Shear-wave Velocity Structure and Interseismic Strain Accumulation in the Updip Region of the Cascadia Subduction Zone: Similarities to Tohoku?

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The updip region of subduction zone thrusts is difficult to study using land based seismic and geodetic networks, yet documenting its ability to store and release elastic strain is critical for understanding the mechanics of great subduction earthquakes and tsunami generation. The 2011 Tohoku earthquake produced extremely large slip in the shallowest portion of the subduction zone beneath a region of the forearc that is comprised of extremely low-velocity, unconsolidated sediments [Tsuru et al. JGR 2012]. The influence of the sediment material properties on the coseismic slip distribution and tsunami generation can be considerable through both the effects on the dynamic wavefield during the rupture [Kozdon and Dunham, BSSA 2012] and potentially the build up of strain during the interseismic period. As part of the 2010-2011 SeaJade experiment [Scherwath et al, EOS 2011], we deployed 10 ocean bottom seismometers on the continental slope offshore of Vancouver Island in the region of the NEPTUNE Canada observatory. There is typically a high level of coherence between the seafloor acceleration recorded on the broadband seismometer and the bottom pressure recorded on the Differential Pressure Gauge (DPG) in the frequency band corresponding to ocean infragravity waves.

We estimate the compliance spectrum in the infragravity wave band in the frequency domain following Crawford [2000]. DPG records are calibrated using teleseismic Rayleigh-wave recordings and we correct for tilt-effects on the vertical component seismograms. Typically the coherences are high (>.7) in the .006 to .03 Hz range. We invert the measured compliances in this frequency band using a genetic algorithm that solves for the S-wave velocity, P-wave velocity, and density in a layered structure. By including constraints on the Vp distribution from active source studies, these parameters appear well constrained down to about 4 km depth from our dataset. There is a clear difference in observed compliance values between stations close to the deformation front (~10 km) and those further up the continental slope (~30-40 km) indicating a region of unconsolidated, high-porosity sediment similar to the off-Tohoku region.

The low S-wave velocities and high Vp/Vs ratios in the updip region correspond to unconsolidated high-porosity sediments. We calculated the effect of this material property contrast on the interseismic strain accumulation in the updip region of the subduction zone using a finite element model and find that the sediments can increase the amount of interseismic strain accumulated in the updip region by >100% relative to a homogenous elastic model.

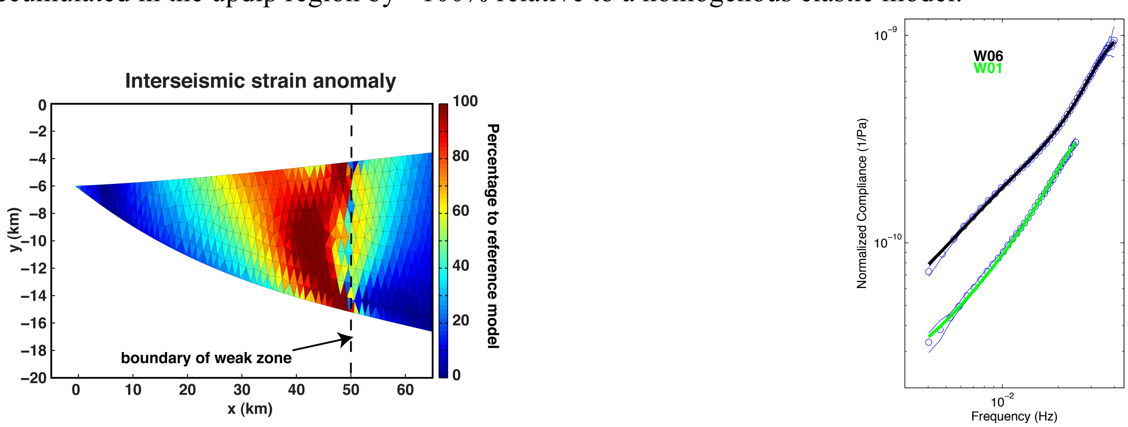

Figure 1. Left) Model of interseismic strain accumulation for a model with a high Vp/Vs ratio accretionary prism extending 50 km from the deformation front. Right) normalized compliance curves for two OBS located 10km (W01) and 40 km (W06) from the deformation front. The factor of five higher compliance at W06 results from the high-porosity sediments.