The Pattern Method for Incorporating Tidal Uncertainty Into Probabilistic Tsunami Hazard Assessment (PTHA)

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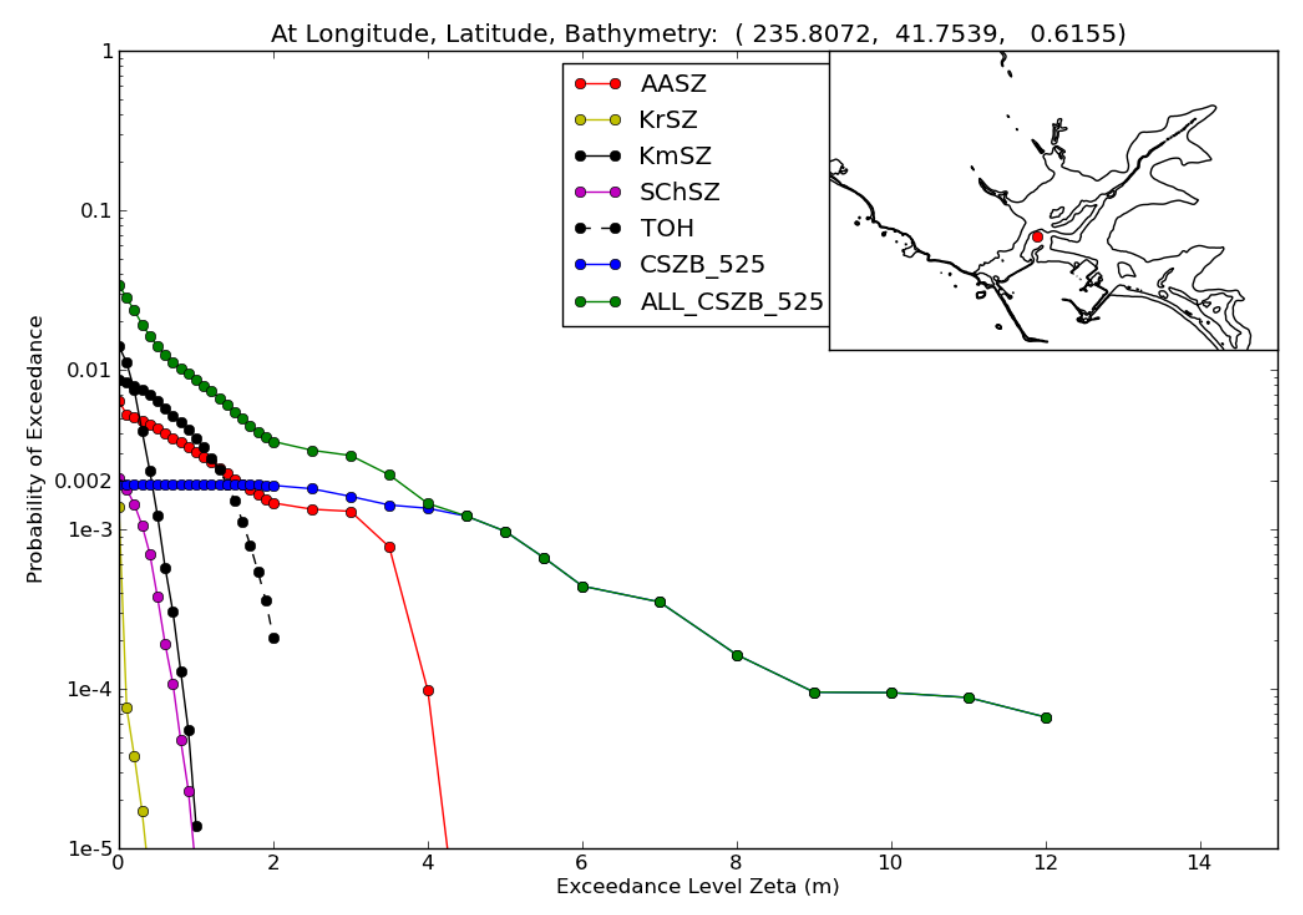
Crescent City PHTA Study

Crescent City

Hazard Curve

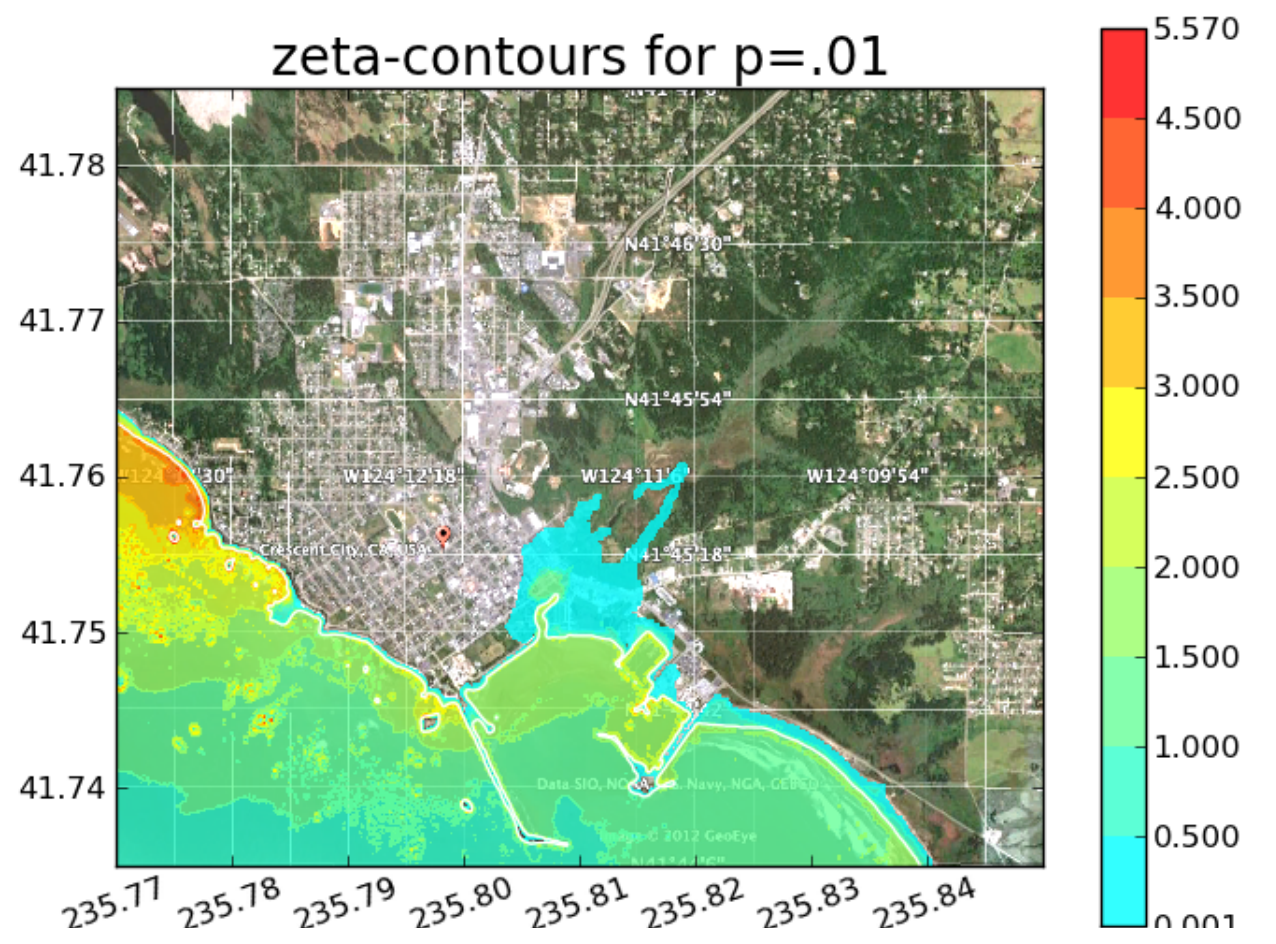


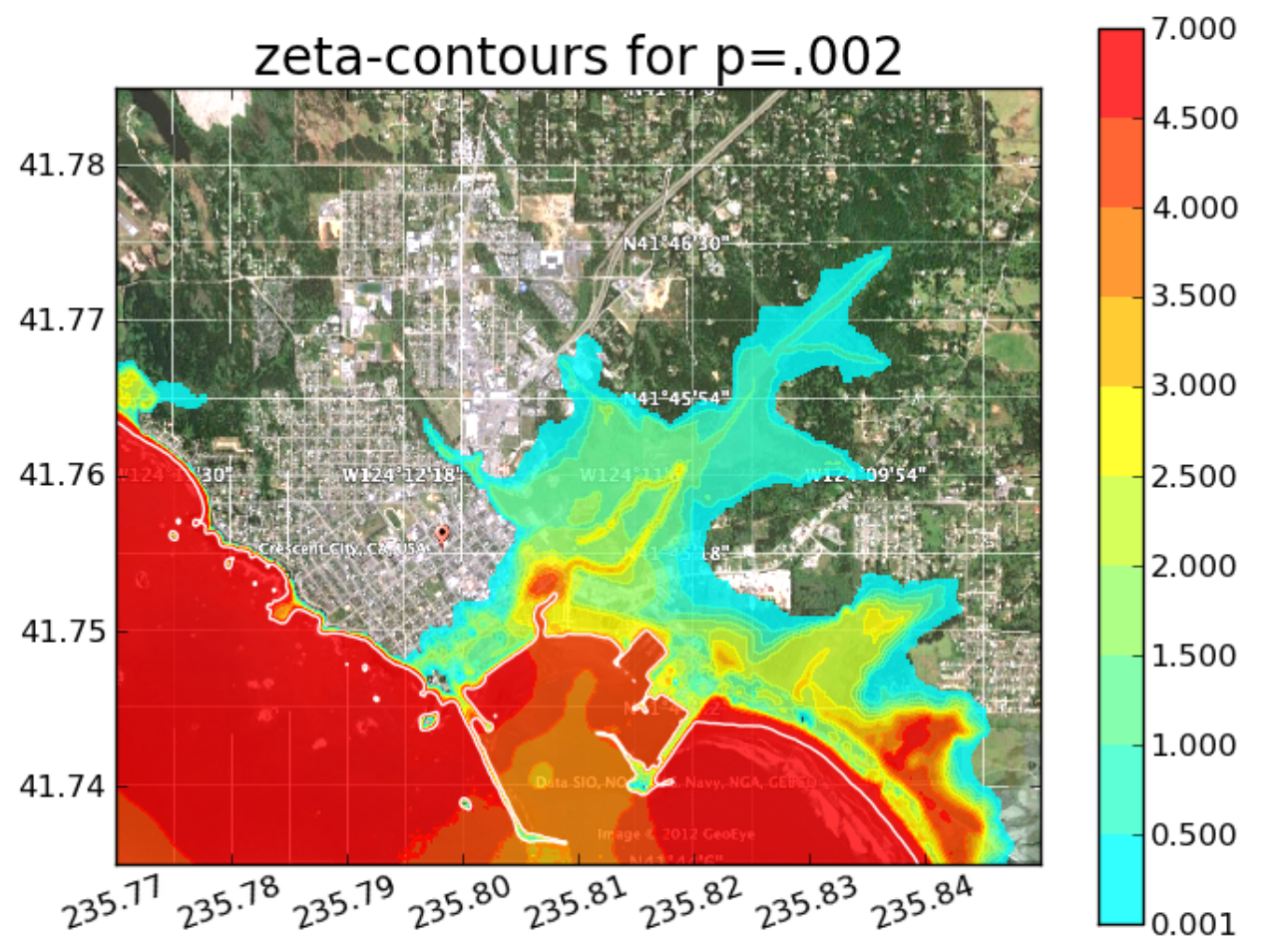
A demonstration PTHA study of Crescent City, CA was funded by BakerAECOM and motivated by FEMA's desire to explore methods to improve products of the FEMA Risk Map program. This study included 15 Far Field earthquakes from the zones AASZ (Alaska), KrSZ (Kurils), KmSZ (Kamchatka), SChSZ (Chile), and Tohoku (Japan), and 1 near field earthquake with 15 realizations from the Cascadia Subduction Zone (CSZ).

We used 35 inundation levels, ζ_i, and 500,000 locations on a fixed grid of Crescent City and its harbor.

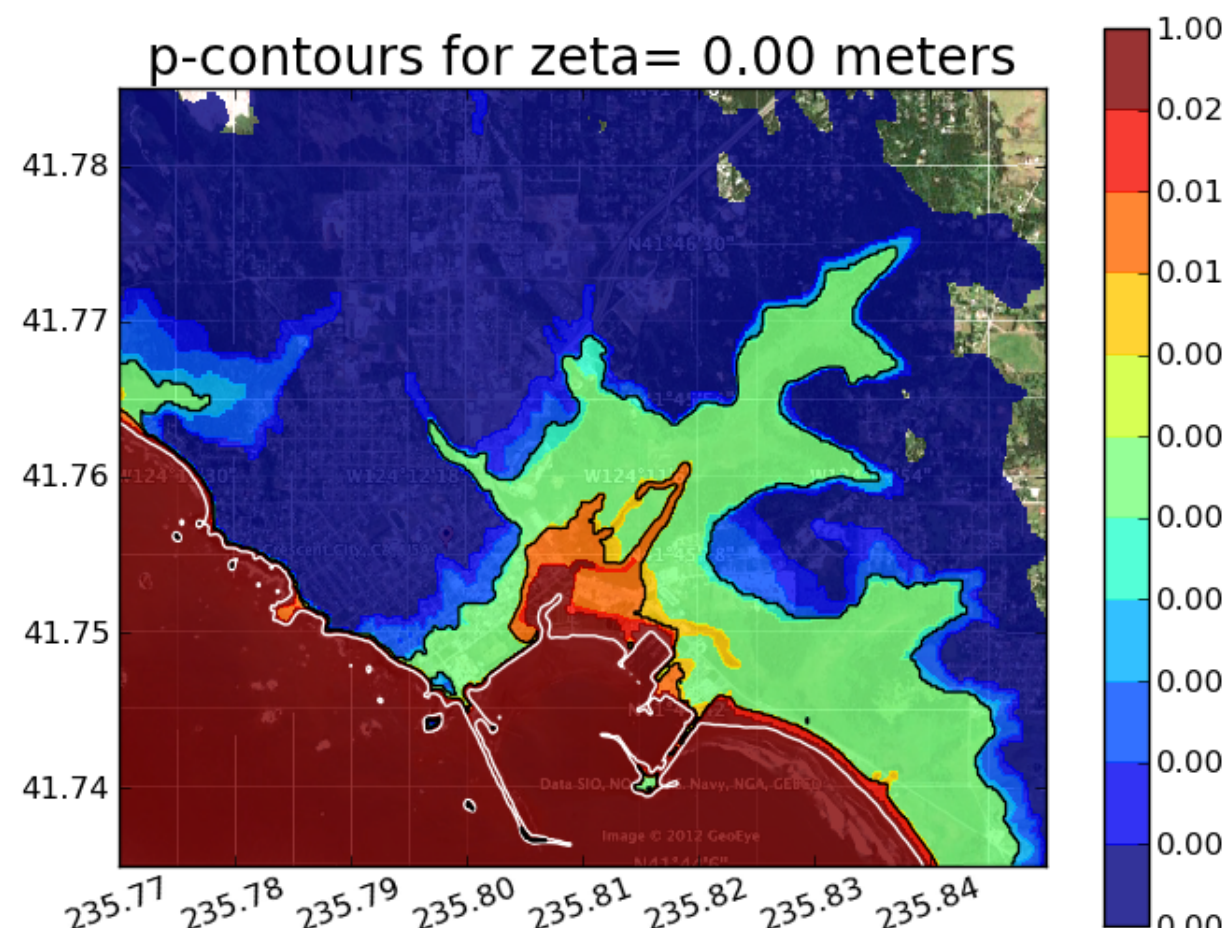
The first output product shown above is a hazard curve for a city location with the influence of different earthquake zones to the total hazard highlighted. The products below are the 100 and 500 yr. flood maps (ζ-contours with fixed probabilities .01 and .002, respectively), and the probability contours (p-contours) showing the probability of exceeding $\zeta = 0$ and $\zeta = 2$ meters, respectively at any location. These outputs are possible after $P(\zeta > \zeta_i)$ is determined at all locations for all ζ_i.

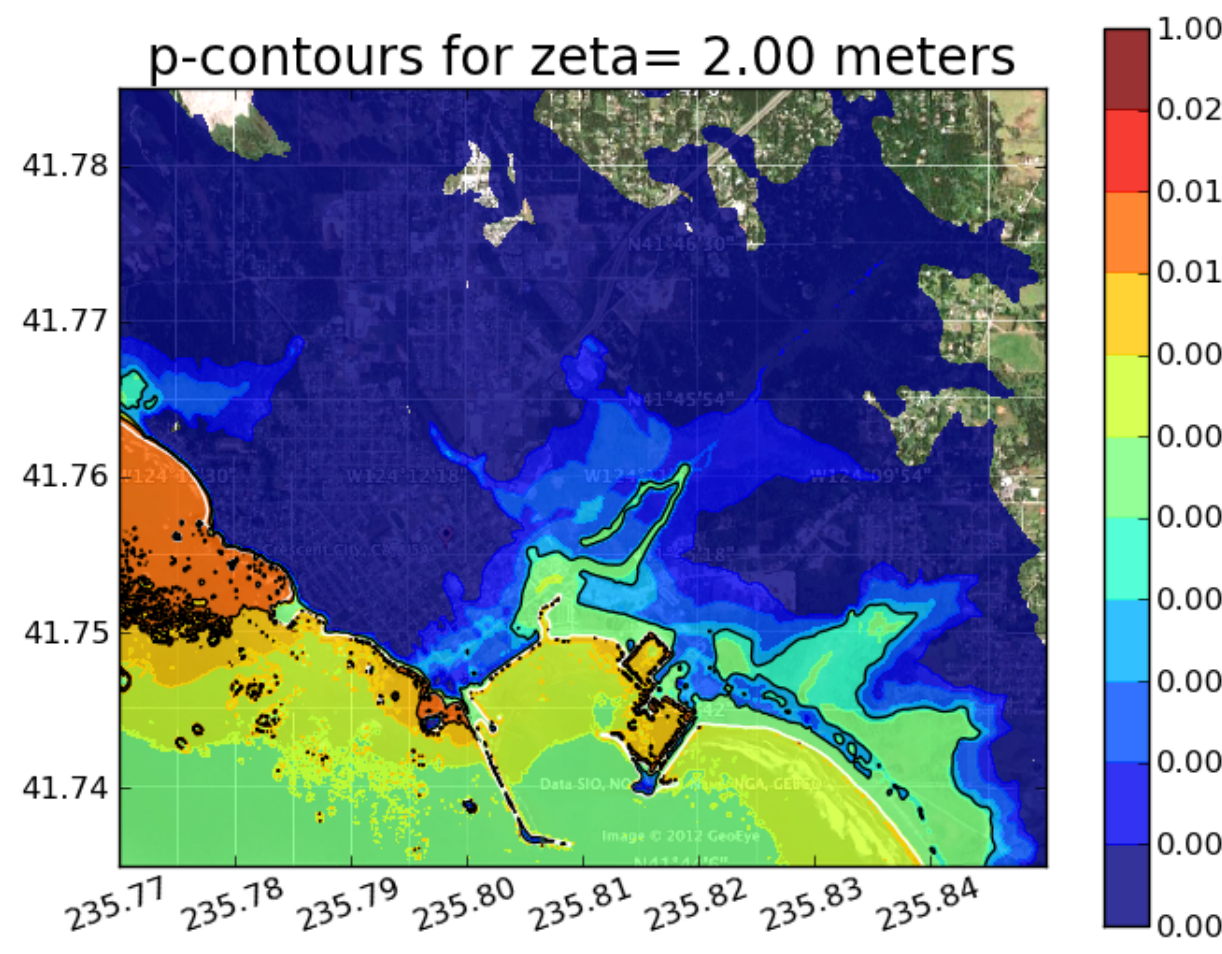
ζ-Contour Maps





p-Contour Maps





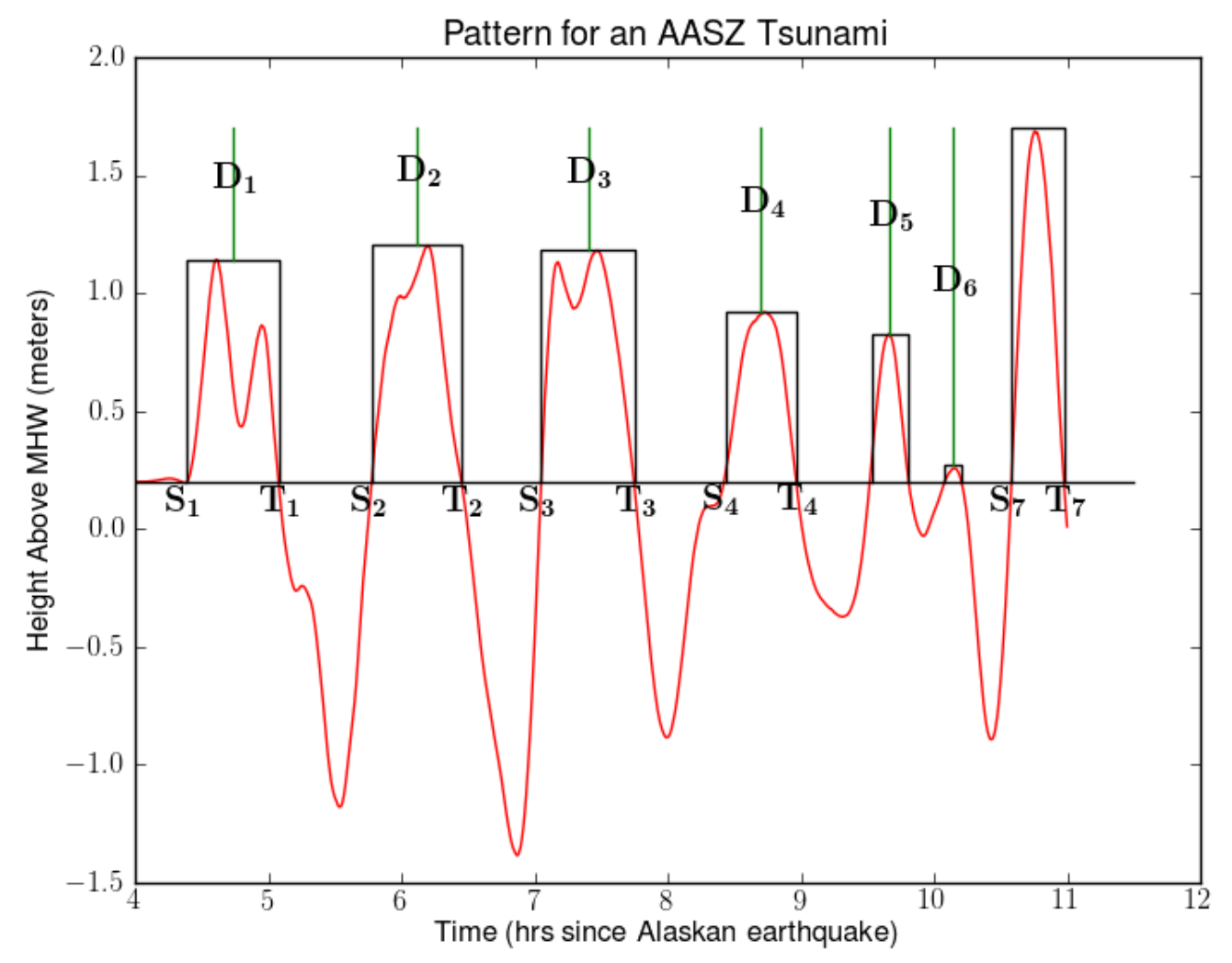
Pattern Method Steps

We assume J tsunami events, E_j. Event E_j recurs with known Poisson rate ν_j and has k_j mutually exclusive realizations, E_{jk}, with known conditional probabilities $P(E_{jk} \,|\, E_j)$.

1. Use tsunami E_{jk}'s pattern and a Yearly Tidal Record to find E_{jk}'s Cumulative distribution.
2. Run GeoClaw for E_{jk} at different tidal levels to make a GeoClaw Simulation Curve for each location.
3. For each location, find $P(\zeta > \zeta_i \,|\, E_{jk})$ using the GeoClaw Simulation and Cumulative curves.
4. Calculate $\mu_{ij} = \sum_{k=1}^{k_j} P(\zeta > \zeta_i \,|\, E_{jk})\, P(E_{jk} \,|\, E_j)$ and $P(\zeta > \zeta_i) = 1 - \prod_{j=1}^{J} e^{-\mu_{ij}}$, $i = 1 \ldots 35$.

1. The Pattern

The Tsunami E_{jk}'s Pattern



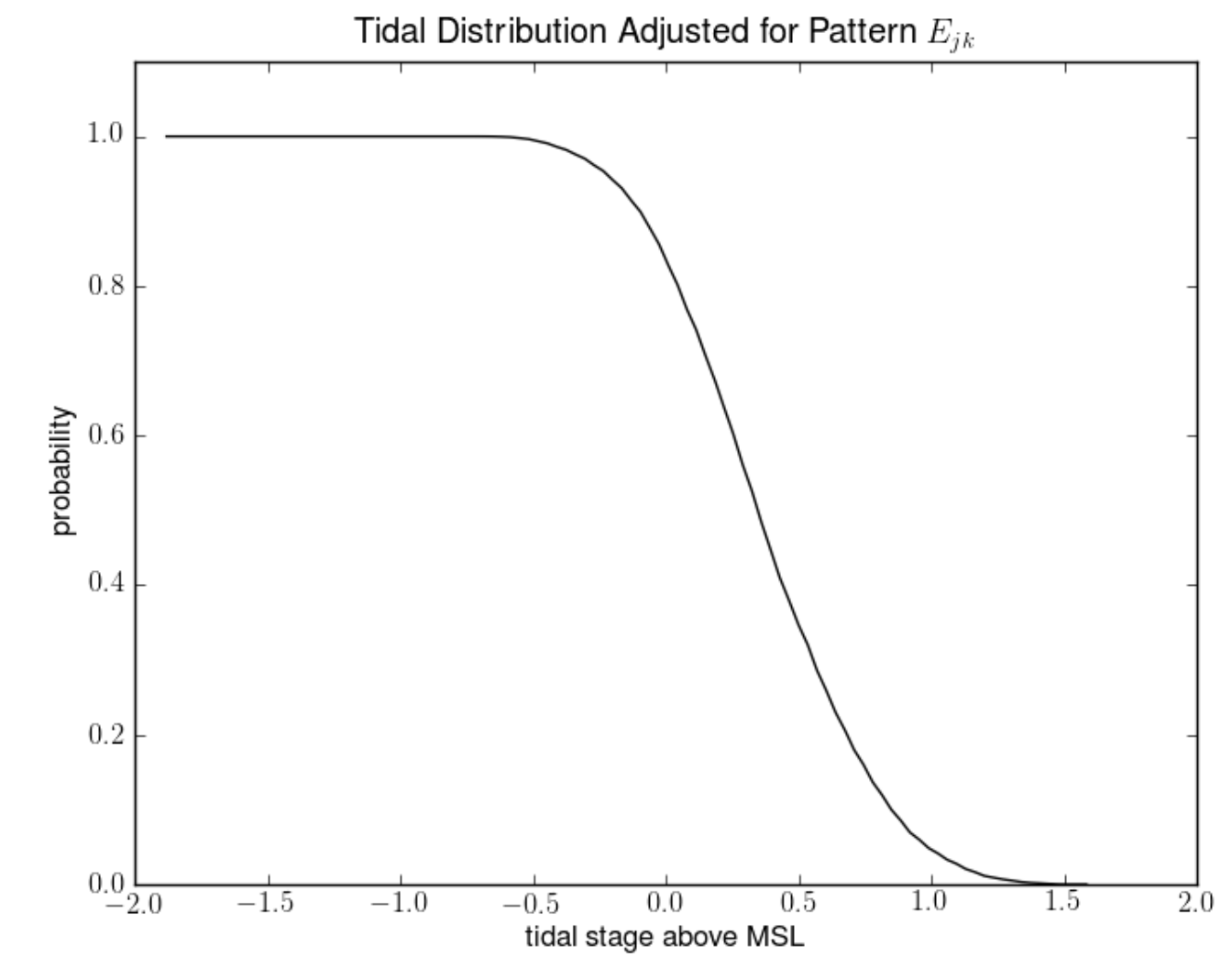
Wave $\mathrm{W_k}$	$\mathrm{I_k = [S_k, T_k]}$ Wave Interval (minutes since $\mathrm{S_1}$)	$\mathrm{D_k}$ (meters) Difference to Tallest Wave
$\mathrm{W_1}$	[000, 042]	0.561
$\mathrm{W_2}$	[084, 124]	0.498
$\mathrm{W_3}$	[160, 202]	0.517
$\mathrm{W_4}$	[243, 275]	0.782
$\mathrm{W_5}$	[309, 325]	0.876
$\mathrm{W_6}$	[342, 349]	1.450
$\mathrm{W_7}$	[372, 396]	0.000

The Cumulative Distribution Algorithm

Let the tsunami pattern start time vary over a year's tidal record for the community of interest.

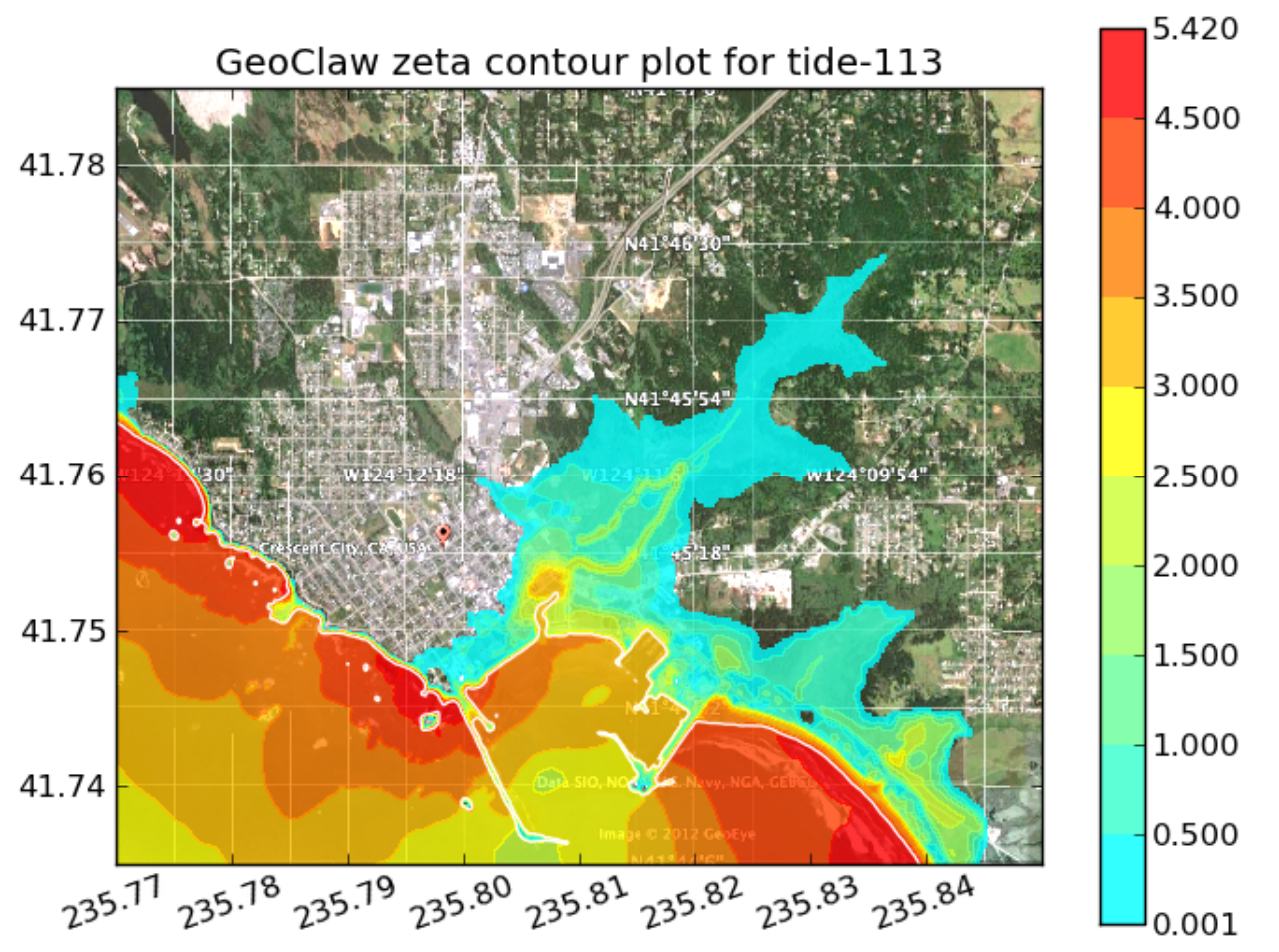
- For each tsunami pattern start time:
  - Find the maximum tide $\mathbf{M_k}$ associated with each $\mathbf{I_k}$.
  - Adjust $\mathbf{M_k}$ to get $\overline{\mathbf{M}}_\mathbf{k}$: $\overline{\mathbf{M}}_\mathbf{k} = \mathbf{M_k} - \mathbf{D_k}$.
  - Compute $\mathbf{M_P} = \max_{\mathbf{k}} \overline{\mathbf{M}}_\mathbf{k}$.
  - Increment a counter in the first bin whose right edge exceeds or equals $\mathbf{M_P}$, and in all lower bins to create a cumulative histogram.
- Divide by the number of start times to get the Cumulative distribution for tsunami E_{jk}.

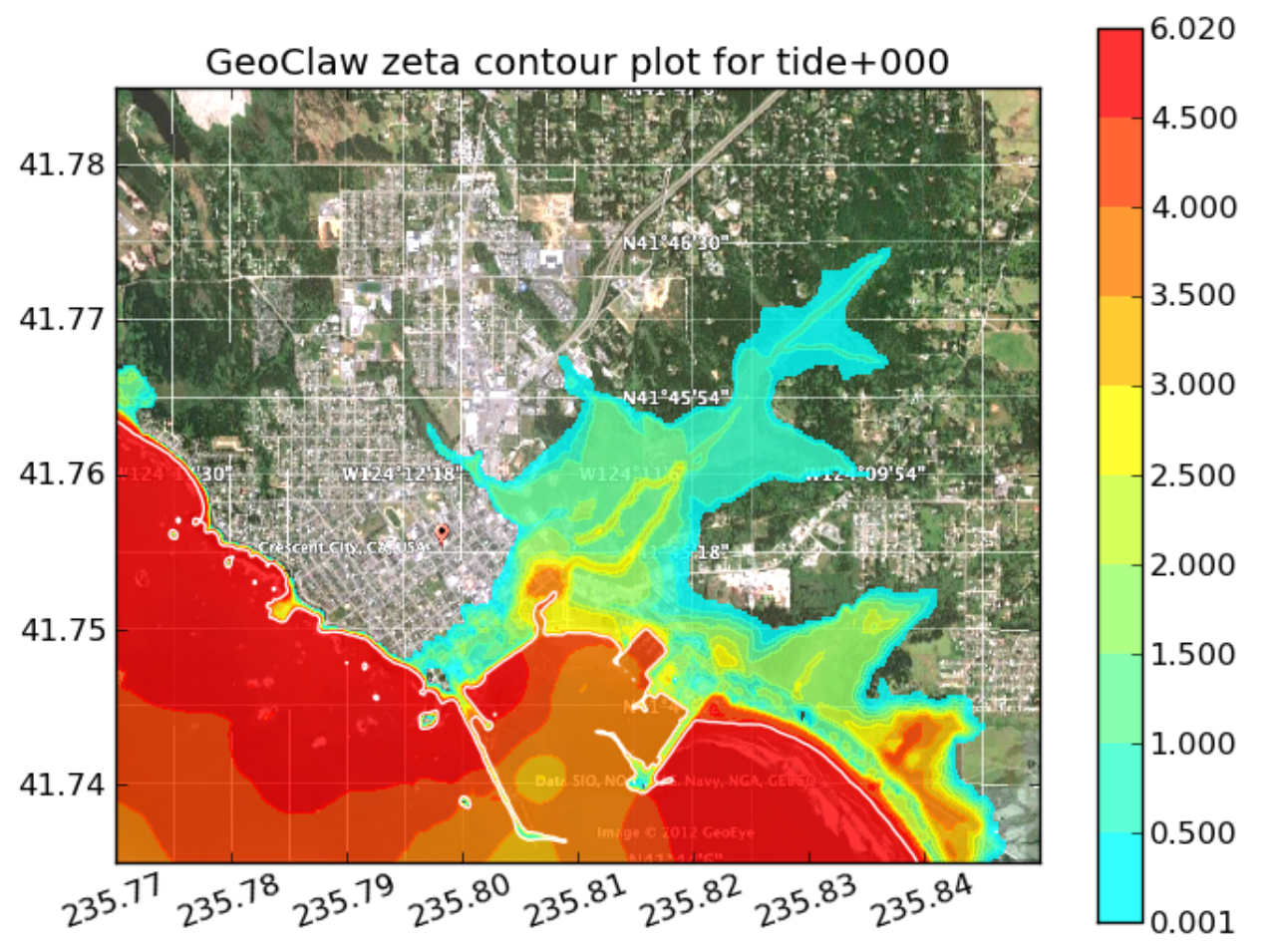
E_{jk}'s Cumulative Distribution

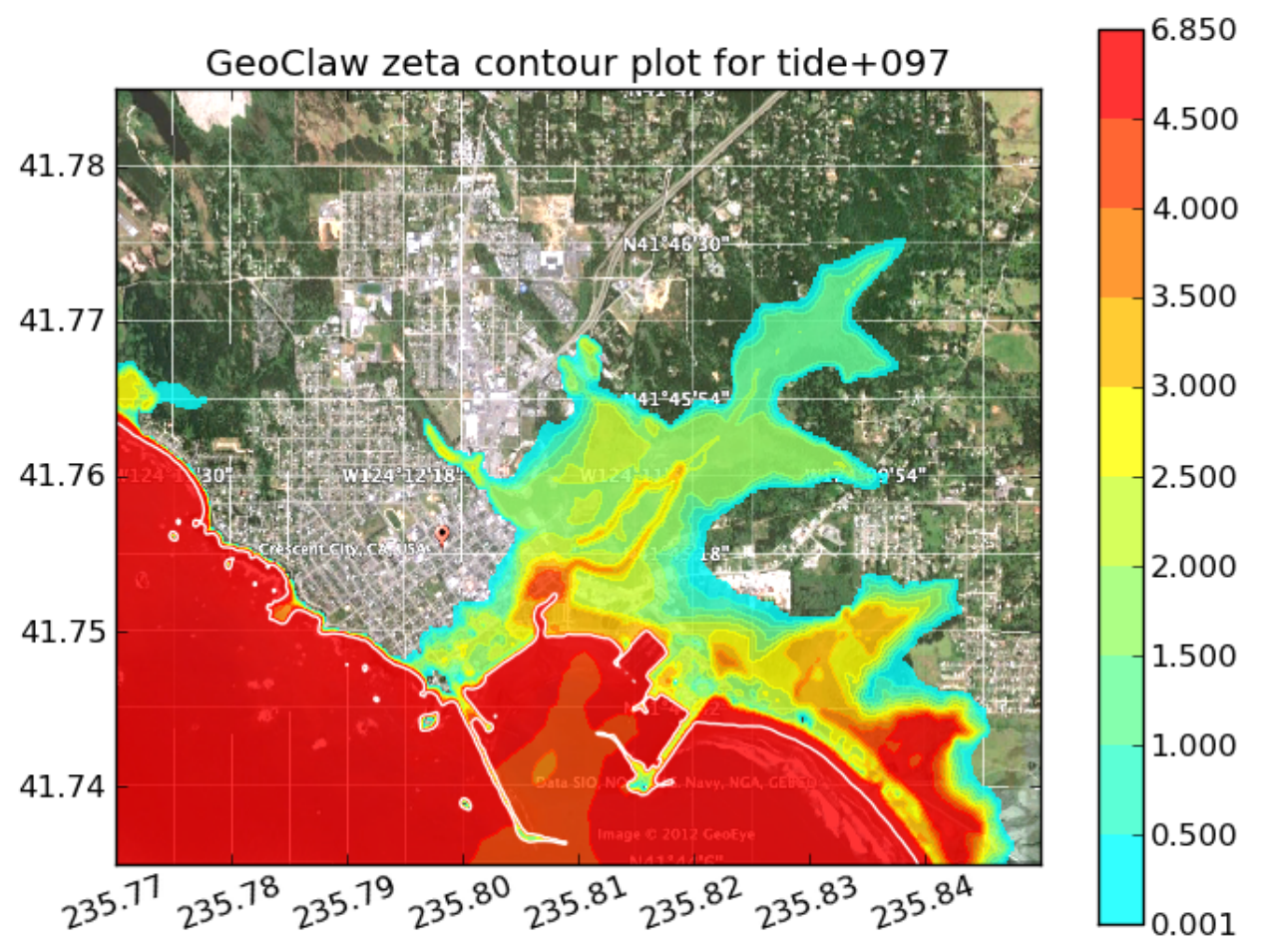


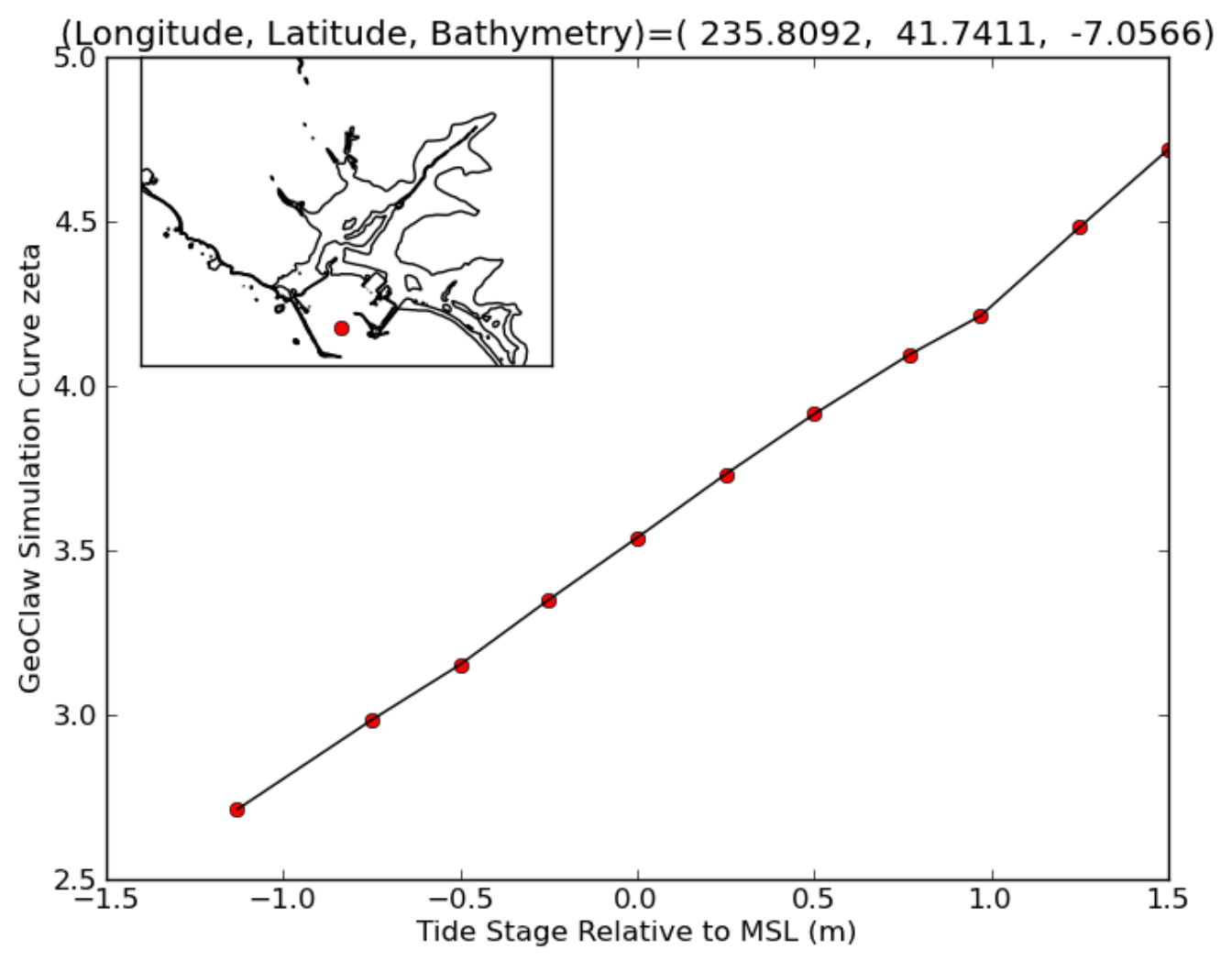
2. GeoClaw Simulation Curves

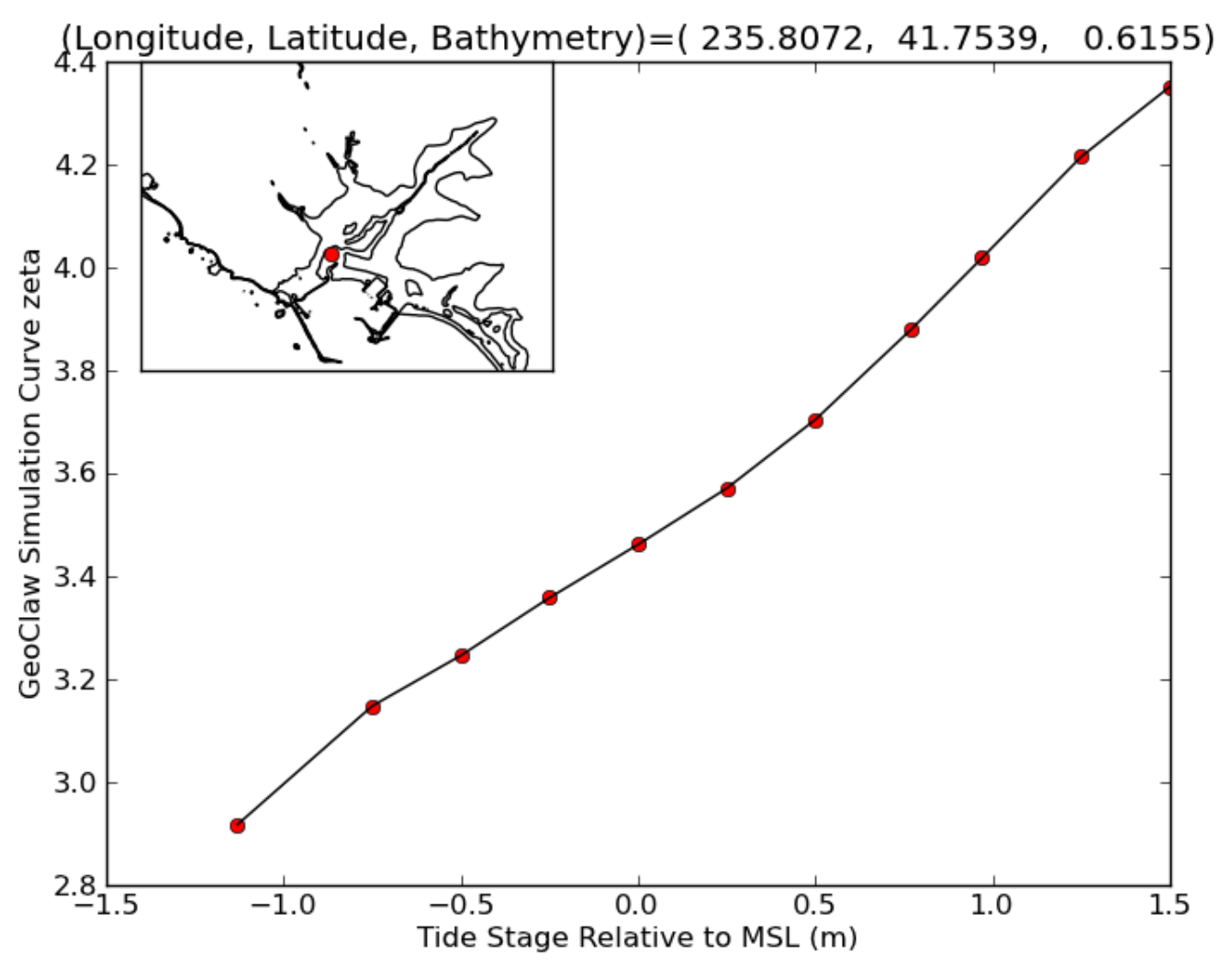
GeoClaw simulations of tsunami E_{jk} are run at multiple tide levels to get an inundation height at all grid locations as shown in the first three figures. A GeoClaw Simulation curve is then produced for each location as demonstrated for two different locations in the last two figures.







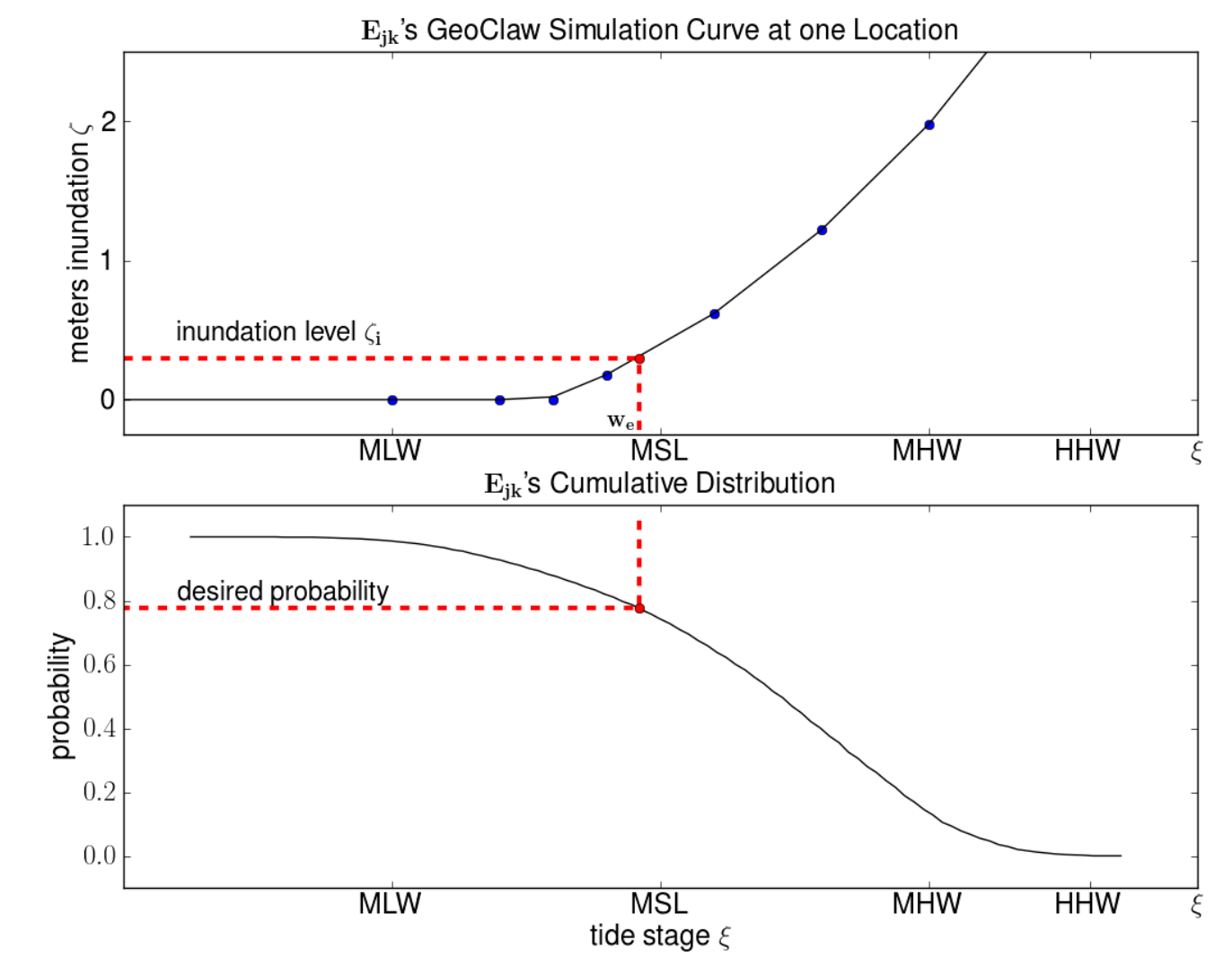




3. $P(\zeta > \zeta_i \,|\, E_{jk})$

GeoClaw + Cumulative

We find $P(\zeta > \zeta_i \,|\, E_{jk})$ for a particular location by using its GeoClaw Simulation curve (top) and tsunami E_{jk}'s Cumulative distribution (bottom) as shown below. ζ_i is located on the vertical axis of the GeoClaw Simulation curve and its associated tide level is matched up with the vertical dotted line to the corresponding tide level in the Cumulative distribution. The desired probability is then read off the vertical axis of the Cumulative distribution by following the bottom horizontal line.



4. $P(\zeta > \zeta_i)$

- Find $\mu_{ij} = \sum_{k=1}^{k_j} P(\zeta > \zeta_i \,|\, E_{jk})\, P(E_{jk} \,|\, E_j)$.
- Find $P(\zeta > \zeta_i) = 1 - \prod_{j=1}^{J} e^{-\mu_{ij}}$, $i = 1 \ldots 35$.

Our Report

http://faculty.washington.edu/lma3/AGU2013/

References

[1] F. I. González, R. J. LeVeque, and L. Adams. Probabilistic tsunami hazard assessment (PTHA) for Crescent City, CA, BakerAECOM Report for PTHA of Crescent City, CA, supported by FEMA Risk MAP Program, 1-118, 2012. Also available at http://hdl.handle.net/1773/22366.

[2] F. I. González, E. L. Geist, B. Jaffe, U. Kanoglu and others. Probabilistic tsunami hazard assessment at Seaside, Oregon, for near-and far-field seismic sources, J. Geophys. Res., **114**, C11023, 2009.

[3] H. O. Mofjeld, F. I. González, V. V. Titov, A. J. Venturato and J. C. Newman. Effects of tides on maximum tsunami wave heights: Probability distributions, J. Atmos. Ocean. Technol., **24(1)**, 117-123, 2007.

Acknowledgements

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