

Advances in regional seismic risk assessment incorporating spatial and structural correlations

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Problems this talk seeks to pose

Problem 1: We have known for more than a decade that some intensity measures predict structural response better than the ones we use. What has held adoption back? Does it make a difference?

Problem 2: Two groups publish vulnerability models for the same building class. One conditions on PGA, the other on $S_a(1s)$. How can we compare? Should they give you the same answer?

Problem 3: Two identical buildings on the same street, and you know they felt the same shaking. One has collapsed. Does that tell you anything about the other?

Posing problems...



Gerard O'Reilly

Offering solutions!



Davit Shahnazaryan

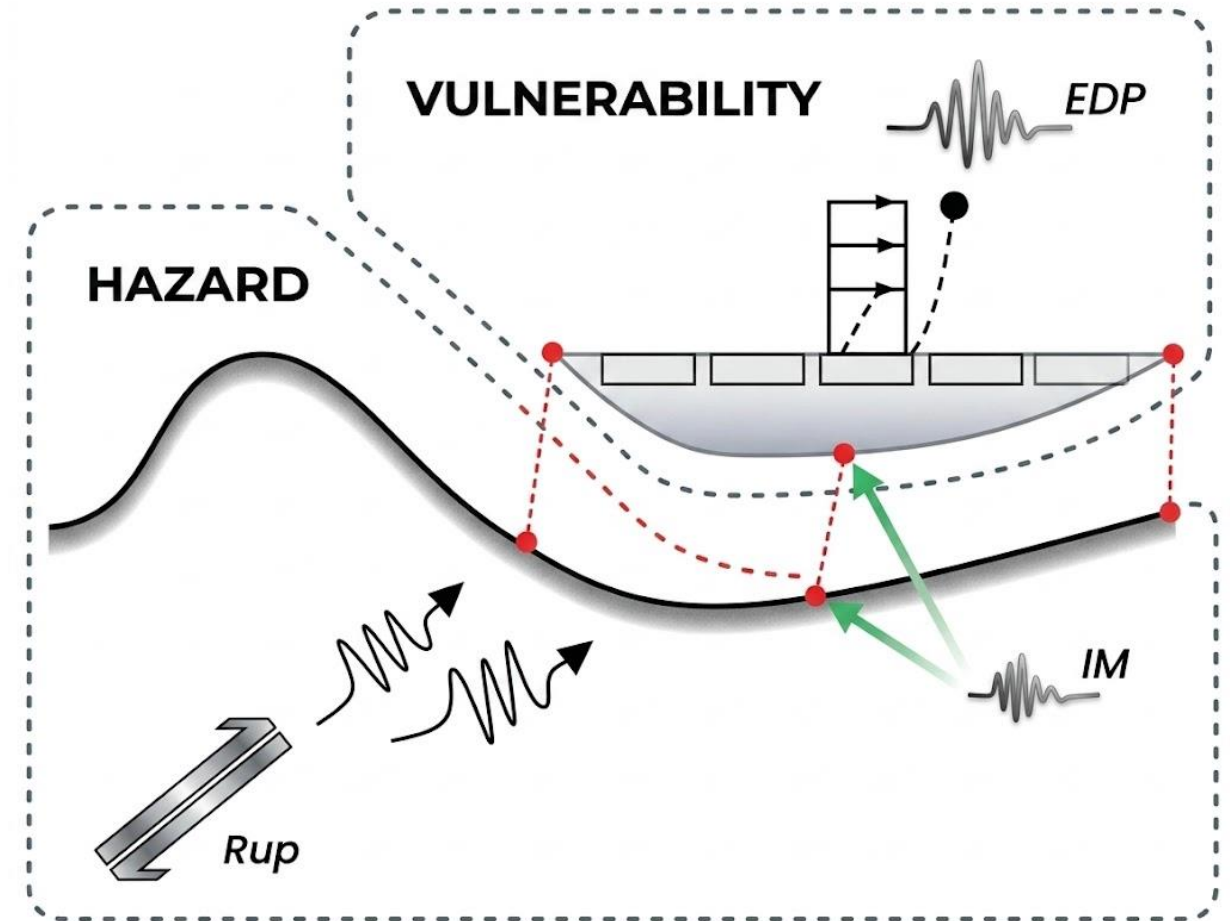
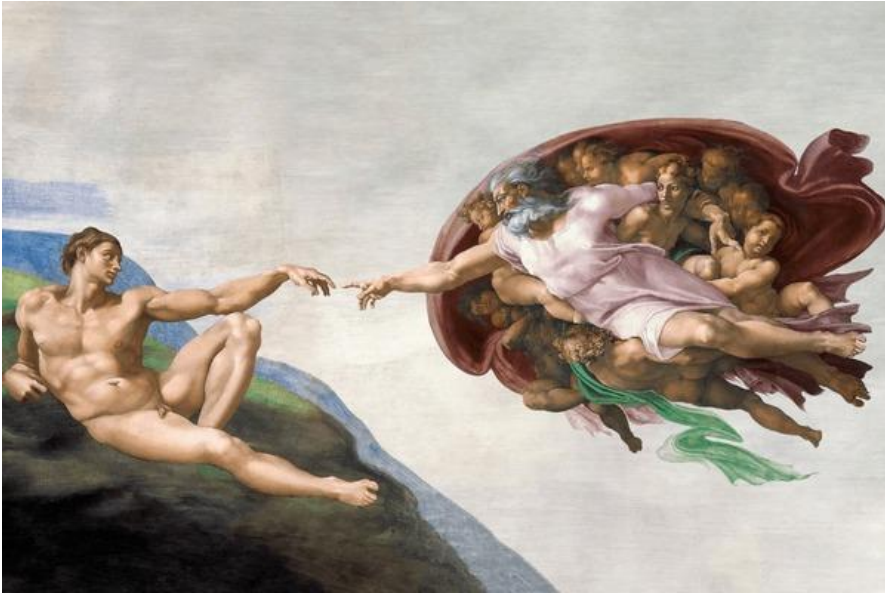


Tomás Mejía



Vítor Monteiro

Intensity measures are the interface variable



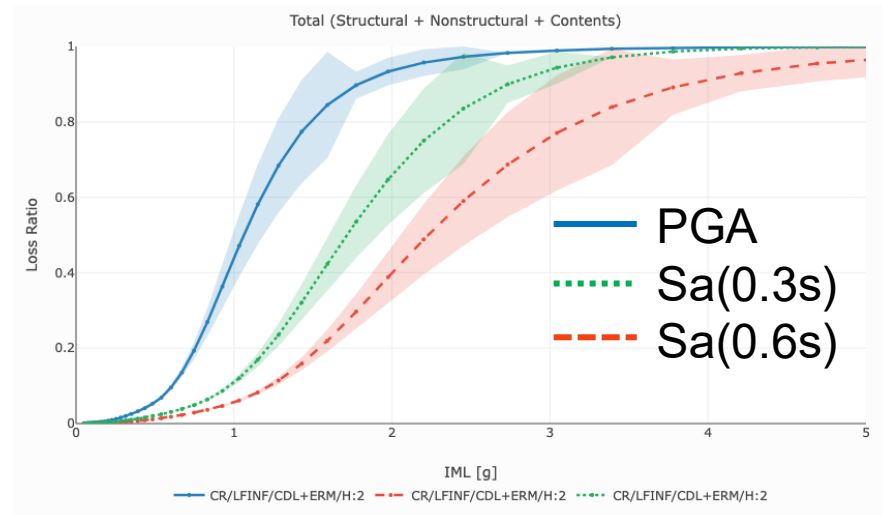
**Problem 1: Better intensity measures
exist. Why do we not use them?**

Legacy IMs have maintained a stronghold in practical applications

- ESRM20 adopted PGA, $S_a(0.3s)$, $S_a(0.6s)$ and $S_a(1s)$
- Average spectral acceleration has 10-15 years of research demonstrating its benefits across a range of structural typologies and seismic scenarios

The screenshot shows the 'GEM Vulnerability Models' web application. On the left is a sidebar with a search bar and a 'CONTENTS' menu listing: Overview, Capacity Models, Ground-Motion Records, Structural Analysis, Fragility Models, and Consequence Models. The main panel is titled 'Selected: Europe' and contains input fields for 'Model' (set to GEM), 'Building Class' (set to CR/LFINF/CDL+ERM/H:2), and 'Occupancy' (set to RES). A dropdown menu for 'IMT' is open, showing options: PGA, SA(0.3), SA(0.6), and SA(1.0), with SA(1.0) selected. Below the inputs are 'Add to Plot' and 'Clear All' buttons. At the bottom, three tags for 'CR/LFINF/CDL+ERM/H:2' are visible.

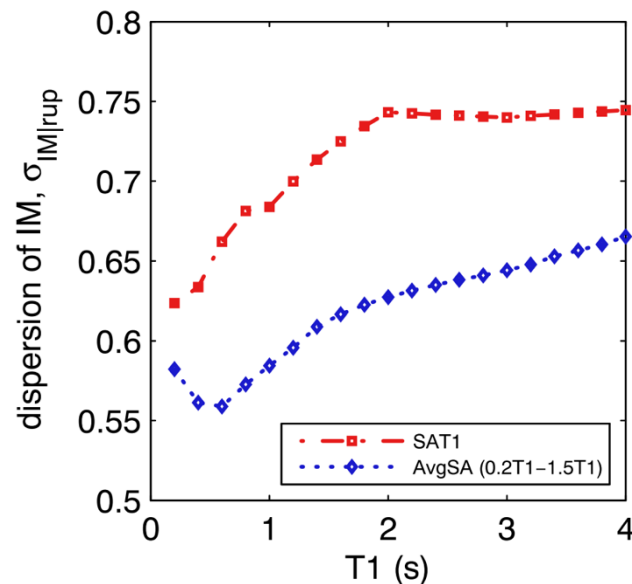
https://docs.openquake.org/vulnerability/vulnerability_models.html



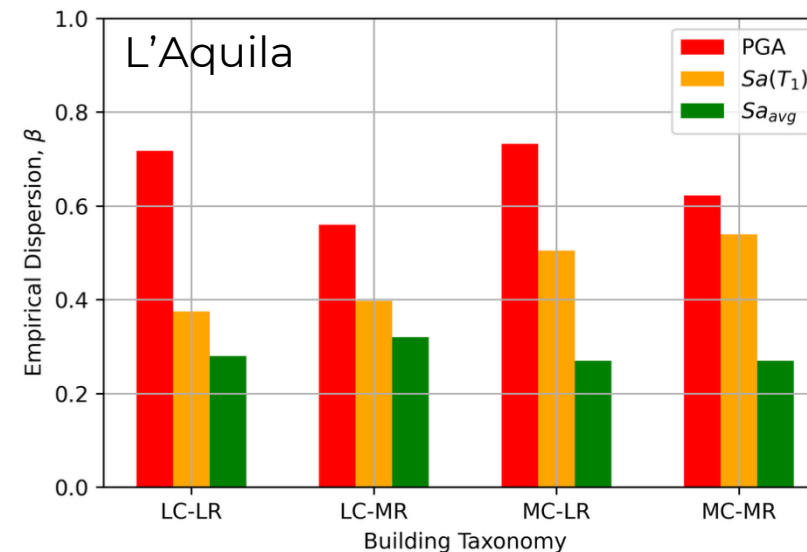
Next-generation IMs reduce aleatory uncertainty

- Compared with $Sa(T)$, the average spectral acceleration ($Sa_{avg}(T)$ but also written as AvgSA) has lower dispersion for **both hazard and vulnerability**

Lower GMM dispersion



Lower empirical fragility function dispersion



Hazard infrastructure missing for risk analysis

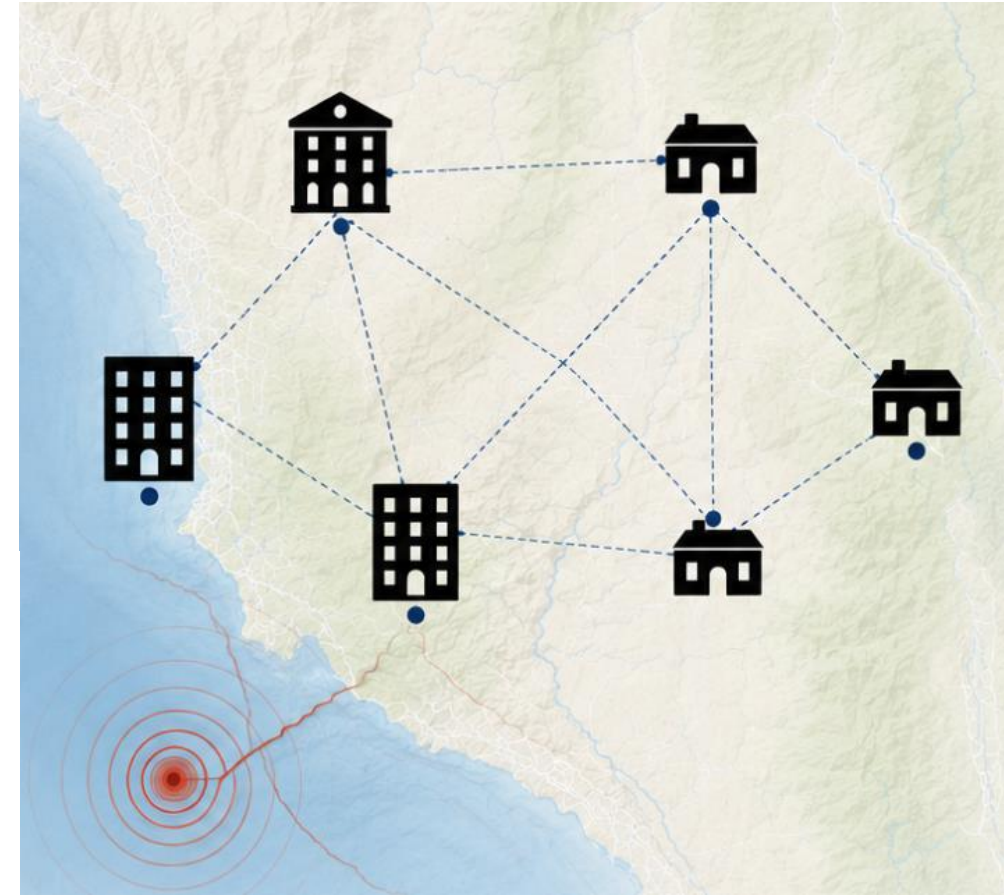
- Very few GMMs or spatial correlation models existed until recently

$$\ln \mathbf{IM}_i = \boldsymbol{\mu}_{\ln IM_i} + \underbrace{\delta b_i \cdot \tau_i \cdot \mathbf{1}}_{\delta B} + \underbrace{\delta \mathbf{w}_i \cdot \boldsymbol{\phi}_i}_{\delta W}$$

Mean: $\boldsymbol{\mu}_{\ln IM_i} = [\mu_{\ln IM_{i,1}}, \dots, \mu_{\ln IM_{i,M}}]^T$

Covariance:

$$\Sigma = \underbrace{\tau_i^2 \cdot \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & 1 & \dots & 1 \\ \vdots & \vdots & \ddots & \vdots \\ 1 & 1 & \dots & 1 \end{bmatrix}}_{\text{between-event term}} + \underbrace{\phi_i^2 \cdot \begin{bmatrix} \rho_{11} & \rho_{12} & \dots & \rho_{1M} \\ \rho_{21} & \rho_{22} & \dots & \rho_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{M1} & \rho_{M2} & \dots & \rho_{MM} \end{bmatrix}}_{\text{within-event term}}$$

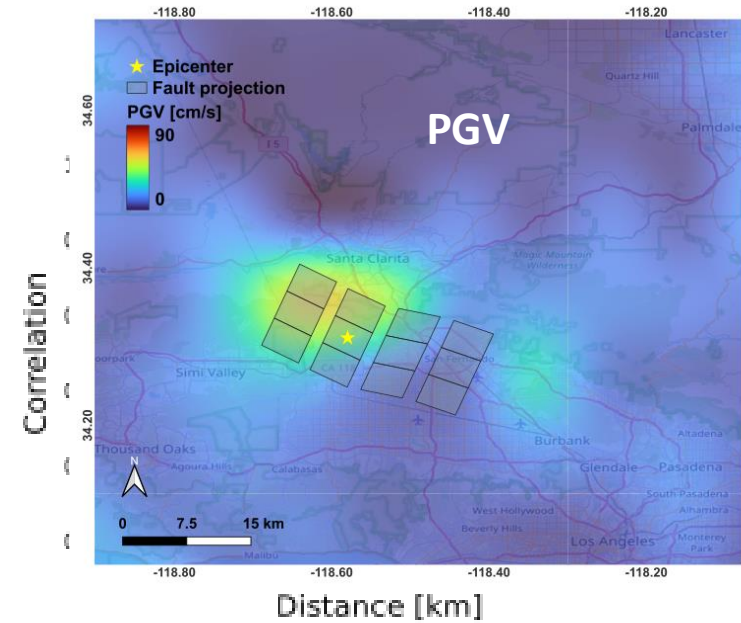


Principal component analysis used to develop spatial cross-correlation models

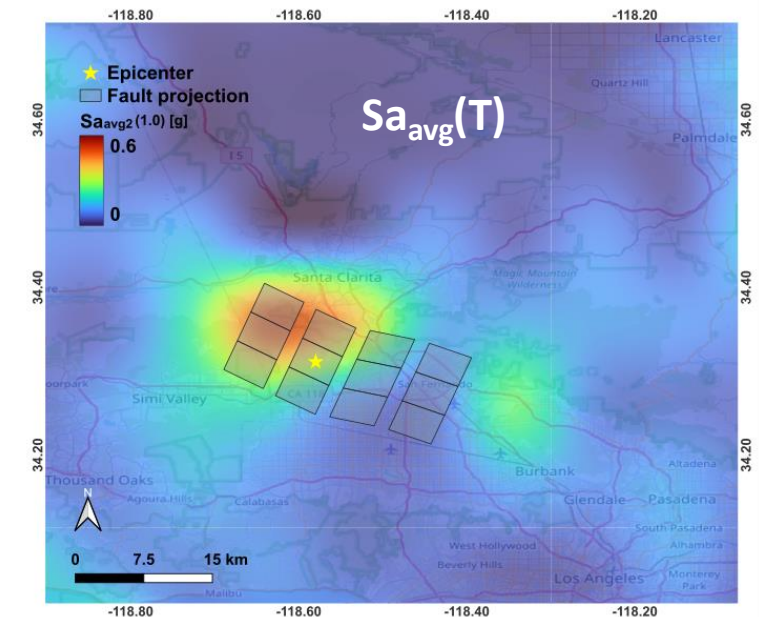
- Considerably faster to use compared to indirect formulations or Cholesky decomposition
- IMs like $Sa_{avg}(T)$ can be efficiently implemented on a regional scale
- Vector-IM fragility/vulnerability models can be used
- With these new options for risk analysis, what are the implications on regional loss assessment?



Vítor Monteiro



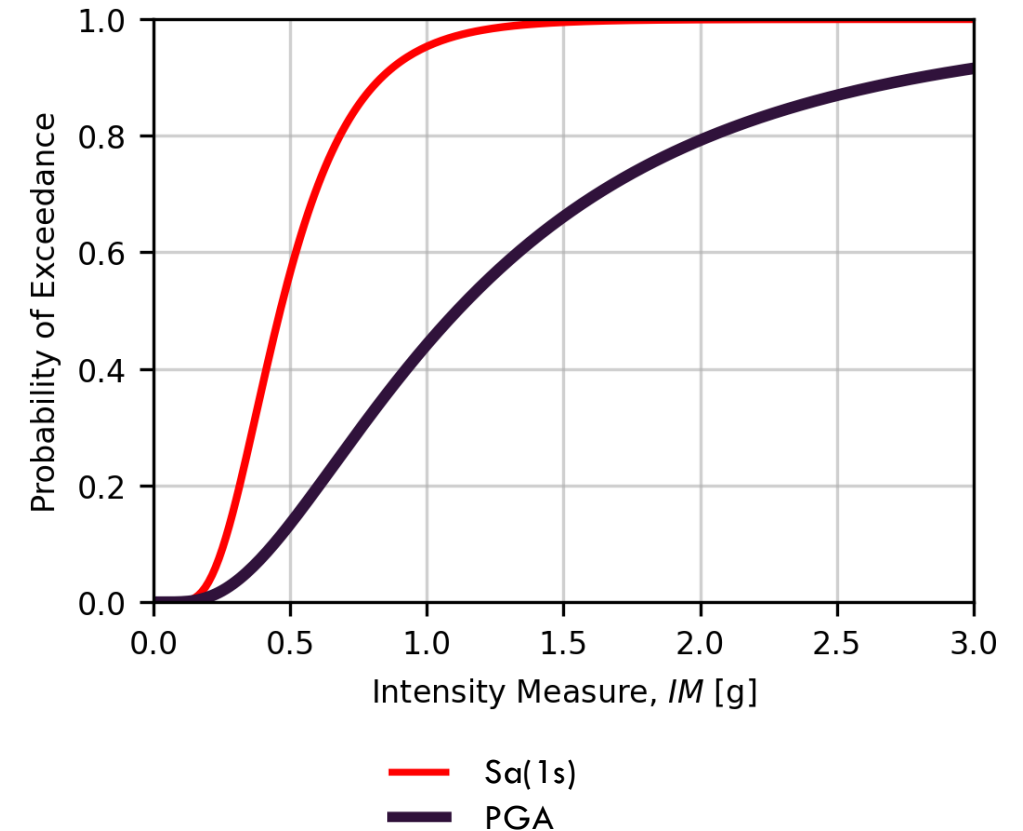
Coherent



**Problem 2: Same buildings, two
fragility/vulnerability models, two
intensity measures**

Resolving model IM incompatibility

- Two groups publish fragility/vulnerability models for the same building class, one on PGA, the other on $S_a(1s)$.
 - How can you compare them?
 - Should they return the same results?
 - Are they equally implementable?
 - Could we harmonise them?

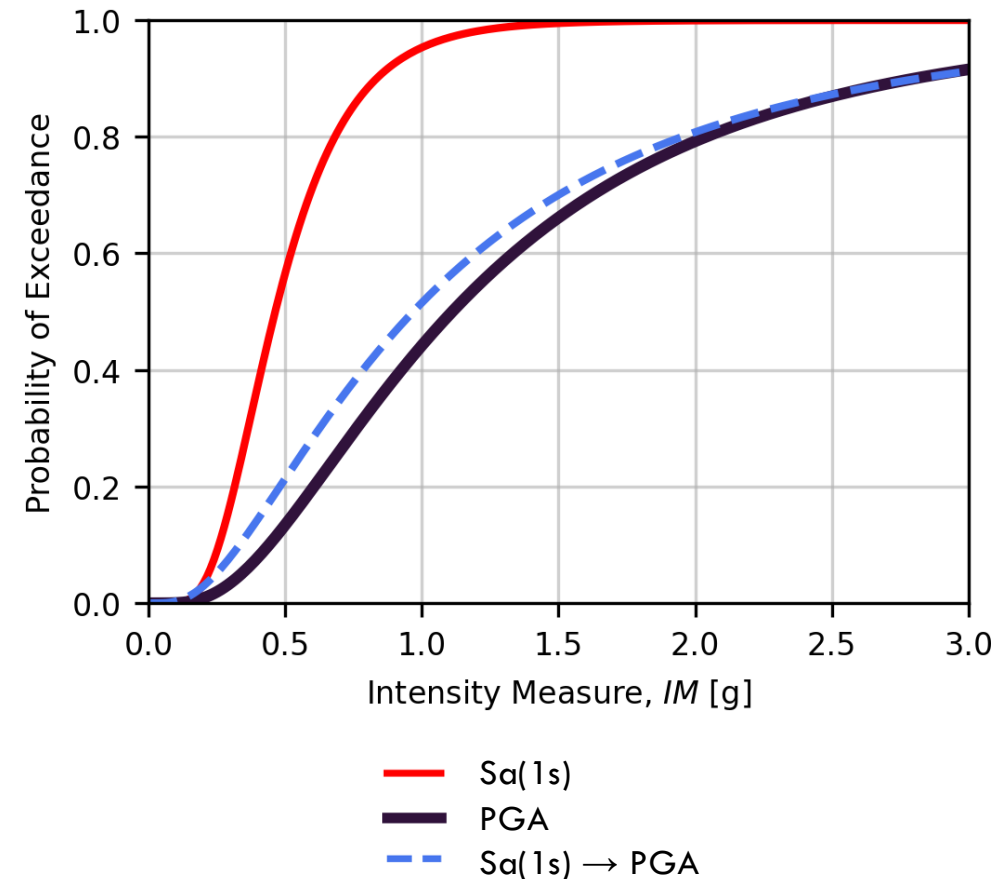


Model IM conversion can be done, but there's a catch

- We looked at existing methods based on simple conversion factors and methods based on total probability
- Some IMs work better than others
- We also extended this to vulnerability functions
- Insights into how we can develop more flexible fragility/vulnerability models



Davit Shahnazaryan



**Problem 3: One building collapses.
What about its neighbour?**

Two identical buildings, same street, same contractor, same year

One of them has not collapsed

Does that tell you anything about the other?



1994 Northridge, USA

- Fracture of welded steel moment connections

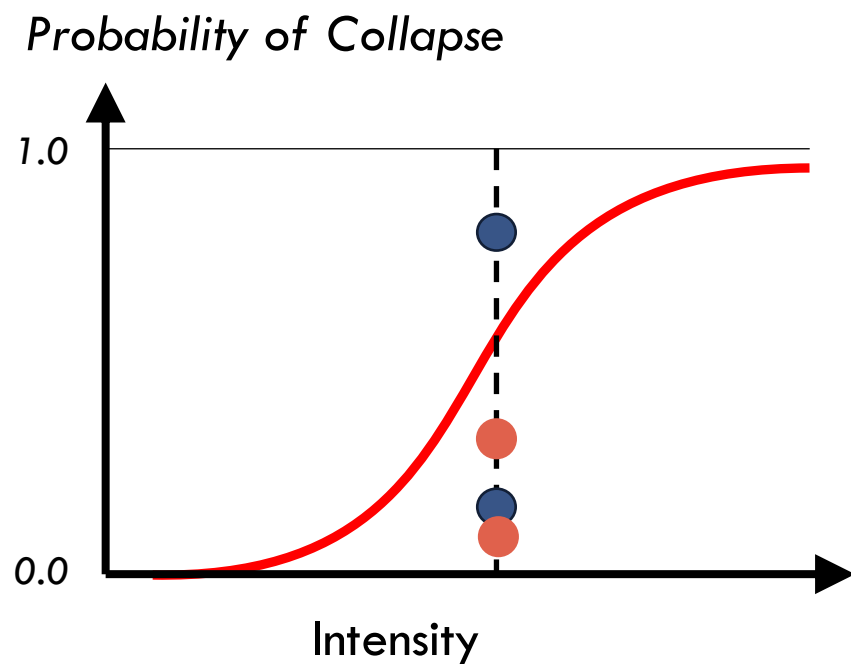
2009 L'Aquila, Italy

- Masonry infill induced damage

2010 Maule, Chile

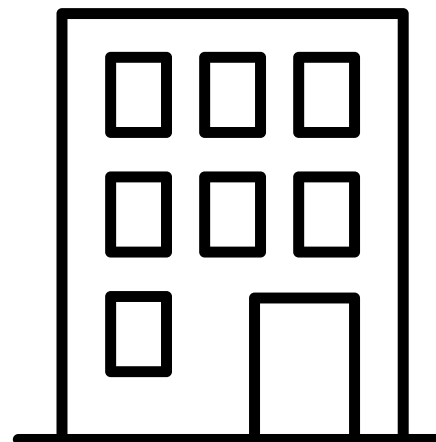
- Shear-wall boundary confinement

Is damage independent?



Which makes more intuitive sense?
Does it even matter?

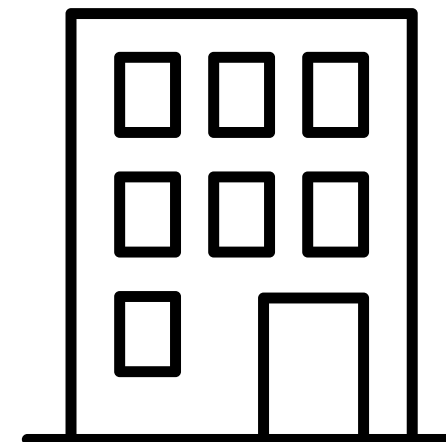
Building A



Uncorrelated: **Collapsed**

Correlated: **Collapsed**

Building B



Not Collapsed

Collapsed

Not conclusions, starting points

- The hazard infrastructure that blocked next-generation IMs now exists.
 - Vítor asks whether it changes regional losses.
- Models on different IMs can be converted, within limits.
 - Davit shows how and where we can improve.
- Response correlation between similar buildings is intuitive.
 - Tomás discusses solutions and impacts of assuming independence.



O'Reilly, Gerard J.; Mejia, Tomas; Monteiro, Vítor A. (2026) "Advances in Regional Seismic Risk Assessment Incorporating Spatial and Structural Correlations", 18th European Conference on Earthquake Engineering, Berlin Germany.