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Seismic Hazards in Seattle

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Much of Seattle, in the northwestern United States, lies atop a sedimentary basin that extends approximately 9 km deep. The basin structure is the result of the evolution of the Puget Lowland fore arc, which combines strike-slip and thrust-fault movements to accommodate right-lateral strike-slip and N-S shortening due to the oblique subduction of the Juan de Fuca Plate beneath North America. The Seattle Basin has been observed to amplify and distort the seismic waves from a variety of moderate and large earthquakes in ways that affect the hazard from those earthquakes. Seismic hazard assessments heavily depend upon upper crustal and near-surface S-wave velocity models, which have traditionally been constructed from P-wave models using an empirical relationship between P-wave and S-wave velocity or by interpolating across widely spaced observations of shallow geologic structures. Improving the accuracy and resolution of shallow S-wave models using direct measurements is key to improving seismic hazard assessments and predictions for levels of ground shaking.
Tomography, with short-period Rayleigh waves extracted using noise interferometry, can refine S-wave velocity models in urban areas with dense arrays of short period and broadband instruments. We apply this technique to the Seattle area to develop a new shallow S-wave model for use in hazard assessment. Continuous data from the Seismic Hazards in Puget Sound (SHIPS) array have inter-station distances that range from a few, to tens of kilometers. This allows us to extract Rayleigh waves between 2 and 10 seconds period that are sensitive to shallow basin shear wave velocities. Our results show that shear wave velocities are about 25% lower in some regions in the upper 3 km than previous estimates and align more closely with surface geological features and gravity observations.
We validate our model by comparing synthetic waveforms to several earthquakes recorded locally on accelerometers operated by the United States Geologic Survey (USGS) and the Pacific Northwest Seismic Network (PNSN). Then, we make predictions on the levels of shaking during likely future events at different areas around Seattle by running simulations using a finite difference code. As is typical in subduction zones, Seattle is exposed to shallow crustal events, intraplate events in the down-going slab, and large megathrust events. Of these three types of events, only large intraplate events have been recorded locally, so simulations are our best opportunity to make predictions for all of the possible scenarios. Our results can be used to update seismic hazard maps for Seattle and can be reproduced in other urban areas with dense arrays of short period and broadband instruments.