2019 USGS HAWAII WORKSHOP

SEISMIC SOURCE AND GROUND MOTION MODEL INSIGHTS

Emel Seyhan, Ph.D.

Principal Modeler, Risk Management Solutions

In this presentation, RMS intellectual property and proprietary modeling details are not shared. Therefore, it only provides a high-level overview of parts of RMS Hawaii Seismic Hazard Model. More scientific/technical details have been discussed during the USGS workshop.*

* Other components such as site response, geotechnical, and vulnerability models are not part of this presentation.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

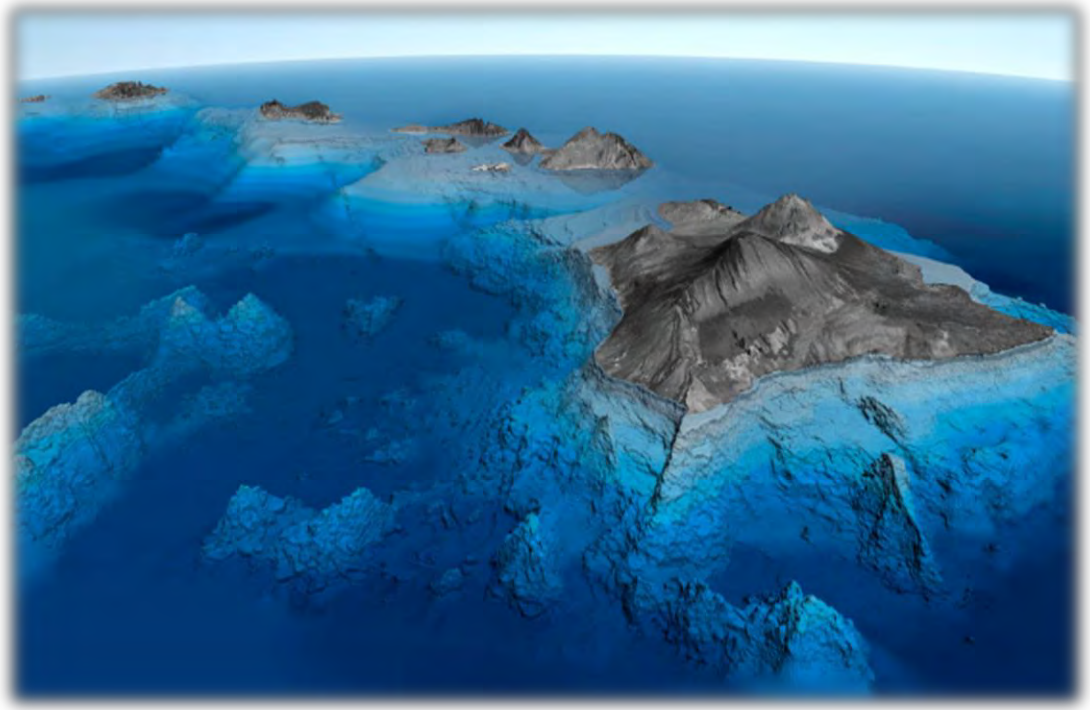
OUTLINE

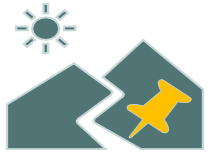
- Motivation
- Source modeling insights
- Ground motion modeling insights
- Example comparion of hazard
- Conclusions

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

MOTIVATION

- Vintage of external Hawaii hazard models is from almost 20 years ago
- Since then,
  - Increase in strong ground motion data, thus, better understanding of GM characterization
  - Improved/new local and global GMM and PSHA studies
  - Significant advances in the engineering applications
- Five years ago,
  - Comprehensive review and update using latest studies and modeling capabilities
  - Preserve relativity consistency with US model





STOCHASTIC EVENTS

Define a set of **earthquake events**

ASSESS HAZARD

Calculate **ground motions** for **all sites** due to each stochastic event

ASSESS DAMAGE

Assess the **mean damage** and associated uncertainty

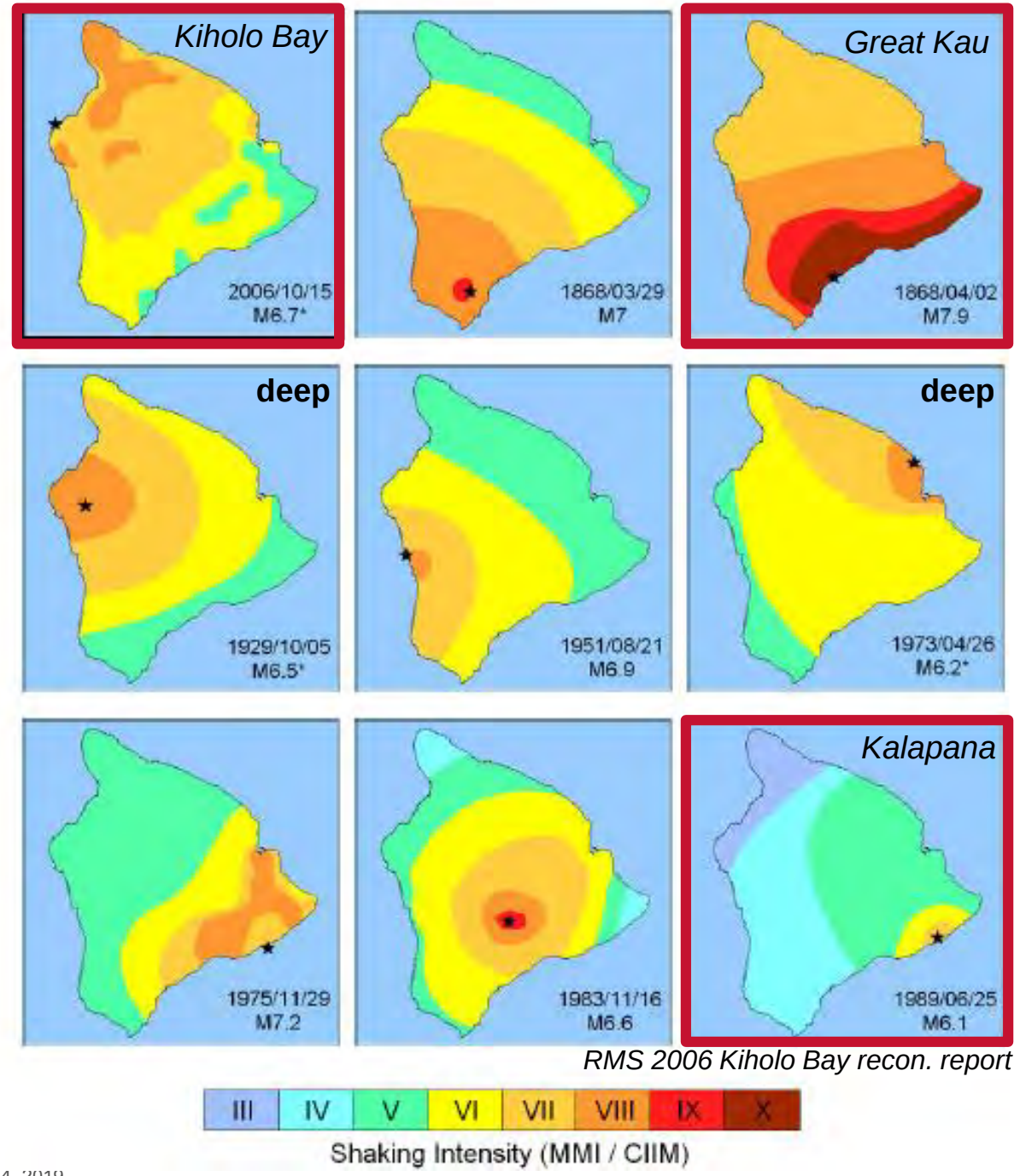
FINANCIAL MODULE

Calculate the **financial impact** for all perspectives

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

SEISMICITY IN HAWAII

- Formed by hot spot: Youngest, highest hazard on flanks and active volcanism
- Earthquakes are common in main island of Hawaii: Numerous damaging earthquakes within 150 yrs
- High rate of eq occurrence + potential for large eqks
- Comparably high hazard with other part of US, e.g. WUS



RMS 2006 Kiholo Bay recon. report

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

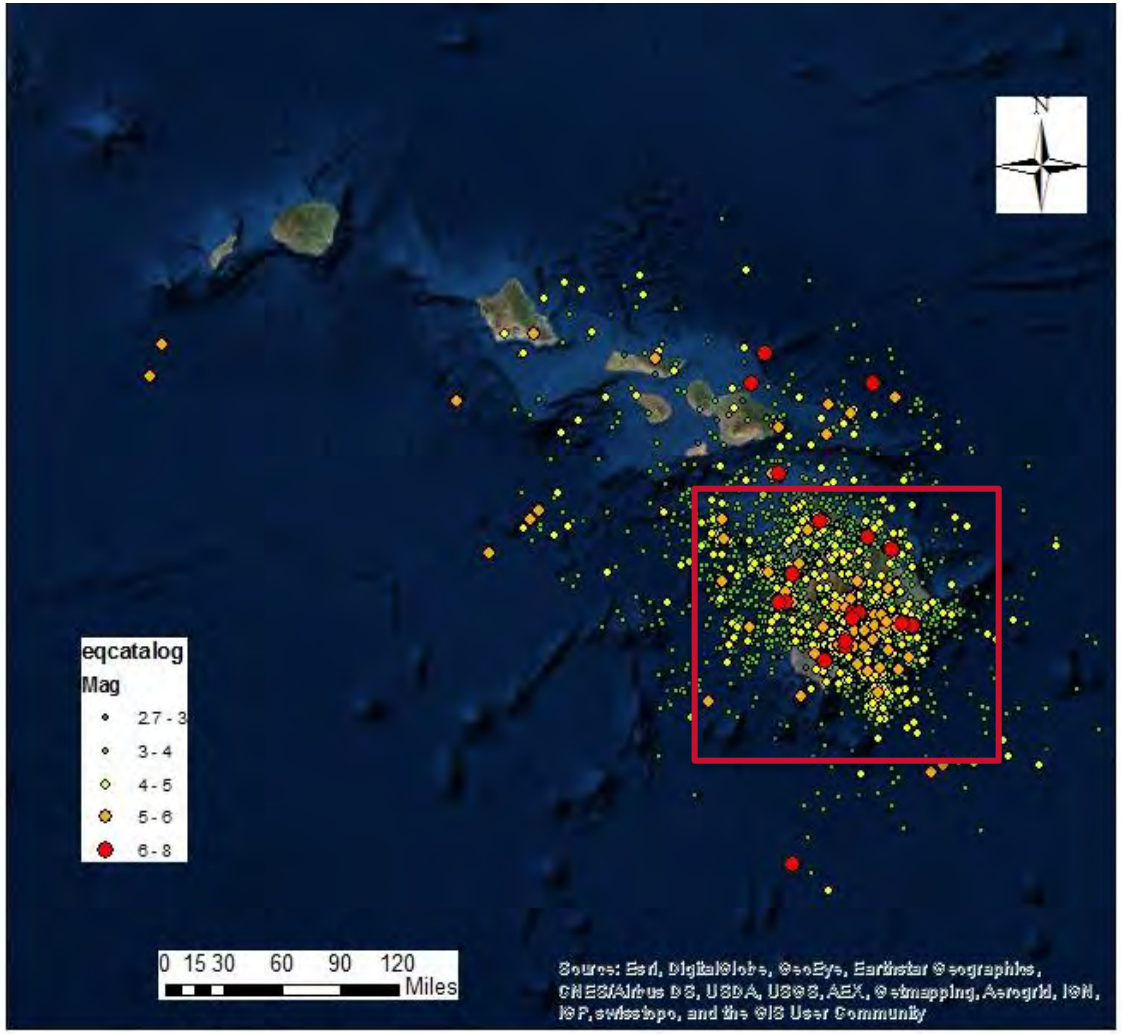
OUTLINE

- Motivation
- Source modeling insights
- Ground motion modeling insights
- Example comparion of hazard
- Conclusions

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

HIGHLIGHTS OF SOURCE MODEL

- Expanded eq catalog update: declustering and completeness
  - 1868 - 1997: Previously declustered 1998 USGS catalog 1868 - 1997 (Klein et al. 2001)
  - 1997 - 2015: Declustered catalog from PDE (HVO) with a full catalog from 1960–2015

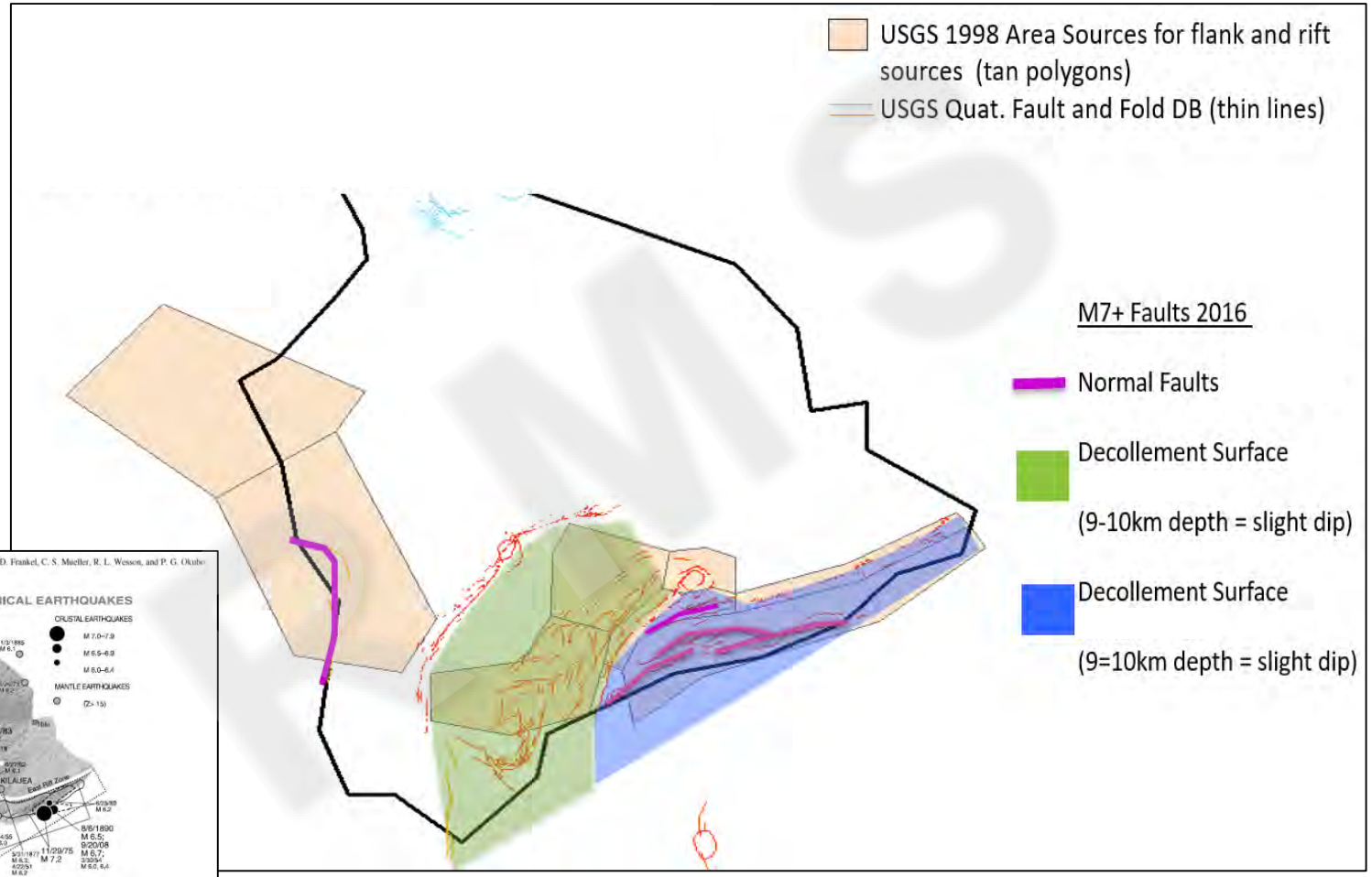


PDE HVO: Preliminary Determination of Epicenters of the Hawaii Volcano Observatory

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

HIGHLIGHTS OF SOURCE MODEL

- Expanded eq catalog update: declustering and completeness
  - 1868 - 1997: Previously declustered 1998 USGS catalog 1868 - 1997 (Klein et al. 2001)
  - 1997 - 2015: Declustered catalog from PDE (HVO) with a full catalog from 1960–2015
- New flank sources and crustal faults
- Simplified decol. sources (1868 M7.9 Kau)



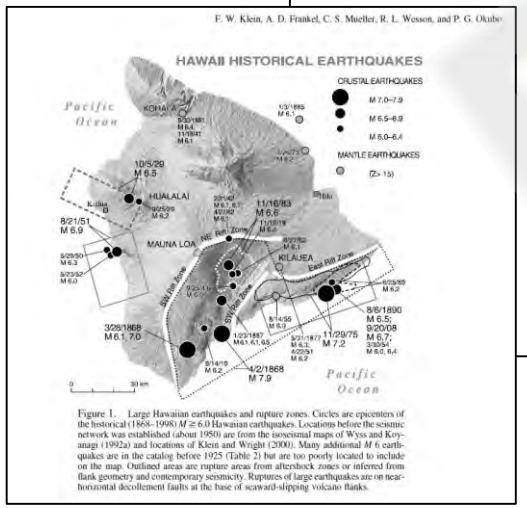


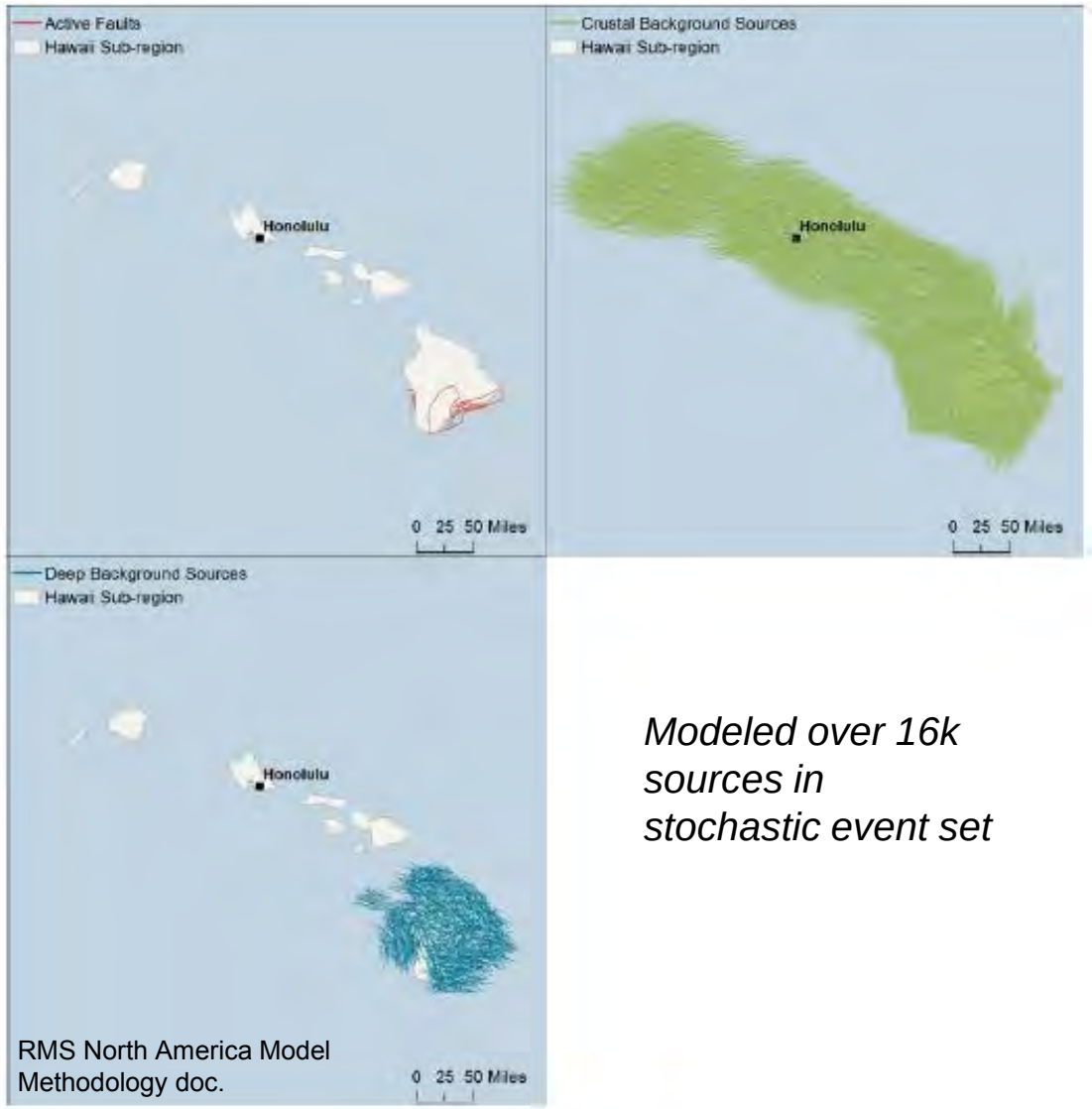
Figure 1. Large Hawaiian earthquakes and rupture zones. Circles are epicenters of the historical (1868–1998) $M \geq 6.0$ Hawaiian earthquakes. Locations before the seismic network was established (about 1950) are from the isoseismal maps of Wyss and Koyanagi (1992a) and locations of Klein and Wright (2000). Many additional M 6 earthquakes are in the catalog before 1925 (Table 2) but are too poorly located to include on the map. Outlined areas are rupture areas from aftershock zones or inferred from flank geometry and contemporary seismicity. Ruptures of large earthquakes are on near-horizontal decollement faults at the base of seaward-slipping volcano flanks.

PDE HVO: Preliminary Determination of Epicenters of the Hawaii Volcano Observatory

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

HIGHLIGHTS OF SOURCE MODEL

- Expanded eq catalog update: declustering and completeness
  - 1868 - 1997: Previously declustered 1998 USGS catalog 1868 - 1997 (Klein et al. 2001)
  - 1997 - 2015: Declustered catalog from PDE (HVO) with a full catalog from 1960–2015
- New flank sources and crustal faults
- Simplified decol. sources (1868 M7.9 Kau)
- Updated rates and background sources
  - Shallow and deep layers
  - Two rate sets
  - Three zones, regional b values



Modeled over 16k sources in stochastic event set

PDE HVO: Preliminary Determination of Epicenters of the Hawaii Volcano Observatory

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

OUTLINE

- Motivation
- Source modeling insights
- Ground motion modeling insights
- Example comparion of hazard
- Conclusions

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

LITERATURE REVIEW
SELECT STUDIES

- 1998 USGS seismic hazard study (Klein et al. 2001)
  - Out-dated models up to 1997
- Latest local and global ground motion studies
- 2010 URS report

Zone	Equation	Parameters	Weight
Shallow & Deep Zones	Boore et al. (1997)	Vs30 = 457 m/s, b1ss	1/3
	Zhao et al. (2006) – shallow crustal set	Site Class = SCII	1/3
	Chiou & Youngs (2008)	Vs30 = 457 m/s, Z1.0 = 0.1 km	1/3

- Detailed review of geologic, volcanic, and tectonic properties

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

LITERATURE REVIEW
CANDIDATE MODELS IN PARENT LIST

- Deep inslab zone (>20km)
  - *Youngs et al. 1997*
  - Atkinson and Boore (2003, Global)
  - Zhao et al. 2006
  - Atkinson and Macias (2009)
  - Atkinson, 2010
  - BC Hydro 2012 (2016, 2018)
  - Wong et al. 2015
  - Zhao et al. 2016
  - NGA-Sub, 20xx (BC Hydro 2018)

- Shallow crustal zones
  - *Boore et al, 1997*
  - *Campbell, 1997*
  - *Munsen and Thurber, 1997*
  - *Sadigh et al. 1997*
  - Mc Verry TVZ, 2000
  - Zhao et al. 2006 (Unk)
  - Atkinson, 2010
  - NGA-West 2, 2014
  - Zhao et al. 2016

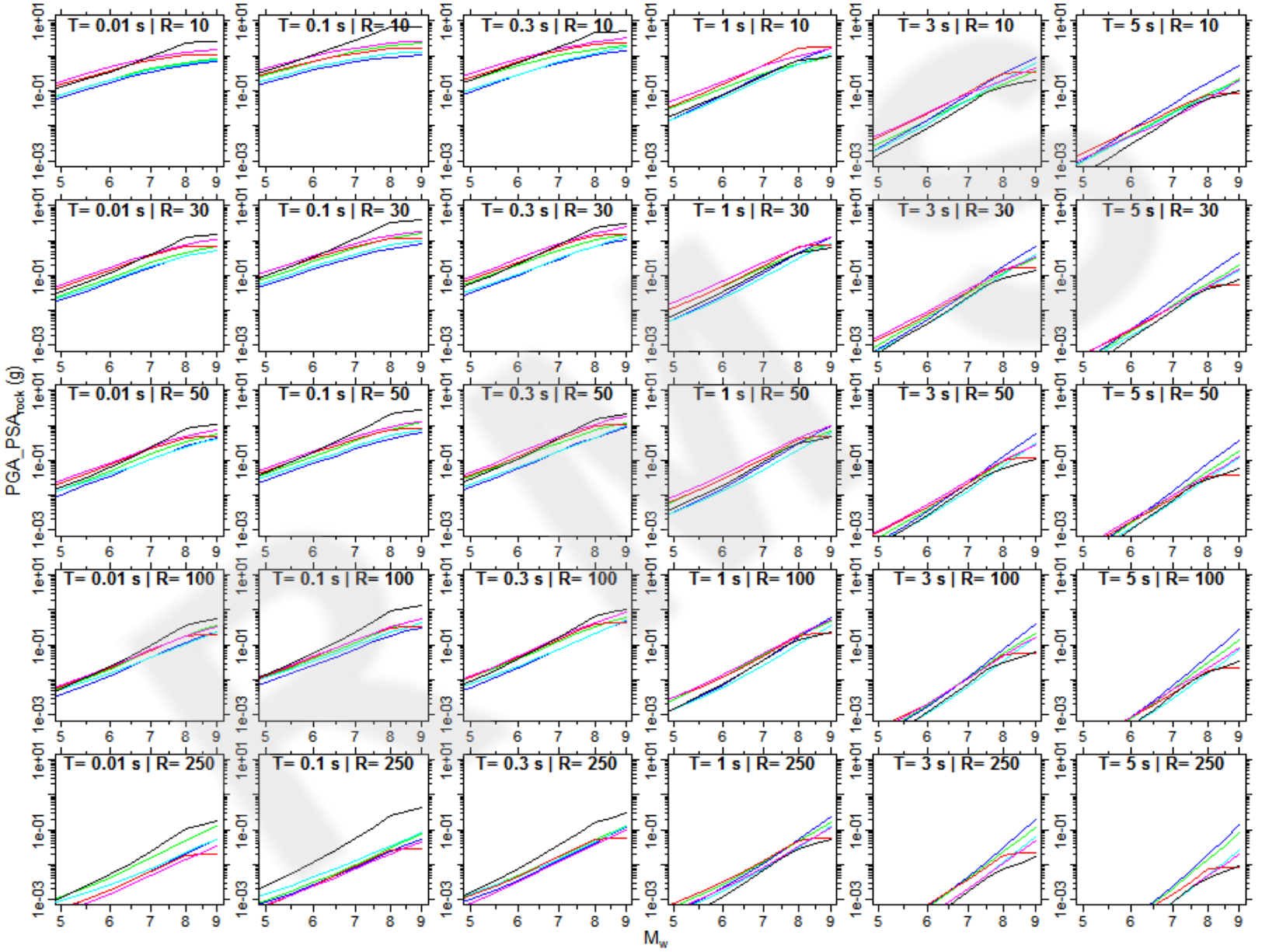
Hawaii specific, volcanic, old models, on-going development

- *Local models perform well against regional eqks, globally derived models are considered due to M-scaling and extrapolation limitations*
- *Assumption of similar tectonic settings: Host GMPEs into target region*

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

PROCESS FOR GMPE EVALUATION/SELECTION

- Review of common trends and outliers
- Trellis plots*: Multi-parametric evaluation (per tec. setting)
  - M-scaling
  - Distance scaling
  - Spectral shape
  - Aleatory variability
- *Spatial and proximity evaluations*
- *Model performance/validation:*
  - *Data-based residuals and statistical analysis*
  - *Regionalization*
  - *Data from other regions*
  - *Spatial distribution and GM footprints*

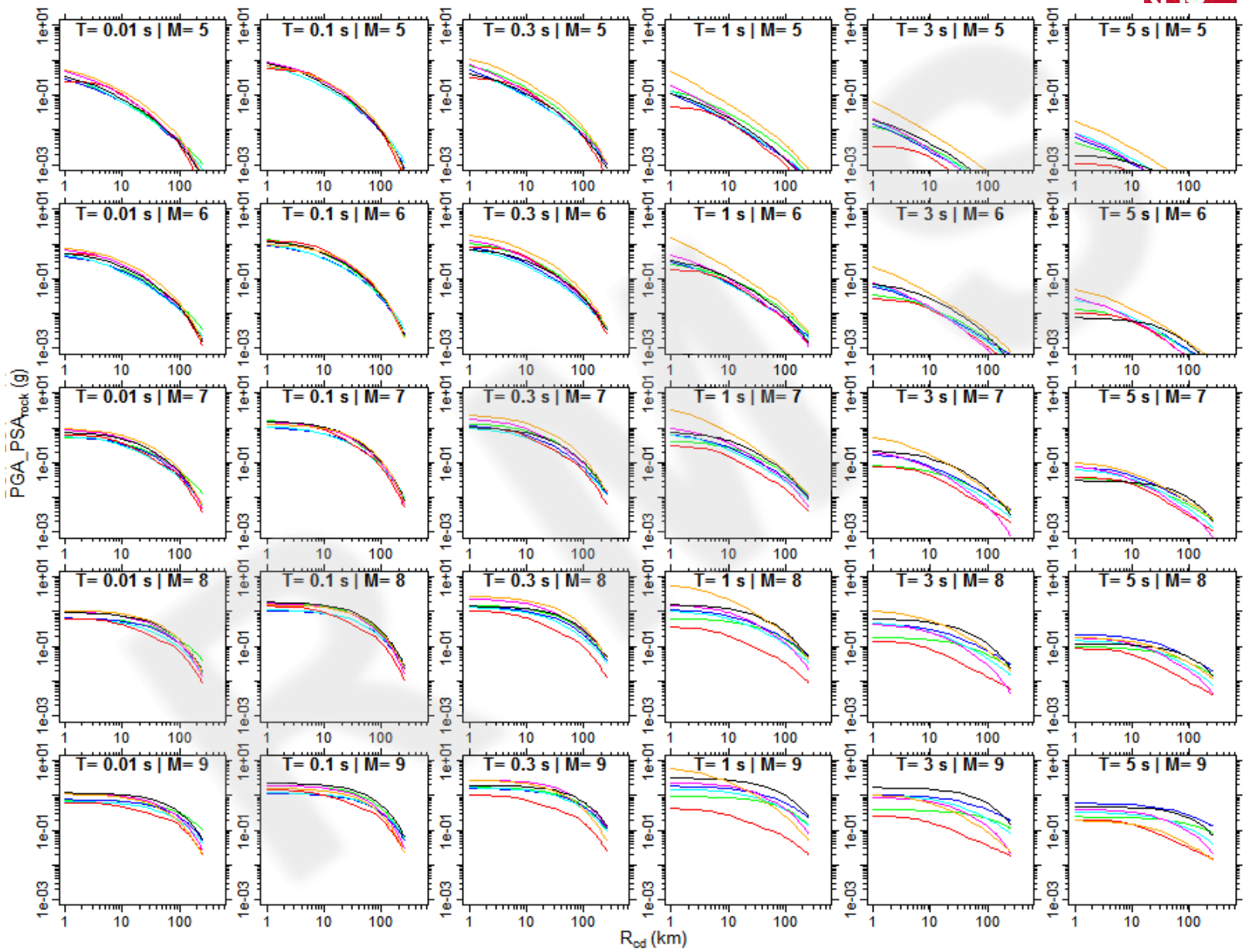


** Similar to GEM and others*

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

PROCESS FOR GMPE EVALUATION/SELECTION

- Review of common trends and outliers
- Trellis plots*: Multi-parametric evaluation (per tec. setting)
  - M-scaling
  - Distance scaling
  - Spectral shape
  - Aleatory variability
- *Spatial and proximity evaluations*
- *Model performance/validation:*
  - *Data-based residuals and statistical analysis*
  - *Regionalization*
  - *Data from other regions*
  - *Spatial distribution and GM footprints*

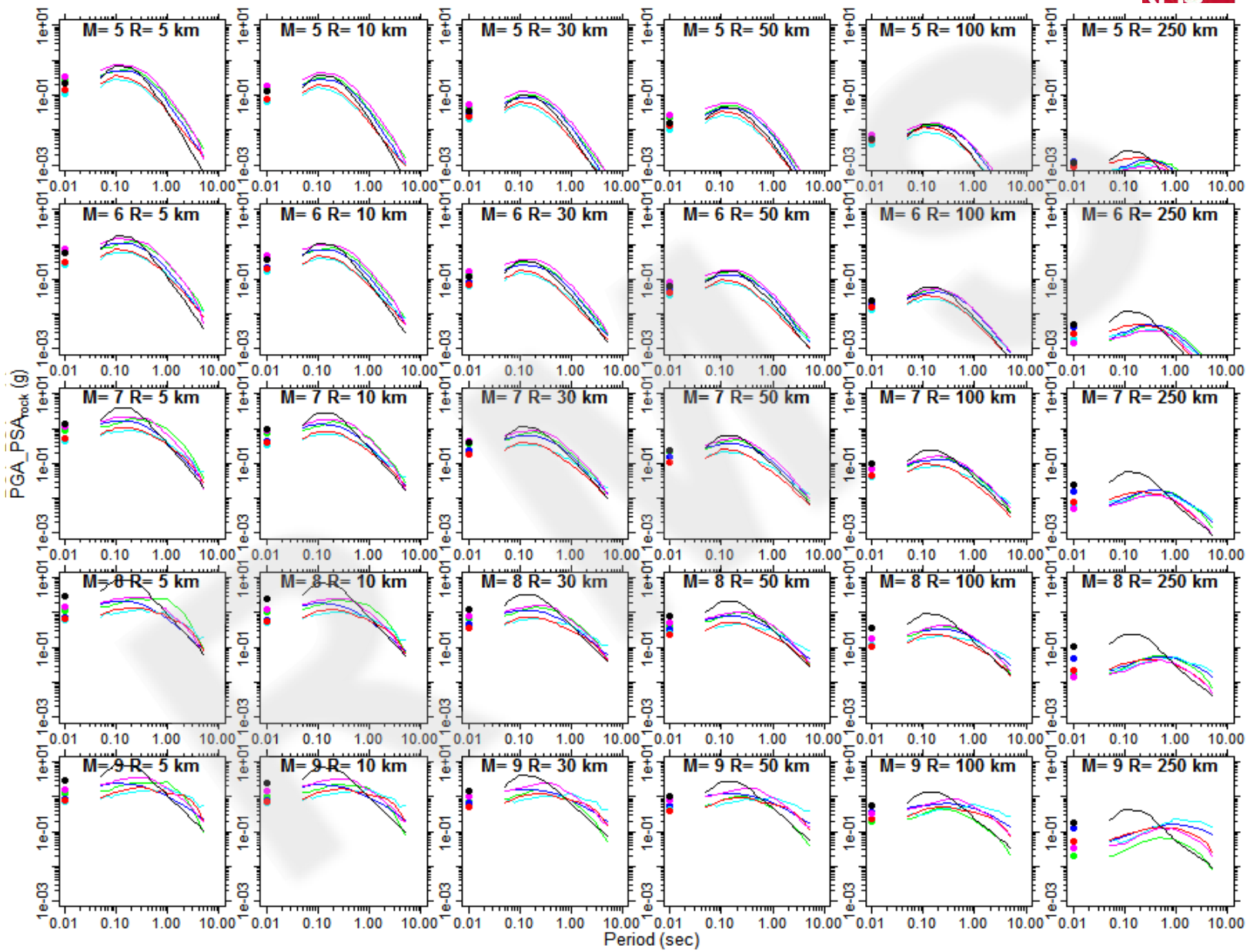


** Similar to GEM and others*

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

PROCESS FOR GMPE EVALUATION/SELECTION

- Review of common trends and outliers
- Trellis plots*: Multi-parametric evaluation (per tec. setting)
  - M-scaling
  - Distance scaling
  - Spectral shape
  - Aleatory variability
- *Spatial and proximity evaluations*
- *Model performance/validation:*
  - *Data-based residuals and statistical analysis*
  - *Regionalization*
  - *Data from other regions*
  - *Spatial distribution and GM footprints*



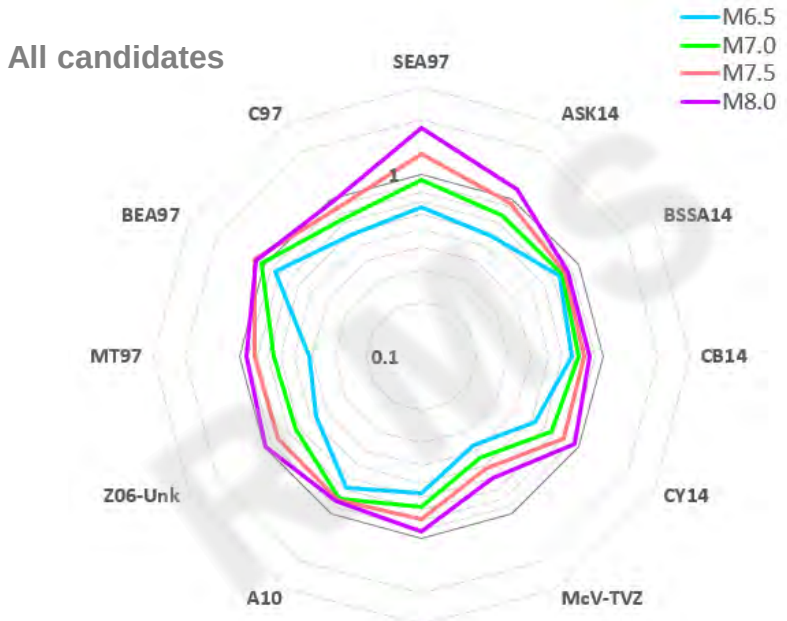
** Similar to GEM and others*

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

GMPE SELECTION/EVALUATION CRUSTAL | M-SCALING
(ONE SAMPLE CASE)

Realizations evaluated for all M, R, T ranges

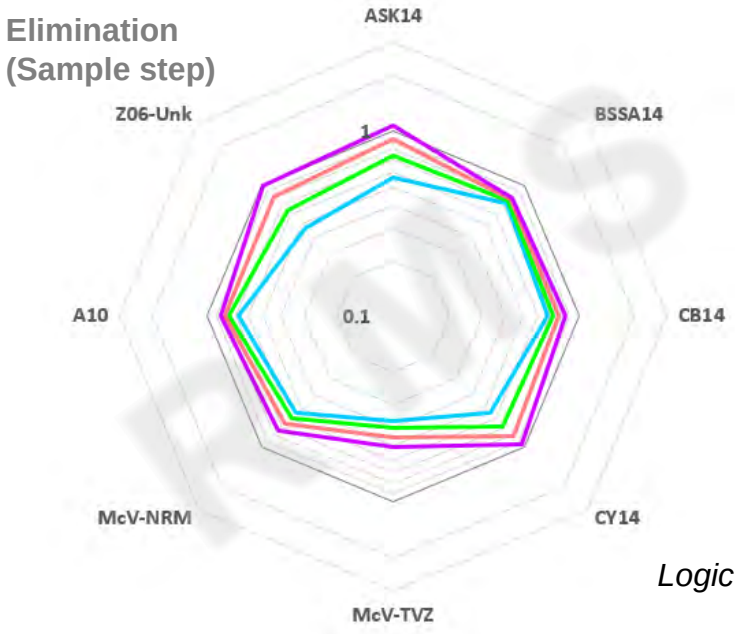
- Evaluate parent list
  - Old models
  - NGA-West 2
  - Local models
  - Volcanic and others
- Method of elimination
- Review of relative trends (for this example)
  - Somewhat uniform M-scaling
  - In general, global and local models seem consistent
  - Volcanic lower than crustal ones, also decays faster with distance
  - SEA97 higher with inc. M



10km
0.2s

Z16 is excluded due to model trends

Normal fault
Default sedimentary depth



10km
0.2s

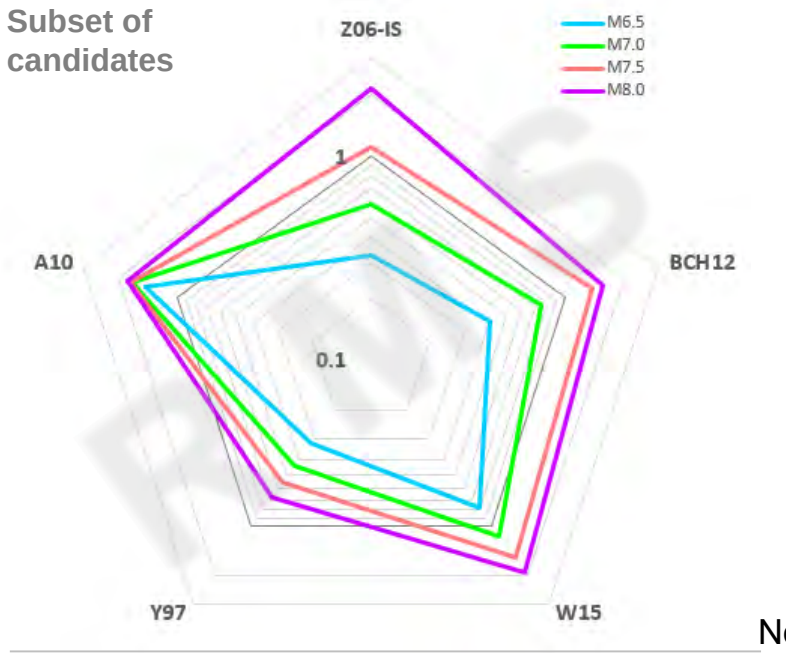
Logic tree decisions not included.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

GMPE SELECTION/EVALUATION DEEP INSLAB | M-SCALING
(ONE SAMPLE CASE)

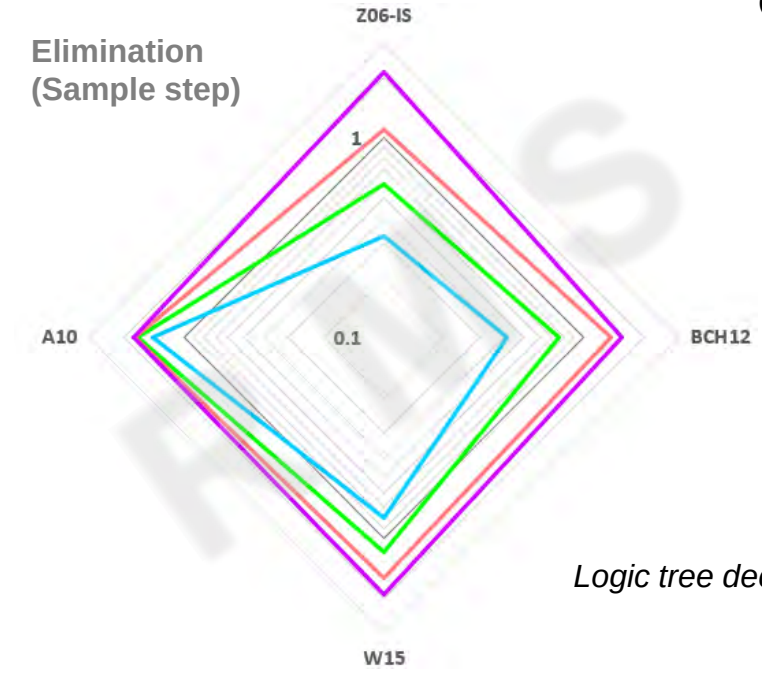
Realizations evaluated for all M, R, T ranges

- Evaluate parent list
  - Old models
  - BC Hydro 2012 (2016, 2018)
  - Zhao et al. 2006
  - Local models
- Method of elimination
- Review of relative trends (for this example)
  - Somewhat uniform M-scaling
  - In general, global and local models seem consistent
  - Y97 is lower than others
  - Short periods, A10 tends to be higher than W15 for 6.0-6.5



10km
0.2s

Normal fault
Considering focal depth

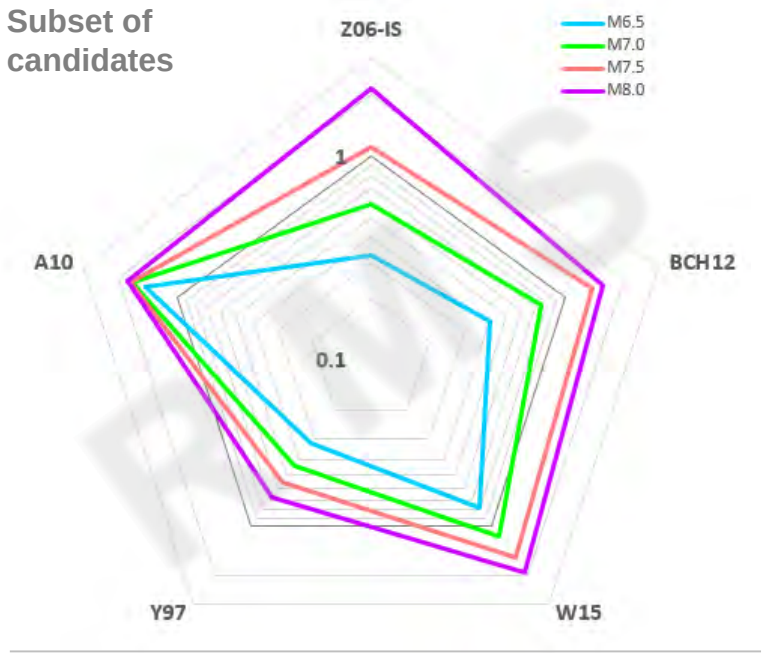


10km
0.2s

Logic tree decisions not included.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

GMPE SELECTION/EVALUATION DEEP INSLAB | M-SCALING
(ONE SAMPLE CASE)



10km
0.2s

Realizations evaluated for all M, R, T ranges

- Evaluate parent list
  - Old models
  - BC Hydro 2012 (2016, 2018)
  - Zhao et al. 2006
  - Local models
- Method of elimination
- Review of relative trends (for this example)
  - Somewhat uniform M-scaling
  - In general, global and local models seem consistent
  - Y97 is lower than others
  - Short periods, A10 tends to be higher than W15 for 6.0-6.5
- Age- and seismic activity differentiation between the islands

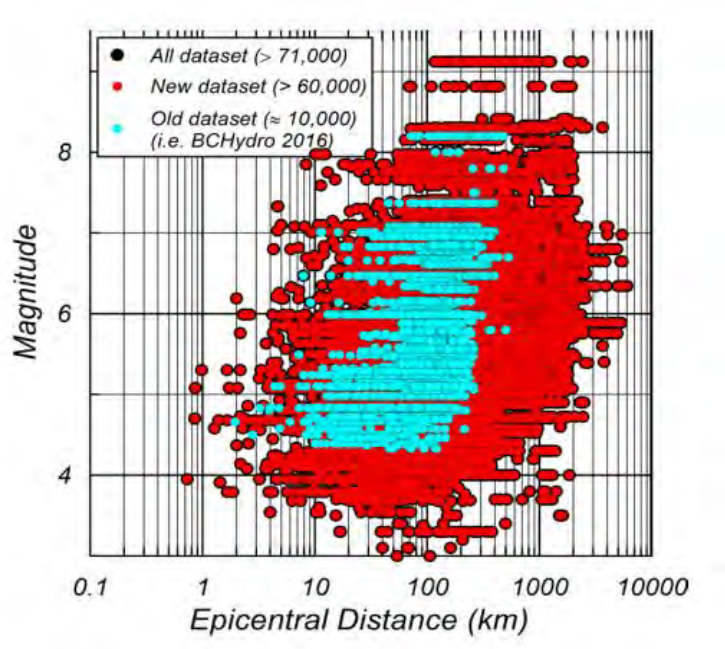
- Background (Older)
- Lower seis.

- Deep inslab
- Active volcanism
- Background (Young)
- High seis.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

CONSIDER DIFFERENCES BETWEEN GMPE UPDATES

- BC Hydro is one of the most widely used GMPEs or subduction zones worldwide
- BC Hydro update since 2012: 2016 and 2018 due to NGA-Sub study
- Evaluation of BCH18 and BCH16
  - Strong magnitude, distance and period dependency
  - No Hawaii regionalization
  - Impact on Hawaiian hazard



Reference: Publicly available NGA-Sub docs.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

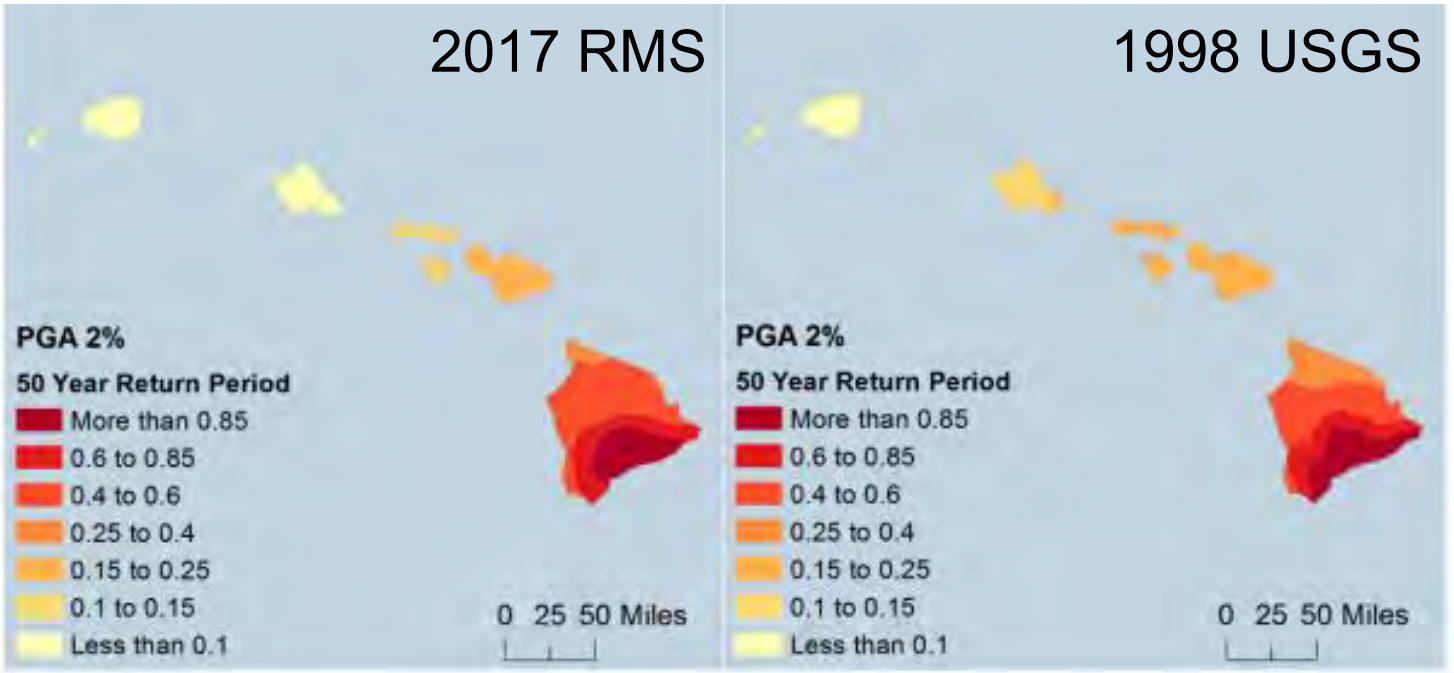
OUTLINE

- Motivation
- Source modeling insights
- Ground motion modeling insights
- Example comparion of hazard
- Conclusions

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

EXAMPLE HAZARD COMPARISON

- Includes all component updates
- Highest hazard in island of Hawaii and tapers off towards other islands
- Slight changes in hazard around flank/decollement zone
- Slight increase towards north of island of Hawaii
- Reduced hazard in other islands, esp. Oahu



RMS North America Model EQ Hazard Validation doc.

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

CONCLUDING REMARKS

- An update is needed
  - Vintage of external hazard models is old (e.g. 1998-2001 USGS HMP)
  - Need to account for latest data and scientific advances
- Improve source model
  - Source geometry for the large flank faults
  - Add ~20 years of eq catalog data through 2016
  - Update rates and background sources
- Improve ground motion and geotechnical models
  - Different age, geologic, tectonic and seismic properties between islands
  - Scarcity in SGM data and stations: Thorough modeling for GM and site response
  - Epistemic uncertainty
  - Spatial distribution against historical events
  - V_{S30} and period dependent hazard
  - Inclusion of landslide and liquefaction
- Evaluation of relative hazard to other parts in the world

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.

THANK YOU

Contact me:
Emel.Seyhan@rms.com

Copyright © 2015 Risk Management Solutions, Inc. All Rights Reserved.