INTRODUCTION

• Why do we update the National Seismic Hazard Maps?
• What have we learned recently that influences the maps?
• What is the uncertainty in the maps?
• What products will help us communicate risk?
Early versions of U.S. hazard maps

U.S. Coast and Geodetic Survey, 1948

Richter, 1958

Algermissen, 1969

Algermissen and Perkins, 1976
Earthquake Source Model
- From length we obtain M 7.5 earthquake
- From slip rate or fault trenching study we obtain recurrence every 250 years or 0.004 events/year

Ground Motion Model
Hypothetical ground motion data for global M 7.5 earthquakes

Probabilistic Hazard Curve and Map
Annual frequency of exceedance

Map of 2% probability of exceedance in 50 years, peak ground acceleration
Comparison of ground motion models
Earthquake Sources
Later versions of the U.S. hazard maps

Frankel et al., 1996

Petersen et al., 2008

Frankel et al., 2002

Petersen et al., 2014
What changed in 2014?

• Ground motion models (NGA-West2, CEUS ground motion models)
• UCERF3 (longer complex sources, regional seismicity rate constraints, new faults, smoothing M 2.5)
• Cascadia subduction zone (new characterization of M 8-8.8 earthquakes)
• Intermountain West/Pacific NW faults (Wasatch Fault, Eglington Fault, geodetic data)
• CEUS SSC Source Characterization (catalog, smoothing)
• Induced Seismicity
Ground Motion Characterization

ATR: NGA-West2

SCR: NGA-East

Magnitude vs. $R_{rup}$ (km)

[Graphs showing distribution of magnitude vs. distance for ATR and SCR.]
2014 CEUS Ground motion models

A

PGA

B

0.2 second SA

C

1 second SA
Ground Motion Characterization: NGA-East

- About 22 Seed models
- NGA-East parameters
  - Average horizontal ground motions (5%-damped PSA for \( f=0.1-100\text{Hz} \)), for
  - Hard rock sites (\( V_S=3000\text{ m/s}, \kappa=0.006\text{ s} \)) located up to 1,500 km from
  - Future earthquakes in CENA M4.0-8.2
- Deliver 29 table-based models derived from Sammons Map
- Adjustment parameters for the Gulf Coast region.
Ground motion models

1. 2014 Median higher for Strike-slip (near) and lower for reverse and normal faulting (near) all fall off faster with distance.
2. Standard deviation higher.
Ground motion models (subduction)

EXPLANATION
- Atkinson and Boore (2003)—Global
- Atkinson and Macias (2009)
- Addo and others (2012)
- Zhao and others (2006)
- Youngs and others (1997)
CALIFORNIA: UCERF3

2014 CA NSHM Logic-tree

Ground motion models: NGAW2
- Abrahamson et al. (0.22)
- Boore et al. (0.22)
- Campbell & Bozorgnia (0.22)
- Chiou & Youngs (0.22)
- Idriss (0.12)

21,600 branches
Uniform California Earthquake Rupture Forecast Model (UCERF3)
UCERF3 San Jacinto Rupture Participation

Ned Field
Peter Powers
2008 to 2014 Hazard Change; PGA 2% in 50-yr

Peter Powers
Hazard Change: Decomposed
2014 minus 2008 Faults Model only
2014 minus 2008 Grid Sources only

A. 5-Hz SA Fault Source Difference

B. 5-Hz SA Grid Source Difference

2% in 50 yr. 5-Hz SA Difference (g)
Hazard Change: Grid Sources

Total Model

A. 5-Hz SA Total Difference

B. 5-Hz SA Grid Source Changes

2% in 50 yr. 5-Hz Difference (g)
Hazard Change: Fault Sources

Changes due to: 1) New Faults  2) Slip/Moment Rate Changes  3) Methodology
Cascadia Subduction Zone

EXPLANATION

1-cm/yr locking contour:
- blue: tapering function (Wang and others, 2003)
- red: Schmidt and others (written commun., 2012)
- green: approximate average

Top of nonvolcanic tremor zone:
- green: Gomberg and others (2010)
- orange: A. Wech (written commun., 2011) catalog

Base of the fully locked zone from Flück and others (1997)
Cascadia Subduction Zone

A

B

C

D

M8.6–9.3
526 yrs

M8.4–9.1
2,500 yrs

M8.3–8.9
1,111 yrs

M8.1–8.8
1,000 yrs
Pacific NW changes due to faults, seismicity, ground motions
Inclusion of geodetic data
WUS changes due to faults, seismicity, ground motions
Central and Eastern U.S.

New Madrid

New catalog, completeness times
Hazard difference of Alternative gridded models

Adaptive-fixed
Induced Seismicity

Bill Ellsworth (USGS)

Cumulative Number of M≥3 Earthquakes

From Jonathan Godt (USGS)
Locations of Potential Induced Earthquakes
M>2.5 Earthquakes within 17 areas of suspected Induced seismicity
Base Case, 5-Hertz

0.04% chance of exceedance per year (2% in 50-years)

1.39% chance of exceedance per year (50% in 50-years)

acceleration of gravity
Comparison of 2014 model with 2008 model (2014-2008 or 2014/2008 5Hz- 2% in 50 )
5-Hz maps showing differences from 2008 (A- seismicity; B- faults; C-GMMs)
Los Angeles Uncertainty Analysis

Los Angeles 5-Hz SA Hazard Curves

- 2% in 50-year exceedance rate

Rate Distribution (below)

Ground Motion Distribution (below)

Median Ground Motion

Rate Distribution

Ground Motion Distribution

Logic Tree Tornado

- U2 SEIS
- Idles14
- M5+ 7.9
- ELL B
- TAPERED
- ABIM
- FM 3.2
- Mmax=7.9

Logic Tree Nodes

- U3 SEIS
- CY14
- M5+ 9.6
- SHAW 08m
- UNIFORM
- NEOK
- FM 3.1
- Mmax=7.3
Challenges

• How can we develop better hazard estimates in the future?

• What products can USGS develop to help people understand the seismic hazard information?

• How can we better assess and communicate uncertainty?

• How can we test the hazard products?
Hazard curves for cities across U.S.
Comparison of 1996 hazard and seismicity

1996 USGS PGA 2% in 50; ★ M4.0 and greater since 1997
Conclusions

• Seismic hazard varies within each cycle based on new data, models, and methods.
• Uncertainties are large for source and ground motion models.
• Earthquake Spectra special issue is planned for release in the next few months.
• USGS will continue to develop hazard products that will be useful for end-user communities.
Hazard Change: Decomposed

Sources
A. 5-Hz SA Source Model Diff. (2008 GMMs)

GMMs
B. 5-Hz SA GMM Difference (2014 Source)

Total
C. 5-Hz SA Combined Difference

2% in 50 yr. 5-Hz Difference (g)

-0.5 -0.25 -0.1 -0.05 -0.02 0.02 0.05 0.1 0.25 0.5