Air Resources Board

PLANNED AIR POLLUTION RESEARCH

Fiscal Year 2008-2009

July 2008

Acknowledgments

TABLE OF CONTENTS

SUMMARY

This report presents the Air Resources Board's planned air pollution research for the fiscal year 2008-2009. Nineteen projects that support the ARB's programs are recommended for funding. An additional eleven projects are offered for consideration, should resources become available. This research portfolio is organized by key policy and regulatory drivers that it supports: Health Effects and Air Quality Standards, Climate Change, Diesel and Goods Movement, Atmospheric Science, State Implementation Plan (SIP) Support, and Toxic Air Contaminants. Issues related to agriculture and environmental justice are integrated into several of these primary categories. From these key policy and regulatory drivers, the following sub-categories are presented with research concepts recommended for funding or for consideration, should resources become available:

- Health Effects and Air Quality Standards
    - Health and Environmental Justice
- Climate Change
    - Mitigation and Science
    - Behavioral Change
    - Emissions
    - Water
- Diesel and Goods Movement
    - Diesel Emissions
    - Goods Movement
- Atmospheric Science
    - CalNEX 2010
- State Implementation Plan (SIP) Support
    - Monitoring
    - Ozone
    - Particulate Matter
- Toxic Air Contaminants
    - Toxic Air Contaminants
    - Ultrafine PM

This annual plan proposes research in the areas listed above, with a significant effort to clarify heath impacts of air pollution, develop technologies and behavioral change strategies to reduce emissions of greenhouse gases, improve emission inventory efforts, characterize and assess the behavior of pollutants in the atmosphere, and reduce emissions of conventional air pollutants and their precursors. The total budget for projects recommended for funding is approximately $6,600,000.

INTRODUCTION

The Air Resources Board (ARB) sponsors a comprehensive program of research addressing the causes, effects, and possible solutions to air pollution problems in California. This research program also provides support for establishing ambient air quality standards. The Board's research program was established by the Legislature in 1971 (Health and Safety Code Sections 39700 et seq.) to develop a better understanding of air pollution in California, including air pollution's effects on health and the environment, atmospheric chemistry and transport of pollutants, and inventory and control of emissions. Several legislative mandates have expanded and further defined the scope of the program in recent years.

The ARB's mission to protect California's public health, welfare, and ecological resources is supported by a Strategic Plan for Research covering the years 2001-2010. Based on regulatory priorities for the next several years, the Strategic Plan provides direction for the ARB's research program. The Plan can be downloaded from: http://www.arb.ca.gov/research/apr/apr.htm.

This research plan is organized according to key policy and regulatory drivers that it supports: Health Effects and Air Quality Standards, Climate Change, Diesel and Goods Movement, Atmospheric Science, State Implementation Plan (SIP) Support, and Toxic Air Contaminants, with issues related to agriculture and environmental justice integrated into several of these primary categories. Brief overviews of specific research areas to be funded (or considered if additional funds become available) under each key policy driver are provided (as listed on p. iv). These topical overviews indicate the link(s) between the research area and ARB's mission, ongoing research efforts in the area, research and knowledge gaps that need to be addressed, and recommended research concepts. Topical overviews are followed by the nineteen projects recommended for funding (p. 20) and the eleven projects recommended if additional funds become available (p. 56).

The proposed research projects are not intended to be exhaustive or exclusive. Unanticipated opportunities, unique or innovative study approaches, or urgency may lead to consideration of other projects.

Objective of the Research Program. The goal of the research program is to provide timely scientific and technical information that will allow the Board and local districts to make sound policy decisions and effectively implement air pollution control programs in California. Specifically, this plan supports ARB's missions to protect public health through health-based air quality standards; develop and implement strategies to reduce greenhouse gas emissions in accord with the near-term (2020) goals of the California Global Warming Solutions Act (AB 32) as well as longer-term (2050) goals; protect Californians from toxic effects of diesel emissions; devise goods movement strategies that are protective of community health; and identify and regulate toxic air contaminants.

Process for Developing this Research Plan. The Board sends out a public solicitation inviting and encouraging the public to contribute ideas for project consideration.

Members of the public, the academic community, and ARB staff submit research ideas. To aid in the evaluation, the Board's Executive Officer established interagency committees, led by ARB staff, to review research ideas. These interagency review teams comprised, in addition to ARB staff, experts from state agencies with resonant research priorities and responsibilities as well as experts from other state, district, federal, and non-profit institutions with scientific research or regulatory authority in areas of policy relevance to ARB. In response to this year's solicitation, approximately 250 research ideas were submitted. Proposed projects were examined for relevance to regulatory questions facing the Board, scientific and technical merit, and opportunities to leverage State resources through co-funding. Proposals were modified as necessary. Reviewers then prioritized candidate projects in order of urgency and importance. The Board's scientific external review committee, the Research Screening Committee (RSC), which was established by Health and Safety Code Section 39705, reviewed these candidate projects. A list of projects recommended for funding, as well as projects to consider pending availability of resources, was compiled based on discussions between interagency review committees, feedback from ARB's divisions, and comments from the RSC as well as an agricultural stakeholder outreach working group. This list of recommended projects was forwarded to the Executive Research Review Committee, whose members are the Executive Officer, his three deputies, and the Chief of the Research Division. The Executive Research Review Committee reviewed all of the proposed projects and modified the draft list of projects recommended for funding based on ARB's most pressing policy and regulatory needs. The RSC reviewed the selected projects and recommended the Plan to the Board.

Implementation of the Plan. The next step for projects approved in the plan will be their development into full research projects. The submission and selection of an idea does not guarantee a resulting contract for the submitter. Rather, the ARB is required to consider public California universities for expertise to execute these projects. If the universities do not possess the expertise, then a public solicitation is issued or a sole source contract is awarded. A list serve distributes updates on research activities. To subscribe to the list serve, visit http://www.arb.ca.gov/listserv/research.htm.

Research Budget. The nineteen recommended projects total approximately $6.6 million. An additional eleven projects totaling $4.1 million are recommended if resources become available. Allocations for the nineteen projects recommended for funding are organized according to key policy or regulatory drivers as follows:

RESEARCH CATEGORY	BUDGET
Health Effects and Air Quality Standards	$ 825,000
Climate Change	$1,650,000
Diesel and Goods Movement	$ 300,000
Atmospheric Science	$2,000,000
State Implementation Plan (SIP) Support	$1,635,000
Toxic Air Contaminants	$ 170,000
TOTAL	**$6,580,000**

Project Co-sponsorships. The Research Division is continually looking for co-funding opportunities and other ways to leverage the State's research dollars. This effort allows the ARB to be part of projects and studies that may otherwise lie beyond the state's fiscal reach. ARB has successfully worked with other research organizations and has participated in multimillion-dollar collaborations.

Summaries of Past Research. Projects completed since the beginning of 1989 are summarized in the Research Division's publication, Air Pollution Research, at www.arb.ca.gov/research/apr/past/past.htm. Research Division's final reports are available at the same web site.

OVERVIEWS OF RESEARCH AREAS

Health Effects and Air Quality Standards

Health and Environmental Justice

Policy Drivers: The majority of health and environmental justice research addresses needs for ambient air quality standards. The relevant legislation driving this area of research includes the Children's Environmental Health Protection Act (SB 25), as well as provisions of Title 17 and the Health and Safety Code that define ambient air quality standards and require regular reviews of the adequacy of the standards. Specifically, projects in the health and environmental justice area focus on (1) the effects of air pollution on individuals, (2) the effects of air pollution on populations, (3) identification of sub-populations that may be more susceptible to adverse effects of air pollution, including infants and children, (4) population groups that are highly exposed due to work or lifestyle factors, (5) biological mechanisms that could explain or support epidemiologic associations between air pollution exposure and adverse health effects.

Ongoing Efforts: The U.S. Environmental Protection Agency, as well as the National Institutes of Health (NIH) and the Health Effects Institute (HEI) are responsible for ongoing extensive research efforts that inform health effects and air quality standards.

Research/Knowledge Gaps: To support its mission to protect public health, the ARB must illuminate knowledge gaps regarding neurotoxicity of PM, biological mechanisms for PM-related health effects, variability of sensitivity to air pollution, responses of children and infants to air pollution exposure, health effects in highly exposed populations, and differential toxicity of PM originating from different sources.

Research on PM has focused primarily on lung-related endpoints, although recent efforts have begun to focus on endpoints related to the heart. Preliminary data suggest that PM may also have adverse effects on some portions of the nervous system, but little is known about the potential of ambient PM to have neurotoxic effects.

While many epidemiologic studies report statistical associations between PM exposure and a range of adverse health effects, research to date has not fully described biological mechanisms that could explain these associations.

To support its responsibility for setting ambient air quality standards, ARB must clarify the basis for the high variability of sensitivity to air pollution within California's population, in particular the susceptibility of children and infants to air pollution exposures.

Little information is available on the effects of PM exposure in sub-populations that are highly exposed, for example, outdoor workers and people who are frequently active outdoors. These groups have considerably higher exposure than populations at risk of death or hospitalization who have chronic diseases, which have been the focus of most PM-related research.

ARB must also resolve the differential toxicity of PM from various sources to support cost-effective emissions control regulations.

Recommended for Funding
Environmental Exposures in Early Childhood Education Environments
This study addresses requirements of SB 25 regarding exposure of infants and children to air pollutants. It will provide an assessment of exposure to toxic air contaminants, volatile and semi-volatile chemicals, pesticides, and allergens in child care facilities. There is little information on these exposures or on this population and the resulting data will directly inform ARB's efforts on indoor air quality in educational institutions. *Proposed funding level: $375,000*

Neurotoxic Effects of Ambient Particulate Matter: The Role of Oxidative Stress
The results of this study will contribute to ensuring that ambient air quality standards are adequately protective of public health. This study addresses a new area of research: effects of air pollution on the neurological system. There little information on air pollution effects on organ systems other than the heart and lungs, and preliminary data suggest that the potential for PM to induce neurotoxicity should be investigated. *Proposed funding level: $300,000*

Personal, Indoor and Outdoor Particulate Air Pollution and Heart Rate Variability in Elderly Subjects with Coronary Artery Disease
Study results will provide support for ambient air quality standards. The study will investigate risk of cardiovascular events in patients who already have cardiovascular disease. This population has already been identified as at elevated risk of adverse effects with PM exposure, and the study will help to clarify the degree to which PM elevates cardiovascular risk. *Proposed funding level: $150,000*

Recommended if Funding Available
Vulnerable Populations Among People Who Exercise or Work Outdoors: Acute Health Effects of Traffic-Related Air Pollution During Outdoor Exercise
This project supports review of ambient air quality standards for PM. The standards are required to protect all groups of people, but there are no epidemiologic studies of the effects of PM exposure on outdoor workers, and only a few small panel studies on people exercising outdoors. While outdoor workers and people exercising outdoors are the most highly exposed to PM by virtue of their time-activity patterns, little is known about the acute effects of PM exposure in these groups. *Proposed funding level: $490,000*

Climate Change

Mitigation and Science

Policy Drivers: Funding recommendations to address AB 32 Mitigation and Science were guided by the needs for technical data to enable development of AB 32 early action measures and for regional resolution of global warming in California. In the area of AB 32 Mitigation, recommendations for funding support early action programmatic needs for collaborative research on N_2O emissions from nitrogen land application and technical assistance to a voluntary "cool communities" program for promoting near-term reduction of GHGs. In the area of AB 32 Science, the recommended project initiates research to resolve source apportionment of particles' climate forcing in California, with an emphasis on vehicular sources and biomass combustion. It is also anticipated that as the Scoping Plan is developed over the next several months, additional research needs and methodological refinements will be identified. For example, the economic analysis currently being applied to support the Scoping Plan will benefit from input received as part of the public process, which is likely to reveal additional opportunities for further economic studies to support implementation of the Plan. To the extent that they support near-term needs, we will bring additional research proposals to the Board prior to completing next year's research plan.

Ongoing Efforts: In the area of nitrogen land application, the California Department of Food and Agriculture (CDFA) is currently sponsoring several research projects in the area of nitrogen fertilizer management. Although these projects will not collect field data on N_2O emissions, they are directly relevant to the related goals of AB 32 early actions and will provide critical information required for developing best management practices for N_2O reductions from agricultural soils. For more than two decades, the Heat Island Group (HIG) at Lawrence Berkeley National Laboratory (LBNL) has quantified the abilities of urban vegetation and solar-reflective surfaces to reduce the need for cooling energy, lower the outdoor air temperature, and improve air quality. In the area of source apportionment of aerosols' climate change impacts, there are pioneering academic efforts in California on detailed emission measurements and source-oriented air quality modeling of aerosols to clarify climate forcing.

Research/Knowledge Gaps: Technical and scientific support for AB 32 early actions is a critical and immediate need for ARB, particularly in the areas of mitigation of non-CO_2 greenhouse gases such as N_2O and support of voluntary actions such as the cool communities program and behavioral change campaigns. Scientific research is also needed to delineate the climate-forcing properties of combustion-derived aerosol and to clarify the health and climate implications of emissions controls. Two areas of potential research interest to the Board that did not result in any two-page submittals in the current ARB public solicitation are vulnerability assessment and adaptation to climate change at the California scale. The California Energy Commission's (CEC's) first overview of "Scenarios of Climate Change in California" included limited work in vulnerability assessment and adaptation. The CEC's current solicitation seeks research on local to regional scale adaption. Mitigation has long been in the center stage of the

climate debate, but increasingly important areas of research include understanding susceptibility to adverse effects of climate change and adjusting to impacts.

Recommended for Funding

Assistance to Develop a Cool Community Program in Support of AB32

ARB has specified a voluntary "cool communities" program as an early action program (TIER 1) in support of AB 32. The recommended project will provide technical assistance to promote energy savings, GHG emissions reductions, and improvements to the urban environment. *Proposed funding level: $350,000*

Radiative Forcing and Source Apportionment of Combustion-Derived Particles in California

Scientific research to support AB 32 will clarify the atmospheric evolution of optical properties of combustion-derived aerosols so that their radiative forcing can be better represented in climate models. This work will also include regional modeling to illuminate source contributions to radiative forcing in California. *Proposed funding level: $750,000*

Collaborative Research to Understand How to Reduce N_2O Emissions from Nitrogen Land Application

Developing strategies to mitigate N_2O emissions requires establishing baseline emissions and measurement protocols to reduce substantial uncertainties in the existing emission inventories, especially for agricultural soil management. This research is expected to characterize the relationship between nitrogen land application and N_2O emissions from agriculture, landscaping, and other uses and the identification of emission reduction opportunities. The Agricultural stakeholder community is supportive of the proposed research-oriented approach included in ARB's AB 32 Early Action Plan and CDFA has expressed strong interest in co-funding some agricultural research. *Proposed funding level: $300,000*

Behavioral Change

Policy Drivers: Meeting near-term (AB 32) and long-term (2050) climate goals will require extensive behavioral changes in home energy and water use, business operations, and transportation patterns. Regarding residential energy consumption, studies indicate that behavioral and demographic factors typically account for as much variability as size, construction features, and efficiency of major home appliances. Nevertheless, behavioral change campaigns and exploitation of demographic determinants to streamline public outreach have been deficient, despite the success of many well-designed and adequately funded initiatives to change behavior in sizeable portions of target populations when behaviors have tangible benefits (including peer approval). While social science research delineating behavioral and demographic determinants of greenhouse gas emissions has historically been neglected, interest is rapidly growing as government agencies recognize the necessity and potentially high returns of this knowledge. Effective policies and social marketing to reduce greenhouse gas emissions must internalize a clear understanding of how behavioral and demographic factors affect individual choices regarding residential consumption, transportation, and business operations that affect carbon footprints.

Ongoing Efforts: Most of the required social science research has not been initiated, but there are a number of projects that should be watched and could complement initiatives that the Air Resources Board may develop. In California, for example, the Public Utilities Commission (PUC), working through the California Institute for Energy and Environment of the University of California, has commissioned a series of white papers on Consumer Behavior and Energy Consumption. They will address energy efficiency potential, measurement, and program evaluation, among other issues. Agencies in other states (e.g., the New York State Energy Research and Development Agency) are starting similar initiatives, and discussions regarding behavioral research are beginning in the U.S. Department of Energy.

Research/Knowledge Gaps: Several questions need to be clarified in the California context to support effective climate mitigation strategies, including:
- *What determines household consumption of energy, water, natural gas, and transportation resources*? Comparable households—with apparently similar perceptions and experiences regarding quality of life—in California can vary by an order of magnitude or more in consumption of these resources. Moreover, pilot research in California suggests that behavioral and demographic factors determine at least half of the variability in consumption patterns. Understanding these social factors will be critical in replicating low- or no-cost household behavioral changes and crafting effective social marketing campaigns.
- *How do choices upstream of households affect home energy efficiency?* Research is needed to clarify how home energy efficiency is shaped by decision makers such as home builders, home equipment manufacturers, mortgage lenders, rental housing owners and managers, heating and cooling system contractors, and appliance retailers and repair personnel.
- *What determines household choices among available homes and equipment?* Little research has been done to clarify an important but little understood trend driving

home energy use, the trend of housing units to grow in size and to contain more and larger energy-using appliances, even while the number of people per household decreases. In particular, research is needed to clarify the role that climate change, energy use, and energy cost considerations might play in the choices underlying these trends.

- *How can better systems be designed to inform consumers about their best options for improving home energy efficiency and reducing their carbon footprints?* Effective outreach requires identifying mistaken beliefs about behaviors with significant mitigation potential, developing and testing ways to correct them, and crafting systems for delivering trustworthy, clear information to consumers at the time of choice.
- *What can be done to decouple energy consumption from perceptions (and misperceptions) of well-being?* This important fundamental research question is of long-term relevance in California with regard to home energy use as well as transportation. Subjective well-being is linked much more closely to meeting needs than to energy consumption, and it is imperative to decouple the two.
- *How can improved government links to energy users promote policy goals?* The most effective outreach is a two-way street: not only does it deliver information to users, but it serves as a source of insight into what information would be useful. For example, research into consumer behaviors during the 2001 electricity deregulation crisis showed that behavioral change was instrumental in curtailing black-outs, but that the critical behavior (turning off A/C) was not the behavior (slightly raising the thermostat) prescribed by outreach campaigns. Knowing what behaviors are actually practiced by citizens would facilitate more effective outreach campaigns.

Recommended for Funding
Behavioral and Demographic Determinants of Low Residential Consumption Patterns Observed in California Households

This project addresses knowledge gaps that are crucial supports to crafting effective behavioral change campaigns. First, it will delineate the demographic and behavioral determinants of household consumption of energy, water, natural gas, and transportation resources. Secondly, it will help forge effective social marketing as well as two-way exchange between government and energy users. Research results will help ARB devise effective outreach strategies and design sound social marketing programs. *Proposed funding level: $250,000*

Emissions

Policy Drivers: The passage of Assembly Bill 32 (AB 32) mandates not only specific targets for the state's aggregate greenhouse gas (GHG) emissions, but also the need to monitor GHG concentrations within California and to verify GHG emission source strengths. Achieving the emissions reductions specified in AB 32 requires a verified emission inventory of GHGs. Given uncertainties in the current emissions inventory, it is possible that sources may be missing or some source strengths inaccurately accounted. Comprehensive measurements of GHG emissions within California are needed to substantiate and constrain the state's emissions inventory.

Ongoing Efforts: There are few GHG measurement efforts within California focusing on identification and quantification of emission sources or inventory verification. Despite ongoing collaboration among extant projects, their combined efforts are inadequate to provide the level of resolution and accuracy needed to verify the greenhouse gas inventory for California and to monitor emissions reductions as mitigation strategies are put in place.

Research/Knowledge Gaps: Methane (CH_4) and nitrous oxide (N_2O) are listed as high research priorities by the California Energy Commission due to the possibility of large uncertainties in the emission inventory for certain source categories.

Recommended for Funding
None

Recommended if Funding Available
Improving Methods for Assessment of California Greenhouse Gas Emissions
The project to be considered for funding directly relates to emissions of methane (CH_4) and nitrous oxide (N_2O), which are significant uncertainties in the current emissions inventory. Results would enhance the understanding of possible errors associated with simulated meteorology when combined with inversion modeling to assess regional emission sources measured at tower monitoring sites. *Proposed funding level: $270,000*

Water

Policy Drivers: Water resource planning in the state is critical to meeting AB 32 goals and adapting to climate change. Concerns regarding climate change and its potential effect on water resources include a projected dramatic decrease in the Sierra Nevada snowpack, challenges in securing adequate water supplies, potential reduction of hydropower, and loss of winter recreation. Given the amount of energy used in transporting and heating water in the state, reductions in water usage offer means to mitigate greenhouse gas emissions through reduced water-related energy consumption. In the AB 32 Early Action Plan by the Climate Action Team, the Department of Water Resources (DWR) identified three discrete early actions dealing with water use efficiency, the State Water Project, and cleaner energy for water supply.

Ongoing Efforts: The Department of Water Resources, which is a member of the Climate Action Team, and the U.S. Bureau of Reclamation have joint forces to manage the complex aspects of water supply, flood management, environmental protection, and recreation of the two massive state projects: the State Water Project and the federal Central Valley Project. DWR conducts climate change studies using global climate models and downscaled data to assess regional impacts on water resources. In addition, CEC's PIER program has funded studies on the potential impact of climate change on water flows in rivers in the state. Presently, PIER and the U.S. Geological Survey have commissioned a roadmap study on snow conditions and water recharge. In concert with this roadmap, CEC's current PIER research solicitation is seeking research on the contribution of snowmelt to underground water recharge.

Research/Knowledge Gaps: Research needs at the water-climate change interface in California include adaptation to shifting hydrological cycles and mitigation to reduce emissions from treatment, distribution, and use of water in California. Research on climate change and water is of interest to the water boards, DWR and SWRCB, and should be coordinated accordingly.

Recommended for Funding
None

Recommended if Funding Available
Assessing the Energy Savings and Greenhouse Reduction Potential of Water Efficiency Improvements in the California Industrial Sector
While a substantial body of information exists on industrial water efficient technologies and practices, no study has assessed the water, energy, and GHG emissions savings potential, life-cycle costs, and sub-sector level applicability of water efficiency measures across California industry. This work will support improved industrial water efficiency to help California meet energy efficiency and GHG emission reduction targets as well as facilitate availability of scarce water resources, reduce peak electrical demand, and reduce air pollution. *Proposed funding level: $300,000*

Diesel and Goods Movement

Diesel Emissions

Policy Drivers: Ten years since the identification of diesel PM as a Toxic Air Contaminant (TAC) and eight years into the Board-adopted Diesel Exhaust Exposure Risk Reduction Management Plan, diesel emissions research continues to play a critical role for supporting and informing inventory and regulation development. With increasingly stringent emission standards for new on- and off-road diesel engines, statewide ultralow sulfur diesel fuel, a world-leading diesel retrofit program, and successful implementation of many regulations, ARB is positioned to continue reducing diesel emissions from all major sources in the state. New research supports clarification of health impacts of exposure to diesel emissions and identification of additional emissions reduction opportunities.

Ongoing Efforts: Research, development, and demonstration of diesel controls are evidenced by the increasingly successful gatherings of the Coordinating Research Council's On-Road Vehicle Emissions Workshop and the U.S. Department of Energy's (DOE's) Diesel Engine Efficiency and Emission Reduction Conference. In addition, the multimillion, multiyear Advanced Collaborative Emissions Study and other efforts in Europe and Japan indicate that diesel emissions research is a high priority for the environmental community at large.

Research/Knowledge Gaps: On-road diesel engines are now 90+% cleaner in terms of PM emission than they were just a year ago and similar reductions in NO_X emissions are expected in two years. Remaining frontiers in diesel emission control are sources such as off-road vehicles and engines, ships, and locomotives as well as characterization of equipment deterioration and retrofit performance. In related research (see Toxic Air Contaminants), measurement of climate and health impacts of diesel emissions under changing controls is a priority.

Recommended for Funding
Measurement of Off-Road Diesel Engine Deterioration
Off-road diesel emissions now account for a significant fraction of all PM emissions from the diesel sector. Just as new off-road engine emissions standards have historically lagged behind standards for new on-road engines, the development and improvement of the inventory model OFFROAD has lagged behind the EMFAC model. This project would improve the OFFROAD model's estimates of deterioration rates. *Proposed funding level: $300,000*

Recommended if Funding Available
On-Road Heavy Duty Vehicle Emissions Measurements Including Ammonia, Sulfur Dioxide, and Nitrogen Dioxide
The concept describes an effort to collect a large set of emissions, including direct emissions of NO_X and PM as well as PM precursors, using remote sensing. The project leverages ARB's funding with co-funding from the SCAQMD and NREL. *Proposed funding level: $100,000*

Goods Movement

Policy Drivers: Activities related to goods movement are a major source of emissions and contribute substantially to health risks in the state. Emissions from this category have SIP implications, and risk assessments for the ports and rail yards indicate an immediate need to clean up emissions associated with goods movement to reduce significant health risks.

Ongoing Efforts: ARB is heavily invested with implementing goods movement regulations, and is working on regulations such as the private truck fleet and main engine ship rules. The agency is also heavily involved in developing emission inventories for goods movement categories, and evaluating the health risks at ports and at rail yards. There are also regional efforts (primarily at the ports) to reduce localized risk.

Research/Knowledge Gaps: A critical need remains for improved emission activity data, especially for trucks. Characterizing truck types and activity at ports is needed to support mitigation of air quality impacts of goods movement. Additionally, exposures of port workers to air pollutants remain uncertain due to their exposure on- and off-site; the project recommended if additional funding becomes available would illuminate port workers' total exposure.

Recommended if Funding Available
Port Workers' Exposure to Air Pollution
The Ports of Los Angeles and Long Beach and their terminal operators provide employment to thousands of workers in on-dock and transportation jobs. Characterizing their potentially elevated exposure to air pollutants will provide important health information to decision makers. The recommended study would utilize a combination of personal monitoring and area sampling to characterize the exposure of port workers. *Proposed funding level: $300,000*

Atmospheric Science

CalNEX 2010

Policy Drivers: This is a unique opportunity to have the National Oceanic and Atmospheric Administration (NOAA) conduct a major field study in California that would improve our understanding of climate change, air quality and their coupling. The air quality and meteorological data collected would improve ARB's air quality models used in SIP development, our understanding of atmospheric formation of ozone and PM and the emission inventories of GHGs and traditional air pollutants and precursors.

Ongoing Efforts: NOAA has extensive experience in field studies (e.g. Central California Ozone Study (CCOS), New England Air Quality Study, Texas Air Quality Study, East Tennessee Ozone Study and Bay Region Atmospheric Chemistry Experiment). California has conducted major air quality field studies in the past (CCOS, California Regional Particulate Air Quality Study (CRPAQS), the 1997 Southern California Ozone Study - North American Research Strategy for Tropospheric Ozone (SCOS97 – NARSTO)) but has not undertaken a major field study focusing on climate and the atmosphere. As part of CalNEX 2010, NOAA would deploy research platforms (e.g., planes and a research vessel) to collect data that is otherwise unavailable. The range of the NOAA planes and vessel allow this study to address a larger spatial extent (the Southern California Air Basin (SoCAB), the San Joaquin Valley, and the San Francisco Bay Area) than previous field studies. NOAA's costs are estimated at $12.7 million over four years, so a $2 million contribution from ARB will leverage State funds by more than six to one.

Research/Knowledge Gaps: The CalNEX study will improve the emissions inventory for GHGs and precursors of ozone and PM. ARB's air quality modeling will also benefit from improved understanding of chemical processes, transport and meteorology in multiple areas of the state.

Recommended for Funding
All of the recommended projects address issues with policy relevance to ARB and would be of value as independent studies. Their benefits will be magnified by the synergism of multiple, simultaneous data collection efforts. As planning proceeds and contributions to CalNEX from other sources become clear, areas that would benefit from additional funding may be revealed. The studies below total approximately $1.4 million, and the balance of $2 million committed to CalNEX collaboration will be devoted to developing additional projects that leverage otherwise unavailable resources.

Nocturnal Chemistry in the Urban Boundary Layer of Los Angeles
This work will address the fact that many air quality models perform poorly at night and have not been validated for nocturnal conditions, introducing considerable uncertainties in our ability to model urban air quality. *Proposed funding level: $200,000*

Chemical Signature Differences between the South Coast & the San Joaquin Air Basins

The purpose of this study is to improve our understanding of differences in the atmosphere in the SoCAB and SJV which can impact response to control measures. *Proposed funding level: $550,000*

Mass Spectral Characterization of Organic Particulate Matter (PM) Sources and Processes Using Novel Instrumentation and Advanced Data Processing Methods
The unique data generated by this investigation will furnish critically needed information on organic aerosols (especially SOA) and their sources and evolution, which will improve air quality modeling of PM formation and source apportionment of OC. *Proposed funding level: $282,000*

Sulfur Study in Bight of Southern California
This work will collect information about the relative contributions of oceanic sources of sulfur, SO_x emissions from maritime shipping activities, and SO_x emissions sources in Mexico. Identification of sources of excess PM sulfate in Southern California is necessary to reduce PM sulfate and the health effect associated with it. *Proposed funding level: $350,000*

<u>**Recommended if Funding Available**</u>
Optical Remote Sensing from Mt. Wilson: A New Approach to Study Sources of Pollutants and Greenhouse Gases in the South Coast Air Basin
This project will provide observations of greenhouse gases (CO_2, CO, CH_4, N_2O) and NO_2, HCHO with a vertical resolution of 0.2 to 1 km, a horizontal resolution of at least one kilometer, and a temporal resolution of 0.5 - 1 hour. Data of such temporal and spatial resolution will be very valuable in validating the GHG inventory and air quality models. *Proposed funding level: $285,000*

Global Chemical/Aerosol Data Assimilation Experiments in support of the proposed 2010 California Air Quality and Climate Study
The integration of satellite observations and global models in this study will benefit ARB's SIP modeling through improved characterization of the temporal, spatial distributions oceanic boundary conditions and from quantification of the contribution of background ozone and PM to California's air quality. *Proposed funding level: $480,000*

Measurement of Ozone Aloft for the 2010 Air Quality and Climate Field Study in California
This work will provide vertical ozone measurements to fill in concentration fields based on surface and aircraft measurements collected during CalNEX and would help answer questions about the magnitude and extent of ozone reservoirs aloft. *Proposed funding level: $600,000*

State Implementation Plan (SIP) Support

Monitoring

Policy Drivers: One of ARB's goals is to provide accurate, relevant, and timely measurements of air pollutants and their precursors in California. ARB's air quality monitoring program collects accurate real-time measurements of ambient level pollutants at over 40 sites located throughout the state. The monitoring program also collects emissions data from cars, trucks, industrial processes, and other sources. The data generated are used to define the nature and severity of pollution in California; determine which areas of California are in attainment or non-attainment; identify pollution trends in the state; develop air quality models and emission inventories, and support regulatory development.

Ongoing Efforts: Recent efforts to improve air quality have increasingly focused on measuring and reducing particulate matter (PM) and ozone formation precursors (e.g., VOCs and NO_X). ARB and outside researchers have led the way in evaluating and deploying both standard methods and new technology for determining the amount of PM and ozone precursors in the air.

Research/Knowledge Gaps: Air quality measurements at ambient monitoring stations routinely show consistent effects for important health endpoints. However, there is also recognition that actual human exposure sometimes differ substantially in temporal and spatial distribution from what these monitoring stations measure. To better understand the relationship of particle exposures and ill-health and to better target control measures to address exposure, there is a need for technologies to monitor particle levels in a wide range of locations, preferably with high temporal resolution.

Recommended for Funding
Inexpensive NO/NO$_2$/NO$_X$/PANs Analyzers for Ambient Monitoring
This research will support development of lower-cost, more accurate NO_2 analyzers that are capable of simultaneous measurement of NO and key chemicals involved with ozone formation. *Proposed funding level: $100,000*

Low-Cost Environmental Sensors for Use in Air Quality Enforcement and Compliance, Surveillance, Exposure and Research Studies
Community groups are interested in particle monitors that can be used to determine spatial and temporal resolution easily to characterize the impact of local pollution sources. This research addresses the need of both technical and community groups for reliable, quiet, portable, long-lasting, easy-to-deploy, quick reading, high temporal resolution, and inexpensive devices for monitoring air quality. *Proposed funding level: $350,000*

Ozone

Policy Drivers: Many areas of the state are non-attainment of the current 8-hour ozone standard, and U.S. EPA has proposed a new, lower standard. Recent SIPs demonstrated the difficulties in achieving the necessary emission reductions to achieve the current standard, and the new standard will require new and innovative control strategies. Some areas of the state, in particular the San Joaquin Valley, have seen little progress recently in ozone design values. The South Coast has seen remarkable progress in their design values over the past two decades, yet recently their progress has leveled off. Until the standards are achieved, much of the state's population will remain exposed to unhealthy levels of ozone.

Ongoing Efforts: Many areas of the country recently prepared, or are in the process of preparing, 8-hour ozone SIPs. ARB and U.S. EPA have ongoing research programs that include projects related to inventory development and science improvements. The Central California Ozone Study has funded several research projects related to ozone, and will be near completion after the final increment of funding is contracted. The SCAQMD funds some ozone work, primarily for SIP support. NOAA's planned 2010 field study would provide data to further our understanding of basic atmospheric chemistry and dynamics relevant to the state's ozone problem.

Research/Knowledge Gaps: Regulatory efforts that rely on reactivity scales (MIRs) are limited by a dearth of data and understanding reflecting the current mixture and behavior of VOCs in California's air districts. Use of low-VOC stain-blocking primers, which could accrue substantial emissions reductions, is thwarted by inadequate performance of available products. There also remains much work to be done to support future ozone SIPs. These include efforts to improve anthropogenic and natural emissions inventories (especially for agriculture, mobile sources, and biogenics), improve our fundamental understanding of atmospheric chemistry, refine precursor relationships in the major non-attainment areas of the state, support optimized monitoring networks, and address the new ozone standard.

<u>Recommended for Funding</u>
Development of an Updated Base Case Ambient VOC Mixture
Many reactivity-based regulations rely on reactivity scales (such as MIRs) to promote or regulate VOC-containing compounds and fuels to be less reactive. However, current reactivity scales were derived in the late 1980s using ambient VOC mixtures that are now approximately 20 years old. The first recommended study would update the mixtures to reflect current conditions, and lead to improved reactivity scales and more effective regulations. *Proposed funding level: $40,000*

Near-Zero VOC Stain Blocking Primer Formulations
New near-zero (emissions substantially less than 100g/L) VOC technology will allow for the maximum reduction in emissions (>2.63 tons/day) while providing performance properties equal to the 350 g/L alkyd based technology that currently dominates California's marketplace. *Proposed funding level: $400,000*

<u>Recommended if Funding Available</u>
Cluster Analysis of Air Quality and Meteorology Data for 1996-2008
This study would explore meteorological influences on ozone and PM air quality at inter-basin and intra-basin scales, using cluster analysis for seven major air basins in the state (San Joaquin Valley, South Coast, Sacramento, San Diego, North and South Central Coast, and Mojave Desert). The results would be useful for assessing how atmospheric processes contribute to ozone and PM exposures over a wide range of actual conditions; this approach complements episodic air quality modeling and provides a conceptual framework for evaluating seasonal and annual air quality modeling. *Proposed funding level: $250,000*

Particulate Matter

Policy Drivers: The South Coast Air Basin and San Joaquin Valley are both non-attainment for PM2.5. The recent SIP for the South Coast demonstrated the uncertainties associated with PM2.5 spatial patterns, speciation, and control. PM levels in the two non-attainment areas are such that a large portion of the state's population is subject to unhealthy levels of PM which have been linked to compromised health.

Ongoing Efforts: Work is ongoing to develop improved monitoring capabilities for organic aerosols, as well as to separate out individual species using ATOFMS (Aerosol Time-Of-Flight Mass Spectrometer) samplers. Work is ongoing to improve PM and precursor inventories at ARB, the SCAQMD, the SJVAPCD, and at universities. The California Regional PM10/2.5 Air Quality Study (CRPAQS) funded several PM-related projects, and although some of these projects are still underway that effort is winding down.

Research/Knowledge Gaps: The recommended projects would improve our fundamental understanding of secondary organic aerosol (SOA) formation, and elucidate the optical properties of fine particulate emissions with diesel particulate filters (DPFs). SOA is an important component of PM that affects visibility, climate, and health. The optical properties of particulate emissions are expected to change with DPFs, and this could have climate implications.

Additionally, uncertainty remains in organic speciation and characterization that facilitate identifying source contributions to the organic carbon portion of PM. Specifically, ARB needs to be able to distinguish the individual contributions of combustion sources (cooking, biomass, etc.) for modern carbon. Since nitrates are a significant portion of the PM loading in the South Coast and San Joaquin Valley, any efforts to improve the NO_X inventory will improve PM SIPs. Also, the climate forcing of particulates remain an area with some uncertainty, especially with the introduction of new control technologies.

<u>**Recommended for Funding**</u>
Formation of Secondary Organic Aerosols: Chamber Study and Modeling
Secondary organic aerosol (SOA) constitutes an important component of fine particulate matter (PM) that impacts visibility, climate, and health. The chemical and physical processes involved in SOA formation are poorly understood, and the semi-empirical models used to predict SOA involve many highly uncertain assumptions. Previous models have under-predicted ambient SOA formation by as much as an order of magnitude. The recommended project would provide a new model that accurately tracks SOA formation. Also, increasingly stringent controls on NO_X emissions for both on-road and off-road sources will lead to changes in the VOC/NO_X ratios within the atmosphere. Such changes in atmospheric reactivity directly impact the extent of gas-to-particle conversion of VOCs. This project would provide the information needed to study SOA formation across a range of VOC/ NO_X ratios. *Proposed funding level: $475,000*

Bridging On-Road and Laboratory Emission Measurements: An Integrated Approach

Particulate emissions measured in the laboratory are not directly comparable with on-road measurements. Discrepancies are particularly pronounced for ultrafine particles. Further, the introduction of diesel particulate filters (DPFs) as a retrofit technology will complicate the formation of ultrafine particles since DPFs removes nearly all solid soot particles in the accumulation mode (0.3 to 1 µm, diameter). Most of these solid soot particles are made of black carbon, a strong light-absorbing compound. Therefore, the optical properties and climatic impact of diesel exhaust are likely to change significantly. This project would evaluate the effects of DPFs on the optical properties of vehicle emissions. *Proposed funding level: $420,000*

Toxic Air Contaminants

Policy Drivers: The Board identifies and regulates toxic air contaminants (TACs) based primarily on their toxicities and the extent of the population's exposures to them, plus other factors such as feasibility of emission reduction and available technologies. Diesel exhaust has remained a high priority since its identification 10 years ago. In past years, metals such as lead, arsenic, and chromium VI, and combustion emissions such as PAHs have also been identified as TACs. In 2007, the Board identified environmental tobacco smoke (ETS) as a TAC and approved an ATCM to limit formaldehyde emissions from composite wood products. A list of compounds for prioritization is currently being assembled and will soon be submitted to the Scientific Review Panel for their review and comment. Crystalline silica has not yet been identified as a TAC, but is currently in the second tier group of compounds on the draft prioritization list.

Ongoing Efforts: The priorities of the TAC program and fuels program include diesel exhaust and projects focused on greenhouse gas reduction, goods movement, and the like. For ETS, staff are currently assessing the further regulations, voluntary measures, and outreach efforts that may be appropriate to address ETS exposures beyond the statewide ban of smoking inside buildings and in vehicles when children are present. Toxic metals are controlled through a variety of regulations, primarily for stationary sources but also for some fuels. Crystalline silica is undergoing study by industry, and CAPCOA is also reviewing information.

Research/Knowledge Gaps: There are substances that may pose public health risks on which ARB still lacks sufficient data. For example, monitoring data suggests that acrylonitrile and acrolein may pose health risks at ambient levels, but we do not have good source information. Conversely, there are other substances that we may not currently monitor that may pose risks of which we are simply unaware. The project that is recommended if funding becomes available would potentially confirm the accuracy and usefulness of a passive monitor for measuring environmental tobacco smoke (ETS) exposure in different parts of a multifamily dwelling, which would help facilitate actions by landlords and local governments to prevent such exposures.

Recommended for Funding
None

Recommended if Funding Available
Guidelines and Sampling Protocols for Measuring ETS in Multifamily Dwellings
ARB identified ETS as a TAC in 2006. Exposures in multifamily dwellings, where households may not be able to control residential ETS exposures, can be quite elevated. *Proposed funding level: $425,000*

Ultrafine PM

Policy Drivers: The ARB may at some time in the future consider a particle number ambient air quality standard. Before enacting a particle number standard, however, ARB will need a measurement protocol and convincing health data to justify the level of the standard. In addition, new limits on and controls for motor vehicle sources may be needed.

Ongoing Efforts: The ARB has on-going research efforts to evaluate the proposed new European methodology for determining particle number emissions and its potential in California for in-use screening. The ARB is also participating in the European Particle Measurement Programme (PMP) program as an unofficial member and has recently reported on the application of the PMP measurement protocol for heavy-duty diesel engine emissions. Also, a number of animal and human studies funded by the ARB are focused on the health effects of ultrafine exposure.

Research/Knowledge Gaps: Research is needed to understand and predict the particle formation potential of an exhaust system for such a standard. Particle number production depends on many factors. They include driving cycle, dilution, temperature, humidity, and particle precursors like semi-volatile organics and sulfates. Also, the toxicity of ultrafine particles relative to fine and coarse particles needs to be determined.

<u>**Recommended for Funding**</u>
Measurement of Diesel Solid Nanoparticle Emissions Using a Catalytic Stripper for Comparison to Europe's PMP Protocol
This project will help inform ARB, should it consider a number standard for PM in the future. It would also critically evaluate the European PMP protocol and characterize the composition of ultrafine particles. *Proposed funding level: $170,000*

<u>**Recommended if Funding Available**</u>
Sources, Composition, Variability and Toxicological Characteristics of Ultrafine Particles in Southern California
This project could add evidence for consideration of UFP particle number standard. The research team is experienced in particle measurement, but lacks toxicological expertise. *Proposed funding level: $650,000*

RESEARCH CONCEPTS RECOMMENDED FOR FUNDING

LIST OF RECOMMENDED RESEARCH CONCEPTS

Health Effects and Air Quality Standards

TITLE: Environmental Exposures in Early Childhood Education Environments

PROBLEM: Approximately 900,000 California children ages 0-5 and 146,000 staff spend up to 40 or more hours per week in child care centers or preschools. Although school environments are known to contribute significantly to older children's exposures to a number of pollutants, including volatile organic compounds (VOCs), there is virtually no information available on environmental exposures to these or semi-volatile organic compounds (SVOCs) such as brominated flame retardants, phthalates, or perfluorinated compounds in California childcare environments. These exposures can cause or exacerbate asthma and other respiratory illnesses or impair neurocognitive functioning in children. Many of these chemicals are serious reproductive toxicants and may be harmful to the developing child; some of these chemicals (e.g. aldehydes) are also carcinogenic. Collectively, Early Childhood Education (ECE) facilities are varied and include home-based providers, centers operated like private schools, or programs run by government agencies (e.g. pre-school in school districts or Head Start) or religious institutions. These facilities are located in different building types, including homes, schools, private commercial buildings, and portable classrooms. Data on exposures in these environments are critical to assess the potential health risks and, if warranted, to devise and implement policies to mitigate these exposures.

PREVIOUS WORK: The First National Environmental Health Survey of Child Care Centers, conducted by the U.S. EPA and Dept. of Housing and Urban Development (HUD), was a probability-based study that tested 168 childcare centers for allergens, pesticides, and lead (1). These compounds were commonly detected; however, few sites were tested in the western U.S., and this study did not test for other pollutants, including VOCs or SVOCs. To date, there are no data available to assess child and staff exposures to these compounds in ECE environments. Sources of exposure include indoor sources such as sanitizers required by licensing regulations and VOCs from building materials, and outdoor activities (e.g., industrial and vehicle emissions). Several studies have also shown that poor housing quality, poor air quality, and other pollutant exposures of children are highest in low-income communities; thus, levels of unhealthy environmental exposures may be higher in facilities located in low-income communities.

OBJECTIVE: To determine levels of Toxic Air Contaminants (TACs) and other chemicals and particulates that may require future regulation in a sample of ECE facilities located in California's urban and agricultural communities.

DESCRIPTION: We will measure air pollutants in 40 ECE facilities including selected VOC and SVOC TACs, some Proposition 65 substances that may warrant consideration for regulation as TACs, and a criteria pollutant (fine and ultrafine particles). We will also conduct detailed facility inspections. To select participants, we will identify all licensed ECE facilities in one urban (Alameda) and one rural (Monterey) county. We will group all licensed facilities (627 in Monterey, 2,522 in Alameda) into home- or center-based facilities, and further subdivide center-based facilities into private for-profit,

governmental, or non-profit categories. Address information will be used to map the facilities by census tract. We will then randomly select 100 facilities, ensuring general representation based on socioeconomic characteristics and urban/rural classification. Facility directors will be asked to participate in a phone questionnaire to collect data.

We will select a subset of 40 facilities (20 in Alameda County and 20 in Monterey County) with a range of conditions and building types, for detailed environmental health inspections and extensive environmental sampling. We will measure VOCs (EPA Method TO-15), aldehydes (formaldehyde, acetaldehyde, etc. by DNPH), phthalates, brominated flame retardants, perfluorinated compounds, and fine and ultrafine particles in air samples. For a subset of 20 facilities, we will also measure brominated flame retardants, phthalates, and perfluorinated compounds in floor/carpet dust. Limited outdoor measurements will be obtained as well. The inspection protocols will follow procedures developed by our research group (2,3), HUD, and school districts, adapted for use in ECE environments.

The environmental measurement data will be used to characterize contaminant levels in ECE environments and estimate potential health risks associated with specific exposures. Where appropriate, concentrations will be compared to chronic or acute reference exposure levels (RELs) or exposure-dose estimates will be calculated and compared to other health-based benchmarks. We will also identify factors associated with the presence of these substances, such as building materials and local land use such as industrial facilities and traffic density.

BENEFITS: Direct benefits to ARB include development of new concentration and exposure data for young children for several volatile and semi-volatile TACs and other chemicals for which there are virtually no data in California. These data may provide useful information for further regulation of TACs and future revisions of the PM2.5 AAQS. Results may also identify new chemicals that should be considered for regulations as TACs, because many of the target chemicals are known or potential reproductive, developmental, or respiratory toxicants. We will also work with our community partners to highlight findings from the study and to build knowledge and support efforts to improve environmental and public health for California's children.

COST: $375,000

REFERENCES:
(1) Westat Inc. (2003). First National Env. Health Survey of Child Care Centers.
(2) Bradman, A et. al. (2006). Pesticides and their Metabolites in the Homes and Urine of Farmworker Children Living in the Salinas Valley, CA. *J of Exp Sci and Environ Epi* online publication, 31 May 2006.
(3) Bradman, A et. al. (2005). Association of Housing Disrepair Indicators with Cockroach and Rodent Infestations in a Cohort of Pregnant Latina Women. *Env H. Perspect* 113(12):1795-1801.

TITLE: Neurotoxic Effects of Ambient Particulate Matter: The Role of Oxidative Stress

PROBLEM: The brain is a potential target for adverse effects after inhalation exposure to particulate matter. Kreyling and others demonstrated that inhaled, nanosize particles quickly left the lungs and were deposited in extra-pulmonary tissues. We and others have shown that the activities of signaling pathways that mediate inflammatory responses are up-regulated in the brains of mice exposed to concentrated ambient particles in areas near primary emission sources. In addition, biomarkers of oxidative stress and tissue injury are observed at higher concentrations in mice after exposure to concentrated ambient particles for as long as 2-weeks post-exposure. It is essential to determine the degree to which neurotoxicity in the central nervous system (CNS) is dependent on particle dose and particle composition as well as how long oxidative stress and injury persist after exposure ceases.

PREVIOUS WORK: Studies of mice exposed to fine and ultrafine PM in southern CA cities showed that these exposures were associated with significant biological activity resulting in increased rates of formation of atherosclerotic-like plaques and changes in cardiac function. In vivo inhalation studies of airway allergies near freeways suggested that the greatest biological activity was associated with the fraction of PM that contained the greatest amounts of elemental carbon and organic carbon compounds (Kleinman et al., 2006). The genetically modified mice (ApoE -/-) used for our cardiovascular disease studies are also a well recognized model for CNS neurotoxicity These mice exhibit heightened levels of oxidative stress and errors in modulating oxidative stress in the brain. Previous work has demonstrated significant upregulation of the immune-related transcription factors NF-kB and AP-1, as well as the principal proinflammatory cytokines IL-1a and TNF-a in the brain after exposure to concentrated ambient particulate matter present in air pollution (Campbell *et al.*, 2005). NF-kB promotes the expression of genes involved in inflammation, such as proinflammatory cytokines and inducible nitric oxide synthase (iNOS). In mice that were similarly exposed to northeast regional (New York) particles, glial fibrillary acidic protein (GFAP) staining, which is highly expressed in the macrophage-like astroglial cells of the brain, was increased significantly and there was evidence of degeneration of dopaminergic neurons (Peters *et al.*, 2006). Loss of dopaminergic neurons is a hallmark of neurodegenerative diseases such as Parkinson's. Thus PM exposure, in addition to contributing to cardiopulmonary disease may also be linked to neurodegenerative diseases.

OBJECTIVE: To examine the neurotoxicity, mechanism of action, persistence of oxidative stress and inflammatory responses, and the role of PM composition on effects in the CNS of mice exposed to concentrated ambient particles. This will be a multicity study that will take advantage of an ongoing program sponsored by the Health Effects Institute at New York University. Exposures will be conducted in New York City, Ann Arbor, MI, Seattle, WA and in Los Angeles, CA as part of an investigation of the role of PM composition and concentration on development and exacerbation of cardiovascular disease. This study will extend the investigation to the examination of neurotoxic outcomes in mice exposed in all four locations.

DESCRIPTION: Brains from mice exposed to CAPs for 6 month durations in 4 U.S. cities will be examined using biochemical, immunohistochemical and molecular biological methods. At each site mice will be exposed to concentrated PM using a preagreed protocol and identical exposure systems. Samples will be collected at each site and analyzed for organic and inorganic constituents. Samples of brains from animals exposed at each location will be prepared and evaluated at UCI as part of this proposed study. The time course of CNS injury and persistence of injury will be determined in mice exposed in LA for acute, subchronic and chronic durations. Neurotoxic outcomes will be examined immediately and 2 weeks post-exposure. To accomplish this, additional mice will be exposed along with the mice exposed for the cardiovascular study. Samples of brains of CAPs and air exposed ApoE-/- mice (6–9/treatment) will be embedded and serially sectioned in the coronal plane. Slides will be immunohistologically stained for markers of oxidative stress (iNOS, heme oxygenase-1) and markers of neurotoxicity (tyrosine hydroxylase (TH), a marker for dopamine containing neurons and glial fibrillary acidic protein (GFAP), a marker of astrocytic proliferation). Frozen tissue processed and Westerns will be run and analyzed for the transcription factors NfkB and AP-1. Extracted tissue will be analyzed for inflammatory cytokines (IL-1, TNFα) and for a marker of lipid peroxidation, malonaldehyde.

BENEFITS: This project may improve understanding of the mechanism of neurotoxic action of urban aerosols and identify specific components of the aerosol causally related to health effects. Dose-response and persistence data from the study will aid regulators and planners in developing air quality regulations and land use guidance to better protect the health of California residents.

COST: $300,000.

REFERENCES:

Campbell, A., Oldham, M., Becaria, A., Bondy, S. C., Meacher, D., Sioutas, C., Misra, C., Mendez, L. B., and Kleinman, M. (2005). Particulate matter in polluted air may increase biomarkers of inflammation in mouse brain. *Neurotoxicology* **26**, 133-140.

Peters, A., Veronesi, B., Calderon-Garciduenas, L., Gehr, P., Chen, L. C., Geiser, M., Reed, W., Rothen-Rutishauser, B., Schurch, S., and Schulz, H. (2006).

TITLE: Personal, Indoor and Outdoor Particulate Air Pollution and Heart Rate Variability in Elderly Subjects with Coronary Artery Disease

PROBLEM: Findings in cohort and time series studies suggest that environmental exposure to particulate matter (PM) air pollution is associated with increases in cardiovascular hospitalization and mortality. Individuals at greatest risk include elderly individuals with preexisting cardiovascular or other diseases that place them at high risk for myocardial infarction or stroke (Pope and Dockery 2006). Pathophysiological mechanisms underlying the epidemiologic studies are beginning to emerge. There is a growing body of recent evidence that proinflammatory characteristics of PM may produce deleterious autonomic effects on cardiac function and vascular tone, which increase the risk of more adverse cardiovascular events. However, air pollutant sources and their causal components responsible for autonomic effects remain to be identified. We hypothesize that traffic-related sources are important.

PREVIOUS WORK: Ultrafine particles (UFP) appear capable of inducing the greatest amount of oxidative stress and inflammation per unit of PM mass (Delfino et al. 2005; 2007). Accurate exposure assessment methods are critical to assess the magnitude of human health effects from UFP (Sioutas et al. 2005). Ambient particulate air pollution has been associated with decreased heart rate variability (HRV) in humans, but there is little data on impacts from personal air pollutant exposures, and few studies have used repeated daily ambulatory ECG, opting instead to record short ECG strips at in-clinic visits (Delfino et al. 2005; Pope and Dockery 2006). We recently reported on results using data from the first of two years of data in the proposed study (Delfino et al. 2007). We showed that elemental carbon and estimated primary organic carbon, as well quasi-ultrafine particles < 0.25 μm in diameter ($PM_{0.25}$) were associated with sustained increases in biomarkers of systemic inflammation and platelet activation, and decreases in antioxidant enzyme activity in elderly people with CAD. Associations were stronger for indoor PM of outdoor origin than uncharacterized indoor PM. Results suggest that products of fossil fuel combustion primarily from traffic are behind associations.

OBJECTIVE: The study will examine relationships between cardiovascular autonomic function and exposures to personal, indoor and outdoor home air pollutants. We hypothesize that $PM_{0.25}$ will be inversely associated with HRV, which will support the view that UFP leads to disturbances of cardiovascular autonomic function. We will evaluate effect modification of associations by genotypes involved in oxidative stress. We will also conduct sensitivity analyses using source tracers, including tracers for vehicular emissions and secondary photochemical processes.

DESCRIPTION:
Population and Design: This proposal will produce new HRV data merged with available intensive exposure and health outcome assessments currently in progress for an NIH, NIEHS-funded panel study. The parent study scope of work included an analysis of ST segment changes and arrhythmias from ambulatory ECGs, but not HRV. Briefly, we are conducting a panel study with repeated measures to evaluate acute cardiovascular health effects of exposure to PM, with a focus on ultrafine particles.
Exposure Assessment: During every person-day of ambulatory ECG monitoring, we collected personal 24-hr quasi-ultrafine ($PM_{0.25}$), accumulation ($PM_{0.25-2.5}$) and coarse

mode ($PM_{2.5-10}$) mass on Sioutas impactors. Extensive exposure data was collected under current funding at both indoor and outdoor home sites.

Analysis: We will conduct multiple regression analyses of HRV using the general linear mixed model that estimates both fixed and random effects. In addition to examining the relationship of HRV to same day and exposures lagged several days, we will conduct hourly analyses to determine whether there are different pollutant effects for various averaging times of hourly air pollutants (cumulative hourly averages and 1, 4 or 8 hour peaks) and for differing proximities to the outcome using polynomial distributed lag models. We will also assess subject susceptibility to decreased HRV with increasing air pollutant exposures, including medication use (e.g., beta-blockers), psychological stress (from hourly PDA diaries), and polymorphisms for genes likely involved in driving oxidative stress or antioxidant responses to air pollutant exposures.

BENEFITS: This project will contribute substantial new data to improve understanding of the air pollutant characteristics and sources that affect cardiac autonomic vulnerability among elderly Californians at greatest risk of cardiovascular morbidity and mortality.

COST: $150,000

REFERENCES:

Delfino RJ, Sioutas C, Malik S, Potential role of ultrafine particles in associations between airborne particle mass and cardiovascular health. *Environ Health Perspect*, 2005; 113:934-46.

Delfino RJ, Staimer N, Tjoa T, Polidori A, Arhami M, Kleinman MT, Vaziri N, Sioutas C. Circulating biomarkers of oxidative stress, inflammation, and thrombosis are associated with urban air pollution in elderly subjects with a history of coronary artery disease. *Proceedings of the American Thoracic Society*, 2007; 175:A959.

Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc* 2006;56:709-42.

Polidori A, Arhami M, Delfino RJ, Allen R, Sioutas C. Indoor-outdoor relationships, trends and carbonaceous content of fine particulate matter in retirement communities of the Los Angeles basin. *J Air Waste Manage Assoc*, 2007;57:366- 379.

Climate Change

TITLE: Assistance to Develop a Cool Community Program in Support of AB32

PROBLEM: The Global Warming Solutions Act of 2006 (AB 32) sets up an enforceable program to cap greenhouse gas emissions in California. AB 32 requires that the state's greenhouse gas emissions be reduced to 1990 levels by 2020. ARB has specified a voluntary "Cool Communities" program as an early action measure for promoting reductions of greenhouse gases that can begin to occur in the near-term. Cool Community technologies, such as reflective roofs, shade trees, and cool pavements, are available and ready for deployment. A mechanism for dissemination of technical information to stakeholders is needed to ensure effective use of Cool Community tools.

PREVIOUS WORK: For more than two decades, the Heat Island Group (HIG) at Lawrence Berkeley National Laboratory (LBNL) has quantified the abilities of urban vegetation and solar-reflective surfaces to reduce the need for cooling energy, lower the outdoor air temperature, and improve air quality. These studies have demonstrated building cooling-energy savings in excess of 20% upon increasing roof solar reflectance from an existing 0.1 – 0.2 to about 0.6. LBNL has also demonstrated that installing shade trees next to a house can reduce its net annual energy consumption by about 10%, with the added benefit of sequestering atmospheric carbon. Increasing the solar reflectance of a city and planting vegetation can also lower the outdoor air temperature and slow the temperature-dependent formation of smog.

OBJECTIVE: The objective of this project is to provide technical assistance for ARB's development of a "cool community" program to save energy and reduce emissions of greenhouse gases.

DESCRIPTION: Developing effective cool community programs requires comprehensive outreach that promotes complete understanding of the technologies and involvement of stakeholders who can potentially benefit from and contribute to such programs. Cool community measures include cool roofs (in some cases also cool walls), cool pavements, and shade trees.

The ultimate goal of this project is to help ARB develop effective implementation programs for cool communities. Such programs need to inform developers, builders, building code authorities, and municipal operations (schools, libraries, and parks) about examples of cool roofs in their climate zone, costs, aesthetic and building material options, and data on energy savings. Deliverables for this project could include web based databases that provide full documentation including images on specific examples of cool roofs and cool pavements, and provide access to regional shade tree collections. Deliverables could also include developing training programs and standards for different parts of the building industry and presentation materials, including case studies, for developers, home owners, commercial building owners, and retail establishments, as well as for cities and counties. The documentation that is developed is expected to include costs, payback periods, lifecycle emission reductions, potential environmental/performance issues, as well as supplemental resources. An online tool

that allows individuals to receive customized guidance will also be explored. Developing scenarios for cool roof market penetration and assistance with toolkits and guidelines for cool communities would also be useful.

Programs need input from all stakeholders and should be customized for each locality. There are many components of a cool community program, including guidelines for public programs (shade trees, cool roofs, cool pavements); local ordinance, codes and standards (model ordinance for new developments, air quality standards); and funding and regulatory options.

BENEFITS: This program supports ARB's "cool communities" early action measure, which will reduce GHG emissions through reduced energy consumption and improve the livability of the urban environment.

COST: $350,000

TITLE: Radiative Forcing and Source Apportionment of Combustion-Derived Particles in California

PROBLEM: Atmospheric aerosols play an important role in the global climate system through modifications of the global radiation budget: directly, by scattering and absorption of radiation; indirectly, by the modification of cloud properties. The effects of aerosols on regional and global climate are extremely complex. A number of factors complicate the understanding of aerosol absorption, even at the local scale. The radiative properties of an individual particle are determined by composition, refractive indices, size, and shape. There are considerable regional differences and uncertainties in the relationship between emissions and radiative forcing.

Understanding the role of aerosols, including black carbon (BC) particles, in climate change requires inclusion of realistic representations of aerosols and their radiative forcings in climate models. Little is currently known about the climate impact of aerosols originally released from different combustion sources in California. Measurements indicate that particles emitted from combustion sources strongly absorb light. However, there are scant measurements of how the optical properties and hygroscopicity of combustion-generated aerosols evolve due to atmospheric aging either by oxidation or condensation of secondary particulate matter (PM).

PREVIOUS WORK: Rosenfeld and co-workers (Lynn et al., *J. Geophys. Res.*, 2007**)** have shown that orographic precipitation in California is strongly influenced by particles that are likely emitted from local sources. This influence has been associated with increased particle number concentration. Rosenfeld et al. speculated that radiative heating due to absorbing soot particles may also play an important role in precipitation suppression. Rigorous model calculations for radiative effects will require information about the atmospheric evolution of particle optical properties that are currently not available.

Jacobson (*Nature*, 2001) indicated that the mixing state of absorbing aerosol (mainly BC) plays a key role in determining the radiative forcing by aerosols. Kirchsteller et al., (2007a) estimated BC concentrations and diesel vehicle emission factors based on coefficient of haze measurements in the San Francisco Bay Area from 1967-2003. Cappa has shown that measurements of light absorption by aerosols using traditional techniques are often biased significantly high, dependent upon the abundance of non-absorbing organic aerosol. Kleeman and his team *(Robert et al., JAWMA, 2007, and Ying and Kleeman, Atm. Env., 2006*) have measured the size-resolved composition of particle emissions from numerous combustion sources. Recently Kleeman (*Howard et al., Atm. Env., 2007)* has developed a transportable reaction chamber to directly study the aging of source-oriented emissions.

OBJECTIVE: This research project will be conducted in two phases. Phase I will: (a) determine past and future trends in BC concentrations by analyzing archived data in California; and (b) include laboratory investigations of the time evolution of combustion aerosol optical properties (in particular, BC particles) and hygroscopicity. This work will facilitate better understanding of how climate-relevant properties evolve after emission to the atmosphere. In Phase II, regional modeling studies will be performed to calculate source contributions to radiative forcing in California.

DESCRIPTION: This research will illuminate past and future trends in BC concentrations throughout California. This task can be performed by deriving statewide temporally (weekly, seasonal, and long term) and spatially resolved BC concentrations, wherein ambient BC concentrations and estimated combustion emission factors can be analyzed by using archived data. Laboratory experiments will be performed to investigate the changes in aerosol mass absorption efficiency and single scattering albedo as particles age. A carbon source characterization laboratory can be performed by using a diffusion flame of methane and air in an inverted flow reactor to generate BC aerosols. A list of additional combustion sources to be investigated will be developed in consultation with ARB staff and is expected to include biomass combustion, diesel engines, gasoline engines.

"Aging" in the lab will mimic atmospheric transformations, such as surface oxidation (changing the surface from hydrophobic to hydrophilic), morphology changes due to the collapse of the BC aggregates by action of the surface tension of water coating, and coating with non-absorbing aerosol species, including salts, organics and sulfates. Advanced techniques such as cavity ring down aerosol absorption spectroscopy (CRD-AES, used to measure total light extinction) and photoacoustic spectroscopy (PAS, used to measure light absorption) will be used to monitor how the optical properties of various combustion aerosols evolve upon aging in a reaction chamber. Additionally, the absorption measurements by the PAS will be compared to absorption measured using filter-based methods, which are traditionally used in ambient monitoring of aerosol absorption, to characterize the biases that likely occur in the filter-based measurements due to the presence of the oxidized semi-volatile material. In Phase II, regional modeling studies will be conducted to calculate source contributions to radiative forcing in California.

BENEFITS: Improved understanding of source contributions to climate forcing originating in California will facilitate reductions to the state's climate "footprint" and demonstrate leadership for the rest of the world to follow. This work will also provide data to substantiate more realistic representation of BC in climate models, which will clarify the impacts of BC emissions.

COST: $750,000

TITLE: Collaborative Research to Understand How to Reduce N$_2$O Emissions from Nitrogen Land Application

PROBLEM: Nitrous oxide, or N$_2$O, is a greenhouse gas (GHG) with a Global Warming Potential (GWP) 298 times higher than CO$_2$. Annual emissions of N$_2$O are roughly 15 MMTCO$_{2E}$, or 3% of the total GHG emission inventory for California in 2004. Agricultural soil is considered the largest source of N$_2$O emissions in California, contributing an estimated 8.1 MMTCO$_{2E}$ or more than 50% of total N$_2$O. Application of synthetic and organic fertilizers account for 5 MMTCO$_{2E}$. Because N$_2$O is generated through microbiological processes of nitrification and denitrification in soil as part of the natural nitrogen cycling, emissions are influenced by the amount of nitrogen compounds in the soil. There remains considerable uncertainty on how much N$_2$O is emitted under California conditions for the wide range of commodities and farming practices in the state.

PREVIOUS WORK: Application of nitrogen fertilizers is an prominent feature of modern agriculture. California is the top agricultural producer in the nation and a major revenue generator in the state, providing 31.4 billion dollars in farm receipts in 2006. The California Department of Food and Agriculture is currently sponsoring several research projects in the area of nitrogen fertilizer management. Although these projects will not collect field data on N$_2$O emissions, they will provide critical information required for assessing N$_2$O reductions from agricultural soils (1-3).

OBJECTIVE: This collaborative research with stakeholders will assess and validate baseline N$_2$O emission estimates for agricultural ecosystems under California-specific conditions and identify practices that could reduce N$_2$O emissions by increasing nitrogen application efficiency. Limiting input of nitrogen sources into agricultural soils by improving nitrogen application efficiency or plant uptake offers a strategy for mitigating N$_2$O emissions. Alternative practices that influence soil microbial activities through modifications to physical, chemical, or biological properties of the soil environment could also offer opportunities to reduce N$_2$O emissions.

DESCRIPTION: The IPCC estimates that, on average, roughly 50% of nitrogen fertilizer applied in the field is lost to the transport pathways of volatilization, leaching, and runoff. Maintaining industrial agricultural productivity while minimizing nitrogen inputs requires improving nitrogen application efficiency. Determining current baseline emissions under a range of California-relevant conditions will aid identification and implementation of methods for reducing emissions through enhanced application efficiency. Because California agriculture is highly variable with respect to crop, soil, and climatic conditions, staff will consult with State experts and other stakeholders to identify preliminary data gaps and research areas in nitrogen management, and will coordinate with stakeholders to prioritize our research activities. The establishment and validation of baseline emission estimates will help refine the greenhouse gas emissions inventory and will inform work that will lead to specific N$_2$O emission reduction strategies.

BENEFITS: The California Global Warming Solutions Act of 2006 (AB 32) mandates that the State reduce greenhouse gas (GHG) emissions to 1990 levels by 2020, and Executive Order S-3-05 of 2005 establishes a goal of 80 percent below 1990 levels by

2050. Under the statutory authority of AB 32, the California Air Resources Control Board (CARB) has identified collaborative research on nitrogen land application an early action measure for the reduction of greenhouse gas emissions. This measure targets reducing N_2O emissions from agricultural soil management through improved nitrogen application efficiency. It is the only measure under CARB's consideration that addresses N_2O emissions. This research effort is expected to improve the existing N_2O inventory and inform work that will lead to development of specific emission reduction strategies.

COST: $300,000

REFERENCES:
(1) Site Specific Fertilizer Application in Orchards, Nurseries, and Landscapes (2007-2009). Principal Investigator: Michael Delwiche et al., Dept. of Biological & Agricultural Engineering, University of California, Davis, CA 95616.
(2) Fertility Management in Rice (2006-2008). Principal Investigator: Chris van Kessel and Bruce Linquist, Department of Agronomy and Range Science, University of California, Davis, CA.
(3) Development of practical fertility monitoring tools for drip-irrigated vegetable production (2007-2009). Principal Investigator: Tim Hartz, Department of Vegetable Crops, University of California, Davis, CA 95616; and Michelle LeStrange, Tulare County Farm Advisor, University of California Cooperative Extension

TITLE: Behavioral and Demographic Determinants of Low Residential Consumption Patterns Observed in California Households

PROBLEM: The role of individuals' behaviors is often acknowledged to be a primary determinant of residential energy and water consumption and often accounts for greater variability in consumption patterns than does efficiency of household appliances or household size. However, the roles played by behavioral factors such as habits, attitudes, and knowledge of energy matters, as well as demographic factors such as age, race, and social class are not well understood. Resolving the behavioral and demographic dimensions of orders-of-magnitude variability in consumption patterns between otherwise similar households is crucial to crafting effective policy efforts to encourage home energy savings. This research will probe a sample of California residences to delineate what factors, decisions, and behaviors differentiate very low-consumption households from their higher-consumption counterparts. Results will indicate what strategies are already working for low-consumption households, facilitate replication of these strategies through public outreach, and support effective social marketing to target groups. This knowledge of behavioral determinants of low residential energy and water consumption is critical to supporting near-term (AB 32) and long-term (2050) climate goals in California.

PREVIOUS WORK: According to data supplied by Pacific Gas & Electric (PG&E), inter-household variation in monthly electricity and gas consumption by residents of the City of Berkeley varies by a factor of one hundred. Similar data from East Bay Municipal Utility District suggest large disparities in residential water consumption. A Berkeley Energy Commissioner initiated and coordinated a series of local contests designed to confirm the existence of extreme low usage, quantify low consumption, and reveal the patterns underlying it. Subsequent research using consumption data acquired through these contests revealed a very low correlation between the energy efficiency of end use technologies and electricity consumption. Rather, behavioral and demographic factors were the primary determinants of low consumption households. Moreover, residents' knowledge of their own consumption patterns was revealed to be deficient. Although levels of energy consumption vary significantly among households, consumption is frequently assumed by the consumer to be average, even when it may diverge from the mean by as much as a factor of ten. Robust social marketing results indicate the importance of visibility of models that are very low-consumption, so it is critical to quantify the level of consumption of these households and characterize the behavioral and social factors that differentiate them from higher consumption residences.

OBJECTIVE: This research aims to identify what factors are responsible for the substantial variation within current energy and water use in the California residential sector, and establish a framework within which to assess the contributions of different social, cultural, and behavioral factors toward such disparate consumption levels. The research will characterize a set of household profiles corresponding to different combinations of behavioral, physical, and demographic factors that yield low residential consumption. These profiles will be used to support outreach campaigns by indicating how messages should be focused for different residential groups, portraying a variety of low-consumption model households, and delineating low- or no-cost behavioral strategies that are effective in reducing household water and energy consumption.

DESCRIPTION: Through in-home interviews and a survey, this research will explore both the factors contributing to low energy and water use as well as attitudes among low use customers about their use of energy.

Data Acquisition: Acquire a dataset from PG&E consisting of usage histories of approximately 4,000 residential accounts at the bottom end of the usage spectrum for both gas and electricity. This number encompasses all residential accounts up to the 5th percentile usage level. These accounts would include 12 consecutive months of electricity and natural gas consumption and either the account number or a code allowing subsequent matching to the account number. The approximate monthly billing cutoff levels for such data extraction are 30 kWh and 5 therms. A similar approach will be engaged with East Bay Municipal Utility District as a source for data regarding water usage.

Screening: Screen the data set to remove apparently unoccupied residences as well as customers whose bills reflect fuel substitution, e.g., low gas users with above-average electric consumption.

Consent Form: Design a study participation consent form. Personal information in the data set would be redacted so that research staff would have no ability to access personal information or contact customers unless and until customers have consented.

Sampling & Interviews: Develop sampling criteria for identifying a subset of participating households to be interviewed in their homes. Conduct and transcribe interviews with low-use households. Interviews are designed to establish a working understanding of the circumstances and parameters corresponding to exceptional use patterns and to facilitate development of appropriate survey questions.

Survey: Draft, pretest, and mail a detailed survey to all household participants.

Analysis: Perform quantitative and qualitative analysis on findings from interviews and household surveys. Identify household profiles using physical, social-demographic, and attitudinal categories developed through analyzing the responses.

Applications: Derive applications, focusing on the potential for significant energy savings through transferable strategies. In particular, design social marketing strategies by delineation of effective segmentation of residential groups, identification of appropriate models of low consumption for various groups, and identification of resonant language and conceptual framing for the different groups. As funds allow, social marketing strategies could be tested in focus groups.

BENEFITS: Reaching both near- and long-term climate goals will require extensive, voluntary behavior change. This research will identify what behaviors are already working in low-consumption households and enable social marketing campaigns based on understanding the behavioral and demographic factors that underlie variability between household consumption patterns. Social scientists have demonstrated the limited efficacy of prescribing standard bundles of technical solutions to everyone. This research will enable effective social marketing based on real-world combinations of technologies, habits, and building characteristics that correspond to low energy consumption patterns commensurate with the mandates of California's Global Warming Solutions Act (AB 32) and Executive Order S-3-05, which established near- and long-term (2050) GHG emission reduction targets.

COST: $250,000

Diesel and Goods Movement

TITLE: Measurement of Off-Road Diesel Engine Deterioration

PROBLEM: Emissions generated by internal combustion engines tend to increase over time. This phenomenon, called deterioration, has a significant impact on emissions inventory estimates and the estimated benefits of emissions controls and regulatory strategies. In diesel engines, deterioration is currently assumed to occur due to tampering, mal-maintenance, and/or malfunction of engine components. Deterioration rates in diesel engines have been developed in OFFROAD 2007 (ARB's emissions inventory model for off-road equipment) based upon limited data representing similar on-road diesel engines. The OFFROAD model represents deterioration in diesel engines 25 HP or higher as the percent increase in emissions per useful life consumed. Depending on the pollutant and type of equipment, emission rates in OFFROAD can increase by 10% to 70% above emission rates for new engines.

Because most off-road engines typically operate under highly variable load and adverse operating conditions, the use of on-road engine deterioration assumptions may not be appropriate. Further, the integration of new control technologies such as diesel particulate filters will have a major impact on deterioration in newer, well controlled engines. Additional studies are required to more fully understand deterioration of off-road diesel engines, and how that deterioration affects emissions estimates and projected regulatory effectiveness.

PREVIOUS WORK: In 1988, Radian Corporation developed 23 specific categories of tampering and component malfunction in on-road heavy duty trucks (Weaver and Klausmeier, 1988). Subsequent review by other contractors revised the Radian estimates for the U.S. Environmental Protection Agency (Weaver et al., 1998). The Radian model has been updated periodically by ARB staff as the model forms the basis for heavy duty diesel truck deterioration estimates in ARB's EMFAC model. Using the results of surveys and discussions with industry, staff have made estimates of tampering, mal-maintenance, and malfunction frequencies and associated emissions impacts in future model year trucks equipped with PM and NO_X controls.

No comprehensive studies have been conducted regarding the deterioration rate for off-road equipment therefore deterioration in OFFROAD2007 is based on assumptions for comparable on-road diesel engines from previous versions of ARB's EMFAC model.

OBJECTIVE: The proposed study will qualitatively and quantitatively assess deterioration in off-road diesel engines for key criteria pollutants including but not limited to NO_X and PM. Key objectives are to: (1) evaluate the impact of engine deterioration on emissions; (2) demonstrate methodologies for better quantification of engine deterioration; and (3) quantify the deterioration rates with regard to emissions.

DESCRIPTION: This study should focus on deterioration in diesel off-road engines caused by tampering, mal-maintenance, malfunction, normal wear caused by accumulative engine use, and any other factors. Elements of the study may include literature review, consultation with engine manufacturers, surveys, engine bench

emissions testing, in-use emissions testing, modeling of engine operations, or any other feasible approach. ARB is looking for bidders to provide a scope of work which they feel can most efficiently accomplish the required goals given the available budget.

BENEFITS: The research will provide critical information to support the incorporation of updated diesel engine deterioration rates into OFFROAD. These new deterioration rates will affect assessments of air quality planning and regulatory effectiveness.

COST: $300,000

Atmospheric Science

TITLE: Nocturnal Chemistry in the Urban Boundary Layer of Los Angeles

PROBLEM: Nocturnal chemistry in urban areas can considerably influence the composition of the boundary layer by removing ozone, NO_X, and hydrocarbons as well as by changing the size and composition of aerosol particles. Studying the mechanisms determining the chemical composition of the nocturnal boundary layer is difficult because of the interplay of homogeneous and heterogeneous chemical processes and weak turbulent mixing. This interaction, coupled with direct emissions of NO and hydrocarbons at the ground, leads to strong vertical variations of trace gas concentrations, rendering the chemistry in the nocturnal boundary layer very altitude-dependent. Many air quality models perform poorly at night and have not been validated for nocturnal conditions, introducing considerable uncertainties in our ability to model urban air quality. Accordingly, nocturnal chemistry has been identified by NOAA and the ARB as one of the most pressing research needs for the proposed 2010 California Air Quality and Climate Study.

PREVIOUS WORK: The researchers have many years of experience in performing field experiments of nocturnal urban boundary layer chemistry, including participation in Mexico City's MIRAGE research in 2006 and Houston's TEXAQS II in 2006. We have recently also lead an ARB-funded field effort in Malibu, CA, to study the potential presence and impact of coastal halogen chemistry on the air quality in the South Coast air basin. Our experimental approach to study nocturnal chemistry is based on the measurement of vertical profiles of the most important nocturnal species, i.e., O_3, NO_2, HONO, NO_3. The observations are interpreted with a one-dimensional chemical transport model that allows us to simulate the field observations of vertical trace gas profiles. Because this model, which was developed specifically for this purpose, is relatively simple and fast, it allows us to study individual chemical processes at night and to elucidate the role of vertical mixing. The results of our previous efforts have been published in a number of papers in the Journal of Geophysical Research and Atmospheric Chemistry and Physics.

OBJECTIVE: We propose to set up an urban field site in the Los Angeles Basin during the proposed 2010 California Air Quality and Climate Study. Our long-path DOAS instrument will be set up to provide continuous measurements of the vertical distribution of O_3, NO_2, NO_3, HONO, HCHO, and SO_2. O_3 and meteorological in-situ sensors will be placed at different altitudes to supplement the DOAS measurements. Our 1D chemical transport model will be used to give insight into various aspects of the chemistry and meteorology that occurs in the South Coast air basin at night. In particular, we are interested in the nocturnal ozone and NO_X budgets, the role of NO_3 / N_2O_5 and HONO chemistry, the impact of vertical mixing, and the influence of these nocturnal processes on daytime ozone and particles.

DESCRIPTION: Studying nocturnal chemistry in urban areas is challenging due to the very strong vertical variation in the atmospheric composition (O_3, NO, NO_2, HONO, and NO_3) in the lowest 200 m in the atmosphere. For example ozone and NO_2 gradients of

20 – 50 ppb over the lowest 100 m are not uncommon. It is therefore crucial to consider not only trace gas concentrations at the ground, where most air monitoring stations are, but the entire lower 200 m of the nocturnal atmosphere. The proposed measurements are based on a long-path Differential Optical Absorption Spectrometer (LP-DOAS), which measures the open air absorptions of various trace gases along an extended path between the main telescope and a reflector array, which is typically placed 2 – 5km away. This absolute (no instrument calibration needed) method is not very sensitive to local emissions and derived path-averaged concentrations often compare better to the grid-cell averaged results of urban air-shed models than in-situ measurements. To measure vertical trace gas profiles 3 – 5 reflectors are mounted at different altitudes on buildings in an urban area. The instrument then aims at these reflectors, thus probing different altitude intervals. Similar measurements were performed in Houston in 2006, at a height interval of 20 – 300 m altitude. We anticipate a similar vertical coverage for Los Angeles. Meteorological sensors will be deployed to measure temperature, RH, and wind speed and direction at the location of the retro-reflectors. In addition, we will seek collaboration with colleagues to increase the number of chemical and meteorological parameters measured at the field site. Interpretation of nocturnal vertical concentration profiles is often quite challenging, requiring the consideration of both chemistry and micrometeorology. We found that 1D chemical transport models, such as the one we are using in our group, provide an ideal tool to interpret the measurements with respect to the combined chemical and mixing processes occurring at night. Through possible collaboration with researchers from the ARB and other universities, we will also compare our observations with the output of 3D urban airshed models, with the goal of improving the description of nocturnal processes.

BENEFITS: The State of California is currently pursuing an ambitious plan to improve its air quality over the next decade. The proposed measurements will provide a unique data set to improve our understanding of the chemical and meteorological mechanisms used in urban airshed models at night. In addition, the data will allow the validation of nocturnal emission inventories for NO_X, SO_2 and HCHO.

COST: $200,000

TITLE: Chemical Signature Differences between the South Coast & the San Joaquin Air Basins

PROBLEM: Responding to control measures that ARB has adopted over the years, the South Coast Air Basin (SoCAB) has experienced some reductions in exposures to ozone and PM2.5. In particular, nitrogen species concentrations have to some extent responded to control measures. The San Joaquin Valley Air Basin (SJVAB) has not responded as well to control measures in terms of ozone, PM2.5 and nitrogen species reductions. Research is needed to clarify whether differential response to the same regulatory control is due to different chemical signatures for the two basins.

PREVIOUS WORK: During the 1993 Los Angeles Free Radical Study, a team from Portland State University used fluorescence assay with gas expansion (FAGE) technique to measure OH and O_2H. These measurements were supported with Unisearch Associates Tunable Diode Laser (TDLAS) and Differential Optical Absorption (DOAS) measurements of HCHO, HONO, H_2O_2, NO_3-, nitric acid, and NO_2. A Pennsylvania State University Team has used laser induced fluorescence to measure OH and O_2H recently in the ambient air and at environmental chambers at University of California Riverside. Professor Sanford Sillman has successfully demonstrated the use of O_3/NO_Y and H_2O_2/HNO_3 as more accurate in describing free radical/ozone/fine particulate chemistry than the standard VOC/NO_X ratios.

OBJECTIVE: To describe differences in ozone/PM2.5 chemistry of SoCAB and SJVAB through measurements of free radicals and trace parent species at one representative site per basin and development of new ratios from these measurements that describe such chemistry more accurately.

DESCRIPTION: The ARB and the National Oceanic and Atmospheric Administration (NOAA) will conduct an intensive field study in California in 2010 (2010 CalNEX). During this study an instrumented airplane capable of similar trace level measurements will be deployed by NOAA. This instrumented airplane would fly over both SoCAB and SJVAB, along transacts to connect the atmospheric chemistry of each site to the general photochemical dynamics that govern the air basins.

As a part of 2010 CalNEX this project will collect data to support an observations-based method (e.g. the Sillman indicator species ratio method) to describe summertime atmospheric chemistry in the SJVAB and SoCAB. Photochemical ratios or signals derived from these trace level measurements (airplane and ground level) will be used to delineate differences between SoCAB and SJVAB photochemical regimes.

BENEFITS: This research will demonstrate any differences between ozone and PM2.5 photochemical regimes of SoCAB and SJVAB. Such differences can guide us to perhaps design SJVAB specific control measures. Such measures that would cost effectively move the basin towards compliance with state and federal ambient air quality standards, including the new stringent 8-hour standards, are of significant value to the San Joaquin Unified Air Pollution Control District and to the ARB.

COST: $550,000

TITLE: Mass Spectral Characterization of Organic Particulate Matter (PM) Sources and Processes Using Novel Instrumentation and Advanced Data Processing Methods

PROBLEM: Aerosols have important effects on human health, visibility, and climate. Mitigation of adverse impacts requires a fundamental understanding of aerosol processes, chemistry, and microphysics. Organic aerosols (OA) constitute a large fraction of the aerosol mass and may be responsible for significant health effects, but their complexity makes quantification of their properties and effects, as well as prediction of effects, difficult. Furthermore, aerosols are deemed the most uncertain component in the radiative forcing of climate [IPCC 2007 Report].

PREVIOUS WORK: The high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), co-developed and demonstrated with Aerodyne [DeCarlo et al., *Anal. Chem.*, 2006], is offers rapid determination of size and chemical composition of submicron aerosols. It has emerged as a powerful tool for the characterization of OA and led to a number of advances in the field. Factor analysis of AMS data by our group has pointed out the dominance of secondary organic aerosols (SOA) in the polluted regions of the Northern Hemisphere [Zhang et al., *ACP* 2005 & *GRL* 2007]. Recent work using Positive Matrix Factorization (PMF) has allowed us to quantify the contributions of various primary sources, such as biomass burning aerosols (BBOA) [Ulbrich et al., *Fall AGU Mtg.* 2006], and is leading to promising advances in the study of SOA formation and aging. Simultaneously, the high mass resolving power of the HR-ToF-AMS has enabled increased source specificity in PMF, as well as fast determination of oxygen-to-carbon ratio (O/C) and nitrogen-to-carbon ratio (N/C) of organic aerosol [Aiken et al., *Anal. Chem.,* 2007].

OBJECTIVE: The proposed work will deploy novel aerosol mass spectrometric instrumentation to a ground-based Supersite as part of the 2010 field campaign in California, for measurement of organic and inorganic aerosol composition and time trends. Field data will be analyzed using PMF and O/C and N/C algorithms. Results will address uncertainties in SOA formation and aging and CCN closure.

DESCRIPTION: All Aerodyne AMSs are capable of quantifying both organic and common nonrefractory inorganic fractions of ambient atmospheric particulate matter in PM1, as well as providing information on several classes of OA. The HR-ToF-AMS provides a mass resolving power (m/Δm) of up to 5000, allowing for the separation of ions of the same nominal mass that have different elemental composition. Such resolution enables the direct separation of inorganic aerosol components, and organic ions can be classified into groups based on the subset of elements they contain (CxHy, CxHyOz, etc.). This allows the measurement of the elemental composition of the aerosol (particulate C, O, N, etc.) with a new method developed by the Jimenez Group [Aiken et al., *Anal. Chem.,* 2007].

A particularly powerful technique in analyzing AMS data and classifying organic aerosol involves Positive Matrix Factorization (PMF), in which the time-dependent mass spectra are deconvolved into their major components. Application of PMF to AMS data has confirmed the identification of several subclasses of organic aerosol, such as OOA with

41

different levels of oxidation, and POA from sources such as motor vehicles and biomass burning [Lanz et al., *ACP*, 2007]. These algorithms will be applied to the California data in order to characterize aerosol sources and processing.

While the AMS represents a great advance for the characterization of organic aerosols, certain types of analysis are hampered by the extensive molecular fragmentation caused by electron impact (EI) ionization, which is the standard ionization method in all AMSs. It is widely surmised that organic aerosols contain hundreds to thousands of organic compounds in many chemical classes [Hamilton et al., *ACP*, 2004], but EI-generated aerosol mass spectra are dominated by peaks corresponding to ubiquitous fragment ions, and molecular identification is generally unattainable. Instead, detected ions are sorted into broad chemical classes, such as hydrocarbon-like OA (HOA), BBOA, oxygenated OA (OOA), etc., and analysis focuses on determining total mass contributions, time trends, and O/C for these various classes. Our group has recently demonstrated a novel metastable atom bombardment (MAB) ionization source with the AMS that yields mass spectra with significantly reduced fragmentation and high sensitivity (~1/10 of EI) that is sufficient for field analysis [Kimmel et al., *FACSS Mtg.,* 2007]. By limiting molecular fragmentation, this source reduces redundancies in the mass spectra of organic aerosols and enables the determination of molecular composition. The source design allows alternating operation between EI and MAB ionization sources in the same instrument on a timescale of minutes. Combination of the quantitative data retrieved from EI mass spectra with the enriched chemical information obtained by MAB ionization will yield more detailed characterization of SOA formation and aging. Likewise, the increased specificity in aerosol mass spectra will greatly expand the power of PMF to isolate OA sources.

The most uncertain effect of aerosols is the indirect effect on cloud properties and precipitation. Clouds are formed when water condenses on a subset of particles (the Cloud Condensation Nuclei or CCN) as the air rises in a cloud. Prediction of which particles will activate to CCN remains a significant challenge, with widely varying degrees of success especially under high organic concentrations [Stroud et al., *J. Atmos. Sci.,* 2007; Ervens et al., *JGR*, 2007]. The techniques developed and applied in this project will result in a more precise and nuanced characterization of the properties and evolution of OA and SOA in the atmosphere. We expect to deploy our instrumentation to a major Supersite where a DMT CCN counter would also be deployed by another group. We will then carry a CCN closure study in which the hygroscopic properties of each type of OA are constrained based on the observed hygroscopicity / CCN activity during periods of strong influence of each component, and/or optimized based on the properties observed in lab studies (e.g. fresh SOA in chambers is relatively hydrophobic, while it becomes more hygroscopic as it ages). This would allow the extension of our results on OA sources and processing to another important climate-relevant property.

BENEFITS. The unique data generated by these techniques will furnish critically needed information on organic aerosols (especially SOA) and their sources and evolution.

COST: $282,000

TITLE: Sulfur Study in Bight of Southern California

PROBLEM: Sulfate concentrations in coastal Southern California are frequently elevated above levels that are consistent with emission estimates. Sulfates are a component of particulate matter, which remains the largest air quality health risk for Californians. The contributions of various sulfur sources resulting in these sulfate concentrations is not well-characterized. Origins of this sulfur could be natural (dimethyl sulfide or DMS) from oceanic metabolism, uncontrolled SO_x emissions from naval warships, SO_x emissions from maritime shipping activities, SO_x emissions sources in Mexico (e.g., Rosarito Beach power plant, maquiladoras), or trans-Pacific transport of SO_x emissions and reaction products. Maritime and Asiatic emissions will undoubtedly increase in the future without additional restrictions on emissions.

PREVIOUS WORK: NOAA has made DMS and other aerosol measurements from ships (Atmospheric Chemistry Program in the Pacific Marine Environmental Laboratory). Scripps Marine Institute has attempted to use isotopic information to characterize ship impacts.

OBJECTIVE: To better characterize and quantify the contribution of various emission sources of sulfur impacting Southern California.

DESCRIPTION: Sulfur emissions, whether as SO_x, DMS, or H_2S, are precursors to sulfate particles, which contribute to the aerosol burden. Sulfur emissions have a complex fate and can substantially influence the cloud albedo and climate. If the sulfur source is anthropogenic in nature, co-emitted pollutants such as CO, NO_X, and VOCs become important in their own right because atmospheric photochemistry, transport, and deposition will influence the ambient concentrations. When these concentrations are measured offshore, aloft, or distant from a central study area, they help create the boundary and initial conditions of air quality model applications, which are extremely important to the accuracy of the modeling results. In order to accurately predict air quality throughout southern California and efficiently regulate pollution sources, it is necessary to better understand the nature and magnitude of emissions of these compounds off the coast of California, in Mexico or at the US-Mexico border, and aloft.

This research effort should be planned to overlap with the CalNEX 2010 study to support and enhance both measurement programs. The effort would entail collocated field measurements of sulfuric compounds and combustion products such as CO and NO_X to improve the estimates of sulfur emissions and to better characterize the sources (natural versus multiple potential anthropogenic). Pollutant ratios and potentially isotopic analysis would be used to indicate the relative contribution of different source types. Supporting measurements collected by NOAA's aircraft could also help to differentiate the sources and help characterize the spatial extent of the impacts.

This project's tasks may include: purchase high-sensitivity sulfur dioxide and carbon monoxide analyzers; arrange for collection and analysis (size and chemistry) of aerosols; make the air quality and meteorological measurements on islands/ships, at the shoreline, inland, and, in possible, aloft (e.g., aircraft, remote sensing, balloons) to quantify the pollutants; analyze the data to characterize the chemical and atmospheric

processes. QA/QC protocols and analysis of the measurements would be conducted to characterize the contributions of the various sources of sulfur and combustion-related pollutants. The coordination of this project with the CalNEX study would enable analysis of additional chemical species and so would provide insights into the atmospheric chemistry and processes involved in oxidation of sulfur compounds.

BENEFITS: This project will help guide the decisions of State and local regulators as they address the sulfate air quality problem in Southern California. Depending on the results, other regions of California could also benefit from what is learned and also develop effective sulfur reduction strategies as needed. The sulfur results would also benefit the climate change research program as it would help characterize the relative contribution of natural and anthropogenic sources of sulfur, which contributes to sulfate particles, which act as cloud condensation nuclei, which affect the weather and climate. The measurements of aerosols, CO, CH_4, NO_X, and VOCs would benefit photochemical modeling efforts for support of the State Implementation Plan (for ozone and PM2.5) as they would better characterize initial and boundary conditions (to which modeling efforts are sensitive).

COST: $350,000

State Implementation Plan (SIP) Support

TITLE: Inexpensive NO/NO$_2$/NO$_X$/PANs analyzers for Ambient Monitoring

PROBLEM: Chemiluminescence NO analyzers are used statewide to determine NO and NO$_2$ levels by conversion of NO$_2$ to NO and detection of NO chemiluminescence. However, chemiluminescence suffers from errors due to water quenching in any environment of non-negligible humidity as well as the generation of species besides NO$_2$ that can produce false signals. These factors can result in significantly reduced NO and NO$_2$ readings (Hargrove, Wang et al. 2006).

PREVIOUS WORK: The technology for measuring NO$_2$ by cavity-attenuated phase shift detection (CAPS) is well-established and not patented (Kebabian, Herndon et al. 2005).

OBJECTIVE: To develop and begin production of cavity-attenuated phase shift (CAPS)-based NO$_2$ analyzers and implement converters that will permit the simultaneous measurement of NO and PANs.

DESCRIPTION: To successfully replace chemiluminescence detection methods, CAPS-based systems must be able to measure NO in addition to NO$_2$. A proprietary technique has been developed that will accommodate this extension. The cost per analyzer will be less than those for chemiluminescence analyzers with similar detection sensitivities. The analyzer that is under development will also be useful for stack measurements and medical applications, where higher concentrations of NO$_X$ will allow for dilution of samples.

BENEFITS: The successful development and marketing of a CAPS-based NO/NO$_2$ analyzer will allow for more accurate NO and NO$_2$ measurements regardless of the humidity. Because CAPS-based analyzers measure a fundamental property of NO$_2$ using time-based measurements, there will be no need for gas calibration and instruments will require only occasional zeroing to attain accurate results.

COST: $100,000

REFERENCES:

Hargrove, J., L. Wang, et al. (2006). "Cavity Ring-Down Spectroscopy of Ambient NO$_2$ with Quantification and Elimination of Interferences." *Environ. Sci. Technol.* **40**(24): 7868- 7873.

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TITLE: Use of Low-Cost Environmental Sensors for Use in Air Quality Enforcement and Compliance, Surveillance, Exposure and Research Studies

PROBLEM: Air pollution surveillance is limited in part by the cost of instrumentation. A typical instrument to collect high-quality air pollution data for comparison with U.S. EPA standards costs on the order of tens of thousands of dollars and usually requires a highly trained person for operations and maintenance. This relatively high cost puts monitoring out of reach of many small businesses and community groups who would use such instrumentation were it affordable. In many cases, a screening instrument is would suffice to meet the needs of small businesses and community groups. Screening instruments can be cheaper because they do not require low detection limits and comparability to EPA federal reference methods.

PREVIOUS WORK: In recent years, there has been a proliferation of low-cost electronics, data logger and miniature sampling instrumentation in the market. For example, there are numerous commercial temperature, humidity, data logger combination devices on the market for less than $200. Furthermore, costs for light emitting diodes, semiconductor lasers and associated electronics have seen drastic falls recently, making optical-based measurements relatively inexpensive.

OBJECTIVE: To build, test and assess several low-cost air pollution sensor designs for use in air pollution surveillance, exposure and fence-line monitoring.

DESCRIPTION: Research will evaluate existing low-cost sensors and data logger packages and assess their suitability for use in surveillance and in exposure assessment. Improvements on extant designs will be proposed and incorporated into development of new sensors packages for sensing ambient aerosols and gas phase pollutants using novel optical and chemical methods. The instrument package will be battery powered, simple to operate, and capable of signaling an alert upon sensing concentrations above a pre-set threshold. The instrument will include a data logger to store data averaged over short (e.g., hourly) time intervals over a period of several weeks. Data will be directly downloadable to personal computer. This convenient instrument package, at a cost on the order of $200, will be an attractive and useful tool for communities.

BENEFITS: Providing low-cost alternatives to expensive instruments for ambient air monitoring will allow community groups to perform independent surveillance. For the general public, this would benefit work on environmental justice projects. Additionally, persons who are particularly sensitive to air pollution might use such instrumentation. Widespread use of such instrumentation in homes, business, and public places could help fine-tune exposure models and illuminate how community scale monitors relate to actual distributions of individual exposure.

COST: $350,000

TITLE: Development of an Updated Base Case Ambient VOC Mixture

PROBLEM: Various types of atmospheric model analysis or model development work of regulatory or research interest requires use of "base reactive organic gas (base ROG)" mixture that appropriately represents mixtures of reactive VOCs emitted into urban atmospheres. These include, but are not limited to: (1) developing condensed mechanisms for airshed models from chemically detailed mechanisms that appropriately incorporate the chemical detail in models; (2) calculation of the MIR and other VOC reactivity scales using models that appropriately represent the chemical composition in the atmosphere; (3) deriving an appropriate base case mixture for use in environmental chamber studies of VOC impacts under chemically realistic conditions; (4) serving as a standard against which to define relative reactivities; and (4) calculating the indirect effects of emissions on secondary pollutants from other VOCs present. The base ROG mixture used to develop condensed versions of the SAPRC99 and SAPRC07 mechanisms, used to derive the most recent MIR and other reactivity scales, and used in most recent chamber experiments for mechanism evaluation, is out of date and needs to be updated.

PREVIOUS WORK: The current base ROG used in the applications discussed above was based primarily on an analysis by Jeffries et al. (1989) of air quality data from 1986, with oxygenated species added based on an analysis by the CARB staff in 1991 of data from the SCAQS database. Since that time, emissions compositions have changed due to ongoing control strategies and other developments, and analytical methods have improved. However, this analysis of base ROG has not been revised.

DESCRIPTION: Available speciated VOC measurements made in various urban areas will be compiled and analyzed. Measurements taken during the morning or during periods of low photochemical reactivity will be utilized to derive an estimated composition of VOCs as emitted. Analytical limitations will be taken into account, and measurements using methods suitable for difficult-to-analyze VOCs will be employed to estimate their levels. Available emissions data will be used to inform the analysis. Recommendations will be made as to a representative mixture for use in various applications such as discussed above.

BENEFITS: Condensed chemical mechanisms developed from detailed mechanisms are more representative of ambient conditions and potentially more accurate. Scenarios used in reactivity scales will better represent ambient conditions.

COST: $40,000

TITLE: Near-Zero VOC Stain Blocking Primer Formulations

PROBLEM: Development of near-zero VOC primers with stain-blocking performance that rivals higher VOC alkyd technology does has proved quite difficult to date. Although water-based primers have been developed and are commercially available, these products typically require application of two coats and suffer marginal results in blocking water soluble stains and tannins. A variety of water-based products have been developed and specified, often in multicoat applications, to do the job that a conventional solvent-based primer often accomplishes with one coat application. There remains a need for a near-zero VOC primer technology that performs similarly to conventional solvent-based primer technology.

PREVIOUS WORK: Resin manufacturers and coating manufacturers alike have been and are actively engaged in the development of technology that will successfully replace alkyd resin technology for specialty applications. Most of this technology is based on aqueous emulsion technology. To date however, this technology is lacking in critical application and performance properties for stain blocking primer applications. Recent work in our laboratories has identified a potential technology that shows promise as a base technology for the development of near-zero VOC (substantially less than 100g/L) stain blocking primers with potential improved properties compared to commercial water-based primers in the market place.

OBJECTIVE: The objective of this research is the development of near-zero VOC stain blocking primers that perform as well as current state of the art solvent-based alkyd primers.

DESCRIPTION: This project goal is development of near-zero VOC stain blocking primer technology. The research involves the development of emulsion technology combined with formulation methodologies and protocols that will result in primer formulations that apply and perform similarly to solvent-based alkyd primers. The research involves identification and/or synthesis and/or validation of emulsion technologies with the base properties required to successfully block a variety of stains, including water-soluble stains and tannins. Novel formulation methodologies and protocols will be applied to the identified emulsions in the development of stain-blocking primer formulations. Specific technical goals for developing optimized near-zero VOC stain-blocking primers include:
a. Identification, synthesis, and validation of emulsion technology;
b. Optimization of pigmentation: concentration and types for flat gloss (<10 gloss at 85 angle) and for sanding;
c. Optimization of adhesion over waxy stains and old painted surfaces;
d. Optimization of cure through:
   - Sanding: preferably within 1 hr, maximum time 4 hours;
   - Recoat (with latex and oil based topcoat): preferably within 1 hour, maximum time 4 hours;
e. Optimization of product stability:
   - Viscosity;
   - Performance;
   - Consistency;

f. Manufacturability.

In addition to laboratory evaluations of product performance, accelerated exposure studies and field studies of the technology will be performed.

BENEFITS: The successful development of this technology would allow Californians and California businesses to utilize environmentally compliant near-zero VOC coating technology. Current solvent-based stain blocking primer technology has a VOC content of approximately 350 g/L. Specialty primers of this VOC range are no longer acceptable according to proposed ARB regulations. Current water-based stain blocking primers do not perform as well, as even stated on their label. New near-zero VOC technology will allow for the maximum reduction in emissions (>2.63 tons/day) while providing performance properties equal to 350 g/L alkyd based technology.

COST: $400,000

TITLE: Formation of Secondary Organic Aerosols: Chamber Study and Modeling

PROBLEM: Secondary organic aerosol (SOA) formed from atmospheric reactions of volatile organic compounds (VOCs) in the presence of NO_X constitutes an important component of suspended fine atmospheric particulate matter (PM) that impacts visibility, climate, and health. Due to limited knowledge of chemical and physical processes involved in SOA formation, SOA modeling is afflicted by large uncertainties (Volkamer et al, 2006; Galbally and Goldstein, 2007; Q. Zhang et al., 2007). Increasingly stringent controls on NO_X emissions for both on-road and non-road sources will lead to changes in the VOC/ NO_X ratios within the atmosphere. Such changes in atmospheric reactivity directly impact the extent of gas-to-particle conversion of VOCs. Development of reliable and effective SOA control strategies depends on model predictions that require nuanced understanding of SOA formation processes.

PREVIOUS WORK: Johnson et al. (2005), Song et al. (2005), and Ng et al. (2007) performed initial characterizations of the role of VOC/NO_X on predicted aerosol formation. These studies indicate that earlier work performed in chambers at high NO_X concentrations may have grossly underestimated the extent of gas-particle partitioning for several aromatic species. Significant changes in aerosol formation potential with changes in atmospheric reactivity must be accounted for in predictive models used to assess fine particle formation in the atmosphere. A model has been developed that tracks the gas phase precursors and applies a semi-empirically determined gas/particle partitioning coefficient to single precursors (Warren et al., 2007). This model shows promise for tracking the influence of NO_X on SOA formation.

OBJECTIVE: Perform controlled environmental chamber studies to facilitate improvement of SAPRC-07 to estimate secondary organic aerosol formation from select VOCs.

DESCRIPTION: Experiments will be carried out in an atmospheric chamber to measure SOA formation from selected aromatic compounds under a range of ambient concentrations and conditions. Parameters varied will include VOC and NO_X concentrations, the presence of other reactive VOCs, temperature and relative humidity. These experiments will provide a basis for evaluating the changing aerosol formation potentials of precursor VOCs through current and future atmospheric reactivities. These data will be used to improve SAPRC-07 to simulate SOA formation using a modeling platform currently used by Air Resources Board. The results will be analyzed with respect to both theoretical predictions of SOA formation and model simulations of gas-phase processes.

BENEFITS: Data on SOA formation in well-characterized experiments representing a range of atmospheric conditions are essential to test and improve our theories and models for predicting SOA in the atmosphere. Since SOA can exceed 70% of the fine particulate burden on highly impacted days, accurately predicting its formation is essential to developing cost-effective control strategies for find PM, and assessing how proposed ozone control strategies may also impact PM. The model will provide critical information to identify regulations to reduce SOA contributions to fine particulate matter.

COST: $475,000

TITLE: Bridging On-Road and Laboratory Emission Measurements: An Integrated Approach

PROBLEM: Understanding the health and climatic impacts of mobile source emissions and developing appropriate control technologies requires laboratory measurements of vehicle emissions that represent in-use conditions. However, there is disparity between particulate emissions measured on road and in the laboratory. This discrepancy is particularly pronounced for ultrafine particles (<100 nm), which are not only directly emitted as a result of incomplete combustion, but also formed in the exhaust dilution process. The possible introduction of a Diesel Particulate Filter (DPF) as a retrofit technology in the state of California would further complicate the formation of ultrafine particles since it removes nearly all solid soot particles in the accumulation mode (0.3 to 1 µm diameter). Most of these solid soot particles are made of black carbon, which is a strong light absorbing compound. Therefore, the optical properties, and thus the climate impact, of diesel exhaust is likely to change significantly if DPFs are widely deployed. It is critical to understand how on-road and laboratory measurements relate and to evaluate the effects of DPFs on optical properties of vehicle emissions.

PREVIOUS WORK: The rapid cooling of hot exhaust by entrainment of ambient air triggers sulfuric-water homogeneous nucleation, generating nuclei around 1 nm. These nuclei grow into detectable, larger sizes via augmentation with sulfate and/or organic materials. Extensive measurements have revealed the highly non-linear nature of ultrafine particle formation and growth processes. There are three major types of sampling methods: laboratory dilution tunnel, on road chasing, and wind tunnel. In the wind tunnel sampling, emissions are characterized by running the test vehicle on a chassis dynamometer located in a wind tunnel. A full scale wind tunnel is able to mimic atmospheric dilution, thus eliminating the sampling artifacts associated with laboratory dilution tunnel measurements. Because the dynamometer is located in the indoor environment, the driving cycles and sampling conditions are well controlled and generally repeatable. Repeatability is essential for particle quantification, and often challenges on-road chasing measurements due to variable atmospheric conditions. Two wind tunnel measurements were carried out recently. The first test was conducted by Ford researchers at the Ford Research Lab, where a garage-like wind tunnel was used. The second test was conducted by researchers from West Virginia University (WVU), who measured emissions from a Class-8 heavy-duty diesel truck in the Langley wind tunnel. The WVU study has demonstrated the feasibility of emissions characterization in a full scale wind tunnel. However, there were several limitations in their study, some of which will be discussed in the Description section. It is worth noting that only unloaded conditions were tested in the WVU study. A literature review did not reveal any optical properties measurements for diesel emissions installed with a DPF.

OBJECTIVES: The objectives are to quantify (1) ultrafine particle formation/growth potentials; and (2) optical properties (scattering, absorption, extinction coefficients) of exhaust particles for representative diesel vehicles with and without a DPF.

DESCRIPTION: Measurements associated with ARB's ongoing laboratory and on-road (using a mobile platform) research, will be complemented by data collection and modeling of vehicle emissions in a full scale wind tunnel at NASA Ames Research

Center in Moffett Field, California. The same diesel vehicles used in the laboratory and on-road studies, selected to represent the current California fleet, will be tested in the Ames wind tunnel. With a test section of 80 by 120 foot (the largest in the world), this wind tunnel is capable of providing a wide range of dilution rates. The flow is non-recirculating so vehicle emissions will not build up over time. (The Langley wind tunnel in WVU's study is a recirculating one). There is 180 ft downwind distance to measure the plume evolution, compared to less than 50 foot in the previously-described WVU study. NASA's wind tunnel is well-suited for investigation of the plume aging process.

Plume dilution rates, determined by using CO_2 or CO as an inert tracer, will be adjusted to match those measured by the mobile platform. The measurements of CO_2 (or CO) at various positions also allow a mapping of the plume trajectories aided by flow visualization. The physical and chemical characteristics of plumes will be measured at 8 downwind distances, under different dilution ratios, temperature and relative humidity. All the instruments will be housed in a gantry-mounted platform, which move along the plume center lines remotely controlled by the staff. The proposed study is unique in that it incorporates: 1) Intensive hydrocarbon measurements. In spite of their important roles in growing nucleation mode particles, hydrocarbons measurements were mostly ignored in previous studies; 2) Evaluation of the contribution of photochemical reactions to ultrafine particle formation/growth by turning on/off UV lights in the wind tunnel; 3) Optical properties measurements of exhaust plumes at several downwind distances (corresponding to different aging stages). The main instrument to be employed is a compact optical properties analyzer using cavity ring-down technology developed by NASA. It has the capacity to conduct in-situ measurement of aerosol extinction and scattering coefficients with a time resolution around 1 second. An additional photoacoustic instrument will also be employed to measure absorption coefficient; 4) Comparison of the results from three sampling methods under similar conditions, i.e., same vehicles, dilution ratios, temperature and relative humidity. The intercomparisons will generate a reference guide on how to improve laboratory sampling systems to represent real-world conditions; 5) Development of a mechanistic, predictive model to quantify the formation and growth potential of ultrafine particles. In addition, we will visualize the quantification in forms of isopleths for each type of vehicles. Furthermore, we will classify each vehicle (with different types of fuels) into sulfur-limited and HC-limited categories, providing a first-order reference for developing control technologies.

BENEFITS: Resolving and reducing the health effects and climatic impacts of diesel particulates are among ARB's main challenges. For the first time, investigators will be able to quantify both the ultrafine particles formation/growth potentials and the optical properties for diesel exhausts. This full-scale wind tunnel study also provides a platform for evaluation of real-time PM measurement instruments. The optical property measurements will provide a critical link between air pollution emitted by diesel trucks and their effects on climate. The effects of DPFs on diesel emissions will be elucidated, providing policy makers with a scientific basis for developing air quality and climate regulations.

COST: $420,000

Toxic Air Contaminants

TITLE: Measurement of Diesel Solid Nanoparticle Emissions Using a Catalytic Stripper for Comparison to Europe's PMP Protocol

PROBLEM: Gravimetric methods currently used for the legal determination of emissions will be challenged to quantify PM mass emissions as regulations continue to get more stringent. The European PMP protocol, developed to measure solid particle number emissions, holds promise to complement regulatory mass measurements. While the method was developed to regulate light duty diesel PM primarily in Europe, CARB has conducted projects to evaluate this method for heavy-duty diesel PM in the last few years. The protocol ignores nucleation-mode particle from diesel exhaust and measures only solid particles in an effort to enhance repeatability and accuracy of the measurement.

Recent experiments conducted using CE-CERT Mobile Emissions Laboratory (MEL) revealed unexpectedly high concentration of particles under the PMP protocol during some conditions on our on-road testing for the CARB European PMP program. These high particle concentrations occur when exhaust temperature downstream of a DPF is higher than a threshold temperature of approximate 350°C. This raises a potential contradiction with the European PMP since it indicates that nucleation can occur under PMP protocol. It is also possible that high particle concentrations reflect penetration of solid partially burned soot or ash particles during regeneration process of DPF or that the particles are composed of low volatile organic compounds that do not evaporate in the evaporation (Sakurai et al. 2003). The possibility of charring of organic particles was excluded in Sakurai et al.'s work but might warrant re-investigation with addition of control technology and PMP system, which can alter emission profiles and charring conditions.

It is necessary to understand the relationship of high particle concetrations under certain conditions to the PMP protocol and to understand what types of particles are either penetrating or forming. The PMP system is designed to ignore semivolatile nucleation mode particles by assuming that semivolatile particles do not survive under PMP protocol or that CPC with a high cutoff diameter (23nm) cannot detect them. However, ARB's recent laboratory work performed using a chassis dynamometer (Herner et al. 2007), revealed solid sub-20nm particles that can make it past the PMP volatile particle remover (a.k.a. evaporation tube). In addition, CECERT found solid particle penetration through the PMP system in our recent on-road work. It is critical to discover whether these presumably solid particles are artifacts or not. If they are not artifacts, then they should be counted in the PMP protocol, which could require a change in the PMP CPC cutoff diameter.

PREVIOUS WORK: CE-CERT performed on-road testing for the CARB European PMP project in June 2007. The objective of that project was to evaluate the proposed PMP method for determining particle emissions from heavy-duty diesels and its potential in California for PM emission measurement and in-use screening. We observed the above mentioned solid particle penetration repeatedly for some operating conditions.

Interestingly, we observed a greater extent of penetration of solid particles past PMP system when we drove our MEL on road without following any specific cycle. We tried increasing the PMP dilution ratio and increasing the temperature of the evaporation tube but we could not remove penetration of particles through PMP. This suggested that the penetrating matter is either solid particles or particles formed in the PMP system. This important finding has been addressed in the literature.

OBJECTIVE: Investigation of particle penetration/formation under PMP protocol to assess its impact on the PMP measurement protocol.

DESCRIPTION: The catalytic stripper (Kittelson et al., 2005) is a small catalytic converter that is maintained at constant temperature to enhance both the evaporation and the oxidation of volatile organics. Volatile organics diffuse to and oxidize on the catalyst-coated wall of the stripper. While the evaporation tube under PMP protocol maintains high temperature to suppress possible nucleation of semivolatiles by lowering the supersaturation ratio, the catalytic stripper makes nucleation of diesel exhaust completely impossible by oxidizing particle precursors. In terms of advantages, the evaporation tube is a simpler, lower cost system, whereas catalytic stripper is more complete in eliminating the possibility of any nucleation. We propose to compare particle number emissions before and after replacing the evaporation tube with the catalytic stripper. This will show whether the high concentration particles we observed in our on-road testing for the CARB European PMP project were solid particles or particles formed by other mechanisms, as discussed in the PROBLEM section herein. We also propose to use the TEM technique to determine the morphology of particles under PMP protocol. A thermophoretic sampler and a low-pressure impactor will be used to collect particles of 2-50nm and above 50nm respectively. TEM technique is going to be used as a complementary or exploratory means since chemical analysis using EDS is going to be challenging for small particles under 10 nm due to weak scattering. We propose to use CE-CERT Mobile Emissions Lab (MEL) as a platform to test the PMP protocol as it was used with our previous project. We propose to run MEL on the road with a repeatable route with and without a catalytic stripper to compare with PMP method. We plan to rent one PMP system from Matter Engineering and we will replace an evaporation tube with a catalytic stripper. We plan to procure another PMP system from ARB to run experiments with two PMP systems in parallel.

BENEFITS: CARB has had a leadership role in improving air quality in California for public health. This project will help CARB scientists critically evaluate PMP protocol, which could be complementary or replace the current regulatory mass measurement as particle emissions standards get more stringent.

COST: $170,000

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Herner et al., 2007 *SAE Tech Paper* 2007-11-1114
Kittelson et al. 2005 *Journal of Aerosol Science* 36, 1089-1107
Sakurai et al. 2003 *Atmospheric Environment* 37, 1199–121

RESEARCH CONCEPTS RECOMMENDED IF FUNDING AVAILABLE

LIST OF RESEARCH RECOMMENDED IF FUNDING AVAILABLE

Health Effects and Air Quality Standards

TITLE: Vulnerable Populations Among People Who Exercise or Work Outdoors: Acute Health Effects of Traffic-Related Air Pollution During Outdoor Exercise

PROBLEM: Little is known regarding the acute health effects of ultrafine particles and air pollutant mixtures like traffic emissions on otherwise healthy individuals during outdoor exercise. Children, the elderly, and persons with lung disease such as asthma, constitute vulnerable populations particularly sensitive to air pollution. Vulnerability can also be a function of a person's activity level in certain microenvironments. Healthy people can become vulnerable to air pollution at relatively low concentrations during exercise due to their higher ventilation rates (Grievnink et al., 1998; Mautz et al., 1988). Chamber studies have been performed to characterize this effect, but chamber studies are limited by their high expense and necessarily small subject numbers. Furthermore, it is difficult to simulate real-world pollution mixtures in chambers. The extent of exercise-induced vulnerability to air pollution, particularly traffic-related air pollution, is not well-characterized. Potentially large numbers of otherwise healthy persons may be experience enhanced vulnerability during high air pollution episodes or at locations of frequent high concentrations, such as athletic fields located close to busy roadways.

PREVIOUS WORK: There were two recent attempts to study the health effects of exposure to real-world traffic pollutant mixtures on adults, but neither sought to address the problem in this study. The North Carolina Trooper Study (Reidiker et al, 2004) tested Troopers working at night under conditions of relatively light traffic. A study funded by ARB, "Cardiovascular Health Effects of Fine and Ultrafine Particles during Freeway Travel," examined cardiovascular effects of freeway PM on elderly subjects (Hinds et al.). Both studies used vehicles as a type of exposure chamber. However, the Trooper study did not measure ultrafine particles. The Hinds study suffered from the difficulty in producing full high versus low exposure contrast, as gaseous pollutants were high in all scenarios. In addition, both studies had relatively low numbers of subjects, nine and 16, respectively, and neither examined the higher ventilation rates that occur during exercise. The few studies that have examined pollutant exposures during intense exercise have been chamber studies with small subject numbers using single pollutants (Grievnink et al.,1998).

OBJECTIVE: The two-fold objective of this work is: to advance knowledge of the effect of exposure to real-world pollutant mixtures, including traffic emissions, on otherwise healthy individuals during periods of sustained high respiration while exercising; and to overcome the limitations of related studies using small numbers of subjects and artificial pollutant mixtures.

DESCRIPTION: We propose to study two, relatively large groups of cyclists (e.g., groups of 12 to 20 per exposure period) undergoing simultaneous exposures while cycling predetermined routes in the L.A. air basin and possibly in Fresno. The study will take advantage of the heightened exposures caused by increased ventilation during exercise.

Investigators will chose routes to maximize exposure differences and to vary specific pollutant concentrations. Routes being considered include an on-road route with high ultrafine particles, high NO_X, and low ozone; two low concentration routes on bike trails where traffic emissions are low, one with higher ozone on a route located inland and ridden by cyclists during the summer months, a route in the Palm Springs area with low traffic emissions but high coarse PM; and a Fresno route with high PM2.5. A suite of lung function tests, blood and respired air markers of inflammation, and urinary biomarkers, will allow comparing relatively large numbers of highly exposed persons to health endpoint measures of lung function, lung inflammation, and blood coagulation. Two large groups of cyclists will be recruited to undergo pre- and post-exercise lung function tests (FEV1, FVC, peak flow), exhaled NO, and to provide pre- and post-exercise blood (e.g., C-reactive protein, IL-6, IL-8, TNF-alpha, fibrinogen) and urine samples for markers of inflammation or oxidative stress (e.g., clara cell proteins, F2-isoprostanes). Buccal (mouth) cells will also be collected and archived for possible later genetic analysis of known genetic vulnerability for lung anti-oxidant protective responses such as the GSTM1 genes. These will be analyzed if acute responses indicate significant divergence in individual acute responses. Heart rate will be monitored to ensure equal exertion and breathing rate during exposures. Pollutants will be continuously monitored (including particle number and mass, ozone, and NO_X) during the ride by either the use of the ARB Mobile Monitoring Platform (MMP), an instrumented electric bicycle, or both. One study PI is already familiar with the MMP and in the analyses of the real-time data it produces. Furthermore, other study PIs have successful experience in subject recruitment, lung function testing including exhaled NO, and in testing biomarkers in blood and urine.

BENEFITS: This study will provide policy makers, epidemiologists, and others with significant new information on the adverse health effects of high activity in traffic-impacted locations on otherwise healthy individuals. It will also add knowledge about the health effects of ultrafine particles. As short-term air quality standards are frequently driven by the effects seen in vulnerable populations, the results of this study may play a helpful role in the evaluation of the adequacy of current air quality standards in protecting the health of the outdoor-exercising portion of the population.

COST: $490,000

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Grievnink, L., Jansen, S., van't Veer, P., Brunekreef, B. (1997) Acute effects of ozone on pulmonary function of cyclists receiving antioxidant supplements. *Occup Environ Med* 55:13-17.

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Reidiker, M., Cascio, W.E., Griggs, T.R., Herbst, M.C., Bromberg, P.A., Neas, L., Williams, R.W., Devlin, R.B. (2004) Particulate matter exposures in cars is associated with cardiovascular effects in healthy young men. *Am J Respir Crit Care Med* 169:934-940.

Climate Change

TITLE: Improving Methods for Assessment of California Greenhouse Gas Emissions

PROBLEM: Significant uncertainty afflicts current emission inventories of greenhouse gases (GHGs), particularly for non-CO_2 gases. These uncertainties must be reduced to accurately quantify current inventories and verify future emission reductions required by AB32. Inverse modeling is a powerful technique for estimating greenhouse gas emissions by comparing measured and predicted atmospheric GHG concentrations to back-calculate the most probable emissions estimates and their uncertainties. Inverse modeling is requires accurate representation of atmospheric transport and mixing. Current mesoscale meteorological models, necessary for inverse modeling of air basins, do not to provide sufficiently accurate and high resolution representations of atmospheric transport to substantially improve many emission inventories. The lack of highly resolved representations of atmospheric transport in non-uniform terrain of coastal California is particularly noteworthy.

PREVIOUS WORK: Efforts to reproduce trace-gas distributions in California have shown that transport model errors limit the accuracy of air quality models and emissions estimates (Wheeler et al., 2006). Recent work also has shown that the performance of transport models can be greatly improved by incorporating high resolution, three-dimensional meteorological data (MacDonald et al., 2000; MacDonald et al., 2006).

Work has shown that CO_2 fluxes caused by California's fossil fuel combustion and net terrestrial ecosystem carbon exchange generate variations in the atmospheric CO2 mixing ratio that are should be readily measurable (Fischer et al., 2004; Riley et al., 2007). One successful approach to estimating continental scales net CO_2 exchange has used CO_2 measurements from aircraft and tower platforms in an inverse model approach (Lin et al., 2003, 2004; Gerbig et al., 2003a,b). Directly relevant to this proposal, the uncertainty in estimated surface emissions due to transport model errors were formally quantified (Lin and Gerbig, 2005). To minimize errors introduced by transport models at regional scales, recent work has focused on development of a specialized version of the NOAA Weather Forecast Research (WRF) model that provides output optimized for use with the stochastic time inverted particle Lagrangian transport model (STILT) and enables assimilation of three-dimensional meteorological data (Nehrkorn et al., in preparation; Eluszkiewicz et al., in preparation).

Until recently, few sites in California exist with the required capabilities to measure multiple GHGs (Li et al., 2005). In 2007, two new projects were initiated. First, the California Air Resources Board (ARB) conducted a series of 10-day measurement campaigns at Mt. Wilson Observatory, overlooking greater Los Angeles. Canister sampling and later analysis revealed strong correlations between different GHGs and carbon monoxide (CO). Under the assumption that GHG:CO concentration ratios reflect the ratio of GHG:CO emissions (e.g., that the emissions are either well-correlated or well-mixed in the LA Basin before reaching Mt Wilson), existing inventories of CO emissions can be used to estimate GHG emissions. Accurate, highresolution meteorology will be an essential tool in testing the validity of the assumption that

emissions are well-mixed, providing a means to identify which subregions of the LA Basin (e.g., port shipping) are responsible for most emissions. Second, in a California Enery Commission Study, measurements of multiple GHGs have begun at a site near Sacramento (Walnut Grove) and in the Bay Area (Sutro Tower). By combining analysis of these (and possibly other) sites, the stage is set to begin assessing emissions of several GHGs that are poorly understood at present (Farrell, 2005). Progress in this area is important in setting the stage for a California Climate and Air Quality (CCAQ) field study being planned by ARB, CEC, and NOAA for 2010.

OBJECTIVE: The objective of this project is to evaluate and enhance a state-of-the-science mesoscale transport model for inverse model studies of GHG and air pollutant emissions.

DESCRIPTION: First, we will assemble month-long meteorological data sets that capture interseasonal and inter-annual (e.g., average, El Niňo, La Niňa) variations. The data sets will include standard meteorological data collected at surface sites and by radiosondes and enhanced data, including hourly mixing heights, vertical profiles of winds, and virtual temperature measured by radar wind profilers, Radio Acoustic Sounding Systems, and sodars. Second, we will perform WRF simulations for each month of measured meteorology for a set of three or four sites identified in cooperation with ARB (e.g., Mt. Wilson, Walnut Grove, Sutro Tower). For each site, simulations will include a set of nested grids from approximately 10 km (covering all of California) down to as small as 1 km (covering perhaps 30 km) for sites in complex terrain. Third, the WRF simulations will then be evaluated by comparing predicted variables (e.g., mean wind velocities, boundary layer depth, turbulent kinetic energy, convective potential energy, etc.) with those obtained from the measured meteorology. Both mean bias and root mean square error will be computed. Fourth, source-receptor influence functions will be calculated for the selected observation sites using ensemble STILT runs driven by the WRF meteorology. The ensembles will include the random components of WRF errors determined above. Best estimates of GHG emissions and their uncertainties due to transport model errors will be quantified. Finally, we will determine the necessary resources to perform similar meteorological data assimilation and additional emissions modeling to support the planning of the 2010 CCAQ field study.

BENEFITS: This project will provide California with the high-resolution meteorology necessary to accurately estimate GHG emissions from previous GHG measurement intensives, allowing a crucial and independent test of (currently uncertain) non-CO2 GHG emission inventories, and identifying the observations and modeling needed to verify future emissions reductions in response to AB-32.

COST: $270,000

TITLE: Assessing the Energy Savings and Greenhouse Reduction Potential of Water Efficiency Improvements in the California Industrial Sector

PROBLEM: Recent estimates by the California Energy Commission (CEC) suggest that roughly 3% of California's annual electricity use and 14% of its annual non-power plant natural gas use can be attributed to the treatment, distribution, and use (e.g., heating, pressurizing, and cooling) of water by the California industrial sector (1). Based on California's latest greenhouse gas (GHG) emissions inventory, this energy use generates around 10% of California's annual non-transportation related GHG emissions arising from fossil fuel combustion (2). Industrial water efficiency improvements can therefore play a significant role in reducing California's energy demand and GHG emissions. While a substantial body of information exists on industrial water efficient technologies and practices, to date no study has assessed the water, energy, and GHG emissions savings potential, life-cycle costs, and sub-sector level applicability of water efficiency measures across California industry. Thus, accurate estimates of the potential statewide benefits and costs of industrial water efficiency improvements are lacking, which constitutes a critical information barrier to policy efforts to reduce the energy use and GHG emissions of California industry.

PREVIOUS WORK: Many "bottom up" resources exist globally on water efficient technologies and practices for individual industrial sub-sectors, some of which are directly applicable to California industry. For example, LBNL developed a water and energy benchmarking tool for California's wine industry, which characterizes the water savings and costs of specific water efficiency measures (3). LBNL also compiles water efficiency data for various industries in support of the U.S. EPA's ENERGY STAR for Industry Program (most recently for the food processing, pulp and paper, and chemical industries (4). Several "top down" studies of statewide water use and efficiency opportunities have been published (5,6), but these studies lack key details on applicable technologies, savings potentials, and implementation costs within industrial sub-sectors. Moreover, available studies applicable to California don't appear to quantify the energy use and GHG emissions savings associated with industrial water efficiency measures.

OBJECTIVE: To perform an assessment of the water use, energy use, and GHG emissions reductions achievable through water efficiency improvements in California's industrial sector. This assessment will be based on detailed study of applicable technologies and strategies within key California industrial sub-sectors, and will include water and energy savings potentials and life-cycle costs associated with each measure.

DESCRIPTION: LBNL has performed detailed energy efficiency potentials studies for a variety of industrial sub-sectors, and is currently leading a statewide industrial energy efficiency potential study for the CEC. The approach employed in these studies for the environmental and economic assessment of energy efficiency opportunities will be applied to water efficiency assessment as follows. First, water use estimates for California industrial sub-sectors will be developed based on state-level water balances, water intensity data for typical sub-sector processes, available case study data, and engineering estimates (e.g., boiler fuel may serve as a proxy for steam system water use). The goal will be to develop reasonable estimates of water use by application (e.g., steam, process cooling, and washing) for major water consuming California subsectors

60

(e.g., food processing and semiconductors). Second, estimates of the energy and GHG savings achievable per liter of water use avoided will be derived for each subsector. Estimates of indirect energy and GHG savings (i.e., due to avoided water purchases and discharges) will be derived based on water system analyses by LBNL's Water Energy Technology Team (WETT). Estimates of direct energy and GHG savings (e.g., due to decreased demand for water heating, pressurization, and cooling) will be based on LBNL's industrial sub-sector energy use studies. Third, data on available water efficient technologies and practices applicable to each sub-sector will be compiled to characterize the potential water savings and life-cycle costs associated with each measure. Finally, a model will be developed to estimate the potential water, energy, and GHG savings associated with the deployment of identified water efficiency measures across California industry. The model will also generate water efficiency supply curves for integrated environmental and economic analysis. A final report will summarize methods, results, and recommendations for water efficiency improvements.

BENEFITS: This work will fill a critical gap in knowledge regarding the energy savings and GHG emissions reduction potentials and costs of specific water efficient technologies and strategies in California's industrial sector, and will therefore provide the detailed information necessary for developing informed action plans and incentives for improving industrial water efficiency. Improved industrial water efficiency can help California meet its energy efficiency and GHG emission reduction targets, and will also lead to greater availability of scarce water resources, reductions in peak electrical demand, and reductions in air pollution in the state.

COST: $300,000

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(1) California Energy Commission (2005). Integrated Energy Policy Report: Chapter Eight: Integrating Water and Energy Strategies. Sacramento, California. CEC-100-2005-007CMF. November.
(2) California Energy Commission (2006). Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004. Sacramento, California. CEC-600-2006-013-SF. December; and California Energy Commission (2007). Revisions to the 1990 to 2004 Greenhouse Gas Emissions Inventory Report. Sacramento, California.
(3) Benchmarking and Energy Saving Tool (BEST) for the Wine Industry: http://water-energy.lbl.gov/node/19
(4) See for example: Masanet, Worrell, Graus, and Galitsky (2007). Energy Efficiency Improvement and Cost Saving Opportunities for the Fruit and Vegetable Processing Industry – An ENERGY STAR Guide for Plant and Energy Managers. Lawrence Berkeley National Laboratory. Berkeley, California. LBNL-59289.
(5) Gleick, Cooley, and Groves (2005). California Water 2030: An Efficient Future. Pacific Institute. Oakland, California. September.
(6) House, L.W. (2006). Water Supply Related Electricity Demand in California. Prepared for the California Energy Commission by the Demand Response Research Center, Lawrence Berkeley National Laboratory. Berkeley, California. LBNL-62041.

Diesel and Goods Movement

TITLE: On-Road Heavy Duty Vehicle Emissions Measurements Including Ammonia, Sulfur Dioxide, and Nitrogen Dioxide

PROBLEM: Starting in 2007, most manufacturers chose to meet increasingly stringent PM emissions standards for on-road, new engine HDDVs using Diesel Particulate Filters (DPFs). To regenerate these filters, intentional NO/NO_2 conversion catalysts are employed. On-road measurements made with a chase vehicle have found that the NO_2/NO_X ratio from DPF-equipped transit buses was 33% whereas non-DPF equipped buses emitted less than 10% of the NO_X as NO_2 (Shorter et al 2005). The ability to measure and monitor on-road NO_2 release from DPF equipped vehicles will be important in evaluating this technology's overall success. There is a CARB standard for the emissions of nitrogen dioxide from future HDDV which can now be verified by on-road techniques. Current HDDV emit no ammonia, but to the extent that future NO_X controls include urea injection, ammonia emissions might well increase from HDDV. Ammonia is a major component of airborne PM2.5 and there are few ammonia sources in the LA basin other than motor vehicles. Sulfur dioxide emissions, especially from diesel vehicles, are a potential indicator of misfueling. This is an illegal activity and the fines are high but the incentives are significant.

PREVIOUS WORK: There has been one previous on-road RSD study of HDDV emissions of NO, CO and HC in the LA basin (Bishop et al 2001). We have now developed a UV based on-road remote emissions sensor which reliably gives not only CO, HC, CO_2 and NO fuel-based mass emissions readings from passing heavy duty vehicles but also provides the same quality of data for ammonia, nitrogen dioxide and sulfur dioxide. The results of a single on-road HDDV study will be published soon in Environ. Sci. Tech. A second HDDV study in Japan has been carried out with this unique instrument because in Japan they have found with their many DPF equipped vehicles that while NO_X has gone down both NO_2 and ozone have increased. Several typical HDDV were observed with 50/50 NO/NO_2 emissions on a molar basis. Regarding misfueling, the 2005 study in Colorado showed perhaps as many as 27 vehicles out of 1409 to be using illegal high sulfur fuel. If future HDDV are significant ammonia emitters, this could have an important impact on PM2.5.

OBJECTIVE: To monitor the above pollutants from approximately 3000 heavy duty vehicles under load as they exit the same weigh and check station in Riverside CA. The results, when combined with fuel sales data, will provide a fuel-based emission inventory and will investigate potential misfueling. The results will also determine the extent to which the new model HDDV meet the new CARB NO_2 emissions standard and perhaps slip excess ammonia from urea decomposition.

DESCRIPTION: The FEAT 3000 is the University of Denver's routine on-road emissions monitor. It has been used in California for the CARB and IMRC at several sites, and for the CRC every two years at a single site, the intersection of LaBrea Blvd. and I-10 in Los Angeles. The instrumentation is fully described in CRC E-23 reports available on the web at www.feat.biochem.du.edu. and in a recent Rev. Sci. Instrum. paper also

available from the web site. The new features which have been added include new optics and a wider UV detector array which allow NO_2, SO_2 and NH_3 to be monitored simultaneously with the routine pollutants. This development was described by Burgard et al at the April 2006 CRC Meeting in San Diego. Colorado and Tulsa HDDV and LDDV results with the new capability will shortly be published in Environmental Science and Technology. In operation, a mobile van sits at the roadside during daylight hours for one week at the measurement location and the sensors are placed on a rented scaffold. We suggest a return to the Riverside site close to the LA basin in part to compare the data with data taken earlier at the same site by the same instrument before the modifications. The techniques or research methods to be employed are identical to those used in two recent studies in the Denver area and in Tulsa OK which were reported at CRC 2006 in San Diego by Burgard et al. Other than the addition of the three new pollutant channels they are identical to those used in the CRC E-23 studies. Tasks to be achieved include apply to CALTRANS for permits for the site, ensure that all calibration gases are available and certified by appropriate authorities, carry out the studies, read partial vehicle ID numbers, match partial vehicle ID numbers with complete VINs (as done in Colorado) for make and model year with California DMV and report the findings.

BENEFITS: New knowledge of the current HDDV ammonia, nitrogen dioxide and sulfur dioxide emissions inventory. An indication as to whether these emissions when measured on-road are within the guidelines set by the new CARB emission standards.

COST: $100,000

TITLE: Port Workers' Exposure to Air Pollution

PROBLEM: The Ports of Los Angeles and Long Beach (Ports) and their terminal operators provide employment to thousands of workers in on-dock and transportation jobs. Current ARB and SCAQMD efforts to characterize air pollution levels in the surrounding communities do not address on-job air pollution exposure. As many of the workers live in the surrounding communities, assessing overall pollutant exposure of this sub-population requires knowledge of occupational exposure as well.

PREVIOUS WORK: A previous study funded by NIOSH and conducted by Cal-EPA measured the on-job pollution exposures of several occupation classes at the Ports. The study did not address many pollutants of concern such as diesel particulate matter. Other studies have assessed diesel exposure in other occupational settings.

OBJECTIVE: To characterize the exposure of Port terminal and transportation workers to air pollutants.

DESCRIPTION: To characterize exposure of Port workers, a combination of personal monitoring and area sampling will be conducted. A set of occupation types and settings will be selected after an initial scoping task to determine jobs and areas with potential for high exposures. This will be accomplished via site visits and include input from occupational hygienists, the Ports, terminal operators, and the local dock workers union (ILWU #13). The exact number of samples, subjects, areas, and sampling durations will be determined based on the scoping exercise and available resources. Once the jobs and areas for sampling are identified, volunteers for personal monitoring and appropriate IRB approval will be sought.

Area sampling will include established methods for air monitoring of selected pollutants and air toxics. PM2.5 and PM10 filter samples will be collected and analyzed for mass, air toxic species, and elemental carbon as an indicator of diesel exhaust. Methods for measuring continuous PM mass will also be considered as resources allow. Ultrafine particle counters will also be considered. Eight-hour duration silanated canisters will collect organic gas air toxics for subsequent analysis.

Personal sampling may include some more recently developed active and passive methods. Many traditional occupational exposure monitors do not have the sensitivity to measure pollutants at ambient levels. Since the objective of the personal monitoring is to measure exposures that may be well below established occupational limits or guidelines and provide comparisons to fixed site monitors, the methods deployed for epidemiological exposure assessment are more appropriate. Methods that will be considered include personal, active PM samplers or impactors, passive and active gas samplers, and particle counters for ultrafine particles. Sampling analysis techniques will be as similar as possible to those used for the area sampling and the other ongoing monitoring studies in the surrounding areas.

Data analysis will include direct comparisons between on-job exposures, area concentrations, and community concentrations as measured by ongoing SCAQMD and

ARB monitoring studies. The specific source of the exposures will be assessed based on the chemical analysis of PM filters, gases, and estimated source profiles.

BENEFITS: Assessing the impact of goods movement includes the health effects costs associated with exposure to air pollution from goods movement activities. Given the large number of jobs associated with Port activities, and the proximity of these jobs to pollution sources, an impact assessment should include the potentially elevated exposures of this sub-population of residents. This study will help to identify these exposures and impacts and provide important information for decision-makers regarding Port operations and pollution mitigation measures.

COST: $300,000

Atmospheric Science

TITLE: Global Chemical/Aerosol Data Assimilation Experiments in support of the proposed 2010 California Air Quality and Climate Study

PROBLEM: The California Air Resources Board (CARB), in partnership with the California Energy Commission and the National Ocean and Atmospheric Administration (NOAA), has begun preliminary planning for a proposed 2010 Air Quality and Climate field study. The 2010 field study will collect data to address key science questions regarding; interactions between air quality and climate change, influences of long-range transport, and characterization of ozone and aerosol precursors and greenhouse gas emissions. These data sets will be used to assess the fidelity of air quality modeling in support of California State Implementation Planning (SIP) activities. Characterization of temporal, spatial distribution of inflow oceanic boundary conditions has been identified as critical due to the influence of long-range transport of ozone, aerosols, and their precursors into California. Quantification of the role of background ozone and aerosol formation on California air quality requires a nested global to regional to local scale modeling approach. Global chemical and aerosol analyses, constrained with satellite trace gas and aerosol observations, can be used to provide the global component of this nested modeling system.

PREVIOUS WORK: The NASA Applied Sciences Program, in partnership with the U.S. EPA, conducted a benchmark study to determine whether lateral boundary conditions based on assimilation of satellite ozone measurements improve air quality prediction within the U.S. EPA CMAQ model [http://aiwg.gsfc.nasa.gov/esappdocs/benchmarks/ AirQuality_CMAQ_Benchmark_Final.pdf]. Results indicated that using boundary conditions generated from the Real-time Air Quality Modeling System (RAQMS) [Pierce et al., 2003, 2007] improved the performance of CMAQ in the middle troposphere. Impacts on surface ozone were largest over the coastal and mountain regions of the western U.S. where high biases were increased slightly (2 ppbv) and diurnal variations were improved by ~10%. Subsequent studies using RAQMS assimilated boundary conditions [Tang et al., 2007, Song et al., 2007] also show that boundary conditions from global chemical analyses improve regional model predictions. RAQMS chemical analyses (constrained with NASA Aura OMI and TES measurements), in conjunction with Lagrangian chemical back-trajectory analysis, where used to quantify the role of background ozone production on local air quality in the Houston and Dallas metropolitan areas during the 2006 NOAA TEXAQS II field study [http://www.tceq.state.tx.us/ assets/public/implementation/ air/am/workshop/20061012-13/RSST_Preliminary_ Findings_Report_20061031.pdf] The RAQMS TEXAQS II study demonstrated the benefit of synthesizing satellite, aircraft, and surface measurements of aerosol and trace gases in conjunction with advanced modeling techniques for characterizing the impact of emissions from remote sources on local air quality.

OBJECTIVE: Conduct global chemical data assimilation experiments utilizing satellite based trace gas and aerosol measurements to provide observationally constrained lateral boundary conditions for regional air quality modeling in support of the California SIP activities.

DESCRIPTION: Assimilation of cloud cleared OMI total column ozone and TES global survey O_3 and CO profile retrievals from the NASA Aura satellite and MODIS aerosol optical depth and wildfire detections from the NASA Terra satellite will be conducted within RAQMS using uni-variate Optimal Interpolation (OI) analyses techniques. RAQMS is a unified (stratosphere/troposphere), multi-scale (global to regional) online (meteorological, chemical, and aerosol) modeling system which has been developed for assimilating satellite based observations of atmospheric chemical composition and providing real-time predictions of trace gas and aerosol distributions [Pierce et al., 2003, 2007; Kittaka et al., 2004]. For an up-to-date description of the RAQMS chemical mechanism see Pierce et al. [2007]. The RAQMS aerosol modules [Chin et al. 2003] and MODIS AOD assimilation has been tested in the regional component of RAQMS. Implementation of aerosols into the global model is currently underway.

Tasks:

1. Retrospective OMI+TES+MODIS chemical and aerosol assimilation experiments will be conducted during Spring and Summer 2008 to provide CARB regional air quality modelers with RAQMS chemical analysis for developing interfaces and evaluating impacts on California air quality assessment modeling.

2. Real-time OMI+MODIS assimilation/forecasting will be conducted during 2010 to provide support for field study activities.

3. Retrospective OMI+TES+MODIS assimilation experiments will be conducted during 2010 to provide CARB regional modelers with lateral boundary conditions for SIP modeling activities.

BENEFITS: Global chemical and aerosol analyses produced under this research activity would be beneficial to the California regulatory planning and technical community at the district, state, and federal levels because they will provide improved constraints on background ozone and aerosol distributions for state implementation plan (SIP) modeling efforts. This work will build capacity for air quality forecasting and assessment through the use of satellite observations.

COST: $480,000

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TITLE: Measurement of Ozone Aloft for the 2010 Air Quality and Climate Field Study in California

PROBLEM: Both ozone and secondary particulate matter are formed in complex photochemical reactions of air pollutants emitted from a wide variety of sources. Despite many years of reducing precursor emissions, many areas in California are classified by the U.S. Environmental Protection Agency as in non-attainment for ozone and particulate matter (PM). In addition both ozone and PM interact with sunlight, affecting the energy input to the atmosphere and earth's surface, thus having potential for contributing to global climate changes. To formulate additional cost-effective emission control strategies, a better understanding of the meteorological and chemical processes contributing to high ozone concentrations is needed. In order to fully understand formation processes it is necessary to have as much concentration as possible in an air shed in order to develop and validate air quality simulation models. While ozone, PM and some precursor concentrations are measured routinely at ground level, there is little current concentration data of the vertical distribution. The draft list of scientific questions proposed for the 2010 Air Quality and Climate Field Study in California (2010 Study) included "What are the important transport corridors for key chemical species" and "What are the sources and physical mechanisms that contribute to high ozone concentrations aloft". In order to address these questions both meteorological and pollutant concentration data are needed as a function of altitude. The following will focus on obtaining ozone data aloft, although meteorological data will also be obtained concurrently.

PREVIOUS WORK: The 1997 Southern California Ozone Study (SCOS97-NARSTO) provided an expanded understanding of the distribution of ozone in Southern California and the mechanism of formation. This study emphasized the collection of data on the vertical distribution of ozone and meteorological parameters. During intensive operating periods or IOPs, ozone concentrations were measured aloft using a number of techniques.

Ozone can be measured aloft by a number of techniques. Instrumented aircraft are commonly used, but they have many limitations. Cost has been a major limitation, especially for sporadic forcasted use, since the crew and aircraft must be maintained while waiting for acceptable study days. In addition to cost, there are several other limitations. To obtain a vertical ozone gradient, the aircraft must perform spirals over one location. It is often difficult to obtain permission to do this in urban areas because of the large amount of air traffic. Except when taking off or landing, aircraft are limited to flying at least 1,000 feet above ground level (AGL) in populated area and 500 feet AGL in unpopulated areas. This would be a significant limitation since during the highest ozone days most of the ozone is within the first 1,000 feet AGL. Ozone vertical distributions also can be measured using tethered balloons. While these balloons can be easily varied in height and do not move spatially, it is difficult to obtain permission from the Federal Aviation Administration to fly them above 200 feet, especially in urban areas or at night, due to potential interference with aircraft. Vertical ozone measurements can also be made remotely by using LIDAR instruments. These are research instruments that are expensive and labor-intensive. Correction factors are often necessary, and the quality of the data is difficult to quantify. Comparison with data

obtained by other methods has shown significant variability. Ozonesondes have advantages to the above-mentioned techniques and were used extensively during the SCOS97-NARSTO study. On a per-measurement basis, their cost is generally less than that of a research aircraft. There are no major limitations as to where they can be flown. The instruments are simple, inexpensive direct measures of ozone that are easily calibrated.

OBJECTIVE: The objective of this research is to determine ozone concentrations and meteorological data as a function of altitude for the critical geographic areas in support of the 2010 Study.

DESCRIPTION: Our approach is to use En-Sci model 2Z ECC ozonesondes flown on helium-filled balloons to make vertical sounding of ozone. Ozone data from the sonde, in addition to air pressure, temperature and humidity, are transmitted to a ground station. From the receiver, the data are sent to a personal computer. The En-Sci model 2Z ECC ozonesonde uses the principle of ozone reacting at constant stoichiometry with a solution of potassium iodide (KI) in a buffered solution of an electrochemical cell. The performance of all ozonesondes will be verified at a central facility prior to deployment in the field. The location and frequency of launches will be finalized during future 2010 Study planning sessions. It is anticipated that launch sites should be located in all of California's major urban air basins and at significant mountain passes that lead from one air basin to another. Thus the San Diego County, South Coast, San Joaquin Valley, Sacramento Valley, and San Francisco Bay Area air basins should be included. Mountain passes between these air basins would include Altamont, Pacheco, Tejon, Cajon, and Tehachapi passes. A total of ten launch sites are therefore likely. In order to follow the transport and transformation processes launches should be made at least four times a day for at least two contiguous days. This is the protocol that was used during SCOS97-NARSTO. The balloons will be filled with helium to produce a free lift of 350 grams. This provides an ascent rate of approximately 1.5 m/s, which will give the maximum vertical resolution while providing a lift rate sufficient for a successful launch.

Site operators (two per site) will be recruited from areas near launch sites. They will be trained to launch the sondes as a group at a central facility. Training launches will be conducted using a tethered sonde. Site operators will be on-call for the entire 2010 Study measurement period. After launching, the data will be monitored on a computer screen until the sonde reached a pressure of 500mb or less. Data will then be immediately sent to a central facility for processing, storage, and validation.

BENEFITS: This project will provide much needed vertical ozone concentration data to answer the scientific questions raised by the 2010 Study.

COST: $600,000

State Implementation Plan Support

TITLE: Cluster Analysis of Air Quality and Meteorology Data for 1996-2008

PROBLEM: This study will assess exposures to fine particulate matter (PM) and ozone throughout California over an extended study period. Certain regions of the state have reduced ambient pollutant levels through emissions reductions (e.g. SoCal), whereas others have not (e.g. SJV). The relationship between pollutant concentrations and emissions reductions is profoundly impacts of atmospheric processes on ambient air quality. Relationships between meteorology and air quality can be elucidated by statistical analysis, providing a complement to detailed episodic analyses of relatively brief air pollution events. Extended records of routine measurements can be used to characterize the full range of meteorological scenarios that are likely to both occur and to have elevated air pollution potentials. This study is the first to perform systematic cluster analysis to explore meteorological influences on air quality at both the intra-basin and inter-basin scales. Results will aid air quality planning by identifying the full range of scenarios across which the benefits of emissions reductions can be evaluated to determine cost effective control strategies.

PREVIOUS WORK: Two related studies are being performed under CCOS and BAAQMD contracts: a 1996-2004 ozone study for Central California and a 1999-2007 PM study for the Bay Area. Both the Bay Area and SJV Districts found research results useful in their planning efforts.

OBJECTIVE: To use advanced statistical modeling to determine the effects of atmospheric processes on ambient pollutant levels to aid in exposure assessment. The study will consider both PM and ozone pollution during the period 1996-2008.

DESCRIPTION: This project is envisioned as a 3-year study, implemented in 3 tasks. Task #1 considers intra-basin effects of meteorology on air quality for 7 air basins defined by District boundaries. Task #2, an inter-basin analysis, explores overall trends in state-wide air quality in response to evolving meteorological conditions. Task #3 performs exploratory receptor modeling for PM source apportionment.

Task #1 performs intra-basin cluster analyses of routine, hourly surface wind measurements to identify meteorological patterns affecting 7 California air basins: Central Coast (North and South), Mojave Desert, Sacramento Valley, San Diego County, San Francisco Bay Area, San Joaquin Valley, and South Coast. For each basin, a separate clustering will be performed for the ozone (1 May through 15 October) and PM (1 October through 28 February) seasons. Through cluster analysis, we will identify key meteorological processes affecting air quality at both the mesoscale and synoptic scales. Emphasis will be placed on mesoscale circulations allowing for the formation of localized ozone or PM "hot spots." For each basin, the air pollution potentials (considering weekday/weekend effects) for both PM and ozone will be assessed under the entire range of atmospheric conditions occurring during the 13-year study period. Results will indicate subtle differences in meteorology that trigger exceedances for a given level of emissions. Vertical (ozone sonde) measurements will

be incorporated in the analyses to assess the potential of ozone layers aloft affecting surface ozone levels. Quality assurance will be performed for the data. This characterization of 1996-2008 meteorology may aid in future climate change research.

Task #2 considers meteorological effects on inter-basin air quality, focusing on temporal coherence between meteorology and air quality in distant regions of California. Meteorologically coupled basins will be identified, with attention to determining scenarios for large-scale flow patterns that could establish source-receptor relationships between adjacent air basins. Meteorological dynamics will be characterized for the flow splitting between the Bay Area, SJV, and Sacramento Valley; variations in oceanic boundary conditions along the Central Coast; potential marine flows from the Central Coast into SJV; scenarios in which the South Central Coast (Ventura County) is upwind of SoCab; and the connectivity between SJV, Mojave Desert, and SoCab. For basins experiencing coupled meteorology, the timing at which evolving meteorological systems (e.g. marine intrusion, migrating anticyclones, or storm activity) influence distant locations will be explored. The evolution of the inter-basin spatial distribution of pollutants will be characterized in response to the meteorological dynamics. This study serves as a basis for an inter-basin transport study by identifying a number of recurring scenarios under which long-range transport mechanisms could occur.

Task #3 is an exploratory use of statistical receptor models for PM source apportionment. A novel approach will be taken to perform the receptor modeling in a "meteorologically disaggregated" framework. For a given basin, receptor modeling will be applied independently to data pooled according to the meteorological patterns identified in task #1. Pooling data by meteorological classes will prevent the receptor model from capturing conflicting trends on days exhibiting vastly different source-receptor relationships and/or degree of airmass photochemical aging. Meteorological disaggregation will enable identification of different sources or source strengths affecting receptor locations under different meteorological conditions. Incorporation of the meteorological patterns identified in task #1 allows for increased insight when interpreting the speciated PM measurements that are not sampled every day.

BENEFITS: This project will leverage enormous datasets on surface meteorology and air quality to enable more accurate assessments of how atmospheric processes contribute to ozone and PM exposures over a range of scenarios. This approach complements episodic air quality modeling, which explores only a limited range of scenarios. This study will provide technical guidance to planners and regulatory agencies to improve public health by providing cleaner air throughout California.

COST: $250,000

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TITLE: Optical Remote Sensing from Mt. Wilson: A New Approach to Study Sources of Pollutants and Greenhouse Gases in the South Coast Air Basin

PROBLEM: Observation of pollutants and greenhouse gases and their spatial and temporal distributions is a crucial aspect of monitoring air quality as well as the current efforts, mandated by AB32, to curb greenhouse gas emissions in California. To date the strategy to monitor atmospheric trace gases on a regional scale has relied upon networks of in-situ ground observations. The limited number of ground sites in these networks often poses challenges due to possible influence of local emissions and large spatial gaps between the stations. Without complementary data from aircraft, balloons, satellites or other exotic platforms, the ground-based network is inadequate to characterize the emissions of pollutants and greenhouse gases, and to monitor their vertical and horizontal distributions. Novel, more readily deployable experimental methods are therefore needed to augment the capabilities of the existing monitoring network.

PREVIOUS WORK: A pilot study using multi-axis Differential Optical Absorption Spectroscopy (MAX-DOAS) to measure NO_2, HCHO, and aerosol extinction from the new NASA-JPL "California Laboratory for Atmospheric Remote Sensing" (CLARS) has been performed in April 2007 at Mt. Wilson. The results of this experiment clearly show that enough information can be derived to retrieve spatial concentration fields of these compounds in the South Coast air basin. These measurements will be continued in Fall 2007.

Through a NASA-sponsored project we have shown the feasibility of near-IR measurements and are currently building a dedicated near-IR FTIR to measure the spatial distribution of various greenhouse gases. The instrument is based on a long heritage of Fourier transform spectrometers developed at JPL for ground-based, aircraft, balloon and spaceflight applications. We anticipate that the near-IR capability will be fully operational by Summer, 2008.

OBJECTIVE: We propose to use optical remote sensing techniques in the UV/Vis and near IR wavelength regions from CLARS to measure the spatial and temporal distributions of various pollutants (NO_2, HCHO, aerosol extinction) and greenhouse gases (CO_2, CO, CH_4, N_2O). We will also explore measurements of the average concentrations of other greenhouse gases (CFC's, HCFC's, etc.) in the South Coast air basin during sunset. The observations can be used to validate and improve current emission inventories and urban airshed models.

DESCRIPTION: JPL's "California Laboratory for Atmospheric Remote Sensing" (CLARS) is located on a mountain ridge at Mt. Wilson with a near full view of the South Coast air basin. We propose to perform four month-long field experiment during different seasons in the years 2009 and 2010, measuring the spatial and temporal distribution of various pollutants (NO_2, HCHO, aerosol extinction via O_4) and greenhouse gases (CO_2, CO, CH_4, N_2O) using a UV-vis MAX-DOAS and a near-IR FTIR spectrometer. Both instruments will use scanning systems to measure the absorptions of these trace gases in different viewing directions. Concentration fields of

these compounds with a vertical resolution of 0.2 to 1km, a horizontal resolution of at least one kilometer, and a temporal resolution of 0.5 - 1 hour, will be retrieved using radiative transfer calculations. Operational software to allow the fast and accurate retrieval of these concentration fields will be developed. We will also perform solar occultation measurements during sunset to explore measurements of the average concentrations of less abundant greenhouse gases, such as CFC's and HCFC's, in the basin. A validation strategy will be developed and applied to ensure the quality of our data. The precise scanning geometry of our measurements can be chosen such that a good overlap with urban airshed models and ground measurements is achieved. Our observations will provide a novel and unique dataset of concentration fields of pollutants and greenhouse gases. The vertical concentration profiles within the boundary layer i.e. surface – 1000m altitude can be used to study the average fluxes of the various trace gases from the surface. By comparing our observations with the output of urban airshed models, emission inventories can be validated. We will seek collaboration with teams specializing in modeling the South Coast air basin to fully exploit our observations.

BENEFITS: The State of California is currently pursuing an ambitious plan to reduce its greenhouse gas emissions and to improve its air quality over the next decade. The proposed measurements will provide a unique data set to support these activities, by allowing the validation of emission inventories and urban airshed models. While we are currently proposing a campaign style observational strategy, the methods that we will employ could also be developed into a year-round observational system to monitor future changes in trace gas concentrations and emissions in the South Coast air basin and other urban areas in California.

COST: $285,000

Toxic Air Contaminants

TITLE: Guidelines and Sampling Protocols for Measuring ETS in Multifamily Dwellings

PROBLEM: The California Air Resources Board (ARB) identified Environmental Tobacco Smoke (ETS) as a Toxic Air Contaminant (TAC) on January 26, 2006. ETS has been associated with many adverse health effects including: Sudden Infant Death Syndrome, lung cancer, heart disease deaths, and acute and chronic respiratory illnesses, including asthma. In multi-family housing, residents may not be able to control their exposure to ETS if a resident in a neighboring unit smokes. Local public health officials report receiving a high number of complaints about secondhand smoke from apartment residents, and in the past two years several California cities have passed local ordinances to restrict smoking in multi-family dwellings. Multi-family dwellings make up nearly 40 percent of California's housing stock and two-thirds of the population in the Los Angeles area lives in multi-family buildings. There are no statewide laws to prevent involuntary exposure to ETS in multifamily housing. Additionally, there are no guidelines or protocols to assist the public or industrial hygienists in the measurement of ETS in multifamily housing. Measurement of ETS in units that may only share heating, ventilation, or plumbing conduits is complicated by the need to determine the nature and extent of the transfer between units. This degree of transfer is complicated by the age of the housing, the degree of ventilation, and the type of heating and air conditioning in the building. Measuring ETS is also complicated by the fact that the substance is a mixture of several thousand pollutants, many of which are also the result of other indoor contaminants. While nicotine is typically used to demonstrate exposure to ETS, the rate of transfer of nicotine from one unit to the next is complicated by the absorption properties of nicotine and particle filtering. Tracer gas studies have demonstrated a high potential transfer rate for the volatile components of ETS, which are also some of the most deleterious; these include 1, 3-butadiene, benzene, formaldehyde and acrolein.

PREVIOUS WORK: The most extensive research on ETS transfer in multifamily dwellings was performed in Minnesota by the Center for Energy and Environment (CEE). Multiple fan pressurization tests and passive tracer gas methods were used to characterize the transfer of ETS between apartment units. These measurements were supplemented by measurements of nicotine and fine particulate mass. Tests were conducted on six multifamily buildings representative of the type most common in Minnesota. Tracer gas studies confirmed that air flow between units could be a significant concern. At least one unit in each of the buildings contained 10 percent of the air from a different unit. Units on higher floors had a greater fraction of air from other units. The average fraction of inter-unit air flow ranged from 2 percent for a new four-story condominium to 35 percent for a 1930-era up/down duplex. The median value for all units was 5 percent. A previous study found 13 to 25 percent transfer in the Pacific Northwest. While there appeared to be a tendency for greater inter-unit air flow in older buildings, one three-story apartment building built after 1999 had unit air flows greater than 20 percent. The Minnesota study concluded that passive monitoring for nicotine was not an effective measure of the transfer between units. This was assumed to be due to the result of nicotine absorption and particulate filtering. The tracer gas transfer

rate ranged from 2 percent to 10 percent higher than the nicotine transfer rate. Measurements of fine particulate matter in this study were hindered by high and variable levels of background PM2.5.

OBJECTIVE: The primary purpose of this research is to document the potential for ETS transfer between units in multifamily housing. The authors will provide a direct measurement sampling protocol for each of a variety of multifamily housing stocks based on investigation of transfer rates as well as report on the results of sampling for nicotine and particulate matter in a variety of exposure settings in multifamily housing.

DESCRIPTION: The investigators will use Census information and information from the State's Department of Housing and Community Development to develop an estimate of the types and ages of multifamily dwellings in California. Using State building code information, the investigators will discuss the types of insulation, ventilation, heating and cooling that can be encountered in these various dwellings. A sampling protocol will be set up to measure ETS in a sample of units that are representative of California's multifamily housing stock. Investigators will then measure tracer gas concentrations, nicotine, and fine particulates (PM2.5, PM1.0) in a variety of dwellings and document the characteristics of each dwelling that could potentially affect the results in similar housing. Specifically, the investigator will answer the questions concerning: 1) Typical contaminant dispersion and airflow rates between apartment units in multifamily dwellings in California; 2) How the transfer of nicotine and fine particulates compare to the transfer of tracer gases; and 3) How air flow and contaminant transfer between units differ by building type. Approximately 8-10 buildings would be investigated, with at least 4-6 units in each building examined under a variety of climatic conditions. The investigator will then write a final report and establish a website for disseminating the information. Ongoing support of the website will be accomplished through collaboration with the Department of Health Services, the investigators, and ARB.

BENEFITS: This information will provide a basis for the development of smoke-free policies in apartment buildings, and will provide residents of multifamily housing, public health authorities, landlords, and property owners needed reliable scientific and technical information on how to demonstrate ETS exposure in multifamily housing. This information will also provide a basis for determining how transfer of ETS can be reduced through better design or ventilation.

COST: $425,000

TITLE: Sources, Composition, Variability and Toxicological Characteristics of Ultrafine Particles in Southern California

PROBLEM: Current regulatory efforts are focused on reduction of ambient levels of particulate mass for PM10 and PM2.5, but recent studies have demonstrated that ultrafine (UF) particles (less than ~100 microns in diameter) are more toxic. Studies that show individual particles penetrating cellular membranes and causing cell damage, suggest that particle number rather than particle mass may be a more health relevant metric of ambient particles. The majority of ambient particle numbers are UF particles, but, due to their small size, only a small fraction of ambient PM mass is UF. Since there is generally low correlation between ambient particle numbers and mass, ambient particle number measurements are becoming more important. Unlike PM2.5, for which there is an abundance of continuous and time-integrated mass (and in several areas chemical speciation) data generated by local and state agencies, a nationwide network of UF monitors is not currently in place, and may or may not become available in the near future. As a result, significantly less is known about the diurnal, spatial and seasonal characteristics of UF particles as well as chemical composition in urban and rural areas of the US. Since these PM characteristics may be important in evaluating the health effects of UFP relative to coarse PM or PM2.5, it is desirable to have intensive UFP measurements that will provide insights into the source, composition and health effects of these particles.

PREVIOUS WORK: UFP measurements in the proximity of freeways have been one of the focal points of the research undertaken by the Southern California Particle Center and Supersite. Results from these studies have been extensively cited in the scientific literature and used in legislation at the state and federal level. More recently, a CARB project granted to our group at USC focuses on the assessment of the spatial variability of ambient particle number concentrations within two impacted communities (source and receptor areas of Long Beach and Riverside, respectively). None of these studies , however, provides information on the larger scale distribution and characteristics of UFP in the Los Angeles Basin, which is the focus of the proposed project.

OBJECTIVE: The objective of this proposal is to provide the much needed and currently unavailable or very limited information on the relationships between UFP sources, spatial and seasonal characteristics, and toxicity in Southern California. Towards this goal, a highly multi-disciplinary research team will investigate the following research questions: a. What are the spatial, daily and seasonal differences in UFP number, mass and chemical composition found in rural and in urban areas of the Los Angeles Basin? b. What is the fraction of chemically speciated UFP that penetrates indoors and how does indoor and outdoor UFP differ toxicologically? c. How do the chemical characteristics of UFP collected in each of the above environments and over different seasons determine their toxicity? d. How does UFP PM toxicity differ from that of fine and coarse PM, measured in studies undertaken by the PIs, and sponsored separately by the recently renewed SCPC? e. How do the physical, chemical and toxicological characteristics of UFP in the urban and rural sites of this study compare to those near light- and heavy-duty freeways, airports and seaports?

DESCRIPTION: The proposed project spans an approximate 30-month cycle of measurements (24 months plus 2 intensive winter summer campaigns of 3 months each) at 10 locations impacted by different PM sources and representing distinctly different areas (urban, rural- receptor and desert) of the Los Angeles Basin (LAB). Seven of these locations are also sampling sites of the MESA (Multi-Ethnic Study of Atherosclerosis) Air Pollution Study ("MESA Air"). Two of them are high schools in urban Los Angeles with a high Hispanic student population. Of the 10 sites, the "*near freeway*" sites will selected to be as proximally close to the neighborhood freeway as possible (typically within a road2 width or so), and the *community sites* are in the generalized recruitment areas for some of the MESA subjects, away from the freeway. The general classification of these sites is as follows 1) the West LA area, from the I-405 Freeway to the coast (listed in the table as "*coastal*"); 2) the metropolitan/greater LA area, across the city and valleys, on either side of the 10 Freeway (listed as "*central*"); 3) the mostly rural-agricultural "*receptor areas*" of Mira Loma /Rubidoux/Riverside portion of Riverside County, situated about 80-90 km downwind of downtown Los Angeles. All of the sites have 115VAC power, are elevated (typically on the roof of a one-story building), and have protected access. In each of our fixed sites, measurements of UF number, mass, inorganic ions (sulfate and nitrate), elemental and organic carbon (EC-OC), speciated organic tracers, trace elements and metals as well as concurrent in vitro measurements of their redox activity and oxidative potential will be conducted on continuous and time-integrated bases. In addition to the UFP measurements listed above, the hourly concentrations of gaseous co pollutants (CO, NO_X, O_3) as well as meteorological parameters (RH, temperature, wind speed and direction) are also available in each site. We will also conduct winter and summer intensive campaigns in these areas. The 24 hr averaged sampling campaigns are designed to give us an estimate of the spatial variability of UF PM metrics in a large metropolitan areas such as the LA Basin, and how they affect the observed particle toxicity, whereas the purpose of the intensive campaigns will be to determine the diurnal variability in chemical composition of these particles. Indoor-outdoor ratios for UF PM mass and each species will be determined for selected sites. UF PM source apportionment and linkages of sources to toxicological outcomes will be a major focus of analysis.

BENEFITS: Our research will help federal and state regulatory agencies understand the linkage between sources, composition and the toxicity of UFP, which provides a strong scientific basis to develop cost-effective strategies to protect the public from the toxic sources of UF particulate matter. The current data will help determine if there is a scientific foundation for controlling UF particulate matter from only a subset of UF particulate sources. Moreover, data on UF PM characteristics will become an invaluable resource to the ongoing and planned PM exposure and health studies in the Los Angeles Basin, including major research programs, such as the Southern California PM Center (SCPC) and MESA Air investigations.

COST: $650,000