SOLVING THE NEAR-FAULT DATA SCARCITY PROBLEM FOR NORMAL-FAULTING EARTHQUAKES USING DYNAMIC RUPTURE SIMULATIONS

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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
- Basin and Range seismicity dominated by normal faulting earthquakes
  - Scarce record due to sparse instrumentation at the time of largest normal-slip events (1915, 1954)
- 2023 U.S. National Seismic Hazard Model (NSHM) active crustal models derived from scarce normal-slip strong motion data
  - ASK14 dip-slip fault hanging wall term generalized from kinematic simulations of thrust faults [1]
- Data scarcity may cause mischaracterization of seismic hazard in populations close to normal faults (e.g. see Figure 1), including cities like Reno, Salt Lake City, etc.

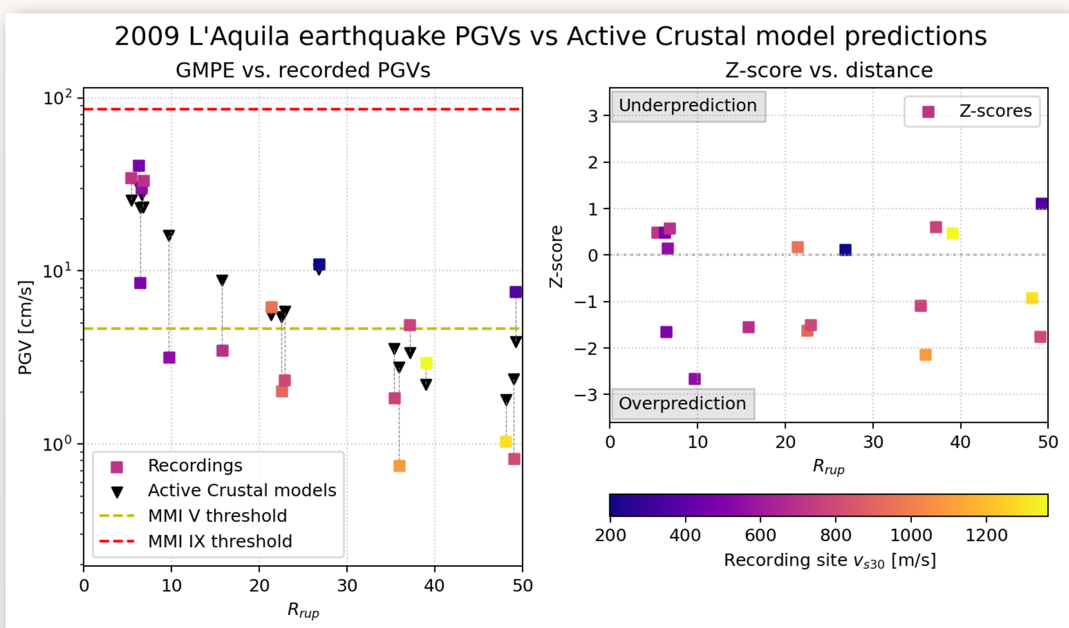


Figure 1: Comparison of recorded PGVs and GM predictions for the M6.3 2009 L'Aquila earthquake. Models use station-specific distance and site parameters. Left plot shows GMDB [2] vs. predicted PGVs. Right plot shows z-scores. Data plotted against R_{rup} (distance from rupture plane). Stations color coded by V_{S30}. Modified Mercalli Intensity (MMI) thresholds for intensities V and IX are plotted as yellow and red dotted lines, respectively.

METHODS

- Run a suite of dynamic rupture simulations in SeisSol
- Normal-slip simulations based on TPV10 benchmark test [3]
  - Fault dimensions: 30x15 km
  - Dip: 60°
  - Nucleation patch: 3x3 km
  - Hypocenter: 12 km down-dip from midpoint of surface fault trace
  - Fault ruptures the surface
  - Embedded in 100x100x42-km domain
  - Depth-dependent stress parameters

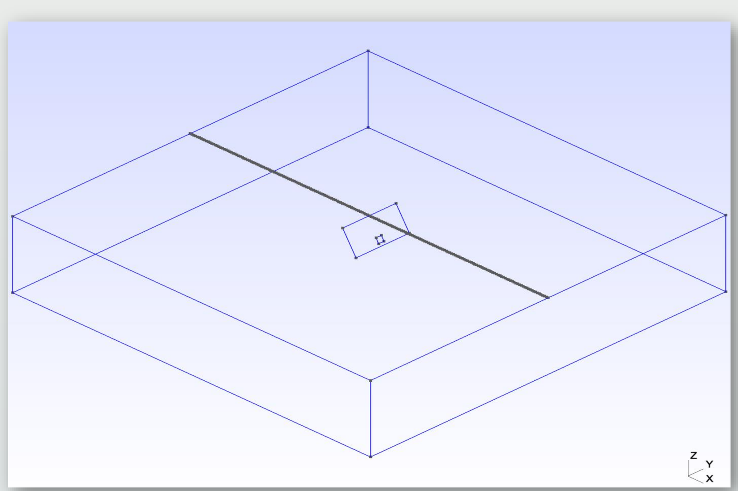


Figure 2: Example of 3D mesh used as SeisSol input for simulations. This is the case of a 60°-dipping fault in a 100x100x42-km domain. Also shown is the line along which PGV is calculated for GMPE comparisons. This line is perpendicular to the surface fault trace and crosses its midpoint.

- Variations in fault parameters for simulations
  - Dip: 25-75° (5° increment)
  - Reverse vs. normal slip
- Compare dynamic rupture simulation data to ground motion models
  - SeisSol data read from mesh output
    - RotD50 velocities computed from V_x and V_y data
  - Ground motion prediction data obtained via OpenQuake library [4]
  - Average of four Active Crustal models used in 2023 NSHM:
    - Boore et al., 2014 (BSSA14)
    - Abrahamson et al., 2014 (ASK14)
    - Campbell & Bozorgnia, 2014 (CB14)
    - Chiou & Youngs, 2014 (CY14)

Scan this QR code to view a digital version of this poster and supplemental materials like simulation animations. Alternatively, visit yairfranco.com/agu2025

RESULTS

- Base case (60° dip) SeisSol simulations return distribution patterns consistent with previous literature [5]
  - Stronger ground motions on hanging wall ($R_x > 0$) side
- Observed discrepancies:
  - Simulation returns ground motions lower than 1σ (standard deviation) below the GMPE median values
  - Dip angle in normal slip has strong effects on ground motion distributions not encapsulated by GMPEs
- GMPE vs. simulation data discrepancy increases with more extreme high/low-angle faulting
  - Near-fault ($R_x < 10$ km) PGVs over 1σ off from GMPEs in several cases
  - Strongest PGVs migrate to hanging wall ($R_x < 0$) in low-angle faulting cases, not seen in GMPEs
  - Reverse-slip PGVs significantly higher on footwall side than in normal-slip

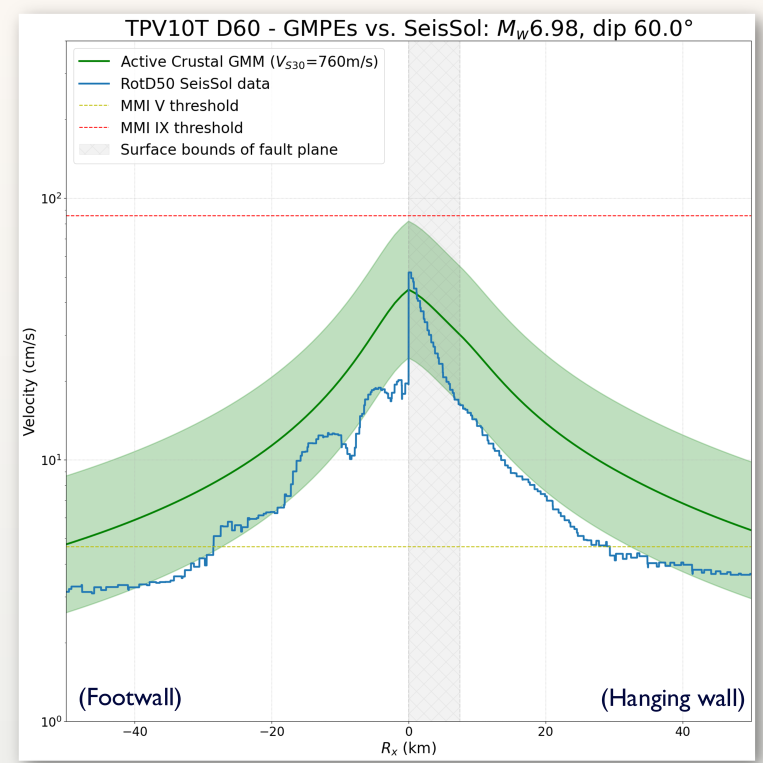


Figure 3: Results from a SeisSol simulation based on TPV10 (60°-dipping, 30x15 km fault rupturing the surface). RotD50 (rotation-independent median of horizontal motion) peak ground velocities (PGVs) computed from SeisSol data are plotted in log-y scale as a blue line. The average of the log-median of the four GMPEs previously listed, matching SeisSol rupture parameters, is plotted in log-y scale as a green line. Infill shows one log-standard deviation (1σ).

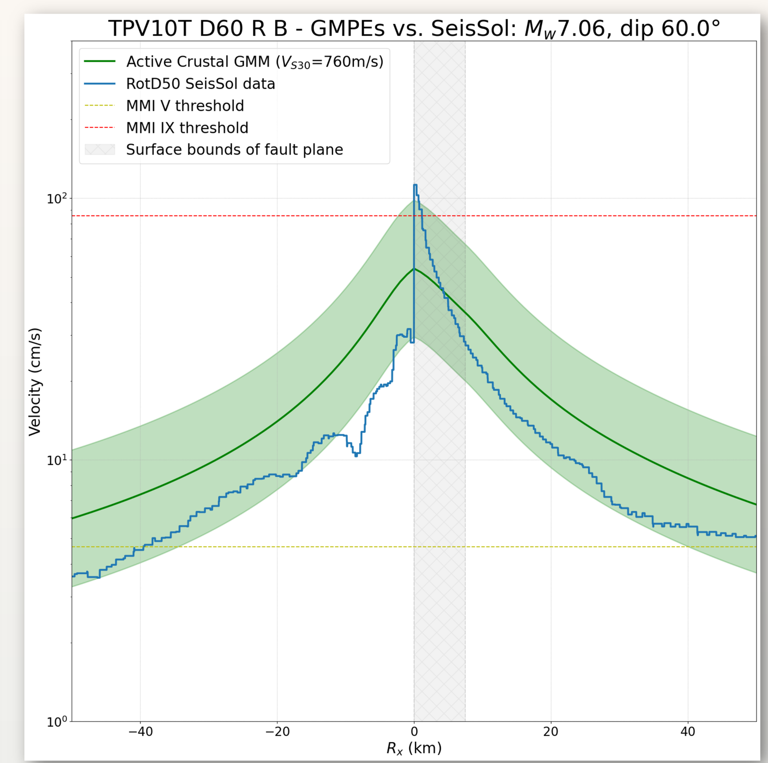
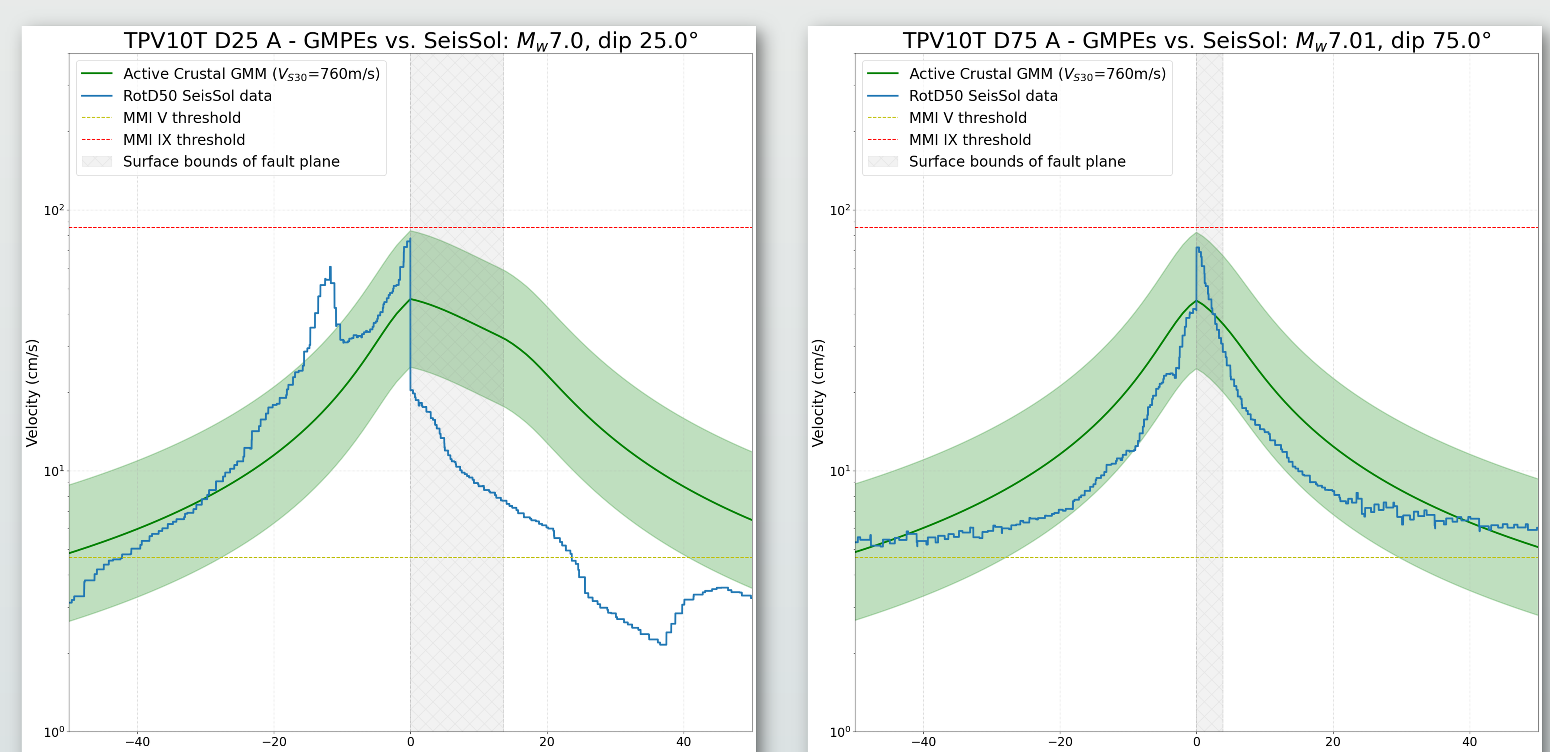
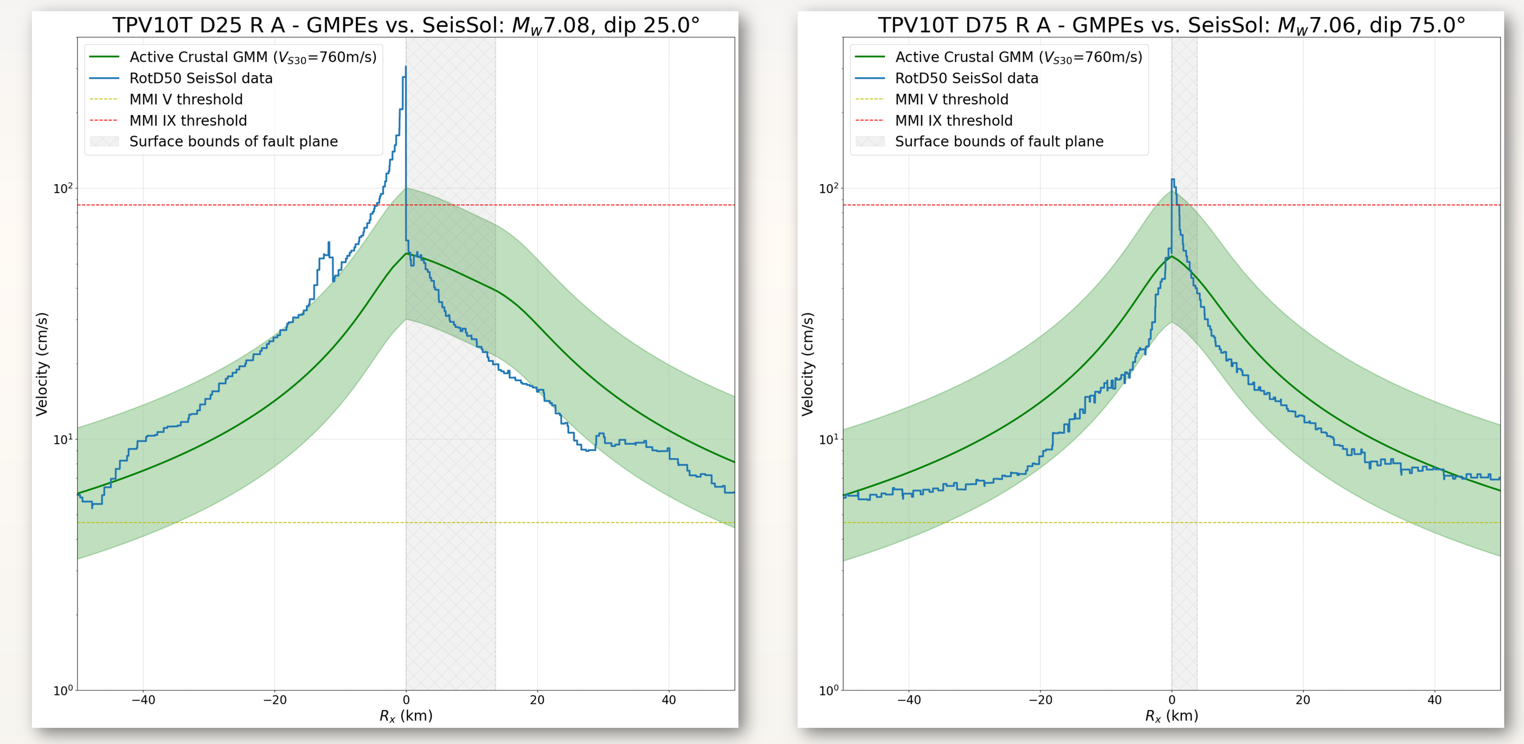


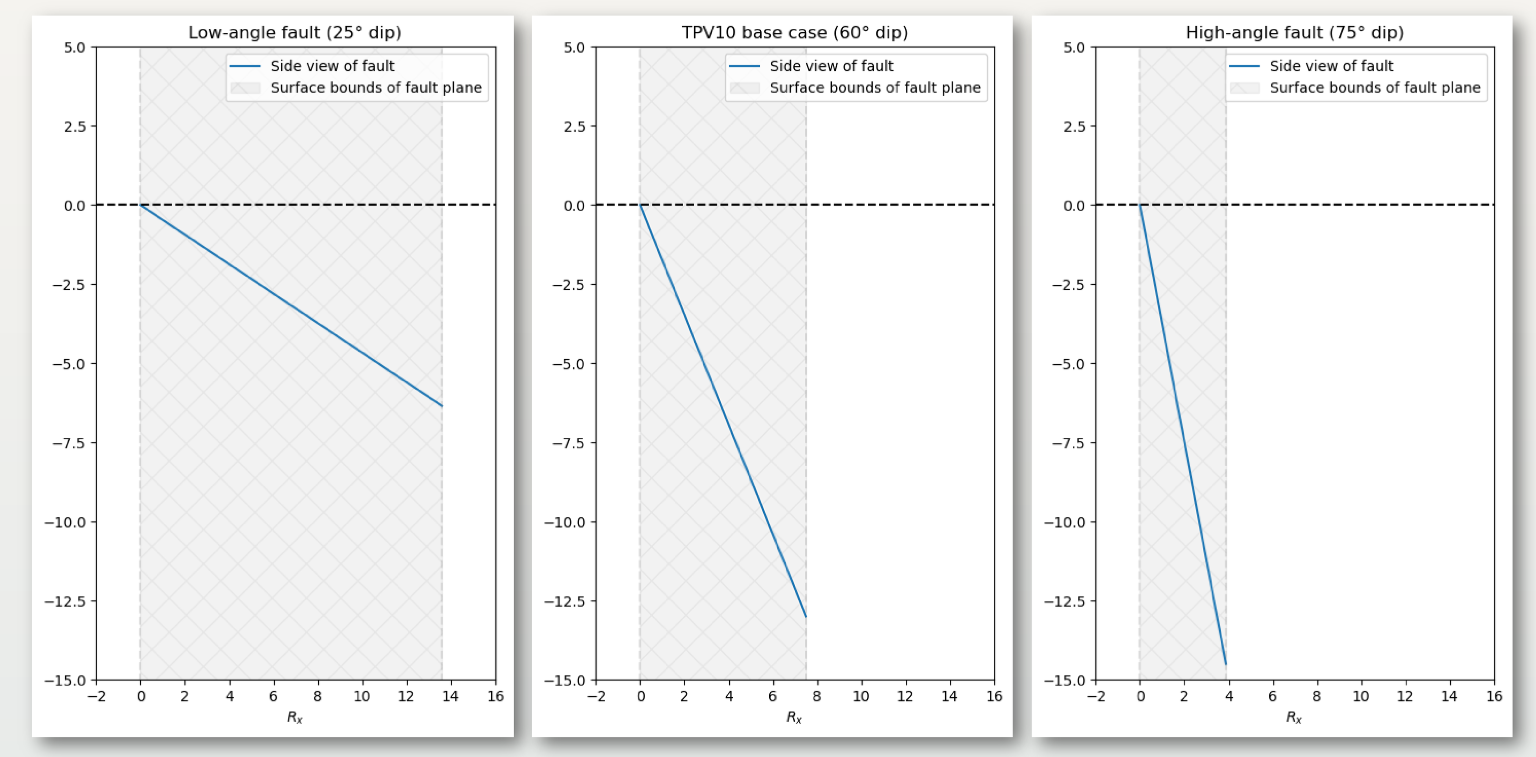
Figure 4: Same as Figure 2, but with data from a reverse-slip simulation. The only difference between these simulations is the down-dip fault traction, which has been reoriented to be up-dip. GMPEs rerun accordingly.



Figures 5a and 5b: SeisSol vs. GMPE data plotted as in Figures 2 and 3, showing the differences between low and high-angle normal faulting. Figure 4a (left) plots PGVs for a normal-slip rupture along a fault dipping 25° (low-angle), and 4b shows the same for 75° (high-angle). Limits of x-axis changed to 50 km per side.



Figures 6a and 6b: SeisSol vs. GMPE data plotted as in 4a and 4b, but for reverse faulting. Note the difference in simulated PGVs between reverse and normal-slip earthquakes.



Figures 7a, 7b, and 7c: Dimensional references for (a) low-angle, (b) base case, and (c) high-angle faulting as shown in previous figures. Axes dimensions are identical for all three plots.

SUMMARY & FUTURE STEPS

- Normal and reverse-slip simulations have starkly different peak PGVs and ground motion distributions
  - Simulated ground motion for dip-slip earthquakes should be distinguished by direction (normal/reverse) when used as substitute for real data
- 2023 NSHM in Basin and Range, if purely based on GM predictions, may mischaracterize hazard
- Future GMPEs would benefit from richer near-fault strong motion data, while dynamic rupture simulations can temporarily substitute for scarce data in current models
- Future work will encompass tests applying basin topography and ground velocity variations and possible earthquake scenarios

REFERENCES

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3. Harris et al. "A Suite of Exercises for Verifying Dynamic Earthquake Rupture Codes." *Seismological Research Letters*, 2018.
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ACKNOWLEDGEMENTS

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