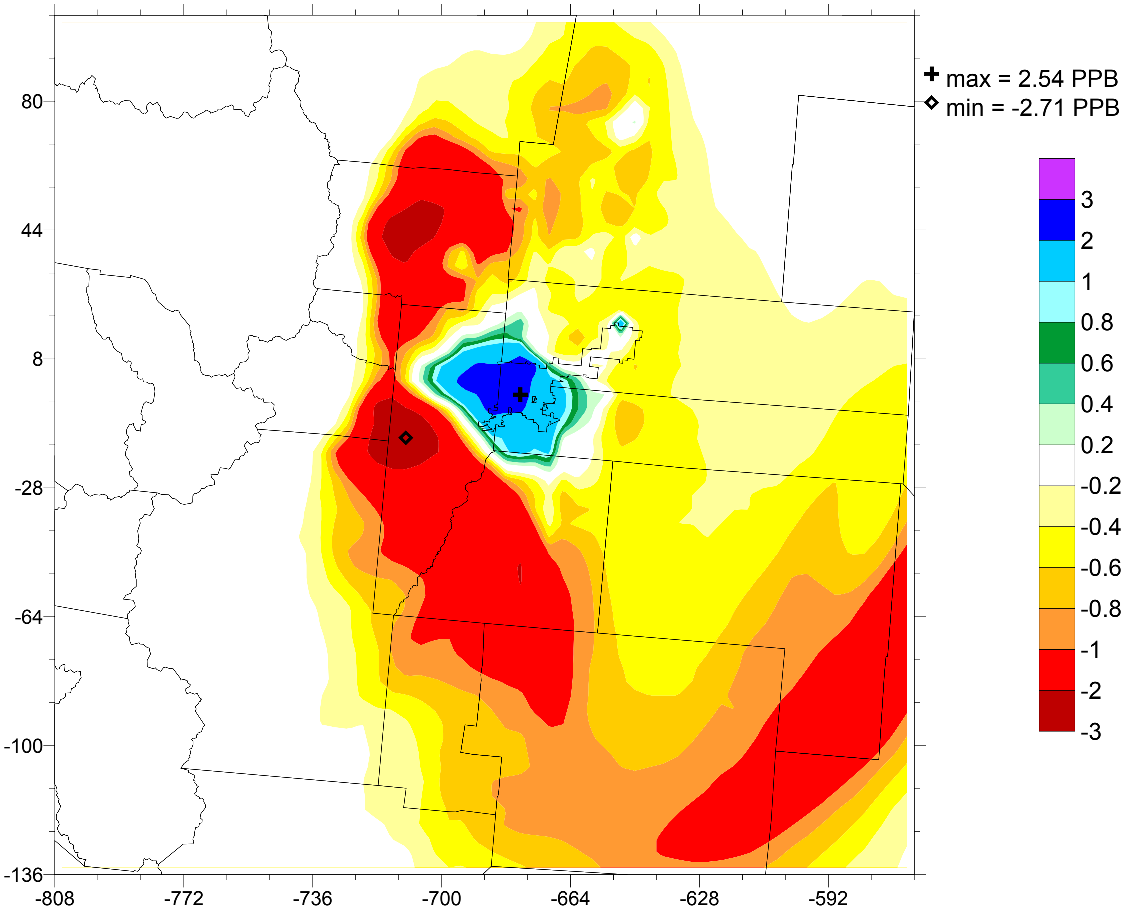
CAMx Difference in Daily Max 8hr O3
June28, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June29, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
June30, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area



CAMx Difference in Daily Max 8hr O3
July01, 2002
Difference from Control #4 with an additional 20% VOC and NOx Reduction in 8-county Denver Area

2007 Base Case, Control Strategy and Sensitivty Analysis Modeling
9-Jan-04
Appendix H

Table of Contents

(Errors were discovered in the 2007 Base Case and 2007 RVP Control runs contained in this document and have been corrected in subsequent reports. Therefore, the results in this report and appendix should be used only for comparing incremental changes from the various scenarios.)

Design Value Scaling
Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld County Tow	81	61	57.2	65.2	60.6	69.4	66.9	**70.9**	1
Rocky Mtn. NP	81	63.1	64.3	67.4	62	**71.4**	**76**	**79.1**	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	**70.7**	**73.5**	2
USAF Academy	73	56.6	63.5	56.6	66.6	61	69.4	**70.6**	1
Welch	70	58.9	66.5	69.8	**71.7**	65.7	**73**	**87.2**	3
Rocky Flats Nor	87	62.8	62.7	**70.9**	62.1	**70.5**	**73.8**	**84.5**	4
NREL	85	60.4	64.6	**70.9**	64.9	63.1	**73.8**	**87.2**	3
Arvada	76	59.8	60	**70.8**	63.1	69.1	**71.8**	**85.1**	3
Welby	66	56.6	55.2	62.6	66.5	**70**	66.2	**72.7**	2
S. Boulder Cree	77	63	62.8	**70.9**	63	**70.9**	**74.1**	**84.5**	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	**71.9**	**83.8**	2
Highland	81	57.4	66.3	62.7	**73**	69.7	**71.9**	**81.6**	3
Chatfield Res.	85	57.9	66.5	63.4	**73**	69.7	**71.9**	**85.9**	3

Future Year: 07run11a-Base

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld County Tow	81	60.5	56.8	64.8	59.9	68.8	65.7	**69.1**	0.9748	79
Rocky Mtn. NP	81	62.6	63.6	66.2	61.3	**70.4**	**74.6**	**76.8**	0.9793	79.3
Fort Collins	71	62.6	62	68.6	58.5	64.7	**71**	**71.2**	0.9867	70.1
USAF Academy	73	56.2	62.6	55.9	64.8	59.7	67.8	**68.5**	0.9707	70.9
Welch	70	58.8	67	69.3	**70.4**	65	**72.1**	**85.2**	0.9822	68.8
Rocky Flats Nor	**87**	62.9	62.1	**70.7**	61.6	**69.7**	**73.7**	**82.9**	0.9913	86.2
NREL	85	60.4	65.5	**70.7**	65.6	62.6	**73.7**	**85.2**	0.9904	84.2
Arvada	76	60	61	**70.7**	62.5	68.4	**71.2**	**84.1**	0.9926	75.4
Welby	66	56	54.7	64.5	65.4	**69.5**	67.8	**73.5**	1.0019	66.1
S. Boulder Cree	77	63	62.2	**70.7**	62.4	**70.4**	**73.7**	**82.9**	0.9913	76.3
Carriage	76	59	64.2	69.6	68.5	66.2	**70.6**	**82.2**	0.9821	74.6
Highland	81	57	66.8	63.3	**71.2**	67.6	**70.6**	**80.8**	0.9827	79.6
Chatfield Res.	85	57.9	66.8	61.7	**71.2**	67.6	**70.6**	**84.1**	0.9788	83.2

Design Value Scaling

Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld County Tow	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn. NP	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Academy	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats Nor	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder Cree	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield Res.	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl1-8.1RVP

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld County Tow	81	60.5	56.8	64.7	59.9	68.8	65.7	69.1	0.974	78.9
Rocky Mtn. NP	81	62.6	63.6	66.1	61.3	70.3	74.5	76.8	0.9785	79.3
Fort Collins	71	62.6	61.9	68.5	58.4	64.7	71	71.2	0.9861	70
USAF Academy	73	56.2	62.6	55.9	64.8	59.7	67.8	68.5	0.9703	70.8
Welch	70	58.7	66.9	69.2	70.3	65	72.1	85.1	0.9809	68.7
Rocky Flats Nor	87	62.7	62	70.6	61.6	69.6	73.6	82.8	0.9898	86.1
NREL	85	60.3	65.4	70.6	65.5	62.6	73.6	85.1	0.9889	84.1
Arvada	76	59.9	60.8	70.6	62.5	68.4	71.1	84	0.9911	75.3
Welby	66	55.9	54.6	64.4	65.4	69.4	67.7	73.3	1.0003	66
S. Boulder Cree	77	62.9	62.1	70.6	62.4	70.3	73.6	82.8	0.9898	76.2
Carriage	76	58.9	64.1	69.4	68.5	66.1	70.6	82.1	0.9809	74.5
Highland	81	57	66.7	63.3	71.1	67.5	70.5	80.7	0.9815	79.5
Chatfield Res.	85	57.9	66.7	61.6	71.1	67.5	70.6	84	0.9776	83.1

Design Value Scalin g
Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld County Tow	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn. NP	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Academy	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats Nor	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder Cree	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield Res.	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl2-Flash

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld County Tow	81	60.2	56.4	64.4	59.7	68.4	65.5	68.9	0.9709	78.6
Rocky Mtn. NP	81	62.4	63.1	66.1	61.2	70.3	74.4	76.7	0.9772	79.2
Fort Collins	71	62.3	61.5	68.2	58.3	64.4	70.8	71.1	0.9848	69.9
USAF Academy	73	56.2	62.6	55.9	64.8	59.7	67.8	68.5	0.9704	70.8
Welch	70	58.8	67	69.3	70.4	65	72	85.2	0.9809	68.7
Rocky Flats Nor	**87**	**62.8**	**61.8**	**70.7**	**61.3**	**69.5**	**73.6**	**82.7**	**0.9895**	**86.1**
NREL	85	60.3	65.5	70.7	65.4	62.6	73.6	85.2	0.9893	84.1
Arvada	76	60	60.9	70.7	62.4	68.2	71.1	84	0.9914	75.3
Welby	66	56	54.6	64.5	65.3	69.3	67.6	73.3	0.9994	66
S. Boulder Cree	77	62.8	62	70.7	62.2	70.2	73.6	82.7	0.9895	76.2
Carriage	76	59	64.1	69.5	68.4	66.1	70.5	82.1	0.9807	74.5
Highland	81	57	66.8	63.3	71.1	67.6	70.5	80.7	0.9815	79.5
Chatfield Res.	85	57.9	66.8	61.7	71.1	67.6	70.5	84	0.9776	83.1

Design Value Scalin g

Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld County Tow	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn. NP	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Academy	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats Nor	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder Cree	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield Res.	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl3-RICE

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld County Tow	81	60.2	56.7	64.8	59.7	68.3	65.6	69.1	0.9737	78.9
Rocky Mtn. NP	81	63.1	63.3	66.2	61.3	70.3	74.4	76.7	0.9772	79.2
Fort Collins	71	62.7	61.9	68.6	58.4	64.5	70.6	71.2	0.9835	69.8
USAF Academy	73	56.2	62.6	55.9	64.8	59.7	67.7	68.3	0.9671	70.6
Welch	70	58.8	67	69.3	70.4	65	72.1	85.2	0.9817	68.7
Rocky Flats Nor	87	63.3	62	70.7	61.7	69.8	73.7	82.9	0.991	86.2
NREL	85	60.4	65.6	70.7	65.6	62.6	73.7	85.2	0.9898	84.1
Arvada	76	60.1	61	70.7	62.6	68.4	71.1	84.1	0.9919	75.4
Welby	66	55.9	54.8	64.4	65.3	69.4	67.8	73.5	1.0009	66.1
S. Boulder Cree	77	63.6	62.2	70.7	62.4	70.3	73.7	82.9	0.9905	76.3
Carriage	76	59.1	64.3	69.5	68.5	66.1	70.6	82.1	0.9814	74.6
Highland	81	57	66.9	63.3	71.1	67.5	70.5	80.7	0.9818	79.5
Chatfield Res.	85	57.9	66.9	61.6	71.1	67.5	70.6	84.1	0.9781	83.1

Design Value Scaling

Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld County Tow	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn. NP	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Academy	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats Nor	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder Cree	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield Res.	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl4-RVP/Flash/RICE

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld County Tow	81	59.9	56.3	64.3	59.5	67.9	65.5	68.7	0.9691	78.5
Rocky Mtn. NP	81	62.8	62.8	66	61	70.1	74.2	76.5	0.9744	78.9
Fort Collins	71	62.3	61.4	68.1	58.2	64.2	70.4	71	0.9811	69.7
USAF Academy	73	56.2	62.6	55.9	64.8	59.7	67.6	68.2	0.9665	70.6
Welch	70	58.7	66.9	69.1	70.2	64.9	71.9	85	0.9791	68.5
Rocky Flats Nor	87	63.1	61.7	70.5	61.3	69.6	73.4	82.6	0.9879	85.9
NREL	85	60.3	65.4	70.5	65.4	62.5	73.4	85	0.9871	83.9
Arvada	76	60	60.8	70.5	62.3	68.1	70.9	83.8	0.9892	75.2
Welby	66	55.9	54.6	64.3	65.2	69.1	67.6	73.2	0.9969	65.8
S. Boulder Cree	77	63.3	61.9	70.5	62.1	70.1	73.4	82.6	0.9873	76
Carriage	76	59	64.1	69.3	68.3	65.9	70.4	81.9	0.9789	74.4
Highland	81	57	66.7	63.2	71	67.5	70.4	80.5	0.9795	79.3
Chatfield Res.	85	57.9	66.7	61.6	71	67.5	70.4	83.8	0.9757	82.9

Design Value Scaling
Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld Coun	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn.	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Aca	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flat	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield R	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl5-20%VOC

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld Coun	81	59.2	55.9	65.2	58.6	66.4	65.3	68.6	0.967	78.3
Rocky Mtn.	81	63.8	62.1	65.1	60.5	68.8	73.8	74.4	0.9578	77.6
Fort Collins	71	62.2	61.1	68.1	57.8	63.3	69.2	70.8	0.9714	69
USAF Aca	73	56.1	62.4	55.7	63.5	59	66.9	67.4	0.9544	69.7
Welch	70	60	68.1	69.1	69.2	64.3	72.5	85.1	0.9778	68.4
Rocky Flat	87	65.9	62.9	70.9	61.2	69.2	74.1	83.5	0.9934	86.4
NREL	85	61.7	67.3	70.9	66.3	64.2	74.1	85.1	0.9924	84.4
Arvada	76	61.9	63.8	70.9	63.9	68.7	71.7	83.6	0.9932	75.5
Welby	66	57.8	58.6	66.4	65.4	69	69.6	76.3	1.018	67.2
S. Boulder	77	65.9	63.4	70.9	61.6	69.3	74.1	83.1	0.9902	76.2
Carriage	76	60.8	66.6	70.3	68.3	66.7	71.2	81.8	0.9832	74.7
Highland	81	57.8	68	63.3	69.3	65.6	70.5	80.6	0.9733	78.8
Chatfield R	85	58.3	68.1	61	69.3	65.6	70.5	83.6	0.9679	82.3

Design Value Scaling

Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld Coun	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn.	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Acad	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield R	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl6-20%NOx

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld Coun	81	59.6	56	63.2	59.3	67.5	65.3	68.3	0.963	78
Rocky Mtn.	81	62.1	62.4	65.5	60.8	69.7	73.7	76.3	0.9696	78.5
Fort Collins	71	61.9	61	67.3	57.9	63.9	70.3	70.9	0.9796	69.6
USAF Acad	73	56.2	62.6	55.9	64.7	59.7	67.4	68.2	0.9662	70.5
Welch	70	58.2	65.8	68.5	69.7	64.6	71.1	84	0.9693	67.8
Rocky Flats	87	61.9	61.2	69.7	60.9	68.9	72.6	81.4	0.9767	85
NREL	85	59.7	64.2	69.7	64.7	62	72.6	84	0.976	83
Arvada	76	59.3	59.6	69.7	61.6	67.2	70.2	82.7	0.9778	74.3
Welby	66	55.6	54.3	63.4	64.6	68.4	66.7	71.8	0.9822	64.8
S. Boulder	77	62.2	61.3	69.7	61.8	69.5	72.6	81.4	0.9761	75.2
Carriage	76	58.2	62.8	68.5	67.6	65.2	69.9	80.9	0.9693	73.7
Highland	81	56.7	65.5	62.9	70.5	67.3	69.9	79.5	0.9713	78.7
Chatfield R	85	57.5	65.6	61.5	70.5	67.3	69.9	82.9	0.9674	82.2

Design Value Scaling
Base Case: run11a

Site	DV	2176	2177	2178	2179	2180	2181	2182	#Days>70
Weld Coun	81	61	57.2	65.2	60.6	69.4	66.9	70.9	1
Rocky Mtn.	81	63.1	64.3	67.4	62	71.4	76	79.1	3
Fort Collins	71	63.2	62.6	69.5	59	65.4	70.7	73.5	2
USAF Acad	73	56.6	63.5	56.6	66.6	61	69.4	70.6	1
Welch	70	58.9	66.5	69.8	71.7	65.7	73	87.2	3
Rocky Flats	87	62.8	62.7	70.9	62.1	70.5	73.8	84.5	4
NREL	85	60.4	64.6	70.9	64.9	63.1	73.8	87.2	3
Arvada	76	59.8	60	70.8	63.1	69.1	71.8	85.1	3
Welby	66	56.6	55.2	62.6	66.5	70	66.2	72.7	2
S. Boulder	77	63	62.8	70.9	63	70.9	74.1	84.5	4
Carriage	76	58.4	62.3	68.8	67.9	66.6	71.9	83.8	2
Highland	81	57.4	66.3	62.7	73	69.7	71.9	81.6	3
Chatfield R	85	57.9	66.5	63.4	73	69.7	71.9	85.9	3

Future Year: 07run11a-cntl7-20% VOC-NOX

Site	DV	2176	2177	2178	2179	2180	2181	2182	RRF DV	Scaled
Weld Coun	81	58.9	55.7	64.2	58.4	66.1	65.1	68.1	0.9603	77.8
Rocky Mtn.	81	63.1	61.7	64.7	60.3	68.5	73.3	74.2	0.9534	77.2
Fort Collins	71	61.9	60.7	67.3	57.6	63.1	69.1	70.7	0.9701	68.9
USAF Acad	73	56.1	62.4	55.7	63.4	59	66.8	67.3	0.9542	69.7
Welch	70	59.3	66.9	68.5	68.7	64	71.8	84	0.9681	67.8
Rocky Flats	87	64.7	61.8	70.1	60.8	68.4	73.4	82.3	0.9817	85.4
NREL	85	60.9	66.1	70.1	65.5	63.6	73.4	84	0.9812	83.4
Arvada	76	60.6	62.4	70.1	63.1	67.9	71	82.7	0.9827	74.7
Welby	66	56.8	57.2	65.4	64.8	68.3	68.8	74.9	1.0038	66.2
S. Boulder	77	64.7	62.4	70.1	61.3	68.8	73.4	82	0.9799	75.5
Carriage	76	59.9	65.2	69.5	67.7	66	70.3	80.8	0.9709	73.8
Highland	81	57.3	66.9	63	69	65.4	70	79.7	0.9652	78.2
Chatfield R	85	57.9	66.9	60.9	69	65.4	70	82.7	0.96	81.6