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

NASA Proposal Number

TBD on Submit

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
Jorge Vazquez	**jorge.vazquez@jpl.nasa.gov**	**818-354-6980**

Street Address (1)	Street Address (2)
4800 Oak Grove Dr	**M/S 300/323**

City	State / Province	Postal Code	Country Code
Pasadena	**CA**	**91109-8001**	**US**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
05 / 01 / 2015	**04 / 30 / 2018**	**449,810.00**	**149,950.00**	**149,900.00**	**149,960.00**

SECTION II - Application Information

NASA Program Announcement Number	NASA Program Announcement Title
NNH14ZDA001N-INCA	**Climate Indicators and Data Products for Future National Climate Assessments**

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
	Electronic Submission Only		

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

International Participation	Type of International Participation
Yes	**Collaborator**

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
095633152	**23835**	**951643307**	**2A**

Organization Name (Standard/Legal Name)	Company Division
Jet Propulsion Laboratory	

Organization DBA Name	Division Number
JET PROPULSION LABORATORY	

Street Address (1)	Street Address (2)
4800 OAK GROVE DR	

City	State / Province	Postal Code	Country Code
PASADENA	**CA**	**91109-8001**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Jorge Vazquez	**jorge.vazquez@jpl.nasa.gov**	**818-354-6980**

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 this solicitation.

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

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

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Jorge Vazquez**	**818-354-6980**	**jorge.vazquez@jpl.nasa.gov**
Organization/Business Relationship		Cage Code	DUNS#
Jet Propulsion Laboratory		**23835**	**095633152**
International Participation	U.S. Government Agency		Total Funds Requested
No	**Other**		**243,380.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Edward Armstrong**	**818-393-6710**	**edward.m.armstrong@jpl.nasa.gov**
Organization/Business Relationship		Cage Code	DUNS#
Jet Propulsion Laboratory		**23835**	**095633152**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Toshio Chin**	**818-393-2510**	**mike.chin@jpl.nasa.gov**
Organization/Business Relationship		Cage Code	DUNS#
Jet Propulsion Laboratory		**23835**	**095633152**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Boris Dewitte**	**33-561332926**	**bxd@legos.obs-mip.fr**
Organization/Business Relationship		Cage Code	DUNS#
Institute for Research and Development		**N/A**	**N/A**
International Participation	U.S. Government Agency		Total Funds Requested
Yes			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Dimitris Menemenlis**	**818-354-1656**	**menemenlis@jpl.nasa.gov**
Organization/Business Relationship		Cage Code	DUNS#
Jet Propulsion Laboratory		**23835**	**095633152**
International Participation	U.S. Government Agency		Total Funds Requested
No	**Other**		**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Vardis Tsontos**	**818-354-1419**	**vardis.m.tsontos@jpl.nasa.gov**
Organization/Business Relationship		Cage Code	DUNS#
Jet Propulsion Laboratory		**23835**	**095633152**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Collaborator	**Cara Wilson**	**831-648-5337**	**cara.wilson@noaa.gov**
Organization/Business Relationship		Cage Code	DUNS#
NOAA/NMFS/SWFSC/ERD		**N/A**	**N/A**
International Participation	U.S. Government Agency		Total Funds Requested
No	**Department of Commerce (DOC)**		**0.00**

PI Name : **Jorge Vazquez**

Organization Name : **Jet Propulsion Laboratory**

NASA Proposal Number

TBD on Submit

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION VII - Project Summary

Coastal upwelling zones support some of world's most productive fisheries. Additionally they are also strongly sensitive to changes in wind patterns, ocean temperatures, and fertilization deposition from streams. Changes in coastal upwelling, and the consequences to the world's most productive fisheries, are a critical component of the third National Climate Assessment.

We propose a new multi-parameter "upwelling" climate indicator for North America that will track how these fisheries and species adaptation relates to changing coastal upwelling. This proposal uses NASA generated state-of-the-art ocean modeling capabilities coupled to sea surface temperature and chlorophyll-a measurements from NASA satellites. These data sets span over 15 years, are well characterized, and are expected to continue with future NASA and NOAA measurements. We expect this new climate data set to be used by Fisheries and and policy makers who have a vested interest in adaptation strategies for coastal ecosystems. Dr. Cara Wilson, one of the collaborators, is a principal investigator at NOAA and will facilitate with implementation strategies of the proposed indicators. The data will be disseminated through the Physical Oceanography Distributed Active Archive Center (PO.DAAC).

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?

Yes

International Collaboration

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

Yes

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

Explanation :

Dr.. Boris Dewitte is an expert on coastal upwelling proceses. He is being asked to lend advice on the methodology for calculating the coastal index

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 : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

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 : **Jorge Vazquez**	**NASA Proposal Number**
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

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 : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Multi-Parameter Upwelling Index

Question 2 : Type of institution:

Answer: NASA Center (including JPL)

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

Answer: Yes

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

Answer: No

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

Answer: No

Question 6 : Research Category:

Answer: 9) Earth System Science applications and decision support

Question 7 : Team Members Missing From Cover Page:

Answer:

Funding is being requested for a Caltech SURF student to support the tasks listed in the proposal

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: Yes

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

Answer: 1

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

Answer: 5

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

Answer:

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:

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

Answer:

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

Answer:

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	79,960.00	80,900.00	82,520.00	243,380.00
B. Direct Labor - Other Personnel	0.00	0.00	0.00	0.00
Total Number Other Personnel	0	0	0	0
Total Direct Labor Costs (A+B)	79,960.00	80,900.00	82,520.00	243,380.00
C. Direct Costs - Equipment	0.00	0.00	0.00	0.00
D. Direct Costs - Travel	5,000.00	5,000.00	5,000.00	15,000.00
Domestic Travel	5,000.00	5,000.00	5,000.00	15,000.00
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	12,660.00	12,510.00	12,400.00	37,570.00
Materials and Supplies	0.00	0.00	0.00	0.00
Publication Costs	0.00	0.00	0.00	0.00
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	12,660.00	12,510.00	12,400.00	37,570.00
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)	97,620.00	98,410.00	99,920.00	295,950.00
H. Indirect Costs	52,330.00	51,490.00	50,040.00	153,860.00
I. Total Direct and Indirect Costs (G+H)	149,950.00	149,900.00	149,960.00	449,810.00
J. Fee	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	149,950.00	149,900.00	149,960.00	449,810.00
Total Cumulative Budget				449,810.00

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2015	**04 / 30 / 2016**	**Project**	**1**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Vazquez, Jorge	PI	0.00				51,190.00	28,770.00	79,960.00
							Total Key Personnel Costs	79,960.00

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)	79,960.00

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2015	**04 / 30 / 2016**	**Project**	**1**

C. Direct Costs - Equipment

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

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**5,000.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**5,000.00**

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 : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2015	**04 / 30 / 2016**	**Project**	**1**

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	12,660.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
8 . Other: **Caltech Post-doc**	0.00
9 . Other: **JPL Services**	0.00
Total Other Direct Costs	12,660.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	97,620.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
APS (Imported as Direct Costs per NASA Prime Contract)	0.00	0.00	25,890.00
Gen. (Imported as Direct Costs per NASA Prime Contract)	0.00	0.00	16,870.00
MPS (imported as Direct Costs per NASA Prime Contract)	0.00	0.00	9,570.00
Cognizant Federal Agency: Jet Propulsion Laboratory		**Total Indirect Costs**	52,330.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	149,950.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	149,950.00

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2016	**04 / 30 / 2017**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Vazquez, Jorge	PI	0.00				51,930.00	28,970.00	80,900.00
							Total Key Personnel Costs	80,900.00

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)	80,900.00

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2016	**04 / 30 / 2017**	**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)	**5,000.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**5,000.00**

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 : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2016	**04 / 30 / 2017**	**Project**	**2**

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	**12,510.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8 . Other: **Caltech Post-doc**	**0.00**
9 . Other: **JPL Services**	**0.00**
Total Other Direct Costs	**12,510.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**98,410.00**

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MPS (imported as Direct Costs per NASA Prime Contract)S	**0.00**	**0.00**	**9,350.00**
ADC (Imported as Direct Costs per NASA Prime Contract)	**0.00**	**0.00**	**25,330.00**
Gen. (Imported as Direct Costs per NASA Prime Contract)	**0.00**	**0.00**	**16,810.00**
Cognizant Federal Agency: Jet Propulsion Laboratory		**Total Indirect Costs**	**51,490.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**149,900.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**149,900.00**

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2017	04 / 30 / 2018	Project	3

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Vazquez, Jorge	PI	0.00				53,300.00	29,220.00	82,520.00
							Total Key Personnel Costs	82,520.00

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)	82,520.00

PI Name : **Jorge Vazquez**	NASA Proposal Number
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**

Proposal Title : **A Climate Index for Upwelling Scale and Intensity**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2017	**04 / 30 / 2018**	**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)	**5,000.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**5,000.00**

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 : **Jorge Vazquez**	**NASA Proposal Number**
Organization Name : **Jet Propulsion Laboratory**	**TBD on Submit**
Proposal Title : **A Climate Index for Upwelling Scale and Intensity**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
05 / 01 / 2017	**04 / 30 / 2018**	**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	12,400.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
8 . Other: **Caltech Post-doc**	0.00
9 . Other: **JPL Services**	0.00
Total Other Direct Costs	12,400.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	99,920.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MPS (imported as Direct Costs per NASA Prime Contract)S	0.00	0.00	8,930.00
ADC (Imported as Direct Costs per NASA Prime Contract)	0.00	0.00	24,270.00
Gen. (Imported as Direct Costs per NASA Prime Contract)	0.00	0.00	16,840.00
Cognizant Federal Agency: Jet Propulsion Laboratory		**Total Indirect Costs**	50,040.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	149,960.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	149,960.00

Contents

Jorge Vazquez 1/25/2015 7:25 PM
Deleted: 1-4

1 Scientific/Technical/Management

1.1 Introduction

Upwelling that brings nutrient rich water from depth is a phenomenon that occurs over the Eastern Boundaries of the World's Oceans. The nutrient rich water that comes to the surface supports some of the world's most productive fisheries. According to the National Climate Assessment (Federal Government Agency, 2014) (NCA) "future projections of coastal ocean conditions (for example, temperature, nutrients, pH, and productivity) are limited, in part, by uncertainty over future changes in upwelling – climate model scenarios show inconsistent projections for likely future upwelling conditions."(NCA p 52). Thus changes in upwelling could potentially have large effects on the world's most productive fisheries. Today's monitoring of coastal upwelling has been dominated by in-situ data that use winds to measure the intensity of the upwelling, but lack the ability to monitor changes in the geographic extent of the upwelling. "Considerable uncertainty also remains in whether, and how, higher average ocean temperatures will influence geographical ranges, abundances, and diversity of marine species, although evidence of changes in pelagic fish species ranges and in production associated with Pacific Ocean temperature variability exists." (NCA p. 52). Additionally the geographical extent and variability of the abundance and diversity of species can also be tied to acidification. "Consequences from ocean acidification for commercial fisheries and marine food web dynamics are potentially very high – while the trend of increasing acidification is very likely, the rate of change and spatial scale within coastal waters are largely unknown and add to the uncertainty of predicting the effect of acidification" (NCA p.52). The change in the spatial extent of the upwelling and its relationship to intensity and surface chlorophyll (productivity) will be addressed through the proposed indicators.

Garcia-Reyes et al. (2014) developed three indices for an area in Northern California. The indices were based on wind stress (intensity), sea surface temperature (SST) (upwelling response) and a nutrient index. They determined that population variability was not explained by intensity, but that SST and the nutrient index explained close to 50% of the variability. Thus SST was a major indicator in population abundance. In summary there is considerable uncertainty in predicting future upwelling changes. However it is clear that a relationship between coastal upwelling and climate changes do exist and that changes in SST and nutrient concentration (chlorophyll-a) associated with climate change will play a major in population abundance and spatial patterns

1.2 Objectives and Expected Significance

1.2.1 Objectives

One of the key areas of focus for the third National Climate Assessment (Federal Government Agency, 2014) (NCA) is coastal upwelling. These regions are home to some of the world's most productive fisheries, yet "Uncertainty in upwelling changes result in low confidence for projections of future change that depend on specific coastal ocean temperatures (NCA). A major component of the uncertainties in upwelling are the spatial scales and potential changes due to climate change and warming. The primary objectives of the proposed work are to

- use NASA satellite data products in order estimate the intensity and extent of upwelling around the US shoreline. The approach will be based on the calculation of multiple indicators and their relationships.
- develop a multi-parameter coastal upwelling index (MUI) that informs about geographic range and spatial variability of the upwelling events. Relate that information to changes in productivity as defined by surface chlorophyll. Different sources of data will be used to produce various upwelling indices. Their commonality will be explored taking into account their uncertainties as determined by comparisons with a high resolution NASA model. The parameters are calculated with potential caveats/limitations of the data due to cloud cover (SST and chlorophyll-a) and resolution and proximity to land (Winds).
- Work with NOAA to integrate indicators for use in fisheries and decision support. Dr. Cara Wilson, a collaborator on the proposal, is a principal investigator with the NOAA Southwest Fisheries Science Center which operates Coastwatch, a distributor of satellite remote sensing products to decision makers and policy makers.

1.2.2 Expected Significance

We anticipate that a direct link will be made for the first time between climate variability and the change in spatial extent and intensity of upwelling. The new index will take advantage of satellite data by adding information on how the width and spatial scales of the upwelling are linked to climate change. The addition of the spatial scale will help with future projections of changes in the geographic extent and diversity of fish populations.

1.3 Technical Approach and Methodology

1.3.1 Relation of upwelling to Climate Variability

Results have now shown relationships between the upwelling intensity and climate signals such as the Pacific Decadal Oscillation (PDO) (Chakkl and Di Lorenzo, 2007). Such changes in upwelling intensity based on climate trends/warming would have a significant impact on fisheries and the coastal ecosystem, We are proposing to develop a new climate indicator for upwelling based on both cross-shore length/width and intensity. This would complement current upwelling indices by adding a spatial scale and variability and relate those changes to intensity. Our intent is to create a climate indicator known as the Multi-Parameter Upwelling Index (MUI) to augment current indicators that focus on specific locations and time.

Some of the major upwelling regions of the world's oceans include the California Current System (CCS), the Peru/Chile Upwelling System (PCUS) off the South American Coast, and the Benquela Current System (BCS) off the African Coast. Several mechanisms can move cold water at depth to the surface. These include the offshore Ekman Transport, Ekman Pumping, and the divergence of surface winds (Pedlosky, 1979). Offshore Ekman Transport is usually driven by equatorward alongshore winds, which cause an offshore transport of water. Ekman pumping is caused by a cyclonic curl of the wind stress, which causes the upward vertical transport of water. As these upwelling centers are driven by atmospheric winds they can be vulnerable to changes in intensity and scale due to changes in intensity of high pressure and low pressure cells that are driven by climate change.

One such example this past year occurred off the coast of California where unusually warm waters where associated with changes in the coastal upwelling of the CCS. The exact mechanism of the interannual variability of the warming is still being researched. Yuan and Yamagata (2014) explained the event as an intense coupling between the ocean and atmosphere. How this warming might be linked to ENSO, the PDO or other climate signals is still an open question.

Significant correlations have been observed between the Pacific Decadal Oscillation (PDO) the North Pacific Gyre Oscillation (NPGO) and the California Upwelling Index (CUI) (Macias et al., 2012) The CUI is a measured index based on the strength of the off-shore Ekman Transport measured at several locations along the California Coast. The calculation is based on the cross-shore transport of water per unit time. The CUI is calculated using the offshore Ekman Transport based on the equatorward along-shore wind stress. Figure 1 (Macias et al, 2012) shows the locations along both the California and Baja California Coasts where the CUI index is calculated. Indices are calculated at specific locations where in-situ measurements are available. A direct relationship between the CUI and the biology, through nitrate concentrations, has been observed by Palacios et al. (2013). MUI would improve on such measurements by adding a spatial scale and intensity changes to the observed values at specific locations.

Palacios et al. (2013) show that at specific locations along the CCS between 30°N to 47°N a significant relationship exists between temperature and the nitrate concentration in the top 200 meters. Predictive models were applied that were able to determine nitrate concentrations from temperature. Data sources included a wide range, including CalCOFI, from 1959-2011. They concluded that for localized studies such predictive models between temperature and nitrate could be adequate. However for ecosystem wide studies, information about the spatial structures are necessary. Much of this is because of differences in water mass.

The relationship to changes in climate has also been shown in the PCUS (Belmadanin et al., 2014). However along the PCUS, Belmadanin et al. (2012) observed using downscaled models, that along-shore winds decreased along the PCS, but intensified along the Chilean Central Coast. They concluded that current changes in winds are coupled to changes in SST. Based on the work by Chelton et al. (2007) these changes would also be coupled to SST gradients. Bakun (1990) showed that upwelling-favorable wind stress along the coastal regions of the world's ocean has increased since the mid twentieth century in response to land-sea-atmosphere feedbacks induced by high CO2 radiative forcing associated to the greenhouse warming.

Additional studies, based on sediment records at 23°S (Vargas et al., 2007) have shown secular trends in upwelling strength that are tied into the Pacific Decadal Oscillation. Vargas et el., (2007) analyzed laminated sediments from an upwelling system in northern Chile (Mejillones Bay, 23°S) which, together with additional short sediment cores from the tropical/subtropical Peru-Chile margin and with twentieth century instrumental data, evidence that this mechanism is a predominant means to enhance coastal upwelling at centennial time scales and particularly during interdecadal El Niño-like periods of the twentieth century. All these studies point directly to climate scale variability in the upwelling system. However all the studies are limited to specific locations and lack the spatial scales that are tied to that variability.

Macias et al. (2012) use a singular value spectral analysis to extract the various CUI at the different loci and determine their relationship to climate indices such as the PDO, the NPGO, and ENSO. However spatial variability was observed in the value of correlations with ENSO having a stronger correlation in the southerly latitudes and PDO more in the northerly latitudes. During the cold phase of the PDO SST values were seen to be colder along the coast, indicative of a stronger upwelling. In summary the CUI is based on specific in-situ measurements, which is used to calculate a strength of the upwelling at a specific location in space and time. We propose a new indicator that, for the first time, is based on observations using high resolution satellite data and model and thus measures a cross-shore upwelling scale. The intensity of the upwelling can then be calculated based on the magnitude of the SST gradient as well as a vertical velocity derived from a high-resolution model. Such a methodology could be applied to upwelling zones anywhere they exist and would not be limited to coastal areas. The MUI could be applied to multiple upwelling areas including the California Current System (CCS) and upwelling zones in the Gulf of Mexico. Thus the new index would take advantage of the 1km spatial coverage of the satellite data as well as high resolution modeling to derive an index that is based on a spatial structure of the upwelling (cross-shore length scale or width) as well as intensity (vertical velocity, sea surface temperature (SST) gradients). It is proposed to add a spatial scale to upwelling by incorporating satellite data to the coverage outlined in Figure 1 and other upwelling regions.

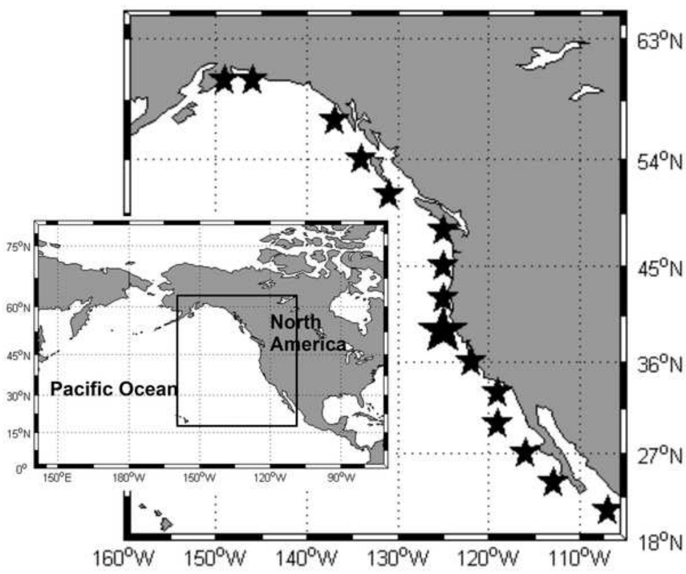

Figure 1: Locations where CUI is calculated based on volume of cross-shore transport of water per unit time. (from Macias et al, 2012).

1.3.2 Methodology

The calculation of the new climate indicator will use the following NASA and European Space Agency products. These products are all publicly available.

- QuikSCAT and RapidScat Winds. ASCAT winds on-board the European Space Agency (ESA) METOP-A platform will also be used to compliment RapidScat winds.
- The Multi-Scale Ultra-High Resolution Sea Surface Temperature Data Set (MUR): SST
- A high resolution (2km) version of the NASA Estimating the Climate and Circulation of the Ocean Phase 2
- Surface Chlorophyll estimates from NASA's Moderate Resolution Imaging Spectroradiomater (MODIS) on-board the Aqua platform.

MUI will be based on the derivation of SST gradients. The relationship is that maximum SST gradients should occur in areas of upwelling. SST gradients also follow changes in the intensity of the upwelling (Vazquez et al., 2012). In a study in the Northern Humboldt Current region Echevin et al. (2008) discovered that surface chlorophyll was out of phase with the intensity of the upwelling in the region. They concluded that mixed layer dynamics led to the paradoxical relationship. Thus the MUI will incorporate surface chlorophyll to relate intensity to changes in productivity.

Model output will be used to derive vertical velocities that can be used as an indicator of upwelling intensity along with the magnitude of the SST gradients. These changes can be related to the critical parameter of productivity through surface estimates of chlorophyll-a.

1.3.2.1 Winds

Satellite remote sensing of winds near the coast remains a difficult problem due to both sampling resolution and issues of quality. RapidScat on board the International Space Station can deliver 12.5km winds. As its technology is based on the QuikSCAT scatterometer that operated from 1999 to 2009, the quality of the measurements should be similar. It is anticipated by the time of implementation the quality of the RapidScat winds will be well documented. The European Space Agency (ESA) Advanced Scatterometer (ASCAT) on board METOP-A makes available a 12.5km resolution product that has inherently a 25km resolution. For the purpose of this proposal we will compare the intensity derived from MUI with derived Ekman Transports from in-situ derived winds (see Figure 1). For the continuation of the time series we will use winds from the RapidScat satellite. ASCAT will be used as a backup if issues with RapidScat arise.

1.3.2.2 Multi-Scale Ultra High Resolution Sea Surface

The Multi-Scale Ultra High Resolution (MUR) is available from June 1, 2002 to the present. The analysis uses data from the Advanced Microwave Scanning Radiometer (AMSR-E) on board the Earth Observing Platform Aqua, the Advanced Very High Resolution Radiometer (AVHRR), and the Moderate Resolution Imaging Spectroradiometer (MODIS) on board both the Terra and Aqua Platforms. With the malfunction of AMSR-E data was replaced with WindSat and AMSR2. Version 4.0 is used in this study and contains WindSat in the analysis for the October-November 2011 time period. MUR is globally gridded at 1km resolution by merging different satellite derived SSTs in an objective analysis technique based on a wavelet decomposition (Chin et al., 1998) is used to process each retrieval data set with respect to its inherent resolution. More information can be found at http://mur.jpl.nasa.gov/. Data descriptions may also be found at:

http://podaac-www.jpl.nasa.gov/dataset/JPL-L4UHfnd-GLOB-MUR, Results (Vazquez et al., 2013) have shown this data set can be very useful for coastal studies.

From the perspective of Level 4 merging approaches fusing data from multiple sensors with different instrument and resolution characteristics poses significant technical challenges. Satellite-based environmental data are in general irregularly sampled and noisy. The satellite swath pattern is unique to each platform, and each SST sensor has individual data drop-off tendency and faces incidental environmental conditions that are space-time dependent. The microwave-based measurements, in particular, capture less of the wavenumber spectrum due to their lower 25-km resolution than the high-resolution infra-red counterparts, while infrared measurements are more prone to data voids due to cloud contamination. In order to interpolate between sampled areas, conventional interpolation schemes are known to smear the small-scale coherent patterns and weaken the high-wavenumber energy (Large et al 1991; Mariano and Brown 1992). The resolving power of an analysis scheme cannot be set arbitrarily high for a given data set; otherwise, spatial continuity would be compromised. To combine the variety of SST data sets, the analysis method must therefore provide a common mathematical platform for a variety of resolutions represented by all the data sets.

The MUR SST analysis relies primarily on the Multi-Resolution Variational Analysis (MRVA; Chin et al 1998) for its data-fusion task. The MRVA method expands and analyzes the data at different scales (20°, 10°, 5°, ... 4km, 2km, 1km, See Figure 2.) by projecting the mean and anomaly components onto the basis functions of the Battle-Lemarie wavelet, a "cardinal" wavelet basis for interpolation (Chui 1992) associated with B-spline (Daubechies 1992; Chin et al 1998). This basis allows projection of the coarse-scale wavelet coefficients to finer-scales exactly (the "dilation relation"; Chin et al 1998), hence maintaining cross-scale consistency in interpolated components. The practical advantages of MRVA over most traditional interpolation schemes are: (i) the multi-scale processing prevents over-fitting to sparsely sampled data; (ii) decomposition into (multi-scale) anomaly components facilitates inter-sensor bias correction; (iii) the use of the continuous basis functions leads to a "mesh-less" analysis, i.e., the longitude-latitude locations of the input L2 data are preserved, and the output analysis can be sampled from the wavelet coefficients at any location post-analysis (not only at pre-determined grid points).

The issue of the projection to finer scales is critical, especially in coastal upwelling areas. The following section describes current results, which show how MUR data, and the incorporation of infrared derived SSTs, are critical for the derivation of Upwelling Scales.

1.3.2.3 Internal Tide and Upwelling-Resolving Ocean Simulation (LLC4320)

Proposal collaborator Menemenlis recently completed a groundbreaking global ocean and sea ice simulation that represents full-depth ocean processes with an unprecedented degree of realism (see Figure 2). The simulation is based on a Latitude/Longitude/polar-Cap (LLC) configuration of the MIT general circulation model (MITgcm; Marshall et al. 1997; Hill et al. 2007). The LLC grid has 13 square tiles with 4320 grid points on each side (hereafter called LLC4320) and 90 vertical levels for a total grid count of 2.2×10^{10}. Horizontal grid spacing ranges from 0.75 km near Antarctica to 2.2 km at the Equator and vertical levels have 1-m thickness near the surface to better resolve the diurnal cycle. The simulation is initialized from a data-constrained global ocean and sea ice solution provided by the Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project (Menemenlis et al. 2005, 2008; Losch et al. 2010). From there, model resolution is gradually increased to LLC1080, LLC2160, and finally LLC4320. Configuration details are similar to those previously used by the ECCO2 project except that the LLC4320 simulation includes atmospheric pressure and tidal forcing (Menemenlis et al. 2014). The inclusion of tides allows successfully reproduces shelf-slope dynamics, water mass modification, and their contribution to global ocean circulation. Surface boundary conditions are from the 0.14° European Center for Medium-Range Weather Forecasts (ECMWF) atmospheric operational model analysis, starting in 2011. Another unique feature of this simulation is that we save hourly output of full 3-dimensional model prognostic variables, making it a remarkable tool for the study of ocean and air-sea exchange processes and for the simulation of satellite observations. At the writing of this proposal, 3 years of output is available for LLC1080 and LLC2160, and 5 months of output is available for LLC4320. Output from this simulation will be used to define and test the multivariate upwelling index.

1.3.2.4 Ocean Color

To relate intensity to productivity (using estimates of chlorophyll-a) from NASA's MODIS Aqua platform will be used. These estimates are available from the Ocean Biology Processing Group (OBPG) at the Goddard Space Flight Center.

As a backup for MODIS Aqua the Visible Infrared Imaging Radiometer will also provide estimates of chlorophyll-a.

1.3.2.5 High Resolution and Coastal Upwelling

To resolve the spatial scales of coastal upwelling one needs products that can resolve features on the order of 20 km or less. MUR SST has a gridding resolution of 1km, RapidScat and ASCAT 12.5km, and the model 2km. In previous and ongoing work a relationship between the magnitude of the SST gradient and intensity of coastal upwelling has been found. Derivation of intensity based on winds can be compared directly with the model. SST gradients can also be compared directly with the model-derived gradients (see Figure 3). Previous results (Vazquez et al., 2013), in an area off the PCUS, have shown that there is a direct relationship between maxima and minima in SST gradients and the intensity of coastal upwelling. Maxima in SST gradients at two locations off Paita and Pisco were seen to coincide with known maxima in Austral summer in the intensity of the coastal upwelling. This relationship can then be exploited to derive a climate indicator that adds a spatial structure to the well established upwelling indices based on Ekman Transport. In turn changes in the spatial scale of the upwelling can be related to ocean productivity and intensity. Comparisons with the model will allow for further validation through comparisons with the wind-driven Ekman Transport and vertical velocity. As SST will be the primary source used for the derivation of the upwelling spatial scales, further clarification of the methodology and justification for using the higher resolution MUR data is warranted.

Further results indicate that when high-resolution data sets such as MUR are sub-sampled to the lower resolution (0.25 degree) NCDC data set gradient magnitudes and variability are similar.

The central question then becomes is higher resolution data a better representation of coastal areas associated with major upwelling zones. Another question is how important is the high-resolution infrared data in resolving coastal upwelling scales. These questions are critical as to the timing of the proposed work as well as the data set usage. The primary approach is use the magnitude of SST gradients to define a coastal spatial scale. Air-sea fluxes can have a large effect on temperatures along coast, but coastal upwelling will primarily be defined by colder water near the coast versus warmer water offshore. Thus the boundary will be defined by a change or gradient in SST.

Figure 2 (a, b, c, d) shows a direct comparison for the mean magnitude of the SST gradients for Oct-Nov. 2011 for the high resolution model, NCDC (25km shown for comparison purposes), (MUR and WindSat). Immediately visible are not only the higher magnitudes (5-7 degrees C/100km), but also the finer scale structures that are associated with the model and the MUR data. Clearly visible also is that in the NCDC data at 30°S it becomes difficult to define the upwelling scale based on the SST gradient. In the WindSat data (figure 2d), for that same period of time, maxima in the magnitude of SST gradients are only visible near the equator. These differences can best be defined by two factors:

- The gridding resolution of the data sets
- The different satellite derived SSTs that went into creating the map.

MUR for example contains not only both microwave (AMSR-E, AMSR2) but also both MODIS and AVHRR. The NCDC data used contains AVHRR+ in-situ data, but gridded at 25km resolution. WindSat is a microwave derived SST and thus has lower spatial resolution (25km). Summarizing it is clear, from comparisons with the high-resolution model that MUR is doing a significantly better representation of the dynamics and scales associated with the PCUS.

To explain why WindSat and NCDC are not adequately representing the upwelling scales off the PCUS figure 3 (a, b, c) shows the magnitude of the SST gradients versus cross-shore distance. The white contour is the theoretical cross-shore width of the upwelling based on a simple dependence on the Coriolis parameter and a 100km cross-shore upwelling scale at 5°S. Between 30°S and 35°S the cross-shore upwelling scale is decreasing too less than 20km, consistent with the theoretical prediction. Such a scale, although identifiable by the resolution of the model and MUR, would not be identifiable by the 25km gridded NCDC or WindSat data sets. Thus by combining the SSTs derived from both the infrared and microwave sensors in an objective way, the MUR data is well suited for detecting upwelling scales. The combination of the data fusion algorithm, along with using both MODIS and AVHRR, provides an optimum data set detecting the spatial scales of coastal upwelling. Additionally, the issue of resolution was also brought up by Pickett and Schwing (2006) with respect to winds. Pickett and Schwing (2006) also found that high-resolution winds were essential for capturing the spatial scales associated with coastal upwelling. Using satellite derived winds from QuikScat they concluded that to resolve coastal upwelling associated with localized features wind jets, high resolution global models are needed. Thus using such winds derived from RapidScat and ASCAT will be essential for correctly resolving the spatial scales of coastal upwelling and intensity.

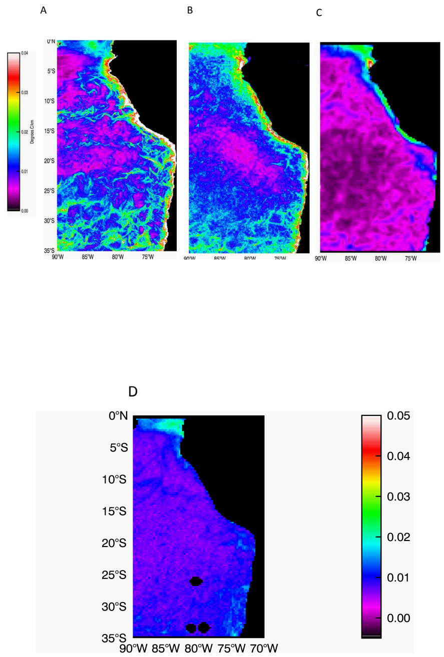

Figure 2. Mean Magnitude of SST gradients for Oct.-Nov. 2011 for a) LLC4320, b) MUR c) NCDC and d) WindSat

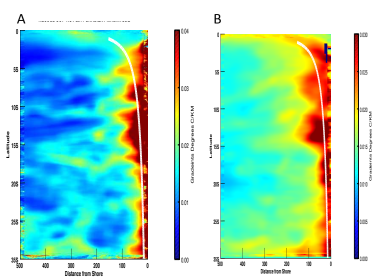

Figure 3. Mean Magnitude of SST gradients versus distance from shore for 2011 a) LLC4320, b) MUR.

1.3.2.6 Calculation of Upwelling Indicators

Four steps will be implemented in deriving the new upwelling index. These are:

- Removal of the annual signal in the SST and Chl-a fields as focus is on climate variability
- Calculation of SST gradients and magnitudes
- Derivation of cross-shore upwelling scale based on SST gradients (using both MUR and model)
- Use of winds directly to calculate an Ekman Transport
- Use of model to derive an offshore volume transport of water
- Comparison of Ekman Transports from satellite derived winds with co-located in-situ data (see Figure 1)
- Extract the co-variabilty between the magnitude of SST gradients and surface chlorophyll to derive relationship between SST gradients (upwelling intensity) and productivity.

As the purpose of calculating the index is to determine changes in upwelling that are related to climate signals, the first step will be to remove the annual signal from the SST data. Two approaches have been applied: the removal of an annual harmonic and subtracting a climatological mean. Initially better results were determined by removing the annual signal. However we will experiment with both approaches. Once the annual signal is removed we will then calculate using a simple centered finite difference approach to determine the magnitude of the SST gradient. The centered finite difference is simply based on the following:

$$SSTG_X(ix,iy)=(SST(lx+1,iy)-SST(ix-1,iy))/2\Delta X \qquad (1)$$

$$SSTG_y(ix,iy)=(SST(ix,iy+1)-SST(ix,iy-1))/2\Delta Y \qquad (2)$$

$$|SSTG| = sqrt(SSTG_x^2 + SSTG_y^2) \qquad (3)$$

Where $SSTG_X$ and $SSTG_{y\ are}$ the gradients in the (x, y) or zonal, meridional directions, ix, iy are the pixel indices representing coordinate position at longitude x, latitude y, and ΔX and ΔY are the distances in kilometers between neighboring pixels. |SSTG| is then simply the amplitude or magnitude of the SST gradient at position (x, y). Once the magnitude of the SST gradients are derived the next step is to calculate the upwelling index.

We will experiment with several approaches to fitting a model to the SST gradients across the upwelling zone. As an example figure 4 shows the average cross section of the magnitude of the SST gradients averaged over three latitude bands: 15° to 5°S, 25° to 15°S, and 35°S to 25°S. For comparison purposes the magnitude of the SST gradients are shown for LLC4320, MUR, NCDC and WindSat. NCDC and WindSat are shown to highlight the importance of the higher resolution to correctly identifying the upwelling scale (Vazquez et al. 2015).

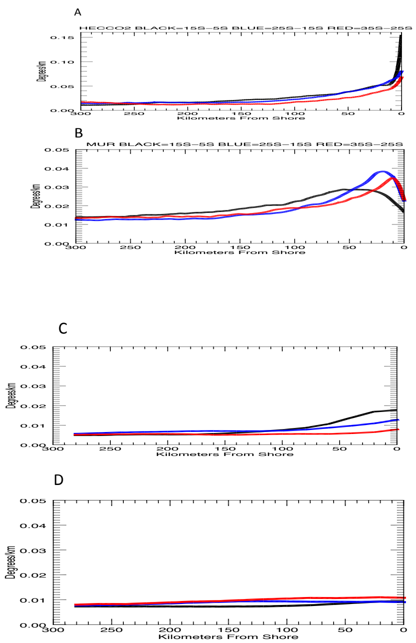

Figure 4. Cross Sections of the magnitude of the SST gradients averaged over three latitude bands black=5°S to 15°S, blue=15°S to 25°S, red=25°S to 35°S for a) high resolution model, b) MUR, c) NCDC and d) WindSat.

Based on both the high-resolution model and MUR graphs, we will experiment with fitting both a Gaussian and quadratic to model the behaviour of SST gradients in the upwelling areas. Twice the width of the Gaussian could then be used as a length scale for the cross-shore width of the upwelling scale. NCDC shows very little change in the magnitude of the SST gradient, especially minimized in the Southerly latitudes. Changes in the WindSat show no perceived change due to the coastal upwelling. To further confirm that the magnitude of SST gradients are correlated with the intensity of the coastal upwelling the principal component of the MUR and NCDC time series were extracted. Time series of the co-variability of the magnitude of the SST gradients and surface chlorophyll-a can be calculated as indicators of changes in the relationship between intensity (SST gradient magnitude, Ekman Transport) and productivity (surface chlorophyll).

Figure 5 (a,b) show the first principal component of MUR and NCDC. Both show a clear annual signal with maximum SST gradients occurring off the Peruvian/Chilean Coasts in Austral summer. The phase of the annual signal in the first principal component is correlated with the known signal in the annual signal of upwelling intensity (Sorbazo et al., 2007;Vazquez et al., 2015). The relationship between SST gradients and upwelling strength allows one to model the cross-shore upwelling scale and it's variability and the relationship to intensity through as measured by SST gradients and vertical velocity. Additionally changes in SST gradients can be compared directly with intensity as derived from the Ekman Transport using both the high-resolution model and the Winds.

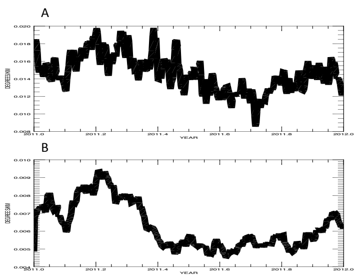

Figure 5: First principal component for a) MUR and b) NCDC for 2011.

A time series of the cross-shore upwelling scale can then be derived. Intensity can be derived and compared from three parameters: Ekman Transport calculated directly from wind stress using the RapidScat data, transport derived from the model, and vertical velocity derived from the model. Figure 6 shows an example plot of coastal winds (Cross-Calibrated Multi-Platform Project Winds which contain QuikSCAT data. Wind vectors along the Peruvian Coast clearly show along-shore winds near the coast which drive coastal upwelling through Ekman Transport.

1.3.2.7 Uncertainty estimates of indicators and sustainability

The combination of model and data to determine climate indicators provides an approach that will allow for uncertainty estimates. For example results have shown that there are periods of persistent cloud cover off both the California and Peruvian Coasts (Vazquez et al., 2013). However this issue should be mitigated over interannual time scales. Additionally topographic features, such as mountain gaps, on land can also introduce errors in wind estimates of offshore Ekman Transport. Indicators calculated directly from the model will provide a methodology to examine the consistency and uncertainties in the indicators. Comparisons with in-situ data co-located with model and satellite derived indicators will provide additional uncertainty estimates. Data sets and model are all planned for continued future production. ASCAT (which is also provided at 12.5km resolution) will provide a backup for RapidScat data while the Visible Infrared Imaging Radiometer (VIIRS) will allow for continuity of MODIS quality SST and ocean color.

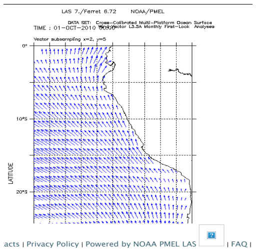

Figure 6: Shows wind vectors along the PCUS for Oct. 2010.

1.4 Perceived Impact to State of Knowledge

Will improve our understanding of the temporal and spatial changes of coastal upwelling and the relationship to climate change. Will provide decision makers and fisheries improved coastal upwelling indicators that include spatial extent and size of upwelling.

1.5 Relevance to Element Programs and Objectives in the NRA

The proposed work is directly traceable to the third National Climate Assessment. The Climate indicator would be directly related to adaptation strategies as outlined by the third NCA. For coastal upwelling this would include adaptation to changing fisheries (species) as well as regional scales of fisheries diversity and abundance.

The NASA data to be used includes the Multi-Scale Ultra High Resolution (MUR) SST analysis and Winds from RapidScat and ASCAT, as well as productivity using estimates of chlorophyll-a. Additional resources include high-resolution simulation results from NASA's Estimating the Climate and Circulation of the Ocean (ECCO2) Phase 2 model, which will help in subsurface interpretation of the observed surface signatures.

An example where the indicator could be applied includes coastal regions where upwelling dominates. Two specific areas important to the National Climate Assessment include the California Coast and the Western Coast of the Gulf of Mexico. It is anticipated that the product will be used widely by the fisheries community and decision support by coastal managers.

The sector covered, as outlined by the NCA is "ecological systems". The index to be calculated will be directly related to better understanding and quantifying changes in coastal upwelling scales that are linked to climate change. This will have consequences for understanding changes in fisheries and species adaptation to changing coastal upwelling. The climate indicator will include quantifying changes in the biogeochemical structure of the upwelling regions. The ECCO2 model will be used to compliment observations with derivations of offshore volume transport of water, along with vertical velocity.

1.6 Work Plan

The results will be disseminated through the Physical Oceanography Distributed Active Archive Center (PO.DAAC). Wind data products from RapidScat and SST using MUR are available through the

PO.DAAC. Thus the plan would be to calculate and distribute the indicators in near real time, as well as archiving historical time series back to 2002 (start of MUR). The PO.DAAC has experience with the distribution of near real time data through the Group for High Resolution Sea Surface Temperature (GHRSST). The upwelling indices could be distributed through the PO.DAACs State of the Ocean (SOTO) tool as well as historical data through the Live Access Server (LAS). The PO.DAAC historically has worked with NOAA and has experience for both the near real time and historical distribution of data.

1.6.1 Key Milestones

- First year:
  - Gather all data products
  - Successfully reading and quality controlling all data products
  - Application of strategy for derivation of cross-shore upwelling scale from SST data.
  - Calculation of anomaly data sets based on removal of annual harmonics
- Second year: Derivation of climate indicators, including the upwelling scale and intensity. Another indicator, based on the co-variability analysis of SST gradients and surface chlorophyll.
- Third year: Distribution of climate indicators through the PO.DAAC.

1.7 Management Structure

1.7.1 Contributions of Principal Investigator and Key Personnel

Principal Investigator:

Dr Jorge Vazquez: Will have the primary responsibility for implementing all aspects of the proposal and coordinating all activities between team members.

Key Personnel

Collaborator Dr. Toshio M. Chin: Will work directly with the principal investigator to implement the calculation of SST gradients and model to derive upwelling scales.
Collaborator Dr. Dimitris Menemenlis: Will provide access and advice pertaining to utilization of the LLC4320 internal-tide-and-upwelling-resolving global ocean simulation that will be used to define and test the multivariate upwelling index. Dr Menemenlis is a member of the International Ocean Vector Wind Science Team.
Collaborators Dr. Vardis Tsontos and Mr. Edward Armstrong: Will assist with issues of data management and distribution
Collaborator Dr. Cara Wilson: Will assist with the implementation of data distribution strategies, specifically making indices available to fisheries and other potential uses. Will also lend scientific and technical expertise on the calculation and application of the indicators. Dr. Wilson has also been a member of the PO.DAAC User Working Group and familiar with the data policies and management of PO.DAAC data sets.
Collaborator Dr. Boris Dewitte: Will provide expertise on how best to proceed for calculating the upwelling scale from the MUR SST data.

Jorge Vazquez 1/25/2015 6:41 PM
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3 Biographical Sketch

3.1 Principal Investigator

Jorge Vazquez
Scientist for Sea Surface Temperature and Salinity
Physical Oceanography Distributed Active Archive Center
JPL/Caltech

EDUCATION
PHD, Geological Sciences, University of Southern California (1991)
MS, Oceanography, Graduate School of Oceanography, University of Rhode Island (1984)
BS, Physics, University of Miami, with honors (1980)

RESEARCH INTERESTS
Validation of satellite derived sea surface temperature data sets
Development and analysis of climate data records
Statistical Modeling of remote sensing data

PROFESSIONAL EXPERIENCE
Task Scientist of the Physical Oceanography Distributed Active
Archive Center. Member of the Global Data Assimilation Experiment High Resolution
Sea Surface Temperature Pilot Project (GHRSST-PP) Science Working Team. Chair of the Data Management Technical Advisory Group (DM-TAG) for GHRSST-PP.
Appointed by NASA to the Data Management and Communications (DMAC) steering committee
Principal Investigator at JPL for the GHRSST-PP project.
Chair of the GHRSST (changed from GHRSST-PP to Group for High Resolution Sea Surface Temperature or GHRSST) Applications and Users Services Technical Advisory Group (AUS-TAG).
Adjunct Faculty in Earth Science at Azusa Pacific University

PROFESSIONAL ASSOCIATIONS
Member of American Geophysical Union
Member of American Meteorological Society
Member of Oceanography Society

Selected PUBLICATIONS

Gierach, M., J. Vazquez-Cuervo, T. Lee, V. Tsontos, Aquarius and SMOS detect effects of extreme Mississippi River flooding event in the Gulf of Mexico, 2013: Geophy. Res. Lett. 40 (19) 5188-5193.

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4 Current and Pending Support

4.1 Current Awards

Jorge Vazquez

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Robert Toaz	Earth Observing System Data and Information System	NASA/EOSDIS Martha Maiden 202 358-2770 Martha.maiden@nasal.gov	Oct. 2007 –present $5300000	6.0
Chelle Gentemann	Multi-sensor Improved Sea-Surface Temperature (MISST) for IOOS	National Ocean Partnership Program (NOPP) Eric Lindstrom 202-358-4540 eric.j.lindstrom@nasa.gov	January 2013-Dec. 2017	1

4.2 Pending Awards

Jorge Vazquez

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Jorge Vazquez	ROSES Climate Indicators and Data Products for Future Climate Assessments (this call)	Lucia Tsaoussi Earth Science Division Science Mission Directorate National Aeronautics and Space Administration Washington, DC 20546-0001 Telephone: (202) 358-4471 E-mail: Lucia.S.Tsaoussi@nasa.gov	05/01/15 – 04/30/18 $450K	3

5 Budget Justification Budget Narrative

5.1.1 Personnel and Work Effort

Name	Organization	Role	Work Commitment		
			Year 1	Year 2	Year 3
Dr. Jorge Vazquez	JPL/Caltech	PI	0.47	0.47	0.47
Dr. Toshio M. Chin	JPL/Caltech	Collaborator	0	0	0
Dr. Dimitris Menenmenlis	JPL/Caltech	Collaborator	0	0	0
Dr. Vardis Tsontos	JPL/Caltech	Collaborator	0	0	0
Dr. Cara Wilson	NOAA	Collaborator	0	0	0
Dr. Boris Dewitte	LEGOS	Collaborator	0	0	0
Mr. Edward Armstrong	JPL/Caltech	Collaborator	0	0	0

5.1.2 Facilities and Equipment

The project will use existing computing and storage facilities. The MUR processing system consists of a multi-CPU (32 total) Dell Server with currently 30 TB of storage. A small amount of 10K is requested in the first year to purchase additional disk storage for the large volumes of VIIRS L2 data necessary for prototyping and development.

5.1.3 Rationale and Basis of Estimate

Labor: Overall the budget contains salary support for the principal investigator as well as a SURF student through the Caltech Student Faculty Research Program. SURF student is budgeted for each of the three years of the proposal.
Travel: Five thousand dollars is being budgeted each year for travel. As implementation of the indicators will require close collaboration with NOAA, travel to and from NOAA facilities is essential.

The cost estimate for this proposal was prepared using JPL's Pricing System and the current internally published Cost Estimation Rates and Factors dated January 2013.

The derivation of the cost estimate is a grassroots methodology based on the expert judgment from a team of experienced individuals who have performed similar work. The team provides the necessary relevant experience to develop a credible and realistic cost estimate. The cognizant individuals identify and define the products and the schedule needed to complete the tasks for each work element. Then they generate the resource estimates for labor, procurements, travel, and other direct costs for each work element. The resource estimates are aggregated and priced using JPL's Pricing System. JPL's process assures that lower level estimates are developed and reviewed by the performing organizations and their management who will be accountable for successfully completing the proposed work scope within their estimated cost.

All investigators have a key role to play in the proposed work. PI Jorge Vazquez has over 30 years experience in remote sensing.

JPL Cost Accumulation System

Introduction

All costs incurred at the Laboratory, including JPL applied burdens, are billed to the Government as direct charges at the rates in effect at the time the work is accomplished.

Allocated Direct Costs

Allocated Direct Cost (ADC) rates contain cost elements benefiting multiple work efforts, including Project Direct, MPS, and Support and Services activities. Rate applications for cost estimates are specific to the given category as stated below:

1) Engineering and Science (E&S)
2) Procurement: Purchase Order, Subcontract, Research Support Agreement (RSA)
3) General and Administrative (G&A): Basic, RSA
4) Specialized G&A applications: Remote Site

The accounting process fully distributes these costs to the respective project/task(s).

Multiple Program Support

The Multiple Program Support (MPS) rate applies costs for program management and technical infrastructure. Cost estimates and system application tools will apply the composite rate to all project direct hours charged to projects managed by JPL.

Employee Benefits

All costs of employee benefits are collected in a single intermediate cost pool, which is then redistributed to all cost objectives as a percentage of JPL labor costs, including both straight-time and overtime. Functions and activities covered by this rate include paid leave, vacations, and other benefits including retirement plans, group insurance plans, and tuition reimbursements.

For this proposal the estimated costs have been derived in the same manner as stated above. However, presentation of the estimated costs in the required tables has been adapted in the following ways:

1. The costs for Employee Benefits are included in the Direct Labor costs stated in this proposal.
2. Engineering and Science ADC and Procurement ADC along with MPS costs are displayed in the “Other” category in the Other Direct Costs section.
3. G&A is shown in the Facilities and Administrative Costs section.
4. JPL’s forecasted labor rates equal an hourly laboratory-wide average for each job family and are further broken down by career level within the job family. Labor cost estimates apply the family average or family average career level rate to the estimated work hours. An actual individual’s labor is considered discrete and confidential information and is only released on an exception basis and only if a statement of work identifies that specific individual as the only one able to perform a task. The use of family average or family average career level rates in consistent with the JPL CAS disclosure statement and the Cost Estimating Rates and Factors CDRL published in response to a requirement in NASA prime contract NAS7-03001 I-10 (d) (1).

The proposed budget of the NRA proposal also covers labor costs for serving on NASA peer-review panels and advisory committee at the request of NASA discipline scientists or program managers.

NSPIRES

Proposal : NASA Roses May 2015 to Aprl 2018 SANS DM - VASQUEZ REV C - 1 20 2015

Budget

Budget Period: Start Date: End Date:	1 May 2015 - Apr 2016	2 May 2016 - Apr 2017	3 May 2017 - Apr 2018	4 -	5 -
A. Senior / Key Person	$79,960.00	$80,900.00	$82,520.00	$0.00	$0.00
B. Other Personnel	$0.00	$0.00	$0.00	$0.00	$0.00
Total Salary and Wages (A+B)	$79,960.00	$80,900.00	$82,520.00	$0.00	$0.00
C. Equipment Description	$0.00	$0.00	$0.00	$0.00	$0.00
D. Travel	$5,000.00	$5,000.00	$5,000.00	$0.00	$0.00
E. Direct Costs - Participant/Trainee Support Costs	$0.00	$0.00	$0.00	$0.00	$0.00
F. Other Direct Costs	$12,660.00	$12,510.00	$12,400.00	$0.00	$0.00
G. Total Direct Costs (A through F)	$97,620.00	$98,410.00	$99,920.00	$0.00	$0.00
H. Indirect Costs	$52,330.00	$51,490.00	$50,040.00	$0.00	$0.00
I. Total Direct and Indirect Costs (G + H)	$149,950.00	$149,900.00	$149,960.00	$0.00	$0.00
J. Fee	$0.00	$0.00	$0.00	$0.00	$0.00
K. Budget Total (I + J)	$149,950.00	$149,900.00	$149,960.00	$0.00	$0.00

5.2 Budget Details – Year 1

Direct Labor – Year 1

- Dr. Jorge Vazquez is the PI and will oversee all aspects of the proposed work. Dr.Vazquez's tiem commitment is 0.47 FTE ($51190 requested salary with $28770 fringe benefits)
- All collaborators on the proposal are involved at no cost.

Other Direct Costs – Year 1

Subcontracts/Subawards

- Subcontract is being request for a Caltech SURF student. This is budgeted at: 12660 dollars. Costs will cover student for the entire year.

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Consultants

- There are no consultants required for this task.

.

Equipment

- There are no major equipment purchases necessary.

Services

None

Supplies and Publications

- none

Travel

- The PI will travel extensively to the NOAA facility in Monterey California for consultations with he collaborator Dr. Cara Wilson. 55k

.

Facilities and Administrative (F&A) Costs – Year 1

- Multiple Program Support (MPS) $9570
- Allocated Direct Costs (ADC) $25890
- Applied General $16870

Other Applicable Costs – Year 1

None

Total Estimated Costs for Year 1: $149,950

5.3 Budget Details – Year 2

Direct Labor – Year 2

- Dr. Jorge Vazquez is the PI and will oversee all aspects of the proposed work. Dr.Vazquez's tiem commitment is 0.47 FTE ($51930 requested salary with $28970 fringe benefits)
- All collaborators on the proposal are involved at no cost.

Other Direct Costs – Year 2

Subcontracts/Subawards

- Subcontract is being request for a Caltech SURF student. This is budgeted at: 12510 dollars. Costs will cover student for the entire year.

.

Consultants

- There are no consultants required for this task.

Equipment

- There are no major equipment purchases necessary.

Services

None

Supplies and Publications

- none

Travel

- The PI will travel extensively to the NOAA facility in Monterey California for consultations with the collaborator Dr. Cara Wilson. $5k

.

Facilities and Administrative (F&A) Costs – Year 2

- Multiple Program Support (MPS) $9350
- Allocated Direct Costs (ADC) $25330
- Applied General $16810

Other Applicable Costs – Year 2

None

Total Estimated Costs for Year 2: $149,900

5.4 Budget Details – Year 3

Direct Labor – Year 3

- Dr. Jorge Vazquez is the PI and will oversee all aspects of the proposed work. Dr.Vazquez's tiem commitment is 0.47 FTE ($53300 requested salary with $29220 fringe benefits)
- All collaborators on the proposal are involved at no cost.

Other Direct Costs – Year 3

Subcontracts/Subawards

- Subcontract is being request for a Caltech SURF student. This is budgeted at: 12400 dollars. Costs will cover student for the entire year.

.

Consultants

- There are no consultants required for this task.

Equipment

- There are no major equipment purchases necessary.

Services

None

Supplies and Publications

- none

Travel

- The PI will travel extensively to the NOAA facility in Monterey California for consultations with he collaborator Dr. Cara Wilson. 5k

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Facilities and Administrative (F&A) Costs – Year 3

- Multiple Program Support (MPS) $8930
- Allocated Direct Costs (ADC) $24270
- Applied General $16840

Other Applicable Costs – Year 3

None

Total Estimated Costs for Year 3: $149,960

Total Costs: $449,810