Science of Ozone and $PM_{2.5}$ Chemistry in the South Coast and San Joaquin Valley

Air Quality Planning and Science Division
California Air Resources Board

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Goals of the Presentation

- Discuss scientific basis of SIP process
- Summarize ozone and $PM_{2.5}$ chemistry and atmospheric processes
- Provide overview of air quality modeling results for South Coast and San Joaquin Valley
- Describe how atmospheric science is used to guide SIP strategy development

California's Investment in Science

- ARB has a long history of air quality research in collaboration with air districts
- Academic partnerships leverage ARB resources and expand scientific expertise in air pollution
- Field studies in the South Coast and San Joaquin Valley provide region-specific understanding of air quality problems

California's History of NO_x Control

- The 1990 Federal Clean Air Act emphasized control of VOC for ozone
- Early on, California recognized the importance of adding NO_x control
- California's regulation of ozone forming pollutants has strongly relied on science with effective results
- New $PM_{2.5}$ standards in 1997 added further importance to NO_x control

Federal Air Quality Standards

- Presentation focuses on standards addressed in 2016 SIPs:
  - 8-hour ozone: 75 ppb
  - Annual $PM_{2.5}$: 12 µg/m^3
- EPA evaluating need for more stringent ozone standard between 60 and 70 ppb
- Attainment deadlines established following promulgation of new standards

Understanding Atmospheric Chemistry and Responses to Emissions Reductions

The Basics: Chemistry of Ozone and $PM_{2.5}$ Formation

Ozone Formation:

$$NO_x + VOC + \text{Sunlight} \rightarrow O_3$$

$PM_{2.5}$ Formation:

$$NO_x + VOC + NH_3 \rightarrow \text{Ammonium Nitrate}$$

$$SO_x + VOC + NH_3 \rightarrow \text{Ammonium Sulfate}$$

$$VOC \rightarrow \text{Secondary Organic Aerosol}$$

The Atmosphere: Complex Multi-Pollutant System

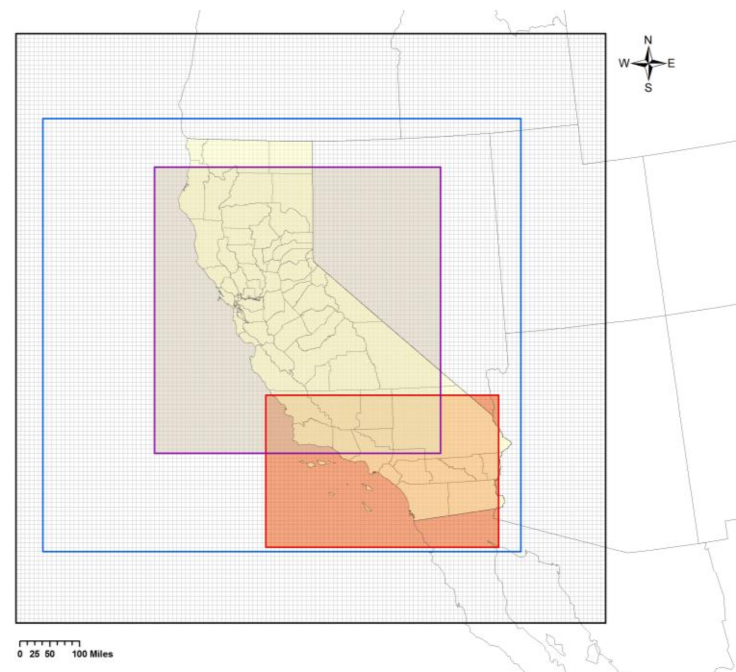
- Ozone and $PM_{2.5}$ air quality reflects multi-pollutant interactions among:
  - Emissions
  - Meteorology
  - Atmospheric chemistry
- Emissions of each precursor vary in space and time
- Meteorology causes transport and dispersion
- Chemical reactions occur with differing time scales and are highly nonlinear

Atmospheric Response to Emissions Controls Depends on Linked Processes

- Controlling common precursors is basis of an effective multi-pollutant control strategy
- Effectiveness of reductions may differ by region and by location within a region
- This relationship may also change over time due to relative pace of emission reductions

Use of Models is Required for SIPs

- Air quality modeling integrates these complex atmospheric processes
- Provides tool to evaluate response to emissions changes
- System consists of:
  - Emissions model
  - Meteorological model
  - Air quality model



Scientific Foundation of California Modeling

- Recent major field studies:
  - 2000 : CRPAQS/CCOS
  - 2000-2010: EPA/ARB Advanced Monitoring Initiative, MATES III, ARCTAS, CalNex
  - 2010+: MATES IV, Discover-AQ
- Annual science meetings:
  - International Conferences on Atmospheric Chemical Mechanisms, Aerosol Modeling Algorithms, and Meteorology Modeling
- Staff publications in peer-reviewed technical journals

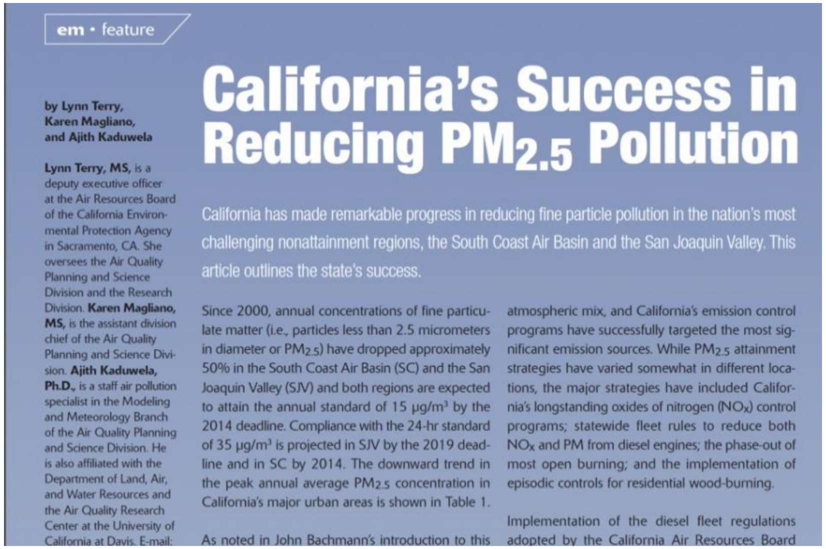
Using Models in SIP Strategy Development

- Assessing relative effectiveness of different precursors
- Identifying magnitude of precursor reductions needed to meet standards
- Evaluating impacts of reductions in different source sectors

Overview of Modeling Results for South Coast and San Joaquin Valley

California's Comprehensive Assessment of $PM_{2.5}$ Science

- Science documented in SIPs, workshops, and peer-reviewed publications
- NO_x most effective on a regional basis
- $PM_{2.5}$ reductions effective for targeted attainment needs



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California's Success in Reducing $PM_{2.5}$ Pollution

by Lynn Terry, Karen Magliano, and Ajith Kaduwela

Lynn Terry, MS, is a deputy executive officer at the Air Resources Board of the California Environmental Protection Agency in Sacramento, CA. She oversees the Air Quality Planning and Science Division and the Research Division. **Karen Magliano, MS,** is the assistant division chief of the Air Quality Planning and Science Division. **Ajith Kaduwela, Ph.D.,** is a staff air pollution specialist in the Modeling and Meteorology Branch of the Air Quality Planning and Science Division. He is also affiliated with the Department of Land, Air, and Water Resources and the Air Quality Research Center at the University of California at Davis. E-mail:

California has made remarkable progress in reducing fine particle pollution in the nation's most challenging nonattainment regions, the South Coast Air Basin and the San Joaquin Valley. This article outlines the state's success.

Since 2000, annual concentrations of fine particulate matter (i.e., particles less than 2.5 micrometers in diameter or $PM_{2.5}$) have dropped approximately 50% in the South Coast Air Basin (SC) and the San Joaquin Valley (SJV) and both regions are expected to attain the annual standard of 15 µg/m³ by the 2014 deadline. Compliance with the 24-hr standard of 35 µg/m³ is projected in SJV by the 2019 deadline and in SC by 2014. The downward trend in the peak annual average $PM_{2.5}$ concentration in California's major urban areas is shown in Table 1.

As noted in John Bachmann's introduction to this

atmospheric mix, and California's emission control programs have successfully targeted the most significant emission sources. While $PM_{2.5}$ attainment strategies have varied somewhat in different locations, the major strategies have included California's longstanding oxides of nitrogen (NO_x) control programs; statewide fleet rules to reduce both NO_x and PM from diesel engines; the phase-out of most open burning; and the implementation of episodic controls for residential wood-burning.

Implementation of the diesel fleet regulations adopted by the California Air Resources Board

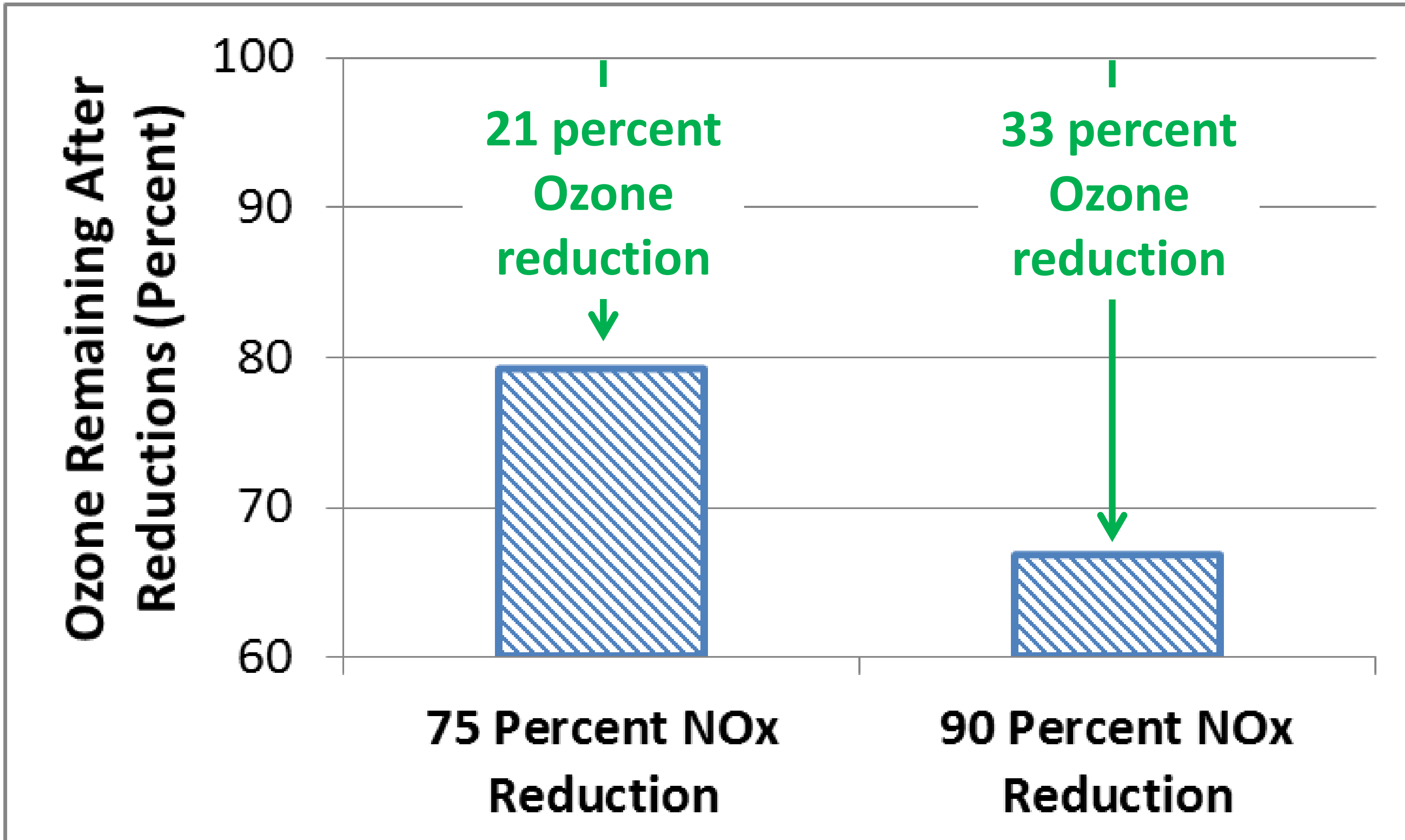
Ozone Modeling to Support Upcoming SIPs

- Initial modeling for South Coast and San Joaquin Valley for 2016 SIPs underway
- Builds upon modeling conducted for prior ozone SIPs in these regions
- Early model runs focus on response to broad emissions reductions

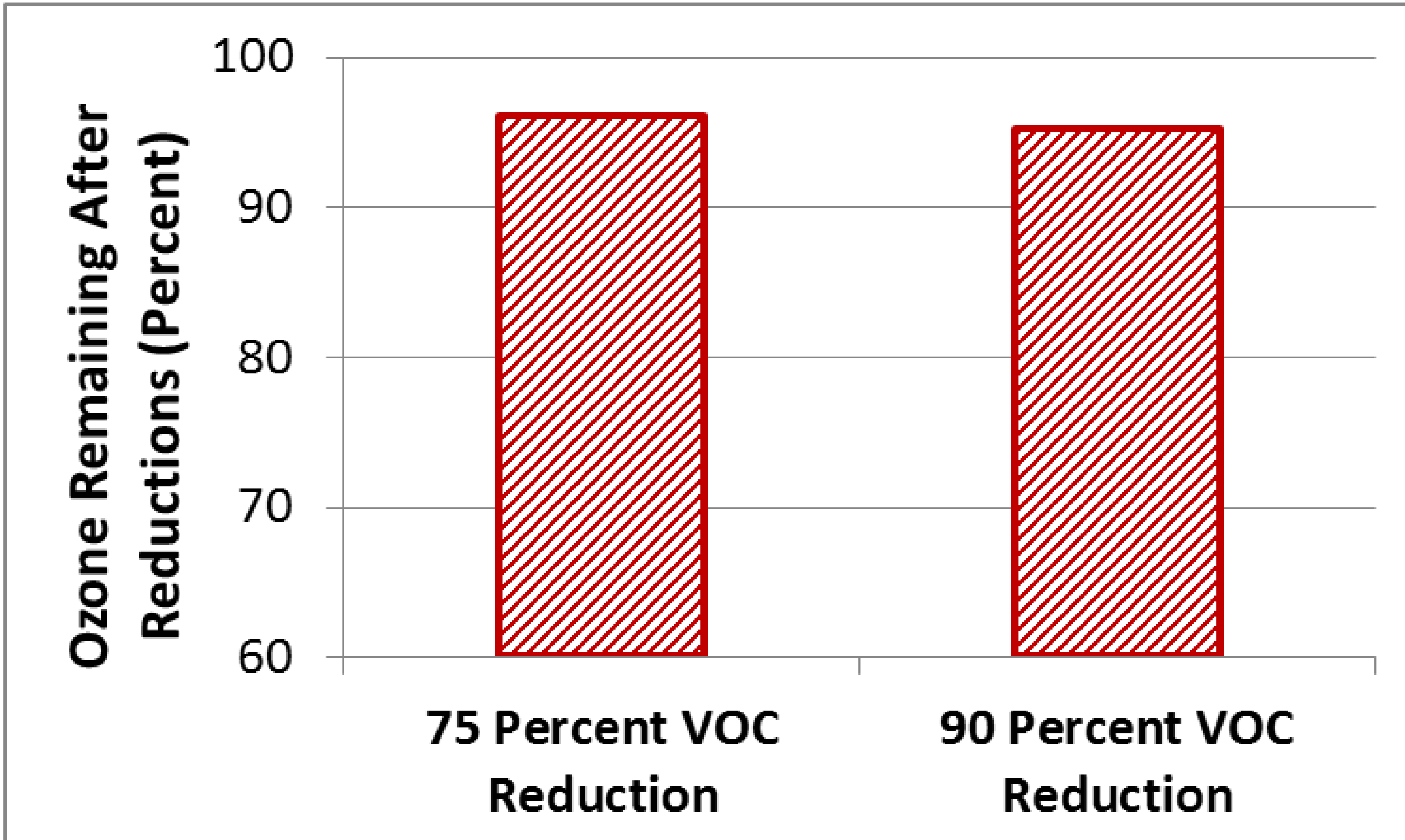
Nature of Modeling Evaluation

- Series of modeling runs evaluate benefits of reducing individual precursors
- Reflects percent reduction from today's emission levels
- Benefits shown as percent ozone remaining after reductions
- Modeling runs also evaluate combinations of VOC and NO_x reductions

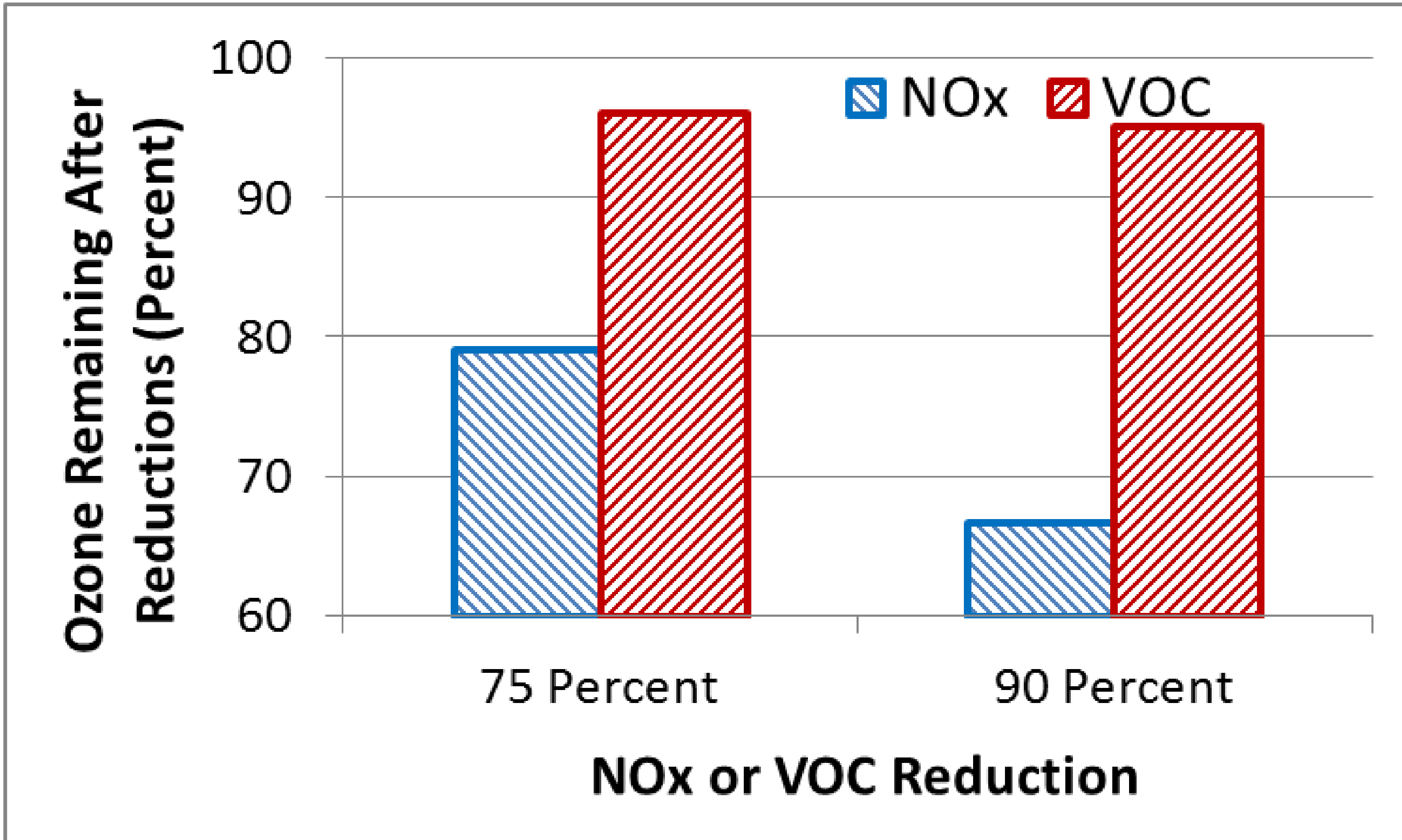
Relative Effectiveness of NO_x Reductions: San Joaquin Valley



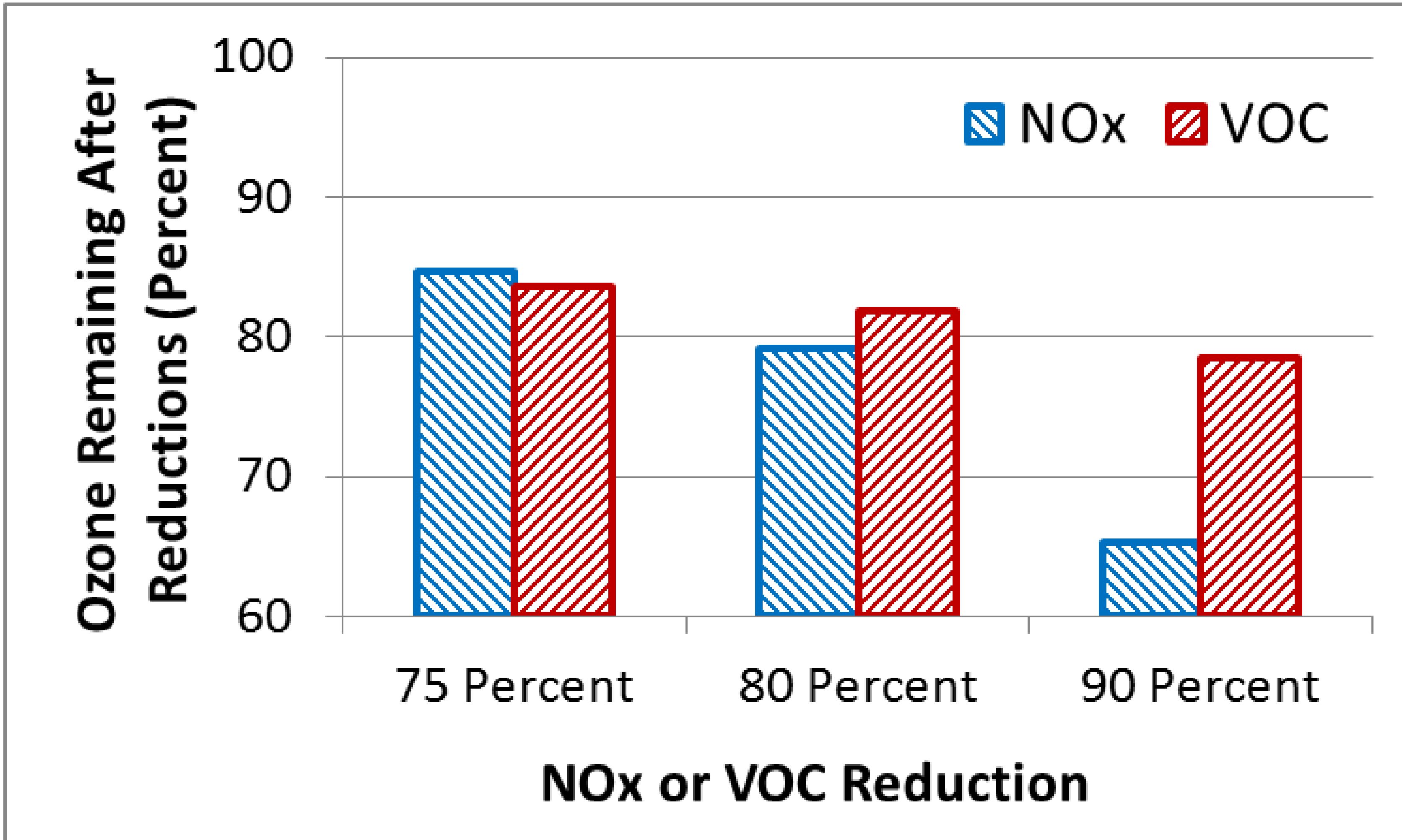
Relative Effectiveness of VOC Reductions: San Joaquin Valley



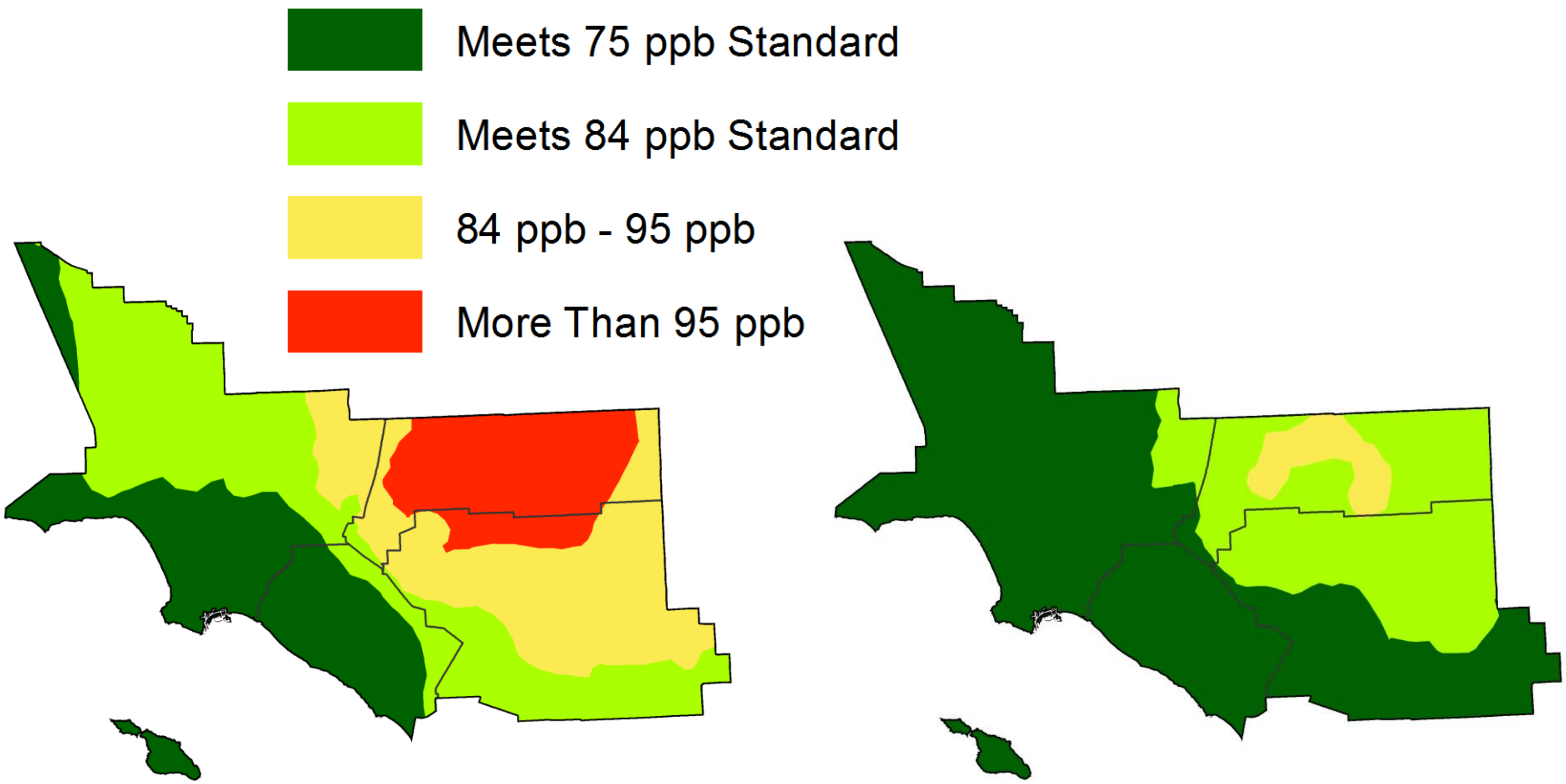
Comparison of Precursor Effectiveness: San Joaquin Valley



Comparison of Precursor Effectiveness: South Coast



Benefits of Combined Strategy: South Coast Ozone



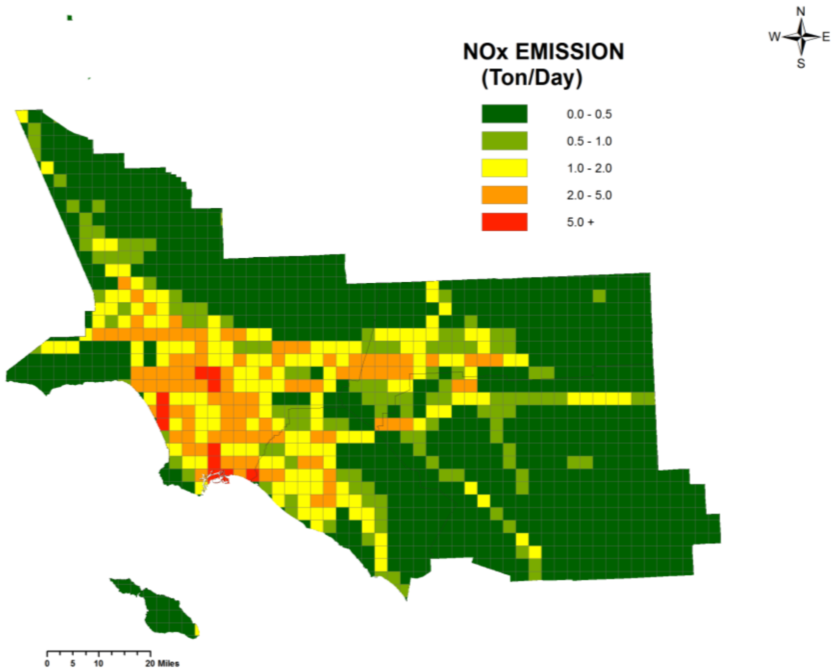
2012 Measured:
8-Hour Ozone Levels

Modeled:
75% NO_x + 40% VOC Reduction

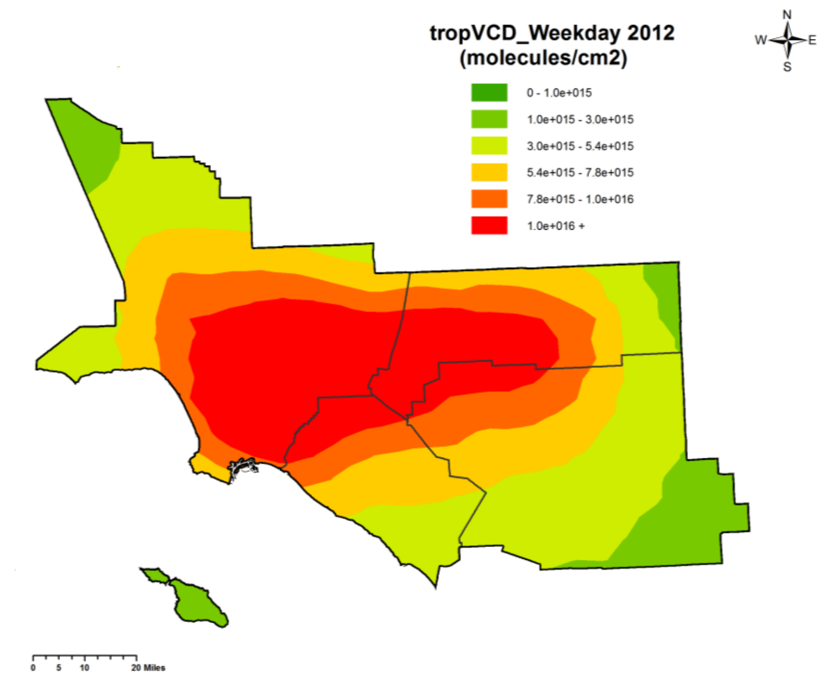
Need for Regional NO_x Reductions in South Coast

- Modeling indicates large NO_x reductions needed for attainment
- Modeling can also assess benefits of reducing emissions from different source sectors or locations
- Emission inventories and satellite images indicate regional distribution of NO_x

Distribution of NO_x in the South Coast



Spatial distribution of summer 2012 NO_x emissions



Satellite image of summer 2012 NO_x concentrations

Modeling Next Steps

- Continued assessment of precursor relationships
- Evaluation of role of natural sources and transport
- Detailed modeling to assess benefits of reductions from individual source sectors and potential strategy scenarios

From Science to Strategy

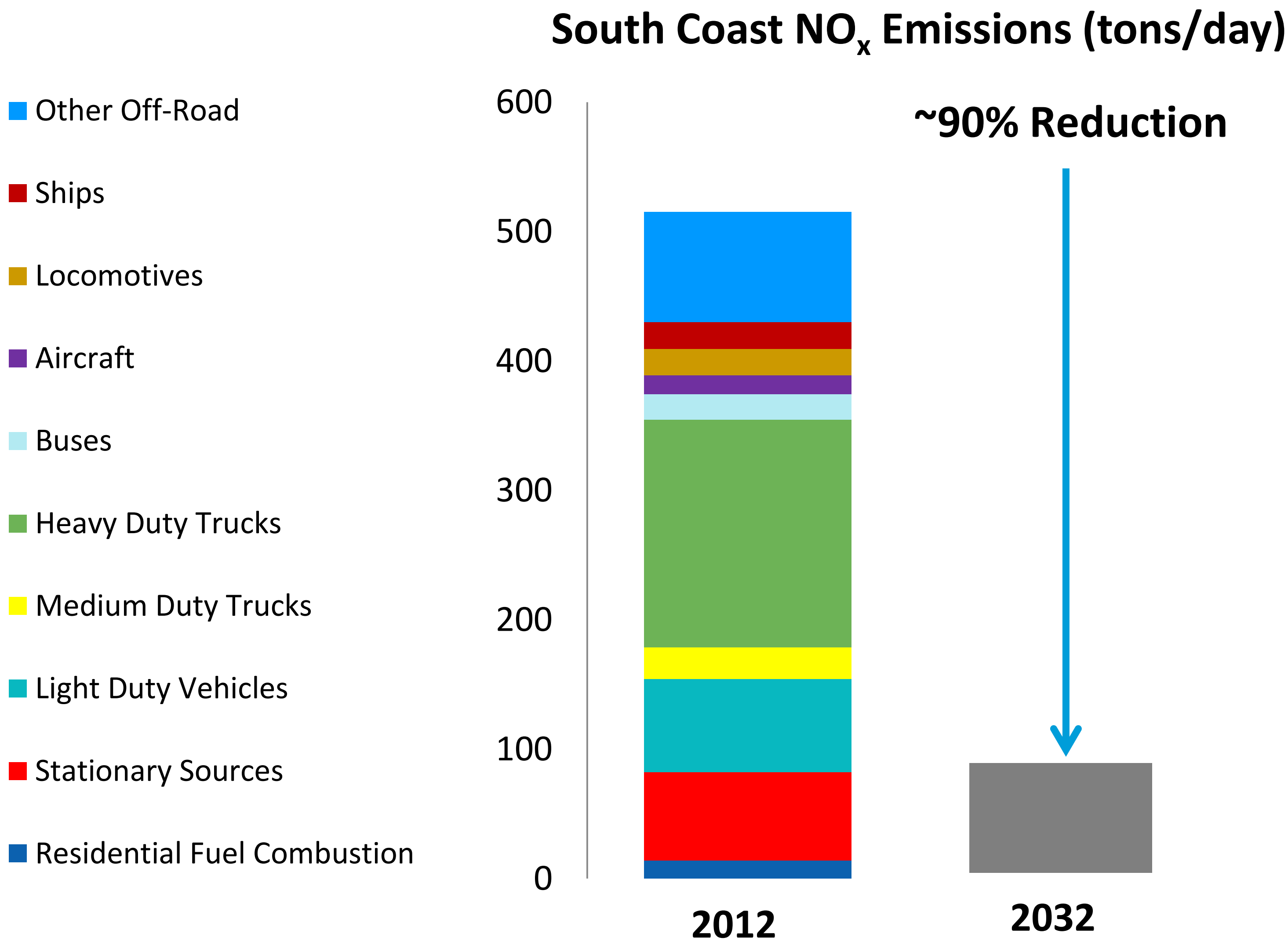
Key Science Findings

- NO_x reductions are key to ozone and $PM_{2.5}$ attainment
- Large NO_x reductions needed, coming from many source sectors
- VOC reductions important for progress in South Coast, less effective in SJV
- Targeted reductions in other precursors beneficial for $PM_{2.5}$

Science to 2016 SIP Strategy

- Science identifies *what* reductions are needed for attainment
- Strategy development process:
  - Identifies from *where* reductions will come
  - Defines *how* reductions will be achieved through specific measures and actions
  - Considers *who* needs to take action through national, state, regional and local controls
  - Integrates *when* those reductions need to occur from multi-pollutant perspective, including climate

Identifying Contributing Sources



Identifying Strategies for 2016 SIP

- Requires long-term, comprehensive reductions across all sectors
- Encompasses improved technology, fuels, energy efficiency, planning, and infrastructure
- Planning scenarios integrate emission benefits of combined air quality and climate actions
- Modeling can then assess air quality benefits of specific scenarios

SIP Planning: 2014-2016

- Ozone and $PM_{2.5}$ SIPs due in 2016
- Collaborative effort involving ARB, air districts, and U.S. EPA
- Air quality modeling has begun, with continuing feedback to strategy development
- SIP planning process will parallel development of the freight strategy

Summary

- Air quality science provides strong foundation for SIPs
- NO_x reductions needed for both ozone and $PM_{2.5}$
- VOC reductions are important for progress in South Coast, less effective in SJV
- As standards become more stringent, role of science becomes increasingly important in SIP process

Leading the Way

- California providing international air quality leadership
- Important to follow science-based process
- Most effective strategies will reflect specific nature of the region