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USGS 2023 National Seismic Hazard Map – Key Updates and Their Implications on the Insurance Industry

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Model Development, Moody's Insurance

Outline

- Overview of 2023 USGS Update
- Impact at important cities across the US
  - AAL change for key cities using a simplified methodology
  - Uncertainty in AAL for California portfolios
- Key questions and challenges of implementing the updates
- Q&A

"Nearly 75% of the U.S. could experience potentially damaging earthquakes and intense ground shaking, putting hundreds of millions of people at risk"

"37 U.S. states have experienced earthquakes exceeding magnitude 5 during the last 200 years, highlighting a long history of seismic activity across this country"

- USGS

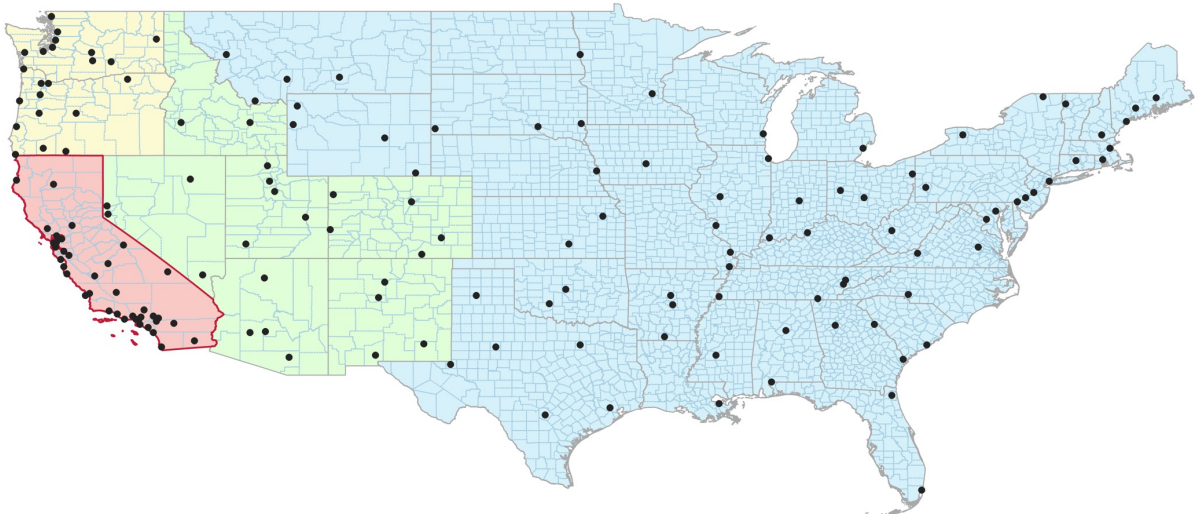
Location Details for Loss Calculations

Location-level analysis

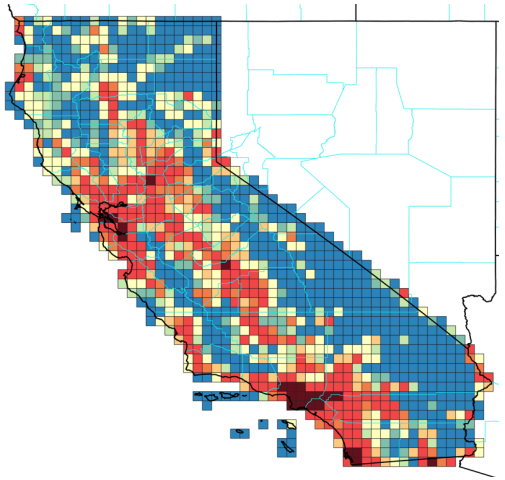
- 160 FEMA sites across the US
- Uniform NEHRP CD site conditions (Vs30=365 m/s)
- HAZUS vulnerability functions
  - Modern Wood Frame Res Bldg
    - Bldg coverage only
- Simplified AAL calculations
  - HAZUS approach (FEMA-366)
  - Reasonable approach for estimating loss change

- Portfolio Analysis
  - 20km uniform grid in California
  - Loss aggregation based on population
  - Uniform NEHRP B/C site conditions (Vs30=760 m/s)
  - Review of loss change for entire California, North CA, South CA, Bay Area, and LA region.
  - Wood Frame residential buildings

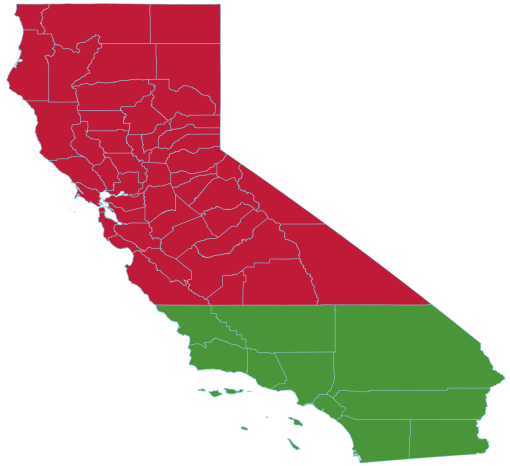
FEMA Sites for Important Cities in US



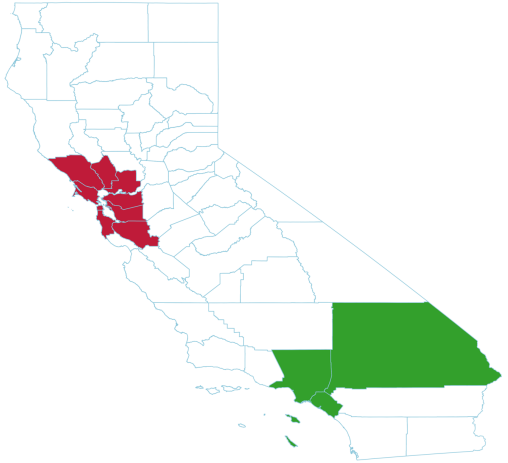
CA Population



CA: North-South

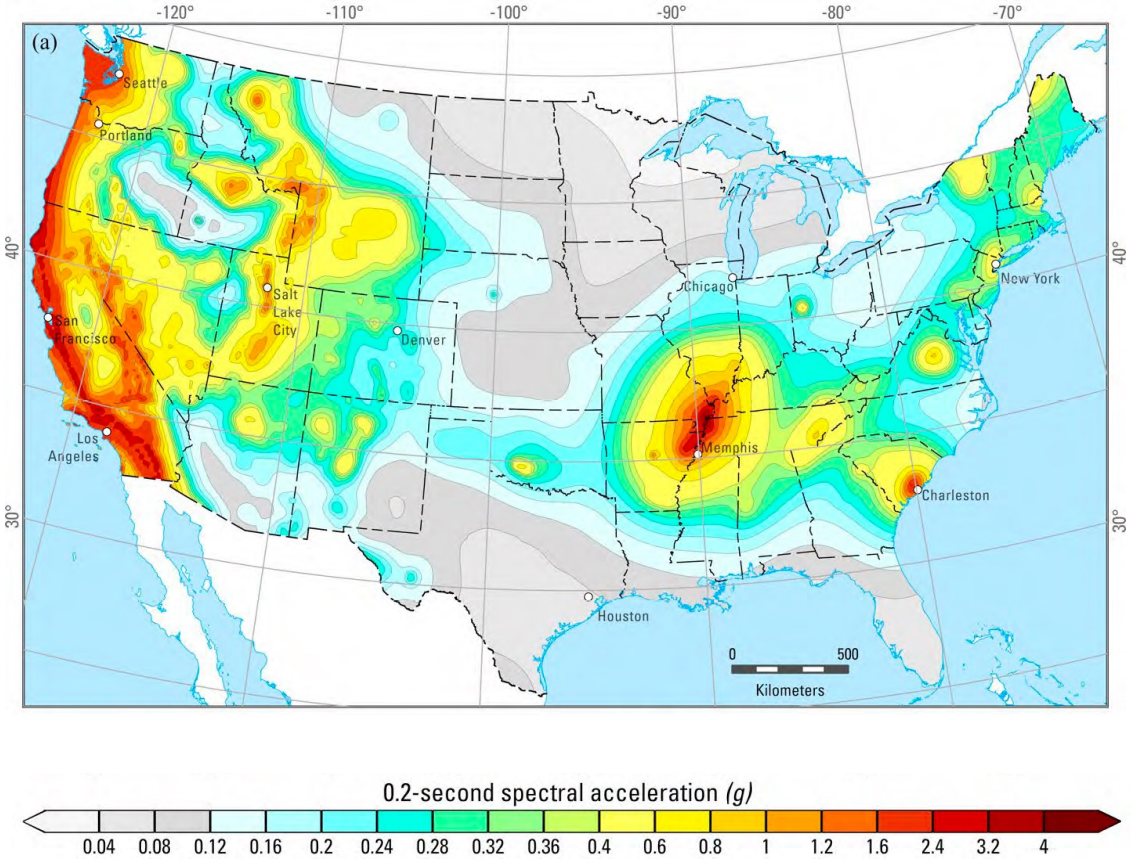


Bay Area and LA Region

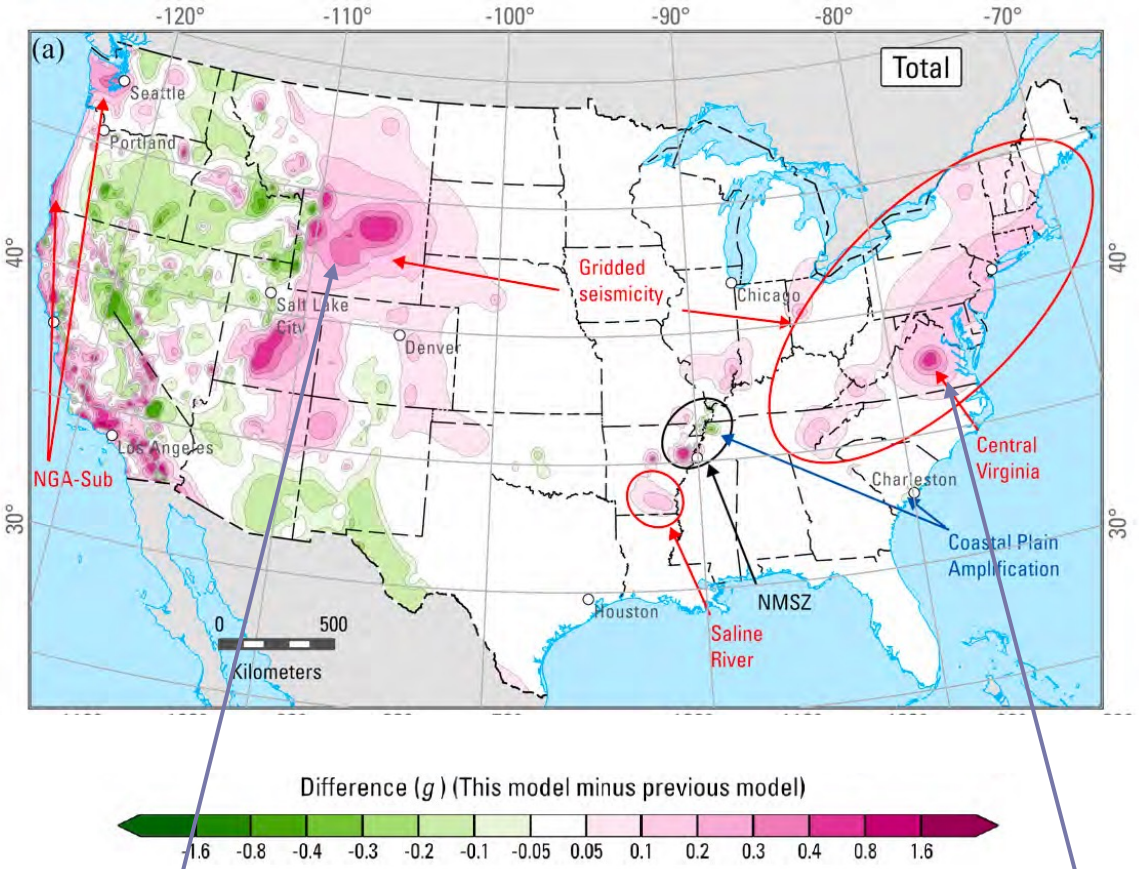


2475-Year Hazard Map: Sa(0.2s) for NEHRP B/C Site Conditions (Vs30=760m/s)

Hazard Map



Difference Map



Shift of East-West boundary

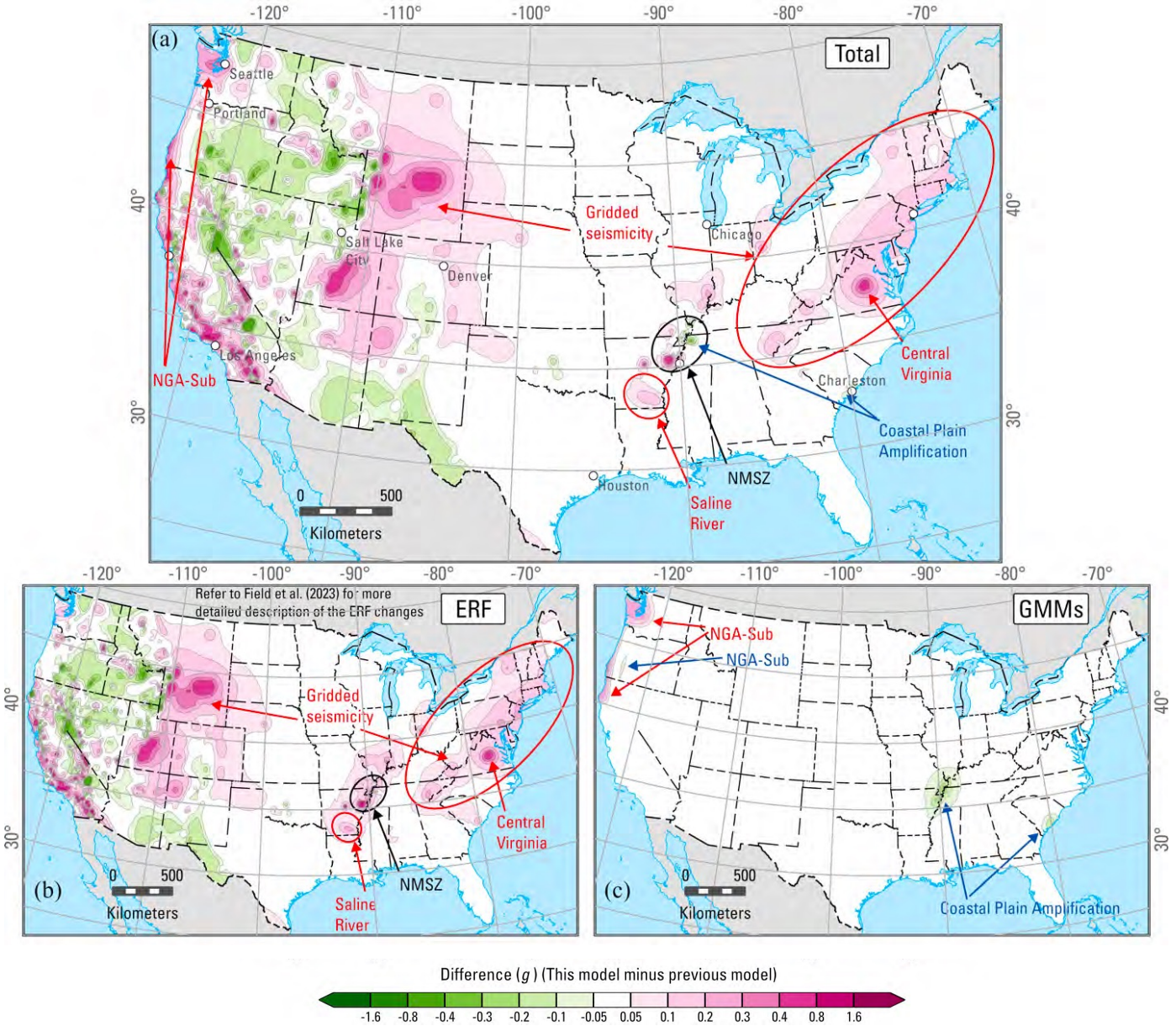
Update of catalog and background seismicity

Petersen, M.D. et al. (2024) "The 2023 U.S. 50-State National Seismic Hazard Model: Overview and Implications", Earthquake Spectra

Summary of 2023 USGS Update

- Earthquake Rupture Forecast (ERF): Source characteristics and event rate
- Ground-Motion Model: Rock ground motion
  - Active region – WUS
  - Stable region – CEUS
  - Subduction – Interface and inslab
- Soil and basin amplification

Difference in 2475-year hazard, Sa (0.2s) by Component

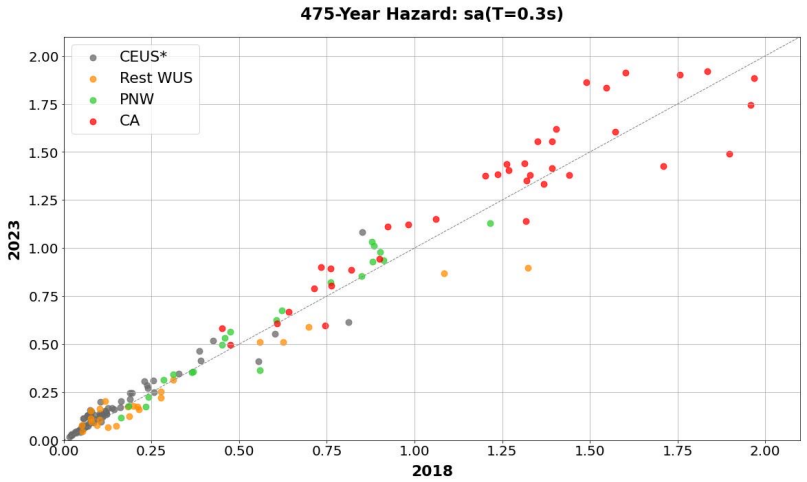


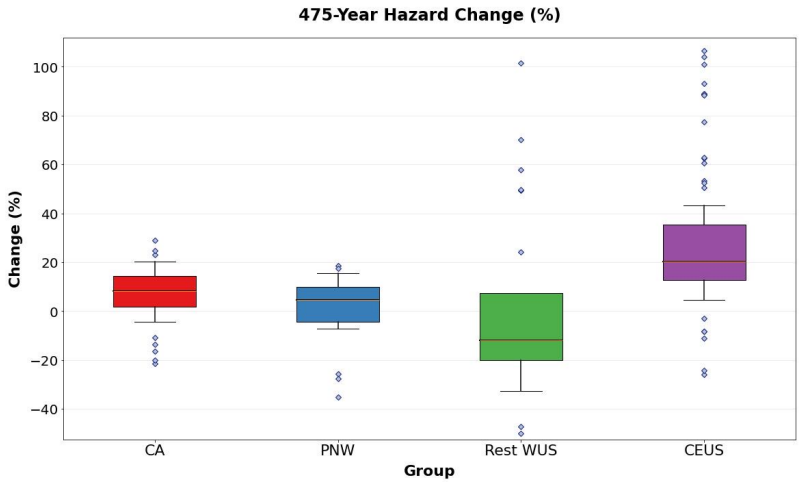
Change in Hazard and AAL: FEMA Sites

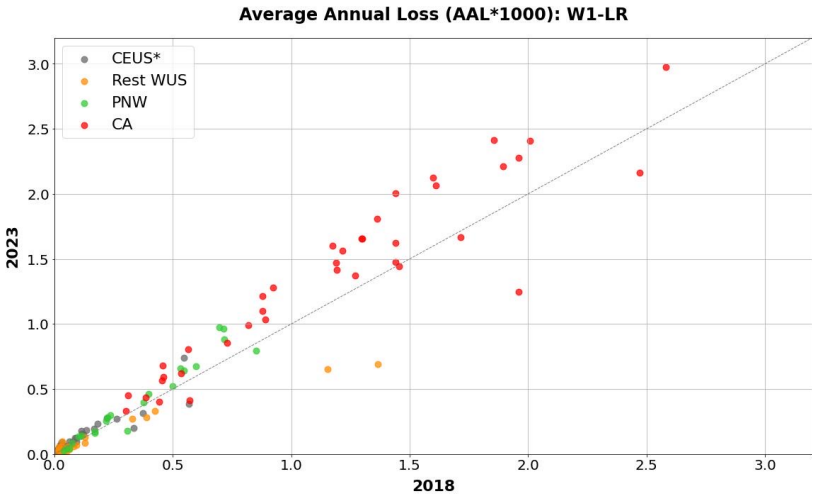
- Significant increase in hazard in CEUS, and smaller increase in CA
  - Hazard is low in CEUS, but high CA
  - Variability of change is high in WUS and CEUS

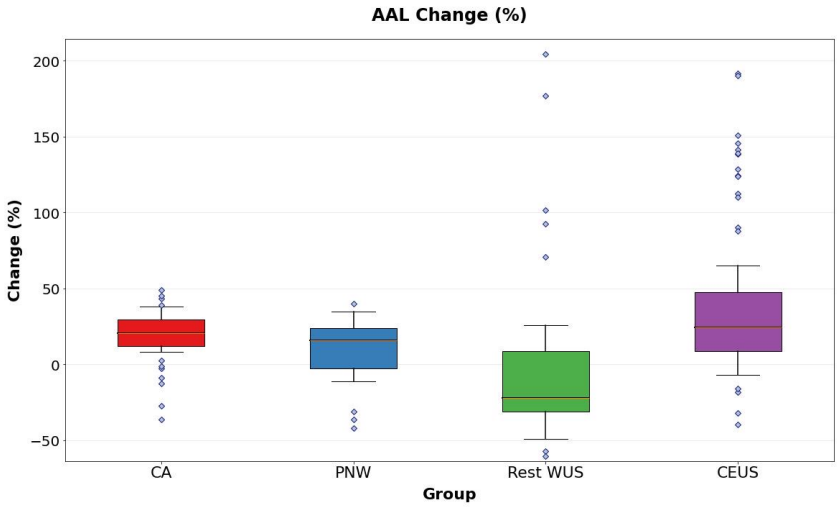
- AAL change is about 1.5-3x higher than hazard change
  - AAL change pattern is similar to hazard change
  - Large increase in CEUS, moderate increase in CA and small increase in WUS and PNW.

Comparison of Hazard and AAL Change for Low-Rise Wood-Frame Buildings between 2023 and 2018 Models









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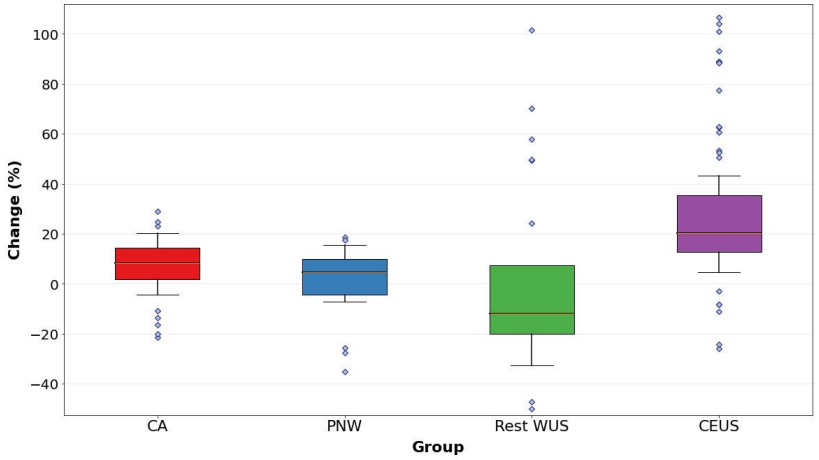
Change in Hazard and AAL: FEMA Sites

- Range of location-level AAL change for each region
  - HAZUS functions for modern WF
  - Soil CD site conditions
  - HAZUS/FEMA AAL calculations

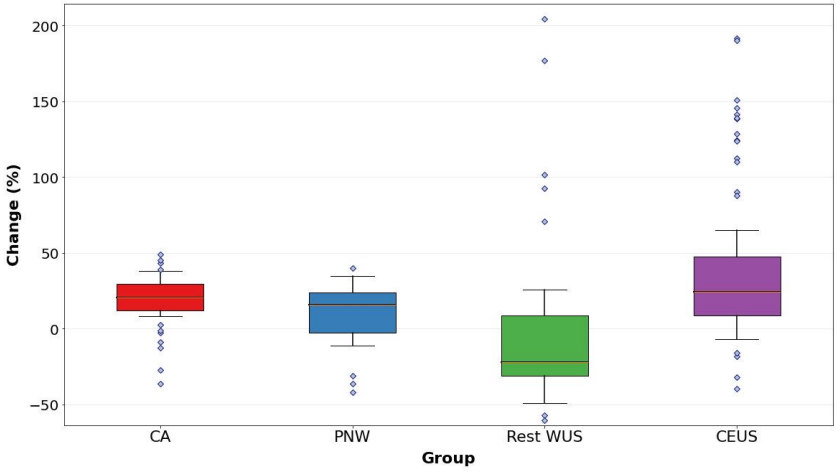
- Similar loss change pattern for MR and HR steel buildings

Range of Hazard and AAL Change (16-84 percentile) for Low-Rise Wood-Frame Buildings between 2023 and 2018 Models

475-Year Hazard Change: -5 to +20% | -5 to +15% | -30 to +50% | +10 to +55%



AAL Change: 0 to +35% | -10 to +25% | -40 to +80% | +5 to +95%



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Perspective on the New Jersey Earthquake

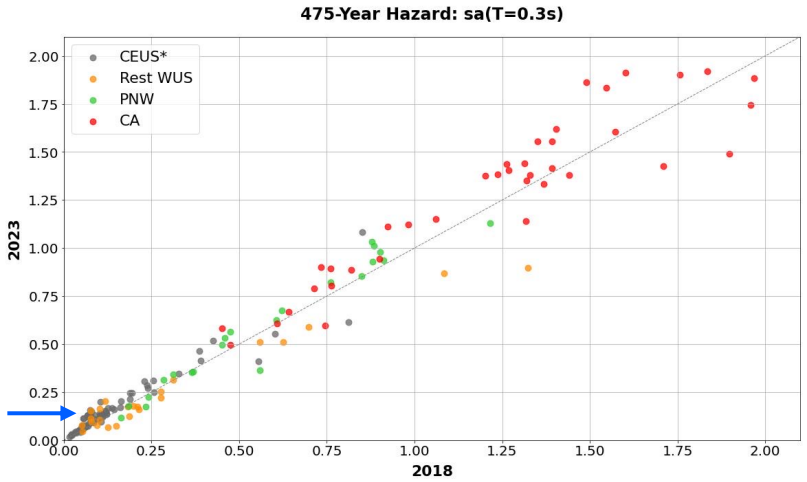
Hazard and AAL Change and M4.8 New Jersey Earthquake

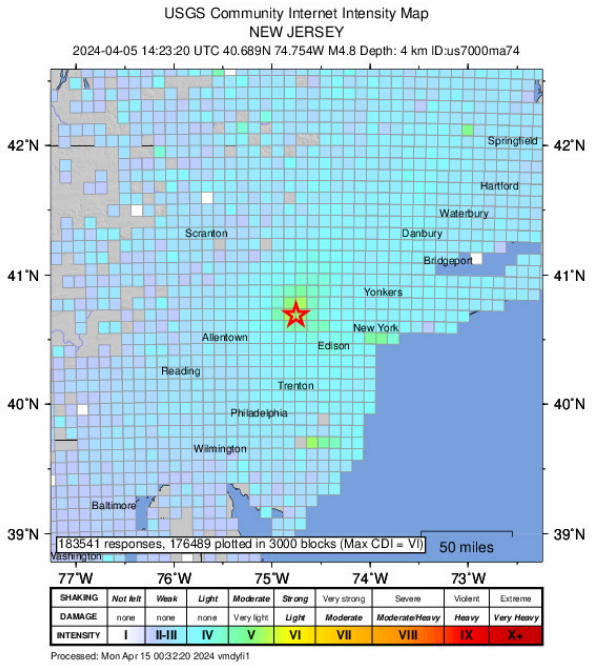
Earthquake details

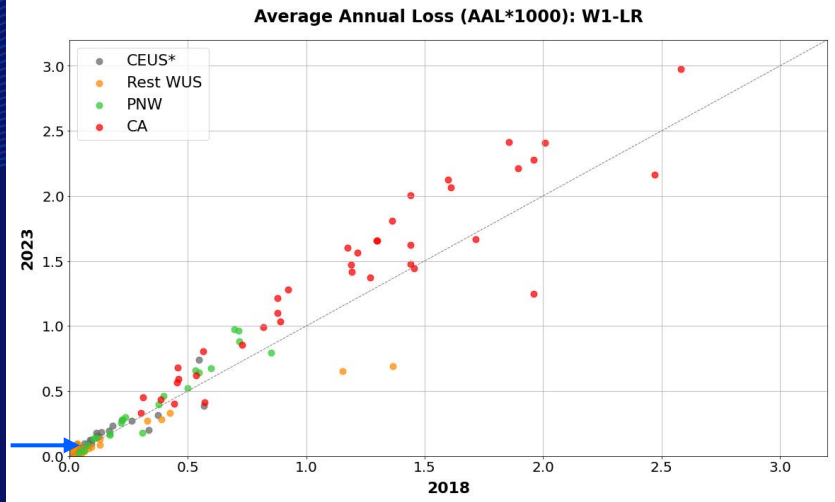
- Magnitude: 4.8
- Date: April 5th, 2024
- Number of M4.5 or greater earthquakes since 1960: 7 (USGS)

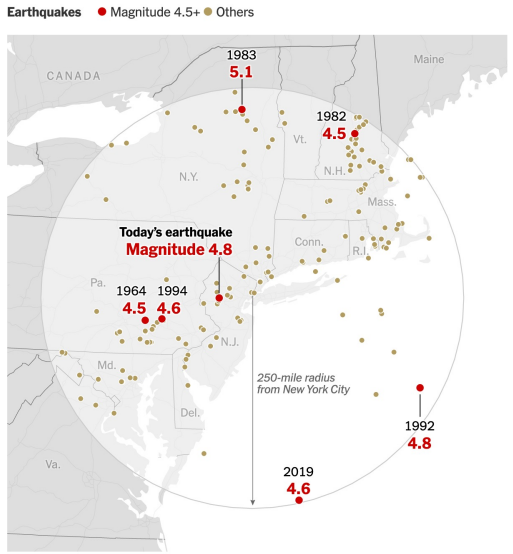
Impact summary

- Max intensity: MMI VI (Califon city)
- 2023 USGS Hazard
  - 475-year hazard: MMI VI (strong shaking and light damage)
  - 2475-year hazard: MMI VIII (severe shaking and moderate to heavy damage)
- Loss Cost (2023): $0.05-0.10 per $1000









Source: USGS and NY Times

Source Char and ERF

Main components

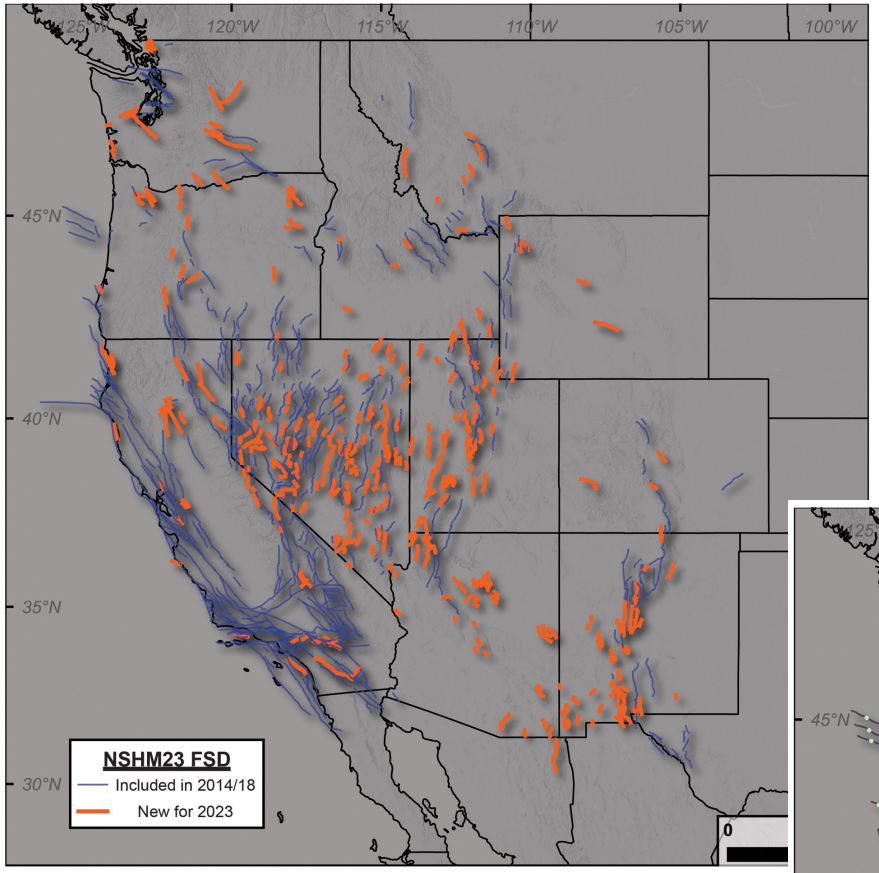
- Fault-based seismicity
- Off-fault/background seismicity

- Earthquake risk in CA is governed by fault-based seismicity

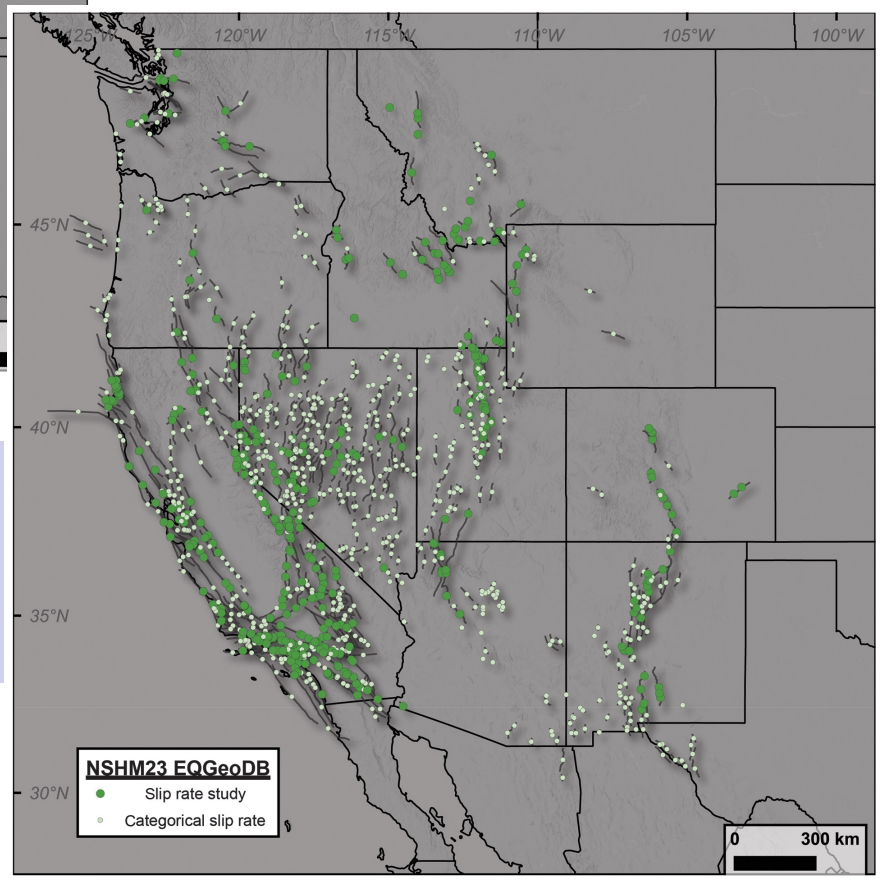
- Hazard generally increase near the newly added faults.

- Slip rates are well constrained at the locations of geologic studies
  - Constrain deformation
  - Low hazard uncertainty

- Paeloseismic event rate constrain
  - Reduces uncertainty and bias



WUS Fault Model. Orange lines indicate new faults in 2023 USGS Hazard Model



WUS Fault Model. Green circles indicate the locations of geologic studies and lighter circles indicate the generic categorical range

The USGS 2023 Conterminous US Time-Independent Earthquake Rupture Forecast, Field EH, et al., BSSA (2024)

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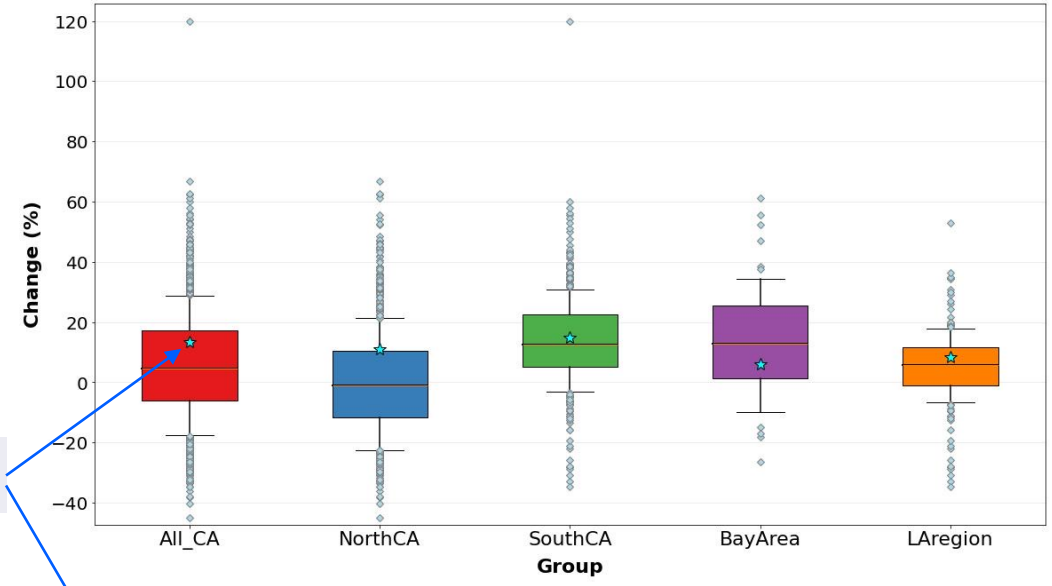
Hazard and AAL Change for Well Distributed Portfolio in CA

- Portfolio: 20km uniform grid in CA, pop-based exposure, modern residential Wood buildings, and Soil B/C site conditions for Time-independent rates
- Significant site-to-site variation in hazard and loss results
  - Range of hazard change is high in North and Bay Area
  - Range of AAL change is quite similar for all the portfolios
- Loss change is significantly higher than hazard change
  - (Weighted) avg loss change is 2-4x higher than hazard change

475-Year Hazard Change

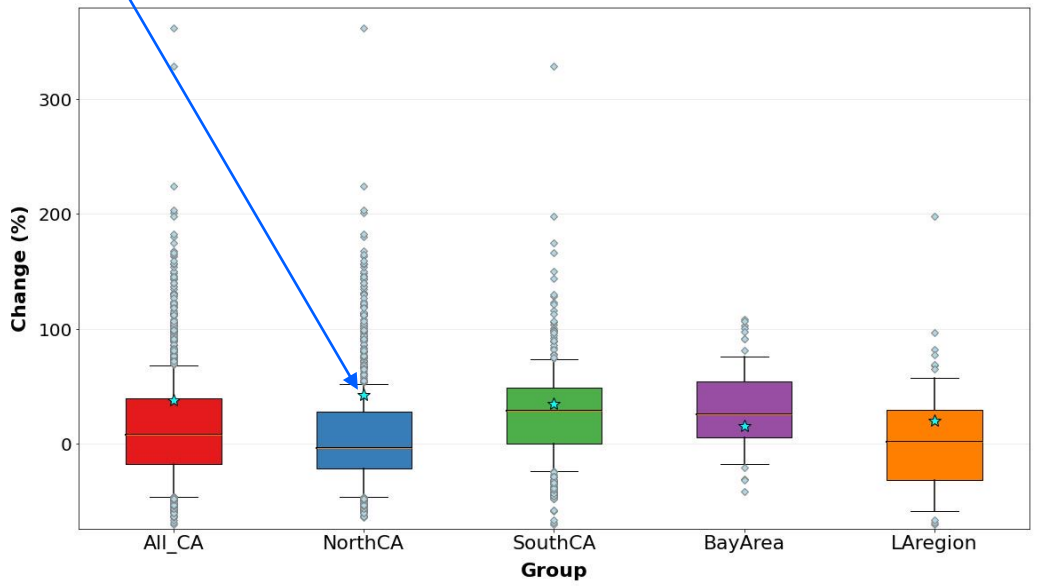
16-84% range	-15 to+ 25%	-20 to +20%	0 to +30%	-5 to +30%	-5 to +15%



Avg (pop wt) change

AAL Change

16-84% range	-30 to +60%	-35 to +50%	-20 to +60%	-5 to +75%	-40 to +40%



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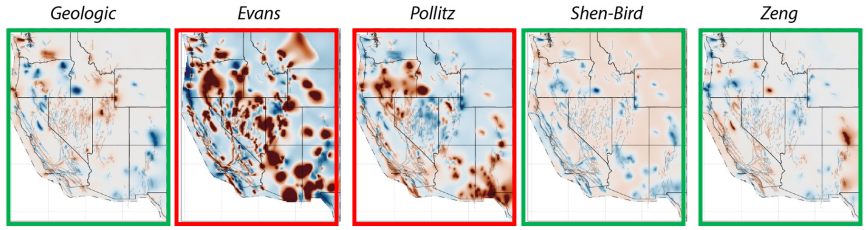
ERF Logic-Tree: Model-to-Model Uncertainty

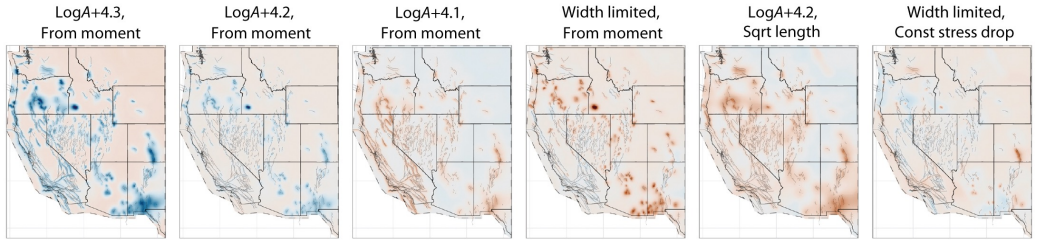
- Logic-tree branches captures model-to-model (epistemic) uncertainty
- Deformation model is the biggest driver of change in USGS23 update
  - Geologic slip-rate constraints
  - GPS data – 2 models and lower weight

Fault Model

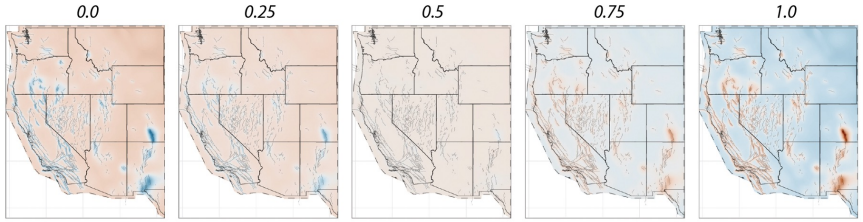
Deformation models:



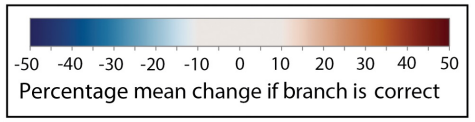
Scaling relationship

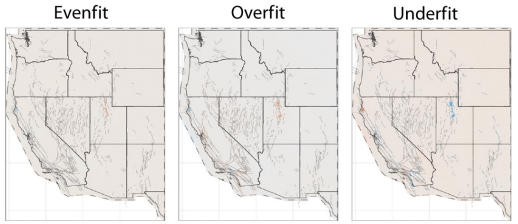


Supra-Seis *b*-value

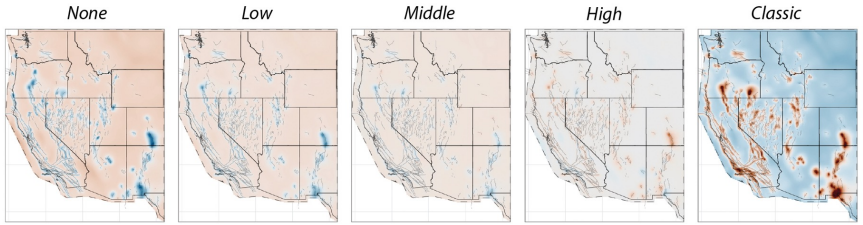


Paleoseismic data fit



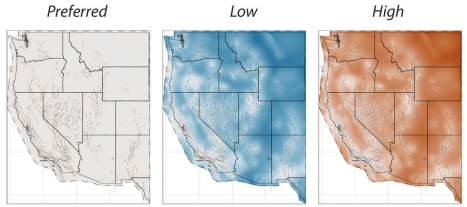


Segmentation model

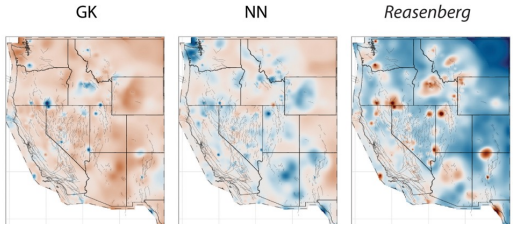


Background Seismicity Model

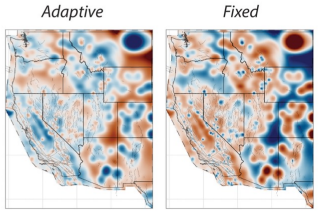
Total $M \geq 5$ rate and *b*-value



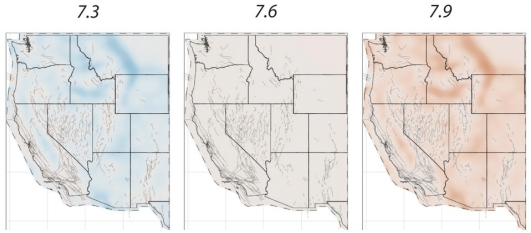
Seismicity declustering



Seismicity smoothing kernel



$M_{max}^{off\text{-}fault}$



Percentage change in PGA hazard for each branch from the average branch solutions

The USGS 2023 Conterminous US Time-Independent Earthquake Rupture Forecast, Field EH, et al., BSSA (2024)

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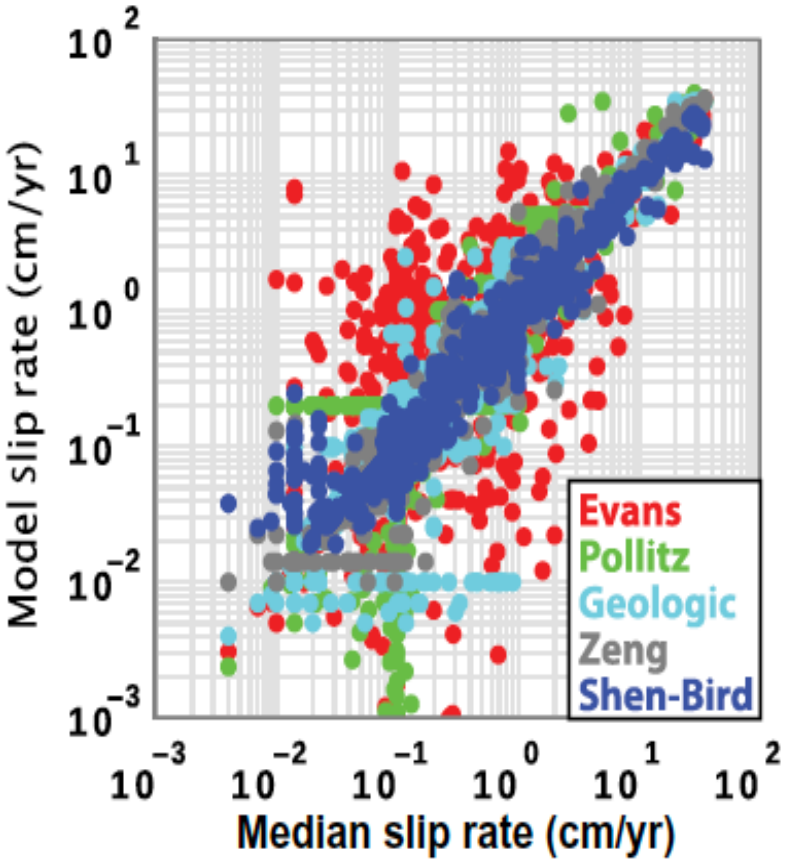
Goodness-of-Fit of The Deformation Models

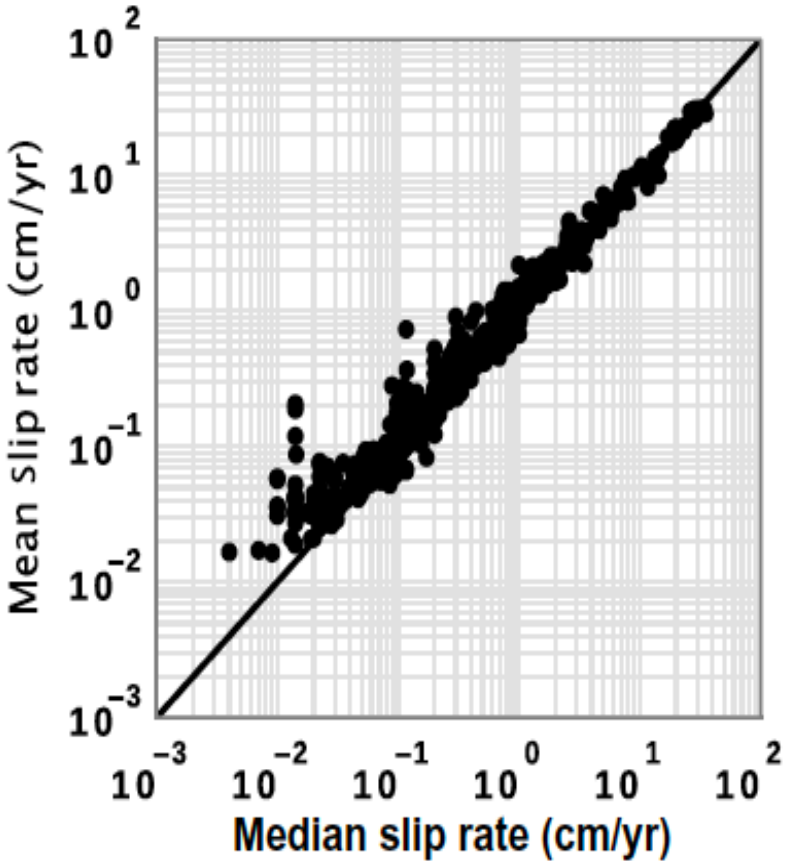
- Slip-rates from model and observed compares well
  - New models – Evans and Pollitz - give higher preference to the GPS data, introducing higher scatter in the results
  - New models has low weight (=10%)
  - Modeled average slip rates compare well with the observed

USGS 2023: Model vs. Observed Slip Rates

Deformation Model



Branch Average



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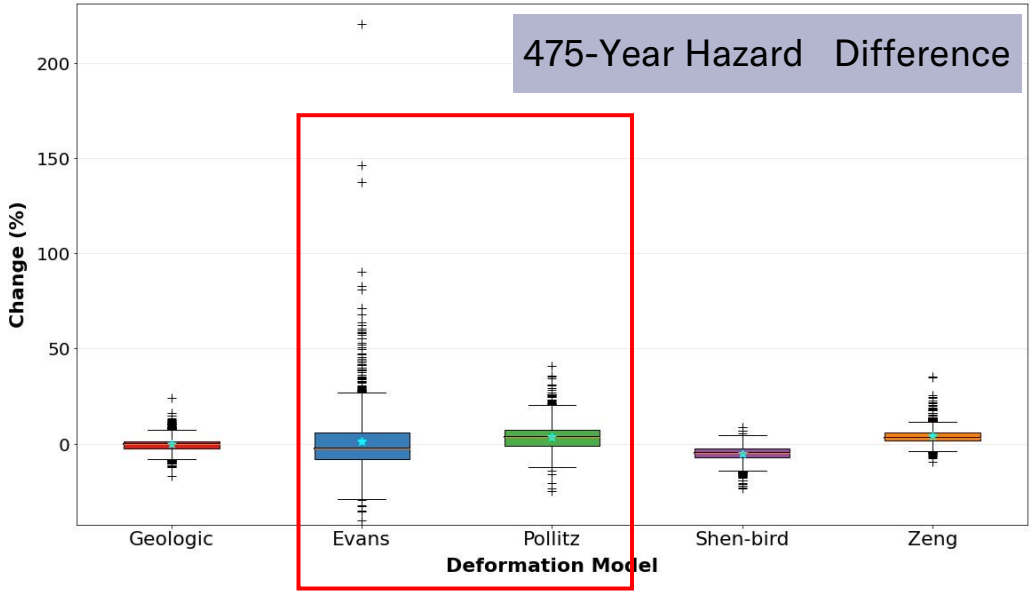
Hazard and AAL Difference for a Well Distributed Portfolio in CA

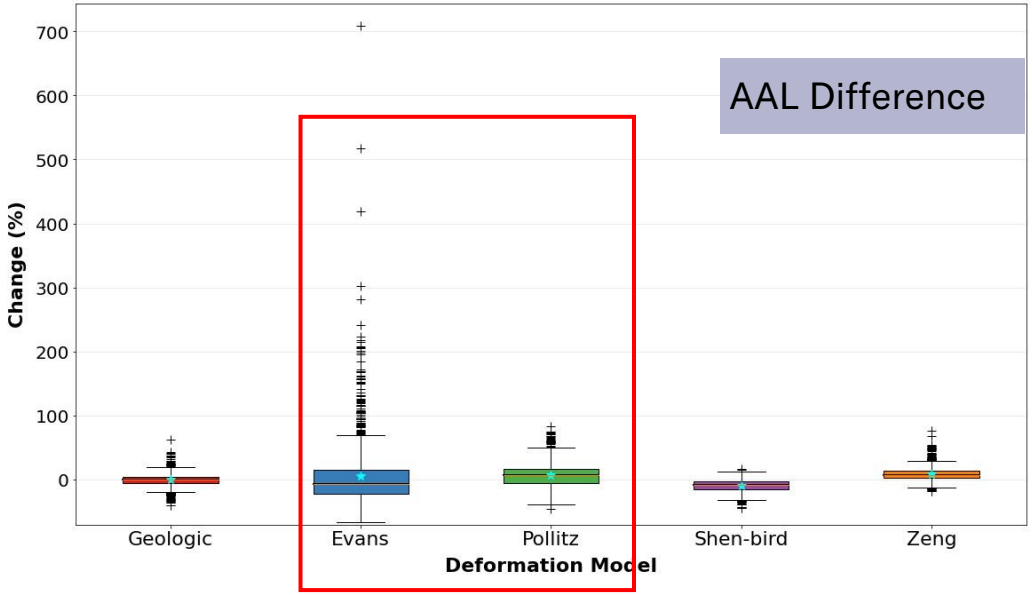
- Calculates the difference in the hazard and AAL between each of the logic-tree branches and the average for each site
- Range of difference in hazard is small, but higher for AAL, especially for Evans and Pollitz models
- Large number outliers for Evans and Pollitz model
- Small difference for statewide portfolios (wt average)
  - -5 to +5% for hazard, and -10 to +10% for AAL

Deformation Model

16-84% range	-5 to+ 5%	-10 to +10%	-5 to +10%	-10 to 0%	0 to +10%



16-84% range	-10 to +10%	-30 to +30%	-10 to +25%	-20 to 0%	0 to +20%



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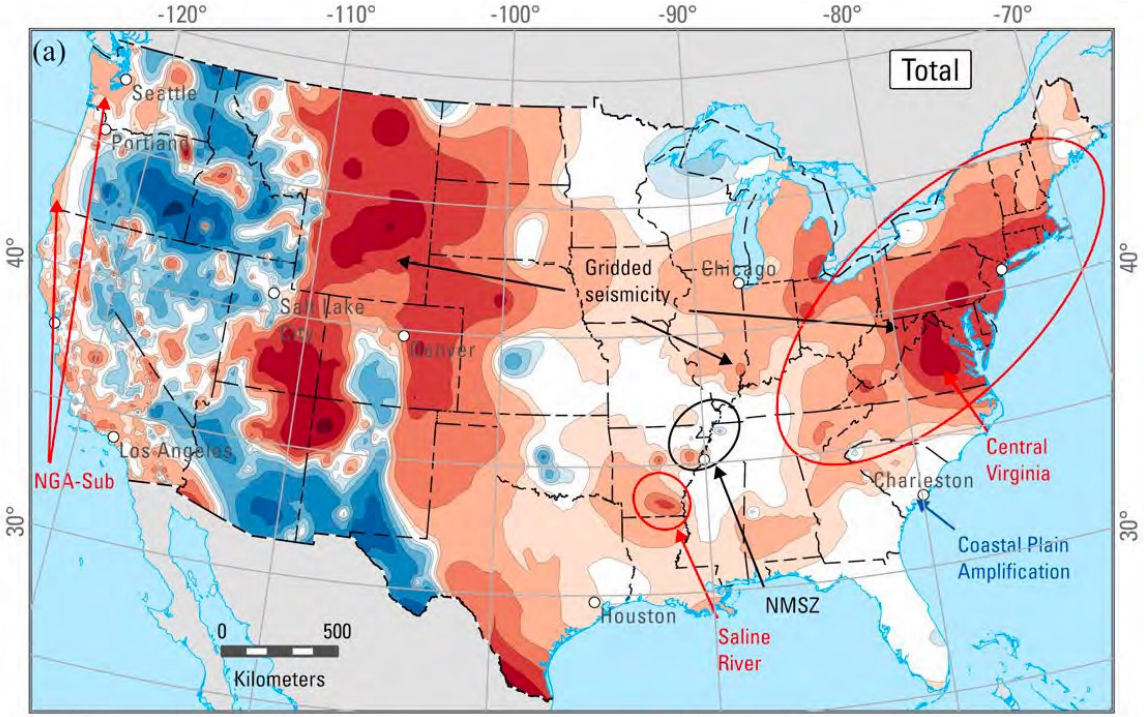
Summary and Next Steps

- Significant changes in hazard, mostly increasing, result in large increase in AAL.
- Results shown are useful for planning of the work on model evaluation and implementation efforts, not intended for decision making.
- Next steps:
  - Implement the USGS model
  - Carry out sensitivity studies of different modeling assumptions on the loss results
  - Identify key issues that require further research before model adoption
    - New Madrid cluster, use of total rate including aftershocks, Gulf and Atlantic basin amplification model, etc.
  - Develop efficient solutions for day-to-day loss analysis work and underwriting
    - USGS can provide stochastic set for loss calculations (intermediate output from hazard tool), but that would require significant computation resources.
  - Time-dependent (TD) model



2475-Year Hazard Map: Sa(0.2s) for NEHRP B/C Site Conditions (Vs30=760m/s)

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Thank you

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