"Seismic hazard in Cascadia: Network support for Pacific Northwest Geodetic Array & Data Analysis Facility"

Final Project Summary
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Investigations Undertaken

NEHRP funded several CWU proposed tasks in FY 2004 and 2005, including convening the two PANGA investigator community meetings (which took place in March of 04 and February 2006), web development in support of results dissemination of time series in standard formats (raw, detrended, and cleaned) and the velocity field, updated semi-annually, and research into the extent to which Cascadia slow slip events occur throught the Cascadia subduction zone.

PANGA Investigator Meetinsg:

Two 2-day PANGA investigator community meeting were convened in March of 2004 at the Cascades Volcano Observatory and February 2006 at the University of Oregon in Eugene. Both years' meetings drew between fifty and 60 attendees, and served their purpose of bringing everybody up to speed on the majority of ongoing, GPS-based tectonics research.

Web development for data product distribution in support of the PANGA investigator community:

Results

We have made great progress on the portion of the NEHERP grant dedicated to development of a near-real time web update system. We developed a PANGA data page that is automatically updated nightly and contains the most recent data processed by the CWU Geodesy Laboratory. This includes latitude, longitude and vertical time series from ~130 PANGA stations, ~50 stations from the EarthScope Plate Boundary Observatory, ~130 IGS stations point-positioned, and roughly 200 additional North American CORS stations, deployed by the National Geodetic Survey, and a subset of these localized to stable cratonic regions east of the Rocky Mountain front. In total, data from over 500

stations is disseminated through this portal. The results of this can be observed at www.geodesy.cwu.edu/panga/index.php and Figure 1 below.

The software written under this grant entails a suite of software tools that parse the Geodesy Lab's data file system, generate lists of processed station-dates, quality-control the resultant positions based on information in the parameter covariance files, and then replicate the data into three products for posting to the web-raw, detrended and cleaned time series. Raw time series in the ITRF2000 reference frame [Altamimi, 2002] are posted, unfiltered and as-is, as are linearly detrended plots. Cleaned time series have linear trends, known offsets due to hardware changes and earthquakes, and phases and amplitudes of annual and semi-annual sinusoids simultaneously estimated and removed. For this last step, automatic execution of in-house software written in C for Unix is controlled by chron programs. These three sets of finalized positions are then plotted for delivery through the CWU Geodesy Lab data page web site. A final chron in the automated processing, scheduled to run at 2 a.m. daily, rebuilds the data page to reflect the newest time series and plots and generates a single tar file containing all Geodesy Lab data products that can be downloaded by any member of the geophysics community. These automated procedures run nightly, and the resultant data page is rarely more than a day old.

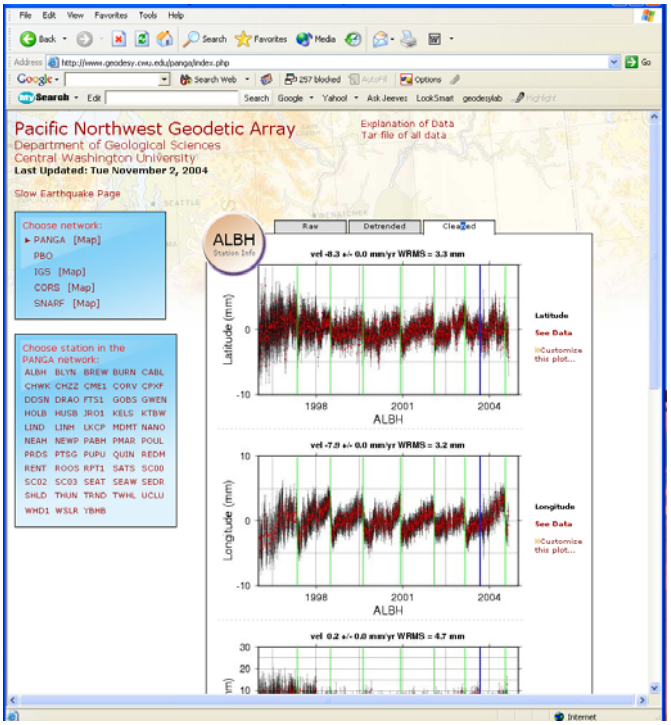

Figure 1. CWU Geodesy Lab data page. Over 4500 raw, detrended and cleaned ITRF2000 time series from the PANGA, IGS, CORS, and PBO networks are updated and posted nightly through a automated sequence of successive software tools. Reconfiguring these to deliver WSRN and OSRN network data is straightforward.

We are continuing development of the semi-annual velocity field publication in concert with a re-run of all data with major improvements to our processing strategy. These will form the focus of the Year 2 effort, together with continued enhancement of the web interface and the time series products.

Altamimi, Z., ITRF2000; a new release of the international terrestrial reference frame for earth science applications, JGR Journal of Geophysical Research B, 107 (10), 19p, 2002.

Published Articles

Two articles have been published as a result of this funding, and a third is currently in press at Journal of Geophysical Research. These articles describe the frequency and occurrence of slow slip events along the Cascadia megathrust. These can be found at www.geology.cwu.edu/facstaff/tim/VITAE/MelbourneEA_GRL_05.pdf and www.geology.cwu.edu/facstaff/tim/VITAE/Szeliga_EA_04.pdf . The third and final manuscript, in press at *Journal of Geophysical Research*, is led by CWU graduate student Walter Szeliga.

Non-technical summary

Global Positioning System (GPS) geodesy allows us to study fault motions and related deformation of the earth's surface. In the Pacific Northwest, seismic risk is posed by both a very large fault off shore, where ocean floor is consumed under the edge of the North American plate, and by smaller, and shallower faults that lie closer to population centers within the edge of the continent. This project uses GPS geodesy to characterize real-time deformation of the Earth's surface in the Pacific Northwest and to better characterize earthquake hazards in the region. This project supports an annual scientific workshop for investigators interested in Pacific Northwest geodesy and development of the PANGA web site to provide data products to a broad scientific community.

Reports published

Journal publications:

Szeliga W., Melbourne T., Miller M., Santillan, V., GPS Constraints of 34 Cascadia Slow Slip Events, 1997-2005, in press, *Journal of Geophysical Research*

Melbourne T., Szeliga W., Miller M., Santillan, V., Extent and duration of the 2003 Cascadia slow earthquake, *Geophysical Research Letters*, 32, L04301,doi:10.1029/2004GL021790 ,2005

Walter Szeliga, Timothy I. Melbourne, M. Meghan Miller, and Victor Marcello Santillian, 2004, Southern Cascadia episodic slow earthquakes. *Geophysical Research Letters*, 31, L16602, doi:10.1029/2004GL020824.

Williams, S. D. P., Y. Bock, P. Fang, P. Jamason, R. M. Nikolaidis, L. Prawirodirdjo, M. Miller, and D. J. Johnson, 2004, Error analysis of continuous GPS position time series, *J. Geophys. Res.*, *109*, B03412, doi:10.1029/2003JB002741.

Theses:

Szeliga, Walter, 2005, Time-dependent inversion of arbitrarily large geodetic networks, M.S. Thesis, Central Washington University. 112 p.

Michael Edward Caron, 2003, Realization of continuous GPS velocities over a neotectonic crustal block model for the Puget Sound area and the implications for

seismic hazard. M.S. Thesis, Central Washington University, Ellensburg, Washington. 92 p.

Abstracts:

Szeliga, W., Melbourne, T., Miller, M., Santillan, V., Sumner, W., 2003, Cascadia-wide rupture of episodic slow earthquakes, Eos, Transactions, American Geophysical Union, v. 84.

T. I. Melbourne, M. M. Miller, V. M., Santillan, W. Sumner, W. Szeliga, 2003, Duration and extent of the 2003 Cascadia Slow Earthquake Eos, Transactions, American Geophysical Union, v. 84.

M. M. Miller, V.M. Santillan, and D. J. Johnson, 2004, Application of a North America reference frame to regional GPS arrays in the deforming plate boundary region: Example from the Pacific Northwest Geodetic Array (PANGA). Eos, Transactions, American Geophysical Union *85*(17), Joint Assembly Supplement, Abstract G21D-06.

G. Blewitt, R. A. Bennett, E. Calais, T. A. Herring, K. M. Larson, M. M. Miller, G. Sella, R. A. Snay, M. E. Tamisiea, 2004, First report of the Stable North America Reference Frame (SNARF) working group. Eos, Transactions, American Geophysical Union *85*(17), Joint Assembly Supplement, Abstract G21C-01.

T. I. Melbourne, M. M. Miller, V. M., Santillan, W. Szeliga, 2004, The 2004 Cascadia slow earthquake. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G21A-0121.

N. Suszek, R. Bilham, R. Flake, T. I. Melbourne, and M. M. Miller, Long baseline tilt meter array to monitor Cascadia's slow earthquakes. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G51B-0089.

A. M. Miner, M. M. Miller, and V. M., Santillan, 2004, Progress towards a multiple-use GPS array in the Puget Sound region. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G21A-0129.

W. Szeliga, T. I. Melbourne, M. M. Miller, and V. M., Santillan, 2004, Cascadia slow earthquakes: Strategies for time independent inversion of displacement fields. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract NG31B-0879.

Szeliga, W., Melbourne, T., Miller, M., Santillan, V., Sumner, W., 2003, Cascadia-wide rupture of episodic slow earthquakes, Eos, Transactions, American Geophysical Union, v. 84.

T. I. Melbourne, M. M. Miller, V. M., Santillan, W. Sumner, W. Szeliga, 2003, Duration and extent of the 2003 Cascadia Slow Earthquake Eos, Transactions, American Geophysical Union, v. 84.

M. M. Miller, V.M. Santillan, and D. J. Johnson, 2004, Application of a North America reference frame to regional GPS arrays in the deforming plate boundary region: Example from the Pacific Northwest Geodetic Array (PANGA). Eos, Transactions,

American Geophysical Union *85*(17), Joint Assembly Supplement, Abstract G21D-06.

G. Blewitt, R. A. Bennett, E. Calais, T. A. Herring, K. M. Larson, M. M. Miller, G. Sella, R. A. Snay, M. E. Tamisiea, 2004, First report of the Stable North America Reference Frame (SNARF) working group. Eos, Transactions, American Geophysical Union *85*(17), Joint Assembly Supplement, Abstract G21C-01.

T. I. Melbourne, M. M. Miller, V. M., Santillan, W. Szeliga, 2004, The 2004 Cascadia slow earthquake. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G21A-0121.

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A. M. Miner, M. M. Miller, and V. M., Santillan, 2004, Progress towards a multiple-use GPS array in the Puget Sound region. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G21A-0129.

W. Szeliga, T. I. Melbourne, M. M. Miller, and V. M., Santillan, 2004, Cascadia slow earthquakes: Strategies for time independent inversion of displacement fields. Eos, Transactions, American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract NG31B-0879.

Data Availability

These data are freely available from the ftp site at ftp://panga.cwu.edu. RINEX data and data products such as the time series can be accessed through the main PANGA web page at http://www.panga.cwu.edu/. The data are in standard RINEX format and any questions regarding data can be directed to Andrew Miner or Marcello Santillan, 509/963-2822, minera@geology.cwu.edu and marcelo@geology.cwu.edu. T