Multi-Hazard Sustainability: From Seismic to Sea-Level Rise Uncertainties

The 42nd Risk, Hazard & Uncertainty Workshop
Hydra, Greece
Jun 23, 2016

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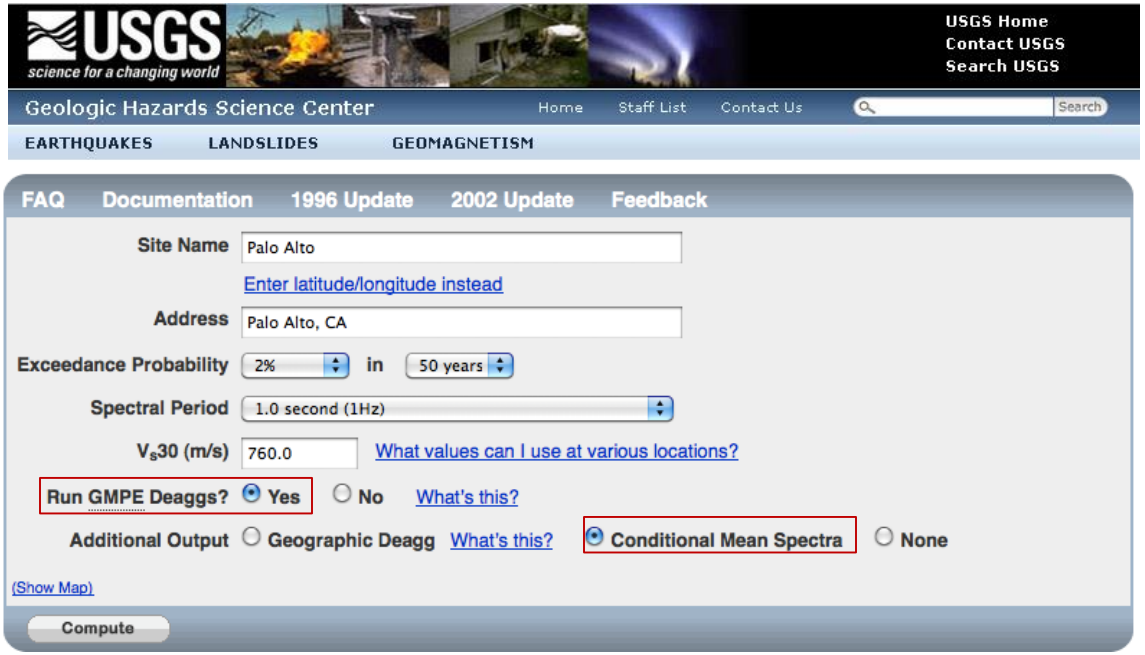
Systems Subjected to Multiple Hazards

Hazard-Consistent Ground Motion Selection Methodology

Science
Curiosity driven

Engineering
Solution seeking

Policy
Action oriented



Lin, Harmsen, Baker, & Luco, *BSSA* (2013)

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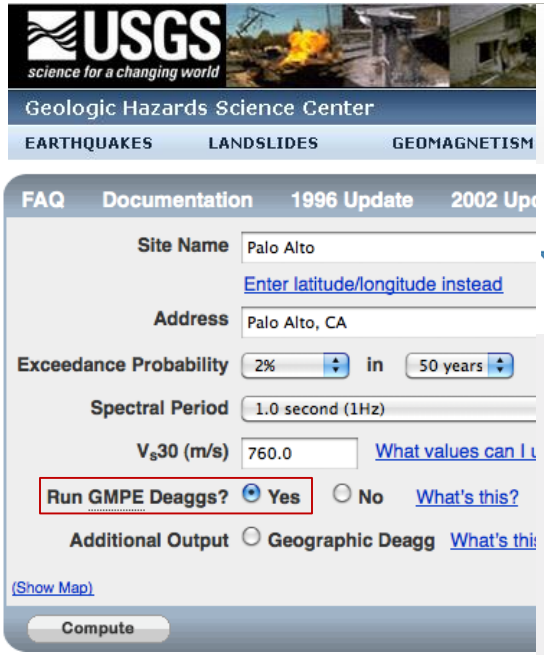

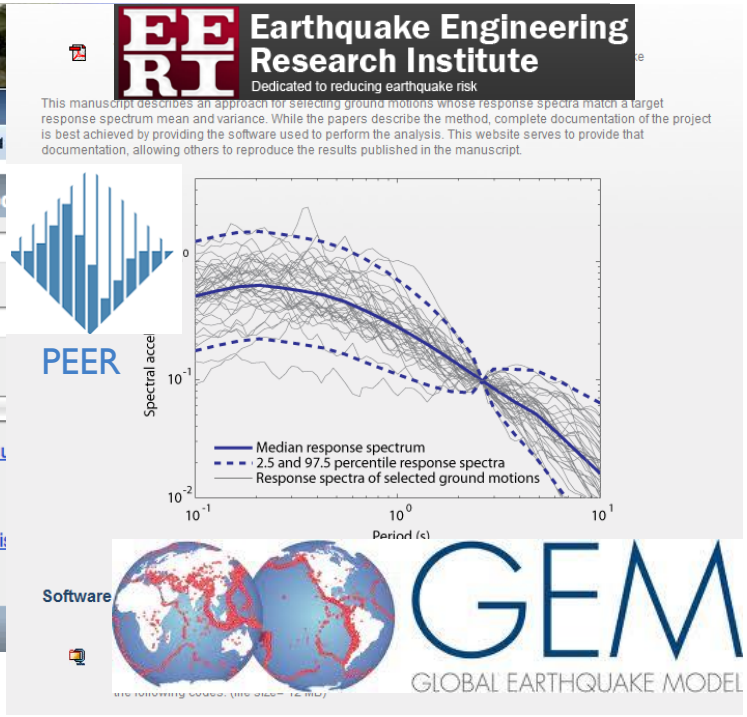

Lin, Harmsen, Baker, & Luco, *BSSA* (2013) Jayaram, Lin, & Baker, *EQ Spectra* (2011)

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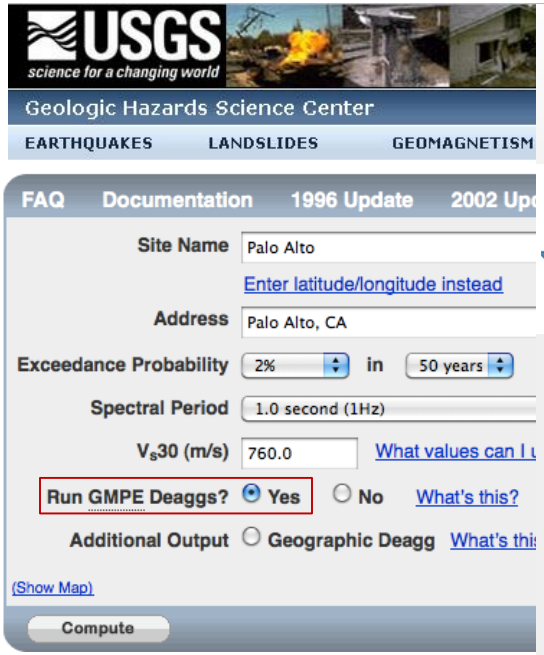
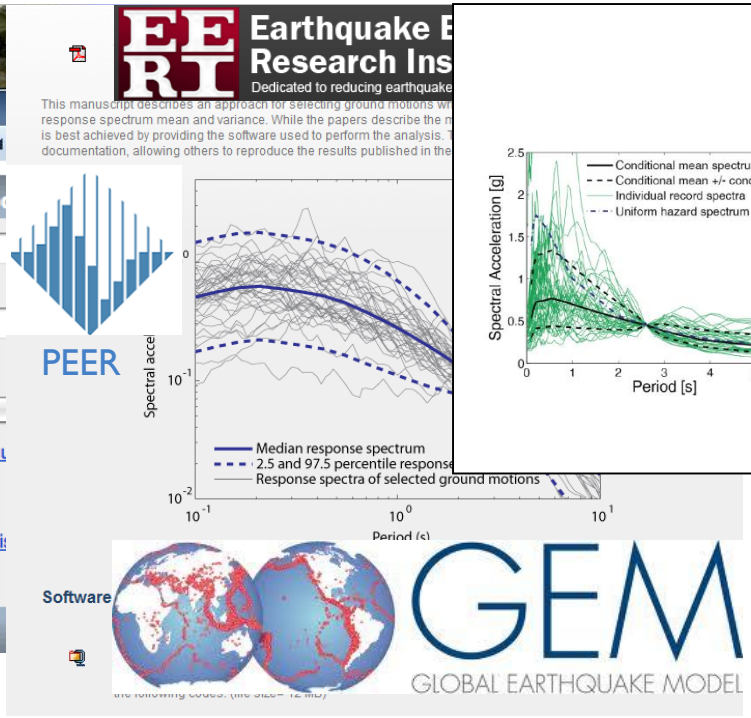
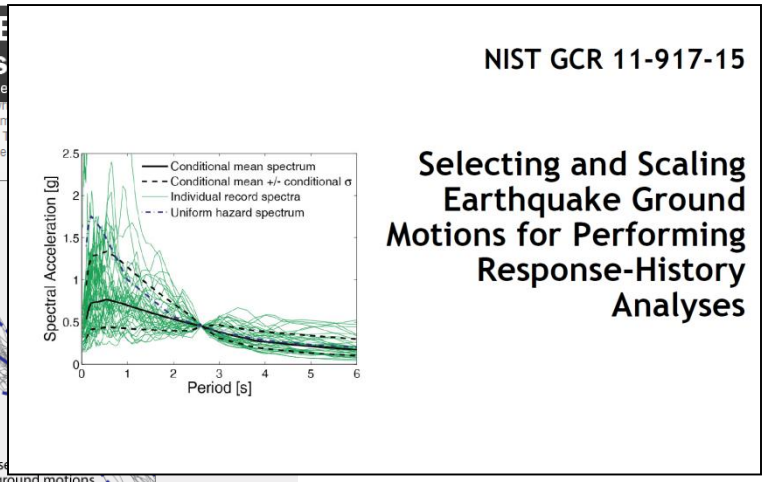






NIST nehrp ATC CUREE

Lin, Harmsen, Baker, & Luco, *BSSA* (2013) Jayaram, Lin, & Baker, *EQ Spectra* (2011) Lin, Haselton, & Baker, *EESD* (2013a, b)

AIDA: PSHA-Consistent IDA

Structural response assessment

Static	Dynamic
Linear	Linear
Nonlinear	Nonlinear
Pushover	**Incremental Dynamic Analysis (IDA)**

Vamvatsikos & Cornell, "IDA," *EESD* (2002)

Ground motion selection

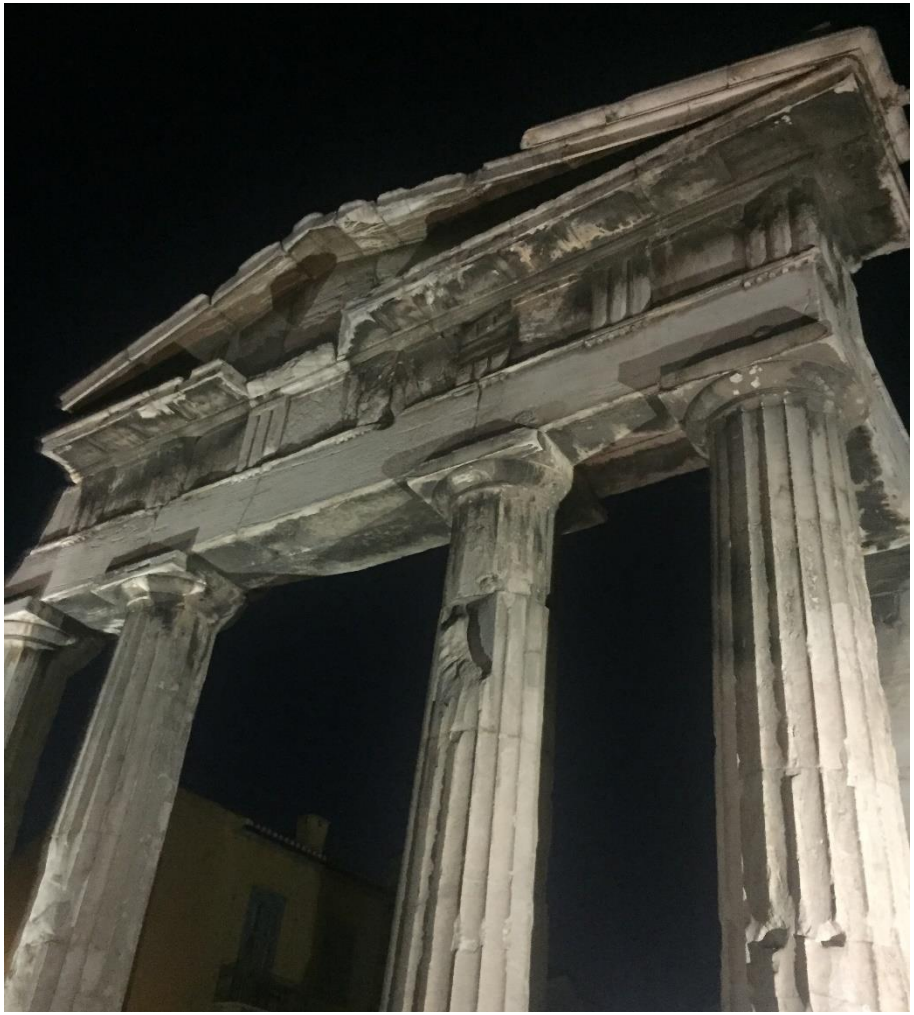
Procedure	Method
Probabilistic Seismic Hazard Analysis (PSHA) and Deaggregation	**Multiple Stripe Analysis (MSA)**
Target response spectrum	**Conditional Spectrum (CS)**

Adaptive Incremental Dynamic Analysis (AIDA)

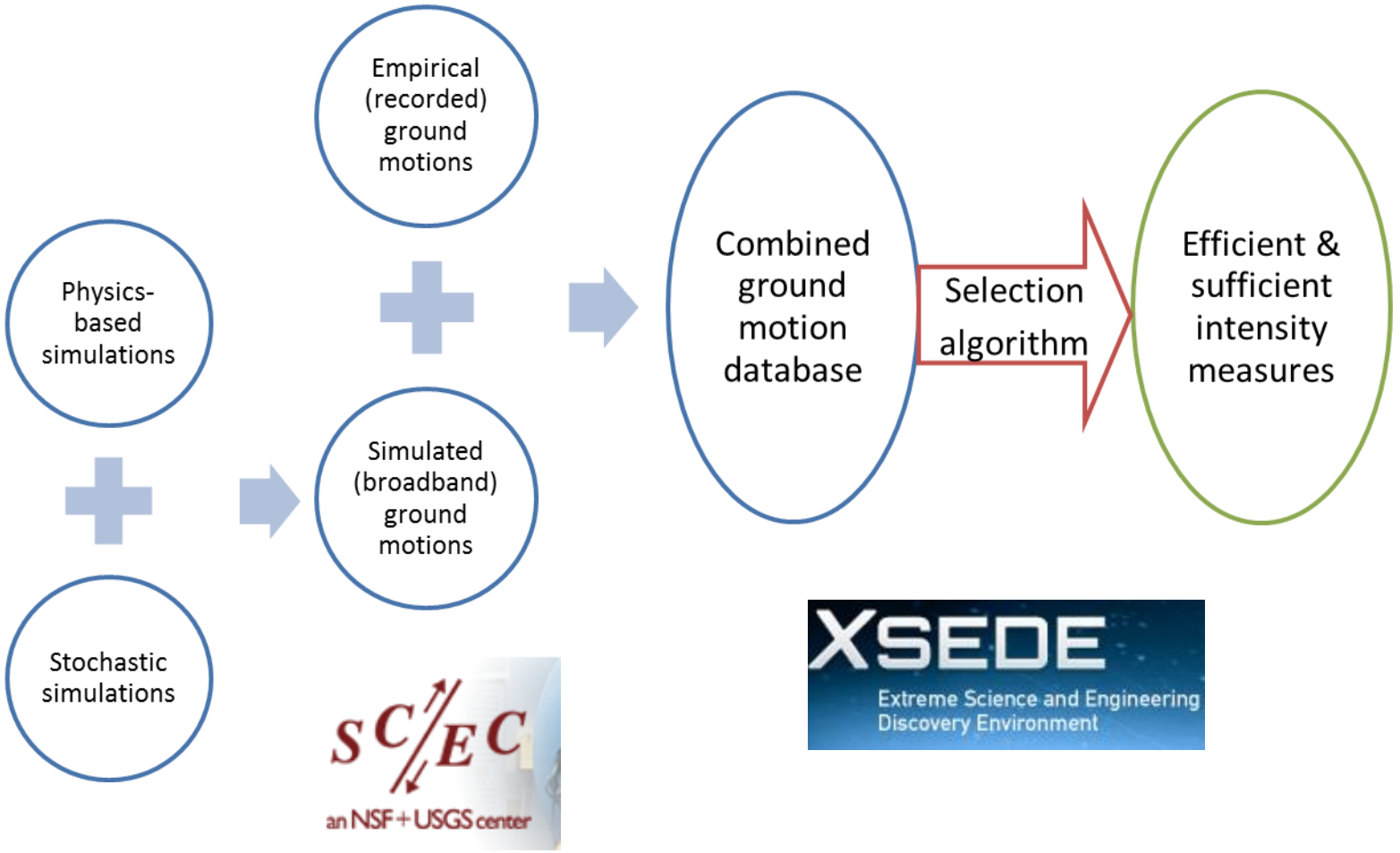
Lin & Baker (2015). "Conditional Spectra," *Encyclopedia of Earthquake Engineering*, 461-472.

Lin & Baker (2013)

History is history



The "future" of ground motion selection (Nov. 2012)

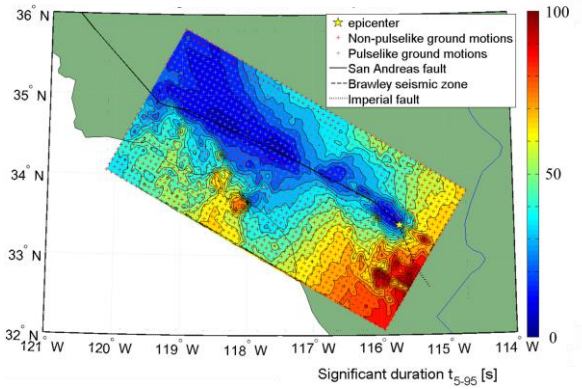


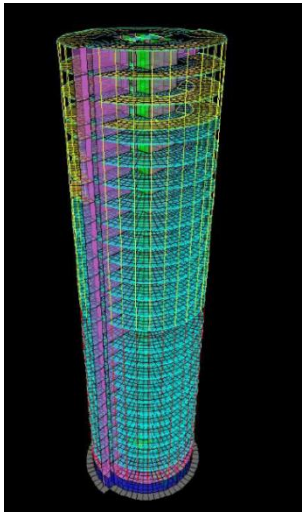
SCEC #13161, 14186, 14228, 15113, 16110, 16139

TG-BCS130008, 140006

Ground Motion Simulation Validation of Tall Buildings

- Examine ground motion properties
  - Consider (independently and jointly) spectral shape, duration and pulse-like characteristics
  - Select ground motions that satisfy a specified set of criteria or generate motions via direct simulations
- Develop archetype classes of tall buildings
  - Include different structural systems, height ranges and layouts
  - Capture important structural behavior such as structural collapse, cumulative damage and “in-cycle” strength and stiffness degradation
- Evaluate structural response subjected to simulated motions
  - Investigate important ground motion properties for nonlinear response history analyses
  - Provide recommendations on use of simulated motions



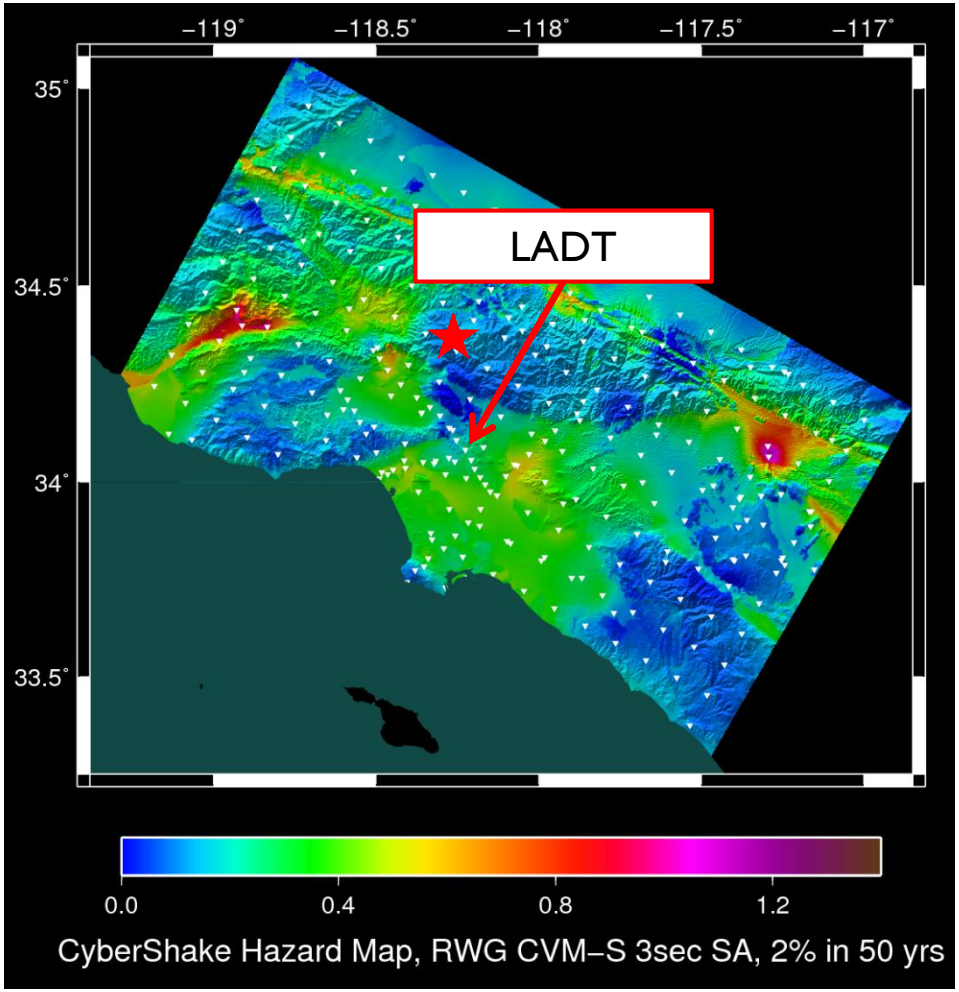


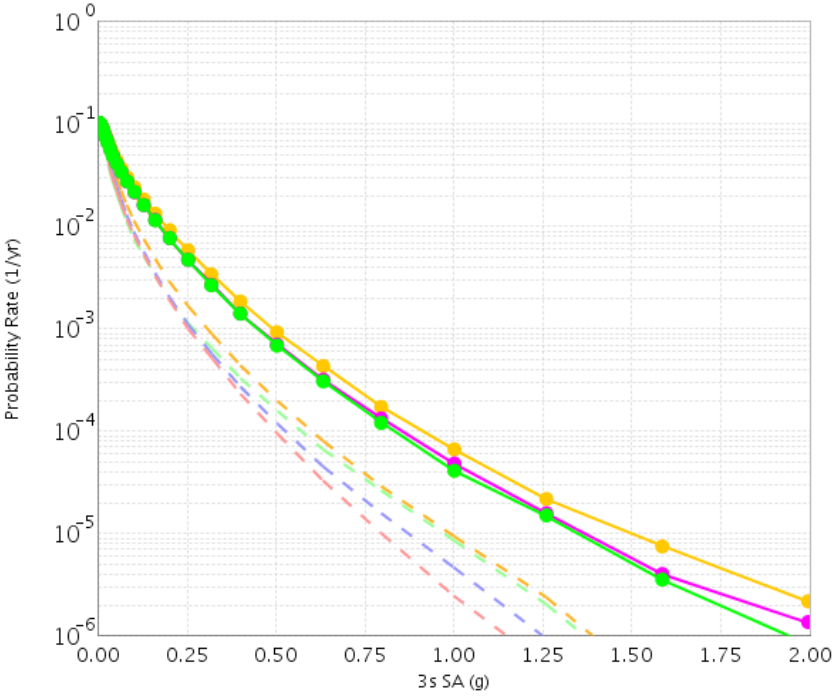
SCEC #13161,TG-BCS130008

Lin, Bijelic, & Deierlein (2013)

Utilization of CyberShake hazard and ground motions

SCEC CyberShake: Physics-based Probabilistic Seismic Hazard Analysis





- 286 Sites (51 with broadband)
- Millions of ground motions
- Hazard curves and maps
- Deaggregation
- Ground motion selection
- Intensity- & risk-based assessments

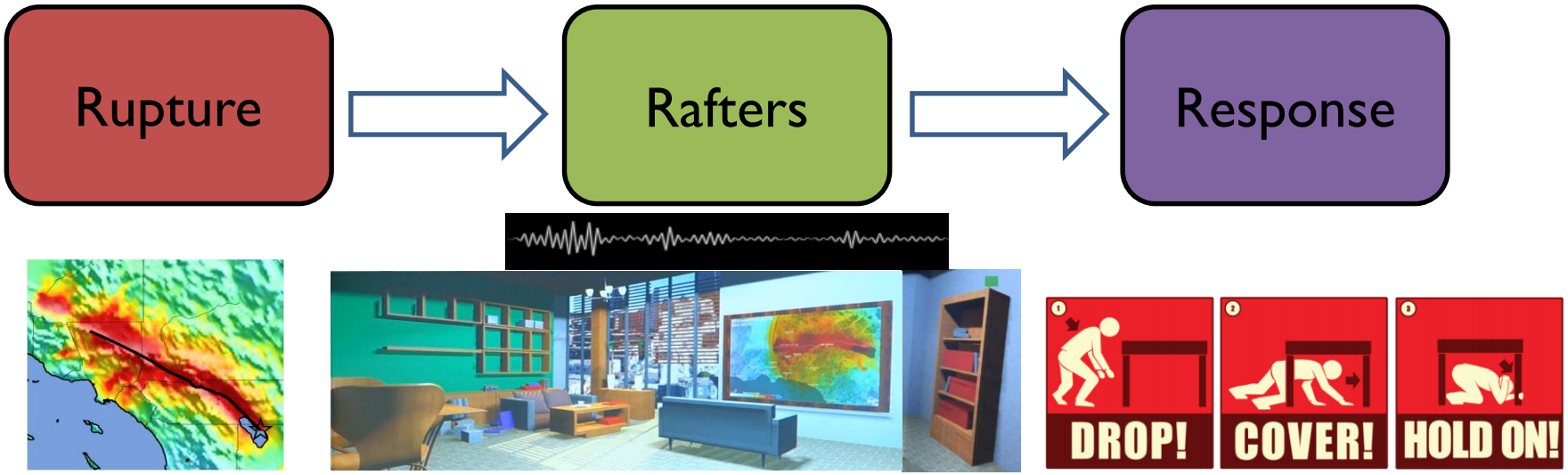
Graves et al. (2011)

SCEC #15113

Bijelic, Lin, & Deierlein (2015)

Visualizing Emergency Response Under Extreme Motions

- Combining ShakeOut and Performance-Based Earthquake Engineering
- Site- and structure-specific scenarios for virtual rooms
- Component tagging based on fragility functions
- Audio feature varying with shaking intensity
- Emergency response practice via virtual reality



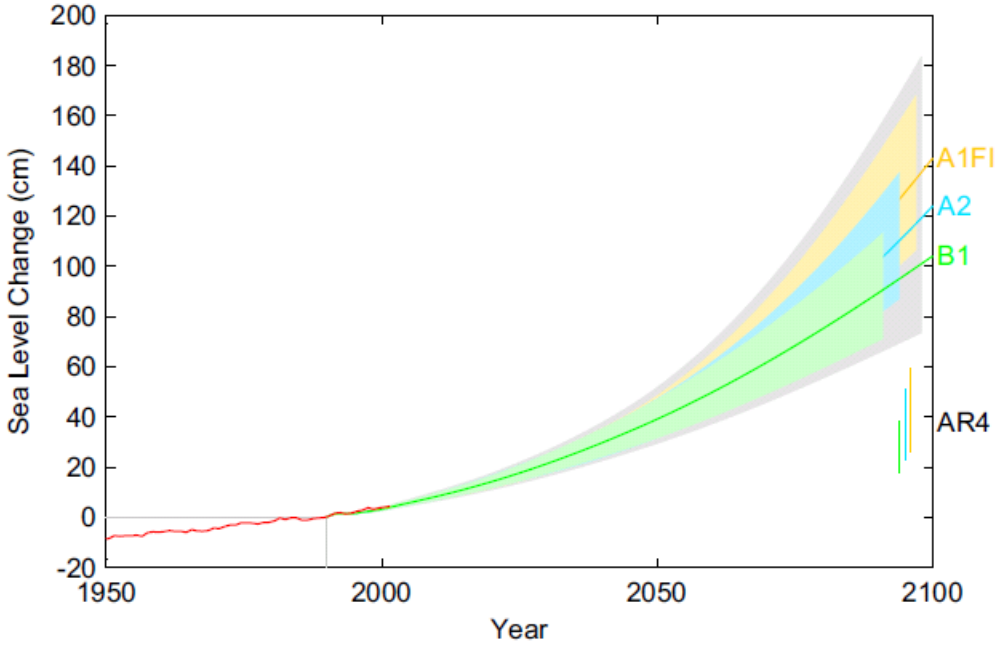
SCEC #14186, SIF #120

Lin, Kren, Larkee, & LaDisa (2014)

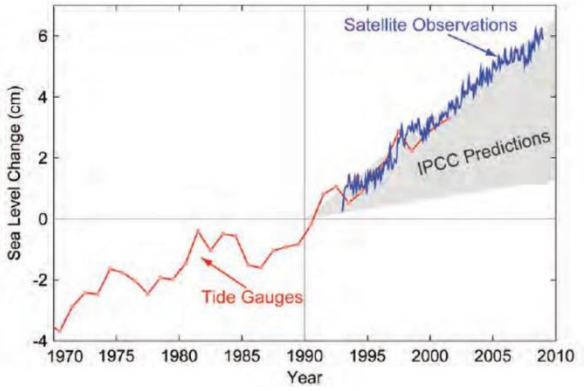
Nikbakht & Lin (2015)

Thanks to USGS, SCEC, ATC, & MARVL

Probabilistic Sea-Level Rise Hazard Analysis



Vermeer and Rahmstorf (2009)



Allison et al. (2009)

- Scenarios
- Models
- Observations

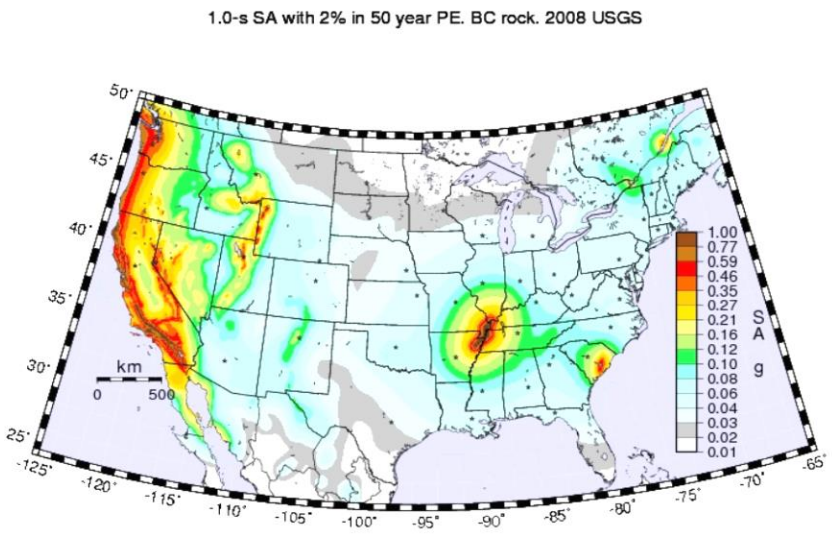
$$\nu(H > y) = \sum_k \sum_j \nu_j \iiint f_{\Theta_1,\Theta_2,\ldots,\Theta_i}(\theta_1, \theta_2, \ldots, \theta_i)$$

$$P(H > y|\theta_1, \theta_2, \ldots, \theta_i, SLRPM_k) d\theta_1 d\theta_2 \ldots d\theta_i P(SLRPM_k)$$

Lin (2012). "Probabilistic Sea-Level Rise Hazard Analysis," *Sustainable Civil Infrastructures – Hazards, Risk, Uncertainty*, 593-598.

Vision for Sea-Level Rise Applications

Hazard map

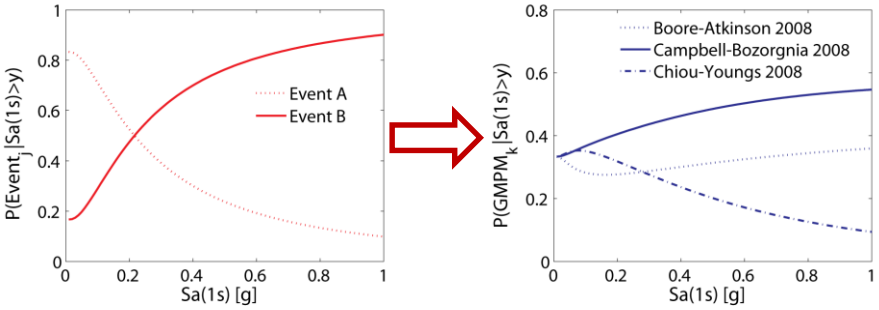


GEM
GLOBAL EARTHQUAKE MODEL

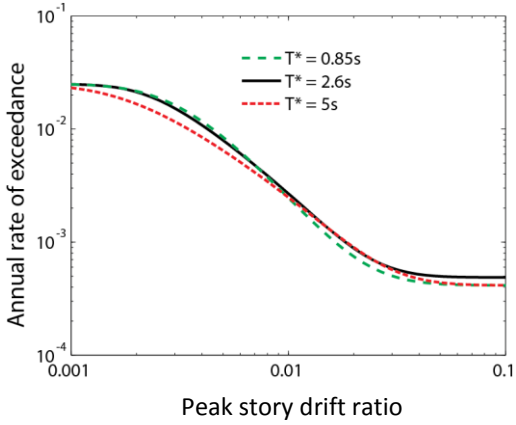
Deaggregation

Aleatory Uncertainties
-*M*, *R*, ε

Epistemic Uncertainties
-GMPMs



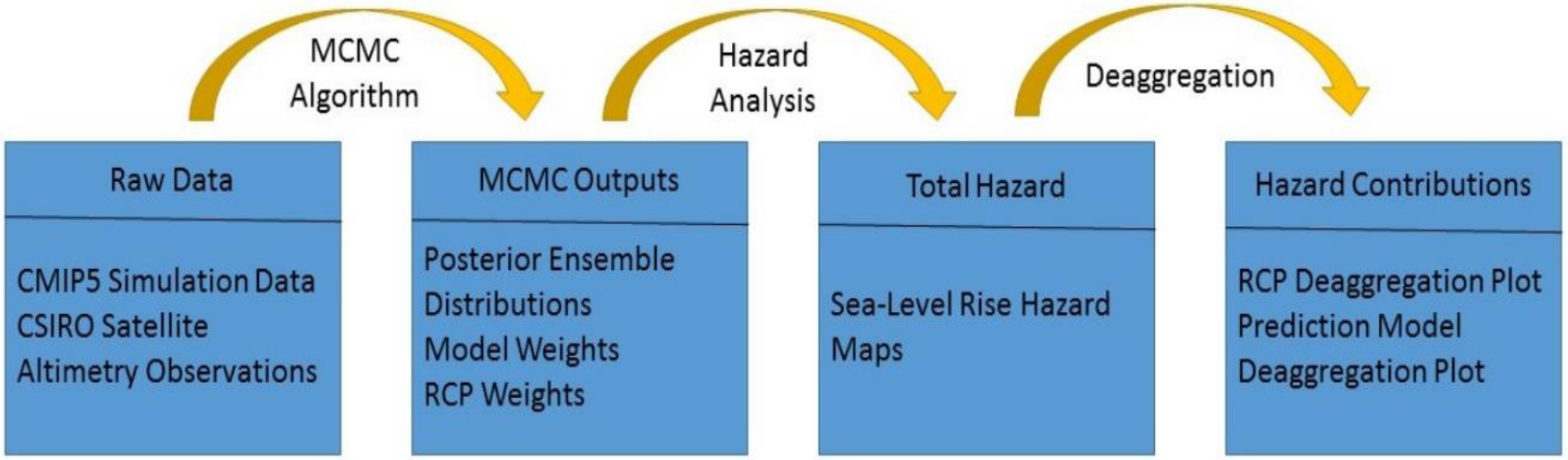
Performance-based engineering



Lin (2012)

Sea-Level Rise Hazard Analysis

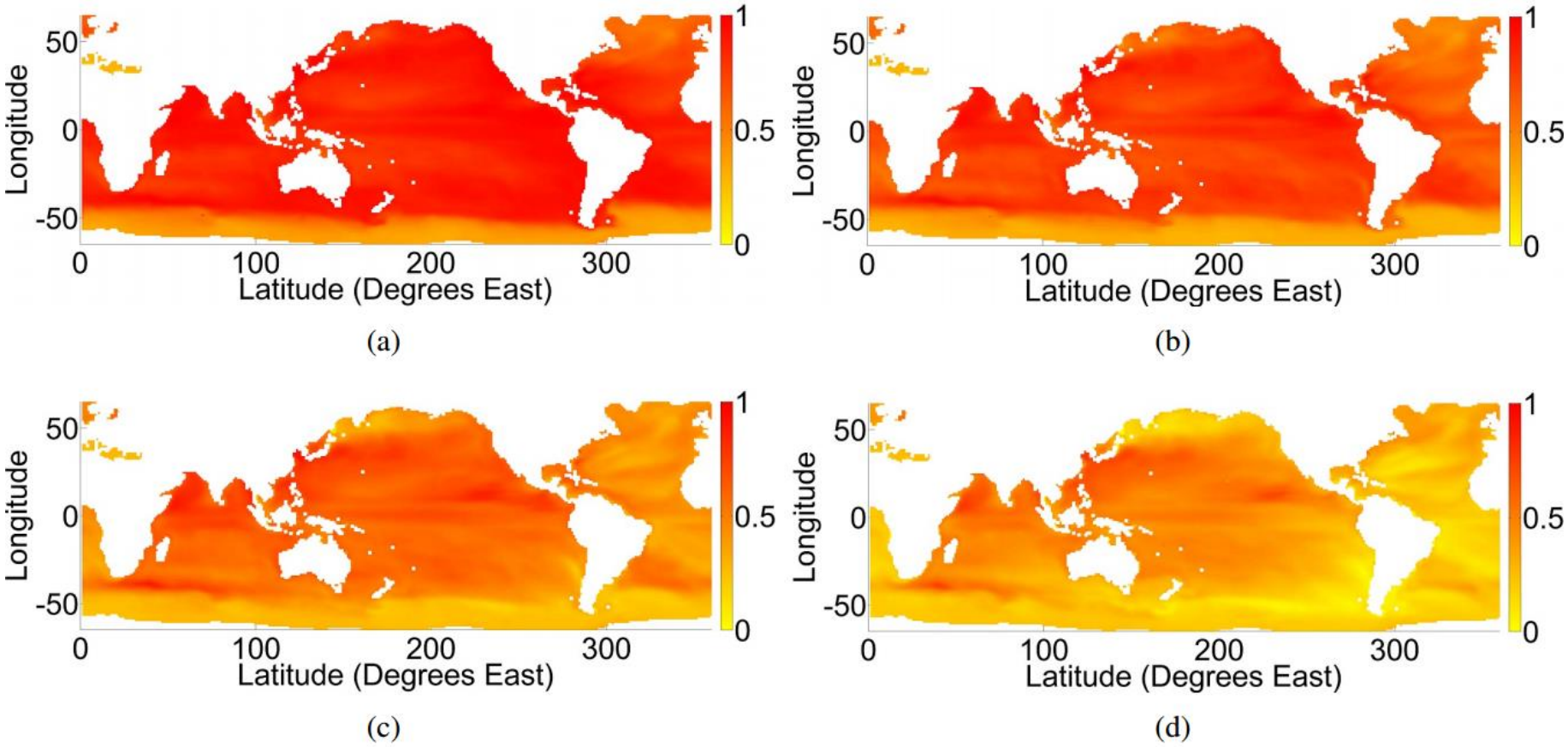
- Scenarios: Representative Concentration Pathways
- Models: Process-based models with high-resolution ocean components
- Observations: Satellite altimetry datasets



- Model and scenario ensemble data can be aggregated to create probabilistic hazard projections
- These projections can then be deaggregated to help us understand the modeling process better

Thomas & Lin (2015)

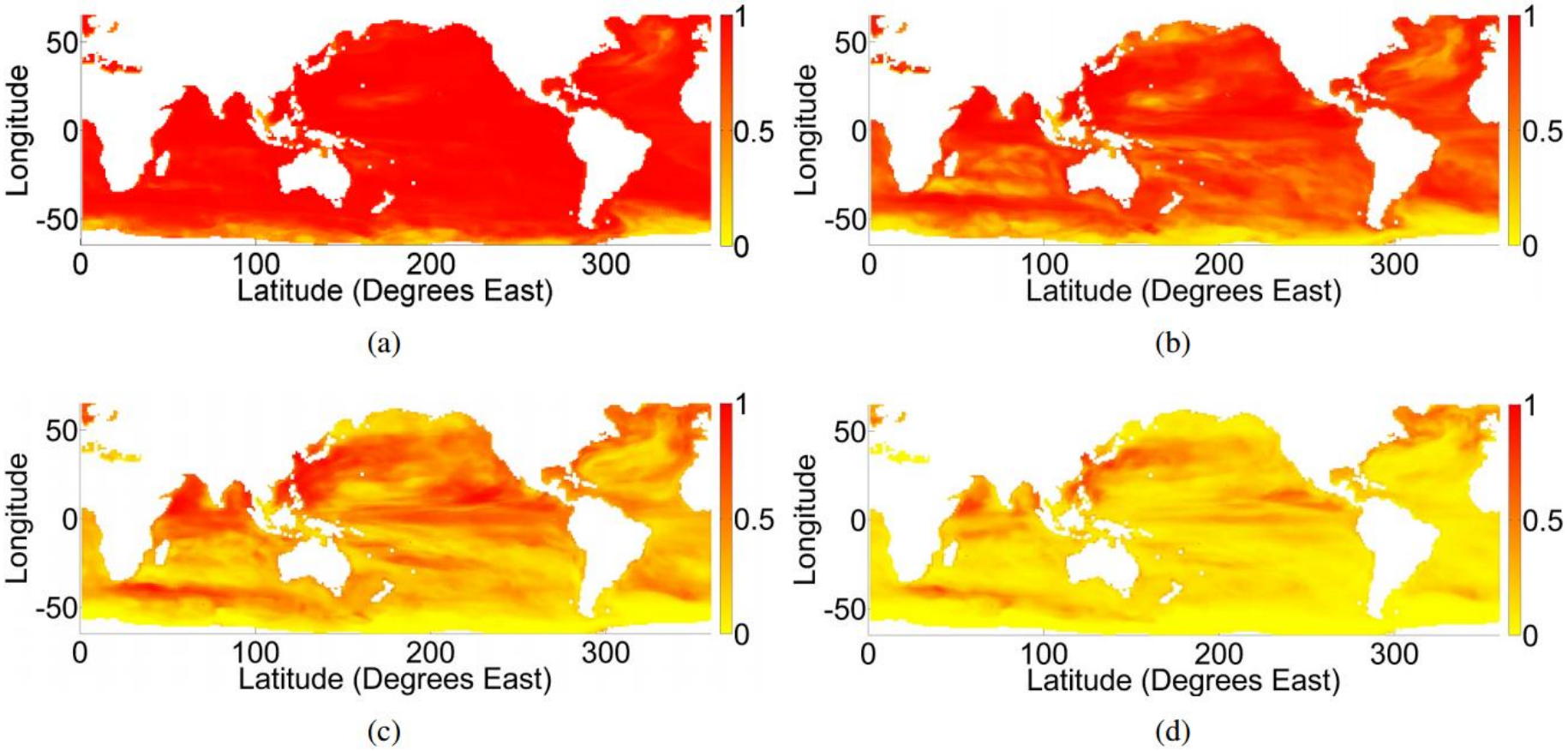
Sea-Level Rise Hazard Maps



Probabilities of exceeding (a) 0.08 m, (b) 0.16 m, (c) 0.24 m, and (d) 0.32 m of thermosteric sea-level rise between 2006 to 2013 and 2093 to 2100 under equal weighting of models and scenarios

Thomas & Lin (2015)

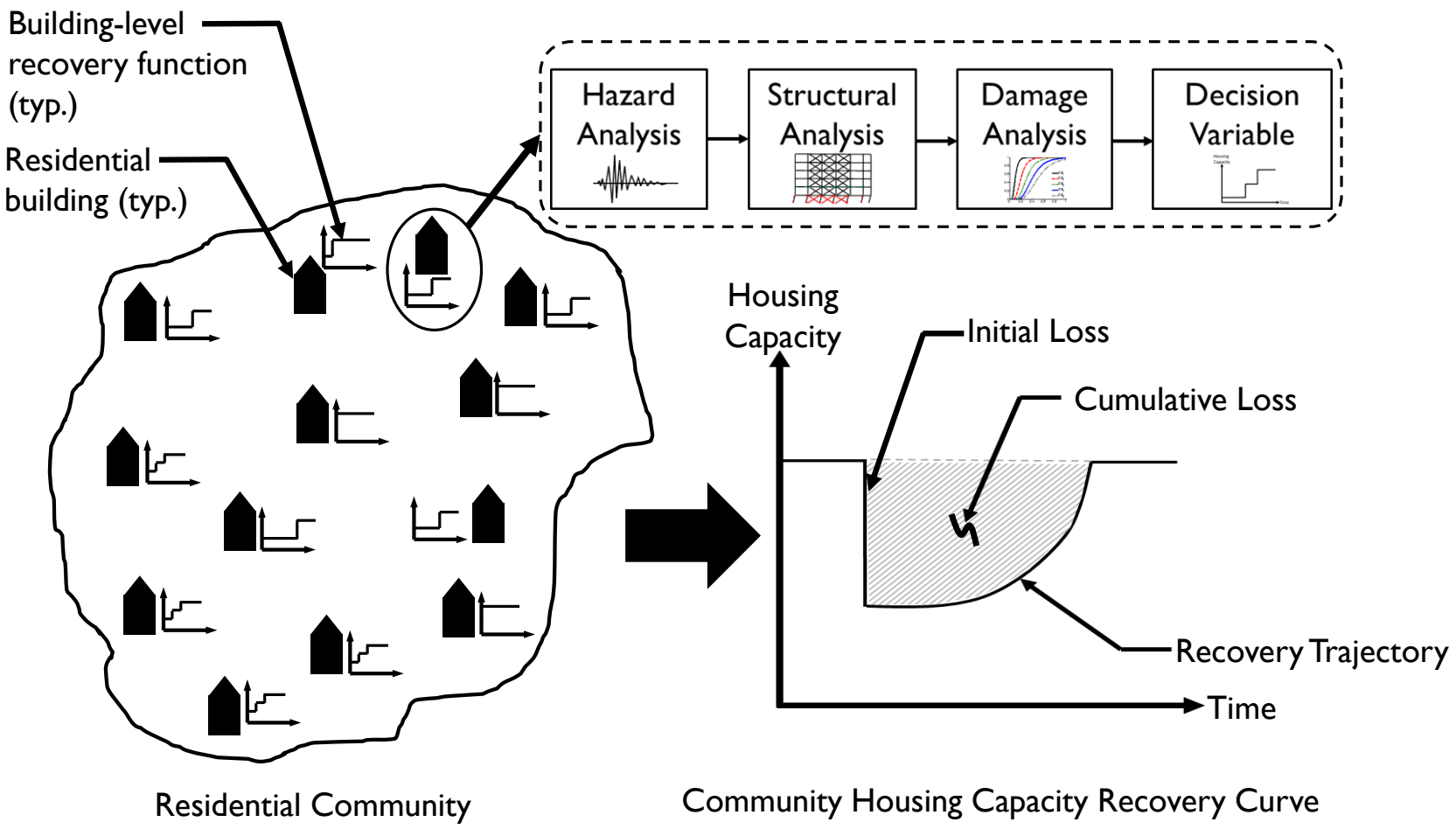
Sea-Level Rise Hazard Maps



Probabilities of exceeding (a) 0.08 m, (b) 0.16 m, (c) 0.24 m, and (d) 0.32 m of thermosteric sea-level rise between 2006 to 2013 and 2093 to 2100 weighting models and RCPs with the MCMC algorithm

Thomas & Lin (2015)

Performance-based resilience assessment framework



Burton, Deierlein, Lallemant, & Lin, *J. Struct. Eng.* (2015)

“Maybe.” What is the probability?

www.HazSus.org