AN EFFICIENT SAMPLING TECHNIQUE FOR LIFELINE RISK ASSESSMENT

Principal Investigator: Jack Baker, Stanford University
Student Investigator: Nirmal Jayaram, Stanford University
The John A. Blume Earthquake Engineering Center

Introduction

- We propose a new simulation-based method to assess the seismic risk of lifelines.
- The primary focus is on efficiently sampling ground-motion intensity maps for use in risk assessment.
- The maps are generated using Importance Sampling and K-Means Clustering in order to achieve high computational efficiency.
- This simulated maps are used to assess the seismic risk of the San Francisco (SF) Bay Area transportation network.

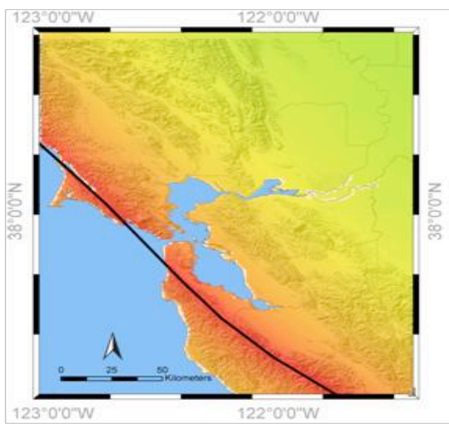
Lifeline Risk Assessment: Issues

- We need to quantify the distribution of spatially-correlated ground-motion intensities.
- Lifeline performance measures are usually not available in closed form.

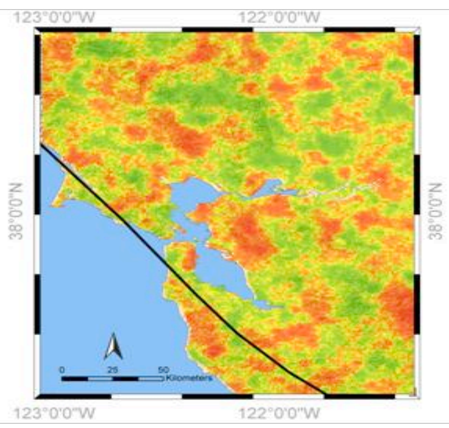
$$v(DV) = \int\int\int dF(DV|DM)\,dF(DM|EDP)\,dF(EDP|S_a)\,v(S_a)$$

Not in closed form — Now, a correlated vector of intensities

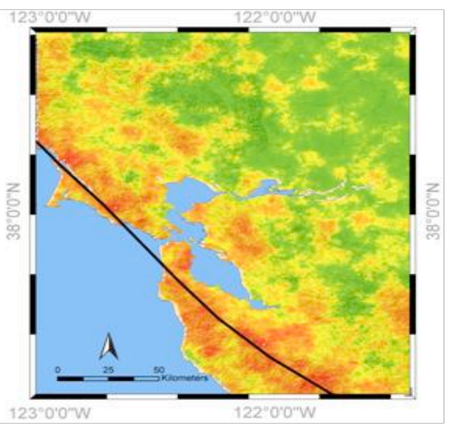
Simulation of Spatially-Correlated Ground-Motion Intensity Maps



Median ground-motion intensity map (from ground-motion models)



Simulated residuals: Randomness in the ground-motion intensity



Final ground-motion intensity map

The simulation procedure is based on the following form of the ground-motion models:

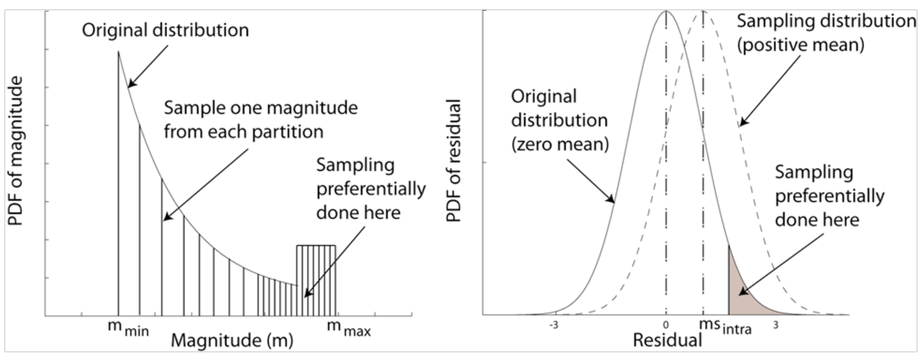
$$\ln S_a = \overline{\ln S_a(M,R,...)} + \varepsilon$$

Intensity — Median Intensity — Residual

- We simulate intensity maps by combining median intensities and residuals, and use these maps to assess lifeline performance.
- Doing this using conventional Monte Carlo simulation, however, is highly computationally expensive due to the large number of maps required for robust performance assessment.

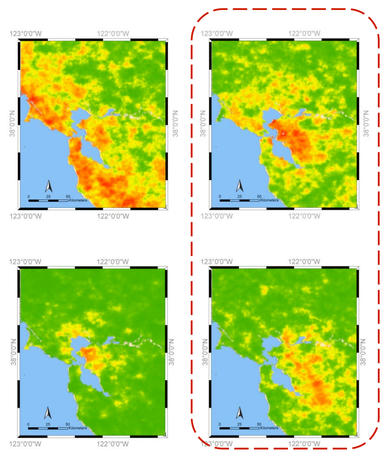
Importance sampling

We use importance sampling (IS) to preferentially sample large magnitude earthquakes and large residuals, which have a significant influence on the lifeline risk.



Data Reduction: K-means clustering

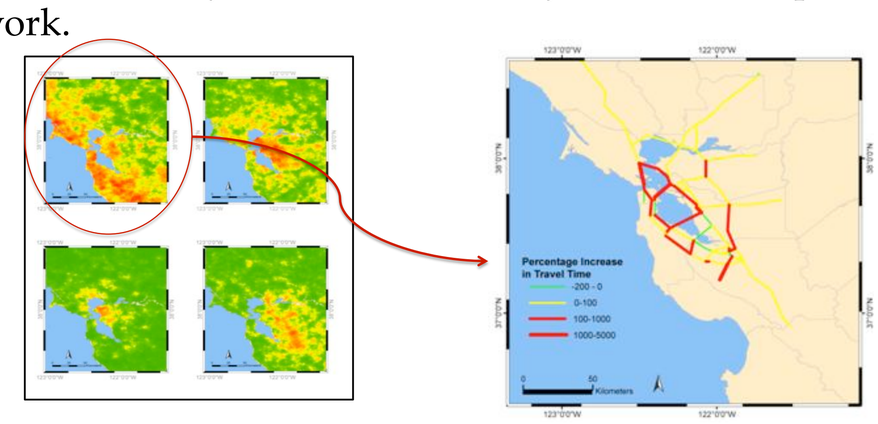
- We use K-means clustering to combine 'similar' maps into a small number of clusters.
- Since the maps within a cluster are similar, we select and use only one map from each cluster for the risk assessment.
- The combination of IS and K-means clustering produces unbiased and probabilistically-representative maps.



Group these in to a cluster

Transportation Network Performance

- We use IS and K-means clustering to produce a catalog of 150 intensity maps that represent the SF Bay Area ground-motion hazard.
- These maps are then used to compute post-earthquake travel-time delays on the SF Bay Area transportation network.



Results and Conclusions

- Delays from the sampled maps are aggregated to the obtain the delay exceedance curve.
- The exceedance curve obtained using the efficiently-sampled maps matches with that from the conventionally-sampled maps.
- Efficient sampling leads to about three orders of magnitude reduction in the computational effort.
- We are planning to make this efficiently-sampled catalog of 150 maps public so that they can be used for other risk assessments if desired.