Deformation measurements across an entire subduction plate boundary: Cascadia Subduction Zone

C. David. Chadwell, Michael D. Tryon, Uwe Send

Scripps Institution of Oceanography, University of California San Diego

Emails: cchadwell@ucsd.edu, mtryon@ucsd.edu, usend@ucsd.edu

Proposed site: Cascadia Subduction Zone

Themes addressed: (From the GeoPRISMS Draft Science Plan)

4.1 What governs the size, location and frequency of great subduction zone earthquakes and how is this related to the spatial and temporal variation of slip behaviors observed along subduction faults?

4.2 How does deformation across the subduction plate boundary evolve in space and time, through the seismic cycle and beyond?

Key existing and forthcoming data/infrastructure: 1) Moored-buoy for continuous GPS-Acoustic measurements of horizontal deformation and continuous seawater pressure measurements at the seafloor with a low-drift sensor and in-situ physical oceanographic measurements for sounds speed and density. 2) Earthscope, Plate Boundary Observatory, Ocean Observatories Initiative-Regional Scale Nodes (seafloor cable) and -Endurance Array (buoys), Cascadia Initiative Ocean Bottom Seismometer array.

Discussion:

We propose an experiment to measure crustal deformation along a profile that crosses the entire region of a subduction zone from the incoming plate, the offshore continental slope and the sub-aerial continent. Subduction thrust faults generate the largest earthquakes and their submerged portions are where tsunami are generated causing the most devastating geo-hazard of recent times (Figure 1). However, little is known about the dynamics or even the kinematics of deformation offshore. Space-based tracking based solely upon electromagnetic energy (GPS, InSAR, etc) can track deformation of the sub-aerial region down to the coast, but cannot follow the deformation offshore where it continues to increase during the interseismic period, and where tsunami are generated with co-seismic release. GPS tracking of surface platforms combined with acoustic ranging to seafloor transponders has proven to be an effective means of measuring offshore deformation within subduction zones with sub-centimeter resolution [*Gagnon et al.,* 2005, *Matsumoto et al.*, 2008]. However, to date, data have been collected infrequently during semi-annual, annual, and bi-annual visits with a ship lasting a few days. Sensors to measure vertical deformation by observing seawater pressure at the seafloor have been left in place to record continuously, but to date they have drift rates of several centimeters per year [*Polster et al.*, 2009]. They also are sensitive to changes in the density of the water column and the sea surface height. To address these issues, we have developed a moored-buoy that provides continuous, sustained measurements of both horizontal and vertical deformation of the seafloor, the sea surface height, and the density of the water column beneath the buoy (Figure 2). Using GPS and acoustics, horizontal positions of the seafloor are measured once per minute. Initial tests in shallow water over a few months show resolution of the horizontal component consistent with previous ship-based systems at the centimeter level [*Chadwell et al.*, 2009]. Vertical deformation is measured with water pressure sensors that periodically switch to a constant pressure standard, allowing sensor drift to be quantified and removed. Oceanographic effects, measured by the buoy and CTD string, are likewise removed from the pressure signal leaving seafloor vertical motion as the residual. Deepwater tests are currently underway and preliminary data suggests cm/yr resolution will be attained.

We propose to deploy this system along a profile cutting across the Cascadia Subduction Zone (CSZ) and supplement it with one or two campaign-style GPS-Acoustic arrays with drift-compensated pressure sensors along the same profile. Sub-aerial deformation is already continuously monitored with GPS at hundreds of sites along the CSZ. Seafloor deformation measurements at just a few sites could meet the Science plan goal 4.2 – "How deformation across the subduction zone evolve?". Additional data sensors from the OOI will contribute to addressing Science plan goal 4.1 –"… what governs large events?... ". Earthquake seismicity and crustal structure derived from the Cascadia Initiative OBS array would also contribute. However, we note that pressure sensors deployed on these OBSs will suffer from several centimeters of drift per year and be unable to resolve interseismic deformation along the plate interface.

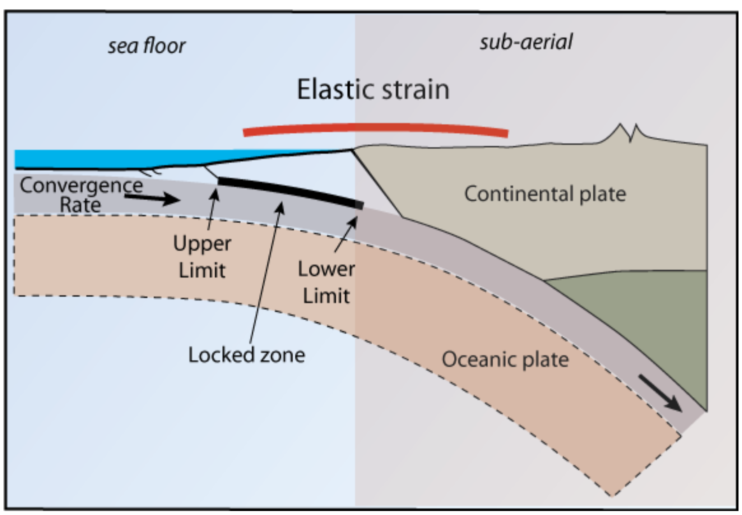

Figure 1: Profile view of subduction process indicating the significance of the offshore region.

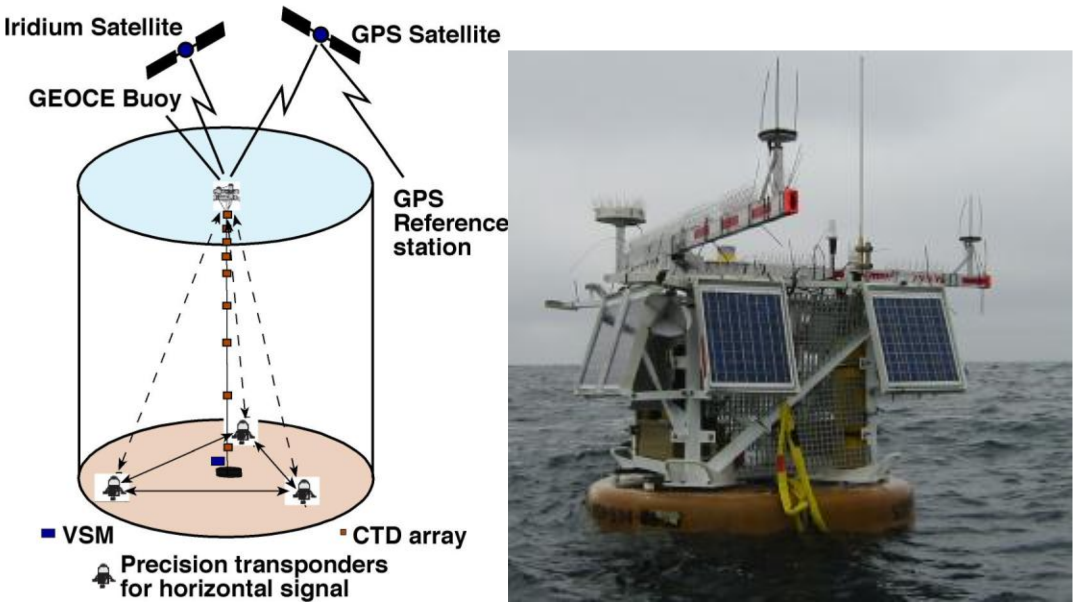

Figure 2: Moored-buoy for continuous horizontal and vertical deformation measurements: concept (left), implementation (right).

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