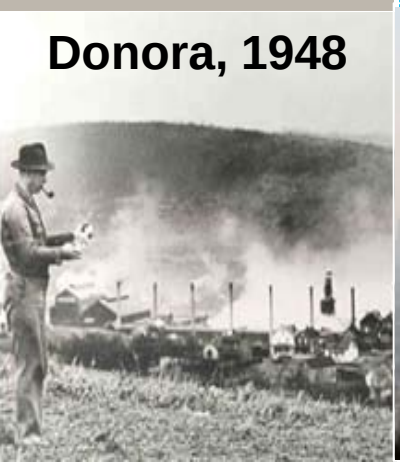


The EPA Air, Climate, and Energy Intramural Research Program (ACE)

Robert Devlin

Office of Research and Development

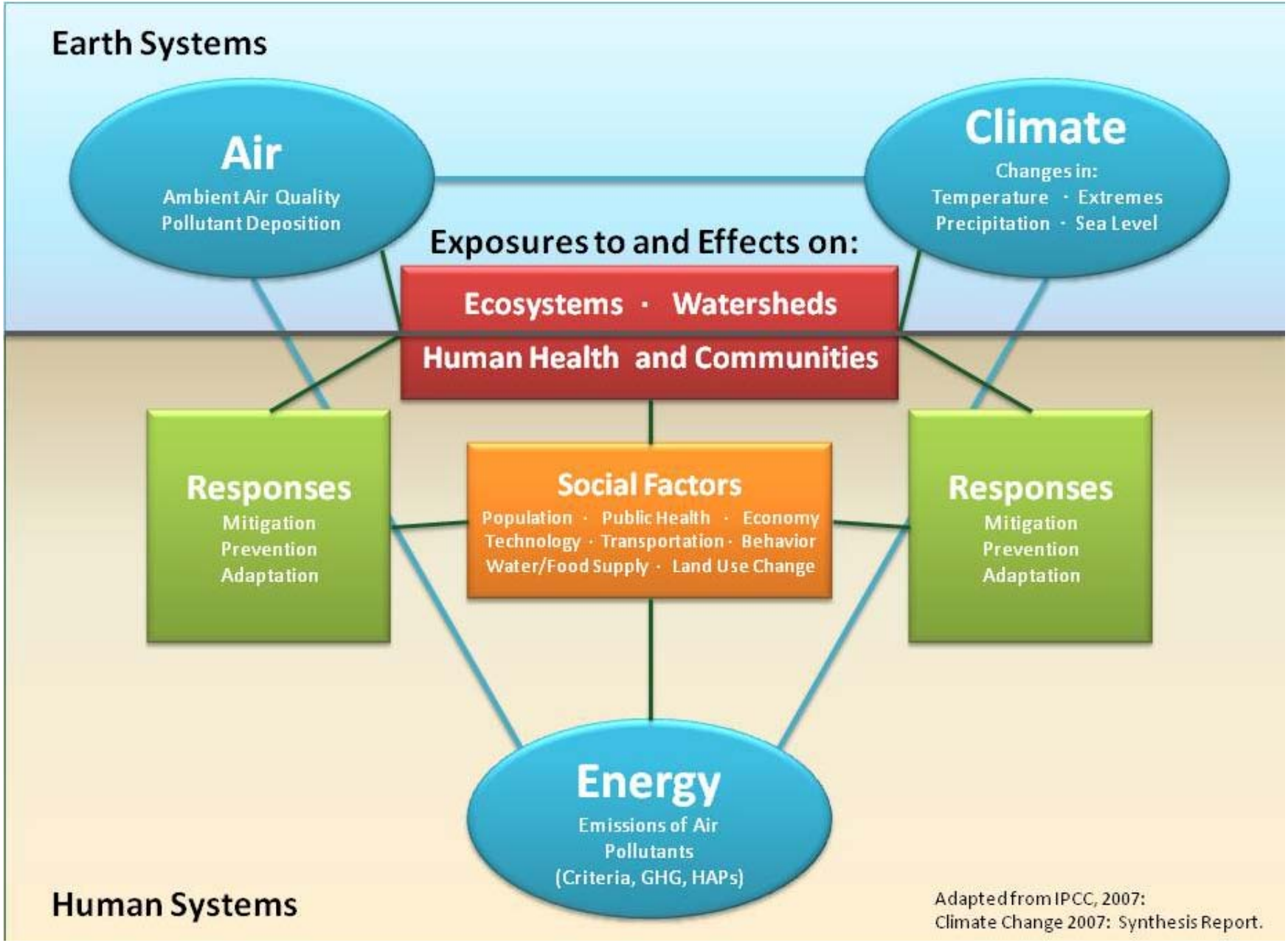
CLARCs Kick-Off Meeting
April 7-8, 2011
RTP, NC

Problem Statement:

Protecting health and the environment from the impacts of climate change and air quality are central 21st century challenges. These challenges are complicated by the interplay between air quality, the changing climate, and emerging energy options.

Vision:

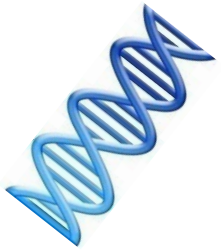
The ACE program will provide cutting-edge scientific information and tools to support EPA's strategic goals to protect and improve air quality and take action on climate change.


Earth Systems
Air
Ambient Air Quality
Pollutant Deposition
Climate
Changes in:
Temperature · Extremes
Precipitation · Sea Level
Exposures to and Effects on:
Ecosystems · Watersheds
Human Health and Communities
Responses
Mitigation
Prevention
Adaptation
Social Factors
Population · Public Health · Economy
Technology · Transportation · Behavior
Water/Food Supply · Land Use Change
Responses
Mitigation
Prevention
Adaptation
Energy
Emissions of Air
Pollutants
(Criteria, GHG, HAPs)
Human Systems
Adapted from IPCC, 2007:
Climate Change 2007: Synthesis Report.

The ACE Approach to Research

Epidemiology

Clinical and Animal Toxicology



Molecular Biology

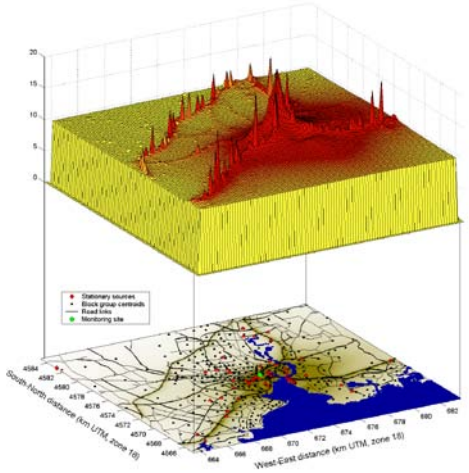
Intramural Research Program

EPA STAR Program (Extramural Grants)

Federal / State / Academic Partners

Emission source characterization

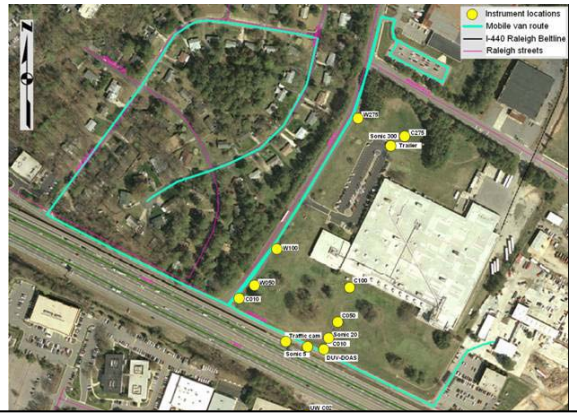
EPA Ambient Monitoring Network (NCore)

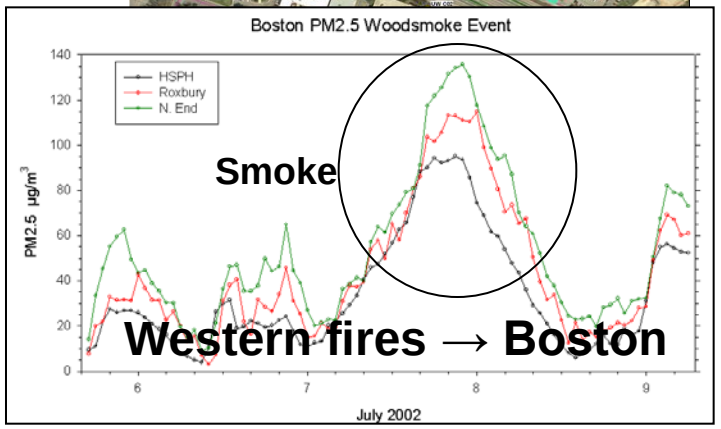


Atmos. measurements & models for exposure

Research Theme 1: Assess Impacts

Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales.





Objectives:

- **Assess multipollutant exposures and effects**
- **Develop innovative approaches to assess exposures and effects of pollutants in the atmosphere**
- **Identify characteristics of populations and ecosystems susceptible to exposure to air pollutants and climate change**
- **Inform review of NAAQS**

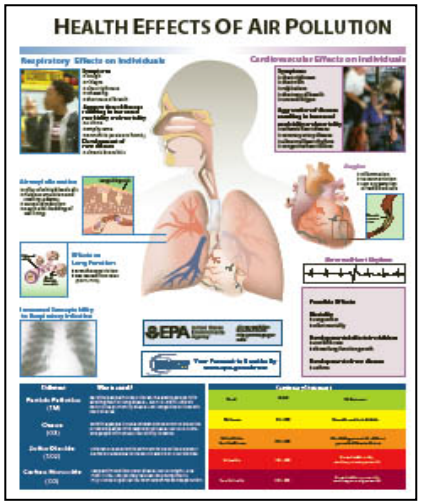
Research Theme 2: Prevent and Reduce Emissions

Provide data & tools to develop and evaluate approaches to prevent and reduce emissions of pollutants to the atmosphere, particularly environmentally sustainable, cost effective, and innovative multipollutant and sector-based approaches

<u>Objectives</u>:

- **Support management air pollution problems at different scales of time and space**
- **Develop methods and data for life-cycle analyses of alternative pollution reduction and energy options**
- **Innovative technologies to support implementation of management strategies**
- **Evaluate pollution reduction and prevention solutions**
- **Support implementation of NAAQS**

Research Theme 3: Respond to Challenges in Climate and Air Quality

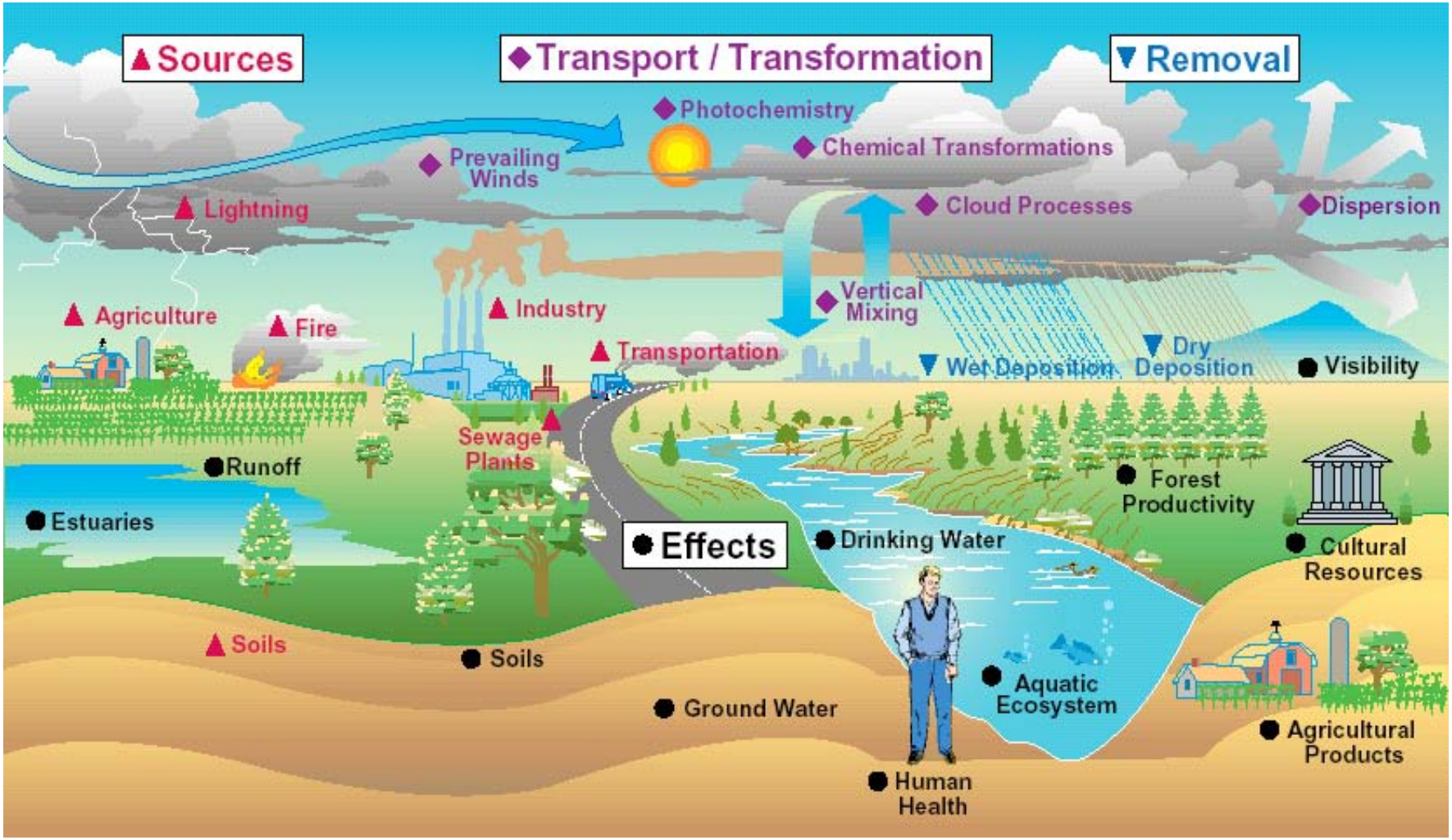


Provide human exposure and environmental modeling, monitoring, metrics and information needed by individuals, communities, and governmental agencies to adapt to the impacts of climate change and make informed public health decisions regarding air quality

<u>Objectives</u>:

- **Evaluate alternative adaptation strategies**
- **Devise innovative methods to inform individual- and community-level adaptation to climate change and decision making for air quality**
- **Evaluate social, behavioral, and economic factors that influence adaptation strategies for climate change and decision making for air quality**

Moving Towards a Multi-pollutant Research Program



EPA – the 5th CLARC?

- **The EPA intramural air pollution research program is often referred to as the "5th Center."**
- **However, in terms of scientific personnel and the amount of dollars invested in air pollution research, this program is larger than all 4 Centers combined.**
- **Approximately 225 people are engaged in air pollutant research in EPA**
- **The EPA intramural program spent nearly 80 million dollars on air pollution research last year.**

It is not feasible to discuss the entire program in 30 minutes. This presentation will focus on a small number of projects which are similar to projects being done by the CLARCs, to facilitate potential collaborations between ORD and the CLARCs.

Project 1. Near Road Studies

- **Near-road Exposures and effects from Urban air pollutants Study (NEXUS)**

  Cooperative agreement with U. Michigan

- **Research Triangle Area Mobile Source Emissions Study (RAMSES)**

NEXUS Looks at Effect of Traffic on Asthmatic Children in Detroit

- **Which measures of traffic-related air pollution are most closely associated with aggravated asthma?**
- **Do children with asthma who live near major highways show more inflammation and other biological responses?**
- **Does traffic exposure influence the likelihood of respiratory viral infections in children with asthma?**

NEXUS Study Design

- 105 children ages 6-16 with persistent asthma
- 3 groups of 35 each who live within 150 m of:
  - High traffic/high diesel truck roadways
  - High traffic/low diesel truck roadways
  - Low traffic roadways
- Respiratory health evaluated seasonally and when children report respiratory viruses
- Leveraged with on-going studies of asthma in Detroit funded by NIEHS
- Concurrent measures of traffic-related air pollutants:
  - Home indoor/outdoor
  - Select schools outdoor

RAMSES Looks at Effect of Traffic Components on People with Cardiovascular Disease in RTP

- **Although near road exposures are known to be particularly potent in causing adverse health effects, there is no consensus as to which components are responsible for these effects.**

- **What are the short and long term impacts of living near roads in those with CV disease.**

RAMSES Has Three Phases

- **Phase 1. A cohort of 7000 people who visited a Duke Clinic for angioplasty and have been followed over time will be used to determine if long term residence near roads with different traffic patterns is associated with severity or progression of CV disease.**

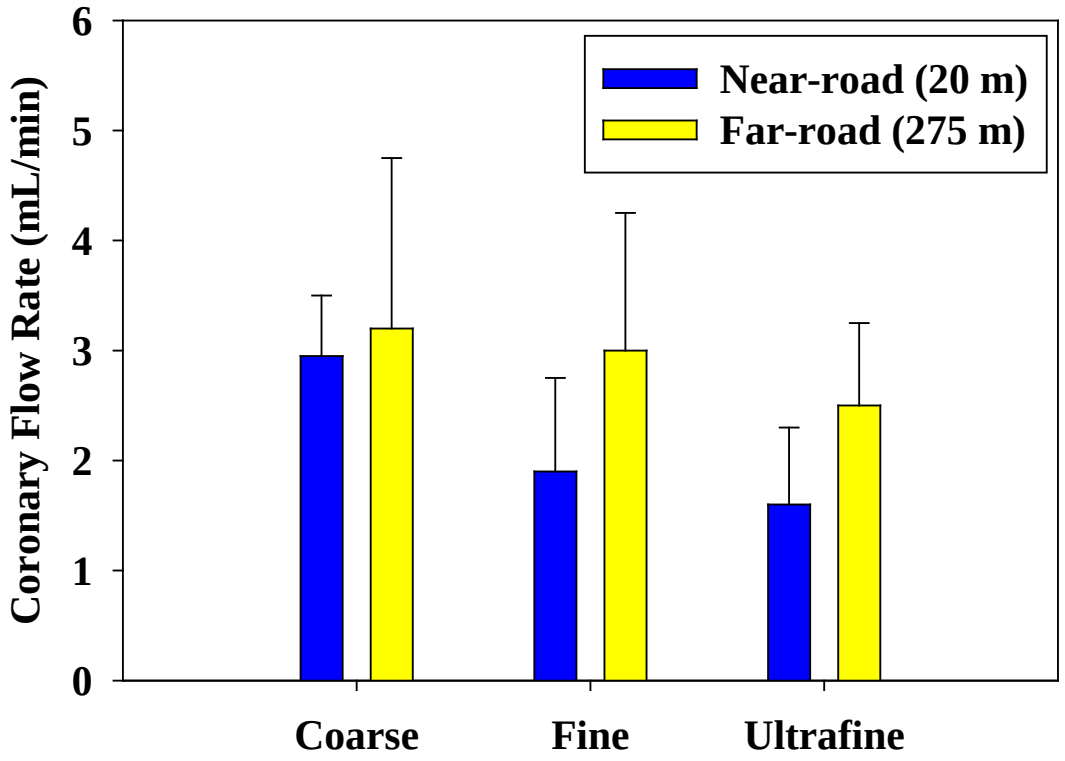
- **Phase 2. A panel of 50 volunteers from the cohort will be used in a follow-up study to associate acute effects with ambient PM, PM components, and gases.**
  Exposure assessment by community, home, and personal monitoring as well as modeling and proximity to roads

- **Phase 3. The phase 2 cohort will be brought to roads that different in traffic patterns (e.g. smooth flow vs stop and go) and acute health effects associated with specific components of near road pollution.**

Near Road Toxicology Studies

- **Size-fractionated particles collected near (20m) and far (275m) from road**

- **Extracted particles:**
  - **Chemically analyzed**
  - **Instilled in mice and allergy & cardiopulmonary responses evaluated**
  - **Used for in vitro toxicology studies**

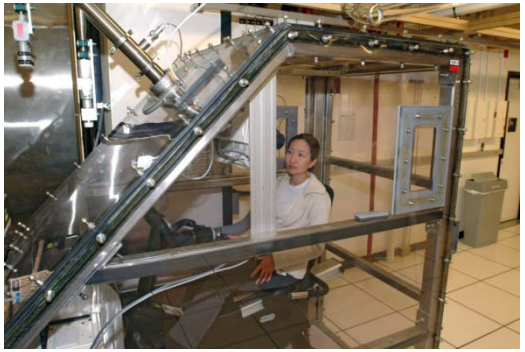


Near-road fine and ultrafine PM reduced blood flow to the heart, suggesting traffic related particles may adversely affect the heart

Project 2. Are there combined effects of multiple pollutants (e.g. synergistic, additive, antagonistic)?

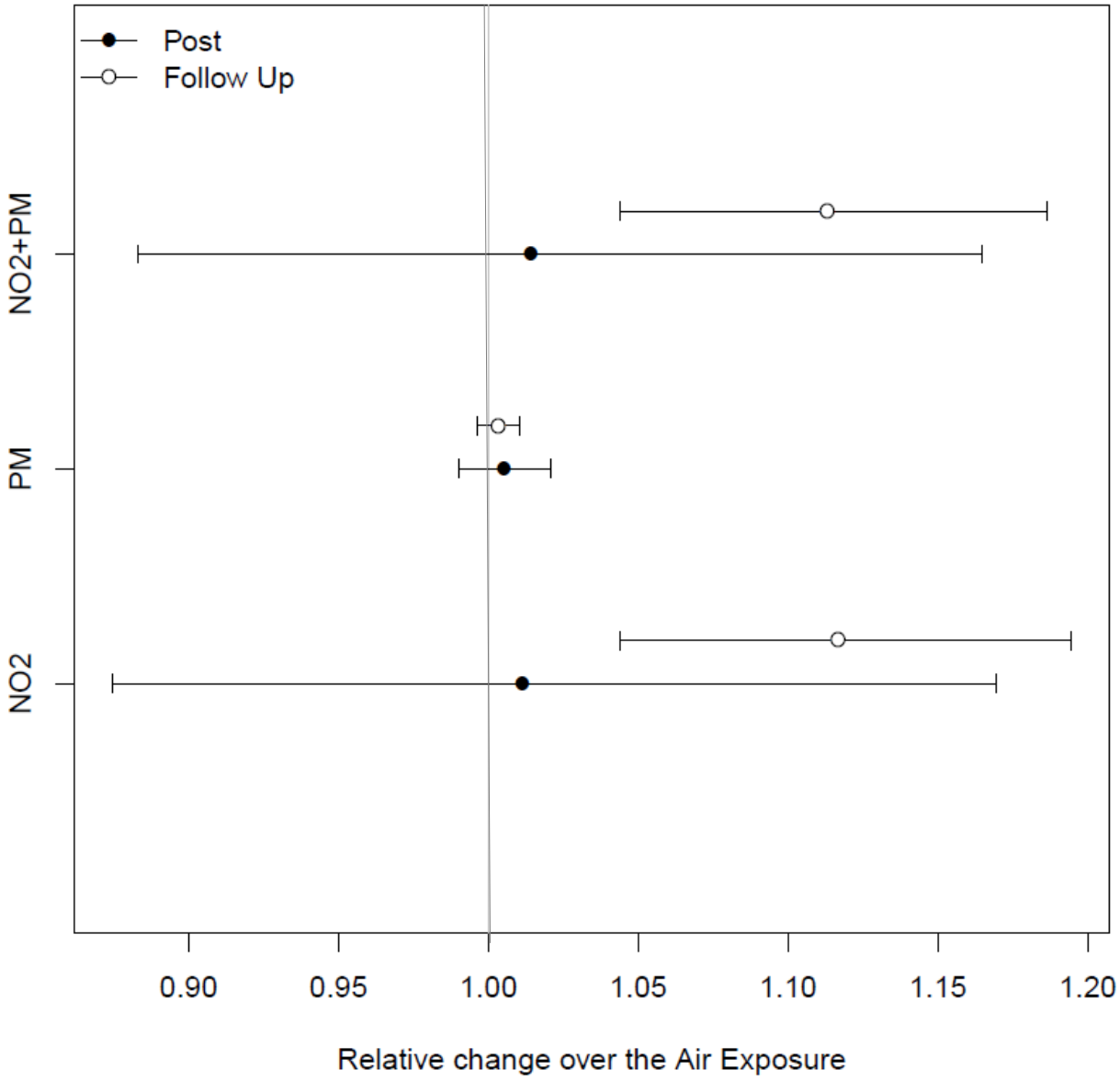
- **It is difficult for epidemiology studies to disentangle the effects of pollutants which are co-located in time and space.**
  - **Does NO_2 cause health effects or is it a surrogate for near road exposures?**

- **Animals or humans can be exposed to simple mixtures (binary, trinary) of air pollutants or agents of climate change.**
  - **CAPS + O3, or diesel + NO2**



Exposure	PM Mass Concentration (ug/m^3)	Pulmonary Function	BAL Fluid Cells	BAL Fluid Markers	Cardiac Endpoints	Plasma Markers
Coarse	89.0 ± 49.5	No Effect	↑ PMNs	↓ Protein	↓ SDNN	↓ tPA
Fine	120.4 ± 14.1	↓ DLCO	↑ Cells ↑ PMNs ↑ Monocytes	↓ IL-8 ↓ Fibrinogen	↑ Norm. QT Var	↑ Fibrinogen ↓ WBCs ↓ VLDL
Ultrafine	47.0 ± 20.2	No Effect	No Effect	↑ IL-8	↑ HF, LF ↑ Norm. QT Var ↓ QTc	↑ D-Dimer ↑ PAI-1 ↓ HDL, VLDL

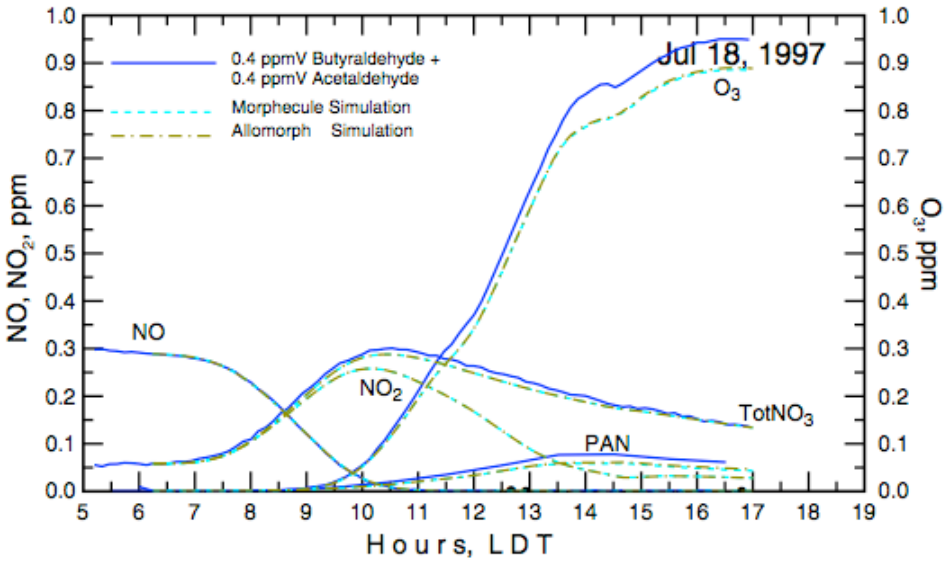
Change in Low Density Lipoprotein



Project 3. Simulated Atmosphere Research

- **Goal is to create artificial atmospheres that are reflective of real world MP mixtures.**
- **Health effects can be associated with different mixes.**
- **Various precursors, including those associated with climate change, can be used.**
- **Goal is to compare biological effects in animals exposed using two different types of chambers.**

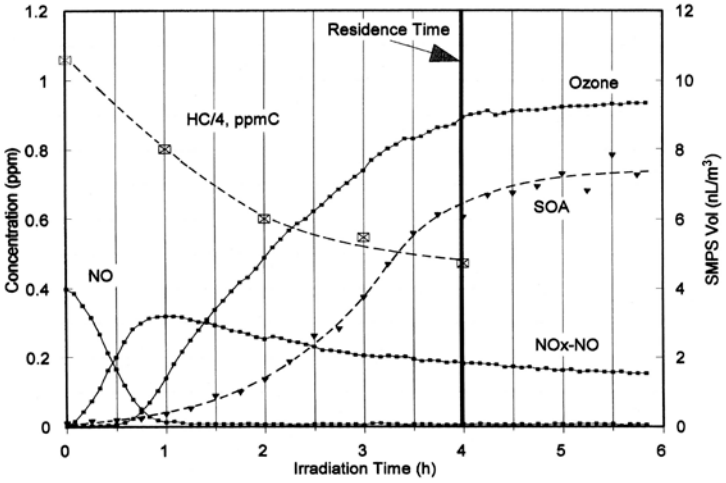
UNC Chapel Hill Chamber



Physicochemical Analyses

- PM size, mass, and morphology
- Inorganic elements
  : XRF, ICP-OES, ICP-MS
- Organic components
  : GC-MS
- Carbonaceous components
  : Elemental and organic carbon, black carbon
- Reactive Oxygen Species
  : EPR, reduction-oxidation potential
- Real-time PM analysis
  : Aerosol Time-Of-Flight Mass Spectrometer (ATOFMS)
- Continuous emission monitoring for gaseous components

EPA Chamber



Biological Models

- Pulmonary inflammation
- Allergic potential
- Viral infectivity
- Atherosclerosis
- Hypertension
- Heart failure
- Mutagenicity

Project 4. Multi-City Studies

- **Enhance results of epidemiology studies through the use of improved exposure metrics**
- **Multi-city Epidemiology Studies**
- **Multi-city Toxicology Studies**

EPA Cooperative Agreement Research to Enhance Results of Epidemiology Studies Through the Use of Improved Exposure Metrics

- **Numerous epidemiologic studies have used measurements from central-site ambient monitors to estimate exposures to air pollution**

- **Central-site monitors may *not* account for:**
  - **spatial and temporal heterogeneity of urban air ambient pollution**
  - **human activity patterns**
  - **infiltration of ambient pollutants indoors**
  - **contributions of indoor sources that may be effect modifiers**

- **Central-site are especially problematic for certain PM components and species (e.g., EC, OC, coarse, ultrafine) that exhibit significant spatial heterogeneity**

- **A number of enhanced exposure assessment approaches have recently been developed and applied in the investigation of air pollution health effects**

Emory Coop

Develop and evaluate six exposure metrics for ambient traffic-related (CO, NO_x and $PM_{2.5}$ EC) and regional (O_3 and SO_4^{2-}) pollutants by applying them to two of ongoing epidemiologic studies on ambient air pollution and acute morbidity in Atlanta, GA

Rutgers Coop

Examine associations between $PM_{2.5}$ mass and species and adverse health using two established epidemiology studies in New Jersey by testing four different tiers of exposure specification

University of Washington Coop

Improve air pollution cohort study health effect estimates by (i) incorporating dispersion model output into an existing spatio-temporal concentration model and (ii) quantifying the impact of exposure misspecification and methods for minimizing this source of error

Overall Goal: Enhance results of epi studies through the use of improved exposure metrics				
Collaborators	**Pollutants**	**Exposure Approach**	**Health Study**	**EPA Role**
Turpin, Rich, Lunden (Rutgers/UMDNJ/LBNL	(1) PM2.5 (2) PM2.5 species: EC,OC,SO4, NO3,NH4	(1) Ambient Monitoring (2) SHEDS (3) Infiltration Model (LBNL) (4) SHEDS-Infiltration Hybrid	(1) NJ MI (2) NJ Birth Outcomes	(1) SHEDS (2) CMAQ
S. Sarnat, J. Sarnat (Emory/Ga Tech)	(1) PM2.5 (2) PM2.5(EC) (3) CO (4) NOx (5) Ozone (6) SO4	(1) Ambient Monitoring (2) Interpolation (3) CMAQ (4) CMAQ/Baseline+AERMOD (5) Air Exchange/Infiltration (6) SHEDS & APEX Exposure modeling	(1) Atlanta ED (2) Atlanta ICD	(1) CMAQ (2) AERMOD (3) Data Fusion (4) SHEDS and APEX
Sheppard, Sampson, Vedal, Larson (University of Washington)	(1) PM2.5 (2) NOx*	Assimilated Data from • Ambient • CMAQ+AERMOD** • Spatio-temporal models (GIS & physically-based)	(1) MESA-Air (2) WHI-OS*	(1) CMAQ** (2) AERMOD** (3) Data Fusion

Multi-city Epidemiology Studies

Research Questions

- What metropolitan areas should have daily monitoring?
- What are the cause-specific concentration-response curves for specific PM-components / co-pollutants?
- Can built-environment and human behavior patterns explain heterogeneity of city-specific associations?
- Do concentration-response slopes for criteria pollutants and components vary over time? (criteria pollutants as indicators)
- What is the modifying effect of climate indices on pollutant mixtures and cause-specific mortality?
- Is SES a vulnerability factor?

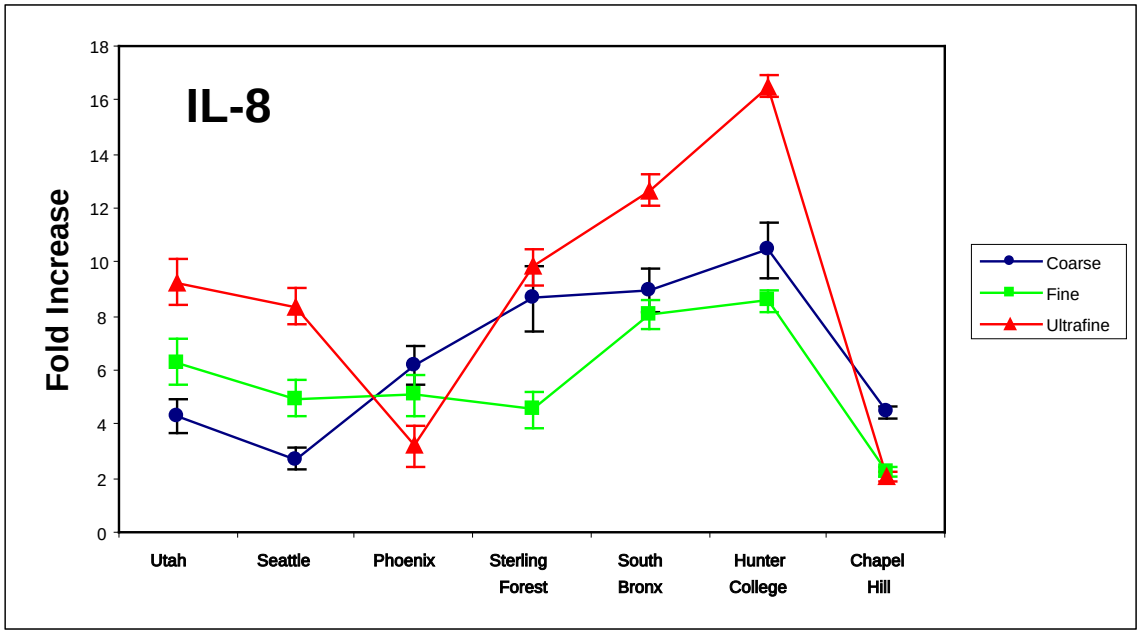
Research in Progress

- **Provide OAQPS with candidate list of metropolitan areas for enhanced daily speciation monitoring**
- **Standard time series methods - associations of cause-specific mortality with PM components / co-pollutant**
- **Innovative Bayesian methods of temporal-spatial models –**
  NCSU cooperative agreement
- **Bivariate models for temperature / pollutants**

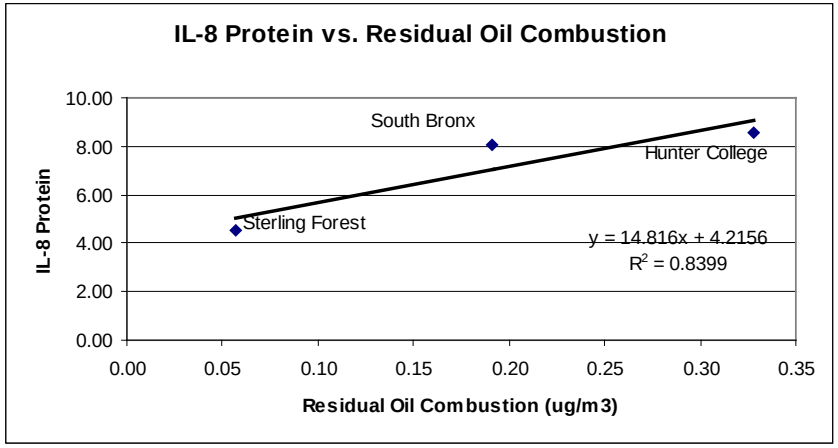
Map of selected STN monitor sites: 49 STN monitors, 2001-2005.

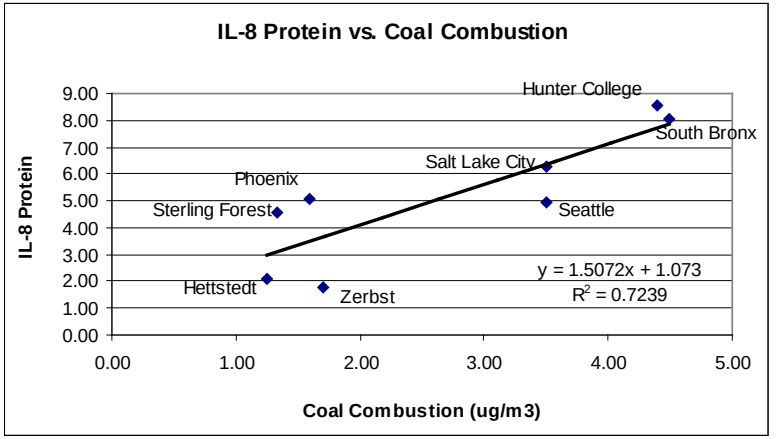
Multi-city Toxicology Studies

- **UF, F, C particles were collected in 7 US (and 2 German) cities**
- **Cities were chosen because they have different source profiles**
- **Each size fraction was analyzed for multiple PM components**
- **Animal instillation and in vitro toxicology studies were used to link biological effects with particle size, components, and sources**

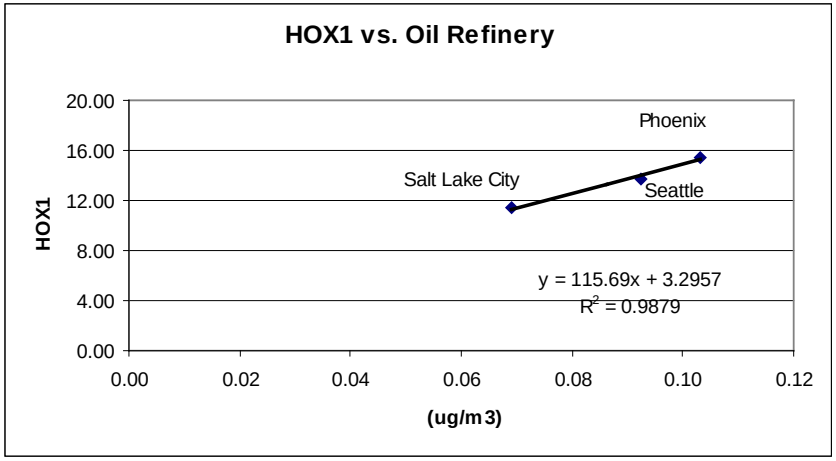


Association of Biological Changes to Sources in MAPS Cities



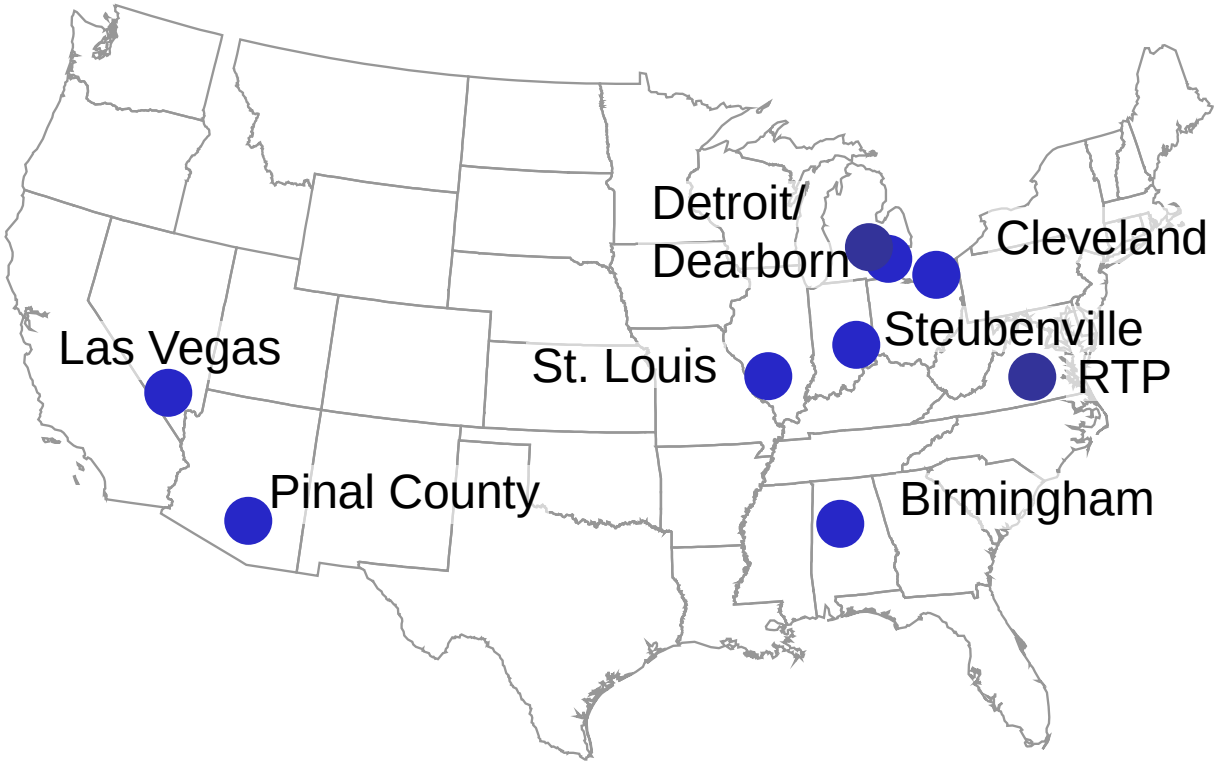


IL-8 protein is strongly correlated with coal combustion (r2=0.72) and residual oil combustion (r2=0.84)



HOX1 is strongly correlated with Oil refinery (r2=0.98)

Size fractionated samples have been collected in additional cities.



Project 5. Factors that Modify Health Effects to Multipollutants

- **Retrospective panel study of subjects used in controlled exposure.**

- **Animal CV responses to pollutants.**

Human Retrospective Study

- **Hundreds of volunteers have been exposed to air pollutants in Chapel Hill over the past six years**
  - **Each person exposed to air and pollutant**
  - **A large number of clinical measurements were taken before and after each exposure**

- **Air pollutant levels have been retrieved for several days prior to each person's clinic visits**
  - **Regional monitors and rooftop monitors in Chapel Hill facility (for PM components)**

- **Associations are being made between ambient levels of pollutants and changes in clinical tests performed prior to air or pollutant exposure .**
  - **Can stratify the population on things such as age, gender, race, genetics, disease, medications, smoking, near road, etc.**

Clinical Measurements for Retro Study

Pulmonary Function

- FEV1
- FVC
- DLCO

Bronchoalveolar Lavage

- Cell Differentials
- Soluble Mediators of cell injury and inflammation
- Epithelial Cells
- Macrophages
- Bronchial Biopsies

Vascular

- BAU
- CBC and differential
- Clotting/coagulation factors
- Cytokines

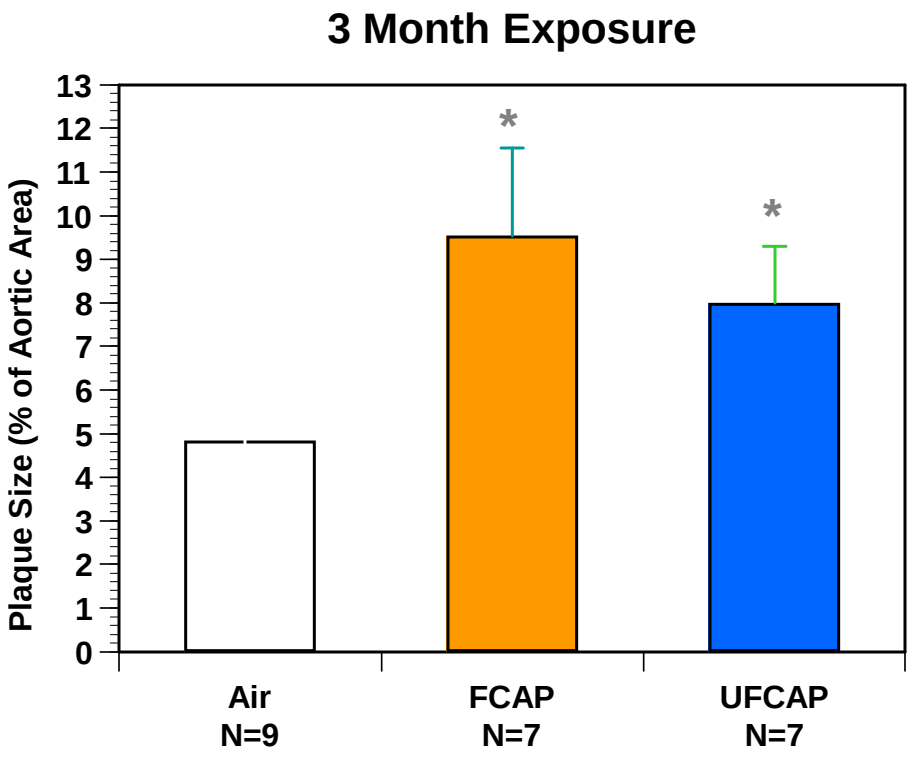
Cardiac

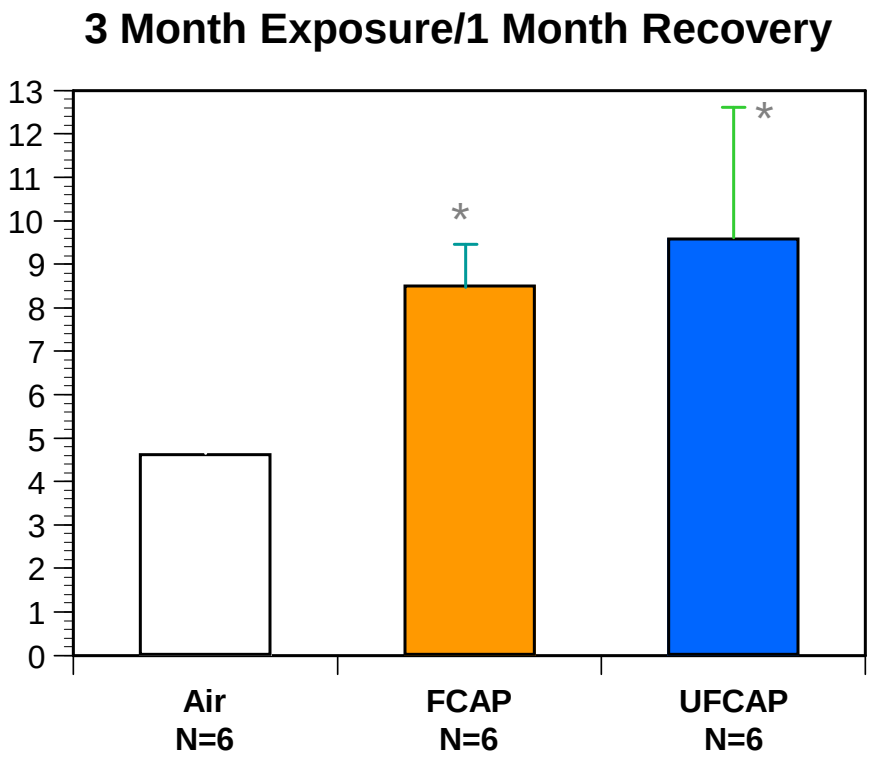
Holter monitoring
time domain
Frequency domain
Repolarization
Ectopic beats

Clinical

Medical History
Genotyping
Age, smoking, medications
Residence

Vascular Effects of a Subchronic Inhalation Exposure to Concentrated Fine and Ultrafine Ambient Air Particles in Atherosclerosis Susceptible Mice





* p<0.05 vs. Air

Acute Effects of Diesel Exhaust on Cardiovascular Function in Aged Heart Failure Rats

Pre-exposure Ultrasound (Echocardiogram)

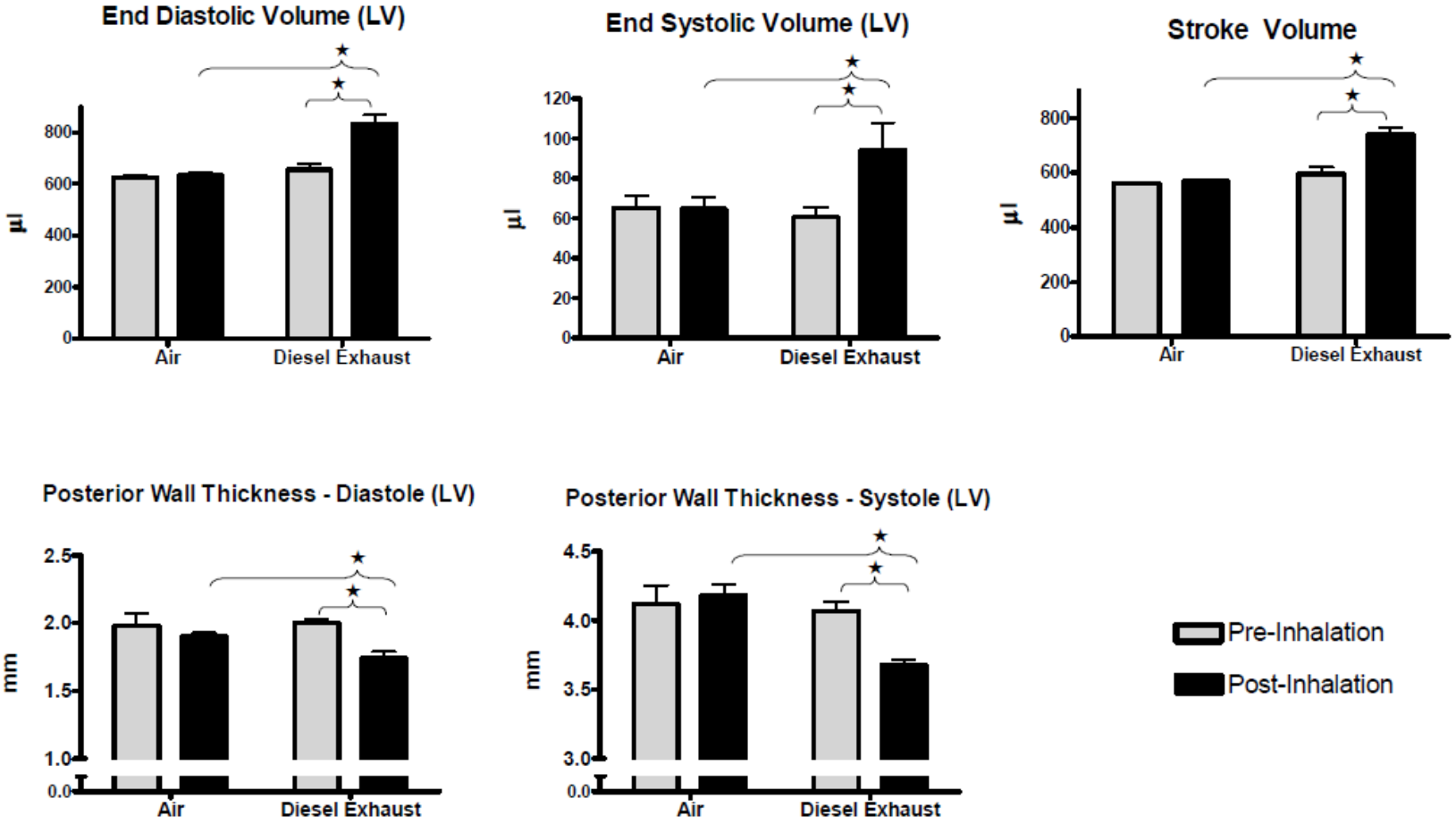
1 day →

4 h whole-body inhalation of diesel exhaust (500 μg/m^3)

1 hour →

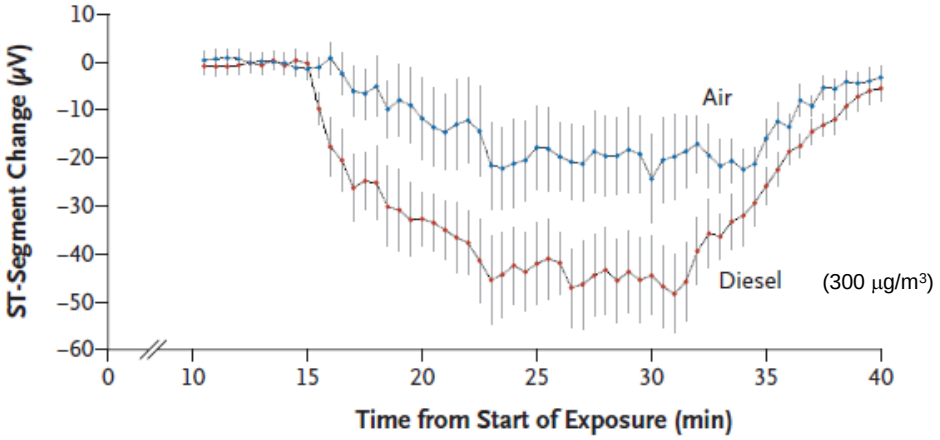
Post-exposure Ultrasound (Echocardiogram)

A Single Diesel Exhaust Exposure Increases Stroke Volume and Decreases Left Ventricular Wall Thickness

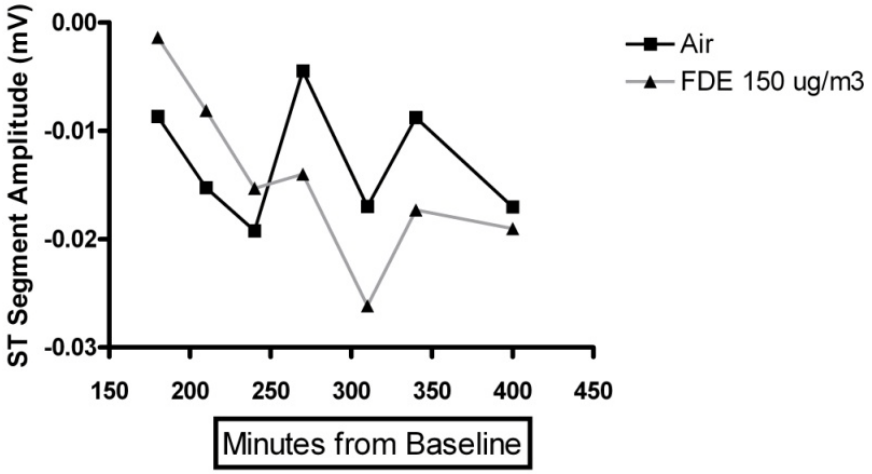


Cardiac Ischemia during Diesel Exhaust Exposure in Humans and Rats at Comparable Concentrations

Humans



Rats



Mills et al, 2007

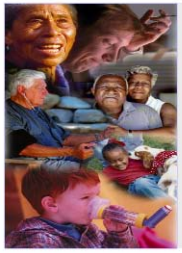
ST segment depression: an electrocardiographic indicator of cardiac ischemia

EPA's Air Pollution Program Provides A Science Foundation for Protecting the Air We Breathe

Air Pollution health and exposure research has significant benefits and impacts:

- **Indicates that the current standards are necessary to protect public health**
- **Strengthens confidence in the scientific basis for these standards**
- **Provides information to inform people, particularly at risk populations, of the harmful effects of air pollutants and to educate them to minimize exposure to air pollutants**

EPA Clean Air Goal



"Protect and improve the air so it is healthy to breathe and risks to human health and the environment are reduced."