Towards Effective Ground Motion Selection: Implementation of Conditional Mean Spectrum (CMS)

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Introduction

•Probabilistic seismic hazard analysis (PSHA) combines probabilities of all earthquake magnitude, distance scenario to compute seismic hazard at a site.

•PSHA also incorporates uncertainties in ground motion prediction, by considering multiple ground motion prediction models (GMPMs).

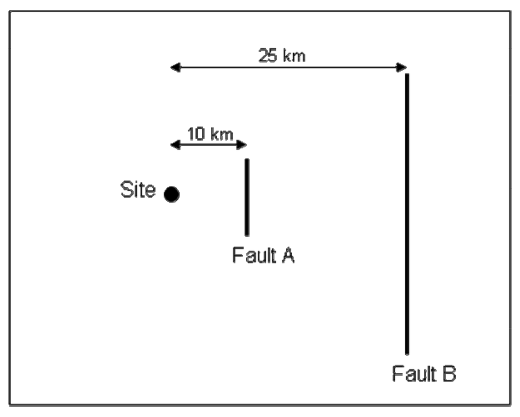
•Current ground motion selection uses the information from earthquake scenario without considering multiple GMPMs.

•Here we consider ways to incorporate multiple GMPMs, using refinements to disaggregation and conditional mean spectrum (CMS).

•CMS utilizes correlation of spectral acceleration (Sa) across periods.

Site Application

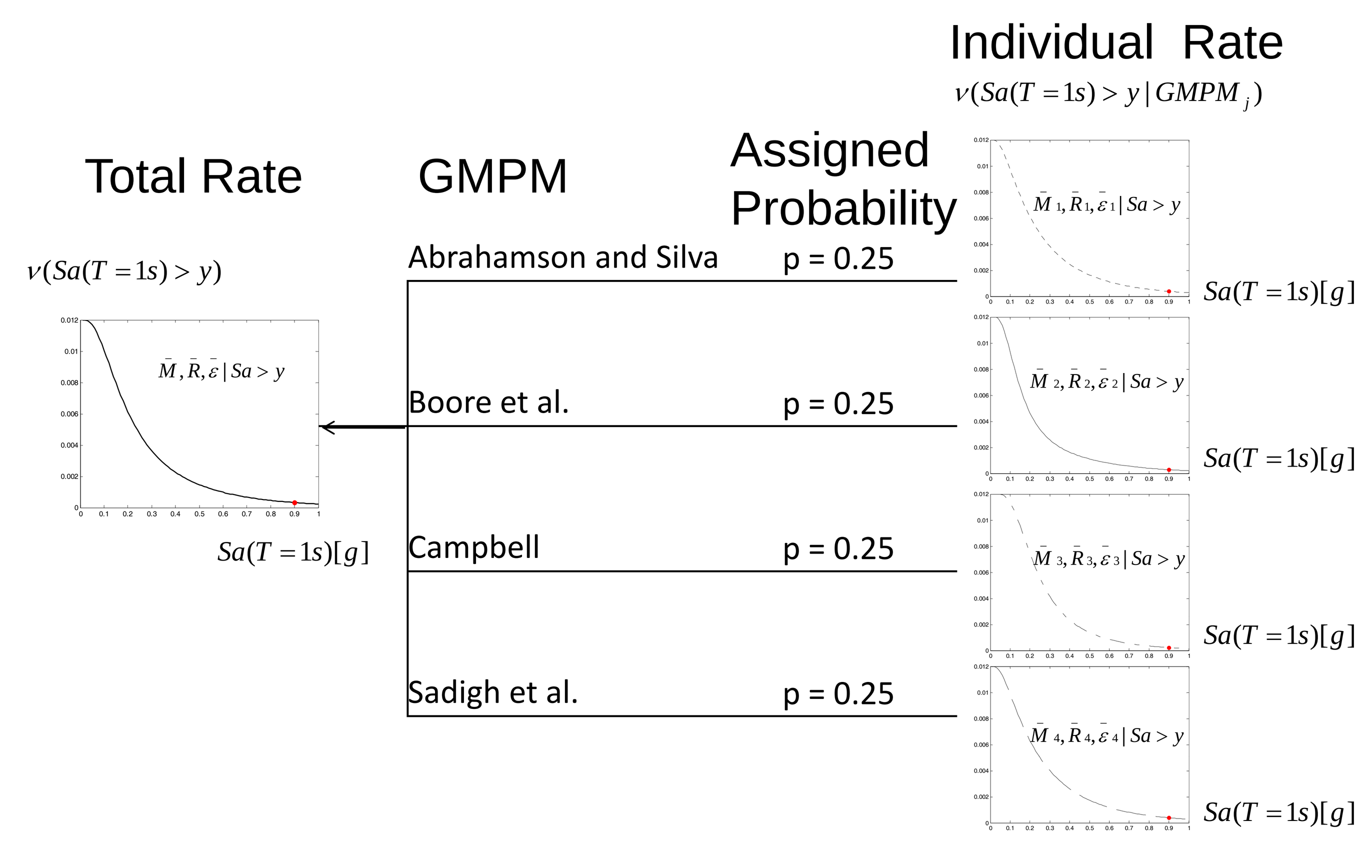
Site Dominated by Event A and B



	Event A	Event B
Magnitude, M	6	8
Distance, R (km)	10	25
Annual rate of occurrence	0.01	0.002

Strike slip fault, Vs30 = 310 m/s

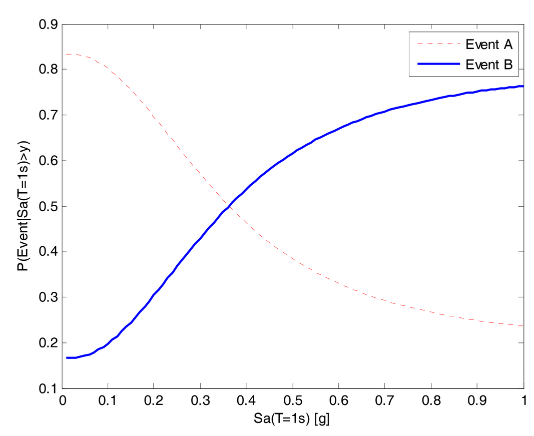
PSHA Using Multiple GMPMs



$$\nu(Sa>y)=\sum_i\sum_j \nu_i\iiint f_{M,R,E}(m,r,\varepsilon)P(Sa>y\mid m,r,\varepsilon,GMPM_j)\,dm\,dr\,d\varepsilon\,P(GMPM_j)$$

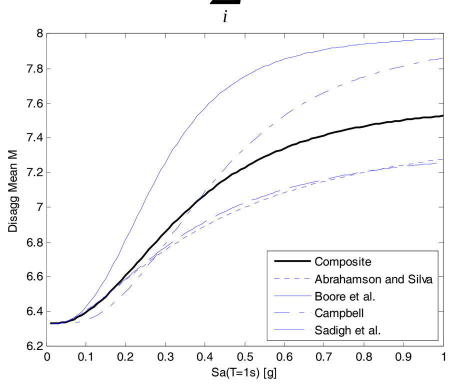
Disaggregation of Events

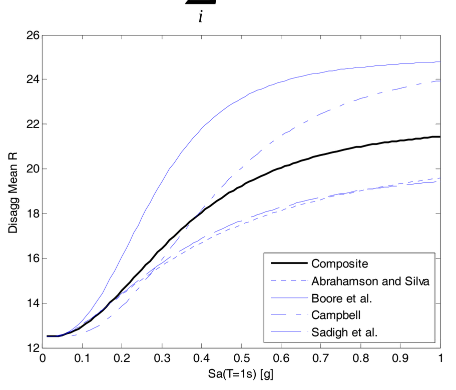
$$P(Event_i\mid Sa>y)=\frac{P(Sa>y\mid Event_i)\nu(Event_i)}{\nu(Sa>y)}$$



$$Event_i=\{M=m_i, R=r_i\}$$

$$\bar{M}\mid Sa>y=\sum_i m_i P(Event_i\mid Sa>y) \qquad \bar{R}\mid Sa>y=\sum_i r_i P(Event_i\mid Sa>y)$$





CMS Computation Approach 1

CMS Computation Approach 0

•First, compute the mean M, R, ε given Sa>y using all GMPMs,

$$\bar{M}\mid Sa>y=\sum_i m_i P(Event_i\mid Sa>y)$$
$$\bar{R}\mid Sa>y=\sum_i r_i P(Event_i\mid Sa>y)$$
$$\bar{\varepsilon}\mid Sa>y=\sum_i \varepsilon_i P(Event_i\mid Sa>y)$$

•Then, compute CMS_j, the CMS computed using $GMPM_j$ and the mean M, R, ε from disaggregated means on all GMPMs.

$$CMS_j=CMS_j(\bar{M},\bar{R},\bar{\varepsilon}\mid Sa>y)$$

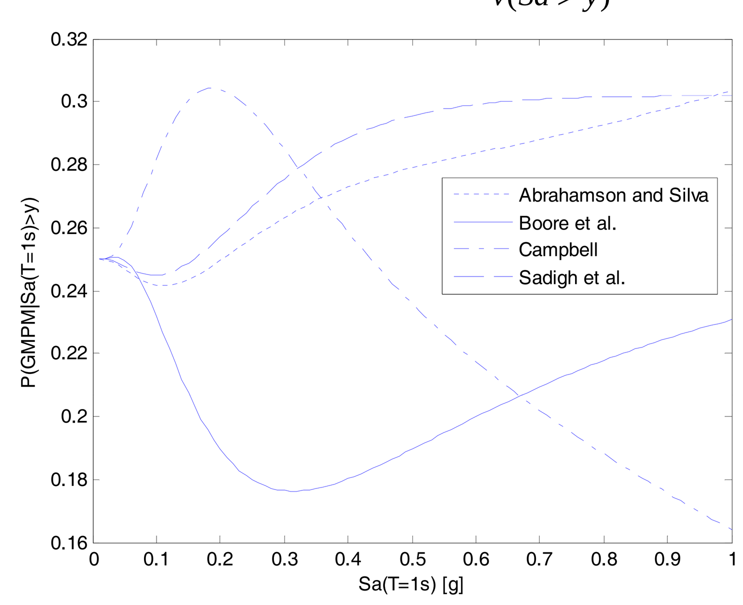
•Finally, compute a weighted sum of these CMS_j, with **assigned probability** of GMPM.

$$CMS=\sum_j CMS_j P(GMPM_j)$$

Disaggregation of GMPMs

Disaggregation of GMPMs is similar to disaggregation of events.

$$P(GMPM_j\mid Sa>y)=\frac{\nu(Sa>y,GMPM_j)}{\nu(Sa>y)}$$



$$\nu(Sa>y,GMPM_j)=\sum_i P(Sa>y\mid GMPM_j,Event_i)P(GMPM_j)\nu(Event_i)$$

CMS Computation Approach 2

•Similarly, first compute the mean given Sa>y using each GMPM. Note that the mean here is **conditional on each GMPM**, instead of all GMPMs in Approach 1.

$$\bar{M}_j\mid Sa>y=\bar{M}\mid GMPM_j,Sa>y=\sum_i (M_i\mid GMPM_j)P(Event_i\mid GMPM_j,Sa>y)$$

•Then, compute CMS_j, the CMS computed using $GMPM_j$ and the mean M, R, ε from disaggregated means for each GMPM.

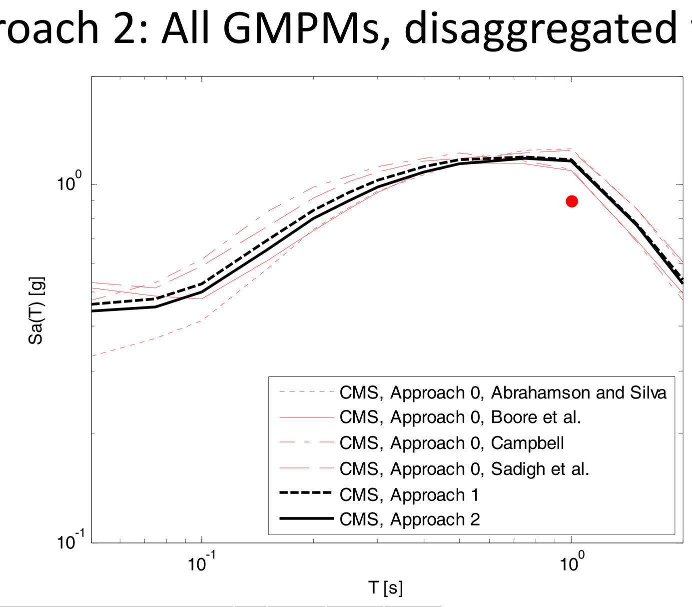
$$CMS_j=CMS_j(\bar{M}_j,\bar{R}_j,\bar{\varepsilon}_j\mid Sa>y)$$

•Finally, compute the weighted sum of CMS_j, with **disaggregated contribution** of GMPM.

$$CMS=\sum_j CMS_j P(GMPM_j\mid Sa>y)$$

CMS Computation Approaches

•Approach 0: One GMPM
•Approach 1: All GMPMs, logic-tree weights
•Approach 2: All GMPMs, disaggregated weights



Approach	0	1	2
Data available	Y	Y	N
Probabilistically consistent	N	N	Y
Computationally accurate	N	?	Y

Approach 1 produces approximate results as the more precise Approach 2.

Conclusion

•Conditional mean spectrum (CMS) can be a new target spectrum for ground motion selection.

•Precise application using multiple ground motion prediction models (GMPMs) requires more data than typically available.

•Here we extended disaggregation to include the required information. The extension is feasible for practical implementation.

•Validation of CMS using multiple GMPMs can lead to the next step in practical implementation for ground motion selection.

•Collaboration with USGS in the future is promising.

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