Cover Page for Proposal Submitted to the National Aeronautics and Space Administration

NASA Proposal Number

10-AURA10-0020

NASA PROCEDURE FOR HANDLING PROPOSALS

This proposal shall be used and disclosed for evaluation purposes only, and a copy of this Government notice shall be applied to any reproduction or abstract thereof. Any authorized restrictive notices that the submitter places on this proposal shall also be strictly complied with. Disclosure of this proposal for any reason outside the Government evaluation purposes shall be made only to the extent authorized by the Government.

SECTION I - Proposal Information

Principal Investigator	E-mail Address	Phone Number
Kelly Chance	**kchance@cfa.harvard.edu**	**617-495-7389**

Street Address (1)	Street Address (2)
60 Garden St	**MS 50**

City	State / Province	Postal Code	Country Code
Cambridge	**MA**	**02138-1516**	**US**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
02 / 01 / 2011	**01 / 31 / 2014**	**898,788.00**	**299,872.00**	**299,945.00**	**298,971.00**

SECTION II - Application Information

NASA Program Announcement Number	NASA Program Announcement Title
NNH10ZDA001N-AURA	**Atmospheric Composition: Aura Science Team**

For Consideration By NASA Organization *(the soliciting organization, or the organization to which an unsolicited proposal is submitted)*
Earth Science

Date Submitted	Submission Method	Grants.gov Application Identifier	Applicant Proposal Identifier
08 / 02 / 2010	**Electronic Submission Only**		**P7584-7-10**

Type of Application	Predecessor Award Number	Other Federal Agencies to Which Proposal Has Been Submitted
New		

International Participation	Type of International Participation
No	

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
003261823	**1PPP1**	**530206027**	**ZZ**

Organization Name (Standard/Legal Name)	Company Division
Smithsonian Institution/Smithsonian Astrophysical Observatory	

Organization DBA Name	Division Number
SMITHSONIAN ASTROPHYSICAL	

Street Address (1)	Street Address (2)
60 GARDEN ST	

City	State / Province	Postal Code	Country Code
CAMBRIDGE	**MA**	**021381516**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Kelly Chance	**kchance@cfa.harvard.edu**	**617-495-7389**

SECTION V - Certification and Authorization

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in the Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing organization (or the individual proposer if there is no proposing organization) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications and one Assurance contained in this NRA (namely, (i) the Assurance of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs, and (ii) Certifications, Disclosures, and Assurances Regarding Lobbying and Debarment and Suspension.

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Authorized Organizational Representative (AOR) Name	AOR E-mail Address	Phone Number
Michael Griffith	**mgriffith@cfa.harvard.edu**	**617-496-7924**

AOR Signature *(Must have AOR's original signature. Do not sign "for" AOR.)* **Date**

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Kelly Chance**	**617-495-7389**	**kchance@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Co-I	**Thomas Kurosu**	**617-495-7213**	**tkurosu@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Co-I	**Xiong Liu**	**617-496-2136**	**xliu@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Collaborator	**Daniel Jacob**	**617-495-1794**	**djacob@fas.harvard.edu**
Organization/Business Relationship: **Harvard College**		Cage Code: **1NQH4**	DUNS#: **082359691**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Collaborator	**Randall Martin**	**902-494-3915**	**rvmartin@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Collaborator	**Caroline Nowlan**	**617-496-7959**	**cnowlan@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Collaborator	**Ross Salawitch**	**626-487-5643**	**rjs@atmos.umd.edu**
Organization/Business Relationship: **University of Maryland, College Park**		Cage Code: **0UB92**	DUNS#: **790934285**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**
Collaborator	**Raid Suleiman**	**617-496-7823**	**rsuleiman@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Omar Torres**	**757-728-6745**	**omar.torres@hamptonu.edu**
Organization/Business Relationship **Hampton University**		Cage Code **4W066**	DUNS# **003135068**
International Participation **No**	U.S. Government Agency		Total Funds Requested **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Rainer Volkamer**	**720-215-9410**	**rainer@alum.mit.edu**
Organization/Business Relationship **University of Colorado at Boulder**		Cage Code	DUNS#
International Participation **No**	U.S. Government Agency		Total Funds Requested **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**jerald ziemke**	**301-614-6034**	**ziemke@jwocky.gsfc.nasa.gov**
Organization/Business Relationship **University of Maryland Baltimore County**		Cage Code **1CDP0**	DUNS# **061364808**
International Participation **No**	U.S. Government Agency		Total Funds Requested **0.00**

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION VII - Project Summary

We will use U.S. Aura satellite observations and selected measurements from the European ERS-2, Envisat, and MetOp satellites to (1) improve the suite of global air quality indicators and (2) perform studies using multiple products to address ongoing issues in atmospheric chemistry and air quality. We will:

Develop glyoxal (CHOCHO) as operational from OMI, addressing issues of why CHOCHO products from different groups, satellites, and algorithms vary substantially;

Continue BrO studies using nadir and limb measurements, chemistry/transport and radiative transfer modeling, and cloud analyses to address bromine enhancements in the UTLS due to atmospheric dynamics, enhanced boundary layer (PBL) bromine at high latitudes and its effects on O3 and on mercury deposition, and potential enhanced bromine in the free troposphere;

Develop multi-species/multi-instrument products, particularly HCHO/aerosol, as tools to investigate biomass burning (as a smoke index) and inclusion of NO2 to provide improved diagnostics of biomass burning conditions. MOPITT CO may be included to improve the extent of measurements. H2O from burning regions will be investigated as a potential probe of combustion conditions as well as convection. Aerosol and cloud effects on PBL gas retrieval will be quantified;

Develop the capability to use SCIAMACHY, GOME-1 and -2, and OMI together to measure secular trends in VOCs. This will be coupled to investigating the relationship of VOCs to humidity, and what the implications may be for organic aerosol formation;

Develop the use of OMI and GOME-2 SO2 measurements from the Smithsonian Astrophysical Observatory (SAO) optimal estimation algorithm to improve top-down constraints on SO2 emissions and PM2.5;

Develop H2O measurements as an OMI scientific product using the 440-450 nm vibrational 7nu polyad.

To perform this research, we will use tools that have been developed for satellite measurements by SAO and our collaborators. These include the SAO fitting algorithms BOREAS (used operationally on OMI for HCHO, BrO, and OClO) and optimal estimation determination of tropospheric ozone and SO2, now working on GOME-1 and -2, SCIAMACHY, and OMI. They also include the GEOS-Chem 3-D chemistry and transport model developed at Harvard; the LIDORT discrete ordinate multiple-scattering radiative transfer code; aerosol measurement capabilities developed for OMI and MODIS; and cloud-slicing capabilities developed for OMI tropospheric ozone.

Our research will improve measurements, and the long-term record, for trace gases and aerosol quantities that are central to understanding climate change and air quality. It addresses all of the science questions within the NASA Atmospheric Composition Focus Area: How is atmospheric composition changing? What trends in atmospheric composition and solar radiation are driving global climate? How does atmospheric composition respond to and affect global environmental change? What are the effects of global atmospheric composition and climate changes on regional air quality? How will future changes in atmospheric composition affect ozone, climate, and global air quality?

In terms of the solicitations goals, our research:

Develops new Level 2 data: CHOCHO.

Uses Aura data to track changes in stratospheric and tropospheric chemistry, determine the exchange of trace gases between the

stratosphere and troposphere, and estimate the transport properties of the stratosphere and upper troposphere: BrO studies and UTLS bromine chemistry; secular trends in VOCs.

Uses Aura data along with other satellite trace gas data sets to quantify and map emissions and quantify the impact of long-range transport and export of trace gases important to air quality: VOC/NOx/aerosol/humidity studies; SO2 and sulfate aerosols.

Uses Aura data to determine the effects of air pollutants such as ozone and aerosols on climate: Secular trends in VOCs.

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?
Yes

International Collaboration

Does this project involve activities outside the U.S. or partnership with International Collaborators?
No

Principal Investigator	Co-Investigator	Collaborator	Equipment	Facilities
No	**No**	**No**	**No**	**No**

Explanation :

NASA Civil Servant Project Personnel

Are NASA civil servant personnel participating as team members on this project (include funded and unfunded)?
No

Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year
Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION VIII - Other Project Information

Environmental Impact

Does this project have an actual or potential impact on the environment?	Has an exemption been authorized or an environmental assessment (EA) or an environmental impact statement (EIS) been performed?
No	**No**

Environmental Impact Explanation:

Exemption/EA/EIS Explanation:

PI Name : **Kelly Chance**	**NASA Proposal Number**
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION VIII - Other Project Information

Historical Site/Object Impact

Does this project have the potential to affect historic, archeological, or traditional cultural sites (such as Native American burial or ceremonial grounds) or historic objects (such as an historic aircraft or spacecraft)?

Explanation:

PI Name : **Kelly Chance**	**NASA Proposal Number**
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Analysis and Applications of Satellite Remote Sensing Measurements

Question 2 : Type of institution:

Answer: Non-profit Organization

Question 3 : Will any funding be provided to a federal government organization including NASA Centers, JPL, other Federal agencies, government laboratories, or Federally Funded Research and Development Centers (FFRDCs)?

Answer: No

Question 4 : Is this Federal government organization a different organization from the proposing (PI) organization?

Answer: N/A

Question 5 : Does this proposal include the use of NASA-provided high end computing?

Answer: No

Question 6 : Research Category:

Answer: 2) Data analysis/data restoration/data assimilation/Earth System modeling (including Guest Observer Activities)

Question 7 : Team Members Missing From Cover Page:

Answer:

Question 8 : This proposal contains information and/or data that are subject to U.S. export control laws and regulations including Export Administration Regulations (EAR) and International Traffic in Arms Regulations (ITAR).

Answer: No

Question 9 : I have identified the export-controlled material in this proposal.

Answer: N/A

Question 10 : I acknowledge that the inclusion of such material in this proposal may complicate the government's ability to evaluate the proposal.

Answer: N/A

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	181,903.00	187,163.00	188,663.00	557,729.00
B. Direct Labor - Other Personnel	10,443.00	10,968.00	11,501.00	32,912.00
Total Number Other Personnel	2	2	2	6
Total Direct Labor Costs (A+B)	192,346.00	198,131.00	200,164.00	590,641.00
C. Direct Costs - Equipment	10,000.00	0.00	0.00	10,000.00
D. Direct Costs - Travel	7,192.00	14,318.00	7,854.00	29,364.00
Domestic Travel	7,192.00	7,518.00	7,854.00	22,564.00
Foreign Travel	0.00	6,800.00	0.00	6,800.00
E. Direct Costs - Participant/Trainee Support Costs	0.00	0.00	0.00	0.00
Tuition/Fees/Health Insurance	0.00	0.00	0.00	0.00
Stipends	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Subsistence	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
Number of Participants/Trainees				0
F. Other Direct Costs	5,300.00	0.00	3,000.00	8,300.00
Materials and Supplies	5,300.00	0.00	0.00	5,300.00
Publication Costs	0.00	0.00	3,000.00	3,000.00
Consultant Services	0.00	0.00	0.00	0.00
ADP/Computer Services	0.00	0.00	0.00	0.00
Subawards/Consortium/Contractual Costs	0.00	0.00	0.00	0.00
Equipment or Facility Rental/User Fees	0.00	0.00	0.00	0.00
Alterations and Renovations	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
G. Total Direct Costs (A+B+C+D+E+F)	214,838.00	212,449.00	211,018.00	638,305.00
H. Indirect Costs	85,034.00	87,496.00	87,953.00	260,483.00
I. Total Direct and Indirect Costs (G+H)	299,872.00	299,945.00	298,971.00	898,788.00
J. Fee	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	299,872.00	299,945.00	298,971.00	898,788.00
Total Cumulative Budget				898,788.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2011	**01 / 31 / 2012**	**Project**	**1**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Chance, Kelly	PI_TYPE	0.00	3.3			48,031.00	13,256.00	61,287.00
Liu, Xiong	CO-I	0.00	3.3			31,830.00	8,785.00	40,615.00
Kurosu, Thomas	CO-I	0.00	3.3			38,990.00	10,761.00	49,751.00
Suleiman, Raid	Collaborator_TYPE	0.00	3.3			23,707.00	6,543.00	30,250.00
							Total Key Personnel Costs	181,903.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Secretarial / Clerical	.5			2,796.00	772.00	3,568.00
1	Division Administrator	.5			5,388.00	1,487.00	6,875.00
2	Total Number Other Personnel					Total Other Personnel Costs	10,443.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	192,346.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2011	**01 / 31 / 2012**	**Project**	**1**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
1	Computer Workstation	10,000.00
	Total Equipment Costs	10,000.00

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	7,192.00
2. Foreign Travel	0.00
Total Travel Costs	7,192.00

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		0.00
2. Stipends		0.00
3. Travel		0.00
4. Subsistence		0.00
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	0.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2011	**01 / 31 / 2012**	**Project**	**1**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	5,300.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	0.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	5,300.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	214,838.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
Direct Operating Overhead	27.70	192,346.00	53,280.00
Material Overhead	5.30	15,300.00	811.00
General and Administrative Overhead	12.20	253,629.00	30,943.00
Cognizant Federal Agency: **Office of Naval Research, Ms. Linda Shipp, 703-696-8559**	**Total Indirect Costs**		85,034.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	299,872.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	299,872.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2012	**01 / 31 / 2013**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Chance, Kelly	PI_TYPE	0.00	3.3			49,073.00	13,544.00	62,617.00
Suleiman, Raid	Collaborator_TYPE	0.00	3.3			23,250.00	6,417.00	29,667.00
Kurosu, Thomas	CO-I	0.00	3.3			40,796.00	11,260.00	52,056.00
Liu, Xiong	CO-I	0.00	3.3			33,560.00	9,263.00	42,823.00
							Total Key Personnel Costs	187,163.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Secretarial / Clerical	.5			2,932.00	810.00	3,742.00
1	Division Administrator	.5			5,663.00	1,563.00	7,226.00
2	Total Number Other Personnel					Total Other Personnel Costs	10,968.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	198,131.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2012	**01 / 31 / 2013**	**Project**	**2**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**7,518.00**
2. Foreign Travel	**6,800.00**
Total Travel Costs	**14,318.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**0.00**

PI Name : **Kelly Chance**	**NASA Proposal Number**
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2012	**01 / 31 / 2013**	**Project**	**2**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	0.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	0.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	212,449.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
Direct Operating Overhead	27.70	198,131.00	54,882.00
General and Administrative Overhead	12.20	267,331.00	32,614.00
Material Overhead	5.30	0.00	0.00
Cognizant Federal Agency: **Office of Naval Research, Ms. Linda Shipp, 703-696-8559**	**Total Indirect Costs**		87,496.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	299,945.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	299,945.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Kurosu, Thomas	CO-I	0.00	3.3			40,013.00	11,044.00	51,057.00
Chance, Kelly	PI_TYPE	0.00	3.3			50,138.00	13,838.00	63,976.00
Liu, Xiong	CO-I	0.00	3.3			33,947.00	9,369.00	43,316.00
Suleiman, Raid	Collaborator_TYPE	0.00	3.3			23,757.00	6,557.00	30,314.00
							Total Key Personnel Costs	188,663.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Secretarial / Clerical	.5			3,068.00	847.00	3,915.00
1	Division Administrator	.5			5,945.00	1,641.00	7,586.00
2	Total Number Other Personnel					Total Other Personnel Costs	11,501.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	200,164.00

PI Name : **Kelly Chance**	NASA Proposal Number
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**7,854.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**7,854.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**0.00**

PI Name : **Kelly Chance**	**NASA Proposal Number**
Organization Name : **Smithsonian Institution/Smithsonian Astrophysical Observatory**	**10-AURA10-0020**

Proposal Title : **Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	3,000.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	0.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	3,000.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	211,018.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
General and Administrative Overhead	12.20	266,463.00	32,508.00
Material Overhead	5.30	0.00	0.00
Direct Operating Overhead	27.70	200,164.00	55,445.00
Cognizant Federal Agency: **Office of Naval Research, Ms. Linda Shipp, 703-696-8559**	**Total Indirect Costs**		87,953.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	298,971.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	298,971.00

Table of Contents

Analysis and Applications of Satellite Remote Sensing Measurements by the Smithsonian Astrophysical Observatory

Summary

We will use U.S. Aura satellite observations, as well as selected measurements from the European ERS-2, Envisat, and MetOp satellites to (1) improve the suite of available global air quality indicators and (2) perform scientific studies using multiple products to address ongoing issues in atmospheric chemistry and air quality. We will:

- Develop glyoxal (CHOCHO) as an operational data product from OMI, addressing issues of why CHOCHO products from different groups, satellites, and algorithms vary substantially;
- Continue BrO studies that use nadir and limb measurements, chemistry/transport and radiative transfer modeling, and cloud analyses to address bromine enhancements in the UTLS due to atmospheric dynamics, enhanced boundary layer (PBL) bromine at high latitudes and its effects on O_3 and on mercury deposition, and potential enhanced bromine in the free troposphere;
- Develop multi-species/multi-instrument products, particularly HCHO/aerosol as a tool to investigate biomass burning (as a smoke index) and inclusion of NO_2 to provide improved diagnostics of biomass burning conditions. MOPITT CO may be included to improve the extent of measurements. H_2O from burning regions, measured by OMI in the 440-450 nm region, will be investigated as a potential probe of combustion conditions as well as convection. Aerosol and cloud effects on PBL gas retrieval will be quantified;
- Develop the capability to use SCIAMACHY, GOME-1 and -2, and OMI together to measure secular trends in VOCs. This will be coupled to investigating the relationship of VOCs to humidity, and what the implications may be for organic aerosol formation;
- Develop the use of OMI and GOME-2 SO_2 measurements from the Smithsonian Astrophysical Observatory (SAO) optimal estimation algorithm to improve top-down constraints on SO_2 emissions and $PM_{2.5}$;
- Develop H_2O measurements as an OMI scientific product using the 440-450 nm vibrational 7v polyad.

In order to perform this research, we will use tools that have been developed over the years for satellite measurements by SAO and our collaborators. These include the SAO fitting algorithms BOREAS (Boas Retrieval for Atmospheric Spectra - used operationally on OMI for HCHO, BrO, and OClO) and optimal estimation determination of tropospheric ozone and SO_2, now working on GOME-1 and -2, SCIAMACHY, and OMI. They also include the GEOS-Chem 3-D chemistry and transport model (CTM) developed at Harvard; the LIDORT discrete ordinate multiple-scattering radiative transfer code (RTM); aerosol measurement capabilities developed for OMI and MODIS; and cloud-slicing capabilities developed for OMI tropospheric ozone.

Our research will improve measurements, and the long-term record, for trace gases and aerosol quantities that are central to understanding climate change and air quality. It addresses all of the science questions within the NASA Atmospheric Composition Focus Area: How is atmospheric composition changing? What trends in atmospheric composition and solar radiation are driving global climate? How does atmospheric composition respond to and affect global environmental change? What are the effects of global atmospheric composition and climate changes on regional air quality? How will future changes in atmospheric composition affect ozone, climate, and global air quality?

In terms of the solicitation goals, our research:

- *Develops new Level 2 data*: CHOCHO (operational), H_2O (science product).
- *Uses Aura data to track changes in stratospheric and tropospheric chemistry, determine the exchange of trace gases between the stratosphere and troposphere, and estimate the transport properties of the stratosphere and upper troposphere*: BrO studies and UTLS bromine chemistry; secular trends in VOCs.
- *Uses Aura data along with other satellite trace gas data sets to quantify and map emissions and quantify the impact of long-range transport and export of trace gases important to air quality:* VOC/NO_x/aerosol/humidity/O_3 studies; SO_2 and sulfate aerosols.
- *Uses Aura data to determine the effects of air pollutants such as ozone and aerosols on climate*: Secular trends in VOCs.

All products and publications will be available at http://www.cfa.harvard.edu/atmosphere/.

1 Introduction

We propose to continue the Smithsonian Astrophysical Observatory (SAO) involvement in the Ozone Monitoring Instrument (OMI) and other U.S. and European satellite instruments as a member of the Aura Science Team. In a three-year program of research, we will:

- Develop CHOCHO as an OMI operational data product
- Perform BrO studies for the UTLS, free troposphere, and planetary boundary layer
- Perform multi-species studies of biomass burning and air quality
- Improve knowledge of secular trends in volatile organic compounds
- Investigate SO_2 distribution and sulfate aerosol formation
- Make required updates to SAO OMI operational data products
- Develop H_2O as an OMI scientific data product

This research will continue and further our ongoing participation as a member of the U.S. OMI Science Team. We have had responsibility for operational HCHO, BrO, and OClO data products. We have also made the first measurements of CHOCHO from space [Kurosu *et al*., 2005], applied optimal estimation to retrieve OMI O_3 profiles/tropospheric O_3 (the subject of a separate proposal by Dr. Xiong Liu) and SO_2, and have determined that OMI can make quantitative measurements of H_2O that complement, in particular, biomass burning studies. The current state of development at SAO is summarized in **Section 4. Scientific background and qualifications**.

2 Proposed research

2.1 Development of CHOCHO as an OMI operational data product

CHOCHO has now been measured successfully by SAO from both OMI and GOME-2 satellite spectra, using the SAO BOREAS algorithm. **Figure 1** shows comparative examples from the two instruments for similar locations and season (variation with solar time is discussed below). The GOME-2 vertical columns are preliminary, using geometric AMFs, since the CTM and RTM studies for GOME-2 are not completed.

Operational development of CHOCHO will include development of a climatological data base of air mass factors (AMFs, where the AMF is the ratio of the measured slant column over the vertical column), and a lookup scheme for interpolation to the time and place of measurements. AMFs are calculated using the GEOS-Chem 3-D chemistry and transport model [Bey *et al*., 2001] together with the VLIDORT discrete ordinate multiple-scattering radiative transfer model [*cf*. Spurr, 2006] using the technique for optically-thin absorbers described in Palmer *et al*., [2001] and Martin *et al*., [2002]. This approach has already been implemented by SAO for operational HCHO from OMI, so the extension to CHOCHO is straightforward; AMFs are less subject to profile shape sensitivity since the CHOCHO measurements are at a longer wavelength range than HCHO.

The final fitting window (currently 433-460 nm) will be re-optimized and the selection of reference spectra will be revisited (especially since reference spectra for the oxygen collision complex, O_2-O_2, are currently evolving). The fitting re-optimization will properly take into account interferences from absorption by NO_2, O_3, H_2O, O_2-O_2, and liquid water.

The OMI Trace Gas Algorithm Theoretical Basis Document [OMI, 2001] will be updated to include CHOCHO, and be submitted to NASA for appropriate review.

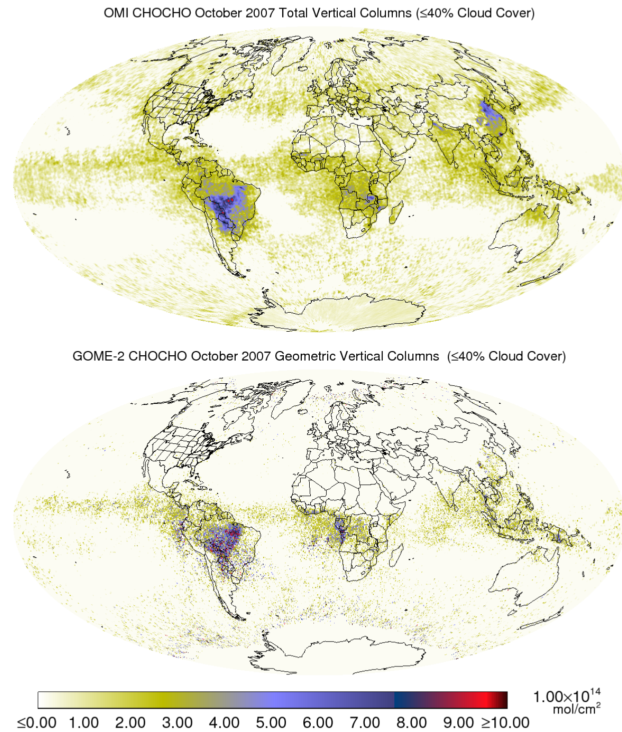

Figure 1. Glyoxal measurements from OMI and GOME-2 for October 2007. Differences are partly due to variation with solar time of measurements (see text), and partly due to the status of algorithm development.

Issues contributing to differences in CHOCHO measurements among algorithms, instruments (OMI, SCIAMACHY, and GOME-2), and research groups will be addressed. We will analyze satellite spectra for CHOCHO as consistently as possible in order to determine, as examples: which differences are due to satellite overpass time; effects of ground pixel size on retrieved CHOCHO; differing choices of reference spectra and fitting windows; alternate choices of fitting functions (*e.g.*, fitting radiances versus fitting high-pass-filtered logarithms of radiances). Comparisons will start with slant column measurements, and will include collaborative comparisons with European colleagues performing fits and with available ground-based measurements. AMF differences will also be addressed, beginning with intercomparisons for measurements by different groups of selected scenarios.

Variation of CHOCHO with satellite overpass time presents difficulty in instrument comparisons but also the opportunity to determine the daily variation in favorable cases. Measurements from sun-synchronous satellites vary with satellite crossing time and with across-track swath position. Measurements near nadir are made at close to the crossing time for low- and mid-latitudes. For CHOCHO, this now includes OMI (1338 crossing time), SCIAMACHY (1000) and GOME-2 (0930). Volkamer *et al*. [2005] have shown that CHOCHO over Mexico City varies from essentially zero at night to a maximum near solar noon, as expected from photochemical modeling. Local concentrations at OMI measurement time readily approach a factor of two increase over those at GOME-2 and SCIAMACHY measurement times.

2.2 BrO studies for the UTLS, free troposphere, and planetary boundary layer

Due to complex roles of bromine chemistry in stratospheric and tropospheric ozone destruction and also in mercury deposition, aspects of BrO measurements and application will be pursued along several research avenues.

It has become increasingly clear [Salawitch *et al*., 2009, 2010] that elevated BrO previously thought to be confined to the PBL is sometimes due instead to stratospheric BrO, supplied to the stratosphere by very short lived biogenic halocarbons (5-10 pptv BrO from this source are required for closure of the BrO budget) and amplified at high northern latitudes by a dynamically-induced low-altitude tropopause, in synoptic weather patterns including the Hudson Bay low [Liu and Moore, 2004] that may be confused with likely PBL sources. Such enhancements may also include mixing of stratospheric air into the upper troposphere. During the spring 2008 phase of the NASA ARCTAS aircraft campaign, there were instances where significantly enhanced BrO as measured by OMI (and GOME-2) did not correspond to lower altitude enhancements measured by the aircraft. **Figure 2** shows an example of enhanced BrO from OMI obtained during ARCTAS showing the patterns of enhancement being addressed here. Two release versions are shown: "TLCF" (Team Leader Computation Facility) and "RC" (Release Candidate): See **Section 3.2** for discussion of current BrO data products. In the proposed research, BrO slant column measurements from OMI will be combined with CTM and dynamical studies by R. Salawitch (UMD) and AMFs calculated using VLIDORT with UMD weighting function matrices. These distinguish sharply between stratospheric and PBL contribution: PBL BrO AMFs are nominally between ×2 and ×4 smaller than stratospheric AMFs because of the difficulty caused by Rayleigh scattering in seeing to lower altitudes. Comparisons including BrO, tropospheric O_3, dynamical maps, and limb BrO will determine which combinations of measurements and modeled profiles correspond to scenarios with PBL enhancements and which correspond to subsidence from stratospheric dynamics increasing the total BrO vertical column. Limb measurements of BrO are from SCIAMACHY data obtained during ARCTAS spring phase (winter/spring 2008), being developed by Harvard and SAO with other funding. Tropospheric O_3, including ozone depletion events, are from *in situ* measurements during ARCTAS and by OMI tropospheric ozone methods, from current algorithms: The SAO optimal estimation method [Liu *et al*., 2010a] and cloud slicing [Ziemke *et al*., 2006]. The overall object is to determine which enhancements are attributable to stratospheric BrO and which are truly lower tropospheric.

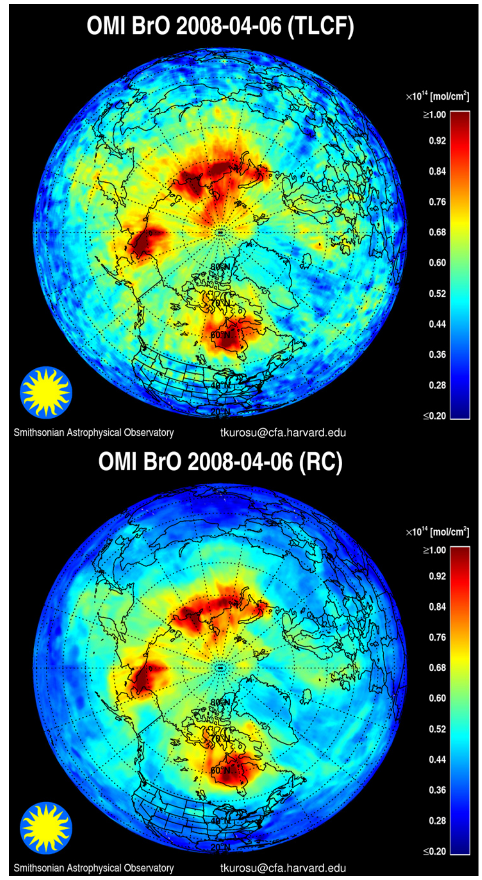

Figure 2 OMI BrO on 6/4/08: current operational ("TLCF", top) and release candidate ("RC", bottom) versions.

An additional, related, research object derives from studies combining GOME-1 BrO measurements with ground-based and balloon measurements made in 1998-1999 [van Roozendael *et al*., 2002]. These seem to show a robust enhancement in free tropospheric BrO of 0.5-1.5 pptv, larger than had been expected from photochemical modeling. They would, presumably, also be due to the very short lived biogenic halocarbon source addressed by Salawitch *et al*. [2009]. This contrasts with measurements from the SAO combined with cloud products from the GOME Initial Cloud Fitting Algorithm, where it was determined that BrO below cloud top height was ≤0.3 pptv for latitudes of ±50° [Chance *et al.*, 1998]. Using OMI BrO measurements, we will revisit the GOME-1 study using more sophisticated correlation techniques: We will collaborate with J. Ziemke, developer of "cloud slicing" for OMI tropospheric ozone, to make a more rigorous study of BrO-cloud correlations at low- and mid-latitudes, including radiative transfer calculations to account for retrieval sensitivity differences between clear and cloudy conditions, in order to determine altitude- and latitude-dependent residual BrO as accurately as possible. The cloud slicing technique, of which the convective cloud differential (CCD) method is a special case, has permitted substantial coverage in satellite-derived tropospheric ozone [Ziemke *et al.*, 1998, 2001, 2005]. It applies when there are persistent high tropopause-level clouds, such as the maritime tropical Pacific and within or near midlatitude continental landmasses. It has allowed the determination of both stratospheric column ozone and tropospheric column ozone at middle and high latitudes in both hemispheres over the Pacific; it is now used to estimate 400- to 1000-hPa lower tropospheric column O_3 and evaluate its spatial and temporal variability. Its application to Aura has been accomplished by subtracting measurements of MLS stratospheric column ozone from OMI total column ozone after adjusting for intercalibration differences of the two instruments using the convective-cloud differential method [Ziemke *et al.*, 2006].

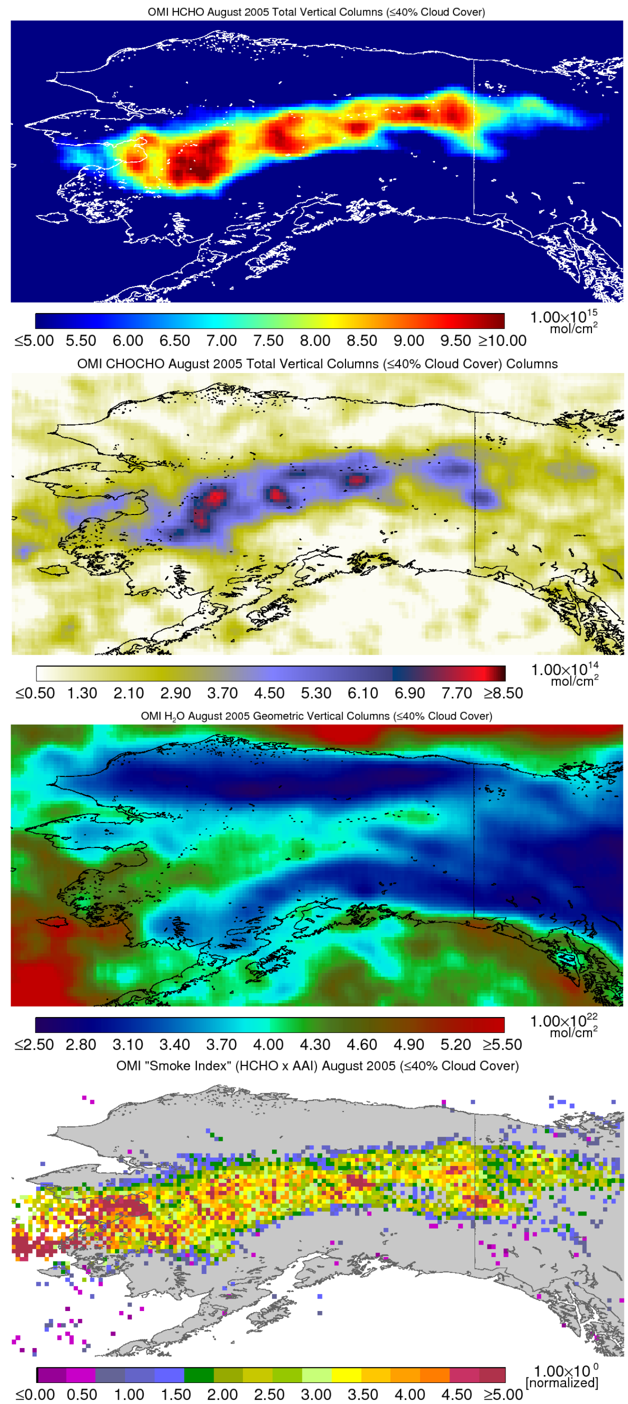

Figure 3. OMI observations of an Alaskan forest fire in August 2005. From top to bottom: HCHO total columns, CHOCHO total columns, H_2O geometric columns, and a Smoke Index (the product of AAI and HCHO, arbitrarily normalized). All values shown are monthly averages for 08/2005.

2.3 Multi-species studies of biomass burning and air quality

Substantial enhancements in H_2O, HCHO, CO, SO_2, O_3, and a wide range of other trace constituents have been measured by aircraft in biomass burning plumes from African savanna and Yucatan forest and crop fires [Yokelson *et al.*, 2003, 2009], and OSIRIS satellite measurements of the smoke plume over Australian wildfires in 2009 (S. Petelina, private communication, 2010). The plume chemistry is generally complex, with post-emission chemistry determining much of the atmospheric impact of smoke from fires: Emission ratios of HCHO relative to CO, for example, have been observed to increase by 50% or more in 1 hour-old plumes downwind of the source [Yokelson *et al*., 2003]. Laboratory studies of the photochemistry in smoke plumes [Grieshop *et al*., 2009a, b] find that photochemical oxidation in aged plumes produces a substantial amount of organic aerosol (OA), more than doubling the OA mass after a few hours of aging under typical summertime conditions [Grieshop *et al*., 2009b], yet less than 20% of OA production are explained by state-of-the-art organic secondary organic aerosol (SOA) models and the measured decay of traditional SOA precursors [Grieshop *et al*., 2009a]. Studies of the impact of seed effects from aqueous-phase organic aerosol photochemistry on SOA formation found evidence for the importance of CHOCHO and H_2O in SOA formation: SOA yields increased linearly with liquid water content and were not limited to clouds (and cloud droplets), pointing to the importance of water-soluble organic carbon photochemistry in SOA formation [Volkamer *et al.*, 2009].

OA is a significant source of absorption predominantly in the near-UV ("brown carbon" absorption), In addition to black carbon. Barnard *et al*. [2008] have shown that the organic aerosol component of the Mass Absorption Cross section over Mexico City falls off rapidly at UV wavelengths, predominantly from absorption by brown carbon aerosols. CHOCHO in fire plumes (**Figure 3**) suggests the substantial presence of brown carbon absorption. We will investigate whether any link between CHOCHO and AAI can be determined.

With the extending range of products observed by OMI, we can study biomass burning events and urban air quality related photochemistry on a global scale in more detail than ever before. OMI routinely observes HCHO, NO_2, total column SO_2, and Absorbing Aerosol Index (AAI), all standard data products that are publicly available (HCHO is produced by the SAO BOREAS algorithm). In this study, we will extend the range of observations to CHOCHO (to be made a standard data product, see **Section 2.1**), tropospheric O_3 (proposed as an operational product separately by Dr. Xiong Liu), and H_2O (to be produced at SAO from the vibrational 7*v* polyad as a science data product, see **Section 2.6**, with data made available through the SAO atmospheric website www.cfa.harvard.edu/atmosphere. (Another reason to measure H_2O in the plume is that it affects the OH and O_3 and some of the other gas-phase chemistry branching ratios, and also provides a readily detectable signature of stratosphere-troposphere exchange.) Improvements to SO_2 observations are also planned as part of this work (**Section 2.5**). Collaborators will have important roles in various aspects of the proposed work: Randall Martin is involved in the improvement of NO_2 air mass factors for the standard product; Omar Torres is the developer of the AAI standard product; and Rainer Volkamer will provide support with his expertise on CHOCHO ground-based measurements and organic photochemistry.

As an example of the potential of OMI air quality and biomass burning studies, and as a demonstration of the feasibility of the proposed work, we show in **Figure 3** four key elements of observed and derived quantities for the case of an Alaskan forest fire in August 2005. From top to bottom, the four panels in **Figure 3** show (a) HCHO total columns from the standard data product, with an empirical background correction applied; (b) CHOCHO total columns from the science product glyoxal retrieval algorithm; (c) H_2O geometrical total columns from a first version of the water vapor retrieval algorithm; and finally (d) a "Smoke Index", derived from the product of HCHO total columns and AAI, normalized to a (so far) arbitrary value. The images clearly demonstrate the potential and feasibility of multi-species studies of biomass burning, combining observations of VOCs, water vapor, and aerosol information. Air quality studies in megacities will pose a greater challenge than biomass burning events, due to the generally smaller column amounts observed in all quantities. Nevertheless, the combination particularly of

VOCs and water vapor (as an indicator of relative humidity) is expected to yield new insights into air-quality related photochemistry and SOA formation in urban environments.

The Smoke Index is an as yet experimental indicator that will be developed into a more sophisticated tool to identify biomass burning events (see also proposal by D. Jacob). It will be improved in several respects, including optimizing the definition beyond a simple VOC-aerosol product, and screening for biogenic VOC production. In addition to the Smoke Index from OMI HCHO and aerosol, we will continue to investigate whether an index derived from addition of the longer-lived carbon monoxide (CO) provides additional information on plume characteristics, improving the extent of measurements (this area has been initiated by collaborator O. Torres).

OMI NO_2 observations are also closely linked to nitrate formation. Lin *et al*. [2010] use trends in MODIS and OMI NO_2 and aerosol columns to argue that despite reductions in SO_2 emissions, fine aerosol formation over China is increasing due to increases in other sources of fine aerosol. Coupling of OMI NO_2 measurements with aerosols and improved SO_2 will thus also potentially provide air quality diagnostics for anthropogenic pollution.

2.4 Secular trends in volatile organic compounds

It is a goal of the Committee on Earth Observation Satellites Atmospheric Chemistry Constellation (www.ceos.org) to have measurements from different satellites analyzed in a consistent fashion, in order to improve the long-term data record. Work to date on this goal has concentrated on NO_2 from the GOME-2 and OMI instruments. SAO and Dalhousie University have contributed to this effort in algorithm support (SAO BOREAS is used at NOAA/NESDIS to analyze GOME-2 NO_2 in near-real-time) and in development to include SCIAMACHY data products. We propose here to extend this goal to improve the long-term data record for measurements of HCHO and CHOCHO.

SAO developed the measurement of VOCs in the UV/visible from space with HCHO measurements from GOME-1 [Chance *et al*., 2000], and made the first CHOCHO measurements from space [Kurosu *et al*., 2005]. Determining a long-term data record from multiple satellite platforms is complicated by instrumental differences, differences in ground measurement footprints, and local solar time of measurements. Comparisons among measurements are further complicated by differences in whether particular source activity is measured at equivalent times.

GOME-1 data are available from June 1995 [Chance *et al*., 2000]. There are now a number of studies using GOME, SCIAMACHY and OMI HCHO [Palmer *et al*., 2001, 2003, 2006; Abbot *et al*., 2003; Shim *et al*., 2005; Fu *et al*., 2007; Millet *et al*., 2008; De Smedt et al., 2008] and, with continuation of the GOME-2 series and the addition of OMPS (for HCHO), the record will potentially extend for decades.

SAO work to improve the time series will begin with slant column determinations using BOREAS to compare OMI, SCIAMACHY, GOME-1 and -2 HCHO and CHOCHO for selected latitude ranges and seasons, for source regions that are expected to be reasonably extended (to avoid FOV dilution effects). Slant columns will be adjusted to constant solar time and measurement geometry using GEOS-Chem and VLIDORT. Remaining differences will be assessed in terms of instrument characteristics over selected fitting window choices. The major anticipated difficulties are for HCHO: There are known issues in the UV region where HCHO (and BrO) is fitted with both SCIAMACHY and GOME-2. They have been overcome in some studies using other than optimum fitting windows and re-scaling of results. We hope to be able to develop algorithmic approaches, perhaps through soft corrections as used in GOME-1 O_3 [Liu *et al*., 2005], that permit constant fitting windows for all instruments that are closer to optimum.

When slant column measurements have been rationalized, we will then apply a consistent database of AMFs, calculated as described in **Section 2.1** [Palmer *et al*., 2001].

2.5 SO_2 measurements and aerosol formation

We will use the SAO optimal estimation algorithm to improve SO_2 measurements from OMI and GOME-2, including providing information on volcanic plume height. The measurements will be used to improve top-down constraints on global anthropogenic SO_2 emissions, which are directly related to enhanced $PM_{2.5}$ [Lee *et al*., 2010].

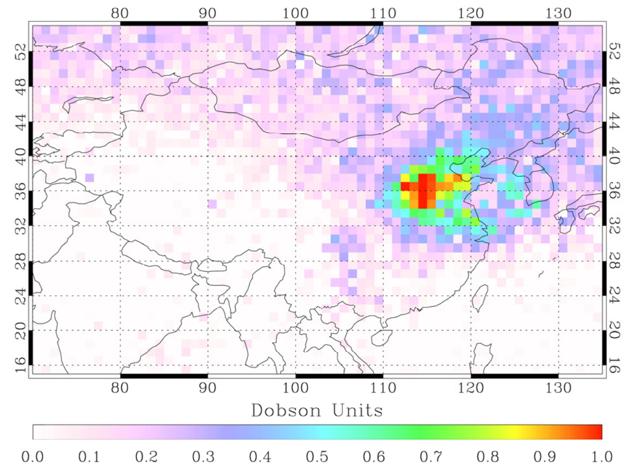

Figure 4. Monthly average of GOME-2 SO_2 for June 2008 over China, derived from the SAO optimal estimation algorithm.

The SAO algorithm [Liu *et al*., 2005; Liu *et al*., 2006a; Liu *et al*., 2010a] currently provides measurements of tropospheric ozone and ozone profiles from the GOME-1, GOME-2, SCIAMACHY, and OMI instruments, and has been extended and optimized for retrievals of SO_2 for GOME-1 [Liu *et al*., 2006b], and GOME-2 and OMI [Nowlan *et al*., 2009] from both anthropogenic and volcanic sources. **Figure 4** shows SO_2 over China in June 2008, derived from GOME-2 data using the optimal estimation algorithm. **Figure 5** shows SO_2 retrieved from the volcanic eruption of Mt. Kasatochi in 2008, where the SAO algorithm is capable of providing SO_2 plume height as well as column abundance from GOME-2 and OMI data [Nowlan *et al*., 2010].

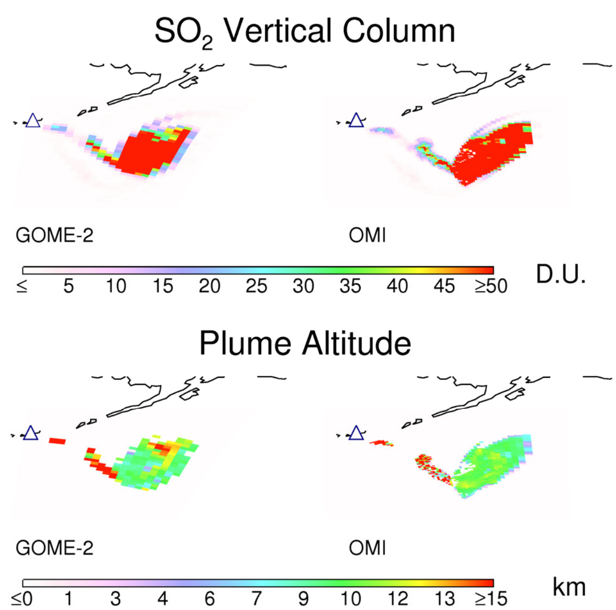

Figure 5. SO_2 vertical column densities and altitudes from GOME-2 and OMI optimal estimation retrieval over Mount Kasatochi, Alaska. The GOME-2 overpass time over the peak of the SO_2 cloud is 9 August 2008 21:06 UTC. The OMI overpass time is 10 August 2008 00:05 UTC. An a priori SO_2 value of 10 km with an uncertainty of 5 km is used in the retrieval.

SO_2 vertical column densities have traditionally been determined by first retrieving slant column densities with a spectral fitting algorithm, and then applying an independently-calculated AMF determined using assumed SO_2 and ozone profiles. In the wavelength region of SO_2 absorption (< 330 nm), the large dynamic range of ozone absorption means the AMF varies significantly with wavelength (varying for example by 10 – 30 % between 313 and 320 nm, depending on viewing geometry and ozone amount). The spectral absorption of SO_2 and ozone are also correlated, adding to uncertainties in SO_2 retrievals in spectra with high ozone signal. The dependence of the Ring effect on ozone causes additional uncertainties in SO_2 when the ozone column in the slant path is not accurately considered [Lee *et al*., 2008].

In order to address these issues, we have applied the SAO ozone profile algorithm to retrieve

SO_2 using an optimal estimation retrieval approach [Rodgers, 2000] in combination with a full radiative transfer calculation using VLIDORT [Spurr, 2006] and climatological profiles from GEOS-Chem. The algorithm implicitly includes the effects of clouds, surface albedo, ozone absorption and scattering in the retrieval, as well as their wavelength dependencies. The Ring spectrum is calculated using a first-order single scattering Rotational Raman model [Sioris and Evans, 2000] and scaling parameters are fitted, accounting for its dependence on ozone and temperature. The algorithm simultaneously retrieves vertical columns of SO_2, BrO, NO_2, HCHO, the ozone profile at 24 vertical levels, effective surface albedo, effective cloud fraction in the UV, as well as appropriate wavelength calibration shifts in ozone cross-sections and irradiance vs. radiance spectra. Additionally, optimal estimation provides a well-developed formal method for error analysis and retrieval characterization [Rodgers, 2000].

Both AMF calculations and the optimal estimation algorithm require the SO_2 profile shape as an input. While under typical anthropogenic cases the profile shape from GEOS-Chem is fairly reliable (generally to within 10% [Lee *et al*., 2009]), the profile for volcanic eruptions is often unknown. Knowledge of the altitude of volcanic SO_2 plumes is also highly desirable for inclusion in climate and chemistry studies. Recent studies [Yang *et al*., 2009; Yang *et al*., 2010] have demonstrated the potential of using UV measurements to determine SO_2 altitudes using the varying photon penetration depth across the UV.

This characteristic can be readily exploited by our optimal estimation algorithm which combines the retrieval with a forward model that considers the vertical properties of the atmosphere, and can retrieve the plume altitude when included as an additional parameter in the solution state vector. It may also be possible to use a similar approach to improve anthropogenic measurements of SO_2. At wavelengths greater than ~305 nm, the weighting functions of SO_2 plume altitude increase with decreasing altitude, so that the altitude retrievals are in fact more sensitive when the plume is near the ground. We are currently examining the feasibility of using altitude measurements of anthropogenic SO_2 to examine possible lofting of pollution in cases where the GEOS-Chem model is unable to spatially or temporally resolve the upwards transport of SO_2 [Nowlan *et al*., 2010].

Epidemiologic and health impact studies of air pollution are limited by the lack of monitoring data, especially in developing countries. As shown in **Figure 6**, van Donkelaar *et al*. [2010] mapped global ground-level fine aerosol ($PM_{2.5}$) concentrations using column aerosol optical depth (AOD) from the MODIS and MISR satellite instruments and coincident aerosol vertical profiles from the GEOS-Chem global chemical transport model. Their evaluation of the satellite-derived estimate with ground-based *in situ* measurements indicates significant spatial agreement with North American measurements ($r = 0.77$; slope = 1.07; $n = 1057$) and with non-coincident measurements elsewhere ($r = 0.83$; slope = 0.86; $n = 244$). The sources that contribute to these particles are of interest.

Lee *et al*. [2009] developed an improved retrieval of SO_2 from OMI and demonstrated OMI's sensitivity to anthropogenic emissions. Lee *et al*. [2010] developed a top-down constraint on anthropogenic SO_2 emissions through inverse modeling of OMI observations, and confirmed the strong SO_2 source in China that contributes to the

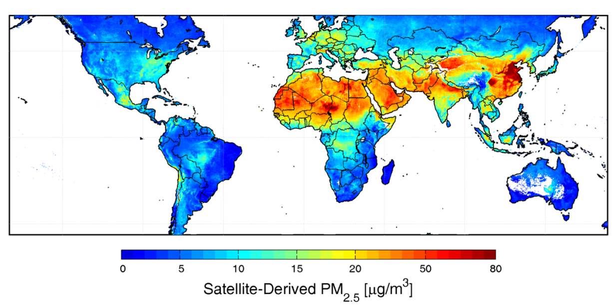

Figure 6. Global satellite-derived PM2.5 averaged over 2001–2006. White space indicates water or locations containing < 50 measurements.

observed $PM_{2.5}$ enhancements. We propose to apply OMI satellite observations to understand the sources contributing to the global$PM_{2.5}$ distribution.

2.6 H_2O scientific data products

Very recent experience, discussed in **Section 2.3** and shown by example in **Figure 3**, suggests that H_2O is an important additional data product associated with fires. H_2O products from UV/visible/NIR satellites including SCIAMACHY and the GOME instruments have been developed using longer wavelengths, *e.g*., from SRON, U. Bremen, U. Heidelberg, and KNMI. To our knowledge, H_2O products have not yet been developed from OMI spectra. However, the vibrational 7*v* polyad region, especially from 440-450 nm, is a very attractive candidate for H_2O measurements. The absorption is fairly weak (peak absorption optical depth about 0.05 for moderate humidity (10 g kg^{-1}) and typical satellite measurement geometry: the absorption is optically thin, so that interpretation as H_2O columns is simplified, yet the absorption is still substantially stronger than that of most trace gases measured by OMI. The fitting region is reasonably clean, and the wavelength window is long enough so that lower tropospheric measurements are not compromised. **Section 2.3** gave an example of H_2O in the plume from Alaskan wildfires. We will continue to develop the H_2O fitting for use in scientific studies.

3 Status of SAO OMI operational data products

As part of our activities as members of the OMI Science Team, SAO has developed and maintains three operational data products: BrO, HCHO, and OClO. Two of these, BrO and HCHO, are relevant to the science studies proposed here. Although the solicitation explicitly excludes proposals to maintain or update existing data products, we feel that it is important to include a short summary of the *status quo* and impending updates to our BrO and HCHO standard products, insofar as they are relevant to the proposed work.

3.1 General status and product non-specific updates

All three data products, derived from OMI Collection 3 data, are routinely processed and are available on the NASA DISC. Each data record is consistent*, i.e*., is available with the same version number (currently algorithm version 2.0) for the entire OMI data record. Practically the entire source code is shared between the different products, with logical flags handling product-specific branching inside the code: Changes to general aspects of the processing structure (*e.g.*, changes required by additions to the Level 1b spectral radiances from which the trace gas columns are derived) automatically apply to all products.

Sometime within the next year, a complete reprocessing of the OMI Level 1b record is planned. This will contain important updates, among other things, of radiance quality flags related to the Row Anomaly (a partial external blockage of the instrument field of view) that OMI has been suffering from increasingly since mid-2008. All Level 2 product algorithms must be updated to include these new flags in order to provide this information to the user of the product. We will implement updated quality flags in all SAO operational data processing algorithms, as well as any other modifications necessitated by the new Level 1b radiances, and will initiate a complete reprocessing of all SAO products.

3.2 Updates to BrO

During science evaluation of data BrO observation acquired during the NASA ARCTAS campaign [Jacob *et al*., 2010], it was found that the operational V2 BrO product was considerably noisy, and an improved off-line data product was developed. This off-line product has now matured to the point that it will become the next release for operational BrO processing.

Briefly, the BrO fitting window was changed from formerly 340.5–357.5 nm to 319.0–347.5 nm, O_4 interference was omitted (for improved fitting stability, *e.g.*, reduction in pixel-to-pixel variation), and the air mass factor (AMF) formulation was changes to include albedo- and wavelength-dependence. **Figure 2** compares the two versions in an example from the ARCTAS spring deployment. The improved "RC" product not only has much reduced noise in pixel-to-pixel variation, but also significantly improved fitting uncertainties, as shown in **Figure 7**. The release candidate version has already been used for high-impact science studies [Salawitch *et al*., 2010]. At the time of this writing, extensive tests of the new BrO release candidate are being conducted, and the update of the operational algorithm is expected to have occurred by the time the study proposed here commences.

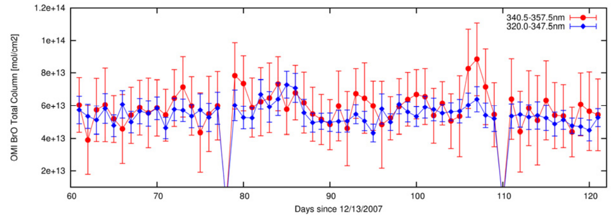

Figure 7. Daily OMI BrO for March and April 2008 over Harestua, Norway, from the currently operational (red) and the release candidate (blue) version.

3.3 Updates to HCHO

The currently operational V2 HCHO data product produces generally high-quality columns that are being used in a range of predominantly air-quality related studies [Millet *et al*., 2008; Duncan *et al*., 2010] as well as a variety of studies on VOC/NO_x ratios currently in preparation. Recent analyses and quality checks of the OMI HCHO record discovered two issues that need to be addressed for the science studies proposed here: (1) A steady increase in background HCHO over the remote Pacific was observed over the OMI life time, starting from 2×10^{15} mol/cm^2 in 09/2004 and reaching 8×10^{15} mol/cm^2 in 09/2009; this increase in background is most likely related to increased in instrument noise, dark current, and hot/dead detector pixels. (2) Erroneous HCHO blooms are observed over the Mediterranean every June; this is a problem in the current HCHO AMF look-up tables (HCHO slant columns are not affected), which were derived from monthly GEOS-Chem 2006 climatologies that contain a Saharan dust event over the Mediterranean in June. Issue (1) will be addressed with an empirical background correction of the HCHO columns, which needs to be validated against available ground-based data. Also, the exact origin of the increase will be investigated and, if found to be not instrumental but algorithmic, corrected. Issue (2) requires a re-calculation of the complete HCHO AMF look-up tables using a different year of GEOS-Chem climatologies – we have identified 2005 for this, and work on the new AMF calculations has already started as of the time of this writing.

In 2010, the HITRAN Advisory Board recommended that the standard reference spectra of HCHO ultraviolet cross sections [Cantrell *et al*., 1990] be amended by scaling the values to the measurement obtained by Meller and Moortgat [2000], in order to improve consistency between ultraviolet and infrared intensities (L. Rothman, personal communication, 2010). The resulting scaling by a factor of 1.11 will lead to a reduction in satellite-derived HCHO, which will necessitate a reprocessing of the OMI data record. This change will be included in the general reprocessing of HCHO for the next collection of the OMI Level 1b data product.

4 Scientific background and qualifications

4.1 The investigators' roles in OMI, GOME, and SCIAMACHY

OMI SAO helped to develop the OMI program, participating in the OMI Scientific Requirements study [Levelt *et al*., 2000]. SAO is a member of the U.S. OMI Science Team, with responsibility for producing operational algorithms for HCHO, BrO, and OClO; we have tested our trace gas retrieval algorithm on both NO_2 and SO_2 providing measurements which are used as diagnostics to assist the development of operational products. We have produced the first measurements of CHOCHO from space, using OMI. The SAO ozone profile/tropospheric ozone algorithm has also been successfully implemented on OMI Level 1 data [Liu *et al*., 2010a,b].

GOME and SCIAMACHY Demonstrated gas measurements from GOME-1 now include O_3, NO_2, BrO, OClO, SO_2, HCHO, and H_2O. O_3 measurements include profiles and tropospheric ozone. Cloud and aerosol measurements are also made. Operational products from GOME include total columns of ozone and NO_2. All other products are produced by the contributing scientific institutions, including the SAO.

The SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY), launched on March 1, 2002, adds limb and solar occultation measurements to the GOME capability, and extends the wavelength coverage to 2.4 µm [Goede *et al*., 1990; Burrows and Chance, 1991]. In addition to gases measured by GOME, SCIAMACHY measurements include CO, N_2O, and CH_4 [Chance *et al*., 1991].

SAO was an original proposer of SCIAMACHY, and has also been involved with the Global Ozone Monitoring Experiment (GOME) since its inception. Our role includes membership in both Scientific Advisory Groups and chairing the data and algorithm subgroups for these committees (the GOME GDAG and the SCIAMACHY SADDU). We have provided much of the algorithm development and prototyping for both instruments, under contract to the German Aerospace Center (DLR).

The research of SAO and our collaborators includes trace gas fitting, aerosol and cloud studies, and radiative transfer modeling. These are based on our substantial background work in spectrum fitting, instrument calibration and characterization, reference spectrum improvement, Ring effect determination, and operational algorithm prototyping.

The SAO initially proposed that ozone profiles, including tropospheric ozone, could be derived from nadir spectroscopic measurements by the GOME and SCIAMACHY instruments [Chance *et al*., 1991; Chance *et al*., 1997]: Observations with sufficiently high spectral resolution and high signal to noise ratio in the Hartley and Huggins bands of ozone make it possible to retrieve the vertical distribution of ozone in the troposphere as well as in the stratosphere. Our algorithm, which combines LIDORT determinations of ozone profile weighting functions [Spurr *et al*., 2006] with an optimal estimation retrieval [Rodgers, 2000] is now fully functional for GOME and OMI, and has been tested successfully on SCIAMACHY and GOME-2 spectra. This method has now been extended to SO_2 measurements from GOME-2 and OMI.

4.2 Algorithm physics

SAO research to support satellite retrievals includes wavelength calibration using cross-correlation with a high-resolution Fraunhofer spectrum, now used routinely for GOME and SCIAMACHY, and implemented for OMI and OMPS [Caspar and Chance, 1997] and spatial and spectral aliasing studies, including correction for most of the effects of spectral undersampling by GOME and SCIAMACHY [Chance, 1998; Slijkhuis *et al*., 1999; Chance *et al*., 2005]. Our undersampling correction method is used operationally on GOME, SCIAMACHY, and OMI. We produced improved molecular parameters and atmospheric corrections, including interferences from absorbing gases, including O_3 and NO_2 [Chance and Spurr, 1997]. SAO Ring effect correction is used operationally on GOME, SCIAMACHY, and OMI. Recently, we have updated the standard solar irradiance spectrum for use in UV, visible, and near infrared atmospheric measurements for most algorithm physics purposes [Chance and Kurucz, 2010].

4.3 Technical approach and methodology

4.3.1 BOREAS

The SAO BOREAS radiance fitting code was initially developed for OMI operational analysis of the trace gases HCHO, BrO, and OClO. It has now successfully been applied to measurements from OMI, SCIAMACHY, and the GOME instruments, and to the molecules CHOCHO, NO_2, and SO_2, as well.

In each case, the BOREAS fitting of slant columns is coupled with AMF determination using the GEOS-Chem 3-D chemical transport model (www.geos-chem.org) together with vector LIDORT [Spurr, 2006] multiple-scattering calculation of scattering weights [Palmer *et al*., 2001; Martin *et al*., 2002], either for the exact time and place of each satellite measurement (GOME-1, GOME-2, and SCIAMACHY), or in a seasonal climatology of AMF values (OMI). Martin *et al.* [2002] developed the AMF algorithm for NO_2 to account for clouds, surface reflectivity, and the relative vertical distribution. We maintain AMF code that can interface with existing instruments (GOME-1, GOME-2, SCIAMACHY, and OMI) for the full range of trace gases.

4.3.2 Optimal estimation

The SAO optimal estimation algorithm [Liu *et al*., 2005; Liu *et al*., 2006a,b; Liu *et al*., 2010a] currently provides O_3 data from the GOME-1 and -2 and OMI instruments. Optimization for SO_2 is currently underway and will be complete in time to apply it to studies proposed here (see **Section 2.5**).

4.3.3 Reference data

We have further critically evaluated the literature and performed calculations to determine the best current reference cross sections to use for analysis of trace gases and interfering species. These include O_3, HCHO, O_2-O_2, (currently evolving) NO_2, BrO, SO_2, OClO, H_2O, and H_2O liquid and liquid Raman. We have re-sampled the available high-resolution solar spectra and produced a further improved solar irradiance reference spectrum for use in OMPS wavelength calibration, Ring effect correction, and undersampling correction. The spectrum [Chance and Kurucz, 2010] is available at http://www.cfa.harvard.edu/atmosphere/. The H_2O Raman (Ring) spectrum has been recalculated using the new sao2010.solref solar reference spectrum.

5 Perceived impact

NASA Science Outcome 3A.1 is Progress in understanding and improving predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition. Our research will improve measurements, and the long-term record, for trace gas and aerosol products that are central to air quality. The proposed research contributes to all of the science questions within the NASA Atmospheric Composition Focus Area. In terms of the solicitation goals, our research: (1) Develops new Level 2 data; (2) Uses Aura data to track changes in stratospheric and tropospheric chemistry, determine the exchange of trace gases between the stratosphere and troposphere, and estimate the transport properties of the stratosphere and upper troposphere; (3) Uses Aura data along with other satellite trace gas data sets to quantify and map emissions and quantify the impact of long-range transport and export of trace gases important to air quality; and (4) Uses Aura data to determine the effects of air pollutants such as ozone and aerosols on climate.

6 Management

Programs of this size are managed within the Atomic and Molecular Physics Division at the SAO. Collaborations with Hampton University, the University of Maryland, Harvard University, and the University of Colorado are handled through the Principal Investigator, Dr. Kelly Chance.

The Principal Investigator is solely responsible for the quality and direction of the proposed research and the proper use of all awarded funds. He is responsible for all technical, management and budget issues. The Co-Is take direction from the PI, and will provide all the data needed to ensure that the PI can effectively manage the entire task.

In addition to managing the proposal, Dr. Chance will be responsible for the overall technical direction of the research, including algorithm design and implementation, data product development, scientific and long-term data studies, and data archiving and distribution.

6.1 Other key personnel

Dr. Thomas P. Kurosu, Co-Investigator, will implement and maintain new and existing operational and scientific data products and participate in scientific and long-term data studies.
Dr. Xiong Liu, Co-Investigator, will lead the production of SO_2 data products using the SAO optimal estimation algorithm and participate in scientific and long-term data studies.
Mr. Raid Suleiman will lead the data archiving and distribution and participate in scientific and long-term data studies.
Dr. Caroline Nowlan will collaborate on the production of SO_2 data products from the OMI and GOME-2 instruments.
Prof. Daniel Jacob will collaborate on the interpretation of VOC measurements.
Prof. Randall Martin will collaborate on the production and interpretation of SO_2 products and on the calculation of air mass factors in general.
Prof. Ross Salawitch will collaborate on BrO measurements, their interpretation, and their use in further process studies.
Prof. Omar Torres will collaborate on production of multi-species/multi-instrument data products, particularly with respect to aerosols and smoke indices.
Dr. Jerald Ziemke will collaborate on BrO/cloud correlations to investigate the abundance of BrO in the free troposphere.
Prof. Rainer Volkamer will collaborate on the interpretation of VOC measurements and their relationships to ground-based pollution measurements at selected surface sites.

6.2 Schedule and expected results

Year 1

1. Tune CHOCHO fitting algorithm; produce climatology of AMFs for determining vertical columns.
2. Initiate BrO studies comparing nadir measurements with dynamical simulations and in situ measurements.
3. Develop multi-species/multi-instrument products, staring with HCHO/aerosol as a smoke index. Initiate comparisons with NO_2 and H_2O for selected burning scenarios. RTM simulations of aerosol and cloud effects on PBL gas retrieval.
4. Improve slant column fitting of HCHO and CHOCHO for GOME-2, to initiate secular trend studies.
5. Develop OMI and GOME-2 SO_2 measurements by optimal estimation.
6. Optimize fitting of the H_2O 7ν polyad with BOREAS.

7. Participate in Aura Science Team activities.

Year 2

1. Produce OMI CHOCHO vertical columns; compare with available in situ measurements.
2. Continue BrO studies comparing nadir measurements with dynamical simulations and in situ measurements; include limb measurements of the UTLS from SCIAMACHY.
3. Continue multi-species/multi-instrument products, including H_2O, and science studies. Implement corrections for aerosol and cloud effects on PBL gas retrieval.
4. Critical comparisons of OMI, GOME-1 and -2, and SCIAMACHY VOC slant column measurements, including RTM and photochemical corrections for measurement geometry and time. Develop consistent cross-platform climatology of AMFs.
5. Use of OMI and GOME-2 SO_2 in process studies to improve top-down constraints on SO_2 emissions and $PM_{2.5}$.
6. Publication of H_2O measurement method and results.
7. Participate in Aura Science Team activities.

Year 3

1. Submit CHOCHO ATBD for NASA review; Publications on retrieval method and scientific studies.
2. Publication of BrO results; dissemination of BrO data products with resolved tropospheric and stratospheric concentrations.
3. Continue multi-species/multi-instrument products and science studies. Publication of fire studies.
4. Publication of time series of VOC measurements from satellites.
5. Continued use of OMI and GOME-2 SO_2 in process studies to improve top-down constraints on SO_2 emissions and $PM_{2.5}$.
6. Participate in Aura Science Team activities.

7 The Smithsonian Astrophysical Observatory

The Smithsonian Astrophysical Observatory was founded in 1890 by Samuel Pierpont Langley, the Smithsonian Institution’s third Secretary. Langley is remembered today as an aeronautical pioneer, but he was trained as an astronomer and was the first American scientist to perceive “astrophysics"” as a distinct field. Langley invented the bolometer and discovered infrared radiation from the Sun. He foreshadowed modern concerns about climate change by searching for links between solar and terrestrial phenomena:

“The distinct object of astrophysics is, in the case of the Sun, for example, not to mark its exact place in the sky, but to find out how it affects the Earth and the wants of man on it; how its heat is distributed, and how it in fact affects not only the seasons and the farmer's crops, but the whole system of living things on the Earth, for it has lately been proven that in a physical sense it, and almost it alone, literally first creates and then modifies them in almost every possible way.”

Secretary Samuel P. Langley
Report of the Secretary of the Smithsonian Institution, June, 1892

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Kelly Chance, Harvard-Smithsonian Center for Astrophysics
Associate Director for Atomic and Molecular Physics,
Senior Physicist, Smithsonian Astrophysical Observatory
Lecturer on Earth and Planetary Sciences, Harvard University

Education
Harvard University, Ph.D., Chemical Physics, 1978

Fields of Investigation
Measurements of the Earth's atmosphere; atmospheric composition and radiative transfer; chemical astrophysics; molecular spectroscopy, structure and dynamics.

Professional Activities
SCIAMACHY Scientific Advisory Group; Chaired Subgroup on Algorithm Development and Data Usage
European Space Agency/Eumetsat Global Ozone Monitoring Experiment Scientific Advisory Group; Chaired Data and Algorithm Subgroup
European Space Agency Category One Advisory Group on Data Usage
Associate Editor, *Journal of Quantitative Spectroscopy and Radiative Transfer*
Harvard University Permanent Representative to UCAR

Atmospheric Satellite Instrument Involvements
Global Ozone Monitoring Experiment (1995); GOME-2 (3 instruments, 1st in 2006)
Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (2002)
Ozone Monitoring Instrument (OMI, 2004 launch on Eos Aura)
Ozone Mapping and Profiler Suite (OMPS, 4 instruments, first launch 2011), proposing team

Relevant Experience Developed algorithm physics for UV/visible gas measurements from space, performed much of the algorithm development and implementation, and invented the method for tropospheric ozone retrieval from nadir UV measurements. Performed the sensitivity and algorithm analyses for SCIAMACHY.

Selected Publications (http://www.cfa.harvard.edu/atmosphere/publications.html)

2010 Ozone profile retrievals from the Ozone Monitoring Instrument, X. Liu, P.K. Bhartia, K. Chance, R.J.D. Spurr, and T.P. Kurosu, *Atmos. Chem. Phys*., **10**, 2521-2537.

2010 An improved high-resolution solar reference spectrum for Earth's atmosphere measurements in the ultraviolet, visible, and near infrared, K. Chance and R.L. Kurucz, *JQSRT*, **111**, 1289-1295.

2008 Net ecosystem fluxes of isoprene over tropical South America inferred from Global Ozone Monitoring Experiment (GOME) observations of HCHO columns, Barkley M.P., P.I. Palmer, U. Kuhn, *et al*., *J. Geophys. Res*., **113**, D20304, doi:10.1029/2008JD009863.

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2007 An ozone depletion event in the sub-arctic surface layer over Hudson Bay, Canada, B.A. Ridley, T. Zeng, Y. Wang, *et al*., *J. Atmos. Chem*., **57**, 255-280.

2007 First observations of iodine oxide from space, Saiz-Lopez, A., K.V. Chance, X. Liu, T.P. Kurosu, and S.P. Sander, *Geophys. Res. Lett*., **34**, L12812, doi:10.1029/2007GL030111.

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2006 SCIAMACHY Level 1 data: Calibration concept and in-flight calibration, G. Lichtenberg, Q. Kleipool, J. M. Krijger, *et al.*, *Atmos. Chem. Phys*., **6**, 5347-5367.

2006 Latitudinal and vertical distribution of bromine monoxide in the lower stratosphere from Scanning Imaging Absorption Spectrometer for Atmospheric Chartography limb scattering measurements, C.E. Sioris, L.J. Kovalenko, C.A. McLinden, *et al*., *J. Geophys. Res*., **111**, D14301, doi:10.1029/ 2005JD006479.

2005 Ultraviolet and visible spectroscopy and spaceborne remote sensing of the Earth's atmosphere, K. Chance, *Comp. Rend. Phys. Special issue on "Molecular Spectroscopy and Planetary Atmospheres,"* **6**, 836-847.

2005 Global partitioning of NO_x sources using satellite observations: Relative roles of fossil fuel combustion, biomass burning and soil emissions, L. Jaeglé, L. Steinberger, R.V. Martin, and K. Chance, *Faraday Discuss*., **130**, 407-423, DOI: 10.1039/b502128f.

2005 Undersampling correction for array-detector based satellite spectrometers, K. Chance, T.P. Kurosu, and C.E. Sioris, *Appl. Opt*., **44**, 1296-1304.

2004 Stratospheric and tropospheric NO_2 observed by SCIAMACHY: First results, C.E. Sioris, T.P. Kurosu, R.V. Martin and K. Chance, *Adv. Space Res. Special issue: Trace Constituents in the Troposphere and Lower Stratosphere*, **34/4**, 780-785.

2003 Seasonal and interannual variability of North American isoprene emissions as determined by formaldehyde column emissions from space, D.S. Abbot, P.I. Palmer, R.V. Martin, *et al.*, *Geophys. Res. Lett*. **30**, 1886, doi:10.1029/2003GL017336.

2003 An overview of the nadir sensor and algorithms for the NPOESS Ozone Mapping and Profiler Suite (OMPS), J.V. Rodriguez, C.J. Seftor, C.G. Wellemeyer, and K. Chance, *Proc. SPIE, Optical Remote Sensing of the Atmosphere and Clouds III*, **4891**, 65-75.

2003 Ultraviolet and visible absorption cross sections for HITRAN, J. Orphal and K. Chance, *JQSRT*, **82**, 491-504.

2003 OMI Algorithm Theoretical Basis Document, Volume IV, OMI Trace Gas Algorithms, K. Chance ed., ATBD-OMI-02, Version 2.0.

2002 An improved retrieval of tropospheric nitrogen dioxide from GOME, R.V. Martin, K. Chance, D.J. Jacob, *et al.*, *J. Geophys. Res.*, **107**, 4437, doi:10.1029/2001JD0010127.

2000 Satellite observations of formaldehyde over North America from GOME, K. Chance, P.I. Palmer, R.J.D. Spurr, *et al.*, *Geophys. Res. Lett.*, **27**, 3461-3464.

1998 Analysis of BrO measurements from the Global Ozone Monitoring Experiment, K. Chance, *Geophys. Res. Lett.*, **25**, 3335-3338.

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1997 Ring effect studies: Rayleigh scattering, including molecular parameters for rotational Raman scattering, and the Fraunhofer spectrum, K. Chance and R.J.D. Spurr, *Appl. Opt.*, **36**, 5224-5230.

1997 Satellite measurements of atmospheric ozone profiles, including tropospheric ozone, from UV/visible measurements in the nadir geometry: A potential method to retrieve tropospheric ozone, K.V. Chance, J.P. Burrows, D. Perner, and W. Schneider, *JQSRT*, **57**, 467-476.

1991 Retrieval and molecule sensitivity studies for the Global Ozone Monitoring Experiment and the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY, K.V. Chance, J.P. Burrows, and W. Schneider, *Proc. SPIE, Remote Sensing of Atmospheric Chemistry*, **1491**, 151-165.

Dr. Xiong Liu
Research Scientist, Smithsonian Astrophysical Observatory, xliu@cfa.harvard.edu

Relevant Experience: Dr. Liu has extensive expertise in satellite retrievals of trace gases (especially tropospheric ozone) and aerosols from UV/visible measurements, radiative transfer modeling and instrumental calibration. He has developed one of the most advanced algorithms to retrieve ozone profiles including tropospheric ozone from GOME, OMI and GOME-2.

Education

Ph.D., Atmospheric Science, University of Alabama in Huntsville, 2002
M.S., Computer Science, University of Alabama in Huntsville, 2002
M.S., Environmental Chemistry, Chinese Academy of Sciences, 1998
B.S., Environmental Chemistry, Nankai University, China, 1995

Previous Positions

5.2007–1.2010, Assistant & Associate Research Scientist, GEST, UMBC
2003–5.2007, Visiting and Research Scientist, Smithsonian Astrophysical Observatory

Honors

2009, NASA Group Achievement Award for OMI Science Team
2006, NASA New Investigator Program Award
1998-2002, UAH Dean's List

Selected Publications

Liu, X., P. K. Bhartia, K. Chance, R. J. D. Spurr, and T. P. Kurosu, Ozone profile retrievals from the Ozone Monitoring Instrument, Atmos. Chem. Phys., 10, 2521-2537, 2010.

Liu, X., P. K. Bhartia, K. Chance, L. Froidevaux, R. J. D. Spurr, and T. P. Kurosu, Validation of OMI ozone profiles and stratospheric ozone columns with MLS measurements, Atmos. Chem. Phys., 10, 2539-2549, 2010.

Yang, K., X. Liu , P. K. Bhartia, N. A. Krotkov, S. A. Carn, E. Hughes, A. J. Krueger, R. J. D. Spurr, S. Trahan (2010), Direct Retrieval of Sulfur Dioxide Amount and Altitude from Spaceborne Hyper-spectral UV Measurements: Theory and Application, J. Geophys. Res., accepted.

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Liu, X., et al., Ozone profile and tropospheric ozone retrieval from GOME: Algorithm description and validation, J. Geophys. Res., 110(D20), D20307, 10.1029/2005 JD006240, 2005.

Liu, X., et al., Mapping tropospheric ozone profiles from an airborne UV/Visible spectrometer, Appl. Opt., 44(16), 3312-3319, 2005.

Thomas P. Kurosu tkurosu@cfa.harvard.edu
Harvard-Smithsonian Center for Astrophysics Phone: 617-495-7213 Fax: 617-496-7538

PROFESSIONAL EDUCATION

University of Bremen, Bremen, Germany	Physics	Dr. rer. nat. 1997
University of Mainz, Mainz, Germany	Physics	Graduate Diploma 1992

RELEVANT EXPERIENCE

Scientist, **Harvard-Smithsonian Center for Astrophysics** **1998 – present**

Dr. Kurosu has more than 15 years experience in satellite remote sensing and radiative transfer, and has authored and co-authored more than 30 peer-reviewed publications. Recent research efforts have focused on the development and implementation of scientific and operational trace gas retrieval algorithms (HCHO, BrO, OClO, CHO-CHO) for the OMI on EOS/Aura. Previous research includes the development of cloud retrieval and cloud radiative transfer algorithms for the GOME instrument on ERS-2. He is a co-developer of the LIDORT radiative transfer model. He has been involved in the US SAGE III and NPP science teams, the Japanese ILAS and ILAS II science teams, the Canadian MEOS science team, and the European GOME, GOME-2, and SCIAMACHY science teams. Dr. Kurosu's primary expertise is the development of UV/visible cloud and trace gas retrieval algorithms based on non-linear least squares optimization methods. He received the NASA Group Achievement Award (2009, 2005) and the NASA GSFC Group Achievement Award (2005) for his involvement in the OMI/Aura Team.

SELECTED PUBLICATIONS

- M.P. Barkley, P.I. Palmer, U. Kuhn, J. Kesselmeier, K. Chance, T.P. Kurosu, R.V. Martin, D. Helmig, and A. Guenther, Net ecosystem fluxes of isoprene over tropical South America inferred from Global Ozone Monitoring Experiment (GOME) observations of HCHO columns, *J. Geophys. Res*. 113 (D20) D20304, 2008
- D.B. Millet, D.J. Jacob, K.F. Boersma, T.-M. Fu, T.P. Kurosu, K. Chance, C.L. Heald, and A. Guenther, Spatial distribution of isoprene emissions from North America derived from formaldehyde column measurements by the OMI satellite sensor, *J. Geophsys. Res*. 113 (D2) D02307, 2008
- P.I. Palmer, P.I., M.P. Barkley, T.P. Kurosu, A.C. Lewis, J.E. Saxton, K. Chance, L.V. Gatti, Interpreting satellite column observations of formaldehyde over tropical South America, *Phil. Trans. R. Soc. A*., 365 (1856), 2007
- P.I. Palmer, D.S. Abbot, T-M. Fu, D.J. Jacob, K. Chance, T.P. Kurosu, A. Guenther, C. Wiedinmyer, J.C. Stanton, M.J. Pilling, S.N. Pressley, B. Lamb, and A.L. Sumner, Quantifying the seasonal and interannual variability of North American isoprene emissions using satellite observations of the formaldehyde column, *J. Geophys. Res*. 111, D12315, doi:10.1029/2005JD006689, 2006.
- K. Chance, T.P. Kurosu, and C. Sioris, Undersampling correction for array detector-based satellite spectrometers, *Appl. Opt*., 44(7), 1296-1304, 2005
- P.I. Palmer, D.J. Jacob, A.M. Fiore, R.V. Martin, K. Chance, and T. Kurosu, Mapping isoprene emissions over North America using formaldehyde column observations from space, *J. Geophys. Res*., 108, 4180, doi:10.1029/2002JD002153, 2003
- R.V. Martin, K. Chance, D.J. Jacob, T.P. Kurosu, R.J.D. Spurr, E. Bucsela, J.F. Gleason, P.I. Palmer, I. Bey, A.M. Fiore, Q. Li, R.M. Yantosca, and R.B.A. Koelemeijer, An improved retrieval of tropospheric nitrogen dioxide from GOME, *J. Geophys. Res.,* 107, 4437, doi:10.1029/2001JD0010127, 2002
- P.I. Palmer, D.J. Jacob, K. Chance, R.V. Martin, R.J.D. Spurr, T.P. Kurosu, I. Bey, R. Yantosca, A. Fiore, and Q. Li, Air mass factor formulation for spectroscopic measurements from satellites: Application to formaldehyde retrievals from the Global Ozone Monitoring Experiment, *J. Geophys. Res.,* 106, 14,539-14,550, 2001

Dr. Kelly Chance
Current

Project Title	SAO Participation in the GOME and SCIAMACHY Satellite Instrument Programs
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NASA/ROSES/ David Considine, 202-358-2277, david.b.considine@nasa.gov
Period of Performance	06/27/2007-05/23/2011
Total Budget	$266,678
Person Months per year	1.3

Project Title	SAO Participation in "A Study of Tropospheric Halogen Chemistry and its Environmental Impact in the Arctic Spring Through Modeling Analysis of In Situ and Remote Sensing Measurements: Chemical/Physical Processes and Interannual Variability"
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	Georgia Tech/Professor Yuhang Wang, 404-894-3995, ywang@ eas.gatech.edu
Period of Performance	01/01/09-7/31/10
Total Budget	$90,000
Person Months per year	1.8

Project Title	Satellite-Based Halogen Oxide Measurements in Support of the ARCTAS Campaign and Tropospheric Science
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNX09AK28G-0 NASA/ROSES/ David Considine, 202-358-2277, david.b.considine@nasa.gov
Period of Performance	05/11/09 -5/11/11
Total Budget	$113,973
Person Months per year	1.2

Project Title	SAO membership in the NPP Science Team: Tropospheric Ozone, Trace Gases, and Development of Climate Data Records
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH06ZDA001N-EOS, NASA Dr. Hal Maring, 202-358-1679, hal.maring@nasa.gov
Period of Performance	03/03/2008 -03/02/2011
Total Budget	$657,493
Person Months per year	2.4

Project Title	SAO membership in the Aura Science Team
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NASA Goddard
Period of Performance	11/21/2008 – 11/20/2010
Total Budget	$429,830

Person Months per year	2.0

Project Title	Investigate the global distribution of tropospheric ozone measured by the OMI and GOME-2 instruments using the GMI chemistry transport model
Principal Investigator	Dr. Xiong Liu / Co-I Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH09ZDA001N-ACMA / NASA Dr. Richard Eckman, 202-358-2567, Richard.S.Eckman@nasa.gov
Period of Performance	03/2010 – 02/28/2013
Total Budget	$380,931
Person Months per year	0.7

Pending

Project Title	The Atmospheric Bromine Experiment: Climate Change Impacts on Tropospheric and Stratospheric Chemistry
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	Purdue University/ Professor Paul Shepson, pshepson@purdue.edu
Period of Performance	06/01/2010 – 05/31/2015
Total Budget	$820,000
Person Months per year	2.25

Project Title	MAESTRO-Mars
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	EXOMARS TRACE GAS ORBITER INSTRUMENTS / NASA Dr. Philippe Crane, 202-358-0716 , Philippe.Crane@nasa.gov
Period of Performance	$21,016,227
Total Budget	10/01/2010 – 04/30/2019
Person Months per year	4.6

Project Title	Development of A New Environmental Data Record for Tropospheric Ozone from NPP OMPS
Principal Investigator	Dr. Xiong Liu / Co-I Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH10ZDA001N-NPP, NASA Dr. Diane E. Wickland, 202-358-0245, Diane.E.Wickland@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$643,242
Person Months per year	1.2

Project Title	Earth Science U.S. Participating Investigator - The Smithsonian Astrophysical Observatory's Role in International Space-Based Earth Monitoring Missions
Principal Investigator	Dr. Thomas Kurosu/ Co-I Dr. Kelly Chance
Program name/Sponsor Point of Contact	NASA - NNH10ZDA001N-ESUSPI: Earth Science U.S. Participating Investigator Dr. Garik Gutman

	Earth Science Division Science Mission Directorate Tel: 202-358-0276 Email: ggutman@nasa.gov
Period of Performance	01/01/2011 – 12/31/2015
Total Budget	$729,949
Person Months per year	1.0

Project Title	Development of Trace Gas EDRs from the NPP Ozone Mapping and Profiler Suite
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH10ZDA001N-NPP: NPP Science Team for CDRs / NASA Dr. Diane E. Wickland, Telephone: (202) 358-0245 E-mail: Diane.E.Wickland@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$750,467
Person Months per year	1.3

Project Title	SAO Participation in the CLARREO Science Definition Team: Contributions to Absolute Radiances and Measurements of Pollutants from other Satellites
Principal Investigator	Dr. Kelly Chance
Program name/Sponsor Point of Contact	NNH10ZDA001N-CLARREO: Science Definition Team for the CLARREO Mission Dr. Kenneth Jucks Earth Science Division Science Mission Directorate Tel: 202-358-0476 Email: kenneth.w.jucks@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$458,878
Person Months per year	1.5

Project Title	A Prototype Sensor for Aerosol and Trace Gas Retrieval Readiness and Airborne Validation to Support the GEO-CAPE Mission
Principal Investigator	Dr. Kelly Chance
Program name/Sponsor Point of Contact	James Leitch BALL AEROSPACE & TECHNOLOGIES CORP Tel: 303-939-5280 Email: jleitch@ball.com
Period of Performance	06/01/2011 – 5/31/2014
Total Budget	$274,968
Person Months per year	1.3

Project Title	Advanced Ozone Profile and Tropospheric Ozone Measurements from the Ozone Monitoring Instrument on EOS Aura
Principal Investigator	Dr. Xiong Liu
Program name/Sponsor Point of Contact	NNH10ZDA001N-AURA: Atmospheric Composition: Aura Science Team Dr. Kenneth Jucks Earth Science Division Science Mission Directorate Tel: 202-358-0476 Email: kenneth.w.jucks@nasa.gov
Period of Performance	02/01/2011 – 1/31/2014
Total Budget	$ 711,385
Person Months per year	1.1

Dr. Xiong Liu
Current Awards

Project Title	SAO membership in the NPP Science Team: Tropospheric Ozone, Trace Gases, and Development of Climate Data Records
Principal Investigator	Dr. Kelly Chance / Co-I Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH06ZDA001N-EOS , NASA Dr. Hal Maring, 202-358-1679, hal.maring@nasa.gov
Period of Performance	03/03/2008 -03/02/2011
Total Budget	$657,493
Person Months per year	1.0

Project Title	Investigate the global distribution of tropospheric ozone measured by the OMI and GOME-2 instruments using the GMI chemistry transport model
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH09ZDA001N-ACMA / NASA Dr. Richard Eckman, 202-358-2567, Richard.S.Eckman@nasa.gov
Period of Performance	03/2010 – 02/28/2013
Total Budget	$380,931
Person Months per year	3.5

Project Title	Retrieval and Assimilation Studies: Ozone Profile Retrievals from OMI and Its Synergy with AIRS/TES, GEOS-5 Assimilation of OMI Retrievals, and Boundary Layer/Tropospheric Ozone Retrieval Sensitivity for GEO-CAPE
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	OMI Core Funding / Aura Dr. PK Bhartia, NASA GSFC, 301-614-5731, pawan.k.bhartia@nasa.gov
Period of Performance	01/2010 – 12/31/2010
Total Budget	$146,798
Person Months per year	6.0

Project Title	AERONET skylight retrievals using polarimetric measurements: toward physically consistent validation of APS aerosol products
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH09ZDA001N-GLORY, University of Nebraska – Lincoln Dr. Jun wang, 857-453-9595, jwang7@unl.edu
Period of Performance	1/01/2011 – 12/31/2013
Total Budget	$49,466
Person Months per year	0.5

Dr. Xiong Liu
Pending Awards

Project Title	MAESTRO-Mars
Principal Investigator	Dr. Kelly Chance / Co-I Dr. Xiong Liu
Program Name/Sponsor Point of Contact	EXOMARS TRACE GAS ORBITER INSTRUMENTS / NASA Dr. Philippe Crane, 202-358-0716 , Philippe.Crane@nasa.gov

Period of Performance	10/01/2010 – 04/30/2019
Total Budget	$21,016,227
Person Months per year	1.0

Project Title	Development of Advanced Nitrogen Dioxide Retrieval Algorithms from Nadir-Viewing Backscattered UV/Visible Measurements
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH09ZDA001N-RST/NASA Dr. Lucia Tsaoussi , 202-358-4471 Lucia.S.Tsaoussi@nasa.gov
Period of Performance	$460,990
Total Budget	1/01/2011 – 12/31/2013
Person Months per year	3.0

Project Title	Advancing Aerosol and Trace Gas Retrievals from BUV Measurements
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH09ZDA001N-RST / University Maryland Baltimore County Dr. Kai Yang, 301-614-6006, Kai.Yang.1@gsfc.nasa.gov
Period of Performance	$78,090
Total Budget	1/01/2011 – 12/31/2013
Person Months per year	1

Project Title	Development of A New Environmental Data Record for Tropospheric Ozone from NPP OMPS
Principal Investigator	Dr. Xiong Liu
Program Name/Sponsor Point of Contact	NNH10ZDA001N-NPP, NASA Dr. Diane E. Wickland, 202-358-0245, Diane.E.Wickland@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$643,242
Person Months per year	3.5 month/year

Project Title	Development of Trace Gas EDRs from the NPP Ozone Mapping and Profiler Suite
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH10ZDA001N-NPP: NPP Science Team for CDRs / NASA Dr. Diane E. Wickland, Telephone: (202) 358-0245 E-mail: Diane.E.Wickland@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013

Total Budget	$750,467
Person Months per year	1.1

Project Title	Earth Science U.S. Participating Investigator - The Smithsonian Astrophysical Observatory's Role in International Space-Based Earth Monitoring Missions
Principal Investigator	Dr. Thomas Kurosu /Co-I Dr. Xiong Liu
Program name/Sponsor Point of Contact	NASA - NNH10ZDA001N-ESUSPI: Earth Science U.S. Participating Investigator Dr. Garik Gutman Earth Science Division Science Mission Directorate Tel: 202-358-0276 Email: ggutman@nasa.gov
Period of Performance	01/01/2011 – 12/31/2015
Total Budget	$729,949
Person Months per year	1.0

Project Title	SAO Participation in the CLARREO Science Definition Team: Contributions to Absolute Radiances and Measurements of Pollutants from other Satellites
Principal Investigator	Dr. Kelly Chance/ Co-I Dr. Xiong Liu
Program name/Sponsor Point of Contact	NNH10ZDA001N-CLARREO: Science Definition Team for the CLARREO Mission Dr. Kenneth Jucks Earth Science Division Science Mission Directorate Tel: 202-358-0476 Email: kenneth.w.jucks@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$458,878
Person Months per year	1.5

Project Title	Advanced Ozone Profile and Tropospheric Ozone Measurements from the Ozone Monitoring Instrument on EOS Aura
Principal Investigator	Dr. Xiong Liu
Program name/Sponsor Point of Contact	NNH10ZDA001N-AURA: Atmospheric Composition: Aura Science Team Dr. Kenneth Jucks Earth Science Division Science Mission Directorate Tel: 202-358-0476 Email: kenneth.w.jucks@nasa.gov
Period of Performance	02/01/2011 – 1/31/2014
Total Budget	$ 711,385
Person Months per year	3.6

Project Title	A Prototype Sensor for Aerosol and Trace Gas Retrieval Readiness and Airborne Validation to Support the GEO-CAPE Mission
Principal Investigator	Dr. Kelly Chance / Co-I Dr. Xiong Liu
Program name/Sponsor Point of Contact	James Leitch BALL AEROSPACE & TECHNOLOGIES CORP Tel: 303-939-5280 Email: jleitch@ball.com
Period of Performance	06/01/2011 – 5/31/2014
Total Budget	$274,968
Person Months per year	1.8

Dr. Thomas Paul Kurosu
Current

Project Title	SAO Participation in the GOME and SCIAMACHY Satellite Instrument Programs
Principal Investigator	Dr. Kelly Chance / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	NASA/ROSES/ David Considine, 202-358-2277, david.b.considine@nasa.gov
Period of Performance	06/27/2007-05/23/2011
Total Budget	$266,678
Person Months per year	2.0

Project Title	SAO Participation in "A Study of Tropospheric Halogen Chemistry and its Environmental Impact in the Arctic Spring Through Modeling Analysis of In Situ and Remote Sensing Measurements: Chemical/Physical Processes and Interannual Variability"
Principal Investigator	Dr. Kelly Chance / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	Georgia Tech/Professor Yuhang Wang, 404-894-3995, ywang@ eas.gatech.edu
Period of Performance	01/01/09-7/31/10
Total Budget	$90,000
Person Months per year	1.8

Project Title	Satellite-Based Halogen Oxide Measurements in Support of the ARCTAS Campaign and Tropospheric Science
Principal Investigator	Dr. Kelly Chance / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	NASA/ROSES/ David Considine, 202-358-2277, david.b.considine@nasa.gov
Period of Performance	01/01/08 -12/31/10
Total Budget	$165,976
Person Months per year	0.35

Project Title	SAO membership in the NPP Science Team: Tropospheric Ozone, Trace Gases, and Development of Climate Data Records
Principal Investigator	Dr. Kelly Chance / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	NNH06ZDA001N-EOS, NASA Dr. Hal Maring, 202-358-1679, hal.maring@nasa.gov
Period of Performance	03/03/2008 -03/02/2011
Total Budget	$657,493
Person Months per year	2.0

Project Title	SAO membership in the Aura Science Team
Principal Investigator	Dr. Kelly Chance / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	NASA Goddard
Period of Performance	11/21/2008 – 11/20/2010
Total Budget	$429,830
Person Months per year	3.3

Project Title	Investigate the global distribution of tropospheric ozone measured by the OMI and GOME-2 instruments using the GMI chemistry transport model
Principal Investigator	Dr. Xiong Liu / Co-I Dr. Kelly Chance
Program Name/Sponsor Point of Contact	NNH09ZDA001N-ACMA / NASA Dr. Richard Eckman, 202-358-2567, Richard.S.Eckman@nasa.gov
Period of Performance	03/2010 – 02/28/2013
Total Budget	$380,931
Person Months per year	0.7

Project Title	Constraints on Global Biogenic Hydrocarbon Emissions and Chemistry From Synthesis of Aura Satellite Observations
Principal Investigator	Dr. Thomas Kurosu
Program Name/Sponsor Point of Contact	University of Minnesota/ Dylan Millet, 612-626-3259, dbm@umn.edu
Period of Performance	05/2010 – 04/30/2013
Total Budget	$52,400
Person Months per year	0.6

Pending

Project Title	The Atmospheric Bromine Experiment: Climate Change Impacts on Tropospheric and Stratospheric Chemistry
Principal Investigator	Dr. Kelly Chance / / Co-I Thomas Kurosu
Program Name/Sponsor Point of Contact	Purdue University/ Professor Paul Shepson, pshepson@purdue.edu
Period of Performance	06/01/2010 – 05/31/2015
Total Budget	$820,000
Person Months per year	2.5

Project Title	MAESTRO-Mars
Principal Investigator	Dr. Kelly Chance
Program Name/Sponsor Point of Contact	EXOMARS TRACE GAS ORBITER INSTRUMENTS / NASA Dr. Philippe Crane, 202-358-0716 , Philippe.Crane@nasa.gov
Period of Performance	$21,016,227
Total Budget	10/01/2010 – 04/30/2019
Person Months per year	4.6

Project Title	Development of an NO2 Aircraft Spectrometer in Support of Geo-Stationary Ocean Color Observations
Principal Investigator	Dr. Thomas Kurosu
Program name/Sponsor Point of Contact	BALL AEROSPACE & TECHNOLOGIES CORP
Period of Performance	07/01/2010 – 6/30/2013
Total Budget	$296,540
Person Months per year	2.0

Project Title	Earth Science U.S. Participating Investigator - The Smithsonian Astrophysical Observatory's Role in International Space-Based Earth Monitoring Missions
Principal Investigator	Dr. Thomas Kurosu
Program name/Sponsor Point of Contact	NASA - NNH10ZDA001N-ESUSPI: Earth Science U.S. Participating Investigator Dr. Garik Gutman Earth Science Division Science Mission Directorate Tel: 202-358-0276 Email: ggutman@nasa.gov
Period of Performance	01/01/2011 – 12/31/2015
Total Budget	$729,949
Person Months per year	1.0

Project Title	Development of Trace Gas EDRs from the NPP Ozone Mapping and Profiler Suite
Principal Investigator	Dr. Kelly Chance / Co-I Dr. Thomas Kurosu
Program Name/Sponsor Point of Contact	NNH10ZDA001N-NPP: NPP Science Team for CDRs / NASA Dr. Diane E. Wickland, Telephone: (202) 358-0245 E-mail: Diane.E.Wickland@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$750,467
Person Months per year	2.0

Project Title	SAO Participation in the CLARREO Science Definition Team: Contributions to Absolute Radiances and Measurements of Pollutants from other Satellites
Principal Investigator	Dr. Kelly Chance/ Co-I Dr. Xiong Liu
Program name/Sponsor Point of Contact	NNH10ZDA001N-CLARREO: Science Definition Team for the CLARREO Mission Dr. Kenneth Jucks Earth Science Division Science Mission Directorate Tel: 202-358-0476 Email: kenneth.w.jucks@nasa.gov
Period of Performance	01/01/2011 – 12/31/2013
Total Budget	$458,878
Person Months per year	1.5

Budget Narrative and Detail

Personnel

Senior/Key Personnel

Dr. Kelly Chance, Principal Investigator, will be responsible for the overall technical direction of the research, including algorithm design and implementation, data product development, scientific and long-term data studies, and data archiving and distribution. (28% per year)

Dr. Thomas P. Kurosu, Co-Investigator, will implement new operational and scientific data products and participate in scientific and long-term data studies (28% per year)

Dr. Xiong Liu, Co-Investigator, will lead the production of SO_2 data products using the SAO optimal estimation algorithm and participate in scientific and long-term data studies. (28% per year)

Mr. Raid Suleiman will lead the data archiving and distribution and participate in scientific and long-term data studies (28% per year)

Other Personnel

We are requesting appropriate support of the Division Administration and Administrative Assistant for project management support.

Fringe benefits

Fringe benefits for SAO scientist and Division Administration are calculated at 27.6%.

Equipment

Year 1: $10k for a computer work station dedicated for development and testing of retrieval algorithm and chemistry models

Travel

We are requesting funds to travel to Washington, DC each year, for meetings at NASA.

A Science Team meeting in the Netherlands is budgeted for year 2.

Also budgeted is one trip (2 travelers) per year to attend the AGU meeting in San Francisco, CA.

Other Direct Costs

Printing/Publications

$3,000 in year 3 for publications in Atmospheric Chemistry and Physics, Geophysical Research Letters, or the Journal of Geophysical Research.

Materials

$5,300 for tape drives and data tapes.

Indirect Costs

Overheads are calculated consistent with the policies established and published by SAO.

Facilities

Standard research facilities for day-to-day operations are already in place. The PI and Co-Is have their own Linux desktop workstations to perform sensitivity studies and develop test retrieval algorithms. The SAO has access to the Smithsonian Institution's high-performance Linux cluster, with 2000 cores and 24TB of pool disk space, which can be used for processing large amounts of NPP OMPS data. In addition, the PI and Co-Is are members of the OMI science team and have access to OMI SIPS and TLCF (Team Leader Computation Facilities) for OMI data processing.

	Year 1 02/1/2011 to 01/31/2012 Hours	 Dollars	Year 2 02/1/2012 to 01/31/2013 Hours	 Dollars	Year 3 02/1/2013 to 01/31/2014 Hours	 Dollars	Total 02/1/2011 to 01/31/2014 Hours	 Dollars
Productive Labor								
PI Dr. Kelly Chance	500	40,532	500	41,412	500	42,311	1,500	124,255
Co-I: Dr. Xiong Liu	500	26,861	500	28,321	480	28,647	1,480	83,829
Co-I Dr. Thomas Kurosu	500	32,903	500	34,427	480	33,766	1,480	101,096
Raid Suleiman	500	20,006	480	19,620	480	20,048	1,460	59,674
Division Administrator	75	4,547	75	4,779	75	5,017	225	14,343
Staff Assistant	75	2,359	75	2,475	75	2,589	225	7,423
Total Productive Labor	2,150	127,208	2,130	131,034	2090	132,378	6,370	390,620
Leave @ 18.5%		23,533		24,241		24,490		72,264
Total Direct Labor		150,741		155,275		156,868		462,884
Fringe Benefits @ 27.6%		41,605		42,856		43,296		127,757
Direct Operating Overhead Base		192,346		198,131		200,164		590,641
Direct Operating Overhead @ 27.7		53,280		54,882		55,445		163,607
Travel		7,192		14,318		7,854		29,364
Printing and Reproduction						3,000		3,000
Materials Overhead @ 5.3%		811						811
General & Administrative Base		253,629		267,331		266,463		787,423
General & Administrative Overhead @ 12.2		30,943		32,614		32,508		96,065
Materials (Tape Drives and Tapes)	5,300						5,300	
Equipment (Workstation)	10,000						10,000	
Material Base		15,300						15,300
Total Estimated Cost		$299,872		$299,945		$298,971		$898,788

TRAVEL SCHEDULE

YEAR 1 Destination	# OF TRIPS	# OF TRAVELERS	# OF DAYS	RATE PER DIEM	TOTAL PER DIEM	AIRFARE	TOTAL AIRFARE	# DAYS AUTO RENTAL	AUTO RATE	TOTAL AUTO	MISC	TOTAL COST
DOMESTIC												
Washington, DC	1	2	3	285	1,710	250	500	3	54	162	300	2,672
Pasadena, CA	1	2	5	275	2,750	600	1,200	5	54	270	300	4,520
TOTAL TRAVEL YEAR 1					**4,460**		**1,700**			**432**	**600**	**7,192**

YEAR 2 Destination	# OF TRIPS	# OF TRAVELERS	# OF DAYS	RATE PER DIEM	TOTAL PER DIEM	AIRFARE	TOTAL AIRFARE	# DAYS AUTO RENTAL	AUTO RATE	TOTAL AUTO	MISC	TOTAL COST
DOMESTIC												
Washington, DC	1	2	3	299	1,794	263	526	3	56	168	300	2,788
Pasadena, CA	1	2	5	289	2,890	630	1,260	5	56	280	300	4,730
FOREIGN												
Netherlands	1	2	5	422	4,220	1,000	2,000	5	56	280	300	6,800
TOTAL TRAVEL YEAR 2					**8,904**		**3,786**			**728**	**900**	**14,318**

YEAR 3 Destination	# OF TRIPS	# OF TRAVELERS	# OF DAYS	RATE PER DIEM	TOTAL PER DIEM	AIRFARE	TOTAL AIRFARE	# DAYS AUTO RENTAL	AUTO RATE	TOTAL AUTO	MISC	TOTAL COST
DOMESTIC												
Washington, DC	1	2	3	314	1,884	276	552	3	58	174	300	2,910
Pasadena, CA	1	2	5	303	3,030	662	1,324	5	58	290	300	4,944
TOTAL TRAVEL YEAR 3					**4,914**		**1,876**			**464**	**600**	**7,854**

CONTRACTUAL AND COST INFORMATION INCLUDING CERTIFICATIONS

The Smithsonian Institution, an independent trust establishment was created by an act of the Congress of 1846 to carry out the terms of the will of James Smithson of England, who had bequeathed his entire estate to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." After accepting the trust property for the United States, Congress vested responsibility for administering the trust in a Smithsonian Board of Regents.

The Smithsonian performs research, educational and other special projects supported by grants and contracts awarded under the cost principles of the Federal Acquisition Regulation, Subpart 31.7 Contracts with Nonprofit Organizations. It is audited by the Defense Contract Audit Agency, Landover, Maryland.

The Charter of the Smithsonian Institution carries a mandate for the "increase and diffusion of knowledge among men." Therefore, any grant or contract that may be awarded as a result of this proposal must be unclassified, in order not to abridge the Institution's right to publish, without restriction, findings that result from this research project.

Considering the nature of the proposed effort, it is requested that a Research Grant with reimbursement via electronic funds transfer be awarded to cover the proposed project in accordance with Subpart C, Section 215.22(e) of Title 2 of the Code of Federal Regulations (CFR) Part 215 [formerly the Office of Management and Budget (OMB) Circular A-110: *Uniform Administrative Requirements for Grants and Other Agreements with Institutions of Higher Education, Hospitals and Other Non-Profit Organizations].*

Pursuant to Subpart C, Section 215.33 and 215.34 of Title 2 CFR Part 215 [formerly OMB Circular No. A-110], it is requested that title to all exempt property and equipment purchased or fabricated under the proposed contract be vested irrevocably in the Institution upon acquisition.

In accordance with an agreement between the Office of Naval Research and the Smithsonian, the Institution operates with predetermined fixed overhead rates with carry-forward provisions. For Fiscal Year 1996 and beyond, the Indirect Cost and Fringe Benefits Rates are developed in accordance with Title 2 CFR Part 230 [formerly OMB Circular A-122: *Cost Principles for Non-Profit Organizations*]. The following approved rates, provided by ONR Negotiation Agreement dated 4 March 2010, shall be used for forward pricing and billing purposes for Fiscal Year 2010. The Fringe Benefits Rate will be applied to the Total Direct Labor Costs. The Material Overhead Rate will be applied to the cost of materials, equipment and subcontracts. The Direct Operating Overhead Rate will be applied to the Direct Labor and Benefits costs. The G&A Rate will be applied to the base consisting of total costs except the costs associated with the materials, equipment and subcontracts.

The following Approved Rates shall be used for forward pricing and billing purposes for Fiscal Year 2010:

Material Burden Rate (Cost of Materials, equipment and subcontracts)	5.3%
Personnel Leave Rate (Total Direct Labor Costs less paid leave and training {Productive Labor})	18.5%
Fringe Benefits Rate (Full/Part Time Employees) (Total Direct Labor Costs)	27.6%
Fringe Benefits Rate (Intermittent Employees) (Total Direct Labor Costs)	8.5%
Direct Operating Overhead Rate (Total Direct Labor and Fringe Benefits Costs)	27.7%
General and Administrative Rate (G&A) (Base consists of Direct Operating Activities less Net Costs Associated with materials, subcontracts and equipment)	12.2%
Central Engineering Overhead Rate (Central Engineering Direct Labor and Benefits Costs)	28.2%

Rate verification can be made by contacting Ms. Linda Shipp, Office of Naval Research, Indirect Costs/ONR 242, 800 N. Quincy Street, Room 704, Arlington, Virginia 22217, telephone (703) 696-8559, or e-mail linda_shipp@onr.navy.mil.

Engineering services are provided by the Central Engineering Department as a Cost Center. Charges by the department to research projects are inclusive of Direct Labor, Fringe Benefits, and Central Engineering Overhead.

CERTIFICATIONS

Pursuant to Executive Order 12549 and implementing rule (FAR 52.209-5), the Smithsonian Institution certifies that it presently is not debarred, suspended, proposed for debarment, declared ineligible or voluntarily excluded from covered transactions by any Federal department or agency.

Pursuant to Section 1352, Title 31, United States Code (USC) and implementing rule (FAR 52.203-12), the Smithsonian Institution certifies that no Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress on his or her behalf in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment or modification of any Federal contract, grant, loan or cooperative agreement.