RD
Contractor: UC, San Diego
Contract # 08-323

FUNDING FISCAL YEAR	FY 08/09	FY 09/10	FY 10/11	
TERM	06/30/09-06/29/11	06/30/09-06/29/11	06/30/09-06/29/11	
PCA	72360	72360	72360	
LINE ITEM/OBJECT	398	398	398	TOTAL
DESCRIPTION				
Contract $	557,482.00	159,281.00	79,640.00	796,403.00
				-
				-
Total, Contract	557,482.00	159,281.00	79,640.00	796,403.00

Payments to Contractor:

Inv. #	Inv. Date	Ser Per				C/S
						-
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						-
Total, Payments			-	-	-	-
Balance Available to Pay Contractor			557,482.00	159,281.00	79,640.00	796,403.00
Balance Must Be Spent By:			*06/30/11*	*06/30/12*	*06/30/13*	

Notes:

Contract Manager: Nehzet Motallebi

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STATE OF CALIFORNIA
STANDARD AGREEMENT
STD 213 (Rev 06/03)

AGREEMENT NUMBER
08-323
REGISTRATION NUMBER

1. This Agreement is entered into between the State Agency and the Contractor named below:

STATE AGENCY'S NAME
Air Resources Board (ARB or State)

CONTRACTOR'S NAME
The Regents of the University of California, UC San Diego (UCSD, University, or Contractor)

2. The term of this Agreement is: June 30, 2009 through June 29, 2011

3. The maximum amount of this Agreement is: **$796,403.00**
(Seven hundred ninety-six thousand four hundred three dollars and no cents)

4. The parties agree to comply with the terms and conditions of the following exhibits which are by this reference made a part of the Agreement.

Exhibit A – Scope of Work	1 Page
Exhibit A - Attachment 1	80 Pages
Exhibit B – Budget Detail and Payment Provisions	2 Pages
Exhibit B – Attachment 1	33 Pages
Exhibit C* – General Terms and Conditions	GIA 101
Check mark one item below as Exhibit D:	
☒ Exhibit - D Special Terms and Conditions (Attached hereto as part of this agreement)	1 Page
☐ Exhibit - D* Special Terms and Conditions	
Exhibit E – Additional Provisions	8 Pages
Exhibit F – Research Report Format	6 Pages

Items shown with an Asterisk (*), are hereby incorporated by reference and made part of this agreement as if attached hereto. These documents can be viewed at www.ols.dgs.ca.gov/Standard+Language

IN WITNESS WHEREOF, this Agreement has been executed by the parties hereto.

CONTRACTOR

CONTRACTOR'S NAME *(if other than an individual, state whether a corporation, partnership, etc.)*
The Regents of the University of California, San Diego

BY *(Authorized Signature)* — DATE SIGNED *(Do not type)* 8/5/09

PRINTED NAME AND TITLE OF PERSON SIGNING
Sandra Varond, Contract and Grant Officer

ADDRESS
Office of Research, Sponsored Programs
9500 Gilman Drive, Mail Code 0210, La Jolla, CA 92093-0210

STATE OF CALIFORNIA

AGENCY NAME
Air Resources Board

BY *(Authorized Signature)* — DATE SIGNED *(Do not type)* AUG 13 2009

PRINTED NAME AND TITLE OF PERSON SIGNING
Socorro Watkins, Chief, Business Management Branch

ADDRESS
1001 I Street, 20th Floor, Sacramento, CA 95814

Sharon Simmons
Contract Services Section Manager
Air Resources Board

California Department of General Services Use Only

APPROVED
AUG 19 2009
DEPT OF GENERAL SERVICES

☐ Exempt per:

EXHIBIT A

SCOPE OF WORK

1. The Regents of the University of California, UC San Diego (UCSD, University, or Contractor) agrees to provide the following services for the project entitled "Black Carbon and the Regional Climate of California," which is attached hereto as Attachment 1 and made a part of this Agreement.

2. Term: The term of this agreement is June 30, 2009 through June 29, 2011; however no work shall commence until receipt of final approval from the Department of General Services (DGS). Consequently, all dates contained in the Exhibits and Attachments shall be considered revised to conform to the actual term of this agreement, and the schedule shall not begin until Contractor receives written notice from ARB of final approval by DGS.

3. The project representatives during the term of this agreement will be:

Requesting Agency: ARB		**Providing Agency: UCSD**	
Name:	Nehzat Motallebi	Name:	V. Ramanathan
Section/Unit:	Research Division	Section/Unit:	Scripps Institution of Oceanography
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Email:	nmotalle@arb.ca.gov	Email:	

The ARB Contract Administrator is: The University's Contract Administrator is:

Requesting Agency: ARB		**Providing Agency: UCSD**	
Name:	Emma Plasencia	Name:	Ms. Sandra Varond
Section/Unit:	Research Division Contracts Analyst	Section/Unit:	Contract & Grants Analyst
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Email:	eplasenc@arb.ca.gov	Email:	svarond@ucsd.edu

TECHNICAL PROPOSAL

Black Carbon and the Regional Climate of California

Principal Investigator:
V. Ramanathan

Official Authorized to Bind this Proposal:

Name: Ms. Sandra Varond, Contract and Grant Officer
Signature:

Prepared for:

State of California Air Resources Board
Research Division
PO Box 2815
Sacramento, CA 95812

Prepared by:

Scripps Institution of Oceanography – UCSD
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December 31, 2008

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I. Abstract.

In California, warmer temperatures, summer water shortages, and increased wildfires have received increasing attention. To address these environmental issues and reduce the warming commitment, the California Air Resource Board (CARB) has adopted the nation's most sweeping global warming plan, outlining for the first time how individuals and businesses will have to meet a landmark 2006 law that made the state of California a leader on curbing the emissions of greenhouse gases. Black carbon (BC), as the main light-absorbing component of soot, has also been recognized as one of the largest contributors to the global warming, and tied to the observed regional climate changes by recent studies. Unlike the greenhouse gases, BC tends to suppress the precipitation and dry the climate through its solar heating of the atmosphere and dimming at the surface. Deposition of BC on snow and ice leads to faster and early onset of snow melting and potentially affects the freshwater availability, emerging as a major driver for the glacier retreats and the decrease of local rainfall. Policy makers and air quality regulators need to be fully informed on the magnitude and importance of the BC radiative impacts, and the subsequent climate response, in their decision making of control strategy on mitigating the climate effects of BC emissions.

We are proposing to adopt a balanced approach between observations, data analyses and modeling studies to provide a comprehensive assessment of the radiative forcing and climate impact by BC aerosols in California. The approach consists of three steps: creating an integrated observational data set of BC regional properties including time series of concentrations and composition, vertical profiles, the mixing state, and deposition on snow; estimating the 3-D structure of the radiative forcing of BC and other aerosols; and finally estimating the impact on climate change and climate feedbacks, using a regional climate model. Specifically, the spatial and temporal variations in the ambient BC concentrations and optical properties throughout California will be evaluated, based on multi-platform (satellite, aircraft, and surface) observational data assimilation for the 1967 to 2007 period. Single-particle measurements (ATOFMS) will be used to make a first investigation of BC mixing state. We will estimate the total radiative forcing of BC based on the assimilated aerosol properties (optical depths, absorption optical depth, vertical distribution, black carbon fraction, mixing state), and use a coupled regional chemical transport model (WRF-Chem) to determine the anthropogenic fraction

of the forcing and attribution to the regional sources. Based on the mass spectral fingerprints from the single particle analyses, which can uniquely identify the sources and degree of atmospheric processing of the soot particles, we will perform source apportionment and make a preliminarily estimate of the BC radiative forcing associated with particular fuels (diesel, ships, biomass burning) using the MACR radiation model. The forcing will be calculated for the 2001 to 2007 period, and scaled backwards in time to 1967 according to time series of the coefficient of haze (COH) data derived from the light attenuation measurements. With the improvements in the estimated BC radiative forcing constrained by observations, we will make a preliminary assessment of the regional climate response including temperature, precipitation, snow melt, etc. based on the regional climate model simulations. The proposed two-year effort combining observational and modeling studies will provide insights on the role of BC aerosols in California weather and climate, and help remove impedance to policy-making decisions.

II. Statement of significance

The fundamental goal of this interdisciplinary proposal is to make the first observationally constrained assessment of the importance of black carbon forcing for California's climate. Over the past decade the issue of black carbon (BC), the main light-absorbing component of soot, has moved to the forefront of climate change research. These aerosols have direct and indirect effects on both regional and global climate due to their unique light absorption properties relative to most other aerosols. It is now recognized that black carbon aerosols are the principal absorber of visible solar radiation in the atmosphere. According to a recent assessment by [*Ramanathan and Carmichael*, 2008], BC is the second largest contributor to global warming with an estimated radiative forcing of 0.9 W/m^2, compared to 1.6 W/m^2 for CO_2 [*Forster et al.*, 2007].

Background:

BC impacts climate in several ways. First, atmospheric black carbon forms extensive "brown clouds" that absorb incoming solar radiation and cause dimming at the planet's surface. This warms the atmosphere relative to the planet's surface, stabilizing the atmosphere and suppressing convection, which in turn reduces regional rainfall and changes the spatial distribution of precipitation [*Chung et al.*, 2005; *Menon et al.*, 2002]. Extensive Atmospheric "brown clouds" (ABCs) generated over the tropics in South America [*Andreae et al.*, 2004], Africa, India, and South East Asia [*Ramanathan et al.*, 2007] decreases the amount of sunlight reaching the adjacent oceans, thereby reducing evaporation in tropical regions which drives the global hydrologic cycle [*Ramanathan et al.*, 2005]. Black carbon aerosols in clouds, interstitial or encapsulated in cloud droplets, can enhance the absorption of solar radiation, increase cloud evaporation and decrease cloud lifetime by heating the atmosphere [*Ackerman et al.*, 2000; *Chylek et al.*, 1984]. Deposition of BC on snow and ice may reduce the reflectivity of the snow or ice surface, heat the surface, and lead to faster and earlier melting of glaciers, sea ice, and mountain snow packs [*Clarke and Noone*, 1985; *Hansen and Nazarenko*, 2004]. Lastly, when BC is internally mixed with sulfate, nitrate, or organic carbon, the absorption efficiency significantly increases. Thus internally mixed BC particles may absorb more than twice the amount of sunlight relative to an external mixture. And scattering aerosols such as sulfate, which tend to exert a cooling effect on the climate, may be converted to strongly absorbing aerosols by

mixing with BC [*Jacobson*, 2001; *Schnaiter et al.*, 2005]. Unlike greenhouse gases, which lead to a warmer wetter world, black carbon aerosols warm and dry the climate.

California's regional climate may especially be sensitive to these radiative effects of BC. Summer water supplies in California rely predominantly on run-off from mountain snow packs located within the state as well as from the Rocky Mountains via the Colorado River. Agriculture, which represents a large fraction of California's economy, suffers drastically during water shortages. The potential impact of aerosols including BC on precipitation and freshwater availability has received increasing attention in California [*Jacobson*, 2007; *Lynn et al.*, 2007]. Furthermore, a warmer atmosphere over already dry regions, combined with less mountain run off during the summer months, leads to optimal conditions for wildfires. A recent study has tied an observed increase in frequency and duration of wildfires in Western United States to warmer temperatures, earlier snowmelt, and drier summers [*Westerling et al.*, 2006]. On the other hand, increases in wildfires serve only to further amplify the concentration of light absorbing carbon particles and subsequent climate impacts on California.

Reducing the positive radiative forcing of short-lived aerosol species such as BC has been suggested as an attractive control strategy for mitigating climate change [*Menon et al.*, 2002; *Ramanathan and Feng*, 2008]. Resolving uncertainties in the radiative forcing of BC will remove impedance to policy-making. This study will use both current and historical data collected at various locations in California, combined with chemical transport, radiative, and climate models to determine the magnitude of BC radiative effects on California's regional climate, as well as the long-range transport and major sources for the observed BC.

Testing of Hypotheses:

This two year effort will address the question: how important is BC to regional climate change in California, particularly with respect to the recent observed trends of warming, drying and early melt of the snow packs. Secondly, we will make preliminary estimates as to the relative source contribution to the black carbon RADIATIVE FORCING in California. While the results of this first phase may not address the specific issues that are of immediate concern to decision makers and other stakeholders (e.g., water managers), it will, by scoping out the magnitude and

importance of the issue, help CARB assess whether more detailed investigations of the BC-CA climate problem are warranted.

III. Project objectives

The goal of this project is to assess the impact of BC on California climate. This will be accomplished through the completion of three tasks which cover observational data and observationally constrained model assessments.

Task 1

First we will evaluate the spatial and temporal patterns of ambient BC concentrations and optical properties throughout California. We will use satellite, aircraft, and surface BC data over California to create a 3-dimensional gridded data set. We will use this data to explore seasonal variability and long term trends in BC concentration. Single particle measurements using the ATOFMS (Aerosol time-of-flight mass spectrometer) (funded last two years by CARB) from sites in California will be used to make a first estimate of BC mixing state. The mixing state of BC is important in determining the optical properties, and therefore the climate forcing in the following tasks. COH (co-efficient of haze) has been correlated with BC concentration and may be used to estimate temporal variations in BC from 1967 to 2003.

Task 2

Second, we will estimate the radiative forcing of BC over California constrained by assimilated aerosol properties (optical depths; absorption optical depth; vertical distribution; black carbon fraction; mixing state) from the previous task. Both the total BC radiative forcing and the anthropogenic fraction of the forcing will be determined using coupled regional chemical transport models. The forcing will range from 1967 to 2007. For the 2001 to 2007 period, we will use assimilated aerosol properties. The forcing thus estimated will be scaled backwards in time to 1967 using time series of the coefficient of haze (COH) determined from light attenuation measurements. We will make a preliminary apportionment of BC radiative forcing associated with the emission sectors (biomass burning, diesel, ships, etc.) in CA, based on the source identification information from the ATOFMS single particle analyses.

Task 3

Third, we will make a preliminary investigation of regional climate responses (temperatures; precipitation; solar radiation including PAR) and feedbacks in the Californian region due to BC aerosols.

IV. Technical plan

1. Previous and current work

Compared to greenhouse gases, aerosol concentrations have much greater spatial and temporal variation because they reside in the atmosphere for much shorter times. Consequently, frequent measurements at numerous sites are needed to reliably track trends in aerosol concentrations and evaluate the changing impact of aerosols on climate over time. There are, however, few extensive records of aerosol concentrations in existence. One of the longest BC records is from coefficient of haze (COH) measurements in California. COH levels recorded at 100 sites throughout California have been archived by the California Air Resources Board (CARB). We previously analyzed a fraction of this data set to derive ambient BC concentrations in the San Francisco Bay Area over the 37-year period from 1967 to 2003 (Figure 1).

Like modern measurements of BC made with the aethalometer, COH values are a measure of light attenuation by particles, and available data indicate that COH values are proportional to BC concentrations [*Allen et al.*, 1999; *Kirchstetter et al.*, 2008]. Our analysis, which addressed the relative importance of BC sources in the Bay Area and provided a temporally resolved record of BC concentrations, demonstrates the value of long-term records of aerosol measurements. Reduced BC concentrations on weekends relative to weekdays are consistent with reduced diesel traffic on weekends, and peak concentrations in winter are consistent with reduced dispersion (mixing height and wind speed) and possibly wood burning in winter (Figs 1a,b). BC concentrations have decreased markedly since 1990 despite continued increase in diesel fuel consumption, consistent with an order of magnitude decrease in on-road diesel vehicle BC emission factors during the past 35+ years (Figs 1c,d). Additionally, preliminary analysis of

annual average BC concentrations in three air basins in California are coincident with an observed statewide surface temperature increase [*Novakov et al.*, 2008], suggesting that a reduction in aerosol concentrations may have contributed to the observed surface temperature increase.

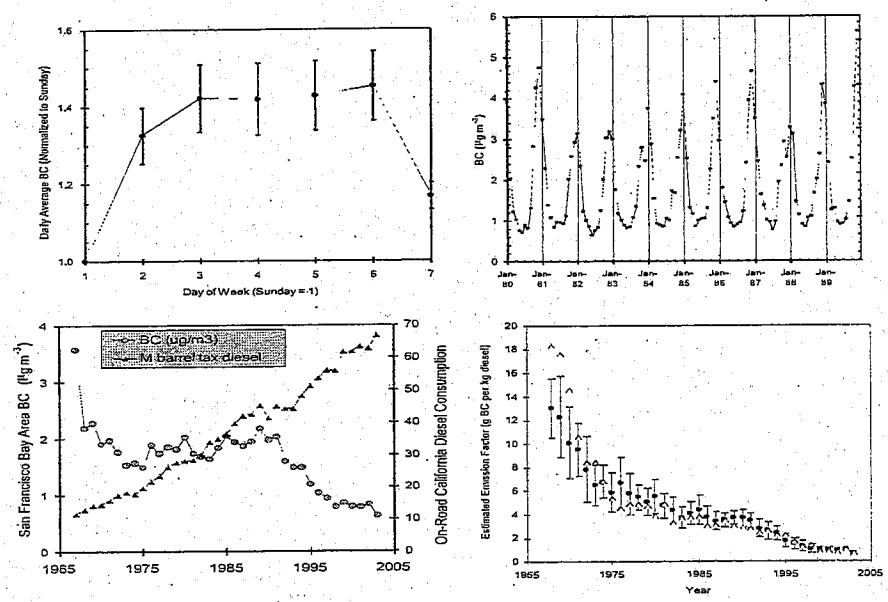

Figure 1. Trends in San Francisco Bay Area BC concentrations [*Kirchstetter et al.*, 2008] (a) day of week, (b) seasonal, (c) long term; and (d) estimated diesel vehicle BC emission factors based on annual average 2007 (•) and summertime average (Δ) Bay Area BC concentrations.

For the long-range transport of BC in California, we estimated that the trans-Pacific transport of BC to the west coast of North America during April 2004 was approximately 25 – 32 Gigagrams, of which roughly 75% originated in Asia [*Hadley et al.*, 2007]. Most of this transport (>78%) was located above 2km, where the westerlies are strongest. Using the CFORS (Chemical weather FOrecast System) chemical transport model, the contribution of Asian BC to total BC over California below 2 km was predicted at 20 to 30%. The model, however, tended to drastically over predict BC in the boundary layer, and therefore the actual contribution at low elevations is likely smaller. In a subsequent study (in preparation), using elemental markers for Asian transport and comparing to observed BC, the estimate of Asian contribution to BC in California's mountain elevations in the spring was lowered to 25 to 30%. At other seasons the

contribution is much smaller as spring marks the peak in observed trans-Pacific transport [*Liu et al.*, 2003]. Based on modeled and measured BC distribution in the atmosphere over California and using the MACR (Monte Carlo – Aerosol Cloud Radiation) model, the estimated mean forcing of BC over California in April 2004 is shown in Table 1.

Table 1. BC forcing (Wm^{-2}) over California [*Hadley et al.*, 2007]

TOA	ATM	SFC	Comments
1.08	2.55	-1.47	Clear sky land (land albedo=0.23 from MODIS)
0.66	1.91	-1.25	Including regional mean cloud properties

In order to determine the possible significance of BC on California mountain snow pack, we collected snow and rain samples at two mountain locations and on the coast in California during March and April 2006. Results from this study are currently in preparation for publication. The concentration of BC in falling snow in California mountains in March 2006 was on average 5 to 8 ng/g. Based on previous modeling studies of the effect of BC on snow albedo [*Chylek et al.*, 1983; *Flanner et al.*, 2007; *Grenfell et al.*, 2002; *Jacobson*, 2004], we estimate that this concentration of BC is sufficient to melt roughly an additional half liter of water per m^2 per day during the spring. This estimate does not account for positive feedbacks, whereby the crystals in aging snow grow larger and increase BC absorption efficiency by more than a factor of three. In addition to snow collection, ambient atmospheric concentration of BC was also measured in the mountains. Comparing this with the amount removed by the snow indicated that heavy snowfall (>10 mm/day) effectively transports all the BC in the atmosphere to the snow pack.

Combining satellite aerosol data, surface network of aerosol remote sensing instruments and field observations together with chemical transport and radiative transfer models, we estimated that the global mean BC direct radiative forcing for the 2001 to 2003 period is 0.9 Wm^{-2} at the top of the atmosphere (TOA), with about ±50% uncertainty [*Chung et al.*, 2005]. This estimate is consistent with and slightly in the high end of the latest IPCC assessment for BC radiative forcing [*Forster et al.*, 2007], 0.45±0.25 Wm^{-2}. This is likely due to our adoption of aerosol absorption retrieved from the worldwide surface network of solar spectral radiometers (AERONET), which tend to be a factor of two or more larger than the GCM-simulated values [*Sato et al.*, 2003; *Schuster et al.*, 2005]. In the Californian region, the annual mean BC-induced surface dimming (reduction in the surface solar radiation) is estimated at about -3 Wm^{-2} to -12

Wm^{-2} according to the global model study, and thus can mask the greenhouse warming at the surface, whereas the increase of solar heating in the atmosphere is about 2 Wm^{-2} to 6 Wm^{-2} and thus can augment the greenhouse warming at high altitudes [*Ramanathan and Carmichael*, 2008]. Note that the annual mean BC forcing at the surface is much greater than the estimate for BC forcing over California during April 2004 (Table 1). This could be due to much greater concentrations of BC measured in the late summer and early autumn in California.

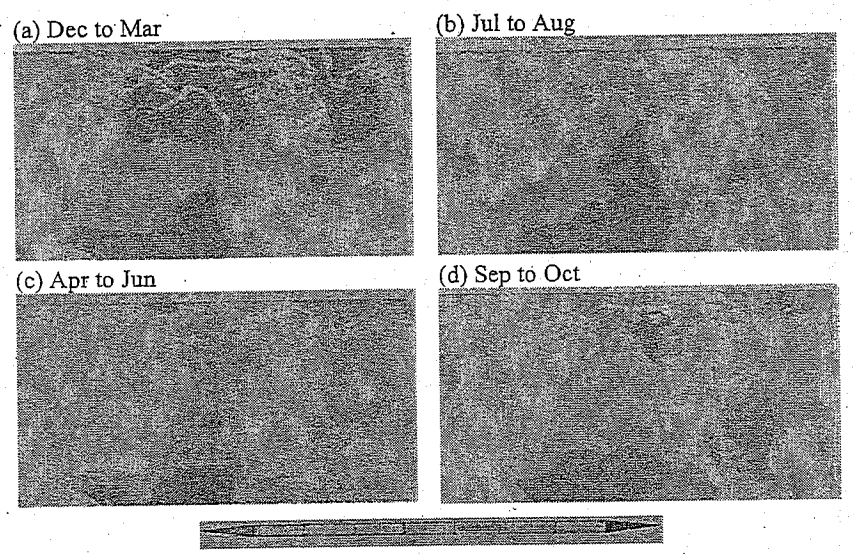

Figure 2. Trans-oceanic, and trans-continental black carbon aerosols, represented by the assimilated anthropogenic aerosol absorbing optical depth in four seasons of the year [*Chung et al.*, 2005; *Ramanathan et al.*, 2007]

Figure 2 illustrates seasonal and geographical variations in the assimilated absorbing aerosol optical depth (mainly due to BC), including both long-range transported and local emissions [*Ramanathan et al.*, 2007]. The largest aerosol absorption occurs during the dry season from Sep to Oct, which also overlaps with the intensive irrigation activities, accompanied with significant land-use changes. Maximum absorbing AOD values reach to ~0.06 in the S. California, Los Angeles area, implying the dominance of local BC emissions. In winter, the anthropogenic AOD is the lowest of the year, as aerosols are mostly washed out by increasing precipitation. From Apr. to Jun., the long-range transported pollution plumes from E. Asia contribute to the build-up of absorbing aerosols on the west coast of California. In spring and summer (Apr through Aug), a heavy anthropogenic pollution plume (both BC and non-BC aerosols) with AOD of 0.4

originates from Central America near Mexico city; although the majority of this plume moves northeastward due to the persistent subtropical Californian high pressure system, some of the pollution may cross into S. California by the small- to meso-scale processes.

Vertical profiles of Black Carbon Measurements using UAVs (Unmanned Aerial Vehicles) over California

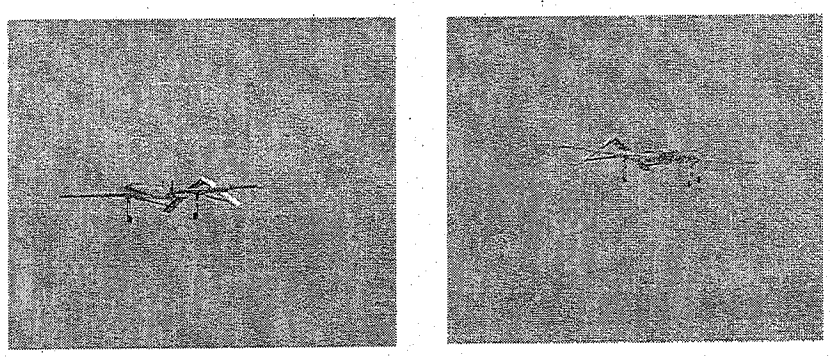

Figure 3. UAVs in flight (left) clear skies and (right) hazy skies.

One of the major uncertainties in calculating BC radiation forcing is the vertical distribution of BC in the atmosphere. With funding from the California Energy Commission, we have been flying UAVs (Unmanned Aerial Vehicles), outfitted with a variety of aerosol and cloud measuring instruments, in California since early May 2008 (Figure 3). Each flight produces data for the vertical distribution of BC (Figure 4) and aerosol number concentration, down welling and upwelling radiation, and cloud droplet concentration.

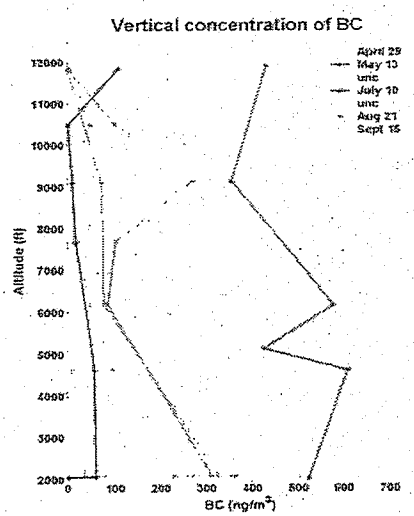

Figure 4. Vertical profiles of BC concentration in April 2008, at NASA Dryden, CA (Corrigan et al. unpublished 2008)

The aircraft also provide data on temperature, pressure, and relative humidity. As these flights are ongoing, they provide information regarding the seasonal variability not only in BC concentration, but in vertical distribution as well.

In the regional climate over California, soot-induced snow albedo changes can have large impacts on the surface energy and water budgets, with important feedbacks. Instead of prescribing surface radiative forcing, we calculated soot-induced snow albedo changes based on BC simulated by the WRF-Chem regional coupled atmosphere-chemical transport model. Two regional climate simulations were then performed using WRF with and without snow albedo changes based on the WRF-Chem simulated BC deposition [*Qian et al.*, 2008]. We estimated that the soot-induced snow albedo perturbations increase surface net solar radiation flux during late winter to early spring, increase surface air temperature, and reduce snow accumulation and spring snowmelt. The indirect forcing of soot accelerates snowmelt and alters stream flows, including a trend toward earlier melt dates in the western US. The estimated snowpack reduction of up to 30% during spring in the Rockies (Figure 5) is comparable to the projected changes in snowpack due to greenhouse warming by the mid-century [*Leung et al.*, 2004].

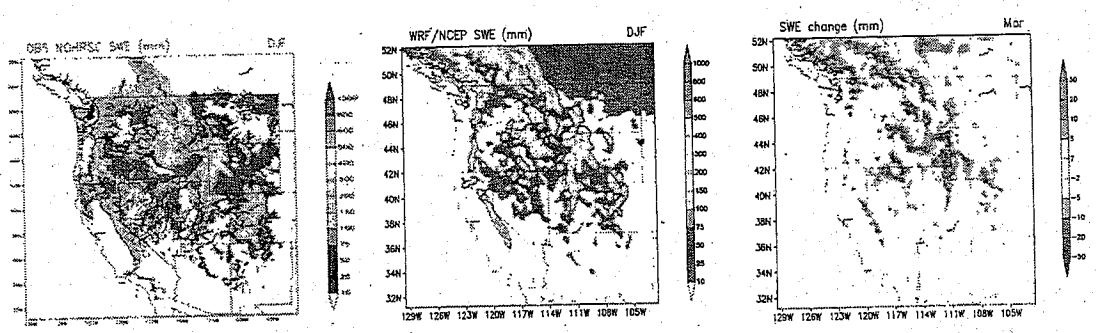

Figure 5. Observed (left) and simulated (middle) snow water equivalent (SWE) in the western U.S., and simulated changes in SWE (right) due to soot-induced snow albedo changes. Model simulations were performed using WRF-Chem at 15 km grid resolution with observed emissions. Two long-term WRF regional climate simulations were then performed with and without the BC deposition and soot-induced snow albedo changes to simulate the impacts of BC on the regional climate of the western US.

Finally, a key component of this proposal will involve using actual single particle mixing state measurements to constrain models used to calculate the radiative forcing of atmospheric soot particles in California. Previous studies have been forced to make major assumptions regarding the size, mixing state, and optical properties of ambient soot particles, resulting in tremendously large uncertainties in predictions of the direct forcing of soot. The Prather group has performed single particle measurements of soot at many locations around the world with a particular focus on California. We have shown in these studies that soot is typically highly mixed with sulfate,

nitrate, or both species the majority of the time. Figure 6 shows a map of the world with all measurements showing that most soot is mixed with some secondary species in most locations. Most research focuses on soot-sulfate mixtures but one can see from this figure that soot in California is more commonly mixed with nitrate. Soot-nitrate vs. soot-sulfate has the same effect on the optical properties. The nitrate coatings along with other secondary components result in a collapsed core-shell arrangement of an absorbing soot core with a reflective thick shell. We will use these findings to guide the inputs into models.

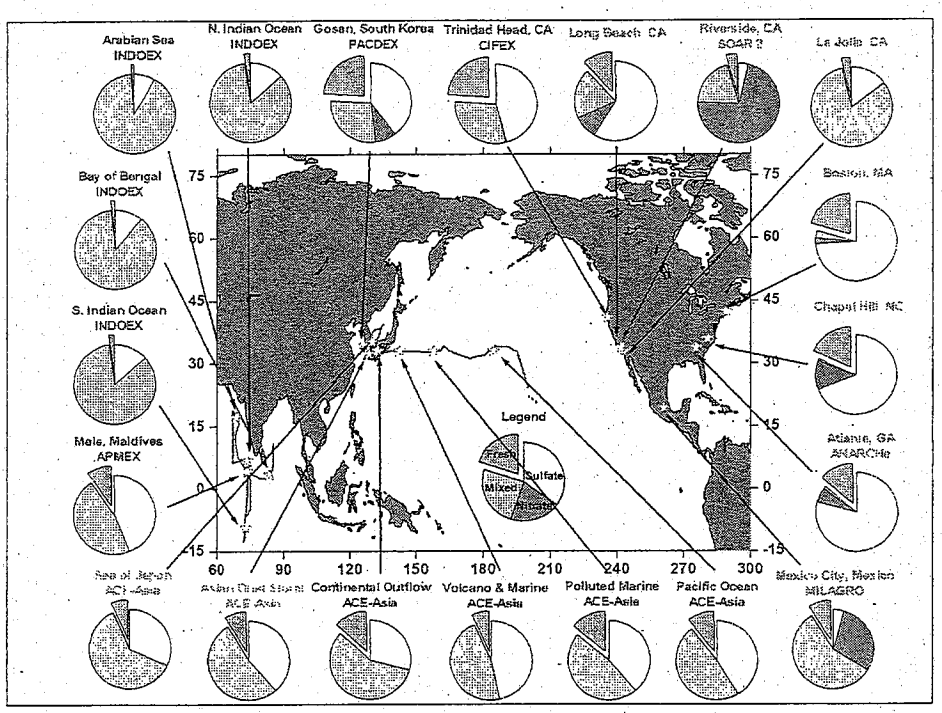

Figure 6. A map of the world with all measurements showing that most soot is mixed with some secondary species in most locations.

2. Proposed work

The 3 tasks in the proposed study fall under two broad categories: 1) Observational estimates and 2) Regional modeling studies with data assimilation. Project management table gives the various sub tasks and the scientists who will be undertaking the various tasks.

Category 1: OBSERVATIONAL ESTIMATES (Tasks 1 & 2)

Task 1: Evaluate spatial and temporal patterns in ambient BC concentrations and optical properties throughout California, based on multi-platform (satellite, aircraft, and surface) observational data assimilation; Single particle measurements (funded last two years by CARB) over limited sites in CA will be used to make a first estimate of BC mixing state; use COH data to estimate temporal variations in BC from 1967 to 2003.

Task 2: Estimate the radiative forcing of BC over California constrained by assimilated aerosol properties (optical depths; absorption optical depth; vertical distribution; black carbon fraction; mixing state) for the total BC radiative forcing and by coupled regional chemical transport models for the anthropogenic fraction of the forcing. The forcing will range from 1967 to 2007. For the 2001 to 2007 period, we will use assimilated aerosol properties. The forcing thus estimated will be scaled backwards in time to 1967 using time series of the coefficient of haze (COH) determined from light attenuation measurements.

The analyses described below will integrate the following data sets:

1) IMPROVE data for seasonal variations in BC and aerosol speciation
2) AERONET data for column averaged single scattering albedo
3) ATOFMS single particle mass spectral and optical data for size-resolved BC mixing state
4) MODIS and MISR satellite data for aerosol optical depths and for one choice of anthropogenic fraction
5) UAV data for aerosol vertical distribution
6) Regional aerosol-chemistry model for filling gaps in aerosol chemical speciation data and data for BC and for anthropogenic fraction
7) COH analyses to scale the forcing back in time for past 40 years

Task 1.1 Spatial and temporal patterns in BC concentrations using the CARB COH data

a) The conversion of COH to BC in [*Kirchstetter et al.*, 2008] was derived from a limited number of collocated BC and COH measurements. At the start of the proposed research, we will work with the Bay Area AQMD to reinstall COH monitors at two monitoring sites currently equipped with aethalometers. Our analysis will seek to strengthen the COH-BC relationship by collecting new data at BAAQMD sites and gathering additional data from regions in and outside of California. These data will be used to verify the relationship between COH and BC and determine temporal and spatial variability.

b) Extending prior analyses for the Bay Area (Figure 1), statewide temporally and spatially resolved BC concentrations will be derived by analyzing COH data recorded at 100 locations throughout California (data available from CARB). Our analysis will evaluate regional BC concentrations over different time scales – diurnal, weekly, seasonal and long term – to infer predominant BC emission sources (e.g., wood burning vs. diesel), assess population exposure to combustion-derived particulate matter, and assess the net effect of growth in source activity and improved emission controls from the 1960s to present day.

c) Prior studies attributed global dimming since the 1950s – the gradual reduction in the direct irradiance at the Earth's surface, which may have masked global warming – and the sudden reversal to global brightening since 1990 to global aerosol levels [*Hegerl et al.*, 2007; *Nazarenko and Menon*, 2005]. California surface temperatures have increased over the past few decades and mostly since 1990 [*Duffy et al.*, 2007]. We will extend our prior work [*Novakov et al.*, 2008] by combining the derived history of BC concentrations with other archived aerosol data for California and comparing them with regional trends in temperature in California. Our analysis will consider the observational evidence for aerosol-mediated surface temperature change in California.

Task 1.2 Multi-platform data analysis for BC and other aerosol properties

The procedure for integrating such multi-platform data sets has been developed over the last 10 years at SIO for the Asian region [*Ramanathan et al.*, 2001; *Ramanathan et al.*, 2007]. We will adopt this approach for California. Basically it consists of the following steps:

i. Column Integrated Aerosol Optical Depths (AOD): Satellite-based aerosol optical depth (both total and that due to small particles) measurements will be used to form the core observational data set for the data assimilation. Both the MODIS (Moderate Resolution Imaging Spectro-radiometer) and MISR (Mulit-angle Imaging Spectro-radiometer), flown on the satellite Terra, provide aerosol optical depth on a daily basis over California at 1°×1° grids. We will rely primarily on MODIS data since it dates back to 2001.

ii. Column integrated Absorption Optical Depths (ABS_AOD): The next important information concerns the absorption optical depth, ABS_AOD, which will be obtained by the AERONET network. Given the sparse nature of this network, we will use the Aerosol Robotic Network (AERONET) sites located in California [*Schuster et al.*, 2005] for the ABS_AOD and use WRF_CHEM regional model (described later) for filling the spatial variations in ABS_AOD between the AERONET sites. The procedure for such gap-filling has been described in Chung et al [*Chung et al.*, 2005].

iii. Vertical profiles of BC. Ramanathan group's UAV (Unmanned Aerial Vehicles) program has begun routine vertical profiling measurements over Southern California. This project, named as CAPPS, is being funded by CEC (http://www-ramanathan.ucsd.edu/capps.html) and has data since May 2008. The ABS-AOD will be scaled by the vertical profile measurements of BC (from the UAV) to obtain vertical variations in absorption optical depths. The employment of the UAVs allows us to make direct and simultaneous measurements of the vertical distribution of aerosols and the atmospheric heating rates due to BC absorption [*Ramana et al.*, 2007], and compare them with the model simulations. The vertical profile of absorbing aerosols is considered to be one of the largest uncertainties in current aerosol models, and yet significantly impacts the estimation of aerosol radiative forcing [*Chung and Seinfeld*, 2002; *Haywood and Ramaswamy*, 1998; *Podgorny and Ramanathan*, 2001]. Therefore, the *in situ* UAVs measurements will greatly improve the model performance on the atmospheric absorption by aerosols. However, the UAV data is available for only one location and we will use this as a representative profile for southern California. We will validate the WRF-CHEM model for this site and use WRF_CHEM model for rest of California.

iv. Optical Properties: In principle, the AOD and ABS-AOD yields over 90% of the information needed to get the forcing. We need the asymmetry parameter (fraction of radiation scattered in the backward direction) and for this purpose we will use ATOFMS data. A unique strength of the proposed project is that we will use direct *atmospheric* soot measurements with unique details on size, chemical mixing state, and the corresponding optical properties [*Prather et al.*, 2008]. We have also measured the timescale for conversion from fresh to aged in previous studies [*Moffet and Prather*, 2008; *Moffet et al.*, 2008]. Single particle mass spectra can be used to identify fresh versus aged soot in previous studies as shown in Figure 7; two distinct types of mass spectra for fresh and aged soot particles are shown.

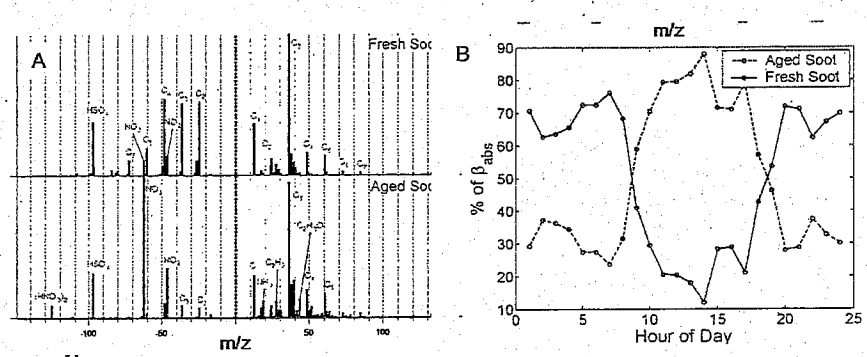

Figure 7. Two distinct types of mass spectra for fresh and aged soot particles.

In the panel on the right, the timescale for the soot to convert from fresh fractal soot to collapsed spherical soot was measured using ATOFMS. In these studies, the optical properties of soot in these different forms were also directly measured. Fresh soot dominated the absorption in the morning hours, whereas aged coated soot dominated in the afternoon. Interestingly the concentrations of soot were much lower in the afternoons, but since the particles were heavily coated with sulfate, nitrate, and other secondary species, they were strongly absorbing. We will use such findings and insights on the temporal evolution of soot in the proposed project to assess the forcing of soot without having to make assumptions on size, shape, chemistry, or optical properties.

v. Forcing due to Snow darkening: Finally, the previous field study on BC deposition on Californian mountain snow pack [*Hadley et al.*, 2007] provides the observational basis to account for the snow albedo changes in regional climate model simulations. Although we do not

anticipate the need for additional measurements to be made for this study, if the necessity of such measurements arises, they will be included.

vi. Validation: The data sets, until this; point, will generate spatial and seasonal variations in aerosol properties including the surface black carbon levels (through the ABS_AOD for the lowest level). A proper validation of this data set will provide a powerful test of the simulated data sets. In addition to the COH data analysis that would provide temporal trends for BC concentrations in California, we are also proposing to compile several years (2001-2007) of BC data taken from multiple locations and platforms in CA. The BC and other aerosol data from the IMPROVE (Interagency Monitoring for Protected visual environments) network collected at 13 remote locations in CA will be used alongside the COH data for surface concentrations of BC. These data are collected every third day and constitute a complete record of BC concentration from 2001 to 2007 giving us spatial as well as seasonal variability in BC concentration. If necessary, the integrated data sets will be adjusted or nudged to agree with the COH and IMPROVE data sets.

Task 2.1 Radiative forcing from 1967 to 2007 based on observed aerosol properties

This task consists of four steps:

a. The observationally determined aerosol properties (developed under Task 1.2) will serve as input to the field tested MACR (Monte-Carlo-Aerosol-Radiation model) developed at SIO (Podgorny and Ramanathan 2001 and Ramanathan et al 2001) for deriving the forcing from the Indian Ocean Experiment. We will do the forcing calculations for 6 years from 2001-2007, during when the regional climate in California experienced rapid changes. The key distinguishing part of MACR is that it adopts observed spatial and seasonal variations in cloud properties (altitudes; fraction; liquid water content) as described in Kim and Ramanathan [*Kim and Ramanathan*, 2008].

b. Step (a) will yield the forcing for the total (natural and anthropogenic) aerosols. But, we need the anthropogenic forcing. For this purpose we need to determine the anthropogenic fraction of the forcing and we will make two independent estimates of this fraction: Use fine particle MODIS as one estimate of anthropogenic aerosols and WRF-CHEM for the second independent estimate of the anthropogenic fraction. In addition, we will keep track of the forcing due to wildfires, since these may also be anthropogenic (being driven by the

drying due to global arming).

c. The next step is to determine the forcing from BC transported from regions outside California. Since the forcing estimates based on the present-day aerosol assimilations cannot distinguish the anthropogenic and natural components, a global aerosol and chemistry transport model (IMPACT) will be adopted to determine the fractional contribution to total concentrations by anthropogenic aerosols in California, and further obtain the anthropogenic influence in BC radiative effects. Furthermore, the global model will be used to determine the attributions to the observed BC in California, from either the long-range transport (from N America; Mexico; East Asian) or local emission sources.

d. The above steps will yield the forcing for 2001 to 2007. We will scale this forcing (for 2001 to 2007) with temporal BC variations from Task 1.1 to derive the long term trends in the forcing from 1967 to 2007.

Task 2.2 Preliminary source apportionment of climate forcing over a few locations

Results from transient climate simulations of the last four decades have clearly demonstrated the impacts of anthropogenic aerosols on surface radiation budgets, precipitation, and surface temperature, which have mapped well with observations from 1960-1990 and 1990-2000 [*Nazarenko and Menon*, 2005]. Regional differences were significant and correlate to policy actions on emissions. Additionally, biomass sources of carbonaceous aerosols have lower forcing efficiencies (ratio of radiative forcing to column burden) than do those for biofuel or fossil fuel sources [*Menon et al.*, 2008].

Another use of the already collected ATOFMS single-particle data in CA in previous studies funded by CARB will be used to identify and determine the radiative forcing of soot particles from different sources in the assimilated aerosol concentration and AODs. As depicted in Figure 8, the ion fingerprints from each single particle can be used to uniquely identify the sources and degree of atmospheric processing of the soot particles. Using ATOFMS, we also have measured how changes in size and chemistry of ambient soot particles affect the measured optical properties of each of these particle types. Based on this information, we will estimate the BC radiative forcing and climate impacts associated with particular fuels (biofuel, diesel, gasoline, biomass) using the MACR radiation model. The ATOMFS data is available at several locations in California.

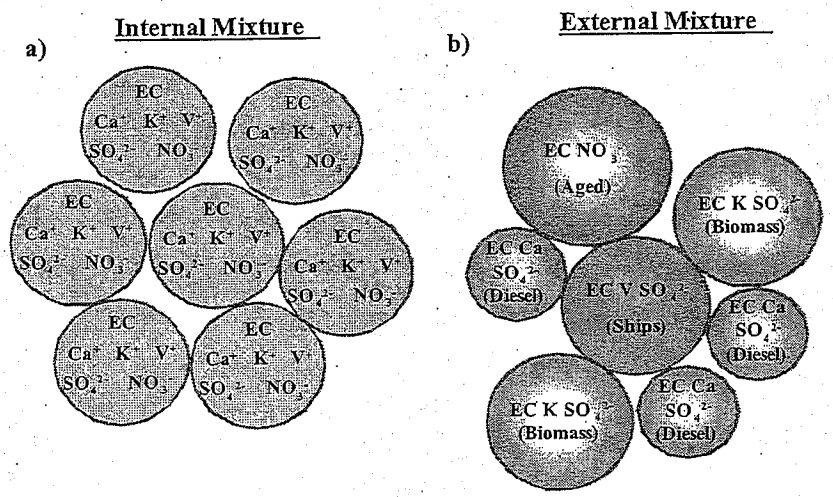

Figure 8 (a) Internal (bulk measurements) versus (b) external mixture (single particle measurements) view of ambient soot particles, showing how size, chemistry, and source can be used to distinguish between different sources of soot. The optical properties of the correct scenario in (b) will be input into models to calculate the radiative forcing of the soot aerosols in California.

These data will allow BC source apportionment near the surface, but they will not provide information on the sources of BC as a function of altitude. The vertical distribution of BC is an important determinant of total BC climate forcing. The altitude dependence of the soot mixing state has been measured in a recent aircraft ATOFMS study conducted in acquired in Colorado. The ATOFMS will also be flown as part of Calnex on the DOE G1 aircraft so further insights will be obtained as to the mixing state of BC for aerosols in California. We will also determine how the sources of BC vary in California as a function of altitude. This information will be combined with the regional transport model to estimate BC source apportionment throughout the troposphere, including the fraction of BC transported from outside of the state. The fraction of forcing due to each source type may be estimated using the results. Alternate estimates can be derived from the regional transport (PNNL) and global (LBNL, UCSD) models. These preliminary source apportionments of the BC climate forcing for the State would be a significant first step toward resolving uncertainties and informing policy for controlling short-lived aerosol species such as BC as strategy for mitigating climate change.

Category 2: REGIONAL MODELING STUDIES WITH DATA ASSIMILATION (Tasks 2 & 3)

Task 2: Estimate the radiative forcing of BC over California constrained by assimilated aerosol properties (optical depths; absorption optical depth; vertical distribution; black carbon fraction; mixing state) for the total BC radiative forcing and by coupled regional chemical transport models for the anthropogenic fraction of the forcing. The forcing will range from 1967 to 2007. For the 2001 to 2007 period, we will use assimilated aerosol properties. The forcing thus estimated will be scaled backwards in time to 1967 using time series of the coefficient of haze (COH) determined from light attenuation measurements.

Task 3: Make a preliminary investigation of regional climate responses (temperatures; precipitation; solar radiation including PAR) and feedbacks in the Californian region due to BC aerosols

Task 2.3 Aerosol forcing from the integration of aerosol observations with the WRF-Chem model

The integration of the observational data sets with a regional chemical transport model (WRF-Chem) will follow an approach similar to the collaborative efforts of the SIO, PNNL, and the Univ. of Iowa groups [*Adhikary et al.*, 2008]. These two studies set the stage for the proposed data assimilation in this study. We propose to use the regional Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) developed at LBNL and UCB to simulate aerosols and their precursors. The spatial scales and nesting features of the WRF-Chem model will allow us to simulate aerosol properties at a fine resolution [*Grell et al.*, 2005], with the built-in option to zoom into a particular region of interest at the km scale. Thus, we will be able to simulate aerosol effects on climate from the urban to the regional scale. Based on the model-simulated aerosol concentrations and chemical species specific extinction coefficients [*Penner et al.*, 2002], we will calculate the two-dimensional distribution of AODs in California. Lastly we will apply an optimal assimilation algorithm [*Adhikary et al.*, 2008] to the model-calculated and observational-based AOD distributions, and yield assimilated fine-mode and total AODs for the entire Californian region, on daily and monthly basis. The data assimilation also impacts the simulated anthropogenic aerosol concentrations (sulfate, black carbon, and organic carbon) linearly, based on the ratio of assimilated fine-mode AOD to the modeled total AOD. We will compare the daily assimilation results for AOD and aerosol mass distributions to AERONET and IMPROVE (PM and BC) data over California, to evaluate the assimilated fields.

We will estimate the aerosol radiative forcing predicted by the WRF-Chem model by using the aerosol sectional method model – MOSIAC (Model for Simulating Aerosol Interactions and Chemistry) that is coupled to the NASA Goddard atmospheric radiation scheme in WRF-Chem. We can then determine differences in radiative forcing that result from using the SIO-MACR model versus those obtained using the NASA Goddard radiation scheme. Based on these differences we may improve the representation of aerosol radiative properties in the NASA Goddard radiation scheme since one of our future objectives is to use WRF-Chem as a predictive tool to simulate future climate change for CA as well as to apportion radiative forcing from different aerosol sources.

Task 3 Assessment of climate impacts due to BC based on the derived radiative forcing from Tasks 2.1 and 2.3.

To determine the impacts of BC on the regional climate of California, we will perform regional climate simulations using the WRF-climate model developed at PNNL [*Leung et al.*, 2004] with and without the derived BC radiative forcing (Task 2.1). Since these simulations will be performed without the chemistry calculation, they will be run at comparable or higher spatial resolution over longer time periods than the WRF-Chem simulations discussed earlier to capture in more details the impacts of orography on the regional climate and hydrological cycle in California, and to better characterize BC effects and their variability due to large interannual variations of atmospheric circulation driven in part by the ENSO cycle. The simulations will be performed for the 1967 to 2007 period. We anticipate an ensemble simulation of about 5 separate runs of 40 years each.

Time and funds permitting, we will also use the inferred BC temporal trends with the improved WRF-Chem model to examine the corresponding long-term variations in the BC radiative forcing. And we will further investigate the correlations of changes in BC concentrations to temperature trend, precipitation, snow cover, and other climate change signals observed since the 1960s. This part of the study will help us to understand the role of BC in the long-term climate change over California.

In the regional climate simulations, the BC effects on snow are significant as indicated in the previous work described in section II. Following a similar approach by *Qian et al.* [*Qian et al.*, 2008], we will calculate soot-induced snow albedo changes on-line in the regional simulations based on the BC concentrations simulated by the improved WRF-Chem through data assimilation and guided by observed snow albedo changes.

To further assess the impacts of BC on water resources, we will perform a WRF simulation with the derived BC radiative forcing and on-line simulation of aerosol effects on cloud droplets and precipitation based on the method of Ghan et al. [*Ghan et al.*, 1997; *Ghan et al.*, 2001] and the WRF-Chem simulated aerosols. Besides studying mean differences across these simulations, analysis will be performed to investigate the role of Atmospheric Rivers (AR) on flooding and the associated BC influence on extreme precipitation. Preliminary analysis by Leung and Qian [*Leung and Qian*, 2008] shows significant skill by the WRF model in simulating the intense precipitation and surface runoff associated with AR (Figure 9).

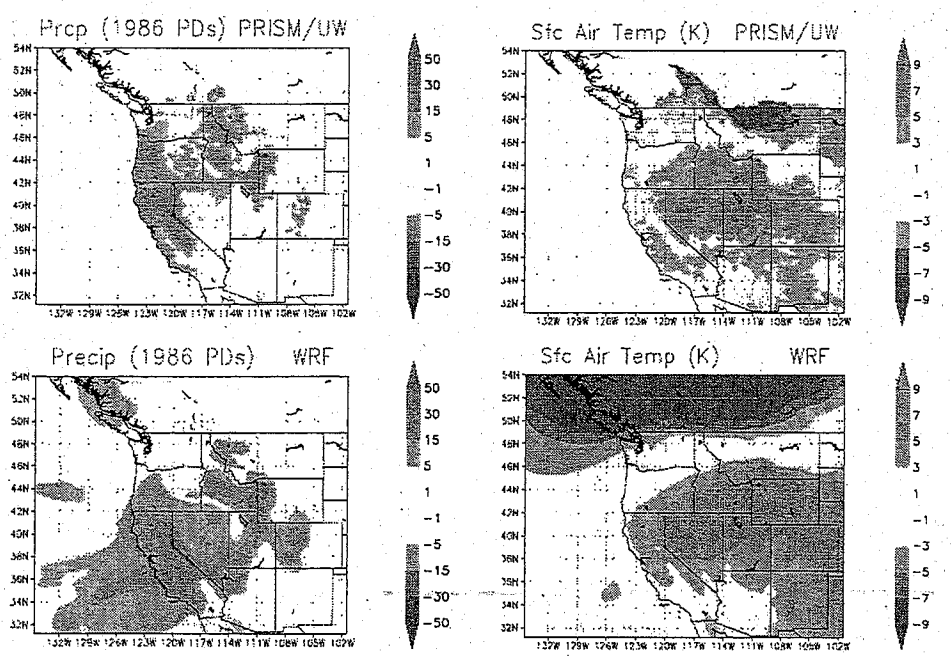

Figure 9. Observed (top) and simulated (bottom) precipitation (left) and surface temperature (right) anomalies of the 1986 President Day "Pineapple Express" event, showing heavy precipitation and warmer than normal temperatures over California. The WRF simulation was a 25-year integration initialized on 1979/9/1 driven by global reanalysis boundary conditions.

The primary goal of the impact study is to provide a preliminary estimate of climate changes and further examine the chain of responses and feedbacks on the regional climate in California due to BC based on more observational constrained model simulations. Climatic changes that will be analyzed include the recent nighttime warming trend, decreased precipitation, and the early onset of snow melt leading to decreased snow cover, changes in the timing and amount of seasonal runoff, and potential influence on intense precipitation and flooding.

3. List of facilities/computer or other resources to be used

This project will employ 3~4 dual-core UNIX workstations newly purchased and maintained by the Ramanathan group at UCSD. Intensive computational efforts such as global/regional transport and radiative transfer model calculations will also be performed at the NCAR supercomputer (Bluefire), the IBM Power 575 cluster with 4064 IBM Power6 processors. In addition to the existing data storage system, a new terabytes data storage device will be purchased by the Ramanathan group for data storing and mining. The UC Berkeley group will make use of a 32 node UNIX cluster purchased and managed jointly by a consortium of UC Berkeley atmospheric science faculty. Office space and other resources necessary to this project will be provided in space available to the PIs.

Two COH monitors will be (re)installed at two Bay Area Air Quality Management District monitoring sites presently equipped with aethaloemeters, assuming we have the cooperation of BAAQMD staff.

4. Disseminate results and prepare final report

Task 4: A final report will be prepared describing observational data, model simulations, analyses, and results.

Task 5: Journal article preparations will be taken up as soon as results emerge, with manuscript(s) submitted to professional journals. We will also present the results at ARB Chair's Air Pollution Seminar and professional conferences.

V. PROJECT SCHEDULE

Task 1.1 Long-term variations in BC
Task 1.2 Multi-platform data analysis
Task 2.1 Radiative forcing
Task 2.2 Preliminary source apportionment
Task 2.3 Regional chemical transport model study (WRF-Chem)
Task 3. WRF regional climate model study
Task 4. Disseminate results and prepare final report
Task 5. Amend final report and publish results

First Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
TASK												
1.1												
1.2												
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2nd Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
TASK												
1.1												
1.2												
2.1												
2.2												
2.3												
3.												
4.												
5.												
	m		p		m		p		m			F

p = Quarterly progress report
d = Deliver draft final report (to be submitted 6 months prior to contract expiration)
f = Deliver final report
m = Meeting with CARB staff

VI. PROJECT MANAGEMENT

	Lead scientists	Other scientists	Task Description
Tasks: Observational estimates	**Ramanathan (PI)**		***1. Evaluate spatial and temporal patterns in ambient BC concentrations and optical properties throughout California.*** ***2. Estimate the radiative forcing of BC over California constrained by assimilated aerosol properties.***
Task 1.1 Long Term variations in BC	Kirchstetter		Analyze coefficient of haze data from over 100 locations in CA dating from 1967 and convert to equivalent BC data; Validate and test the conversion factors. Provide a historical and seasonal record of BC in CA, Compare with temperature record. ***Period: 1967 to 2003***
Task 1.2 Multi platform data analysis	Hadley & Ramanathan	SIO: Post grad researcher (PGR); grad student (GS)	Compile BC data from the IMPROVE network, SSA from AERONET, AOD from MODIS and MISR, BC deposit in snow, ATOFMS data for mixing state and optical properties of BC, and UAV vertical profiles of BC; Create gridded observational data set for radiative forcing estimates & data assimilation. ***Period: 2001 to 2007***
Task 2.1 Radiative Forcing	Feng	Ramanathan, Menon, SIO-PGR	a. Estimate observationally constrained Radiative forcing estimates for 2001 to 2007; b.Use fine particle MODIS and WRF-CHEM for two independent estimates of anthropogenic fraction; c. Use the global IMPACT model to determine role of long range transport from N America, Mexico and E Asia to CA forcing d. Scale forcing for 2001 to 2007 with temporal BC variations from Task 1.1 to go back in time to 1967. ***Period : 1967 to 2007***
Task 2.2 Source apportionment	Prather	Leung, Feng, Menon, SIO-GS	Use ATOMFS data for preliminary source apportionment of surface BC concentration for the 2001 to 2007 period; Combine the ATOFMS data results with transport models to estimate source apportionment at higher altitudes; Estimate the forcing associated with the different source types.
Tasks: Model Simulations	**Menon**		***2. Estimate the radiative forcing of BC over California using WRF-CHEM model.*** ***3. Make a preliminary investigation of regional climate responses (temperatures; precipitation; solar radiation including PAR).***
Task 2.3 WRF Regional Chem model	Menon	Hadley, UCB-GS	Simulate BC and aerosol concentrations and optical properties with WRF-CHEM. Use assimilated data from Task 1.2 for validation; Calculate radiative forcing and validate with data from Task 2.1.
Task 3 WRF regional climate model	Leung	Feng, Menon, Ramanathan	***Make a preliminary investigation of regional climate responses.*** Two 40-year simulations; one using the 1967 to 2007 forcing derived under Task 2.1; and another using simulated aerosol properties from Task2.1.

Task 4 Disseminate results and prepare final report	Ramanathan, Kirchstetter	Hadley, Menon, Cohen, Leung, Prather, Feng	***A final report will be prepared describing observational data, model simulations, analyses, and results.***
Task 5 Amend final report and publish results	Ramanathan, Kirchstetter	Hadley, Menon, Cohen, Leung, Prather, Feng	***Journal article preparations will be taken up as soon as results emerge, with manuscript(s) submitted to professional journals. We will also present the results at ARB Chair's Air Pollution Seminar and professional conferences.***

VII. CURRICULUM VITAE

CVs of the key scientific personnel are included on the following pages

1. V. Ramanathan
2. Kimberly Prather
3. Tom Kirchstetter
4. Ronald Cohen
5. Surabi Menon
6. Ruby Leung
7. Yan Feng
8. Odelle Hadley

CIRRICULUM VITAE

V. RAMANATHAN

EDUCATION:

B.E., 1965 Annamalai University, India (Engg.)
M.Sc., 1970 Indian Institute of Science, India (Engg.)
Ph.D., 1974 State University of New York at Stony Brook (Planetary Atmospheres)

RESEARCH POSITIONS:

1979-date: Principal Investigator, NASA Earth Radiation Budget Experiment
1982-1986: Senior Scientist, NCAR, Boulder, CO
1985-1988: Affiliate Professor, Colorado State University, Fort Collins, CO
Visiting Professor, Universite Catholique de Louvain, Belgium
1986-1990: Professor, Department of Geophysical Sciences, University of Chicago, Chicago, IL
1990-date: Victor C. Alderson Professor of Applied Ocean Sciences, and Professor of Climate and Atmospheric Sciences, Scripps Institution of Oceanography, University of California, San Diego, CA
1991-date: Director, Center for Clouds, Chemistry and Climate, Scripps Institution of Oceanography, University of California, San Diego, CA
1996-date: Director, Center for Atmospheric Sciences, Scripps Institution of Oceanography, University of California, San Diego, CA
1998: First K.R. Ramanathan Visiting Professor, Physical Research Laboratory, India
2004-date: Distinguished Professor of Atmospheric and Climate Sciences, Scripps Institution of Oceanography, University of California, San Diego, CAs

OTHER POSITIONS:

1992-date: Board of Directors, Tata Energy Research Institute, Arlington, VA
1993: Chief Scientist, Central Equatorial Pacific Experiment (CEPEX)
1996-2002: Co-Chief Scientist, Indian Ocean Experiment (INDOEX)
1996-2002: Chair, International Steering Committee, INDOEX
1999-date: Science Editorial Board, NASA Earth Observatory
2002-date: Atmospheric Brown Cloud Project (ABC)
2002-date: Member, Geophysical Institute Review Panel for Atmospheric Sciences
2005-date: Member, Advisory Board, World Clean Air Congress
2005-date: Member, NCAR, Earth Observing Laboratory External Advisory Committee
2005-date: Chairman, ABC project
2006-date: Chair, United States Climate Change Science Program (CCSP)

HONORS

- Zayed Prize for scientific and technological achievements in environment with co-recipient Prof. Jane Lubchenco, June 2008
- Global and Regional Climate Change: Underlying Science and Emerging Riddles, 8th Annual Henry W. Kendall Memorial Lecture, MIT, May 2, 2008
- PNAS Article, Integrated Model Shows that Atmospheric Brown Clouds and Greenhouse gases have reduced rice harvest in India, recognized as an exceptional paper published in 2006 by the Editorial Board of PNAS, Winner of the Cozzarelli Prize, 2007
- Recognized by the AGU Atmospheric Sciences Section for Bjerknes Lecture, Global Dimming and Its Masking Effect on Global Warming, 2006
- Elected to American Philosophical Society, 2006
- Member, Pontifical Academy of Sciences, 2004
  Elected to U.S. National Academy of Sciences, 2002-Date."for fundamental contributions to our modern understanding of global climate change and human impacts on climate and environment"
- Volvo Environment Prize, 1997 (shared with S. Manabe).
  "for pioneering work over several decades has helped us to understand one of the critical aspects of human activity"
- Foreign Member, Academia Europaea, 1996
- Johannes Gutenberg Lecturer, 2004
- Pioneer Award, the National Science Foundation, October 2003
  "In recognition of your vision, leadership, and entrepreneurial spirit in pioneering the Science and Technology Center concept."
- Fellow, Indian Meteorological Society, October 2003
- Alexander M. Cruickshank Lecturer, 2003
  Rossby Medal, American Meteorological Society, 2002. The highest award given by AMS, "for fundamental insights into the radiative roles of clouds, aerosols and key gases in the earths climate system."
- W. S. Jardetzky Lecturer, Lamont Doherty Observatory, Columbia University, 2000
- Elected to Stonybrook 40; Among Stony Brook's Finest Philosophers, Financiers, Administartors, Inventors, Jurists, Philanthropists.....
  State University of Stony Brook, 1998
- Fellow, American Academy of Arts and Sciences, 1995
- Buys Ballot Medal, Royal Netherlands Academy of Sciences, 1995
  One of the oldest prizes by the academy established in 1887 and given once every ten years."for outstanding scientific work in the science of the atmosphere over the last decade or two"
- Medal for Exceptional Scientific Achievement, NASA, 1989
- Fellow, American Association for the Advancement of Science
- Fellow, American Meteorological Society
- Fellow, American Geophysical Union
- Distinguished Alumnus Award, SUNY, Stony Brook, 1984
- Outstanding Publication Award, NCAR, 1981
- Special Achievement Award, NASA, 1975

Peer-reviewed Journal Papers

1. Flanner, M.G., C.S. Zender, P.G. Hess, N.M. Mahowald, T.H. Painter, V. Ramanathan and P.J. Rasch (2008). Springtime warming and reduced snow cover from carbonaceous particles. *Atmos. Chem. Phys. Discuss., 8,* 19819-19859.
2. Ramanathan, V., Y. Feng (2008). On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead. *Proc. Natl. Acad. Sci., 105,* 14245-14250.
3. Adhikary, B., S. Kulkarni, A. Dallura, Y. Tang, T. Chai, L.R. Leung, Y. Qian, C.E. Chung, V. Ramanathan and G.R. Carmichael. (2008). A regional scale chemical transport modeling of Asian aerosols with data assimilation of AOD observations using optimal interpolation technique. *Atmospheric Environment*, XXX, 1-16 (Article in press).
4. Spencer, M.T., J.C. Holecek, C.E. Corrigan, V. Ramanathan and K.A. Prather (2008). Size-resolved chemical composition of aerosol particles during a monsoonal transition period over the Indian Ocean. *J. of Geophys. Res., 113,* D16305, doi:10.1029/2007JD008657.
5. Roberts, G.C., M.V. Ramana, C. Corrigan, D. Kim, and V. Ramanathan (2008). Simultaneous observations of aerosol– cloud–albedo interactions with three stacked unmanned aerial vehicles. *PNAS, 105(21)*, 7370-7375.
6. Ramanathan, V. and G. Carmichael (2008). Global and regional climate changes due to black carbon. *Nature Geoscience, 1,* 221-227.
7. Lau, K.-M., V. Ramanathan, G.-X. Wu, Z. Li, S.C. Tsay, C. Hsu, R. Sikka, B. Holben, D. Lu, G. Tartari, M. Chin, P. Koudelova, H. Chen, Y. Ma, J. Huang, K. Taniguchi and R. Zhang (2008). The Joint Aerosol-Monsoon Experiment. *Bull. Amer. Meteor. Soc., 89,* 1-15.
8. Corrigan, C.E., G.C. Roberts, M.V. Ramana, D. Kim and V. Ramanathan (2008). Capturing vertical profiles of aerosols and black carbon over the Indian Ocean using autonomous unmanned aerial vehicles. *Atmos. Chem. & Phys., 8*, 737-747.
9. Kim, D., and V. Ramanathan (2008). Solar radiation budget and radiative forcing due to aerosols and clouds. *J. Geophys. Res.*, 113, D02203, doi:10.1029/2007JD008434.
10. Ramanathan V., M.V. Ramana, G. Roberts, D. Kim, C.E. Corrigan, C.E. Chung & D. Winker (2007). Warming trends in Asia amplified by brown cloud solar absorption. *Nature,* 448, 575-578 doi:10.1038/nature06019.
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156. Augustsson, T. and V. Ramanathan, 1977: A Radiative-Convective Model Study of the CO2-Climate Problem. J. Atmos. Sci., 34: 448-451.
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161. Ramanathan, V., 1975: Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications. Science, 190: 50-52.
162. Ramanathan, V. and R. D. Cess, 1974: Radiative Transfer within the Mesospheres of Mars and Venus. Astrophysical J., 188: 407-416.
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164. Cess, R. D. and V. Ramanathan, 1972: Radiative Transfer in the Atmosphere of Mars and that of Venus Above the Cloud Deck. J. Quant. Spect. Rad. Trans., 12: 933-945.
165. Prasad, K.K. and V. Ramanathan, 1972: Heat Transfer by Free Convection from a Longitudinally Vibrating Vertical Plate. Int'l. J. Heat Mass Transfer, 15: 1213-1223.

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ACADEMIC PREPARATION

University of California, Davis	Chemistry	B. S.	1985
University of California, Davis	Chemistry	Ph.D.	1990
University of California, Berkeley	Chemistry	Postdoctoral Fellow	1990 - 1992

APPOINTMENTS

2001- present	Professor, Univ. of California, San Diego, Dept. of Chemistry and Biochemistry
2001 – present	Professor, Univ. of California, San Diego, Scripps Institution of Oceanography
2000 – 2001	Professor, Univ. of California, Riverside
1996 – 2000	Associate Professor, Univ. of California, Riverside
1994 – 2001	Research Associate, Statewide Air Pollution Research Center
1992 – 1996	Assistant Professor, Univ. of California, Riverside

PUBLICATIONS MOST RELATED TO PROPOSAL

Moffet, R. C., X. Y. Qin, et al. (2008). "Chemically segregated optical and microphysical properties of ambient aerosols measured in a single-particle mass spectrometer." Journal of Geophysical Research-Atmospheres **113**(D12).

Prather, K. A., C. D. Hatch, et al. (2008). "Analysis of Atmospheric Aerosols." Annu. Rev. Anal. Chem. **1**: 601-626.

Cubison, M. J., B. Ervens, et al. (2008). "The influence of chemical composition and mixing state of Los Angeles urban aerosol on CCN number and cloud properties." Atmospheric Chemistry and Physics **8**(18): 5649-5667.

Toner, S. M., L. G. Shields, et al. (2008). "Using mass spectral source signatures to apportion exhaust particles from gasoline and diesel powered vehicles in a freeway study using UF-ATOFMS." Atmospheric Environment **42**(3): 568-581.

Furutani, H., M. Dall'osto, et al. (2008). "Assessment of the relative importance of atmospheric aging on CCN activity derived from field observations." Atmospheric Environment **42**(13): 3130-3142.

Shields, L. G., X. Y. Qin, et al. (2008). "Detection of ambient ultrafine aerosols by single particle techniques during the SOAR 2005 campaign." Aerosol Science and Technology **42**(8): 674-684.

Denkenberger, K. A., R. C. Moffet, et al. (2007). "Real-time, single-particle measurements of oligomers in aged ambient aerosol particles." Environmental Science & Technology **41**(15): 5439-5446.

Shields, L. G., D. T. Suess, et al. (2007). "Determination of single particle mass spectral signatures from heavy-duty diesel vehicle emissions for PM2.5 source apportionment." Atmospheric Environment **41**(18): 3841-3852.

Spencer, M. T., L. G. Shields, et al. (2007). "Simultaneous measurement of the effective density and chemical composition of ambient aerosol particles." Environmental Science & Technology **41**(4): 1303-1309.

Sullivan, R. C., S. A. Guazzotti, et al. (2007). "Direct observations of the atmospheric processing of Asian mineral dust." Atmospheric Chemistry and Physics 7: 1213-1236.

Muhle, J., T. J. Lueker, et al. (2007). "Trace gas and particulate emissions from the 2003 southern California wildfires." Journal of Geophysical Research-Atmospheres **112**(D3).

Spencer, M. T., L. G. Shields, et al. (2006). "Comparison of oil and fuel particle chemical signatures with particle emissions from heavy and light duty vehicles." Atmospheric Environment **40**(27): 5224-5235.

Toner, S. M., D. A. Sodeman, et al. (2006). "Single Particle Characterization of Ultrafine and Accumulation Mode Particles from Heavy Duty Diesel Vehicles Using Aerosol Time-of-Flight Mass Spectrometry." Environmental Science & Technology **40**(12): 3912-3921.

Qin, X. Y., P. V. Bhave, et al. (2006). "Comparison of two methods for obtaining quantitative mass concentrations from aerosol time-of-flight mass spectrometry measurements." Analytical Chemistry **78**(17): 6169-6178.

Spencer, M. T. and K. A. Prather (2006). "Using ATOFMS to determine OC/EC mass fractions in particles." Aerosol Science and Technology **40**(8): 585-594.

Qin, X. Y. and K. A. Prather (2006). "Impact of biomass emissions on particle chemistry during the California Regional Particulate Air Quality Study." International Journal of Mass Spectrometry **258**(1-3): 142-150.

Sodeman, D. A., S. M. Toner, et al. (2005). "Determination of Single Particle Mass Spectral Signatures from Light-Duty Vehicle Emissions." Environmental Science and Technology **39**(12): 4569-4580.

Gross, D. S., A. R. Barron, et al. (2005). "Stability of single particle tracers for differentiating between heavy- and light-duty vehicle emissions." Atmospheric Environment **39**(16): 2889-2901.

Guazzotti, S. A., D. T. Suess, et al. (2003). "Characterization of carbonaceous aerosols outflow from India and Arabia: Biomass/biofuel burning and fossil fuel combustion." Journal of Geophysical Research-Atmospheres **108**(D15).

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Whiteaker, J. R., D. T. Suess, et al. (2002). "Effects of Meteorological Conditions on Aerosol Composition and Mixing State in Bakersfield, CA." Environmental Science and Technology **36**(11): 2345-2353.

SYNERGISTIC ACTIVITIES MOST RELATED TO PROPOSAL

- Performs studies worldwide to assist in furthering our understanding of the role of aerosol in climate change and air pollution including California, Mexico, Asia, India, and the United States.
- Selected as member of the $PM_{2.5}$ Subcommittee for the U.S. EPA Clean Air Scientific Advisory Committee (2006-present)
- Selected as member of the National Academy of Sciences Board for Atmospheric Science and Climate (BASC) (2008-2011)
- Three existing patents for developments in on-line mass spectrometry: Development of Aerosol Time-of-Flight Mass Spectrometry (ATOFMS) (US Patent 5,681,752), on-line the development of Transportable ATOFMS (US Patent 5,998,215), MALDI-IM-ortho-TOF mass spectrometry with simultaneous positive and negative mode detection (w/ J. Albert Schultz) (US Patent: 7,170,052)
- Spends significant time giving public lectures in an effort to educate the public on climate and air pollution issues by giving lectures at the SIO Birch Aquarium, San Diego Natural History Museum, radio and TV broadcasts (PBS, CNN), and at elementary, middle, and elementary schools.

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EDUCATION

Ph.D. Environmental Engineering, University of California at Berkeley, 1998
M.S. Environmental Engineering, University of California at Berkeley, 1994
B.S. Atmospheric Science and Mathematics, State University of New York at Albany, 1991

CURRENT POSITION

Staff Scientist and Aerosol Group Leader in the Atmospheric Sciences Department at the Lawrence Berkeley National Laboratory, 2000 – present

Research interests: Climate effects of particles in the atmosphere • Aerosol analytical techniques and instrumentation • Motor vehicle emissions • Air quality and air pollutant emission trends

TEACHING EXPERIENCE

Taught two semester courses at the University of California, Berkeley, Civil and Environmental Engineering Department

- Environmental Engineering (upper division), Spring 2008
  - Contaminant transport and transformation, reactor models, water treatment, and air quality
- Environmental Engineering and Science (lower division), Spring 2005
  - Population growth, energy consumption, air pollution, climate change, and water treatment

PROFESSIONAL ACTIVITY

- Editor, Journal Atmospheric Chemistry and Physics, 2006 – present
- Organization of the International Conference on Carbonaceous Particles in the Atmosphere
  - 9th: Chair and Organizer, Berkeley, California, 2008
  - 8th: Co-organizer, Vienna, Austria, 2004
  - 7th: Co-organizer, Technical secretary, Proceedings Coordinator, San Juan, Puerto Rico, 2000
- Research mentor for graduate students (3 Ph.D. theses) and undergraduate student interns

AWARDS

- Outstanding Mentor Award, DOE, Office of Science Undergraduate Research Program, 2005
- Research & Development Award, Lawrence Berkeley National Laboratory, 2007, 2002
- Alexander Hollaender Distinguished Postdoctoral Fellowship, Department of Energy, 1998
- Golden West Section Graduate Scholarship, Air & Waste Management Association, 1994
- Science and Engineering Research Semester Award, Department of Energy, 1992

PEER-REVIEWED PUBLICATIONS (*1200+ mostly favorable citations, h-index = 18*)

38. Kirchstetter, TW; Aguiar, J; Tonse, S; Novakov, T; Fairley, D. (2008) Black carbon concentrations and diesel vehicle emission factors derived from coefficient of haze measurements in California: 1967-2003. *Atmos. Environ., 42,* 480-491.

37. Novakov, T; Kirchstetter, TW; Menon, S; Aguiar, J. (2008) Anthropogenic aerosol and California temperature change, Submitted for publication in *Geophys. Res. Letters.*

36. Hadley, OL; Corrigan, CE; Kirchstetter, TW. (2008) Modified Thermal-Optical Analysis Using Spectral Absorption Selectivity to Distinguish Black Carbon from Pyrolized Organic Carbon, Accepted for publication in *Environ. Sci. & Technol.*

35. Ban-Weiss, George; Lunden, Melissa; Kirchstetter, Thomas; Harley, Robert (2008) Measurement of Black Carbon and Particle Number Emission Factors from Individual Heavy-Duty Trucks, Submitted to *Environ. Sci. & Technol.*

34. Lunden, MM, Kirchstetter, TW, Thatcher, TL, Hering, SV, and Brown, NJ. (2008) Factors affecting the indoor concentration of carbonaceous aerosols of outdoor origin. *Atmos. Environ.*, *42*, 5660-5671.

33. Kean, A; Littlejohn, D; Ban-Weiss, G; Harley, R; Kirchstetter, TW; Lunden M. (2008) Trends in On-Road Vehicle Emissions of Ammonia, Accepted for publication in *Atmos. Environ.*

32. Ban-Weiss, GA; McLaughlin, JP; Harley, RA; Lunden, MM; Kirchstetter, TW; Kean, AJ; Strawa, AW; Stevenson, ED; Kendall, GR. (2008) Lon-term changes in emissions of nitrogen oxides and particulate matter from on-road gasoline and diesel vehicles, *Atmos. Environ., 42,* 220-232.

31. Kirchstetter, T.W.; Novakov, T. (2007) Controlled generation of black carbon particles from a diffusion flame and applications in evaluating black carbon measurement methods. *Atmos. Environ.*, *41*, 1874-1888, doi:10.1016/j.atmosenv.2006.10.067.

30. Kirchstetter, TW. (2007) Evaluating past and improving present and future measurements of black carbon particles in the atmosphere. California Energy Commission, PIER Energy-Related Environmental Research. Final report CEC-500-2007-042.

29. Jimenez, J; Claiborn, C; Larson, T; Gould, T; Kirchstetter, TW; Gundel, L. (2007) Loading effect correction for real-time aethalometer measurements of fresh diesel soot, *J. Air Waste Manage.,57,* 868-873.

28. Hering, SV; Lunden, MM; Thatcher, TL; Kirchstetter, TW; Brown, NJ. (2007) Using regional data and building leakage to assess indoor concentrations of particles of outdoor origin. *Aerosol Sci. Technol.*, *41*, 639-654.

27. Harley, RA; Hooper, DS; Kean, AJ; Kirchstetter, TW; et al. (2006) Effects of reformulated gasoline and motor vehicle fleet turnover on emissions and ambient concentrations of benzene, *Environ. Sci. Technol.*, *40*, 5084-5088, doi:10.1021/es0604820.

26. Novakov T, Menon S, Kirchstetter TW, Koch, D; Hansen, JE. (2005) Aerosol organic carbon to black carbon ratios: analysis of published data and implications for climate forcing, *J. Geophys. Res., 110,* D21205.

25. Kirchstetter, TW; Novakov, T; Hobbs, PV. (2004) Evidence that spectral light absorption by aerosols emitted from biomass burning and motor vehicles is different due to organic carbon. *J. Geophys. Res., 109*, D21208, doi:10.1029/2004JD004999.

24. Magi, B.; Hobbs P.V.; Kirchstetter, T.W.; Novakov, T.; Hegg, D.A.; Gao, S.; Redemann, J.; Schmid, B. (2005) Aerosol properties and chemical apportionment of aerosol optical depth at locations off the United States east coast in July and August 2001. *J. Atmos. Sci., 62,* 919-933.

23. Sinha, P.; Hobbs P.V.; Yokelson, R.J.; Blake, D.R.; Gao, S; Kirchstetter, T.W. (2004) Emissions from miombo woodland and dambo grassland savanna fires, *J. Geophys. Res,109,* D11305.

22. Sinha, P.; Hobbs P.V.; Yokelson, R.J.; Blake, D.R.; Gao, S.; Kirchstetter, T.W. (2003) Distributions of trace gases and aerosols during the dry biomass burning season in southern Africa. *J. Geophys. Res., 108* , 4536, doi:10.1029/2003JD003691.

21. Kirchstetter, T.W.; Novakov, T.; Hobbs P.V.; Magi, B. (2003) Airborne measurements of carbonaceous aerosols in southern Africa during the dry, biomass burning season. *J. Geophys. Res.*, 108, 10.1029/2002JD002171.

20. Novakov, T.; Ramanathan, V.; Hansen, J.; Kirchstetter, T.W.; Sinton, J.E.; Sathaye, J.A. (2003) Large historical changes of fossil-fuel black carbon aerosols. *Geophys. Res. Letters*, 30, 10.1029/2002GL016345.

19. Gao, S.; Hegg, D.A.; Hobbs, P.V.; Kirchstetter, T.W.; Magi, B.I.; Sadilek, M. (2003) Water-soluble organic components in aerosols associated with savanna fires in southern Africa: identification, evolution, and distribution. *J. Geophys. Res.*, 108, 10.1029/2002JD002324.

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17. Sinha, P.; Hobbs P.V.; Yokelson, R.J.; Bertschi, I.T.; Blake, D.R.; Gao, S.; Kirchstetter, T.W.; Novakov, T. (2003) Emissions of trace gases and particles from savanna fires in southern Africa. *J. Geophys. Res.*, 108, *10*.1029/2002JD002325.

16. Hobbs, P. V., P. Sinha, R. J. Yokelson, T. J. Christian, D. R. Blake, S. Gao, T. W. Kirchstetter, T. Novakov, and P. Pilewski. (2003) Evolution of gases and particles from a savanna fire in South Africa, *J. Geophys. Res.*, 108, *10.1029/2002JD002352.*

15. Sinha, P., P.V. Hobbs, R.J. Yokelson, T.J. Christian, T.W. Kirchstetter, R. Bruintjes. (2003) Emissions of trace gases and particles from two ships in the southern Atlantic Ocean. *Atmos. Environ.*, 37, 2139-2148.

14. Currie L.A.; Kirchstetter, T.W.; et al. (2002) A critical evaluation of interlaboratory data on total, elemental, and isotopic carbon in the carbonaceous particle reference material, NIST SRM 1649a. *J. Res. Nat. Inst. Stand. Technol.*, *107*, 279-298.

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12. Kirchstetter, T.W.; Corrigan, C.E.; Novakov, T. (2001) Laboratory and field investigation of the adsorption of gaseous organic compounds onto quartz filters. *Atmos. Environ.*, *35*, 1663-1671.

11. Gao, S.; Hegg, D.A.; Frick, G.; Caffrey, P.F.; Pasternack, L.; Cantrell, C.; Sullivan, W.; Ambrusko, J.; Albrechcinski, T.; Kirchstetter, T.W. (2001) Experimental and modeling studies of secondary organic aerosol formation and some applications to the marine boundary layer. *J. Geophys. Res.*, *106*, 27619-27634.

10. Kirchstetter, T.W.; Novakov, T.; Morales, R.; Rosario, O. (2000) Differences in the volatility of organic aerosol in unpolluted tropical and polluted continental atmospheres. *J. Geophys. Res.*, *105*, 26547-26554.

9. Novakov, T.; Andreae, M.O.; Gabriel, R.; Kirchstetter, T.W.; Mayol-Bracero, O.L.; Ramanathan, V. (2000) Origin of carbonaceous aerosols over the tropical Indian Ocean: Biomass burning or fossil fuels? *Geophys. Res. Letters*, *27*, 4061-4064.

8. Kirchstetter, T.W.; Harley, R.A.; Hering, S.V.; Stolzenburg, M.R.; Kreisberg, N.M. (1999) On-road measurement of fine particle and nitrogen oxide emissions from light- and heavy-duty motor vehicles. *Atmos. Environ.*, 1999, *33*, 2955-2968.

7. Marr, L.C.; Kirchstetter, T.W.; Harley, R.A.; Miguel, A.H.; Hering, S.V.; Hammond, S.K. Characterization of polycyclic aromatic hydrocarbons in motor vehicle fuels and exhaust emissions. *Environ. Sci. Technol.*, *33*, 3091-3099.

6. Kirchstetter, T.W.; Singer, B.C.; Harley, R.A.; Kendall, G.R.; Traverse, M. (1999) Impact of California reformulated gasoline on motor vehicle emissions: 1. Mass emission rates. *Environ. Sci. Technol.*, *33*, 318-328.

5. Kirchstetter, T.W.; Singer, B.C.; Harley, R.A.; Kendall, G.R.; Hesson, J.M.(1999) Impact of California reformulated gasoline on motor vehicle emissions: 2. Volatile organic compound speciation and reactivity. *Environ. Sci. Technol.*, *33*, 329-336.

4. Singer, B.C.; Kirchstetter, T.W.; Harley, R.A.; Kendall, G.R.; Hesson, J.M. (1999) A fuel-based approach to estimating motor vehicle cold start emissions. *J.Air Waste Manag. Assoc.*, *49*, 125-135.

3. Miguel, A.H.; Kirchstetter, T.W.; Harley, R.A.; Hering, S.V. (1998) On-road emissions of particulate polycyclic aromatic hydrocarbons and black carbon from gasoline and diesel vehicles. *Environ. Sci. Technol.*, *32*, 450-455.

2. Kirchstetter, T.W.; Harley, R.A.; Littlejohn, D. (1996) Measurement of nitrous acid in motor vehicle exhaust. *Environ. Sci. Technol.*, *30*, 2843-2849.

1. Kirchstetter, T.W.; Singer, B.C.; Harley, R.A.; Kendall, G.R.; Chan, W. (1996) Impact of oxygenated gasoline use on California light-duty vehicle emissions. *Environ. Sci. Technol.*, *30*, 661-670.

RESEARCH APPOINTMENT HISTORY

Staff Scientist, Aerosol Group Leader, Oct 2000 – present
Atmospheric Sciences Department, Lawrence Berkeley National Laboratory Alexander

Alexander Hollaender Distinguished Postdoctoral Fellow, Sept 1998 – Sept 2000
Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, CA

DOE Science and Engineering Research Semester & Summer, Jan – Aug 1992
Energy Science Division, Brookhaven National Laboratory, NY

Undergraduate Research Assistant, Jun – Aug 1991
Atmospheric Sciences Division, State University of New York at Albany

Curriculum Vitae

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Research Interests

Global climate modeling, Aerosol-cloud-climate interactions, Climate trends and impact assessment, Climate-Air quality effects, Socio-economic projections of climate change impacts

Professional Experience

2003-: Physicist Staff Scientist at Lawrence Berkeley National Laboratory
2006-: Adjunct Faculty at Purdue University
2003-2006: Adjunct Associate Research Scientist at Columbia University and NASA Goddard Institute for Space Studies (GISS)
2000-2003: Associate Research Scientist at Columbia University and NASA GISS.
1999-2000: Post-doctoral Research Scientist at Columbia University and NASA GISS.
1995-1998: Research Assistant - North Carolina State University
1995-1996: Teaching Assistant – North Carolina State University
1992-1994: Research Assistant - Purdue University

Professional Activities

- Contributing author to IPCC "Nobel Peace Prize" Report (2007)
- Panel Review Member – NASA, NOAA, DOE (2005-)
- DOE, NSF and LBNL Mentor for Summer Students – (2005-)
- LBNL Committee on Multi-division Climate Program Expansion, Climate Seminars (2005-) and Chair of Distinguished lecture series (2008-)
- Science Committee
  - 9th International Conf. on Carbonaceous Particles in the Atmosphere – August 2008, Berkeley, CA
  - Goldschmidt Conference, Davos, Switzerland, June 2009
- International Advisory Committee (Energy security and climate change, Bangkok, Thailand, August 2008)
- Conference Session Co-Convener and Session Chair (AGU 2002-2006, AEROCOM 2006, IAMAS 2005, Goldschmidt 2009)
- Advisory Board Member of Thimmakka.org (Not for profit environment organization) (2008-)
- Planning Committee for the Workshop on Boundary Layer Clouds and the Aerosol Indirect Effect - June 2002, Toulouse, France.
- Working Group member
  - Stanford University's Energy Modeling Forum subgroup on carbonaceous emissions (2004-)
  - DOE Atmospheric Radiation Measurement Program (ARM) Cloud Modeling Working Group (2005-)
  - UC Berkeley Roundtable Discussion on Natural Disasters and Resilient Communities (2007-)
- Science Team Member of NASA Global Aerosol Climatology Project (1999-2001)
- Coordinator of Intl. Workshop– Aerosol Climate Effect- May 2000, New York, NY

Principal and Co-Principal Investigator

NASA

- Climate Modeling, Analysis and Prediction Program (2005-)
- Climate Modeling Program (2003-)
- Global Water and Energy Cycle Program (2002-2005)

DOE

- Climate Integrated Assessment Program (2005-)
- ARM Program (2004-)
- Laboratory Directed Research and Development Program (2003-2005, 2008-)

NSF

- Modeling of Aerosol Indirect Effect (2000–2003)
- Student travel support for Intl. Carbon Conf. (August 2008)

California Energy Commission

- Urban albedo effects on surface temperature (2007–)

European Union

- International Collaborative project on Aerosol Climatic Effects (2000-2003)

Education

North Carolina State University, Ph.D. (December 1998): Atmospheric Science
Purdue University, M.S. (December 1994): Atmospheric Science
University of Bombay, India, M.Sc. (Part I) (August 1992): Physics
University of Bombay, India, B.Sc. (with highest Distinction) (June 1991): Physics/Mathematics
(Awarded scholarship for all years of undergraduate work; Ranked first in graduating class and in the top 4 city-wide).

Teaching Experience

Sep 22-26, 2008: Intl. Summer school on Atmospheric and Oceanic Sciences, L'Aquila, Italy
Aug 1995-May 1996: Atmospheric Science Laboratories, North Carolina State University
Aug 1995-Dec 1995: Physics Laboratories, North Carolina State University
Aug 1995-Dec 1995: North Carolina State University's Science tutor for student athletes.

Field Experience

May-Aug 1995-1997: Chief Technical Officer and Project Leader in cloud-aerosol field experiments.

Advisory Role

Students:

N Burns (Cal Poly, Summer 2005), N Chmura (Cornell University, Summer 2005), P Singh (SUNY Buffalo, Summer 2006), B Zheng (UC Berkeley, Summer 2008), G Persad (Stanford University, Summer 2008)

Post-doctoral Research Scientist and Principal Research Associate:

Igor Sednev (LBNL, 2004-)

Ph.D. Committee:

T. Storelvmo (Univ. of Oslo, Norway): Graduated 2006. (Chief opponent of the advisory committee)
Hsin-I Chang (Purdue University): To graduate in 2008.

Complete List of Publications

2008

Akbari, H., S. Menon and A. Rosenfeld, 2008: Global cooling: Increasing world-wide urban albedos to offset CO_2. *Climatic Change*, In Press.

Klein, S., R. McCoy, H Morrison, A Ackerman, A Avramov, G de Boer, M Chen, J Cole, A Del Genio, M Falk, M Foster, A Fridlind, J-C Golaz, T Hasino, J. Harrington, C Hoose, M Khairoutdinov, V Larson, X Liu, Y Luo, G. McFarquhar, S Menon, R Neggers, S Park, M Poellot, J Schmidt, et al. 2008: Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-phase Arctic cloud experiment. Part I: Single layer cloud. *Q. J. Roy. Meteor. Soc.*, In Review.

Koch, D., S. Menon, A.D. Del Genio, S. Warren, R. Ruedy, I. Alienov, G. Schmidt, 2008: Distinguishing aerosol impacts on climate over the past century, *J. Climate*, In Press.

Menon, S., A.D. Del Genio, Y. J. Kaufman, D. Koch, R. Bennartz, N. Loeb, and D. Orlikowski, 2008: Analyzing signatures of aerosol-cloud interactions with satellite retrievals and the GISS GCM to constrain the aerosol indirect effect. *J. Geophys. Res.*, **113**, doi:10.1029/2007JD009442.

Menon, S., N. Unger, D. Koch, J. Francis, T.J. Garrett, I. Sednev, D. Shindell, D. Streets 2008: Aerosol climate effects and air quality impacts from 1980 to 2030. *Envt. Res. Lettr.*, 3, 024004. **Solicited Article. Resulted in media coverage.**

Menon, S., I. Sednev, S. Bauer, D. Koch, R. McGraw, A.D. Del Genio, P. DeMott and H. Morrison 2008: Effects of cloud nucleation schemes on cloud properties, precipitation and climate, *J. Geophys. Res.*, In Submission.

Menon, S., D. Koch and G. Beig, 2008: Decadal climate trends in India: Role of black carbon aerosols on precipitation, snow-cover and radiation, *Science*, In submission.

Novakov, T., T.W. Kirchstetter, S. Menon and J. Aguiar 2008: Response of California temperature to regional anthropogenic aerosol changes, *Geophys. Res. Lettr.*, 35, doi:10.1029/2008GL034894.

Quinn, P.K., T.S. Bates, E. Baum, N. Doubleday, A. Fiore, M. Flanner, A. Fridlind, T. Garrett, D. Koch, S. Menon, D. Shindell, A. Stohl, and S.G. Warren, 2008: Short-Lived pollutants in the Arctic: Their climate impact and possible mitigation strategies, *Atmos. Chem. Phys.* **8**, 1723-1735.

Sednev, I., S. Menon, and G. McFarquhar: 2008: Simulating mixed-phase Arctic stratus clouds: Sensitivity to ice initiation mechanisms. *Atmos. Chem. Phys..Discuss*, **8**, 11755-11819.

2007

Denman, K., G. Brasseur et al. 2007: Couplings between changes in the climate system and biogeochemistry. In Climate Change, 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change {Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.. Avery, M. Tigor and H. Miller (eds)} Cambridge University Press, Cambridge, United Kingdom and New York, NY USA. Contributing author to the IPCC 2007 **"Nobel Peace Prize"** report. **Resulted in media coverage**

Hansen, J., Mki. Sato, R. Ruedy, L. Nazarenko, A. Lacis, K. Lo, G.A. Schmidt, G. Russell, I. Aleinov, M. Bauer, S. Bauer, E. Baum, N. Bell, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Geno, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N. Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, R.L. Miller, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, M. Yao, and S. Zhang 2006. Dangerous human-made interference with climate: A GISS modelE study. *Atmos. Chem. Phys.*,7, 2287-2312.

Hansen, J., M. Sato, R. Ruedy, P. Kharecha, A. Lacis, R.L. Miller, L. Nazarenko, K. Lo, G.A. Schmidt, G. Russell, I. Aleinov, S. Bauer, E. Baum, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Cohen, A. Del Genio, G. Faluvegi , E. Fleming, A. Friend, T. Hall, C. Jackman, J. Jonas, M. Kelley, N.Y. Kiang, D. Koch, G. Labow, J. Lerner, S. Menon, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, R. Schmunk, D. Shindell, P. Stone, S. Sun, D. Streets, N. Tausnev, D. Thresher, N. Unger, M. Yao, and S. Zhang 2006. Climate simulations for 1880-2003 with GISS modelE. *Climate Dynam.*, doi:10.1007/s00382-007-0255-8.

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Niyogi, D., H-I. Chang, L. Gu, S. Menon, R.A. Pielke Sr., 2007: Potential impacts of aerosol-land-atmosphere interactions on the Indian monsoonal rainfall characteristics. *Natural hazards – Special Issue on Monsoons*, doi:10.1007/s11069-006-9085-y.

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Shindell, D., G. Faluvegi , S. Bauer , D. Koch , N. Unger , S. Menon , R. Miller , G. Schmidt , D. Streets, 2007: Climate response to projected changes in short-lived species under the A1B scenario from 2000-2050 in the GISS climate model. *J. Geophys. Res.* 112, D20103, doi:10.1029/2007JD008753.

2006

Menon, S., and L. Rotstayn, 2006: The radiative influence of aerosol effects on liquid-phase cumulus and stratus clouds based on sensitivity studies with two climate models. *Climate Dynamics*, **27**, 345-356.

2005

Hansen, J., L. Nazarenko, R. Ruedy, Mki. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, Ju. Perlwitz, G. Russell, G.A. Schmidt, and N. Tausnev 2005. Earth's energy imbalance: Confirmation and implications. *Science* **308**, 1431-1435.

Hansen, J., Mki. Sato, R. Ruedy, L. Nazarenko, A. Lacis, G.A. Schmidt, G. Russell, I. Aleinov, M. Bauer, S.S. Bauer, N. Bell, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, M. Kelley, N. Kiang, D. Koch, J. Lean, J. Lerner, K. Lo, S. Menon, R. Miller, P. Minnis, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, D. Shindell, P. Stone, S. Sun, N. Tauznev, D. Thresher, B. Wielicki, T. Wong, M. Yao, and S. Zhang 2005. Efficacy of climate forcings. *J. Geophys. Res.*, **110**, doi:101029/2005JD005776.

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Qian, Y., Q. Song, S. Menon, S. Yu, S. Liu, G. Shi, R. Leung, and Y. Luo, 2005: Impacts of atmospheric sulfate and black carbon aerosols on the regional climate of East Asia. In "*Global Environmental Change Research in East Asia*".

2004

Menon, S., Current uncertainties in aerosol climate effects. *Annual Reviews*, **29**, 1-30. **Solicited Article**.

2003

Menon, S., J-L Brenguier, O. Boucher, P. Davison, A. D. Del Genio, J. Feichter, S. Ghan, S. Guibert, X. Liu, U. Lohmann, H. Pawlowska, J. E. Penner, J. Quaas, D. L. Roberts, L. Schüller and J. Snider, 2003: Evaluating Cloud-Aerosol Process Parameterizations with Single Column Models and ACE-2 Cloudy Column Observations, *J. Geophys. Res.*, **108**, doi:10.1029/2003JD003902

2002

Menon, S., J. Hansen, L. Nazarenko and Y. Luo, 2002: Climate effects of black carbon aerosols in China and India, *Science*, **297**, 2250-22. **Resulted in extensive media coverage**.

Menon, S., A.D. Del Genio, D. Koch and G. Tselioudis, 2002: GCM simulations of the aerosol indirect effect: Sensitivity to cloud parameterization and aerosol burden, *J. Atmos. Sci.*, **59**, 692-713.

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Lui, Li, M. Mishchenko, S. Menon, A. Macke, A. Lacis, 2002: The effect of black carbon on scattering and absorption of solar radiation by cloud droplets. *J. Quant. Spec. Rad. Trans.*, **74**, 195-204.

2000

Menon, S., V.K. Saxena and B.D. Logie, 2000: Chemical heterogeneity across cloud droplet size spectra in continental and marine air masses, *J. Appl. Meteorol.*, **39**, 887-903.

1999

Saxena, V.K. and S. Menon, 1999: Sulfate-induced cooling in the southeastern U.S.: An observational assessment, *Geophys. Res. Lettr.*, **26**, 2489-2492.

1998

Menon, S. and V.K Saxena, 1998: Role of sulfates in cloud-climate feedback mechanisms, *Atmos. Res.*, **48-49**, 299-315.

1996

Saxena, V.K., P.A. Durkee, S. Menon, J. Anderson, K.L. Burns and K.E. Nielsen, 1996: Physico-chemical measurements to investigate regional cloud-climate feedback mechanisms, *Atmos. Environ.*, **30**, 1573-1579.

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2007-	**Professor, Associate Professor (2002-2007), Assistant Professor (1995-2002),** Departments of Chemistry and of Earth and Planetary Science, University of California at Berkeley;
2006-	**Director,** Berkeley Atmospheric Sciences Center
1996-	**Faculty Scientist,** Lawrence Berkeley National Laboratory, Energy and Environment Technologies Division
2006-2007	**Visiting Professor,** Max Planck Institute for Chemistry, Division of Biogeochemistry, Mainz, Germany
2008-	**Editor**, Atmospheric Measurement Techniques
2007-	**Member,** Advisory Editorial Board, Chemical Physics Letters
2006-	**Editor**, Atmospheric Chemistry and Physics

Research Interests: Climate and air quality with a focus on a) chemical controls over atmospheric oxidants and the role of oxidants in controlling surface UV, air quality, and climate, b) the paleotemperature record and the hydrologic cycle--chemistry and meteorology controlling process of cloud drop formation, the isotopic composition of rainwater and of glacial ice, and c) the use of space-based observations to infer emissions and lifetimes of NO_x, N_2O and aerosol.

1991-1996 **Postdoctoral Fellow, Research Associate** Dept. of Chemistry, Harvard University

Education:

Ph.D. Department of Chemistry, The University of California, Berkeley, 1991
BA with High Honors, Wesleyan University, Middletown, Connecticut, June 1985

Awards & Honors

NASA Group Achievement Award, June 2008, for efforts during the Tropical Clouds, Convection, Climate and Chemistry Experiment (TC^4) June 2007-August 2007
NASA Group Achievement Award, June 2005, for efforts during the Intercontinental Chemical Transport Experiment--North America June 2004-August 2004
Hellman Family Faculty Fund, 1999;
Regents Junior Faculty Fellowship, 1998
NASA Group Achievement Award, July 1998; for efforts during the POLARIS experiment, April 1997-September 1997;

Memberships:

American Association for the Advancement of Science, American Geophysical Union, American Chemical Society, European Geophysical Union

Publications of Ronald C. Cohen 2004-present

128. J.L. Fry, A. Kiedler-Scharr, A.W. Rollins, P.J. Wooldridge, S.S. Brown, H. Fuchs, W. Dube, A. Mensah, M. dal Maso, R. Tillman, H.P. Dorn, T. Brauers, and R.C. Cohen, *Organic nitrate and secondary organic aerosol yield from NO_3 oxidation of β-pinene evaluated using a gas-phase kinetics/aerosol partitioning model*, Atmos. Chem. Phys. Disc. **8**, 18039–18089, 2008.

127. G. M. Wolfe, R. Yatavelli, J. A. Thornton, M. McKay, A. H. Goldstein, B. LaFranchi, R. C. Cohen, W. H. Brune, Z. Chen, X. Ren, and J. Mao, *Eddy covariance fluxes of acyl peroxy nitrates above a ponderosa pine forest,* Atmos. Chem. Phys. Discuss., **8**, 17495–17548, 2008.

126. A. Fried, J.R. Olson, J.G. Walega, J.H. Crawford, G. Chen, P. Weibring, D. Richter, C. Roller, F. Tittel, M. Porter, H. Fuelberg, J. Halland, T.H. Bertram, R.C. Cohen, K. Pickering[7], B.G. Heikes, J.A. Snow, H. Shen, D.W. O'Sullivan, W.H. Brune, X. Ren, D.R. Blake, N. Blake, G. Sachse, G.S. Diskin, J. Podolske, S.A. Vay, R.E. Shetter, S.R. Hall, B.E. Anderson, L. Thornhill, A.D. Clarke, C.S. McNaughton, H.B. Singh, M.A. Avery, L.G. Huey, S. Kim, and D.B. Millet, *The Role of Convection in Redistributing Formaldehyde to the Upper Troposphere over North America and the North Atlantic during the Summer 2004 INTEX Campaign,* J. Geophys. Res., **113**, D17306, doi:10.1029/2007JD009760. 2008.

125. J. Mao, X. Ren . H. Brune, J. R. Olson, J. H. Crawford, A. Fried, L.G. Huey, R.C. Cohen, B. Heikes, H.B. Singh, D.R. Blake, G.W. Sachse, G.S. Diskin, S.R. Hall, R.E. Shetter, *Airborne measurement of OH reactivity during INTEX-B,* Atmos. Chem. Phys. Disc. **8**, 14217-14246, 2008

124. K.F. Boersma, D.J. Jacob, E.J. Buscela, A.E. Perring, R. Dirksen, R. van der A, R. Yantosca, R. Park, M. Wenig, T.H. Bertram, R.C. Cohen *Validation of OMI tropospheric NO_2 observations during INTEX-B and application to constrain NOx emissions over the eastern U.S. and Mexico*, Atmos. Env. **42**, 4480-4497, 2008.

123. Bucsela, E.J., A.E. Perring, R.C. Cohen, K.F. Boersma, E.A. Celarier, J.F. Gleason, M.O. Wenig, T.H. Bertram, P.J. Wooldridge, R. Dirksen, J.P. Veefkind, *Comparison of tropospheric NO_2 from in situ aircraft measurements with near-real-time and standard product data from OMI*, J. Geophys. Res., **113**, D16S31, doi:10.1029/2007JD008838, 2008.

122. A.E. Perring, T.H. Bertram, P.J. Wooldridge, A. Fried, B.G. Heikes, J. Dibb, J. Crounse, P.O. Wennberg, N.J. Blake, D.R Blake, W.H. Brune and R.C. Cohen, *Airborne Observations of total $RONO_2$: New constraints on the yield and lifetime of isoprene nitrates,* Atmos. Chem. Phys. Disc. **8**, 12313-12341, 2008.

121. W.S. Drisdell, C.D. Cappa, J.D. Smith, R.J. Saykally and R.C. Cohen, *Determination of the evaporation coefficient of D_2O,* Atmos. Chem. Phys. Disc. **8**, 8565-8583, 2008; Atmos. Chem. Phys. **8**, 6699-6706, 2008.

120. L.Zhang, D.J.Jacob, K.F.Boersma, D.A.Jaffe, J.R.Olson, K.W.Bowman, J.R.Worden, A.M.Thompson, M.A.Avery, R.C.Cohen, J.E.Dibb, F.M.Flocke, H.E.Fuelberg, L.G.Huey, W.W.McMillan, H.B.Singh, and A.J.Weinheimer. *Transpacific transport of ozone pollution and the effect of recent Asian emission increases on air quality in North America: an integrated analysis using satellite, aircraft, ozonesonde, and surface observations* Atmos. Chem. Phys. Disc. **8**, 8143-8191, 2008

119. X. Ren, J.R. Olson, J.H. Crawford, W.H. Brune, J. Mao, R.B. Long, G. Chen, M.A. Avery, G.W. Sachse, J.D. Barrick, G. Diskin, L.G. Huey, A. Fried, R.C. Cohen, B. Heikes, P.O. Wennberg, H.B. Singh, D.R. Blake, R.E. Shetter, *HO_x Observations and Model Comparison during INTEX-A 2004* J. Geophys. Res. 113, D05310, doi:10.1029/2007JD009166, 2008.

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117. A.L. Steiner, S. Tonse, R.C. Cohen, A.H. Goldstein, R.A. Harley, *Biogenic 2-methyl-3-buten-2-ol increases regional ozone and HO_x sources,* Geophys. Res. Lett., 34, L15806, doi:10.1029/2007GL030802 2007.

116. D.A. Day, P.J. Wooldridge, and R.C. Cohen, *Observations of the temperature dependence of HNO_3, ΣANs, ΣPNs and NO_2* Atmos. Chem. Phys. Disc. 7, 11091-11121 2007, Atmos. Chem. Phys. **8**, 1867-1879,2008.

115. C. Fountoukis, A. Sullivan, R. Weber, T. Vanreken, M. Fischer, E. Matías, M. Moya, D.K. Farmer, R.C. Cohen and A. Nenes *Thermodynamic characterization of Mexico City Aerosol during MILAGRO 2006,* Atmos. Chem. Phys. Disc. 7, 9203-9233 2007.

114. R.B. Pierce, T. K. Schaack, J. Al-Saadi, T. D. Fairlie, C. Kittaka, G. Lingenfelser, M. Natarajan, J. Olson, A. Soja, T. H. Zapotocny, A. Lenzen, J. Stobie, D. R. Johnson, M. Avery, G. Sachse, A. Thompson, R.C. Cohen, J. Dibb, J. Crawford, D. Rault, R. Martin, J. Szykman, J. Fishman, *Chemical data assimilation estimates of continental US ozone and nitrogen budgets during INTEX-A,* J. Geophys. Res., 112, D12S21, 2007.

113. D.K. Farmer and R.C. Cohen, *Observations of HNO_3, ΣAN, ΣPN and NO_2 fluxes: Evidence for rapid HO_x chemistry within a pine forest canopy,* Atmos. Chem. Phys. Disc., 7, 7087-7136, 2007. Atmos. Chem. Phys, 8, 3899-3917, 2008.

112. C.P. Loughner, D.J. Lary, L.C. Sparling, R.C. Cohen, P. DeCola, and W.R. Stockwell, *A method to determine the spatial resolution required to observe air quality from space*, IEEE Transactions on Geoscience and Remote Sensing, **45**, 1308-1314 2007.

111. Q. Liang, L. Jaegle, R.C. Hudman, S. Turquety, D.J. Jacob, M.A. Avery, E.V. Browell, G.W. Sachse, D.R. Blake, W.H. Brune, X. Ren, R.C. Cohen, J.E. Dibb, A. Fried, H. Fuelberg, M. Porter, B.G. Heikes, L.G. Huey, H.B. Singh, P.O. Wennberg, *Summertime influence of Asian pollution in the free troposphere over North America*, J. Geophys. Res. **112**, D12S11, doi:10.1029/2006JD007919 2007.

110. L.W. Horowitz, A.M. Fiore, G.P. Milly, R.C. Cohen, A.E. Perring, P.J. Wooldridge, P.G. Hess, L.K. Emmons, and J-F. Lamarque, *Observational constraints on the chemistry of isoprene over the Eastern U.S.*, J. Geophys. Res., **112**, D12S08, doi:10.1029/2006JD007747, 2007.

109. C.D. Cappa, J.D. Smith, W.S. Drisdell, R.J. Saykally and R.C. Cohen, *Interpreting the H/D isotope fractionation of liquid water during evaporation without condensation*, J. Phys. Chem. C., **111**, 7011-7020 , 2007.

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105. I.M. Perez, P.J. Wooldridge and R.C. Cohen, *Laboratory evaluation of a novel thermal dissociation chemiluminescence method for in situ detection of nitrous acid*, Atmospheric Environment. **41**, 3993-4001 2007.

104. J.G. Murphy and R.C. Cohen, *Chemistry and Transport of Nitrogen Oxides on the Western Slopes of the Sierra Nevada Mountains: Implications for Lake Tahoe*, http://www.arb.ca.gov/research/ltads/ltads-report.htm California Air Resource Board Report 02-331, February 2007.

103. S. Kim, L.G. Huey, R.E. Stickel, D.J. Tanner, J. H. Crawford, J. R. Olson, G. Chen, W. H. Brune, X. Ren, R. Lesher, P. J. Wooldridge, T. H. Bertram, A.E. Perring, R. C. Cohen, B. Lefer, R. E. Shetter, M. Avery, G. Diskin, and I. Sokolik, *Measurement of HO_2NO_2 in the Upper Troposphere during ICARTT-INTEX-NA 2004* J. Geophys. Res. **112**, D12S01, doi:10.1029/2006JD007676, 2007.

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101. P.A. Cleary, P.J. Wooldridge, D.A. Day, D.B. Millet, M. McKay, A.H. Goldstein, and R.C. Cohen, *Observations of total peroxy nitrates and aldehydes: measurement interpretation and inference of OH radical concentrations,* Atmos. Chem. Phys. Disc., **6**, 12929-12965, 2006, Atmos. Chem. Phys. 7, 1947-1960, 2007.

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EDUCATION

B.S. (Honors) Physics & Statistics, Chinese University of Hong Kong 1984
M.S. Atmospheric Science, Texas A&M University 1988
Ph.D. Atmospheric Science, Texas A&M University 1991

WORK EXPERIENCE

Research Assistant Texas A&M University 1986-1991
Research Associate Pacific Northwest National Laboratory 1991-1992
Senior Scientist Pacific Northwest National Laboratory 1992-2004
Laboratory Fellow Pacific Northwest National Laboratory 2004-present
Affiliate Scientist National Center for Atmospheric Research 2004-present

RESEARCH EXPERIENCE

Dr. Leung is a recognized leader in regional climate modeling. She has been actively involved in the modeling of regional and global climate, developing subgrid cloud parameterizations, and coupling land and atmosphere models. She has applied regional and global climate models and hydrology models to understand the impacts of climate variability and change on water resources in the U.S. and East Asia. Dr. Leung's research on climate change impacts has been featured in *Science*, *Popular Science*, *Wall Street Journal*, *National Public Radio*, and many major newspapers. She develops subgrid cloud parameterizations to represent the influence of subgrid-scale terrain variations on orographic precipitation, and turbulence and cloud-radiation interaction effects on stratocumulus clouds. Her research approach consists of formulating the subgrid parameterizations, implementing them in regional and global climate models, and evaluating the parameterizations. Through the development of the subgrid orographic precipitation scheme, she developed a unique framework for coupling atmospheric, land surface, and ecosystem processes to improve simulations of hydrologic and ecologic conditions over mountain watersheds. In collaboration with the National Climate Center of the China Meteorological Administration, Dr. Leung applies regional climate models to study atmospheric processes of the East Asian summer monsoon and aerosol effects on regional climate and hydrological cycle. She is collaborating with NCAR scientists on an effort to develop a next generation regional climate model based on the Weather Research and Forecasting (WRF) model for upscaling and downscaling. Dr. Leung has published over 70 peer-reviewed papers and book chapters. She has been session chairs and invited speakers in many workshops and conferences.

AWARDS AND HONORS

Fellow, American Association for the Advancement of Science (AAAS), elected 2008

DISSERTATION COMMITTEES

Dissertation Committee of Shourong Wang, Institute of Atmospheric Physics, Chinese

Academy of Sciences (1998 - 2001)
Formal Member of the Doctoral Dissertation Committee, National Climate Center, China Meteorological Administration (1999 - present)
Dissertation Committee of Jianzhong Guo, Department of Environmental and Civil Engineering, University of California - Berkeley (2001- 2006)
Dissertation Committee of Chunmei Zhu, Department of Environmental and Civil Engineering, University of Washington (2005 – 2007)
Dissertation Committee of Aditya Murthi, Department of Meteorology, Texas A&M University (2008 – present)

SYNERGISTIC ACTIVITIES

- Member, TIIMES (The Institute for Integrative and Multidisciplinary Earth Studies) Advisory Panel, National Center for Atmospheric Research, since 2008
- Organizer, North American Mountain Hydroclimate and Water Resources Workshop, cosponsored by NOAA and NASA, October 17 – 19, 2007, Boulder, CO
- Associate Editor, Journal of Geophysical Research – Atmosphere, since 2007
- Chair, Science Panel, NOAA Climate Prediction Program for the Americas (CPPA), since 2006
- Member, NASA Energy and Water Cycle Study (NEWS) Science Team, since 2005
- Organizer, Workshop on Research Needs and Directions of Regional Climate Modeling Using WRF and CCSM, sponsored by NCAR, March 22-23, 2005, Boulder, CO
- Member, Weather Research and Forecasting model (WRF) Research Applications Board (RAB), since 2005
- Chair, WRF Regional Climate Modeling Working Group, since 2004
- Member, Science Advisory Group, GEWEX Americas Prediction Project (GAPP) co-sponsored by NOAA/NASA, 2003 - 2005
- Member, National Advisory Panel, Aspen Global Change Institute, since 2005
- Co-chair, Working Group on Applications of Climate Information to the Water Resource Sector, The 10th U.S.-Japan Workshop on Global Climate Change: Climate and Water, January 15-17, 2003, Irvine, CA
- Organizer and Program Committee Chair, Workshop on "Regional Climate Research: Needs and Opportunities", co-sponsored by the National Science Foundation and Department of Energy (DOE), April 2001, Boulder, CO
- Chair, Science Working Group, NCAR Community Regional Climate Model (1999 – 2001)
- Consultant to the Zhejiang Provincial Meteorological Bureau, China Meteorological Administration (2003-2005)
- Task Leader, DOE-China Meteorological Administration Bilateral Agreement on Regional Climate Research Science Team (1996 – present)
- Served on Proposal Review Panels for EPA Science-To-Achieve Results (STAR) Grant Program, NASA Global Water and Energy Cycle (GWEC) Program, NOAA GEWEX Americas Prediction Project (GAPP) and Climate Dynamics and Experimental Prediction (CDEP) program, NASA Cloudsat panel, and the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
- Proposal review for NOAA, NASA, EPA, DOE, NSF, USGS, CEC, and CFCAS
- Journal review for *J. Clim.*, *Mon. Wea. Rev.*, *Geophysical Res. Letters.*, *Clim. Dynamics*, *J. Appl. Meteorol.*, *J. Hydrometeorology*, *Bull. Amer. Meteorol. Soc.*, *J. Geophys. Res.*, *Climatic Change*, *J. American Water Resources Assoc.*, *J. Hydrology*, *J. Meteor. Soc. of Japan*, *Annales Geophysicae*, *Interannual Journal of Climatology*, *Canadian Water Resources Journal*, *Cold Region Science and Technology*, *Adv. In Atmos. Sci.*, and *Terrestrial, Atmospheric and Oceanic Sciences*

PEER-REVIEWED PUBLICATIONS AND BOOK CHAPTERS

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2. Khain, A.P., B.H. Lynn, L.R. **Leung**, and S.J. Ghan. 2008. "Effects of Aerosols on the Dynamics and Microphysics of Squall Lines Simulated by Spectral Bin and Bulk Parameterization Schemes." J. Geophys. Res., submitted.
3. Qian, Y., D. Gong, J. Fan, L.R. **Leung**, R. Bennartz, D. Chen, and W. Wang. 2008. "Heavy Pollution Suppresses Light Rain in China: Observations and Modeling." J. Geophys. Res., submitted.
4. Wang, Y., C.N. Long, L.R. **Leung**, J. Dudhia, S. McFarlane, J.H. Mather, and S.J. Ghan. 2008. "Evaluating High-Resolution, Regional Cloud Resolving Simulations of the WRF ARW Model for the TWP-ICE (Darwin 2006)." J. Geophys. Res., submitted.
5. **Leung**, L.R., and Y. Qian. 2008. "Atmospheric Rivers Induced Heavy Precipitation and Flooding in the Western U.S. Simulated by the WRF Regional Climate Model." Geophys. Res. Lett., submitted.
6. Lu, N., T. Taylor, W. Jiang, J. Correia, L.R. **Leung**, and P.C. Wong. 2008. "Climate Change Impacts on Residential and Commercial Loads in the Western U.S. Grid." IEEE Trans. on Power Systems, submitted.
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9. Chung, E.C., V. Ramanathan, G.R. Carmichael, Y. Tang, L.R. **Leung**, and Y. Qian. 2008. "Anthropogenic Aerosol Radiative Forcing in Asia Derived from Regional Models with Atmospheric and Aerosol Data Assimilation." Tellus B., submitted.
10. Weaver, C.P., L.R. **Leung**, and co-authors. 2008. "A Preliminary Synthesis of Modeled Climate Change Impacts on U.S. Regional Ozone Concentrations." Bull. Amer. Meteorol. Soc., submitted.
11. Qian, Y. W.I. Gustafson, Jr., L.R. **Leung**, and S.J. Ghan. 2008. "Effects of Soot-induced Snow Albedo Change on Snowpack and Hydrological Cycle in Western U.S. Based on WRF Chemistry and Regional Climate Simulations." J. Geophys. Res., accepted.
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the Western U.S." In Global Change and Mountain Regions: A State of Knowledge Overview, U.M. Huber, H.K.M. Bugmann, and M.A. Reasoner, (eds.), Springer, Dordrecht, pp355-366.

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39. Liang, X., J. Guo, and L.R. **Leung**. 2004. "Assessment of the Effects of Spatial Resolutions on Daily Water Flux Simulations." J. Hydrology, 298(1-4):287-310.
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41. Wood, A.W., L.R. **Leung**, V. Sridhar, and D.P. Lettenmaier. 2004. "Hydrologic Implications of Dynamical and Statistical Approaches to Downscaling Climate Model Outputs." Climatic Change, 62(1-3):189-216.
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45. Qian, Y., L.R. **Leung**, S.J. Ghan, and F. Giorgi. 2003. "Effects of Increasing Aerosol on Regional Climate Change in China: Observation and Modeling. Tellus B, 55(4), 914-934.
46. **Leung**, L.R., Y. Qian, and X. Bian. 2003. "Hydroclimate of the Western United States Based on Observations and Regional Climate Simulation of 1981-2000. Part I: Seasonal Statistics." J. Clim., 16(12):1892-1911.
47. **Leung**, L.R., Y. Qian, X. Bian, and A. Hunt. 2003. "Hydroclimate of the Western United States Based on Observations and Regional Climate Simulation of 1981-2000. Part II: Mesoscale ENSO anomalies." J. Clim., 16(12):1912-1928.
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76. North, G.R., J.K. Yip, L.R. **Leung** and R.M. Chervin. 1992. "Forced and Free Variations of the Surface Temperature Field." J. Clim. 5:227-239.
77. **Leung**, L.R., and G.R. North. 1991. "Atmospheric Variability on a Zonally Symmetric Land Planet." J. Clim. 4:753-765.
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Curriculum Vitae

Yan Feng

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Education

Ph.D. Atmospheric Sciences, University of Michigan, Ann Arbor, MI. (January, 2005)

M.S. Computer Science Engineering, University of Michigan, Ann Arbor, MI. (April, 2002)

B.S. Atmospheric Sciences, Peking University, Beijing, P.R. China. (May, 1997)

Professional Experience

Jul. 2005 - Present	**Postdoctoral research associate** (with Prof. V. Ramanathan), **Scripps Institution of Oceanography**, Center for Atmospheric Sciences, University of California, San Diego, CA.
Feb. 2005 – Jul. 2005	**Postdoctoral research associate** (with Prof. Joyce Penner), Department of Atmospheric, Oceanic, and Space Sciences, **University of Michigan**, Ann Arbor, MI.
Sep. 1997 – Dec. 2004	**Graduate student research assistant** (Thesis advisor: Prof. Joyce Penner),, Department of Atmospheric, Oceanic, and Space Sciences, **University of Michigan**, Ann Arbor, MI.
Jun. 2001 - Aug. 2001	**Visiting graduate student research fellow** (Mentor: Dr. Andrew Lacis), 2001 Graduate Student Summer Program in Earth System Science sponsored by **Goddard Space and Flight Center, Goddard Institute for Space Studies**, New York.

Honors and Awards

- Student travel grant for the 2002 AGU fall meeting, 2002.
- Fellowship for the Graduate Student Summer Program in Earth System Science sponsored by Goddard Space and Flight Center, 2001.

Publications

Peer-reviewed Articles

1. Rotstayn, L. D., M. A. Collier, **Y. Feng**, H. B. Gordon, S. P. O'Farrell, I. N. Smith, and J. Syktus (2008), Improved simulation of Australian climate and ENSO-related rainfall variability in a GCM with an interactive aerosol treatment, submitted to *International Journal of Climatology*, in Aug., 2008.
2. Stith, J. L., V. Raman than, W. A. Cooper, G. Roberts, P. J. DeMott, G. Carmichael, C. D. Hatch, B. Adhikary, C. H. Twohy, D. C. Rogers, D. Baumgardner, A. J. Prenni, T. Campos, R. Gao, J. Anderson, and **Y. Feng** (2008), Cross-Pacific transport of Asian dust-mode particles, soot and cloud active nuclei, *J. Geophys. Res.*, doi:10.1029/2008JD010924, in press, 2008.

3. Ramanathan, V., H. Akimoto, P. Bonasoni, M. Brauer, G. Carmichael, C. E. Chung, **Y. Feng**, S. Fuzzi, S. Hasnain, M. Iyngararasan, A. Jayaraman, M. Lawrence, T. Nakajima, T. Panwar, M.V. Ramana, M. Rupakheti, S. Weidemann, S.-C. Yoon, Y. Zhang and A. Zhu, (2008). Atmospheric Brown Cloud: Impacts on regional climate change, water resources, agriculture, and human health, Part I: Atmospheric Brown Clouds and Regional Climate Change. *UNEP first regional assessment report with focus on Asia*, 150 pages.
4. Ramanathan, V., and **Y. Feng** (2008). On avoiding dangerous anthropogenic interference with the climate system: formidable challenges ahead. *Proc. Natl. Acad. Sci., 105,* 14245-14250.
5. Ramanathan, V., and **Y. Feng** (2008). Air pollution, greenhouse gases and climate change: global and regional perspectives. *Atmos. Environ.*, accepted, 37 pages.
6. **Feng Y.**, and J. E. Penner (2007), Global modeling of nitrate and ammonium: Interaction of aerosols and tropospheric chemistry, *J. Geophys. Res.*, 112, D01304, doi:10.1029/2005JD006404.
7. Rotstayn, L. D., W. Cai, M. R. Dix, G. D. Farquhar, **Y. Feng**, P. Ginoux, M. Herzog, A. Ito, J. E. Penner, M. L. Roderick, and M. Wang (2007), Have Australian rainfall and cloudiness increased due to the remote effects of Asian anthropogenic aerosols? *J. Geophys. Res.*, 112, D09202, doi:10.1029/2006JD007712.
8. Liu, X., J. E. Penner, B. Das, D. Bergmann, J. M. Rodriguez, S. Strahan, M. Wang, and **Y. Feng** (2007), Uncertainties in global aerosol simulations: Assessment using three meteorological datasets, *J. Geophys. Res.*, in press.
9. Liu, H., J.H. Crawford, R.B. Pierce, P. Norris, S.E. Platnick, G. Chen, J.A. Logan, R.M. Yantosca, M.J. Evans, C. Kittaka, **Y. Feng**, and X. Tie (2006), Radiative effect of clouds on tropospheric chemistry in a global three-dimensional chemical transport model, *J. Geophys. Res.*, 111, D20303, doi:10.1029/2005JD006403.
10. **Feng, Y.**, J.E. Penner, S. Sillman, and X. Liu (2004), Effects of Cloud Overlap in Photochemical Models, *J. Geophys. Res., Vol. 109, No. D4, D0431*010.1029/2003JD004040.
11. Penner, J.E., S.Y. Zhang, M. Chin, C.C. Chuang, J. Feichter, **Y. Feng**, I.V. Geogdzhayev, P. Ginoux, M. Herzog, A. Higurashi, D. Koch, C. Land, U. Lohmann, M. Mishchenko, T. Nakajima, G. Pitari, B. Soden, I. Tegen, and L. Stowe, A comparison of model- and satellite-derived aerosol optical depth and reflectivity, *J. Atmos. Sci.* 59, 441-460, 2002
12. Penner, J.E., M. Andreae, H. Annegarn, L. Barrie, J. Feichter, D. Hegg, A. Jayaraman, R. Leaitch, D. Murphy, J. Nganga, and G. Pitari, *Chapter 5: Aerosols, their Direct and Indirect Effects*, in *Climate Change 2001: The Scientific Basis*, Report to the Intergovernmental Panel on Climate Change from the Scientific Assessment Working Group (WGI), 2001, Cambridge University Press. (**Y. Feng** listed as one of the contributing authors)

Papers in preparation

1. **Feng Y.**, and V. Ramanathan. Investigation of aerosol-cloud interactions using a chemical transport model constrained by satellite observations, submitted to *Tellus*, in revision, 2008.

Selected Presentations

1. Poster at the 2007 AGU Fall meeting at San Francisco, Investigation of Aerosol-Cloud Interactions using Chemical Transport Model Constrained by Satellite Observations, 2007.
2. Presentation at the 2006 Western Pacific Geophysics Meeting, A Study of Sea Salt Aerosol Indirect Effect on Marine Cloud Optical Thickness, 24-27 July, Beijing, China, 2006.
3. Presentation at the 8th Conference on Atmospheric Chemistry as part of the American Meteorological Society (AMS) 86th Annual Meeting, Direct and Indirect Effects of Nitrate and Ammonium Aerosol: A Column Model Study, 29 January-2 Feburary, Atlanta, GA, 2006.

4. Presentation at the 2005 American Geophysical Union (AGU) Fall Meeting, Global Modeling of Nitrate and Ammonium: Implications on Direct and Indirect Aerosol Forcing, 5-9 December, San Francisco, CA, 2005.
5. Presentation at the 24th Annual American Association for Aerosol Research (AAAR), Global Modeling of Nitrate and Ammonium: Heterogeneous Interaction of Aerosols and Tropospheric Chemistry, 17-21 October, Austin, TX, 2005.
6. Presentation at Atmospheric Sciences Division, Environmental Sciences Department, Brookhaven National laboratory, Modeling of Nitrate and Ammonium Aerosols in a Global Aerosol-Chemistry Model, December, Upton, NY, 2004.
7. Presentation at Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Modeling of Nitrate and Ammonium Aerosols in a Global Aerosol-Chemistry Model, November, Cambridge, MA, 2004.
8. Presentation at Geophysical Fluid Dynamics Laboratory (GFDL), Princeton University, Modeling Nitrate and Ammonium Aerosols: Impact on Tropospheric Aerosols and Chemistry, October, 2003.
9. Presentation at the DOE Atmospheric Chemistry Meeting: Penner, J.E., Y. Feng, M. Herzog, A. Itoh, X. Liu, Heterogeneous Chemistry Modeling: Progress on Integrating an Atmospheric Chemistry Model and Aerosol Model, 2003.
10. Presentation at the DOE Atmospheric Chemistry Meeting: Penner, J.E., Y. Feng, M. Herzog, A. Itoh, Progress on Integrating an Atmospheric Chemistry Model and Aerosol Model: Approximations and Current Results, 2002.
11. Presentation at the DOE Atmospheric Chemistry Meeting: Penner, J.E., Y. Feng, Nitrate and Ammonium in Aerosols: Effects of Dust and Sea Salt, 2001.
12. Poster at the 2002 AGU Fall meeting at San Francisco, Impact of Nitrate and Ammonium Aerosols on Global Concentrations, Size Distributions, and Radiative Forcing, 2002.
13. Poster at the 1999 AGU Fall meeting at San Francisco, Impacts on Climate Forcing by Anthropogenic Nitrate and Ammonium Aerosols, 1999.

Professional Activities

- Reviewer for Atmospheric Environment, 2006.
- Investigator in PACific Dust Experiment (PACDEX) funded by NSF, 2007 April-May.

Odelle L. Hadley (née Larivière) curriculum vitae

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Education:

Scripps Institution of Oceanography
University of California, San Diego

Ph.D - Earth Sciences (June 2008)

Dissertation Title: An Evaluation of Black Carbon Transport and Deposition to the California Mountains

Advisor: Professor V. Ramanathan

The Evergreen State College
Olympia, WA

B.S. - Physical Chemistry (September 2000)
B.A. - World Literature and History (June 1994)

Employment:

Senior Learning Skills Counselor - Jacobs School of Engineering (Summer 2006)
COSMOS (California State Summer School for Mathematics and Science) Cluster 7: The Living Oceans and Climate Change

Air Quality Specialist and Monitoring Technician (2000 – 2002)
Olympic Region Clean Air Agency, Olympia WA, 98502
Tel: (360) 586-1044

Honors & Recognition:

Participant in the French-German Summer School: Aerosols, Heterogeneous Chemistry, and Climate. (September-October 2004), Ile d'Oleron, France

Participant in the AGCI meeting on Aerosols and the Hydrologic Cycle (July 2004)
Aspen Global Change Institute, Aspen CO
NASA Space Grant, O.U.R. Earth Summer Research Internship (1999)
University of Washington, Seattle WA

Publications:

Hadley OL, Corrigan CE, Kirchstetter TW, "Modified Thermal-Optical Analysis using Spectral Absorption Selectivity to Distinguish Black Carbon from Pyrolized Organic Carbon" *Environmental Science and Technology*, 2008, *42* (22), pp 8459–

8464

Hadley OL, Ramanathan V, Carmichael GR, et al, "Trans-Pacific Transport of black carbon and fine aerosols into North America" *Journal of Geophysical Research-Atm* 112 (D5): Art. No. D05309 MAR 14 2007

Roberts G, Mauger G, **Hadley O**, et al., "North American and Asian aerosols over the eastern Pacific Ocean and their role in regulating cloud condensation nuclei" *Journal of Geophysical Research-Atm* 111 (D13): Art. No. D13205 JUL 12 2006

Presentations:

Hadley OL, Corrigan CE, Kirchstetter TW, Cliff SS,Ramanathan V, "Black Carbon Mass Concentration in California Mountain Snow" *oral presentation at American Geophysical Union Fall meeting (2007), San Francisco CA*

Hadley OL, Corrigan CE, Ramanathan V, Kirchstetter TW, Aguiar J, "Application of a New Thermal-Optical Evolved Gas Analysis Method to Quantify Black Carbon in Precipitation" *poster presentation at AAAR(American Association for Aerosol Research) 26thth Annual Conference (2007), Reno NV*

Hadley OL, Corrigan CE, Ramanathan V, Kirchstetter TW, Aguiar J, "Black carbon in Rain and Snow in the Sierra Nevada Mountains" *oral presentation at the CEC (California Energy Commission) 4th Annual Research Conference on Climate Change (2007), Sacramento CA*

Hadley OL, Corrigan CE, and Ramanathan V, "Black carbon and Aerosol Analysis in Rain and Snow During SUPRECIP – 2" *oral presentation at the CEC (California Energy Commission) 3rd Annual Research Conference on Climate Change (2006), Sacramento CA*

Larivière O, Ramanathan V, Carmichael GR, Roberts GC, Tang Y, and Mauger GS, "Trans-Pacific Transport of Black Carbon and Dust during the Cloud Indirect Forcing Experiment (CIFEX)" *oral presentation at AMS (American Meteorological Society), 7th Conference on Atmospheric Chemistry (2005), San Diego CA*
Ramanathan V, **Larivière O**, Roberts G, Wilcox E, Mauger G, Carmichael G, Haimov S, Schmitt C, and Tang Y, "Observations from the Cloud Indirect Forcing Experiment (CIFEX)" *oral presentation at WPAGU (Western Pacific American Geophysical Union) (2004), Honolulu HW*

Larivière O, Ramanathan V, Carmichael GR, Roberts GC, Tang Y, and Mauger GS, "Trans-Pacific Transport of Black Carbon and Dust during the Cloud Indirect Forcing Experiment (CIFEX)" *poster presentation at WPAGU (Western Pacific American Geophysical Union) (2004), Honolulu HW*

VIII. RELATED RESEARCH

UCSD - Ramanathan:

CAPPS (California AUAV Air Pollution Profiling Study): Autonomous Unmanned Aerial Vehicles are being used to measure vertical aerosol concentrations over NASA Dryden Research Center and Vandenberg Airforce Base. Included in these measurements are vertical distribution of BC and solar flux. In addition to the aircraft study, snow and rain is collected at several surface sites and analyzed for BC concentration. The precipitation collectors are accompanied by surface aerosol measurements, including ambient BC concentration. This study is currently funded by California Energy Commission.

UCSD - Prather:

In situ measurements of atmospheric particles using on-line single particle mass spectrometry (ATOFMS) provide unique insights into sources, size distributions, and both the degree and type of atmospheric processing. Comparison of source emission measurements to ambient data has permitted source apportionment of particle loadings. Measurements of the optical properties of particles as a function of size and chemistry directly link the mixing state of species, such as black carbon, to optical properties measured with the single-particle mass spectrometer. The Prather group has performed single particle measurements of soot at many locations around the world with a particular focus on California. Measurements have shown in these studies that soot is typically highly mixed with sulfate, nitrate, or both species the majority of the time.

ATOFMS research began in 1992 in the research laboratory of Prof. Kimberly Prather at the University of California at Riverside. Her research group moved in 2001 to the University of California at San Diego. Three generations of in-house spectrometer instruments have been developed. The newest instruments have been used to determine the source of aerosols "on the fly" using a library of major sources developed in our group over the past 10 years.

Current Support for Prather

Project/Proposal Title: Development of Chemical Ionization Time-of-Flight-Mass Spectrometer for Analysis of Organic-Nitrogen Compounds
Source of Support: Electric Power Research Institute
Total Award Amount: $273,000 Total Award Period Covered: 06/01/05 to 05/30/09

Project/Proposal Title: Field Laboratory and Modeling Investigations of Heterogeneous Processing of Asian Dust
Source of Support: NSF
Total Award Amount: $523,550 Total Award Period Covered: 08/15/06 – 07/31/09
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

Project/Proposal Title: Characterization of the Chemical Composition of Atmospheric Ultrafine Particles
Source of Support: EPA Subcontract w/Clarkson University
Total Award Amount: $462,750 Total Award Period Covered: 10/01/05 to 09/30/10
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

Project/Proposal Title: Environmental Postdoctoral Fellow: Studies of atmospheric aerosols
Source of Support: Camille and Henry Dreyfus Foundation
Total Award Amount: $120,000 Total Award Period Covered: 04/01/07 – 03/31/09
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

Project/Proposal Title: Using on-line mass spectrometry to probe single particle mixing state during ICE-L

Source of Support: NSF
Total Award Amount: $373,774 Total Award Period Covered: 03/02/07 – 03/01/10
Location of Project: University of California, San Diego
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 1.00 Sumr: 0.00

LBNL - Kirchstetter:

A retrospective analysis of ambient BC concentrations, based on archived measurements of coefficient of haze (COH), showed that COH levels can be converted to BC concentrations. Estimated annual BC concentrations for the San Francisco Bay Area, where diesel vehicles are the dominant BC source, decreased by a factor of ~3 from the late 1960s to the early 2000s despite a factor of ~6 increase in diesel fuel consumption. Derived diesel BC emission factors decreased from ~13 to <1 g kg^{-1} over this period. The decreases in ambient concentrations and emission factors are attributed to pollutant abatement policies. This research was funded by the California Energy Commission PIER program.

P.I.	Thomas Kirchstetter
Title	Effect of Aerosol Mixing State on BC Radiative Forcing Properties
Supporting Agency	NASA Radiation Sciences Program
Budget	$200,000 (Feb 1 2009 – Jan 30 2010)
Calendar months	4.0 months

Co-P.I.	Thomas Kirchstetter
Title	Assessing Near-Field Exposures from Distributed Residential Wood Smoke Combustion Sources
Supporting Agency	CARB (via subcontract with CalPoly)
Budget	$66,500 (Jan 1 2009 – Dec 31 2009)
Calendar months	1.0 months

Pending Support

P.I.	Thomas Kirchstetter
Title	Effect of Aerosol Mixing State on BC Radiative Forcing Properties
Supporting Agency	NASA Radiation Sciences Program
Budget	$200,000 (Feb 1 2010 – Jan 30 2011)
Calendar months	4.0 months

Co-P.I.	Thomas Kirchstetter
Title	Assessing Near-Field Exposures from Distributed Residential Wood Smoke Combustion Sources
Supporting Agency	CARB (via subcontract with CalPoly)
Budget	$70,500 (Jan 1 2010 – Dec 31 2010)
Calendar months	1.0 months

P.I.	Thomas Kirchstetter
Title	Characterization of Black Carbon Contaminated Snow
Supporting Agency	California Energy Commission
Budget	$261,000 (July 1 2010 – June 30 2011)
Calendar months	4.0 months

LBNL - Menon:

Under NASA funded studies, climate impacts of all aerosols, including carbonaceous aerosols are estimated using the NASA Goddard Institute for Space Studies global climate model. Studies include characterizing the role of aerosols from different sources on cloud properties, radiative forcing and climate. Special emphasis has been placed on the impact of black carbon aerosols on precipitations, radiative forcing, snow albedo changes and climate. Physical aerosol processes are investigated using both a bulk aerosol model and a quadrature method of moments based aerosol model. Ongoing work includes comparing model predicted aerosol-climate effects with observations, both satellite-based and field-based.

P.I.	Surabi Menon
Title	Understanding cloud systems and their role in climate change through observations, WRF simulations and general circulation model simulations.
Supporting Agency	DOE ARM Program
Budget	$267,000 (Feb 1 2009 – Jan 30 2010)
Calendar months	3.5 months
Co-P.I.	Surabi Menon
Title	Development of aerosol microphysics, radiative and cloud microphysics schemes for the GISS climate model
Supporting Agency	NASA Modeling Analysis and Prediction Program
Budget	$150,000 (Feb 15 2008 - Feb 14 2009)
Calendar months	4.0 months
Co-P.I.	Surabi Menon
Title	Optimal Coordination and Synchronization in Local Air Quality and GHG Emissions: An Economic Study of Multi-Gas Issues in Integrated Assessment of Global Climate Change
Supporting Agency	DOE IA Program
Budget	$68,000 (Feb 1 2008 – Jan 30 2009) (1 yr extension)
Calendar months	0 months
Pending Support	
Co-P.I.	Surabi Menon
Title	Climate and chemistry changes from 1975 to 2000 as observed and modeled in the coupled chemistry-aerosol-climate GISS ModelE Earth-system Model
Supporting Agency	NASA Modeling, Analysis and Prediction Program
Budget	$104,000 (Feb 1 2009 – Jan 31 2013)
Calendar months	3.2 months
Co-P.I.	Surabi Menon
Title	Predictability of historical variations in western US climate using the Goddard Earth Observing System Model Version 5
Supporting Agency	NASA Applied Sciences Program
Budget	$310,000 (Feb 1 2009 – Jan 30 2013)
Calendar months	2 months

P.I.	Surabi Menon
Title	Linking energy, natural resources, climate and the economy for assessing climate stabilization and carbon price scenarios
Supporting Agency	NASA Applied Sciences Program
Budget	$310,000 (Feb 1 2009 – Jan 30 2013)
Calendar months	2 months

UCB - Cohen:

Chemical Signature Differences between the South Coast & the San Joaquin Air Basins, California Air Resources Board PIs R.C. Cohen and A.H. Goldstein, coIs William H. Brune (Penn State), Frank Keutsch (Univ. Wisconsin), Joel Thornton (Univ. Washington) and Paul Wennberg (Caltech), $1,050,000 pending.

Evaluating the Benefits of Climate Change Mitigation Measures for Air Quality Management in California, EPA PI R.A. Harley, CoIs R.C. Cohen and A.H. Goldstein, $600,000 pending

ARCTAS-California 2008: An airborne mission to investigate California air quality, California Air Resources Board , P.I.s D.R. Blake UC Irvine, R.C. Cohen, Berkeley, H.B. Singh NASA Ames, $400,000 ($190,000 to Berkeley) (May 2008-April 2009).

Validation and interpretation of OMI measurements applied to urban and agricultural NO_x, NASA Earth Science Enterprise $380,056 (July 2008-June 2011).

Observing NO_x Controls Over Arctic Photochemistry, NASA Earth Science Enterprise $454,268 (March 2008-February 2010).

Analysis of satellite measurements to improve California's models for O_3 and PM, California Air Resources Board, $350,724 (May 2007-April 2009).

Oxidation Processes in Forest Canopies and Biosphere-Atmosphere Exchange of Nitrogen Oxides National Science Foundation, $579,341 (February 2007-January 2010).

Environmental postdoctoral fellowship: atmospheric chemistry of reactive nitrogen: ozone, aerosols and biosphere-atmosphere exchange, Camille and Henry Dreyfus Foundation, $120,000 (January 2007-December 2008)

The Berkeley Hydrowatch Center Keck Foundation, P.I. Inez Fung, co-I's R.C. Cohen, J. Kirchner, D.J. DePaolo, W. Dietrich, M. Conrad, $1.600,000 (January 2006-December 2009)

PNNL - Leung and Qian:

Previously we have worked with Dr. Ramanathan and Dr. Carmichael using a regional model (MM5) to simulate the meteorological forcing for an aerosol/chemistry model and a radiative transfer model to develop an observationally-constrained aerosol radiative forcing for Asia. More recently, the WRF model is being used in several studies to improve our understanding of aerosol effects on the hydrological cycle. For example, we have performed WRF simulations with and without interactive atmospheric chemistry and aerosols (WRF-Chem) to study the

effects of soot deposition on snow albedo and the subsequent impacts on snowpack and runoff in the western US.

To assess aerosol effects on precipitation, we have implemented a prognostic cloud droplet number parameterization in a bulk microphysics scheme and compared simulations of precipitation for different types of clouds (orographic, supercell, and squall line) with simulations obtained using spectral bin microphysics scheme. We are applying a similar modeling approach combined with observed precipitation to assess the impacts of aerosols on the changing characteristics of precipitation in China.

IX. RELEVANT PUBLICATION LISTS

Ramanathan, V. & Carmichael, G. Global and regional climate changes due to black carbon. Nature Geoscience 156, 221-227 (2008). **ATTACHED**

Ramanathan, V. et al. Atmospheric brown clouds: Hemispherical and regional variations in long-range transport, absorption, and radiative forcing. Journal of Geophysical Research-Atmospheres 112, D22S21 (2007). **ATTACHED**

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Ramanathan, V., Crutzen, P. J., Mitra, A. P. & Sikka, D. The Indian Ocean Experiment and the Asian Brown Cloud. Current Science 83, 947-955 (2002).

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Qian, Y., W. I. Gustafson Jr., L. R. **Leung**, S. J. Ghan. Effects of soot-induced snow albedo change on snowpack and hydrological cycle in western U.S. based on WRF chemistry and regional climate simulations, J. Geophys. Res., in press, 2008. **ATTACHED**

Leung, LR, and Y. Qian; Atmospheric Rivers Induced Heavy Precipitation and Flooding in the Western U.S. Simulated by the WRF Regional Climate Model *(submitted to Geophys. Res. Let. Oct. 2008)*.

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EXHIBIT B

BUDGET DETAIL AND PAYMENT PROVISIONS

1. Invoicing

A. For services satisf actorily rendered in accordance with this agreement and upon receipt and approval of the invoices which properly detail all charges the Air Resources Board agrees to compensate the Regents of the University of California, San Diego for actual expenditures incurred in accordance with the rates specified herein or attached hereto.

B. Invoices shall inclu de the Agreement Number and shall be submitted in triplicate not more frequently than quarterly in arrears to Ms. Emma Plasencia at the address stated in Exhibit A, Article 3.

C. Budget Flexibility: Subject to the prior review and approval of the contract manager, line item shifts of up to $25,000 or ten percent of the annual contract total, whichever is less, may be made up to a cumulative maximum of $25,000 or 10%, whichever is less, for all line item shifts over the life of the contract. There must be a substantial business justification for any shifts made. Fund shifts which increase Indirect, Overhead or General Expense line items are prohibited. Line item shifts may be proposed/requested by either the State or the University in writing and must not increase or decrease the total contract amount allocated. Any line item shifts must be approved in writing by the Division Chief of the Research Division, or his or her designee, and must be sent to the Contracts Section within 10 days of approval for inclusion in the contract folder. If the contract is formally amended, any line item shifts agreed to by the parties must be included in the amendment.

2. Budget Contingency Clause

A. It is m utually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to Contractor or to furnish any other considerations under this Agreement and Contractor shall not be obligated to perform any provisions of this Agreement.

B. If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either cancel this Agreement with no liability occurring to the State, or offer an agreement amendment to Contractor to reflect the reduced amount.

3. Payment

A. Costs for this Agreement shall be computed in accordance with State Administrative Manual Sections 8752 and 8752.1.

B. Nothing herei n contained shall preclude advance payments pursuant to Article 1, Chapter 3, Part 1, Division 3, Title 2 of the Government Code of the State of California.

C. ARB shall withhold payment equal to ten percent of the total Agreement cost until completion of all work and submission to ARB by University of a final report (including computer diskette copy) approved in accordance with Exhibit F, by ARB. It is University's responsibility to submit an invoice in triplicate with the revised final report for ten percent withheld.

D. University will be paid for the payment period completed upon receipt, by ARB, of an invoice and progress report satisfying the requirements of this Agreement. The invoice and progress report must be deemed by ARB to reflect reasonable work performed in accordance with the Agreement.

E. Th e amount to be paid to University under this Agreement includes all sales and use taxes incurred pursuant to this Agreement. University shall not receive additional compensation for reimbursement of such taxes and shall not decrease work to compensate therefore.

Budget Submittal Form

This form is supplied for presenting budget detail to the Air Resources Board.

UCSD 20092207

PLEASE TYPE OR PRINT:

Title of Proposal:	Black Carbon and the Regional Climate of California
Total Budget Requested:	$796,403
Period Covered (months):	24
University:	Scripps Institution of Oceanography University of California, San Diego
Address:	9500 Gilman Drive, Mail Code 0210, La Jolla, CA 92093-0210
Name of person authorized to bind this bid:	Ms. Sandra Varond
Title:	Contract and Grant Officer Scripps Institution of Oceanography
Phone:	(858) 534 - 0841

Signature of person authorized to bind this bid: _____

Budget Summary

Budget details must be supplied on pages 3-11 and on additional pages if necessary.
Instructions and definitions of terms are provided in Attachment 1 of the Guidelines for Proposals.

NOTE: Totals in categories in this summary are automatically updated from pages 3-11 when using Excel file.

Direct Costs		
1.	Labor & Employee Fringe Benefits	$273,572
2.	Subcontractor(s)/Consultant(s)	$462,750
3.	Equipment	$0
4.	Travel & Subsistence	$14,774
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$800
7.	Mail, Telephone, and Fax	$2,480
8.	Materials & Supplies	$1,845
9.	Analyses	$0
10.	Miscellaneous	$10,000
	Total Direct Cost	**$766,221**

Indirect Costs		
11.	Overhead	$30,182
	Total Indirect Cost	**$30,182**

Total Direct and Indirect Cost:	**$796,403**

Budget Detail
I. Direct Costs

1a. Labor Charges for Universities and Other State Agencies

Note: Total Salary Requested cells automatically calculate when using Excel file

	Individual's Name	Work Title	Mo. Salary	Est. Months	% of Effort or % of Salary	Total Salary Requested
A.	V. Ramanathan	PI, Professor	$21,938	1.00	100.00%	$22,491
B.	Yan Fang	Postgraduate Researcher	$6,040	8.00	100.00%	$49,326
C.	TBN	Postgraduate Researcher	$5,467	22.80	100.00%	$122,939
D.	TBN	Graduate Student Researcher	$4,450	11.62	100.00%	$52,167
E.						$0
(use additional page if necessary)						

Subtotal: $246,923

Cost justifications. Describe exactly why each individual listed in the Budget Detail is needed in this project (i.e., their role in the project), why this particular person was chosen for this role, and why their proposed level of effort is necessary. Describe, for each position listed, why the specified rate is reasonable or competitive. (Use additional page if necessary).

Dr. Ramanathan will lead the project and was chosen as PI due to his expertise in the field. Yan Fang is the lead PGR for this project. She will assist Dr. Ramanathan with the task at hand. She was chosen for this project due to her experience. Two TBN personnel will be joining the project (a PGR and a GSR). Both new team members will be chosen by the PI should this project be successful. The level of effort proposed is necessary in order to complete the tasks for the proposed research project. SIO salary rates are salary recharge rates. Salary recharge rates are calculated for actual productive time only (except for non-faculty sick leave, which is charged as direct). The rates include components for employee benefits, provisions for applicable merit increases and range adjustments in accordance with University policy.

1b. Fringe Benefits

Note: COST cells automatically calculate when using Excel file.

	Individual's Name	BASE ($)	RATE (%)	COST
A.	TBN	$26,649.00	100.00%	$26,649
B.				$0
C.				$0
(use additional page if necessary)				

Subtotal: $26,649

Cost justifications. Provide the Basis for the Fringe Benefit Rates. (Use additional page if necessary).

The fringe benefits listed above are for the tuition remission for the graduate student researcher (GSR). The GSR will be joining the project for both years therefore, tuition remission for both years are also requested.

2. Subcontractors & Consultants

List all subcontractors and consultants. **Also submit separate Budget Submittal Form for each subcontractor and consultant.**

	Subcontractor or consultant	Cost
A.	UC Berkeley	$387,750
B.	PNNL (Batelle)	$75,000
C.		
D.		
(use additional page if necessary)		

Subtotal: $462,750

Cost justifications. Describe exactly why each subcontractor is needed in this project (i.e., their role in the project). Describe, for each subcontractor, why the specified rate is reasonable or competitive. (Use additional page if necessary).

These subcontractors were chosen due to their expertise in black carbon and climate of California as well as their on going collabortion with Dr. Ramanathan.

3. Equipment (Itemize)

	Item	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Describe exactly why each listed equipment item is needed in this project, and why the cost is reasonable. (Use additional page if necessary).
(Refer to Exhibit E, page 19)

4. Travel and Subsistence (Itemize). Use State Rates (Appendix IV). NO FOREIGN TRAVEL ALLOWED.

	Description	Cost
A.	Air transportation	$5,806
B.	Ground transportation	$1,920
C.	Per diem or subsistence	$2,048
D.	Other (Lodging & Parking)	$5,000

Subtotal: $14,774

Cost justifications. Describe the purpose and duration of each trip and explain why the travel is necessary. (Use additional page if necessary).

Travel are for the PI and/or other SIO team members to attend scientific conferences (two trips per year are budgetted for scientific conferences). The results of this research will be presented in these meetings.

In addition, funds are also included for two trips per year for team members to travel to Richland, WA to meet and collaborate with Dr. Leung at PNNL.

5. Electronic Data Processing (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

6. Photocopying & Printing (Itemize)

	Description of product	Cost
A.	Photocopying and printing	$800
B.		

Subtotal: $800

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

These costs are necessary as the project requires analysis and data will need to be printed and/or photocopied so it can be reviewed and shared with the projects' team members.

7. Mail, Telephone & Fax (Itemize)

	Item	Cost
A.	Telephone, communications charge, mailing, etc. in support of research	$2,480
B.		
C.		

Subtotal: $2,480

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

Project specific costs that include telephone network use charges, tolls, voice and data communication charges, faxing, postage, subscriptions, and lother research related supplies are requested. Supply and expense items, categorized as project specific, and computer and networking services are for expenses that specifically benefit this project and are reasonable and necessary for the performance of this project

8. Materials & Supplies (Itemize)

	Item	Cost
A.	Supplies and Materials in Support of Research	$1,845
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal: $1,845

Cost justifications. Describe exactly why each item listed above is needed in this project. Explain why the proposed cost is reasonable. (Use additional page if necessary).

Supply and expense items categorized as project specific are for expenses that specifically benefit this project, are reasonable and necessary for the performance of this project, and can be readily allocable to this project.

Supplies and Materials (paper, Recordable CDs, disks, tapes - for data storage and analysis)
Year 1: $900
Year 2: $945
TOTAL: $1,845

9. Analyses (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$0**

Cost justifications. Describe the purpose of each different analysis and explain why it is needed in this project. Explain why the proposed rate is reasonable. (Use additional page if necessary).

10. Miscellaneous (Itemize)

	Item	Cost
A.	Publication Charges	$10,000
B.		
C.		
D.		

Subtotal: $10,000

Cost justifications. Justify all costs not included in the categories above. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

Publication charges are for the costs of publishing this project's results in scientific journals.

Publication Charges (estimates based on publication charges on projects similar to this one) – costs do vary depending on the number of pages, # of colored pages versus black and white pages--:
Year 1: $5,000
Year 2: $5,000
TOTAL: $10,000

Total Direct Costs (add subtotals for categories 1-10): $766,221

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	MTDC (Base: $301,822)	10.00%	$30,182
B.			$0
C.			$0

Subtotal: $30,182

Total Indirect Cost: $30,182

Total Project Cost: $796,403

Budget Submittal Form

This form is supplied for presenting budget detail to the Air Resources Board.

PLEASE TYPE OR PRINT:

Title of Proposal: Black Carbon and the Regional Climate of California

Total Budget Requested: $387,748

Period Covered (months): Jun 2009-May 2011

University: The Regents of the University of California - Berkeley

Address: Sponsored Projects Office, 2150 Shattuck Avenue, Suite 313, Berkeley, CA 94720-5940

Name of person authorized to bind this bid: Patricia Gates

Title: Assistant Director, Sponsored Projects Office

Phone: 510-642-8109

Signature of person authorized to bind this bid: _____

Budget Summary

Budget details must be supplied on pages 3-11 and on additional pages if necessary.
Instructions and definitions of terms are provided in Attachment 1 of the Guidelines for Proposals.

NOTE: Totals in categories in this summary are automatically updated from pages 3-11 when using Excel file.

Direct Costs		
1.	Labor & Employee Fringe Benefits	$299,488
2.	Subcontractor(s)/Consultant(s)	$0
3.	Equipment	$0
4.	Travel & Subsistence	$6,150
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$0
7.	Mail, Telephone, and Fax	$0
8.	Materials & Supplies	$27,825
9.	Analyses	$0
10.	Miscellaneous(tuition)	$20,939
	Total Direct Cost	**$354,402**

Indirect Costs		
11.	Overhead	$33,346
	Total Indirect Cost	**$33,346**

Total Direct and Indirect Cost:	**$387,748**

Budget Detail
I. Direct Costs

1a. Labor Charges for Universities and Other State Agencies

Note: Total Salary Requested cells automatically calculate when using Excel file

	Individual's Name	Work Title	Mo. Salary	Est. Months	% of Effort or % of Salary	Total Salary Requested
A. Year 1	Ronald Cohen	Professor	$11,456.00	0.50	100.00%	$5,728
B. Year 1	Thomas Kirchstetter	LBNL Scientist	$10,026.00	3.75	100.00%	$37,598
C. Year 1	Odelle Hadley	LBNL Postdoc	$5,252.00	4.00	100.00%	$21,008
D. Year 1	Surabi Menon	LBNL Scientist	$10,296.00	2.00	100.00%	$20,592
E. Year 1	Graduate Student	Graduate Student	$2,197.92	12.00	100.00%	$26,375
F. Year 2	Ronald Cohen	Professor	$12,028.80	0.50	100.00%	$6,014
G. Year 2	Thomas Kirchstetter	LBNL Scientist	$10,527.30	3.75	100.00%	$39,477
H. Year 2	Odelle Hadley	LBNL Postdoc	$5,514.60	4.00	100.00%	$22,058
I. Year 2	Surabi Menon	LBNL Scientist	$10,810.80	2.00	100.00%	$21,622
I. Year 2	Graduate Student	Graduate Student	$2,265.67	12.00	100.00%	$27,188

(use additional page if necessary)

Subtotal: $227,660

Cost justifications. Describe exactly why each individual listed in the Budget Detail is needed in this project (i.e., their role in the project), why this particular person was chosen for this role, and why their proposed level of effort is necessary. Describe, for each position listed, why the specified rate is reasonable or competitive. (Use additional page if necessary).

Cohen will supervise all aspects of the Berkeley team's contributions.
Kirchstetter will collect and validate COH data.
Hadley will compile BC data from field and satellites.
Menon will investigate regional climate responses in California.
One graduate student will conduct WRF-Chem experiments under the direction of Cohen and data analysis.

1b. Fringe Benefits

Note: COST cells automatically calculate when using Excel file

	Individual's Name	BASE ($)	RATE (%)	COST
A. Year 1	Ronald Cohen	$5,728.00	12.70%	$727
B. Year 1	Thomas Kirchstetter	$37,598.00	42.80%	$16,093
C. Year 1	Odelle Hadley	$21,008.00	42.80%	$8,991
D. Year 1	Surabi Menon	$20,592.00	42.80%	$8,813
E. Year 1	Graduate Student	$26,375.00	1.3% and 3%	$418
F. Year 2	Ronald Cohen	$6,014.00	12.70%	$764
G. Year 2	Thomas Kirchstetter	$39,477.00	42.80%	$16,896
H. Year 2	Odelle Hadley	$22,058.00	42.80%	$9,441
I. Year 2	Surabi Menon	$21,622.00	42.80%	$9,254
J. Year 2	Graduate Student	$27,188.00	1.3% and 3%	$431
(use additional page if necessary)				

Subtotal: $71,828

Cost justifications. Provide the Basis for the Fringe Benefit Rates. (Use additional page if necessary).

Note for GSR benefits, 1.3% is 10 months academic rate and 3% is 2 months at the summer rate

2. Subcontractors & Consultants

List all subcontractors and consultants. **Also submit separate Budget Submittal Form for each subcontractor and consultant.**

	Subcontractor or consultant	Cost
A.		
B.		
C.		
D.		
(use additional page if necessary)		

Subtotal: $0

Cost justifications. Describe exactly why each subcontractor is needed in this project (i.e., their role in the project). Describe, for each subcontractor, why the specified rate is reasonable or competitive. (Use additional page if necessary).

3. Equipment (Itemize)

	Item	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Describe exactly why each listed equipment item is needed in this project, and why the cost is reasonable. (Use additional page if necessary).
(Refer to Exhibit E, page 19)

4. Travel and Subsistence (Itemize). Use State Rates (Appendix IV). NO FOREIGN TRAVEL ALLOWED.

	Description	Cost
A.	Air transportation	$2,000
B.	Ground transportation	
C.	Per diem or subsistence	
D.	Other (Lodging & Parking, conference registration fees)	$4,150

Subtotal: $6,150

Cost justifications. Describe the purpose and duration of each trip and explain why the travel is necessary. (Use additional page if necessary).

Travel to one domestic conference to present results each year of project.

5. Electronic Data Processing (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

6. Photocopying & Printing (Itemize)

	Description of product	Cost
A.		
B.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

7. Mail, Telephone & Fax (Itemize)

	Item	Cost
A.		
B.		
C.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

8. Materials & Supplies (Itemize)

	Item	Cost
A.	Materials and supplies: electronic parts to install COH monitors at two BAAQMD sites at the start of the project, WRF-Chem computing services, publications, and other costs	$27,825
Breakdown		
	Installation COH monitors (refurbishing 2 monitors; LabView software, data acquisition & control electronics, tubing & Swagelok)	$9,500
	Publications (2 publications)	$4,100
	WRF-Chem computing service fee, software purchase, data storage & backup services	$9,225
	Other (aethalometer calibration & upgrade of floppy to flash drive, office supplies)	$5,000

Subtotal: $27,825

Cost justifications. Describe exactly why each item listed above is needed in this project. Explain why the proposed cost is reasonable. (Use additional page if necessary).

Costs are based on average expenditures in recent projects of similar scope adjusted for inflation. Two COH monitors will be refurbished and installed at two BAAQMD sites at the start of the project. This cost includes purchase of data acquisition and instrument control electronic supplies. The publication cost is conservative for two publications. Computing related costs include fees to use the computer network, purchase software and data storage and backup. Remaining costs include service calibration of aethalometers and upgrade of data storage from floppy to flash, and office supplies.

9. Analyses (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$0**

Cost justifications. Describe the purpose of each different analysis and explain why it is needed in this project. Explain why the proposed rate is reasonable. (Use additional page if necessary).

10. Miscellaneous (Itemize)

	Item	Cost
A.	Tuition and Fees	$20,939
B.		
C.		
D.		

Subtotal: $20,939

Cost justifications. Justify all costs not included in the categories above. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

The amount for resident tuition and fees for one semester is $5,107 per the University of California – Berkeley Registrar's website at:

http://registrar.berkeley.edu/Registration/feesched.html

Two semesters per year for each Graduate Student Researcher are included in the proposal budget. A 5% increase is included for Year 2.

Total Direct Costs (add subtotals for categories 1-10): $354,402

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	Total Direct Costs $354.402 less Tuition $20,939	10.00%	$33,346
B.	equals		
C.	$333,463.00		$0

Subtotal: $33,346

Total Indirect Cost: $33,346

Total Project Cost: $387,748

Budget Submittal Form

This form is supplied for presenting budget detail to the Air Resources Board.

PLEASE TYPE OR PRINT:

Title of Proposal: Black Carbon and the Regional Climate of California

Total Budget Requested: $75,000

Period Covered (months): 12

Institution: Battelle Pacific Northwest Division

Address: P.O. Box 999, Richland, WA 99352

Name of person authorized to bind this bid:

Title: Susan Turner

Phone: (509) 375-3810

Signature of person authorized to bind this bid: _____

Budget Summary

Budget details must be supplied on pages 3-11 and on additional pages if necessary.
Instructions and definitions of terms are provided in Attachment 1 of the Guidelines for Proposals.

NOTE: Totals in categories in this summary are automatically updated from pages 3-11 when using Excel file.

Direct Costs		
1.	Labor & Employee Fringe Benefits	$30,310
2.	Subcontractor(s)/Consultant(s)	$0
3.	Equipment	$0
4.	Travel & Subsistence	$1,797
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$0
7.	Mail, Telephone, and Fax	$0
8.	Materials & Supplies	$3,899
9.	Analyses	$0
10.	Miscellaneous	$0
	Total Direct Cost	**$36,006**

Indirect Costs		
11.	Overhead	$38,994
	Total Indirect Cost	**$38,994**

Total Direct and Indirect Cost:	**$75,000**

Budget Detail
I. Direct Costs

1a. Labor Charges for Universities and Other State Agencies

Note: Total Salary Requested cells automatically calculate when using Excel file

	Individual's Name	Work Title	Mo. Salary	Est. Months	% of Effort or % of Salary	Total Salary Requested
A. Year	Leung,Lai-Yung	Laboratory Fellow		0.71		$11,555
B. Year	Qian,Yun	Sr. Scientist		1.23		$9,743
C. Year	Scortzaru,Daniela R	Specialist		0.08		$464
D. Year	Ronfeld,Debbie M	Administrator		0.08		$282
E. Year						$0
F. Year						
G. Year						
H. Year						
I. Year						

(use additional page if necessary)

Subtotal: $22,044

Cost justifications. Describe exactly why each individual listed in the Budget Detail is needed in this project (i.e., their role in the project), why this particular person was chosen for this role, and why their proposed level of effort is necessary. Describe, for each position listed, why the specified rate is reasonable or competitive. (Use additional page if necessary).

1b. Fringe Benefits

Note: COST cells automatically calculate when using Excel file

	Individual's Name	BASE ($)	RATE (%)	COST
A. Year	Leung,Lai-Yung			$4,333
B. Year	Qian,Yun			$3,654
C. Year	Scortzaru,Daniela R			$174
D. Year	Ronfeld,Debbie M			$105
E. Year				
F. Year				
G. Year				
H. Year				
I.				
(use additional page if necessary)				

Subtotal: $8,266

Cost justifications. Provide the Basis for the Fringe Benefit Rates. (Use additional page if necessary).

Direct labor costs are based on average charge-out rates for specific job categories. Averae Charge-out rates are computed as follows:

Average Salary x (1 + Fringe Benefit Rate)/Productive Hours

Average charge-out rates are calculated each fiscal year (FY is October 1 through September 30) as follows:
FY; Salary Increase (compounding annually); Fringe Benefit Rate; Productive Hours
2009; 0.00%; 38.20%; 1832
2010; 4.16%; 37.50%; 1832
2011; 4.47%; 37.50%; 1832

Salary increases are based on Consumer Price Index forecasts, staff growth, and salary history. Productive hours in a year exclude holidays, vacation, and other absences. The fringe benefit rate for limited term and hourly employees are 16.4%.

2. Subcontractors & Consultants

List all subcontractors and consultants. **Also submit separate Budget Submittal Form for each subcontractor and consultant.**

Subcontractor or consultant	Cost
A.	
B.	
C.	
D.	
(use additional page if necessary)	

Subtotal: $0

Cost justifications. Describe exactly why each subcontractor is needed in this project (i.e., their role in the project). Describe, for each subcontractor, why the specified rate is reasonable or competitive. (Use additional page if necessary).

3. Equipment (Itemize)

Item	Cost
A.	
B.	
C.	
D.	

Subtotal: $0

Cost justifications. Describe exactly why each listed equipment item is needed in this project, and why the cost is reasonable. (Use additional page if necessary).
(Refer to Exhibit E, page 19)

4. Travel and Subsistence (Itemize). Use State Rates (Appendix IV). NO FOREIGN TRAVEL ALLOWED.

	Description	Cost
A.	Air transportation	$857
B.	Ground transportation	$211
C.	Per diem or subsistence	$729
D.	Other (Lodging & Parking)	

Subtotal: $1,797

Cost justifications. Describe the purpose and duration of each trip and explain why the travel is necessary. (Use additional page if necessary).

Two trips for one staff member to San Diego, CA to collaborate with UCSD project team.

5. Electronic Data Processing (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

6. Photocopying & Printing (Itemize)

	Description of product	Cost
A.		
B.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

7. Mail, Telephone & Fax (Itemize)

	Item	Cost
A.		
B.		
C.		

Subtotal: $0

Cost justifications. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

8. Materials & Supplies (Itemize)

	Item	Cost
A.	Publication Costs	$3,899
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal: $3,899

Cost justifications. Describe exactly why each item listed above is needed in this project. Explain why the proposed cost is reasonable. (Use additional page if necessary).

Publication costs.

9. Analyses (Itemize)

	Description	Cost
A.		
B.		
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$0**

Cost justifications. Describe the purpose of each different analysis and explain why it is needed in this project. Explain why the proposed rate is reasonable. (Use additional page if necessary).

10. Miscellaneous (Itemize)

	Item	Cost
A.		
B.		
C.		
D.		

Subtotal:	**$0**

Cost justifications. Justify all costs not included in the categories above. Explain the need for the expenditure and the basis for the costs. (Use additional page if necessary).

Total Direct Costs (add subtotals for categories 1-10):	**$36,006**

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	ORGANIZATIONAL OVERHEAD		$10,218
B.	PROGRAM DEV AND MGMT (PDM)		$2,668
C.	COST OF FACILITIES 414		$323
D.	GENERAL AND ADMINISTRATIVE COST		$18,967
E.	FEE		$6,818

Subtotal: $38,994

Total Indirect Cost: $38,994

Total Project Cost: $75,000

EXHIBIT D

SPECIAL TERMS AND CONDITIONS

1. Termination

A. This Agreement may be canceled at any time by either party, upon thirty (30) days written notice to the other party.

B. In the case of early termination, the performing agency will submit an invoice in triplicate and a report in triplicate covering services to termination date, following the invoice and progress report requirements of this Agreement. A copy and description of any data collected up to termination date will also be provided to ARB.

C. Upon receipt of the invoice, progress report, and data, a final payment will be made to the performing agency. This payment shall be for all ARB-approved, actually incurred costs in accordance with Exhibits A and B, and shall include labor, and materials purchased or utilized (including all noncancellable commitments) to termination date, and pro rata indirect costs as specified in the proposal budget.

2. Disputes

A. ARB reserves the right to issue an order to stop work in the event that a dispute should arise, or in the event that the ARB gives the performing agency a notice that this Agreement will be terminated. The stop-work order will be in effect until the dispute has been resolved or this Agreement has been terminated.

B. Any dispute concerning a question of fact arising under the terms of this Agreement which is not disposed of within a reasonable period of time by agency employees normally responsible for the administration of this agreement, shall be brought to the attention of the Executive Officer or designated representative of each agency for joint resolution.

3. Amendments

ARB reserves the right to amend this agreement for additional time and/or additional funding.

EXHIBIT E

ADDITIONAL PROVISIONS

1. Equipment Provisions

A. Equipment is defined as movable articles of nonexpendable property that meet the following requirements:

1. have a normal useful life (including extended life due to repairs) of at least one year;
2. have a unit acquisition cost of at least $5,000 for other than land and structures (for example, identical assets costing $3,000 each for a $12,000 total would not meet the requirements); and
3. be used to conduct work under this contract, and/or
4. any and all EDP equipment used to conduct work under this contract.

B. The cost of equipment includes the purchase price plus all costs to acquire, install, and prepare equipment for its intended use.

C. The ARB reserves the right to purchase total equipment whose cost is greater than $25,000 and any and all EDP equipment for this contract, through the State procurement process. Contractor's proposed cost of this equipment will be deducted from the total amount payable to the Contractor. The equipment provided by ARB will be equivalent to Contractor's specifications, as described in Contractor's proposal.

D. In the event Contractor purchases with ARB funds, procures, uses, or otherwise takes possession of equipment owned by ARB to perform work under this contract, title to such equipment shall remain with ARB and such equipment shall become ARB's equipment upon delivery thereof into the Contractor's control or possession.

E. Contractor shall obtain written approval from ARB prior to the purchase of equipment that is not specifically identified and listed in the approved budget and which is valued at more than $5,000. The contract funding shall be adjusted for any equipment or supplies furnished by ARB.

F. ARB reserves the right to full and adequate access to ARB equipment.

G. Contractor shall maintain and administer a program for the utilization, maintenance, repair, protection, and preservation of ARB equipment, whether acquired from the ARB or purchased with ARB funds from a third party, so as to assure its full availability and usefulness for performance of this contract or as long as this equipment remains in the control or possession of the Contractor.

The Contractor will install upon each item of equipment a tag identifying the equipment as belonging to the ARB and will maintain location records of all equipment. The Contractor shall take steps to comply with all appropriate directions or instructions that the ARB may prescribe for the protection of ARB equipment.

H. Contractor shall provide to ARB, with the final invoice, a final equipment inventory. The final invoice shall contain an itemization of equipment purchased with ARB funds or procured through the State procurement process, including the type of equipment, manufacturer, serial number, and cost. All ARB equipment shall be returned to the ARB at ARB's expense in full operating condition upon termination of this contract, unless ARB approves a different disposition in writing. Disposition of the equipment shall be in accordance with the instructions from ARB, to be issued after receipt of the final inventory.

2. Reports and Data Compilations

A. ***With respect to each invoice period, University shall forward to the ARB Contract Administrator, one (1) electronic copy of the progress report and mail one (1) copy of the progress report along with each invoice. (Do not use Express Mail). When emailing the progress report, the "subject line" should state the contract number and the billing period. Each progress report will begin with the following disclaimer:***

> *The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.*

B. Each progress report will also include:

1. A brief narrative account of project tasks completed or partially completed since the last progress report;

2. A brief discussion of problems encountered during the reporting period and how they were or are proposed to be resolved;

3. A brief discussion of work planned, by project task, before the next progress report; and

4. A graph or table showing allocation of the budget and amount used to date.

5. A graph or table showing percent of work completion for each task.

C. If the project is behind schedule, the progress report must contain an explanation of reasons and how the University plans to resume the schedule.

D. Six months prior to Agreement termination date, University will deliver to ARB twenty (20) bound copies of a draft final report. The reports may be stapled or spiral bound, depending on size. The draft final report will conform to Exhibit F.

E. Within forty-five (45) days of receipt of ARB's comments on the draft Final Report (Exhibit F), University will deliver to ARB's Contract Manager two (2) copies of the Final Report incorporating all reasonable alterations and additions requested by ARB. Upon approval of the amended final report approved by ARB in accordance to Exhibit F, University will within two (2) weeks, deliver to ARB two (2) camera ready UNBOUND originals of a Final Report incorporating all final alterations and additions. The final report will conform to the Contract Final Report Format, Exhibit F.

F. Together with the final report, University will deliver a copy of the report on diskette/CD, using any common word processing software (please specify the software used) and a set of all data compilations as specified by the ARB Contract Manager.

G. University's obligation under this Agreement shall be deemed discharged only upon submittal to ARB of an acceptable final report in accordance to Exhibit F, report diskette/CD, all required data compilations, and any other project deliverables.

H. Prior to completion of this Agreement, University shall be entitled to release or make available reports, information, or other data prepared or assembled by it pursuant to this Agreement, in scientific journals and other publications and at scientific meetings, provided however, that a copy of the publication be submitted to ARB for review and comment 45 days prior to such publication. Further, University shall place the disclaimer statement in a conspicuous place on all such reports or publications. Health related reports should include an acknowledgment to the late Dr. Friedman. Nothing in this provision shall be construed to limit the right of State to release information obtained from the University or to publish reports, information, or data in State publications.

3. **Copyrightable Materials**

In recognition of the policy of ARB and University to promote and safeguard free and open inquiry by faculty, students and the members of the public and in furtherance of such policy, both parties agree to the following with respect to rights in data and copyrights under this Agreement:

A. The term "Subject Data" shall mean all original and raw research data, notes, computer programs, writings, sound recordings, pictorial reproductions, drawings or other graphical representations, and works of any similar nature, produced by University in performance of this Agreement, but specifically excluding "Reports," as defined in this Agreement. Subject Data also excludes financial reports, cost analyses, and similar information incidental to contract administration.

B. The term "Reports" shall have the meaning assigned to it in this Exhibit F of this Agreement.

C. Ownership of all Subject Data and copyrights arising from Subject Data shall be vested in University while ownership of all Reports and copyrights arising from the Reports delivered under this Agreement shall be vested in ARB. University agrees to make available to the public for public benefit, to the extent the University shall have the legal right to do so, without license or fee, any scholarly articles which are published from the Subject Data.

D. Nothing in this exhibit or Agreement shall be construed to limit the right of University faculty, students or staff to publish the Subject Data in the form of scholarly articles in academic journals nor to affect, abrogate or limit the right of University faculty, staff or students to make use of the Subject Data.

4. Travel & Per Diem

A. Any reimbursement for necessary travel and per diem shall be at the University's approved travel rates.

B. No foreign travel shall be reimbursed unless prior written authorization is obtained from ARB.

5. Meetings

A. Initial meeting. Before work on the contract begins, the Principal Investigator and key personnel will meet with the ARB Contract Manager and other staff to discuss the overall plan, details of performing the tasks, the project schedule, items related to personnel or changes in personnel, and any issues that may need to be resolved before work can begin.

B. Progress review meetings. The Principal Investigator and appropriate members of his or her staff will meet with ARB's Contract Manager at quarterly intervals to discuss the progress of the project. This meeting may be conducted by phone.

C. Technical Seminar. The Contractor will present the results of the project to ARB staff and a possible webcast at a seminar at ARB facilities in Sacramento or El Monte.

6. Confidentiality

A. It is understood that in the course of carrying out this Agreement, State may wish to provide University with proprietary or confidential information of State (Proprietary Information). University agrees to use its best efforts to hold proprietary information in confidence and shall return it to State upon the completion of the project.

B. This obligation shall apply only to proprietary information that is designated or identified as such in writing by State prior to the disclosure thereof. All proprietary information shall be sent only to the Principal Investigator. Moreover, this obligation shall not apply to any proprietary information which: a) is or becomes publicly known through no wrongful or negligent act on the part of University; b) is already known to University at the time of disclosure; c) independently developed by University without breach of this agreement; or d) is generally disclosed to third parties by State without similar restrictions on such third parties.

7. Studies Involving Human or Animal Subjects

A copy of the Institutional Review Board (IRB) approval must be submitted to ARB upon receipt by the investigator.

8. Patent Provisions

These provisions apply only to non-state entity subcontractors that may be a part of this Agreement.

A. Definitions

1. "Invention" means any discovery or product of creative imagination, thought, mental synthesis, or purposeful experimentation conceived or first reduce to practice in the course of or under this Agreement. The term "invention" includes, but is not limited to, any art, method, process, device, machine, manufacture, design, or composition of matter, or any new and useful improvement or application thereof, or any variety of plant, that is or may be patentable under the patent laws of the United States of America.

2. "Agreement" means any legally enforceable agreement, covenant, compact grant, or other arrangement or subcontract setting forth terms and conditions to do or not to do something and entered into by or for the benefit of the State where a purpose of the agreement is the conduct of experimental, developmental, or research work.

3. "Subcontract" means an agreement under or subordinate to a previous or prime agreement, including this Agreement.

4. "Subcontractor" means an individual or firms that contracts with Contractor to perform part or all of the prime Contractor's work under this Agreement.

5. "To bring to the point of practical application" means to manufacture in the case of a composition or product, to practice in the case of a process, or to operate in the case of a machine, device, or system and, in each case, under such conditions as to establish that the invention is being worked, operated, or utilized, and that its benefits are reasonable accessible to the public.

B. **Rights Granted to the State**

Subcontractor agrees to grant to State all right, title, and interest in and to each invention discovered, conceived, or first reduced to practical application during performance of the Subcontract, subject to the reservation of a non-exclusive paid-up worldwide license to Subcontractor.

C. **Invention Disclosures and Reports**

With respect to each invention, Subcontractor shall furnish to ARB:

1. A written disclosure of each invention within six (6) months after conception or first actual reduction to practice, whichever occurs first under the Subcontract, sufficiently complete in technical detail to convey to one skilled in the art to which the invention pertains a clear understanding to the nature, purpose, and operation, and the physical, chemical, and electrical characteristics of the invention;

2. A final report listing all inventions, including all those previously disclosed, or certifying that there are no inventions prior to final payment under this Subcontract.

3. Information in writing, as soon as is practicable, of the date and identity of any public use, sale, or publication of any such invention made by or known to Subcontractor, or of any contemplated publication by Subcontractor;

4. Upon request, such duly executed instruments and other papers as deemed by ARB necessary to vest in State the rights granted it under this patent provision and to enable State to apply for and prosecute any patent application in any country covering such invention where State has the right under this patent provision to file such application; and

5. Upon request, an irrevocable power of attorney to inspect and make copies of any United States patent application filed by or on behalf of Subcontractor. This demand may also be made under subdivision 8.

D. **License Granted by Subcontractor to Others Subject to State's Rights**

Subcontractor recognizes that State may contract for property or services with respect to which the vendor may be liable to Subcontractor for royalties for the use of an invention on account of such a contract. Subcontractor further recognizes that it is the policy of State not to pay, in connection with its agreements, charges for use of patents in which the State holds title. In recognition of this policy, Subcontractor agrees to participate in and make appropriate arrangements for the exclusion of such charges from such agreements or for the refund of amounts received by Subcontractor with respect to any such charges not so excluded.

E. **Subcontracts**

1. Contractor shall, unless otherwise authorized or directed by State, include a patent rights clause containing all the terms of this patent provision in any Subcontract hereunder where the purpose of the subcontract is the conduct of experimental, developmental, or research work. In the event of refusal by a Subcontractor to accept this patent provision, Contractor:

   (1) shall promptly submit a written report to the State setting forth the Subcontractor's reasons for such refusal or the reasons Contractor is of the opinion that the inclusion of this clause would be unacceptable, and other pertinent information that may expedite disposition of this matter; and

   (2) shall not proceed with the Subcontract without the written authorization of State.

2. Contractor shall not, in any Subcontract or by using such a Subcontract as consideration thereof, acquire any rights to inventions for its own use (as distinguished from such rights as may be required solely to fulfill its agreement obligations to State in the performance of this Agreement).

3. Contractor, at the earliest practicable date, shall also notify State in writing of any Subcontract containing a patent rights clause, furnish to State a copy of such Subcontract, and notify State when such Subcontract is completed. It is understood that State is a third party beneficiary of any Subcontract clause granting rights to State in inventions, and Contractor hereby assigns to State all the rights that Contractor would have to enforce the Subcontractor's obligations for the benefit of State with respect to inventions. Contractor shall not be obligated to enforce the agreements of any Subcontractor to State with regard to inventions.

F. **Right to Disclose Inventions**

State may duplicate and disclose reports and disclosures of inventions required to be furnished by Subcontractor pursuant to this patent provision.

G. **Forfeiture of Rights in Unreported Inventions**

Subcontractor shall forfeit to State all rights in any invention which Subcontractor fails to report to State, at or prior to the time Subcontractor (1) files or causes to be filed a United States or foreign application thereon, or (2) submits the final report required by 3., B of this patent provision, whichever is later, provided that Subcontractor shall not forfeit rights in an invention if (a) contending that the invention is not an invention, it nevertheless reports the invention and all the facts pertinent to Subcontractor's contention to State, the time specified in 3. A above, or (b) Subcontractor establishes that the failure to report was due entirely to causes beyond Subcontractor's control and without Subcontractor's fault or negligence. Subcontractor shall be deemed to hold any such forfeited invention and the patent applications and patent pertaining thereto, in trust for State pending written assignment of the invention. The right accruing to State under this paragraph shall be in addition to and shall not supersede any other rights State may have in relation to unreported inventions.

H. **Examination of Records Relating to Inventions**

State shall, until the expiration of three years after final payment under this agreement, have the right to examine any books, records, documents, and other supporting data of Subcontractor that State shall reasonably deem directly pertinent to the discovery or identification of inventions or to compliance by Subcontractor with the requirements of this patent provision.

EXHIBIT F

RESEARCH FINAL REPORT FORMAT

The research contract Final Report (Report) is as important to the contract as the research itself. The Report is a record of the project and its results, and is used in several ways. Therefore, the Report must be well organized and contain certain specific information. The ARB's Research Screening Committee (RSC) reviews all draft Final Reports, paying special attention to the Abstract and Executive Summary. If the RSC finds that the Report does not fulfill the requirements stated in this Appendix, the document will not be approved for release, and final payment for the work completed may be withheld. This Appendix outlines the requirements that must be met when producing the Report.

Note: In partial fulfillment of the Final Report requirements, the Contractor shall submit a copy of the Report on a CD in PDF format and in a word-processing format, preferably in Word - Version 6.0 or later. This is in addition to the submission of any paper copies required. The diskette shall be clearly labeled with the contract title, ARB contract number, the words "Final Report", and the date the report was submitted.

Legibility. Each page of the approved Final Report must be legible and camera-ready.

Binding. The draft Report, including its appendices, must be either spiral bound or stapled, depending on size. The revised Report and its appendices should be spiral bound, except for two unbound, camera-ready originals.

Cover. Do not supply a cover for the Report. The ARB will provide its standard cover.

One-sided vs. two-sided. To conserve paper, both the draft Report and the revised Report, except for the unbound camera-ready copies, should be printed on both sides of the page. The unbound camera-ready copies must be printed on only one side of the page.

Title. The title of the Report should exactly duplicate the title of the contract unless a change is approved in writing by the contract manager.

Spacing. In order to conserve paper, copying costs, and postage, please use single or one-line (1) spacing.

Page size. All pages should be of standard size (8 ½" x 11") to allow for photo-reproduction.

Large tables or figures. Foldout or photo-reduced tables or figures are not acceptable because they cannot be readily reproduced. Large tables and figures should be presented on consecutive
8 ½" x 11" pages, each page containing one portion of the larger chart.

Color. Color presentations are not acceptable; printing shall be black on white only.

Corporate identification. Do not include corporate identification on any page of the Final Report, except the title page.

Unit notation. Measurements in the Reports should be expressed in metric units. However, for the convenience of engineers and other scientists accustomed to using the British system, values may be given in British units as well in parentheses after the value in metric units. The expression of measurements in both systems is especially encouraged for engineering reports.

Section order. The Report should contain the following sections, in the order listed below:

Title page
Disclaimer
Acknowledgment (1)
Acknowledgment (2)
Table of Contents
List of Figures
List of Tables
Abstract
Executive Summary
Body of Report
References
List of inventions reported and copyrighted materials produced
Glossary of Terms, Abbreviations, and Symbols
Appendices

Page numbering. Beginning with the body of the Report, pages shall be numbered consecutively beginning with "1", including all appendices and attachments. Pages preceding the body of the Report shall be numbered consecutively, in ascending order, with small Roman numerals.

Title page. The title page should include, at a minimum, the contract number, contract title, name of the principal investigator, contractor organization, date, and this statement: "Prepared for the California Air Resources Board and the California Environmental Protection Agency"

Disclaimer. A page dedicated to this statement must follow the Title Page:

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgment (1). Only this section should contain acknowledgments of key personnel and organizations who were associated with the project. The last paragraph of the acknowledgments must read as follows:

This Report was submitted in fulfillment of [ARB contract number and project title] by [contractor organization] under the [partial] sponsorship of the California Air Resources Board. Work was completed as of [date].

Acknowledgment (2). Health reports should include an acknowledgment to the late Dr. Friedman. Reports should include the following paragraph:

This project is funded under the ARB's Dr. William F. Friedman Health Research Program. During Dr. Friedman's tenure on the Board, he played a major role in guiding ARB's health research program. His commitment to the citizens of California was evident through his personal and professional interest in the Board's health research, especially in studies related to children's health. The Board is sincerely grateful for all of Dr. Friedman's personal and professional contributions to the State of California.

Table of Contents. This should list all the sections, chapters, and appendices, together with their page numbers. Check for completeness and correct reference to pages in the Report.

List of Figures. This list is optional if there are fewer than five illustrations.

List of Tables. This list is optional if there are fewer than five tables.

Abstract. The abstract should tell the reader, in nontechnical terms, the purpose and scope of the work undertaken, describe the work performed, and present the results obtained and conclusions. The purpose of the abstract is to provide the reader with useful information and a means of determining whether the complete document should be obtained for study. The length of the abstract should be no more than about 200 words. Only those concepts that are addressed in the executive summary should be included in the abstract.

Example of an abstract:

A recently developed ground-based instrument, employing light detecting and ranging (lidar) technology, was evaluated and found to accurately measure ozone concentrations at altitudes of up to 3,000 meters. The novel approach used in this study provides true vertical distributions of ozone concentrations aloft and better temporal coverage of these distributions than other, more common methods, such as those using aircraft and ozonesonde (balloon) techniques. The ozone and aerosol measurements from this study, in conjunction with temperature and wind measurements, will provide a better characterization of atmospheric conditions aloft and the processes involved in the formation of unhealthful ozone concentrations than can be achieved with traditional ground-based monitors.

Executive Summary. The function of the executive summary is to inform the reader about the important aspects of the work that was done, permitting the reader to understand the research without reading the entire Report. It should state the objectives of the research and briefly describe the experimental methodology[ies] used, results, conclusions, and recommendations for further study. All of the concepts brought out in the abstract should be expanded upon in the Executive Summary. Conversely, the Executive Summary should not contain concepts that are not expanded upon in the body of the Report.

The Executive Summary will be used in several applications as written; therefore, please observe the style considerations discussed below.

Limit the Executive Summary to two pages, single spaced.

Use narrative form. Use a style and vocabulary level comparable to that in Scientific American or the New York Times.

Do not list contract tasks in lieu of discussing the methodology.

Discuss the results rather than listing them.

Avoid jargon.

Define technical terms.

Use passive voice if active voice is awkward.

Avoid the temptation to lump separate topics together in one sentence to cut down on length.

The Executive Summary should contain four sections: Background, Methods, Results, and Conclusions, described below.

THE BACKGROUND SECTION. For the Background, provide a one-paragraph discussion of the reasons the research was needed. Relate the research to the Board's regulatory functions, such as establishing ambient air quality standards for the protection of human health, crops, and ecosystems; the improvement and updating of emissions inventories; and the development of air pollution control strategies.

THE METHODS SECTION. At the beginning of the Methods section, state what was done in general, in one or two sentences.

The methodology should be described in general, nontechnical terms, unless the purpose of the research was to develop a new methodology or demonstrate a new apparatus or technique. Even in those cases, technical aspects of the methodology should be kept to the minimum necessary for understanding the project. Use terminology with which the reader is likely to be familiar. If it is necessary to use

technical terms, define them. Details, such as names of manufacturers and statistical analysis techniques, should be omitted.

Specify when and where the study was performed, if it is important in interpreting the results.

The findings should not be mentioned in the Methods section.

THE RESULTS SECTION. The Results section should be a single paragraph in which the main findings are cited and their significance briefly discussed. The results should be presented as a narrative, not a list. This section must include a discussion of the implications of the work for the Board's relevant regulatory programs.

THE CONCLUSIONS SECTION. The Conclusions section should be a single short paragraph in which the results are related to the background, objectives, and methods. Again, this should be presented as a narrative rather than a list. Include a short discussion of recommendations for further study, adhering to the guidelines for the Recommendations section in the body of the Report.

Body of Report. The body of the Report should contain the details of the research, divided into the following sections:

INTRODUCTION. Clearly identify the scope and purpose of the project. Provide a general background of the project. Explicitly state the assumptions of the study.

Clearly describe the hypothesis or problem the research was designed to address. Discuss previous related work and provide a brief review of the relevant literature on the topic.

MATERIALS AND METHODS. Describe the various phases of the project, the theoretical approach to the solution of the problem being addressed, and limitations to the work. Describe the design and construction phases of the project, materials, equipment, instrumentation, and methodology. Describe quality assurance and quality control procedures used. Describe the experimental or evaluation phase of the project

RESULTS. Present the results in an orderly and coherent sequence. Describe statistical procedures used and their assumptions. Discuss information presented in tables, figures and graphs. The titles and heading of tables, graphs, and figures, should be understandable without reference to the text. Include all necessary explanatory footnotes. Clearly indicate the measurement units used.

DISCUSSION. Interpret the data in the context of the original hypothesis or problem. Does the data support the hypothesis or provide solutions to the research problem? If appropriate, discuss how the results compare to data from similar or related studies. What are the implications of the findings? Identify innovations or development of new techniques or processes. If appropriate, discuss cost projections and economic analyses.

SUMMARY AND CONCLUSIONS. This is the most important part of the Report because it is the section that will probably be read most frequently. This section should begin with a clear, concise statement of what, why, and how the project was done. Major results and conclusions of the study should then be presented, using clear, concise statements. Make sure the conclusions reached are fully supported by the results of the study. Do not overstate or overinterpret the results. It may be useful to itemize primary results and conclusions. A simple table or graph may be used to illustrate.

RECOMMENDATIONS. Use clear, concise statements to recommend (if appropriate) future research that is a reasonable progression of the study and can be supported by the results and discussion.

References. Use a consistent style to fully cite work referenced throughout the Report and references to closely related work, background material, and publications that offer additional information on aspects of the work. Please list these together in a separate section, following the body of the Report. If the Report is lengthy, you may list the references at the end of each chapter.

List of inventions reported and publications produced. If any inventions have been reported, or publications or pending publications have been produced as a result of the project, the titles, authors, journals or magazines, and identifying numbers that will assist in locating such information should be included in this section.

Glossary of terms, abbreviations, and symbols. When more than five of these items are used in the text of the Report, prepare a complete listing with explanations and definitions. It is expected that every abbreviation and symbol will be written out at its first appearance in the Report, with the abbreviation or symbol following in parentheses [i.e., carbon dioxide (CO_2)]. Symbols listed in table and figure legends need not be listed in the Glossary.

Appendices. Related or additional material that is too bulky or detailed to include within the discussion portion of the Report shall be placed in appendices. If a Report has only one appendix, it should be entitled "APPENDIX". If a Report has more than one appendix, each should be designated with a capital letter (APPENDIX A, APPENDIX B). If the appendices are too large for inclusion in the Report, they should be collated, following the binding requirements for the Report, as a separate document. The contract manager will determine whether appendices are to be included in the Report or treated separately. Page numbers of appendices included in the Report should continue the page numbering of the Report body. Pages of separated appendices should be numbered consecutively, beginning at "1".