Scaling Rupture Characteristics Across Earthquake Sizes: Insights from 3D Dynamic and Kinematic Simulations

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1 Motivation

- Earthquake rupture dynamics exhibit strong spatial and temporal complexity, influencing seismic energy radiation and ground-motion patterns that are important for accurate seismic hazard assessment.
- Dynamic rupture modelling requires specifying the initial stress state on prescribed faults, extrapolating friction laws and rock strength from laboratory conditions, and defining the nucleation process. As a result, they generate physically self-consistent earthquake rupture models.
- A previous study by Mai et al. (2017) incorporated fault roughness into 3D dynamic rupture simulations, providing insights on how variations in roughness pattern affect rupture propagation and seismic radiation.
- **Study objective: Develop a method to rescale time-dependent kinematic rupture parameters, extracted from dynamic simulations, to characterize small-magnitude seismic source.**

2 Algorithm for rupture rescaling and dataset

- We present a three-step algorithm designed to rescale spatial grid size (dx), temporal grid size (dt), and slip velocity amplitudes.
- **Step 1:** The spatial grid size is scaled based on the fault rupture areas of the reference (A_{ref}) and target (A_{tar}) events. The rupture area for the target event is estimated using the empirical scaling relation given by Thingbaijam et al. (2017). The grid size for the target event is given by:

$$dx_{tar}^2 = \left(\frac{A_{tar}}{A_{ref}}\right) dx_{ref}^2$$

- **Step 2:** The temporal grid size for the target event (dt_{tar}) is estimated by preserving the ratio of spatial to temporal discretization.

$$\frac{dx_{ref}}{dt_{ref}} = \frac{dx_{tar}}{dt_{tar}} \quad \Longrightarrow \quad dt_{tar} = \frac{dt_{ref}}{dx_{ref}} dx_{tar}$$

- **Step 3:** Slip-velocity amplitudes are rescaled based on the ratios of seismic moments and rupture areas of target and reference events.

$$sv_{tar} = \left(\frac{M_{0_{tar}}}{M_{0_{ref}}}\right) \left(\frac{A_{ref}}{A_{tar}}\right)^{3/2} sv_{ref}$$

- We first rescale kinematic properties extracted from a M_w 6.87 dynamic rupture model to generate kinematic properties for other magnitudes (M_w = 8.0, 5.0, 3.0, 1.0). We then apply our algorithm to other dynamic models with varying hypocenter locations, different roughness realizations and roughness amplitudes.

Figure 1: Slip, peak slip velocity (PSV), slip velocities for rescaled Mw 5.0

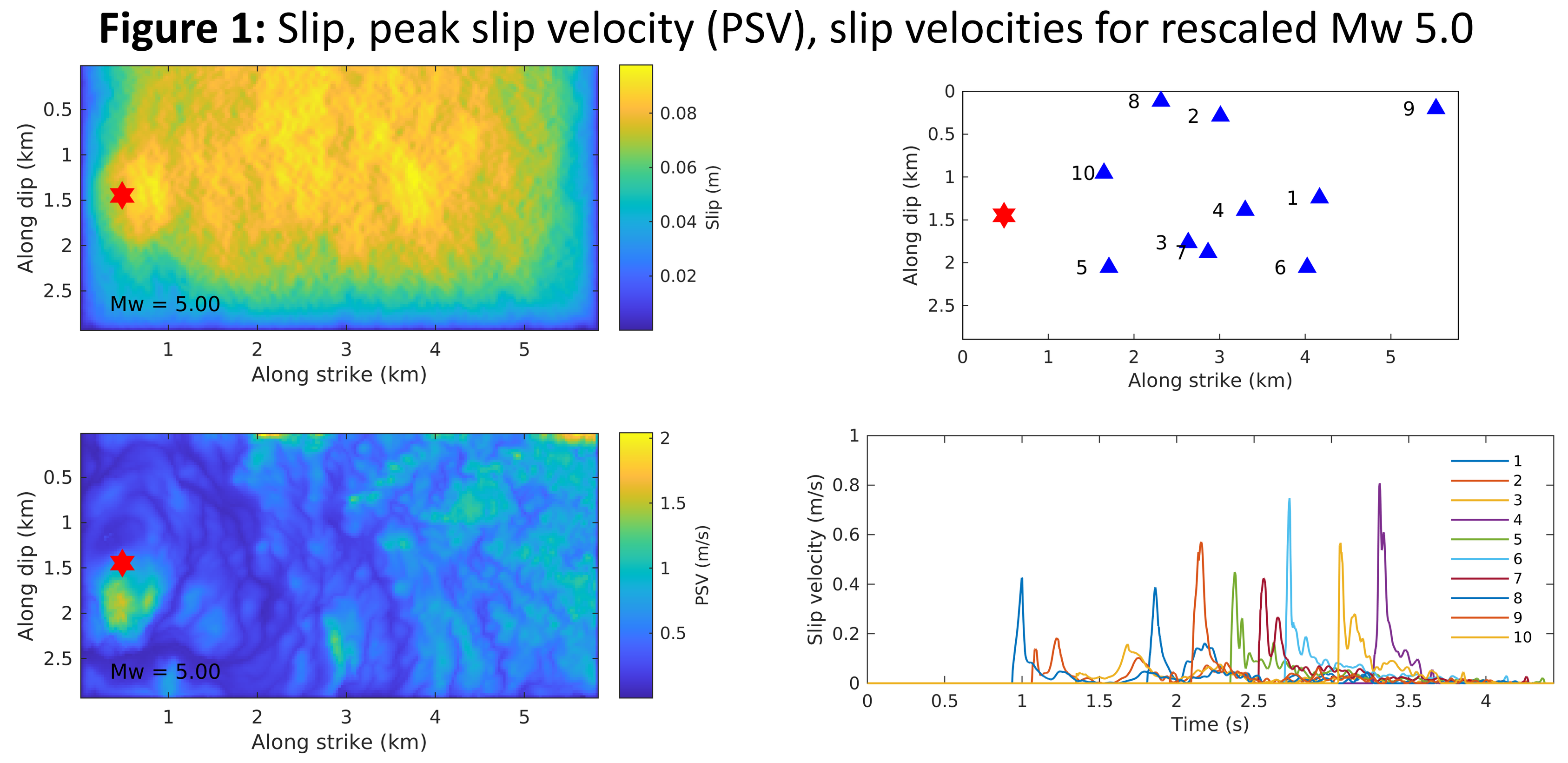
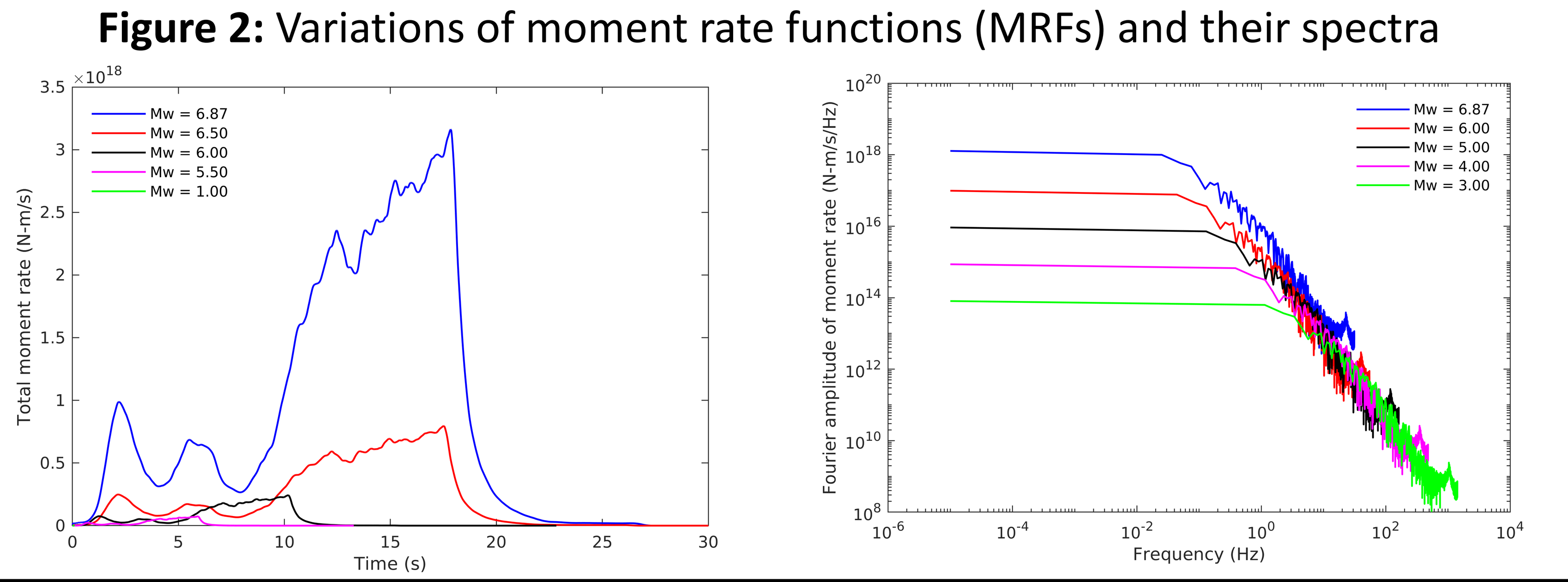


Figure 2: Variations of moment rate functions (MRFs) and their spectra



3 Waveforms and PGA comparison

Figure 3: Comparison of Acceleration Waveforms: Model A1 vs. Rescaled Mw 5.0

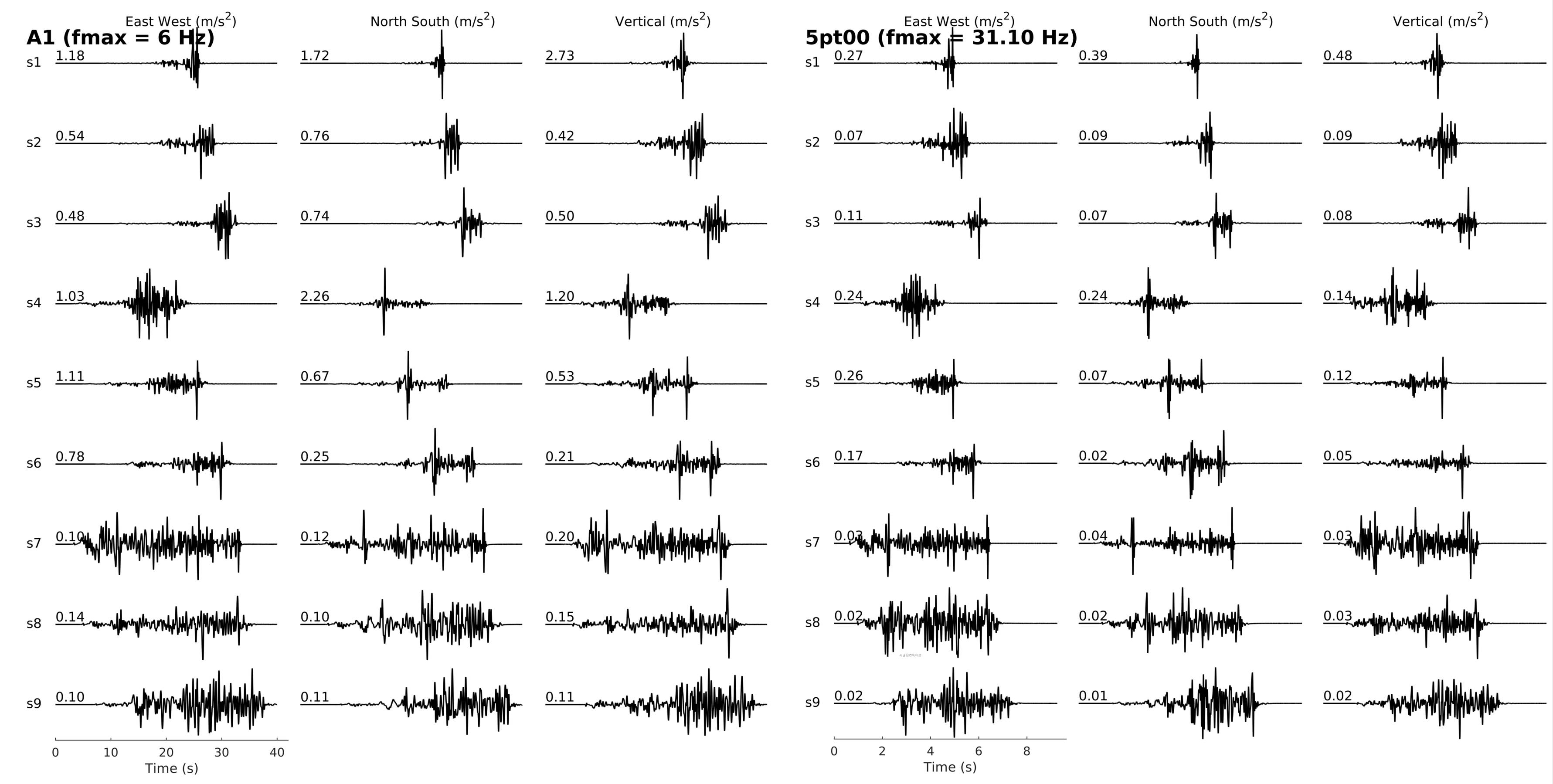
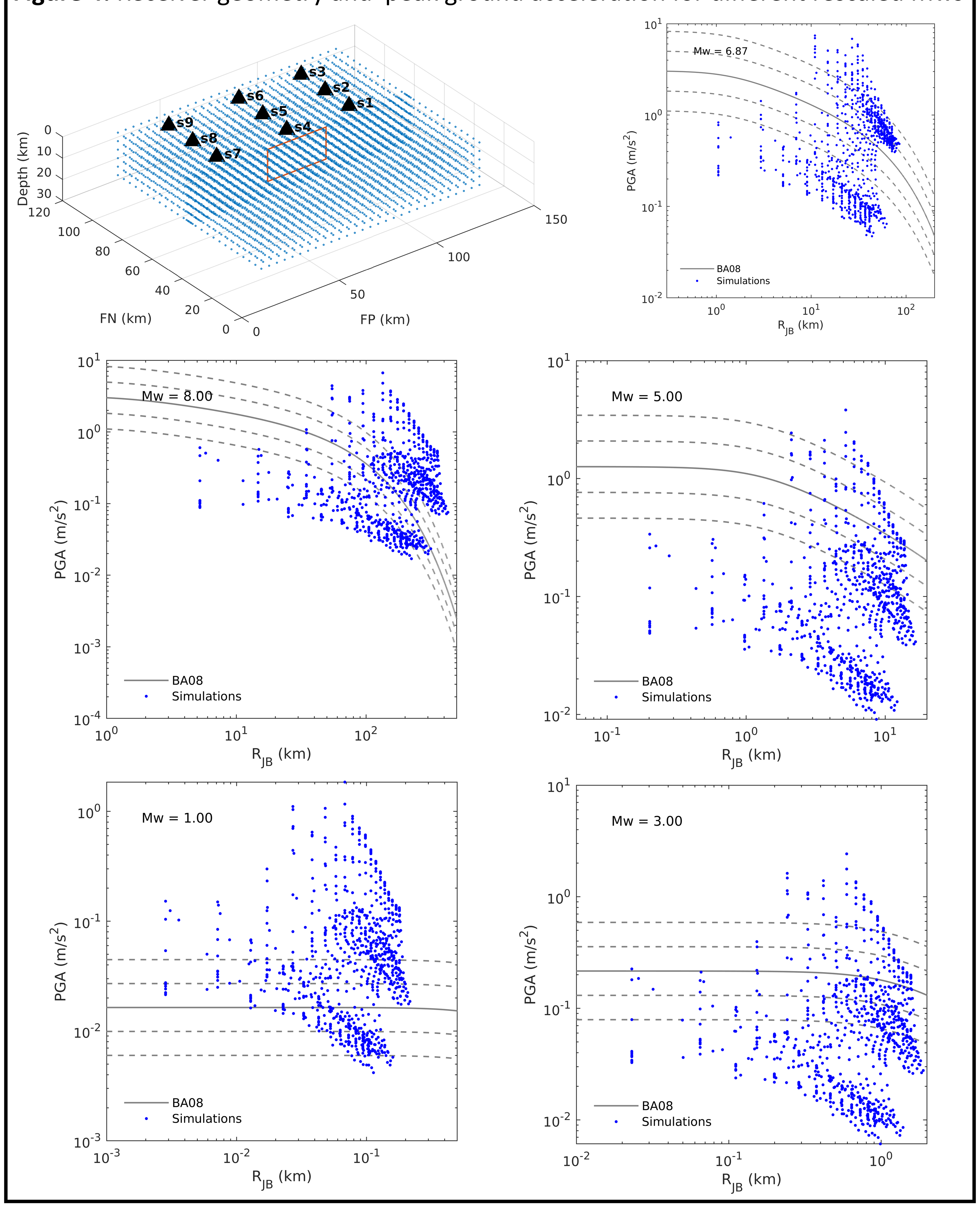


Figure 4: Receiver geometry and peak ground acceleration for different rescaled Mws



4 Conclusions and implications

- **We have developed a three-step algorithm to rescale time-dependent kinematic rupture parameters to any target earthquake magnitude.**
- **Our algorithm has been verified using rough-fault models of Mai et al. (2017) with different hypocenter locations, roughenss amplitudes and roughness realizations.**
- **Our findings reveal how kinematic rupture properties can be scaled for different-size events. Our method will simplify future ground-motion simulations, because existing physics-based rupture models can be rescaled to scenario events of different target magnitudes.**