Research Division

Contractor: Regents of UC Irvine

Contract # 07-335

FUNDING FISCAL YEAR	FY 07/08	FY 08/09	FY 09/10	
TERM	~~05/01/08-10/31/09~~	~~05/01/08-10/31/09~~	~~05/01/08-10/31/09~~	
Amd 1	05/01/08-05/15/10	05/01/08-05/15/10	05/01/08-05/15/10	
PCA	72380	72380	72380	
LINE ITEM/OBJECT	398	398	398	TOTAL
DESCRIPTION	Collect & analyze air samples			

	FY 07/08	FY 08/09	FY 09/10	TOTAL
Contract $	$ 280,000.00	$ 80,000.00	40,000.00	$ 400,000.00
Y-E Funding change by RD (6/26/08)	$ 120,000.00	$ (80,000.00)	(40,000.00)	$ -
Rebudget Request by RD (12/29/08)	$ (124,826.00)	$ 124,826.00		$ -
	$ 68,091.00	$ (68,091.00)		
Rebudget Request by RD (12/29/08)	$ 9,415.00	$ (9,415.00)		$ -
Rebudget Request by RD (04/07/09)	$ 47,320.00	$ (47,320.00)		$ -
Amd. #1 - Time only (10/07/09?)				
Total, Contract	$ 400,000.00	$ -	$ -	$ 400,000.00

Payments to Contractor:

Inv. #	Inv. Date	Ser Per					C/S
Q1-18610	8/1/2008		56,690.04			56,690.04	C080394
Q2-18610	12/1/2008		46,974.31			46,974.31	C080394
Q3-18610	3/23/2009		21,118.83			21,118.83	C080687
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
						-	
Total, Payments			$ 124,783.18	$ -	$ -	124,783.18	
Balance Available to Pay Contractor			$ 275,216.82	$ -	$ -	$ 275,216.82	
Balance Must Be Spent By:			*6/30/2010*	*6/30/2011*	*6/30/2012*		

Notes:

Contract Manager: Jim Pederson

17

RCVD AUG

UNIVERSITY OF CALIFORNIA, IRVINE

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C080394

Air Resource Board Research Div.
Attn: Emma Plasencia
P.O. Box 2815
Sacramento, CA 95812

ACCOUNTING OFFICE
111 ACADEMY WAY, SUITE 210
IRVINE, CALIFORNIA 92697-1050
FAX NUMBER: (949) 824-3895

1 Aug 08

RE: Contarct Number: 07-335
Project Title: "ARCTAS California 2008: An Airborne Mission to Investigate California Air Quality"
P.I. Dr. Donald Blake
Period of Performance 05/01/08-10/31/09
UCI Fund Number 111200-18610

INVOICE# Q1-18610
Period of Claim: 05/01/08-06/30/08

	Current Charges	Prev Charges	Cumulative Charges
Major Cost Elements:			
Personnels	36,790.59	0.00	36,790.59
Supplies Expenses	3,093.73	0.00	3,093.73
Equipment *	0.00	0.00	0.00
Travel	0.00	0.00	0.00
Benefits	9,721.55	0.00	9,721.55
GRA Benefits	2,123.60		2,123.60
Other	0.00	0.00	0.00
Total Direct Cost	51,729.47	0.00	51,729.47
Overhead @ J10.0%	4,960.57	0.00	4,960.57
Total Cost Due	56,690.04	0.00	56,690.04
Payments Received To Date			0.00
Balance Due >>>>>>>>>>>			**56,690.04**

Please make your check payable to **The Regents of the University of California Irvine** and mail to the above address. If there is any problem preventing your prompt payment, please contact Elena Abad for assistance. She can be reached at 949-824-4505 or email emabad@uci.edu. Thank you for your assistance.

Sincerely,

Original Signed By
Janet Mendoza
Janet Mendoza
Manager, C & G Accounting

PAYMENT APPROVED:

BART E. CROES, P.E.
CHIEF, RESEARCH DIVISION
DATE 12/17/08

RCVD DEC 19 2008

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RCVD DEC 8 '0

ACCOUNTING OFFICE
111 ACADEMY WAY, SUITE 210
IRVINE, CALIFORNIA 92697-1050
FAX NUMBER: (949) 824-3895

Air Resource Board Research Div.
Attn: Emma Plasencia
P.O. Box 2815
Sacramento, CA 95812

1 Dec 08

RE: Contarct Number: 07-335
Project Title: "ARCTAS California 2008: An Airborne Mission to Investigate California Air Quality"
P.I. Dr. Donald Blake
Period of Performance 05/01/08-10/31/09
UCI Fund Number 111200-18610

INVOICE# Q2-18610
Period of Claim: 07/01/08-07/31/08

	Current Charges	Prev Charges	Cumulative Charges
Major Cost Elements:			
Personnels	33,913.97	36,790.59	70,704.56
Supplies Expenses	2,614.84	3,093.73	5,708.57
Equipment *	0.00	0.00	0.00
Travel	0.00	0.00	0.00
Benefits	6,175.09	9,721.55	15,896.64
GRA Benefits	0.00	2,123.60	2,123.60
Other	0.00	0.00	0.00
Total Direct Cost	42,703.90	51,729.47	94,433.37
Overhead @ J10.0%	4,270.41	4,960.57	9,230.98
Total Cost Due	46,974.31	56,690.04	103,664.35
Payments Received To Date			0.00
Balance Due >>>>>>>>>>			**103,664.35**

Please make your check payable to **The Regents of the University of California Irvine** and mail to the above address. If there is any problem preventing your prompt payment, please contact Gysla Smith for assistance. She can be reached at 949-824-6259 or email gssmith@uci.edu. Thank you for your assistance.

Sincerely,

Original Signed By
Rebecca Tangen

Rebecca Tangen
Manager, C & G Accounting

PAYMENT APPROVED:

BART E. CROES, P.E.
CHIEF, RESEARCH DIVISION
DATE 12/17/08

RCVD DEC 19 2008

UNIVERSITY OF CALIFORNIA, IRVINE

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO · SANTA BARBARA · SANTA CRUZ

RCVD APR 6 '09

C080687

ACCOUNTING OFFICE
111 ACADEMY WAY, SUITE 210
IRVINE, CALIFORNIA 92697-1050
FAX NUMBER: (949) 824-3895

Air Resource Board Research Div.
Attn: Emma Plasencia
P.O. Box 2815
Sacramento, CA 95812

23 Mar 09

RE: Contarct Number: 07-335
Project Title: "ARCTAS California 2008: An Airborne Mission to Investigate California Air Quality"
P.I. Dr. Donald Blake
Period of Performance 05/01/08-10/31/09
UCI Fund Number 111200-18610

INVOICE# Q3-18610

Period of Claim: 10/27/08-12/31/08

	Current Charges	Prev Charges	Cumulative Charges
Major Cost Elements:			
Personnels	6,845.76	70,704.56	77,550.32
Supplies Expenses	6,900.93	5,708.57	12,609.50
Equipment *	0.00	0.00	0.00
Travel	0.00	0.00	0.00
Benefits	2,039.98	15,896.64	17,936.62
GRA Benefits	3,753.50	2,123.60	5,877.10
Other	0.00	0.00	0.00
Total Direct Cost	19,540.17	94,433.37	113,973.54
Overhead @ J10.0%	1,578.66	9,230.98	10,809.64
Total Cost Due	21,118.83	103,664.35	124,783.18
Payments Received To Date			103,664.35
Balance Due >>>>>>>>>>			**21,118.83**

Please make your check payable to **The Regents of the University of California Irvine** and mail to the above address. If there is any problem preventing your prompt payment, please contact Gysla Smith for assistance. She can be reached at 949-824-6259 or email gssmith@uci.edu. Thank you for your assistance.

Sincerely,

Original Signed By
Rebecca Tangen

Rebecca Tangen
Manager, C & G Accounting

PAYMENT APPROVED:

BART E. CROES, P.E.
CHIEF, RESEARCH DIVISION
DATE 4/17/09

RCVD APR 21 2009

000 0.00G

21,118.83
1,661.03 +
3,250.79

003 26,030.65

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

AGREEMENT NUMBER	07-335
REGISTRATION NUMBER	39000508306112

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

STATE AGENCY'S NAME
Air Resources Board (State)

CONTRACTOR'S NAME
The Regents of the University of California, Irvine

2. The term of this Agreement is: May 01, 2008 through October 31, 2009

3. The maximum amount of this Agreement is: $ 400,000.00
Four Hundred Thousand 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, Technical Proposal	49 pages
Exhibit B – Budget Detail and Payment Provisions	2 pages
Exhibit B, Attachment 1, Budget Summary	23 pages
Exhibit C* – General Terms and Conditions	GIA 101
Exhibit D - Special Terms and Conditions	1 page
Exhibit E – Additional Provisions	4 pages
Exhibit F – Research Final 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, Irvine (UCI)

BY *(Authorized Signature)* Caron Thomas — DATE SIGNED *(Do not type)* 3/21/08

PRINTED NAME AND TITLE OF PERSON SIGNING
Caron Thomas, Principal Contract & Grant Officer

ADDRESS
Office of Research Administration, 300 University Tower,
Irvine, CA 92697-7600

STATE OF CALIFORNIA

AGENCY NAME
Air Resources Board

BY *(Authorized Signature)* Sharon Simmons, Contract Services Manager — DATE SIGNED *(Do not type)* 3/27/08

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

ADDRESS
P.O. Box 2815, Sacramento, CA 95812

California Department of General Services Use Only

APPROVED
APR 8
DEPT OF GENERAL SERVICES

KYates

☐ Exempt per:

University Agreement Terms and Conditions

EXHIBIT A

SCOPE OF WORK

1. The Regents of the University of California, Irvine (UCI, University, or Contractor) agrees to provide the following services for the project entitled "ARCTAS-California 2008: An Airborne Mission to Investigate California Air Quality," which is attached hereto as Attachment 1 and made a part of this Agreement.

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

Requesting Agency: ARB	**Providing Agency:**
Name: James Pederson	Name: Dr. Donald Blake
Research Division	Department of Chemistry
1001 "I" Street, 5th Floor	University of California, Irvine
Sacramento, CA 95814	Irvine, CA 92697
Phone: (916) 322-7221	Phone: (949) 824-4195
Fax: (916) 322-4357	Fax: (949) 824-2905
Email: jrpeders@arb.ca.gov	Email: drblake@uci.edu

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

Requesting Agency: ARB	**Providing Agency: UCI**
Ms. Sally Jorgensen	Lesley Dowd
Research Division	Office of Research Administration
1001 "I" Street, 5th Floor	300 University Tower
Sacramento, CA 95814	Irvine, CA 92697-7600
Phone: (916) 327-1500	Phone: (949) 824-8109
Fax: (916) 322-4357	Fax: (949) 824-2094
Email: sjorgens@arb.ca.gov	Email: ldowd@uci.edu

ARCTAS-California 2008: An airborne mission to investigate California air quality

D. R. Blake[1], R. C. Cohen[2], and H. B. Singh[3]
1. UC-Irvine, 2. UC-Berkeley, 3. NASA Ames Research Center

Abstract:

It is proposed that NASA* and CARB join forces to take advantage of a unique opportunity for a dedicated California atmospheric field campaign during the summer of 2008. From a base in Palmdale-California, instrumented NASA DC-8 and P-3 aircraft will be available for a California focused air quality and climate change study (ARCTAS-California). The range and altitude capability of the DC-8 and P-3 allows nearly all regions of California to be sampled from the surface to the upper troposphere. Both aircraft are equipped to measure detailed gas and aerosol composition using in-situ and remote sensors. The primary constituents of interest are ozone and precursors, aerosols and precursors, and the long-lived greenhouse gases. The ARCTAS-California airborne effort will be supported by forecasts from meteorological and chemical models, satellite observations, and surface networks. NASA will allocate 25 flight hours each to the DC-8 and P-3 for ARCTAS-California. As a cost share, CARB will fund two investigators from UC-Berkley and UC-Irvine to support this effort. This leveraged interagency cooperation is expected to be highly beneficial to studies of air quality and climate change in California.

*Acronyms: AMS-Aerosol Mass Spectrometer; AOD-Aerosol Optical Depth; ATC-Air Traffic Control; ARCTAS-Arctic Research of the Composition of the Troposphere from Aircraft and Satellites; CARB-California Air Resources Board; ESA-European Space Agency; INTEX-Intercontinental Chemical Transport Experiment; IPY-International Polar Year; NASA-National Aeronautics and Space Administration; UC-University of California

1. Introduction:

In 2008 NASA plans to undertake an atmospheric science campaign to investigate the transport and transformation of pollutants to high latitudes using airborne and satellite observations (ARCTAS; http://cloud1.arc.nasa.gov/arctas/). This NASA activity is a part of the IPY 2007/8 international effort, undertaken every 4-5 decades, when the global community joins together for dedicated research in polar regions (http://www.ipy.org/). In preparation for the summer 2008 ARCTAS effort, two instrumented NASA aircraft (DC-8 and P-3) will be available from a base in Palmdale, California. This has presented an ideal opportunity for NASA and CARB to collaborate on a mission focused entirely on California. Approximately 25 flight hours for each of the two instrumented aircraft will be part of NASA's contribution to this effort. CARB will fund two University of California (Berkeley and Irvine) investigators to support this effort. Data collected will be available to all investigators in this project for further analysis. The range and altitude capability of the DC-8 and P-3 will allow nearly all key California regions to be sampled from the surface to the free troposphere. The observational and modeling capability offered in this joint effort will greatly enhance our current knowledge of atmospheric composition over California as well as provide data for planning future field missions anticipated for 2010. The Berkeley and Irvine teams along with other NASA supported collaborators are committed to playing a leadership role in the experiment design and to insuring that analyses based on the ARCTAS California flights advances our understanding of key science questions that will be the underpinning for future management decisions regarding air quality and climate change policies in California.

2. Scientific themes and tasks of ARCTAS-California

As stated earlier, ARCTAS-California will involve approximately 3 targeted and coordinated flights of the DC-8 and P-3 (25 flight hours each) for dedicated California air quality studies. Additional data may be acquired during transit to and from Palmdale for other ARCTAS flights conducted at high latitudes during both spring and summer. The primary constituents of interest are ozone and precursors, aerosols and precursors, and the long-lived greenhouse gases. Both observational data and models will be used for analysis and interpretations. Project tasks and science themes will include:

- Chemical processes with focus on ozone, reactive nitrogen (NO_x and precursors), free radicals (HO_x and precursors), aerosols (primary and secondary), mercury, and possibly halogens
- Boundary condition characterization, ocean-land interactions, and vertical profiles over source regions
- Characterization of anthropogenic and biogenic emissions over water (ship emissions), land (power plants, forested regions), and greenhouse gas emissions over the Central Valley
- Satellite validation of NO_2, HCHO, CO, O3, and aerosol optical depth.
- Relating satellite derived aerosol, NO_2, and O_3 tropospheric columns to boundary layer observations
- Aerosol radiative forcing from aerosol pollution over ship channels and Central Valley

In addition we will be prepared to investigate targets of opportunity such as California fires and pollution transport from Mexico or Asia as appropriate.

3. Platforms, payloads, and models for ARCTAS-California

ARCTAS-California is envisioned as an integrated satellite-aircraft-model experiment. Principal airborne platforms are the instrumented DC-8 and P-3. The DC-8 has a nominal range of nearly 7000 km (endurance 9 hrs) and is capable of substantial sampling at all altitudes between 0.1 to 12 km. The somewhat slower flying P-3 has a nominal range of 4000 km (endurance 9 hrs) and is capable of sampling at altitudes between 0.05 to 8 km. The DC-8 is the ideal platform for satellite validation as it can cover the entire tropospheric column. The P-3 offers several complementary advantages due to its slower speed and excellent boundary layer sampling capability. Figures 1 and 2 show examples of the types of studies the DC-8 and P-3 have previously performed including pollution mapping, photochemistry, emission characterization, and satellite validation.

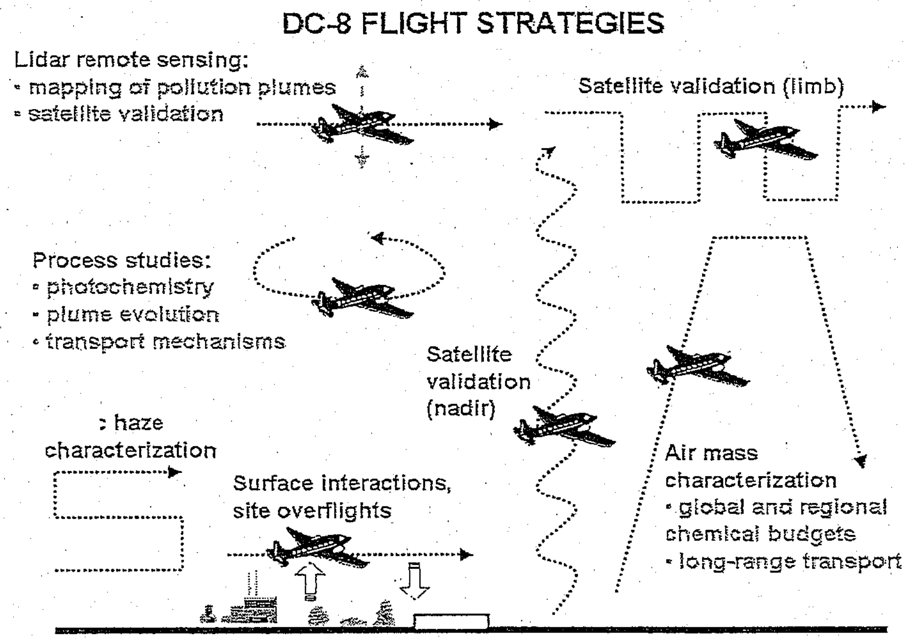

Figure 1. Nominal DC-8 flight patterns during ARCTAS-California

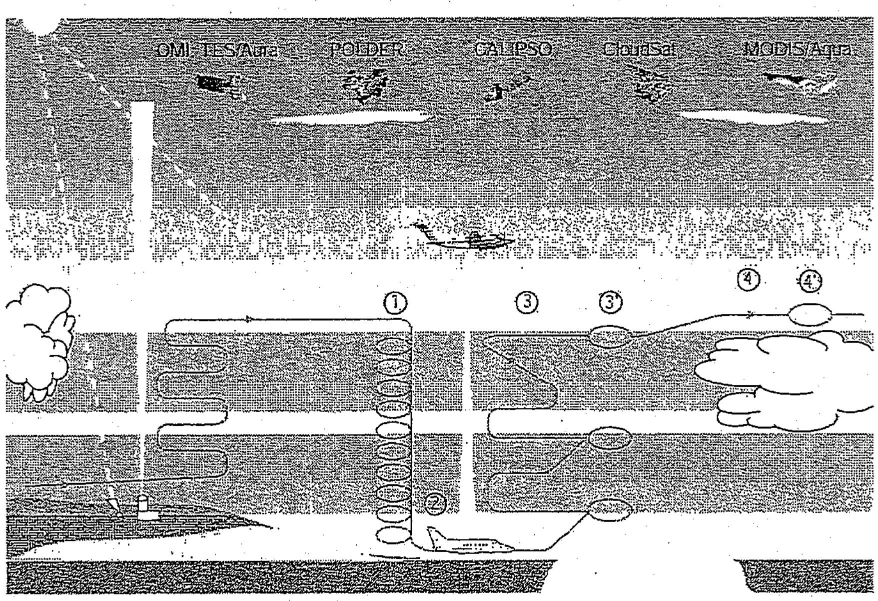

Figure 2. Nominal P-3 flight patterns for studies of aerosol radiative forcing. (1) Survey vertical profile. (2) Minimum-altitude transect. (3) Stepped profile (parking garage). (3') Stepped profile orbits. (4) Above-cloud transect. (4') Above-cloud orbit.

The in-situ and remote measurement capabilities available in ARCTAS-California are summarized in Table 1. The DC-8 has extensive capability for in situ measurements of gas and aerosol composition. These include ozone, greenhouse gases, aerosol, tracers, free radicals, and actinic fluxes. Typical time resolution for measurements ranges from 1 second (e.g., O_3, CO, CO_2, CH_4, H_2O), up to 30 seconds (e. g. NO_x, HO_x, HCHO) up to about 2 minutes (e.g., VOC, OVOC, aerosol composition). A nadir and zenith viewing lidar remotely measures ozone and aerosol distributions above and below the aircraft. The P-3 is focused on optical and physical properties of aerosols and their linkage with satellite observations. California also has a large network of ground stations and these data will be used in integrated analyses. There is a further possibility that enhanced ozonesonde releases will be added to this activity.

In addition to airborne observations, several polar orbiting satellites are able to measure column densities of gases (e. g. O_3, NO_2, HCHO, CO) and aerosols in the troposphere and will be integrated in this effort. Our principal focus will be on NASA satellite instruments such as OMI, AIRS, MOPITT, and MODIS that have large swaths and excellent spatial resolution. The CALIPSO satellite will provide valuable information on the vertical distribution of aerosols. We will also pay attention to observations from the ESA satellite based instruments including SCIAMACHY and GOME-II.

Global and regional scale Chemical Transport Models will be used both for flight planning as well as post mission data analysis. Among the models routinely available to all investigators are GEOS-Chem (global), STEM (regional), and 0-D photochemical models. The Berkeley group is working on a WRF-CHEM product for California that will be used in post-mission analyses. Meteorological products will provide trajectory and weather analysis both in forecast and post mission modes. All model products will be prepared along the aircraft flight tracks and made available to all investigators.

While the NASA team will provide these flight planning and modeling services, full participation by CARB investigators in the prioritization, planning, and execution of flights is welcomed. Their additional California-specific modeling expertise and perspective are critical to the success of these flights and the interpretation of the data collected.

4. Flight planning

The ARCTAS-California mission will take place in the June/July 2008 time frame although exact dates are not defined yet. We envision this to be a roughly 1-week long dedicated activity suitable for the available flight hours. In the early part of 2008, straw-man flight plans will be prepared using climatology as a guide. We will ensure that restricted areas over California and the Pacific are well identified and ATC permissions obtained where appropriate. Detailed flight planning will occur during the mission and will involve meteorological and chemical forecasts from several modeling teams, analyses of near-real-time satellite data and satellite validation needs, as well as inputs from the aircraft science teams. The modeling and satellite instrument science teams will be present in the field, and discussions will be conducted in an inclusive manner at daily flight planning meetings. Typically a flight plan will be ready at least 24-h prior to mission start. In-flight changes based on real time in-situ and remote sensing observations will be made as necessary to correct for any inaccuracies in forecasts. The NASA team has extensive experience in flight planning and execution and has successfully performed such roles in previous missions involving multiple aircraft most recently in INTEX-B. Input from CARB teams with California specific experience will be especially sought during flight planning.

Table 1: Observational capabilities during ARCTAS-California

DC-8*	P-3	Satellite/Remote[†]
In-situ:	**In-situ:**	**Tropospheric columns:**
O_3	Aerosol composition	- O_3
CO	(AMS)**	- HCHO
CH_4		- NO_2
H_2O	Aerosol microphysics	- CO
CO_2	and optical properties**	- Aerosol
N_2O		
NO, NO_2, NO_y	**Remote:**	
PANs, Alkyl nitrates	Sunphotometer	
HNO_3	(AOD) **	
HCHO		
Peroxides	Solar flux radiometer	
BrO		
OH	Cloud absorption	
HO_2	radiometer	
OVOC		
VOC/CFC/DMS/OCS		
Organic acids		
HCN, CH_3CN		
Hg speciation		
SO_2		
Aerosol comp.(bulk)**		
Aerosol comp. (PM 2.5) **		
Aerosol comp. (AMS) **		
Aerosol microphysical & optical properties**		
Actinic fluxes & photolytic frequencies		
Remote:		
O_3 (Nadir/zenith Lidar)		
Aerosol (Nadir/zenith Lidar)		

* Typical measurement time resolution is 1-30 s. In several cases (e. g. VOCs, HNO_3, aerosol composition) time resolution is 1-2 minutes. For details of techniques refer to http://cloud1.arc.nasa.gov/arctas/

** Organic carbon, sulfates, nitrates, and other ions are measured. Microphysical and optical properties include aerosol size, number, absorption, scattering, extinction, and cloud water content. AMS: Aerosol Mass Spectrometer; AOD: Aerosol Optical Depth

[†] Principally MOPITT, OMI, MODIS, CALIPSO, GOME, and TES. Global coverage.

Table 2: Compounds to be measured and archived by UC-Irvine during ARCTAS

Compound	Formula	Lifetime	LOD (pptv)	Precision (%)	Accuracy (%)
Hydrocarbons					
Ethane	C_2H_6	2-3 mo	3	0.5	5
Ethene	C_2H_4	1-2 d	3	0.7	5
Ethyne	C_2H_2	12-17 d	3	0.5	5
Propane	C_3H_8	10-15 d	3	0.7	5
Propene	C_3H_6	8-12 hr	3	16	5
Propyne	C_3H_4	2 d	3	2	5
n-Butane	C_4H_{10}	4-6 d	3	0.6	5
i-Butane	C_4H_{10}	5-7 d	3	1	5
1-Butene	C_4H_8	9 hr	3	2	5
cis-2-Butene	C_4H_8	5 hr	3	2	5
trans-2-Butene	C_4H_8	5 hr	3	2	5
1,3-Butadiene	C_4H_6	5 hr	3	2	5
n-Pentane	C_5H_{12}	5 d	3	2	5
i-Pentane	C_5H_{12}	5 d	3	2	5
Isoprene	C_5H_8	1-2 hr	3	2	5
2-Methylpentane	C_6H_{14}	2-3 d	3	2	5
3-Methylpentane	C_6H_{14}	2-3 d	3	2	5
Benzene	C_6H_6	9-13 d	3	2	5
Toluene	C_7H_8	2-3 d	3	3	5
m-Xylene	C_8H_{10}	1 d	3	5	5
o-Xylene	C_8H_{10}	1-2 d	3	5	5
p-Xylene	C_8H_{10}	1-2 d	3	5	5
Ethylbenzene	C_8H_{10}	2 d	3	5	5
m-Ethyltoluene	C_9H_{12}	17 hr	3	5	5
o-Ethyltoluene	C_9H_{12}	1 d	3	5	5
p-Ethyltoluene	C_9H_{12}	1 d	3	5	5
1,2,4-Trimethylbenzene	C_9H_{12}	10 hr	3	5	5
1,3,5-Trimethylbenzene	C_9H_{12}	5 hr	3	5	5
α-Pinene	$C_{10}H_{16}$	6 hr	3	5	5
β-Pinene	$C_{10}H_{16}$	4 hr	3	5	5
Alkyl Nitrates					
Methyl nitrate	CH_3ONO_2	1 mo	0.02	2	10
Ethyl nitrate	$C_2H_5ONO_2$	2-4 wk	0.02	1	10
1-Propyl nitrate	$C_3H_7ONO_2$	1-2 wk	0.02	1	10
2-Propyl nitrate	$C_3H_7ONO_2$	1-3 wk	0.02	2	10
2-Butyl nitrate	$C_4H_9ONO_2$	1-2 wk	0.02	1	10
2-Pentyl nitrate	$C_5H_{11}ONO_2$	4-5 d	0.02	2	10
3-Pentyl nitrate	$C_5H_{11}ONO_2$	4-5 d	0.02	2	10

Table 2, continued. Compounds to be measured and archived by UC-Irvine during ARCTAS

Compound	Formula	Lifetime	LOD (pptv)	Precision (%)	Accuracy (%)
Halocarbons					
CFC-11	$CFCl_3$	45 yr	1	0.8	2
CFC-12	CF_2Cl_2	100 yr	10	0.7	2
CFC-113	CCl_2FCClF_2	85 yr	1	1.2	2
CFC-114	$CClF_2CClF_2$	300 yr	1	1.9	5
Methyl chloroform	CH_3CCl_3	4.9 yr	1	1.0	5
Carbon tetrachloride	CCl_4	35 yr	0.1	0.7	5
Halon-1211	$CBrClF_2$	11 yr	0.05	1.1	5
Halon-2402	$CBrF_2CBrF_2$	<20 yr	0.05	2.5	5
HCFC-22	CHF_2Cl	11.8 yr	1	2.0	5
HCF-134a	CH_2FCF_3	13.6 yr	1	5.2	10-20
HCFC-141b	CH_3CCl_2F	9.2 yr	1	4.2	10-20
HCFC-142b	CH_2CClF_2	18.5 yr	1	3.6	10-20
Methyl bromide	CH_3Br	9-10 mo	0.1	1.7	5
Methyl chloride	CH_3Cl	1.3 yr	5	1.5	5
Methyl iodide	CH_3I	4 d	0.01	1.1	10
Methylene bromide	CH_2Br_2	3-4 mo	0.05	1.6	10-20
Methylene chloride	CH_2Cl_2	3-5 mo	1	4.5	10
Chloroform	$CHCl_3$	3-5 mo	0.1	1.1	5
Trichloroethene	C_2HCl_3		0.05	1.5	5
Tetrachloroethene	C_2Cl_4	2-3 mo	0.05	1.2	10
1,2-Dichloroethane	$C_2H_4Cl_2$	1-2 mo	0.05	5.0	20
Bromodichloromethane	$CHBrCl_2$	2-3 mo	0.01	2.0	10-20
Dibromochloromethane	$CHBr_2Cl$	2-3 mo	0.01	9.3	20
Bromochloromethane	CH_2BrCl	5 mo	0.01	7.4	20
Sulfur Compounds					
Carbonyl sulfide	OCS	16 yr	10	2	10
Dimethyl sulfide	CH_3SCH_3	1-2 d	1	2	10
Dimethyl disulfide	CH_3SSCH_3	1 hr	10	2	10
Carbon disulfide	CS_2	2-3 d	5	2	10

5. Post-mission data analysis

Observational data and model derived results will be available to all investigators for further analysis. The post-mission analysis will focus on the science themes of this study, integrating the information from the aircraft with satellites and models to improve our understanding of atmospheric composition and climate. Much observational data in the eastern Pacific and over the west coast were collected during INTEX-B and these will also be available for analysis. We envision publication of a wide range of studies drawing on results from this mission and involving different levels of integration between the aircraft data, satellite data, and models. We expect these studies to include aspects of photochemical processes, source attributions, radiative forcing, satellite validation, and model based evaluations. Data from all instruments are considered science team data and thus can and will be used by any and all groups on the science team. During aircraft deployment most groups will submit data to the preliminary archive that can be used by all science team members. Some groups, such as whole air, require several months before submitting prelim data. Final archive of data will occur 6-9 months after the field mission and release of the data archive to the public will occur 12 to 18 months after the field deployment. Thus, the science team will have exclusive access to the final data for about 6 months prior to release to the public. At that time all data are public domain. Dr. Hanwant Singh will be the coordinator of the final CARB report.

6. Staffing and budget

The principal investigator of this effort will be Prof. D. R. Blake of UC-Irvine. The UC-Irvine group will be responsible for collecting whole air samples on the DC-8 and making laboratory measurements of VOC, CFCs, $RONO_2$, DMS and several other select trace constituents using GC and GC-MS techniques. Prof. R. C. Cohen of UC Berkeley will be a co-principle investigator and will make in-situ measurements of NO_2, ΣPANs, and Σalkyl nitrates using a Laser Induced Fluorescence technique. Both groups have successfully performed these measurements in several past missions, most recently in INTEX-B. Dr. H. B Singh from NASA Ames, ARCTAS co-Mission Scientist, will coordinate overall activities with these and other partners at no cost to CARB.

The total CARB budget of $400 K will be directed to UC-Irvine ($210 K) and UC-Berkeley ($190 K) groups for their efforts in data collection and analysis. Budgets details for the UC groups are provided below. Services of all other ARCTAS participants including scientists, navigators, pilots, and flight crews will be provided by NASA at no cost to CARB. NASA will also supply approximately 25 hours each of DC-8 and P-3 flight time as well as satellite data. Additional airborne data may be acquired during transit to and from Palmdale. It is estimated that the NASA co-share of the ARCTAS-California budget will be in excess of 1 million dollars.

1. Budget –Don Blake
2. Budget=R. Cohen

Technical Proposal

For submission to the California Air Resources Board

ARCTAS- California 2008: An airborne mission to investigate California air quality

Principal Investigator
DONALD R. BLAKE

Professor, Department of Chemistry
University of California, Irvine (UC-Irvine)
Irvine, California 92697
1-949-824-4195
1-949-824-2905 (Fax)
drblake@uci.edu

This proposal provides support to a joint UCI, UC Berkeley, NASA proposal aimed at making observations of atmospheric composition in California in support of ARB regulatory objectives with respect to air quality and climate change. Tasks the Blake team at Irvine will contribute to the ARCTAS-California 2008 experiments are as follows.

1) *Employ our specialized sampling equipment to collect whole air samples aboard the NASA DC-8. We propose to collect up to 168 air samples per flight, with 1-minute sampling every 4-5 minutes during horizontal flight legs, and more frequent sampling during ascents and descents.*
2) *Participate in flight planning discussions using our long experience with previous California ground based experiments as a guide.*
3) *Return whole air samples to our Irvine laboratory where more than 60 trace gases will be identified and quantified in each sample – including C_2-C_{10} NMHCs, C_1-C_2 halocarbons, C_1-C_5 alkyl nitrates, and selected sulfur compounds – using GC/FID, GC/ECD and GC/MSD. In addition, exploratory measurements of HCN, CH_3CN and other nitrogen containing compounds will be made using a nitrogen phosphorus detector (NPD)*
4) *Complete final data from the Irvine measurements and report it to the NASA archive in a format that is also accessible to ARB.*
5) *Initial observation based analyses: Although final analyses will require more time than is provided under this contract, the Irvine group whole-air analyses provides a wide suite of tracer species to better understand the variety and impact of different sources from metropolitan, agricultural and coastal areas and their impact on the surrounding region. We provide tracers that are specific for automotive sources, biogenic emission, solvent use, etc. The large dynamic range of our tracer measurements (ppbv – pptv) allows a sensitive measure of the regional extent of pollutant plumes as they mix into the regional atmosphere. Monitoring changes of organic gases of different reactivity,*

including the formation and loss of second generation oxidation products (e.g. alkyl nitrates) are necessary to test understanding of the chemical reactivity of individual plumes and to test models of secondary organic aerosol formation and growth and the production of O_3. We expect to provide initial assessment of progress in these areas during this contract and then to complete analyses and publish them with continued NASA support after the expiration of this contract.

6) *Prepare Final Report: The Irvine group will contribute to preparation of the final report.*

Amend Final report: The Irvine group will contribute to amending the final report.

Technical Sub-Contract Proposal

**To the University of California, Irvine
For submission to the California Air Resources Board**

ARCTAS- California 2008: An airborne mission to investigate California air quality

Principal Investigator
Ronald C. Cohen

Professor, Department of Chemistry and
Department of Earth and Planetary Science
University of California, Berkeley
Berkeley, CA 94720-1460
(510) 642-2735
(510)643-2156 (FAX)
e-mail: rccohen@berkeley.edu

This subcontract provides support to a joint UCI, UC Berkeley, NASA proposal aimed at making observations of atmospheric composition in California in support of ARB regulatory objectives with respect to air quality and climate change. Tasks the Cohen team at Berkeley will contribute to the ARCTAS-California 2008 experiments are as follows.

7) *Integrate instrument for measurement of NO_2 total peroxynitrates, total alkyl and multifunctional nitrates and HNO_3 aboard the NASA DC-8.*
8) *Participate in flight planning discussions using recent experience in BEARPEX and other California ground based experiments and modeling analyses as a guide .*
9) *Complete final data from the Berkeley measurements and report to the NASA archive. Provide aid to ARB, if desired, in making the complete NASA archive of all measurements in CA as a separate data file.*
10) *Initial observation based analyses: Although final analyses will require more time than is provided under this contract, the Berkeley group plans to focus its efforts on observation based analyses aimed at using observations to assessing correlated sources of VOC and NO_x, sources of NO_x alone and the effects of NO_x on a) HO_x radicals, b) inorganic and organic aerosol production and c) production of O_3. We expect to provide initial assessment of progress in these areas during this contract and then to complete analyses and publish them with continued NASA support after the expiration of this contract.*
11) *Prepare Final Report: The Berkeley group will contribute to preparation of the final report.*
12) *Amend Final report: The Berkeley group will contribute to amending the final report.*

APPENDIX: Curriculum Vitae of D. R. Blake, R. C. Cohen, and H. B. Singh

Curriculum Vitae of Hanwant B. Singh

MS 245-5, NASA Ames Research Center, Moffett Field, CA 94035
[Hanwant.b.singh@nasa.gov; Phone: (650)604-6769; http://geo.arc.nasa.gov/sgg/singh/]

1 Education

B. Tech.	1968	Chemical Engineering, Indian Institute of Technology, New Delhi
M. S.	1970	Chemical Engineering, University of Pittsburgh, Pittsburgh, PA
Ph.D.	1972	Chemical Engineering, University of Pittsburgh, Pittsburgh, PA
Postdoctoral	1972-1974	Environmental Sciences, Rutgers University, New Brunswick, NJ

2 Professional Experience

NASA Ames Research Center (1985-present)
- Project Scientist for Intercontinental Chemical Transport Experiment-North America (2003-2008; INTEX-NA). INTEX is a multi-country experiment on the impact of global pollution on air quality and climate (http://cloud1.arc.nasa.gov/intex-na/)
- Project Scientist (with A. Thompson) for the Subsonic Assessment Ozone and NO_x Experiment (SONEX, 1996-1998). SONEX was an international effort that studied the atmospheric impact of subsonic aircraft NO_x emissions
- Group Leader, Atmospheric Chemistry (1985-present)
- Chief (Acting) Earth Science Division (1998)
- Chief (Acting) Atmospheric Chemistry & Dynamics Branch (1989-1990; 1994-)

SRI International (formerly Stanford Research Institute) Menlo Park, CA (1974-1985)
- Director, Atmospheric Chemistry Program (1980-85)
- Senior Research Scientist (1975-80)

3 Scientific Contributions

25 years of leading studies on the composition and chemistry of the atmosphere. Proposed and led major atmospheric field experiments. Developed highly sensitive instrumentation and provided key measurements in the atmosphere and the oceans using surface and airborne platforms. Applied these measurements to provide new insights into the chemistry of the atmosphere. Presently leading an international effort to investigate the impact of air pollution transport on intercontinental scales. Following are examples of contributions (made with colleagues) that have had a significant impact on this field:

- First to detect and measure phosgene in the atmosphere.

- First to demonstrate that atmospheric carbon tetrachloride was of man-made origin, now a widely accepted view.
- First to propose and apply the concept of using methyl chloroform as an indicator of OH radicals. This has emerged as a central technique in the development of atmospheric chemistry research over the last two decades and is the primary means to measure the oxidation capacity of the atmosphere.
- First to propose that a large background of PAN must be present in the global troposphere. Developed new instrumentation and performed field studies to demonstrate its important role in global nitrogen and ozone chemistry.
- Provided the first global measurement of important oxygenated organic species and proposed a new source of HO_X radicals from oxygenated species.
- Developed unique techniques to explore the significance of chlorine atom chemistry in the troposphere.

4 Honors and Awards

- *NASA Exceptional Achievement Medals* for "outstanding contribution to atmospheric sciences" (2005, 1998).
- 2005 **Fellow of the World Innovative Foundation**
- In the ISI list of **25 most cited in Geosciences**
- *Distinguished Alumni* (2001), Indian Institute of Technology, Delhi.
- *Fellow of the American Geophysical Union* (2000) for "pioneering contributions essential to the understanding of atmospheric composition, chemistry, and climate".
- *1999 HJ Allen Prize* for the best scientific paper (shared with M. Kanakidou, P. Crutzen, and D. Jacob).
- Elected *"Ames Associate Fellow"* (NASA Ames's highest annual award) for "sustained innovative contributions to research" (1991).
- *Executive Editor* of the international *Journal of Atmospheric Environment* (1990-present)
- *Frank A. Chambers Award* by the Air and Waste Management Association for "outstanding achievement in the science and art of air pollution" (1989)
- Elected member of *CACGP* (Commission on Atmospheric Chemistry and Global Pollution) (1996-2006).
- Member *Ames Basic Research Council* and *Science and Technology Advisory Council*
- Member/Chair *Bay Area Air Quality Management District Advisory Council* (1985-1997)

4.1 Scientific Societies/Committees

- American Geophysical Union
- American Chemical Society
- NCAR/UCAR/NASA/EPA/DOE Scientific Program Evaluation Committees
- Numerous invitations for national and international presentations

4.2 Publications

Over 190 scientific publications in major scientific journals
One textbook titled *"Composition, Chemistry and Climate of the Atmosphere"*

Donald R. Blake
Professor of Chemistry and Earth System Science
University of California, Irvine

A. Education

University of California, Los Angeles, 1978, B.S. in Chemistry

University of California, Irvine, 1980, M.S. in Chemistry

University of California, Irvine, 1984, Ph.D. in Chemistry

B. Positions and Honors

U.S. Navy, 1971-1974
Research Assistant, University of California Irvine, 1978-1984
Postdoctoral Research Associate, University of California Irvine, 1984-1985
Research Specialist, University of California Irvine, 1985-1991
Associate Research Chemist, University of California Irvine, 1991-1994
Research Chemist, University of California Irvine, 1994-1998
Professor of Chemistry, University of California Irvine, 1998- present
Chair, Department of Chemistry, University of California Irvine, 2007-present

C. Selected peer-reviewed publications (from a total of 277)

1. Blake, D. R. and F. S. Rowland, "Global Atmospheric Concentrations and Source Strength of Ethane", *Nature*, *321*, 231-233 **1986**.
2. Blake, D. R., and F. S. Rowland, "Continuing World-wide Increase in Tropospheric Methane, 1978 to 1987", *Science*,*23 9*,1129-1131, **1988**.
3. Blake, D. R., D. F. Hurst, T. W. Smith, Jr., W. J. Whipple, T. Y. Chen, N. J. Blake and F. S. Rowland, "Summertime Measurements of Selected Nonmethane Hydrocarbons in the Arctic and Subarctic during the 1988 Arctic Boundary Layer Experiment (ABLE-3A)", *J. Geophys. Res.*, *97*, 16,559-16,588, **1992**.
4. Blake, D. R., and F.S. Rowland, "Urban Leakage of Liquefied Petroleum Gas and Its Impact on Mexico City Air Quality", *Science*, *269*, 953-956, **1995**.
5. Colman, J. J., D. R. Blake and F. S. Rowland, "The Atmospheric Residence Time of Methyl Bromide Estimated from the Junge Spatial Variability Relationship", *Science*, *281*, 392-396, **1998**.
6. Wingenter, O. W., D. R. Blake, N. J. Blake, B. C. Sive, and F. S. Rowland, Tropospheric hydroxyl and atomic chlorine concentrations, and mixing time scales determined from hydrocarbon and halocarbon measurements made over the Southern Ocean, *J. Geophys. Res.*, 104, 21,819-21,828, **1999**.
7. T. Chen, I. J. Simpson, D. R. Blake, and F. S. Rowland, "Impact of the Leakage of Liquefied Petroleum Gas (LPG) on Santiago Air Quality", *Geophysical Research Letters* **2001**, *28*, 11, 2193-2196.
Isobel J. Simpon, T.-Y. Chen, D. R. Blake, and F. S. Rowland, "Implications of the Recent Fluctuations in the Growth Rate of Tropospheric Methane", *Geophysical Research Letters,* 29, 10.1029/2001GL014521
2002
8. S. Meinardi, I. J. Simpson, N. J. Blake, D. R. Blake and F. Sherwood Rowland. *"Dimethyl Sulfide (DMDS) and Dimethyl Sulfide (DMS) Emissions from Biomass Burning in Australia" Geophysical Research Letters, 108,* doi:10.1029/2003GL016967, **2003**.
9. Aaron Swanson, Nicola J. Blake, Elliot Atlas, Frank Flocke, Donald R. Blake, and F. Sherwood Rowland, *"Seasonal Variations of C2-C4 Nonmethane Hydrocarbons and C1-C4 Alkyl Nitrates at the Summit Research Station in Greenland" Journal of Geophysical Research,* 108, *doi:10.1029/2001JD001445,* ***2003***.
10. P. Sinha, P. V. Hobbs, R. J. Yokelson, D. R. Blake, S. Gao, and T. W. Kirchstetter

"Emissions from Miombo Woodland and Dambo Grassland Savanna Fires" Journal of Geophysical Research,109(D11), D11305/1-D11305/13, **2004**

11. "Volatile Organic Compounds in 43 Chinese Cities" *Atmospheric Environment, 39* 5979-5990, **2005**
B. Barletta, S. Meinardi, F. S. Rowland, C.-Y. Chan, X. Wang, S. Zou, L. Y. Chan and D. R. Blake

12. "Breath Ethanol and Acetone as Indicators of Serum Glucose Levels: an initial report" *Diabetes Technol Ther.* 7(1):115-23, Galassetti PR, Novak B, Nemet D, Rose-Gottron C, Cooper DM, Meinardi S, Newcomb R, Zaldivar F, Blake DR., **2005**

13. "Breath Sulfides and Pulmonary Function in Cystic Fibrosis", *Proceedings of the National Academy of Sciences of the United States of America, 102* (44), 15762-15767, M. A. Kamboures, D. R. Blake, D. M. Cooper, R. L. Newcomb, M. Barker, J. K. Larson, S. Meinardi, E. Nussbaum, and F. S. Rowland, **2005**

"Hydrocarbon Emissions from a Modern Commercial Airliner" *Atmospheric Environment, 40* (19), 3601-3612, **2006**
B. E.Anderson, G. Chen, and D. R. Blake

14. "Direct Measurements of the Convective Recycling of the Upper Troposphere" *Science, 325* (5813) 816-820, **2007**
T. H. Bertram, A. E. Perring, P. J. Wooldridge, J. D. Crounse, A. J. Kwan, P. O. Wennberg, E. Scheuer, J. Dibb, M. Avery, G. Sachse, S. Vay, J. H. Crawford, C.S. McNaughton, S. Ceameron, A. Clarke, K. E. Pickering, H. Fuelberg, G. Huey, D. R. Blake, H. B. Singh, S. R. Hall, R. E. Shetter, A. Fried, B. G. Heikes, and R. C. Cohen

D. Synergistic Activities

NASA Group Achievement Award,	1993, 1998, 2000, 2006
Outstanding Professor Alpha Phi Society,	2000, 2002, 2005
ACS Chuck Bennett Service through Chemistry	2004
Excellence in Undergraduate Research	2001
UCI Chemistry Department Outstanding Teaching Award	1979
Bank of America Chemistry Award	1975

Current Funding

11/15/05 – 11/14/08 National Aeronautical and Space Administration
Whole Air Sampling during INTEX-B
The purpose of this study was to analyze the air samples obtained while traveling over the North America region.
Role: PI 5%

08/15/03 – 07/31/07 National Science Foundation
Collaborative Research: Antarctic Tropospheric Chemistry Investigation (ANTCI)
The purpose of this study is to investigate the photochemistry at the snow/ice interface at the South Pole.
Role: Co-PI 5%

06/01/06 – 05/31/10 National Aeronautical and Space Administration
Continued Monitoring and Trends of Selected Trace Gases at Remote Locations between 71 degrees North and 47 degrees South
The purpose of this study is to obtain remote air samples and determine their composition.
Role: PI 5%

08/01/05 – 07/31/07 National Science Foundation
Collaborative Research: Organic Trace Gas Studies from Whole Air Sampling during MIRAGE-Mex
The purpose of this study is to study ground and plane based samples in Mexico.
Role: PI 5%

02/01/06-01/31/09 Private funding from the Comer Foundation
Identification and Quantification of Climate Change Gases
The purpose of this study is to study gases that could affect abrupt climate change
Role: PI 5%

10/01/05 – 09/30/07 California Air Resources Board
Volatile Organic Compound Emissions from Dairies
The purpose of this study is to identify gases emitted during dairy practices that contribute to ozone formation
Role: PI 5%

04/01/06-03/31/11 Doris Duke Foundation
Mitochondrial Inborn Errors of Metabolism and ANT Defects in Mitochondrial Diseases; A Master Protocol
The purpose of this study is to determine if subjects with mitochrondrial diseases give off specific biomarkers in their exhaled breath
Role: Co-PI 8%

RONALD CARL COHEN

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2007-	**Professor, (2002-2007) Associate Professor, (1995-2002) Assistant Professor,** 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
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 and b) the paleotemperature record and the hydrologic cycle--chemistry and meteorology controlling the isotopic composition of rainwater and glacial ice. Development of new strategies for observing the composition of the atmosphere. Recent efforts have focused on satellite measurements to improve our understanding of atmospheric nitrogen, on observations of nitrogen oxide fluxes between the atmosphere and the biosphere and the role of reactive nitrogen fluxes in the global carbon balance, on the role of convection in the redistribution of atmospheric reactive chemicals and on integrated analyses of observations from multiple research stations to provide novel observational constraints on atmospheric chemical and transport processes.

1991-1996 **Postdoctoral Fellow, Research Associate** 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

NOAA Outstanding paper award (Cooper et al.) 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

Selected recent publications of R.C. Cohen

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,* submitted to J. Geophys. Res. July 2007, revised October 2007.

118. A.L. Steiner, R.C. Cohen, R.A. Harley, S. Tonse, A.H. Goldstein, *VOC reactivity in central California: comparison to ground-based measurements,* Atmos. Chem. Phys. Dis., 7, 13077-13119, 2007.

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 2007.

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

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

105. I.M. Perez, P.J. Wooldridge and R.C. Cohen,*Labora tory 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.

102. T.H. Bertram, A.E. Perring, P.J. Wooldridge, J.D. Crounse, A.J. Kwan, P.O. Wennberg, E. Scheuer, J. Dibb, M.A. Avery, G. Sachse, S.A. Vay, J.H. Crawford, C.S. MacNaughton, A. Clarke, H. Fuelberg, L.G. Huey, D.R. Blake, H.B. Singh, S.R. Hall, R. E. Shetter, A. Fried, B.G. Heikes and R.C. Cohen, *Direct measurements of convective recycling of the upper troposphere*, Science, 10.1126/science.1134548, **315**, 816-819, 2007.

100. J.G. Murphy, D.A. Day, P.A. Cleary, P.J. Wooldridge, D.B. Millet, A.H. Goldstein and R.C. Cohen, *The weekend effect within and downwind of Sacramento: Part 2. Observational evidence for chemical and dynamical contributions,* Atmos. Chem. Phys. Disc. **6**, 11971-12019, 2006.

99. J.G. Murphy, D.A. Day, P.A. Cleary, P.J. Wooldridge, D.B. Millet, A.H. Goldstein and R.C. Cohen, *The weekend effect within and downwind of Sacramento: Part 1. Observations of ozone, nitrogen oxides, and VOC reactivity,* Atmos. Chem. Phys. Disc. **6**, 11427-11464, 2006, Atmos. Chem. Phys. 7, 5327-5339, 2007.

95. A.L. Steiner, S. Tonse, R.C. Cohen, A.H. Goldstein, R.A. Harley, *The influence of future climate and emissions on regional air quality in California*, J. Geophys. Res. **111**, D18303, doi:10.1029/2005JD006935 2006.

94. R.V. Martin, C.E. Sirois, K Chance, T.B. Ryerson, T.H. Bertram, P.J. Wooldridge, R.C. Cohen, A.A. Neuman, A. Swanson, F.M. Flocke, *Evaluation of space based constraints on nitrogen oxide emissions with regional aircraft measurements over and downwind of eastern North America*, J. Geophys. Res. **111**, D15308, doi:10.1029/2005JD006680, 2006.

86. T.H. Bertram, A. Heckel, A. Richter, J. Burrows and R.C. Cohen, *Satellite measurements of daily variations in soil NO_x emissions*, Geophys. Res. Lett. 32 L24812, doi:10.1029/2005GL024640 2005.

Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS)

A NASA contribution to the International IGAC/POLARCAT Experiment For the International Polar Year 2007-8

White paper prepared by

Daniel J. Jacob (Harvard), P.K. Bhartia (NASA/GSFC), William H. Brune (Penn State), Brian Cairns (NASA/GISS), Kelly V. Chance (Harvard-SAO), James H. Crawford (NASA/LaRC), Jack E. Dibb (UNH), John C. Gille (NCAR), D.B.A. Jones (U. Toronto), Ralph Kahn (JPL), Qinbin Li (JPL). Wallace McMillan (UMBC), Bradley Pierce (NASA/LaRC), Lorraine A. Remer (NASA/GSFC), Philip B. Russell (NASA/ARC), Hanwant B. Singh (NASA/ARC), Andreas Stohl (NILU), Chip R. Trepte (NASA/LaRC), John Worden (JPL)

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Daniel J. Jacob (djacob@fas.harvard.edu)

February 7, 2007

1 INTRODUCTION

The Arctic is a beacon of global change. It is where warming has been strongest over the past century, accelerating over the past decades. It is an atmospheric receptor of pollution from the northern mid-latitudes continents, as manifested in particular by thick aerosol layers ("arctic haze") and by accumulation of persistent pollutants such as mercury. It is increasingly beset by emissions from massive forest fires in boreal Eurasia and North America. Perturbations to the arctic environment trigger unique regional responses including melting of ice sheets and permafrost, decrease in snow albedo due to deposition of black carbon, and halogen radical chemistry from sea salt aerosols deposited to the ice. These responses make the Arctic a particularly vulnerable place, subject to dramatic amplification of environmental change with possibly global consequences. The urgent need for research to better understand changes in arctic atmospheric composition and climate is discussed by the Arctic Climate Impact Assessment (http://amap.no/acia/) and the U. S. Global Change Research Program (http://www.usgcrp.gov). Major research activities to address this need will take place in 2007-2008 under the auspices of the Third International Polar Year (IPY; http://www.ipy.org/).

NASA has the opportunity to play a leadership role in arctic atmospheric research during IPY through the unique and timely vantage point offered by its polar-orbiting satellites (Terra and the A-train). These satellites observe the long-range transport of mid-latitudes pollution and its seasonal accumulation in the Arctic, enabling a better understanding of pollution sources, transport pathways, and radiative implications. They detect fires and the associated smoke plumes. They measure aerosol optical depths and other aerosol properties, and the concentrations of gas-phase species such as ozone, CO, NO_2, and BrO that are important drivers of arctic chemistry. The Arctic is a vast, remote, sparsely sampled place, and the information available from space-based sensors has unique potential to advance our understanding.

The NASA ARCTAS aircraft mission described in this document will unleash the potential of NASA space-based observations for Arctic research by providing retrieval algorithm validation and correlative information uniquely accessible from aircraft platforms (Figure 1). Satellite retrievals in the Arctic must deal with reflective, cold surfaces, low sun angles, seasonal darkness, and extensive cloud cover. Targeted retrieval algorithm development and validation using aircraft observations is essential. Beyond validation, the supplemental information available from aircraft can deliver considerable added value for extrapolating the satellite observations and improving their integration with models. Much of pollution transport in the Arctic takes place in the lower troposphere, where satellites have limited sensitivity; in addition, many species of environmental interest (e.g., mercury) are not directly observable from space. The correlative information and error characterization available from ARCTAS aircraft measurements will enable effective assimilation of the space-based observations into Earth science models including chemical transport models (CTMs), general circulation models (GCMs), and Earth system models (ESMs). Developing the capability to integrate measurements from diverse platforms into

Earth science models for societal benefit is a key issue facing the U.S. Group on Earth Observations (http://usgeo.gov/). ARCTAS will provide an important demonstration of current capability with regard to USGEO goals for assessing and forecasting air quality (http://usgeo.gov/docs/nto/Air_Quality_NTO_2006-0925.pdf).

The ARCTAS mission will provide a critical link to enhance the value of NASA satellite observations for Earth science models. The modeling and satellite communities will be involved at all stages of mission design and execution to ensure that the data are collected optimally to serve model needs. Only through Earth science models can one predict how the arctic environment will respond to future perturbations under different scenarios of global environmental change. NASA has been a leader in the development of these models, and this end-to-end approach has served it extremely well for identifying priority measurements from space and for maximizing scientific return from the measurements. Aircraft missions of the NASA Tropospheric Chemistry Program over the past 15 years have focused on continental outflow and intercontinental transport in the tropics (TRACE-A, PEM-Tropics) and northern mid-latitudes (PEM-West, TRACE-P, INTEX-A and -B), and they have considerably improved the relevant capabilities of CTMs. The TRACE-P and INTEX missions of the EOS era involved increasing partnerships with EOS satellite science teams for instrument validation and for integrated applications to source characterization and intercontinental transport at northern mid-latitudes. It is time to turn our attention to the Arctic, particularly in the context of the opportunity offered by IPY. In doing so, ARCTAS will build on previous U.S. aircraft missions to the Arctic including the NASA ABLE-3 and SOLVE missions and the NSF TOPSE mission.

ARCTAS will take place as two 3-week aircraft deployments, in April and July 2008. It will involve the NASA DC-8 as an in situ platform for detailed atmospheric composition. To focus more closely on aerosols and radiation, two smaller aircraft may be involved. One would serve as a remote sensing platform generally flying constant altitude transects in the middle to upper troposphere. The other would be a profiling aircraft for examining radiative fluxes and in situ aerosol properties. The spring deployment will target anthropogenic pollution including arctic haze, stratosphere-troposphere exchange, and sunrise photochemistry including halogen radicals. The summer deployment will target boreal forest fires, stratosphere-troposphere exchange, and summertime photochemistry. ARCTAS will be part of the international IPY/POLARCAT arctic field program for atmospheric composition (http://zardoz.nilu.no/~andreas/POLARCAT/), which involves a consortium of countries (United States, Canada, Germany, France, Norway, Russia…) and agencies (including NSF, NOAA, and DOE for the United States), and an ensemble of aircraft, surface, and ship-based measurement platforms. Table 1 gives a list of currently planned POLARCAT activities, and Figure 2 shows how POLARCAT will link with other IPY activities in the arctic. ARCTAS will be a leading partner of POLARCAT through its deployment of a high-altitude, long-range aircraft and complementary specialized aircraft, its link to satellite observations, and its engagement of models in mission design and execution. Taken together with the ensemble of POLARCAT and broader IPY activities, ARCTAS offers an unprecedented opportunity for NASA to contribute to an integrated arctic research program. Such an opportunity is unlikely to present itself again within the next 30 years.

2 SCIENTIFIC THEMES OF ARCTAS

ARCTAS has four major scientific themes, on which we elaborate below:

1. **Long-range transport of pollution to the Arctic** including arctic haze, tropospheric ozone, and persistent pollutants such as mercury;
2. **Boreal forest fires** and their implications for atmospheric composition and climate;
3. **Aerosol radiative forcing** from arctic haze, boreal fires, surface-deposited black carbon, and other perturbations;
4. **Chemical processes** with focus on ozone, aerosols, mercury, and halogens.

2.1 Long-range transport of pollution to the Arctic

The arctic troposphere in winter-spring is heavily polluted by long-range transport from northern mid-latitudes continents. This pollution has a number of environmental consequences. Radiative forcing from thick aerosol layers ("arctic haze") and black carbon deposition to snow modify regional and global climate. Seasonal build-up of tropospheric ozone and its precursors affects the ozone budget on a hemispheric scale. Deposition of mercury transported from mid-latitudes is a recognized threat to arctic ecosystems. The Arctic may further be an important route for intercontinental transport of aerosol pollution at northern mid-latitudes. There remain large uncertainties regarding the transport pathways from mid-latitudes to the Arctic, and the relative contributions of different source regions to arctic pollution. Integration of satellite and aircraft observations with models through ARCTAS provides a means to address this issue.

Polar orbiting satellites, having dense spatial coverage in polar regions, offer a unique vantage point for observing the transport of northern mid-latitudes pollution to the Arctic. Space-based observations of CO (TES, AIRS, MOPITT), ozone (TES, OMI, MLS, HIRDLS), and aerosols (CALIPSO, OMI, MODIS, MISR) are of particular interest. They can characterize synoptic transport events, the seasonal build-up of pollution during winter-spring and its ventilation to mid-latitudes in spring-summer, and the interannual variability driven by climatological features such as the Arctic Oscillation (AO). This capability is illustrated by TES arctic observations of CO in March and July 2006 (Figure 3) and of seasonal variations of tropospheric ozone and CO (Figure 4). TES provides correlative information on ozone and CO vertical profiles that can be particularly useful to relate ozone enhancements to anthropogenic influence.

The augmentation of satellite observations with aircraft measurements during ARCTAS will enhance considerably the value of the satellite data for improving understanding of pollution transport to the Arctic, not just for the duration of the mission but for the longer term. The aircraft will observe transport at different altitudes, complementing the coarser vertical resolution available from satellites. The extensive chemical payload aboard the aircraft will enable extrapolation of the satellite observations to a wide range of correlated species. Tracer measurements on the aircraft (e.g., halocarbons) will provide signatures to separate contributions from North America, Europe, and Asia. Coordination with other POLARCAT sampling platforms in Table 1 will provide additional information. Surface measurements will be particularly valuable to link the pollution layers observed from aircraft to their manifestations at ground level.

A major focus of ARCTAS will be to evaluate chemical transport model (CTM) simulations of source-receptor relationships for pollutants in the Arctic. Modeling the long-range transport of mid-latitude pollutants to the Arctic is a challenge because of the complexity of the transport patterns involved, the paucity of meteorological data, the stratification of the atmosphere, uncertain chemistry and surface interactions, and numerical filtering necessary for pole-converging Eulerian grids. Arctic atmospheric observations to test the CTMs have mainly been limited to long-term time series at a small number of surface sites, but this is grossly inadequate as the long-range transport processes are known to be decoupled from the surface. The TOPSE aircraft mission was a milestone in that regard but still provided only limited geographical coverage. The linked aircraft and satellite observations during ARCTAS will provide critical information for CTM testing and improvement, and greatly increase confidence in the application of these models to develop strategies for protecting the arctic environment.

2.2 Boreal forest fires

Summertime boreal fires are a major atmospheric perturbation to the Arctic. Smoke emissions have a direct influence on the radiation budget and exert indirect influence through impact on cloud processes. Deposition of pyrogenic black carbon to snow and ice surfaces decreases surface albedo and may accelerate melting. Chemistry in the fire plumes leads to formation of tropospheric ozone, which exerts a significant climate forcing in the Arctic. When transported to lower latitudes, boreal fire emissions contribute to poor air quality and exacerbate pre-existing air quality problems. Pyroconvective events can inject fire emissions to the lowermost stratosphere with possibly long-lasting implications for radiation and for stratospheric chemistry. The potential for a positive feedback between climate change and fire emissions is highlighted by the recent increase in extreme fire seasons in Siberia, Alaska, and Canada associated with warm and dry years (Figure 5).

NASA satellites can play a critical role for improving our understanding of boreal fire emissions and their impacts. CALIPSO provides unprecedented resolution of the vertical distribution of smoke plumes while other aerosol sensors (OMI, MISR, MODIS) and CO sensors (TES, MOPITT, AIRS) provide horizontal mapping of the regional extent of fire influence (Figure 6). MISR can determine fire injection heights from its multiangle view of the fresh plumes (Figure 7) while the combination of OMI and CALIPSO can be used to estimate the strength of particle absorption. Pyroconvective injection of CO is observable by MLS and TES. Tropospheric ozone enhancements associated withthe fires should be observable from TES and OMI, and may contribute to the high June-July ozone concentrations seen by TES in Figure 4.

Combination of aircraft and satellite observations during ARCTAS will both verify the utility and improve the interpretation of the satellite observations. The DC-8 payload will have the capability to observe the detailed chemical composition and aerosol properties of fire plumes. This is critical to examine how the aging of gases and aerosols is influenced by plume composition, altitude, transport path, etc. Aerosol and radiation measurements on the smaller aircraft will focus on determining aerosol types, optical properties, and radiative effects as the fire plumes evolve. ARCTAS will complement the DLR and Canadian aircraft to be deployed in summer 2008 with focus on pyroconvective injection of fire plumes (Table 1).

Integration of the ARCTAS observations into CTMs and climate models will enable better understanding of the perturbation to the arctic environment from boreal forest fires, and provide a foundation for study of positive feedbacks between fires and arctic climate change. The testing of satellite capabilities for observing fire injection heights will enable development of process models to predict these heights as a function of fire intensity and local meteorological stability. The combination of satellite and aircraft observations will improve constraints for inverse models used to derive fire emission estimates from satellite observations of CO, and allow extrapolation of these emission estimates to a wide range of species on the basis of the enhancement ratios measured by the aircraft.

2.3 Aerosol radiative forcing

The Arctic is a region of particular interest for radiative forcing of climate, in part because of the rapid pace of arctic climate change and in part because of the unique radiative environment. Low solar elevation angles and highly reflective surfaces increase slant optical depths and associated radiative effects of both scattering and absorbing particles and gases. Arctic haze in spring and smoke from boreal forest fires in summer are easily detectable from space and represent large perturbations to the regional radiative budget. High-latitude clouds are modified by aerosols in a number of ways, thereby extending aerosol radiative forcing to IR wavelengths.

NASA and other polar-orbiting satellites bring a wealth of capabilities to the study of aerosol radiative forcing in the Arctic. Complementary techniques of UV/Vis/IR reflectances, multi-angle sensing, lidar, and radar are available from sensors presently in space including MISR, MODIS, OMI, CALIPSO, CloudSat, and POLDER. The Glory Aerosol Polarimetry Sensor (APS) to be launched in December 2008 into the A-train orbit will provide NASA's first polarimetry measurements of Earth from space; airborne simulation of APS measurements during ARCTAS will provide valuable preparation.

Determination of aerosol radiative forcing on the basis of satellite measurements alone is difficult, due to lack of information on aerosol optical and chemical properties as well as surface reflectances. This lack of information also compromises efforts to synthesize the different spaceborne measurements into a more comprehensive characterization of the aerosol. Considerable added value can be provided by aircraft measurements of aerosol optical depth, radiative fluxes, radiances (including polarized radiances), and in situ vertical profiles of the aerosol size distribution, composition, mixing state, phase, extinction, absorption, and scattering phase function. Aircraft measurements of radiant flux and radiance can characterize surface albedo and the bidirectional reflectance distribution function (BRDF) to improve satellite aerosol retrievals. ARCTAS will attempt to coordinate with the DOE aircraft mission in April 2008 over Alaska focused on aerosol-cloud radiative interactions (Table1).

Radiative forcing by black carbon due to its deposition to arctic ice and snow has received much attention recently. Observing this forcing from space is difficult because other variables, such as snow grain size and melting state, also affect snow and ice albedo. Low-altitude mapping of UV/Vis./NIR surface albedo and (polarized) BRDF during ARCTAS will provide unique information that, in co-ordination with surface measurements of ice and snow properties and black carbon concentration, can be used to evaluate the potential of satellite measurements to map black carbon deposition and the resulting albedo effect in the Arctic.

There is controversy as to whether the major sources of black carbon to the Arctic are from fossil fuel combustion (and if so, whether from Europe, Asia, or North America) or from biomass burning (and if so, whether from tropical or boreal fires). Aerosol observations from CALIPSO, MODIS, MISR, and OMI, together with aircraft in situ characterization of aerosol plumes, will greatly help to constrain source-receptor relationships. Aircraft measurements will also provide information on the evolving mixing state of the black carbon aerosol prior to deposition, and how this mixing state varies with source type and source region.

2.4 Chemical processes

The arctic troposphere is a very reactive environment despite its high latitude. Seasonal accumulation of PAN in winter, followed by decomposition to NO_x in the spring, is a driver for fast ozone production and likely contributes to the observed springtime maximum in tropospheric ozone. Extremely high acidities in arctic haze aerosol could drive fast heterogeneous chemistry. Reactive nitrogen and organic species deposited to the ice drive photochemical emission of NO_x and of a variety of oxygenated organics. Sunrise photochemistry involving sea salt deposited to sea ice is a major source of halogen radicals; the resulting Cl and Br atoms provide a fast oxidation sink for hydrocarbons transported from mid-latitudes, as well as a catalytic loss mechanism for ozone that frequently drives concentrations to sub-ppbv levels. Fast oxidation of elemental mercury by Br atoms leads to "mercury depletion events" where the resulting Hg(II) deposits rapidly, causing accumulation of mercury in arctic ecosystems.

Current understanding of Arctic air chemistry has mostly relied on surface observations. Two past aircraft missions have significantly added to that understanding: the NASA/ ABLE-3 missions in the summers 1990 and 1992 and the NSF/TOPSE mission in Feb-May 2000. ARCTAS observations will expand considerably on these missions not only through a larger ensemble of instrumentation and geographical coverage, but also through the link with satellite observations and the ensemble of other POLARCAT surface and airborne platforms.

Joint satellite-aircraft observations will be of particular importance for improving understanding of halogen radical chemistry, with implications not only for arctic spring but also for the global troposphere. Satellite observations of BrO tropospheric columns by solar backscatter, first from GOME and subsequently from SCIAMACHY and OMI (Figure 8), have played a crucial role in demonstrating the importance and widespread nature of this radical chemistry in the Arctic. They suggest, as shown in Figure 8, a more widespread geographical importance of bromine radical chemistry ("bromine cloud") than is apparent from the limited surface data. In the absence of a satisfactory process-based understanding of the mechanisms for BrO generation in the arctic troposphere, satellite observations have been widely used as direct constraints in CTMs to calculate ozone and Hg(0) loss rates. But they have never been validated and they offer no information on the vertical distribution of BrO in the troposphere. ARCTAS will address these issues.

A high priority for ARCTAS will be to include in situ measurements of BrO on the DC-8, depending on available technology. Vertical profiles in bromine-enhanced regions (as determined from the satellite observations) will validate the satellite data under a range of conditions and determine whether the halogen radical chemistry is confined to the near-surface air or extends throughout the troposphere. Correlations with ozone and mercury measured on the aircraft will help to develop better understanding of halogen-driven depletion events. Combination of the information from the aircraft and from space will enable the development and testing of models including process-based representation of halogen chemistry for application not just to the Arctic but to the global troposphere.

ARCTAS will also provide an opportunity to better understand the tropospheric chemistry of hydrogen oxide radicals ($HO_x \equiv OH + H +$ peroxy radicals), with particular focus on the hydroxyl radical OH, the main tropospheric oxidant. Tropospheric OH cannot be measured directly from space, but could be inferred from measurements of species that regulate its abundance (ozone, water vapor, CO, NO_2) if the underlying chemistry is understood. A focus of ARCTAS will be to help develop this capability. Tropospheric OH measurements from aircraft have so-far mainly been made by two methods, Chemical Ionization Mass Spectrometry (CIMS) and Laser-Induced Fluorescence (LIF). These two techniques have never been flown on the same aircraft, and intercomparisons between different aircraft have been inconclusive. Recent NASA tropospheric aircraft missions have found large discrepancies between observed HO_x concentrations and the values simulated by locally constrained photochemical models. This implies either instrument errors or fundamental flaws in current understanding of tropospheric HO_x chemistry. ARCTAS will consider the possibility of deploying two HO_x airborne instruments using different techniques to address this issue.

Stratosphere-troposphere exchange (STE) may play an important role in the budget of tropospheric ozone in the Arctic at all times of year, and simulation of this process in CTMs is notoriously difficult. Achieving a better understanding of STE at high northern latitudes will be an important objective of ARCTAS. Satellite observations from HIRDLS provide global mapping of ozone vertical distributions with ~ 1-km resolution in the tropopause region. These will be validated with the DC-8 aircraft in regions of tropopause folds. The possibility of significant HNO_3 input to the Arctic troposphere in spring from sedimentation of arctic polar stratospheric clouds (PSCs) will also be investigated.

3 AIRCRAFT PLATFORMS, PAYLOADS, AND DEPLOYMENTS

3.1 Platforms

ARCTAS will include the NASA DC-8 aircraft as its in situ sampling platform, and may include other smaller platforms focused on aerosols and radiation. These aircraft would coordinate closely in flights targeted at the aerosol radiative forcing theme of the mission. This coordination is described in section 4.5. The DC-8 will also have broader regional and chemical objectives that take advantage of its endurance and payload.

The DC-8 has a ceiling of 39-41 kft, an endurance of 10 hours (12 hours with augmented flight crew), and a cruising speed of 450 kts. It has the range needed for targeting regional opportunities (fires, pollution events, BrO hot spots, etc.), and for validating satellite data under a wide range of conditions. Its ceiling is adequate for complete vertical profiling of the arctic troposphere, extending to the lowermost stratosphere.

The small profiling aircraft would focus on remote sensing of the shortwave radiative effects of atmospheric constituents (aerosols, water vapor, clouds, ozone), in situ aerosol properties, and possibly surface albedo including the BRDF. The constant-level, remote-sensing aircraft would focus primarily on targeted opportunities to sample pollution and fire plumes coincident with A-train satellite overpasses.

3.2 Payloads

The DC-8 will include a comprehensive chemical payload targeted at aerosol formation, tropospheric ozone, pollution sources, radical chemistry, and mercury. Table 2a lists priority species. Table 2b outlines desired observations for the two smaller aircraft focused on aerosols and radiation.

3.3 Deployments

We anticipate two 3-week ARCTAS deployments, in April and July 2008. April is the peak in seasonal accumulaion of northern mid-latitudes pollution in the Arctic (Figure

4), and the seasonal onset of solar radiation results in significant radiative forcing from arctic haze and black carbon. This is also the time of year when high-BrO events are regularly observed (Figure 9), presumably reflecting sunrise photochemical effects on sea salt accumulated over the sea ice during winter. July is a photochemically active period and the most likely time for large boreal forest fires (Figure 10). Stratosphere-troposphere exchange will be of interest in both spring and summer.

The spring deployment will be based at North American and/or European arctic/subarctic sites. Candidate bases for the DC-8 are limited by availability of a sufficiently long runway. They include Anchorage, Fairbanks, Thule, Winnipeg, Cold Lake, and Kiruna. Figure 11 shows the ranges accessible from these and a few other bases. The two smaller aircraft have more flexibility in terms of operational bases. Selection of the bases and of operating areas will draw upon analyses of (1) CTM hindcasts and satellite data from previous years; (2) logistics and costs; and (3) linkages with other POLARCAT elements. An attractive possibility would be to base the DC-8 for 1-2 weeks in Kiruna followed by 1-2 weeks in Fairbanks, with the smaller aerosol platforms remaining in Fairbanks.

The summer deployment will be based at North American arctic/subarctic sites. The Canadian POLARCAT sub-component will operate out of Yellowknife but the runway there is too short for the DC-8. Fairbanks, Cold Lake, Churchill, and Thule are attractive possibilities. Base selection will rely on analyses similar to those for the spring deployment.

4 FLIGHT PLANNING: INTEGRATION WITH SATELLITES AND MODELS

4.1 General approach

ARCTAS is an integrated satellite-aircraft mission where the focus of the aircraft is to add value to the satellite observations for facilitating their exploitation by atmospheric Earth science models, in particular CTMs and GCMs. Satellite and model science teams will be involved at all stages of pre-mission flight planning, flight execution, and post-mission data interpretation. Development of a flight menu prior to the mission will rely heavily on hindcast CTM simulations and analyses of satellite observations for previous years. Specific pre-mission questions to be addressed using a combination of literature, satellites, and models include:

1. What are the dominant pathways and receptor regions for transport of northern mid-latitudes pollution to the Arctic?
2. How are the transport pathways for arctic haze expected to differ from those for long-lived gases and ozone?
3. Where are forest fires most likely to occur and where are the plumes most likely to be transported?

4. What are typical cloud frequencies and cloud types during the deployment months and around candidate deployment bases? How do clouds typically vary with time of day, frontal passages, inflows from lower latitudes, etc.?

Day-to-day flight planning during the mission will involve meteorological and chemical forecasts from several modeling teams, analyses of near-real-time satellite data and satellite validation needs, inputs from the aircraft science teams, and reviews of progress in meeting mission objectives. The modeling and satellite instrument science teams will be present in the field, and discussions will be conducted in an open and inclusive manner at daily flight planning meetings. This will follow the successful procedure used in past NASA aircraft missions, notably INTEX-B. In what follows we describe nominal fight menus for the individual aircraft and then discuss the coordination between the three aircraft in the field.

4.2 DC-8

The DC-8 will have a flight allocation of 140 hours for the mission (70 hours for each deployment). Flights will typically be long (~9 hours) to take advantage of the aircraft range. Each deployment will include 8 flights, taking place every 2-3 days, for a total of about 3 weeks in the field. The DC-8 will conduct a number of different flight patterns over the course of the mission (Figure 12). Brief descriptions of these patterns are given below. A given flight will typically involve a combination of several patterns, depending on the opportunities offered by weather conditions, satellite overpasses, and other factors. Coordination with the smaller aircraft is described in section 4.5.

1. **Nadir satellite instrument validation.** This involves vertical spirals coincident in time and space with the satellite overpass.
2. **Limb satellite instrument validation**. This involves "crenellated" flights along the orbit track extending vertically over the depth of the limb measurement.
3. **Pollution and boreal fire plumes.** Typical flight pattern includes lidar detection of the altitude and thickness of the plumes, vertical profiling through the plumes, and level legs inside the plumes.
4. **Arctic haze.** This involves in situ characterization of the chemical and optical properties of the aerosols, as well as lidar remote sensing of the aerosol layers. 'Wall" flight patterns with level legs above, within, and below the layers may be most appropriate.
5. **Background air composition and chemical processes.** This entails extensive vertical profiling through a wide range of air masses and extending from the boundary layer to the lowermost stratosphere.

6. **Linkages and intercomparisons with other POLARCAT platforms.** Formation flying with other POLARCAT aircraft (wingtip-to-wingtip if possible) and fly-bys of surface sites.

4.3 Smaller profiling aircraft

Each 3-week deployment will have a flight allocation of 65 hours. Flight durations are expected to average ~3 hours, thus allowing for about 20 flights. The key flight patterns (Figure 13) are:

1. **Survey vertical profile.** Often flown when first arriving at a measurement site, this spiral pattern provides profiles of AOD, aerosol extinction, column water vapor (CWV), and water vapor density. 5-min transects at profile top and bottom provide radiant flux and radiance measurements describing the surface and the atmospheric column.
2. **Minimum-altitude transect.** Usually flown at or near satellite overpass time, this transect provides AOD and CWV measurements of the full column viewed by the satellite while radiometers measure the surface. Long transects can measure gradients and other spatial structure in the satellite scene.
3. **Stepped profile** (also called "parking garage"). This includes horizontal legs and linking ramps. The horizontal legs permit measurements of radiative fluxes and radiances describing selected aerosol layers, at altitudes chosen on the basis of the survey vertical profile.

3'. **Stepped profile orbit.** This provides radiance measurements to characterize surfaces and aerosols.

4. **Above-cloud transect.** This provides measurements of AOD spectra and CWV above cloud, plus radiometric measurements of cloud properties.

4'. **Above-cloud orbit.** This provides radiance measurements to characterize clouds.

5. **Linkages and intercomparisons with other POLARCAT platforms.** This involves spirals and transects within lidar curtains of other aircraft, and fly-bys of surface sites (including AERONET sun/sky radiometers).

4.4 Smaller constant-level aircraft

This platform will have a flight allocation of 140 hours for the mission (70 hours for each deployment) allowing for up to 18 flights (including transits) for each deployment. Depending on the primary airfield location and the range needed to reach areas of interest, many of the flights can be expected to last ~7 hours with a refueling stop. Extending the range of this platform might be possible through overnight stays at distant airfields. Some portion of flights will be associated with satellite validation (e.g., CALIPSO, MODIS, MISR). Flights will also be conducted in concert with the profiling aircraft and DC-8 to more fully characterize the morphology and composition of arctic haze and boreal fire plumes.

4.5 Coordination between the three aircraft

The three aircraft will operate out of a common base for at least part of each deployment and will conduct several coordinated flights addressing the aerosol radiative forcing theme of the mission. We envisage two types of coordinated flight patterns involving the three aircraft (Figure 14):

1. **Development and validation of satellite retrieval algorithms.** This will focus on improving and verifying the capabilities of MODIS and MISR for observing aerosol optical depths, and of CALIPSO for physical and optical characterization of aerosol layers; it will also provide pre-mission test scenes for APS aboard Glory. Construction and testing of aerosol retrieval algorithms for space-based sensors requires 3-D information on the physical, chemical, and optical properties of the aerosol over the field of view (viewing scene) of the sensor. The three ARCTAS aircraft will work together to achieve this 3-D characterization; the profiling and constant-level aircraft will horizontally survey the scene with back-and-forth, criss-cross, or L-shaped patterns, while the DC-8 will conduct one vertical profile through the scene. The profiling aircraft will provide reflectance information at different altitudes, separating in particular the contributions from the surface and from the aerosol to the reflectances observed from space. Remote sensing from the constant-level aircraft will provide information on the vertical distributions and properties of the aerosol layers in the scene. Vertical profiling with the DC-8 will provide a large ensemble of in situ data on aerosol properties.
2. **Characterization of the radiative effects of fire and pollution aerosol layers and their evolution with time.** Characterization of the radiative effects of an aerosol layer, and how these effects depend on the composition and other properties of the aerosol, will involve 'parking garage' legs by the DC-8 through the aerosol layer, level legs below and above the aerosol layer by the smaller profiling aircraft, and remote sensing by the constant-level aircraft flying above the aerosol layer (Figure 14). This type of coordinated flight pattern will be carried out for a number of different types of aerosol layers, of different ages, to provide a better understanding of the radiative forcings associated with different aerosol sources.

5 POST-MISSION DATA ANALYSIS

The post-mission data analysis will focus on the science themes described in section 2, integrating the information from the aircraft with satellites and models, and enabling development of the next generation of models to improve our understanding of arctic atmospheric composition and climate. Results will be presented at special sessions of AGU meetings and published in special issues of journals such as the *Journal of Geophysical Research*. We expect publication of a wide range of studies drawing on diverse results from the mission and involving different levels of integration between the aircraft data, satellite data, and models. Some of the types of publications expected to emerge within a few years of ARCTAS execution include:

- **Satellite validation papers** using the aircraft data to assess the quality of satellite sensors for the unique conditions of the arctic environment. We expect that cross-sensor validation of aerosol products and validation of tropospheric BrO will be of particular interest.
- **Satellite interpretation papers** using the aircraft observations to confirm and model studies to interpret features of the satellite observations. An example would be satellite identification of events of long-range transport of pollution or fire plumes, combined with detailed chemical characterization of these events using the aircraft observations.
- **Aerosol radiative forcing papers** using satellite measurements together with aircraft remote and in situ measurements of aerosol, cloud, and surface properties and radiative effects to better quantify aerosol radiative forcing from different source regions and source types.
- **Process papers** using the aircraft observations to improve our understanding of chemical and aerosol processes. An example would be the intercomparison of HO_x measurements and their comparison with photochemical models.
- **Source attribution papers** using CTMs evaluated with the combination of aircraft and satellite observations to quantify source-receptor relationships for pollution in the Arctic and make projections for the future.
- **Climate modeling papers** using radiative constraints from the satellite and aircraft observations to improve the representation of arctic aerosol and tropospheric ozone radiative forcings in GCMs, and assess the implications for arctic climate change.
- **Data assimilation papers** using the information from the aircraft to evaluate and improve the assimilation of satellite observations into CTMs, GCMs, and ESMs. An example would be the construction of improved error covariance matrices for satellite observations based on the detailed data provided by the aircraft.

This brief list is no more than an illustrative sample of the richness of the ARCTAS data set and its expected use by the atmospheric composition and climate research communities. The data collected in ARCTAS are certain to provide a major reference and anchor in the decades ahead for our understanding of arctic environmental change.

Table 1. U.S. and international POLARCAT activities during IPY

Agency/Country	Platform	Location	Focus	Duration	Status	Contact
NASA	DC-8, and two smaller aircraft	TBD (see section 3.3)	pollution transport, fires, radiative forcing, regional chemistry	Apr and Jul 08	pending	J.H. Crawford, NASA; D.J. Jacob, Harvard
NOAA	WP-3D aircraft	Iqaluit	N American export of pollution, aerosol-cloud interactions	Apr 08	tentative	C. Brock and M. Trainer NOAA
NOAA	R/V Ron Brown	Arctic cruise	gas and aerosol chemistry	Feb-Mar 08	funded	T. Bates, NOAA
NSF-ATM, NSF-OPP	Surface	Summit	radical chemistry, ice interactions	Apr 07 – Aug 08	funded	J.E. Dibb, U. New Hampshire
DOE	aircraft	Alaska North Slope ARM site	aerosol-cloud interactions and radiative forcing	Apr-May 08	funded	S. Ghan, DOE
Russia, France, Norway	Antonow aircraft	Russian Arctic	General	TBD	funded	K. Law, CNRS
France (CEA)	AN-30 aircraft	TBD	C cycle	TBD	funded	P. Ciais, CEA
Germany (DLR)	Falcon aircraft	NE Canada	pollution transport, satellite validation, heterogeneous chemistry, UT/LS, pyroconvection	Mar-Apr 07, summer 08	funded (07), pending (08)	H. Schlager, DLR
Canada	3 aircraft	Yellowknife	pyroconvection	Jun-Jul 07 and 08	pending	B.J. Stocks
Russia, Norway	Train (TROICA instrumented carriage)	Transsiberian	fires, arctic haze	spring and summer 08	funded	B. Belan and N. Elansky, Russia
Norway	surface, Lagrangian balloons	Spitsbergen	fires, mid-latitudes pollution, albedo effects,POLARCAT coordination	2007-2009	funded	A. Stohl, NILU
Canada, Europe, Russia	Surface sites	Arctic	regional chemistry, C cycle, ice interactions	IPY	funded	various investigators

Table 2a. DC-8 priority measurements in ARCTAS.

Species/Parameter	Priority[1]	Detection Limit	Desired Resolution
Gas phase in situ			
O_3	1	3 ppb	1 s
H_2O	1	10 ppm	1 s
CO	1	3 ppb	1 s
NO_2	1	10 ppt	30 s
NO	1	5 ppt	5 s
$OH/HO_2/RO_2$	1	.01/0.1 ppt	30 s
BrO	1*	1 ppt	1 min
CO_2	2	0.5 ppm	1 s
CH_4	2	10 ppb	1 s
Speciated NMHC	2	5 ppt	1 min
Oxygenated VOCs	2	10 ppt	2 min
Halocarbons	2	5 ppt	2 min
HNO_3	2	5 ppt	1 min
PAN, PPN, MPAN, etc.	2	5 ppt	1 min
HO_2NO_2	2	10 ppt	1 s
HCHO	2	50 ppt	30 s
H_2O_2	2	15 ppt	30 s
CH_3OOH	2	25 ppt	30 s
HCN/CH_3CN	2	10 ppt	2 min
SO_2	2	10 ppt	1 s
Hg(0)	2 *	0.2 ng m^{-3}	5 min
Reactive gasesous mercury (RGM)	2 *	20 pg m^{-3}	60 min
Total particulate mercury	2 *	20 pg m^{-3}	60 min
HOBr, ClO, HOCl	2 *	1 ppt	5 min
N_2O	3	1 ppb	10 s
$RONO_2$	3	10 ppt	30 s
NO_y	3	5 ppt	1 s
NH_3	3*	30 ppt	1 min
Organic acids	3	10 ppt	1 min
Aerosol in situ			
Aerosol number	1	NA	1 s
Aerosol size distribution	1	NA	10 s
Optical properties (scattering/absorption)	1	NA	1 s
Aerosol volatility	2	NA	1 s
Aerosol hygroscopicity, f(RH)	2	NA	10 s
Aerosol composition, inorganic	2	50 ng m^{-3}	5 min
Aerosol composition, OC and BC	2	100/50 ng m^{-3}	5 min
Size-resolved aerosol composition	2	100 ng m^{-3}	5 min
Droplet size distribution (and phase)	3	NA	5 s
Condensed water content	3	NA	5 s
CCN	3	NA	5 s
Radionuclides (^{222}Rn, ^{7}Be, ^{210}Pb)	3	1/100/1 fCi/m^{-3}	5 min
Remote Sensing			
O3 (nadir/zenith)	1	5 ppb	Z < 500 m
Aerosol extinction (nadir/zenith)	1	NA	Z < 100 m
BrO (zenith column)	1*	$3x10^{13}$ molec/cm^2	5 min

[1] Priority code: 1 = top priority; 2 = high priority; 3 = medium priority. Asterisks recognize exploratory, high-risk measurements – at least one of these will be included in the payload.

Aerosol depolarization (nadir/zenith)	2	NA	z < 100 m
UV spectral actinic flux (4π sr)	2	10^{-5} s^{-1} J's	10 s

Table 2b. Priority measurements for the smaller aerosol and radiation platforms in ARCTAS

Measurement type	Detail
Optical depth spectra	Near-UV→Vis→Near-IR
Radiative flux spectra	Upwelling and downwelling, Near-UV→Vis→Near-IR
Radiance spectra	Angular scanning, Near-UV→Vis→Near-IR, preferably polarized
Lidar backscatter coefficient	
Lidar extinction coefficient	
Lidar aerosol depolarization	
In situ aerosol properties	See Table 2a

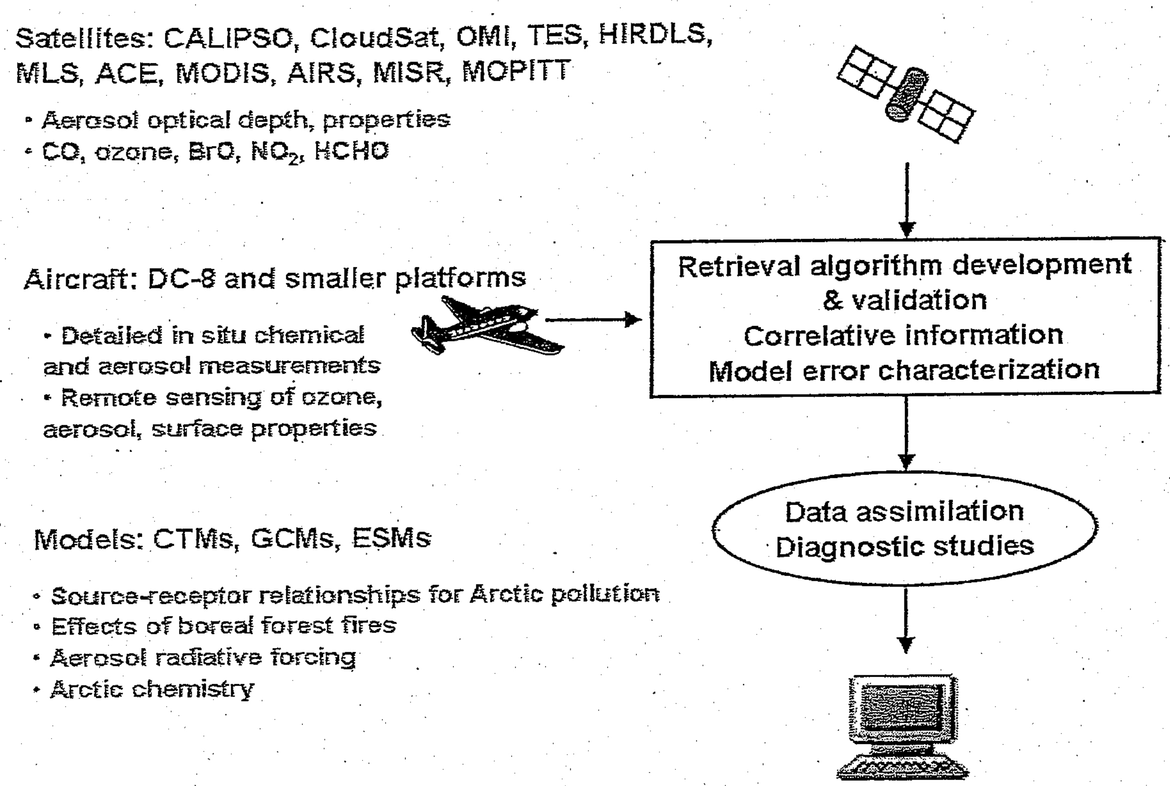

Figure 1. ARCTAS strategy for enabling exploitation of NASA satellite data to improve understanding of arctic atmospheric composition and climate

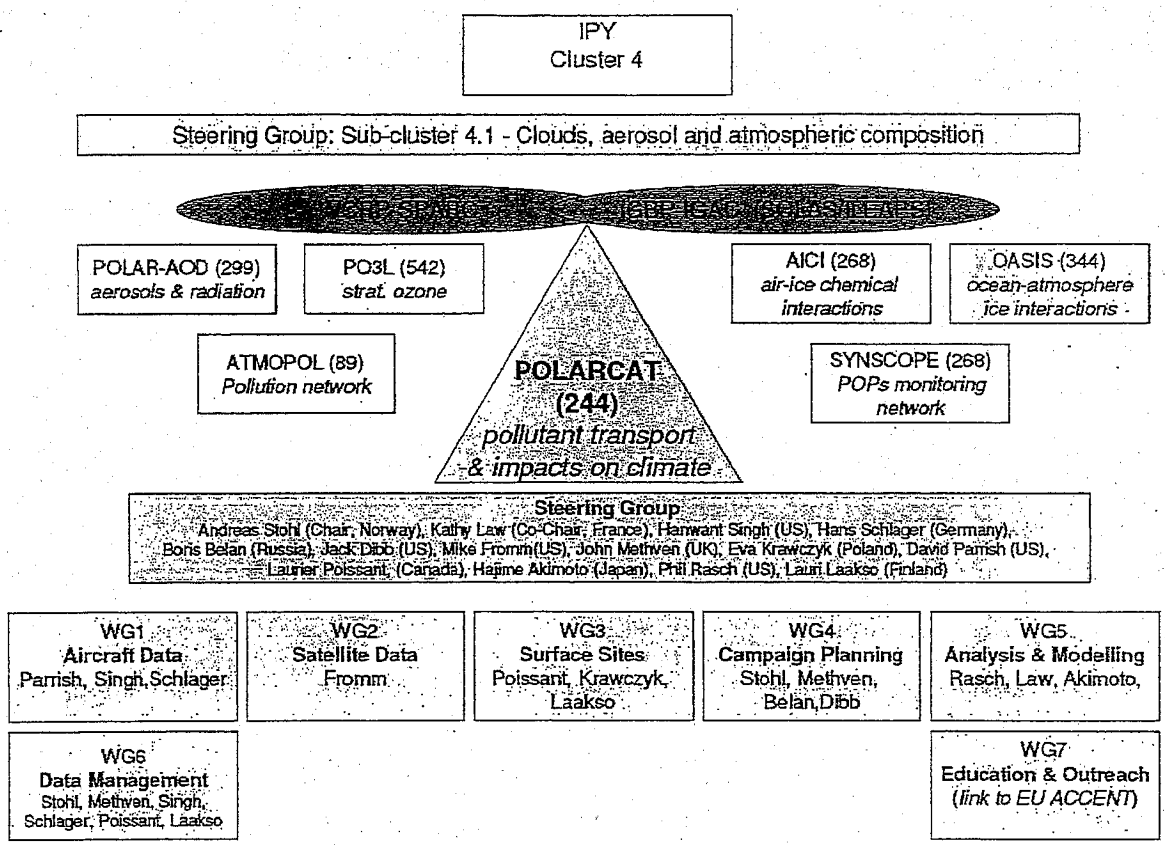

Figure 2. POLARCAT as an element of the IPY cluster "Clouds, aerosols, and atmospheric composition". Major partner activities are identified.

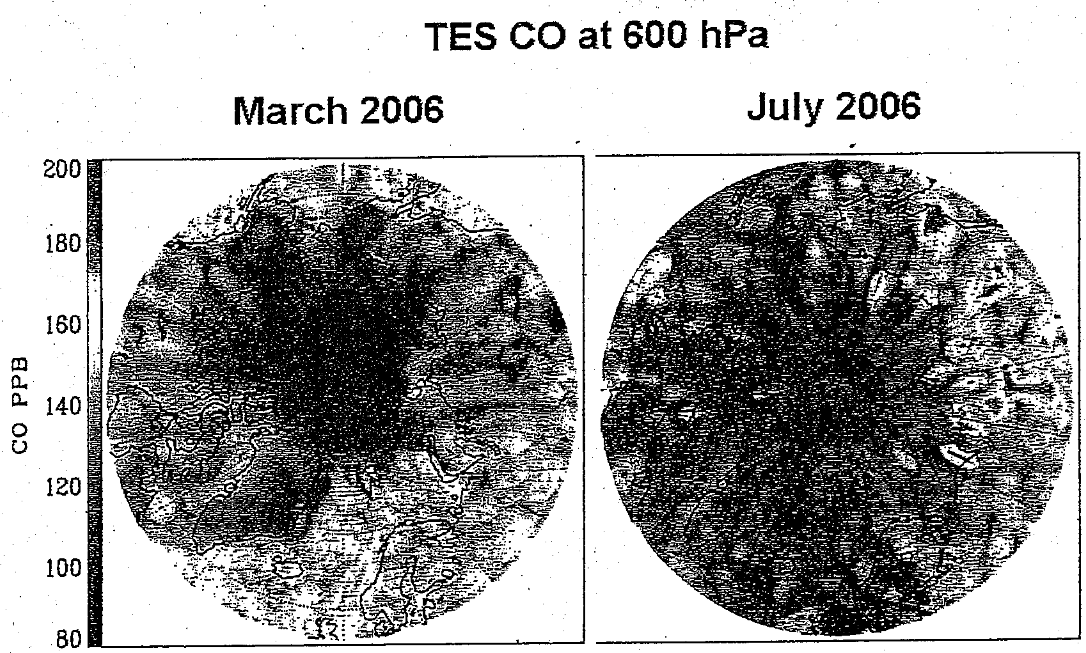

Figure 3. TES observations of arctic CO concentrations at 600 hPa. Values are monthly means for March and July 2006. Observations are marked by crosses. There are no observations above 82°N because of the inclination of the Aura satellite. (John Worden, TES Science Team).

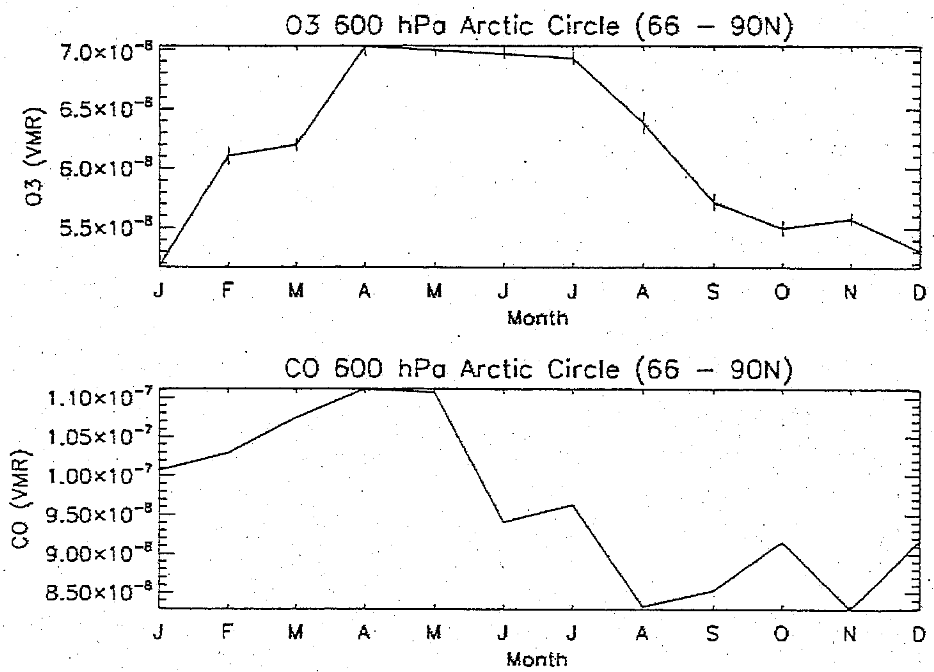

Figure 4. Seasonal variations of ozone and CO concentrations at 600 hPa over the Arctic as observed by TES. The error bars represent the errors on the mean monthly values which do not include sampling error. The errors on the CO mean values are too small to show. (John Worden, TES Science Team)

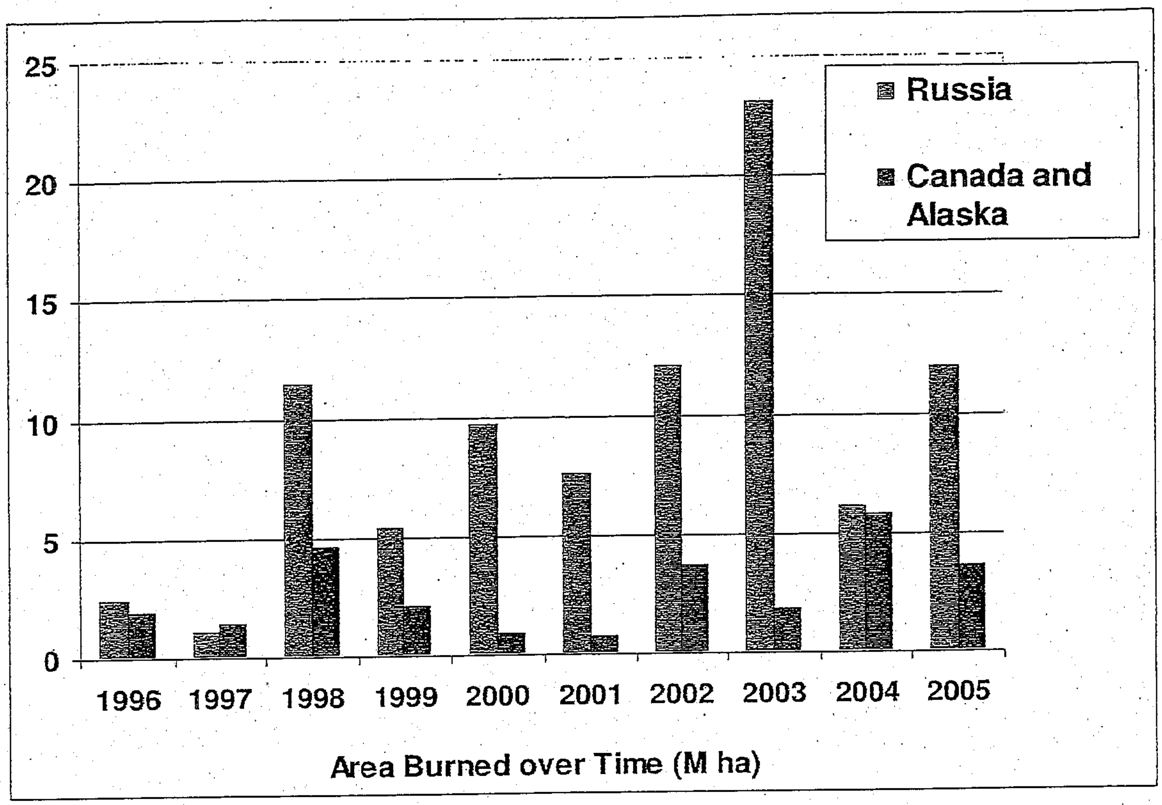

Figure 5. Boreal fire trends over the past decade (Amber Soja, NASA/LaRC)

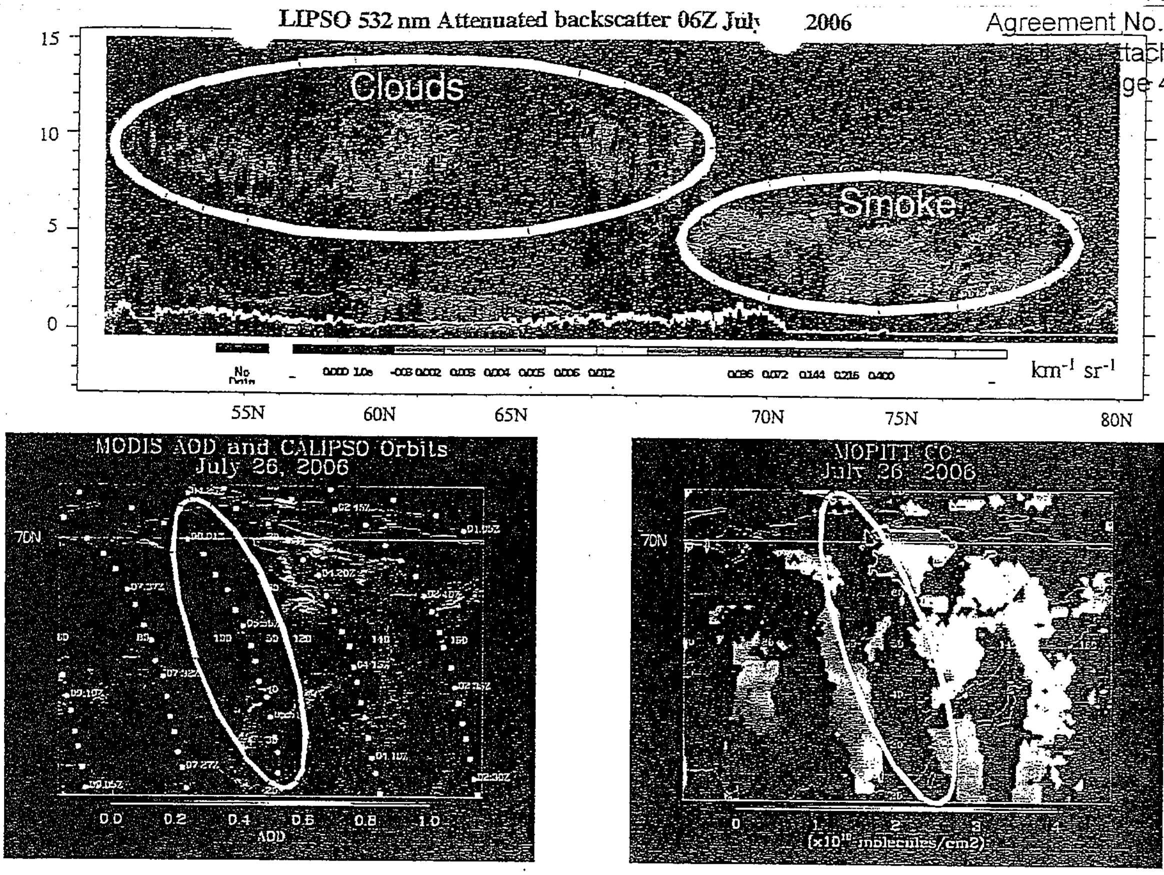

Figure 6. Concurrent views of Siberian boreal fire activity on July 26, 2006 by multiple satellites: CALIPSO observations of smoke (top), MODIS AOD (bottom left), and MOPITT CO (bottom right). CALIPSO provides information on the altitude of fire emissions while MODIS and MOPITT observations offer a view of the regional extent of elevated AOD and CO downstream of fires.

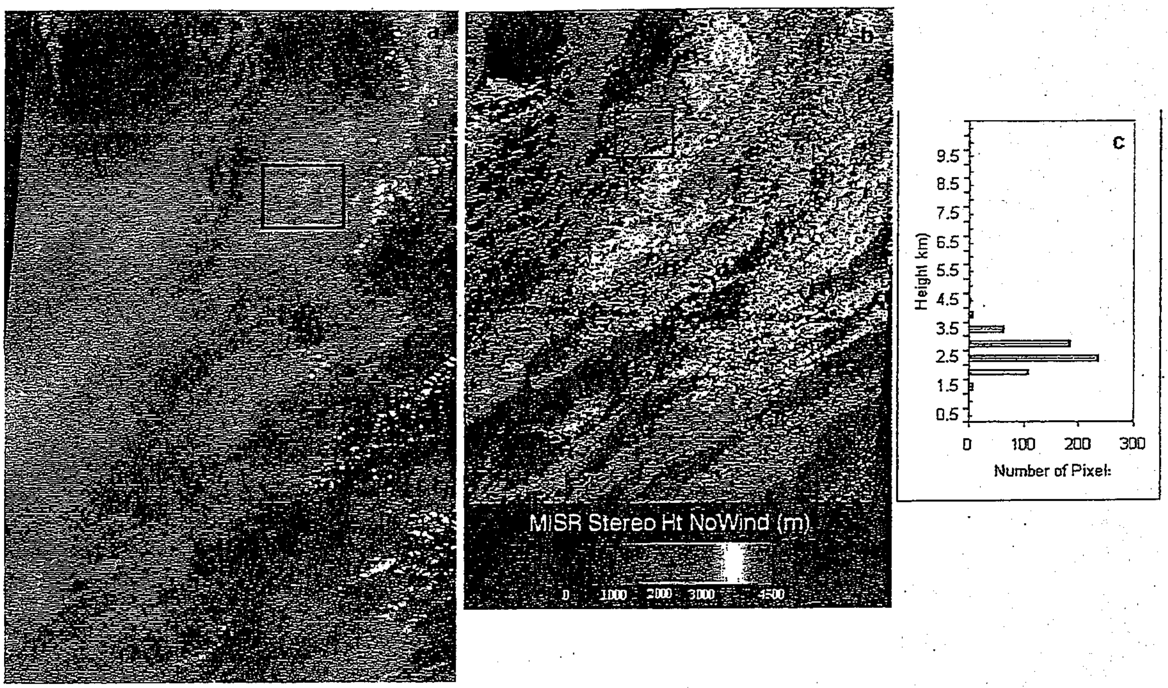

Figure 7. MISR plume height analysis for the June 11, 2003 boreal fire in the Siberian taiga near Lake Baikal (51-54° N, 110-112° E), Orbit 18506, Path 130, Blocks 47-49. (a) MISR true-color nadir image with black box marking the study patch. (b) MISR Stereo Height product (Version 13, without wind correction), for the region shown in (a). (c) Plume height histogram from the MISR Standard Stereo Height product, for the study patch.

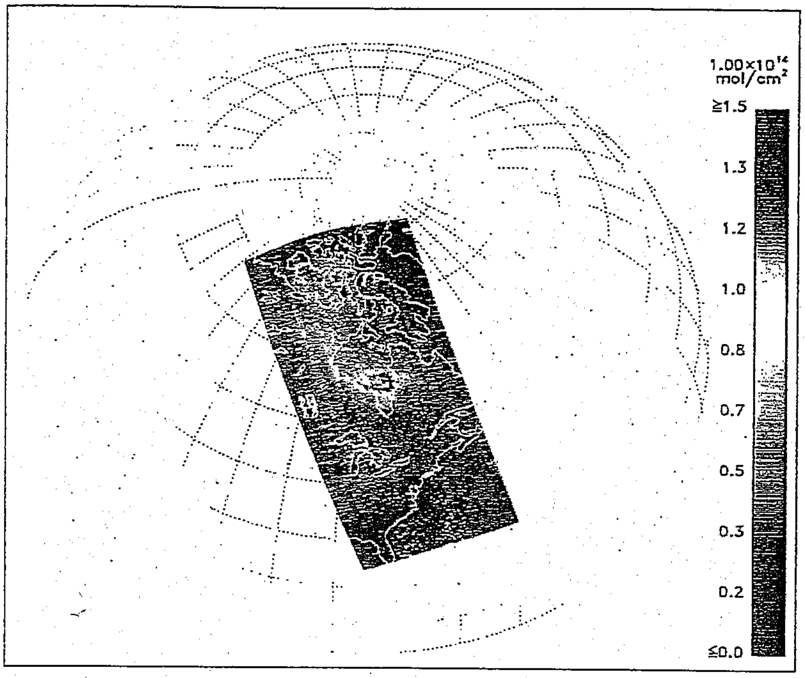

Figure 8. Tropospheric BrO column observed by OMI on March 11, 2005 (Thomas Kurosu, OMI Science Team)

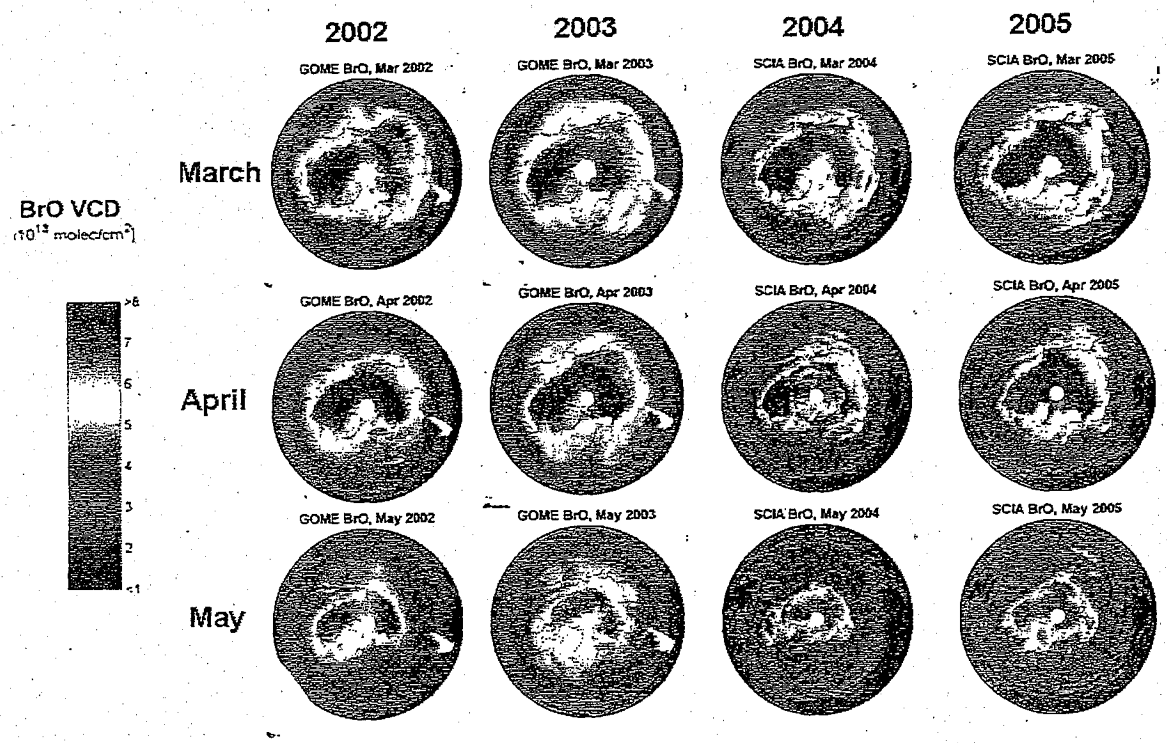

Figure 9. Monthly mean March-May tropospheric BrO columns observed from space by GOME (2002-2003) and SCIAMACHY (2004-2005). Imagery from U. Bremen, http://www-iup.physik.uni-bremen.de

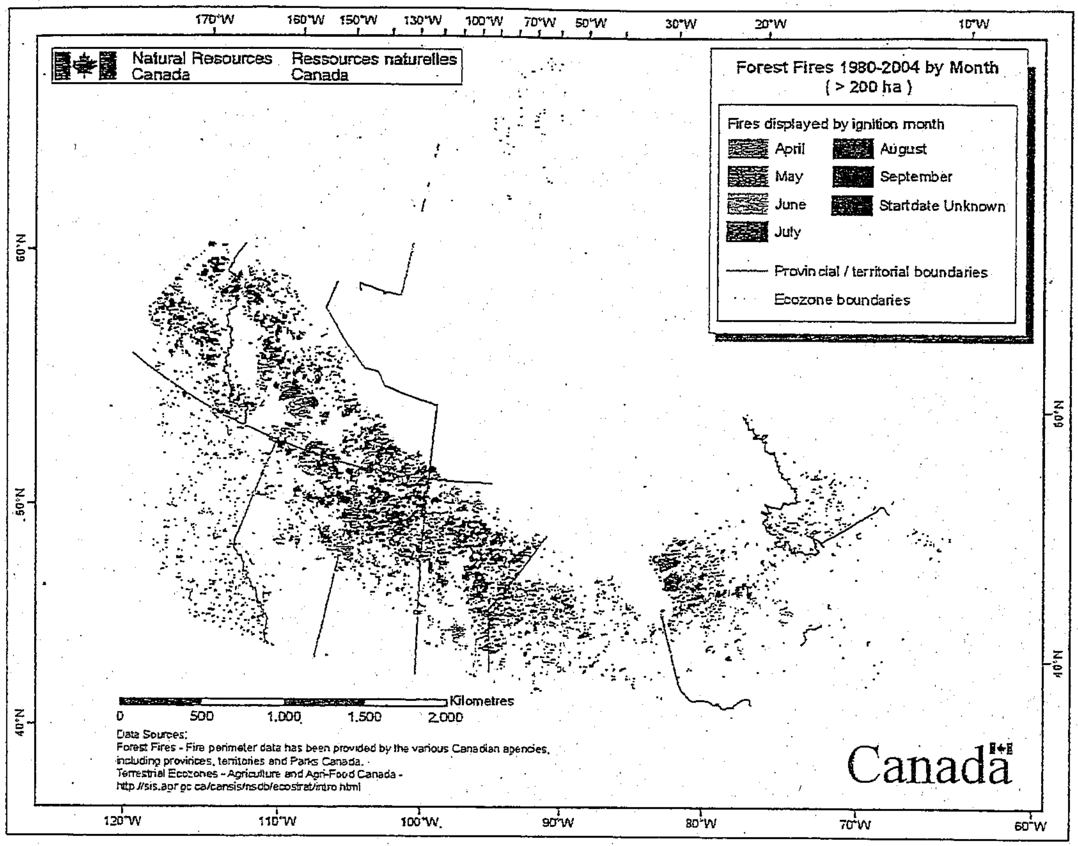

Figure 10. Seasonal distribution of large (>200 ha) Canadian fires in 1980-1994 (from Brian J. Stocks, Canadian POLARCAT White Paper)

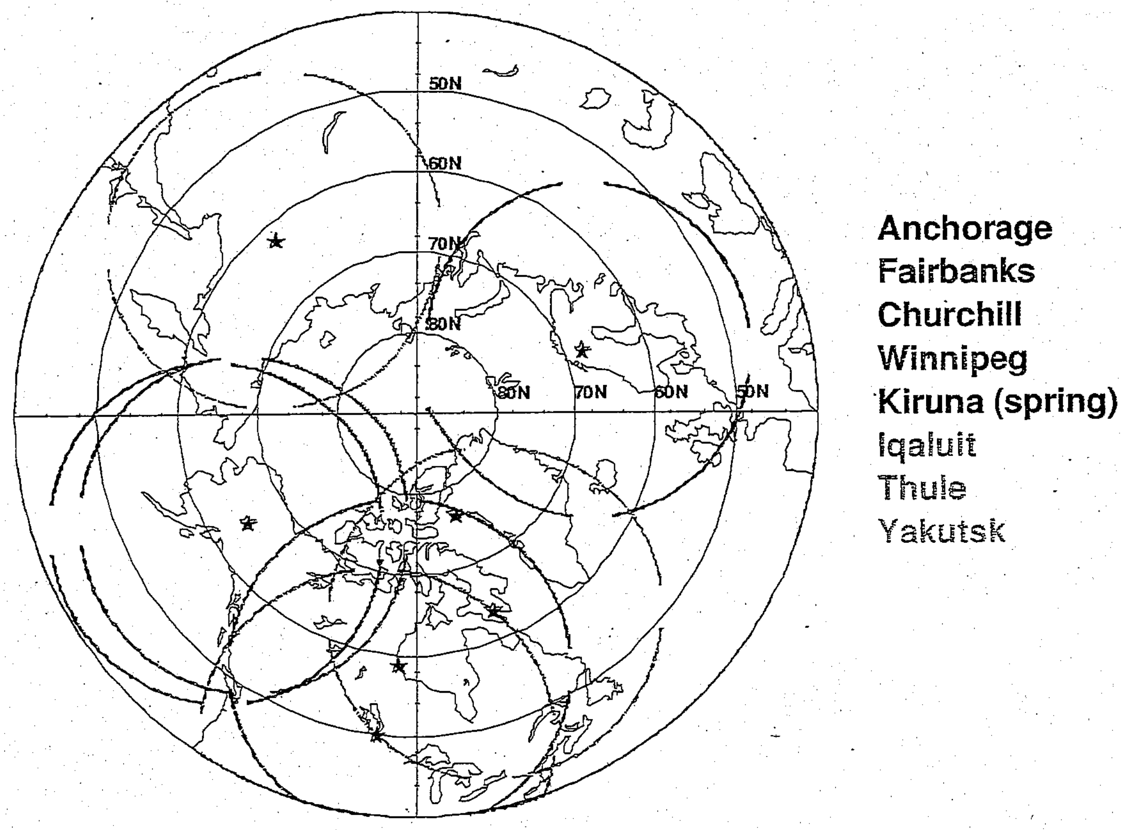

Figure 11. Range of the DC-8 aircraft from candidate bases, based on 4 hours out and back with nominal vertical profiling.

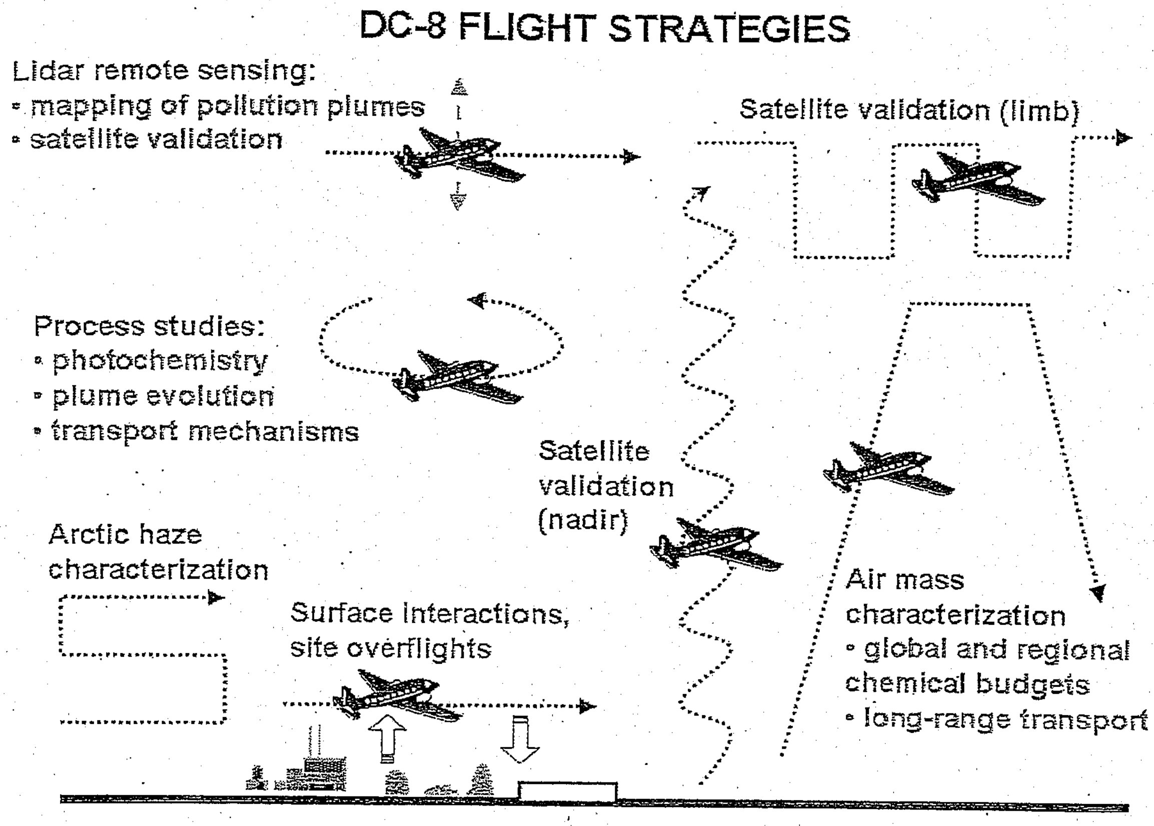

Figure 12. Nominal DC-8 flight patterns in ARCTAS

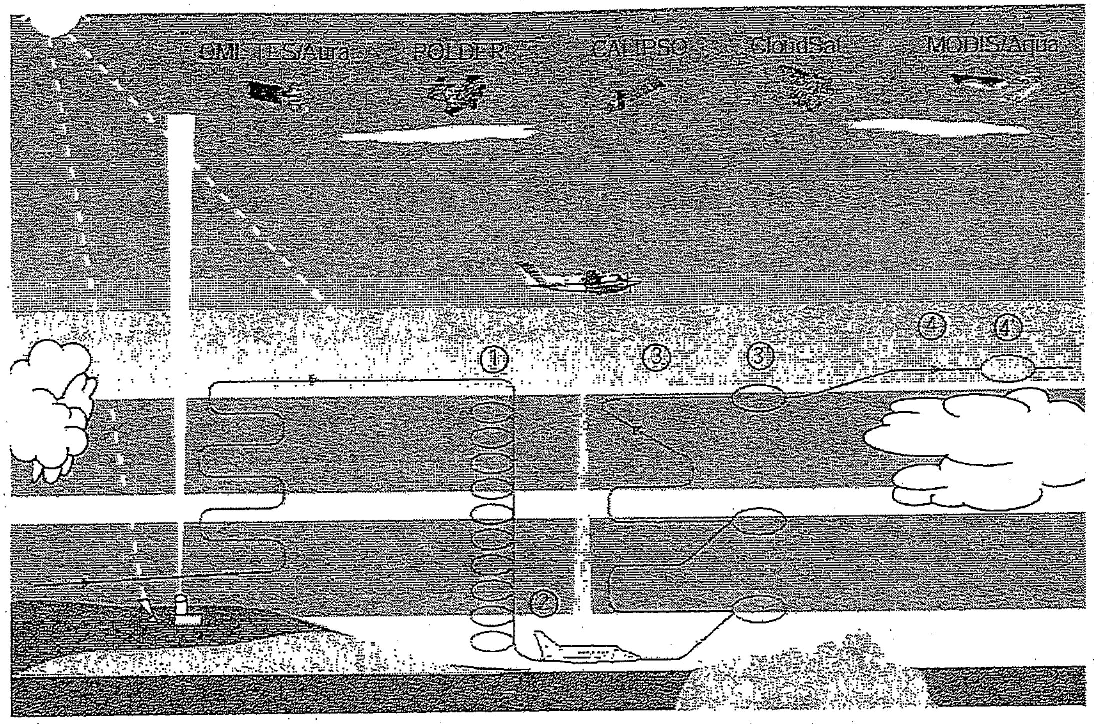

Figure 13. Flight patterns for studies of aerosol radiative forcing in ARCTAS. (1) Survey vertical profile. (2) Minimum-altitude transect. (3) Stepped profile (parking garage). (3') Stepped profile orbits. (4) Above-cloud transect. (4') Above-cloud orbit. See text for details.

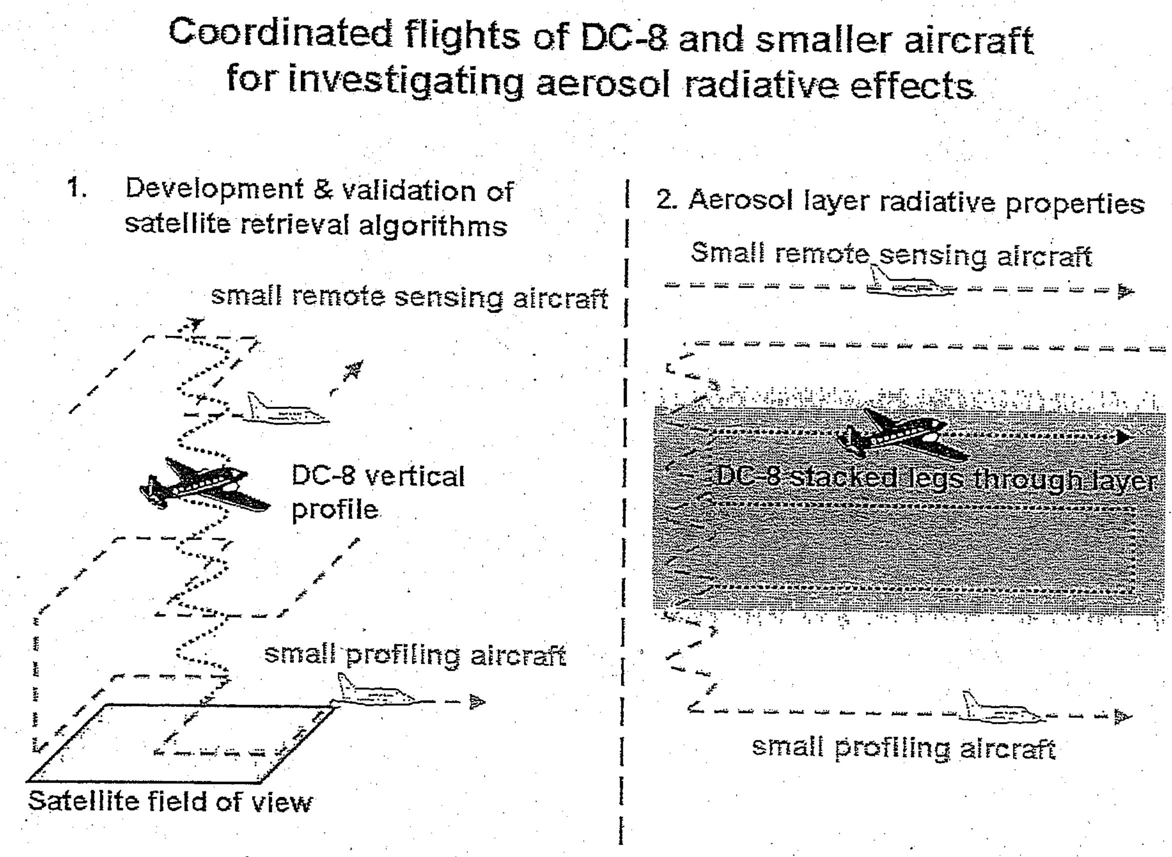

Figure 14. Nominal patterns for coordinated DC-8 flights with smaller aircraft during ARCTAS.

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, Irvine 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 below:

Ms. Emma Plasencia
Research Division
1001 “I” Street, 5th Floor
Sacramento, CA 95814

C. University may rebudget funds up to a maximum of ten percent between major budget categories with prior notice to ARB's Contract Manager.

D. Upon mutual agreement, ARB will give consideration to requests to rebudget funds in excess of ten percent, however, no rebudgeting in excess of ten percent and no rebudgeting of funds into the travel category may be performed without Research Division Chief approval. The total agreement cost will remain unchanged.

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.

PLEASE TYPE OR PRINT:

Title of Proposal: ARCTAS- California 2008: An airborne mission to investigate California air quality

Total Budget Requested: $400,000

Period Covered (months): 18

University: The Regents of the University of California, Irvine

Address:

Name of person authorized to bind this bid: Tam Tran

Title: Contract and Grant Officer

Phone: 949 824 7813

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	$159,490
2.	Subcontractor(s)/Consultant(s)	$190,000
3.	Equipment	$0
4.	Travel & Subsistence	$0
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$0
7.	Mail, Telephone, and Fax	$0
8.	Materials & Supplies	$32,068
9.	Analyses	$0
10.	Miscellaneous	
	Total Direct Cost	**$381,558**

Indirect Costs			
11.	Overhead	10% of $184,415	$18,442
		Total Indirect Cost	**$18,442**

Total Direct and Indirect Cost:	**$400,000**

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.	Donald Blake	Professor	$16,922.00	1.00	27.00%	$4,569
B.	Nicola Blake	Researcher	$5,942.00	2.00	100.00%	$11,884
C.	F. S. Rowland	Research Professor	$24,411.00	1.00	25.00%	$6,103
D.	Isobel Simpson	Assoc. specialist	$4,310.00	2.00	100.00%	$8,620
E.	Stan Tyler	Researcher	$8,798.00	6.00	50.00%	$26,394
F.	Melissa Yang	Graduate Student Researcher	$3,229.00	3.55	100.00%	$11,463
G.	Matt Carlson	Graduate Student Researcher	$3,229.00	3.55	100.00%	$11,463
	Matt Gartner	Graduate Student Researcher	$3,229.00	3.55	100.00%	$11,463
H.	Gloria Liu	Laboratory Assistant III	$2,544.00	5.00	100.00%	$12,720
I.	Brent Love	SRA	$4,010.00	5.00	100.00%	$20,050
J.	Barbara Chisholm	Asst. Analyst	$4,186.00	4.00	50.00%	$8,372
(use additional page if necessary)						
					Subtotal:	**$133,101**

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).

Donald Blake will supervise all aspects of the UCI team's contributions. Nicola Blake will direct the field aspect of the mission. F. S. Rowland will assist in the planning of the research. Stan Tyler will be responsible for the carbon research. Isobel Simpson will assist in the field. Melissa Yang, Matt Carlson, and Matt Gartner will be responsible for working in the field and obtaining samples, and will assist in the analysis of the samples. Gloria Liu will assist Brent Love in completing all of the sample analysis, which will be directed by Brent Love. Barbara Chisholm will be responsible for mission logistics, and in the shipping of canisters, and the travel of personnel.

1b. Fringe Benefits

Note: COST cells automatically calculate when using Excel file.

	Individual's Name	BASE ($)	RATE (%)	COST
A.	Donald R. Blake	$4,569.00	12.70%	$580
B.	Nicola Blake	$11,884.00	17.00%	$2,020
C.	F. S. Rowland	$6,103.00	12.70%	$775
D.	Isobel Simpson	$8,620.00	17.00%	$1,465
E.	Stan Tyler	$26,394.00	17.00%	$4,487
F.	Brent Love	$20,050.00	22.00%	$4,411
G.	Gloria Liu	$12,720.00	22.00%	$2,798
H.	Barbara Chisholm	$8,372.00	22.00%	$1,842
I.	Graduate Student Researchers	$9,687.00	1.30%	$126
J	Graduate Student Researchers	$24,702.00	3.00%	$741
K	Graduate Student Researchers/fees	$7,143.00	100.00%	$7,143
L				$0

(use additional page if necessary)

Subtotal: $26,389

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

All benefit rates are specified by the University of California Irvine.
The benefit rate for all students while they are in classes during the academic calendar is 1.3%
The benefit rate for all students during the summer period is 3.0%
Fees for 3 students come to $7,143. Fees are considered benefits as students will not be able to teach when they are in the field.
The University of California, Irvine is on the quarter system so the length of their summer session and academic sessions varies from that of the University of California, Berkeley.

2. Subcontractors & Consultants

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

	Subcontractor or consultant	Cost
A.	Subcontract to UC Berkeley, R. Cohen's Research Group	$190,000
B.		
C.		
D.		
(use additional page if necessary)		

Subtotal: $190,000

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).

R. Cohen's group will accomplish all the research as described. This work is necessary to the completion of the project.

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)

No equipment is to be purchased.

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

Description	Cost
A.	
B.	
C.	
D.	

Subtotal:	

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

No travel is being requested. NASA will fund the travel expenses for the UCI group.

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).

N/A

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).

N/A

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).

N/A

8. Materials & Supplies (Itemize)

	Item	Cost
A.	Liquid Nitrogen, 65,170 liters @$0.40/liter	$26,068
B.	Carbon 14 Analysis charges @ $100/sample	$6,000
C.		
D.		
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$32,068**

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).

All gases are necessary to complete the analysis of the trace gas samples.

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).

N/A

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): $381,558

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	$184,415.00	10.00%	$18,442
B.			$0
C.			$0

Subtotal: $18,442

Total Indirect Cost: $18,442

Total Project Cost: $400,000

Sponsored Projects Office
University of California, Berkeley
2150 Shattuck Avenue, Suite 313
Berkeley, CA 94740-5940

Principal Investigator: Ronald C. Cohen
Fellow:
Project Title: An Airborne Mission to Investigate California Air Quality

Please accept the enclosed proposal submitted on behalf of The Regents of the University of California Berkeley campus. Should this proposal be selected for funding, award documents should be issued using the information provided below.

Endorsed for the Regents by:

1/31/08
Jyl Baldwin
Assistant Director
Compliance & Special Projects

If you have any questions or need additional information regarding this proposal, please contact:

Dan Jacobs
Principal Research Administrator
Phone: (510) 643-7365
Fax: (510) 642-8236
Email: dan_jacobs@berkeley.edu

AWARDS SHOULD BE MADE TO:	CHECKS SHOULD BE MADE PAYABLE TO:
The Regents of the University of California	**The Regents of the University of California**
c/o Sponsored Projects Office University of California, Berkeley 2150 Shattuck Avenue, Suite 313 Berkeley, CA 94704-5940	CHECKS SHOULD BE SENT TO:
email address for electronics awards: spoawards@berkeley.edu	Cynthia Kane, Manager Extramural Funds Accounting University of California, Berkeley 2195 Hearst Avenue, Room 130 Berkeley, CA 94720-1103 Telephone: 510/642-1371 Fax: 510/643-8997 Email: cjkane@berkeley.edu
Main Office: (510) 642-0120 Fax: (510) 642-8236 Website: http://spo.berkeley.edu	

Budget Submittal Form

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

PLEASE TYPE OR PRINT:

Title of Proposal: ARCTAS- California 2008: An airborne mission to investigate California air quality

Total Budget Requested: $190,000

Period Covered (months): 18

University: The Regents of the University of California at Berkeley

Address: Sponsored Projects Office, 2150 Shattuck Ave., Suite 313, Berkeley, CA 94720

Name of person authorized to bind this bid: Jyl Baldwin

Title: Acting Assistant Director for Non-Federal Programs

Phone: 510 642 8114

Signature of person authorized to bind this bid: Jyl Baldwin 1/31/08

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	$163,386
2.	Subcontractor(s)/Consultant(s)	$0
3.	Equipment	$0
4.	Travel & Subsistence	$0
5.	Electronic Data Processing	$0
6.	Photocopying & Printing	$0
7.	Mail, Telephone, and Fax	$0
8.	Materials & Supplies	$11,126
9.	Analyses	$0
10.	Miscellaneous	
	Total Direct Cost	**$174,512**

Indirect Costs		
11.	Overhead	$15,488
	Total Indirect Cost	**$15,488**

Total Direct and Indirect Cost:	**$190,000**

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.	Ronald Cohen	Professor	$11,456.00	1.00	100.00%	$11,456
B.	Paul Wooldridge	Assoc Specialist	$5,211.00	12.00	100.00%	$62,532
C.	Graduate Student	Graduate Student Researcher	$4,508.75	12.00	50.00%	$27,053
D.	Graduate Student	Graduate Student Researcher	$4,508.75	12.00	50.00%	$27,053
E.						
F.						
G.						
H.						
I.						
J.						
(use additional page if necessary)						4
					Subtotal:	**$128,093**

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.
Wooldridge will have primary responsibility for instrument integration, and data quality.
The two graduate students will each divide the work of supporting instrument integration and data analysis.
The graduate students will work for 12 months, two semesters.

1b. Fringe Benefits

Note: COST cells automatically calculate when using Excel file.

	Individual's Name	BASE ($)	RATE (%)	COST
A.	Ronald Cohen	$11,456.00	12.70%	$1,455
B.	Paul Wooldridge	$62,532.00	19.00%	$11,881
C.	Graduate Student Researchers	$54,105.00	1.30%	$703
D.	Graduate Student Researchers	$54,105.00	3.00%	$1,623
E.	Graduate Student Fees	$19,631.00	100.00%	$19,631
F.				
G.				
H.				$0
I.				$0
J				$0
K				$0
L				$0
(use additional page if necessary)				

Subtotal:	**$35,294** 3

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

All benefit rates are specified by the University of California at Berkeley. Fees are considered benefits as, students will not be able to teach when they are in the field. Fees for one student for 2 semesters is $9,815.50, thus $19,631 for both students total

For Graduate Student Researcher Benefits, 1.3% is for the academic year amount and 3% is for the summer rate, when classes are not in session. Since Berkeley is on the semester calandar, the Graduate Student Researchers will not be able to teach for a full academic year.

Note: Fees at different UC school will vary. Different schools will include different items in the fees, so fees will vary from UC branch to UC branch.

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.	
B.	
C.	
D.	

Subtotal:	

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

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).

N/A

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).

N/A

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).

N/A

8. Materials & Supplies (Itemize)

	Item	Cost
A.	Analytical Chemicals	$3,000
B.	Analytical Supplies: tubing fittings, galssware, electonic parts	$4,700
C.		
D.	Optics	$3,426
E.		
F.		
G.		
H.		
I.		

Subtotal:	**$11,126**

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).

All items included will be used in the analytical of the samples obtained for the completion of this project.

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).

N/A

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): $174,512

II. Indirect Costs

11. Overhead and Other Indirect Costs

	Base (Salaries, total direct costs, etc.) ($)	Rate (%)	Cost
A.	$154,881.00	10.00%	$15,488
B.			$0
C.			$0

Subtotal:	$15,488

Total Indirect Cost:	$15,488

Total Project Cost:	~~$190,000~~ 191,000

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. **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.

2. 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.

3. 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.

4. 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.

5. 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.

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. 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. 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".