

Sustained Offshore Geophysical Monitoring in Cascadia

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From our perspective, there are a number of requirements for a successful Subduction Zone Observatory (SZO). First, it must address important scientific topics that cannot be addressed without the facility. Second, it should be seen as societally relevant by contributing to the understanding and mitigation of subduction zone hazards. Third, it needs to be seen as a good investment, which means it should build upon existing knowledge, infrastructure and data sets and it should leverage NSF funds through careful coordination with related stakeholders. These stakeholders could include federal agencies responsible for monitoring and mitigating subduction zone hazards in the US, state and local governments with commensurate responsibilities, major corporations with at-risk infrastructure, and international partners. We argue that the Cascadia subduction zone fulfills these requirements, making it a logical component of a SZO. Furthermore, for any subduction zone, acquiring offshore observations will be necessary to fully understand the system. Cascadia is well positioned to host continuous and sustained observations of the offshore environment for scientific study, hazard mitigation, and early warning of the megathrust source and tsunami.

A key objective of subduction zone science is to understand the great earthquake cycle and the mechanisms of strain accumulation and strain release through slip on the plate boundary. Because the last great earthquake in Cascadia was in 1700, the subduction zone is in the late stages of interseismic deformation, and studies in Cascadia complement those in subduction zones that have failed more recently. For reasons that are poorly understood, most of the subduction zone is unusually seismically quiet and the plate interface is almost devoid of small thrust earthquakes. This is commonly taken as evidence that the megathrust is completely locked but it could equally well indicate that portions of the plate are creeping aseismically. Offshore geodetic data are lacking and the geodetic observations on land provide limited resolution of the locked zone, which resides mostly offshore. Down dip of the locked zone, Cascadia is characterized by extensive episodic tremor and slip. It is unknown whether slow slip occurs seaward of the locked zone, and if so, whether it is coupled temporally to slow slip down dip.

There is evidence that the subduction zone is segmented along-strike from a variety of sources suggest, including paleoseismology, the distribution of episodic tremor and slip and deep seismicity, forearc topography and deformation, arc volcanism, structural mapping of the accretionary prism, and geophysical imaging of the overriding plate. An important scientific pursuit is to understand the linked processes and conditions that control this segmentation. The segmentation appears to begin at the trench and continue down dip with the subducting slab. In contrast to the rest of the subduction zone, it appears from geodetic studies that the plate interface may be only partially locked off central Oregon in a region where offshore earthquakes are detected on the plate interface; but otherwise it is unknown how the segmentation of the subduction zone is manifested in the dynamics of the plate interface.

Offshore geodetic studies of secular and episodic strain are urgently required in Cascadia to constrain the distribution of plate locking and its variations along strike. Existing seafloor seismic observations are not dense or sustained enough to be certain that small earthquakes or tremor are always absent from the plate interface. Seafloor hydrological observation on the accretionary prism

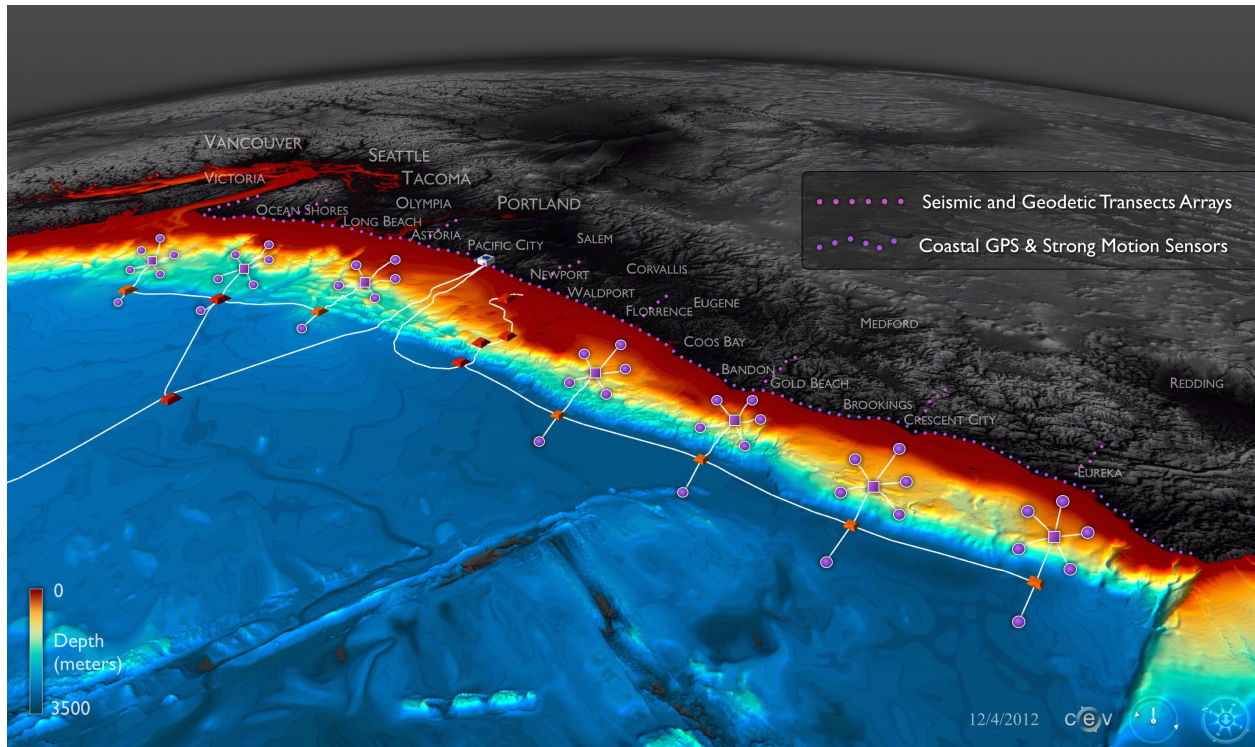
may also be quite sensitive to transitory strain events. While these issues can and should be addressed with autonomous experiments, a systematic search for episodic behavior with unknown timescales and spatial distributions will require sustained observations over large regions, which are likely only feasible with permanent cabled instrumentation.

There is also a strong case to be made for installing an offshore cabled network with real-time capability for hazards applications. The USGS is working with partner institutions to install an earthquake early warning system along the UW west coast. In the Pacific Northwest, early warning will use data streams from the seismic and geodetic networks on land as well as from the few instruments available from the ocean cabled networks. For earthquakes that initiate offshore in the subduction zone, the existing network will provide a warning. However, the availability of real-time offshore instrumentation along the entire subduction zone would improve its reliability and accuracy, add up to 15 s to the warning time, and ensure an early warning in seconds-to-minutes for coastal communities nearest the epicenter where the strongest ground shaking will occur. The DART buoy network of the NOAA tsunami warning system is designed primarily to warn West Coast communities that might be struck by tsunamis generated by distant earthquakes; but locally-generated tsunami warnings require a network of seafloor pressure sensors that cover the offshore subduction zone and the Straits of Juan de Fuca. These real-time data are needed for early and continuously updated predictions of the impact on coastal communities on the West Coast, in the Straits and in Puget Sound; in the immediate aftermath, these updated tsunami impact predictions will provide critical guidance for decision-makers on prioritizing the safe and efficient deployment of human and material resources for intelligence gathering, search, rescue, and recovery.

Long-term on- and off-shore monitoring will also provide baseline observations can also be used to detect and evaluate temporal changes in the subduction environment. Tantalizing evidence from the most recent great earthquakes in Japan and Chile suggests that these events may have seismically and geodetically observable precursory signals, but improved monitoring is required to understand the degree to which they are predictive. Additionally, an offshore network of instruments could be leveraged for additional scientific pursuits, including the collection of valuable data on gas hydrates, shallow fluid flow in the prism, oceanographic signals in the water column, and the activity of turbidity currents.

On land there are large modern seismic and geodetic networks and geophysical imaging experiments have been conducted for various objectives at a variety of scales. An SZO component in Cascadia would add to the extensive infrastructure and data sets that are already in place. Numerous offshore experiments contribute to a foundational data set for the region, including active source seismic profiles that cross the margin, the Cascadia Initiative and contemporaneous ocean bottom seismometer experiments, and the 2014 MOCHA experiment - an extensive amphibious magnetotelluric data set for three-dimensional imaging. Both NSF's Ocean Observatories Initiative and Ocean Networks Canada operate regional cabled seafloor observatories that cross the subduction zone off central Oregon and at two sites off Vancouver Island, respectively. These real-time observatories already host geophysical instrumentation but have a limited footprint along strike, although they were designed with expansion in mind.

It has long been recognized within NSF that successful studies of subduction zones require an amphibious approach; this was a primary justification for the establishment of the MARGINS and GeoPRISMS programs and it has also motivated the Cascadia Initiative community geophysical experiment and the proposed Alaska Amphibious community experiment. An SZO facility in Cascadia would facilitate observations that would build upon and substantially expand such efforts, and would provide an opportunity to collect long-term, broad-scale observations of the whole subduction zone systems that could serve both hazard monitoring and basic scientific objectives.



Schematic diagram showing a possible expansion of the Ocean Observatories Initiative cabled array that would extend along the full strike of the US portion of the Cascadia subduction zone for the purposes of earthquake and tsunami early warning, hazards mitigation and scientific research.