

**02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and
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PI/PD Name: Robert E Reilinger

Gender: ☒ Male ☐ Female

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

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☐ None

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

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

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

Ethnicity Definition:

Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

Race Definitions:

American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.

Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

Black or African American. A person having origins in any of the black racial groups of Africa.

Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information received from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

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

SUGGESTED REVIEWERS:

Not Listed

REVIEWERS NOT TO INCLUDE:

Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29					FOR NSF USE ONLY	
NSF 09-542		07/06/09			NSF PROPOSAL NUMBER	
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)						
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				001425594		
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)		
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Massachusetts Institute of Technology			Massachusetts Institute of Technology			
AWARDEE ORGANIZATION CODE (IF KNOWN)			77 Massachusetts Avenue			
0021782000			Cambridge, MA. 021394307			
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE			ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE			
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IS Awardee ORGANIZATION (Check All That Apply) ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE						
☐ (See GPG II.C For Definitions) ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS						
TITLE OF PROPOSED PROJECT Postseismic deformation for the Izmit-Duzce, Turkey earthquake sequence: Implications for the mechanics of the earthquake cycle and rheology of the continental lithosphere						
REQUESTED AMOUNT		PROPOSED DURATION (1-60 MONTHS)		REQUESTED STARTING DATE		SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
\$ 519,242		60 months		01/01/10		
CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW						
☐ BEGINNING INVESTIGATOR (GPG I.G.2) ☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____						
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e) Exemption Subsection _____ or IRB App. Date _____						
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d) ☒ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)						
☐ HISTORIC PLACES (GPG II.C.2.j) ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1) TU						
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1) ☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)						
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____						
PHS Animal Welfare Assurance Number _____						
PI/PD DEPARTMENT			PI/PD POSTAL ADDRESS			
Dept. of Earth, Atmos. & Planetary Scis.			Earth Resources Laboratory			
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CO-PI/PD						

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

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

Conflict of Interest Certification

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

Drug Free Work Place Certification

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

Debarment and Suspension Certification

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

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes ☐

No ☒

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

Certification Regarding Lobbying

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

Certification for Contracts, Grants, Loans and Cooperative Agreements

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

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

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

Certification Regarding Nondiscrimination

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

Certification Regarding Flood Hazard Insurance

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

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

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

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

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE		SIGNATURE	DATE
NAME			
TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS		FAX NUMBER

* EAGER - EARly-concept Grants for Exploratory Research

** RAPID - Grants for Rapid Response Research

Summary

The Izmit-Duzce earthquake sequence (M=7.4, 17/08/1999; M=7.2, 12/11/1999) offers a unique opportunity to answer long-standing, fundamental questions about the nature of the earthquake cycle (mechanics of strain accumulation and release), and the rheology of the crust and upper mantle. The geodetic data set we are compiling for these earthquakes includes both a well-determined pre-earthquake velocity field around the earthquake fault, and a network of GPS stations within the coseismic deformation zone (near and far field) that captured the initial rapid, and ongoing, longer-term postseismic deformation. This is one of the most complete geodetic records of deformation for any major continental earthquake anywhere in the world. Interpretation of the geodetic record is facilitated by detailed seismic observations before, during, and following the earthquake sequence, field mapping of fault offsets, satellite image (SPOT) and geodetic (InSAR) studies, and geologic studies of the 20th Century sequence of earthquakes that propagated along the North Anatolian Fault (NAF) from E to W fracturing almost the full 1200 km length of the fault (excluding the Marmara segment). Furthermore, the NAF has a long and well recorded historical seismic record extending back almost 2000 years that, along with the well-constrained paleoseismic record and recent geodetic observations, provides an extensive data set for testing time- and slip- predictable earthquake models of continental faulting. Using this rich data set, and observations made over the next decade, we should be able to answer some fundamental questions about how, in 4 dimensions, tectonic strain is accumulated and released in the continental lithosphere, and thus infer both rheological and fault properties associated with continental deformation.

We propose to continue to precisely monitor deformation following the Izmit-Duzce earthquake sequence in collaboration with our Turkish partners, and to extend our modeling effort to produce a quantitative description of the dynamics of the NAF system seismic cycle. The proposed research builds on our prior efforts undertaken in collaboration with our Turkish partners (Ergintav et al., 2009; Hearn et al., 2009) that included analysis of 6.5 years of postseismic GPS observations (both continuous [CGPS] and survey [SGPS]) to characterize the temporal and spatial behavior of postseismic motions, and dynamic modeling for the initial 2.5 year period following the earthquake sequence. These studies demonstrate the importance of rapid postseismic afterslip, and the need to incorporate viscoelastic relaxation with non-linear, lower crust and upper mantle rheologies to account for the pattern of pre-earthquake strain accumulation and the 4-D character of postseismic deformation. In addition, the GPS observations indicate postseismic extensional strain normal to the earthquake fault that is incompatible with any of the postseismic models investigated and may be related to regional tectonic stress and changes in fault or lower crustal rheology induced by the earthquakes.

Specific initiatives we propose include: 1) extend our prior studies to include data that are now available for the past 4 years, 2) maintain the CGPS network and undertake annual surveys of the postseismic survey network, 3) incorporate in our analysis and dynamic modeling studies, new GPS, gravity, INSAR, and geologic data (long-term fault slip rates and pre-historic earthquake record), and 4) undertake quantitative modeling to constrain lithospheric rheology and fault mechanics. Each of these initiatives will be highly leveraged by the substantial investment by our Turkish partners to continue GPS monitoring for earthquake hazards in the greater Istanbul area, by our University of Montpellier partners who have independent support for continued dynamic modeling, and GFZ with which we propose to collaborate to install continuous GPS monitoring at seismic stations and on deep seismic array boreholes on the Princes Islands in the Marmara Sea near the NAF (GFZ PIREs project and GONAF proposal pending with ICDP).

Intellectual Merit: The proposed research will provide an important set of observations on the nature of the earthquake cycle for a major continental strike-slip fault with direct implications for earthquake mechanics, estimating earthquake repeat times, crust and upper mantle rheology as a function of the state of stress, and interaction between earthquake processes and regional tectonics.

Broader Impacts: This case study provides information on the mechanics of continental strike-slip faults in general, including the San Andreas Fault, the rheological character of the lower crust and upper mantle, earthquake and tsunami hazards in the greater Istanbul area, and opportunities for international collaboration and student research.

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Appendix (List below.) (Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	<u> </u>	<u> </u>
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.

PROJECT DESCRIPTION

1. RESULTS FROM PRIOR NSF SUPPORT

EAR-9909730; \$325,334; 3/1/00 – 2/29/2004 (1-year no-cost extension); 0337497; \$639,126; 01/15/04 – 12/31/08; “Present-day kinematics and dynamics of the eastern Mediterranean and Caucasus”. EAR-00-01095; INT-0001143; “Post-seismic Deformation for the Izmit—Düzce Earthquake Sequence”; \$120,920; 8/15/2000—7/31/2003; PI. R. Reilinger. These projects have provided quantitative information on continental dynamics in a complex zone of plate interaction, new constraints on the mechanics of the earthquake cycle, and on the rheology of the crust and upper mantle. Our main results for postseismic deformation following the Izmit—Duzce earthquake sequence are described in the body of this proposal and the cited references. Regional geodynamic results for our E Mediterranean studies are described in the following, selected post-2000 publications.

- Allmendinger, R.W., R. Reilinger, and J. Loveless, Strain and rotation rate from GPS in Tibet, Anatolia, and the Altiplano, *Tectonics*, 26,TC3013, doi:10.1029/2006TC002030, 2007.
- Burgmann, R., et al., Deformation during the 11/12/99 Düzce, Turkey earthquake from GPS and InSAR, *Bull. Seismol. Soc. Am.*, 92, 161-171, 2002.
- Ergintav, S., et al., Postseismic deformation near the Izmit earthquake (08/17/99, M=7.5) rupture zone, *Bull. Seismol. Soc. Am.*, 92, 194-207, 2002.
- Ergintav, S., S. McClusky, E. H. Hearn, R. E. Reilinger, R. Cakmak, T. Herring, H. Ozener, O. Lenk, and E. Tari, Seven years of postseismic deformation following the 1999, M = 7.4 and M = 7.2, Izmit-Düzce, Turkey earthquake sequence, *J. Geophys. Res.*, doi:10.1029/2008JB006021, in press, 2009.
- Feigl, K., et al., Estimating slip distribution for the Izmit main shock from coseismic GPS, SPOT, and ERS-1 measurements, *Bull. Seismol. Soc. Am.*, 92, 161-171, 2002.
- Hearn, E. H., Hager, B., and Reilinger, R., Viscoelastic deformation from North Anatolian Fault Zone earthquakes and the eastern Mediterranean GPS velocity field, *Geophys. Res. Lett.*, 29, 10.1029/2002GL014889, 2002a.
- Hearn, E. H., S. McClusky, S. Ergintav, and R. E. Reilinger, Izmit Earthquake postseismic deformation and dynamics of the North Anatolian fault zone, *J. Geophys. Res.*, doi:10.1029/2008JB006026, in press, 2009.
- Mahmoud, S., R. Reilinger, S. McClusky, P. Vernant, and A. Tealeb, GPS evidence for northward motion of the Sinai block: Implications for E. Mediterranean tectonics, *Earth and Planetary Sci. Lett.*, 238, 217-227, 2005.
- McClusky et al., GPS constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus, *J. Geophys. Res.*, 105, 5695-5719, 2000.
- McClusky, S., R. Reilinger, S. Mahmoud, D. Ben Sari, and A. Tealeb, GPS constraints on Africa (Nubia) and Arabia plate motion, *Geophys. J. Int.*, 155, 126-138, 2003.
- Meade, B.J., et al., Estimates of seismic potential in the Marmara region from block models of secular deformation constrained by GPS measurements, *Bull. Seismol. Soc. Am.*, 92, 208-215, 2002.
- Reilinger, R.E., S. Ergintav, R. Burgmann, et al., Coseismic and postseismic fault slip for the 17 August, M=7.5, Izmit, Turkey Earthquake, *Science*, 289, 1519-1524, 2000.
- Reilinger, R., S. McClusky, P. Vernant, and 20 others, GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions, *J. Geophys. Res.*, B05411, doi:10.1029/2005JB004051, 2006.
- Reilinger, R.E., S. McClusky, D. Paradissis, S. Ergintav, and P. Vernant, Geodetic constraints on the tectonic evolution of the Aegean region, *Tectonophysics*, doi:10.1016/j.tecto.2009.05.027, in press, 2009.
- Vernant, P., and J. Chéry, Mechanical modeling of oblique convergence in the Zagros, Iran, *Geophys. J. Int.*, 165, 991-1002, 2006.

2. OBJECTIVES AND JUSTIFICATION

The overarching objective of this proposed research is to understand the mechanics of continental deformation. This involves determining how strain (and stress) is accumulated in the lithosphere (crust and upper mantle) as a function of space and time, and similarly how accumulated strain (and stress) is released during and following earthquakes. This and the related questions of the forces driving/resisting plate motions, and the rheology of the continental lithosphere are the main objectives of all of our research efforts (see Current and Pending Support). While these are “lofty goals”, we believe they are achievable and that the unique data presently available, and here proposed, for the Izmit-Duzce earthquake sequence, analyzed within the context of strain accumulation and release on the NAF system in general (Figure 1, 2), and integrated with seismic, gravimetric, morphologic, and paleoseismic observations, offer an opportunity to make substantial progress on deciphering the mechanics of continental deformation.

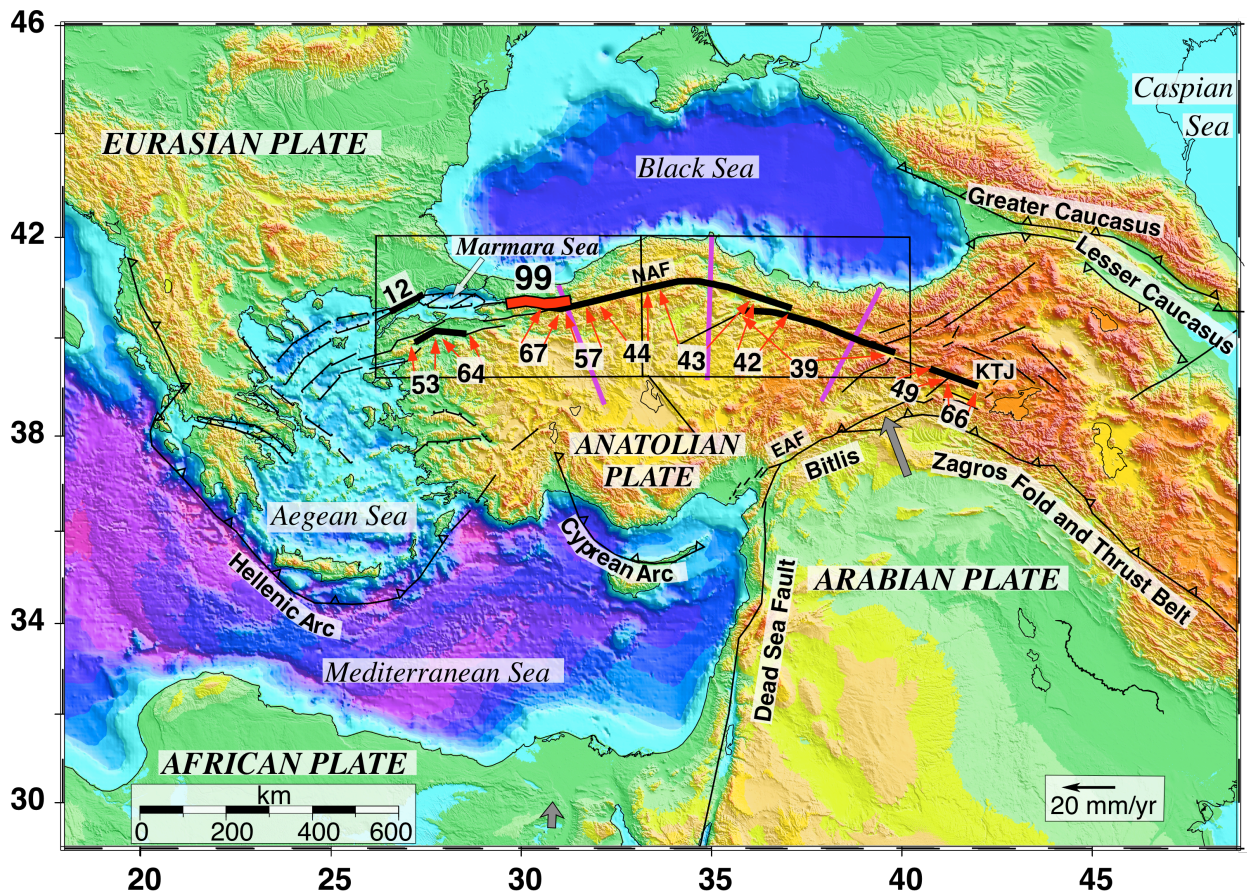


Figure 1. Schematic tectonic/topographic/bathymetric map showing the location of the 1999 earthquake rupture (red segment) within the context of 20th Century earthquake ruptures on the NAF. Numbers indicate the year the earthquakes occurred (i.e., 12 = 1912), and red arrows the extent of mapped surface breaks for each event. Pink lines show locations of trans-NAF GPS profiles (see Figure 2) that our Turkish partners and we are monitoring as part of our regional geodynamic studies (supported in part by NSF EAR-0838488 to MIT).

Specific objectives of the research proposed here include, 1) extend our geodetic analysis to include GPS data from the Izmit postseismic monitoring network now available for the past 4 years, 2) continue high quality and well documented continuous and survey-mode GPS monitoring of the Izmit-Duzce earthquake sequence postseismic deformation, 3) incorporate newly available GPS data (including 2 stations we propose to install) and other observations relevant to earthquake cycle processes (i.e., repeat gravity, InSAR, seismicity, geologic information on historic and prehistoric earthquake activity) to determine better the 4-D character of postseismic motions and their relation to long-term fault behavior, and 4) use the resulting, improved estimates of earthquake cycle deformation to investigate quantitative models for the earthquake deformation cycle.

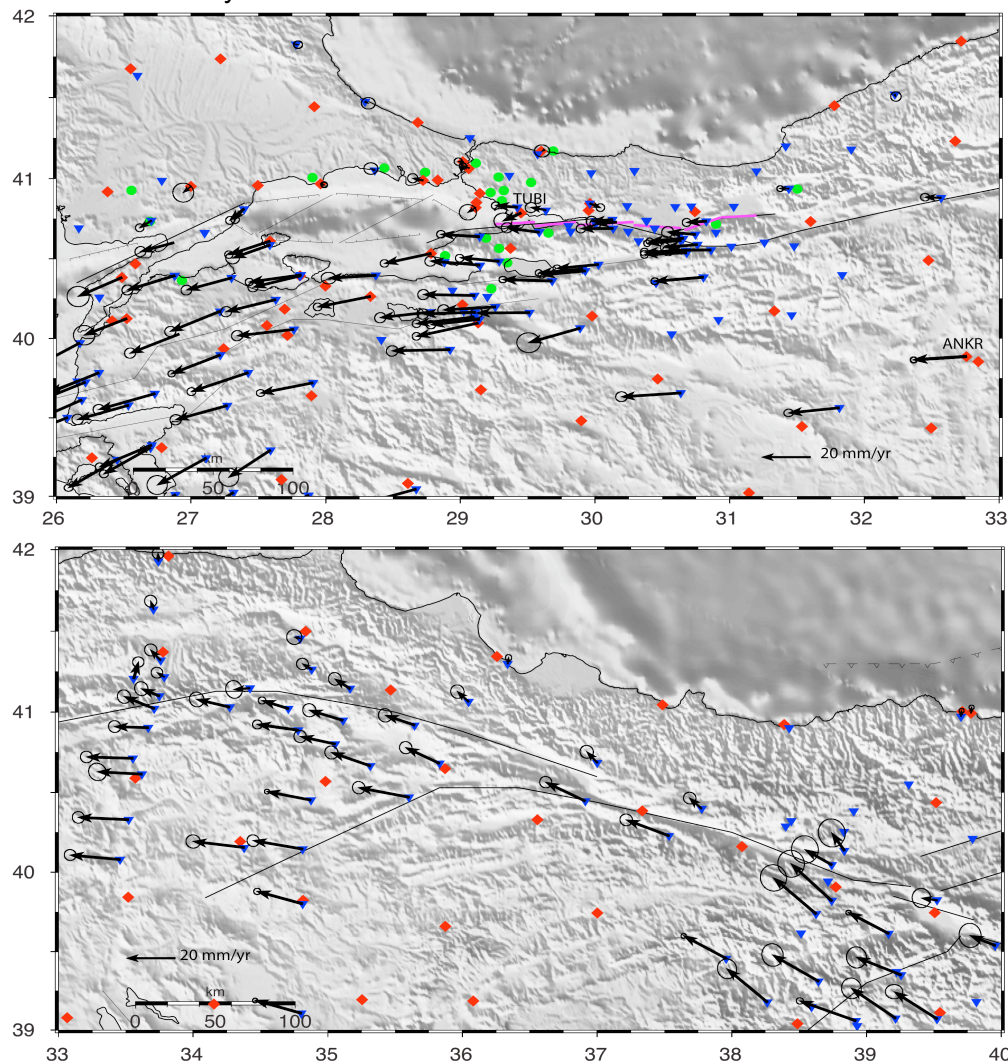


Figure 2. Observed GPS velocities along the western (top) and eastern (bottom) sections of the NAF (velocities in the top panel are from pre-1999 earthquake data only). Red diamonds are CGPS stations and blue triangles SGPS sites – symbols with no velocities remain to be incorporated in our analysis, as here proposed. Green circles indicate the location of gravity measurements. Light lines show schematic representation of the NAF and its main splays – hatched lines are normal faults in the Sea of Marmara. The location of the August 27th 1999 Izmit/Duzce earthquake rupture is shown by the purple line.

the JGR web site (<http://www.agu.org/journals/jb/papersinpress.shtml>). Here we briefly review the main results of these studies.

Figure 1 shows the location of the Izmit-Duzce earthquake sequence within the context of the 20th Century sequence of earthquakes that ruptured almost the entire NAF (excluding the seismic gap in the Marmara Sea). Figure 2 (top) shows the observed pre-earthquake, “secular” velocity field and Figure 3 the secular velocity field determined from an elastic block model (Reilinger et al., 2006) constrained by GPS during the 10-year period prior to the 1999 earthquake sequence (Ergintav et al., 2009). The pink velocities in Figure 3 are the residual velocities (observed – modeled) from the elastic block model. The velocity profile crossing the Izmit coseismic fault is consistent with elastic strain accumulation (i.e., arctangent) along the NAF with a locking depth (~20 km) that is consistent with earthquake hypocenter depths on this segment of the fault (e.g., Reilinger et al., 2006, Figure 5 of that paper). The small residual velocities in Figure 3 suggest that the pre-earthquake block model provides a reliable estimate of pre-earthquake strain accumulation (i.e., discrepancies of 1 – 2 mm/yr). This is important because our estimates of changes in site velocities following the earthquake sequence (i.e., isolating postseismic motions) rely on accurate estimates of pre-earthquake site velocities, including for locations where pre-earthquake observations are not available. Part of our proposed research involves incorporating newly available geodetic data to further constrain pre-earthquake strain accumulation (Initiative 3).

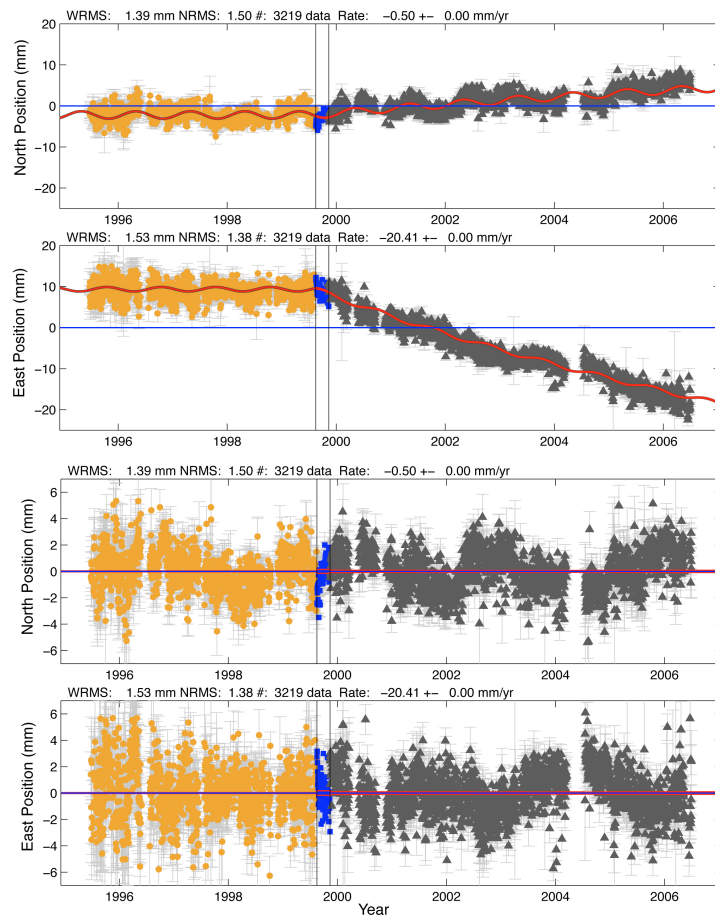


Figure 4. Top 2 panels show ANKR GPS displacement time series (see Figure 2 for station location). North and east position time series are shown, with weekly positions and one-sigma errors (68% confidence limits). Coseismic offsets and offsets due to the interseismic velocity have been removed from these data. Displacements are relative to a fixed Eurasian plate. Symbols are colored blue after August 17, 1999 (Izmit earthquake) and gray after November 12, 1999 (Duzce earthquake). NRMS and WRMS refer to the normalized and weighted root mean squared residual, indicating the quality of the fit of the log function to the GPS data. Rate refers to the interseismic (pre-1999) velocity. Bottom 2 panels show ANKR GPS displacement time series, but after the removal of a single logarithmic term with a 10-year decay time (red line in top 2 panels).

Figures 4 (top 2 panels) and 5 (top left 2 panels) show time series for the continuous GPS stations at Ankara (ANKA; >200 km from earthquake fault), and Gebze (TUBI; < 10 km from the earthquake fault) (see Figure 2 for locations). Both stations indicate postseismic motions that are consistent in orientation with the double-couple pattern expected from afterslip and/or viscoelastic relaxation (Figure 6c). As indicated in Figures 4, and 5, the Ankara station shows a change in velocity at the time of the earthquake sequence that is consistent with logarithmic decay with a time constant of ~ 10 years. In contrast, the Gebze station located near the fault requires 3 time constants (1 day, 5 months, and 10 years) to account for the postseismic velocity change.

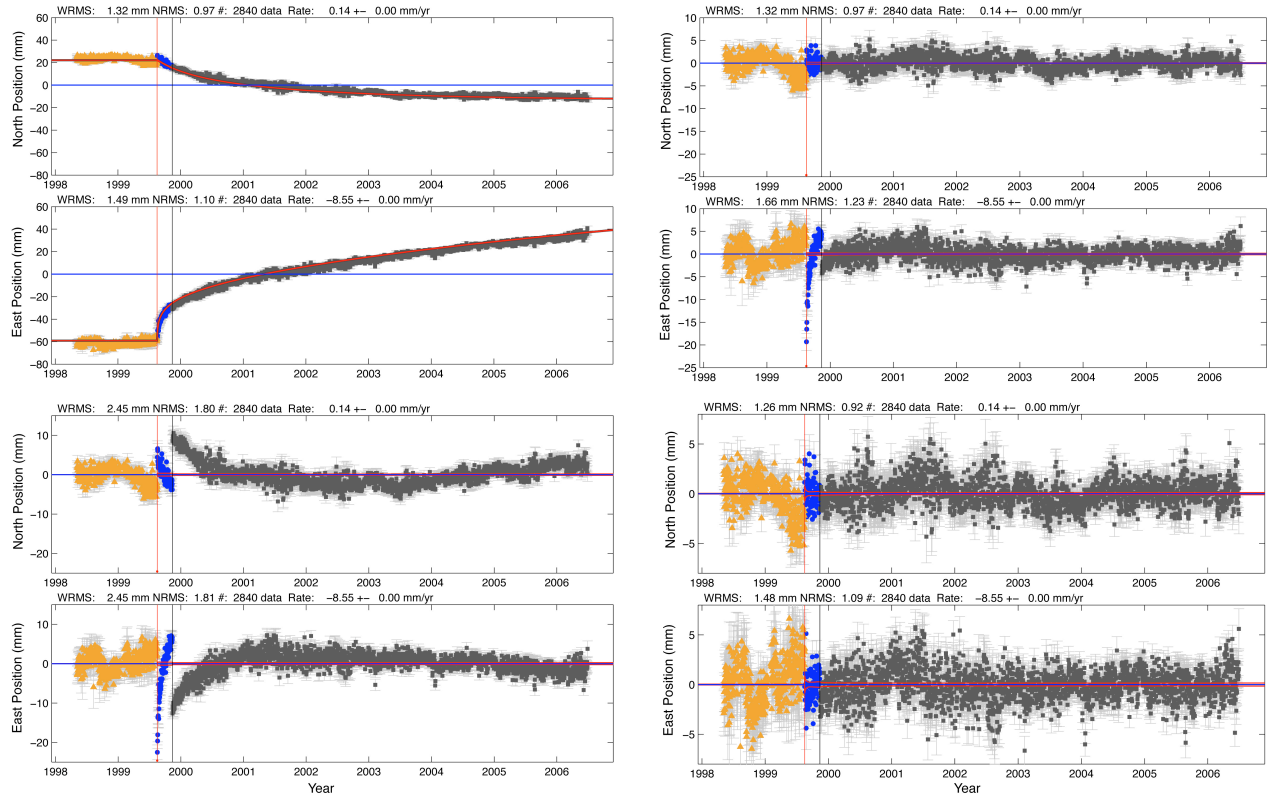


Figure 5. Panels 1 and 2 (top left) show TUBI north and east GPS displacement time series, fit with the complete, three-term log function (red line). Coseismic offsets and offsets due to the interseismic velocity have been removed from these data, and displacements are relative to a fixed Eurasian plate. NRMS and WRMS refer to the normalized and weighted root mean squared residual, indicating the quality of the fit of the log function to the GPS data. Rate refers to the secular (pre-1999) velocity. Symbols are colored blue after August 17, 1999 and gray after November 12, 1999.

Panels 3 and 4 (bottom left) show TUBI displacement time series, after removal of the 3500-day logarithmic function term. The east and north components clearly show remaining, rapidly decaying velocities that are not adequately modeled.

Panels 5 and 6 (top right) show TUBI displacement time series, after removal of the 3500-day and 150-day logarithmic function terms. The east component still shows a remaining, very rapidly decaying term.

Panels 7 and 8 (bottom right) show TUBI displacement time series, after removal of the one-day, 150-day, and 3500-day logarithmic function terms that provides an acceptable fit to the full time series.

In order to constrain the 10-year relaxation term with only 6 years of postseismic data, we assumed that all stations within the postseismic deformation zone will return to their pre-earthquake velocities prior to the next earthquake (historic and paleoseismic studies indicate repeat times of ~200 – 300 years; Klinger et al., 2003, Rockwell et al., 2001, Utkucu et al., 2008). Extending our monitoring of postseismic deformation (Initiative 2) will provide the data to directly test this assumption.

Figure 6 shows GPS postseismic motions at 1 week, 6 months, and 6 years following the earthquake sequence, determined by subtracting the modeled pre-earthquake, secular velocities (Figure 3) from velocities estimated from post-earthquake observations (i.e., the secular velocity field has been removed leaving only the component of postseismic motion). We make the following first-order observations that are relevant to the research here proposed:

- 1) Six years after the Izmit-Duzce earthquake sequence, postseismic motions persist, exceeding 7 mm/yr near the coseismic fault, and exceeding 3 mm/yr out to at least 200 km from the fault (Figure 6c). These rates are equivalent to 30 – 15% of the geodetically measured tectonic loading rate of the NAF (near and far from fault, respectively).
- 2) Postseismic motions during the first week following the earthquake (Figure 6a) show the expected double-couple pattern with motions decaying rapidly with distance away from the coseismic rupture. These motions are consistent with afterslip on shallow fault patches that slipped less coseismically than surrounding areas, and slip below the fault segments with the largest coseismic slip (Ergintav et al., 2009).
- 3) Postseismic motions are distributed roughly symmetrically across the fault (as were coseismic motions; Reilinger et al., 2000), indicating that crustal elastic parameters do not differ greatly north and south of the fault. This is important because Le Pichon et al. (2003) suggest that large variations in elastic properties across the fault may account for the low level of strain accumulation observed N of the fault in the Marmara Sea (Figure 2, top). An alternate interpretation suggested by Meade et al. (2002), appeals to a shallow locking depth for the Main Marmara Fault to account for the low strain N of the fault, suggesting that future earthquakes in the Marmara seismic gap will be smaller than some prior estimates (Hubert-Ferrari et al., 2000) and more consistent with historic earthquake studies (Ambraseys, 2002).
- 4) Although the postseismic deformation pattern adjacent to the coseismic fault is overall consistent with the expected double-couple pattern, GPS sites on the Armutlu Peninsula (CINA, FIST, DUMT, etc.; Figure 6c) also indicate southerly motion, and sites west of the rupture in the Marmara Sea region indicate south to southeast motions following the earthquake sequence. This “non-double-couple” motion is difficult to ascribe to expected postseismic processes (Savage, 1990, Ergintav et al., 2009). Regional tectonic stresses and changes in fault strength as a result of the earthquake sequence (Hearn et al., 2009) may be able to account for these motions, but additional observations (Initiative 1, 2) are needed to test further this hypothesis.
- 5) Initial dynamic modeling of early postseismic deformation (2.5 years after the earthquake sequence) confirms initial afterslip but also suggests viscoelastic relaxation of lower crust and upper mantle after several months following the earthquakes with a viscosity on the order of $2\text{--}5 \times 10^{19}$ Pa s (Hearn et al., 2009).
- 6) While this linear viscous rheology can account for the postseismic motions, this range of viscosity values is not consistent with the observed localized strain accumulation prior to the earthquake sequence (Hearn et al., 2009), possibly implying a transient (or Burgers body) rheology (Hetland and Hager, 2004).

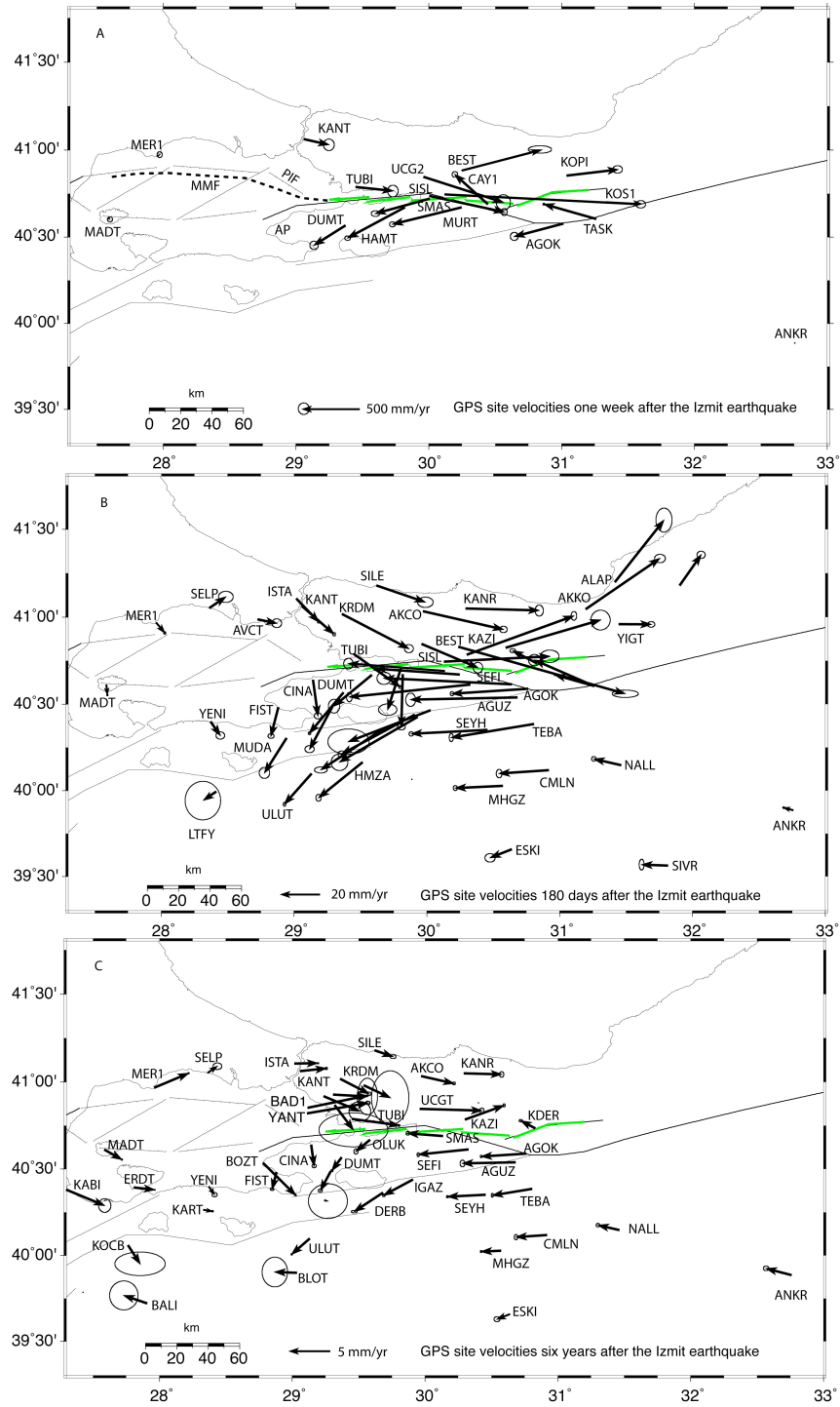


Figure 6. GPS site velocities (a) one week, (b) six months, and (c) six years after the 1999 Izmit earthquake. These velocities have been corrected for interseismic deformation using the pre-Izmit velocity field shown on Figure 3. On Figure 6a, MMF is the Main Marmara Fault (based on Demirbag et al., 2003), AP is the Armutlu Peninsula, and PIF is the Princes Island Fault. Gray lines show the Izmit earthquake rupture trace. Only velocities from GPS sites that were being monitored during the relevant time intervals are shown on these plots.

3. PROPOSED RESEARCH

As indicated in the prior section of this proposal, substantial questions remain concerning the temporal and spatial character of postseismic deformation, and accordingly, the rheological structure of the crust and upper mantle, and the physical processes and fault characteristics that control strain accumulation and release (and hence, earthquake occurrence) on the North Anatolian and similar continental strike slip faults. Specific questions we expect to address with the research proposed here include, 1) Does our present representation of postseismic deformation (i.e., 3 log terms with “time constants” of days, months, and 10 years) define well the most recent motions (including those we will deduce from the observations here proposed through 2014, extending to 15 years after the earthquake), or are longer time constant terms, or other functional representations required? 2) What is the time behavior of the anomalous motions observed in the western Marmara region – are these motions decaying to the observed pre-earthquake motions, thereby supporting the notion that they are associated with postseismic processes, and if so, what are the implications for earthquake-induced variations in fault behavior and earthquake interactions? 3) If the anomalous motions observed in the western Marmara region are not decaying to their pre-earthquake rates, could they be a result of improper modeling of the pre-earthquake strain field, and if so, what are the implications for pre-earthquake strain accumulation and earthquake hazards? 4) Are there alternative postseismic deformation models/processes that could better describe the observed deformation, particularly at large distances from the coseismic rupture? Addressing these questions will require incorporating post-2006.5 GPS data from our MRC partners and other available data in our analysis, continuing deformation monitoring, investigating a range of analytical descriptions to best define the temporal and spatial character of the postseismic deformation field, and integrating other data in our analysis to constrain dynamic models for the observed deformations.

We propose 4 specific initiatives to be completed during the 5-year grant period requested.

Initiative 1. Extend our geodetic analysis to include data that are now available for the past 4 years. Our prior geodetic analysis of Izmit postseismic GPS observations extended through mid-2006 when we terminated data processing to focus on analysis, modeling, interpretation, and publication of our results. All the CGPS stations used in our analysis continue to operate and all these data have already been provided to us by MRC. In addition, MRC reobserved Izmit-Duzce postseismic survey sites in 2006.5, 2007.5, 2008.5, and is presently planning observations for a 2009 survey (see attached letter from MRC). Incorporating these data in our analysis will extend our time series by roughly 30%. This will provide an important test of our analytical approach to fitting station time series and will offer opportunities to develop better ways to characterize postseismic deformation. Accordingly, our first initiative will be to process and analyze these available data.

Initiative 2. Continued monitoring of Izmit-Duzce postseismic deformation with continuous and survey GPS observations. As described in the previous section, our analysis indicates “double-couple like” deformations following the earthquake sequence that are generally consistent with anticipated mechanisms of postseismic deformation (i.e., afterslip and/or viscoelastic relaxation) as well as “anomalous” motions that appear to be incompatible with our present understanding of postseismic processes. Both of these aspects of the postseismic deformation require further observations; “double-couple like” deformations to constrain better the temporal and spatial

characteristics of the longer time constant characterizing this process, and the “anomalous” motions to determine better their temporal and spatial character to help constrain underlying dynamic processes.

Our Turkish partners, under the direction of the Marmara Research Center (MRC), are providing the bulk of the support needed to both maintain the Marmara CGPS Network and to undertake annual observations of the survey network (Figure 2). We here request support to augment the 2011 annual survey and for an MIT scientist to contribute to planning, pre-survey equipment testing, and training for each of the annual surveys. Our intent is to assure that the observations are of the highest quality possible.

Although not an explicit item in our MIT budget, a significant objective of this proposal is to assure continued support of the Marmara continuous GPS network by UNAVCO. This would involve mainly “remote” technical assistance including providing MRC the most up to date information on GPS equipment, telecommunications, and monumentation. We do not anticipate the need for in-field engineering support from UNAVCO. We do request living expenses for an MRC engineer to visit UNAVCO for 1 week during the 1st year of the project – they will provide their own travel costs. Again, UNAVCO support for MRC will assure the highest quality CGPS data to constrain on-going deformation.

In addition to continuing observations of the existing GPS network, we request support to install continuous GPS stations at two locations on the Princes Islands (Figure 3). These stations would be located within the PIRESE seismic array on the GONAF deep boreholes being proposed to the ICDP by colleagues from the GFZ in collaboration with MRC (see letter of cooperation from GFZ). These locations are very close (~5 km or less) to the segment of the NAF that connects the Izmit coseismic rupture with the northern branch of the NAF that is located along the northern margin of the Marmara Sea. The north branch of the NAF is now known to accommodate the main slip along the fault system (e.g., Le Pichon et al., 2003, Meade et al., 2002), and as such represents the principal hazard in the greater Istanbul region (Hubert-Ferrari et al., 2000). These new GPS stations will help constrain the transfer of strain through the eastern Marmara (aseismic vs seismic slip, fault locking depth and dip) and the role of block rotations and basin extension in accommodating this strain transfer (note the apparent postseismic, counterclockwise rotation of the Armutlu Peninsula and the SW Marmara blocks; Figure 6c). We propose to use UNAVCO GPS systems for these stations (see UNAVCO letter of support), and logistical support for the installations will be provided by GFZ and MRC. We request in our budget only minimum peripheral equipment for these stations (we will use power and communications available at the borehole sites).

Initiative 3. Incorporate new GPS, gravity, INSAR, and geologic data (long-term fault slip rates and pre-historic earthquake record) in our analysis. Additional continuous and survey-mode GPS data in the postseismic deformation zone recorded since the earthquake sequence by independent projects are now available to include in our analysis. Figure 2 shows new GPS sites, including survey and continuous sites from the General Command of Mapping (O. LENK, GCM, personal communication, 2009), and continuous stations that constitute the Turkish CORS Network (K. Erin, Kultur University, personal communication, 2009). These data will allow us to extend our postseismic analysis to greater distances from the coseismic fault, providing better constraints on far-field deformation, and presumably deeper viscoelastic

relaxation, and will strengthen our postseismic analysis of intermediate and long-term relaxation parameters (i.e., these stations were installed 3 – 9 years after the earthquake sequence).

The MRC has also been conducting repeat gravity surveys since 2003 across the western end of the Izmit coseismic rupture, around Istanbul, and across the Dardanelles, west of the Marmara Sea (Figure 3). The gravity stations are all co-located with either continuous or survey GPS sites in the Izmit postseismic network. Initial analysis (2003-2005, Ergintav et al., 2007) indicates gravity changes that are consistent in sign with expected vertical motions from viscoelastic relaxation (Hearn et al., 2009), but the amplitude of the gravity changes are 5-10 times larger than those indicated by GPS (using free air gravity correction). Possible effects of seasonal changes in surface moisture and ground water levels remain a concern that we will address with the most recent observations. MRC has continued to conduct biannual gravity surveys of this network, and they are now compiling water level and meteorological data to estimate possible effects of water table changes and soil moisture. We will continue to work closely with MRC and their partners on this project (Darmstadt University of Technology) in order to determine better the implications of these data, if any, for postseismic deformation processes.

In addition to the GPS data, information on Izmit-Duzce postseismic deformation may be available from InSAR measurements. We propose to work with colleagues from Istanbul Technical University (Ziyadin Cakir) on this aspect of our proposed study. Cakir et al. (2005, 2009) used InSAR and repeated ground-based LIDAR to quantify fault creep along the Ismetpasa segment of the NAF, east of the Duzce surface break. They are acquiring additional InSAR scenes around the Izmit surface break during the postseismic period and are investigating image-stacking and permanent scatter approaches to determine ground motions (personal communication, Zaydin Cakir, 2009). They are presently working with our Turkish collaborators at MCR, facilitating our broader collaboration (see MRC letter of support).

Following the 1999 earthquake sequence, a renewed effort was made to determine better the nature of historic and prehistoric earthquakes (i.e., timing, locations, offsets) along the NAF system. This has included a re-evaluation of the 2000-year historic earthquake record (e.g., Ambraseys, 2002, 2009), paleoseismic studies (e.g., Rockwell et al., 2001), and quantitative geomorphological studies of offset features over a range of time scales (e.g., Hubert-Ferrari et al., 2002, Kozaci et al., 2009). A consistent result of these studies is a tendency for longer-term slip rates to be roughly 10 – 15% less than geodetic estimates (i.e., 15 – 20 mm/yr geologic; 25 ± 2 mm/yr geodetic; James Dolan, personal communication, 2009). Possible explanations for this apparent discrepancy include, 1) failure of narrow-aperture geologic slip-rate measurements to capture slip across the complex NAF system (Sengor et al., 2004), 2) less total slip near the surface, where geologic slip rate estimates are determined, than on deeper parts of the fault that determine geodetic slip rates (e.g., Feigl et al., 2002), presumably due to anelastic deformation of the less consolidated surface materials, 3) issues associated with locking depth in the geodetic models (Reilinger et al., 2006, Figure 10 of that paper), and 4) viscoelastic earthquake-cycle effects, including possible contamination of the geodetic data by postseismic signals associated with earlier earthquakes in the 20th Century sequence (Figure 1; Mantovani et al., 2001, Hearn et al., 2002a). Quantifying better the longer-term postseismic effects of the Izmit-Duzce earthquake sequence, as we propose here, will provide direct constraints on the possible continuing impact of postseismic processes of the 20th Century NAF earthquake sequence on present-day (geodetic) slip rate estimates as well as on estimates of Anatolia plate motion.

Better constraints on NAF “secular” slip rates are important for estimating earthquake repeat times, and accordingly earthquake hazards. Similarly, better constraints on postseismic effects at GPS stations in the far field (e.g., Ankara) are important for regional plate dynamics because the rapid present day eastward motion of the Anatolian Plate compared with motion of Arabia has been used to argue against the extrusion model (e.g., Sengor et al, 1985) and for models that favor rollback of the subducting African plate along the Hellenic and Cyprus trenches driving Anatolia motion (e.g., Royden, 1993, ten Veen et al., 2004, Reilinger et al., 2006, Almendinger et al., 2007).

Initiative 4. Quantitative modeling to constrain rheology and fault mechanics.

Our prior three initiatives are all aimed at quantifying the spatial and temporal behavior of Izmit-Duzce postseismic deformation. This, and presenting the results in a timely and consistent way (i.e., both observed and functional representations of all site/station time series with well-defined uncertainties) remain our first priority. However, as stated earlier, our principal objective is to use these unique data to constrain models for the mechanics of continental deformation and the earthquake cycle. While we hope and expect that other geodynamicists will use the results of our proposed study to develop and constrain earthquake cycle models, we believe we are in a strong position to contribute to this effort because, 1) we are familiar with the geodetic network and observations, 2) we understand the strengths and limitations of the basic observations and analytical representations of the deformation field, 3) our ongoing monitoring of deformation along the length of the NAF provides a basis to place the Izmit results in the broader context of strain accumulation and release as a function of time in the earthquake cycle (Figure 1), and 4) our ongoing studies of regional plate kinematics and dynamics provide a broad context from which to evaluate the interaction between plate dynamics and fault kinematics (i.e., the possible impact of fault dynamics on the motion of the Anatolian plate [Mantovani et al., 2001, Hearn et al., 2002], possible interaction between regional stress field and postseismic deformation processes [Ergintav et al., 2009]).

We propose to work directly with partners at the University of Montpellier II and CNRS (Jean Chery, Michel Peyret and Philippe Vernant), who have independent support to develop models for the mechanics of postseismic deformation (see letter of cooperation from CNRS). Our aim is to develop and test physical models for the mechanics of faulting and crustal/uppermantle rheology that are consistent with the observed strain associated with all phases of the earthquake cycle for the Izmit-Duzce earthquake sequence. We will begin by developing analytic and semi-analytic models that provide insight into the extent to which afterslip and variable fault properties can account for observed deformation throughout the entire earthquake seismic cycle, extending the study of Ergintav et al. (2009). Additionally, we will use numeric models to explore a wider range of geometries and rheologies than the analytic models can allow. We will use our 3-D finite element code (Chery et al., 2001) constrained by our estimates of coseismic fault slip (e.g., Feigl et al., 2002, Burgmann et al., 2002), interseismic tectonic loading (Reilinger et al., 2006; this proposal) and postseismic relaxation (Ergintav et al., 2009; this proposal) to determine the suite of realistic lithospheric rheologies, and fault parameters that are admissible (e.g., Provost and Chery, 2006). The advantage of 3D finite element models is that they allow the simple implementation of the numerous rheologies and fault geometries that honor the known structure of the lithosphere (from seismology and other geophysical data). As stated, these model-based inferences are most often non-unique, and thus instead of providing a single preferred model, will define a range of models and parameters consistent with

the observations. The range of acceptable models will be determined from “reasonable” values for these parameters. Based on our earlier studies (Hearn et al., 2009), we anticipate the need to include viscoelastic relaxation of the lower crust and/or upper mantle to account for the longer-term postseismic motions. Accordingly, we will systematically investigate crustal and mantle rheological structures that, in combination with afterslip can account for the observed postseismic deformation as well as the pattern of pre-earthquake strain accumulation. The unique data set for the Izmit-Duzce earthquake sequence should provide useful constraints on allowable viscous properties of the fault zone and the lithosphere. An additional, important output of the model will be the prediction of strain and stress transfer to other fault segments, thus constraining the time dependent probability of further earthquakes in the Marmara region.

An important feature of many continental earthquakes is that they do not occur regularly but rather as clusters in time. The San Andreas fault (e.g., Weldon et al., 2004), Dead Sea fault (Meghraoui et al., 2003), and faults in Mongolia (Chery et al., 2001a) exhibit earthquake clustering behavior. In contrast, the NAF apparently exhibits a mixed behavior including a systematic propagation of earthquakes along the strike of the fault (e.g., Ambraseys, 2002, Stein et al., 1997) as well as earthquake clustering on the longer term (Nur and Cline, 2000). Developing mechanical models that can account for these different behaviors will further constrain allowable fault mechanical and rheological models, and is mandatory to establish time dependent earthquake probabilities. We will use the long historical earthquake record on the NAF to study earthquake interaction and clustering. Both coseismic and postseismic stress transfer will be computed for each known rupture sequence, varying fault parameters and crustal/mantle rheology within bounds established from our earlier modeling studies. All these stress transfers plus the secular loading will be combined in a global earthquake generator in order to compute synthetic earthquake sequences (Chery et al., 2001b). These simulations will help clarify which mechanical parameters may control earthquake time clustering. We expect that comparative studies between the mechanics of faulting on the NAF and SAF will provide insights into the mechanics of both faults with implications for estimating earthquake recurrence times.

Schedule

Year 1 (2010):

- Process/analyze available GPS data; Plan/organize SGPS of Marmara network (survey financed by MRC); Install Princes Islands CGPS at GFZ PIRES/GONAF seismic array sites (if GFZ is not supported by ICDP, MRC will provide logistical support for the installations); Acquire and begin processing SAR data (ITU and MRC); Begin developing eq cycle models (Montpellier); MRC visit to UNAVCO and MIT.

Year 2 (2011):

- Acquire GPS data from GCM and CORS-TR; Plan/organize SGPS of Marmara network (survey costs supplemented by this grant); Process/analyze newly available GPS data; Refine pre-earthquake strain accumulation model and compare to other trans NAF profiles; CNRS visit to MIT for data analysis/modeling.

Year 3 (2012):

- Plan/organize SGPS of Marmara network (survey financed by MRC); Process/analyze newly available GPS data; Compile gravity data (and hydrologic meta-data) and work with MRC and Darmstadt on processing and analysis; evaluate InSAR results from ITU and, if

appropriate, integrate with GPS deformation results; MRC visit to MIT for data analysis/preparation of AGU presentation.

Year 4 (2013):

- Plan/organize SGPS of Marmara network (survey financed by MRC); Process/analyze newly available GPS data; Analytic characterization of GPS postseismic time series; Integrate GPS, gravity, InSAR data to constrain full eq cycle deformation (including vertical from CGPS, gravity, InSAR); Continue modeling to constrain afterslip/viscoelastic relaxation processes.

Year 5 (2014):

- Plan/organize SGPS of Marmara network (survey financed by MRC); Process/analyze newly available GPS data; Analytic characterization of GPS postseismic time series; Integrate GPS, gravity, InSAR data to constrain full eq cycle deformation (including vertical from CGPS, gravity, InSAR); Continue modeling to constrain afterslip/viscoelastic relaxation processes; MRC and CNRS visits to MIT to complete data analysis and modeling, and to prepare AGU presentations and papers.

Partner Contributions

The research we are proposing highly leverages substantial contributions from our international partners. The TUBITAK (Turkish NSF) Marmara Research Center (MRC) is providing the great majority of funding for annual re-observation of the postseismic GPS survey network (≈ 40 survey sites measured annually – only 1 survey supplemented by funds requested here). As in the past, MRC will coordinate participation from our partners from Istanbul Technical University and Kandilli Observatory in these annual surveys. In addition, MRC is taking full responsibility for maintaining, downloading (including all telecom costs), and providing data to MIT from the 23 station MAGNET CGPS Network. We request only technical support from UNAVCO for the CGPS network. MRC also maintains an extensive seismic network around the Izmit-Duzce earthquake area, including the Marmara Sea region, data from which will be available to aid with interpretation of the geodetic results. MRC will also collaborate with MIT scientists and their partners from Darmstadt University on the analysis of repeat gravity measurements for estimating postseismic vertical motions, and with ITU (Ziyadin Cakir) on integrating InSAR deformation estimates with the GPS results (InSAR research fully funded by TUBITAK).

In 2005 the Turkish government authorized the establishment of a National GPS Reference Network (CORS_TR) with average station spacing of about 50 km (Figure 2; <http://cors-tr.iku.edu.tr/index.php?lang=en>). MIT will have access to the CORS-TR data in and around the Izmit-Duzce postseismic deformation zone through our cooperative agreements with TUBITAK MRC and Kultur University. We anticipate that these data will aid in defining the broad scale deformation late in the postseismic period (stations were installed between 2006 and 2008). Additional GPS survey data from the Turkish National Network (Figure 2, top) may also be provided for joint analysis with our Turkish collaborators (personal communication, Onur Lenk, GCM).

Finally, the geodynamic modeling effort we propose will be accomplished in cooperation with our colleagues from the University of Montpellier II and CNRS (Chery, Vernant, Peyret) who have independent support for this initiative.

Broader Impact

The research we propose is aimed at clarifying the mechanics of strain accumulation and release on a major continental strike slip fault and as such has implications for the nature of continental deformation in general. Furthermore, understanding the role of postseismic deformation in modifying the spatial and temporal character of “secular” strain accumulation is essential for quantitatively estimating earthquake repeat times and seismic hazards. This is very critical in light of the present high probability of a major earthquake in the Marmara Sea that will have a potentially catastrophic impact on the heavily populated and industrialized Istanbul region (Parsons et al., 2000). Given that the NAF system is analogous in many ways to the San Andreas system (e.g., Stein et al., 1997), the information garnered from this study will aid in understanding earthquake generation on this fault system as well, with likely implications for estimating earthquake hazards in California.

In addition to implications for earthquake hazards for the North Anatolian and San Andreas fault systems, the proposed research involves international collaboration with research groups in Turkey (TUBITAK MRC, Istanbul Technical University, Kultur University, and others), France (University of Montpellier II, and CNRS, Montpellier, including student research), and Germany (GFZ). The proposed research thus provides an opportunity for US scientists to continue to play a leading role in this important international initiative.

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- Reilinger, R.E., S. Ergintav, R. Burgmann, et al., Coseismic and postseismic fault slip for the 17 August, M=7.5, Izmit, Turkey Earthquake, *Science*, 289, 1519-1524, 2000.
- Reilinger, R., S. McClusky, P. Vernant, and 20 others, GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions, *J. Geophys. Res.*, B05411, doi:10.1029/2005JB004051, 2006.
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- Sengör, A.M.C., N. Gorur, and F. Saroglu, Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study, in *Strike-slip Faulting and Basin Formation*, (Biddle, K.T. and N. Christie-Blick, eds.), *Society of Econ. Paleont. Min. Sec. Pub.*, 37, 227--264, 1985.
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- Weldon, R.J., T. Fumal, G. Biasi, Wrightwood and the earthquake cycle: What a long recurrence record tells us about how faults work, *GSA Today* 14 doi:10.1130/1052-5173, 2004

Biographical Sketch

Robert Eric Reilinger

Earth Resources Laboratory
Department of Earth, Atmospheric, and Planetary Sciences
Massachusetts Institute of Technology, E34-406
Cambridge, MA 02139

a. Professional Preparation.

Villanova University, Physics, Minor in Mathematics, B.S. Cum Laude, 1969
Cornell University, Physics, Minor in Astrophysics, M.S., 1972
Cornell University, Geophysics, Ph.D., 1979

b. Appointments.

Principal Research Scientist, Department of Earth, Atmospheric, and Planetary Sciences, Earth Resources Laboratory, October 1985-present
Visiting Scholar, Air Force Geophysics Laboratory. Visiting Scientist, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, October 1983-October 1985
Research Associate, Department of Geological Sciences, Cornell University, January 1979-October 1983.

b. Related Publications.

Reilinger, R., S. McClusky, P. Vernant, and 20 others, GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions, *J. Geophys. Res.*, B05411, doi:10.1029/2005JB004051, 2006.
Hearn, E., S. McClusky, S. Ergintav, and R. Reilinger, Izmit earthquake postseismic deformation and the dynamics of the North Anatolian fault zone, *J. Geophys. Res.*, doi:10.1029/2008JB006026, in press, 2009.
Ergintav, S., S. McClusky, E. Hearn, R. Reilinger, and 5 others, Seven years of postseismic deformation following the 1999, M=7.4, and M=7.2 Izmit-Duzce, Turkey earthquake sequence, *J. Geophys. Res.*, doi:10.1029/2008JB006021, in press, 2009.
Reilinger, R.E., et al., Coseismic and postseismic fault slip for the 17 August, M=7.5, Izmit, Turkey Earthquake, *Science*, 289, 1519-1524, 2000.

Other Significant Publications

Reilinger, R.E., S. McClusky, D. Paradissis, S. Ergintav, P. Vernant, Geodetic constraints on the tectonic evolution of the Aegean region and strain accumulation along the Hellenic subduction zone, *Tectonophysics*, doi:10.1016/j.tecto.2009.05.027, in press, 2009.
Podgorski, J., et al., Postseismic deformation following the 1991 Racha, Georgia, earthquake, *Geophys. Res. Lett.*, 34, L04310, doi:10.1029/2006GL028477, 2007.
Allmendinger, R.W., R. Reilinger, and J. Loveless, Strain and rotation rate from GPS in Tibet, Anatolia, and the Altiplano, *Tectonics*, 26, TC3013, doi:10.1029/2006TC002030, 2007.

Hearn, E. H., Hager, B., and Reilinger, R., Viscoelastic deformation from North Anatolian Fault Zone earthquakes and the eastern Mediterranean GPS velocity field, *Geophys. Res. Lett.*, 29, 10.1029/2002GL014889, 2002.

Owen, S., et al., Early postseismic deformation from the $M_w=7.1$ Hector Mine earthquake as measured by survey-mode GPS, *Bull. Seismol. Soc. Am.*, 92, 1423-1432, 2002.

c. Professional and Synergistic Activities

Board Member, IAG Commission XIV (WEGENER)
UNAVCO Inc. Board Member (2002-2003)
Steering Committee Member for COMET (Center for Observation and Modeling of Earthquakes and Tectonics; NERC Center of Excellence, Oxford, England), 2003-2008.

e. Collaborators and Other Affiliations

Barazangi, Muawia (Cornell University)
Bendick, Rebecca (U of Montana)
Burchfiel, Clark (MIT)
Gomez, Francisco (U of Missouri)
Hager, Bradford (MIT)
Hearn, Elizabeth (UBC, Canada)
Masson, Frederik (CNRS, Strasbourg)
Vernant, Philippe (U of Montpellier, France)
Collaborating with 24 institutions in 17 countries in the Mediterranean/Middle East

Graduate Students Advised

Shawn Larsen (PhD)
Burc Oral (PhD)
Richard Bennett (PhD)
Lynn Smith (MSc.)
Shawn Lawrance (MSc.)

Research Advisers

Jack Oliver, Cornell University
Daniel Karig, Cornell University
Kenneth Greison, Cornell University (Physics)

BIOGRAPHICAL SKETCH

Simon C. McClusky

Department of Earth Atmospheric & Planetary Sciences,
Massachusetts Institute of Technology,
77 Massachusetts Avenue, 54-614
Cambridge, MA, 02139
USA.

a. Professional Preparation

University of New South Wales, School of Geomatic Engineering, Surveying (Honors Class1), B.S., 1989.

University of New South Wales, School of Geomatic Engineering, Surveying, Thesis title: "First Epoch Determination of Crustal Motion in Papua New Guinea by Comparison of a 1981 Doppler Survey and a 1990 GPS Survey." Ph.D., 1993.

b. Appointments

Research Scientist, Massachusetts Institute of Technology, Department of Earth, Atmospheric and Planetary Sciences. August, 1996- present.

Visiting Scholar, Massachusetts Institute of Technology, Department of Earth, Atmospheric and Planetary Sciences. August, 1993 – August, 1996.

c. Related Publications

Ergintav, S., S. McClusky, E. H. Hearn, R. E. Reilinger, R. Cakmak, T. Herring, H. Ozener, O. Lenk, and E. Tari, Seven years of postseismic deformation following the 1999, M = 7.4 and M = 7.2, Izmit-Düzce, Turkey earthquake sequence *J. Geophys. Res.*, doi:10.1029/2008JB006021, in press.

Hearn, E. H., S. McClusky, S. Ergintav, and R. E. Reilinger, Izmit earthquake postseismic deformation and dynamics of the North Anatolian Fault Zone, *J. Geophys. Res.*, doi:10.1029/2008JB006026, in press.

McClusky S., S. Balassanian, A. Barka, C. Demir, S. Ergintav, I. Georgiev, O. Gurkan, M. Hamberger, K. Hurst, H. Kahle, K. Kastens, G. Kekelidze, R. King, V. Kotzev, O. Lenk, S. Mahmoud, A. Mishin, M. Nadariya, A. Ouzounis, D. Paradissis, Y. Peter, M. Prilepin, R. Reilinger, I. Sanli, H. Seeger, A. Tealeb, M.N. Toksöz, and G. Veis, GPS Constraints on Plate Kinematics and Dynamics in the Eastern Mediterranean and Caucasus, *J. Geophys. Res.*, 105(B3), 5695-5719, March 2000.

Reilinger, R., S. McClusky, P. Vernant, S. Ergintav, F. Kadiro, I. Guliev, R. Stepanyan, S. Mahmoud, A. ArRajehi, D. Paradissis, M. Prilepin T. Guseva, E. Evren, A. Dmitrotsa, and S. Filikov, GPS Constraints on Continental Deformation in the Africa-Arabia-Eurasia Continental Collision Zone and Implications for the Dynamics of Plate Interactions, *J. Geophys. Res.*, Vol. 111, No. B5, May 2006.

Ergintav, S., R. Bürgmann, S. McClusky, R. Çakmak, R. E. Reilinger, O. Lenk, A. Barka, and H. Özener, Postseismic Deformation near the Izmit Earthquake (17 August 1999, M 7.5) Rupture Zone, *Bull. Seism. Soc. Am.*, 92(1), 194-207, 2002.

Other significant publications

Bürgmann, R., M. E. Ayhan, E. J. Fielding, T. J. Wright, S. McClusky, B. R. Aktug, C. Demir, O. Lenk, and A. Türkezer, Deformation during the 12 November 1999 Düzce, Turkey, Earthquake, from GPS and InSAR Data, *Bull. Seism. Soc. Am.*, 92(1), 161-171, 2002.

McClusky, S., R. Reilinger, S. Mahmoud, D. Ben Sari, and A. Tealeb, GPS Constraints on Africa (Nubia) and Arabia Plate Motions, *Geophys J. Int.*, 155(1), 126-138, 2003.

Bendick R., S. McClusky, R. Bilham, L. Asfaw, S. Klemperer, Distributed Nubia-Somalia relative motion and dike intrusion in the Main Ethiopian Rift, *Geophys. J. Int.*, 165 (1): 303-310 Apr 2006.

Gomez F., G. Karam, M. Khawlie, S. McClusky, P. Vernant, R. Reilinger, R. Jaafar, C. Tabet, K.

Khair, M. Barazangi, Global Positioning System measurements of strain accumulation and slip transfer through the restraining bend along the Dead Sea fault system in Lebanon, *Geophys J. Int.*, 168, 1021-1028, doi:10.1111/j.1365-246X.2006.03328.x, 2007.

Fadil, A., P. Vernant, S. McClusky, R. Reilinger, and 5 others, Active tectonics of the western Mediterranean: GPS evidence for roll back of a delaminated subcontinental slab beneath the Rif Mountains, Morocco, *Geology*, 34, 529-532, doi:10.1130/G22291.1, 2006.

Podgorski J., E.H. Hearn, S. McClusky, R. Reilinger, T. Taymaz, O. Tan, M. Prilepin, T. Guseva M. Nadariya, Postseismic Deformation following the 1991 Racha, Georgia Earthquake, , *Geophys. Res. Lett.*, 34 (4): Art. No. L04310 Feb 2007.

d. Synergistic Activities

USGS Facilities and Instrumentation review panel (2003-2004).
 Member of the UNAVCO Facilities Standing Committee (FSC) (2005-2008).
 Editor of Sensors special issue: "Sensors for Deformation Monitoring"

Professional Affiliations:

Member of the American Geophysical Union (1990-2008).
 Member Geological Society of America (2003-2006).
 Member of the New South Wales Institute of Surveyors (1986-1993).

e. Collaborators and Other Affiliations

(i) Collaborators of Last Four Years

Rebecca Bendick, University of Montana, Semih Ergintav, TUBITAK, Turkey, Kurt Feigl, University of Wisconsin, Brad Hager, MIT, Elizabeth Hearn University of British Columbia, Canada, Thomas Herring, MIT, Hans Kahle, ETH-Z, Switzerland, Robert King, MIT, Haluk Ozener, Kandilli Observatory, Turkey, Robert Reilinger, MIT ERL, Ergin Tari, Istanbul Technical University, Turkey, Paul Tregoning, ANU, Australia.

(ii) Graduate and Post Doctoral Advisors

Postdoctoral Sponsor: Dr. Robert King and Prof. Thomas Herring, MIT, Cambridge.
 Graduate Advisors: Prof. Art Stolz and Prof. Fritz Brunner, UNSW, Sydney, Australia.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION Massachusetts Institute of Technology				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Robert E Reilinger				PROPOSAL NO.	DURATION (months)		
				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
				CAL	ACAD	SUMR	
1. Robert E Reilinger - Principal investigator				3.00	0.00	0.00	\$ 29,640
2. Simon McClusky - Research Scientist				2.00	0.00	0.00	14,196
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				5.00	0.00	0.00	43,836
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. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							43,836
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							13,956
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							57,792
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)							2,700
2. FOREIGN							2,650
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							2,460
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							4,000
5. SUBAWARDS							0
6. OTHER							16,800
TOTAL OTHER DIRECT COSTS							23,260
H. TOTAL DIRECT COSTS (A THROUGH G)							86,402
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Off Campus (Rate: 6.5000, Base: 61035) (Cont. on Comments Page)							
TOTAL INDIRECT COSTS (F&A)							21,217
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							107,619
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 107,619 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PI NAME Robert E Reilinger				FOR NSF USE ONLY			
ORG. REP. NAME*				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**

On Campus (Rate: 68.0000, Base 25368)

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION				FOR NSF USE ONLY		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR				PROPOSAL NO.		DURATION (months)
AWARD NO.				Proposed		Granted
Massachusetts Institute of Technology Robert E Reilinger						
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer
				CAL	ACAD	SUMR
1. Robert E Reilinger - Principal investigator				2.00	0.00	0.00
2. Simon McClusky - Research Scientist				2.00	0.00	0.00
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				4.00	0.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00
3. (0) GRADUATE STUDENTS						
4. (0) UNDERGRADUATE STUDENTS						
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)						
6. (0) OTHER						
TOTAL SALARIES AND WAGES (A + B)						
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)						
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)						
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)						
TOTAL EQUIPMENT						
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)						
2. FOREIGN						
F. PARTICIPANT SUPPORT COSTS						
1. STIPENDS \$ _____ 0						
2. TRAVEL _____ 0						
3. SUBSISTENCE _____ 0						
4. OTHER _____ 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS						
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						
2. PUBLICATION COSTS/DOCUMENTATION/DISEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER SERVICES						
5. SUBAWARDS						
6. OTHER						
TOTAL OTHER DIRECT COSTS						
H. TOTAL DIRECT COSTS (A THROUGH G)						
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)						
Off Campus (Rate: 6.5000, Base: 29612) (Cont. on Comments Page)						
TOTAL INDIRECT COSTS (F&A)						
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)						
K. RESIDUAL FUNDS						
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)						
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$		
PI/PI NAME				FOR NSF USE ONLY		
Robert E Reilinger				INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*				Date Checked	Date Of Rate Sheet	Initials - ORG

2 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

**** I- Indirect Costs**

On Campus (Rate: 68.0000, Base 27062)

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION Massachusetts Institute of Technology				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Robert E Reilinger				PROPOSAL NO.	DURATION (months)		
				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
				CAL	ACAD	SUMR	
1. Robert E Reilinger - Principal investigator				2.00	0.00	0.00	\$ 21,372
2. Simon McClusky - Research Scientist				3.00	0.00	0.00	23,032
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				5.00	0.00	0.00	44,404
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							44,404
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							14,539
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							58,943
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)							4,510
2. FOREIGN							1,780
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							0
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							4,000
5. SUBAWARDS							0
6. OTHER							0
TOTAL OTHER DIRECT COSTS							4,000
H. TOTAL DIRECT COSTS (A THROUGH G)							69,233
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Off Campus (Rate: 6.5000, Base: 30205) (Cont. on Comments Page)							
TOTAL INDIRECT COSTS (F&A)							28,501
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							97,734
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 97,734 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PI NAME Robert E Reilinger				FOR NSF USE ONLY			
ORG. REP. NAME*				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

SUMMARY PROPOSAL BUDGET COMMENTS - Year 3

**** I- Indirect Costs**

On Campus (Rate: 68.0000, Base 39027)

SUMMARY PROPOSAL BUDGET

YEAR 4

ORGANIZATION Massachusetts Institute of Technology				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Robert E Reilinger				PROPOSAL NO.		DURATION (months)	
						Proposed Granted	
				AWARD NO.			
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	
				CAL	ACAD	SUMR	Funds granted by NSF (if different)
1. Robert E Reilinger - Principal investigator				3.00	0.00	0.00	\$ 33,341
2. Simon McClusky - Research Scientist				3.00	0.00	0.00	23,953
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				6.00	0.00	0.00	57,294
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							57,294
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							18,787
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							76,081
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)							0
2. FOREIGN							2,300
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							0
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							4,000
5. SUBAWARDS							0
6. OTHER							0
TOTAL OTHER DIRECT COSTS							4,000
H. TOTAL DIRECT COSTS (A THROUGH G)							82,381
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Off Campus (Rate: 6.5000, Base: 46643) (Cont. on Comments Page)							
TOTAL INDIRECT COSTS (F&A)							27,334
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							109,715
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 109,715 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PI NAME Robert E Reilinger				FOR NSF USE ONLY			
ORG. REP. NAME*				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet		Initials - ORG

SUMMARY PROPOSAL BUDGET COMMENTS - Year 4

**** I- Indirect Costs**

On Campus (Rate: 68.0000, Base 35738)

SUMMARY PROPOSAL BUDGET

YEAR 5

ORGANIZATION Massachusetts Institute of Technology				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Robert E Reilinger				PROPOSAL NO.	DURATION (months)		
				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
				CAL	ACAD	SUMR	
1. Robert E Reilinger - Principal investigator				3.00	0.00	0.00	\$ 34,675
2. Simon McClusky - Research Scientist				3.00	0.00	0.00	24,911
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				6.00	0.00	0.00	59,586
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							59,586
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							19,538
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							79,124
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							6,010
2. FOREIGN							1,780
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							0
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							2,000
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							4,000
5. SUBAWARDS							0
6. OTHER							500
TOTAL OTHER DIRECT COSTS							6,500
H. TOTAL DIRECT COSTS (A THROUGH G)							93,414
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Off Campus (Rate: 6.5000, Base: 48397) (Cont. on Comments Page)							
TOTAL INDIRECT COSTS (F&A)							33,758
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							127,172
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 127,172 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PI NAME Robert E Reilinger				FOR NSF USE ONLY			
ORG. REP. NAME*				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

5 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 5

**** I- Indirect Costs**

On Campus (Rate: 68.0000, Base 45017)

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION Massachusetts Institute of Technology				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Robert E Reilinger				PROPOSAL NO.		DURATION (months)	
				Proposed		Granted	
				AWARD NO.			
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	
				CAL	ACAD	SUMR	Funds granted by NSF (if different)
1. Robert E Reilinger - Principal investigator				13.00	0.00	0.00	\$ 139,578
2. Simon McClusky - Research Scientist				13.00	0.00	0.00	100,856
3.							
4.							
5.							
6. () OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)				26.00	0.00	0.00	240,434
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (0) UNDERGRADUATE STUDENTS							0
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							240,434
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							78,400
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							318,834
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)							14,720
2. FOREIGN							10,290
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							2,460
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							4,000
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							20,000
5. SUBAWARDS							0
6. OTHER							17,800
TOTAL OTHER DIRECT COSTS							44,260
H. TOTAL DIRECT COSTS (A THROUGH G)							388,104
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
TOTAL INDIRECT COSTS (F&A)							131,137
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							519,241
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 519,241 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PI NAME Robert E Reilinger				FOR NSF USE ONLY			
ORG. REP. NAME*				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Explanation

We request 5 years of support for this proposed project. This is longer than the typical request period for NSF, but is needed to acquire a long enough time series to address critical questions about the longer-term deformation processes associated with postseismic deformation. While we expect to answer many of the questions being addressed in this proposal during the pending grant period, we believe it will be fruitful to continue this research beyond the 5 years proposed here. However, we anticipate that subsequent participation of MIT will be restricted to data analysis, interpretation, and modeling, requiring a reduced effort from MIT.

This proposal heavily leverages continuing work by TUBITAK-MRC. MRC will cover all costs for 4 of the 5 surveys being proposed, and will supplement the 1 survey for which we request support here. The work further leverages participation of CNRS/Univ. of Montpellier II that will carry out the main modeling in collaboration with MIT with independent EU support, and by GFZ that will provide logistical support for the 2 stations we propose installing on the Princes Islands.

A. Senior Personnel: The main support we request is for salaries for Reilinger and McClusky to carry out the proposed research. The time requested is minimum, but sufficient to complete the proposed research initiatives. Reilinger will oversee the project, coordinate the work with MRC (GPS, Gravity, InSAR), CNRS (modeling), UNAVCO, and GFZ, install the 2 GPS stations on the Princes Islands, contribute to the survey observations each year and to the interpretation (data integration and analysis) and preparation of presentations and publications resulting from this project. McClusky will be responsible for GPS data reduction, error analysis, developing analytic representations of the GPS time series, and will contribute to the interpretation and preparation of presentations and publications.

B. Other Personnel: None

C. Fringe Benefits: MIT Fringe Benefits are 22% on and 20% off campus FY2010. On campus rates expected to increase to 24% and off campus rates to 22% in FY 2011. Vacation accrual is 8.5% on and 11% off campus.

E. Travel: The travel budget includes support for Reilinger to install the CGPS stations (year 1) and contribute to the GPS survey planning and coordination each year, and for an MIT scientist to participate in the Fall AGU Meeting (years 3 and 5). We also request partial support (they will provide international airfare) for a visitor from MRC to MIT/UNAVCO (year 1) and to MIT/AGU Meeting (years 3, 5). In years 2 and 5 we request partial support (living costs only) for a visitor from CNRS/Univ. of Montpellier to MIT/AGU Meeting. Further detail of costs is below.

Domestic travel:

1) MRC to MIT for Data Analysis and to present results at AGU in San Francisco: air to San Francisco: \$600, living @\$150/day X 10 days, AGU Registration @\$380 (\$2,480, years 3 & 5).

2) MRC visit to MIT and UNAVCO, Air: \$600, Living @\$150/dy X 14 days (\$2700, year 1).

3) CNRS visit to MIT for data analysis and modeling: Living@\$150/day X 10 days, (years 2 & 5)

4) MIT to AGU Meeting in San Francisco, Meeting registration \$380 Air: \$600, Living @ \$150/day X 7 days (\$1500, years 3 & 5).

Foreign Travel for Fieldwork:

1) MIT to Istanbul to install borehole GPS: Air:\$1000., Living@\$150/dy X 10 days, local transportation @\$150- (\$2,650, year 1).

2) MIT to Istanbul for Survey Air:\$1000.,living@\$130/dayX 6 days (\$1780, years 2,3, and 5 and year 4 for 10 days, \$2,300)

F. Participant Support: None

G.1. Materials and supplies: Other budgeted costs include peripheral equipment for the 2 CGPS stations, \$2460 in year 1(receivers and antennas being provided by UNAVCO), and shipping peripheral equipment to Istanbul (year 1).

G.2. Publication costs: \$2000 in years 2 and 5.

G.3. Consultant Services: None

G.4. Computer Services: We are requesting \$4,000/year for computer charges for the data reduction and analysis, and analytical modeling of time series being done at MIT.

G.5. Subawards: None

G.6. Other: We request \$14,800 for survey costs for the 2010 (year 1) survey network, to be used as follows: 37 survey points observed each for 2 days @ \$200/survey day (car rentals, fuel, living expenses for 2 operators). We note that living costs in the Istanbul area are comparable to those in the rest of Europe.

I. Indirect costs: Indirect costs are at 68% on campus and fixed for the period July 1, 2008 through June 30, 2009 using current MIT guidelines as negotiated with ONR. All costs associated with fieldwork and Reilinger's time in field are charged off campus rates. Our cognizant ONR representative is Linda B. Shipp, telephone# 703-696-8559.

Current & Pending Support
Robert E. Reilinger, Principal Research Scientist
June 2009
Current Support

Source: NSF #EAR-0609730

Title: Deciphering the dynamics of continental deformation in the Arabia-Eurasia collision zone.

Award amount: \$359,931

Period Covered: 8/15/06-7/31/10

Location: Turkmenistan, Azerbaijan

Person-months: 2.5/1.5/1/1.25/ yr

Source: NSF #EAR-0635702

Title: Collaborative Research: GPS measurements of deformation associated with rifting along the Red Sea, Afar Triple Junction and main Ethiopian Rift: Implications for continental rheology and lithosphere dynamics

Award amount: \$504,854

Period Covered: 2/1/07-1/31/11

Location: Ethiopia, Eritrea, Saudi Arabia, Egypt, Yemen

Person months: 4/3/3/4/ yr

Source: NSF #EAR-0838488

Title: Present-day kinematics and dynamics of the eastern Mediterranean and Caucasus

Award amount: \$700,818.

Period Covered: 5/01/09-4/30/13

Location: Caucasus, Turkey, Greece

Person months: 5/5/5/5/ yr

Pending:

Source: NSF –Tectonics

Title: Collaborative Research: Space-based measurements of crustal deformation along the entire Dead Sea fault (Eastern Mediterranean)

Award amount: \$96,857.

Period Covered: 1/01/10-12/31/13

Location: Saudi Arabia

Person months: 1.5/1.5/1/1.5/ yr

Source: NSF –Tectonics (This Solicitation)

Title: Postseismic deformation for the Izmit-Duzce, Turkey earthquake sequence: Implications for the mechanics of the earthquake cycle and rheology of the continental lithosphere

Award amount: \$519,241

Period Covered: 1/01/10-12/31/14

Location: Turkey

Person months: 3/2/2/3/3/ yr

Current & Pending Support
Simon McClusky
June 2009

Current Support:

Source: NSF #EAR-0609730

Title: Deciphering the dynamics of continental deformation in the Arabia-Eurasia collision zone.

PI: Robert Reilinger

Award amount: \$359,931

Period Covered: 8/15/06-7/31/10

Location: Cambridge

Person-months: 1/1.5/2/2/ yr

Source: NSF #EAR-0635702

PI: Robert Reilinger

Title: Collaborative Research: GPS measurements of deformation associated with rifting along the Red Sea, Afar Triple Junction and main Ethiopian Rift: Implications for continental rheology and lithosphere dynamics

Award amount: \$504,854

Period Covered: 2/1/07-1/31/11

Location: Cambridge

Person months: 3/ yr

Source: UNAVCO

PI: R. King

Title: UNAVCO Community and Facility: Geodesy Advancing Earth Science Research

Award amount: \$576,371

Period Covered: 1/1/08-12/31/12

Location: Cambridge

Person months: 0.5 /yr

Source: UNAVCO

PI: T.A. Herring

Title: PBO Center Coordinator

Award amount: \$575,580

Period covered: 10/01/08 - 9/30/13

Location: Cambridge, Massachusetts

Person-months: 1.55/1.5/1.45/1.37/1.33

Source: USGS

PI: T. Herring

Title: TRACK Kinematic GPS Software

Award amount: \$51,408

Period Covered: 9/15/08-9/30/09

Location: Cambridge

Person months: 2/ yr

Source: NSF EAR- #EAR-0838488

PI: Robert Reilinger

Title: Present-day kinematics and dynamics of the eastern Mediterranean and Caucasus

Award amount: \$700,818

Period Covered: 1/01/09-12/31/12

Location: Cambridge, Massachusetts

Person months: 5/5/5/5 yr

Pending:

Source: NSF –Tectonics (This solicitation)

PI: Robert Reilinger

Title: Postseismic deformation for the Izmit-Duzce, Turkey earthquake sequence: Implications for the mechanics of the earthquake cycle and rheology of the continental lithosphere

Award amount: \$519,241

Period Covered: 1/01/10-12/31/14

Location: Cambridge, Massachusetts

Person months: 2/2/3/3/3/ yr

Facilities, Equipment, and Other Resources.

Members of our group have experience with the installation of continuous GPS stations in remote areas as well as with GPS survey data acquisition and training necessary to carry out the proposed fieldwork. Our group at MIT has one of the most advanced GPS data analysis facilities currently available, supported by over 20 UNIX-based workstations and 35TB of on-line storage. We also have use of the MIT Alliance for Computational Earth Science (ACES) computing cluster, comprising both a 500 CPU PC cluster with over 1TB of distributed memory, and a 16 CPU SGI Altix 350 super computer with 80GB of NUMA shared memory. Members of our group are responsible for coordinating with UCSD and others the on-going development of the GAMIT/GLOBK software used by over 200-research groups world-wide. An abundance of software for routine analysis of both static and dynamic ground motions has been developed and tested in our lab over the last decade. This software includes both forward modeling and inversion algorithms that we routinely use to analyze near- and far-field seismic body waves, episodic crustal deformation, and regional deformation associated with relative plate motions. The 500 CPU ACES cluster enables us to run the Computational Infrastructure for Geodynamics (CIG) parallel-3D modeling codes, like the short-term crustal dynamics applications PyLith and LithoMop, and long-term crustal dynamics program Gale. We also are using the parallel 3-D spherical flow code, CitComS, and its sister code, CitComT.

Other members of MIT's Dept. of Earth, Atmospheric, and Planetary Sciences with whom we actively collaborate (Burchfiel, Hager, Herring, King, Royden, Toksoz, and van der Hilst) provide a rich environment in which to carry out the studies we have proposed.



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rreilinger@hotmail.com

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Deleted (103)

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oldmail (1158)

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Approved PSR: IZMIT EARTHQUAKE POSTSEISMIC DEFORMATION 2010-2014From: **achaia@unavco.org**

Sent: Wed 6/10/09 5:45 PM

To: jeffries@unavco.org; megan@unavco.org; krantz@unavco.org; bolter@unavco.org; maggert@unavco.org; symank@unavco.org; effendi@unavco.org; bjorn@unavco.org; owen@unavco.org; friesen@unavco.org; bartel@unavco.org; morrison@unavco.org; pettit@unavco.org; ruud@unavco.org; mlee@unavco.org; normandeau@unavco.org; educationandoutreach@unavco.org; eriksson@unavco.org; doelger@unavco.org; reilinge@erl.mit.edu; simon@mit.edu

UNAVCO has accepted your request for support.

We have the following information concerning your project:

Project Name: IZMIT EARTHQUAKE POSTSEISMIC DEFORMATION 2010-2014

Request Date: 6/10/2009 6:48:00 AM

Primary Contact: ROBERT Reilinger

Contact Phone: 6172537860

Contact Email: reilinge@erl.mit.edu

Contact Address: DEAPS, MIT, 54-326, 77 MASSACHUSETTS AVE., CAMBRIDGE MA 02130

Contact Affiliation MIT

Project Category: NSF-EAR PI Project

Support Type: Pool equipment loan, Technical support, Proposal preparation, budgeting & letter of support

Project Type: Permanent GPS Network

Project Description: Monitoring postseismic deformation for the Izmit-Duzce, Turkey earthquake sequence.

PI: Robert Reilinger

Co PI: Simon McClusky

Funding Source: NSF-EAR: Tectonics

Funding Status: N/A - PROPOSAL SUPPORT

Program Manager: DAVID FOUNTAIN

Proposal Name: Monitoring and modeling postseismic deformation
Izmit-Duzce, Turkey earthquake sequence: Implications for the evolution
of the earthquake cycle and rheology of the continental lithosphere

Proposal Number: N/A - PROPOSAL SUPPORT

Proposal Dates: 01/01/2010 - 12/31/2014

Rx Requested: 2 Trimble NetRS

Ant Requested: 2 Standard

Equip Dates: 4/1/2010 12/31/2014

Ship Type: D

Ship Date: 3/25/2010

FE Requested: N

FE Dates:

2:35 PM



June 18, 2009

Dr. Robert Reilinger
ERL/MIT 54-326
77 Massachusetts Avenue
Cambridge, MA 02139

Re: UNAVCO Facility support of Izmit Earthquake Postseismic Deformation Project

Dear Dr. Reilinger:

UNAVCO is pleased to provide this Letter of Support for your **Monitoring and modeling postseismic deformation for the Izmit-Duzce, Turkey earthquake sequence: Implications for the mechanics of the earthquake cycle and rheology of the continental lithosphere** proposal to National Science Foundation (NSF), Division of Earth Sciences (EAR): Tectonics project. In the event your proposal is successfully reviewed and funded, the UNAVCO Facility will provide two (2) Trimble NetRS systems with Zephyr antennas on loan from the UNAVCO equipment pool and technical support for the installation of the GPS sites.

We wish you the best of luck with your proposal and hope we have the opportunity to be of service by supporting this important effort.

Sincerely,

A handwritten signature in blue ink that reads "Charles Meertens".

Dr. Charles Meertens
UNAVCO Facility Director

cc: F. Boler
A. Krantz
J. Normandeau
L. Morgan
G. Strobel
D. Wilson

GFZ

Helmholtz Centre
POTSDAM

GFZ · Postfach 60 07 51 · 14407 Potsdam · Germany

Dr. Simon McClusky
54-827
Dept. of Earth, Atmospheric, and
Planetary Sciences
77 Massachusetts Ave.
Massachusetts Institute of Technology
Cambridge, MA 02139-4307 USA

HELMHOLTZ CENTRE POTSDAM
**GFZ GERMAN RESEARCH CENTRE
FOR GEOSCIENCES**
Telegrafenberg
14473 Potsdam · Germany

Prof. Dr. Georg Dresen
Sect. 3.2 Geomechanics & Rheology

2009-06-17

dre@gfz-potsdam.de

Phone: +49 (0)331 288-1320/1321

Fax: +49 (0)331 288-1328

Dear Simon,

with regard to our previous discussions I would very much like to invite you to participate in the collaborative research project:

Princess Island Realtime Earthquake Monitoring System (PIRES)

The purpose of the cooperation is a collaborative study of earthquake related processes in the Marmara Sea and surroundings. The Prince Islands/Cinarcik Basin region is the main target area of the cooperation, but can be extended to neighbouring areas if scientific need arises.

The PIREs array on the Prince Islands currently represents a cooperative research effort of Kandilli Observatory and Earthquake Research Institute in Istanbul/Turkey and the German Research Centre for Geosciences (GFZ) in Potsdam to monitor the seismic activity at North Anatolian Fault in the Sea of Marmara. As of today a seismic array consisting of a total of ten stations was installed for permanent operation on the islands (five each on Yassıada and Sivriada islands). To extend PIREs we would aim at integrating our seismological observations with geodetic measurements by installation of permanent GPS stations. In this context we would very much appreciate collaboration with your group at MIT.


G. Dresen


M. Bohnhoff

HELMHOLTZ-ZENTRUM POTSDAM
DEUTSCHES GEOFORSCHUNGSZENTRUM GFZ
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Montpellier, June 11th, 2009

To: Robert Reilinger,
DEAPS, 54-326,
MIT, Cambridge, MA 02139

Dear Rob,

Our Geodynamics Group is pleased to have the opportunity to work with your group at MIT and Semih's group at MRC on the analysis and modeling of earthquake cycle deformation around the Izmit-Duzce earthquake sequence. Our present research with Semih's group on Marmara Sea kinematics and fault mechanics will facilitate this broader cooperation, as will our continuing cooperation with MIT on Mediterranean geodynamics.

Our principal effort will be on the modeling aspects of the proposed research. I will direct this effort together with my colleagues Philippe Vernant and Michel Peyret, and we expect to include a student on the project. CNRS will provide support for travel to MIT in years 2 and 5 of the proposed project to coordinate the data analysis and modelling efforts, and to prepare presentations (AGU) and papers.

Good luck with your proposal.

Sincerely,

Jean Chéry,
CNRS Researcher, Géosciences Montpellier,
Université de Montpellier, France





Dr. Robert Reilinger
MIT, DEAPS
Cambridge, MA 02139 USA

10 June 2009

Dear Rob,

We're glad to learn that you and Simon are planning to continue our cooperative project to monitor and model postseismic deformation for the Izmit-Duzce earthquake sequence. We're also happy that you plan to collaborate with Jean Chery and his colleagues at CNRS, Montpellier University. As you know, we have been working with Jean on modeling deformation in the Marmara region and we are very pleased with the progress we are making. We are also working closely with Ziyaddin Cakir on InSAR in and around Istanbul – the inclusion of these data in our analysis could prove useful, particularly for investigating vertical motions (also our gravity observations made with the Darmstadt group). As in the past, we will cooperate fully with MIT on the analysis of all data relevant to postseismic deformation for the Izmit-Duzce earthquake sequence.

In regard to your NSF proposal, MRC and our partners on this project from Yildiz Technical University will work with your group to plan and carryout GPS observations of the Izmit-Duzce postseismic network on an annual basis. We expect to continue this effort through the end of your proposed grant period (2015). Continued monitoring is necessary to more fully define the temporal and spatial character of deformation – and this has direct implications for estimating earthquake repeat times, and hazards in the vulnerable Istanbul area. We plan to provide full support for the survey work, with the inclusion of the support you are proposing for our 2011 survey. We will provide these data to MIT immediately following acquisition. We are also glad that UNAVCO will continue to provide technical support for our network operations, and we will make good use of our technical visit to the UNAVCO Facility to assure the best network performance.

Finally, we will continue to work closely with you and Simon on the data processing, and analysis, including analytical characterization of the site/station time series. We are confident that the collaborative research you are proposing will advance our understanding of continental deformation and earthquake hazards in NW Turkey.

Sincerely,

Assoc. Prof Semih Ergintav
Deputy Director
TUBITAK MRC
Earth and Marine Research Institute

