TOWARD ENHANCED PORTFOLIO SEISMIC RISK ESTIMATES VIA PHYSICS-BASED GROUND MOTION SIMULATIONS

Preetish Kakoty[1], Pouria Kourehpaz [2], Carmine Galasso [1], Carlos Molina Hutt [3], Brendon A Bradley [4]

[1] University College London, UK
[2] First Street, New York, USA
[3] University of British Columbia, Vancouver, Canada
[4] University of Canterbury, New Zealand

UCL

June 23 - 25, 2026
University of Zagreb, Croatia
GEM CONFERENCE
FROM FAULTS TO FUTURE SCENARIOS

BACKGROUND

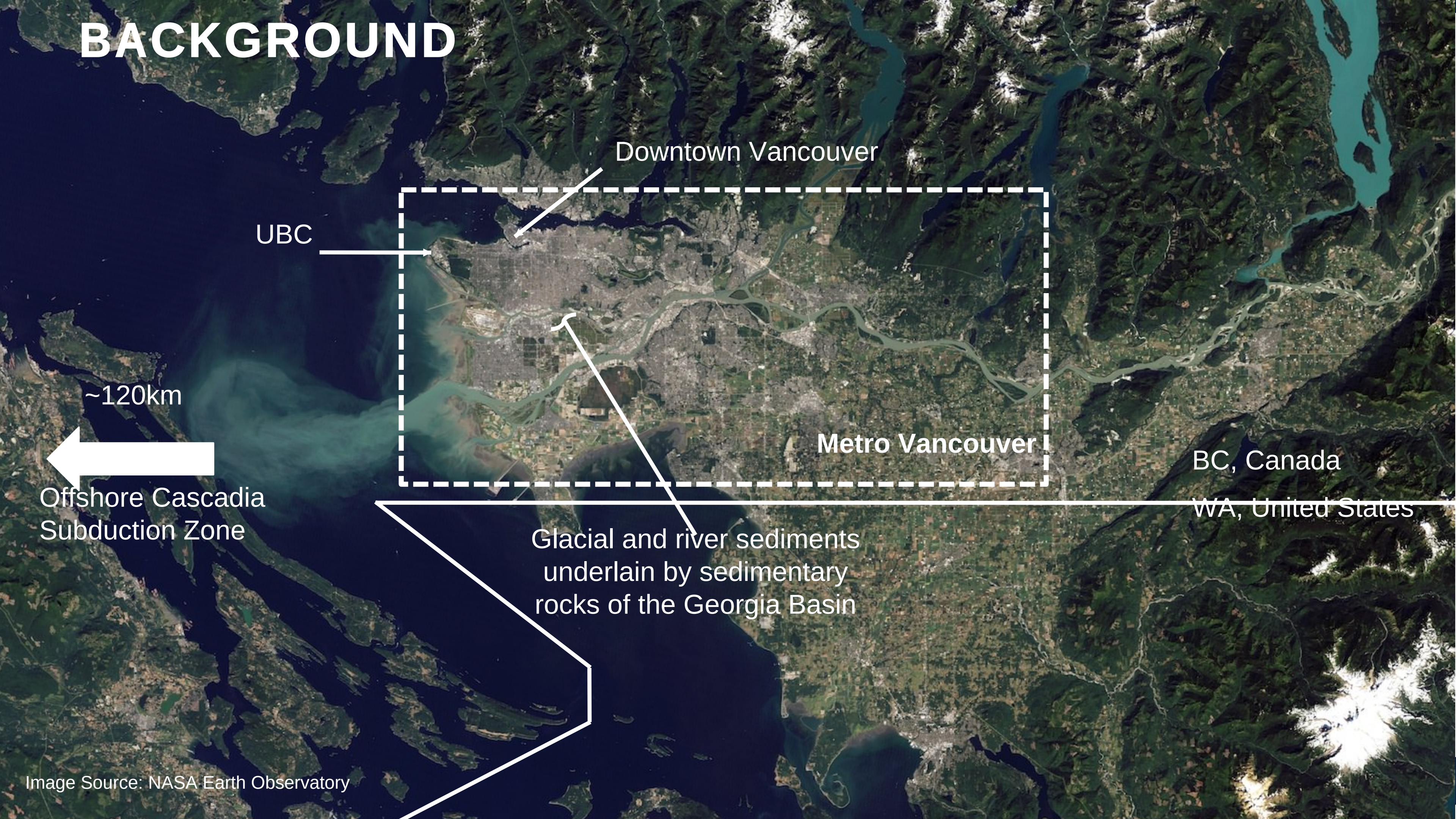


Image Source: NASA Earth Observatory

Traditionally, empirical ground motion models are used for seismic hazard characterization, but they contain critical gaps.

Earthquake records are unevenly distributed

Sparse coverage in many regions leaves site-specific hazard poorly constrained.

Few near-fault, large-magnitude records

The events that matter most for hazard are the least represented in the data.

Basin and site effects go unrepresented

Empirical models miss the long-period amplification that drives tall-building demand.

Physics-based simulation of ground motions provide a robust alternative to augment traditional seismic hazard assessment.

Simulates the heterogeneous rupture process

Variable slip, rupture speed, and directivity are modelled explicitly, not averaged away.

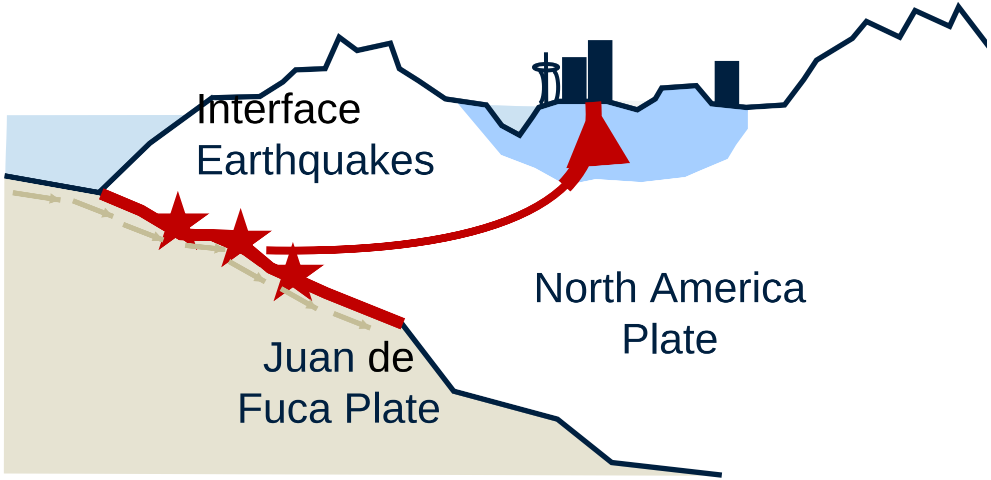
Captures spatial correlation of ground motion

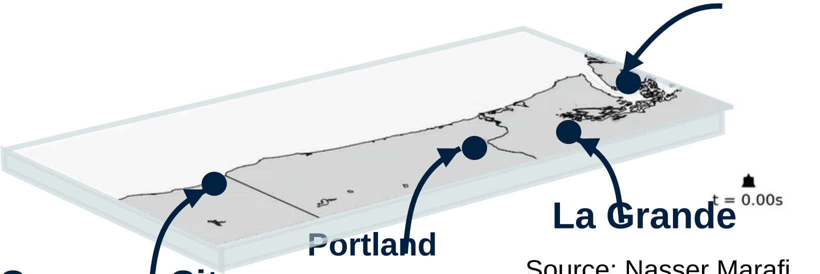
Shaking at nearby sites varies together, giving realistic loss patterns across a portfolio.

Model 3D wave propagation and basin effects

Waves travel through a realistic velocity structure, capturing the basin amplification.

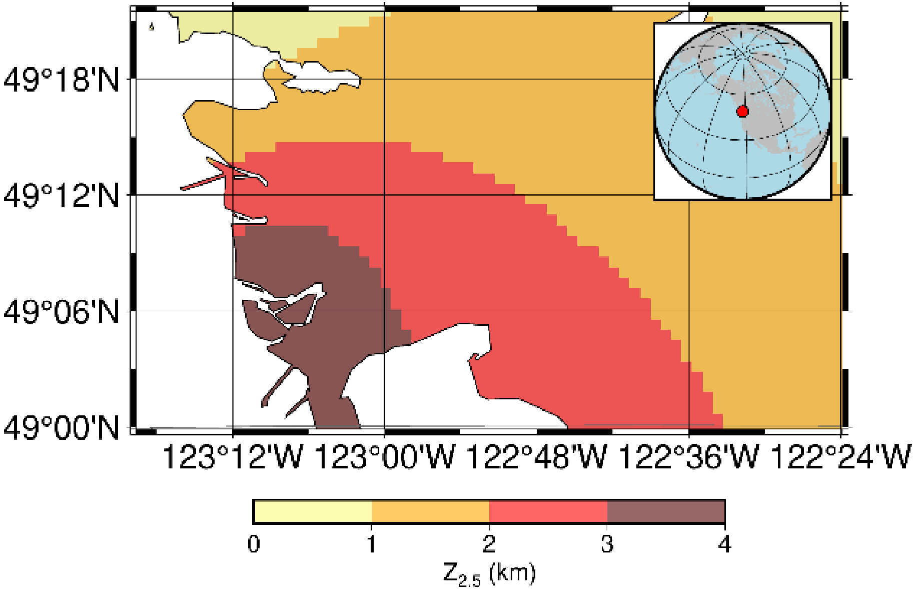
30 scenarios of an M9 Cascadia subduction zone earthquakes were simulated capturing variations in rupture parameters.

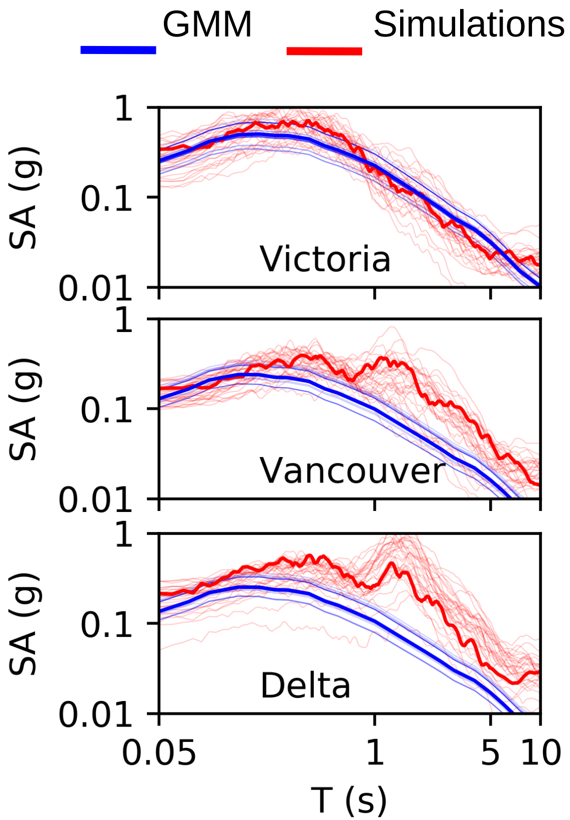




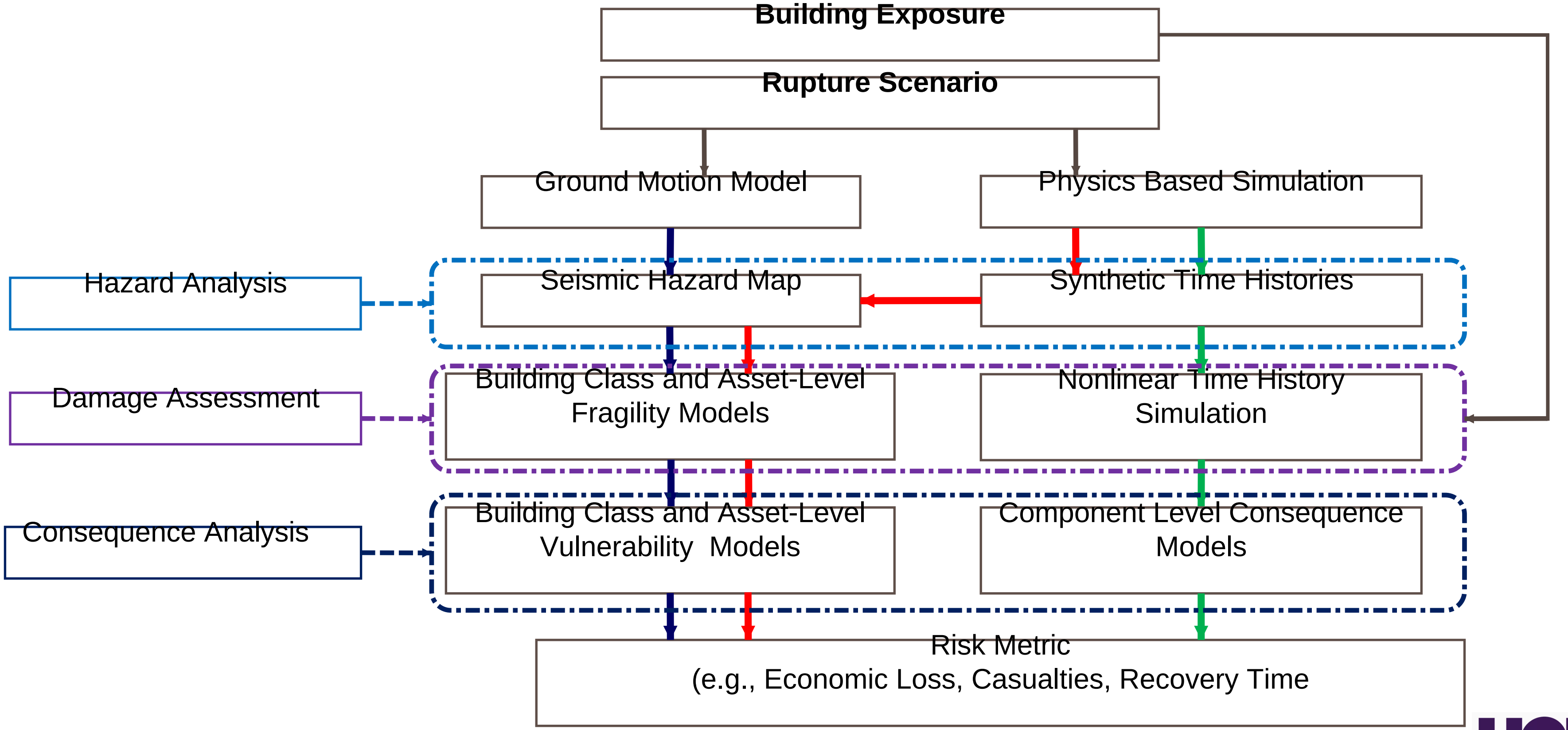
Source: Nasser Marafi

Basin amplification effects are more proportionally higher at deeper basin sites.

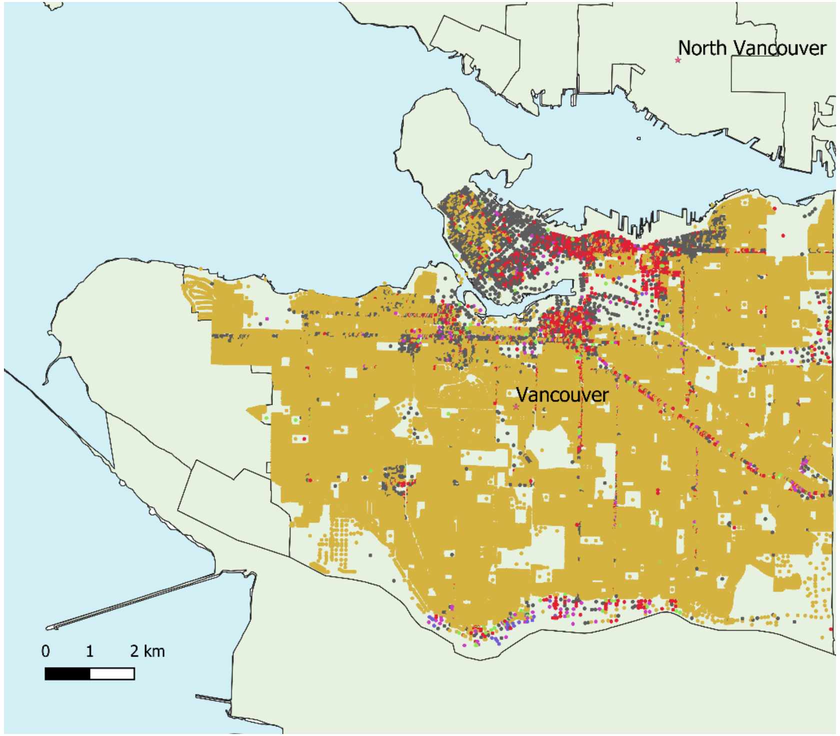




A framework is proposed to incorporate physics-based simulation into seismic risk assessment of building portfolio.



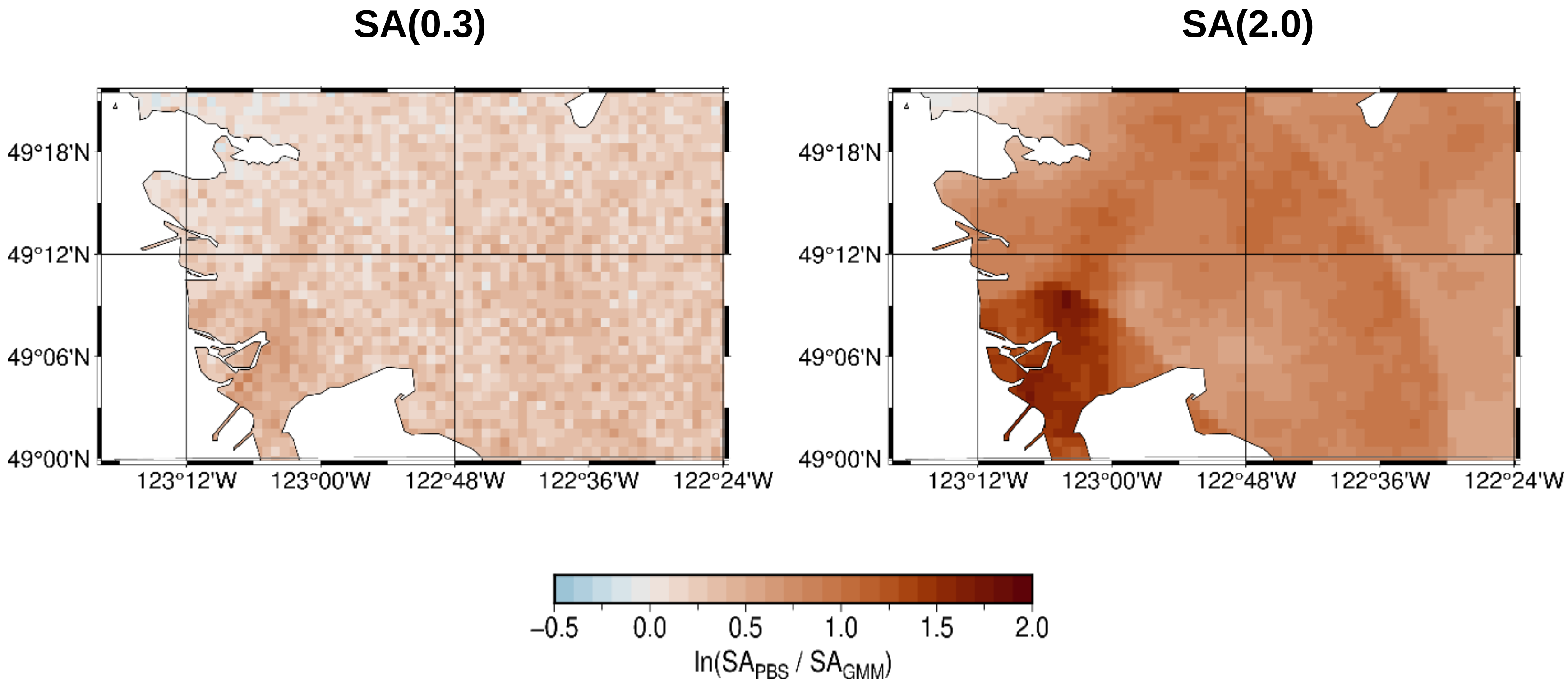
Wood-frame buildings dominate the exposure, but tall buildings hold a disproportionate share of replacement value.



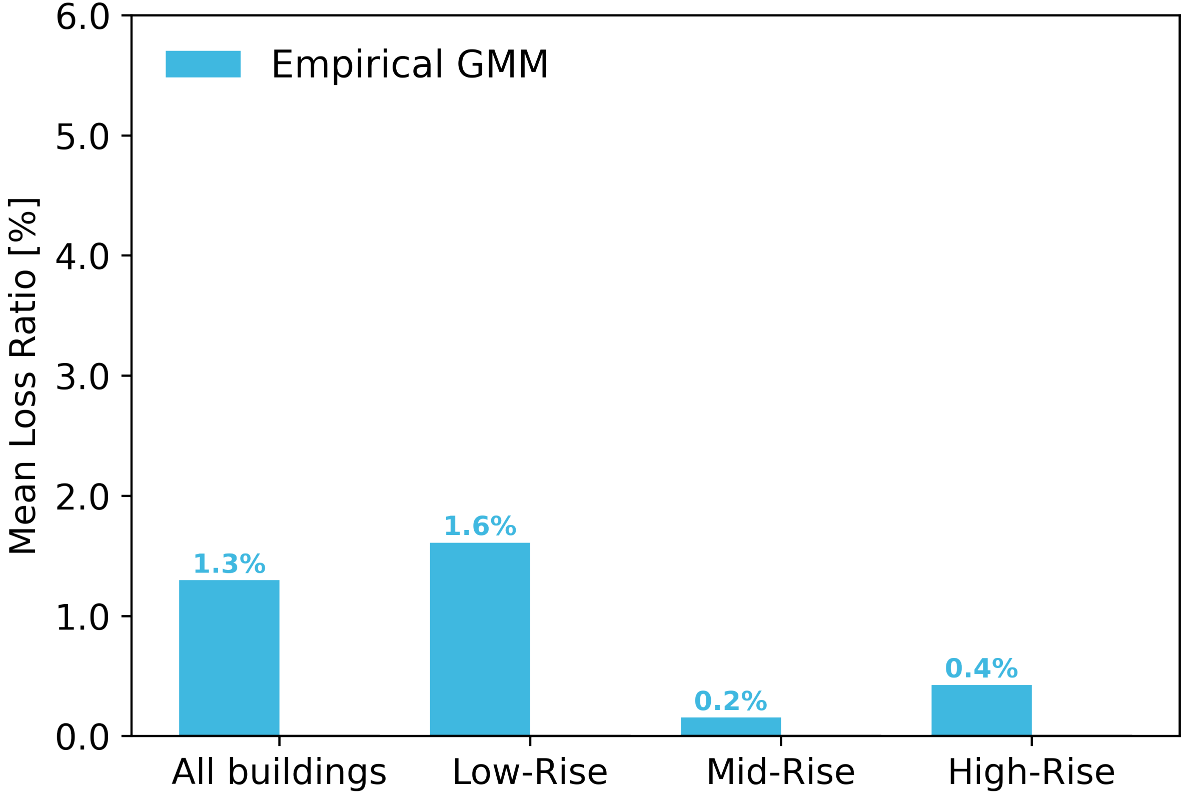
Building Material

- Wood (94.39%)
- Concrete (2.96%)
- Steel (0.27%)
- Reinforced Masonry (0.22%)
- Unreinforced Masonry (2.13%)
- Precast Concrete (0.03%)

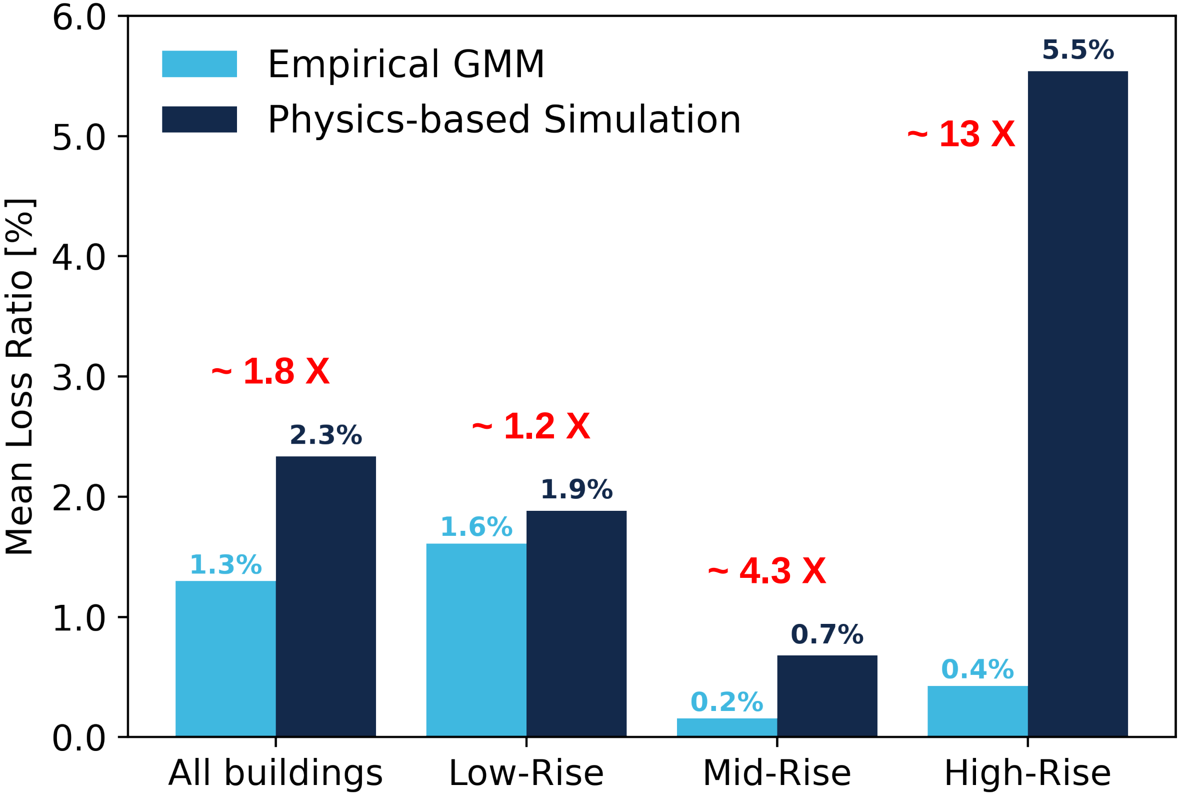
For long period shaking, simulation-based ground motions exceed GMM estimates — most strongly within the sedimentary basin.



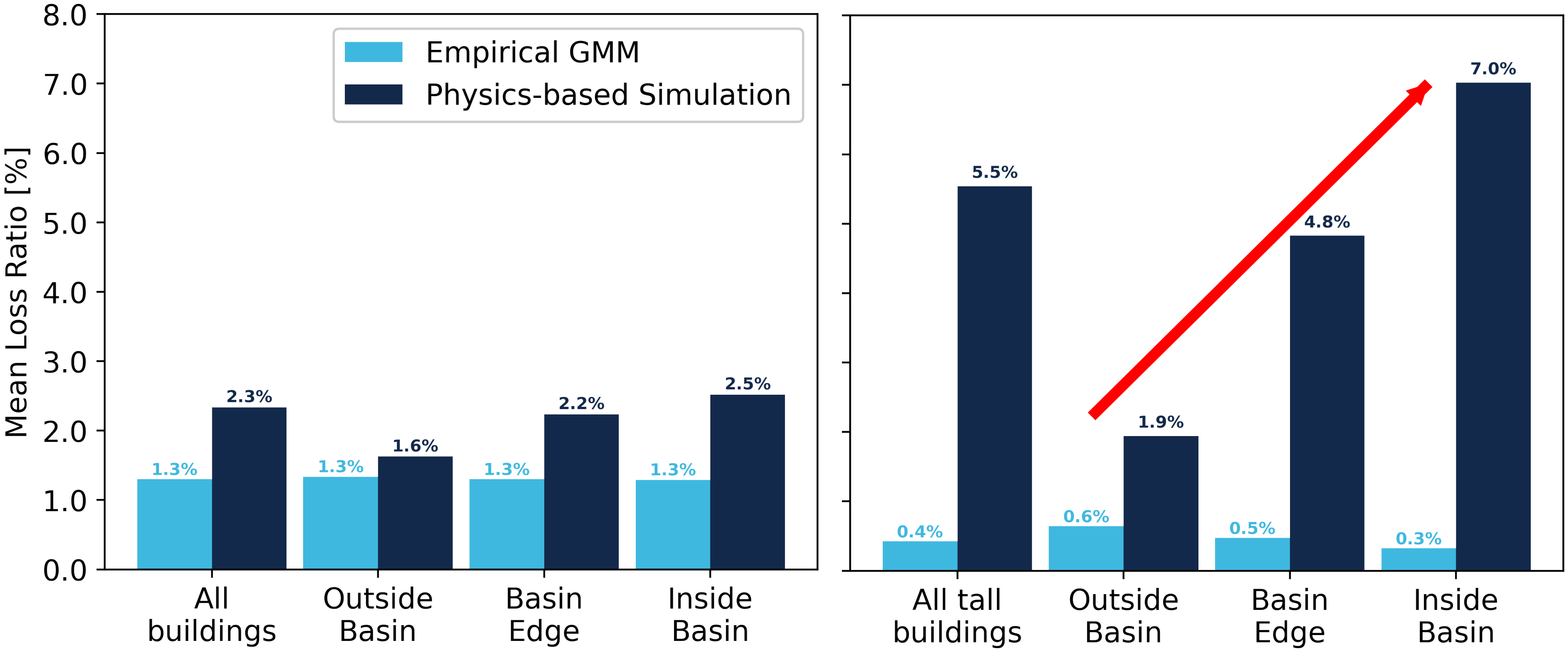
The divergence between simulation- and GMM-based losses is modest for low- and mid-rise but widens sharply for high-rise.



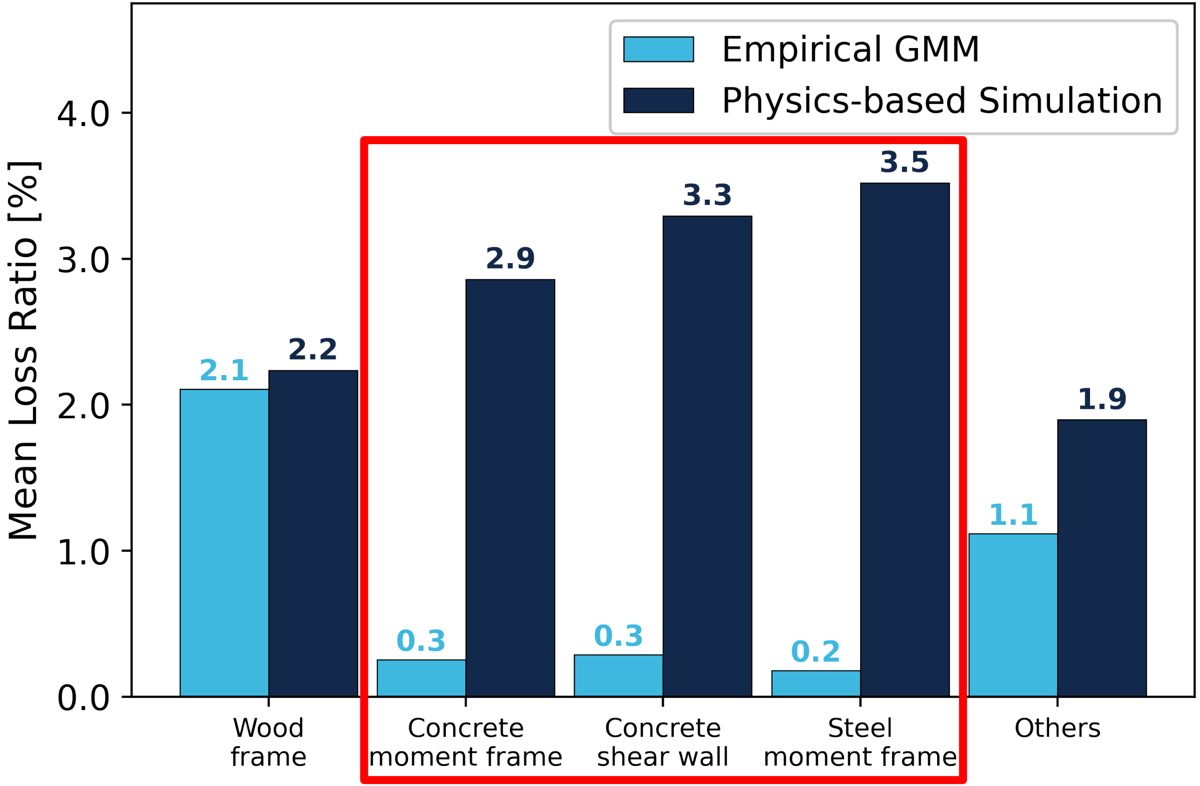
The divergence between simulation- and GMM-based losses is modest for low- and mid-rise but widens sharply for high-rise.



The loss discrepancy deepens with the basin for tall buildings, but stays uniform across the full portfolio.



The largest loss discrepancies fall on the structural systems used in tall buildings.



DE|RISC Lab

Summary

Portfolio-aggregate losses mask the tall-building impact.

Simulation- and GMM-based losses are within ~1.8× at the portfolio level, but diverge by 13× for high-rise buildings.

The simulation–GMM discrepancy scales with basin depth.

For tall buildings, the loss ratio underestimation by GMMs increases monotonically with Z2.5, from ~13× outside the basin to 21.6× in the deepest sediments — consistent with long-period basin amplification absent from the NSHM GMMs.

The discrepancy is concentrated in structural systems of tall buildings.

Concrete and steel moment-frame and shear-wall systems show 8–12× underestimation, while short-period wood-frame systems agree within 1.1×. The divergence is period-dependent, not a uniform bias.

THANK YOU!

June 23 - 25, 2026

University of Zagreb, Croatia

GEM CONFERENCE

FROM FAULTS TO FUTURE SCENARIOS

p.kakoty@ucl.ac.uk

preetishkakoty.github.io