Regional Development, Population Trend, and Technology Change Impacts on Future Air Pollution Emissions in the San Joaquin Valley

Michael Kleeman, Mark Hixson, Deb Niemeier, Susan Handy, Jay Lund, Song Bai, Sangho Choo, and Shengyi Gao

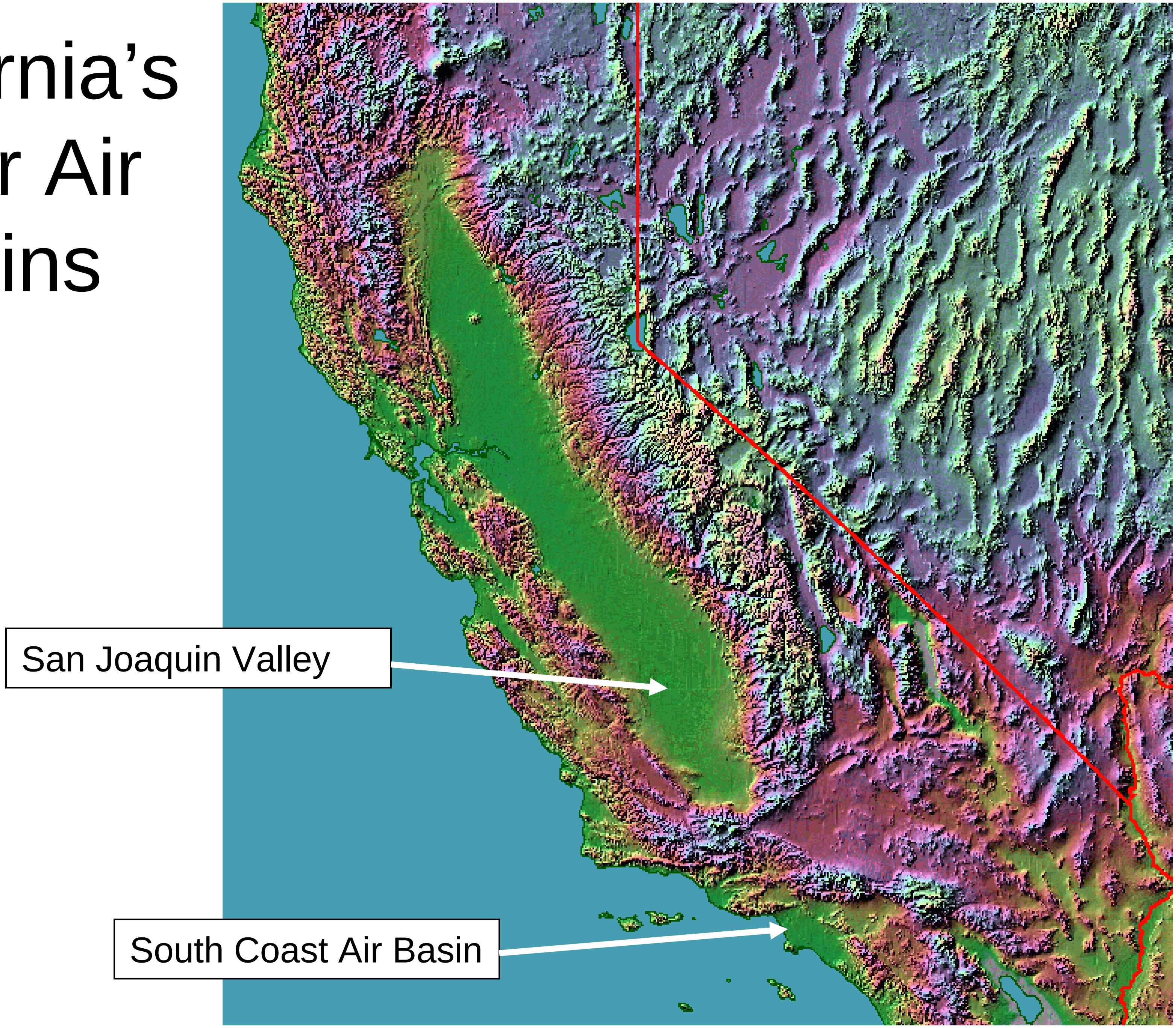
University of California Davis

Dana Sullivan

Sonoma Technology

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD-83184201

California's Major Air Basins



Project Objectives

- Develop a system of models for evaluating the impact of **local and regional** policies and trends on air quality in the San Joaquin Valley
  - Global variables from sources like IPCC, California Department of Finance
- Apply this system to the San Joaquin Valley to evaluate the sensitivity of air quality to different policy scenarios.

Projected Population Growth

- Current SJV population ~3M
- Projected 2030 SJV population ~6M (California Department of Finance)

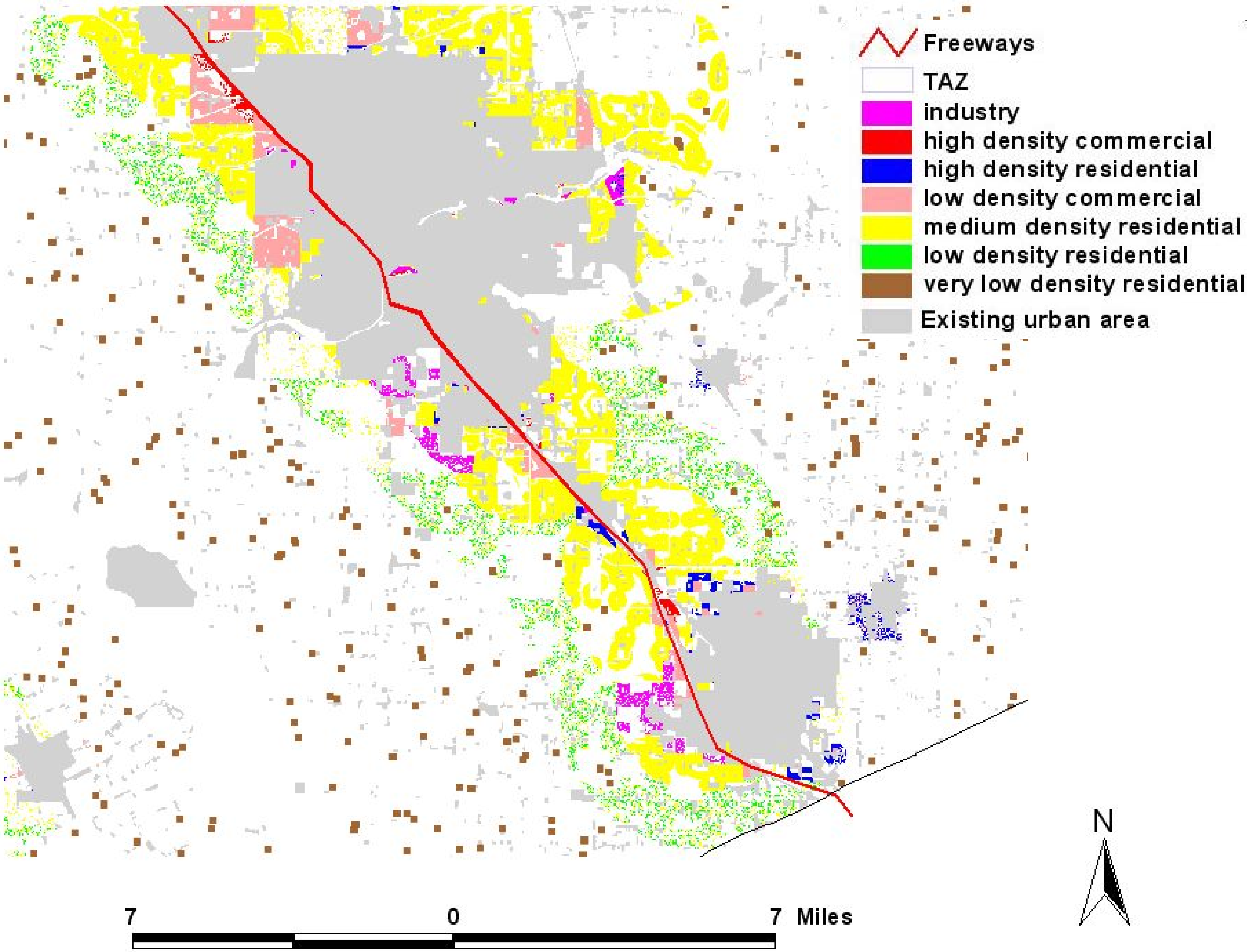
Scenarios

	Scenario 1: Baseline	**Scenario 2: Controlled**	**Scenario 3: Uncontrolled**	**Scenario 4: As Planned**
Transportation	No change	No new roads High Speed Rail	New roads No High Speed Rail	New roads High Speed Rail
Land use	No change	High-density residential Transit-oriented development Infill and redevelopment Increased ag preservation Increased habitat preservation	Low- and very-low density residential	Residential densities as planned Some increased preservation

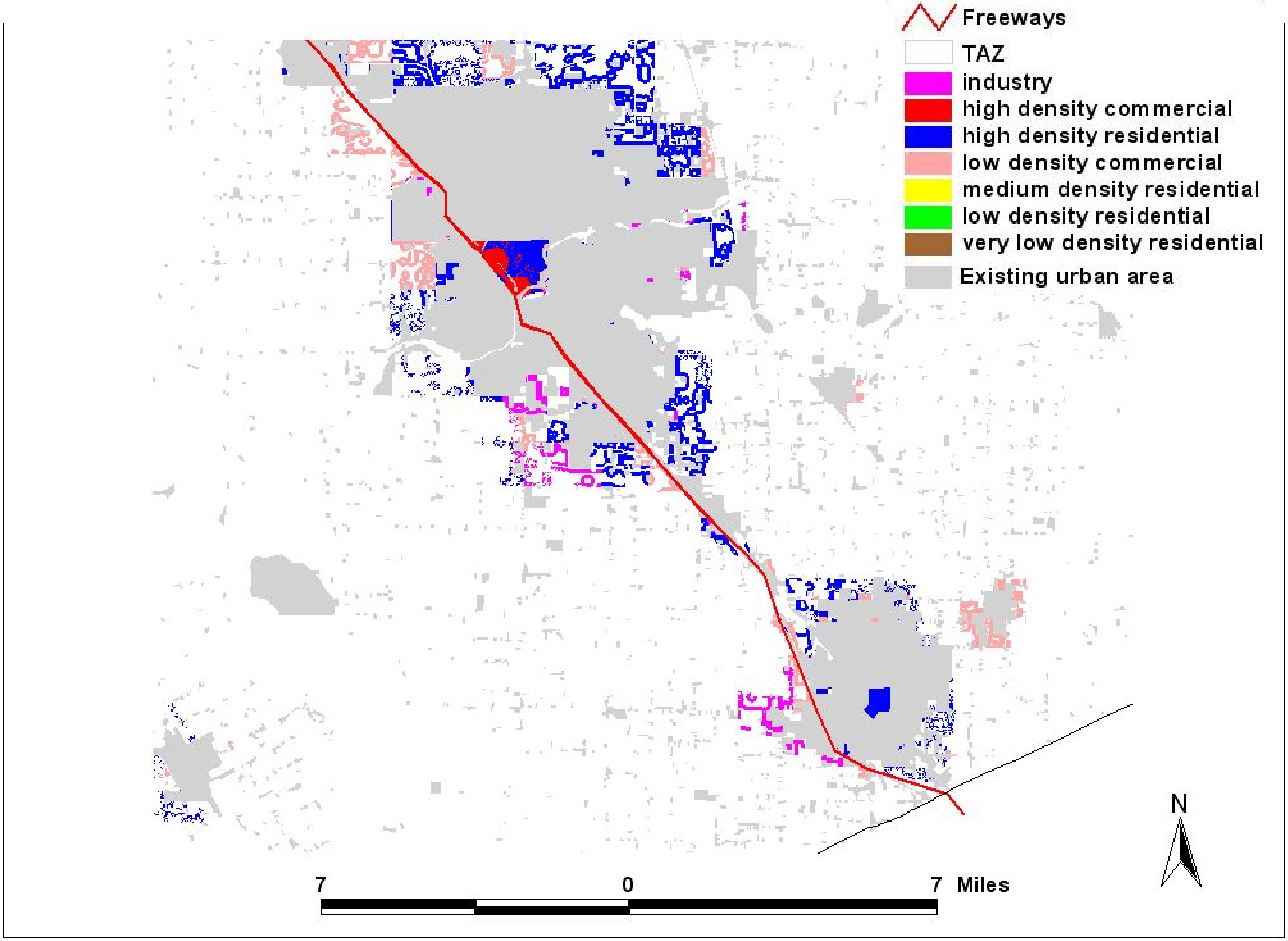
Scenarios: continued

	Scenario 1: Baseline	**Scenario 2: Controlled**	**Scenario 3: Uncontrolled**	**Scenario 4: As Planned**
Other regional variables	No change	Decentralized power Complete burning ban Ag dust reduction	No change	Some decentralized power State rules on burning Some ag dust reduction
Technology variables (some options to be implemented in the next phase)	No change	Improved vehicle efficiency Fuel cell adoption Mandate alternative energies Complete diesel retrofit Dairy bio-energy	No change	No change

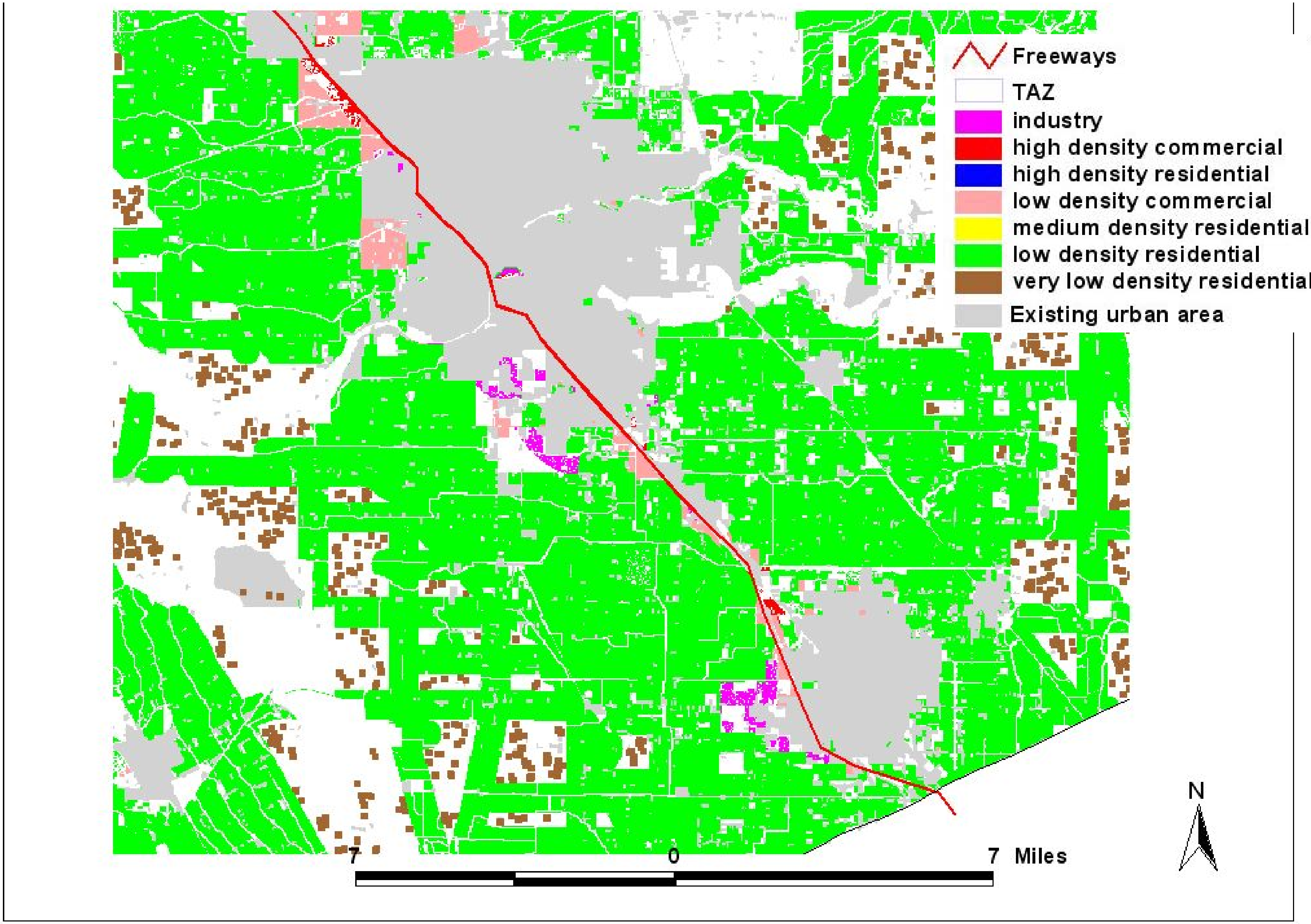
Stanislaus County "As Planned"



Stanislaus County "Controlled Growth"

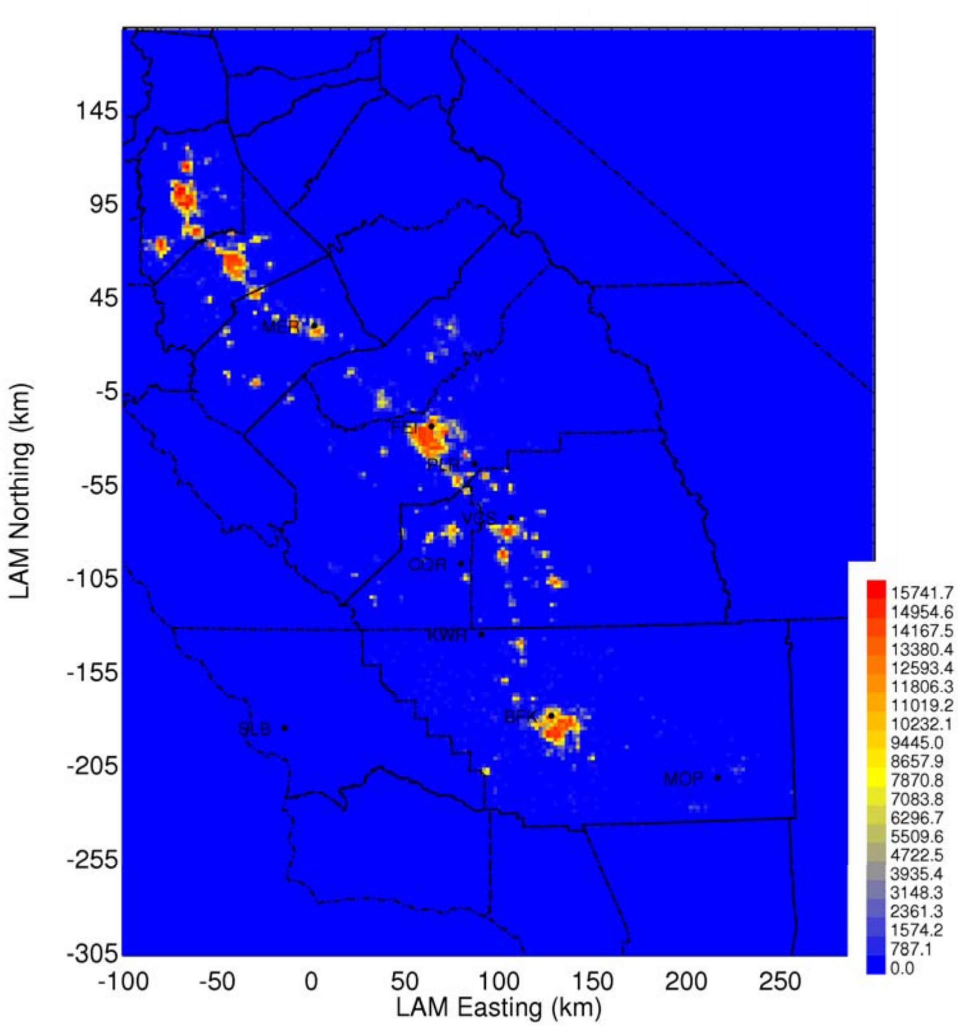


Stanislaus County "Uncontrolled Growth"

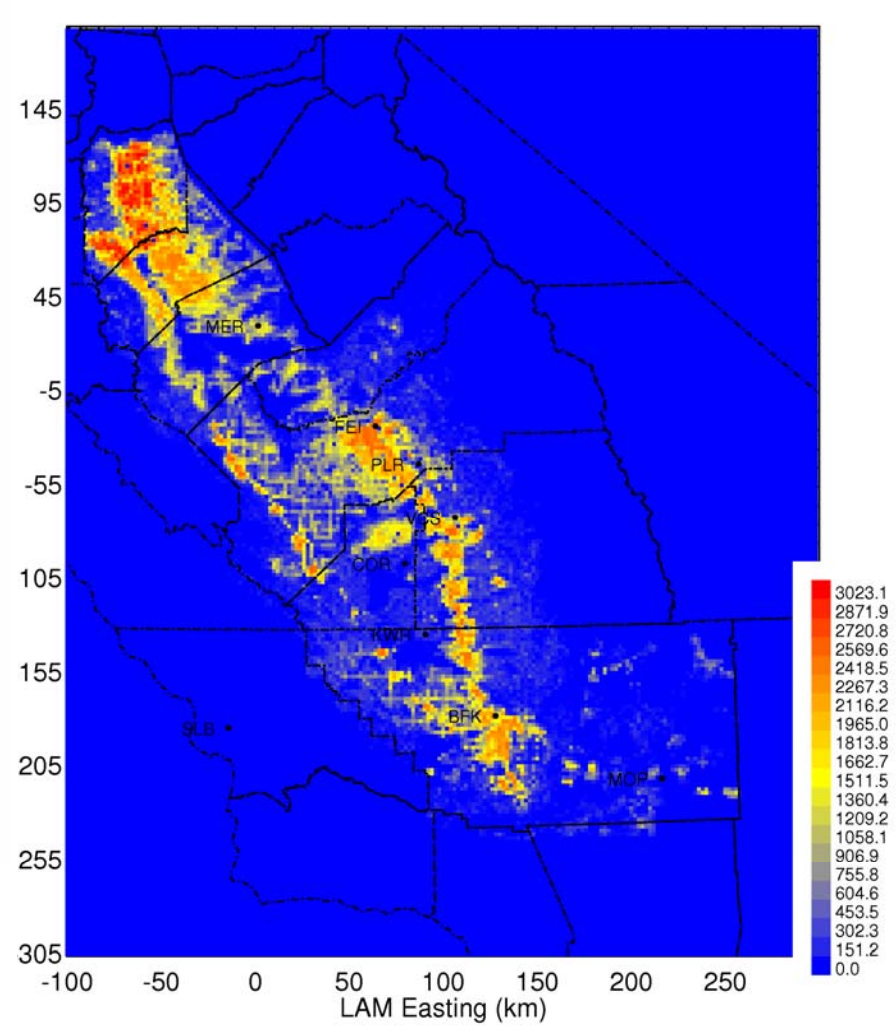


Projected Population Distribution

Scenario 2 – Controlled Growth
3935 people/km^2



Scenario 3 – Uncontrolled Growth
756 people/km^2

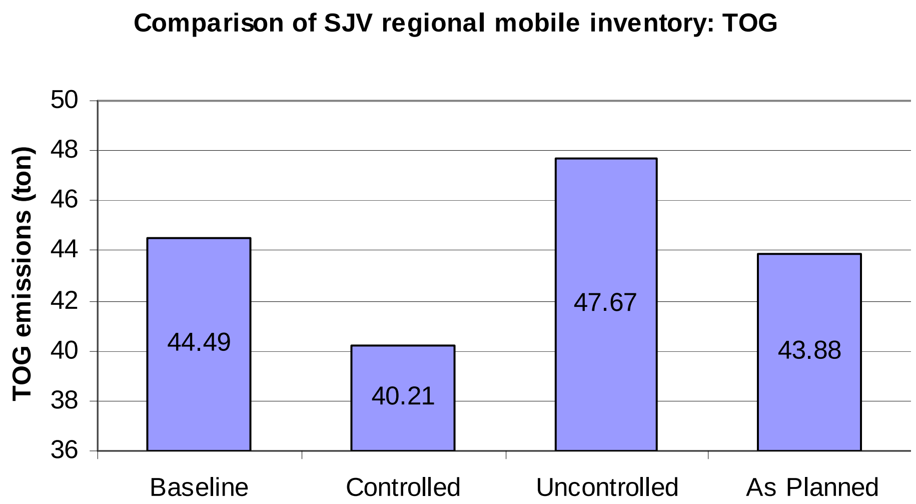


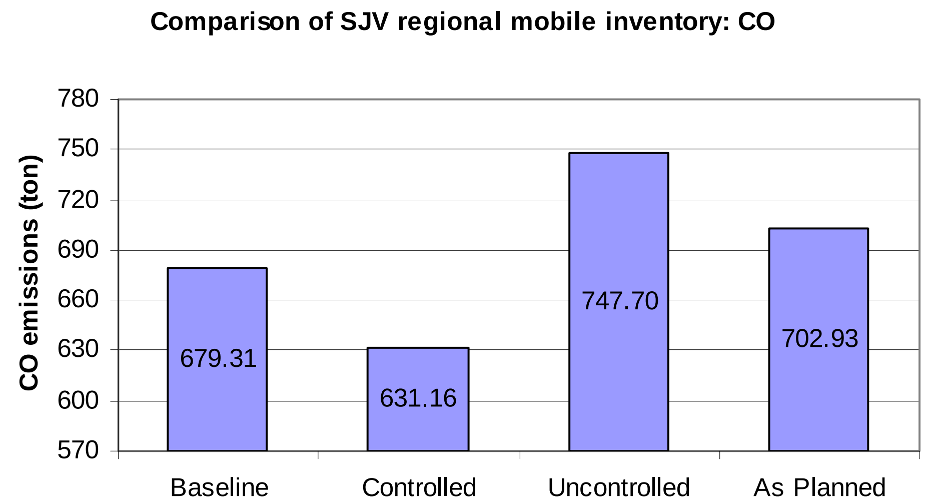
SJV Travel Demand Modeling Results

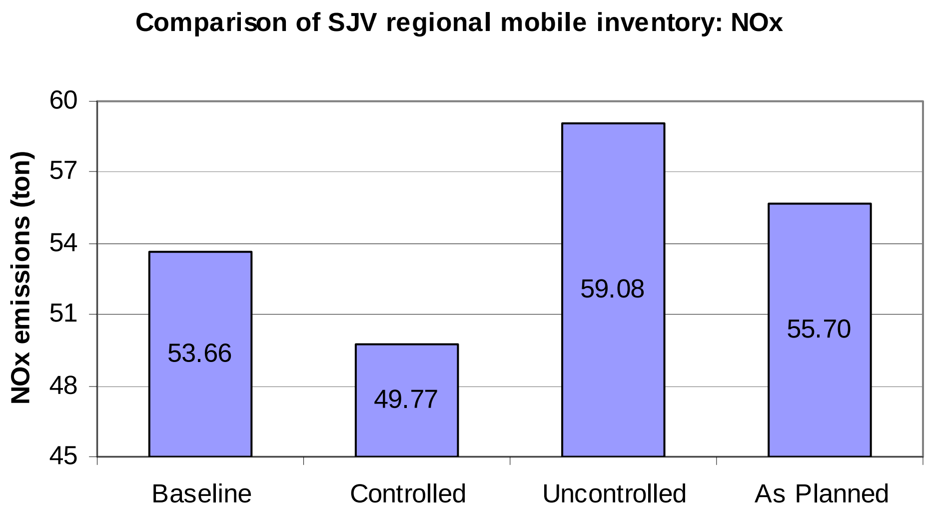
Regional Traffic Activity	Scenario 1 Baseline	Scenario 2 Controlled Growth	Scenario 3 Uncontrolled Growth	Scenario 4 As-Planned
VMT (1000 miles)	184,164	172,252 (-6.5%)	206,789 (+12.3%)	193,915 (+5.3%)
VHT (hour)	6,142,470	5,372,364 (-12.5%)	6,609,367 (+7.6%)	6,035,425 (-1.7%)
Trips (one-trip)	16,653	16,044 (-3.7%)	16,668 (+0.1%)	16,675 (+0.1%)
Trip Distance (mile)	11.06	10.74 (-2.9%)	12.41 (+12.2%)	11.63 (+5.2%)

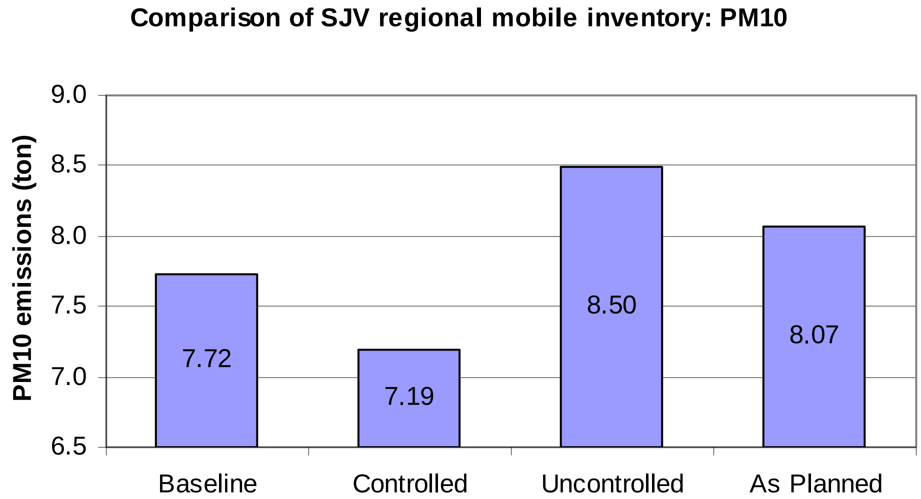
Source: S. Bai et al., "Integrated Impacts of Regional Development, Land Use Strategies and Transportation Planning on Future Air Pollution Emissions", Submitted to 2007 Transportation Land Use, Planning, and Air Quality Conference

SJV Travel Demand Modeling



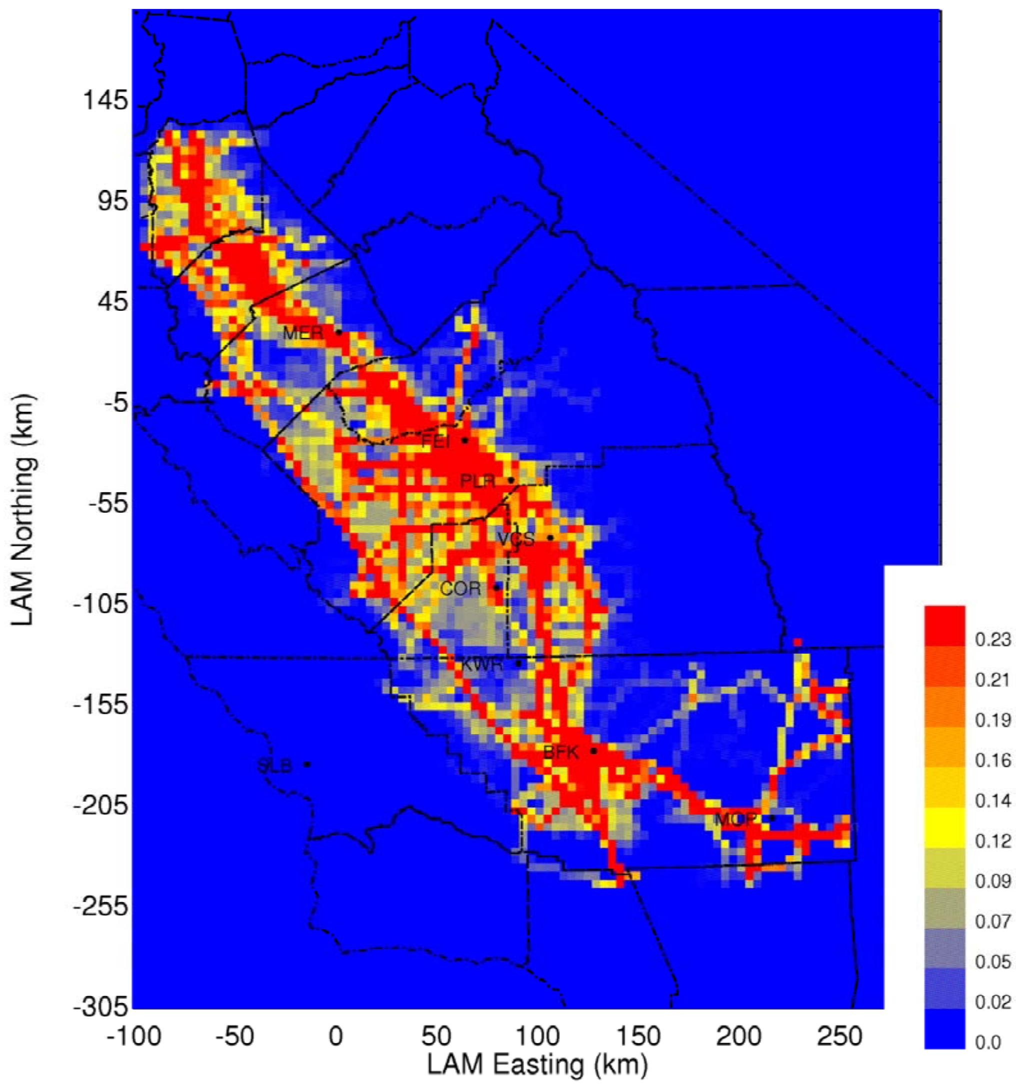




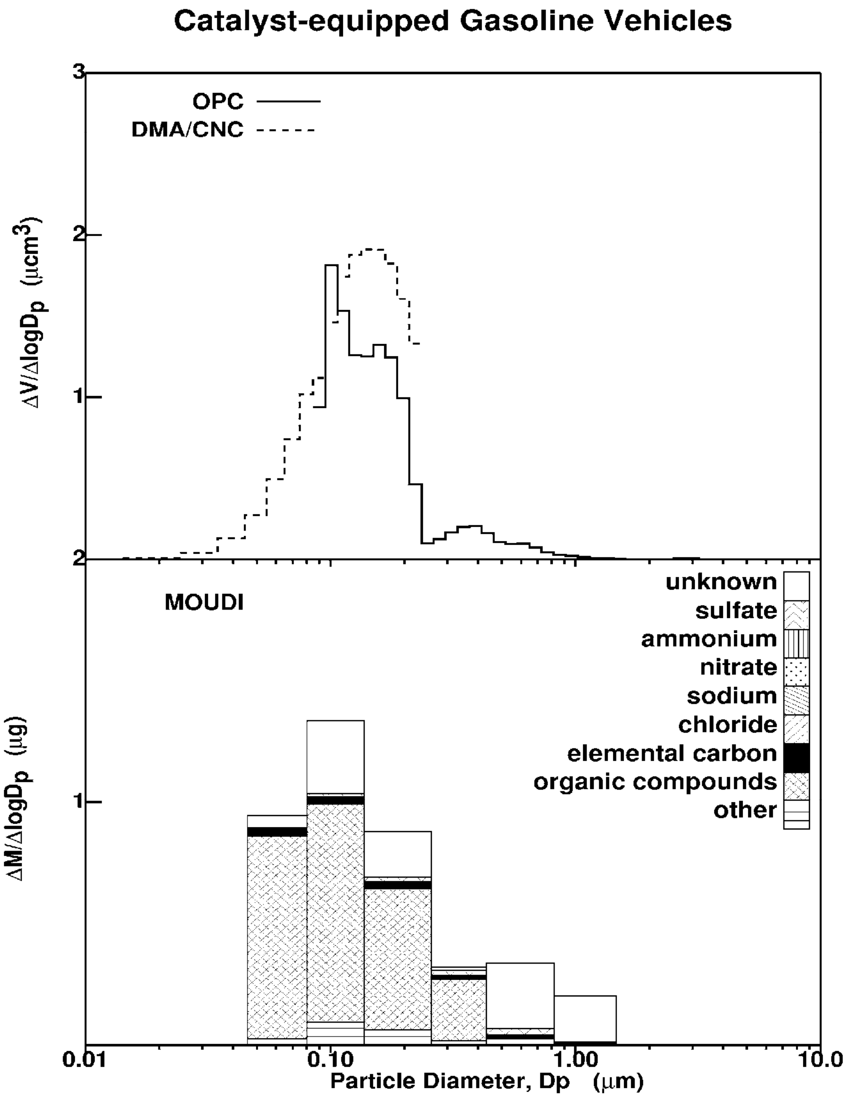


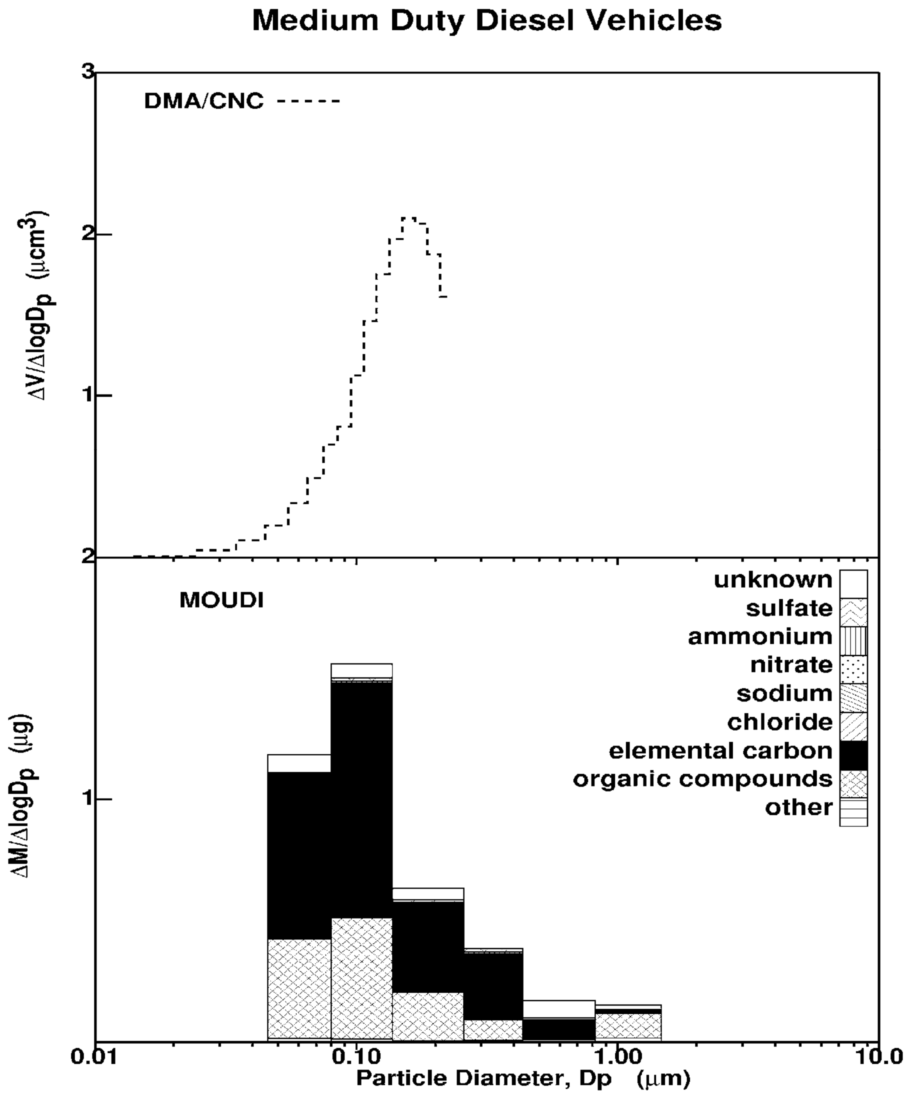
Source: S. Bai et al., “Integrated Impacts of Regional Development, Land Use Strategies and Transportation Planning on Future Air Pollution Emissions”, Submitted to 2007 Transportation Land Use, Planning, and Air Quality Conference

Distribution of Diesel PM Emissions



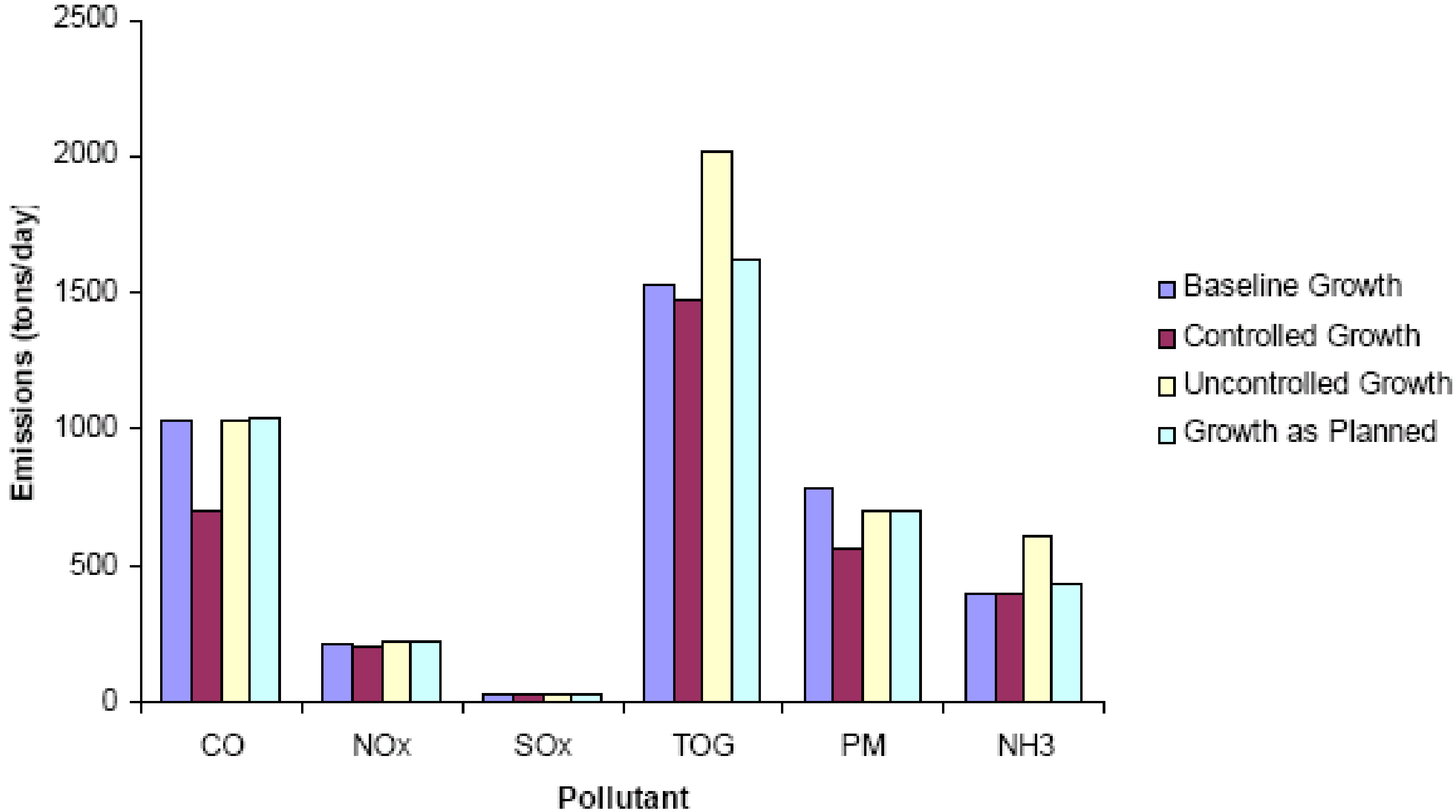
PM Source Profiles





Source: M. Kleeman et al., "Size and Composition Distribution of Fine Particulate Matter Emitted from Motor Vehicles. Environmental Science, and Technology, 34:1132-1142, 2000.

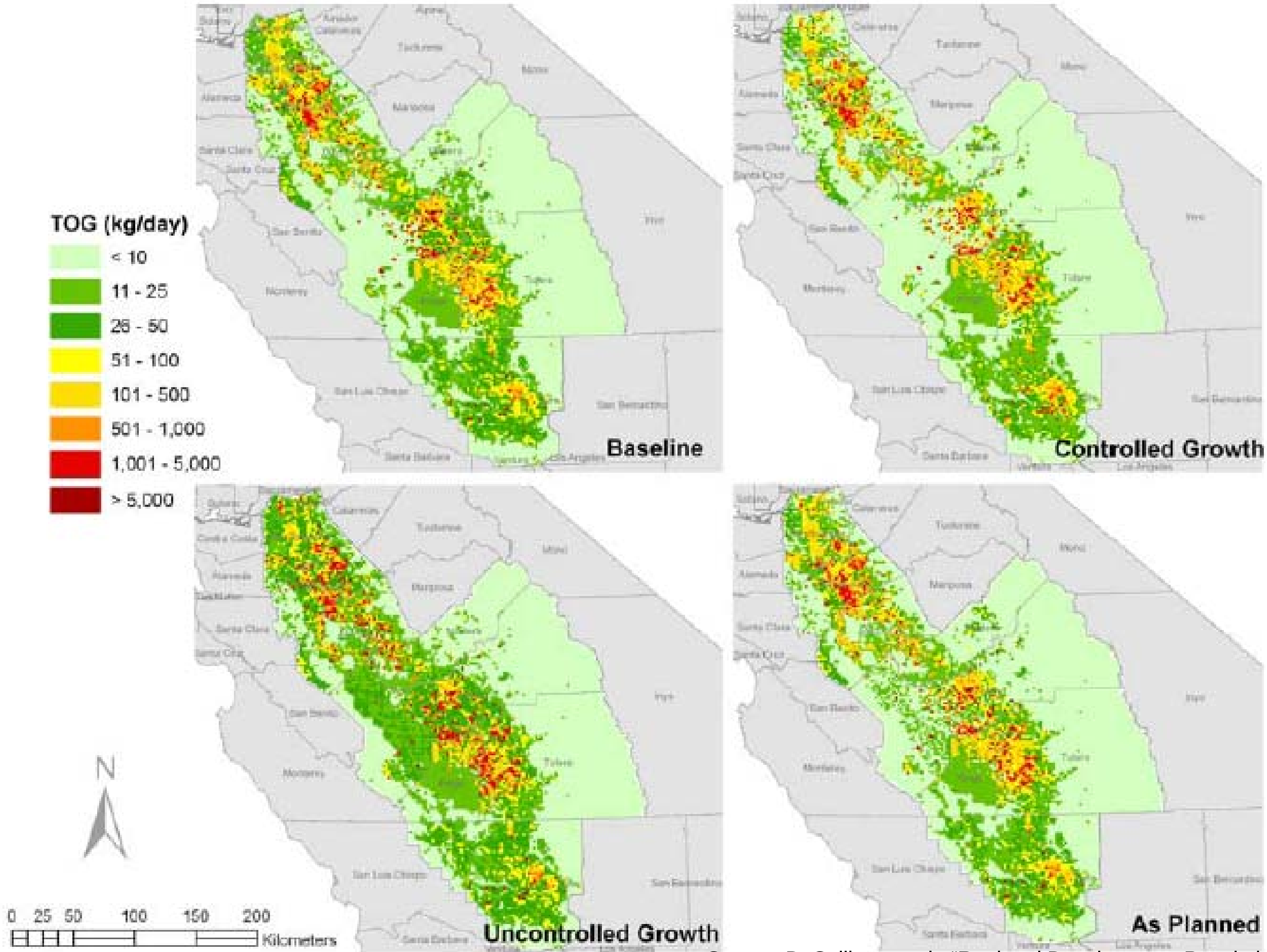
SJV Area, Non-road Mobile, and Point Source Summary



Note: Emissions of on-road mobile sources are omitted.

Source: D. Sullivan et al., “Regional Development, Population Trend, and Technology Change Impact on Future Air Pollution Emissions”, Final Report STI-905011.01-3239.TM, Sonoma Technology Inc.

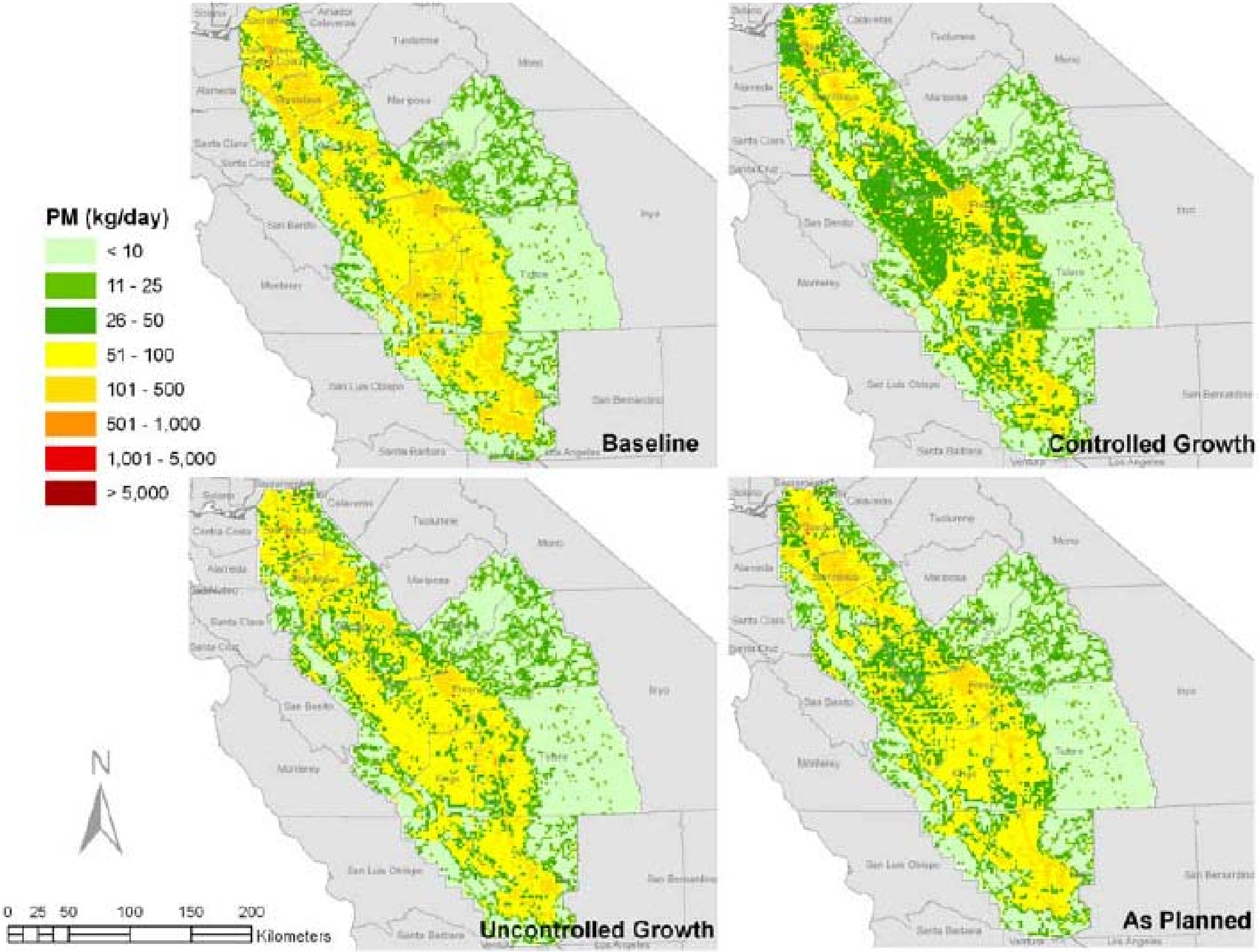
SJV Area, NRM and Point TOG Emissions



Note: Emissions of on-road mobile sources are omitted.

Source: D. Sullivan et al., "Regional Development, Population Trend, and Technology Change Impact on Future Air Pollution Emissions", Final Report STI-905011.01-3239.TM, Sonoma Technology Inc.

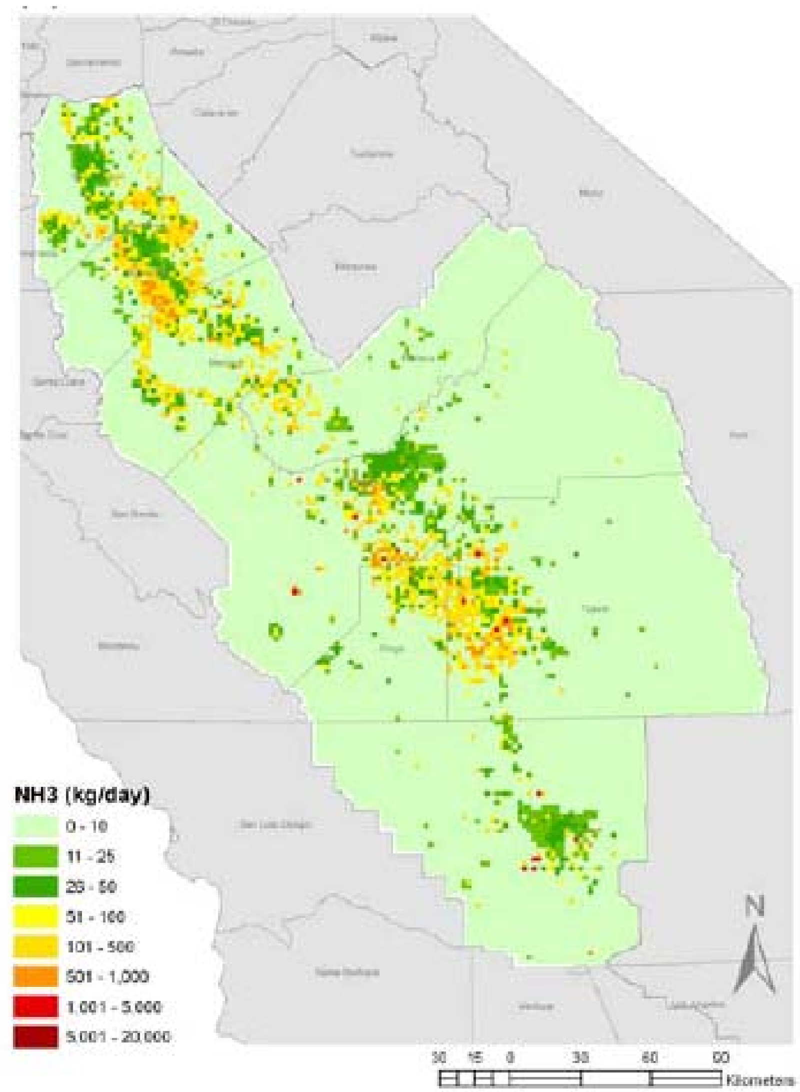
SJV Area, NRM and Point PM Emissions



Note: Emissions of on-road mobile sources are omitted.

Source: D. Sullivan et al., "Regional Development, Population Trend, and Technology Change Impact on Future Air Pollution Emissions", Final Report STI-905011.01-3239.TM, Sonoma Technology Inc.

SJV Area, NRM, and Point NH3 Emissions



Source: D. Sullivan et al., “Regional Development, Population Trend, and Technology Change Impact on Future Air Pollution Emissions”, Final Report STI-905011.01-3239.TM, Sonoma Technology Inc.

Meteorological Conditions

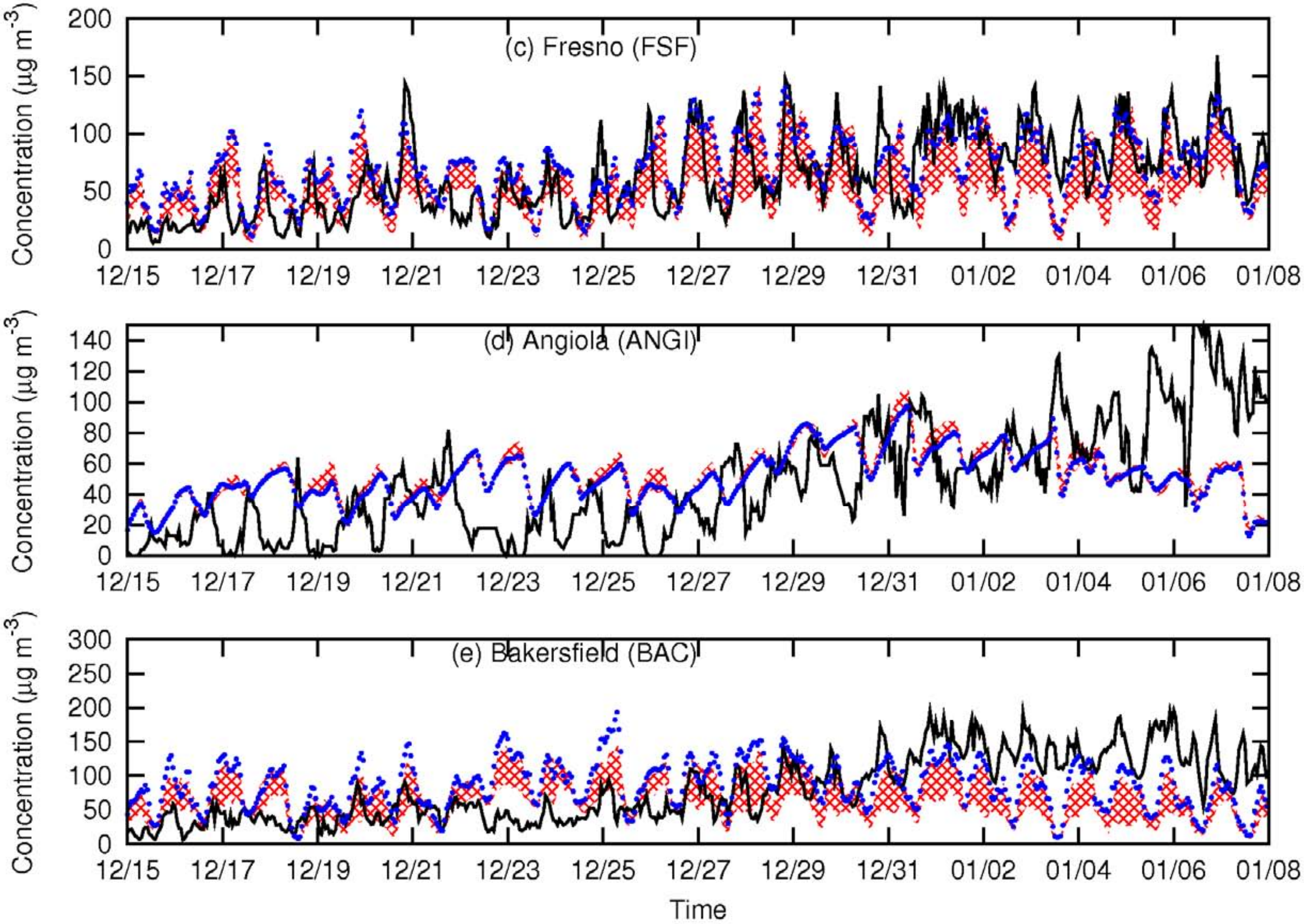
- December 15, 2000 – January 7, 2001
- Severe winter stagnation event
  - Nighttime temperatures < 5^{o}C
  - Daytime temperatures < 18^{o}C
  - Persistent elevated inversion
  - Nighttime ground-level inversion
  - Surface winds ~1-2 m sec^{-1}
- Air Quality model has been evaluated extensively for this episode

Air Quality Model

- UCD/CIT source-oriented air quality model
- SAPRC90 gas phase chemistry with updates to key rate constants
  - Expanded to track secondary source contributions
- PM chemistry based on thermodynamic equilibrium for inorganic salts
  - 15 model size bins, +50 chemical species
  - Fully dynamic gas-particle exchange
  - SOA formation based on simple absorption model using coefficients derived from smog chambers

Basecase Model Evaluation

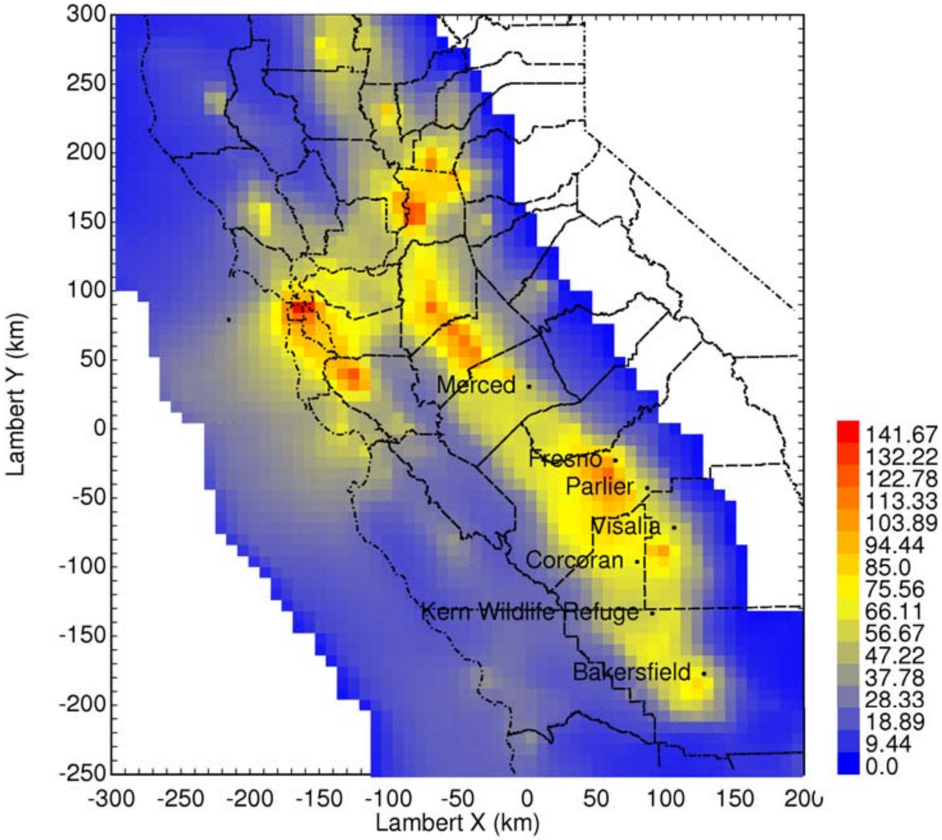
Measured: black
Predicted: blue
50% Quantile: red



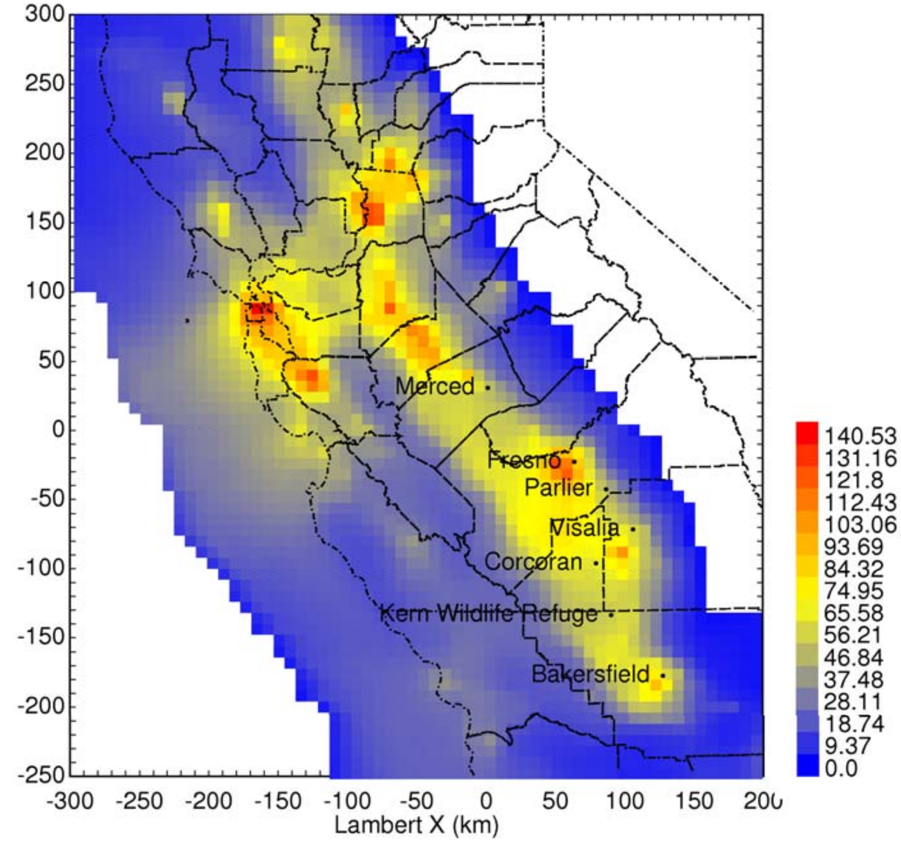
Source: Q. Ying et al., "Modeling Air Quality During the California Regional PM10 / PM2.5 Air Quality Study (CRPAQS) Using the UCD/CIT Source-Oriented Air Quality Model. Part 1: Basecase Model Results", Atmospheric Environment, in press, 2008.

PM2.5 Average
December 25 2030 – January 7, 2031

Scenario 1 (Static)
Domain Max = 142 μg m^{-3}
SJV Max = 115 μg m-3



Scenario 4 (As Planned)
Domain Max = 141 μg m^{-3}
SJV Max = 115 μg m-3

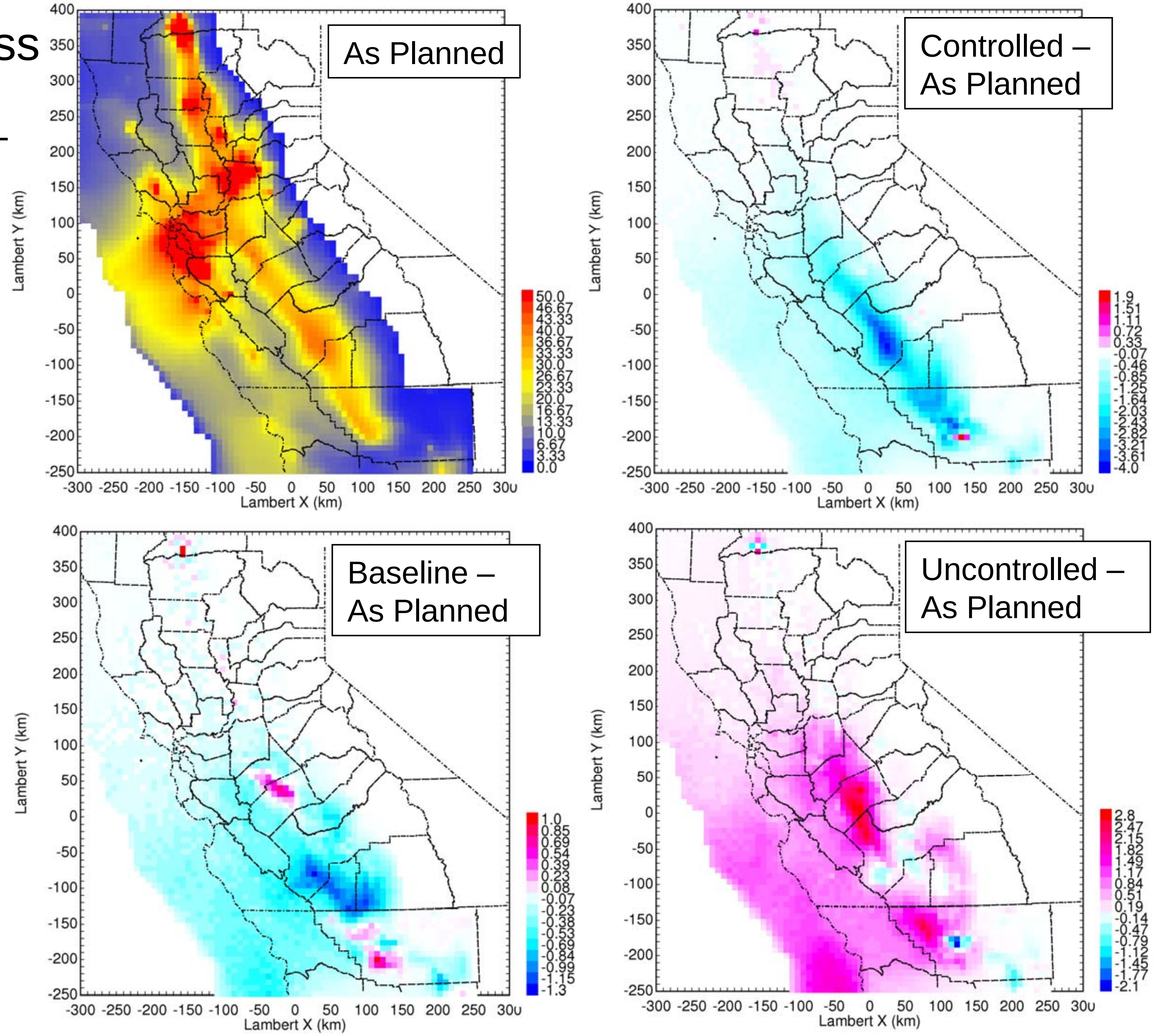


Additional Emissions Controls Applied to SJV Only

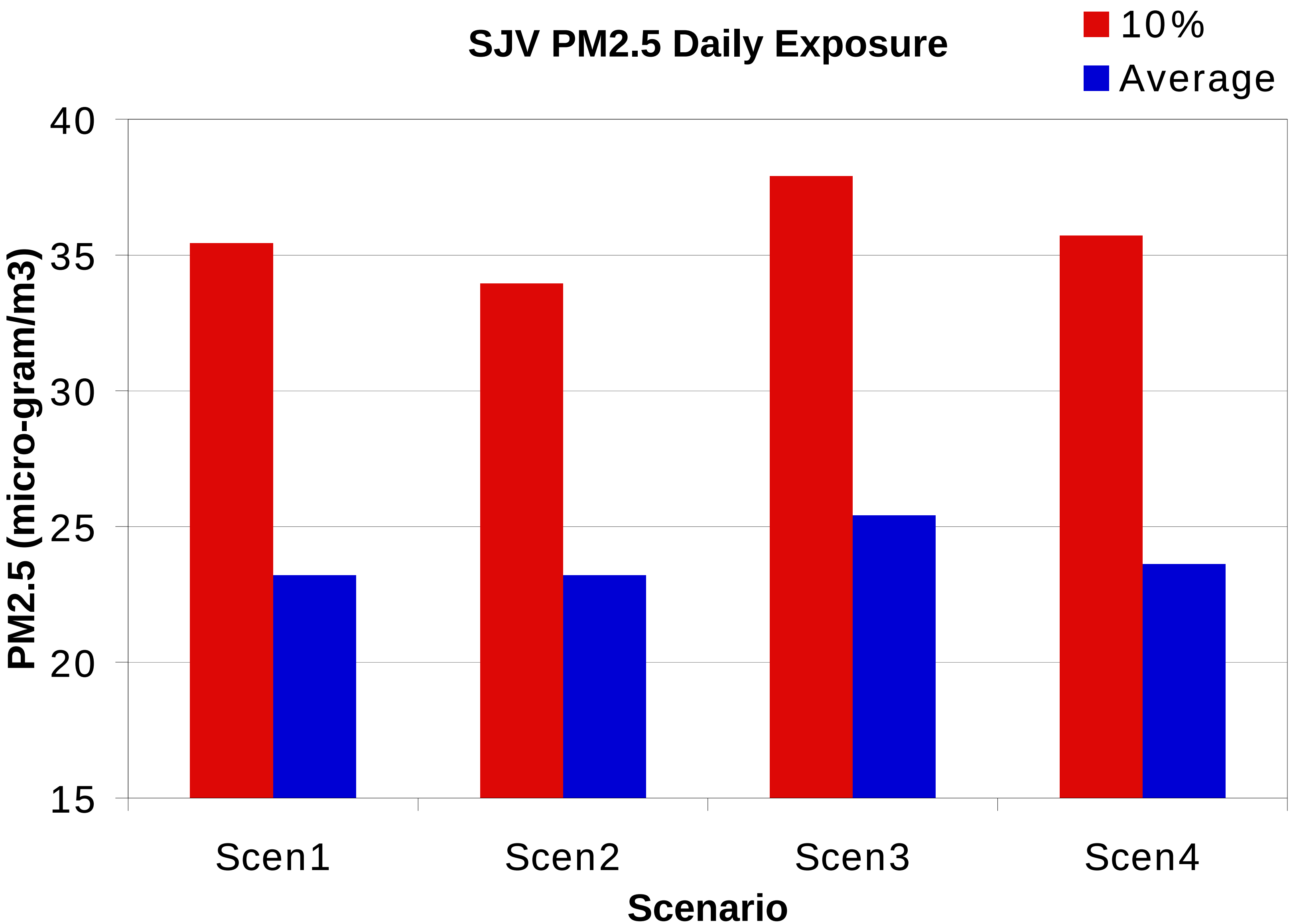
- Complete ban on residential wood combustion for all scenarios

PM2.5 Mass

Dec 25 2030 –
Jan 7 2031

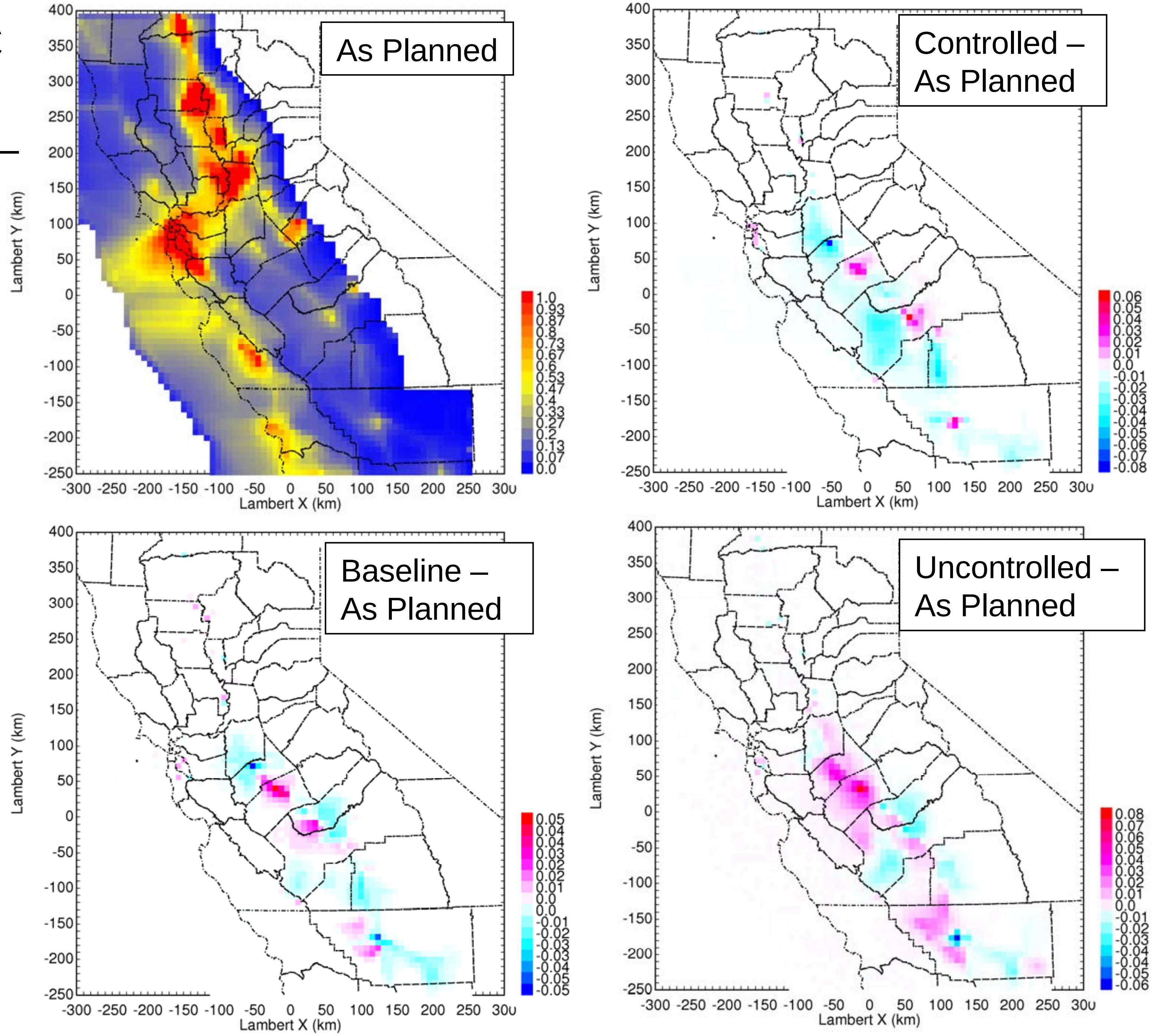


December 25 2030 – January 7, 2031

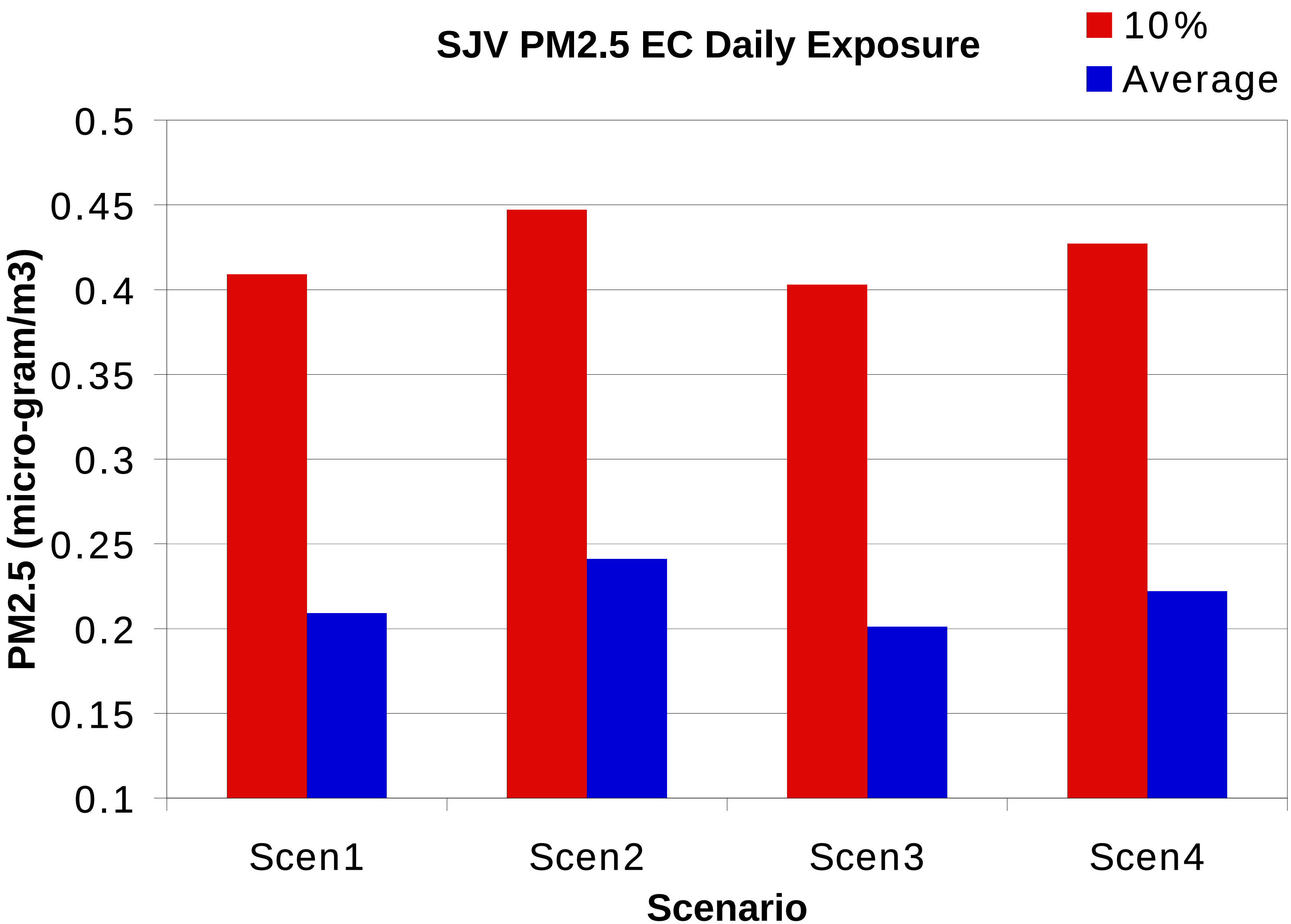


PM2.5 EC

Dec 25 2030 – Jan 7 2031



December 25, 2030 – January 7, 2031



Denver Aerosols Sources & Health (DASH) PM-induced Health Effects

(bulk chemistry results)

Median (IQR*) daily total deaths and $PM_{2.5}$ component concentrations (µg/m^3), and corresponding effect estimates (RR**)						
	deaths	**$PM_{2.5}$**	**EC**	**OC**	**SO_4**	**NO_3**
median	33	7.0	0.48	2.77	0.88	0.23
IQR*	28-37	4.9-9.5	0.31-0.72	2.06-3.62	0.51-1.32	0.13-1.05
RR**		1.012	1.035	1.012	1.005	1.005
95% CI		0.998-1.027	1.013-1.058	0.991-1.034	0.991-1.020	0.996-1.015

*IQR = interquartile range; **RR=rate ratio per IQR

1.2 % increase in mortality for an increase of 4.6 µg/m^3 of $PM_{2.5}$

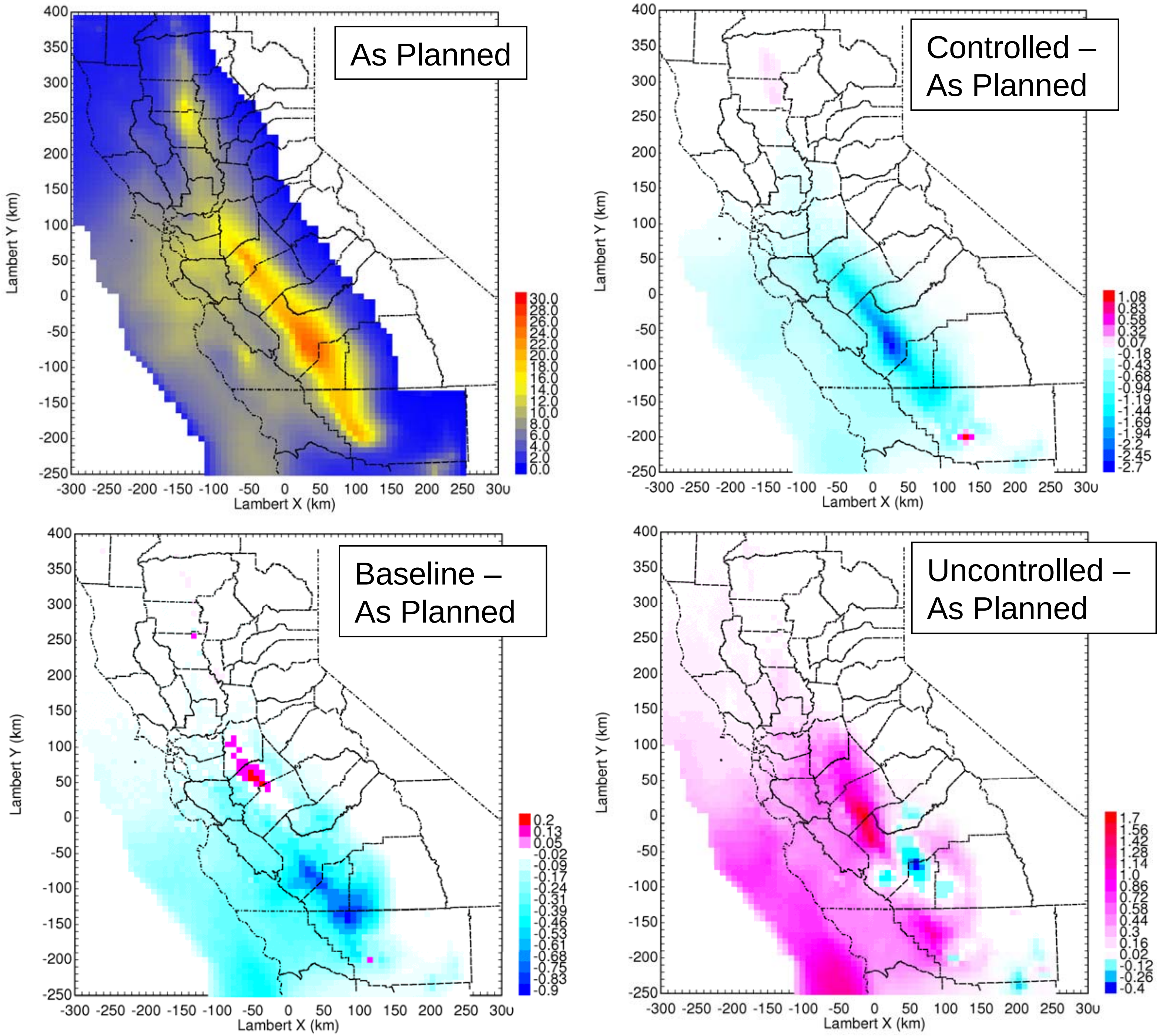
3.5 % increase in mortality for an increase of 0.4 µg/m^3 of EC

Also, only EC was associated with daily cardiorespiratory deaths

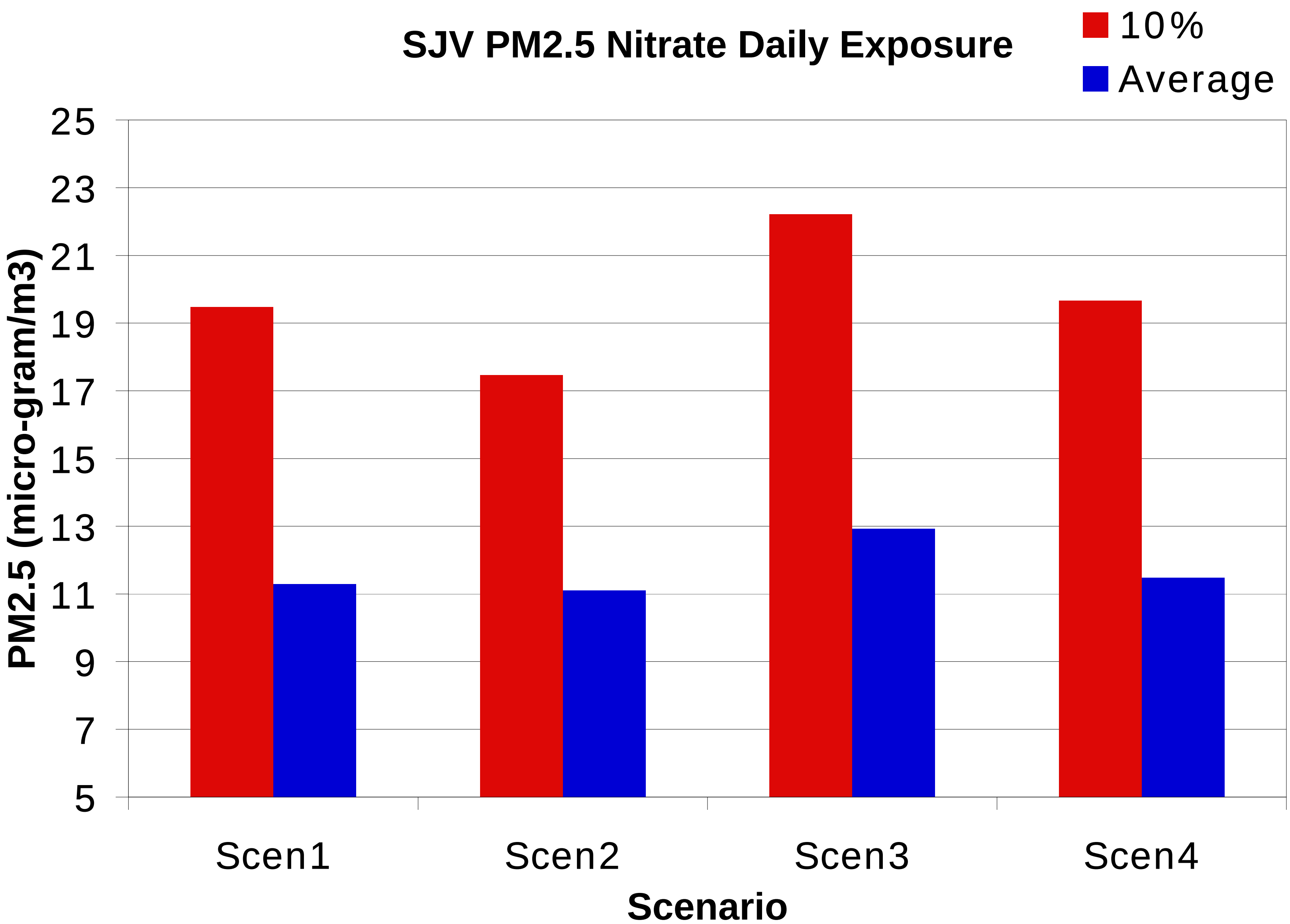
Source: M. Hannigan et al., University of Colorado

PM2.5 Nitrate

Dec 25 2030 –
Jan 7 2031



December 25, 2030 – January 7, 2031



Conclusions For the SJV Under the Severe Winter Stagnation Conditions Studied

- Landuse choices can reduce on mobile source emissions in the SJV
  - Greenhouse gas benefits
  - Approximately 18% change in criteria pollutants
- Landuse choices have modest impact on exposure to primary PM
  - EC exposure may increase in scenarios with higher population density
- Landuse choices have modest impact on exposure to secondary PM
  - Nitrate exposure may increase in scenarios where population moves into regions with the highest nitrate concentrations
- Technology change and/or further bans on target sources will be evaluated next

Acknowledgements

- United States Environmental Protection Agency Science to Achieve Results (STAR) Grant # RD-83184201
- Darrell Winner and Bryan Bloomer (EPA)

Work In Progress

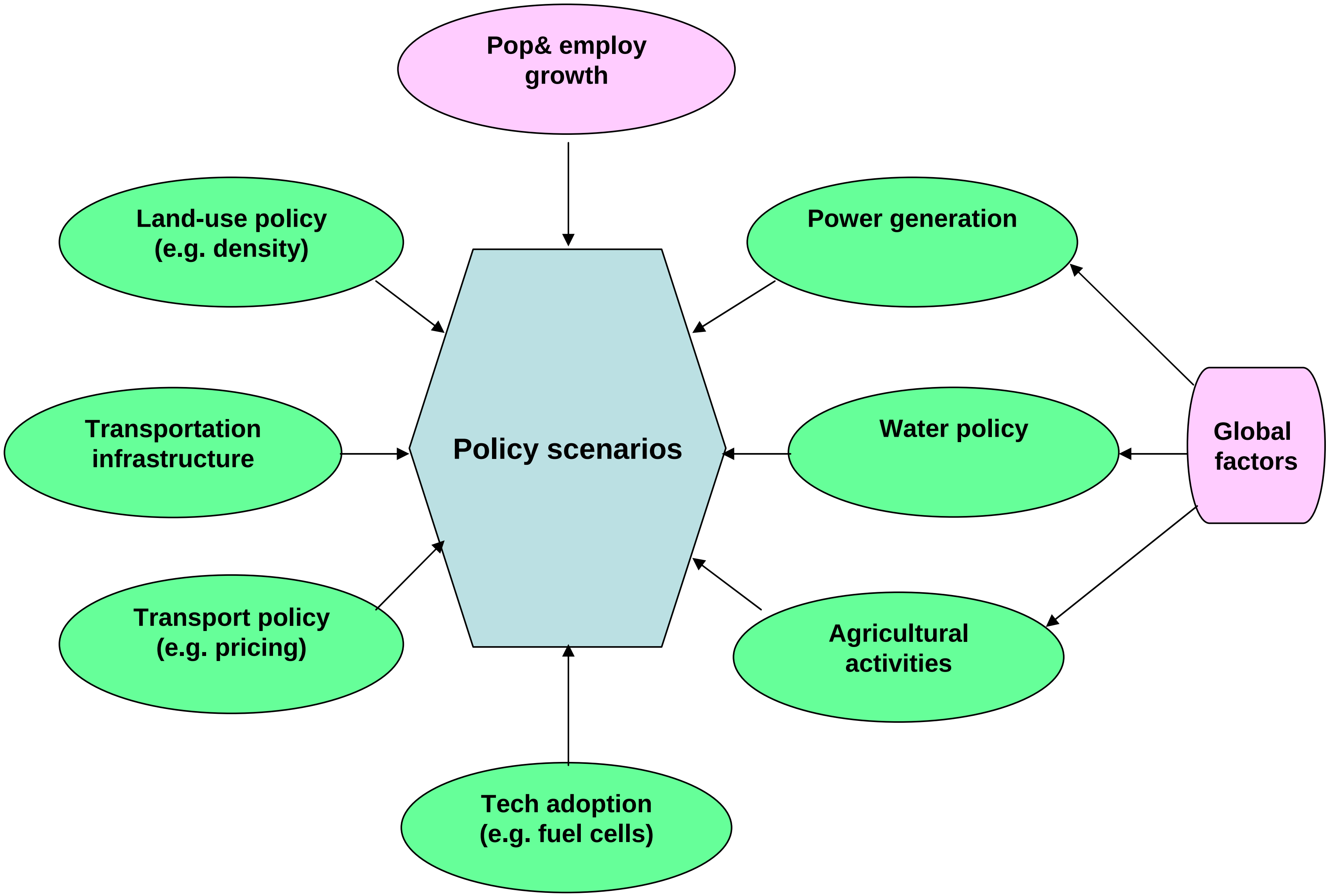
- Future Emissions Inventory Projection (EPA project # RD-83184201 and CARB project#04-349)
  - SJV 2050; SoCAB 2050
- Dynamic Downscaling of PCM results using WRF (CARB project#04-349)
  - 2000-06; 2027-33; 2047-53
  - SJV summer (O3) and winter (PM)
  - SoCAB summer (O3) and fall (PM)
- Integrating the Source-Oriented Particle Approach Directly into WRF (EPA project#R833372)
- Measurement of PM Emissions Profiles from Vehicles powered by alternative fuels (EPA project#R833372)

Supporting Information

Project Phases

- Phase 1
  - Develop policy scenarios for the SJV
  - Run land use models (UPLAN)
  - Run travel demand models (TP+/Viper)
- Phase 2
  - Create mobile emissions inventory
  - Create stationary source inventory
  - Create biogenics inventory
- Phase 3
  - Ambient air quality model analysis

Factors Affecting Policy Scenarios

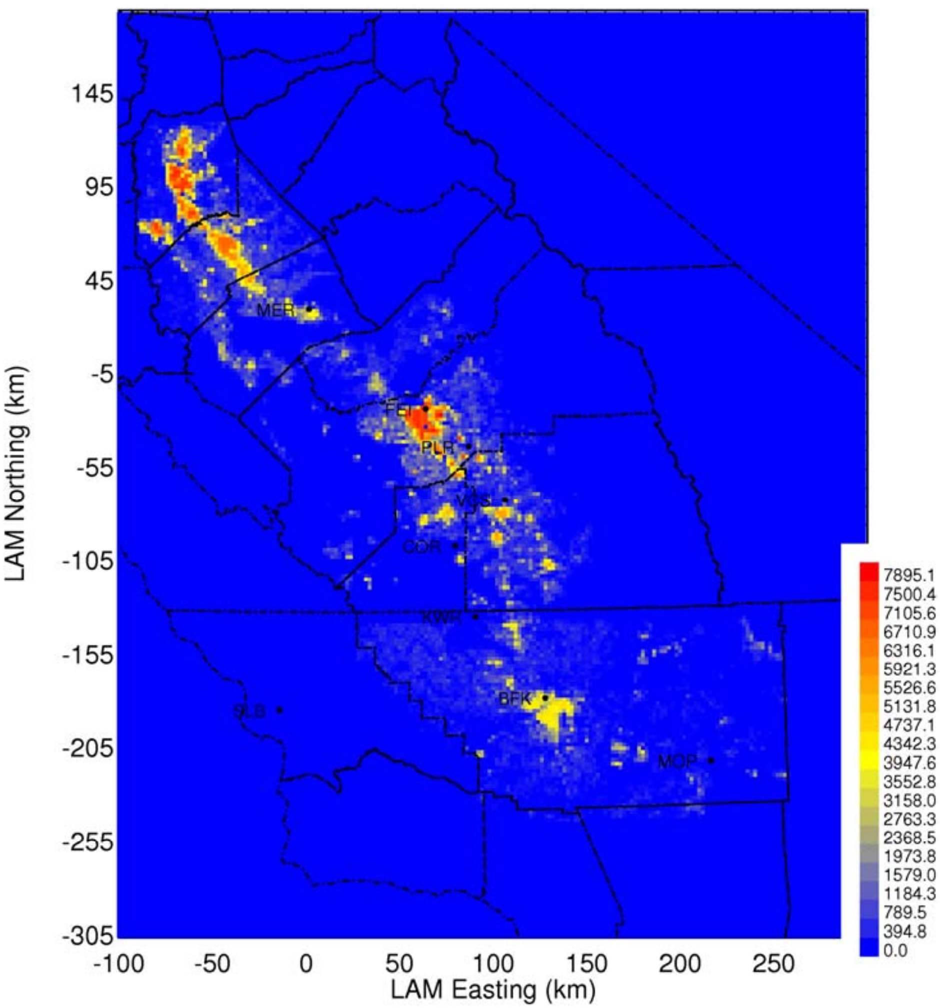


Scenario Development

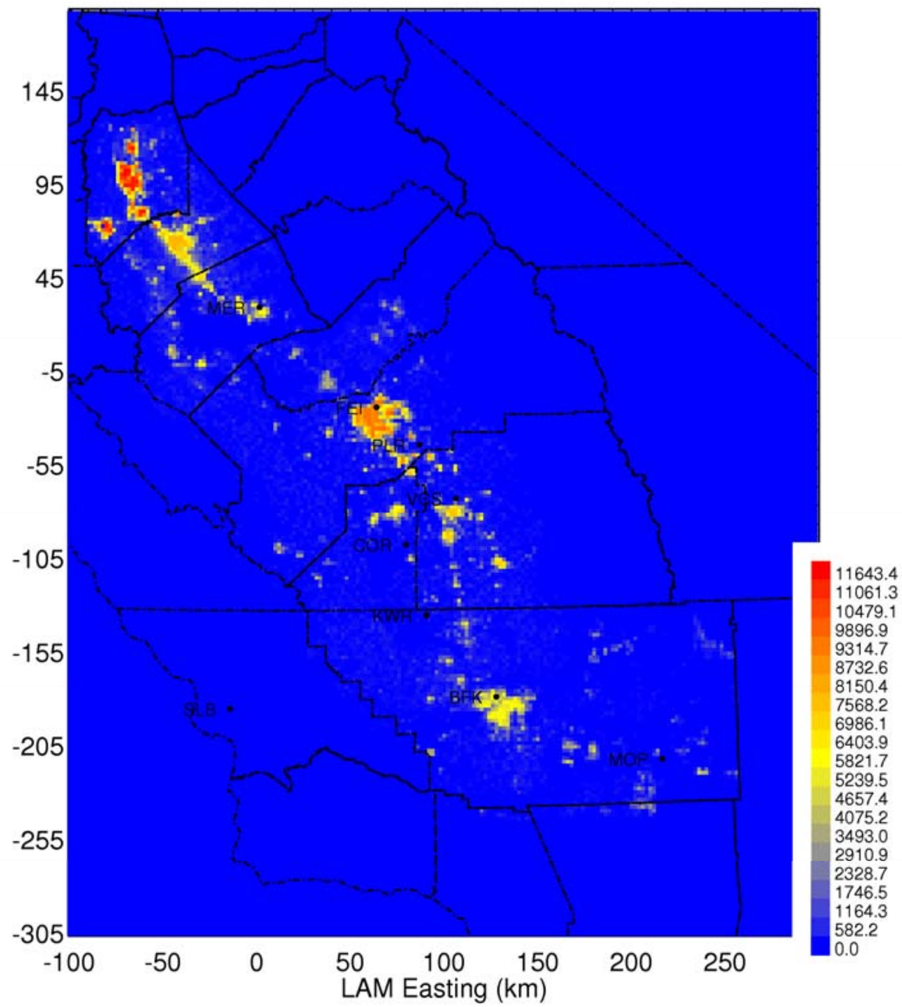
- Create Initial list of variables
- Background research and preparation of white papers
- Initial levels and combinations of variables
- Expert panel review – April 2005
  - Caltrans, California High Speed Rail Authority
  - California Air Resources Board
  - Additional experts in economics and agriculture
- Finalization of variables, levels, combinations
- Translation of variables into model inputs

Projected Population Distribution

Scenario 1 – No Change
1974 people/km



Scenario 4 – As Planned
2911 people/km

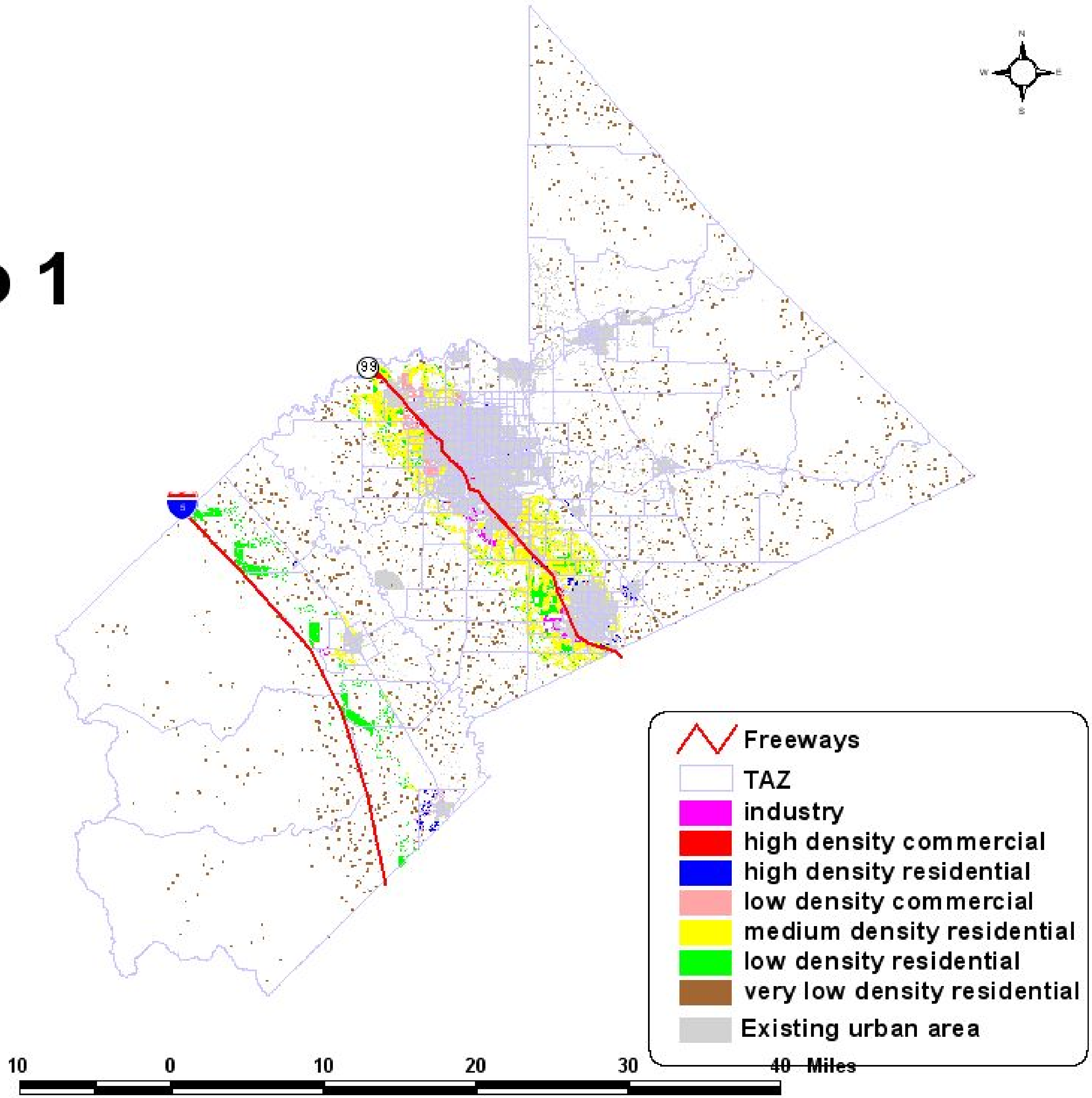


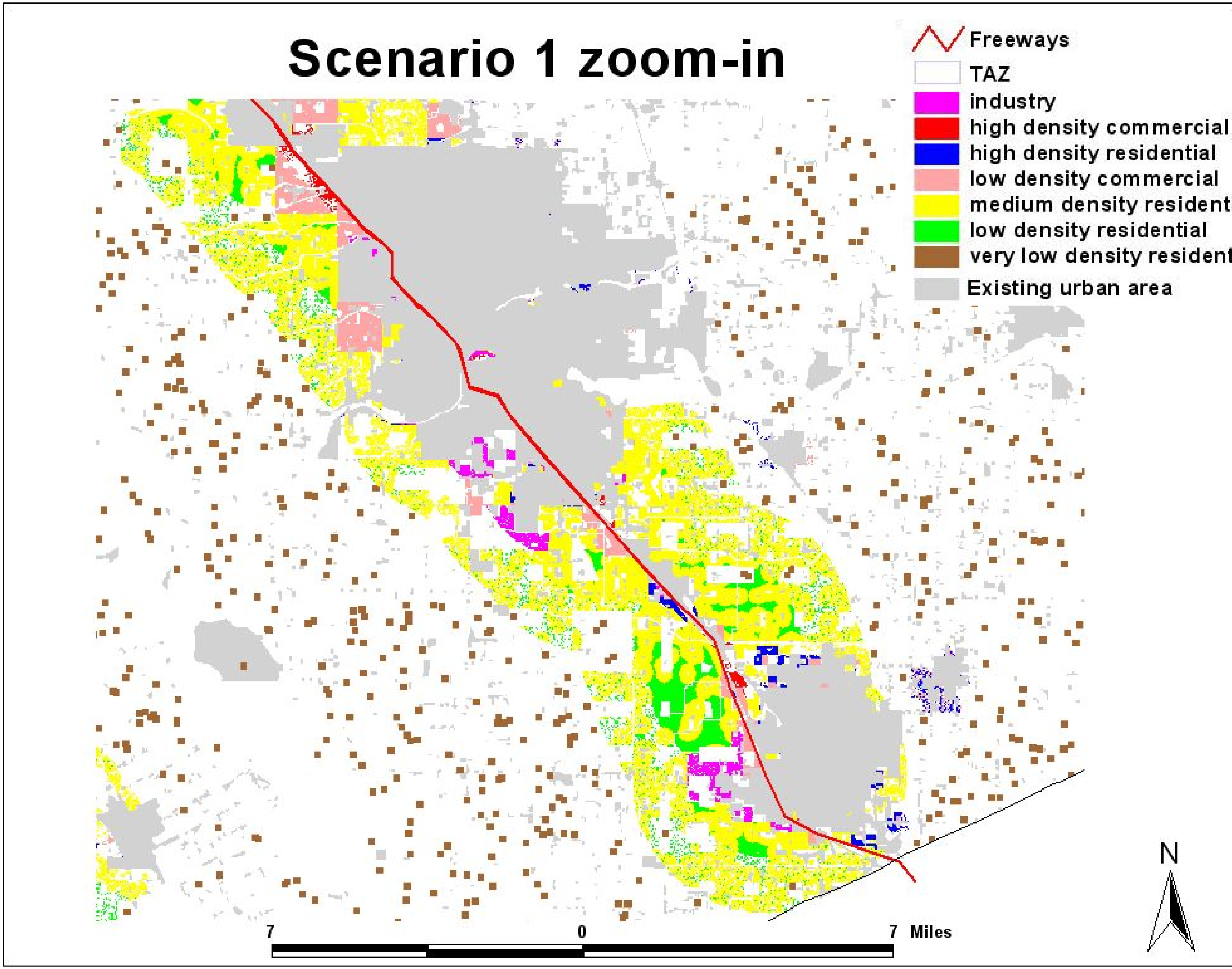
Example: Stanislaus County Growth

	2000	2030	Change
Population	446,997	744,599	+66.6%
Households	145,154	263,789	+81.7%
Employment	174,066	293,938	+68.9%

Scenario 1

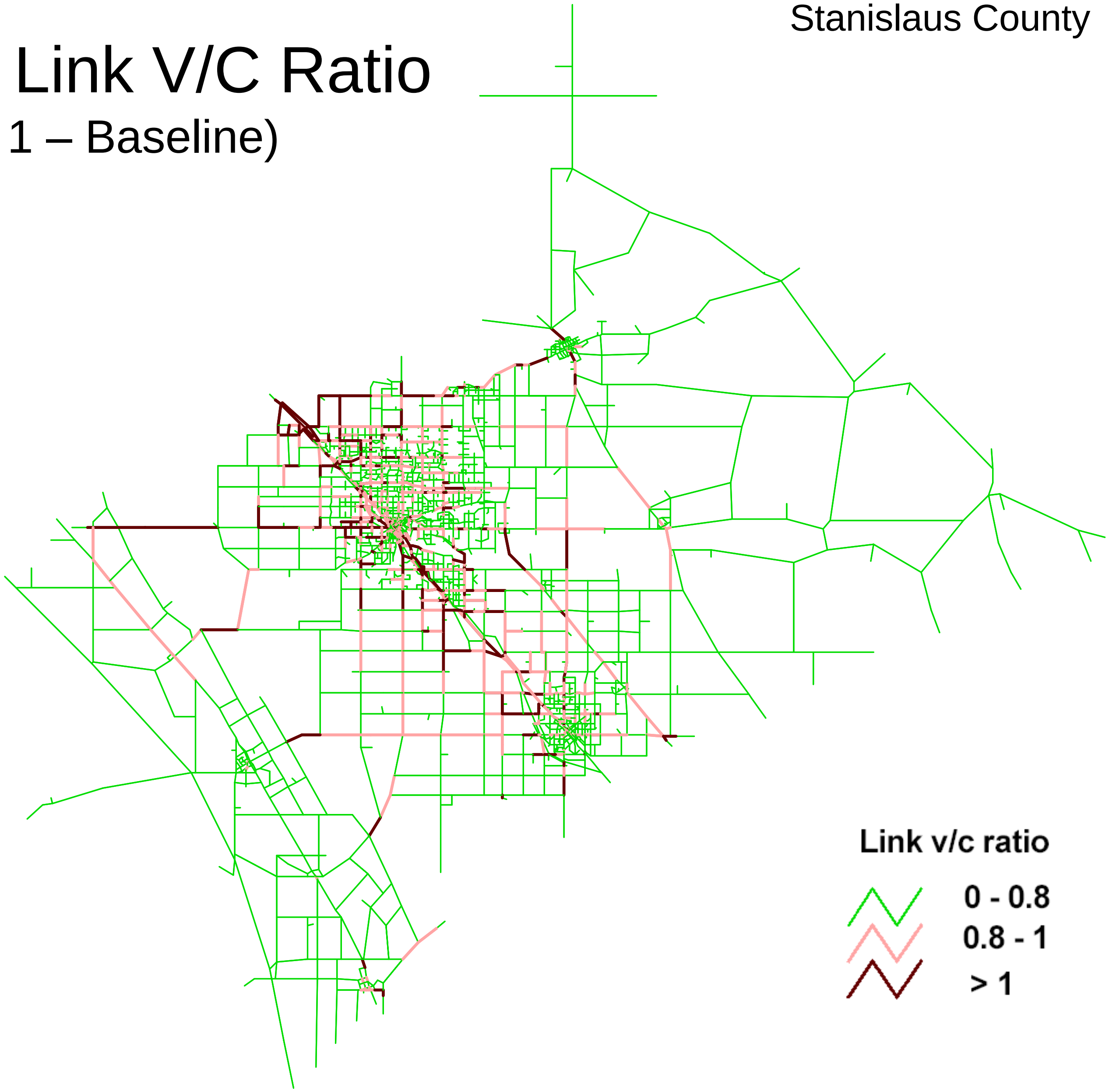
Baseline




Scenario 1 zoom-in
Freeways
TAZ
industry
high density commercial
high density residential
low density commercial
medium density residential
low density residential
very low density residential
Existing urban area
7
0
7 Miles
N

Network Link V/C Ratio
(Scenario # 1 – Baseline)

Stanislaus County



SJV Travel Demand Modeling Results

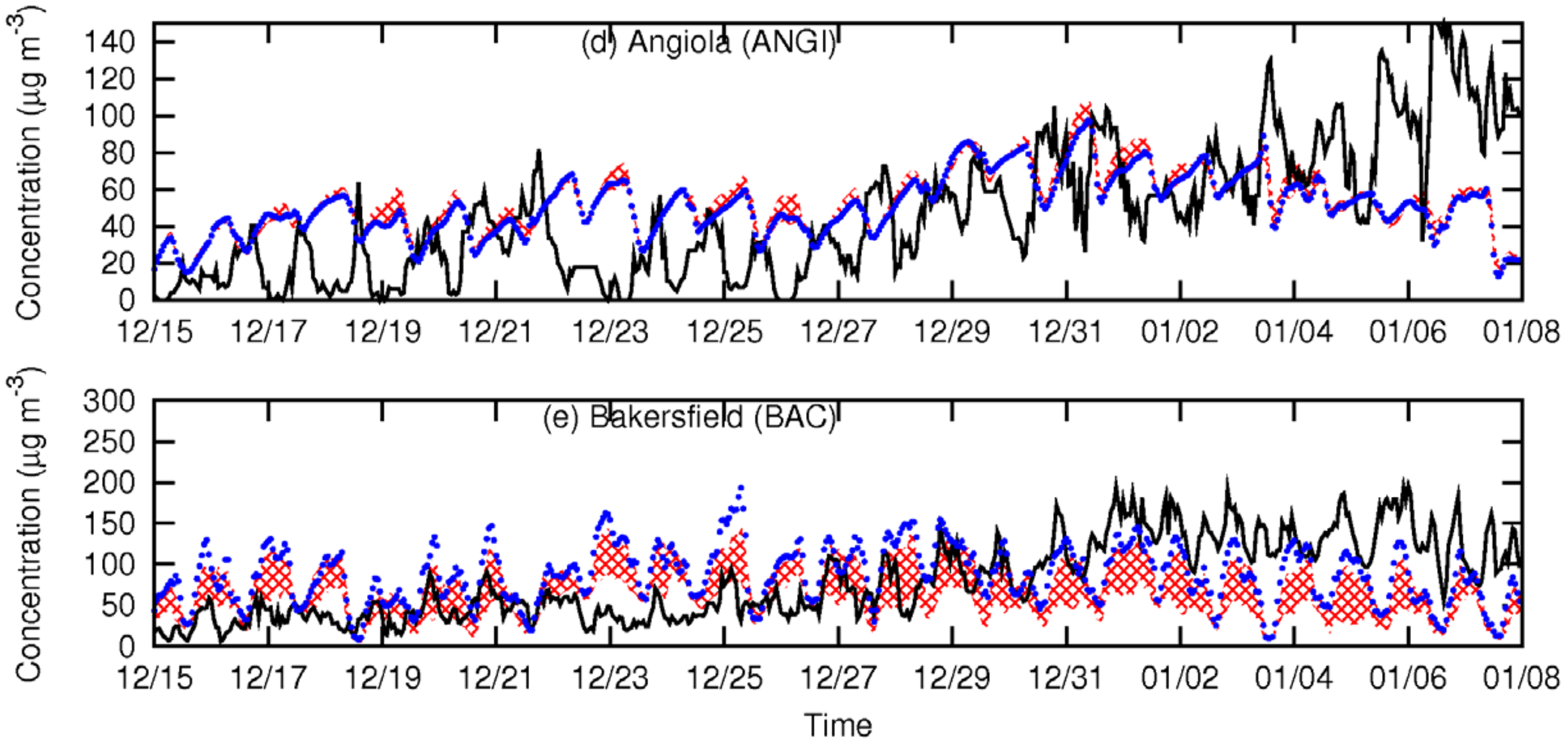
Regional Totals	Scenario 1 Baseline	Scenario 2 Controlled Growth	Scenario 3 Uncontrolled Growth	Scenario 4 As-Planned
TOG (ton)	44.49	40.21 (-9.6%)	47.67 (+7.2%)	43.88 (-1.4%)
CO (ton)	679.31	631.16 (-7.1%)	747.70 (+10.1%)	702.93 (+3.5%)
NOx (ton)	53.66	49.77 (-7.2%)	59.08 (+10.1%)	55.70 (+3.8%)
PM (ton)	7.72	7.19 (-6.9%)	8.50 (+10.0%)	8.07 (+4.6%)

Source: S. Bai et al., "Integrated Impacts of Regional Development, Land Use Strategies and Transportation Planning on Future Air Pollution Emissions", Submitted to 2007 Transportation Land Use, Planning, and Air Quality Conference

Area, Non-road Mobile (NRM), and Point Sources

- Focus on the most important area, non-road mobile, and point sources (large emitters and categories of research interest for this project).
  - Assess Growth
    - Review existing tools and establish improvements or beneficial alternatives.
    - Demonstrate use and synthesis of area-specific and source-specific data to estimate growth.
  - Assess Spatial Allocation
    - Evaluate spatial surrogates for future-year conditions and establish a recommended spatial allocation scheme.
    - Demonstrate application of spatial allocation techniques.

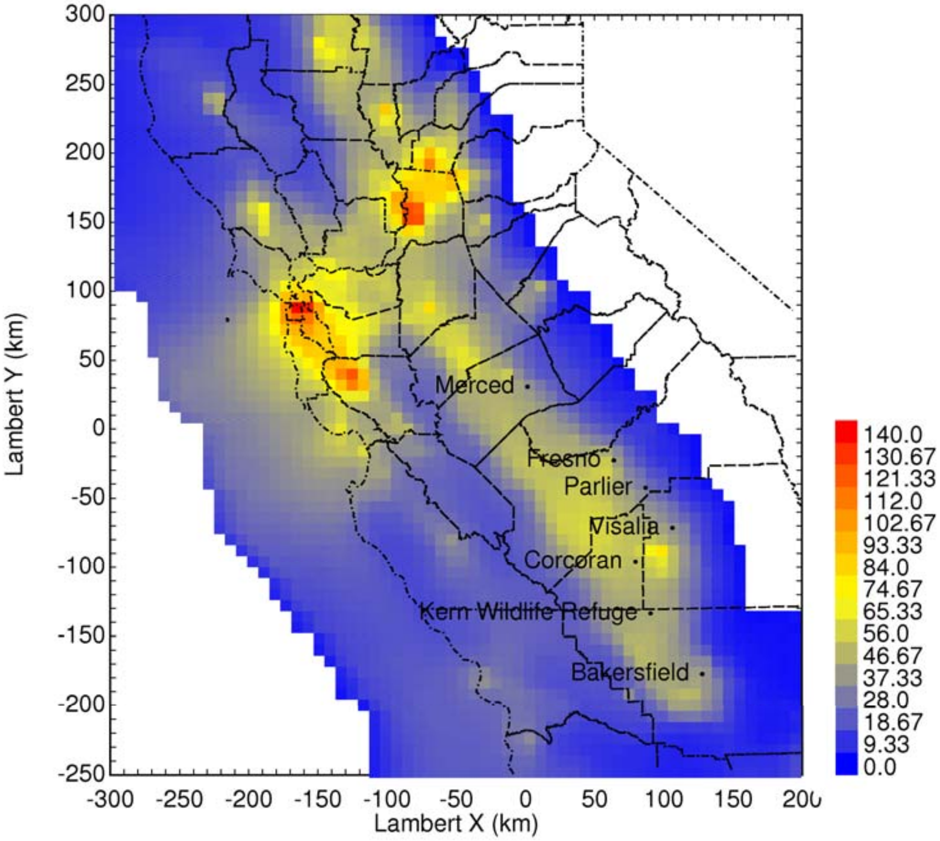
Basecase Model Evaluation



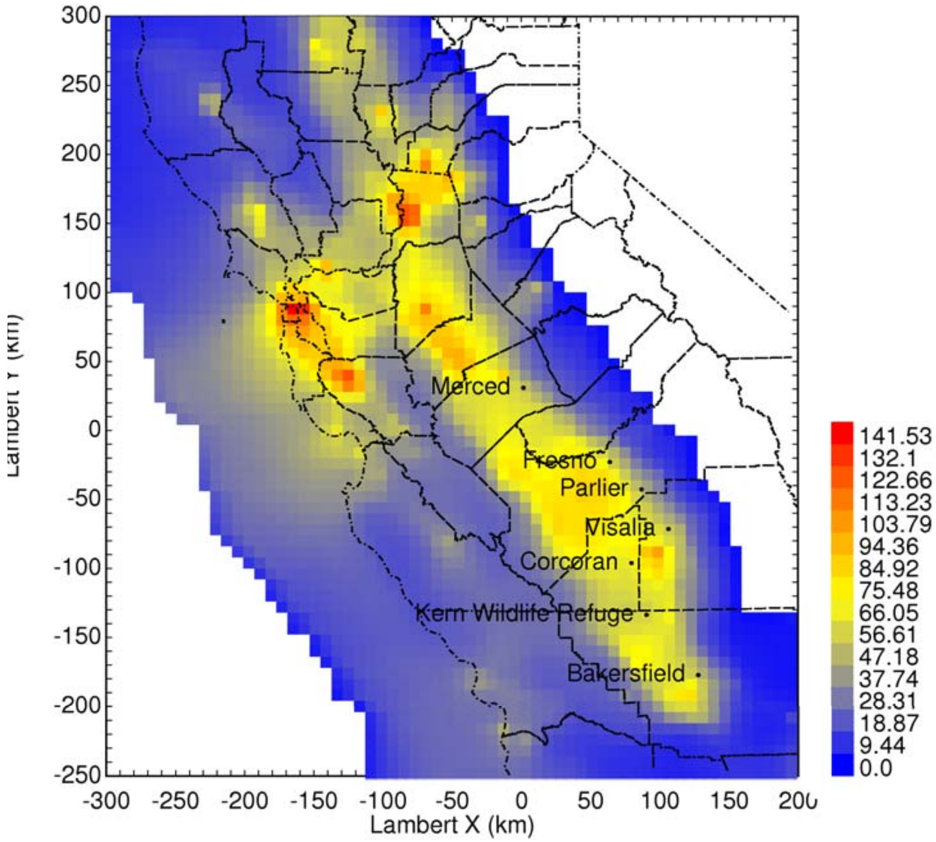
Source: Q. Ying et al., "Modeling Air Quality During the California Regional PM10 / PM2.5 Air Quality Study (CRPAQS) Using the UCD/CIT Source-Oriented Air Quality Model. Part 1: Basecase Model Results", Atmospheric Environment, in press, 2008.

PM2.5 Average
December 25 2030 – January 7, 2031

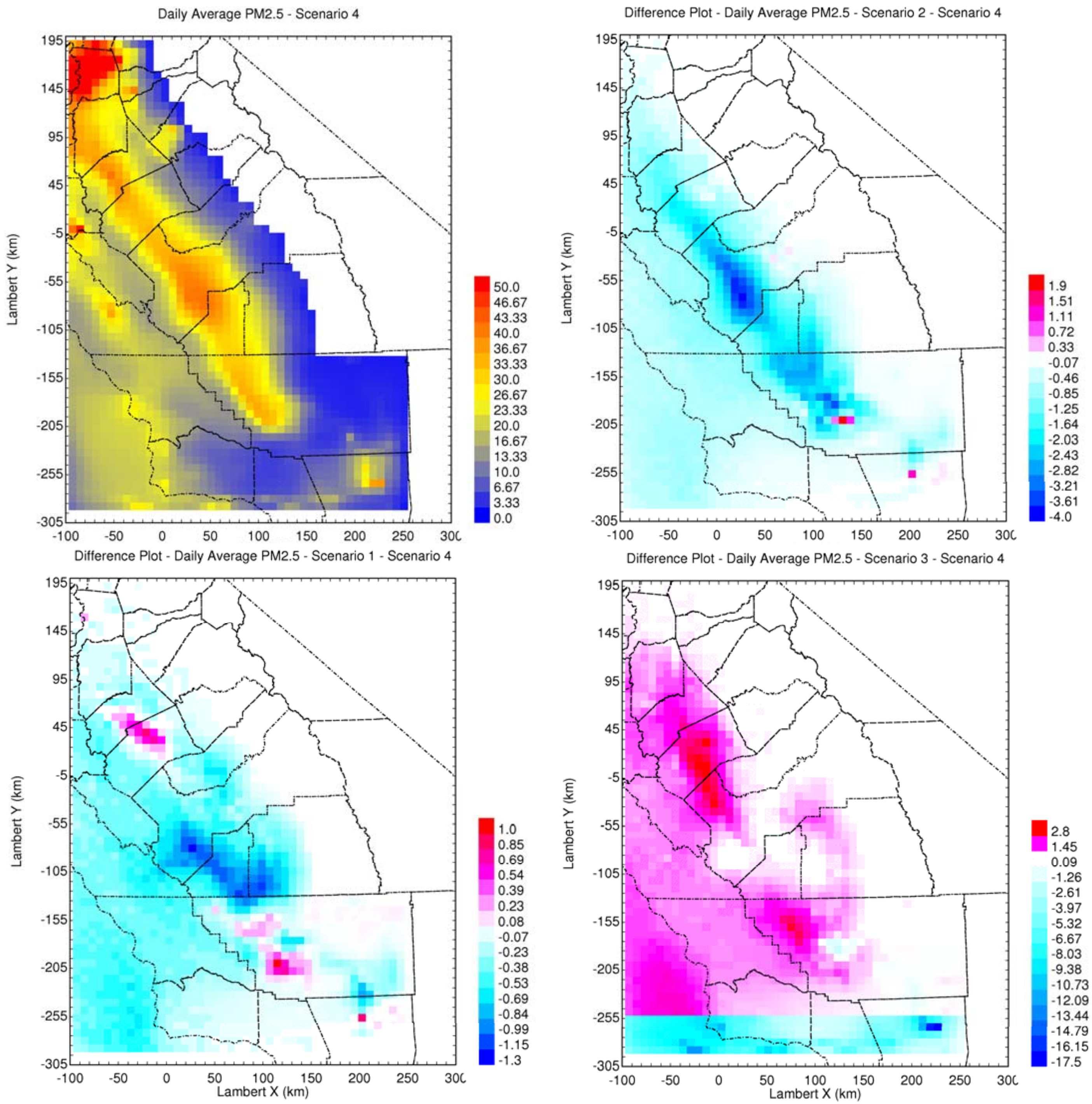
Scenario 2
Domain Max = 140 μg m^{-3}
SJV Max = 65 μg m-3



Scenario 3
Domain Max = 141 μg m^{-3}
SJV Max = 85 μg m-3



PM2.5 Mass


Daily Average PM2.5 - Scenario 4
Difference Plot - Daily Average PM2.5 - Scenario 2 - Scenario 4
Difference Plot - Daily Average PM2.5 - Scenario 1 - Scenario 4
Difference Plot - Daily Average PM2.5 - Scenario 3 - Scenario 4
Lambert Y (km)
Lambert X (km)
195
145
95
45
-5
-55
-105
-155
-205
-255
-305
-100
-50
0
50
100
150
200
250
300
50.0
46.67
43.33
40.0
36.67
33.33
30.0
26.67
23.33
20.0
16.67
13.33
10.0
6.67
3.33
0.0
1.9
1.51
1.11
0.72
0.33
-0.07
-0.46
-0.85
-1.25
-1.64
-2.03
-2.43
-2.82
-3.21
-3.61
-4.0
1.0
0.85
0.69
0.54
0.39
0.23
0.08
-0.07
-0.23
-0.38
-0.53
-0.69
-0.84
-0.99
-1.15
-1.3
2.8
1.45
0.09
-1.26
-2.61
-3.97
-5.32
-6.67
-8.03
-9.38
-10.73
-12.09
-13.44
-14.79
-16.15
-17.5