Collaborative SCEC/USGS Efforts to Improve Seismic-Hazard Analysis

Edward (Ned) Field
USGS, Pasadena

Plus many others in SCEC!

5th UJNR, 2004

This Talk:

Status of SHA

and what we're doing about it:

RELM

OpenSHA

Status of Seismic Hazard Analysis (SHA)

(1) SHA needs a more physics based approach to modeling.

(2) Lack of consensus means we'll have multiple options.

(3) All viable models need to be considered for "proper" SHA.

(4) SHA needs a computational infrastructure capable of handling a potentially great number of arbitrarily complex models

(a "Community Modeling Environment").

Goal of SHA:

The probability that some

"Intensity-Measure Type"

(e.g. Spectral Acceleration)

will exceed a specified

"Intensity-Measure Level"

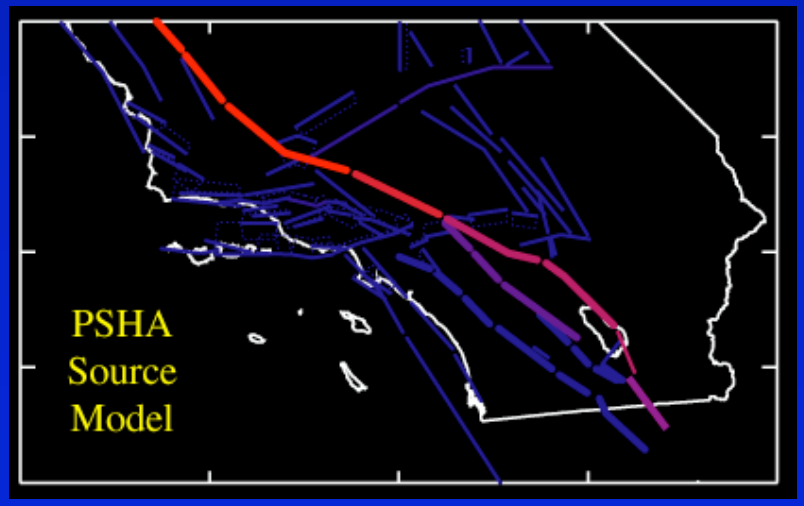
(e.g. 0.5 g)

$$\left[\; Prob(IMT \geq IML) \; \right]$$

SHA has two model components:

(1) Earthquake-Rupture Forecast (ERF)

Probability of all possible fault-rupture events (M≥~5) for region & time span



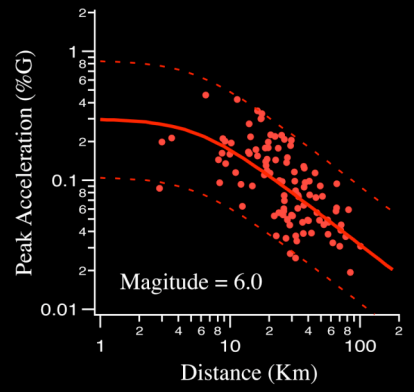
(2) Intensity-Measure Relationship (IMR)

Gives Prob(IMT≥IML) for a given site and fault-rupture event

Attenuation Relationships

(traditional)

(no physics)

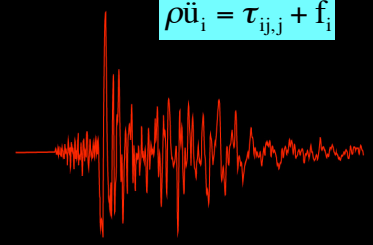


Full-Waveform Modeling

(developmental)

(more physics)

$$\rho \ddot{u}_i = \tau_{ij,j} + f_i$$

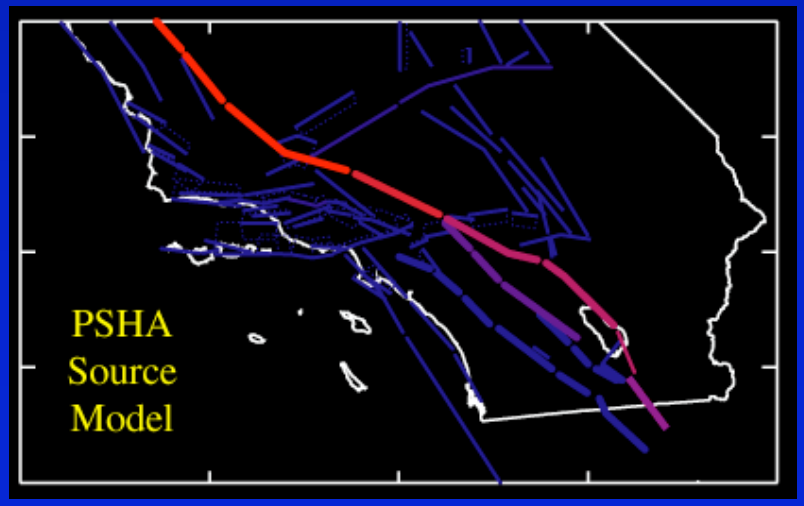


$$\tau_{ij} = \lambda \delta_{ij} \varepsilon_{pp} + 2\mu \varepsilon_{ij}$$

More physics & multiple models:

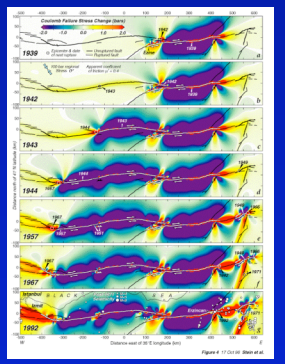
(1) Earthquake-Rupture Forecast (ERF)

Probability of all possible fault-rupture events (M≥~5) for region & time span



The model used in our National Hazard Maps assumes that each earthquake rupture is completely independent.

Others see time-dependent effects and interactions:



(Stein & Others)

No consensus on how to build these types of models.

Thus, the ***RELM*** working group is developing a variety (more later).

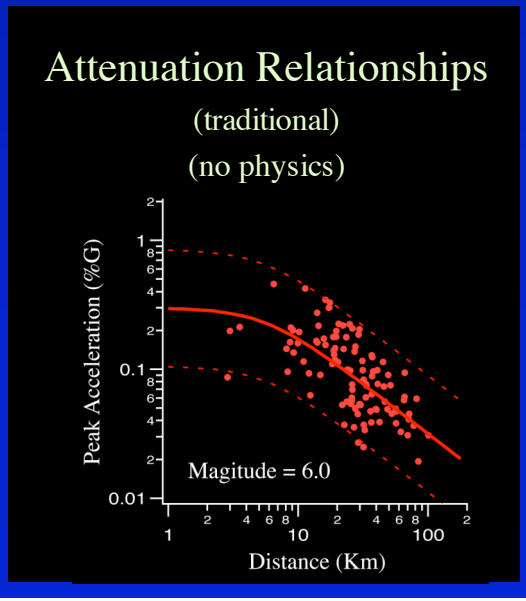
More physics & multiple models:

(2) Intensity-Measure Relationship (IMR)

Inherent limits with respect to accuracy (SCEC Phase III report).

Gives Prob(IMT≥IML) for a given site and fault-rupture event

Lack of physics can lead to non-physical results (e.g., a mean PGA of 14 g predicted for the Yucca Mt Repository).



More physics & multiple models:

(2) Intensity-Measure Relationship (IMR)

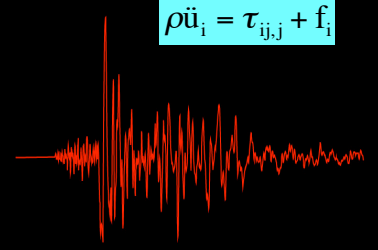
Gives Prob(IMT≥IML) for a given site and fault-rupture event

Potentially more accurate, but …

Computation limits with respect analyzing many scenarios, high frequencies, and uncertainties associated with the structural model and slip distribution.

Full-Waveform Modeling
(developmental)
(more physics)

$$\rho \ddot{u}_i = \tau_{ij,j} + f_i$$



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More physics & multiple models:

(2) Intensity-Measure Relationship (IMR)

Next Generation Attenuation (NGA) relationship project

(including hybrids)

Gives Prob(IMT≥IML) for a given site and fault-rupture event

Attenuation Relationships

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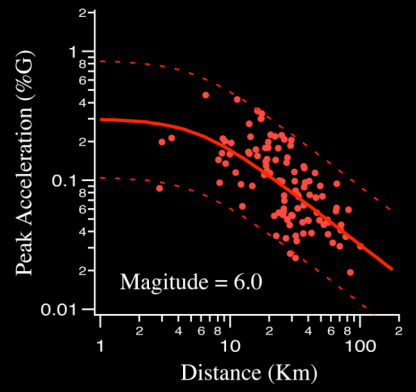
(no physics)



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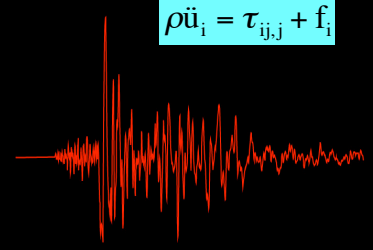

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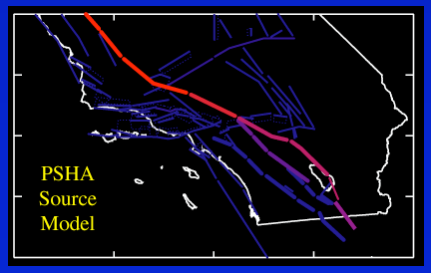
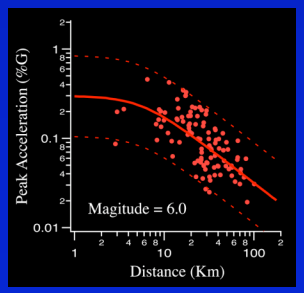
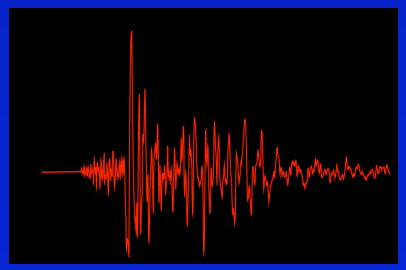
RELM



NGA



Many working on this.



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(3) All viable models need to be considered for "proper" SHA (SSHAC Report, 1995)

To account for epistemic uncertainties in the hazard estimate.

We have yet to achieve this.

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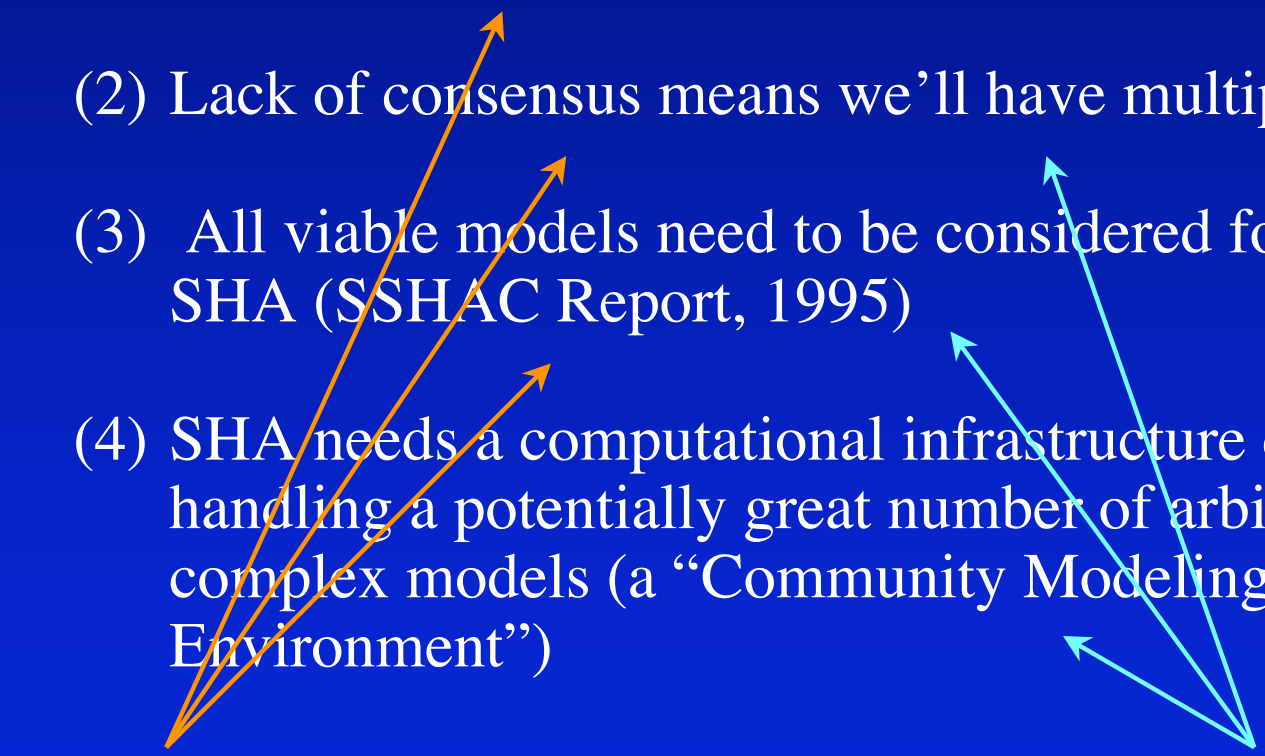
(4) SHA needs a computational infrastructure capable of handling a potentially great number of arbitrarily complex models (a "Community Modeling Environment")



RELM

***OpenSHA* & ITR CME**

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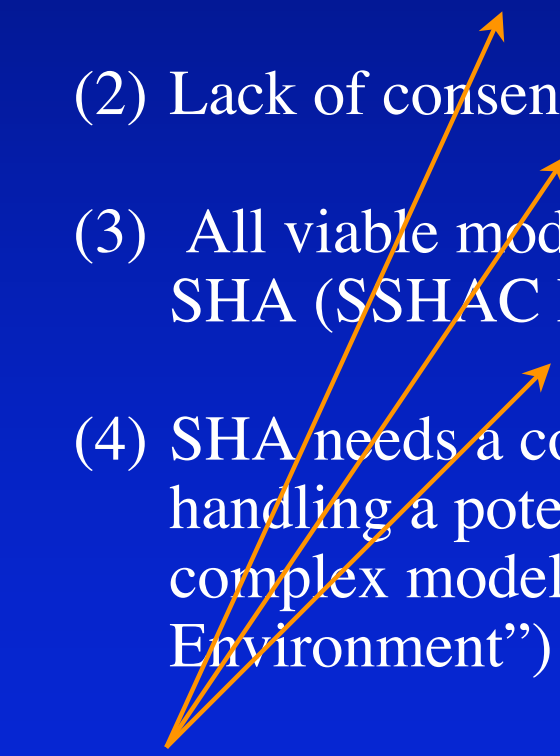

RELM

RELM

A Southern California Working Group

for the Development of

Regional Earthquake Likelihood Models

(Earthquake-Rupture Forecasts)

SCEC

USGS
science for a changing world

RELM

Goals:

(1) To develop a range of viable, potentially physics-based earthquake-rupture forecast models (not just one "consensus" model).

(2) To test these models against existing & future geophysical data.

(3) To examine the seismic hazard implications of each model , which will help …

- achieve proper SHA in terms of defining uncertainties
- identify research topics needed to reduce these uncertainties
- identify which models are exportable to regions where options are fewer

RELM models slated for publication (e.g., in *BSSA*)

Blanpied et al.	The WGCEP-2002 model for the San Francisco Bay area
Petersen et al.	The California model used in the 2002 USGS/CGS National Hazard Maps
Ward	Different Models Based on Geologic, Seismic, and Geodetic Constraints.
Jackson & Kagan	An Earthquake Rupture Forecast Based on Smoothed Seismicity
Shen & Jackson	An Earthquake Rupture Forecast Based on the Geodetic Strain-rate Field
Field et al.	The SCEC ERF – A WGCEP-type model that is system level, accounts for stress/seismicity changes, and can adapt in near real time (living).
Liu & Bird	A Time-Independent Forecast Based on NeoKinema
Wiemer, et al.	Asperity Based Likelihood Models (ALMs).
Bowman et al.	A Model that Incorporates Accelerating Moment Release and Coulomb Stress Change
Tiampo et al.	A Earthquake Forecast Based on Pattern Informatics (previously known as PDPC)
Gerstenberger et al.	Short-Term Earthquake Probability (STEP) model
Helmstetter et al.	Epidemic Type Aftershock Sequence (ETAS) model
Helmstetter & Dieterich	A Forecast Based on Observed Seismicity Rate Changes and Rate & State Friction
Ward	Standard Physical Earthquake Model for Southern California (simulation based model).
Rundle et al.	The Virtual California Earthquake Simulation Model

see: **www.RELM.org**

other *RELM* elements (e.g., in *BSSA*)

Papers on Supporting Developments

Plesch, Shaw et al.	Formalization of Alternative Fault-System Representations from the SCEC Community Fault Model
Dolan	A Synoptic View of Paleoseismology in the Greater Los Angels Region
Rockwell	A Synoptic Paleoseismic View of on the San Jacinto Fault and the Easter California Shear Zone
Weldon, Fumal, & Biasi	Earthquake Rupture Models for the San Andreas Constrained by Bayesian Analyses of Paleoseismic Data
Perry et al.	The SCEC Reference Geologic Fault Parameters and the Fault Information System (FIS)
Bird et al.	The NeoKinema deformation model based on the SCEC CFM, FAD, and CMM
Hager et al.	Fault Slip Rate Estimates Based on the SCEC Community Block Model (CBM), CMM, and FAD
Powers et al.	Stress Change Calculators
Maechling et al.	The SCEC, distributed Community Modeling Environment (CME) and its support of the RELM working group

Papers on Evaluations/Implications of the Models

Schorlemmer , Wiemer, Jackson, Kagan, Helmstetter, & Gerstenberger (order?)	Standardized, Web-enabled Tests for any Earthquake-Rupture Forecast, and Their Application to *RELM* Models
Bowman et al.	Testing Arbitrary *RELM* Forecast Scenarios for Accelerating Moment Release
Stirling et al.	Use of the Historical Intensity Data & Precarious Rocks to Test Probabilistic Seismic Hazard Models
Field et al.	Evaluation of Hazard Implications of the Various *RELM* Models Using *OpenSHA*
Seligson & Campbell	Risk/Loss Implications of the *RELM* Models (*OpenSHA* → *HAZUS*)
A panel of independent, authoritative experts	Evaluation of *RELM* Models for Practical Use (independent evaluation of the complete suite of models); this could constitute the next 200X WGCEP

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This effort may get replaced by a CEA-supported statewide effort

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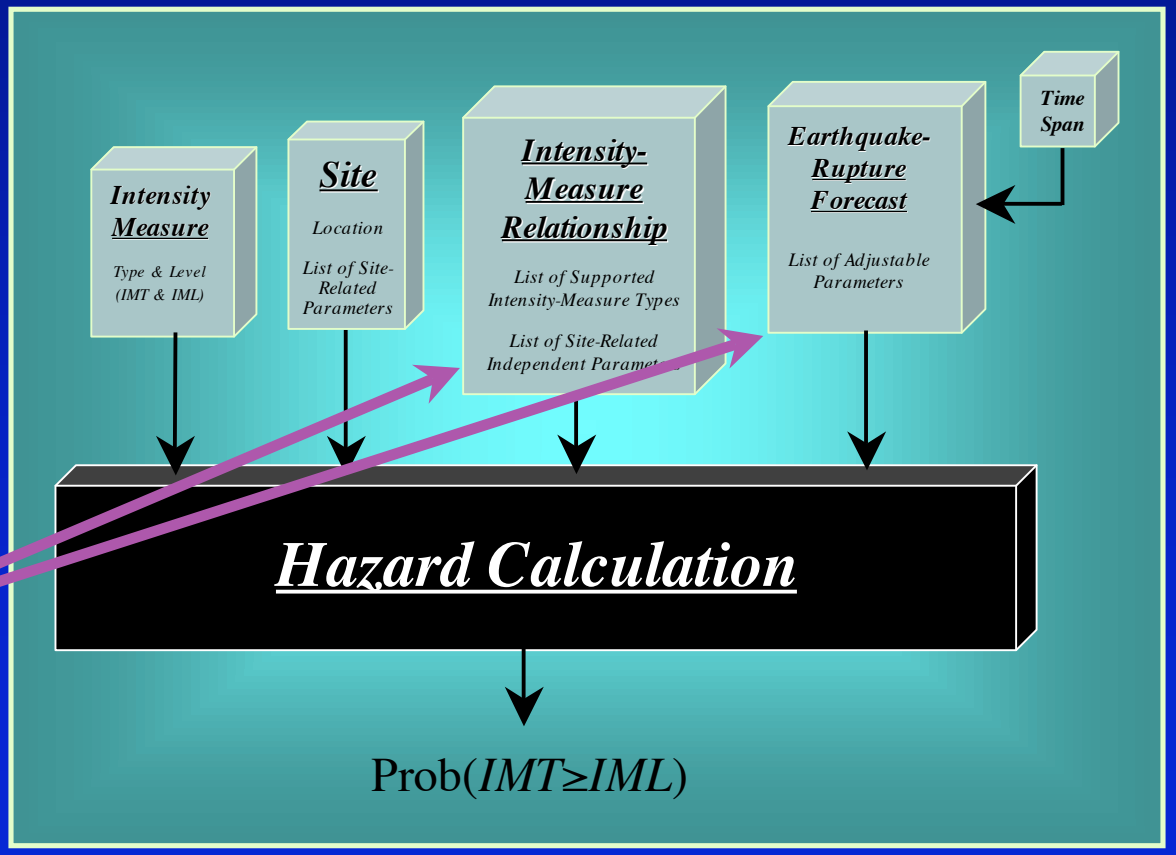
OpenSHA & ITR CME

OpenSHA:

A framework where any arbitrarily complex (e.g., physics based) SHA component can "plug in" for end-to-end SHA calculations.

- open source
- object oriented
- platform ind.
- web/GUI enabled
- distributed (potentially)
- Java (or wrapped code)
- validated

Any IMR or ERF can be plugged in



OpenSHA:

SHA Models Implemented:

Intensity-Measure Relationships
(Attenuation Relationships)

Boore et al. (1997)
Abrahamson & Silva (1997)
Campbell (1997)
Sadigh et al. (1997)
Field (2000)
Abrahamson (2000)
Campbell & Bazorgnia (2003)
ShakeMap (2003)
SEA (Spudich et al., 1999)
USGS Combined (2004)
Wells & Coppersmith (1994)

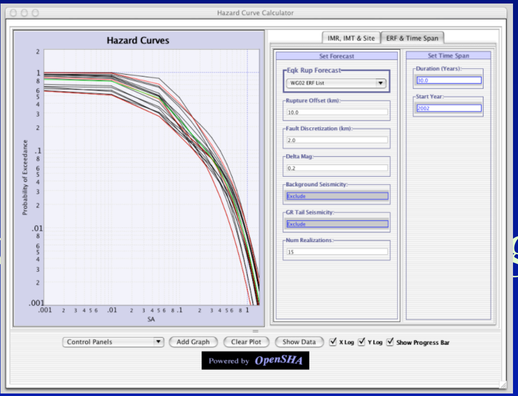
Earthquake Rupture Forecasts

PEER Area
PEER Non-Planar Fault
PEER Multi-Source
PEER Logic Tree
Poisson Fault ERF
Fault Rupture ERF
USGS/CGS (1996)
STEP So. Cal. (2003)
STEP Alaska Pipeline (2003)
WGCEP (2002)
USGS/CGS (2002)

OpenSHA:

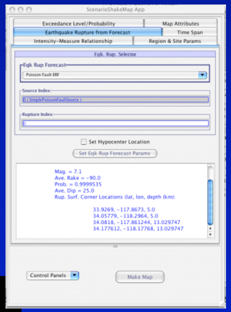
Applications Available:

1) Hazard Curve Calculator *(to anyone from ... g)*



curves for WGCEP-2002

2) Scenario ShakeMap Calculator



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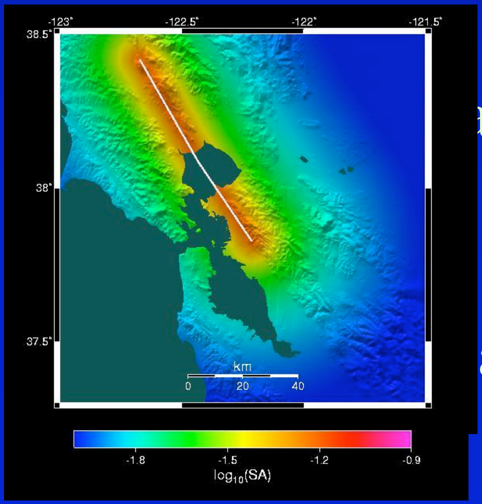
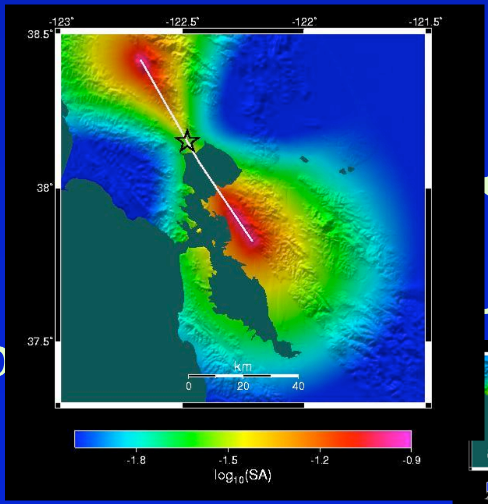
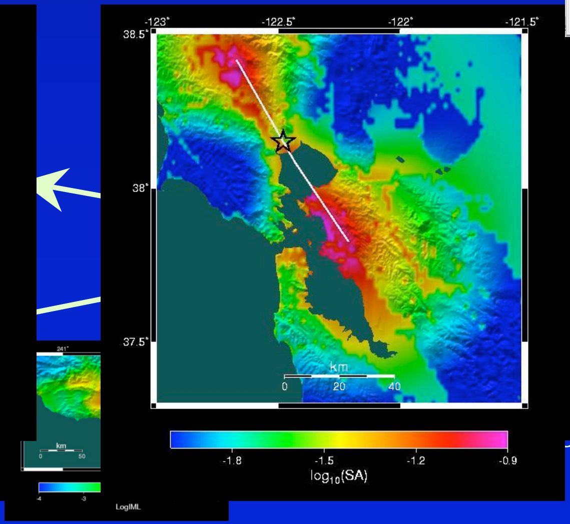






Advanced IT Elements:

(made possible by the SCEC ITR collaboration)

A) Components can be geographically distributed (using web-services and distributed object technologies)

1. Wills et al. (2000) map and CVM (for setting site types)
2. GMT Map Making Service
3. Earthquake Rupture Forecasts (ERFs):

Makes applications lightweight and puts maintenance onus on the host.

e.g., WGCEP-2002 Forecast as wrapped Fortran Code

Advanced IT Elements:

(made possible by the ITR collaboration)

A) Components can be geographically distributed (using web-services and distributed object technologies)

B) GRID computing for full hazard maps

Idle UNIX workstations in USC's Condor pool are used to get the job done faster (by more than an order of magnitude).

Advanced IT Elements:

(made possible by the ITR collaboration)

A) Components can be geographically distributed (using web-services and distributed object technologies)

B) GRID computing for full hazard maps

C) Digital libraries used to store large datasets.

OpenSHA Impact:

1. Code validation via PEER PSHA Working Group
2. More flexible option to the "official" USGS ShakeMaps
3. Scenarios computed for M 7.1-7.5 Puente Hills (→ HAZUS); paper submitted
4. Fault-offset probability computed for Alyeska at the Alaska Oil Pipeline
5. Hazard calculations for the WGCEP-2002 Earthquake Rupture Forecast (forthcoming paper)
6. Hazard calcs for the USGS Short-Term Earthquake Probability (STEP) maps
7. Paper on hazard-map comparison for So. Cal. using different attenuation relations. (also discussing GRID computing)
8. PEER PSHA test-cases result submission/comparison
9. HAZUS study of >100 WG02, Bay-Area scenarios (Reasenberg)

In Summary:

OpenSHA

+

other SCEC/ITR elements

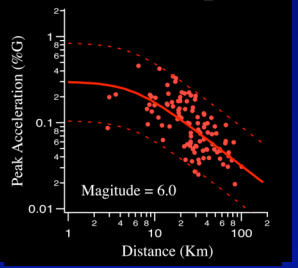
=

CME for SHA

enabling the use of more physics-based approaches and multiple models as needed for improved seismic-hazard

OpenSHA:

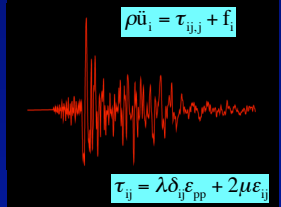
Attenuation Relationships

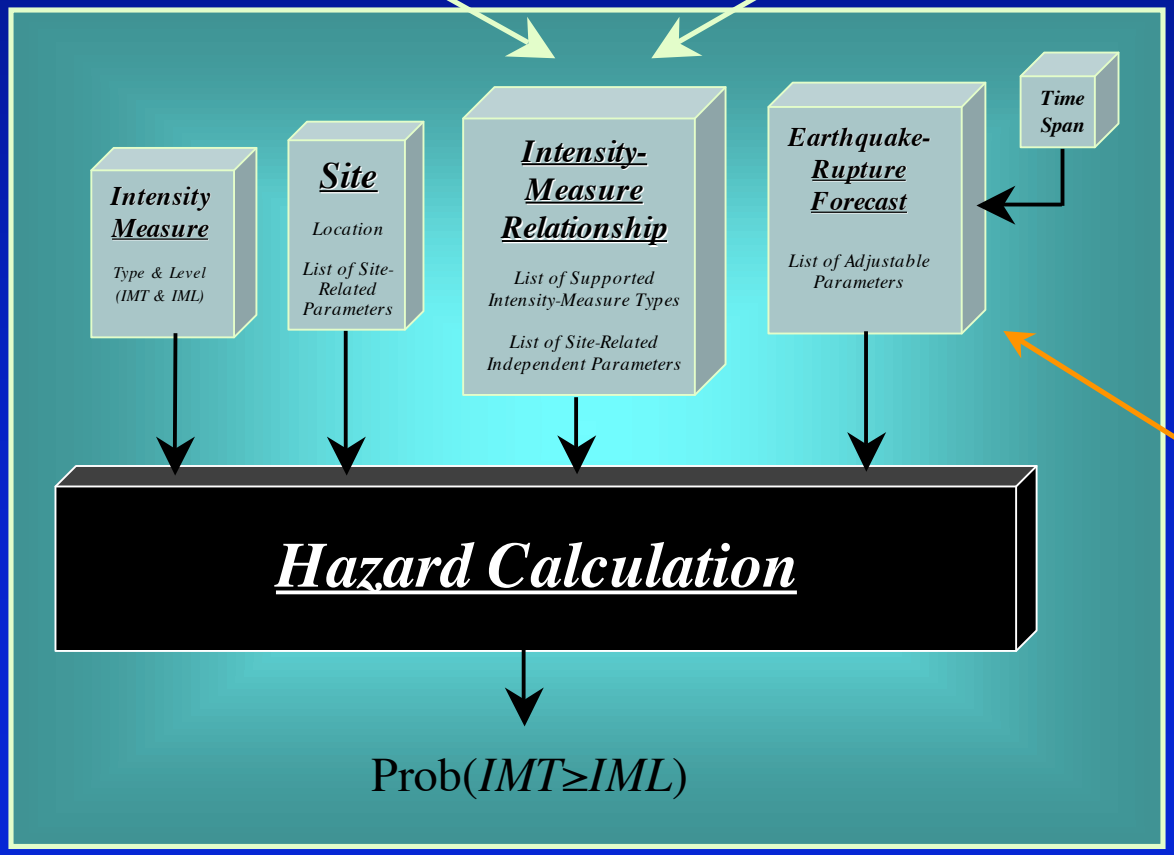


"Pathway 1" or "Pathway 2"

NGA models next

Full-Waveform Modeling





RELM models