COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 13-1	FOR NSF USE ONLY
NSF 11-581 07/01/13	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) EAR - GEOINFORMATICS	1347184

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/28/2013	3	06030000 EAR	7255	965088057	07/01/2013 2:03pm S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
996000354	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Hawaii	HONOLULU, HI 968222234 US
AWARDEE ORGANIZATION CODE (IF KNOWN) 0016105000	

NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
University of Hawaii at Manoa	University of Hawaii at Manoa 1680 East-West Rd Honolulu ,HI ,968222234 ,US.

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

TITLE OF PROPOSED PROJECT **Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 126,626	36 months	01/01/14	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________
Exemption Subsection ____ or IRB App. Date ________
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Department of Geology and Geophysics	1680 East-West Road Post 806 Honolulu, HI 96822 United States
PI/PD FAX NUMBER 808-956-5154	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME Paul Wessel	PhD	1990	808-956-4778	pwessel@hawaii.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

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

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

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:
By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A;
that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization's expenditure of any funds under the award, in accordance with the organization's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

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

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

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

Certification Regarding Lobbying

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

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

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

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
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CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

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

Certification Regarding Federal Tax Obligations

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

Certification Regarding Unpaid Federal Tax Liability

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

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

Certification Regarding Criminal Convictions

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

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

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Naomi R Chow	Electronic Signature	Jun 28 2013 2:57PM

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
808-956-3105	mitake@hawaii.edu	808-956-9081

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

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 13-1		FOR NSF USE ONLY
NSF 11-581	07/01/13	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		1347204
EAR - GEOINFORMATICS		

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/28/2013	3	06030000 EAR	7255	175104595	07/01/2013 2:04pm S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
956006144	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of California-San Diego Scripps Inst of Oceanography	8602 La Jolla Shores Dr Univ of California-San Diego LA JOLLA, CA 92093-0210
AWARDEE ORGANIZATION CODE (IF KNOWN): 0013177010	

NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
University of California-San Diego Scripps Inst of Oceanography	University of California-San Diego Scripps Inst of Oceanography CA ,920930210 ,US.

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

TITLE OF PROPOSED PROJECT **Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 101,081	36 months	01/01/14	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________
Exemption Subsection ________ or IRB App. Date ________
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
____

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Inst. of Geophysics & Planetary Physics	8795 Biological Grade, Room 1104 La Jolla, CA 920930225 United States
PI/PD FAX NUMBER: 858-534-2902	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME David T Sandwell	PhD	1980	858-534-7109	dsandwell@ucsd.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

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

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The undersigned certifies, to the best of his or her knowledge and belief, that:
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(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

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CERTIFICATION PAGE - CONTINUED

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

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Ann F Dunbar**	**Electronic Signature**	**Jun 28 2013 4:36PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
858-534-1293	**adunbar@ucsd.edu**	**858-534-9642**

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

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 13-1		FOR NSF USE ONLY
NSF 11-581	07/01/13	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		**1347190**
EAR - GEOINFORMATICS		

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/28/2013	3	06030000 EAR	7255	161202122	07/01/2013 2:04pm S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
396006492		

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Wisconsin-Madison	21 North Park Street Suite 6401 MADISON, WI 53715-1218
AWARDEE ORGANIZATION CODE (IF KNOWN) 0038950000	
NAME OF PRIMARY PLACE OF PERF	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
University of Wisconsin-Madison	University of Wisconsin-Madison WI ,537151218 ,US.

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

TITLE OF PROPOSED PROJECT **Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 127,820	36 months	01/01/14	

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

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

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Geoscience	1215 W. Dayton St. Madison, WI 537061692 United States
PI/PD FAX NUMBER 608-262-0693	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME Kurt L Feigl	PhD	1991	608-262-0176	feigl@wisc.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

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By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

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

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

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

Certification Regarding Lobbying

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

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

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

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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

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

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

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

Certification Regarding Federal Tax Obligations

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

Certification Regarding Unpaid Federal Tax Liability

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

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

Certification Regarding Criminal Convictions

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

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

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Tisha Kawahara	Electronic Signature	Jun 28 2013 3:35PM

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
608-890-3044	tnkawahara@ls.wisc.edu	

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

B. Summary: Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology

The Generic Mapping Tools (GMT) is a software package for analyzing and displaying geoscience data. GMT includes more than 80 modules that share a common set of command options, file structures, and documentation. Its power to produce publication-quality graphic presentations with complete flexibility has made it the *de facto* standard for a large scientific community that now includes more than 25,000 individual registered users. GMT permeates work published in journals such as *Nature Geoscience*, the *Journal of Geophysical Research* and *Geophysical Journal International*. The peer-reviewed publications announcing new releases of GMT have been cited more than 8000 times, the GMT website is visited by over 20,000 times per month, and logs indicate ~2000 full downloads per month.

Since 1993, the Geoscience directorate within the U.S. National Science Foundation (NSF) has supported the development, maintenance, documentation, and distribution of GMT. The community of scientists using GMT in their work has grown from the Marine Geology & Geophysics (MGG) program to include seismologists, geodesists, geodynamicists, and geologists. Although GMT serves the community's map-making needs quite well, several aspects of GMT require updating. In addition, new scientific opportunities prompt a targeted expansion. Accordingly, PIs Wessel, Sandwell, and Feigl propose to undertake "software development and code hardening" in four areas:

(1) Extend GMT to analyze and display more diverse types of data: the proposed project will improve code for plotting velocity vectors and their uncertainties as arrows with confidence ellipses (e.g., "Q-tips") and earthquake focal mechanisms as hemispherical projections (e.g., "beach-balls") on cartographically correct maps. In addition, the proposers will strengthen GMT in the areas of time-series analysis, ternary diagrams, and geologic symbols.

(2) Build an Application Programming Interface (API) between GMT and Python. Currently, most users of GMT run its modules using a series of commands in shell scripts. Increasingly, the high-level language Python is emerging as a common framework for modern computational workflows. The proposed work will develop an API that will allow calling GMT modules directly from Python. This effort will build on the prototype API that is already under development in GMT5.

(3) Build tools for Interferometric Synthetic Aperture Radar: InSAR is a geodetic method for measuring the deformation of the Earth's surface associated with earthquake-generating faults, active volcanoes, moving glaciers, and unstable landslides, as well as the engineered withdrawal and/or injection of petroleum, natural gas, geothermal fluids, and carbon dioxide. Using version 4 of GMT, Co-PI Sandwell and colleagues have developed a prototype GMTSAR supplemental package to focus, register, and analyze InSAR data. This proposed work will extend the InSAR tools to: (a) enable the interface between GMTSAR and GMT5; (b) develop two pre-processor sub-packages to ingest the new data to be provided by two new satellite missions to be launched in late 2013 — Sentinel-1 and ALOS-2; (c) further develop the ScanSAR-to-ScanSAR InSAR processing capabilities for these new data; (d) resampling phase values using a quad-tree algorithm; (e) filtering using a smoothed version of the power spectrum; (f) improve speed and portability by leveraging the new API between GMT and Python.

(4) Develop scripts for deploying GMT on the Open Science Grid (OSG). High-throughput computing will facilitate large applications of GMT involving production-mode analysis of large global data sets that can run many independent jobs in parallel. High-performance computing will speed up inverse modeling using iterative, stochastic algorithms.

Intellectual merit of the proposed activity: After more than twenty years of application, GMT has demonstrated its power to enable scientific research by facilitating both quantitative analysis and graphic display of quantitative results. The proposed activity will solidify and extend this capability using modern enabling information technology. The Python API will both streamline and accelerate workflows for modern research in geoscience and beyond.

Broader impacts of the proposed activity: The source code will be distributed, free of charge, under the GNU Lesser General Public License. The software tools to be developed under the proposed research activity will serve and enlarge a large community that already includes more than 25,000 scientists. A post-doctoral researcher who specializes in scientific data analysis and software development will receive broad training.

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

Appendix Items:

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

TABLE OF CONTENTS

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

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Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology

Introduction

Overview

The Generic Mapping Tools (GMT) is a software package for analysis and display of geoscience data. The open-source GMT "toolbox" now includes more than 80 modules sharing a common set of command options, file structures, and documentation. Its power to produce publication-quality graphic presentations with complete flexibility has made it the *de facto* standard for a large scientific community that now includes more than 25,000 individual registered users (*Fig. 1*). GMT permeates work published in journals such as *Nature Geoscience*, the *Journal of Geophysical Research* and *Geophysical Journal International*. The peer-reviewed publications announcing new releases of GMT have been cited ~8000 times, our website has > 20,000 visits per month, and ftp logs show ~2000 downloads per month.

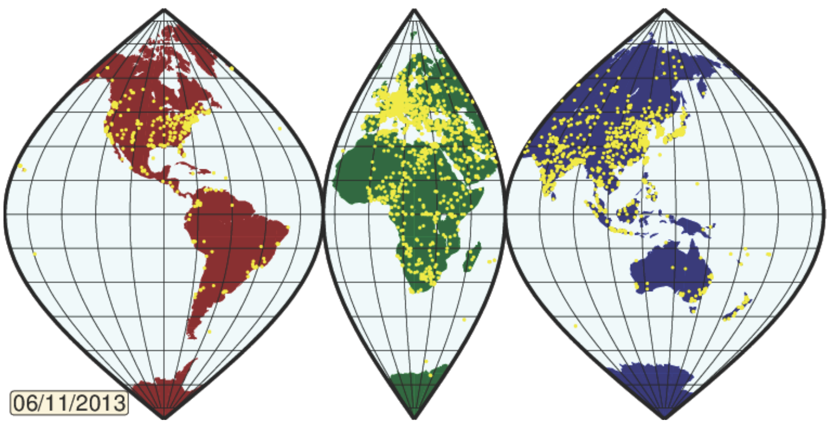

Fig. 1. Example of an interrupted sinusoidal map made with GMT, showing the global distribution of our users. Each yellow dot represents a 15'-by-15' block with one or more registered user or institution. So far, ~2500 such blocks have been registered, representing more than 25,000 individual GMT users. However, most users are unlikely to register so the number of actual users is much higher.

Since 1993, the Geoscience directorate within the U.S. National Science Foundation (NSF) has supported the development, maintenance, documentation and distribution of GMT. The community of scientists using GMT in their work has grown from the Marine Geology & Geophysics (MGG) program to include terrestrial seismologists, geodesists, geodynamicists and geologists. Although GMT serves these communities' map-making needs quite well, several aging aspects of GMT are due for updating and new scientific opportunities require a targeted expansion into new areas. Accordingly, we propose four tasks of "software development and code hardening":

Task 1: Extend GMT to analyze and display more diverse types of data
Task 2: Build an Application Programming Interface (API) between GMT and Python
Task 3: Build tools for Interferometric Synthetic Aperture Radar (InSAR)
Task 4: Develop scripts for deploying GMT on the Open Science Grid (OSG)

In each of these areas, we will follow the same protocol for writing, debugging, testing and distributing the code as for previous versions of GMT, as described in the Work Plan. After elaborating on the rationale for extending GMT, we describe the details of the programming for each of these tasks.

Reponsiveness to the Solicitation in Geoinformatics

This proposal specifically addresses the requirements for a NSF Geoinformatics proposal. It is firmly rooted in the geoscience community and responsive to specific community needs (seismology and geodesy, in particular, but also geodynamics and geology). The deliverables will integrate with existing infrastructure (GMT) and the Python interface will greatly expand GMT inter-operability with other software and computational environments. We can guarantee broad acceptance given their distribution with GMT and the present GMT usage within the target communities. Because of this connection, all deliverables will be open source, platform independent, and highly portable, and we will strongly leverage both the GMT core grant and the talents of capable volunteers. GMT tools scale very well, their foundation is rigorously maintained, and we actively seek input from computational scientists to ensure efficient implementations. Our discipline-specific activities will provide new fundamental tools that are expected to see very modest maintenance costs beyond the project timeline.

Relationship between this proposal and current support

Now in version 5, GMT has long been supported by the Ocean Science division (the Marine Geology & Geophysics program), as described in the Results from Previous Support for PI Wessel. The current grant, "Support for the Generic Mapping Tools" (number OCE-1029874) to PI Wessel will expire August 31, 2015. The OCE grant supports: (a) development for the core GMT tools; (b) upkeep of web-based system for distribution of open-source code; (c) installation on new releases of operating systems, e.g., Mac OSX 10.8; (d) refinement of databases, e.g., coastlines; (e) documentation, e.g., online bug tracker; and (f) outreach, e.g., wiki forum.

In addition, the GMT team has been exploring the concept of a high-level Application Programming Interface (API) for GMT. Currently, the architecture of GMT5 rests on a foundation of an API in C/C++. To build more sophisticated workflows, many members of the OCE/MGG community are using Matlab, a proprietary software package and/or Octave, an open-source equivalent. Accordingly, the core GMT team has focused on developing an API to sit above GMT5 and below Matlab [*MathWorks*, 2007]. Work on the Matlab API continues and may have reached users as a beta release by January 2014.

Other communities, however, have requested other APIs. In particular, scientists in computationally intensive fields such as geodynamics, geodesy, and seismology, have requested an API between GMT and Python, an open-source programming language that is well-suited for high-throughput computing (HTC) and high-performance computing (HPC) in parallel. To meet this new need (that has emerged since the proposal for the current grant was written in 2009), we propose to develop an API between GMT and Python. Consequently, we have very carefully focused this proposal on new tasks not explicitly covered by any other grant, and furthermore the work proposed requires new collaboration between the scientists at SOEST, SIO, and UW-Madison.

What GMT5 will contribute

Since GMT5 is new, yet essential, to this proposal, we will first discuss how it will enable the proposed work. Prior to version 5, the bulk of GMT functionality was coded directly in program modules (e.g., **surface.c**, **psxy.c**, **grdimage.c**, etc.). The GMT library only offered access to low-level functions from which those high-level GMT programs were built. However, the design of the main programs prevented developers from leveraging GMT functionality from within other programming environments. Access to GMT tools could only be achieved via system calls or via an ever-changing myriad of low-level library functions. Consequently, all input and output (I/O) of data had to be done via temporary files. This design also prevented the GMT developers themselves from taking advantage of these modules directly. For instance, the tool **pslegend** needed to make extensive use of system calls to **psxy** and **pstext** in order to plot the lines, symbols and text that make up a map legend, making it a very awkward program to maintain, especially across platforms. Thus, relying on external system calls made the use of GMT outside shell scripts cumbersome and slow. Attempting to program custom functionality via the undocumented GMT low-level library was tedious and subject to frequent change at the whim of the GMT developers. To rectify these limitations, PI Wessel led the development team to GMT5.

GMT5 will be released in ~September 2013 (to be timed with an EOS publication) and brings many new capabilities to scientific computing and visualization. As in previous releases, there are a few new tools, numerous improvements to existing capabilities, new options to many of the tools, and improved documentation, more examples, unified development environment (cmake), better testing (over 400 test scripts covering all the programs) and bug reporting (wiki with bug and feature tracking). However, the most important (and time-consuming) change is under the hood. Each of the GMT executable programs has been reconfigured to be a module in C/C++ library. Thus, the I/O for the standard GMT objects (grids, data tables, text tables, CPT files, and images) has been standardized. The high-level functions are now accessible to developers via an API. For the first time, this new API is fully documented. For clarity, we refer to the classic GMT programs as "GMT programs" and the functions they have become as "GMT modules" in GMT5.

In order for this interface to be as flexible as possible, we have generalized the notion of input and output. In addition to the current (version 4) mechanism for passing file names, GMT5 can specify the source of input data and/or the location of output data in several different manners, including: (a) data already loaded into memory from an application invoked previously; (b) file pointers; (c) file descriptors. Thus for a typical table of data, the GMT API takes care of the task of assembling any combination of files, pointers, and memory locations into *a single virtual data set* from which the GMT module may read: (a) all records at once into memory, or (b) read one record at a time. Likewise, GMT modules may write their output to a virtual destination, which might be a memory location in the user's application, a file pointer or descriptor, or an output file. The GMT modules are unaware of these details and simply read from a "source" and write to a "destination".

Consequently, the separate executable files from version 4 no longer exist. Instead, GMT5 includes only a single executable **gmt**. Its first argument is the name of the module of interest. For example, the command "**gmt pscoast**" would launch the **pscoast** module. This approach is now the recommended way of using GMT. (It solves persistent problems for package managers because several GMT tools have generic names that clash with those of other packages (e.g., **triangulate**, **surface**, **pstext**). All examples and documentation now use this new syntax. Modules are now accessible in several other ways:

(1) For compatibility with existing scripts, users can use a "classic" mode that will install links with the names of the previous executables (e.g., **blockmean**, **pscoast**, …). These links all point to the same single executable **gmt**, and the link name tells gmt which module to launch.

(2) Developers using C/C++ can call any of the modules via the API function **GMT_Call_Module** () and may now develop complex custom programs that use GMT modules as building blocks. In addition to the ~80 modules, developers may also use the rest of the GMT API to read and write GMT objects, process options, access default parameters, and many other common tasks.

(3) All modules are called dynamically and loaded as needed from shared libraries. We have therefore decoupled the main GMT (core) modules from the supplement modules, the latter being found in a separate (and optional) shared library. This keeps the core truly generic and eliminates the need to distribute supplements to those who do not require them.

(4) Developers can choose to write their own modules, and by following our guidelines their modules (stored in one or more shared libraries) can be loaded by the main **gmt** executable in exactly the same manner as the core and supplemental modules. This allows developers to leverage the GMT framework by letting GMT handle I/O, default and option processing, selecting optimal FFTs, generic data processing, and plotting.

Finally, the GMT API also contains low-level functions specifically written for FORTRAN 77 that allow reading and writing any GMT-supported grid format from legacy FORTRAN programs widely used within the geodynamics community. Thus, GMT5 is now uniquely positioned to allow rapid development of custom applications, dramatic speed-up of scripted workflows, and custom expandability.

TASK 1: EXTEND GMT TO ANALYZE AND DISPLAY MORE DIVERSE TYPES OF DATA

Graphic display of geodetic results

The GMT tool **psvelo** plots velocity vectors and their uncertainties as arrows with confidence ellipses (also known as "Q-tips") on cartographically correct maps, as illustrated in Fig. 2. Making such a map is straightforward using GMT, but tedious using any other software package. In addition, we will add the ability to plot arrows (called "geo-vectors" in GMT5) that are tangent to a great circle or a small circle on a sphere. Such arrows are particularly useful for visualizing the motion predicted by models such as MORVEL [*DeMets et al.*, 2010] or MORVEL-NNR [*Argus et al.*, 2011]. The proposed work will update the existing C source code to GMT5 standards and use the new internal functions in GMT5. This effort should be straightforward because PI Feigl wrote the original code for **psvelo.**

Graphic display of results from seismology

The GMT tool **psmeca** plots earthquake focal mechanisms as hemispherical projections (also known as “beach-balls”) on a map in a cartographic projection, as illustrated in *Fig. 3*. Such maps help seismologists visualize an earthquake rupturing on a fault plane by projecting an intrinsically three-dimensional phenomenon in to two dimensions, as shown in a tutorial illustration (*Fig. 4*).

The GMT tool **pscoupe** plots earthquake focal mechanisms in a vertical cross-section using a polar projection from the hypocenter onto the hemisphere behind it, as illustrated in Fig. 5. The proposed work will update the existing C source code to GMT5 standards and use the new internal functions in GMT5. This effort should be straightforward because PI Feigl collaborated with Genevieve Patau on the original design of **psmeca** and **pscoupe**.

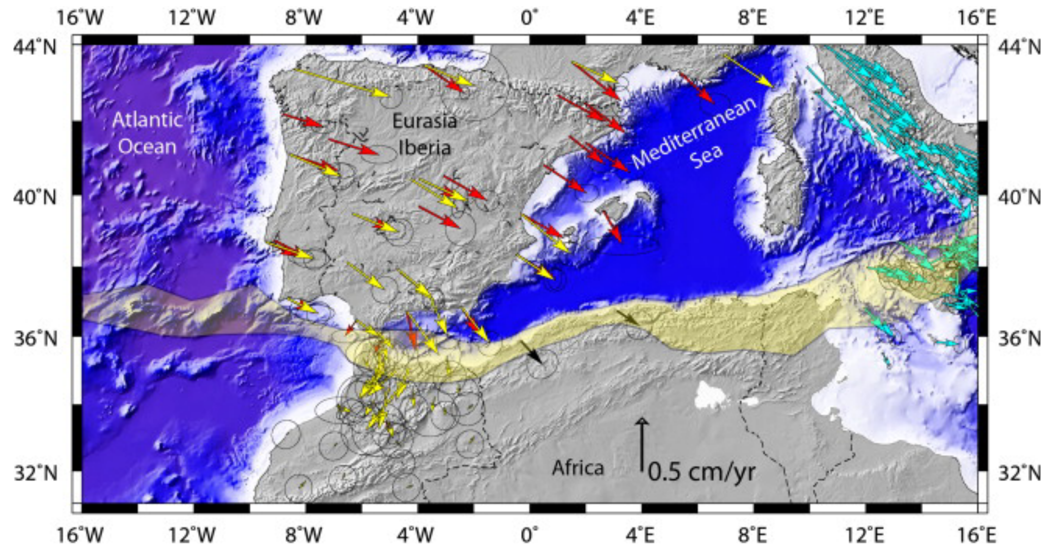

*Fig. 2. Example of a published figure using the GMT function **psvelo** to display a tectonic velocity field as vectors with confidence ellipses. The map of the Mediterranean basin shows recent GPS results in the western Mediterranean with Nubia fixed [Ozener et al., 2013].*

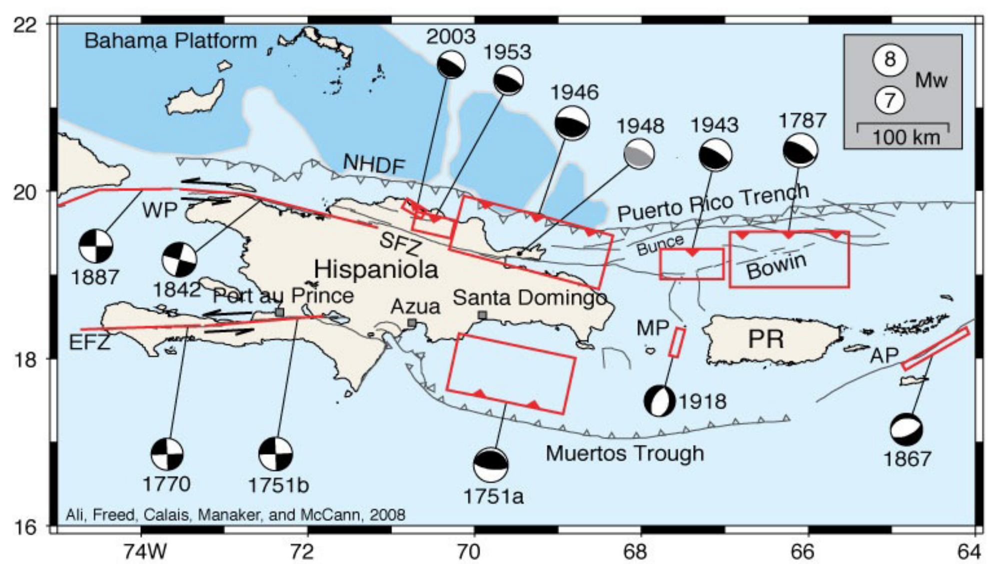

*Fig. 3. Example of a published figure using the GMT function **psmeca** to display earthquake focal mechanisms around Haiti. The disastrous earth-quake of 2010 occurred near the gray square denoting the city of Port au Prince. [Ali et al., 2008].*

Improved tools for modeling trends in time series

One of the GMT tools (**trend1d**) allows users to fit either a polynomial or a Fourier trend to a 1-D data set (e.g., a time-series) using least squares, optionally modified using weights or robust estimation. We have received many requests to modify **trend1d** to allow fitting a model that combines both polynomial and Fourier terms. Such models are routinely required for fitting a combination of secular and seasonal changes to sea level [e.g., *Leuliette and Scharroo*, 2010], ground motion measured by GPS (Dong et al., 2001), and even atmospheric records [e.g., *Thoning et al.*, 1989]. Since many geodesists have implored us to implement this feature and we propose to add it to the GMT core as part of the proposed work.

Ternary diagrams

Geochemists and petrologists use ternary diagrams to display the composition of rocks or minerals that are composed of three primary components, as shown in *Fig. 6*. Although many of these scientists use GMT for making maps, GMT does not currently offer ternary diagrams. Although none of the developers on the core GMT team had a personal need for such a capability, we have received numerous requests for such a tool from our colleagues. To meet this need, we propose to add ternary diagrams to GMT via a new tool **psternary**. Since the required low-level functions (axes annotation, projection functions, contouring) are already present in the GMT library, we expect this task to be straightforward. It will have a large impact on the geoscience community.

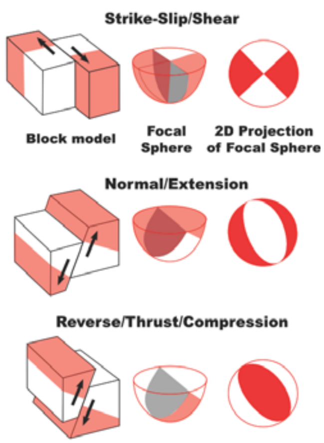

Fig. 4. Explanation of earthquake focal mechanisms showing 3 different views for each of 3different types of earthquake. [Rowan, 2009].

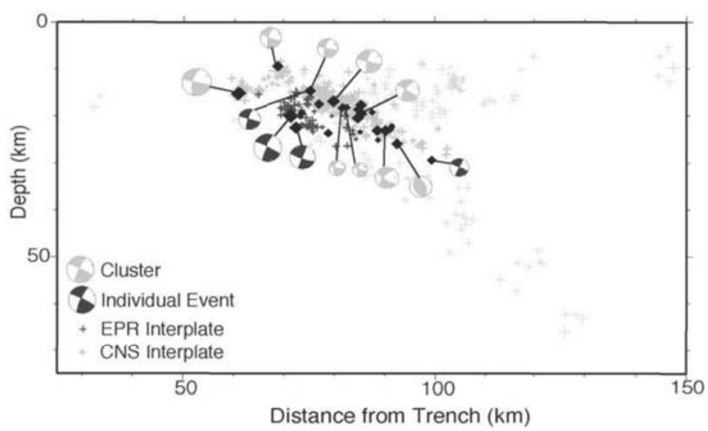

*Fig. 5. Example of a published figure using the GMT function **pscoupe** to display earthquake focal mechanisms in cross section for a subduction zone (the Middle America Trench [Hansen et al., 2006].*

Design custom symbols for geology, glaciology, and hydrology

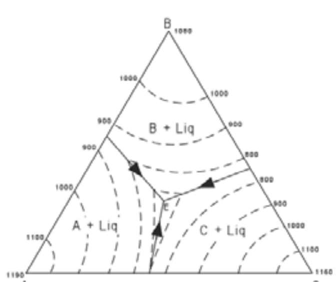

Fig. 6. Examples of a ternary diagram showing the relative compositions of 3 components, A, B, & C as triplets and temperature (°C) as contours [S Nelson, Tulane U.].

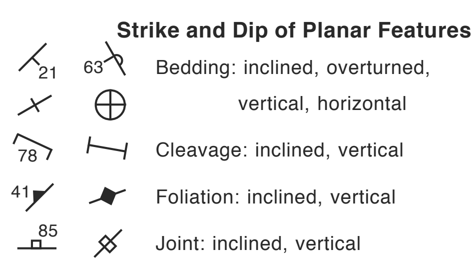

Fig. 7. Examples of custom symbols for geology from microimages.com.

To enhance a map's capacity to convey information, many geoscientists employ specialized symbols. For example, *Fig. 7* shows cartographic symbols used in geology. Glaciology, hydrology, meteorology, sedimentology also have their own symbols. Simple symbols could be drawn in version 4 of GMT4 using a very basic capability in **psxy** and **psxyz**. In GMT5, however, more sophisticated symbols can be defined using an enhanced macro language. This approach allows two essential functions. First, the macro language includes arguments for complex multi-parameter symbols. For example, the macro to draw the geologic symbol for the strike and dip of a rock unit uses three arguments: length, width, and orientation. Second, the macro language allows conditional rendering of each individual symbol component. This feature allows the symbol to change in appearance, depending on the value of the data. For example, the strike-and-dip symbol will show a tick on both sides of the strike if the dip is 90° from horizontal. This capability will allow hundreds of geological symbols to be plotted in GMT without new coding (other than designing the macros). We propose to take the lead in designing a set of exemplar symbols, communicate this feature and opportunity to the community, and enable user-submitted symbols to be hosted on the GMT website.

TASK 2: APPLICATION PROGRAMMING INTERFACE (API) BETWEEN GMT AND PYTHON

Currently, most users of GMT run its modules using a series of commands in a scripting language contained within an operating system such as UNIX, LINUX, CYGWIN or DOS. Increasingly, however, the high-level language Python is emerging as a common framework for modern computational workflows. As described on its official web site, "Python is a remarkably powerful dynamic programming language that is used in a wide variety of application domains. Python is often compared to Tcl, Perl, Ruby, Scheme or Java. Some of its key distinguishing features include: very clear, readable syntax; strong introspection capabilities; intuitive object orientation, natural expression of procedural code; full modularity, supporting hierarchical package; exception-based error handling; very high level dynamic data type; and extensive standard libraries" [*python.org*, 1990]. Python runs on Windows, Linux/Unix, Mac OS X, and has been ported to the Java and .NET virtual machines. Python is free to use, even for commercial products, because of its open source license as approved by the Open Source Initiative [*OSI*, 1998]. Python is the foundation for the modeling program Pylith [*Aagaard et al.*, 2013] developed by the Computational Infrastructure for Geodynamics [*CIG*, 2009] initiative funded by the Earth Science (EAR) Directorate of the U.S. National Science Foundation (NSF).

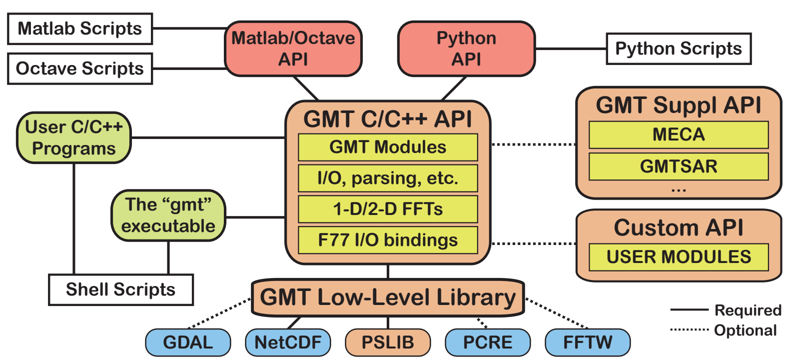

Fig. 8. Conceptual block diagram of GMT dependencies. In GMT5, the high-level functionality resides in the API and any module may be called via the single ***gmt*** *executable. Supplemental and custom APIs may also be accessed this way. The Matlab/Octave and proposed Python API allow scripts in those languages direct access to GMT modules. In contrast, shell scripts can only call the* ***gmt*** *executable.*

To meet the need for a higher-level interface, as expressed by our community, the proposed work will develop an Application Programming Interface (API) that will allow calling GMT functions directly from Python scripts. This effort will build on lessons learned from designing the prototype API for Matlab and Octave that is currently under development in GMT5. The proposed concept will extend the Python language with new loadable GMT modules, as sketched in *Fig. 8*.

The current work on developing the API for Matlab/Octave will greatly facilitate designing an API for Python. In both cases, the API will pass arguments to a GMT module via strings that resemble those used to run the **gmt** executable on the command line. In the API, however, the primary input and output file destinations may be omitted. In this case, they are implied to derive from Matlab/Octave variables (in memory). For example, the Matlab script below reads triplets of (x,y,z) data, then calls GMT to filter them using **blockmedian**, grid them with **surface**, draw contours of equal elevation in Matlab and finally make a complete map, including the coast line (**pscoast**) using GMT.

```
% Initialize the GMT/Matlab session:
gmt ('create');
% Load in a table of (x, y, z) triplets
data = load ('my_data_table.txt');
% Decimate by spatial median by GMT & return D as Nx3 matrix to Matlab
D = gmt ('blockmedian -R10/90/-30/60 -I2', data);
% Grid data D using GMT's surface module & return a grid structure
G = gmt ('surface -R -I2 -T0.2 -N1000', D);
% Make a basic contour plot of grid structure G in Matlab
contour (G.x, G.y, G.z);
% Make a nice contour map in GMT, overlying gray land areas:
gmt ('pscoast -R -JM6i -Ggray -P -Ba -O ->map.ps');
gmt ('grdcontour -J -K -C2 -A10 -V ->>map.ps', G);
% Terminate the GMT session:
gmt ('destroy');
```

The Python API will share many similarities with the GMT API for Matlab/Octave, such as the ability to return one or more objects and to accept objects as input instead of files. For instance, the Python interface would rely on *tuples* to handle more than one output item from a GMT module. Because of our experience with the Matlab/Octave API we expect the Python API to see rapid development and completion once the main issues have been ironed out. The GMT Python API will be exceedingly beneficial to a wide range of EAR scientists, in particular geodynamicists, as many of their workflows are written in Python.

We expect to involve the broad GMT user community in helping to design the interface to ensure a buy-in from all interested groups. Specifically, we plan to set up a discussion forum for interested Python users to design an API that addresses their concerns. We will also reach out to communities already using Python in their workflows. As usual, we will leverage volunteer support for the implementation, which will be under subversion control at the GMT site.

TASK 3: TOOLS FOR INTERFEROMETRIC SYNTHETIC APERTURE RADAR

Interferometric analysis of synthetic aperture radar images (InSAR) is a geodetic technique that calculates the interference pattern caused by the difference in phase between two images acquired by a space-borne SAR sensor at two distinct times. The resulting interferogram is a contour map of the change in distance between the ground and the radar instrument. These maps provide an unsurpassed spatial sampling density (~100 pixels/km^2), a competitive precision (~10 mm) and a useful observation cadence (1 pass/month) [e.g., *Bamler and Hartl*, 1998; *Madsen and Zebker*, 1998; *Massonnet and Feigl*, 1998; *Simons and Rosen*, 2007]. Since its first applications to agricultural fields that inflated after irrigation [*Gabriel et al.*, 1989] and the magnitude-7 earthquake in Landers, California [*Massonnet et al.*, 1993], InSAR has become a powerful metrological tool. It can measure the deformation of the Earth's surface associated with earthquake-generating faults, active volcanoes, moving glaciers, and unstable landslides, as well as the engineered withdrawal and/or injection of petroleum, natural gas, geothermal fluids and carbon dioxide.

Increases in computer capability over the past decade, coupled with precise orbits for the new InSAR satellites, have made it possible to perform much of the InSAR processing using standard software tools such as GMT and Matlab. PI Sandwell and colleagues [2011] have assembled a software package called GMTSAR for analyzing InSAR data. Written in the C programming language, it is open-source licensed under the (GNU General Public License). Designed for users familiar with the toolbox approach of

GMT, the individual tools are combined into a workflow using scripts written in C-shell (csh). GMTSAR requires installation of GMT and Network Common Data Format (NetCDF) libraries and supports several different libraries for fast Fourier transforms (FFT).

The GMTSAR software has three main components: (1) a preprocessor for each satellite data type (currently ERS, Envisat, and ALOS) to convert the native format and orbital information into a generic format; (2) an InSAR processor to focus and align stacks of images, map topography into phase, and form the complex interferogram; and (3) a postprocessor, mostly based on GMT, to filter interferograms and construct interferometric products of phase, coherence, phase gradient, and line-of-sight displacement in both radar and geographic coordinates. GMT is used to display the products as *PostScript* files and keyhole markup language (KML) overlays for Google Earth. A set of C-shell scripts has been developed for standard 2-pass processing as well as image alignment for stacking and time series. ScanSAR processing is also possible (*Fig. 9*) but requires a knowledgeable user. GMTSAR has been used in several published studies [e.g., *Tong et al.*, 2010; *Kaneko et al.*, 2013; *Tong et al.*, 2013]. The software, satellite orbits, and a tool for generating custom digital elevation models are available at http://topex.ucsd.edu/gmtsar. A tutorial and algorithm document is available at the same site. A number of short courses have been given to broaden the InSAR science community (e.g., http://www.unavco.org/edu_outreach/short-courses/2013/insar/insar.html).

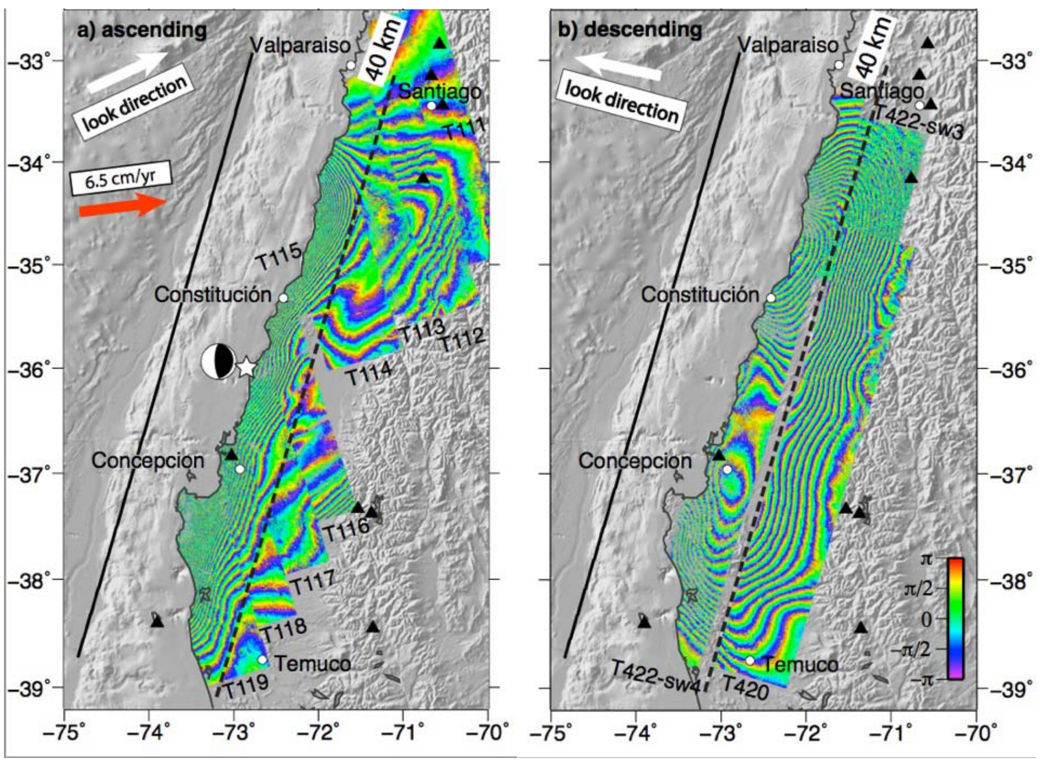

*Fig. 9. ALOS interferometry for the 2010 Maule Chile processed with GMTSAR [Tong et al., 2010]. (a) Nine tracks of ascending interferograms (swath mode) and (b) two subswaths of descending interferograms (ScanSAR-ScanSAR mode). The black triangles show the locations of 13 GPS sites used to measure the earthquake displacement. These LOS data are hosted on the UNAVCO supersite (*http://supersites.earthobservations.org/chile.php*).*

Full integration of GMTSAR into a GMT5 supplement

The current version of GMTSAR is external to GMT4 and requires the full GMT4 source tree in order to compile and link with the GMT and netCDF I/O libraries. The remainder of GMTSAR is a set of shell scripts that call the standard GMT modules for post-processing, analysis, and display. We propose to tighten this integration in four ways. First we propose to call the new API I/O routines in GMT5 from the relevant GMTSAR C codes to make this connection more robust. This improvement will increase the number of file formats that GMTSAR can read and write. It will also simplify maintaining the code. Second, we propose to use the optimized capabilities for Fast Fourier Transforms (FFT) from GMT5 into the SAR processor, image cross correlator, and phase filtering codes. Currently, the FFT routines in GMTSAR are optimized for the Mac OSX system but use sub-optimal FFT routines on other UNIX platforms (e.g., UBUNTU and FEDORA). In contrast, GMT5 automatically provides the best FFT available. The third integration involves converting the workflows from csh scripts to Python programs, thereby allowing the use of the (to-be-developed) Python API to GMT. This improvement will increase portability (e.g., to Windows) and speed up execution by avoiding unnecessary temporary files. The final integration will automate the installation of GMTSAR so it is simple for any platform with GMT5 installed. Over the past 6 months, Wessel and Sandwell have begun experimenting with the full integration of GMTSAR into a proper GMT5 supplement. We propose to complete and harden this integration over the next three years.

Importing the data from new SAR missions to be launched in 2013

A second major task of this proposal will be to develop two new pre-processors for data from two new InSAR satellite missions to be launched in late 2013 (Sentinel-1, ESA and ALOS-2, JAXA). Prior to the development of GMTSAR, we wrote preprocessing codes for the ALOS-1 PALSAR, which ingest the raw data files provided by JAXA to extract the metadata, orbital information, and raw unfocused SAR imagery. The preprocessor codes also combine the DEM and orbital information to create a pixel-by-pixel mapping from geographic coordinates to radar coordinates and vice versa as well as precise interferometric baseline information. This ALOS pre-processor is independent of GMTSAR and also has custom output modes for the ROI_PAC InSAR processing package. The new data streams to be provided by Sentinel-1 and ALOS-2 have two fundamental differences from prior InSAR satellites. First, the lowest level data to be distributed will be fully focused imagery. Second, most of the data acquisitions will be in the ScanSAR mode and repeat pass InSAR will be possible because both satellites will control the alignment of the reference and repeat bursts in real time. We have an investigation approved by JAXA to have early access to the ALOS-2 calibration/validation data for the development of the new ALOS-2 preprocessor software.

Forming an interferogram from two ScanSAR images

Forming an interferogram from standard strip-mode SAR data (e.g., *Fig. 9a*) is a routine exercise that can be performed using a variety of software packages (e.g., GMTSAR, ROI_PAC, Gamma, Doris, Diapason) on a modern laptop or desktop computer. In contrast, ScanSAR-to-ScanSAR interferometry (e.g., *Fig. 9b*) is much more challenging and there are only a few labs in the world who have the software and expertise to do this processing (*Balmer and Einder* [1996]; *Guarnieri and Prati,* [1996]; *Ortiz and Zebker*, [2007]; *Tong et al.,* [2010]). The main reason space agencies are moving to ScanSAR data acquisition is the reduced time for global acquisition. Standard strip-mode (70 km swath) achieves global coverage in 35-46 days while ScanSAR (350 km swath) achieves global coverage in 12-14 days.

The drawback of the ScanSAR approach is that the data are acquired in bursts of ~256 echoes in each of 5 sub-swaths (*Fig. 10*). Complete wide swath coverage is not possible because the time between echoes must be greater than the time it takes the radar pulse to traverse the swath. Incredibly, a SAR image for each sub-swath can be constructed from one fifth of the full along-track coverage. However, interferometric phase coherence can only be achieved if the bursts on the repeat pass are well aligned with the bursts of the reference pass. This condition requires the timing of the repeated radar bursts to be accurate to about 3 milliseconds, based on GPS position and time information. Both of the new InSAR satellites, Sentinel-1 and ALOS-2, will be operated primarily in this ScanSAR mode. Theoretically, this improvement will increase the number of possible interferograms and lower the repeat interval by a factor of 4. Today, however, no existing software packages can deal with these new data streams in a systematic way. The key to automating ScanSAR-to-ScanSAR interferometry is to have robust software, combined with satellite orbits with accuracies better than 50 cm so that the sub-swaths can be interfered independently and combined seamlessly into a single large interferogram. This requires phase precision of better than 1/8 the radar wavelength (7 mm at C-band and 28 mm at L-band). Automation of the image co-registration requires that the geometric accuracy be better than about 10 m. As part of this proposal, we propose to develop tools to completely automate ScanSAR-to-ScanSAR interferometry. We believe that this task is possible in the 3-year time frame of this proposal as long as the space agencies provide well-focused imagery that is burst-aligned along with accurate orbital information.

Resampling values using a quad-tree algorithm

The quad-tree algorithm, originally developed for image compression [e.g., *Samet*, 1984] has been applied to InSAR data in three different ways. Jonsson et al. [2002] apply a quad-tree algorithm to unwrapped interferograms, i.e., the scalar field of range change (in millimeters). Simons et al. [2002] use a similar approach, based on the curvature of the unwrapped interferogram. More recently, Ali and Feigl [2012] have applied a quad-tree algorithm to *wrapped* phase implanted in a program named **pha2qls.c** (for "Phase to Quad-tree LiSt") by PI Feigl and P. Sobol. For each square patch of pixels, the **pha2qls** quad-tree algorithm estimates three parameters: the circular mean direction, the partial derivative of phase with respect to the easting coordinate, and the partial derivative of phase with respect to the northing coordinate. The misfit to this simple, 3-parameter empirical model for a planar phase ramp, as measured by the circular mean deviation [*Mardia and Jupp*, 2000] of the wrapped residual phase, is the criterion for subdividing the patch in the quad-tree algorithm. If the misfit exceeds a pre-set threshold (e.g., 0.25 cycles), then the patch is sub- divided into four more square patches. If, on the other hand, the misfit is less than or equal to the threshold value, then the value of the partial derivative of phase with respect to the easting coordinate is recorded for the patch. The smallest allowable patch is 2 pixels in length by 2 pixels in width. This process continues recursively until completion. The quad-tree procedure thus provides a set of range gradient values that are suitable for inversion.

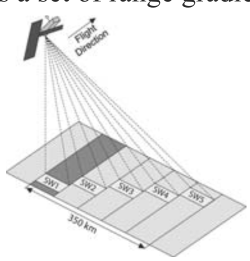

Fig. 10. Stripmap acquisition in dark grey versus ScanSAR acquisition in light grey. During ScanSAR mode, the satellite electronically steers the beam between subswaths, whereas during stripmap mode, the beam is maintained within a single subswath [Ortiz and Zebker, 2007].

For example, Fig. *11* shows the phase values before (left panel) and after (right panel) the quad-tree resampling procedure. The resampling procedure reduces the computational burden and mitigates correlations between neighboring pixels. We propose to modify **pha2qls.c** to use the GMT5 API for I/O and include it in the GMT core as a generic tool.

The quad-tree resampling procedure provides three scalar fields corresponding to the values of the three parameters estimated for each patch: (a) the circular mean phase, (b) the discrete derivative of range change with respect to the easting coordinate, and (c) the discrete derivative of range change with respect to the northing coordinate. Since each of these fields is derived from the same original field of wrapped phase, any one of them can be used to represent the deformation field. For example, the right panel of Fig. *11* shows the values of the eastward component of the range change gradient in cycles per pixel.

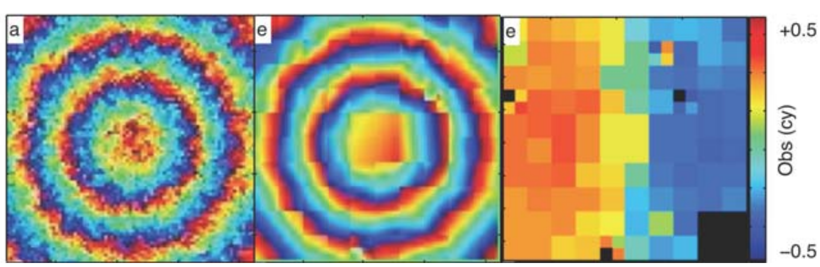

*Fig. 11. Example of quad-tree resampling, showing: (at left) original wrapped phase values calculated from a simulation of an active volcano [Mogi, 1958]; (in center), the filtered phase values after the quad-tree resampling function **pha2qls**; and (at right) values of the eastward component of the range change gradient in cycles per pixel. Figure [Ali and Feigl, 2012].*

The range gradient offers a number of advantages as an observable quantity for subsequent analysis. Unlike wrapped phase change, the range change gradient is continuous and differentiable [*Sandwell and Price*, 1996]. Just as the phase shift measured by InSAR is sensitive to displacement, the range change gradient is sensitive to strain. Mathematically, the range change gradient is equivalent to a particular component of the "deformation gradient" tensor [*Malvern*, 1969]. For example, a difference of 0.1 cycles in phase or 2.8 mm in range change over the 100 m distance between adjacent pixels in the interferogram corresponds to a range gradient of 2.8×10^{-5}.

Since the range change gradient is a continuous function, the strategy avoids the pitfalls associated with phase unwrapping techniques. Using the gradient of range change as an observable quantity also avoids the pitfalls of phase unwrapping, as discussed by Feigl and Thurber [2009]. Since the fundamental condition for InSAR implies that the horizontal gradient of range cannot exceed half a cycle per pixel, this new observable quantity is unwrapped, by construction.

Filtering using a smoothed version of the power spectrum

As described by Goldstein and Werner [1998], "the power spectra of interferograms are typically the sum of a narrow-band component combined with broad-band noise." They designed an "adaptive filtering algorithm that dramatically lowers phase noise, improving both measurement accuracy and phase unwrapping, while demonstrating graceful degradation in regions of pure noise" [*Goldstein and Werner*, 1998]. An example appears in *Fig. 12*.

In the proposed work, we will combine build on two existing implementations of this algorithm. The first has been coded by Zhong Lu and Tim Wright in **psfilt2**. The second implementation, **phasefilt**, has been coded by GMTSAR collaborator Rob Mellors. We propose to develop several new improvements, including: (1) varying the degree of smoothing according to the spatial coherence [*Baran et al.*, 2003]; (2) estimating the 2-dimensional spectrum using a taper such as Butterworth's; and (3) handling edges, missing data, and masks. After testing and hardening the code, we will introduce the filtering module into GMT5's GMTSAR supplement by using the GMT C API.

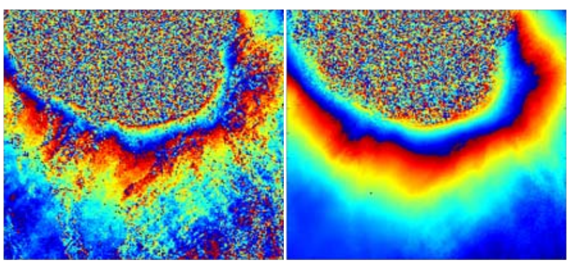

Fig. 12. Example of adaptive filtering, showing: (at left) original wrapped phase values and (at right), the filtered phase values after the applying the power-spectral filter ***psfilt2****.*

TASK 4: DEPLOYING GMT ON THE OPEN SCIENCE GRID

The Open Science Grid (OSG)

The Open Science Grid (OSG) is a "multi-disciplinary partnership to federate local, regional, community and national cyber-infrastructures to meet the needs of research and academic communities at all scales" [*OSG*, 2011]. OSG is "jointly funded by the Department of Energy and the National Science Foundation to: build, operate, maintain, and evolve a facility that will meet the current and future needs of large scale scientific computing; and, promote and support better utilization of local campus resources and improved access to the national cyber- infrastructure from those campuses". The OSG was instrumental in the recent discovery of the Higgs Boson [e.g., *Garisto and Agarwal*, 2012]. Although many users of GMT perform computationally intensive calculations that would be well suited to the OSG, we are aware of relatively few members of the earth-science community currently using OSG. For example, the large global data sets from seismology and/or InSAR seem particularly well suited for High Throughput Computing.

High Throughput Computing

For large applications of GMT involving production-mode analysis of large global data sets, running many independent jobs in parallel makes sense. For example, a typical InSAR data product is geocoded map of phase change on a cartographic grid. Such computation is a good match for high-throughput computing on the Open Science Grid. For each single-threaded task, the requirements are: (a) run time of the order of on hour; (b) memory on the order of 2 GByte; (c) temporary file storage on the order of 3 GByte; and (d) generic binary executable files, e.g., GMTSAR with GMT5 and its API. Accordingly, we propose to deploy GMT on the Open Science Grid. Specifically, we plan to work with OSG software engineers at UW-Madison to install GMT5 and its Python API on all of the computers in the OSG via the OSG standard library.

High Performance Computing (HPC)

In a typical geophysical inverse problem, the model defines the fitting function that calculates the observable quantity (e.g., a displacement field measured by geodesy) from a set of parameters. In most geodetic studies to date, the fitting function is an analytic solution. Although computationally inexpensive, such solutions no longer suffice to account for the detail and precision of InSAR measurements [e.g., *Masterlark*, 2003; *Masterlark*, 2007]. Instead, several groups are using the Finite Element Method (FEM) to evaluate the fitting function [e.g., *Williams and Wadge*, 2000; *Masterlark et al.*, 2012]. Although the FEM has the ability to account for complexities such as heterogeneous material properties, non-linear rheology, or time-dependent sources, the fitting function becomes computationally expensive. One evaluation can take ~10 minutes to run.

With any fitting function, the goal is to estimate the set of parameters that best explain the observations. To do so, we solve the non-linear inverse problem to minimize the misfit between the observed and modeled values of this quantity. For example, we present the strategy developed and applied by *Ali and Feigl* [2012] for InSAR measurements. In this case, the authors used an open-source FEM code named **defmod** [*Ali*, 2011]. To quantify the misfit between the observed and modeled values of the range change gradient, their objective function calculates the cost as the circular mean deviation [*Mardia and Jupp*, 2000] of their residual difference, averaged over all points in the resampled data set. To minimize the objective function, we *Ali and Feigl* [2012] a simulated annealing algorithm [*Kirkpatrick et al.*, 1983] implemented in FORTRAN [*Goffe*, 1996] and parallelized using the Message Passing Interface (MPI). This algorithm typically requires more than ~10,000 evaluations of the fitting function to find the optimum solution: the estimate of the model parameters that produces the lowest value of cost. For computational efficiency, we approximate the fitting function using a second-order Taylor series. The simulated annealing algorithm then evaluates the approximate and fast version of the fitting function. After performing these two steps several times, the scheme converges, typically in 5–15 iterations. Since the iteration involves looping and testing, the algorithm's flowchart cannot be described by a Directed Acyclic Graph (DAG). Consequently, the algorithm is not a good match for high-throughput computing. Instead, the communication between threads requires High Performance Computing (HPC).

Ali and Feigl [2012] have applied this strategy for inversion to Krafla central volcano in Iceland using the "lonestar" HPC cluster at the Texas Advanced Computing Center (TACC) with a one-year-only "startup" allotment of computer time granted by the Extreme Science and Engineering Discovery Environment [*XSEDE*, 2010]. *Ali and Feigl* [2012] analyzed a data set composed of eight interferometric pairs acquired by the ERS-1 and ERS-2 satellites over a 6-year interval between 1993 and 1999, they estimate the four parameters in a Mogi model. Their results indicate a source at 4.98 ± 0.21 km depth and a deflation rate that decays exponentially over the interval, in agreement with prior studies. The results are equivalent to, computationally more efficient than, and more robust than those obtained using wrapped phase.

In the proposed work, we plan to develop the HPC approach further by: (1) reading the InSAR data directly from GMTSAR through its Python API; (2) exploring other FEM packages such as Pylith [*Aagaard et al.*, 2013]; and (3) exploring other algorithms for optimization such as Markov Chain Monte Carlo — MCMC [e.g., *Johnson et al.*, 2005].

WORK PLAN

To develop the software above, we propose a 3-year plan for research that includes the four components listed below. *Fig. 13* shows the protocol for software development.

WP 1 — (a) Adapting code for graphic display of geodetic and seismological results: In this work package, PIs Feigl and Wessel will adapt the three programs, **psvelo.c**, **psmeca.c** and **pscoupe.c** from the existing and working code in the "velo-meca" supplement to version 5 of GMT. We will also expand the documentation, add validation scripts, and provide additional realistic examples. *(b) Adding tools for time-series analysis, plotting ternary diagrams and geologic symbols:* PI Wessel will work with the core GMT development team on the implementation of the time-series modeler and a new ternary diagram plot tool, and engage the GMT geologic community to help develop new symbol macros.

WP 2 — Building an Application Programming Interface (API) between GMT and Python: In this work package, PI Wessel, with assistance from the core GMT team and other motivated volunteers, will design, develop, test and distribute a Python API for GMT5 that will allow users to call each of the GMT modules directly from Python scripts.

WP 3 — Building tools for Interferometric Synthetic Aperture Radar: In this work package, PIs Sandwell and Feigl, in collaboration with Rob Mellors and postdoctoral researcher Xiaopeng Tong, will design, develop, test and distribute source code and Python scripts for the InSAR tools described above. PI Wessel will assist with the GMT5 module integration and supplement packaging.

WP 4 — Grid Computing: In this work package, PIs Feigl and Wessel, in collaboration with the post-doctoral researcher to be recruited, will design, develop, test and distribute Python scripts for grid computing under the auspices of the Open Science Grid [*OSG*, 2011] and the Extreme Science and Engineering Discovery Environment [*XSEDE*, 2010].

MANAGEMENT PLAN

We anticipate the involvement of four researchers in the project. PI Wessel will oversee the project as well as closely supervise the development of the GMT source code, with which he is already extremely familiar. PI Feigl will lead WP 1.a and 4 and contribute to WPs 3. PI Sandwell will lead WP 3. The post-doctoral research associate to be recruited for this project will focus on incorporating his or her expertise in Python to WPs 2 and 3. PI Wessel will lead WP 1.b and 2. All investigators, including the post-doctoral associate, will contribute to WP 4. Our team will benefit from the expertise and volunteerism of a worldwide community of GMT users. The source code will be distributed, free of charge, under the GNU Lesser General Public License, at the GMT website. The PIs will use the new software in their work, to be published in the international, peer-reviewed literature such as *J. Geophys. Res.* or *Geophys. J. Int.* All source code and documentation will be archived at the University of Hawaii at Mānoa, as specified by the NSF/EAR data policy [*NSF*, 2002] and described in the Data Management Plan.

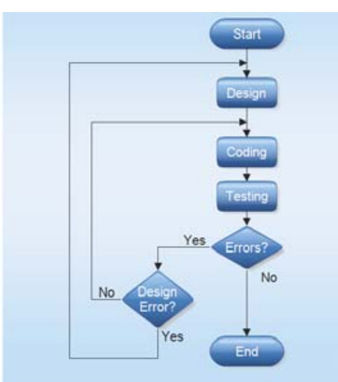

Fig. 13. Flow chart for development protocol, showing the steps of designing, coding, and testing. The GMT5 API provides structure to the coding and minimizes code repetition. Testing and validation is a key step in the process and can be very difficult to perform completely. We will rely on the GMT philosophy, which is to create validation scripts for all modules, and as problems are detected we add additional scripts such that a module has to pass numerous tests before its release. Given the complexity of geophysical software this approach has proven to be invaluable. While not in the flowchart, documentation of all modules is also considered critical, as are examples of use, including realistic test data sets.

BROADER IMPACT OF THE PROPOSED ACTIVITY

The source code will be distributed, free of charge, under the GNU Lesser General Public License. The software tools to be developed under the proposed research activity will serve and enlarge a large community that already includes more than 25,000 of scientists. A post-doctoral researcher who specializes in scientific data analysis and software development will receive broad training. Documentation and test modules may be used for classes and workshops, as needed.

RESULTS OF PRIOR SUPPORT: PI PAUL WESSEL (UNIVERSITY OF HAWAII)
(a) NSF Award Number: OCE 0452126; *Amount:* $212,941 *Period of Support:* 7/1/2005-06/30/2011
(b) Title of the project: Support of the Generic Mapping Tools (GMT)
(c.1) Summary of Results (Intellectual Merit): During the 5-year project 2005–2010 period we have made available 13 GMT releases, which have involved continued revisions of GMT internals. We have also added much new capability to GMT in terms of new programs (e.g., spline-in-tension Green's function interpolator), new options to existing programs (e.g., make Google Earth *.kmz files from GMT maps), and completely new supplements (e.g., sph – a GMT front-end to spherical interpolation and triangulation via the STRIPACK and SSRFPACK Fortran libraries of R. Renka). We have rewritten aspects of the *PostScript* plotting library pslib and enabled GMT to read any COARDS-compliant netCDF file (even data files created by other programs).
(c.2) Summary of Results (Broader Impact Activities): We have, with international cooperation, added GMT-format output capabilities to the GDAL/OGR library of tools, making it possible to use OGR to translate shapefiles to GMT-formatted ASCII tables. We have also added experimental tools that allow GMT users to drape their GMT-produced maps onto Google Earth. Our coastlines (GSHHS) have been refined further, including splitting the continents along the Suez and Panama canals and the complete removal of artifacts like crossings. Finally, we have been updating our documentation by adding more examples, in particular how to make animations with GMT (animated GIFs or full-fledged HD video). We have had several collaborations with the EarthByte group in Sydney where Wessel spent a sabbatical, laying the groundwork for the next versions of Gplates to access GMT5 functionality. We have also published three technical papers about software and techniques relevant to or included with GMT, and given several presentations about GMT to international audiences. We have continued to refine our installation procedures and now offer simple Windows installers as well as our general Linux/Unix/OSX install script. We maintain a large website where all documentation, example scripts, tutorials, and access to source code are available to anyone. We also maintain traditional mailing lists for registered users. In 2010 we were funded to build and maintain GMT5 for 2012-2015 (OCE 1029874).
(d) publications resulting from the NSF award; and (e) Research products:
Wessel, P. et al., The Generic Mapping Tools, http://gmt.soest.hawaii.edu,
Wessel, P. and W. H. F. Smith, GSHHG, A Global Self-consistent, Hierarchical, High-resolution Geography Database http://www.soest.hawaii.edu/pwessel/gshhg.

RESULTS OF PRIOR SUPPORT: PI DAVID SANDWELL (SCRIPPS INST. OCEANOGRAPHY)
(a) NSF Award Number: EAR-Geophysics 0811772; *Amount:* $298,000 *Period:* 7/1/2008-06/30/2012
(b) Title: Observations and Modeling of Shallow Fault Creep Along the San Andreas Fault System
(c) *Summary of Results (Intellectual Merit):* Precise measurements of ground motion were used to study the distribution and magnitude of slow creep along faults of the San Andreas Fault (SAF) system. Measuring and modeling fault creep is improving our understanding of both earthquake hazard and earthquake physics. Much of the creep signal is close to the fault and therefore, best observed by a space-based technique called Interferometric Synthetic Aperture Radar (InSAR) because of its complete 100-m spatial resolution. The new aspect of this research was the use of L-band InSAR data from the ALOS spacecraft (JAXA). L-band interferogram remain coherent over longer time intervals than the previously available C-band interferograms. These new data were especially important in central and northern California where C-band permanent scattering methods are only partially successful in measuring slow crustal deformation.
(c.2) Summary of Results (Broader Impact Activities): The three-year investigation included the following tasks: (1) Participate in the Western North America InSAR consortium (WInSAR) to assemble the data needed for this investigation as well as to prepare for future seismic events in California. (2) Analyze InSAR data from ERS-1/2, ENVISAT, and ALOS to recover slow inter-seismic creep signals along the SAF system. The investigators refined methods for stacking ERS and ENVISAT interferograms, as well as developed new software for the analysis of L-band ALOS data. (3) Use the measurements of fault creep to improve our understanding of physical models for fault friction at shallow depth. In particular the analysis revealed the relationship between creep rate, shallow stress accumulation

rate, and major earthquake recurrence intervals. While the GMTSAR software was developed during the timeframe of this investigation, its development was largely a voluntary effort with some support from ConocoPhillips.

RESULTS OF PRIOR SUPPORT: PI KURT FEIGL (UNIVERSITY OF WISCONSIN)

(a) NSF Award Number: EAR 0810134; *Amount:* $252,456 *Period of Support:* 9/15/2008-09/13/2012

(b) Title of the project: Collaborative research: Geodetic measurements and mechanical models of rifting in onshore segments of mid-ocean ridges

(c.1) Summary of Results (Intellectual Merit): Post-doc Ali and PI Feigl have introduced more sophisticated modeling procedures into the GIPhT approach for analyzing InSAR data [Ali and Feigl, 2012]. We have applied this approach in a manuscript describing the transient deformation attributed to viscoelastic rheologic properties in the Northern Volcanic Zone of Iceland [Ali et al., in review] from which a figure follows.

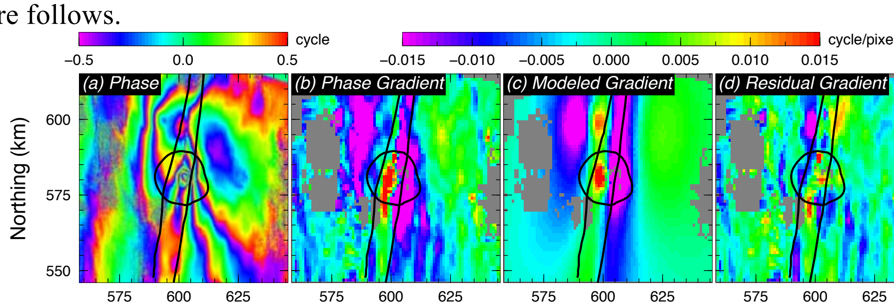

Figure 14 (a) Interferogram showing wrapped phase change values for the best ERS pair spanning the period 1993.48-1998.63. One colored fringe corresponds to one cycle of phase change, or 28 mm of range change; (b) observed values of the range gradient in 28-mm cycles per 100-m pixel such that 0.05 cycles/pixel corresponds to 1.4×10^{-4} or 140 microstrain; (c) modeled values of the range change gradient calculated from the final estimate of the parameters in the model; (d) residual range gradient values. Coordinates in km. Figure and caption [Ali et al., 2013 in review.].

(c.2) Summary of Results (Broader Impact Activities): Training post-doctoral scientist Tabrez Ali and a graduate student, Brett Carr [Carr, 2008]. This project facilitated work on the Eyjafjallajökull volcano that erupted in early 2010 leading to a poster at EGU in Vienna [Hreinsdóttir et al., 2010] and a RAPID grant awarded to PI Feigl at UW-Madison [EAR-1042103]. A special session was organized for the AGU Fall Meeting 2009 in Geodesy, Session G11: Recent advances in volcano deformation models. Conveners: T. Masterlark & A. Newman. The session included work by post-doc Ali et al. [2009].

(d) publications resulting from the NSF award:

Ali, S. T., and K. L. Feigl (2012), A new strategy for estimating geophysical parameters from InSAR data: application to the Krafla central volcano, Iceland, *G-cubed, 13*. http://dx.doi.org/10.1029/2012GC004112

Ali, T., K. Feigl, C. Thurber, T. Masterlark, B. Carr and F. Sigmundsson (2010), Geodetic measurements and models of rifting in Northern Iceland for 1993-1998 (invited), Amer. Geophys. Un.

Carr, B. C. (2008), Geodetic Measurements and Numerical Models of Rifting in Northern Iceland for 1993-1999, M.S. thesis, 42 pp, University of Wisconsin, Madison.

Dickinson, T. Masterlark, K.L. Feigl, R. Pedersen, and F. Sigmundsson (2009), Finite Element Models for the deformation of the Askja volcanic complex and rift segment, Iceland., AGU-Fall Meeting.

Ali, S.T., K.L. Feigl, B.B. Carr, T. Masterlark and F. Sigmundsson, (in review 2013), Geodetic measurements and numerical models of rifting in Northern Iceland for 1993 – 2008.

(e) research products:

Ali, S. T. (2011), Defmod - Finite element code for modeling crustal deformation http://defmod.googlecode

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Ali, S. T. (2011), Defmod - Finite element code for modeling crustal deformation. http://defmod.googlecode.com

Ali, S. T., and K. L. Feigl (2012), A new strategy for estimating geophysical parameters from InSAR data: application to the Krafla central volcano, Iceland, Geochemistry, Geophysics, Geosystems, 13. http://dx.doi.org/10.1029/2012GC004112

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DeMets, C., R. G. Gordon, and D. F. Argus (2010), Geologically current plate motions, Geophys. J. Int., 181, 1-80. http://dx.doi.org/10.1111/j.1365-246X.2009.04491.x

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Tong, X., D. Sandwell, K. Luttrell, B. Brooks, M. Bevis, M. Shimada, J. Foster, R. Smalley, H. Parra, J. C. Báez Soto, M. Blanco, E. Kendrick, J. Genrich, and D. J. Caccamise (2010), The 2010 Maule,

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XSEDE (2010), The Extreme Science and Engineering Discovery Environment https://http://www.xsede.org/

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EDUCATION:

Ph. D., Geological Sciences, Columbia University, New York, 1990
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B. S., Geology, University of Oslo, Norway, 1982

RESEARCH INTERESTS:

Plate tectonics, intraplate seamount volcanism, scientific software, data analysis

PROFESSIONAL SOCIETY MEMBERSHIPS:

Fellow: Geological Society of America [2003]
Fellow: American Geophysical Union [2012]
Member: Sigma Xi

PROFESSIONAL APPOINTMENTS:

Jul 1998 to present	Full Professor, Dept. of Geol. & Geophysics, SOEST, UH
Jul 1995 – Jun 1998	Associate Professor, Dept. of Geol. & Geophysics, SOEST, UH
Jul 1991 - Jun 1995	Assistant Professor, Dept. of Geol. & Geophysics, SOEST, UH
Dec 1989 - Jul 1991	Post-Doctoral Research Fellow, HIG, UH
Jan 1985 - Nov 1989	Graduate Research Assistant, Lamont-Doherty Earth Observatory

RECENT HONORS:

Green Scholar, IGPP, Scripps Institution of Oceanography, UCSD, 2012–1013
International Visiting Fellow, University of Sydney, Australia, Fall 2009
Visiting Professor, University of Sydney, Australia, Fall 2005, Spring 2006
Visiting Professor, University of Oslo, Norway, Fall 1998, Spring 1999
UH Board of Regents Medal for Excellence in Research, Spring1998

FIVE PRODUCTS MOST RELEVANT TO THE PROPOSAL:

1. **The Generic Mapping Tools**, Software accessible from http://gmt.soest.hawaii.edu.
2. **The Global Self-consistent High-level Hierarchical Geography**, Data set accessible from http://www.soest.hawaii.edu/pwessel/gshhg.
3. **Wessel, P.,** 2009, A general-purpose Green's function-based interpolator, *Computers & Geosciences, 35,* 1247–1254*,* http://dx.doi.org/10.1016/j.cageo.2008.08.012.
4. **Wessel, P.,** and J. Becker, 2008, Gridding of spherical data using a Green's function for splines in tension, *Geophys. J. Int.*, *174*, 21–28*,* http://dx.doi.org/10.1111/j.1365-246X.2008.03829.x.
5. **Wessel, P.,** and W.H.F. Smith, 1998, New, improved version of Generic Mapping Tools released, *Eos Trans., AGU*, *79*, 579.

FIVE OTHER PRODUCTS:

1. Sandwell, D. T., Mellors, R., Xiaopeng, T., Wei, M., and **Wessel, P**., 2011, Open radar interferometry software for mapping surface deformation, *Eos Trans. AGU, 92*, no. 28, p. 234–235.
2. **Wessel, P.,** 2010. Tools for analyzing intersecting tracks: the x2sys package, *Computers & Geosciences, 36*, 348–354, http://dx.doi.org/10.1016/j.cageo.2009.05.009.

3. Chandler, M. T., and **P. Wessel**, 2008, Improving the Quality of Marine Geophysical Trackline Data: Along-track Analysis, *J. Geophys. Res.*, *113* (B02102), http://dx.doi.org/10.1029/2007JB005051.
4. Kim, S.-S., and **P. Wessel**, 2008, Directional median filtering for regional-residual separation of bathymetry, *Geochem. Geophys. Geosyst.*, *9*(Q03005), http://dx.doi.org/10.1029/2007GC001850.
5. **Wessel, P.**, 2003, Compression of large data grids for Internet transmission, *Computers & Geosciences*, 29 (5), 665-671.

FIELD EXPERIENCE:

April 1985	R/V Robert D. Conrad Cruise RC-2603/4, Barbados Ridge
July 1986	GPS/NAVSTAR fiducial site operator, Onsala, Sweden
June 1987	M/S Liberty Star, SeaMARC I survey, Cape Hatteras
May 1988	R/V Thomas Washington cruise RNDB-II, Honolulu
August 1990	R/V Maurice Ewing cruise EW9006, SeaMARC, Norway Basin
August 1991	R/V Discoverer, Seabeam/gravity/magnetics survey, Hawaii
Nov/Dec 2001	R/V Revelle, Multibeam/Dredging, Easter-Nazca Ridge

SYNERGISTIC ACTIVITIES:

1. **Development and maintenance of GMT**. The Generic Mapping Tools is a data analysis and visualization software package that runs on all computer platforms and is presently used by tens of thousands of scientists in the US and elsewhere; its use extends far beyond my scientific specialty [gmt.soest.hawaii.edu].
2. **Podcast production**. Development and dissemination of learning materials in the form of high-resolution video podcasts presenting the views of 16 plate tectonics experts [Wessel, P., Anderson, T., Austin, R., Benediktsdottir, Á., Chandler, M. T., Conley, M. M., Kim, S.-S., Michaud, R. L., Rumpf, M. E., Sleeper, J. D., and Weiss, J. R., 2009, Seminar 2.0: Learning with Skype and video podcasts, *Eos Trans. AGU, 90*, no. 17, p. 145–147]. Get podcasts at [www.soest.hawaii.edu/pwessel/podcasts] or visit http://deimos3.apple.com/WebObjects/Core.woa/Browse/hawaii.edu.1986778238.
3. **Scientific software**. Development of data analysis and plate tectonics methodology and dissemination of their computer implementations via downloads available from my data web page [http://www.soest.hawaii.edu/pwessel].
4. **Member**, Lamont IEDA User Comm., 2011–.

NON-UH COLLABORATORS WITHIN LAST 48 MONTHS NOT LISTED ON PAPERS ABOVE:

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APPOINTMENTS:

Present Professor of Geophysics, Scripps Institution of Oceanography
1989 – 93 Scripps Institution of Oceanography, Associate Professor
1985 – 89 University of Texas at Austin, Research Scientist
1982 – 85 National Geodetic Survey, Research Geophysicist

PRODUCTS: (available at http://topex.ucsd.edu/sandwell/publications/publications.html)

Five Relevant:

Sandwell, D. T. and E. J. Price, Phase gradient approach to stacking interferograms, *J. Geophys. Res., 103*, 30183-30204, 1998.

Fialko, Y., D. Sandwell, M. Simons, and P. Rosen, Three-dimensional deformation caused by the Bam, Iran, earthquake and the origin of shallow slip deficit, *Nature, 435*, 19 May, 2005.

Tong, X., D. T. Sandwell, and Y. Fialko, Coseismic Slip Model of the 2008 Wenchuan Earthquake Derived From Joint Inversion of InSAR, GPS and Field Data, *J. Geophys. Res., 115,* B04314, doi:10.1029/2009JB006625, 2010.

Wei, M., D. Sandwell, Y. Fialko, and R. Bilham Slip on faults in the Imperial Valley triggered by the 4 April 2010 Mw 7.2 El Mayor-Cucapah earthquake revealed by InSAR *Geophys. Res. Lett., 8*, L01308, doi:10.1029/2010GL045235, 2011

Tong, X., D. T. Sandwell, and B. Smith-Konter, High-resolution interseismic velocity data along the San Andreas Fault from GPS and InSAR, *J. Geophys. Res.; Solid Earth, 118*, doi:10.1029/2012JB009442, 2013.

Five Significant:

Sandwell, D. T., Biharmonic Spline Interpolation of GEOS-3 and SEASAT Altimeter Data, *Geophys. Res. Lett., 14*, 139-142, 1987.

Smith, W. H. F. and D. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, Science, 277, p.1956-1962, 1997.

Sandwell, D. T., D. Myer, R. Mellors, M. Shimada, B. Brooks, and J. Foster, Accuracy and resolution of ALOS interferometry: Vector deformation maps of the Father's Day Intrusion at Kilauea, *IEEE Trans. Geosciences and Remote Sensing,* 46, 3524-3534, 2008.

Sandwell, D. T., and W. H. F. Smith, Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate, *J. Geophys. Res., 114*, B01411, doi:10.1029/2008JB006008, 2009.

Sandwell, D. ., R. . Mellors, X. Tong, M. Wei, and P. Wessel, Open radar interferometry software for mapping surface deformation, *Eos Trans. AGU, 92(28)*, doi:10.1029/2011EO280002, 2011.

SYNERGISTIC ACTIVITIES:

Provided global bathymetry SRTM30_PLUS currently used in Google Earth by ~100 Million people.

Teach graduate classes: *Geodynamics; Satellite Remote Sensing; Synthetic Aperture Radar.*

Developed and distribute global gravity and topography data for research and education: http://topex.ucsd.edu

Developed and distribute GNU free InSAR processing package based on GMT http://topex.ucsd.edu/gmtsar.

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a. Professional Preparation:

Yale University, Geology & Geophysics, B. S. *summa cum laude*, 1985

Massachusetts Institute of Technology, Geophysics, Ph.D., 1991

Institut de Physique du Globe de Paris, post-doctoral fellow (tectonic geodesy), 1991–1992

Université P. Sabatier, Toulouse, France, *Habilitation à diriger les recherches*, 2001

b. Appointments

2010 –	Professor, Department of Geoscience, University of Wisconsin-Madison
2006 – 2010	Associate Professor, Department of Geology and Geophysics, University of Wisconsin-Madison
1992 – 2006	Research Scientist, Centre Nationale de Recherche Scientifique (CNRS), Toulouse, France
1991 – 1992	Research Associate, Institut de Physique du Globe de Paris, France
1986 – 1991	Graduate Student, Earth, Atmospheric and Planetary Sciences, MIT
1985 – 1986	Research Technician aboard *Research Vessel R. D. Conrad* Lamont-Doherty Geological Observatory, Columbia University

c.i Products: Five Related Publications

Feigl, K. L., J. Gasperi, F. Sigmundsson, and A. Rigo (2000), Crustal deformation near Hengill volcano, Iceland 1993-1998: coupling between volcanism and faulting inferred from elastic modeling of satellite radar interferograms, *J. Geophys. Res, 105*, 26,555-525,670. http://www.agu.org/journals/jb/jb0011/2000JB900209/pdf/2000JB900209.pdf

Dubois, L., K. L. Feigl, D. Komatitsch, T. Àrnadòttir, and F. Sigmundsson (2008), Three-dimensional mechanical models for the June 2000 earthquake sequence in the South Icelandic Seismic Zone, *Tectonophysics, 457*, 12-29. http://dx.doi.org/10.1016/j.tecto.2008.05.020

Feigl, K. L., and C. H. Thurber (2009), A method for modelling radar interferograms without phase unwrapping: application to the M 5 Fawnskin, California earthquake of 1992 December 4, *Geophysical Journal International, 176*, 491-504. http://dx.doi.org/10.1111/j.1365-246X.2008.03881.x

Masterlark, T., K. L. Feigl, M. Haney, J. Stone, C. Thurber, and E. Ronchin (2012), Nonlinear estimation of geometric parameters in FEMs of volcano deformation: Integrating tomography models and geodetic data for Okmok volcano, Alaska, *J. Geophys. Res. 117*, B02407. http://dx.doi.org/10.1029/2011JB008811

Ali, S. T., and K. L. Feigl (2012), A new strategy for estimating geophysical parameters from InSAR data: application to the Krafla central volcano, Iceland, *G-cubed*, http://dx.doi.org/10.1029/2012GC004112

c.ii Products: Five Other Significant Publications

Massonnet, D., and K. L. Feigl (1998), Radar interferometry and its application to changes in the Earth's surface, *Rev. Geophys*., 36, 441-500. http://dx.doi.org/doi:10.1029/97RG03139

Arnadottir, T., S. Jonsson, F. Pollitz, W. Jiang, K. L. Feigl, E. Sturkell, and H. Geirsson (2005), Post-seismic deformation following the June 2000 earthquake sequence in the south Icelandic seismic zone, *J. Geophys. Res, 110*. http://www.agu.org/journals/jb/jb0512/2005JB003701/2005JB003701.pdf

Feigl, K. L., Measurement of coseismic deformation by satellite geodesy, in *Int. Handbook of Earthquake and Engineering Seismology*, edited by W. H. K. Lee, H. Kanamoori, and P. C. Jennings, Academic, 2001.

Feigl, K. L., and W. Thatcher (2005), Geodetic observations of post-seismic transients in the context of the earthquake deformation cycle, *Comptes Rendus - Geoscience*, 338, 1012 - 1028, 2006. http://dx.doi.org/10.1016/j.crte.2006.06.006

Sigmundsson, F., S. Hreinsdóttir, A. Hooper, T. Árnadóttir, R. Pedersen, M. J. Roberts, N. Óskarsson, A. Auriac, J. Decriem, P. Einarsson, H. Geirsson, M. Hensch, B. G. Ófeigsson, E. Sturkell, H. Sveinbjörnsson, and K. L. Feigl (2010), Intrusion triggering of the 2010 Eyjafjallajökull explosive eruption, *Nature 468,* 426-430. http://dx.doi.org/10.1038/nature09558 10.1038/nature09558 *d. Synergistic Activities*

First prize, Geophysical Images Contest, AGU 1994 (with Massonnet et al.).
Best Paper Award for the paper judged outstanding in Computers and Geosciences, IAMG, 1999.
Geo-EARTHSCOPE InSAR working group, 2006-2008.
UNAVCO Facility Advisory Committee, 2008-2010.
Member, SAR Mission Science Definition Team, NASA, 2012–2015.

e.i Collaborators and co-editors (2009 – 2013)

Ackerman, Steven A. (U. Wisconsin-Madison); Akarvardar, Samuray (CNRS Toulouse); Ali, Syed Tabrez (U. Wisconsin); Amaral, P. (Azores gov't); Árnadóttir, Thóra (U. Iceland); Aswasereelert, Wassinee (U. Wisconsin-Madison); Auriac, Amandine (U. Iceland); Ben-Sari, Driss (Rabat-Morocco); Bennington, Ninfa (U. Wisconsin-Madison); Berthier, Etienne (CNRS Toulouse); Brandtsdottir, Bryndis (U. Iceland); Briole, Pierre (IPG Paris); Brodsky, Emily (U. C. Santa Cruz); Calais, E. (ENS Paris); Carr, Brett B (U. Wisconsin-Madison); Carroll, Allan R (U. Wisconsin-Madison); Decriem, Judicael (U. Iceland); DeMets, Chuck (U. Wisconsin-Madison); Dickinson, Haylee (Purdue); Dorbath, Louis (Strasbourg-France); Einarsson, Pall (U. Iceland); Ergintav, Semih (TUBITAK-Turkey); Fabien, Albino (U. Iceland); Fadil, Abdelali (School of Mines-Rabat-Morocco); Fournier, Tom (Cornell U.); Gaspar, Joao (CVUA -Azores); Geirsson, Halldor (IMO Reykjavik); Gomez, Francisco (U. Missouri); Graham, Shannon (U. Wisconsin-Madison); Gudmundsson, Magnus Tumi (U. Iceland); Gudmundsson, Olfafur (Onsala); Haney, Matt (USGS Fairbanks); Hensch, Martin (U. Iceland); Hitchman, Matthew (U. Wisconsin-Madison); Hjaltadottir, Sigurlaug (U. Iceland); Holmjarn, Josef (U. Iceland); Hooper, Andrew J (Delft); Houlie, Nicholas (UC-Berkeley); Hreinsdottir, Sigrun (U. Iceland); Hughes, Kristin (U. of Alabama); Ingvarsson, Thorgils (U. Iceland); Jónsson, Sigrujon (KAUST); Lu, Zhong (USGS Vancouver); Masterlark, Timothy (S. Dakota Sch. Mines & Tech.); Mastin, Larry (USGS Portland); McClusky, Simon (MIT); Meyers, Stephen R. (U. Wisconsin-Madison); Mourabit, Taufik (U. Tangiers-Morocco); Mukhopadhyay, Anosua (TheSixSigmaWay); Murray-Moraleda, Jessica (USGS); Ofeigsson, Benedikt G. (U. Iceland); Ohlendorf, Summer (U. Wisconsin-Madison); Olin, Paul (Boise State U.); Óskarsson, Níels (U. Iceland); Pedersen, Rikke (U. Iceland); Pesicek, Jeremy (U. Wisconsin-Madison); Peters, Shanan E. (U. Wisconsin-Madison); Pinel, Virginie (U. Chambery-France); Rigo, Alexis (CNRS Toulouse); Roberts, Matthew J. (IMO Reykjavik); Rodrigues, R. (CVUA -Azores); Serroukh, Mostafa (Tetouan-Morocco); Sigmundsson, Freysteinn (U. Iceland); Singer, Bradley S. (U. Wisconsin); Smith, Mike E. (Sonoma State U.); Steinthórsson, Sveinbjörn (U. Iceland); Sturkell, Erik C (U. Gothenburg); Sveinbjoernsson, Hjoerleifur (U. Iceland); Tahayt, Abdelilah (Tetouan-Morocco); Thurber, Clifford H. (U. Wisconsin-Madison); Tobin, Harold (U. Wisconsin-Madison); Trota, Antonio (CVUA -Azores); Vogfjord, Kristin S (IMO Reykjavik); Wang, Herbert (U. Wisconsin-Madison);

e.ii Advisors

Thesis: Thomas H. Jordan (USC), Robert W. King (MIT), Thomas A. Herring (MIT)
Postdoctoral: Jean-Claude Ruegg (IPG Paris)

e.iii Doctoral Thesis Students Advised and Post-Doctoral Scientists Sponsored

Gilbert Ferhat (Ph.D. 1997 *Université Paul Sabatier* in Toulouse),
Duong Chi Cong (Ph. D., 2000, University of Hanoi, Vietnam),
Jêrome Gasperi (Ph.D., 1999, *Université Paul Sabatier* in Toulouse),
Loic Dubois (Ph.D. 2006, *Université Paul Sabatier* in Toulouse),
Samuray Akarvardar (Ph.D. 2008 at both *U. Paul Sabatier* in Toulouse & Istanbul Technical in Turkey),
Abdelilah Tahayt (Ph.D. 2008 at both *U. Paul Sabatier* in Toulouse & Abdelmalek Essaadi U. in Morocco).
Total Ph. D. students advised: 6

Andreas Kohlhase (post-doc 1999 – 2002, Toulouse),
Benoît Legresy (post-doc, 2000, CNRS, Toulouse),
S. Tabrez Ali (post-doc, Oct. 2009 – present, Madison
Total post-docs sponsored: 3

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
University of Hawaii

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Paul Wessel

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Paul Wessel - Professor	1.00	0.00	0.00	13,937	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	13,937	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (1) UNDERGRADUATE STUDENTS				5,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				18,937	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,185	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				25,122	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,250	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				400	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,650	
H. TOTAL DIRECT COSTS (A THROUGH G)				29,272	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 41.0000, Base: 28872)					
TOTAL INDIRECT COSTS (F&A)				11,838	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				41,110	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				41,110	

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

PI/PD NAME
Paul Wessel

ORG. REP. NAME*
Naomi Chow

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

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION
University of Hawaii

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Paul Wessel

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Paul Wessel - Professor**	1.00	0.00	0.00	**14,355**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	**14,355**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**1**) UNDERGRADUATE STUDENTS				**5,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**19,355**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**6,369**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**25,724**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**4,800**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**250**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**400**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**650**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**31,174**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 41.5000, Base: 30774)**					
TOTAL INDIRECT COSTS (F&A)				**12,771**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**43,945**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**43,945**	

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

PI/PD NAME
Paul Wessel

ORG. REP. NAME*
Naomi Chow

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

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION	FOR NSF USE ONLY		
University of Hawaii	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Paul Wessel	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Paul Wessel - Professor	1.00	0.00	0.00	14,786	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	14,786	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (1) UNDERGRADUATE STUDENTS				5,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				19,786	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,560	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				26,346	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,500	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				250	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				400	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				650	
H. TOTAL DIRECT COSTS (A THROUGH G)				29,496	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 41.5000, Base: 29096)					
TOTAL INDIRECT COSTS (F&A)				12,075	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				41,571	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				41,571	

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

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

1347184

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Hawaii**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Paul Wessel**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Paul Wessel - Professor**	3.00	0.00	0.00	**43,078**	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.00	0.00	0.00	**43,078**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**3**) UNDERGRADUATE STUDENTS				**15,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**58,078**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,114**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**77,192**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**9,800**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**1,750**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**1,200**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**2,950**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**89,942**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**36,684**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**126,626**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**126,626**	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Paul Wessel**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Naomi Chow**	Date Checked	Date Of Rate Sheet	Initials - ORG

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

1347184

G. Budget Justification

Senior Personnel

Paul Wessel is a marine geophysicist who specializes in plate tectonics, mapping intraplate volcanism with altimetry, and developing scientific software. He is the key developer responsible for most of GMT, the Generic Mapping Tools, having initiated the GMT juggernaut back in 1987. Wessel is also the day-to-day GMT manager. He will supervise the Python API software development (to be coded by Wessel, the rest of the GMT core team, and expert volunteers), strengthen GMT's time series modeling, add ternary diagram plotting, and kick-start designs of macros for geologic symbols. He will also assist co-PIs Sandwell and Feigl in developing GMTSAR into a new GMT5 supplement. PI Sandwell will supervise the post-doc and work with Feigl and Wessel on making required changes to GMTSAR, and the post-doc will help convert existing assembly of C-shell scripts to Python scripts. Feigl will take the lead in revising the meca-velo supplement, with assistance from Wessel, and lead the Open Science Grid script development. As lead PI, Wessel requests 1-month salary support per year for the three-year collaborative project. Cost of living and merit increases have been projected at 3% per annum.

Other Personnel

We request funds to involve an undergraduate student with background in computer science in website design and maintenance, routine coding, module validation and documentation.

Fringe Benefits

Fringe benefits have been listed at the current University of Hawaii proposed rate for each salaried employee (i.e., PI Wessel and undergraduate student).

Equipment

None.

Travel

Travel funds are requested for two separate destinations: (a) Annual 5-day trips to UCSD, La Jolla, CA for Wessel to meet with co-PIs Sandwell and Feigl and the post-doc to discuss the status of the project, resolve issues, coordinate software releases, documentation, and publications, and (b) one trip to San Francisco to present results at the AGU Fall Meeting in Year 2 of the project.

Other Direct Costs

Nominal funds are requested for access fees for the UH/SOEST computer network, and miscellaneous expenses, including a Year 1 hard drive replacements for the GMT server.

Indirect costs

Indirect costs are calculated in accordance with University of Hawaii federally negotiated DHHS Rate Agreement dated 04/03/2013. Rates are budgeted at 41.0% of MTDC in Year 1 and will increase to 41.5% in Years 2 & 3.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
University of California-San Diego Scripps Inst of Oceanography

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Sandwell

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	**13,500**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**1**) OTHER				**3,737**	
TOTAL SALARIES AND WAGES (A + B)				**17,237**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**0**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**17,237**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**1,745**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**780**	
5. SUBAWARDS				**0**	
6. OTHER				**600**	
TOTAL OTHER DIRECT COSTS				**1,880**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**20,862**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 55.0000, Base: 20862)**					
TOTAL INDIRECT COSTS (F&A)				**11,474**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**32,336**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**32,336**	

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

PI/PD NAME
David Sandwell

ORG. REP. NAME*
Ann Dunbar

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

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

1347204

SUMMARY PROPOSAL BUDGET

YEAR 2

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

ORGANIZATION

University of California-San Diego Scripps Inst of Oceanography

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR

David Sandwell

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	14,175	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				3,924	
TOTAL SALARIES AND WAGES (A + B)				18,099	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				18,099	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,745	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				780	
5. SUBAWARDS				0	
6. OTHER				600	
TOTAL OTHER DIRECT COSTS				1,880	
H. TOTAL DIRECT COSTS (A THROUGH G)				21,724	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 55.0000, Base: 21724)					
TOTAL INDIRECT COSTS (F&A)				11,948	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				33,672	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				33,672	

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

PI/PD NAME	FOR NSF USE ONLY		
David Sandwell	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG
Ann Dunbar			

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

1347204

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
University of California-San Diego Scripps Inst of Oceanography

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Sandwell

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL SCHOLARS	3.00	0.00	0.00	14,883	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				4,120	
TOTAL SALARIES AND WAGES (A + B)				19,003	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				19,003	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,745	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				780	
5. SUBAWARDS				0	
6. OTHER				600	
TOTAL OTHER DIRECT COSTS				1,880	
H. TOTAL DIRECT COSTS (A THROUGH G)				22,628	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 55.0000, Base: 22628)					
TOTAL INDIRECT COSTS (F&A)				12,445	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				35,073	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				35,073	

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

PI/PD NAME
David Sandwell

ORG. REP. NAME*
Ann Dunbar

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

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

1347204

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
University of California-San Diego Scripps Inst of Oceanography

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
David Sandwell

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1.	0.00	0.00	0.00		
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (0) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (3) POST DOCTORAL SCHOLARS	9.00	0.00	0.00	42,558	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (3) OTHER				11,781	
TOTAL SALARIES AND WAGES (A + B)				54,339	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				54,339	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				5,235	
2. FOREIGN				0	

F. PARTICIPANT SUPPORT COSTS

1. STIPENDS $	0
2. TRAVEL	0
3. SUBSISTENCE	0
4. OTHER	0

TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS	0	
G. OTHER DIRECT COSTS		
1. MATERIALS AND SUPPLIES	1,500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION	0	
3. CONSULTANT SERVICES	0	
4. COMPUTER SERVICES	2,340	
5. SUBAWARDS	0	
6. OTHER	1,800	
TOTAL OTHER DIRECT COSTS	5,640	
H. TOTAL DIRECT COSTS (A THROUGH G)	65,214	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)		
TOTAL INDIRECT COSTS (F&A)	35,867	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)	101,081	
K. RESIDUAL FUNDS	0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)	101,081	

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

PI/PD NAME
David Sandwell

ORG. REP. NAME*
Ann Dunbar

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

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

G. Budget Justification - SIO

Personnel

We request 3 months of salary support per year for Postdoctoral Scholar, Xiaopeng Tong. Dr. Tong is one of the original co-authors of GMTSAR. He will work with Sandwell and other GMTSAR authors to develop the pre-processors for Sentinel-1 and ALOS-2. In addition Dr. Tong will work with PI's Feigl and Sandwell to convert existing assembly of C-shell scripts to Python.

Salary support is also requested for a Research Project Assistant (0.5 mo./yr) for tasks that will specifically benefit this project, will be assigned by the Principal Investigator, charged on a time reported basis, and will not exceed the percent of effort requested. These tasks normally include researching and procuring project materials, making travel arrangements and coordination of efforts between project participants.

Salary recharge rates are calculated for actual productive time only (except for non-faculty sick leave, which is charged as direct). The rates include components for employee benefits, provisions for applicable merit increases and range adjustments in accordance with University policy.

Travel

Travel funds are requested for one person to attend Fall AGU in San Francisco each year.

Other Direct Costs

Materials and Supplies – Funds are requested to purchase backup media and computer software.

Computer Services - We request funds each year for computer and networking services, which are for expenses that specifically benefit this project and are reasonable and necessary for performance of this project.

Communication Charges - Project specific costs that include telephone tolls, voice and data communication charges, photocopying, faxing, postage are also requested. UCSD applies a direct charge equivalent exclusion calculating the D.A. indirect costs, as required in the draft interpretations of A-21 section F.6.b.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of Wisconsin-Madison**			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kurt Feigl**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kurt Feigl - Professor**	0.00	0.00	1.00	9,836	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	9,836	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (**0**) GRADUATE STUDENTS				0	
4. (**0**) UNDERGRADUATE STUDENTS				0	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (**1**) OTHER				5,833	
TOTAL SALARIES AND WAGES (A + B)				15,669	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,405	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				21,074	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **Computational server for ACI** $ 10,000					
TOTAL EQUIPMENT				10,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				34,074	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **University of Wisconsin MTDC (Rate: 50.5000, Base: 24074)**					
TOTAL INDIRECT COSTS (F&A)				12,157	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				46,231	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				46,231	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Kurt Feigl**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Tisha Kawahara**	Date Checked	Date Of Rate Sheet	Initials - ORG

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

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **University of Wisconsin-Madison**		FOR NSF USE ONLY			
		PROPOSAL NO.	DURATION (months)		
			Proposed	Granted	
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kurt Feigl**		AWARD NO.			

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kurt Feigl - Professor**	0.00	0.00	1.00	10,229	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	10,229	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				6,066	
TOTAL SALARIES AND WAGES (A + B)				16,295	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,784	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				22,079	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 0					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				2,500	
H. TOTAL DIRECT COSTS (A THROUGH G)				26,579	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **University of Wisconsin MTDC (Rate: 50.5000, Base: 26579)**					
TOTAL INDIRECT COSTS (F&A)				13,422	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				40,001	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				40,001	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Kurt Feigl**	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Tisha Kawahara**	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 3

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

ORGANIZATION
University of Wisconsin-Madison

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kurt Feigl

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kurt Feigl - Professor	0.00	0.00	1.00	10,638	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	10,638	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (1) OTHER				6,309	
TOTAL SALARIES AND WAGES (A + B)				16,947	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,186	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				23,133	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 0					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				2,500	
H. TOTAL DIRECT COSTS (A THROUGH G)				27,633	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) University of Wisconsin MTDC (Rate: 50.5000, Base: 27633)					
TOTAL INDIRECT COSTS (F&A)				13,955	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				41,588	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				41,588	

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

PI/PD NAME
Kurt Feigl

ORG. REP. NAME*
Tisha Kawahara

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

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

1347190

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION
University of Wisconsin-Madison

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Kurt Feigl

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Kurt Feigl - Professor	0.00	0.00	3.00	30,703	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	3.00	30,703	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (3) OTHER				18,208	
TOTAL SALARIES AND WAGES (A + B)				48,911	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				17,375	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				66,286	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 10,000					
TOTAL EQUIPMENT				10,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,000	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				4,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				6,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				88,286	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				39,534	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				127,820	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				127,820	

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

PI/PD NAME
Kurt Feigl

ORG. REP. NAME*
Tisha Kawahara

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

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

BUDGET JUSTIFICATION

Calendar

The proposed research activity would begin 1 January 2014 and run for 36 months.

Personnel

The team includes the PI, Professor Kurt L. Feigl and a software engineer (TBD) at the University of Wisconsin-Madison.

Equipment and Computer Services

The budget includes the purchase cost of a rack-mounted Linux computational server with the technical specifications listed below. Such a server is required in order to provide a development platform for testing in the Advanced Computing Infrastructure (ACI) at the University of Wisconsin-Madison. The ACI is the new campus-wide effort to provide shared research computing resources and services at the University of Wisconsin-Madison[1]. The ACI aggregates computing, storage, and networking infrastructure along with the technical support required to advance scholarly discoveries. The university pays for the ACI staff, the physical facility, and some computing resources, thereby augmenting researchers' contributions and providing CPU cycles for new users who are not (yet) committed to or able to purchase their own nodes. ACI partners with the Center for High Throughput Computing (CHTC) to operate and provide access to a variety of computing resources relevant to this proposal:

- CHTC provides fair share open access to a high-performance computing (HPC) cluster that will be used in this project at no cost.
- CHTC provides open access to a variety of high throughput computing (HTC) resources. These resources will be used in this project at no cost.

The workstation requested here will be added to CHTC resources and configured so that this project has priority access. In particular, it will provide priority access to a multi-core platform that supports both HPC and HTC modes of computation, within the larger shared computing environment. Software development often relies on near-interactive testing, something that the ACI resources are not configured to reliably provide for both HPC and HTC computing modes. This will allow developers supported by this work to more efficiently modify the software products for deployment on other ACI resources and the broader OSG resources. With control over the configuration of this workstation, we can identify optimal scheduling strategies for GMT and InSAR computation. These may lead to more effective use of the larger ACI resources in the future.

ACI requires the following characteristics for compatibility

- 16 cores (2x8)
- 96 GB RAM (6 GB/core)
- 18 TB Disk for short-term storage of intermediate results
- 2x300 GB Disk for Operating System

In addition, we would add more large-capacity RAID level-5 disk drives for long-term storage of InSAR data and results:

- 18 TB of RAID storage

Based on past experience at CHTC, the price of such a computational server is approximately $10,000.

Travel

To harmonize the design and implementation of the GMT software, the PIs need to meet at least once per year. Domestic travel funds are requested for PI Feigl to travel to San Diego, California for collaborative meetings with the other PIs (Wessel and Sandwell) and the post-doctoral researcher.

[1] http://aci.wisc.edu/

		Year 1	Year 2	Year 3	total
	start date	2014-01-01	2015-01-01	2016-01-01	2014-01-01
	end date	2014-12-31	2015-07-01	2016-06-30	2016-06-30
A. Senior Personnel					
PI: Kurt Feigl (1 month/yr) plus 4% per year		9,836	10,229	10,638	30,703
B. Other Personnel					
Instrumentation Specialist, 1 month per year plus 4% per year		5,833	6,066	6,309	18,208
Total Salaries:		15,669	16,295	16,947	48,911
C. Fringe Benefits					
Senior personnel: 34.5% +1%/yr		3,393	3,631	3,883	10,907
Other Professionals 34.5% +1 %/yr		2,012	2,153	2,303	6,468
Total Fringe benefits		5,405	5,784	6,186	17,375
Total Salaries and Fringe Benefits:		**21,074**	**22,079**	**23,133**	66,286
D. Permanent Equipment					
Computational server for ACI		10,000	0	0	10,000
Total Permanent Equipment:		**10,000**	**0**	**0**	10,000
E. Travel					
1. Collaborative meeting; 1 person-trip per year		2,000	2,000	2,000	6,000
Total Travel		**2,000**	**2,000**	**2,000**	6,000
G. Other Direct Costs					
1. Materials and Supplies		1,000	500	500	2,000
2. Publication costs			2,000	2,000	4,000
3. Consultant services					
4. Computer services					
5. Subawards					
6. Other					
Total Other Direct Costs		**1,000**	**2,500**	**2,500**	6,000
H. Total Direct Costs:		**34,074**	**26,579**	**27,633**	88,286
I. Total Indirect Costs					
MTDC: University of Wisconsin-Madison on-campus rate 50.5%		12,157	13,422	13,955	**39,534**
Total Indirect Costs		**12,157**	**13,422**	**13,955**	**39,534**
J. TOTAL Direct and Indirect Costs		**46,231**	**40,001**	**41,588**	**127,820**
K. Residual Funds					
L. Amount of this Request		**46,231**	**40,001**	**41,588**	**127,820**

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

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

Investigator: Paul Wessel

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Support for the Generic Mapping Tools

Source of Support: NSF/OCE/MGG
Total Award Amount: $ 253,115 Total Award Period Covered: 09/01/10 - 08/31/15
Location of Project: University of Hawaii at Manoa
Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 1.00 Sumr: 1.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Hawaiian Ridge age, source, composition and melt flux variations: Implications for plume dynamics and plate kinematics [PI: M. Garcia, co-PI: P. Wessel]

Source of Support: NSF/EAR/PET&GEO
Total Award Amount: $ 349,922 Total Award Period Covered: 09/01/12 - 08/31/14
Location of Project: University of Hawaii at Manoa
Person-Months Per Year Committed to the Project. Cal:1.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology [THIS PROPOSAL]

Source of Support: NSF/EAR/Geoinformatics
Total Award Amount: $ 126,626 Total Award Period Covered: 01/01/14 - 12/31/16
Location of Project: University of Hawaii at Manoa
Person-Months Per Year Committed to the Project. Cal:1.00 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: The Absolute Motion of the Africa Plate (with 1-year NCE)

Source of Support: NSF/OCE/MGG
Total Award Amount: $ 153,634 Total Award Period Covered: 03/01/11 - 02/28/14
Location of Project: University of Hawaii at Manoa
Person-Months Per Year Committed to the Project. Cal:1.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

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

Current and Pending Support
Investigator: David Sandwell

CURRENT

Title: Study of Postseismic Deformation Due to the 2010 M7.2 El Mayor (Mexico) Earthquake (Y. Fialko, PI)
Source of Support: NSF EAR 1053627
Total Award Amount: $418789
Total Award Period: 05/01/11-04/30/14
Location of Project: SIO
Person-Months on Project: 0

Title: Cryosat Altimetry, Arctic Gravity Enhancements, Investigation of Ice Freeboard Measurements, and InSAR Code Development
Source of Support: ConocoPhillips
Total Award Amount: $120,000
Total Award Period: 03/01/11-02/28/14
Person-Months on Project: 0

Title: A Factor of 2-4 Improvement in Marine Gravity and Predicted Bathymetry from Cryosat, Jason-1, and Envisat Radar Altimetry: Arctic and Coastal Regions
Source of Support: ONR N00014-12-1-0111
Total Award Amount: $157,071
Total Award Period: 10/01/11-09/30/14
Location of Project: SIO
Person-Months on Project: 0

Title: A Factor of 2 Improvement in Global Marine Gravity from Cryosat, Jason-1, and Envisat
Source of Support: NSF OCE 1128801
Total Award Amount: $229,188
Total Award Period: 02/15/12-01/31/16
Location of Project: SIO
Person-Months on Project: 0

Title: Collaborative Research: Strain Rate and Moment Accumulation Rate Along the San Andreas Fault from InSAR and GPS
Source of Support: NSF EAR 1147435
Total Award Amount: $220,015
Total Award Period: 06/15/12-5/31/15
Location of Project: SIO
Person-Months on Project: 0

Title: Improving the Community Geodetic Model with GPS and InSAR
Source of Support: USC/SCEC 20123827SCEC
Total Award Amount: $23,500
Total Award Period: 02/01/12-01/31/14
Location of Project: SIO
Person-Months on Project: 0

Title: Improving Coastal Marine Gravity
Source of Support: NGA HM0177-13-1-0008
Total Award Amount: $447,487
Total Award Period: 02/11/13-02/10/16
Location of Project: SIO/PSU
Person-Months on Project: 0

PENDING

Title: Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy Geodynamics and Geology
Source of Support: NSF – Geoinformatics (THIS PROPOSAL)
Total Award Amount: $101,081
Total Award Period: 01/01/14-12/31/16
Location of Project: SIO
Person-Months on Project: 0

Title: Monitoring Oil Field Deformation with L-Band InSAR and Continued Improvements in Global Marine Gravity
Source of Support: ConocoPhillips
Total Award Amount: $120,000
Total Award Period: 03/01/14-02/28/17
Location of Project: SIO
Person-Months on Project: 0

Current and Pending Support - PI Kurt Feigl

Support: Current
Project/Proposal Title: COLLABORATIVE RESEARCH: Geodetic measurements and mechanical models of the volcano deformation cycle (with C.H. Thurber as co-I)
Source of Support: NSF Geophysics
Total Award Amount: $190,660 Total Award Period Covered: 7/1/10 to 6/30/13
Location of Project: University of Wisconsin-Madison
Person-Months Per Year Committed to the Project. Cal: 0.0 Acad: 0.0 Sumr: 0.75

Support: Current
Project/Proposal Title: "Development of tools for coupled InSAR and Seismicity monitoring of EGS reservoir development and management" (with N. Davatzes as (lead) "applicant")
Source of Support: U.S. Department of Energy (DOE)
Total Award Amount: $245,989 (subcontract to UW-Madison from Temple U.)
Total Award Period Covered: 10/01/2011 to 09/30/2014
Location of Project: University of Wisconsin-Madison
Person-Months Per Year Committed to the Project. Cal: 0.0 Acad: 0.0 Sumr: 0.75

Support: Current
Project/Proposal Title: Constraining the Rheology of the Earth's Crust by Interferometric Radar measurements and Numerical Models
Source of Support: NASA Science Definition Team for the DESDynI-Radar Mission (NNH11ZDA001N-DESSDT)
Location of Project: University of Wisconsin-Madison
Total Award Amount: $74,970 Total Award Period Covered: 07 / 01 / 2011 to 06 / 30 / 2013
Person-Months Per Year Committed to the Project: Cal: 0.0 Acad: Sumr: 0.75

Support: Pending
Project/Proposal Title: FESD Type 1: Physics of induced earthquakes in geothermal systems
Source of Support: FESD
Location of Project: University of Wisconsin-Madison
Total Award Amount: approximately $4850K Total Award Period Covered: 09/01/2013 to 08/31/2018
Person-Months Per Year Committed to the Project: Cal: 0.0 Acad: 0.0 Sumr: 0.5

Support: Pending
Project/Proposal Title: FESD Type I: Dynamic processes driving super-eruptions
Source of Support: FESD
Location of Project: University of Wisconsin-Madison
Total Award Amount: approximately $ 4250K Total Award Period Covered: 09/01/2013 to 08/31/2018
Person-Months Per Year Committed to the Project: Cal: 0.0 Acad: 0.0 Sumr: 0.5

Support: Pending (this proposal)
Project/Proposal Title: Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology
Location of Project: University of Wisconsin-Madison
Source of Support: NSF Geoinformatics
Total Award Amount: approximately $ 135K to UW-Madison
Total Award Period Covered: 36 months starting 1 January 2014
Person-Months Per Year Committed to the Project: Cal: 0.0 Acad: 0.0 Sumr: 1.0

SOEST, University of Hawaii at Manoa (UHM)

Facilities, Equipment and Other Resources

Laboratory:

Paul Wessel is responsible for the POST 832 Lithosphere Geodynamics and Plate Tectonics Laboratory. It houses the GMT subversion repository server (gmtserver.soest.hawaii.edu), one aging Mac Pro (2007 model) for development, color printer, monochrome printer, and one large-format digitizer (Calcomp III). External RAID disks are used for backup and redundancy.

Classrooms:

SOEST has its own educational classrooms, including a computer lab with 20 workstations. Wessel teaches a graduate class called GG675 The Generic Mapping Tools on alternate years.

Computer Resources:

Current development takes place on a Mac Pro (2009 model), 16 Gb RAM, 8 cores, for day-to-day development and testing activities, MacBook Air 11" laptop for travel, lectures, workshops, etc. SOEST has generously agreed to update the Mac Pro to a new model this fall, in recognition of the broad use of GMT within the school itself.

Office: POST 806, a 400 sq.ft office with standard communication (phone, Skype, email) and adequate desk space.

Other:

SOEST maintains its own Research Computing Facility for rapid and dedicated assistance to SOEST faculty of any computer-related issue. Basic assistance is provided via the SOEST network fee; additional service can be contracted as needed.

SIO Facilities, Equipment, and Other Resources

Software and Data – As described in the proposal we have developed a full InSAR processing system called GMTSAR (http://topex.ucsd.edu/gmtsar). As developers of the system, we have an intimate knowledge of the inner workings of the software and can develop custom procedures for large-scale processing. SIO, UH, UWM are members of the WInSAR consortium so we have access to all the ERS, Envisat, and ALOS-1 data for western North America.

General Computing Equipment – The Sandwell Lab at SIO maintains state-of-the-art workstations and disk facilities for processing all types of satellite radar data including satellite altimetry and InSAR. We have access to a 30-terabyte mass storage system for backup and archival of results.

ALOS 1 and 2 coverage of the San Andreas Fault System - Sandwell was the PI on the original WInSAR ALOS-1 proposal and has been continually requesting SAR acquisitions along both ascending and descending passes along the San Andreas Fault System. In addition, we have installed and maintain three radar corner reflectors at the Pinon Flat Observatory (PFO). JAXA plans to use these corner reflectors for calibration of ALOS-2 and we have an accepted investigation for ALOS-2 data acquisitions over the entire SAFS. Since ALOS-2 has only a SAR instrument and no optical cameras as were on ALOS-1, we will request imagery along both ascending and descending passes on a 14-day repeat interval. Over the nominal 5-year lifetime of the spacecraft, this could result in 130 repeats from each look direction – nearly an order of magnitude more data than provided by ALOS-1. While part of this effort is beyond the proposed funding period, it is important to help develop the ALOS-2 plan at least one year prior to the launch of ALOS-2 in late 2013.

FACILITIES, EQUIPMENT, AND OTHER RESOURCES: THE UNIVERSITY OF WISCONSIN-MADISON

The Department of Geoscience has an established graduate program in Geophysics.

PI Feigl's research group at UW-Madison operates a computer network of 2 Linux quad-core servers with 8 Tbytes of RAID 5 disk storage, 2 iMac workstations, and 1 Dell desktop computer that have adequate computational power for the proposed project. In addition, the group has access to laser printers (color and B&W) and a 36" wide printer-plotter.

For intensive computations, the group has requested resources from the following organizations.

The Advanced Computing Infrastructure (ACI) is the new campus-wide center for research computing resources and services at the University of Wisconsin-Madison. **"**The ACI aggregates computing, storage, and networking infrastructure along with the technical support required to advance scholarly discoveries."[1] ACI partners with the Center for High Throughput Computing (CHTC) to operate and provide access to two primary resources.[2] For High Performance Computing (HPC) applications that require communication and/or shared memory between threads, the ACI provides a shared HPC cluster with 48 nodes. The cluster employs an Infiniband backplane and shared file system. A SLURM scheduler has been implemented for managing HPC jobs. For High Throughput Computing (HTC) applications that need to run a single application many times with different parameters and/or data as completely independent jobs, the ACI provides access to more than 13,000 "slots" on 64-bit Linux machines distributed across campus. Jobs can be scheduled using HTCondor[3].

The Open Science Grid (OSG) "advances science through open distributed computing. The OSG is a multi-disciplinary partnership to federate local, regional, community and national cyber-infrastructures to meet the needs of research and academic communities at all scales. OSG is jointly funded by the Department of Energy and the National Science Foundation to: build, operate, maintain, and evolve a facility that will meet the current and future needs of large scale scientific computing; and, promote and support better utilization of local campus resources and improved access to the national cyber-infrastructure from those campuses." [4] For the high-throughput computing applications in the current proposal, PI Feigl has requested a startup allocation on the OSG of 100 KSU (thousand "service units", where 1 SU is 1 hour of time on a single-core CPU).

The **Extreme Science and Engineering Discovery Environment (XSEDE)** "is the most advanced, powerful, and robust collection of integrated advanced digital resources and services in the world. It is a single virtual system that scientists can use to interactively share computing resources, data, and expertise. The five-year, $121-million project is supported by the National Science Foundation. It replaces and expands on the NSF TeraGrid project. More than 10,000 scientists used the TeraGrid to complete thousands of research projects, at no cost to the scientists."[5]. For the high performance computing applications in the current proposal, PI Feigl has requested a one-time-only startup allocation on the San Diego Super Computer (SDSC) Appro Linux Cluster (Trestles) of 100 KSU (thousand "service units", where 1 SU is 1 hour of time on a single-core CPU) for the first year of the proposed project.

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[1] http://aci.wisc.edu

[2] http://chtc.cs.wisc.edu

[3] http://research.cs.wisc.edu/htcondor

[4] http://osg-docdb.opensciencegrid.org/0008/000839/004/OSG%20Intro%20v23.pdf

[5] https://www.xsede.org/

COLLABORATIVE RESEARCH: IMPROVING THE GENERIC MAPPING TOOLS FOR SEISMOLOGY, GEODESY, GEODYNAMICS AND GEOLOGY

Wessel, Sandwell, Feigl

Data Management Plan

This proposal will not produce data but software. All software will be coded either in POSIX C or Python scripts. Software will be stored in a subversion repository on the University of Hawaii at Manoa GMT server [gmtserver.soest.hawaii.edu] and be read-only accessible to all and read-write accessible to the PIs, the post-doctoral researcher, the core GMT team, and other trusted volunteers. While we will use subversion as our repository management tool, users may connect to it as well via git. Official releases are also available by a worldwide network of mirror sites.

Software Licensing:

Because the proposed software will be included in the GMT core or via GMT supplements, all software products will be released under the same license, i.e. the GNU Lesser Public License. We prefer the LGPL to the general GPL in order to enable a wider distribution of GMT outside of academia. Existing supplement contributors have all agreed to use the LGPL.

Software sharing:

The software deliverables from this project will be included in the official GMT releases that typically are updated a few times a year. However, the latest snapshot of development is always available to anybody directly from the GMT server via subversion.

Documentation:

The core GMT documentation has recently been converted from a mix of Unix man pages (nroff format) and PDF documentation (derived from Latex files) to ReStructured Text (RST). New documentation, ranging from man pages to web pages to PDF, are produced from the RST files via Python/sphinx and made available on the GMT server (and distributed with the official GMT releases).

Availability:

All software developed under this project will be available instantly since the subversion repository is open to the public. There is no grace period or embargo; users are informed that a product may be pre-release, in beta testing, or officially released.

Accessibility:

The GMT server presents a wiki for GMT development (currently gmtrac.soest.hawaii.edu) where GMT users may lodge bug reports and feature requests. It also gives access to the source code, discussion forums, and instructions for download and installation. Official releases will be made available from this site as well as from the traditional ftp server (ftp.soest.hawaii.edu/gmt).

Postdoctoral Mentoring Plan

Xiaopeng Tong, the named postdoc for this project, is being jointly mentored by David Sandwell, Bridget Smith-Konter (University of Texas, El Paso), and Paul Wessel. This project would provide 25% of his salary support so additional support and related mentoring will involve two other projects: i) an NSF-EarthScope study of the San Andreas Fault System and ii) an industry-funded InSAR study of the Sumatra transform fault. Sandwell provides the single point of contact for administrative matters, and will be responsible for ensuring that nothing is neglected as a consequence of the divided responsibility. The diversity of mentors provides Tong a rich environment in which to work. Mentoring will primarily include training activities appropriate for a career in research. These will include: participation in proposal preparation and review; collaboration with researchers in Japan and Europe to co-develop best practices in the analysis of ALOS-2 and Sentinel-1 data; attendance at US and international meetings; and opportunities for informal and formal teaching responsibilities. Tong will meet with Sandwell weekly to discuss research progress and objectives. In addition he will be involved in quarterly teleconferences with Wessel to discuss progress on GMTSAR and monthly teleconferences with Smith-Konter to discuss the San Andreas Fault project. Tong also plans to visit ConocoPhillips in Houston Texas to work on the Sumatran Transform Project. Research expectations will clearly communicated at beginning of the postdoctoral appointment, when mentors develop a written plan in collaboration with the appointee. In accordance with Scripps' policy, the postdoc's progress is evaluated on an annual basis. This assessment includes a frank face-to-face discussion of what has been accomplished, versus what might have been anticipated. Postdocs are encouraged to provide commentary during this assessment and usually contribute to the planning for the next phase of their work while keeping in mind their broader career goals.

Robert Mellors
L-046, LLNL
7000 East Avenue
Livermore CA, 94550
mellors1@llnl.gov
June 25, 2013

Dear David, Paul, and Kurt,

Thank you for sending us a copy of your proposal to the National Science Foundation on "*Collaborative Research: Improving the Generic Mapping Tools for Seismology, Geodesy, Geodynamics and Geology*". Here, we are engaged in several related studies (both in imaging geodesy and in large-scale computational data analysis) and I write to support your proposal wholeheartedly.

In particular, I will be happy to assist, as I can (within the constraints of Laboratory regulations and any binding agreements) on extending GMT to include more data types, test the use of other languages such as Python and build pre-processors for new upcoming satellites (e.g. Sentinel-1 and ALOS-2). We note that we cannot provide any funding or access to Laboratory resources.

Adding this capability to GMT, which is an already proven and highly useful package, will be extremely valuable in aiding the widespread use of space imaging. Imaging geodesy possesses multiple uses in areas such as monitoring subsurface deformation due to geothermal energy extraction and in monitoring earthquake sources. Linking this technique to modern computational techniques in handling large datasets is an essential next step. Providing wide access to these techniques is also critical for training the next generation of geoscientists. I wish you the best of luck in your proposal and look forward to continuing what has been a fruitful and agreeable collaboration.

Thank you,

Rob Mellors

Deputy Group Leader, Seismology
Associate Program Lead, Geothermal
Lawrence Livermore National Laboratory