Long-term simultaneous imaging of slow and fast quakes using small-aperture seismic arrays

Abhijit Ghosh[1] (aghosh.earth@gmail.com), Kenneth C Creager[2], John E Vidale[2]
[1]Dept of Earth & Planetary Sciences, University of California Santa Cruz
[2]Dept of Earth & Space Sciences, University of Washington

Plate boundary faults experience both fast and slow slip. Fast slip dominates the locked seismogenic zone, the nucleation zone of large megathrust earthquakes. Slow slip and associated tremor, on the other hand, mainly occur directly downdip of the locked zone. Fast and slow slips likely interact with each other. It is even suggested that slow slip might have preceded the dynamic rupture of the recent great megathrust earthquake in Japan [*Kato et al.*, 2012].

Cascadia witnessed great megathrust earthquakes. It is characterized by frequent tremor episodes along the entire margin and slow earthquakes as large as Mw ~7.0. The relationship between slow slip and associated tremor with fast slip (regular earthquakes), however, remain unknown. Addressing this issue requires high-resolution long-term imaging of the seismicity, associated with both fast and slow slip, with enhanced detection capability. Existing regional seismic networks are not designed to capture this level of details in the seismic activity. Small-aperture seismic arrays are successfully used in Cascadia to image slow and fast earthquakes in unprecedented resolution [e.g., *Ghosh et al.*, 2010a; *Vidale et al.*, 2011], and greatly enhanced detectability compared to conventional methods using existing network data.

We propose to install two small-aperture seismic arrays in strategic locations in northern Cascadia, part of which we previously imaged using array techniques [*Ghosh et al.*, 2009]. The proposed arrays will reoccupy the sites of two previous similar arrays (Figure 1) operating in this area until recently as a part of an EarthScope project (CAFE). This will allow us to combine newly collected data with the existing ones to study the seismicity pattern for a relatively longer time period, which would be useful to reliably interpret the observations. Moreover, these two locations are suitable to image a very active part of the fault where repeating tremor patches with dimension of 20-30 kms have been identified, several LFEs are located and several large slow earthquakes appeared to have nucleated.

The arrays would provide a close look of the activities in and around the tremor patches, which appear to control the evolution of slow earthquakes [*Ghosh et al.*, 2012]. This will enable us to study possible spatiotemporal changes in the activities of tremor and regular earthquakes and explore connection between them. The arrays would track several repeating LFEs already identified in this area [*Sweet et al.*, 2010], and will be used to find more LFEs to get a more complete spatial coverage. Tracking LFE activity over a long time-period is essential to study variability in the recurrence behavior of LFEs in time and along the dip of the tremor zone. This would help understand the frictional regime of the conditionally stable part of the subduction fault. Based on the previous activity of slow earthquakes in this area, the arrays would likely record initiation of many small, several moderate-size and couple of large slow earthquakes. High-resolution imaging of initiation of multiple slow earthquakes of different size might be critical to understand how they nucleate, grow and start rupturing. Why do some event grow larger while others don't? Rapid tremor migration over short time scales, known as tremor streaks [*Ghosh et al.*, 2010b], provides a unique view of the complexities in the evolution of the slip during slow earthquakes. So far, only a handful of streaks are identified, inadequate for useful statistical analyses. The arrays would help grow our streak catalog allowing us to study the interplay between stress and fault structure during slow earthquakes. The arrays would also be helpful for the existing tremor and earthquake monitoring mechanism providing data with high signal-to-noise ratio using array-stacking techniques.

Long-term high-resolution imaging of seismicity, associated with both fast and slow slip, with small aperture seismic arrays in strategic locations will provide an opportunity to study spatiotemporal evolution of fault slip in a level beyond the capability of any existing regional network. This study will address some of the key issues underlying the generation, evolution and termination of slow earthquakes, possible connection between slow and fast earthquakes, and help better understand the physics of fault slip and its implications in the subduction zone dynamics.

References:

Ghosh, A., J. E. Vidale, J. R. Sweet, K. C. Creager, and A. G. Wech (2009), Tremor patches at Cascadia revealed by array analysis, *Geophys. Res. Lett.*, *36*, L17316, 10.1029/2009GL039080.

Ghosh, A., J. E. Vidale, J. R. Sweet, K. C. Creager, A. G. Wech, and H. Houston (2010a), Tremor bands sweep Cascadia, *Geophys. Res. Lett.*, *37*, L08301, 10.1029/2009gl042301.

Ghosh, A., J. E. Vidale, J. R. Sweet, K. C. Creager, A. G. Wech, H. Houston, and E. E. Brodsky (2010b), Rapid, continuous streaking of tremor in Cascadia, *Geochem. Geophys. Geosyst.*, *11*, Q12010, 10.1029/2010GC003305.

Ghosh, A., J. E. Vidale, and K. C. Creager (2012), Asperities in the transition zone control evolution of slow earthquakes, *submitted*.

Kato, A., K. Obara, T. Igarashi, H. Tsuruoka, S. Nakagawa, and N. Hirata (2012), Propagation of Slow Slip Leading Up to the 2011 Mw 9.0 Tohoku-Oki Earthquake, *Science*, *335*(6069), 705-708, doi:10.1126/science.1215141.

Sweet, J. R., K. C. Creager, A. Ghosh, and J. E. Vidale (2010), Low-Frequency Earthquakes in Cascadia: Results from Array of Arrays, *Abstract S23A-2090 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13 - 17 Dec.*

Vidale, J. E., A. J. Hotovec, A. Ghosh, K. C. Creager, and J. Gomberg (2011), Tiny intraplate earthquakes triggered by nearby episodic tremor and slip in Cascadia, *Geochem. Geophys. Geosyst.*, *12*, Q06005, 10.1029/2011GC003559.

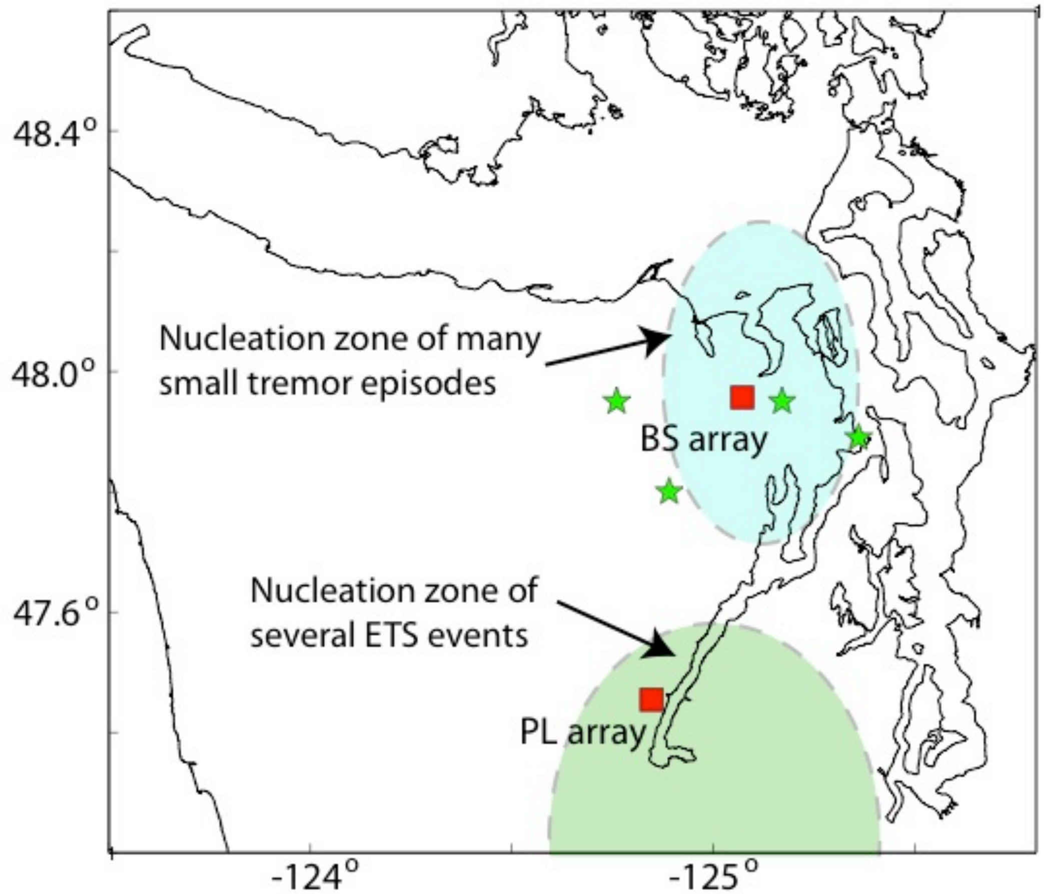

Figure 1: Map showing the arrays (red squares) we are proposing to reoccupy. The light blue area hosts three patches that experience repeated tremor episodes, and appears to be the nucleation zone of frequent small to moderate-sized tremor episodes. The light green area marks the zone from where several ETS events got started in the last few years. Green stars represent the locations of the low-frequency earthquake identified so far using array analysis.