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Tsunami hazard in Cascadia from M7--9 earthquake ruptures

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The Cascadia Subduction Zone (CSZ) is a 1,200 km plate boundary that poses the greatest seismic hazard in the Pacific Northwest United States. Cascadia tsunamis have been the primary subject of studies on tsunami scenarios along the United States west coast. However, the geographic extent as well as the final size of potential future ruptures in Cascadia are poorly known. This has caused the result of previous studies to remain mostly hypothetical and simply serve as “worst-case scenarios”.

In this study, we calculate the hazard of M7-9 earthquakes using more realistic models that systematically vary both the geographic extent and slip of the rupture. To achieve this goal, we use rupture simulations derived from locking models to provide estimates of coseismic deformation at the ocean floor, and design several rupture scenarios with variable hypocenters and rupture propagation. We then apply shallow water approximation to simulate the full tsunami waveforms and generate tsunami amplitude profiles along the Cascadia coastline. By varying the seismic moment thresholds of the rupture models, we find that regional maximum coastal amplitudes are not unique for a given rupture size. This phenomenon is mostly due to the special coastal geometry as well as the particular slip partitioning of the elongated north-south rupture. In fact, our simulations reveal that beyond a magnitude of $M_w \approx 8.5$, increasing the rupture size will not significantly vary the tsunami hazard, especially in southern Cascadia, with the central segments playing the most crucial role. This result has significant implications in identifying the main sources of tsunami hazard along the US west coast, especially as the worst-case rupture scenario does not uniquely correspond to the worst-case tsunami scenario at a given location.