

2008/2018 Ozone Sensitivity Modeling for the Greater Denver Area



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Acknowledgements

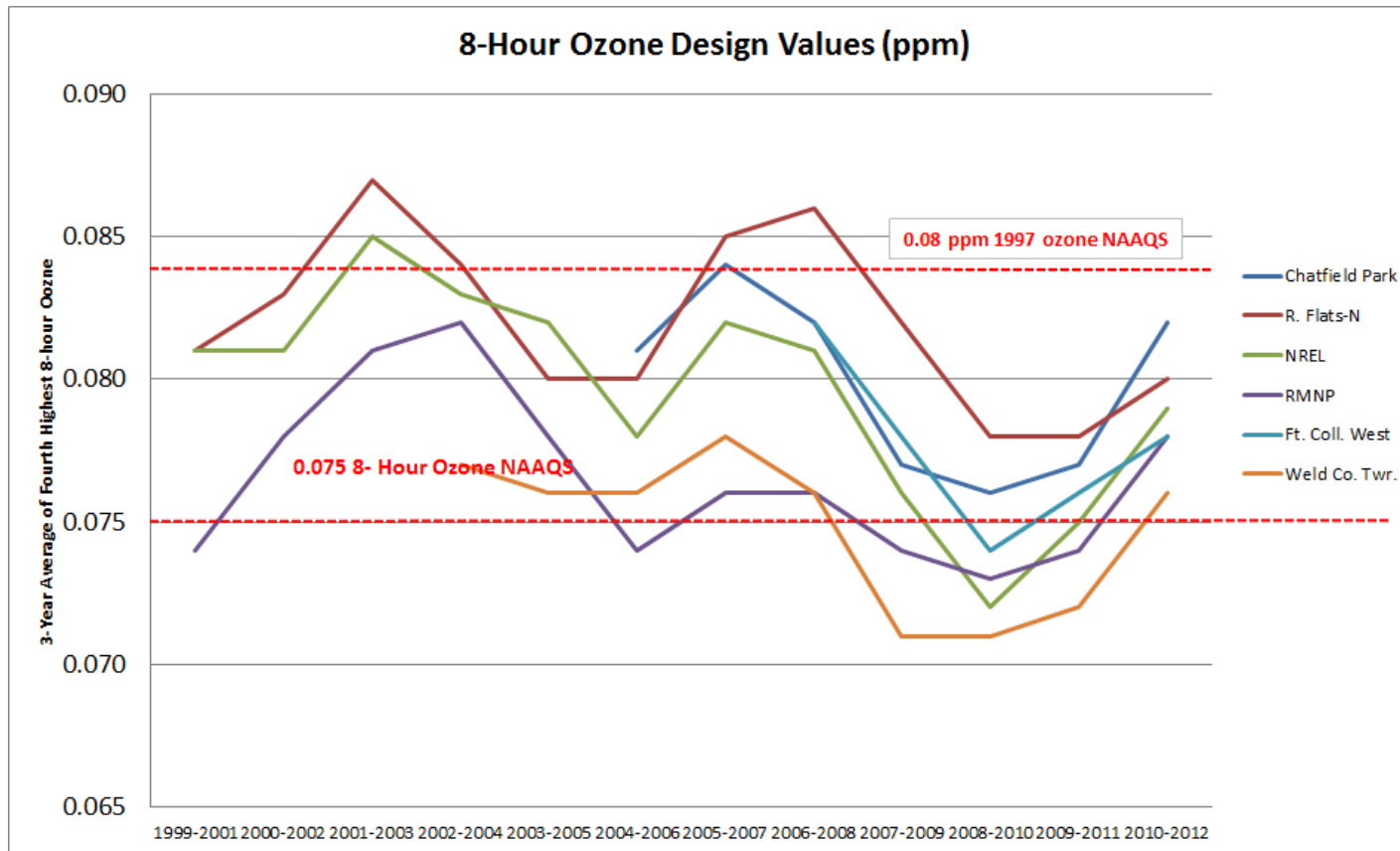
- Regional Air Quality Council (RAQC)
- Colorado Department of Health and Environment (CDPHE)

Caveats

- Future year oil and gas emissions being updated

Background

- 2008 Denver ozone SIP demonstrated the region would achieve the 1997 0.08 ppm 8-hour ozone NAAQS by 2010
- March 2008: new 8-hour ozone NAAQS w/ threshold of 0.075 ppm
- April 2011: Denver designated a Marginal O₃ nonattainment area



Purpose

- Perform ozone sensitivity modeling of the Denver Metropolitan Area and North Front Range (DMA/NFR) region to lay the ground work for potential development of a new ozone State Implementation Plan (SIP) for the region in the future
- Take advantage of model improvement studies carried out after the 2008 DMA/NFR ozone SIP to develop a new 2008 ozone modeling platform
- Perform 2018 sensitivity modeling to estimate ozone levels in the DMA/NFR to assist in ozone air quality planning to achieve the March 2008 0.075 ppm ozone NAAQS

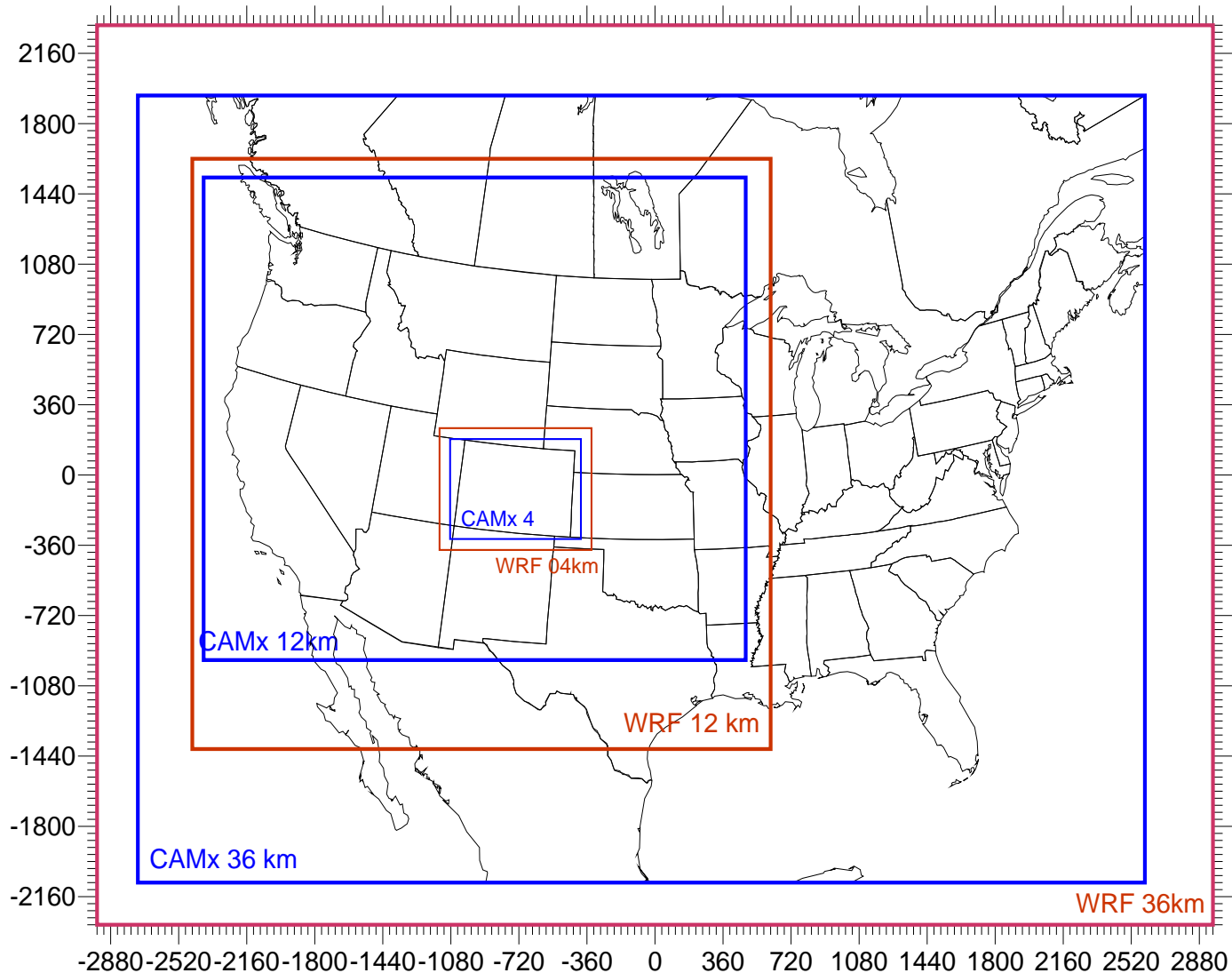
MM5/WRF Testing with 2006 Episode

- 11 MM5 Configurations
 - Initialization Datasets
 - Vertical Structure
 - Data Assimilation
- 19 WRF Model Configurations
 - Moisture Schemes
 - Land Surface Models
 - Diffusion Options
- WRF Chosen for 2008

Denver 2008 Modeling Platform Development

- Episode Selection Report, 3/24/11
 - May – August 2008
- Domain Selection Report, 3/24/11
 - 36/12/4 km domain
- Modeling Protocol, April 2011
 - Road map for conducting modeling
- WRF Meteorological Modeling PPT, 11/14/11
 - Several iterations to reduce overactive precipitation
- Preliminary Model Performance Evaluation, June 2012
- Revised Model Performance Evaluation, August 2012
 - Updated O&G emissions, Plume-in-Grid, in-line TUV

WRF/CAMx 36/12/4 km Modeling Domains



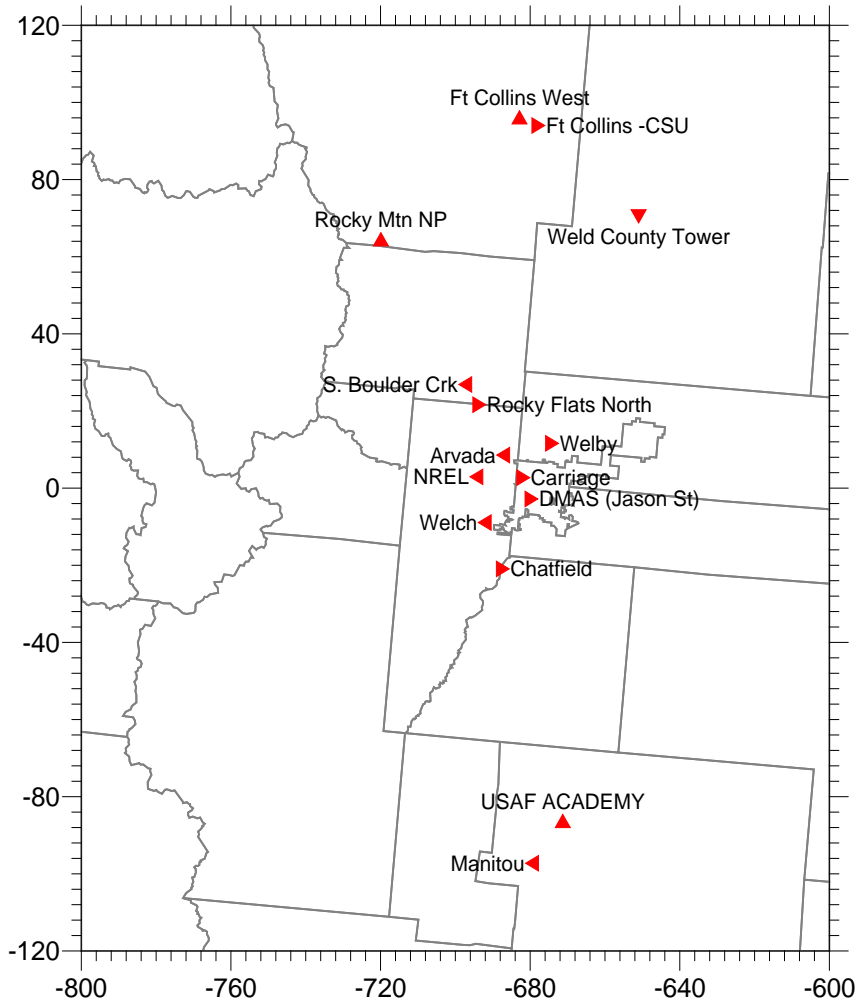
2008 Base Case Emissions Scenario

- CDPHE/APCD provided 2008 emissions for Colorado
 - Permitted O&G from APEN
 - w/ 75% Capture Efficiency Flash Emissions from Condensate Tanks
 - WRAP 2006 O&G projected to 2008 for non-permitted sources
- On-Road Mobile Sources
 - EPA's MOVES2010 On-Road Mobile Source Emissions Model
 - Colorado: SMOKE-MOVES w/ day-specific met
 - DMA/NFR NAA: CONCEPT-MV w/ link-based data (DRCOG/NFRMPO)
- 2008 National Emissions Inventory (NEI) V1.5 outside CO
- MEGAN Biogenic Emissions Model
- Fire Inventory from NCAR (FINN)

WRF Options

- Long/Short Wave Radiation: RRTMG
- Mixed Phase Water: WSM-3
- Land Surface Model: NOAH
- PBL Scheme: YSU
- Cumulus Parameterization: Kain-Fritsch
- Initialization Dataset: 12km NAM

2008 Model Performance Evaluation



2008 AQS Ozone Monitoring Sites near Denver

- Model performance statistics compared with EPA goals
 - Peaks $\leq \pm 20\%$
 - Bias $\leq \pm 15\%$
 - Error $\leq 35\%$
- Time Series of predicted and observed ozone
- Spatial Maps of predicted and observed ozone
- Ozone sonde evaluation of ozone aloft (Boulder)
- Ozone precursor evaluation (limited)

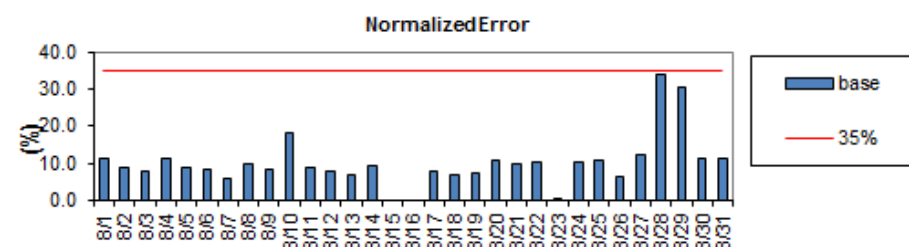
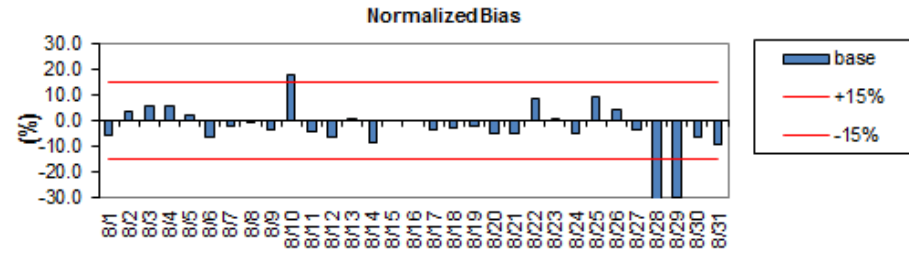
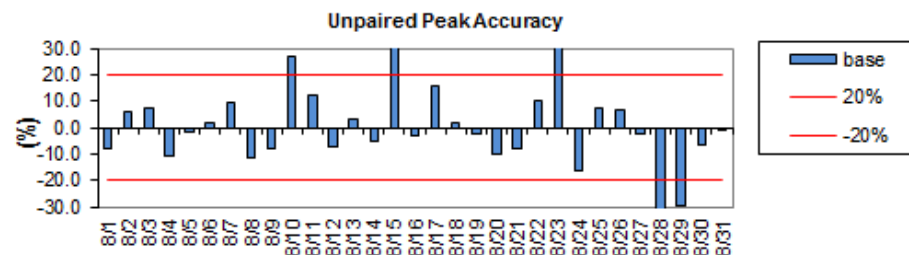
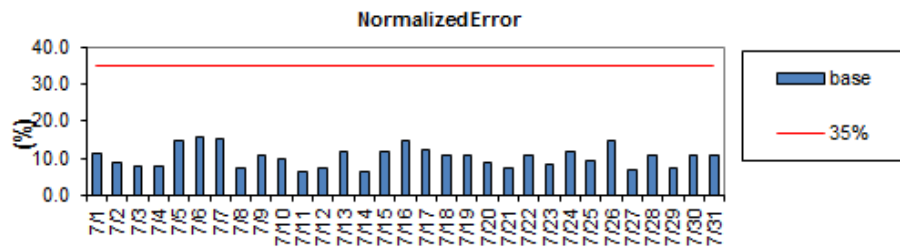
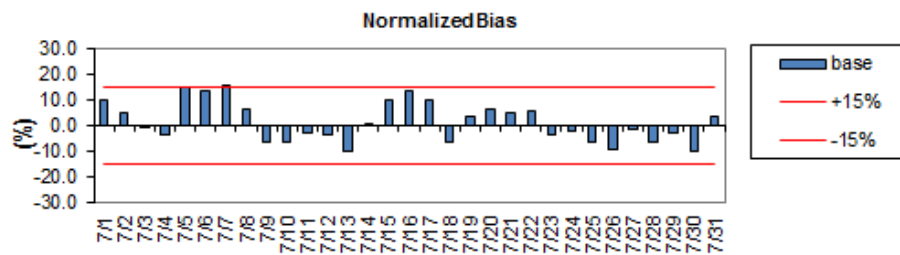
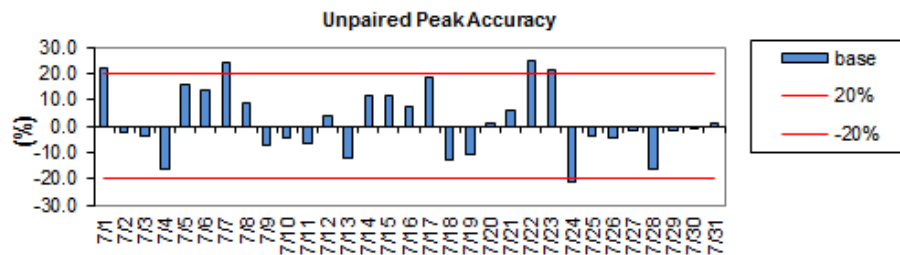
Hourly Ozone Performance Statistics

- July 2008

- UPA $\leq \pm 20\%$ 26/31 days (84%)
- Bias $\leq \pm 15\%$ 30/31 days (97%)
- Error $\leq 35\%$ 31/31 days (100%)

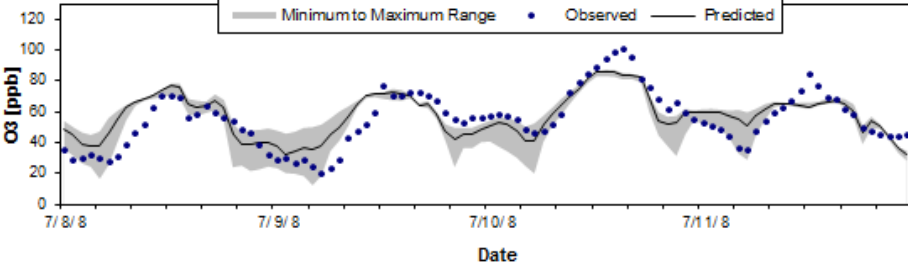
- August 2008

- UPA $\leq \pm 20\%$ 26/31 days (84%)
- Bias $\leq \pm 15\%$ 28/31 days (90%)
- Error $\leq 35\%$ 31/31 days (100%)

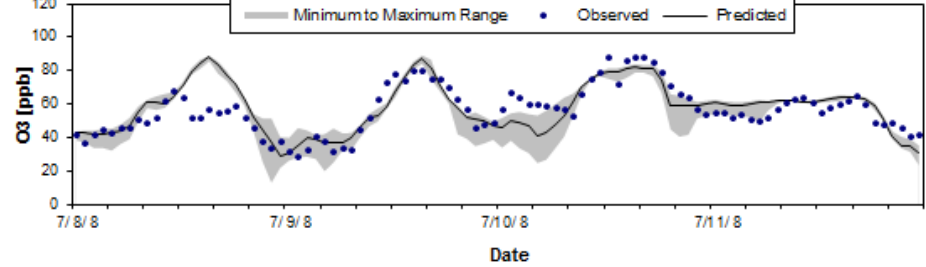


Time Series July 8-11, 2008

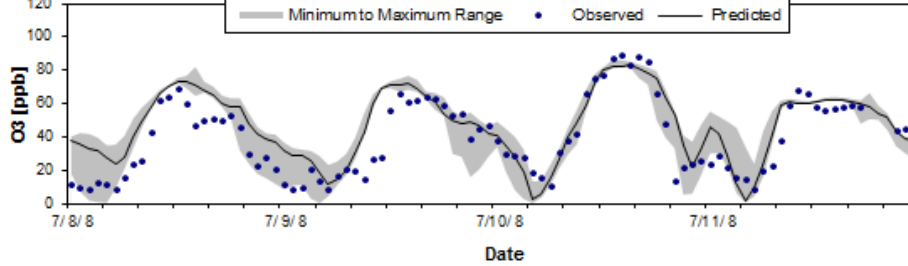
80350004: Chatfield-2 -687.313 -20.937



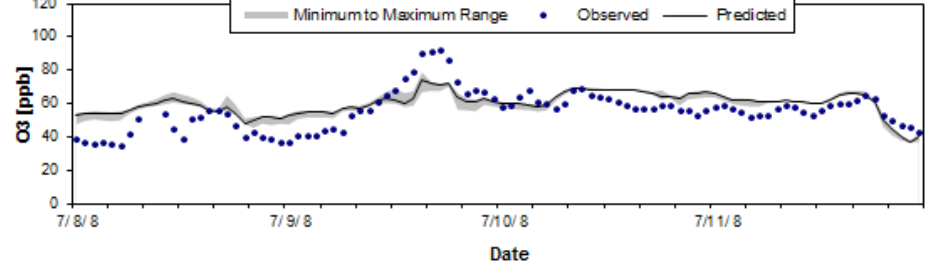
80590006: Rocky Flats North -693.592 21.629



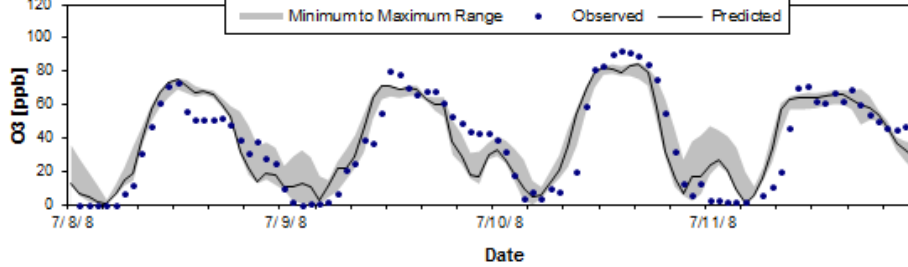
80310014: Carriage -681.834 2.717



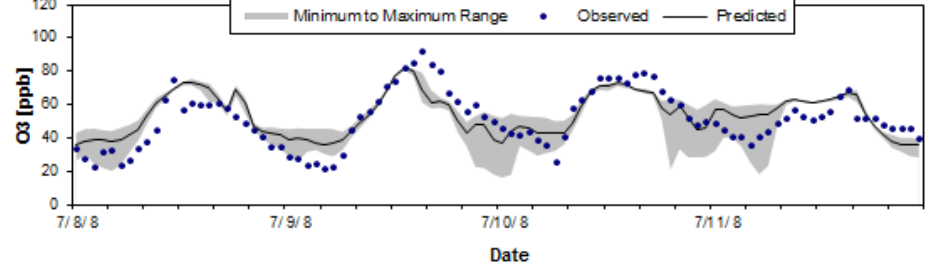
80690007: Rocky Mtn NP -719.909 64.528



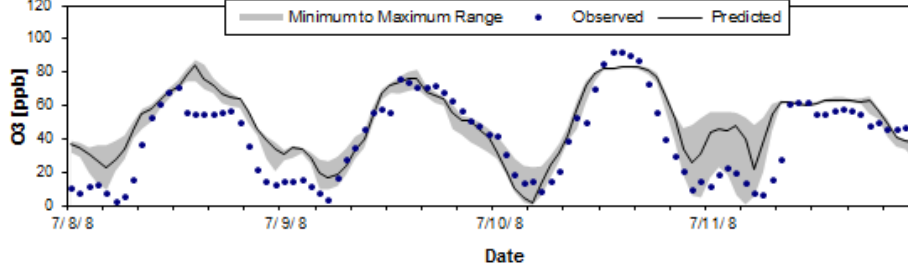
80013001: Welby -674.141 11.613



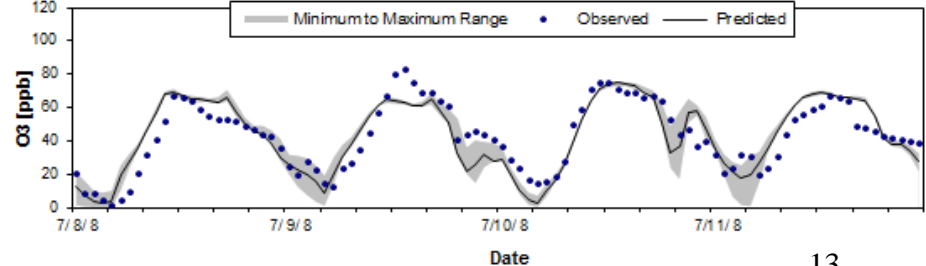
80690011: Ft Collins West -682.854 96.141



80590002: Arvada -687.213 8.568



81230009: Weld County Tower -651.000 70.457



2018 Emissions Scenario

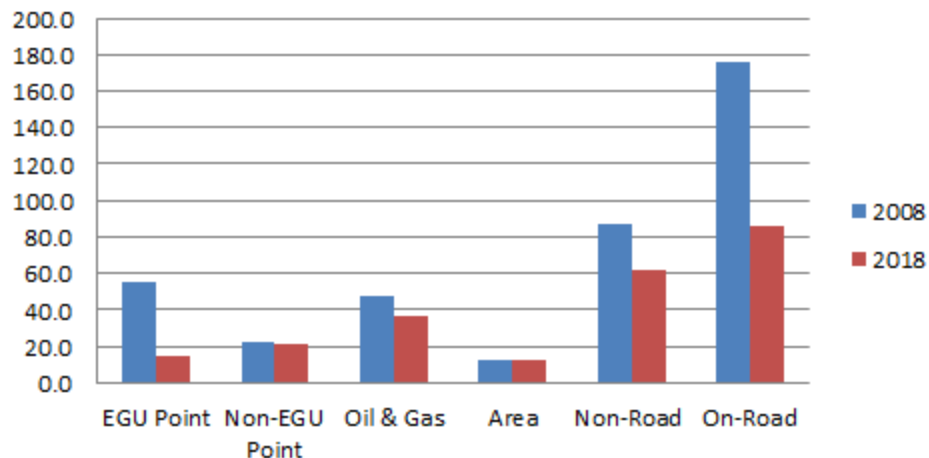
- 2018 emissions for Colorado provided by CDPHE/APCD
 - On-Road: 2018 VMT w/ MOVES (TDM from DRCOG/NFRMPO; New December 2012 I/M program)
 - Non-Road: EPA NONROAD Model
 - EGU Point: Recent plans by operators (e.g., HB1365)
 - Non-EGU Point (APEN) and Area: County population growth
 - Oil and Gas Emissions: Next slides
- In U.S. outside of Colorado use 2020 NEI
 - Developed by EPA for PM_{2.5} NAAQS Rulemaking
- Hold constant at 2008 levels:
 - Mexico and Canada Emissions
 - Biogenic, Lightning and Fires (FINN)
 - MOZART 2008 36 km CONUS Boundary Conditions (BCs)

Colorado 2018 Oil and Gas Emission Projections

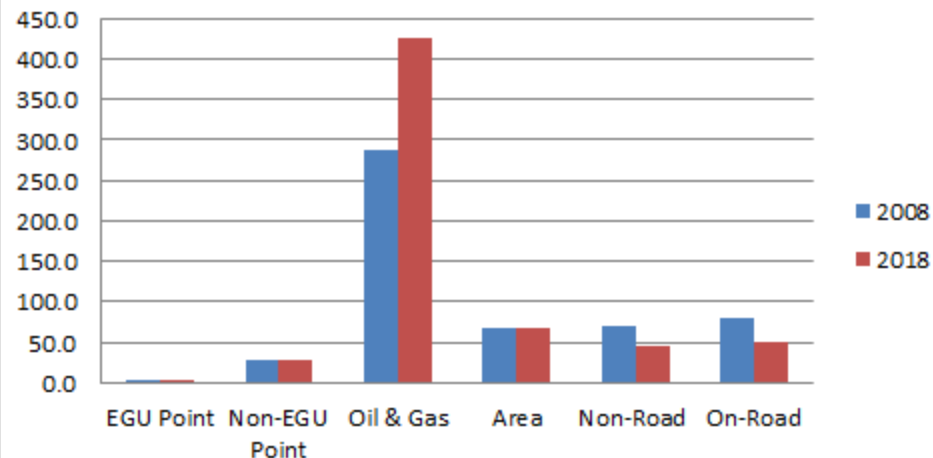
- Develop CO Basin-specific linear growth factors using WRAP Phase III and/or COGCC 2006 and 2011 production statistics for four parameters:
 - Total Condensate/Oil Production (Bbls)
 - Total Gas Production (MCF)
 - Total Number of Wells
 - Total Number of Spuds (Drilling)
- Apply Control Factors based on NONROAD Model
 - 58% NO_x control for drill rigs, workover rigs and compressors
 - 17% NO_x control for miscellaneous engines
- Revised capture efficiency recognizing newer engineered wells sites/tank batteries and existing facilities

2018/2008 Emissions in DMA/NFR NAA

NAA NO_x Emissions (TPD)



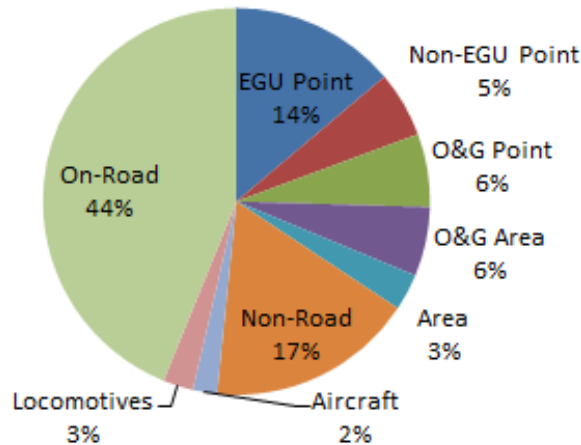
NAA VOC Emissions (TPD)



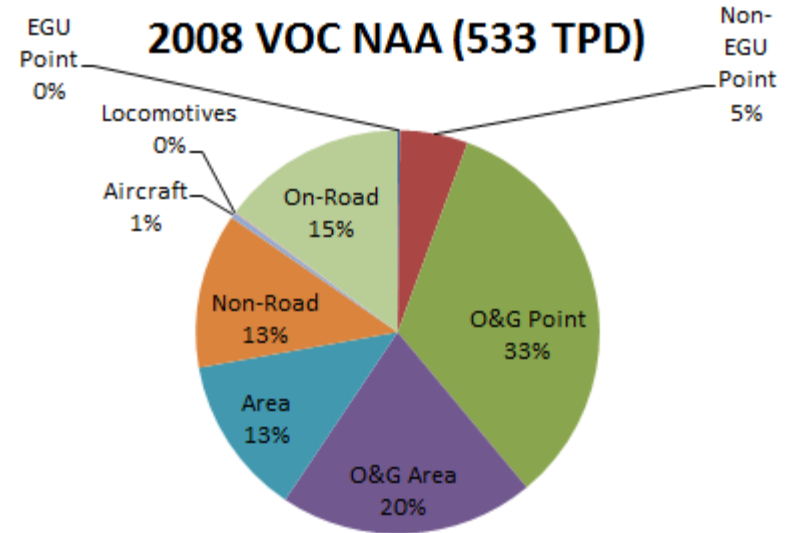
DMA/NFR NAA Category	NO _x Emissions (TPD)			VOC Emissions (TPD)		
	2008	2018	%	2008	2018	%
Total Anthropogenic	400.3	232.2	-42.0%	533.1	618.8	16.1%
Biogenic	5.0	5.0	0.0%	135.1	135.1	0.0%
Total	405.3	237.2	-41.5%	668.2	753.8	12.8%

Source Contributions to NO_x/VOC in NAA

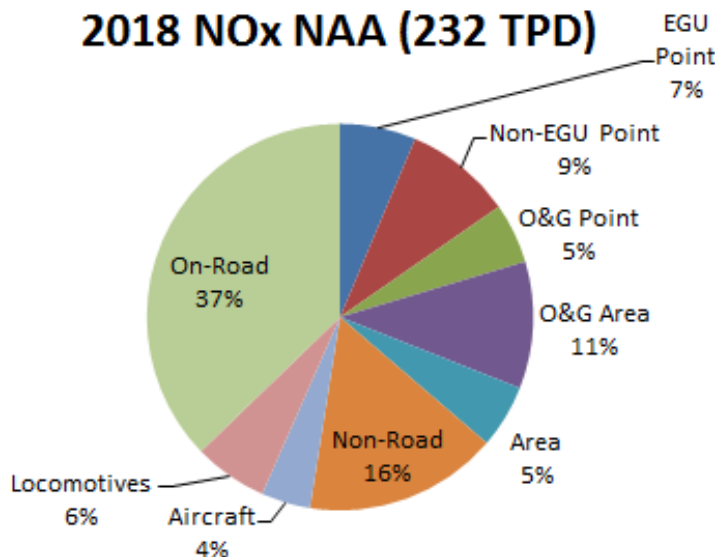
2008 NO_x NAA (400 TPD)



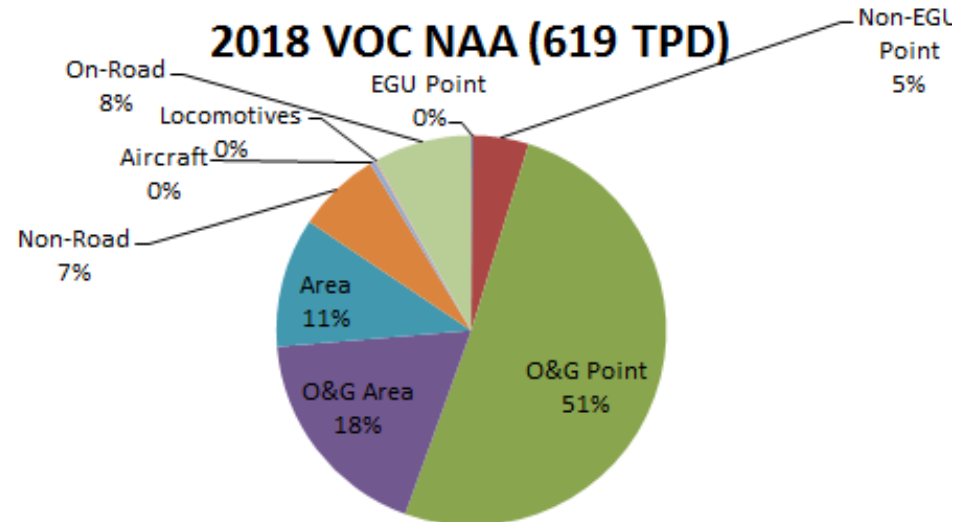
2008 VOC NAA (533 TPD)



2018 NO_x NAA (232 TPD)

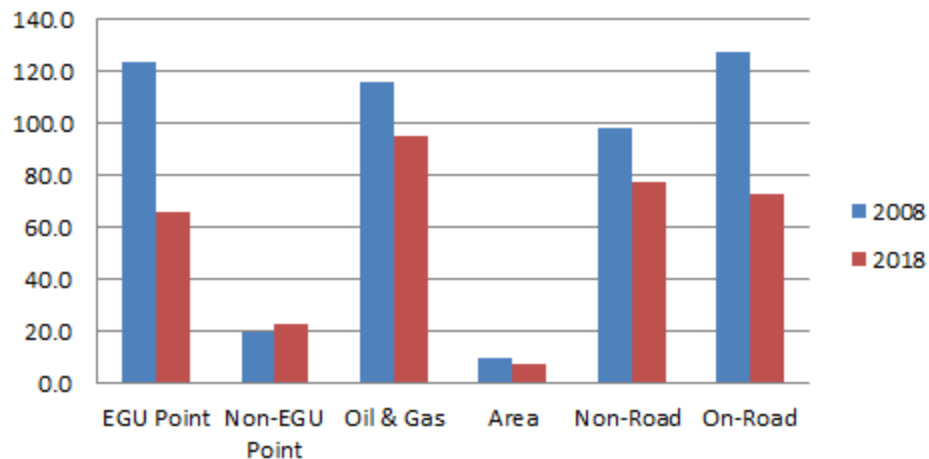


2018 VOC NAA (619 TPD)

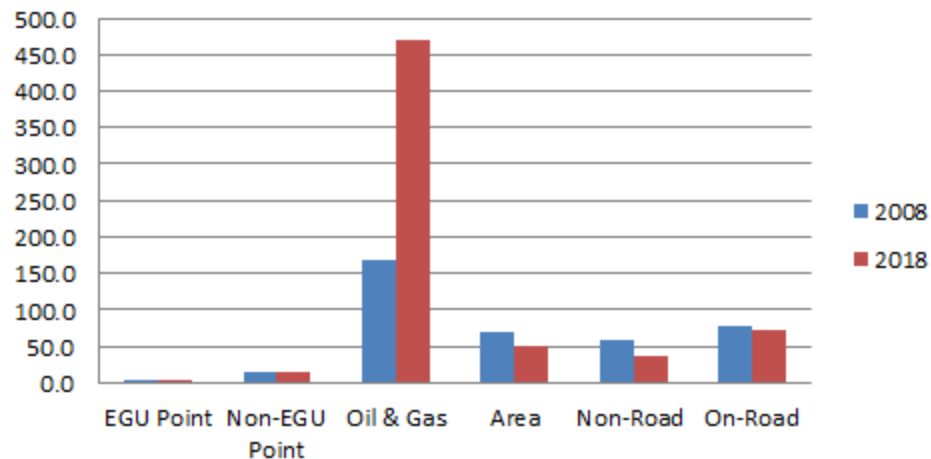


2018/2008 Colorado Emissions Outside NAA

CO Non-NAA NO_x Emissions (TPD)



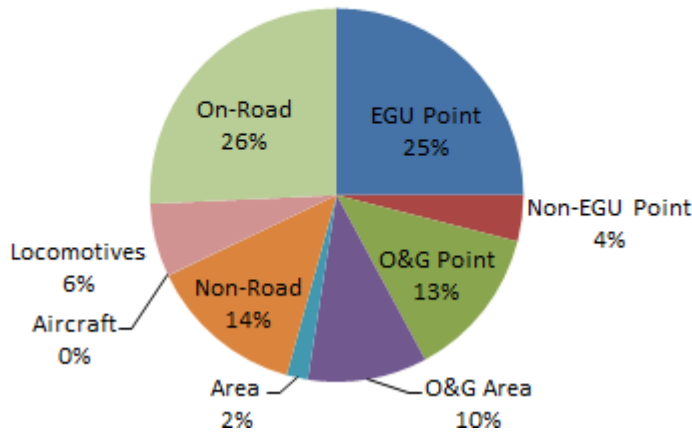
CO Non-NAA VOC Emissions (TPD)



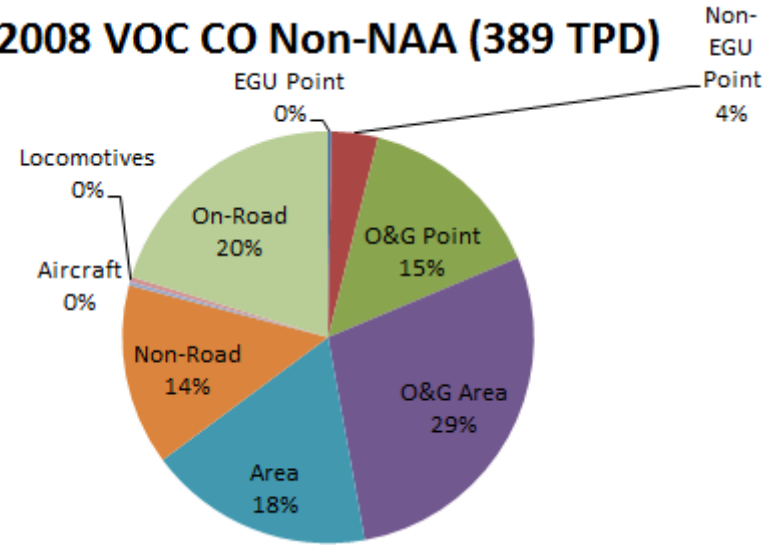
DMA/NFR NAA Category	NO _x Emissions (TPD)			VOC Emissions (TPD)		
	2008	2018	%	2008	2018	%
Total Anthropogenic	492.4	340.1	-30.9%	389.2	644.7	65.6%
Biogenic	87.4	87.4	0.0%	2264.7	2264.7	0.0%
Total	579.8	427.5	-26.3%	2653.9	2909.4	9.6%

Source Contributions to NO_x/VOC outside NAA

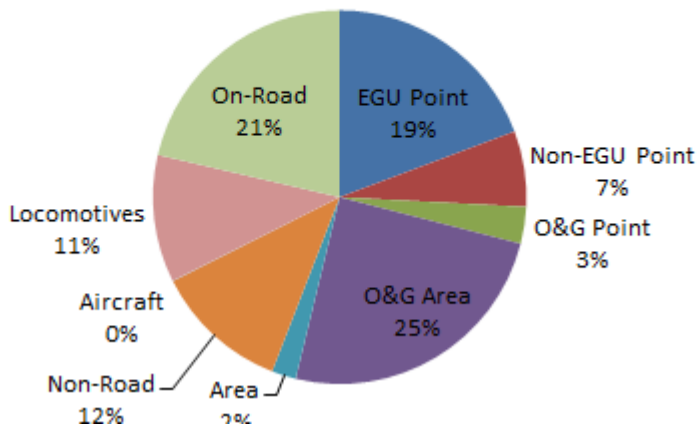
2008 NO_x CO Non-NAA (492 TPD)



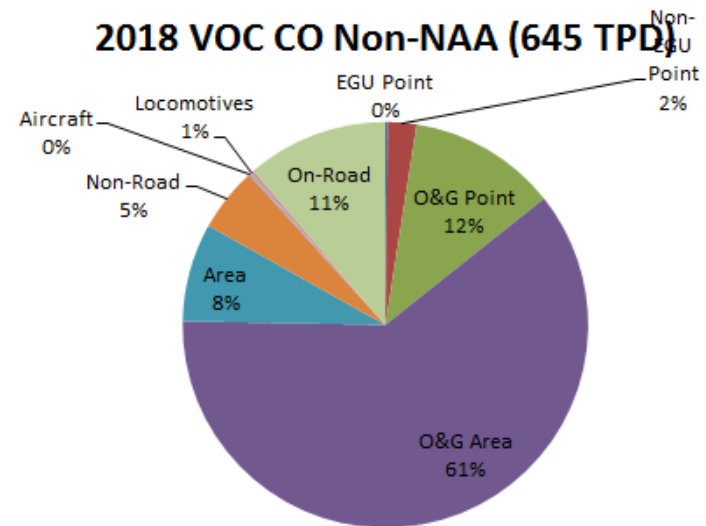
2008 VOC CO Non-NAA (389 TPD)



2018 NO_x CO Non-NAA (340 TPD)



2018 VOC CO Non-NAA (645 TPD)



EPA Guidance 2018 O₃ Projections Procedures

- Start with a current year observed Design Value (DVC)
 - EPA recommends average of three Design Values (DVs) centered on modeling year (2008) (5-Year DV)
 - DVC averaged of DVs from 2006-2008, 2007-2009 and 2008-2010
- Use relative changes in 2018 & 2008 modeling results to scale DVC to obtain future year Design Value (DVF)
 - Relative Response Factors (RRFs) based on ratio of 2018 to 2008 modeling results
$$\text{DVF} = \text{DVC} \times \text{RRF}$$
- Compare DVF with March 2008 0.075 ppm ozone NAAQS
 - Current study not a SIP attainment demonstration analysis

2018 Projections for Sensitivity Tests

- Sensitivity to current year DVC
 - 5-Year DVC based on 2006-2010 and 2008-2012 observations
- Sensitivity to 2018 oil and gas (O&G) projections
 - Use CDPHE/APCD 2018 O&G projections (2018a2)
 - Use 2008 O&G with 2018 other emissions (a2 08COOG)
 - See benefits of other source emission reductions without complication of O&G emission increases

2018 DVF Projections O&G Sens Tests

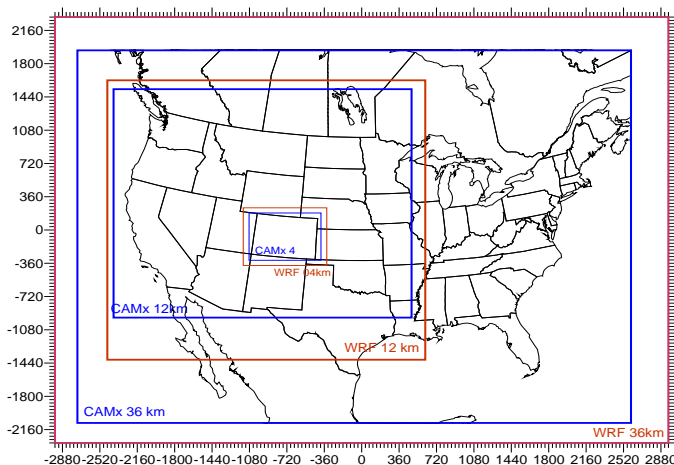
Name	2006-2010 DVC				2008-2012 DVC			
	DVC	2018a2 DVF	a2 08COOG DVF	Diff	DVC	2018a2 DVF	a2 08COOG DVF	Diff
Welby	71.0	67.6	66.5	-1.1	70.3	66.9	65.9	-1.0
Highland	NA	NA	NA	NA	75.5	71.2	70.6	-0.6
S. Boulder Creek	77.3	73.6	72.4	-1.2	73.3	69.8	68.6	-1.2
Carriage	70.3	67.9	67.0	-0.9	70.0	67.6	66.7	-0.9
Chatfield State Park	78.3	73.9	73.4	-0.5	78.3	73.9	73.4	-0.5
USAF Academy	68.0	61.6	61.6	0.0	68.3	61.9	61.9	0.0
Manitou Springs	70.3	64.0	64.0	0.0	71.0	64.6	64.6	0.0
Arvada	75.0	72.7	71.7	-1.0	73.5	71.3	70.2	-1.1
Welch	74.3	70.7	70.1	-0.6	73.3	69.7	69.2	-0.5
Rocky Flats North	82.0	78.1	76.9	-1.2	78.7	75.0	73.8	-1.2
NREL	76.3	73.9	73.0	-0.9	75.3	72.9	72.0	-0.9
La Plata1004	70.0	64.8	65.2	0.4	72.7	67.3	67.7	0.4
La Plata7001	66.0	61.3	61.8	0.5	67.7	62.9	63.4	0.5
La Plata7003	67.0	62.7	63.0	0.3	67.0	62.7	63.0	0.3
Larimer0007	74.3	67.7	67.3	-0.4	74.7	68.0	67.6	-0.4
Fort Collins - West	78.0	73.9	71.3	-2.6	76.0	72.0	69.5	-2.5
Fort Collins	67.3	64.1	61.5	-2.6	66.3	63.1	60.6	-2.5
Montezuma0101	69.3	64.4	64.4	0.0	68.0	63.2	63.2	0.0
Greeley - Weld Tower	72.7	73.3	66.8	-6.5	73.0	73.7	67.1	-6.6
Average	72.6	68.7	67.7	-1.0	72.3	68.3	67.3	-1.0

2018 Projection Conclusions

- 2018 Ozone Projections Sensitive to 2018 O&G emissions projection assumptions and starting current year DVC
 - RFNO DVF = 78.1 vs. 76.9 ppb using 2006-2010 DVC
 - RFNO DVF = 75.0 vs. 73.8 ppb using 2008-2012 DVC
- Keeping O&G emissions constant between 2008 to 2018 reduces the 2018 DVFs by up to 6.6 ppb from current year DVCs due to controls on other sources (~150 TPD or 40% reduction in NO_x)
- 2018 DVFs using 2018 O&G projections are typically ~1-3 ppb higher than when O&G emissions are held constant at 2008 levels
 - ~ 6.5 ppb higher at Greeley in Weld County
- 2008-2012 DVCs are from 0 to 3 ppb lower than 2006-2010 DVCs
 - -3.1 ppb at RFNO and 0.0 ppb at CHAT

Next Steps -- Denver Ozone Sensitivity Study

- RAQC Modeling Forum meeting in next two months
- Update O&G 2018 emissions projections and quality assure
- Continue 2018 ozone sensitivity modeling
- Ozone source apportionment using linked 36/12/4 km CAMx database:
 - Source Regions (e.g., NAA, non-NAA, states)
 - Source Categories (e.g., EGU Point, non-EGU Point, on-road, O&G, etc.)
 - 2018 O&G projections?



Questions?
(Which author is living in the past?)

