Seismic evidence for megathrust fault-valve behavior during episodic tremor and slip

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The periodic occurrence of slow earthquakes, including episodic tremor and slip (ETS), has been observed in several subduction zones and is believed to be related to cyclic fluid processes. The ETS source region is characterized by a layer of anomalously-low seismic-wave velocities (LVL) interpreted as subducting oceanic crust and/or shear zone material, which require near-lithostatic pore-fluid pressures and a weak megathrust fault. Hydro-mechanical models describe fluid motion during fault slip as ‘fault valving’, wherein fluids are able to migrate within and through faults when low-permeability barriers are ruptured during fault motion. Such models necessitate fluctuations in pore-fluid pressures near the fault. However, evidence for cyclic fluid processes during ETS is limited and indirect. Here we use repeated seismic scattering observations in the Cascadia subduction zone to show a change in the seismic velocity structure of the LVL following ETS. We interpret this velocity change as a response to a temporary reduction in pore-fluid pressure of approximately 1-10 MPa, which is comparable with recent observations of stress-switching within the shallow slow earthquake source region in Hikurangi. The observed change in seismic velocity structure is limited to stations located above the intersection of the slab with the hydrous mantle wedge corner, suggesting a link between slow fault slip and fluid storage within the overlying continental margin. Our results provide direct evidence of a change in the mechanical properties of the megathrust and fluid flow following ETS, and support models of fault-valve control on deep episodic slow earthquakes.

Keywords: Subduction zone structure, Slow earthquakes, Fluid pressure cycling

