

# Weight of Evidence Approach to Support the Denver 8-hr Ozone SIP Modeling

Presentation for the  
Regional Air Quality Council  
Stakeholder Meeting  
September 4, 2008

# Rationale for a Weight of Evidence (WOE) Analysis

- EPA's 8-hour ozone modeling guidance recommends a WOE analysis to support the modeled attainment determination if the maximum modeled 8-hour ozone future design value is between 0.082 ppm and 0.087 ppm at more than one monitor.
  - The future 2010 base year model analysis had four monitoring locations (Rocky Flats North, Fort Collins West, Chatfield and NREL) that had modeled design value concentrations that fall into the 0.082-0.087 ppm range.
- Supplemental analyses used in a weight of evidence will help determine whether attainment is likely where modeled attainment test results indicate future air quality levels are near the NAAQS.

# Why is a weight of evidence needed for attainment demonstration purposes?

- Models are necessary and reasonable but simplistic approximations of complex phenomena.
- Model inputs (emissions, meteorological, IC/BC, landuse, etc.) and model code are subject to uncertainty.
- In recognition of these uncertainties, ozone modeling has evolved:
  - from using models in an absolute sense w/ attainment “bright lines” (90s),
  - to currently using models in a relative sense to project an expected change in ozone which can be used to assess whether attainment will be reached in the future via a “bright line” determination (recent national rules and guidance),
  - The future is to use modeling as the primary element in a suite of tools that assist in an assessment of present and future air quality trends (75 ppb standard attainment demonstrations).

# What is a Weight of Evidence Analysis?

- **Weight of evidence differs from supplemental analyses in that:**
  - WOE is a set of supplemental analyses for areas whose attainment test results indicate future AQ levels near the NAAQS.
  - WOE combines and weighs the various supplemental analyses with the results of the attainment test
  - The goal of the WOE is to present an aggregate, weighted, and subjective conclusion as to whether a set of control strategies will yield attainment by the relevant future year.

# Elements of the Supplemental Analyses for the for the Denver SIP WOE

- Air quality related trends
- Ozone conceptual model for the north front range
- Use other modeled metrics to assess the changes in ozone
- Alternative attainment test methodologies
- Assess the efficacy of SIP, state-only and voluntary control strategies

# Emissions and Air Quality Trends

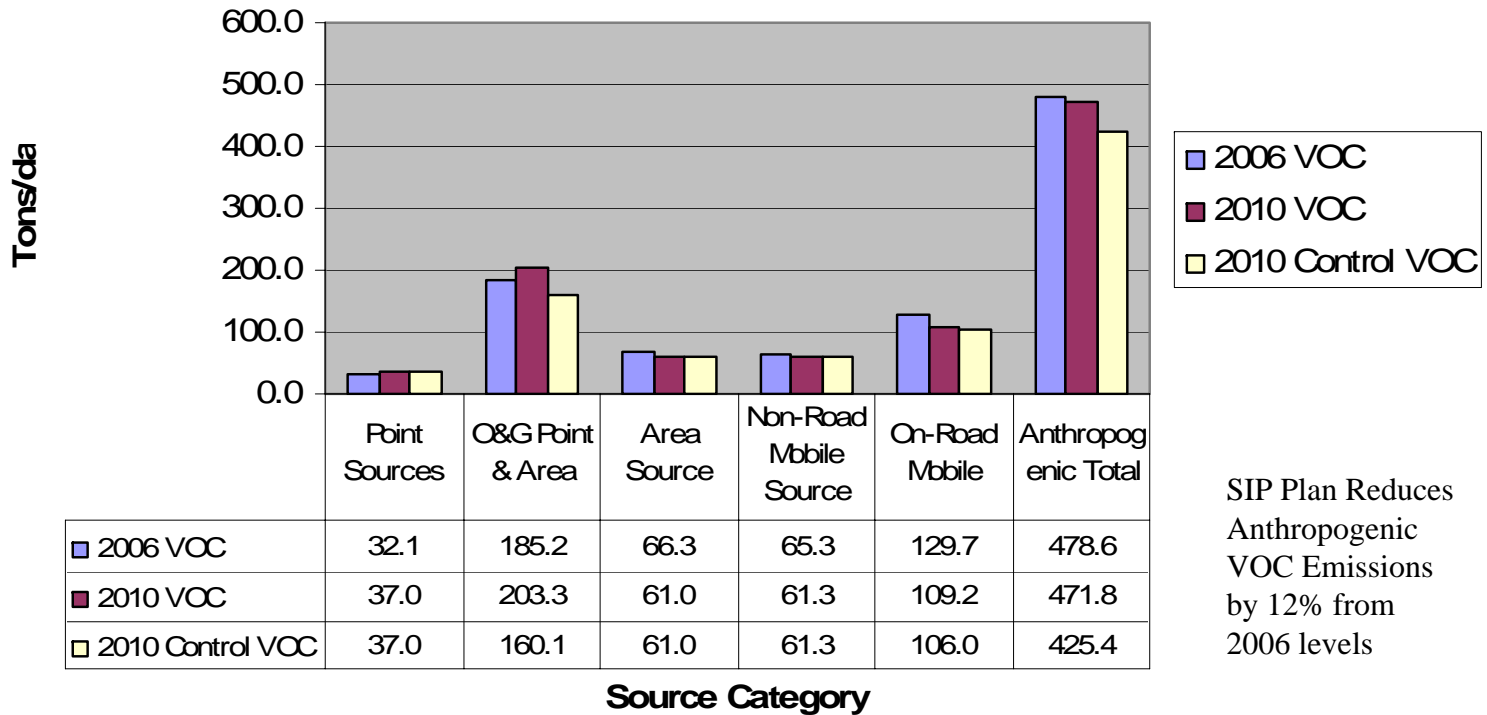
- Supplementary trend analysis
  - Emissions Trends
  - Trends in monitored 1<sup>st</sup> maximum and 4<sup>th</sup> maximum ozone values
  - Trends in three year design values

# Emission Trends

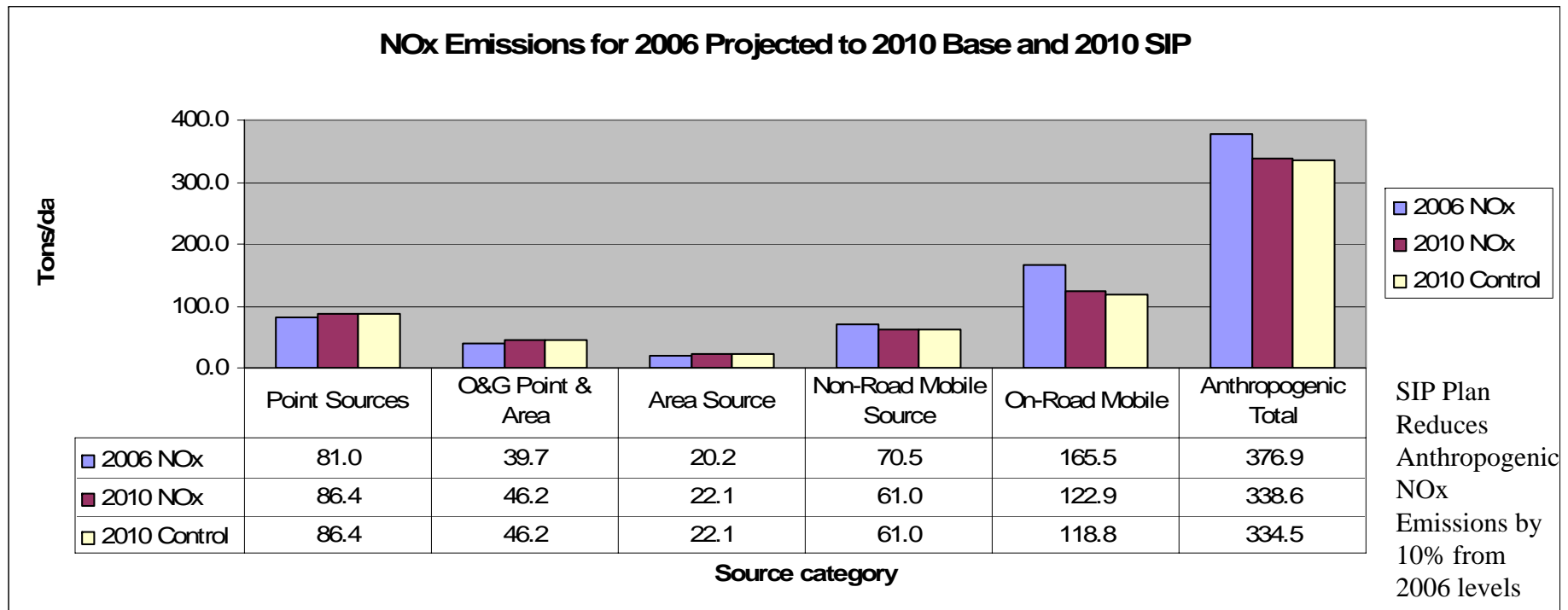
- Impacts of federal tail pipe regulations have continued to reduce mobile source emissions of VOC and NOx over time.
- The Tier 2 & 3 no-road mobile regulations reduce both NOx and VOC
- Reformulation of paints and consumer products reduce VOC emissions in the area source category.
- Point source growth has been modest
- The one area of significant emissions growth since 2002 has been in the oil & gas industry.
- Despite continued growth in VMT, population and housing in the DMA, the region has seen declining emissions of VOC and NOx in mobile, non-road and area sources.

# Projected VOC Emission Trends

VOC Emissions for 2006 Projected to 2010 Base and 2010 SIP



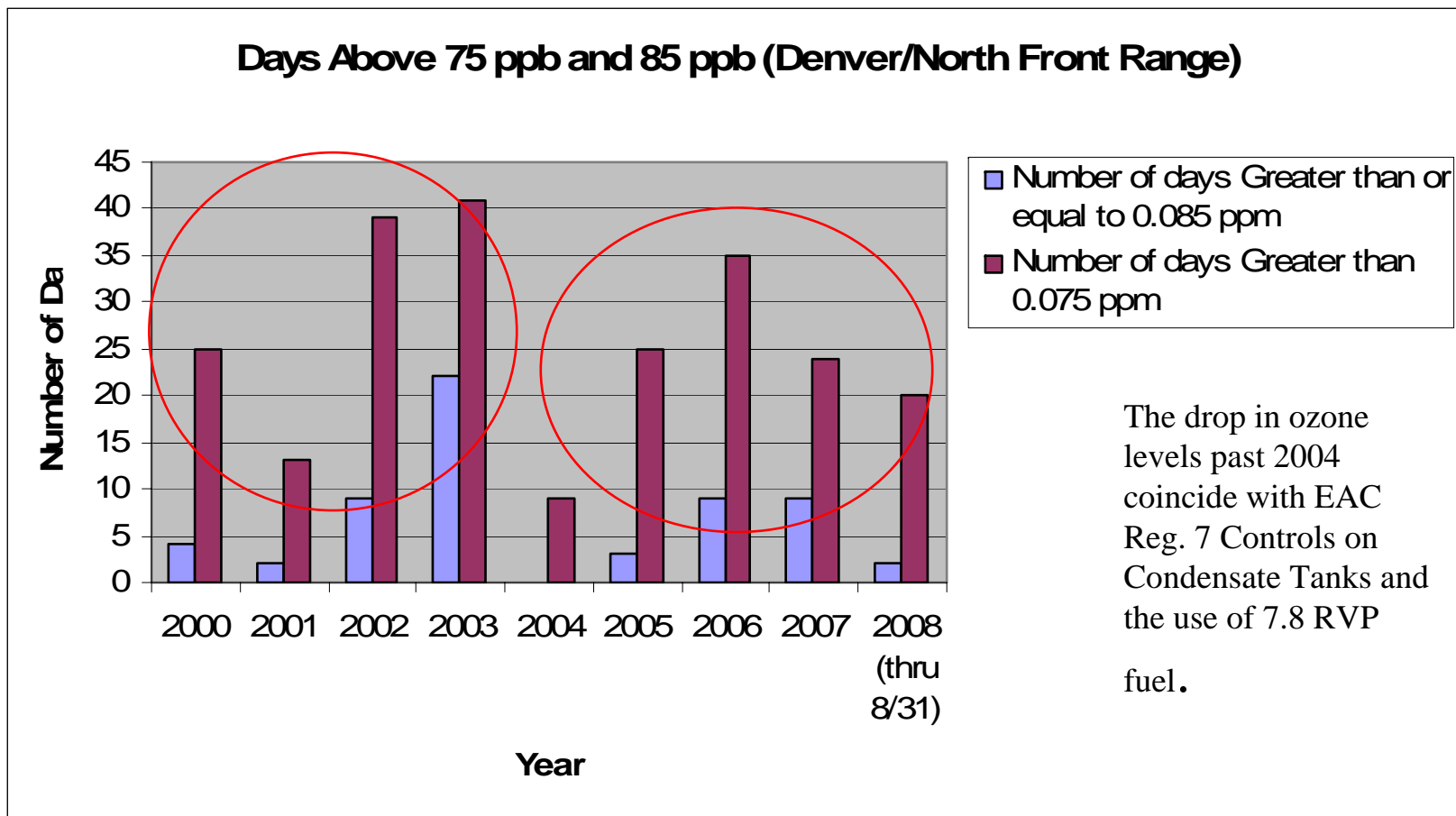
# Projected NOx Emission Trends



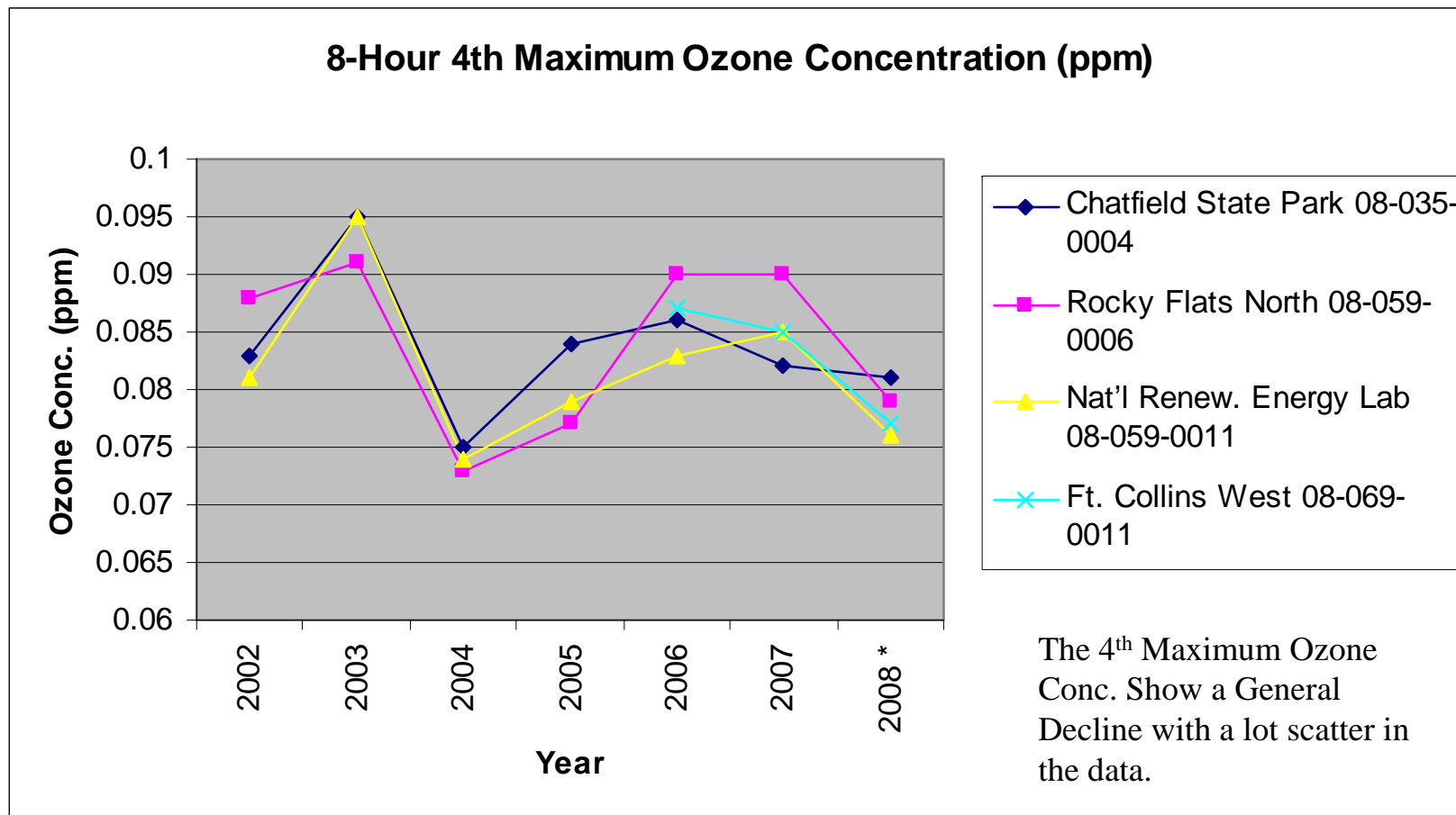
# Projected Emission Trend Conclusion

- Reductions in NO<sub>x</sub> and VOC emission are consistent with the sensitivity test
- Local NO<sub>x</sub> controls can be effective in reducing ozone, but can also produce local ozone increases in metropolitan Denver and at locations of point sources
- Increases due to NO<sub>x</sub> controls were mainly at receptors that do not exceed the current standards
- Local VOC controls also reduce ozone and do not exhibit adverse effects

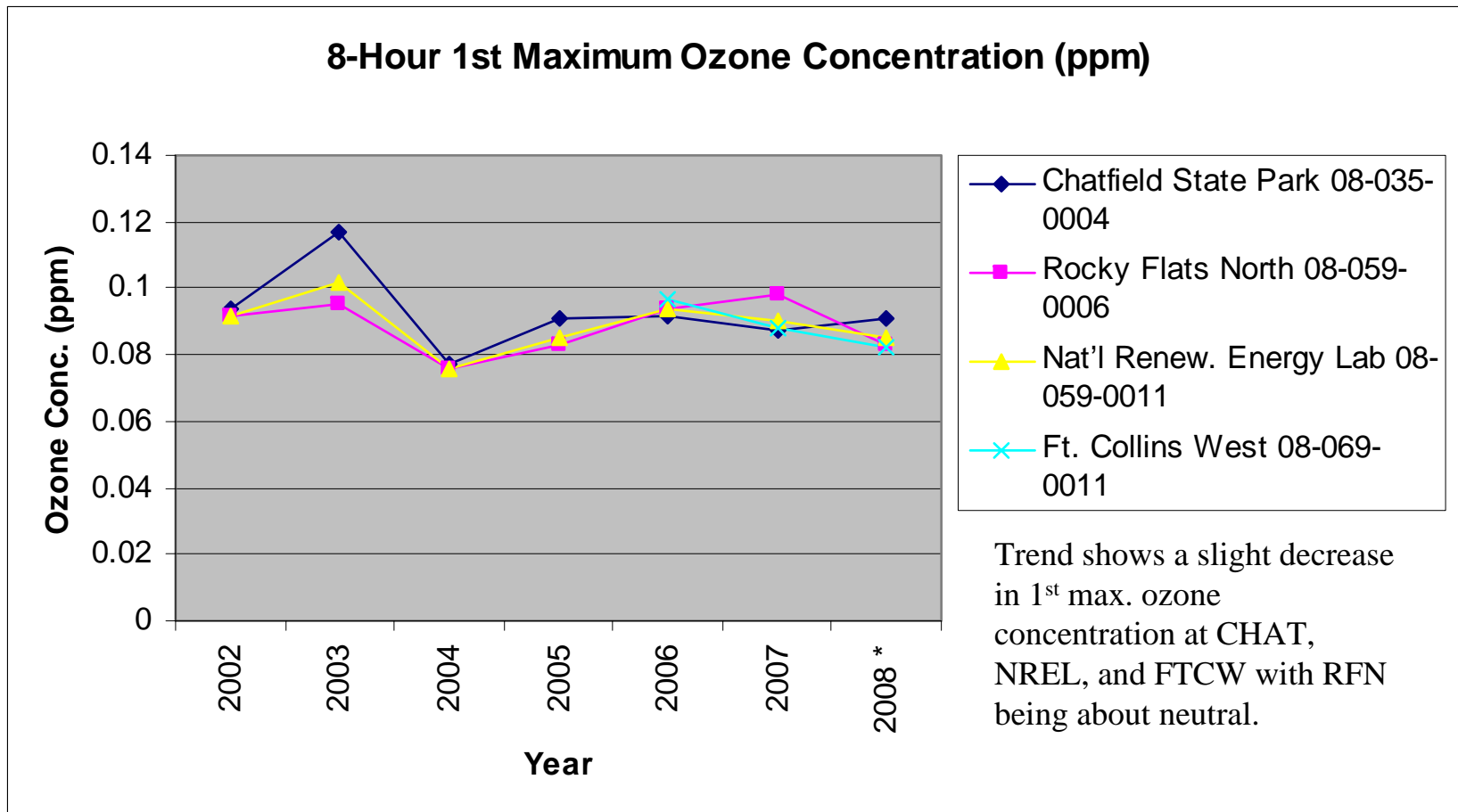
# Monitoring Trends-Days Exceeding 0.085 ppm and 0.075 ppm



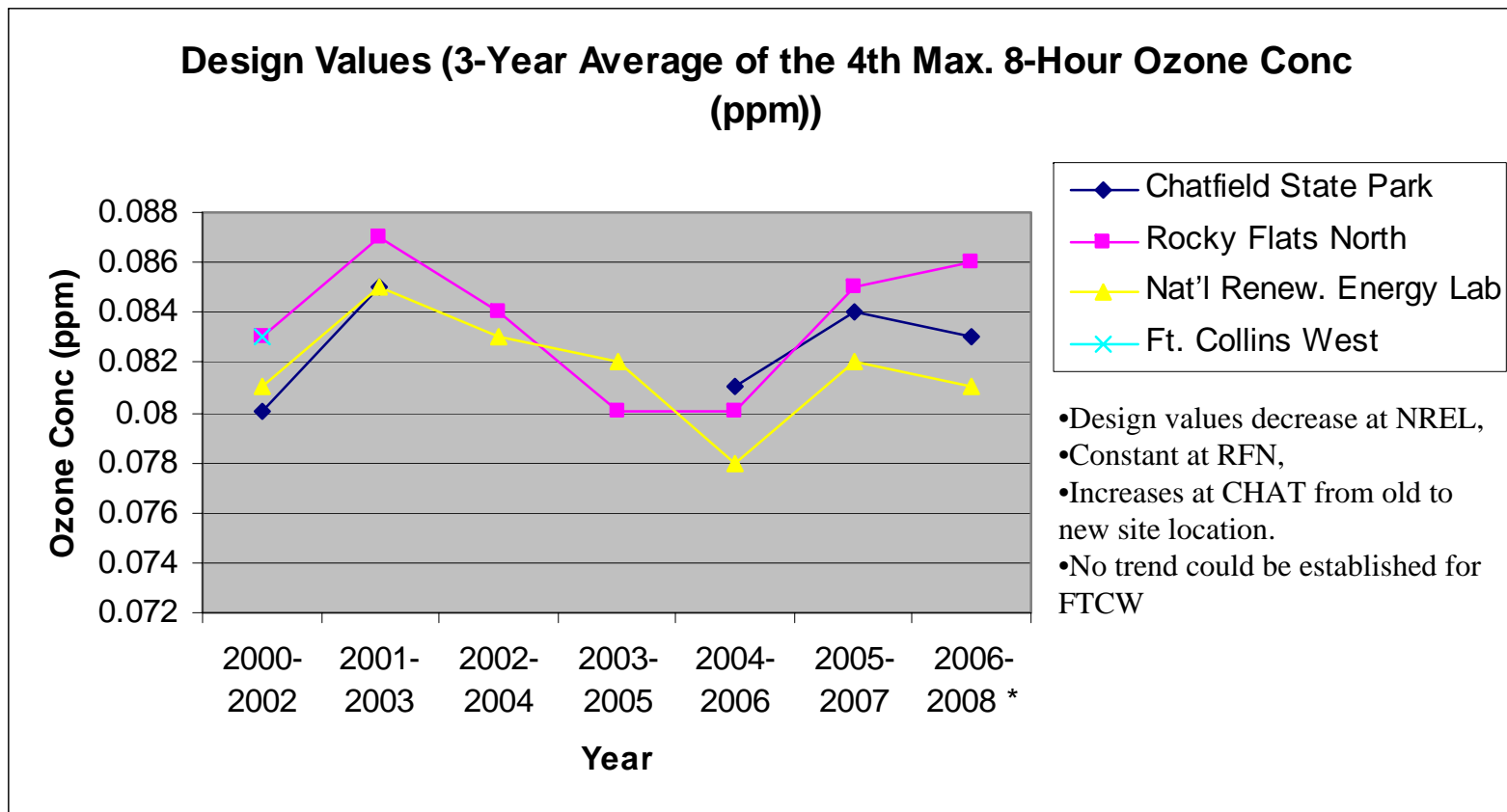
# Monitoring Trends-4<sup>th</sup> Maximum Ozone Concentration at Key Monitors



# Monitoring Trends-1st Maximum Ozone Concentration at Key Monitors



# Monitoring Trends-Design Value Trends

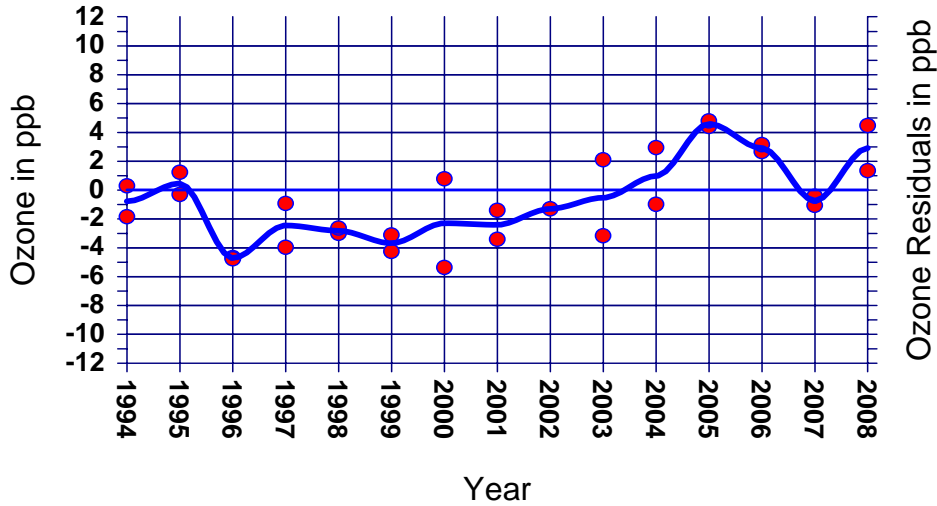


# Ozone Conceptual Model for the North Front Range

- A conceptual model describes the local meteorological conditions and associated large-scale weather patterns experienced during periods of high ozone
- Key meteorological ingredients for high ozone at the surface
  - Light winds
  - A deep layer of thermally-driven upslope flow during the day
  - Cloud-free skies
  - Warm temperatures are key ingredients for high ozone at the surface
  - Local vertical re-circulation to around 18,000 Feet (~500 mb height)

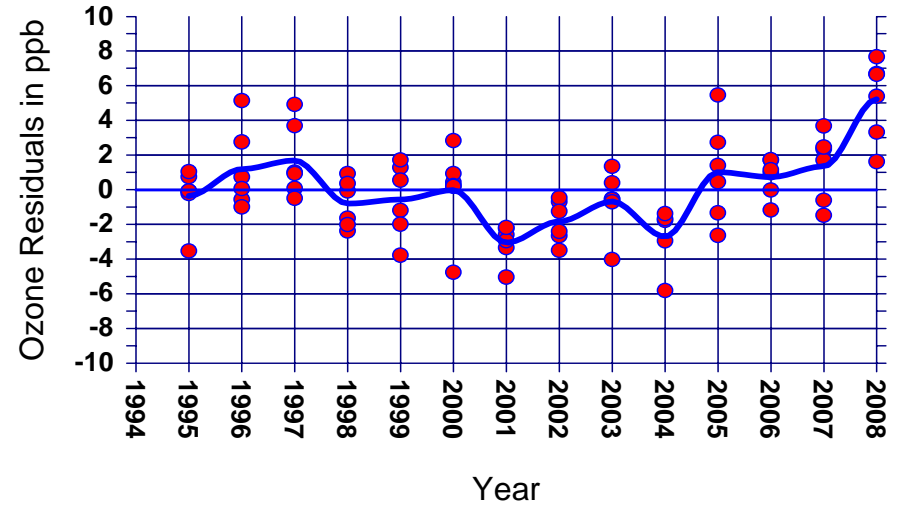
- July monthly mean daily maximum 8-hour ozone is more strongly correlated with upper level high pressure strength than any of a host of other logical choices for significant predictors of ozone, including temperatures, winds aloft, cloud cover, solar radiation, and number of days with temperatures above 90 degrees.
- July monthly mean daily maximum 8-hour ozone correlates with upper level high pressure strength with R-squared values as high as 0.84.
- July is the pivotal month for our ozone season, and high pressure strength in July has a pivotal effect on annual 4<sup>th</sup> max ozone. R-squared values for 4<sup>th</sup> max concentrations and 500 mb heights are as high as 0.77.
- The strong linear relationships between ozone and 500 mb heights at most sites can be used to remove the effects of weather from the ozone record.

Trend in FTC/GRE July Mean Daily Max 8-hr Ozone, Effect of Mean 500 mb Heights Removed



(Residuals are differences between actual and weather predicted ozone.)

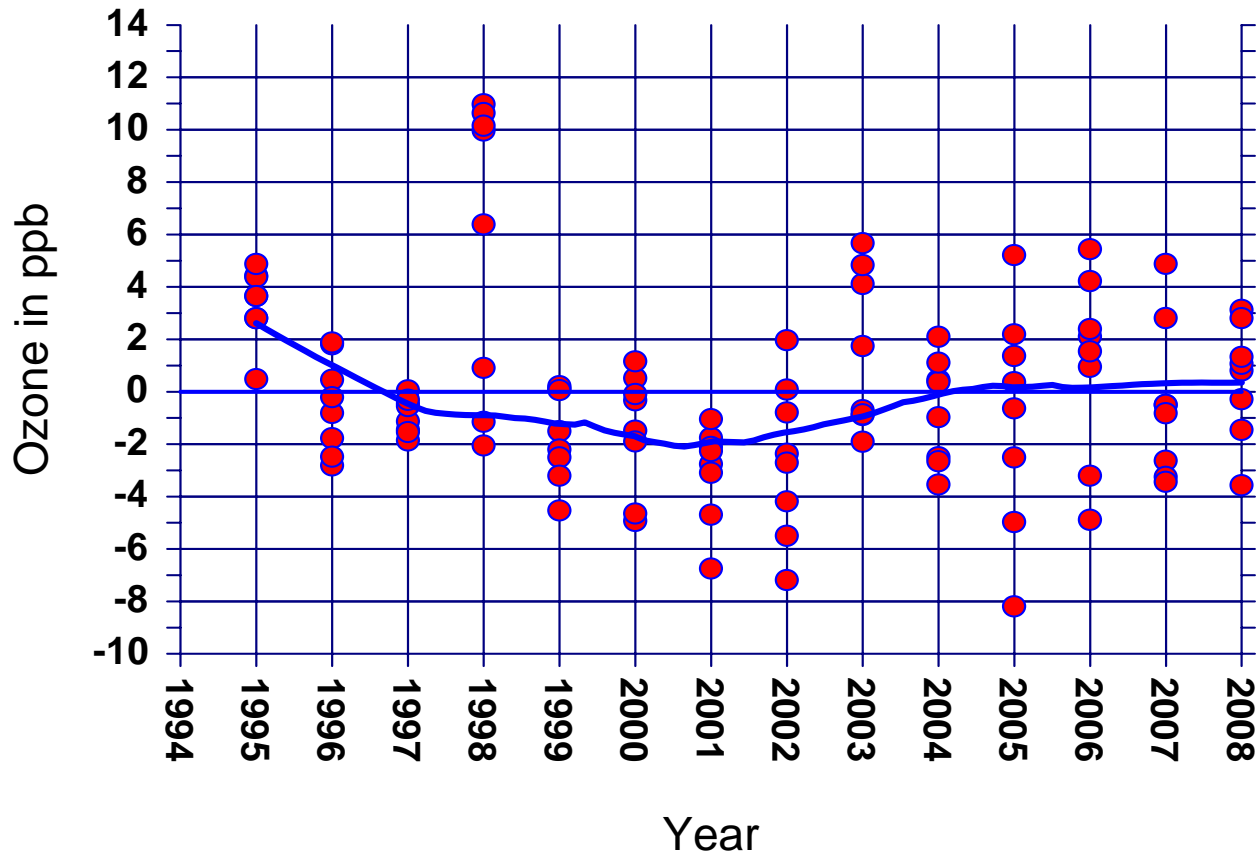
Trend in DEN Metro July Mean Daily Max 8-hr Ozone, Effect of Mean 500 mb Heights Removed



(Residuals are differences between actual and weather predicted ozone.)

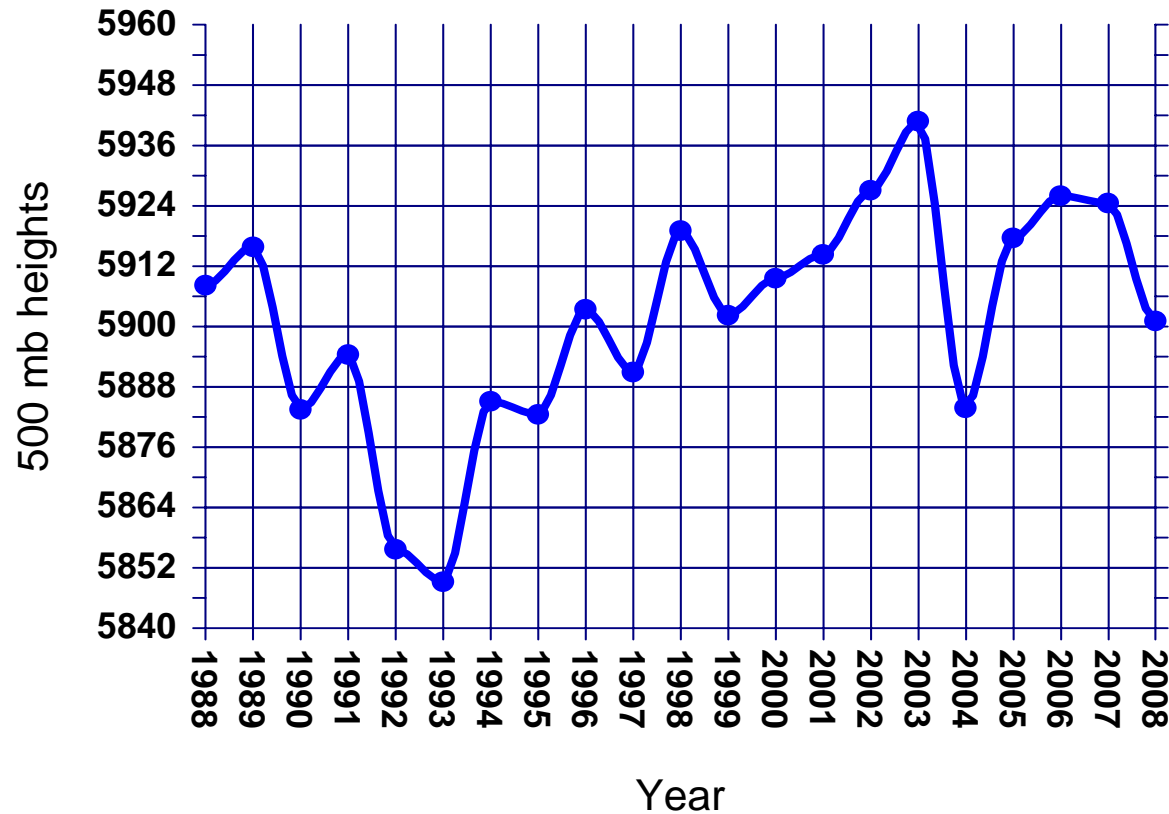
Weather-corrected ozone trends show the possible impacts of oil and gas controls in Ft. Collins and Greeley and a regional increase in ozone of 4 ppb in 2008. The cause(s) of this increase are not yet known, but might be the result of significant changes in summer VMT across the West.

## Trend in Front Range 4th Max Ozone Effect of Mean 500 mb Heights Removed



The weather-corrected 4<sup>th</sup> max time series shows a period of decline followed by a rise and ending in a level line from 2004 through 2008. This is consistent with the idea that ozone is difficult to control but increases have ceased since 2004. In addition, the possible increase in regional background in 2008 seen in earlier plots does not appear to have had an impact on these worst-case concentrations.

## Mean Strength of July Upper Level High Pressure



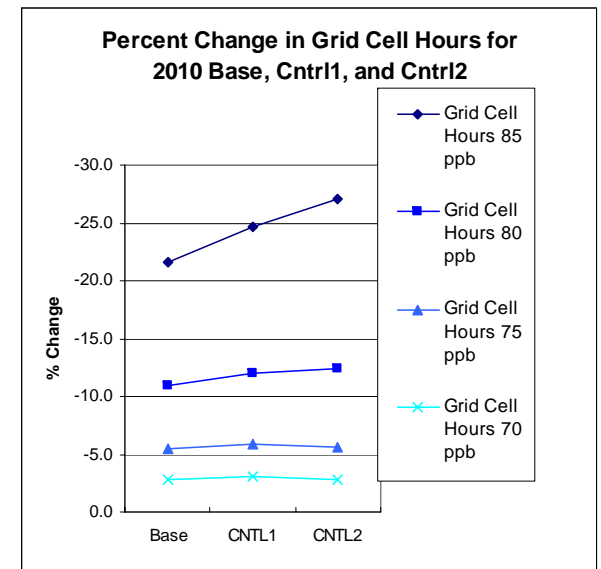
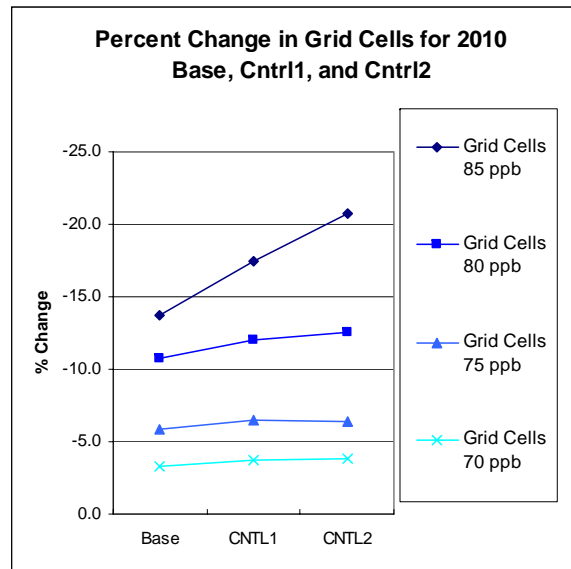
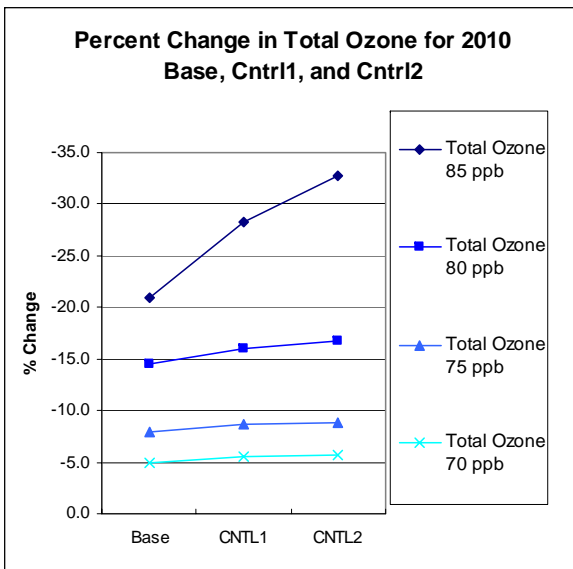
Since our ozone is so strongly affected by upper-level high pressure strength, what are the trends for this? Time series for 500-millibar heights show that a long period of increases has recently shifted to a leveling off or perhaps a decline since 2003. Climate change or “natural” patterns of drought and heat may alter this trend in the future, but there would appear to be a reasonable chance for relatively lower heights through 2010. A continued cessation in rapid increases in heights would help the area reach attainment by 2010.

# Alternative Modeled Metrics to Assess the Changes in Ozone Levels in the NAA

- EPA guidance recommends that at least 3 additional model outputs be examined in the weight of evidence (WOE) determination to provide assurance that passing or nearly passing the recommended attainment and screening tests indicates attainment
- These test measure how much estimated elevated 8-hour ozone concentrations are reduced from the current year base case conditions to the future-year control strategy.
- The three metrics used for this SIP are:
  - Number of Grid-Hours:
  - Number of Grid-Cells:
  - Change in Total Ozone:

# Alternative Model Metrics

Threshold	% Change								
	Total Ozone			Grid Cells			Grid Cell Hours		
	Base	CNTL1	CNTL2	Base	CNTL1	CNTL2	Base	CNTL1	CNTL2
85 ppb	-20.9	-28.2	-32.7	-13.7	-17.4	-20.7	-21.6	-24.7	-27.1
80 ppb	-14.4	-16.0	-16.8	-10.7	-12.0	-12.5	-10.9	-12.0	-12.4
75 ppb	-8.0	-8.7	-8.9	-5.8	-6.5	-6.4	-5.4	-5.8	-5.6
70 ppb	-5.0	-5.6	-5.7	-3.3	-3.7	-3.8	-2.8	-3.1	-2.8



# Alternative Attainment Test Methodologies

- Supplementary analysis suggested for use for the attainment test:
  - EPA's recommended average for base Design Value (DVB) of the three Design Values over a five-year (2004-2008) timeframe
    - Currently using a single 2005-2007 design value which is a more stringent case
  - Use of Different Thresholds for Selecting Days for the RRF Calculation
    - This analysis is not complete. It is expected that the RRFs calculated with days greater than or equal to 80 ppb will yield increases in reduction of ozone concentration in the 2010 Base and Control Case.

# EPA's Preferred DVF Methodology

2010 Base Case Design Values for Each Monitoring Site for  
Modeled Days greater than 0.075 ppm

Site Name	Current (2004-08*) Base Case Design Value (ppm)	Relative Response Factors	Calculated 2010 Base Case Design Value (ppm)	Truncated 2010 Base Case Design Value (ppm)
Welby	0.0707	1.0042	0.0710	0.071
Arvada	0.0777	1.0026	0.0779	0.077
NREL	0.0808	1.0039	0.0811	0.081
Rocky Flats North	0.0840	0.9994	0.0839	<b>0.083</b>
S. Boulder Creek	0.0791	0.9976	0.0789	0.078
Fort Collins	0.0728	0.9878	0.0719	0.071
Fort Collins West**	0.083	0.9874	0.0820	<b>0.082</b>
Carriage	0.0728	1.0022	0.0730	0.073
Welch	0.0740	1.0004	0.0740	0.074
CAMP	0.0560	1.0017	0.0561	0.056
Weld County Tower	0.0769	0.9964	0.0766	0.076
Highland	0.0760	0.9916	0.0754	0.075
Chatfield Res.	0.0829	0.9934	0.0824	<b>0.082</b>
Rocky Mtn. N.P.	0.0759	0.9903	0.0752	0.075

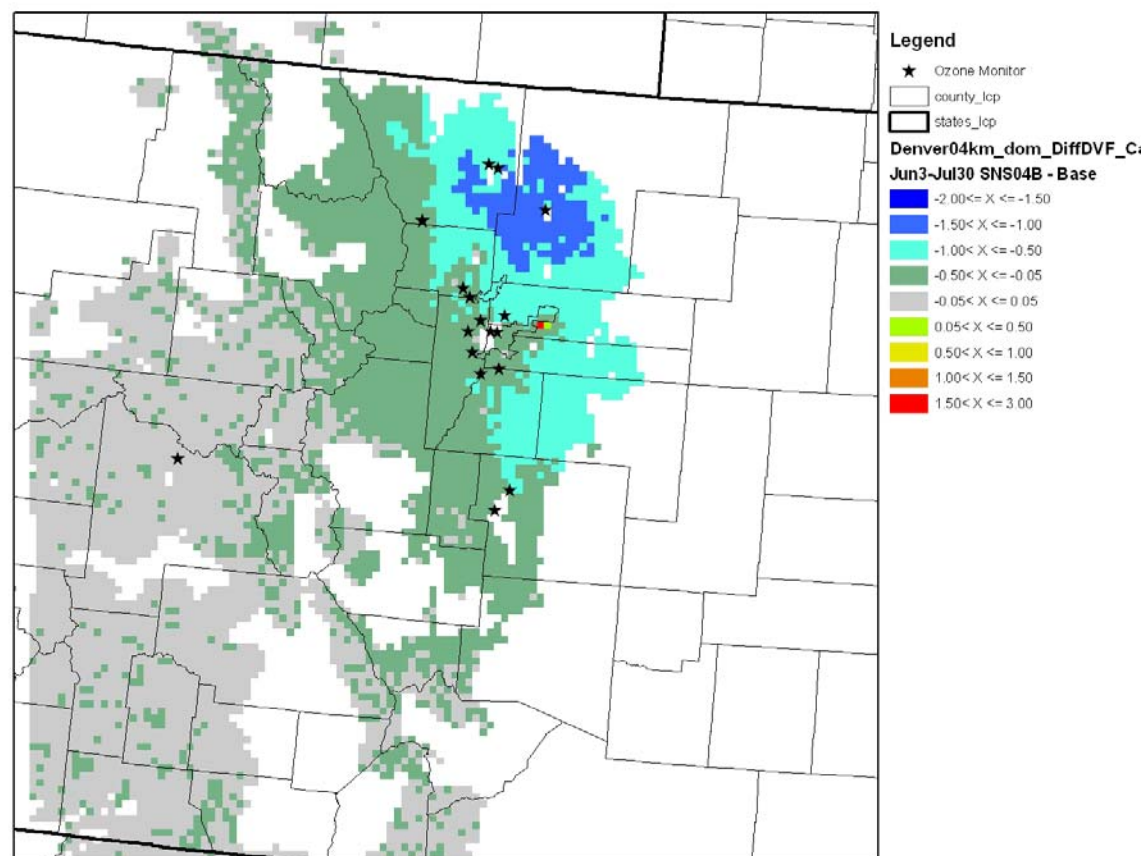
\* thru August 31, 2008, 2008 data is not Quality Assured at this time;

\*\* FCW only has three years of data and is presented as a true Design Value to three places

# Assess the Efficacy of SIP, State-only and Voluntary Control Strategies

- The 2010 Base Case and the 2010 SIP and state-only Control Cases have reductions of VOC and NO<sub>x</sub> emissions that demonstrate reductions in the ozone concentrations at the problem monitors
- There is evidence that there is some negligible increases in ozone concentration in the central part of Denver probably due to NO<sub>x</sub> emissions reductions, however, the increases at central Denver monitors does not threaten a violation of the 1997 8-hour ozone standard of 0.085 ppm
- It appears that reduction in VOC and NO<sub>x</sub> emissions together offer the best response to lowering ozone concentrations, but reduction of either VOC or NO<sub>x</sub> also lowers ozone concentrations.

# Change in Ozone Design Value from the 2010 Base-Sens04b



## 20% VOC and NO<sub>x</sub> Reduction from Area, Point, Non-Road O&G in the NAA

- Ozone reductions occur throughout the NAA and especially Weld and eastern Larimer Counties due to combined VOC and NO<sub>x</sub> reductions.

- A dis-benefit may occur near DIA

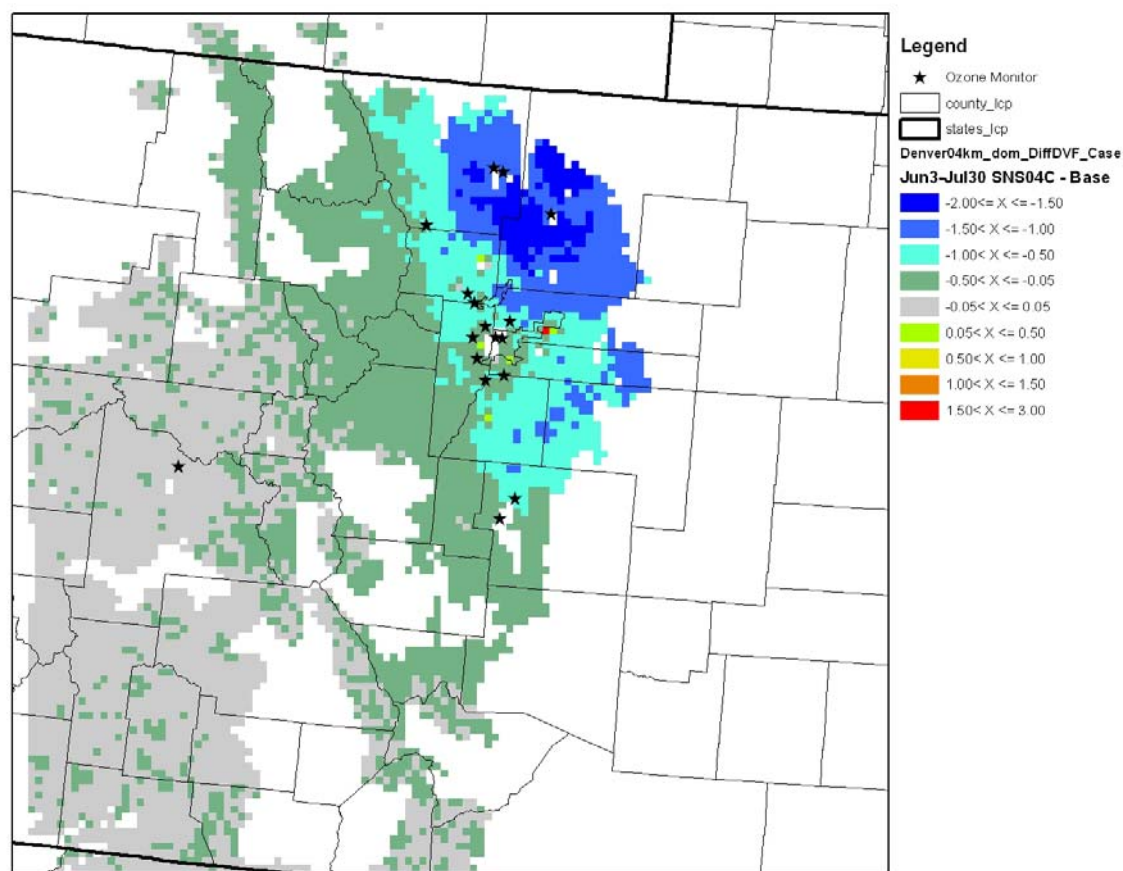
Statewide 4-km Grid

- Max increase 1.8 ppb
- Max decrease -1.4 ppb

- Rocky Flats North DV decreases by 0.5 ppb.

- Fort Collins West DV decreases by 1.1 ppb.

# Change in Ozone Design Value from the 2010 Base-Sens04c



## 20% VOC and 30% NO<sub>x</sub> Reduction from Area, Point, Non-Road O&G in the NAA

- Ozone reductions occur throughout most of the NAA and especially Weld and eastern Larimer Counties due to combined VOC and NO<sub>x</sub> reductions.
- A dis-benefit may occur near DIA and some locations along the foothills

### Statewide 4-km Grid

- Max increase 2.8 ppb
- Max decrease 2.0 ppb
- Rocky Flats North DV decreases by 0.7 ppb.
- Fort Collins West DV decreases by 1.6 ppb.

# Conclusions for the WOE

- The final WOE will combine and weigh the various supplemental analyses with the results of the attainment test resulting in an aggregated, qualitative and quantitative conclusion as to whether the proposed set of control strategies will result in the Denver Front Range reaching attainment by 2010.
- *The full WOE analysis anticipated is currently incomplete though a large portion of the basic WOE analyses has been presented. The WOE analysis will continue to be refined through the AQCC Public Hearing process.*