COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
PD 98-1670 **02/15/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1735664

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

OCE - CHEMICAL OCEANOGRAPHY, OCE - BIOLOGICAL OCEANOGRAPHY, (continued)

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
02/09/2017	2	06040000 OCE	1670	077474757	02/10/2017 10:37am S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
016006001

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)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Bigelow Laboratory for Ocean Sciences

AWARDEE ORGANIZATION CODE (IF KNOWN)
4025045000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
Bigelow Laboratory for Ocean Sciences
60 Bigelow Drive
East Boothbay, ME. 045440380

NAME OF PRIMARY PLACE OF PERF
Bigelow Laboratory for Ocean Sciences

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Bigelow Laboratory for Ocean Sciences
60 Bigelow Drive
East Boothbay ,ME ,045440380 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ 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: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 1,198,953	48 months	08/01/17	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **SF**
☒ COLLABORATIVE STATUS **A collaborative proposal from multiple organizations (PAPPG II.D.3.b)**

PI/PD DEPARTMENT

PI/PD POSTAL ADDRESS
60 Bigelow Drive
P.O. Box 380
East Boothbay, ME 04544
United States

PI/PD FAX NUMBER
202-747-3257

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **William M Balch**	**PhD**	**1985**	**207-315-2567**	**bbalch@bigelow.org**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) 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 conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). 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).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Lobbying

This 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 Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) 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.

Certification Regarding Responsible Conduct of Research (RCR) (This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.B. , the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **James McManus**	**Electronic Signature**	**Feb 9 2017 6:43AM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
	jmcmanus@bigelow.org	

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) - continued from page 1
(Indicate the most specific unit known, i.e. program, division, etc.)

OCE - PHYSICAL OCEANOGRAPHY

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
PD 98-1670 **02/15/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1735783

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

OCE - CHEMICAL OCEANOGRAPHY, OCE - BIOLOGICAL OCEANOGRAPHY, (continued)

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
02/09/2017	2	06040000 OCE	1670	875635161	02/10/2017 10:37am S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
060706038

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)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Bermuda Institute of Ocean Sciences (BIOS), Inc.

AWARDEE ORGANIZATION CODE (IF KNOWN)
4001707000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
Bermuda Institute of Ocean Sciences (BIOS), Inc.
17 Biological Station
St. George's, GE01, Bermuda, .

NAME OF PRIMARY PLACE OF PERF
Bermuda Institute of Ocean Sciences (BIOS), Inc.

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Bermuda Institute of Ocean Sciences (BIOS), Inc.

BD.

IS AWARDEE ORGANIZATION (Check All That Apply)
☐ 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: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 626,010	48 months	08/01/17	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **BD**
☒ COLLABORATIVE STATUS **A collaborative proposal from multiple organizations (PAPPG II.D.3.b)**

PI/PD DEPARTMENT

PI/PD POSTAL ADDRESS
17 Biological Station Lane
Ferry Reach, GE01
Bermuda,
Bermuda

PI/PD FAX NUMBER
441-297-8143

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Nicholas R Bates**	**PhD**	**1995**	**441-297-1880**	**nick.bates@bios.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

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Drug Free Work Place Certification

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

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

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CERTIFICATION PAGE - CONTINUED

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(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

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Certification Regarding Criminal Convictions

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Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Victoria C Millett**	**Electronic Signature**	**Feb 9 2017 2:47PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
441-297-1880	**victoria.millett@bios.edu**	**441-297-2222**

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) - continued from page 1
(Indicate the most specific unit known, i.e. program, division, etc.)

OCE - PHYSICAL OCEANOGRAPHY

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
PD 98-1670 **02/15/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1735846

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

OCE - CHEMICAL OCEANOGRAPHY, OCE - PHYSICAL OCEANOGRAPHY, (continued)

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
02/09/2017	2	06040000 OCE	1670	078339587	02/10/2017 10:37am S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
840412668

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)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
University Corporation For Atmospheric Res

AWARDEE ORGANIZATION CODE (IF KNOWN)
4062600000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
Boulder, CO 803012252
US

NAME OF PRIMARY PLACE OF PERF
National Center for Atmospheric Research

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
National Center for Atmospheric Research
3090 Center Green Drive
Boulder ,CO ,803012252 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ 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: Biogeochemical and physical conditioning of Sub-Antarctic Mode Water in the Southern Ocean**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 401,453	48 months	08/01/17	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED

☒ COLLABORATIVE STATUS
A collaborative proposal from multiple organizations (PAPPG II.D.3.b)

PI/PD DEPARTMENT
CGD/NCAR

PI/PD FAX NUMBER

PI/PD POSTAL ADDRESS
3090 Center Green Drive

BOULDER, CO 80301
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Matthew Long**	**PhD**	**2010**	**303-497-1000**	**mclong@ucar.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

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Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Lobbying

This 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.

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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:
(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.

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(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
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CERTIFICATION PAGE - CONTINUED

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(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
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Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Jeffrey Wild**	**Electronic Signature**	**Feb 9 2017 4:50PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
	jeffwild@ucar.edu	

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) - continued from page 1
(Indicate the most specific unit known, i.e. program, division, etc.)

OCE - BIOLOGICAL OCEANOGRAPHY

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
PD 98-1670 **02/15/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY
NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
OCE - CHEMICAL OCEANOGRAPHY, OCE - BIOLOGICAL OCEANOGRAPHY, (continued)

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				001766682	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
042105850

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)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Woods Hole Oceanographic Institution

AWARDEE ORGANIZATION CODE (IF KNOWN)
0022301000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
FENNO HOUSE MS#39
WOODS HOLE, MA 025431041
US

NAME OF PRIMARY PLACE OF PERF
Woods Hole Oceanographic Institution

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Woods Hole Oceanographic Institution

MA ,025431041 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ 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: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **860,908**	**48** months	**08/01/17**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **SF**
☒ COLLABORATIVE STATUS **A collaborative proposal from multiple organizations (PAPPG II.D.3.b)**

PI/PD DEPARTMENT
Applied Ocean Physics & Engineering

PI/PD POSTAL ADDRESS
MS 11

Woods Hole, MA 02543
United States

PI/PD FAX NUMBER
508-457-2194

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Dennis J McGillicuddy**	**PhD**	**1993**	**508-289-2683**	**dmcgillicuddy@whoi.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) 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 conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). 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).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures 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 PAGE - CONTINUED

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(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

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Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) - continued from page 1
(Indicate the most specific unit known, i.e. program, division, etc.)

OCE - PHYSICAL OCEANOGRAPHY

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
PD 98-1670 **02/15/17**

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1735436

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

OCE - CHEMICAL OCEANOGRAPHY

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
02/08/2017	**2**	**06040000 OCE**	**1670**	**790877419**	**02/10/2017 10:38am S**

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
591961248

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)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Florida State University

AWARDEE ORGANIZATION CODE (IF KNOWN)
0014894000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
TALLAHASSEE, FL 323064166
US

NAME OF PRIMARY PLACE OF PERF
Florida State University/NHMFL

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Florida State University/NHMFL
1800 East Paul Dirac Drive
Tallahassee ,FL ,323103706 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ 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: Biogeochemical and Physical Conditioning of Subantarctic Mode Water in the Southern Ocean**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **259,749**	**48** months	**08/01/17**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED **XJ**
☒ COLLABORATIVE STATUS **A collaborative proposal from multiple organizations (PAPPG II.D.3.b)**

PI/PD DEPARTMENT
Nat'l High Magnetic Field Lab

PI/PD POSTAL ADDRESS
1800 East Paul Dirac Drive

Tallahassee, FL 323103706
United States

PI/PD FAX NUMBER
850-644-0827

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Peter Morton**	**PhD**	**2010**	**850-645-4639**	**pmorton@fsu.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

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CERTIFICATION PAGE - CONTINUED

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Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

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OVERVIEW: Subantarctic Mode Water (SAMW) is a major Southern Ocean (SO) water mass, subducted equatorward in all three SO sectors, with the strongest formation in the Indian Ocean. Two classes of biomineralizing phytoplankton, diatoms and coccolithophores, grow in SAMW formation regions. Diatoms dominate at the Polar Front, while the coccolithophores are concentrated to the north at the Subantarctic Front and Subtropical Front in a zonal band of high-reflectance water known as the Great Calcite Belt (GCB). Both algal groups produce dense mineral shells that ballast organic debris, driving the biological pump; they condition the water before and during subduction. SAMW chemistry and biology dominate marine ecosystems and the biological pump in subtropical and tropical waters; it is estimated that SAMW controls 75% of the biological production of waters north of 30^{o}S, as well as the functional groups of algae that grow there on contemporary to glacial/interglacial time scales. This proposal will quantify how coccolithophore and diatom production in SAMW conditions water mass chemistry. Furthermore, this proposal will evaluate whether the production balance between these two groups impacts their growth at low latitudes. We propose two January research cruises to the SE Indian Ocean. One unique feature of this region is the presence of mesoscale eddies that form at the various frontal boundaries; these are rich in either coccolithophore or diatom assemblages and associated microbial communities. Such eddies provide an ideal, semi-enclosed, water parcel to observe the rates of conditioning of SAMW over time scales of months, enabling estimates of the physiological and ecological controls on nutrient, trace metal, carbonate system composition of SAMW. **There are three goals to this work.** The ***first*** is to determine the rates that SAMW coccolithophores and diatoms condition the CO_2-carbonate chemistry (alkalinity, dissolved inorganic carbon, pH, pCO_2, $CaCO_3$ saturation state (Ω) plus nutrient and trace metal concentrations). The taxonomic and physiological diversity will also be assessed across the study area using microscopy plus traditional and next-generation sequence profiling for DNA and RNA. The ***second*** goal is to experimentally determine whether the conditioning of SAMW water is limited by iron, silicate and/or nitrate, and understand the controls on algal species assemblages and genetic diversity. The work will determine whether these SO waters act as a net CO_2 source or sink. The ***third*** goal is to combine these findings with the best estimates of Ekman- and eddy-driven subduction of SAMW to scale-up the biogeochemical impact to the basin scale, using both observations and global numerical models. We will occupy PIC-rich and PIC-poor mesoscale eddies and measure changes in their ecology, production (both inorganic and organic), alkalinity, pH, pCO_2, Ω, plus nutrient concentrations of the SAMW at its point of formation. We will perform a meridional survey from 30^{o}S-60^{o}S to characterize the larger-scale variability of the carbonate chemistry, nutrients, productivity, genetics and biomass of various plankton groups as the SAMW is subducted northwards. **INTELLECTUAL MERIT:** This research integrates ocean physics, chemistry and biology. SAMW sustains primary production and controls the ecology and chemistry of the lower latitudes. Global data show that SAMW waters, initially conducive to coccolithophore growth in the GCB, show the lowest surface coccolithophore concentrations by the time SAMW is upwelled at the equator some 40 years later (lower than in subtropical gyres). Iron and nutrient conditioning appear to play integral roles in determining which algal classes dominate (with obvious ramifications to the biological pump) and whether the waters act as net CO_2 source or sink. Proposed modeling will ultimately allow proper scaling and integration of the chemistry, biology and physics to define the basin-scale impact of this phenomenon. **BROADER IMPACTS:** This work will extend the research findings of the project into educational opportunities beyond the oceanographic community. Along with student involvement in the research cruises and summer REU positions, a high-school educator will go on both cruises to broaden public and classroom outreach. This person will make initial contact with multiple schools around the country to introduce the scientific problem, then the teacher will organize daily interactions with the students, answering questions, blogging, using social media and video conferencing, all to broaden reach in a quantifiable fashion. Public lay-presentations will be made at the Bigelow's Café Scientifique program held in Boothbay Harbor, ME (which attracts >1000 participants annually). A postdoctoral scholar will be trained in the development and application of an Earth system model at the National Center for Atmospheric Research.

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Response to previous reviews: This is a resubmission of a proposal submitted in 2015 (OCE1559261). Two primary criticisms from the reviews were: (1) a single cruise was insufficient to provide representative sampling; and, (2) the third goal, upscaling from ship observations to the larger-scale phenomenon, needed more effort—i.e., to take what was learned about the conditioning of Subantarctic Mode Water (SAMW) from eddy studies and deck experiments, and combine it with best-estimates of Ekman- and eddy-driven subduction of SAMW to describe the large-scale biogeochemical conditioning by the coccolithophore feature known as the Great Calcite Belt (GCB). We have revised this proposal by: (**1**) addition of a second cruise in year two, extending the project to four years (the second cruise will examine four more eddies instead of two); (**2**) addition of a geophysical modeler (Dr. Matthew Long, NCAR) who will supervise a postdoctoral scientist focused on scaling-up our observations and quantifying the global-scale biogeochemical impact of the SAMW conditioning; **(3)** addition of Dr. Pete Morton (FSU/NHMFL) to provide the critical iron measurements (the death of Bigelow Executive Director, Dr. Graham Shimmield in December, 2016 and subsequent appointment of Dr. Ben Twining (Co-I on the previous proposal) as the Interim Executive Director of Bigelow Laboratory, meant that Dr. Twining needed to withdraw from this effort. Dr. Morton will be aided by Twining's Research Associate, Sara Rauschenberg); (**4**) exploration of the ecological consequences of conditioning by diatoms and coccolithophores in deck experiments with the addition of hypotheses to address those ecological effects; **(5)** using a Video Plankton Recorder (VPR) to survey the eddies instead of the Moving Vessel Profiler and gliders) to allow improved biological characterization of the microplankton communities in the eddies while maintaining the critical hydrographic surveys; and, **(6)** addition of Drs. C. Brownlee and D. Schroeder (Marine Biological Assoc., U.K.) as no-cost foreign collaborators to document population metagenomics and single-cell indicators of iron limitation in the eddies.

Overview: SAMW is formed at the Sub-Antarctic Front (SAF;(Herraiz-Borreguero and Rintoul, 2011) just north of the diatom-rich Polar Front (PF) and within the GCB, the largest coccolithophore-rich region on Earth. Conditioning of SAMW (i.e., changing of the chemical characteristics through utilization of critical growth-limiting nutrients has been recognized to impact primary production of low-latitude waters, from contemporary to glacial time scales (Griffiths et al., 2013; Sarmiento et al., 2004). SAMW is estimated to control 75% of the biological production of waters north of 30^{o}S, as well as the functional groups of algae that grow there, depending on the amount of silicate that "leaks" from the Southern Ocean (SO) into SAMW (Sarmiento et al., 2004). Subducted SAMW arrives to the equatorial zone ~40 years later. Conditioning of the SAMW by diatoms was suggested before the GCB had been described as a major circumpolar feature sitting just north of the diatom-rich PF waters. New results (Balch et al., 2016) suggest that along with conditioning of SAMW by diatoms, GCB coccolithophores draw down trace metals and macronutrients as well as change seawater CO_2-carbonate chemistry. We document evidence of unusually low coccolithophore concentrations in equatorial upwelling regions, lower than the oligotrophic subtropical gyres (Balch et al., 2017). In short, two classes of algae most responsible for ballasting organic debris and driving the biological pump (diatoms and coccolithophores) are conditioning SAMW at its site of formation which appears to affect low latitude productivity, with implications for marine ecosystems and the biological pump in subtropical and tropical waters to the north. We look to address how coccolithophore and diatom production affect the water mass properties (alkalinity, nutrients, iron) of SAMW in the present-day mean climate and whether the balance between production by these two groups in SAMW formation regions impacts their growth at low latitudes.

The key to addressing this problem lies in understanding the controls on diatom and coccolithophore productivity prior and during subduction in relation to the rates of SAMW formation (see our conceptual model in Fig. 1). Conveniently, coccolithophore- and diatom-rich eddies are visible from space after they are shed from the SAF and PF, respectively; the eddies provide semi-enclosed water masses to follow the rates of algal conditioning over monthly time scales as microbial ecosystems are advected northwards. We take advantage of these characteristics in our experimental design and scale-up the observations to the basin scale by applying our shipboard results to geophysical circulation models that resolve both Ekman pumping and eddy transport of SAMW.

1. Introduction

1.1 The Southern Ocean: Physical Fronts, Eddies, Subantarctic Mode Water and Biogeochemistry:

The Southern Ocean is dominated by the Antarctic Circumpolar Current (ACC) and two associated oceanographic fronts: the subtropical convergence (STF) that separates subtropical waters from subpolar waters, and the Antarctic Convergence (Polar Front; PF) that separates Antarctic waters from Subantarctic waters (Deacon, 1933; Gordon, 1967). The global biogeochemical impact of the SO results from strong deep water ventilation and overturning circulation. Four frontal boundaries: the STF, the SAF, the PF and the Antarctic Divergence demarcate the surface waters contributing to the upper and lower overturning cells, which are characterized by different ventilation time scales. Surface productivity in these regions is subject to varying constraints of nutrient limitation by unique microbiological communities (Longhurst, 1998) (Table 1) and exerts control on deep ocean nutrient and carbon inventories in proportion to surface nutrient utilization efficiency (Ito and Follows, 2005). The Indian Sector of the SO is less studied than the Atlantic or Pacific Sectors and is more complex due to the presence of an extra frontal boundary, the Agulhas Return Current (ARC), north of the SAF (Lutjeharms and Valentine, 1984). The SO has proved to be uniquely sensitive to climate change. Antarctic winds have increased over the last 30 years (Thompson and Solomon, 2002) which means that the wind-induced Ekman transport is increased, accompanied by complex changes in eddy-mediated transport (Hogg et al., 2015; Meredith and Hogg, 2006). Exchange of CO_2 between the deep-ocean and atmosphere, as well as nutrient upwelling, is controlled by these winds, up to glacial-interglacial time-scales (Anderson et al., 2009). Over the next century, winds are predicted to increase further, accompanied by southward movement of the core of surface westerlies (Chen and Held, 2007; Marshall, 2003).

Table 1. Frontal boundaries and water masses of SO with indication of iron or silicate deficiency, as well as phytoplankton populations and underlying sediment types (summarized from Longhurst (1998). Note, some define two STFs in the SO (Belkin and Gordon, 1996; Tsuchiya et al., 1994). Antarctic divergence or East Wind Drift not included here due to space constraints and application to this proposal.

Front	Water Mass	Lat.	Fe Def?	Si Def.?	Algal Pops	Sediments
	Sub-Trop Gyre		N	Y	Coccos, Nanos, Picos	Carbonate
STF/Agulhas		40°S				
	STFZ		Y	Y	Coccos, Nanos, Picos	Carbonate
SAF		45°S				
	SAFZ		Y/N	Y/N	Coccos, diatoms	Carbonate
PF		50°S				
	PFZ		Y/N	N	Diatoms	Opal

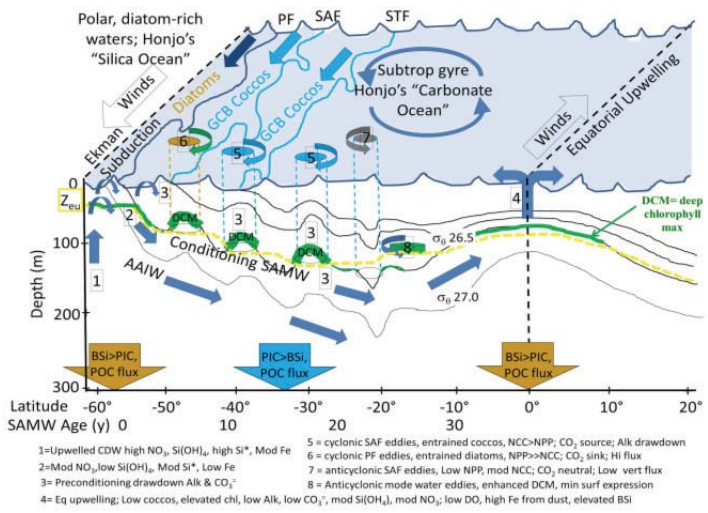


Fig. 1- Conceptual model of changes in biology and chemistry associated with preconditioning of SAMW. Definitions: Si* = Silicate-Nitrate; NPP = Net Primary Production; NCC = Net coccolithophore calcification; BSi=biogenic silica; PIC=Particulate Inorganic Carbon; DCM= deep chlorophyll maximum; CDW=Circumpolar Deep water; AAIW=Antarctic Intermediate Water. This model incorporates the concept of the carbonate and silica ocean (Honjo et al, 2008) and uses the density range for SAMW (Cerovečki et al., 2013).

SAMW is formed at the northern edge of the SAF and is characterized by a density (sigma-theta) between 26.5-27.1 (Cerovečki et al., 2013)(Fig. 1). It is then subducted equatorward in all three ocean sectors with a total transport rate of ~17-18 Sv. Strongest SAMW formation is in the Indian Ocean (9-11 Sv), where it is partially destroyed by diapycnal mixing (-3 to -7 Sv; (Cerovečki et al., 2013). Less formation of SAMW is seen in the Atlantic [e.g., Naveira Garabato et al., (2009) and SE Pacific (e.g., Carter et al., 2013)]. The unique oceanographic setting of the ACC means that mesoscale eddies play a leading-order role in controlling the dynamics of the current and its associated overturning circulation (Thompson, 2008). Moreover, cyclonic eddies there have been shown to be hot spots of productivity in the SO (Kahru et al., 2007).

1.1.1 Oceanographic Significance of Coccolithophores:

Coccolithophores are $CaCO_3$-producing phytoplankton that significantly influence upper ocean optical properties, seawater CO_2-carbonate

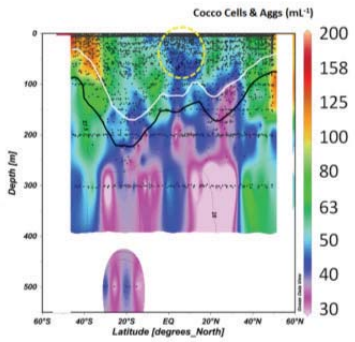


Fig. 2. North-South combined section of coccolithophore concentration along the Atlantic Meridional Transect cruises 15-22 from the UK to the Falkland Islands. Counts are based on birefringent microscopy. Concentrations are keyed to the logarithmic color scale on the right. Upper boundary of SAMW (σ_θ =26.5) is highlighted in white. Lower boundary of SAMW (σ_θ=27.1) is highlighted in black (Cerovečki et al., 2013). Note, lowest surface concentrations of coccolithophores are in Equatorial upwelling waters where SAMW gets closest to the surface (region designated by yellow dashed line).

chemistry and impact global biogeochemical cycles. Blooms of *E. huxleyi* are often associated with shelf fronts or the stratified edge of diatom-dominated filaments and often follow spring diatom blooms (Holligan et al., 1993). The diversity of coccolithophore assemblages decreases with increasing latitude until the remaining species, *E. huxleyi*, disappears in waters colder than 2°C (McIntyre and Be, 1967; Mohan et al., 2008). Coccolithophore populations are characterized by low chlorophyll concentrations with low optical absorption but intense scattering from their calcite coccoliths. For eight Atlantic Meridional Transect cruises, we observed a remarkably consistent paucity of coccolithophores in the equatorial Atlantic (Fig. 2), even lower concentrations than observed in the subtropical gyres (Balch et al., 2017). This is unexpected given that the upwelled SAMW that was once highly conducive to coccolithophore growth in the GCB some 40 years prior (Fig. 1).

1.1.2 The Great Calcite Belt in the Southern Ocean: Remote sensing of PIC allows quantitative estimates of coccolithophore particulate inorganic carbon (PIC) concentrations (Balch et al., 2005; Gordon et al., 2001) with an RMS error of ±11% in the SO (Balch et al., 2016). A consistent feature in the global ocean color PIC imagery is a belt of elevated PIC near the STF, SAF, and PF of the SO, covering 16% of the global ocean (Fig. 3). Bright areas further south are likely not due to PIC but highly reflective ice or glacial flour. The GCB appears south of ~38°S and extends southwards to ~60°S with an area of ~52 x 10^6 km^2. Climatological mean PIC concentrations are highest just east of the Drake Passage and diminish to the east (Fig.3), remaining discernable through the Indian and Pacific sectors of the SO. Satellite PIC estimates show that, on an annual basis, 28% of global suspended PIC is found in the GCB (Balch et al., 2005). The GCB is arguably the largest coccolithophores-dominated biome on Earth**.** We verified this in shipboard studies (Balch et al., 2016; Balch et al., 2011; Balch et al., 2014) as well as 14 other studies too numerous to list here, in all SO sectors (see Holligan et al.(2010) for a summary of these studies).

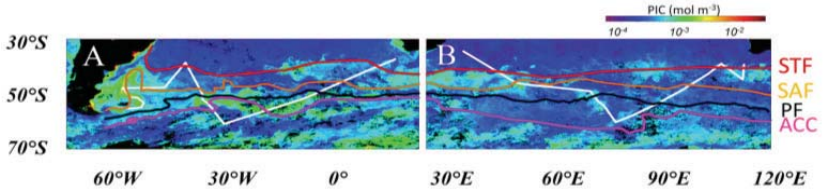


Fig. 3. (A) PIC (mol m^{-3}) from MODIS Aqua;Jan. 2011 (9-km resolution;period of GBC1 cruise across Atlantic sector of the SO), with cruise track overlaid (white line). (B) PIC concentration from MODIS Aqua;Feb. 2012 (9-km resolution; period of GBC2 cruise across Indian sector of the SO). The climatological position of the frontal boundaries are indicated (Orsi et al.,1995) with different colored lines: red = subtropical front, orange = subantarctic front, black = polar front, violet= ACC boundary.

1.1.3 Iron Limitation of coccolithophores and diatoms: Trace metals are required for numerous metabolic functions in phytoplankton, and their availability influences phytoplankton growth and community structure in large sectors of the ocean (de Baar et al., 1995; Martin et al., 1990). Diatoms typically respond most readily to Fe additions (de Baar et al., 2005), and coccolithophores appear less prone to metal limitation than diatoms and other microplankton (Sunda and Huntsman, 1995). Fe limitation of coccolithophores has been reported in regions of the N. Atlantic and Pacific Oceans (Crawford et al., 2003; Nielsdottir et al., 2009). In the southern hemisphere, continental dust downwind from the Patagonian Plateau, South Africa and Australia, in addition to possible island mixing effects, may be supporting coccolithophore production(Measures et al., 2005; Planquette et al., 2007). On glacial time scales, strong correlations have been noted in sediment records from the SAF zone between fluxes of dust and alkenones (i.e., coccolithophore biomarkers (Jaccard et al., 2013; Martínez-Garcia et al., 2014), solid evidence that coccolithophores are stimulated by nutrient inputs from dust. Diatoms can be co-limited by dissolved Fe and silicate (Brzezinski et al., 2011). Given adequate Fe and silicate, SO diatoms appear to outcompete coccolithophores via faster growth rates, but with limiting silicate, coccolithophores

have a growth advantage (Balch et al., 2016). Thus, total productivity and the relative balance between diatoms and coccolithophores is likely to have an imprint of both Si and Fe supply.

2. Background

2.1 Previous work on the GCB: Our previous work elucidated the distribution and controls on the GCB (Balch et al., 2016). Our observations of significant shifts in inorganic carbon cycling in surface waters of the GCB now motivate us to investigate the implications of these processes for lower-latitude regions via conditioning of SAMW. Previous work focused on the Atlantic and Indian sectors of the SO examined the general oceanographic aspects of the GCB and Patagonian Shelf (which has the highest coccolithophore concentrations in the GCB) (Balch et al., 2014) and not without surprises.

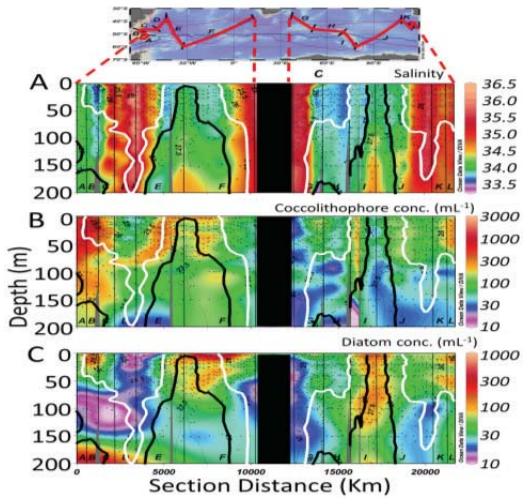


Fig. 4. Sections from GCB cruises 1 and 2 in Atlantic and Indian sectors of the SO. Chart at top shows cruise track (red) with sections identified with letters. Climatological positions of fronts shown (from north: STF, SAF, PF). (A) Salinity, B) Coccolithophore concentration (per mL) and C) Diatom concentration (per mL). Beginning and ending of each section leg is demarcated by a vertical line with section letter corresponding to the section in the upper chart. Isopleths of density anomaly (σ_θ) overlaid on each section. Upper density surface of SAMW (σ_θ=26.5) shown in white and lower density surface (σ_θ=27.1) shown in black (Cerovečki et al., 2013).

2.1.1 Abundance and diversity of coccolithophore populations in the GCB: Satellite-derived PIC and shipboard measurements of coccolithophore concentration show highest values within the fast-moving waters of the ACC (Balch et al., 2016), in moderate salinity Atlantic sector waters, decreasing eastward into the Indian sectors of the GCB. While the diversity of coccolithophore populations decreased southward (as expected), the number of coccolithophore species increased from one (*E. huxleyi*) off Patagonia to eight off Africa and thirteen SW of Australia(Smith, 2014; Smith et al., 2017a). Coccolithophore concentrations were also elevated near the SAF and STF. Diatoms were most abundant south of the PF and co-occurred with coccolithophores near the STF near Australia and near the PF in the Atlantic sector (Fig. 4).

2.1.2 Coccolithophore calcification and seawater CO_2-carbonate chemistry: Typically, the pCO_2 (partial pressure of CO_2) of the SO is thought to vary seasonally; drawdown in the austral summer results from intense net primary production, often associated with diatoms, leading to seasonal CO_2 uptake. However, we have found that seawater pCO_2 is highly variable, especially in SAF waters, ranging from <300 to >430 µatm overall. Large regions of the SAF zone (e.g., near the Falklands, Crozet, Kerguelen and Heard Islands—with elevated PIC during Jan. and Feb.) show up to 100 µatm higher seawater pCO_2 (and low salinity normalized total alkalinity (TA) and TA:DIC ratios) when compared to adjacent low PIC areas in regions of similar temperature in the SAF (Balch *et al*., 2016). These features are also seen in data from CROZEX (Pollard et al., 2007) and the Southern Ocean CO_2 Atlas (SOCAT) (Bakker et al., 2007). Near Crozet, there are strong inverse correlations (r^2 >0.5) between TA and optical backscattering contributed by coccolithophores (proportional to PIC) plus increasing pCO_2 (and TA uptake) associated with higher PIC and calcification (Fig. 5).

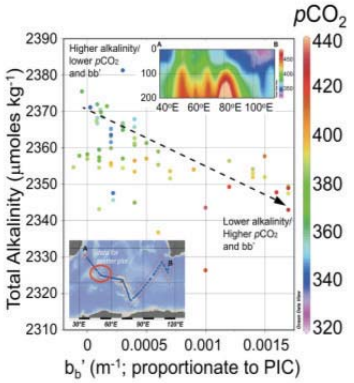


Fig. 5. Total alkalinity vs. acid-labile backscattering (b_b') from region near Crozet Islands (circled in inset at bottom). Upper inset: Depth section (over top 200 m) of pCO_2 (color scale goes from 375-475 ppm) where A and B mark the start and end of the transect (also shown in lower map).

Evidence from our previous work suggests that seasonal occurrence of coccolithophore calcification in the GCB has a significant impact on CO_2 dynamics in the SAF zone that are measureable using TA and DIC techniques (Bates et al., 2014). The GCB is visible from space for 7 months of the year (Oct.-April) with PIC concentrations typically from 0.2-0.7 mmol m^{-3} (µmol L^{-1}; Fig. 3). The turnover time of PIC is about the same or faster than for POC, with mean turnover times of ~3d

(Balch et al., 2000; Poulton et al., 2006). Thus, for the 7 months that the PIC is visible from space, it will have turned over ~70 times for a net TA drawdown of ~28 to 100 μmol kg^{-1} ([PIC] x 70 * 2 [the factor of 2 is due to divalent Ca cations] and DIC drawdown of ~14-50 μmol kg^{-1}. During the anual period when the GCB is visible to satellite, the estimated integral PIC is ~3 megatons in the Subantarctic region (Balch *et al*., 2005). If this is turned over 70X annually, then the CO_2 production associated with this calcification would be 0.2 Pg C y^{-1} which is ~10% of the CO_2 drawdown due to primary production of the entire Southern Ocean (including pelagic, marginal ice zone, shelf and MIZ/shelf waters; mean=1.95±0.06 Pg C y^{-1}(Arrigo et al., 2008).

The summer association of high coccolithophore biomass with elevated pCO_2 relative to diatom-dominated waters likely reflects a combination of competing processes, including upwelling, net community organic production (NCP) and net coccolithophore calcification (NCC). In those areas where upwelling and Ekman pumping bring up nutrients and CO_2, the influence of seasonal NCP is likely greater than upwelled/Ekman transported CO_2 with the net result that pCO_2 decreases (especially when diatoms dominate). However, in areas of high coccolithophore growth and biomass, generation of CO_2 by NCC offsets drawdown of CO_2 by NCP. **Thus, conceptually, there are three scenarios explaining the range of pCO_2 observed across the SAF: (1) where NCP > NCC, and pCO_2 is likely to decrease; (2) where NCP~NCC, seawater pCO_2 is likely to remain unchanged (in this scenario, NCC is slightly greater than NCP), and; (3) where NCP<NCC, and pCO_2 is likely to increase.** The three scenarios all likely occur in the SAF near Crozet. For scenario 3, coccolithophore calcification can potentially shift SAF waters from a summertime CO_2 sink to source (Fig. 5), a finding only hinted at in a few previous studies (Bates, 2007; Robertson et al., 1994; Smith et al., 2012). Such shifts in the CO_2 sink-source status of SAF surface waters have direct relevance to global air-sea CO_2 fluxes and positive/negative coccolithophore–CO_2 feedbacks.

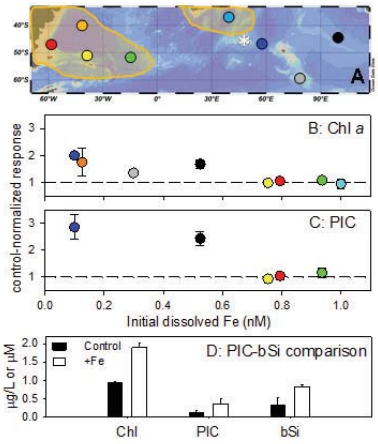


Fig. 6. (A) Location of incubation experiments; shading indicates areas of elevated dust flux. Asterisk=Crozet; (B) Response of Chl *a* or PIC (C) to Fe additions, plotted against initial dissolved Fe concentration. (D) Responses of total Chl, PIC, and bSi to Fe addition at end of Crozet incubation expt (dark blue circle).

2.1.3 Coccolithophores and iron limitation: Metal addition experiments conducted during GCB cruises showed a general phytoplankton (i.e., Chl. *a*) response to adding 2 nM Fe in incubations conducted in waters with <0.6 nM dissolved Fe (Fig. 6B). Furthermore, coccolithophores (i.e., PIC) also responded significantly (≥2.4 fold) to Fe in the incubations conducted within the GCB in the Indian sector, but coccolithophores did not respond at Atlantic GCB stations with higher preexisting Fe (Fig. 6C)(Twining et al., 2017). There was less data for PIC because PIC was below the limit of detection at 3 incubations conducted outside of GCB. Near Crozet, diatoms also responded significantly to added Fe (Fig. 6D). These results by Twining et al.(2017) match and extend the findings of previous Fe-addition incubations in sub-Antarctic waters around Crozet (Moore et al., 2007). Given these results, trace metal micronutrients appear to control the distribution and growth of coccolithophores in the GCB as well as influence the balance between calcification (e.g., NCC) and POC production (e.g., NCP) by other phytoplankton groups, impacting pCO_2. Determining the impact of Fe on the balance of growth by coccolithophores, diatoms and other non-calcifying plankton is a primary objective of this proposal.

2.1.4 PIC-rich eddies produced from the GCB. Remotely-sensed PIC data were critical for finding high PIC waters in the GCB. We observed PIC-rich (as well as low-PIC) eddies in our studies, north of the SAF that demonstrated that PIC was being advected northward through warmer water. In the Atlantic sector cruise, we sampled the middle of a nascent, PIC-rich eddy, and verified the presence of enhanced coccolith concentrations (not shown). We also tracked two PIC-rich eddies in the Indian sector over several weeks as they separated from the SAF and moved northwest (Fig. 7). These eddies measured about 150 km in diameter and were cyclonic but the more southerly eddy had a cold core while the NW eddy had minimal SST signature. The PIC concentration within both eddies was 4-7 x 10^{-4} mol m^{-3}, 4-7X above the PIC concentration outside the eddies (1 x 10^{-4} mol m^{-3}). An anti-cyclonic eddy was also visible

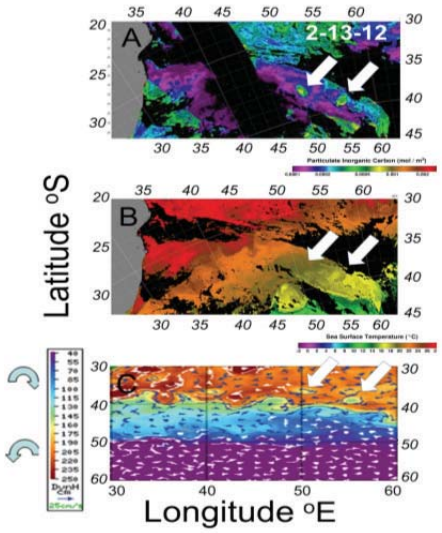


Fig. 7. Satellite imagery of SE Indian Ocean on 2-13-12. (A) PIC concentration, (B) SST. (C) Dynamic height estimated from satellite-derived altimetry. Color scales for panels A and B shown to lower right and panel C shown to left. Double white arrows indicate positions of PIC-rich eddies. Also note that map projection for panels A and B is a Gauss–Krüger, transverse ellipsoidal Mercator projection while for panel C is a cylindrical Mercator projection.

in the altimetry (38°S x 42°E) that showed no PIC signal in several weeks of imagery and minimal SST signature (Fig. 7C). During the CROZEX, a PIC-rich eddy was sampled in this same region containing 21 µg L^{-1}(1.75 mmol m^{-3}), levels found in a moderate coccolithophore bloom (Read et al., 2007). Indeed, CROZEX documented a temporal shift from diatom to coccolithophore production likely identical to that observed elsewhere when silicate is depleted (Boyd et al., 2010; Leblanc et al., 2009).

2.1.5 Consistencies of our conceptual understanding of the GCB: Synthesis of our previous data and other studies demonstrates the following consistencies in our understanding of the GCB and its biogeochemical significance to the conditioning of SAMW (Balch et al., 2016):

1. The GCB is a globally substantial seasonal feature across the SAF zone with high concentrations of coccolithophores and elevated calcification.

2. In the reflective, PIC-rich waters of the GCB, seawater pCO_2 is elevated relative to adjacent low reflectance waters. Calcification is associated with TA drawdown and low TA:DIC ratios.

3. Trace metal supply is implicated in the control of coccolithophores and the NCC:NCP ratio, which is critical for determining biological impacts on surface pCO_2.

4. PIC-rich and PIC-poor eddies are common near the SAF and their presence provides natural mesocosms to define the conditioning of GCB water during SAMW formation over monthly time scales.

2.1.6 Inconsistencies of our conceptual understanding of the GCB: The ratio of PIC to alkalinity drawdown is not uniform in the GCB, and "instantaneous" estimates of PIC from satellite imagery are not high enough to account for the observed alkalinity drawdown. As noted above, this is probably due to the coccolithophore bloom timing, and rapid turnover of PIC on the order of days (the carbonate pump). This inconsistency between PIC and alkalinity is critical if we are to understand the GCB conditioning of SAMW, as well as CO_2 source/sink behavior in the SO.

3. Goals, Hypotheses and Rationale

3.1 Goal #1. SAMW Conditioning: Determine the extent that coccolithophores, diatoms and associated microbial community condition upper ocean CO_2-carbonate chemistry (alkalinity, DIC, pH, pCO_2, $CaCO_3$ saturation state, Ω) plus nutrient concentrations (silicate, Fe) of SAMW at its point of formation, prior to subduction. **Hypotheses**: **H1.** PIC-rich surface waters contribute substantively different carbonate and nutrient characteristics than low-PIC, diatom-rich surface waters to SAMW. **Rationale:** The diatom-rich polar front and coccolithophore-rich SAF waters are co-located with the region of SAMW formation. However, there are no direct, whole ecosystem measurements of NCP and NCC, at monthly or seasonal time scales upon which to base estimate of the conditioning of SAMW. Spatial and temporal lags between NCC, NCP and export complicate interpretations of available observations, leading to the above inconsistency in our understanding. PIC-rich mesoscale eddies within the SAF zone, provide an exceptional opportunity to examine the time-evolution of conditioning in a quasi-Lagrangian framework over periods well in excess of the PIC turnover time with changes in the carbonate system well above the S/N of the carbonate system analyses. Moreover, such changes would likely involve wholesale changes in the microbial ecology extending from primary to secondary producers. Precise characterization of the time evolution of water properties and the upper ocean plankton community composition would provide a basis for understanding physiological and ecological controls on SAMW conditioning.

3.2 Goal #2. Biological and chemical conditioning experiments: Determine whether conditioning of SAMW by the resident phytoplankton community, is limited by iron, silicate, nitrate or another constituent present in 0.2 µm-filtered SAMW (derived from below the euphotic zone). Elucidate whether this conditioning is consistent with the waters being a net summertime CO_2 source or sink. **Hypotheses: H2**. There will be limitation of the coccolithophore community and associated calcification (based on changes in cell counts/biomass and PIC production) by iron and nitrate. **H3**. Diatom conditioning of SAF waters (based on changes in diatom cell counts/biomass and biogenic silica production) will be limited by silicate and iron (but not nitrate). **H4**. Coccolithophore growth in whole ecosystem, SAMW enriched samples, when released from iron and nitrate limitation, will have NCC>NCP and thus significantly increase the source of CO_2. **H5.** Coccolithophore species diversity will increase in iron-depleted waters. **Rationale:** Our previous work suggests that the balance of NCP and NCC ultimately dictates whether waters of the SAF are net summertime sources or sinks for CO_2. Silicate, nitrate and iron appear to be critical in this balance (Figs. 5, 6 and 9). The GCB shows highest PIC in low silicate, SAF waters, and in regions of strong Ekman pumping where iron concentrations may be elevated due to upwelling (Figs. 5, 6). The success of various algal classes has major consequences to the pCO_2 and efficiency of export (Balch et al., 2016). Moreover, previous work illustrated that coccolithophore diversity increased as iron stress increased (Balch et al., 2016; Balch et al., 2017).

3.3 Goal #3 Scaling-up our observations: Take what is learned in Goals #1 and #2 about the conditioning of SAMW and potential nutrient limitation and combine it with best estimates of Ekman- and eddy-driven subduction of SAMW to describe the biogeochemical impact of the diatom and coccolithophore conditioning. **Hypotheses: H6.** Coccolithophore calcification in the GCB is significantly conditioning the inorganic carbon and nutrient chemistry in SAMW, which, through Ekman- and eddy-driven subduction, will ultimately become the source waters for subtropical and tropical surface growth of two classes of mineralizing phytoplankton, coccolithophores and diatoms, the tests of which are responsible for ballasting sinking POC in equatorial waters. **Rationale:** The first two goals are directed to understanding and quantifying the physiological and ecological controls on conditioning of SAMW waters by coccolithophores and diatoms. Under Goal #3, we aim to integrate the experimental observations from Goals #1 and #2 with physical observations and numerical simulation of SAMW subduction to quantify the relevance of this conditioning in the context of global biogeochemical cycles and overturning circulation. Our observations will fill a critical void through extensive characterization of summertime transformations in surface waters in subduction regions. Simulations and analysis of physical variables will enable quantifying the role of these processes in setting SAMW properties.

4 Research Approach

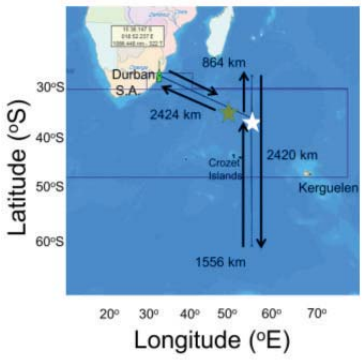


Fig. 8. Cruise plan. Expected locations of PIC-rich and low-PIC eddies (based on previous observations) shown with white and green stars respectively.

We propose to address the above hypotheses in two 38-day cruises, of a global- or ocean-class UNOLS vessel steaming from Durban, South Africa to the SAF in the SE Indian Ocean during austral summer. We choose this region because: (A) it has some of the highest rates of SAMW formation in the SO (Cerovečki et al., 2013); (B) there are high concentrations of diatoms and coccolithophores there (Balch et al., 2016); (C) there appears to be strongly enhanced pCO_2 (20-30 µatm) associated with PIC-rich SAMW waters, and; (D) PIC-rich eddies in this region allow us to measure the conditioning of the SAMW as whole ecosystems are isolated within semi-enclosed eddies that proceed to the northwest.

4.1 Overview of work plan and experimental design: The proposed cruise plan for Year 1 is shown in Fig. 8, which has the ship departing Durban, S.A. during austral summer, January 2018, and sailing to the SE, towards the region where PIC-rich eddies have been spotted previously. As before, we will use an adaptive sampling strategy based on the locations and age of eddy features, determined from satellite sea surface height (SSH). Previous SSH data, combined with ocean color, reveal cyclonic, PIC-poor, chlorophyll-rich eddies

originating from the PF, likely rich in diatoms, that will provide a comparison to the PIC-rich eddies, important for defining types and rates of conditioning of SAMW (including the effect of calcification on inorganic carbon chemistry). We will occupy a PIC-rich and a PIC-poor eddy during the first cruise, then perform a meridional survey north and south of the PIC-rich eddy to characterize the larger-scale variability of the carbonate chemistry, nutrients, productivity and biomass of various plankton groups in the SAMW subduction region. Eddies will be surveyed at the beginning and end of the cruise, separated by the period of the meridional transect (~21 d). To aid in the tracking of the eddies, a Lagrangian drifter with ARGOS transmitter will be deployed at the center for reference. Each survey will involve high-resolution Video Plankton Recorder (VPR) transects (measuring pressure, T, S, fluorescence, oxygen, and plankton abundance, 50 μm-1 cm size range), undulating between the surface and 120 m depth at 10 kts; the VPR deployments will be used to define the physical properties of the eddies as well as changes in the micro-phytoplankton and zooplankton communities across them (see example in Fig. 9).

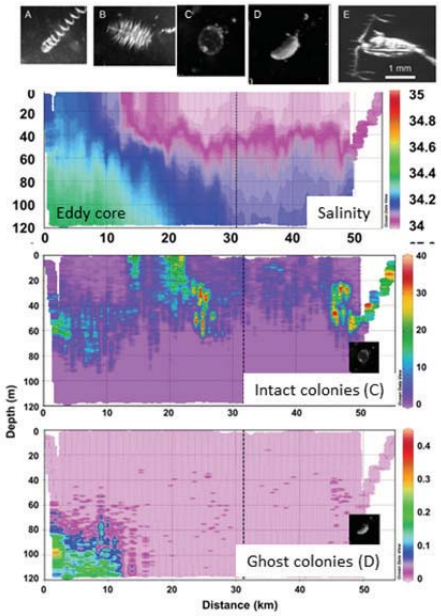


Fig. 9. Example images from the VPR from an eddy in the eastern Ross Sea (from Smith et al., 2017): (A) helical diatom chain, (B) *Chaetoceros* chain, (C) intact *Phaeocystis* colony, (D) *Phaeocystis* ghost colony, (E) copepod. Scale bar in (E) applies to all images. Lower panels: distributions of salinity, intact, and ghost colonies of *Phaeocystis* (# mL^{-1}). VPR undulations are indicated by a faint back line. Note the accumulation of ghost colonies deep in the core of the eddy (x=0 km).

Continuous surface underway measurements will be made across the eddies to define changes in the coccolithophore backscattering (measured as acid-labile backscattering) as well as optical changes representative of the general algal community (total backscattering, chlorophyll fluorescence, spectral attenuation and absorption [and by difference, scattering], as well as chemical changes of nitrate (Satlantic SUNA) and pCO_2. CTD/Rosette and Niskin-X casts will be used to sample water for CO_2-carbonate chemistry, nutrients, dissolved iron, oxygen, salinity, CFC's (as transient tracers for aging SAMW) and phytoplankton species composition (using a FlowCAM for particles 4–100 μm, polarized microscopy for enumeration of coccolithophores and detached coccoliths, SEM for absolute identification of algal species), species-specific cell-cell variability of photosynthetic efficiency (using imaging PAM fluorescence; related to Fe limitation). Moreover, we will obtain parallel RNA and DNA samples for genetic analysis to determine the spatial and temporal variation of species and strains of coccolithophores and diatoms across the eddies.

The Year 2 cruise will also base out of Durban, SA, similar to Year 1 except there will be no large-scale meridional transect performed (one is sufficient to document the age of SAMW extending to the north). The Year 2 cruise effort will focus on four more eddies that have pinched off from the SAF and PF (coccolithophore-rich and diatom-rich, respectively).

4.2 Sampling

4.2.1 Hydrographic stations and meridional survey: During standard ship transits, the VPR will be deployed to provide physical, bio-optical, and biological information with resolution of 1 m in the vertical and 1-2 km in the horizontal direction. The ship will be stopped every 80 km (43 nautical miles) to lower the CTD to 1000 m. Every other station will involve sampling water (using CTD) for discrete measurements of DIC and TA, oxygen, standard nutrients, salinity, PIC, particulate organic carbon/nitrogen (POC/PON), extracted chlorophyll, biogenic silica, total coccolithophore counts (polarized light microscopy), coccolithophore species (SEM) and phytoplankton functional groups (FlowCAM), species and strain-specific F_v/F_m and parallel sampling for RNA and DNA. Dissolved and particulate trace metal sampling will be done using TM cleaned Niskin-X samplers hung on Kevlar line. Primary production/calcification will be measured daily using simulated in situ deck incubations. During the meridional transect, water samples will be taken for CFC analysis (CFC-11, CFC-12 and SF6) and shipped to the University of Miami (lab of Dr. Rana Fine; see letter) to determine mean age (Fine, 1993)

based on partial pressures of dissolved CFCs (pCFC-11 and pCFC-12) or from the ratio of the partial pressures (pCFC-11:pCFC-12).

4.2.2 Eddy surveys: A transect to the PIC-rich and low-PIC eddies will involve hydrographic and productivity stations noted above. SSH data from satellite altimetry and ocean color data from MODIS-Aqua or NPP-VIIRS will be used to target these eddies. , and they will be surveyed with the VPR described above. CTD casts will be performed during eddy surveys to provide water samples and hydrographic information at depths below that which is sampled by the VPR.

4.2.3 Deck incubations to assess limitations on growth: Samples from 20 m depth (bottom of the mixed layer to avoid Fe contamination from ship) will be taken from the eddy center with 30 L GO-FLO bottle casts and water immediately sampled (in triplicate) for PIC, POC, nutrients, dissolved iron (dFe), CO_2-carbonate chemistry (i.e., DIC and TA), BSi, chlorophyll, coccolithophore counts and abundance of phytoplankton functional groups [e.g., pennate and centric diatoms, dinoflagellates, nanoeukaryotes amongst other rarer groups). Remaining water will be divided in triplicate polycarbonate carboys followed by 6 treatments: no addition (control), +nitrate (20 μM), +silicate (20 μM), +iron (2 nM), a combined iron+silicate treatment (to assess co-limitation of diatoms vs. other algal classes) and 0.2 μm-filtered, sub-euphotic SAMW, to assess the growth response of coccolithophores versus other nanoeukaryotes to upwelled deep SAMW. Bottles will be incubated in simulated in situ conditions of temperature and light in deck incubators for 3-4 days before final sampling. Parallel single cell studies of Fv/Fm will provide further data on the iron limitation of different taxa (Brownlee) and molecular evidence for species shifts in the carboys (Schroeder).

4.2.4 Profiling float deployments: We are working with the Southern Ocean Carbon and Climate Observations and Modeling project (SOCCOM) to deploy six of their BIO-ARGO profiling floats in the Southern Indian Ocean. These floats measure temperature, salinity, pH, nitrate, particle backscattering and oxygen. The floats typically will be parked at 1000 m, then every 10 days will descend down to 2000 m, then profile to the surface, uplink the data, then return to 1000 m. Data from these floats (and any others in the region) will benefit us by: (1) tracing deep profiler trajectories in this region of the SAF; (2) identifying SAMW depths, and; (3) providing profiles of nitrate, oxygen, particle backscattering and pH information which provide further evidence of conditioning of SAMW. Our independent cruise data will be used to calibrate the floats and define the salinity/TA relationship in the region, so that the profiler data can be used to generate TA as a second input, which, together with pH can be input into CO2SYS (e.g., Robbins et al., (Robbins et al., 2010) to define the complete seawater CO_2-carbonate system). We will provide SOCCOM with critical calibration profiles for deployment of each float. We have included 6 deep casts within our cruise plan to facilitate this. See letter of collaboration from J. Sarmiento.

4.2.5 Modeling approach: The modeling aspect of this project will use the Community Earth System model (CESM), which includes an ocean biogeochemistry component called the Biogeochemical Elemental Cycle (BEC) model. The BEC model has been used extensively in studies examining the role of atmospheric nutrient deposition (Doney et al., 2009; Krishnamurthy et al., 2009), interactions between the marine nitrogen and iron cycles (Krishnamurthy et al., 2009; Moore and Doney, 2007), the mechanisms driving variability in air-sea exchange of CO_2 (Long et al., 2013; Lovenduski et al., 2013), and interactions of ocean biogeochemical cycles with climate variability and change (Krumhardt et al., 2016; Long et al., 2016a). We note that BEC remains in active development; however, it has been repackaged into a modular code base called MARBL (the Marine Biogeochemistry Library). MARBL is designed to be base-model independent, enabling different ocean general circulation models (OGCM) to invoke the same biogeochemistry code. Efforts are either planned or underway to couple MARBL to OGCMs other than POP, which is the current CESM ocean component; these models include ROMS, MPAS, and MOM6.

The BEC model represents multiple nutrient co-limitation (N, P, Si, and Fe) and includes three explicit phytoplankton functional groups (diatoms, diazotrophs, and "small" pico/nano phytoplankton), and one implicit group (calcifiers) (Moore et al., 2004). The model simulates sinking particulate matter, subject to ballasting by mineral dust, biogenic calcite and Si following Armstrong et al. (2002). Iron inputs include atmospheric deposition and sedimentary iron, which is applied using subgrid-scale bathymetry as described by Moore and Braucher (2008). The model has recently been modified to

improve the simulation of NPP in sea-ice dominated regions (Long et al., 2015). Calcification is simulated as a fraction of small phytoplankton NPP, decreasing with nutrient limitation and low temperatures and increasing under bloom conditions. The addition of an explicit calcifying group is in progress, however, led by Kristen Krumhardt, a Ph.D. student with N. Lovenduski (Univ. Colorado, Boulder) and involving close collaboration with co-PI Long at NCAR.

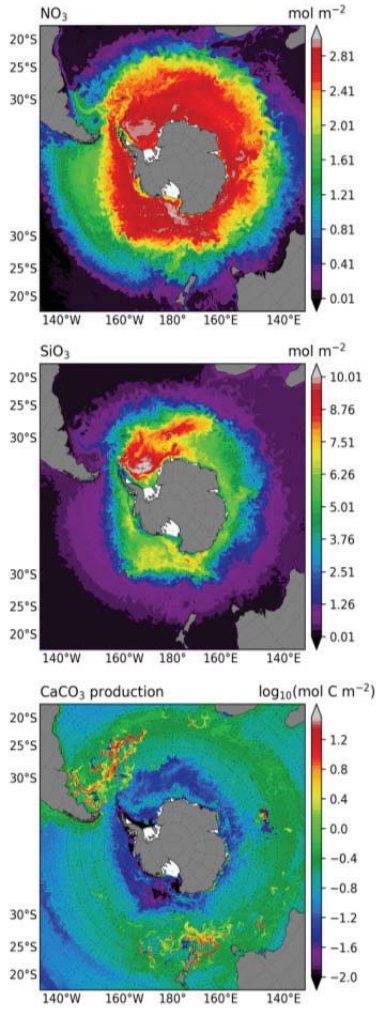


Figure 10: Upper 100-m integrals of (top) nitrate, (middle) dissolved silica, and (bottom) log transformed calcite production from a global eddy-resolving integration of CESM.

Most global integrations conducted with the BEC model have been performed at 1° resolution, which enables climate-timescale ($O(10^3)$ year) studies. We conducted shorter BEC runs in a global eddy-resolving (0.1°) configuration (Fig 10). These integrations produce rich mesoscale variability and provide a basis for studying physical-biological coupling in the context of realistic flow (Long et al., 2016b). As Fig. 10 illustrates, the eddy-resolving model captures the sharp frontal zonation in the SO, the associated gradients in surface nutrient fields driving algal community composition, and the strong mesoscale dynamics that stir these properties. This project will make use of a community integration that will begin in Spring, 2017: the CESM Ocean Model Working Group will run a global ocean-ice, eddy-resolving simulation with the BEC model for the period 1948-near-present, forced under the Coordinated Ocean-Ice Reference Experiment protocol (Griffies et al., 2009; Large and Yeager, 2009), but using a new forcing dataset based on the JRA-55 reanalysis. In addition to this run, we have access to computing resources through the bi-annual Computational & Information System Lab High-performance computing Allocations Panel call (https://www2.cisl.ucar.edu/chap), thereby enabling additional, more targeted, integrations at 1° and 0.1° resolution.

5. Workplans

5.1 Balch (BLOS): *Continuous underway surface mapping:* Surface mapping of the eddies will be done using a semi-continuous underway sampling system applied over much of the global ocean (Balch et al., 2010; Balch et al., 2001). It measures temperature, salinity, pH, and chlorophyll fluorescence. Total backscattering at 543 nm ($b_{b\,tot}$) is measured using a WetLABS ECO-VSF (3 angle). Backscattering then is measured following acidification of seawater to dissolve calcite and aragonite ($b_{b\,acid}$), and by difference, acid labile backscattering (b_b') (Balch and Drapeau, 2004) which can be calibrated to PIC. Regular discrete water samples will be collected for chlorophyll (JGOFS, 1996), PIC and POC (Poulton et al., 2006) to calibrate the system. The underway system also measures spectral absorption and attenuation (WetLABS ac-9) of raw and 0.2 µm-filtered water. Biogenic silica will be sampled (Brzezinski and Nelson, 1989). *Satellite data processing for PIC:* Regional PIC concentration (moles m^{-3}) will be measured by satellite using the standard NASA PIC product (Balch et al., 2005; Gordon et al., 2001) with both MODIS or VIIRS data, in real-time (for guiding the ship) as well as post-cruise. *Microscopy: Polarized light microscopy:* This technique allows enumeration of coccolithophores based on calcite birefringence. Total coccolith and coccolithophore abundance will be measured by the HA filter/optical adhesive technique (Poulton et al., 2010) with polarized light microscopy. Images of coccoliths and plated coccolithophores are processed with CCC image software (Balch and Utgoff, 2009; Balch et al., 2011). Sample volumes are 60 mL, thus the lower limit of detection is 17 particles L^{-1}. *FlowCAM Particle Size Analyzer:* This imaging cytometer allows enumeration of all particles from 4-100 µm, excellent for enumeration of functional groups as well as measuring particle-specific backscattering, chlorophyll, phycoerythrin fluorescence and particle size. The sample volume is 10 mL thus the lower limit of detection to 0.1 cells mL^{-1}. Image analysis software estimates various particle attributes. Particle

volume will be converted to cell C according to Menden-Deur and Lessard (2000). The FlowCAM is calibrated to both the size of particles and their concentration using latex beads (Sieracki and Sieracki, 1997; Sieracki et al., 1998). *Scanning Electron Microscopy (SEM):* Taxonomic identification of coccolithophore species requires SEM. Surface and chlorophyll maximum samples from the daily productivity cast will be prepared for SEM analysis on Bigelow's Zeiss Supra25 field emission scanning electron microscope according to Goldstein et al. (2003). *Calcification/ Photosynthesis:* Calcification and photosynthesis will be measured using the ^{14}C microdiffusion technique (Paasche and Brubak, 1994), with modifications by Balch et al. (2000) to estimate NCP and NCC. Water will be drawn from pre-dawn casts and sampled from 6 light depths over the euphotic zone (to 0.1% light). Simulated-in situ deck incubations will be used, corrected for both light quantity and quality using blue acetate and neutral density screens. *Incubation experiments (Balch, Bates,Morton):* For the seawater grow-out experiments, water will be first sampled from 20m depth with a 30L GO-FLO bottle and mixed prior to placing aliquots in polycarbonate bottles, then into seawater-cooled incubators. There will be six treatments: control (no addition), or added nitrate (20 μM), silicate (20 μM), iron (2 nM), iron+silicate to test for co-limitation and filtered, deep SAMW to examine overall impact of conditioning. The measurements that will be made on each eddy incubation are: chlorophyll, BSi, PIC, POC, polarized microscopy, FlowCAM and SEM. *ARGOS Drifter Observations:* We will deploy Brightwaters Model 115 drifters in the eddies with 10 m sock drogues to mark the eddy centers for VPR eddy transects.

5.2 Bates (BIOS): The Bates group will be responsible for the sampling, collection, and analysis of inorganic carbon parameters (i.e., DIC, TA, and underway pCO_2) at all CTD/hydrocast stations and for all experiments. Sampling methods and analyses follow standard guidelines (Dickson et al., 2007). At CTD/hydrocast stations and shipboard experiments, samples for DIC and TA will be fixed with 200 μl saturated mercuric chloride and analyzed at sea. Analytical methods follow standardized protocols (Bates et al., 1996; Bates et al., 2001; Dickson et al., 2007; Knap et al., 1993) and we plan to analyze both DIC and TA samples onboard using highly precise (0.02%; 0.4 μmoles kg^{-1}) VINDTA (**V**ersatile **In**strument for **D**etection of **TA**) analytical system with replicates samples also returned to BIOS (Bates, 2007; Bates et al., 1996; Bates and Peters, 2007). Both DIC and TA analyses have a precision of ~0.5 μmoles kg^{-1} and similar accuracy (using calibrated reference materials for shipboard and lab work). The ship will be outfitted with a flow-through "SAMI" pCO_2 and pH sensor (Sunburst Sensors). Post-cruise analysis and synthesis using established QC/QA integrated steps, and merging with core hydrographic data. Carbonic acid dissociation constants appropriate for temperate/polar seas, and temperature, salinity and depth data will be used to compute pH, pCO_2, $[CO_3^{2-}]$ and Ω for aragonite/calcite. Salinity normalization and property-property analyses will also be performed. Remote sensing and shipboard temperature data will be used to assess rates of air-sea CO_2 gas (and drivers of flux) on pCO_2 in the SO.

5.3 Morton (FSU/NHMFL): Morton will lead the trace metal sampling and analysis efforts, including establishing clean lab conditions during cruises, deploying/recovering 5L Niskin-X and 30L GO-FLO samplers, subsampling for dissolved and particulate TMs (dTM and pTM), and analyzing subsamples using the ELEMENT 2 HR-ICP-MS housed in the NHMFL's Geochemistry division after sample pretreatment. Ultimately, dTM and pTM concentrations (especially Fe) will be determined in profiles from 20 stations from the eddies and meridional transect. *Trace metal sampling:* Trace-metal-clean water samples will be collected from the upper 1000m at nine depths using Teflon-coated Niskin-X bottles hung on Kevlar line and tripped with Teflon messengers (Lin et al., 2011). Subsampling for dTM and pTM will be done in a HEPA-supplied clean van or temporary "bubble" lab space. Seawater will be filtered using 0.2 μm polycarbonate track-etched (PCTE) filters directly into rigorously acid-cleaned, low-density polyethylene bottles from pressurized (<8 psi) Niskin-X samplers following GEOTRACES guidelines (Cutter et al., 2010). Samples for dTM will be immediately acidified to pH ~1.7 with ultra-high purity HCl (Fisher Optima) and triple-bagged for storage and transport. Marine particles from 2-5 L of seawater will be collected inline onto 0.2 μm 47 mm PCTE filters, which will be cut into ~equal halves with a rotary ceramic blade (Cutter et al., 2010), and stored at -20°C until processing on land. *Dissolved trace metals:* Briefly, dTMs will be measured following extraction from seawater and pre-concentration using a flow-through-Nobias Chelate PA-1 resin system, and the concentrations quantified by isotope dilution or standard addition (Grand et al., 2015; Milne et al., 2010). *Total and labile particle digestion:* PCTE filter

halves will be treated by two different methods to determine the bulk pTM concentrations and the labile (e.g., biogenic, Mn-oxides) fractions, to better resolve biogenic processes related to coccolithophore dynamics and to complement the dTM concentrations and gradients. Briefly, one filter half will be subjected to total digestion (HNO_3+HCl+HF/HNO_3+H_2O_2; (Ohnemus et al., 2014)) while the other filter half will be subjected to a weak acetic acid/reducing agent leach (Berger et al., 2008). Additionally, published molar pTM/Al, pTM/Ti and pTM/Zr ratios in crustal material will be used to correct for mineral contributions (Martin et al., 1989; Rudnick and Gao, 2003) in order to estimate bulk biogenic pTM concentrations. *TE instrumental analysis*: TM concentrations will be measured using dedicated sample-specific front-end components (i.e., dTM vs pTM) with the aforementioned Thermo ELEMENT2 HR-ICP-MS at FSU/NHMFL, where Morton has independently performed regular analyses since 2007. All elemental ICPMS analyses will be optimized for minimum isobaric interferences (e.g., oxides, doubly-charged species, etc.) and calculated corrections (including instrumental drift corrections monitored by internal standards) will be applied as needed. Concentrations of dTM will be quantified by isotope dilution or standard additions along with SAFe/GEOTRACES intercalibration standards to ensure traceability (Cutter et al., 2010), while pTM concentrations will be quantified by multi-element external calibration curve along with certified reference materials (including NRCC MESS-3, HISS-1, and PACS-2 marine sediments and IRMM BCR-414 reference materials) to verify sample digestion recovery.

5.4 McGillicuddy (WHOI): Eddy features will be monitored prior to and during the field campaigns with a combination of satellite altimetry, AVHRR, and ocean color. Because altimetry is not affected by cloud cover, it is the most reliable method of feature tracking. Such techniques have been used to provide spatial context for inter-disciplinary field studies (e.g. JGOFS North Atlantic Bloom Experiment (McGillicuddy et al., 1995; Robinson et al., 1993), Bermuda Atlantic Time-series Study (McGillicuddy et al., 1998; Sweeney et al., 2003), and EDDIES project (McGillicuddy Jr et al., 2007). Target eddies identified in satellite data will be surveyed with the Video Plankton Recorder (Davis et al., 1992; Davis et al., 2004). The VPR takes digital images of the plankton (sampling rate 30 Hz) as they pass through a ~1 cm^3 volume between the nose cone and starboard wing and automated image processing/ classification facilitates data analysis (Fig. 9). The VPR has been used extensively in shelf, slope, and open-ocean waters to map abundance patterns of plankton over long distances (1000s of km) with very high spatial resolution (cm in the vertical, 0.1 to 1 km in the horizontal`) (Davis and McGillicuddy, 2006; Davis et al., 2005). More recently the VPR was used to document mesoscale variations in the distribution of *Phaeocystis antarctica* Fig. 9); elsewhere in the Ross Sea, high concentrations of chain-forming diatoms were encountered and quantified. We recognize that the VPR will not be able to quantify coccolithophores due to their small size. However, diatoms figure prominently into the conceptual model and hypotheses, and we do expect to quantify these with the VPR. Surveys from the VPR will serve several purposes. First, the data will provide characterization of mesoscale and submesoscale variations in physical and bio-optical properties, as well as the distributions of microplankton including diatoms and mesozooplankton. Second, the VPR surveys will be used to site the process studies in which the full suite of water properties will be measured. Third, the observed variations in the mesoscale environment will be compared with those from a global eddy resolving model (section 5.5 below).

5.5 Long (NCAR): Modeling activities will augment the observational program by enabling evaluation of the hypotheses articulated above in a global, self-consistent framework. The first task will be an intensive validation of simulated Subantarctic surface properties in the 0.1° and 1° CESM solutions. Direct comparisons with *in situ* observations as well as remotely sensed data products will be made in both Eulerian and (for the high-resolution model) eddy-centric (e.g., Gaube et al., 2014) reference frames. A key question in this effort will be whether the model appropriately captures changes in the relative abundance of diatoms versus coccolithophores as a function of nutrient distributions. We will consider model configurations that include explicit as well as implicit calcifiers, using small phytoplankton biomass and calcification rates to develop a proxy for coccolithophores in the latter case.

A clear understanding of the model's skill, following some tuning perhaps, will enable further analyses. In particular, we will aim to quantify the mechanisms controlling the spatial distribution of diatom and coccolithophore production and the impact these distributions have on waters contributing to SAMW formation. Diagnostic output from eddy-resolving integrations will be used to examine cross-

frontal nutrient transport, thereby connecting the viability of diatom versus coccolithophore habitat to physical processes. Subduction rates will be estimated from the model (e.g., Sallée et al., 2012; Kwon et al., 2016); these fields will be examined and related to surface NCP and NCC distributions to understand the mechanisms setting SAMW properties. Since SAMW takes decades to reemerge at low latitudes following subduction, it is desirable to conduct some experiments at 1° resolution; the expense of eddy-resolving simulations precludes long integrations. However, the 1° model parameterizes the effects of mesoscale eddies (e.g., Gent and McWilliams, 1990), which play a leading order role in modulating subduction (Sallée et al., 2010). Thus, explicit comparisons between the 1° and 0.1° solutions, as well as with observations, will be required to inform our interpretation of coarse-resolution results, particularly the degree to which this model can simulate SAMW formation and transport to the subtropical thermocline. Our objective will be to use the coarse-resolution model as a framework in which to quantify the role of NCC:NCP ratios in SAMW on low-latitude productivity, algal community composition and export production. We will analyze the solution from an 1850-control integration spanning several hundred years. This analysis will inform the design of sensitivity experiments (Marinov et al., 2006), enabling more direct estimation of target effects.

5.6 Brownlee and Schroeder (MBA, Plymouth, UK) Foreign Collaborators (no cost): Drs. Brownlee and Schroeder will characterize the genetic and physiological diversity across the study area, which vary in coccolithophore and diatom abundance (see letter of collaboration). They will use both traditional and next-generation sequence profiling (e.g., Illumina Hi-seq) for DNA and RNA to accomplish this, new approaches for physiological characterization of populations *in situ*. This work is funded in part until 2020 by a *European Research Council Advanced Grant* (to CB) for the development of new microscopy instrumentation for assessing cell-cell variability in photosynthetic efficiency, along with a number of important physiological parameters (including calcification state and oxidative stress).

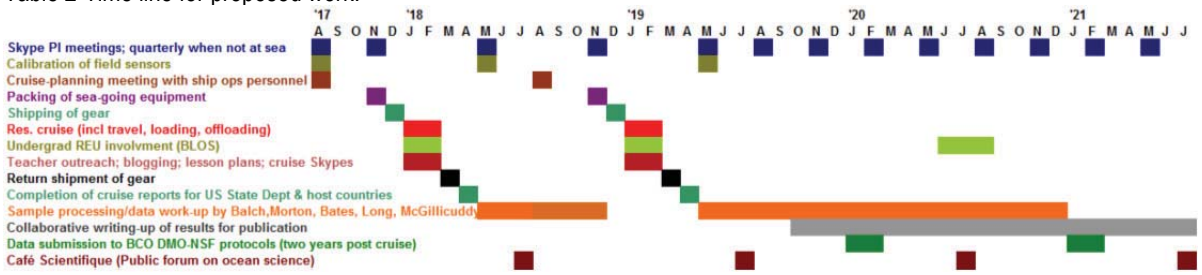
5.7 Work Plan Integration of Goals and Hypotheses Testing: This work builds on our previous GCB work by establishing the extent that the GCB coccolithophores as well as PF-derived diatoms condition the carbonate and nutrient chemistry of the SAF waters prior to being subducted equatorward as SAMW. Goals #1 and #2 establish the extent of this conditioning by coccolithophores, the nutrients that limit their growth and the influence of the coccolithophores as sources or sinks for CO_2. The presence of semi-enclosed, mesoscale, PIC-rich eddies allows us to address these goals since the whole coccolithophore-rich ecosystem is held for time scales of months, which provides far superior S/N in determining the extent of conditioning relative to a low-PIC eddy. Goal #3 is meant to take what is learned over the course of a roughly one-month cruise (including hydrographic observations from ship, floats; CFC transient tracers) and, through remote sensing and modeling, extend these observations to larger spatial and temporal scales. The third goal will provide the magnitude of SAMW conditioning, which ultimately controls the nutrient and inorganic carbon chemistry of surface waters in the subtropics and tropics.

6. Management of the Project and Resources: WMB is the primary coordinator of this project. He will be in charge of working with ship operations and marine technical support personnel for cruise planning. He will also be in charge of scheduling quarterly Skype meetings of the science personnel and coordinating reporting to NSF. WMB also will be directly supervising his laboratory personnel and scientific operations. DJM, NRB, ML, PM, CB and DS will supervise their respective personnel. WMB will coordinate data submission to BCO-DMO.

7. Deliverables: Manuscripts resulting from this work will make advances in seawater carbonate chemistry, algal physiology and ecology (regulation of coccolithophore calcification by nutrients and trace metals; resource competition with diatoms). It will also elucidate the physical factors affecting phytoplankton biogeography and ultimately the cohort of variables determining the conditioning of SAMW. We will validate CESM solutions in relation to these topics and apply this modeling framework to develop mechanistic understanding of physical processes that control the biogeochemistry of SAMW, its conditioning, subduction, and transport at basin to global scales.

8. Project Time Line: See Table 2.

Table 2-Time line for proposed work.



9. Broader Impacts: The sheer size of the GCB (52 x 10^6 km^2; 16% of the global ocean) suggests that it plays a major role in global biogeochemistry. Our previous GCB cruises have demonstrated that coccolithophores can strongly influence the source/sink behavior for CO_2. Greater than half the total global SAMW formation occurs in the Indian sector. Understanding the conditioning of SAMW by the two types of mineralizing phytoplankton, coccolithophores and diatoms, along with modeling efforts, will allow its impact on the carbonate chemistry, and productivity and calcification of shallow sub-tropical and tropical waters to be determined.

Several endeavors will further extend research components of the project into educational opportunities, including some beyond the oceanographic community. Bigelow Laboratory is a non-profit research institution that has an educational partnership with Colby College. Funds are requested for participant support to take two Colby undergraduates one on each cruise as well as training another student the following summer (year 3). Funds are requested for each student to attend an ASLO Ocean Sciences meeting. If no Colby students are available, we will recruit from another Maine-based college. Under-represented minorities will be given preference for these opportunities. We also have requested travel funds to bring a high school-level educator on the cruise as we did with great success in previous SO cruises for public and classroom outreach. This work will involve making initial contact with multiple schools around the country to introduce the scientific problem of the SAMW conditioning, then the teacher will devote half their ship time to daily interactions with the students, answering questions, blogging and video conferencing and the other half to helping with deck and lab operations. The teacher would use additional avenues to broaden reach, including establishing a Facebook page, a Twitter account with #SAMWlive!, an Instagram account, and creating short videos for posting on YouTube and other social media sites. As we have done in the past, we would call upon foreign observers (Crozet is a French protectorate) to translate the outreach materials to French to broaden reach. Public lay-presentations by Balch will be made at the Bigelow's Café Scientifique program held in Boothbay Harbor, ME (which attracts >1000 participants annually; http://www.bigelow.org). A BIOS student will also be supported by separate BIOS funding to work on the project (sample analyses and data synthesis). Funds are requested to support a postdoctoral scholar at NCAR, who will work on the modeling aspects of this project. This individual will be trained in the development and application of CESM, enabling more effective use of this resource throughout her or his career.

10. Significance: The GCB gained notoriety with the advent of ocean color remote sensing when it was realized that seemingly unrelated ship observations of enhanced coccolithophores were part of a basin-scale, elevated reflectance feature that encircled the SO. The SAF of the SO gained notoriety when it was discovered that SAMW formed there, subducted to the north and supported the productivity of subtropical and tropical waters. Variations in diatom production at the PF and SAF, combined with intense Ekman-induced subduction, were shown to affect the "leakage" of silicate-rich water to the north, thereby affecting low-latitude diatom productivity on glacial-interglacial scales. The confirmation of the GCB as a coccolithophore feature at the SAF suggests that it, too, is conditioning the SAMW carbonate chemistry, changing the pCO_2, alkalinity, DIC and nutrients of this northward flowing water mass. The paucity of coccolithophores in equatorial Atlantic waters further suggests that SAMW conditioning has inhibited their subsequent growth when it arrives in equatorial waters. This proposal addresses the factors affecting the conditioning SAMW waters for subsequent growth of minerogenic phytoplankton. In this work, we need to know: (1) mean rates of photosynthesis and calcification in the PF and SAF waters; (2)

what nutrients/trace metals limit growth of calcifying and non-calcifying groups, (3) how the inorganic carbon chemistry and pCO_2 balance is affected by NCC, NCP and associated nutrient limitation, (4) how the biomass and diversity of the plankton communities changes; and, (5) how to scale-up our localized observations to broader spatial and temporal scales associated with SAMW formation. Direct field estimates of coccolithophore calcification are rare and in situ, bottle-free, whole ecosystem estimates of coccolithophore calcification are rarer still. PIC-rich and diatom-rich eddies that form from the SAF and PF regions(containing coccolithophore-rich and diatom-rich SAMW) provide the means to measure such conditioning in semi-enclosed mesoscale features and at long enough time scales to make meaningful conclusions as to their impact on global productivity.

11. Results from previous work (last 5 years only):

Balch: *OCE-0961660 "Collaborative Research: The Great Southern Coccolithophore Belt"* **$755K; 06/15/2010 - 02/28/2015.** ***Intellectual merit:*** We studied the biogeochemistry of the high reflectance GCB, found across the Southern Ocean. Results demonstrated that it is indeed caused by coccolithophores and it has ramifications to air-sea CO_2 balance and sinking fluxes of POC. Shipboard experiments demonstrated that coccolithophores (as well as diatoms) in the Indian sector of the GCB can be limited by iron availability. Data have been submitted to BCO-DMO. Nine publications resulted from this work. See boldface citations in references. ***Broader impacts****:* A high school teacher participated in both cruises, working with students across the country. Seventeen students were trained during this project, including graduates and undergraduates, and all are now pursuing careers in science or science and law. Seven public talks were given.

Bates: *OPP-1107457* "*Collaborative Research Pacific-Arctic Carbon Synthesis-Transformations, Fluxes, and Budgets"* **$120K, 10/1/11-9/30/14**. ***Intellectual Merit:*** Our group focused on ocean carbon cycle biogeochemistry in the western Arctic Ocean including Bering, Chukchi, and Beaufort Sea shelves, and interactions between shelf and Arctic Ocean basin waters. We find that the surface waters transitioned to a very strong sink for CO_2 and that OA impacts are evident in bottom waters across the Western Arctic shelves. Twelve papers resulted from this work (see boldface citations in references). ***Broader impacts****:* Project data was incorporated into a BIOS graduate course on Modern Observation Oceanography and a graduate course (SOES 6073) at the Univ. of Southampton, May 2015-17.

McGillicuddy *with W. Smith (VIMS) and E. Hofmann/J.Klinck/M. Dinniman (ODU): ANT-0944165* **$649,317** to WHOI**; 07/01/2011 - 06/30/2016**), *Collaborative Research: Impact of Mesoscale Processes on Iron Supply and Phytoplankton Dynamics in the Ross Sea*. ***Intellectual merit:*** Using field observations and models, we constructed what we believe to be the most quantitative regional estimates of iron supply and demand in an Antarctic plankton ecosystem to date (McGillicuddy et al., 2015). Detailed profile data reveal a significant benthic source of iron (Marsay et al., 2014), a process that has been inferred in other areas but seldom documented with near-bottom measurements. A total of 17 refereed journal articles have resulted from the project thus far (shown in boldface in references), and a special issue of *Journal of Marine Systems* (McGillicuddy et al., 2017) synthesizes the results of this project and related efforts. ***Broader impacts:*** The project provided training for four graduate students, three undergraduate students and two post-doctoral fellows. Educational outreach efforts included development of a website STEMinACTION and use of project-generated materials in a science methods course for pre-service teachers. Two blogs provided chronicles of the our seagoing field work on the RVIB *Nathaniel B. Palmer* (http://rosssea2011.blogspot.com) and STEM education outreach by a Ph.D. student. A STEM-related poster and book are in development.

Long: *PLR-1501993*, *"Collaborative Research: The O_2/N_2 Ratio and CO_2 Airborne Southern Ocean (ORCAS) Study",* $1.4M; 05/15/2015-04/30/2018. **Intellectual merit**: We performed intensive airborne surveys over the Southern Ocean aboard the NSF/NCAR Gulfstream V aircraft during Jan-Feb 2016. High resolution measurements of atmospheric O_2, CO_2, and related gases were made to provide constraints on Southern Ocean air-sea exchange. Additional observations included numerous reactive gases and hyperspectral remote sensing (PRISM) of the surface ocean. In addition to the field component, ORCAS includes Earth system and transport modeling activities aimed at guiding sampling strategies and synthesizing observations. Publications are in preparation. **Broader impacts**: ORCAS has generated a valuable and publicly available data set and explicitly integrates modeling and observations. Three postdoctoral scholars are supported on the project and two graduate students participated in the field work.

Morton *with Salters and Twining: OCE-1436019* **$430,334; 12/01/2014 - 11/30/2017**), *Collaborative Research: Biogeochemical Cycling of Particulate Trace Elements in the Western Arctic Basin*. ***Intellectual merit:*** We successfully collected nearly 400 water column, sea ice, and melt pond samples for the determination of suspended particulate trace element concentrations. To date, 200 of the samples have been processed and analyzed for total elemental concentrations and 240 samples have been processed and analyzed for labile trace element concentrations. Our first results showing the offshore transport of particulate trace elements and their biological cycling will be presented at the 2017 Aquatic Sciences Meeting. ***Broader impacts:*** Public presentations were given during a local "Science Café" and at an RET summer program, detailing the state of the Arctic and the U.S. investment into understanding changes in ice coverage and the associated biological impact.

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Smith, W.O., D.J. McGillicuddy, E.B. Olson, V. Kosnyrev, E.E. Peacock, and H.M. Sosik. 2017b. Mesoscale variability in intact and ghost colonies of Phaeocystis antarctica in the Ross Sea: Distribution and abundance. *J. Mar. Syst.* 166:97-107.

Stern, A.A., M.S. Dinniman, V. Zagorodnov, S.W. Tyler, and D.M. Holland. 2013. Intrusion of warm surface water beneath the McMurdo Ice Shelf, Antarctica. *Journal of Geophysical Research: Oceans*.

Sunda, W.G., and S.A. Huntsman. 1995. Iron uptake and growth limitation in oceanic and coastal phytoplankton. *Marine Chemistry [MAR. CHEM.]*. 50:189-206.

Sweeney, E.N., D.J. McGillicuddy, and K.O. Buesseler. 2003. Biogeochemical impacts due to mesoscale eddy activity in the Sargasso Sea as measured at the Bermuda Atlantic Time Series (BATS) site. *Deep-Sea Res. II*. 50:3017-3039.

Thompson, A.F. 2008. The atmospheric ocean: Eddies and jets in the Antarctic Circumpolar Current. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 366:4529-4541.

Thompson, D.W.J., and S. Solomon. 2002. Interpretation of recent Southern Hemisphere climate change. *Science*. 296:895-899.

Tsuchiya, M., L.D. Talley, and M.S. McCartney. 1994. Water-mass distributions in the western South Atlantic; A section from South Georgia Island (54S) northward across the equator. *Journal of Marine Systems*. 52:55-81.

Twining, B.S., S. Rauschenberg, A. Ruacho, B. Honisch, and P. Morton. 2017. Control of diatom and coccolithophore growth by trace metal micronutrients along the Great Calcite Belt. *Deep-Sea Research (Part I, Oceanographic Research Papers)*. In preparation.

Valiadi, M., S.C. Painter, J.T. Allen, W.M. Balch, and M.D. Iglesias-Rodriguez. 2014. Molecular detection of bioluminescent dinoflagellates in surface waters of the Patagonian Shelf during early austral summer, 2008. *PLoS ONE*. 9:e98849.

BIOGRAPHICAL SKETCH - William McKay Balch

Senior Research Scientist
Bigelow Laboratory for Ocean Sciences
POB 380; 60 Bigelow Drive
E. Boothbay, ME 04544
bbalch@bigelow.org

PROFESSIONAL PREPARATION

Cornell University, B.A., 1980. Cum laude; biology; Advisor J. Kingsbury
Scripps Institution of Oceanography, Ph.D., 1985; Advisor R.W. Eppley
Post-doctoral Investigator, Marine Ecology Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S., Canada. 1985-1986. Advisor W.G. Harrison.
Post-doctoral Investigator. Institute of Marine Resources, Scripps Institution of Oceanography, San Diego, California. 1986-1987. Advisor R.W. Eppley

APPOINTMENTS

Senior Research Scientist, Bigelow Laboratory for Ocean Sciences, 1995-present. http://www.bigelow.org/research/srs/william_m_balch/
Research Faculty, Colby College, 2010-present.
Adjunct Professor. Div. Life Sciences, University of New England, Biddeford, ME. 1996-2005
Associate Professor. Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida. 1992-1995. Tenure awarded 6/94.
Assistant Professor. Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida. 1988-1992.

PUBLICATIONS

Five Publications Most Closely Related to Proposed Work

Balch, W. M., Bates, N. R., Lam, Phoebe J., Twining, B. S. , Rosengard, S. Z., Bowler, B.C., Drapeau, D.T., Garley, R., Lubelczyk, L., Mitchell, C. E., Rauschenberg, S. (2016), Factors regulating the Great Calcite Belt in the Southern Ocean and its biogeochemical significance, *Global Biogeochem. Cycles*, *10.1002/2016GB005414*.

Rivero-Calle, S., DelCastillo, C.E., Gnanadesikan, A., **Balch, W.M.**, Guikema, S.D., 2015. Increase of coccolithophorids in the North Atlantic over recent decades. **Science**. 350:6267, 1533-1537. *DOI:* 10.1126/science.aaa8026.

Rosengard, S.Z., Lam, P.J., **Balch, W.M.**, Auro, M.E., Pike, S.M., Drapeau, D.T., Bowler, B.C., 2015. Carbon export and transfer to depth across the Southern Ocean Great Calcite Belt. Biogeosciences. 12: 3953–3971, 2015 www.biogeosciences.net/12/3953/2015/ ; doi:10.5194/bg-12-3953-2015.

Balch, W.M., Drapeau, D. T., Bowler, B. C., Lyczkowski, E., Lubelczyk, L. C., Poulton, A. J., and Painter, S. C., 2014, Surface biological, chemical and optical properties of the Patagonian Shelf coccolithophore bloom, the brightest waters of the Great Calcite Belt: Limnology and Oceanography. 59 (5): 1715-1732.

Balch WM, Drapeau DT, Bowler BC, Booth ES, Lyczskowski E, Alley D (2011) The contribution of coccolithophores to the optical and inorganic carbon budgets during the Southern Ocean Gas Experiment: New evidence in support of the "Great Calcite Belt" hypothesis. **Journal of Geophysical Research-Oceans** Special Issue. VOL. 116, C00F06, doi:10.1029/2011JC006941.

Five Other Publications related to project

Poulton, A.J., Painter, S., Young, J.R., Bates, N.R., Bowler, B.C., Drapeau, D.T., Lyczskowski, E., **Balch, W.M.** 2013. The 2008 *Emiliania huxleyi* bloom along the Patagonian Shelf: Ecology, biogeochemistry and cellular calcification. Global Biogeochemical Cycles. 27: 1-11. DOI: 10.1002/2013GB004641

Balch W.M., Poulton A., Drapeau D, Bowler B, Windecker L., and Booth. E.S. (2011) Zonal and meridional patterns of phytoplankton biomass and carbon fixation in the Equatorial Pacific Ocean, between 110°W and 140°W. **Deep-Sea Research II**. 58: 400-416. doi:10.1016/j.dsr2.2010.08.004.

Balch, W.M., Bowler, B.C., Drapeau, D. T., Poulton, A., and Holligan, P. Biominerals and the vertical flux of particulate organic carbon from the surface ocean. (2010) **Geochemical Research Letters.** *37* (L22605), 1-6doi:10.1029/2010GL044640.

Balch, W. M., Howard Gordon, B. C. Bowler, D. T. Drapeau, E. S. Booth. 2005. Calcium carbonate measurements in the surface global ocean based on MODIS Data. **Journal of Geophysical Research-Oceans**. **110**, C07001 doi:10.1029/2004JC002560.

Gordon, H. R., G. C. Boynton, **W.M. Balch**, et al. 2001. Retrieval of Coccolithophore Calcite Concentration from SeaWiFS Imagery. **Geophysical Research Letters**, 28: 1587-1590.

SYNERGISTIC ACTIVITIES

-Leader of **G**ulf of Maine **N**. **A**tlantic **T**ime **S**eries (GNATS), a 19-year, NASA time series sampling across the Gulf of Maine which documents long-term change in bio-optical variables and ecosystem variability and their connections to satellite remote sensing of ocean color. The GNATS program now includes seasonal deployments of a Slocum glider.

-Appointed to the Subcommittee on Ocean Acidification (part of the U.S. Ocean Carbon and Biogeochemistry Program) September 2008 to 2011.

-NASA Ocean Color Research Teams; SeaWiFS (1992-2010), MODIS (1996-present) and NPP/VIIRS (May, 2011-present).

-Ocean Carbon and Biogeochemistry (OCB) Steering Committee, 2012 (3 year term).

- Councilor for Biological Oceanography -The Oceanography Society (2015-present)

Nicholas R. Bates

Senior Research Scientist[1] and Director of Research[2]
Bermuda Institute of Ocean Sciences (BIOS), 17 Biological Station Lane, Ferry Reach, GE01, Bermuda
Tel: 441-297-1880 x209; Fax: 441-297-8143; e-mail: nick.bates@bios.edu; http://www.bios.edu
Professor of Ocean Biogeochemistry[3], Dept. of Ocean and Earth Science (OES), Univ.of Southampton, Southampton, UK.

a. **Professional preparation:**

2015	D.Sc., *Oceanography* (second doctorate), University of Southampton, UK
1995	Ph.D., *Oceanography (Chemical and Biological)*, Univ. of Southampton, UK
1990	M.Sc., *Geochemistry*, Brock University, Canada.
1985	B.Sc. (Honours), *Geology*, Kings College, University of London, U.K.

b. **Professional appointments:**

2013-present	Professor of Ocean Biogeochemistry[3] (joint appointment), Ocean and Earth Sciences, Univ. of Southampton, UK
2011-2012	Interim Director, BIOS (Nov 2011-Sept 2012)
2005-present	Director of Research[2], BIOS
2004-present	Adjunct Full Professor, CMES, Univ. of Delaware.
2002-present	Senior Scientist[1], BIOS
2001-2007	Adjunct Associate then Adjunct Full Professor (2004-2007), Duke University
1999-2002	Assistant Scientist (1996-1998) and Associate Scientist (1998-2002), BIOS.
1995	Staff Scientist (1991-1994) and Postdoctoral Research Associate (1995), BIOS
1990-1991	Lecturer, Centre of Earth and Ocean Res., University of Victoria, Canada
1989-1990	Specialist Instructor, Dept. Geography, University of Victoria, Canada
1987-1989	Graduate Research Assistant, Dept. of Geol. Sciences, Brock Univ., Canada
1985-1986	Petroleum Geologist, Deminex Oil and Gas Ltd, U.K.

c1. **Five most relevant papers/products (of ~150 peer-review papers)**

1. Bates, N.R., 2017. Twenty years of marine carbon cycle observations at Devils Hole Bermuda provide insights into seasonal hypoxia, coral reef calcification and ocean acidification. *Frontiers in Marine Science* **4** (Article 36); February 2017; doi: 10.3389/fmars.2017.00036.
2. Bates, N.R., Astor, Y.M., Church, M.J., Currie, K., Dore, J.E., Gonzalez-Davila, M., Lorenzoni, L., Muller Karger, F.E., Olafsson, J., and Santana-Casiano, J.M., 2014. Changing ocean chemistry: A time-series view of ocean uptake of anthropogenic CO_2 and ocean acidification. *Oceanography*. http://dx.doi.org/10.5670/oceanog.2014.03
3. Bates, N.R., Garley, R., Frey, K., Shake, K., and Mathis, J.T., 2014. Sea-ice melt CO_2-carbonate chemistry in the western Arctic: meltwater contributions to air-sea CO_2 gas exchange, mixed layer properties and rates of net community production. *Biogeosciences*, 11, 6769-6789, doi: 10.5194/bg-11-6769-2014.
4. Bates, N.R., 2015. Assessing ocean acidification variability in the Pacific–Arctic Region (PAR) as part of the Russian–American Long–term Census of the Arctic (RUSALCA). *Oceanography,* 28(3*),* 36–45, http://dx.doi.org/10.5670/oceanog.2015.56.
5. Bates, N.R., Orchowska, M.I., Garley, R., and Mathis, J.T., 2013. Summertime calcium carbonate undersaturation in shelf waters of the western Arctic Ocean – how biological processes exacerbate the impact of ocean acidification. *Biogeosciences*, **10**, 5281-5309, doi: 10:105194/bg/bg-10-5281-2013.

c2. **Five other relevant papers/products**

6. Bates, N.R., 2012. Multi-decadal uptake of carbon dioxide into subtropical mode waters of the North Atlantic Ocean. *Biogeosciences*, 9, 2649-2659, doi: 10.10.5194/bg-9-2649-2012.

7. Bates, N.R., Best, M.H., Neely, K., Garley, R., Dickson, A.G., and Johnson, R.J., 2012. Indicators of anthropogenic carbon dioxide uptake and ocean acidification in the North Atlantic Ocean. *Biogeosciences,* **9**, 2509-2522, doi: 10.10.5194/bg-9-2509-2012.
8. Bates, N.R., Amat, A., and Andersson, A.J., 2010. The interaction of carbonate chemistry and coral reef calcification: the carbonate chemistry coral reef ecosystem feedback (CREF) hypothesis. *Biogeosciences,* **7** (5), 2509-2530, doi:10.5194/bg-7-2509-2010.
9. Bates, N.R., Jeffries, M.A., and Mathis, J.T., 2011. Air-sea CO_2 fluxes in the Bering Sea. *Biogeosciences*, **8**(5), 1237-1253, doi: 10.5194/bg-8-1237-2011.
10. Bates, N.R., Cai, W.-J., and Mathis, J.T., 2011. The ocean carbon cycle in the western Arctic Ocean: Distributions and air-sea fluxes of carbon dioxide (CO_2). *Oceanography,* 24(3), 186-201, doi: 10.5670/oceanog.2011.71; http://dx.doi.org/10.5670/oceanog. 2011.71.

d. **Synergistic activities**

- Participation in national and international committees and working groups, including peer review panels for NSF, DOE, NOAA and NASA, and more recently a NERC Arctic Scoping Group (May 2015). Research interests include ocean biogeochemical cycling of carbon, nitrogen and dissolved organic matter; physical and biological processes influencing ocean-atmosphere gas exchange of CO_2; coupling between ocean biogeochemical processes and climate variability; calcifying phytoplankton and subpolar/polar ocean chemistry and ecosystems (>40 papers).
- IOC-UNESCO member of SSG for the *One Ocean, One Planet* meeting in Brazil, 2015. Member of IOC-UNESCO working group International Group for Marine Ecological Time-series (IGMETS; 2013 to present).
- Lecturer and course curriculum for undergraduate/graduate level courses at BIOS, including course on *Ocean Acidification* as part of the POGO/Nippon Foundation sponsored 10 month internship at BIOS and Duke University-BIOS joint program including *Marine Biogeochemistry* (1997), *Marine Microbial Ecology* (1999, 2000)*, Environmental Principles and Policy* (1997-2004, 2006), *Modern Observational Oceanography* (BIOS, June, 2016) and graduate course at University of Southampton (SOES-6073; May 2015; May 2016)
- Scientific steering group member of the U.S. Carbon Cycle (CCSSG) group supporting the CCIWG for federal agencies; past SSG member of the IOC-UNESCO International Ocean Carbon Coordination Project (IOCCP); member SOLAS-IMBER working group on surface observations, CarboOCEAN (working groups for North Atlantic and Arctic Ocean); Pacific Arctic Group (PAG) member Arctic carbon synthesis (2009); Surface Ocean CO_2 Atlas (SOCAT) Project member.
- Contributor to the IPCC 4th assessment chapter (Bindoff *et al*. 2007) and 5th assessment (Rhein *et al*., 2013); SOLAS-IMBER carbon implementation report (2005); chapter on Arctic Ocean carbon fluxes for WWF report (2009); contributor to EPA on ocean change reports.

Biographical Sketch

Matthew C. Long
National Center for Atmospheric Research
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(a) Professional Preparation

Tufts University	Medford, MA	Environmental Engineering	B.S.	1998
Tufts University	Medford, MA	Environmental Engineering	M.S.	2000
Stanford University	Stanford, CA	Oceanography	Ph.D.	2010
National Center for Atm. Res.	Boulder, CO	Postdoc in Oceanography	2010–2012	

(b) Appointments

2014–present **Scientist I**, National Center for Atmospheric Research, Climate and Global Dynamics Laboratory, Oceanography Section

2012–2014 **Project Scientist I**, National Center for Atmospheric Research, Climate and Global Dynamics Division, Oceanography Section

2010–2012 **Postdoctoral Fellow**, Advanced Study Program, National Center for Atmospheric Research, Climate and Global Dynamics Division

2005–2010 **Research Assistant**, Stanford University

2004–2009 **Teaching Assistant**, Stanford University

2003–2004 **Water Resources Engineer**, Camp Dresser & McKee Inc., Cambridge, MA

2003 **Field and Laboratory Technician**, Desert Research Institute, Reno, NV

2000–2002 **High School Physics & Geography Teacher**, US Peace Corps, Ashira Girls Secondary School, Marangu, Tanzania

1998–2000 **Teaching Assistant**, Tufts University, Dept of Civil and Env. Engineering

1999 **Environmental Analyst**, MA Dept of Public Health

(c) Publications

(i) Five most relevant publications:

[1] **Long, M. C.**, C. A. Deutsch, and T. Ito, 2016: Finding forced trends in oceanic oxygen. *Global Biogeochem. Cycles*, 30, doi:10.1002/2015GB005310.

[2] **Long, M. C.**, K. Lindsay, and M. M. Holland, 2015: Modeling photosynthesis in sea ice covered waters. *J. Adv. Model. Earth Syst.*, **07**, doi:10.1002/2015MS000436.

[3] **Long, M. C.**, K. Lindsay, S. Peacock, J. K. Moore, and S. C. Doney, 2013: Twentieth-Century Oceanic Carbon Uptake and Storage in CESM1(BGC). *J. Climate*, **26 (18)**, 6775–6800, doi:10.1175/JCLI-D-12-00184.1.

[4] **Long, M. C.**, L. N. Thomas, and R. B. Dunbar, 2012: Control of phytoplankton bloom inception in the Ross Sea, Antarctica, by Ekman restratification. *Global Biogeochem. Cycles*, **26 (1)**, GB1006, doi:10.1029/2010GB003982.

[5] **Long, M. C.**, R. B. Dunbar, P. D. Tortell, W. O. Smith, D. A. Mucciarone, and G. R. DiTullio, 2011: Vertical structure, seasonal drawdown, and net community production in the Ross Sea, Antarctica. *J. Geophys. Res.*, **116 (C10029)**, doi:10.1029/2009JC005954.

(ii) Five other significant publications:

[1] McKinley, G. A., D. J. Pilcher, A. R. Fay, K. Lindsay, **M. C. Long**, and N. Lovenduski, 2016: Timescales for detection of trends in the ocean carbon sink. *Nature*, **530**, 469–472, doi:10.1038/nature16958.

[2] Bishop, S. P., P. R. Gent, F. O. Bryan, A. F. Thompson, **M. C. Long**, and R. Abernathy, 2016: Southern Ocean Overturning Compensation in an Eddy-Resolving Climate Simulation. *J. Phys. Oceanogr.*, **46 (5)**, doi:10.1175/JPO-D-15-0177.1.

[3] Moore, J. K., K. Lindsay, S. C. Doney, **M. C. Long**, and K. Misumi, 2013: Marine ecosystem dynamics and biogeochemical cycling in the Community Earth System Model [CESM1(BGC)]: Comparison of the 1990s with the 2090s under the RCP4.5 and RCP8.5 scenarios. *J. Climate*, **26 (23)**, 9291–9312, doi:10.1175/JCLI-D-12-00566.1.

[4] Tortell, P. D., **M. C. Long**, C. D. Payne, A.-C. Alderkamp, P. Dutrieux, and K. R. Arrigo, 2012: Spatial distribution of pCO_2, ΔO_2/Ar and dimethylsulfide (DMS) in polynya waters and the sea ice zone of the Amundsen Sea, Antarctica. *Deep Sea Res., Part II*, **71**, 77–93, doi:10.1016/j.dsr2.2012.03.010.

[5] Tortell, P. D. and **M. C. Long**, 2009: Spatial and temporal variability of biogenic gases during the Southern Ocean spring bloom. *Geophy. Res. Lett.*, **36**, L01603, doi:10.1029/2008GL035819.

(d) Synergistic Activities

2015	Steering group and writing team member for the NASA Ocean Biology and Biogeochemistry Advanced Science Plan and pre-Decadal Survey Report
2013	Lead organizer of the 2013 NCAR Advanced Study Program Graduate Student Colloquium: *Carbon-climate connections in the Earth System* http://www2.cgd.ucar.edu/events/asp-colloquium-2013
2012-2015	Member: CLIVAR/OCB Working Group, Oceanic carbon uptake in CMIP5 models
2010-present	Reviewer: *Biogeosciences*, *J. Climate*, *Geophys. Res. Let.*, *J. Geophys. Res.*, *Mar. Ecol. Prog. Ser.*, *J. Mar. Sys.*
2006	Antarctic Service Medal

Dennis Joseph McGillicuddy, Jr.

Senior Scientist
Department of Applied Ocean Physics and Engineering
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

phone: 508-289-2683
fax: 508-457-2194
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Professional Preparation:

1987 B.A., *cum laude*, Engineering Sciences, Harvard College, Cambridge, MA.
1989 M.S., Applied Physics, Harvard University, Cambridge, MA.
1993 Ph.D., Earth and Planetary Sciences, Harvard University, Cambridge, MA.

Appointments:

2007-Present Senior Scientist, Woods Hole Oceanographic Institution.
1999-2007 Associate Scientist (tenure in 2003), Woods Hole Oceanographic Institution.
1995-1999 Assistant Scientist, Woods Hole Oceanographic Institution.
1993-1995 Postdoctoral Scholarship, Woods Hole Oceanographic Institution.
1993-1995 Modeling Fellowship, University Corporation for Atmospheric Research.
1990-1993 Research Assistant, Harvard University.
1989 Visiting Scientist, Institut Für Meereskunde, Kiel, Germany.
1987-1990 Graduate Fellowship, Office of Naval Research.

Products Most Relevant to Proposal:

1. **McGillicuddy, D.J.**, Robinson, A.R., Siegel, D.A., Jannasch, H.W., Johnson, R., Dickey, T.D., McNeil, J., Michaels, A.F., and A.H. Knap, 1998. Influence of mesoscale eddies on new production in the Sargasso Sea. *Nature*, **394**, 263-265.
2. Davis, C.S. and **McGillicuddy, D.J.**, 2006. Transatlantic Abundance of the N2-Fixing Colonial Cyanobacterium *Trichodesmium*. *Science*, **312**, 1517-1520.
3. **McGillicuddy, D.J.**, Anderson, L.A., Bates, N.R., Bibby, T., Buesseler, K.O., Carlson, C.A., Davis, C.S., Ewart, C., Falkowski, P.G., Goldthwait, S.A., Hansell, D.A., Jenkins, W.J., Johnson, R., Kosnyrev, V.K., Ledwell, J.R., Li, Q.P., Siegel, D.A. and D.K. Steinberg, 2007. Eddy/Wind Interactions Stimulate Extraordinary Mid-Ocean Plankton Blooms. *Science*, **316**, 1021-1026.
4. **McGillicuddy, D.J.**, Sedwick, P.N., Dinniman, M.S., Arrigo, K.R., Bibby, T.S., Greenan, B.J.W., Hofmann, E.E., Klinck, J.M., Smith, W.O., Mack, S.L., Marsay, C.M., Sohst, B.M., and G.L. van Dijken, 2015. Iron supply and demand in an Antarctic shelf ecosystem. *Geophysical Research Letters*, **42**, doi:10.1002/2015GL065727.
5. **D.J. McGillicuddy**, 2016. Mechanisms of physical-biological-biogeochemical interaction at the oceanic mesoscale. *Annual Review of Marine Science*, **8**, 125-159, DOI: 10.1146/annurev-marine-010814-015606.

Other Significant Products:

1. **McGillicuddy, D.J.** and A. Bucklin, 2002. Intermingling of two *Pseudocalanus* species on Georges Bank. *Journal of Marine Research*, **60**, 583-604.
2. **McGillicuddy, D.J.**, Anderson, L.A., Doney, S.C., and M.E. Maltrud, 2003. Eddy-driven sources and sinks of nutrients in the upper ocean: results from a 0.1 degree resolution model of the North Atlantic. *Global Biogeochemical Cycles*, **17**(2), 1035, doi:10.1029/2002GB001987.

3. **McGillicuddy, D.J.**, Anderson, D.M., Lynch, D.R. and D.W. Townsend, 2005. Mechanisms regulating the large-scale seasonal fluctuations in *Alexandrium fundyense* populations in the Gulf of Maine. *Deep-Sea Research II*, **52**, 2698-2714.
4. **McGillicuddy, D.J.**, 2011. Eddies Masquerade as Planetary Waves. *Science*, **334**, 318-319.
5. **McGillicuddy, D.J.**, 2015. Formation of intra-thermocline lenses by eddy-wind interaction. *Journal of Physical Oceanography*, **45**, 606-612, DOI: 10.1175/JPO-D-14-0221.1.

Synergistic Activities

- Development and presentation of a public outreach lecture "Oases in the Oceanic Desert: Turbulent Storms in the Sea and their Impact on Biological Productivity."
- Service on national and international scientific steering committees (U.S. JGOFS, U.S. GLOBEC, GEOHAB).
- Teaching in the MIT/WHOI Joint Program; guest lectures in undergraduate and graduate level courses in ocean science.
- Development of a general computational tool for inversion of the two-dimensional advection-diffusion reaction equation ("Scotia 1.0").

Biographical Sketch

Peter L. Morton
Florida State University
National High Magnetic Field Laboratory
Tallahassee, Florida 32310-3706
Phone: (850) 644-4331
Fax: (850) 644-0827
E-mail: pmorton@fsu.edu

A. Professional Preparation

George Mason University, Fairfax, VA	Chemistry	BA, 1996
Old Dominion University, Norfolk, VA	Chemistry	MS, 2003
Old Dominion University, Norfolk, VA	Oceanography	PhD, 2010

B. Appointments

2014-present Assistant In Research OPS, Florida State University, National High Magnetic Field Laboratory, Tallahassee, FL
2009-2014 Post-Doctoral Research Associate, Florida State University, Tallahassee, FL

C. Products

Five products Most Closely Related to the Proposed Project

1. Grand, M.M., Measures, C.I., Hatta, M., **Morton, P.L.**, Barrett, P., Milne, A., Resing, J.A., Landing, W.M., 2015. The impact of circulation and dust deposition in controlling the distributions of dissolved Fe and Al in the south Indian subtropical gyre. Mar. Chem. 176, 110–125. doi:10.1016/j.marchem.2015.08.002.
2. Twining, B.S., Rauschenberg, S., **Morton, P.L.**, Vogt, S., 2015. Metal contents of phytoplankton and labile particulate material in the North Atlantic Ocean. Prog. Oceanogr. 137, 261–283. doi:10.1016/j.pocean.2015.07.001.
3. **Morton, P.L.**, Landing, W.M., Hsu, S.-C., Milne, A., Aguilar-Islas, A.M., Baker, A.R., Bowie, A.R., Buck, C.S., Gao, Y., Gichuki, S., Hastings, M., Hatta, M., Johansen, A.M., Losno, R., Mead, C., Patey, M., Swarr, G., Vandermark, A., Zamora, L.M, 2013. Methods for the sampling and analysis of marine aerosols: results from the 2008 GEOTRACES aerosol intercalibration experiment. Limnology and Oceanography: Methods 11, 62-78. doi:10.4319/lom.2013.11.62.
4. Zurbrick, C.M., **Morton, P.L.**, Gallon, C., Shiller, A.M., Landing, W.M., Flegal, A.R., 2012. Intercalibration of cadmium and lead concentration measurements in the northwest Pacific Ocean. Limnology and Oceanography: Methods 10, 270-277. doi:10.4319/lom.2012.10.270.
5. Milne, A., Landing, W.M., Bizimis, M., **Morton, P.L.**, 2010. Determination of Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb in seawater using high resolution magnetic sector inductively coupled mass spectrometry (HR-ICP-MS). Analytica Chimica Acta 665 (2), 200-207. doi:10.1016/j.aca.2010.03.027.

Five Other Significant Products

None by choice

D. Synergistic Activities

- Reviewer: Marine Chemistry, Deep Sea Research, Geophysical Research Letters, Progress in Oceanography, International Journal of Environmental Analytical Chemistry, Journal of Marine Systems.
- Session organizer: 2013 Aquatic Sciences Meeting, 2016 Ocean Sciences Meeting

- Contributor, Marine suspended particulate material intercalibration, 2010-2013. SCOR particulate intercalibration workshop, March 2013, University of Hawaii-Manoa Submitted results to B.S. Twining (Bigelow) and P.J. Lam (WHOI) for Al, Ti, Pb, P and bioactive trace metals
- Coordinator, Trace metal sample collection, U.S. GEOTRACES intercalibration cruises, 2008-2009, U.S. GEOTRACES North Atlantic cruises, 2010-2011
- Contributor, SAFe and GEOTRACES consensus material multi-element project, 2008-current. Submitted results to K. Bruland (UCSC) for total dissolved Fe, Mn, Cd, Co, Cu, & Pb

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Bigelow Laboratory for Ocean Sciences

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William Balch

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. **William M Balch - Senior Research Scientist**	3.00	0.00	0.00	**42,996**	
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)	3.00	0.00	0.00	**42,996**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**4**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.50	0.00	0.00	**60,289**	
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)				**103,285**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**51,642**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**154,927**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,500**	
2. INTERNATIONAL				**19,815**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **2,500**					
2. TRAVEL **7,926**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**2**) TOTAL PARTICIPANT COSTS				**10,426**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**39,651**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**40,500**	
TOTAL OTHER DIRECT COSTS				**80,151**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**266,819**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 67.0000, Base: 256394)**					
TOTAL INDIRECT COSTS (F&A)				**171,784**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**438,603**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**438,603**	

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

PI/PD NAME
William Balch

ORG. REP. NAME*
James McManus

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION: **Bigelow Laboratory for Ocean Sciences**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **William Balch**

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. **William M Balch - Senior Research Scientist**	3.00	0.00	0.00	**43,856**	
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)	3.00	0.00	0.00	**43,856**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**4**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.50	0.00	0.00	**61,495**	
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)				**105,351**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**52,675**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**158,026**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,530**	
2. INTERNATIONAL				**20,211**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **2,550**					
2. TRAVEL **8,085**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**2**) TOTAL PARTICIPANT COSTS				**10,635**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**40,444**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**36,414**	
TOTAL OTHER DIRECT COSTS				**76,858**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**267,260**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 67.0000, Base: 256626)**					
TOTAL INDIRECT COSTS (F&A)				**171,939**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**439,199**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**439,199**	

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

PI/PD NAME: **William Balch**

ORG. REP. NAME*: **James McManus**

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
Bigelow Laboratory for Ocean Sciences

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William Balch

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. **William M Balch - Senior Research Scientist**	2.00	0.00	0.00	**29,822**	
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)	2.00	0.00	0.00	**29,822**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**3**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.00	0.00	0.00	**24,742**	
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)				**54,564**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**27,282**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**81,846**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,561**	
2. INTERNATIONAL				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **6,500**					
2. TRAVEL **1,500**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**1**) TOTAL PARTICIPANT COSTS				**8,000**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**2,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,500**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**15,240**	
TOTAL OTHER DIRECT COSTS				**18,740**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**110,147**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 67.0000, Base: 88947)**					
TOTAL INDIRECT COSTS (F&A)				**59,594**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**169,741**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**169,741**	

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

PI/PD NAME
William Balch

ORG. REP. NAME*
James McManus

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
Bigelow Laboratory for Ocean Sciences

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William Balch

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. **William M Balch - Senior Research Scientist**	2.00	0.00	0.00	**30,418**	
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)	2.00	0.00	0.00	**30,418**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**3**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	5.00	0.00	0.00	**25,236**	
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)				**55,654**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**27,827**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**83,481**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,592**	
2. INTERNATIONAL				**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				**1,530**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**2,061**	
TOTAL OTHER DIRECT COSTS				**5,591**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**90,664**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 67.0000, Base: 90666)**					
TOTAL INDIRECT COSTS (F&A)				**60,746**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**151,410**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**151,410**	

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

PI/PD NAME
William Balch

ORG. REP. NAME*
James McManus

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
Bigelow Laboratory for Ocean Sciences

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
William Balch

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. **William M Balch - Senior Research Scientist**	10.00	0.00	0.00	**147,092**	
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)	10.00	0.00	0.00	**147,092**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**14**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	35.00	0.00	0.00	**171,762**	
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)				**318,854**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**159,426**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**478,280**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**6,183**	
2. INTERNATIONAL				**40,026**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **11,550**					
2. TRAVEL **17,511**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**5**) TOTAL PARTICIPANT COSTS				**29,061**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**84,095**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**3,030**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**94,215**	
TOTAL OTHER DIRECT COSTS				**181,340**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**734,890**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**464,063**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,198,953**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,198,953**	

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

PI/PD NAME
William Balch

ORG. REP. NAME*
James McManus

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget justification (Balch)
Bigelow Laboratory for Ocean Sciences is a non-profit [501(c)(3)] research and education organization subject to *CFR 200 OMB's Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards.* The Senior Research Scientists (SRS) at Bigelow are responsible for conceiving, funding, and carrying out their research programs. SRS receive up to 2 months of Laboratory support per calendar year for time spent writing proposals and for participating in non-grant related activities. SRS are expected to raise the rest of their salary for themselves and their staff by writing proposals and obtaining sponsored research grants and contracts from a variety of sources. NSF has confirmed that salary support beyond 2 months per year can be justifiable for Bigelow SRS.

Salaries and wages:
Support is requested for PI Balch (3, 3, 2, 2 months per year of the project) who will coordinate the overall project, participate in the two cruises, as well as oversee the radioisotope calcification work, coccolithophore sampling and analytical work (PIC, POC, chlorophyll, bSi, FlowCAM, SEM), sampling and nutrient limitation experiments on the cruise. Support is also requested for a Senior Research Associate (D. Drapeau; 3, 3, 2 and 2 months) who will be in charge of cruise preparations/shipping, participate in the cruises and coordinate the overall cruise logistics for the Balch lab. He will be involved in the calcification/primary productivity sampling and data work-up post cruise. Support is requested for a Senior Research Associate (Bruce Bowler; 3, 3, 1 and 1 months) in the four years of the project) who will be responsible for all electronic data acquisition/data storage/data archiving during the cruises and post cruise. Mr. Bowler also attends to day-to-day data checks, validation and quality control issues and is responsible for data submission to BCO-DMO. He also will be responsible for satellite image analysis during the cruise and post cruise analysis of the remotely-sensed data. Support is requested for a research technician (Amy Wyeth; 3.73, 3.73, 2 and 2 in the four-year project). She will participate in the research cruise, assist with cruise preparation, be responsible for preparation, acquisition and workup of cell count, FlowCAM, BSi, SEM analyses. She also assists in data analysis and visualization using Ocean Data View. Support is also requested for a Senior Research Associate, Sara Rauschenberg (2.77, 2.77, 0, 0 months per year in the four year project). She will be aiding Pete Morton during the cruise years. She will undertake cruise preparations, participate in the cruises, and help with the dissolved and particulate Fe analyses. This salary time request includes compensatory sea pay for the two cruises.

A labor month is equal to 163 hours. Vacations, holidays, sick time, and other paid absences are included in Employee Benefits. Salary costs are for actual research time. The fringe rate of 50% includes 19% paid leave (vacation, holiday, sick) and 31% paid benefits.

Equipment: No capital equipment is being requested in this proposal

Travel:
Balch
Domestic Travel is budgeted for $1,500, $1,530, $1,561 and $1,592 (including a 2% annual inflation rate) for years 1-3, respectively. This will support attendance of WMB to one domestic oceanography meeting each year.
International Travel is budgeted for Balch, Drapeau, Bowler, Wyeth and Rauschenberg to participate in the research cruises out of Durban, South Africa. This includes costs for bus, taxi, airfare, per diem (GSA authorized meals & incidentals for Durban as of this writing are $237 plus $81, respectively) with four days in port prior to sailing and 2 days in port following the cruise. The total foreign travel cost will be $19,815 in year 1 and $20,211 in year 2 (assuming 2% inflation).

Participant support: Funds are requested for a student stipend ($2,500) and travel expenses ($7,926) for an undergraduate student and high school teacher to participate in the cruise. Travel funds are also requested in year 2 for a student stipend ($2,550) and funds to bring a student and high school teacher to

sea ($8,085). For year 3, funds are requested for an REU student to work in the Balch lab on sampling processing and data analysis. They will do independent research over 10 weeks with the cruise data set as part of their summer experience. The stipend for this 10-week experience is $5,000 and housing costs at Bigelow in the summer cost $150/week (or $1,500 per student for the 10 weeks). Funds are requested for the REU student to attend a domestic science meeting and present their results in year 3.

Other direct costs:
Materials and supplies
Balch
Funds are requested to cover the costs of a) consumables and processing cruise samples and experimental samples. Costs for consumables and analysis costs are budgeted at $39,651, $40,444, $ 2,000 and $2,000 over the 4-year period of the project. The year 1 and 2 requests include costs to sample an average of 76 depth profiles over the cruise for particulate inorganic carbon ($14.00 per sample), biogenic silica ($6 per sample), POC ($15), chlorophyll *a* ($1.50) cell counts ($5 per sample), SEM ($2.00 per sample in supplies, SEM cost on the Bigelow Zeiss SEM is $50 per sample) and FlowCam ($6 per sample). The microdiffusion calcification technique involves the following consumables and other miscellaneous costs: ^{14}C-bicarbonate radioisotope, consumable items such as gloves, pipette tips, diaper paper, 0.4 μm pore-size polycarbonate filters, polycarbonate incubation bottles, phosphoric acid, phenethylamine, scintillation vials, rubber septa with hanging buckets, scintillation cocktail plus radioisotope shipping and disposal and the total cost per water sample (which includes three replicate subsamples plus one formalin-killed control per water sample) is $37.90/sample). Depth profiles for calcification and photosynthesis have been planned for 34 stations over the duration of the cruise. For the incubation experiments at 4 stations (two eddy stations (PIC-rich; low PIC eddy) sampled twice over the cruise), samples will be processed for chlorophyll, POC, PIC, BSi, coccolithophore counts, FlowCAM, SEM and calcification/photosynthesis. The year 2 request is 2% more expensive to account for inflation. The year 3 and 4 supply requests cover costs associated with the environmentally safe disposal of samples and used reagents. Costs for in-house processing of SEM samples are $13,200 in year 3. Costs for software upgrades and annual licenses are included here ($1,000, $1,020, $1,040, $1,061 for years 1-4, respectively).

Publication costs
Balch
Publication costs are included at $1,500 and $1530 per year in years 3 and 4, respectively.

Other costs:
Balch
Shipping costs (and associated insurance) are estimated to be $27,200 in year 1 ($12,000 each way for Balch gear, $2,000 insurance and $1,200 for shipping costs incurred for standard purchases) and $27,744 in year 2 (2% more with inflation). Calibrations are critical for the accuracy of our underway measurements. Funds for instrument calibration for Balch's underway system (5 instruments total) are estimated at $1,500 per instrument. Costs for CFC analysis at the University of Miami (Dr. Rana Fine laboratory) are $100 per sample and we have budgeted 48 samples to be collected along the meridional transect (see support letter from Dr. Fine).

Bigelow calculates the overhead rate (67%) as a percent of modified total direct costs, as allowed by *CFR 200 OMB Uniform Guidance*. The base excludes participant support costs, subaward amounts over the first $25,000, ship-time in excess of $5,000 per year, in-house fees for service and capital equipment. Bigelow cannot "waive" or reduce overhead rates on any sponsored research project due to the structure of our negotiated rate agreement with NSF. When a program sets limits on overhead, Bigelow must use Laboratory unrestricted funds (usually from our Annual Fund) to pay the unfunded portion of the indirect costs.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Bermuda Institute of Ocean Sciences (BIOS), Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Nicholas Bates

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. **Nicholas R Bates - prof.**	2.00	0.00	0.00	**36,070**	
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)	2.00	0.00	0.00	**36,070**	
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.)	7.00	0.00	0.00	**33,280**	
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)				**69,350**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**13,730**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**83,080**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**7,530**	
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				**7,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**30,000**	
TOTAL OTHER DIRECT COSTS				**37,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**127,610**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Indirect Cost Recovery of 58% (Rate: 58.0000, Base: 127610)**					
TOTAL INDIRECT COSTS (F&A)				**74,014**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**201,624**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**201,624**	

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

PI/PD NAME
Nicholas Bates

ORG. REP. NAME*
Victoria Millett

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION
Bermuda Institute of Ocean Sciences (BIOS), Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Nicholas Bates

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. **Nicholas R Bates - Prof.**	2.00	0.00	0.00	**37,152**	
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)	2.00	0.00	0.00	**37,152**	
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.)	7.00	0.00	0.00	**34,145**	
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)				**71,297**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**14,109**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**85,406**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**7,755**	
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				**7,210**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**30,900**	
TOTAL OTHER DIRECT COSTS				**38,110**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**131,271**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Indirect Cost Recovery of 58% (Rate: 58.0000, Base: 131271)**					
TOTAL INDIRECT COSTS (F&A)				**76,137**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**207,408**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**207,408**	

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

PI/PD NAME
Nicholas Bates

ORG. REP. NAME*
Victoria Millett

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Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
Bermuda Institute of Ocean Sciences (BIOS), Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Nicholas Bates

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. **Nicholas R Bates - Prof.**	2.00	0.00	0.00	**38,267**	
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)	2.00	0.00	0.00	**38,267**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	3.00	0.00	0.00	**13,506**	
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)				**51,773**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,116**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**60,889**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**2,200**	
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				**1,500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**1,060**	
TOTAL OTHER DIRECT COSTS				**4,560**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**67,649**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Indirect Cost Recovery of 58% (Rate: 58.0000, Base: 67649)**					
TOTAL INDIRECT COSTS (F&A)				**39,236**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**106,885**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**106,885**	

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

PI/PD NAME
Nicholas Bates

ORG. REP. NAME*
Victoria Millett

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
Bermuda Institute of Ocean Sciences (BIOS), Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Nicholas Bates

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. **Nicholas R Bates - Prof.**	2.00	0.00	0.00	**39,415**	
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)	2.00	0.00	0.00	**39,415**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	3.00	0.00	0.00	**13,911**	
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)				**53,326**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,390**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,716**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**2,266**	
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				**1,545**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,060**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**1,092**	
TOTAL OTHER DIRECT COSTS				**4,697**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**69,679**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Indirect Cost Recovery of 58% (Rate: 58.0000, Base: 69679)**					
TOTAL INDIRECT COSTS (F&A)				**40,414**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**110,093**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**110,093**	

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

PI/PD NAME
Nicholas Bates

ORG. REP. NAME*
Victoria Millett

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
Bermuda Institute of Ocean Sciences (BIOS), Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Nicholas Bates

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. **Nicholas R Bates - Prof.**	8.00	0.00	0.00	**150,904**	
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)	8.00	0.00	0.00	**150,904**	
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.)	20.00	0.00	0.00	**94,842**	
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)				**245,746**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**46,345**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**292,091**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**19,751**	
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				**17,255**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**4,060**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**63,052**	
TOTAL OTHER DIRECT COSTS				**84,367**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**396,209**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**229,801**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**626,010**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**626,010**	

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

PI/PD NAME
Nicholas Bates

ORG. REP. NAME*
Victoria Millett

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

This proposal requests funds for the four year project with twocruise planned in the Southern Ocean in 2018 and 2019. These funds will support field and laboratory research on these cruises. Throughout the duration of the project, Bates will oversee cruise and program coordination, sample processing and data analysis, and present research findings at relevant meetings and publish these findings in peer-reviewed journals. The budget runs for four years, allowing cruise participation, sample and data analysis and synthesis in Years 1 to 3, with data synthesis and interpretation in Year 4.

General:

BIOS is a U.S. 501 (c) 3 and 509 (a) not-for profit research and educational institution incorporated in the state of New York, and located on the island of Bermuda. BIOS has an EIN number of **060706038**, a DUNS of **875635161** and awardee organizational code of **4001707000**. There are no sources of hard support to resident scientists, senior research personnel and technicians at BIOS. Therefore, resident scientists at BIOS must raise full salary support (12 months per year) through grant-sponsoring agencies such as NSF, NOAA and NASA.

Personnel:

Two month of support per year is requested for Prof. Nick Bates. Bates will be responsible for project management, supervision and coordination of the field studies, subsequent analyses, and QC/QA of DIC, total alkalinity (TA), pCO_2 and pH datasets in context with biogeochemical and physical datasets from this project, and samples from the experimental manipulations. He will also synthesize the data with other PI's and collaborators in testing of hypotheses developed in this proposal. Bates's lab will be responsible for collection and analyses of DIC and TA as part of the core measurements undertaken as part of the project. Reports will take the form of participation PI meetings, presentations at national meetings, and peer reviewed publications. Bates will supervise the activities of one research specialist and one research technician. Bates has worked for more than fifteen years on polar marine carbon cycle measurements, including the Southern Ocean (COPAS, 2008; Great Belt 2011, 2012), Ross Sea and Arctic field programs.

Seven, months of support are requested in Years 1 and 2 and three months in Years 3 and 4 technician/research specialist time (Rebecca Garley, Keven Neely) related to field sampling, sample analyses, cruise logistical support activities, and data management activities. Time allocation includes: (a) cruise participation; (b) cruise preparation (including instrument, standard and acid preparation), post-cruse breakdown, shipping/receiving, and initial, level 1, QC/QA of DIC/TA datasets; (c) one research specialist to attend cruise planning meeting, and (d) data merging with hydrographic datasets, data visualization in aid of QC/QA activities, data report preparation, data submissions and administrative duties associated with the project.

Sea pay of $60 per day plus fringe benefits (i.e., 2 people per cruise) is also included in the budget.

Fringe Benefits:

All PI and technical salaries are in accordance with current BIOS salary structures, and are assessed a 3% cost-of-living increase each year in compliance with BIOS policy. Fringe benefits are calculated 15% of gross salary in Years 1-5 for the PI and 25% of gross salary for the Research Specialist in Years 1 to 5. This is the average benefits cost for BIOS employees who are non-Bermudian, and reflects the BIOS contributions to health benefits, taxes and pension contributions and is in accordance with BIOS policy

Travel:

Funds are requested in the first year for two people to participate in the Southern Ocean cruise in Year 1 and 2 and investigator meeting in Year 3 and 4 (per NSF Program document 12-500). These costs are budgeted based upon experience attending society meetings and travel to/from Bermuda over the past ten years. All travel originating in Bermuda is considered foreign travel.

Permanent Equipment Costs:

No permanent equipment is requested.

Other Direct Costs:

Supplies and Materials:

In Year 1 and 2, this primarily reflects costs associated with solvents, gases, sample bottles, maintenance of instruments, shipping crates and other expendables used in the field and laboratory analyses. Annual supplies costs are based upon current numbers of samples processed and estimated vender costs. This compares to typical costs associated with other similar projects at BIOS (e.g., SBI, RUSALCA, Bermuda Atlantic Time-series Study). Supplies and materials also include purchase of certified reference materials for alkalinity analyses. Based upon past experience with various venders, these costs are afforded a 3% increase per annum to cover increases in vendor costs. Based upon prior experience (>20 years), costs for consumables for the cruise are budgeted at $7,000 for Years 1 and 2, with $1,500 and $1,545 for minor consumables included in Year 3 and 4. This includes $2,500 for calibration, maintenance costs for the underway SAMI pCO_2 and pH systems we have in the laboratory. Supplies and materials costs include Certified Reference Materials (CRM), coulometer solutions, reagent costs and other associated sample/laboratory analyses costs. We have sufficient Pyrex bottles for DIC/TA samples at BIOS for this project (about $15,000 in value). Publication costs of $2,000 and are included in Year 3 and adjusted for inflation (3%) in Year 4. Communication costs of $1,000 are included in Year 1 and in subsequent years adjusted for inflation (3%).

Publication/Documentation/Commnication:

This line item includes page charges for publication in scientific journals, publishing of technical reports, postage, parcel shipping/delivery (including regular shipping of CTD sensors to SeaBird Electronics for calibration), long distance phone charges, photocopying costs, and other charges associated with the successful completion/documentation of this project.

We request ~$29,000 in Year 1 and 2 for shipping costs associated with the cruise (and shipping of the SAMI sensors to and from Sunburst sensors. This cost is based upon the average shipping cost between BIOS and Durban and back again (based on previous shipping costs for cruises in the western Indian Ocean). Costs are allocated for communications and air-freight of supplies and instruments between BIOS and staging port for the cruises. Shipping costs for the shipping of instruments, purchase and return of certified reference materials, and other field and laboratory supplies and materials are included.

Indirect Costs:

BIOS' Indirect Cost Recovery Rate is computed based on the guidelines established in OMB circular A-122 and is reviewed annually with NSF, our cognizant agency. This rate is currently 58%. All direct costs are subject to this overhead rate, barring equipment and capped subawards.

Table of Salary Commitments: N.R. Bates

Grant	Agency/Grant No.	2017	2018	2019	2020	2021
Current Awards						
A	NOAA NA16GP2009	2.0	2.0	__		
B	NSF-OCE-1258622	4.0	4.0	__		
C	NSF-OCE 1233706	1.0	__			
D	NSF OCE-1153693	1.0	1.0	1.0	1.0	1.0
E	NSF-OPP 1107457	1.0	__			
Pending Awards						
	This Proposal	1.0	1.0	1.0	1.0	1.0

A. NOAA NA16GP2009. N.R Bates; *Initial Steps Towards a Global Surface Water pCO_2 Observing System*, 1 September 2016-31 August 2018, ~$125,000 per annum.

B. NSF OCE-1258622. N.R. Bates, M. Lomas, R. Johnson; *The Bermuda Atlantic Time-series Study (Years 21-25)*, 1 August 2013-30 July 2018, $5,257,102.

C. NSF OCE-1233706. N.R Bates, C.A. Carlson. *Collaborative Research: Seawater Inorganic and Organic Carbon Measurements for the US GEOTRACES Eastern Pacific Zonal Transect.* P.I. N.R. Bates, (BIOS), BIOS budget, $272,076. 1 Feb 2015-31 Jan 2017. Two-year project.

D. NSF OCE-1153693. *The Panulirus Hydrographic Stations: Years 65-69.* P.I. N.R. Bates, (BIOS), BIOS budget, $800,000. Ist April 2017–31st March. 2022

E. NSF OPP-1107457 *Collaborative Research Pacific-Arctic Carbon Synthesis - Transformations, Fluxes, and Budgets.* J.T. Mathis (SFOS-UAF), N.R. Bates, (BIOS), BIOS budget, ~$119,606. 1 October 2011-30 September 7

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
University Corporation For Atmospheric Res

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Matthew Long

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.	0.00	0.00	0.00		
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**0**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**0**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,724**	
2. INTERNATIONAL				**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				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,724**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs, on-site (Rate: 56.9000, Base: 1724)**					
TOTAL INDIRECT COSTS (F&A)				**981**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,705**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**2,705**	

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

PI/PD NAME
Matthew Long

ORG. REP. NAME*
Jeffrey Wild

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

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
Matthew Long

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.	0.00	0.00	0.00		
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. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	1.25	0.00	0.00	**9,639**	
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)				**9,639**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**5,398**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**15,037**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,724**	
2. INTERNATIONAL				**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				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**1,411**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**1,411**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**18,172**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs, on-site (Rate: 56.9000, Base: 16761)**					
TOTAL INDIRECT COSTS (F&A)				**9,537**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**27,709**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**27,709**	

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

PI/PD NAME
Matthew Long

ORG. REP. NAME*
Jeffrey Wild

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
University Corporation For Atmospheric Res

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Matthew Long

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.	0.00	0.00	0.00		
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. (**1**) POST DOCTORAL SCHOLARS	10.32	0.00	0.00	**66,416**	
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)				**66,416**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**37,193**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**103,609**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,724**	
2. INTERNATIONAL				**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				**3,652**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**11,629**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**15,281**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**120,614**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs, on-site (Rate: 56.9000, Base: 108985)**					
TOTAL INDIRECT COSTS (F&A)				**62,012**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**182,626**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**182,626**	

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

PI/PD NAME
Matthew Long

ORG. REP. NAME*
Jeffrey Wild

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
University Corporation For Atmospheric Res

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Matthew Long

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.	0.00	0.00	0.00		
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. (**1**) POST DOCTORAL SCHOLARS	10.32	0.00	0.00	**69,070**	
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)				**69,070**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**38,679**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**107,749**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,724**	
2. INTERNATIONAL				**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				**3,200**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**11,629**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**14,829**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**124,302**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs, on-site (Rate: 56.9000, Base: 112673)**					
TOTAL INDIRECT COSTS (F&A)				**64,111**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**188,413**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**188,413**	

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

PI/PD NAME
Matthew Long

ORG. REP. NAME*
Jeffrey Wild

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
University Corporation For Atmospheric Res

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Matthew Long

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.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**0**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**2**) POST DOCTORAL SCHOLARS	20.64	0.00	0.00	**135,486**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	1.25	0.00	0.00	**9,639**	
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)				**145,125**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**81,270**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**226,395**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**6,896**	
2. INTERNATIONAL				**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				**3,652**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**3,200**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**24,669**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**31,521**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**264,812**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**136,641**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**401,453**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**401,453**	

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

PI/PD NAME
Matthew Long

ORG. REP. NAME*
Jeffrey Wild

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

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

NCAR Budget Justification
2017-0179

Salary and Benefits

Proposed salary expenses are budgeted at 86% of individual annual salaries to include direct labor charges only for time worked. (Vacation, holidays, sick time, and other standard non-worked time are paid from the UCAR benefits pool.) Salary is budgeted with an increase of 4% each fiscal year for inflation.

A. Other Personnel: NCAR requests salary support and benefits for one Postdoctoral Researcher (PDR) at the 1.00 FTE level for the last two years of the project. Under the supervision of NCAR PI Dr. Long, the PDR will have the primary responsibility of conducting the proposed research using the Community Earth System Model (CESM) in conjunction with observations. Year 1 $0.00; Year 2 $0.00; Year 3 $ 66,416; Year 4 $ 69,070, (Salary requested: $135,486).

   NCAR also requests partial salary support and benefits for one Software Engineer/Programmer II (SEII) at the 0.12 FTE level for year 2. Under the supervision of the PIs, the SEII will provide support with technical aspects of using CESM. In particular, this person will assist with the implementation of an explicit calcifier parameterization, as well as assembling data sets, running the model and post-processing output. (Salary requested: $9,639)

   Total Salary requested: **$145,125**

B. Fringe Benefits: Year 1 $0.00; Year 2 $ 5,398; Year 3 $ 37,193; Year 4 $ 38,679 Total: **$81,270**

Total Salaries, Wages, & Fringe Benefits:
Year 1 $0; Year 2 $15,037; Year 3: $103,609; Year 4: $107,749 Total: **$226,395**

C. Equipment: None

D. Travel: **$6,896** is requested for travel, all domestic. This includes, in all 4 years, funds for one annual, 4-day trip for one person to travel to a collaborative meeting at Bigelow to discuss topics related to this effort, estimated to cost $1,724 per year (airfare $736; per diem $179; rental car $300: lodging $459; other cost $50).

   All cost estimates are based on recent NCAR travel rates and include airfare, lodging, ground transportation, IRS-approved per diem rates, and registration fees, if applicable.

E. Participant Support Costs: None

F. Other Direct Costs: **$31,521**
   1. Materials & Supplies: **$3,652** requested on year 3. Funds are requested for a computer and monitor for PDR to connect to the NCAR supercomputers, as well as perform local analyses and writing. The postdoctoral researcher will be exclusively focused on this project, and this system will only be used for the work proposed here.
   2. Publication Costs: **$3,200** requested on year 4. Publication costs/page are budgeted for one journal article at the end of the effort. The estimated publication costs are typical for publications with color graphics in trade journals such as those published by the American Meteorological Society (AMS), Bulletin of the AMS (BAMS) or similar. (Current costs range from $105 - $405 per page, depending on manuscript length, $150-490 for color files, depending on number of files, $800 to provide immediate web access to all on the AMS website.)
   3. Consultant Services: None
   4. ADP/Computer Services: Computing Service Centers (CSC): **$24,669**

(Year 1 $0.00; Year 2 $1,411; Years 3 & 4, $11,629/year) Scientific, computing and networking support costs have been allocated to this project through the Computer Service Center (CSC), in accordance with 2 CFR 200, OMB Uniform Guidance, and NCAR management policy allocating the costs of scientific computing system infrastructure. Indirect costs are not applied to CSC costs.

5. Subawards: None
6. Other: None

G. Total Direct Costs (A through G): **$264,812**

H. Indirect Costs: Modified Total Direct Costs (MTDC) of 56.9% applied to MTDC base of $240,143 for a total of **$136,641**

I. Total Direct and Indirect Costs: **$401,453**

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. Budgets include provisional rates, which are subject to review and approval of NSF. Out year rates are estimated based on current provisional rates and are subject to change.
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 budget may include a charge for scientific computing and networking support in accordance with 2 CFR 200, OMB Uniform Guidance and NCAR management policy allocating the costs of scientific computing system infrastructure.
5. 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 2 CFR 200, OMB Uniform Guidance, as it is borne by the Federal Government.
6. 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 and Geospace Sciences (AGS).
7. For Federal Interagency Agreement Fund Transfers, NSF Administrative Cost recovery is applied at the current rate to total transfers. 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 (CA) No. 0753581, or any successor agreement.

As a condition of NSF's entering into an interagency agreement or funds transfer, other Federal agencies must agree to the following conditions:

- NSF will not itself be directly responsible for the provision of goods or services contemplated under NCAR's proposal to the other Federal agency.
- 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 other agency's agreement.
- NSF assumes no liability for any costs above the funds obligated against this CSA.
- In accordance with NSF Policy, a portion of the incoming 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 predetermined by NSF.
- All fund transfers will be accepted and work performed under the terms and conditions of this CA.

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. Amy Smith, Manager, UCAR Contracts, 3090 Center Green Drive, Boulder, CO 80301-2252, Phone (303) 497-8872, Fax (303) 497-8501. Please refer to NCAR's proposal number on all correspondence with UCAR.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Woods Hole Oceanographic Institution

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Dennis McGillicuddy

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. **Dennis J McGillicuddy - Principal Investigator**	2.00	0.00	0.00	**49,875**	
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)	2.00	0.00	0.00	**49,875**	
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.)	4.00	0.00	0.00	**57,936**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**3,451**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**111,262**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**38,286**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**149,548**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,348**	
2. INTERNATIONAL				**14,520**	
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				**3,500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**26,000**	
TOTAL OTHER DIRECT COSTS				**29,500**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**194,916**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Facility & Administrative (Modified Total Direct Costs) (Rate: 58.0000, Base: 188738)**					
TOTAL INDIRECT COSTS (F&A)				**109,468**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**304,384**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**304,384**	

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

PI/PD NAME
Dennis McGillicuddy

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**

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION
Woods Hole Oceanographic Institution

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Dennis McGillicuddy

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. **Dennis J McGillicuddy - Principal Investigator**	2.00	0.00	0.00	**51,621**	
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)	2.00	0.00	0.00	**51,621**	
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.)	4.00	0.00	0.00	**59,969**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**3,571**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**115,161**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**39,626**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**154,787**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,457**	
2. INTERNATIONAL				**15,972**	
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				**3,500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**26,000**	
TOTAL OTHER DIRECT COSTS				**29,500**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**201,716**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Facility & Administrative (Modified Total Direct Costs) (Rate: 58.0000, Base: 195320)**					
TOTAL INDIRECT COSTS (F&A)				**113,286**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**315,002**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**315,002**	

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

PI/PD NAME
Dennis McGillicuddy

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**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
Woods Hole Oceanographic Institution

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Dennis McGillicuddy

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. **Dennis J McGillicuddy - Principal Investigator**	1.00	0.00	0.00	**17,929**	
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)	1.00	0.00	0.00	**17,929**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	3.00	0.00	0.00	**25,058**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**3,698**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**46,685**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,485**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**67,170**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**1,566**	
2. INTERNATIONAL				**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				**3,500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,200**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**4,700**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**73,436**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Facility & Administrative (Modified Total Direct Costs) (Rate: 58.0000, Base: 73436)**					
TOTAL INDIRECT COSTS (F&A)				**42,593**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**116,029**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**116,029**	

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

PI/PD NAME
Dennis McGillicuddy

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**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
Woods Hole Oceanographic Institution

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Dennis McGillicuddy

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. **Dennis J McGillicuddy - Principal Investigator**	1.00	0.00	0.00	**18,556**	
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)	1.00	0.00	0.00	**18,556**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	3.00	0.00	0.00	**25,928**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**1**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**3,826**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**48,310**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**21,198**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**69,508**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**5,218**	
2. INTERNATIONAL				**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				**3,500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,200**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**4,700**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**79,426**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Facility & Administrative (Modified Total Direct Costs) (Rate: 58.0000, Base: 79426)**					
TOTAL INDIRECT COSTS (F&A)				**46,067**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**125,493**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**125,493**	

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

PI/PD NAME
Dennis McGillicuddy

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**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
Woods Hole Oceanographic Institution

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Dennis McGillicuddy

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. **Dennis J McGillicuddy - Principal Investigator**	6.00	0.00	0.00	**137,981**	
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)	6.00	0.00	0.00	**137,981**	
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.)	14.00	0.00	0.00	**168,891**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**4**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**14,546**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**321,418**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**119,595**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**441,013**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**9,589**	
2. INTERNATIONAL				**30,492**	
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				**14,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,400**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**52,000**	
TOTAL OTHER DIRECT COSTS				**68,400**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**549,494**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**311,414**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**860,908**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**860,908**	

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

PI/PD NAME
Dennis McGillicuddy

ORG. REP. NAME*

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

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Information

The Woods Hole Oceanographic Institution (WHOI) is a non-profit [501c(3)] research and education organization subject to the cost principles of 2 CFR 200. WHOI Principal Investigators are responsible for conceiving, funding and carrying out their research programs. Senior Personnel are expected to raise 12 months of support for themselves and their staff by writing proposals and obtaining sponsored research grants and contracts from a variety of sources. Some teach voluntarily in WHOI's Joint Program, but support for this is limited. NSF has confirmed to WHOI that salary support from grants beyond 2 months per year can be justifiable for these Principal Investigators.

The rates included in the proposal are negotiated with our cognizant government agency.

For 2017 and beyond, WHOI has a negotiated rate agreement with the Office of Naval Research and uses the method of allocation of indirect costs to Modified Total Direct Costs (MTDC). The normal exclusions contained in 2 CFR 200.68 (MTDC) apply, as well as the following cost categories; ship use, submersible use, vessel charters and ship fuel.

A proposed labor month is equal to 152 hours or 1824 hours annually versus 2080 hours (40 hours/week for 52 weeks). The difference is for vacations, holidays, sick time, and other paid absences, which are included in the Paid Absences calculation. WHOI cannot "waive" or reduce overhead rates on any sponsored research project due to the structure of our negotiated rates with our cognizant government agency (Office of Naval Research). When a program sets limits on overhead, WHOI must use Institution unrestricted funds to pay the unfunded portion of the overhead costs.

McGillicuddy laboratory:

The specific at-sea responsibilities of Dr. McGillicuddy's laboratory include acquisition and analysis of (1) hydrographic data at CTD stations, (2) alongtrack ADCP data, and (3) Video Plankton Recorder (VPR) surveys. All of these data streams will be used together with satellite observations of sea level, SST, and ocean color to synthesize a synoptic view of the mesoscale environment for execution of the proposed process studies.

We note that the VPR will be made available as part of WHOI's shared use equipment pool. McGillicuddy's laboratory has worked successfully in the past with the VPR as shared use equipment, including cruises in the Sargasso Sea in 2004 and 2005 (McGillicuddy et al., 2007), as well as in the Ross Sea in 2012 (McGillicuddy et al., 2015; Smith et al., 2017; Li et al., 2017).

Dr. McGillicuddy will field a team of three in both cruises, providing one person per watch for 24/7 operations of the various sampling platforms. Salary requests for the seagoing team amount to two months each for Dr. McGillicuddy, O. Kosnyrev, and J. Eaton (VPR tech) in years 1 and 2 for mobilization, cruise participation, and demobilization. Years 3 and 4 will be focused on analysis and synthesis of the results and integration with PI Long's modeling work, for which Dr. McGillicuddy requests one month per year. He will be assisted by O. Kosnyrev (three months per year) in data analysis and visualization, as well as interrogation of relevant model results.

Two weeks of administrative assistance (S. Barkley) are requested each year to assist with annual reports, budget tracking, manuscript preparation, travel, and other administrative tasks that are related to the project and are not supported by overhead.

Travel:

Domestic: Support is requested for Dr. McGillicuddy to attend annual PI meetings at Bigelow Labs in East Boothbay, Maine. Annual trips include per diem for 4 days and rental vehicle for 5 days ($1,348/$1,457/$1,566/$1,670). We also request funds to attend one national scientific meeting in year 4 to report on the results of the project. Expenses include 6 days of per diem, airfare, meeting registration, and general ground transportation ($3,548). For budgeting purposes, the estimated cost of attending a meeting in San Francisco, CA (e.g., AGU) is specified for domestic travel.

Foreign: Air travel costs to and from Durban South Africa are included for participation in the field work in years 1 and 2. Per diem and ground transportation costs are budgeted for three people for 8 days [4 days staging, 2 days demobilization, 2 days travel] ($14,520/$15,972).

Estimates for airfare are based on rates currently available on Expedia for refundable tickets and include an allowance for baggage and agent fees. Ground transportation costs include rental car(s) and transportation to/from the airports. Meeting registration fees are based on previous meetings. Per diem expenses are based on rates currently available via the GSA website (http://www.gsa.gov/portal/category/21287) for domestic travel or via the State Department (http://aoprals.state.gov/content.asp?content_id=184&menu_id=78) for foreign per diem. All rates are increased in subsequent years to account for rate hikes.

Other Direct Costs:

Materials and Supplies: The network of workstations and servers currently available in Dr. McGillicuddy's laboratory will generally be sufficient for the data analysis and modeling activities proposed herein. However, this infrastructure must be kept current. Therefore, allowances for computer supplies (CPU upgrades, backup units, toner cartridges, printer paper, batteries and electronic storage devices), are requested ($3,500 per year).

Publications: Publication costs and charges for color figures are requested in years 3 and 4 to cover dissemination of the scientific results in peer-reviewed journals.

Other: Shipment costs are requested in years 1 and 2 to transport a 20' container with the VPR and other equipment to be used during the cruise ($26,000 per year).

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Florida State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Peter Morton

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. **Peter Morton - PI**	4.00	0.00	0.00	**22,500**	
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)	4.00	0.00	0.00	**22,500**	
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**22,500**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,137**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**28,637**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**4,500**	
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				**12,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**12,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**45,137**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Florida State University MTDC (Rate: 70.0000, Base: 45137)**					
TOTAL INDIRECT COSTS (F&A)				**31,596**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**76,733**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**76,733**	

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

PI/PD NAME
Peter Morton

ORG. REP. NAME*
Kenneth Bauer

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION
Florida State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Peter Morton

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. **Peter Morton - PI**	4.00	0.00	0.00	**23,175**	
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)	4.00	0.00	0.00	**23,175**	
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**23,175**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,156**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**29,331**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**0**	
2. INTERNATIONAL				**4,500**	
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				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**36,831**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Florida State University MTDC (Rate: 70.0000, Base: 36831)**					
TOTAL INDIRECT COSTS (F&A)				**25,782**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**62,613**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**62,613**	

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

PI/PD NAME
Peter Morton

ORG. REP. NAME*
Kenneth Bauer

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
Florida State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Peter Morton

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. **Peter Morton - PI**	4.00	0.00	0.00	**23,870**	
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)	4.00	0.00	0.00	**23,870**	
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**23,870**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,175**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**30,045**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**35,045**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Florida State University MTDC (Rate: 70.0000, Base: 35045)**					
TOTAL INDIRECT COSTS (F&A)				**24,532**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**59,577**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**59,577**	

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

PI/PD NAME
Peter Morton

ORG. REP. NAME*
Kenneth Bauer

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

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

ORGANIZATION
Florida State University

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Peter Morton

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. **Peter Morton - PI**	4.00	0.00	0.00	**24,586**	
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)	4.00	0.00	0.00	**24,586**	
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**24,586**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,194**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**30,780**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**2,000**	
2. INTERNATIONAL				**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				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**35,780**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Florida State University MTDC (Rate: 70.0000, Base: 35780)**					
TOTAL INDIRECT COSTS (F&A)				**25,046**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**60,826**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**60,826**	

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

PI/PD NAME
Peter Morton

ORG. REP. NAME*
Kenneth Bauer

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION: **Florida State University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Peter Morton**

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. **Peter Morton - PI**	16.00	0.00	0.00	**94,131**	
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)	16.00	0.00	0.00	**94,131**	
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. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**94,131**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**24,662**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**118,793**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**4,000**	
2. INTERNATIONAL				**9,000**	
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				**21,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**21,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**152,793**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**106,956**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**259,749**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**259,749**	

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

PI/PD NAME: **Peter Morton**

ORG. REP. NAME*: **Kenneth Bauer**

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

FLORIDA STATE UNIVERSITY - BUDGET JUSTIFICATION

SENIOR PERSONNEL

Peter Morton, PI/PD, (4 months effort) will be responsible for the overall implementation of the project and will conduct the research. Dr. Morton is in a non-tenured OPS position. He has approval from Florida State University to take the lead on this project. Dr. Morton is entirely research funded and receives no funds from the University in support of his salary.

Vincent Salters, co-PI, will serve as a mentor to Dr. Morton. He will be available to Dr. Morton to provide any assistance or guidance as needed.

Fringe benefits are calculated at 2.75%, including insurance costs prorated at $16,555 per year.

The salaries include institution wide annual salary increases based on historical models and expectations for the subsequent years of 3%.

EQUIPMENT

None.

TRAVEL

Travel funds are requested for travel for the PD/PI to Durban, South Africa to board the ship to cruise to the areas of research. There will be one trip in Years 1 and 2 at a cost of $4500 each year ($2400 airfare, $1,415 for lodging, $485 for meals and incidentals and, $200 for travel meals, parking and other miscellaneous expenses). Conference travel has been included in Years 3 and 4 to travel to the Ocean Sciences Meeting one year and the Aquatic Sciences Meeting the second year at a cost of $2,000 each to present results ($450 airfare, $800 for lodging, $450 registration fee and $300 for meals and other miscellaneous expenses).

SUPPLIES

A budget for laboratory supplies in the amount of $3,000 is requested each year which includes acids ($340), sample bottles ($1,160), consumable parts ($700) and miscellaneous lab supplies ($800). In addition in Year 1, an additional $9,000 is requested for resins ($1,000), sampling filters ($3,000), sampling consumables ($2,000), reagents ($2000) and for sample storage ($1,000).

INDIRECT COSTS

The rate is 70% of the modified total direct costs. Equipment and Tuition are excluded from Indirect Costs. Florida State's F&A Rate Agreement is dated 06/26/14 and has been approved by the DHHS Director of Cost Allocation, Cohen Building Room 1067, 330 Independence Avenue SW, Washington, DC 20201, (202) 401-2808.

12. Current and Pending Support-

Investigator: William M. Balch Bigelow Laboratory for Ocean Sciences	Other agencies to which this proposal has been/will be submitted. None

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: Ocean Acidification-- Effects of ocean acidification on *Emiliania huxleyi* and *Calanus finmarchicus*; insights into the oceanic alkalinity and biological carbon pumps

Source of Support: NSF
Total Award Amount: $999,956 (as of 4/30/16; $69,262 remaining Balch funds; NCE requested)
Total Award Period Covered: 6/1/2012 to**7/31/17**; Location of Project: Bigelow Laboratory for Ocean Sciences Person-Months Per Year Committed to the Project. Cal:0.5, 0.5, 0.5 Acad: Sumr:

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: Science data analysis: Integrating the MODIS PIC product into the climate data record
Source of Support: NASA
Total Award Amount:) $763,210 Total Award Period Covered: 9/1/14 to **8/31/17**
Location of Project: 36 months
Person-Months Per Year Committed to the Project. Cal: 2.5, 2.5, 2.5 Acad: Sumr:

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: "Combining satellite-, AUV-, and ship-based measurements from the multi-decadal time series "GNATS" to model the carbon cycle in the Gulf of Maine"
Source of Support: NASA
Total Award Amount: $1,299,051 Total Award Period Covered: 9/1/14 to **8/31/17**
Location of Project: Bigelow Laboratory
Person-Months Per Year Committed to the Project. Cal: 2.5, 2.5, 2.5 Acad: Sumr:

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: "Use of Suomi NPP for deriving science data records of ocean particulate inorganic carbon concentration: algorithm improvements, product validation and achieving EOS product continuity"
Source of Support: NASA
Total Award Amount: $939,340 Total Award Period Covered: 9/21/14 to **9/28/17**
Location of Project: Bigelow Laboratory
Person-Months Per Year Committed to the Project. Cal: 0.5, 0.5, 0.5 Acad: Sumr:

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: Maintenance and refinement of the MODIS algorithm for particulate inorganic carbon
Source of Support: NASA
Total Award Amount: $558,994 Total Award Period Covered: 9/22/14 to **9/21/18**
Location of Project: Bigelow Laboratory
Person-Months Per Year Committed to the Project. Cal: 2,2,2,Acad: Sumr:

Support: **[X] Current** [] Pending [] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: Towards early detection and forecasting of harmful algal blooms in the Gulf of Maine
Source of Support: NASA EPSCOR
Total Award Amount: $120,955 Total Award Period Covered: 8-1-16 to **7-31-19**
Location of Project: Bigelow Laboratory for Ocean Sciences
Person-Months Per Year Committed to the Project.Cal:0.25, 0.25, 0.25 Acad: Sumr: Support: []

* If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Support: **[X] Current** [] Pending [] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: Coccolithophore mixotrophy
Source of Support: NSF
Total Award Amount: $669,755 Total Award Period Covered: 8/1/2016-**7/31/2019**
Location of Project: Bigelow Laboratory for Ocean Sciences
Person-Months Per Year Committed to the Project. Cal: 2,2,2 Acad: Sumr: Support: []

Support: **[X] Current** [] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: GNATS: An experimental observatory documenting the Gulf of Maine carbon cycle
Source of Support: NASA
Total Award Amount: $1,328,402 Total Award Period Covered: **8/15/2017-8/14/2020**
Location of Project: Bigelow Laboratory
Person-Months Per Year Committed to the Project. Cal: 2.5, 2.5, 2.5 Acad: Sumr: Support: [] Current [ ] Pending [ ]

Support: [] Current **[X]Pending** [] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title: **THIS PROPOSAL-** Collaborative Research: Biogeochemical and physical conditioning of Sub-antarctic Mode Water in the Southern Ocean
Source of Support: NSF
Total Award Amount: $1,198,953 (Bigelow portion) Total Award Period Covered: **8/1/17-7/31/21**
Location of Project: Bigelow Laboratory for Ocean Sciences
Person-Months Per Year Committed to the Project. Cal: Acad: 3,3,2,2 Sumr: Support: [] Current [ ] Pending [ ]

Support: [] Current [ ] Pending [ ] Submission Planned in Near Future [ ] *Transfer of Support
Project/Proposal Title:
Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project: Bigelow Laboratory for Ocean Sciences
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: Support: [] Current [ ] Pending [ ]

* If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

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: **Nicholas R. Bates**

Other agencies (including NSF) to which this proposal has been/will be submitted.
None

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] * Transfer of Support

Project/Proposal Title:
Initial Steps Towards a Global Surface Water pCO_2 Observing System

Source of Support: NOAA NA16GP2009
Award Amount (or Annual Rate): $ ~$124,000 per annum Period Covered: 1st Sep. 2014-31st Aug. 2016
Location of Project: BIOS
Person-Months Committed to the Project. Cal.: 2m/yr Acad: Summ:

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] * Transfer of Support

Project/Proposal Title:
The Bermuda Atlantic Time-series Study (Years 21-25)

Source of Support: NSF OCE-1258622
Award Amount (or Annual Rate): ~$1,100,000 per annum Period Covered: 1st Aug. 2013 - 30th July 2018
Location of Project: BIOS
Person-Months Committed to the Project. Cal.: 4m/yr Acad: Summ:

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] * Transfer of Support

Project/Proposal Title:
Collaborative Research: Seawater Inorganic and Organic Carbon Measurements for the US GEOTRACES Eastern Pacific Zonal Transect

Source of Support: NSF OCE-1233706
Award Amount (or Annual Rate): $272,076 Period Covered: 1st Feb. 2013-31st Jan 2016
Location of Project: BIOS
Person-Months Committed to the Project. Cal.: 1m/yr Acad: Summ:

Support: [x] Current [ ] Pending [ ] Submission Planned in Near Future [ ] * Transfer of Support

Project/Proposal Title:
The Panulirus Hydrographic Stations: Years 59-64

Source of Support: NSF OCE-1233706
Award Amount (or Annual Rate): $ $695,718 Period Covered: 1st April 2012-31st Aug. 2017
Location of Project: BIOS
Person-Months Committed to the Project. Cal.: 0.5m/y Acad: Summ:

Support: [ ] Current [x] Pending [ ] Submission Planned in Near Future [ ] * Transfer of Support

Project/Proposal Title:
Coupling of offshore and coral reef physical-biogeochemical processes in the context of ocean warming and acidification

Source of Support: NASA
Award Amount (or Annual Rate): $ $476,247 Period Covered: 1st Feb 2017-31st Jan 2020
Location of Project:
Person-Months Committed to the Project. Cal.: 1m/yr Acad: Summ:

* If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

Matthew Long

Project Title: NCAR Research Focus Area: Climate and Global Dynamics Laboratory Oceanography Section
Program Name: NSF/NCAR Internal Base Funding
Time Committed to the Project: *9.3 person mths/yr
Source of Support: NSF Cooperative Agreement #M0856145
Award Amount (or amount requested): $195,585
Duration of Award: 10/1/13 - 9/30/18
X **Current** **Pending**
Contact: Sarah Ruth, 703-292-8521, sruth@nsf.gov

Project Title: Multi-scale Satellite Analysis of the Biophysical Dynamics Governing Ocean Phytoplankton Community Structure
Time Committed to Project: 2.0 person mths/yr 0.0 person mths/yr supported by
Source of Support: WHOI Subaward A1011146/NASA NSF base funds
Award Amount (or amount requested): $101,466
Duration of Award: 7/2/14 - 7/1/17
X **Current** **Pending**
Contact: Paula Bontempi, 202-358-1508, paula.bontempi@nasa.gov

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Project Title: A modular biogeochemical modeling suite for next-generation ocean models
Time Committed to Project: 2.4 person mths/yr 0.0 person mths/yr supported by
Source of Support: DOE Award DE-SC0012603 NSF base funds
Award Amount (or amount requested): $1,218,749
Duration of Award: 8/15/14 - 8/14/17
X **Current** **Pending**
Contact: Dorothy M. Koch, 301-903-0105, dorothy.koch@science.doe.gov

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Project Title: Southern Ocean Uptake in the MPAS-Ocean Model
Time Committed to Project: 1.5 person mths/yr 0.0 person mths/yr supported by
Source of Support: DOE Award DE-SC0012605 NSF base funds
Award Amount (or amount requested): $1,179,762
Duration of Award: 8/15/14 - 8/14/17
X **Current** **Pending**
Contact: Dorothy M. Koch, 301-903-0105, dorothy.koch@science.doe.gov

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Project Title: Collaborative Research: The O2/N2 Ratio and CO2 Airborne Southern Ocean (ORCAS) Study
Time Committed to Project: 0.0 person mths/yr 1.2 person mths/yr supported by
Source of Support: NSF Award 1501993 NSF base funds
Award Amount (or amount requested): $555,236
Duration of Award: 1/1/15 - 12/31/17
X **Current** **Pending**
Contact: Peter Milne, 703-292-4714, pmilne@nsf.gov

Project Title: Defining the "Ocean Carbon States": Using data to assess climate models
Time Committed to Project: 0 person mths/yr 0.4 person mths/yr supported by
Source of Support: Columbia University/NASA NSF base funds
Award Amount (or amount requested): $0
Duration of Award: 10/1/16 - 9/30/18
Current X **Pending**
Contact: Paula Bontempi, 202-358-1508, paula.bontempi@nasa.gov

Matthew Long

Project Title: Collaborative Research: The impact of climate change on the physics and biology of the ocean on scales down to the submesoscale

Time Committed to the Project: 0.0 person mths/yr 0.36 person mths/yr supported by NSF Base funds
Source of Support: NSF
Award Amount (or amount requested): $230,653
Duration of Award: 3/1/17 - 2/29/20
____ **Current** __X__ **Pending**
Contact: Eric Itsweire, 703-292-8582, eitsweir@nsf.gov

Project Title: Collaborative Research: Theory and Observations of Global Ocean Deoxygenation

Time Committed to the Project: 0.0 person mths/yr 0.52 person mths/yr supported by NSF Base funds
Source of Support: NSF
Award Amount (or amount requested): $348,772
Duration of Award: 1/1/2018 - 12/31/2020
____ **Current** __X__ **Pending**
Contact: Henrietta Edmonds, 703 292 7427, hedmonds@nsf.gov

Project Title: Collaborative Research: Biogeochemical and physical conditioning of Sub-Antarctic Mode Water in the Southern Ocean (Current proposal)

Time Committed to the Project: 0.0 person mths/yr 0.52 person mths/yr supported by NSF Base funds
Source of Support: NSF
Award Amount (or amount requested): $401,453
Duration of Award: 8/1/2017 - 7/31/2020
____ **Current** __X__ **Pending**
Contact: Henrietta Edmonds, 703 292 7427, hedmonds@nsf.gov

*In the event that a pending project is awarded and an overlap in effort occurs, the effort on the NCAR Internal Funds will be adjusted accordingly. The award amount indicates the internal base funding for this project for the current fiscal year.

Current and Pending Support

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: **DENNIS MCGILLICUDDY**

Other Agencies (including NSF) to which this Proposal has been/will be submitted.

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

Project/Proposal Title:

J. STEGEMAN, D. ANDERSON, D. MCGILLICUDDY, M. HAHN, N. ALURU, D. RALSTON - WHCOHH: Harmful Algal Bloom Dynamics and Epigenetic Mechanisms of Toxin Action

POC:Frederick L. Tyson 919-541-0176 tyson2@niehs.nih.gov

Source of Support: *National Institutes of Health (NIH) 1P01ES021923/5P/3P/4F*

Total Award Amount: $2,108,838 Total Award Period Covered: 9/24/2012 - 7/31/2017

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0.39/0.47/0.60/0.87/1.20 Acad: Sumr:

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

Project/Proposal Title:

D. ANDERSON, D. MCGILLICUDDY - MERHAB: GOM-ESP: Incorporation of Environmental Sample Processor Technology into Gulf of Maine HAB Monitoring and Management

POC:Marc Suddleson 301-713-3338 ext. 162 Marc.Suddleson@noaa.gov

Source of Support: *National Oceanic & Atmospheric Admin.(NOAA) NA11NOS*

Total Award Amount: $5,307,591 Total Award Period Covered: 9/1/2011 - 8/31/2017

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0.32/1.00/1.00/0.50/1.00 Acad: Sumr:

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

Project/Proposal Title:

J. STEGEMAN, D. ANDERSON, D. MCGILLICUDDY - WHCOHH: Harmful Algal Bloom Dynamics and Epigenetic Mechanisms of Toxin Action

Source of Support: *Director's Other Innovative C/S 21192300*

Total Award Amount: $18,899 Total Award Period Covered: 9/1/2012 - 8/31/2017

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0 Acad: Sumr:

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

Project/Proposal Title:

D. MCGILLICUDDY - Collaborative Research Type 2 L02170291 MOBY: Modeling Ocean Variability and Biogeochemical Cycles

POC:Eric C. Itsweire 703-292-8582/7593 eitsweir@nsf.gov

Source of Support: *National Science Foundation (NSF) OCE-1048897*

Total Award Amount: $1,236,042 Total Award Period Covered: 3/1/2011 - 9/30/2017

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 2.00/1.50/1.25/1.00/1.00 Acad: Sumr:

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

Project/Proposal Title:

D. MCGILLICUDDY - Physical and Biological Dynamics of Nonlinear Mesoscale Eddies: Satellite Observations, In Situ Measurements, and Numerical Simulations on a Global Scale

POC:Eric Lindstrom 202-358-4540 eric.j.lindstrom@nasa.gov

Source of Support: *NASA Grants NNX13AE47G*

Total Award Amount: $899,538 Total Award Period Covered: 1/15/2013 - 1/14/2018

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 2.00/1.00/1.00/1.00 Acad: Sumr:

Current and Pending Support

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: **DENNIS MCGILLICUDDY**

Other Agencies (including NSF) to which this Proposal has been/will be submitted.

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

Project/Proposal Title:

J. STEGEMAN, D. ANDERSON, D. MCGILLICUDDY, M. HAHN - WHCOHH: Harmful Algal Bloom Dynamics and Epigenetic Mechanisms of Toxin Action

POC:Henrietta N. Edmonds 703-292-8029/7427 hedmonds@nsf.gov

Source of Support: *National Science Foundation (NSF) OCE-1314642*

Total Award Amount: $4,321,138 Total Award Period Covered: 3/15/2013 - 2/28/2018

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0.90/0.68/0.77/1.21/1.31 Acad: Sumr:

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

Project/Proposal Title:

D. MCGILLICUDDY, M. PURCELL, R. STANLEY - Adaptive Sampling of Hotspots in Net Community Production Using the VPR, REMUS, and Traditional Hydrographic Methods

POC:Rob Munier rmunier@whoi.edu

Source of Support:

Total Award Amount: $437,095 Total Award Period Covered: 3/28/2016 - 3/31/2018

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0 Acad: Sumr:

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

Project/Proposal Title:

D. ANDERSON, B. KEAFER, D. MCGILLICUDDY - ECOHAB: Interannual Variability of PSP Toxicity in Eastern Maine: Testing the Leaky Gyre Hypothesis and Improving Regional Forecasts and Management

POC:Quay Dortch (240) 533-0198 Quay.Dortch@noaa.gov

Source of Support: *National Oceanic & Atmospheric Admin.(NOAA) NA15NOS*

Total Award Amount: $731,817 Total Award Period Covered: 9/1/2015 - 8/31/2018

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 0.50/0.50/0.50 Acad: Sumr:

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

Project/Proposal Title:

D. MCGILLICUDDY - NSFGEO-NERC: Collaborative Research: Bloom Initiation Dynamics in the Ross Sea (BID-RS)

Source of Support: *National Science Foundation (NSF)*

Total Request Amt: $739,723 Total Award Period Covered: 3/1/2017 - 2/28/2020

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 2.00/1.00/1.00 Acad: Sumr:

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

Project/Proposal Title:

D. MCGILLICUDDY, H. SOSIK, W. ZHANG, R. STANLEY - Collaborative Research: Shelfbreak Frontal Dynamics: Mechanisms of Upwelling, Net Community Production, and Ecological Implications

Source of Support: *National Science Foundation (NSF)*

Total Request Amt: $1,993,155 Total Award Period Covered: 10/1/2017 - 9/30/2020

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 2.00/1.00/1.00 Acad: Sumr:

Current and Pending Support

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: **DENNIS MCGILLICUDDY**	Other Agencies (including NSF) to which this Proposal has been/will be submitted.

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

Project/Proposal Title:

D. MCGILLICUDDY - Collaborative Research: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean

* This Proposal

Source of Support: *National Science Foundation (NSF)*

Total Request Amt: $860,909 Total Award Period Covered: 8/1/2017 - 7/31/2021

Location of Project: WHOI

Person-Months Per Year Committed to the Project: Cal: 2.00/2.00/1.00/1.00 Acad: Sumr:

Current and Pending
Peter Morton

Current

OCE-1436019 Morton (PI) 12/1/2014-11/30/2017 10 calendar months
NSF $430,334
Collaborative Research: Biogeochemical Cycling Of Particulate Trace Elements In The Western Arctic Basin
Role: PI

FSU-CRC Morton (PI) 05/16/2016-05/15/2017 0 calendar months
FSU $13,000
PG: Tracing the Sources and Fates of Industrial Activities through Lead Isotopes
Role: PI

Pending

PD 98-1670 Morton (PI) 03/01/2017-02/28/2020 2 calendar months
NSF $146,938
Collaborative Research: Iron Incorporation into Biogenic Silica
Role: PI

PD 98-1670 Morton (PI) 08/01/2017-07/31/2021 4 calendar months
NSF *This Proposal* $259,749
Collaborative Research: Biogeochemical and Physical Conditioning of Subantarctic Mode Water in the Southern Ocean
Role: PI

Overlap

None.

W. Balch-Facilities, Equipment, and Other Resources- Bigelow Laboratory for Ocean Sciences

FACILITIES: *Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. Use additional pages if necessary.*

Laboratory: Bigelow Laboratory is a small, independent research laboratory with 18 senior research scientists. The research is focused on biological oceanography associated with the lower levels of the food web. It houses the national culture collection for marine phytoplankton (NCMA), the Flow Cytometer and Image Analysis Facility and Single-Cell Genomics Center (SCGC). Bigelow has the facility to handle many types of remote sensing data (thermal, microwave, and ocean color imagery). Bigelow Laboratory moved from its old West Boothbay Harbor campus to a new 60,000 ft2 campus in East Boothbay in 2013. The laboratory space that WMB works in contains culture facilities and incubators, a microscope room (outfitted with micro-video system), space with a flow hood for processing analytical samples (e.g. PIC and biogenic silica), nutrients, ICP-OES analyses, elemental analyses, etc.), and experimental laboratory. Radioactive work is done in a state-of-the-art radiochemistry laboratory, containing dedicated incubator space, safety hood, etc. Bigelow Laboratory's radiochemistry laboratory contains a Perkin-Elmer Tri-carb 3110TR Liquid Scintillation Counter for low-level counting, two dedicated, stackable incubators for maintaining radioactive experiments at different temperature, CO_2 and light conditions and two temperature-controlled photosynthetron incubators (Composite High Pressure Technologies) for measuring photobiological rates as a function of irradiance (e.g., P vs. E curves) of marine microbiota. The laboratory also has a Zeiss Supra25 field emission scanning electron microscope (SEM). The Bigelow Analytical Services (BAS) Facility is located on Bigelow Laboratory's Ocean Science and Education Campus in East Boothbay, Maine. BAS uses modern analytical approaches to provide quantitative analysis of biotoxin concentrations in shellfish biomass. Analytical approaches include HPLCPCOX (high-pressure liquid chromatography–post-column oxidation) and LC-QQQ-MS (liquid chromatography triple-quadrupole mass-spectrometry).

Computing: The Balch laboratory contains a number of MSWindows machines. We use a variety of software for data processing such as Excel, Access, IDL, and MATLAB, Ocean Data View, as well as custom-designed acquisition and processing software (LabVIEW). In 2013, Bigelow laboratory installed a high-performance elastic computing system consisting of 160 processor cores and 1.3 TB of RAM, backed by 200TB of high performance, highly available storage. This system facilitates data-intensive marine and oceanographic research at Bigelow Laboratory for Ocean Sciences. These resources also provide an infrastructure framework that support the Laboratory's long-term data management strategy and the varied research needs of current and future Bigelow scientists. These resources also support Bigelow Laboratory's education initiatives for training high school students, college and university undergraduates, science teachers, and postdoctoral researchers.

Office: Balch has a standard senior scientist office at the Bigelow Laboratory for Ocean Sciences.

Other: Mobile Laboratory/Lab container on flat-bed truck for taking on commercial ferries

MAJOR EQUIPMENT: *List the most important items available and, as appropriate identifying the location and pertinent capabilities of each.*

The Balch laboratory houses the following equipment: two Wyatt Laser light scattering photometers(model Dawn and EOS), two Turner Design fluorometers, Biospherical PNF solar-stimulated fluorometer, Biospherical hand-held PAR sensor, Instrumar Ltd Visible-band Reflectometer, incubators for incubating primary productivity samples at sea, two SeaBird thermosalinographs for underway analyses, Flow-through system (run by a Windows computer) for measuring and logging fluorescence, temperature, salinity, pH, and light scattering, FlowCAM image analysis system, Olympus BH2 microscope w/ phase, epifluorescence, and polarization optics, plus video camera, motorized stage, Sony video system and recorder for microscope, high sensitivity CCD array camera for low-light birefringence samples, Two chemostats, Two plant incubators (Percival), Camspec single-beam spectrophotometer w/ integrating sphere, Hitachi dual beam spectrophotometer, Satlantic SAS radiometer/SeaWiFS simulator and MicroSAS radiometer w/ water and sky radiance sensors and sky irradiance sensor, Sable Systems 4-channel dissolved oxygen analyzer, Hobi Labs Hydroscat-2 optical backscattering detector, three Wet Labs ac-9s, two WETLab ECO-VSFs, two WETLabs ECO-triplet sensors, Satlantic OCP free-fall 7 band radiometer, Brooke Ocean Moving Vessel Profiler MVP 200, equipment for performing micro-diffusion calcification measurements. In 2008 and 2014 we purchased two Webb-Teledyne Slocum Electric Gliders, respectively, equipped with Satlantic radiance and irradiance sensors plus WETLABS ECO-triplet puck sensor chlorophyll, backscattering and CDOM fluorescence. The second glider is equipped to measure the same variables plus oxygen. We also have a shipboard chilling/heating system for maintaining large volume seawater samples at temperatures from 0^{o}C-25^{o}C. We have two ARGOS lagrangian drifters which will be used in this proposed work for marking the centers of eddies. The Twining laboratory is making available their equipment for trace-metal clean water collection including: nine 5-L General Oceanics Niskin-X bottles modified for trace-metal work (Teflon coated, all steel parts replaced with Ti, external, Teflon-coated springs), 1500 m of ¼" polyester-coated Kevlar line, and a 30-L General Oceanics GO-Flo bottle for trace-metal clean collection of larger volumes of seawater (See letter of collaboration from Dr. Ben Twining).

OTHER RESOURCES: *Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual/subaward arrangements with other organizations.*

The Bigelow microscopy facility has a field-emission scanning electron microscope (Zeiss Supra25) and associated sample preparation instrumentation, including 2 ultramicrotomes, plus a 4-channel Zeiss confocal microscope for cellular visualization and imaging. Shared walk-in culture incubators are available in the Bigelow Center for Blue Biotechnology, as well.

Secretarial services are provided by Bigelow at no direct cost to research grants.

General:

The Bermuda Institute of Ocean Sciences (BIOS) is a U.S. 501 (c) 3 and 509 (a) not-for profit research and educational institution incorporated in the state of New York, and located on the island of Bermuda. BIOS has an EIN number of **060706038**, a DUNS of **875635161** and awardee organizational code of **4001707000**.

Laboratory facilities:

Laboratory and water sampling facilities will be available at BIOS for this research project. A new 15,000 ft^2 science building (Naess Building) has been occupied since April 2005. Adequate lab space exists at BIOS for this project.

Computer facilities and infrastructure:

Computing facilities are already in place for this project in the laboratory of N. Bates. Two high-speed workstations are available in our lab. Mac, PC, storage/backup and printing facilities are also present in the laboratory of N. Bates. Software licenses include a Matlab license (a Matlab server will also be available). The organization provides the services of three computer system administrators, internet connectivity and web services.

Analytical facilities:

Seagoing and laboratory instruments for the measurement of dissolved inorganic carbon (DIC), total alkalinity (TA), and underway seawater pCO_2 already exist in the laboratories of N. Bates associated with the Marine Biogeochemistry Laboratory and Bermuda Atlantic Time-series Study (BATS). This also includes instruments for high–quality measurements of salinity, dissolved oxygen, inorganic nutrients, chlorophyll and HPLC, particulate organic matter, bacteria enumeration, and rate measurements.

Analytical instrumentation includes: (1) a coulometer system (or SOMMA) for the measurement of DIC with a precision of ~0.02% (~0.4 μmoles kg^{-1}); (2) an automated VINDTA system used to determine DIC with a precision of ~0.04 % (~0.8 μmoles kg^{-1}); (3) a LiCOR NDIR based DIC analyzer capable of determining small volume DIC with a precision of ~0.06% (~1.2 μmoles kg^{-1}); (4) two automated VINDTA systems used to determine TA with a precision of ~0.04 % (~1 μmoles kg^{-1}); (5) a couple of manual alkalinity titrators and basic pH meters; (6) an underway pCO_2 system based on a seawater equilibrator and older LiCOR 6252 detector; and (7) a SAMI flow-through seawater pCO_2 system. Several different CO_2-in-air standards will also be available for the project. Bates lab also possesses a YSI 556 multi-parameter sonde that will be used in both fieldwork and *in vitro* experiments. A LiCOR 6262 detector is available for monitoring CO_2 gas concentration in the *in vitro* experiments.

1. Dissolved Inorganic Carbon (DIC) analyses

Three instruments for the measurement of dissolved inorganic carbon (DIC) are available in the lab at BIOS. A SOMMA-Coulometer system has been used at BIOS for the last 20 years, providing highly precise (~0.02%; ~0.4 μmoles kg^{-1}) and accurate DIC measurements (Bates *et al*., 1996). A second DIC system based on the SOMMA has been manufactured by Marianda Co. and termed a VINDTA 3D system (model VINDTA 3D; http://www.marianda.com). It has similar precision and accuracy to the SOMMA. A third, combined DIC and total alkalinity VINDTA system (model VINDTA 3C;

http://www.marianda.com) also has similar precision and accuracy. Both VINDTA instruments are based on coulometric detection and have a sample throughput of ~4 samples per hour. We anticipate that the second system will be used on the cruises.

2. Alkalinity (TA) systems

Two automated VINDTA system (model VINDTA 3C; built by L. Mintrop at Marianda Co.) will be available for the measurement of alkalinity.

NCAR Facilities, Equipment and Other Resources

Laboratory: N/A

Clinical: N/A

Animal: N/A

Computer: Technical support provided by the Information Systems Group of NCAR's Climate and Global Dynamics Laboratory.

Office: Provided for the NCAR participants by NCAR's Climate and Global Dynamics (CGD) Laboratory.

MAJOR EQUIPMENT

Data Analysis and Visualization (DAV): The DAV resource is made up of three systems: *Geyser* offering 16 large-memory nodes (1 TB in each node) designed to facilitate large-scale data analysis; *Caldera*, designed for NVIDIA Kepler-based GPU-enabled visualization activities; and *Pronghorn*, an iDataPlex system with 16, dual-socketed Xeon nodes with dual Xeon Phi accelerators.

Centralized file systems and archival storage: The file system is integrated with Yellowstone, Caldera and Geyser systems and has a 16-PB capacity on storage devices. In addition an HPSS tape library system provides permanent, archival preservation of data and has a capacity of 100PB.

Network: The Networking and Telecommunications Section at NCAR supports high-speed, reliable, secure network connectivity to six NCAR/UCAR campuses and over 300 logical networks. UCAR also participates in the management and operation of wide-area high-speed optical networks and aggregated services including the Front Range GigaPoP (FRGP), UCAR Point of Presence (UPoP), the Boulder Point of Presence (BPoP), and the Bi-State Optical Network (BiSON). National R&E and commodity networking is provided at 10Gbps via the FRGP to Internet2, National LambdaRail, ESnet, and the Teragrid.

OTHER RESOURCES

Other Resources: The NCAR PI (Dr. Long) will be responsible for overseeing the NCAR effort and will supervise the postdoctoral researcher and software engineer. Dr. Long is a key developer of the Community Earth System Model's ocean biogeochemistry component, which is called MARBL. He has extensive experience running and analyzing the CESM model, including ocean biogeochemistry runs in a global eddy-resolving configuration.

Facilities, Equipment and other Resources: WHOI

Laboratory: NA

Clinical: NA

Animal: NA

Computer:

The computational infrastructure of Dr. McGillicuddy's laboratory consists of a network of eight Dell Precision T7400n Workstations operating Redhat Enterprise Linux 5.2, each unit with two quad core Xeon processors running at 3.00GHz, 8 GB memory, and 500 GB disk space. Also available is a 32-processor SGI *Altix* server. A 2.6TB and a 3.4TB Raid server are available for local storage of model results and visualizations. These systems are sufficient to carry out the proposed data analysis and model diagnoses.

Office: All personnel have adequate office space.

Other: NA

Other resources:

A wide range of shop services and facilities is available to WHOI staff including a precision machine shop, carpentry shop, and graphics services. WHOI's Computer and Information Services (CIS) group provides computer services including technical support, consulting and applications programming services for distribution and central computing systems used by the WHOI community.

Facilities at Florida State University/National High Magnetic Field Laboratory

Laboratory:
The geochemistry facility includes:
1. A mass spectrometry laboratory
2. A plasma facility
3. An 800 square feet clean laboratory
4. A dirty laboratory for mineral separation and rock crushing
5. A wet chemistry laboratory

Major equipment:
The facility has six mass spectrometers, which in order of antiquity are:

1. A fully automated 9 collector Finnegan mass spectrometer equipped with a RPQ-system for increased abundance sensitivity and a 13 sample turret. This second mass spectrometer is used for Sr isotope analyses.
2. A high resolution magnetic sector ICP-MS Finnegan ELEMENT2 for elemental analyses and speciation studies.
3. A high resolution magnetic sector ICP-MS Finnegan ELEMENT XR dedicated to low concentration measurements of extra terrestrial materials.
4. A Finnegan Delta plus XP stable isotope mass spectrometer, with autosampler, GC and elemental analyzer.
5. An Agilent 7500cs quadrupole ICP-MS with collision cell.
6. A multi collector ICP-MS: ThermoElectron Neptune. This instrument is now routinely used for Nd, Pb, Hf, Hg and Os isotope analysis
7. Peripherals instrumentation for the ICP-MS like APEX inlet system and New Wave 193nm laser system.

Other resources:

We have access to a fully staffed machine shop as well as an electronics shop and computer support. Access to these facilities allows for a very smooth operation of the mass spectrometry lab.

Departmental support provides access to Graduate Research Assistants, travel support and other support for operations/needs of the laboratories.

DATA MANAGEMENT PLAN: Collaborative Research: Biogeochemical and Physical Conditioning of Subantarctic Mode water in the Southern Ocean

Data Management Plan: W. Balch, BLOS ; **N. Bates**, BIOS; **M. Long**, OS, CGD/NCAR; **D. McGillicuddy**, WHOI; **P. Morton**, Florida State University

Our data management plan is based on guidelines established by the National Science Board and the NSF and covers dissemination and sharing of materials and data that are expected to be collected as part of the research described in the above named proposal. This project entails both the collection of observational data and generation of model output, the data management plan is divided into two sections.

OBSERVATIONAL DATA

(1) Types of data, samples, physical collections. We will collect data associated with two cruises to the Southern Ocean (Durban, S. Africa to Crozet Island region to Durban, S. Africa in January 2018 and 2019). Field data will be collected at a total of 152 stations per cruise. Water sampling will be done at 76 stations. Protocols will include CTD profiles typically to 500m+ with about one cast per day to 1000 m. Depth-profile data will be binned to 1m intervals). Half the stations will involve no water collection (i.e., Niskin bottles not tripped) and the other half of the stations will include water sampling using a 12-place rosette with 30 L Niskin bottles for the seawater carbonate system (TA, DIC [Bates]), chlorophyll *a*, particulate organic carbon (POC), particulate inorganic carbon (PIC), coccolithophore microscopy/enumeration, FlowCAM imaging cytometry, SEM, and ^{14}C photosynthesis/ calcification (only taken at daily pre-dawn water cast) [Balch]. Water samples will also be drawn for nutrients (nitrate, nitrite, phosphate, silicate and ammonium), dissolved O_2 and salts. Underway DIC/TA samples and autonomous pCO_2/pH data will be collected [Bates]. Ship's ADCP and Video Plankton Recorder (microplankton, optical and hydrographic data) will be collected [McGillicuddy]. Dissolved and particulate trace metals will be sampled using Niskin-X trace-metal-clean sample bottles [Morton].

In targeted eddies, samples from 20m depth will be taken from the eddy center with a 30L GO-FLO bottle and water immediately sampled for PIC, POC, nutrients, dFe, carbonate chemistry, BSi, chlorophyll, coccolithophore counts and FlowCAM abundance of phytoplankton functional groups [e.g. pennate and centric diatoms, dinoflagellates, nanoeukaryotes along with other rarer groups), single cell F_v/F_m and metagenomics analysis. Deckboard incubators will be maintained at the ambient temperature with recirculating surface seawater supplemented by a heater/chiller, as needed. Incubators will be exposed to 50% incident irradiance. Following time-zero sampling, the remaining water will be divided into triplicate polycarbonate bottles followed by 6 treatments: no addition (control), +nitrate (20μM), +silicate (20μM), +iron (+2nm), a combined iron+silicate to examine nutrient co-limitation and 0.2μm-filtered sub-euphotic SAMW to examine the whole community response. The grow-out experiments will be incubated at ambient water temperature. After 4 d, the bottles will be sampled for nutrients, dissolved and particulate trace metals, POC, PIC, Chl, BSi, microscopy, and FlowCAM, TA and DIC, single-cell F_v/F_m and metagenomics analysis.

(2) Standards to be used for data and metadata formatting and content. Tabular data and metadata from CTD casts will be in Sea Bird formatted files. Other variables sampled from water casts will be kept primarily as tabular data in Excel spreadsheets; SEM and light microscope images will be stored as TIF files. The data will be made available online via the BCO-DMO data system (http://bco-dmo.org/data/) and BCO-DMO will submit all data to the NODC for long-term archive.

(3) Mechanisms for access and sharing including provisions for appropriate protection of privacy, confidentiality, security, intellectual property, or other rights or requirements. For sharing files between the Balch, Morton, McGillicuddy and Bates laboratories we will use password-protected Dropbox software. Distribution of data to BCO-DMO will be done within two years of their collection via password-secure FTP. All data generated as a result of research performed at the respective laboratories, or with each respective laboratory's funds, shall be the intellectual property of the respective laboratory, as well as the investigator or co-investigator overseeing the research. As such, each laboratory will retain an implied copyright for these data.

(4) Policies and provisions for re-use, re-distribution, and the production of derivatives. Data from this work will be submitted to BCO-DMO where they will be publically available two years after collection. Peer-reviewed papers will be written about these data, along with details of their collection and data interpretation.

(5) Plans for archiving data, samples, and other research products, and for preservation of access - Each investigator is responsible for maintaining data associated with their own research group's activities, and in accordance with any institutional requirements of the PI's home institution. Basic practices for key areas are outlined. **Lab notebooks.** All information connected with initial data collection, analysis, and results shall be kept in a lab notebook and in cases digital notebooks may be used. Regardless of media, these notebooks shall be stored securely. Hard-copy notebooks shall be situated to enable institutional retrieval. Digital notebooks will follow short-term and long-term policies of each laboratory outlined below. All research notebooks of each investigator are property of their home institution. **Short-term storage and data management. Data volumes.** Data storage shall be appropriately and redundantly stored using computer hardware and software that is available to the each laboratory, and may include in-house and/or off-site resources. The PI and Co-Is are responsible for due diligence with respect to short-term storage of data. Additionally, all data shall be retrievable from primary media or back-ups, as well as reasonably protected from accidental loss due to corruption, power loss, or failure of computer hardware. **Data security.** Data shall be stored on either off-network mobile devices (external hard drives) or off-site cloud resources. Password protection will be utilized. This data must be made available to senior institution officials in the case that any institutional liability issues should arise. **Data backup.** Stored data shall be backed-up weekly. Balch will use the Bigelow Laboratory high-performance elastic computing system backed by 200TB of high performance storage. This system facilitates the Laboratory's long-term data management strategy as well as short-term hourly backups. The McGillicuddy and Bates laboratories use external drive backups. **Deposit and long-term preservation. Long-term strategy.** Within two years of data collection, data will be transferred to BCO-DMO for public access and long-term storage. After the project has been completed, arrangements shall be made to transfer data at each home institution from short-term storage to a long-term archival system. **Length of archival.** Data will be kept in long-term storage for at least five years, or until it has been successfully uploaded to and made publically available through a nationally or internationally funded database specific to that data.

MODELING DATA

Data Types. The modeling data created by this project will be output from the Community Earth System Model (CESM). As such, we will abide by the CESM Data Management Plan, available here: http://www.cesm.ucar.edu/management/docs/data.mgt.plan.2011.pdf. Output will be produced from (1) Development Simulations and (2) Production Simulations. Development simulations entail runs conducted to evaluate model behavior during the development cycle, including for the purposes of tuning and testing performance. Data from these runs does not typically have much use beyond completion of developments and will thus not be archived or made publically available. Data from Production Simulations is what will be used to conduct the proposed research; these data will be made publicly available and archived. **Data Format**: The model output data will be in netCDF format, and the file size will range from 1 GB to 150 GB. The data files will be named and structured using the following convention: CaseName.ComponentName.OutputType.Date.nc. See here for additional information: http://www.cesm.ucar.edu/models/cesm1.0/filename_conventions_cesm.html. **Metadata**: File level metadata for each data file will be recorded automatically through the header section of the netCDF file, which is also compliant to the Climate and Forecast (CF) metadata convention. **Access to Data and Data Sharing Practices and Policies**: During the project lifetime, all data generated during the project will be stored and available for project use and for other interested parties on a request basis that recognizes proprietary access to the project members. The final results of the project will be moved into the public domain and be made publicly available through the Earth System Grid (https://www.earthsystemgrid.org). While public access is free of charge, a registration process with the Earth System Grid will be required. This is to help in tracking the data's distribution and usage. **Policies for Re-Use, Re-Distribution**: Those who are interested in using the project's final data can obtain access via Earth System Grid as described in the above section. Users are expected to cite the project and the corresponding data according to the citations that will be established by the project team.

Postdoctoral Scholar Mentoring Plan

National Center for Atmospheric Research

We are requesting funds to support a 2-year postdoctoral scholar position at NCAR. The postdoc will contribute to defining the research, designing and analyzing model experiments and observational data. The training and mentoring of this junior researcher will primarily be accomplished through a close working relationship with Dr. Long while immersed in a model development group at NCAR. In the following, we describe in more detail the guidelines for the environment in which the postdoctoral scholar will work in support of the research objectives.

Clear communication of mutual expectations throughout the project will be a consistent element in our mentoring plan. This will begin with the development of an individual progress plan formulated upon the postdoc's arrival and re-evaluated on a regular basis. It is our expectation that the postdoc takes ownership and conducts independent research on topics aligned with her (or his) interests. We will commit to providing support in the form of intellectual and technical resources necessary for success. Furthermore, we will operate with an "open-door" policy, and encourage frequent, informal interactions concerning scientific and other questions. At every juncture, we will ensure that the postdoc's work is focused on elements of the project that promote long-term career objectives, and assist with work flow recommendations to optimize productivity. We will encourage the postdoc to fully immerse in the scientific culture at NCAR by attending seminars and engaging with researchers in the Climate and Global Dynamics Laboratory and beyond. The postdoc will be encouraged to attend national meetings to present their work. Presentations and publications will be prepared by the postdoc under the close direction of Dr. Long. The postdoc will be considered an integral team member, with full access to all datasets and modeling products.

In addition to a strong collaborative research environment, we will provide support for other elements of career development. Regular virtual meetings with the project team will provide opportunities to develop teaching and mentoring skills, through presentations, brainstorming, and the informal exchange of ideas. The postdocs will also be encouraged to further develop teaching and mentoring skills by helping guide the research efforts of students participating in the project. We will facilitate interactions with other members of the scientific community with specific areas of expertise as appropriate, given the research questions being pursued. The postdoc will have access to the numerous career counseling resources available at NCAR. These include the Early Career Scientist Assembly (http://www.asp.ucar.edu/ecsa/ecsa.php), which holds semi-regular seminars on topics related to the academic career track, and the NCAR Fellows Association, which facilitates interactions between postdocs across NCAR.

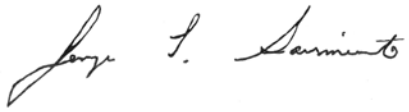
PRINCETON UNIVERSITY

Program in Atmospheric and
Oceanic Sciences
Forrestal Campus
300 Forrestal Road, Sayre Hall
Princeton, New Jersey 08540-6654

January 18, 2017

To: NSF Chemical Oceanography

If the proposal submitted by Dr. William Balch entitled "Collaborative Research: Biogeochemical and physical conditioning of Sub-Antarctic Mode Water in the Southern Ocean" is selected for funding by NSF, it is the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) Project's intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.



Jorge Sarmiento, Director
Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) Project

Bigelow | Laboratory for Ocean Sciences

Benjamin S. Twining, PhD
Interim Executive Director
Senior Research Scientist
Vice President for Research and Education
(207) 315-2567 x309
btwining@bigelow.org

February 6, 2017

Dr. William Balch
Senior Research Scientist
Bigelow Laboratory for Ocean Sciences
POB 380, 60 Bigelow Drive
East Boothbay, Maine 04544

To Whom It May Concern:

If the proposal submitted by Dr. William M. Balch entitled "Collaborative Research: Biogeochemical and physical conditioning of Subantarctic Mode Water in the Southern Ocean" is selected for funding by NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely

Benjamin S. Twining, PhD
Interim Executive Director
Senior Research Scientist

The Marine Biological Association
Established 1884, incorporated by Royal Charter 2013

Patron: HRH The Prince Philip, Duke of Edinburgh
President: Professor Sir John Beddington, CMG FRS
Director: Professor Colin Brownlee

The Laboratory
Citadel Hill
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fax: **+44 (0)1752 426274**
email: **sec@mba.ac.uk**
w**ww.mba.ac.uk**

February 6, 2017

To: NSF Chemical Oceanography:

If the proposal submitted by Dr. William M. Balch entitled "Collaborative Research: Biogeochemical and physical conditioning of Subantarctic Mode Water in the Southern Ocean" is selected for funding by NSF, it is our intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal.

Sincerely

Professor Colin Brownlee
MBA Director

Dr Declan Schroeder
MBA Senior Research Fellow

THE ROSENSTIEL SCHOOL

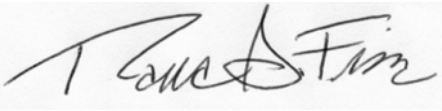
February 7, 2017

National Science Foundation
Division of Ocean Sciences
Arlington, VA

To Whom It May Concern:

If the proposal submitted by Dr. William M. Balch, entitled "Collaborative Research: Biogeochemical and Physical Conditioning of Subantarctic Mode Water in the Southern Ocean", is selected for funding by NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment and Other Resources section of the proposal. This letter is to also affirm that we will charge $100 per sample for CFC-11, CFC-12 and SF6 analysis of water samples in our laboratory. Furthermore, we will provide guidance on sampling protocols and data interpretation to insure the best accuracy possible.

Sincerely,



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UNOLS Ship Time Request Form - Section ONE - Project Information

Project Title: Collaborative Research: Biogeochemical and physical conditioning of Subantarctic Mode Water in the Southern Ocean
Project Short Title: Conditioning SAMW Project Status: Submitted
UNOLS Project ID #: 105633 Version #: 1
Last Modified: 2/8/2017 5:03:00 PM Date Submitted: 2/8/2017
Project Created By: William M. Balch

P.I. Name: William M. Balch Institution: Bigelow
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Matthew C. Long	UCAR	(303) 497-1311	mclong@ucar.edu

Science Discipline: ChemOce Large Program Abbr: None Selected
If Other Science Discipline, specify:
Large Program Comments:

Project Status: New Proposal

Agency/Division/Program	Grant/Project Number	Agency Funding Status
NSF/OCE/CO	1559261	To Be Submitted

Agency Description: NSF Chemical Oceanography (note, however, project also has relevance to Biological Oceanography and Physical Oceanography divisions at NSF and may be involved in the review, as well)
Institutional Proposal #:
Proposal Deadline submitted for: 2/15/2017
Project Start Date: 8/1/2017 End Date: 7/31/2021
Project Budget: $3,237,451

Ship(s) Requested	Total	Repeat/Multi-ship/

Year	(Name or Size)	Days Req.	Start Date	Clearance Req./Estimated Cost
2018	Roger Revelle	43	1/7/2018	No/No/Yes/$1,812,235
2019	Roger Revelle	43	1/7/2019	No/No/Yes/$1,902,836

Project Webpage:

Summary of Field Work: We are proposing two cruises out of Durban, South Africa,(returning to Durban, S.A.) to sample the chemical conditioning of SubAntarctic Mode Water (SAMW) around the region near the Crozet Islands and its effects on subsequent growth of minerogenic phytoplankton as that water is subducted towards the north. The two cruises would be during the austral summer of Jan. 2018 and 2019. We realize that depending on ship availability due to previous schedules and locations, the two cruises may have to be done in 2019 and 2020, in which case, the spending profile of the NSF project would have to be adjusted accordingly). The total length of the cruise track from Durban, S.A. to the study site and back to Durban is ~5930 nautical miles. We will study the conditioning of carbonate chemistry as well as, nutrient and trace metal chemistry of SAMW by coccolithophores and diatoms, each of which is abundant in waters of the SubAntarctic Front and Polar Front, respectively; both algal groups are major players in ballasting of particulate organic matter and driving the ocean's biological pump at the site of SAMW formation as well as northwards into subtropical and tropical waters.

The first cruise will involve two parts: surveying two mesoscale eddies (A) one that is rich in coccolithophores, examine how the carbonate, nutrient and trace metal chemistry changes over a time scale of a month cruise in these mesoscale, semi-enclosed water masses. These observations will be compared to (B) a low-PIC eddy and its associated changes in carbonate chemistry. We also will perform nutrient/iron-addition (or 0.2um-filtered, deep SAMW water addition) experiments aboard the ship to examine factors that are limiting phytoplankton growth. Lastly, we will perform a section between 60oS and 30oS, along the 55oE meridian to provide the larger-scale view of the rate of conditioning of the subducting SAMW, both at the site of formation by the diatoms of the Polar Front and the coccolithophores of the Great Calcite Belt, or further to the north as the water heads towards the equator. The second cruise will not repeat the meridional section between 60oS and 30oS. Instead, that cruise will focus exclusively on surveying four more eddies in the region as they are shed from the Subantarctic Front and Polar Front and move water to the north and west. Vertical water sampling will go through the base of the eddies and reach vertically down to the SubAntarctic Mode Water (as deep as 1000-1500m). We are offering to the SOCCOM program (Southern Ocean Carbon and Climate Observations and Modeling)

to help them deploy new profiling fronts in this poorly-sampled Indian Ocean region (see letter of commitment in the proposal from J. Sarmiento) and will use SOCCOM data in our study of SAMW conditioning.

Summary of Facility Requirements: We will need facilities for the following work:

1) Isotope van for 14C tracer work

2) UNOLS trace-metal clean van

3) Metal free block/sheave for running Kevlar line through (Balch will bring (non-conducting) line to put on the Sperry deck winch for hanging bottles). We need to keep the Kevlar line clean in terms of trace iron contamination.

4) Bow-mounted radiometers (several years ago the R/V Revelle fabricated an elegant mount for us to do this which they may still have on the ship.

5) Flowing seawater system for underway measurements of optics and SAMI pCO2 system

6) Video Plankton Recorder (supplied by Bigelow Laboratory) will need to be mounted on the ship's quarter at the stern for performing detailed eddy sections.

7) CTD/hydrocast capabilities

8) Fume hood (for working with acetone)

9) Access to Met/Nav data

10) ADCP

11) Thermosalinograph data

12) Marine tech support for running nutrient (NO3, NO2, PO4, Si(OH)4), NH4, DO and Salinity at ~76 profiles, plus running nutrients on four carboy experiments.

13) We will need space on the fan tail for flow-through seawater incubators. They have a foot print of 4' x 4' and we expect to have at least four of them. These will be to incubate carboys in ambient seawater plus smaller bottles for primary production/calcification incubations. We would have one temperature control unit for maintaining the temperature where the water was sampled over 3-4d periods.

14) Co-investigator McGillicuddy (and his research associates) will be helping with the VPR surveys, and using the ADCP data for defining current velocities.

15) At the centers of each surveyed eddy, we will deploy a lagrangian drifter equipped with ARGOS in order to center the ship surveys. The drifters will be recovered after the survey is complete.

16) If possible, we would like to load as much as possible of equipment, hazmats, radioisotopes, gases in a US port before the ship sails . We fully understand that this must be cleared at multiple levels and is not a "given".

Summary of Other Requirements or Comments: The cruise tracks are designed in

order that the available time for dedicated science on station is 5d out of the 38 days requested (with one weather day built in). There will be several types of station sampling: 1) underway sampling for hydrography and optics, 2) CTD no-water, 3) CTD with water (for measuring everything except productivity), 4) CTD with water including productivity and a separate cast of trace-metal clean Niskin-X bottles, 5) VPR deployments, 6) in-water optics sampling, 7) two drogued drifters equipped with ARGOS transmitters will be deployed in the core of each eddy to mark the eddy center and 8) four incubation stations for carboy incubations with nutrient or iron additions will be performed in the first cruise (in the second cruise, there will be 8 carboy experiments); 9) CFC's will be measured (water samples only) on the meridional transect in cruise #1 in order to age the SAMW.

The reason for this stratified sampling is related to both finances and time. Underway sampling will provide us the fastest way to survey each eddy. Productivity stations are the most costly in terms of supplies, wire time and technician time to process. At the other extreme are CTD/no-water casts which can be done quickly and cheaply. Thus, we are planning ~149 CTD casts for the trip, half of which will involve collecting water (the other half would be CTD only) which will provide a horizontal resolution of the hydrography of ~80km. We will sample at finer scale near the eddy edges since gradients will be stronger there. Profiles of other discrete water samples (including chlorophyll, POC, PIC, DIC, cell counts, biogenic silica, CTDs, etc.) will be measured at ~75 stations (with effective station spacing of ~160km). Productivity casts will always be done pre-dawn and will include all particulate analyses and CTD measurements. The incubations will always run for 24h. There will ideally be one productivity station per day or about 34 for the cruise (station spacing for productivity/calcification will be ~400km). A free-fall optical profiler will be deployed at local apparent noon when sea-state permits and skies are clear (thus maybe 10 profiles per cruise leg?). These provide subsurface radiance and irradiance estimates as a function of depth, which can be inverted to derive inherent optical properties (that can be related to POC and PIC distributions). Carboy experiments will be conducted on the main deck involving nutrient and trace metal limitation . There will be 4 such experiments over the course of the first cruise and 8 experiments in the second cruise.

UNOLS Ship Time Request Form - Ship Request #1 Information

Project Short Title: Conditioning SAMW UNOLS Project ID #: 105633

PI Name: William M. Balch Version #: 1

Last Modified: 2/8/2017 5:03:00 PM Date Submitted: 2/8/2017
Institution: Bigelow - Bigelow Laboratory for Ocean Sciences
Funding Agencies: NSF/OCE/CO

UNOLS Request ID #: 1009125 Last Modified: 2/8/2017
Request Type: Primary Date Submitted: 2/8/2017
Submitted By: William M. Balch

Year	Ship/Facility	Optimum Start	Earliest Start	Latest Start
2018	Roger Revelle	1/7/2018	1/1/2018	2/1/2018

Dates To Avoid: The coccolithophores that we will be studying peak during austral summer in January/February (and diatoms can still be found further to the south)

	Science Days	Mob Days	DeMob Days	Transit Days (Est)	Total
Op Days Needed	38	3	1	1	43

Multi-Ship OP? No Description: We are open to using other vessels, if necessary, in the interest of getting the work done.
Repeating Cruise? No # of Cruises: 0 Interval:
Repeating Description:
Schedule Justification:

	Lat/Long	Marsden Grid	Navy Op Area
Beginning:	29.72167° S/31.12667° E	404	IN03
Ending:	29.72167° S/31.12667° E	404	IN03

Op Area Summary: S. Ocean
Op Area Size: 1500
Op Area Details: 55oE, 30oS to 60oS

Foreign Clearance Required: Yes
Coastal States: France, South Africa
ITAR/EAR regulated equipment: No
If yes, permit applied for: No
Foreign Clearance Comments:

Start Port: Durban, South Africa
Intermediate Ports: None
End Port: Durban, South Africa
Port Explanation: Durban is the closest port for accessing the Crozet Islands. Moreover, the transit there would take us across the Aghulas, Sub Tropical, Sub-Antarctic fronts, regions that we wish to study.

Chief Scientist: William M. Balch

in Science Party: 21 # of Science Teams: 6 # of Marine Techs: 4

Science Party Explanation: The cruise would require two SIO ship techs for round the clock CTD operation, a chemist for running nutrients/O2/salts, and computer tech for data archival

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Instrumentation that affects scheduling

Dynamic Positioning

Radioisotope use - briefly describe

Instrumentation Explanation: a) Radioisotope use- 14C primary production/calcification work (the same that we have done aboard R/V Revelle on 4 previous cruises.

b) The trace metal work would either be done on the ship by creating a trace-metal clean "bubble" in one of the ship's labs or (preferably) using a UNOLS trace metal clean van (if one is available)

c) CTD/hydrocast capability with 30L Niskins

d) We are requesting dynamic positioning since surface current sheer is high in the region of the Subantarctic Front which can make station keeping more challenging

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Major Ancillary Facilities

Towfish

Clean Lab Van

Radioisotope Lab Van

Portable Winch

Ancillary Facilities Explanation: A trace-metal clean van will be required for Morton to collect and process trace iron samples.

A radioisotope van will be required for Balch's group for doing 14C calcification/photosynthesis work.

On our previous Revelle cruise, we used the SIO Sperry (light-duty?) deck winch for handling Kevlar line for hanging trace-metal-clean 5L Niskin-X bottles and 30L trace-metal-clean GoFLO bottles. We would need to wrap the drum with clean fabric, then wind on 1500m of the 1/4" Kevlar line. This is critical to the work so we mark "Portable Winch" here, but if SIO still has the Sperry, then we could not need the WHOI portable light-duty winch.

UNOLS Ship Time Request Form - Ship Request #2 Information

Project Short Title: Conditioning SAMW UNOLS Project ID #: 105633

PI Name: William M. Balch Version #: 1

Last Modified: 2/8/2017 5:03:00 PM Date Submitted: 2/8/2017
Institution: Bigelow - Bigelow Laboratory for Ocean Sciences
Funding Agencies: NSF/OCE/CO

UNOLS Request ID #: 1009126 Last Modified: 2/8/2017
Request Type: Primary Date Submitted: 2/8/2017
Submitted By: William M. Balch

Year	Ship/Facility	Optimum Start	Earliest Start	Latest Start
2019	Roger Revelle	1/7/2019	1/1/2019	2/1/2019

Dates To Avoid: The coccolithophores that we will be studying peak during austral summer in January/February (and diatoms can still be found further to the south)

	Science Days	Mob Days	DeMob Days	Transit Days (Est)	Total
Op Days Needed	38	3	1	1	43

Multi-Ship OP? No Description: We are open to using other vessels, if necessary, in the interest of getting the work done.
Repeating Cruise? No # of Cruises: 0 Interval:
Repeating Description:
Schedule Justification:

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Op Area Summary: S. Ocean
Op Area Size: 1500
Op Area Details: 55oE, 30oS to 60oS

Foreign Clearance Required: Yes
Coastal States: France, South Africa
ITAR/EAR regulated equipment: No
If yes, permit applied for: No
Foreign Clearance Comments:

Start Port: Durban, South Africa
Intermediate Ports: None
End Port: Durban, South Africa
Port Explanation: Durban is the closest port for accessing the Crozet Islands. Moreover, the transit there would take us across the Aghulas, Sub Tropical, Sub-Antarctic fronts, regions that we wish to study.

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