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

NASA Proposal Number

10-AURA10-0002

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
Steven Massie	**massie@ucar.edu**	**303-497-1404**

Street Address (1)	Street Address (2)
1850 Table Mesa Dr	

City	State / Province	Postal Code	Country Code
Boulder	**CO**	**80305-5602**	**US**

Proposal Title : **Decadal changes in cloud geographical distributions**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
06 / 01 / 2011	**06 / 01 / 2014**	**613,631.00**	**197,153.00**	**204,447.00**	**212,031.00**

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 / 29 / 2010	**Electronic Submission Only**		**2010-542**

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
078339587	**0SEF6**	**840412668**	**8H**

Organization Name (Standard/Legal Name)	Company Division
University Corporation For Atmospheric Research (UCAR)	

Organization DBA Name	Division Number
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR)	

Street Address (1)	Street Address (2)
1850 TABLE MESA DR	

City	State / Province	Postal Code	Country Code
BOULDER	**CO**	**803055602**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Steven Massie	**massie@ucar.edu**	**303-497-1404**

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
Virginia Taberski	**taberski@ucar.edu**	**303-497-2132**

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

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Steven Massie**	**303-497-1404**	**massie@ucar.edu**
Organization/Business Relationship: **University Corporation For Atmospheric Research (UCAR)**		Cage Code: **0SEF6**	DUNS#: **078339587**
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	**Qiang Fu**	**206-685-2070**	**qfu@atmos.washington.edu**
Organization/Business Relationship: **University of Washington**		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
Co-I	**Rashid Khosravi**	**303-497-2926**	**rashid@ucar.edu**
Organization/Business Relationship: **University Corporation For Atmospheric Research (UCAR)**		Cage Code: **0SEF6**	DUNS#: **078339587**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION VII - Project Summary

The latitudinal width of the tropics has increased during the last 25 years. The latitudinal width of cirrus geographic distributions has likely also increased as the latitudinal extent of the tropopause has increased. We propose to use AURA HIRDLS observations of cloud distributions and CALIPSO lidar cloud observations to determine the latitudinal extent of cirrus in the upper troposphere, and compare these 2005-2010 tropical widths to those using SAGE, HALOE, ISAMS, and CLAES observations during 1985-2005.

The expansion of the Hadley circulation implies a poleward expansion of the band of subtropical subsidence leading to mid-latitude warming and a poleward shift in the subtropical dry zone, and less high clouds. We will prepare latitude-longitude maps of cirrus frequency of occurrence at selected pressure levels during 1985 - 2010 in the sub-tropics. Comparisons of these maps will indicate if cirrus frequency of occurrence has changed in the sub-tropics.

Since the experiments observe at different wavelengths, we will determine the best way to inter-compare the extinction data sets. This task will be approached from an empirical viewpoint (i.e. co-located extinction observations will be compared) and theoretical viewpoint (i.e. cirrus extinction versus cirrus radii curves at all observation wavelengths will be calculated and inter-compared).

Analyses of the Level 2 data fields from the various experiments will produce time and spatially averaged data products (i.e. longitude-latitude maps at specific pressure levels), over a 25 year period of time, that will be made available to the research community. These maps will serve as useful constraints upon the multi-decadal cloud distributions generated by chemical-transport-microphysical and climate models.

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?
Yes

International Collaboration

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

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

Explanation :

NASA Civil Servant Project Personnel

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

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

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

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 : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

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 : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Decadal changes in cloud geographical distributions

Question 2 : Type of institution:

Answer: Other Federal Agency (including Government labs and FFRDCs other than JPL)

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: Yes

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

Answer: No

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 : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	53,637.00	55,783.00	58,015.00	167,435.00
B. Direct Labor - Other Personnel	44,916.00	46,713.00	48,580.00	140,209.00
Total Number Other Personnel	1	1	1	3
Total Direct Labor Costs (A+B)	98,553.00	102,496.00	106,595.00	307,644.00
C. Direct Costs - Equipment	0.00	0.00	0.00	0.00
D. Direct Costs - Travel	2,500.00	2,500.00	2,500.00	7,500.00
Domestic Travel	2,500.00	2,500.00	2,500.00	7,500.00
Foreign Travel	0.00	0.00	0.00	0.00
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	28,837.00	29,621.00	30,437.00	88,895.00
Materials and Supplies	1,000.00	1,000.00	1,000.00	3,000.00
Publication Costs	0.00	0.00	0.00	0.00
Consultant Services	0.00	0.00	0.00	0.00
ADP/Computer Services	6,354.00	6,354.00	6,354.00	19,062.00
Subawards/Consortium/Contractual Costs	21,483.00	22,267.00	23,083.00	66,833.00
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)	129,890.00	134,617.00	139,532.00	404,039.00
H. Indirect Costs	61,521.00	63,875.00	66,323.00	191,719.00
I. Total Direct and Indirect Costs (G+H)	191,411.00	198,492.00	205,855.00	595,758.00
J. Fee	5,742.00	5,955.00	6,176.00	17,873.00
K. Total Cost (I+J)	197,153.00	204,447.00	212,031.00	613,631.00
Total Cumulative Budget				613,631.00

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**
Proposal Title : **Decadal changes in cloud geographical distributions**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2011	**06 / 01 / 2012**	**Project**	**1**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Massie, Steven	PI_TYPE	0.00				35,521.00	18,116.00	53,637.00
							Total Key Personnel Costs	53,637.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Project Scientist II				29,746.00	15,170.00	44,916.00
1	Total Number Other Personnel					Total Other Personnel Costs	44,916.00

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	98,553.00

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2011	**06 / 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)	**2,500.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**2,500.00**

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 : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2011	**06 / 01 / 2012**	**Project**	**1**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	1,000.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	6,354.00
5. Subawards/Consortium/Contractual Costs	21,483.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	28,837.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	129,890.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
NCAR Indirect Costs	49.80	123,536.00	61,521.00
Cognizant Federal Agency: National Science Foundation, Mr. Laurence Dash, 703-292-4252, 4201 Wilson Blvd., Arlington, VA 22230	**Total Indirect Costs**		61,521.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	191,411.00

J. Fee

	Funds Requested ($)
Fee	5,742.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	197,153.00

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2012	**06 / 01 / 2013**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Massie, Steven	PI_TYPE	0.00				36,942.00	18,841.00	55,783.00
							Total Key Personnel Costs	55,783.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Project Scientist II				30,936.00	15,777.00	46,713.00
1	Total Number Other Personnel					Total Other Personnel Costs	46,713.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	102,496.00

PI Name : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2012	**06 / 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)	**2,500.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**2,500.00**

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 : **Steven Massie**	**NASA Proposal Number**
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2012	**06 / 01 / 2013**	**Project**	**2**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	1,000.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	6,354.00
5. Subawards/Consortium/Contractual Costs	22,267.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	29,621.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	134,617.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
NCAR Indirect Costs	49.80	128,263.00	63,875.00
Cognizant Federal Agency: National Science Foundation, Mr. Laurence Dash, 703-292-4252, 4201 Wilson Blvd., Arlington, VA 22230		**Total Indirect Costs**	63,875.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	198,492.00

J. Fee

	Funds Requested ($)
Fee	5,955.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	204,447.00

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2013	**06 / 01 / 2014**	**Project**	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Massie, Steven	**PI_TYPE**	**0.00**				**38,420.00**	**19,595.00**	**58,015.00**
							Total Key Personnel Costs	**58,015.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Project Scientist II**				**32,173.00**	**16,407.00**	**48,580.00**
1	**Total Number Other Personnel**					**Total Other Personnel Costs**	**48,580.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**106,595.00**

PI Name : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2013	**06 / 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)	**2,500.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**2,500.00**

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 : **Steven Massie**	NASA Proposal Number
Organization Name : **University Corporation For Atmospheric Research (UCAR)**	**10-AURA10-0002**

Proposal Title : **Decadal changes in cloud geographical distributions**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
06 / 01 / 2013	**06 / 01 / 2014**	**Project**	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	1,000.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	6,354.00
5. Subawards/Consortium/Contractual Costs	23,083.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	30,437.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	139,532.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
NCAR Indirect Costs	49.80	133,178.00	66,323.00
Cognizant Federal Agency: National Science Foundation, Mr. Laurence Dash, 703-292-4252, 4201 Wilson Blvd., Arlington, VA 22230	Total Indirect Costs		66,323.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	205,855.00

J. Fee

	Funds Requested ($)
Fee	6,176.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	212,031.00

NCAR: 2010-542

August 2010

A proposal to:
National Aeronautics and Space Administration

Title:

Decadal changes in cloud geographical distributions

Subsection A.15: AURA Science Team

By:
National Center for Atmospheric Research (NCAR)*
Atmospheric Chemistry Division
PO Box 3000
Boulder, CO 80307

Principal Investigators: Steven T. Massie (NCAR)
Co-investigators: Rashid Khosravi (NCAR)
Qiang Fu (University of Washington)

NASA Research Announcement: ROSES 2010 NNH10ZDA001N-AURA

Proposed Period of Performance: 1 June 2011 – 1 June 2014

Funding requested: 1st year ($197,153), 2nd year ($204,447),
3rd year ($212,031), Total $613,631

Submission date: August 2, 2010

*The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Decadal changes in cloud geographical distributions

The latitudinal width of the tropics has increased during the last 25 years. The latitudinal width of cirrus geographic distributions has likely also increased as the latitudinal extent of the tropopause has increased. We propose to use AURA HIRDLS observations of cloud distributions and CALIPSO lidar cloud observations to determine the latitudinal extent of cirrus in the upper troposphere, and compare these 2005-2010 tropical widths to those using SAGE, HALOE, ISAMS, and CLAES observations during 1985-2005.

The expansion of the Hadley circulation implies a poleward expansion of the band of subtropical subsidence leading to mid-latitude warming and a poleward shift in the subtropical dry zone, and less high clouds. We will prepare latitude-longitude maps of cirrus frequency of occurrence at selected pressure levels during 1985 - 2010 in the sub-tropics. Comparisons of these maps will indicate if cirrus frequency of occurrence has changed in the sub-tropics.

Since the experiments observe at different wavelengths, we will determine the best way to inter-compare the extinction data sets. This task will be approached from an empirical viewpoint (i.e. co-located extinction observations will be compared) and theoretical viewpoint (i.e. cirrus extinction versus cirrus radii curves at all observation wavelengths will be calculated and inter-compared).

Analyses of the Level 2 data fields from the various experiments will produce time and spatially averaged data products (i.e. longitude-latitude maps at specific pressure levels), over a 25 year period of time, that will be made available to the research community. These maps will serve as useful constraints upon the multi-decadal cloud distributions generated by chemical-transport-microphysical and climate models.

Table of Contents

1. Introduction

Clouds are recognized as an important uncertainty in the prediction of future climate change, and in general have an important impact upon the radiation budget of the atmosphere [*Trenberth, Fasullo, and Kiehl*, 2009]. Clouds are also involved in the microphysical-transport processes that transfer water vapor from the upper troposphere into the stratosphere [*Jensen and Pfister*, 2004]. Changes in tropospheric temperatures and cirrus likely will lead to changes in the water vapor mixing ratio in the stratosphere, which has important implications for stratospheric ozone chemistry. Changes in cloud frequency of occurrence and the geographical distribution of cirrus are therefore linked to climate change in both the stratosphere and troposphere.

The geographical distribution of cirrus is likely changing, since the latitudinal width of the tropics has increased by 2 to 8° during the last 25 years [*Seidel et al.*, 2008]. Figure 1, from *Seidel et al.* [2008], illustrates that various studies consistently indicate that the width of the tropics has increased since 1979. *Seidel and Randel* [2007] report an expansion of 5 to 8° in the latitudinal extent of the tropopause during 1979-2005 (i.e. an expansion of 1.9 to 3.1° per decade, considering both hemispheres). *Hu and Fu* [2007] report a 2 to 4.5° expansion of the tropics during 1979-2005, based upon an analysis of three outgoing longwave radiation (OLR) data sets and the streamfunction fields from three reanalysis data sets. *Fu et al*. [2006] used satellite-based microwave observations of atmospheric temperature to calculate a mid-latitude tropospheric warming and a 2° net widening of the tropics during 1979-2005. *Hudson et al*. [2006] demonstrated that 1979 – 2003 trends in ozone columns are in part due to an expansion of the tropics at a rate of 2.5° per 25 years for the Northern hemisphere. The observed widening appears to have occurred faster than climate models have predicted [*Johanson and Fu*, 2009].

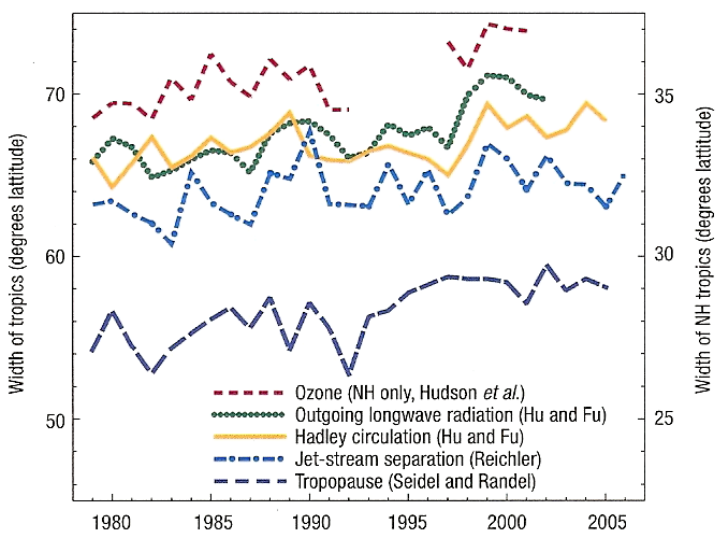

Figure 1. Changes in the width of the tropics since 1979 as determined by several studies that utilize different field variables, as presented in *Seidel et al.* [2008].

Our proposal focuses upon using AURA, other A-train, and previous satellite data, with a focus on altitude-resolved cloud extinction data, to quantify how cloud geographical distributions have changed during the last 25 years. Changes of interest include the width of the tropics, and changes in cloud frequencies of occurrence in the tropics and subtropics. Analyses of the Level 2 data fields from the various experiments will produce new time and spatially averaged data products (i.e. longitude-latitude maps at specific pressure levels), over a 25 year period of time, that will be made available to the research community. These maps will serve as useful constraints upon multi-decadal cloud fields generated by chemical-transport-microphysical and climate models.

The latitudinal width of cirrus has likely increased as the latitudinal extent of the tropical tropopause (i.e. the latitudinal extent of cold temperatures) has increased. We propose to use AURA observations of HIRDLS cloud distributions in the troposphere in conjunction with CALIPSO lidar cloud observations to determine the current latitudinal extent of cirrus in the tropics, and compare these 2005-2010 widths to those using SAGE, HALOE, ISAMS, and CLAES observations during 1985-2005. (See Table 1 on page 3 for an explanation of the Acronyms).

As discussed by *Hu and Fu* [2007], an expansion of the Hadley circulation implies a poleward expansion of the band of subtropical subsidence leading to mid-latitude warming, a poleward shift in the subtropical dry zone, and less high clouds. We will prepare latitude-longitude maps of cirrus frequency of occurrence at selected pressure levels throughout 1985 - 2010 in the sub-tropics (with details discussed below in section 3.3). Comparisons of these maps will indicate if cirrus frequency of occurrence has changed in the sub-tropics.

For the pre-Aura time frame we will analyze SAGE, HALOE, ISAMS, and CLAES experiments which measured altitude dependent cloud extinction profiles. The HALOE, ISAMS, and CLAES experiments on the Upper Atmosphere Research Satellite (UARS) measured cirrus extinction from 1991 to 2005 (see Table 2 below for specifics). The following paragraphs briefly discuss these data sets, discuss our rationale, and place our proposed analyses in relation to previous studies.

Longitude-latitude seasonal maps of SAGE 1.02 μm opaque and subvisual (i.e. optically thick and thin) cirrus in the troposphere, averaged for 1985 – 1990, are presented in *Wang et al.* [1996] at various tropospheric altitudes. *Wang et al*. [2002] used SAGE 1.02 μm opaque cloud data to infer that mean cloud opacity decreased in the upper troposphere during 1985 – 1998 in the tropics. This finding needs to be confirmed from an analysis of HALOE data. Trends in SAGE and HALOE subvisual cirrus in the upper troposphere in the tropics and subtropics have not yet been quantified.

We will subset our data processing and analyses into three categories: all clouds, opaque, and subvisual cirrus, since the physical origins of opaque and subvisual cirrus are different. Opaque cirrus most likely is directly related to deep convection. *Massie et al*. [2002] used HALOE cirrus extinction data to determine that 50% of the subvisual cirrus is related to in-situ processes (i.e. the uplift of humid layers which are not related to deep convection),

Massie et al. [2000] used HALOE extinction data to quantify that El Nińo related longitudinal shifts in deep convection produce longitudinal shifts in upper troposphere cirrus. Cirrus geographical distributions are therefore dependent upon where large relative humidity is located, time dependent patterns of deep tropical convection, and sea surface temperature patterns that are modulated by El Nińo / La Nińa cycles. Our analysis will calculate tropical widths with and without specific years in which El Nińo events are present.

Since the experiments observe at different wavelengths, we will determine the best way to inter-compare the extinction data sets and determine how to put the various extinction data sets onto a common footing. This task will be approached from an empirical viewpoint (i.e. co-located extinction observations will be compared) and theoretical viewpoint (i.e. cirrus extinction versus cirrus radii curves at all observation wavelengths will be calculated and inter-compared). The way in which the extinction data sets from the different experiments will be inter-compared is discussed below in section 3.2. Previous research has not analyzed the extinction data in a unified manner.

One benefit in using the altitude dependent data is that it provides an independent calculation of high level cirrus cloud trends. There are differences in trends in high level clouds calculated from nadir view radiometer data. *Wylie et al.* [2005] note that HIRS data from 1979 to 2001 show a small but statistically significant increase in high level clouds in the tropics and northern hemisphere (i.e. 2% per decade in the mid-latitudes), while ISCCP data indicates little change in high clouds. Since the CALIPSO experiment and the five limb-view experiments are sensitive to high level cirrus, our analyses of cirrus trends will help resolve this discrepancy.

We will also use MSU (channel 2) radiance and HIRS 6.3 μm (channel 12) radiance data, to prepare latitude-longitude maps of (T2 – T12) brightness temperature differences in a manner similar to the cirrus maps. As discussed below in section 3.1, changes in (T2 – T12) are associated with changes in upper troposphere humidity. We will determine if there are coherent geospatial patterns and trends that indicate a consistent picture (e.g. whether changes in cloud frequency of occurrence in the tropics and subtropics are correlated with changes in relative humidity).

The following sections discuss our objectives, the data that we will process, and the calculations that we will perform in order to determine how cirrus has changed during the last 25 years.

2. Objectives

Our objectives are to:

A) Use radiative transfer cirrus calculations and co-located extinction datasets at different wavelengths to determine how to inter-compare cirrus data from the different satellite experiments.

B) Determine if the latitudinal distributions of opaque and subvisual cirrus in the troposphere have changed during the last 25 years in the tropics and subtropics.

C) Determine if changes in the cirrus distributions in the tropics and subtropics are associated with changes in relative humidity in the upper troposphere.

D) Produce time and spatially averaged data products (i.e. longitude-latitude maps at specific pressure levels), from the experiments discussed above, that will be made available to the research community. These new data products will place useful constraints on cloud field simulations by 3d chemical-transport-microphysical and climate models.

3. Technical Approach and Methodology

This section of the proposal discusses our technical approach to meet the objectives outlined above. Section 3.1 discusses the data sets we will use in our analyses, Section 3.2 discusses how the inter-satellite comparisons will be accomplished, and Section 3.3 discusses our proposed observational analyses.

3.1 Observations

Since our proposal focuses upon analyses of many satellite data sets, we start with an acronym list, followed by a tabulation of the extinction fields that will be analyzed.

Table 1. Acronyms

Acronym	
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CLAES	Cryogenic Limb Array Etalon Spectrometer
HALOE	Halogen Occultation Experiment
HIRDLS	High Resolution Dynamics Limb Sounder
HIRS	High Resolution Infrared Radiometer Sounder
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISCCP	International Satellite Cloud Climatology Project
MSU	Microwave Sounding Unit
RL-GEOPROF	Radar-Lidar Geometrical Profile Product
SAGE	Stratospheric Aerosol and Gas Experiment
UARS	Upper Atmosphere Research Satellite

Table 2. Listing of extinction and cloud layer data sets.

Experiment	Observation Years	Observation Wavelengths
SAGE	1985 – 1999	1.02, 0.525, 0.452, 0.386 μm
UARS HALOE	1991 – 2005	5.26, 3.46, 3.40, 2.45
UARS CLAES	1991 – 1993	12.8, 12.6, 11.9, 11.4, 10.8, 7.9, 6.2
UARS ISAMS	1991 – 1992	12.1, 6.2
AURA HIRDLS	2005 – 2007	12.1
CALIPSO	2006 – present	1.064, 0.532
RL-GEOPROF	2006 – present	1.064, 0.532, and 94 GHz

Table 3. Long term data.

Experiment	Observation Years
MSU radiances (channels 2 and 4)	1985-present
HIRS radiances (6.3 μm)	1985-present

Table 2 emphasizes that the AURA HIRDLS and UARS CLAES and ISAMS experiments all measure extinction at 12 μm. Gas optical depths in the infrared are the lowest possible at 12 μm, and this “window region” is very sensitive to the presence of aerosol and clouds. Many of the experiments also measure extinction at other wavelengths.

SAGE and HALOE solar occultation experiments have vertical fields of view of 0.5 and 1.6 km, respectively. The solar occultation technique is "self calibrating" since signal counts at high and lower altitudes are used to derive very accurate atmospheric transmissions. Validation of SAGE and HALOE extinctions (with accuracies on the order of 20 and 30 %, respectively) are discussed by *Hervig and Deshler* [2002]. CLAES and ISAMS are limb-view emission experiments with vertical resolutions of 2.5 and 2.4 km, respectively. Validation of CLAES and ISAMS extinctions (with accuracies on the order of 33 and 25 %, respectively) are discussed by *Massie et al.* [1996] and *Lambert et al.* [1996], respectively.

The HIRDLS experiment on the AURA platform is also a limb-view emission experiment. HIRDLS suffered a serious problem during launch when instrument insulation came loose and covered, depending upon the particular spectral channel, 80% to 98% of the scan mirror. The HIRDLS team, however, has been able to correct the observed radiances for the obscuration signal for many of the 21 HIRDLS channels, archiving temperature, O_3, CFC11, CFC12, HNO_3, and 12 μm extinction profiles [*Khosravi et al*., 2009]. Validation of the HIRDLS cloud products is discussed by *Massie et al.* [2007]. HIRDLS has a vertical resolution of 1 km, making a complete set of measurements every 10 seconds.

The CALIPSO nadir-viewing lidar in the NASA A-train observes at 0.532 and 1.064 μm [*Winker et al.* 2007] and has high vertical resolution (~100 m). We use CLay (i.e. cloud layer) data files, and average the data into vertical altitude bins of 1 km. These files specify the tops and bottoms of all detected cloud layers for each 5 km ground-track horizontal length, from which cloud frequency of occurrence can be calculated.

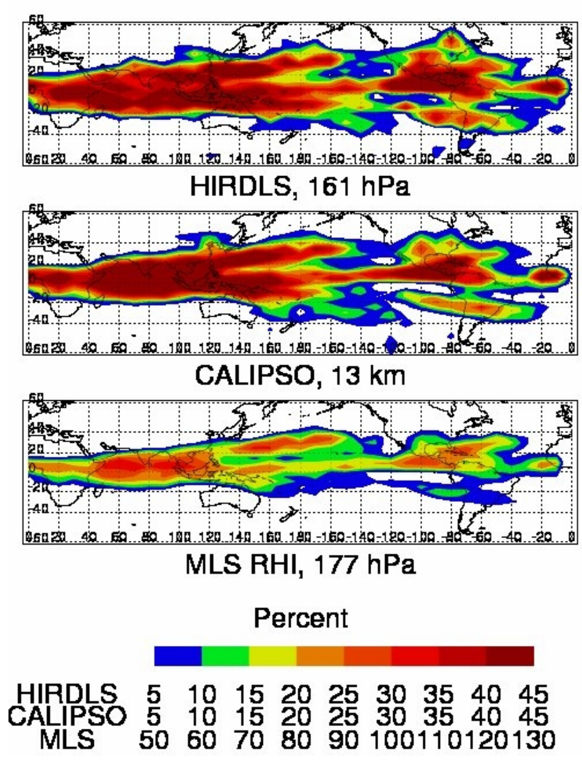

Figure 2. Cloud frequency of occurrence from HIRDLS and CALIPSO observations in June of 2007 at 161 hPa and 13 km, respectively, and MLS RHI at 177 hPa [*Massie et al.* 2010]. The vertical resolutions are ~ 1km for the HIRDLS and CALIPSO maps, while the MLS RHI data has a 4 km vertical field of view.

We also will analyze the RL-GEOPROF data product [*Mace et al*. 2009], which specifies the upper and lower altitudes of cloud layers as observed jointly by the CloudSat and CALIPSO experiments. The CloudSat 94 GHz radar and CALIPSO lidar are separated by 10 seconds in the A-train, and together measure cloud structure throughout the troposphere. The CloudSat and CALIPSO experiments are sensitive to optically thick clouds in the lower troposphere and optically thin clouds in the upper troposphere, respectively.

The cloud maps produced by HIRDLS agree very well with those produced by the CALIPSO experiment. Figure 2 presents cloud frequency of occurrence maps for a single month (June 2007) at 161 hPa (for HIRDLS) and 13 km (for CALIPSO). The HIRDLS map was produced by using extinction in the 9.0×10^{-4} to 1.0×10^{-2} km^{-1} range. The 9.0×10^{-4} km^{-1} 12 μm cirrus threshold was determined by *Mergenthaler et al*. [1999] based upon an analysis of CLAES 12 μm extinction data. The CALIPSO map was produced from analysis of CALIPSO CLay files. It is apparent that the geospatial features from the two experiments are very similar.

Figure 2 indicates that sampling is sufficient for the HIRDLS and CALIPSO experiments to calculate monthly longitude-latitude maps at specific pressure levels with a vertical resolution of ~ 1 km. These monthly maps, for 2005 – present, have many fine geospatial details, and will serve as stringent tests of the accuracy of the cloud fields generated by chemical-transport-microphysical and climate models.

We will also relate the cirrus cloud fields to proxy relative humidity data to determine if moisture is increasing or decreasing during the last 25 years for the tropics and sub-tropics (i.e. determine if changes in cirrus frequency of occurrence are correlated with changes in upper tropospheric humidity). Long-term data sets of relative humidity, however, are of various degrees of suitability. *Soden et al.* [2005] discuss the difficulties in using weather balloon, global reanalysis, and other datasets to quantify changes in relative humidity. *Soden et al*. [2005] use HIRS 6.3 μm water vapor band radiances and MSU channel 2 radiances in their study of upper tropospheric moistening. HIRS channel 12 radiances (i.e. T12 brightness temperatures) are sensitive to water vapor in the upper troposphere from 200 to 500 hPa, while the MSU channel 2 radiances (i.e. T2 brightness temperatures) are sensitive to temperature from 200 to 800 hPa. Changes in (T2 – T12) brightness temperature differences are related to changes in atmospheric moisture. *Soden et al*. [2005] report an increase in (T2 – T12) during 1984 – 2004, indicating a moistening of the upper troposphere. We slightly modify the Soden methodology by using MSU channel 4 brightness temperatures to remove the stratospheric contribution to T2 (i.e. see equation 1 of *Fu et al*., 2004), calculating a modified T2 brightness temperature T2*. We will determine if changes in (T2* – T12) are correlated with changes in cirrus frequency of occurrence. Drs. Fu and Johanson have direct experience with these data sets [*Fu et al*., 2004; *Fu et al*., 2006; *Hu and Fu*, 2007].

3.2 Inter-satellite comparisons

Since the various experiments observe at different wavelengths (λ), it is important to determine the best way to inter-compare the extinction data sets. We essentially need to know for subvisual cirrus of radii between r_1 and r_2, and opaque cirrus of radii between r_3 and r_4, the extinction ranges $[\beta(\lambda, r_1), \beta(\lambda, r_2)]$ and $[\beta(\lambda, r_3), \beta(\lambda, r_4)]$, and scaling curves $[\beta(12\ \mu m, r) / \beta(\lambda, r)]$, for each wavelength for each experiment. This knowledge will allow us to put the different extinction data sets on a common footing. The extinction ranges will be used to calculate cloud frequencies of occurrence, while the scaling curves will allow us to calculate "12 μm scaled" extinctions.

We approach this task from both empirical and theoretical viewpoints.

a) Theoretical calculations

From the theoretical point of view, we will calculate $\beta(\lambda, r_m)$ for representative cirrus size distributions, with r_m standing for the mean radius of the size distributions. This allows us to calculate extinction ranges $[\beta(\lambda, r_1), \beta(\lambda, r_4)]$, $[\beta(\lambda, r_1), \beta(\lambda, r_2)]$, and $[\beta(\lambda, r_3),\beta(\lambda, r_4)]$ for the three cloud cases (all clouds, subvisual cirrus, and opaque cloud cases), as well as the scaling curves $[\beta(12\ \mu m, r) / \beta(\lambda, r)]$. This task requires knowledge of the particle radii (r) ranges of the opaque and subvisual cirrus, particle size distributions, the most likely habits (shapes) of these particles, the wavelength dependence of the indices of refraction of ice, and the optical properties of the cirrus (e.g. $Q_{ext}(r, \lambda)$ extinction efficiencies).

Many of these specifications are fairly well known. Previous work has adopted reasonable ranges of extinction for opaque and subvisual cirrus. Figure 1 of *Wang et al*. [1996] specifies that SAGE subvisual and opaque cloud 1.02 μm extinction ranges correspond to the 2.5×10^{-4} to $3.0 \times 10^{-2}\ km^{-1}$ range, and extinctions greater than $2.5 \times 10^{-2}\ km^{-1}$, respectively. Previous work also has determined that subvisual cirrus corresponds to radii between 0.5 and 25 μm [*Lynch and Sassen*, 2002]. *Yang et al.* [2005] tabulate Q_{ext}, particle volume, area, scattering albedo, asymmetry parameter, and phase functions for six crystal habits for single particles ranging in size from 2 to 9950 μm at 49 wavelengths from 3.08 to 100 μm. *Bi et al*. [2009] discusses extinction ratios for realistic cirrus particles at the CALIPSO wavelengths of 0.532 and 1.064 μm. The indices of refraction of ice [*Warren and Brandt*, 2008] are well established. We will also consult with Dr. Andrew Heymsfield of NCAR as to which cloud radii, shape, and cloud particle size distributions are most appropriate for our opaque and subvisual cirrus radiative transfer calculations.

b) Empirical scaling curves

From Table 2 it is apparent that there is temporal and spatial overlap between many of the experiments. For example, SAGE observes for many years (1991-1999) that overlap with those of HALOE, and with CLAES for a smaller number of years (1991-1993). We propose to calculate CLAES versus HALOE, CLAES versus SAGE, and SAGE versus HALOE etc, scatter graphs of co-located extinction to determine empirically the extinction scaling curves.

The second empirical set of calculations will involve taking ratios of extinction, e.g. the ratio of 6 and 12 μm ISAMS or CLAES extinction. 6 μm is the peak of the infrared extinction spectrum of sulfate aerosol. The ratio $\beta(6\ \mu m) / \beta(12\ \mu m)$ is different from unity for sulfate aerosol, and asymptotes towards unity as cirrus particle size increases (since the Q_{ext} efficiency coefficient approaches a value of 2 for "large" particles at both wavelengths). Graphs of $\beta(6\ \mu m) / \beta(12\ \mu m)$ versus $\beta(12\ \mu m)$ will indicate the lower extinction threshold of cirrus detection at 12 μm.

c) Radii analyses

We will analyze multi-wavelength extinction from HALOE observations to estimate cirrus radii (i.e. calculate probability distribution functions of cirrus r_m values). The wavelength dependence of the HALOE cirrus extinction spectrum is dependent upon cloud particle size. For large particles the extinction efficiency asymptotes to a value of 2, and the HALOE extinction spectra is flat. Analysis of HALOE extinction data will provide useful estimates of subvisual cirrus radii which can be used to confirm the calculations in step (a).

Figure 3A displays observed HALOE extinction ratios form 30 S to 30 N from 1998 through 2005 for pressures between 171 and 100 hPa. As discussed in *Massie et al* [2002], HALOE 3.46 μm extinctions greater than 4 x 10^{-4} km^{-1} are most likely cirrus. The ratios in Figure 3A change in a systematic manner as extinction increases. The utilization of ratios is useful since the number density of the cirrus size distribution cancels out in the numerator and denominator of the ratio of the extinction integrals. The 5.26 to 3.46 μm extinction ratios are ~1.07 on average. Column shapes are more likely than hexagonal plates, since the 3.40 to 3.46 μm extinction ratio is greater than unity. The data in Figure 3 are consistent with column-shaped cirrus with radii near 8.5 μm.

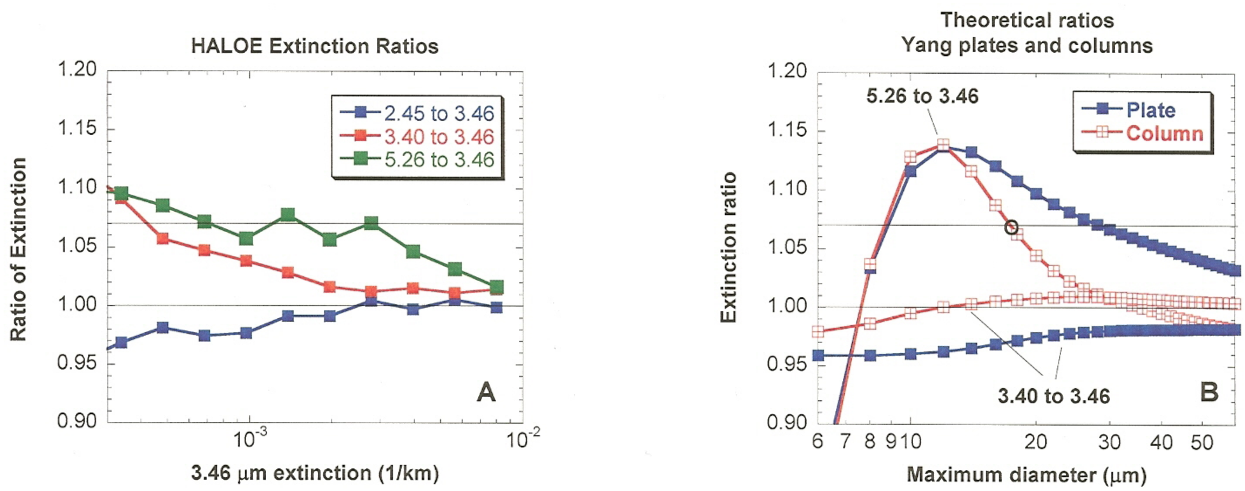

Figure 3. A) HALOE extinction ratios expressed as a function of 3.46 μm extinction. The 5.26 to 3.46 μm extinction ratio is ~1.07. B) Extinction ratios for hexagonal plates and solid columns are calculated using the *Yang et al.* [2005] scattering database. The solid column curves suggest a maximum diameter near 17 μm, marked by the "O" in panel B.

We anticipate that there will be a consistent story indicated by the calculations of steps a), b), and c). Based upon our synthesis of the calculations, we will produce scaling curves [$\beta(12\ \mu m, r) / \beta(\lambda, r)$], and extinction ranges for all three cloud types (all clouds, opaque clouds, and the subvisual cirrus), for all wavelengths at which the different instruments measure extinction.

3.3 Observational analyses

Since solar occultation experiments observe only ~30 occultations per hemisphere per day, while limb-view emission experiments observe more often, sampling statistics are an important consideration. We propose to prepare latitude-longitude maps at various pressure levels and spatial and temporal scales in order to perform a trend analysis of cloud extinction and frequency of occurrence with adequate sampling statistics.

We will first prepare latitude-longitude maps of cirrus frequency of occurrence for each experiment at selected pressure levels, for each available month at a resolution of 2.5° in latitude by 10° in longitude. The frequency of occurrence will be calculated using the extinction ranges for the three cloud types. Maps also will be prepared for the original extinctions and scaled extinctions (based on the scaling curves). These maps will then be averaged both in time and space (to lower horizontal resolutions) for each month, season (DJF, MAM, JJA, SON), and year, and also averaged in 5 year time bins from 1985 through 2010.

Using these maps, zonal averages for the tropics (20 S – 20 N) and northern subtropics (20 N – 40 N), and southern subtropics (40 S – 20 S) will be calculated. Time series of the zonal averages will be graphed, and least squares fitting will determine if there is a meaningful trend in the averages. Trend analysis will be done individually for each separate extinction data set. The trend analysis will also be performed for a subset of longitudes, e.g. over the Maritime continent (Indonesia). If the time trends are positive for the tropics and negative for the subtropics, then this result will be consistent with the general concept of changes in the Hadley circulation that are discussed above in the Introduction.

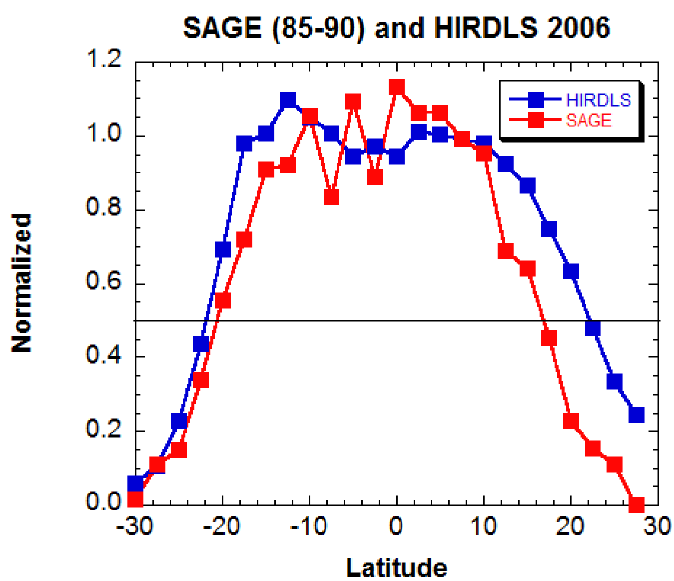

Figure 4. Preliminary normalized distributions of cirrus frequency of occurrence as measured by the SAGE experiment in 1985 – 1990 for 14.5 – 16 km and the HIRDLS experiment in 2006 for 100 - 121 hPa for 60 E to 180 E. The full-width half-max difference in the tropical widths is 6.7° (i.e. 3.5° per decade expansion of the tropics).

Zonal mean cloud frequency of occurrence will also be calculated in 2.5° bins of latitude for 30 S to 30 N at various pressure levels in the upper troposphere for each of the 5 year time periods. Full-width half-max (FWHM) widths of the tropics will be calculated for each of the data curves individually for each experiment. Figure 4 presents a preliminary set of SAGE and HIRDLS curves, normalized to unity for each curve. An extinction ratio technique, using β(1.02 μm) / β(0.525 μm) ratios, was applied to the SAGE data [*Massie et al*., 2003], and a cirrus extinction threshold of 9.0 x 10^{-4} km^{-1} was used for the HIRDLS data.

The solid line at a normalized value of 0.5 indicates that the SAGE tropical width (37.5°) is less than that of the HIRDLS tropical width (44.2°). The FWHM difference in the tropical widths of the two experiments is 6.7° (i.e. 3.5° per decade expansion in the tropics). The curves illustrate that the SAGE and HIRDLS data can be used to calculate tropical widths.

It is known that several issues need to be considered in our analysis. It is well known that the Mt. Pinatubo eruption perturbed the stratospheric aerosol field. The time bin for 1990-1994 may be anomalous. El Nińo conditions are known to shift the longitudinal distribution of cirrus [*Massie et al*., 2000], and 1997 was a year of a significant El Nińo. Calculations need to be carried out with and without 1997 for the 1995-1999 time bin.

We will use MSU (channels 2 and 4) radiances and HIRS 6.3 μm (channel 12) radiance data, to prepare latitude-longitude maps of (T2* – T12) brightness temperature differences in a manner similar to the cirrus maps. (The last paragraph of section 3.1 discusses the modified T2 brightness temperature T2*.) We will determine if there are coherent geospatial longitude-latitude patterns and trends that indicate a consistent picture (e.g. changes in cloud frequency of occurrence in the tropics and subtropics are correlated with changes in relative humidity). Of particular interest is to see if there are decreases in cirrus in the upper troposphere in the sub-tropics that are related to decreases in relative humidity.

5. Expected Significance

If trends in the geographical distributions (i.e. frequency of occurrence) of cirrus in the tropics and subtropics are detected, they will provide important constraints on the cloud fields predicted by 3D transport-chemistry-microphysical and climate models that will be used to predict future changes in the troposphere and stratosphere.

By determining how one can inter-relate the multi-wavelength extinction data sets, the usefulness of the individual data sets will be enhanced.

6. Relevance to NASA objectives

Section A.15 of the NASA ROSES AO lists research topics and objectives of particular importance to the Aura Science Team program. Our work is aligned with the following NASA science objectives:

A) Combine AURA data with data from other sensors within the A-train and/or other satellites to study relevant scientific questions.

B) Determine the impacts of trace gases on climate.

C) Develop new data products not supported by the Aura core data analysis budget.

We assume in B) that changes in the Hadley circulation are due to global warming (i.e. increases in CO_2).

With these objectives in mind, we:

A) Analyze data from AURA (HIRDLS), A-train (CALIPSO, CloudSat), and other 20th century experiments (SAGE, HALOE, ISAMS, CLAES, MSU, HIRS).

B) Determine if the latitudinal width of cirrus has increased during the last 25 years. This will add to the consistent evidence from other studies that the Hadley circulation is changing.

C) Develop data products (i.e. longitude-latitude maps of cloud frequency of occurrence and extinction at various spatial and temporal resolutions for 1985 - 2010) that are based upon analyses of Level 2 data from multiple satellite experiments. These derived data products will be made available to the research community.

7. General Plan of Work and Management Approach

Qiang Fu is author on several papers on the theme of decadal changes of several important climate variables including tropospheric temperature, tropical widths, the Hadley circulation, and the Brewer-Dobson circulation. He is also an expert on the radiative properties of cirrus clouds. He will supervise postdoc Dr. Celeste Johanson who will work one month per year on this project. Steven Massie has worked directly with many of the extinction datasets discussed in this proposal, in validation and application studies. Rashid Khosravi has direct experience with the HIRDLS retrieval. Massie and Khosravi are members of the HIRDLS science team. They will work 37% per year on this project. Massie, Khosravi, Fu, and Johanson are responsible for the definition of tasks and the organization of the satellite data file processing. The data file processing tasks are primarily shared by Massie and Khosravi. Interpretation of the results is a shared activity by all four investigators.

Year 1

a) Process the original satellite data into files at specific pressure levels and various spatial (longitude-latitude) and temporal scales (from monthly to 5 year averages).

b) Determine the extinction ranges for three cases (i.e. all clouds, opaque clouds, subvisual cirrus), prepare wavelength dependent scaling curves, and produce frequency of occurrence, unscaled extinction, and scaled extinction maps.

Year 2

a) Calculate trends in frequency of occurrence and extinction during 1985-2010 for the tropics and subtropics.

b) Calculate tropical cloud distribution widths and trends.

Year 3

a) Refine the calculations, updating observations not available in the first two years of the study.

b) Investigate questions that invariably arise from the research conducted in the first two years of the project.

c) Make available to NASA and the research community the spatial and temporally averaged data files (e.g. longitude-latitude maps).

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Massie, S. T., et al., Validations studies using multi wavelength Cryogenic Limb Array EtaIon Spectrometer (CLAES) observations of stratospheric aerosol, *J. Geophys. Res*., **101**, D6, 9757-9773 (1996).

Massie, S. T., P. Lowe, X. Tie, M. Hervig, G. Thomas, and J. Russell, Effect of the 1997 El Nino on the distribution of upper tropospheric cirrus, *J. Geophys. Res*., **105**, 22725-22741 (2000).

Massie, S., A. Gettelman, W. Randel, and D. Baumgardner, Distribution of tropical cirrus in relation to convection, *J. Geophys. Res*., **107**, No. D21, 4591, doi:10.1029/2001JD001293, (2002).

Massie, S., W. Randel, F. Wu, D. Baumgardner, and M. Hervig, Halogen Occultation Experiment and Stratospheric Aerosol and Gas Experiment II observations of tropopause cirrus and aerosol during the 1990s, *J. Geophys. Res*., **108** (D7), 4222, doi:10.1029/2002JD002662 (2003).

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Massie, S. T., J. Gille, C. Craig, R. Khosravi, J. Barnett, W. Read, and D. Winker, HIRDLS and CALIPSO observations of tropical cirrus, *J. Geophys. Res*., **115**, D00H11, doi:10.1029/2009JD012100 (2010).

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P.-H. Wang, P. Minnis, B. A. Wielicki, T. Wong, and L. Vann, Satellite observations of long-term changes in tropical cloud and outgoing longwave radiation from 1985 to 1998, *Geophys. Res. Lett*., **29**, No 10, 10.1029/2001GL014264 (2002).

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Facilities and Equipment

Data storage capacity and computational machinery at NCAR is very sufficient to handle and process the satellite data that is required to carry out the proposed tasks. The Atmospheric Chemistry Division (ACD) at NCAR has a terabyte storage device, while the Computational and Information Systems Laboratory (CISL) at NCAR has a 2 petabyte mass store system. We currently access and process the data sets mentioned in this proposal using the divisional computer in ACD.

Curriculum Vitae

Steven T. Massie

Education:
A.B. (Astronomy) University of California, Berkeley, 1974
Ph.D. (Astro-Geophysics) University of Colorado, Boulder, 1979
Post-doc, Lunar and Planetary Laboratory, Tucson, 1979-1982

Employment at the National Center for Atmospheric Research
Associate Scientist III 1984-1995, Scientist I 1983, 1995-1998
Scientist II, 1998-2002, Scientist III, 2002- 2010,
Senior Scientist, 2010-present
Atmospheric Chemistry Division
Boulder, Colorado

Selected Publication List:

Massie, S. T., et al. (2010), HIRDLS and CALIPSO observations of tropical cirrus, *J. Geophys. Res*., **115**, D00H11, doi:10.1029/2009JD012100.

Heymsfield,A., et al. (2010), Aircraft-Induced Hole Punch and Canal Clouds, *Bull. Am. Met. Soc*., **91**, 753-766.

Rothman, L. et al. (2009), The HITRAN 2008 Molecular Spectroscopic database, *J. Quant. Spect. and Rad Transf*, **110**, 533–572.

Khosravi, R., et al. (2009), Overview and characterization of retrievals of temperature, pressure, and atmospheric constituents from the High Resolution Dynamics Limb Sounder (HIRDLS) measurements. *J. Geophys. Res*., **114**, D20304, doi:10.1029/2009JD011937.

Jiang, J. H., et al. (2009), Aerosol-CO relationship and aerosol effect on ice cloud particle size: Analyses from Aura Microwave Limb Sounder and Aqua Moderate Resolution Imaging Spectroradiometer observations. *J. Geophys. Res*., **114**, doi:10.1029/2009JD012421.

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Massie, S. T., et al. (2007), Aerosol indirect effects as a function of cloud top pressure, *J. Geophys. Res* , **112**, doi:10.1029/2005JD007383.

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Porch, W., et al. (2007), Trends in Aerosol Optical Depth for Cities in India, *Atmos. Environ*., **41**, 7524-7532.

Park., M., et al. (2007), Transport Above the Asian Summer Monsoon Anticyclone inferred from Aura MLS Tracers. *.J. Geophys. Res*., **112**, D16309, doiL10.1029/2006JD008294.

Seifert, P., A. et al. (2007), Seasonal dependence of geometrical and optical properties of tropical cirrus determined from lidar, radiosonde, and satellite observations over the Indian Ocean (Maldives) during INDOEX, *J. Geophys. Res*., *112,* doi:10.1029/2006JD008352.

Kim, Y. J., et al. (2006), PSCs observed by the ILAS-II in the Antarctic region: Dual Compositions and Variation of Compositions during June-August of 2003. *J. Geophys. Res*., **111**, D13S90, doi:10.1029/2005JD006445.

Edwards, D. P., et al. (2006), Satellite Observed Pollution from Southern Hemisphere Biomass Burning. *J. Geophys. Res*., **111**, D14312, doi:10.1029/2005JD006655.

Massie, S. T., et al. (2004), TOMS observations of increases in Asian aerosol in winter from 1979 to 2000. *J. Geophys. Res*., **109**, D18211,doi: 10.1029/2004JD004620

Massie, S. T., and A. Goldman (2003), The infrared absorption cross-section and refractive-index data in HITRAN. *J. Quant. Spect. Radiat. Transf*., **82**, 413-428.

Massie, S., et al. (2003), Halogen Occultation Experiment and Stratospheric Aerosol and Gas Experiment II observations of tropopause cirrus and aerosol during the 1990s. *J. Geophys. Res*., **108**, doi:10.1029/2002JD02662.

Massie, S. T., et al. (2002), Distribution of tropical cirrus in relation to convection. *J. Geophys. Res*., **107**, doi:10.1029/2001JD001293.

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Massie, S. T., et al. (1998), Estimation of polar stratospheric cloud volume and area densities from UARS extinction data. *J. Geophys. Res.*, **103**, 5773-5783.

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Curriculum Vita: Rashid Khosravi (rashid@ucar.edu)

Current Position: (AURA) HIRDLS Algorithm Scientist, NCAR, Boulder, CO

Employment

- National Center for Atm. Research, Atm. Chem. Division, Boulder, CO
  Project Scientist II, 2006-present; Project Scientist I, 2004-2006; 1998-2001; Associate Scientist III, 2001-2004; Graduate Research Assistant, 1995-1998
- Martin Marietta Aerospace, Denver, CO: Engineer, 1985-1989; Sr. Engineer, 1989-1992

Publication List

Khosravi, R, A. Lambert, H. Lee, J. Gille, J. Barnett, G. Francis, D. Edwards, C. Halvorson, S. Massie, C. Craig, C. Krinsky, J. McInerney, K. Stone, T. Eden, B. Nardi, C. Hepplewhite, W. Mankin, and M. Coffey (2009), Overview and Characterization of Retrieval of Temperature, Pressure, and Atmospheric Constituents from HIRDLS Measurements, *J. Geophys. Res.*, 114, D20304, doi:10.1029/2009JD011937.

Khosravi, R., G.P. Brasseur, A.K. Smith, D.W. Rusch, S. Walters, S. Chabrillat, and G. Kockarts (2002), Response of the mesosphere to human-induced and natural perturbations, *J. Geophys. Res.*, 107, 4355, doi:10.1029/2001JD001235.

Khosravi, R., G.P. Brasseur, A.K. Smith, D.W. Rusch, J.W. Waters, and J.M. Russell III (1998), Significant reduction in the stratospheric ozone deficit using a three-dimensional model constrained with UARS data, *J. Geophys. Res.*, 103, 16203-16219.

Massie, S., J. Gille, R. Khosravi, H. Lee, D. Kinnison, G. francis, et al. (2007), High Resolution Dynamics Limb Sounder observations of polar stratospheric clouds and subvisible cirrus, *J. Geophys. Res.*, 112, D24S31, doi:10.1029/2007JD008788.

Livesey, N.J., J.W. Waters, R. Khosravi, G.P. Brasseur, G.S. Tyndall, and W.G. Read (2001), Stratospheric CH_3CN from the UARS Microwave Limb Sounder, *Geophys. Res. Lett.*, 28, 779-782.

Brasseur, G.P., A.K. Smith, R. Khosravi, T. Huang, S. Walters, S. Chabrillat, and G. Kockarts (1999), Natural and Human-Induced Perturbations in the Middle Atmosphere: A Short Tutorial, Proceedings of the Chapman conference on Atmospheric Science Across the Stratopause.

Massie, S., J. Gille, C. Craig, R. Khosravi, J. Barnett, W. Read, D. Winker (2010), HIRDLS and CALIPSO Observations of Tropical Cirrus, *J. Geophys. Res.* 115, D00H11, doi:10.1029/2009JD012100

Kinnison, D. E., J. Gille, J. Barnett, C. Randall, L. Harvey, A. Lambert, R. Khosravi, et al. (2008), Global Observations of HNO_3 from the High Resolution Dynamics Limb Sounder (HIRDLS): First results, *J. Geophys. Res.*, 113, D16S44, doi: 10.1029/2007JD008814.

Pan, L.L., W. J. Randel, J. C. Gille, W.D. Hall, B. Nardi, S. Massie, V. Yudin, R. Khosravi, P. Konopka, and D. Tarasick (2009), Tropospheric Intrusions Associated with the Secondary Tropopause, J. Geophys. Res., doi:10.1029/2008JD011374.

Alexander, M. J., J. Gille, C. Cavanaugh, M. Coffey, C. Craig, T. Eden, G. Francis, C. Halvorson, J. Hannigan, R. Khosravi, et al. (2008), Global estimates of gravity wave momentum flux from High Resolution Dynamics Limb Sounder Observations, *J. Geophys. Res.*, 113, D15S18, doi:10.1029/2007/JD008807.

Education: Ph.D., Atm. Sci., U. of CO, Boulder; MS, Physics, U. of CO, Boulder; MS, Chem. Eng., W.Va. U., Morgantown, W. Va.; BS, Chem. Eng., Wayne State U., Detroit, MI

CURRICULUM VITA: QIANG FU

PRESENT POSITION

Professor, Department of Atmospheric Sciences, University of Washington
Seattle, Washington 98195-1640, USA

RESEARCH AREAS

Light scattering and radiative transfer; Parameterization of atmospheric radiation and cloud processes; Cloud/aerosol/radiation/climate interactions; Remote sensing; Climate change.

EDUCATION

Ph.D.(1991) in Meteorology, U. of Utah; MS(1985) and BS(1983) in Atmos. Physics, Peking U.

EMPLOYMENT RECORD & Recognition

Dr. Fu is a professor at the Dept of Atmospheric Sciences, Univ. of Washington since 2006, where he was an associate professor (2003-2006) and an assistant professor (2000-2003). He was an associate professor (1999-2000) and an assistant professor (1994-1999) at the Dept of Oceanography, Dalhousie Univ., and a research associate at the Dept of Meteorology, Univ. of Utah (1991-1994). Dr. Fu was a visiting professor at the Univ. of Tokyo (03-07/2007), a senior visiting fellow at GFDL/Princeton Univ. (10/2006-02/2007), and a visiting scientist at the NASA Langley Research Center (05-07/1998). Dr. Fu was selected as the AMS fellow in 2009.

15 SELECTED JOURNAL PUBLICATIONS SINCE 2004 [Dr. Fu have authored/co-authored more than 100 refereed journal papers with a H factor of **29**.]

1) Virts, K.S., J.M. Wallace, Q. Fu, and T.P. Ackerman, 2010: TTL cirrus: Formation mechanisms and association with planetary scale waves. *J. Atoms. Sci.* (accepted).
2) Yang, Q., Q. Fu, and Y.X. Hu, 2010: Radiative impacts of clouds in the tropical tropopause layer. *J. Geophy. Res.*, *115*, D00H12, doi:10.1029/2009JD012393.
3) Fu, Q., S. Solomon, and P. Lin, 2010: On the seasonal dependence of tropical lower-stratospheric temperature trends. *Atmos. Chem. Phys*., 10, 2643-2653.
4) Lin, P., Q. Fu, S. Solomon, and J.M. Wallace, 2009: Temperature trend patterns in Southern Hemisphere high latitudes: Novel indicators of stratospheric change. *J. Climate*, 22, 6325-6341.
5) Fu, Q., T.J. Thorsen, J. Su, J.M. Ge, and J.P. Huang, 2009: Test of Mie-based single-scattering properties of non-spherical dust aerosols in radiative flux calculations. *J. Quan. Spectro. Rad. Trsnsfer*, 110, 1640-1653.
6) Johanson, C.M., and Q. Fu, 2009: Hadley cell expansion: Model simulations versus observations. *J. Climate*, 22, 2713-2725.
7) Yang, Q., Q. Fu, J. Austin, A. Gettelman, F. Li, and H. Vomel, 2008: Observationally derived and model simulated stratospheric upward mass fluxes. *J. Geophys. Res*., doi:10.1029/2008JD009945.
8) Fu, Q., 2007: A new parameterization of an asymmetry factor of cirrus clouds for climate models. *J. Atmos. Sci.*, 64, 4144-4154.
9) Fu, Q., Y.X. Hu, and Q. Yang, 2007: Identifying the top of the tropical tropospause layer from vertical mass flux analysis and CALIPSO lidar cloud observations. *Geophys. Res. Lett*., 34, L14813, doi:10.1029/2007GL030099.
10) Hu, Y.Y., and Q. Fu, 2007: Observed poleward expansion of the Hadley circulation since 1979. *Atmos. Phys. Chem*., 7, 5229-5236.
11) Fu, Q., and W.B. Sun, 2006: Apparent optical properties of spherical particles in absorbing medium. *J. Quan. Spectro. Rad. Trsnsfer*, 100, 137-142.
12) Fu, Q., C.M. Johanson, J.M. Wallace, and T. Reichler, 2006: Enhanced mid-latitude tropospheric warming in satellite measurements. *Science*, 312, 1179.
13) Fu, Q., and C.M. Johanson, 2005: Satellite-derived vertical dependence of tropical tropospheric temperature trends. *Geophys. Res. Lett.*, 32, L10703, doi:10.1029/2004GL022266.
14) Fu, Q., C.M. Johanson, S.G. Warren, and D.J. Seidel, 2004: Contribution of Stratospheric Cooling to Satellite-Inferred Tropspheric Temperature Trends. *Nature*, 429, 55-58.
15) Fu, Q., and S. Hollars, 2004: Testing mixed-phase cloud water vapor parameterizations using SHEBA/FIRE-ACE observations. *J. Atmos. Sci.*, 61, 2083-2091.

Current and Pending Non-Base Support for Scientific Staff

Steven Massie

In the event that an unanticipated overlap does occur, the level of effort would be adjusted, and/or additional personnel would be added, in concurrence with funding sources. Some projects may be ending as others are beginning.

Project Title: Investigating the influence of anthropogenic pollution on clouds: A combined multi-satellite observations and modeling approach

PI: Steve Massie

Time Committed to the Project: 1.8 person-months 0.0 person-months/year support by NSF base funds

Source of Support: Jet Proposal Laboratory

Contact Information: Jonathan H. Jiang, (818) 354-7135, jonathan.h.jiang@jpl.nasa.gov

Award Amount (or amount requested): $108,859.00 **Duration of Award:** 7/01/07-12/31/10

Award Status: Award

Project Title: HIRDLS and CALIPSO Observations of Tropical Cirrus

PI: Steve Massie

Time Committed to the Project: 5.5 person-months 0.0 person-months/year support by NSF base funds

Source of Support: NASA

Contact Information: Richard S. Eckman, richard.s.eckman@nasa.gov, 757-864-5822

Award Amount (or amount requested): $398,264.00 **Duration of Award:** 6/01/08-5/31/11

Award Status: Award

Project Title: Aerosol Effects on Cloud Heights and Precipitation

PI: Steven Massie

Time Committed to the Project: 2.4 person-months 0.0 person-months/year support by NSF base funds

Source of Support: NASA

Contact Information: Hal Maring, (202) 358-1679, Hal.Maring@nasa.gov

Award Amount (or amount requested): $625,744.00 **Duration of Award:** 1/24/10-1/23/13

Award Status: Pending

Project Title: Collaborative Research: Type 1: Chemistry and Climate over Asia: Understanding the Impact of Changing Climate and Emissions on Atmospheric Composition (L02170219)

PI: Mary Barth

Time Committed to the Project: 1.0 person-months 0.0 person-months/year support by NSF base funds

Source of Support: NSF

Contact Information: Jay Fein, GEO/AGS, (703) 292-8527, jfein@nsf.gov

Award Amount (or amount requested): $707,785.00 **Duration of Award:** 1/1/11-12/31/13

Award Status: Pending

Current and Pending Non-Base Support for Scientific Staff

Steven Massie

Project Title: Advanced Limb Infrared Chemistry Experiment (ALICE)- Measuring the Response of the Atmosphere to Climate Change

PI: Bruno Nardi

Time Committed to the Project: 0.0 person-months 0.0 person-months/year support by NSF base funds

Source of Support: NASA

Contact Information: Mr. Parminder Ghuman, Earth Science Technology Office, NASA GSFC,
301-286-8001, Parminder.S.Ghuman@nasa.gov

Award Amount (or amount requested): $4,497,832.00 **Duration of Award:** 05/1/11-04/30/14

Award Status: Pending

Rashid Khosravi

There are no current or pending proposals at this time.

CURRENT AND PENDING SUPPORTS AS PI/CO-PI

Dr. QIANG FU

A. Current Supports

PI:	Qiang Fu
Title:	Understanding Tropical Stratosphere-Troposphere Exchange through Analyses of EOS Satellite Data and Global Climate Modeling
Source:	NASA
Period:	01/01/08 – 12/31/10
Amount:	$485,000
Committed time:	One summer month

PI:	Qiang Fu
Title:	Detecting Atmospheric Trends and Investigating Their Causes
Source:	NOAA
Period:	6/15/2008 – 6/14/2011
Amount:	$273,000
Committed time:	0.5 summer month

PI:	Qiang Fu
Title:	Radiative Energy Balance in the Tropical Tropopause Layer: An Investigation with ARM Data.
Source:	DOE ARM
Period:	6/15/2009 – 6/15/2012
Amount:	$418,148
Committed time:	One summer month

PI:	Qiang Fu
Title:	Soot and Dust Aerosols in the Seasonal Snow of Western and Northern China
Source:	University of Washington
Period:	September 15, 2009 – September 14, 2010
Amount:	$33,630
Committed time:	One academic month

BUDGET JUSTIFICATION – NARRATIVE
STEVEN MASSIE, PI

1. Table of Proposed Work Effort

PERSONNEL	Role	Person-Months
Dr. Steven Massie Senior Scientist	PI	4.4
Dr. Rashid Khosravi Project Scientist II	Co-I	4.4
Dr. Qiang Fu Professor	Co-I	0.5
Dr. Celeste Johanson Postdoctoral Fellow	Postdoctoral Fellow	1.0

- ***Steven Massie*** is the PI of this proposal and will be responsible for the overall management of this project. Dr. Massie has worked directly with many of the extinction datasets discussed in this proposal, in validation and application studies.
- ***Rashid Khosravi*** has direct experience with the HIRDLS retrieval.
- ***Qiang Fu*** is the author on several papers on the theme of decadal changes of several important climate variables including tropospheric temperature, tropical widths, the Hadley circulation, and the Brewer-Dobson circulation. He is also an expert on the radiative properties of cirrus clouds. He will supervise postdoc ***Celeste Johanson***.

Massie, Khosravi, Fu, and Johanson are responsible for the definition of tasks and the organization of the satellite data file processing. The data file processing tasks are primarily shared by Massie and Khosravi. Interpretation of the results is a shared activity by all four investigators.

2. Description of Facilities and Equipment

The Atmospheric Chemistry Division (ACD) provides computational support for staff and visitors' ranging from desktop systems to small clusters running Linux, Mac OSX, or Microsoft Windows operating systems. Additional resources to facilitate research include several computational, graphical, and productivity software packages, printers, and high speed network access.

As a part of UCAR and NCAR, ACD has access to high-end computational and mass storage resources, a visualization laboratory, and the extensive technical expertise provided by the Computational and Information Systems Laboratory. State of the art networks provide wide area connections which include a gigabit path to the Front Range Gigapop with high bandwidth connections to National Lambda Rail, Internet 2, and the commodity Internet. The core computer room, networking closets, and network equipment are supported by uninterrupted power supplies and emergency power generation facilities. These systems and networks are monitored around the clock by a dedicated operations staff who are prepared to resolve problems or escalate to expert staff should the need arise.

3. Rationale and Basis of Estimate for all Components, Including Procurements, Travel, Publications Costs and all Sub awards

Travel: The budget includes travel funding for one person to attend the American Geophysical Union (AGU) fall meeting held each year in San Francisco, California in December for five days each year. Cost estimates are based on the average travel expenses for such meetings in the past.

Materials and Supplies: The budget includes funds for miscellaneous supplies as needs, such as computer upgrades and peripherals.

Subaward: A subaward is requested for Dr. Qiang Fu, who is a uniquely qualified co-investigator working from the University of Washington. The request for Dr. Fu would support one half of one month salary each year for him and one month salary each year for his postdoctoral fellow, as wells as costs for travel to NCAR for collaboration on the proposed research.

4. Award Instrument

Should this proposal be selected for award we request that a grant be awarded to the University Corporation of Atmospheric Research (UCAR).

BUDGET JUSTIFICATION – DETAILS
STEVEN MASSIE, PI

1. Direct Labor
For this effort, the PI is budgeted at 37% time each year. Dr. Rashid Khosravi, Project Scientist II, is also budgeted at 37% effort each year. Dr. Qiang Fu, Professor at the University of Washington (UW), is budgeted at 4.2% effort each year through a subaward to UW. Dr. Celeste Johanson, Postdoctoral Fellow, is budgeted at 8.3% effort each year through the same subaward.

   Salaries are calculated at 86% for worked-time only. Salary is budgeted with an increase of 4% each fiscal year for inflation and merit raises. Benefits are calculated at 51% of salary for fiscal year 2011. (Vacation, holidays, sick time, and other non-worked time are paid from the UCAR benefits pool).

2. Other Direct Costs
Subawards: See the attached statement of work, budget and budget justification of the University of Washington.

   The budget includes funds for miscellaneous materials and supplies necessary to perform the proposed work. These costs include but are not limited to software upgrades and other computer peripheral needs. The cost is based on past purchases and numerous web searches. These items will be used solely for this activity, for the direct research as well as for the presentations of the results.

   Travel: This budget includes costs for travel to cover meetings and related travel expenses as follows:

   Domestic Travel, all years
   One traveler, 5 days

AGU Travel Cost	
Airfare	$450
Per Diem	550
Lodging	800
Registration	500
Transportation: shuttle, local mileage, etc.	200
Total Estimated Cost	$2,500

3. Facilities and Administrative Costs
Indirect Costs are calculated at 49.8% for FY2011. The effective period of the rate is October 1, 2010 to September 30, 2011. Indirect Costs are applied to all modified total direct costs (MTDC). Items excluded from MTDC are equipment costing $5,000 or more, participant costs, and individual subcontract amounts in excess of $25,000 per fiscal year.

   The UCAR management fee is a fixed fee, calculated at 3% of MTDC and NCAR applied indirect costs.

   Computing Service Center (CSC) expenses are a method of distributing the cost of computer support personnel fairly among many different projects. The CSC rate for FY11 is $4.80 per work hour of support. The CSC rates are established each year within the framework of “Specialized Service Centers’ in OMB Circular A-122.

B&P Check - Final Budget

NCAR Division: ACD

Project Title: Decadal changes in cloud geographical distributions
NCAR PI(s): Steven Massie
NCAR Proposal # 2010-542
Period of Performance: 2/1/11 - 1/31/14
Date: 7/22/10
Initials:

						YEAR 1	YEAR 2	YEAR 3	TOTAL
						NASA	NASA	NASA	NASA
SALARIES & BENEFITS									
Regular Salaries	**Participant Name**	**Annual Salary**	**% Effort**	**CSC Rate**					
PI	Steven Massie	110,167	37%	ACD $4.80		35,521	36,942	38,420	110,883
Proj Scientist II	Rashid Khosravi	92,255	37%	ACD $4.80		29,746	30,936	32,173	92,855
TOTAL Salaries						**65,267**	**67,878**	**70,593**	**203,738**
Regular Benefits @	**0.51**					**33,286**	**34,618**	**36,002**	**103,906**
MATERIALS & SUPPLIES									
Misc						1,000	1,000	1,000	3,000
SUBTOTAL						**1,000**	**1,000**	**1,000**	**3,000**
PURCHASED SERVICES									
Subaward Univ of Washington						21,483	22,267	23,083	66,833
SUBTOTAL						**21,483**	**22,267**	**23,083**	**66,833**
TRAVEL									
Domestic						2,500	2,500	2,500	7,500
SUBTOTAL						**2,500**	**2,500**	**2,500**	**7,500**
SUBTOTAL Modified Total Direct Costs (MTDC)						**123,536**	**128,263**	**133,178**	**384,977**
NCAR INDIRECT COSTS (IC) @	**0.498**					**61,521**	**63,875**	**66,323**	**191,719**
MTDC Items that include IC									
COMPUTING SERVICE CENTER	$4.80					6,354	6,354	6,354	19,062
TOTAL MTDC + Applied IC						**191,411**	**198,492**	**205,855**	**595,758**
UCAR Management Fee (Applied to MTDC + IC)	**0.03**					**5,742**	**5,955**	**6,176**	**17,873**
TOTAL Funding to UCAR						**197,153**	**204,447**	**212,031**	**613,631**

Decadal Changes in Cloud Geographical Distributions
University of Washington
Dr. Qiang Fu

Statement of work:

Dr. Qiang Fu of the University of Washington will be a co-Investigator in Dr. Steven Massie's (NCAR-ACD) proposal entitled "Decadal changes in cloud geographical distributions" to be submitted to the NASA Research Announcement ROSES 2010 NNH10ZDA001N-AURA. He will conduct tasks for the project as specified in the following:

1) Define the specific data file analysis tasks in collaboration with Massie and Khosravi.

2) Define the data analyses in collaboration with Massie and Khosravi.

3) Oversee the task comparing the width of tropics using various indices.

4) Participate in the interpretation of the data analyses.

5) Co-author scientific papers that document research findings from the above tasks.

6) Report the findings of the studies at scientific meetings.

BUDGET

Name	Annual salary	Effort	Y1	Y2	Y3
Q. Fu (co-I)	$135,831	4.2% (0.5 month)	$5,660	$5,886	$6,121
C. Johanson (postdoc)	$52,000	8.3% (0ne month)	$4,333	$4,507	$4,687
Benefits (25.8%)			$2,578	$2,681	$2,788
Travel			$1,200	$1,200	$1,200
Total direct cost			$13,771	$14,274	$14,797
Indirect cost (56%)			$7,712	$7,993	$8,286
Totals			$21,483	$22,267	$23,083

JUSTIFICATION

- **Qiang Fu, Professor at the University of Washington** (P.I., 0.5 month summer salary/year). He will conduct tasks by defining the data analyses in collaboration with Massie and Khosravi, and participating in the interpretation of the data analyses, and write and report the research funding.
- **Celeste Johanson, Postdoc at the University of Washington.** Funding is requested to support Dr. Johanson for one month per year to perform work comparing the cloud fields as the index for the width of the tropics with other indices.
- **Benefits:** The University of Washington pays benefits (Social Security, Health Insurance, Retirement, etc.) for employees, and these benefits are considered direct costs for personnel on this project.
- **Travels:** $1,200 is budgeted per year for Qiang Fu/Celeste Johanson to visit Massie/Khosravi at NCAR for three days for the collaboration on the project.
- **Indirect Cost:** Indirect costs are requested for all expenses, excluding equipment and graduate student tuition. Rates are based on the most recent HHS/UW agreement.

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH ♦ UCAR OFFICE OF PROGRAMS

Melissa D. Miller
Director
Budget and Finance
P.O. Box 3000 ♦ Boulder, CO 80307
303/497-8575 ♦ fax: 303/497-8579
melissa@ucar.edu

March 26, 2010

Ms. Carol Orlando
Cost Analysis and Audit Resolution Branch
Division of Institution and Award Support (BFA/DIAS)
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

Dear Carol,

Enclosed is the FY2011 UCAR Indirect Cost Rate Proposal. The UCAR President's Council reviewed and approved the draft budgets and rates on February 26, 2010.

We appreciate the cooperation of DIAS, DACS, and AGS in this process and look forward to discussing any questions you may have regarding the proposal.

Sincerely,

Melissa D. Miller
Director, Budget and Finance

c:

K. Spencer (NSF)
S. Nelson (NSF)
L. Dash (NSF)

J. Young
J. Reaves
D. Wilson
R. Brasher-Alleva
H. Mauriello
C. Huddle
C. Chambers
G. Taberski
K. Alipit

UCAR President's Council:
R. Anthes
M. Hagan
J. Fellows
R. Wakimoto
K. Schmoll

University Corporation for Atmospheric Research
FY2011 Summary of Indirect Cost Rates

	FY2009 Actual	FY2010 Approved	FY2011 Proposed
Employee Benefit, Indirect Cost Rates:			
Reduced Benefit Rate	11.0%	9.3%	8.4%
Full Benefit Rate	52.8%	51.9%	51.0%
Communications Indirect Cost Rate	$2,669	$3,108	$3,319
Facilities Indirect Cost Rate	$21.27	$22.64	$23.49
UCAR G&A Indirect Cost Rate	13.8%	13.9%	13.8%
NCAR Indirect Cost Rate	50.8%	49.1%	49.8%
UCP/E&O Indirect Cost Rates:			
On-Site	33.2%	33.1%	32.6%
Off-Site/Visitor Program	21.5%	21.5%	21.5%

University Corporation for Atmospheric Research
National Center for Atmospheric Research
FY2011 Indirect Cost Rate Computation

	FY2009 Actual	FY2010 Approved	FY2011 Proposal
Laboratory Indirect Cost Pools [1]	13,101,912	13,886,875	14,369,461
Director's Office	2,201,990	2,337,652	2,483,205
Subtotal NCAR	15,303,902	16,224,527	16,852,666
Communications Allocation	2,653,457	3,248,362	3,550,997
Facilities Allocation	12,152,808	12,449,507	13,270,321
Total NCAR before UCAR G&A Allocations	30,110,167	31,922,396	33,673,984
UCAR G&A Allocation	16,936,774	18,356,001	18,952,846
Total NCAR Indirect Cost Pool Before Variance	47,046,942	50,278,397	52,626,830
Prior Year Variance Carryforward	(123,938)	(1,071,220)	(1,056,429)
Total NCAR Indirect Cost Pool	46,923,003	49,207,177	51,570,401
NCAR Modified Total Direct Cost Base [2]	92,445,921	100,246,138	103,479,896
NCAR Indirect Cost Rate (before variance)	50.9%	50.2%	50.9%
NCAR Indirect Cost Rate	50.8%	49.1%	49.8%

(1) Estimate only. NCAR Indirect Cost Pool operating budget revisions will be completed when the FY2011 NSF Program Plan is developed.

(2) Represents projected expenditures only. NSF and other budgets will not be known for up to another year.

NCAR

National Center for
Atmospheric Research

RENA BRASHER-ALLEVA
Director
NCAR Budget and Planning

P. O. Box 3000, Boulder, CO 80307-3000 USA
Phone: 303.497.1116 Fax: 303.497.1194
rena@ucar.edu www.ncar.ucar.edu

March 17, 2010

Ms. Carol Orlando
Cost Analysis and Audit Resolution Branch
Division of Institution and Award Support
(BSA/DIAS)
National Science Foundation
4201 Wilson Blvd.
Arlington, VA 22230

Dear Carol,

Enclosed for review and approval are UCAR's proposed **FY2011 Aircraft Maintenance Rates (AMR), Service Center Rates (CSC and Machine Shop) and System User Rates (SUR and GAU).**

The Earth Observing Laboratory's (EOL) SURs and the Computational and Information Systems Laboratory's (CISL) GAU rates have not changed from the approved FY2010 rates.

As with previous rate submissions, the attached summary page has approval lines for NSF signatures. If you have any questions regarding the FY2011 proposed rates, please give me a call at (303) 497-1116 or you can reach me at rena@ucar.edu.

Sincerely,

Rena B Alleva

Rena Brasher-Alleva
Budget & Planning Director

cc: L. Dash, S. Nelson, K. Spencer, J. Huning; NSF
UCAR President's Council
Center Administrators
C. Chambers, E. Chapin, B. Tan, J. Reaves, M. Miller, K. Alipit, J. Young

National Center for Atmospheric Research
Boulder, Colorado
FY 2011 Approved Rate Summary

1. Aircraft Maintenance Rate

Aircraft Maintenance Rate (AMR)	FY 2009 Actual	FY 2010 Submitted	FY 2011 Proposed
C-130 Aircraft	$523 /Hour	$496 /Hour	$511 /Hour
GV Aircraft (Gulfstream HIAPER)	$789 /Hour	$901 /Hour	$1,044 /Hour

2. Service Center Rates

Division Computing Service Centers	FY 2009 Actual	FY 2010 Submitted	FY 2011 Proposed
Climate and Global Dynamics (CGD)	$6.47 /Hour	$6.34 /Hour	$6.49 /Hour
Atmospheric Chemistry Division (ACD)	$4.95 /Hour	$4.80 /Hour	$4.80 /Hour
High Altitude Observatory (HAO)	$6.34 /Hour	$6.62 /Hour	$6.62 /Hour
Mesoscale & Microscale Meteorology (MMM)	$6.27 /Hour	$6.50 /Hour	$6.50 /Hour
Research Applications Laboratory (RAL)	$6.72 /Hour	$6.94 /Hour	$7.14 /Hour

Machine Shop

Machine Shop Rate	$71 /Hour	$73 /Hour	$73 /Hour

3. System User Rates

Earth Observing Laboratory (EOL)	FY 2009 Actual	FY 2010 Submitted	FY 2011 Proposed
Systems User Rates (SUR)		*(Unchanged)*	*(Unchanged)*
ISFF	$684 /Day	$373 /Day	$373 /Day
ISS	$420 /Day	$670 /Day	$670 /Day
Dropsonde Data System	$3,319 /Day	$1,487 /Day	$1,487 /Day
ELDORA	$1,016 /Day	$2,456 /Day	$2,456 /Day
S-Pol Radar	$1,172 /Day	$5,504 /Day	$2,456 /Day
C-130 Aircraft	$13,289 /Day	$10,288 /Day	$10,288 /Day
Gulfstream Aircraft (HIAPER)	$14,877 /Day	$9,843 /Day	$9,843 /Day
Mechanical Design	$1,063 /Day	$549 /Day	$549 /Day
Machine Shop	$201 /Day	$117 /Day	$117 /Day

Comp. & Information Systems Lab (CISL)	FY 2009 Actual	FY 2010 Submitted	FY 2011 Proposed
		(Unchanged)	*(Unchanged)*
General Accounting Unit (GAU)	$0.39 /Hour	$0.44 /Hour	$0.44 /Hour

APPROVED:

Steve Nelson, Acting Section Head
UCAR and Lower Atmospheric Facilities

Subject: [Fwd: [Fwd: RE: FY2011 Proposed Indirect Cost Rates]]
From: Caron Chambers <cchamber@ucar.edu>
Date: Thu, 15 Apr 2010 10:00:25 -0600
To: valerie koch <valeriek@ucar.edu>, elizabeth chapin <echapin@ucar.edu>, rebecca greenberg <rebgreen@ucar.edu>

Subject: [Fwd: RE: FY2011 Proposed Indirect Cost Rates]
From: "Justin Young" <justiny@ucar.edu>
Date: Thu, 15 Apr 2010 09:04:18 -0600
To: "taberskigina" <taberski@ucar.edu>, hanne mauriello <hanne@ucar.edu>, "brasher-allevarena l" <rena@ucar.edu>, caron chambers <cchamber@ucar.edu>
CC: "monk-ryananita" <amonk@ucar.edu>, "millermelissa" <melissa@ucar.edu>, colleen huddle <huddle@ucar.edu>

Here is the approval from NSF to begin using the FY2011 rates for proposal planning!

jy

-------- Original Message --------
Subject: RE: FY2011 Proposed Indirect Cost Rates
Date: Wed, 14 Apr 2010 17:34:27 -0400
From: Dash, Laurence K. <ldash@nsf.gov>
To: Justin Young <justiny@ucar.edu>
References: <4BC39573.2060508@ucar.edu>

Justin,
I received the rate submission. Yes, you have approval to begin using the rates for budgeting and planning for fy2011 and to apply them to actual costs if still in a proposed status. Because we are so understaffed, I think Carol will assign it to Linda Toms again for review, but I will keep myself in the loop.

Laurence

-----Original Message-----
From: Justin Young [mailto:justiny@ucar.edu] Sent: Monday, April 12, 2010 5:50 PM
To: Dash, Laurence K.
Subject: FY2011 Proposed Indirect Cost Rates

Hi Laurence,

I want to verify that you have received a copy of the FY2011 UCAR Indirect Cost Rate Submission. I would also like to seek approval for UCAR to begin using these rates for proposal budgeting and planning purposes for funding requests in FY2011. In addition, I would like to request approval to apply these rates to actual costs in FY2011 if they are still in a proposed status. Please let me know if you have any questions.

Thanks,

Justin

Justin Young <justiny@ucar.edu>
Manager, Budget Analysis
Finance & Administration
University Corporation for Atmospheric Research

[Fwd: RE: FY2011 Proposed Indirect Cost Rates].eml	**Content-Type:**	message/rfc822
	Content-Encoding:	7bit

Standard Information:

1. The National Center for Atmospheric Research (NCAR) is operated by the University Corporation for Atmospheric Research (UCAR), DUNS# 078339587, under the sponsorship of the National Science Foundation (NSF). NSF, our cognizant audit agency, approves UCAR rates annually. Out year rates are estimated based on current rates and are subject to change. During certain time periods, budgets may include proposed rates, which are subject to review and approval of NSF.

2. The salary budget includes direct labor charges only for time worked. The employee benefit rate includes direct charges for non-work time of vacation, sick leave, holidays and other paid leave, as well as standard staff benefits. The casual benefit rate applies to casual employees who do not receive the full benefit package.

3. Indirect Costs are applied to all modified total direct costs (MTDC). Items excluded from MTDC are equipment costing $5,000 or more, participant costs, and individual subcontract amounts in excess of $25,000 per fiscal year.

4. The UCAR management fee is a fixed fee, calculated as a % of proposed MTDC and NCAR applied indirect costs.

5. The budget may include a charge for scientific computing and networking support in accordance with OMB circulars and NCAR management policy allocating the costs of scientific computing system infrastructure.

6. NSF Co-sponsorship is defined as the value of resources funded by NSF to NCAR through the UCAR cooperative agreement that contribute to the performance of research sponsored by another organization. NSF Co-sponsorship should not be viewed as cost sharing, as defined in OMB Circular A-110, as it is borne by the Federal Government.

7. Non-NSF and NSF Grant research at NCAR is monitored by our sponsor, the National Science Foundation, in accordance with criteria and guidelines approved by NSF/Division of Atmospheric Sciences.

8. For Federal Interagency Agreement Fund Transfers, NSF Administrative Cost recovery is applied at the current rate to total transfers. As a condition of NSF's entering into an interagency agreement or fund transfer, other Federal agencies must agree to the following conditions:

- NSF will implement the agreement by awarding a Cooperative Support Agreement (CSA), or by amendment to an existing, applicable CSA issued to the University Corporation for Atmospheric Research under Cooperative Agreement No. ATM-0753581, or any successor agreement.
- All fund transfers will be accepted and work performed under the terms and conditions of the Cooperative Agreement. NSF will not, itself, be directly responsible for the provision of the goods or services contemplated under NCAR's proposal to the other Federal Agency.
- NSF assumes no liability for any costs above the funds obligated against the Cooperative Support Agreement. .
- It is NCAR’s responsibility to provide the necessary financial and technical reports to the sponsoring agency in accordance with the terms and conditions of the sponsoring agency’s agreement.
- In accordance with NSF policy, a portion of the fund transfer will be set aside to recover costs that NSF incurs in the management, administration and oversight of the funded activities at a rate determined by NSF.

For funds provided by federal interagency agreement or fund transfer with NSF, the contact is, Ms. Kristin Spencer, Grant and Agreement Specialist, Division of Acquisition and Cooperative Support, National Science Foundation, 4201 Wilson Boulevard, Room 475 S, Arlington, VA 22230. Phone (703) 292-4585, Fax (703) 292-9141. If a proposal was written with the expectation of being funded by interagency transfer, the total funds requested include funds to cover NSF's administrative costs, based on NSF's current rate, related to undertaking this activity. The following language should be included in the interagency transfer documentation: “This agreement includes funds to cover NSF's administrative costs related to undertaking this activity.” Please refer to NCAR’s proposal number on all correspondence with NSF.

For funds provided by direct agreement with UCAR, contractual arrangements should be made with Ms. Virginia Taberski, Manager of Sponsored Agreements, UCAR Sponsored Agreements, 1850 Table Mesa Drive, Boulder, CO 80305, Phone (303) 497-2132, Fax (303) 497-8501. Please refer to NCAR’s proposal number on all correspondence with UCAR.