02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Christopher S Bretherton

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

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Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

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PI/PD Name: Carlos R Mechoso

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☒ Hispanic or Latino ☐ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☒ Other on file
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

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PI/PD Name: Sungsu Park

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29	FOR NSF USE ONLY
NSF 09-568 — 09/24/09	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) ATM - GEO/ATM - Climate & Large-Scale Dynamics	0968571

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
09/21/2009	1	06020000 ATM	5740	605799469	09/22/2009 11:19am

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☒ NO ☐ IF YES, LIST ACRONYM(S)
916001537		NOAA

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Washington	4333 Brooklyn Ave NE SEATTLE, WA 98195-9472
AWARDEE ORGANIZATION CODE (IF KNOWN) 0037986000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions) ☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Collaborative Research: CPT for Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 327,206	36 months	07/01/10	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________ PHS Animal Welfare Assurance Number ________
- ☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________ Exemption Subsection ________ or IRB App. Date ________
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) ________
- ☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Department of Atmospheric Sciences	Box 351640 Seattle, WA 981951640 United States
PI/PD FAX NUMBER 206-685-9302	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Christopher S Bretherton	PhD	1984	206-685-7414	breth@washington.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

Electronic Signature

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 09-29). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be dislosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Kathryn Hovick	Electronic Signature	Sep 21 2009 4:30PM

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
206-543-3608	hovick@u.washington.edu	206-685-1732

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29		FOR NSF USE ONLY
NSF 09-568	09/24/09	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		
ATM - GEO/ATM - Climate & Large-Scale Dynamics		

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				092530369	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
956006143	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of California-Los Angeles	11000 Kinross Avenue Suite 102 LOS ANGELES, CA 90095-1406
AWARDEE ORGANIZATION CODE (IF KNOWN) 0013151000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions) ☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

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$ 809,428	36 months	07/01/10	

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☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
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PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________
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____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Department of Atmospheric Sciences	7127 Math Sciences Building 405 Hilgard Avenue, Box 951565 Los Angeles, CA 900951565 United States
PI/PD FAX NUMBER 310-206-5219	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Carlos R Mechoso	PhD	1979	310-825-3057	mechoso@atmos.ucla.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

TPI 6948176

CERTIFICATION PAGE

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(2) building (and any related equipment) is covered by adequate flood insurance.

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29	FOR NSF USE ONLY
NSF 09-568 09/24/09	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) ATM - GEO/ATM - Climate & Large-Scale Dynamics	

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
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EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
840412668	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

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University Corporation For Atmospheric Res	1850 TABLE MESA DR BOULDER, CO 80305-5602
AWARDEE ORGANIZATION CODE (IF KNOWN) 4062600000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE National Center For Atmospheric Research	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE Nat Ctr For Atmos Res P.O. Box 3000 Boulder, CO 80307-3000
PERFORMING ORGANIZATION CODE (IF KNOWN) 4007944000	

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions) ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Collaborative Research: Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 319,955	36 months	07/01/10	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________ PHS Animal Welfare Assurance Number ________
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- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) ________
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PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
CGD	1850 TABLE MESA DR BOULDER, CO 803055602 United States
PI/PD FAX NUMBER 303-497-1324	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Sungsu Park	PhD	2002	303-497-1000	sungsup@ucar.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

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CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 09-29). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be dislosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

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(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

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Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

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Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

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In 2007 the IPCC reiterated that *clouds remain the largest source of uncertainty* in climate projections. In this context, boundary layer clouds, and in particular the transition from stratocumulus to cumulus, play a key role in the cloud-climate feedback. These clouds are also important to the surface energy balance and the sea surface temperature distribution and are key elements in biases in seasonal coupled model forecasts and simulated mean climate.

Current climate and weather models are still far from realistically representing clouds. Improving the representation of clouds in climate models is fundamental to improving confidence in both seasonal and long-term climate projections. Both the NCAR and NCEP models have been recently upgrading their cloud, boundary layer, and shallow cumulus convection parameterizations. Several recent studies (e.g. the GCSS Pacific Cross Section Intercomparison and the Pre-VOCALS model intercomparison) have shown that these models are nevertheless not adequately simulating subtropical stratocumulus and the transition to cumulus.

The objectives of this proposal are to improve the representation of the stratocumulus-to-cumulus transition in the NCAR and NCEP climate models by (i) improving the interactions between existing model parameterizations by combining careful single-column modeling with sensitivity studies using weather-forecast mode and coupled-ocean global simulations, (ii) implementing probability density function (PDF) cloud parameterizations for boundary layer clouds, (iii) implementing a combined eddy-diffusivity and mass-flux vertical mixing parameterization; (iv) careful comparison with large-eddy simulations, all in conjunction with an international GCSS intercomparison effort on this transition.

Scientific merits of the proposed work include the development of more physically realistic parameterizations of boundary layer cloud and development of a better fundamental understanding of how the most important low-latitude boundary layer cloud transition depends on precipitation processes and feeds back on El Nino.

Its broader impacts include serving the US public and policy makers by improving climate projections (especially cloud feedbacks and biases) with the NCAR climate model, and improving weather and seasonal/El Nino forecasts with the NCEP model.

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For font size and page formatting specifications, see GPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

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Results from Prior NSF Support

C. Bretherton

ATM-0433712 – 11/2004 to 11//2007 - $353,816, "Observations and Modeling of Southeast Pacific Boundary Layer Clouds" (co-PI): Data from ongoing research cruises (2001, 2003-2006) to the SEP have been synthesized with satellite observations and modeling. The work builds on results from EPIC2001. New results are that coherent mesoscale (~20 km) circulations (cloud base inflow, cloud top outflow) are critical to the dynamics of SEP stratocumuli (Comstock et al. 2005, 2007), that mesoscale variability is strongest during periods of strong drizzle. Transitions between the two main organizational states (closed and open cells, Stevens et al. 2005) were found from satellite data to occur predominantly at night (Wood et al. 2008) and coincide with dramatic depletions in CCN concentrations, which are attributable to coalescence scavenging (Wood 2007). Drizzle over the SEP is controlled both by variability in cloud drop concentration and LWP: both are modulated by synoptic variability (Wood et al. 2008). Modeling work includes a mixed layer model (MLM) assessment of cloud-climate feedbacks in the tropics (Caldwell and Bretherton 2009a), investigations of aerosol indirect effects within an MLM framework (Wood 2007; Caldwell and Bretherton 2009a), and simulations of the diurnal cycle of entrainment using large eddy simulations (Caldwell and Bretherton 2009b).

ATM 0745702 - 4/08-3/11 - $702,000, "VOCALS: C-130 Observations and Numerical Modeling of Marine Boundary Layer Clouds during the VOCALS Regional Experiment (REx)" (co-PI): Directed the NSF C-130 component of REx during 10-11/2008, a major cloud-aerosol field study over the SE Pacific. Data analysis is in progress; highlights include multiple surveys of clouds and aerosols from the polluted coastal region to deeper, drizzlier pristine stratocumulus, capped boundary layers 1600 km offshore with cloud radar and new chemical sensors, and penetration into several pockets of open cells (POCs). An LES study of one POC is ongoing.

ATM-0841237 – 8/2008-7/2009, "SGER: Upgrading Community Atmosphere Model (CAM) Cloud Macrophysics" Postdoc Sungsu Park (now hired at NCAR) and PI implemented and tested a more consistent approach to parameterizing cloud condensate and cloud fraction in the NCAR CAM3.6, including consistent separation between cumulus and stratiform cloud. This approach is now included in the development version CAM4.

C. R. Mechoso and C. Bretherton as joint co-PIs (PI R. Wood).

ATM-0617283 "VOCALS Regional Experiment Scientific Program Overview":

ATM-0650551 "Coordination and Planning for the VOCALS Regional Experiment": These two small grants funded scientific planning and organizational support for the VOCALS Regional Experiment, as described in Wood and Mechoso (2008) and Wood et al. (2008).

1. Introduction and motivation

1.1 Boundary layer clouds and the global climate

In 2007 the IPCC reiterated that clouds remain the largest source of uncertainty in climate projections. Climate projections with the current generation of coupled climate models exhibit a wide range of cloud feedbacks (Soden and Held 2006). Bony and DuFresne (2005), Bony et al. (2006) and others have shown that subtropical boundary layer clouds are the biggest cause of this spread. Subtropical boundary-layer clouds also contribute to the global cloud response to anthropogenic aerosol perturbations. Uncertainties in this 'aerosol indirect effect' are the biggest issue in quantifying the relative roles of greenhouse gases vs. aerosols in producing the climate change of the last 150 years, and are a major modeling target for the next IPCC assessment. Lastly, subtropical boundary layer clouds are essential to the surface energy balance and SST distribution and are key elements in biases in seasonal/ENSO coupled model forecasts.

Over the subtropical oceans, the prevalent cloud regimes are stratocumulus (Sc) and shallow cumulus (Cu), capped by subsiding warm dry air aloft. Sc are prevalent over the cooler parts of the subtropical ocean off the west coast of continents. Their high albedo leads to a significant local and global reduction in solar heating (Klein and Hartmann 1993). Cu-topped boundary layers have a much lower area-averaged albedo. They favor the warmer subtropics, where they play a fundamental role in the regulation of ocean surface evaporation and convergence of moisture into deep convective regions (e.g. Tiedtke et al. 1988). Better understanding and more accurate simulation of the subtropical stratocumulus to shallow cumulus (Sc-Cu) transition is of great importance to climate modeling, and is the theme of our proposed Climate Process Team (CPT).

1.2 Transition from stratocumulus to cumulus convection

Significant research on the mechanisms responsible for stratocumulus break-up goes back over 40 years to early mixed-layer models (Lilly 1968; Wakefield and Schubert 1981), which incorrectly predicted that Sc-capped mixed layers should persist across almost the entire subsiding branch of the Hadley circulation. Deardorff (1980) and Randall (1980) proposed cloud-top entrainment instability as a mechanism for rapid breakup of Sc layers when some mixtures of overlying and cloudy air are negatively buoyant and can spontaneously sink into the Sc layer. After a decade, observational studies (e. g. Kuo and Schubert 1988) have cast doubts on this mechanism, although mixing-induced evaporative cooling is still regarded as an important process (e. g. Nicholls and Turton 1986; Lilly 2002; Lock 2009).

A modern consensus about understanding the Sc-Cu transition has emerged from observations and large-eddy simulation (LES), although important basic science questions remain. As the trade winds blow boundary layer air from cool waters off the west coasts of the subtropical landmasses toward the warm deep convection regions, the boundary layer is subjected to an increase in sea surface temperature (SST) and weaker subsidence. The boundary layer correspondingly evolves from a shallow, well-mixed stratocumulus layer under a strong sharp inversion to a deeper 'cumulus-coupled' layer in which cumulus rise into a thin stratocumulus layer, which finally dissipates downstream to leave a yet deeper cumulus layer capped by a weaker and vertically diffuse trade inversion. Two-dimensional large-eddy simulation (LES) models have captured the essence of this process (e.g. Krueger and McLean 1995; Wyant et al. 1997; Bretherton et al 1999) and helped guide parameterization development.

Climate and weather prediction models have found it challenging to accurately simulate the cloud cover and vertical structure of subtropical marine boundary layers, because this involves several interacting parameterizations (turbulent transport, cumulus convection, subgrid cloud distribution and condensation, cloud microphysics and radiation), some with significant uncertainties. Stratocumulus-capped boundary layers are topped by thin cloud layers and sharp inversions, which are usually poorly resolved by the model grid. In models, they are often unrealistically shallow and have too little cloud (e.g., Duynkerke and Teixeira, 2001; Stevens et al. 2005; Hannay et al. 2009). Simulated trade cumulus layers often have too high an albedo, and a poor vertical distribution of cloud cover (e.g. Siebesma et al 2003, 2004). While there are still uncertainties in our fundamental understanding of cloud-topped boundary layers, involving processes such as entrainment, detrainment and cloud-aerosol-drizzle interaction, the bigger challenges have been (i) to devise parameterizations that reflect our current physical understanding, and (ii) to make these parameterizations work well as a system by properly interacting with each other and reflecting a consistent underlying model of the subgrid variability.

Simulation of the Sc-Cu transition is an archetypical problem that tests a global model by bringing out these challenges. Designing the turbulence and shallow cumulus parameterizations to work well together without violent switching behavior is of particular importance in obtaining a good simulation. One way to do this is to design an integrated parameterization that encompasses both processes (e. g. Golaz et al. 2002; Neggers et al. 2009). Another cheaper approach is to carefully design the parameterizations to work together using single-column model (SCM) testing (Bretherton et al. 2004). Using this second approach in a regional model, McCaa and Bretherton (2004) simulated the Sc-Cu transition in the NE and SE Pacific with considerable success.

Global modeling groups have recognized the need to improve boundary-layer cloud simulations in general and the Sc-Cu transition in particular. This goal motivated intense work at the two leading US models participating in this CPT proposal, the NCAR Community Climate System Model (CCSM) and the NCEP Global Forecast System (GFS). These models have been upgrading their cloud, turbulence, and shallow cumulus convection parameterizations, with encouraging results (e. g. Park and Bretherton 2009). However, recent studies such as the GCSS Pacific Cross Section Intercomparison (GPCI; Siebesma et al. 2004; Teixeira et al. 2008, 2009) and the Pre-VOCALS model assessment (PreVOCA; Wyant et al. 2009) have shown that the models still have serious biases in the Sc-Cu transition that affect their overall climate (see Sec. 1.3).

This CPT will also allow NCAR and NCEP to leverage off the upcoming activities of the GCSS BLCWG, in which PIs Bretherton and Teixeira have played leading roles. As discussed further in Sec. 3, the BLCWG has chosen the Sc-Cu transition as its next theme for intercomparison. In addition to global model improvement, basic scientific questions about Sc-Cu transition motivated this selection. These questions include the mechanism that finally dissipates the Sc (Lock 2009), the sensitivity of the Sc-Cu transition to precipitation processes and cloud-aerosol interaction, and the degree to which modern LES and observations quantitatively agree. The BLCWG is developing two Sc-Cu case studies for late 2010 for comparing LES, SCMs, and observations. NCEP has not previously participated in BLCWG cases, and both modeling centers stand to gain from rigorous application of the GCSS approach to improving model physics, as UKMO and ECMWF already have done.

We believe that by using the Sc-Cu transition as a SCM test case, we can quickly identify and address problems in both models in the context of the interaction between the parameterizations. We will further improve their performance by implementing one key new parameterization in each model – a PDF-based cloud parameterization in the NCAR model and the Eddy Diffusivity – Mass Flux (EDMF) turbulence parameterization in the NCEP model, based on approaches described in Section 2 and already successfully implemented elsewhere. The external lead scientists (Teixeira, Bretherton, Klein and Mechoso) bring formidable experience in GCM and parameterization development to these tasks, have worked closely with these new parameterizations, and as a group are already well-acquainted with the NCAR and NCEP models.

In summary, our vision as a CPT is to be small and efficient, leveraging on what has already been developed at NCAR and NCEP, and using the Sc-Cu transition as a testbed to mold each model into a better whole, while recognizing that model changes must also produce improvements in global climate statistics to be viable. Recent and ongoing international model intercomparison efforts bring state-of-the-art observations and process modeling into our effort, and provide a discipline and cross-fertilizing interactions that help bring quick progress. In the process, we also plan to explore some new science, such as the sensitivity of ENSO to boundary-layer cloud parameterization improvements, and the role of aerosols and precipitation in modulating the Sc-Cu transition.

1.3 Comparisons of global models with observations of the Sc-Cu transition

Because simulation of Sc and the Sc-Cu transition are long-standing and important parameterization challenges, they have motivated an extensive foundation of observational and modeling studies. ASTEX (June 1992) in the NE Atlantic focused on observing the transition by conducting two successful multiple-aircraft Lagrangian experiments (Bretherton et al. 1995), which have been compared with process models and SCMs (Bretherton et al. 1999), the first of which sampled 36 hours of a Sc-Cu transition, albeit somewhat unrepresentative. Insights from ASTEX underlie much of the parameterization work thereafter that has led to many large-scale models now having some form of Sc-Cu transition.

Satellite-based studies have provided increasingly good tests of the Sc-Cu transition simulations by models. The best example is the GEWEX Cloud Systems Study Pacific Cross-section Intercomparison (GPCI) project, coordinated by co-I Teixeira (Teixeira et al. 2008, 2009). Figure 1 shows a summertime (JJA) low cloud cover climatology based on ISCCP (Rossow and Schiffer 1999) through which is drawn a Pacific Ocean transect, from California to the equator that exhibits a clear Sc-Cu transition. GPCI examined output along this transect from 23 weather and climate prediction models from around the world. Several observational data sets, including ISCCP, AIRS, CloudSat and CALIPSO were compiled and utilized to assess the models. This approach complements the more traditional SCM-oriented cases of

GCSS, providing a simple framework for evaluation of fundamental cloud regimes and their transitions in full three-dimensional weather and climate prediction models.

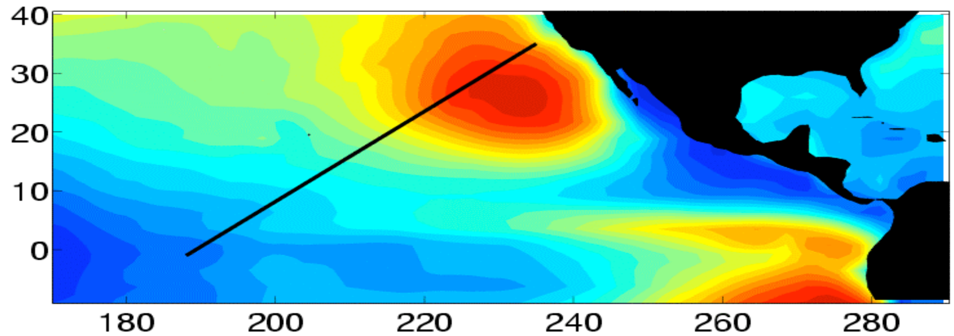

Figure 1: GPCI transect and the contours of boundary layer cloud cover climatology (ISCCP): dark red corresponds to values of 60% cloud cover, and dark blue to 0% cloud cover.

GPCI exposed interesting model biases going beyond mean climatology. Histograms of 3-hourly cloud cover along the cross-section differ significantly from model to model. Figure 2 shows that some models (e.g., UKMO/HadGEM) exhibit a quasi-bimodal structure with cloud cover being either close to 100% or 0, while other models (e.g., NCAR/CAM3) showed a more continuous transition. The ISCCP observations are between these two extreme behaviors. These different patterns reflect the different nature of the parameterizations. Some models (e.g., UKMO) base their parameterizations on distinct regimes with sharp transitions (Lock et al. 2000) while other models (e.g., NCAR) base aspects of their cloud parameterizations (in this case, low cloud fraction) on empirical fits to climatology.

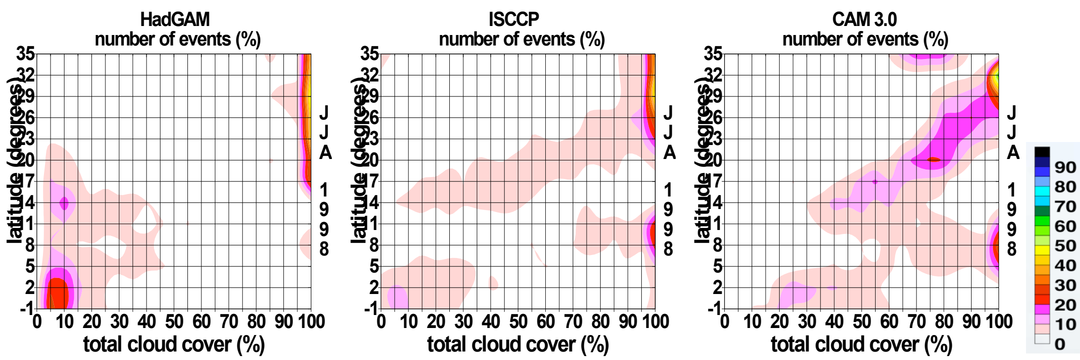

Figure 2: Histograms of total cloud cover versus latitude along the GPCI cross-section for June-July-August 1998 from the UKMO/HadGAM model, ISCCP and the NCAR/CAM3 model.

Another recent study involving PIs Bretherton and Mechoso, the Pre-VOCALS Model Assessment (PreVOCA; Wyant et al. 2009) used a similar approach to evaluate global model simulations of the SE Pacific Sc regime, based on 5-day forecasts for each day of October 2006. Figure 3 compares the monthly-mean low cloud cover from MODIS satellite retrievals with the participating NCAR, NCEP and ECMWF model versions. The ECMWF model matches the observations fairly well, while the NCAR model has the Sc-Cu transition much too close to the coast, while the NCEP model has too little coastal Sc. This shows that some global models (notably ECMWF and UKMO) currently obtain a much better simulation of the Sc-Cu transition than either NCAR or NCEP.

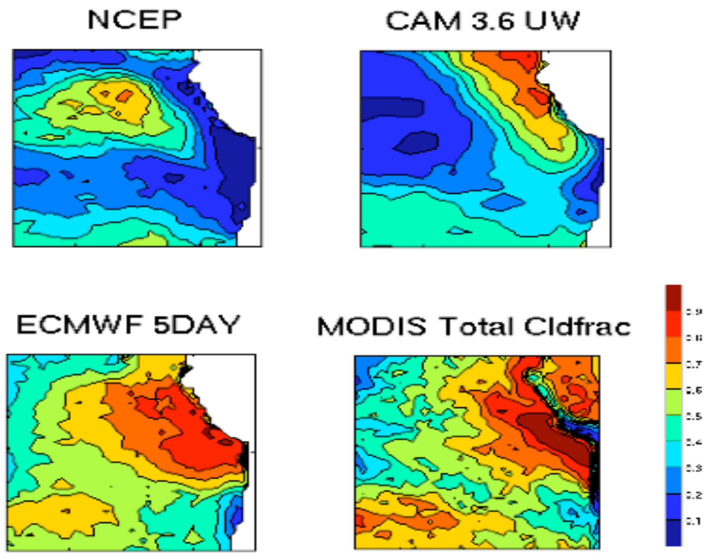

Fig. 3: Mean low cloud fraction from the PreVOCA model assessment (Wyant et al 2009) over the SE Pacific (10-30S, 70-100W) from 5-day forecasts for Oct. 2006 with the GFS, an early version of the CAM4 model, the ECMWF model, and MODIS.

2. Participating models and their needs

In this section, we describe the development versions of the NCAR and NCEP global models, which we refer to as CAM4 and GFSdev, and some known issues with them that are relevant to the Sc-Cu transition. This provides needed background for our strategy to improve these models.

2.1 NCAR CAM4 model and boundary layer cloud issues

The NCAR Community Atmospheric Model (CAM) is an open-source finite volume global atmospheric model run with 26 or 30 vertical levels and roughly 250 km or 125 km horizontal resolution. NCAR and external model developers work together on CAM's diagnosis and improvement as a component of the CCSM earth system model. CAM's development version, here called CAM4, incorporates major enhancements to the moist physical parameterizations as compared to CAM3 (Collins et al. 2006). These include new moist turbulence and shallow cumulus parameterizations (Bretherton and Park 2009; Park and Bretherton 2009), modifications to the deep convection scheme (Neale et al. 2008; Richter and Rasch 2008), new two-moment cloud microphysics (Morrison and Gettelman 2008; Gettelman et al. 2008), a new modal aerosol model, and an aerosol activation scheme (Abdul-Razak and Ghan 2000). In addition, CAM4 uses a new radiation scheme (RRTM; Mlawer et al. 1997). Together, these components provide a foundation for simulating aerosol indirect effects on climate, an important goal of the CCSM project. Since December 2008 model developers at and outside NCAR have been gaining experience with this new atmospheric model, particularly on its optimization for coupled climate simulations. At this point, when coupled to the other model components, CAM4 can produce a slightly superior mean climate and similarly good ENSO variability compared to CAM3.5, and its aerosol indirect effect has a plausible magnitude of 1.5 W m^{-2} as measured by comparing simulations with 2000 vs. 1850 aerosol emissions.

The CAM4 parameterizations collectively include the individual physical processes needed to provide a good representation of the Sc-Cu transition. However, the need to rapidly develop CAM4 for coupled modeling has forced an emphasis on model tuning to get reasonable results on a global scale. The values of some parameters, therefore, have been set well away from their observational best-guess values to satisfy global constraints. For instance, in an attempt to reduce a nearly 10% high bias in globally-integrated atmospheric water vapor the precipitation efficiency of shallow cumulus clouds is much higher than GCSS case studies suggest. To prevent midlatitude stratus clouds from encroaching too much into the subtropics a parameter governing the efficiency of turbulent mixing into cumulus cloud tops has been reduced. Such examples show that it is not enough for a climate model to produce credible subtropical Sc-Cu transitions; it must also do it while maintaining the climatology of clouds elsewhere, both in coupled and uncoupled simulations.

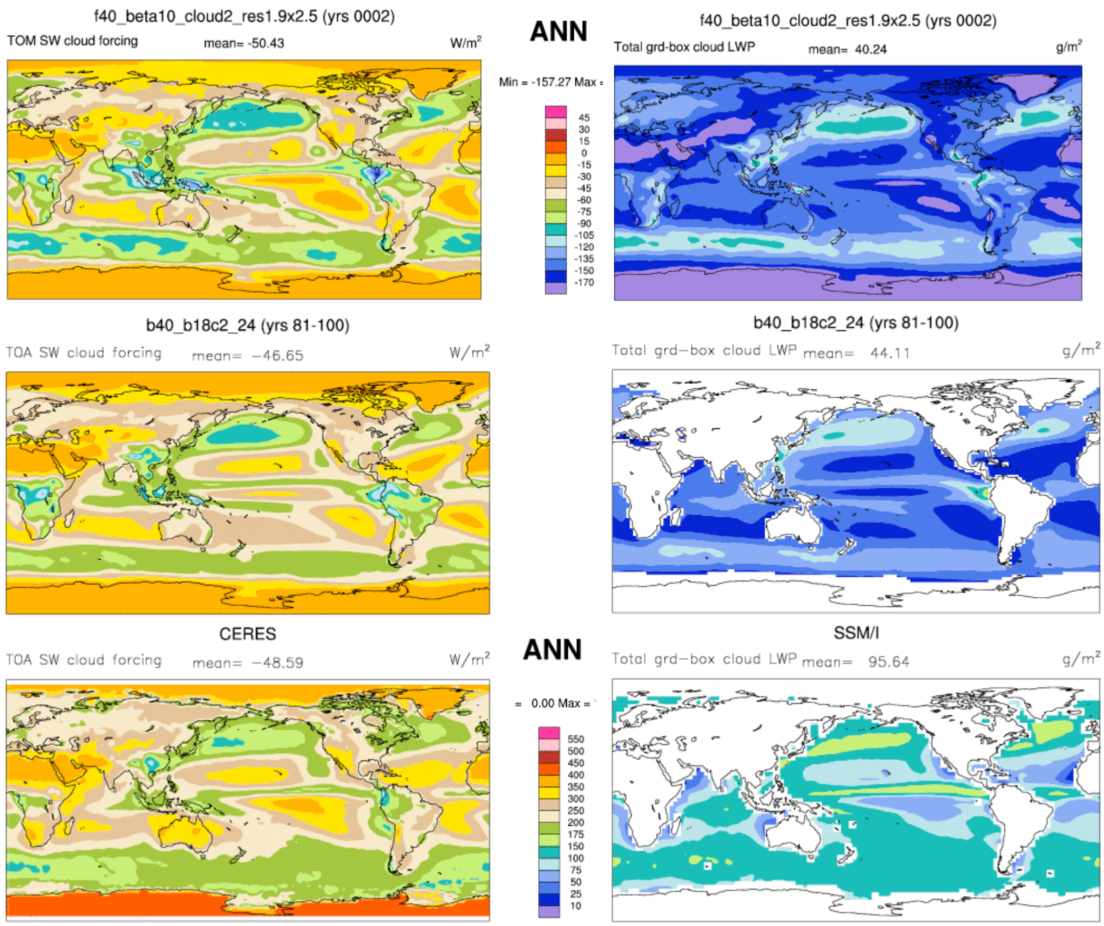

Fig. 4: Annual-mean SWCF (left) and liquid water path (right) from (top) CAM4 with prescribed SSTs, (middle) CAM4 coupled, and (bottom) satellite observations. Color scales: top: SWCF, bottom: LWP.

The left panels of Fig. 4 show uncoupled and coupled simulations of annual-mean global-mean shortwave cloud forcing (SWCF) with recent versions of CAM4. SWCF is a particularly important metric for the cloud simulation in a climate model because of its impact on surface and top-of-atmosphere energy balance. CAM4 model parameters are routinely adjusted to control biases in its global mean and large-scale patterns, but SWCF is still a useful indicator. Both simulations do have subtropical stratocumulus and trade cumulus regions. The NE Pacific stratocumulus is slightly too weak, the SE Pacific stratocumulus does not extend far enough from the Chile/Peru coast (as also seen in Fig. 3 for an earlier model version), and there is excessive low cloud over the equatorial cold tongue.

Because the cloud droplet size is internally determined in CAM4, one can obtain a reasonable SWCF with cancellation of errors, for instance droplets that are too small combined with a liquid water path (LWP) that is too small. The right hand panels of Fig. 4 show liquid water path simulations with uncoupled and coupled versions of CAM4, compared with an observational dataset. While there are larger uncertainties in satellite-derived LWP compared to SWCF, CAM4 is clearly underpredicting LWP, suggesting boundary-layer cloud microphysics problems hidden by the SWCF plots.

A particularly challenging issue in improving CAM4 is the tight coupling of turbulence, convection, cloud fraction, microphysics, aerosols, and radiation. These are six separate model parameterizations.

Even if each parameterization were nearly perfect, interfacing the parameterizations is a complex task. For instance, the microphysics calculates a vertical profile of cloud droplet concentration, and the turbulence and cumulus parameterizations need to modify this profile. Cloud droplet concentration is not an adiabatically conserved variable, but in the current CAM4, it is treated as such for the purpose of turbulent transport. This will result in cloud droplets getting turbulently transported outside of clouds and other non-sequiturs. Even mundane issues like the order of parameterizations can significantly impact the simulations. The quick development path of CAM4 has precluded adequate attention to these process interaction issues. The Sc-to-Cu transition is an ideal framework for addressing them in a well-observed and important context that involves all of the moist physical parameterizations working together.

2.2 NCEP GFS/GFSdev and boundary layer cloud issues

The NCEP Global Forecast System (GFS) is a global spectral atmospheric model currently run operationally with 50 km (T382) horizontal resolution and 64 vertical levels. The parameterizations most relevant to boundary layer clouds are as follows. Deep and shallow convection is treated separately, as in CAM. Deep convection is parameterized following the simplified Arakawa-Schubert (1974) scheme of Pan and Wu (1995). Shallow convection is parameterized by a constant eddy diffusivity between cumulus base and top. Cloud fraction is computed following Xu and Randall (1996) as function of relative humidity, mean liquid water, and cumulus mass flux. The sources of prognostic cloud condensate are convective detrainment and grid-scale condensation (Zhao and Carr 1997). Dry boundary layer mixing is parameterized using a K-profile approach (e.g. Troen and Mahrt, 1986) with an eddy diffusivity profile prescribed based on surface buoyancy flux and boundary layer height (Hong and Pan, 1996).

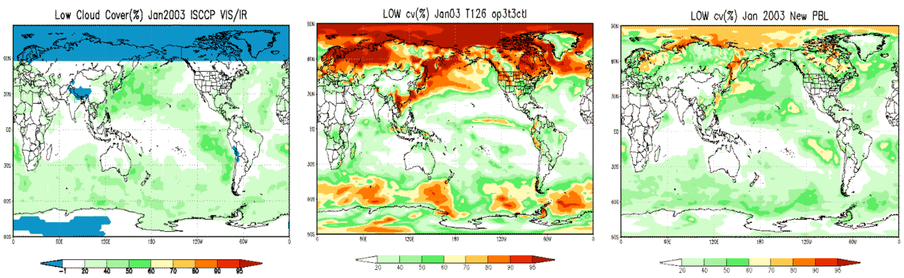

Fig. 5: Jan. 2003 low cloud cover from ISCCP (left), GFS (center) and GFSdev (right).

There are longstanding biases in GFS simulations of low-latitude boundary layer clouds. Fig. 5 compares low cloud cover for Jan 2003 from ISCCP observations (left) with a corresponding free-running GFS simulation (center). The operational GFS severely underestimates cloud cover in the Sc regions while overestimating mid-latitude low cloud. These cloud biases have an impact on the skill of medium-range GFS and seasonal ocean-coupled (CFS) forecasts, where they affect the ocean surface energy budget and help induce SST and tropical circulation biases in the CFS (other factors such as poorly resolved ocean upwelling and coastal wind stress errors may also contribute, as noted by Large and Danasoglobu 2006). Figure 6 shows the twenty-year mean difference between SON SST from the CFS and an SST analysis. There are warm SST biases of a few degrees centered in the stratocumulus regions, a common problem in coupled models. (e.g. Mechoso et al. 1995, Ma et al 1996).

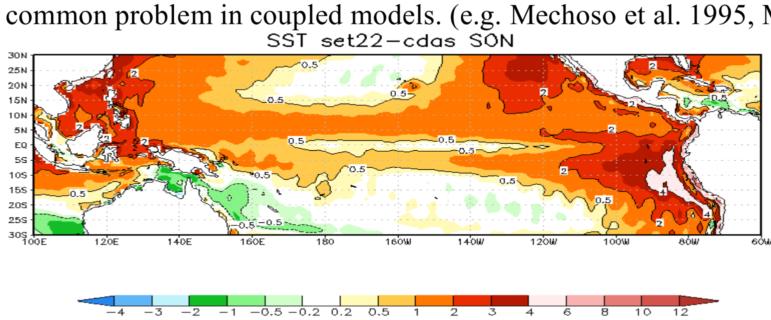

Figure 6: Difference between SST from a CFS coupled forecast and the analysis for SON.

Because of the problems described above, NCEP has recently developed a GFS version, which we will call GFSdev, including new parameterizations designed to better represent boundary layer cloud processes. The boundary layer parameterization was revised to account for moist processes and stratocumulus-top driven entrainment by mixing moist-conserved variables, enhancing the eddy diffusivity in cloudy air and by specifying an explicit entrainment term at the boundary layer top (Han and Pan, 2009, pers. comm.) In addition, in GFSdev shallow cumulus convection is parameterized with a Tiedtke (1989)-like mass flux scheme with the same precipitation scheme as used for deep convection but a much higher entrainment rate. The separation of deep and shallow convection is determined by cloud depth (currently 150 mb). The new parameterizations in GFSdev have led to improvements in subtropical cloud distribution (Fig. 5, right), but they have not yet raised the medium-range forecast skill of the model to the point where it is ready to become operational, and they have not yet produced a Sc-Cu transition with the observed position and strength.

In parallel, under prior NOAA funding, PI Mechoso has been working with postdoc Sun to improve the Sc and coupled climatology of the operational GFS/CFS. They have demonstrated that appropriate representation of inversion temperature/moisture jumps and their controls on the depth of shallow convection improves low cloud cover over the eastern subtropical oceans. While not directly applicable to GFSdev due to its different shallow cumulus parameterization, Sun and Mechoso's research suggests that attention should be paid in GFSdev to the representation of mixing at cumulus tops, a sensitivity also found in other models (e. g. McCaa and Bretherton 2004).

3. Model Improvement Strategy

We expect to make short-term progress in representing the Sc-Cu transition in the CAM4 and GFSdev by diagnosing and improving process interactions, with the help of two new GCSS cases and LES results. We will also implement two major new parameterizations that have helped improve other global models by elegantly addressing the representation of two key processes in cloudy boundary layers: i) the fluxes due to turbulence, including cumulus convection; and ii) the subgrid variability of cloud properties. Specifically, **we propose to implement the Eddy-diffusivity/Mass-flux (EDMF) scheme for turbulent fluxes in GFSdev and a Probability Density Function (PDF) approach to subgrid cloud variability in CAM4 and GFSdev**. These schemes are attractive because they unify the functions of two current parameterizations, thereby simplifying the representation of their interactions that challenge the current models. The EDMF scheme permits a more unified treatment of boundary layer turbulence and shallow cumulus convection in the NCEP model, without the level of complexity in higher-order closure turbulence parameterizations such as Golaz et al. (2002). The PDF-based cloud scheme will unify the cloud fraction and cloud microphysics/condensation/evaporation parameterizations in both models. **We will assess the effects of our parameterization improvements in a coupled model setting on regional SST and circulation biases in the E Pacific and ENSO amplitude**.

3.1 Improving process interactions for the Sc-Cu transition

A primary goal of the CPT is testing and improving the *interactions* between the moist physical parameterizations in the NCAR and NCEP models, using the Sc-Cu transition as a testbed. Both modeling centers have recently upgraded their moist physics to address boundary layer cloud biases, resulting in some improvements. However, we believe that the fundamental structure of the new parameterizations is capable of producing much better simulations of subtropical boundary layer clouds, and that the quickest and easiest road to improvements is through better understanding of the interactions between the model components and addressing inconsistencies that we uncover. This is where we expect to make measurable improvements in simulations with both models in the next 2-3 years.

Implementation in CAM4 and GFSdev

We will use the strategy refined within GCSS for model improvement, using SCM simulations of the two upcoming Sc-Cu transition cases to isolate model deficiencies in a realistic but controlled setting. Our CPT is perfectly timed to take advantage of this major international effort. One case, led by Stephan de

Roode of TU Delft (Netherlands), will revisit the 1995 BLCWG study of ASTEX Lagrangian 1 (Bretherton et al. 1999), featuring a 36-hour Sc-Cu transition with rapid boundary layer deepening and extensive precipitation. The original study included only 3 SCMs and 3 2D coarse-resolution LES models; 15 years later, both SCMs and LESs have greatly improved, allowing for more discerning and quantitative comparison with observed cloud and boundary layer properties. The other new case, led by Irina Sandu of MPI-Hamburg, will simulate multiday composite cases built up from satellite observations in the NE and SE Pacific. This will be used to explore sensitivities of the Sc-Cu transition to the slightly different environments in the subtropical Sc regimes in the two hemispheres. LES and SCM simulations of both cases will be requested from the GCSS community sometime during the latter half of 2010, just after our funding begins, and will be an initial focus of our CPT activity. We propose to contribute simulations to both intercomparisons with SCM versions of CAM4 and GFSdev and with an LES, and we plan to also use these cases for sensitivity studies.

At NCAR, PI Park has simulated many of the past GCSS BLCWG cases with recent versions of CAM (Bretherton and Park 2009; Park and Bretherton 2009). However, important new elements in CAM4 not studied in this way are (i) the inclusion of the Morrison microphysics and (ii) chemical/aerosol transport in moist turbulence and cumulus convection. Thus, Park proposes to also reexamine these past cases with CAM4. At NCEP, use of GCSS SCM cases will be a new focus, and research scientist Dr. Matt Wyant at UW will work with NCEP to carry out and evaluate the needed simulations.

We will adopt another new model improvement strategy for CAM4 and GFSdev, the use of frequent short (5 year or less) coupled simulations to evaluate potential physics improvements, rather than just relying on uncoupled simulations for most model evaluation. This recognizes that a key function of both models is as a component of a coupled ocean-atmosphere-land model. The coupled CAM4 simulations will be carried out and evaluated by NCAR Project Scientist Dr. Cecile Hannay. Coupled GFSdev simulations will be carried out and analyzed by a postdoc under the joint supervision of Mechoso (UCLA) and H. Pan (NCEP), who will spend 50% time in residence at NCEP and 50% at UCLA.

Use of LES

A keystone of the GCSS approach is the use of LES to complement observations for SCM intercomparisons. LES are not perfect process models, but to the extent their results do agree with available observations, they can provide valuable statistics about hard-to-measure quantities such as cloud fraction and precipitation profiles, turbulent mixing rates (e.g. lateral entrainment/detrainment into cumuli, Siebesma et al. 2003), turbulence statistics and covariances. GCSS cases are typically simulated by many LES groups to get a good sense of which LES results are robust. Recent GCSS cases of nonprecipitating and precipitating nocturnal Sc based on observations from the DYCOMS-II experiment show typical LES biases (overly efficient entrainment at typical vertical grid spacings, creating Sc layers with too little liquid water) but also much higher inter-LES consistency than in a similarly diverse group of SCMs (Stevens et al. 2005; Zhu et al. 2005; Wyant et al. 2007; Ackerman et al. 2009).

The UW group proposes to contribute to the LES component of the two upcoming GCSS Sc-Cu cases, using the System for Atmospheric Modeling (SAM) 6.7 LES of Dr. Marat Khairoutdinov of Stony Brook University (Khairoutdinov and Randall 2003). Dr. Peter Blossey of UW, who will carry out these simulations, has extensive experience with use of this model for boundary layer cloud simulations (e. g. Bretherton et al. 2007; Blossey et al. 2009). SAM runs efficiently on our local 80-node Linux cluster, for which we are requesting two extra nodes as a contribution to its long-term sustenance. The value of this LES modeling to the CPT is that it gives us direct access to all useful LES statistics for SCM analysis. In Years 2-3, Blossey will conduct LES Sc-Cu transition sensitivity studies (e. g. to suppression of precipitation or changes in aerosol concentration) based on the GCSS cases that will also provide illuminating comparisons with SCM CAM4 and GFSdev model simulations.

3.2 EDMF

For turbulent fluxes, the common practice, used in CAM4 and GFSdev, is to use the eddy-diffusivity (ED) approach in the sub-cloud layer and in the Sc cloud layer, in which turbulent eddies extend across the entire layer, and through a mass-flux (MF) approach in the Cu cloud layer, in which turbulence is localized in small fractions of the layer in and around active cumulus clouds. This separation poses challenges and can result in discontinuities in model integration associated with switching between the turbulence (e.g. ED) and convection (e.g., MF) parameterizations. Careful design of the layer turbulence and Cu parameterizations can largely overcome these issues (Bretherton et al. 2004), and this strategy is used in the UW moist turbulence and shallow Cu schemes in CAM4 (Bretherton and Park 2009; Park and Bretherton 2009). However, it involves complex and somewhat delicate computer code.

The GFSdev has not addressed this switching issue. Rather than using the approach in CAM4, we propose to implement in GFSdev the recently developed, more elegant EDMF approach. By carefully combining the ED and MF approaches, EDMF has the flexibility to circumvent many of the shortcomings of current schemes, improving the representation of processes like top entrainment, counter-gradient fluxes and the interaction between clouds and the sub-cloud layer, without the mathematical complexity, extra prognostic variables, and fine time/height grid needed for high-order turbulence closure schemes such as the Golaz et al (2002) approach. When also integrated appropriately with the shallow convection parameterization (Neggers et al. 2009), we expect that it will allow for a smoother and more realistic Sc-Cu transition because the ED and MF contributions are treated within a single numerical solver such that the MF in cumulus updrafts is naturally connected to the subcloud layer.

EDMF was first proposed by Siebesma and Teixeira (2000) and subsequently tested in the ECMWF model (Teixeira and Siebesma 2000). Recent studies have shown the potential of the approach to represent the dry convective boundary layer (Siebesma et al. 2007) and the shallow convection boundary layer (Soares et al. 2004). Versions of EDMF have been recently implemented operationally in the ECMWF model (Koehler 2005), and used in the context of air quality studies (Angevine 2005). These changes have significantly improved ECMWF simulations of stratocumulus regimes (Koehler 2005).

One can think of the EDMF closure as a scale decomposition where local mixing by small eddies is parameterized by the ED term while non-local mixing due to boundary-layer spanning thermals is represented by the MF term (see Figure 7). In both the sub-cloud and cloud layers, the MF term represents the effect of strong updrafts (dry and with liquid water, respectively). These updrafts are represented by a simple entraining rising parcel, which determines the boundary layer depth and, if present, the lifting condensation level and cloud top. The MF profile is a function of the vertical velocity of the updrafts, which is affected by lateral entrainment. In the dry convective boundary layer the mass flux acts as a counter-gradient term. Because the MF term is always active, one avoids discontinuities in model integration associated with switching between the turbulence and convection parameterizations. It also avoids the need to make ad hoc assumptions about the cumulus-base mass flux (e.g., Tiedtke et al. 1988).

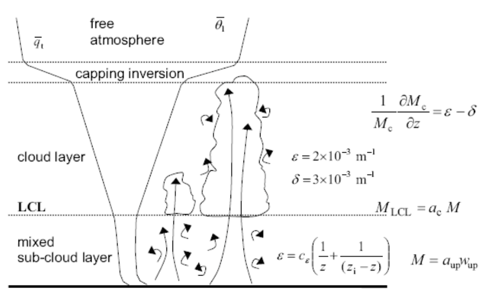

Figure 7: Schematic illustrating the EDMF approach for shallow cumulus boundary layers.

Mathematically, we partition the turbulence (layer-like or cumuliform), into an updraft area fraction a_u containing the strongest updrafts, and a remaining environmental region. Within each region, a prime denotes perturbations about the mean for that region. It is possible to decompose the turbulent flux of a conserved variable, ϕ, in 3 terms (e.g., Siebesma and Cuijpers, 1995; Siebesma and Teixeira 2000):

$$\overline{w'\phi'} = a_u \overline{w'\phi'}^u + (1-a_u)\overline{w'\phi'}^e + a_u w_u(\phi_u - \phi_e), \qquad (1)$$

where the u and e subscripts refer to the updraft and the environmental regions, and the over-bar represents a mean. We make the following assumptions: 1) the fractional area covered with strong vertical motion is small, $a_u \ll 1$, so the 1st term on the r.h.s. of (1) can be neglected; 2) $\phi_e \cong \overline{\phi}$, and, 3) the environmental turbulent flux (second term on the r.h.s.) is represented by an ED closure. Then the vertical turbulent flux is a linear combination of ED and MF terms:

$$\overline{w'\phi'} \cong -K\frac{\partial\overline{\phi}}{\partial z} + M(\phi_u - \overline{\phi}) \qquad (2)$$

where $M = a_u w_u$ is the mass-flux associated with the strong updrafts. To complete the EDMF parameterization, the ED coefficient K, the MF coefficient M, and the updraft properties ϕ_u, are determined based on other equations and LES-derived relationships (Siebesma et al. 2007), rather like the Troen-Mahrt (1986) nonlocal scheme for a dry convective boundary layer (DCBL).

Figure 8 compares the hourly mean potential temperature profiles from an LES with two parameterizations of a DCBL at hours 4 and 8 of the simulation; 'BL89' is a traditional ED approach and 'new' is the EDMF approach. The agreement between the LES profiles and EDMF is clearly better than with the ED approach, especially the slightly stable stratification in the upper half of the convective boundary layer and more accurate top entrainment.

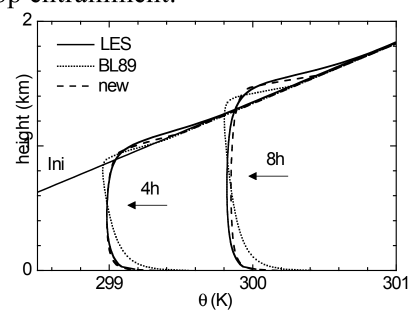

Figure 8: Hourly mean potential temperature profiles (4 and 8 hours of simulation) from an LES of a dry convective boundary layer, the 'BL89' ED approach, and the 'new' EDMF approach.

EDMF is particularly well-suited to simulate Cu boundary layers, because the MF in the subcloud layer can be partitioned logically into updrafts that reach their level of neutral buoyancy and those that do not (Neggers et al. 2009), and the former updrafts can form the starting point for a bulk Cu parameterization. Lenderink et al. (2004) compared LES and SCM simulations of daytime development of shallow continental Cu in a GCSS case. In this case, no single model was able to correctly predict the evolution of cloud cover and cloud-top height. With EDMF, the cumulus field starts and dissipates at approximately the correct time, as can be seen in Fig.9, and shows a low level of intermittency (i.e. switching problems have been circumvented). Though EDMF is theoretically capable of handling the Sc-Cu transition, how well it does so is an important open question that we will investigate in this project.

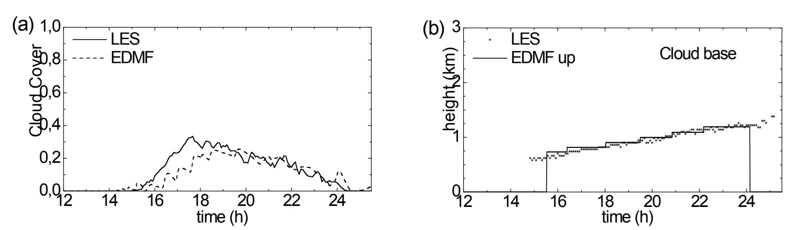

Figure 9: Results from EDMF and LES: time series (UTC) of (a) cloud cover (b) cloud base height.

<u>*Implementation in GFSdev.*</u>

The first step will be to upgrade the current ED (vertical diffusion) numerical solver in the model in order to include the MF component. The ED profiles will be initially based on the present version of

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GFSdev. We will start by using a similar (profile) methodology for the MF coefficient. This work will be conducted by UCLA Assistant Researcher Dr. M. Witek working with PI Teixeira at JPL.

Bretherton, together with J. Han of NCEP, will aim to adapt NCEP's nascent Tiedtke-type shallow cumulus parameterization to work within EDMF. This involves replacing the Grant and Brown (1999) closure for the cloud base mass flux with the dual test parcel methodology of Neggers et al. (2009).

This work will coordinate with a separate NOAA proposal by Bretherton to work with H. Pan and J. Han (NCEP) to improve the development version of NCEP's shallow Cu parameterization using GFS SCM modeling of selected past GCSS cases. That proposed work will give Bretherton's group the capability to run and modify the SCM GFS, which will also be needed for the proposed CPT work. Both projects clearly provide a strong foundation for the NCEP component of the CPT and for allowing NCEP to take better advantage of GCSS for model development and testing, like ECMWF and UKMO do now.

3.3 PDF-based cloud parameterizations

A second critical parameterization issue is the representation of subgrid cloud variability. Many models, including both CAM4 and GFSdev, diagnose a subgrid cloud fraction as a function of relative humidity, the amount of Cu convection, and other empirical predictors. A prognostic equation is used to predict condensate phase and amount in the cloudy regions. This approach involves internally inconsistent assumptions about the subgrid variability. For instance, in CAM4 all cloud is assumed to have the same amount of condensate, but the slightest change in grid-mean relative humidity can change cloud fraction.

Theoretically, the cloud cover and mean liquid/ice water content could be consistently determined given the joint PDFs of relevant thermodynamic variables within each grid box. PDF-based cloud parameterizations do just this by using estimates of the PDFs of moist conserved thermodynamic variables. PDF cloud parameterization methods based on assuming Gaussian distributions of these variables have been used in LES for some time (e.g., Sommeria and Deardorff 1977), but only relatively simplified versions have been implemented in weather and climate prediction models (e.g., Smith 1990; Tompkins 2002; Chaboureau and Bechtold 2002), for which an appropriate specification of a PDF is more challenging because of the diversity of subgrid cloud-producing mechanisms.

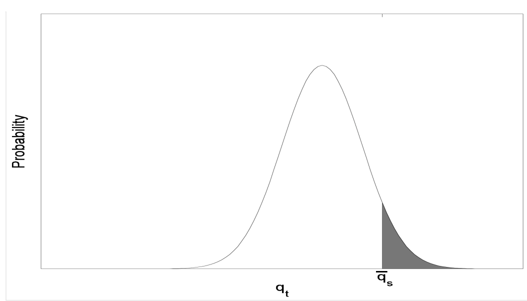

Figure 10: A probability density function (PDF) within one grid box of total water content q_t (specific humidity plus liquid/ice water content), where $\overline{q_s}$ is the mean saturation specific humidity.

The essence of PDF-based cloud parameterizations is illustrated in Fig.10, which shows a hypothetical PDF of total water content within a grid-box (the more complete version of a PDF cloud parameterization should involve the joint PDF of moist conserved variables). Cloud-filled points inside the grid-box have a total water content (that is the sum of the specific humidity and the liquid/ice water content) larger than the mean saturation value. Other points are cloud-free. From the PDF $p(q_t)$, we can estimate the cloud fraction a as the integral of the PDF right of the saturation value and the mean liquid water as the first moment of the PDF of the positive difference between total water and mean saturation.

The major issue in PDF cloud parameterization is characterizing the PDF. Assuming a Gaussian distribution for simplicity and taking into account that the mean values are known, what remains to be determined is the variance. To estimate the variance of the total water content the following prognostic equation (e.g., Garratt 1992) can be used:

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$$\frac{\partial}{\partial t}\left(\overline{q_t'q_t'}\right) = -2\overline{w'q_t'}\frac{\partial q_t}{\partial z} - \frac{\partial}{\partial z}\left(\overline{w'q_t'q_t'}\right) - \frac{\overline{q_t'q_t'}}{\tau_q}$$

where τ_q is a dissipation time-scale. For computational efficiency, this prognostic equation is often simplified by neglecting the storage and transport terms:

$$\overline{q_t'q_t'} = -2\tau_q\overline{w'q_t'}\frac{\partial q_t}{\partial z}$$

With this simplification, it suffices to solve a simple algebraic equation to determine the variance, instead of a PDE. The flux $\overline{w'q_t'}$ is calculated using the turbulent mixing parameterization (e. g. EDMF).

Aircraft observations (e.g., Larson et al. 2001) and Large Eddy Simulation (LES) models (e.g., Cuijpers and Bechtold 1995) suggest that for stratocumulus clouds, a Gaussian PDF is a realistic approximation. However, for cumulus clouds a double-Gaussian PDF is a much better approximation; Neggers (2009) has suggested a specification of the second Gaussian hump associated with cumulus updrafts, making use of the information in a bulk cumulus parameterization. In this project, we will test whether this specification is adequate for the Sc-Cu transition.

Implementation in CAM4 and GFSdev

Former NCAR postdoc Ben Johnson implemented a simple PDF scheme in CAM3 but returned to UKMO before it was fully functional. This scheme assumed that the subgrid total water PDF is Gaussian with a standard deviation equal to a fixed fraction of the saturation mixing ratio, and did not explicitly couple to the cumulus parameterizations. CPT collaborators Caldwell and Klein (LLNL) will take up this effort again. Initially, the cumulus parameterization will internally predict cumulus cloud fraction and condensate amount, as in CAM4, and the PDF scheme will be used to predict stratiform cloud properties in the remainder of the grid cell. Once this approach is satisfactorily implemented (a 1-2 year task including full testing), the PDF will be modified to a double Gaussian consistent with the cumulus parameterizations and computed similar to Neggers (2009). The LLNL group intends to test this approach in Arctic and continental cumulus boundary layer sets as well, using ARM comparison datasets.

For GFSdev, we will initially assume a Gaussian PDF but will introduce the above diagnostic variance equation to calculate the width of the total water PDF. As with CAM4, these simplifying assumptions may be relaxed as the project proceeds according to the results obtained, and the ultimate goal is to go from improving the Sc-Cu transition to improving global boundary-layer cloud simulations.

3.4 Impacts of parameterization changes on the East Pacific regional circulation and ENSO

As part of the assessment of proposed CAM4 and GFSdev improvements, the seasonal cycle of the tropical atmosphere-ocean system will be examined in coupled and uncoupled simulations. Coupled model versions will be run for decades to obtain a representative sample of interannual variability. ENSO amplitude, spatial structure, and time evolution will then be examined in view of the atmosphere-ocean interactions (Yu and Mechoso 2001; Guilyardi et al. 2003, 2004). Lastly, relevant versions of both CAM4 and GFSdev will contribute to the upcoming VOCA model assessment. This initiative will use a similar protocol to PreVOCA (http://www.atmos.washington.edu/~robwood/PreVOCA/index.html) to study global model performance across the SE Pacific stratocumulus regime using short-range forecasts during 15 Oct.-15 Nov. 2008, during which VOCALS-REx was taking intensive in-situ observations in the region. A new feature of VOCA especially relevant to testing the CAM4 is that the chemical transport, aerosols and cloud droplet concentrations can be assessed using the REx in-situ measurements.

Implementation

CFS simulations will be run and analyzed by H. Xiao working with Mechoso at UCLA/NCEP. This postdoc will also be responsible for NCEP's contribution to VOCA. CAM4 coupled and VOCA simulations will be run and analyzed by C. Hannay of NCAR.

4. Broader impacts of the proposed research

The most important broad impact of the proposed work involves enhanced infrastructure for research and education that also directly benefits society through improvements in weather forecasting and climate projection. Specifically, the CPT aims to improve the primary US global weather and seasonal forecast model (the GFS) and the only US community earth system model (the CCSM), which is used by hundreds of research groups around the world. In addition, the CPT aims to promote a better fundamental understanding of the Sc-Cu transition, an important feature of global climate, and to strengthen partnerships between climate modeling groups in the US and other countries through active engagement in GCSS and CLIVAR. Results will be disseminated at CCSM annual meetings and NCEP workshops, which attract a large fraction of the US climate modeling community. The CPT also brings together researchers at two universities and four national labs funded through four separate agencies (NCAR/NSF, NCEP/NOAA, JPL/NASA, LLNL/DOE), strengthening connections between the US academic community and national labs that often work rather independently on related problems.

5. CPT personnel and roles

The PIs have extensive experience in the parameterization, process modeling and observational study of boundary layer clouds. In particular, the PIs have developed and implemented cloud and boundary layer parameterizations in a variety of leading global weather and climate prediction models, including at ECMWF, NCAR, GFDL and UCLA.

The overall project coordinator is Dr. Joao Teixeira. As a JPL scientist, he cannot be directly funded by the CPT nor be an official PI, though he will be formally affiliated with the CPT as a co-I through UCLA, and will supervise a CPT-funded research scientist. Dr. Chris Bretherton will serve as the formal CPT lead scientist.

CPT funding is requested by three institutions, UCLA, University of Washington, and NCAR. Three other institutions, NCEP, PCMDI/LLNL, and JPL are collaborating under their own funding. Letters of support and CVs from these institutions attached as Supplementary Material outline their commitments.

Dr. Teixeira will lead regular bimonthly group teleconferences to coordinate CPT efforts. In addition, the CPT will hold an annual PI meeting each spring, which will alternate between NCEP (where it will be coordinated with a broader GFS/CFS physical parameterization workshop to be organized by Mechoso), and NCAR (coordinated with a CAM Atmospheric Model Working Group meeting). Additional travel funding is requested for junior personnel to visit NCEP and NCAR for collaboration on model technical issues, for CPT participation in GCSS meetings, and for dissemination of results at scientific conferences.

The CPT personnel and their roles are listed below:

Requesting CPT funding:

<u>UW ($327K total over 3 years)</u>:

Prof. Chris Bretherton (1 mo/yr): Oversight of Blossey and Wyant, collaboration with Park and Hannay at NCAR, presentation of the CPT contribution in GCSS Boundary Layer Cloud Working Group and VOCALS Assessment workshops, and organization of the publication of UW CPT research findings.

Dr. Matt Wyant (Research Scientist; 3 mos/yr): Runs single column GFS and CAM4 on GCSS Sc-Cu case and submits results; detailed analysis of global model and SCM simulations from both models, with emphasis on model-observation intercomparison for NE and SE Pacific cross-sections.

Dr. Peter Blossey (Research Scientist; 2 mo/yr): LES simulations in support of CPT, including preparation, submission and writing up GCSS cases and needed sensitivity studies

<u>JIFRESSE/UCLA ($809K total over 3 years)</u>:

Prof. C. Roberto Mechoso: Oversight of Xiao, collaboration with Hannay at NCAR on analysis of CAM4 and CCSM runs, CPT liaison with NCEP development efforts, liaison to CLIVAR.

Dr. Marcin Witek (JIFRESSE Assistant Researcher, 12 mo/yr): Responsible for development, implementation and evaluation of EDMF approach in NCEP GFS.

Dr. Heng Xiao (12 mo/yr, 50% of period at NCEP): Implementation of PDF-based cloud parameterization in NCEP model. Analysis of how Sc-Cu biases impact coupled simulations, focusing on ENSO feedbacks and seasonal cycle of SST/circulation.

NCAR ($320K total over 3 years):

Dr. Sungsu Park (Scientist I, 6 mo/yr NCAR internal funding): CAM4 model development

Dr. Cecile Hannay (Project Scientist, 6 mo/yr): CAM4 and CCSM model runs (including CAM4 weather-forecast-mode simulations), model diagnostics, and sensitivity studies.

CPT externally-funded contributors:

JPL

Dr. Joao Teixeira (4 mo/yr, JPL internal funding): Overall CPT leader, responsible for project coordination including regular teleconferences, oversight of the NCEP collaboration with external CPT PIs and collaborators. Organizes CPT simulations of GPCI and their comparison with observations. Communicates CPT findings to broader climate model development community.

NCEP

Dr. Hualu Pan (20% NCEP internal funding) Oversees NCEP contribution to CPT and design of GFS moist physics parameterization.

Dr. Jongil Han (50% internally supported NCEP contractor): Performs GFS global simulations, GFS model code development with a focus on shallow cumulus convection and boundary layer mxing.

LLNL (DOE co-sponsorship):

Dr. Steve Klein (40%): Oversight of PDF cloud parameterization implementation in CAM4.

Dr. Peter Caldwell (100%)*:* Implementation and testing of PDF cloud parameterization in CAM4.

5.1 Postdoctoral Researcher Mentoring Plan for Dr. Heng Xiao

Dr. Mechoso will have responsibility for mentoring the proposed CPT postdoc Dr. Heng Xiao. He will provide Dr. Xiao with career counseling, guidance in preparing talks and papers, and advice on how to distill scientifically interesting and generalizable results from a model development project.

6. Task Plan

YEAR 1:

a) Simulations of Sc-Cu GCSS cases with single-column CAM4 (NCAR), GFSdev and LES (UW);
b) Submission/analysis of CAM4 and GFSdev simulations to VOCA cloud forecast assessment.
c) Initial development/implementation of PDF-based cloud parameterization in CAM4 (PCMDI) and GFSdev (JIFRESSE/JPL);
d) Feedback analysis of ENSO response to cloud changes between CAM4 vs. CAM3.5 (NCAR) and GFSdev vs. GFS (UCLA).
e) Implementation of MF component in dry convective boundary layer parameterization within single-column GFSdev;

YEAR 2:

a) Comprehensive evaluation and refinement of interaction of microphysics, turbulent/cumulus mixing, and new PDF cloud parameterization in both models using Sc-Cu cases, sensitivity studies, LES and uncoupled/coupled global simulations (all groups).
b) Implementation of moist EDMF in single-column GFSdev (JIFRESSE/JPL/NCEP)
c) Incorporation of EDMF concepts into CAM4 moist mixing schemes (NCAR/UW).

YEAR 3:

a) Integration of shallow convection in EDMF framework for GFSdev (JIFRESSE/NCEP) and CAM4 (UW/NCAR);
b) Comprehensive testing of GFSdev EDMF and PDF parameterizations in SCM, forecast and coupled seasonal mode (JIFRESSE/NCEP/UCLA).
c) Feedback/sensitivity analysis of coupled model simulation biases, boundary layer vertical structure and ENSO response to new moist physics in both models (UCLA/NCAR/UW).
d) Submit BAMS article about the CPT and its progress; contribute to technical publications documenting specific model improvements and GCSS/VOCA intercomparison results (all groups).

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Professional Preparation

Ph. D., Massachusetts Institute of Technology, Mathematics, September, 1984

B. S., California Institute of Technology, Applied Mathematics, June, 1980

Professional Appointments

September 2006 to present	Director, University of Washington Program on Climate Change
September 1996 to present	Professor of Atmospheric Science and Applied Mathematics, University of Washington.
September 1989 to August 1996	Associate Professor of Atmospheric Science and Applied Mathematics, University of Washington.
September 1988 to September 1989	Assistant Professor of Applied Mathematics and Atmospheric Science, University of Washington.
October 1985 to September 1988	Assistant Professor of Applied Mathematics, University of Washington.
October 1984 to September 1985	Postdoctoral Fellow, Advanced Study Program, National Center for Atmospheric Research.

Five Recent Relevant Publications

Bretherton, C. S., T. Uttal, C. W. Fairall, S. Yuter, R. Weller, D. Baumgardner, K. Comstock, and R. Wood, 2004: The EPIC 2001 stratocumulus study. *Bull. Amer. Meteor. Soc*., **85**, 967-977.

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Five Other Significant Publications

Wyant, M. C., C. S. Bretherton, H. A. Rand, and D. E. Stevens, 1997: Numerical simulations and a conceptual model of the stratocumulus to trade cumulus transition. *J. Atmos. Sci*., **54**, 168- 192.

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Zhang, M., and C. S. Bretherton, 2008: Mechanisms of low cloud climate feedback in idealized single-column simulations with the Community Atmospheric Model (CAM3). *J. Climate*, **21**, 4859-4878.

Caldwell, P., and C. S. Bretherton, 2009: Response of a subtropical stratocumulus-capped mixed layer to climate and aerosol changes. *J. Climate*, **22**, 20-38.

Synergistic Activities

(1) Incorporation of cloud-topped boundary layer (CTBL) research results and datasets into my Boundary Layer Meteorology graduate class. (2) CTBL parameterization work for NCAR Community Atmosphere Model. (3) shaping process studies such as VOCALS to better serve modelers through my leadership in GCSS and CCSM, (4) Co-leadership with M. Zhang of the GCSS-CFMIP column cloud feedbacks intercomparison, which brings the cloud feedbacks and cloud process modeling communities together.

Collaborators (other than past advisees) during last 48 months:

Dennis L. Hartmann (UW, Qiang Fu (UW), Sandra Yuter (UW), Rob Wood (UW), Minghua Zhang(SUNY), Phil Rasch (PNL), Chris Fairall (NOAA), David Randall (CSU), Marat Khairoutdinov (CSU), C. R. Mechoso (UCLA), Sungsu Park (NCAR).

Doctoral Advisor: Kerry A. Emanuel (MIT); (no postdoctoral sponsor)

Doctoral (D, 5 total) and Postdoctoral (P, 5 total)) Advisees, last 5 years

Matthew Peters (D), Kim Comstock (D), Larissa Back (D), Peter Caldwell (D), Rob Wood (P), Ping Zhu (P), Zhiming Kuang (P), Charles Cornish (P), Sungsu Park (P).

Professional Duties and Societies

Editor, *Journal of the Atmospheric Sciences*, 1/95-12/99.

Member, American Meteorological Society, American Geophysical Union. Have served on AMS Committees on Waves and Stability (1989-1991, 1996-1998, as chair and conference chair 1997-8), Mesoscale Meteorology conference co-chair in 1992, Program Committee of the AMS-sponsored Second International Air-Sea Interaction Conference, Lisbon, September 1994, the Haurwitz Prize Selection Committee, 1993-1994, and the AMS Fellows selection committee since 2006.

Current National Committees and Science Teams

World Meteorological Organization Global Cloud System Studies (GCSS) Boundary Layer Cloud Working Group, May 1993-present, Chair 12/01-12/05.

VAMOS Ocean-Cloud-Atmosphere-Land (VOCALS) Scientific Steering Comm. 2003-present.

Community Climate System Model Scientific Steering Committee, 1/02-present.

Honors

NSF Presidential Young Investigator in Atmospheric Science	1988-1994
American Meteorological Society Editor's Award	Jan. 2002
UW Department of Atmospheric Sciences Annual Teaching Award	2001-2002
Elected Fellow of the American Meteorological Society	Jan. 2004

C. Roberto Mechoso Biographical Sketch

February 2009 (www.atmos.ucla.edu/~mechoso)

C. Roberto Mechoso is Professor of Atmospheric Dynamics in the Department of Atmospheric and Oceanic Sciences at the University of California Los Angeles (UCLA). Mechoso's current research interests are ocean-atmosphere interactions, numerical weather prediction, meteorology aand climatology of the Southern Hemisphere, and high performance computing. He is author of more that 150 scientific publications in his fields of interest. The goal of his research is to increase the understanding of climate variability using analyses of highly realistic simulations with numerical models, complemented by studies with observational data. Targeted topics have been El Niño/Southern Oscillation and its impacts, American monsoon systems, stratospheric warnings, instabilities on atmospheric fronts, and distributing computing for climate modeling.

Professional Preparation

University of Uruguay, Electro-Mechanical Engineering, Engineer 1974; Princeton, University, Geophysical Fluid Dynamics, MA 1977, Ph.D. 1978.

Appointments

Professor of Atmospheric Dynamics, UCLA, since July 1991. Associate Professor of Atmospheric Dynamics, UCLA, July 1986 - June 1991. Assistant Professor of Atmospheric Dynamics, UCLA, July 1981 - June 1986. Adjunct Assistant Professor, UCLA, January 1979 - June 1981. Graduate Student, Princeton University, September 1975 - December 1978. Research Assistant, Geophysical Fluid Dynamics Program, Princeton University, January - August 1975. Lecturer (Fluid Mechanics and Continuum Mechanics), School of Engineering, University of Uruguay, 1968-1974. Directeur de Recherche, Ecole Polytechnique, France, October-November 2000. Distinguished Visitor, Universidad Complutense, Madrid, 2007.

Publications closely related to the proposed project

Mechoso, C. R., A. W. Robertson, N. Barth, M. K. Davey, P. Delecluse, P. R. Gent, S. Ineson, B. Kirtman, M. Latif, H. Le Treut, T. Nagai, J. D. Neelin, S. G. H. Philander, J. Polcher, P. S. Schopf, T. Stockdale, M. J. Suarez, L. Terray, O. Thual and J. J. Tribbia, 1995: The seasonal cycle over the Tropical Pacific in General Circulation Models. *Mon. Wea. Rev*., **123**, 2825-2838.

Ma, C.-C., C. R. Mechoso, A. W. Robertson and A. Arakawa, 1996: Peruvian stratus clouds and the tropical Pacific circulation - a coupled ocean-atmosphere GCM study. *J. Climate*, **9,** 1635-1645.

Mechoso, C. R., J.-Y. Yu and A. Arakawa, 2000: A coupled GCM pilgrimage: From climate catastrophe to ENSO simulations. *General Circulation Model Development: Past, present and future*. Proceedings of a Symposium in Honor of Professor Akio Arakawa. D. A. Randall. Ed., Academic Press, 539-575.

Xiao, Heng, and C. R. Mechoso, 2009: Seasonal Cycle-El Niño Relationships: Validation of Hypotheses. *J. Atmos. Sci.* **66,** 1633-1653.

Toniazzo, T., C. R. Mechoso, L. Shaffrey and J. Slingo, 2009: Ocean surface heat budget and ocean eddy transport in the Southeastern Pacific in a high resolution coupled model. *Int. J. Climat., sub judice.* Available at http://www.cgam.nerc.ac.uk/len/VOCALS/

Other relevant publications

Ma, C.-C., C. R. Mechoso, A. W. Robertson and A. Arakawa, 1996: Peruvian stratus clouds and the tropical Pacific circulation - a coupled ocean-atmosphere GCM study. *J. Climate*, **9,** 1635-1645.

Yu, J. -Y., and C. R. Mechoso, 2001: A coupled atmosphere-ocean GCM study of the ENSO cycle. *J. Climate*, **14**, 2329-2350.

Mechoso, C. R., J. D. Neelin, and J. -Y. Yu, 2003: Testing simple models of ENSO. *J. Atmos Sci.*, **60**, 305-318.

Richter, I. and C. R. Mechoso, 2006: Orographic influences on subtropical stratocumulus clouds. *J. Atmos. Sci.* 63, 2585-2601.

Xiao, Heng and C. R. Mechoso, 2009: Correlative Evolutions of ENSO and the Seasonal Cycle. *J. Atmos. Sci.* **66,** 1041–1049.

Rodriguez-Fonseca, B., I. Polo, J. Garcia-Serrano, T. Losada, E. Mohino, C. R. Mechoso, and F. Kucharski. 2009: Are Atlantic Niños enhancing Pacific ENSO events in recent decades? *Geophys. Res. Lett.* In Press. Available at www.atmos.ucla.edu/~mechoso

Synergistic Activities

Mechoso chairs the Science Working Group of the WCRP/CLIVAR VAMOS-Ocean-Clouds-Atmosphere-Land-Systems (VOCALS) project of the Panel on the Variability of American Monsoon Systems (VAMOS). He is a member of International WCRP/ /CLIVAR Scientific Steering Group (SSG).

Collaborators

(i) *Collaborators:* A. Arakawa (UCLA), B. Klinger (George Mason), C. S. Konor (USC), Matt Harrison (GFDL), A. W. Robertson, (IRI, Lamont), J. Schubert (UCLA), R. Walterscheid (Aerospace), R. Wood (U. Wash), Y. Xue (UCLA).

(ii) *Graduate and Postdoctoral Advisors*: Isidoro Orlanski (Geophysical Fluid Dynamics Laboratory, NOAA/Princeton University)

(iii) *Thesis Advisor and Postgraduate-Scholar Sponsor*: M. Chen, L. A. Drummond, J. D. Farrara, J.-H. Jung, K. Hines, A. Kitoh, C. S. Konor, M. Köhler, J.-L. Li, C.-C. Ma, G. Manney, A. Mariotti, I. Richter, A. W. Robertson, D. Sinton, R. Terra, L. Tseng, K. Yamazaki, H. H. Xeng, J.-Y. Yu, L. Zamboni

Number of graduate students advised: 10

Number of postgraduate scholars sponsored: 10

Biographical Sketch

João Teixeira

Education and Training

Jan. 2000 - Doctor in Physics (Meteorology), University of Lisbon, Portugal.
Oct. 1992 - Licentiate in Geophysical Sciences, University of Lisbon, Portugal.

Research and Professional Experience

2008-present	Visiting Researcher, JIFRESSE, University of California, Los Angeles, USA
2008-present	Research Scientist, Jet Propulsion Laboratory, Pasadena, CA, USA
2005–2007	Senior Scientist (A3), NATO Undersea Research Centre, La Spezia, Italy.
2000–2005	UCAR Scientist (VSP), Naval Research Laboratory, Monterey, CA, USA.
1993–1999	Scientist (A2), European Centre for Medium-range Weather Forecasts, UK.

Publications

- Teixeira, J., B. Stevens, C. S. Bretherton, R. Cederwall, J.D. Doyle, J.C. Golaz, A. A.M. Holtslag, S. A. Klein, J. K. Lundquist, D. A. Randall, A. P. Siebesma and P.M.M. Soares, 2008: The parameterization of the atmospheric boundary layer: a view from just above the inversion. *Bulletin of the American Meteorological Society*, **89**, 453-458.
- Teixeira, J., P. May, M. Flatau, and T. F. Hogan, 2008: On the sensitivity of the SST from a global ocean-atmosphere coupled system to the parameterization of boundary layer clouds. *Journal of Marine Systems*, **69**, 29–36.
- Teixeira, J., and C. A. Reynolds, 2008: Stochastic nature of physical parameterizations in ensemble prediction: a stochastic convection approach. *Mon. Wea. Rev.*, **136,** 483-496.
- Siebesma, A. Pier, Pedro M. M. Soares, and João Teixeira, 2007: A Combined Eddy-Diffusivity Mass-Flux Approach for the Convective Boundary Layer. *Journal of the Atmospheric Sciences*, **64**, 1230-1248.
- Soares, P.M.M, P.M.A. Miranda, A.P. Siebesma and J. Teixeira, 2004: An Eddy-diffusivity/Mass-flux scheme for dry and shallow convection. *Quarterly Journal of the Royal Meteorological Society*, **130**, 3365-3384.
- Teixeira, J., and S. Cheinet, 2004: A simple mixing length formulation for the eddy-diffusivity parameterization of dry convection. *Boundary Layer Meteorology,* **110**, 435-453.
- Teixeira, J. and T.F. Hogan, 2002: Boundary layer clouds in a global atmospheric model: simple cloud cover parameterizations. *Journal of Climate,* **15**, 1261-1276.
- Teixeira, Joao, 2001: Cloud fraction and relative humidity in a prognostic cloud fraction scheme. *Monthly Weather Review,* **129**, 1750-1753.
- Duynkerke, P.G. and J. Teixeira, 2001: Comparison of the ECMWF Reanalysis with FIRE I observations: diurnal variation of marine stratocumulus**.** *Journal of Climate*, **14**, 1466-1478.
- Teixeira, Joao, 1999: Simulation of Fog with the ECMWF Prognostic Cloud Scheme. *Quarterly Journal of the Royal Meteorological Society*, **125-B**, 529-553.

Synergistic Activities

- Associate Editor: *Monthly Weather Review* – since 2005.
- Member: JIFRESSE Executive Committee – since 2009.
- Member: Process Studies and Model Improvement Panel, US CLIVAR, - since 2009.
- Chair: GCSS Pacific Cross-section Intercomparison (GPCI) working group – since 2005
- Member: GEWEX Cloud System Study (GCSS) scientific steering committee - since 2004

Collaborators and co-editors: Li, F. J.-L. (JPL), D. Waliser (JPL), C. Woods (JPL), J. Bacmeister (GSFC), J. Chern (GSFC), B.-W. Shen (GSFC), A. Tompkins (ICTP, Italy), W.-K. Tao (GSFC), M. Köhler (ECMWF, UK), Aumann, H.H. (JPL), A. Ruzmaikin (JPL), Reynolds, C.A. (NRL), J. McLay (NRL), Y.-J. Kim (NRL), Witek, M.L. (JPL), P. J. Flatau (Scripps), B. Stevens (MPI, Germany), C. S. Bretherton (U. Washington), R. Cederwall (retired), J.D. Doyle (NRL), J.C. Golaz (GFDL), A. A.M. Holtslag (U. Wageningen, The Netherlands), S. A. Klein (LLNL), J. K. Lundquist (LLNL), D. A. Randall (CSU), A. P. Siebesma (KNMI, The Netherlands), P.M.M. Soares (IDL, Portugal), K. Judd (U. Western Australia, Australia), P. May (CSC), M. Flatau (NRL), T. F. Hogan (NRL), P.M.A. Miranda (U. Lisbon, Portugal), von Engeln, A. (EUMETSAT, Germany), J. Wickert (GFZ, Germany), S. Buehler (LTU, Sweden), D. Westphal (NRL), G. Beyerle (GFZ, Germany), Ao, C.O. (JPL), T.K. Chan (JPL), B.A. Iijima (JPL), A.J. Mannucci (JPL), B. Tian (JPL), E. Fetzer (JPL), E. Fishbein (JPL). Postdoctoral associates: George Matheou (JPL), Marcin Witek (Caltech), Kay Suselj (Caltech), Daniel Chung (JPL).

Sungsu Park

Education

Ph.D.	University of Washington (Seattle, WA), Department of Atmospheric Sciences, Sept.1998-Nov.2002
B.S.	Seoul National University (Seoul, South Korea), Atmospheric Sciences (major); Physics (minor), Summa Cum Laude, Mar.1991-Feb.1995

Appointments

Jan.2009-Present	Scientist I, Climate and Global Dynamics Division/NCAR
Jan.2005-Dec.2008	Research Associate, Dept. of Atmospheric Sciences, University of Washington, Seattle
Dec.2002-Dec.2004	Advanced Study Program, Postdoctoral Fellow at the National Center for Atmospheric Research (NCAR)
Sep.1998-Nov.2002	Graduate Research Assistant, Dept. of Atmospheric Sciences, Univ. of Washington, Seattle
Mar.1995-Jul.1998	Officer, Military service in the Republic of Korea Air Force

Related Publications

Park, S., and C. S. Bretherton, 2009: The University of Washington Shallow Convection and Moist Turbulence Schemes and Their Impact on Climate Simulations with the Community Atmosphere Model. *J. Climate*, 22, 3449-3469.

Bretherton, C. S., and **S. Park**, 2009: A New Moist Turbulence Parameterization in the Community Atmosphere Model. *J. Climate*, 22, 3422-3448.

Bretherton, C. S., and **S. Park**, 2008: A New Bulk Shallow-Cumulus Model and Implications for Penetrative Entrainment Feedback on Updraft. *J. Atmos. Sci.* 65, 2174-2193.

Park, S., C. B. Leovy, and M. A. Rozendaal, 2004: A New Heuristic Lagrangian Marine Boundary Layer Cloud Model. *J. Atmos. Sci.*, 61, 3002-3024.

Other Publications

Klein, S. *et al. including* **S. Park**, 2009: Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-Phase Arctic Cloud Experiment. Part I: Single layer cloud. *Quart. J. R. Met. Soc.*, 641, 979-1002.

Matthew, C. W., C. S. Bretherton, A. Chlond, B. M. Griffin, H. Kitagawa, C. Lappen, V. E. Larson, A. Lock, **S. Park**, S. R. de Roode, J. Uchida, M. Zhao, and A. S. Ackerman, 2007: A single-column-model intercomparison of a heavily drizzling stratocumulus topped boundary layer. *J. Geophysical Research – Atmosphere, 112, D24204, doi:10.1029/2007JD008536.*

Park, S., M. A. Alexander, and C. Deser, 2006: The impact of cloud radiative feedback, remote ENSO forcing, and entrainment on the persistence of North Pacific sea surface temperature anomalies. *J. Climate*, 19, 6243-6262.

Park, S., C. Deser, and M. A. Alexander, 2005: Estimation of the surface heat flux response to sea surface temperature anomalies over the global oceans. *J. Climate*, 18, 4582-4599.

Park, S., and C. B. Leovy, 2004: Marine low-cloud anomalies associated with ENSO. *J. Climate*, 17, 3448-3469.

Synergistic Activities

Developed a new University of Washington Moist Turbulence and Shallow Convection Schemes with Prof. Christopher Bretherton at the University of Washington. Implemented these schemes into the NCAR CAM4.

Developed and implemented a revised macrophysics scheme into CAM4

Collaborators

Collaborators: Michael Alexander, Christopher S. Bretherton, Clara Deser, Stephen A. Klein, Conway B. Leovy, Matthew C. Wyant

Thesis advisor: Conway B. Leovy, University of Washington, Seattle, WA.

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Washington

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Christopher S Bretherton

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher S Bretherton - Principal Investigator	0.00	0.00	1.00	$ 13,419	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	13,419	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.00	0.00	0.00	28,542	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				41,961	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				11,530	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				53,491	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Two computers @ $2500 each $ 5,000					
TOTAL EQUIPMENT				5,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,029	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				812	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				2,750	
5. SUBAWARDS				0	
6. OTHER				950	
TOTAL OTHER DIRECT COSTS				4,512	
H. TOTAL DIRECT COSTS (A THROUGH G)				69,032	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Assessed on all direct costs, less equipment (Rate: 56.0000, Base: 64032)					
TOTAL INDIRECT COSTS (F&A)				35,858	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				104,890	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 104,890	$

M. COST SHARING PROPOSED LEVEL $ 0 — AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Christopher S Bretherton

ORG. REP. NAME*
Kathryn Hovick

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION: University of Washington	FOR NSF USE ONLY				
	PROPOSAL NO.	DURATION (months) Proposed	Granted		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Christopher S Bretherton	AWARD NO.				

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher S Bretherton - Principal Investigator	0.00	0.00	1.00	$ 14,090	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	14,090	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.00	0.00	0.00	29,969	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				44,059	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				12,107	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				56,166	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,271	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				845	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				2,860	
5. SUBAWARDS				0	
6. OTHER				988	
TOTAL OTHER DIRECT COSTS				4,693	
H. TOTAL DIRECT COSTS (A THROUGH G)				67,130	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Assessed on all direct costs (Rate: 56.0000, Base: 67130)					
TOTAL INDIRECT COSTS (F&A)				37,593	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				104,723	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 104,723	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: Christopher S Bretherton	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: Kathryn Hovick	Date Checked	Date Of Rate Sheet	Initials - ORG

2 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of Washington**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Christopher S Bretherton**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Christopher S Bretherton - Principal Investigator**	0.00	0.00	1.00	$ **14,795**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**14,795**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.00	0.00	0.00	**31,468**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**46,263**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**12,713**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**58,976**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**6,522**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**879**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**5,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**2,975**	
5. SUBAWARDS				**0**	
6. OTHER				**1,028**	
TOTAL OTHER DIRECT COSTS				**9,882**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**75,380**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Assessed on all direct costs (Rate: 56.0000, Base: 75380)**					
TOTAL INDIRECT COSTS (F&A)				**42,213**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**117,593**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **117,593**	$
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Christopher S Bretherton**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kathryn Hovick**	Date Checked	Date Of Rate Sheet	Initials - ORG

3 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0968571

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION University of Washington				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Christopher S Bretherton				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher S Bretherton - Principal Investigator	0.00	0.00	3.00	$ 42,304	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	3.00	42,304	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (6) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	15.00	0.00	0.00	89,979	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				132,283	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				36,350	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				168,633	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 5,000					
TOTAL EQUIPMENT				5,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				18,822	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,536	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				5,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				8,585	
5. SUBAWARDS				0	
6. OTHER				2,966	
TOTAL OTHER DIRECT COSTS				19,087	
H. TOTAL DIRECT COSTS (A THROUGH G)				211,542	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				115,664	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				327,206	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 327,206	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME Christopher S Bretherton	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* Kathryn Hovick	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0968571

Collaborative Research:
CPT for Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models

Christopher Bretherton, Ph.D., Principal Investigator

Budget Justification: Narrative

A. SALARIES (\$132,283)

- ***Principal Investigator: (\$42,304)*** For each of Years 1-3, funding is requested for CHRISTOPHER BRETHERTON for one month of summer salary @ 100% FTE to oversee Blossey and Wyant, collaborate with Park and Hannay at NCAR, present the CPT contribution in GCSS Boundary Layer Cloud Working Group and VOCALS Assessment workshops, and organize the publication of UW CPT research findings.

- ***Research Scientist: (\$34,407)*** For each of Years 1-3, funding is requested for PETER BLOSSEY for 2 months of salary @ 100% FTE to perform LES simulations in support of CPT, including preparation and submission of GCSS cases and needed LES sensitivity studies based on these cases.

- ***Research Scientist: (\$55,572)*** For each of Years 1-3, funding is requested for MATTHEW WYANT for 3 months of salary @ 100% FTE to run single column GFSdev and CAM4 on GCSS Sc-Cu case and submit results, and perform detailed analysis of global model and single-column model simulations from both models, with emphasis on model-observation intercomparison for NE and SE Pacific cross-sections.

- A 5% annual increase has been factored into all salaries.

B. BENEFITS: (\$36,350)

The University of Washington pays benefits (Social Security, Health Insurance, Retirement) for employees, and these benefits are considered direct costs for personnel on this project. Funding is requested for employee benefits for Years 1-3, at the current rates of:

- 23.6% for instructional & research faculty
- 29.3% for professional staff

C. EQUIPMENT: (\$5,000)

The University of Washington considers instrumentation or parts for use as part of a project exceeding \$2000 to be equipment. This equipment will be used for research purposes only.

***Year 1**:* Funds are requested to purchase two computer workstations for the research scientists to perform work as detailed in proposal.

***Year 2**:* *N/A.*

***Year 3**:* *N/A.*

D. TRAVEL: ($18,822)
Funds are requested in Years 1-3 as described below for travel to conferences to disseminate research results, and to collaborate with colleagues at the National Center for Environmental Prediction (NCEP) in Silver Springs, MD, and at the National Center for Atmospheric Research (NCAR) in Boulder, CO. All travel is expected to be domestic.

YEAR 1: ($6,029) [one person/trip] (location is unknown, but based on San Francisco)

Conference ($1,815)
- *Airfare: ($429)* RT airfare to conference, (includes taxes and fees)
- *Lodging: ($540)* For 3 nights, includes hotel and sales taxes
- *Per Diem: ($296)* For 4 days @ $74/night
- *Ground Transportation: ($100)* Transportation to/from airports
- *Conference Fee: ($450)* Conference registration fee

Collaboration (NCEP) ($1,446) [one person/trip]
- *Airfare: ($600)* RT airfare to NCEP in Silver Springs, MD, from Seattle, WA, (includes taxes and fees)
- *Lodging: ($450)* For 3 nights, includes hotel and sales taxes
- *Per Diem: ($296)* For 4 days @ $74/night
- *Ground Transportation: ($100)* Transportation to/from airports

Collaboration (NCAR) ($1,384/trip; two trips/year = $2,768) [one person/trip]
- *Airfare: ($650)* RT airfare to NCAR in Boulder, CO, from Seattle, WA, (includes taxes and fees)
- *Lodging: ($378)* For 3 nights, includes hotel and sales taxes
- *Per Diem: ($256)* For 4 days @ $64/night
- *Ground Transportation: ($100)* Transportation to/from airports

YEAR 2: ($6,271) Travel requirements for Year 2 are as detailed in Year 1.
YEAR 3: ($6,522) Travel requirements for Year 3 are as detailed in Year 2.

E. OTHER DIRECT COSTS: ($19,087)
Funding is requested to purchase the following goods and/or services to perform the work detailed in the proposal during Years 1-3:

1. ***Materials and Supplies: ($2,536)***
   For hard drives to backup research data. $812/year

2. ***Publication Costs/Documentation/Dissemination: ($5,000)***
   As it is estimated at least one publication will result from this project, funding is requested in Year 3 for publication costs: 15 pages @ $200/page, plus $2,000 for color charges

3. ***Computer Services: ($8,585)***
   Computer services to conduct work as detailed in the proposal. This is for computing services in addition to the basic network connections provided from indirect costs. Funding is requested for three computers per year for Years 1-3.

4. ***Other: ($2,966)***
   - *Long-Distance Telephone, Mailing Services, and Duplicating Services: ($1,717)* Years 1-3 @ $550/year.
   - *Equipment Insurance: ($1,249)* To cover 100% of the costs to insure the new computer workstations purchased for use on this project.

- A 4% annual increase has been factored into all direct costs, except where noted.

F. TOTAL DIRECT COSTS: ($211,542)

G. INDIRECT COSTS: ($115,664)

Indirect costs are requested for all expenses, excluding equipment and graduate student tuition. The indirect cost rate for Years 1-3 is 56.0%. Rates are based on the DHHS/UW agreement dated November 5, 2008.

H. TOTAL DIRECT AND INDIRECT COSTS: ($327,206)

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Los Angeles

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Carlos R Mechoso

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Carlos R Mechoso - Professor	0.00	0.00	1.00	$ 14,689	$
2. T TBN - Assistant Researcher	12.00	0.00	0.00	57,500	
3. Joao Teixeira - Visiting Researcher	0.00	0.00	0.00	0	
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	12.00	0.00	1.00	72,189	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	48,000	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				120,189	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				29,960	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				150,149	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				10,900	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,500	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,000	
5. SUBAWARDS				0	
6. OTHER				1,019	
TOTAL OTHER DIRECT COSTS				6,519	
H. TOTAL DIRECT COSTS (A THROUGH G)				167,568	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MDTC (Rate: 54.0000, Base: 167568)					
TOTAL INDIRECT COSTS (F&A)				90,487	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				258,055	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 258,055	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Carlos R Mechoso

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

TPI 6948176

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Los Angeles

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Carlos R Mechoso

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Carlos R Mechoso - Professor	0.00	0.00	1.00	$ 15,423	$
2. T TBN - Assistant Researcher	12.00	0.00	0.00	60,375	
3. Joao Teixeira - Visiting Researcher	0.00	0.00	0.00	0	
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	12.00	0.00	1.00	75,798	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	50,400	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				126,198	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				31,459	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				157,657	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				10,900	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,500	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,000	
5. SUBAWARDS				0	
6. OTHER				1,019	
TOTAL OTHER DIRECT COSTS				6,519	
H. TOTAL DIRECT COSTS (A THROUGH G)				175,076	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MDTC (Rate: 54.0000, Base: 175076)					
TOTAL INDIRECT COSTS (F&A)				94,541	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				269,617	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 269,617	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Carlos R Mechoso

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

TPI 6948176

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION: University of California-Los Angeles	FOR NSF USE ONLY		
	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Carlos R Mechoso	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Carlos R Mechoso - Professor	0.00	0.00	1.00	$ 16,195	$
2. T TBN - Assistant Researcher	12.00	0.00	0.00	63,394	
3. Joao Teixeira - Visiting Researcher	0.00	0.00	0.00	0	
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	12.00	0.00	1.00	79,589	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	52,920	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				132,509	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				33,031	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				165,540	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				10,900	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,500	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,000	
5. SUBAWARDS				0	
6. OTHER				1,019	
TOTAL OTHER DIRECT COSTS				6,519	
H. TOTAL DIRECT COSTS (A THROUGH G)				182,959	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MDTC (Rate: 54.0000, Base: 182958)					
TOTAL INDIRECT COSTS (F&A)				98,797	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				281,756	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 281,756	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: Carlos R Mechoso	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

TPI 6948176

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION	FOR NSF USE ONLY		
University of California-Los Angeles	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Carlos R Mechoso	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Carlos R Mechoso - Professor	0.00	0.00	3.00	$ 46,307	$
2. T TBN - Assistant Researcher	36.00	0.00	0.00	181,269	
3. Joao Teixeira - Visiting Researcher	0.00	0.00	0.00	0	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	36.00	0.00	3.00	227,576	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (3) POST DOCTORAL SCHOLARS	36.00	0.00	0.00	151,320	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				378,896	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				94,450	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				473,346	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				32,700	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				6,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				7,500	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				3,000	
5. SUBAWARDS				0	
6. OTHER				3,057	
TOTAL OTHER DIRECT COSTS				19,557	
H. TOTAL DIRECT COSTS (A THROUGH G)				525,603	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				283,825	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				809,428	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 809,428	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME	FOR NSF USE ONLY		
Carlos R Mechoso	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

UCLA Budget Justification

PI: **Carlos R. Mechoso**
Title: **Collaborative Research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models**
Dates: **07/01/10 to 06/30/13**

Salary
1.00 sum mo/yr: PI, Carlos Mechoso, Professor
0.00 cal mo/yr: coI, Joao Teixeira, Visiting Researcher
12.00 cal mo/yr: TBN, Assistant Researcher
12.00 cal mo/yr: TBN, Post Doctoral Researcher

Benefit
Mechoso: 12.7%
Asst Res: 33%
PostDoc: 19%

Travel
PI, Asst Res, and PostDoc will travel to annual conference and meetings each year :

	AGU	CCSM	NCEP
	San Francisco, CA	Boulder Co	Silver Spring, MD
Airfare	$300	$500	$800
Lodging 5 days:	$750 ($150/night)	$750 ($150/night)	$750 ($150/night)
Meals 5 days:	$300 ($60/day)	$300 ($60/day)	$300 ($60/day)
Registration:	$350		
Taxi/Shuttle:	$100	$150	$150
Total:	$1800/yr x 1 = $1800	$1700/yr x 3 = $5100	$2000/yr x 2 = $4000

Other Cost
Publication: requested for all three years to cover cost of editing and producing scholarly, articles related to this project. The cost is calculated at $250/page x 10 pages of scientific paper resulting from this project: $2500/yr

Material and Supplies: toner, poster board, software, research related telecommunication: $2000/yr

Computer Services: Access, support, and maintenance of high-performing network of computers needed for project: $1000/yr

Other: Technology Infrastructure Fee (TIF) is accessed to each project fund number to support the technology infrastructure services that support the entire campus, including the CLA backbone, Commodity Internet, Internet2, BOL services, Connect2, and underground inter-building wiring/cabling and maintenance. Project specific Information Technology Services are also charged to this project. Cost $40.75/month/FTE: $1019/yr

Indirect Cost
Facilities and Administration (F&A) Cost of On-Campus rate of 54.0% of the Modified Total Direct Cost (MTDC). Only the first $25K of each subcontract is subject to overhead. A copy of agreement can be found: http://www.research.ucla.edu/ocga/sr2/idcinfo.htm

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University Corporation For Atmospheric Res**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Sungsu Park**				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Sungsu Park - Park**	0.00	0.00	0.00	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**1**) OTHER				**37,445**	
TOTAL SALARIES AND WAGES (A + B)				**37,445**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,434**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**56,879**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**3,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**5,605**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**8,605**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**70,484**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **indirect cost (Rate: 49.1000, Base: 64879)**					
TOTAL INDIRECT COSTS (F&A)				**31,856**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**102,340**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **102,340**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Sungsu Park**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

TPI 6949672

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University Corporation For Atmospheric Res

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Sungsu Park

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Sungsu Park - Park	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				39,318	
TOTAL SALARIES AND WAGES (A + B)				39,318	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				20,406	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				59,724	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				5,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				3,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				5,605	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				8,605	
H. TOTAL DIRECT COSTS (A THROUGH G)				73,329	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) indirect cost (Rate: 49.1000, Base: 67724)					
TOTAL INDIRECT COSTS (F&A)				33,252	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				106,581	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 106,581	$

M. COST SHARING PROPOSED LEVEL $ 0 — AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Sungsu Park

ORG. REP. NAME*

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

TPI 6949672

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION: University Corporation For Atmospheric Res				**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Sungsu Park				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. Sungsu Park - Park	0.00	0.00	0.00	$ 0	$	
2.						
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0		
3. (0) GRADUATE STUDENTS				0		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (1) OTHER				41,284		
TOTAL SALARIES AND WAGES (A + B)				41,284		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				21,426		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				62,710		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT				0		
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				5,000		
2. FOREIGN				0		
F. PARTICIPANT SUPPORT COSTS						
1. STIPENDS $ 0						
2. TRAVEL 0						
3. SUBSISTENCE 0						
4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				3,000		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				5,605		
5. SUBAWARDS				0		
6. OTHER				0		
TOTAL OTHER DIRECT COSTS				8,605		
H. TOTAL DIRECT COSTS (A THROUGH G)				76,315		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) indirect cost (Rate: 49.1000, Base: 70710)						
TOTAL INDIRECT COSTS (F&A)				34,719		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				111,034		
K. RESIDUAL FUNDS				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 111,034	$	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME: Sungsu Park				**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*				Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

TPI 6949672

SUMMARY PROPOSAL BUDGET

Cumulative

	FOR NSF USE ONLY		
ORGANIZATION **University Corporation For Atmospheric Res**	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Sungsu Park**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Sungsu Park - Park	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (3) OTHER				118,047	
TOTAL SALARIES AND WAGES (A + B)				118,047	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				61,266	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				179,313	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				15,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				9,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				16,815	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				25,815	
H. TOTAL DIRECT COSTS (A THROUGH G)				220,128	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				99,827	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				319,955	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 319,955	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

	FOR NSF USE ONLY		
PI/PD NAME **Sungsu Park**	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

TPI 6949672

NCAR budget justification: NCAR prop. 2009-521

Salary

Salary is requested for .5 FTE Associate Scientist, level 3 or 4. This Associate Scientist will be responsible for running CAM4 and CCSM models, including CAM4 weather-forecast-model simulations, generation and archiving of model diagnostics, and sensitivity studies.

NSF will cosponsor[1] approximately 5% FTE each year for NCAR PI Dr. Sungsu Park's salary/benefits, overhead, and computer services. Dr. Park is an expert in modeling boundary turbulence, convection, and cloud macrophysics processes, and has developed these components for CAM4 (Community Atmosphere Model, version 4). He will be responsible for further developments in CAM, including implementation of probability density function (PDF)-based cloud macrophysics and a combined turbulence-convection scheme into the CAM.

Materials and Supplies

Years 1-3: $3000 is requested per year for journal publication costs. This estimate is based on $150 per page (color).

Travel (domestic)

Travel support is requested at $5000 per year, so that NCAR PI may attend two collaborative meetings (2x$1500=$3000) and one conference ($2000) per year.
(Estimate for collaborative meetings: Air $500; lodging $650; per diem $350 = $1500)
(Estimate for conference trips: Air $500; lodging $700; per diem $400; registration $400 = $2000)

Administrative Costs

Indirect costs are calculated at 49.1% and are applied to all Modified Total Direct Costs (MTDC). Computing Service Center (CSC) expenses are a method of distributing the cost of computer support personnel fairly among many different projects. The CSC rate is $6.34 per hours worked. These rates are based on FY10 rates, which have not yet been approved. However, NSF has given permission for NCAR to begin using these rates for budgeting purposes. A detailed budget by year is attached.

[1] National Science Foundation (NSF) Cosponsorship is defined as the value of resources funded by NSF to the National Center for Atmospheric Research (NCAR) through the University Corporation of Atmospheric Research (UCAR) cooperative agreement that contribute to the performance of research sponsored by another organization. NSF Cosponsorship should not be viewed as cost sharing, as defined in OMB Circular A-110, as it is borne by the Federal Government.

B&P Check - Final Budget

NCAR Division: CGD

Project Title **Collaborative Research: CPT for Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models**

NCAR PI(s): Sungsu Park

NCAR Proposal # 2009-521

Period of Performance: 7/1/10 - 6/30/13

Date: 9/11/09

Initials: clw

			YEAR 1		YEAR 2		YEAR 3		TOTALS		
			NSF	**NSF Co-spnsr**	**NSF**	**NSF Co-spnsr**	**NSF**	**NSF Co-spnsr**	**NSF**	**NSF Co-spnsr**	**Overall Total**
SALARIES & BENEFITS	**FTE**	**FTE**									
Regular Salaries											
PI		0.05	0	3,793	0	3,983	0	4,182	0	11,958	11,958
AS III/IV	0.5		37,445	0	39,318	3,932	41,284	0	118,047	3,932	121,979
SUBTOTAL			37,445	3,793	39,318	7,915	41,284	4,182	118,047	15,890	133,937
Regular Benefits @	0.519		19,434	1,969	20,406	4,108	21,426	2,170	61,266	8,247	69,513
MATERIALS & SUPPLIES											
Page Charges			3,000	0	3,000	0	3,000	0	9,000	0	9,000
SUBTOTAL			3,000	0	3,000	0	3,000	0	9,000	0	9,000
PURCHASED SERVICES											
Misc.			0	0	0	0	0	0	0	0	0
SUBTOTAL			0	0	0	0	0	0	0	0	0
TRAVEL											
Domestic	3 TRIPS		5,000	0	5,000	0	5,000	0	15,000	0	15,000
SUBTOTAL			5,000	0	5,000	0	5,000	0	15,000	0	15,000
SUBTOTAL Modified Total Direct Costs (MTDC			**64,879**	**5,762**	**67,724**	**12,023**	**70,710**	**6,352**	**203,313**	**24,137**	**227,450**
NCAR INDIRECT COSTS (IC) @	0.491		**31,856**	**2,829**	**33,252**	**5,903**	**34,719**	**3,119**	**99,827**	**11,851**	**111,678**
MTDC Items that include IC											
SCD COMPUTING (GAUs)	$0.44 /GAU		0	0	0	0	0	0	0	0	0
COMPUTING SERVICE CENTER			5,605	560	5,605	1,121	5,605	560	16,815	2,241	19,056
TOTAL MTDC + Applied IC			**102,340**	**9,151**	**106,581**	**19,047**	**111,034**	**10,031**	**319,955**	**38,229**	**358,184**
UCAR Management Fee (Applied to MTDC + IC)	**0**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL Funding to UCAR			**102,340**	**9,151**	**106,581**	**19,047**	**111,034**	**10,031**	**319,955**	**38,229**	**358,184**

1 NSF Cosponsorship is defined as the value of resources funded by NSF to the National Center for Atmospheric Research (NCAR) through the University Corporation of Atmospheric Research (UCAR) cooperative agreement that contribute to the performance of research sponsored by another organization. NSF Cosponsorship should not be viewed as cost sharing, as defined in OMB Circular A-110, as it is borne by the Federal Government.

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.

Current and Pending Support (September 21, 2009)

CHRISTOPHER STEPHEN BRETHERTON

Current Funding and Summer Salary Support

VOCALS: C-130 Observations and Numerical Modeling of Marine Boundary Layer Clouds during the VOCALS Regional Experiment (REx) 4/08-3/11

$702,000 (NSF, co-PI; lead PI Rob Wood) – 1 mo.

Modeling and Analysis of Cloud and Aerosol Effects in Climate Change 1/09-12/11

$1,050,000 (NASA – Co-PI; lead PI Dr. Dennis Hartmann) – 0.5 mo.

Pending Funding

Improving the Representation of Shallow Cumulus in the NCEP GFS Model

$359,470 (NOAA) – 1 mo. 6/10-5/13

Collaborative research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models

$327,206 (NOAA) – 1 mo. 7/10-6/13

Current and Pending Support

UCLA

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: ***C. Roberto Mechoso***

Other agencies (including NSF) to which this proposal has

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

To improve modeling, simulation and prediction of the tropical climate with coupled GCMs

Source of Support: NOAA - NA07OAR4310236

Total Award Amount: $348,226 Total Award Period Covered: 07/01/07 – 06/30/10

Location of Project: UCLA

Person-Months Per Year Committed to the Cal: Acad: Sumr: 1.0

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Studies of Waves and Circulation Features in the Antartic Stratosphere Using Vorcore Data

Source of Support: NSF - ATM-073222

Total Award Amount: $461,977 Total Award Period Covered: 10/01/07 – 09/30/10

Location of Project: UCLA

Person- Cal: Acad: Sumr: 1.0

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

To improve modeling, simulation and prediction of the tropical climate with the coupled atmosphere-ocean GCMs

Source of Support: NOAA

Total Award Amount: $444,349 Total Award Period Covered: 06/01/10 – 05/31/13

Location of Project: UCLA

Person- Cal: Acad: Sumr: 1.0

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Collaborative Research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models

Source of Support: NOAA

Total Award Amount: $809,428 Total Award Period Covered: 07/01/10 – 06/30/13

Location of Project: UCLA

Person- Cal: Acad: Sumr: 1.0

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Collaborative Research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models (this proposal)

Source of Support: NSF

Total Award Amount: $809,428 Total Award Period Covered: 07/01/10 – 06/30/13

Location of Project: UCLA

Person- Cal: Acad: Sumr: 1.0

Current and Pending Non-Base Support for Scientific Staff

Sungsu Park

Project Title: Collaborative Research: Improving the Representation of the Stratocumulus to Cumulus Transition in Climate Models

Time Committed to the Project:	0.0	person mths/yr	0.6 person mths/yr supported by NSF Base funds
Source of Support:	NSF		
Award Amount (or amount requested):	$319,955		
Duration of Award:	7/1/10-6/30/13		

____ **Current** _X_ **Pending**

Facilities, Equipment and Other Resources

The Department of Atmospheric Sciences will provide office space and computational resources for the PI and the two Research Scientists. The budget includes funding to help support the 7th Floor Linux Cluster, which will be used for all computations and model output analysis performed at UW, including disk storage, software/hardware troubleshooting, and backup services. Global simulations with the CAM4 and GFSdev models will primarily be performed at NCAR and NCEP with the help of our collaborators at those institutions.

NCAR FACILITIES

MAJOR EQUIPMENT

- IBM Power 575 supercomputer, based on world's fastest microprocessor, IBM POWER6 dual core chip
- 4.7 GHz clock speed
- 4064 processors
- 76.4 teraflops (peak)
- 12 terabytes of memory
- 150 terabytes of high-performance disk

Mass Storage System - The tape archive is front-ended by 48 Terabytes of StorageTek RAID, which is known as the MSS internal disk cache. This disk cache provides an overall read hit ratio of 60 to 70 percent for files up to 1 gigabyte in size. In early 2008, NCAR's Mass Storage System (MSS) surpassed 5 petabytes of data storage (including second copies), with a net growth rate of 80 - 100 terabytes per month. While some of the data stored on the NCAR MSS originate from field experiments and observations, the bulk of the data is generated by global climate-simulation models, mesoscale weather models, and other earth-science models that run on supercomputers.

Network - high-speed, reliable, secure network connectivity to five campuses that requires supports over 117 logical networks, approximately 210 monitorable network devices, and over 3000 network-attached devices, plus management commitments to additional municipal and wide-area networks

Computing Center - a sophisticated computing center that houses our supercomputers and enterprise servers, with a professional operations staff who provide support 24 hours a day, 365 days per year

TeraGrid Resources - NCAR also operates TeraGrid cyberinfrastructure since August 1, 2007. These resources include:

A Blue Gene/L supercomputer based on the power-efficient PowerPC440 core:

-750 MHz

-2048 processors

-5.7 teraflops (peak)

-1 terabyte of memory

-23.2 terabyte of high-performance disk

107 terabyte shared Lustre filesystem

1.43 petabyte capacity Sun tape library, 1 petabyte tape media, HPSS tape archive system.

Sun visualization server

Earth System Grid science gateway

Jet Propulsion Laboratory
California Institute of Technology

4800 Oak Grove Drive
Pasadena, California 91109-8099

September 4, 2009

Prof. Christopher Bretherton
Director, UW Program on Climate Change
University of Washington, Box 351640
Seattle, WA 98195-1640 USA

Subject: Letter of Support

Dear Prof. Bretherton,

It is our understanding that the University of Washington is submitting a proposal to the National Science Foundation, entitled "Collaborative Research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models." JPL can, on a non-exclusive and best-effort basis, develop Eddy-Diffusivity/Mass-Flux (EDMF) and Probability Density Function (PDF) parameterizations and coordinate the CPT research being proposed in improving the representation of the stratocumulus to cumulus transition in the NCAR and NCEP global models.

Given the importance of this research to the science community and its value to the Earth Science Mission activities JPL is currently performing for NASA, JPL is prepared to perform this work for the University of Washington on a no-exchange-of-funds basis. (This can be considered an approximate $253.61K total 3-year cost share to the project.) Consequently JPL's informal cost estimate to the University of Washington is $0. No formal agreement between the University of Washington and NASA/JPL is anticipated; however, should the need for formal terms arise, JPL will consider those terms at that time, subject to NASA prior approval, as appropriate.

Please be advised that JPL is an operating division of the California Institute of Technology (Caltech) and as such, all work must be performed in accordance with all the terms and conditions of NASA/Caltech Prime Contract Number NAS7-03001 and JPL policies. This is a Cost Reimbursable Award Fee type of contract. Government audit is performed on a regular basis by the Defense Contract Audit Agency.

Please contact Dr. Joao Teixeira at (818) 354-2761 for technical matters; James K. Wolfenbarger at (818) 354-3821 for programmatic issues; or Douglas Gilbertson, (818) 354-3458, for contractual matters.

Sincerely,

Daniel J McCleese

Dan McCleese, Director
Office of the Chief Scientist

Cc: Joao Teixeira
James K. Wolfenbarger
D. Gilbertson
Robert Cox

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
National Centers for Environmental Prediction
5200 Auth Road
Camp Springs, Maryland 20746
Telephone: 301-763-8000

September 11, 2009

Prof. Christopher Bretherton
Director, UW Program on Climate Change
University of Washington, Box 351640
Seattle, WA 98195-1640 USA

Subject: Letter of Support

Dear Prof. Bretherton,

It is our understanding that the University of Washington is submitting a proposal to the National Science Foundation, entitled "Collaborative Research: CPT for improving the representation of the stratocumulus to cumulus transition in climate models."

Given the importance of this research to the improvement of the operational global prediction systems at the National Centers for Environmental Prediction (NCEP), the NCEP Environmental Modeling Center will support this proposal by committing 50% of a post-doc's time and 20% of a senior scientist's time at no additional cost to the University of Washington.

Sincerely,

Stephen J Lord

Digitally signed by Stephen J Lord
DN: cn=Stephen J Lord, o=EMC, ou=NCEP, email=stephen.lord@noaa.gov, c=US
Date: 2009.09.11 10:25:10 -04'00'

Stephen J. Lord
Director, Environmental Modeling Center
NCEP

PCMDI
Program for Climate Model Diagnosis and Intercomparison

Dr. Stephen A. Klein
PCMDI, Lawrence Livermore
National Laboratory
P.O. Box 808, Mail Stop L-103
Livermore, CA 94551

TEL: (925) 423-9777
FAX: (925) 422-7675
e-mail: klein21@llnl.gov

September 4, 2009

Professor Christopher Bretherton
University of Washington
Department of Atmospheric Sciences
Box 351640
Seattle, WA 98195-1640

Dear Professor Bretherton,

With this letter, I indicate that the activities that my group will perform as an unfunded Co-Investigator on your proposal, "Collaborative Research: Climate Process Team for Improving the Representation of the Stratocumulus-to-Cumulus Transition in Climate Models" with Co-Principal Investigator Dr. João Teixeira (Jet Propulsion Laboratory), and Co-Investigators Prof. C. Roberto Mechoso (Univ. California at Los Angeles), Dr. Sungsu Park (National Center for Atmospheric Research), and Dr. Hua-Lu Pan (National Center for Environmental Prediction) that is being submitted to the National Science Foundation's Climate Process and Modeling Teams (CPT) program solicitation NSF 09-568. The activities outlined below have been funded through a newly awarded project entitled "Improving the Characterization of Clouds, Aerosols, and the Cryosphere in Climate Models". This is a 5-year Department of Energy multi-laboratory project and the activities described below are one part of the work to be performed at Lawrence Livermore National Laboratory (LLNL) by myself (~0.4 FTE) and Dr. Peter Caldwell (1 FTE). Curricula Vitae for myself and Dr. Caldwell are attached.

Our related work is to incorporate Probability Density Function (PDF) approaches for stratiform clouds into the Community Atmosphere Model (CAM). In particular, we will incorporate a PDF approach for the condensation and evaporation of stratiform cloud liquid. Utilizing the PDF we will then consistently incorporate the radiative effects of the PDF stratiform clouds and separately predicted convective clouds into a cloud generator that provides randomly sampled cloud profiles for the Monte Carlo Independent Column Approximation in the new CAM radiation code. We will examine and improve the existing cloud-overlap parameterizations and test the use the cloud generator to more accurately predict cloud microphysical process rates. We are planning to develop PDF approaches for cloud ice. Of particular relevance will be an effort to test improved predictions of PDF shapes that are properly coupled to the parameterizations of boundary turbulence and convection.

Thus our work is highly relevant to the current proposal and both efforts will benefit from collaboration. In particular, cloud parameterizations will only succeed if the interactions with the other model parameterizations are properly examined and resolved. Both you and Co-Investigator Park have created new parameterizations of boundary layer turbulence and convection that will be incorporated into the next version of the CAM. For our work to succeed it is essential that we collaborate closely with you.

In addition to this, my group at LLNL has additional diagnostic capability that will provide useful to the project. In particular, through other DOE funding, LLNL operates a project that performs weather forecasts with climate models. This project, the Climate Change and Prediction Program – Atmospheric Radiation Measurement program Parameterization Testbed, (CAPT), have developed techniques to compare to advanced cloud and radiation observations collected by the ARM program. We will be testing new CAM parameterizations (including any developed under this proposal) against relevant field program data. This can include VOCALS observations as well as marine stratocumulus observations from a new ARM site in the Azores (http://www.arm.gov/sites/amf/azores/). We will also be testing new parameterizations against ARM observations of Arctic liquid and mixed-phase stratocumulus clouds and potentially against trade cumulus observations that will be collected by a Max Planck Institute advanced remote sensing station to be placed in the Caribbean for 2010 (PI Bjorn Stevens, http://www.mpimet.mpg.de/en/presse/pressemitteilungen/aerosole-wolken-niederschlag-und-klima-messkampgne-auf-barbados-geplant.html - c7692).

I eagerly look forward to collaboration with you and your Co-Investigators on this new project.

Sincerely yours,

Stephen A. Klein
PCMDI / LLNL

Joao Teixeira - Biographical Sketch

Education and Training

Jan. 2000 - Doctor in Physics (Meteorology), University of Lisbon, Portugal.
Oct. 1992 - Licentiate in Geophysical Sciences, University of Lisbon, Portugal.

Research and Professional Experience

2008-present	Visiting Researcher, JIFRESSE, University of California, Los Angeles, USA
2008-present	Research Scientist, Jet Propulsion Laboratory, Pasadena, CA, USA
2005–2007	Senior Scientist (A3), NATO Undersea Research Centre, La Spezia, Italy.
2000–2005	UCAR Scientist (VSP), Naval Research Laboratory, Monterey, CA, USA.
1993–1999	Scientist (A2), European Centre for Medium-range Weather Forecasts, UK.

Synergistic Activities

- Associate Editor: *Monthly Weather Review* – since 2005.
- Member: JIFRESSE Executive Committee – since 2009.
- Member: Process Studies and Model Improvement Panel, US CLIVAR, - since 2009.
- Chair: GCSS Pacific Cross-section Intercomparison (GPCI) working group – since 2005
- Member: GEWEX Cloud System Study (GCSS) scientific steering committee - since 2004

Ten Selected Publications

- Teixeira, J., B. Stevens, C. S. Bretherton, R. Cederwall, J.D. Doyle, J.C. Golaz, A. A.M. Holtslag, S. A. Klein, J. K. Lundquist, D. A. Randall, A. P. Siebesma and P.M.M. Soares, 2008: The parameterization of the atmospheric boundary layer: a view from just above the inversion. *Bulletin of the American Meteorological Society*, **89**, 453-458.
- Teixeira, J., P. May, M. Flatau, and T. F. Hogan, 2008: On the sensitivity of the SST from a global ocean-atmosphere coupled system to the parameterization of boundary layer clouds. *Journal of Marine Systems*, **69**, 29–36.
- Siebesma, A. Pier, Pedro M. M. Soares, and João Teixeira, 2007: A Combined Eddy-Diffusivity Mass-Flux Approach for the Convective Boundary Layer. *Journal of the Atmospheric Sciences*, **64**, 1230-1248.
- Teixeira, J., J. P. Ferreira, P.M.A. Miranda, T. Haack, J. Doyle, A. P. Siebesma and R. Salgado, 2004: A new mixing length formulation for the parameterization of dry convection: implementation and evaluation in a mesoscale model. *Mon. Wea. Rev.*, **132**, 2698-2707.
- Soares, P.M.M, P.M.A. Miranda, A.P. Siebesma and J. Teixeira, 2004: An Eddy-diffusivity/Mass-flux scheme for dry and shallow convection. *Quarterly Journal of the Royal Meteorological Society*, **130**, 3365-3384.
- Teixeira, J., and S. Cheinet, 2004: A simple mixing length formulation for the eddy-diffusivity parameterization of dry convection. *Boundary Layer Meteorology,* **110**, 435-453.
- Teixeira, J. and T.F. Hogan, 2002: Boundary layer clouds in a global atmospheric model: simple cloud cover parameterizations. *Journal of Climate,* **15**, 1261-1276.
- Teixeira, Joao, 2001: Cloud fraction and relative humidity in a prognostic cloud fraction scheme. *Monthly Weather Review,* **129**, 1750-1753.
- Duynkerke, P.G. and J. Teixeira, 2001: Comparison of the ECMWF Reanalysis with FIRE I observations: diurnal variation of marine stratocumulus**.** *Journal of Climate*, **14**, 1466-1478.
- Teixeira, Joao, 1999: Simulation of Fog with the ECMWF Prognostic Cloud Scheme. *Quarterly Journal of the Royal Meteorological Society*, **125-B**, 529-553.

Stephen A. Klein Vitae

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Professional Preparation

Oberlin College	Physics	B.A., 1989
University of Washington	Atmospheric Sciences	Ph.D., 1994
Princeton University/GFDL	Atmospheric Sciences	1995-1997
European Centre for Medium Range Weather Forecasts		1997

Appointments

Research Scientist	PCMDI/LLNL	2004-present
Research Meteorologist	NOAA/GFDL	1998-2004

Selected Publications during Last Three Years

Hannay, C., D. L. Williamson, J. J. Hack, J. T. Kiehl, J. Olson, S. A. Klein, C. S. Bretherton, and M. Köhler, 2009: Evaluation of forecasted southeast Pacific stratocumulus in the NCAR, GFDL and ECMWF models. *J. Clim.*, **22**, 2871–2889.

Klein, Stephen A., and 40 co-authors, 2009: Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-Phase Arctic Cloud Experiment. Part I: Single layer cloud. *Quart. J. Roy. Met. Soc.*, **135**, 979-1002, doi: 10.1002/qj.416.

Boyle, J., S. A. Klein, G. Zhang, S. Xie, and X. Wei, 2008: Climate model forecast experiments for TOGA-COARE. Mon. Wea. Rev., **136**, 808–832.

Xie, S., J. Boyle, S. A. Klein, X. Liu, and S. Ghan, 2008: Simulations of Arctic mixed-phase clouds in forecasts with CAM3 and AM2 for M-PACE. *J. Geophys. Res.*, **113**, D04211, doi: 10.1029/2007JD009225.

Ming, Y., V. Ramaswamy, L. J. Donner, V. T. J. Phillips, S. A. Klein, P. A. Ginoux, and L. H. Horowitz, 2007: Modeling the interactions between aerosols and liquid water clouds with a self-consistent cloud scheme in a general circulation model. *J. Atmos. Sci.*, **64**, 1189-1209.

Five Other Relevant Publications

Delworth, T. L., and 41 co-authors including S. A. Klein, 2006: GFDL's CM2 global coupled climate models. Part I: Formulation and simulation characteristics. *J. Clim.*, **19**, 643–674.

Pincus, R., R. Hemler, and S. A. Klein, 2006: Using stochastically-generated subcolumns to represent cloud structure in a large-scale model. *Mon. Wea. Rev.*, **134**, 3644-3656.

Klein S. A., R. Pincus, C. Hannay, and K.-M. Xu, 2005: How might a statistical cloud scheme be coupled with a mass-flux convection scheme? *J. Geophys. Res.*, **110**, D15S06, doi: 10.1029/2004JD005017.

The GFDL Global Atmospheric Modeling Development Team, 2004: The new GFDL global atmosphere and land model AM2/LM2: Evaluation with prescribed SST simulations. *J. Clim.*, **17**, 4641-4673. (S. A. Klein was the corresponding author of this article.)

Klein, S. A. and D. L. Hartmann, 1993: The seasonal cycle of low stratiform clouds. *J. Clim.*, **6**, 1587-1606.

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Education:

Ph.D Atmospheric Science; University of Washington, Seattle, WA (3/02-7/07)
- Dissertation Topic: "Subtropical Stratocumulus and its Effect on Climate"
- Advisor: Christopher S. Bretherton

M.Sc. Mathematics; Western Washington University, Bellingham, WA (9/99-6/01)
- Thesis Topic: "The Hartmann-Grobman Theorem and its Application to HIV Dynamics"
- Advisor: Sebastian J. Schreiber

B.Sc. Mathematics; Western Washington University, Bellingham, WA (9/95-6/99)

Appointments:

Staff Scientist PCMDI, Lawrence Livermore National Lab, Livermore, CA (8/09-present)

Postdoc PCMDI, Lawrence Livermore National Lab, Livermore, CA (9/07-7/09)

Publications:

Caldwell, P., H.-N. Chin, D. C. Bader, and G. Bala: Evaluation of a WRF-based Dynamical Downscaling Simulation over California. *Climatic Change*.**95** 499-521.

Caldwell, P., and C. S. Bretherton: Large Eddy Simulation of the Diurnal Cycle in Southeast Pacific Stratocumulus. *J. Atmos. Sci.* **66** 432-449.

Caldwell, P., and C. S. Bretherton: 2009: Response of a Subtropical Stratocumulus-Capped Mixed Layer to Climate and Aerosol Changes. *J. Clim.* **22** 20-38.

Caldwell, P., C. S. Bretherton, and R. Wood: 2005, Mixed-layer budget analysis of the diurnal cycle of entrainment in Southeast Pacific Stratocumulus. *J. Atmos. Sci.*, **62**, 3775-3791.

CURRICULUM VITAE: HUA-LU PAN

1. Vital Statistics

Born: 8 July 1947, Shanghai, China

Present Position: Climate Modeling Team Leader
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2. Education

B.S. (1970) - Physics, Tsing-Hua University, Taiwan

M.A. (1973) - Physics, Temple University

M.S. (1975) - Meteorology, Florida State University

Ph.D. (1979) - Meteorology, Florida State University

3. Professional Employment

1981-1987: Assistant Professor, Department of Atmospheric Sciences, Oregon State University, Corvallis, Oregon

1988-1998: Research Meteorologist, Environmental Modeling Center, National Centers for Environmental Prediction, Washington, D.C.

1998-2002: Chief, Global Modeling Branch, Environmental Modeling Center, NCEP, NWS, Washington, D.C.

2002-2004: Chief, Global Climate and Weather Modeling Branch, Environmental Modeling Center, NCEP, NWS, Washington, D.C.

2004-2009: Deputy Director, Climate Test Bed, NCEP, NWS, Washington, D.C.

2004-present: Climate Modeling Team Leader, Environmental Modeling Center, NCEP, NWS, Washington, D.C.

4. Professional Affiliation

Member, American Meteorological Society

5. Community Service

Member, U.S. CLIVAR Process Studies and Model Improvement Panel 2005-2007

Member, WMO WCRP Working Group on Seasonal to Interannual Prediction 2004-present

Member, External advisory committee of the Experimental Climate Prediction Center at Scripps Institute of Oceanography 2006-present

6. Honors and Awards

Fellow, American Meteorological Society, 2006

Gold Medal, Department of Commerce, 2005

7. Publications in Reviewed Literature

2006: Sensitivity of hurricane intensity forecast to convective momentum transport parameterization. *Mon. Wea. Rev*., **134**, 664-674 (Jongil Han and Hua-Lu Pan)

2006: The NCEP climate forecast system. *J. Climate*, **19**, 3483-3517 (S. Saha, S. Nadiga, C. Thiaw, J. Wang, W. Wang, Q. Zhang, H. M. Van den Dool, H.-L., Pan, S. Moorthi, D. Behringer, D. Stokes, M. Pena, S. Lord, G. White, W. Ebisuzaki, P. Peng, and P. Xie)

2006: Evaluation of the NCEP Global Forecast System at the ARM SGP site. Mom. Wea. Rev., **134**, 3668-3690 (F. Wang, H.-L. Pan, S. Krueger, S. Moorthi, and S. Lord)

2008: Role of convection triggers in the simulation of the diurnal cycle of precipitation over the United States Great Plains in a general circulation model. J. Geophys. Res., **113**, D02111 (Lee, M., S. D. Schubert, M. J. Suarez, J. E Schemm, H. Pan, J. Han, and S. Yoo)

Curriculum Vitae for Jongil Han

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Education:

- PhD, Atmospheric Sciences, North Carolina State University, Raleigh, NC, June 1998.
- MS, Atmospheric Sciences, Seoul National University, Seoul, Korea, Feb. 1992.
- BS, Atmospheric Sciences, Seoul National University, Seoul, Korea, Feb. 1990.

Work History:

- **Research Scientist,** Wyle/EMC/NCEP/NOAA, Camp Springs, MD, 01/2008 - present.
- **Research Scientist,** RSIS/EMC/NCEP/NOAA, Camp Springs, MD, 02/2002 – 12/2007.
- **Research Associate**, Climate Research Division, Scripps Institution of Oceanography, University of California, San Diego, CA, 04/2000 – 01/2002.
- **Research Associate**, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, 06/1998 – 03/2000.
- **Research Assistant**, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, 08/1994 – 05/1998.
- **Teaching Assistant**, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, 08/1997 – 05/1998.
- **Researcher**, Meteorological Research Institute, Seoul, Korea, 07/1992 – 07/1994.
- **Research Assistant**, Department of Atmospheric Sciences, Seoul National University, Seoul, Korea, 03/1990 – 06/1992.
- **Teaching Assistant**, Department of Atmospheric Sciences, Seoul National University, Seoul, Korea, 03/1990 – 02/1992.

Publications and Presentations:

Han, J. and H.-L. Pan, 2009: Sensitivity of a Moist PBL Turbulence Parameterization on the NCEP GFS Forecast. 23rd Conference on Weather Analysis and Forecasting/19th Conference on Numerical Weather Prediction, 1-5 June 2009, Omaha, NE

Han, J. and H.-L. Pan, 2007: Revision of the Boundary Layer Mixing Scheme and Mass-Flux Parameterization of Shallow Cumulus Convection in the NCEP Global Forecast System. 7th EMS Annual Meeting / 8th European Conference on Applications of Meteorology, 01–05 October 2007, San Lorenzo de El Escorial, Spain.

Han, J. and H.-L. Pan, 2006: Sensitivity of Hurricane Intensity Forecast to Convective Momentum Transport Parameterization. Monthly Weather Review, Vol. 134, No. 2, 664–674, 2006.

Han, Jongil, and Daewon W. Byun, 2005: An improvement of the two-stream model for vertical mixing of passive tracer in the convective boundary layer. Atmos. Environ., **39**, 1775-1788.

Han, J., and H.-M. H. Juang, 2004: Recent update of NCEP operational regional spectral model. Preprints of the Symposium on the 50th Anniversary of Operational Numerical Weather Prediction, College Park, MD.

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Leung, L. Ruby, Yun Qian, Xindi Bian, Warren M. Washington, Jongil Han, and John O. Roads, 2004: Mid-Century Ensemble Regional Climate Change Scenarios for the Western United States. Climate Change, 62(1-3), 75-113.

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Hann-Ming Henry Juang, Jun Wang, Jongil Han, and Stephen Lord, 2003: The NCEP RSM for IRI/ARCS Regional Application Project, NOAA's 28th Climate Diagnostics and Prediction Workshop, 20-23 October 2003, Reno, Nevada.

Han, J. and Roads, J., 2001: Influence of Increased CO2 on Regional Climate Simulations. AGU 2001 Fall Meeting, San Francisco, CA, 10-14 December 2001.

Leung, L., Bian, X., Qian, Y., Roads, J., Han, J., and Mason, S., 2001: A Summary of ACPI Climate Downscaling Studies for the Western United States. AGU 2001 Fall Meeting, San Francisco, CA, 10-14 December 2001.

Han J., 2001: RSM Developments and Regional Climate Simulations, Scripps ECPC Advisory Panel Meeting, La Jolla, California, December 2001.

Han, J. and Roads, J., 2001: Influence of Increased CO2 on Regional Climate Simulations. The 3rd International RSM Workshop, Taipei, Taiwan, July 2001.

Han J., Juang, H.-M. H., Hong, S.-Y., Kanamitsu, M., and Roads, J., 2000: Experimental Simulations with a New NCEP RSM. The 2nd International RSM Workshop, Maui, Hawaii, July 2000.

Han, J., Shen, S., Arya, S. P., and Lin, Y. -L., 2000: An Estimation of Turbulent Kinetic Energy and Energy Dissipation Rate Based on Atmospheric Boundary Layer Similarity Theory. NASA/CR-2000-210298, June 2000, 25 pp.

Han, J. and Byun, D. W., 2000: A Multi-stream Model for Vertical Mixing of a Passive Tracer in the Convective Boundary Layer. 11th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Long Beach, California, January 2000, 6 pp.

Lin, Y. -L., Han, J., Zhang, J., Ding, F., Arya, S. P., and Proctor, F. H., 2000: Large Eddy Simulation of Wake Vortices in the Convective Boundary Layer. 38th AIAA Aerospace Sciences Meeting & Exhibit, Reno, NV, January 2000, 8 pp.

Han, J., Lin, Y. -L., Schowalter, D. G., Arya, S. P., and Proctor, F. H., 2000: Large Eddy Simulation of Aircraft Wake Vortices Within Homogeneous Turbulence: Crow Instability. AIAA J., 38 (2), 292-300.

Han, J., Lin, Y. -L., Arya, S. P., and Proctor, F.H., 2000: Numerical Study of Wake Vortex Decay and Descent in a Homogeneous Atmospheric Turbulence. AIAA J., 38 (4), 643-656.

Proctor, F. H., Hamilton, D. W., and Han, J., 2000: Wake Vortex Decay in Ground Effect: Vortex Linking with the Ground. 38th AIAA Aerospace Sciences Meeting & Exhibit, Reno, NV, January 2000, 14 pp.

Lin, Y. -L., Han, J., Hamilton, D. W. and Huang, C. -Y., 1999: Orographic Influence on a Drifting Cyclone. J. Atmos. Sci., 56 (4), 534-562.

Han, J., Lin, Y. -L., Arya, S. P., and Proctor, F. H., 1999: Large Eddy Simulation of Aircraft Wake Vortices in a Homogeneous Atmospheric Turbulence: Vortex Decay and Descent. 37th Aerospace Sciences Meeting & Exhibit, Reno, NV, AIAA-99-0756, 21 pp.

Han, J., Lin, Y. -L., Arya, S. P., Shen, S., and Proctor, F. H., 1999: Decay of Aircraft Wake Vortices in a Homogeneous Atmospheric Turbulence: A Large Eddy Simulation Study. 13th Symposium on Boundary Layers and Turbulence, Dallas, TX, 2 pp.

Proctor, F. H. and Han, J., 1999: Numerical Study of Wake Vortex Interaction with the Ground Using the Terminal Area Simulation System. 37th Aerospace Sciences Meeting & Exhibit, Reno, NV, AIAA-99-0754, 12 pp.

Shen, S., Ding, F., Han, J., Lin, Y. -L., Arya, S. P., and Proctor, F. H., 1999: Numerical Modeling Studies of Wake Vortices: Real Case Simulations. 37th Aerospace Sciences Meeting & Exhibit, Reno, NV, AIAA-99-0755, 16 pp.

Han, J., Lin, Y. -L., Schowalter, D. G., Arya, S. P., and Proctor, F. H., 1997: Large-Eddy Simulation of Aircraft Wake Vortices: Atmospheric Turbulence Effects. 12th Symposium on Boundary Layers and Turbulence, Vancouver, Canada, 237-238.

Han, J., Lin, Y. -L., Arya, S. P., and Kao, C., 1997: Large-Eddy Simulation of Aircraft Wake Vortices: Atmospheric Turbulence Effects. NASA First Wake Vortex Dynamic Spacing Workshop Proceedings, Hampton, VA, NASA CP-97-206235, 131-144.

Proctor, F. H., Hinton, D. A., Han, J., Schowalter, D. G., and Lin, Y. -L., 1997: Two-Dimensional Wake Vortex Simulations in the Atmosphere: Preliminary Sensitivity Studies. 35th Aerospace Sciences Meeting & Exhibit, Reno, NV, AIAA-97-0056, 13 pp.

Niyogi, D. S., Raman, S., Alapaty, K., and Han, J., 1997: A Dynamic Statistical Experiment for Atmospheric Interactions. Environmental Modeling and Assessment, 1-16.

Lim, E. -H., Han, J., and Eom, W. -G., 1996: Three-Dimensional Numerical Simulation to Evaluate the Effects of Incident Wind Shear and the Aspect Ratio on the Flow Around the Building. J. Korean Meteor. Soc., 32 (2), 303-313.

Han, J. and Park, S. -U., 1992: A Numerical Study on Nocturnal Drainage Flows using a Simplified Second-Moment Turbulent Closure over the Mountainous Terrain. J. Korean Meteor. Soc., 28 (3), 225-241.

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September 14, 2009

Dr. Chris Bretherton
University of Washington
Atmospheric Science and Applied Mathematics
P.O. Box 351640
Seattle, WA 98195

Dear Dr. Bretherton:

The purpose of this letter is to affirm the strong commitment to CLIVAR Climate Process Teams (CPT) by all levels of management at the National Center for Atmospheric Research (NCAR). The call for proposals to form CPTs gives a special role to national climate modeling centers such as NCAR and we intend to fulfill that role responsibly. We are grateful for this opportunity to have the national community contribute their ideas, expertise and energy to our climate model development. The success of this particular CPT is important to NCAR, because it has the potential to significantly advance climate modeling.

As NCAR director, I will designate Dr. W. Large, director of the Climate and Global Dynamics (CGD) Division, to interact with the lead NCAR PI to collaborate in CPT management as necessary, and to assure that the NCAR institutional resources, commensurate with team plans, will be available and devoted to team activities. Most importantly, NCAR and CGD will co-sponsor the NCAR science team, including the lead NCAR PI and other NCAR contributors to the CPT that are not supported directly through the proposal. Also crucial will be the computer resources necessary to meet project milestones related to the implementation and testing of new developments and parameterizations in NCAR's climate model, as well as CPT designed model experiments. With a successful proposal would come access to computer resources from CGD and from the Climate Systems Laboratory (CSL), through allocations both to general CCSM (Community Climate System Model) development and to specific CPT proposals.

Sincerely,

Eric J. Barron
NCAR Director

William Large
Climate and Global Dynamics Director

Enclosure

cc: G. Taberski
NCAR B&P
C. Wimert