Ground Motion Variability

- For a given earthquake scenario (Mag, rupture location, rupture geometry, site location), there is a large variability in the ground motions
- Worst-Case (largest possible) ground motion due to physical limits
  - Extreme ground motion project addressed this issue
  - The worst-case ground motions are very large
    - Costly for use in design
    - Too rare to justify the high cost
- Sample distributions of source parameters for future earthquakes
  - Empirical vs numerical simulations

Use of Numerical Simulations in PSHA

- Replace empirical ground motions models with numerical simulations
  - Hutchings et al (2007)
  - SCEC CyberSHAKE
- Advantages
  - Remove ergodic assumption
    - Use the region-specific crustal structure and source specific geometries
    - Removes epistemic uncertainties from the aleatory variability
  - Physically based
    - Avoids unphysical combinations that may results from extrapolating statistical models

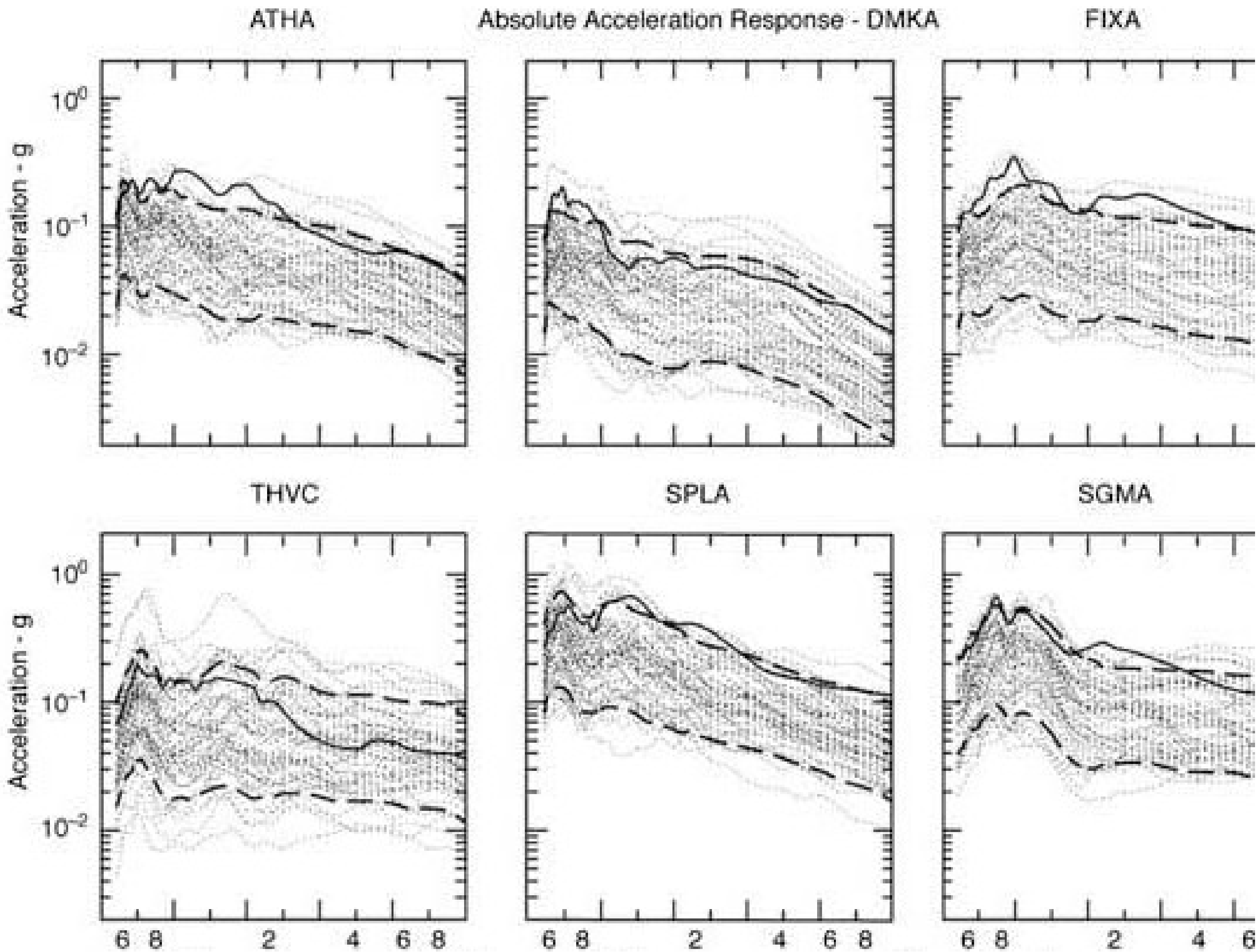
Use of Numerical Simulations in PSHA

- Advantages (cont)
  - More complete sampling of earthquakes
    - Empirical models are based on just a small set of earthquakes that were recorded by strong motion networks
    - Numerical simulations can sample a complete distribution of earthquakes
      - Earthquakes that have not yet been recorded by strong motion networks can be included
      - May increase the variability

Hutching et al (2007)

- Example site with hazard dominated by a single source
  - M6 earthquake
- Empirical GF Method
- Multiple realizations (500) of the M6 earthquake with variability in source parameters
  - Rupture geometry (area and aspect ratio)
  - Strike, Dip, Rake
  - Slip distribution (asperity size and number)
  - Hypocenter
  - Rupture roughness
  - Rupture velocity
  - Healing velocity

Example: Variability from Numerical Simulations



57 M6 eqks at a single location

(Hutching et al 2007)

Dashed Lines Show ± 1 sigma Including modeling uncertainty

Why Increased Sigma from FFS?

- Empirical data under-estimates sigma
  - Sparse sampling of earthquakes in empirical set does not represent all future earthquakes
- FFS over-estimates sigma
  - Too much variability in the source parameters
    - Not accounting for correlations of the source parameters that reduce variability?

Inputs for Kinematic FFS

- Distributions of Inputs for Kinematic models
  - Generally based on marginal distributions for individual source parameters developed from source inversions
- Improving constraints on source parameter distributions
  - Focus on joint distributions
    - Avoid combinations of source parameters that are not physically realizable
  - Use dynamic rupture models to develop suites of source models for future earthquakes
  - Parameterize into kinematic model inputs
  - Run suites of kinematic simulations

Inputs for Kinematic FFS

- Two Approaches for Inputs for Kinematic models based on dynamic rupture models
  - 1. Use the sources from dynamic rupture runs directly
    - More direct, but requires dynamic rupture calculations for each case
  - 2. Parameterize the sources into statistical models of the source parameters including correlations
    - Develop a kinematic source parameter generator
      - Avoids having to run the dynamic rupture model for each realization
      - Short-coming: model excluded super-shear ruptures

Use of Dynamic Rupture Models

- Addresses issue of correlation of kinematic source parameters
- Adds new problem:
  - Need to specify the distributions for inputs to the dynamic rupture models
  - Topic of today’s workshop

Approach for ExGM project

- Objective
  - Use numerical simulations for M6.5 normal faulting earthquake
    - Estimate median ground motions
    - Estimate the distribution of ground motions
    - Range of frequencies: 0.02 sec (50 Hz) to 5 sec
- Approach
  - Kinematic models will be used to generate broad-band ground motions
  - Use dynamic rupture models to specify the suite of correlated source parameters for kinematic runs
    - 50-100 cases
    - Use dynamic rupture models directly, not a statistical model
  - Parameterize the M6.5 results and develop adjusted empirical models (median and distribution) to extrapolate to other magnitudes and distances
    - PSHA requires all magnitudes and distances