PM2.5 SIP Modeling In The San Joaquin Valley

Air Quality Planning & Science Division
California Air Resources Board

San Joaquin Valley Public Advisory Workgroup
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Acknowledgements

- CARB Staff
  - Atmospheric Modeling and Support Section
  - Meteorology Section
  - Air Quality Planning Branch
  - Mobile Source Analysis Branch
  - Consumer Products and Air Quality Assessment Branch
- District Staff
- University/Scientific collaborators
- US EPA R9/Headquarters

Outline

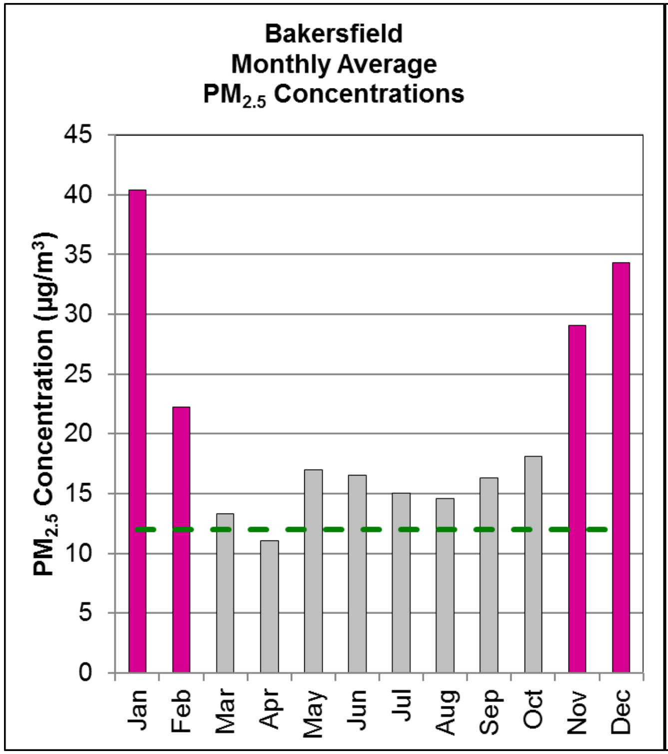
- Modeling Overview
- The PM2.5 SIP Modeling Process:
  - Model Attainment Demonstration
- The Current SJV PM2.5 SIP:
  - Scientific Foundation
  - Modeling Results
  - Ongoing Analysis & Next Steps

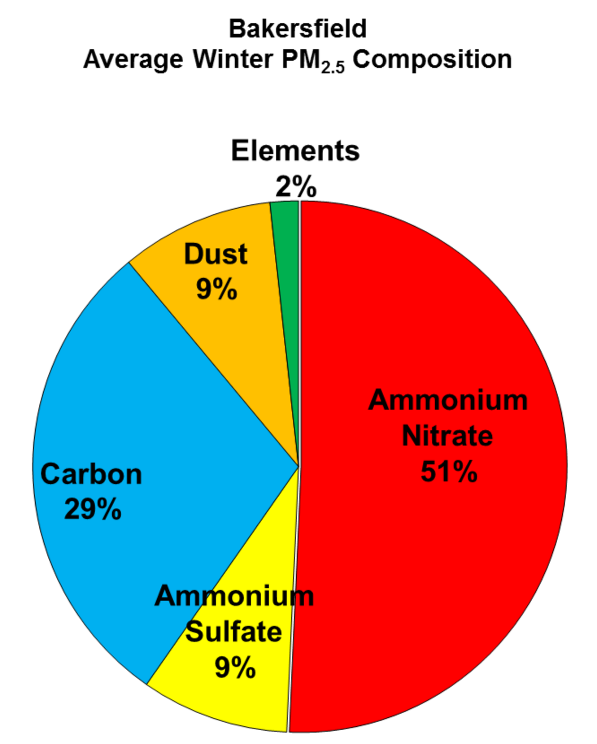
Modeling Overview

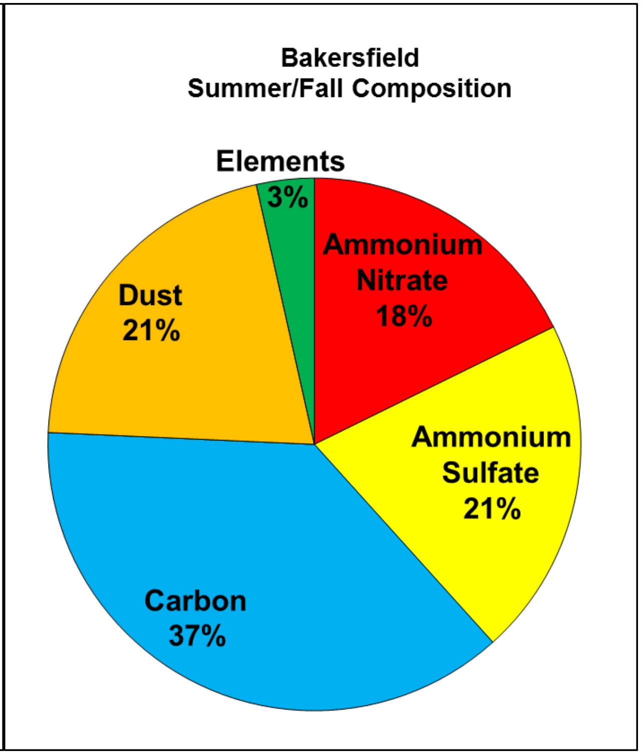
Modeling's Role in SIP Development

- Quantify the benefits of the current control programs
- Determine the emission reductions that are needed to meet air quality standards
- Evaluate the effectiveness of various PM2.5 precursors
- Assess contributions from different source categories or different sub-regions

PM2.5 Pollution and Composition in the SJV







PM2.5 Sources and Chemistry

NO_x → HNO_3 → NH_4NO_3 ← NH_3 → $(NH_4)_2SO_4$ ← H_2SO_4 ← SO_x

NH_4NO_3
(Ammonium nitrate)

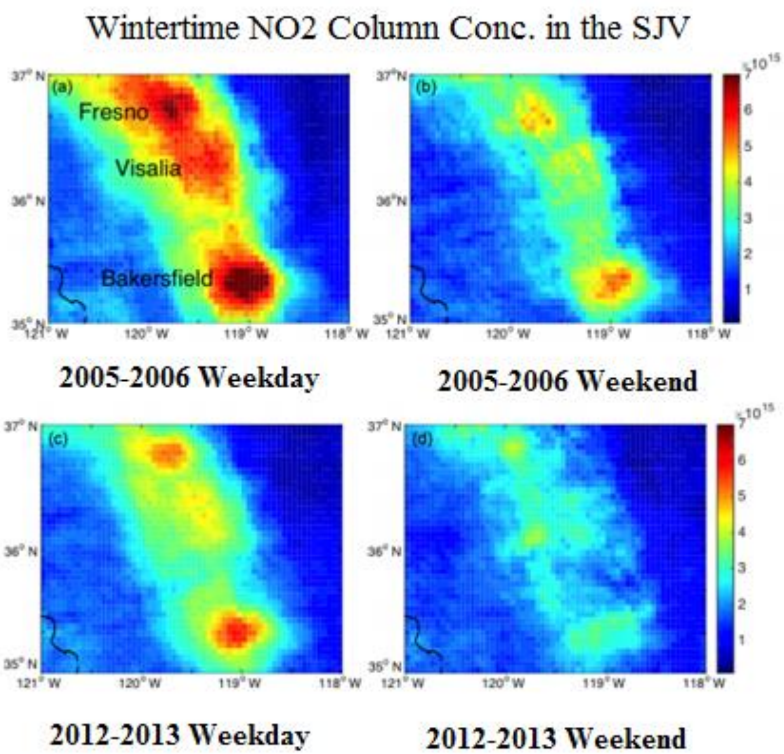
$(NH_4)_2SO_4$
(Ammonium sulfate)

Dust

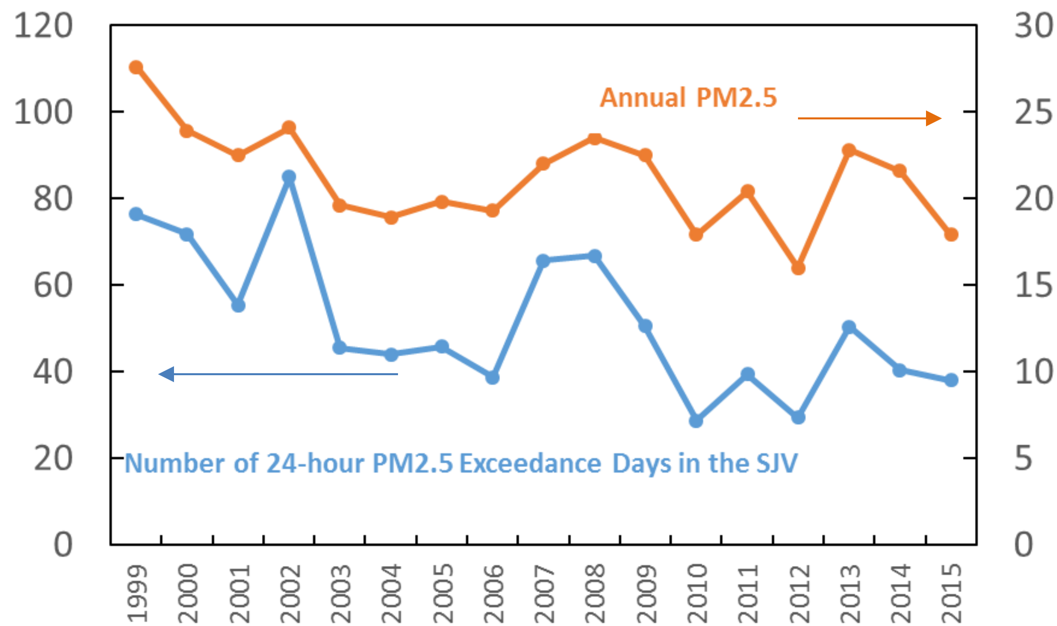
OC (Organic carbon)

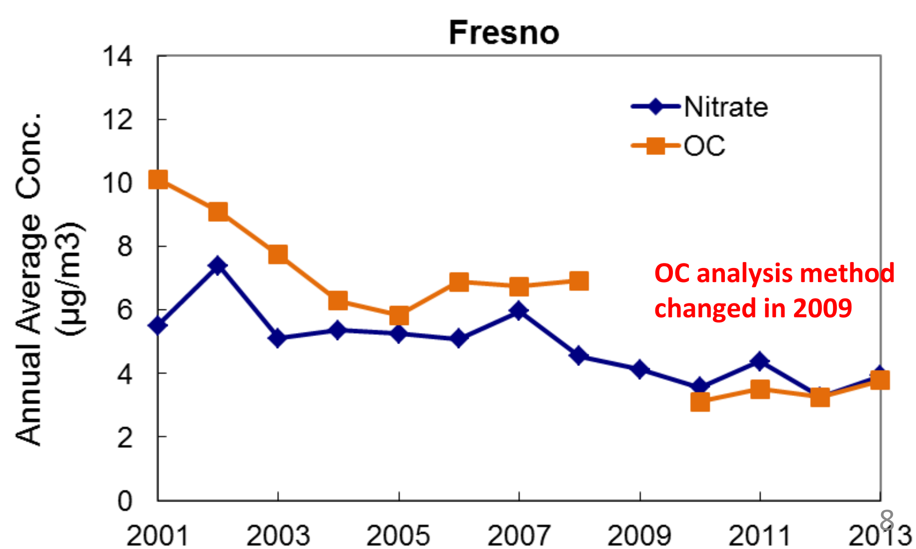
EC
(Elemental carbon)

Where We Were, Where We Are Now

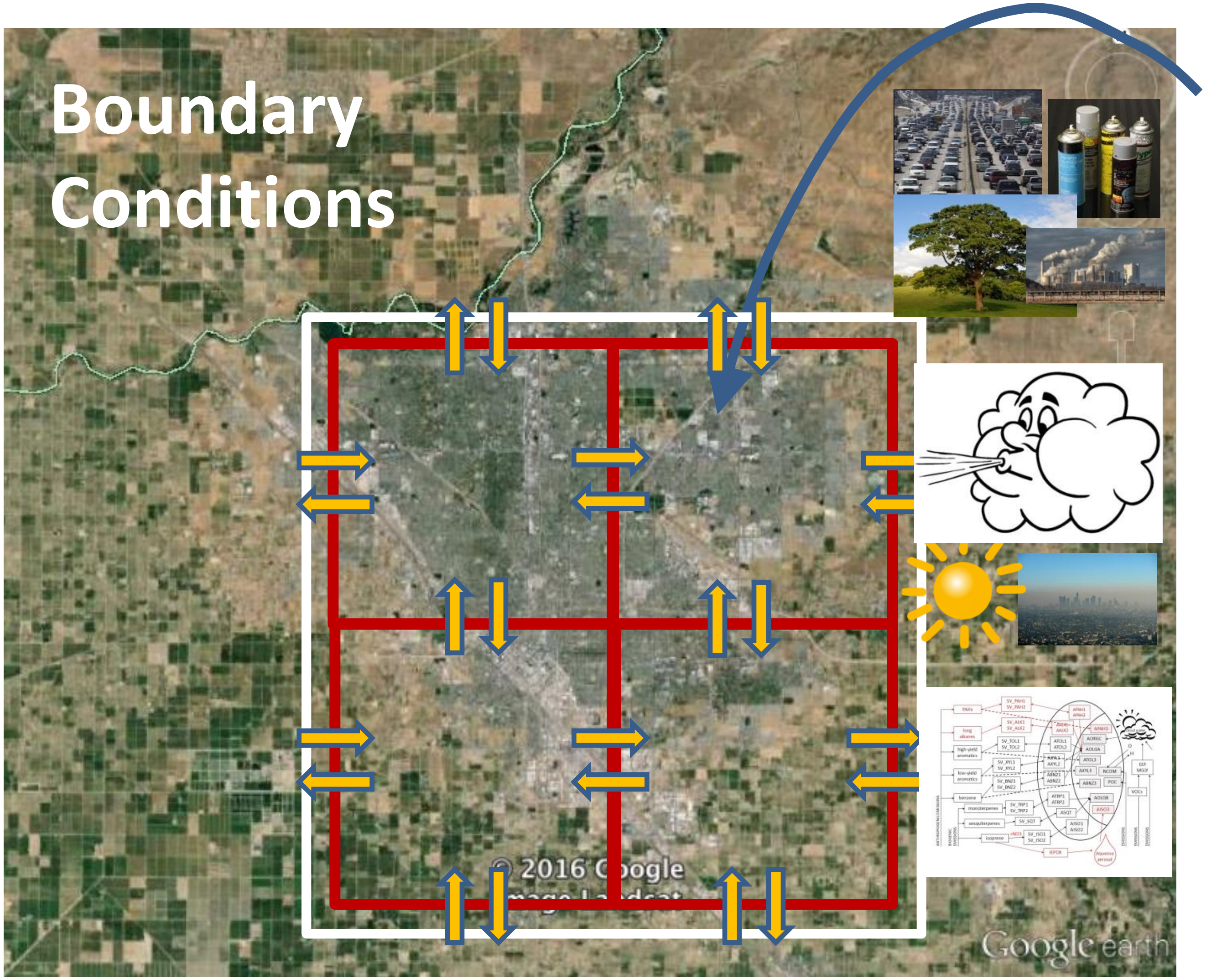


Adapted from Pusede et al., ACP, 2016





Modeling Overview



Emissions

human induced

natural (plants)

Meteorology

Winds, temp.,

Mixing Height

Chemistry

NOx, VOCs, Ozone

Aerosol

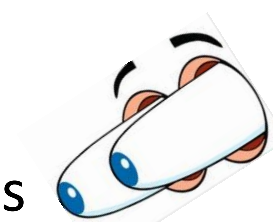
Ammonium nitrate,

OC, etc.

BCs

External

conditions



Numerical representation of atmospheric processes

Modeling Overview *(cont.)*

Emissions

- Models require hourly emissions for each grid cell
- California's EI is one of the most complete and robust in the world

Meteorology

- Generated using a 3-D numerical model
- Very time consuming to exercise and fine-tune

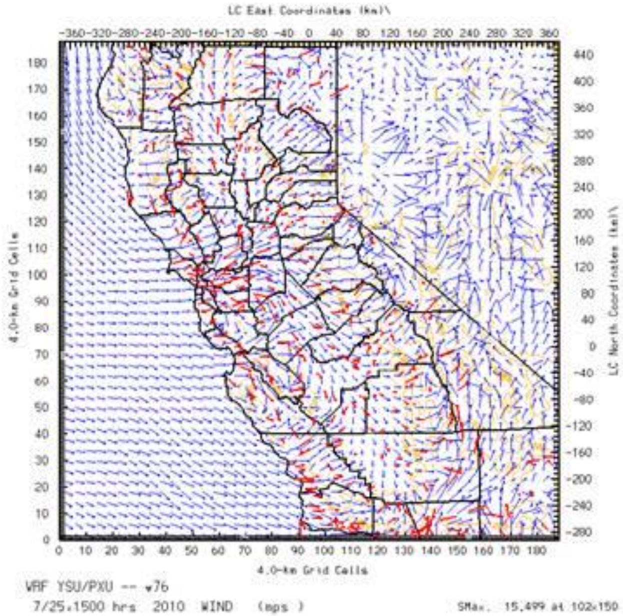
Chemistry

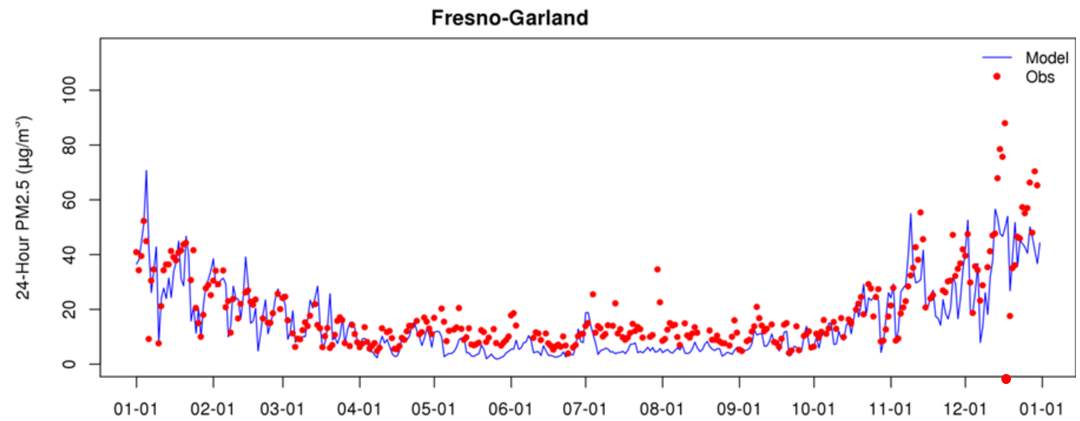
- Chemistry (or chemical mechanism) plays a central role in air quality modeling; Describes the photochemical reactions that take place in the atmosphere and that lead to ozone formation
- Aerosol chemistry describes the formation of inorganic and organic aerosol

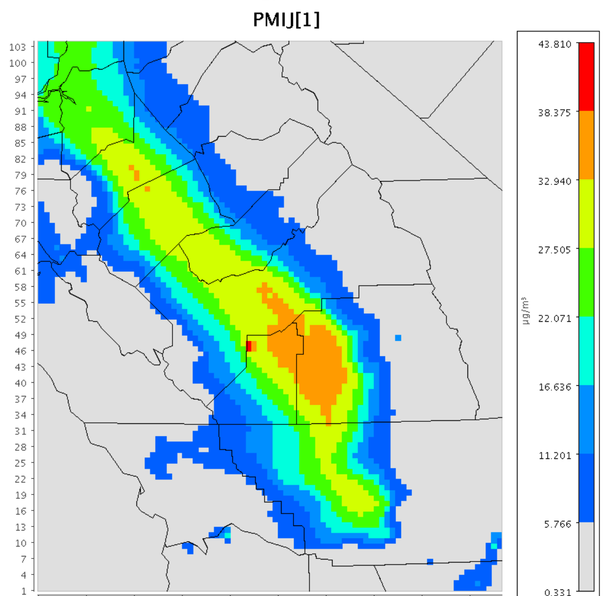
Boundary Conditions

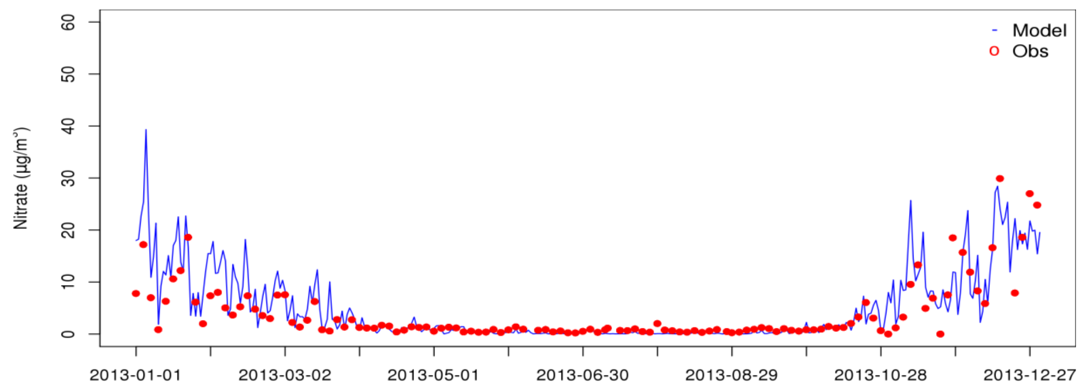
- Derived from global models to provide time- and space-varying information
- Capture the transport of external emissions that could affect modeling region

Modeling Procedures



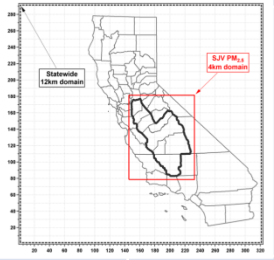






The PM2.5 SIP Modeling Process

Updates to the 2012 SIP Modeling Approach

	2012 SIP	2016 SIP
Period Modeled	October - March 2007	Annual 2013
Domain	4-km SJV and 12-km statewide	 Slightly larger 4-km SJV and 12-km statewide
Boundary Conditions	Downscaled from global chemistry model MOZART-4	Downscaled from global chemistry model MOZART-4 **(SAME)**
Meteorological Model	MM5 v3.7.2	WRF v3.6 **(UPDATED SCIENCE)**
Air Quality Model	CMAQ v4.7.1	CMAQ v5.0.2 **(UPDATED SCIENCE)**
Chemical Mechanism	SAPRC99	SAPRC07 **(UPDATED SCIENCE)**
Aerosol Chemistry	Aero5	Aero6 **(UPDATED SCIENCE)**

The PM2.5 SIP Modeling Process

Model Attainment Demonstration

- Using models in a relative sense
  - Scientific studies have determined using the relative change in the model in conjunction with observed values is most appropriate
    - Future year PM2.5 / Base year PM2.5
    - We call this relative change a Relative Response Factor (RRF)
    - Tie the relative change to PM2.5 concentration using the Design Value (RRF x DV)
- This approach was used in SJV's 2008 annual PM2.5 and 2012 24-hour PM2.5 SIPs

Model Attainment Demonstration

- Projecting the average DV to the future requires three model simulations:
  1. **Base year** simulation (2013): assessing model performance
  2. **Reference year** simulation (2013): used in RRF calculation
     - Same as base year simulation except no wildfire emissions, Chevron fire, etc.
  3. **Future year** simulation (2025): used in RRF calculation
     - Same as reference year, except anthropogenic emissions are for the future year (e.g., same meteorology and calendar)
- Future Year Design Value (Component specific):

$$DV_F = DV_R \times RRF$$

  - DV_F is Future Year Design Value for PM2.5 Component
  - DV_R is Reference Year Design Value for PM2.5 Component
  - RRF is the *RRF* for PM2.5 Component

Day-specific Emission Inventory

- Residential wood combustion emissions are based on actual base year curtailment days
- Emissions from paved and unpaved roads are adjusted according to rain conditions
- Agricultural burning emissions are based on actual permitted burns
- Mobile source emissions are adjusted by day-specific meteorological conditions

The Current SJV PM2.5 SIP

Scientific Foundation of SIP Modeling

- Ambient measurement data from an extensive routine monitoring network in the SJV
- Unique measurements (i.e., not available from routine monitors) from special field campaigns in the SJV (e.g., CRPAQS, CalNex, DISCOVER-AQ)
- Latest meteorological/air quality models which reflect our best knowledge about atmospheric processes

CRPAQS/CCOS

- Develop a statewide Integrated Transportation Network and a system for updating the network
- Improve spatial and temporal distribution of area sources, including agricultural-related sources
- Improve the estimation of emissions from PM and VOC from cooking; livestock ammonia; and ammonia and NOx from soil
- Characterize and quantify air emissions from dairies; evaluate technologies to improve the management and treatment of dairy manure in the San Joaquin Valley
- Conduct technical analyses comparing emissions inventories and air measurements to guide inventory improvements
- Characterize cotton gin PM emissions
- Evaluate trends in composition and reactivity of VOC from motor vehicles

DISCOVER-AQ (2013)

- Ammonium nitrate and OC are two major PM2.5 components
- Secondary ammonium nitrate formation in the nighttime residual layer is an important pathway for nitrate formation
- Aerosol mass spectrometer (AMS) identified major OC sources in Fresno, including biomass burning (wood smoke), cooking, motor vehicles, etc.
- The Valley is NH_3 saturated, such that NH_3 fully neutralizes the ambient nitrate and sulfate ions, leaving a large excess of NH_3
- Meteorology plays an important role in forming PM2.5 episodes, by influencing buildup of pollutants, as well as primary emissions; the meteorology of 2013/14 was especially severe

Reference: Young et al. (2016, Atmos. Chem. Phys.)

SIP Modeling Timeline

- SIP modeling process begins well in advance (2-3 years) before a SIP is due
- ARB and the districts spend years reviewing and improving emission inventories
- Uses field campaigns (e.g., CRPAQS, DISCOVER-AQ) to improve air quality model performance
- Requires hundreds of modeling simulations to properly reflect observed meteorology and air quality patterns
- Must reflect ongoing improvements to emission inventory (iterative process)

Preliminary Model Results

Annual NOx Emissions:
Benefits of Current Control Program

	2013 (tpd)	2021 (tpd)	Change from 2013 to 2021	2025 (tpd)	Change from 2013 to 2025
Medium & heavy-duty trucks	156.4	76.5	-51%	45.7	-71%
Farm equipment	48.4	34.0	-30%	26.6	-45%
Light-duty vehicles	20.7	8.6	-58%	6.5	-69%
Trains	13.4	12.9	-4%	11.6	-13%
Construction, mining & logging equipment	10.8	9.9	-8%	6.0	-44%
Irrigation pumps	10.2	3.7	-64%	3.0	-71%
Off-road equipment	8.4	5.0	-40%	4.0	-52%
Glass and related products	6.2	4.5	-27%	4.7	-24%
Buses	6.0	3.0	-50%	2.0	-67%
Residential gas and oil combustion	5.9	6.0	2%	5.9	0%
Remaining emission categories	31.7	32.1	1%	33.7	6%
Total	**318.1**	**196.2**	-38%	**149.7**	-53%

Annual PM2.5 Emissions:
Benefits of Current Control Program

	2013 (tpd)	2021 (tpd)	Change from 2013 to 2021	2025 (tpd)	Change from 2013 to 2025
Tilling, cultivation, harvesting	11.6	11.2	-3%	11.0	-5%
Fugitive windblown dust	7.5	7.3	-3%	7.1	-5%
Paved road dust	4.8	5.4	12%	5.8	21%
Medium & Heavy-duty trucks	4.8	1.4	-71%	1.2	-75%
Residential wood combustion	4.4	3.8	-14%	3.8	-14%
Unpaved road dust	3.7	3.7	0%	3.7	0%
Commercial cooking	3.6	4.1	14%	4.3	19%
Farm Equipment	2.8	2.0	-29%	1.6	-43%
Managed farm burning	2.0	1.9	-5%	1.9	-5%
Fuel use, oil & gas production	1.7	1.4	-18%	1.3	-24%
Remaining emission categories	16.6	17.4	5%	17.7	7%
Total	**63.5**	**59.6**	**-6%**	**59.4**	**-6%**

Annual SOx Emissions:
Benefits of Current Control Program

	2013 (tpd)	2021 (tpd)	Change from 2013 to 2021	2025 (tpd)	Change from 2013 to 2025
Glass & related products	2.0	2.0	**0%**	2.1	**5%**
Industrial fuel combustion	0.8	0.8	**0%**	0.8	**0%**
Chemical manufacturing and storage	0.8	0.9	**13%**	1.0	**25%**
Fuel use, oil and gas production	0.7	0.3	**-57%**	0.2	**-71%**
Power generation	0.6	0.6	**0%**	0.6	**0%**
Food production	0.6	0.5	**-17%**	0.5	**-17%**
Oil and gas	0.5	0.4	**-20%**	0.4	**-20%**
Mineral processes	0.4	0.5	**25%**	0.5	**25%**
Medium & heavy duty trucks	0.4	0.4	**0%**	0.3	**-25%**
Commercial & service fuel combustion	0.4	0.3	**-25%**	0.3	**-25%**
Remaining emission categories	1.3	1.5	**15%**	1.7	**31%**
Total	**8.5**	**8.2**	**-4%**	**8.4**	**-1%**

Annual Ammonia Emissions:
Benefits of Current Control Program

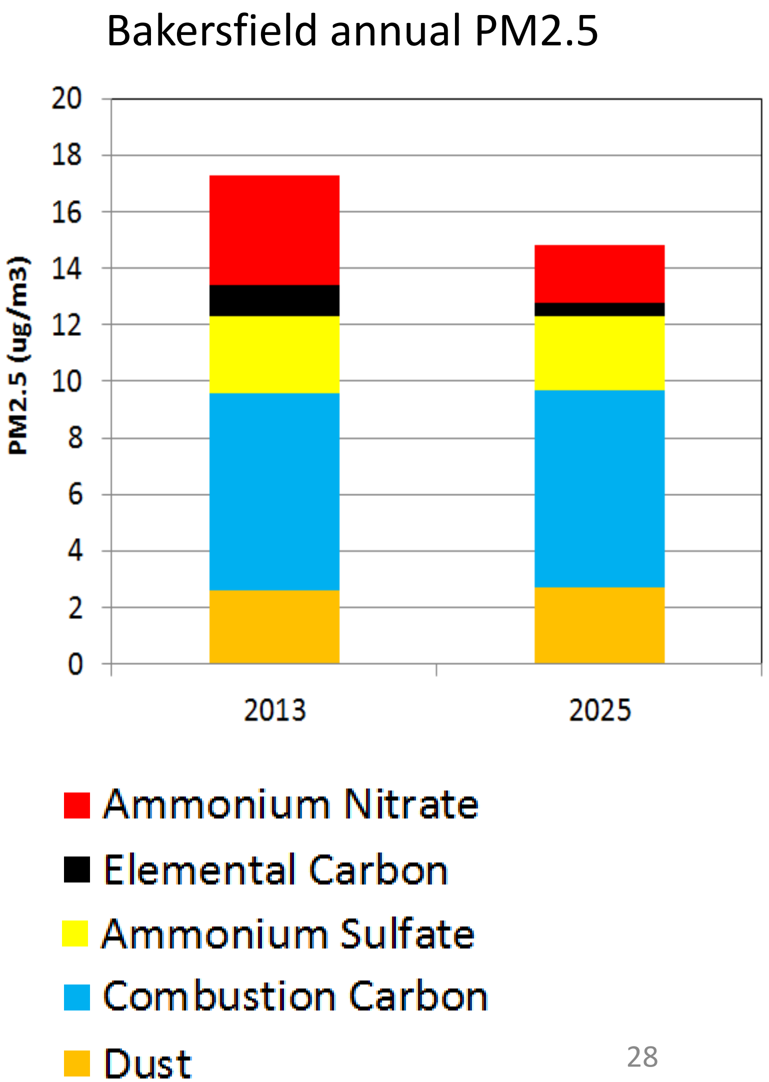
	2013 (tpd)	**2021 (tpd)**	Change from 2013 to 2021	**2025 (tpd)**	Change from 2013 to 2025
Dairy cattle	125.3	125.3	**0%**	125.3	**0%**
Pesticides and fertilizers	117.6	112.5	**-4%**	109.9	**-7%**
Other livestock	61.2	61.2	**0%**	61.2	**0%**
Other waste disposal	8.7	9.9	**14%**	10.6	**22%**
Other miscellaneous processes	6.1	6.9	**13%**	7.3	**20%**
Light-duty vehicles	2.5	2.2	**-12%**	2.2	**-12%**
Power generation	1.8	1.7	**-6%**	1.8	**0%**
Medium and heavy-duty trucks	1.6	1.0	**-38%**	0.7	**-56%**
Chemical manufacturing and storage	1.1	1.3	**18%**	1.4	**27%**
Landfills	0.7	0.8	**14%**	0.8	**14%**
Remaining emission categories	2.3	2.5	**9%**	2.5	**9%**
Total	**328.9**	**325.2**	**-1%**	**323.9**	**-2%**

Selection of 2025 as Initial Modeling Year

- Defining ultimate attainment target is independent of the year
- Modeling 2025 allows us to examine the maximum benefits of the current control programs
- The emission reductions from current control programs are large enough in 2025 to produce response in PM2.5 concentrations

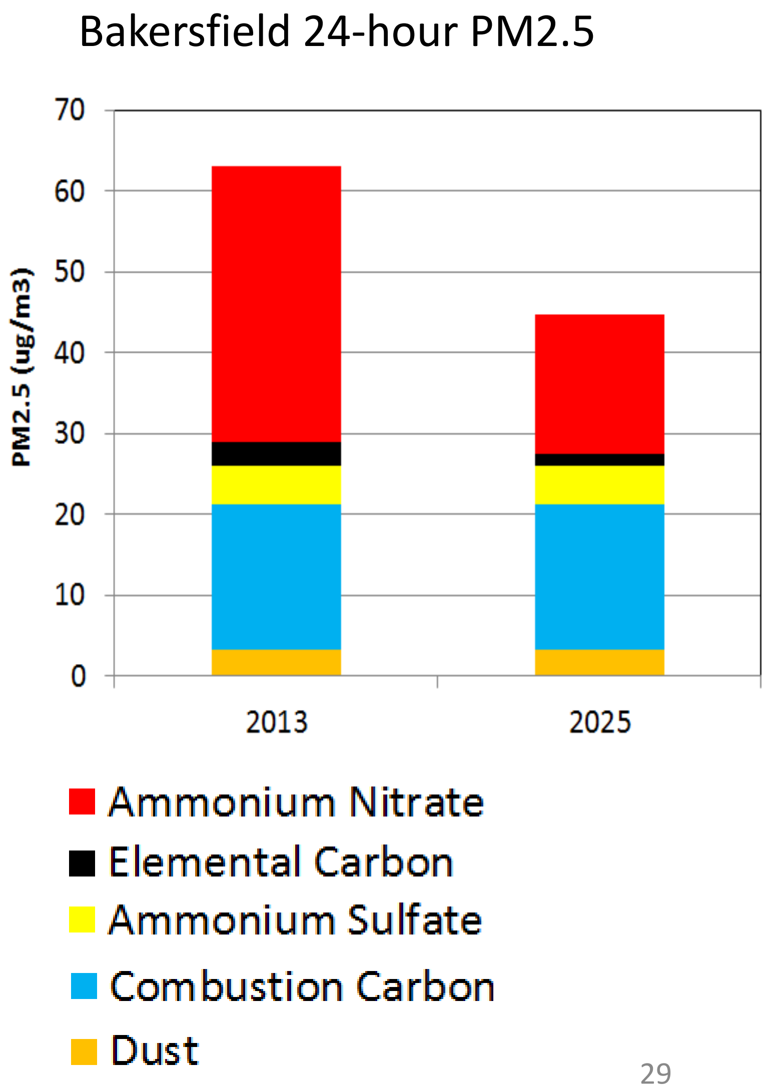
Preliminary Annual PM2.5 Design Values

Site	Weighted DV (2012, 2013, 2014)	2025 DV from baseline program
Bksfld-Planz	17.3	14.8
Madera-28261a	16.9	13.9
Hanford-Irwn	16.5	12.3
Corcoran-Pat	16.3	13.8
Visalia-NChur	16.2	13.4
Clovis-NVilla	16.1	14.3
Bksfld-Cal	16.0	13.5
Fresno-Gar	15.0	13.1
Turlock-SMin	14.9	12.4
Fresno-HW	14.2	12.5
Stockton-Haz	13.1	11.4
Merced-SCoff	13.1	10.8
Modesto-14th	13.0	10.9
Merced-MStr	11.0	9.6
Manteca-Fis	10.1	8.6
Tranq-WAA	7.7	6.2



Preliminary 24-Hour PM2.5 Design Values

Site	Weighted DV (2012, 2013, 2014)	2025 DV from baseline program
Bksfld-Cal	63.1	44.8
Fresno-Gar	60.0	47.9
Hanford-Irwn	60.0	40.2
Clovis-Nvilla	55.8	43.1
Visalia-Nchur	55.5	41.7
Bksfld-Planz	55.4	40.6
Fresno-HW	51.6	42.0
Madera-28261A	51.0	40.0
Turlock-Smin	50.7	38.7
Corcoran-Pat	48.0	35.4
Modesto-14th	47.9	36.6
Merced-MStr	42.0	32.3
Stockton-Haz	42.0	33.7
Merced-Scoff	41.1	30.7
Manteca-Fis	37.2	29.9
Tranq-WAA	29.6	21.1



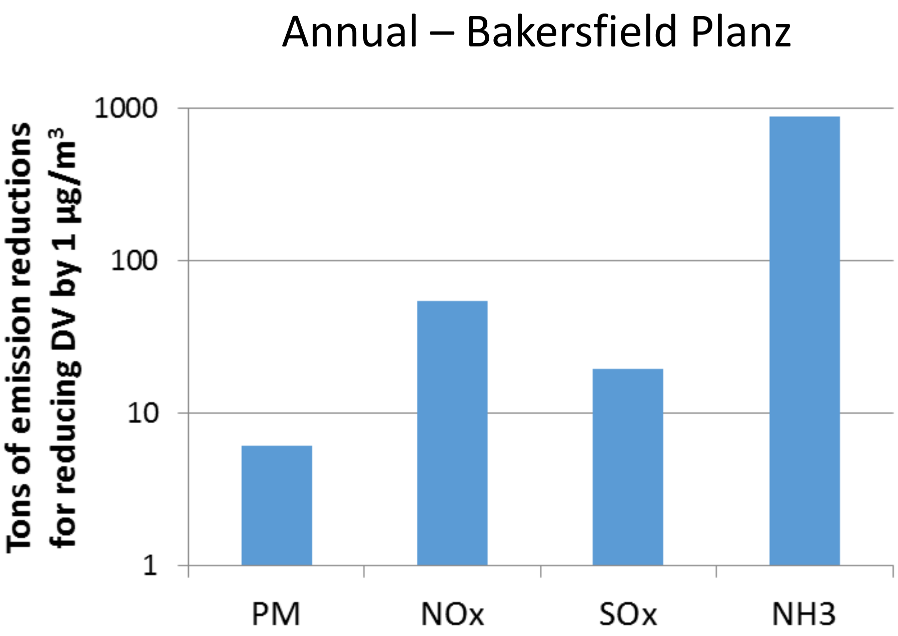
Purpose of Model Sensitivity Runs

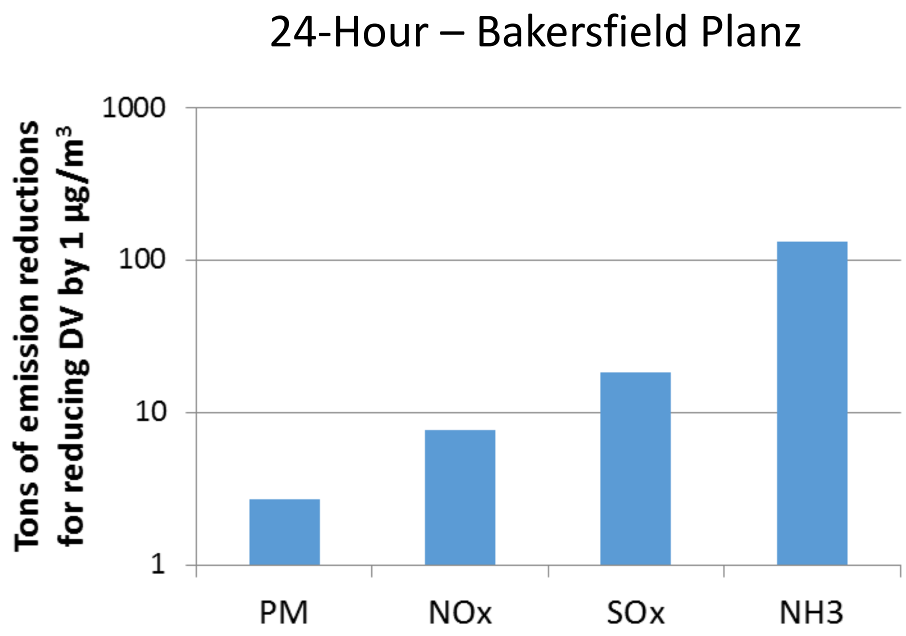
- Precursor sensitivity analysis (i.e., determine the effectiveness of controlling different PM2.5 precursors)
- PM source apportionment (e.g., determine contributions from different source categories to the modeled OC concentrations)
- Sensitivity to sub-regional emission controls (instead of uniform valley-wide control)

Draft U.S. EPA PM2.5 Precursor Demonstration Guidance

- Draft released in late-2016
- Specifies modeling approach to demonstrate whether precursor emissions contribute significantly to PM2.5 levels
- Recommends modeling 30-70% reductions in anthropogenic precursor emissions in the nonattainment area
- Recommends thresholds below which air quality change is considered "insignificant":
  - 0.2 $\mu g/m^3$ for annual PM2.5
  - 1.3 $\mu g/m^3$ for 24-hour PM2.5

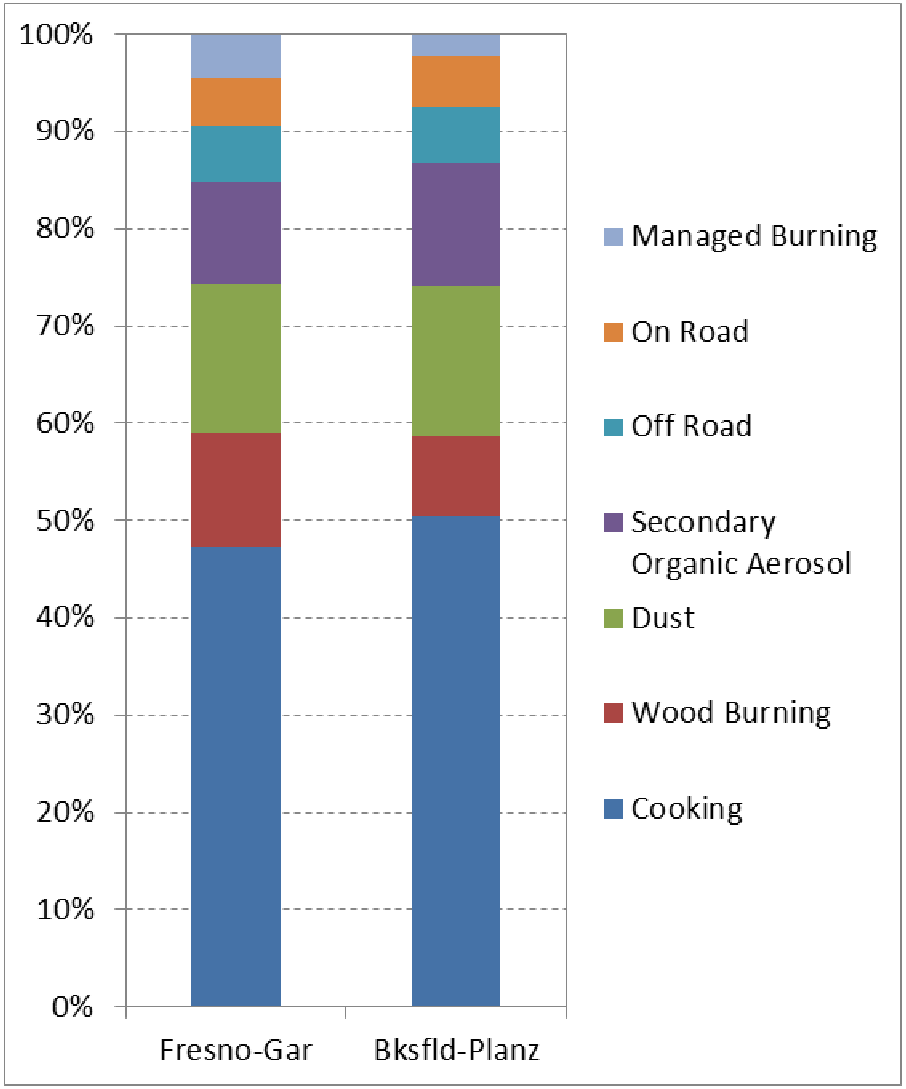
Preliminary Precursor Effectiveness





- Based on modeling runs that scale domain-wide emissions by plus/minus 15%
- Plots show tons of emissions reductions that are needed for reducing annual and 24-hour PM2.5 DV by 1 µg/m^3, respectively: Primary PM most effective, followed by NOx and SOx, NH3 is the least effective
- A previous study (Kleeman, et al., 2005) showed that each gram of NOx emitted in the SJV in the winter only produced 0.2-0.3 grams of ammonium nitrate, far less than 1.7 grams expected from complete conversion

OC Source Contributions in 2025 (Annual Average)



Completed Emissions Updates

- Updated EMFAC2014 on-road emissions
- Updated OGV, locomotive line haul emissions
- Updated pesticide emissions from DPR
- Updated rice tilling operations for the SJV
- Updated paved road dust
- Updated residential fuel combustion in the SJV
- Updated control profile for rule 4905 (natural gas fired central furnaces)

Future Emissions Updates

Working with District Staff on:

- Review of temporal distribution associated with crop calendars
- Spatial allocation and updated growth profile for cooking emissions
- More in-depth review of the Tier 1 residential wood combustion curtailment method
- Identify further emissions improvement opportunities

Ongoing Analysis & Modeling

- Update modeling based on updated inventory
- Revisit precursor sensitivity analysis based on EPA draft guidelines and new emission inventory
- Additional model sensitivity runs:
  - Sub-regional controls
  - Specific source categories
  - Runs to help inform control strategy
- Unmonitored area analysis:
  - Ensure areas without monitors meet standards
  - Combines ambient observations with modeled spatial distributions

Thank You!

Questions?