USING DYNAMIC RUPTURE SIMULATIONS TO IMPROVE SEISMIC HAZARD MODELS FOR NORMAL-SLIP EARTHQUAKES

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BACKGROUND

- Normal faults under populated areas are known to have high damage potential
  - 2009 L'Aquila, 2016 Amatrice and Norcia earthquakes
- Normal-slip earthquakes common in U.S. Basin and Range region
  - Scarce data due to sparse instrumentation at the time of largest normal-slip events (1915, 1954)
- 2023 U.S. National Seismic Hazard Model (NSHM) active crustal (AC) ground motion models (GMMs) derived from scarce global records of large normal-slip events
  - ASK 14 dip-slip hanging wall term generalized from kinematic simulations of reverse-slip ruptures
- Data scarcity may lead to hazard mischaracterizations for populations on normal faults, including cities like Reno, Salt Lake City, etc.

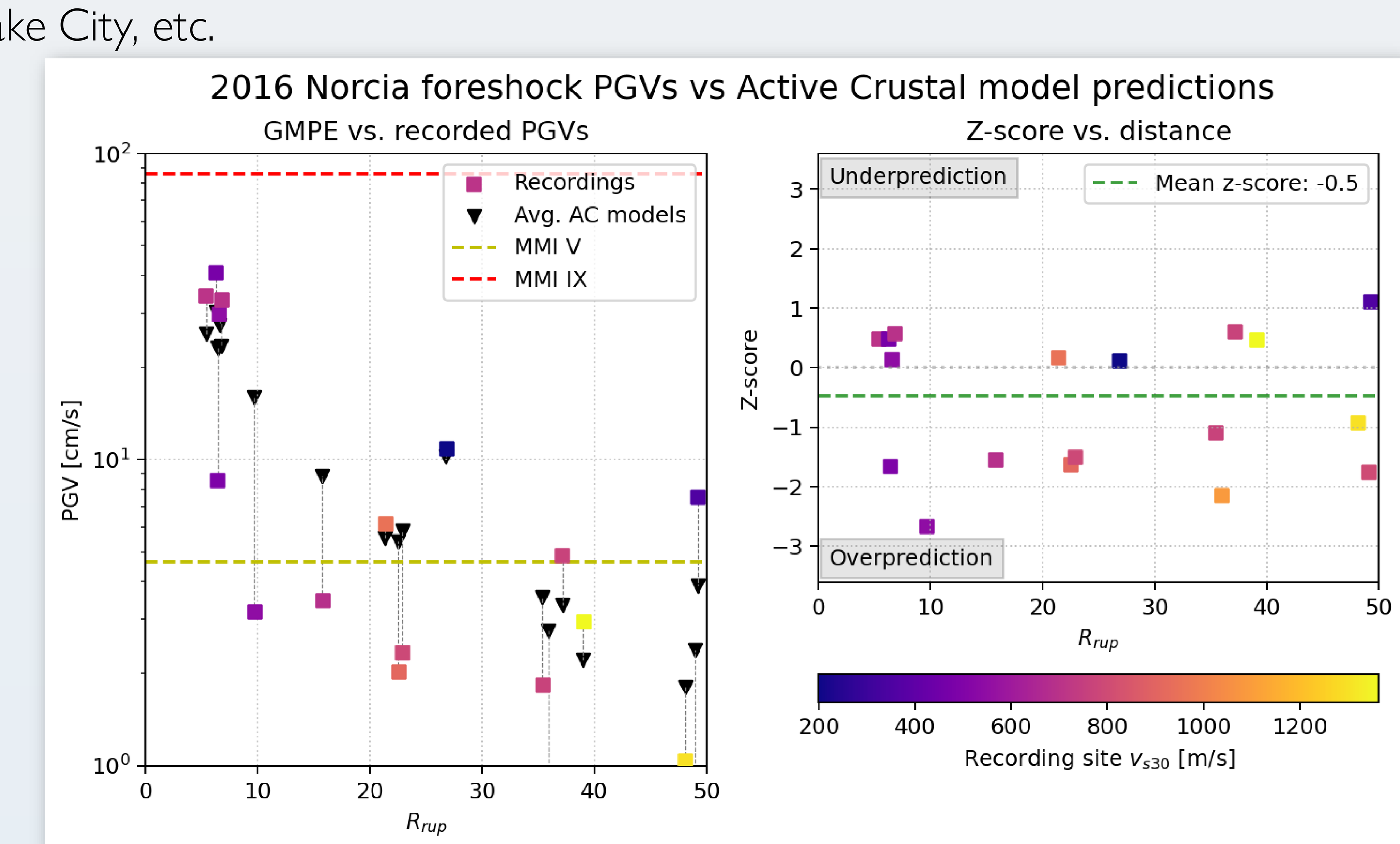


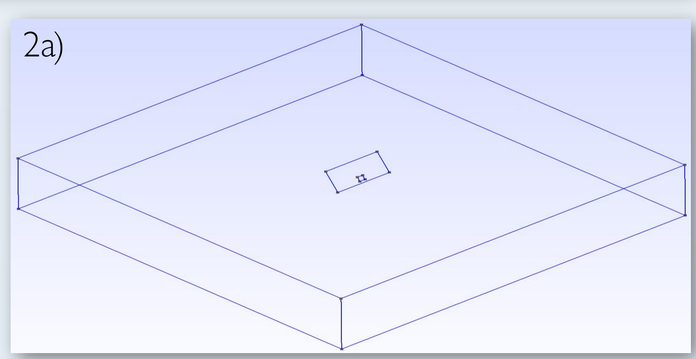
Figure 1: Comparison of recorded PGVs and GMM predictions for the M6.3 2009 L'Aquila earthquake. Left plot shows GMDB vs. predicted PGVs vs. Rrup (distance from rupture plane). Right plot shows z-score per station.

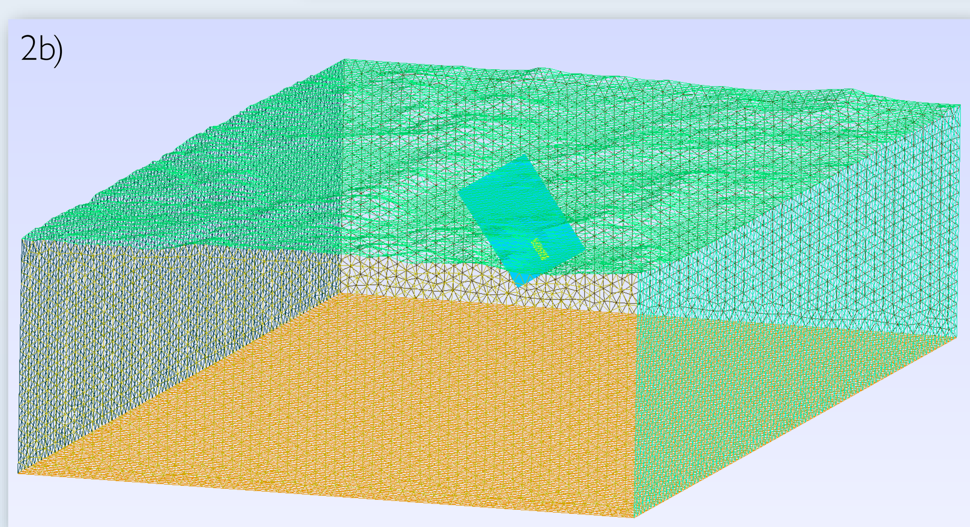
METHOD

- Analysis of dip-slip rupture dynamics in SeisSol.

Suite of simulations testing variables:
  - Fault dimensions: 30x15 km
  - Dip: base case 60°
  - Nucleation: 3x3 km high-stress patch
  - Hypocenter: 12 km down-dip, centered along strike
  - Surface rupturing fault
  - Depth-dependent stress parameters
  - No topography, velocity model

- Simulation for large event in Reno area
  - Fault dimensions: 30x15 km
  - Dip: 55°
  - Nucleation: 3x3 km low-friction patch
  - Hypocenter: 9 km depth
  - Surface rupturing fault
  - Depth-dependent stress parameters
  - 3D velocity model and topography





Figures 2a and 2b: Examples of 3D models used for (a) dip-slip experiment suite and (b) Reno scenario with topography.

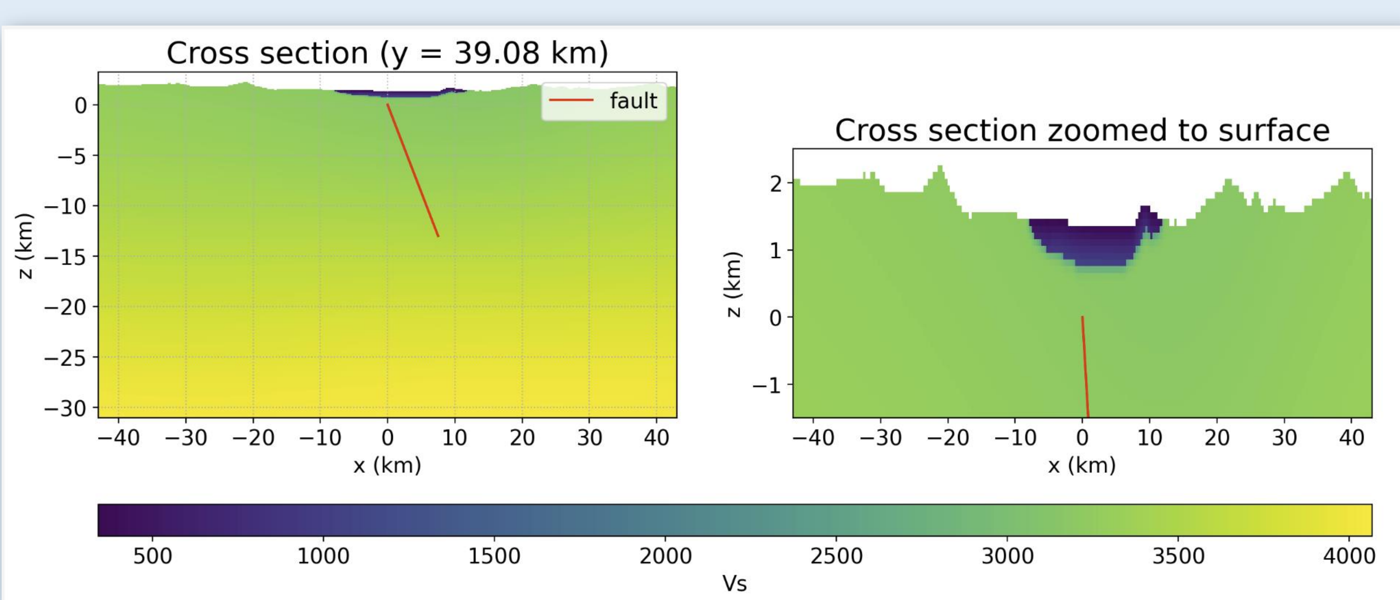


Figure 3: Preview of velocity model used for Reno scenario. This cross section shows the velocities in the basin directly under the Reno area in topography. Elevation is from sea level.

RESULTS

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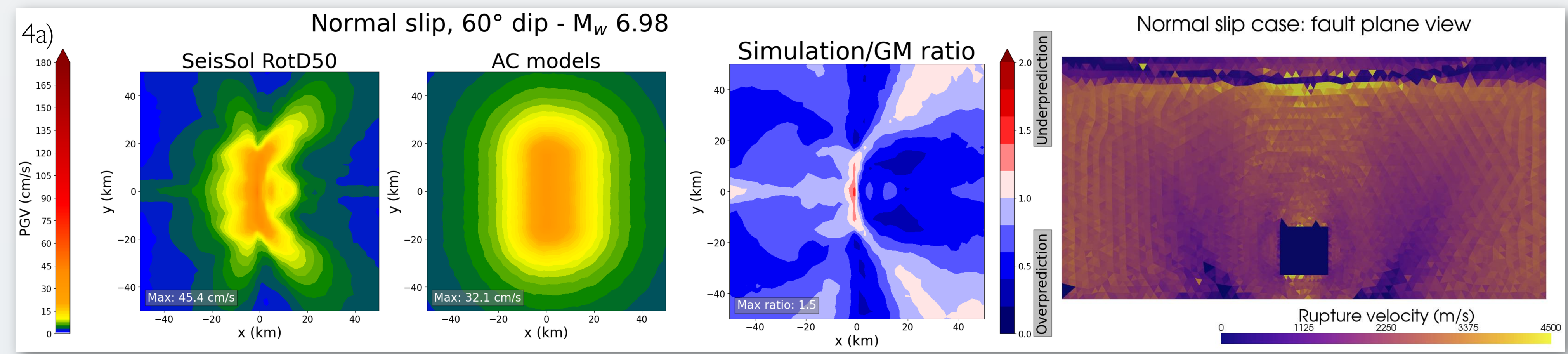
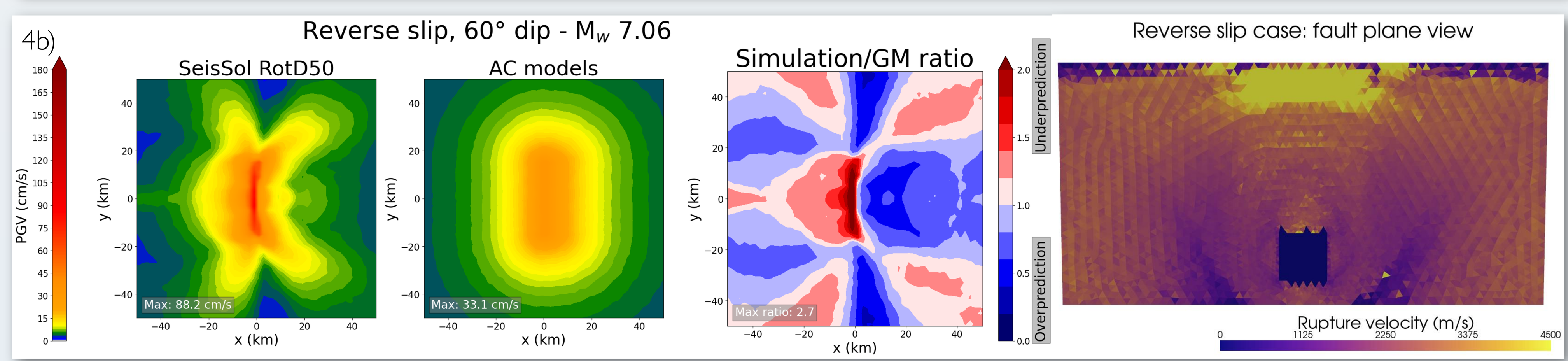
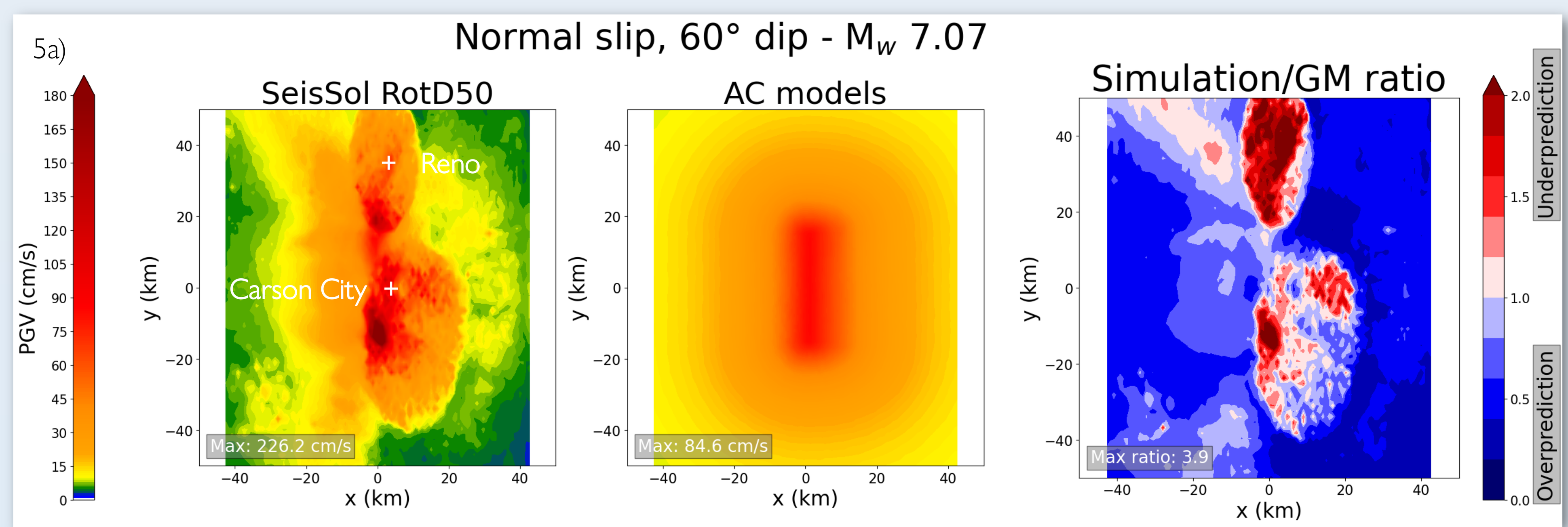
Part I: Dip-slip experiment suite
- Near-surface rupture bifurcation phenomenon in normal slip
- Nucleation depth, varying material properties affect rupture propagation
- More intense near-fault ground motion in reverse-slip earthquakes
- Dip and mechanism affect ground motion distribution (*see additional material*)





Figures 4a and 4b: Selected results from the dip-slip experiment suite, with (a) ground motion and rupture velocity for the base, normal-slip, 60° dip case, and (b) the same for an identical reverse slip case.

Part II: Reno scenario (preliminary)
- Several simulation setup issues to improve:
  - Adjust stress field and frictional parameters for lower slip
  - Refine mesh resolution to prevent extreme ground velocities
  - Investigate factors affecting behavior of rupture bifurcation
- Goal: demonstrate basin effects in close proximity to ruptures combined with influence of dynamic rupture phenomena



Figures 5a, 5b, 5c: Results from a preliminary simulation on a M7.3 normal-slip event in the Reno area with (a) simulated vs. GMM ground motions and their ratio, (b) moment release over time, and (c) rupture velocities along the fault plane.