Assistance Award 01HQGR0162

"ENHANCING PANGA FOR SEISMIC RISK ASSESSMENT: COLLABORATIVE RESEARCH, CENTRAL WASHINGTON UNIVERSITY, OREGON STATE UNIVERSITY, AND UNIVERSITY OF WASHINGTON"

Proposal dated Spring, 2000.

Final Technical Report
(budget period 02/01/01-/01/31/02)

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Program Element: Elements I, II
Key Words: GPS-Continuous, Regional Modeling, Neotectonics, Seismotectonics

Assistance Award 01HQGR0054
"Enhancing PANGA for Seismic Risk Assessment: Collaborative Research with Central Washington University, Oregon State University, and University of Washington" Proposal dated Spring, 2000.
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Abstract

In the Pacific Northwest, efforts to quantify the hazards associated with the Cascadia subduction zone and crustal faults have been hampered by the difficulty of geologic field work and the lack of plate boundary seismicity. Global Positioning System (GPS) measurements now offer a new methodology applicable to just this type of difficult tectonic problem. GPS measurement of crustal motion have rapidly taken the lead in the study of plate boundary interactions at subduction and transform boundaries worldwide. We address large scale plate-margin-scale deformation as well as local seismic risk by continued monitoring of widely spaced PANGA sites and developing a much denser network of high-quality observations by integrating campaign and continuous measurements into a regional velocity field.

PANGA is a consortium of US and Canadian institutions engaged in GPS geodetic investigation of the Cascadia plate boundary system. Currently, 50 permanent GPS sites have been installed and are now collecting continuous data in the Pacific Northwest. These sites are funded by NSF, US Geological Survey, and the Geologic Survey of Canada and are supplemented by non-geodetic quality sites operated by the NGS. The primary focus of PANGA is to establish a velocity field for the Cascadia region that can be used directly to assess seismic hazards from the Cascadia plate interface, and also to understand the complex kinematics of the Pacific Northwest as a whole.

Along strike variability in plate locking, the position of the coupled interface relative to population centers, the importance of the second tectonic signal propagating northward from the distributed Pacific-North America plate boundary system, and the as yet unknown signature of active crustal faults are crucial to an assessment of earthquake hazards in Cascadia. This project has two principal objectives designed to address these issues: 1) Generation of an integrated velocity field that combines regionally available campaign observations with continuous data from PANGA and adjacent networks and sets them in an internally consistent and robust reference frame will provide constraints to the National Seismic Hazards Mapping Project and improve our understanding of the budget of megathrust coupling vs. crustal deformation. This aspect of the project has direct impact on estimated budgets of seismic strain. The velocity field will be continually updated as new data, improved methods, and new constraints from other disciplines become available. 2) The PANGA Investigators Community Meeting. The continuous data have added important new constraints to characterizing crustal deformation in the Pacific Northwest and vastly strengthen the context of campaign results, allowing us to rigorously address reference frame issues and characterize error spectra.

Goals of the project:

Seismic risk in the Pacific Northwest is concentrated in the populous fore-arc region, and realistic assessment of such risk hinges on understanding along-strike variation in subduction zone dynamics as well as the role of crustal faults in generating earthquakes. This objective requires an integrated view of the three-plate interaction zone, achieved by the overall PANGA network of permanent and campaign sites. We set out to integrate regional GPS campaign results into the PANGA velocity field, and enhance these regional studies through a coordination of the investigator community. These collectively form the basis for characterizing seismic risk in densely populated regions of the Pacific Northwest.

Integrated Velocity Field

Determining seismic risk in the Pacific Northwest from GPS observations critically hinges on separating mutually interfering deformation fields. Elastic and viscoelastic deformation from subduction zone coupling dominates the velocity field close to the coast and diminishes to the east; its effects penetrate at least as far to the east as the Puget trough and Willamette Valley. Along this corridor, crustal faults are known to play an important part in posing urban seismic risk and, at least in the case of the Seattle fault, slip rates of several mm/yr or more are high enough to be well resolved with GPS. These deformation fields are mutually interfering, yet each has a distinctive pattern with different strain gradients that allow their separation where data of sufficient precision and density are available. Yet estimates of the crustal deformation budget are very sensitive to how elastic strain on the megathrust is modeled. Thus, a dense and precise velocity field, sufficient to extract these mutually interfering deformation sources, will provide a major advance to quantifying seismic risk in the Pacific Northwest and in particular, the urban corridor.

Continuous and campaign GPS data, taken together, can provide the precision and density needed to address this problem. Continuous GPS observations have established a high precision backbone for recent GPS studies in the Pacific Northwest. Yet the expense of new continuous GPS stations with geodetic grade monuments has made a continuous network of high density prohibitively expensive in the recent past. In contrast, campaign GPS observations have provided the much needed spatial density, but rely on the temporal sampling of continuous stations to provide error budget estimates and fiducial control that establishes firm links to plate-scale reference frames. To date, campaign GPS studies published by different investigator groups are plagued by differences in treatment of reference frames. Relative station velocities within these solutions are generally robust, but absolute motion relative to various realizations of nominal North America include strong biases. These biases are very important to resolving fore-arc motion, for instance, relative to North America. Such fore-arc motion is a key constraint on subduction zone coupling scenarios, which in turn affects the estimates of strain accommodated by crustal deformation.

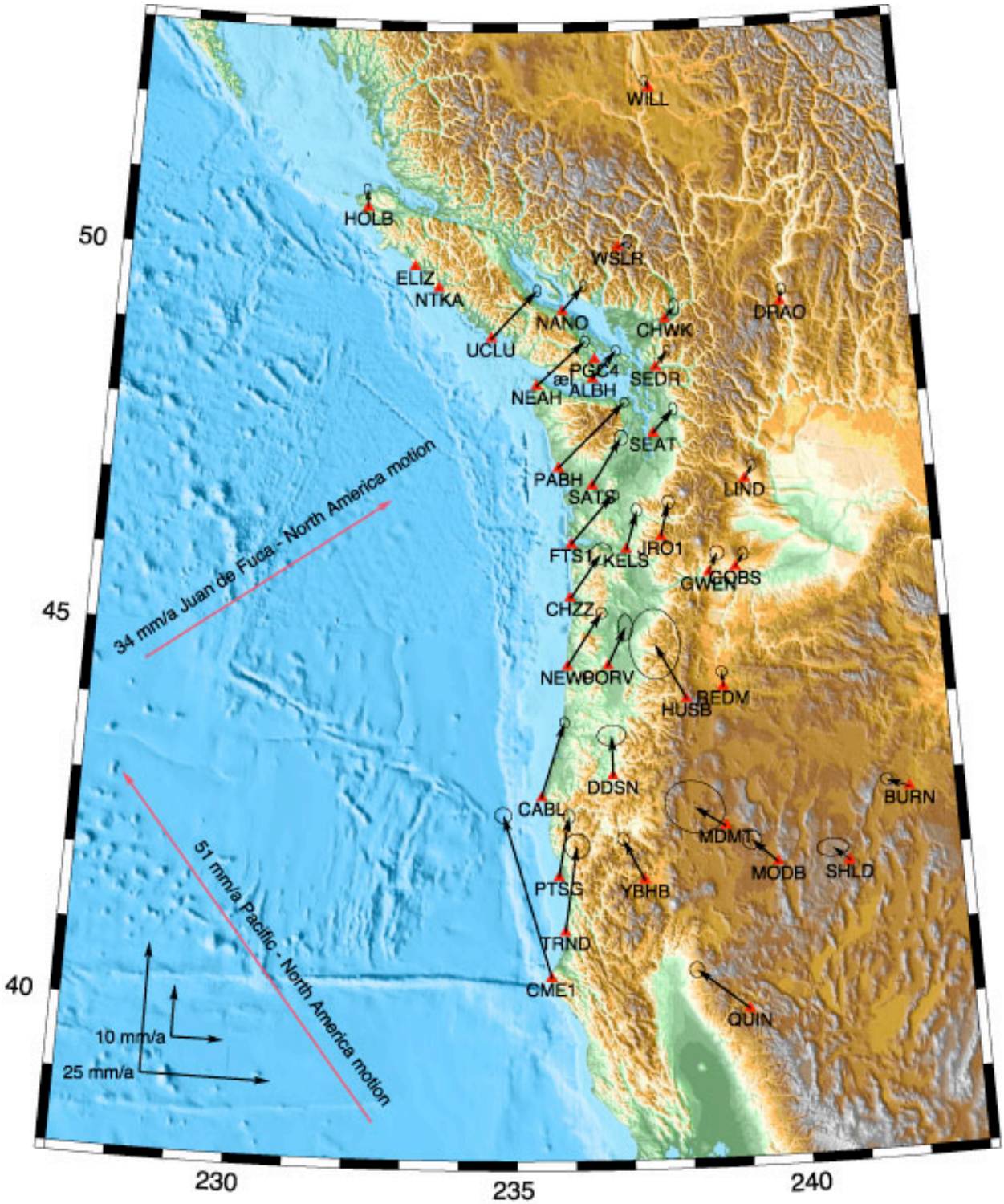

Figure 1. GPS-determined velocity field, Pacific Northwest Geodetic Array (PANGA)Velocity Field Version 2. Data analysis is described in Miller et al. [2001]; this version also includes ambiguity resolution and improved regional stabilization. Velocities plotted relative to North America, defined by 16 GPS stations in the plate interior and are based on 3.8 years of data from continuously operating GPS stations. Error ellipses show two-dimensional 95% confidence regions. HUSB shows only 10 months of data from an actively deforming volcanic edifice.

Results

PANGA integrated velocity field:

We have undertaken producing a high-quality, regional velocity field from integrating continuous data and published or publicly available campaign results from USGS, CVO, NGS, UW, CWU, RPI/OSU and Univ. of Alaska. Reoccupation of many campaign stations were undertaken by the UW part of this project during the contract period. This field work was done using the same receivers and techniques used in their original establishment. These data were then integrated into the common reference frame based on the continuous data to establish a relatively high density, common basis velocity field. Using this velocity field, we can establish the relative budgets of megathrust coupling strain and crustal deformation, and to develop protocols and data products based on this velocity field that will provide primary constraints for the National Seismic Hazards Mapping Project. An ancillary goal is to provide a publicly available data product similar to the Southern California Earthquake Center Velocity Field, Version 2, that can be accessed by investigators for seismic risk or geodynamics investigations. Once the data integration of historical data is complete and the scripts and storage configuration for calculating the velocity field are established, new data can be incorporated, and adjustments can be made for such things as reference frame improvements, orbit improvements, better antenna phase center models and other enhancements.

The first step in the integration process was an update of the continuous GPS velocity field (Figure 1). Several stations now have mature velocity determinations that are included in the regional velocity field for the first time. Others, like HUSB, we include because of their timely interest (this is the new USGS station on Husband, near the deforming Sisters edifice). In addition, enhancement to our data processing strategy and improved uncertainty estimates are included in this version. Next, we undertook the assembly of campaign data with some success. We were able to gather the USGS, CWU, and NGS data sets, which required various levels of work on the actual metadata. The USGS and CWU data sets were in good shape, but a lot of effort was expended in editing rinex files for consistency in antenna heights, antenna types, etc. From some of these data we were able to run solutions, although we don't yet have a robust velocity field for all of the campaign data, much of which is comes from relatively short observations. Outstanding issues with antenna types and heights, and inconsistency in station i.d. remain, primarily with the pre-1996 data, where there is more variability among antenna types. The other item that remains to be sorted out is correlation of stations between multiple data sets. The results from part of the campaign observations along the Columbia River corridor are shown in Figure 2.

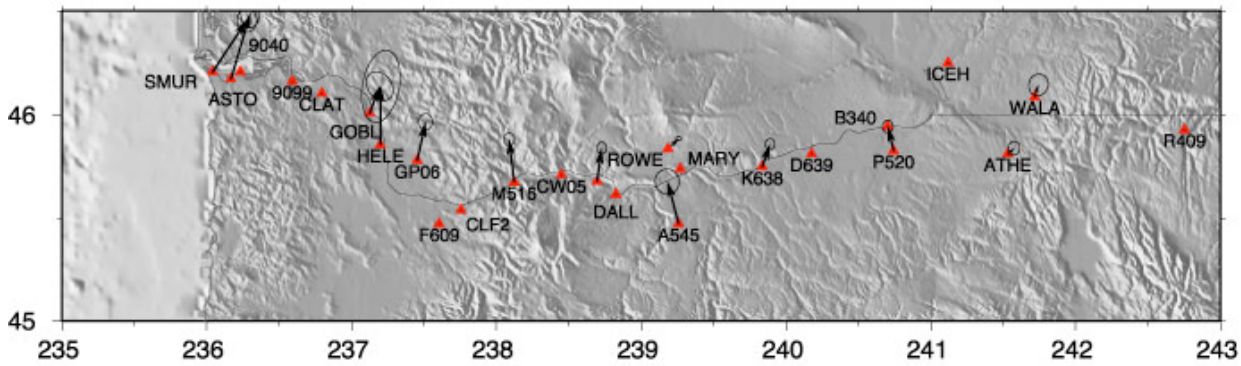

Figure 2. GPS-determined velocity field, Columbia River corridor. Velocities transformed into a PANGA continuous GPS station frame that is determined relative to North America, defined by 16 GPS stations in the plate interior (see Figure 1). Velocities are based on only 2 epochs of data, two years apart. Each epoch includes three to five days comprising 8-24 hour observations. Error ellipses show two-dimensional 95% confidence regions, and for such a small data set almost certainly underestimate true uncertainties. Additional occupations will provide a better basis for uncertainty estimates.

Reports published

Journal publication:

Theses:

Abstracts:

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Data Availability

All PANGA data are freely available from the ftp site at ftp://panga.cwu.edu. The data are in standard RINEX format and any questions regarding data can be directed to Dan Johnson, dan@geology.cwu.edu.