MODELED / OBSERVED OZONE TRENDS IN THE SCAB – DYNAMIC EVALUATION OF 2012 AND 2016 AQMP DATABASES

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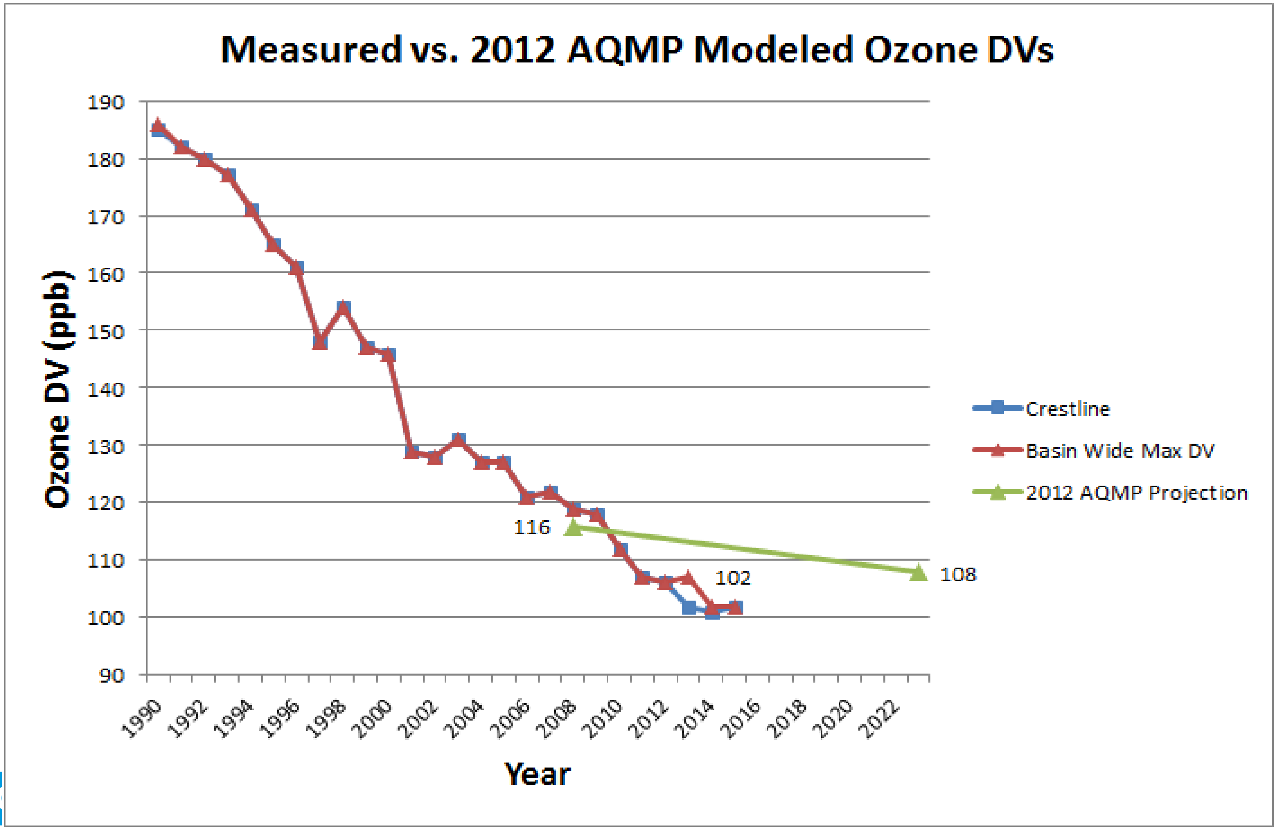
MOTIVATION

- The 2012 AQMP 2023 Base Case (no new controls) ozone projections failed to reproduce observed rate of ozone reductions
  - o 2014 max ozone DV (102 ppb) below 2012 AQMP 2023 level (108 ppb)
  - o Change in 2023 ozone levels from 108 to 102 ppb alone would increase NOx carrying capacity from 112 TPD to ~175 TPD



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INTRODUCTION

- The air quality modeling in the last several AQMPs for the South Coast Air Basin (SCAB) have consistently underestimated the observed rate of ozone reductions over time
- This results in overstated future year ozone levels and an overstatement of the level of NOx emission controls needed to attain the ozone National Ambient Air Quality Standard (NAAQS)
- The Truck Engine and Manufacturer's Association (EMA) has contracted with Ramboll Environ (RE) and Sonoma Technology, Inc. (STI) to study this issue by:
  - Conducting a dynamic evaluation of the AQMP model's ability to reproduce observed ozone trends;
  - Compare emission, model and observed precursor and key indicator species; and
  - Collaborate with SCAQMD and ARB to identify model improvements so that modeled ozone trends match observed ozone trends better for future AQMP/SIP modeling

MODEL ENHANCEMENT COLLABORATION GOALS

- Build on over 2 decades of STMPR Advisory Group efforts
- Meet ARB/SCAQMD goals of stakeholder collaboration
- Collaboratively understand and reconcile model prediction/monitored data discrepancies
- Identify key additional model enhancement needs that directly impact carrying capacity
- Model enhancement plan for 2016 and 2019 AQMPs

COMPARISON OF 2012 AQMP 2023 OZONE PROJECTIONS WITH 2014 OBSERVED VALUES

Location	2014 measured O_3 DV	2023 projections (Table 5-5, 2012 AQMP)
San Bernardino	97	108
Crestline	101	107
Glendora	93	107
Upland	96	106
Fontana	99	104
Redlands	102	103
Riverside	93	100
Pomona	86	100
Azusa	80	95
Santa Clarita	97	94
Banning	93	94
Pasadena	78	92
Reseda	87	90
Ferris	89	88
Lake Elsinore	82	85
Burbank	88	76
Basin-Wide Max	102	108

OBJECTIVES AND APPROACH

- Evaluate modeled ozone trends using 2012 AQMP modeling database over a long period (25 years) to determine if modeled response to emissions changes over this period is slower than indicated by measurements
- Draft 2016 AQMP modeling database has been recently released (in August 2016) and has been stated to correct some of the deficiencies in the 2012 AQMP modeling database
    - Determine if draft 2016 AQMP modeling database shows a similar or improved response to emission changes over the years as compared to final 2012 AQMP modeling database
- Approach: Use final 2012 AQMP modeling database and draft 2016 AQMP modeling database as starting points to conduct CMAQ simulations for historical and recent years

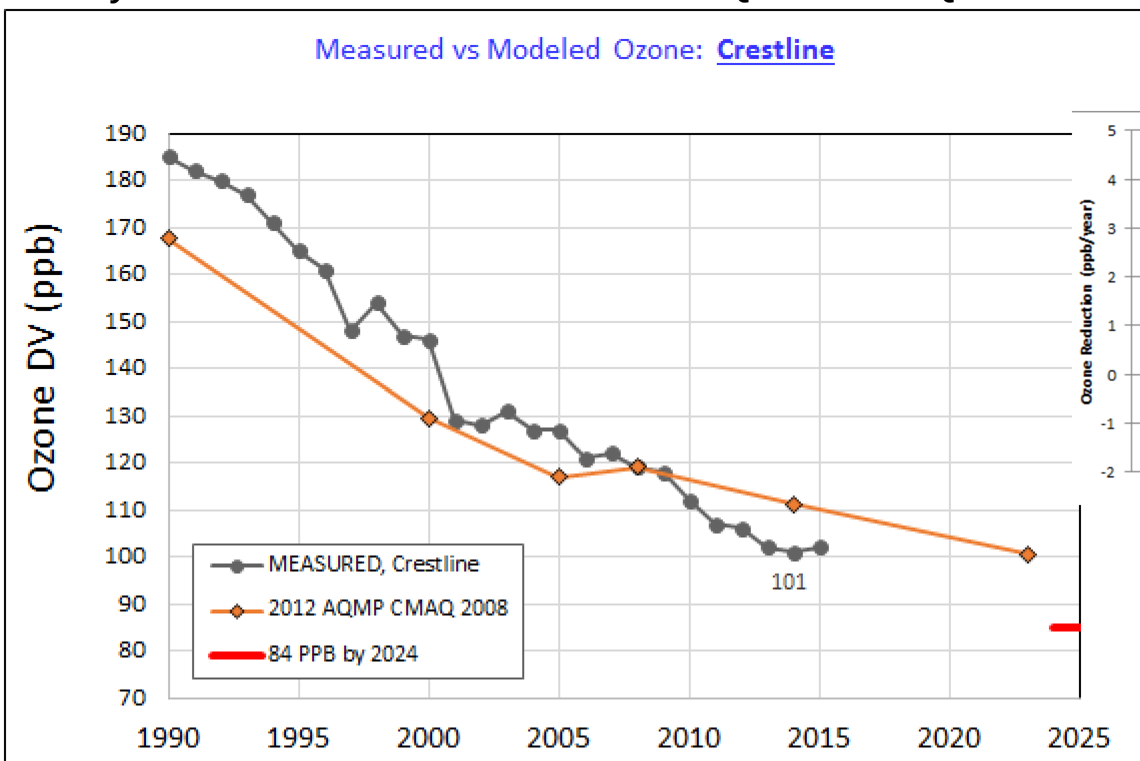
EPA GUIDANCE (2007; 2014) RECOMMENDS 4 TYPES OF MODEL PERFORMANCE EVALUATION

- Operational: Determine whether model simulated variables are comparable to measurements.
- Diagnostic: Process-oriented analysis to determine whether individual processes or components of modeling system are working correctly.
- Dynamic: Assess the ability of the air quality model to predict changes in air quality due to changes in emissions or meteorology.
- Probabilistic: Assess level of confidence in model predictions through techniques such as ensemble model simulations.
- AQMPs have focused on Operational and Diagnostic evaluation and have been silent on Dynamic and Probabilistic evaluations.

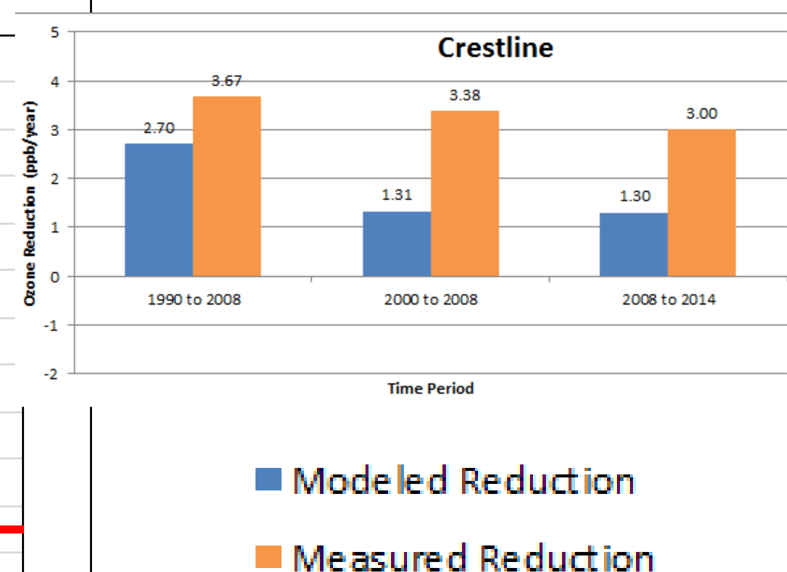
DYNAMIC EVALUATION OF 2012 AQMP CMAQ 2008 MODELING DATABASE

- Model 1990, 2000, 2005, 2008 and 2014 emissions using 2012 AQMP 2008 CMAQ modeling database
- CMAQ underestimates observed rate of ozone reduction between 1990-2014 by greater than factor of 2

Dynamic evaluation of 2012 AQMP CMAQ 2008



2012 AQMP CMAQ 2008 Database vs. observed ozone reduction (ppb/year)



KEY DIFFERENCES BETWEEN 2012 AQMP AND 2016 AQMP

- 2012 Final AQMP
  - Base year: 2008
  - Meteorology: WRF 3.3
  - CMAQ Version: 4.7.1
  - Chemistry: SAPRC99
  - Emissions for base year and future years (2014, 2023)

- 2016 Draft AQMP
  - Base year: 2012
  - Meteorology: WRF 3.6
  - CMAQ Version: 5.02
  - Chemistry: SAPRC07
  - Emissions for base year and future years (2023, 2031)

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DYNAMIC EVALUATION APPROACH

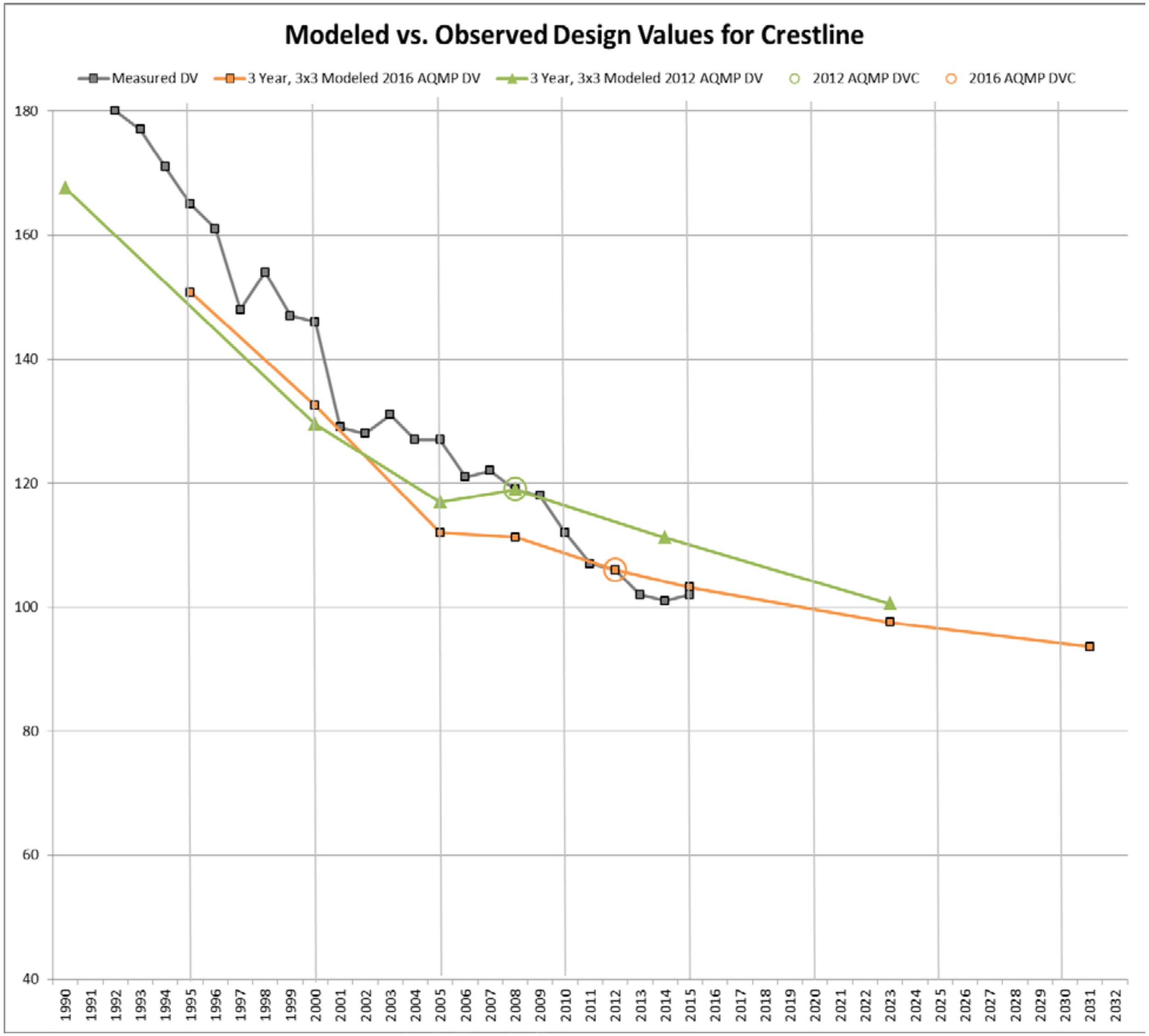
- 2012 Final AQMP (Base year 2008) Dynamic Evaluation:
  - Compare ozone changes between 2008 and 2014 with observed changes
  - Develop historical year (1990, 2000, 2005) emissions from 2008 emissions
  - Compare modeled and measured ozone trends from 1990 to 2014
- 2016 Draft AQMP (Base year 2012) Dynamic Evaluation:
  - Develop historical year (1995, 2000, 2005, 2008) and current year (2015) emissions from 2012 emissions
  - Compare modeled and measured ozone trends from 1995 to 2014
- 2012 AQMP vs. 2016 AQMP
  - Compare ozone trends from two different modeling databases (2012 and 2016 AQMP)
  - Compare future year ozone reduction rates from 2012 and 2016 AQMP

DEVELOPMENT OF HISTORICAL YEAR EMISSIONS FOR MODELING

- Scale base year CMAQ-ready emissions using SoCAB summer season emission totals for base years and historical years (from California ARB emission summaries)
  - Spatial and temporal variation of historical emissions same as in base year
  - Account for changes in ozone forming potential of volatile organic gas (VOC) emissions (i.e., VOC speciation) between base year and historical year
- Base year and historical year emissions also used by study collaborator, STI, for emissions reconciliation analysis with ambient measurements (discussed later)
- Boundary Conditions (BCs) around 4 km domain remain constant
  - Competing effects of reductions in California emissions and increases in ozone transport from Asia from past to current time

SOCAB MONITORING LOCATIONS

OZONE DESIGN VALUES AT CRESTLINE



ppb reduction / year

3.5: Obs_1990-2015

2.4: 2012AQMP_1990-2014

2.4: 2016AQMP_1995-2015

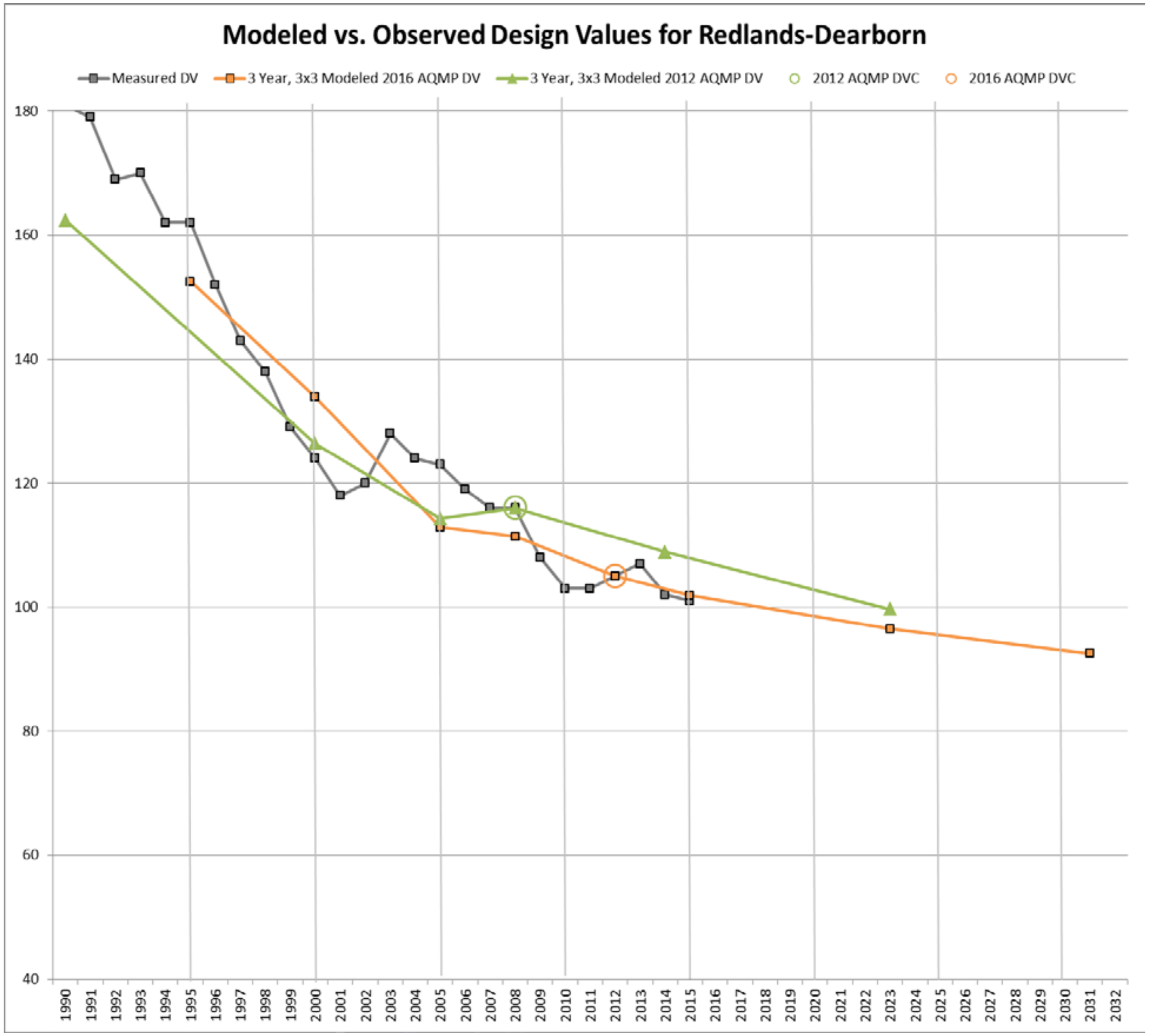
2.8: Obs_2008-2015

1.3: 2012AQMP_2008-2014

1.2: 2016AQMP_2008-2015

Observed rate of ozone reduction ~1.5 (1990-2015) to ~2.1 (2008-2015) faster than predicted by CMAQ

OZONE DESIGN VALUES AT REDLANDS



ppb reduction / year

3.2: Obs_1990-2015

2.24: 2012AQMP_1990-2014

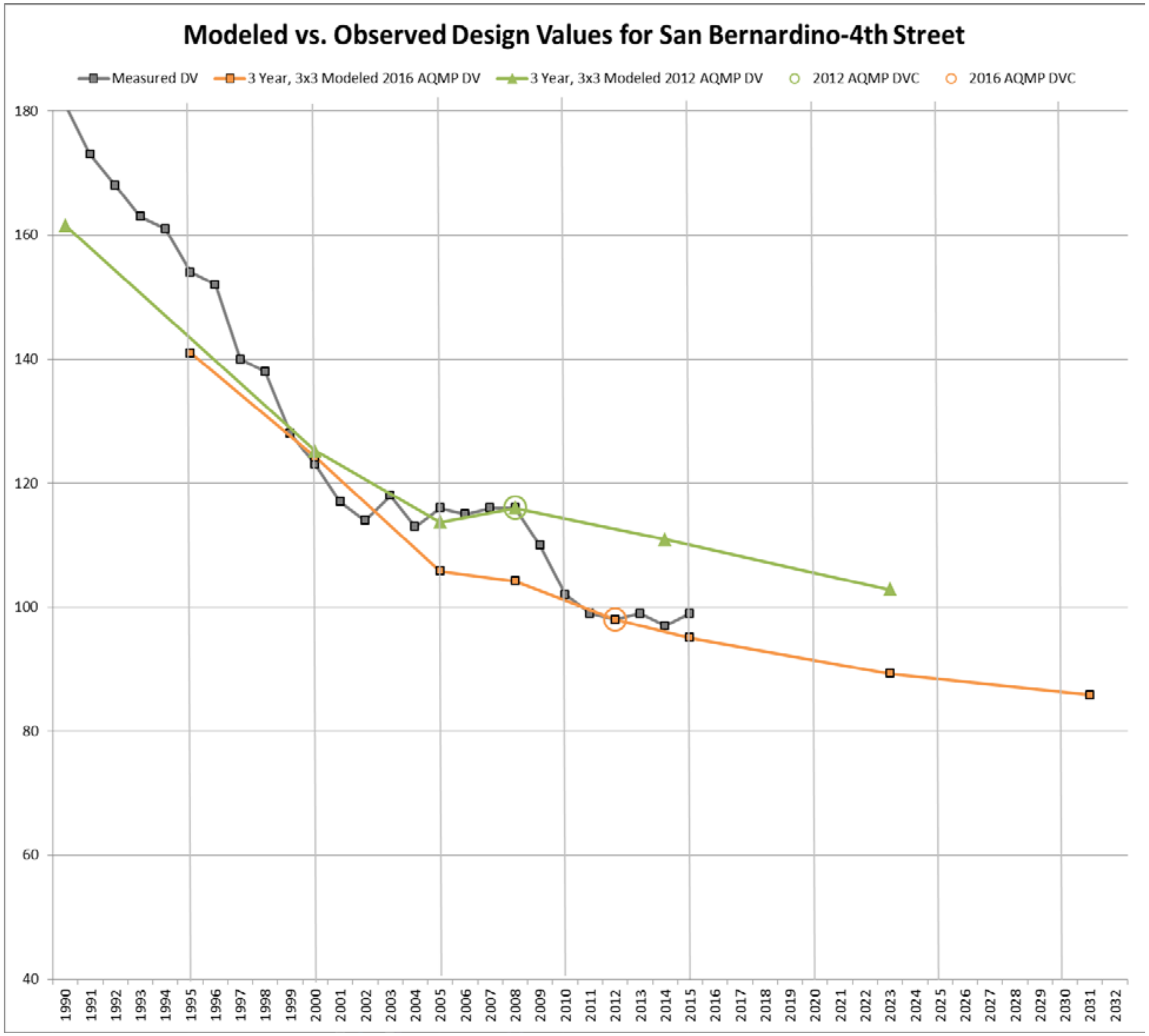
2.5: 2016AQMP_1995-2015

1.4: Obs_2008-2015

1.2: 2012AQMP_2008-2014

1.4: 2016AQMP_2008-2015

OZONE DESIGN VALUES AT SAN BERNARDINO



ppb reduction / year

3.2: Obs_1990-2015

2.1: 2012AQMP_1990-2014

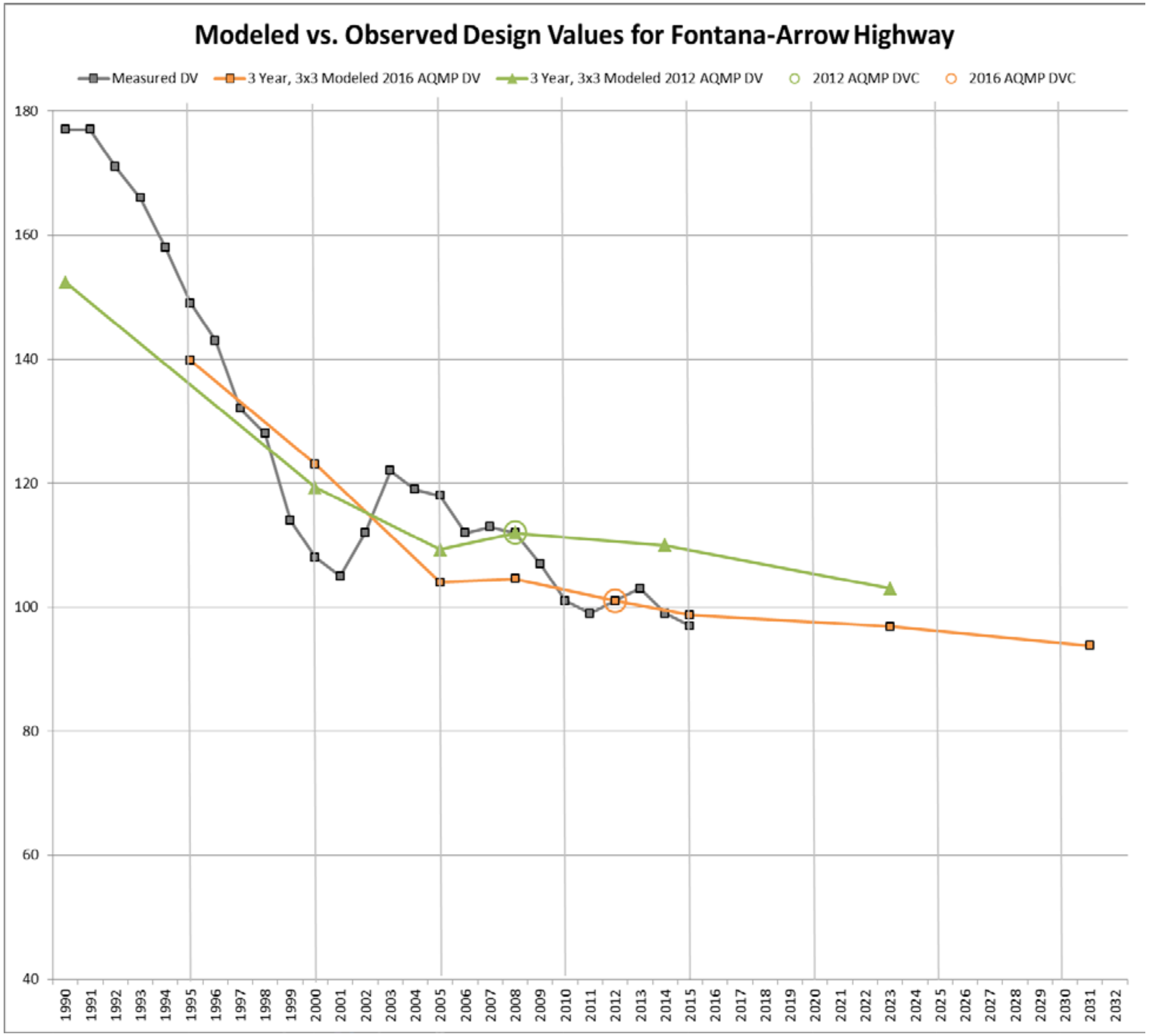
2.3: 2016AQMP_1995-2015

2.3: Obs_2008-2015

0.9: 2012AQMP_2008-2014

1.3: 2016AQMP_2008-2015

OZONE DESIGN VALUES AT FONTANA



ppb reduction / year

3.0: Obs_1990-2015

1.8: 2012AQMP_1990-2014

2.0: 2016AQMP_1995-2015

1.6: Obs_2008-2015

0.3: 2012AQMP_2008-2014

0.8: 2016AQMP_2008-2015

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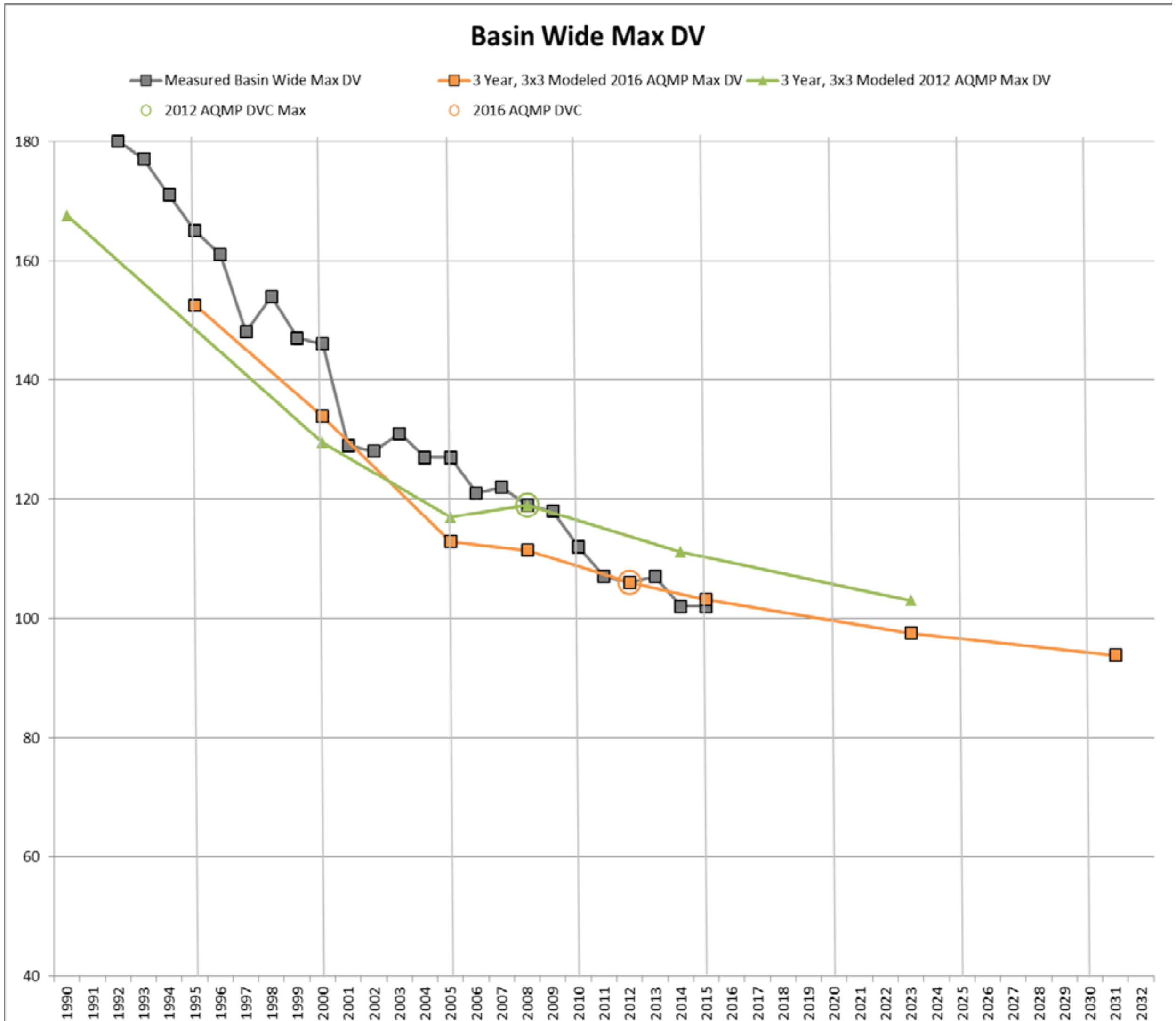
BASIN-WIDE MAXIMUM OZONE DESIGN VALUES



ppb reduction / year

3.5: Obs_1990-2015

2.4: 2012AQMP_1990-2014

2.5: 2016AQMP_1995-2015

2.6: Obs_2008-2015

1.3: 2012AQMP_2008-2014

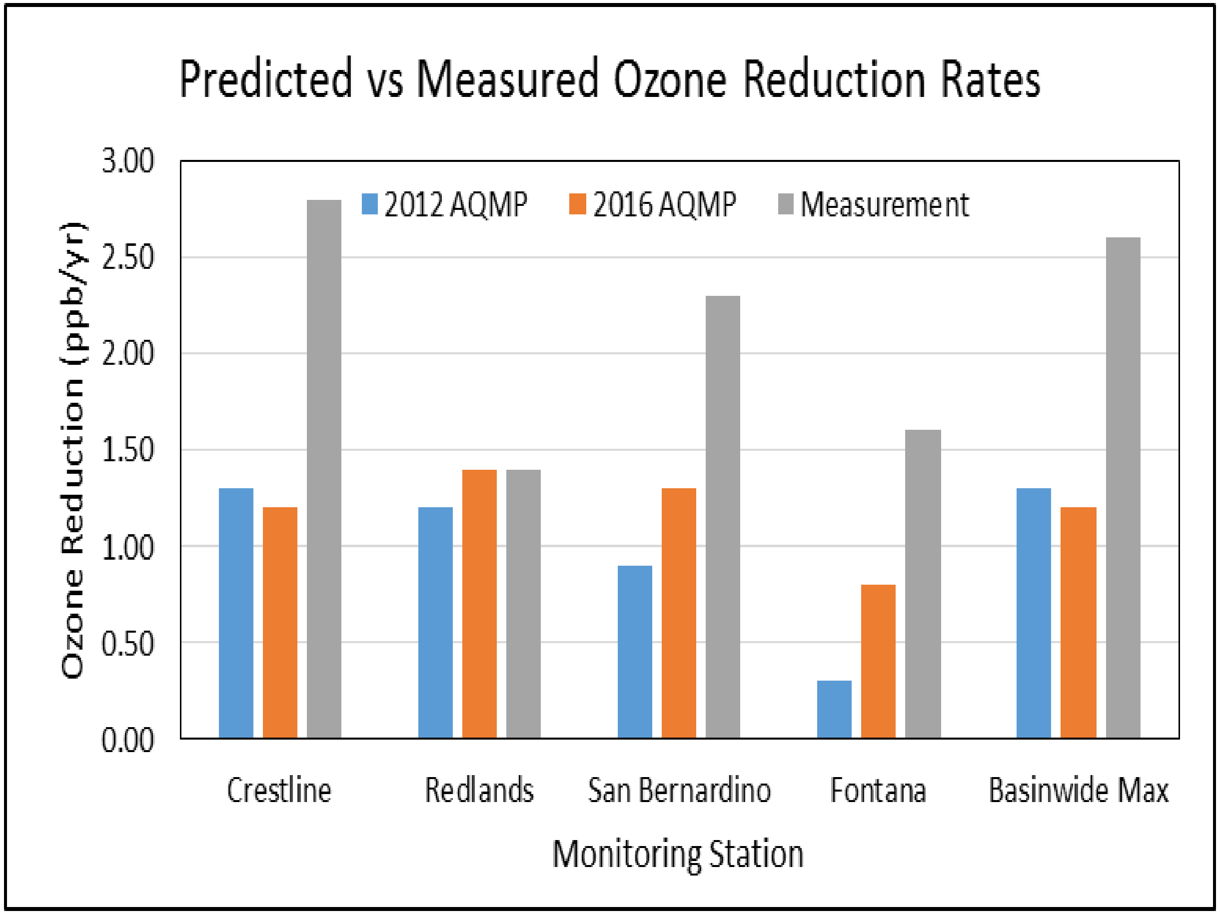
1.2: 2016AQMP_2008-2015

Observed rate of ozone reduction 1.4-2.0 times faster than predicted by CMAQ in both AQMPs

SUMMARY OF OBSERVED OZONE REDUCTIONS 2008-2015 COMPARED 2012 & 2016 AQMP

Location	Predicted Ozone Reduction Rates (ppb/year)		Measured Ozone Reduction Rates (ppb/yr)
	2012 AQMP (2008-2014)	2016 AQMP (2008-2015)	Stations (2008-2015)
Crestline	1.3	1.2	2.8
Redlands	1.2	1.4	1.4
San Bernardino	0.9	1.3	2.3
Fontana	0.3	0.8	1.6
Basin-Wide Max	1.3	1.2	2.6

PREDICTED VS MEASURED OZONE REDUCTION RATES 2008→2015



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HOW DO PROJECTED FUTURE RESPONSES FROM 2012 AQMP AND 2016 AQMP COMPARE?

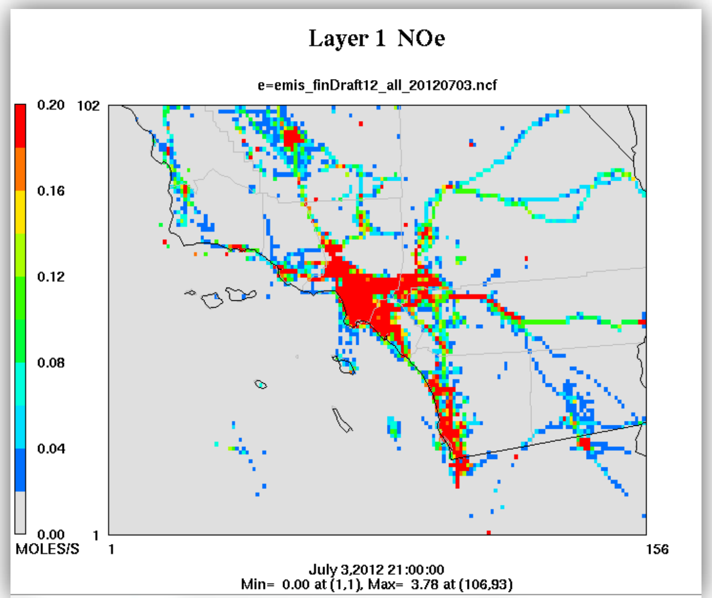
Location	Ozone Reduction Rate, 2008 to 2023 (ppb/year)		Ozone RRF (2023 DV/2008 DV)	
	2012 AQMP	2016 AQMP	2012 AQMP	2016 AQMP
Crestline	1.23	0.92	0.85	0.88
Redlands	1.09	1.00	0.86	0.87
San Bernardino	0.88	1.00	0.89	0.86
Fontana	0.60	0.51	0.92	0.93
Basinwide Max	1.07	0.93	0.87	0.88

DYNAMIC EVALUATION SUMMARY

- Modeled rates of ozone reductions at key monitors over a 20 to 25 year period are lower than observed rates using both the 2012 AQMP and 2016 AQMP modeling databases
- Modeled rates of ozone reductions at key monitors over the last 7 years are lower than observed rates by about 50% using both the 2012 AQMP and 2016 AQMP modeling databases
- Future year ozone relative response factors from the two modeling databases are remarkably similar, indicating that differences in future year ozone projections from the two databases are primarily due to differences in the base year design values (i.e., 2008 vs. 2012)
- Control strategy decisions are guided by modeling results so it is essential to understand the reasons for the lower rates of ozone reductions predicted by the model than observed and to improve model projections of future air quality

EMISSIONS RECONCILIATION (1 OF 2)

- Emissions inventories are critical components of air quality management plans
- Accurate emission inputs are required for photochemical modeling efforts
- Emissions reconciliations help to evaluate model-ready inventories by comparing emission estimates with ambient monitoring data



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EMISSIONS RECONCILIATION (2 OF 2)

- Focuses on pollutant ratios (e.g., VOC/NO_x) rather than the absolute magnitude of emissions
- Most applicable to situations where the observed concentrations are dominated by local emissions
- **Rule of thumb:** ambient- and emissions-derived ratios that are within **±25-50%** are considered to be in good agreement

AMBIENT-EMISSIONS RECONCILIATION

Objective:

- Evaluate emissions data used for modeling done in support of the 2016 South Coast AQMP
- Companion to dynamic model performance evaluation
- Key elements
  - Ambient/emissions comparisons for 2012 baseline year
  - Trends comparisons using backcast (1995, 2000, 2005, 2008) and projected (2015) inventories

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TECHNICAL APPROACH – AMBIENT DATA

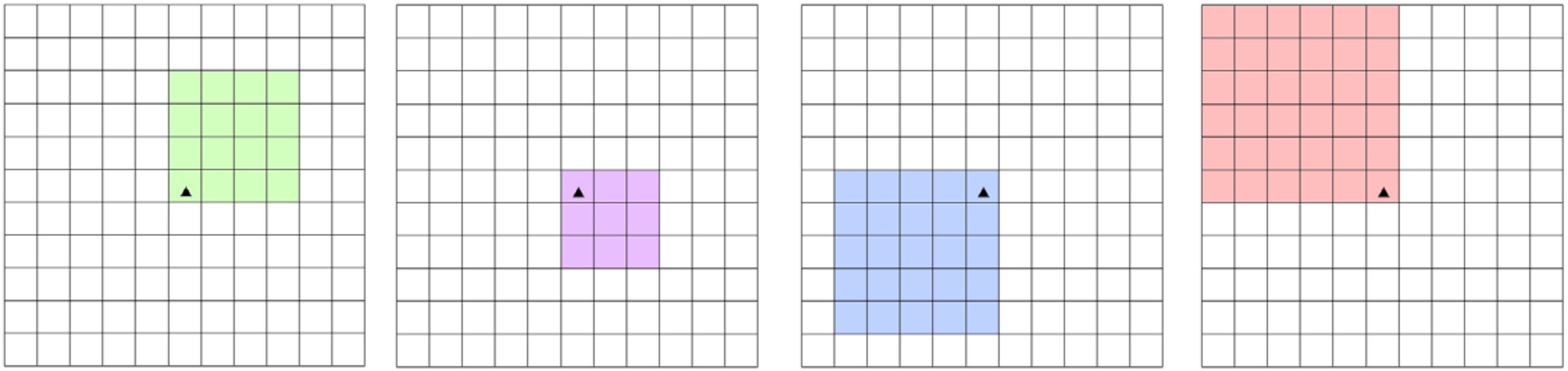
- Evaluated PAMS and other monitoring sites in the SoCAB
- Identified eight sites with suitable data
- Selected ozone season (May through October) data from early morning hours (0500–0900 PST)
- Validated and screened data

TECHNICAL APPROACH – EMISSIONS DATA

- Started with CMAQ-ready emissions inputs
  - 4-km grid resolution
  - SAPRC07 chemical mechanism
- Eliminated SAPRC07 species not detected by PAMS instruments (e.g., methane)
- Converted VOC emissions to moles of carbon (moles-C) to match the PAMS data (reported as ppbC)

TECHNICAL APPROACH – EMISSIONS DATA

- Selected data from morning hours (0500-0900 PST) and grid cells of interest
- Grid analysis zones for each monitoring site was defined based on average morning wind speeds

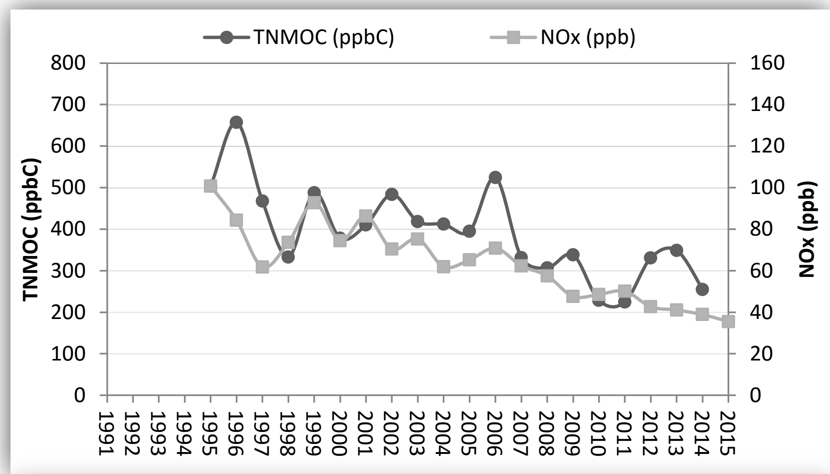


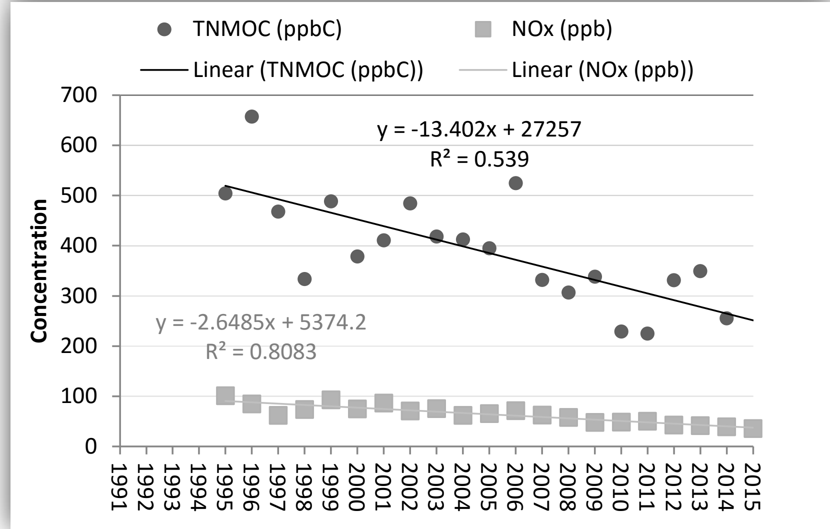
Wind Quadrant 1 (1-90°) Wind Quadrant 2 (91-180°) Wind Quadrant 3 (181-270°) Wind Quadrant 4 (271-360°)

AMBIENT/EMISSIONS COMPARISONS

- Compared historical trends in ambient pollutant concentrations and emissions inventory data
- Calculated and compared trends in TNMOC/NO_x and CO/NO_x ratios for ambient concentrations and emissions inventory data

Example Trends for Azusa





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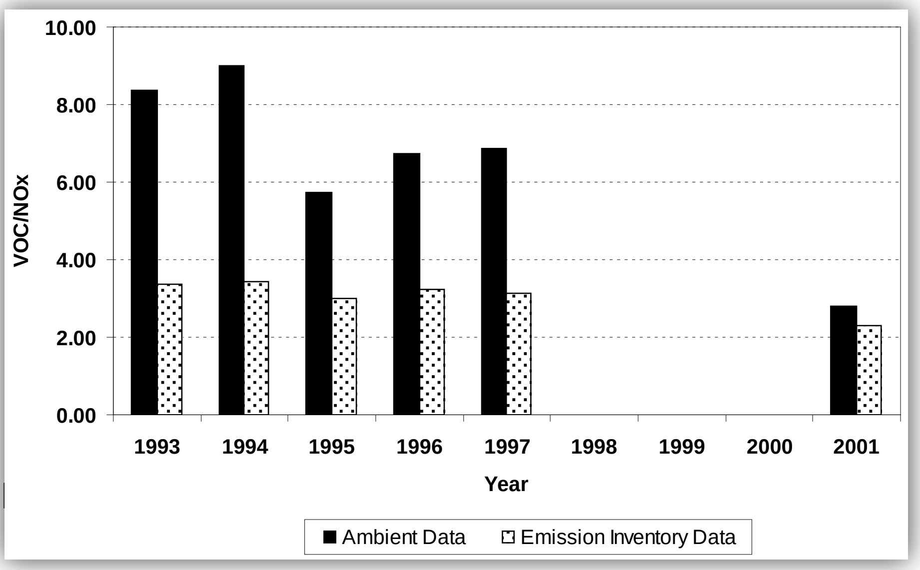
PAST STUDIES: 2005 STI STUDY FOR SCAQMD

- SoCAB PAMS Analysis
- Ambient data from North Main site for summer mornings (0500-0800 PST)
- ARB inventories for LA County, 1993-2001
- Ambient VOC/NO_x ratios declining over time
- Agreement between ambient- and emissions inventory-derived ratios improved over time



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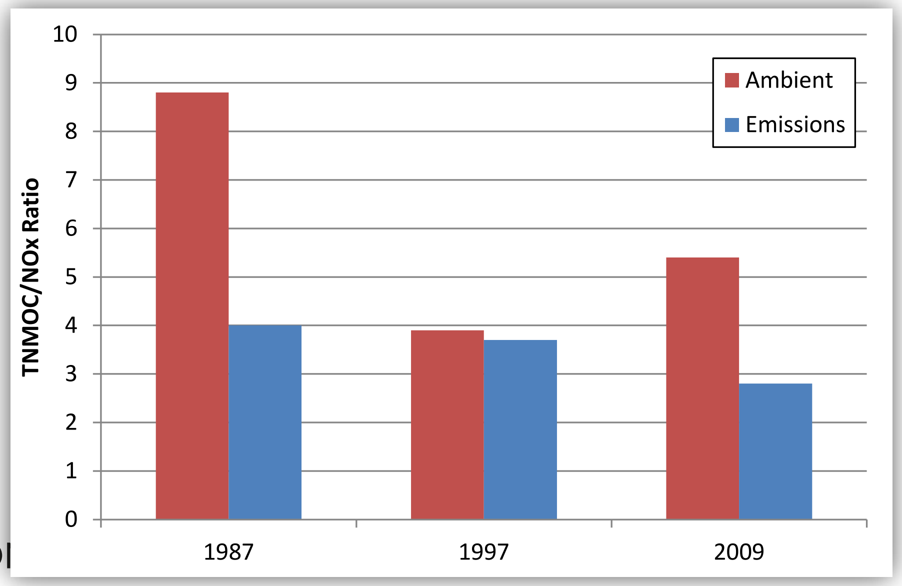
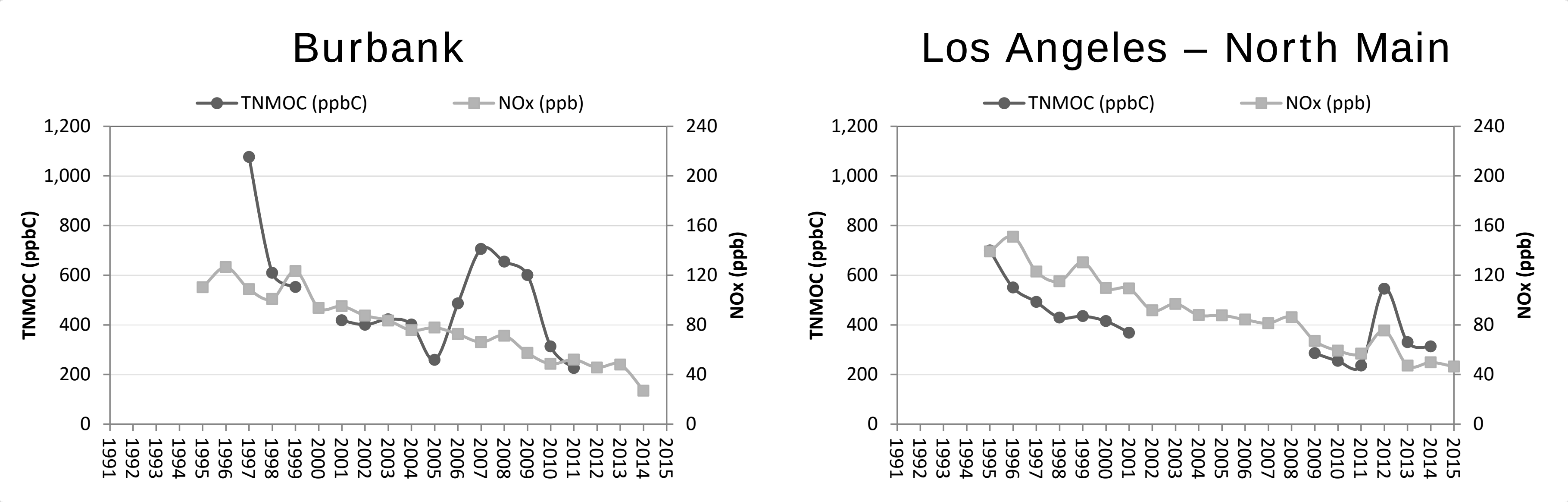
PAST STUDIES: 2013 DRI STUDIES

- 2013 JAWMA Paper (Fuijita, Campbell, Stockwell and Lawson, 2013)
- Ambient TNMOC/NO_x ratio twice as high as emission ratio in 1987
- Good agreement in 1997
- In 2009, ambient ratio increases relative to 1997, while emission ratio continues to decrease
- 2009 ambient TN MOC/NOx ratio again twice as high as emission ratio



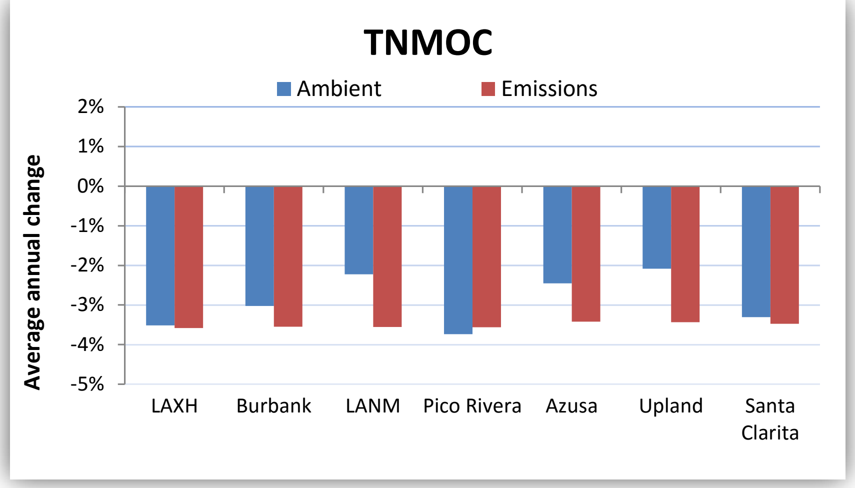
AMBIENT DATA TRENDS

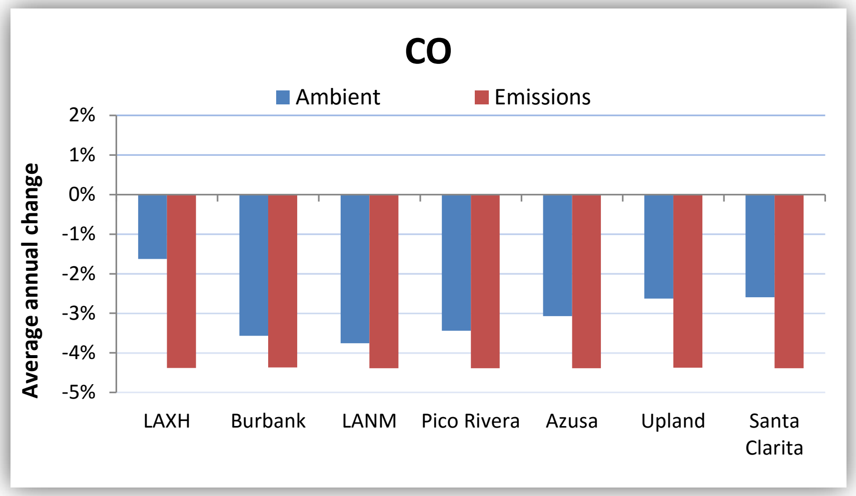
- Overall "glide path" shows decreases in pollutant concentrations over time
- However, significant year-to-year variability occurs at some sites

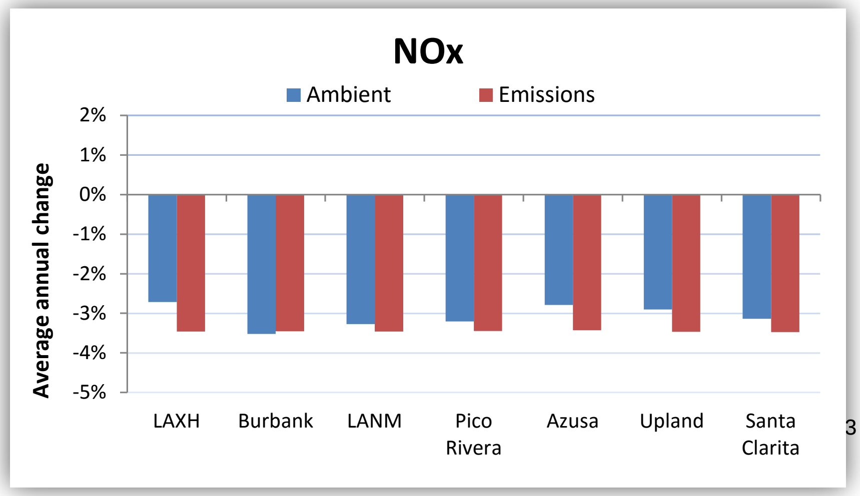


AMBIENT/EMISSIONS TRENDS: 1995-2015

- Calculated average annual changes in concentrations and emissions from 1995 to 2015
- Generally good agreement, although emissions trends do not capture potential site-specific variations over time



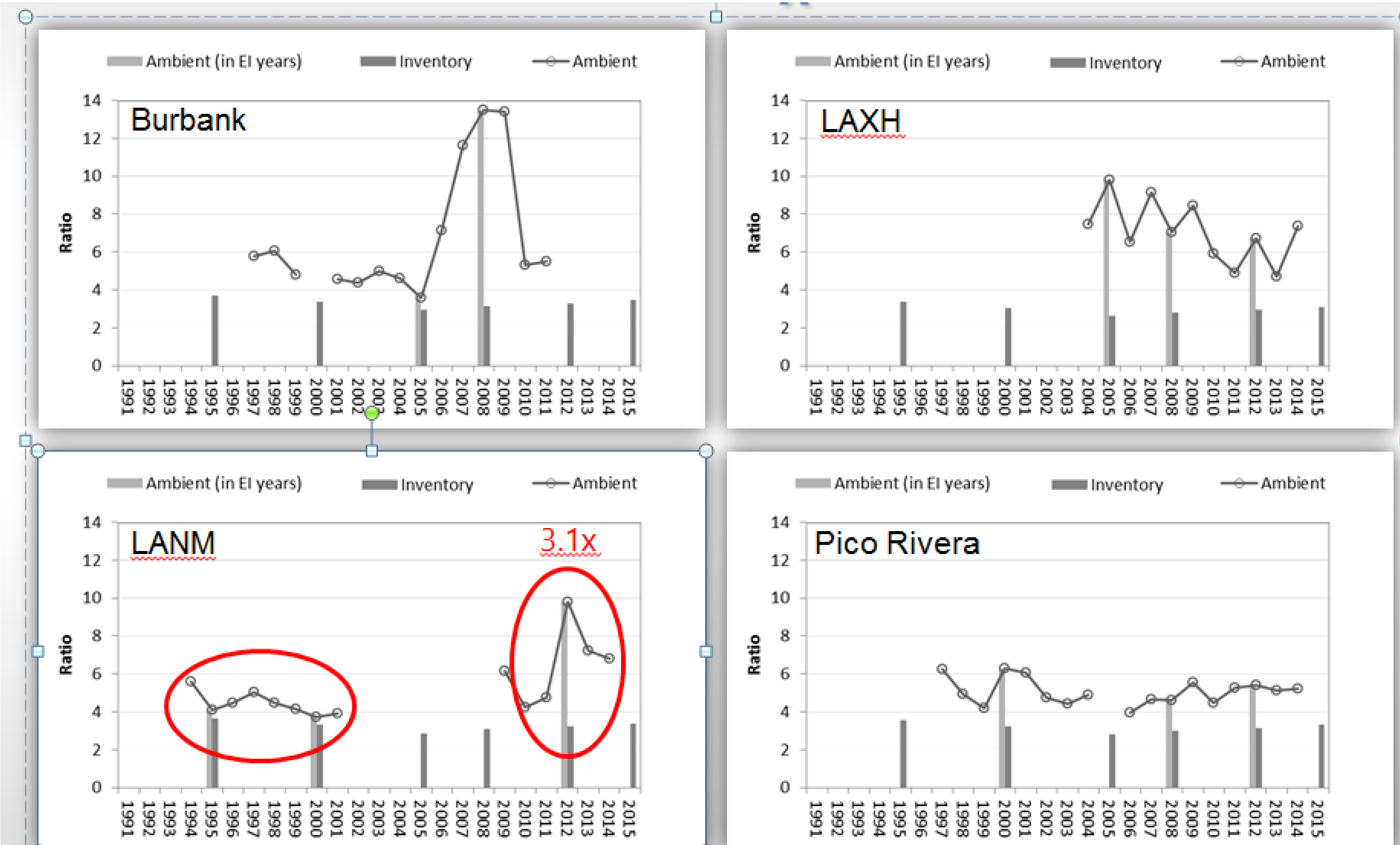




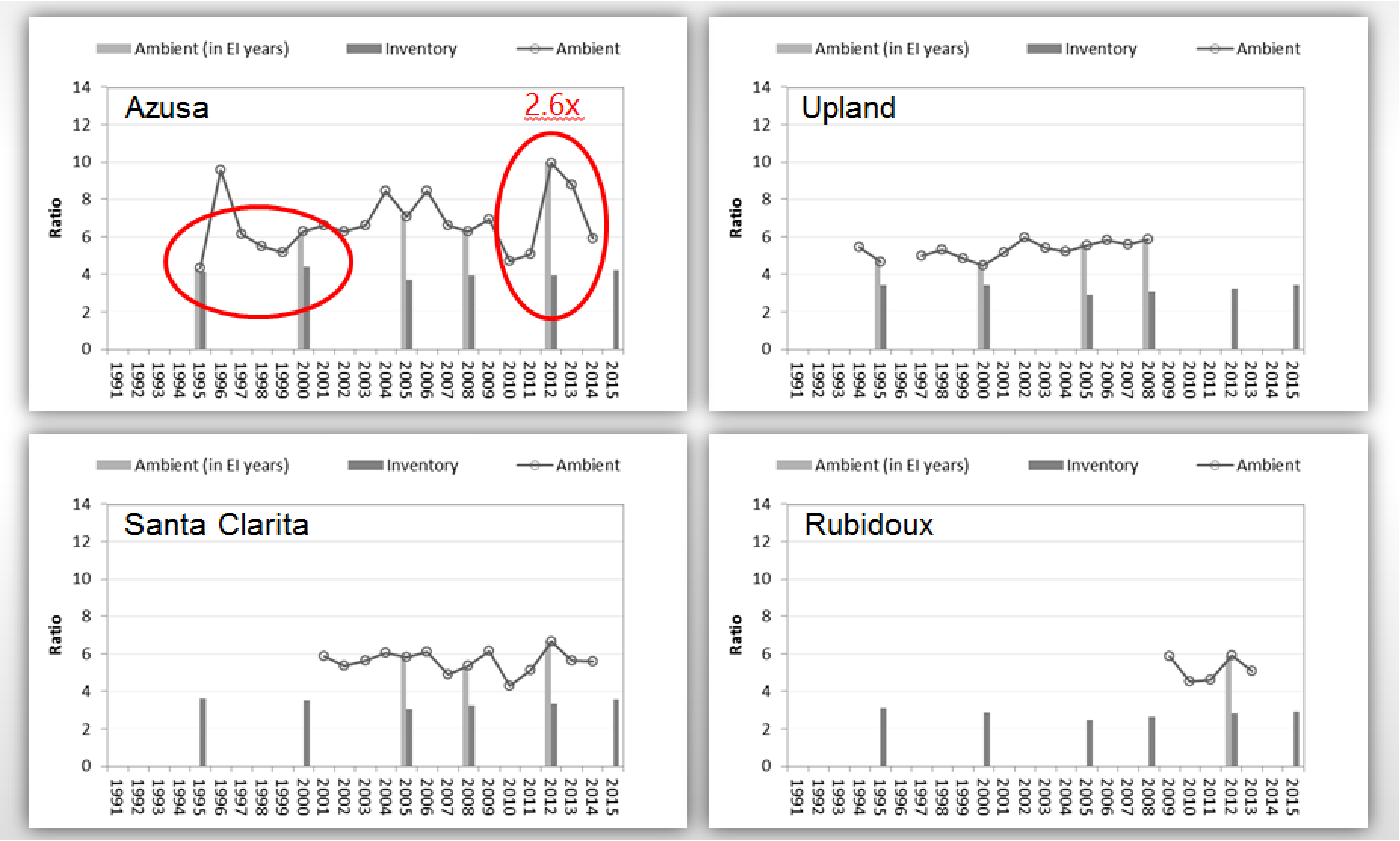
2012 AMBIENT/EMISSIONS TNMOC/NOX AND CO/NOX RATIO COMPARISONS

Site	TNMOC/NOx			CO/NOx		
	Ambient	Emissions	Ambient/Emissions	Ambient	Emissions	Ambient/Emissions
Burbank	--	--	--	9.5	9.4	1.0
LAXH	6.7	2.9	2.3	--	--	--
LANM	9.8	3.2	3.1	14.0	9.3	1.5
Pico Rivera	5.4	3.2	1.7	8.1	8.9	0.9
Azusa	10.0	3.9	2.6	10.5	8.1	1.3
Rubidoux	5.9	2.8	2.1	10.1	6.7	1.5
Santa Clarita	6.7	3.3	2.0	10.2	7.6	1.3
Average	7.4	3.2	2.3	10.4	8.3	1.2

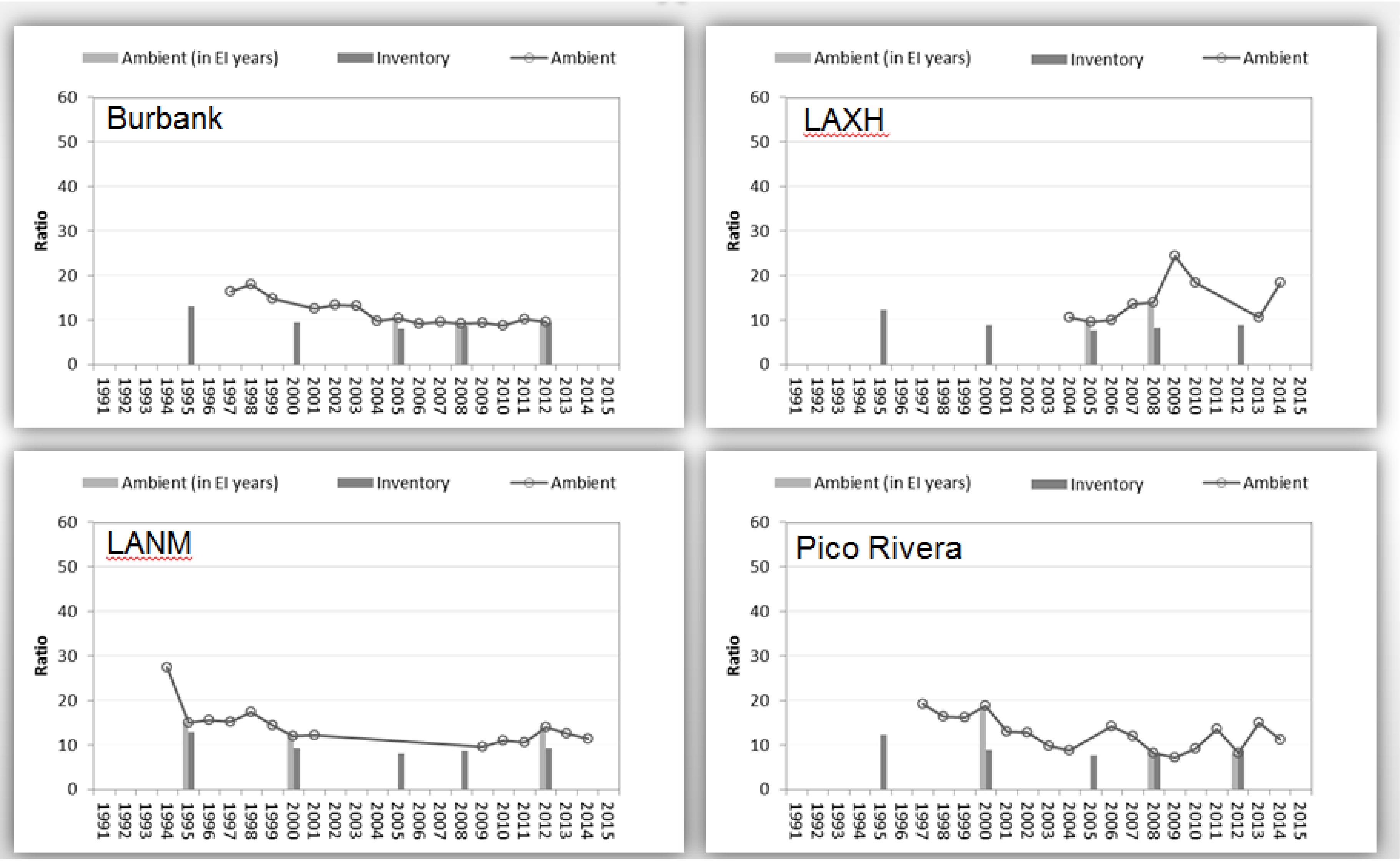
AMBIENT VS. EMISSIONS TNMOC/NOX RATIO COMPARISON TRENDS (1 OF 2)



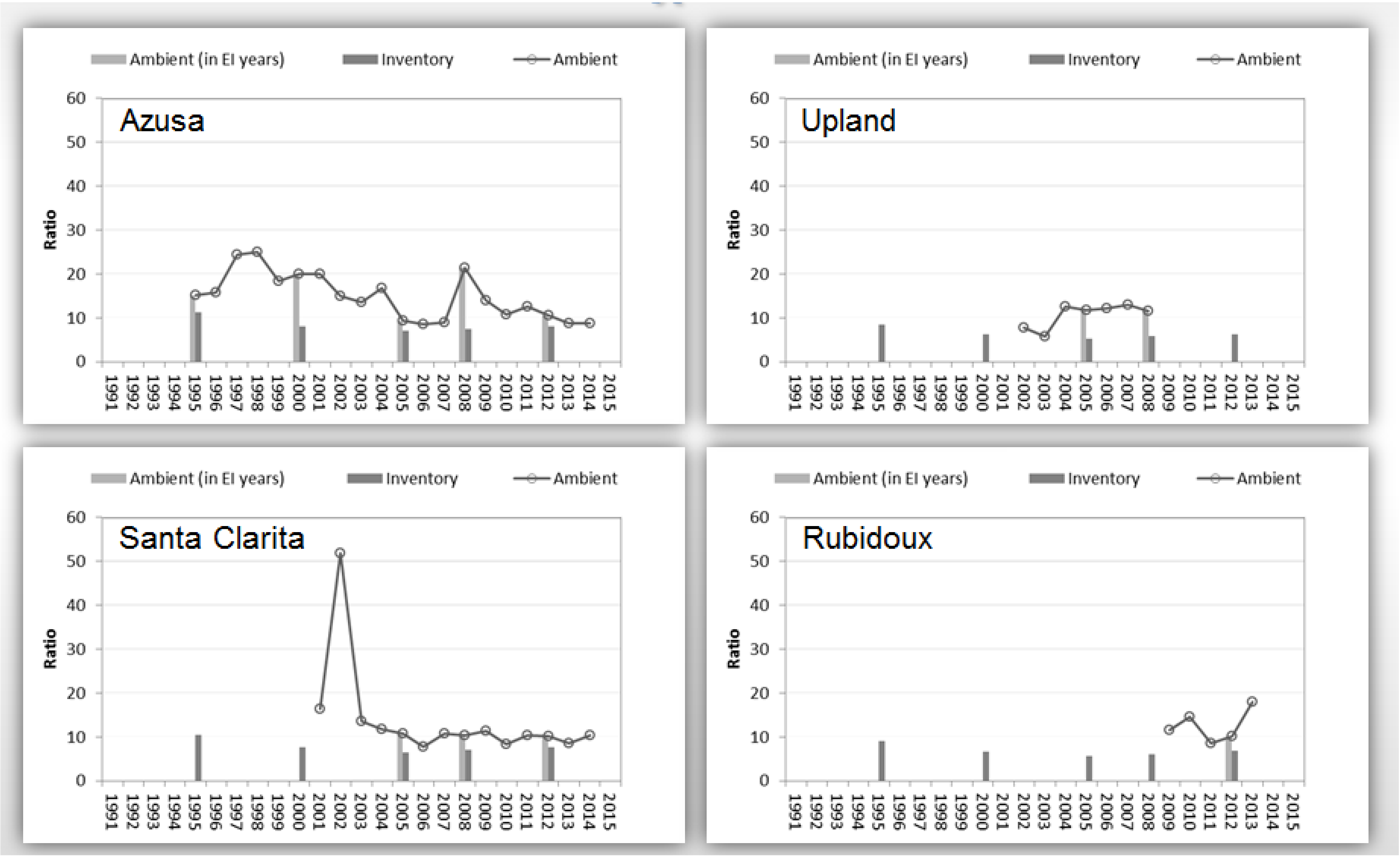
AMBIENT VS. EMISSIONS TNMOC/NOX RATIO COMPARISON TRENDS (2 OF 2)



AMBIENT VS. EMISSIONS CO/NOX RATIO COMPARISON TRENDS (1 OF 2)



AMBIENT VS. EMISSIONS CO/NOX RATIO COMPARISON TRENDS (2 OF 2)



AMBIENT/EMISSION CONCLUSIONS (1 OF 2)

- Trends analysis
  - Overall decrease in ambient concentrations, with significant year-to-year variations
  - General agreement between annual average decreases in pollutant concentrations and emission levels
- TNMOC/NO_x ratios
  - Consistently higher in the ambient data than in the emissions inventory data (by a factor of ~2 to 3 in 2012)
  - Indicates that TNMOC emissions are under-estimated, NOx emissions are over-estimated, or both
  - At some sites, agreement between ambient- and emissions-derived ratios less favorable in 2012 than in previous years

AMBIENT/EMISSION CONCLUSIONS (2 OF 2)

- CO/NO_x ratios
  - Generally higher in the ambient data than in the emissions data
  - Agreement is good (within 50%) for most sites and years
- Potential emission inventory issues
  - Temperature effects on evaporative emissions
  - NO_x zero-hour emission rates and deterioration rates for heavy duty vehicles (see EMA comments on EMFAC)

NEXT STEPS: ONGOING & FUTURE WORK

- Continue ambient vs. emissions reconciliation
- Quantify uncertainties via sensitivity studies:
  - Boundary Conditions; Meteorology; Chemistry; Emissions
- Sensitivity tests to investigate causes of poor dynamic modeling performance evaluation
  - For example, align emissions inventory with ambient TNMOC/NOx ratios
- Investigate EMFAC limitations and use findings to develop alternative mobile source emission scenarios
- Review previous work to reduce ozone forecast errors and apply methods to improve model response
- Collaborate with SCAQMD and ARB on model improvements

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