Validating Spontaneous Rupture Ground-Motion Simulations

Capturing Epistemic Uncertainty
(Why getting the same answer may be bad)

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USGS science for a changing world

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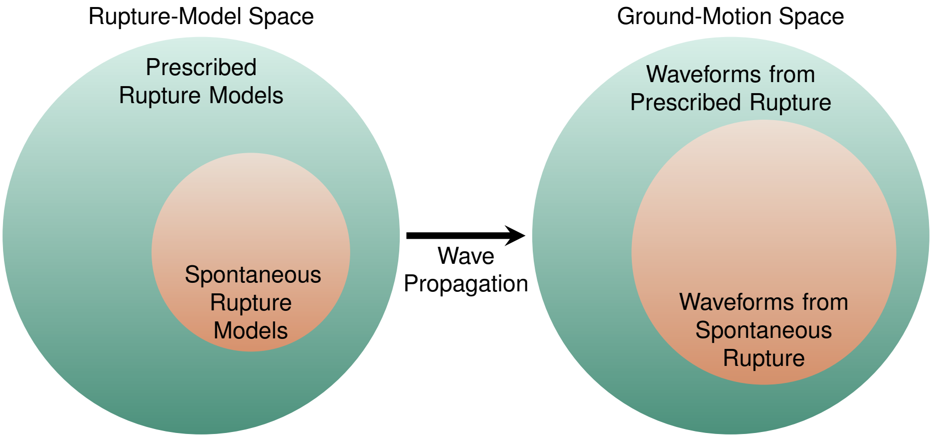
Using Spontaneous Rupture Simulations for Ground Motions

Motivation: Limit our ground-motion models to physically viable (i.e., spontaneous rupture) models



Validation, Verification, and Code Comparison

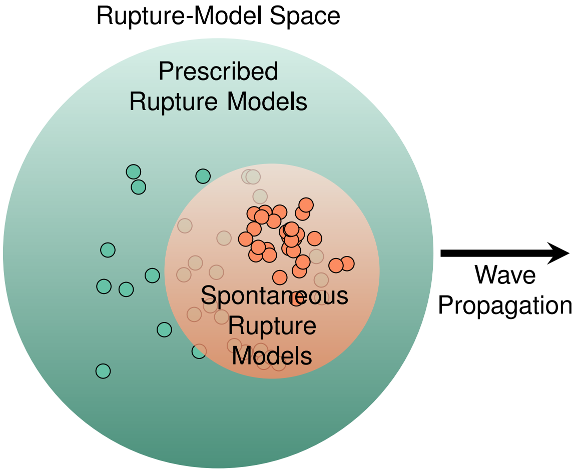
- **Code comparison**
  Quantify match in results produced by different computer codes
  - TPV5, . . . , TPV34
- **Verification**
  Verify a computer code accurately implements a numerical method
  - Example: Quantify rate of convergence matches order of spatial discretization
  - Useful methodology: Method of manufactured solutions
- **Validation**
  Verify a model fits observations to within some tolerance

Validation of Spontaneous Rupture Simulations

- Some observations available for use in validation
  - Earthquake ground-motion records
  - GPS/GNSS displacement (time series)
  - InSAR/LiDAR displacements
  - Surface rupture slip measurements
- **Goal: Validate methodology for using spontaneous rupture simulations to forecast earthquake ground motion**
- Apply methodology to test suite of earthquakes in the same way as it would be used to forecast ground motions.
  - Can only use information available before hypothetical earthquakes
  - Methodology must be completely reproducible
  - Quantify misfit in order to estimate uncertainty in forecasted ground motions

Capturing Epistemic Uncertainty

Need to understand clustering and breadth of models



Capturing Epistemic Uncertainty

See Scherbaum et al. Earthquake Spectra 26(4), 2010, and Atkinson et al. SRL 85(6), 2014

- **Goal**: Distribution of “technically-defensible interpretations” (Atkinson et al.) of spontaneous rupture ground-motion models
- **Issues**
  - Want to capture all viable models
  - Avoid redundant models (our Parkfield “validation” benchmark)
  - Account for models not represented in our suite of models
- **Approaches**
  - Logic tree of alternative models and weights
  - Representative suite of models (central plus high & low alternatives)
    - NGA West/East visualize model differences using Sammon’s mapping
    - Sammon’s mapping: 2D projections of higher dimension data preserving distance

Validation with Epistemic Uncertainty

Following PEER NGA West/East projects (multi-year, very involved effort)

- **Carefully vetted data set**
  - Suite of earthquakes with recorded ground motions that are representative of the earthquakes for which we want to forecast ground motions
  - Metadata for earthquake source and recorded ground motions
- **Spontaneous rupture ground-motion simulation models**
  - Select subset of data based on quality, etc.
  - Quantify ground-motion model space based on data selection
  - Reproducible methodology for generating ground motions using spontaneous rupture simulations
- **Analysis of models to determine central plus high & low alternatives**

Validation: Potential Next Step

Redo Parkfield benchmark w/focus on capturing "technically-defensible" spontaneous rupture models

- **Carefully vetted data set**
  - Recorded ground motions
  - Available seismic velocity models
  - Metadata for earthquake source and recorded ground motions
- **Spontaneous rupture ground-motion simulation models**
  - Reproducible methodology for generating ground motions using spontaneous rupture simulations
  - Free to choose fault constitutive model
  - Free to choose which parameters are uniform and which are spatially variable
  - Generate suite of synthetic ground motions (vary parameters that are not fixed)
- **Analyze models to determine central plus high & low alternatives**
- **Likely an order of magnitude more work than previous benchmarks**