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Summary of Transportation-Related Research in ORD

Rich Baldauf

EPA STAR Grant Meeting

March. 5, 2014

Ann Arbor, MI

Office of Research and Development
National Risk Management Research Laboratory/Air Pollution Prevention and Control Division

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Overview

- Introduction
  - Overall Research Approach
  - Implementation Process
- Research Programs
  - Facilities/Capabilities
  - Example Projects
  - Example Results
- Future Work

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Introduction

- Transportation research in ORD integrates many disciplines to meet scientific and programmatic needs on emissions, air quality, exposures, and health effects
- This research also addresses broader scientific questions and community planning issues
  - What mitigation can reduce/eliminate public health concerns related to traffic emission exposures?
  - How can we design more sustainable transportation systems?
  - How can we promote more healthy, livable communities?
- Transportation research in ORD primarily implemented through two programs:
  - Air, Climate and Energy (ACE)
  - Sustainable and Healthy Communities (SHC)

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Research Programs

- **Emissions Characterization**
  - **Chassis Dynamometers**
  - **On-board Measurements (PEMS)**
  - **Analytical Laboratories**
- Air Quality and Exposure Assessments
  - Mobile Monitoring
  - Fixed-site Sampling
  - Portable Sensors
  - Wind Tunnel
  - CFD Modeling
- Health Effects
  - Epidemiological
  - Toxicological

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Emissions Characterization

- Chassis Dynamometers
  - Light-duty car and truck laboratory dynamometer
    - Temperature controlled (-30ºC to 45ºC)
    - Passenger cars, trucks, SUVs
  - Heavy-duty truck laboratory dynamometer
  - Portable light-duty dynamometer
- On-board emissions measurements
  - CO, NO_x, HC, PM
  - Real-world driving
- Analytical laboratories
  - Criteria Pollutants
  - Particulate matter speciation
  - Gaseous VOC speciation

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Recent Projects

- Emissions while operating on **alternative and renewable fuels**
  - Ethanol-blend gasoline
  - Biodiesel
- **In-use and new technology** vehicle emissions
  - Tier 2 Light-Duty
  - Gasoline Direct Injection (GDI)
  - 2010 compliant Heavy-Duty
- Effects of **cold temperature/cold start** conditions
- **Brake and tire** wear (including nano-materials)
- Influence of **driving activity** on emission changes

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Ambient Temperature Effects

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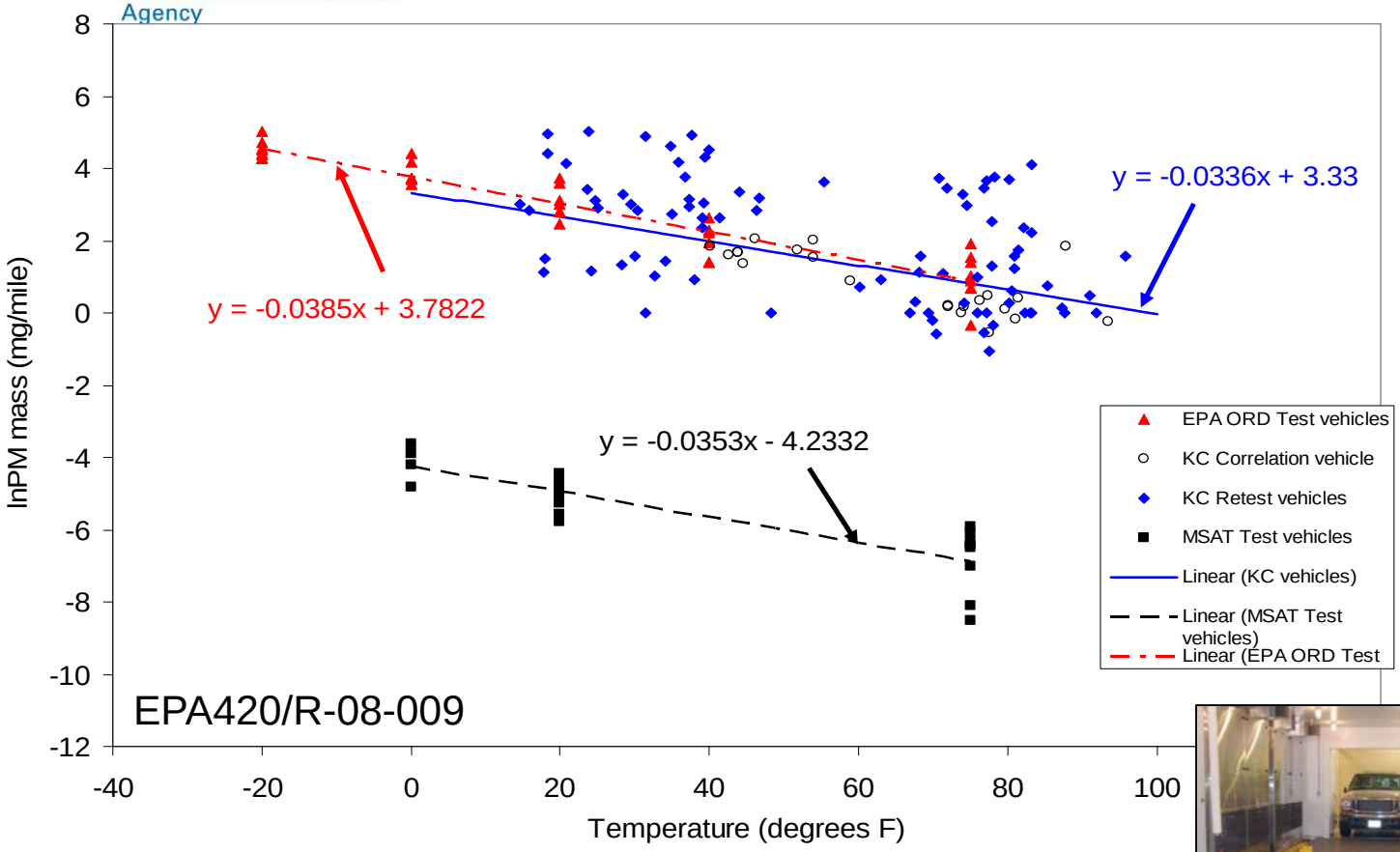

EPA's MOVES emissions model now accounts for ambient temperature effects on PM emissions

Temperature effects have been seen in field and laboratory studies with varying vehicle technologies and fuels

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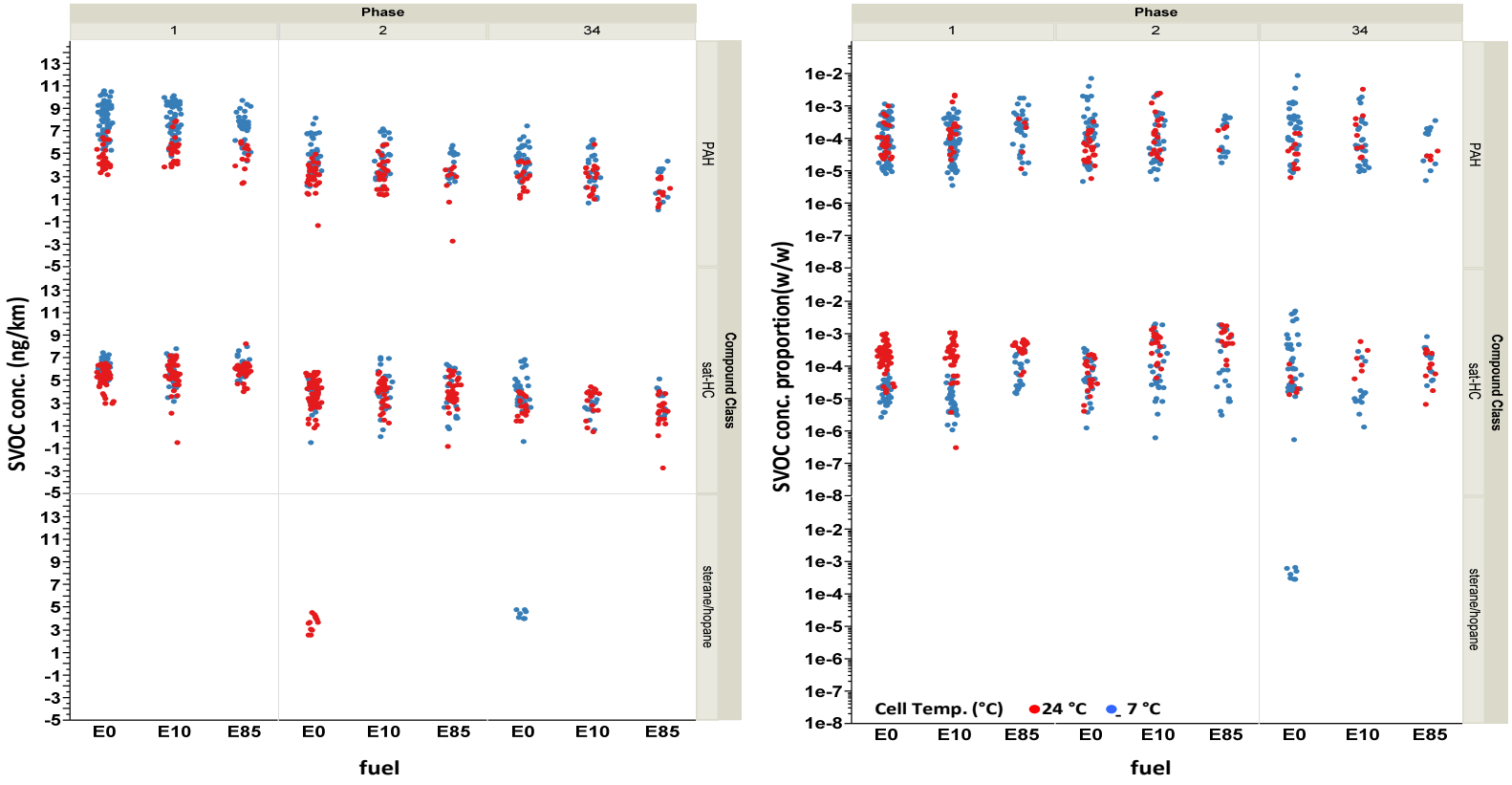
Fuel, Temperature and Driving Effects

Hays et al, E(2013)



Advanced analytical techniques provide speciated PM emissions by operating conditions. Cold temperatures/cold start and high acceleration increased PAH emissions more than saturated-HCs

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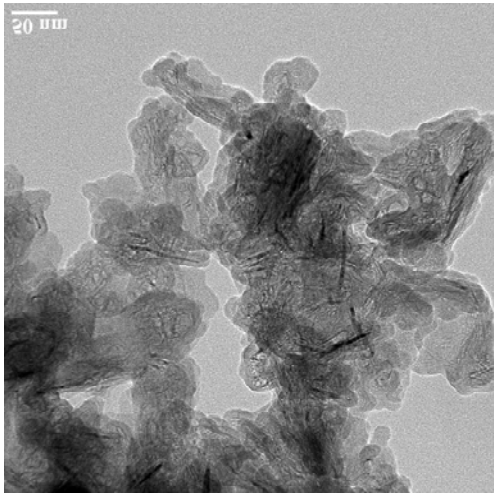
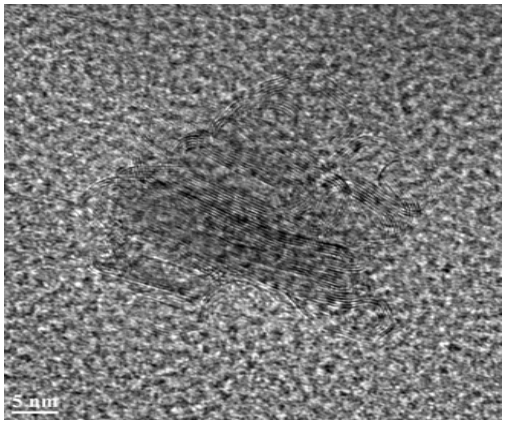
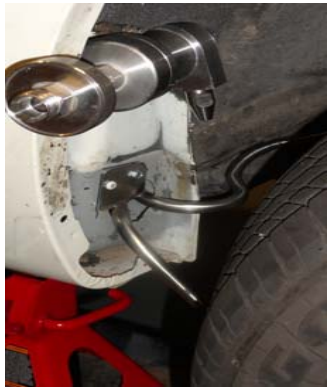
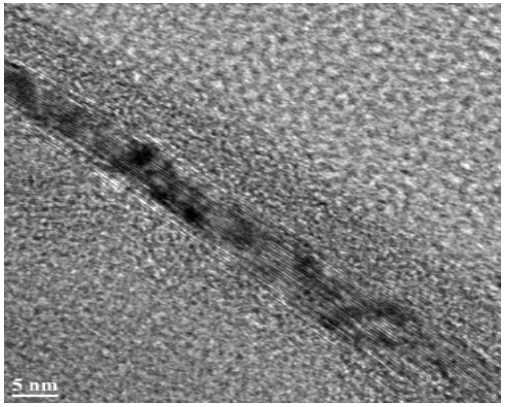
Brake and Tire Wear

PM emissions from brake and tire wear include coarse, fine and ultrafine particles. Nano-materials used in manufacturing can be found in near-source emissions









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Emissions from Aircraft Engines

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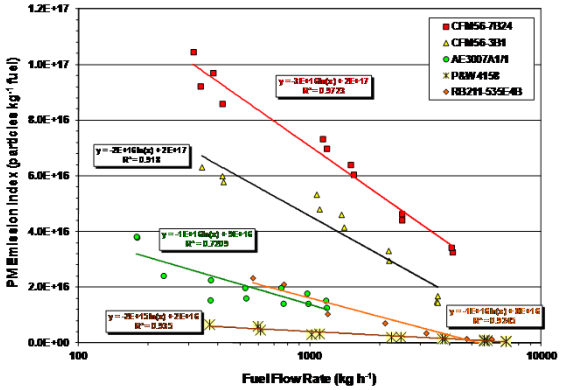
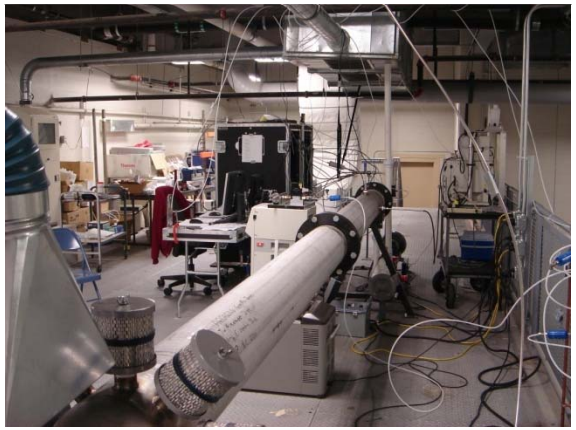
- Aircraft emissions testing conducted at the engine exit, the evolving plume, and under controlled laboratory conditions
  - Black carbon emissions from aircraft engines and similar sources of particular interest
- Standard test method (Aerospace Information Report) has been developed in support of EPA and ICAO





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  - **CFD Modeling**
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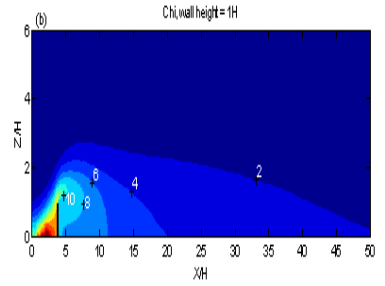
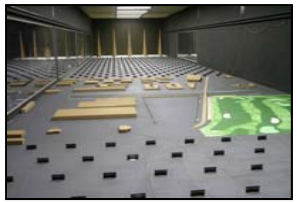
Air Quality and Exposure

- Field measurements of traffic, meteorology and air quality
  - Fixed site measurements
  - Mobile monitoring
  - Portable sampling
- Wind tunnel assessments
  - General road configurations
  - Simulations of field sites
- Modeling assessments
  - Computational Fluid Dynamics (CFD)
  - Research dispersion models (RLINE)
  - EPA regulatory emissions (MOVES) and dispersion (AERMOD) models
  - EPA mapping software (e.g. EnviroAtlas)





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Recent Projects

- Characterize air quality and exposures **near major transportation facilities**
  - Highways
  - Railyards
  - Ports
- Associations among near-road **air quality and adverse health effects**
- Determine the effectiveness of **mitigation** strategies
  - Emission standards
  - Reduced vehicle activity
  - Roadway Design (including noise walls and vegetation)

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FHWA/EPA Near-Road Collaboration

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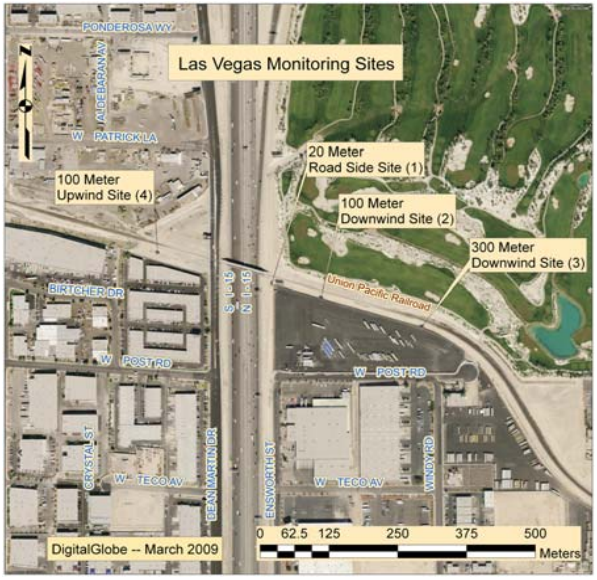
- Long-term near-road studies
  - Three cities
    - Las Vegas
    - Detroit
    - Raleigh
  - Multiple monitoring locations
    - 100 m upwind
    - 20, 100, 300 m downwind
  - Multiple pollutants
    - PM (mass, number, BC)
    - Gases (CO, NO/NO2/NOx)
    - Speciation (VOC, PM)



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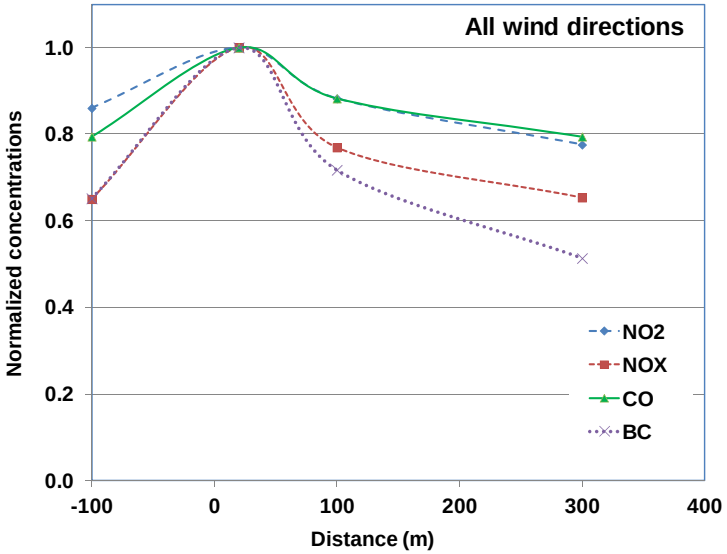
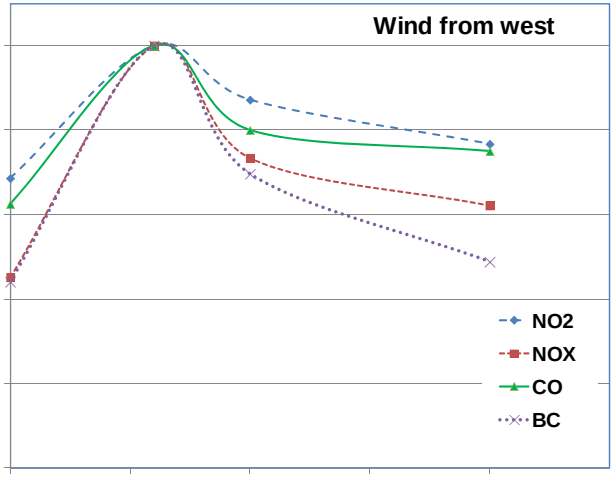
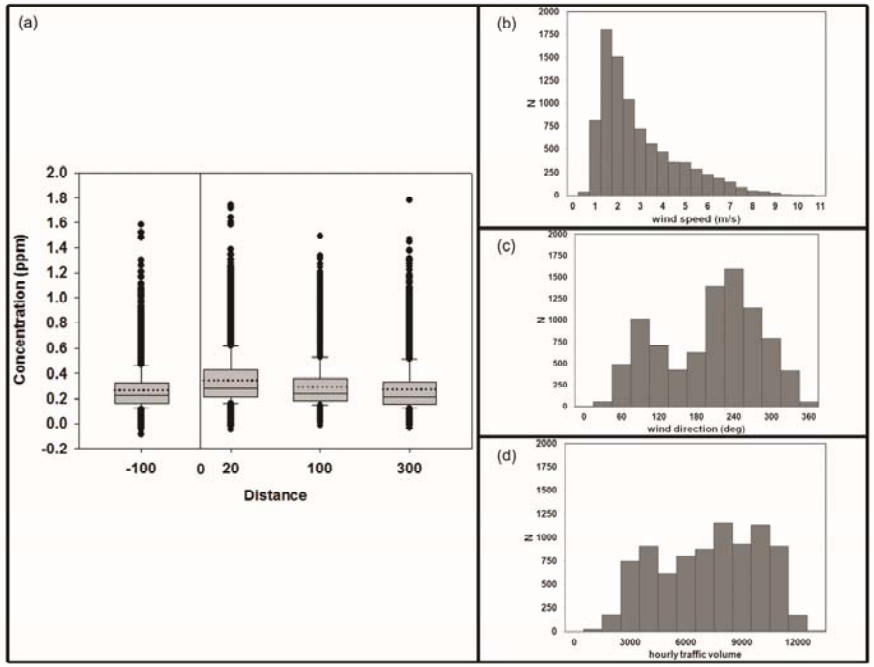




Long-term monitoring provides trends on concentration gradients and associations among key parameters across seasons and varying traffic/meteorological conditions for model evaluation and exposure assessment



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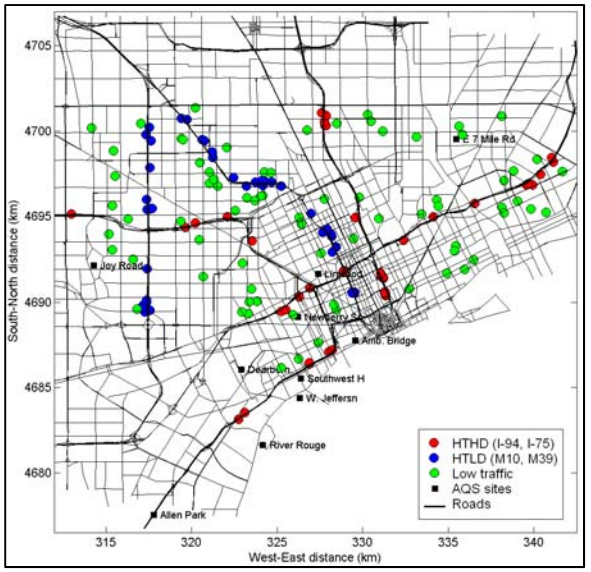
NEXUS

Near-road EXposures and effects of Urban air pollutants Study

United States Environmental Protection Agency

- ORD collaboration with University of Michigan STAR grant
- Exposure and health study
  - Asthmatic children living near major roads in Detroit, MI with different types of traffic:
    - High traffic with high diesel
    - High traffic with lower diesel
    - Low traffic
  - Seasonal respiratory health measurements (Fall 2010 - Fall 2012)
  - Exposures to traffic-related air pollutants estimated using modeling, evaluated with limited measurements



Vette et al. (2013)

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NEXUS

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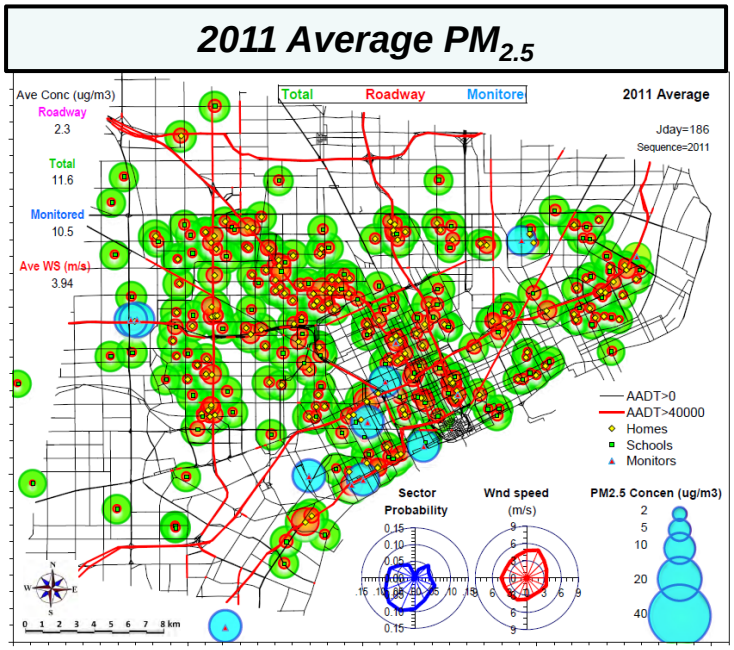
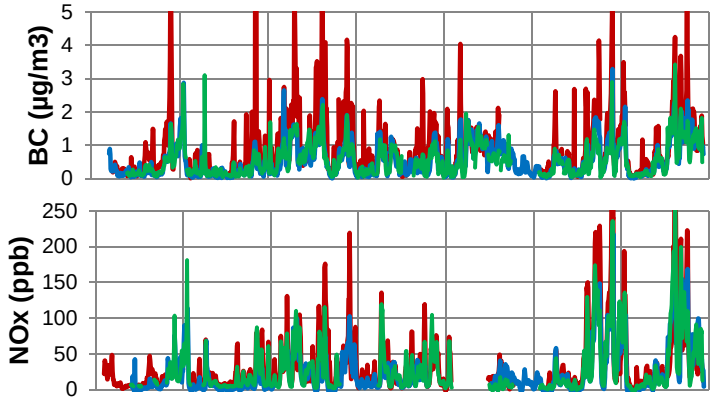
United States Environmental Protection Agency

- Daily pollutant concentration surfaces capture spatial and temporal variability over 2 years of health data for multiple pollutants ($PM_{2.5}$ total/primary, EC from diesel, NO_x, CO)
- Preliminary epidemiology analyses using model-based exposure estimates indicate potential to help discern relationships between traffic-related air pollutants and health outcomes

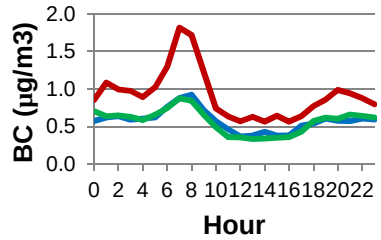


Batterman et al. (2014)



Traffic exposures:

RED *= High traffic / high diesel*
BLUE *= High traffic / low diesel*
GREEN *= Low traffic / low diesel*



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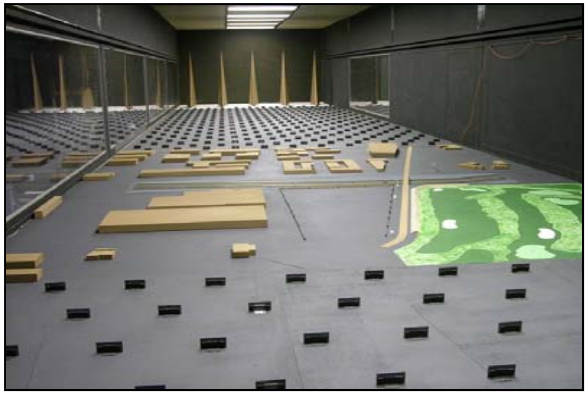
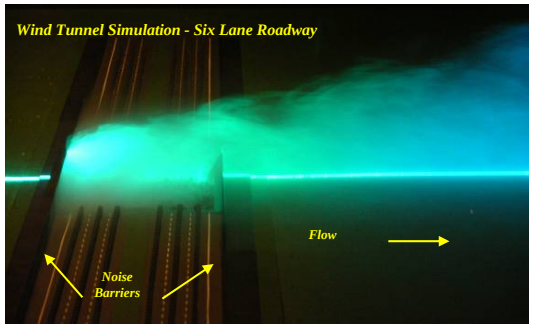
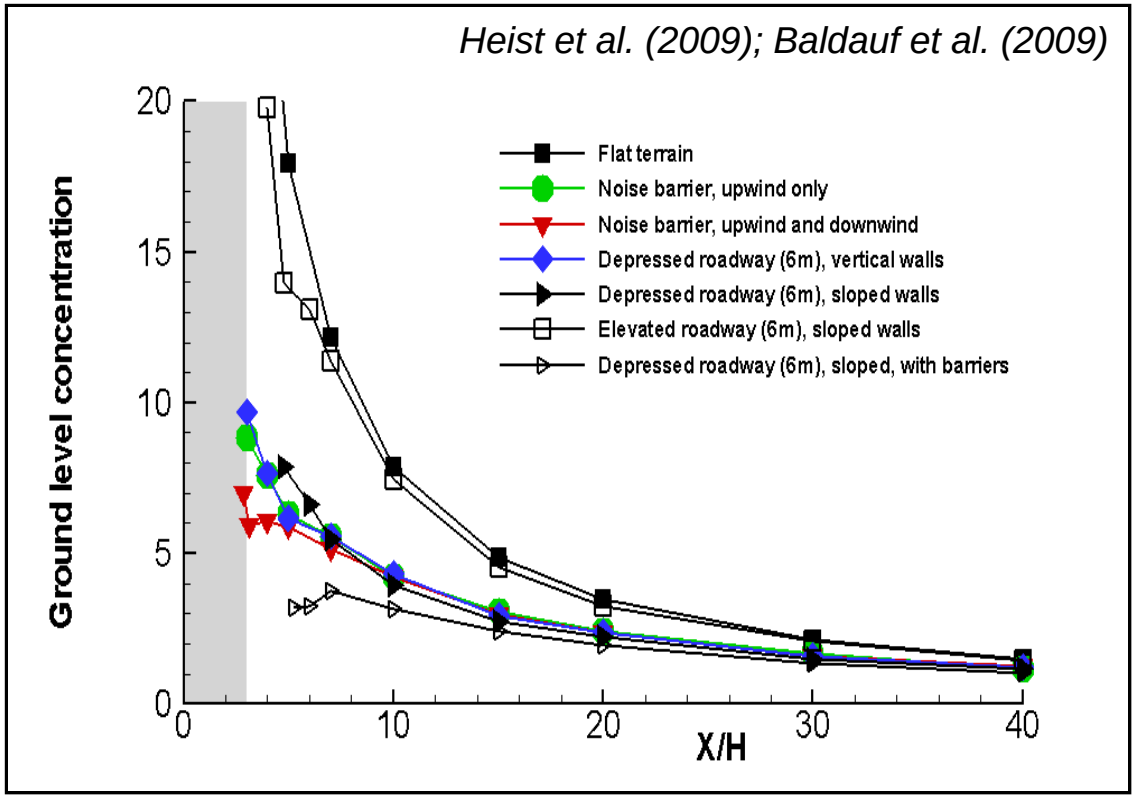
Wind Tunnel Near-Road Assessments

United States Environmental Protection Agency







Wind tunnel simulations show roadway design effects on pollutant transport and dispersion. Highest levels occur with at-grade and elevated fill roads. Lowest levels occur with noise barriers and cut section roads

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Noise Barriers and Vegetation

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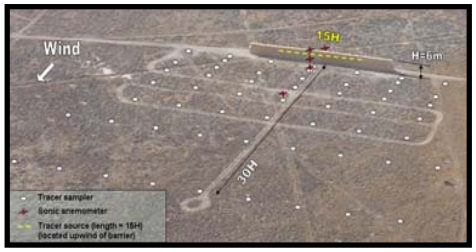
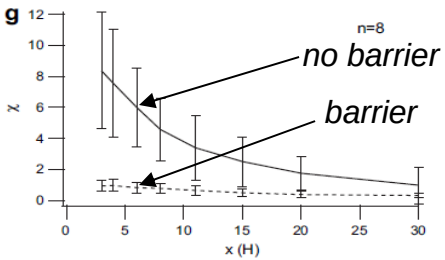
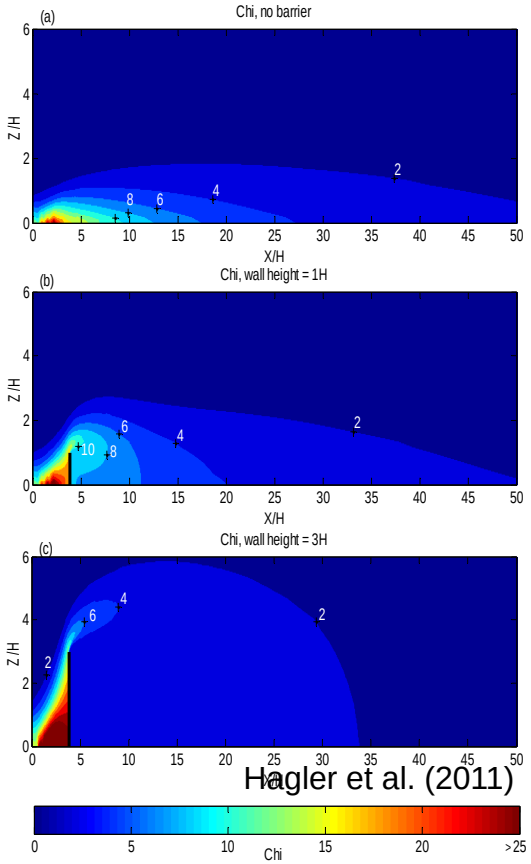
Field, CFD, and wind tunnel studies demonstrate potential of noise barriers and vegetation to reduce downwind air pollutant concentrations

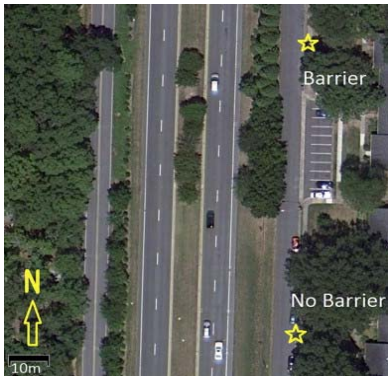


Finn et al., (2010)

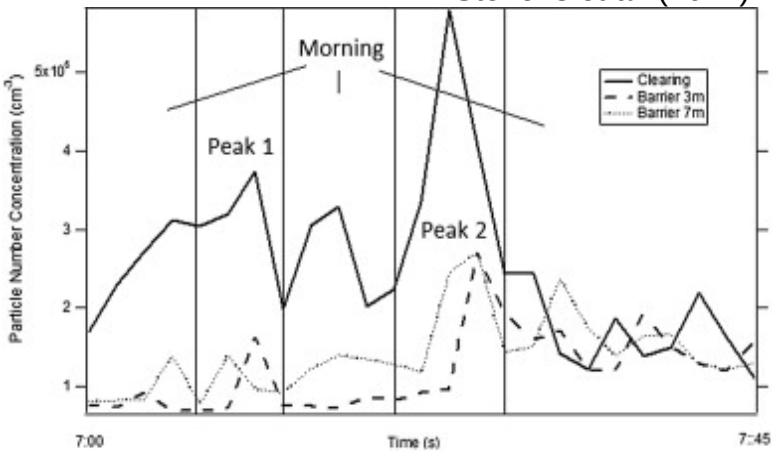




Hagler et al. (2011)



Steffens et al. (2012)



Highlight associations among barriers and air quality. Dispersion models being developed to quantify mitigation potential of barriers

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Near-Source Impacts from Freight Activity

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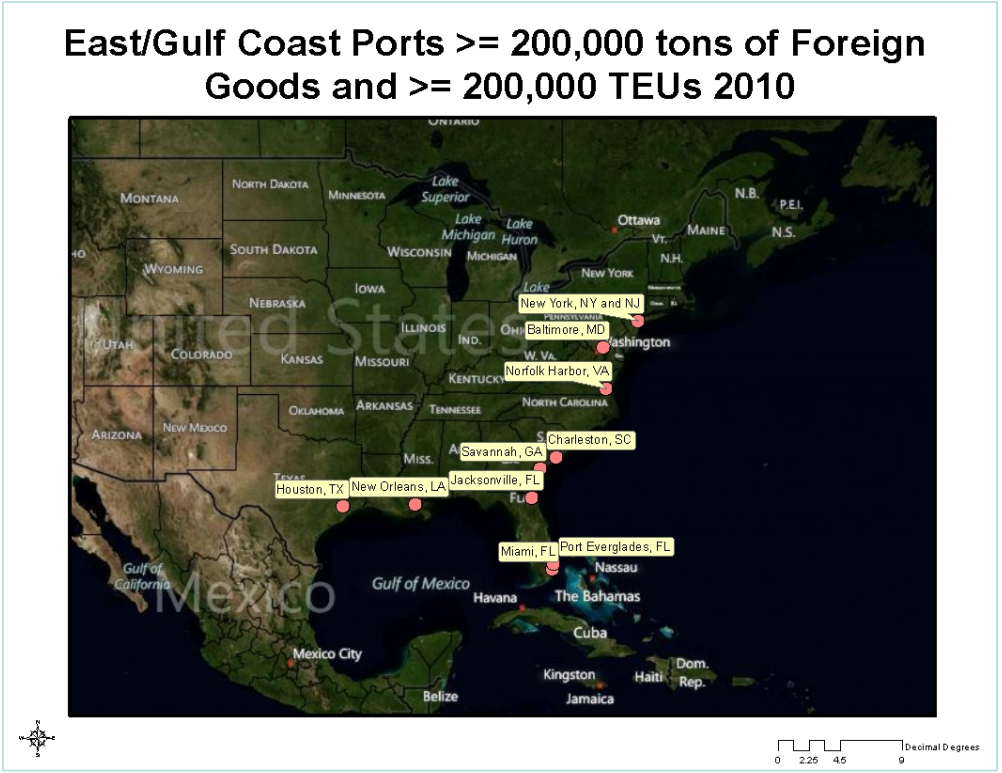
- Multi-modal freight activity can greatly impact local and regional air quality
  - Marine vessels
  - Rail
  - On-road
  - Aircraft
- Panama Canal expansion may further increase freight activity, especially on the US east coast
  - GIS assessment underway on population demographics and baseline air quality near ports and port-related freight corridors



Hagler et al. (2013)

- Developing community-scale model for “what if” scenario assessments

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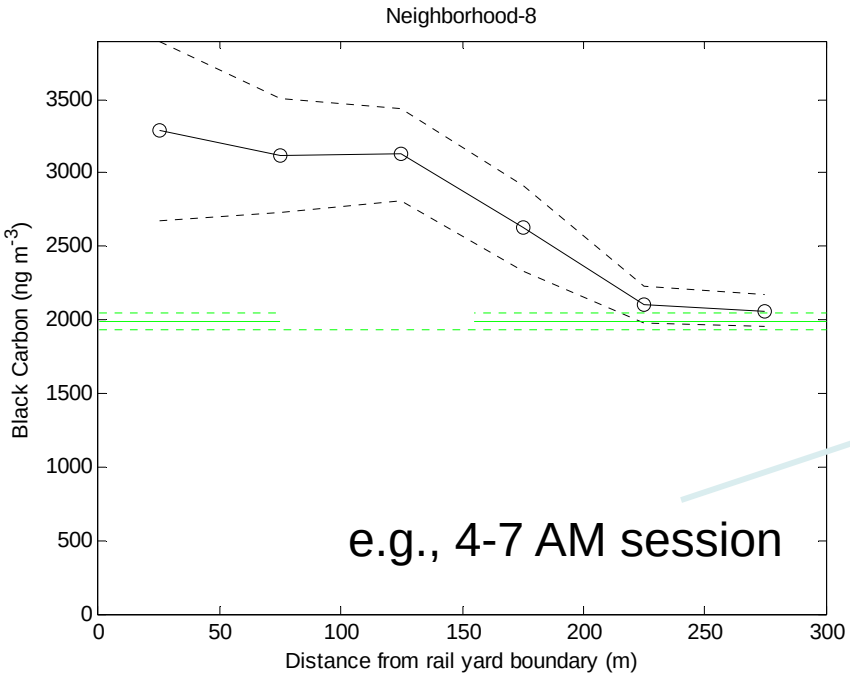
Rail Yard Impacts

United States Environmental Protection Agency

Hagler et al., 2011



Black carbon elevated in downwind residential areas as far as several hundred meters from a Chicago rail yard boundary during early morning and evening periods. Other measurements (PM2.5, PM10, CO, particle count) did not show consistent upwind/downwind differences

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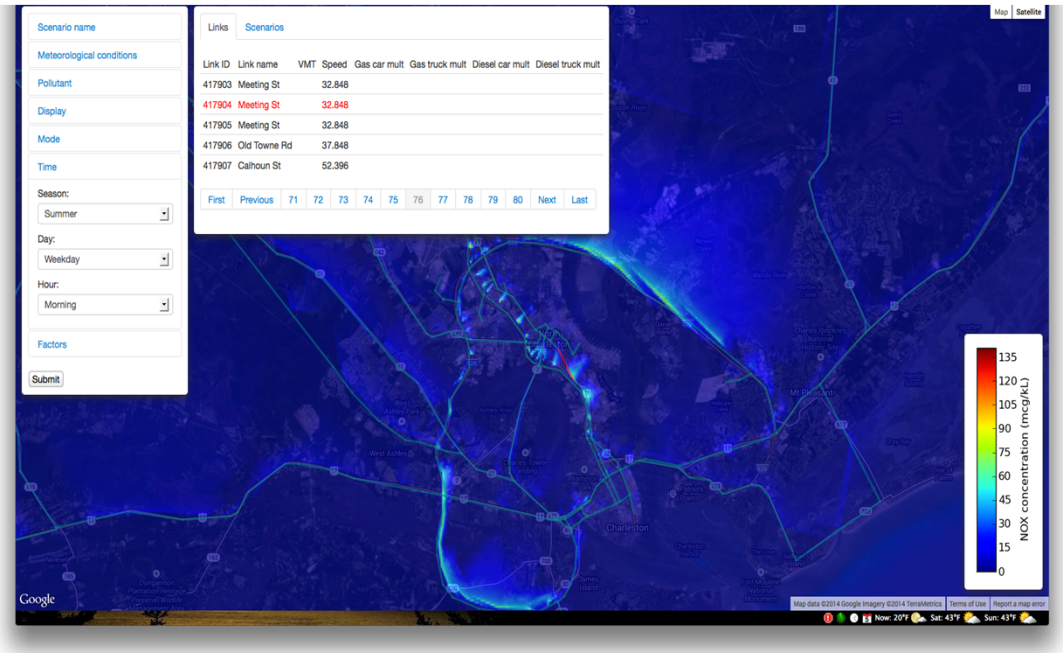
Multi-modal Transportation Modeling

- Interest in reduced-form models capable of local-scale air quality analysis
  - Identify potential locations of elevated air pollution
  - Initial ports focus: Assess ships, truck traffic, rail, and loading activities



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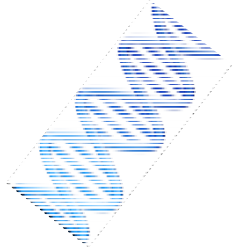
Health Effects Research

Epidemiology

Clinical and Animal Toxicology



Molecular Biology

- Which chemical components of air pollution (either singly or in combination) cause health effects?
- What are the likely sources and do production conditions (e.g. engine type, combustion efficiency, fuel etc) and atmospheric transformation change toxicity?
- Does air pollution enhance or potentiate particular diseases and if so how?

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Approaches to Examining the Role of Emissions in Health Effects

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Field studies

Controlled in vitro exposure cells, organs

Controlled human exposures in vivo

Sensitivity Factors

Extrapolation Factors

Controlled animal models in vivo

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Recent Projects

- **Epidemiological studies** identifying associations among roadway proximity, air quality exposures, and adverse health effects
- **Animal toxicity studies** linking exposures to adverse health effects
  - Diesel and biodiesel exhaust
    - Including comparison of “fresh” vs. “aged”
  - Near-road
  - Ethanol and ethanol-blend gasoline vapors
- **Human toxicity studies** comparing effects of diesel/biodiesel exhaust to ambient air exposures

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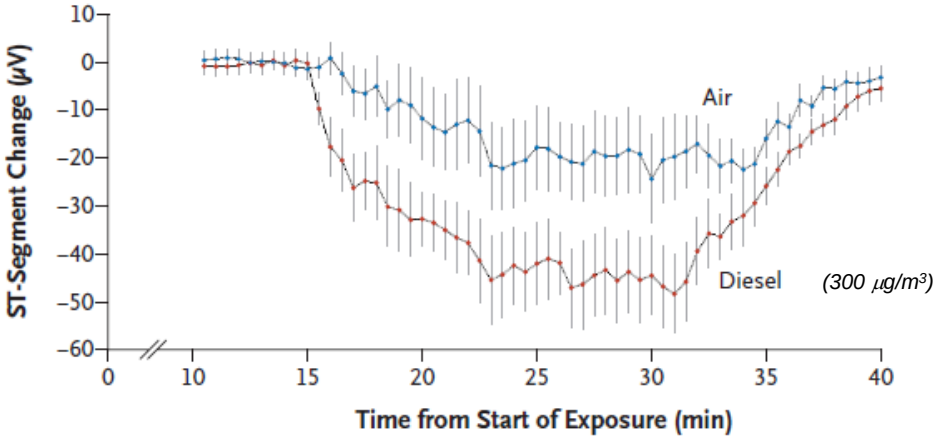
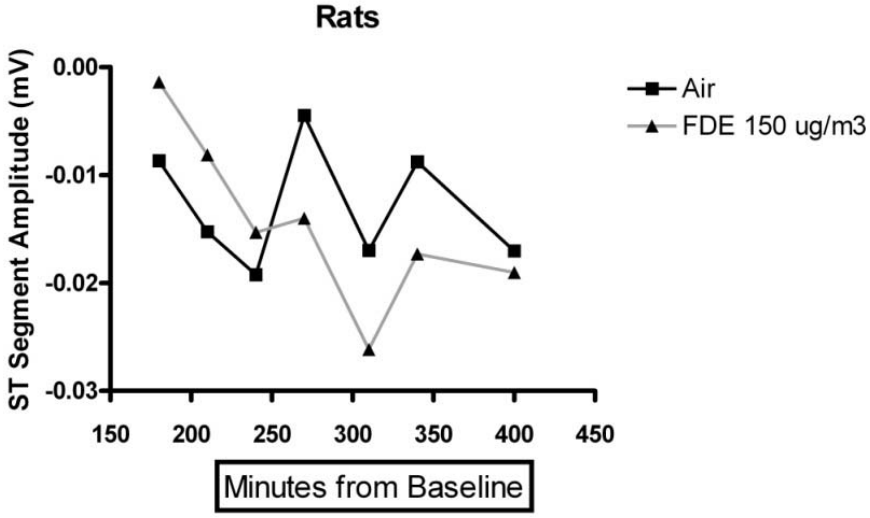
Cardiac Ischemia during Diesel Exhaust Exposure in Humans and Rats at Comparable Concentrations

Humans



Rats



Mills et al, 2007

Exposure to diesel exhaust in both humans and rats results in ST-segment depression, which is an electrocardiographic indicator of cardiac ischemia

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Exposure to Gasoline-Ethanol Blends

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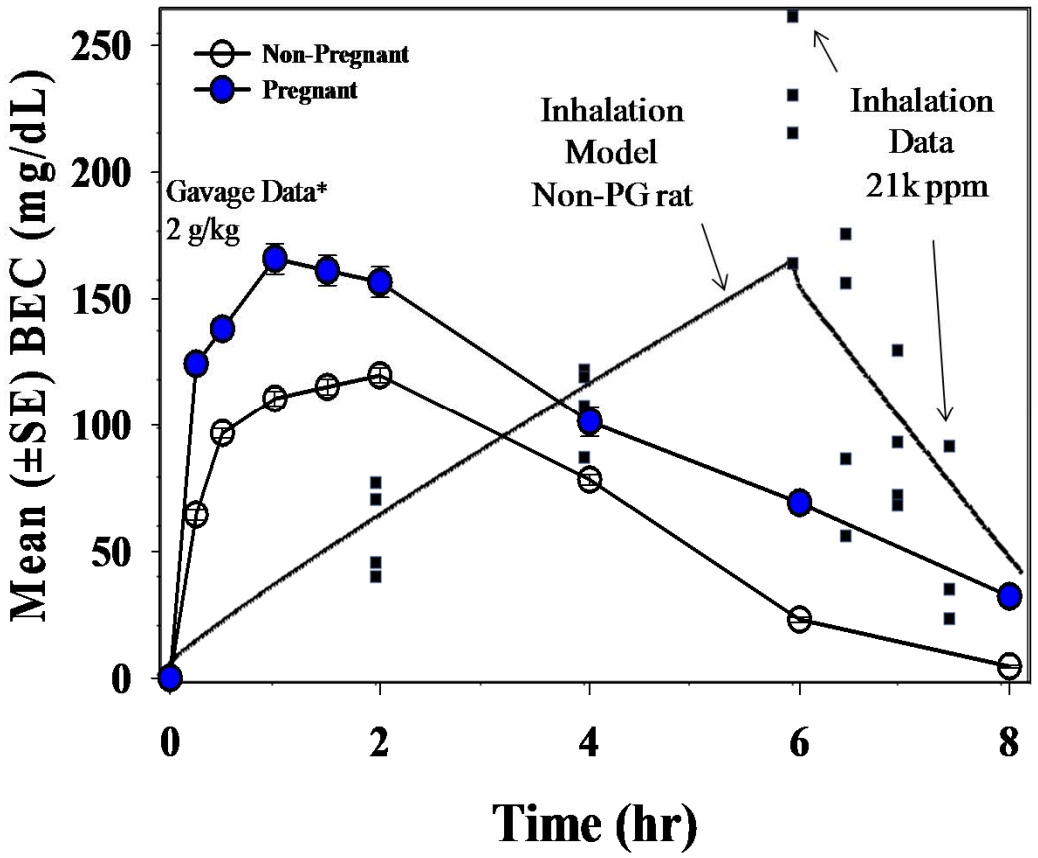
- Study investigating whether adding ethanol to gasoline changes its toxicity
- Expose pregnant rats by inhalation to vapors of E0, E15, E85 and E100
- Test offspring for developmental effects

Conclusions:

- *Inhaled ethanol is rapidly cleared: concentrations in tissues thus rise slowly and remain relatively low*
- *Even at high internal doses, inhaled ethanol had few effects on offspring, probably because of slow rise in blood levels relative to oral doses*
- *Gasoline-ethanol mixtures not more toxic than ethanol or gasoline itself*



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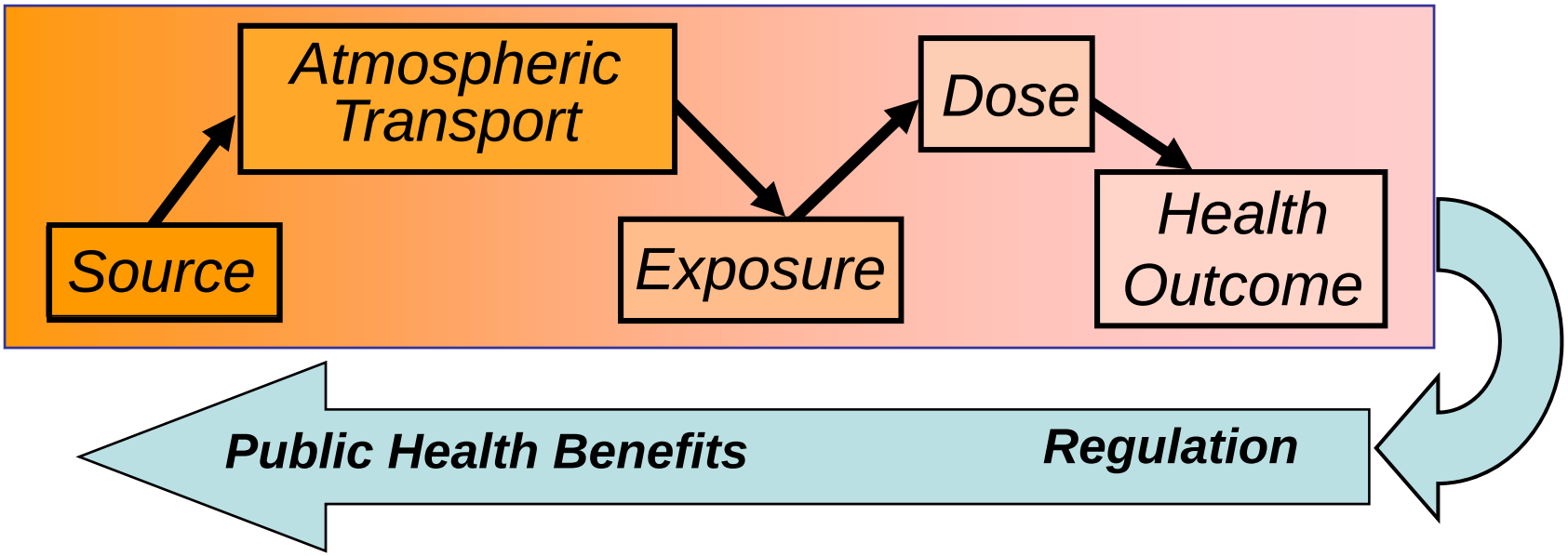

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Future Work/Directions

- Emissions Characterization
  - Alternative fuels and vehicle technologies
  - PM measurement methods (including UFP)
- Air Quality and Exposure
  - Advancements in near-source and exposure modeling
  - Options for mitigating exposures and adverse health effects
- Health Effects
  - Identify mechanisms of adverse effects
  - Multi-pollutant risk evaluation

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Future Work/Directions

- Multiple Sectors
  - On-road transportation
    - Personal vehicles
    - Freight movement
  - Rail/Railyards
  - Marine Ports (coastal and inland)
  - Airports
- Land Use and Transportation Planning
- Climate impacts and mitigation

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Kevin Black
Mark Ferroni
Adam Alexander