Note: All names mentioned in the following slides are USGS scientists, unless noted otherwise.

Highest hazard

Lowest hazard

NSHMP 2023 50-State NSHM Update - Kickoff Meeting

The National Seismic Hazard Model Project (NSHMP)

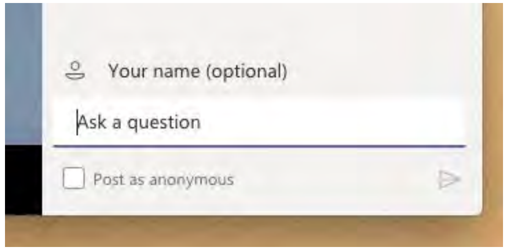
Virtual Meeting (Microsoft Teams Live Event) – January 22, 2021

10:00 am – 12:00 pm MST

U.S. Department of the Interior
U.S. Geological Survey
Geologic Hazard Science Center (Golden, CO)
https://www.usgs.gov/natural-hazards/earthquake-hazards/hazards

Microsoft Teams Live Event

- Unlike a Microsoft Teams Meeting, with a Live Event, the presenters are unable to hear or see participants. **You will need to use the Live event Q&A feature to ask a question. Please type your full name when asking a question.**
- Feel free to enter questions throughout the meeting. If there are a few minutes left after a presentation, we will try and answer a few questions related to that presentation. Note: There is about a 20 second delay between presenters and the Live stream.
- We have reserved time at the end of the meeting for general Q&A.
- Tip: You can go back in the recording if you missed something. Just remember to hit the "Live" button to return to the live presentation.
- A recording of this Live Event will be available shortly after the Live Event has ended. We also plan to post it on our website.
- Please visit our website for up-to-date information on timelines and workshops! https://www.usgs.gov/natural-hazards/earthquake-hazards/hazards



Agenda

10:00 – 10:20 am **Overview (*M. Petersen*)**

Update Timeline

List of Potential Updates

List of Regional/Topical Workshops

Review Process

Implementation and Products (*P. Powers*)

10:20 – 10:45 am **Earthquake Rupture Forecast (ERF) (*N. Field*)**

Overall Goals

Disciplinary Groups

Model Construction

10:45 – 11:10 am **Ground Motion Model (GMM) (*M. Moschetti*)**

GMMs

Site Effects

11:10 – 11:25 am **Alaska and Hawaii NSHMs (*P. Powers and M. Petersen*)**

11:25 – 11:40 am **Engineering & Risk (*N. Luco*)**

Building Code

Risk

Scenarios

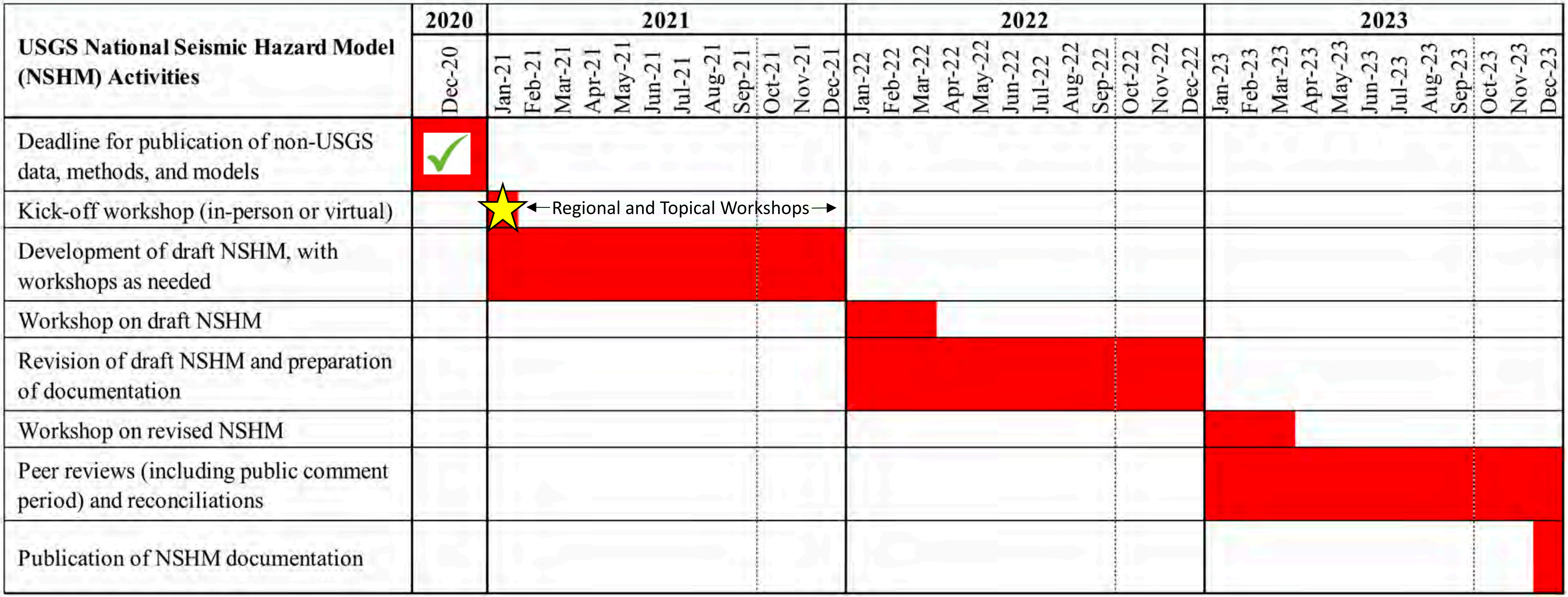
11:40 – 12:00 pm **Discussion (*A. Shumway*)**

Other data, models, or methods we should consider?

Comments and Questions from Teams Live Q&A

12:00 pm **Adjourn**

2023 NSHM Update Timeline



https://www.usgs.gov/natural-hazards/earthquake-hazards/science/request-hazard-modeling-contributions?qt-science_center_objects=0 - qt-science_center_objects

Priority Updates ("Top 10" List)

1. Address issues that we didn't have enough time to assess or implement in the last model (e.g., basin amplifications, non-linearity in CEUS GMMs).
2. Apply better and more comprehensive representations of epistemic uncertainties and aleatory variability and evaluate their impact on hazard and risk (e.g., additional epistemic uncertainty applied in GMMs, nonergodic GMMs).
3. Apply more uniform methodologies across all regions, except where regionalization is clearly justified (e.g., catalogs, basin response).
4. Improve earthquake rupture forecasts by relaxing segmentation, accommodating more multi-fault ruptures, geologic and geodetic constraints, and a broader range of declustering and smoothed-seismicity approaches.
5. Update and improve GMMs (e.g., NGA-subduction, basin effects based on depth, 3D simulations for basins, CEUS/WUS attenuation boundary, directivity, nonergodic GMMs, and shallow site effects).
6. Make long-term forecasts more compatible with other products (e.g., operational earthquake forecasting, loss modeling).
7. Engage users earlier in the model-development process to improve usability, quality control, and overall buy-in. Encourage interactions with engineering communities on construction codes.
8. Develop example scenarios and risk assessments that illustrate impacts of faults, basin effects in urban areas.
9. Continued code development: web services, web applications (e.g., disaggregation), Unified Hazard Tool (UHT) update.
10. Develop two types of models: (1) model recommended for building codes/public policy and (2) research models that consider new or innovative data, models, methods (e.g., time dependence, accounting for full catalog rates).

2021 Regional/Topical Workshops

October 2020
- Coastal Plain Amplification (10/5 and 10/7) – O. Boyd

November 2020
- IMW Geology (11/10) – A. Hatem
- CA Geology (11/12) – A. Hatem
- PacNW Geology (11/17) – A. Hatem
- 2021 Hawaii NSHM (11/18) – M. Petersen

January 2021
- 2023 50-State NSHM Update Kickoff (1/22) - M. Petersen

February 2021
- Cascadia Recurrence (2/23) – A. Frankel, E. Wirth, B. Sherrod, and S. Angster (Seattle, WA)

March 2021
- EERI Annual Meeting Info Session: "Convening Construction-Code Users of the USGS NSHM" - N. Luco and S. Rezaeian
- EERI Annual Meeting Workshop (3/30): "Latest USGS Web Tools for ASCE-7 Site-Specific Ground Motion Hazard Analysis" - P. Powers and N. Luco

April 2021
- SSA Technical Session: "Updating the U.S. NSHMs" - P. Powers et al.
- SSA Technical Session: "Recent Engineering Uses of the NSHMs" - N. Luco et al.

May 2021
- Use Cases/Needs - N. Luco et al.
- Update of the Alaska NSHM (5/25) - P. Powers

June 2021
- NGA-Subduction GMMs for 2023 NSHM – S. Rezaeian

Other Potential Workshops
- Simulated GM/CyberShake - M. Moschetti
- Simulated GM/M9 - A. Frankel and E. Wirth
- CEUS/WUS Attenuation Boundary
- Directivity – K. Withers
- Basin Amplification at Basin Edge Sites – M. Petersen
- Simulation Validation – S. Rezaeian
- Non-Ergodic GMMs for NSHMs

As dates are finalized, information will be posted to our Workshop website:
https://www.usgs.gov/natural-hazards/earthquake-hazards/nshmp-workshops

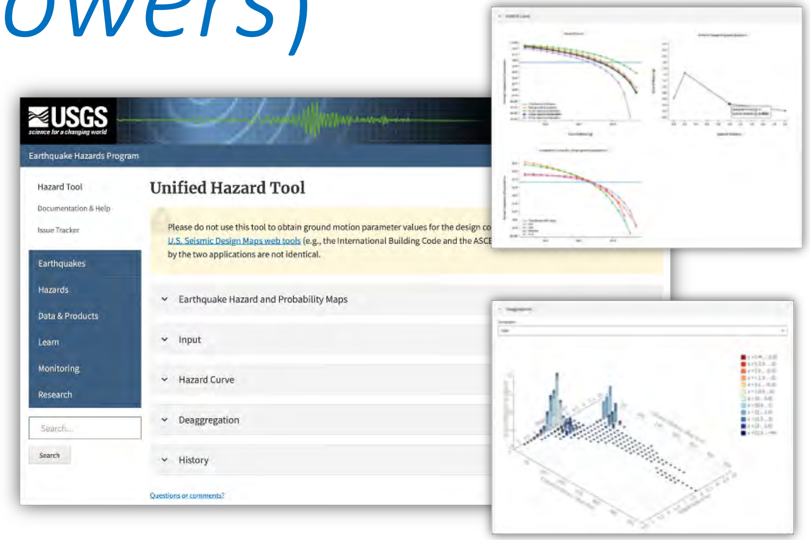
Review Process

- Goal: models account for best science, defensible, mature, collectively exhaustive models
- NSHMP review
- Steering Committee responsible for primary review – they may use others in community to supplement their technical assessment
- Workshops, meetings, and 30-day public review period provide external groups opportunity to suggest new ideas, and input
- *Earthquake Spectra* peer review process
- USGS technical and editorial review process

Implementation and Products (*P. Powers*)

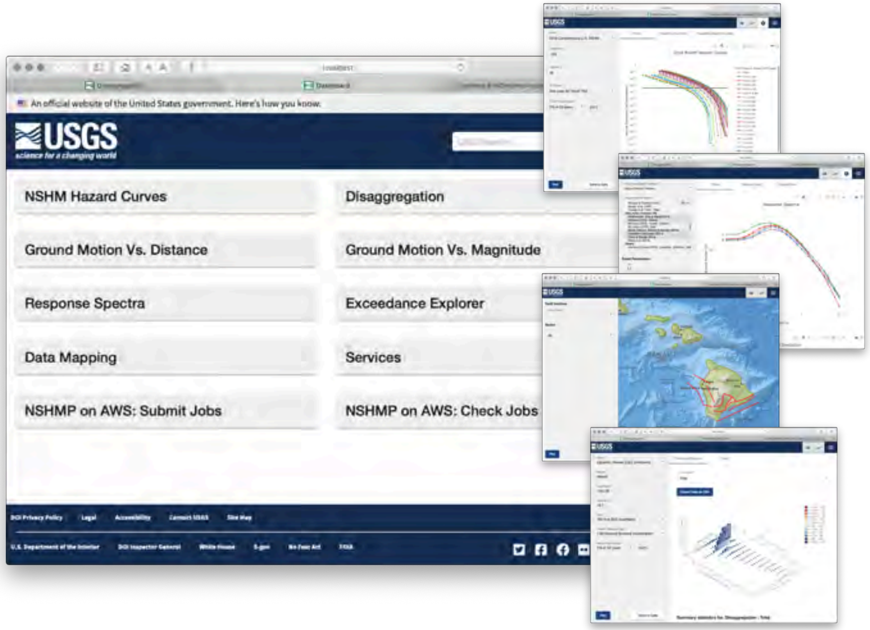
Continued code development

- Automation of model component updates
- Streamlined sensitivity and change testing
- Uncertainty analysis
- Improved logic tree representation and management
- Improved (more uniform) representation of epistemic uncertainty
- Web service architecture: chain hazard to engineering and risk



Update to Unified Hazard Tool (UHT)

- Web application for hazard and disaggregation
- New tools to query ground motion and source models:
  - Response Spectra, Conditional Spectrum
  - Magnitude-Frequency Distributions, Geographic Disaggregation
  - Model Ingredients (fault sources, catalogs), Site Data



Migration to AWS

Earthquake Rupture Forecast (ERF) Development

Edward (Ned) Field

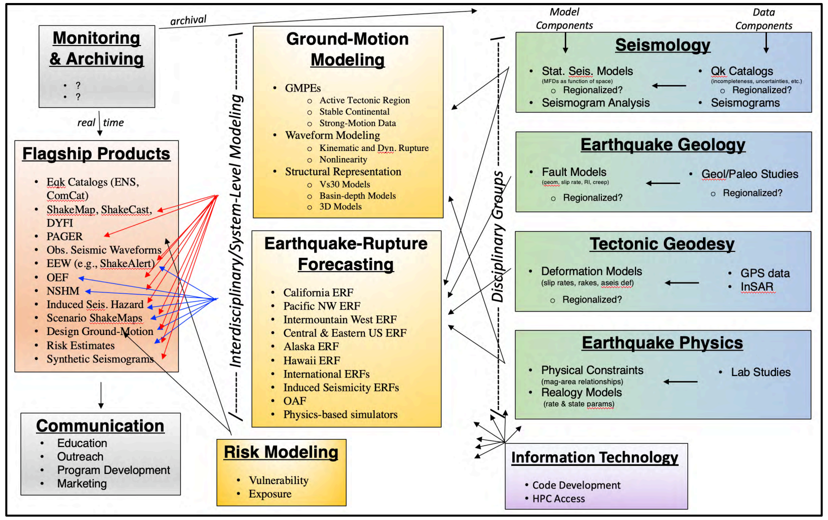
NSHMP 2023 50-State NSHM Update - Kickoff Meeting
Friday, January 22nd, 2021
10:00 am – 12:00 pm MST
Virtual Meeting (Microsoft Teams)

Earthquake Rupture Forecast (ERF) Development

Main Goals:

- Construct a uniform, nationwide long-term ERF
- More comprehensive and consistent representation of epistemic uncertainties
- Prototype nationwide OEF model by 2024 (not just NSHM)

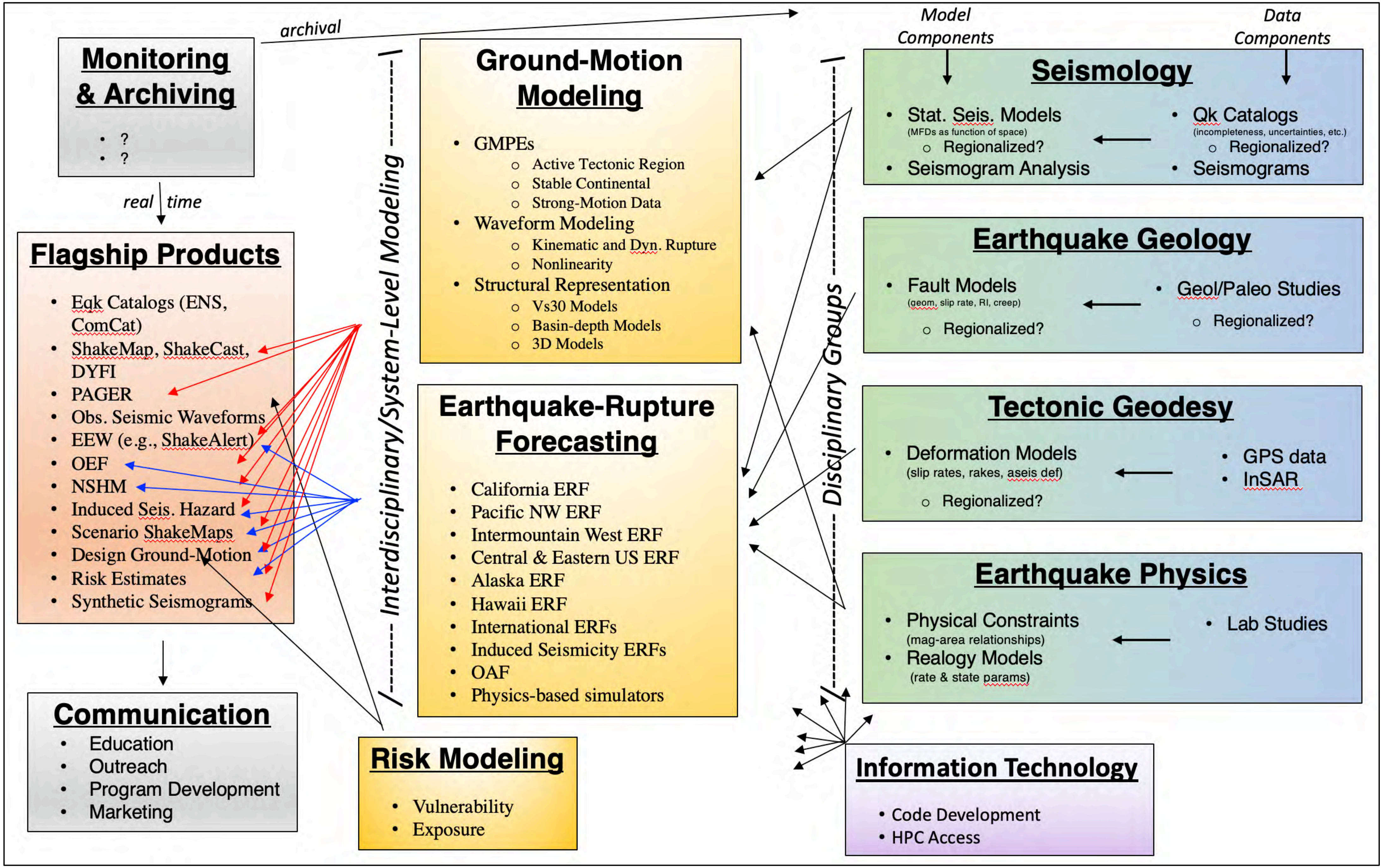
Coordination:



Planning Docs:

- ERF Strategic Plan
  (https://1drv.ms/w/s!AmJyDLFYxbeAab2CIlTt_bW5iME)
- UCERF4 Plan, version 1.0 (applicable to all regions)

Schedule/Gantt:



One way of categorizing scientific activities of the USGS Earthquake Science Program

Our strategic plan calls for a de-regionalization of ERF model development, a broadening of purview from the NSHMP to the Earthquake Hazards Program, and a more disciplinary approach to developing the various model components (rather than different groups building entire models separately for different regions).

This, we believe, will allow us to:

- **Achieve more with less** (including OEF, induced seismicity, physics-based simulators; plus model verification, validation, and valuation)
- Ensure **uniformity across regions** with respect to: best available science & methodologies; assumptions & approximations; products; and epistemic-uncertainty treatment (the latter to illuminate what areas need attention)
- Enable **more frequent and simultaneous updates everywhere** (rather than current triage mode)
- Build **robustness with respect to personnel departures** (by having groups, rather than individuals, building components)

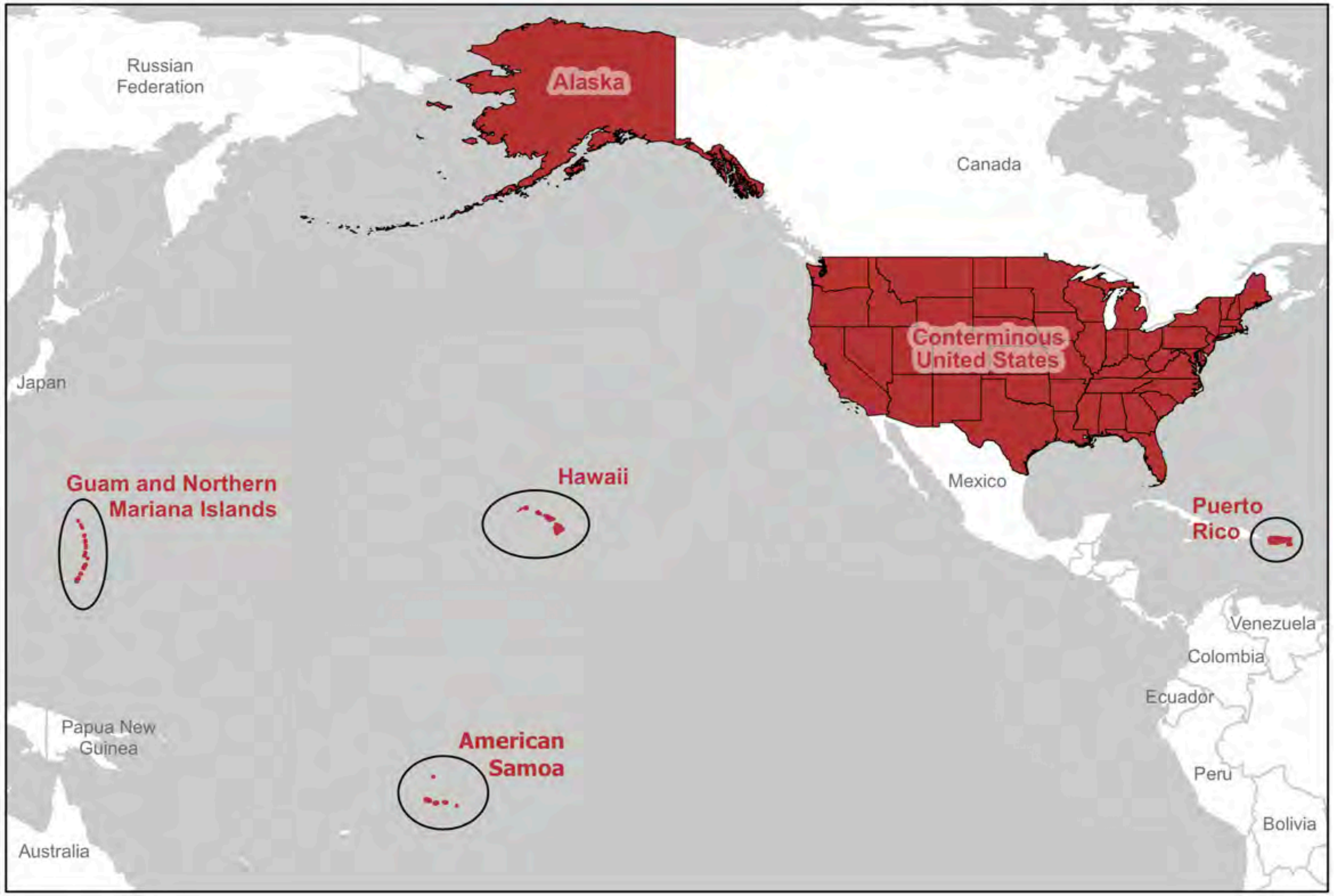
A Strategic Plan for Developing USGS Earthquake Rupture Forecasts

Table of Contents

Some General Issues & Goals:

USGS Regions:

California
Pacific NW
Intermountain West
Central & Eastern US
Alaska
Hawaii
Territories (Puerto Rico & US Virgin Is., Guam & N. Mariana Is., Am. Samoa)



Some General Issues & Goals:

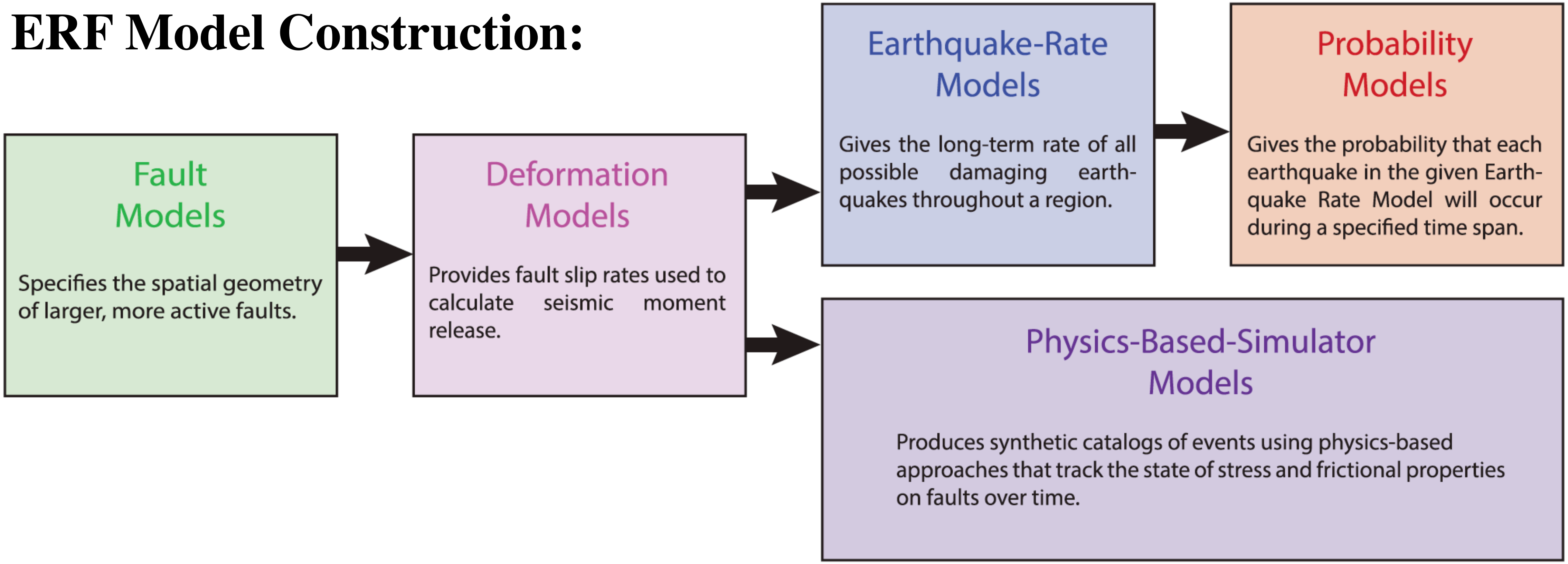
USGS Regions: California
Pacific NW
Intermountain West
Central & Eastern US
Alaska
Hawaii
Territories (Puerto Rico, Guam, Am. Samoa, US Virgin Is., N. Mariana Is.)

Data Paucity at Large Magnitudes Implies:

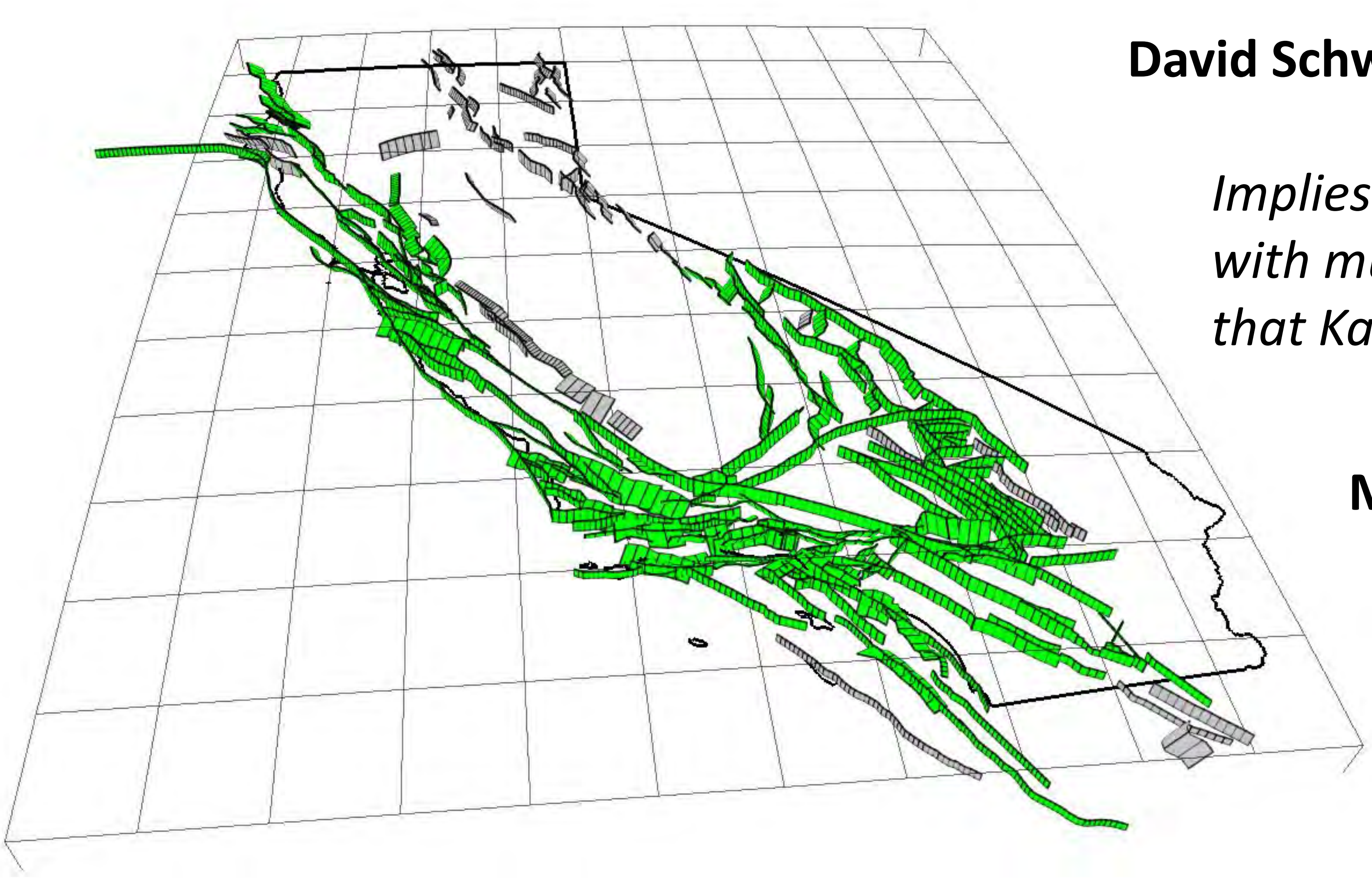
1) We need good epistemic uncertainty representation (ours our currently limited, heterogeneous, and increasing) ***Immediate Priority***

2) We need more physics-based approaches (more efficient utilization of current resources will hopefully allow us to do more here) ***Longer-term Priority***

ERF Model Construction:



Important Goal: alternative branches (epistemic uncertainty) for more and less fault connectivity, in all areas



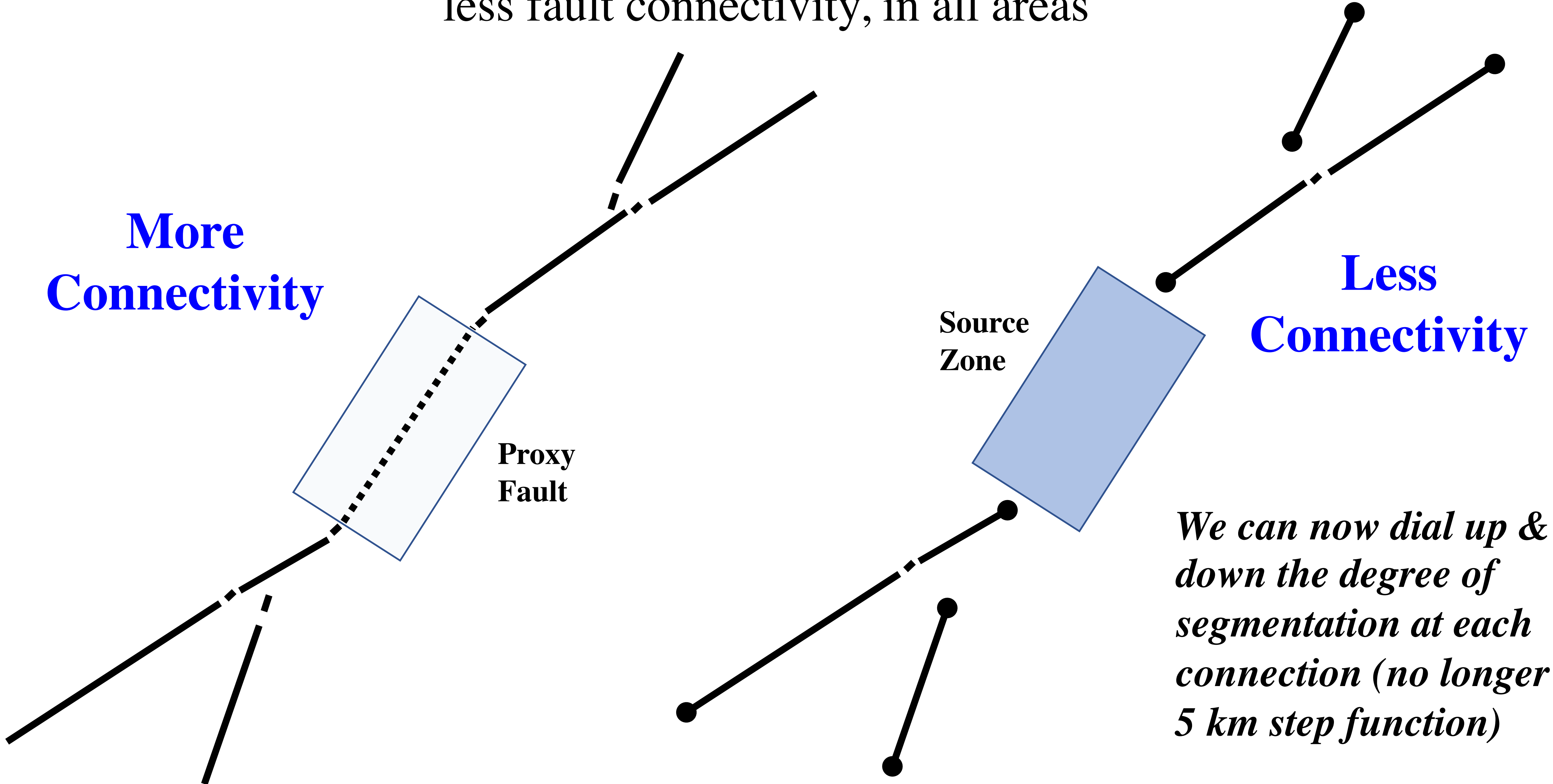
David Schwartz (BSSA, 2018):

Implies UCERF3 went too far with multi-fault ruptures (and that Kaikoura was anomalous)

Morgan Page (BSSA, 2020):

Rebutted that actually "More Fault Connectivity is Needed…"

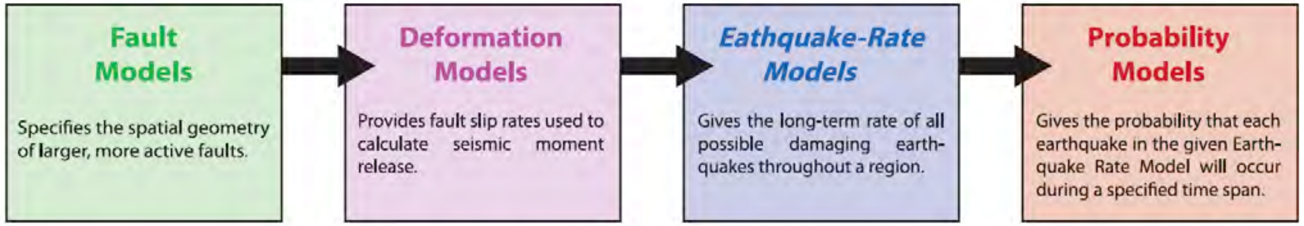
Important Goal: alternative branches (epistemic uncertainty) for more and less fault connectivity, in all areas

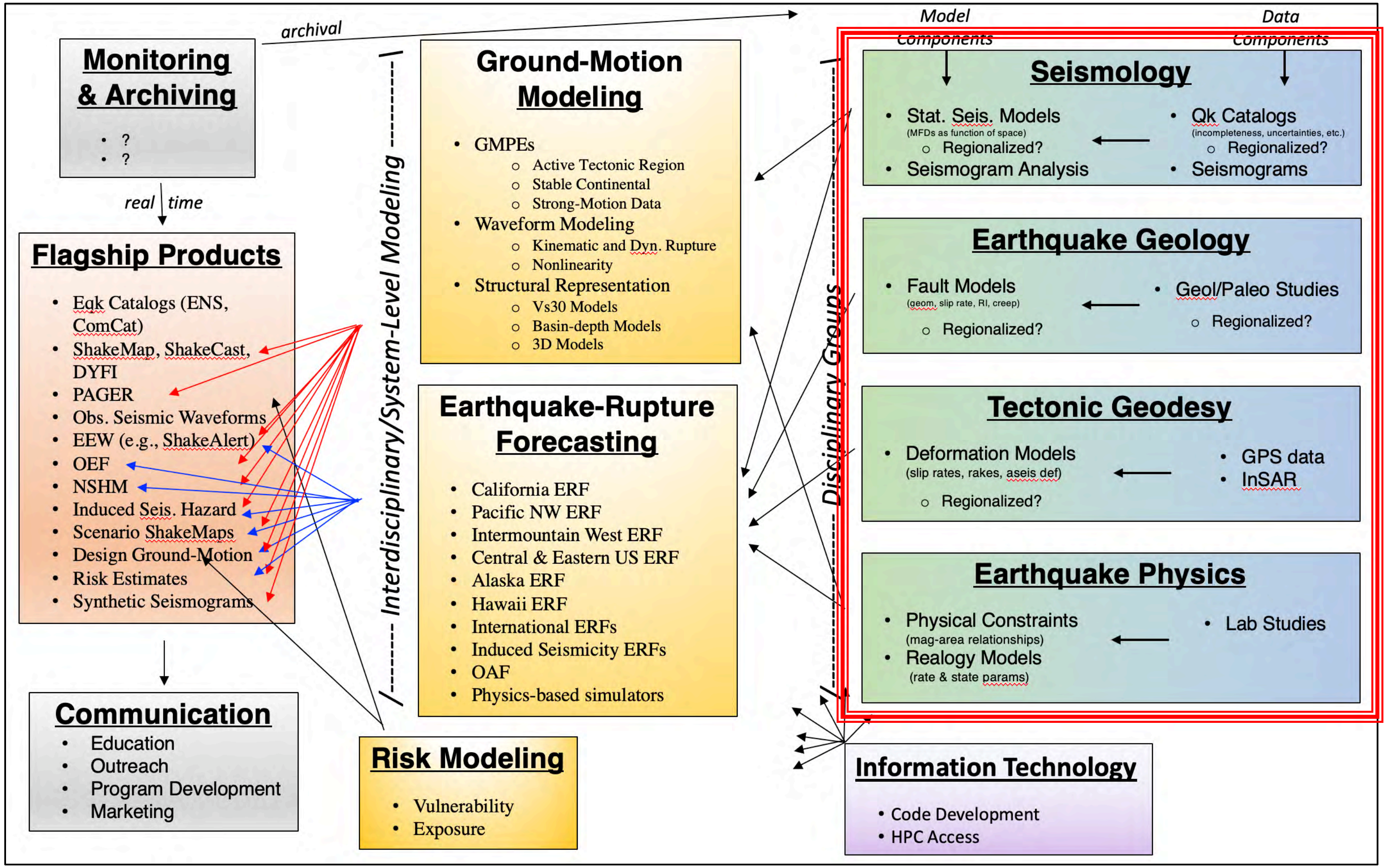


We can now dial up & down the degree of segmentation at each connection (no longer a 5 km step function)

Components from Disciplinary Groups

(& Who's Doing What)





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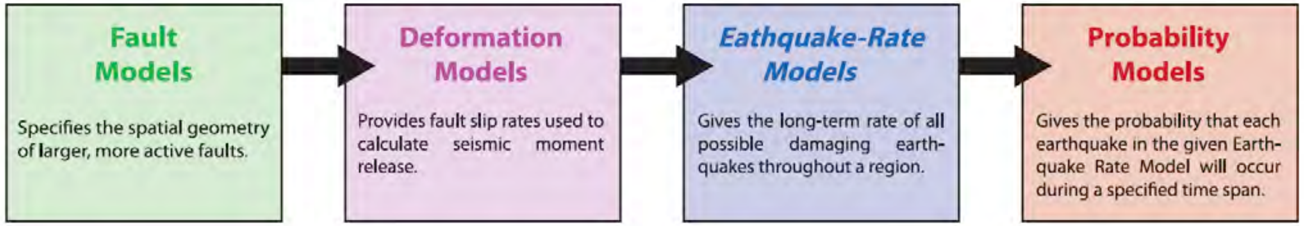
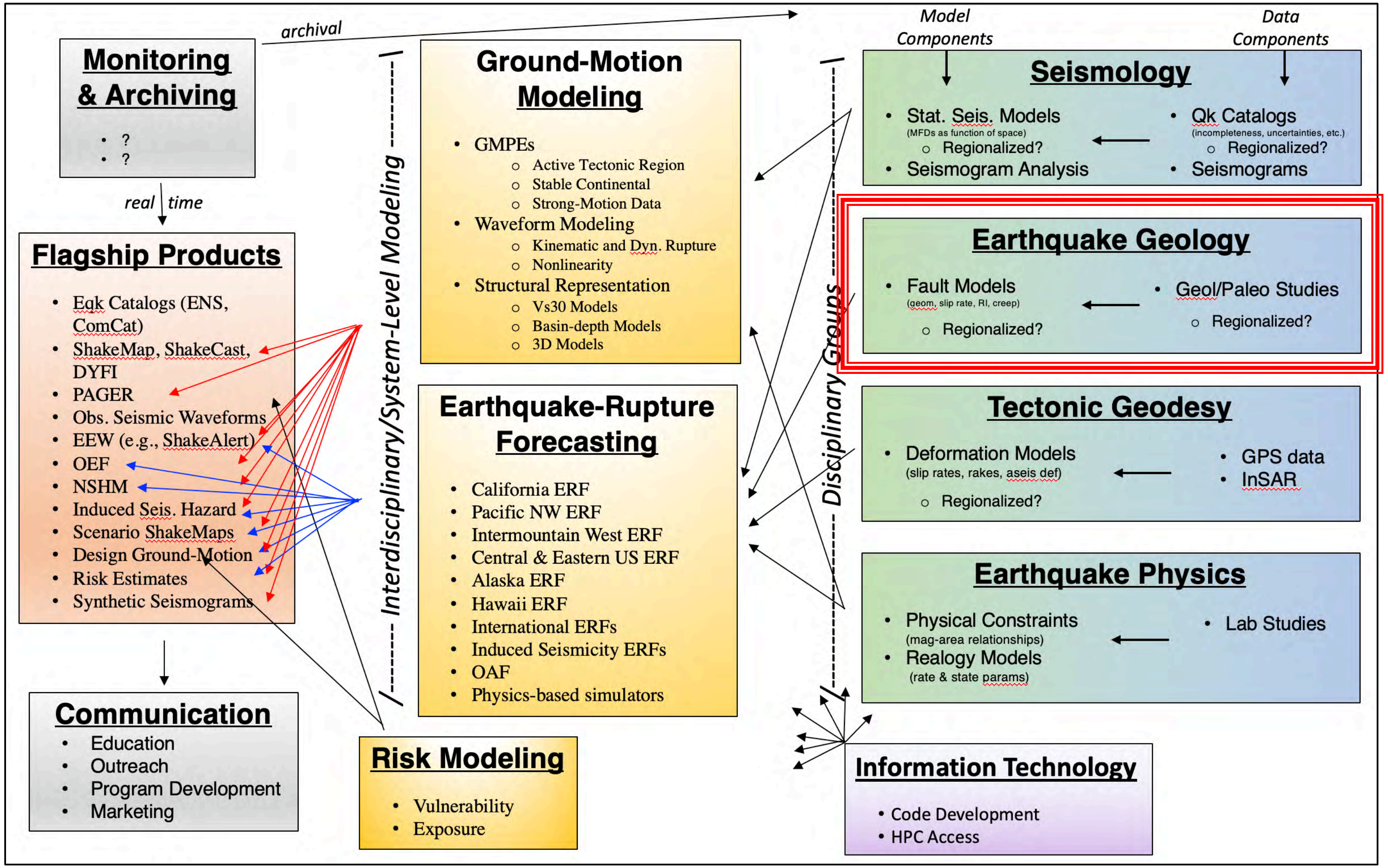


Earthquake Geology

Led by A. Hatem and R. Gold



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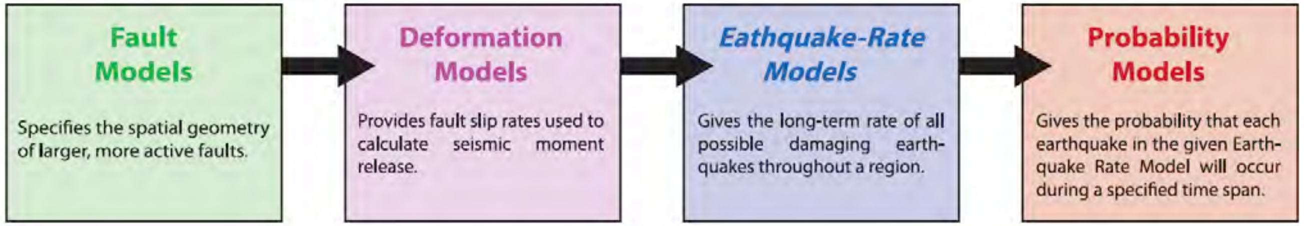

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4) Paleo RI & Prob. of Missed Events (D. McPhillips & K. Scharer)
5) Paleo Ave Slip at Points
6) Geol. Segmentation Constraints (A. Elliott)
7) Database Implementations (P. Powers)

~~Geologic Creep Observations~~

Participants/Contributors:

GHSC (USGS): A. Hatem, R. Gold, R. Briggs, C. DuRoss. C. Collett, P. Powers, J. Jobe, N. Field

ESC (USGS): K. Scharer, D. McPhillips, A. Elliott, K. Knudson, S. Angster, B. Sherrod, P. Haeussler, S. Hecker

Others: T. Dawson (CGS), J. Zachariasen (CGS), R. Weldon (UO), G. Biasi (USGS), A. Bender (USGS), R. Witter (USGS), *and other state representatives*

Components from Disciplinary Groups

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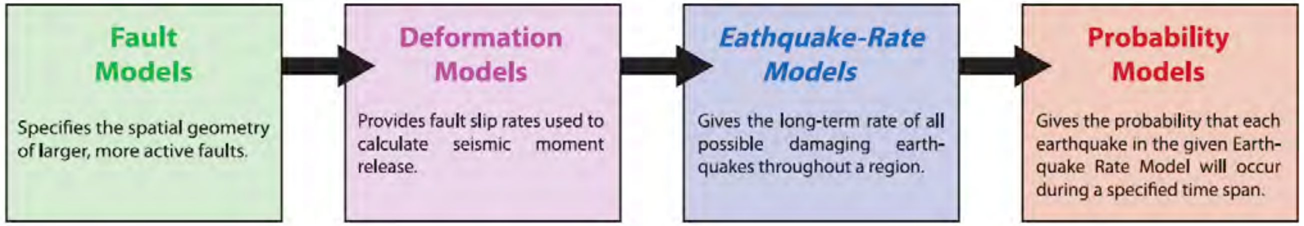

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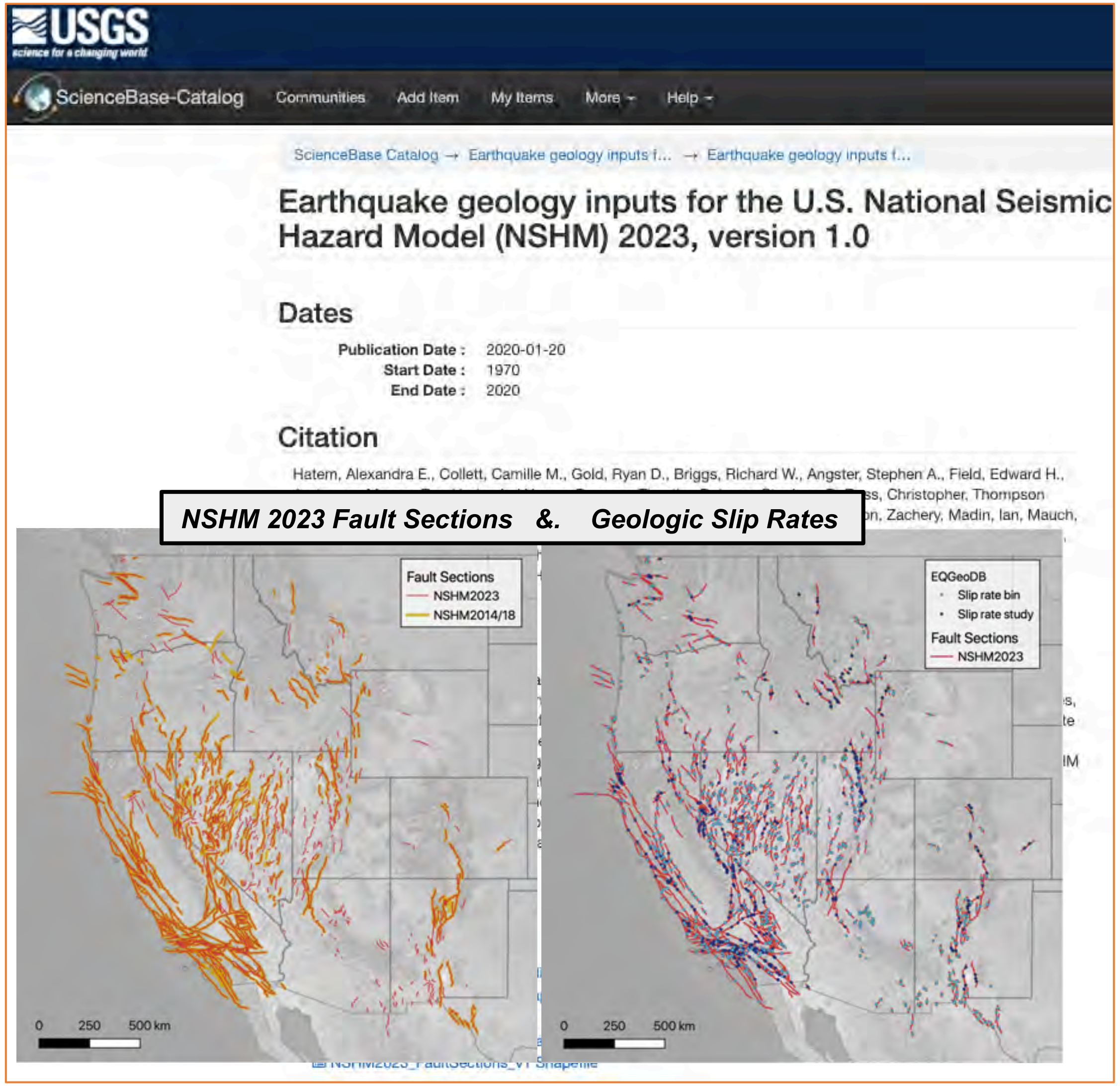

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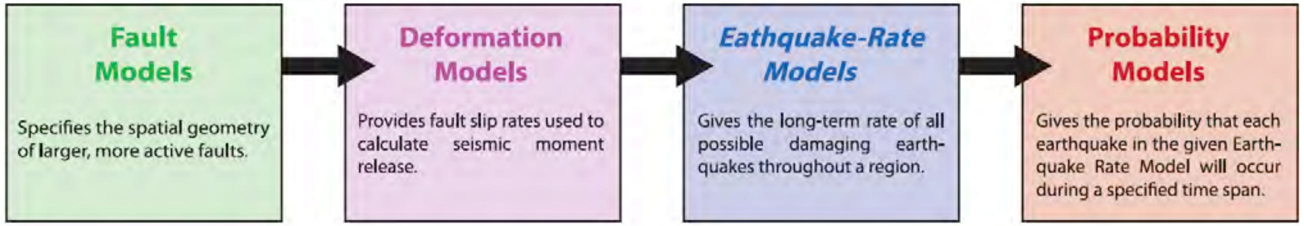
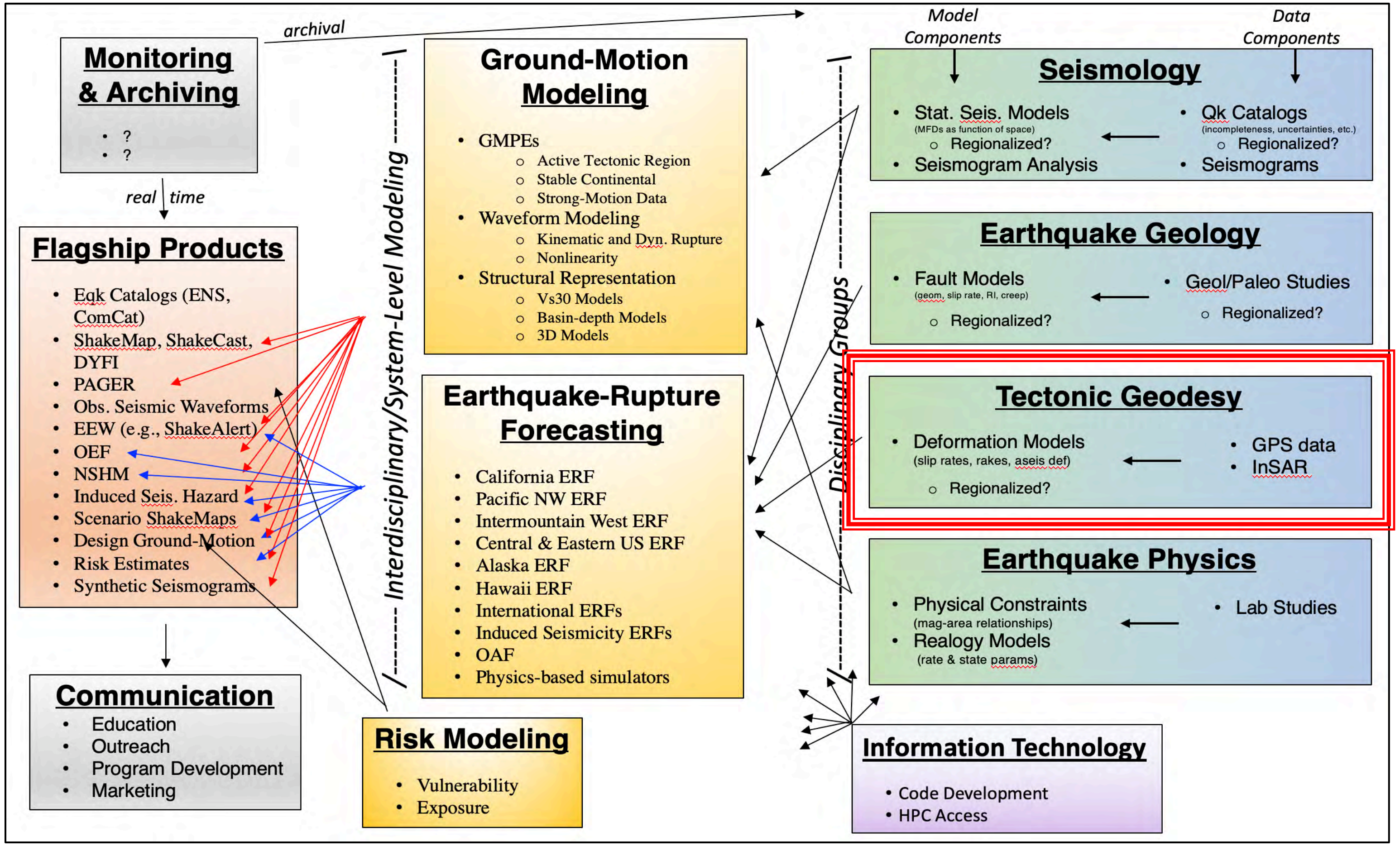


Tectonic Geodesy/Deformation Modeling

Led by Fred Pollitz



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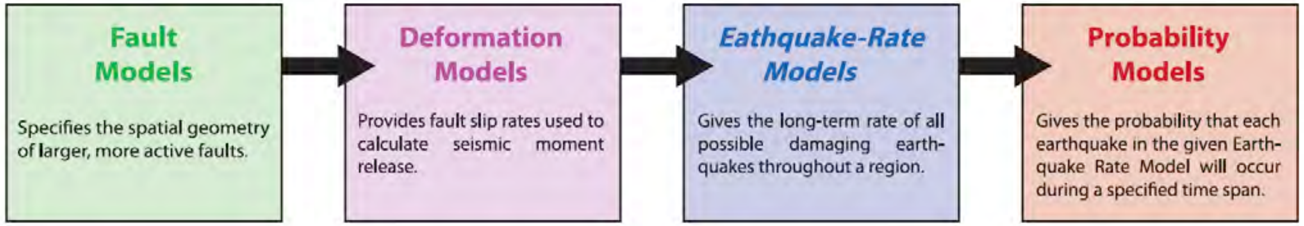

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3) Fault Creep Model (J. Murray/K. Johnson (IU))
4) Ghost Transient Investigations (L. Hearn (Consultant))
5) Any special requirements for use in multi-cycle physics-based simulators?
6) Formal Review (T. Parsons?)

Participants/Contributors:

GHSC (USGS): Y. Zeng, A. Hatem, R. Gold, R. Briggs, P. Powers, N. Field

ESC (USGS): F. Pollitz, J. Murray

Others: Z. Shen (UCLA), J. Elliott (Purdue), E. Evans (CSUN), K. Johnson (IU), L. Hearn, T. Dawson (CGS), J. Zachariasen (CGS), R. Weldon (UO), T. Parsons (USGS)

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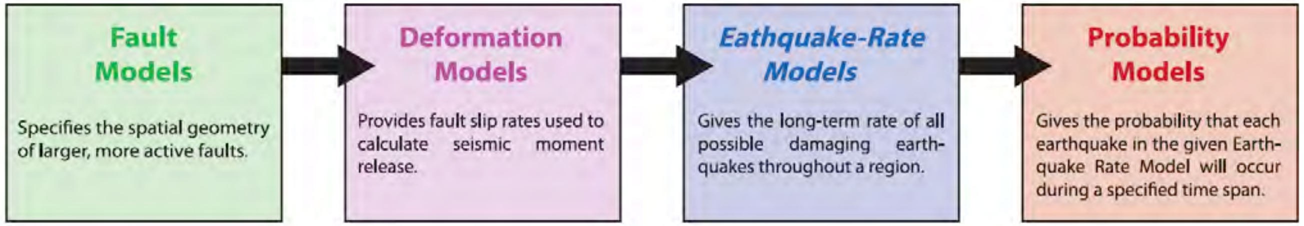

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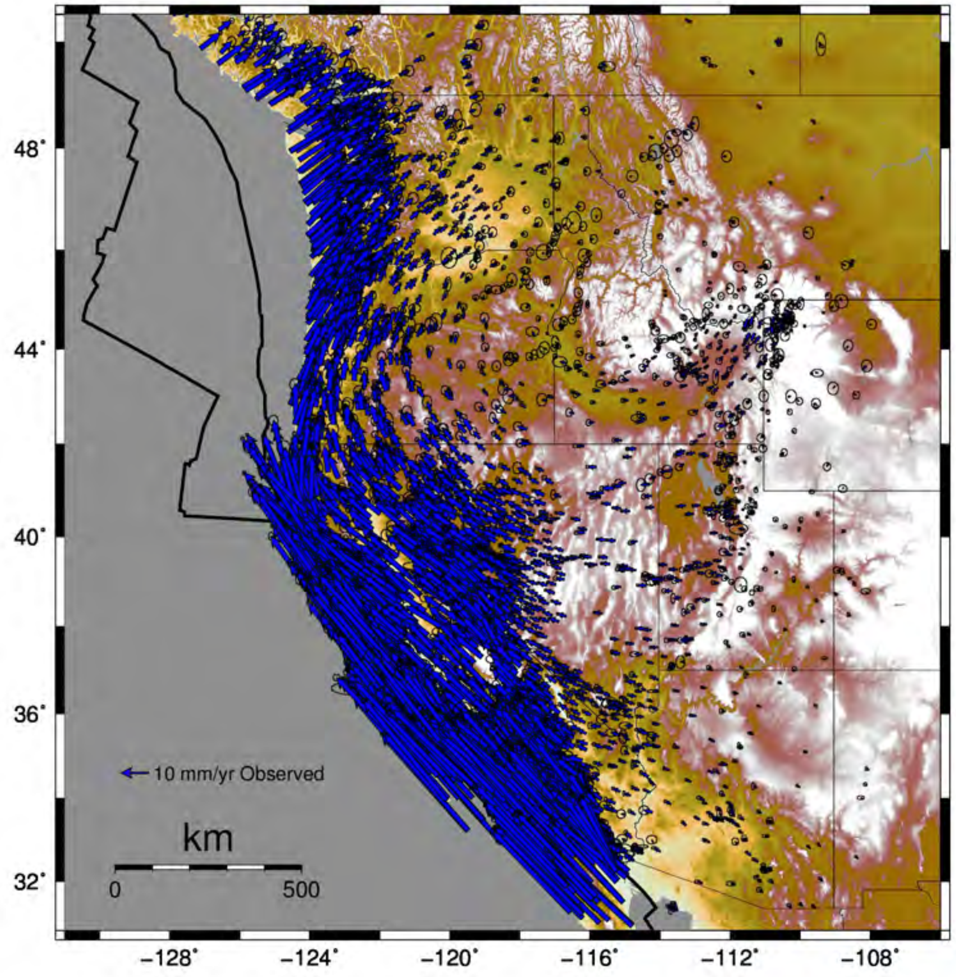

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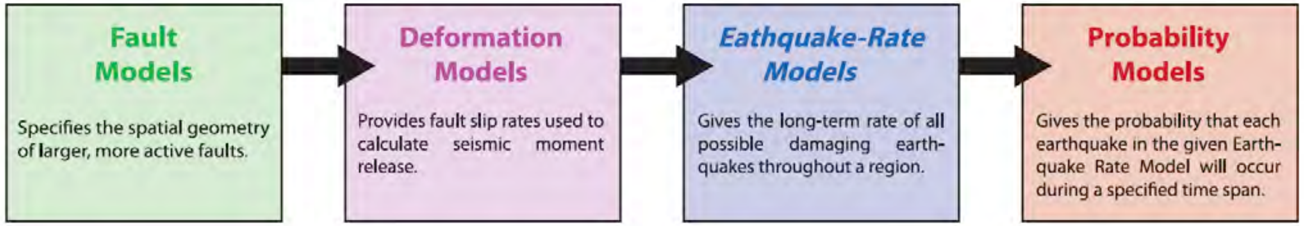

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Model	W. US	Cascadia	Alaska
Geologic (A. Hatem et al.)	√		√
F. Pollitz Viscoelastic	√	√	
Y. Zeng Model	√	√	√
Neokinema (Z. Shen (UCLA), P. Bird (UCLA))	√	√	√
Eileen Evans (CSUN) Block Model	√	√	
Julie Elliott (Perdue) Block Model			√

Components from Disciplinary Groups

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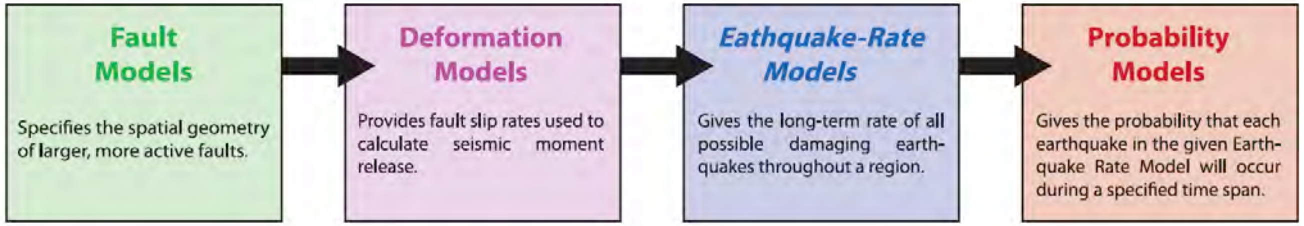
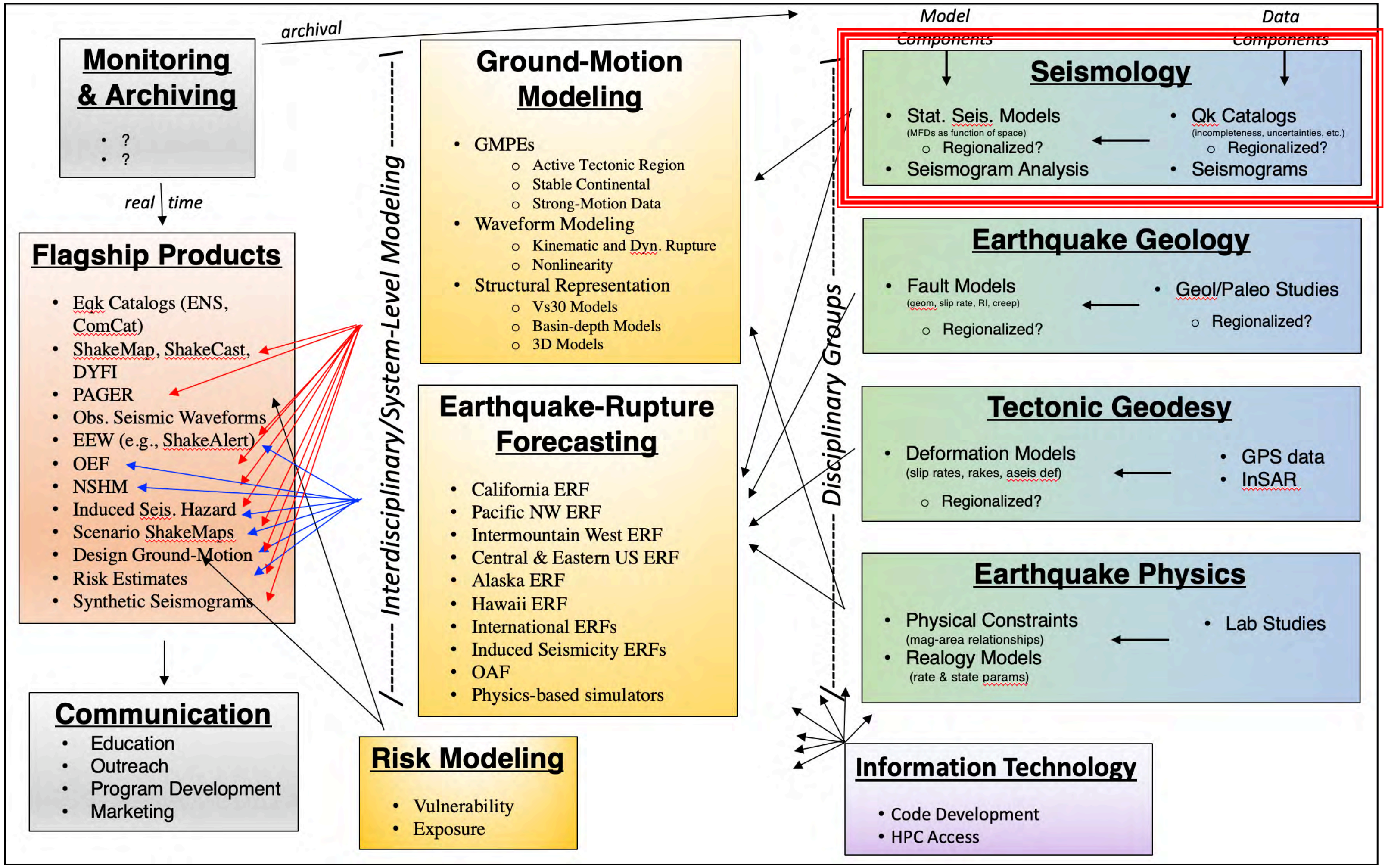


Statistical Seismology



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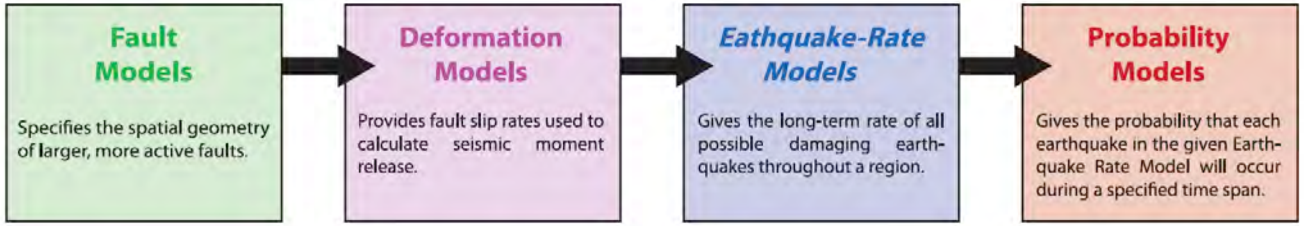

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4) Code Development and Operationalization

Participants/Contributors:

GHSC (USGS): A. Llenos, A. Shumway, C. Mueller, P. Powers, N. Field, M. Moschetti

ESC (USGS): A. Michael, M. Page, N. van der Elst, J. Hardebeck?

Others: B. Savran (USC)

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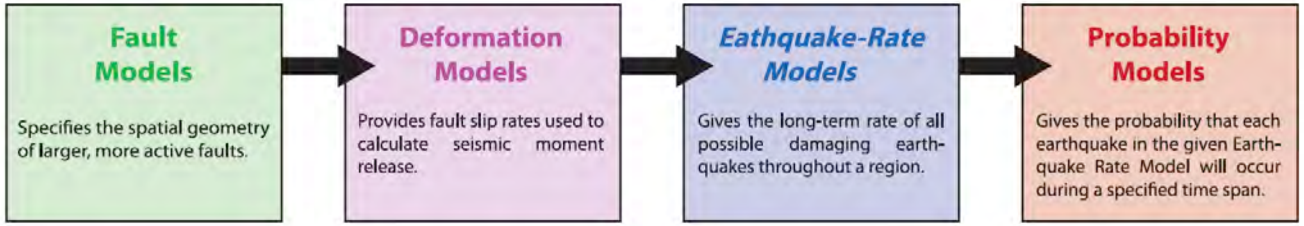

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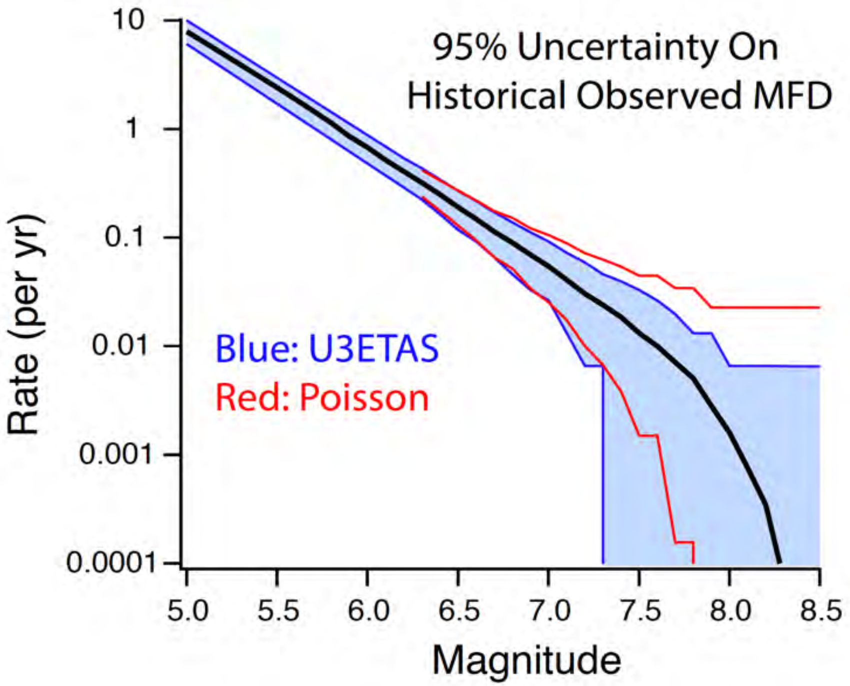
Quantify long-term rate uncertainties inside arbitrary volumes of space



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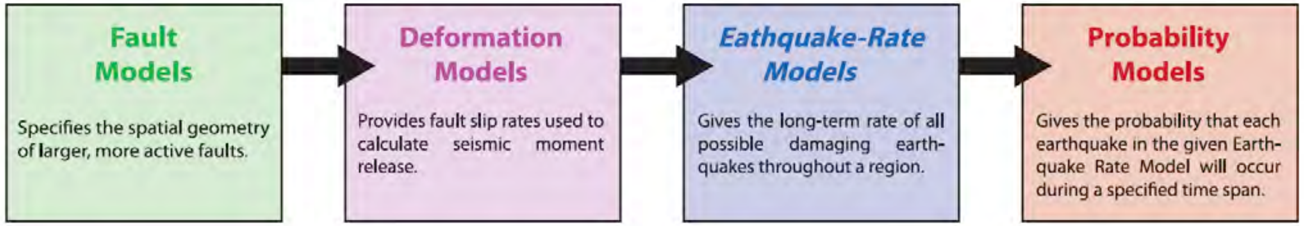

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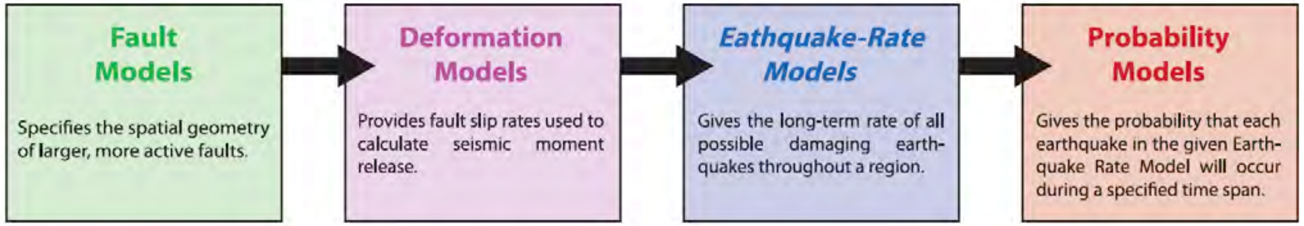
From ***NEPEC_Report_November2017.pdf:***

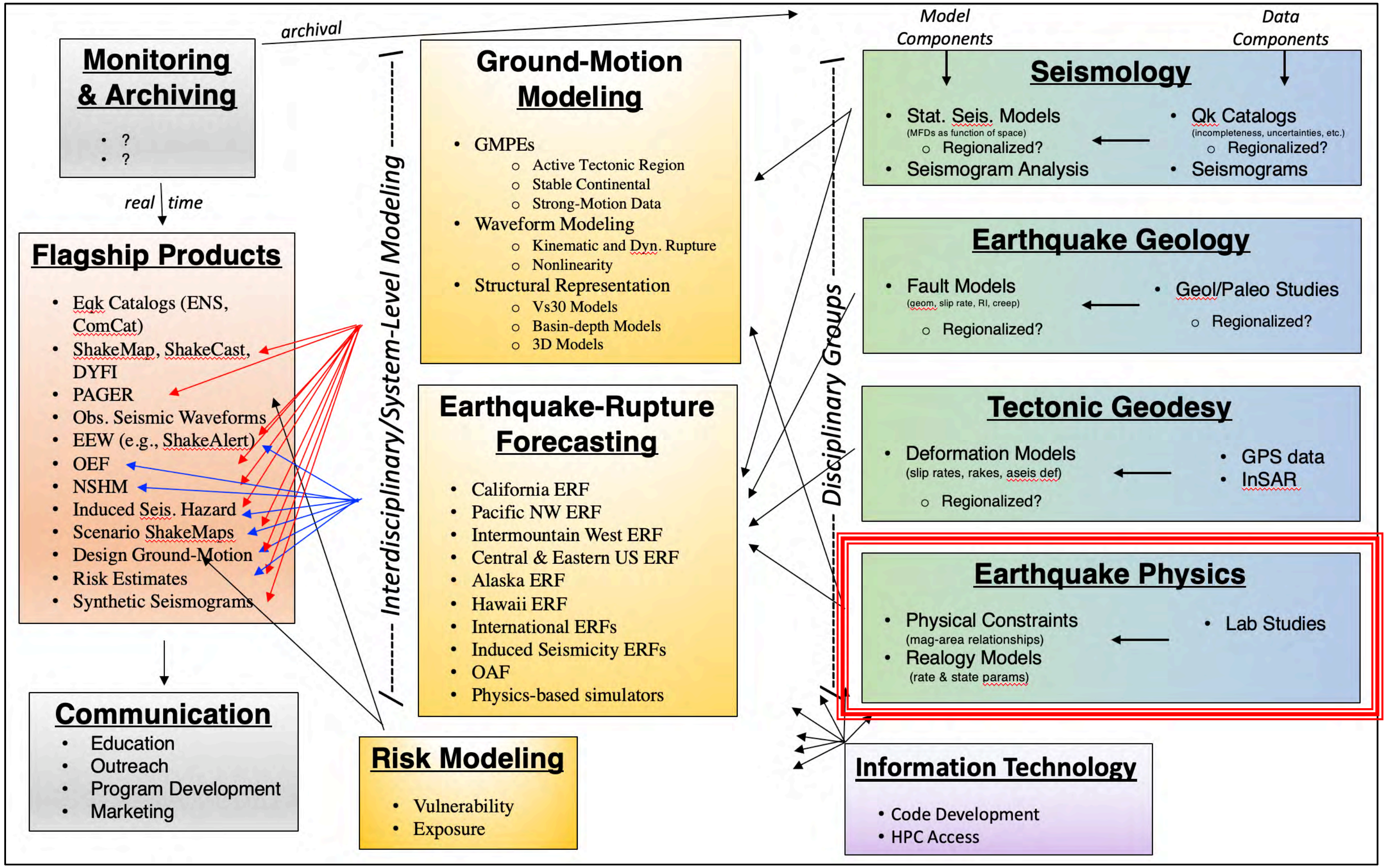
"…the Council strongly recommends that the USGS press forward to develop a fully operationalized nationwide OEF system that carries calculations, combining the background rate of seismicity and earthquake clustering, through to hazard."

Components from Disciplinary Groups

(& Who's Doing What)



Earthquake Physics



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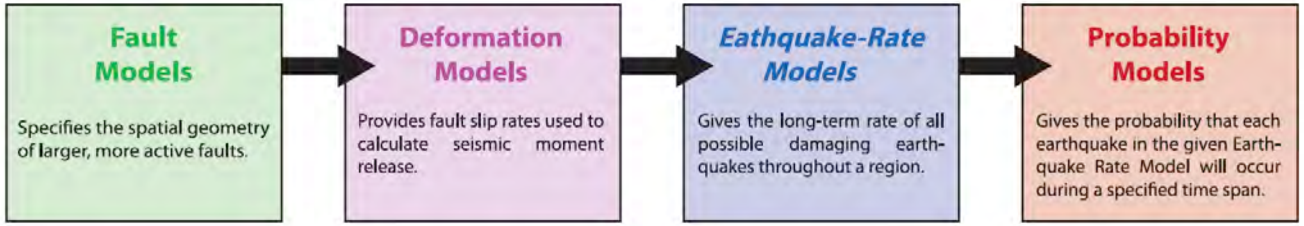


Earthquake Physics

1) Scaling Relationships (B. Shaw (LDEO) & M. Stirling (Otago))

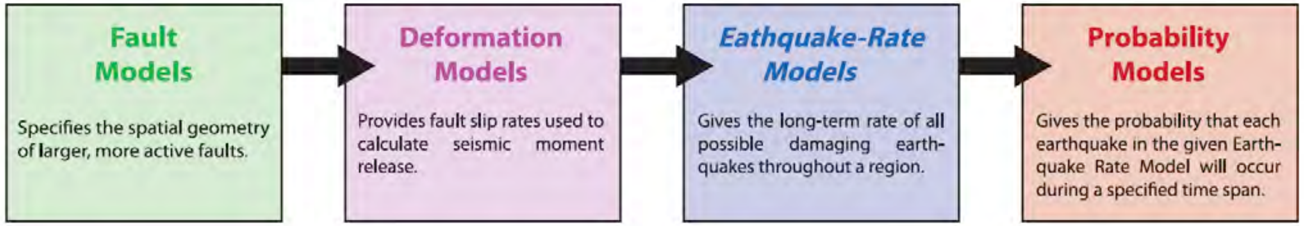
2) Rupture Plausibility (K. Milner (USC))

3) Elastic-Rebound Predictability (N. Field)

4) OEF-Related Questions (N. Field)

Components from Disciplinary Groups

(& Who's Doing What)



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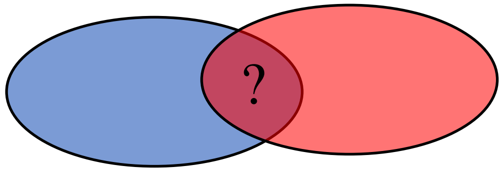
4) OEF-Related Questions (N. Field)

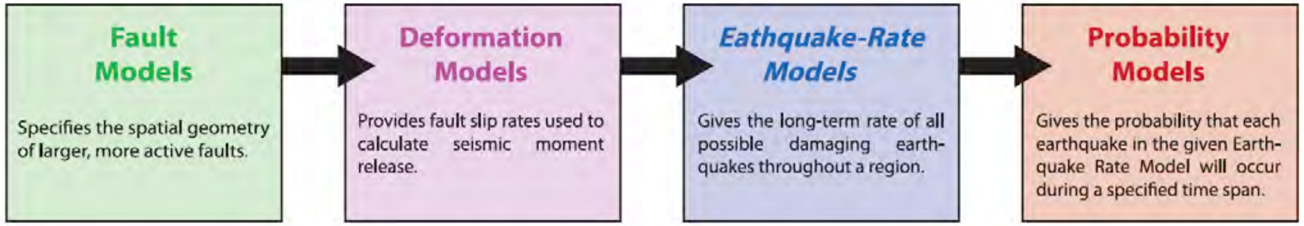
e.g.,

- If one large event quickly triggers another, how much can their ruptures overlap?



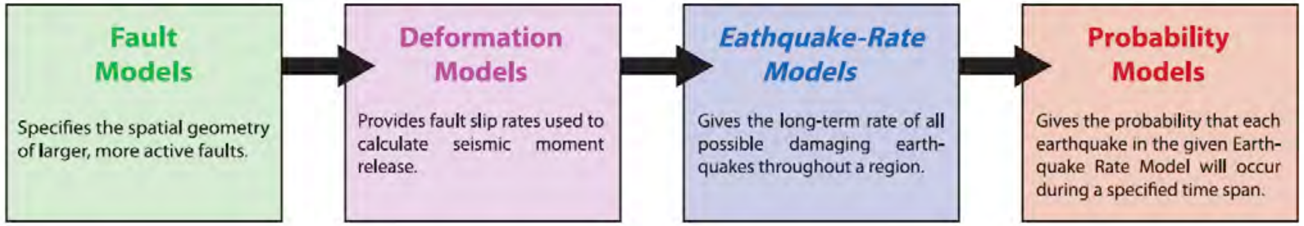
- Where can the second event nucleate from?

- Is ETAS really an adequate proxy at the large magnitudes we care about?



ERF Construction:

Putting all the pieces together (many participants)



ERF Construction:

1) Generalizing, simplifying, and operationalizing Inversion-Based Fault System Solutions (N. Field, K. Milner (USC), and M. Page)

2) Creep Model (M. Page)

3) Cascadia model (A. Frankel)

4) Influence of declustering on hazard and risk metrics (N. Field)

5) Implementation Details/Issues (P. Powers, N. Gregor (Consultant))

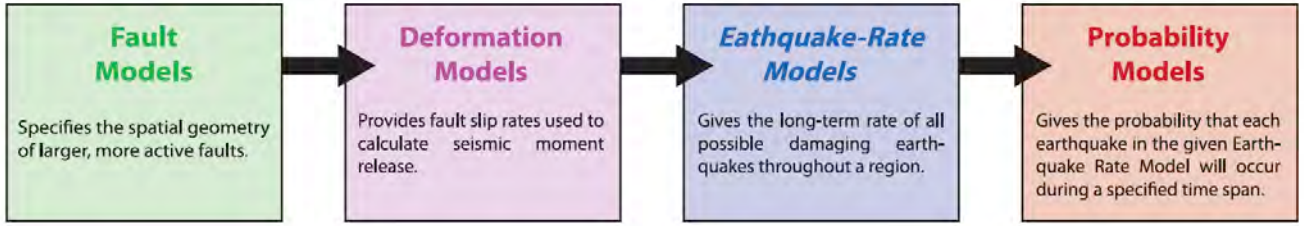
6) Standardize verification, validation, and valuation as much as possible

Participants/Contributors:

GHSC (USGS): N. Field, A. Hatem, A. Llenos P. Powers, R. Gold, A. Shumway

ESC (USGS): M. Page, N. van der Elst, A. Frankel, A. Michael, A. Elliott, F. Pollitz

Others: K. Milner (USC), B. Shaw (LDEO), N. Gregor (Consultant), B. Savran (USC), T. Dawson (CGS), R. Weldon (UO), & ?????



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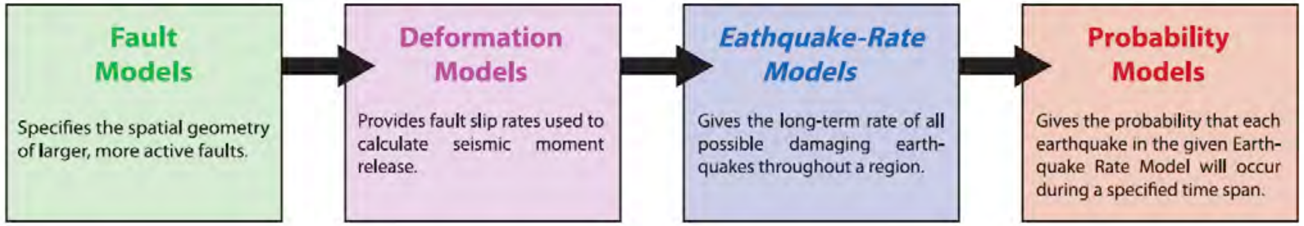
We recently published a BSSA paper that articulates a general protocol for solving for the magnitude, location, and rate of multi-fault ruptures in a fault system, which we intend to apply anywhere we have a significantly interconnected fault system



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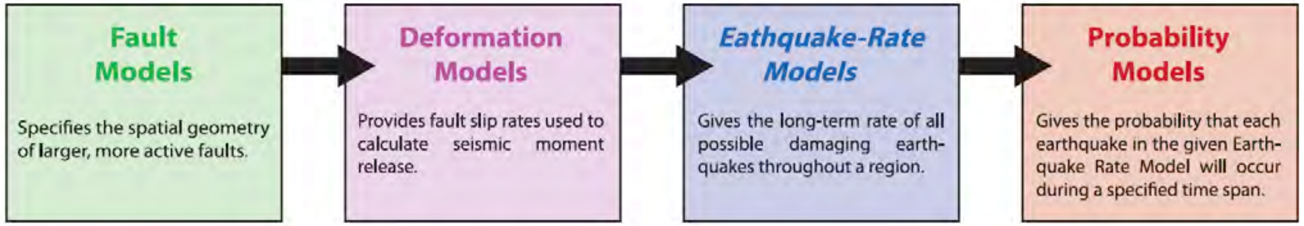
6) Standardize verification, validation, and valuation as much as possible

- It accommodates simple segmentation constraints
- It articulates how to construct a range of models (epistemic uncertainties)
- We aim to enable anyone to rerun these calculations themselves



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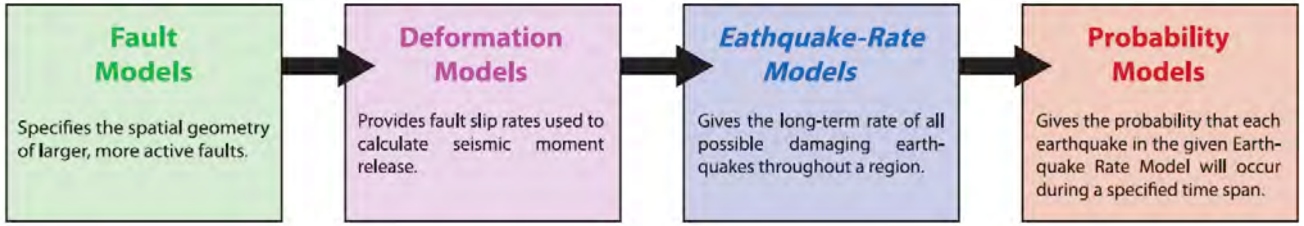
5) Implementation Details/Issues (P. Powers, N. Gregor (Consultant))

6) Standardize verification, validation, and valuation as much as possible

e.g., should building-code design maps really be based on Gardner Knopoff (1974) declustered models?



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4) Influence of declustering on hazard and risk metrics (N. Field)

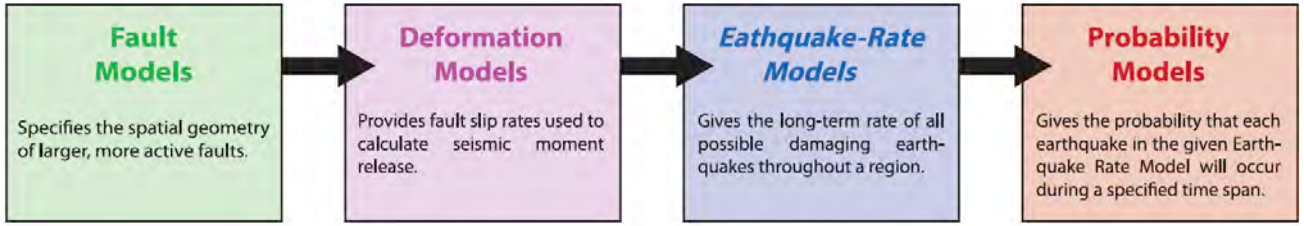
5) **Implementation Details/Issues (P. Powers, N. Gregor (Consultant))**

6) Standardize verification, validation, and valuation as much as possible

e.g.,

How to set depth to top of rupture given creep model?

How to set GMM parameters for complex multi-fault ruptures?



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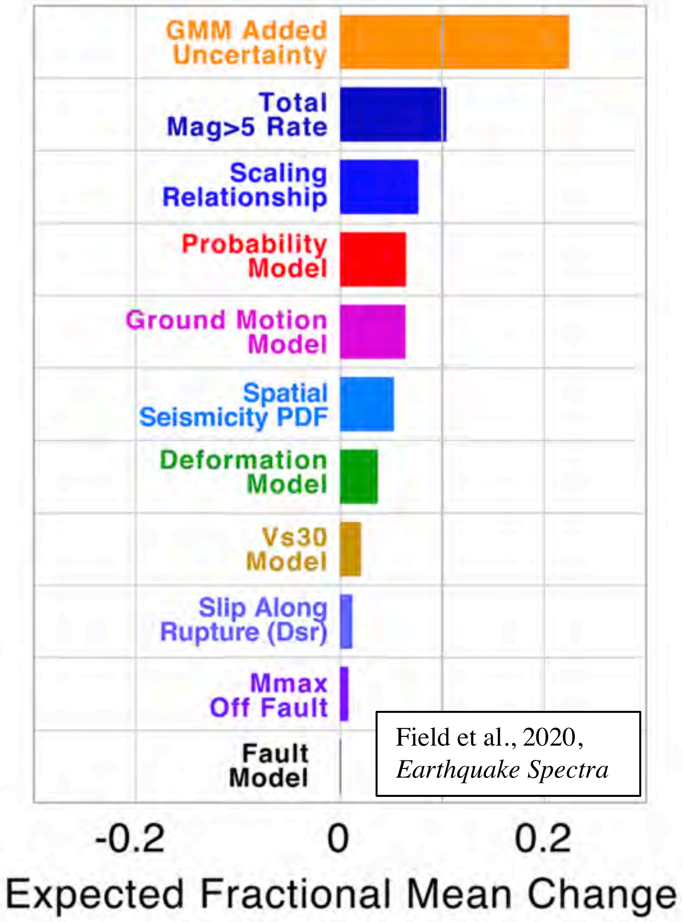
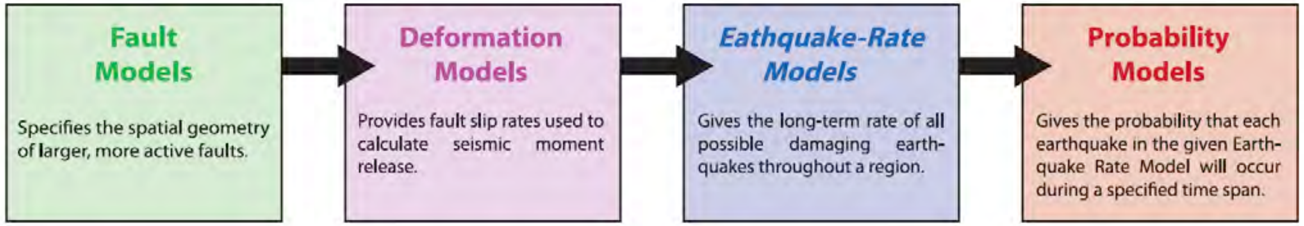
5) Implementation Details/Issues (P. Powers, N. Gregor (Consultant))

6) **Standardize verification, validation, and *valuation* as much as possible**

Influence of epistemic uncertainties on CA average annual loss (insurance rates)





ERF Construction – *some loose ends?*

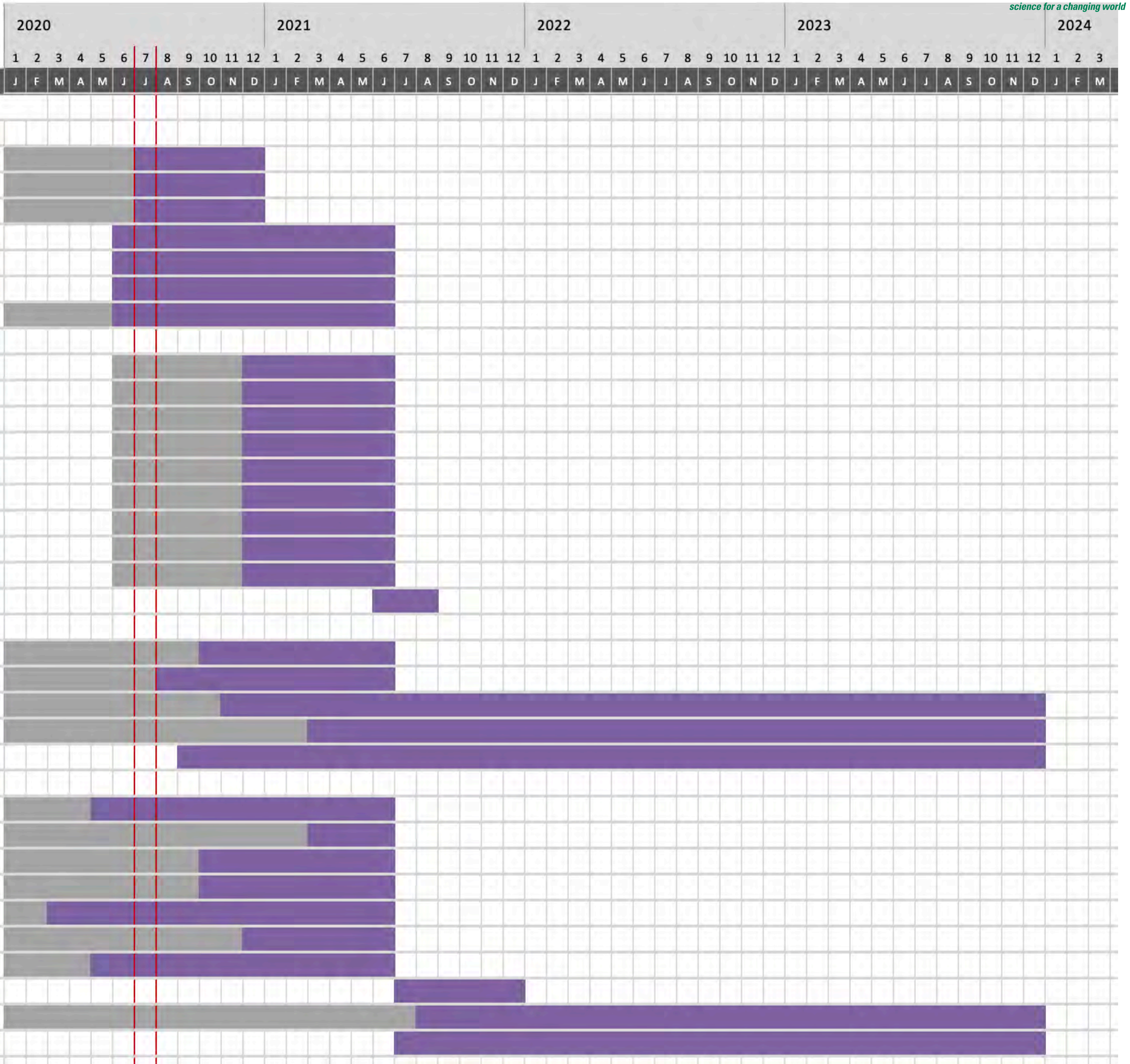
- Exactly how we represent uncertainties on fault models (e.g., fault polygons)
- CEUS sources (e.g., fault area source zones; Mmax based on seismotectonic zonation)
- Focal mechanism PDF as function of space; point source → finite rupture
- Code consolidation
- Other things?

USGS Earthquake Rupture Forecast (ERF) Development

Coordinator: Ned Field

Project Start: 1/1/20

TASK	LEADER(S)	PROGRESS	START	END
Earthquake Geology	Alex Hatem & Ryan Gold			
Fault Section Data	Alex Hatem	50%	1/1/20	1/1/21
Slip Rates at Points	Alex Hatem	50%	1/1/20	1/1/21
Default Slip Rates	Alex Hatem	50%	1/1/20	1/1/21
Paleo Recurrence Intervals	Devin McPhillips	0%	6/1/20	7/1/21
Paleo Average Slip	Alex Hatem	0%	6/1/20	7/1/21
Geologic Segmentation	Austin Elliott	0%	6/1/20	7/1/21
Database Implementations	Peter Powers	25%	1/1/20	7/1/21
Tectonic Geodesy (Def. Models)	Fred Pollitz			
GPS Data Compliation	Yuehua Zeng	50%	6/1/20	7/1/21
Zeng Deformation Model	Yuehua Zeng	50%	6/1/20	7/1/21
NeoKinema Def. Model	Zhengkang Shen	50%	6/1/20	7/1/21
Pollitz Def. Model	Fred Pollitz	50%	6/1/20	7/1/21
Geologic Def. Model	Alex Hatem	50%	6/1/20	7/1/21
Alaska Def. Model	Julie Elliott	50%	6/1/20	7/1/21
Block Model Development	Eileen Evans	50%	6/1/20	7/1/21
Artifact Corrections Etc.	Elizabeth Hearn	50%	6/1/20	7/1/21
Geodetic Creep Model	J Murray & K Johnson	50%	6/1/20	7/1/21
Review Options	Tom Parsons	0%	6/1/21	9/1/21
Statistical Seismology	N Field (for now)			
Catalog Dev. & Curation	C Mueller and A Shumway	50%	1/1/20	7/1/21
Declustering & Smoothing	A. Llenos	40%	1/1/20	7/1/21
OEF Components Dev	N van der Elst???	20%	1/1/20	1/1/24
CSEP Validation	????????	30%	1/1/20	1/1/24
Code Dev. & Operationalization	N Field & P Powers	0%	9/1/20	1/1/24
ERF Model Construction				
Scalind Relationship Dev.	Bruce Shaw	20%	1/1/20	7/1/21
Fault System Solutions	Ned Field	80%	1/1/20	7/1/21
Plausibility Filter	Kevin Milner	50%	1/1/20	7/1/21
Creep Model	Morgan Page	50%	1/1/20	7/1/21
Hazard Implications of Decluster	Ned Field	10%	1/1/20	7/1/21
Code Dev & Operationalization	Peter Powers	60%	1/1/20	7/1/21
Cascadia	Art Frankel	20%	1/1/20	7/1/21
Finalize Time-Ind Models	Ned Field	0%	7/1/21	1/1/22
Verification, Validation & Valuat	Ned Field	40%	1/1/20	1/1/24
Time Dependent Components	Ned Field	0%	7/1/21	1/1/24



Ground motion models (GMMs) for 2023 NSHM: Potential updates

Morgan Moschetti

B. Aagaard, S. Ahdi, O. Boyd, A. Frankel, R. Graves, M. D. Petersen, P. Powers, J. Rekoske, S. Rezaeian, A. Shumway, J. Smith, B. Stephenson, E. Thompson, E. Wirth, K. Withers

2023 NSHM Kickoff Workshop, January 22, 2021

Potential GMM updates for 2023 NSHM

1. Evaluation, implementation, and weighting of GMMs
2. Basin and deep-sediment response (WUS and CEUS)
3. Use of 3D ground-motion simulations
4. Evaluation and Implementation of Directivity Models
5. Towards non-ergodic PSHA

(1) Evaluation, implementation, and weighting of GMMs

- New GMMs
  - NGA-Subduction
  - WUS, CEUS
- Evaluation of GMMs
  - Logic tree weighting
  - Model corrections/adjustments
  - Evaluation of current GMMs and model components
- Ground motion observations for evaluating GMMs
- Additional Epistemic uncertainty
- WUS/CEUS boundary

Evaluation and Implementation of NGA-Subduction

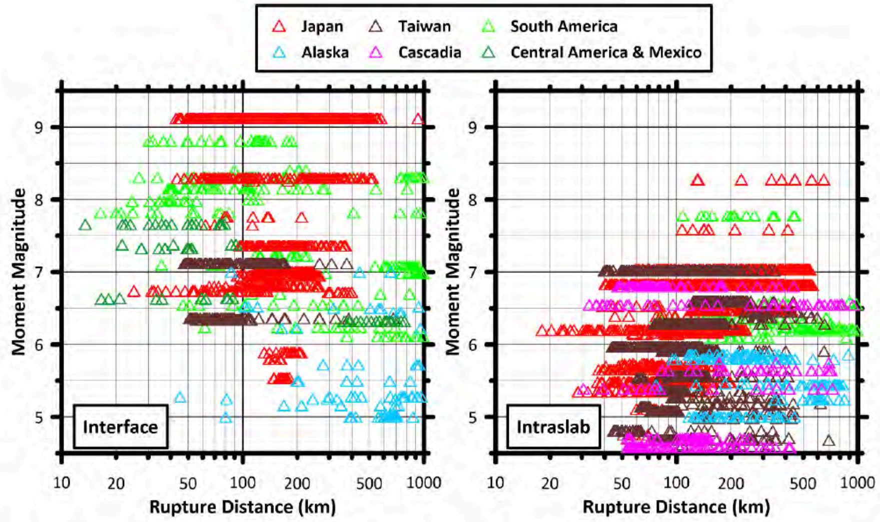
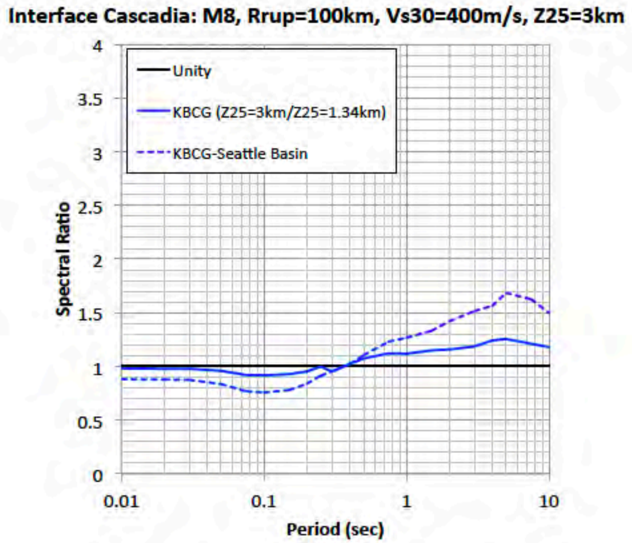
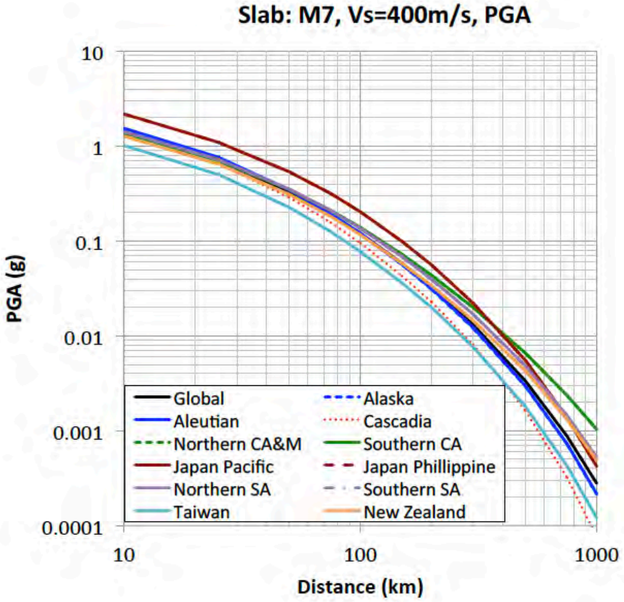
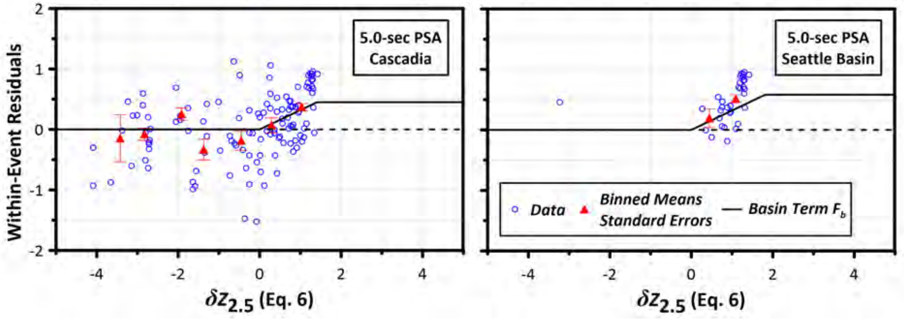


Figure 2.1 Magnitude-distance distribution of recordings from interface (left) and intraslab (right) events, color-coded by region.







Parker et al. (2020, PEER)

Kuehn et al. (2020, PEER)

- GMM and seismic hazard comparisons between NGA-Sub and with previous GMMs
- Evaluating regional terms in NGA-Sub—attenuation, source, basin amplification
- Comparison with regional data sets
- Data limitations Cascadia
- Independent data set for Alaska intraslab

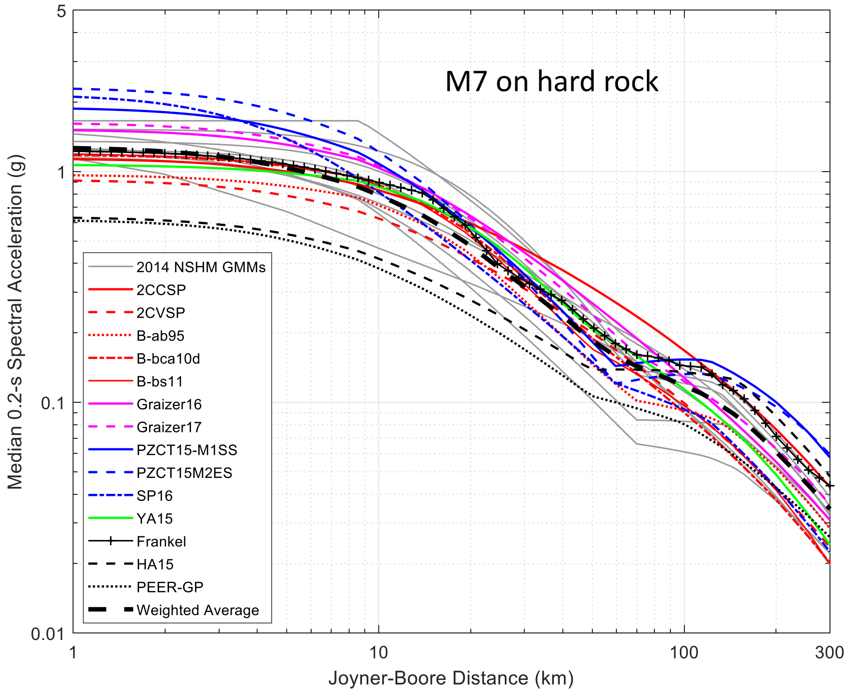
USGS science for a changing world

CEUS GMMs for 2018 (Re-visit for 2023):

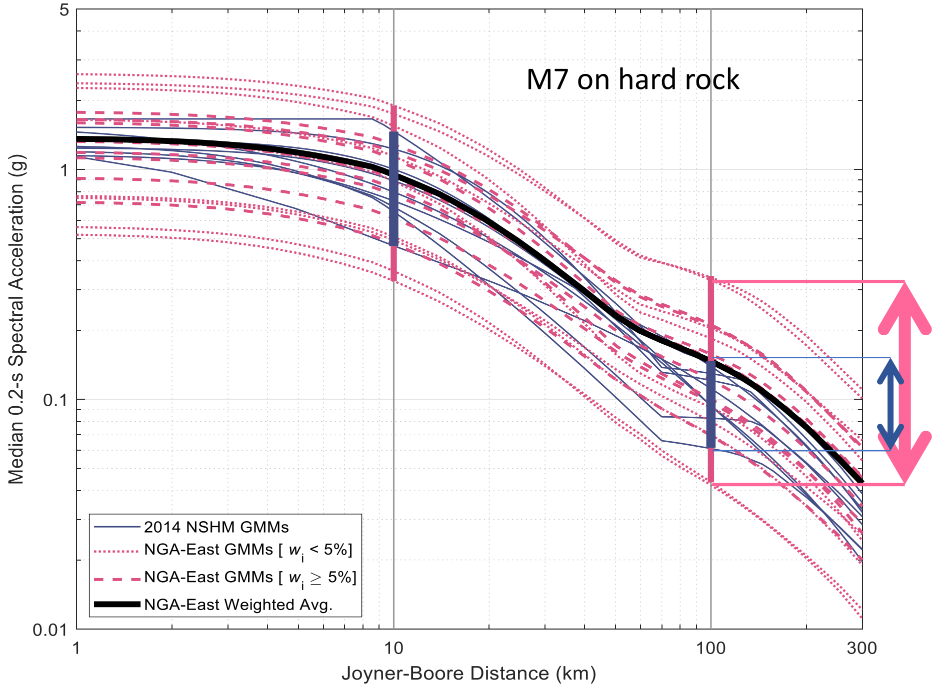
- **GMMs and their weights should be revisited for 2023 NSHM.**

Rezaeian S, Powers PM, Shumway AM, Petersen MD, Luco N, Frankel AD, Moschetti MP, Thompson EM, and McNamara DE (2021) The 2018 Update of the U.S. National Seismic Hazard Model: Ground motion models in the central and eastern U.S. *Earthquake Spectra*, (In Press).

14 Updated Seed GMMs:



17 NGA-East GMMs:



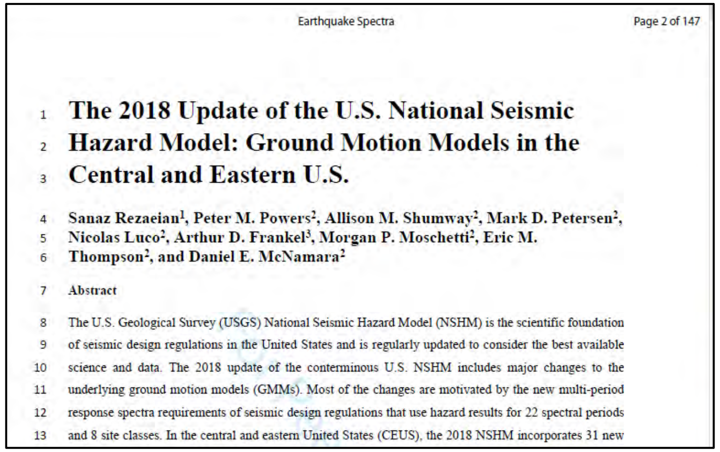
CEUS GMMs and their weights for hard rock @ 3000 m/s.

(slide courtesy S. Rezaeian)

CEUS Site-Effects Model for 2018:

- **Consider an alternative version of $F_{nonlinear}$ (Hashash and others, 2020)—not available for 2018.**
- **Lack of adjustment causes a ‘shoulder effect’ for soft soil just below 1 sec.**
- **Also, check validity of F_{760} for periods shorter than 0.1 sec in 2023 NSHM.**

Details of Site Effects implementation in Rezaeian and others (2021):



The 2018 Update of the U.S. National Seismic Hazard Model: Ground Motion Models in the Central and Eastern U.S.

Sanaz Rezaeian[1], Peter M. Powers[2], Allison M. Shumway[2], Mark D. Petersen[2], Nicolas Luco[2], Arthur D. Frankel[3], Morgan P. Moschetti[2], Eric M. Thompson[2], and Daniel E. McNamara[2]

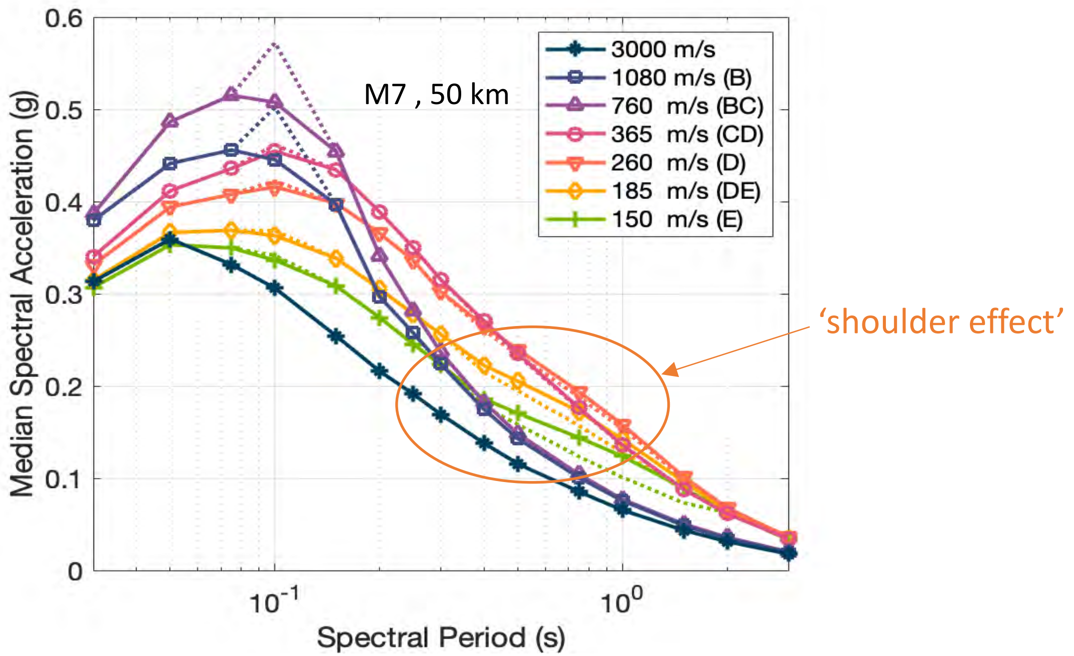
Abstract

The U.S. Geological Survey (USGS) National Seismic Hazard Model (NSHM) is the scientific foundation of seismic design regulations in the United States and is regularly updated to consider the best available science and data. The 2018 update of the conterminous U.S. NSHM includes major changes to the underlying ground motion models (GMMs). Most of the changes are motivated by the new multi-period response spectra requirements of seismic design regulations that use hazard results for 22 spectral periods and 8 site classes. In the central and eastern United States (CEUS), the 2018 NSHM incorporates 31 new

<u>Site Effects based on :</u>

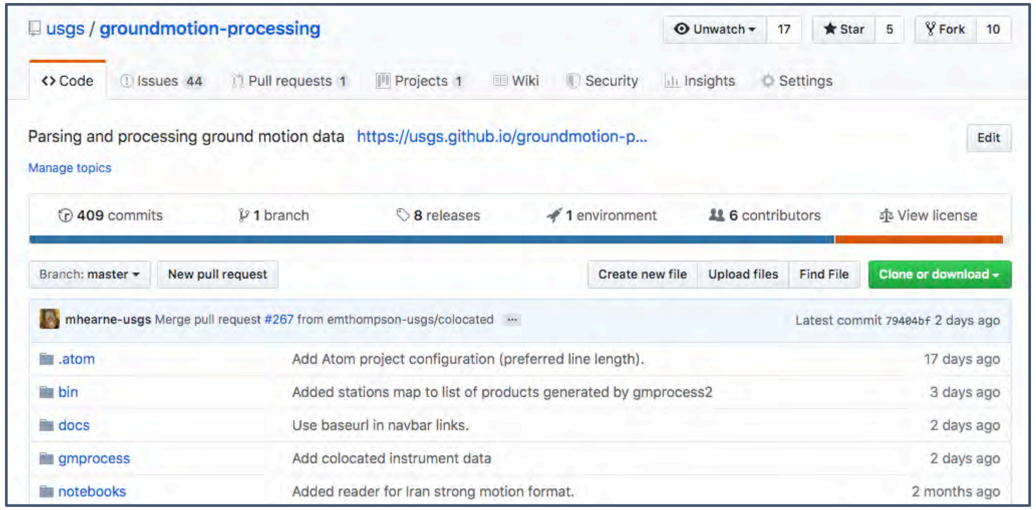
Stewart and others (2020), *Earthquake Spectra 36(1)*
Hashash and others (2020), *Earthquake Spectra 36(1)*

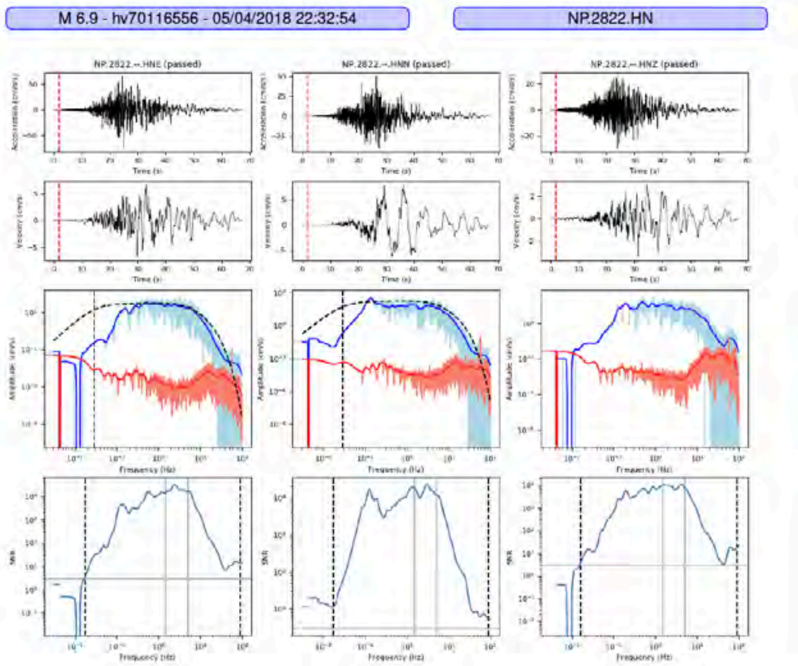
Site Effects = F_{760} + F_{linear} + $F_{nonlinear}$



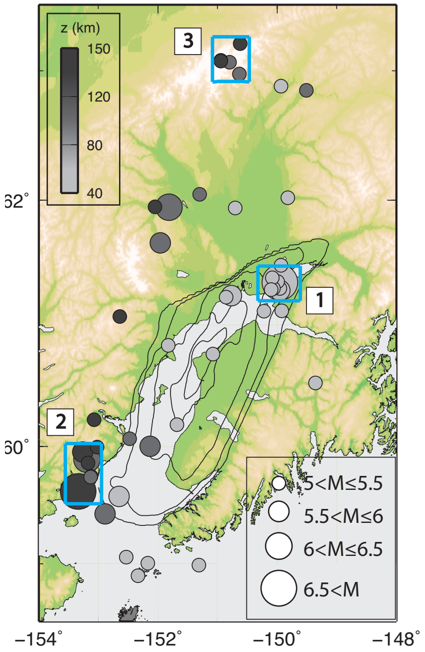
(slide courtesy S. Rezaeian)

https://github.com/usgs/groundmotion-processing

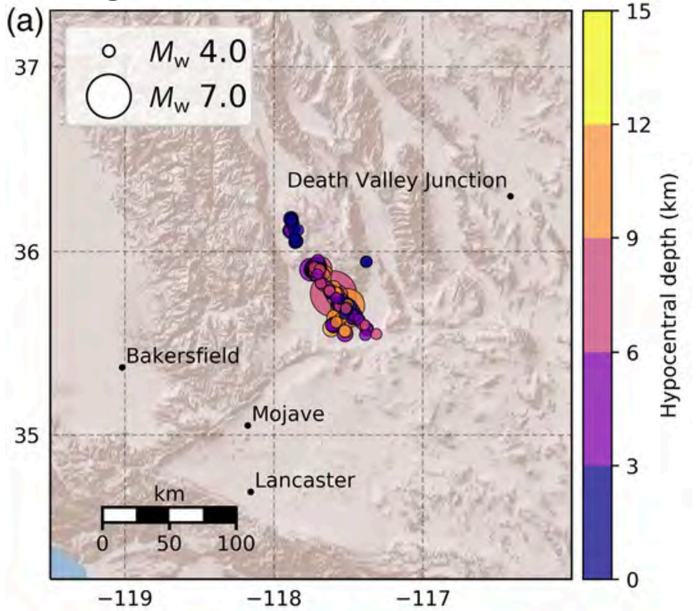




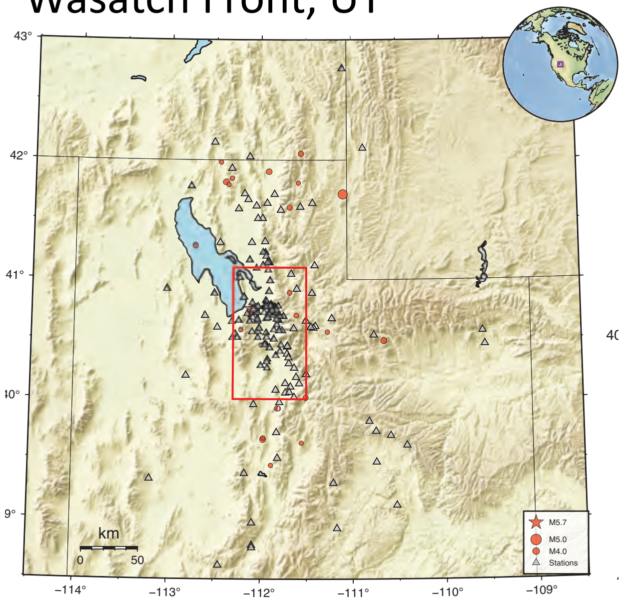
Alaska subduction



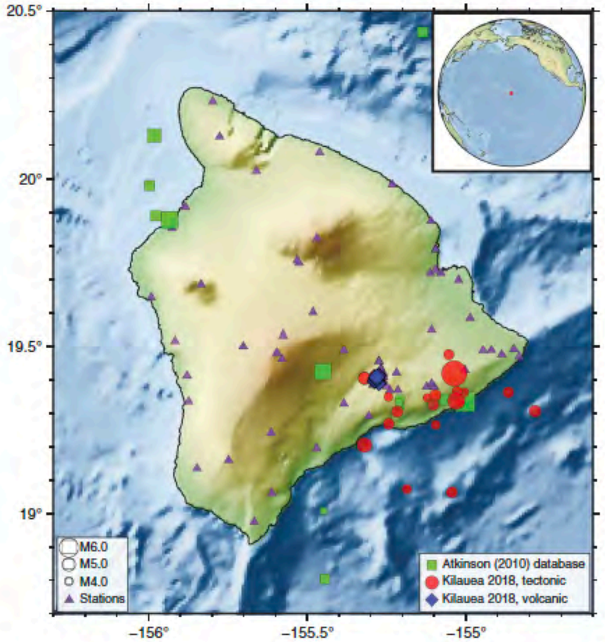
Ridgecrest, CA



Wasatch Front, UT



Volcanic/Tectonic, Hawaii



Slide courtesy E. Thompson

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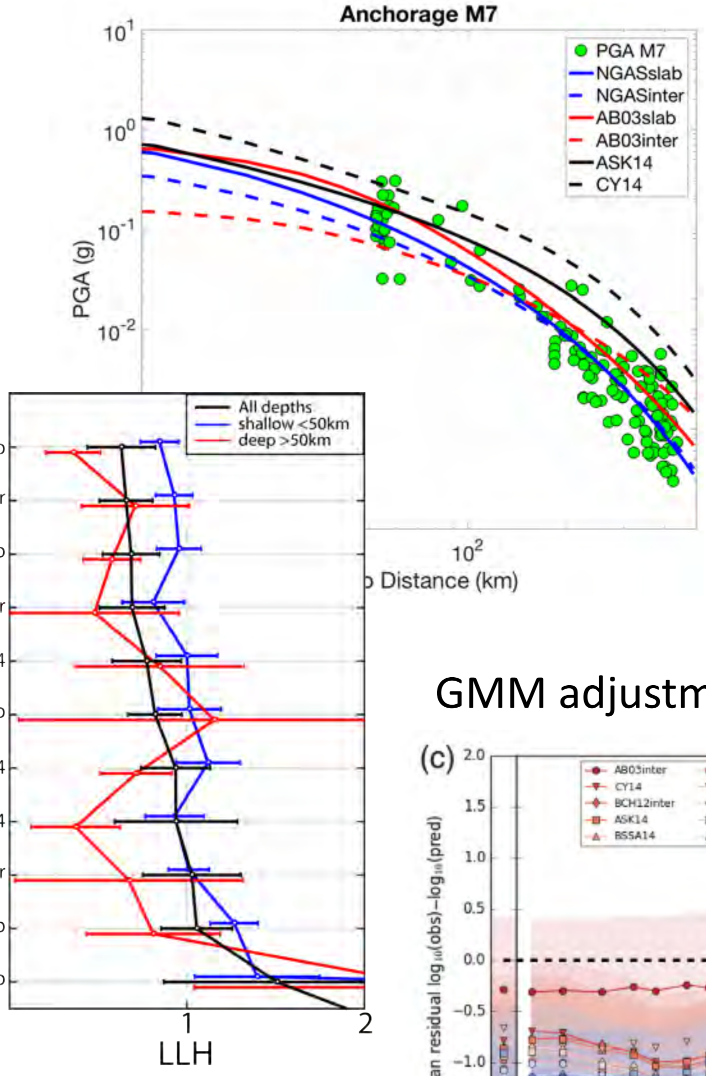
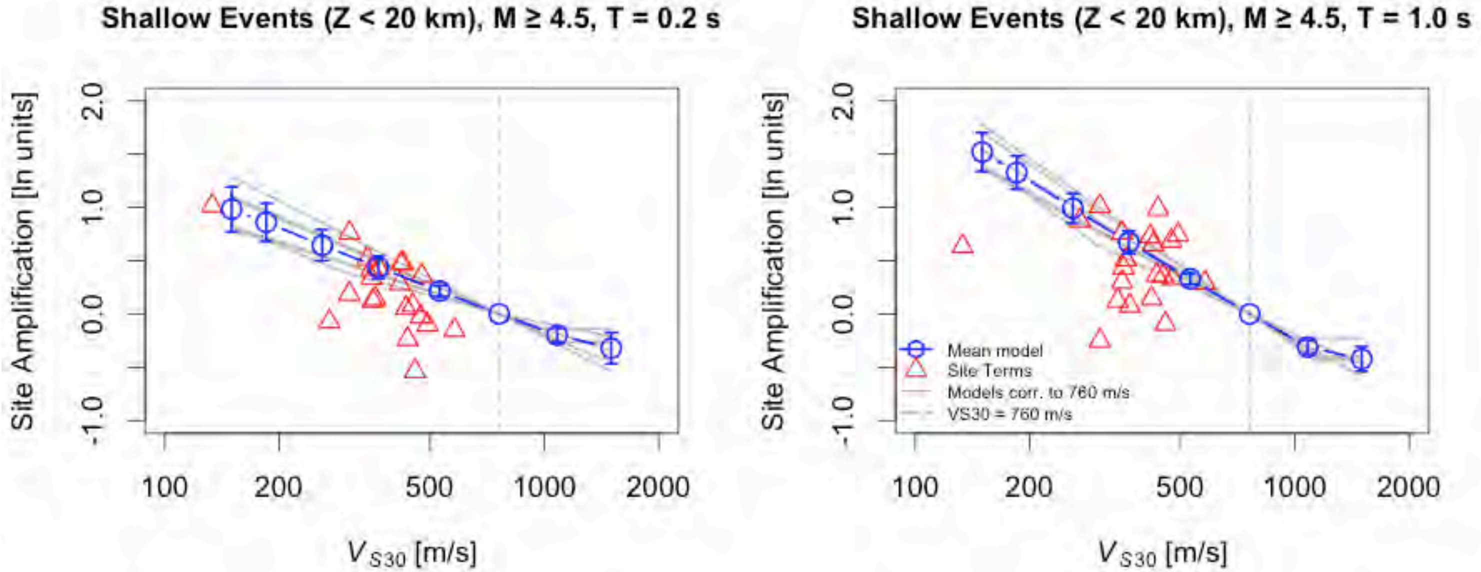
Evaluating GMMs, Alaska intraslab

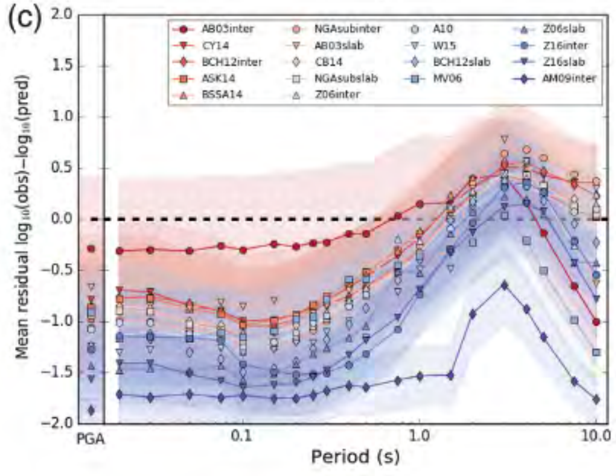


McNamara et al. (2020)

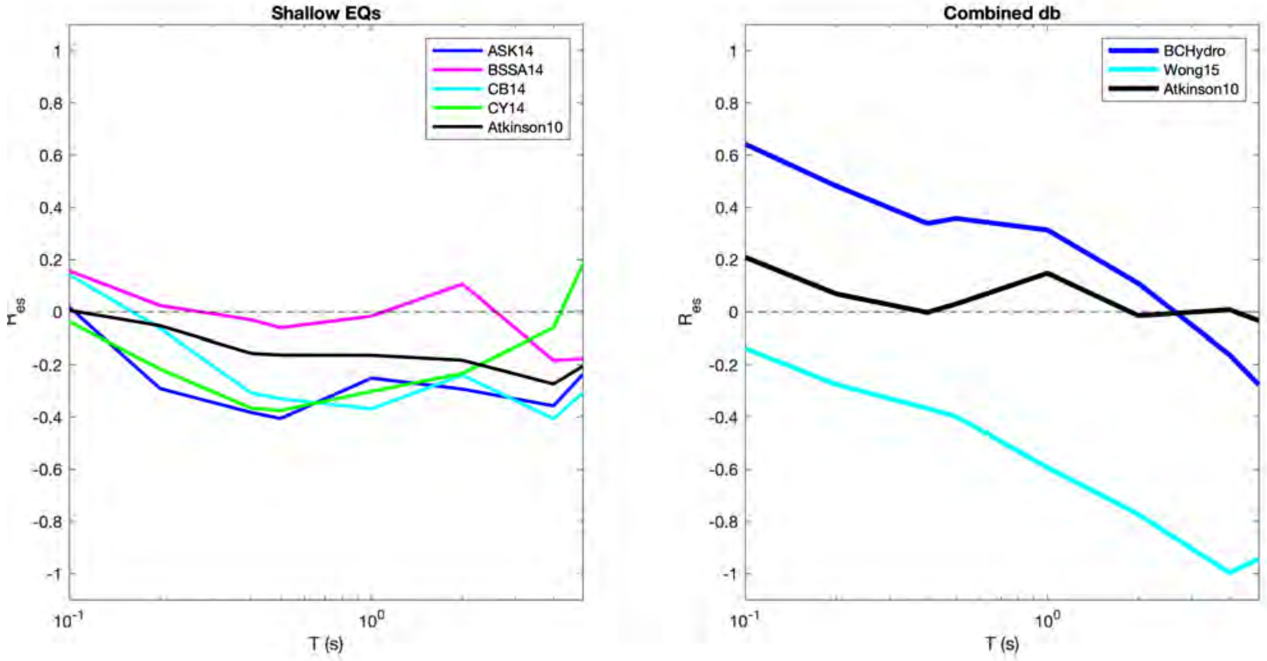
Evaluating site response models, Hawaii



GMM adjustments, Hawaii

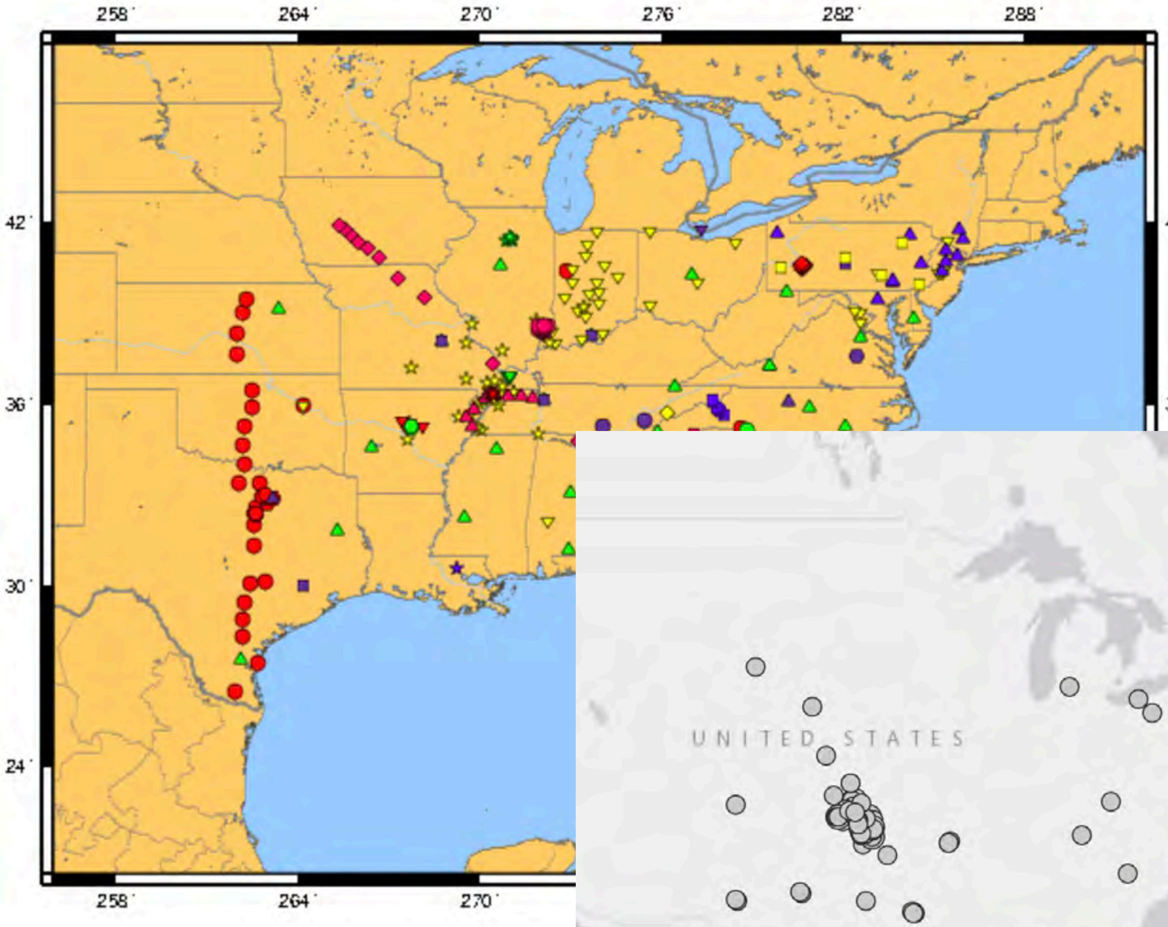


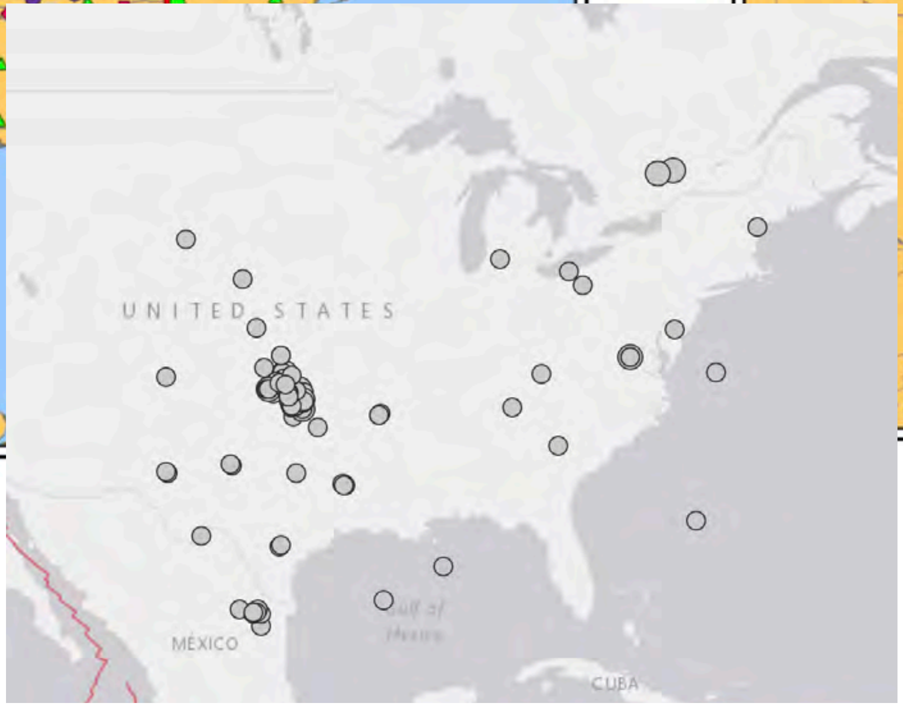
Weighting GMM logic trees, Hawaii



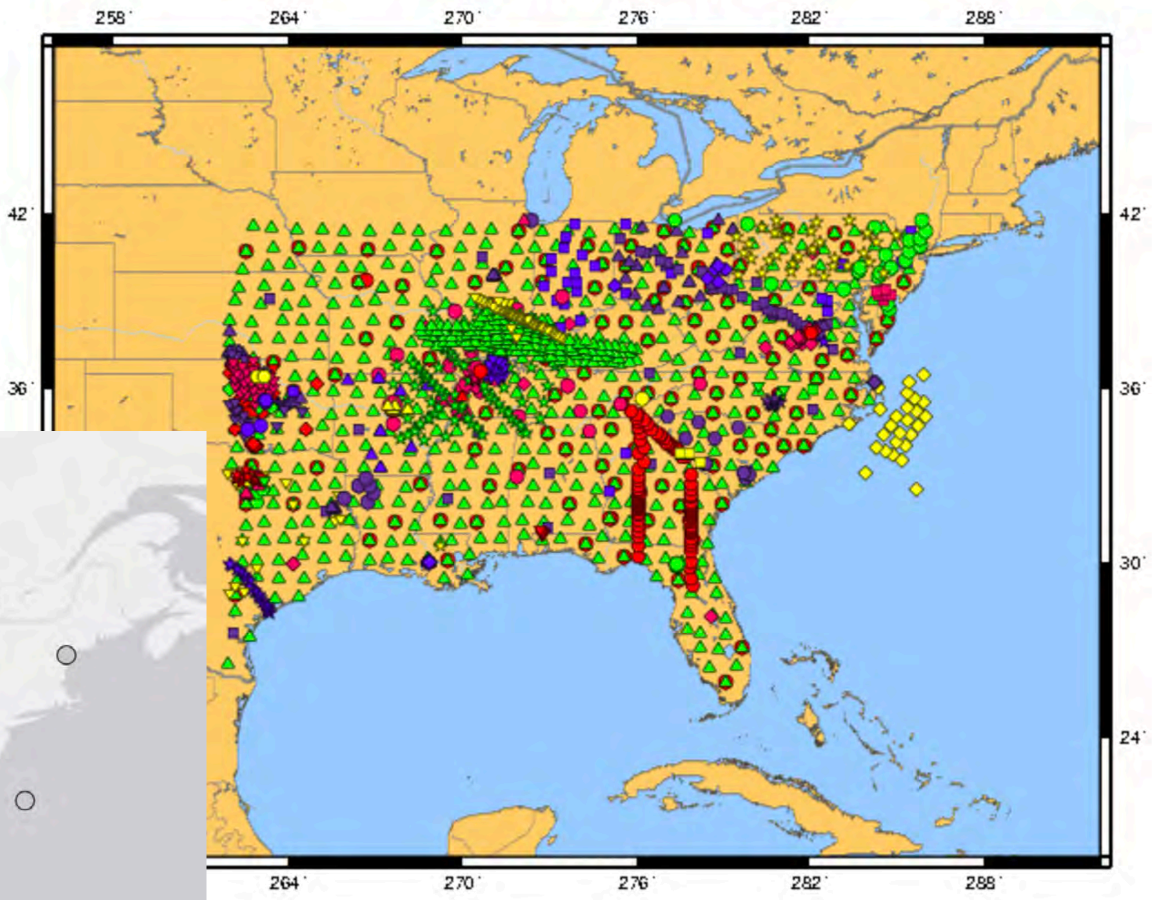
Evaluating CEUS site response models

Seismic stations, 2000-2010



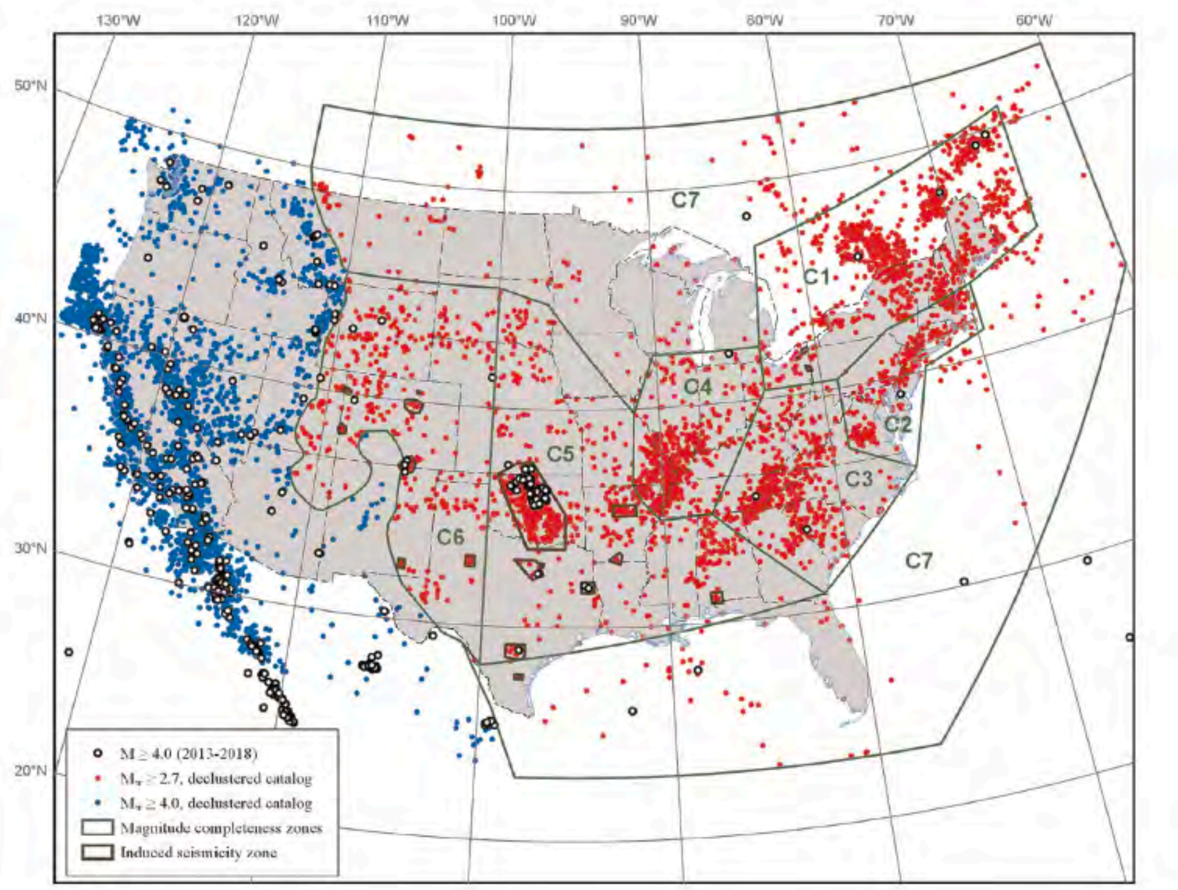


Seismic stations, 2010-2020



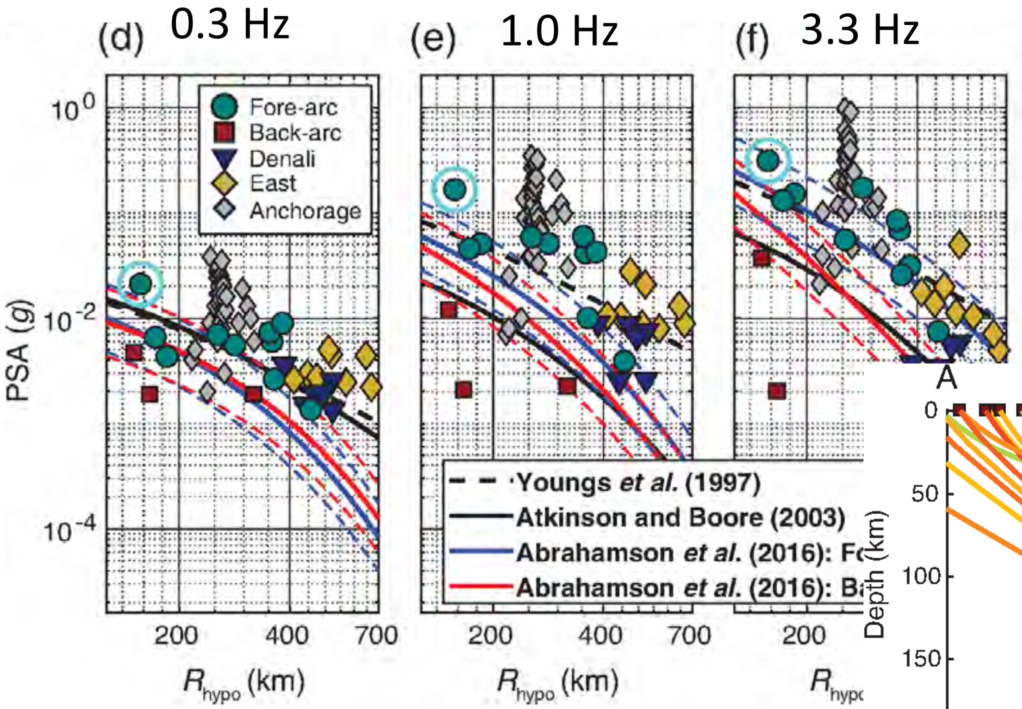
USGS
science for a changing world

Consideration of CEUS-WUS boundary

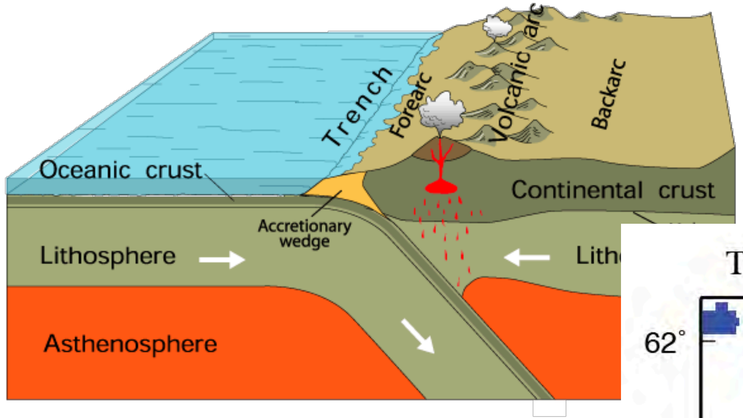


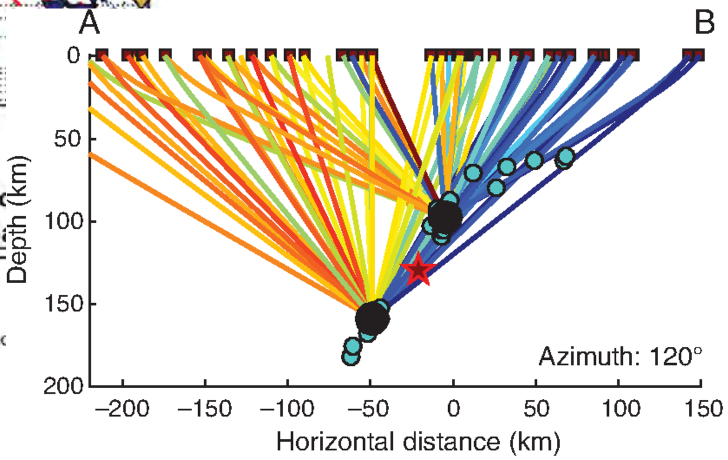
- Update geometry of boundary
- Consider updated treatment of GMMs for paths crossing CEUS-WUS boundary

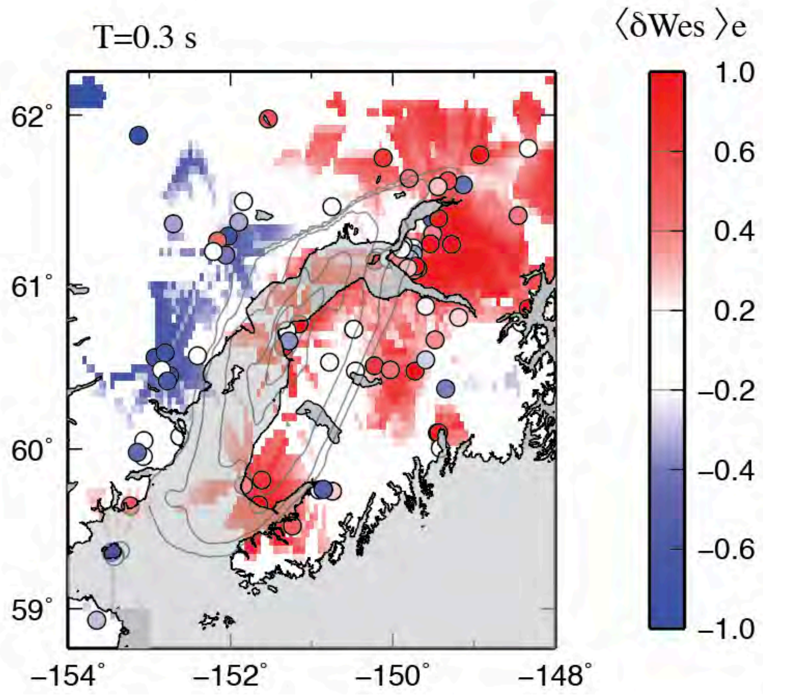
Regional GMM adjustments: Alaska subduction



Mann and Abers (2020)







Basin and deep-sediment response

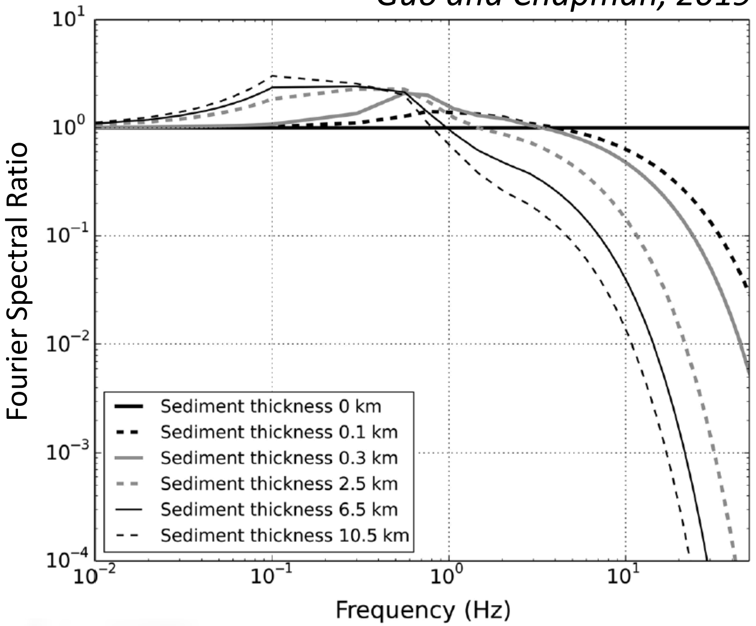
Central and Eastern U.S.: Coastal Plain Site Amplification Models

- **Site amplification models developed for the Atlantic and Gulf Coastal Plains:**
    1. *Chapman and Guo, in press*
    2. *Pratt and Schleicher, in review*

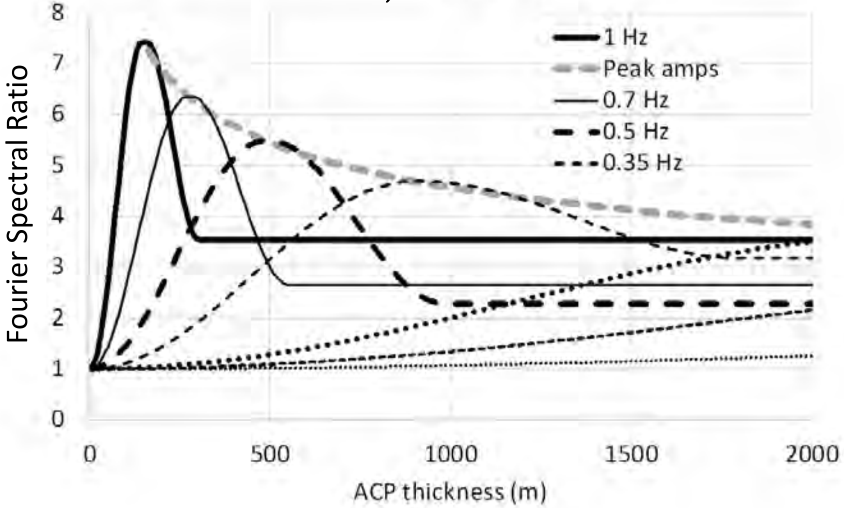
    with application of a unified Coastal Plain sediment thickness model by Boyd and others, in prep.

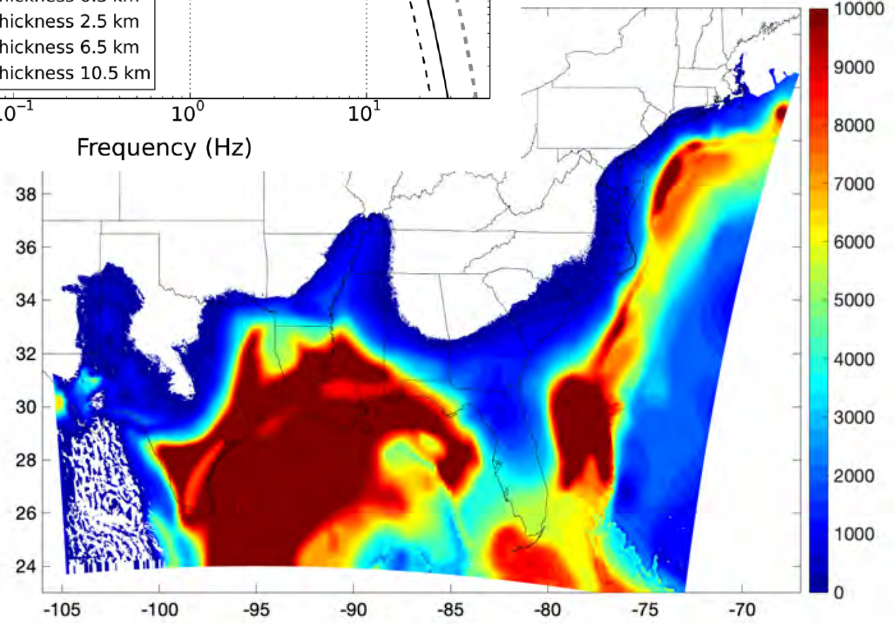
- **Consider other Coastal Plain models**
    1. *NGA-East Gulf Coastal Plain adjustment*
    2. *Harmon and others, 2019*
    3. *Pezeshk and others, 2017*
    4. *Cramer, 2017*

Guo and Chapman, 2019



Pratt and Schleicher, in review



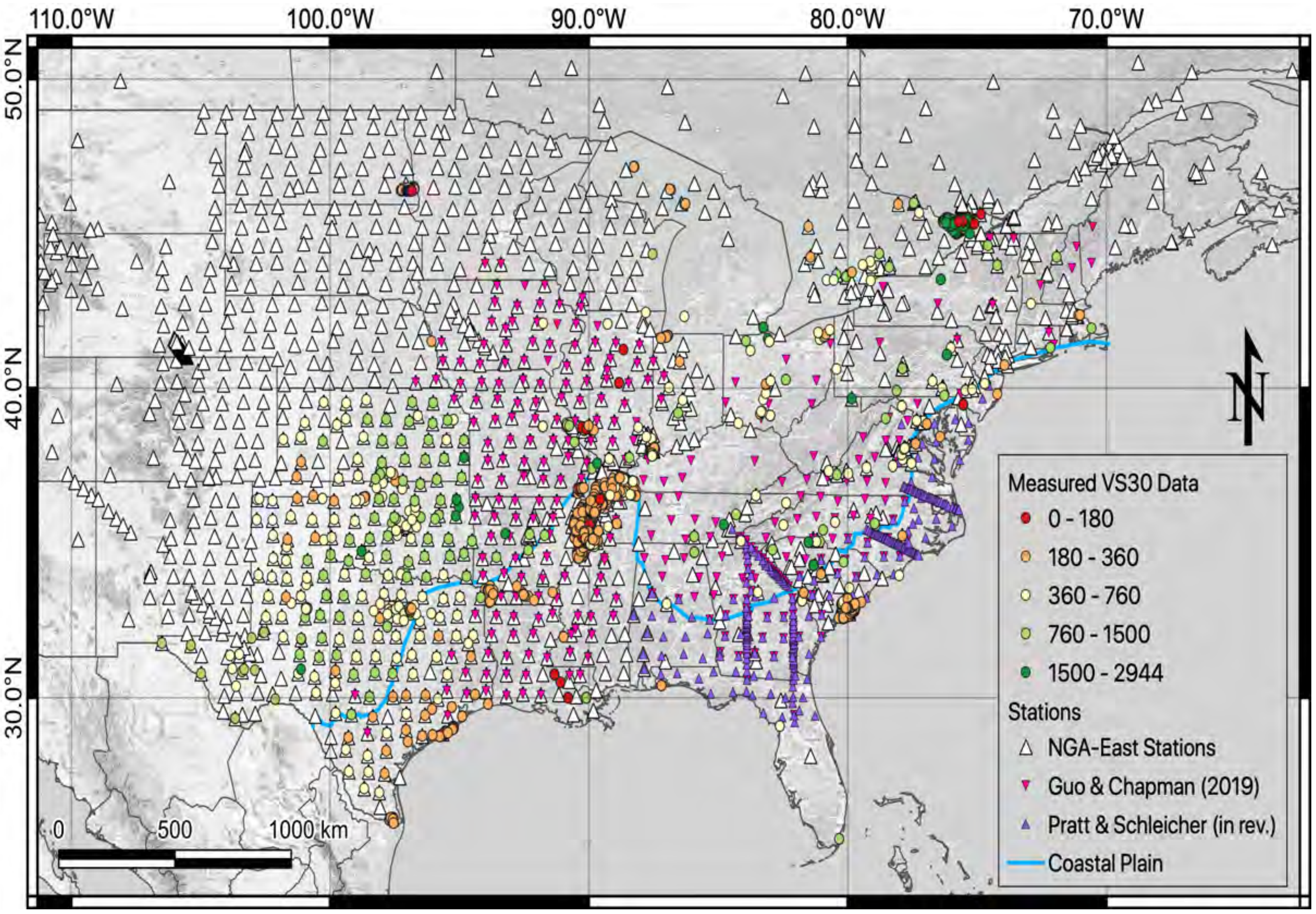


Boyd and others, in prep

(slide courtesy O. Boyd)

Central and Eastern U.S.: Site Metadata Compilation

- **Gather geophysical information at CEUS sites**
  1. V_{S30}
  2. Sediment thickness
  3. *Fundamental period, HVSR*
  4. *Velocity profiles*



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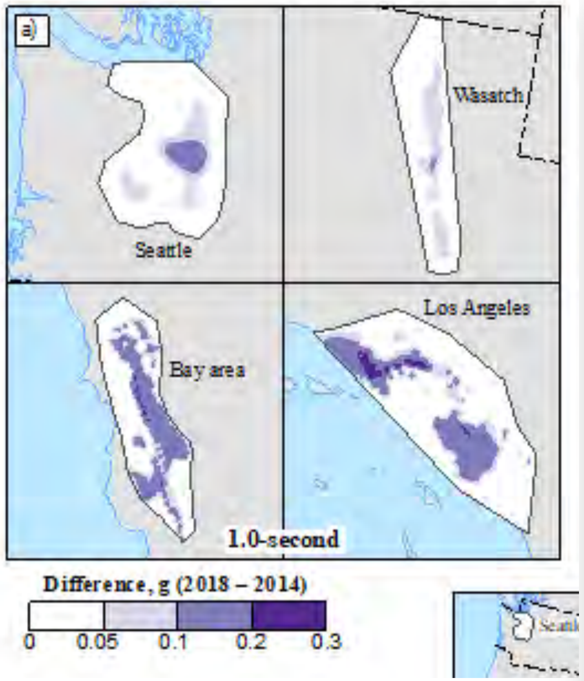
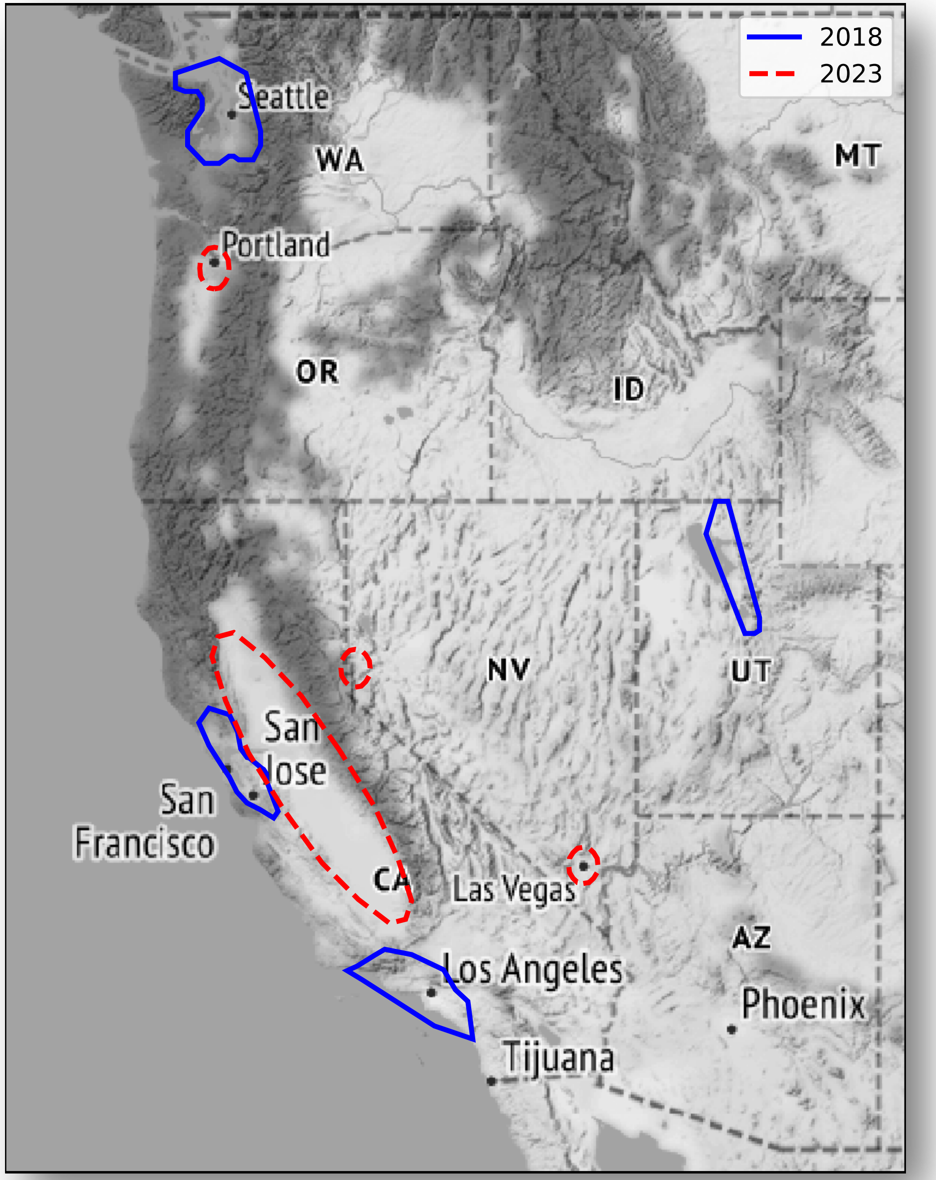
(slide courtesy O. Boyd and S. Ahdi)

WUS Sedimentary Basins

- 2018 NSHM
  - Z1.0 and Z2.5 where Z2.5 > 3 km
    - Southern CA
    - Seattle
    - San Francisco Bay region
    - Wasatch Front
  - No deamplification where Z2.5 < 3 km
  - Regional treatments (e.g., Z2.5-preference for Seattle basin)





Powers, P.M., S. Rezaeian, N. Luco, A. M. Shumway, M. D. Petersen, O. S. Boyd, M. P. Moschetti, A. D. Frankel, and E. M. Thompson The 2018 Update of the U.S. National Seismic Hazard Model: Ground Motion Models in the Western U.S. (in revision, Earthquake Spectra)

Petersen, M.D., A.M. Shumway, P.M. Powers, C.S. Mueller, M.P. Moschetti, A.D. Frankel, S. Rezaeian, D.E. McNamara, S.M. Hoover, N. Luco, O.S. Boyd, K. Rukstales, K. Jaiswal, E.M. Thompson, B. Clayton, E.H. Field, and Y. Zeng (2020, Earthquake Spectra)

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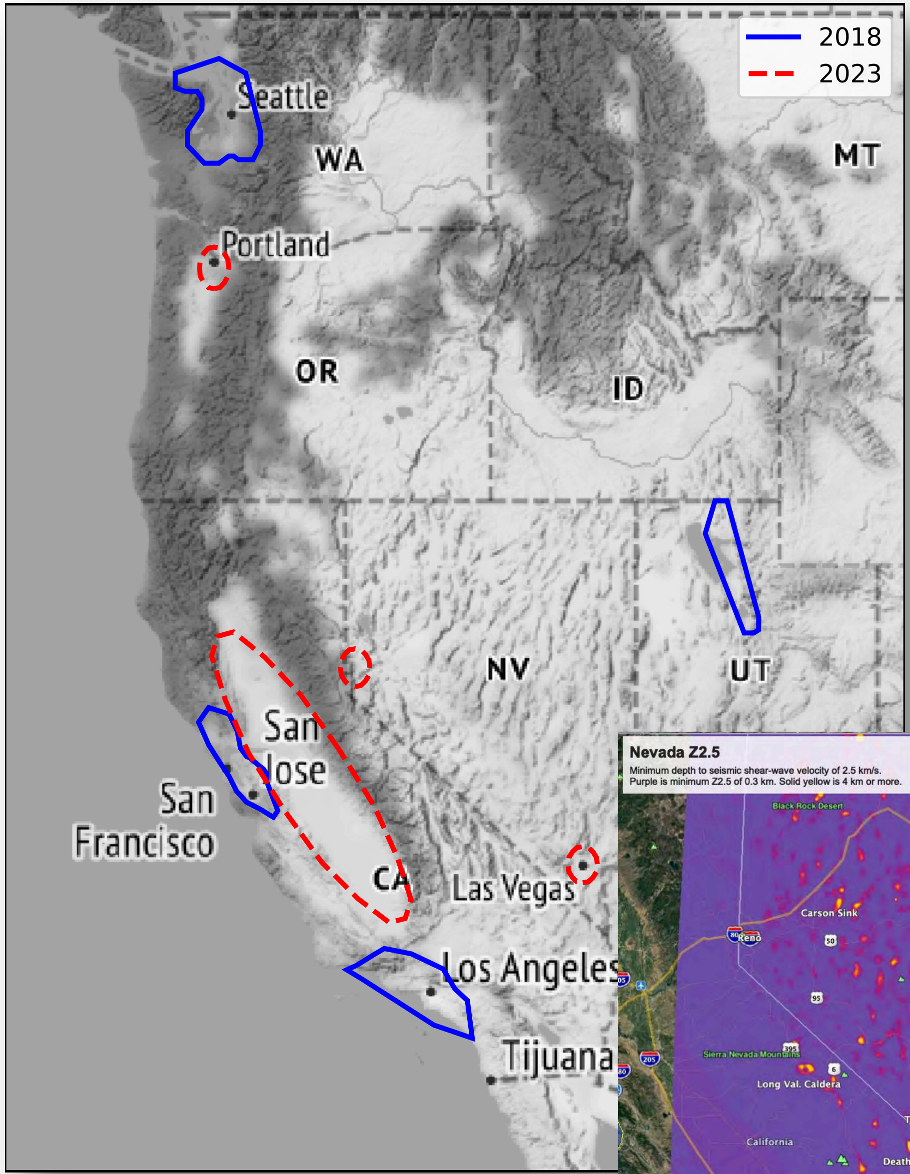
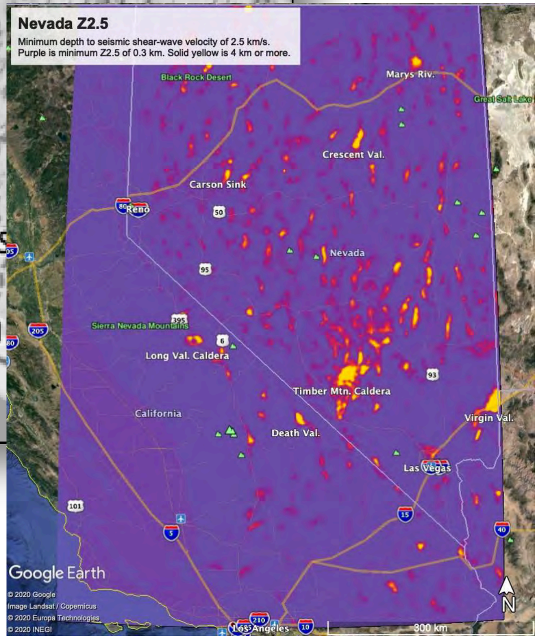
(slide courtesy B. Aagaard)

WUS Sedimentary Basins

- 2023
  - Improve amplification factors associated with Z1.0 and Z2.5
    - Consider new Z1.0 and Z2.5 models
      - CA: Great Valley
      - NV: Reno and Las Vegas (Simpson and Louie, 2020)
      - OR: Portland and Tualatin (Frankel and Grant, 2020)
      - WUS: National Crustal Model (Boyd and Shah, 2018)
    - Steps to incorporation of Z1/Z2.5 models
      - Evaluate seismic velocity models—comparison and consistency between models
      - Identification of preferential Zx values and model adjustment/development
      - Comparison with ground motion data
  - Assess amplification / variability when Z2.5 < 3 km
  - Use of 3D ground-motion simulations

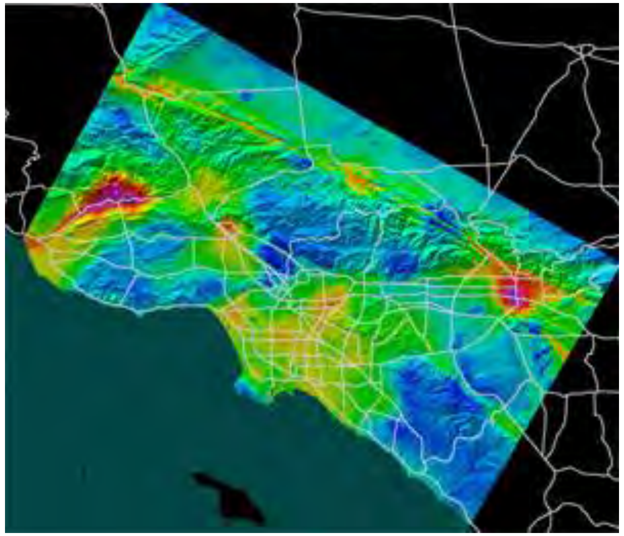




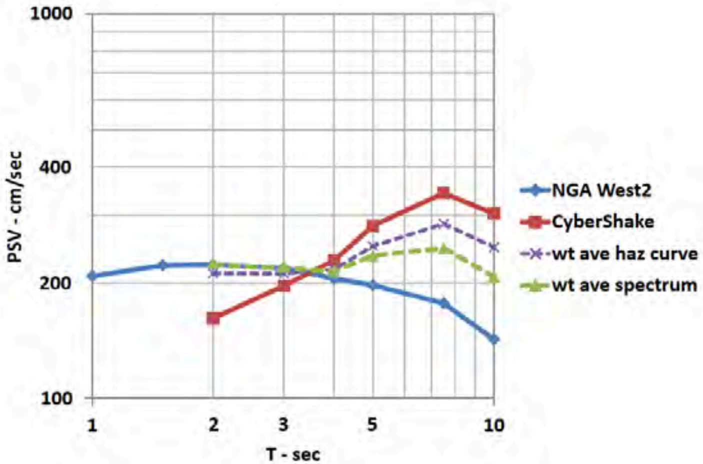
(slide courtesy B. Aagaard and S. Ahdi)

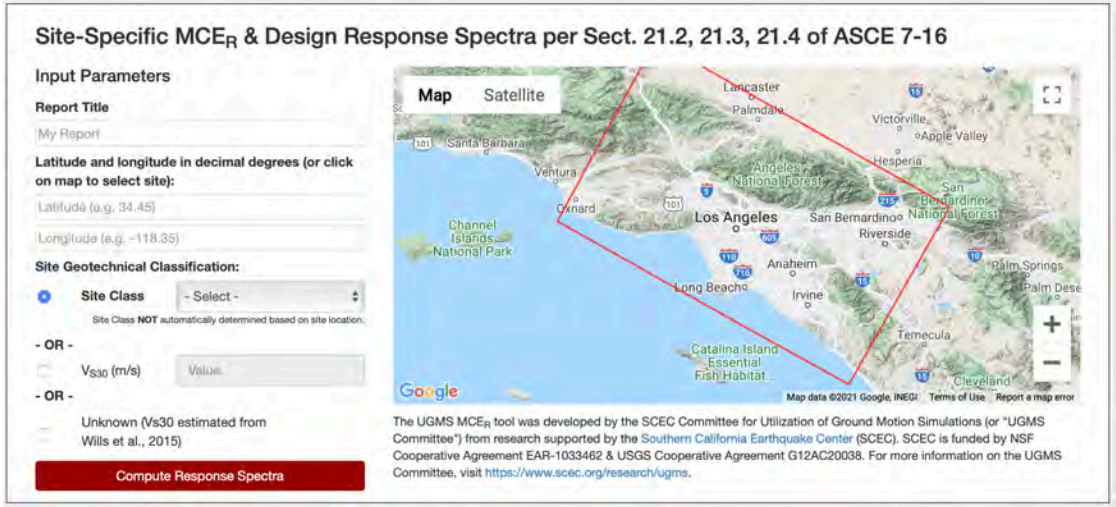
Use of 3D ground-motion simulations: Southern California and PNW

Southern California: SCEC CyberShake

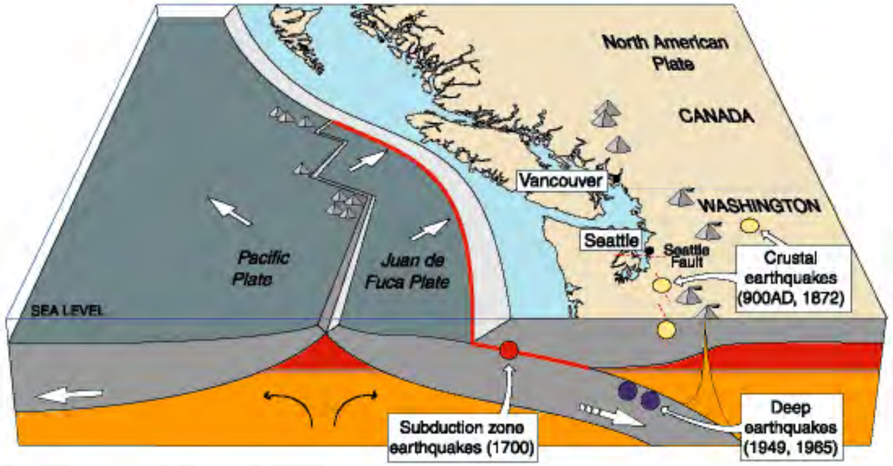


SCEC-UGMS: Site COO





PNW: M9 Project



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2018 Report on Incorporating Sedimentary Basin Response into the Design of Tall Buildings in Seattle, Washington

By Erin A. Wirth, Susan W. Chang, and Arthur D. Frankel

Open-File Report 2018–1149

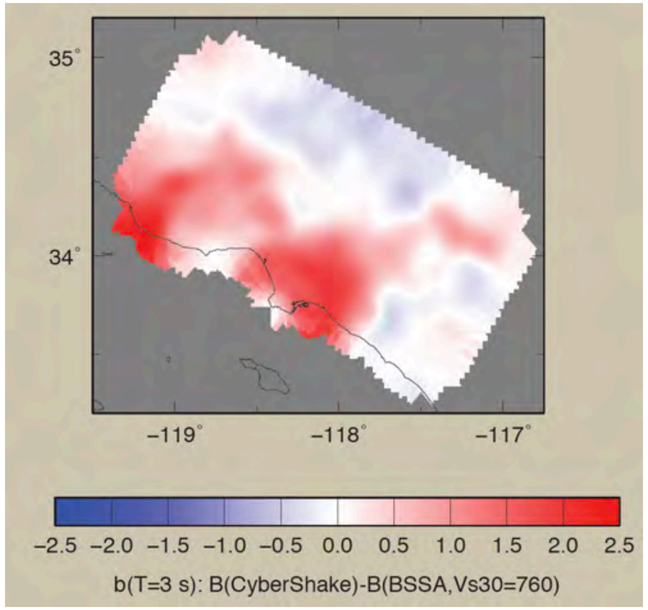
Use of 3D ground-motion simulations: Southern California

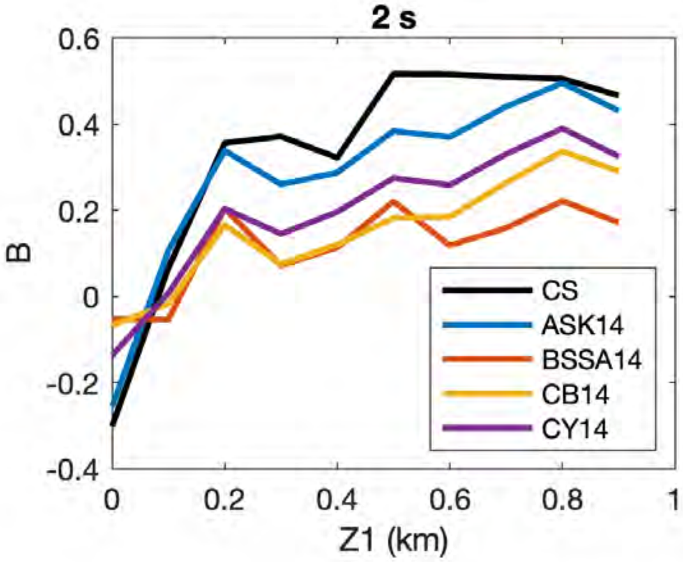
$$lnY(M,R,T,\boldsymbol{x},\ldots) = lnY^{BSSA14,760}(M,R,T,\ldots) + b(T,\boldsymbol{x}) + c(T)$$

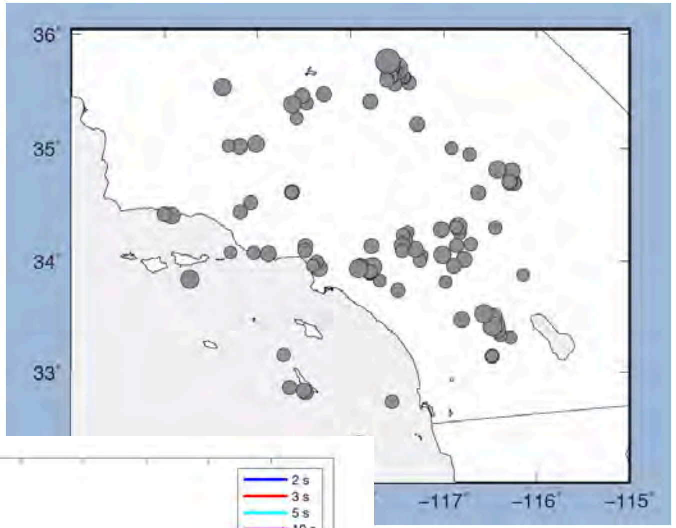
Bulletin of the Seismological Society of America, Vol. 104, No. 3, pp. 1230–1257, June 2014, doi: 10.1785/0120130263

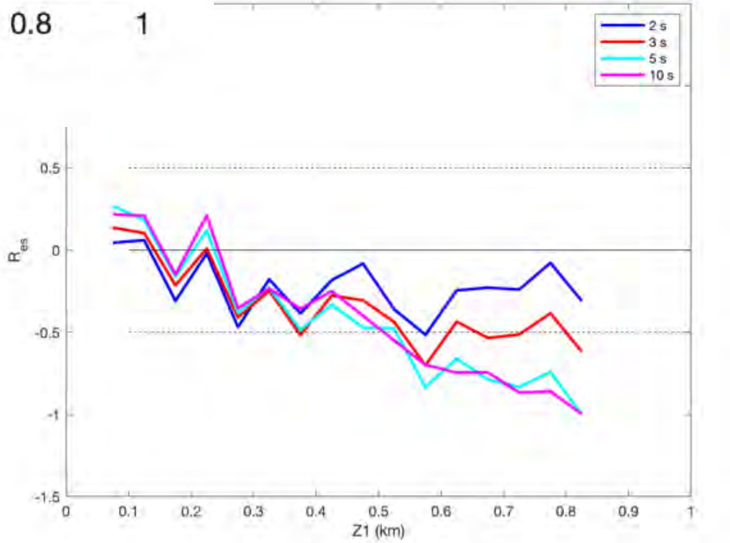
Comparison of Probabilistic Seismic-Hazard Models Using Averaging-Based Factorization

by Feng Wang* and Thomas H. Jordan









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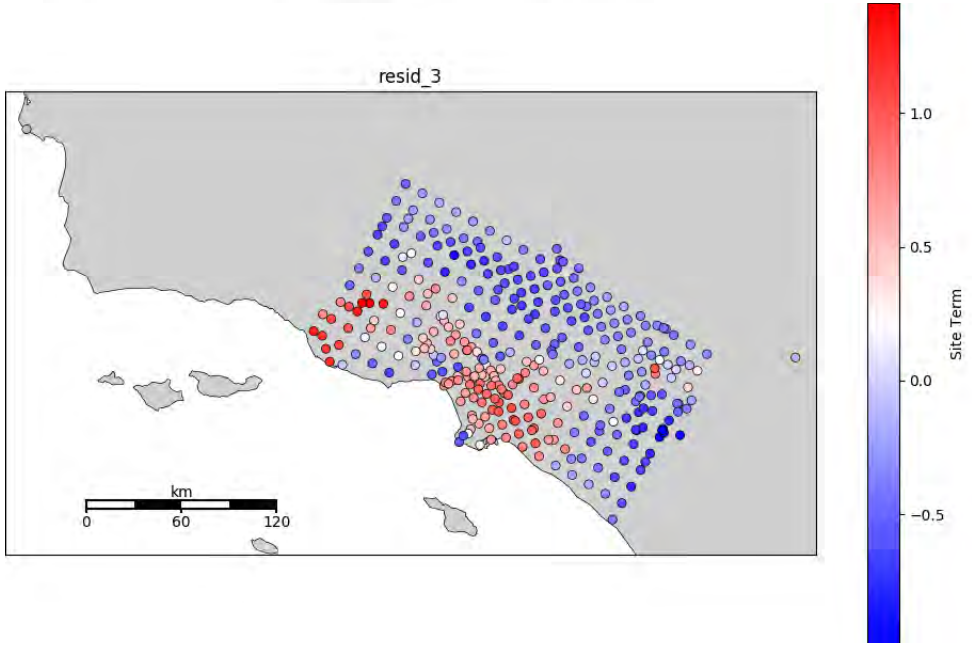
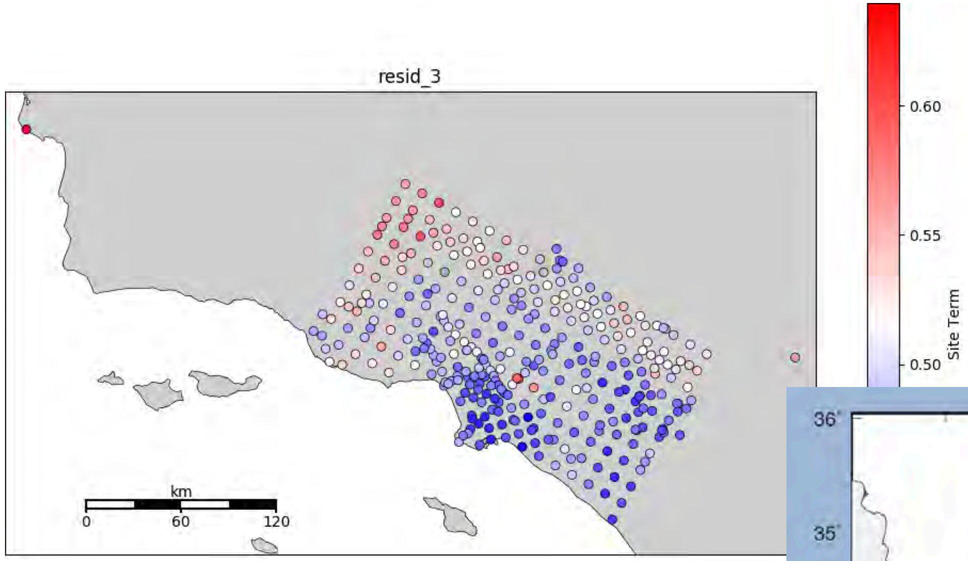
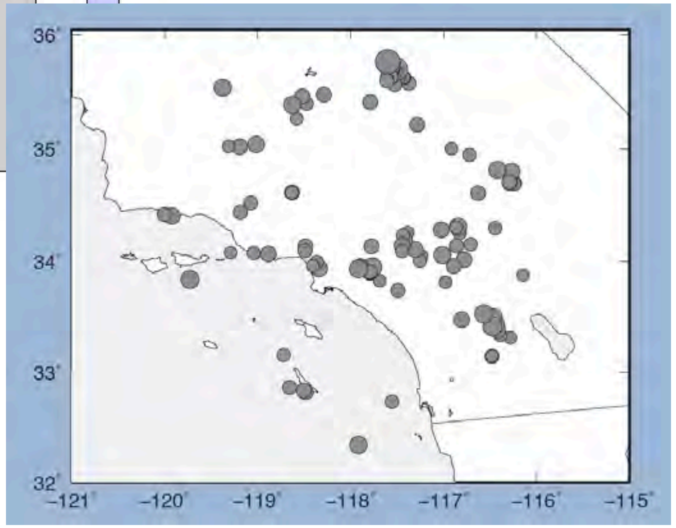
Use of 3D ground-motion simulations: Southern California

Basin amplification and site response from ground motion residual analysis:

$$R_{es} = c + \delta E_e + \delta S_s + \epsilon_{es}$$







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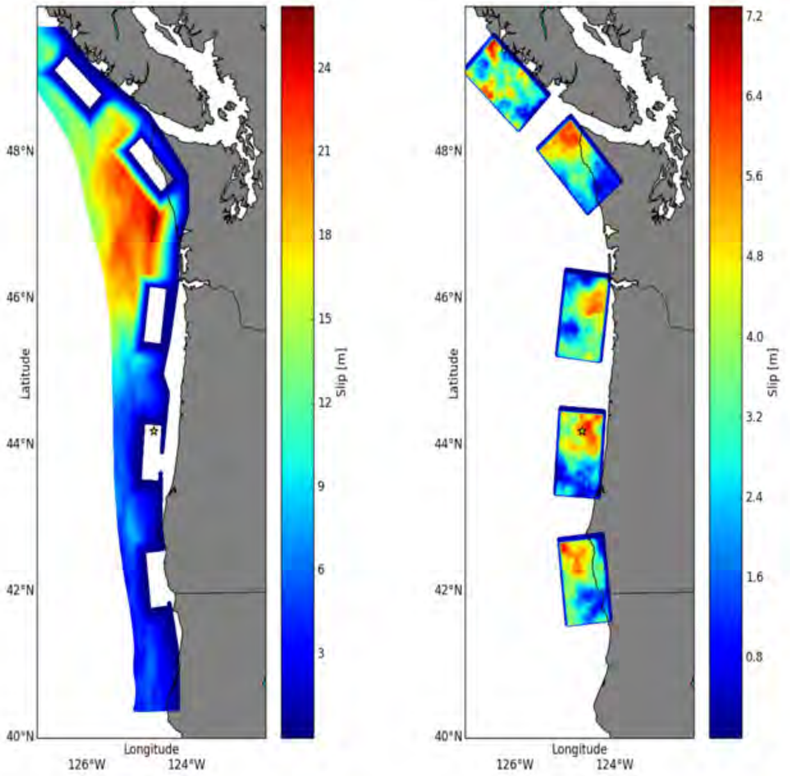
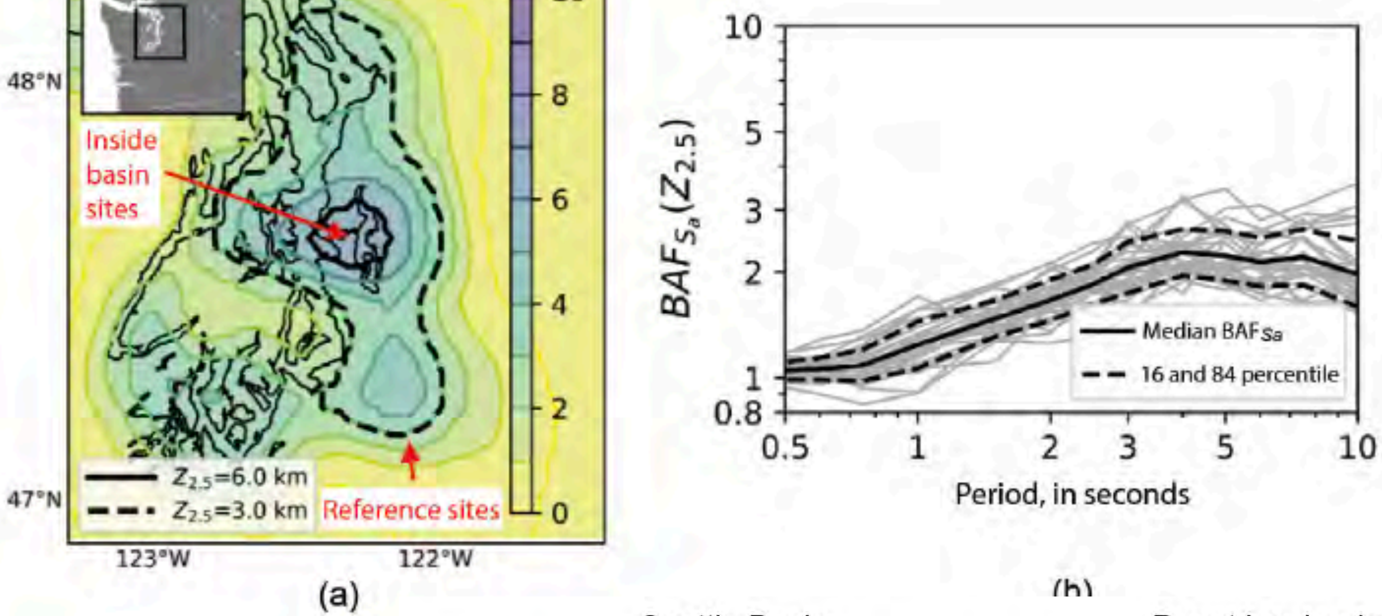
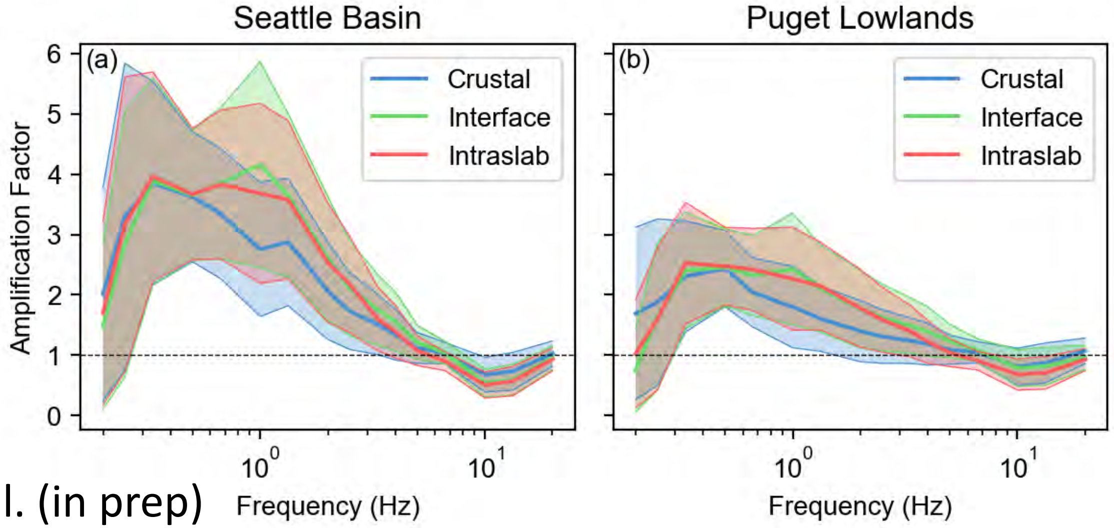
WUS Sedimentary Basins: Use of 3D ground-motion simulations , M9



Frankel et al. (2017)

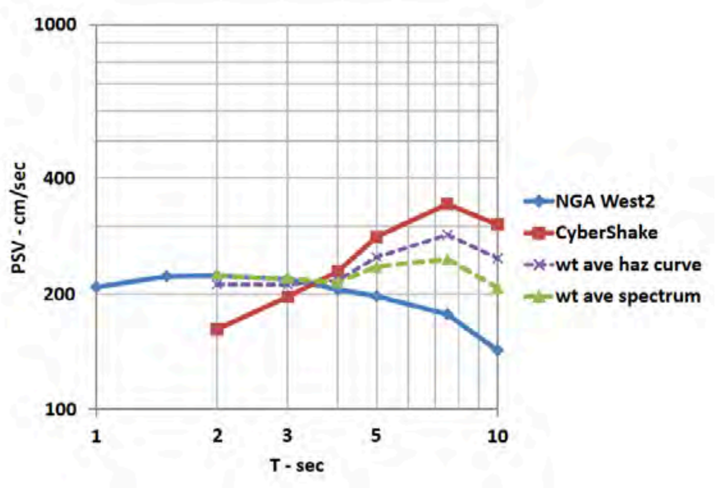
Wirth et al. (2018)





Rekoske et al. (in prep)

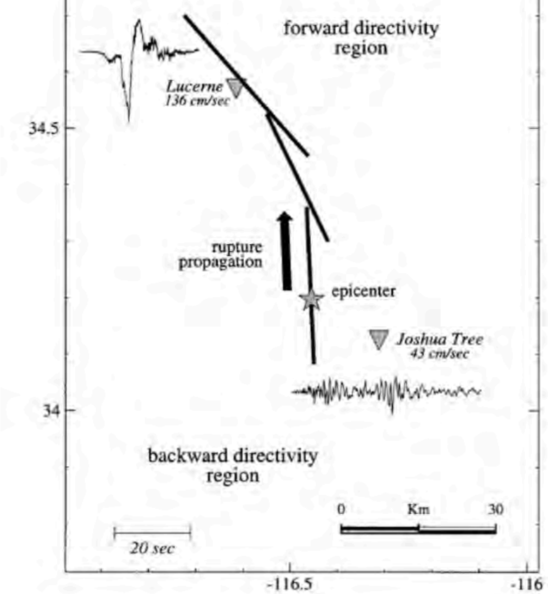
Use of 3D ground-motion simulations: NSHM implementation



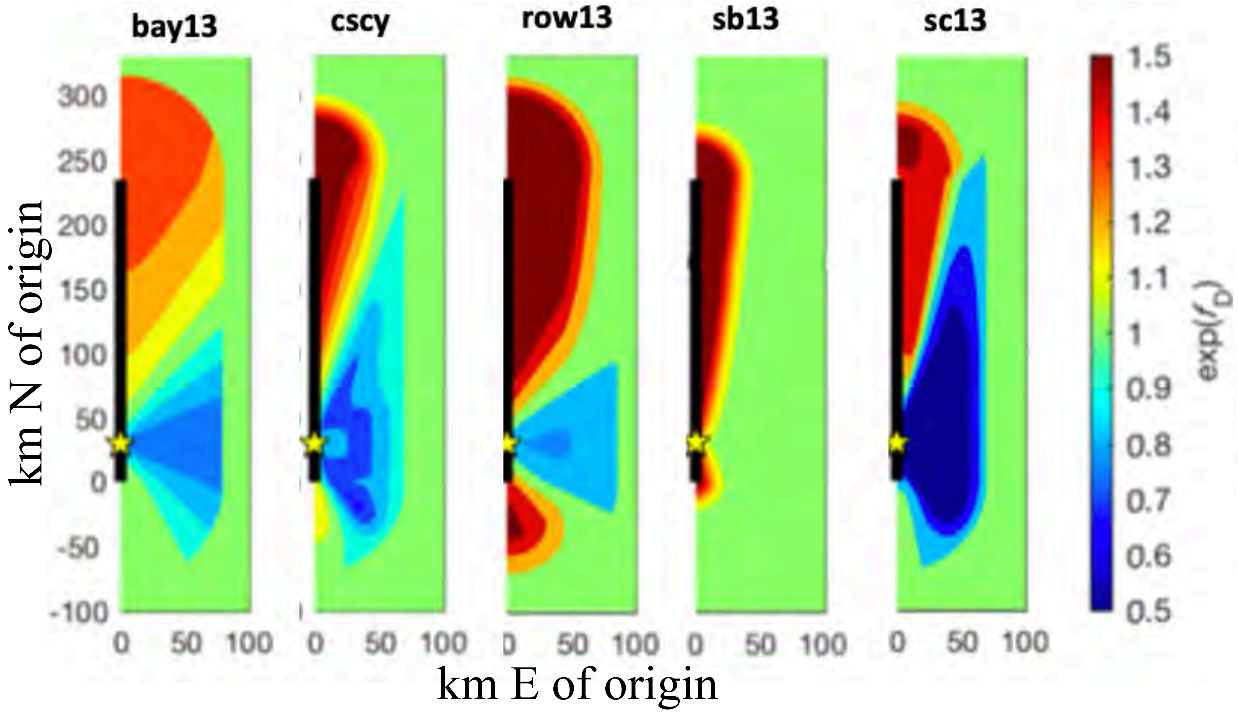
- What features of simulations are ready for implementation in NSHM
- Ground motion simulation validation (S. Rezaeian, building from SCEC-GMSV)
- How to combine simulation-based GMMs with empirical GMMs
- Modify aleatory variability?

Evaluation and Implementation of Directivity Models

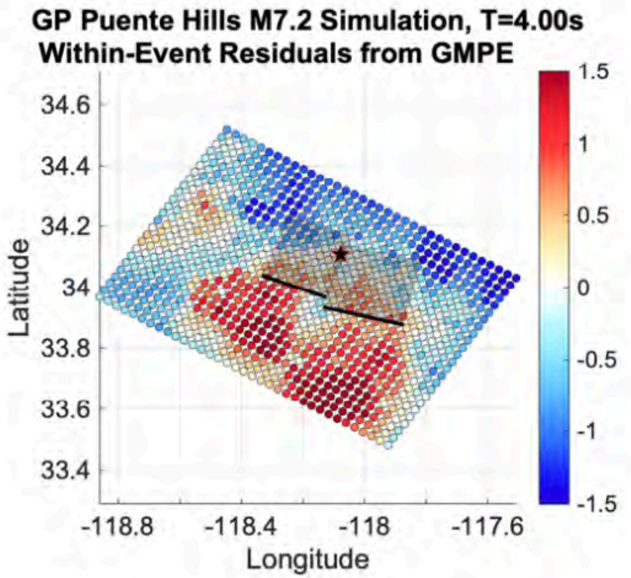
- Develop rupture directivity models (DMs) for implementation into NSHM derived from empirical relationships in combination with guidance from simulated data

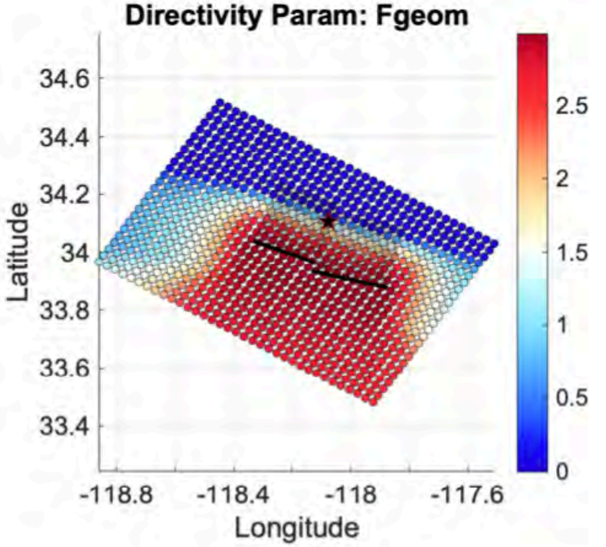


Somerville et al., 1997



modified from Donahue et al., 2019

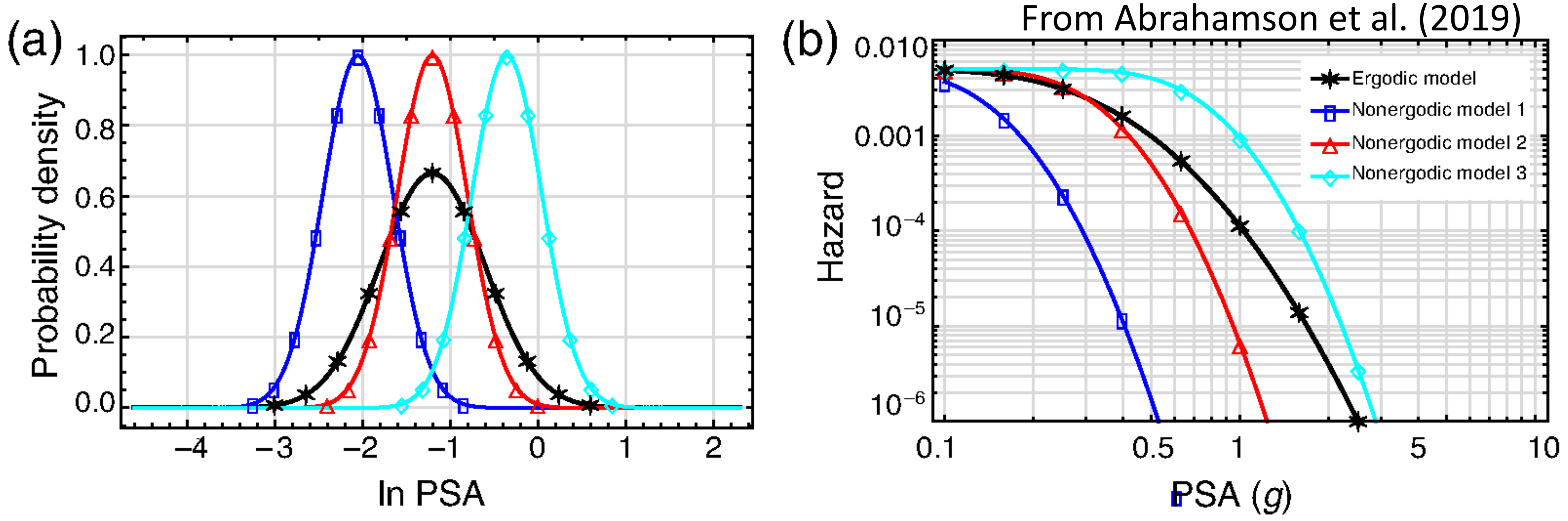




Bayless et al., 2020

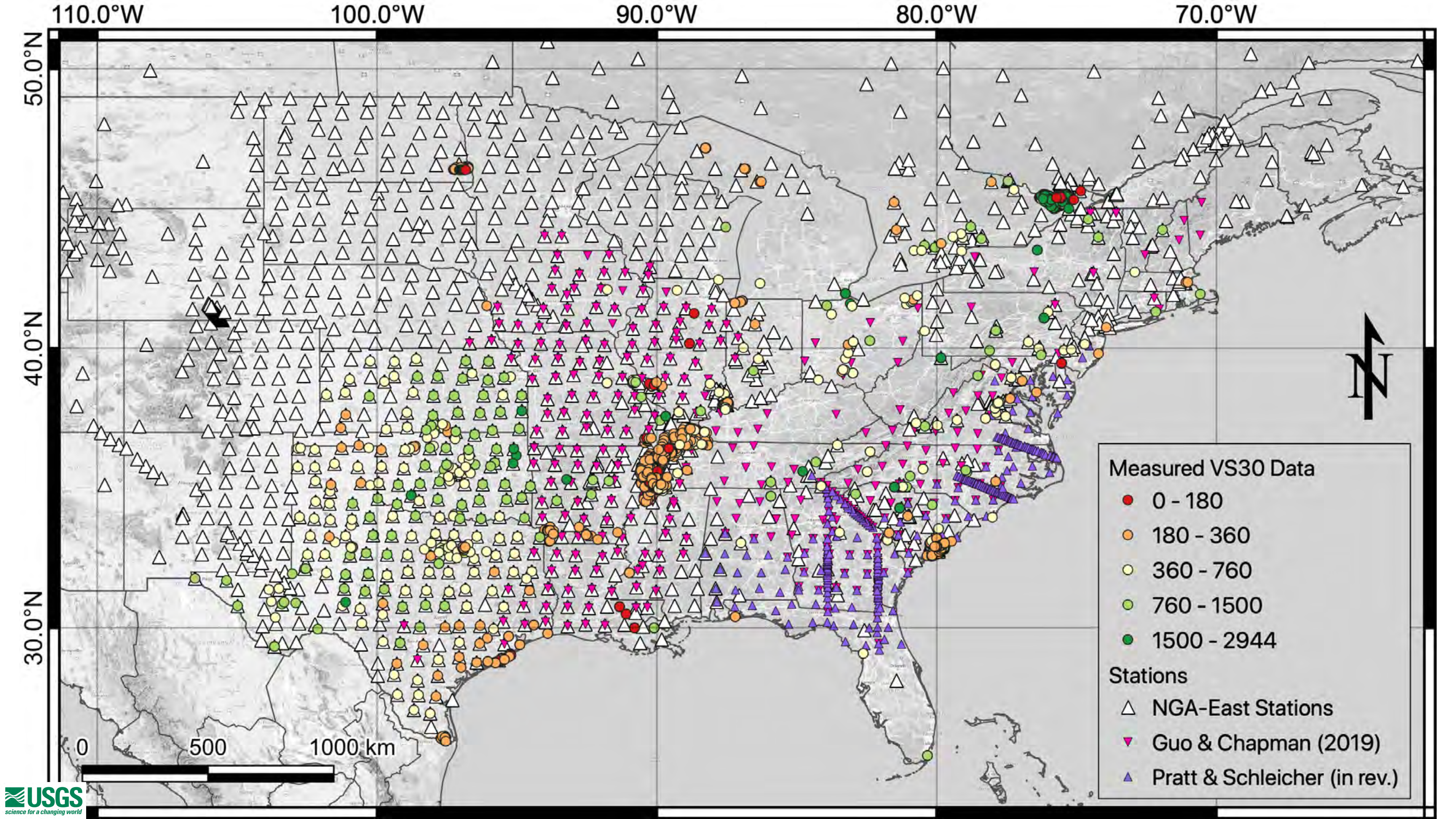
(Slide courtesy K. Withers)

Towards non-ergodic GMMs



From Abrahamson et al. (2019)

- Seismic hazard sensitivity of NSHM to non-ergodic framework
- Consideration of non-ergodic models for national-scale seismic hazard assessment
  - Not high-resolution spatial variations in source properties, site response, path attenuation
  - Broad, regional-scale
  - Evaluate non-ergodic aleatory variabilities


110.0°W
100.0°W
90.0°W
80.0°W
70.0°W
50.0°N
40.0°N
30.0°N
Measured VS30 Data
0 - 180
180 - 360
360 - 760
760 - 1500
1500 - 2944
Stations
NGA-East Stations
Guo & Chapman (2019)
Pratt & Schleicher (in rev.)
0
500
1000 km
N
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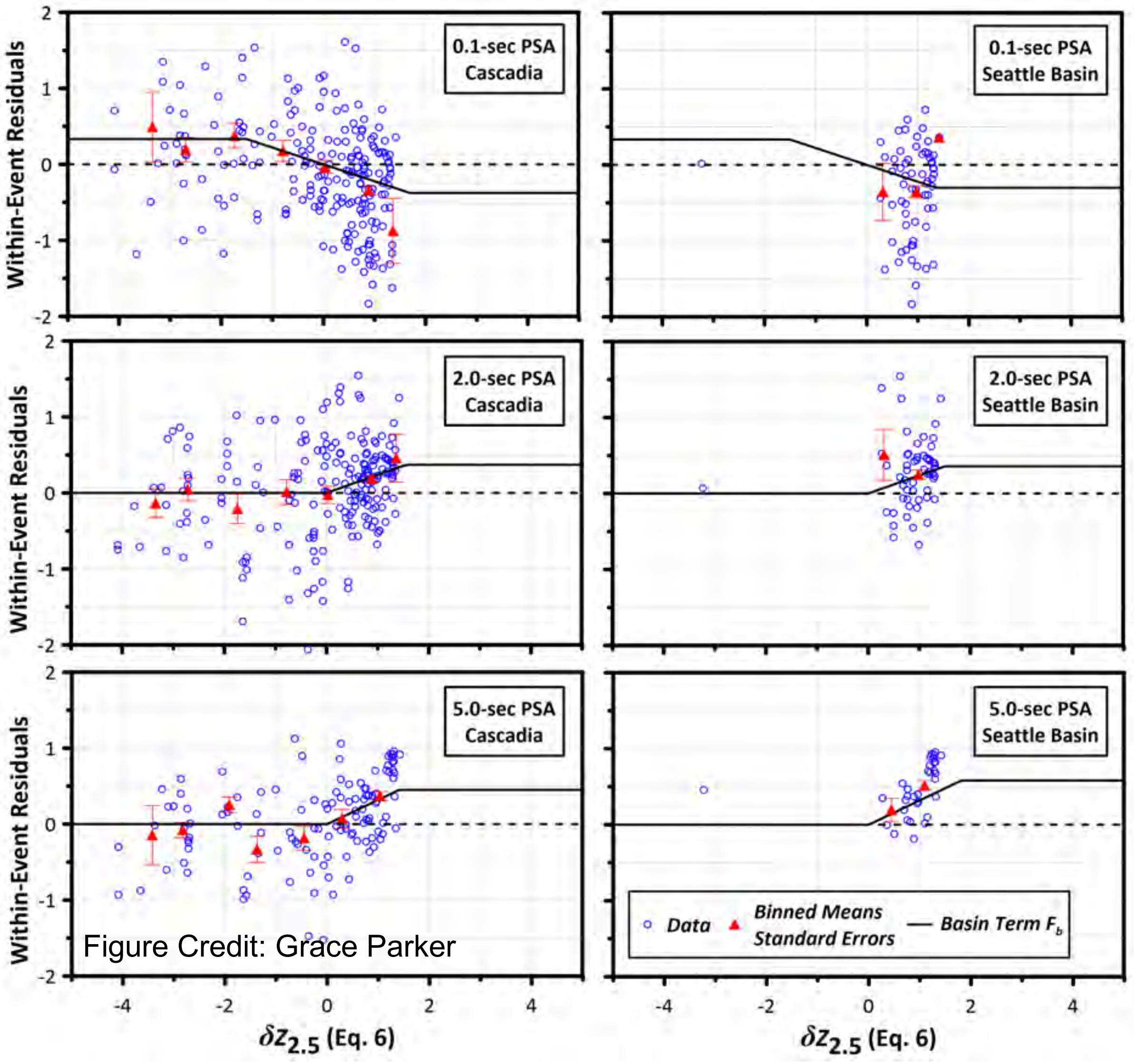
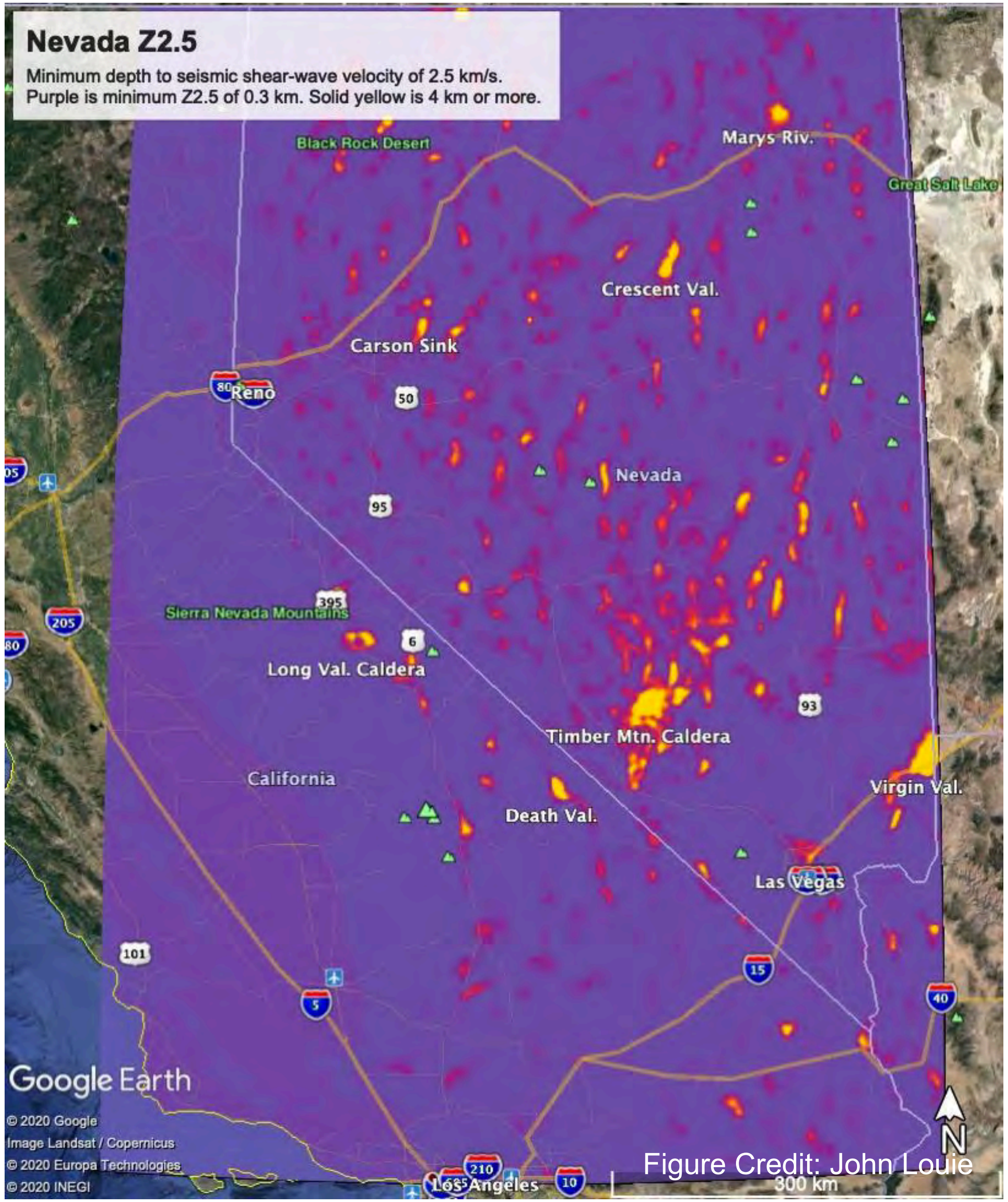
Future work - Basins

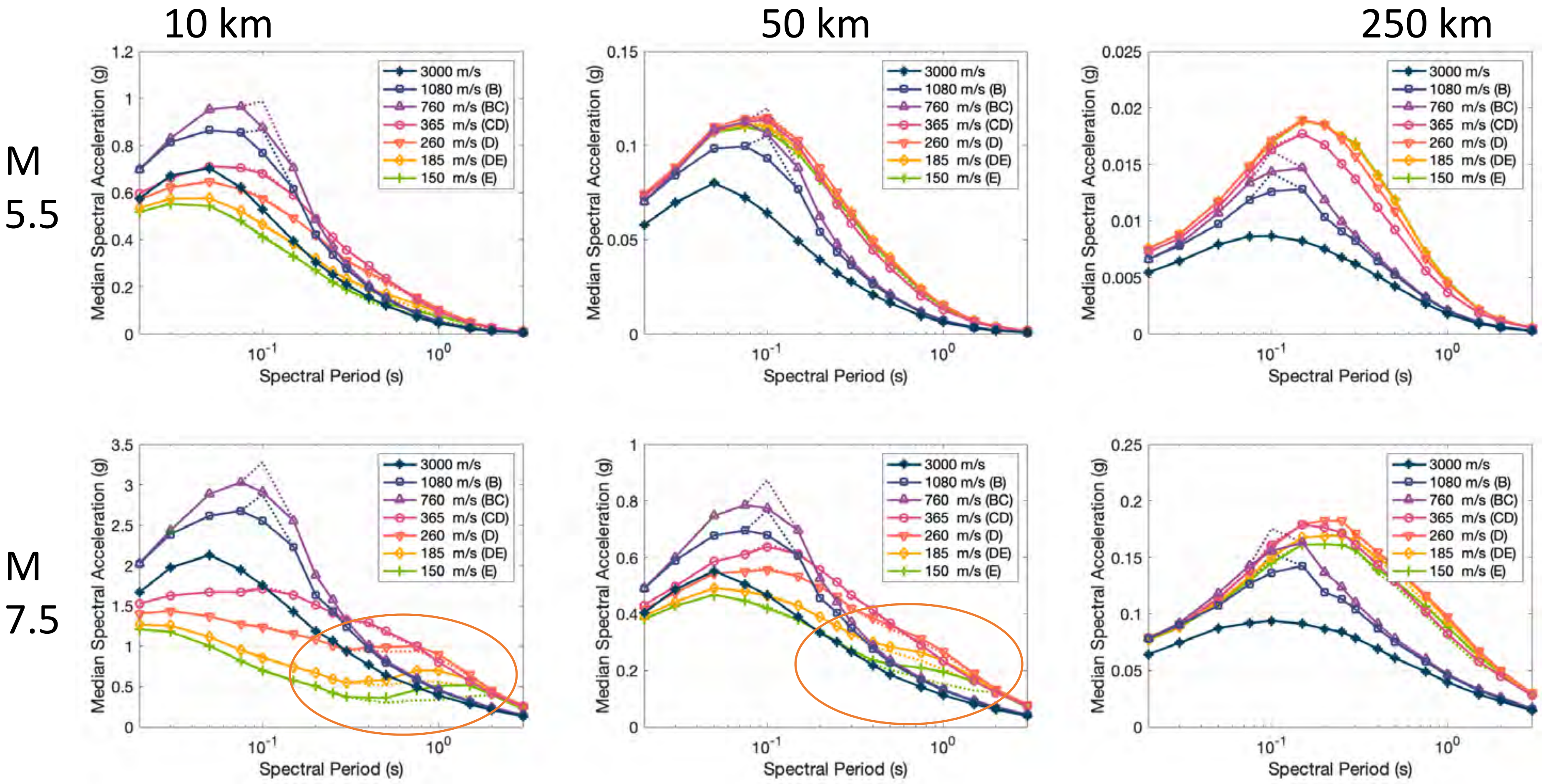




Left: Parker et al. (2020) Cascadia-specific NGA-Sub GMM: Within event residuals (total residuals – event terms), versus delta-Z2.5, the differential basin depth based on an average Z2.5 for a given VS30. delta_Z > 0 means deeper than average sediment depth: GM increases, the model term is positive at long periods; delta_Z < 0 means shallower than average sediment depth.
Right: Simpson & Louie (2020): UNR/NSL estimations of Z2.5 for Nevada, Eastern California, and specifically the Reno and Las Vegas basins.

CEUS Site-Effects Model for 2018:

- **Further illustration of the ‘shoulder effect’, magnitude and distance dependence:**



Rezaeian and others, in press

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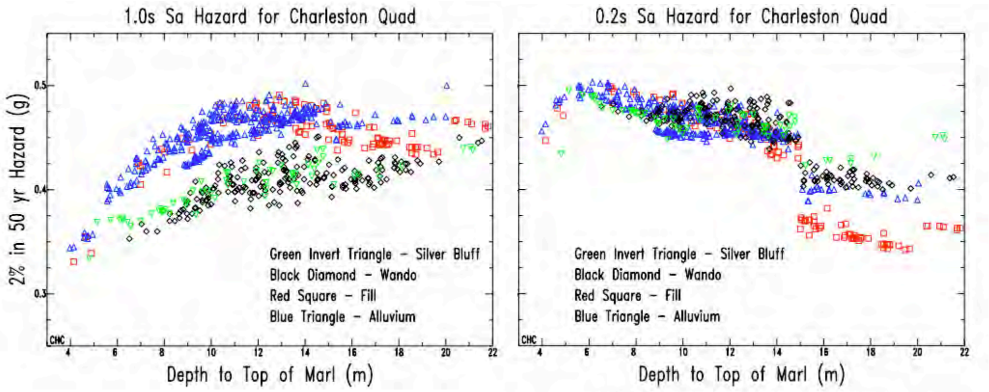
Simulation-Based Site Amplification Factors

- **Consider application of relative amplification factors using**

  1-D wave propagation methods though 3D velocity structure in:

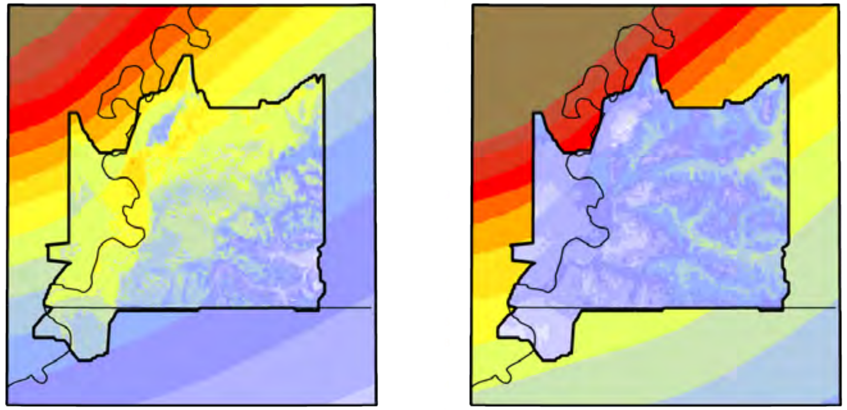
  1. *Memphis, TN*
  2. *St Louis, MO*
  3. *Evansville, IN*
  4. *Charleston, SC*



Cramer and others, 2015

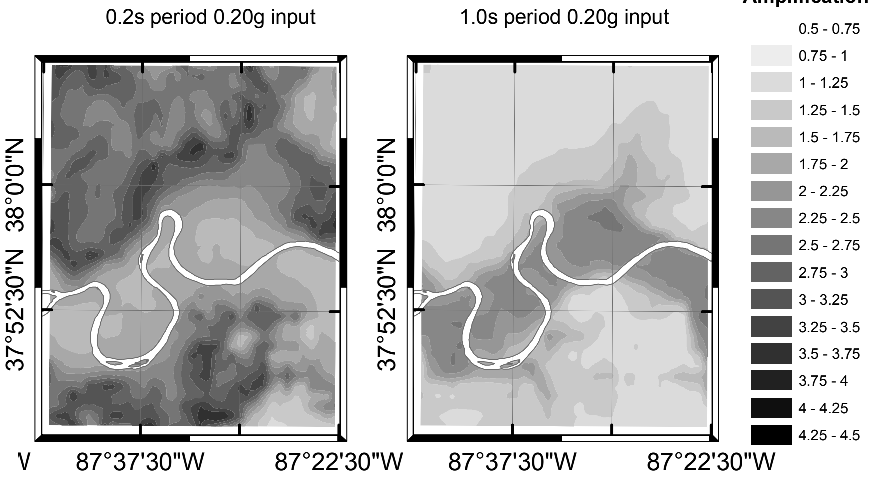
*Background maps assume V_{S30} of 760 m/s

Shelby County, TN (Memphis)*



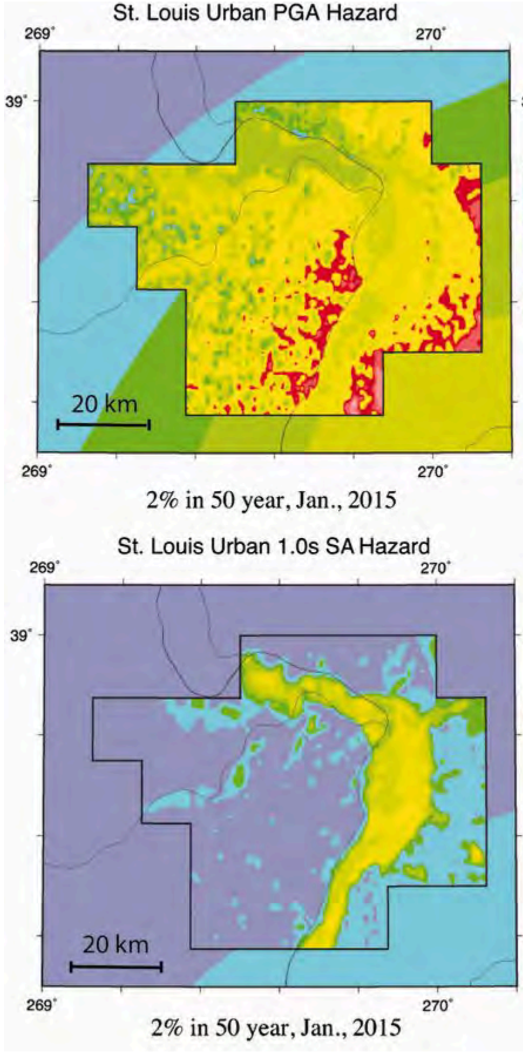
Cramer and others, 2014

Evansville, IN



Haase and others, 2011

St Louis, MO*



Cramer and others, 2017

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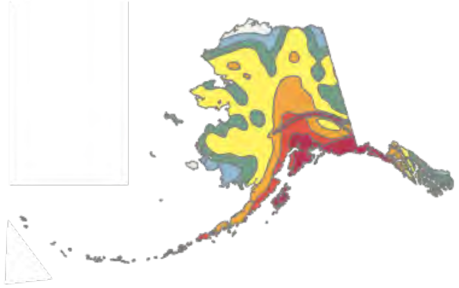
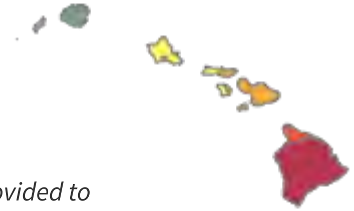
Alaska NSHM Update (2023)

Contact: Peter Powers pmpowers@usgs.gov
Workshop: Tuesday May 25th, 2021



Hawaii NSHM Update (2021)

Contact: Mark Petersen mpetersen@usgs.gov



These data are preliminary or provisional and are subject to revision. They are being provided to meet the need for timely best science. The data have not received final approval by the U.S. Geological Survey (USGS) and are provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the data.

Alaska NSHM Updates

Prior models: 1999, 2007

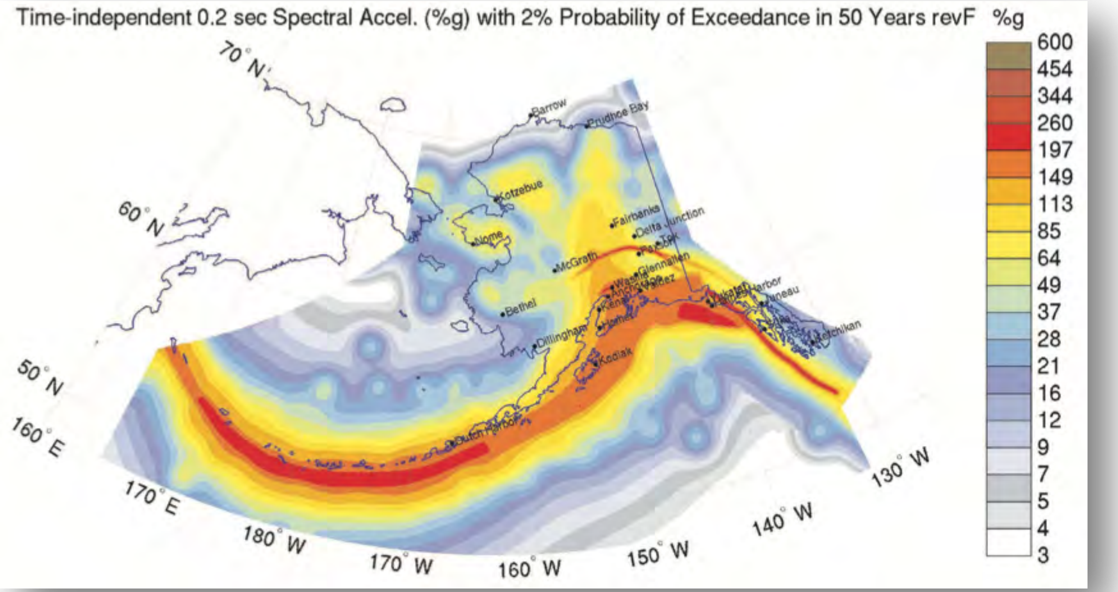
Goal: Apply uniform methodology to all NSHMs

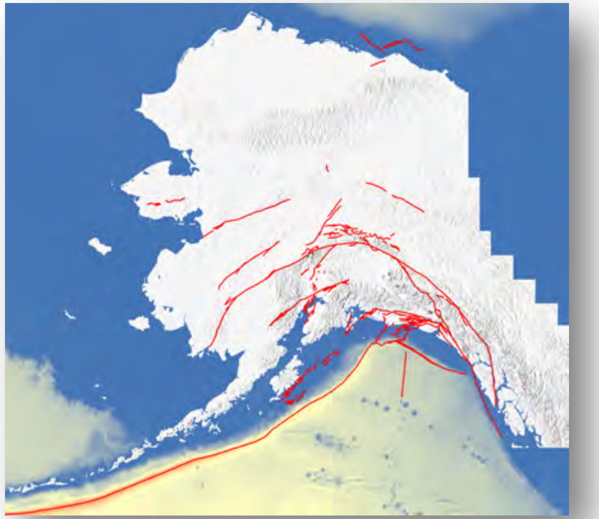
Crustal fault sources

- Fault section inventory
  - Consider area/zone sources
- Geologic and geodetic deformation models
  - Elliott/Freymueller, Zeng (USGS), Shen (NeoKinema)
- Rate model (inversion methodology)
  - Multi-fault ruptures
  - Along strike variations in slip

Gridded (smoothed) seismicity sources

- Earthquake catalogs
- Updated declustering/smoothing methods
- Segregate catalogs by tectonic setting (SLAB2)





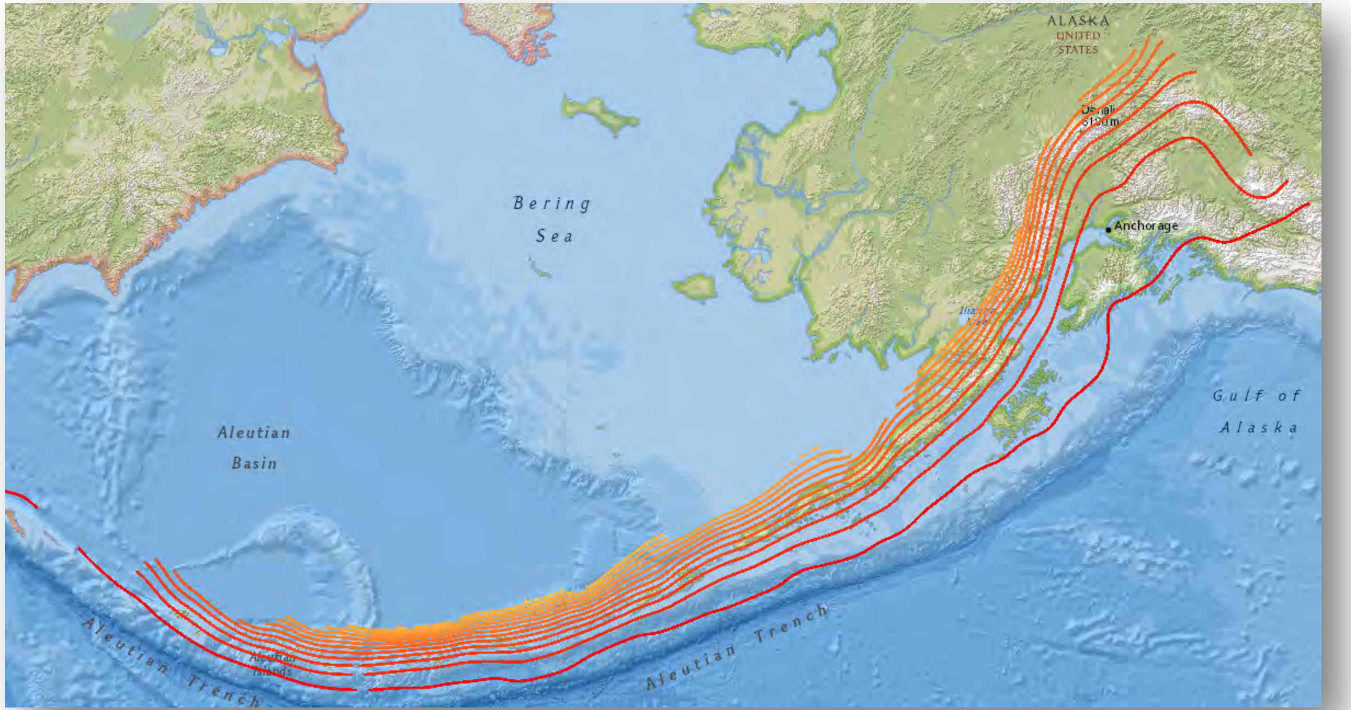
Alaska NSHM Updates

Aleutian megathrust

- Geometry (SLAB2)
- Segmentation and recurrence
- Down-dip width, coupling uncertainty

Ground motion models (GMMs)

- Interface/slab: NGA-Subduction
  - Regionalized models for AK
  - Improved site and basin effects
- Crustal: NGA-West2
- Basin and localized effects
  - Fore-arc/Back-arc, slab guide
- Basin models
  - Cook Inlet – Susitna, Nenana, possible others



Contact: pmpowers@usgs.gov

Workshop: Tuesday May 25th, 2021

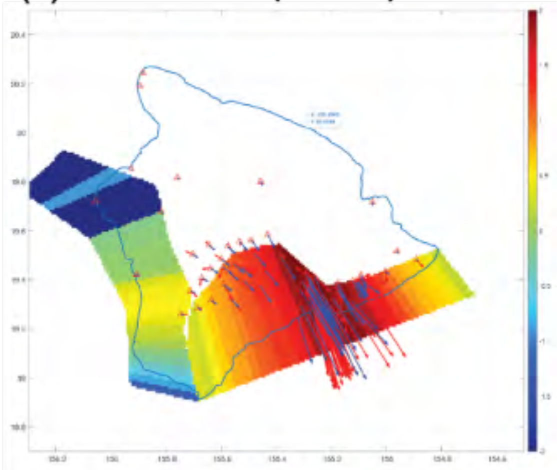
Hawaii Earthquake Sources

- Several thousand new earthquakes (M>=3) were recorded since last update. A newly developed earthquake catalog improves the magnitudes and locations of past events and adds more recent events. We implement three 60-year catalogs which show earthquake rates decreasing with time.
- New methods for statistical seismicity include: (1) declustering earthquake catalogs to remove spatial and temporal rate biases that are applied R85, NN; (2) adaptive smoothing models to update the older seismicity models applied in 2001.
- A model for caldera A model for caldera collapse earthquakes formulated by Llenos and Michael (2021) is applied to make better shaking assessments near the Kīlauea caldera.
- A new Quaternary fault map shows locations and slip rates of dozens of faults (Cannon et al., 2007). We modified fault geometry and rates based on these data.
- HVO currently records GPS data from 66 stations installed over the past few decades. These data along with the geologic data were used to develop décollement models for the south and west flanks of the island of Hawaii with indications the south flank is factor of 10+ times more active than the west flank.

(a) Flank Source Geometries

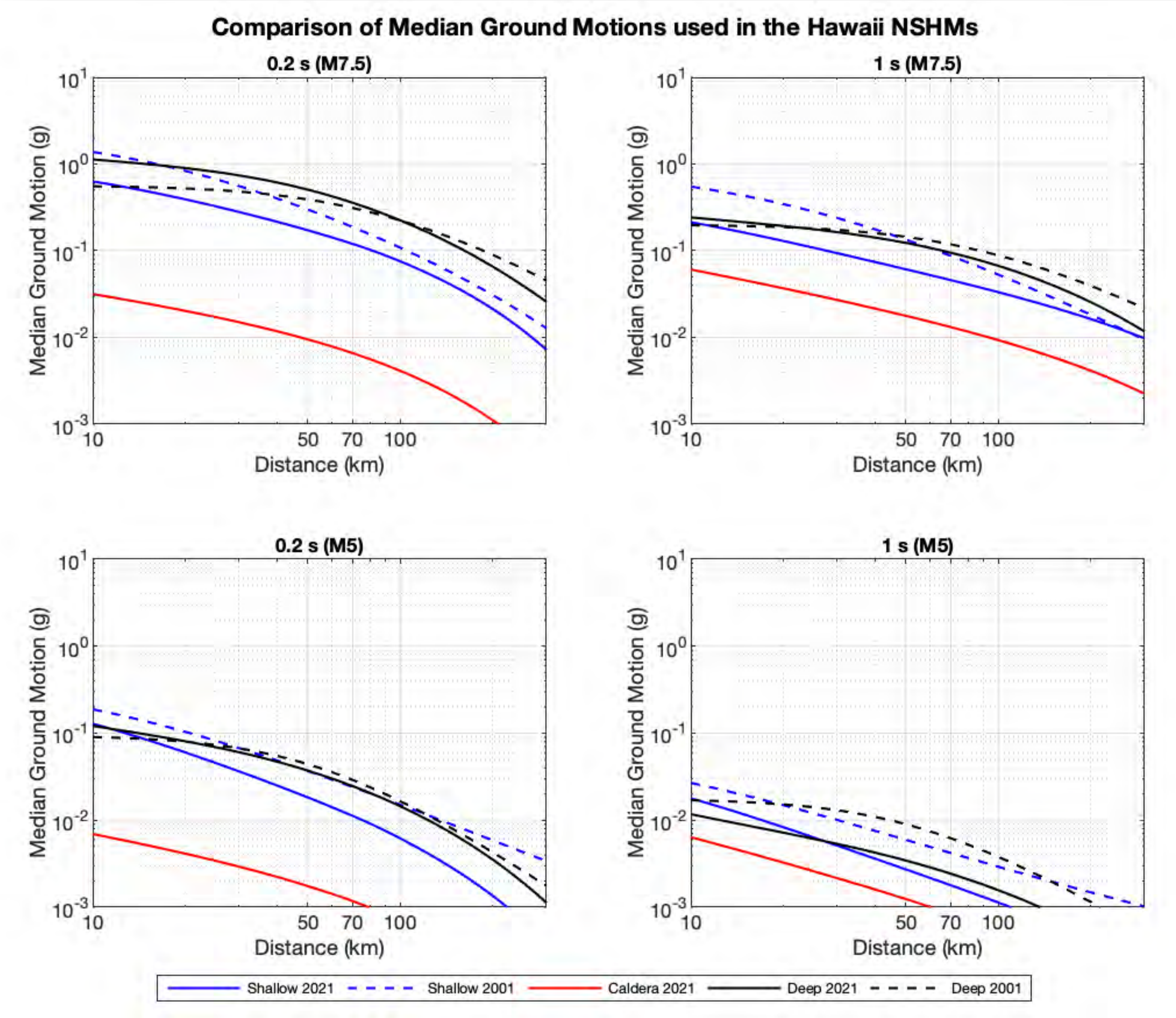
(b) Quaternary Faults

(c) Strain Rate (1.0e-9)

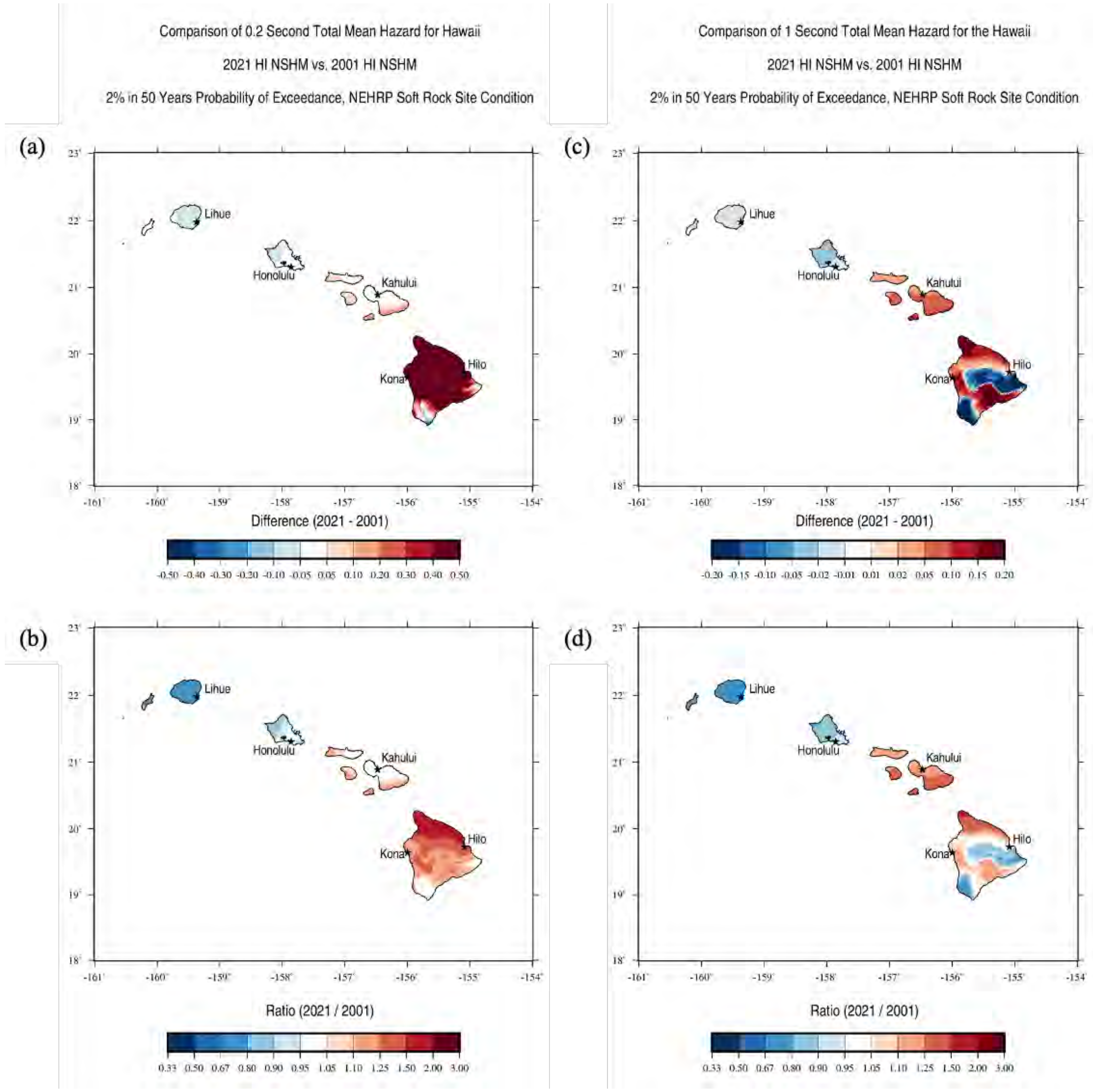


Hawaii Ground Motion Models

- About 70 strong motion instruments recorded hundreds of ground motions over the past several decades. Two large earthquake sequences in 2006 (M6.7 Kiholo Bay) and 2018 (M6.9 Kalapana) provided important shaking data. New Hawaiian specific GMMs were developed to provide a better assessment of strong ground shaking in Hawaii and strong motion data were used to evaluate global GMMs that best fit the Hawaii shaking data.
- Soils underlying strong motion stations were characterized to understand the site effects (Wong et al., 2011). Data were applied to evaluate Hawaii amplification functions.



Hawaii NSHM Preliminary Hazard Results



Comparison of 2% in 50 Years Probability of Exceedance for 0.2s Ground Motions							
Site	lat	long	2001	2021	Diff	Ratio	Ratio (%)
Hilo	19.7	-155.06	1.8	2.46	0.66	1.37	37%
Kona	19.66	-156	2.43	2.88	0.45	1.18	18%
Kahului	20.9	-156.5	0.97	0.95	-0.02	0.98	-2%
Honolulu	21.3	-157.86	0.61	0.62	0.01	1.02	2%
Lihue	21.96	-159.36	0.25	0.18	-0.07	0.71	-29%
Comparison of 2% in 50 Years Probability of Exceedance for 1s Ground Motions							
Site	lat	long	2001	2021	Diff	Ratio	Ratio (%)
Hilo	19.7	-155.06	0.77	0.73	-0.04	0.95	-5%
Kona	19.66	-156	0.92	0.98	0.06	1.06	6%
Kahului	20.9	-156.5	0.25	0.30	0.05	1.19	19%
Honolulu	21.3	-157.86	0.18	0.16	-0.02	0.92	-8%
Lihue	21.96	-159.36	0.07	0.05	-0.02	0.72	-28%

Engineering & Risk Uses of the 2023 USGS National Seismic Hazard Model

NSHMP 2023 50-State NSHM Update - Kickoff Meeting

Nicolas Luco, PhD
Research Civil Engineer

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Geologic Hazards Science Center
Golden, Colorado

Outline of Presentation

Engineering & Risk Project

Objectives: Civil engineering research and applications that directly inform natural-disaster mitigation, by improving
(1) the usefulness of USGS hazard assessments and
(2) their extensions to risk and impact assessments.

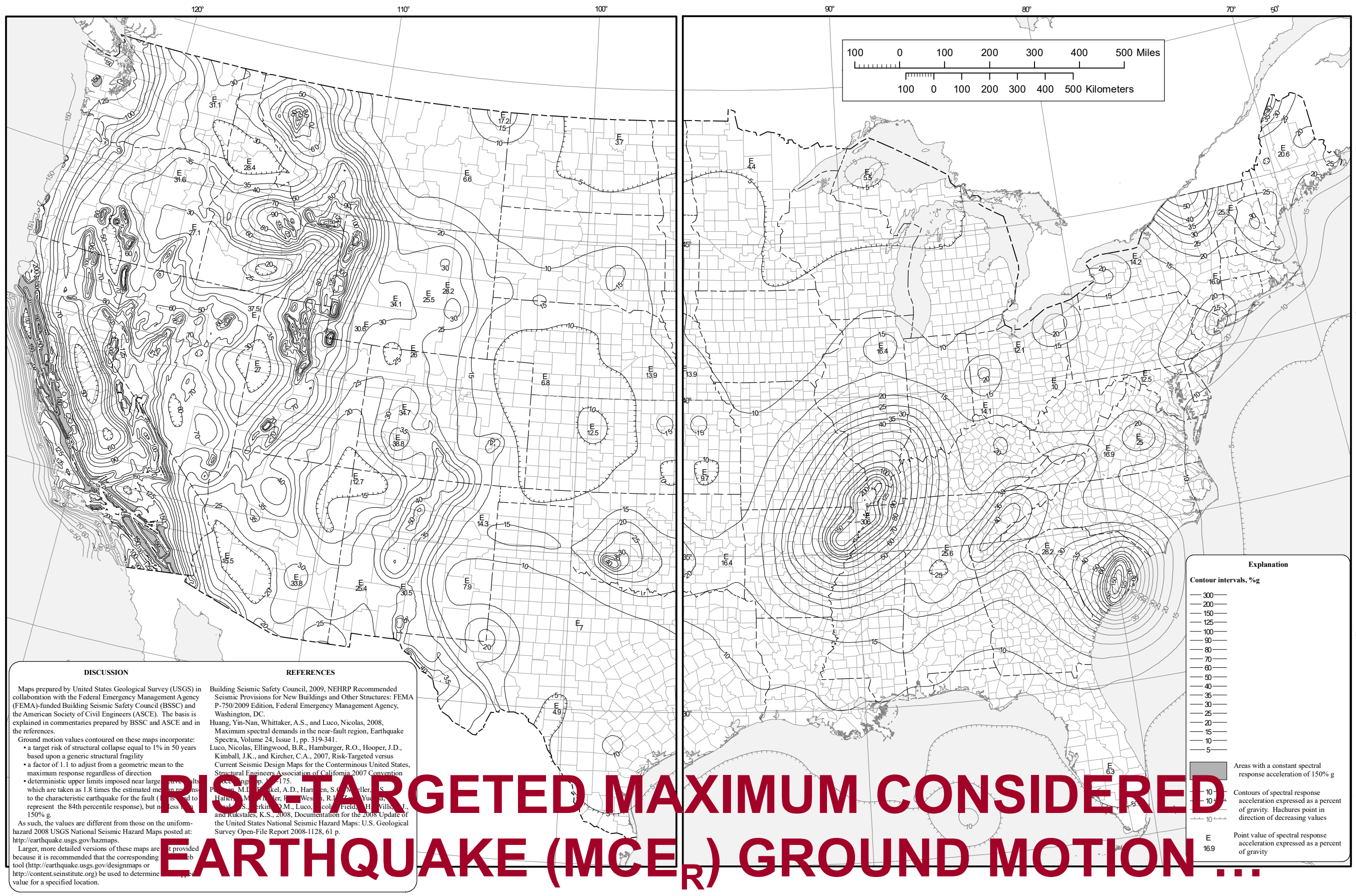
People:

- 4 structural engineers (Jaiswal, Rezaeian, Luco, & Kwong)
- 2 geotechnical engineers (Mason & Makdisi)
- Student interns (Stephens & searching for more)
- Numerous internal (e.g., Chase) & external collaborators

NSHM-Related Research & Applications

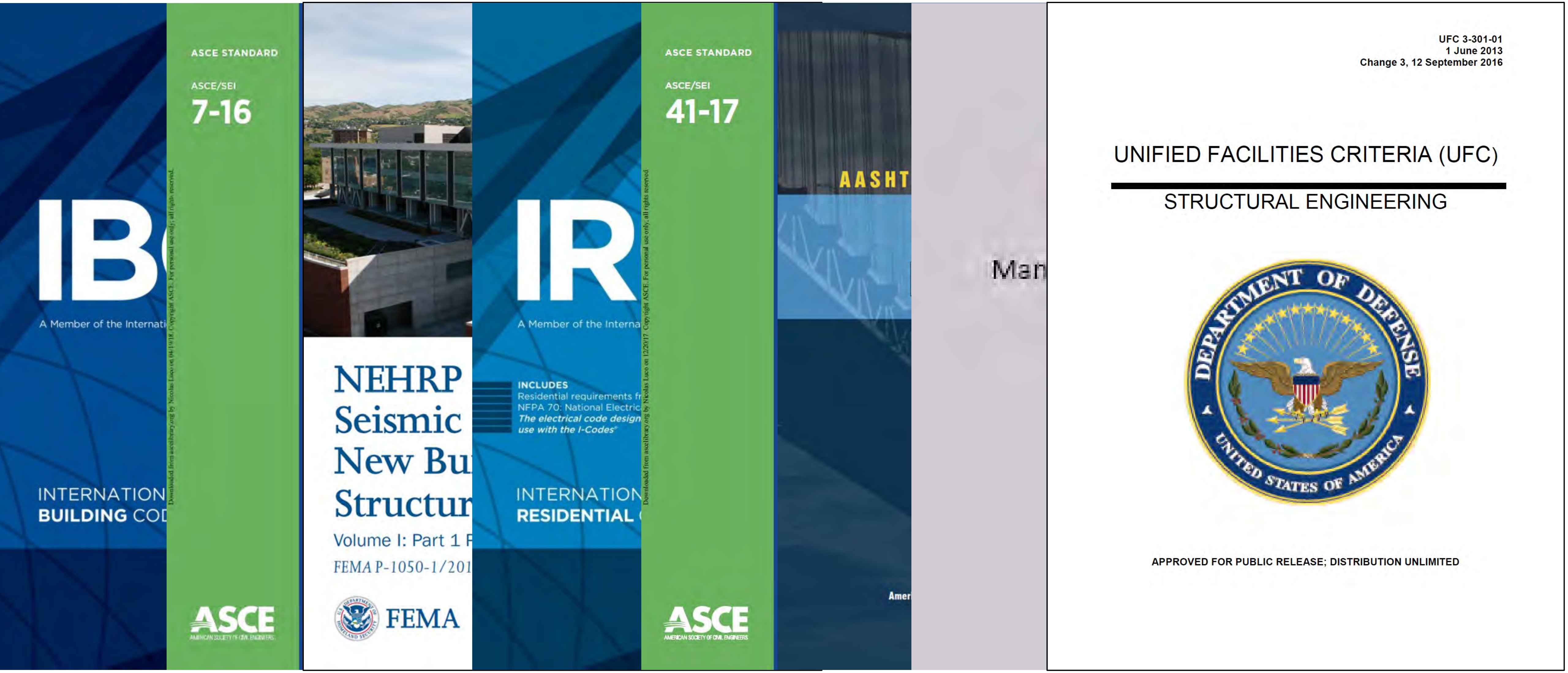
- ❑ Construction/building codes
- ❑ Selection/scaling/simulation of ground-motion time series
- ❑ Risk assessments

Construction/Building Codes



RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE (MCE_R) GROUND MOTION …

Construction/Building Codes



Construction/Building Codes

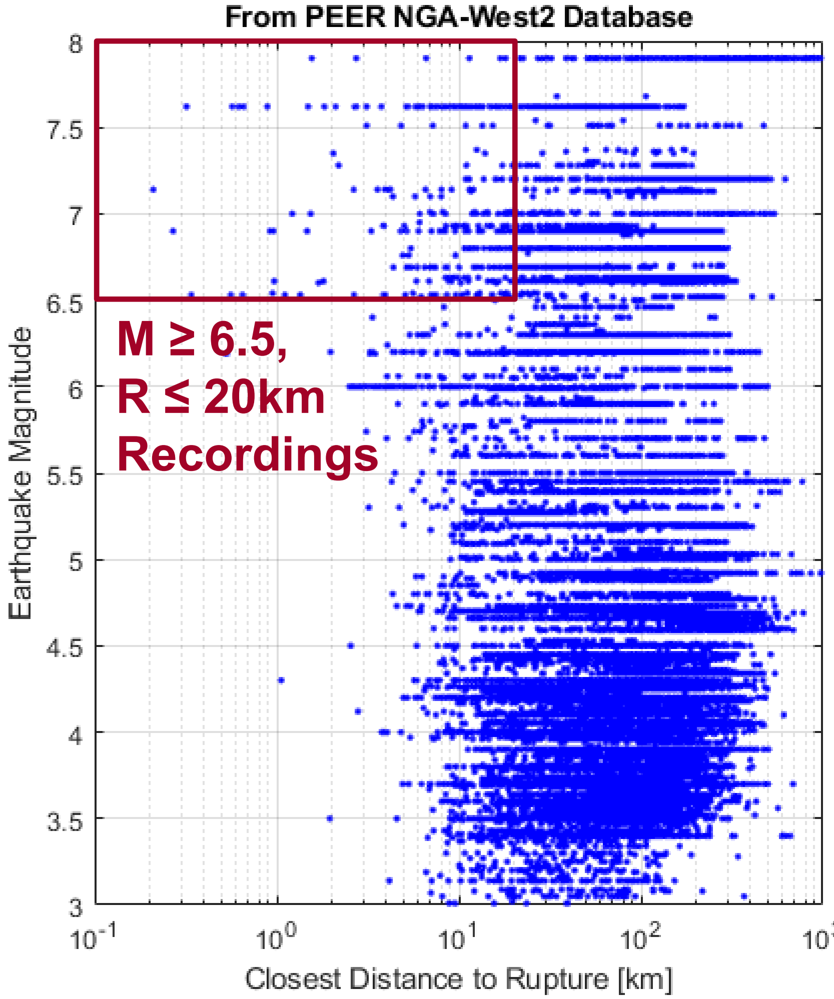
2021 EERI
Virtual **Annual Meeting**

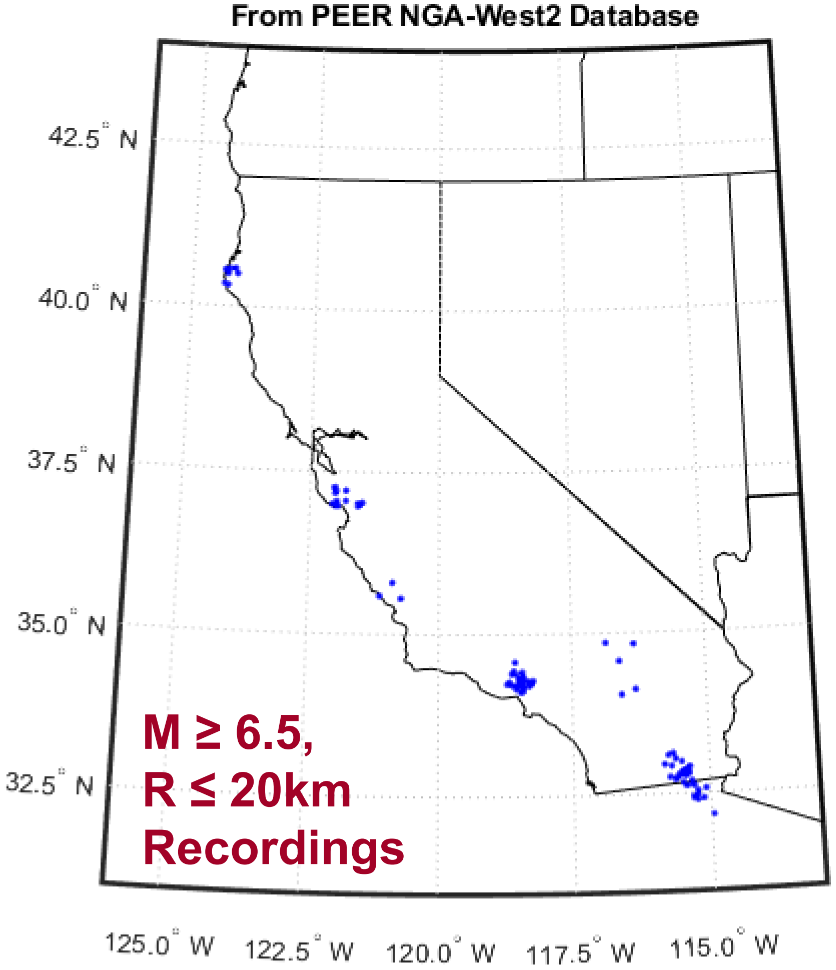
MARCH 23 - 25, 2021

Info Session: Convening Construction-Code Users of the USGS National Seismic Hazard Model

… Numerous construction codes use the USGS National Seismic Hazard Model (NSHM) in establishing their seismic design loads, but the committees that develop them do so independently. Would an annual symposium of construction-code NSHM users facilitate direct exchange between the committees while the USGS engages numerous committees at once? …

Ground-Motion Time Series





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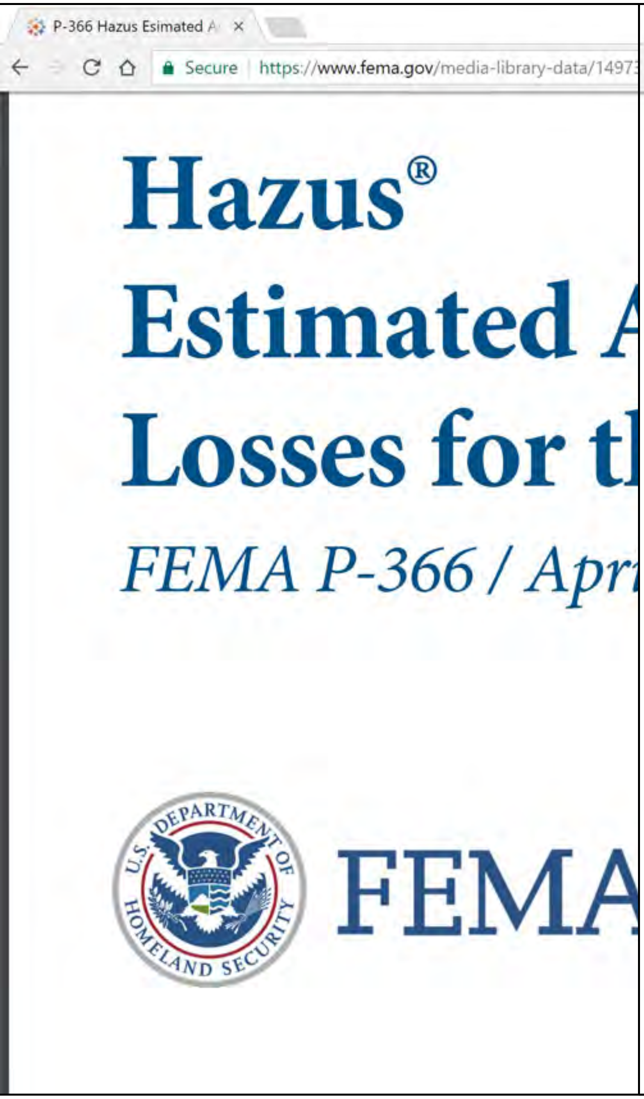
Ground-Motion Time Series

SCEC5 GMSV TAG

Ground Motion Simulation Validation (GMSV) Technical Activity Group (TAG)

SCEC has established this TAG focused on GMSV in order to develop and implement, via collaboration between ground motion modelers and engineering users, testing/rating methodologies for simulated ground motions to be used in engineering applications.

Risk Assessments



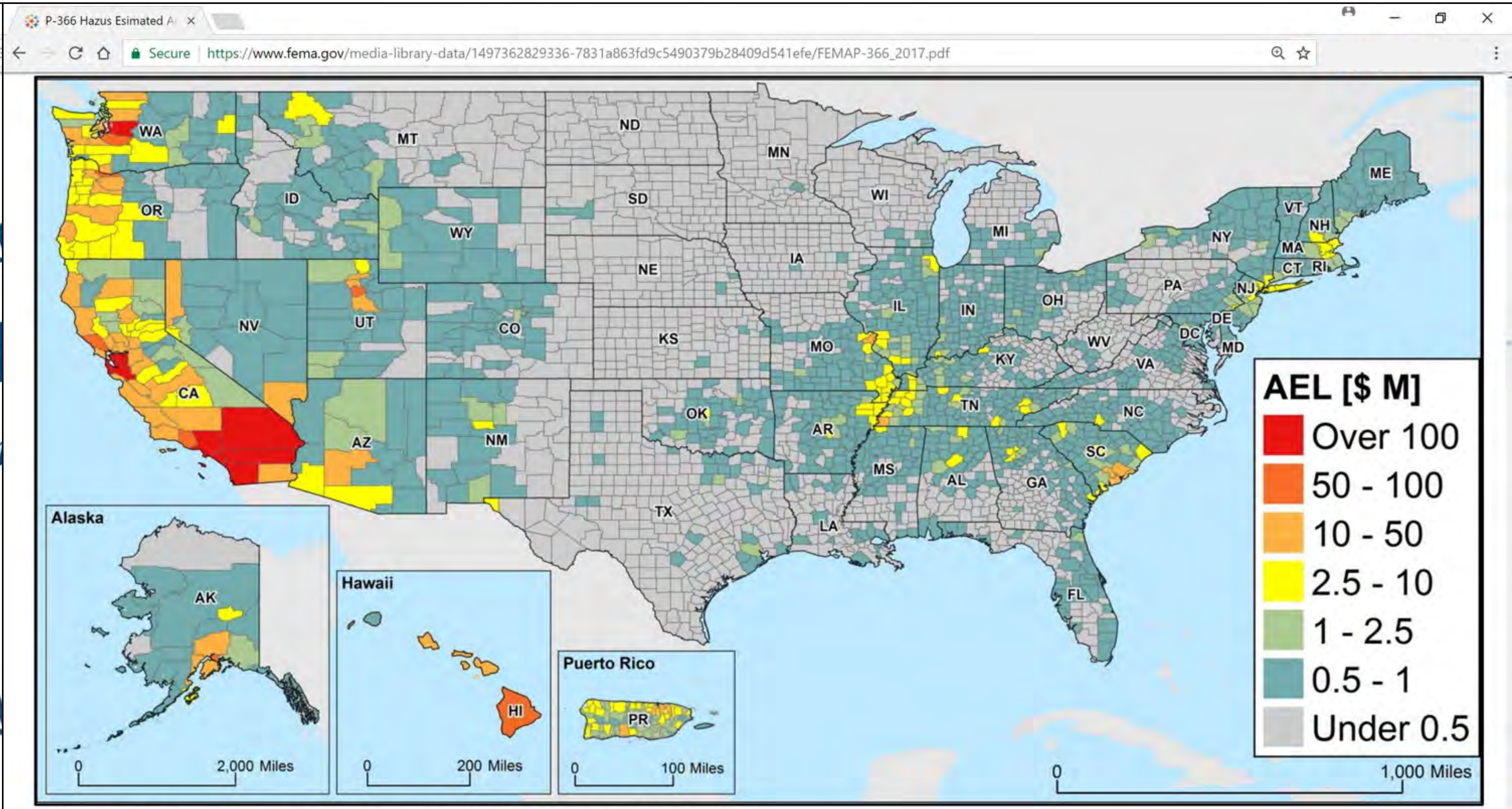
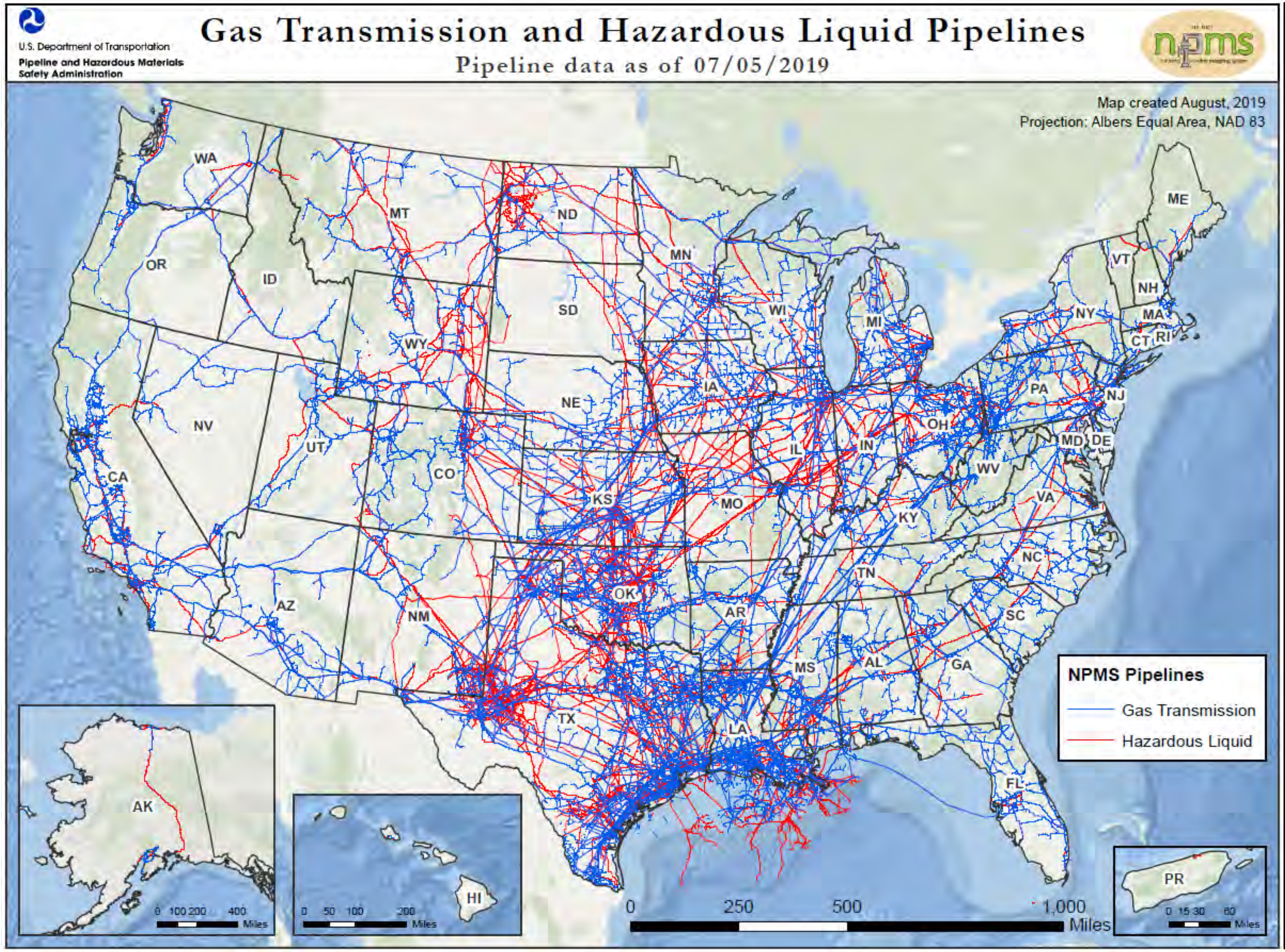


Figure 3-3. Annualized Earthquake Losses by County

Risk Assessments



ASCE Conference Proceedings Paper

Preliminary national-scale seismic risk assessment of natural gas pipelines in the United States

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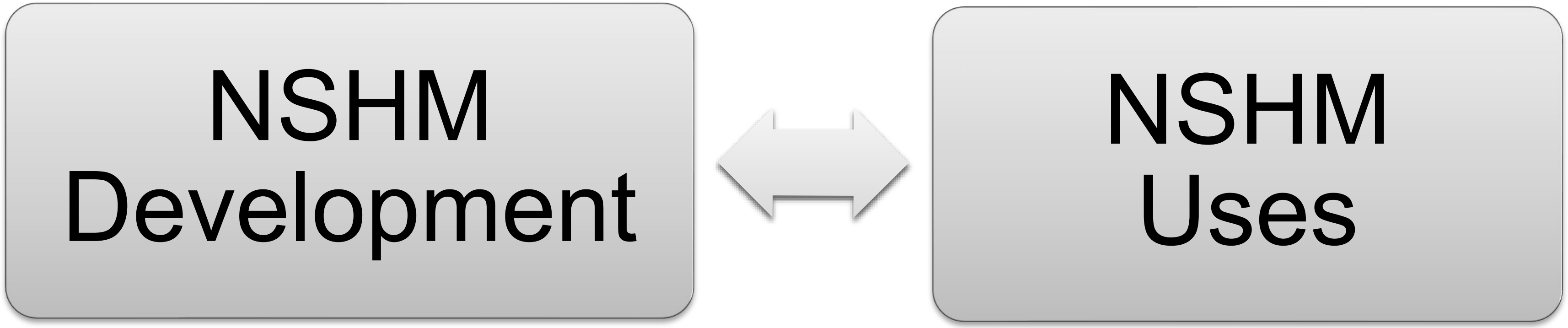
ABSTRACT

While the gas pipeline infrastructure in the United States is vulnerable to the seismic hazards of (i) strong ground shaking and (ii) ground failures induced by surface faulting, liquefaction, or landslides, limited national guidance exists for operators to consistently evaluate the earthquake response of their pipelines. To provide additional information for stakeholders and establish more consistency at a national scale, we develop preliminary estimates of seismic risk for gas transmission pipelines in the conterminous United States (CONUS). We integrate the Pipeline and Hazardous Materials Administration's (PHMSA's) latest National Pipeline Mapping System (NPMS), the U.S. Geological Survey's (USGS's) latest National Seismic Hazard Model (NSHM), and several candidate models from the literature for estimating pipeline damage. Through this effort, we highlight major research needs for ultimately reducing the many uncertainties associated with a comprehensive seismic risk assessment of gas pipelines.

Updates/Expansions with 2023 NSHM

- ☑ Construction/building codes
- ☑ Selection/scaling/simulation of ground-motion time series
- ☑ Risk assessments
- ? Impact scenarios

Effects on 2023 NSHM



Some NSHM uses affect/change the development of the NSHM, e.g., …

Effects on NSHM: Web Form

Uses of the USGS National Seism

forms.office.com/Pages/ResponsePage.aspx?id=urWTBhhLe02TQfMvQApUlCwuDwlyx2BPkaw_f0DI-khUQkhNU1BDNjU1WDRRUUgzUUU0TjNQV1k3VC4u

Uses of the USGS National Seismic Hazard Model (NSHM)

The purpose of this form is to log uses of the USGS NSHM, particularly those that might affect the development of its 2023 update. For questions/comments, contact nluco@usgs.gov.

* Required

1. Your email address (optional)

nluco@usgs.gov

Effects on NSHM: Examples

Uses of the USGS National Seis

forms.office.com/Pages/ResponsePage.aspx?id=urWTBhhLe02TQfMvQApUlCwuDwlyx2BPkaw_f0DI-khUQkhNU1BDNjU1WDRRUUgzUUU0TjNQV1k3VC4u

2. Use of the USGS NSHM *

Example: The "2020 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures" uses hazard curves for spectral periods from 0 to 10 seconds.

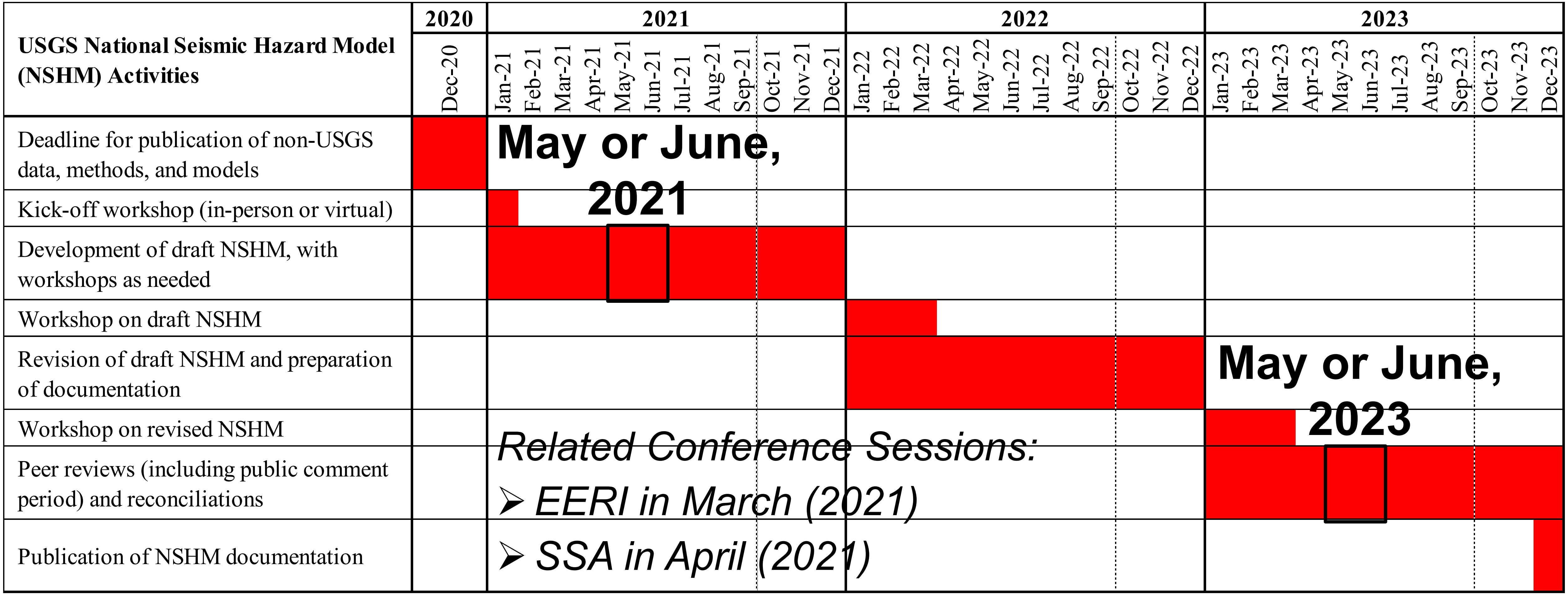
The "PEER Tall Buildings Initiative" and "Los Angeles Tall Buildings Structural Design Council" design guidelines use "service-level" spectral accelerations at a return period of 43 years (50% exceedance probability in 30 years).

3. Effects on the development of the USGS NSHM (optional)

Example: For the longer-period (e.g., >1-second) hazard curves, the effects of deep sedimentary basins should, where possible, be included in the NSHM.

To provide spectral accelerations at such low return periods (high exceedance probabilities), the effects of NSHM catalog declustering should be considered.

“Uses of the USGS NSHM” Workshops



Conclusions

- With the 2023 NSHM, the Engineering & Risk Project will update/expand its research and applications in …
  - **construction/building codes,**
  - **selection/scaling/simulation of ground-motion time series,**
  - **risk assessments, &**
  - **impact scenarios, potentially.**

- Some of these updates/expansions will **affect/change the development of the 2023 NSHM**.

- To identify additional effects/changes, we plan to convene a **"Uses of the USGS NSHM" workshop in May or June**.

Questions / Comments ?

- ☑ Construction/building codes (e.g., nluco@usgs.gov)
- ☑ Selection/scaling/simulation of ground-motion time series (e.g., srezaeian@usgs.gov)
- ☑ Risk assessments
- ? Impact scenarios

(e.g., kjaiswal@usgs.gov)