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

NASA Proposal Number

10-AURA10-0012

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
Omar Torres	**omar.torres@hamptonu.edu**	**757-728-6745**

Street Address (1)	Street Address (2)
23 Tyler St	

City	State / Province	Postal Code	Country Code
Hampton	**VA**	**23668-0001**	**US**

Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
02 / 02 / 2011	**02 / 01 / 2014**	**599,999.00**	**202,122.00**	**197,429.00**	**200,448.00**

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**		

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
003135068	**4W066**	**540505990**	**8H**

Organization Name (Standard/Legal Name)	Company Division
Hampton University	

Organization DBA Name	Division Number

Street Address (1)	Street Address (2)
QUEENS AND TAYLOR ST	

City	State / Province	Postal Code	Country Code
HAMPTON	**VA**	**23668-0001**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Omar Torres	**omar.torres@hamptonu.edu**	**757-728-6745**

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
Tiajuana Jackson	**tiajuana.jackson@hamptonu.edu**	**757-727-5363**

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

PI Name : **Omar Torres**	NASA Proposal Number
Organization Name : **Hampton University**	**10-AURA10-0012**

Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**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**
Co-I	**Changwoo Ahn**	**301-867-2171**	**changwoo.ahn@ssaihq.com**
Organization/Business Relationship: **Science Systems And Applications, Inc.**		Cage Code: **5S009**	DUNS#: **087694808**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Collaborator	**Pawan Bhartia**	**301-614-5731**	**pawan.bhartia@nasa.gov**
Organization/Business Relationship: **NASA Goddard Space Flight Center**		Cage Code: **36FC1**	DUNS#: **004968611**
International Participation: **No**	U.S. Government Agency: **NASA Goddard Space Flight Center**		Total Funds Requested: **0.00**
Collaborator	**Santiago Gasso'**	**301-614-6244**	**santiago.gasso@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 : **Omar Torres**	NASA Proposal Number
Organization Name : **Hampton University**	**10-AURA10-0012**

Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION VII - Project Summary

Aerosol layers are commonly observed above low level clouds. Their occurrence is generally associated with efficient particle lifting mechanisms such as convection and eolic activity that rapidly mobilizes aerosol material (predominantly carbonaceous and desert dust aerosols) from their surface sources to above the boundary layer. Once in the free troposphere desert dust and smoke aerosol layers are transported across the oceans thousands of kilometers away with much of this transport taking place above clouds. The radiative transfer effects of absorbing aerosols above clouds (AAAC's) are very important in climate studies since the net direct radiative forcing of AAAC's may become positive (warming) depending on the aerosol absorption optical depth as well as on the underlying cloud's optical depth and fraction.

AAAC's are currently detected from space using Aura-OMI near UV observations and reported in terms of the absorbing aerosol index (AAI). The sensitivity of satellite measurements of back-scattered UV radiation to aerosol absorption above highly reflective backgrounds has been amply demonstrated with TOMS and OMI observations. Absorbing aerosols above or inside clouds generate a clear absorption-related signal that extends beyond the UV to a broad spectral range in the visible and near IR. The near-UV detection of AAAC's in conjunction with OMI and Aqua-MODIS observations in the visible can be used to quantify the aerosol absorption optical depth of AAAC's, and to identify different aerosol types based on the observed wavelength dependence of the retrieved aerosol absorption optical depth or aerosol absorption angstrom exponent.

We propose a research effort to 1) produce global quantitative estimates of the near-UV aerosol absorption optical depth (AAOD) of AAAC's using OMI observations; and 2) combine OMI near-UV and visible observations (354 to 500 nm) with Aqua MODIS visible observations to characterize the wavelength dependence of aerosol absorption in a wider spectral range from the near-UV to the near-IR. The first component of the proposed research work is a continuation of a project started under the previous Aura Science Team funding cycle in which a detailed sensitivity analysis for the retrieval of aerosol properties over clouds was carried out, and an inversion algorithm prototype was developed. The expected outcome of the first proposed research task is an operational retrieval algorithm that will be applied to the entire OMI record to produce a multiyear record of aerosol absorption optical depth above clouds. The availability of this product will facilitate the evaluation of the direct radiative forcing effect of AAAC's that requires information on the atmospheric aerosol load. The new data product will also be useful for the study of intercontinental transport of aerosol material.

The second part of the project takes advantage of the near-simultaneity of Aura-OMI and Aqua-MODIS to identify the presence of absorbing aerosols, and using collocated OMI-MODIS observations infer the spectral aerosol absorption optical depth in the near-UV/near-IR range. The spectral dependence of particle absorption, a strong function of aerosol composition, is usually defined in terms of the aerosol absorption angstrom exponent (AAE). Aerosol absorption optical depth of particles whose main absorbing component is black carbon exhibit a weaker wavelength dependence (AAE ~1) than those particles whose main absorbing species is organic carbon (AAE >1). In the proposed methodology the measured spectral radiance at the top of the atmosphere is explained, using Beer-Lambert law, as the result of the attenuation by an aerosol layer of the cloud reflected radiance. These measurements when applied to global satellite observations can be used to identify different aerosol composition (black and organic carbon and other types of absorbing aerosols) in terms of their AAE.

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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)?
Yes

Fiscal Year **2010**	Fiscal Year **2011**	Fiscal Year **2012**	Fiscal Year **2013**	Fiscal Year
Number of FTEs **0.0**	Number of FTEs **0.0**	Number of FTEs **0.0**	Number of FTEs **0.0**	Number of FTEs

PI Name : **Omar Torres**	NASA Proposal Number
Organization Name : **Hampton University**	**10-AURA10-0012**

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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 : **Omar Torres**	NASA Proposal Number
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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:

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SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Aerosols aboce clouds from OMI observations

Question 2 : Type of institution:

Answer: Educational 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 : **Omar Torres**	NASA Proposal Number
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	14,011.00	14,431.00	14,865.00	43,307.00
B. Direct Labor - Other Personnel	45,041.00	46,392.00	47,785.00	139,218.00
Total Number Other Personnel	3	3	3	9
Total Direct Labor Costs (A+B)	59,052.00	60,823.00	62,650.00	182,525.00
C. Direct Costs - Equipment	0.00	0.00	0.00	0.00
D. Direct Costs - Travel	7,400.00	8,000.00	8,000.00	23,400.00
Domestic Travel	2,000.00	2,000.00	2,000.00	6,000.00
Foreign Travel	5,400.00	6,000.00	6,000.00	17,400.00
E. Direct Costs - Participant/Trainee Support Costs	33,500.00	36,845.00	37,200.00	107,545.00
Tuition/Fees/Health Insurance	11,500.00	11,845.00	12,200.00	35,545.00
Stipends	21,000.00	24,000.00	24,000.00	69,000.00
Travel	1,000.00	1,000.00	1,000.00	3,000.00
Subsistence	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
Number of Participants/Trainees	1	1		2
F. Other Direct Costs	60,070.00	60,070.00	60,068.00	180,208.00
Materials and Supplies	70.00	70.00	68.00	208.00
Publication Costs	0.00	0.00	0.00	0.00
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	60,000.00	60,000.00	60,000.00	180,000.00
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)	160,022.00	165,738.00	167,918.00	493,678.00
H. Indirect Costs	42,100.00	31,691.00	32,530.00	106,321.00
I. Total Direct and Indirect Costs (G+H)	202,122.00	197,429.00	200,448.00	599,999.00
J. Fee	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	202,122.00	197,429.00	200,448.00	599,999.00
Total Cumulative Budget				599,999.00

PI Name : **Omar Torres**	**NASA Proposal Number**
Organization Name : **Hampton University**	**10-AURA10-0012**

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SECTION X - Budget

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

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Torres, Omar	PI_TYPE	0.00				11,560.00	2,451.00	14,011.00
							Total Key Personnel Costs	14,011.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Post Doctoral Associates				29,760.00	6,309.00	36,069.00
1	Secretarial / Clerical				3,889.00	824.00	4,713.00
1	Tech Support				3,514.00	745.00	4,259.00
3	Total Number Other Personnel					Total Other Personnel Costs	45,041.00

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B) 59,052.00

PI Name : **Omar Torres**	**NASA Proposal Number**
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

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

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)	**2,000.00**
2. Foreign Travel	**5,400.00**
Total Travel Costs	**7,400.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**11,500.00**
2. Stipends		**21,000.00**
3. Travel		**1,000.00**
4. Subsistence		**0.00**
Number of Participants/Trainees: 1	**Total Participant/Trainee Support Costs**	**33,500.00**

PI Name : **Omar Torres**	**NASA Proposal Number**
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

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

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**70.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**60,000.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
Total Other Direct Costs	**60,070.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**160,022.00**

H. Indirect Costs

	Indirect Cost Rate (%)	**Indirect Cost Base ($)**	**Funds Requested ($)**
IDC	**46.00**	**0.00**	**42,100.00**
Cognizant Federal Agency: **Hampton University**		**Total Indirect Costs**	**42,100.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**202,122.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**202,122.00**

PI Name : Omar Torres	NASA Proposal Number
Organization Name : Hampton University	10-AURA10-0012

Proposal Title : A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations

SECTION X - Budget

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

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Torres, Omar	PI_TYPE	0.00				11,907.00	2,524.00	14,431.00
							Total Key Personnel Costs	14,431.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Post Doctoral Associates				30,653.00	6,498.00	37,151.00
1	Secretarial / Clerical				4,006.00	849.00	4,855.00
1	Tech Support				3,619.00	767.00	4,386.00
3	Total Number Other Personnel					Total Other Personnel Costs	46,392.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	60,823.00

PI Name : **Omar Torres**	NASA Proposal Number
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 02 / 2012	**02 / 01 / 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)	**2,000.00**
2. Foreign Travel	**6,000.00**
Total Travel Costs	**8,000.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**11,845.00**
2. Stipends		**24,000.00**
3. Travel		**1,000.00**
4. Subsistence		**0.00**
Number of Participants/Trainees: 1	**Total Participant/Trainee Support Costs**	**36,845.00**

PI Name : **Omar Torres**	NASA Proposal Number
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

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

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	70.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	60,000.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	60,070.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	165,738.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
IDC	46.00	0.00	31,691.00
Cognizant Federal Agency: Hampton University		Total Indirect Costs	31,691.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	197,429.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	197,429.00

PI Name : **Omar Torres**	NASA Proposal Number
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Proposal Title : **A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 02 / 2013	**02 / 01 / 2014**	**Project**	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Torres, Omar	**PI_TYPE**	**0.00**				**12,265.00**	**2,600.00**	**14,865.00**
							Total Key Personnel Costs	**14,865.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Post Doctoral Associates**				**31,573.00**	**6,693.00**	**38,266.00**
1	**Secretarial / Clerical**				**4,126.00**	**875.00**	**5,001.00**
1	**Tech Support**				**3,728.00**	**790.00**	**4,518.00**
3	**Total Number Other Personnel**					**Total Other Personnel Costs**	**47,785.00**

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	62,650.00

PI Name : **Omar Torres**	NASA Proposal Number
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SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 02 / 2013	**02 / 01 / 2014**	**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)	**2,000.00**
2. Foreign Travel	**6,000.00**
Total Travel Costs	**8,000.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**12,200.00**
2. Stipends		**24,000.00**
3. Travel		**1,000.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**37,200.00**

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SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 02 / 2013	**02 / 01 / 2014**	**Project**	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	68.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	60,000.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	60,068.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	167,918.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
IDC	46.00	0.00	32,530.00
Cognizant Federal Agency: Hampton University		**Total Indirect Costs**	32,530.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	200,448.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	200,448.00

A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations

A proposal submitted to
The National Aeronautics and Space Administration
by
Hampton University

In response to the NASA Research Announcement
NNH10ZDA001N-Atmospheric Composition: AURA Science Team

Principal Investigator:
Dr. Omar Torres

Hampton University
Department of Atmospheric and Planetary Sciences
Hampton, VA 23668

Co-I
Dr. Changwoo Ahn
Science Systems and Applications, Inc.
10210 Greenbelt Road, Suite 600
Lanham, Maryland 20706

Collaborators

Dr. P.K. Bhartia
NASA Goddard Space Flight Center
Greenbelt, MD, 20771

Dr. Santiago Gassó
GEST Center
University of Maryland Baltimore County
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Summary

Aerosol layers are commonly observed above low level clouds. Their occurrences are generally associated with efficient particle lifting mechanisms such as convection and eolic activity that rapidly mobilizes aerosol material (predominantly carbonaceous aerosol and desert dust) from their surface sources to above the boundary layer. Once in the free troposphere desert dust and smoke aerosol layers are transported across the oceans thousands of kilometers away with much of this transport taking place above clouds. The radiative transfer effects of absorbing aerosols above clouds (AAAC's) are very important in climate studies since the net direct radiative forcing of AAAC's may become positive (warming) depending on the aerosol absorption optical depth as well as on the underlying cloud's optical depth and fraction.

AAAC's are currently detected from space using Aura-OMI near UV observations and reported in terms of the absorbing aerosol index (AAI). The sensitivity of satellite measurements of backscattered UV radiation to aerosol absorption above highly reflective backgrounds has been amply demonstrated with TOMS and OMI observations. Absorbing aerosols above or inside clouds generate a clear absorption-related signal that extends beyond the UV to a broad spectral range in the visible and near IR. The near-UV detection of AAAC's in conjunction with OMI and Aqua-MODIS observations in the visible can be used to quantify the aerosol absorption optical depth of AAAC's, and to identify different aerosol types based on the observed wavelength dependence of the retrieved aerosol absorption optical depth or aerosol absorption angstrom exponent.

We propose a research effort to 1) produce global quantitative estimates of the near-UV aerosol absorption optical depth (AAOD) of AAAC's using OMI observations; and 2) combine OMI near-UV and visible observations (354 to 500 nm) with Aqua MODIS visible observations to characterize the wavelength dependence of aerosol absorption in a wider spectral range from the near-UV to the near-IR. The first component of the proposed research work is a continuation of a project started under the previous Aura Science Team funding cycle in which a detailed sensitivity analysis for the retrieval of aerosol properties over clouds was carried out, and an inversion algorithm prototype was developed. The expected outcome of the first proposed research task is an operational retrieval algorithm that will be applied to the entire OMI record to produce a multi-year record of aerosol absorption optical depth above clouds. The availability of this product will facilitate the evaluation of the direct radiative forcing effect of AAAC's that requires information on the atmospheric aerosol load. The new data product will also be useful for the study of intercontinental transport of aerosol material.

The second part of the project takes advantage of the near-simultaneity of Aura-OMI and Aqua-MODIS to identify the presence of absorbing aerosols, and using collocated OMI-MODIS observations infer the spectral aerosol absorption optical depth in the near-UV/near-IR range. The spectral dependence of particle absorption, a strong function of aerosol composition, is usually defined in terms of the aerosol absorption angstrom exponent (AAE). Aerosol absorption optical depth of particles whose main absorbing component is black carbon exhibit a weaker wavelength dependence (AAE ~1) than those particles whose main absorbing species is organic carbon (AAE >1). In the proposed methodology the measured spectral radiance at the top of the atmosphere is explained, using Beer-Lambert law, as the result of the attenuation by an aerosol layer of the cloud reflected radiance. These measurements when applied to global satellite observations can be used to identify different aerosol composition (black and organic carbon and other types of absorbing aerosols) in terms of their AAE.

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1.0 Introduction

1.1 Importance of spectral characterization of aerosol absorption

Aerosol particles are an important atmospheric component, significantly affecting both climate and air quality. The climate related effects of aerosol scattering and absorption take place primarily in the visible and near IR spectral region whereas the same processes in the UV hold great importance for atmospheric chemistry. Traditionally, the main climate process studied has been the cooling effect associated with aerosol scattering back to space of a fraction of the incoming solar radiation. Only recently more attention has been given to the potential climate effects of aerosol absorption. Although, the impact of aerosol absorption on climate is still a subject of considerable debate [*Penner et al.,* 2003], published theoretical analyses suggest that black carbon may be the second most important global warming substance (in terms of its direct radiative forcing effect) after carbon dioxide, and larger than methane [*Jacobson,* 2002]. Not only does aerosol absorption decrease the direct cooling effect of aerosols (less scattering), but it also has the potential to reduce the natural cooling effect of clouds via the so-called second indirect effect or 'burning of clouds' [*Andrae et al.,* 2004]. Under clear-sky conditions the net direct radiative forcing effect (NDRF) of most aerosols is still negative (cooling) even for absorbing aerosol types such as carbonaceous particles. For absorbing aerosols located above clouds, however, the NDRF effect may switch sign (become warming) depending on the aerosol single scattering albedo and on cloud optical depth and cloud fraction [*Keil and Haywood,* 2003]. The effect of aerosol absorption on climate is, therefore, an issue that needs to be better understood in order to reduce the currently large uncertainties of aerosol radiative forcing.

An important fraction of the global atmospheric aerosol load is commonly observed above clouds. These events are generally associated with the presence of layers of light absorbing carbonaceous and desert dust aerosols lofted above the boundary layer and transported over large distances thousands of kilometers away from their sources. Some of the intercontinental transport of aerosols from Asia to North America across the Pacific Ocean and from Northern Africa to the South east US, the Caribbean and Northern South America across the Atlantic Ocean takes place above clouds. Also the presence of pollution clouds off the coast of China and west coast of Southern Africa is well known.

The quantification of absorbing aerosols above clouds (AAAC's) remains a big challenge in remote sensing. The application of aerosol detection based on scattering effects does not work over clouds as it requires the separation of the small aerosol scattering signal from a many times larger cloud scattering signal. Thus scattering-based techniques are not applicable to aerosol detection over clouds. AAAC's are currently detected using OMI near UV observations *[Torres et al.,* 2007] and reported in terms of the absorbing aerosol index (AAI). The sensitivity of satellite measurements of backscattered UV radiation to aerosol absorption above highly reflective backgrounds has been amply demonstrated with TOMS and OMI observations. Recently, progress has been made to turn the qualitative near-UV information into a quantitative representation of aerosol properties [*Torres et al*, 2010, manuscript in preparation]. Absorbing aerosols above or inside clouds generate a clear absorption-related signal that extends beyond the UV to a broad spectral range in the visible and near IR. The near-UV detection of AAAC's in conjunction with OMI and Aqua-MODIS observations in the visible can be used to quantify the aerosol absorption optical depth of AAAC's, and identify different aerosol types based on the observed wavelength dependence of the retrieved aerosol absorption optical depth. The near UV remote sensing capability over clouds in combination with measurements in the visible and near IR constitutes a powerful aerosol remote sensing tool for space-based characterization of aerosol composition.

We propose a research effort to 1) produce global quantitative estimates of the near-UV aerosol absorption optical depth (AAOD) of AAAC's using OMI observations; and 2) combine OMI near-UV and visible observations (354 to 500 nm) with Aqua MODIS visible observations to characterize the wavelength dependence of aerosol absorption in a wider spectral range from the near-UV to the near-IR.

The first component of the proposed research work is a continuation of a project started under the previous Aura Science Team funding cycle in which a detailed sensitivity analysis for the retrieval of aerosol properties over clouds was carried out, and an inversion algorithm prototype was developed. The expected outcome of the first proposed research task is an operational retrieval algorithm that will be applied to the entire OMI record to produce a multi-year record of aerosol absorption optical depth above clouds. The availability of this product will facilitate the evaluation of the radiative forcing effect of AAAC's that requires information on the atmospheric aerosol load, and will also be useful in the analysis of inter-continental transport of aerosols.

The second part of the project takes advantage of the near-simultaneity of Aura-OMI and Aqua-MODIS to identify the presence of AAAC's, and using collocated OMI-MODIS observations infer the spectral aerosol absorption optical depth in the near-UV/near-IR range. The spectral dependence of particle absorption, a strong function of aerosol composition, is usually defined in terms of the aerosol absorption angstrom exponent (AAE). Since long term observational records of multi-spectral and hyper-spectral cloud reflectance already exist (OMI, MODIS, GOME, GOME-2, etc) the study of the wavelength dependence of aerosol absorption can be carried out making use of a suitable measuring technique that integrates the UV capability with visible and near IR observations. The space-based study of the AAOD spectral dependence making use of satellite observations is particularly useful over the ocean and other remote regions no easily accessible to surface-based observations.

*1.2 Previous related research work***:**

Several research activities leading to significant improvement in the cloud-free OMI near UV retrieval algorithm (OMAERUV) took place during the previous AURA Science Team funding cycle.

-Aerosol layer height from CALIOP observations

CALIOP observations of 1064 nm attenuated backscatter were used to generate a 30-month climatological data set of aerosol layer height. The CALIOP-based climatology replaced the previously used scheme to prescribe aerosol layer height based on a combination of a CTM-generated aerosol height climatology to infer the altitude of dust aerosol layers, and a fixed latitude dependent height for smoke layers [Torres et al, 2007]. Evaluation of the effect of using the CALIOP climatology indicates a noticeable improvement in the accuracy of retrieved aerosol optical depth as compared to AERONET observations [Torres et al., 2010].

- AIRS CO observations to distinguish smoke from desert dust

Distinguishing smoke from desert dust aerosols has been a long-standing issue in the OMAERUV algorithm. The near-UV information used in the retrieval algorithm allows the separation of absorbing and non-absorbing aerosols. Differentiating between different types of absorbing aerosols according to particle size, however, is not easy as the wavelength separation of the channels used in the retrieval is not large enough to produce meaningful Ångstrom exponent information. A method of addressing this issue was developed by making use of the Aqua-AIRS data on CO column amount. Since CO is a by-product of biomass burning when combined with the OMI Absorbing Aerosol Index it can be used as a tracer of carbonaceous aerosols. Thus high AI and high CO values indicate biomass burning aerosols whereas the combination of high AI and low CO values indicates the presence of desert dust. This approach has been implemented in the OMAERUV algorithm to reduce the ambiguity of aerosol type identification in areas and times of the year where the presence of either type is equally probable.

- *Extending OMAERUV's retrieving capability to cloud-aerosol mixtures*.

Since the introduction of the Aerosol Index as a simple yet efficient way of identifying aerosol absorption it has been known that in the near-UV it is possible to detect absorbing aerosol even when aerosols and clouds are both present in the same scene, or if the aerosols are above clouds. Work on developing retrieval approaches to produce quantitative estimates of aerosol properties in the presence of clouds have been carried out. A detailed sensitivity analysis for the retrieval of aerosol properties over clouds was done, and an inversion algorithm prototype was developed. The continuation of this research activity is proposed as part of this proposal.

2.0 Objectives

2.1 Retrieving aerosol absorption for aerosol above clouds

The aerosol absorption detection capability using near UV observations works equally well over all backgrounds regardless of the brightness of the scene. The quantitative interpretation of the information content of the Aerosol Index in the presence of clouds, however, requires accounting for the scattering effects of clouds. An inversion algorithm that derives AAOD and effective cloud optical depth for application to OMI observations is currently under development as part of AURA science activities over the previous funding cycle. Results of sensitivity analysis using a plane parallel cloud (PPC) approximation to represent the cloud content of at atmospheric column indicate that it is possible to separate the aerosol absorption effects from the scattering effects of clouds. This can be done by the combined use of the satellite measured top of the atmosphere reflectance and the derived aerosol index.

In addition to reasonable assumptions on aerosol particle size distribution to retrieve the aerosol optical depth of an above-cloud aerosol layer using near UV observations, knowledge of the aerosol single scattering albedo and the optical thickness of the underlying cloud are required. A two-parameter inversion procedure similar to the one used for the retrieval of aerosol optical depth and single scattering albedo under clear sky conditions can be used. The retrievable parameters in the AAAC scenario are the extinction optical depths of both the aerosol layer (AOD) and the cloud layer below (COD). A reasonable assumption on the aerosol single scattering albedo can be used or, if available, it can directly be taken from a nearby cloud-free pixel where the standard cloud-free retrieval has been successfully applied. The cloud-free region must be close enough to the overcast pixel to justify the assumption that the obtained single scattering albedo is representative of the absorption of the AAAC conditions. Another possibility is to make direct use of available data on COD as provided by Aura-MODIS after correcting for aerosol absorption effects as suggested by *Wilcox et a*l [2009]. That approach would allow the retrieval of the aerosol SSA, eliminating thus the need of assumptions.

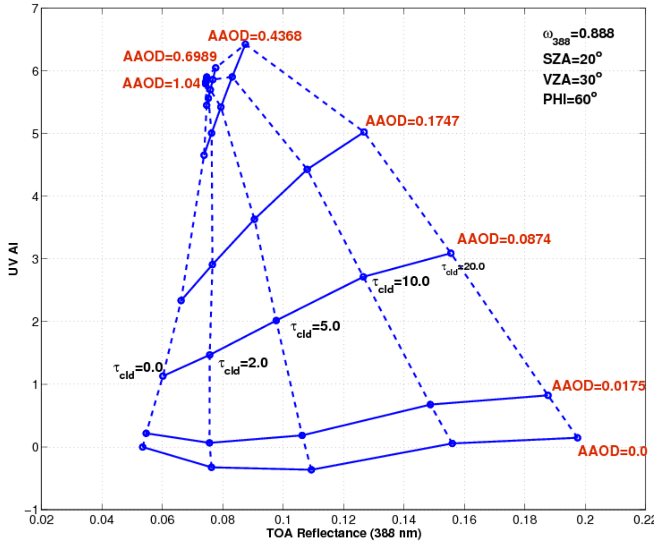

Figure 1. Retrieval scheme to obtain AAOD and effective cloud optical depth.

Figure 1 show the orthogonal representation of the AOD-COD retrieval domain when the SSA is assumed to be known. Solid lines are curves of constant aerosol absorption optical depth (AAOD) whereas dashed lines are associated with constant cloud optical depth. In this retrieval scheme a set of observations (reflectance and aerosol index) are associated with a set of retrieved parameters: AAOD and effective cloud optical depth. Preliminary results of a case study of the above-cloud aerosol retrieval on September 7, 2008 are illustrated in Figures 2 and 3. The left top panel in Fig. 2 shows the Aqua-MODIS RGB image depicting a horizontally extended (approximately 4000 km X 1500 km) cloud layer from the coasts of Angola and Namibia to the 45˚W meridian in the middle of the Southern Atlantic Ocean. The OMI Aerosol Index map on the right top panel shows the presence of an equally extended smoke layer located about 1 km above the stratocumulus cloud deck (based in CALIOP observations, not shown). The bottom panels of Fig. 2 illustrate the retrieved parameters: 388 nm aerosol optical depth (for a single scattering albedo value of 0.88), and the effective cloud optical depth (right). The obtained aerosol optical depth varies from 0.2 to about 0.8.

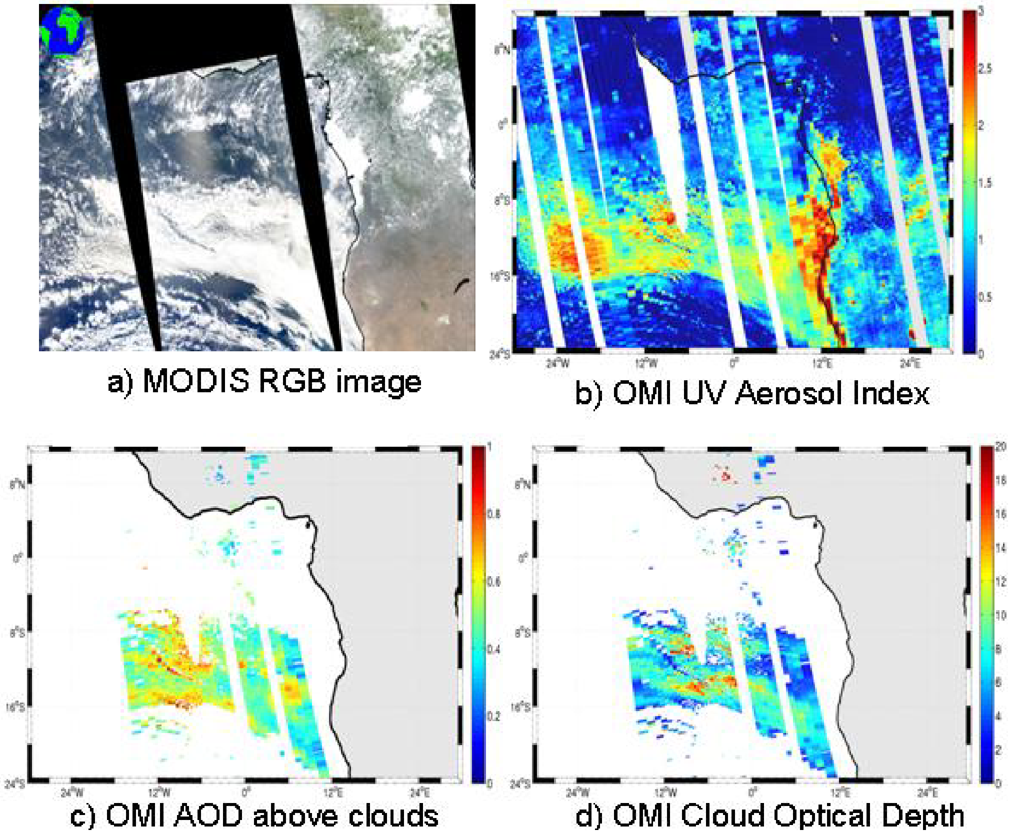

Figure 2. OMI application of aerosol-cloud mixtures.

Assessing the accuracy of the aerosol optical depth above clouds is a complicated task. We can, however, evaluate at least qualitatively the OMI cloud optical depth field by direct comparison with the MODIS cloud field. An acceptable level of consistency between the two cloud products provides confidence on the reasonableness of the aerosol optical depth product. The OMI retrieved cloud optical depth field and the Aqua-MODIS operational cloud optical depth product are compared in Figure 3. Accounting for the differences in spatial resolution, the spatial patterns of the OMI cloud optical depth product closely resembles those of the MODIS product. The scatter plot in the bottom panel of figure 3 shows a direct quantitative comparison of the OMI-MODIS cloud optical depth retrievals. Although the retrievals are highly correlated, the OMI values show a negative bias of about 3. The observed COD bias may be related to particular assumptions on aerosol-cloud separation, single scattering albedo, or cloud properties. Additional research is needed to understand these issues with a detailed sensitivity analysis.

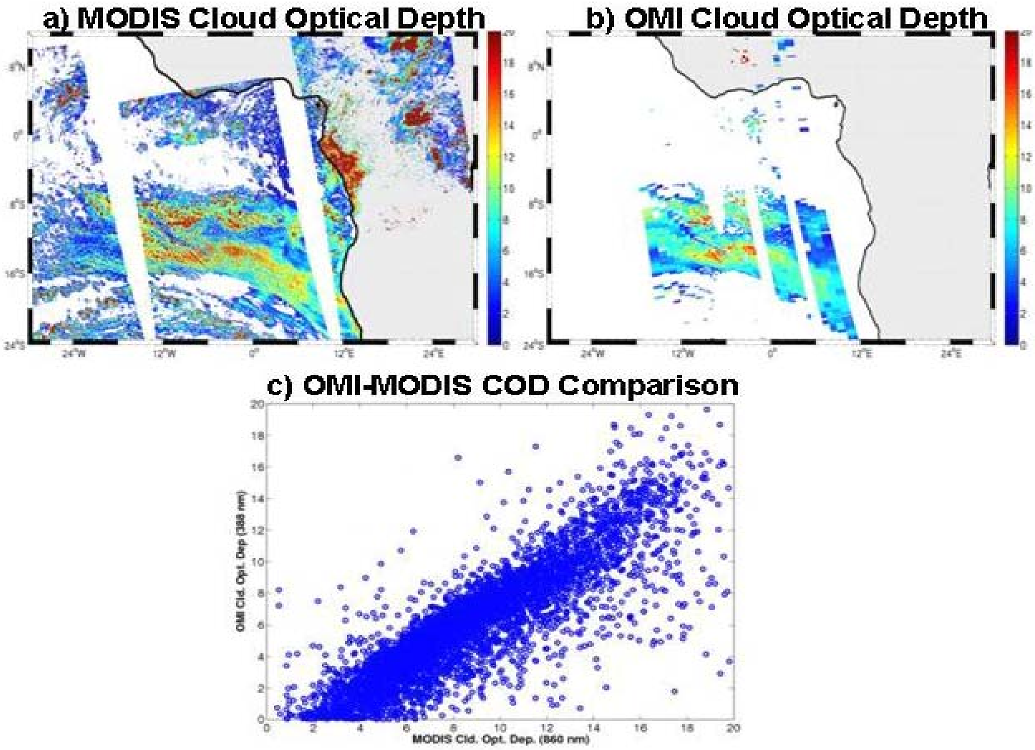

Figure 3. MODIS retrieved cloud optical depth (top left); OMI retrieved cloud optical depth (top right); scatter plot of MODIS and OMI cloud optical depth retrievals (bottom).

2.2 Estimation of spectral UV-VIS aerosol absorption

The imaginary component of the complex refractive index of aerosol particle components is the fundamental optical property driving particle absorption of incoming solar radiation. Information on aerosol refractive index and aerosol particle size distribution is used in conjunction with the appropriate scattering theory (generally Mie Theory for spherical particles) to calculate the scattering and absorption coefficients. The spectral dependence of aerosol absorption is thus directly determined by the aerosol composition. Following the theoretical work of *van de Hulst* [1957] the wavelength dependence of aerosol absorption is described as following a power-law function using an Absorption Ångstrom exponent (AAE) in a way similar to that used for describing the spectral dependence of extinction. As originally formulated the power-law relationship describing aerosol absorption is given by

$$\alpha_{ap} = K\lambda^{-AAE} \quad (1)$$

where α_{ap} is the aerosol absorption efficiency, K is a constant, and λ is the wavelength of the incident light. Grey aerosol types (i.e., wavelength independent imaginary refractive index) such as soot aerosols yield AAE values close to 1, whereas colored aerosols such as mineral dust produce AAE values significantly larger than unity. The above relationship has been verified with both laboratory measurements [*Bond,* 2001]. Recent theoretical and observational analysis [*Martins et al.* 2009; *Kirchstetter et al.,* 2004 and references therein] show that the spectral dependence of light attenuation due to absorption by black and organic carbon are indistinguishable in the visible spectral region but are markedly different in the UV as shown in Figure 4.

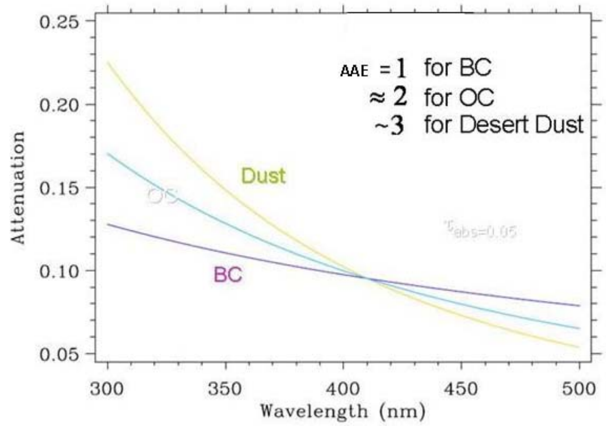

Figure 4. Typically observed spectral dependence of aerosol attenuation in terms of Angstrom exponent for black carbon, organic carbon, and desert dust aerosols (right)

The need to understand the wavelength dependence of the aerosol absorption optical depth (AAOD) has recently received considerable attention. Since the spectral dependence of the AAOD is linked to aerosol composition, knowledge of the AAOD wavelength dependence may be useful for the unambiguous differentiation of anthropogenic aerosol types (black carbon containing aerosols) from those of predominantly natural origin (organic carbon and hematite containing particles). Equation (1) can also be expressed in terms of column AAOD,

$$AAOD = K\lambda^{-AAE} \quad (2)$$

The above relationship has been verified with ground-based measurements of column aerosol absorption optical depth and other related aerosol data [*Russell el at,* 2010].

When absorbing aerosol layers lie above clouds, the observed reflectance is significantly reduced relative to what should be observed if no aerosols were present. This effect is illustrated in Figure 5 that shows the presence of an absorbing aerosol layer overlying a cloud as seen by the OMI Aerosol Index (left) in Southern China on April 14, 2006. The MODIS RGB (right) not only shows an underlying cloud deck but it also shows the darkening effect of the absorbing aerosols over the same area where the OMI AI indicates the presence of substantial absorbing aerosol amounts.

The spectrally dependent AAOD of the aerosol layer can be inferred making use of Beer's law,

$$\rho_\lambda(\theta, \theta_0, \phi) = \rho_{0_\lambda}(\theta, \theta_0, \phi) e^{-m\tau_{abs\,\lambda}} \quad (3)$$

where ρ_λ is the TOA reflectance, ρ_{0_λ} includes the combined effect of cloud reflectance, aerosol scattering, and molecular scattering, *m* represents the geometric air mass factor (or slant path), and τ_{abs_λ} represents the aerosol absorption optical depth. The reflectance is a function of solar zenith angle (θ), satellite zenith angle (θ_0) and relative azimuth angle (Φ). For an optically thick cloud the additional reflectance associated with the aerosol scattering effects is negligibly small and can be neglected. The molecular component, although small, can be accurately calculated. In this approximation the cloud is required to occupy the entire pixel of the sensor (i.e., the geometrical cloud fraction must be 1), and be so optically thick that the satellite measurement is not sensitive to the underlying surface effects.

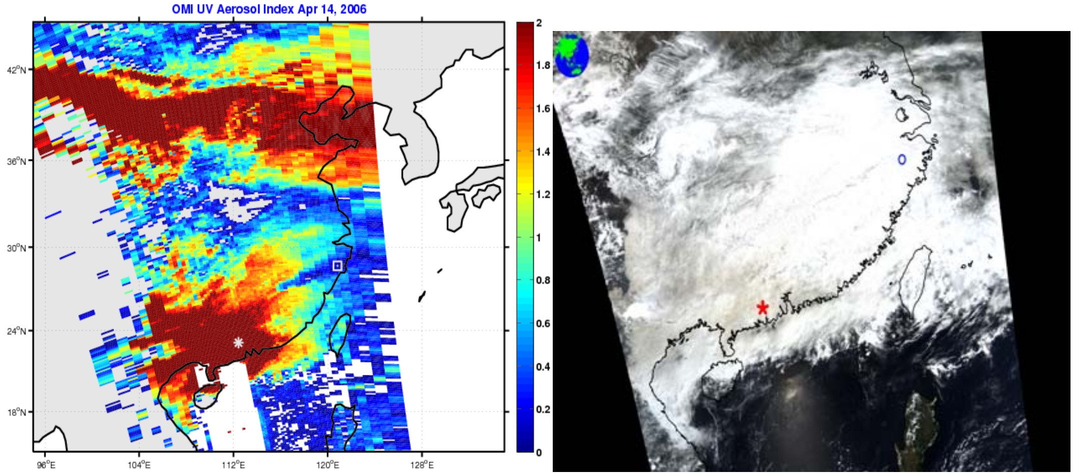

Figure 5. Left: absorbing aerosol layer as seen by the OMI aerosol index over Southern China on April 14, 2006. Right: Aqua-MODIS RGB image.

When both ρ_λ and ρ_{0_λ} are known, equation (3) can be solved for τ_{abs_λ} using multi-spectral or hyper-spectral satellite observations from the UV to the near IR. The term ρ_λ is directly given by the satellite measurement. The challenge in the application of this simple approach is the estimation of ρ_{0_λ} the cloud reflectance in the absence of aerosols. Figure 6 (left) depicts the reflectance in the 350-500 nm spectral range associated with an aerosol-free cloudy pixel (blue line) and that of the cloud-aerosol ensemble (red line). The symbols on the MODIS image (Figure 5) indicate the locations of the aerosol-laden (red star) and aerosol free (blue circle) pixels. Two aerosol-related effects are clearly observed in figure 6: a significant reduction of the reflectance at all wavelengths, and the introduction of a spectral dependence associated with the wavelength-dependent aerosol absorption effect acting on the almost wavelength-independent cloud reflectance.

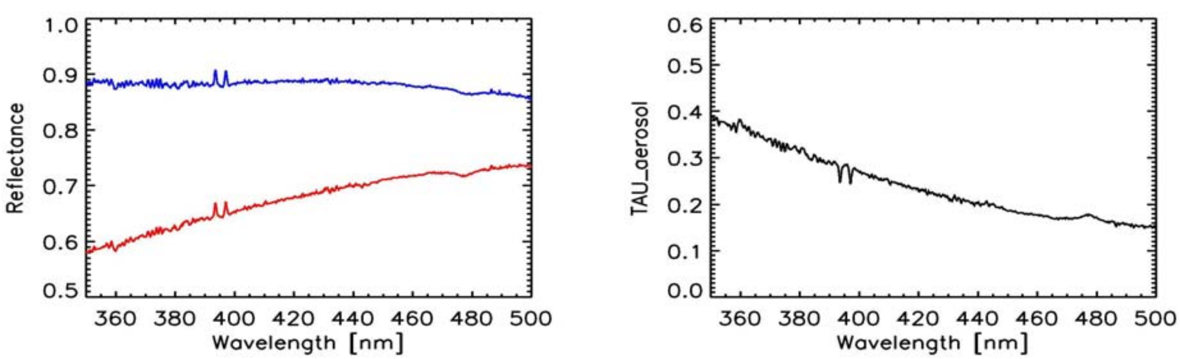

Figure 6. OMI measured reflectance (left), and derived spectral AAOD (right).

For illustration purposes, a simplified approximation of the proposed method has been applied to the OMI and MODIS observed reflectances. In this approximation, it has been assumed that the OMI reflectance field associated with the cloudy aerosol-free pixel is representative of the ρ_{0_λ} value for the pixel where both clouds and aerosols are present. The difference in viewing geometry between the two pixels is a source of uncertainty. The right panel of figure 6 shows the resulting spectral AAOD for the April 15, 2006 aerosol episode in

Southern China derived from OMI observations. The uncorrected effect of absorption associated with the O_2- O_2 complex at 477 nm is apparent. The spatial distribution of the OMI 388 nm and MODIS 470 nm AAOD are shown in Figure 7. In this demonstration application the 388 (470) nm cloud reflectance associated with the OMI (MODIS) pixel deemed free of aerosol interference was assumed to be representative of the entire region mapped in Figure 7.

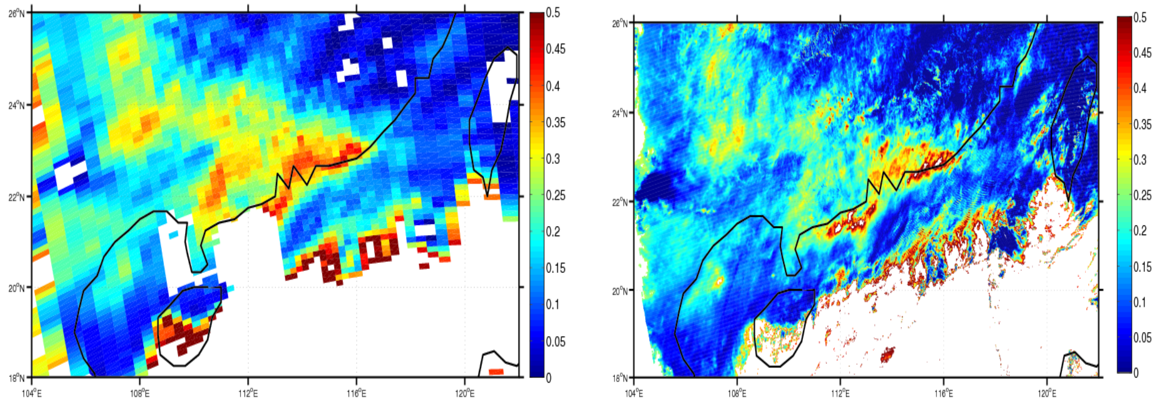

Figure 7. Spatial Distribution of AAOD at 388 (OMI) and 470 (MODIS) nm.

This AAOD measuring approach can also be applied to the near IR as long as the aerosol-free cloud radiance can be estimated. Thus, a key step in process is the characterization of the cloud reflectance properties. The MODIS observed spectral radiance of an optically thick cloud in India is shown in Figure 8. The reflectance of the observed opaque cloud at wavelengths up to 0.8 µm range exhibits a very weak spectral dependence. At wavelengths longer than about 0.8 µm, cloud reflectance decreases with wavelength.

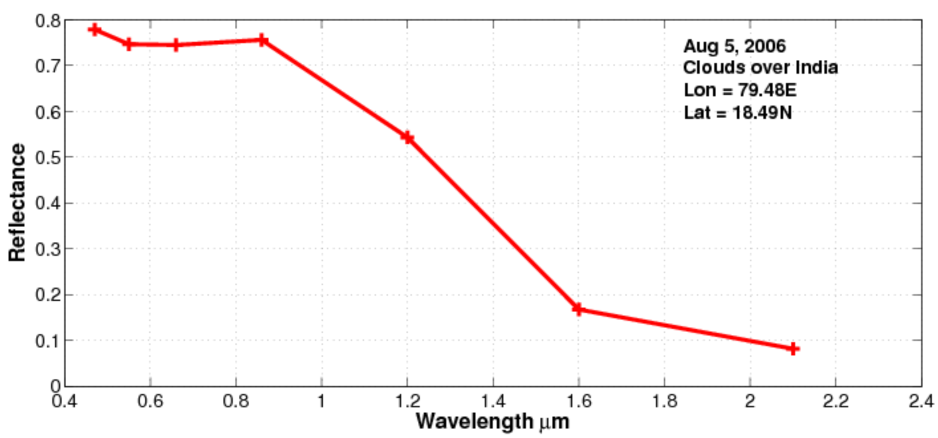

Figure 8. Cloud reflectance as a function of wavelength as observed by MODIS

The extinction optical depth of small particle aerosol types decreases rapidly with wavelength and becomes negligibly small in the shortwave infrared (SWIR). For instance, it has been shown [*Kaufman et al,* 1997] than the aerosol extinction optical depth at 2.1 µm is negligibly small and therefore the satellite observed reflectance at this wavelength can be interpreted as a direct measurement of the reflectance of the lower boundary of the atmospheric column. It may be possible to identify a similarly suitable SWIR channel where aerosol absorption becomes negligibly small so that it can be advantageously used to estimate the actual cloud reflectance in the presence of absorbing aerosols. A parameterization of the visible cloud reflectance in terms of the SWIR can be developed making use of satellite observations and radiative transfer calculations. Such a parameterization will be a function of a cloud properties and satellite viewing geometry.

2.3 Relevance to NASA Objectives

This proposed research furthers our National Objective to **"Study the earth system from space and develop new space-based and related capabilities for this purpose."** Aerosols are a fundamental part of the earth system, and this proposed study aims to focus on the very core nature of aerosol particles by developing and then using a new space-based method to determine aerosol composition.

This study is particularly relevant to the first of NASA's objectives under our National Objective, **"Conduct a program of research and technology development to advance Earth observation from space, improve scientific understanding, and demonstrate new technologies with the potential to improve future operational systems."** The proposed study will advance Earth observation from space by developing and applying an innovative remote sensing technique for studying the wavelength dependence of aerosol absorption from space.

In addition the proposed study is ideally suited to answer the first question from the atmospheric composition chapter of the U.S. Climate Change Science Program Strategic Plan, **What are the climate-relevant chemical, microphysical, and optical properties, and spatial and temporal distributions, of human-caused and naturally occurring aerosols?** We are proposing to provide a characterization of aerosol absorption properties as a function of wavelength that will enable us to clearly characterize aerosols according to their composition. More importantly we expect to contribute to the characterization of aerosol absorption, which is the single most climate-relevant aerosol property. An important likely outcome of this research is the capability of differentiating between natural and anthropogenic aerosols.

3.0 Proposed Work

3.1 Description

We propose a research effort to 1) produce global quantitative estimates of the near-UV aerosol absorption optical depth of aerosols above clouds using OMI observations in the manner described in section 2.1 of this proposal. We also propose the use of existing satellite observations (UV to near IR) under cloudy conditions to study the wavelength dependence of aerosol absorption as described in section 2.2.

In the proposed work the Absorbing Aerosol Index, derived from observations by sensors with UV-capability, will be used to identify the occurrence of absorbing aerosols above clouds. Measured spectral reflectances in the 0.35-0.8 μm spectral range associated with the AAI signal above clouds will be inverted to calculate the spectral aerosol absorption optical depth. A key step in process is the characterization of the cloud reflectance properties. The most promising approach is the identification of a spectral region in the shortwave infrared (SWIR) where the sensitivity to aerosol absorption effects is sufficiently small so that the measured reflectance in the presence of an absorbing aerosol layer can effectively be interpreted as the actual cloud reflectance.

3.2 Methodology

3.2.1 Task 1: Retrieving near-UV properties of AAAC's

-Continue work on sensitivity analysis to aerosol-cloud separation and single scattering albedo.

-Conduct tests on two retrieval approaches:

1) An OMI standalone method in which the aerosol SSA is prescribed and aerosol (AOD) and cloud optical depth (COD) are the retrieved parameters.
2) An OMI-MODIS combined approach in which MODIS COD is used as input and the retrieved parameters are AOD and SSA.
-Coding and testing of operational algorithm
-Application to OMI record

-Analysis of results

3.2.2 Task 2: Estimating spectral UV-VIS aerosol absorption optical depth

This study involves both theoretical and actual data analysis. Radiative transfer calculations will be used to model cloud reflectance as a function of wavelength, cloud parameters (cloud optical thickness, cloud top pressure, cloud drop effective radius), and viewing geometry. Calculations will be done for cloud only as well as cloud-aerosol combinations.

Radiative transfer calculations in conjunction with actual observations will be used to derive a parameterization scheme that will allow predicting visible cloud reflectance based on SWIR observations.

Activities to be carried out as part of the proposed work include:
-Sensitivity of cloud reflectance to particle size and cloud optical depth.
-Simulation of cloud reflectance and comparison to MODIS and OMI observations.
-Investigate the use of a channel in the SWIR as a predictor of cloud reflectance in the visible spectral region.
- Analysis and assessment of results.

3.3 Personnel

The proposed work will be carried out by Drs. Omar Torres (PI) from Hampton University and Changwoo Ahn (Co-I) from Science Systems and Applications Inc. Drs. Torres and Ahn have ample combined experience in satellite-based sensing of aerosol properties using backscattered solar radiation measurements. Dr. Pawan Bhartia of NASA Goddard Space Flight Center will participate as collaborator and offer his valuable experience in the analysis of satellite measured spectral data. Dr. Gassó of the University of Maryland Baltimore County who is involved in the combined use of OMI and MODIS observation for aerosol absorption characterization will collaborate in aspects related to collocation and integration of OMI, MODIS and other satellite data sets.

4.0 Anticipated Results

We anticipate the availability of a global OMI multi-year record of near UV aerosol optical depth above clouds, and global distribution of aerosol absorption Angstrom Exponent, an indicator of aerosol composition (black carbon, organic carbon, desert dust). In principle, if additional resources are obtained from other funding sources, this record can be extended back in time by applying the AAAC algorithm to the TOMS record. This data set will be instrumental in the characterization of the direct radiative forcing effect of aerosols above clouds and intercontinental transport.

5.0 Work Schedule

The listing below shows a chronology of activities to be carried out during the proposed two-year period. First year involves a series of preparatory tasks leading to the full implementation of the project as well as data analysis and assessment activities in year two.

Year 1

- Extend sensitivity analysis to quantify uncertainties associated with assumed aerosol and cloud parameters.
- Completion of AAAC algorithm development

- Prepare publication on initial results.

Year 2

- Application of AAAC algorithm to OMI record

-Assessment and evaluation of AAAC product

-AAAC product release

- Analysis of existing data hyper-spectral and multi-spectral cloud reflectance data sets (MODIS, OMI, others).

-Sensitivity analysis of aerosol effects on near-UV to near-IR radiances.

- Development of parameterization scheme to infer the aerosol-free cloud reflectance of aerosol contaminated cloudy pixels.

- Prepare publication on AAAC OMI product.

Year 3

- Application of measuring technique to OMI and MODIS observations.

- Analysis and assessments of results.

- Global characterization of aerosol types in terms of composition (desert dust, black and organic carbon) based on the obtained global distribution of the Ångstrom absorption exponent.

- Prepare publication on obtained results.

6.0 Facilities and Equipment

The work will be done using existing computing facilities at Hampton University and SSAI. No new equipment is requested.

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8.0 Biographical sketches

Dr. Omar Torres
Associate Professor
Hampton University
Email: omar.torres@hamptonu.edu
Voice: 757 728 6745

RESEARCH AREA EXPERIENCE
Radiative Transfer Modeling, Remote Sensing of Aerosols, Aerosol optical and physical properties

EDUCATION
-1978 - B.S., Geodetic Engineering, F.J.C. University, Bogota, Colombia
-1982 - M.S., Meteorology, University of The Philippines, Quezon City, The Philippines,
-1989 - Ph.D., Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA

CURRENT POSITION
-Associate Professor, 2008 – present, Department of Atmospheric and Planetary Sciences, Hampton University, Hampton, Virginia, 23668

PREVIOUS POSITIONS
- Associate Research Professor, 1999 – 2007, Joint Center for Earth Systems Technology, University of Maryland, Baltimore County, Baltimore, MD, 21250
-Principal Scientist, 1989 -1999, Raytheon STX Corporation, Lanham, MD
-Graduate Research Assistant, 1984-1989, School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA

SCIENCE TEAMS
-OMI Science Team, current member
-NPOESS Preparatory Project (NPP) Science Team, current member
-CALIPS0 Science Team, current member
-Glory-APS Science Advisory Group, current member

AWARDS
-NRL Alan Berman, Research Publications Award, 2008
-William T. Pecora Group Award, Total Ozone Mapping Spectrometer Team, December 13, 2006
-NASA Group Achievement Award, TOMS Team, April 27, 2006
-NASA Group Achievement Award, Aura Project, May 17, 2005
-GSFC Aerocenter Journal Citation Award, January 7, 2005

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Satheesh S.K, **O. Torres**, L.A. Remer, S. Suresh Babu, V. Vinoj, T.F. Eck **,** R.G. Kleidman and B.N. Holben, Improved Assessment of Aerosol Absorption using OMI-MODIS Joint Retrieval, *J. Geophys. Res*, 114, D05209, doi:10.1029/2008JD011024, 2009

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Dr. Changwoo Ahn

Dr. Changwoo Ahn is a senior research scientist with Science Systems and Applications Inc., to support the atmospheric chemistry and dynamics related studies at NASA Goddard Space Flight Center. For the last ten years, he has actively involved in developing algorithms for the total/profile ozone and aerosol products from space-borne UV instruments including TOMS, SBUV, and OMI. As a core member of the EOS Aura-OMI science team, he has responsibility for the development and maintenance of the operational OMI UV aerosol algorithm (OMAERUV) that is a unique data set for providing UV absorption properties of aerosols in a global scale. He also has extensive experience in analyzing and visualizing those products for the validation with external sources of other satellite sensors (i.e., MODIS, MISR, CALIPSO, AIRS, GOME, and GOES), and ground instruments (i.e., Dobson/Brewer, Sonde, Lidar, Microwave, UV-MFRSR, Umkehr, and AERONET sun photometer). His current research interests include developing a new innovative technique for retrieving aerosol absorption optical depth above clouds by making comparison with a sophisticated radiative transfer modeling approach in the UV through near IR wavelengths, and improving the UV Aerosol Index with wavelength dependent surface albedo data base and cloud models in the forward calculation of the top of the atmosphere radiance.

Prior to joining SSAI, he was a research associate with USRA (1997-1999) in support of the NASA's New Millennium Program EO-1 project at GSFC. During this period, he conducted a research for the pre-flight characterization of EO-1 by simulating broad band data from hyper-spectral airborne data (i.e., AVIRIS), and making performance comparisons with various novel detection and classification techniques.

He received a Ph.D. degree in remote sensing and GIS program from Purdue University (1996), and a M.S. degree in biometeorology and a B.S. degree in environmental science and ecological engineering from Korea University (1990 and 1988). Results from numerous NASA sponsored research projects he involved have been published in peer-reviewed journals, and presented at nationally and/or internationally recognized meetings/conferences.

He is the recipient of the NASA Group Achievement Award (OMI Instrument Team, 2009), SSAI Publication and Performance Awards (2008), the William T. Percora Award (TOMS Science Team, 2006), the NASA Group Award (Aura Project, 2005), the NASA/GSFC Exceptional Achievement Group Award (Aura Team, 2005), the Stevan J. Kristof Outstanding Graduate Student in Remote Sensing Award (1997), and a Purdue Research Fellowship (1996).

9.0 Current and Pending Support

9.1 Torres (PI)

Funded proposals as PI, current:

- Enhanced OMI Aerosol Product: Use of Information from A-train Sensors and Extension of Retrievas to Aerosol-Cloud mixtures;

NNX08AP85G-AST; 165K$/year, 5/12/2008 – 5/11/2011; PI Torres (0.08 FTE)

- EOS and NPP satellite data fusion to develop a long-term record on aerosol absorption

NNX08A047G: 133K$/year, 05/05/2008-05/04/2011; PI Torres (0.08 FTE)

- Particle Absorption Characterization fir the Retrieval of aerosol oprical depth from CALIPSO observations

NNX08AR46G-CCST 81.5K$/year, 05/05/2008-05/04/2011; PI Torres (0.08 FTE)

- Consulting in support of Glory-APS measurements of aerosol single scattering albedo

NNX08AO81G, 39K$/year, 05/05/2008-05/04/2010; PI Torres (0.08 FTE)

10.0 Budget justification

Table 1. Summary of proposal personnel and work efforts

Name	FY11	FY12	FY13
Omar Torres (HU)	0.08	0.08	0.08
Post-Doc Assoc. (HU)	0.50	0.50	0.50
Administration (HU)	0.08	0.08	0.08
Tech. support (HU)	0.08	0.08	0.08
C. Ahn (SSAI)	0.40	0.40	0.40

9.1 Hampton University

Year 1

Salaries:

A PI time dedication of 1 month/year (or 0.08 FTE) is included. The PI will oversee the overall project progress and be involved as needed in all aspects of the project. The PI will be closely involved in algorithm development, and data analysis. A post-doctoral research associate with a time dedication of 3 months/year (0.50 FTE) will directly oversee operational aspects of the project under the PI's supervision. Administration activities with a total of 0.08 FTE per year has been included. Technical support activities with a total of 0.08 FTE per year has been included. Standard HU fringe rates of 21.2% are used factored in the salaries section of the budget.

Travel:

Year 1 domestic travel budget includes trips to SSAI headquarters in Maryland by the PI or a project representative to attend work planning and progress report meetings with the SSAI co-I and NASA collaborators. It also includes at least one conference meeting to present results at a professional organization (i.e., AGU, AMS) gathering.

Travel to locations outside the United States once per year is planned. These trips are intended for participation in international conferences related to the topic of the research. All foreign travel expenses have been budgeted using Federal Government guidelines for international travel. .

Years 2, 3

Salaries:

These are the same as in year 1, except for a projected 3% increase. Travel justification is same as for year 1.

11.0 Budget details: *Hampton University*

Proposal Title:	**A UV-VIS record of aerosol absorption optical depth above clouds from A-train OMI and MODIS observations**							
Proposal:	**NASA - ROSES 10**							
	NNH10ZDA001N-AURA Science Team							
Principal Investigator:	**Omar Torres, Hampton University**							
Co-I :	**Changwoo Ahn , SSAI**							
Collaboraters:	**Pawan Bhartia, NASA-GSFC**							
	Santiago Gasso, UMBC							
Proposal Term:	**February 2, 2011 to January 31, 2014**							
Hampton Budget								
		YEAR 1		YEAR 2		YEAR 3		TOTAL
Salaries	FTE							
Omar Torres	1mo	11,560	3.0%	11,907	3.0%	12,265		35,732
Post Doctoral Research Associate	6mo	29,760	3.0%	30,653	3.0%	31,573		91,986
Technical Support	1mo	3,514	3.0%	3,619	3.0%	3,728		10,861
Administrative	1mo	3,889	3.0%	4,006	3.0%	4,126		12,021
Total Salary		48,723		50,185		51,692		150,600
Fringes								
0	21.2%	2,451	21.2%	2,524	21.2%	2,600		7,575
0	21.2%	6,309	21.2%	6,498	21.2%	6,693		19,500
Tech Support	21.2%	745	21.2%	767	21.2%	790		2,302
Administrative	21.2%	824	21.2%	849	21.2%	875		2,548
Total Fringe Benefits		10,329		10,638		10,958		31,925
Total Salary and Fringes		**59,052**		**60,823**		**62,650**		**182,525**
Graduate Student (tuition/aid) No IDC	2sem/su	11,500	3.0%	11,845	3.0%	12,200		35,545
Graduate Student Stipend No IDC $1750/mo/YR1 $2(		21,000		24,000		24,000		69,000
Graduate Student Travel Dom/For		1,000		1,000		1,000		3,000
Total Student Tuition/Aid		**33,500**		**36,845**		**37,200**		**107,545**
Subcontractor								
SSAI (IDC 25K)		60,000		60,000		60,000		180,000
Total Subcontractor		**60,000**		**60,000**		**60,000**		**180,000**
Other Direct Costs								
Domestic Travel		2,000		2,000		2,000		6,000
Foreign Travel		5,400		6,000		6,000		17,400
Publications								
Other Supplies		70		70		68		208
Total Other Direct Costs		**7,470**		**8,070**		**8,068**		**23,608**
Total Direct Costs		**160,022**		**165,738**		**167,918**		**493,678**
MTDC		91,522		68,893		70,718		231,133
Indirect Costs	46%	42,100		31,691		32,530		106,321
Total Hampton Costs		**202,122**		**197,429**		**200,448**		**599,999**
DC		160,022		165,738		167,918		493,678
less tuition/aid		(33,500)		(36,845)		(37,200)		(107,545)
less subcontractor over 25K		(35,000)		(60,000)		(60,000)		(155,000)
MTDC		91,522		68,893		70,718		231,133

SSAI SCIENCE SYSTEMS AND APPLICATIONS, INC.

July 19, 2010

Ms. Cheryl Keeling
Dept. of Atmospheric and Planetary Sciences
Hampton University
Hampton, Virginia 23668

Subject: Cost Proposal in Response to Statement of Work

Dear Ms. Keeling:

Science Systems and Applications, Inc. (SSAI) is pleased to submit our Cost Proposal for supporting "A UV-VIS Record of Aerosol Absorption Optical Depth Above Clouds From A-train OMI and MODIS Observations".

This proposal is valid for 180 days. Attached is a copy of the budget, the response to the statement of work and letter of commitment.

If you should have any questions, please contact Cindy Martin at 301-867-6315.

Sincerely,

for Jenni Good

Linda Aguirre
Controller

Encl.

❑ **Headquarters:** 10210 Greenbelt Road, Suite 600 • Lanham, MD 20706 • (301) 867.2000 • Fax: (301) 867.6246
❑ **Hampton Office:** 1 Enterprise Parkway, Suite 600 • Hampton, VA 23666 • (757) 951.1600 • Fax: (757) 951.1900
www.ssaihq.com

SSAI SCIENCE SYSTEMS AND APPLICATIONS, INC.

July 19, 2010

Ms. Cheryl Keeling
Dept. of Atmospheric and Planetary Sciences
Hampton University
Hampton, Virginia 23668

Dear Ms. Keeling,

SSAI hereby acknowledges that Dr. Changwoo Ahn is identified by name as the Co-Investigator on the proposal entitled "A UV-VIS Record of Aerosol Absorption Optical Depth Above Clouds From A-train OMI and MODIS Observations". Dr. Ahn intends to carry out all responsibilities identified for him in this proposal. SSAI understands that the extent and justification of Dr. Ahn's participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal.

Sincerely,

Anoop Mehta
Vice President and CFO

❑ **Headquarters:** 10210 Greenbelt Road, Suite 600 • Lanham, MD 20706 • (301) 867.2000 • Fax: (301) 867.6246
❑ **Hampton Office:** 1 Enterprise Parkway, Suite 600 • Hampton, VA 23666 • (757) 951.1600 • Fax: (757) 951.1900
www.ssaihq.com

SSAI SCIENCE SYSTEMS AND APPLICATIONS, INC.

Statement of Work

Dr. Changwoo Ahn (Co-I, SSAI) will contribute with his expertise on the OMI retrieval algorithm and data analysis. He will develop a new innovative technique for retrieving aerosol absorption optical depth (AAOD) over optically thick clouds from the direct measurement of radiances in the UV to Visible from space (e.g. OMI and MODIS) by accounting for spectral dependence of AAOD for smoke and dust. Those new products will be compared with results from sophisticated radiative transfer calculations with carefully prepared known parameters from observations, model simulations, and field measurements of airborne sun photometer (AATS) and flux spectrometer. Dr. Ahn will collaborate closely with the team of Dr. Omar Torres currently conducting a NASA funded project for retrieving AAOD over clouds independently.

Changwoo Ahn, Ph.D.
Science Systems and Applications, Inc.
301-867-2171
changwoo.ahn@ssaihq.com

BUDGET JUSTIFICATION

BUDGET DETAILS

This proposal is submitted by Science Systems and Applications, Inc. (SSAI). This proposal includes labor for Changwoo Ahn (Co-I) and a minimal labor amount for Management personnel. This research is planned to run for three years (FY2011, FY2012 and FY2013). Table 1 below shows a breakdown of the funds that are proposed. The indirect costs include the employee fringe benefits, overhead, as well as SSAI General and Administrative charges (G&A).

TABLE 1: Breakdown of costs that are to be sent directly to SSAI to finance the proposal.

SSAI Proprietary Information

A UV-VIS Record of Aerosol Absorption Optical Depth Above Clouds From A-train OMI and MODIS Observations
Period of Performance: February 2, 2011 - January 31, 2014

Element of Cost	Year 1	Year 2	Year 3	Total
Ahn, Chang Woo . HOURS	732	697	663	2,092
PROGRAM MANAGER HOURS	44	42	40	126
CONTRACT ADMINISTRATOR HOURS	44	42	40	126
TOTAL HOURS	820	781	743	2,344
Ahn, Chang Woo . COST	52,655	52,638	52,638	157,932
PROGRAM MANAGER COST	4,739	4,749	4,749	14,238
CONTRACT ADMINISTRATOR	2,606	2,612	2,612	7,831
DIRECT LABOR COST	$60,000	$60,000	$60,000	$180,000
Total	**$60,000**	**$60,000**	**$60,000**	**$180,000**

*Note these costs are loaded through fee.

SSAI Direct Labor

Changwoo Ahn, Co-I, SSAI:
Years 1 - 3 approximately 0.4 FTE (or 4.8 calendar months)

INDIRECT COSTS

Facilities and Administration Costs: DCAA has not established any forward pricing agreements with us. Our indirect costs are applied to this price proposal in accordance with approved accounting practices as audited by DCAA. We provide the following data for the applicable indirect cost pools: ***Fringe Benefit Expense Pool:*** This pool contains our budget for expenses related to employee welfare. The fringe benefit rate is rolled into the on-site overhead, off-site overhead and general and administrative pool to calculate these indirect rates. ***Overhead Costs:*** Overhead costs are those costs that cannot be assigned to a particular contract or costs, which are not directly identified with a single, final cost objective, but are costs identified with two or more final cost objectives. Our overhead costs include, but are not limited to, employee fringe benefits, general operating expenses, and depreciation. Our overhead costs are allocated in accordance with standards promulgated by the Cost Accounting Standards (CAS) Board and/or in accordance with generally accepted accounting principles. The overhead rates are calculated by dividing the company's overhead pool total by our direct labor dollar base. ***General and Administrative:*** General and Administrative (G&A) costs include all necessary costs of doing business, other than those appropriately classified as overhead and/or direct costs. These include the salaries of officers (unless directly chargeable to one of the other areas), salaries of all clerical help not directly charged elsewhere, general legal, auditing, recruiting, and other professional expenses. The allocation of G&A cost is in accordance with generally accepted accounting principles. Our G&A rate is calculated by dividing the company's G&A pool total by the total cost input base. The total cost input base includes, direct labor, overhead, direct costs, and unallowable expenses (e.g., entertainment, interest).

The name and address and number of the DCAA agency official having cognizance is as follows:

Ms. Alisa Sheppard

SSAI Proprietary Information