An Unexplained Tsunami: Was there Megathrust Slip During the M7.6 Sand Point, Alaska Earthquake?

*Sean Santellanes[1], Dara Goldberg[2], Pablo Koch[3], Diego Melgar[1], Brenden Crowell[4], Jiun-Ting Lin[1]

1. University of Oregon, Eugene, OR, USA, 2. United States Geological Survey, Golden, CO, USA, 3. Centro Sismologico Nacional de Chile, Santiago, CHL, 4. University of Washington, Seattle, WA, USA

The 2020 M7.6 Sand Point, Alaska, USA, earthquake and its resulting tsunami demonstrate the limit of our knowledge regarding tsunamigenic earthquakes. Of the three M7+ earthquakes spanning the Shumagin and Semedi segments from 2020-2021, the M7.6 Sand Point earthquake produced the largest tsunami, despite having the lowest moment magnitude and a predominately right-lateral strike-slip focal mechanism. This work aims to understand this seemingly conflicting behavior.

We used various inversion approaches (both static and kinematic) to understand the event. First, we used water level and geodetic data (static hydrodynamic) to invert for the sea surface deformation necessary to recreate the tsunami waveforms observed at water level stations in Alaska and Hawaii and at Deep-ocean Assessment and Reporting of Tsunamis (DART) stations. Second, we performed a static slip inversion for strike-slip and megathrust geometries to test if megathrust activation was needed to fit the water level and geodetic waveforms. In addition, we tested how well strike-slip, oblique slip, and/or megathrust slip could fit the data. Finally, we employed the Wavelet and simulated Annealing SliP (WASP) kinematic inversion code to invert teleseismic seismograms, DART observations, and regional seismic and geodetic data allowing slip on both strike-slip and megathrust orientations. We ran the sea surface deformation from each inversion result in the tsunami modeling code, GeoClaw, to compare the tsunami generation of each slip model to tsunami observations.

We found that a strike-slip source alone is unable to recreate the tsunami waveforms at any of the water level or DART stations; the strike-slip source can account for only ~50% of the maximum observed wave amplitude. The hydrodynamic inversion resulted in good fits to the first arrival of the tsunami at the water level and DART stations, as well as the overall wave packet behavior. The hydrodynamic model is indicative of megathrust co-seismic slip along with a potential submarine landslide —in particular, to fit the large-amplitude waveforms at King Cove, Alaska. The static inversions of geodetic data, allowing slip on a strike-slip and megathrust geometry, were unable to recreate the tsunami waveforms as well as the hydrodynamic inversion. Notably, the static geodetic inversion severely underpredicted the water level waveforms at the King Cove sea level station. WASP kinematic inversions were able to adequately fit the geodetic, strong motion, teleseismic, and DART water level data, but again, severely underpredicted amplitudes at King Cove. The overall focal mechanism of the WASP solution is in agreement to the United States Geological Survey (USGS) W-phase moment tensor. However, the preferred slip model has a larger total moment magnitude than suggested by the USGS moment tensor solution.

These results strongly suggest that a strike-slip mechanism alone is unable to be the sole cause of the Sand Point tsunami and hints towards a more complicated fault rupture. The static inversion scheme shows that co-seismic slip along the megathrust, in addition to the observed strike-slip co-seismic slip, is needed to explain the resulting tsunami. WASP inversions showed that it is possible to have solutions that reconcile the ocean- and land-based observations and provide a focal mechanism like that of the USGS W-phase solution. However, the slip model magnitude (M8.0) is considerably larger than USGS analysis suggests, and the modeled duration is ~300s long. Finally, a small submarine landslide in the western edge of the deforming region is likely needed to explain the local, large tsunami amplitudes at King Cove.

