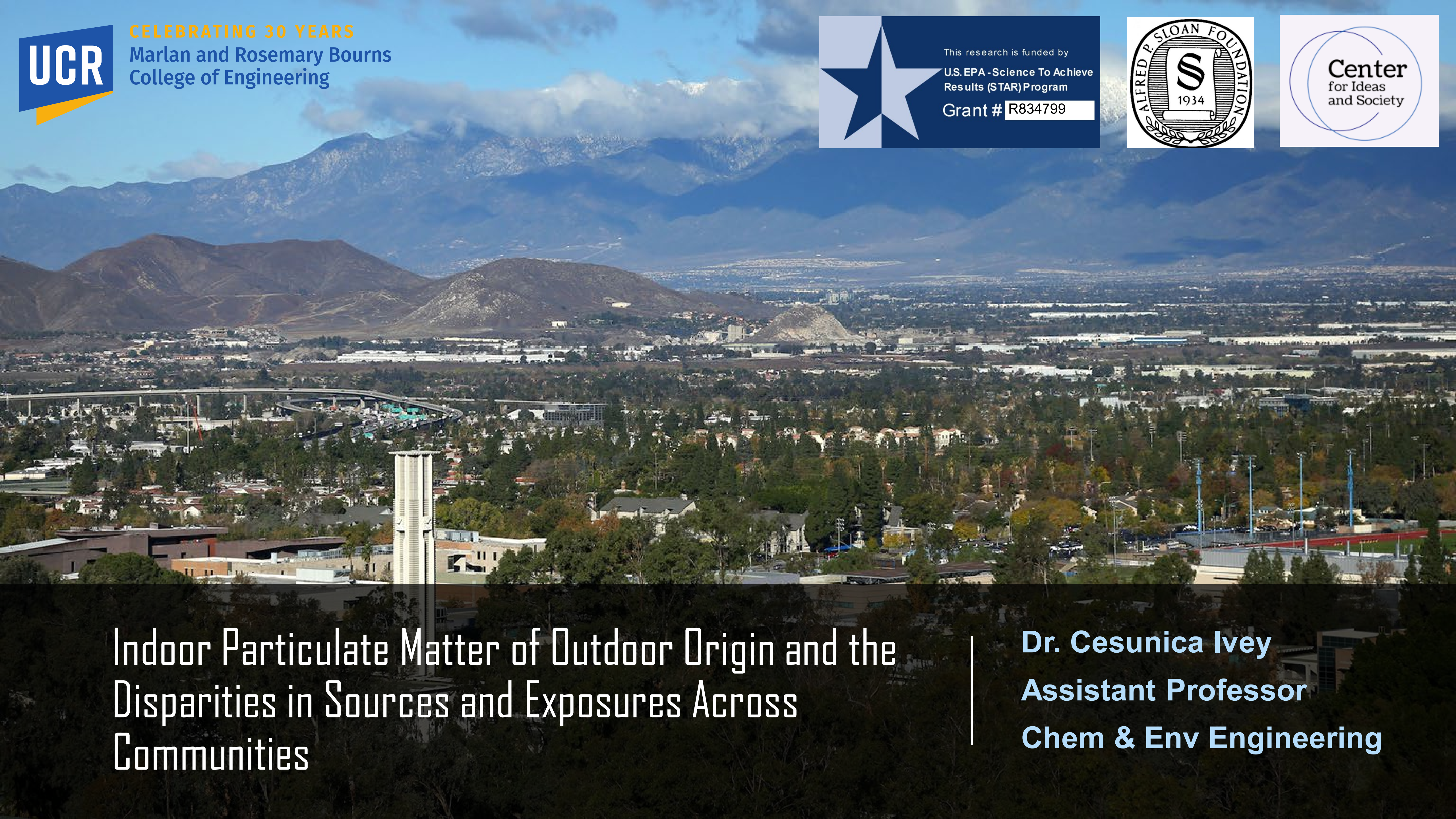


CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R834799

Alfred P. Sloan Foundation 1934

Center for Ideas and Society

Indoor Particulate Matter of Outdoor Origin and the Disparities in Sources and Exposures Across Communities

Dr. Cesunica Ivey

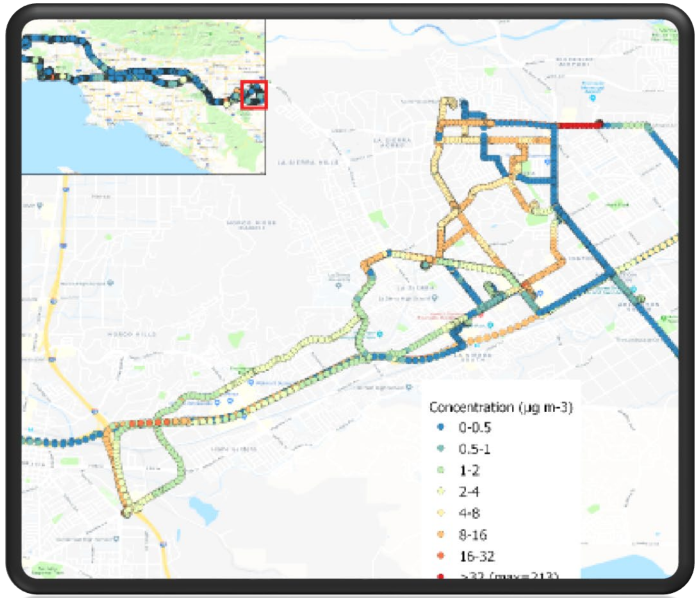
Assistant Professor

Chem & Env Engineering

Presentation Overview

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

1. $PM_{2.5}$ Sources: Regulatory vs. Community Perspectives



2. $PM_{2.5}$ Exposure Modeling: Are We Getting It Right?

3. Emerging Challenges for Source Mitigation

Presentation Overview

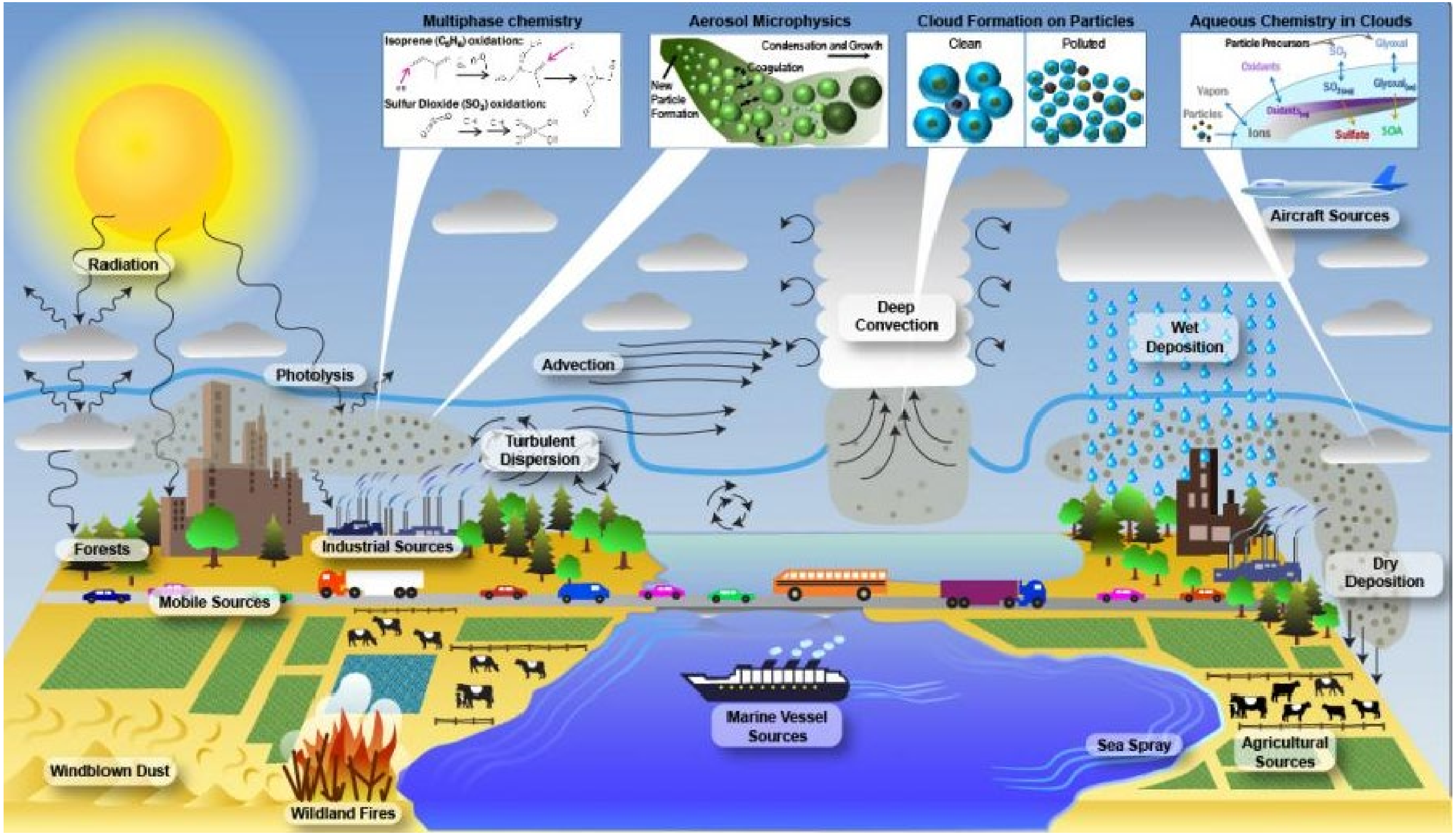
CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

1. $PM_{2.5}$ Sources: Regulatory vs. Community Perspectives

2. $PM_{2.5}$ Exposure Modeling: Are We Getting It Right?

3. Emerging Challenges for Source Mitigation

Diverse Origins of $PM_{2.5}$



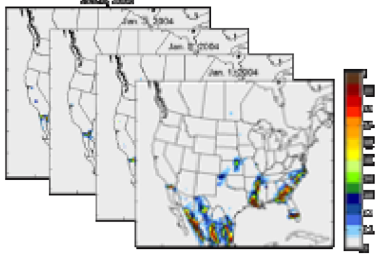
https://www.epa.gov/cmaq/overview-science-processes-cmaq

Hybrid Source Apportionment Modeling

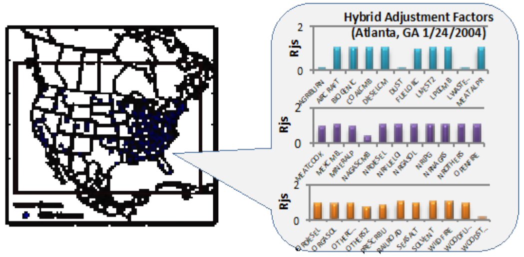
CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

We leverage *source apportionment* to attribute ambient pollutant concentrations back to the source. Model fusion with observations reduces concentration bias, improves source impacts.

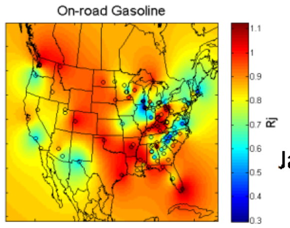
1. CMAQ-DDM Source Impacts (Daily)



2. Hybrid Analysis at Monitors (Sparse)

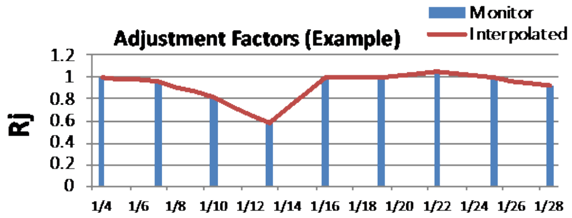


3. Spatial Interpolation of Adjustment Factors (Kriging)

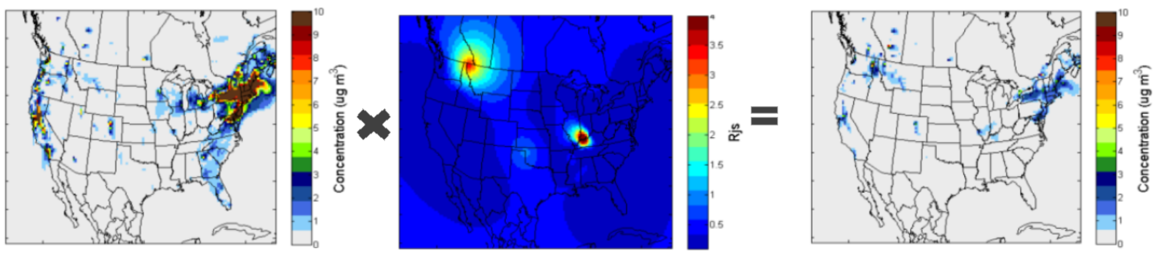


January 4, 2004

4. Temporal Interpolation of Adjustment Factors



5. Adjust CMAQ-DDM Spatial Fields (Daily, Spatially Dense)



$$X^2 = \sum_{i=1}^{N}\left[\frac{[(c_i^{obs} - c_i^{sim} - \sum_{j=1}^{J} SA_{i,j}^{base}(R_j - 1))]^2}{\sigma_{i,obs}^{\ 2} + \sigma_{i,SP}^{\ 2}}\right] + \Gamma \sum_{j=1}^{J} \frac{ln(R_j)^2}{\sigma_{ln(R_j)}^{\ \ 2}}$$

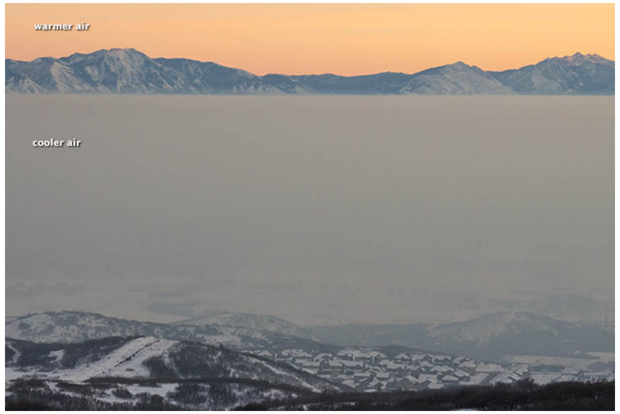
agricultural activities and livestock operations
aircraft
biogenics
coal combustion
dust
fires (wild, prescribed)
fuel oil combustion
meat cooking
metals processing
natural gas combustion
non-road diesel
non-road gasoline
non-road others
on-road diesel
on-road gasoline
others
other combustion
solvents
sea salt
wood burning

Ivey et al., ***Geosci Mod Dev***, 2015

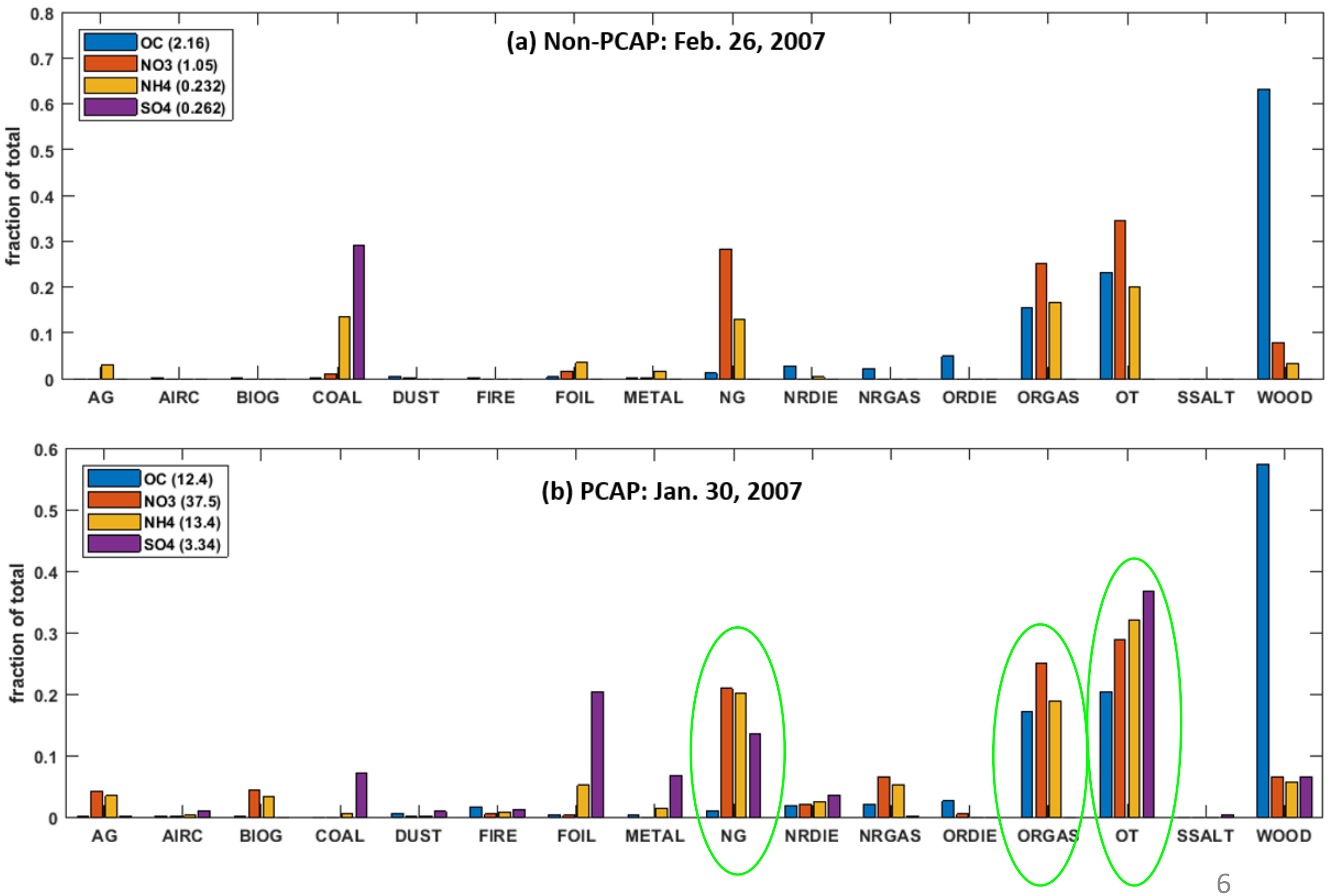
PCAP Source Apportionment

Source-oriented hybrid approach provided specific origins of secondary pollution during 2007 wintertime *persistent cold air pools* (PCAPs).

- Gasoline mobile and natural gas combustion are top sources during PCAP
- Others is highest source:
  - Refineries
  - Smelters
- Recommendation: reduce emissions from sources of nitrate precursors during PCAPs



Ivey et al., ***Atm Env***, 2019; ***FESE*** 2016



California Statewide $PM_{2.5}$ Sources

Top primary $PM_{2.5}$ sources include residential fuel combustion, windblown fugitive dust, and managed burning and disposal.

2016 SIP Emission Projection Data

2020 Estimated Annual Average Emissions

STATEWIDE

STATIONARY SOURCES	**TOG**	**ROG**	**CO**	**NOX**	**SOX**	**PM**	**PM10**	**PM2.5**	**NH3**
FUEL COMBUSTION	133.3	28.2	245.5	190.6	25.8	35.3	29.2	25.8	19.7
WASTE DISPOSAL	2249.1	57.1	4.7	4.7	1.5	68.3	20.5	2.9	30.9
CLEANING AND SURFACE COATINGS	255.0	161.0	0.1	0.1	0.0	3.2	3.1	2.9	0.5
PETROLEUM PRODUCTION AND MARKETING	484.9	87.8	12.1	4.9	4.6	3.5	2.3	2.1	0.3
INDUSTRIAL PROCESSES	68.2	61.2	36.4	65.6	26.5	214.3	111.6	44.5	12.0
*** TOTAL STATIONARY SOURCES**	**3190.4**	**395.2**	**298.8**	**266.0**	**58.5**	**324.7**	**166.7**	**78.3**	**63.4**
AREAWIDE SOURCES	**TOG**	**ROG**	**CO**	**NOX**	**SOX**	**PM**	**PM10**	**PM2.5**	**NH3**
SOLVENT EVAPORATION	407.2	358.6	-	-	-	0.0	0.0	0.0	179.1
MISCELLANEOUS PROCESSES	1323.7	215.1	643.4	60.6	4.0	2206.0	1194.8	244.8	337.9
*** TOTAL AREAWIDE SOURCES**	**1730.9**	**573.7**	**643.4**	**60.6**	**4.0**	**2206.0**	**1194.8**	**244.8**	**516.9**
MOBILE SOURCES	**TOG**	**ROG**	**CO**	**NOX**	**SOX**	**PM**	**PM10**	**PM2.5**	**NH3**
ON-ROAD MOTOR VEHICLES	233.7	210.6	1535.2	494.5	4.6	62.7	61.5	27.1	32.1
OTHER MOBILE SOURCES	278.4	246.8	1978.6	600.2	13.1	32.4	31.3	28.0	0.5
*** TOTAL MOBILE SOURCES**	**512.1**	**457.4**	**3513.8**	**1094.7**	**17.8**	**95.1**	**92.7**	**55.1**	**32.6**
GRAND TOTAL FOR STATEWIDE	**5433.5**	**1426.3**	**4456.0**	**1421.3**	**80.3**	**2625.8**	**1454.3**	**378.2**	**612.9**

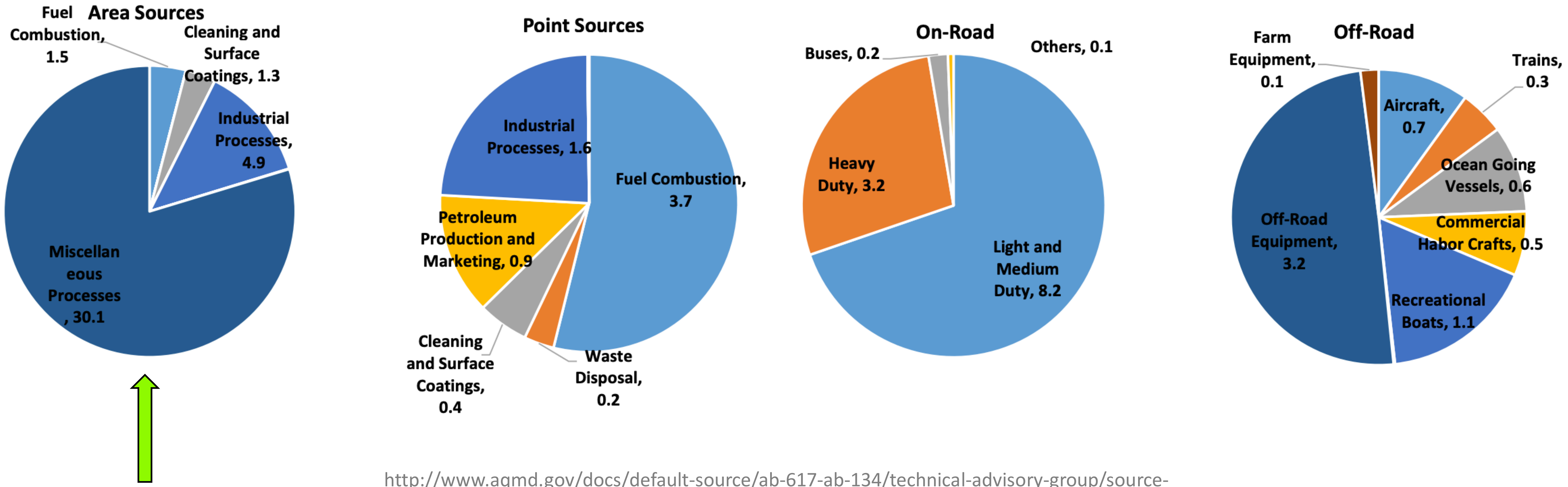
arb.ca.gov

Southern California $PM_{2.5}$ Sources

UCR
CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

Top primary $PM_{2.5}$ sources include cooking and paved road dust.

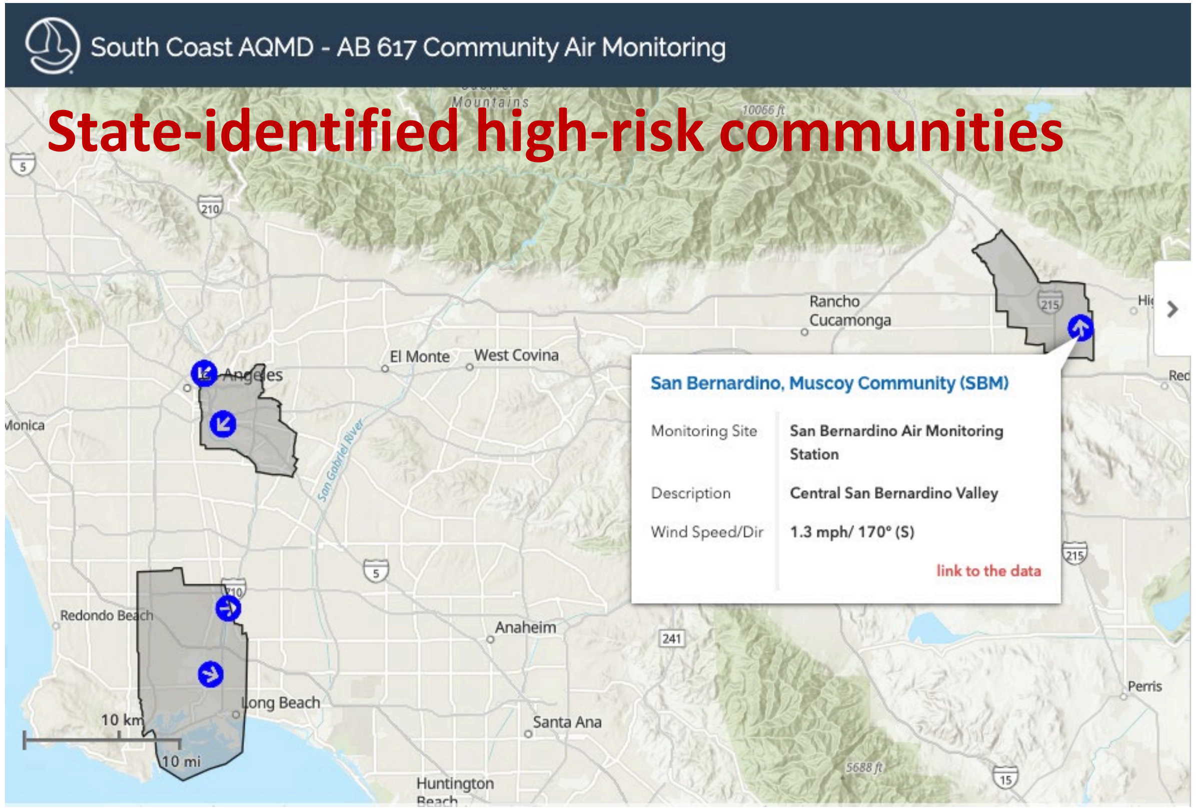
2017 $PM_{2.5}$ Emissions in the South Coast Air Basin (Tons per Day)



http://www.aqmd.gov/docs/default-source/ab-617-ab-134/technical-advisory-group/source-attribution-methodology.pdf?sfvrsn=14

Multiple Air Toxics Exposure Study (MATES) IV identifies diesel $PM_{2.5}$ as the dominant driver of cancer risk

Phase 1 AB 617 Communities



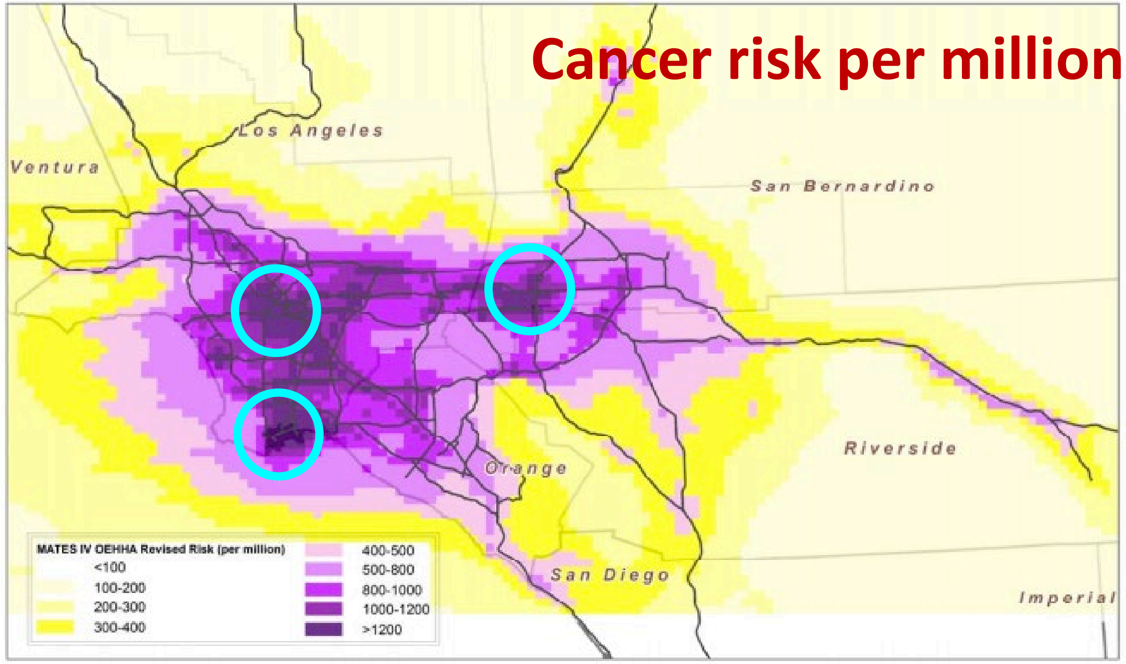


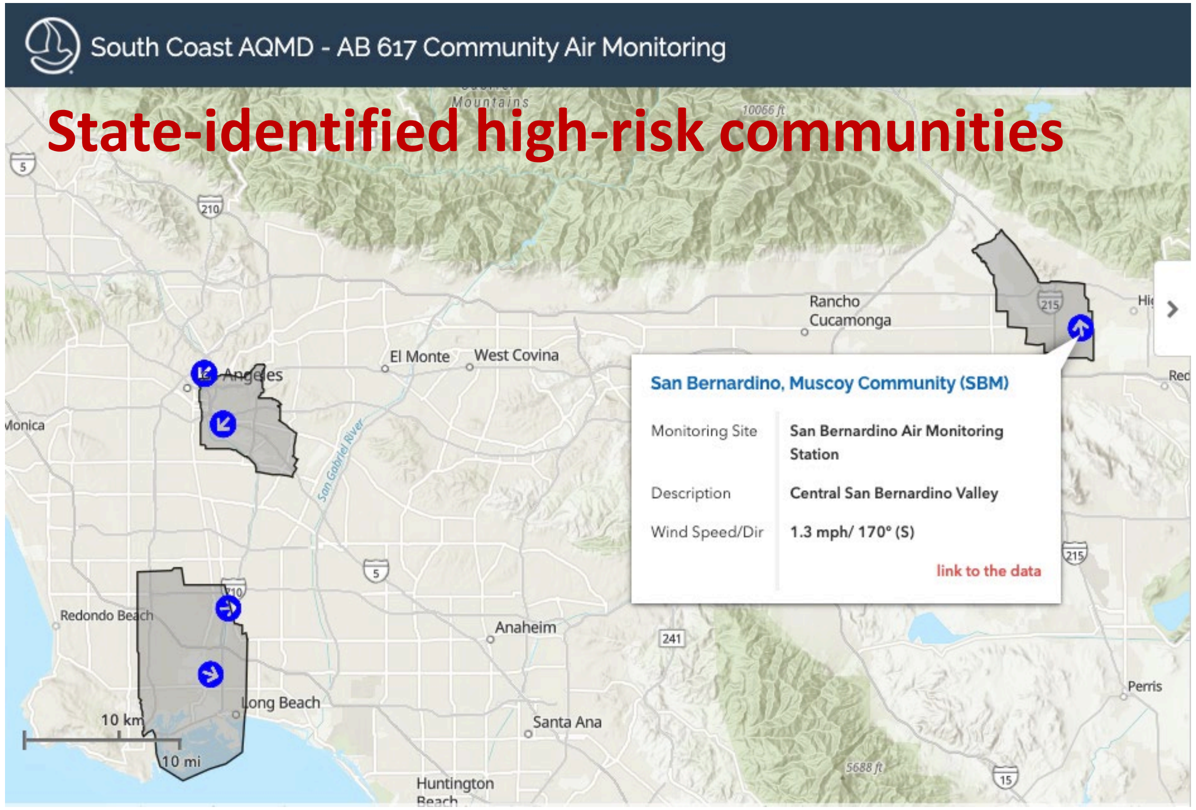
Figure ES-7
MATES IV Modeled Air Toxics Risks Estimates Using Updated OEHHA Methodology

Environmental Justice: AB 617 Communities

CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

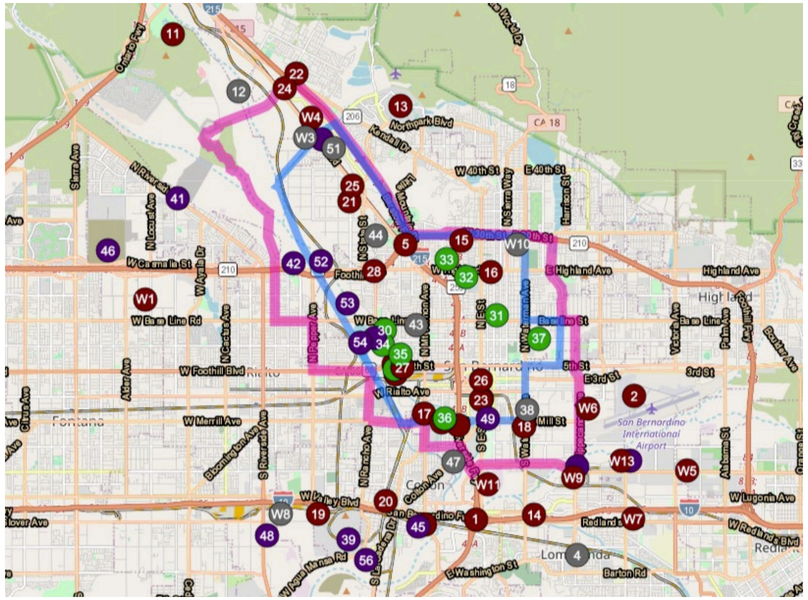
Assembly Bill 617 requires targeted air monitoring and emissions reductions in overburdened communities

Phase 1 AB 617 Communities

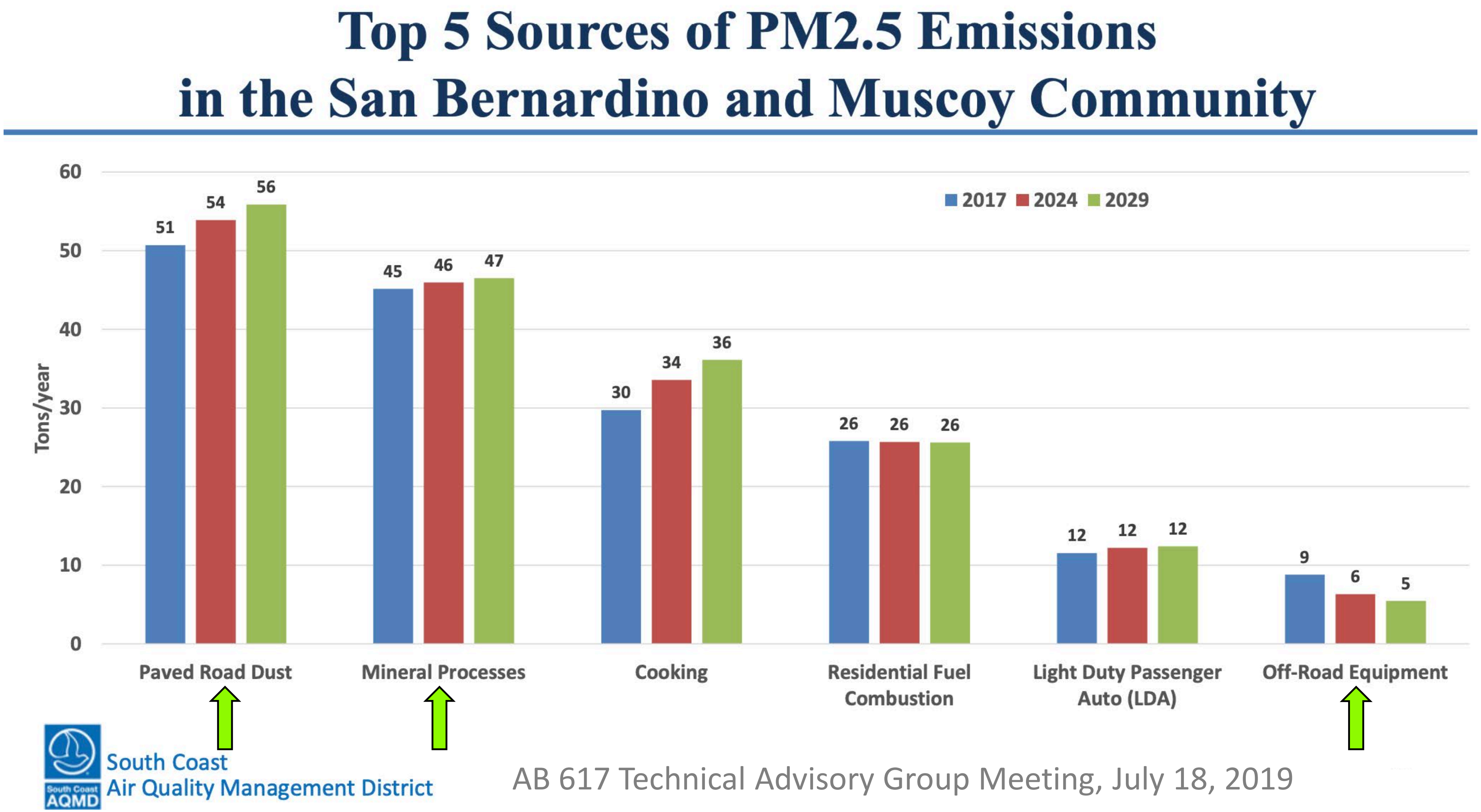


San Bernardino/Muscoy: truck idling, truck traffic, cement plant, BNSF railyard, auto body shops

Community Concerns



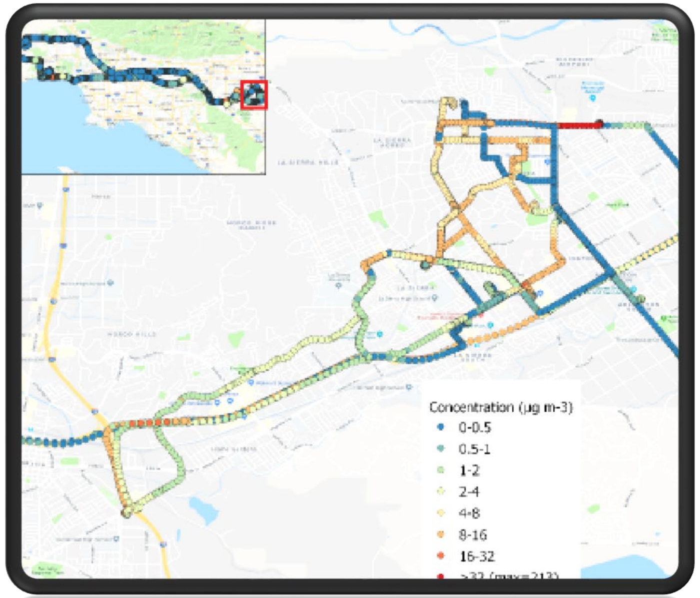
San Bernardino/Muscoy



AB 617 Technical Advisory Group Meeting, July 18, 2019

Presentation Overview

1. $PM_{2.5}$ Sources: Regulatory vs. Community Perspectives



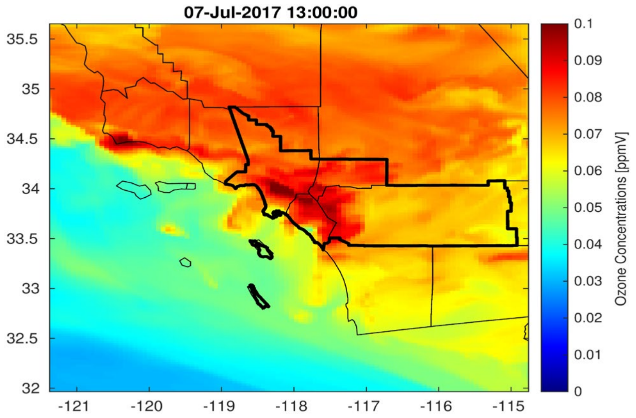
2. $PM_{2.5}$ Exposure Modeling: Are We Getting It Right?

3. Emerging Challenges for Source Mitigation

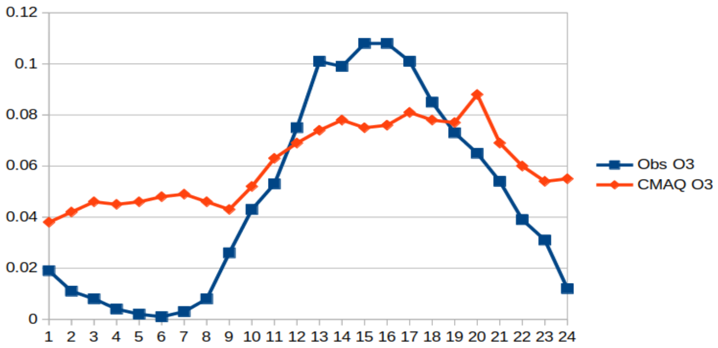
Modeling Weaknesses for Exposure Studies?

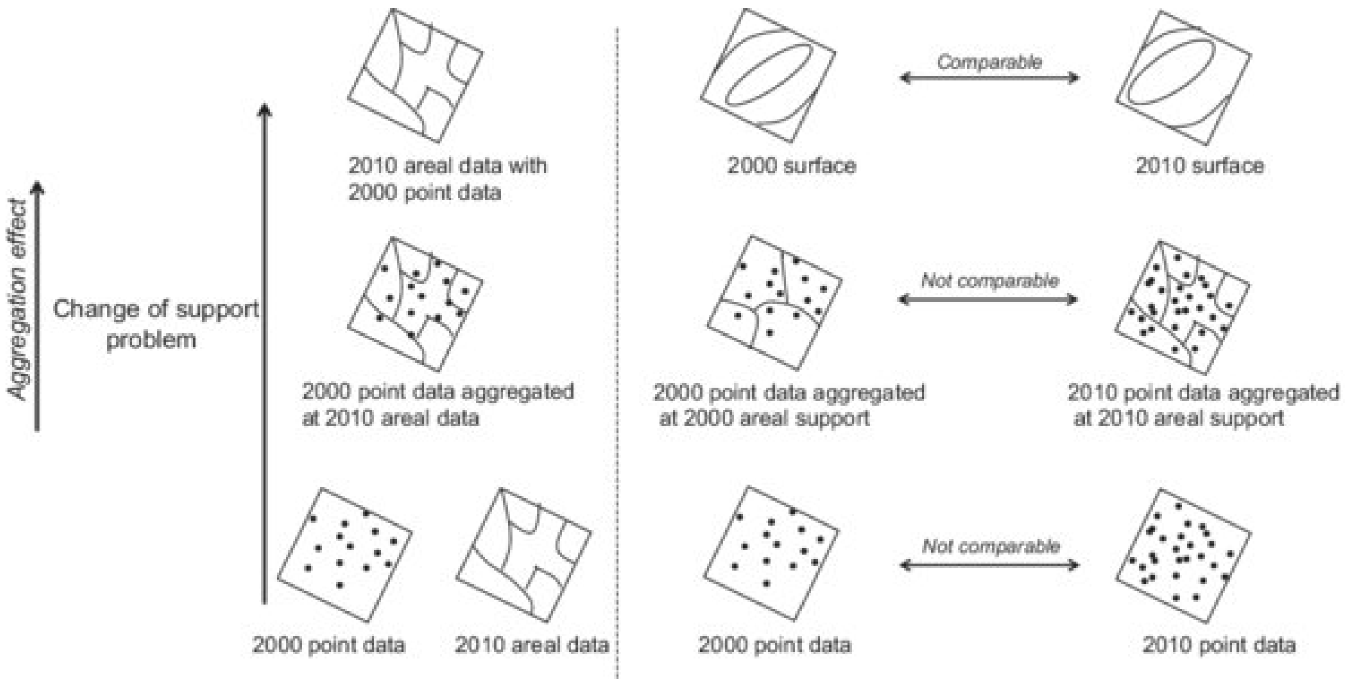
Spatial and temporal biases may confound acute exposure estimates. The change of support problem also confounds individual exposure assessments.

Ozone in SoCAB July 7, 2017



Hourly Ozone July 7, 2017 at Fontana





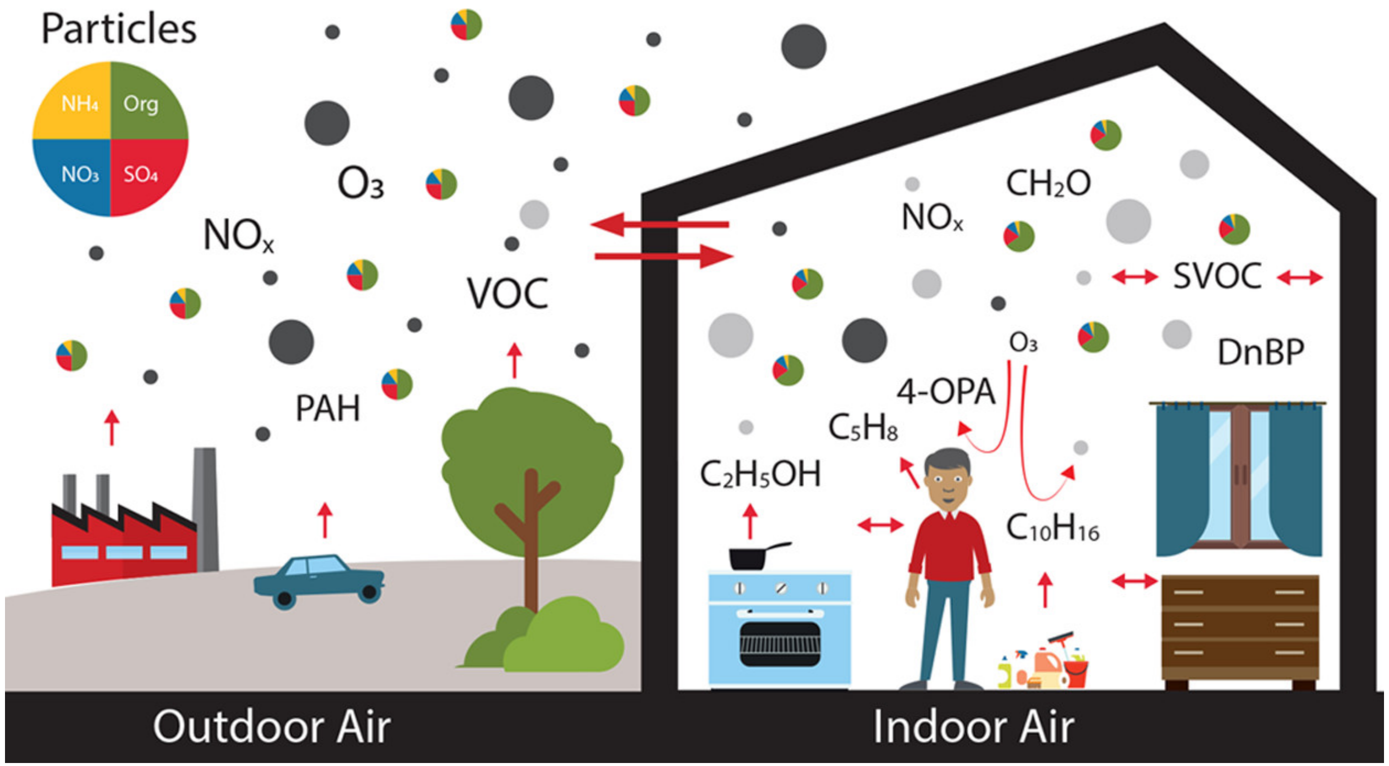
Gelfand, Zhu, and Carlin, ***Biostatistics,*** 2001; Rongerude and Haddad, Housing Policy Debate, 2016

Ivey, Russell, and Blanchard, **Ozone Met Study: Quarter 3 Report**, 2020

Ambient $PM_{2.5}$ Indoors

"…Epidemiological studies of the link between outdoor air pollution and health generally do not effectively address the often-substantial exposure to air pollutants of indoor origin…"

- Very small and very large ambient particles are removed once crossing the building envelope
- $PM_{2.5}$ infiltration factors range from 0.3 to 0.8
- Assessment of how global mortality might shift with changes in outdoor $PM_{2.5}$ concentrations…neglects the role of buildings as attenuators and modulators of exposure



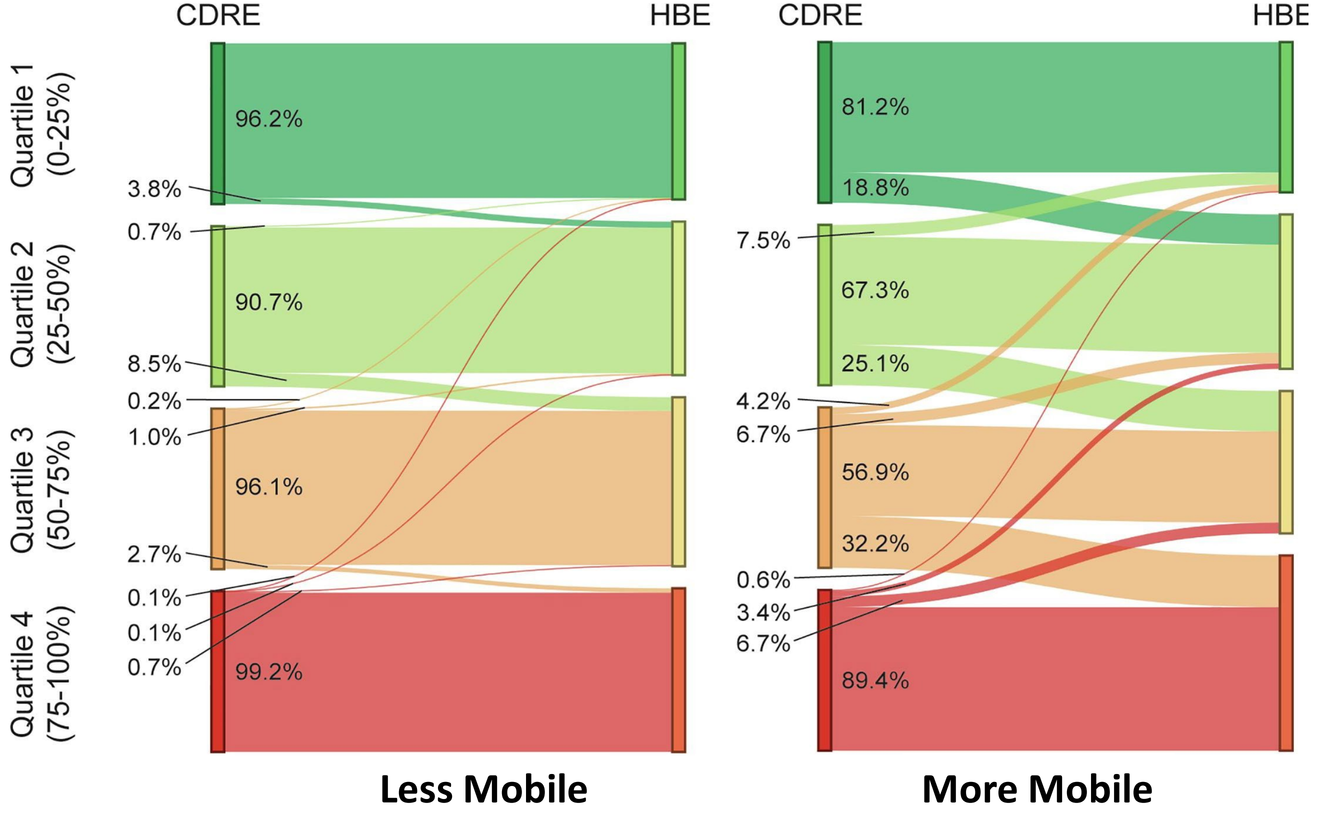
Goldstein et al., ***ES&T***, 2020

Human Mobility Confounds Exposures?

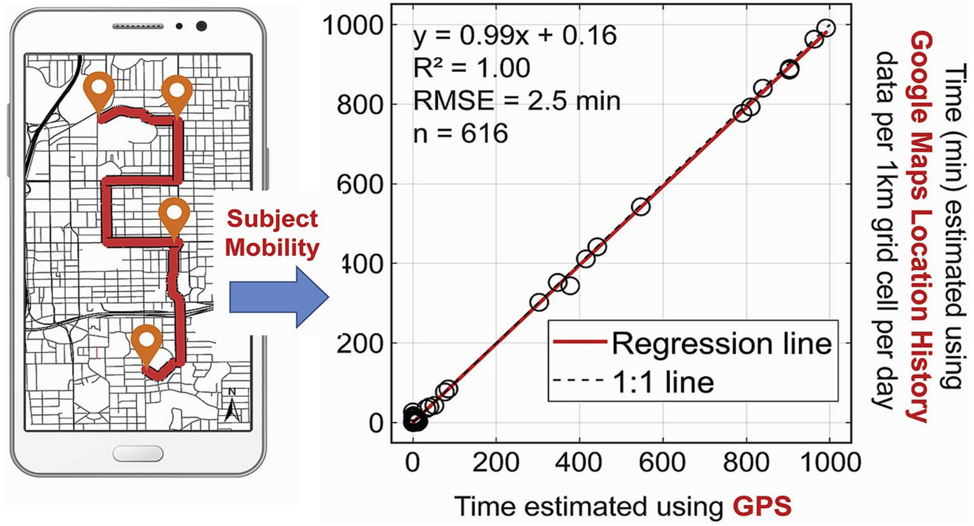
UCR CELEBRATING 30 YEARS Marlan and Rosemary Bourns College of Engineering

Higher mobility leads to higher potential for exposure misclassification. Cellular data is relatively effective for characterizing individual and population scale mobility.

$PM_{2.5}$ Exposure Misclassification



Google Maps Location History



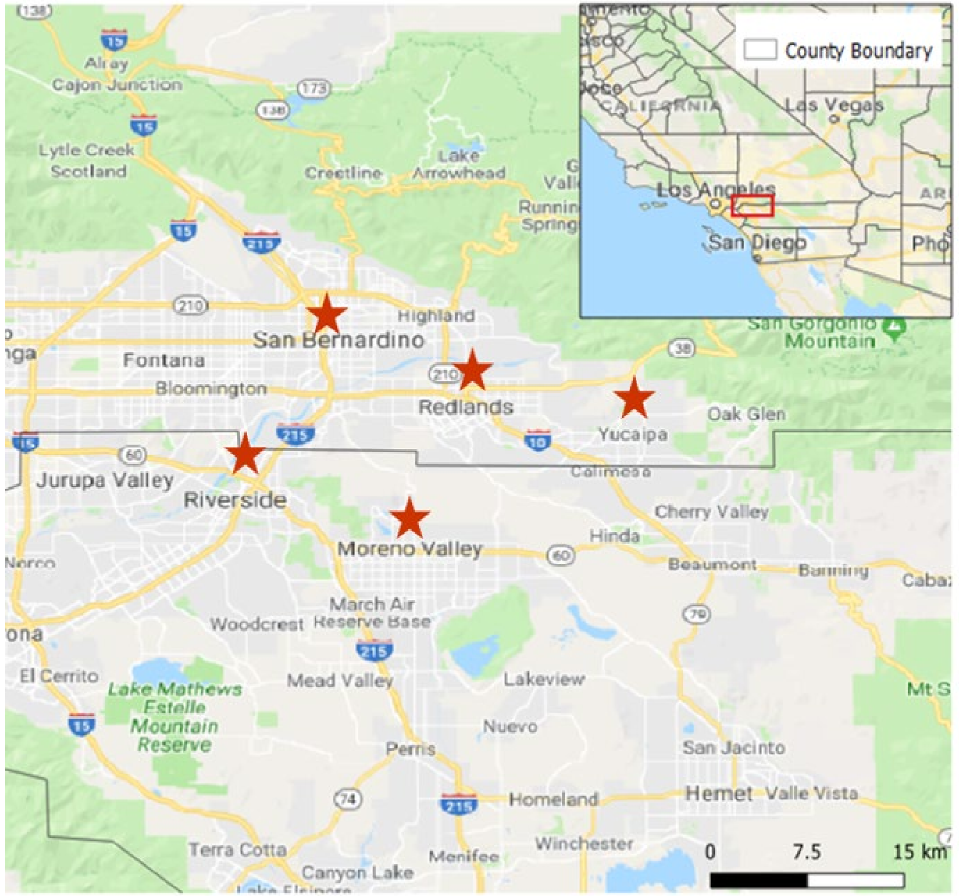
Yu, Ivey et al., ***Env Poll***, 2019; ***Env Int***, 2020

- Based on call detail records (CDR) Individuals with greater daily mobility are at greater risk for exposure misclassification
- Google Maps Location History data is an *effective* way to track human mobility

Personal $PM_{2.5}$ Exposure Pilot Study

CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

To what extent does human mobility impact personal exposure disparities?



Do, Velasquez, Ivey et al., ***J Aer Sci***, 2021

- Pilot CBPR field campaign: March 10th – April 14th 2019
- Participants from Moreno Valley, Redlands, Riverside, San Bernardino, Yucaipa
- Collected personal exposure data with accessible wearable monitors (15-sec) for 18 individuals for 7 days each
- Collect position with GPS data logger (5-sec)

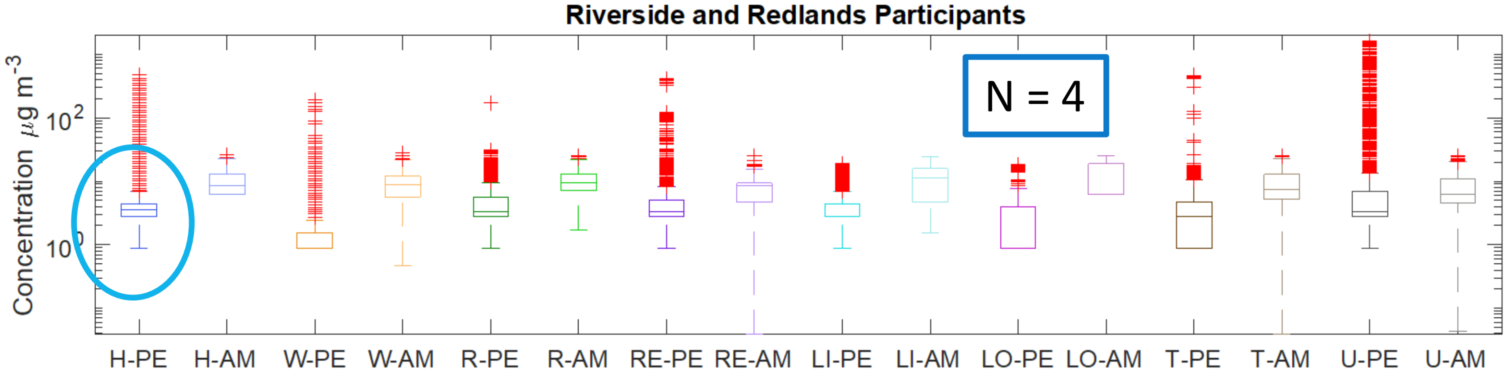
Applied Particle Technology, St. Louis, MO

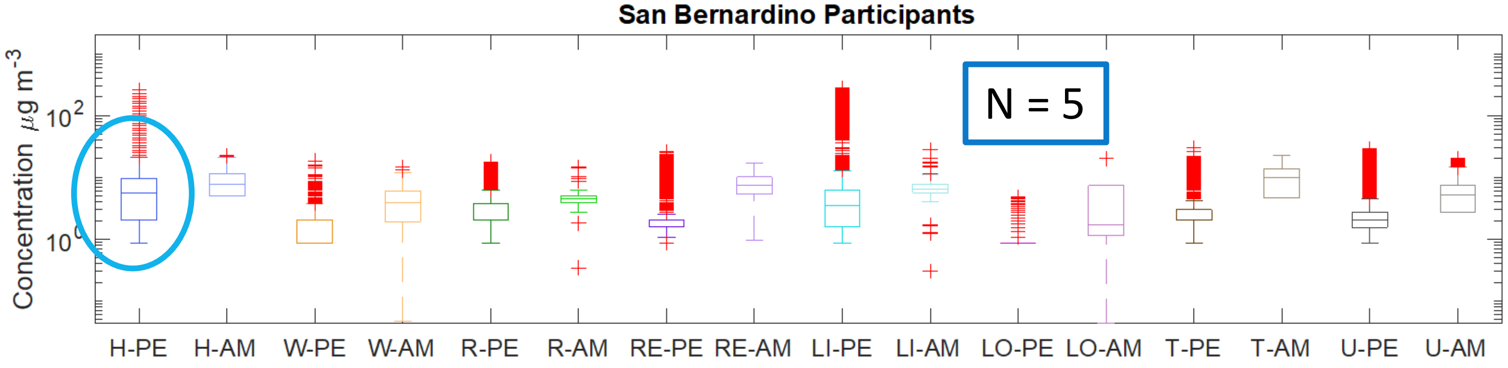
$PM_{2.5}$ Exposure Disparities

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

San Bernardino residents are more at risk in their homes, despite high participant mobility.

JAS 2021





Do, Velasquez, Ivey et al., ***J Aer Sci***, 2021

- ME: home, work/uni, restaurant, retail, leisure indoor, leisure outdoor, transient
- Microenvironment exposures were highly variable among participants with > 50% data recovery.

City	Median Household Income	Poverty Rate
Moreno Valley	$63,572	19.9%
Redlands	$72,523	13.6%
Riverside	$65,313	15.6%
San Bernardino	$43,136	28.4%
Yucaipa	$63,657	12.3%

Human Mobility & Air Pollution Exposure

UCR CELEBRATING 30 YEARS Marlan and Rosemary Bourns College of Engineering

Despite high mobility, disparities in exposure still exist. Home-based hypothesis is corroborated, but non-home acute exposures are also important.

- Inland Empire pilot exposure study builds a foundation for larger exposure assessments
- High-resolution wearable optical particle counters and GPS data loggers enable precise personal exposure measurements
- Exposures related to personal behaviors and the visitation of high-risk non-residential points of interest should be continuously monitored

	Redlands and Riverside	San Bernardino
# of Data Points (% Recovery)	387,219 (73%)	301,428 (72%)
Time Spent (%)		
Home	66	70
Work or University	23	9
Restaurant	3	1
Retail	2	7
Leisure Indoor	2	4
Leisure Outdoor	< 1	<1
Transient	< 1	4
Unclassified	3	5

Do, Velasquez, Ivey et al., ***J Aer Sci***, 2021

Presentation Overview

CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

1. $PM_{2.5}$ Sources: Regulatory vs. Community Perspectives

2. $PM_{2.5}$ Exposure Modeling: Are We Getting It Right?

3. Emerging Challenges for Source Mitigation

Emerging Challenges for Source Mitigation

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

- We should potentially consider a new way to approach $PM_{2.5}$ source mitigation to more effectively address exposure disparities.
- Requires a deep understanding of confounding effects, historical inequities, as well as present-day experiences for those most negatively impacted.

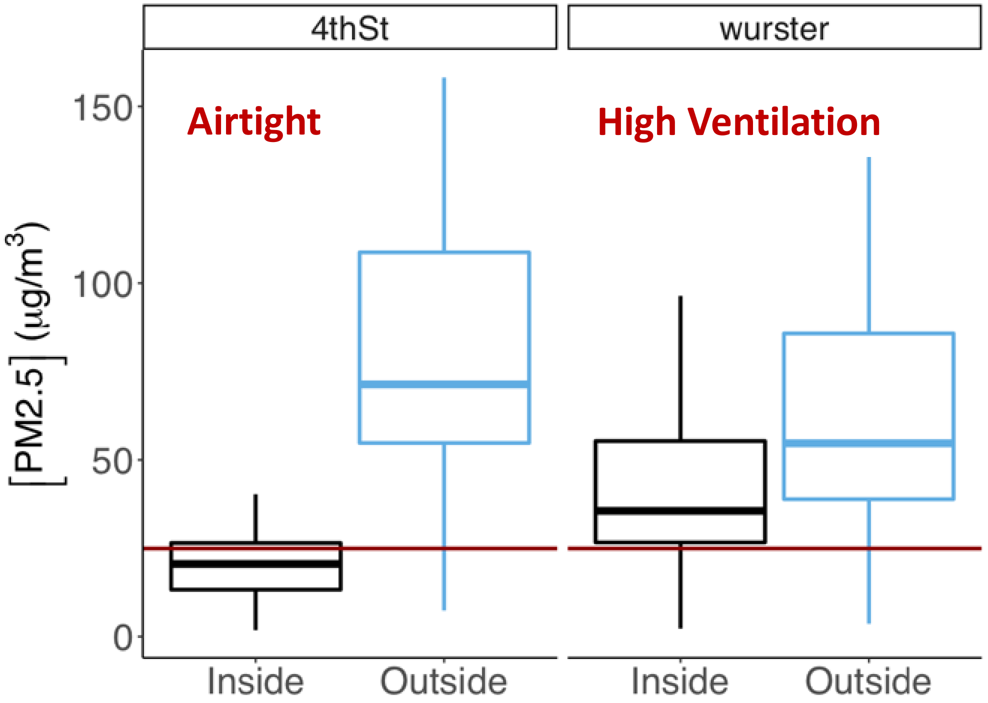
Unintentional Disparities

vs.

Intentional Disparities

Unintentional Exposure Disparities

Wildfires are an emerging air pollution crisis given changing climate.



Using IoT Sensing to Determine the Resilience of Buildings to Wildfire Pollution

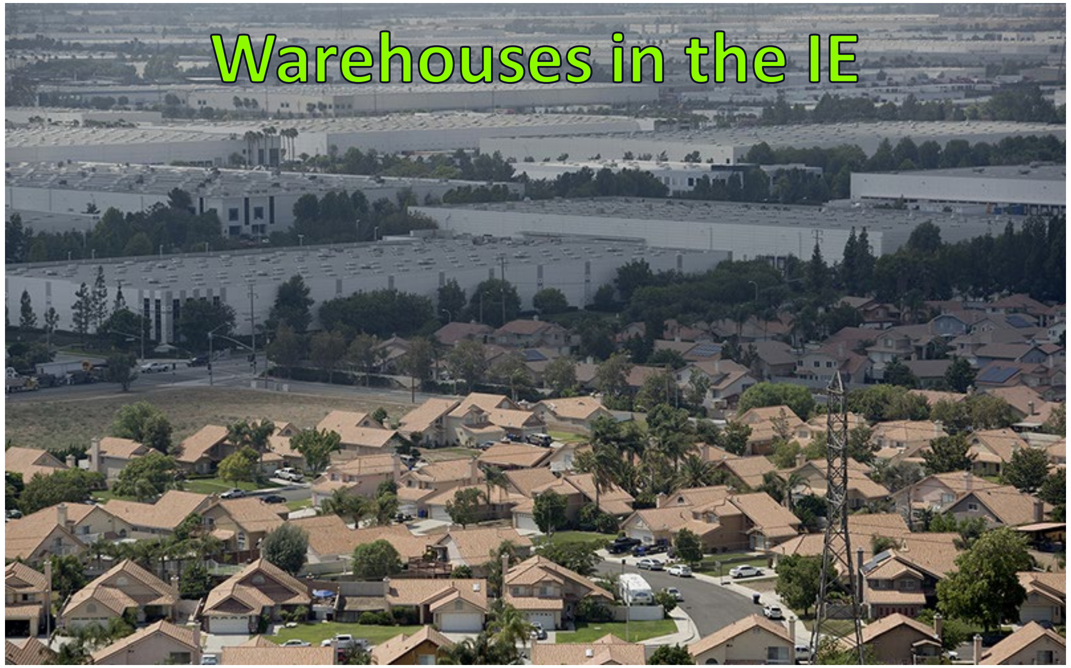
JOVAN PANTELIC AND MEGAN DAWE | JULY 10, 2019

CBE CENTER FOR THE BUILT ENVIRONMENT

Intentional Exposure Disparities

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

Where you live and the local decisions on land use have grave consequences. Inland Empire residents live in close proximity to commercial and industrial sources.



CALIFORNIA AIR RESOURCES BOARD

Immediate Action Items

Recent legislation (CA Senate) has been introduced to prevent zoning and development that harms historically burdened communities.

Senator Leyva: "SB 499…will ensure that disadvantaged communities no longer bear a disproportionate burden of pollution and environmental hazards."

Nature 2020: "Those who live in such areas will continue to take a disproportionate hit unless ***land-use equity*** is made a priority in governance."

Ivey, ***Nature***, 2020

Take Home Messages

1. Air pollution modeling has paved the way for understanding source-receptor relationships and associated health impacts at the population scale.

2. Misclassification and confounders complicate our understanding of exposure disparities and implications for health effects and mitigation for underserved communities.

3. Building envelopes are critically important to consider for future exposure-health assessments that rely on ambient source impact data.

4. Mitigation of exposure disparities will require a commitment to sustainable and equitable zoning and development.

Thank you

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering

Cesunica Ivey
AQMEL Principal Investigator

cesunica@ucr.edu

dr_sun_shine

www.iveylab.com

www.iveylab.com

UC RIVERSIDE BREATHE

Bridging Regional Ecology, Aerosolized Toxins, & Health Effects

Center for Geospatial Sciences

UC RIVERSIDE Center for Environmental Research and Technology

UC RIVERSIDE Environmental Toxicology Graduate Program

CELEBRATING 30 YEARS
UCR Marlan and Rosemary Bourns College of Engineering