Earthquake Simulators and Seismic Hazard Maps

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Earthquake Hazard

- Can’t wait for physics uncertainties to be resolved
- Longstanding methodology developed
  Probabilistic Seismic Hazard Analysis [PSHA]
- Difficulties with PSHA
  Many uncertainties
  Many assumptions
  Difficult to test due to long recurrence times
  Whole construct has been questioned
  Society investing huge resources on uncertain ground
UCERF3 includes multi-fault ruptures
Logic Tree for Uncertainties

UCERF3 Logic-Tree Branches (for Long-Term Models)

Fault Models:
- FM3.1 (0.5)
- FM3.2 (0.5)

Deformation Models:
- Geologic (0.3)
- AveBlockMod (0.1)
- NeoKinema (0.3)
- Zeng (0.3)

Earthquake Rate Models:
- Scaling Relationships
  - mag-area & slip-length relationships
  - Shaw09mod for both (Shaw, 2013a, 2013b) (0.20)
  - Ellsworth8 for both (Ellsworth, WGCPS, 2009) (0.20)
  - HanksBakun08 for both (Hanks & Bakun, 2008) (0.20)
  - Ellsworth8 w/ SqrtLength (Shaw, 2013b) (0.20)
  - Shaw09mod w/ Const Stress Drop (Shaw, 2013b) (0.20)

- Slip Along Rupture (Dsr)
  - Tapered (Sin^1/2) (0.5)
  - Boxcar (0.5)
  - Slip-Rate proportional (0.0)

- Total M ≥ 5 Event Rate (yr⁻¹)
  - 6.5 (0.1)
  - 7.9 (0.6)
  - 9.6 (0.3)

- Inversion Model
  - Characteristic
    - UCERF2 Constrained (1.0)
    - Characteristic Unconstrained (0.0)
    - Gutenberg-Richter Constrained (0.0)
    - Gutenberg-Richter Unconstrained (0.0)

- Mₘₗₐₓ off-fault
  - 7.3 (0.1)
  - 7.6 (0.8)
  - 7.9 (0.1)

- Off-Fault Spatial Seis PDF (or, SpatialPDF)
  - UCERF2 Smoothed Seis (0.5)
  - UCERF3 Smoothed Seis (0.5)
  - Deformation Model Based (0.0)

- Fault Moment Rate Fix
  - Apply implied Coupling Coefficient (0.0)
  - Relax MFD Constrnt (0.0)
  - Apply Both Options (0.0)
  - Do Nothing (1.0)
Earthquake Simulators

- Physically consistent tool
- Bring simulators into hazard space to begin dialogue
- Hope to have something in ballpark enough to compare and then tune like “flux corrections to climate models”
- Are Epistemic uncertainties too large?
- Approximations to dynamics to make computationally tractable
Simulator Features & Approximations

- Complex geometries
- Quasistatic boundary elements
- Rate-and-state friction
- Fixed fast sliding rate
- Time step just during state changes so extremely fast
Seismicity in Different Timescales

- Aftershocks along mainshock rupture area
Untuned model did really well on recurrence intervals

- Push further into hazard comparison
Standard Hazard Measure

- On-fault hazard only
- Remarkable agreement!! Why?!
- Also push further into other measures
Model closer to UCERF3 than UCERF3 is to UCERF2
Full hazard curves at a point

- Hazard curves agree well, especially at low prob.
Mean Absolute Ln Ratio small useful measure
Agrees well annual prob < repeat time large events
Agree well over wide range of engineering interest (0.2-1s)

[Rule of thumb .1s/story in building]
Simulators and Hazard

- Remarkable agreement: Mean Absolute Ln is a small useful measure for complex system comparison.
- Remarkable agreement over range of engineering importance.
- Insensitivities of some hazard measures to known unknowns.
- Simulators ready to contribute.
- Simulators new tool for exploring epistemic uncertainties.
- Simulators require fewer parameters and assumptions.
- Profound cross-validation of PSHA.
Further Work

Help UCERF Statistical Models
- Rupture plausability filter
- Nucleation locations for triggering
- Focal mechanism effects

Improve Simulator Estimates
- Improve connectivity at fault tears
- Aid deformation model consistency
- Improve code scaling with new approximations

Source Model for Ground Motions
- Compare with ground motions models
- Improve rupture propagation velocities
- Help with variability estimates
- Full-physics-based PSHA (cybershake)