Using Dynamic Rupture Simulations to Improve Ground Motion Hazard Models for Normal Faults

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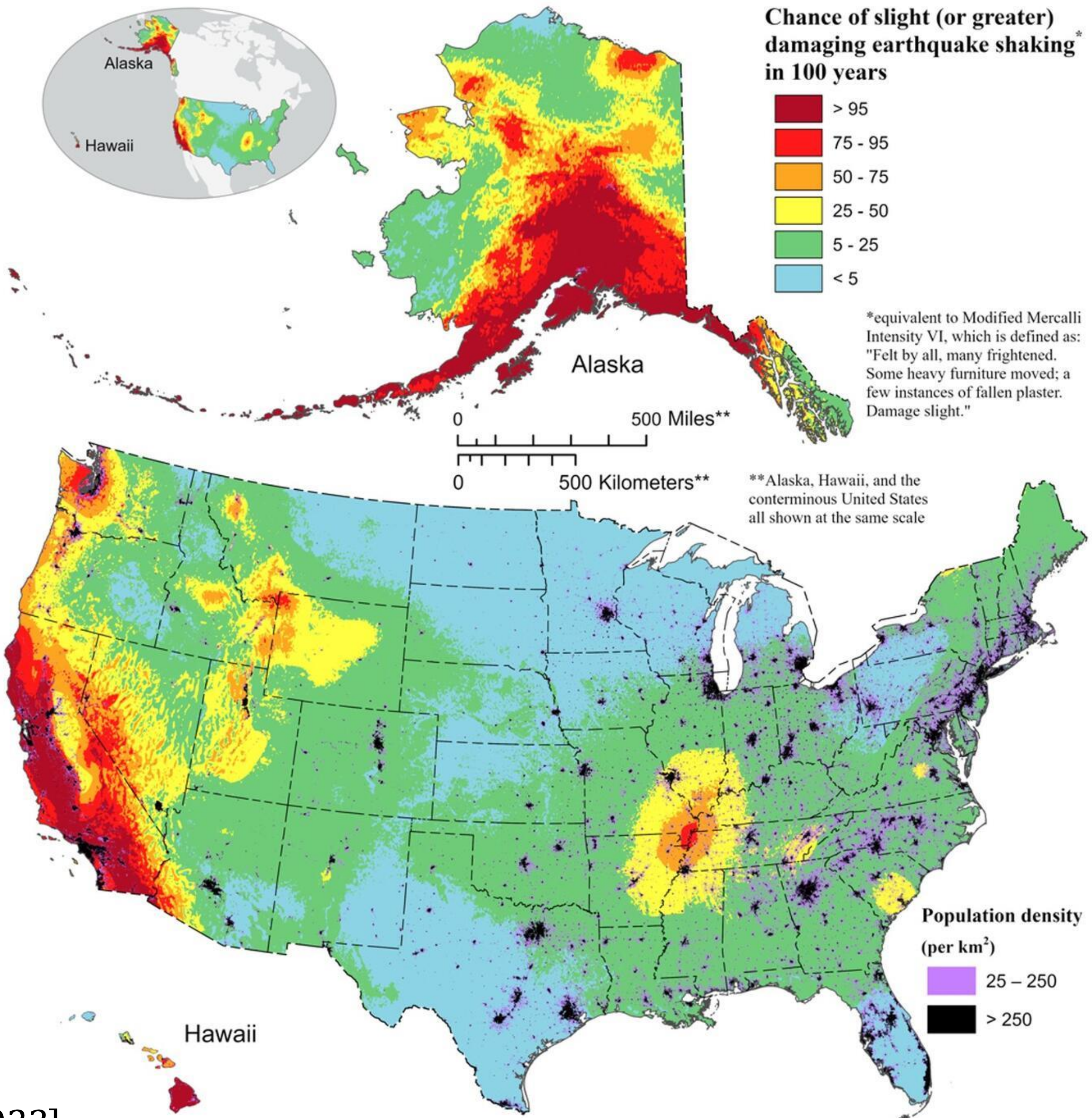
Motivation

- Hazard assessments are basis for earthquake preparation
- Developed in part with ground motion models (GMMs)
- GMMs depend largely on empirical ground motion records

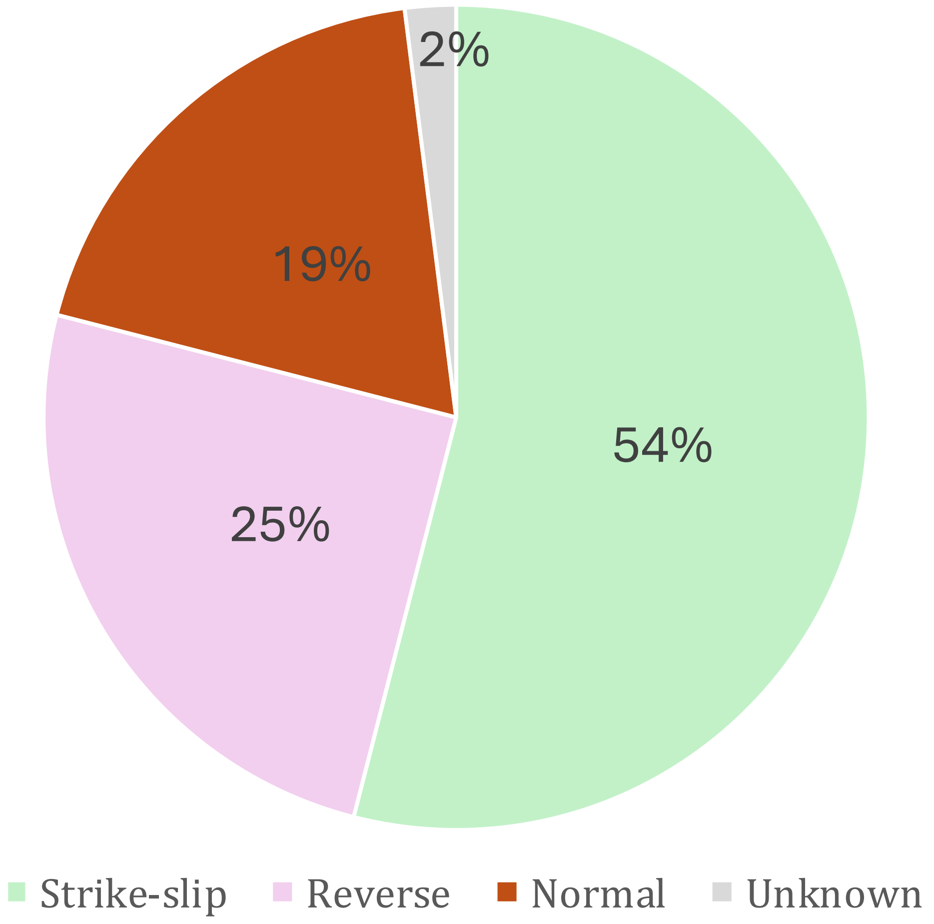


[Petersen et al., 2023]

Motivation

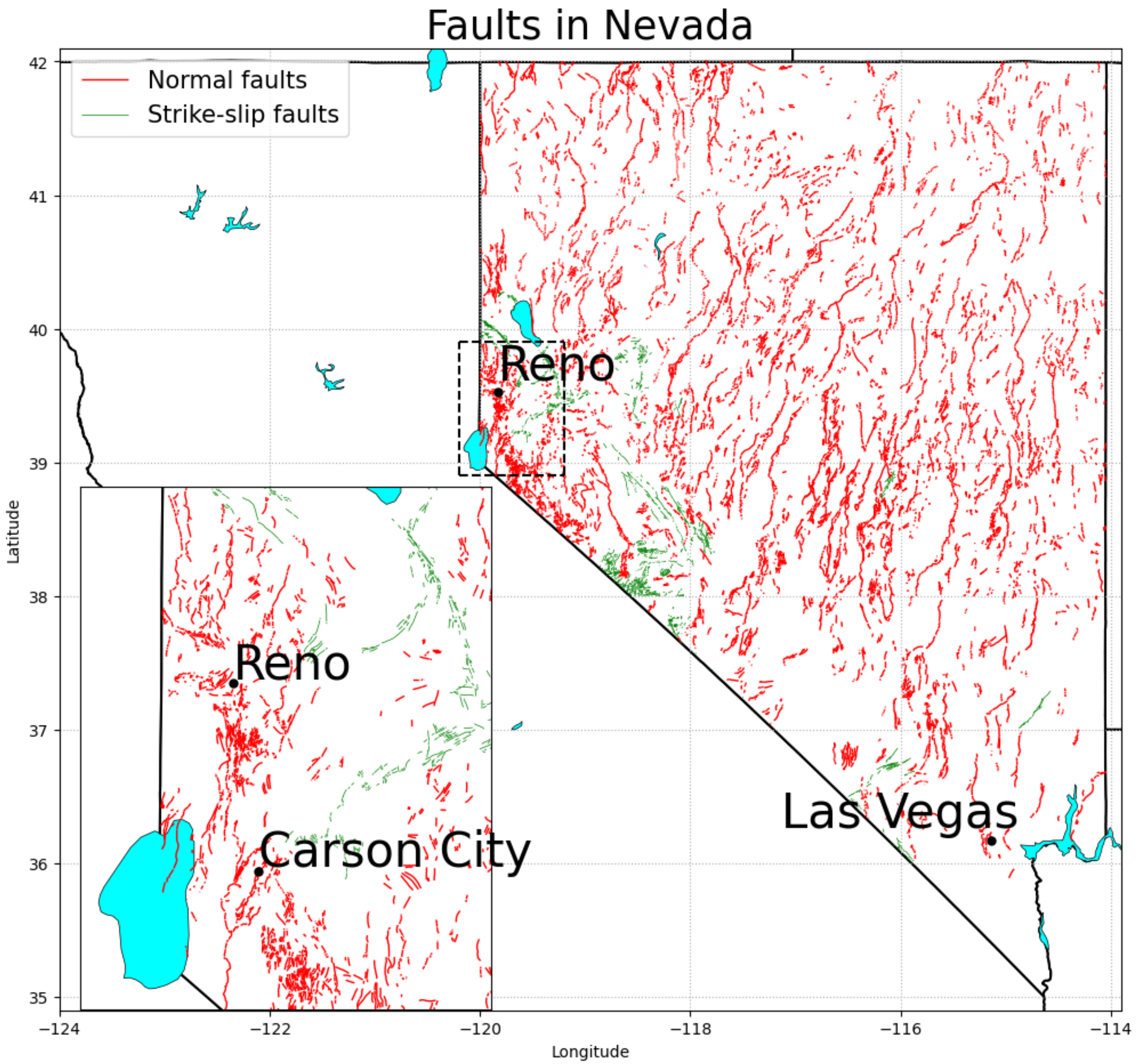
- Ground motion data for large normal-faulting earthquakes is relatively <u>scarce</u>
  - Particularly near-fault records
- Could this be affecting hazard estimates in normal-faulting environments?

Mechanism distribution of NGA-West2 records (Ancheta et al., 2014)



Motivation

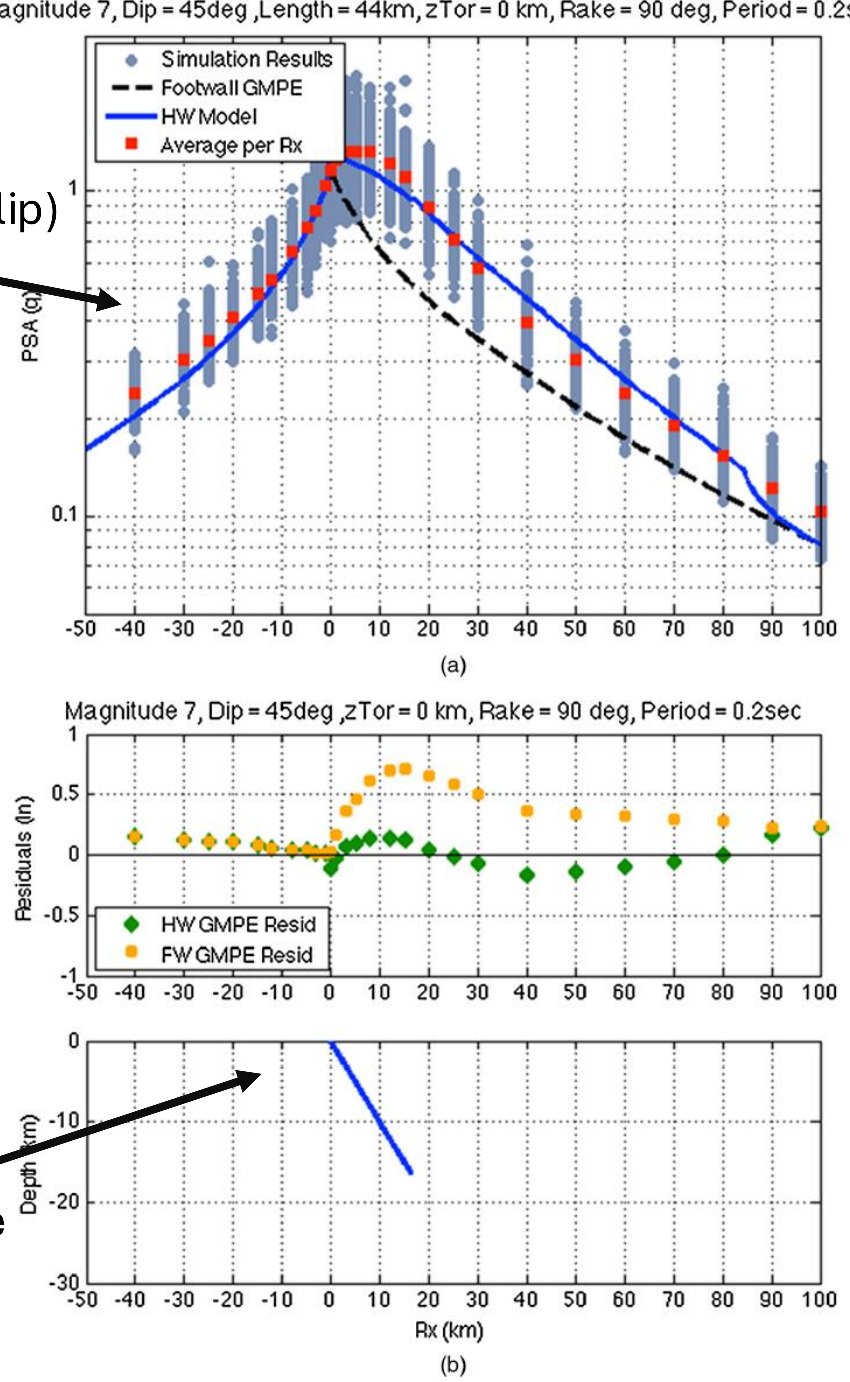
- Normal fault hazard may not be as well constrained as for other mechanisms
- Implications for areas where normal faulting is more common



Motivation

- Dynamic simulations: see physical effects on ground motion
- Simulation data has been used for developing GMMs
    - Kinematic – neglect some important dynamic effects
    - Assumptions made on dip-slip mechanisms

(Hanging wall term regression for dip-slip)

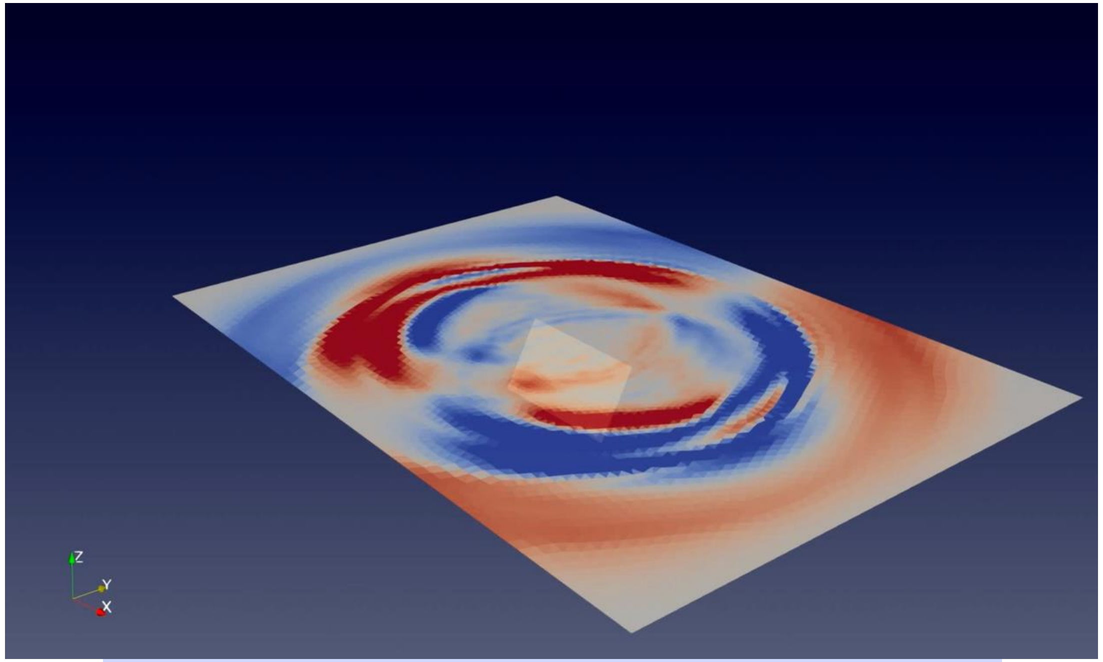


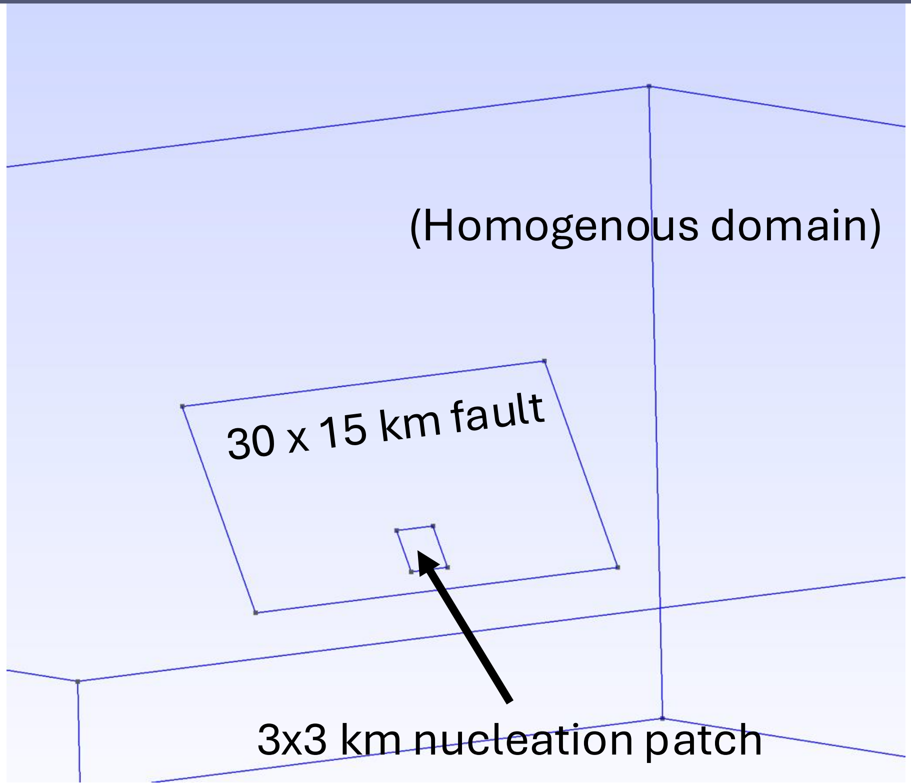
(All simulations here are reverse-slip)

(Donahue & Abrahamson, 2014)

Method

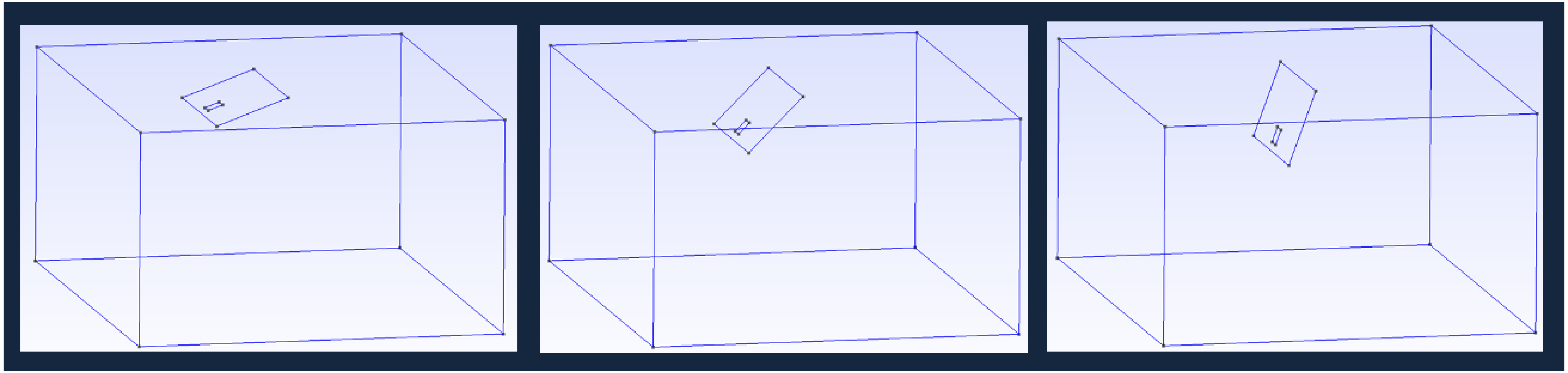
- SeisSol: 3D dynamic rupture simulations
- Scenarios adapted from SCEC TPV10 model
  - Normal fault dipping 60°
- Velocity data from simulation converted to RotD50





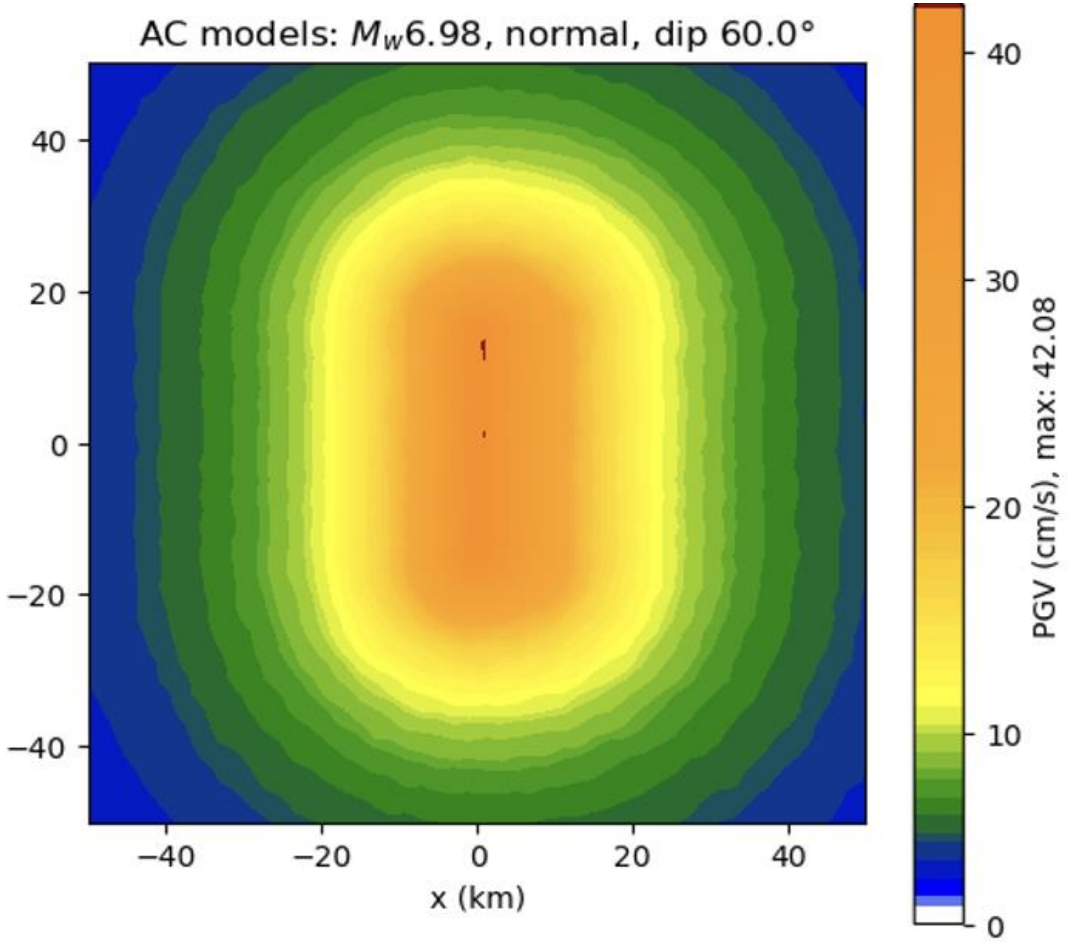
Method

- Scenarios tested:
  - Changing fault dip (25°-75°)
  - Reverse-slip mechanism
  - Moving nucleation patch
  - Adding a 1D velocity model



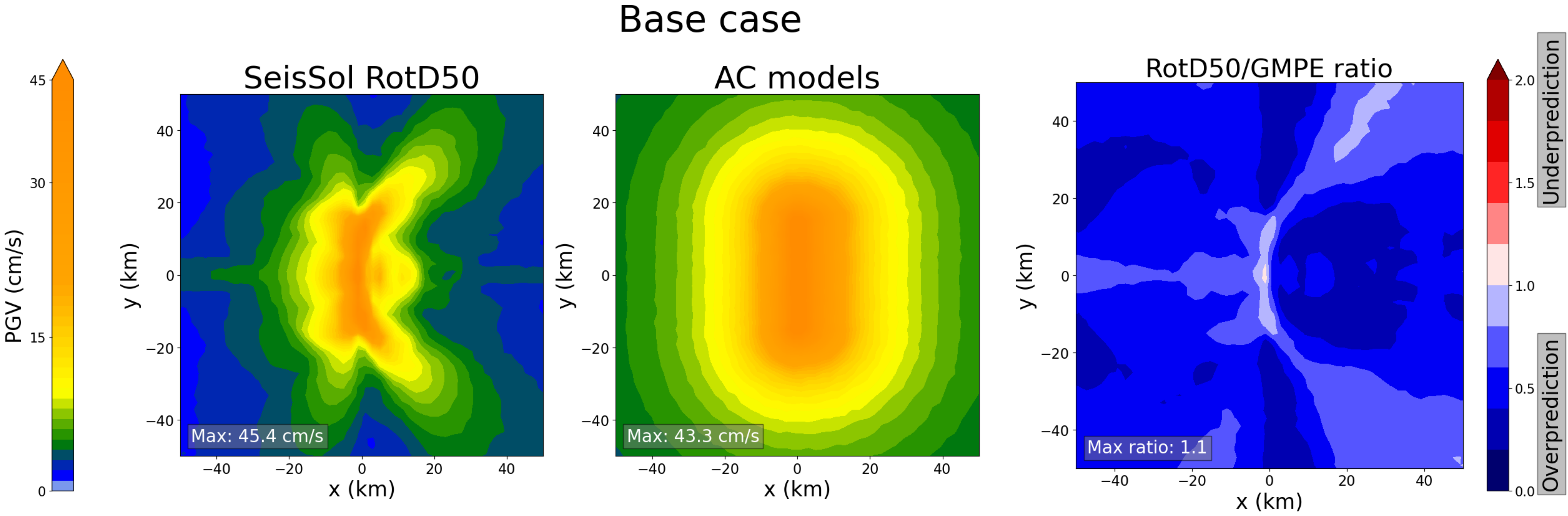
Method

- GMM comparison:
  - Data obtained via OpenQuake
  - Active Crustal models
    - Used in 2023 National Seismic Hazard Model
  - Ratio of average of models vs. SeisSol PGVs used for comparison



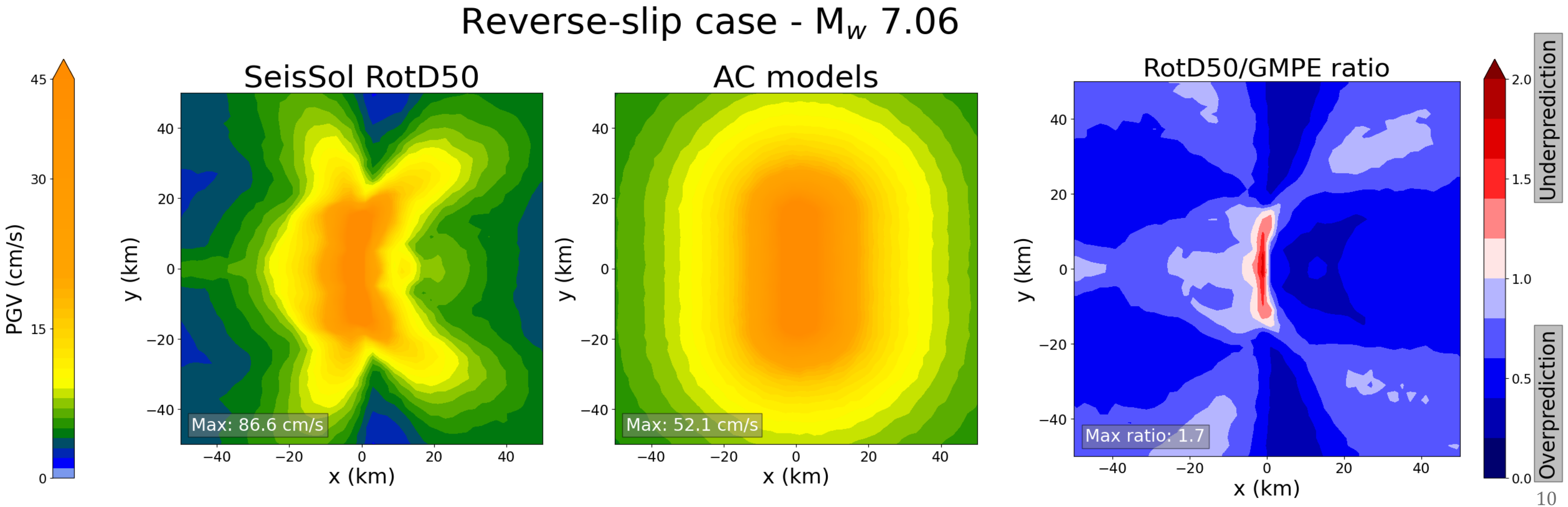
Results — base case

- Trend towards underprediction except at surface trace
- Radiating areas of higher PGV



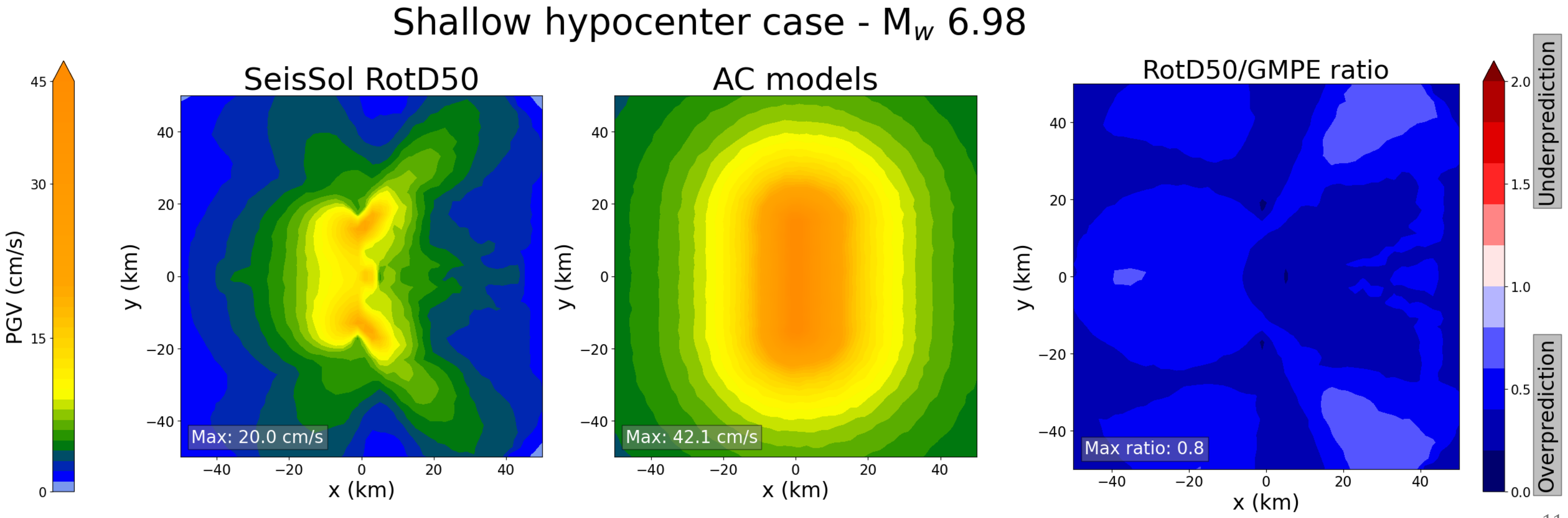
Results — reverse-slip case

- Stronger ground motions than normal-slip (expected)
- Greater underpredictions near the surface trace
- Similar trend towards overprediction elsewhere



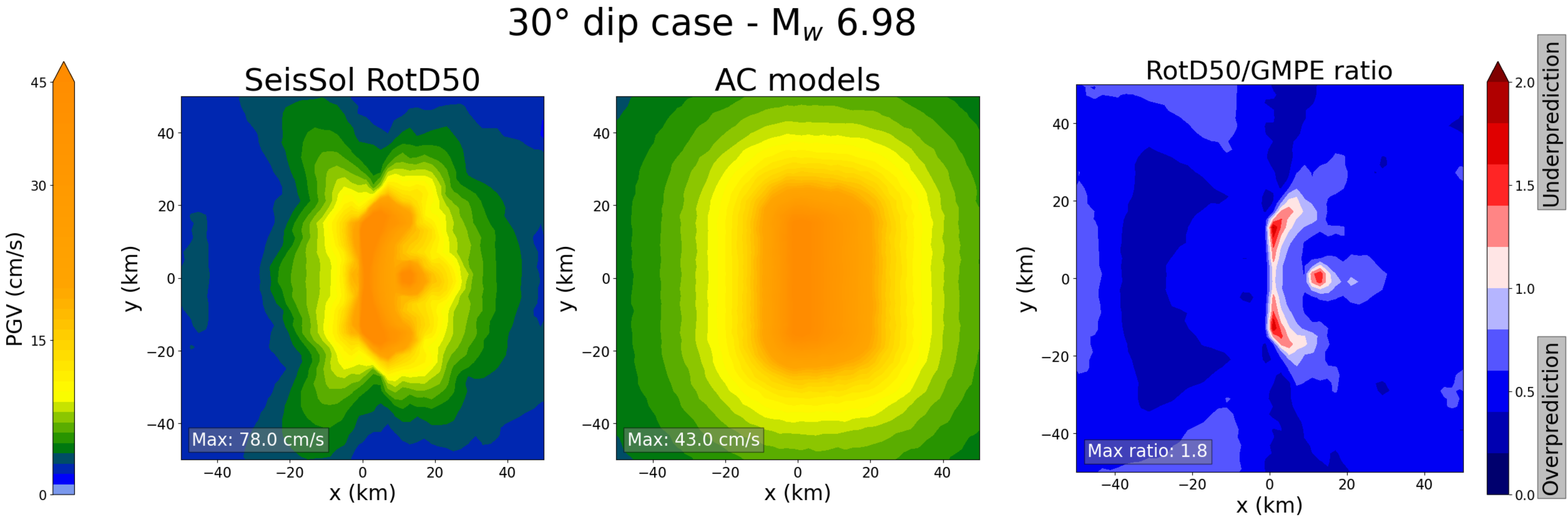
Results — shallower hypocenter

- Max PGVs lower than base case
- Underprediction more prevalent



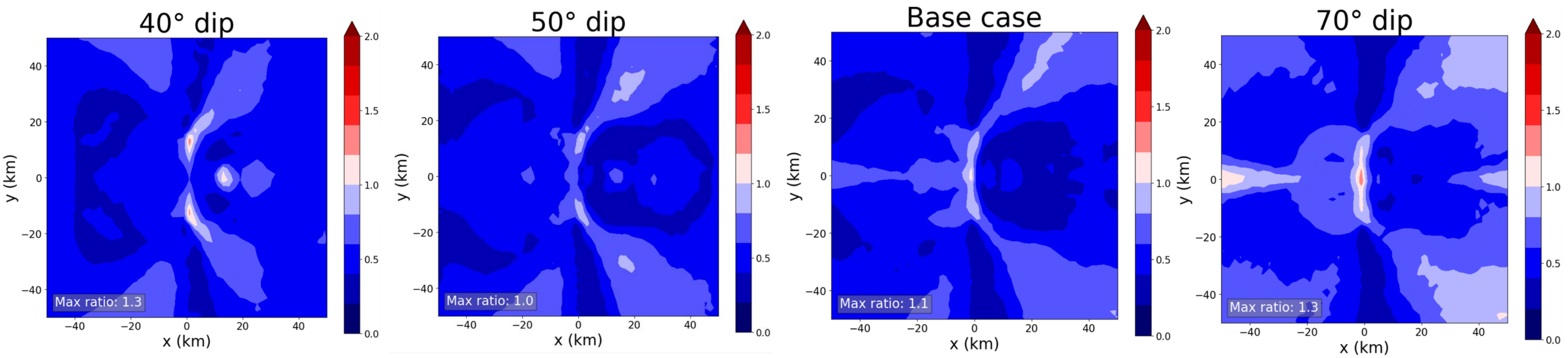
Results — changing dip

- Stronger localized discrepancies in shallow dip (30°)



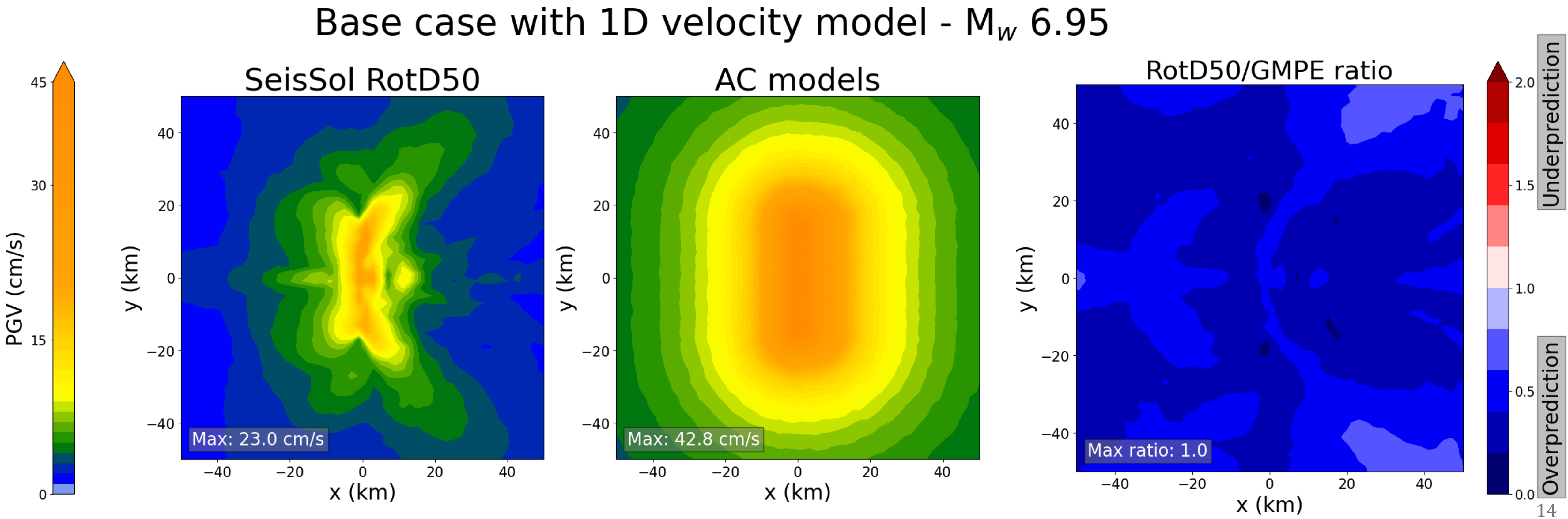
Results — changing dip

- Pattern changes with dip
- Constructive interference at y = 0 (centered along strike) more apparent at steeper dips
- Normal faults are more commonly in the 50-70° range



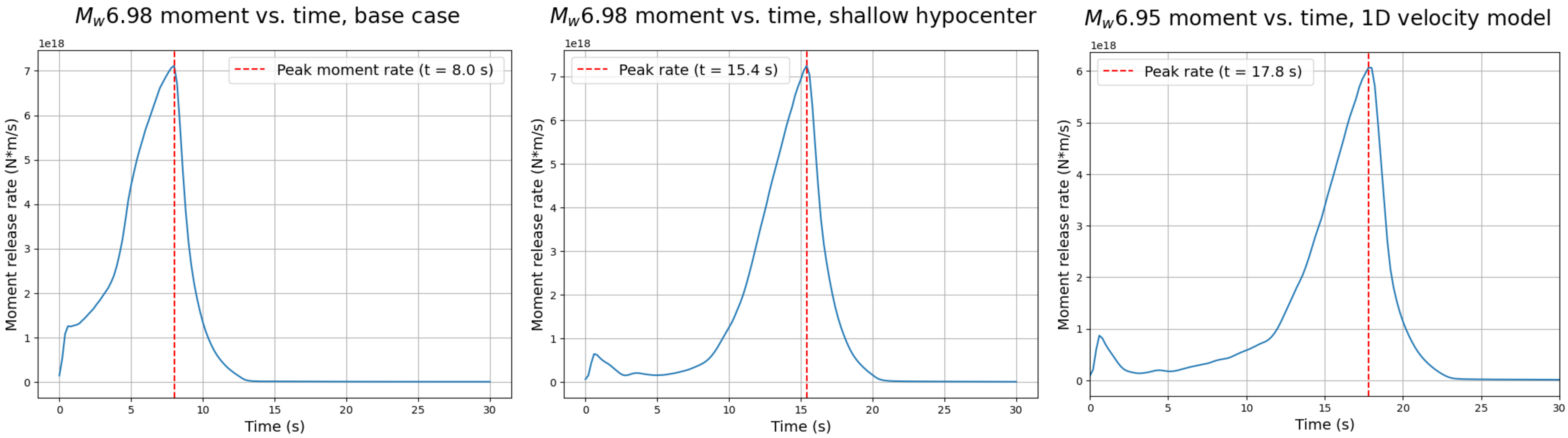
Results — 1D velocity model

- V_p = 5 km/s, V_s = 2.9 km/s in the top 5 km
- Overprediction throughout entire area



Results — physical effects

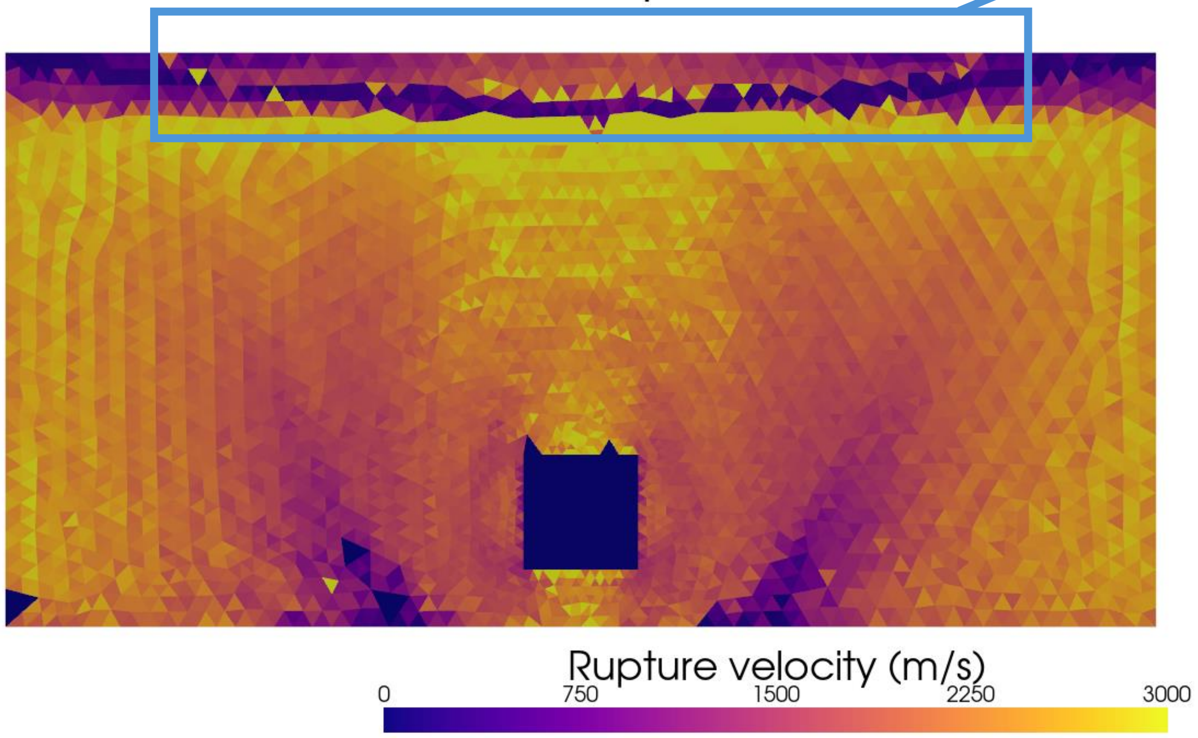
- Multi-stage rupture effect in some scenarios
- Possibly caused by differences in stress



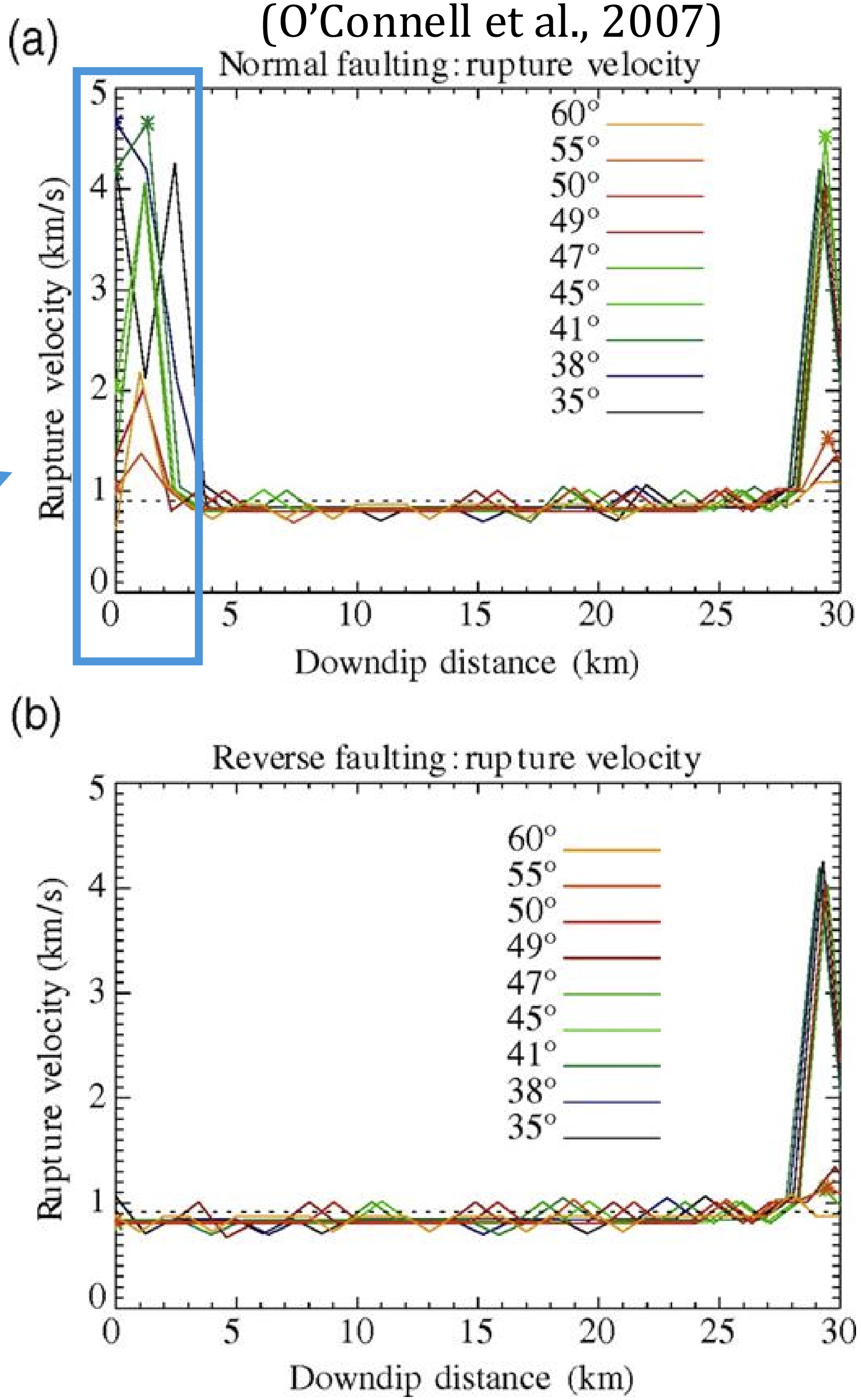
Results — physical effects

- Near-surface ”unclamping effect” unique to normal-slip

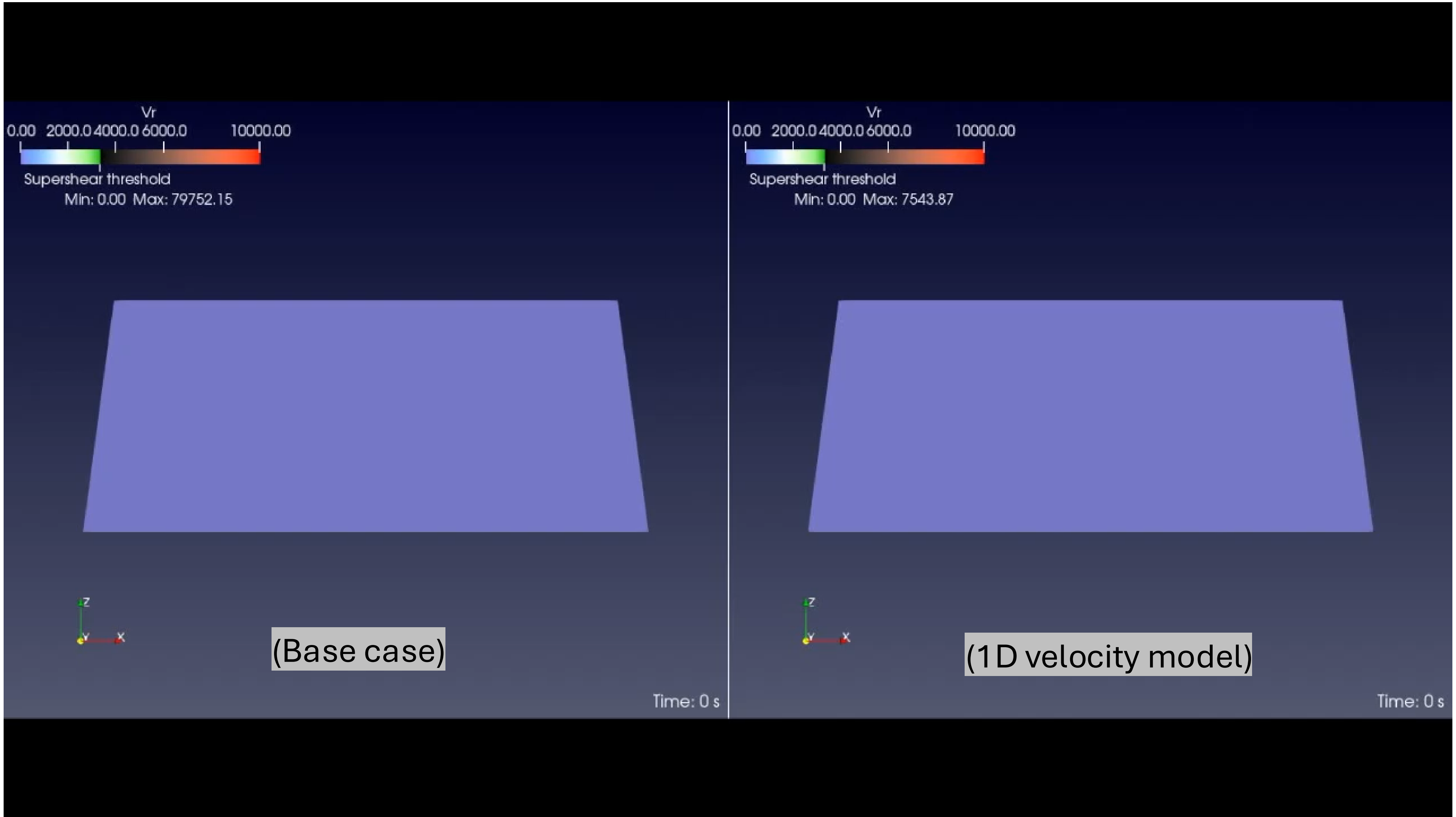
Base case: fault plane view



(O’Connell et al., 2007)



Results — physical effects



Conclusions

- Rupture simulations show dynamic effects that affect ground motion
  - Rupture speeds and breaks in propagation
- Variability beyond GMM uncertainties in a lot of cases
- Hazard estimates would benefit from richer dataset including dynamic rupture simulation results