CAT MODELING, APPLICATION TO INSURANCE INDUSTRY: UNKNOWNS AND POSSIBLE SOURCES OF BIAS IN PRICING

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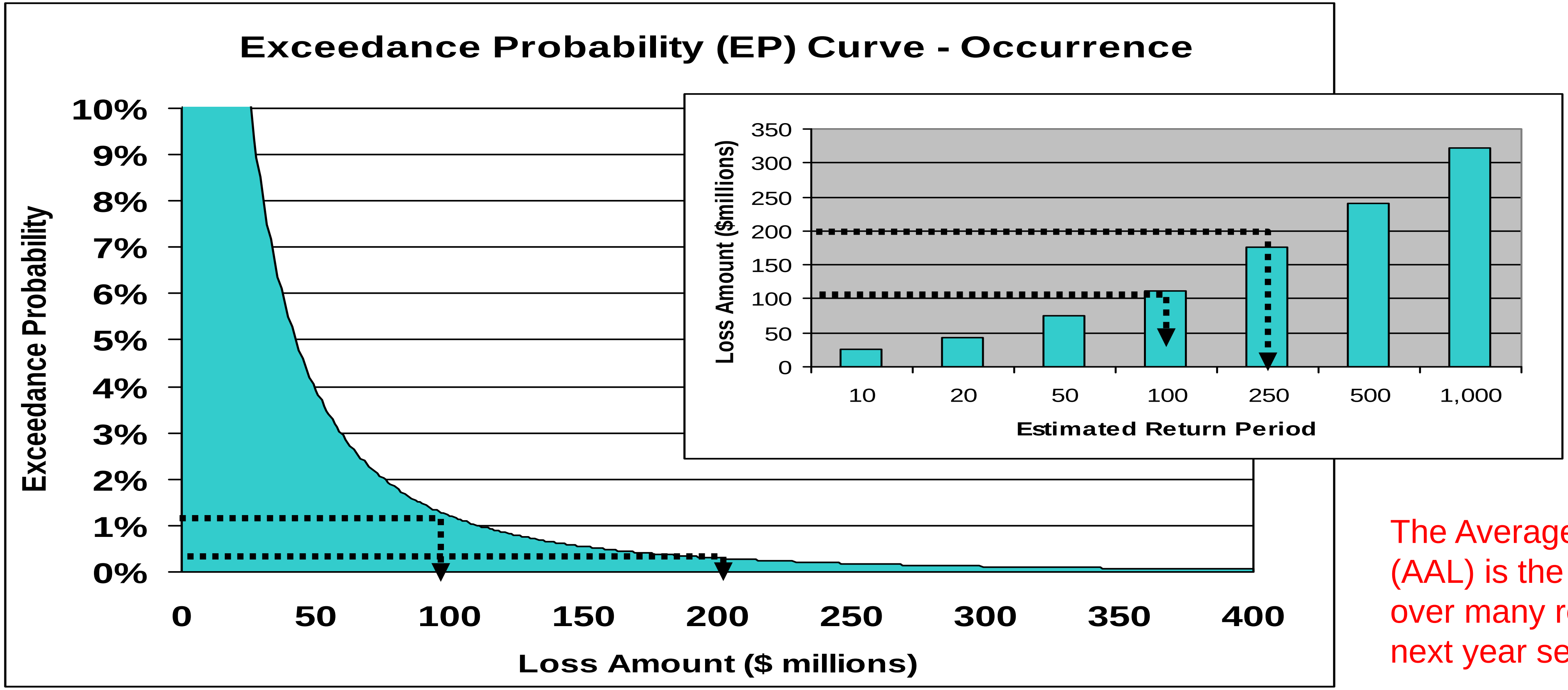
International Workshop on Advances in Assessment and Modeling of Earthquake Loss , Istanbul, Turkey, Nov 4-5, 2019

Standard Output is a Loss Exceedance Probability Curve



The Average Annual Loss (AAL) is the mean loss over many realizations of next year seismicity

Typical Users of Cat Models

- Primary Insurance companies (buildings, crops, etc.) and Reinsurance Companies
- Investors/hedge funds
- Life, Accident, and Workers' Compensation Insurers
- Catastrophe/relief funds and risk pools (e.g., TCIP, California Earthquake Authority, CCRIF)
- Rating Agencies (S&P, Moody's, Fitch)
- Real estate management and investment
- Mortgage lending
  - Fannie Mae, Freddie Mac and the secondary mortgage market
- Governments and their departments (U.S. Department of Homeland Security, U.S. Navy, U.S.D.A., Mexican Government, Caribbean Caricom Governments, etc.)
- Major Corporations (Dow Chemical, Devon Energy, Arkema, Sony, General Motors, etc.)
- …

Catastrophe Risk Models Are Used for Modeling a Wide Variety of Insurance Contracts

Enterprise Risk Management

- Manage the impact of catastrophe risk on surplus
- Communicate with ratings agencies
- Accumulation/risk-aggregation management

Reinsurance Purchasing

- Use models to evaluate reinsurance purchases
- Streamline efficiency of communication with reinsurance intermediaries

Pricing

- Use model outputs in rate filings and in pricing of individual policies or programs

Underwriting

- Catastrophe model output used for risk selection and pricing at the point of sale

Claims

- Advance planning, resource deployment, post-event communications

Portfolio Optimization

- Identify areas to grow or retract based on model-based risk metrics
- Perform model-based analyses to understand and manage the drivers of catastrophe risk

Insurance Pricing is the last component of the Underwriting (UW) process

Factors controlling the UW process are:

1. client selection (judgmental, nothing to do with cat modeling)
2. wordings acceptability (marginally related to cat modeling)
3. portfolio fit (e.g., risk diversification, diminish volatility, etc)
4. Price (cat models provide the quantitative support for pricing)

Role of Cat Models in Insurance Pricing

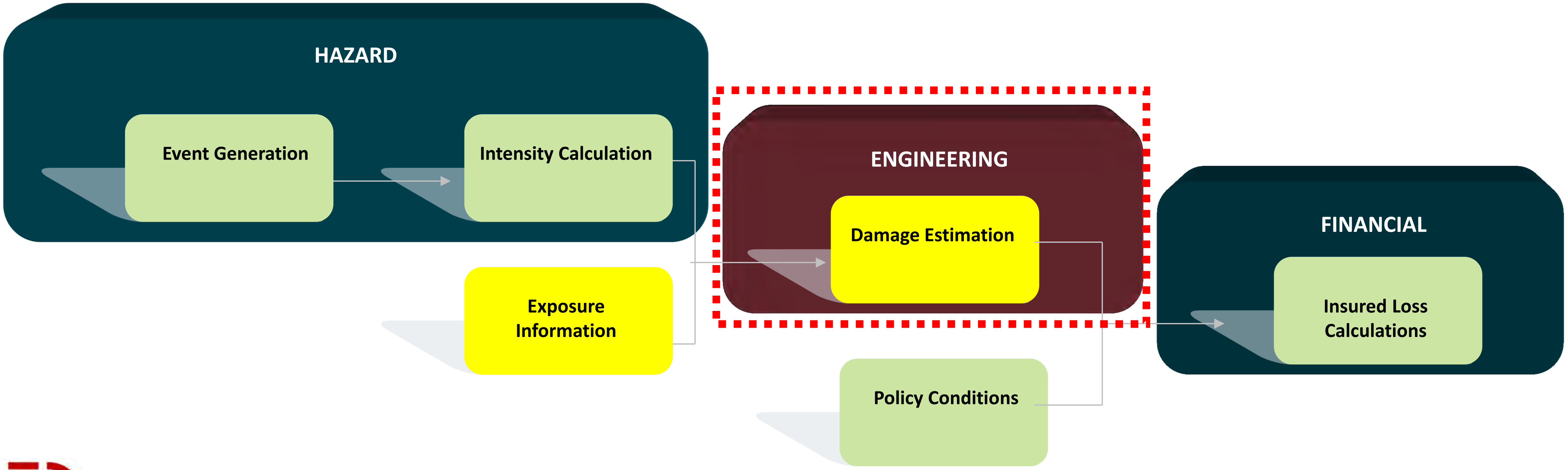
Objective: to determine how much to charge to cover the cost of the product and generate sufficient profit

Simplistically, the technical price consists of:

1. Expected loss (also called pure premium)
2. Expense loading (to account for internal operational costs, taxes, fees, commissions, reinsurance and retrocession costs, cost of capital, etc.)
3. Profit loading
4. Risk loading (to account for unmodeled perils and unknowns)

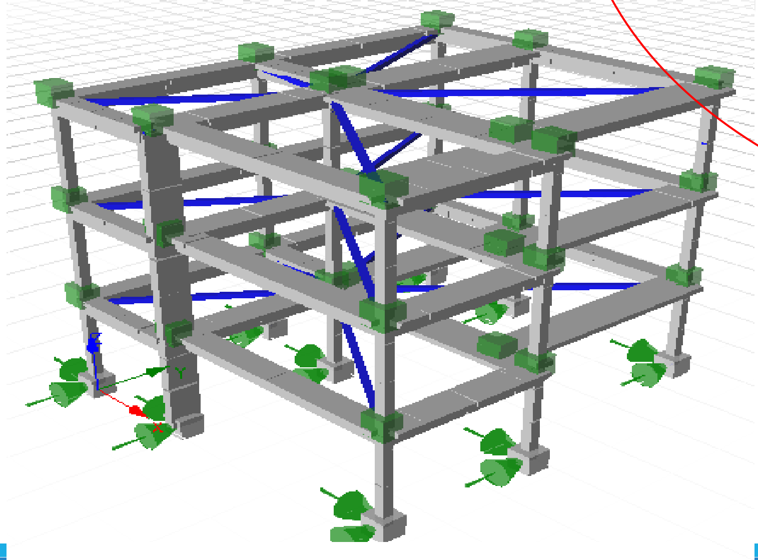
NOTE: Technical price may differ from the market price, i.e., the price that the customer pays. The market price can be higher or lower than the technical price according to internal business strategies

Vulnerability/Fragility Curves for Classes of Buildings for classes of buildings

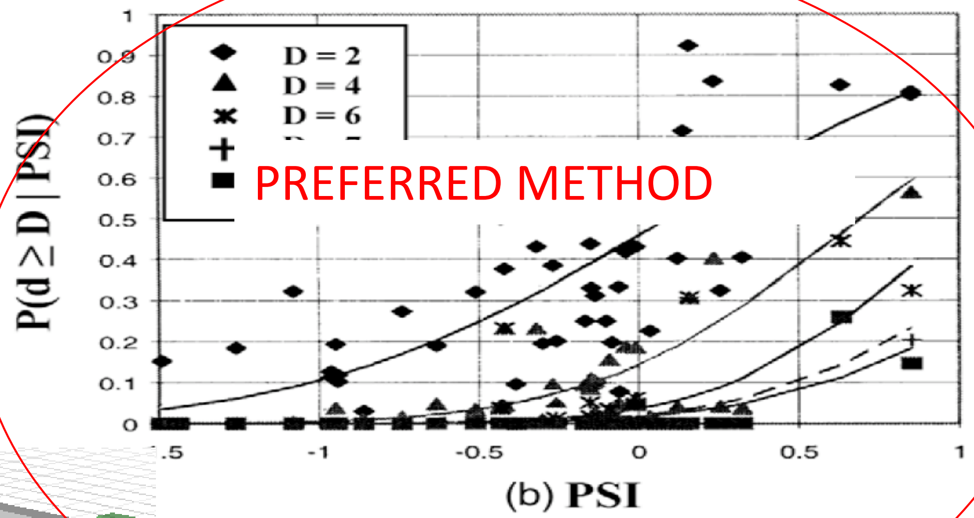


Three Methods for developing vulnerability (or fragility curves) for classes of buildings

Expert opinion

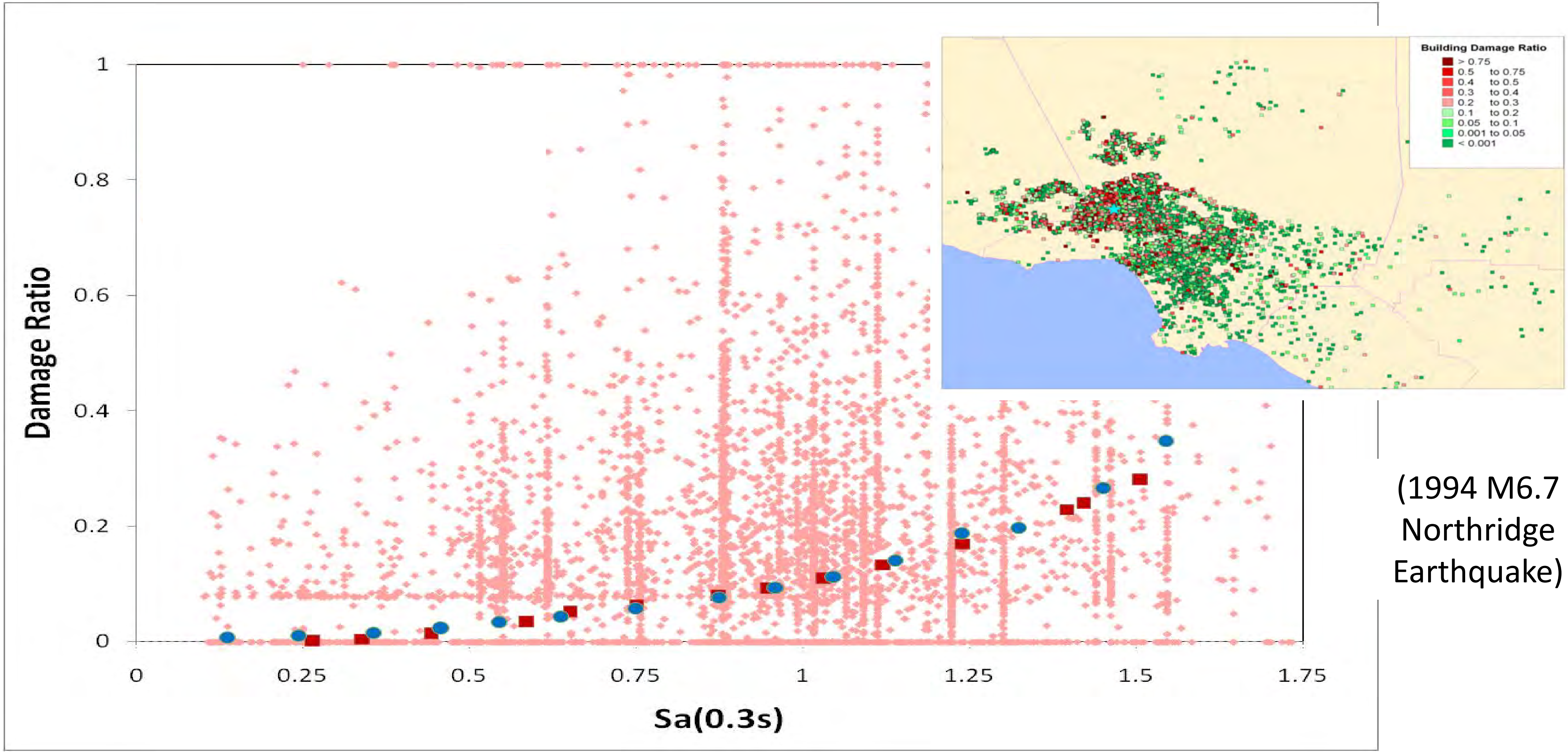


Analytical



Empirical

Mean Damage Function for California Wood Frame Buildings of given Vintage (Claims Data)



(1994 M6.7 Northridge Earthquake)

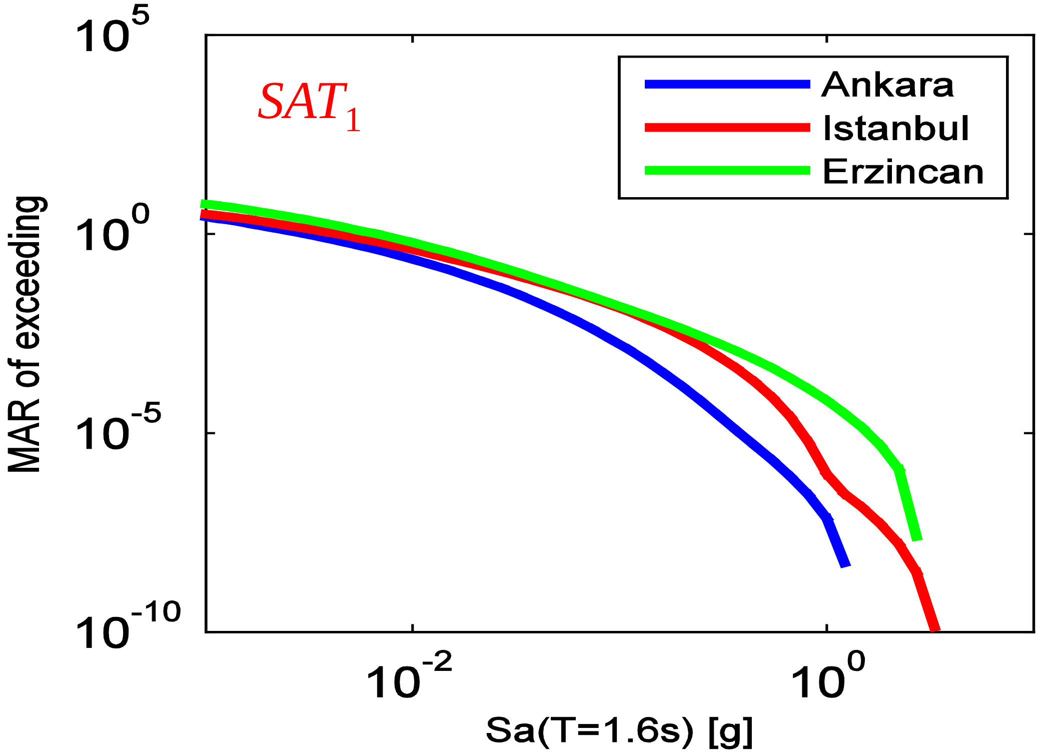
Vulnerability/Fragility of 3 Identical 7story RC Buildings in Istanbul, Ankara and Erzincan

Hazard analysis/Disaggregation

- Hazard source model from SHARE Project, hazard source model
- GMPE proposed by Boore and Atkinson (2008)

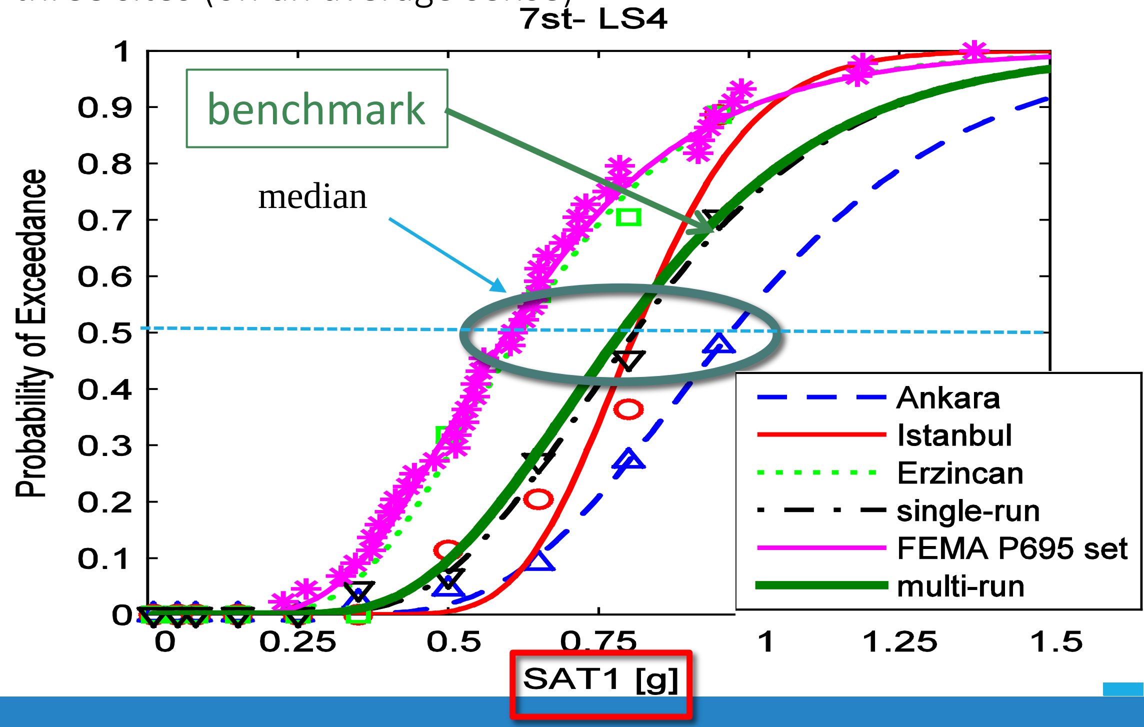
Building Vulnerability/Fragility Curves Are Site-dependent

SA(T_1) Hazard curves for the 3 sites



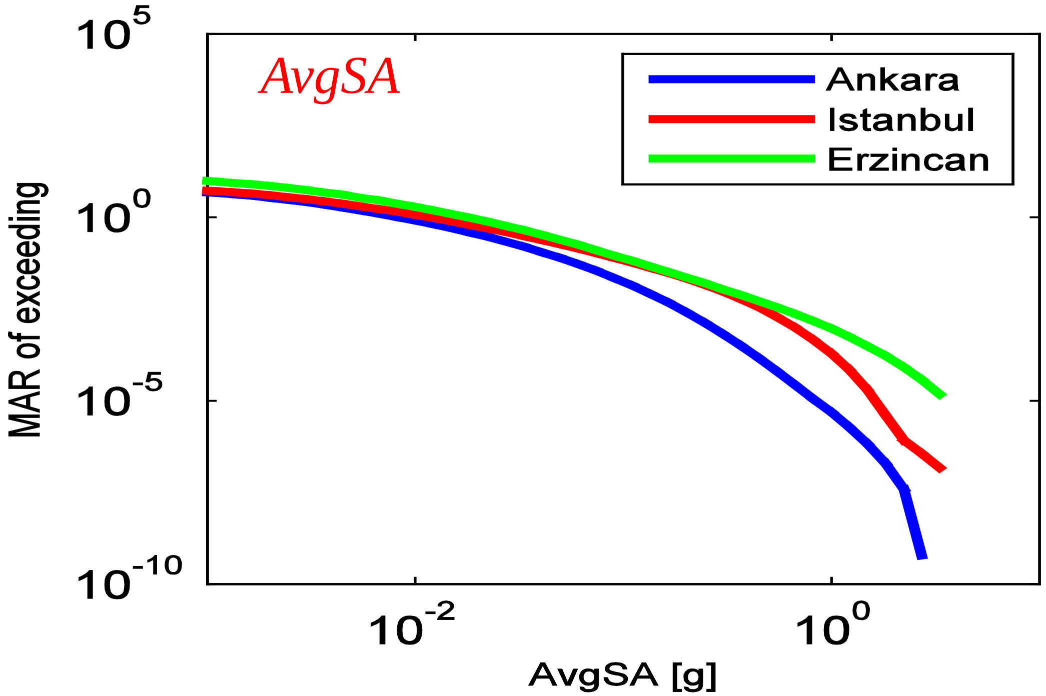
Fragility Curves for Collapse are computed in five different ways:

- Hazard consistent ground motion records at each one of the 3 sites
- Arbitrary set of scaled records from FEMA P695
- Two variants of ground motions consistent with hazard at all three sites (on an average sense)



Using AvgSA decreases site-dependence of Building Vulnerability/Fragility Curves

AvgSA Hazard curves for the 3 sites



AVGSA in $[0.2T_1 - 2.0T_1] \approx [0.3s - 3.0s]$

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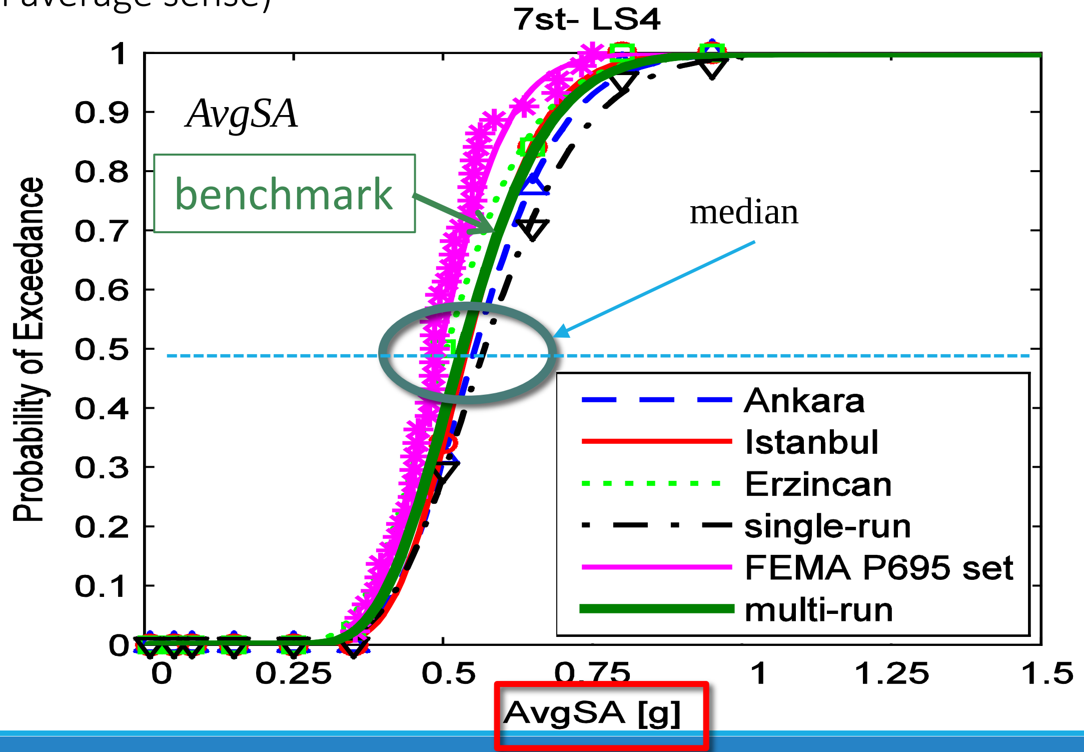
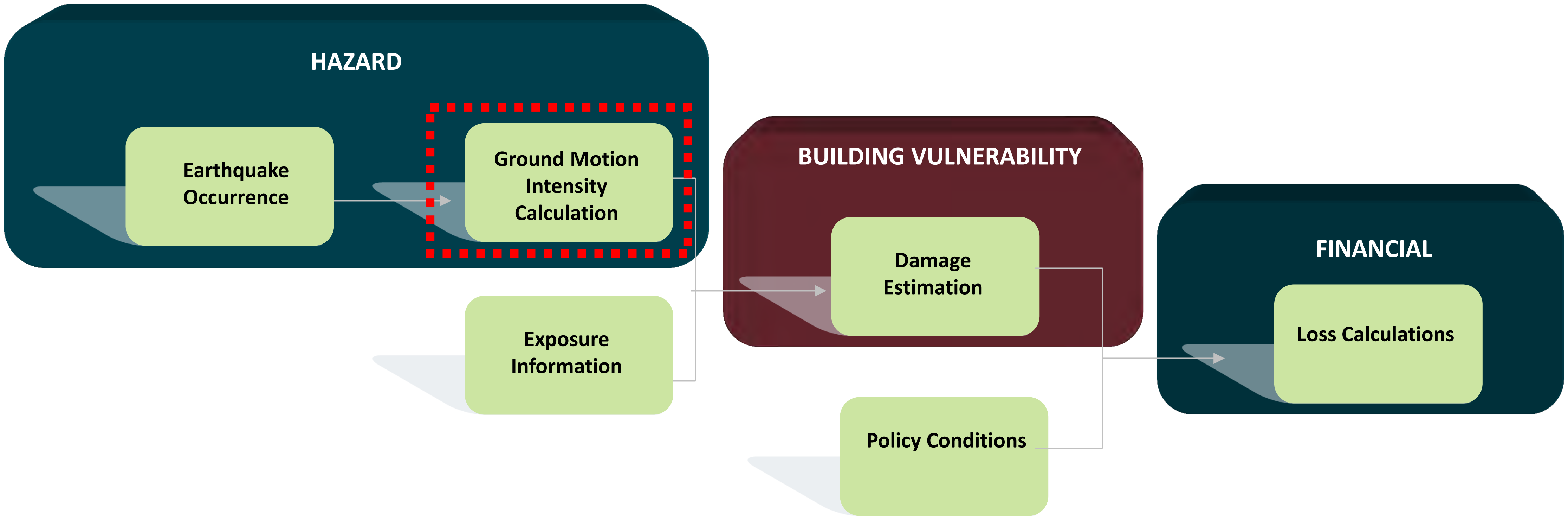
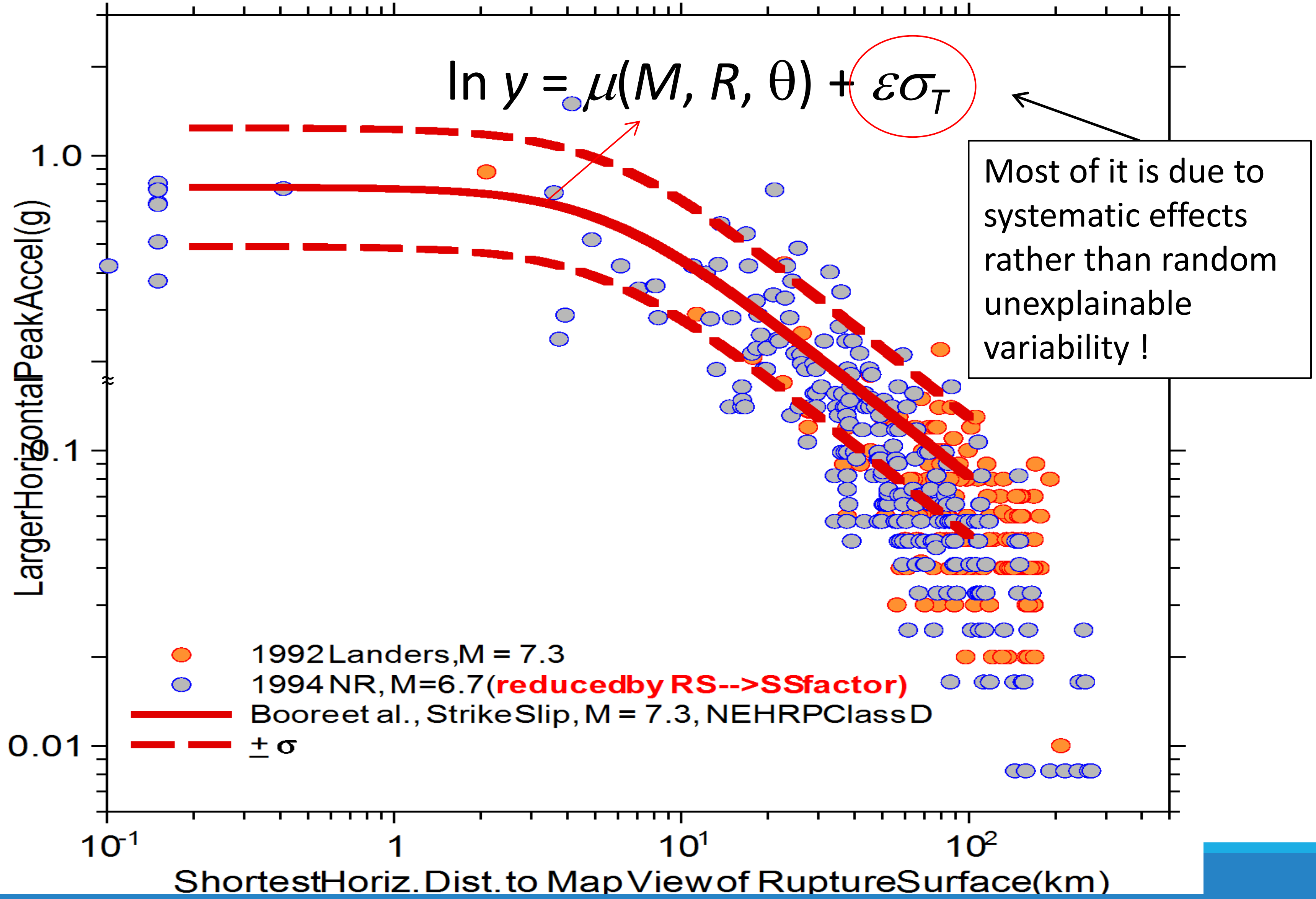


Moving towards empirical non-ergodic Ground Motion Prediction Equations (GMPEs)

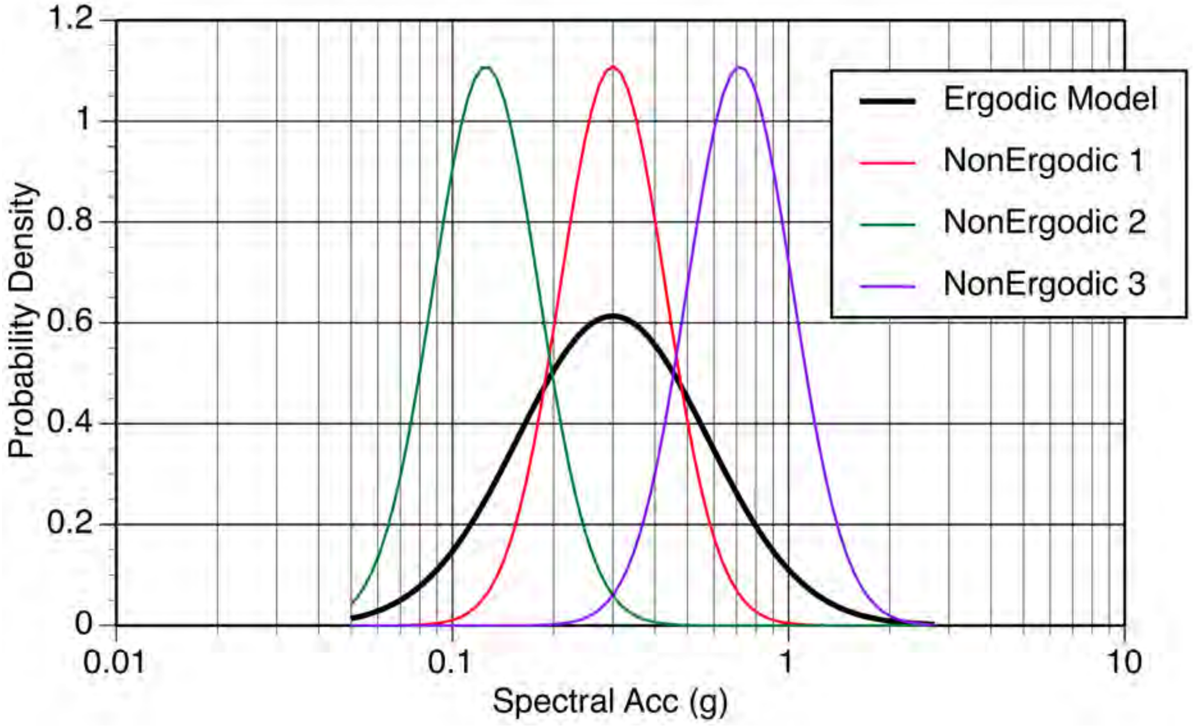


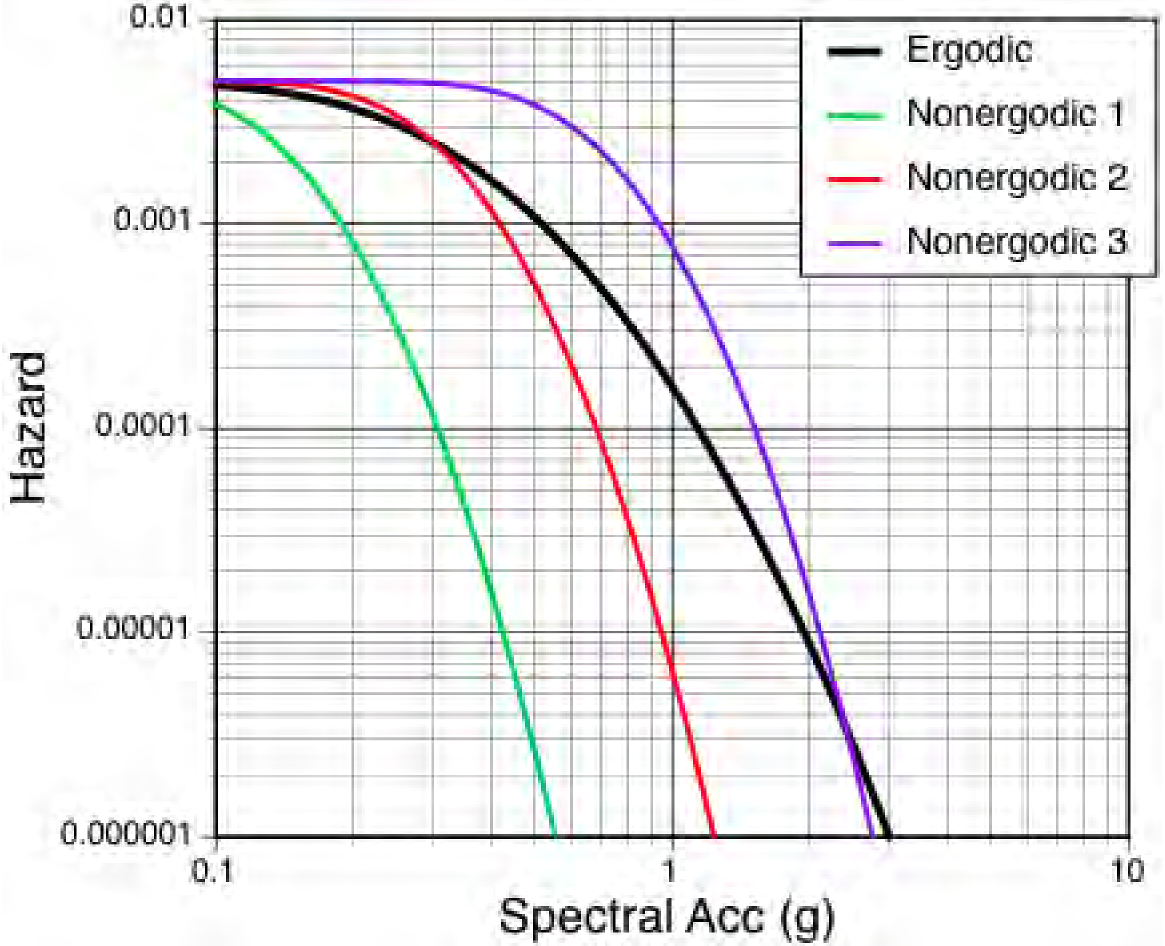
Classical Ergodic (site-generic) GMPE

Gives mean and standard deviation of response-spectrum ordinate (at a particular frequency) as a function of magnitude distance, site conditions, and perhaps other variables.



Towards non-Ergodic (site-specific) GMPEs

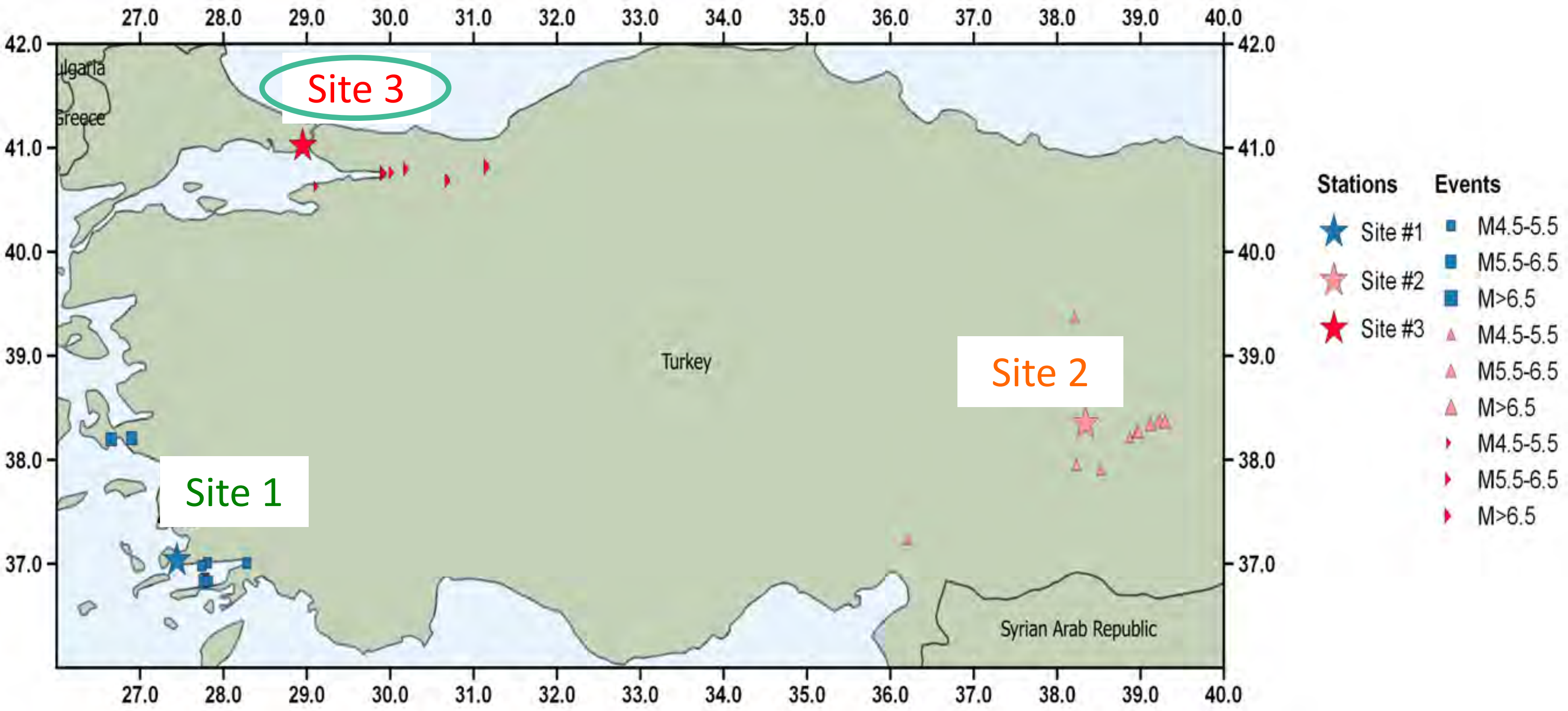


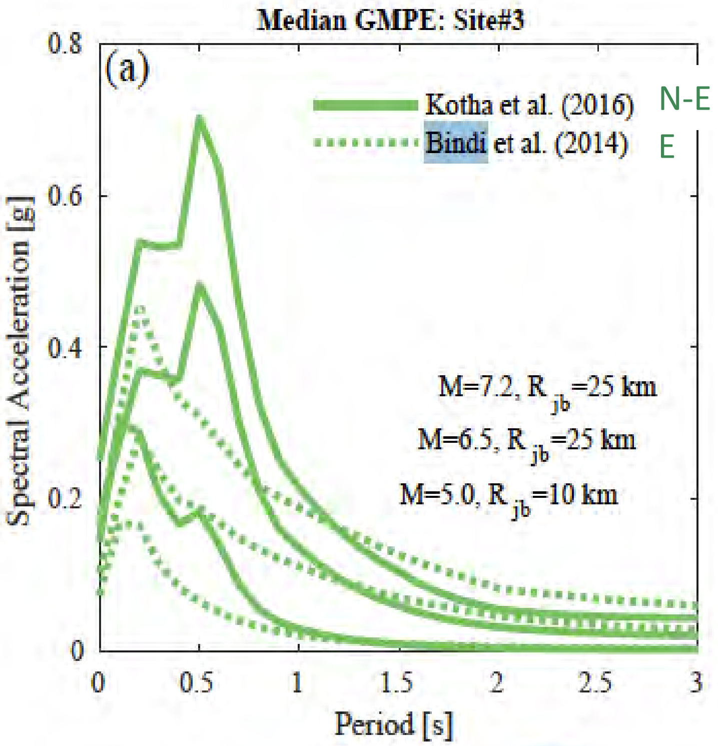


All sites have the same Vs30

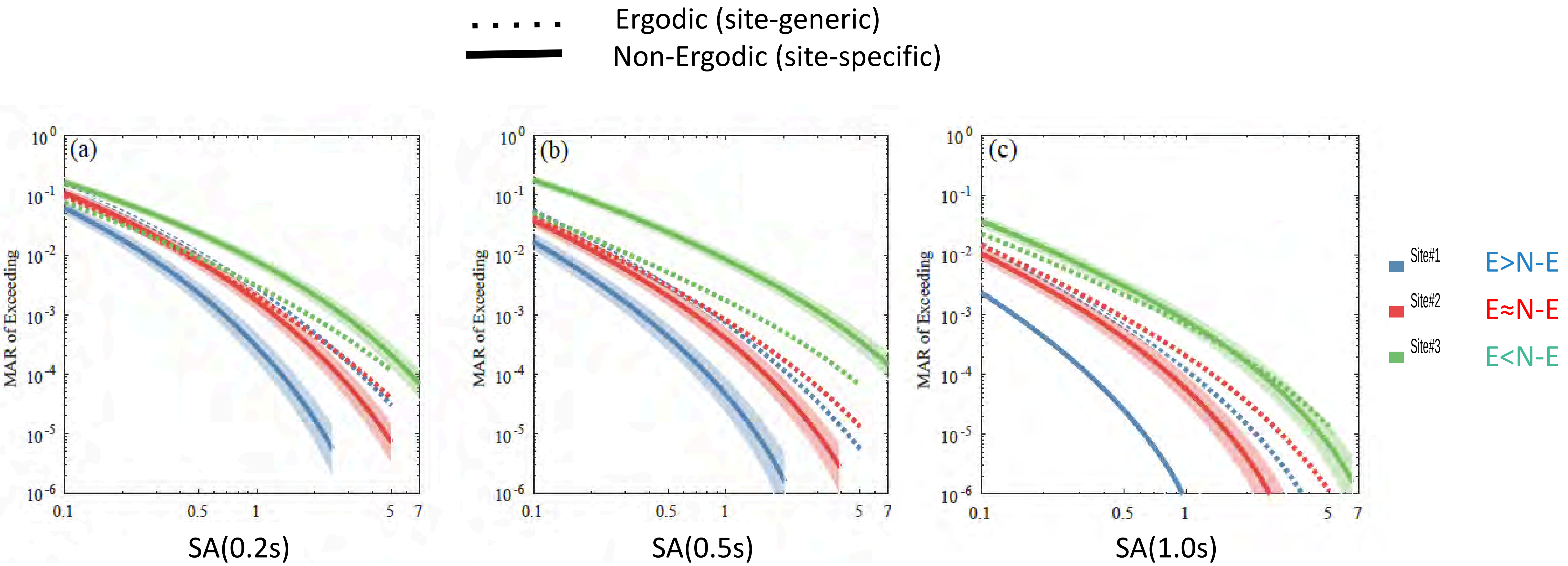
Courtesy: Dr. Norm Abrahamson

What is the impact on non-ergodic (site-specific) GMPEs on risk?

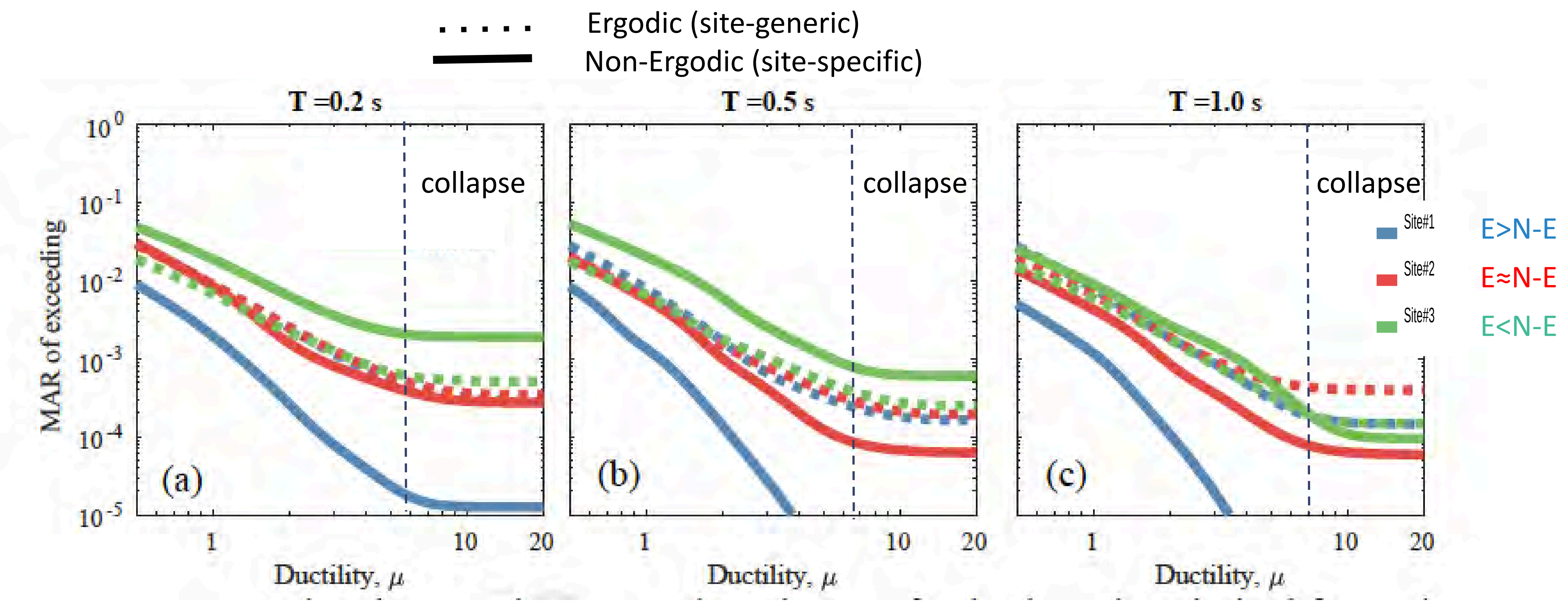




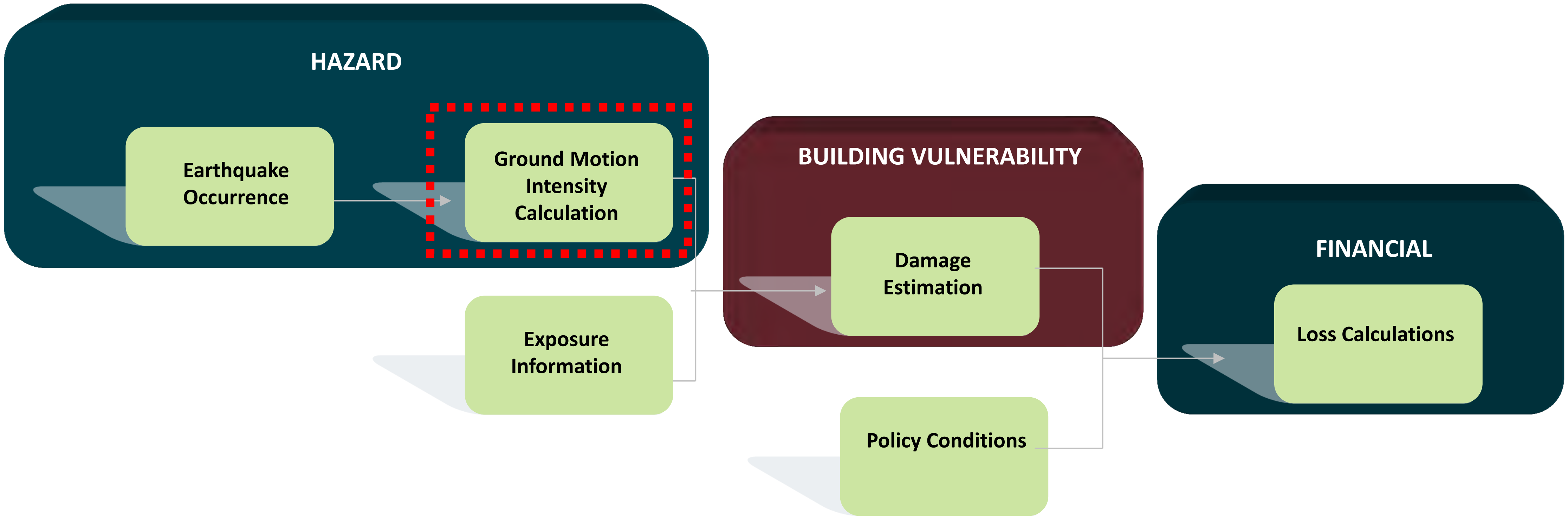
Site-generic vs. Site-Specific Hazard Curves



Site-generic vs. Site-Specific Response Hazard Curves (risk)



Moving towards Broadband Ground Motion Simulations

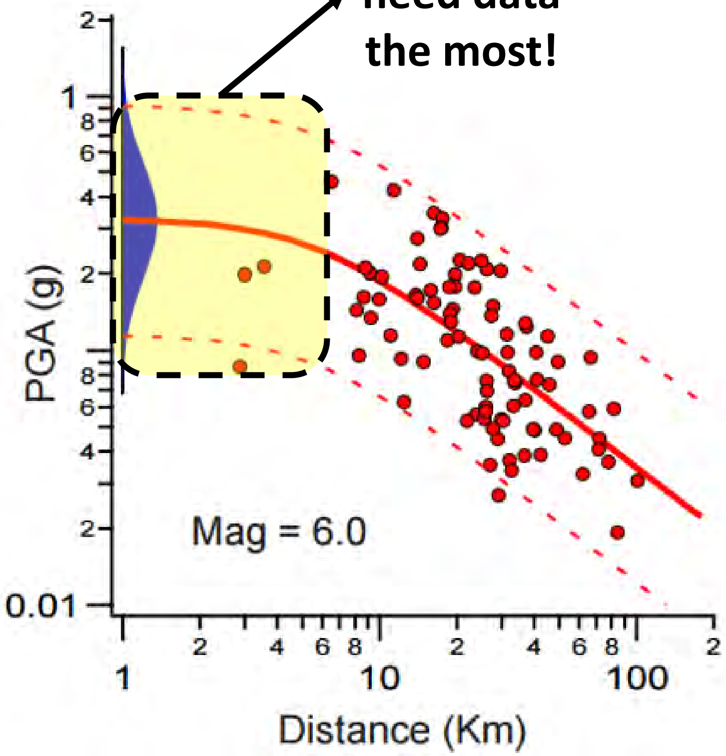


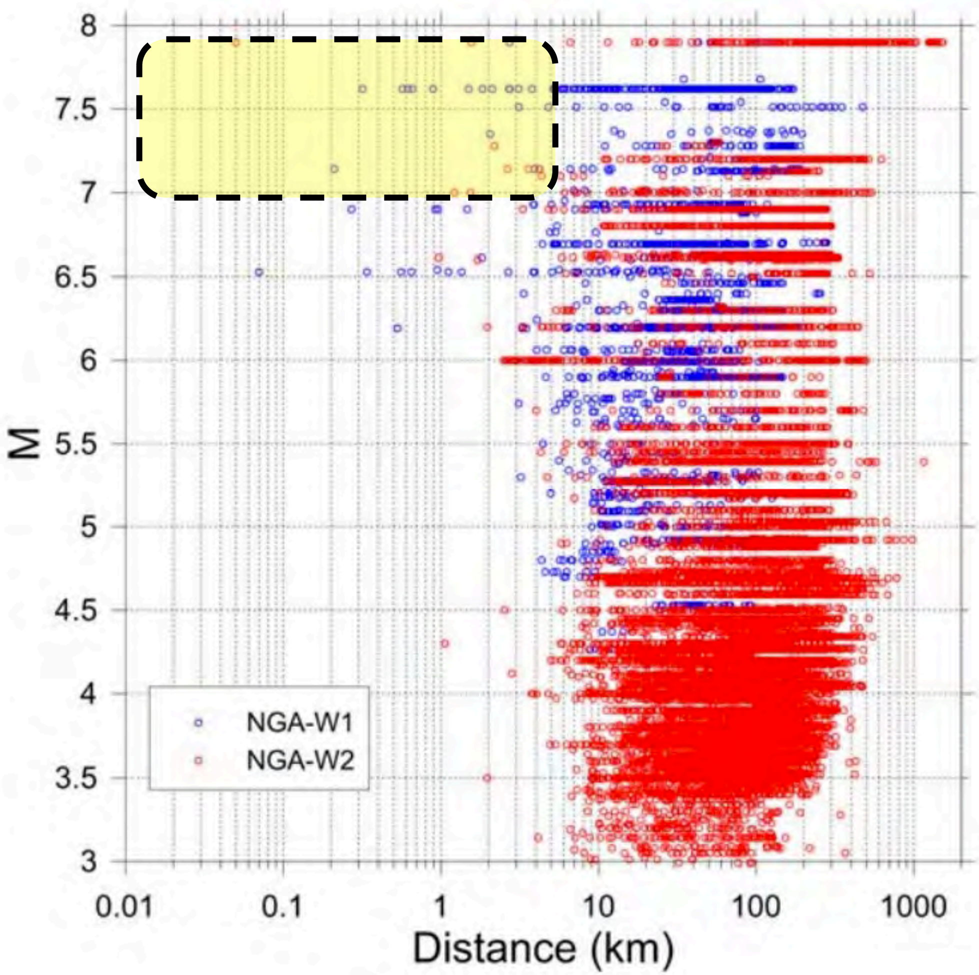
Beyond purely empirical GMPEs

http://visservices.sdsc.edu/projects/scec/terashake/imagery/

Why using ground motion simulation?

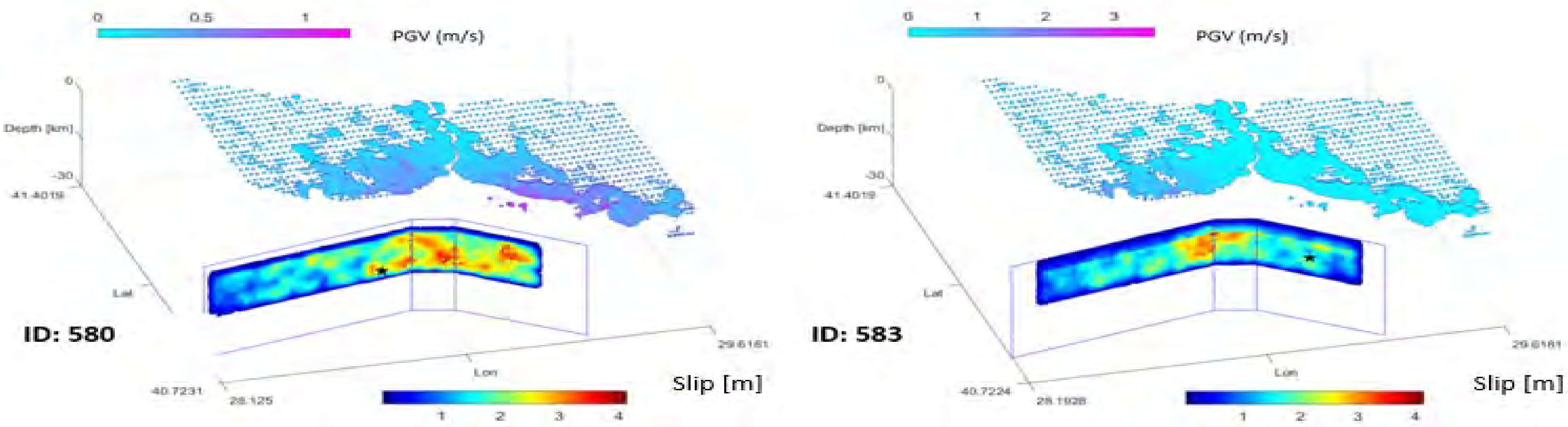
Where we need data the most!





Broadband Physics-based Simulations

M7.2 on the North Anatolia Fault



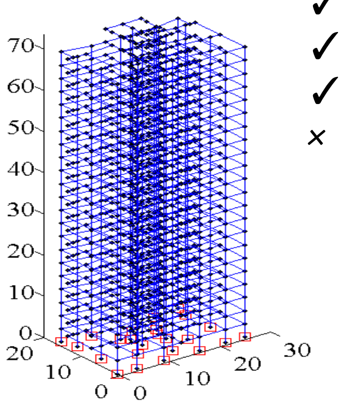
Gridded contours across the land indicate the PGV of the simulated (broadband) motions via the SPEED engine (http://speed.mox.polimi.it)

Excerpted from Paolucci et al (2017)

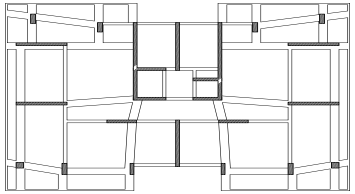
Effects of Physics-based Simulations on Risk: Tall Buildings in Istanbul

Archetype Model

We tested the 3D model of a 23-story reinforced concrete core shear wall building.



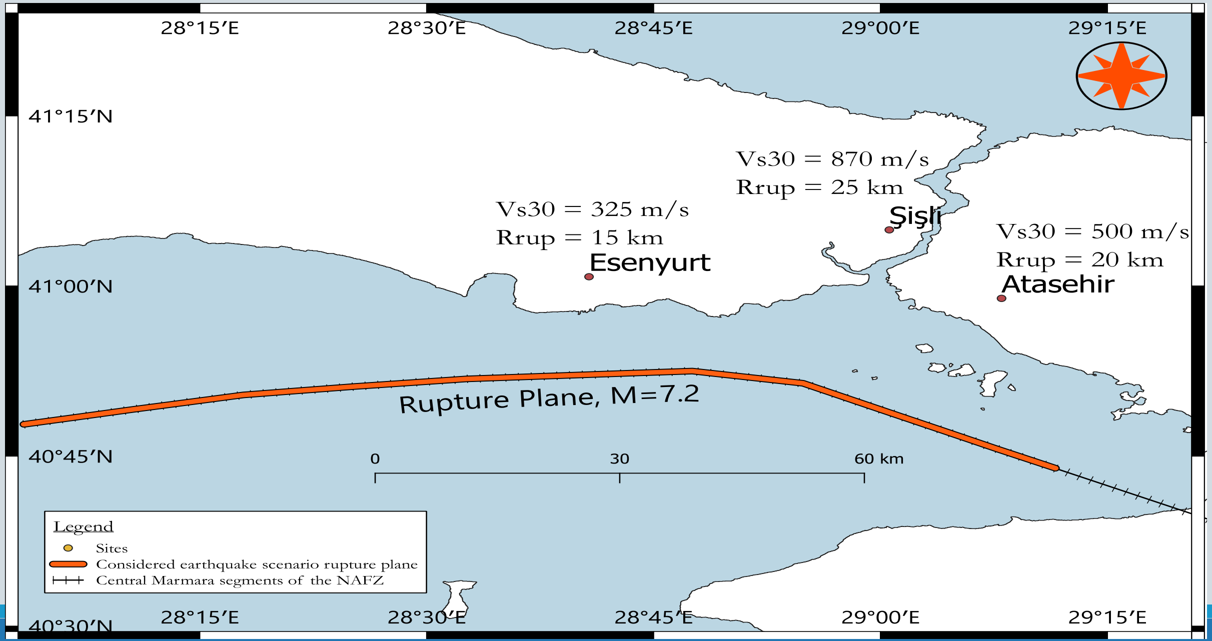
- ✓ *force-based fiber elements*
- ✓ *aggregated shear hinges*
- ✓ *fixed base modelling*
- × *underground stories ignored*



Analysis Sites

Three sites are selected for analysis

- Esenyurt : V_{s30}=325m/s R_{rup}=15km
- Atasehir : 500m/s 20km
- Sisli : 870m/s 25km



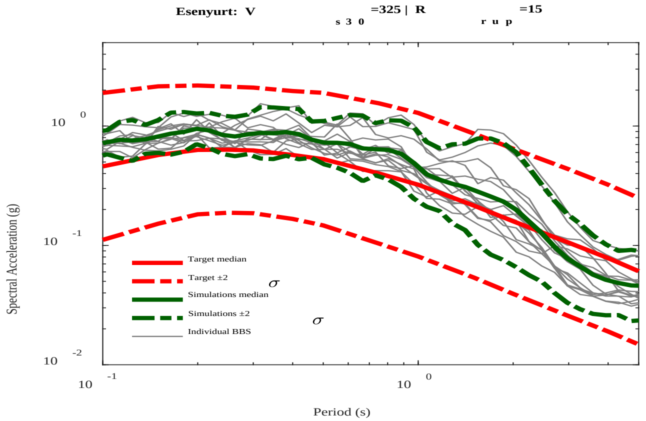
Considered Earthquake Rupture

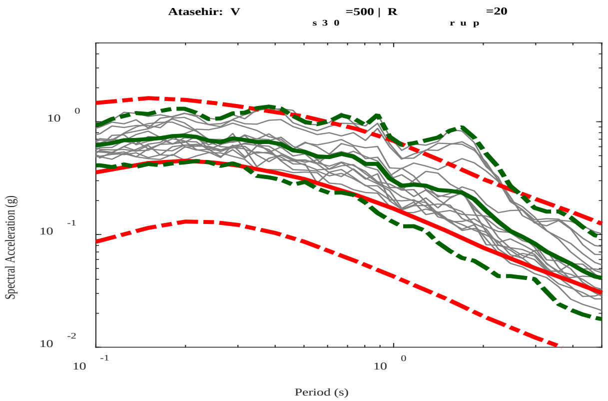
Magnitude : M_w *7.2*
Mechanism : *strike-slip*
Dimensions : *84 × 15 km*

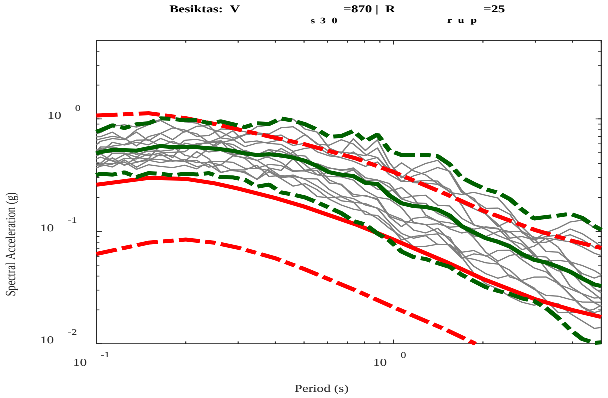
RED RISK ENGINEERING+DEVELOPMENT www.redrisk.com
IUSS Scuola Universitaria Superiore Pavia

Simulated vs Empirical ground motions Spectra

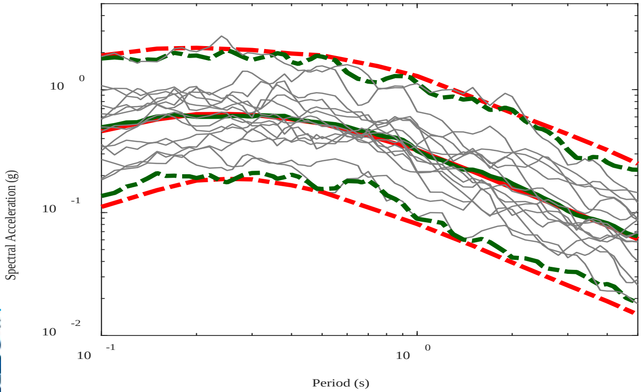
Simulated: 15 ground-motion simulations for same M7.2 event but different rupture kinematics are generated using the SPEED engine (http://speed.mox.polimi.it).

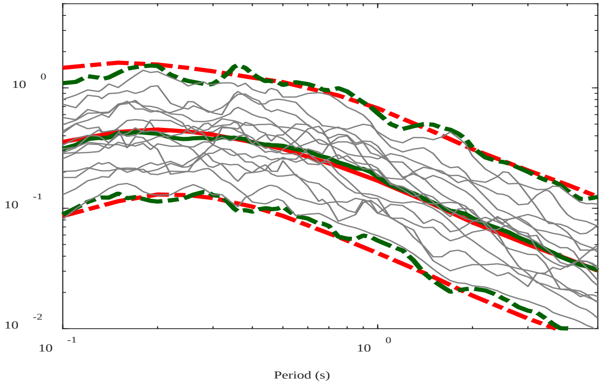


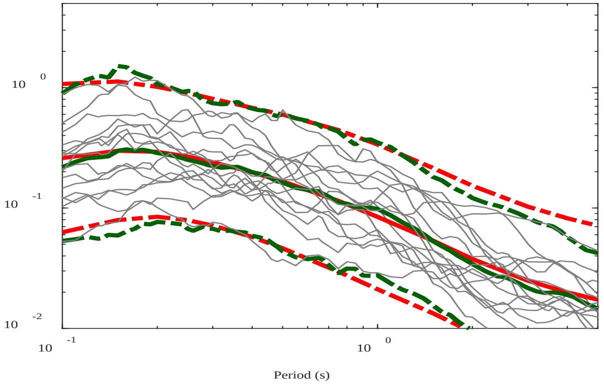




Real: Real accelerograms are selected and scaled to match the M7.2 target spectrum and its variability





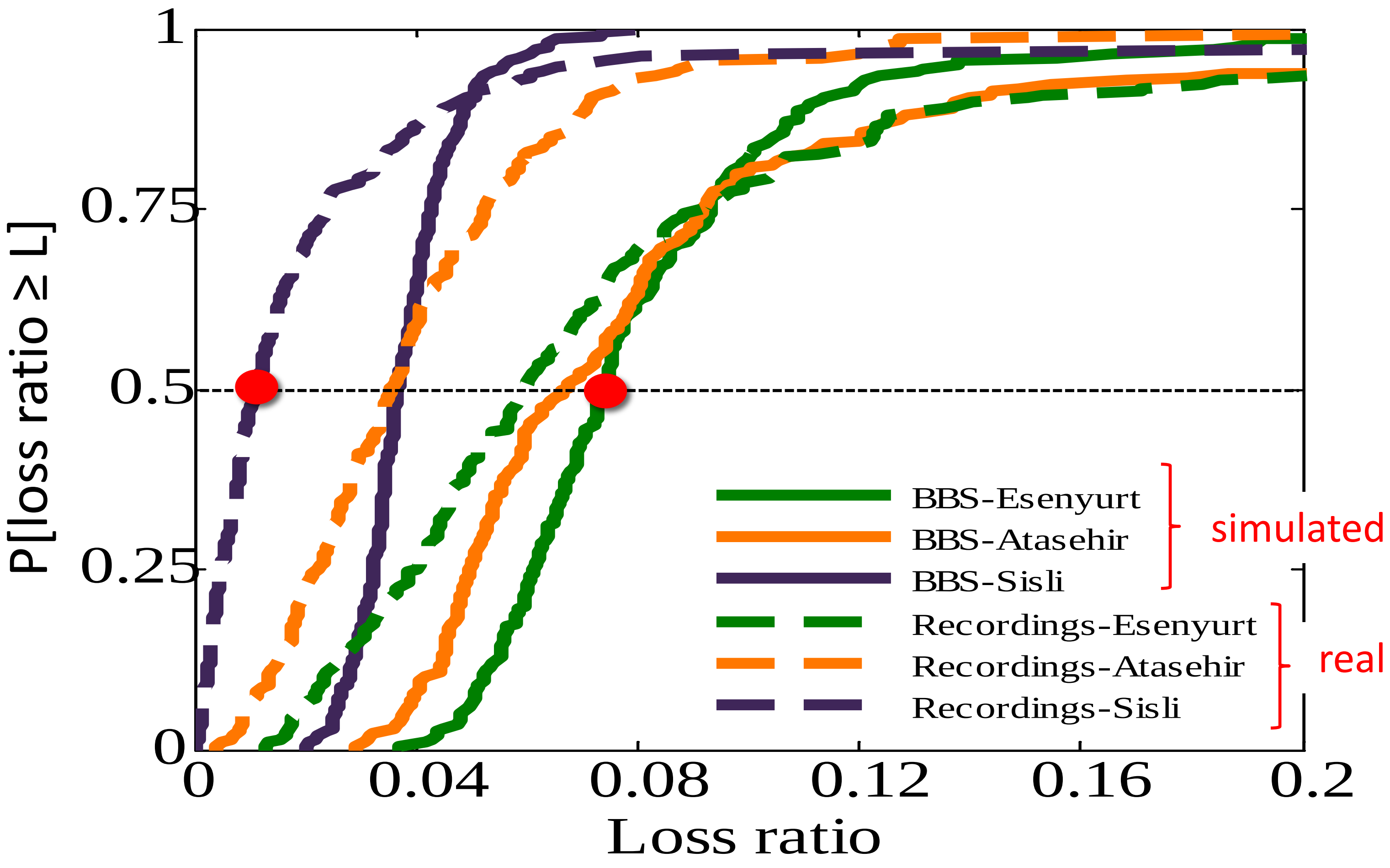


Higher Risk for Simulated Ground Motions

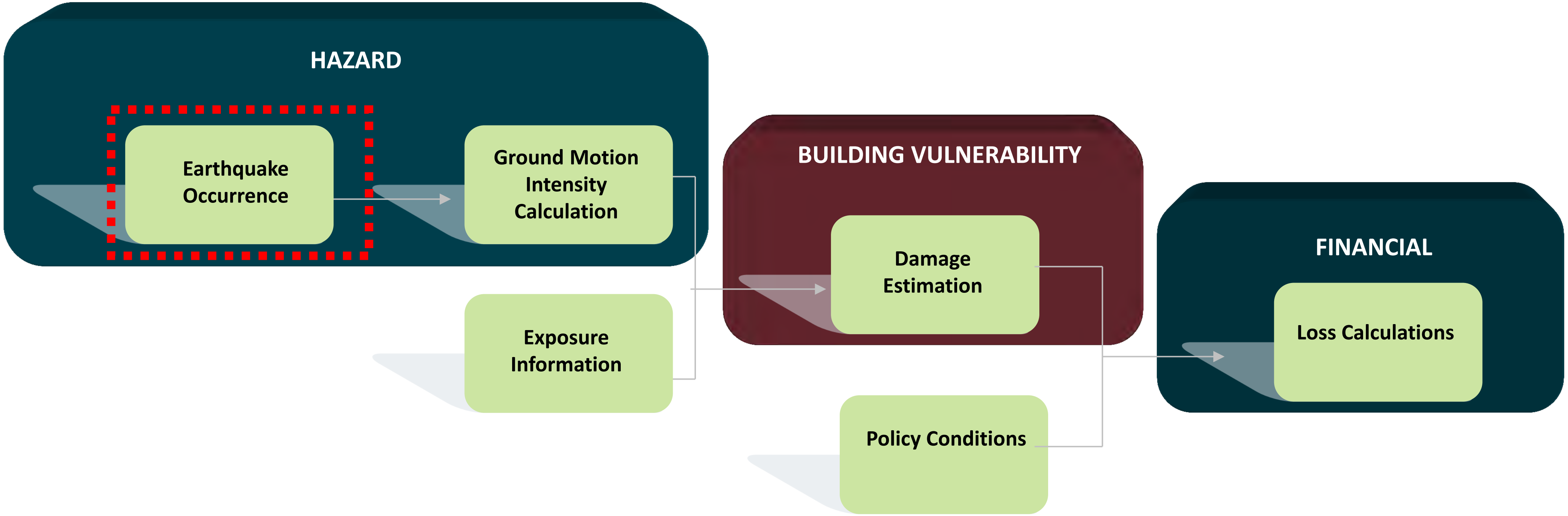
1. Simulated ground motions more aggressive for this M7.2 earthquake

2. Median loss ranged 2-7% of the total replacement cost

3. Simulated motions lead to 25-300% increase in the median losses.

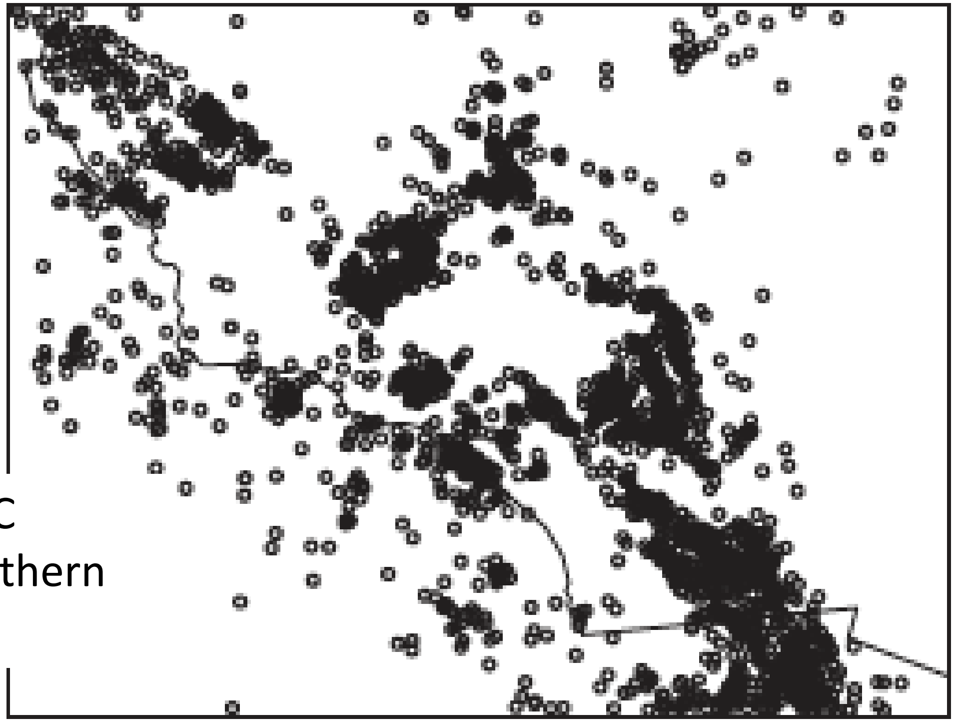


Are there any source of bias in the pure premium estimates from EQ Cat Models?



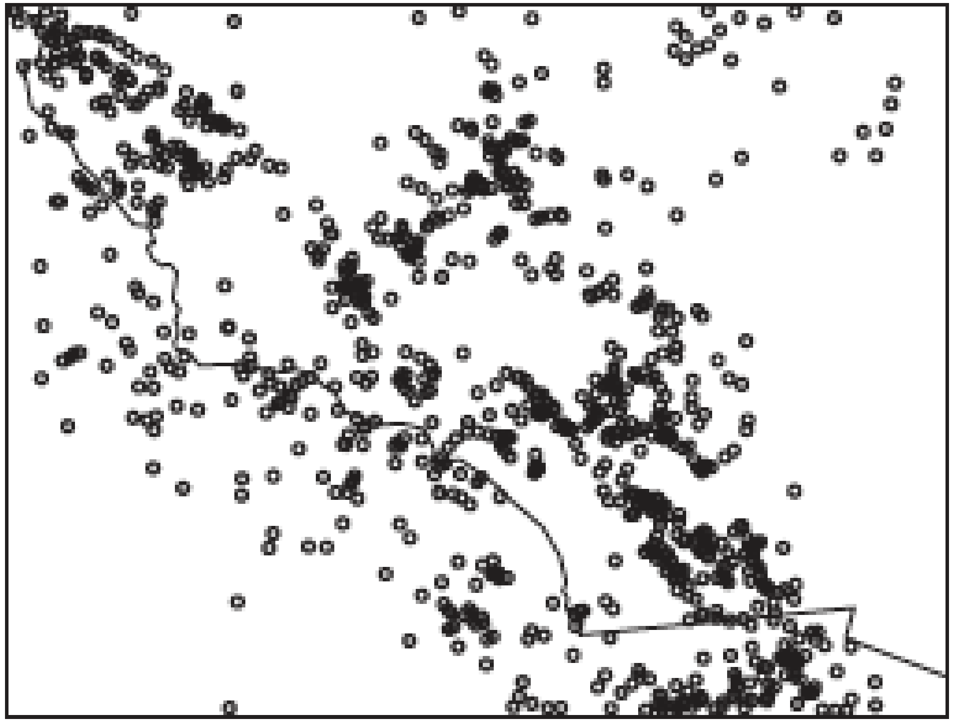
Only mainshocks are considered in EQ cat risk models

all events



3368 events with M>3.8 in 78 years
(43 events per year on average)

Mainshock only (after declustering)

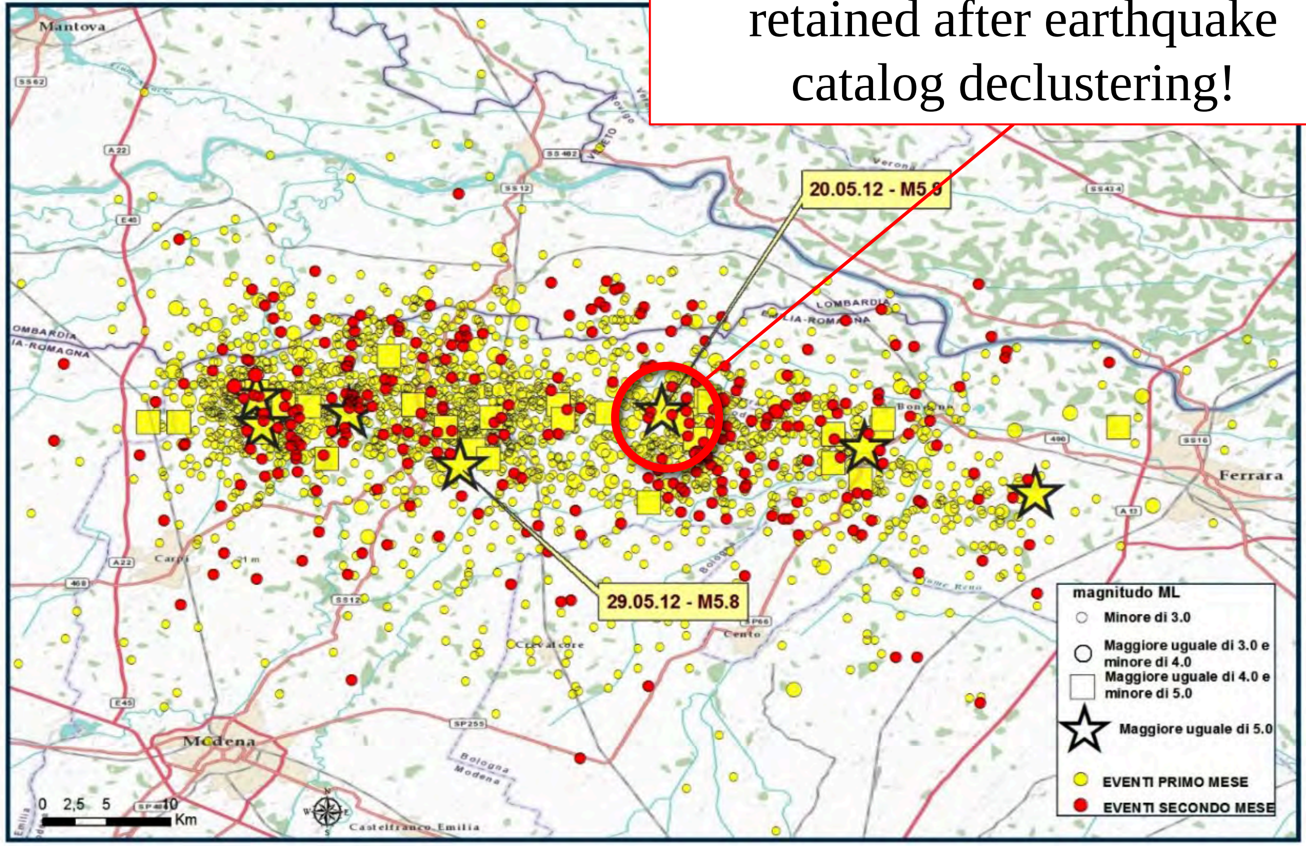


913 mainshock events with M>3.8 in 78 years
(11 events per year on average)

1932–2010 SCEC catalogue in Southern California.

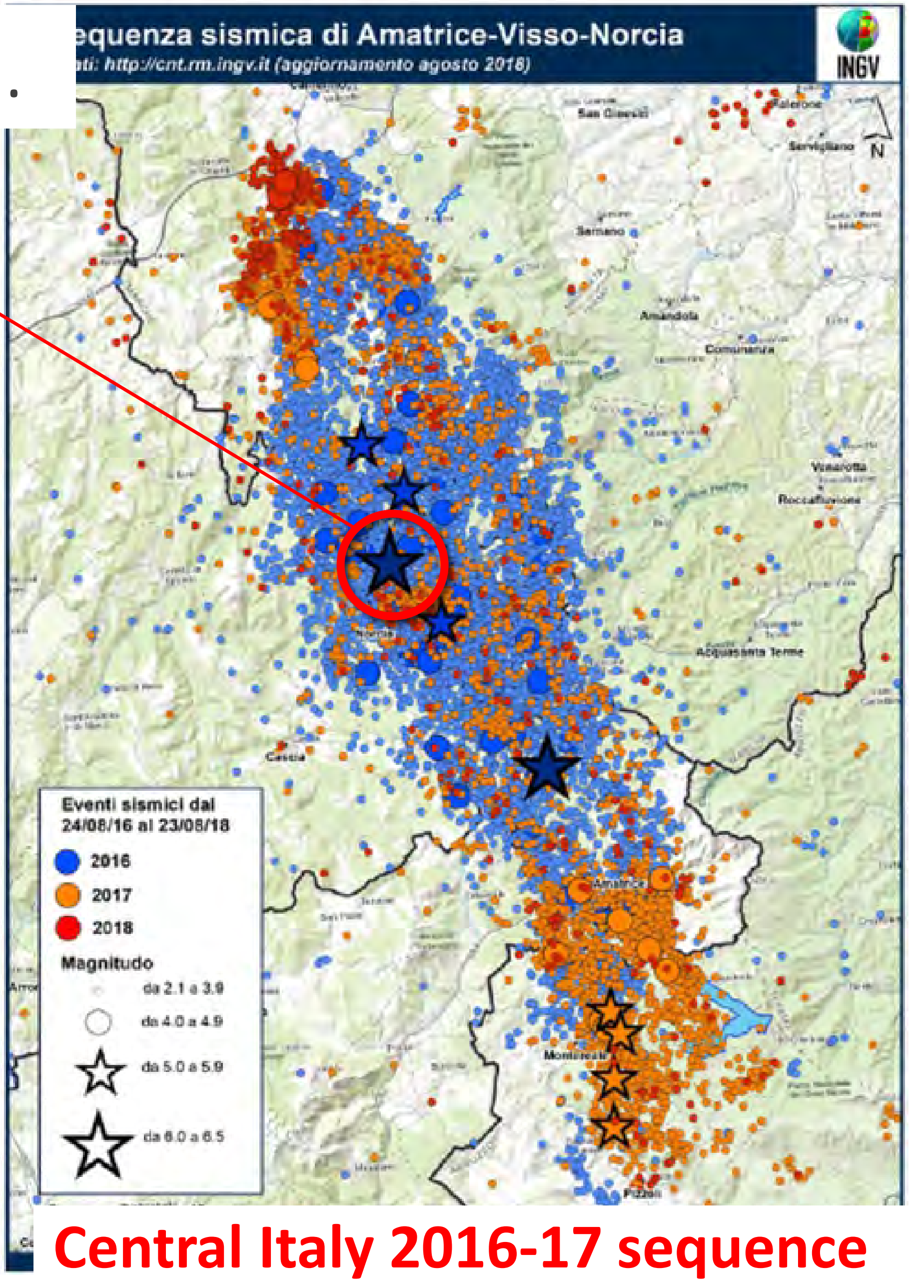
And then, after declustering, there were one…

Only one event per sequence is retained after earthquake catalog declustering!



Emilia 2012 Sequence

(two M5.9 but 7 M5+ in the sequence)



Central Italy 2016-17 sequence

(one M6.5 but 9 M5+ in the sequence)

Damage Accumulation

Amatrice, Central Italy 2016

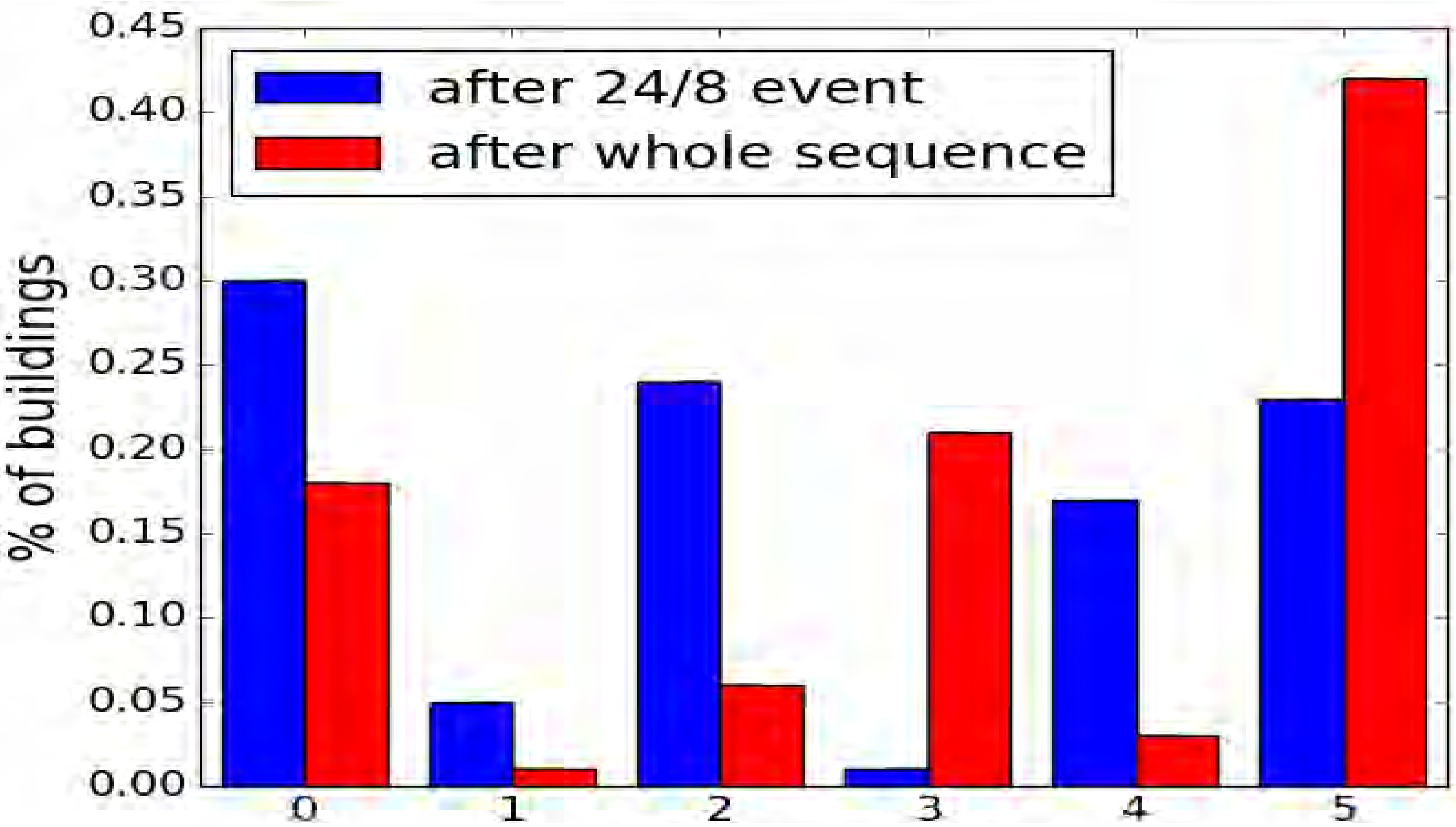
24 August 2016 | End of the sequence

Excerpted from Sextos et al. (2018)]

Evolution of damage states during the 2016-17 Central Italy Sequence

Adapted from GEER (2017), Report No. GEER-050D

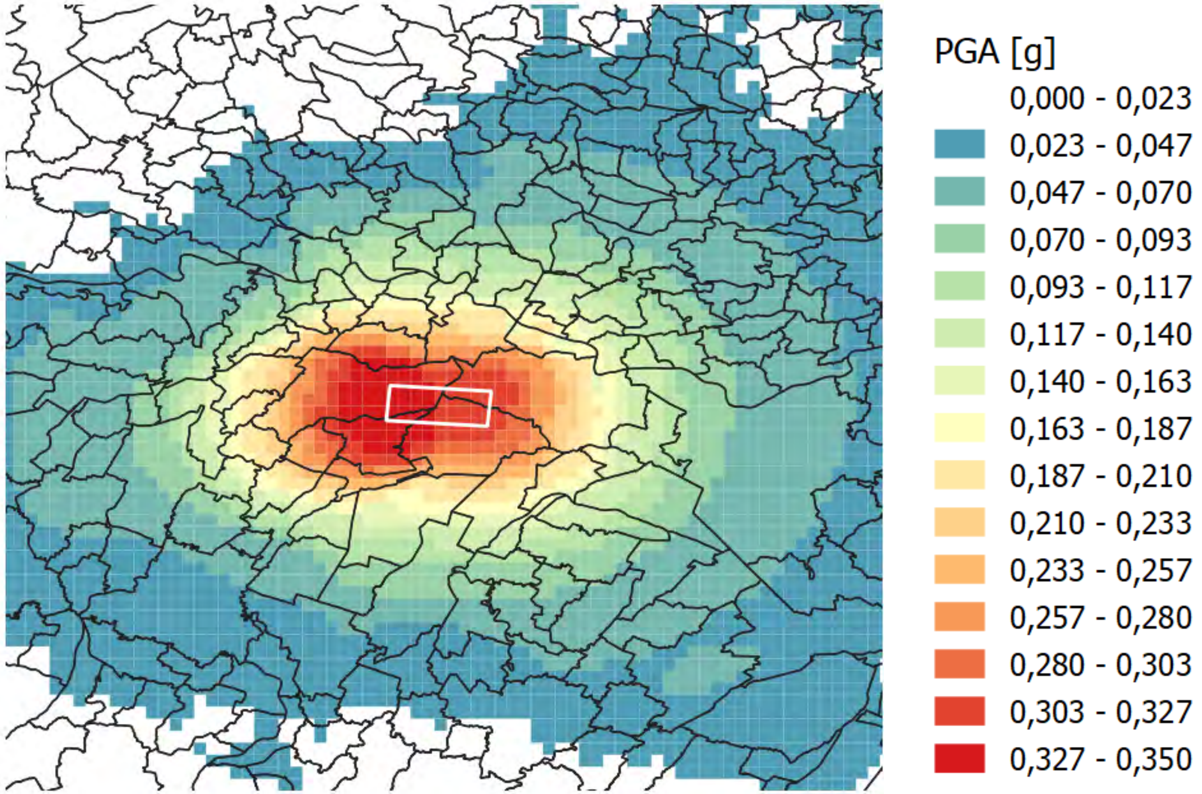
Amatrice



Damage state
(0= no damage; 5= complete collapse)

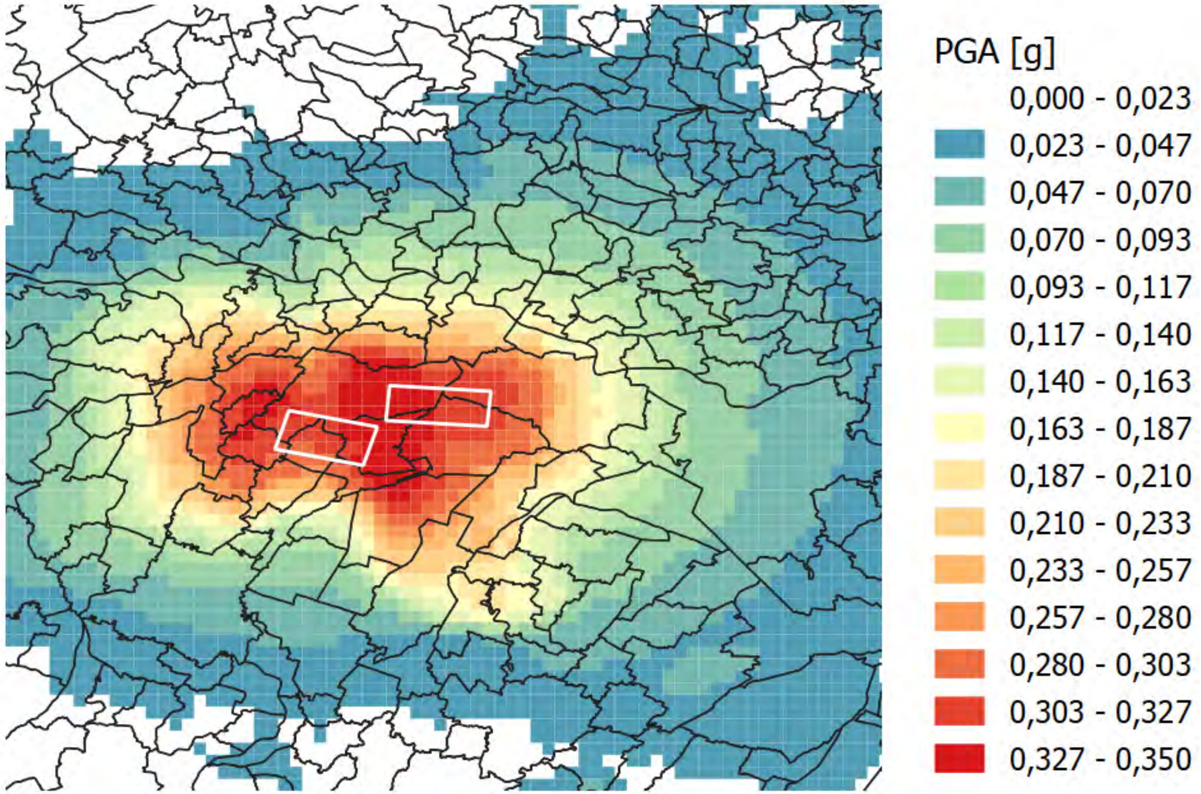
Larger Footprint of Damaged Building Stock

Max PGA Shakemap from
M_w=5.8, 20/5/2012 Emilia earthquake

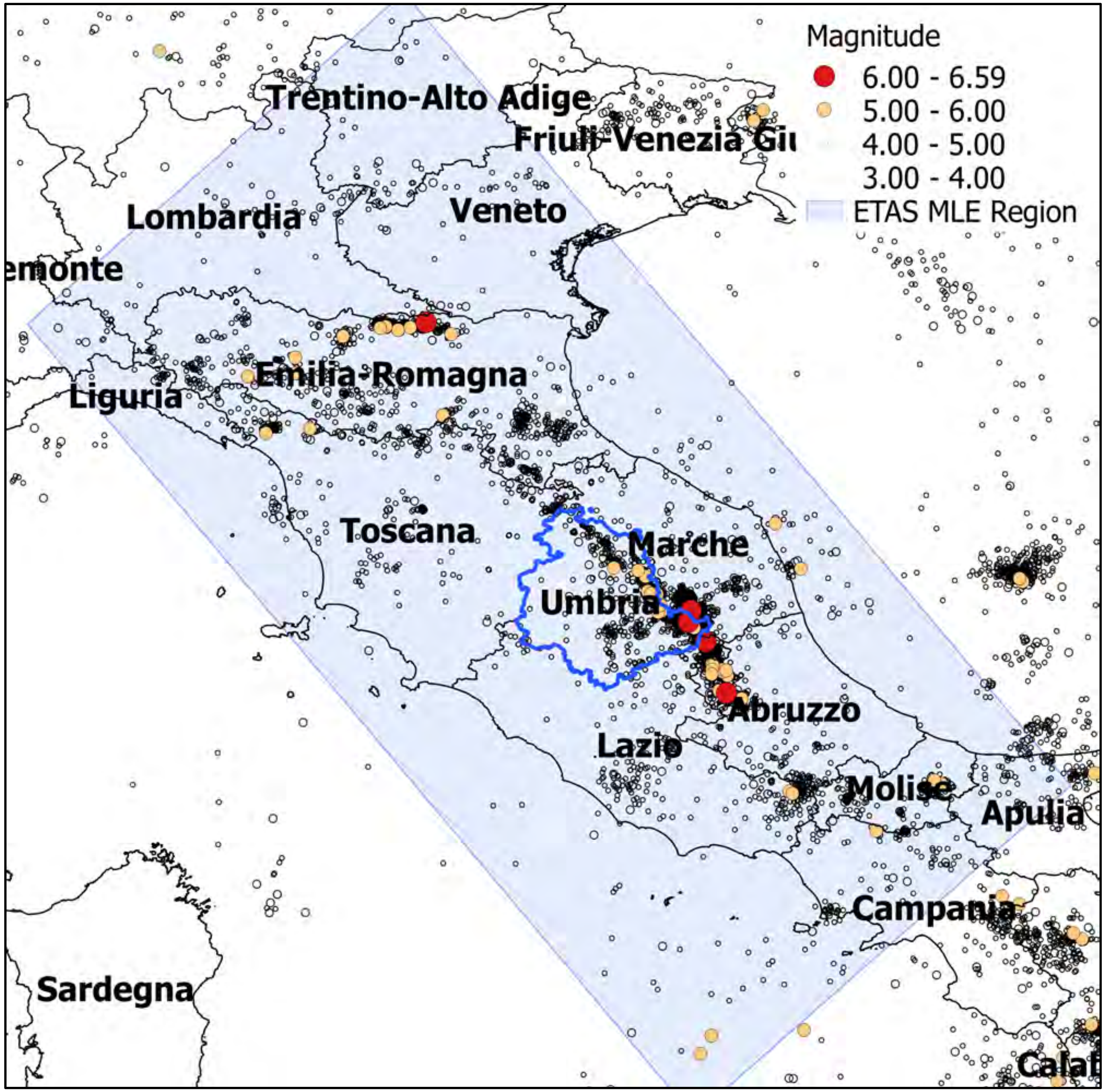


Larger Footprint of Damaged Building Stock

Max PGA Shakemap from
M_w=5.8, 20/5/2012 Emilia earthquake
M_w=5.6, 29/5/2012 Emilia earthquake

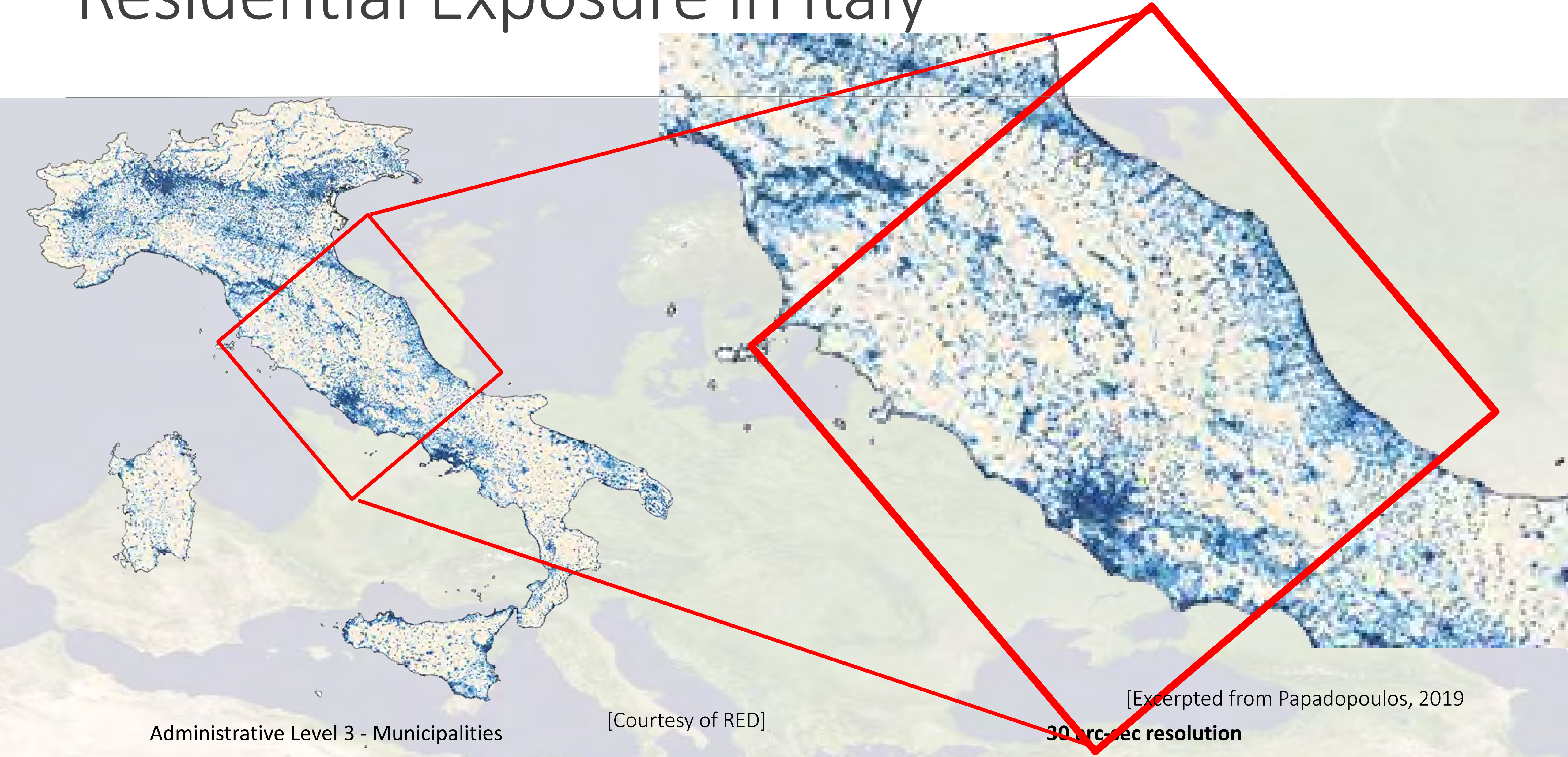


Generation of stochastic catalogues with all earthquakes



[Excerpted from Papadopoulos and Bazzurro, 2019

Residential Exposure in Italy



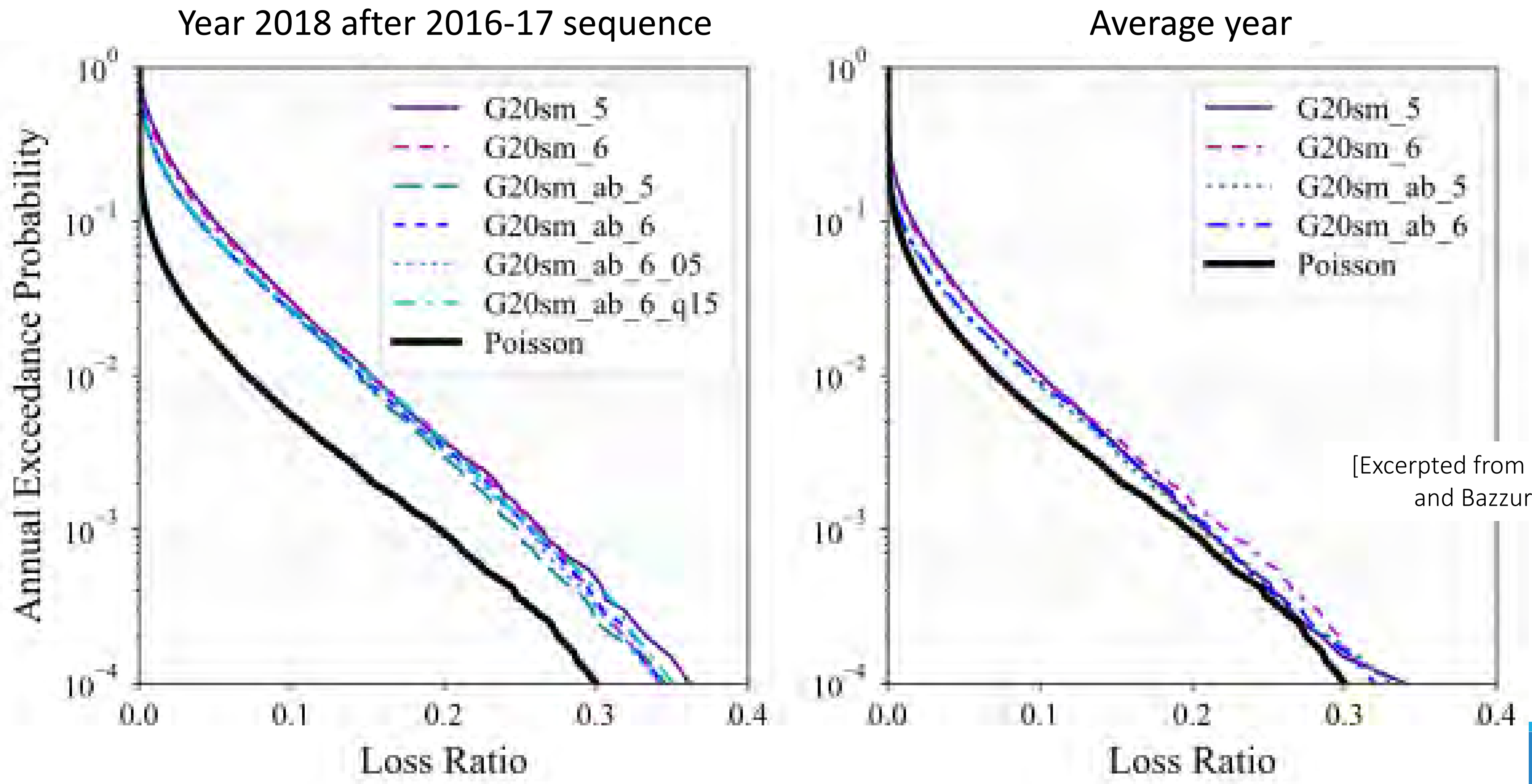
[Excerpted from Papadopoulos, 2019

Administrative Level 3 - Municipalities

[Courtesy of RED]

30 arc-sec resolution

Seismic risk in Umbria region with all earthquakes

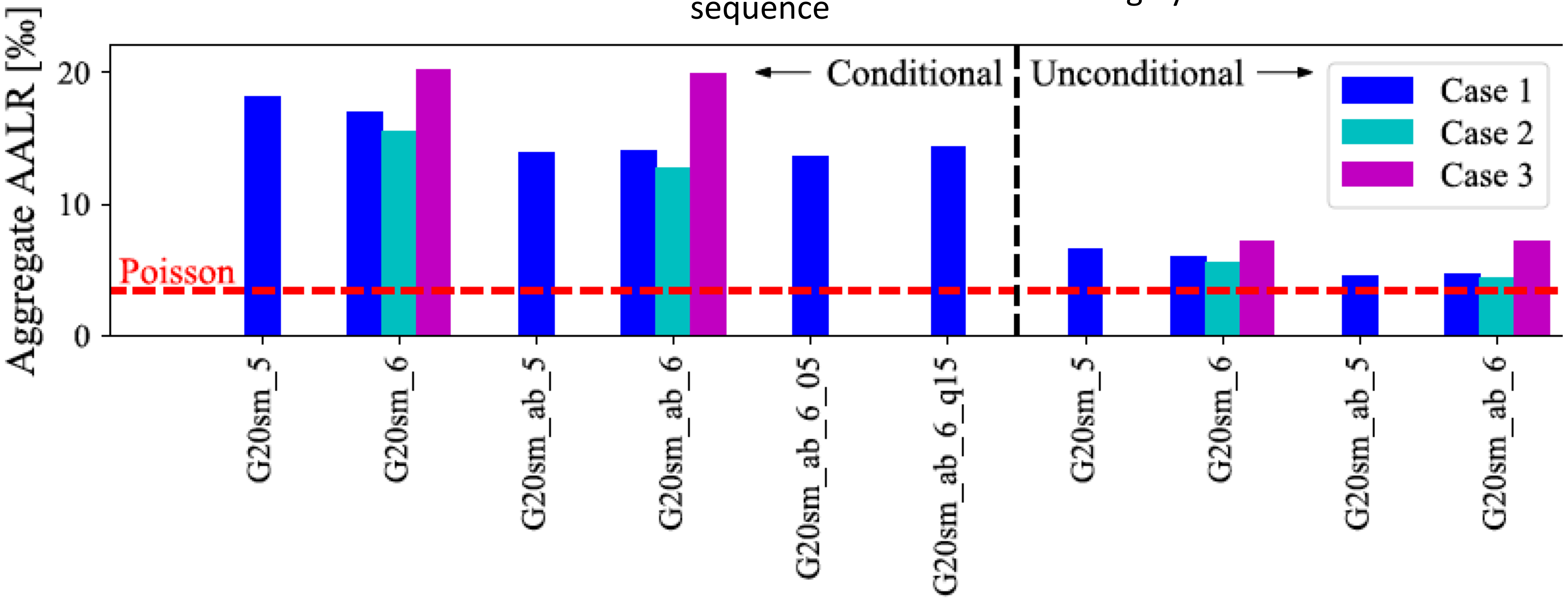


[Excerpted from Papadopoulos and Bazzurro, 2019

Systematic Underestimation of AAL's

First year after the sequence

Average year



[Excerpted from Papadopoulos and Bazzurro, 2019

Final Remarks

- For 25+ years now Cat Risk Models have been underpinning many decisions regarding risk assessment of portfolios of buildings including pricing
- Premium computations is based on AAL from these models plus loading factors that include, among others, unmodeled sources of risk (e.g., earthquake induced landslides or ground failure) and unknowns
- Many are the sources of bias and volatility in the current models, we explored four
- Clustered seismicity cannot be excluded any longer from seismic risk assessment
- Hazard-consistent vulnerability functions for classes of buildings to avoid biased loss estimates
- Future ground motion predictions tools will remove sources of bias in loss estimates from current models