



# AGENDA

## 33rd CRC REAL WORLD EMISSIONS WORKSHOP

### *Co-Sponsors*

California Air Resources Board  
Truck and Engine Manufacturers Association  
US EPA  
South Coast Air Quality Management District  
National Renewable Energy Laboratory

### *Workshop Organizers*

Mike Viola, General Motors (Co-Chair)  
Jim Baustian, BP (Co-Chair)  
Michael Aldridge, US EPA  
Sam Cao, SCAQMD  
Tao Huai, CARB  
Yusuf Khan, Cummins  
Andrew Kotz, NREL  
Joseph Martin, US EPA  
Rada Purushothaman, Caterpillar  
Heidi Vreeland, US EPA  
Seungju Yoon, CARB

Renaissance Long Beach Hotel, Long Beach, California  
March 26-29, 2023

The purpose of this workshop is free exchange of ideas, research, data, etc. Please do not record or take photos of presentations. All submitted presentation content will be available to participants in the Workshop Proceedings. Sponsorship of or participation in the workshop by CRC or others does not reflect any endorsement of information.

## Sunday, March 26, 2023

4:30-6:00 PM Registration and Poster Setup in Farrell's Lounge

6:00-7:00 PM Welcome Reception in SIP Patio

## Monday, March 27, 2023

*All sessions take place in Bixby Ballroom, unless otherwise noted*

7:00 AM Registration in Bixby Foyer and Continental Breakfast in Farrell's Lounge

8:00 AM Welcome from the Chairs: Mike Viola, General Motors, & Jim Baustian, BP

8:15 AM **Keynote Address: Jed R. Mandel**  
**President, Truck & Engine Manufacturers Association**

### SESSION 1

9:00 AM **In-Use Emissions for Light- and Heavy- Duty Vehicles**

*Introduction by Session Leaders: Andrew Kotz, NREL and Tao Huai, CARB*

9:05 AM USE OF REMOTE SENSING DATA TO ASSESS I/M PROGRAM EFFECTIVENESS Jim Lyons Trinity Consultants

9:20 AM INVESTIGATION OF FLEET EMISSIONS USING ENHANCED INSPECTION AND MAINTENANCE METHODS Daisy Thomas 3DATX

9:35 AM INFLUENCE OF SNOWFALL ON CO2 AND NOX EMISSIONS OF WINTER MAINTENANCE VEHICLES Will Northrop University of Minnesota

9:50 AM OVERVIEW OF DIESEL ENGINE MANUFACTURERS' DF VALIDATION RESULTS Precious Ofoegbu California Air Resources Board

10:05 AM **Poster Session and Demonstrations in Farrell's Lounge**

10:40 AM IN-USE EMISSIONS TESTING AND FUEL USAGE PROFILE OF ON-ROAD HEAVY-DUTY VEHICLES – 200 VEHICLE STUDY – NOX EMISSIONS Tom Durbin University of California, Riverside

10:55 AM ANALYSIS AND EVALUATION OF SENSOR-BASED ONBOARD SENSING, ANALYSIS, AND REPORTING (OSAR) FROM SEVERAL CLASS 8 TRUCKS DURING A LONG TERM MEASUREMENT STUDY Grace Johnson University of California Riverside

11:10 AM CHARACTERIZATION OF IN-USE HEAVY-DUTY DIESEL TRUCK EMISSION RATES OVER THE PAST DECADE AND EMISSION CONTROL TECHNOLOGY PERFORMANCE Chelsea Preble UC Berkeley

11:25 AM IMPACT OF LOW AMBIENT TEMPERATURE ON THE TAILPIPE EMISSIONS OF A 2027 HEAVY DUTY LOW NOX ENGINE ON REAL-WORLD DUTY CYCLES Bryan Zavala Southwest Research Institute

11:40 AM EVALUATING THE IMPACT OF CONNECTED VEHICLE TECHNOLOGY ON HEAVY-DUTY VEHICLE EMISSIONS Stanislav Gankov Southwest Research Institute

11:55 AM General Discussion and Open Q & A

12:15 PM **Lunch Break in Banyan Court and Lawn**

### SESSION 2

1:45 PM **Emissions Control Measures**

*Introduction by Session Leader: Seungju Yoon, CARB*

1:50 PM LONG-TERM TRENDS OF IN-USE NOX AND CO2 EMISSIONS FROM HEAVY-DUTY ON-ROAD VEHICLES IN CALIFORNIA Georges Saliba California Air Resources Board

2:05 PM COMPREHENSIVE INTEGRATED SIMULATION FOR ENABLING NEAR ZERO EMISSION VEHICLES Andrea Strzelec University of Wisconsin-Madison

2:20 PM EVALUATION OF EMISSION WARRANTY COST ESTIMATION METHODS FOR THE CALIFORNIA AIR RESOURCES BOARD'S HEAVY-DUTY ENGINE AND VEHICLE OMNIBUS REGULATION Shunsuke Nakao California Air Resources Board

2:35 PM PM EMISSION BENEFITS FROM A NEW U.S. LIGHT-DUTY VEHICLE STANDARD Michael Geller MECA Clean Mobility

2:50 PM General Discussion of Session 2

3:00 PM **Poster Session and Demonstrations in Farrell's Lounge**

**Monday, March 27, 2023**

**SESSION 3**

3:30 PM	<b>Off Road / Non-Road</b>		
	<i>Introduction by Session Leader: Rada Purushothaman, Caterpillar</i>		
3:35 PM	CARB'S OFF-ROAD IN-USE COMPLIANCE PILOT PROGRAM	Hyun Ji (Julie) Lee	California Air Resources Board
3:50 PM	MODELING SPATIAL VARIABILITY IN LOCOMOTIVE FUEL USE AND EMISSION RATES BASED ON REAL-WORLD MEASUREMENTS	Tongchuan Wei	North Carolina State University.
4:05 PM	DEVELOPMENT OF AN OFF-ROAD EMISSIONS SCREENING PROCEDURE FOR ANALYZING IN-USE EMISSIONS USING A THREE-BIN MOVING AVERAGE WINDOW (3B-MAW) METHOD.	Christian Bartolome	California Air Resources Board
4:20 PM	General Discussion of Session 3		
4:30 PM	Logistics for Dinner Event	Jan Tucker	Coordinating Research Council, Inc.
4:35 PM	<b>END OF DAY</b>		
5:45 PM	Meet in Lobby to Leave for Networking Dinner, Last Bus Leaving at 6:00 PM		

## Tuesday, March 28, 2023

7:00 AM	Registration in Bixby Foyer and Continental Breakfast in Farrell's Lounge
8:00 AM	Keynote Introduction by Workshop Co-Chair, Mike Viola, General Motors
8:05 AM	<b>Keynote Address: Chris Tennant, Coordinating Research Council</b>

### SESSION 4

8:50 AM	<b>Electric and Hybrid Vehicles</b>		
	<i>Introduction by Session Leader: Andrew Kotz, NREL</i>		
8:55 AM	POTENTIAL EMISSION BENEFITS OF ZERO EMISSION TECHNOLOGY ADOPTION SCENARIOS IN OFF-ROAD EQUIPMENT SECTORS	Junhyeong Park	California Air Resources Board
9:10 AM	CHALLENGES FOR REALGHG REDUCTION UNDER CURRENT TAILPIPE REGULATIONS	Graham T Conway	Southwest Research Institute
9:25 AM	ACTIVITY AND PERFORMANCE FOR HEAVY-DUTY DIESEL AND BATTERY ELECTRIC VEHICLES IN REAL-WORLD OPERATIONS	Tianyi (Jerry) Ma	UC Riverside, CE-CERT
9:40 AM	General Discussion of Session 4		
9:50 AM	<b>Poster Session and Demonstrations in Farrell's Lounge</b>		

### SESSION 5

10:15 AM	<b>Improving the Emissions Inventory</b>		
	<i>Introduction by Session Leader: Sam Cao, SCAQMD</i>		
10:20 AM	A TALE OF TWO FLEETS: RSD MEASUREMENTS IN NORTHERN BAJA, MEXICO AND IMPLICATIONS FOR THE BORDER EMISSIONS INVENTORY	John Koupal	Eastern Research Group
10:35 AM	NEXT STEP OF EMFAC DEVELOPMENT: HIGHER SPATIAL RESOLUTION EMISSION INVENTORY	Jiachen Zhang	California Air Resources Board
10:50 AM	APPLICATION OF AUTOMATED LICENSE PLATE READERS (ALPR) FOR FLEET CHARACTERIZATION AND EMISSIONS INVENTORY	Sara Forestieri	California Air Resources Board
11:05 AM	APPLYING REAL-WORLD HEAVY-DUTY EMISSIONS DATA TO INFORMING INVENTORY DEVELOPMENT – DATA ANALYSIS ON PEMS	Mo Chen	California Air Resources Board
11:20 AM	CONTINUED AND EXPANDED REMOTE SENSING MEASUREMENTS OF THE CALIFORNIA VEHICLE FLEET	Alan Stanard	Eastern Research Group
11:35 AM	WHEN AND WHERE SUPER-CLEAN GASOLINE- AND DIESEL-POWERED VEHICLES OUTPERFORM ZEVS ON CRITERIA POLLUTANT EMISSION REDUCTIONS	Gary Yowell	Stillwater Associates
11:50 AM	General Discussion of Session 5		
12:00 PM	<b>Lunch in Pike Ballroom</b>		

## DAY TWO Tuesday, March 15, 2022

### SESSION 6

1:30 PM	<b>Emissions Modeling</b>		
	<i>Introduction by Session Leader: Michael Aldridge, US EPA</i>		
1:35 PM	A FINE-SCALE ROADWAY EMISSIONS INVENTORY FOR SAN FRANCISCO BAY AREA USING TELEMATICS-BASED DATA AND EMFAC2021	Yuan Du	Bay Area Air Quality Management District
1:50 PM	EVALUATION OF MODEL PREDICTIONS OF REAL-WORLD EMISSION HOTSPOTS BASED ON MEASURED VEHICLE ACTIVITY AND EMISSIONS	Christina Quaassdorff	Technical University of Madrid / NC State University
2:05 PM	SWITCHING FROM MOVES2014B TO MOVES3: CHANGES IN EMISSION RATES AND IMPLICATIONS ON AIR QUALITY PLANNING	Chaoyi Gu	Texas A&M transportation Institute
2:20 PM	EPA PLANS FOR ELECTRIC VEHICLES MODELING DEVELOPMENT IN MOVES	Tiffany Mo	U.S. EPA Office of Transportation and Air Quality (OTAQ)
2:35 PM	PREDICTING HEAVY-DUTY VEHICLE EMISSIONS USING ADVANCED MACHINE LEARNING ALGORITHMS	Abdul Motin Howlader	California Air Resources Board
2:50 PM	General Discussion of Session 6		

### 3:00 PM Poster Session and Demonstrations in Farrell's Lounge

### SESSION 7

3:30 PM	<b>Air Quality / Effects of COVID-19 on Air Quality</b>		
	<i>Introduction by Session Leader: Heidi Vreeland, US EPA</i>		
3:35 PM	NEW EUROPEAN STANDARDISED METHOD FOR MEASURING PARTICLE AND CARBON DIOXIDE POLLUTION IN THE VEHICLE CABIN	Nick Molden	Emissions Analytics Ltd
3:50 PM	COVID-19 PANDEMIC EFFECTS ON VEHICLE ACTIVITY AND EMISSIONS	Allison DenBleyker	Eastern Research Group
4:05 PM	USE OF LINEAR REGRESSION TECHNIQUES FOR DEMONSTRATING THE EXCEPTIONAL IMPACT OF THE COVID-19 HEALTH EMERGENCY ON OZONE AIR QUALITY IN THE DISTRICT OF COLUMBIA	Joseph Jakuta	District of Columbia Department of Energy and the Environment
4:20 PM	COVID-19 AND VEHICLE EMISSIONS INSPECTION FRAUD IMPACT	Chris Klaus	NCTCOG
4:35 PM	General Discussion of Session 7		
4:45 PM	<b>END OF DAY</b>		
5:30 PM	<b>Poster Session, Demonstrations, and Evening Reception in Farrell's Lounge</b>		

**DAY THREE Wednesday, March 29, 2023**

7:30 AM Registration in Bixby Foyer and Continental Breakfast in Farrell's Lounge

**SESSION 8**

## 8:00 AM Fuel Effects on Emissions

*Introduction by Session Leader: Michael Viola, General Motors*

8:05 AM	EFFECT OF FUEL PROPERTIES ON PM EMISSIONS FROM 4-CYCLE GASOLINE NONROAD ENGINES	Aron Butler	EPA's Office of Transportation and Air Quality
8:20 AM	LOW-CARBON SYNTHETIC FUELS FOR ULTRA-LOW TAILPIPE EMISSIONS IN THE LIGHT-DUTY VEHICLE SECTOR	Alexander Voice	Aramco Americas
8:35 AM	SHORT-TERM FUEL IMPACTS ON TAILPIPE EMISSIONS FROM A 2027 HEAVY-DUTY LOW NOX ENGINE	Chris Sharp	Southwest Research Institute
8:50 AM	General Discussion of Session 8		

**SESSION 9**

## 9:00 AM Brake and Tire Wear

*Introduction by Session Leader: Seungju Yoon, CARB*

9:05 AM	DEVELOPMENT OF NEW BRAKE WEAR EMISSION RATES FOR EPA'S MOVES MODEL	Michael Aldridge	U.S. EPA Office of Transportation and Air Quality
9:20 AM	TRACE METALS AND CHEMICAL COMPOSITION ANALYSIS FROM BRAKE WEAR PARTICULATE MATTER (BWPM) EMISSION AMONG DIFFERENT BRAKING PAD MATERIAL TYPES ON LIGHT-DUTY VEHICLE BRAKING SYSTEMS	Chia-Li Chen	California Air Resources Board
9:35 AM	ELEMENTAL CONTENT OF BRAKE AND TIRE WEAR PM2.5 AND PM10 AT NEAR-ROAD ENVIRONMENTS.	Brenda Lopez	University of California Riverside
9:50 AM	CHARACTERIZING PARTICLE SIZE DISTRIBUTION AND TOXICITY OF BREAK AND TIRE WEAR EMISSIONS	Molly Haugen	University of Cambridge
10:05 AM	General Discussion of Session 9		
10:15 AM	<b>Poster Session and Demonstrations in Farrell's Lounge</b>		

**SESSION 10**

## 10:45 AM Emissions Measurements Methods

*Introduction by Session Leaders: Tao Huai, CARB and Joe Martin, US EPA*

10:50 AM	DEVELOPMENT, APPLICATION, AND DEMONSTRATION OF A SENSOR-BASED ONBOARD SENSING, ANALYSIS, AND REPORTING (OSAR) FOR EMISSION AND ACTIVITY DATA COLLECTION	Kent Johnson	University of California, Riverside
11:05 AM	PEAQs EMISSION CLUSTERING FOR CLASSIFYING HIGH-EMITTING HD TRUCKS	Daniel Phillips	California Air Resources Board
11:20 AM	A COMPREHENSIVE EVALUATION OF ALL THE NEW STATE OF THE ART 1065 COMPLIANT PEMS DESIGNED FOR EMISSIONS AT AND BELOW 0.05 G/HP-HR NOX.	Kent Johnson	University of California, Riverside
11:35 AM	HORIBA TORQUE MATCHING – ELIMINATING THE NEED FOR ON-ROAD EMISSIONS MEASUREMENT	Alex Mason	HORIBA MIRA
11:50 AM	General Discussion of Session 9		

## 12:00 PM Lunch in Pike Ballroom

**SESSION 11**

1:20 PM	<b>Particulate Emissions and Measurement</b>		
	<i>Introduction by Session Leader: Yusuf Khan, Cummins, Inc and Heidi Vreeland, US EPA</i>		
1:25 PM	DRIVE CYCLE PM MASS MEASUREMENTS CAPABLE OF RESOLVING GPF-LEVEL EMISSIONS FROM LIGHT-DUTY VEHICLES	Stanislav Bohac	U.S. EPA Office of Transportation and Air Quality
1:40 PM	LUBE OIL EFFECTS ON PARTICLE EMISSIONS FROM A GDI ENGINE OPERATING ON HIGH AND ULTRA-LOW PMI GASOLINE FUEL	Imad Khalek	Southwest Research Institute
1:55 PM	APPARENT TEMPERATURE DEPENDENT REMOVAL EFFICIENCY OF CRANKCASE CONTROL DEVICES	David Kittelson	University of Minnesota
2:10 PM	ASSESSMENT OF CPC-BASED PN-PEMS FOR HEAVY-DUTY CNG ENGINES	Thinnes Ragupathy	Western Michigan University
2:25 PM	EVALUATION OF PM AND SUB-23 NM PARTICLE NUMBER EMISSIONS FROM A HEAVY-DUTY DIESEL VEHICLE DURING ON-ROAD OPERATION	Tianyi (Jerry) Ma	UC Riverside, CE-CERT
2:40 PM	General Discussion of Session 9		
2:50 PM	<b>Closing Remarks from Real World Group Chairs</b> <b>Jim Baustian, BP</b> <b>Mike Viola, General Motors</b>		
3:00 PM	<b>END OF WORKSHOP</b>		

## POSTERS

### EMISSIONS CONTROL MEASURES: I/M, OBD, TECHNOLOGIES AND STRATEGIES

INCORPORATING NOX TEST IN ENHANCED I/M – ANALYSIS OF METHODS	Daisy Thomas	3DATX
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### IN-USE HEAVY DUTY

CHARACTERIZING IN-USE STREET SWEEPER ACTIVITY AND EMISSIONS	George Scora	University of California Riverside
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### IN-USE LIGHT DUTY

AN ANALYSIS OF THE BENEFITS OF AN I/M PROGRAMS, PAST, PRESENT, AND FUTURE	Jim Lyons	Trinity Consultants
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ROADSIDE LIGHT-DUTY VEHICLE EMISSIONS IN UTAH VALLEY	Darrell Sonntag	Brigham Young University
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### OFF-ROAD/NON-ROAD

EMISSION TESTING OF COMMERCIAL HARBOR CRAFT (CHC) USING MINI-PEMS	Tianbo Tang	University of California Riverside
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COLLECTION OF AGRICULTURAL EQUIPMENT ACTIVITY DATA	Chas Frederickson	University of California Riverside
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CARB'S OFF-ROAD LARGE SPARK IGNITION (LSI) ENGINE IN-USE COMPLIANCE PROGRAM	Axel Freund	California Air Resources Board
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### AIR QUALITY

HYPER-LOCAL REAL TIME AIR QUALITY MAP ENABLED BY A NETWORK OF VEHICLES EQUIPPED WITH AIR QUALITY SENSORS	Heejung Jung	University of California Riverside
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FUNDING OPPORTUNITIES OVERVIEW	Chris Klaus	NCTCOG
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### ELECTRIC AND HYBRID VEHICLES

ACTIVITY DATA OF ZERO AND NEAR-ZERO EMISSIONS VEHICLES AND EQUIPMENT	Chas Frederickson	University of California, Riverside
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EMISSIONS AND PERFORMANCE INVESTIGATIONS OF A CNG PLUG-IN HYBRID ELECTRIC HEAVY-DUTY TRUCK	Tianyi (Jerry) Ma	University of California, Riverside
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### EMISSIONS MODELING

DIGITAL TWINNING – IMPROVING VEHICLE AND POWERTRAIN DEVELOPMENT AND EFFICIENCY USING VIRTUAL TESTING	Alex Mason	HORIBA MIRA
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AN IDEA FOR TRADING CARBON AND EMISSIONS USING ON-BOARD MEASUREMENT: UNLOCK THE BENEFIT TO INDUSTRY AND INNOVATION	Kent Johnson	University of California Riverside
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DATABASE FOR AIR QUALITY AND NOISE ANALYSIS (DANA) TOOL	Chris Dresser	Federal Highway Administration
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FHWA MOVES3 SENSITIVITY ANALYSIS	Chris Dresser	Federal Highway Administration
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REVS: A NEW APPROACH TO DYNAMIC EMISSIONS MODELLING	Nick Molden	Emissions Analytics Ltd
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EPA PLANS FOR MOVES DEVELOPMENT	Megan Beardsley	EPA's Office of Transportation and Air Quality
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<b>IMPROVING THE EMISSIONS INVENTORY</b>		
CALCULATING THE IMPACT OF NRMM EMISSIONS FROM THE CONSTRUCTION SECTOR IN THE UNITED KINGDOM.	Carl Desouza	Imperial College London
AIR CONDITIONING REFRIGERANT LEAKAGE FOR MODEL YEARS 2021-2023 HEAVY-DUTY VEHICLES CERTIFIED FOR SALE IN CALIFORNIA	Rajvir Nijjar	California Air Resources Board
<b>EMISSIONS MEASUREMENT METHODS</b>		
IN-SITU AND HANDHELD SUB-PPM LASER-BASED SENSORS FOR VEHICULAR EXHAUST MANAGEMENT AND REPORTING	Ritobrata Sur	Indrio Technologies
SAMPLING AND ANALYZING REFRIGERANT LEAKAGE AT CALDECOTT TUNNEL	Tao Zhan	California Air Resources Board
ESTIMATING UP AND DOWN-DRAFT PLUME CAPTURE EFFECTIVENESS USING REPEAT VEHICLE OBSERVATIONS AT A SEMI-PERMANENT DEPLOYMENT OF THE PEAQS SYSTEM.	Michael R Olson	California Air Resources Board
TORQUE MATCHING METHOD BRINGS LABORATORY PRECISION TO REAL WORLD TESTING	Leo Breton	HORIBA Instruments, Inc.
<b>BRAKE AND TIRE WEAR</b>		
COMPARATIVE CHEMICAL COMPOSITION OF US AND EUROPEAN TYRES, AND THEIR EMISSIONS OF 6PPD	Nick Molden	Emissions Analytics Ltd
<b>FUEL EFFECTS ON EMISSIONS</b>		
AMMONIA AND NITROUS OXIDE EMISSIONS EVALUATION FROM A FLEET OF GDI AND PFI VEHICLES OPERATED ON E10 AND E15 FUELS	Tianbo Tang	University of California Riverside
REAL-WORLD EMISSIONS OF VOLATILE ORGANIC COMPOUND SPECIES BETWEEN DIFFERENT GASOLINE FORMULATIONS	Nick Molden	Emissions Analytics Ltd
<b>PARTICULATE EMISSIONS AND MEASUREMENT</b>		
EFFECTS OF POROSITY, WALL THICKNESS AND LENGTH ON THE FILTRATION EFFICIENCY OF GASOLINE PARTICULATE FILTERS	Fadi Araji	Environment and Climate Change Canada
ON ROAD PM AND PARTICLE NUMBER EMISSIONS COMPARISON BETWEEN DIESEL AND NATURAL GAS HEAVY-DUTY TRUCKS	Zisimos Toumasatos	University of California Riverside
NEW OXIDATION FLOW REACTOR FOR SECONDARY AEROSOL STUDIES	Erkki Lamminen	Dekati Ltd.

**DEMONSTRATIONS**

FAST RESPONSE EMISSIONS ANALYZERS

Jerry Hall

Cambustion

AVL PEMS SOLUTIONS

Meagan Cortez

AVL

**NOTES**