Practical Applications of GeoClaw (www.geoclaw.org) to Tsunami Hazard Assessment

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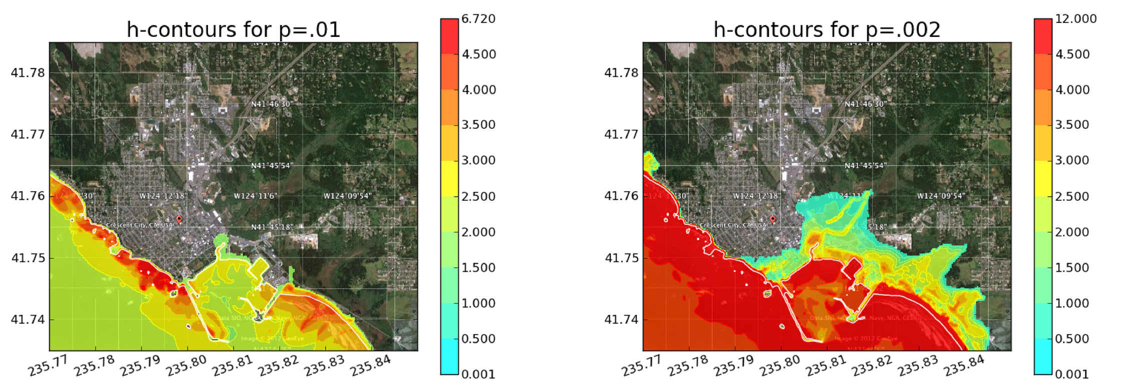
Probabilistic Tsunami Hazard Assessment (PTHA)

Input: Probability distribution of potential earthquakes.
Goal: Probabilistic map of expected inundation, current velocities, momentum flux, etc. for a community at risk.

Crescent City, CA pilot project

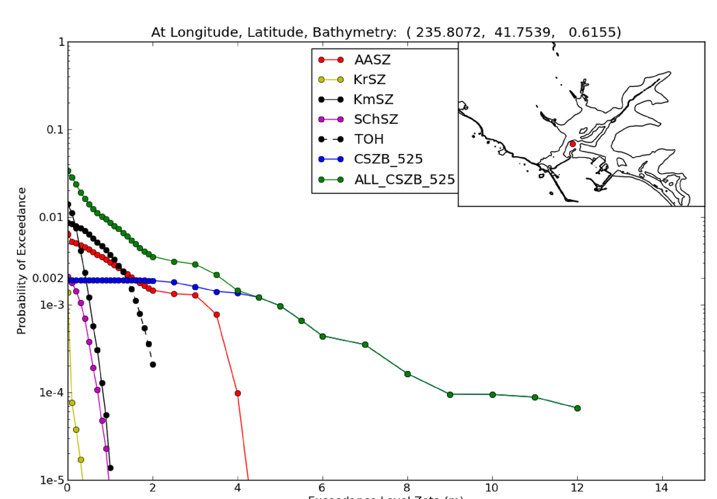
Sample maps showing depth of inundation expected with annual probability 0.01 or 0.002 (100- and 500-year floods):



These are based on hazard curves at each point, constructed by running GeoClaw tsunami model on suite of farfield and nearfield earthquakes.

Sample hazard curve

Subdivided into contribution from different subduction zones:



Based on:

- 8 AASZ realizations (including 1964)
- 2 Kamchatka SZ realizations
- 3 Kuril SZ realizations
- 1 Southern Chile realization (1960)
- 1 Japan realization (2011)
- 15 CSZ realizations

Also includes tidal uncertainty based on running each at 3 tide stages.

Acknowledgments.

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Cascadia Subduction Zone (CSZ)

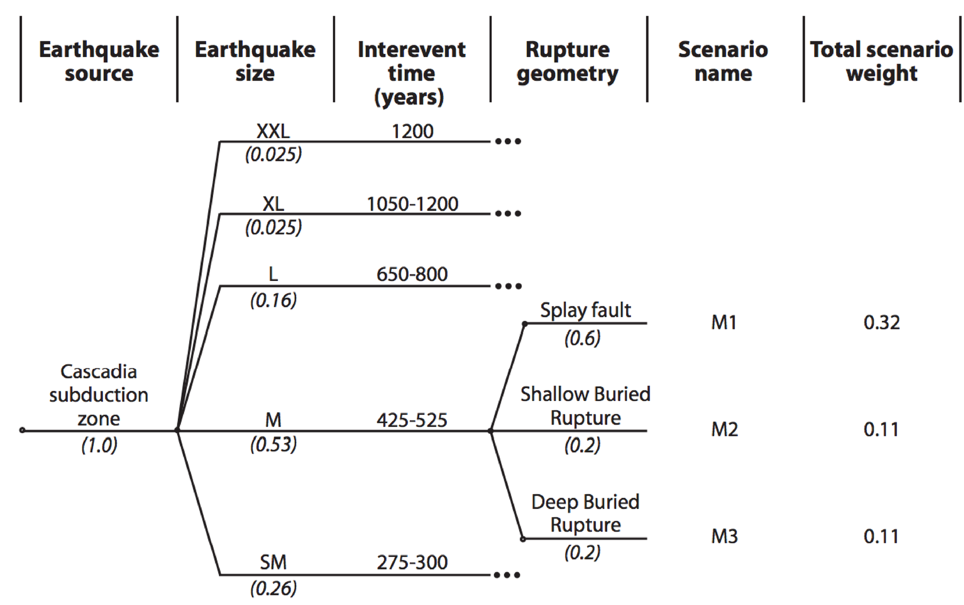
CSZ is the biggest source of uncertainty:

- Magnitude 9 event has return time ≈ 525 years, large variance.
- Major contributor to hazard curves at large exceedance values.
- Computed inundation varies greatly with slip pattern on fault.

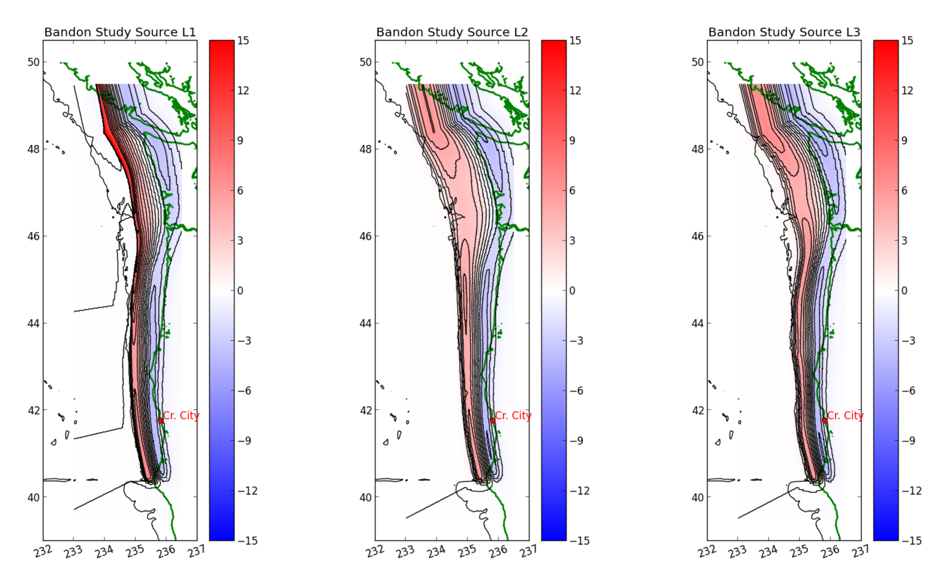
Challenges: Determine correct probability distribution, Sample it efficiently.

Logic tree approach

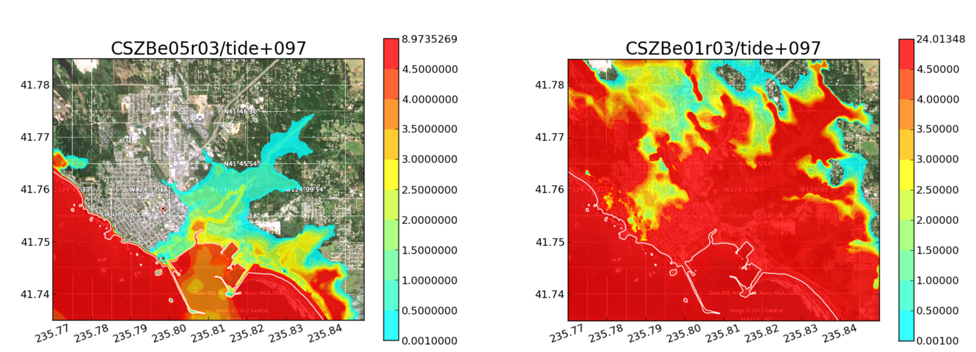
Current results based on logic tree of Witter, et al. (2011).



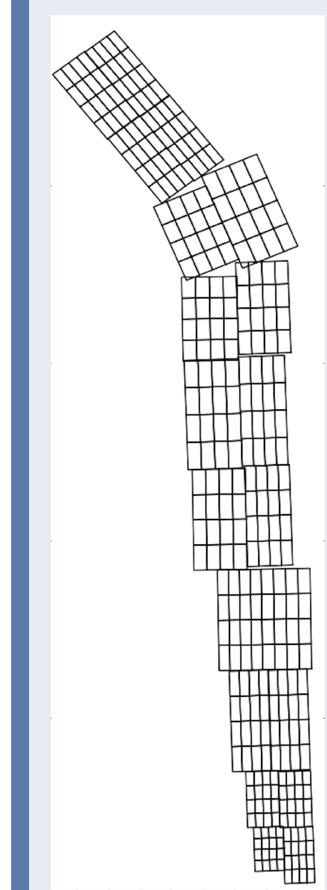
Sample seafloor deformations



Sample inundation at MHHW (SM3 and XXL3)



Karhunen-Loève (KL) Expansion



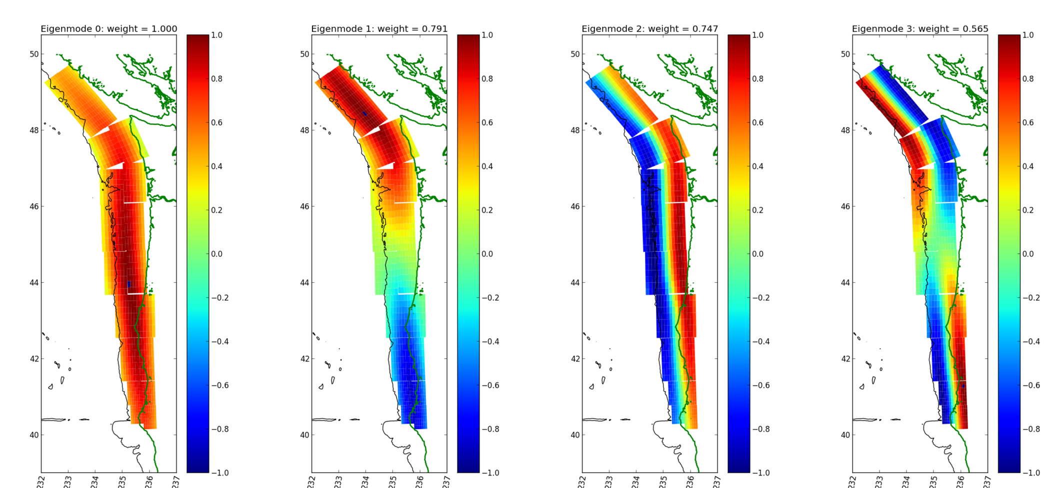
- Subdivide fault into m patches
- d_{ij} = distance from patch i to j
- Assign value C_{ij} to correlation matrix C
- Compute eigenvalues λ_k, eigenvectors v_k of C
- Eigenvectors $v_k(x_i, y_j)$ give modes for expansion.
- Large correlation length $\Longrightarrow$ rapid decay of λ_k.

Karhunen-Loève expansion for random field:

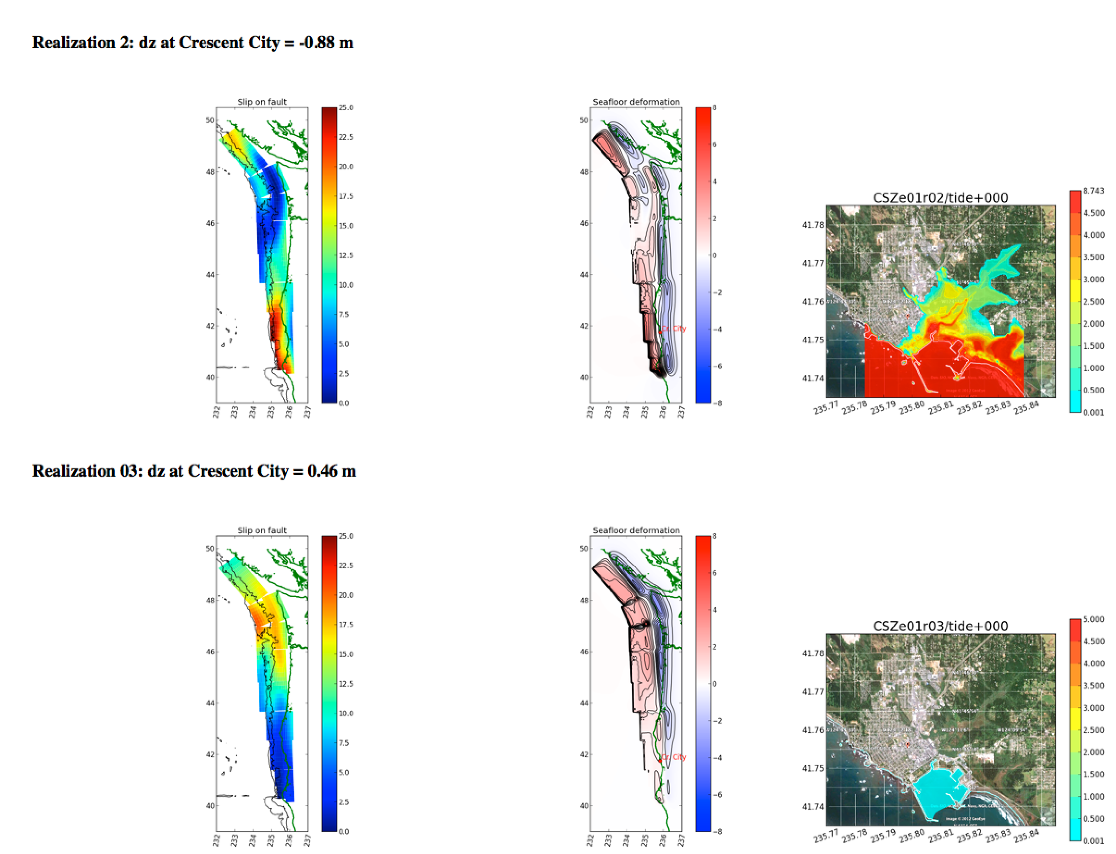
$$d(x,y) = \mu(x,y) + \sum_{k=1}^{m} z_k \sqrt{\lambda_k}\, v_k(x,y)$$

where μ is the mean slip and the z_k are chosen to be *independent* random numbers, $\mathcal{N}(0,1)$.

First 4 KL modes (eigenvectors of C)

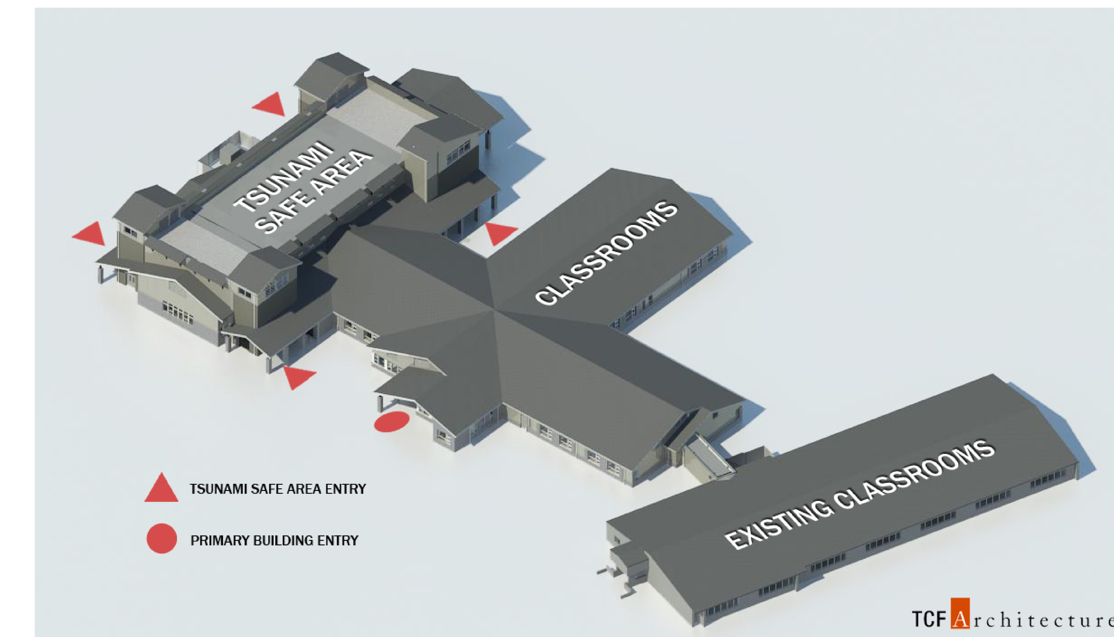


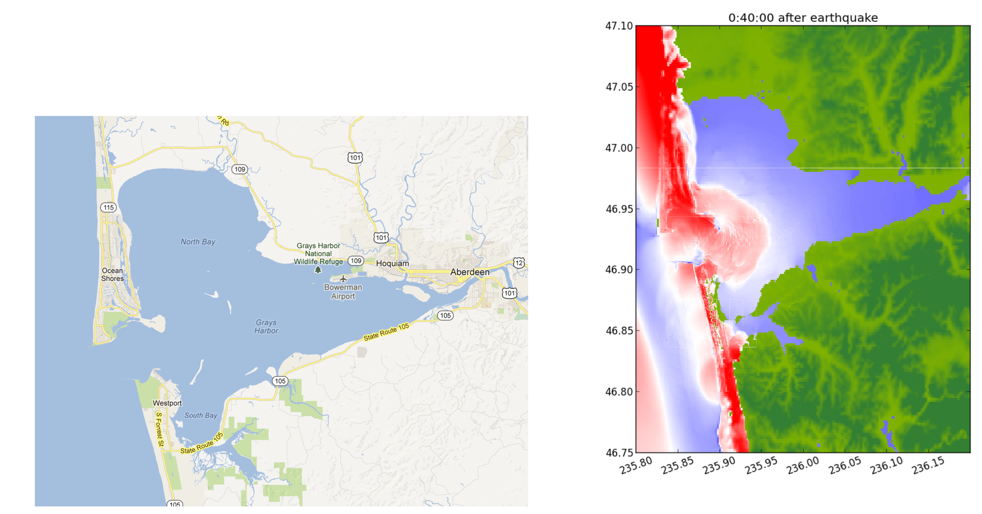
Sample stochastic realizations

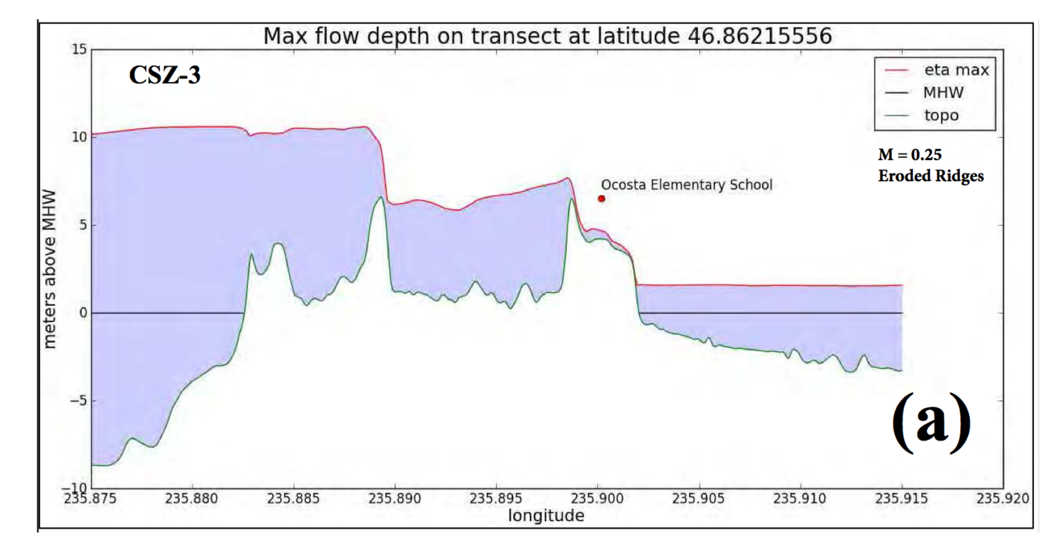


Ocosta Elementary School, Westport, WA

- First vertical evacuation structure in US.
- Designed by TCF Architecture of Tacoma, WA, with structural engineering work by Degenkolb Engineers.
- Tsunami modeling with GeoClaw, supported by WA State Emergency Management Division, DNR, Project Safe Haven, NTHMP.







References (see also www.geoclaw.org)

- González, LeVeque, Adams, Goldfinger, Priest, Wang, *Probabilistic Tsunami Hazard Assessment (PTHA) for Crescent City, CA. Final Report*, 2014, `http://faculty.washington.edu/rjl/pubs/CCptha2`
- González, LeVeque, Adams, *Tsunami Hazard Assessment of the Ocosta School Site in Westport, WA* , 2013, `http://faculty.washington.edu/rjl/pubs/Ocosta/`
- Mai and Beroza, *A spatial random field model to characterize complexity in earthquake slip*, J. Geophys. Res. 107(2002).
- Witter, Zhang, Wang, Priest, Goldfinger, Stimely, English, and Ferro, *Simulating tsunami inundation at Bandon, Coos County, Oregon, using hypothetical Cascadia and Alaska earthquake scenarios.* Oregon DOGAMI Special Paper 43, 2011.