A Vision for Offshore Geodetic Studies in Cascadia

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Recent devastating megathrust earthquakes off Sumatra, Chile and Japan have illustrated the hazard posed by subduction zones and raised awareness for a comparable earthquake along the coast of the Pacific Northwest. Because subduction zones extend across the coastline and continental shelf, geophysical investigations of subduction zone processes are optimally supported by terrestrial and seafloor observing networks. With the terrestrial network already established in Cascadia, significant recent efforts have been devoted to extending earthquake monitoring offshore. Both the NEPTUNE Canada and Ocean Observatory Initiative regional cabled observatories include broadband seismometers, and the Cascadia Initiative is supporting a four-year deployment of 70 autonomous ocean bottom seismometers. While these efforts will bolster the seismological observations, relatively little attention has been given to the need for complementary offshore geodetic observations, despite their importance for understanding the basic science and hazard of the Cascadia subduction zone.

Seafloor geodetic measurements of long-term vertical and/or horizontal deformation above the shallow slab are necessary to constrain the updip extent of locking with important implications for the size and tsunamigenic potential of a megathrust earthquake. Onshore observations of crustal deformation provide no constraint on the degree or extent of locking on the outer accretionary prism. Recent observations in Japan, New Zealand, and Costa Rica suggest that slow slip and tremor can occur at relatively shallow depths (<20 km) in the subduction system. In Japan, transient slip events have been detected offshore, beneath the outer accretionary prism. Currently, there is inadequate instrumentation off the coast of Cascadia to detect aseismic slip transients, let alone characterize their behavior, recurrence, and magnitude. Slow slip events near the trench would also further constrain the up-dip extent of the locked zone.

We present a series of elastic half space models that elucidate the observational requirements for steady-state interseismic deformation in Cascadia and for shallow slow slip events. Convergence rates are ~3 cm yr^{-1} off Oregon and ~4 cm yr^{-1} off Washington. On the seafloor near the updip limit of the locked zone, the models predict maximum linear strain rates of $<10^{-6}$ yr^{-1}, maximum differential uplift rates of ~1 cm yr^{-1} and maximum shear strain rates of ~2×10^{-7} yr^{-1}. Measurements of horizontal and vertical motions will require a strike-perpendicular spacing of about 20 km and 10 km, respectively, to adequately resolve the locked zone. The expected maximum horizontal and vertical signals from slow slip events with moment magnitudes between 6 and 7, range from a few millimeters to a few centimeters.

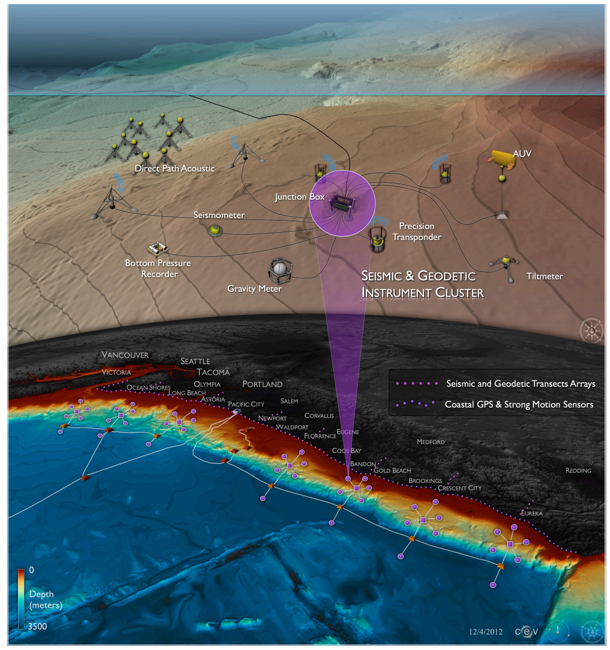

Figure 1. *Illustrative diagram showing a possible configuration of the US component of a Cascadia cabled seafloor geodetic and seismic array and seafloor instrumentation at one node based on expanding the Ocean Observatory Initiative's regional cabled observatory (courtesy UW Center for Environmental Visualization).*

Presently, there are nascent efforts in Cascadia to initiate offshore geodetic observations, but their scale is dwarfed by efforts in Japan. In order to characterize the locked zone and its variation along strike, multiple geodetic profiles must be occupied in Cascadia. Offshore geodesy will be challenging with the expected signals hovering near the expected noise level of many techniques. Field campaigns should be accompanied by continued efforts to develop new technologies including those with significant power requirements that are best supported by cabled deployments.

Once the basic patterns of deformation have been characterized by campaign measurements there is likely to be a desire for long-term geodetic monitoring offshore. In Japan considerable resources are being invested in the deployment of extensive cabled observatories to support geophysical observations. In Cascadia the OOI and NEPTUNE Canada observatories could be expanded to extend along the full length of the subduction zone and to include extensive geodetic and seismic networks (Figure 1).