NASA logo	Cover Page for Proposal Submitted to the National Aeronautics and Space Administration	**NASA Proposal Number** **13-PO13-0032**

NASA PROCEDURE FOR HANDLING PROPOSALS

This proposal shall be used and disclosed for evaluation purposes only, and a copy of this Government notice shall be applied to any reproduction or abstract thereof. Any authorized restrictive notices that the submitter places on this proposal shall also be strictly complied with. Disclosure of this proposal for any reason outside the Government evaluation purposes shall be made only to the extent authorized by the Government.

SECTION I - Proposal Information

Principal Investigator	E-mail Address	Phone Number
Marlos Goes	**mgoes@rsmas.miami.edu**	**305-361-4533**

Street Address (1)	Street Address (2)
4301 Rickenbacker Cswy	**225/2**

City	State / Province	Postal Code	Country Code
Miami	**FL**	**33149-1026**	**US**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
02 / 01 / 2014	**01 / 31 / 2016**	**312,357.00**	**163,274.00**	**149,083.00**	**0.00**

SECTION II - Application Information

NASA Program Announcement Number	NASA Program Announcement Title
NNH13ZDA001N-PO	**Physical Oceanography**

For Consideration By NASA Organization *(the soliciting organization, or the organization to which an unsolicited proposal is submitted)*

NASA , Headquarters , Science Mission Directorate , Earth Science

Date Submitted	Submission Method	Grants.gov Application Identifier	Applicant Proposal Identifier
06 / 28 / 2013	**Electronic Submission Only**		

Type of Application	Predecessor Award Number	Other Federal Agencies to Which Proposal Has Been Submitted
New		

International Participation	Type of International Participation
No	

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
152764007	**1NV47**	**590624458**	**8H**

Organization Name (Standard/Legal Name)	Company Division
University Of Miami, Key Biscayne	**SPONSORED PROGRAMS - RSMAS**

Organization DBA Name	Division Number
UNIVERSITY OF MIAMI ROSENSTIEL MARINE	

Street Address (1)	Street Address (2)
4600 RICKENBACKER CSWY	

City	State / Province	Postal Code	Country Code
KEY BISCAYNE	**FL**	**33149-1031**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Bonnie Townsend	**btownsend@rsmas.miami.edu**	**305-421-4084**

SECTION V - Certification and Authorization

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in the Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing organization (or the individual proposer if there is no proposing organization) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications and one Assurance contained in this NRA (namely, (i) the Assurance of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs, and (ii) Certifications, Disclosures, and Assurances Regarding Lobbying and Debarment and Suspension.

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Authorized Organizational Representative (AOR) Name	AOR E-mail Address	Phone Number
Bonnie Townsend	**btownsend@rsmas.miami.edu**	**305-421-4084**

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

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Marlos Goes**	**305-361-4533**	**mgoes@rsmas.miami.edu**
Organization/Business Relationship		Cage Code	DUNS#
University Of Miami, Key Biscayne		**1NV47**	**152764007**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I/Institutional PI	**Ryan Sriver**	**574-514-0848**	**rsriver@illinois.edu**
Organization/Business Relationship		Cage Code	DUNS#
University Of Illinois, Urbana-Champaign		**4B808**	**041544081**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Gregory Foltz**	**305-361-4430**	**gregory.foltz@noaa.gov**
Organization/Business Relationship		Cage Code	DUNS#
National Environmental Satellite, Data And Information Service, Miami		**1DJC8**	**039261847**
International Participation	U.S. Government Agency		Total Funds Requested
No	**National Oceanic and Atmospheric Administration (NOAA)**		**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Gustavo Goni**	**305-361-4339**	**gustavo.goni@noaa.gov**
Organization/Business Relationship		Cage Code	DUNS#
National Environmental Satellite, Data And Information Service, Miami		**1DJC8**	**039261847**
International Participation	U.S. Government Agency		Total Funds Requested
No	**National Oceanic and Atmospheric Administration (NOAA)**		**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Ben Kirtman**	**305-421-4046**	**bkirtman@rsmas.miami.edu**
Organization/Business Relationship		Cage Code	DUNS#
University Of Miami, Key Biscayne		**1NV47**	**152764007**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION VII - Project Summary

ABSTRACT

The aim of this project is to develop a better understanding of the interactions between tropical cyclones (TCs) and the upper-ocean on a global scale, with special focus on impacts on upper-ocean heat budgets and the dynamic oceanic response to transient TC forcing. We will combine a suite of observation-based NASA/CLIVAR products with high-resolution fully-coupled global climate model experiments (featuring an eddy-resolving ocean component) to address three fundamental questions: (1) What are the local impacts of TCs on upper-ocean heat content, stratification, and the dynamics of sea level? (2) How do TC-induced sea level and heat anomalies propagate from their source regions, and what are the remote influences on tropical-to-subtropical ocean properties? (3) What are the impacts of TC forcing on ocean dynamics, and how does spatial grid resolution affect the response in a fully-coupled Earth system model (featuring an eddy-resolving versus eddy-permitting ocean model component)?

To confront these questions, we will combine observational analyses from NASA remote sensing and CLIVAR data products, with the most current ocean reanalysis products and a state-of-the-art high-resolution coupled climate model (0.5 degree atmosphere and 0.1 degree ocean). We will synthesize these multiple sources of information to investigate near-surface ocean-TC interactions, in order to examine how TCs influence upper ocean energy/mixing budgets on a global scale and explore dynamical implications. We will diagnose the ocean response to TC forcings on various spatial and temporal scales: from daily time scales examining local storm responses, seasonal time scales important for TC predictability, and interannual-to-decadal time scales focusing on basin-wide variability and possible teleconnections with tropical modes of variability.

The project will feature novel use of multiple observational platforms, including: local and global SST (e.g. GHRSST) and salinity (e.g. AQUARIUS/SMOS) responses to TC forcing, surface winds and ocean currents to diagnose the ocean wave response (CCMP/ IBTraACS and OSCAR), and the evolution of changes in ocean heat content and transport using altimetry, gravimetry, and moorings (e.g. GOCE/GRACE, AVISO, TAO, PIRATA).

The overarching goals of this project are to: quantify the impact of tropical cyclones on upper-ocean stratification and sea level, examine possible impacts on oceanic circulations and dynamics on multiple spatial and temporal scales, and create a new metric for the potential impact of the subsurface ocean state on tropical cyclone intensification (potentially improving on current common metrics such as tropical cyclone heat potential). These goals fit directly within both of NASA's key research priority areas related to analyzing and interpreting ocean circulation using satellite and in-situ data, and development of new remote sensing techniques for physical oceanography. The end result will be a better mechanistic understanding of how TCs contribute to upper-ocean dynamics and variability, with implications for improving predictability on multiple spatial and temporal scales, such as TC intensity forecasts, interseasonal climate outlooks and interannual to interdecadal climate predictability.

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?

Yes

International Collaboration

Does this project involve activities outside the U.S. or partnership with International Collaborators?

No

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

Explanation :

NASA Civil Servant Project Personnel

Are NASA civil servant personnel participating as team members on this project (include funded and unfunded)?

No

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

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION VIII - Other Project Information

Environmental Impact

Does this project have an actual or potential impact on the environment?	Has an exemption been authorized or an environmental assessment (EA) or an environmental impact statement (EIS) been performed?
No	**No**

Environmental Impact Explanation:

Exemption/EA/EIS Explanation:

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION VIII - Other Project Information

Historical Site/Object Impact

Does this project have the potential to affect historic, archeological, or traditional cultural sites (such as Native American burial or ceremonial grounds) or historic objects (such as an historic aircraft or spacecraft)?

No

Explanation:

PI Name : **Marlos Goes**	**NASA Proposal Number**
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Mechanisms of tropical cyclones-ocean interactions

Question 2 : Type of institution:

Answer: Educational Organization

Question 3 : Will any funding be provided to a federal government organization including NASA Centers, JPL, other Federal agencies, government laboratories, or Federally Funded Research and Development Centers (FFRDCs)?

Answer: No

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

Answer: N/A

Question 5 : Does this proposal include the use of NASA-provided high end computing?

Answer: No

Question 6 : Research Category:

Answer: 2) Data analysis/data restoration/data assimilation/Earth System modeling (including Guest Observer Activities)

Question 7 : Team Members Missing From Cover Page:

Answer:

N/A

Question 8 : This proposal contains information and/or data that are subject to U.S. export control laws and regulations including Export Administration Regulations (EAR) and International Traffic in Arms Regulations (ITAR).

Answer: No

Question 9 : I have identified the export-controlled material in this proposal.

Answer: N/A

Question 10 : I acknowledge that the inclusion of such material in this proposal may complicate the government's ability to evaluate the proposal.

Answer: N/A

Question 11 : Does the proposed work include any involvement with collaborators in China or with Chinese organizations, or does the proposed work include activities in China?

Answer: No

Question 12 : Are you planning for undergraduate students to be involved in the conduct of the proposed investigation?

Answer: No

Question 13 : If yes, how many different undergraduate students?

Answer: N/A

Question 14 : What is the total number of student-months of involvement for all undergraduate students over the life of the proposed investigation?

Answer: N/A

Question 15 : Provide the names and current year (1,2,3,4) for any undergraduate students that have already been identified.

Answer:

N/A

Question 16 : Are you planning for graduate students to be involved in the conduct of the proposed investigation?

Answer: No

Question 17 : If yes, how many different graduate students?

Answer: N/A

Question 18 : What is the total number of student-months of involvement for all graduate students over the life of the proposed investigation?

Answer: N/A

Question 19 : Provide the names and current year (1,2,3,4, etc.) for any graduate students that have already been identified.

Answer:

N/A

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	33,179.00	34,174.00	0.00	67,353.00
B. Direct Labor - Other Personnel	4,934.00	5,082.00	0.00	10,016.00
Total Number Other Personnel	1	1	0	2
Total Direct Labor Costs (A+B)	38,113.00	39,256.00	0.00	77,369.00
C. Direct Costs - Equipment	5,000.00	0.00	0.00	5,000.00
D. Direct Costs - Travel	3,000.00	3,000.00	0.00	6,000.00
Domestic Travel	3,000.00	3,000.00	0.00	6,000.00
Foreign Travel	0.00	0.00	0.00	0.00
E. Direct Costs - Participant/Trainee Support Costs	0.00	0.00	0.00	0.00
Tuition/Fees/Health Insurance	0.00	0.00	0.00	0.00
Stipends	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Subsistence	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
Number of Participants/Trainees				0
F. Other Direct Costs	79,699.00	81,601.00	0.00	161,300.00
Materials and Supplies	0.00	0.00	0.00	0.00
Publication Costs	2,000.00	2,000.00	0.00	4,000.00
Consultant Services	0.00	0.00	0.00	0.00
ADP/Computer Services	0.00	0.00	0.00	0.00
Subawards/Consortium/Contractual Costs	77,699.00	79,601.00	0.00	157,300.00
Equipment or Facility Rental/User Fees	0.00	0.00	0.00	0.00
Alterations and Renovations	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
G. Total Direct Costs (A+B+C+D+E+F)	125,812.00	123,857.00	0.00	249,669.00
H. Indirect Costs	37,462.00	25,226.00	0.00	62,688.00
I. Total Direct and Indirect Costs (G+H)	163,274.00	149,083.00	0.00	312,357.00
J. Fee	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	163,274.00	149,083.00	0.00	312,357.00
Total Cumulative Budget				312,357.00

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2014	01 / 31 / 2015	Project	1

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Goes, Marlos	PI	0.00	4			24,008.00	9,171.00	33,179.00
							Total Key Personnel Costs	33,179.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Programmer	1			3,570.00	1,364.00	4,934.00
1	Total Number Other Personnel					Total Other Personnel Costs	4,934.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	38,113.00

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2014	**01 / 31 / 2015**	**Project**	**1**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
1	Computer	5,000.00
	Total Equipment Costs	5,000.00

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	3,000.00
2. Foreign Travel	0.00
Total Travel Costs	3,000.00

E. Direct Costs - Participant/Trainee Support Costs

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

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2014	**01 / 31 / 2015**	**Project**	**1**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	2,000.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	77,699.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	79,699.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	125,812.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC	55.00	68,113.00	37,462.00
Cognizant Federal Agency: DHHS, Darryl Mayes, 301/492-4855		**Total Indirect Costs**	37,462.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	163,274.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	163,274.00

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2015	**01 / 31 / 2016**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Goes, Marlos	**PI**	**0.00**	**4**			**24,728.00**	**9,446.00**	**34,174.00**
							Total Key Personnel Costs	**34,174.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Programmer**	**1**			**3,677.00**	**1,405.00**	**5,082.00**
1	**Total Number Other Personnel**					**Total Other Personnel Costs**	**5,082.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**39,256.00**

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**
Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2015	**01 / 31 / 2016**	**Project**	**2**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**3,000.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**3,000.00**

E. Direct Costs - Participant/Trainee Support Costs

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

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
02 / 01 / 2015	**01 / 31 / 2016**	**Project**	**2**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	2,000.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	79,601.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	81,601.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	123,857.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC	57.00	44,256.00	25,226.00
Cognizant Federal Agency: **DHHS, Darryl Mayes, 301/492-4855**		**Total Indirect Costs**	25,226.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	149,083.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	149,083.00

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Goes, Marlos	**PI**	**0.00**				**0.00**	**0.00**	**0.00**
							Total Key Personnel Costs	**0.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
0	Total Number Other Personnel					Total Other Personnel Costs	**0.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**0.00**

PI Name : **Marlos Goes**	NASA Proposal Number
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**0.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**0.00**

E. Direct Costs - Participant/Trainee Support Costs

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

PI Name : **Marlos Goes**	**NASA Proposal Number**
Organization Name : **University Of Miami, Key Biscayne**	**13-PO13-0032**

Proposal Title : **Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**3**

F. Other Direct Costs

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

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	0.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
Cognizant Federal Agency:		**Total Indirect Costs**	0.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	0.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	0.00

Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts

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1. Background

Tropical cyclones (TC) are transient natural events that cause the greatest amount of accumulated economic losses in developed countries. TCs derive their energy primarily from the upper ocean energy is provided mainly by the ocean along the translation of the storm. TCs interact with the ocean in a complex way through fluxes of heat, freshwater and momentum, which can influence upper-ocean temperature and salinity stratification along storm paths (Figure 1). These interactions can have a wide range of implications for a variety of important and outstanding topics, including TC predictability (Goni et al., 2010), ocean energy budgets (Sriver and Huber, 2007; Sriver et al., 2008; Jullien et al., 2012), ocean circulations (Jansen and Ferrari, 2009; Fedorov et al., 2010; Sriver et al., 2010; Scoccimarro et al., 2011), tropical modes of variability (Sriver et al., 2013), and coupled climate feedbacks (Emanuel,2001; Korty et al., 2008).

Modeling (Bender and Ginis, 1993; Wada, 2005; Wang et al., 2012) and observational (Black and Dickey, 2008; Huang et al., 2009; Cuypers et al., 2013) studies have sought to constrain the importance of the mechanisms responsible for TC-induced cooling and mixing of the upper ocean. TCs cool the upper ocean through multiple mechanisms such as geostrophic and near-inertial advection, surface fluxes, and entrainment across the base of the mixed layer (Dickey et al., 1998; Jacob et al., 2000). Research has shown that the dominant factor for TC-induced upper-ocean cooling is entrainment at the base of the mixed layer caused by the excitation of the near-inertial wave field (Shay et al., 1992; Shay et al., 1998; Jacob et al., 2000; Black and Dickey, 2008). The shear between the inertial currents in the mixed layer and the background velocity within the thermocline induces vertical velocities, which propagate wave energy to significant depths and to small scales necessary for diapycnal mixing. Ocean-atmosphere surface fluxes contribute far less than mixing/entrainment to the surface cooling, accounting for approximately 10 to 20% of the overall upper ocean cooling (Jacob et al., 2000; Ginis, 2002; D'Asaro et al., 2007). Features associated with ocean fronts and eddies are likely to have considerable advective contributions to surface cooling (Oey et al., 2007). Additional important components of the vertical redistribution of seawater are Ekman pumping (i.e., upwelling), especially for slowly translating storms (Yablonsky and Ginis, 2009) and the geostrophic response to cyclonic wind forcing (Manucharyan et al., 2011).

The relative contributions of the inertial and the geostrophic responses to the vertical mixing budget depend on multiple factors, including TC size, intensity, and translation speed (Mei et al., 2012). A slow-moving large storm will likely lead to more upwelling via Ekman pumping and enable a stronger geostrophic response compared to a fast-moving small storm, which will likely yield a larger inertial wave response (Ginis, 2002). However, the ocean response also depends on the background regional and seasonal conditions (Park et al., 2011; Wang et al., 2012).

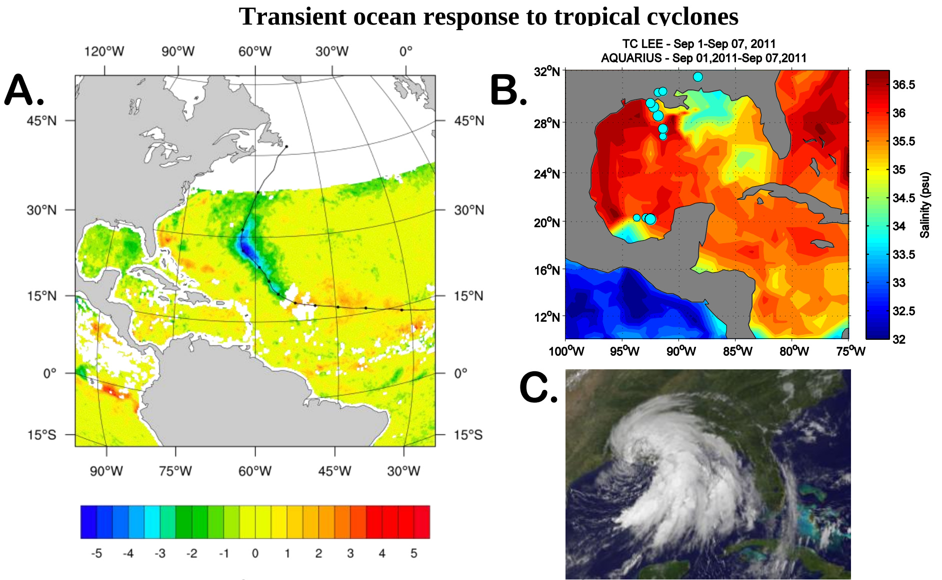

Figure 1: (A) (Adapted from Done et al., 2009). Sea surface temperature anomaly (in deg C) following Hurricane Gert, 1999. The figure highlights the impact of a single tropical cyclone on the upper ocean. Mixing area is equivalent in size to the US eastern seaboard, and surface cooling reflects upwelling depths of more than 100 meters. (B) Aquarius salinity (contour) and the tropical storm Lee track (Sep 2011) in the Gulf of Mexico. (C) Satellite image of storm Lee.

TC-induced upwelling cools and deepens the mixed layer, decreasing the mixed layer heat content, as observed via altimeter-derived surface height anomalies (Shay et al., 2000). The near-surface cooling, which depresses the SST, is accompanied by downward pumping of heat into the upper-thermocline (Huang et al., 2009). Tropical cyclone-induced cooling is caused mostly by entrainment due to mixing (Bender et al., 1993), resulting in a net deepening of the thermocline. The extent of TC-induced mixing is apparent in the depressed SST occurring in the wakes of the storms (Price, 1981) and in phytoplankton blooms observed after storm passage (Lin et al., 2003; Babin et al., 2004). Observed phytoplankton blooms indicate upwelling from within the euphotic zone (Lin et al., 2003) (50 - 150 meters), but mixing-induced temperature anomalies may penetrate up to depths of 300-400 meters (Ginis, 2002; Price, 2009). After the storm passage, air-sea fluxes restore SSTs and the stratification of the mixed layer to climatologically normal values on the timescale of days to weeks, promoting the uplift of the thermocline and leaving a pronounced warm anomaly beneath the mixed layer (Price et al., 1994; Zedler et al., 2002; Price et al., 2008).

During storm passage, the air-sea enthalpy (sensible plus latent heat) flux is an important parameter that affects TC intensification (Cione and Uhlhorn, 2003; Lloyd and Vecchi, 2011), and most of the energy exchange occurs in a limited area near the eyewall (Cione and Uhlhorn, 2003). Therefore, regions with a high SST (generally > 26°C) are very conducive to TC intensification. However, SST does not always reflect the subsurface thermal conditions that are reflected more accurately in altimetry data (Ali et al, 2007), as observed in the decreased upper ocean energy after the storm passage (Figure 2). In fact, several regional studies (e.g., Shay et al, 2000; Mainelli et al., 2008) have demonstrated that the bulk upper ocean heat content (UOHC) under the storm is the main driving force for TC intensity changes, and UOHC is still widely used in operational forecasts (DeMaria et al., 2005; Knaff et al., 2005). The definition of this "tropical cyclone ocean heat content" (UOHC) is still controversial, since low values of UOHC

(<50 KJ/m^2) are generally not correlated to TC intensity (Price, 2009) and recent studies call for further regional validations and improvements in the methodologies of UOHC (Pun et al., 2007; Goni et al., 2009; Price, 2009).

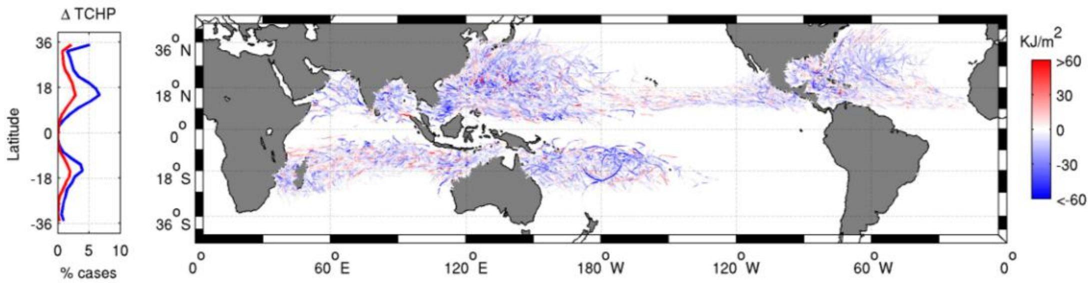

Figure 2: Changes in UOHC along TC tracks calculated by the difference between 10 days after and 10 days before the storms. Left panel shows the histogram with the percentage of cases that shows cooling (blue) and warming (red) after the storm passage.

More generally, studies performed in all ocean basins indicate that TC intensification is highly dependent on upper ocean temperature stratification, emphasizing that the role of the ocean still needs to be adequately quantified. In addition to the upper-ocean thermal structure, salinity stratification and TC-induced freshwater fluxes can influence the mixed layer both locally and globally. Locally, the freshwater input by TCs can reduce the mixed layer depth after the passage of the TC (Jourdain et al., 2013), reducing cold water entrainment. Important salinity effects may arise where there is a comparatively fresh ocean surface layer, which often occurs in a coastal ocean, and especially down-coast from the estuary of a major river (Figure 1B; Price, 1981; Bingham, 2007, Grodsky et al., 2012). Also, salinity stratification can contribute to the static stability of the upper ocean by forming barrier layers (when the bottom of the mixed layer is shifted with respect to the bottom of the isothermal layer) in the western basins, which can prevent entrainment of cold water from below into the mixed layer (Maes et al., 2005; Foltz and McPhaden 2009) and enhance TC intensification by 50% on average (Balaguru et al., 2013); or act to increase the density stratification where temperature and salinity stratification are coincident with depth.

Heat pumped downward in the ocean by TCs can also have implications for global climate. The process of storm-induced cooling and post-storm warming within the upper ocean represents a net column-integrated heating in the affected regions, which has been hypothesized to be balanced by the equivalent amount of heat transferred poleward (~1.4 pW) on longer timescales (Emanuel, 2001). Recent observational estimates, however, indicate that heat pumping induced by TCs is more likely on the order of ~0.3 to 0.5 PW (Sriver and Huber, 2007; Sriver et al., 2008; Jansen et al., 2010). The discrepancy between estimates is primarily due to the relatively slow dynamical response of the ocean compared to seasonal thermocline adjustments. Deepening of the mixed layer during the winter season can reabsorb a large fraction of the heat accumulated during the previous TC season through enhanced vertical mixing. This excess heat is subsequently released back to the atmosphere (Jansen et al., 2010). This is because water mass formation through subduction processes is strongly tied to the winter season, when the mixed layer is deeper (Stommel, 1979; Williams et al., 1995; Goes et al., 2008). However, mixing induced by TCs can produce a second seasonal peak of effective detrainment, and change the seasonality of the subduction rates (Liu et al., 2011). Temporal changes in the mixed layer can alter subduction rates and produce anomalies in the subtropical cells (Valdivieso da Costa et al., 2005). In this way, the heat stored below the thermocline will likely follow a path in the subtropical cells around the subtropical gyre and toward the equator, into the equatorial upwelling region (Lu et al., 1998; Schott et al 2004).

Climate models show a strong equatorial response to the turbulent mixing caused by hurricanes (Sriver et al., 2010). However, past studies are inconclusive about the ocean mechanisms that govern the advection of heat anomalies in the tropics, and the importance of a dynamical ocean response on intra-seasonal to annual timescales is unclear. Idealized representations of TC mixing support the importance of mixing in the subtropical latitudes for determining thermal structure of the upper equatorial Pacific (Jansen and Ferrari, 2009; Fedorov et al., 2010). However, the only mechanisms described is that TC-induced mixing in the western Pacific injects warm water into the return branch of the subtropical overturning cell, which feeds this anomalously warm water into the equatorial undercurrent where it is upwelled in the eastern equatorial Pacific. The end result, in steady-state conditions, is an anomalously warm eastern equatorial cold tongue, similar to a permanent El Niño-like temperature pattern, though the physical mechanisms at play are fundamentally different from those involved in ENSO dynamics (e.g., Wyrtki, 1975; Battisti and Hirst, 1989).

The TC influence on the tropical variability may also be triggered by oceanic waves, a mechanism that is unique from the conventional pathway through the shallow subtropical cells. Past observational (Keen, 1982; Nitta, 1989) studies have hypothesized that TCs may be important for triggering the onset of El Niño events through generation of coastal and equatorial Kelvin waves. Recent results (Sriver et al., 2013; Figure 3) show how TC winds can indeed influence the equatorial wave guide in an Earth system model (CCSM3) through generation of Kelvin and Yanai waves in the Pacific basin, which are also recorded by the Tropical Atmosphere Ocean (TAO) buoy array. These model results point to potentially strong connections between interseasonal to interdecadal climate variability and changes in spatial and temporal distributions of TCs, through linkages to tropical Pacific modes of variability. It is also possible that the tropical Atlantic main modes of coupled ocean-atmosphere variability, the Equatorial Mode, similar to the Pacific El-Niño (Zebiak, 1993), and the Atlantic Meridional Mode (AMM)(Servain et al., 1999; Xie and Carton, 2004), are affected by seasonal hurricane activity (Vimont and Kossin, 2007; Zhu et al., 2012).

The observational and modeling studies discussed above have broken important new ground on global scale TC-ocean interactions, uncovering important implications for upper-ocean heat content variability, TC predictability, ocean dynamics, and ocean-atmosphere climate feedbacks. However, the observational studies to date have been typically limited by the inability to observe processes beneath the surface on a global scale. Thus, any impacts of TCs on subsurface properties and dynamics are largely inferred. Further, modeling studies are typically limited by: model resolution, lack of atmosphere-ocean coupling, and/or inadequate representation of TC effects through either parameterizing TC-induced vertical mixing or prescribing TC wind fields.

Modeled (A) and observed (B) tropical ocean waves excited by tropical cyclones

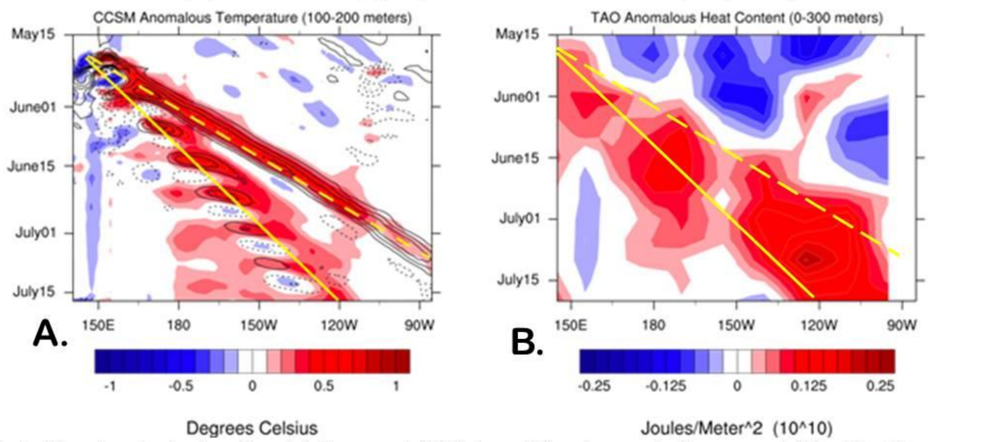

Figure 3. A. Time-longitude plot of modeled equatorial Kelvin and Yanai waves in the equatorial Pacific. The waves were excited by tropical cyclone wind forcing and correspond to 3 real near-simultaneous events occurring in May 2003. Yellow lines denote the model's internal Kelvin wave phase/group speed (dashed), and Yanai wave group speed for the 1st baroclinic mode (solid). B. Observed passage of a Kelvin wave by the TAO buoy array in the equatorial Pacific. The timing and characteristics of the observed wave event are consistent with the simulated wave. Figure 3 provides evidence that TCs are capable of influencing the equatorial wave guide, which are well-represented in the CCSM ocean model (A) and observations (B).

2. Project Objectives

The fundamental goal of these analyses is to build a better understanding of how the cumulative effects of transient, yet extreme, events like tropical cyclones can affect climate variability, ultimately leading to improved predictability on decision-relevant timescales.

Therefore we propose to use a unique set of observations and numerical model experiments to analyze global scale TC-ocean interactions in more detail than heretofore possible. We will combine a suite of observation-based NASA/CLIVAR products with high-resolution fully coupled climate model experiments, which feature a 0.5 degree atmosphere capable of resolving realistic TC-like circulations coupled to a 0.1 degree eddy-resolving ocean model. The overarching goals of this project are to: quantify the impact of tropical cyclones on upper-ocean stratification and sea level, examine possible impacts on oceanic circulations and dynamics on multiple spatial and temporal scales, and create a new metric for the potential impact of the subsurface ocean state on tropical cyclone intensification. Our research plan is built upon three central questions:

1. What are the local impacts of TCs on upper-ocean heat content and stratification on the dynamics of sea level?
2. How do TC-induced sea level and ocean heat anomalies propagate from their source regions, and what are the remote influences on the tropical-to-subtropical ocean?
3. What are the impacts of TC forcing on ocean dynamics, and what is the sensitivity of the modeled response to the horizontal resolution (eddy-permitting versus eddy-resolving)?

The proposed objectives will focus on answering these three outlined questions. Our proposed work will combine syntheses of NASA/CLIVAR data products, model reanalysis and a high-resolution coupled general circulation model, which spontaneously forms realistic TC-like circulations, to examine how tropical cyclones contribute to dynamic variability of the global tropical and subtropical oceans on daily to inter-decadal time scales. Therefore, we put forth three key project objectives:

In **Objective 1)** we will use satellite observations of sea level, SST and SSS, along with in-situ ocean observations to construct daily gridded temperature and salinity profiles in the tropical/subtropical ocean basins. UOHC will be calculated from weekly synthetic temperature profiles and associated with the background ocean state based on local climatologies. A new metric for UOHC for TC intensification will be developed and tested. We will analyze mechanistically the contributions of TCs to the upper ocean circulation by decomposing the sea level into its dynamical components and analyze how they change during the passage of TCs. We will assess how observations and daily reanalysis products capture those processes.

In **Objective 2)** we will utilize the tools and products developed as an outcome of Objective 1 to investigate remote impacts and pathways of TC-induced heat content and sea level anomalies through wave and advective mechanisms. We will study the dominant mechanisms of sea level and UOHC changes in different regions, and how the sea level anomalies propagate away from the affected source regions. We will explore the possible remote impacts of TCs on larger-scale ocean properties and dynamics, focusing on internal wave responses in the coastal and equatorial regions.

In **Objective 3)** we will analyze local and remote impacts of TC in recently performed coupled model simulations under different ocean resolutions. We will use daily outputs from the coupled model simulations as a testbed for analyzing the relationships outlined in Objective 1), and we will explore implications for ocean dynamics and coupled climate feedbacks posed in objective 2), taking into account the sensitivity of the modeled response to changes in ocean model resolution.

The combination of these three components will enable a deeper understanding of the overall contribution of TCs to variability of Earth's climate system through exploration of local and non-local effects, and possible oceanic teleconnections (such as advective and wave mechanisms shown in Figure 3). The connections between TC-induced tropical and subtropical responses have yet to be explored, though previous observational and model analyses have pointed to important connections between TCs and the main modes of tropical variability.

3. Research Plan

3.1 Observational platforms

The proposed research will rely strongly on in situ and remotely sensed data analysis in the tropical oceans. The data will be used along with model reanalysis data to infer and validate observed physical properties of the ocean. We will examine local and propagating ocean effects triggered by TCs through analysis of sea level budgets and upper ocean heat anomalies, wave mechanisms, and subtropical cells. The main data products we will use are:

i) **Satellite altimetry and gravimetry**: Satellite altimetry provides optimally interpolated, cross-calibrated global coverage of the sea level anomaly (SLA). Here we use the Archiving, Validation, and Interpretation of Satellite Oceanographic Data (AVISO) delayed mode product (http://www.aviso.oceanobs.com), which consists of gridded weekly SLA relative to the 1993-1999 period mean, obtained from a multi-satellite mission (Le Traon et al., 1998), available continuously since October 1992, on a 1/3° horizontal grid. Gravimetry data is given from the Gravity field and Steady-State Ocean circulation (GOCE) and Gravity Recovery and Climate

Experiment (GRACE), which gives the mass changes in the global ocean at a 1x1 deg and monthly resolution since March 2002.

ii) **Ocean currents**: OSCAR (Ocean Surface Current Analysis Real-time) contains near-surface ocean current estimates, derived using quasi-linear and steady flow momentum equations (Bonjean and Lagerloef, 2002). The horizontal velocity is directly estimated from sea surface height, surface vector wind and sea surface temperature. These data were collected from the various satellites and in situ instruments. The model formulation combines geostrophic, Ekman and Stommel shear dynamics, and a complementary term from the surface buoyancy gradient. Data are on a 1/3 degree grid with a 5 day resolution since October 1992.

iii) **Winds**: The pseudo-wind stress data are obtained from the cross-calibrated, multi-platform (CCMP level 4), multi-instrument ocean surface wind velocity data set. This product combines data derived from SSM/I, AMSRE, TRMM TMI, Quikscat, and other missions using a variational analysis method to produce a consistent record of global ocean surface vector winds at a 25 km resolution and is available 6-hourly since July 1987 (Atlas et al., 2011). Best Track data (IBTrACS) merges best track, maximum wind speed and pressure data of tropical cyclones from individual agencies in one worldwide database, and is distributed at www.ncdc.noaa.gov.

iv) **Sea surface temperature (SST) and salinity (SSS)**: Satellite SST data from the multi-agency GHRSST project (www.ghrsst.org) are available in daily composites. This product exploits the synergy from using SST derived from in situ, satellite microwave, and satellite infrared sensors, daily and in a high resolution (≤ 25 km) format (Donlon et al., 2007), and is available since 1981 in different resolutions. Satellite SSS data from Aquarius/SMOS are available in a 1° x 1° resolution with daily images starting in 2010.

v) **In-situ data**: As part of CLIVAR, TAO (McPhaden 1995) and PIRATA (Bourlés et al., 2008) moored arrays provide a high temporal resolution velocity, temperature and surface fluxes data in the equatorial Pacific and Atlantic basins. These data have been used successfully for validation for satellite measurements and models, and to study wave mechanisms in the equatorial regions. Monthly historical temperature and salinity profiles from 1992 to the present will be retrieved from the CORIOLIS website (CORA3 dataset: ftp://eftp.ifremer.fr/data/CORA-GLOBAL-03/). CORA3 includes Argo, XBT, MBT and CTD data, and is available in the upper 2000 m at a 0.5° x 0.5° horizontal resolution in the tropics.

vi) **Ocean Reanalyses:** For comparison with observational estimates and error assessment, the HYCOM/NCODA (Chassignet et al., 2009; www.hycom.org) which is available at a 1/12° horizontal resolution from 2008-present; and possibly the Estimating the Circulation and Climate of the Ocean, Phase 2 (ECCO2; Menemenlis et al., 2008; http://www.ecco-group.org) which is available at a 1/3° horizontal resolution since 1992-present will be used.

3.2 Observed Exploration of Oceanic Response to Tropical Cyclone Forcing

Local effects of TCs, such as mixing, decrease sea surface temperature which can reduce the TC intensity, while non-local or propagating effects can reach the coastal areas, increasing the potential for ocean intensification through coastal effects, and propagating equatorward through trapped coastal waves or subtropical cells. Established methodologies can be applied to decompose the sea level into its thermodynamic and dynamic components, which would greatly increase our understanding of the local and remote impacts of TCs in the ocean, and also to better constrain the effects of the ocean on mixing and possible feedbacks to TC intensification.

To achieve our objectives, we will combine analyses of the remote sensing and in-situ observational products described in Section 3.1. Our study period will be 1992 to the present, which comprises the altimetric period. Our methodology will be based on the following steps in order to improve the ocean state estimation for TC analysis and applications:

i) Weekly synthetic temperature and salinity profiles will be estimated from the thermosteric and halosteric SLH components, respectively.

In order to investigate the impacts of TCs on the global ocean it is necessary to analyze high spatial and temporal resolution hydrographic and oceanic velocity fields. Current observational measurements are unable to sample the ocean subsurface at the required scales. Therefore, CORA3 monthly temperature and salinity fields cannot adequately capture the highly transient TC-forced ocean changes. One approach to improve the temporal (monthly) resolution of the CORA3 dataset, for the studied period from 1992 to the present, is to produce (weekly) synthetic temperature and salinity profiles. This can be achieved by regressing steric (temperature and salinity) anomalies onto surface parameters measured by satellites. Available algorithms (Cooper and Haines, 1996; Maes and Behringer, 2000; Willis et al., 2004; Goes et al., 2013b) have used SLA measured from altimetry to project changes in oceanic profiles. Here we will regress monthly averaged SLA onto monthly temperature and salinity data to interpolate these values to weekly fields. We will include SST and SSS (when available) as surface boundary conditions for the estimation of the vertical profiles, and constrain the weekly estimates to have the same monthly averages as the CORA3 original data. A statistical analysis will be performed to evaluate the error structure of the synthetic profiles through comparison to existing observations.

One important issue in relating time variability of ocean steric changes to altimetry is that altimetry contains both the steric (density) and non-steric (mass) contributions (Gill and Niiler, 1973; Chambers et al., 1997), such that :

$$\eta_{steric} \cong \eta - \eta_{B\,\mathrm{Pr}} \cong \eta_{Sal} + \eta_{Temp} + \eta_{Bot}$$

i.e., SLH (η) is formed by its steric (η_{steric}) and the non-steric or bottom pressure (η_{BPr}) components. The steric sea level can be further decomposed into its halosteric (η_{Sal}), thermosteric (η_{Temp}) and bottom (η_{Bot}) contributions using a linear equation of the state approximation (Tabata et al., 1986; Antonov et al., 2002). Additionally, the current hydrographic data might neglect steric contributions to the total sea level variability below 1000 m (η_{Bot}), although η_{Bot} contribution may be negligible, as most of the variability occurs in the upper ocean (Antonov et al., 2005; Wunsch et al., 2007; Goes et al., 2013b). Therefore we will separate the steric contribution of sea level in order to produce the synthetic profiles using available methods (e.g., Willis et al., 2004; Guinehut et al., 2006; Goes et al., 2013a), which require the use different observational platforms. In this work we will calculate η_{steric} by subtracting the residuals between the monthly dynamic height anomalies from hydrography and the altimetric SLA (Goes et al., 2013a). Uncertainties of the decomposition method can be estimated by comparing with different methodologies, for example using gravimetry from GOCE and GRACE, which measure directly the non-steric component of sea level (Cazenave et al., 2009, Chambers and Willis, 2010; Leuliette and Miller, 2010), and comparing with model reanalysis (ECCO2, HYCOM/NCODA).

ii) Relationship between upper ocean heat content metrics and the background ocean state.

SST and UOHC changes induced by TCs are mostly driven by entrainment from mixing of colder water from below the mixed layer. The amount of mixing is in turn influenced by the background stratification of the ocean. Understanding these differences would ultimately allow for improving TC intensity forecasts. Here we will use the weekly synthetic temperature and salinity profiles resulting from step (i) to determine the regional differences in stratification, and then correlate these differences with TC-induced UOHC changes. First, we will assess the uncertainty of current methods using three established methodologies for calculating UOHC under TCs, i.e., (i) using the temperature integral above the 26C isotherm (Mainelli et al., 2008), (ii) the average temperature in the top 100 m of the ocean (Price et al., 2009), and (iii) a more complex relationship between idealized profiles before and after the TC passage (Vincent et al., 2012a). As shown in Figure 2, one of these metrics is capable of capturing the cooling of the upper surface layer, but results vary regionally and in time. We will estimate how changes in the UOHC vary in different regions for the three methods, and how they correlate with the depths of the temperature and salinity stratifications, with their relative stratification depths (i.e., differences in the depths of strongest temperature and salinity stratification, which are related to the barrier layer thickness), and with TC intensification (changes in Power Dissipation Index, PDI; Emanuel, 2005) in the IBTRACS data. Therefore we will be able to make regional statistics of surface cooling potential, mixing strength and ocean stratification.

This analysis will provide us feedbacks to potentially improve currents metrics, which should be parsimonious enough to make a new product available operationally. A new metric should be instead density based and consistent with a reduced gravity approach. We hypothesize that the UOHC definition should be conservative, and account for ocean stratification. We will define a new metric as:

$$UOHC = \left(h_1 T_1 + h_2 T_2\right) / h_1 ,$$

where h_1 and h_2 are isopycnal layers, from the surface to the base of the mixed layer (h_1), and below the mixed layer to the isopycnal near the depth of 14°C (h_2) (Palmer and Haines, 2009). T_1 and T_2 are the average temperatures in each of the two layers, respectively. Defining the UOHC this way conserves heat, since the potential for cooling of the surface layer through vertical mixing and entrainment will depend on the stratification between the upper and lower layers, and the heat exchange between the lower layer and the well mixed upper layer agrees with the flux form of the Navier-Stokes temperature entrainment processes. The new UOHC metric will be used in step (iii) to track subsurface changes in heat induced by TCs. Results will be compared to ocean reanalyses (HYCOM/NCODA; ECCO2) to diagnose the improvement of a new metric on model and observational estimates.

iii) A comprehensive sea level budget will be performed and dynamical properties of the upper ocean, such as hurricane forced mixing and entrainment rates, will be decomposed and analyzed in terms of standing and propagating sea level anomalies.

We will use approximations to the Navier-Stokes equation (Stevenson and Niiler, 1983; Goni et al., 1996; Vivier et al., 1999; Goes et al., 2009; Palmer and Haines, 2009) to decompose the steric sea level locally in terms of its dynamical components. In particular, we are interested in calculating the mixing (differentiating before and after storm T profiles; Buongiorno Nardelli and Santoleri, 2004), Ekman (deriving CCMP winds stress curl and method of Vivier et al., 1999) and advection components (using OSCAR product or the method of Skagseth and Mork, 2012). Standing and propagating sea level components can be derived from altimetry analysis using longitude-time plots and reduced gravity modeling (Geisler 1970; Young and Joyce, 2006; Goes et al., 2009). Propagating speeds will be calculated using a modified Radon transform (Barron et al., 2007) over longitude-time plots, and associated to the linear wave theory. TC-induced propagating features in sea level will be compared with the ones from item (ii)

iv) We will examine seasonal-to-interannual variability of heat uptake by TCs, including seasonal recovery due to early season versus late season TC passage, and ranking by TC intensity and basin location.

This task will be accomplished by investigating the links between weekly to decadal variability of upper ocean heat content and changes in TC seasonality, location and intensity. To examine the remote impacts of TC-induced heat content changes, we will use three techniques: (1) Heat content anomalies will be tracked from the TC affected region, by tracking anomalies of the thermocline depth in time and space; (2) Correlations between equatorial SST/SSH anomalies and TC events will be assessed to investigate causal relationships (with TC leading) between these processes. We will also examine annual composites of the events which the time lag between the TC and equatorial SSTs converge to the wave speed mechanisms in a given region. An analysis of the subduction of warm anomalies across the base of the mixed layer will be performed following Liu (2007) and Goes et al., (2008), by using the time variability of the derived upper layer depth (h_1). Subsequent pathways along the subtropical cells will be identified by tracking the advection of heat anomalies integrated between two isopycnals, or along the deeper layer (h_2). We will investigate the seasonal to decadal variability of subduction processes and heat uptake related to TCs, and the effect of these anomalies in the tropical regions. Seasonality and reentrainment of heat anomalies into the mixed layer in the following winter, which is the time of maximum deepening (Jansen et al., 2010), will be taken into account. Additionally in this calculation, we will take into account interannual variability of the mixed layer depth using, for example, mixed layer estimates from the UOHC method, which was not included in Jansen et al. (2010). TAO and PIRATA moorings will be used as auxiliary data to verify changes in the heat content along the equatorial region (similar to Figure 3).

3.3 Model Experiments

Simulating the ocean's response to TC forcing depends critically on: 1) model resolution, 2) atmosphere-ocean coupling, and 3) parameterizations of subgrid-scale processes in the model (such as vertical mixing and eddy transports). To date, the majority of global modeling studies examining the effect of tropical cyclones on the upper-ocean mean state and dynamics have employed approaches that either: parameterize TC-induced vertical mixing (e.g. Korty et al., 2008; Pasquero and Emanuel 2008; Jansen and Ferrari, 2009; Sriver et al., 2010; Fedorov et al., 2011; Manucharyan et al., 2011), or impose prescribed tropical cyclone forcing (Hu and Meehl, 2009; Sriver and Huber, 2010; Vincent et al., 2012b; Sriver et al., 2013). Several recent studies have examined the role of TCs on the ocean using fully-coupled models, with high-resolution atmosphere components (~0.5 degrees) capable of simulating TC-like circulations (e.g. Scoccimaro et al., 2011). However, these studies are limited by the use of relatively coarse resolution ocean model components incapable of realistically simulating important dynamical responses to TC-forcing, such as eddies, and/or lack of integration years to analyze long-term impacts on ocean dynamics (McClean et al., 2011).

In this project, we will analyze TC-induced ocean-atmosphere interactions and the upper-ocean response from a pre-existing high-resolution fully-coupled modeling experiment using the Community Climate System Model (CCSM version 3.5), which is the predecessor of the Community Earth System Model (CESM). The model experiments have been documented previously (Kirtman et al., 2012), and the model output is being provided by Ben Kirtman at the University of Miami, who is participating as a no-cost collaborator to this project. The CCSM experiment consists of two 155-year present day climate simulations. Both simulations use a ~0.5° resolution atmosphere/land-surface model configuration, however, the grid resolution of the ocean/sea-ice model combination vary from eddy-permitting to eddy-resolving. The eddy-permitting simulation uses the gx1 resolution for the ocean/sea-ice component models, featuring constant zonal resolution (1.2°) and varying meridional resolution (0.27° at the equator to 0.54° in the mid-latitudes). The eddy-resolving simulation features a 0.1° resolution ocean/sea-ice model configuration. The model output contains daily gridded fields of key atmospheric and oceanic state variables (e.g. surface wind forcing, ocean temperature, surface fluxes, and precipitation), making it well-suited for examining the transient nature of TC-ocean connections and evaluating the proposed observation-based methodologies described in section 3.2.

TC-like circulations are formed spontaneously in the 0.5° atmosphere model, with realistic circulation structures and surface wind forcing (McClean et al., 2011). Figure (4) highlights an example of a simulated TC circulation and the ocean’s thermal response in the eddy-resolving run. The cold wake produced by the simulated TC agrees with a typical observed cold wake (Figure 1), indicating the model is realistically and robustly capturing the transient upper-ocean response to TC events.

This project offers the unique opportunity to analyze TC-induced ocean-atmosphere interactions within a high-resolution, fully-coupled Earth system model, in which we can analyze TC-induced ocean-atmosphere interactions on a variety of spatial and temporal time scales. For the first time, we will analyze the effect of TCs on upper-ocean properties and dynamics in a high-resolution fully-coupled modeling framework for runs spanning ~150 years, thus we can robustly test the hypotheses linking TCs to transient ocean dynamics proposed by more idealized modeling studies. An additional novelty of this work is in the use of multiple ocean grids (eddy-permitting to eddy-resolving) for the same atmosphere grid resolution (0.5 degree), thus allowing for sensitivity analysis of the effect of grid resolution on the transient and mean state ocean response to TC forcing, on daily to inter-annual timescales. These experiments will serve as a testbed for analyzing global budgets of TC-induced ocean effects from observation-based analyses and explore dynamic implications of TC-induced impacts on upper-ocean circulations, building from previous methodologies (Sriver and Huber, 2007; Sriver et al., 2008; Sriver et al., 2010; Sriver and Huber 2010; Sriver et al., 2013). Because the model simulates its own TCs, we will construct basin scale climatologies of TC activity for each model run using integrated TC activity metrics such as power dissipation (Emanuel, 2005). We will identify TC circulations based on surface wind stress curl anomalies and apply normalized metrics to account for potential model biases of TC intensity (e.g. Sriver and Huber, 2006). Even with the inherent limitations associated with simulating TCs in a coupled model (e.g. uncertain mixing parameterizations, intensity biases, etc.) the analysis presented here offers an unprecedented view of TC-ocean interactions in a fully-coupled framework, which enables exploration of macroscopic ocean impacts important for TC prediction and climate variability through ocean dynamics and ocean-atmosphere feedbacks.

Specific tasks will include: 1) compare and contrast TC-induced impacts on upper ocean heat content, sea-level height anomalies and salinity effects with observation-based analysis described in section (3.2); **2)** examine the effect of transient extreme wind forcing on ocean dynamics on multiple spatial and temporal scales, such as remote effects of TCs on coastal/equatorial waves and energy budgets (Fedorov et al., 2010; Sriver et al., 2010; Sriver et al., 2013); **3)** quantify global climatologies of TC-induced ocean effects (e.g. global mixing budgets, mixed layer deepening, ocean heat convergence, etc.) and compare with observation-based estimates (Sriver and Huber, 2007; Sriver et al., 2008); **4)** analyze relationships between interannual variability in modeled TC activity and tropical modes of variability such as ENSO, as well as implications for sea-level budgets, upper-ocean heat content, and feedbacks on atmospheric circulations and transports (Brierley et al., 2009; Sriver and Huber, 2010); and **5)** and analyze the sensitivity of TC-ocean interactions to the ocean grid resolution and explore possible implications for simulating TC effects in coupled models.

Simulated TC-like circulation and ocean response in CCSM3.5

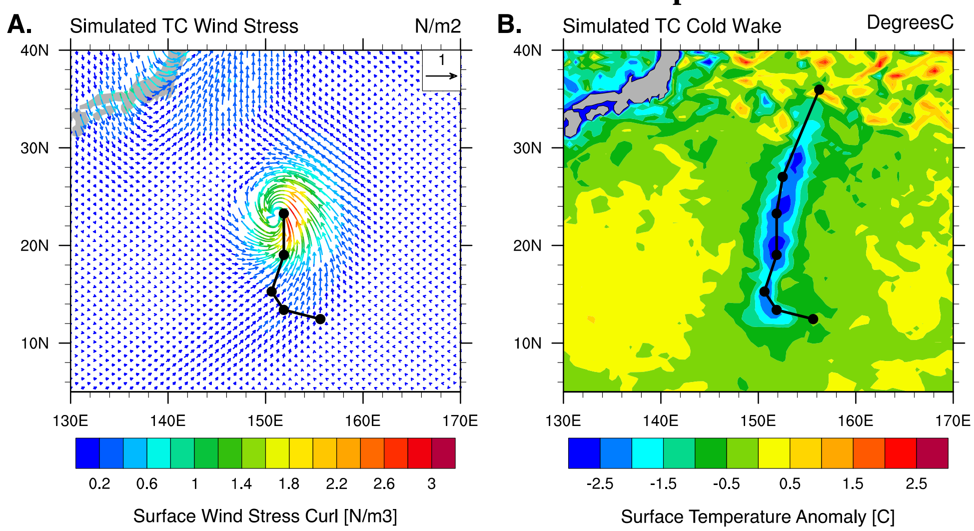

Figure 4. A. Simulated TC circulation using the 0.5 degree atmosphere model. In the model, TC-like circulations are formed spontaneously. B. The corresponding surface temperature anomaly from the 0.1 degree eddy-resolving ocean component, for the TC shown in A. The temperature anomaly is estimated as the post-storm minus pre-storm temperature fields, and the shape and magnitude of the simulated anomaly is generally consistent with observed cold

The proposed methodologies will build on previous results primarily by employing a high-resolution coupled modeling framework that directly simulates realistic TC circulations and features multiple ocean grid resolutions (from eddy-permitting to eddy-resolving). This approach reflects a significant advance from previous efforts discussed earlier that were limited by lack of coupling, relatively short integration length, coarse resolution, and/or prescribed TC forcings. Ultimately these analyses will be useful for analyzing the cumulative effects of TCs on the upper ocean in a more complete way than heretofore possible and for exploring possible climate linkages between TCs and the general ocean circulations through fundamental physical mechanisms and dynamic feedbacks on multiple spatial and temporal scales.

4. Relevance to the NASA Announcement

TCs are transient phenomena that affect coastal regions directly and indirectly, by affecting the large scale circulation and heat storage in the ocean. A better understanding of the TC effects on the ocean's circulation, heat balance and associated air-sea exchange will consequently improve climate predictions. This work will advance the state of knowledge by 1) Developing a better understanding between TCs, ocean heat content and stratification, 2) Improving products such as the ocean heat potential for TC intensification prediction using comprehensive remote sensing observations (e.g. satellite altimetry), and 3) Analyzing remote effects of TC on ocean dynamics and circulations on intra-seasonal to inter-annual timescales.

We will use a rich collection of data products distributed by NASA and CLIVAR, including satellite altimetry, surface wind stress, high-resolution sea surface temperature and sea surface salinity, and in-situ temperature and salinity profiles, complemented by ocean reanalyses products. In addition we will analyze a state-of-art coupled Earth-system model, which will provide an unprecedented view of the regional and global effects of TCs within the coupled climate system. Results from this analysis will improve our knowledge of the representation of TCs in model simulations, and will provide guidance for model improvements to seasonal forecasts/outlooks to longer-term climate projections. *The project goals fit directly within both of NASA's key research priority areas related to analyzing and interpreting ocean circulation using satellite and in situ data, and development of new remote sensing techniques for physical oceanography*. Fundamentally, *this study will advance NASA's goals to understand the ocean's role in climate variability and prediction*, by providing a better mechanistic understanding of how the ocean responds to TCs, from transient dynamic effects to cumulative impacts over broader spatial scales and their influence on tropical climate variability and coastal circulation patterns.

5. Management Plan and Data-Sharing Policy

5.1 Management plan

This multi-disciplinary collaborative project combines novel utilization of state-of-the-art observations systems with cutting edge climate model analysis, to examine the role of TC impacts on tropical to subtropical oceanic processes and variability on multiple spatial and temporal scales. The proposed research tasks will ultimately lead to improved understanding of TC-ocean interactions, with implications for TC predictability and climate variability and projections. The project will be led by PI Goes, in close collaboration with Co-PI Sriver. The PIs have a long publication track record in the fields of ocean observations, tropical cyclones, ocean-atmosphere interactions, data-model evaluation/synthesis and climate modeling, as evidenced by their publication records in peer-reviewed journals (please see CVs in the appendix for references). PI Goes will lead the overall project management, reporting and budgeting. PIs Goes and Sriver will coordinate efforts on communication and outreach. Goes will also lead the subprojects (see section 6) focusing on development of synthetic temperature and salinity profiles, and evaluation/development of metrics relating upper-ocean heat content to tropical cyclone development and changes in intensity (subprojects 2 and 4). PI Sriver will lead the subproject focusing on the coupled model diagnostics, sensitivity analysis, and model/data evaluations (subproject 3). Both PIs will coordinate efforts in developing global TC-sea level budget to analyze standing/propagating TC-induced ocean heat content anomalies, as well as the remote effects on coastal/equatorial ocean dynamics and circulations (subproject 5). The PIs will also collaborate on subproject (6) to summarize the results in the form of manuscripts for submission to peer reviewed publications and to reach out to the Earth system and operational modeling community, as well as the general public, through presentation of key findings/results at scientific conferences and developing/maintaining a project web-page.

The PIs request support for a graduate student researcher during both years of the project. He/She will collaborate with both institutions but will be primarily under supervision of Co-PI Sriver, and will be responsible for the analysis of the modeling subprojects, which will be performed at the University of Illinois, and data analysis with additional coordination and mentorship from PI Goes. Travel funds are budgeted to allow for the student to visit the University of Miami and NOAA AOML for 1-4 weeks/ year, working with PI Goes and NOAA colleagues on analyzing observational products and data-model syntheses. Due to the large amount of data to be analyzed, both PIs Goes and Sriver budgeted funds for computer storage to be used to analyze/share data between institutions and facilitate dissemination of value-added observational data sets resulting from these analyses. The PIs will coordinate project meetings at annual national conferences and also conduct bi-weekly project meetings via videoconference.

5.2 Collaborations and support personnel

As described in the Project Objectives (Section 2), the project will have two main pillars of research, one using observational-based products and one using experiments from a state-of-art coupled climate model. Therefore, institutional collaboration will be necessary for the best realization of the activities. The project will assign three main collaborators to provide supervision in their areas of expertise. Their mentorship will be provided at no-cost, since their interests are strongly tied to these areas of research. They will interact with PI Goes on a daily basis for discussion of results, advices and data sharing. The collaborators are:

Dr. Gustavo Goni (NOAA/AOML) will offer expertise in remote sensing analysis such as gravimetry and altimetry, and in design the methodology for producing the UOHC and synthetic profiles observed via satellite altimetry.

Dr. Gregory Foltz (NOAA/AOML) will closely advise sea level and heat budget analysis primarily through observations, examination of TC impacts on sea surface under different ocean stratification, and also using TAO and Pirata mooring data.

Dr. Ben Kirtman (UM/RSMAS) will provide the daily coupled model runs in high- and low- resolutions, and provide his expertise on the model analysis, including a detailed understanding of the model parameterizations in the two model resolution modes.

5.3 Data Sharing Policy

We will provide the data necessary to recreate our results (e.g., model codes, input files, value-added data sets, and the specific model simulations results and data/model diagnostics) on a project web-page for at least five years after the project end. Co-PI Sriver has been involved with previous efforts to document CCSM modification and setup using an editable web page (Wiki) intended as a learning tool for new users. This endeavor was highly successful and served as a valuable resource where new users could reference useful setup descriptions and techniques. In addition, it is budgeted one month a year for support personnel at University of Miami who will be in charge of distribution the new UOHC product and related deliverables for operational activities. We will use this previous experience as a tool for documenting our modeling and data analysis so that they are easily accessible and interpretable to the public. Our results will be published in recognized scientific journals easily assessable for the scientific community.

6. Sequence of Project Activities

The sequence of project activities is as follows

			Year 1				Year 2			
#	Subproject	Lead	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collect and assemble observational data and model products	All	■	■						
2	Construct synthetic Temperature/Salinity profiles from sea-level decomposition	Goes	■	■	■	■				
3	Coupled Model diagnostics and sensitivity analysis	Sriver		■	■	■	■	■		
4	Evaluate TC heat potential and develop new metric from remote sensing	Goes			■	■	■	■		
5	Develop global TC-sea level budget to analyze standing/propagating anomalies	All				■	■	■	■	
6	Summarize results and outreach	All				■	■	■	■	■

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Williams, R. G., M. A. Spall, and J. C. Marshall, 1995: Does Stommel's mixed layer ‘‘demon'' work? *J. Phys. Oceanogr*., 25, 3089–3102.
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Biographical Sketch
Marlos Goes

Cooperative Institute for Marine and Atmospheric Studies
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149
Phone: (305) 361-4533
Fax: (305) 361-4457
E-Mail: mgoes@rsmas.miami.edu

(a) Professional Preparations:

Educational Institution	*Major*	*Degree*	*Degree Year*
University of Campinas, Brazil	Physics	B.Sc / Licenciate	1999
University of Sao Paulo, Brazil	Oceanography	M.Sc.	2001
University of Reading, UK	Oceanography	Doctorate fellow	2005
University of Sao Paulo, Brazil	Oceanography	Ph.D.	2006
Penn State University, USA	Climate studies	Post-doc.	2009

(b) Appointments:

2010 - present	Assistant Research Scientist, Cooperative Institute for Marine and Atmospheric Studies, University of Miami
2007-2009	Post-doctoral fellow, The Pennsylvania State University
2007	Visitor Scientist, POGO-SCOR scholarship, University of Maryland
2004-2005	Visitor research Assistant, CAPES scholarship, University of Reading, UK
2000-2006	Graduate Research Assistant, University of Sao Paulo, Brazil

(c) Publications

Five publications related to the proposed research:

Goes, M., G. Goni, V. Hormann, R. C. Perez (2013), Variability of the Atlantic off-equatorial eastward currents during 1993-2010 using a synthetic method, in press at J. Geophys. Res., doi: 10.1002/jgrc.20186.

Sriver, R. L., **M. Goes**, M. E. Mann, and K. Keller (2010), Climate response to realistic tropical cyclone-induced ocean mixing in an Earth system model of intermediate complexity, J. Geophys. Res.-Oceans, doi:10.1029/2010JC006106.

Goes, M., Urban, N. M., Tonkonojenkov, R., Haran, M., Schmittner, A., and Keller, K. (2010), What is the skill of ocean tracers in reducing uncertainties about ocean diapycnal mixing and projections of the Atlantic Meridional Overturning Circulation?, J. Geophys. Res., doi:10.1029/2010JC006407.

Goes, M., Marshall, D. P., and Wainer, I. (2009), Eddy Formation in the Tropical Atlantic Induced by Abrupt Changes in the Meridional Overturning Circulation. J. Phys. Oceanogr., 39, 3021–3031.

Goes, M., Wainer, I., Gent, P. R., and Bryan, F. O. (2008), Changes in subduction in the South Atlantic Ocean during the 21st century in the CCSM3, Geophys. Res. Lett., 35, L06701, doi:10.1029/2007GL032762.

Five additional publications:

Goes, M., G. Goni, S. Dong, M. O. Baringer (2013), An optimal XBT-based monitoring system for the Atlantic meridional transport at 34°S, Prepared for J. Atmos. Ocean. Tech.

Goes, M., G. Goni, K. Keller (2013), Reducing biases in XBT measurements by including discrete information from pressure switches, J. Atmos. Ocean. Tech., 30, 810-824, doi:10.1175/JTECH-D-12-00126.1.

Wainer, I., **M. Goes**, L. N. Murphy, and E. Brady (2012), Changes in the Water Mass Formation Rates in the Global Ocean for the Last Glacial Maximum, Mid-Holocene and Pre-Industrial Climates, Paleoceanography, Vol. 27, PA3101, doi:10.1029/2012PA002290.

Olson, R., R. Sriver, **M. Goes**, N. M. Urban, H. D. Matthews, M. Haran, and K. Keller (2012), A climate sensitivity estimate using Bayesian fusion of instrumental observations and an Earth System model, *J. Geophys. Res.*, 117, D04103, doi:10.1029/2011JD016620.

Bhat, K.S., Haran, M., and **M**. **Goes** (2010), Computer model calibration with multivariate spatial output, in "Frontiers of Statistical Decision Making and Bayesian Analysis", eds. M-H. Chen et al., New York: Springer-Verlag, 2010.

(d) Synergistic activities

Member of the AOML's Buoys and Gulls employee organization.
Reviewer for: Research proposals (NOAA, FACEPE/Brazil), and research articles (*J. Geophys. Res.*, *Climatic Change*, *Geophys. Res. Lett., J. Atmos. Ocean Tech., Earth System Dyn.*).
Referee in the state finals of the 2009 Pennsylvania Junior Sciences and Humanities Symposium.
Lecturer and tutor in Physical Oceanography for the local community, Cananeia, Sao Paulo, July 17-21, 2006.

(e) Collaborators & Other Affiliations
Collaborators:
Gustavo Goni (NOAA/AOML), George Halliwell (NOAA/AOML), Molly Baringer (NOAA/AOML), Lisa N. Murphy (U. Miami), Renellys Perez (U. Miami), Verena Hormann (U. Miami), Klaus Keller (Penn State), Nancy Tuana (Penn State), Ryan Sriver (Penn State), Nathan M. Urban (Princeton), Roman Olson (Penn State), Michael E. Mann (Penn State), Murali Haran (Penn State), Andreas Schmittner (Oregon State U.), Ilana Wainer (U. Sao Paulo).

Ryan L. Sriver

Assistant Professor, Department of Atmospheric Sciences
University of Illinois at Urbana Champaign, 105 South Gregory Street (MC 223), Urbana, IL 61801
Phone: 217-300-0364 ; Fax: 217-244-1752 ; Email - rsriver@illinois.edu
Website - http://www.atmos.illinois.edu/~rsriver

Professional Preparation

Purdue University, Earth and Atmospheric Sciences	Ph.D., 2008
Purdue University, Physics	M.S., 2003
Purdue University, Physics	B.S., 2001

Appointments

- Assistant Professor, Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, 08/2012-present
- Research Associate, Department of Geosciences, Pennsylvania State University, 06/2010 – 07/2012
- NOAA Climate and Global Change (C&GC) Postdoctoral Research Fellow, Department of Meteorology, Pennsylvania State University, 06/2008 – 05/2010

Relevant Publications

Sriver, R. L., Timmermann, A., Mann, M. E., Keller, K., and Goosse, H. (2013), Improved representation of tropical Pacific ocean-atmosphere dynamics in a coarse-resolution Earth system model, In Review at *Journal of Climate*.

Olson, R., **Sriver, R. L.**, Haran, M., Chang, W., Urban, N. M., and Keller, K. (2013), What is the effect of unresolved internal climate variability on climate sensitivity estimates? In Press at *Journal of Geophysical Research-Atmospheres*.

Sriver, R. L., Huber, M., and Chafik, L. (2013), Excitation of equatorial Kelvin and Yanai waves by tropical cyclones in an ocean general circulation model, *Earth System Dynammics*, 4, 1-10, doi:10.5194/esd-4-1-2013.

Sriver, R. L., Urban, N. M., Olson, R., and Keller, K. (2012), Toward a physically plausible upper bound of sea-level projections. *Climatic Change*, 115, 893-902, doi:10.1007/s10584-012-0610-6.

Lempert, R., **Sriver, R. L.**, and Keller, K. (2012), Characterizing uncertain sea level rise projections to support infrastructure investment decisions, California Energy Commission, Publication Number: CEC-500-2012-056. In review at *Global Environmental Change*.

Wang, J.-W., Han, W., and **Sriver, R. L.** (2012), Impact of tropical cyclones on the ocean heat budget in the Bay of Bengal during 1999, Part II: Processes and interpretations, *Journal of Geophysical Research-Oceans*, 117, C9, doi:10.1029/2012JC008373.

Wang, J.-W., Han, W., and **Sriver, R. L.** (2012), Impact of tropical cyclones on the ocean heat budget in the Bay of Bengal during 1999, Part I: Model configuration and evaluation, Prepared for *Journal of Geophysical Research-Oceans*, 117, C9, doi:10.1029/2012JC008372.

Olson, R., **Sriver, R. L.**, Goes, M., Urban, N. M., Matthews, H. D., Haran, M., and Keller, K. (2012), A climate sensitivity estimate using Bayesian fusion of instrumental observations and an Earth System model, Journal *of Geophysical Research-Atmospheres, 117*, D04103, doi:10.1029/2011JD016620.

Tuana, N., **Sriver, R. L.**, Svoboda, T., Tonkonojenkov, R., Irvine, P. Haqq-Misra, J., and Keller, K. (2012), A research agenda for an integrated ethical and scientific analysis of geoengineering proposals, Prepared for *Ethics, Policy, & Environment*, 15(2), doi: 10.1080/21550085.2012.685557.

Irvine, P., **Sriver, R. L.**, and Keller, K. (2012), Tension between reducing sea-level rise and global warming through solar radiation management, *Nature Climate Change, 2*, 97-100, doi:10.1038/nclimate1351.

Sriver, R. L. (2011), Climate Change: Man-made cyclones, *Nature*, *479*, 50-51, doi:10.1038/479050a.

Woodruff, J. D., **Sriver, R. L.**, and Lund, D. C. (2011), Tropical cyclone activity and western North Atlantic stratification over the last millennium: A comparative review with viable connections, *Journal of Quaternary Science*, doi:10.1002/jqs.1551.

Sriver, R. L. (2010), Climate Change: Tropical cyclones in the mix, *Nature*, 463, 1032-1033, doi:10.1038/461032a.

Sriver, R. L., Goes, M., Mann, M. E., and Keller, K. (2010), Climate response to tropical cyclone-induced ocean mixing in an Earth system model of intermediate complexity, *Journal of Geophysical Research-Oceans*, *115*, C10042, doi:10/1029/2010JC006106.

Sriver, R. L., and Huber, M. (2010), Modeled sensitivity of upper thermocline properties to tropical cyclone winds and possible feedbacks on the Hadley circulation, *Geophysical Research Letters, 37,* L08704, doi:10.1029/2010GL042836.

Warnaar, J., Bijl, P. K., Huber, M., Sloan, L., Brinkhuis, H., Rohl, U., **Sriver, R. L.**, and Visscher, H. (2009), Orbitally forced climate changes in the Tasman sector during the Middle Eocene, *Palaeogeography, Palaeoclimatology, Palaeoecol*ogy, *280*, 361-370, doi:10.1016/j.palaeo.2009.06.023.

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Sriver, R. L., and Huber, M. (2007), Observational evidence for an ocean heat pump induced by tropical cyclones, *Nature, 447,* 577-580, doi:10.1038/nature05785.

Sriver, R. L., and Huber, M. (2006), Low frequency variability in globally integrated tropical cyclone power dissipation, *Geophysical Research Letters, 33,* L11705 doi:10.1029/2006GL026167.

<u>Prior Research Efforts</u>

R. Sriver's research centers on climate dynamics, Earth system modeling, ocean-atmosphere interactions, tropical cyclones, climate change impacts, uncertainty quantification, and risk analysis. Previous projects funded by DOE, EPA, NOAA, NSF, and USGS have focused on utilizing models and observations to gain mechanistic insight into: ocean-atmosphere dynamics and feedbacks, effect of transient extremes (e.g. tropical cyclones) on the mean climate state, climate variability and change, and quantification of uncertainties surrounding future projections of key climate change metrics. R. Sriver's work during the past ~5 years has led to advances in research areas related to: tropical cyclone-climate interactions (Sriver and Huber, 2006) and effects on global ocean heat and mixing budgets (Sriver and Huber, 2007; Sriver et al., 2008); sea level rise projections, future coastal flooding risk assessment, and investment decision strategies (Sriver et al., 2012; Lempert et al., 2012); uncertainty quantification and model parameter estimation (Olson et al., 2012; Sriver et al., 2012; Olson et al., 2013); utility of global model ensembles in analyzing climate variability at regional scales (Sriver et al., 2013); integration of scientific and ethical considerations in Earth system science (Irvine et al., 2012; Tuana et al., 2012); and utilization of global climate models to analyze feedbacks between tropical cyclones and the mean climate state (Sriver and Huber, 2010; Sriver et al., 2010; Sriver et al., 2013), as well as regional responses of upper-ocean processes to tropical cyclone forcing (Wang et al., 2012).

Current and Pending Support for Marlos Goes

Current

None

Pending

Agency: National Oceanic and Atmospheric Administration (NOAA)
Funding Opportunity: NOAA OAR Sandy Supplemental
Title: Development and Demonstration of a Relocatable Ocean OSSE System: Optimizing Ocean Observations for Hurricane Forecast Improvement and Broader Applications.
Investigator Months/yr: 1
Total Award Amount: Projected ~ $1,859,625 ($469,236 NOAA/AOML; $1,390,389 CIMAS)
Role in project: Collaborator from CIMAS/UM
Location of research: University of Miami

Current and Pending Support for Ryan Sriver

Current
None

Pending
Agency: Department of Energy (DOE)
Title: Integrated Assessment Model Development, Comparison and Diagnostics Project
Investigator Months/yr: 0.25
Total Award Amount: Projected ~ $2,058,024 ($75,174 to UIUC)
Duration: 09/01/2013 – 08/31/2016
Role in project: PI on Sub-Contract from Stanford to UIUC
Location of research: University of Illinois
Agency: National Oceanic and Atmospheric Administration (NOAA)
Title: Midwest Network for Actionable Climate Science (M-NACS): Facilitating a Resilient Future.
Investigator Months/yr: 0.5
Total Award Amount: Projected ~ $510,089 to UIUC
Duration: 01/01/2014 – 12/31/2018
Role in project: PI on Sub-Contract from Purdue to UIUC
Location of research: University of Illinois

BUDGET JUSTIFICATION (Marlos Goes)

A. Senior Personnel

Salary support is requested for the PI M. Goes, for 4 months each year of the project. The collaborators G. Goni, G. Foltz, and B. Kirtman will work on this project for two months per year at no additional salary cost.

B. Other Personnel

Salary for IT personnel or research support is included for 1 month/year for computational and operational support.

C. Fringe Benefits

Fringe benefits are charged at a rate of 38.2% on senior salary. Benefits include retirement, worker's compensation, health, life and dental insurance, termination, and Medicare.

D. Equipment

Computer Costs: One personal computer for Marlos Goes to be used for data storage and analysis associated with this project is budgeted as $5000 in the first year.

E. Travel

Support of $3000/year for domestic travel throughout the course of the project is requested for meetings with collaborators as necessary. This also includes travel, registration and abstract fees for attending an annual scientific meeting to present results.

San Francisco-CA: For a 5-day AGU fall meeting estimate is US$2100:
Fixed: Airfare ($515); Land Transp. ($150); Registration ($350); Abstract ($60)
Daily: Accommodation ($155/day=$775); Per diem ($50/day=$250)

Urbana -Il: For a 3-day visit: Total Estimate = US$900:
Fixed: Airfare ($452); Land Transp. ($100);
Daily: Accommodation ($66/day=$198); Per diem ($50/day=$150);

F. Other Direct Costs

Publication Costs: The budget includes $2,000 each year as the estimated cost of preparing and publishing project results.

Subcontract to University of Illinois: Please see the next attached paperwork in reference to the subcontract.

G. Facilities and Administrative Costs

This work will be carried out at the U. Miami/RSMAS and NOAA/AOML facilities. The University of Miami's negotiated F & A rate is 55% for year 1 and 57% for year 2 with DHHS.

BUDGET JUSTIFICATION (Ryan Sriver)

Senior Personnel – Salaries proposed include one half of a month salary for the PI, Ryan Sriver, for each year of the project as necessary to accomplish the research tasks. Three percent cost of living adjustments have been added to each year of the proposal.

Other Personnel – Salary for a 50% graduate research assistant is proposed for 11 months per year on the project. Three percent cost of living adjustments have been added to each year of the proposal for the graduate student.

Fringe Benefits – Fringe benefits applied have been calculated by a method approved by the Federal Government. Fringe benefits for senior personnel are at the rate of 44.67%. Graduate student fringe benefits are assessed at 5.99% for academic months.

Travel – Travel may include airfare, hotel, and per diem for trips for the PI and a grad student to travel to AGU conferences and for the grad student to travel to the University of Miami for two weeks for collaborative research with the sponsor and/or other partners on this project.

Other Direct Expenses – The budget includes estimates

- **Publication costs** are requested in the second year to cover page charges and costs to publish research data and results related to this project.
- **Conference registration fees** are requested to cover the costs of the AGU conferences. Budget figures are estimated from historical costs.
- **Services** funds are requested for data storage. There will be a large amount of computational data with this project that will need to be managed and the storage will facilitate dissemination.

Tuition Remission – Tuition Remission is assessed at 64.0% of graduate student’s salary.

Indirect Costs – Indirect cost rate has been applied to MTDC (not assessed on tuition remission) and has been negotiated and approved by the Office of Naval Research, on March 1, 2012. The indirect rate is 58.6%.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration Atlar
Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway Miami FL 33149

26 June 2013

Dear Program Manager:

I acknowledge that I have been identified as a collaborator to the proposed investigation entitled "Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts" that is submitted by Marlos Goes and Ryan Sriver to the NASA Research Announcement NNH13ZDA001N-PO. I intend to carry out all responsibilities outlined for me in this proposal with no cost. I have read the entire proposal and I agree that the proposal correctly describes the nature of my collaboration to the proposed investigation. For the purposes of conducting work for this investigation, my participating organization is the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration.

I will be glad happy to provide Marlos and Ryan my expertise in sea level budget under Tropical Cyclones, synthetic methodology to estimate temperature profiles and upper ocean heat content analyses, and provide advices in the area of tropical cyclones interactions with the ocean and observational data analysis. I believe this work will provide valuable and much needed enhanced understanding of air-sea ocean dynamics, which will enhance the predictability of these sparse but strong events.

Sincerely,

Gustavo Goni
NOAA/Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Cswy.
Miami, FL 33149

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway Miami FL 33149

25 June 2013

Dear Marlos and Ryan,

I am happy to collaborate on your proposal entitled "Improving global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts" that is submitted to the NASA Research Announcement NNH13ZDA001N-PO by Marlos Goes and Ryan Sriver. I intend to carry out all responsibilities identified for me in this proposal. Specifically, I will provide my expertise in observational data analysis and upper-ocean heat and sea level budget analyses. I have read the entire proposal and agree that the proposal correctly describes my commitment to the proposed investigation. I understand that the extent and justification of my participation as stated in this proposal will be considered during peer review. For the purposes of this work, my participating organization is the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration.

Improving our understanding of tropical cyclone-ocean interactions is important for advancing climate research, and the combined data analysis and modeling approach outlined in this proposal is well suited for addressing this problem. I look forward to working with both of you on the work outlined in this proposal.

Sincerely,

Gregory Foltz

Gregory Foltz
NOAA/Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Cswy.
Miami, FL 33149

UNIVERSITY OF MIAMI
ROSENSTIEL
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ATMOSPHERIC SCIENCE

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University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149, USA

Phone: 305-421-4046 Email: bkirtman@rsmas.miami.edu

26 June 2013

Dr. Marlos Goes
Assistant Scientist
Cooperative Institute for Marine and Atmospheric Studies (CIMAS)
University of Miami
4600 Rickenbacker Causeway
Miami FL, 33149

Dear Dr. Goes,

I am writing to indicate my support for your proposal (with Dr. Ryan Sriver) submitted to the recent NASA call for proposals (NNH13ZDA001N-PO) entitled "Improved global analysis of tropical cyclone-ocean interactions: physical mechanisms and oceanic impacts."

In particular, I intend to provide guidance and technical support in obtaining and analyzing the very high-resolution simulation described in Kirtman et al (2012, Climate Dynamics, DOI 10.1007/s00382-012-1500-3) including high frequency (i.e., daily) output. Data from a control simulation at more modest resolution will also be made available to the research team.

I understand that the extent and justification of my participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal. I have read the entire proposal, including the management plan and budget, and I agree that the proposal correctly describes my commitment to the proposed investigation.

We look forward to collaborating with you and your team, by providing technical support and having regular scientific exchange.

Sincerely,

Ben Kirtman
Professor and Associate Dean for Research
Program Director: Physical Sciences and Engineering, Center for Computational Science
Division of Meteorology and Physical Oceanography
Rosenstiel School of Marine and Atmospheric Sciences

UNIVERSITY OF ILLINOIS
AT URBANA - CHAMPAIGN

Office of Sponsored Programs
and Research Administration
1901 South First Street, Suite A
Research Park
Champaign, IL 61820

June 26, 2013

Bonnie Townsend

U of I REF. NO. 2013-07065
TITLE: "Improving Global Analysis of Tropical Cyclone-Ocean Interactions: Physical Mechanisms and Oceanic Impacts"
AMOUNT : $ 157,300
PERIOD: 02/01/14-01/31/16
PRINCIPAL INVESTIGATOR(s): Ryan Sriver
DEPARTMENT: Atmospheric Sciences
TYPE OF REQUEST: New Request

Enclosed are copies of the above referenced proposal. This proposal has been approved for submission by the proper University administrative official(s).

Your consideration will be appreciated. Any contract or grant supporting the above described project must be issued in the University's corporate name, The Board of Trustees of the University of Illinois, Urbana, Illinois 61801.

Any questions of a non-technical nature regarding this proposal should be addressed to the individual below at (217) 333-2187:

Kimberly Groller

Sincerely,

David W. Richardson

David W. Richardson
Associate Vice Chancellor for Research
Director of Office of Sponsored Programs and Research Administration
University of Illinois at Urbana - Champaign

DWR: KWG

Enclosure

cc: Stephanie Cresap

telephone: (217) 333-2187 · fax (217) 239-6830

ATTACHMENT TO PROPOSAL TRANSMITTAL LETTER

(The following General Information is provided to assist potential Sponsors. It is recognized some information may not be applicable to this specific proposal and, if inappropriate, should be disregarded.)

1. **The University of Illinois reserves the right to negotiate the terms and conditions of any definitive Contract/Grant which may result from this proposal application. UIUC is a public research university subject to an increasing number of state and federal regulations that are unique to higher education. As a result, most contracts provided by our sponsors require minor revisions before we can legally sign them.**

2. **Any resulting Contract/Grant should be made in the University's legal corporate name, "The Board of Trustees of the University of Illinois", c/o Office of Sponsored Programs & Research Administration, at the address listed below in item 3.**

3. **All contractual correspondence should be mailed to:**

   University of Illinois
   Office of Sponsored Programs
   & Research Administration (OSPRA)
   1901 South First Street, Suite A
   Champaign, IL 61820
   E-mail: **gcoaward@uillinois.edu**

   Contractual Signature Authority:

   ____
   Walter K. Knorr, Comptroller

4. **General Information, Mailing Instructions, Representations/Certifications, etc: (217) 333-2187**

Proposals		Contracts/Grants	
Scott Corum	(217) 265-7794	Stephanie Russell	(217) 265-7682

5. **University Contacts related to Proposal Review: PHONE (217) 333-2187 FAX #(217) 239-6830**

   Kathy Dams, Assistant Director (217) 244-8212

Kim Groller	(217) 265-7685	Geoff Dehler	(217) 265-7687
Kamil Tamimie	(217) 244-0315	Julie McCabe	(217) 244-9029
Tim Tufte	(217) 265-7708		

6. **Cognizant Federal Admin. Agency:**

   Office of Naval Research
   230 South Dearborn Avenue, Rm. 380
   Chicago, IL 60604-1595
   Attn: Administrative Contact
   (312) 886-5423; E-Mail: ONR_Chicago@onr.navy.mil

7. **Contract/Grant payments should be mailed to:**

   University of Illinois at Urbana-Champaign-Grants & Contracts
   PO Box 4610
   Springfield, IL 62708-4610

   DUNS # 04-154-4081
   FEIN # 37-6000.511
   Cage Code: 4B808

8. **Authorized Institutional Officials for Submitting Proposal Applications:**

Administrative:	Business:
Peter Schiffer, Chair	David W. Richardson, AVCR/Director
Research Board	Office of Sponsored Programs & Research Administration

9. **The following research indirect cost rates have been currently negotiated with the Office of Naval Research:**

MTDC Indirect Cost Rate	Graduate Asst. Tuition	Period
58.6%	64.0%	7/1/12 – 6/30/15

Statement of work to be done at University of Illinois

As discussed in the proposal main text, co-PI Sriver will lead all subprojects related to the model analysis, diagnostics, and data-model comparison components of the project. This includes performing the model diagnostics and sensitivity analysis from pre-existing CCSM3.5 experiments. Co-PI Sriver will also contribute to the development of the global gridded fields and tropical cyclone surface budgets from observational products, in coordination with PI Goes and NOAA collaborators Goni and Foltz.

The requested graduate student will be under the supervision of co-PI Sriver at the University of Illinois during project years 1 and 2. He/She will be responsible for the day-to-day operations of the model/data subprojects by: providing support in post-processing, analyzing the climate model output, and assisting in the data-model synthesis and analysis. The student will also contribute to data/observation subprojects led by PI Goes (and NOAA collaborators), through semi-annual visits to the University of Miami and weekly virtual group meetings.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

School of Earth Society and Environment

College of Liberal Arts and Sciences
245 Natural History Building MC-103
1301 W. Greet Street
Urbana, IL 61801

June 25, 2013

Bonnie Townsend
Sponsored Programs
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Dear Ms. Townsend:

The University of Illinois at Urbana-Champaign is pleased to submit a proposal entitled, "Improving global analysis of tropical cyclone-ocean interactions: Physical mechanisms and oceanic impacts", in support of your proposed NASA project. This proposal was prepared by Dr. Ryan Sriver in the Department of Atmospheric Science.

For information relating to the technical portions of this project, you may contact Dr. Ryan Sriver, at the University of Illinois at Urbana-Champaign, Department of Atmospheric Science, 105 South Gregory Street, Urbana, IL, 61801, (217) 300-0364, or rsriver@illinois.edu.

Negotiations concerning fiscal aspects of this project or any other official correspondence should be addressed to the Office of Sponsored Programs and Research Administration, 1901 South First Street, Suite A, Champaign, IL, 61820, (217) 333-2187.

Sincerely,

Scott Morris
Associate Director for Operations

Peter Schiffer
Chair, Research Board

Telephone 217-244-4064 • *fax* 217-244-6323 • *email* hatche@uiuc.edu