Probabilistic Earthquake Sources for Tsunami Hazard Assessment or Structural Engineering Design

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Several workshop participants have an interest in the characterization of potential earthquakes on subduction zones, and in the design of earthquake sources for tsunami modeling and hazard assessment. We would like to propose two specific projects related to this.

The first project is to explore techniques for specifying a probability distribution of hypothetical events that is (a) easy to sample from, e.g. in order to generate thousands of sample realizations for Monte Carlo simulation, and (b) geophysically reasonable and defensible, based on the best available science. There is no way to determine the "correct" probability distribution for future events, but many constraints are known (e.g. the subduction zone fault geometry, a reasonable range of slip values and overall magnitude, spatial correlation lengths of slip in past earthquakes, limits on how much subsidence at the coast is realistic, as inferred from records of past events, etc.). How can this information be best incorporated into the probability distribution, and how can the remaining epistemic uncertainty best be modeled?

One approach we have studied is use of a Karhunen-Loeve (K-L) expansion to generate slip distributions as Gaussian fields with specified means and covariance between subfaults [1]. In joint work with Diego Melgar, 1300 samples from such a distribution on the Cascadia Subduction Zone have been generated [2]. Melgar's group has used these for testing GPS-based earthquake and tsunami early warning systems. We have used a similarly generated set of 400 realizations to develop and test methodologies for probabilistic tsunami hazard assessment (PTHA) in work funded by FEMA [3]. In these cases, no claim was made that the probability distribution was at all "correct" for CSZ, only that it was easy to sample and sufficiently realistic to give suitable test data for new algorithms. We would like to explore whether it is possible to choose the parameters in these models in such a way that the resulting distribution is defensible as a basis for actual PTHA modeling, in the sense that the probabilities of flooding (hazard curves) that come out of tsunami modeling based on such a distribution can be viewed as "correct" in any sense.

The second project is to develop best practices for defining a single earthquake scenario that in some sense represents a 2500-year event (or some other return time, e.g. as dictated by building codes for vertical evacuation structures). Or perhaps a small ensemble of scenarios that collectively represent this return time (at some particular location). We have faced serious issues in this regard when trying to determine the tsunami modeling necessary to meet new guidelines proposed in ASCE/SEI 7-16 for tsunami evacuation structures [4]. Similar guidelines may be adopted in the international building code (IBC), and so international discussion of this issue would be timely.

References

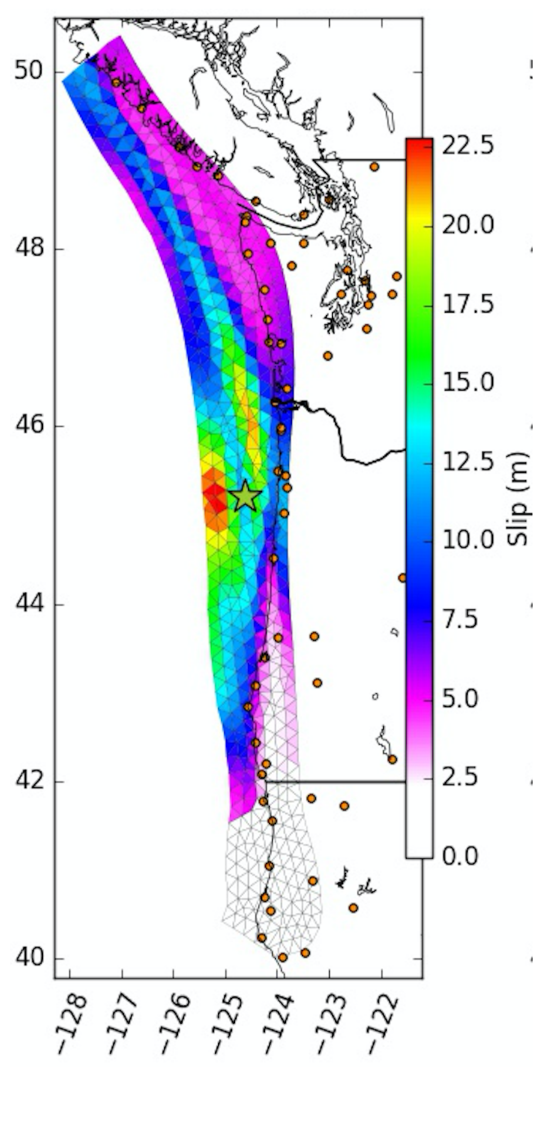
[1] LeVeque, R. J., Waagan, K., Gonzalez, F. I., Rim, D., & Lin, G. (2016). Generating Random Earthquake Events for Probabilistic Tsunami Hazard Assessment. Pure Appl. Geophys., 173, 3671–3692. https://doi.org/10.1007/s00024-016-1357-1

[2] Melgar, D., LeVeque, R. J., Dreger, D. S., & Allen, R. M. (2016). Kinematic rupture scenarios and synthetic displacement data: An example application to the Cascadia subduction zone. Journal of Geophysical Research: Solid Earth, 121(9), 6658–6674. https://doi.org/10.1002/2016JB013314

[3] Adams, L. M., LeVeque, R. J., Rim, D, and Gonzalez, F. I., Probabilistic Source Selection for the Cascadia Subduction Zone. Results from a study supported by FEMA Region IX, 2017. http://depts.washington.edu/ptha/FEMA/index.html

[4] Chock, G. Y. K. (2016). Design for Tsunami Loads and Effects in the ASCE 7-16 Standard. Journal of Structural Engineering, 142(11), 04016093. https://doi.org/10.1061/(ASCE)ST.1943-541X.0001565

Sample realization from [2]:



Resulting tsunami: