Preliminary Earthquake Detection and Location Using the Cascadia Iniative Amphibious Dataset

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Introduction

The Cascadia Subduction Zone (CSZ) presently hosts episodic tremor and slip (ETS), small intraplate and few small interplate earthquakes.

No great earthquakes instrumentally or historically recorded, but geologic evidence for past great earthquakes (~18 in the last 9800 years), with the most recent occurring in 1700 and estimated to have been ~Mw 8.7-9.2.

The seismogenic zone of the CSZ is located primarily offshore, the extent of which is estimated by thermal modeling. Geodetic analysis indicates that the seismogenic zone is presently locked.

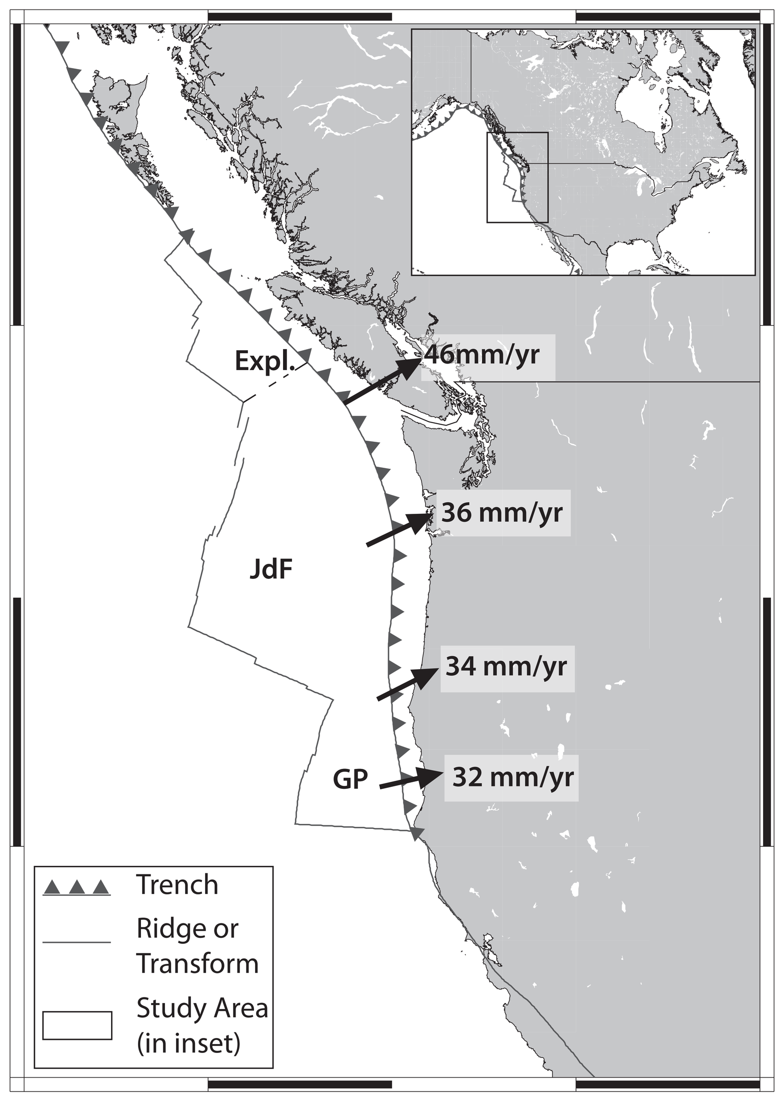
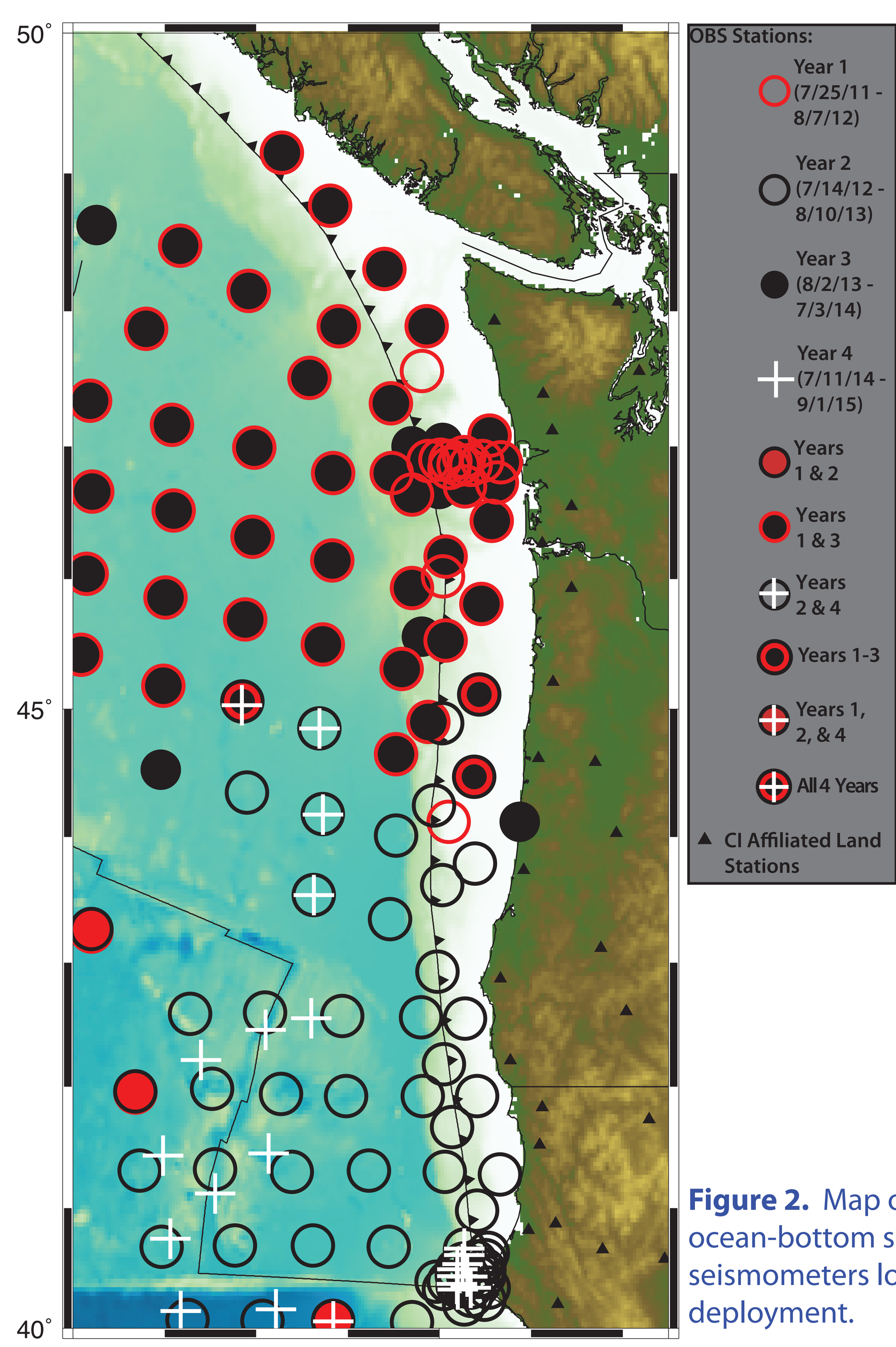


Figure 1. Regional and tectonic setting of the CSZ, where the Juan de Fuca (JdF) and Gorda (GP) plates are subducting beneath the North American plate at ~3-4.5 cm/yr.



CI includes ~60 OBS stations and 94 land stations from various networks (Berkeley BK, Global Seismograph Network IU, Earthscope TA, Univ. Oregon UO, U.S. National Seismic Network US, Pacific NW Regional Network UW)

CI was developed to study questions related to the megathrust, volcanic arc, and the subduction Juan de Fuca and Gorda plates.

The new presence of seismometers directly over the seismogenic zone enable us to better detect interplate earthquakes occurring within the seismogenic zone.

Here we detect and locate repeating seismogenic zone earthquakes, which likely represent megathrust asperities.

Figure 2. Map of the Cascadia Iniative (CI) ocean-bottom seismometer (OBS) and ffiliated land seismometers locations during the 4 years of deployment.

Subspace Detection

A portion of the data corresponding to a sliding window is projected onto a subspace spanned by the basis vectors. Comparison of the orignal windowed data with the projected data gives a z-statistic (like a correlation coefficient) for each step through the data.

For a given data file containing unknown signals, we end up with a distribution of correlation coefficients and/or z-statistics. Those above a chosen threshold likely correspond to events.

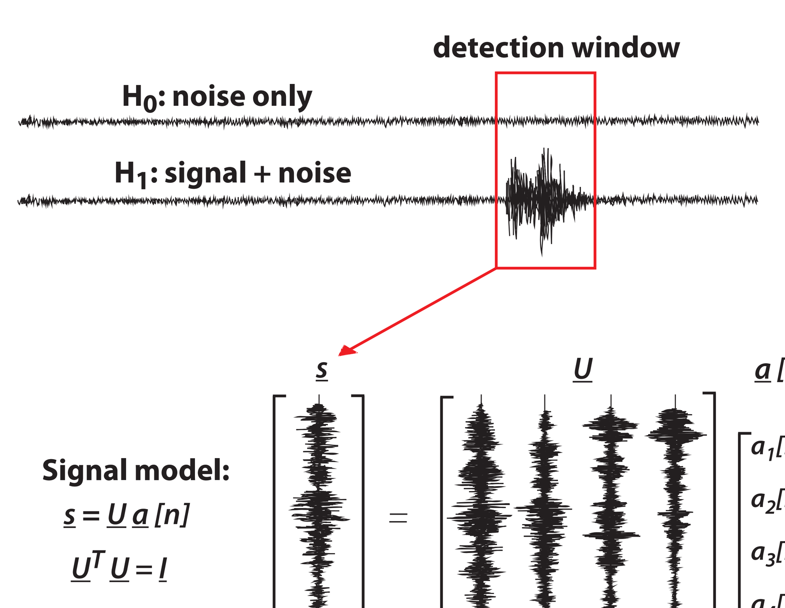


Figure 3. Modified from Harris [2006] and Harris and Paik [2006]. The subspace detector uses multiple template events to compare with the data containing unknown signals. An unknown signal, s, in the data can be represented by a linear combination of the basis vectors of the set of templates, U, with coefficients a[n].

Event Detection

Implementation

We use land-seismometer based catalogs (NEIC , ANF, PNSN, and Canadian NEDB) to identify clusters and individual interface earthquakes to use as templates.

We find these events on OBSs and few additional coastal land stations (Earthscope, Global Seismic Network, US National Seismic Network, U. Washington/Pacific NW Regional Seismic Network, and Canadian Seismic Network) to create templates.

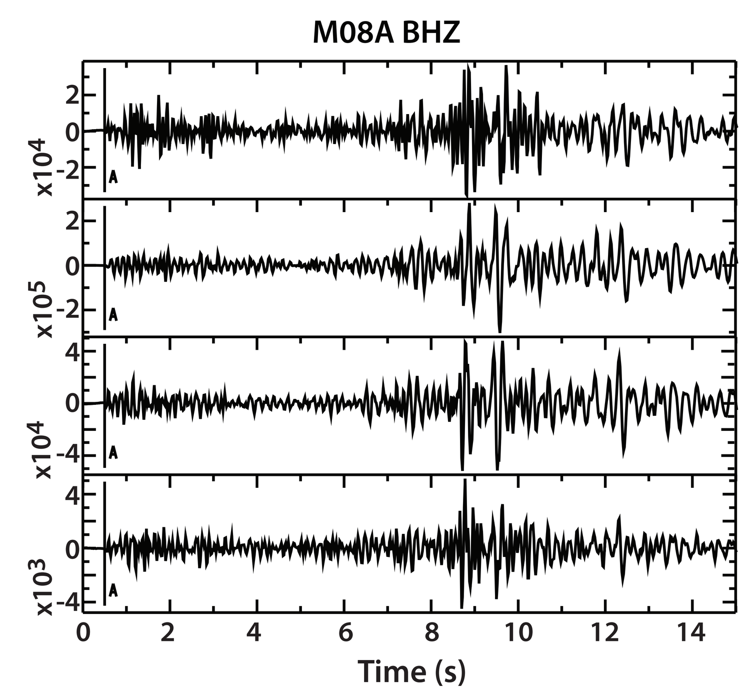


Figure 5. Templates on OBS station M08A, highlighted in box on Figure 4. Earthquakes occurred March 12, 2012 - March 26, 2012 and range in magnitude from 1.9 to 3.7. Templates are high-passed filtered with corner frequency at 5 Hz.

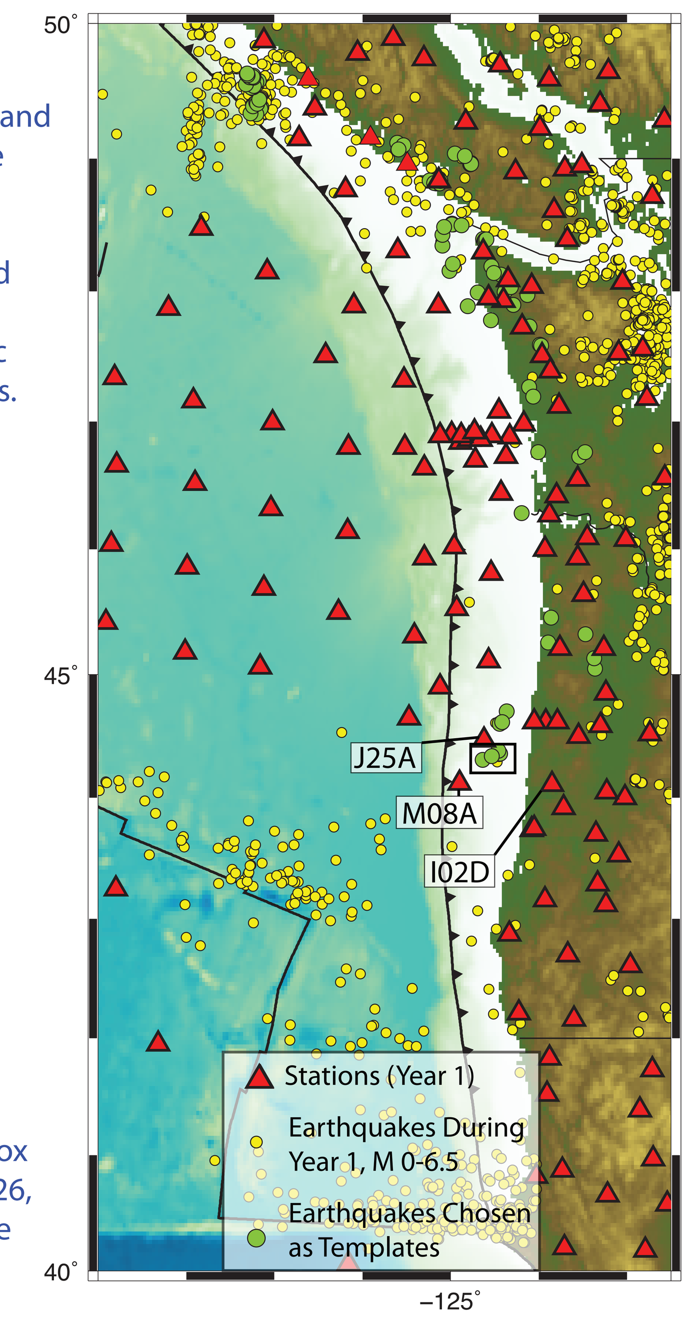


Figure 4. Map of seismicity during the first year of CI deployment with events used as templates highlighted by the box. Stations M08A, J25A, and I02D used for subspace detection.

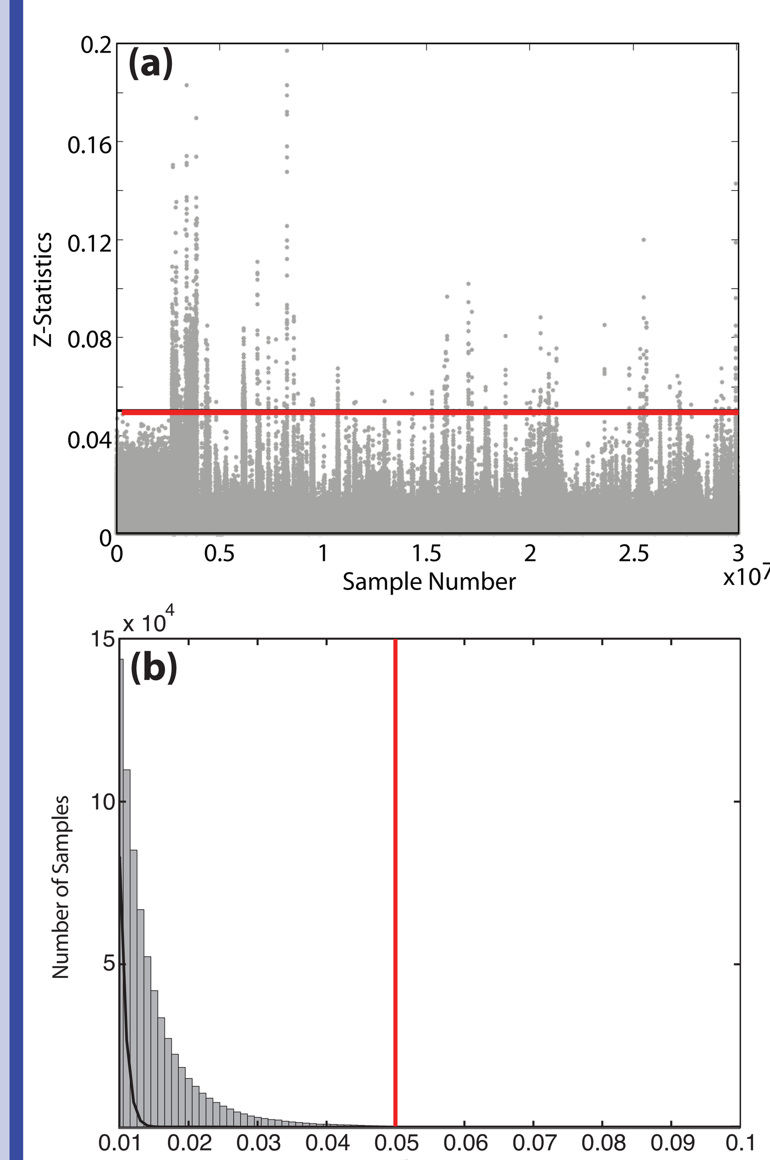


Figure 6. Z-statistic distribution through time (a) and histogram of z-statistics (b) for the first weekd of data scanned for M08A (October 21, 2011 - October 27, 2011). Thresholds were chosen for each month of data scanned based on the z-statistcs from scanning the first week of each month. Here, the threshold is 0.05 (red line). For the first cluster, thresholds were chosen visuall. Subsequent cluster are chosen as ~14.55 or 10.08 (for OBS and land, respectively) standard deviations above the distribution mean, which was the mean trend of the cluster one thresholds.

Number of Unique Detections for Subset Year 1 Data: 263

M08A	J25A	I02D
175	80	48

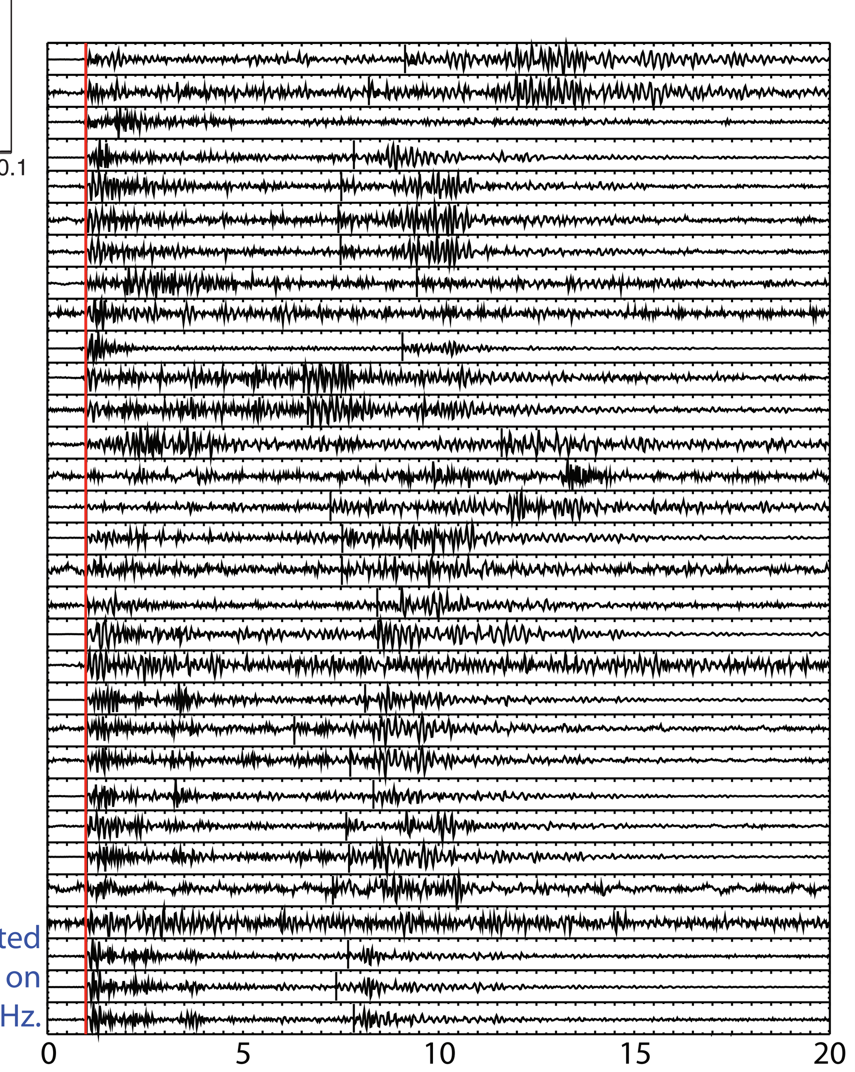
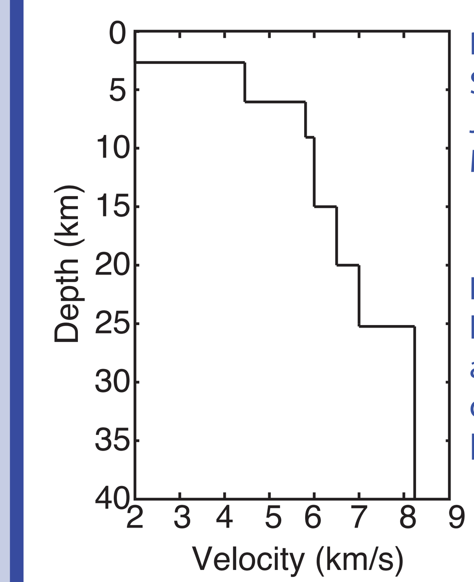


Figure 7. Subset of events detected on station M08A, aligned on P-arrival. High-pass filtered at 5 Hz.

Locations



Preliminary locations were found using HYPOINVERSE [Klein, 1985]. P and S wave picks were made (when visible) on 10 nearby OBS (M08A, J25A, J26A, J33A, and M07A) stations from the CI network and land (I02D, NEWO, MPO, BABR, RNO) stations from the TA and UW networks.

Figure 8. Vp Velocity model used for preliminary locations, as was used by Williams et al. [2011] and Trehu et al. [2015: ORWELL1 model], developed from seismic data from Gerdom et al. [2000]. Vp/Vs of 1.77 was used for S velocity.

154 of the 263 detected events were only visible on 1 or 2 stations. HYPOINVERSE abandoned 6 events with only 3 readings

103 events were located.

Horizontal errors: 1 to 75.2 km, with the lowest errors being in the targeted cluster (due to station coverage), and vertical errors range 1.4 to 99 km. Depths range -4.4 km to 30.0 km (negative values due to shifting station elevations to all positive values).

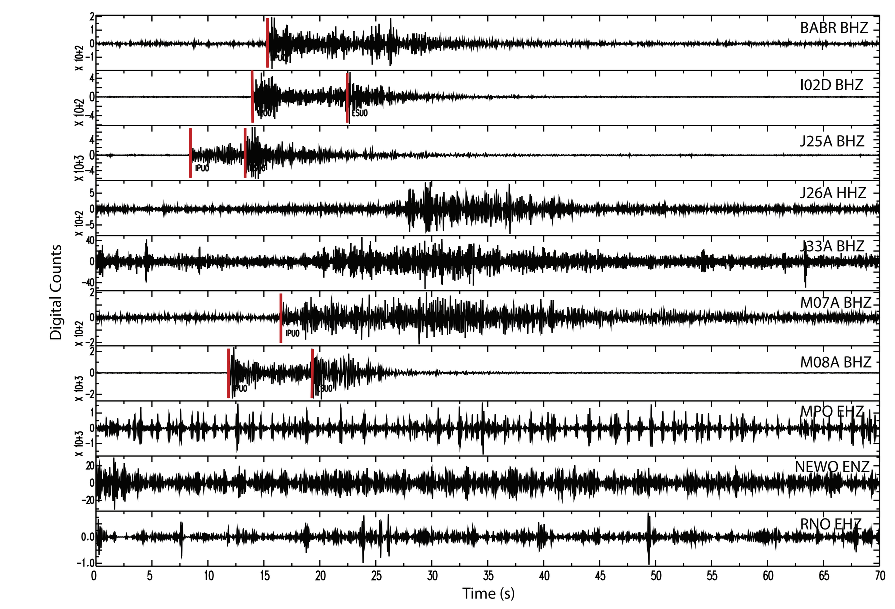


Figure 9. Phase picks (red lines) for detected event on May 17, 2012 on OBS and land stations

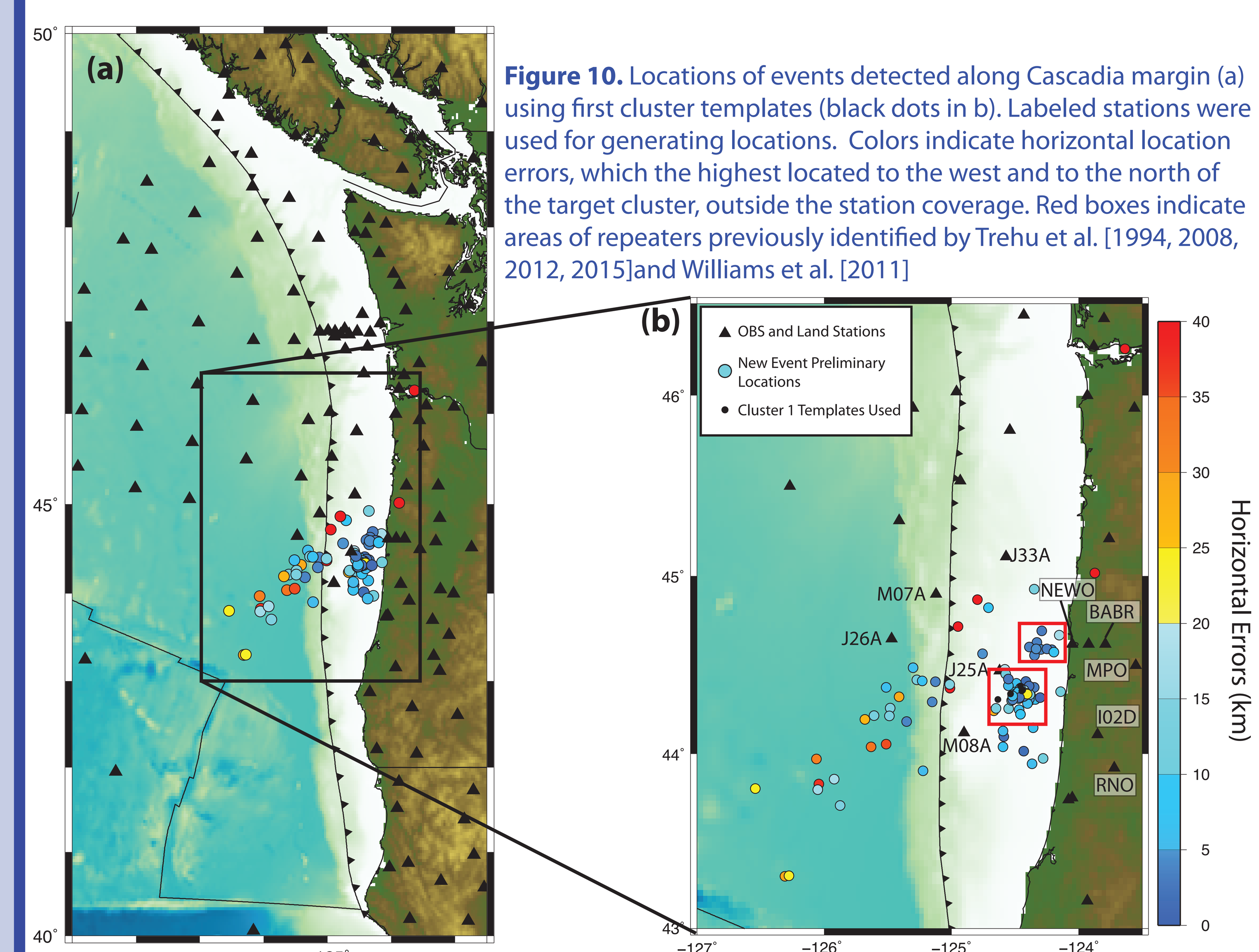


Figure 10. Locations of events detected along Cascadia margin (a) using first cluster templates (black dots in b). Labeled stations were used for generating locations. Colors indicate horizontal location errors, which the highest located to the west and to the north of the target cluster, outside the station coverage. Red boxes indicate areas of repeaters previously identified by Trehu et al. [1994, 2008, 2012, 2015]and Williams et al. [2011]

Conclusions / Future Work

During the first year of CI deployment, 263 events were detected with the target cluster templates on stations M08A, J25A, and I02D. We have preliminary locations for the 103 events that appear on multiple stations.

The majority of the new events are located within the target cluster, where previous repeaters have been observed [e.g. Trehu et al., 1994; 2008; 2012;2015; and Williams et al., 2011]

We will continue running detection codes using templates along the margin for all four years of deployment and locate all detected events along the CSZ, as well as compute source parameters of detected events.

Locations and source parameters will be compared to variations in overriding-plate geology and varying structure on the subducting plates.

Acknowledgements

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