2010 SCEC Proposal

GPS and CHIRP Surveys of the Imperial and Cerro Prieto Faults, Mexico

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Amount of requested funding: $ 10,000 (SIO Budget Only)

Proposal Categories:
Category A. Data Gathering and Products
Category D. Communication, Education, and Outreach

Science Priority Objectives:
A1. Define slip rates and earthquake history of southern San Andreas fault system for the last 2000 years
A2. Investigate implications of geodetic/geologic rate discrepancies

Start date: Feb. 1, 2010
End date: Jan. 31, 2011

Technical Description

1. Results from 2009 SCEC support

This proposal is a continuation of our 2009 SCEC proposal to perform a campaign-style GPS survey of the Imperial Fault. A shortened version of that 2008 proposal follows in section 4. SCEC funding was used to support a graduate Student Brendan Crowell to organize and lead the GPS surveys described below. The survey teams consisted of students and faculty from two classes *GPS and radar interferometry of the Imperial Fault* (SIO 239) and *Introduction to GIS* (SIO 110). The participating faculty included Yehuda Bock, Yuri Fialko, David Sandwell, and Duncan Agnew. Each winter our students and faculty perform campaign GPS surveys of the southernmost San Andreas fault system. Much of this field work is sponsored by SCEC. Brendan Crowell has done most of the analysis for the 2008-2009 surveys.

As of March 2009, three rapid static GPS surveys have been performed from the US-Mexico border to the northern extent of the Salton Sea encompassing the Imperial, Superstition Hills, Brawley, San Jacinto and San Andreas fault zones. The first survey was performed in February, 2008, and included 16 scientists and graduate students from Scripps, SDSU and Cornell. The survey consisted of 56 densely spaced monuments (**Figure 1**, blue dots), of which, 14 were installed by the National Geodetic Survey (NGS) and 42 were installed by Imperial College, London, in the 1970s and previously surveyed in 1993, 1999 and 2000 [*Genrich et al.*, 1997; *Lyons et al*., 2002]. In addition to surveying these 56 monuments, 10 monuments were installed and surveyed along the irrigation culverts, creating a dense transect across the Imperial Fault in 2 locations.

The second survey was performed in late October, 2008, and aimed to cover a much greater area to encompass more of the Brawley seismic zone up to the southern extent of the Salton Sea. This survey was performed by 6 scientists and graduate students from Scripps and included 54 NGS and California Department of Transportation (CALTRANS) geodetic monuments (**Figure 1**, orange dots). Of the 54 monuments, 20 of them were installed by CALTRANS in 2004, and have only been surveyed once. The results of the first two surveys can be seen in **Figure 2**.

The third survey was performed in February, 2009 by 10 Scripps scientists, graduate and undergraduate students. This survey was aimed at encompassing as much of the strain transfer zone between the San Andreas, San Jacinto, Superstition Hills and Imperial Faults, and included 37 geodetic monuments along both sides of the Salton Sea into the Coachella Valley (**Figure 1**, purple dots). Also surveyed were the 10 monuments installed in February, 2008 during the first survey. During the survey of the dense transects across the Imperial Fault, several large cracks in the road bed across the fault were observed, which were not there in February 2008. The cracks range in size from 1 mm up to ~10 mm in width. We propose that a creep event took place at some point in 2008 to early 2009, which we plan to investigate further when all of the GPS data is fully processed.

A unique aspect of these surveys was near real-time processing of results while the GPS antenna was collecting. We did this by first streaming data from receivers over Bluetooth to Verizon XV6700 smartphones equipped with Geodetics, Inc. RTD Rover software, which utilizes the Real Time Kinematic (RTK) technique. An Ethernet connection is acquired between the smartphone and SOPAC servers to download detailed ephemeris and tropospheric information for use in processing. Positions are computed every second relative to the three closest base-stations in the California Real Time Network (CRTN), and the statistics of the previous position estimates are used to improve the accuracy of the measurements. One of the practical benefits of real-time, mm-accuracy positions was to locate a number of buried monuments in cases where the nearby cultural location markers have been removed since the 1993, 1999, or 2000 occupations. The final step will be to model the strain distribution throughout the Imperial Valley to properly determine the extent of the Brawley fault zone and see how strain is transferred between all of the faults.

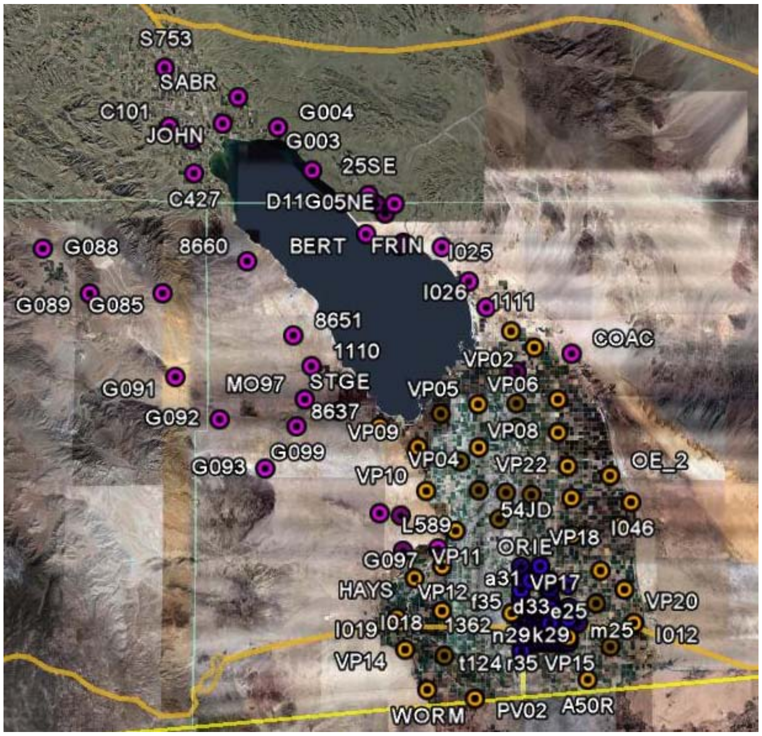

Figure 1: Overview of the 3 GPS surveys performed. The blue circles represent the February, 2008 survey, the orange circles are the October, 2008 survey, and the purple circles are the February, 2009 survey.

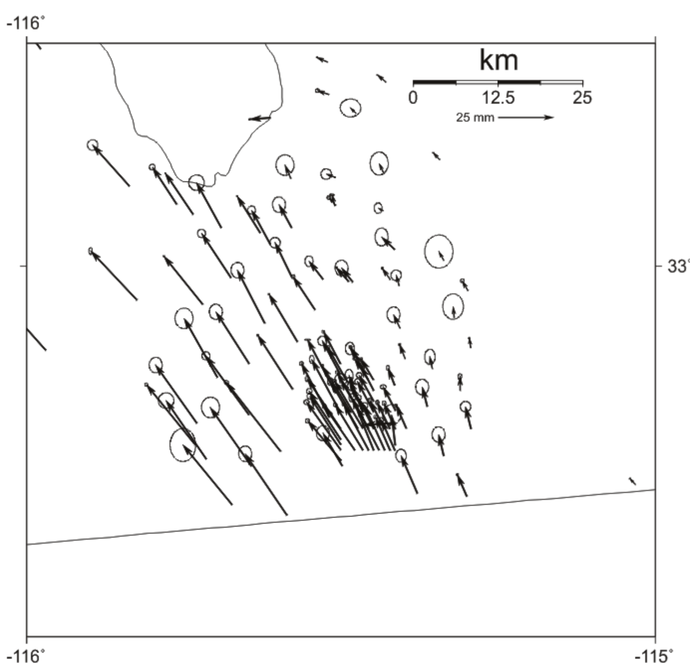

Figure 2: Preliminary crustal motion vectors from the February, 2008 and October, 2008 GPS surveys with 95% confidence intervals plotted. The nearby CGPS stations are also included.

2. Proposed Field Program GPS and CHIRP

We propose to fully analyze the data from the three surveys and perform repeated surveys of selected monuments as necessary (**Figure 1**). In addition we propose to extend the survey area to the Mexican section of the Imperial Fault and Cerro Prieto geothermal area (**Figure 3**). The Mexican surveys will be performed in collaboration with Javier Gonzales and graduate students from CICESE, Ensenada Mexico. As in the previous surveys, we will use a rapid-static technique to make the measurements. We will setup at each point at least twice for 15-20 minutes. We will make use of real-time CGPS stations, part of the California Real Time Network (CRTN - http://sopac.ucsd.edu/projects/realtime/) [*Genrich and Bock*, 2006]. CRTN was extended by SIO into Imperial County with funding from NASA/JPL and in collaboration with PBO. We will use the instantaneous positioning technique [*Bock et al*., 2000] and the CRTN infrastructure to process the data in real-time to verify that the two occupations agree to within the precision goal (< 1 cm). Any stations that do not meet this criteria will be resurveyed while we are still in the field. In addition, we will also post-process the data as a check on the real-time solutions. All participants will be trained in the use of CRTN. In addition to 7 GPS instruments available at SIO, we have obtained10 Zephyr antennae from UNAVCO, and 10 receivers from the retrofitted SCIGN stations (John McRaney/SCEC). These additional instruments will be used in our proposed campaign survey.

A new component of our proposal is to explore the possibility of investigating the paleoseismic history of the northern end of the Cerro Prieto fault using a towed CHIRP to image the upper 10 m of sediment. InSAR, leveling, and GPS analysis (Glowacka et al., 2009; Sarychikhina et al., 2009) as well as geological studies show that the trace of the Cerro Prieto fault passes beneath the recharge ponds of the geothermal fields (**Figure 3**). Depending on the amount of disturbance due to the excavation of the ponds and the natural characteristics of the sub-bottom reflectors it may be possible to image the offset stratigraphy to recover the slip history of this fault for the past 1-2 thousand years. Recently *Brothers et al* (2009) performed a CHIRP survey of the Southern Salton Sea and recorded the offsets from 10 earthquakes spanning the past 2000 years (**Figure 4**). This proposal includes a small amount of seed funding ($5k) to perform a reconnaissance CHIRP survey of this fault. We will request additional funding from the UCSD Academic Senate. The survey will be performed in collaboration with Javier Gonzales from CIECESE, Ensenada Mexico.

3. Education and Outreach

The surveys will be part of an SIO/SDSU graduate course taught each year. The course focuses on application of InSAR and GPS methods to tectonic deformation in the Salton Trough region of Southern California. Students and faculty from SIO, San Diego State and Cornell University participated in the Imperial surveys described above (**Figure 1**). Brendan Crowell (third year graduate student) will spend 1 months analyzing the GPS data under the guidance of Yehuda Bock. The other students and faculty learned the operational aspects of GPS as well as reviewed the scientific publications related to the tectonics of the region. Rowena Lohman participated in the 2008 field program and is incorporating the observations the Active Tectonics course at Cornell University. We will coordinate the 2010 surveys with Javier Gonzales who offers a similar field course at CIECESE, Ensenada, Mexico. Duncan Agnew will also participate in the experiment/class and will help to assemble all the diverse campaign-mode GPS data.

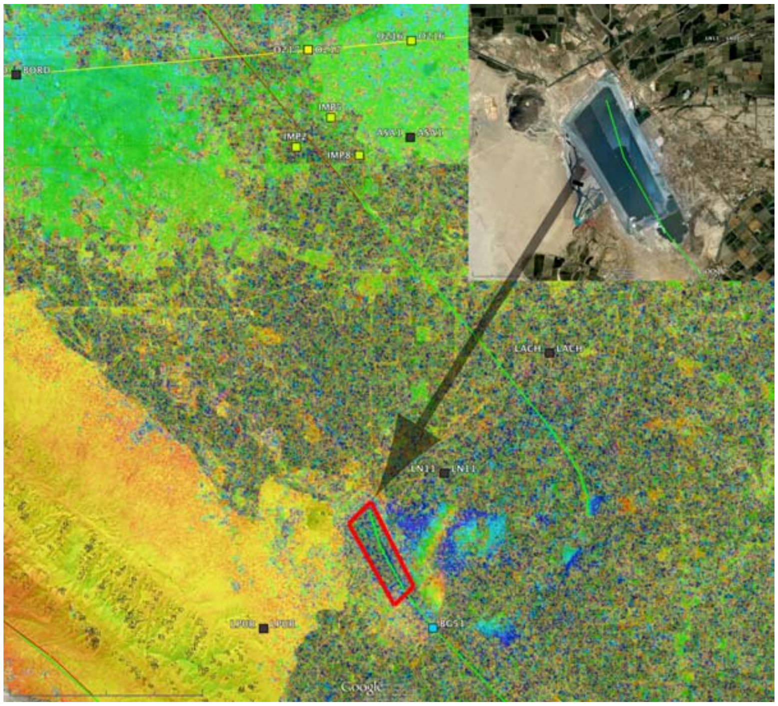

Figure 3: Map of Mexicali, Baja, Mexico including the traces of the Imperial and Cerro Prieto Faults. US Mexico Border is the yellow line near top of map. We propose to re-survey 12 GPS monuments on the Mexican side of the border. Colored image is 2-year ALOS interferogram showing 15 cm of subsidence in the stepover region between the two major faults. The Northern end of the Cerro Prieto Fault terminates beneath a 5-km long geothermal recharge pond that is 2-4 m deep (inset image). We propose a reconnaissance CHIRP survey to image the offset stratigraphy of the fault.

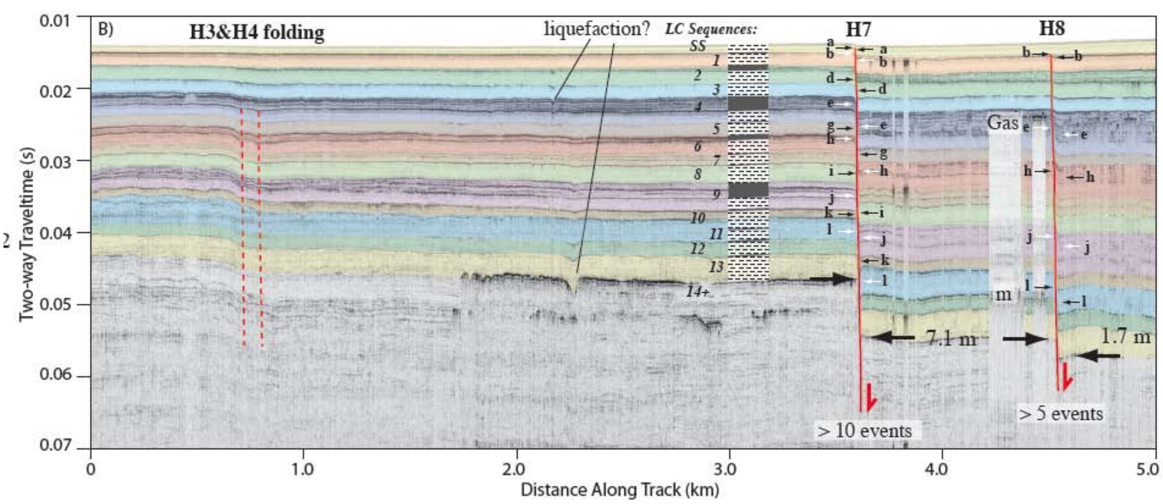

Figure 4: CHIRP survey line collected in the Salton Sea across a normal fault reveals details of the rupture history of the fault (*Brothers et al.*, 2009; *Brothers Ph. D. Defense, October*, 2009). More than ten events are identified along H7 and five on H8 based on growth patterns. Large black arrows denote cumulative offset across the base of 13L. Alternating white and black arrows point to event horizons on the footwall and hangingwall. Earthquakes with the same lettering on separate faults appear to have occurred within the same stratigraphic interval.

We anticipate that SDSU students will participate in the GPS field survey but do not request additional separate funding as student field expenses will be covered by SDSU SCEC matching funds. The primary goal is to provide experience in GPS surveying and processing for SDSU students. Once SDSU students have acquired the necessary expertise working on the Imperial fault survey, we plan to apply the expertise to re-survey one array (out of nineteen alignment arrays) that were installed along the Elsinore and San Jacinto faults in 1991 by T. Rockwell and

H. Magistrale [*Rockwell et al.,* 1992]. This is intended as a pilot effort to evaluate the possibility of re-surveying the other arrays in the future.

4. Introduction from 2008/2009 SCEC proposal

Located southwest of the Salton Sea, the Imperial Valley has experienced numerous large seismic events over the last century: 1906 (M=6.0+), 1915 (M_L=6.1 and 6.3), 1917 (M=5.5), 1927 (M=5.8), 1940 (M_L=7.1), 1979 (M_L=6.9) [*Genrich, et al.,* 1997]. Most of the seismic moment release from these earthquakes has occurred along the Imperial Fault, a right-lateral strike-slip fault which runs for 69 km through the eastern portion of El Centro and the western side of Holtville, south into the Mexicali Valley. The Imperial Fault is one of the fastest-moving faults in Southern California, with the average slip rate estimates varying from 15-20 mm/yr based on shoreline deposits [*Thomas and Rockwell*, 1996] to 35-43 mm/yr based on geodetic surveys [*Bennett, et al*., 1996; *Genrich, et al.,* 1997; *Wdowinski, et al*., 2001; *Lyons et al.,* 2002]. Geodetic rates suggest that the Imperial Fault accommodates almost 80% of the total plate motion between the North American and Pacific Plates. The earthquake recurrence interval for the Imperial Fault is on the order of 40 years for M_L=6.0 and 700 years for M_L=7.0+ [*Southern California Earthquake Center,* 2000]. The Imperial Valley is one of the most rapidly growing areas in California, and the next major earthquake on the Imperial Fault will have a considerable societal impact.

While the Imperial Fault accommodates the bulk of relative motion between the North American and Pacific plates, there is currently a debate about the partitioning of the plate boundary deformation between the San Andreas and San Jacinto strands further to the northwest [*Fay and Humpreys*, 2005]. Early studies suggest that the San Andreas is slipping at approximately twice the rate of the San Jacinto, at around 25 and 12 mm/yr respectively, with the Elsinore fault being far less active at 4 mm/yr [*Keller et al.,* 1982; *Weldon and Sieh,* 1985; *Rockwell et al.,* 1990; *Petersen and Wesnousky,* 1994; *Humphreys and Weldon,* 1994]. Additional geological [*Kendrick et al.,* 2002] and geodetic [*Johnson et al.,* 1994; *Anderson et al.,* 2003] studies suggest that the San Jacinto Fault is slipping at a higher rate than the San Andreas Fault. More recent geodetic modeling of the present-day GPS [*Fay and Humphreys,* 2005] and combined GPS/InSAR data [*Fialko*, 2006] find the San Andreas; San Jacinto velocity partitioning to be 21.4+/-0.5mm/yr; 15.2+/-0.9mm/yr and 25mm/yr; 19mm/yr, respectively.

A major unsolved issue involves the details of how this strain is transferred from the Imperial fault to the San Andreas and San Jacinto Strands. The primary transfer zone between the Imperial fault and the San Andreas is the Brawley fault zone, which also ruptured during the 1940 and 1979 Imperial Valley earthquakes. Several other episodes of slip have been noted on this fault system as well with the most recent occurring in 2002 and 2005 [*Meltzner et al*, 2006; *Lohman and McGuire,* 2007]. Recent paleoseismic studies show that the vertical slip (both co-seismic and creep) since 1970 has exceeded the long-term average. This may indicate an escalation of the slip in the Brawley zone [*Meltzner et al.,* 2006]. A second issue is the extent of interseismic creep and the effectively locked portions on the Imperial fault, and possible variability of the locking depth through the earthquake cycle. Radar interferometry would be an ideal tool for resolving these issues, but unfortunately agricultural activities in the Imperial Valley adversely affect the coherence of the radar phase over time intervals of just a few months. Persistent scattering methods have been partially successful in the regions north of the Salton Sea [*Lyons and Sandwell*, 2003] but temporal decorrelation is much worse in the area to the south [*Lohman and McGuire,* 2007; *Lohman*, SCEC Meeting, 2007].

References

Anderson, G., D. C. Agnew, and H. O. Johnson (2003), Salton Trough regional deformation estimated from combined trilateration and surveymode GPS data, Bull. Seismol. Soc. Am., 93, 2402–2414.

Bennett, R. A., W. Rodi, and R. E. Reilinger, Global Positioning System constraints on fault slip rates in southern California and northern Baja, Mexico, J. Geophys. Res., 101, 21,943–21,960, 1996.

Bock, Y., et al., Southern California Permanent GPS Geodetic Array: Continuous measurements of crustal deformation between the 1992 Landers and 1994 Northridge earthquakes, J. Geophys. Res., 102, 18,013 – 18,033, 1997.

Bock, Y., R. Nikolaidis, P. J. de Jonge, and M. Bevis, Instantaneous geodetic positioning at medium distances with the Global Positioning System, J. Geophys. Res., 105, 28,223– 28,253, 2000.

Brothers, D. S., N. W. Driscoll, G. M. Kent, A. J. Harding, J. M. Babcock and R. L. Baskin, Tectonic evolution of the Salton Sea inferred from seismic reflection data *Nature Geoscience* **2**, 581 - 584 (2009) doi:10.1038/ngeo590

Cohn, S. N., C. R. Allen, R. Gilman, and N. R. Goulty, Preearthquake and postearthquake creep on the Imperial Fault and the Brawley fault zone, in The Imperial Valley, California, Earthquake of October 15, 1979, U.S. Geol. Surv. Prof. Pap., 1254, 15– 24, 1982.

Crook, C. N., R. G. Mason, and P. R. Wood, Geodetic measurements of horizontal deformation on the Imperial Fault, U.S. Geol. Surv. Prof. Pap., 1254, 183–191, 1982.

Crowell, B.W., Y. Bock, D.T. Sandwell, Y. Fialko, and R.B. Lohman, Near real-time processing of results from the 2008 Imperial Valley, California, GPS survey, *2008 SCEC Annual Meeting*, poster 2-030, 2008.

Crowell, B.W., and Y. Bock, Near real-time processing and archiving of GPS surveys for crustal motion monitoring, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract G41C-0637, 2008.

Fay, N. P., and E. D. Humphreys (2005), Fault slip rates, effects of elastic heterogeneity on geodetic data, and the strength of the lower crust in the Salton Trough region, southern California, J. Geophys. Res., 110, B09401, doi:10.1029/2004JB003548.

Fialko, Y. , Interseismic strain accumulation and the earthquake potential on the southern San Andreas fault system, Nature, 441, 968-971, doi:10.1038, 2006.

Genrich, J. F., Geophysical applications of GPS kinematic techniques, Ph.D. thesis, Univ. of Calif., San Diego, 1992.

Genrich, J. F. and Y. Bock, Instantaneous geodetic positioning with 10-50 Hz GPS Measurements: Noise characteristics and implications for monitoring networks, *J. Geophys. Res., 111,* B03403, doi:10.1029/2005JB003617, 2006.

Genrich, J. F., Y. Bock, and R. G. Mason, Crustal deformation across the Imperial Fault: Results from kinematic GPS surveys and trilateration of a densely-spaced, small-aperture network, J. Geophys. Res., 102, 4985– 5004, 1997.

Glowacka, E., O. Sarychikhina, F. Suarez, F. Alejandro Nava, and R. Mellors, **2009**, Anthropogenic subsidence in the Mexicali Valley, Baja California, Mexico, and slip on the Saltillo fault, 2009, in press, *Environ Earth Sci*, DOI 10.1007/s12665-009-0137-y.

Goulty, N. R., R. O. Burford, C. R. Allen, R. Gilman, C. E. Johnson, and R. P. Keller, Large creep events on the Imperial Fault, California, Bull. Seismol. Soc. Am., 68, 517–521, 1978.

Hartzell, S. H., and T. H. Heaton, Inversion of strong ground motion and teleseismic waveform data for the fault rupture history of the 1979 Imperial Valley, California, earthquake, Bull. Seismol. Soc. Am., 73, 1553– 1583, 1983.

Hartzell, S. H., and D. V. Helmberger, Strong-motion modeling of the Imperial Valley earthquake of 1979, Bull. Seismol. Soc. Am., 72, 571– 596, 1982.

Humphreys, E. D., and R. J. Weldon (1994), Deformation across the western United States: A local estimate of Pacific –North America transform deformation, J. Geophys. Res., 99, 19,975–20,010.

Johnson, C. E., and D. P. Hill, Seismicity of the Imperial Valley, in The Imperial Valley, California, Earthquake of October 15, 1979, U.S. Geol. Surv. Prof. Pap., 1254, 15– 24, 1982.

Johnson, H. O., D. C. Agnew, and F. K. Wyatt (1994), Present-day crustal deformation in southern California, J. Geophys. Res., 99, 23,951– 23,974.

Keller, E. A., M. S. Bonkowski, R. J. Korsch, and R. J. Shlemon (1982), Tectonic geomorphology of the San Andreas fault zone in the southern Indio hills, Coachella Valley, California, Geol. Soc. Am. Bull., 93, 46– 56.

Kendrick, K. J., D. M. Morton, S. G. Wells, and R. W. Simpson (2002), Spatial and temporal deformation along the northern San Jacinto fault, southern California: Implications for slip rates, Bull. Seismol. Soc. Am., 92, 2782– 2802.

King, N. E., and W. Thatcher, The coseismic slip distributions of the 1940 and 1979 Imperial Valley, California, earthquakes and their implications, J. Geophys. Res., 103, 18,069–18,086, 1998.

Langbein, J., A. McGarr, M. J. S. Johnston, and P. W. Harsh, Geodetic measurements of postseismic crustal deformation following the 1979 Imperial Valley earthquake, California, Bull. Seismol. Soc. Am., 73, 1203– 1224, 1983.

Lohman, R. B., and McGuire, J. J. (2007) Earthquake swarms driven by aseismic creep in the Salton Trough, California. *J. Geophys. Res*., **112**, doi:10.1029/2006JB004596.

Lyons, S. N., Y. Bock, and D. T. Sandwell, Creep along the Imperial Fault, southern California, from GPS measurements, J. Geophys. Res., 107(B10), 2249, doi:10.1029/2001JB000763, 2002.

Lyons, S., and D. Sandwell, Fault creep along the southern San Andreas from interferometric synthetic aperture radar, permanent scatterers, and stacking, J. Geophys. Res., 108(B1), 2047, doi:10.1029/2002JB001831, 2003.

Mason, R. G., Geomensor surveys in the Imperial Valley, California, report, Geol. Dep., Imperial College, London, 1987.

Meltzner, A.J., T.K. Rockwell, and L.A. Owen (2006), Recent and long-term behavior of the Brawley fault zone, Imperial Valley, California: an escalation in slip rate?, *Bull. Seismol. Soc. Am*., *96*, 2304-2328, doi:10.1785/0120050233.

Olson, A. H., and R. J. Apsel, Finite faults and inverse theory with applications to the 1979 Imperial Valley earthquake, Bull. Seismol. Soc. Am., 72, 1969– 2001, 1982.

Petersen, M. D., and S. G. Wesnousky (1994), Fault slip rates and earthquake histories for active faults in southern California, Bull. Seismol. Soc. Am., 84, 1608– 1649.

Rockwell, T. K., C. Loughman, and P. Merifield (1990), Late Quaternary rate of slip along the San Jacinto fault zone near Anza, southern California, J. Geophys. Res., 95, 8593– 8605.

Rockwell, T. K., H. Magistrale, C. Haraden, C. K. Hirabashi, Emplacement of alignement arrays along the Elsinore and San Jacinto fault zones, Southern California, U.S.G.S Final technical report, grant no. 14-08-0001-G1771, 1992.

Sarychikhina, O., E. Glowacka, R. Mellors, R. Vázquez, L. Munguía and M. Guzmá, **2009**, Surface displacement and groundwater level changes associated with the 24 May 2006, Mw5.4 Morelia fault earthquake, Mexicali Valley, Baja California, Mexico, in press, *Bull. Seismo. Soc. Amer*.

Savage, J. C., and M. Lisowski, Inferred depth of creep on the Hayward Fault, central California, J. Geophys. Res., 98, 787– 793, 1993.

Savage, J. C., and R. W. Simpson, Surface strain accumulation and the seismic moment tensor, Bull. Seismol. Soc. Am., 87, 1354– 1361, 1997. Sharp, R. V., et al., Surface faulting in the central Imperial Valley, in The Imperial Valley, California, Earthquake, October 15, 1979, U.S. Geol. Surv. Prof. Pap., 1254, 119– 144, 1982.

Snay, R. A. and A. R. Drew, Supplementing geodetic data with prior information for crustal deformation in the Imperial Valley, California, Tech. Rep. No. 6, Univ. of Stuttgart, Stuttgart, Germany, 1988.

Southern California Earthquake Center (SCEC) Crustal Deformation Working Group, SCEC horizontal deformation map v.2.0, Los Angeles, 1999.

Thomas, A. P., and T. K. Rockwell, A 300- to 500-year history of slip on the Imperial Fault near the U.S. –Mexico border: Missing slip at the Imperial fault bottleneck, J. Geophys. Res., 101, 5987– 5997, 1996.

Wdowinski, S., Y. Sudman, and Y. Bock, Distribution of interseismic deformation along the San Andreas

fault system, southern California, Geophys. Res. Lett., 28, 2321–2324, 2001.
Weertman, J., Continuous distribution of dislocations on faults with finite friction, Bull. Seismol. Soc. Am., 54, 1035– 1058, 1964.
Weldon, R. J., and K. E. Sieh (1985), Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California, Geol. Soc. Am. Bull., 96, 793–812.
Working Group on California Earthquake Probabilities, Seismic hazard in southern California: Probable earthquakes, 1994 to 2024, Bull. Seismol. Soc. Am., 85, 379–439, 1995.

Budget Page
GPS and CHIRP Surveys of the Imperial and Cerro Prieto Faults, Mexico

SALARY RECHARGES: (includes fringe benefits)	Mo. Salary	%	# mos.	TOTAL
David Sandwell				n/c
Yehuda Bock				n/c
Yuri Fialko				n/c
Neal Driscoll				n/c
TRAVEL:	**Rate**		**# people**	
SCEC Annual Meeting in Palm Springs	$250		2	500
Survey costs, 6 people for 5 days			6	1,973
OTHER PROJECT RELATED EXPENSES				
Shipping and deployment of CHIRP to Cerro Prieto				5,000
TOTAL DIRECT COSTS				7,473
Less SIO Matching Funds				1,000
				6,473
INDIRECT COSTS:	**Base**	**Rate**		
	6,473	54.5%		3,527
TOTAL COST TO SCEC				10,000

Budget Justification

The experiment will involve at least 6 people from SIO for 5 or more days. We request $1,973 in travel expenses for car rental, hotel, camping, and food. Finally we request travel support for two people to attend the SCEC annual meeting. The shipping and deployment includes trucking from San Diego to Cerro Prieto, small boat rental, backhoe rental to deploy boat and CHIRP.