Cover Page for Proposal Submitted to the National Aeronautics and Space Administration	NASA Proposal Number **10-AURA10-0011**

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
Michael Newchurch	**mike@nsstc.uah.edu**	**256-961-7825**

Street Address (1)	Street Address (2)
320 Sparkman Dr NW	

City	State / Province	Postal Code	Country Code
Huntsville	**AL**	**35805-1912**	**US**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
02 / 01 / 2011	**01 / 31 / 2014**	**657,713.00**	**216,393.00**	**220,875.00**	**220,445.00**

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
07 / 30 / 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
Yes	**Other**

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
949687123	**9B944**	**630520830**	**2A**

Organization Name (Standard/Legal Name)	Company Division
University Of Alabama, Huntsville	

Organization DBA Name	Division Number
UAHUNTSVILLE	

Street Address (1)	Street Address (2)
301 SPARKMAN DR NW	

City	State / Province	Postal Code	Country Code
HUNTSVILLE	**AL**	**35805-1911**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Michael Newchurch	**mike@nsstc.uah.edu**	**256-520-1882**

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
Gloria Greene	**greeneg@uah.edu**	**256-824-2657**

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

PI Name : **Michael Newchurch**	**NASA Proposal Number**
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Michael Newchurch**	**256-961-7825**	**mike@nsstc.uah.edu**
Organization/Business Relationship: **University Of Alabama, Huntsville**		Cage Code: **9B944**	DUNS#: **949687123**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Randall Martin**	**902-494-3915**	**rvmartin@cfa.harvard.edu**
Organization/Business Relationship: **DALHOUSIE UNIVERSITY**		Cage Code: **L3832**	DUNS#: **207799404**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Thomas Kurosu**	**617-495-7213**	**tkurosu@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Astrophysical Observatory**		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	**Xiong Liu**	**617-496-2136**	**xliu@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Astrophysical Observatory**		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
Consultant	**Jae Kim**	**256-961-7825**	**iamjaekim@gmail.com**
Organization/Business Relationship: **Pusan National University, South Korea**		Cage Code: **N/A**	DUNS#: **N/A**
International Participation: **Yes**	U.S. Government Agency:		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Postdoctoral Associate	**Lihua Wang**	**256-961-7786**	**lihuawang@nsstc.uah.edu**
Organization/Business Relationship: **University Of Alabama, Huntsville**		Cage Code: **9B944**	DUNS#: **949687123**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION VII - Project Summary

We propose a three-year plan to study the global, four-dimensional characterization of the spatio-temporal variability/covariability of critical air-quality species measured by AURA and other instruments over long time periods, using a new scientific approach, the empirical orthogonal function (EOF) and singular value decomposition (SVD).

We will conduct EOF/SVD analyses on satellite observations (OMI, GOME, SCIAMACHY, MOPITT, AIRS, ATSR) of trace gases (HCHO, CO, NO2, O3, CHOCHO, etc) and fire counts. By studying the spatial and temporal patterns obtained from EOF/SVD analyses, we will evaluate our hypotheses that (1) AURA measurements reveal geophysical patterns in trace gases similar to SCIAMACHY and GOME observations, (2) The spatial and temporal patterns of AURA trace-gas measurements are consistent with known processes affecting those gases.

We will calculate EOF/SVD metrics for the GEOS-Chem model calculations of species and quantities involved in the processes controlling HCHO, NO2, and O3 in Africa, South America, and North America. The result of this research will be an improvement in our ability to produce air-quality forecasts and to assess importance of controlling processes.

PI Name : **Michael Newchurch**

Organization Name : **University Of Alabama, Huntsville**

NASA Proposal Number

10-AURA10-0011

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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?

Yes

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

Explanation :

Professor Jae Kim (Pusan National University) will collaborate on statistical analyses of satellite retrievals from Aura and possibly satellites.

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 : **Michael Newchurch**	**NASA Proposal Number**
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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 : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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 : **Michael Newchurch**	**NASA Proposal Number**
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: EOF Analyses of Aura 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 : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	20,561.00	21,590.20	22,669.00	64,820.20
B. Direct Labor - Other Personnel	84,750.00	88,029.80	92,748.00	265,527.80
Total Number Other Personnel	4	4	4	12
Total Direct Labor Costs (A+B)	105,311.00	109,620.00	115,417.00	330,348.00
C. Direct Costs - Equipment	0.00	0.00	0.00	0.00
D. Direct Costs - Travel	5,995.00	5,929.00	6,641.00	18,565.00
Domestic Travel	2,451.00	2,385.00	2,301.00	7,137.00
Foreign Travel	3,544.00	3,544.00	4,340.00	11,428.00
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	35,600.00	36,005.00	36,430.00	108,035.00
Materials and Supplies	4,100.00	4,305.00	4,520.00	12,925.00
Publication Costs	4,000.00	4,200.00	4,410.00	12,610.00
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	27,500.00	27,500.00	27,500.00	82,500.00
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)	146,906.00	151,554.00	158,488.00	456,948.00
H. Indirect Costs	69,487.00	69,321.00	61,957.00	200,765.00
I. Total Direct and Indirect Costs (G+H)	216,393.00	220,875.00	220,445.00	657,713.00
J. Fee	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	216,393.00	220,875.00	220,445.00	657,713.00
Total Cumulative Budget				657,713.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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 ($)	Funds Requested ($)
Newchurch, Michael	PI_TYPE	153,911.00	1.2			15,344.00	5,217.00	20,561.00
							Total Key Personnel Costs	20,561.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students	12			19,200.00	11,575.00	30,775.00
1	Undergraduate Students	12			9,360.00	0.00	9,360.00
1	Research Coordinator	1.2			4,296.00	1,461.00	5,757.00
1	Research Associate	7.2			28,999.00	9,859.00	38,858.00
4	Total Number Other Personnel					Total Other Personnel Costs	84,750.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	105,311.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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 ($)
	Total Equipment Costs	0.00

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	2,451.00
2. Foreign Travel	3,544.00
Total Travel Costs	5,995.00

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 : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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	4,100.00
2. Publication Costs	4,000.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	27,500.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	35,600.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	146,906.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC	47.30	146,906.00	69,487.00
Cognizant Federal Agency: DHHS, Darryl Mayes, Director, (202) 401-2808		**Total Indirect Costs**	69,487.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	216,393.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	216,393.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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 ($)	Funds Requested ($)
Newchurch，Michael	PI_TYPE	161,607.00	1.2			16,112.00	5,478.20	21,590.20
							Total Key Personnel Costs	21,590.20

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students	12			19,200.00	12,154.00	31,354.00
1	Undergraduate Students	12			9,828.00	0.00	9,828.00
1	Research Associate	7.2			30,450.00	10,353.00	40,803.00
1	Research Coordinator	1.2			4,511.00	1,533.80	6,044.80
4	Total Number Other Personnel					Total Other Personnel Costs	88,029.80

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	109,620.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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)	**2,385.00**
2. Foreign Travel	**3,544.00**
Total Travel Costs	**5,929.00**

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 : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

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	4,305.00
2. Publication Costs	4,200.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	27,500.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	36,005.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	151,554.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC	47.30	146,554.00	69,321.00
Cognizant Federal Agency: DHHS, Darryl Mayes, Director, (202) 401-2808		**Total Indirect Costs**	69,321.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	220,875.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	220,875.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2013	**01 / 31 / 2014**	**Project**	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Newchurch, Michael	PI_TYPE	169,687.00	1.2			16,917.00	5,752.00	22,669.00
							Total Key Personnel Costs	22,669.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students	12			20,400.00	12,759.00	33,159.00
1	Undergraduate Students	12			10,400.00	0.00	10,400.00
1	Research Associate	7.2			31,972.00	10,870.00	42,842.00
1	Research Coordinator	1.2			4,736.00	1,611.00	6,347.00
4	Total Number Other Personnel					Total Other Personnel Costs	92,748.00

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	115,417.00

PI Name : **Michael Newchurch**	NASA Proposal Number
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2013	**01 / 31 / 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)	**2,301.00**
2. Foreign Travel	**4,340.00**
Total Travel Costs	**6,641.00**

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 : **Michael Newchurch**	**NASA Proposal Number**
Organization Name : **University Of Alabama, Huntsville**	**10-AURA10-0011**

Proposal Title : **Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2013	**01 / 31 / 2014**	**Project**	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	4,520.00
2. Publication Costs	4,410.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	27,500.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	36,430.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	158,488.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC	47.30	130,988.00	61,957.00
Cognizant Federal Agency: DHHS, Darryl Mayes, Director, (202) 401-2808		**Total Indirect Costs**	61,957.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	220,445.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	220,445.00

Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Processes and Photo-chemical Consistency

Principal Investigator
Professor Michael J. Newchurch
Atmospheric Science Department
University of Alabama in Huntsville

Co-Investigators
Jae Kim
Randall Martin
Lihua Wang

Collaborators
Thomas Kurosu
Xiong Liu

In Response to NASA Solicitation No. NNH10ZDA001N-AURA

Research Opportunities in Atmospheric Composition: Aura Science Team --2010

August 2, 2010

Table of Contents

1. Summary of Proposed Research

We propose a three-year plan to study the global, four-dimensional characterization of the spatio-temporal variability/covariability of critical air-quality species measured by AURA and other instruments over long time periods, using a new scientific approach, the empirical orthogonal function (EOF) and singular value decomposition (SVD).

We will conduct EOF/SVD analyses on satellite observations (OMI, GOME, SCIAMACHY, MOPITT, AIRS, ATSR) of trace gases (HCHO, CO, NO_2, O_3, CHOCHO, etc) and fire counts. By studying the spatial and temporal patterns obtained from EOF/SVD analyses, we will evaluate our hypotheses that
(1) AURA measurements reveal geophysical patterns in trace gases similar to SCIAMACHY and GOME observations, (2) The spatial and temporal patterns of AURA trace-gas measurements are consistent with known processes affecting those gases.

We will calculate EOF/SVD metrics for the GEOS-Chem model calculations of species and quantities involved in the processes controlling HCHO, NO_2, and O_3 in Africa, South America, and North America. The result of this research will be an improvement in our ability to produce air-quality forecasts and to assess importance of controlling processes.

2. Scientific/Technical/Management

2.1 Introduction to proposed research

Formaldehyde (HCHO) plays an important role in atmospheric chemistry as an oxidation product from a large number of VOCs and a tracer molecule for the production of the HOx family, which is a major oxidizer throughout the entire atmosphere. In urban areas, anthropogenic Volatile Organic Compound (VOC)s are the most significant source of HCHO production, but biogenic VOCs dominate elsewhere especially during the growing season, with the largest contribution coming from isoprene (*Dufour, et al.*, 2009; *Millet, et al.*, 2008; *Palmer, et al.*, 2006; *Palmer, et al.*, 2003). In addition, large sources of HCHO are directly emitted from biomass burning (*Lee, et al.*, 1997), incomplete combustion of fuels from mobile sources (*de Serves*, 1994), process emissions from oil refineries, and vegetation (*Kesselmeier and Staudt*, 1999; *Lathière, et al.*, 2006). Therefore, the various source types correspond to different spatial and temporal HCHO distributions across the globe.

The GOME instrument provides the first global coverage of HCHO measurements with a spatial resolution of 40 x 320 km^2 (*Thomas, et al.*, 1998). Currently, OMI and SCIAMACHY are observing global HCHO with better spatial resolutions (OMI: 13 x 24 km^2; SCIAMACHY: 60 x 30 km^2). These global observations have identified elevated HCHO concentrations associated with biogenic isoprene emissions, biomass burning, and urban pollution (*Chance, et al.*, 2000; *Kurosu, et al.*, 2008).

The direct result from satellite HCHO retrieval is the HCHO slant column, which is converted to vertical columns using a reference table of air mass factors (AMFs) (*Kurosu, et al.*, 2008). Large uncertainties exist in these HCHO vertical columns, which typically range from 40-105% (*Kurosu, et al.*, 2008; *Palmer, et al.*, 2006).

There have been various methods to validate the retrieved data for (1) quantifying the errors and (2) extracting physically meaningful results. The evaluations of satellite HCHO measurements with in-situ observations have been limited by sparse spatial sampling in the lower mixed layer (*Heland, et al.*, 2002; *Ladstätter-Weißenmayer, et al.*, 2003). Comparisons with box models and chemical transport models show that OMI HCHO columns over the seasons are 35% lower than GEOS-CHEM and the Model of Emissions of Gases and Aerosols from Nature (MEGAN), but GOME HCHO columns are 10-30% higher than GEOS-CHEM and MEGAN (*Dufour, et al.*, 2009; *Millet, et al.*, 2008; *Palmer, et al.*, 2006). In addition, there is a significant discrepancy between the seasonality of GOME-measured and GEOS-CHEM-simulated HCHO (*Shim, et al.*, 2005). Inter-comparison between the satellite HCHO measurements are challenging because: (1) GOME HCHO retrievals are no longer reliable due to the advanced instrument degradation; and (2) SCIAMACHY data are strongly influenced by instrument artifacts that render the retrieval of HCHO challenging. In evaluation of consistency by comparing HCHO column measurements from the same season in different years, OMI HCHO vertical columns over regions with enhanced HCHO are in reasonable agreement with what has been observed from GOME in the past and is currently retrieved by SCIAMACHY (*Kurosu, et al.*, 2008). However, OMI columns over such hot-spots are about 30% lower than GOME and SCIAMACHY (*Kurosu, et al.*, 2008). OMI HCHO columns over North America fall 2-14% below the curve defined by the ensemble of the GOME data (*Millet, et al.*, 2008).

The nitrogen oxides, NO and NO_2 (NO_x), are important trace gases in the troposphere. The presence of sufficient quantities of NO_x may result in the photochemical production of ozone. Important NO_x sources include fossil-fuel combustion, biomass burning, microbial activity in soils, and lightning. OMI tropospheric NO_2 columns are retrieved based on Bucsela et al. (2006) and Celarier et al. (2008)'s method and available through the NASA Goddard Earth Sciences Data and Information Services Center (GES-DISC).

The carbon monoxide, CO, plays a key role in controlling the abundance of tropospheric ozone and the hydroxyl radical. In addition, CO is an important indicator of biomass burning, and thus precursor of organic aerosol.

2.2 Research objectives and expected significance

We propose a three-year plan to study the global, four-dimensional characterization of the spatio-temporal variability/co-variability of critical air-quality species over extended measurement periods, using a new scientific approach, the empirical orthogonal function (EOF) and singular value decomposition (SVD).

We will conduct EOF/SVD analyses on satellite observations (OMI, GOME, SCIAMACHY, MOPITT, AIRS, ATSR) of trace gases (HCHO, CO, NO_2, O_3, CHOCHO, etc.) and fire counts. By studying the spatial and temporal patterns obtained from EOF/SVD analyses, we will evaluate our hypotheses that

(1) AURA measurements reveal geophysical patterns in trace gases similar to SCIAMACHY and GOME observations,

(2) The spatial and temporal patterns of AURA trace-gas measurements are consistent with known processes affecting those gases

We also propose to create a 5-year GEOS-Chem model simulation for the time period of OMI HCHO observations. We will apply EOF/SVD analyses to model-simulated trace-gas fields, in order to understand the factors (i.e., processes, Air Mass Factor, etc.) that contribute to the observed spatio-temporal variability in the satellite observations. We will evaluate the photo-chemical consistency between satellite observations and GEOS-Chem model calculations in North America, Africa, and South America.

We expect the proposed research will quantify the extent to which the AURA satellite trace-gas observations allow us to improve air-quality forecasts and assessments.

2.3 Scientific approach and methodology

2.3.1 EOF and SVD methods

The disagreement between various satellite measurements and models (described in section 2.1) brings into question the ability of remote-sensing of tropospheric composition to verify our present understanding of tropospheric chemistry. In the mean time, most comparisons mentioned above have been preceded by statistical regression analysis. Regression is a generic term for all methods attempting to fit a model to observed data in order to quantify the relationship between two groups of variables. However, the disadvantage of regression analysis is that the obtained relationship may not be scientifically useful or valid. Therefore, the results of regression equations should be interpreted with caution (*Strik,* 1995). The regression analyses in satellite HCHO comparisons reveal some agreement within confined regions and time periods, resulting in only two-dimensional evaluations. Therefore, a new way of satellite HCHO evaluation is required (*Kurosu, et al.,* 2008).

In this proposal, we plan to use a new scientific approach to provide four-dimensional results of comparisons with a global picture over long measurement periods. Instead of using the typical station-to-station inter-comparison, we will perform the evaluation at the global scale using temporal and spatial patterns derived from the statistical analyses, which can provide four-dimensional results. An additional advantage of this approach is that it will enable us to evaluate the satellite trace-gas measurements based on morphology and seasonality of emission sources and chemical process from various tropospheric constituents. This task can be achieved by assessing the homogeneity of the satellite HCHO products derived from different platforms. In this approach, other satellite measurements linked to trace gas distributions, such as biomass-burning fire counts observed by ATSR, MOPITT CO, satellite NO_2, and others, will be used jointly with HCHO measurements to examine photochemical consistency of their spatial and temporal patterns. The tool is the empirical orthogonal function (EOF) and the singular value decomposition (SVD), a promising statistical tool for identifying spatio-temporal patterns of individual/two parameters. This approach will be different from the conventional ways of comparing patterns.

The EOF/SVD approach has been used for decades in weather research (*Lorenz*, 1956; *Quadrelli and Wallace*, 2004; *Smith, et al.*, 1996), but has not been used extensively with satellite chemical data or output from global chemical transport models. The EOF method analyzes the variability of a single field, finds the spatial patterns of variability (called the EOFs), its time variation (called the EOF time series or expansion coefficients), and gives a quantitative measure of the importance of each pattern. For example, the EOF analyses of GOME, SCIAMACHY, and OMI HCHO, and MOPITT CO show dipole distributions oscillating between northern and southern equatorial Africa with annual cycles (Figure 1). The locations of maximum HCHO and CO agree well with the fires over south central Africa for the southern burning season. Maximum burning was observed in July followed by maximum HCHO in August and maximum CO during the September-October period over southern Africa.

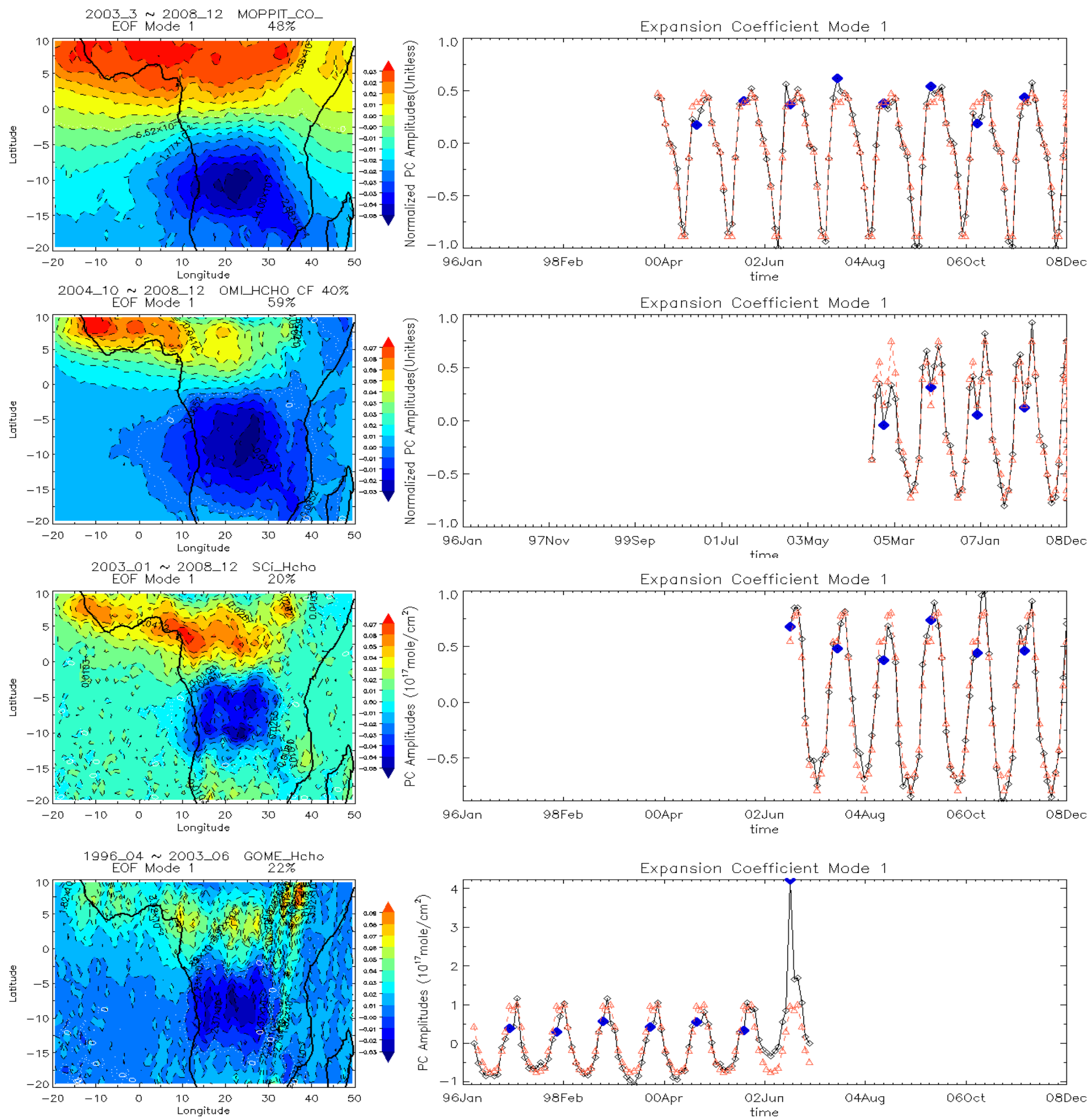


Figure 1. EOF analyses of MOPITT CO, OMI HCHO, GOME HCHO, and, SCIAMACHY HCHO over Africa, respectively. The left panels are the first mode of EOF, and the right panels show the time series of the corresponding expansion coefficient of EOF mode 1 (black lines) with January values marked as blue diamonds. The red line represents the monthly average over the entire measurement period.

The SVD method examines the coupled variability of two fields. Each pair of singular vectors describes a fraction of the square covariance (SC) between the two variables. The first mode describes the largest fraction of the SC, and each succeeding pair describes the maximum remaining fraction of the SC that is unexplained by the previous pairs. The square covariance fraction accounted for by the k^{th} pair of singular vectors is proportional to the square of the k^{th} singular value. The k^{th} time-series expansion coefficient of each variable is computed by projecting the respective k^{th} singular vector onto each original data field. The correlation value r between the k^{th} time-series expansion coefficients of the two variables indicates the strength of the relationship between the coupled patterns (*Venegas, et al.*, 1997). The SVD analyses with OMI HCHO and MOPITT CO (Figure 2 (a)), SCIAMACHY HCHO and MOPITT CO (Figure 2 (b)) shows that the dipole distribution feature over Africa is exactly coincident with the spatial and temporal pattern of biomass burning. The statistical analyses of all data agree well with the biomass-burning activity over South America, too, due to well-defined prominent biomass burning in September over southern tropical South America (Figure 3 and Figure 4).

(a) (b)

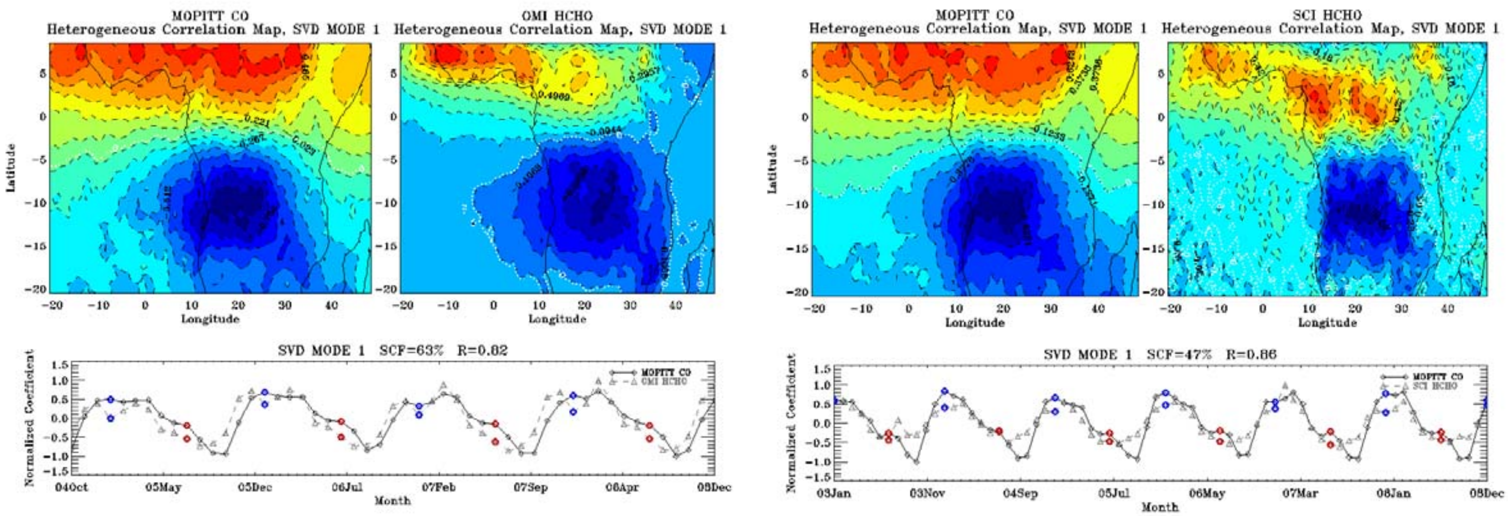


Figure 2 (a) The first mode of the SVD between OMI HCHO and MOPITT CO over Africa. The solid black line represents MOPITT CO, and the dashed line represents OMI HCHO. (b) The first mode of the SVD between SCIAMACHY HCHO and MOPITT CO over Africa. The solid black line represents MOPITT CO, and the dashed line represents SCIAMACHY HCHO. The blue symbols indicate the month of January throughout the measurement period. The red symbols indicate the month of July.

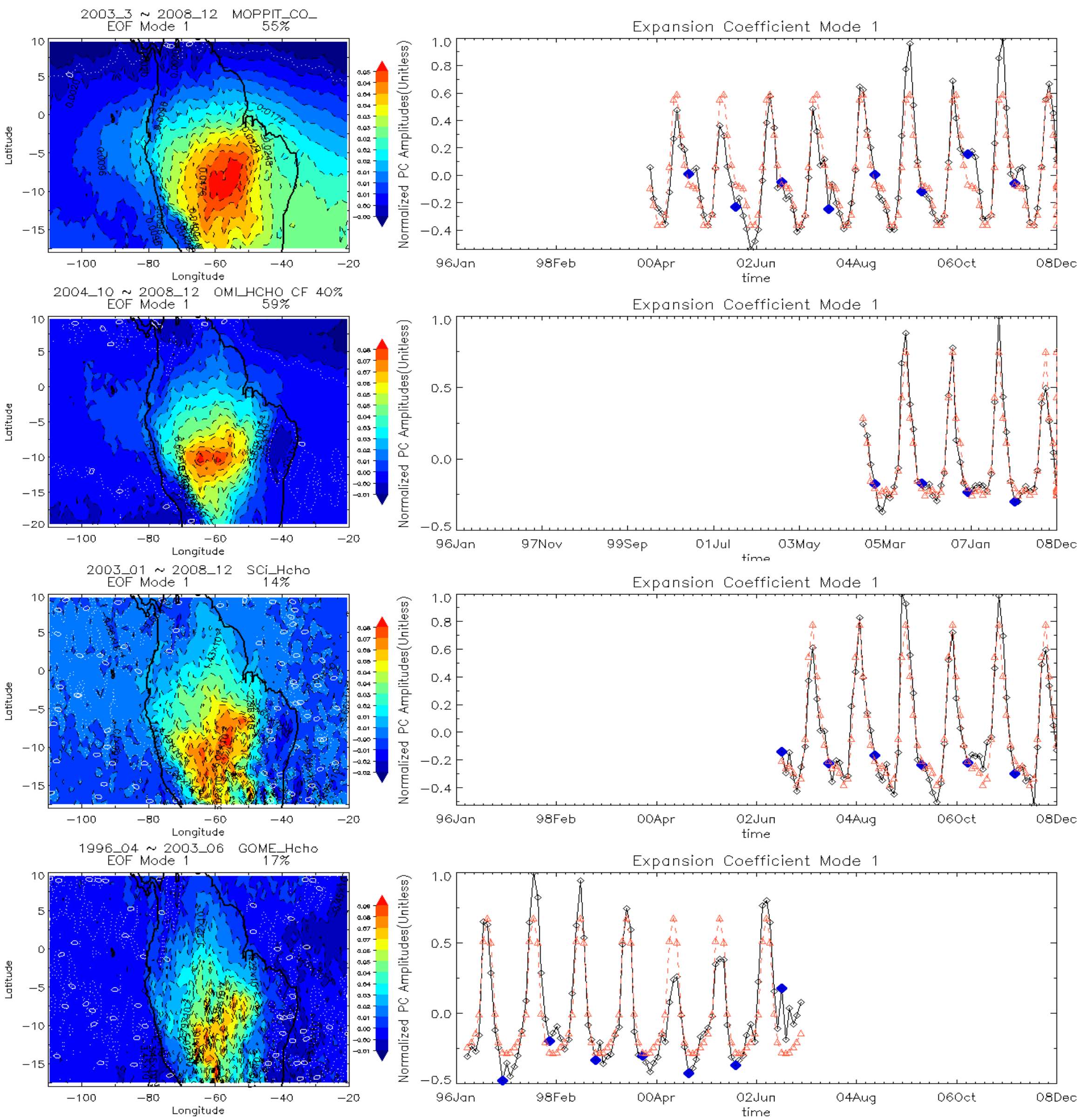
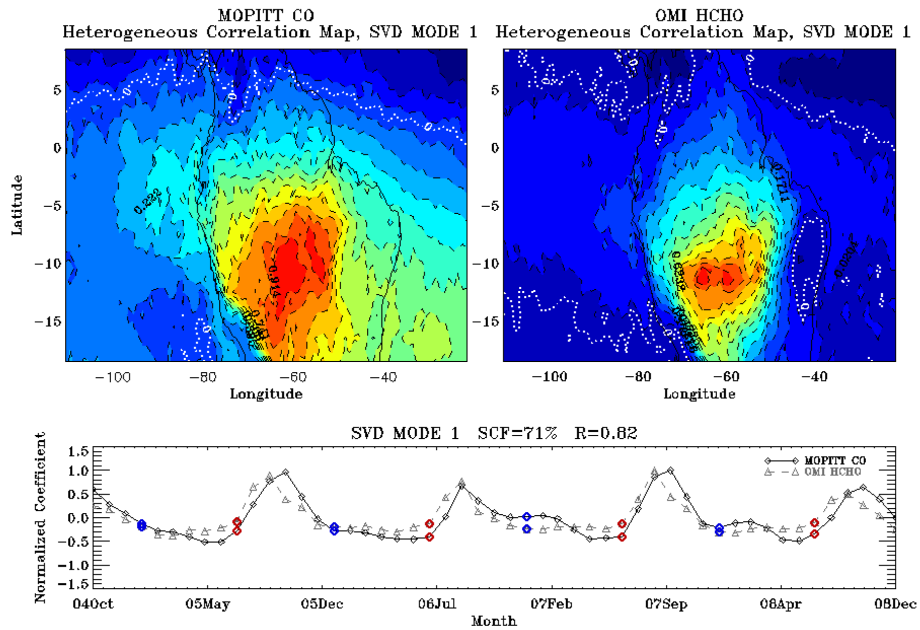


Figure 3. EOF analyses of MOPITT CO, OMI HCHO, GOME HCHO, and, SCIAMACHY HCHO over South America, respectively. The left panels are the first mode of EOF, and the right panels show the time series of the corresponding expansion coefficient of EOF mode 1 (black lines) with January values marked as blue diamonds. The red line represents the monthly average over the entire measurement period.

(a)



(b)

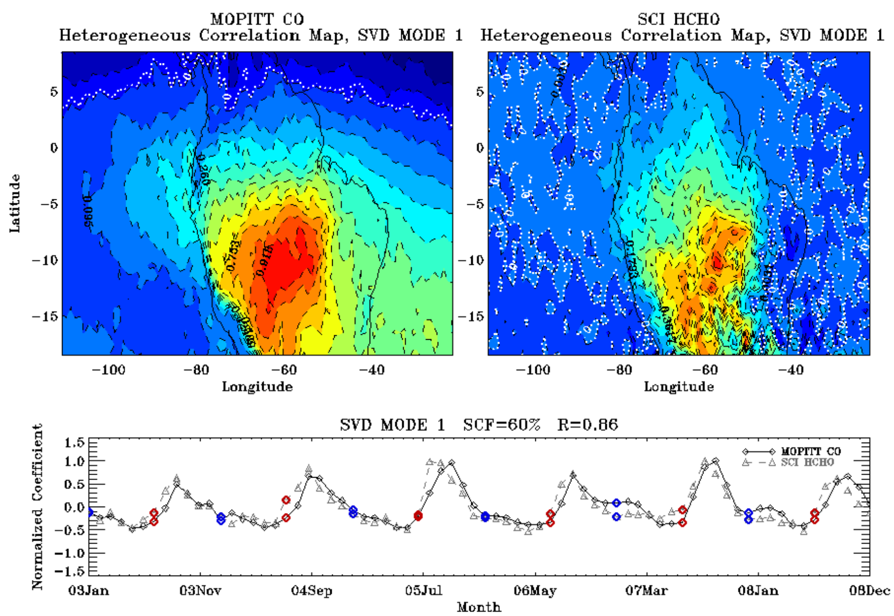


Figure 4 (a) The first mode of the SVD between OMI HCHO and MOPITT CO over South America. The solid black line represents MOPITT CO, and the dashed line represents OMI HCHO. (b) The first mode of the SVD between SCIAMACHY HCHO and MOPITT CO over South America. The solid black line represents MOPITT CO, and the dashed line represents SCIAMACHY HCHO. The blue symbols indicate the month of January throughout the measurement period. The red symbols indicate the month of July.

2.3.2 GEOS-Chem model

The GEOS-Chem chemical transport model (*Bey, et al.*, 2001) (http://www.as.harvard.edu/ctm/geos/index.html) will also be employed to complement the SVD and EOF analysis of the AURA data. GEOS-Chem is a global 3-D model of tropospheric chemistry driven by assimilated meteorological observations from the Goddard Earth Observing System at the NASA Goddard Global Modeling Assimilation Office. The GEOS-Chem model includes a detailed simulation of tropospheric chemistry coupled to aerosols. Isoprene emissions are based on MEGAN (*Guenther, et al.*, 2006). Biomass-burning emissions are from Global Fire Emissions Database (GFED) (*Giglio, et al.*, 2006; *Van der Werf, et al.*, 2006). The GEOS-Chem model has been applied to numerous analyses of satellite observations of trace gases in North America (*Abbot, et al.*, 2003; *Martin, et al.*, 2004a; *Martin, et al.*, 2004b; *Millet, et al.*, 2008; *Palmer, et al.*, 2006; *Palmer, et al.*, 2001; *Palmer, et al.*, 2003), Asia (*Fu, et al.*, 2007), and the tropics (*Sauvage, et al.*, 2007; *Shim, et al.*, 2005).

We propose to use the GEOS-Chem and LInearized Discrete Ordinate Radiative Transfer (LIDORT) models to understand the factors that contribute to the observed spatio-temporal variability in the AURA observations. An important consideration in our proposed analysis of OMI observations with GEOS-Chem simulations is the trace gas shape factor (or a priori profile) used in the air mass factor (AMF) calculation. Use of a shape factor from a different model would lead to ambiguity in determining whether differences between the retrieved and simulated columns arise from the satellite observations or from the retrieval assumptions. We will apply the approach of (*Lamsal, et al.*, 2010) in which OMI NO_2 scattering weights were used to effectively remove the effects of the NO_2 shape factors from the TM4 model. This approach has been implicit in previous HCHO analyses (*Palmer, et al.*, 2003) and NO_2 analyses (*Martin, et al.*, 2006) since the shape factors used in the retrieval are from the same GEOS-Chem simulation used in the analysis.

In this proposal, we plan to make a 5-year global run of GEOS-Chem model for the time period of OMI HCHO observations. One simulation can archive the model fields (HCHO, O_3, NO_2, CO, production rates, etc.) at the A-Train overpass time with a spatial resolution of 2 x 2.5 degrees. We will conduct EOF/SVD analysis of the model fields, as well as a direct model-satellite comparison, in order to (1) examine the photo-chemical consistency between satellite-observed and model-simulated trace gases; (2) assess the processes contributing to satellite data variability (both spatial and temporal); (3) study the impact of shape factors on satellite retrieval.

2.3.3 Data sources

We will use GOME, SCIAMACHY (http://www.temis.nl/airpollution/ ch2o.html), and OMI HCHO (http://mirador.gsfc.nasa.gov) along with MOPITT (ftp://l4ftl01.larc.nasa.gov/MOPITT) and AIRS (http://disc.sci.gsfc.nasa.gov/AIRS) CO measurements. The SP dataset (version 3) of OMI tropospheric NO_2 columns (*Ahmad, et al.*, 2003) can be obtained from the NASA Goddard Earth Sciences Data and Information Services Center (GES-DISC).

Dr. Xiong Liu, one of our collaborators, will provide OMI O3 retrievals (2004-2009) for EOF/SVD analyses. This data set contains O_3 concentrations at 24 layers, with each layer having an approximate thickness of 2.5-km, from the surface to ~60 km using 270-330-nm OMI radiances (currently an off-line data product) (*Liu, et al.*, 2005).

We will also use the total fire counts (2000-2009) measured by the Along-Track Scanning Radiometer (ATSR) (http://dup.esrin.esa.int/ionia/wfa/index.asp) to evaluate the impact of biomass burning on CO and HCHO variations.

3. Perceived impact of the proposed work to on the state of knowledge in the field

There have been various methods to assess satellite observations and attempts to extract physically meaningful causal relationships. The EOF/SVD approach has been used for decades in weather research, but has not been used extensively with satellite data or output from global chemical models. We expect this work to be beneficial to understanding the spatio-temporal variations in important atmospheric trace gases and the causes of these variations.

4. Relevance of the proposed work to AURA Science Team program

This proposal uses multiple statistical methods (EOF/SVD) in combination with a chemical transport model to (1) study the spatio-temporal variability of satellite trace gases; (2) study the factors that contribute to these variabilities; and (3) assess the accuracy and photo-chemical consistency of satellite observations of trace gases. It addresses the following NASA ROSES10 Atmospheric Composition Aura Science Team science questions:

How is atmospheric composition changing?
How does atmospheric composition respond to global environment change?
What are the effects of global atmospheric composition change on regional air quality?

5. Work plan

5.1 Anticipated key milestones of accomplishment

Year #1: Collect satellite data and pre-processing them with same selection criteria (i.e. cloud fraction filter) and spatial resolution; apply EOF to each satellite data; apply SVD analysis to HCHO and CO, HCHO and fire counts, HCHO and O_3; set up a GEOS-CHEM model and make a 1-year test run; obtain output (HCHO, CO, NO_2, O_3, emissions, production rates, cloud cover, etc.)

Year #2: Analyze EOF/SVD results, make inter-comparison of HCHO retrieved from different satellite, and find photochemical consistency between these major species; apply EOF/SVD to 1-year GEOS-Chem model results; compare with satellite observations; make a 5-year simulation (OMI HCHO observation period).

Year #3: EOF/SVD analysis of 5-year model results; comparisons between satellite retrievals and model results. We will publish our results at peer-reviewed journals (i.e., JGR, AE).

6. Data-sharing plan

We will put results of the proposed work (EOF/SVD analyses of satellite trace gases and fire counts, GEOS-Chem model results) on our website (http://nsstc.uah.edu/atmchem/#) to share with all researchers who have interests.

7. References

Abbot, D. S., P. I. Palmer, R. V. Martin, K. V. Chance, D. J. Jacob, et al. (2003), Seasonal and interannual variability of North American isoprene emissions as determined by formaldehyde column measurements from space, *Geophys. Res. Lett.*, *30* (*17)*, 1886, doi:10.1029/2003GL017336.

Ahmad, S. P., P. F. Levelt, P. K. Bhartia, E. Hilsenrath, G. W. Leppelmeier, et al. (2003), Atmospheric Products from the Ozone Monitoring Instrument (OMI), Proceedings of SPIE conference on Earth Observing systems VII, San Diego, CA, 3-8 August.

Bey, I., D. J. Jacob, R. M. Yantosca, J. A. Logan, B. D. Field, et al. (2001), Global modeling of tropospheric chemistry with assimilated meteorology: Model description and evaluation, *J. Geophys. Res.*, *106* (*D19)*, 23073-23096, doi:10.1029/2001JD000807.

Bucsela, E., E. A. Celarier, M. O. Wenig, J. F. Gleason, J. P. Veefkind, et al. (2006), Algorithm for NO_2 vertical column retrieval from the Ozone Monitoring Instrument, *IEEE Trans. Geosci. Remote Sens.*, *44*, 1245-1258.

Celarier, E. A., E. J. Brinksma, J. F. Gleason, J. P. Veefkind, A. Cede, et al. (2008), Validation of Ozone Monitoring Instrument nitrogen dioxide columns, *J. Geophys. Res.*, *113,* D15S15.

Chance, K., P. Palmer, R. J. D. Spurr, R.V. Martin, T. Kurosu, et al. (2000), Satellite observations of formaldehyde over North America from GOME, *Geophys. Res. Lett.*, *27* (*21)*, 3461-3464.

de Serves, C. (1994), Gas phase formaldehyde and peroxide measurements in the Arctic atmosphere, *J. Geophys. Res.*, *99* (*D12)*, 25,391-25,398, doi:10.1029/94JD00547.

Dufour, G., S. Szopa, M. P. Barkley, C. D. Boone, A. Perrin, et al. (2009), Global upper-tropospheric formaldehyde: Seasonal cycles observed by the ACE-FTS satellite instrument, *Atmos. Chem. Phys. Discuss.*, *9*, 1051-1095.

Fu, T.-M., D. J. Jacob, P. I. Palmer, K. Chance, Y. X. Wang, et al. (2007), Space-based formaldehyde measurements as constraints on volatile organic compound emissions in East and South Asia and implications for ozone, *J. Geophys. Res.*, *112,* D06312, doi:10.1029/2006JD007853.

Giglio, L., G. R. van der Werf, J. T. Randerson, G. J. Collatz and P. Kasibhatla (2006), Global estimation of burned area using MODIS active fire observations, *Atmos. Chem. Phys.*, *6* (*4)*, 957-974.

Guenther, A., T. Karl, P. Harley, C. Wiedinmyer, P. I. Palmer, et al. (2006), Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature), *Atmos. Chem. Phys.*, *6*, 3181-3210.

Heland, J., H. Schlager, A. Richter and J. P. Burrows (2002), First comparison of tropospheric NO_2 column densities retrieved from GOME measurements and in situ aircraft profile measurements, *Geophys. Res. Lett.*, *29* (*20)*, 1983, doi:10.1029/2002GL015528.

Kesselmeier, J. and M. Staudt (1999), Biogenic volatile organic compounds (VOC): An overview on emission, physiology, and ecology, *J. Atmos. Chem.*, *33*, 23-88.

Kurosu, T. P., K. Chance and C. E. Sioris (2008), OMIHCHO README FILE, in http://www.cfa.harvard.edu/.

Ladstätter-Weißenmayer, A., J. Heland, R. Kormann, R. von Kuhlmann, M. G. Lawrence, et al. (2003), Transport and build-up of tropospheric trace gases during the MINOS campaign: Comparison of GOME, in situ aircraft measurements and MATCH-MPIC-data, *Atmos. Chem. Phys.*, *3*, 1887-1902.

Lamsal, L. N., R. V. Martin, A. van Donkelaar, E. A. Celarier, F. K. Boersma, et al. (2010), Indirect validation of tropospheric nitrogen dioxide retrieved from the OMI satellite instrument: Insight into the seasonal variation of nitrogen oxides at northern midlatitudes, *J. Geophys. Res.*, *115* (*D05302)*, doi:10.1029/2009JD013351.

Lathière, J., D. A. Hauglustaine, A. D. Friend, N. De Noblet-Ducoudré, N. Viovy, et al. (2006), Impact of climate variability and land use changes on global biogenic volatile organic compound emissions, *Atmos. Chem. Phys.*, *6*, 2129-2146.

Lee, M., B. G. Heikes, D. J. Jacob, G. Sachse and B. Anderson (1997), Hydrogen peroxide, organic hydroperoxide, and formaldehyde as primary pollutants from biomass burning, *J. Geophys. Res.*, *102* (*D1)*, 1301-1309, doi:10.1029/96JD01709.

Liu, X. , K. Chance, C. E. Sioris, R. J. D. Spurr, T. P. Kurosu, et al. (2005), Ozone profile and tropospheric ozone retrievals from Global Ozone Monitoring Experiment: Algorithm description and validation, *J. Geophys. Res.*, *110*, D20307, doi:10.1029/2005JD006240.

Lorenz, E. N. (1956), Empirical orthogonal functions and statistical weather prediction, Technical report, Statistical Forecast Project Report 1, Dept. of Meteor., MIT, 49pp.

Martin, R. V., A. M. Fiore and A. Van Donkelaar (2004a), Space-based diagnosis of surface ozone sensitivity to anthropogenic emissions, *Geophys. Res. Lett.*, *31*, L06120, doi:10.1029/2004GL019416.

Martin, R. V., D. D. Parrish, T. B. Ryerson, D. K. Nicks Jr., K. Chance, et al. (2004b), Evaluation of GOME satellite measurements of tropospheric NO_2 and HCHO using regional data from aircraft campaigns in the southeastern United States, *J. Geophys. Res.*, *109*, D24307, doi:10.1029/2004JD004869.

Martin, R. V., C. E. Sioris, K. Chance, T. B. Ryerson, T. H. Bertram, et al. (2006), Evaluation of space-based constraints on global nitrogen dioxide emissions with region aircraft measurements over and downwind of eastern United States, *J. Geophys. Res.*, *111*, D15308, 2006JD006680.

Millet, D. B., D. J. Jacob, K. F. Boersma, T -M. Fu, T. P. Kurosu, et al. (2008), Spatial distribution of isoprene emissions from North America derived from formaldehyde column measurements by the OMI satellite sensor, *J. Geophys. Res.*, *113*, D02307, doi:10.1029/2007JD008950.

Palmer, P. I. , D. S. Abbot, T. -M. Fu, D. J. Jacob, K. Chance, et al. (2006), 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.

Palmer, P. I., D. J. Jacob, K. Chance, R. V. Martin, R. J. D. Spurr, et al. (2001), Air mass factor formulation for spectroscopic measurements from satellites: Application to formaldehyde retrievals from the Global Ozone Monitoring Experiment, *J. Geophys. Res.*, *106* (*D13)*, 14,539-14,550, doi:10.1029/2000JD900772.

Palmer, P. I., D. J. Jacob, A. M. Fiore, R. V. Martin, K. Chance, et al. (2003), Mapping isoprene emissions over North America using formaldehyde column observations from space, *J. Geophys. Res.*, *108* (*D6)*, 4180, doi:10.1029/2002JD002153.

Quadrelli, R. and J. M. Wallace (2004), A simplified linear framework for interpreting patterns of Northern Hemisphere wintertime climate variability, *J. Climate*, *17*, 3728-3744.

Sauvage, B. , R. V. Martin, A. van Donkelaar, X. Liu, K. Chance, et al. (2007), Remote sensed and in situ constraints on processes affecting tropical tropospheric ozone, *Atmos. Chem. Phys.*, *7* (*3)*, 815-838.

Shim, C., Y. Yang, Y. Choi, P. I. Palmer, D. Abbot, et al. (2005), Constraining global isoprene emissions with Global Ozone Monitoring Experiment (GOME) formaldehyde column measurements, *J. Geophys. Res.*, *110*, D24301, doi:10.1029/2004JD005629.

Smith, T. M., R. W. Reynolds, R. E. Livezey and D. C. Stokes (1996), Reconstruction of historical sea surface temperatures using empirical orthogonal functions, *J. Climate*, *9*, 1403-1420.

Strik, H. (1995), A regression analysis of the relation between physiological signals and F0, Stockholm University, Stockholm, 2, XIIIth International Congress of Phonetic Sciences (ICPhS'95).

Thomas, W., E. Hegels, S. Slijkhuis, R. Spurr and K. Chance (1998), Detection of biomass burning combustion products in Southeast Asia from backscatter data taken by the GOME spectrometer, *Geophys. Res. Lett.*, *25* (*9)*, 1317-1320.

Van der Werf, G. R., J. T. Randerson, L. Giglio, G. J. Collatz and P. S. Kasibhatla (2006), Interannual variability in global biomass burning emission from 1997 to 2004, *Atmos. Chem. Phys.*, *6*, 3423-3441.

Venegas, S. A., L. A. Mysak and D. N. Straub (1997), Atmosphere-ocean coupled variability in the South Atlantic, *J. Climate*, *10*, 2904-2920.

8. Facilities and Equipment

Normal research facilities are already in place. No additional facilities or equipment is required.

9. Management and Roles of Investigators

Professor Michael Newchurch at the University of Alabama in Huntsville will direct all aspects of this research and participate directly in the NASA Aura Science Team. He will coordinate interactions between the post doc/research associates and publication of results.

Dr. Lihua Wang, a post doc/research associate at the University of Alabama in Huntsville, will collaborate with Professor Jae Kim on statistical analyses of satellite retrievals from Aura and other satellites.

Dr. Randall Martin will make a 5-year GEOS-Chem model run and provide the output for analysis.

Dr. Thomas Kurosu will provide OMI data and help diagnose causes of observed OMI HCHO spatio-temporal patterns.

Dr. Xiong Liu will provide OMI ozone profile data for the EOF/SVD analyses.

10. Budget Justification

UAHuntsville requests a total of $657,712 over a three-year Period of Performance (POP); $216,393 for Year One, $220,875 for Year Two, and $220,445 for Year Three. Of the total proposed amount, $330,348 will fund all research personnel, which includes personnel salaries and fringe benefits based upon funding precedent set by UAHuntsville.

Operating costs, which include travel, supplies, and publications, account for $44,100 of the total proposed budget. Travel during the proposed POP ($18,565) includes annual trips to necessary meetings and scientific conferences.

Supplies required during the proposed POP ($12,925) include any necessary supplemental materials required for research and operations during the POP.

Publication costs cover all fees associated with the process of submitting articles to peer-reviewed journals ($12,610).

Subcontracts account for $82,500 for the three-year POP and include subcontracts to Jae Hwan Kim (Pusan National University) and Randall Martin (Dalhousie University).

Facilities and Administrative costs fund the required UAHuntsville facilities usage and administrative costs. These costs account for $200,764 of the budgeted total.

11. Current and Pending and Biographical Sketches

Current and Pending Support- August 2010

Professor Michael J. Newchurch

Current

- **Tropospheric Ozone Lidar and Ozonesondes at RAPCD for EOS AURA Validation, NASA/SMD**
  - PI- Dr. Michael J. Newchurch
  - Period of Performance- 2005-2010
  - Program Manager – Ernest Hilsenrath, NASA Headquarters, ernest.hilsenrath@nasa.gov
  - Agency- NASA Headquarters
  - Total Budget- $763K
  - Person-month commitment- 1.0 mo/yr.
  - Project Summary- This proposal offers to validate AUQA/OMI and TES with dedicated ozone lidar and ozonesonde measurements.

- **UAHuntsville Proposal to Support NOAA's Air Quality and Climate Mission Goals for South Eastern United States**
  - PI- Dr. Sundar Christopher
  - Period of Performance- 2008-2010
  - Program Manager- Ms. Patty J. Mayo, Program Support Specialist
  - Agency- DOC, NOAA
  - Total Budget- $325K
  - Person-month commitment- 0.7 mo/yr.
  - Project Summary: This proposal offers to perform case studies to determine the efficacy of using satellite measurements of air quality to improve air-quality forecasts.

- **Incorporating Space-borne Measurements to Improve Air Quality Decision**
  - Co-PI- Arastoo Pour-Biazar; Co-I- Dr. Michael J. Newchurch
  - Period of Performance- 2009-2012
  - Program Manager- NASA Headquarters
  - Agency- NASA
  - Total Budget- $872K
  - Person-month commitment- 0.2 mo/yr.
  - Project Summary: This proposal offers to reduce the sources of uncertainty in the simulations and increasing the confidence in the model results is of outmost importance to the regulatory agencies.

- **Satellite-Based Assessment of Climate and Air Quality**
  - Co-PI- Dr. Michael J. Newchurch
  - Period of Performance- 2009-2011
  - Program Manager- Ms. Patty J. Mayo, Program Support Specialist
  - Agency- DOC, NOAA
  - Total Budget- $300K
  - Person-month commitment- 0.5 mo/yr.

- Project Summary: This proposal offers to assess the quality of satellite data, assimilate fire emission products from polar and geostationary satellites, and assess ozone, CO, PM2.5.

Pending

- **UAHuntsville's Application to the NASA Air-Quality Applied Science Team**
  - PI- Dr. Michael J. Newchurch
  - Period of Performance- 2010-2015
  - Program Manager- NASA , Headquarters, Science Mission Directorate , Earth Science
  - Total Budget- $1.4M
  - Person-month commitment- 3.0 mo/yr.
  - Project Summary: UAHuntsville proposes to become a member of the NASA Applied Sciences Team to perform a variety of applied research tasks. We have demonstrated capabilities in satellite remote sensing retrieval and analyses, regional air-quality modeling, lightning NOx-produced ozone, ozonesonde observations from our HSV station and other station data, tropospheric ozone DIAL measurements, EPA surface observations, statistical analyses of satellite data for ozone trends and tropospheric chemistry, in-situ FTIR based cryogenically-cooled preconcentrated gas analyses, and planning for the NASA Decadal Survey GEO-CAPE geostationary mission.

MICHAEL J. NEWCHURCH- Biosketch

PROFESSIONAL PREPARATION

Ph.D. Atmospheric Sciences, Georgia Institute of Technology, 1986
B.S Industrial Sciences, Colorado State University, 1974

ACADEMIC APPOINTMENTS

2005-present Professor, Atmospheric Science Dept., Univ. of AL in Huntsville
1991-present Senior Research Scientist, Earth System Science Ctr., Univ. of AL in Huntsville

RESEARCH SUMMARY

Professor Newchurch's most significant achievements resulted from his publication with colleagues of the first stage of the recovery of the stratospheric ozone layer. This discovery confirmed the effectiveness of the Montreal Protocol and amendments. It received world-wide attention both in scientific circles and in the popular press. It was the most popular story on the AAAS website in 2003, the most popular story ever on the AGU site, and a top-10 NASA accomplishment in 2003. He was awarded the NASA group achievement award for his role as Assistant Mission Scientist on the ATLAS-2 and ATLAS-3 missions in 1992 and 1993.

PROFESSIONAL ACTIVITIES

Professor Newchurch's current fields of interest include tropospheric ozone profile measurements with lidars and ozonesondes, retrievals from satellite instruments, atmospheric photochemical modeling, and ozone trend analyses. He conceived, designed, built, and now directs the Regional Atmospheric Profiling Center for Discovery (RAPCD), an active lidar and passive remote-sensing facility which includes the UAH/NOAA Ozonesonde station, a UV DIAL ozone lidar, Doppler wind lidar, elastic aerosol lidar, and several in situ aerosol and gas samplers. His past and current science team memberships include OMI, TOMS, SAGE, HALOE, AIRS, ATMOS, POAM, and SBUV. He has served on the NOAA/CREST external advisory Board, the NASA Space Station Utilization Advisory Subcommittee (SSAUS), and numerous UAH committees. He has 4 Ph.D. graduates, 4 M.S. graduates, 3 current Ph.D. students, and 27 undergraduate researchers. His professional organizations include the American Geophysical Union, American Meteorological Society, American Academy for the Advancement of Science, Sigma Xi, and the Optical Society of America.

PUBLICATIONS, M. J. NEWCHURCH (Many available at http://nsstc.uah.edu/atmchem/)

Kuang, S., J. F. Burris, M. J. Newchurch, S. Johnson, S. Long (2010), Differential Absorption Lidar to Measure Sub-hourly Variation of Tropospheric Ozone Profiles, *IEEE Trans. Geosci. Remote Sens.,* in press.

Lightner K. J., W. W. McMillan, K. J. McCann, R. M. Hoff, M. J. Newchurch, E. J. Hintsa, C. D. Barnet (2009), Detection of a tropospheric ozone anomaly using a newly developed ozone retrieval algorithm for an up-looking infrared interferometer, J. Geophys. Res., 114, D06304, doi:10.1029/2008JD010270.

Yang, E.-S., D. M. Cunnold, M. J. Newchurch, R. J. Salawitch, M. P. McCormick, J. M. Russell III, J. M. Zawodny, S. J. Oltmans (2008), First stage of Antarctic ozone recovery, *J. Geophys. Res.*, 113, D20308, doi:10.1029/2007JD009675.

Jae Hwan Kim

Department of Atmospheric Science, Pusan National University
Kumjung-Ku Jangjun-Dong, Pusan, Korea 609-735
(51) 510-2172 • Fax (51) 515-1689 • jaekim@pusan.ac.kr

Education

- Ph.D., Meteorology, University of Maryland at College Park, 1995
Dissertation: New methods of deriving a tropical tropospheric column ozone from radiances measured by TOMS: Intercomparison and analysis
- M.A., Astronomy, University of Texas at Austin, 1986
- B.S., Physics, Pusan National University, 1983

Research Interest

- Tropospheric chemistry.
- Satellite remote sensing of tropospheric ozone and aerosols
- Observation and analysis of air pollution
- Impact of air pollution and weather on public health

Professional Experience

- Associate Professor, Pusan National University (Sep 1999 – Present)
- Adjunct Assistant Profess, University of Alabama in Huntsville (Jan 2002 – Present)
- Assistant Professor, Korea National University of Education (Sep 1996 – Aug 1999)
- NRC research associate, NASA/MSFC (May 1996 – Aug 1996)
- Post-Doc, University of Alabama in Huntsville (June 1995 – April 1996)
- Research Assistant, Department of Meteorology, University of Maryland at College Park (1991-1995).

Professional Activities and Affiliations

- Reviewer, NASA proposals.
- Member, NASA/TOMS science team, since 1998
- Member, Space project for future satellites in Korea, since 2000
- Member, American Geophysical Union, 1991-present
-

Selected Publications

J. H. Kim, Kim, J. H., S. Na, R. V. Martin, K. W. Seo, and M. Newchurch, Singular value decomposition analyses of tropical tropospheric ozone determined from TOMS, Geophys. Res. Lett., doi:10.1029/2008GL033690, 2008.

J. H. Kim, Hyunjin Lee, and Sanghee Lee, The characteristics for the seasonal variation of tropospheric ozone from Pohang ozonesounding measurements, Korea, Environmental Monitoring and Assessment, 2006.

J. S. Ha, **J. H. Kim**, and H.J. Lee, The analysis of threshold and sensitivity for dust aerosols with satellite infrared bands, Korean Journal of Remote Sensing, 22, 6, 2006.

J.H. Kim, H.J. Lee, H. Fukushima, K.J. Ha, The measurements of biomass burning aerosols from GLI data, Korean Journal of Remote Sensing, 21, 4, 2005.

J.H. Kim, Sunmi Na, and M.J. Newchurch, and R.V. Martine, Tropical tropospheric ozone morphology and seasonality seen in satellite, model, and in-situ measurements, Journal of Geophysical Research – Atmospheres, D110, NO, D2, DO2303, 2005.

Oltmans, S.J., B.J. Johnson, J.M. Harris, A.M. Thompson, H.Y. Liu, H. Vomel, C.Y. Chan, T. Fujimoto, V.G. Brackett, W.L. Chang, J.-P. Chen, **J.H. Kim**, L.Y. Chan, and H,-W. Chang. Tropospheric Ozone Over the North Pacific From Ozonesonde Observations. Journal of Geophysical Research - Atmospheres, January 2004, in press.

Kim, J.H., S. Na, and M.J. Newchurch, Comparison of Scan-Angle Method and Convective Cloud Differential Method, Environ. Monit. Assess, 92, 25-33, 2004.

Newchurch, M.J., D. Sun, **J.H. Kim**, and X. Liu, Tropical tropospheric ozone derived using Clear-Cloudy Pairs (CCP) of TOMS measurements, Atmos. Chem. Phys. 3, 683-695, 2003.

Liu, X., M.J. Newchurch, and **J.H. Kim**, Occurrence of ozone anomalies over cloudy areas in TOMS version-7 level-2 data. Atmos. Chem. Phys. 3, 1,113-1,129, 2003.

Kim, J. H., M. J. Newchurch, and K. Han, Distribution of Tropical Tropospheric Ozone determined by the Scan-Angle Method applied to TOMS measurements, *J Atmos. Sci. 58,* 18, 2699-2708, 2001.

Randall V. Martin (Co-Investigator)

Appointments

2003-present: Research Associate, Harvard-Smithsonian Center for Astrophysics
2010-present: Killam Professor, Dalhousie University
2007-present: Associate Professor, Dalhousie University
2003-2007: Assistant Professor, Dalhousie University
2002-2003: Postdoctoral Research Fellow, Harvard-Smithsonian Center for Astrophysics

Education

Ph.D. (Engineering Sciences), Harvard University, 2002
M.S. (Engineering Sciences), Harvard University, 2001
M.Sc. (Environmental Science), Oxford University, 1998
B.S. (Engineering), Cornell University, 1996

Research Experience and Interests

Satellite remote sensing and global numerical modeling of tropospheric chemistry. Air quality. Tropospheric ozone. Aerosols. Lightning. Ozone precursor emissions.

Honors

Killam Prize (2010) for a young scientist with "exceptional research ability"
Editors' Citation for Excellence in Refereeing for JGR-Atmospheres (2008) and GRL (2007)
Invited presentation at Gordon Research Conference in Atmos. Chem., 2005

Selected Activities

Associate Editor, J. Geophys. Res., 2009-

Co-chair International Global Atmospheric Chemistry (IGAC) / Commission on Atmospheric Chemistry and Global Pollution (CACGP) Conference, 2009-2010

Selected Publications (From >70 Peer Reviewed)

Walker, T.W., R.V. Martin, A. van Donkelaar, et al., Trans-Pacific transport of reactive nitrogen and ozone to Canada during spring, *Atmos. Chem. Phys.*, submitted.

Lamsal, L.N., R.V. Martin, A. van Donkelaar, E.A. Celarier, F.K. Boersma, R. Dirksen, C. Luo, and Y. Wang, Indirect validation of tropospheric nitrogen dioxide retrieved from the OMI satellite instrument: Insight into the seasonal variation of nitrogen oxides at northern midlatitudes, *J. Geophys. Res.*, **115**, D05302, doi:10.1029/2009JD013351, 2010.

Lee, C., R.V. Martin, A. van Donkelaar, G. O'Byrne, N. Krotkov, A. Richter, G. Huey, and J.S. Holloway (2009), Retrieval of vertical columns of sulfur dioxide from SCIAMACHY and OMI: Air mass factor algorithm development and validation, *J. Geophys. Res.*, **114**, D22303, doi:10.1029/2009JD012123, 20pp, 2009.

Wespes, C., D. Hurtmans, C. Clerbaux, M.L. Santee, R.V. Martin, and P.F. Coheur, Global distributions of nitric acid from IASI/MetOP measurements, *Atmos. Chem. Phys.*, **9**, 7949-7962, 2009.

Barkley, M. P., 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 GOME observations of HCHO columns, *J. Geophys. Res.*, **113**, D20311, doi:10.1029/2007JD009632, 2008.

Martin, R.V., Satellite remote sensing of surface air quality, *Atmos. Environ.*, **42**, 7823-7843, 2008.

Martin, R.V., B. Sauvage, I. Folkins, C.E. Sioris, C. Boone, P. Bernath, and J.R. Ziemke, Space-based constraints on the production of nitric oxide by lightning, *J. Geophys. Res.*, **112**, D09309, doi:10.1029/2006JD007831, 12pp, 2007.

Sauvage, B., R.V. Martin, A. van Donkelaar, X. Liu, K. Chance, L. Jaeglé, P.I. Palmer, S. Wu, and T.-M. Fu, Remote sensed and in situ constraints on processes affecting tropical tropospheric ozone, *ACP*, 7, 815-838, 2007.

Sauvage, B., R.V. Martin, A. van Donkelaar, and J.R. Ziemke, Quantification of the factors controlling tropical tropospheric ozone and the South Atlantic maximum, *J. Geophys. Res.*, **112**, D09309, doi:10.1029/2006JD007831, 2007.

Martin, R.V., D.D. Parrish, T.B. Ryerson, D.K. Nicks Jr., K. Chance, T.P. Kurosu, D.J. Jacob, E. D. Sturges, A. Fried, and B.P. Wert, Evaluation of GOME satellite measurements of tropospheric NO_2 and HCHO using regional data from aircraft campaigns in the southeastern United States, *J. Geophys. Res.*, **109**, D24307, doi:10.1029/2004JD004869, 2004.

12. <u>Statements of Commitment and Letters of Support</u>

Letter of Commitment

Jae Hwan Kim, Adjunct Professor
Department of Atmospheric Science
University of Alabama in Huntsville
iamjaekim@gmail.com

I acknowledge that I am identified by name as consultant to the investigation, entitled "Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Processes and Photo-chemical Consistency" that is submitted by Mike Newchurch to the NASA ROSES NRA NNH10ZDA001N-AURA and that I intend to carry out all responsibilities identified for me in this proposal. I understand that the extent and justification of my participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal. I have read the entire proposal, including the management plan and budget, and I agree that the proposal correctly describes my commitment to the proposed investigation.

Jae Hwan Kim

July 13, 2010

23 July 2010

Professor Michael Newchurch
Atmospheric Science Department
University of Alabama in Huntsville
Huntsville, AL 35805

Dear Mike,

I am pleased to be a co-investigator on your proposal entitled "Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Processes and Photo-chemical Consistency" that will be submitted to the NASA ROSES NRA NNH10ZDA001N-AURA. We will conduct model calculations and sensitivity studies to interpret the proposed satellite retrievals. The attached budget will support our effort. I look forward to continuing our work together.

Sincerely yours,

Randall Martin
Research Associate at the Smithsonian Astrophysical Observatory
Killam Professor at Dalhousie University

13. Subcontractors' Budgets

Jae Hwan Kim Values in US Dollars	**Year 1**	**Year 2**	**Year 3**	**Total Cost**
Man Hours @ $45 an hour	$ 12,000.00	$ 12,000.00	$ 12,000.00	$ 36,000.00
Travel	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 9,000.00
Total	$ 15,000.00	$ 15,000.00	$ 15,000.00	$ 45,000.00

The Office of Research Services
Dalhousie University
5248 Morris St.
Halifax, Nova Scotia B3J 1B4
Canada

23 July 2010

Professor Michael Newchurch
Atmospheric Science Department
University of Alabama in Huntsville
Huntsville, AL 35805

Dear Professor Newchurch,

The following research will be conducted at Dalhousie University to support the NASA proposal on "Spatio-temporal Eigenanalysis of Aura Composition Measurements to Assess Accuracy and Photo-chemical Consistency".

Randall Martin (principal investigator) will work with a student to conduct the GEOS-Chem model calculations and sensitivity studies as described in the proposal. The budget below will support our effort.

Values in US Dollars

	Year 1	Year 2	Year 3
Graduate Student (50%)	9,583	9,583	9,583
Travel (one trip/yr)	1,000	1,040	1,082
Overhead (20%)	1,917	1,917	1,917
Total	12,500	12,500	12,500

Sincerely,

Jody Rice Gallagher
Research Services