

California Environmental Protection Agency



Air Resources Board

**PLANNED AIR POLLUTION
RESEARCH**

Fiscal Year 2007-2008

May 2007

The statements and conclusions in this paper are not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported is not to be construed as either actual or implied endorsement of such products. To obtain this document in an alternative format, please contact the Air Resources Board ADA Coordinator at (916) 322-4505, TDD (916) 324-9531, or (800) 700-8326 for TDD calls from outside the Sacramento areas. This report is available for viewing or downloading from the Air Resources Board's Internet site at <http://www.arb.ca.gov/research/apr/apr.htm>.

Acknowledgments

This report was prepared with the assistance and support of managers and staff from the Research Division, Mobile Source Control Division, Monitoring and Laboratory Division, Planning and Technical Support Division, and Stationary Source Division of the Air Resources Board. We would also like to acknowledge the members of the academic community, government agencies, private businesses, and the public who submitted research ideas.

Prepared by:

Annmarie Mora, Air Pollution Specialist
Sarah Barnett, Office Technician

Reviewed By:

Research Screening Committee

Harold Cota, Ph.D. (Chairman)

John Balmes, M.D. (abstained)

Robert Devlin, Ph.D.

Barbara Finlayson-Pitts, Ph.D.

Steven Japar, Ph.D.

Chung Liu, D.Env.

Rachel Morello-Frosch, Ph.D. (abstained)

Tracy Thatcher, Ph.D.

Forman Williams, Ph.D.

Ex Officio Member

Michael Prather, Ph.D.

Executive Research Review Committee

Catherine Witherspoon, Executive Officer

Thomas Cackette, Chief Deputy Executive Officer

Michael Scheible, Deputy Executive Officer

Lynn Terry, Deputy Executive Officer

Bart Croes, P.E., Chief, Research Division

External Reviewers and Collaborators

California Energy Commission

Coordinating Research Council

Health Effects Institute

South Coast Air Quality Management District

United States Environmental Protection Agency

TABLE OF CONTENTS

Summary	v
Introduction	vi
Research Project Descriptions	viii
Health and Welfare Effects.....	1
Exposure Assessment	15
Global Air Pollution	37
Technology Advancement and Pollution Prevention	48

Summary

This report presents the Air Resources Board's planned air pollution research for the fiscal year 2007-2008. Twenty-six projects are proposed. Twenty-one projects are recommended for funding and five are recommended if funding is available. This research portfolio is organized into four main areas of research: Health and Welfare Effects, Exposure Assessment, Global Climate Change, and Technology Advancement and Pollution Prevention. Although the plan does not have a dedicated section to address agriculture and environmental justice, aspects of these areas can be found throughout several projects in other subject areas.

This annual plan proposes research in the four areas mentioned above, with a significant effort to determine health effects of air pollution, improve emission inventory efforts, characterize and assess the behavior of pollutants in the atmosphere, and develop technologies to reduce and control greenhouse gases and determine corresponding impacts. The proposed budget for recommended projects is approximately \$5,600,000.

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, and 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 the various aspects of air pollution, including air pollution's effects on health and the environment, the atmospheric reactions and transport of pollutants, and the inventory and control of air polluting emissions. In recent years, several legislative mandates have expanded and further defined the scope of the program.

The ARB's mission to protect California's public health, welfare, and ecological resources is supported through a Strategic Plan for Research covering the years 2001-2010. The Strategic Plan is based on the ARB's regulatory priorities for the next several years and provides direction for the ARB's research program. The four main areas of research identified in the Strategic Plan are: Health and Welfare Effects, Exposure Assessment, Technology Advancement and Pollution Prevention, and Global Climate Change. They are also the categories that guide this plan. These areas encompass the comprehensive mission of ARB's air pollution research. A copy of the Plan can be downloaded at the following address <http://www.arb.ca.gov/research/apr/apr.htm>.

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 the timely scientific and technical information that will allow the Board and local districts to make the public policy decisions necessary to implement an effective air pollution control program in California.

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. In response to this year's solicitation, approximately 200 research ideas were submitted. Proposed projects were examined for relevance to regulatory questions facing the Board and modified as necessary. Committee members 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. The list of projects, along with comments from the RSC, was forwarded to the Executive Research Review Committee, whose members are the Executive Officer, her three deputies, and the Chief of the Research Division. The Executive Research Review Committee reviewed all of the proposed projects and established project priorities. Selected projects are then placed

into two categories: 1) those that are recommended for funding, and 2) those that are recommended if additional funding becomes available. 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. There is a list serve that can be subscribed to in order to receive updates on research activities. For more information about the list serve, visit www.arb.ca.gov/listserv/research/research.htm.

Research Budget. The 21 recommended projects total approximately \$5,600,000. The allocations for the proposed recommended projects among research categories are as follows:

RESEARCH CATEGORY	BUDGET
Health and Welfare Effects	\$2,265,000
Exposure Assessment	\$1,800,000
Global Climate Change	\$1,055,000
Technology Advancement and Pollution Prevention	\$ 500,000
TOTAL	\$5,620,000

Project Co-sponsorships. The Research Division is continually looking for cofunding 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 be out of the state’s fiscal reach. ARB has had past success in working with other research organizations and has been part of collaborative multimillion-dollar. Several of the projects in this plan have either confirmed or have potential cofunding dollars included in the cost category.

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.

Electronic copies of all of the Research Division’s final reports are available for downloading at the same web site.

RESEARCH PROJECT TABLE OF CONTENTS

HEALTH AND WELFARE EFFECTS – *the projects funded under this section are dedicated to the memory of Dr. William Friedman, former ARB Board Member who passed away on August 25, 2005. Dr. Friedman was a strong advocate for the ARB’s health research and guided many of the projects that have increased the Board’s understanding of how air pollution affects human health, especially children’s health.*

Health and Air Pollution – Recommended Projects

In-vehicle Air Pollution Exposure Assessment of Pregnant Women in the National Children's Study, Orange County California Vanguard Center, \$450,000 1

The objective is to collect in-vehicle air pollution data in Orange County, develop and validate models to predict in-vehicle exposure, and apply the models to estimate in-vehicle exposure of women in the Orange County California Vanguard Center.

Is Disparity in Asthma Among Californians Due to Higher Pollutant Exposures, Greater Susceptibility, or Both?, \$300,000 3

The objective is to examine associations between long-term air pollution exposures and asthma among a diverse range of Californians.

Pre- and Post-Natal Air Pollution Exposure and Early Childhood Respiratory Disease in the UCLA Environment and Pregnancy Outcomes Study Cohort, \$715,000 5

The objective is to assess the impact of both pre- and postnatal air pollution exposures on respiratory illness in an assembled cohort.

Cardiopulmonary Health Effects: Toxicity of Semi-volatile and Non-volatile Components Particulate Matter Near Sources, \$450,000 7

The objective is to determine how the toxicity of fine and ultrafine particles depend on the concentration and characteristics of semi-volatile and non-volatile fractions of particulate matter emitted from vehicles and other sources.

Effect of GSTM1 Phenotype on Ozone-induced Allergic Airway Inflammation (proposed amendment to contract 03-315), \$250,000..... 9

The objective is to investigate whether pre-exposure to allergen enhances the subsequent inflammatory response to ozone exposure and to investigate the influence of GSTM1 genotype on responses to allergen and ozone.

Anti-Wood Burning Campaigns with Concurrent Wintertime Reductions in Ambient Pollution and Childhood Respiratory Morbidity, \$100,000	11
---	----

The objective is to identify communities where increases in wood burning regulations along with public outreach efforts have been followed by a decrease in particulate pollution during the burning season and evaluate if emergency room visits and hospital admissions have experienced a concurrent decrease.

Recommended if funding available

Respiratory Health Effects Related to Ultrafine Particle Concentrations and Properties, \$50,000	13
--	----

The objective is to examine the existing ultrafine particulate matter and health data from the Southern California Children’s Health Study to assess the relationships of the properties of ultrafine particles exposure to pulmonary health measurements.

EXPOSURE ASSESSMENT

Personal and Indoor – *Recommended Project*

Activity Patterns Study for Estimating California’s Exposures to Air Pollutants, \$600,000	15
--	----

The objective is to provide an updated, representative, statewide activity pattern database that can be used in exposure models to improve estimates of Californians' exposures to air pollutants, including information on time lived in residences and distance traveled for daily trips.

Atmospheric Processes – *Recommended Projects*

Foothill Ozone Isoprene Experiment: Measurements and Modeling of Isoprene in Central California, \$200,000	17
--	----

The objective is to measure isoprene fluxes and concomitant meteorological and vegetation parameters used in biogenic volatile organic carbon emission models, at a range of spatial and temporal scales within an oak woodland site in California.

Source Apportionment of Carbonaceous Aerosols Using Integrated Multi-Variant and Source Tracer Techniques and a Unique Molecular Marker Data Set, \$400,000	19
---	----

The objective is to generate a full year of hourly organic and elemental carbon measurements and daily molecular markers measurements that can be used for complementary source apportionment and statistical analysis methods to apportion the contributions of primary and secondary sources on carbonaceous aerosol concentrations.

Emissions Inventory – Recommended Projects

On-Road Motor Vehicle Emissions Measurements Including Ammonia, Sulfur Dioxide and Nitrogen Dioxide, \$95,000. 21

To monitor carbon monoxide, hydrocarbon, carbon dioxide, and nitrogen oxide emissions from light duty vehicles in the Los Angeles basin, the Central Valley, and the San Francisco Bay Area.

Improved Geospatial Forecasting of Commercial Marine Vessels, \$40,000 23

To extend previous work to help reveal how different vessels types contribute to cargo ship emissions along major trade routes and how different growth rates among commodities shipped may affect the nation-level forecasts currently used by ARB and SECA team agencies.

Development of a California-Specific Intermodal Freight Transport Model, \$200,000. 25

To develop a single, statewide intermodal freight modeling system linked to California freight flows, vehicle activity, and state/national transportation infrastructure.

Measuring Agricultural Fumigant Pesticide Emissions through In-Field Testing, \$100,000 26

To conduct additional field research to build upon the ongoing work to estimate the emissions and potential volatile organic compound reductions from fumigant pesticides.

Multi-Media – Recommended Projects

Source Apportionment of Atmospheric Dry and Wet Deposition of Mercury and Other Toxic Metals through Linkage to Atmospheric Measurements, \$165,000 27

The objective is to provide a more comprehensive assessment of toxic metal deposition in California, supplementing existing measurements that connect to the National Mercury Deposition Network.

Recommended if funding available

Environmental Exposures in Early Childhood Education Environments, \$500,000 29

The objective is to assess environmental quality in a representative sample of child care facilities located in California's urban and agricultural communities.

Development of Improved Environmental Chamber Experiments for Evaluating Contributions of Oxidation Products Ozone Impacts of Volatile Organic Compounds, \$200,000 31

The objective is to develop and evaluate the current chemical mechanisms that are used to predict the impacts of individual Volatile

Organic Compounds on ozone formation. Specifically, chamber experiments will be designed and conducted to improve sensitivities of chamber experiments to product reactions and other aspects of the mechanisms that are important in ambient conditions.

Formal Uncertainty Analysis for Modeling of Secondary Air Pollutants, \$260,000 33

The objective is to evaluate air quality model performance against continuously measured ozone, gaseous ammonia and nitric acid, and PM nitrate.

Comparative Assessment Entrained and Directly Emitted Particulate Emissions of Agricultural Field Equipment, \$240,000 35

The objective is to develop an improved testing procedure to quantify agriculture field equipment emissions on a comparable basis.

GLOBAL CLIMATE CHANGE

Climate Change Emissions Inventory – *Recommended Projects*

Developing a California Inventory for Industrial Applications of Perfluorocarbons, Sulfur Hexafluoride, Hydrofluorocarbons, Nitrogen Trifluoride, Hydrofluoroethers, and Ozone Depleting Substances, \$200,000 37

The objective is to quantify emissions rates (during production and use), application growth rates, chemical substitution rates, banks, and end-of-life disposal emissions (if applicable) for high global warming potential greenhouse gases in each application.

Climate Change Impacts – *Recommended Projects*

A Spatial Synoptic Classification Approach to Projected Heat Vulnerability in California under Future Climate Change Scenarios, \$175,000 39

The objective is to evaluate the heat vulnerability of the California population in the future, based on the air mass types most closely associated with observed current-day heat-related mortality.

Climate Change Mitigation – *Recommended Projects*

The Climate Change Industry in California: An Economic Analysis Assessing the Current Market and Prospects for Growth in the Global Economy, \$200,000 41

The objective is to define and quantify the climate change industry, forecast future growth scenarios, and characterize California's place in this industry.

Evaluation of Efficiency Activities in the Industrial Sector Undertaken in Response to Greenhouse Gas Emission Reduction Targets, \$100,000.....	42
--	----

The objective is to identify the characteristics of successful industrial sector greenhouse gas emissions reduction and energy efficiency programs in other countries in order to provide a summary of lessons learned and make recommendations for specific industrial sector program designs in support of AB 32.

Retail Climate Change Mitigation: Life-Cycle Emission Labels and Standards, \$300,000	44
---	----

The objective is to develop a framework that allows for the estimation of the potential emissions reductions that could be attained through the funding of incentives, product endorsements, performance labels, or public sector buying programs for low life-cycle greenhouse gas emission products.

Long Range Transport – *Recommended Project*

Asian Aerosol Impacts in Urban and Interior California, \$80,000	46
--	----

The objective is to use a combination of an annualized lead emission inventory for Asia and transport analytical methodologies to assess low altitude Asian pollutant impact to major California air basins and to calibrate tropospheric mixing to low altitudes.

TECHNOLOGY ADVANCEMENT AND POLLUTION PREVENTION

Technology Advancement and Pollution Prevention – *Recommended Project*

Particulate Matter Measurement for the 21st Century: Implementing a Program to Quantify Internal Combustion Engine PM Using Real-Time Measurement Techniques, \$500,000	48
---	----

To implement a comprehensive study for addressing particulate matter measurement issues by using various real-time instruments.

TITLE: In-vehicle Air Pollution Exposure Assessment of Pregnant Women in the National Children's Study, Orange County California Vanguard Center

PROBLEM: There are no known prospective cohort studies that are examining the effects of exposure to in-vehicle air pollution during pregnancy on birth outcomes and the occurrence of childhood respiratory disease and allergy. The Southern California Association of Governments (SCAG) predicts that commuting times will double by 2020 due to population growth in the Los Angeles area (SCAG, 1997), adding urgency to research evaluating the impact of increased vehicle-related exposures on children's health. In-vehicle exposure to toxic air pollutant components may dominate total exposures during the workweek. It has been estimated that over 50 percent of black carbon (BC) and ultrafine particle (UFP) exposures for nonsmoking urbanites in Los Angeles comes from time in vehicles (Fruin, 2004; 2005). The proposed study focuses on improving the exposure assessment of in-vehicle air pollution among 1,250 pregnant women and their newborn children enrolled in the National Children's Study (NCS) cohort of the Orange County California (OCCA) Vanguard Center.

PREVIOUS WORK: The University of California, Irvine was selected as one of six Vanguard Centers for the NCS, an unprecedented national effort that will follow more than 100,000 children from before birth until age 21 to examine environmental, genetic, social and behavioral determinants of health and disease. Relevant to this effort are recent asthma panel studies in southern California by Dr. Ralph Delfino and colleagues showing associations of personal and ambient PM, including carbon fractions, with lung function and asthma symptoms (Delfino et al. 2003; 2004; 2005). Previous work by co-investigator Beate Ritz and colleagues examined adverse birth effects due to air pollution and traffic density among infants in southern California (Ritz et al. 2000, 2002, Wilhelm and Ritz 2003). Their current study (Ritz, Wilhelm and Jerret) showed 52 percent of women worked outside of the home during pregnancy, and the risk of delivering a preterm or low birth weight infant increased 50 percent among women commuting 45 minutes or more compared with 5 minutes or less. Previous ARB studies have identified important conditions that contribute to in-vehicle exposures (Fruin 2004; 2005; Sabin 2005; Westerdahl 2005). In-vehicle UFP concentrations on freeways in Los Angeles were well predicted by annual average Caltrans truck counts ($R^2 = 0.84$, Fruin, 2005). Other important factors include particular road and direction, hour of day, vehicle followed, speed, and overall congestion. However, these studies were conducted mostly on freeways, in Los Angeles area, and for a single season. None of the studies were directly linked to any health outcome research.

OBJECTIVE: The goal of this project is to collect in-vehicle air pollution data in Orange County, develop and validate models to predict in-vehicle exposure, and apply the models to estimate in-vehicle exposure of 1,250 enrolled women in the OCCA Vanguard Center of the NCS.

DESCRIPTION: A mobile monitoring platform loaded with instruments will be driven on Orange County freeways, as well as major surface streets in and around 20 targeted OCCA NCS neighborhoods. In-cabin measurements will be conducted for pollutants

that have the potential to induce oxidative stress and adverse impacts on pregnancy and fetal development, such as UFP, polycyclic aromatic hydrocarbons (PAH), BC, NO, NO₂, CO, PM_{0.2}, PM_{0.2-2.5}, and PM_{2.5-10} mass, and other particle characteristics relevant to health effects (e.g., TSI EAD 3070A). Measurements will be conducted across the year to account for possible seasonal differences in exposure due to temperature, RH, and air stagnation. The measured data will be combined with roadway characteristics, e.g., proportion of gas versus diesel vehicles, traffic load by time of day, traffic congestion, and stop-and-go traffic patterns on surface streets, etc. Data from other regions (e.g., Los Angeles) will be incorporated if possible in case subjects commute outside of Orange County (Fruin 2004; 2005; Westerdahl 2005).

Prediction models will be developed from known driving conditions, season, time of day, roadway characteristics, and locations using the in-vehicle measurement data. It is anticipated that results from exposure prediction models may be similar for NO, ultrafine particles and polycyclic aromatic hydrocarbons since these were strongly correlated in the recent Los Angeles on-road study (R^2 , 0.69-0.76) (Westerdahl 2005). The models will be translated into the questionnaire items needed to capture the predictive conditions, travel durations and times of day, and locations of in-vehicle exposures. The model will incorporate the Orange County geographic information system spatial-temporal grid of on-highway exposures using methods similar to the time-activity-based exposure model developed by Gulliver and Briggs (2005). Estimated exposure will be weighted based on type and age of car and modes of transportation based on other studies conducted in southern California (Sabin 2005; Y Zhu, personal communication). The prediction model will be tested in a representative subjects who will complete an NCS questionnaire on in-vehicle exposure and will wear global positioning system devices planned for NCS women during a selected period of the first trimester and second or third trimester. Test subjects will be followed on representative days with the chosen air pollutant measurements used for the final prediction models. Refinements may be needed for questionnaires, including different transformations of questionnaire data. The predicted in-vehicle air pollutant exposures will be combined with predicted exposure at home and work derived from our complementary concept proposal submitted with this proposal that will predict air pollutant exposures at home and at work during pregnancy using land use regression, and related modeling techniques based on traffic data, microenvironmental, neighborhood, and ambient monitoring data.

BENEFITS: This research augments in-cabin measurement data for the NCS, presenting a unique opportunity to examine whether exposure to in-vehicle air pollution adversely affects birth outcomes and promotes the occurrence of atopic sensitization and childhood respiratory diseases, including asthma. The results will allow quantitative estimates of in-vehicle exposure of various pollutants given known driving conditions and other parameters. It will guide other epidemiological studies focused on commuters' health outcomes, and help inform policy decision makers concerning motor vehicle emissions control.

COST: \$450,000

TITLE: Is Disparity in Asthma Among Californians Due to Higher Pollutant Exposures, Greater Susceptibility, or Both?

PROBLEM: According to the 2003 California Health Interview Survey (CHIS 2003), 4.5 million Californians suffer from asthma and an additional 3.4 million Californians suffer from asthma-like breathing problems. The elderly, children, racial/ethnic minorities, women, and low-income Californians suffer disproportionately from asthma or asthma-like symptoms. There is no routine asthma registry in California. Questions remain whether the disproportionate health burden among these subpopulations is related to higher air pollution exposures, or greater susceptibility due to other risk factors, such as poor access to care and health behaviors, or both.

PREVIOUS WORK: Gunier et al. (2003) previously reported that Californians in the lowest quartile of median family income were three times more likely to live in high-traffic areas than those in the highest income quartile. Children of color were also about three times more likely to live in higher traffic areas than white children. In previous CDC-funded studies linking 2001 CHIS and ambient air monitoring and traffic data in Los Angeles and San Diego Counties, it was found that individuals living near heavy traffic or in areas with high ozone and PM10 levels were more likely to report chronic severe asthma (daily/weekly symptoms) or acute asthma exacerbations (emergency department visits or hospitalization due to asthma). Children, the elderly, and low income subjects were also more likely to have severe asthma. However, the sample size and data items were too limited in 2001 to perform meaningful sub-population analyses, e.g. impacts of race/ethnicity and related vulnerability factors on the pollutant-asthma outcome associations. CHIS 2003 and subsequent surveys provide better information on residential location, school location for children, housing conditions, indoor exposures, health behaviors, and asthma outcome measures.

OBJECTIVE: The goal of the project is to use CHIS 2003 data to identify: 1) which subpopulations among those with asthma or asthma-like-symptoms are more exposed and/or more susceptible to air pollution; and 2) what are the characteristics contributing to increased susceptibility, e.g. differences in underlying health status, access to medical care, and exposure to indoor triggers. Based on CHIS 2003, 7,509 respondents reported an asthma diagnosis and an additional 5,522 respondents reported asthma-like symptoms.

DESCRIPTION: CHIS 2003 data will be linked with measurement data for criteria air pollutants (O₃, PM10, PM2.5, and NO₂) from the California Statewide Air Monitoring Network, and with residential and school-based traffic density (TD) values based on daily traffic counts from Caltrans. CHIS, a geographically-stratified random-digit-dial telephone survey, has been conducted biannually since 2001. CHIS 2003 collected information on approximately 54,500 non-institutionalized Californians, including 12,500 children using five languages. About 15 percent of children and 12 percent of adults reported an asthma diagnosis. An additional 10 percent of Californians reported suffering from asthma-like breathing problems without having received an asthma diagnosis. Residential address information was collected from more than 90 percent of

households since CHIS 2003. Contractors will restrict the study population to respondents who lived in the same house or neighborhood for a certain length of time (e.g., 2 years), to ensure pollutant measures are accurate proxies for long-term exposures. The major tasks of the proposed study are as follows:

1. Characterizing air pollution exposures by: (1) linking geocoded subject residence locations to appropriate air monitoring stations and calculating annual average air pollutant concentrations for the year prior to the interview date; and (2) calculating traffic density values for each CHIS 2003 respondent based on their home addresses;
2. Identifying sub-populations that are highly exposed to a single pollutant or pollutant mixes, and quantify the degree to which their health is compromised due to outdoor air pollution. Specifically, for those with diagnosed asthma, the contractor will examine associations between estimated exposures and the following asthma outcomes: prevalence of chronic severe asthma (daily/weekly symptoms), asthma attacks or episodes, use of daily medication to control asthma, school or work absences, asthma emergency room visits, and the number of doctor visits for asthma in the previous 12 months. Among those with asthma-like breathing problems, associations with frequency of asthma-like symptoms, number of times medical care was sought for breathing problems, and work/school days missed for breathing problems in the previous 12 months will be examined.
3. Identifying factors that contribute to or modify the susceptibility to air pollution among sub-populations. The factors to be examined include: socioeconomic status (e.g., educational attainment, poverty, and employment status); access to care (health insurance status, received asthma management plan); health behaviors (overweight/obesity, smoking, walking for transportation or leisure, physical activity); exposure to indoor triggers (environmental tobacco smoking and indoor allergens, e.g., cockroaches, dogs and cats); housing conditions (e.g., type of house or household crowding); and neighborhood factors (neighborhood safety or, rural/urban neighborhoods).

BENEFITS: CHIS data provide a unique opportunity to examine associations between long-term air pollution exposures and asthma among a diverse range of Californians. The proposed research will provide crucial information on whether current federal or state air quality standards sufficiently protect vulnerable subpopulations. The project directly addresses a major goal of the ARB Environmental Justice Policy to support “research to better characterize the variety of air pollution exposures in communities and to better assess health impacts, especially non-cancer effects, cumulative effects, and effects from long-term low-level exposures.” This project could also lay groundwork for future studies of the effect of air pollution on other diseases in vulnerable populations, such as diabetes and heart disease.

COST: \$300,000

TITLE: Pre- and Postnatal Air Pollution Exposure and Early Childhood Respiratory Disease in the UCLA Environment and Pregnancy Outcomes Study Cohort

PROBLEM: A growing body of evidence suggests development and overall growth of the lung can be affected by exposure to chemicals and particles. In a recent review, Pikerton and Joad (2006) emphasized lung development is a multi-event process that is not restricted to prenatal life and the importance of examining exposures during critical development windows. Evidence is also accumulating that prenatal air pollution exposure leads to preterm and low weight birth suggesting an indirect route by which air pollution may be linked to adverse respiratory outcomes. However, few studies to date have examined the single or combined effects of outdoor air pollution exposures during pregnancy and early childhood on the occurrence of respiratory diseases during the first years of life.

PREVIOUS WORK: In 2003, data was collect for 2,543 infants born in Los Angeles County, California and assessed the influence of air pollution exposures on preterm and low weight birth. This National Institute of Environmental Health Sciences funded study – known as the Environment and Pregnancy Outcomes Survey (EPOS) – is one of only two U.S. studies to assemble a birth cohort to assess air pollution effects on pregnancy outcomes. The survey included data collection for a wide range of potentially important risk factors for perinatal health including family income, prenatal care, prenatal tobacco and alcohol consumption, exposure to indoor air pollution and allergen sources during pregnancy, and breastfeeding practices. There is now the unique opportunity to follow for six years this established birth cohort of 2,470 children (those who agreed to be re-contacted) to examine whether exposure to outdoor air pollution from conception to Kindergarten influences the occurrence of childhood respiratory and asthmatic diseases. The babies enrolled in the cohort are an especially vulnerable population since by design half of them were preterm and/or low weight births and many of them are living in disadvantaged neighborhoods in Los Angeles County.

OBJECTIVE: The goals of this project are to re-contact the women who participated in EPOS to collect data that will allow examination whether: (1) exposure to outdoor air pollution during pregnancy and/or in early childhood alone or in combination contribute to early childhood infections, respiratory diseases, and asthmatic symptoms; (2) effects are stable when adjusting for individual and neighborhood risk factor (confounder) information obtained in surveys and from other data sources; (3) exposures to additional indoor, in-vehicle, or occupational air pollution sources during pregnancy and early childhood confound and/or modify the effect observed for outdoor pollutants; (4) pollutant effects vary between population subgroups (girls vs. boys, children born and living in various neighborhoods, with a specific nutritional status [obesity], born preterm/low weight, atopic versus non-atopic children, etc.), due to increased or decreased susceptibility or additional exposures. Furthermore, in a nested case-control approach home visits will be conducted for children reporting asthmatic symptoms or allergies during follow-up and unaffected matched controls to perform skin prick testing

for common allergens to assess atopy and to assess lung function through testing using portable spirometers.

DESCRIPTION: The first step will be to actively follow 2,470 children included in the first birth cohort survey with two additional telephone surveys conducted at approximately 3.5 and 5.5 years of age to gather information on residential history, daycare attendance, exposure to indoor air pollution sources, commuting habits, and other individual- and neighborhood-level risk factors for respiratory diseases including asthmatic symptoms (the 3.5 year age interviews as discussed below are currently being conducted). The incidence and prevalence of respiratory diseases and allergic and asthmatic symptoms will be assessed at each survey using a modified version of the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire (applicable to this very young age group). Home visits will be conducted to perform lung function testing using portable spirometers and skin prick tests in a nested group of children who screen positive in the interviews for asthmatic symptoms and atopy and a group of unaffected matched controls selected from the cohort (approximately 700 children total). Maternal and childhood air pollution exposures will be derived using air pollution concentration data from existing ambient monitors, traffic density metrics and pollution surfaces estimated through land use regression (LUR) and geostatistical modeling. Exposure estimates will take into consideration the residential, daycare and school mobility patterns of mothers and children based on our survey data. These methods have been successfully employed in our previous and current studies. We will determine the influence of individual level risk factors (individual level data collected in our repeated surveys) and use multi-level models to evaluate neighborhood and health care related factors (neighborhood or community level factors) for the diseases studied, including the potential of certain risk factors – individual or neighborhood level – to modify effects of air pollutants.

BENEFITS: There is a unique opportunity to assess the impact of both pre- and postnatal air pollution exposures on respiratory illnesses in an assembled cohort, which has only been done in four other studies, only one of which has been in the U.S. Los Angeles' diversity of population characteristics and the availability of an extensive air monitoring network in combination with current LUR modeling work in this region creates an ideal situation for studying the effects of air pollution on respiratory health in early childhood. Although increases in respiratory diseases due to outdoor air pollution may be small in a relative sense, the potential for disease prevention may be enormous since millions of mothers and young children are and in the future will be exposed to similar (or greater) air pollution concentrations worldwide. Improving child health early in life is an important public health goal. The results of this research will provide information for future air quality standard setting in California and the United States.

COST: \$715,000

TITLE: Cardiopulmonary Health Effects: Toxicity of Semi-volatile and Non-Volatile Components Particulate Matter Near Sources

PROBLEM: Epidemiological and *in vivo* exposure studies demonstrate that particles (fine and ultrafine) in close proximity to mobile source emissions are more toxic than particles in the air more distant from the source. The reason for this change in toxicity is not known. Coincident with the reduction of toxicity with distance, the size and composition of the ultrafine particles undergo rapid changes. However if these changes are responsible for the changes in toxicity of the particles, the phenomenon cannot be effectively tested using collected samples because of the apparently short-lived duration of causal agents involved. The problem can however be addressed with *in vivo* inhalation studies.

PREVIOUS WORK: Studies of mice exposed to fine and ultrafine particulate matter (PM) 50 meters from a freeway showed that these exposures had significant biological activity which was associated with elemental and organic carbon fractions of the aerosol. When exposures were performed 150 meters downwind of the freeway the biological activity was greatly diminished and there were no measurable exposure-related effects (Kleinman et al., 2006). Careful measurements in a roadway tunnel (Phuleria et al. 2006) and near a major freeway with heavy-duty diesel traffic (Kuhn et al., 2005; Biswas et al., 2006) have demonstrated that there are rapid shifts in aerosol size and composition within minutes of emission and that the volatility of the PM increases with decreasing particle size. Sioutas and colleagues have developed the capacity to couple a thermal denuder to a Versatile Aerosol Concentration Enrichment System (VACES). The thermal denuder heats the aerosol to a specified temperature to evaporate and remove semi-volatile components, and then returns the aerosol to the original temperature. The VACES can increase the concentration of the processed aerosol by factors of 20 to 30 to provide adequate concentrations for performing acute *in vivo* toxicology exposure studies.

OBJECTIVE: The goal of the project is to determine how the toxicity of fine and ultrafine particles depends on the concentration and characteristics of semi-volatile and non-volatile fractions of PM emitted from vehicles and other sources. The proposed hypothesis is that the toxicity of near-source PM is due to nanoparticles that are composed largely of semi-volatile components and that biological activity will be attenuated by removal of those components from the aerosol. Use of *in-vivo* rodent exposure system will be used in combination with the VACES thermal denuder technology to separately study the cardiopulmonary effects of PM, before and after the removal of the semi-volatile components. The PM will be studied at sites scheduled for detailed chemical and physical characterization examination of PM emitted by specific sources as part of the Southern California Particle Center (SCPC) research program. The sites will be in proximity to the Los Angeles-Long Beach Harbor and at a dynamometer facility where emissions from vehicles with and without exhaust mediation (catalysts, filter traps etc.) are being tested.

DESCRIPTION: Acute and chronic cardiopulmonary inflammation and injury will be examined using rats implanted with ECG and blood pressure telemetry devices to test the hypothesis that exposure to ultrafine particles composed of semi-volatile compounds causes inflammation and oxidative stress resulting in pulmonary and cardiovascular injury. The study will address the question of whether adverse effects associated with exposures in close proximity to sources of mobile source emissions are due to specific classes of reactive organic compounds such as aldehydes or other oxygenated hydrocarbons. Endpoints will include markers of inflammation, histological examinations for evidence of pathology, heart muscle cell hypertrophy and cardiopulmonary function measurements. The *in vivo* biological responses will be correlated with physical and chemical composition of the particles and the *in vitro* potential of these particles to produce free radicals and induce cytotoxicity, which will be measured by the SCPC. These experiments will be conducted over a period of three years.

BENEFITS: This project could provide improved understanding of the mechanism of toxic action of freshly-emitted combustion aerosols and identify fractions of the aerosol causally related to health effects. This information will also aid regulators and planners in developing air quality regulations and land use guidance to better protect the health of California residents.

COST: \$450,000

TITLE: Effect of GSTM1 Phenotype on Ozone-induced Allergic Airway Inflammation (proposed amendment to contract 03-315)

PROBLEM: Controlled human exposure studies that have investigated the effect of ozone exposure on asthmatics have not consistently found ozone-induced enhancement of responses to a subsequent allergen challenge. In contrast, ambient ozone has been associated with asthma exacerbation in several epidemiologic studies. This raises several questions, including (1) whether there is more than one subpopulation of asthmatics, each with a different degree of vulnerability that is genetically determined, or (2) whether the timing of O₃ challenge relative to allergen challenge is a significant factor in explaining the discrepancies in the literature.

PREVIOUS WORK: Ozone exposure is known to induce oxidative stress in the lungs, which leads to airways inflammation. There is also evidence, at least in some asthmatics, that ozone enhances allergen-induced airway inflammation. The GSTM1 gene regulates a key antioxidant enzyme involved in protection from and repair of damage from oxidative stress reactions in the lungs. Several studies also suggest that a common genetic variant in GSTM1 (null type) results in the absence of a key antioxidant enzyme that appears to play a key role in the toxicity of inhaled ozone, and may be a basis for differences between individuals in susceptibility to adverse effects from ozone inhalation. In addition, most studies investigating possible interactions of ozone and allergen have presented the allergen challenge after ozone exposure, while the opposite pattern, with the allergen challenge prior to ozone exposure, is more representative of the real world, and has only been investigated in one paper.

Contract 03-315 with the University of California, San Francisco (UCSF), was approved in September 2004. The project, as approved, was designed to investigate three objectives: (1) whether ozone exposure enhances specific lower airway inflammatory responses of asthmatic subjects during late-phase reactions to inhaled allergen, (2) to determine whether the GSTM1 null genotype is an important predictor of susceptibility of asthmatic subjects to develop enhanced late-phase reactions to allergen challenge presented after ozone exposure, and (3) to determine whether pre-exposure to allergen enhances the subsequent inflammatory responses to ozone exposure.

The UCSF human subjects committee will not approve the protocol as funded, based on their belief that the study involves too many bronchoscopies per subject. Staff proposes to address this issue by splitting the funded project into two independent experiments, each with a different group of subjects, and augmenting the original contract so as to maintain the original intent of the project.

Experiment one would address objectives one and two of the currently funded project, and would consist of two experiments: (1) filtered air – allergen, and (2) ozone – allergen. There would be a total of 30 mild to moderate asthmatic subjects, 15 who are GSTM1 positive, and 15 who are GSTM1 null, as outlined in the funded project.

Objective three would be moved to experiment two, which would have a different group of subjects. This research idea would provide the funding augmentation required to complete the proposed experiment two, which is described below in more detail.

OBJECTIVES: The goals of the project are to investigate whether pre-exposure to allergen enhances the subsequent inflammatory response to ozone exposure and to investigate the influence of GSTM1 genotype on responses to allergen and ozone.

DESCRIPTION: Fifteen subjects with mild to moderate asthma who are specifically sensitized to house dust mite will participate in two exposures, one to filtered air (FA), and one to 0.16 ppm ozone. Local endobronchial allergen challenge will occur the day before both exposures, with the sampling bronchoscopy following the O₃ exposure. The exposures will be four hours in duration, and will involve intermittent exercise. Various cellular and biochemical indices of airway inflammation will be assayed in bronchoscopically obtained samples. Subjects will also be genotyped for GSTM1 and several other genes that may be related to susceptibility to adverse effects of O₃ exposure (GSTT1, GSTP1, NQO1, SOD2, GPX1, and catalase). The distribution of variants of these genes, except for GSTM1, in the population is unknown, and consequently these will be exploratory analyses. However, the results from these exploratory analyses will help guide development of future investigations into the biological foundations of susceptibility to O₃ exposure.

BENEFITS: Greater understanding of how ozone might be causing exacerbations of asthma will accrue from this study. In addition, the study will investigate the responses of a vulnerable population using a relevant outcome (allergic airway inflammation).

COST: \$250,000

TITLE: Anti-Wood Burning Campaigns with Concurrent Wintertime Reductions in Ambient Pollution and Childhood Respiratory Morbidity

PROBLEM: Concern over the health effects from residential wood burning has risen over the past decade. In some California communities, wood smoke from home heating can comprise over one third of ambient particulate pollution during the wintertime. Wood smoke is comprised of several pollutants, including: CO, NO₂, PM10 and PM2.5, and subsequent polycyclic aromatic hydrocarbons (PAHs). Residential wood burning affects ambient and indoor air quality throughout the neighborhood. Other factors contributing to wintertime pollutants include fuel-burning heat sources and cooking smoke. An inversion layer often forms in cooler, dryer weather and prevents pollutants from dispersing. Infants and children are particularly susceptible to the effects of these wintertime pollutants. Their respiratory and immune systems are immature, and mobile infants and young children spend time on the floor where particles and PAHs bind to dust. Enormous costs are associated with the care and treatment of these infants, and long-term effects from early life exposures are unknown. Respiratory-related symptoms and disease are the most common reasons for hospitalization of children in California. Concern over air quality has prompted several communities to regulate and/or ban residential burning when air quality forecasts are poor. Implementation of these regulations has been coupled with public education and there are indications that some of these campaigns have been successful in improving air quality.

PREVIOUS WORK: Previous work has shown that wood smoke is positively associated with adverse health effects such as asthma, and respiratory-related emergency room and hospital visits. Pino et al. has linked PM2.5 with wheezing in infants. However, potential changes in air quality and health responses to community/district actions against residential wood burning have not been addressed.

OBJECTIVE: The goals of the project are to (1) identify communities within the Bay Area Air Quality Management District and the San Joaquin Air Pollution Control District where increases in wood burning regulations along with public outreach efforts have been followed by a decrease in particulate pollution during the burning season, and (2) evaluate if postneonatal emergency room visits and hospital admissions due to respiratory causes have experienced a concurrent decrease in these specific communities.

DESCRIPTION: This study is comprised of two phases. The first phase includes identifying communities within the Bay Area AQMD and the San Joaquin APCD that have implemented wood burning regulations and public education/outreach campaigns over the past decade. Programs will be evaluated on the 1) intensity of their outreach, 2) if they have instituted recommendations, regulations, and/or bans of residential burning, and 3) if they offer rebates for change-outs. Intensity of outreach is defined by the use of billboards, radio, television, and newspaper advertising, and information booths at public events. After identifying these communities, there will be a determination of whether ambient monthly average and maximum concentrations of CO, NO_x, PM10 and PM2.5, and subsequent PAHs decreased significantly during the

burning season following implementation of public education and regulations, compared to the burning season in the prior year. These potential differences will be adjusted for change in climate, etc. A pre- and post-intervention analysis will be performed, with each community serving as its own control. If these communities are not experiencing similar decreases in pollutant concentrations, it will provide further evidence that decreases identified are attributable to interventions. In this study, the wood-burning season is defined from November 1 through March 31 of each year, although this differs slightly among AQMDs. Following identification of communities with a reduction in pollution during burning season, we will begin the second phase of the study by examining the rates of respiratory related hospitalizations among infants and children aged 28 days through under 18 years. Statewide, there are over 100,000 of these respiratory related admissions among children per year. Eligible major diagnostic categories include: respiratory infections and inflammations, simple pneumonia and pleurisy, bronchitis and asthma, respiratory signs and symptoms, and other respiratory system diagnoses, except influenza. Outcome data will be obtained from the Office of Statewide Health Planning and Development (OSHPD). There will be a determination if there were significant decreases in the rates of these outcomes that were concurrent with decreases in pollution. Some individual level covariates are available through admission records, while zip code level variables are available from U.S. Census data. We will examine communities with large populations in isolation, while we may lump together smaller communities.

BENEFITS: This study will help determine if current wood burning regulations and outreach efforts are effective in reducing wintertime pollution and postneonatal respiratory morbidity in California. Evidence will be generated that can be used to evaluate which methods are most effective.

COST: \$100,000

TITLE: Respiratory Health Effects Related to Ultrafine Particle Concentrations and Properties

PROBLEM: Health effects are now well documented for particulate matter pollution. The ultrafine fraction of the PM, which is largely dominated by combustion sources, appears to be of particular importance in the cause of health effects. This is often inferred to be a factor of exposure to traffic related pollution. In many studies the traffic density is used as a surrogate for pollutant exposures. There remains a question as to what property of ultrafine PM is most responsible for the respiratory health effects associated with the ultrafine PM (number count concentration, surface area, mass concentration, count median size, etc.) This project will use the health and ultrafine particle datasets generated by the Southern California Children's Health Study (CHS) to assess these relationships.

PREVIOUS WORK: A number of studies have looked at ultrafine PM counts and health, but most commonly these studies use a single central site monitor as an indicator of exposures. Transect studies have shown that ultrafine PM is very sensitive to the proximity to the source; the particle counts have been shown to drop off exponentially downwind from a highway and by approximately 300 meters from the highway the count has returned to approximately the level seen upwind of the highway. The CHS datasets include health and ultrafine PM exposure data from 12 communities in southern California reflecting a variety of community exposure and health profiles. Although a number of analyses have been conducted relating the pollutant concentrations and respiratory development of children, the ultrafine PM data collected in the CHS has not been analyzed to date; this remains a missing piece of the health and exposure puzzle.

Preliminary examination of the CHS data from publicly available data sources indicates the relationship between accumulation mode size particles and the FEV1 measure of lung health is stronger than other sizes or the total ultrafine counts. Other properties have not yet been examined, but *in vitro* and rodent studies have implied that the particle source, size, and surface area may have significant effects in addition to the total count concentration.

OBJECTIVE: The goal of the project is to examine the existing ultrafine PM and health data from the Southern California Children's Health Study to assess the relationships of the properties of ultrafine particles exposure to pulmonary health measurements (asthma, FEV1, FEF, etc.).

DESCRIPTION: The project will analyze lung function data available from the CHS health dataset and ultrafine particle data available from the CHS ambient exposure dataset and from the ARB's SMPS project conducted by the University of Southern California. The ultrafine PM data used will include hourly data so factors in addition to the annual average can be calculated and analyzed. The ultrafine particle number, surface area, mass, size (several size bins: e.g. <50 nm, 50-100 nm, >100 nm), and count median size using daily, monthly, seasonal, annual averages, seasonal variation, diurnal variation, and average highest hour will be used to the extent possible. The

analyses will analyze within and between community variation of exposure and health effects.

If enough subjects are available for statistical validity, subjects will be restricted to areas near monitors to get maximum similarity of subjects and exposures. Or subjects will be restricted to similar areas (near freeways or other roads, etc.) if possible. These subject restrictions will attempt to adjust for the usual problems of ultrafine PM spatial variability.

BENEFITS: The results from this work will improve our understanding of the respiratory health effects of ultrafine PM.

COST: \$50,000

TITLE: Activity Patterns Study for Estimating California's Exposures to Air Pollutants

PROBLEM: The data used to understand the activity patterns of Californians, and their potential exposure to air pollution, are nearly 20 years old. For accurate exposure assessment, current data are needed that reflect the ways in which people now carry out the activities of their lives. For example, a wide range of electronic products (personal computers, printers, cell phones) are now commonly in use that either were unavailable or rarely used by most people 20 years ago, potentially resulting in increased exposure to ozone, PBDEs, fine particles, and other pollutants. Also, previous studies did not obtain data on the time (years) Californians live at their different residences over their lifetime, and on the distances traveled on their daily trips for commuting, errands, and so on. This has been a significant data gap in recent population exposure assessments.

PREVIOUS WORK: In 1986 and 1987, the Survey Research Center (SRC) of the University of California, Berkeley conducted two projects for ARB to study the activity patterns of California adults and children. These studies provided extensive information about potential exposure of Californians to emissions from indoor and outdoor air pollutants. The data were collected by telephone interview and contained minute-by-minute detail of the activities and the locations of the respondents over a 24-hour period. These projects provided a representative database that was subsequently incorporated into an ARB exposure model, the California Population Indoor Exposure Model (CPIEM). The data have been used in other ARB exposure projects, especially for the Toxic Air Contaminants Program, and also by the Office of Environmental Health Hazard Assessment to develop their stochastic exposure guidelines. These projects also served as the research models for a subsequent national study, the National Human Activity Pattern Survey (NHAPS) sponsored by the U.S. Environmental Protection Agency (EPA) that was conducted between 1992 and 1994. This national project provided comprehensive exposure information over broad geographical and temporal scales, particularly for use in probabilistic population exposure models.

OBJECTIVE: The primary goal of the project is to provide an updated, representative, statewide activity pattern database that can be used in exposure models to improve estimates of Californians' exposures to air pollutants, including additional information on time lived in residences and distance traveled in daily trips. A secondary objective is to accomplish this at a proportionately lower equivalent cost and more rapid timeframe than previous studies.

DESCRIPTION: The core of the 1986-87 activity pattern studies will be replicated by conducting a statewide representative sample telephone survey of both adults and children, but to enhance that work by including questions on residence time and distances traveled and incorporating various improvements in the methodology. In order to enhance the ability to identify precise locations where activities take place, the survey will ask questions about the zip code, the address and/or other location identifiers for each travel endpoint reported. The interviews will be conducted using a Computer-

Assisted Telephone Interviewing (CATI) survey instrument to collect 24-hour retrospective diaries of the activity patterns of household members, along with answers to a number of exposure-related questions for each respondent. The resulting diary records will contain beginning and ending times for each distinct combination of location and activity occurring during the diary day. Additionally, the ancillary questions will obtain current information on people's use of and proximity to selected sources of indoor and outdoor pollutants.

BENEFITS: A key benefit of this new project is that it will provide current activity pattern data to update and enhance ARB's exposure models and estimates. The data are now nearly 20 years old and there have been a number of major changes in American society that need to be better reflected in the exposure models used by ARB and other agencies. In addition, children's activity patterns may have changed during this time. Reduced levels of outdoor activity by some children may have contributed to the national problem of childhood obesity; while at the same time, some children have grown increasingly active in sports and other physical activities. This study will provide valuable information about the current state of their activity patterns and their current potential exposure to air pollutants.

COST: \$600,000

TITLE: Foothill Ozone Isoprene Experiment (FOZIE): Measurements and Modeling of Isoprene in Central California

PROBLEM: Photochemical models are essential tools used to develop State Implementation Plans (SIPs) for ozone and particulate matter. Models are sensitive to spatial and temporal distribution and source strengths of VOCs, NO_x, meteorological fields, sinks, and chemical reactions. Isoprene is the most abundant biogenic VOC (BVOC) emitted in North America (Guenther et al., 2000), and is several times more reactive than vehicle exhaust (Carter, 1994). BVOCs comprise significant fractions of emission inventories within California. The role of isoprene chemistry in tropospheric ozone production is well understood, but the magnitude and spatial and temporal distribution of isoprene emissions in California remain uncertain. Current BVOC emissions models such as U.S. EPA's Biogenic Emission Inventory System (BEIS), National Center for Atmospheric Research (NCAR) Model of Emissions of Gases and Aerosols from Nature, and ARB's Biogenic Emission Inventory Geographical Information System predict significant emissions of isoprene from oak woodlands distributed throughout the foothills and the Sierra-Nevada mountains of California. However, there have been no measurements of isoprene flux in these oak woodlands at a spatial scale larger than leaves and branches. Measurements at Blodgett Forest, approximately 30 km upwind of major sources of BVOCs show that isoprene and its oxidation products are dominant contributors to VOC reactivity in this region (Lamanna and Goldstein, 1999). Three-dimensional photochemical transport modeling suggests that large isoprene emissions may contribute to the ozone burden in adjacent urban areas of central and southern California, and this is supported by analyses of ozone contributions from isoprene oxidation based on measurements of isoprene oxidation products (Dreyfus et al., 2002). A coordinated set of isoprene flux measurements at leaf, canopy, landscape, and regional scales is needed to evaluate methods used to extrapolate leaf- and branch-level emission measurements to regional model scales, and to evaluate BVOC emission model performance. Such measurements would reduce uncertainty in BVOC emission inventories from oak woodland ecosystems that are likely the dominant isoprene contributors in California.

PREVIOUS WORK: Research supported by ARB's Biogenic Working Group (<http://www.arb.ca.gov/research/ecosys/biogenic/biogenic.htm>) generated essential databases and tools used in the development of ARB's BVOC emissions model BEGIS (Scott and Benjamin, 2003). Measured BVOC concentrations in ambient air and emission measurements taken from leaf to canopy scales have shown that BVOCs are emitted throughout California (Arey, et al., 1991, 1995; Baker et al., 1999; Corchnoy, et al., 1992; Harley, et al., 1998; Helmig and Arey, 1992; Karlik and Winer, 2001; Klouda et al., 2002; Kurpius and Goldstein, 2003; Goldstein and Schade, 2000; Schade et al., 1999, 2000; Schade and Goldstein, 2001; Winer et al., 1992). Satellite observations suggest areas of very high isoprene emissions in areas of California (Palmer, et al., 2003) which are home to native oak species with high isoprene emission potential (Karlik and Winer, 2001; Geron et al., 2001). Detailed isoprene flux measurements at scales ranging from leaf to region have been reported for emission model development elsewhere in the U.S., but none in California.

OBJECTIVE: The goal of this project is to measure isoprene fluxes and concomitant meteorological parameters (e.g., temperature, sunlight, sensible and latent heat flux) and vegetation parameters (e.g., species canopy cover, leaf biomass density, leaf density, leaf area index) used in BVOC emission models, at a range of spatial and temporal scales within an oak woodland site in California. Scales would include leaf (and/or branch) enclosure, canopy (micrometeorology tower), and regional (aircraft). The measurements will be used to provide a critical comparison of how well BVOC emission and 3-D photochemical models predict observed emissions rates and atmospheric isoprene mixing ratios.

DESCRIPTION: An oak woodland site will be selected that is representative of oak density in the foothills of the central Valley of California and is well suited to eddy covariance flux measurements from a tower. Quantitative descriptions of biomass, leaf mass, and leaf area index (LAI) for isoprene-emitting plant species at the site will be assessed through ground-based surveys and will be compared to regional estimates based on remote sensing. Canopy-scale fluxes of isoprene will be measured continuously for one year using an instrumented tower that will extend to above the height of the plant canopy. Aircraft-based measurements will be used to extrapolate the tower-based measurements of isoprene flux to a regional scale. The data collected from these measurements will be used to evaluate the performance of the California BVOC model Biogenic Emission Inventory Geographic Information System for isoprene. In addition, the measurements will be used to evaluate the combined performance of the emissions, chemical, and dynamical components of regional air quality models for predicting isoprene concentrations.

BENEFITS: Measurements at the range of proposed scales will provide bounds on regional isoprene emission and photochemistry air quality models. These measurements will also provide a test of approaches and factors used for scaling various types of plant emission measurements to regional models. The measurements will specifically address the magnitude and spatial variability of isoprene from California oak woodlands.

COSTS: \$200,000 (Additional funds to be requested from the South Coast Air Quality Management District and the San Joaquin Valley Air Pollution Control District for a total project budget of \$500,000.)

TITLE: Source Apportionment of Carbonaceous Aerosols Using Integrated Multi-Variant and Source Tracer Techniques and a Unique Molecular Marker Data Set

PROBLEM: Organic carbon and elemental carbon are important contributors to fine particle concentrations throughout the State of California. This carbonaceous material is important to human health, visibility and regional climate forcing. Although significant advances have been made in mechanistic and receptor based source apportionment models, there still exists significant uncertainty in the contributions primary and secondary sources make to carbonaceous particulate matter (PM) in non-attainment areas of California. There is a great need to apply tools that can provide a more definitive understanding of the impact of gasoline powered vehicles, diesel engines, biogenic derived secondary organic aerosol and anthropogenic derived secondary organic aerosol in California to develop effective PM control strategies and to support health and climate forcing studies.

PREVIOUS WORK: The Midwest St. Louis Supersite, funded by U.S. EPA, generated a time series of carbonaceous aerosol measurements that includes hourly fine particle organic carbon and elemental carbon concentrations, daily fine particle organic speciation measurements for a full two years. In addition, these measurements have been supplemented by monthly average molecular markers for both primary and secondary sources at five cities in the Midwestern United States. The unique data set, that has been made possible by analytical and instrumental advances for carbonaceous aerosol measurements, have led to significant advances in the application of receptor based source apportionment models and statistical methods to understand sources of organic carbon, elemental carbon and fine PM. Parallel measurements and subsequent receptor modeling efforts have yet to be employed in California.

OBJECTIVES: The goal of the project is to generate a full year of hourly organic and elemental carbon measurements and daily molecular markers measurements at a central site in the Los Angeles basin that can be used for complementary source apportionment and statistical analysis methods to apportion the contributions of primary and secondary sources on carbonaceous aerosol concentrations. A secondary objective of the project is to quantitatively determine the viability and uncertainty of using simple measurements, such as water soluble carbon, elemental carbon, and water soluble potassium, as source tracers in the Los Angeles basin.

DESCRIPTION: The project can be divided into two major thrusts: measurements and data analysis. The measurement thrust of the project will generate a year long time series of hourly elemental carbon and organic carbon measurements, daily molecular marker measurements, and daily measurements of bulk fine particle parameters including water soluble organic carbon, water soluble potassium and ultrafine particle number. The data analysis thrust of the project involves the applications of parallel source apportionment models methods including molecular marker chemical mass balance modeling (MM-CMB), molecular marker positive matrix factorization (MM-PMF) modeling, molecular marker iterative confirmatory factor analysis (MM-ICFA) modeling, as well as statistical analysis to identify trends in day-of-the-week, time-of-day, and

plume analysis to identify the strengths and weaknesses of these complementary models. The data analysis thrust of the project will also include a comparison of the source apportionment results with elemental carbon, water soluble organic carbon, water soluble potassium, and particle number to determine accuracy of using these simple measurements as tracers for diesel PM, secondary organic aerosol, wood smoke, and mobile source emissions for health and climate forcing studies. More details on these efforts are provided below.

Measurements: Hourly organic and elemental carbon concentrations will be obtained using a Sunset Labs semi-continuous elemental and organic carbon analyzer, which were operated continuously at the St. Louis Supersite for four years (Bae et al. 2004). Twenty-four hour fine PM samples will be collected with a medium volume sampler designed by the University of Wisconsin-Madison and commercially sold by URG (Chapel Hill, NC) that operates at 92 lpm. Section of the daily samples will be analyzed by optimized GCMS methods that allow the required 400 samples to be cost effectively measured for primary and secondary organic tracers. The optimized gas chromatography/mass spectrometry methods have been developed under funding from the U.S. EPA and Electric Power Research Institute and were used for the analyzed of parallel samples from the St. Louis Supersite. Sections of the 24-hour fine PM samples will be extracted in high purity water and analyzed for water soluble organic carbon and water soluble potassium using a total organic carbon analyzer and ICPS-OES. In parallel to the filter based measurements, ultrafine particle number and fine particle mass will measured in real time using and ultrafine particle condensation nucleus detectors and a TEOM.

Data Analysis: The proposed data set will be analyzed using a MM-CMB model originally developed by Schauer et al. (1996) under funding from ARB using updated source profiles from the DOE Gas/Diesel Split Study and source profiles that are being generated from the Southern California PM Center (SCPC), which were based on samples analyzed by the University of Wisconsin-Madison. The MM-CMB model will also include source profiles for biogenic and anthropogenic derived secondary organic aerosol developed at the U.S. EPA, which have been previously integrated in the MM-CMB analysis though collaboration between the U.S. EPA and the University of Wisconsin, Madison. In parallel to the MM-CMB analysis, the MM-PMF and MM-ICFA models, which are multivariate receptor models that does not require source profiles as inputs, will be applied to the data. In addition other statistical methods will be used for the analysis of the data including day-of-the-week analysis (Lough et al. 2006), hour-of-the-day analysis (Bae et al. 2004), and plume analysis (Bae 2006) will be employed to further elucidate information about sources.

BENEFITS: The project will significantly reduce the uncertainty in the contributions of primary and secondary sources to carbonaceous aerosol concentrations in the Los Angeles basin and will help identify the most cost effective strategies for source apportionment efforts associated with State SIP development and future health studies.

COST: \$400,000

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

PROBLEM: There is very little information on ammonia emissions from real vehicles on the road. Ammonia is a major component of airborne PM_{2.5} and there are few other ammonia sources in the Los Angeles basin. Dynamometer studies at UC Riverside have shown that ammonia emissions vary with load and with the tier of emission control. Sulfur dioxide emissions, especially from diesel vehicles, are a potential indicator of misfueling.

PREVIOUS WORK: There has been one published study of on-road ammonia emissions measured by means of on-road remote sensing (Baum et al. 2000) which observed a relatively small number of vehicles. There is now an ultraviolet (UV) based on-road remote emissions sensor which reliably gives not only CO, HC, CO₂ and NO fuel-based mass emissions readings from passing light duty vehicles but also provides the same quality of data for nitrogen dioxide, ammonia, and sulfur dioxide. This development was described by Burgard et al. at the April 2006 Coordinating Research Council (CRC) Meeting in San Diego. The results from the only on-road light-duty diesel vehicle (LDDV) studies in Tulsa and Denver will be published shortly in Environmental Science and Technology. An emission inventory for the Los Angeles basin published by Huai et al. predicts that ammonia emissions are currently dominated by the ammonia emissions from older cars.

OBJECTIVE: The goal of the project is to monitor the above pollutants from approximately 60,000 light duty vehicles, 20,000 each in three regions of California, the Los Angeles basin, the Central Valley and the San Francisco Bay Area. The results, when combined with fuel sales data, will provide a fuel-based emission inventory and will investigate if there are any differences between the three regions in terms of emissions and in terms of potential misfueling.

DESCRIPTION: The FEAT 3000 is the University of Denver's routine on-road emissions monitor. It has been used in California for the IMRC in 1999 at several sites and for the CRC every two years at a single site, at the intersection of LaBrea Boulevard and I-10 in Los Angeles. The instrumentation and the normally available data including speed and acceleration and vehicle make and model year are fully described in CRC E-23 reports available on the web at www.feat.biochem.du.edu. The new features which have been added include new optics and a wider UV detector array which allow NO₂, SO₂, and NH₃ to be monitored simultaneously with the routine pollutants.

In operation, a mobile van sits at the roadside during daylight hours for about one week at each location. The sites to be monitored will be the La Brea site in Los Angeles, a return to the interchange ramp (101N to 880N) in San Jose, and a suitably chosen site in the Central Valley. 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: 1) location of a suitable central valley site, preferably one used in previous ARB remote sensing studies, 2) apply to CALTRANS for permits for all sites, 3) ensure that all calibration gases are available and certified by appropriate authorities, 4) carry out the studies, 5) read license plates and match plates for make and model year with California DMV, 6) and report the findings.

BENEFITS: New knowledge of the current mobile-source ammonia, nitrogen dioxide and sulfur dioxide emissions inventory. An indication as to whether these emissions vary from region to region within California.

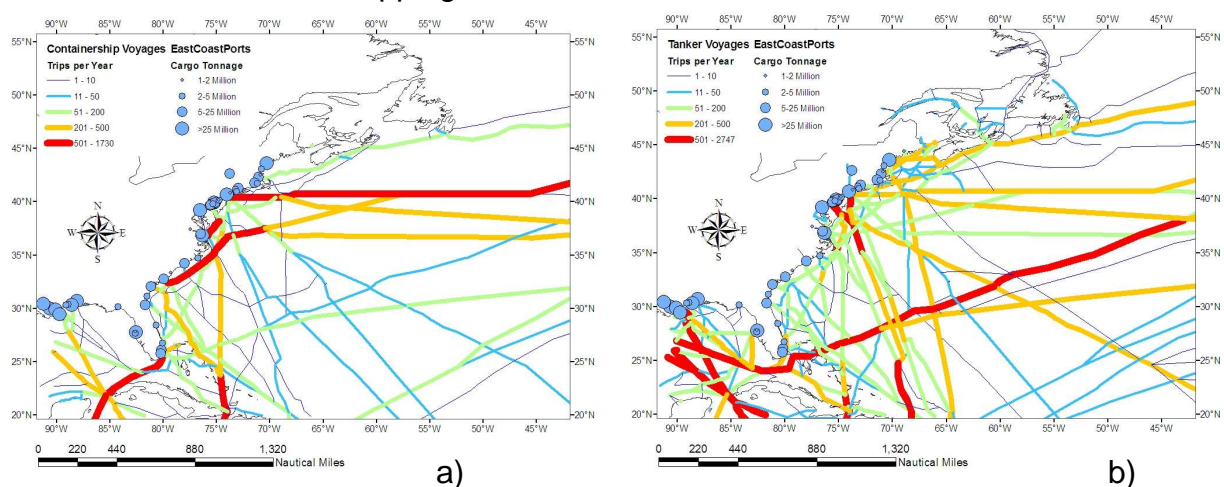
COST: \$95,000

TITLE: Improved Geospatial Forecasting of Commercial Marine Vessels

PROBLEM: Growth in goods movement, particularly seaborne imports and exports, is expected to remain strong for California over the next decades. These insights follow from forecast scenarios developed for and with ARB by Professor James Corbett, as cited in ARB documents for the California Goods Movement Action Plan. However, the current mix of types of ships and cargos are expected to change as containerized shipping dominates overall trade growth compared other cargo types, such as tankers and general cargo carriers. These differences can be modeled in the abstract from currently available data, but GIS-based modeling is needed to understand how asymmetric growth among vessel types will affect forecasts of ship emissions off the U.S. West Coast.

PREVIOUS WORK: A baseline inventory model for commercial marine vessels engaged in foreign commerce has been developed that uses “complete” arrival and departure data for ships calling on U.S., Canadian, and Mexican ports. This Ship Traffic Energy and Emissions Model (STEEM) was used to produce the first set of North American emissions inventories for a base-year of 2002 and forecast years 2010 and 2020. ARB and the Council on Environmental Cooperation supported its application as part of the multi-agency effort to understand the benefits of emissions reductions from ships, particularly a SO_x emissions control areas (SECA) designation. This work produced aggregate inventories for all vessel types and used national average growth rates to produce forecast scenarios. California-specific forecasts were developed from the methodology used in the North American forecasts, but not implemented regionally in the model due to potential discontinuities with national inventory results.

Similar work to separate traffic by vessel type was part of National Oceanic Atmospheric Administration funded work using an East Coast domain for STEEM. Routes dominated by different route types are illustrated in the figure below for a) container ships, and b) tankers. One may surmise that common routes or routes dominated by faster growing containership traffic would result in higher emissions in future years than routes that do not serve containerized shipping.



OBJECTIVE: The goal of the project is to extend the previous work to help reveal how different vessel types contribute to cargo ship emissions along major trade routes and how different growth rates among commodities shipped may affect the national-level forecasts currently used by ARB and SECA team agencies.

DESCRIPTION: This project will re-run 2002 base year data by vessel type and by month to better correlate observed port calls with coastal and offshore emissions. It will use these vessel-specific results for 2002 and available forecasts developed by Dr. Corbett and by SECA team contractors to perform more detailed forecasting for 2010 and 2020 (or different and/or additional years as needed).

BENEFITS: This work will continue to utilize the full North American data set, which means that improved insights for California will also be comparable with forecasts at the national level. This enables ARB to continue to understand how its Goods Movement Action Plan may benefit the state in the context of global seaborne trade. These results can enable both air quality modeling and climate change impact assessment to understand the impact of freight transportation on these issues, according to California's regulatory and policy priorities. Moreover, these results will advance STEEM capabilities to link with multimodal/intermodal models for freight transportation, providing both the most advanced waterway network and a source from which to estimate the numbers of truck and rail trips generated by imports and exports through California ports.

COST: \$40,000

TITLE: Development of a California-Specific Intermodal Freight Transport Model

PROBLEM: It is expected that goods movement through California's ports will increase dramatically in the next twenty years, significantly impacting the state's transportation network and air quality. However, California does not have a freight transportation model that relates truck, locomotive, and ocean-going vessel activity with emissions models and commodity flow data. Such a tool is needed for decision makers to assess different strategies for mitigating the air quality impacts of goods movement.

PREVIOUS WORK: There are no known freight models that link emissions models and commodity flow data. The U.S. Department of Transportation (DOT) is currently funding development of a multi-modal freight transportation model on the East Coast, which will provide a GIS-based tool to describe and optimize freight flows across existing and modified transportation networks including ocean-going vessels, trucks, and trains as well as domestic and international commodity flows. That work would serve as a fundamental basis for this contract, and could incorporate California-specific elements through collaboration with current projects.

OBJECTIVE: The goal of this project is to develop a single, statewide intermodal freight modeling system linked to California freight flows, vehicle activity, and state/national transportation infrastructure.

DESCRIPTION: This project will build upon the national freight network being developed for the U.S. DOT by applying the national model framework to California. The model will integrate existing California-specific emission inventory tools and commodity flow data in a GIS environment. A multi-criteria optimization framework implicit in the model design will allow for comparative analyses of preferred routing and tradeoffs (economic, energy, fuel use, emissions/air quality) under both existing and alternate transportation scenarios.

BENEFITS: Development of an intermodal freight transport model will allow for analysis of the greenhouse gas and ozone precursor emissions impact of potential goods movement infrastructure improvements in California.

COST: \$200,000

TITLE: Measuring Agricultural Fumigant Pesticide Emissions through In-Field Testing

PROBLEM: Fumigant pesticides are the largest contributors to the pesticide volatile organic compound (VOC) inventory. Under current assumptions, nearly 100 percent of the VOC emissions from fumigants are thought to be released to the atmosphere. Although there is ongoing work to obtain in-field measurements, additional research is needed to validate and expand on the work that is currently being done.

PREVIOUS WORK: In fiscal year 2004-2005, Dr. Scott Yates of the University of California, Riverside was granted a contract by ARB to look at different methods to reduce fumigant pesticide emissions. Dr. Yates will conduct a series of field experiments that are designed to estimate the emissions and potential VOC reductions for three fumigant pesticides that are most commonly used in California: metam sodium, 1,3-dichloropropene (1,3-D), and chloropicrin. The purpose of the experiments is to determine emissions estimates based on different application techniques including (a) broadcast shank fumigation with and without intermittent water seals, (b) shank fumigation comparing surface packing with an intermittent water seal, and (c) broadcast-shank fumigation with and without a surface treatment. Each of the experiments will be conducted on 5-acre fields in the San Joaquin Valley. Due to the high cost of in-field research, a limited number of parameters are included in this research. Therefore, additional work is needed to consider other parameters that may also reduce fumigant pesticide emissions.

OBJECTIVE: The goal of this project is to conduct additional field research to build upon the ongoing work to estimate the emissions and potential VOC reductions from fumigant pesticides.

DESCRIPTION: Perform in-field testing on commercial agricultural fields to measure fumigant pesticide emissions. Examples of additional work may include variations in application technique, water sealing practices, mitigation measures, fumigant type, soil type, and/or geographic region.

BENEFITS: This additional research will improve the accuracy of ARB's pesticide emissions inventory. It will also benefit the development of State Implementation Plans and assist in identifying additional mitigation strategies.

COST: \$100,000 (Cofunded by the California Department of Pesticide Regulation)

TITLE: Source Apportionment of Atmospheric Dry and Wet Deposition of Mercury and Other Toxic Metals through Linkage to Atmospheric Measurements

PROBLEM: Atmospheric deposition is an important contributor to the overall input of mercury and other toxic metals to California's aquatic habitats. The inputs of these toxic metals threaten critical aquatic habitats, and in the case of mercury, present a probable human health threat. However, considerable uncertainty exists in the understanding the sources and atmospheric processes that control deposition of toxic metal deposition to California watersheds and water bodies. The contributions of wet and dry deposition from point and non-point sources need to be quantified to support efforts to develop control strategies to protect California aquatic habitats.

PREVIOUS WORK: There have been numerous studies to identify atmospheric sources and deposition fluxes of toxic metals. These studies include the Lake Michigan Mass Balance Study, an ongoing Natural Science Foundation (NSF) funded Greenland project, a Health Effects Institute (HEI) funded study addressing metal emissions from mobile sources, and U.S. EPA funded studies of speciated atmospheric mercury that have examined sources of mercury in St. Louis, Milwaukee, rural Wisconsin, Yellowstone National Park, and the Los Angeles basin. The tools developed in the completed and ongoing studies are readily adaptable to studying the sources of toxic metals depositing to California aquatic habitats. In addition, the project team has pioneered methods to measure mercury, methyl mercury, and toxic metals in the atmosphere, rainwater, lake and estuary water, and biota, which are needed to assess the impact of atmospheric deposition on aquatic habitats.

OBJECTIVE: The goals of the project are to: (1) enhance the measurements of toxic metals in wet deposition at an existing California site of the National Mercury Deposition Network (MDN) to include methyl mercury and toxic metals for one full year; (2) obtain collocated dry deposition measurements of toxic metals and mercury species; (3) obtain collocated measurements of speciated atmospheric mercury and toxic metals in parallel with the wet and dry deposition measurements; and (4) employ existing receptor based source apportionment models and dry deposition models to quantify the source and receptor relationships for atmospheric transport and to quantify the air/deposition relationships.

DESCRIPTION: Through a coordinated effort with the ARB and other California stakeholders, the specific sampling site for the project will be selected. If one of the four active MDN sites that currently exist in California (i.e. Yurok Tribe-Requa (CA20), San Jose (CA72), Sequoia National Park-Giant Forest (CA75), and Converse Flats (CA94)) is not appropriate, then project efforts will be directed at one of the twelve California NADP sites or another suitable location. There will be collaboration with the network operators to obtain wet deposition samples from the network site that would be suitable for mercury, methyl mercury and trace metals analysis to avoid the need to duplicate sampling. Researchers at the University of Wisconsin, Madison Water Science and Engineering Laboratory have a long history of working with the MDN network to obtain samples from the Great Lakes region for these purposes.

Dry deposition sampling, atmospheric particulate sampling and real-time atmospheric mercury speciation measurements will be conducted in parallel to the wet deposition sampling for a full year. Dry deposition will be directly measured using passive samplers and surrogate surfaces, and values compared with those calculated from indirect approaches. Size resolved atmospheric particulate matter samples will be collected using a PCIS (SKC) cascade impactor, which has been widely used in the past by the project team for metal analysis and atmospheric metal speciation efforts. The cascade impactor will be operated every third day to obtain three particulate matter size fractions ($>2.5 \mu\text{m}$, $1-2.5 \mu\text{m}$, and $<1 \mu\text{m}$) for trace metals analysis by ICPMS analysis. The ICPMS methods developed by the project allow the quantitative determination of about 40 elements using microwave assisted acid digestion and high resolution ICPMS analysis. Mercury will be analyzed using established cold vapor atomic fluorescence (CVAF) methods. Although all 40 elements are not important toxic elements, the comprehensive analysis of 40 elements supports source apportionment efforts and deposition velocity calculations. The same suite of elements will be analyzed in the rain water sample, the dry deposition samples and the particulate matter samples.

A Tekran mercury speciation monitor that measures hourly reactive gaseous mercury (RGM), particulate mercury and elemental mercury (Hg^0) will be operated at the site for one full year. The project team has previously operated the Tekran speciation monitor for a full year in Milwaukee and Wisconsin and Devil's Lake State Park (Mercury TMDL site). Such data sets provide important insight into the dynamics of atmospheric mercury including plumes from sources impacting the sites as well as diurnal and seasonal patterns that can be linked to sources and atmospheric processing.

The data analysis portion of the project will focus on three major activities: 1) source apportionment, 2) quantifying wash out ratios and deposition velocities for toxic metals, and 3) assessing the seasonality of wet and dry deposition fluxes. Source apportionment tools will include identification of mercury plumes, as well as multi-variant receptor modeling and size resolved metals clustering methods to identify sources of the toxic metals.

BENEFITS: The proposed project will provide a more comprehensive assessment of toxic metal deposition in California, supplementing existing measurements that connect to the National MDN network. In addition, the project will provide critical information on the sources of toxic metal deposition in California, while providing a new framework for monitoring to support atmospheric source/deposition relationships for future studies and source apportionment efforts. The study will also provide critical data for the validation of mechanistic atmospheric transport models that are being used to predict present and future dry and wet deposition of toxic metals.

COST: \$330,000 (The project is contingent upon the State Water Resources Control Board providing cofunding. The Water Board is currently considering the request.)

TITLE: Environmental Exposures in Early Childhood Education Environments

PROBLEM: Almost no information is available about environmental exposures in California's Early Childhood Education (ECE) facilities, although school environments are known to contribute to children's exposure to several pollutants, including molds, lead, and pesticides. These exposures can cause or exacerbate asthma and other respiratory illnesses or impair neurocognitive functioning in children. A total of 550,000, 50 percent of California children ages 3-5 years and 345,000, 23 percent of children under 3 years attend child care or preschools, and may spend up to 40 or more hours in these environments each week. Additionally, 146,000 staff work in the approximately 40,000 licensed facilities in California. Collectively, 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. Few states, including California, have developed policies to protect infants and children in childcare and preschools.

PREVIOUS WORK: The First National Environmental Health Survey of Child Care Centers, conducted by the U.S. EPA and Department of Housing and Urban Development (HUD), was a probability-based study that tested 168 childcare centers for allergens, pesticides, and lead. These compounds were commonly detected, however few sites were tested in the western U.S. (~20), and data are not available to project exposures in California. This study also did not test for other pollutants, including endotoxin, phthalates, and VOCs, compounds potentially associated with childhood asthma. A questionnaire-based survey of 284 California facilities found that problems with mold, cockroaches, and other factors potentially associated with respiratory disease problems were common. However, no on-site inspections to validate the questionnaire were completed, and the response rate was less than 25 percent. Several studies have shown that poor housing quality, and allergen and pollutant exposures to children are highest among low-income communities. Thus, it is likely that levels of unhealthy environmental exposures are higher in ECE facilities located in low-income communities.

OBJECTIVE: The goal of the project is to assess environmental quality in a representative sample of child care facilities located in California's urban and agricultural communities.

DESCRIPTION: The assessments will include environmental monitoring, administration of detailed questionnaires, and facility inspections. There will be an identification of all licensed ECE facilities in one urban (Alameda) and one rural (Monterey) county. According to the California Child Care Resource and Referral Network, there are approximately 627 facilities in Monterey and 2,522 in Alameda. Using publicly available data, all licensed facilities will be grouped 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. Two hundred facilities will be randomly selected, ensuring general representation based on socioeconomic characteristics and urban/rural classification. Directors of these

facilities will be invited to participate in a detailed phone questionnaire to collect data about each facility's environment. If a director refuses to participate, the next facility on the list will be contacted.

For a subset of 45 facilities (23 in Alameda County and 22 in Monterey County), detailed environmental health inspections will be performed to validate the questionnaire data, and extensive environmental sampling will be performed. Pesticides, brominated flame retardants, phthalates, perfluorinated compounds, allergens, and endotoxin in dust will be measured. VOCs (EPA Method TO-15), aldehydes, pesticides, endotoxin, and particulates in air samples will also be measured. The inspection protocols will follow developed procedures, HUD, and school districts to inspect homes and schools that will be adapted for use in ECE environments. Standard analytical methods such as GC-MS and immunoassays for allergens will be used to quantify indoor contaminants in air and dust samples. Standardized methods previously validated will include appropriate quality assurance and quality control procedures

The environmental measurement data will be used to characterize contaminant levels in ECE environments and estimate potential health risks associated with specific exposures. Factors associated with the presence of these substances, including pesticide use, building materials, pest and mold infestations, and local land use such as agriculture and industrial facilities will also be identified.

BENEFITS: Specific benefits include the development of new indoor concentration and exposure data for several volatile and semivolatile Toxic Air Contaminants and other chemicals for which there are little or no data in California. This information will allow ARB to greatly improve exposure assessments for young children by focusing on an environment where young children and their teachers spend large amounts of time. This work will include community partners to highlight findings from the study. Through these partnerships, knowledge and support efforts are built to improve environmental and public health for California's children.

COST: \$500,000

TITLE: Development of Improved Environmental Chamber Experiments for Evaluating Contributions of Oxidation Products Ozone Impacts of Volatile Organic Compounds

PROBLEM: For maximum accuracy in assessing effects of control strategies on ground-level ozone formation, models must use chemical mechanisms that have been shown to correctly predict the impacts of individual volatile organic compounds (VOC) on ozone formation. Because of this, chemical mechanisms used in airshed models need to be evaluated using environmental chamber data. However, it has been found that for some VOCs the magnitude of the impact of the VOC on ozone formation is different in chamber experiments than in atmospheric simulations. A modeling analysis indicates that this is due to chamber experiments being much less sensitive to the effects on ozone of the reactions of the VOCs' oxidation products than is calculated to be the case for the atmosphere. This means that an important aspect of the mechanism affecting predictions of ozone in the atmosphere is not being adequately tested, and may not be giving correct predictions in airshed models. This is a particular concern because reactions of products tend to be the most uncertain aspect of the mechanisms of most VOCs, and most mechanisms represent them in a highly simplified manner.

PREVIOUS WORK: There is a large database of environmental chamber experiments used in the development and evaluation of the SAPRC-99 mechanism. This includes experiments in the University of California, Riverside Environmental Protection Agency (UCR EPA) environmental chamber, which was developed to improve representation of ambient conditions and permit use of lower, more representative, reactant concentrations. Compounds such as higher molecular weight alkanes and glycol ethers and esters used in coatings are found to have low or negative impacts in chamber experiments but the same mechanism that simulates the chamber results predicts positive ozone impacts in the atmosphere. A modeling analysis indicates that this is due to lower integrated radical levels in chamber experiments compared to the atmosphere. Exploratory calculations indicate that integrated radical levels can be increased by increasing the light intensity, duration, and/or UV intensity or by adding radical initiators in the experiments. However, some of these modifications result in lower sensitivities of the experiments to other aspects of the mechanism that are important in the atmosphere.

OBJECTIVE: The objective of this project is to develop and evaluate the current chemical mechanisms that are used to predict the impacts of individual VOCs on ozone formation. Specifically, chamber experiments will be designed and conducted to improve sensitivities of chamber experiments to product reactions and other aspects of the mechanisms that are important in ambient conditions.

DESCRIPTION: Methods to modify the UCR EPA chamber experiments to improve sensitivities of chamber experiments to product reactions and other aspects of the mechanisms that are important in ambient conditions will be investigated, first by modeling analysis and then by experimental tests. This may include increasing reaction durations, light and ultraviolet intensity, and experiments with injection of HONO, and

probably several types of experiments will be investigated. Evaluations will be conducted using representative compounds with various types of mechanisms and reaction products. The new methods will be used to evaluate mechanisms for compounds important in coatings and other emissions sources.

BENEFITS: If successful, environmental chamber experiments will give results that correlate better with predictions of atmospheric reactivity, which will increase the confidence in atmospheric reactivity predictions, and reduce chances for compensating errors in models. A significant source of uncertainty in model predictions of ozone impacts of individual VOCs, and ozone impacts in general, would be reduced.

COST: \$200,000

TITLE: Formal Uncertainty Analysis for Modeling of Secondary Air Pollutants

PROBLEM: Atmospheric models are used to study the effects of future emission changes, and to demonstrate that comprehensive emission control strategies will lead to attainment of air quality standards. Models also synthesize understanding of relevant processes including emissions, transport, chemical reaction, and removal. Though use of models is required for regulatory purposes, there is widespread skepticism about model results due to uncertainties in model formulation and input data. A formal scheme for quantifying and ranking uncertainty contributions would facilitate improved communication of uncertainties and research needs among modelers, experimentalists, and policy makers.

PREVIOUS WORK: Comprehensive uncertainty analyses for atmospheric models are scarce, especially for the case of spatially-resolved models where computational costs are high. The few studies that have been done have only addressed ozone. Monte Carlo analysis of Lagrangian and Eulerian model results for ozone have been reported previously (Bergin et al. 1999, Hanna et al. 1998, 2001). Martien et al. (2006) describe and apply an adjoint sensitivity analysis procedure (ASAP) to a 3-D air quality model in southern California. They computed model sensitivity to approximately 900 model inputs, including emission rates, boundary and initial conditions, reaction rate coefficients, and surface deposition velocities. The adjoint method is especially well-suited to the case where there are many uncertain inputs and a few model outputs of interest. In contrast, the direct decoupled method (DDM-3D; Yang et al., 1997) is well-suited for studying effects of changes to a few model input parameters on many model outputs.

OBJECTIVES: The goals of this project are to: 1) evaluate air quality model performance against continuously measured ozone, gaseous ammonia and nitric acid, and PM nitrate; 2) conduct sensitivity analysis for ozone, nitric acid, and PM nitrate; and 3) calculate and rank input parameter/data uncertainties contributing to model uncertainty for each pollutant.

DESCRIPTION: Air pollution will be modeled in southern California for a weeklong period in the second half of August 1997 when continuous online measurements of ozone, PM nitrate and precursors were made at Riverside (Stolzenburg and Hering 2000). Retrospective emission estimates for summer 1997, as well as emission forecasts for 2010 will be considered, both factoring in the State's newly updated EMFAC 2007 model. CMAQ with SAPRC chemistry, driven by un-nudged MM5 model runs already done by ARB will be used. The adjoint sensitivity analysis procedure (Martien and Harley 2006) will be used to compute sensitivities for ozone, nitric acid, and PM nitrate at Riverside to hundreds of model inputs including all reaction rate coefficients, emissions of each species, boundary conditions, and deposition velocities. Quantifying sensitivity of population-weighted integrals of each pollutant throughout the study domain will also be performed. Sensitivities to anthropogenic VOC and NO_x emissions will be apportioned spatially and mapped, showing the emission grid cells that most strongly influence the model predictions.

The rate parameters of gas-phase reactions identified in previous studies as critical for ozone and nitrate production will be considered uncertain variables. Uncertainty factors for rate parameters of inorganic reactions will be obtained from the most recent atmospheric chemical kinetics panel reviews (e.g., Sander et al. 2006). Uncertainty estimates developed by Stockwell et al. (1994) and Wang et al. (2000) for parameters specific to the SAPRC mechanism will be updated for this study. Uncertainties in anthropogenic VOC and NO_x emissions, and biogenic VOC emissions will be estimated based on literature review and consultation with ARB staff. Uncertainty estimates for ozone and nitric acid deposition velocities will be developed based on the Wesely (1989) resistance model. A first-order uncertainty propagation will be done using sensitivity analysis results, and uncertainty contributions will be ranked for each model response listed above.

As a preliminary step in extending adjoint sensitivity and uncertainty analysis capabilities to secondary aerosol concentrations, an uncertainty analysis will be performed for the ISORROPIA aerosol thermodynamics model (Nenes et al., 1998) used in CMAQ. This analysis will be conducted with ISORROPIA used in a box model, with specified values of relative humidity and temperature and total concentrations of sodium, sulfate, nitric acid, chloride and ammonia. A range of conditions relevant to southern California will be studied. The results will be used to help guide the sensitivity and uncertainty analysis for PM nitrate in the full CMAQ model.

PM nitrate and precursor concentrations will be evaluated against continuous surface observations at Riverside over the same weeklong period modeled above. There will be an examination of vertical profiles of PM nitrate, as Neuman et al. (2003) have measured strong vertical gradients, with higher PM nitrate aloft where temperature is lower, within an otherwise well-mixed daytime boundary layer above Riverside.

BENEFITS: The quantification and ranking of model uncertainties provides a rational basis for prioritizing research to improve understanding of relevant processes. California would be well-served by application of a new analytical framework for air quality modeling, proposed here, that includes communication of uncertainties.

COST: \$260,000

TITLE: Comparative Assessment Entrained and Directly Emitted Particulate Emissions of Agricultural Field Equipment

PROBLEM: While the agricultural community has demonstrated a willingness to consider actions to reduce emissions (established by positive, cooperative response to San Joaquin Valley Air Pollution Control District Conservation Management Practices process), very little information is available to allow the comparison of field equipment operations on the basis of air pollution fugitive particulate (PM10) emissions. The comparative fugitive emissions of various field equipment types have not been quantified. This information would be valuable for decision-making processes for selection of controls to reduce fugitive particulate emissions.

PREVIOUS WORK: USDA-funded University of California, Davis field studies did not successfully include equipment comparison. The California Regional PM10/PM2.5 Air Quality study obtained extensive funding through USDA to assess agricultural field operation emissions. The results of this research were used to develop improved emission estimates for many agricultural activities. The type of equipment used to conduct activities was documented; however, when different equipment types were studied, the ambient measurement methods were not able to establish differentiation with statistical confidence. Soil variations that occur within agricultural fields make it difficult to establish equivalent testing for comparisons.

OBJECTIVE: The goal of this project is to develop an improved testing procedure to quantify agriculture field equipment emissions on a comparable basis. The improved test method will be used to identify the PM10 reduction potential of various types of currently available agricultural field equipment. Frequently used techniques, practices and equipment types that have a significant likelihood of providing a potential for reduction of PM10 emissions from agricultural activities will also be assessed.

DESCRIPTION: Measurement protocols will be developed for improved methodology for equipment fugitive emission comparisons. Project selection will identify advanced methods, using laser based measurements or other techniques that have a demonstrated ability to make field measurements to compare equipment operation and fugitive particulate emissions from the agricultural activity. The next step in the project will be to evaluate and certify the improved methodology. The improved methodology will be used to evaluate the particulate entrainment of various implements, whether used individually or in combination with other implements. A classification system of equipment options for various agricultural practices and their applicability to various crop and animal husbandry practices will be developed as the final aim of the project.

Equipment for review would include devices in current use for:

- Land preparation activities,
- Manure management activities
- Harvest activities
- Activities for reducing agricultural burn (e.g. shredding)
- Cultural activities (e.g. weed management)

Assessment will include comparison of fuel use to ensure that additional direct particulate emissions from fuel combustion are included in the comparison. Decreased fuel efficiency or increased operating hours to conduct the same operations with different methods will be included in the comparative analysis.

The latest PM10 emission inventory shows nut crops as having the highest emission factor for harvest activities of 40.8 lbs of PM10 per acre compared to the lowest emission factor of 0.085 lbs of PM10 per acre for tree fruits. A similar analysis can be done for the other agricultural activities. Based upon the emissions estimates for crop activities, priorities can be established for the review of equipment in common use for the higher emitting activities. Evaluation of operational constraints for applicability of equipment use, such as farm size, may assist in identifying reasonable equipment limitations and usage.

BENEFITS: Evaluation will be helpful in reducing PM10 emissions by providing improved methods for assessment and quantification of emissions that subsequently guide control efforts of the agricultural operators. The information will also be useful for the update and improvement of emissions inventory estimates and the quantification of control measures that are implemented.

COST: \$240,000

TITLE: Developing a California Inventory for Industrial Applications of Perfluorocarbons, Sulfur Hexafluoride, Hydrofluorocarbons, Nitrogen Trifluoride, Hydrofluoroethers, and Ozone Depleting Substances

PROBLEM: With the passage of AB 32, the California Air Resources Board (ARB) is charged with developing and implementing workplans to enable the State of California to reach its goal of CO₂-equivalent greenhouse gas (GHG) emission reductions to 1990 levels by 2020. Originally, the Climate Action Team (CAT) only examined hydrofluorocarbons (HFC) reduction strategies, but upon further investigation, it has become apparent to ARB staff that greater global warming potential (GWP) greenhouse gas reductions are possible if other, high GWP GHGs are considered in addition to HFCs.

Roughly 3.75 million metric tons (MMT) of SF₆ (in CO₂-equivalents) and 5.4 MMT of perfluorocarbons (PFC) (in CO₂-equivalents) were emitted in CA in 2005¹. The 2020 CAT target is estimated to be 400 MMT, and although high GWP gas emissions from non-refrigerant and air conditioning (RAC) industrial applications do not account for a large percentage of the total emissions, cost-effective GHG emissions reductions may be possible. Additionally, potential emissions from other high GWP GHGs used in non-RAC industrial applications are unknown, but may significantly contribute to overall GHG emissions.

PREVIOUS WORK: There have been no California-specific inventory efforts to quantify banks and emissions of high GWP GHGs in non-RAC industrial applications. The U.S. EPA developed a “Vintaging Model” to estimate banks and emissions of high GWP gases on the national level, but this model relies on inputs that are classified as Confidential Business Information by the U.S. EPA and cannot be disclosed to or utilized by ARB. It is therefore necessary to develop a California-specific inventory to quantify emissions rates and banks of high GWP GHGs by application.

OBJECTIVES: The goals of the project will be to quantify emissions rates (during production and use), application growth rates, chemical substitution rates, banks, and end-of-life disposal emissions (if applicable) for each high GWP GHG in each application. Mitigation strategies, such as emissions reductions associated with chemical substitutes, alternatives, or process changes will be examined in terms of costs and benefits as well as life cycle climate performance (LCCP). The cost and benefits of recovery and destruction of high GWP GHGs in each application will be estimated.

DESCRIPTION: A detailed bottom-up inventory for high-GWP GHG in California will be developed. A methodology for generating the inventory that may include data gathering from trade associations as well as surveying the industrial sectors that employ high GWP GHG in various applications will be necessary as part of this project

¹ Numbers from U.S. EPA report “U.S. High GWP Emissions 1990-2010”; distributed to CA by 2005 population fraction, 12.8 percent

The following should be addressed:

- PFC use, banks, and emissions in California (semiconductor manufacturing, aluminum smelters, fire extinguishing, Ozone Depleting Substances (ODS) substitution; PFC/PFPE emissions from solvents)
- Sulfur Hexafluoride (SF₆) use, banks, and emissions in California (semiconductor manufacturing, electric power transmission and distribution, magnesium production and parts casting)
- HFC use, banks, and emissions in California (semiconductor manufacturing, aerosols, fire extinguishing, solvents)
- Nitrogen Trifluoride (NF₃) use, banks, and emissions in California (semiconductor manufacturing)
- HCFC-22 emissions from HFC-23 production
- Hydrofluoroethers (HFE) use, banks, and emissions in California (HFEs have relatively low GWPs, but may be used in large quantities in industrial applications, clothing dry cleaners, and by consumers)
- ODS banks and emissions in California (stockpiles of Class I and II ODS, such as CFCs, HCFCs, Halon 1211, 1301, and 2402, carbon tetrachloride, and methyl chloroform, used in the past for solvent cleaning, fire extinguishing and explosion protection [industrial, aviation, military, and other applications])

In terms of overall emissions of high GWP gases (PFCs, HFCs, and SF₆), the most important sector is projected to be semiconductor manufacturing in 2010.² All other sectors such as solvents, aerosols, fire extinguishing, HCFC-22 production, magnesium and aluminum production, and electric power transmission/distribution are expected to be similar in magnitude in terms of projected emissions in 2010. Stockpiled Class I and II ODS are not included in estimates of high GWP GHG emissions, and stockpiled quantities of these substances in California are currently unknown, although 1996 national stockpile estimates exist for some chemicals utilized in solvent cleaning applications².

BENEFITS: By improving the inventory of high GWP GHGs used in non-RAC industrial applications, it will be possible to identify cost-effective reduction strategies. Some of the benefits of inventory development and high GWP GHG emissions abatement could include:

- Control of high GWP emissions in industrial applications could be a cost-effective way to reduce high GWP gas emissions without having to change consumer behavior.
- Carbon offsets could possibly be given to entities that recover and destroy high GWP GHG.
- Control of high GWP emissions from stockpiles could mitigate impacts on stratospheric ozone depletion as well as global warming.

COST: \$200,000

² U.S. EPA, The U.S. Solvent Cleaning Industry and the Transition to Non Ozone Depleting Substances, Prepared by ICF Consulting, 2004.

TITLE: A Spatial Synoptic Classification Approach to Projected Heat Vulnerability in California under Future Climate Change Scenarios

PROBLEM: Excessive heat is the leading cause of weather-related deaths across the United States. In addition to its direct impacts, sustained extreme heat events exacerbate pre-existing cardiovascular, respiratory, and other conditions. During the summer of 1980, as many as 10,000 deaths in the US may have been associated with oppressive heat, while the summer heat wave of 2003 claimed over 15,000 lives in France and 40,000 throughout Europe. In addition, considerable research has shown that the elderly are disproportionately affected by the heat; by 2030 the number of Californians 65 and older is expected to more than double, to over eight million, with those 85 and older increasing to over two million. Atmosphere-ocean general circulation models (AOGCM) projections indicate summer temperatures in California could increase by up to 10 degree Celsius. Such changes are likely to have substantial and perhaps disproportionate effects on extreme heat and related health impacts.

PREVIOUS WORK: Under a range of climate scenarios, heat vulnerability is likely to significantly increase relative to present-day levels. Using statistically downscaled data from two AOGCM for higher and lower emission scenarios, a lengthening in the annual heat wave season across California by up to 9-13 weeks was reported, yielding 6 to 8 times as many oppressively hot days, and, in the absence of acclimatization, leading to up to a tenfold increase in heat-related mortality for Los Angeles by century's end.

OBJECTIVES: The goal of this project is to evaluate the heat vulnerability of the California population in the future, based on the air mass types most closely associated with observed current-day heat-related mortality. To achieve this objective, four main questions need to be answered: 1) How do present heat-health relationships vary with age and other factors? 2) To what degree have large-scale atmospheric circulation patterns and their associated air masses already changed, and are projected to change in the future? 3) What is the projected impact on human health assuming model-simulated temperature increases and changes in air-mass frequency, duration, and timing? 4) What is the expected adaptation potential of the population in each city to changing conditions? These questions will be answered for seven California metropolitan areas: Los Angeles, Sacramento, Fresno, San Bernardino / Riverside, San Diego, San Jose, and San Francisco.

DESCRIPTION: In order to project future heat vulnerability, a thorough reanalysis of the heat-health relationship based on available local historical mortality data for each of the metropolitan areas listed above will be conducted. An analysis will be performed by classifying past days according to the holistic Spatial Synoptic Classification (SSC) air mass that has been incorporated into heat warning system development. Variations of standardized mortality within oppressive air masses will be assessed by developing an algorithm based on supplemental factors. Algorithms will be developed for mortality that account for the three most important variants: the air mass on the particular day, how long the offensive air mass has persisted, and the time of season.

Climate projections for future conditions based on the Intergovernmental Panel on Climate Change, Fourth Assessment Report, Special Report on Emissions Scenarios (SRES) high (A1fi), mid-high (A2), and lower (B1) emission scenarios will be obtained from three of the latest generation of coupled atmospheric/oceanic GCMs (AOGCMs): the NCAR/DOE Parallel Climate Model, the UK Meteorological Office HadCM3 model, and the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory CM2.1 model. Two primary sets of experiments and subsequent diagnostic studies will be conducted to quantify the individual and combined impacts of global climate changes on human health. First, historical simulations will be driven by global climate conditions selected from the period 1957-2000 for the historical GCM simulations as well as the NCEP/DOE reanalysis of observed data. Simulations using the reanalysis will serve as the base for validation, while others will be the baseline reference to determine the individual and combined impacts of global climate change. Second, future projections for the SRES A1fi, A2 and B1 scenarios for each of three general circulation models (PCM, GFDL and HadCM3) will be used to drive altered future conditions, changes in SSC air mass type frequencies and persistence, and the projected change in heat-related human mortality assessed as described next.

Utilizing NCEP ERA-40 reanalysis data, four times-daily gridded 700-hPa geopotential height fields and 850mb temperature and humidity over North America (20°N to 60°N; 60°W to 130°W) for the entire warm-season period of May 1 to September 30 for the years 1957-2003. These gridded data will first be resampled to the same resolution as the AOGCM output. Using principal components analysis and hierarchical cluster analysis (Yarnal 1993), each of these days will be classified into one of several circulation types that represents the large-scale mid-tropospheric flow.

The impact of acclimatization will be assessed by a new acclimatization procedure first utilized in Hayhoe et al. (2004). Rather than using "analog cities" where population characteristics and demographics may be significantly different than the target cities, this new acclimatization procedure assumes that people will most likely respond to heat under climate change conditions as they do today during the very hottest summers.

BENEFITS: Despite any potential future acclimatization, results will show, due to the aging of the US population, a general rise in heat-related mortality; in a warmer world, this vulnerability would increase significantly further. The physically based nature of the modeling system will result in a more complete scientific understanding of the complex interactions among global and regional climate, extreme heat events, and human health, as well as the uncertainties involved.

COST: \$175,000

TITLE: The Climate Change Industry in California: An Economic Analysis Assessing the Current Market and Prospects for Growth in the Global Economy

PROBLEM: Government policies relating to air pollution and greenhouse gas emissions in combination with rising oil prices and a strong desire for energy security are creating market drivers of what could be called the climate change industry. Just as the oil and gas industry is one of the world's largest industries today, alternative energy and power sources in a post-petroleum economy will be one of the world's largest industries tomorrow. However, a clear definition and quantification of climate change industry is lacking, along with an idea of where California ranks in the U.S. and global markets in this increasingly important sector.

PREVIOUS WORK: Little has been done to define and quantify the climate change industry in total. Some market analysis has been done in solar energy, wind power, geothermal energy, fuel cells, hydrogen, biofuels, emissions trading and other broad areas like clean energy, but aggregating this information into a clear picture has not been performed.

OBJECTIVE: The goal of this project is to define and quantify the climate change industry, forecast future growth scenarios and characterize California's place in this industry.

DESCRIPTION: Research would involve defining the climate change industry into segments, identifying companies in each segment, and collecting and compiling revenue data on as many companies as possible. Building databases of companies, reviewing existing information, conducting surveys, performing interviews would all be elements of the research. The research project would include data collection, data analysis, and segment and industry modeling.

BENEFITS: There is an emerging and potentially very large industry up for grabs, framing the climate change industry and assessing its potential could be very instrumental in developing state and other programs in support of the industry. In addition, there will likely be considerable resistance to ARB and other agency policies to reduce GHG emissions by the generating community, so a clear argument demonstrating the economic contribution of a climate change industry that would develop would provide a positive counter argument.

COST: \$200,000

TITLE: Evaluation of Efficiency Activities in the Industrial Sector Undertaken in Response to Greenhouse Gas Emission Reduction Targets

PROBLEM: In 2005, Governor Schwarzenegger announced greenhouse gas (GHG) emission reduction targets for California which call for reducing emissions to 2000 levels by 2010, to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050. The 2020 targets were included in the California Global Warming Solutions Act of 2006. Meeting these goals will require input from all sectors, including the industrial sector. Many countries around the world have similar national level GHG reduction or energy efficiency targets, and comprehensive programs focused on implementation of energy efficiency and GHG emissions mitigation measures in the industrial sector are essential for achieving their goals. A combination of targets and industry-focused supporting programs has led to significant investments in energy efficiency as well as reductions in GHG emissions within the manufacturing sectors in these countries; information on the successful elements of these programs can help California meet its goals.

PREVIOUS WORK: This research will build on programmatic work that has already been completed in other countries, and will report their successes or failures, evaluating lessons learned and applicable elements for California. For example, many countries have had comprehensive industrial sector energy efficiency programs since the 1990s that actively engage a large portion of the national industrial sector (e.g. 90 percent of industrial energy use is covered by the programs in the Netherlands and the UK) and that have delivered significant energy savings. The UK's Climate Change Agreement program, for example, which includes industries that are important in California such as semiconductors, food processing, and cement manufacturing, has consistently exceeded the program's GHG emissions reduction targets. Lawrence Berkeley National Laboratories (LBNL) researchers previously performed two related studies that were not focused on California: 1) Tax and Fiscal Policies for Promotion of Industrial Energy Efficiency: A Survey of International Experience, and 2) Energy Efficiency Programs and Policies in the Industrial Sector in Industrialized Countries (available at <http://industrial-energy.lbl.gov/node/129> and <http://industrial-energy.lbl.gov/node/132>).

OBJECTIVE: The goal of this research is to identify the characteristics of successful industrial sector greenhouse gas emissions reduction and energy efficiency programs in other countries in order to provide a summary of lessons learned and make recommendations for specific industrial sector program designs that could be implemented in California in support of the 2020 GHG emissions reduction target outlined in the 2006 Global Warming Solutions Act.

DESCRIPTION: This research begins with a characterization of the industrial sector in California, determining which industrial sub-sectors are the top energy consumers and largest CO₂ emitters. Industrial sector energy efficiency and GHG emission reduction programs in other countries (such as Australia, Canada, Denmark, France, Japan, Netherlands, and the UK) that focus on the industrial sub-sectors that are most important in California will then be examined.

For each program identified that addresses industries that are important in California, the general program design will be described along with an assessment of the level of industry participation and the realized energy savings. Program design elements such as information dissemination related to efficiency options, facility auditing, benchmarking, facility-level target-setting, development of implementation plans, energy management programs, monitoring of progress toward targets, and financial incentives will be described. Further, a survey of program managers will be conducted to identify the top barriers faced when initiating the program, both real and perceived by the manufacturers, and to understand how these barriers were addressed. To the extent possible, detailed information on specific GHG emission reduction technologies and measures that were undertaken by facilities participating in national level GHG emission reduction programs in the top GHG emitting sub-sectors in California will be compiled.

The project will conclude with a summary of lessons learned from comprehensive industrial energy efficiency or GHG mitigation programs in other countries and there will be recommendations for specific industrial sector program designs that could be implemented in California in support of the 2020 GHG emissions reduction target outlined in the 2006 Global Warming Solutions Act.

BENEFITS: The industrial sector consumes 25 percent of the energy used in California and emits 28 percent of CO₂ produced in the state. This project will identify program and policies that have effectively targeted this sector in other countries to achieve real energy and CO₂ savings. Increased energy efficiency and reduced GHG emissions can also lead to cost savings and improved competitiveness for industries, reduced emissions of NO_x, SO_x, and particulate matter, reduced water consumption, reduced production of waste, and improved product quality.

COST: \$100,000

TITLE: Retail Climate Change Mitigation: Life-Cycle Emission Labels and Standards

PROBLEM: AB 32 established caps on greenhouse gas (GHG) emissions in California. The caps mandate a 25 percent decrease in emissions by the year 2020 and a further 80 percent reduction by 2050. A key obstacle to implementing the law is leakage: as emission levels are restricted in the state, what will prevent businesses from simply moving out of state and exporting their products back into California with their high embedded carbon content?

The Climate Action Team (CAT) report (Cal-EPA 2006)¹ discusses leakage in the context of the market-based cap and trade systems envisioned for California's emission reduction at low cost. The CAT report describes five key elements in a sector-based cap and trade strategy: electricity generation, oil and gas extraction, oil refining, cement production, and landfills. However, these sectors produce only about 30 percent of the state's GHG emissions. Furthermore, the CAT report does not present an emission allowance policy that is relevant to regular product purchases and imports of consumable products and durable equipment other than automobiles. If the climate impacts of regular retail purchases are not apparent in the new emission-cap market, most consumers will be unable to participate in climate change mitigation decisions. Thus, the formulation of a system of embedded GHG emission accounting, pricing, incentives and trading activities remains a fundamental need in the development of comprehensive climate change mitigation markets in the state. Many products such as beef, cheese, milk, and fertilizer can have as much if not more emissions per dollar spent than gasoline.

PREVIOUS WORK: Masanet et al. (2005)² devised a method for estimating the life-cycle carbon content of many common retail products as a function of how they are made, used, and disposed of. A labeling and incentive program that allows California consumers to respond to and use this information is the next logical step.

OBJECTIVE: The goal of this project is to develop a framework that allows for the estimation of the potential emissions reductions that could be attained through the funding of incentives, product endorsements, performance labels, or public sector buying programs for low life-cycle GHG emission products.

DESCRIPTION: A labeling and information system framework for embedded life-cycle emission impacts that can be implemented in retail businesses will be developed. The keys to the proposed retail information system are credible default GHG emission intensities for different classes of products and a workable certification scheme wherein product suppliers can document and certify life-cycle GHG emission intensities that

¹ California Environmental Protection Agency (Cal-EPA). 2006. *Climate Action Team Report to Governor Schwarzenegger and the Legislature*. http://www.climatechange.ca.gov/climate_action_team/reports/2006-04-03_FINAL_CAT_REPORT.PDF. Sacramento, California: California Environmental Protection Agency (Cal-EPA).

² Masanet, E., L. Price, S. de la Rue du Can, R. Brown, and E. Worrell. 2005. *Optimization of Product Life Cycles to Reduce Greenhouse Gas Emissions in California*. CEC-500-2005-110-F. Sacramento, California: California Energy Commission, PIER Energy-Related Environmental Research.

deviate from the default values. Creating an “opt-in” market for low-carbon-content products will allow businesses to compete actively for “green” consumer demand, and consumers to aid climate change mitigation through “climate-aware” purchase decisions.

The estimation method described in Masanet et al. can be used for estimating the life-cycle GHG emission content of various products. To assess the potential consumer response a model of brand competition in a “carbon-aware” market will be developed. Using elasticities derived for similar type programs or products, such as the U.S. EPA Energy Star program, the market for organic foods or other “green” label products, or through consumer surveys or market experiments, the total possible emissions mitigation attainable through the substitution of high-emission product for lower-emission products will be projected. Finally, several market-enabling policy and program alternatives that could be implemented will be investigated to determine which type of type of program is the most applicable for each product type.

Specifically, this study will be a policy analysis and design effort to examine how to maximize the potential economic demand-side leverage of product life-cycle emission information through labeling and incentive programs in the retail sector. The final output of the research will be a report that includes a list of the products in California that may be the most amenable to life-cycle GHG emissions labeling and/or product standards, an estimate of the GHG emissions reduction potential, and recommendations of how such programs should be enacted in California to maximize emissions reductions.

BENEFITS: This project will result in a method, framework, and potential programs for tracking, reporting, and responding to the life-cycle carbon emission content of a diversity of retail products. As such, it will provide new opportunities for attaining GHG emissions in additional sectors that represent many millions of tons of CO₂-equivalent life-cycle emissions per year. By providing for these new emissions reduction opportunities and mechanisms, this research may provide tens to hundreds of millions of dollars worth of environmental benefits to the state over the long term.

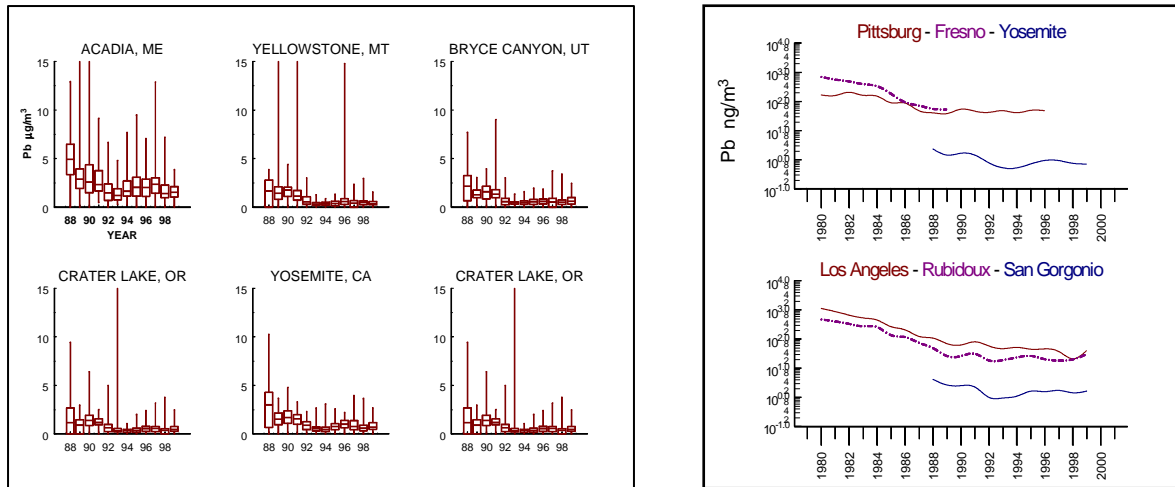
COST: \$300,000

TITLE: Asian Aerosol Impacts in Urban and Interior California

PROBLEM: Global-scale pollutant transport increases the local “background” pollutant burden in California, reducing the amount of local emissions that can be permitted and still attain State and Federal Ambient Air Quality Standards. Asian dust, combustion aerosols, and ozone all contribute to the pollutant burden in the lower free troposphere over California. Future growth of Asian emissions will increase this background burden and may complicate attainment of air quality standards in California.

High altitude monitoring sites have shown that Asian aerosols dominate the mean composition of the lower free troposphere over California, while coastal sites show minimal impact. The degree of mixing of Asian pollutants at low altitudes at inland sites is expected to be greater than at the coast, but there are no published assessments of this impact.

PREVIOUS WORK: Unpublished data (left plot) show that the IMPROVE network captured the last few years of U.S. leaded gasoline use, and that there was a significant



rebound in lead at IMPROVE sites in the years 1995-1998, presumably due to the Asian economic boom of that period. Comparing IMPROVE with ARB lead data (right) shows a weak rebound at Rubidoux, an inland site, and a no clear rebound at Los Angeles North Main, nearer the coast; in central California, Pittsburg, in the Sacramento –San Joaquin Delta, shows a possible rebound, while data from Fresno are incomplete.

OBJECTIVE: The goal of this project is to use a combination of an annualized lead emission inventory for Asia and transport analytical methodologies to assess low altitude Asian pollutant impact to major California air basins (South Coast, San Francisco Bay, San Joaquin, and Sacramento) in the 1990s and to calibrate tropospheric mixing to low altitudes to extrapolate more recent IMPROVE observations to present conditions.

DESCRIPTION: The analysis will consist of five tasks: 1) develop an annually-resolved lead emission inventory for lead in Asia for the 1990s; 2) assess Asian lead transport to

the IMPROVE sites in California by association with Asian soil markers as described in peer-reviewed literature; 3) using the Asian lead emission inventory for the 1990s, develop a statistical relationship between Asian emissions and observed IMPROVE lead concentrations; 4) develop “transfer coefficients” that statistically relate lead concentrations at IMPROVE sites to the low altitude lead data for the period 1995-1998; and 5) combine results to estimate transport efficiency for Asian emissions to low altitude California, and thus predict the impact of Asian emissions growth on California air quality.

BENEFITS: The data from this project will provide a direct estimate of past and present impacts of Asian emissions on air quality in California’s most polluted air basins. Constructing quantitative links between Asian lead emissions and California lead concentrations will provide a tool to evaluate the risks to California from current rapid Asian economic growth and consequent expansion of emissions.

COST: \$80,000

TITLE: Particulate Matter Measurement for the 21st Century: Implementing a Program to Quantify Internal Combustion Engine PM Using Real-Time Measurement Techniques

PROBLEM: Ultrafine particulate matter (UFPM), especially UFPM from combustion sources, has recently become a heightened concern for the ARB. The ARB faces a situation where both the quantity (i.e., mass) and quality (i.e., composition) of internal combustion engines (ICE) PM emissions are changing, at the same time as the ARB is implementing new or revised methods of measuring PM mass emissions. The modern, low PM-emitting technologies being deployed, concerns regarding UFPM emissions, and the measurement issues and problems being encountered when measuring such low emissions, combined with the advent of real-time PM measurement technologies, suggests that there is now a convergence between PM mass and UFPM number concentration measurements, and that it is time to visit a number of issues. These issues include the viability of the current filter-based methods, making relevant UFPM measurements, and the potential for real-time PM measurement techniques to simultaneously address the issues of measuring PM mass emissions as well as UFPM number concentrations (or some other UFPM metric). Meanwhile, on a separate front, there is an immediate need to reconcile the different PM mass emissions results reported by different currently available PM portable emission measurement systems (PM PEMS). In this way, PM PEMS can be used with confidence for emissions inventory development and other ARB needs.

In essence there are two distinct problems: 1) addressing near-term (immediate) PM PEMS data needs for ongoing and upcoming programs such as emissions inventory and emissions monitoring, and 2) addressing longer-term needs such as measurement issues and methods for late model, very low mass-emitting engines.

PREVIOUS WORK: A large body of work exists regarding both PM mass emissions measurements, as well as UFPM particle characterization. Laboratory, roadside, on-roadway, and atmospheric studies have been, and are being conducted to better understand PM formation, fate, and public exposure.

On a parallel path, a variety of real-time PM measurement instruments have been under development and are being refined. This includes such measurement techniques as laser light scattering, photoacoustic, laser-induced incandescence, quartz crystal microbalance, and taper element oscillating microbalance for mass emissions, and methods using electrical mobility for particle characterizations.

OBJECTIVE: The goal of the project is to implement a comprehensive study for addressing PM measurement issues by using various real-time instruments. The project will include both a near-term and a longer-term study.

DESCRIPTION: The project will be centered on the evaluation of real-time PM measurement instruments and would involve interested stakeholders, including other federal and state government agencies, engine/vehicle manufacturers, instrument

manufacturers, and members from academia. The overall study will include the formation of a "PM measurements panel" under the auspices of the Coordinating Research Council. The PM measurements panel would serve an advisory role on PM measurement research, and would be involved in the organization of a PM measurement workshop. The workshop would establish the best metrics to utilize to fully characterize PM emissions such as mass, number concentrations, surface area, etc., and would provide guidance to instrument manufacturers and to stakeholders planning to sponsor PM measurement-related research projects.

The study will include a near-term element that would address immediate ARB programmatic needs such as emissions inventory and emissions monitoring projects (e.g., the off-road showcase project), and would involve currently commercially available PM PEMS and focus on PM mass emissions measurements. To the extent possible, ARB test facilities would be offered as an in-kind contribution to this program, and similar in-kind (and dollar) contributions would be sought from other stakeholders. The near-term program would be expected to highlight PM measurement issues, and to some extent, serve as a prelude to the longer-term program.

The study will also include a longer-term element. For the longer-term, the objective would be to approach the problem of PM emissions measurement from the scientific perspective of health effects and atmospheric processes, but to culminate in the development of practical engineering solutions to PM emissions measurements. For example, laboratory, wind tunnel, or other methods could be evaluated for their viability to study PM formation and fate under controlled conditions with an eye towards developing test procedures and methods. Other techniques such as using particle number and morphology as a means of quantifying PM mass could also be investigated. In addition to studying real-time PM measurement methods, the viability of continued use of PM mass collected on filter-media as the regulatory 'gold standard' (reference method) would be critically evaluated.

BENEFITS: This project would benefit the ARB by establishing a single PM measurement method (or at least a set of complementary methods) that could span the entire PM mass and size domains. One immediate benefit would be the development and implementation of consistent PM measurement methods across the domain of ARB programs (something that is currently not the case). The methods developed could be used for mass emissions measurements, but could also be utilized in the event that the ARB decides to regulate ultrafine PM emissions from ICEs and other combustion sources.

COST: \$500,000 (Cofunding will be necessary to carry out this project.)