

Random Sampling of Virtual Rupture Scenarios in PSHA for Diffuse Seismicity

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Objectives

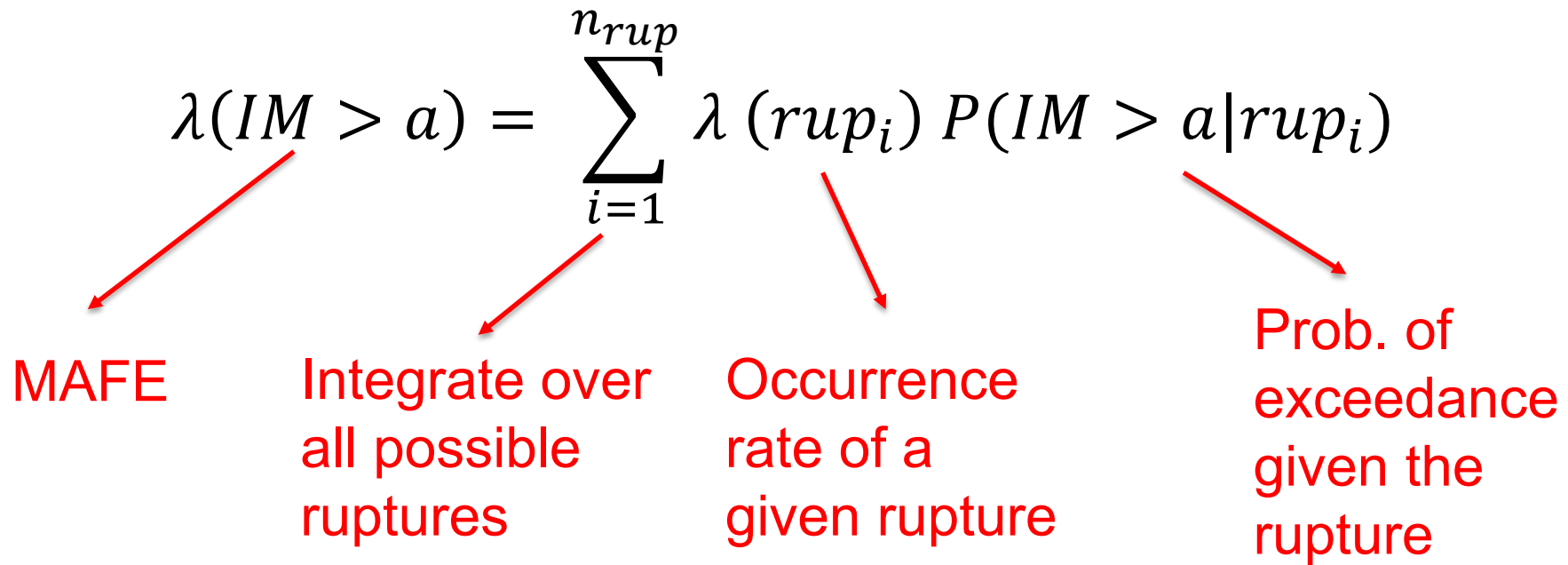
- With increasingly complex PSHA models, computational time has increased exponentially
- Modeling virtual fault ruptures is one of the complexities involved in modern PSHA
 - VF parameters are often modelled as aleatoric; hence need to account for all possible values
 - The number of rupture scenarios scales exponentially with the number of rupture parameters considered
- Can we limit the number of modelled rupture scenarios with minimal loss to accuracy?

What are virtual faults?

- Earthquakes are modeled as a rupture along a finite-fault
- But not all faults are mapped or known. To account for seismicity from these unknown faults, Areal sources are considered.
 - We assume imaginary faults within the areal source (hence called virtual fault)
 - The location of virtual faults within the area is assumed to be random. Hence, we integrate over all possible locations.
 - We assume a rupture occurs on this virtual fault generating the earthquake

Theoretical consideration

Rate of exceedance is given by (Hazard Integral)

$$\lambda(IM > a) = \sum_{i=1}^{n_{rup}} \lambda(rup_i) P(IM > a | rup_i)$$


MAFE

Integrate over all possible ruptures

Occurrence rate of a given rupture

Prob. of exceedance given the rupture

Theoretical consideration

For a given rupture scenario,

$$\lambda(rup_i) = \lambda(EQ) f_M(m_i) dm_i f_{\theta|M}(\theta_i|m_i) d\theta$$

Probability of realization of rupture i

θ is the vector of parameters defining the rupture and $f_{\theta|M}(\theta)$ is their joint PDF conditional on M

Virtual Rupture Parameters

1. Location of the fault
2. Strike
3. Dip
4. Style of Faulting
5. Rupture dimensions (Length, width or Area)
6. Location of hypocenter on the rupture plane
 - a) Along strike
 - b) Along dip

Note: There are other parameters that physically define fault rupture. But current GMMs don't parameterize them.

Full integral

- For robust evaluation of the hazard integral, discretize θ into N cells (or quadrature nodes) with corresponding probabilities from the joint density function $f_{\theta}(\theta)$
- If each parameter θ_j is discretized into m_j points, then the total number of discrete states is

$$N = \prod_{j=1}^n m_j,$$

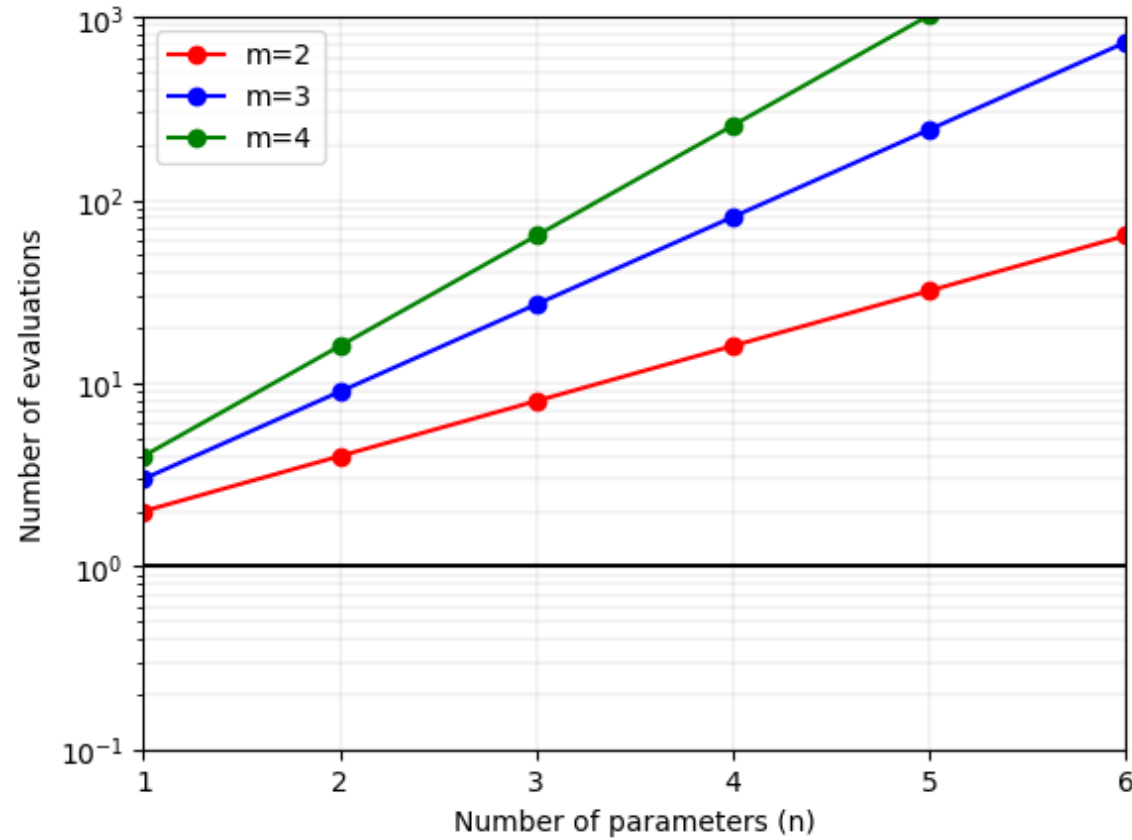
n is the number of rupture parameters

- The computation cost scales with $O(N)$

Random Sampling

- With little loss in accuracy, the evaluation can be simplified by randomly sampling one set of rupture parameters from $f_{\theta}(\theta)$
- The computational cost reduces significantly.
 - 1 evaluation instead of N evaluations before
- By sampling multiple times, the results would converge to the traditional approach.

Computational cost



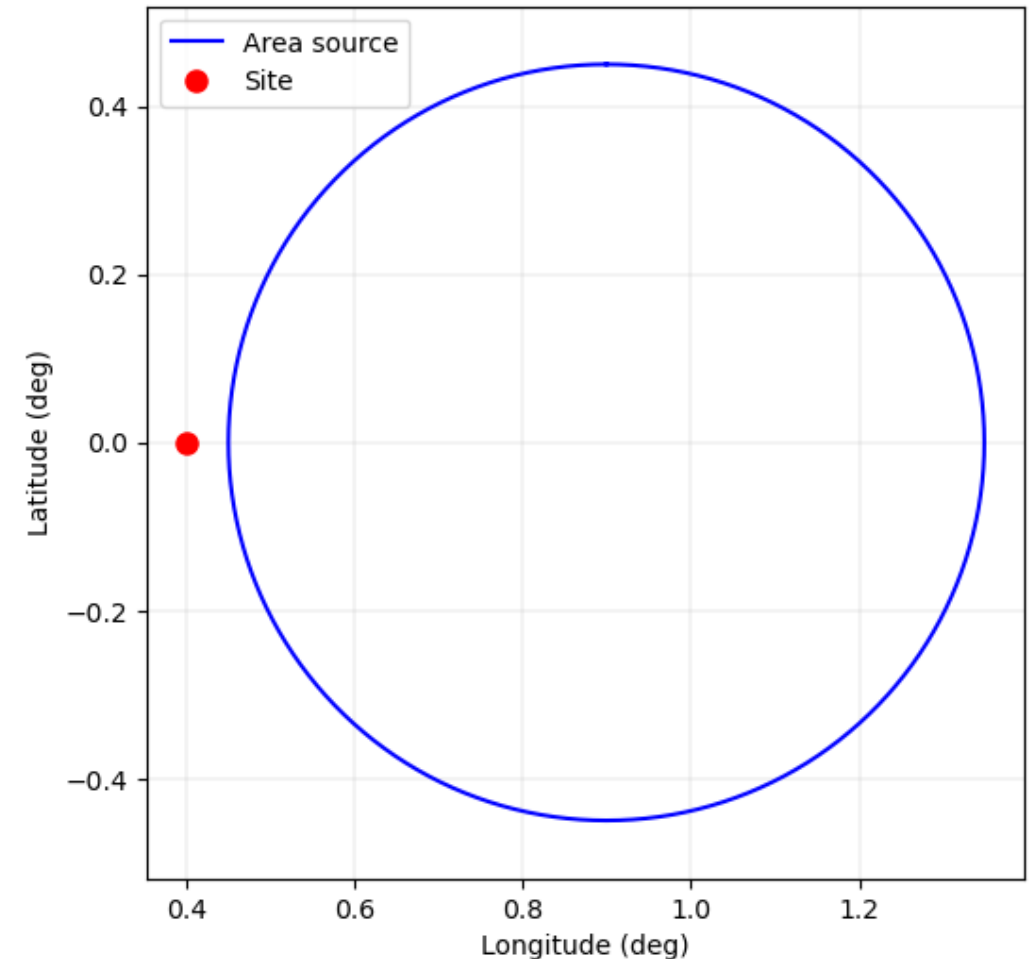
m – number of bins
for each parameter

Example case

Aleatory distribution of rupture parameters

SOF (θ_1)	Strike (θ_2)	Dip (θ_3)	$f_{\theta}(\theta)$
SS	250	80	0.06
SS	250	90	0.06
SS	70	80	0.06
..	..	..	..
RV	250	35	0.04
RV	70	35	0.04
RV	70	45	0.04

20 combined bins to capture the distribution



Results

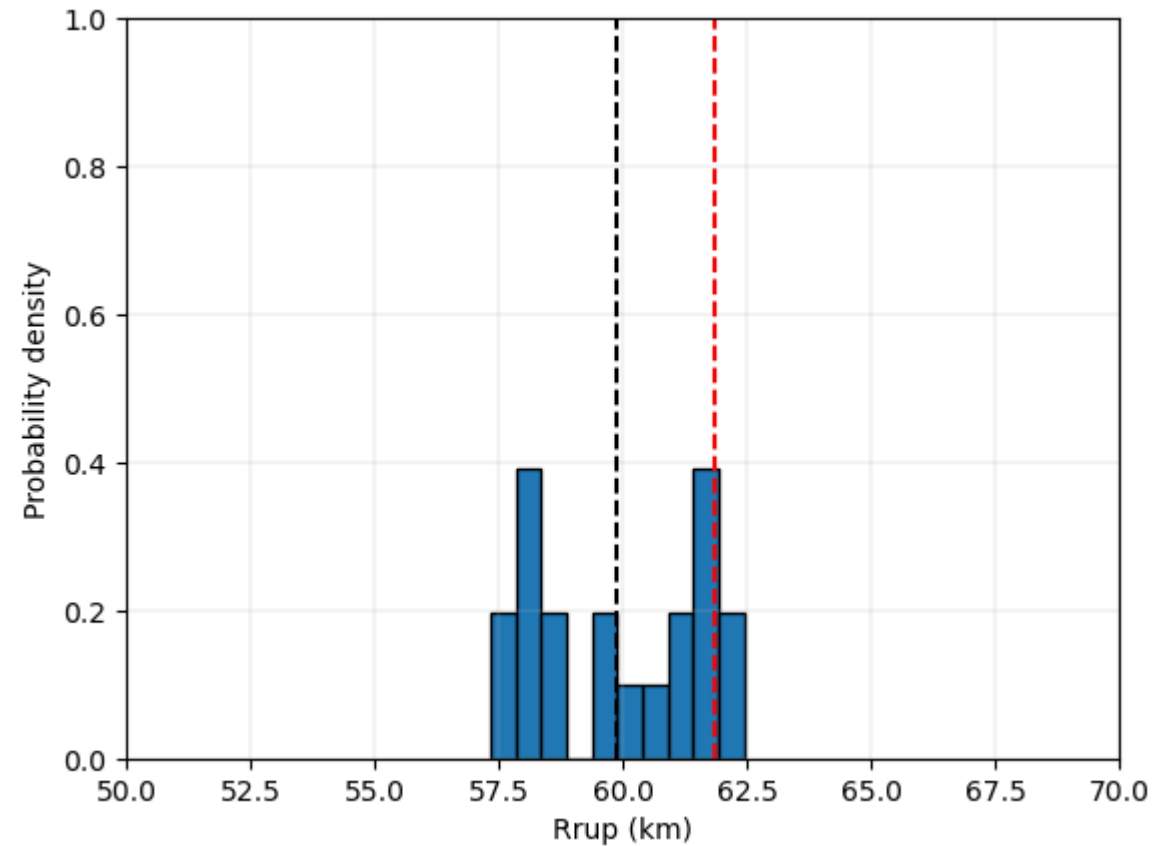
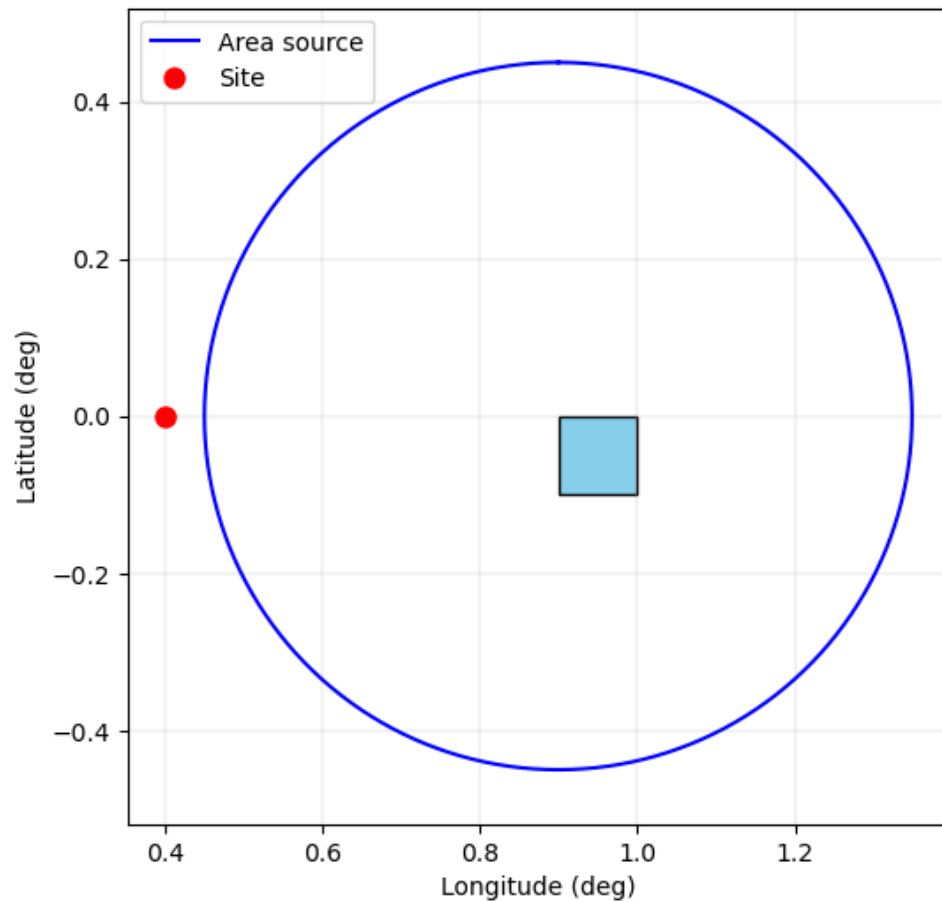
(a) Distribution of Rupture Distance

- Ground motion predictions (by current GMMs) depend on finite-fault distance metrics
- Other secondary effects – Hanging wall effect might be relevant in certain cases
- Distribution of rupture distances arising from aleatory variability of rupture scenarios should be preserved.

Results

(a) Distribution of Rupture Distance

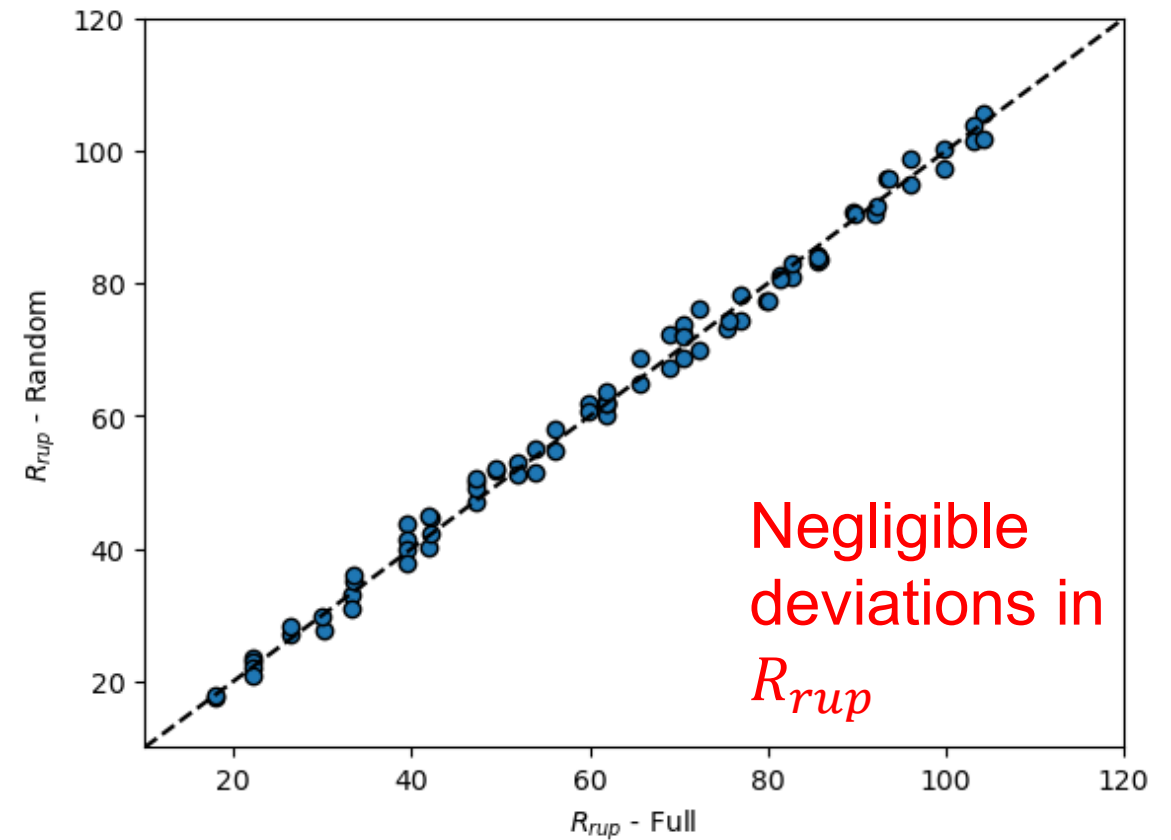
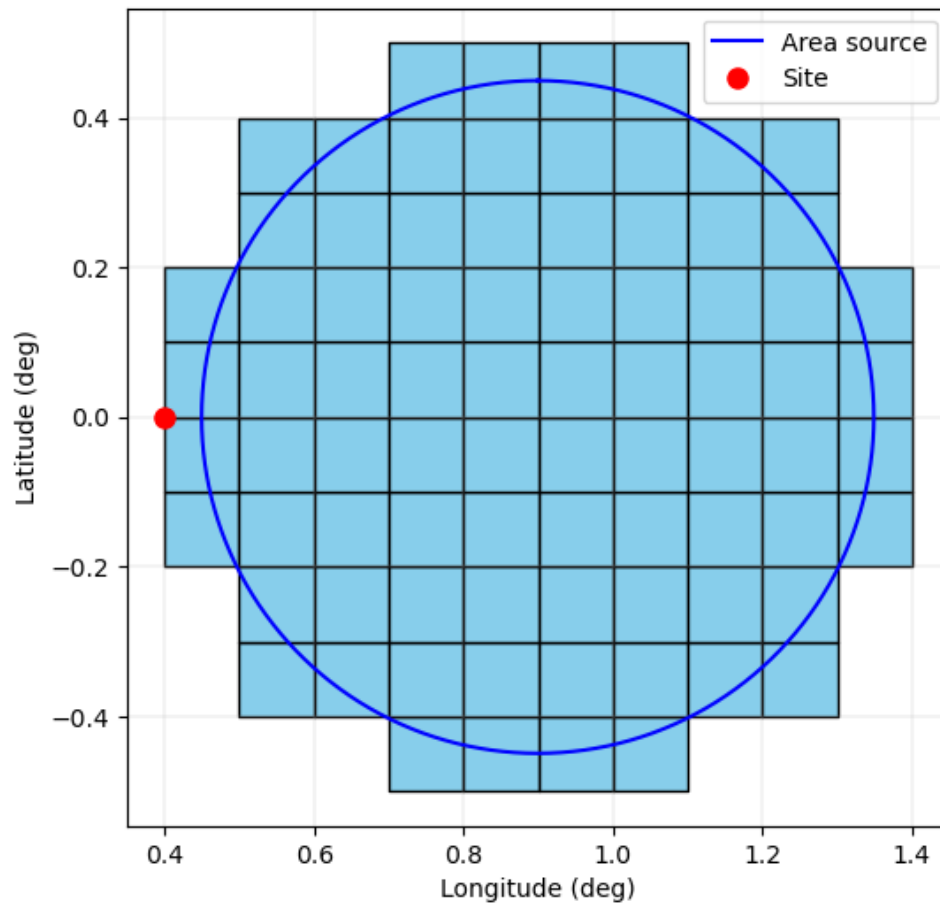
For $M_w = 6$



Results

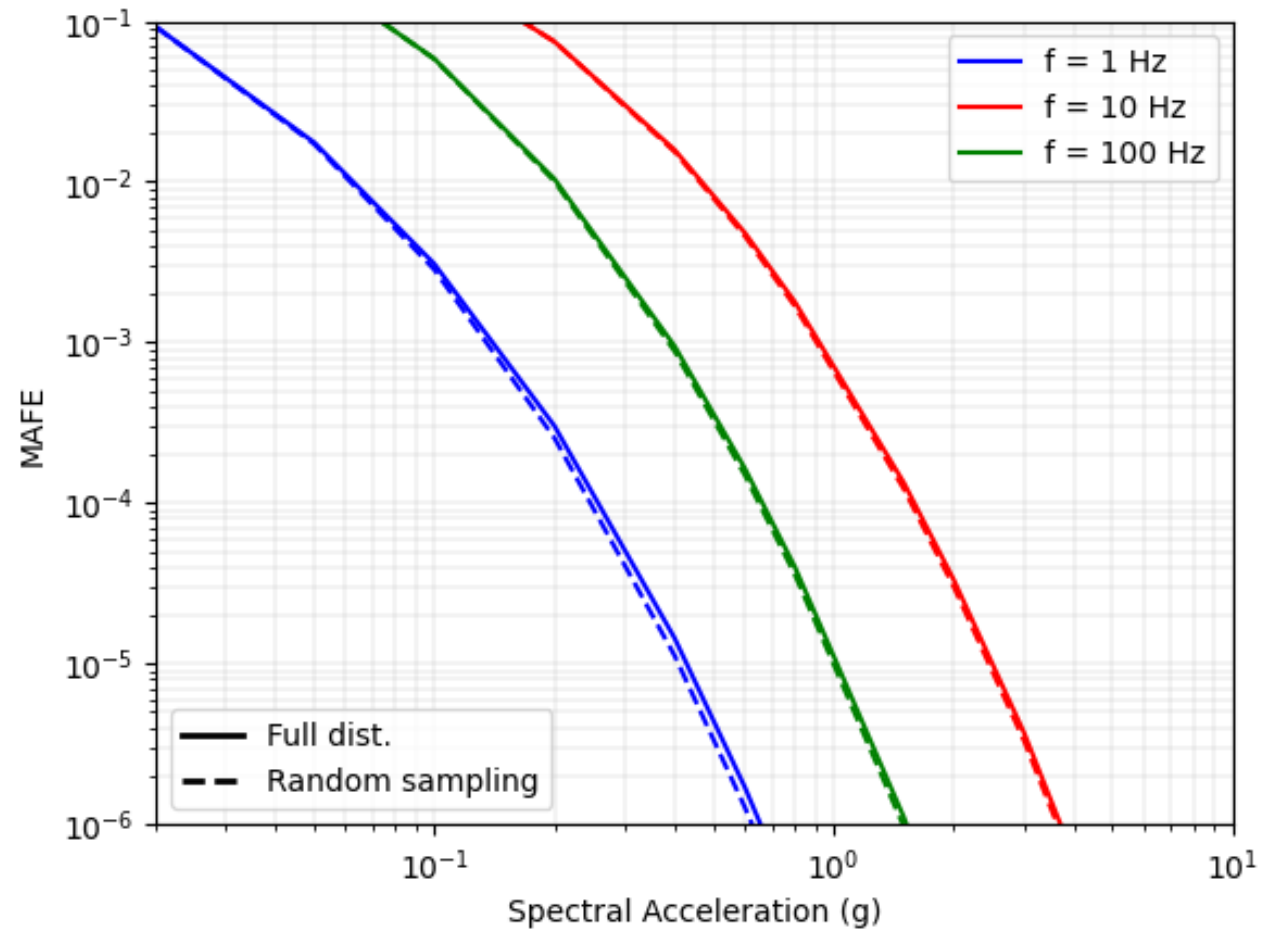
(a) Distribution of Rupture Distance

For $M_w = 6$



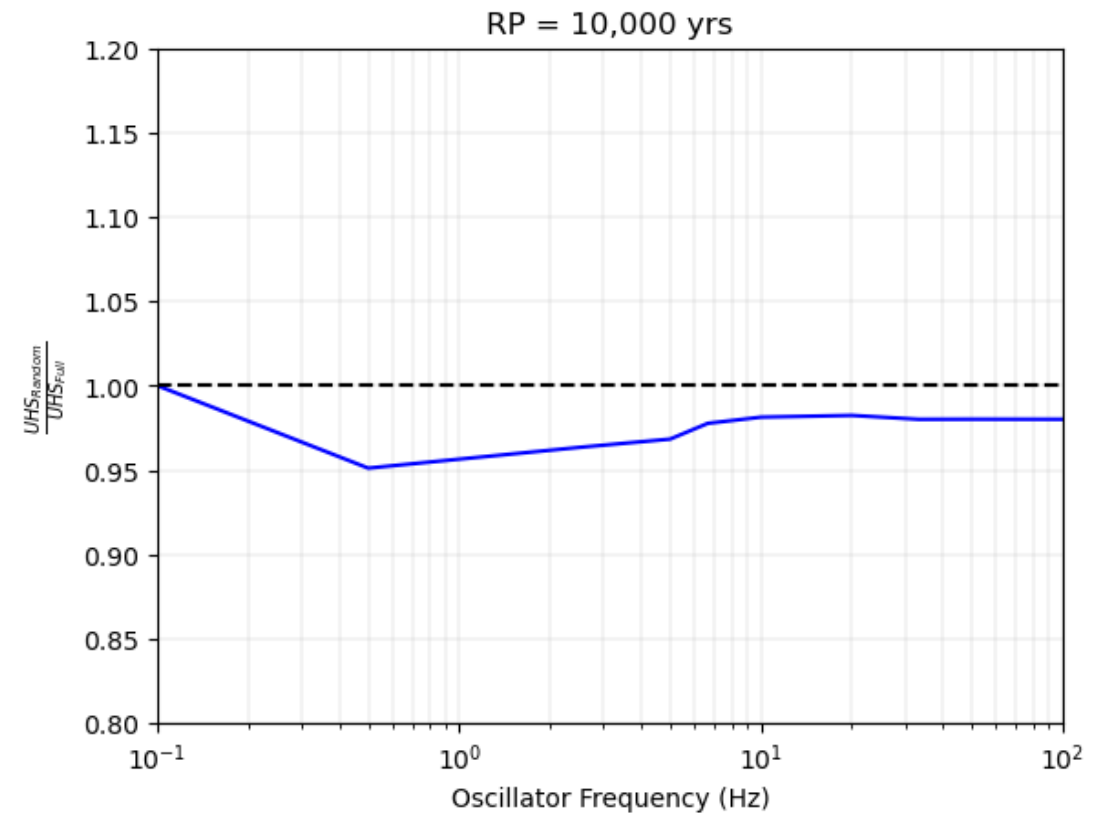
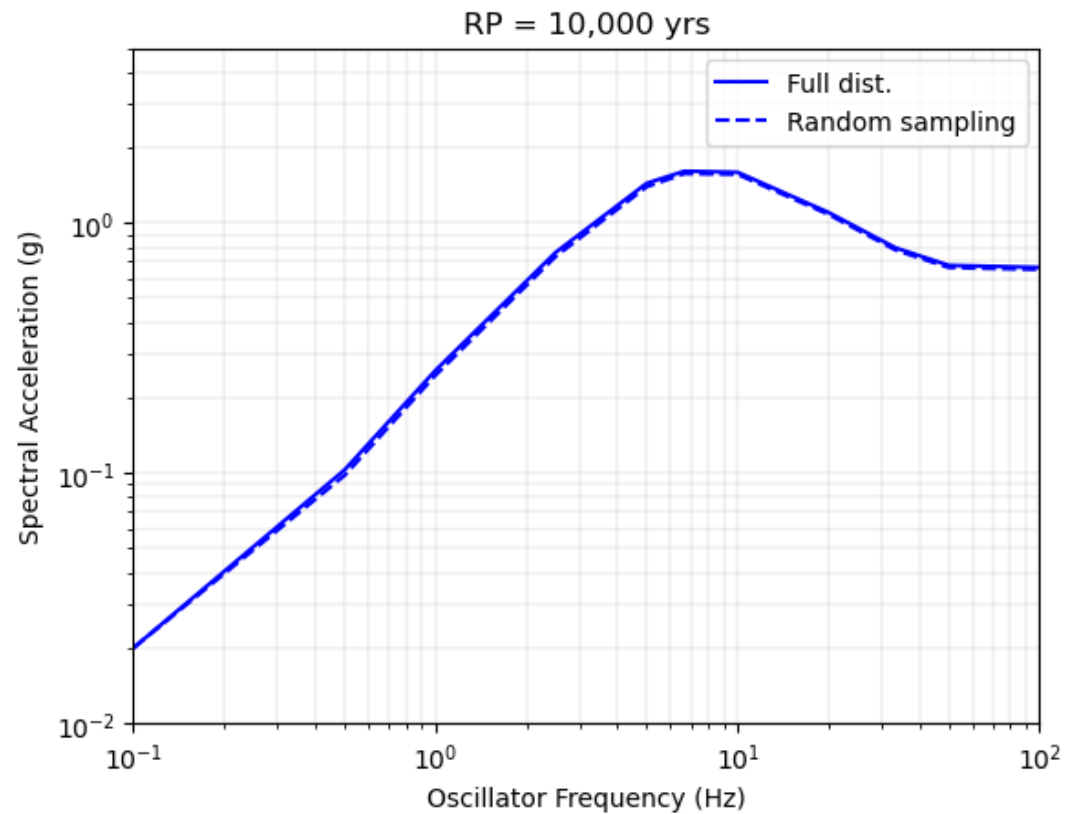
Results

(b) Hazard



Results

(c) Uniform Hazard Spectra



Summary

- The objective is to reduce the computational effort in PSHA calculations
 - Reducing the number of virtual ruptures modelled
- With little loss in accuracy, randomly sampling virtual ruptures greatly reduces the computational effort
- The results show less than 5% difference in hazard-consistent ground motions
- If the error tolerance is within limits, the proposed approach can lead to significant improvement in computational speed.