An Updated Central and Eastern United States Ground-Motion Model

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Project Description

- **Project Goals:**
  - Review and, if necessary, update the EPRI (2004, 2006) Ground-Motion Model (GMM)
  - Obtain Participatory Peer Review Panel (PPRP) and Nuclear Regulatory Commission (NRC) acceptance of the Updated Ground-Motion Model (GMM)
- **Approach**
  - Use enhanced SSHAC Level 2 assessment process with PPRP review of technical process and findings and NRC review of the SSHAC Level 2 Report
- **Schedule**
  - SSHAC Level 2 Study - March 8, 2012 to May 31, 2013 (15 months)
  - NRC Review - June 3, 2013 to August 30, 2013 (3 months)
  - Total Duration – March 8, 2012 to August 30, 2013 (18 months)

Questions Addressed by Project

- Is the EPRI (2004, 2006) Ground – Motion Model (GMM) based on data, models and methods compiled and evaluated from 2002 to 2004 consistent with current (2012) data, models and methods?

- Should the EPRI (2004, 2006) GMM be updated before using it to calculate GMRS at existing nuclear power plants in response to the NRC RFI 50.54(f) letter dated March 12, 2012?

- Does the preponderance of evidence obtained from Phase 1 require that Phase 2 be completed to assess the seismic hazard differences obtained when using the old and updated EPRI (2004, 2006) GMM?

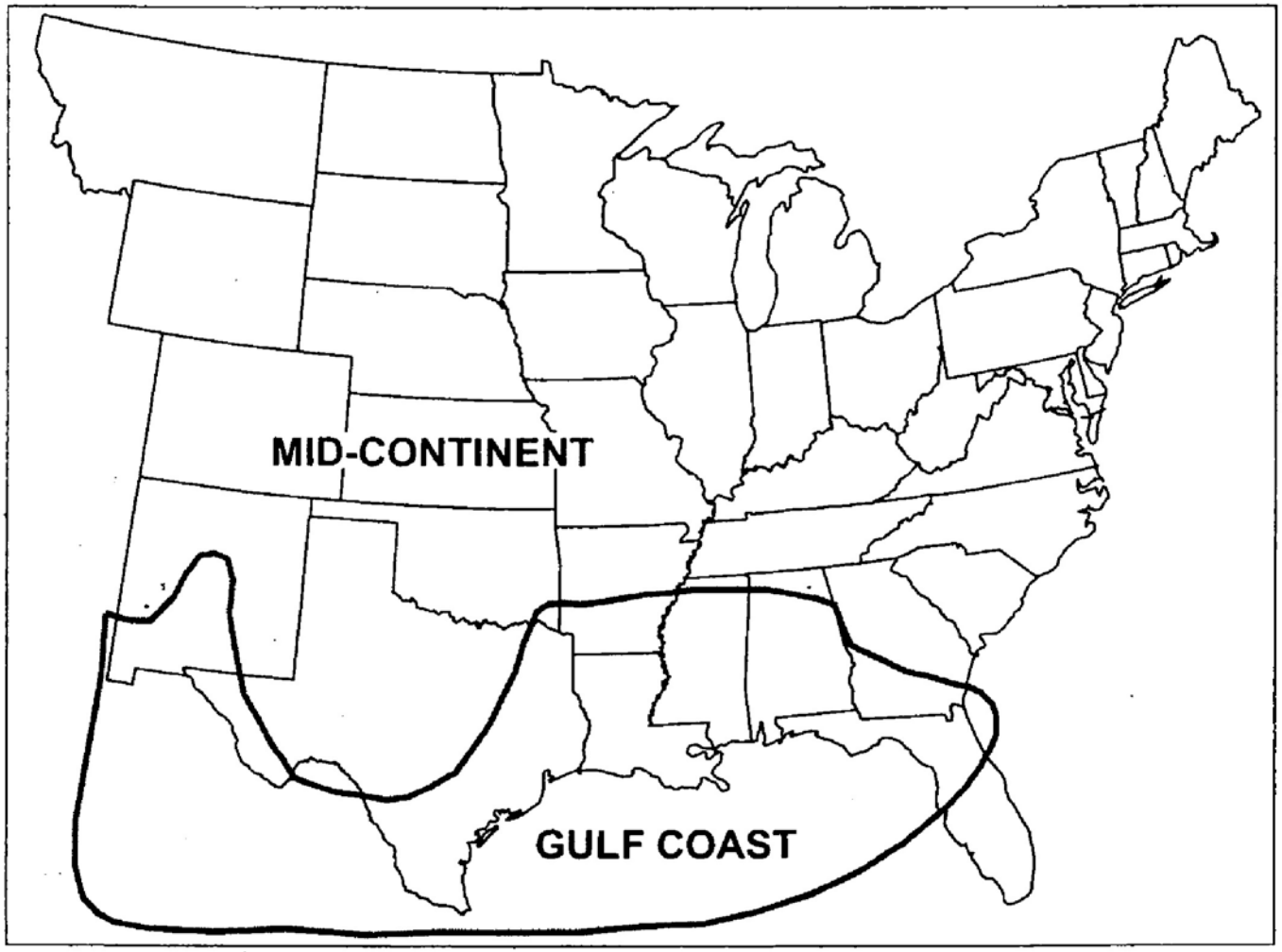
EPRI (2004) Ground-Motion Model Grouped By Cluster

EPRI (2004) Ground-Motion Models Grouped by Cluster

Cluster	Model Type	Models[1]
1	Single-Corner Stochastic	Hwang and Huo (1997) Silva et al. (2002) – SC-CS Silva et al. (2002) – SC-CS-Sat Silva et al. (2002) – SC-VS Toro et al. (1997) Frankel et al. (1996)
2	Double-Corner Stochastic	Atkinson and Boore (1995) Silva et al. (2002) DC Silva et al. (2002) – DC-Sat
3	Hybrid	Abrahamson and Silva (2002) Atkinson (2001) and Sadigh et al. (1997) Campbell (2003)
4	Finite-Source /Green's Function	Somerville et al. (2001)

[1] SC = single-corner; DC = double-corner; CS = constant stress; VS = variable stress; Sat = saturation.

EPRI (2004) Regionalization



Basis for Updating EPRI (2004, 2006) GMM

- Ground motion experts, who developed seven (7) of the thirteen (13) ground motion prediction equations (GMPEs) used in the EPRI (2004, 2006) GMM, recommended that their GMPEs be replaced with newer models developed during the last ten (10) years.
- There are three new GMPEs developed by ground motion experts during the past ten (10) years which should be evaluated and possibly integrated into an update of the EPRI (2004, 2006) GMM.
- A new ground motion database for the Central and Eastern North America (CENA) is now available with nearly 28,000 earthquake recordings. Eighty percent (80%) of the earthquake records are from earthquakes that occurred after the development of the EPRI (2004, 2006) GMM in 2004.
- Comparisons to the database indicate that the EPRI (2004, 2006) GMM overpredicts ground motions at some magnitude-distance-frequency ranges that are important in PSHAs for nuclear power plants.

Updated EPRI (2004, 2006) Clusters and Models

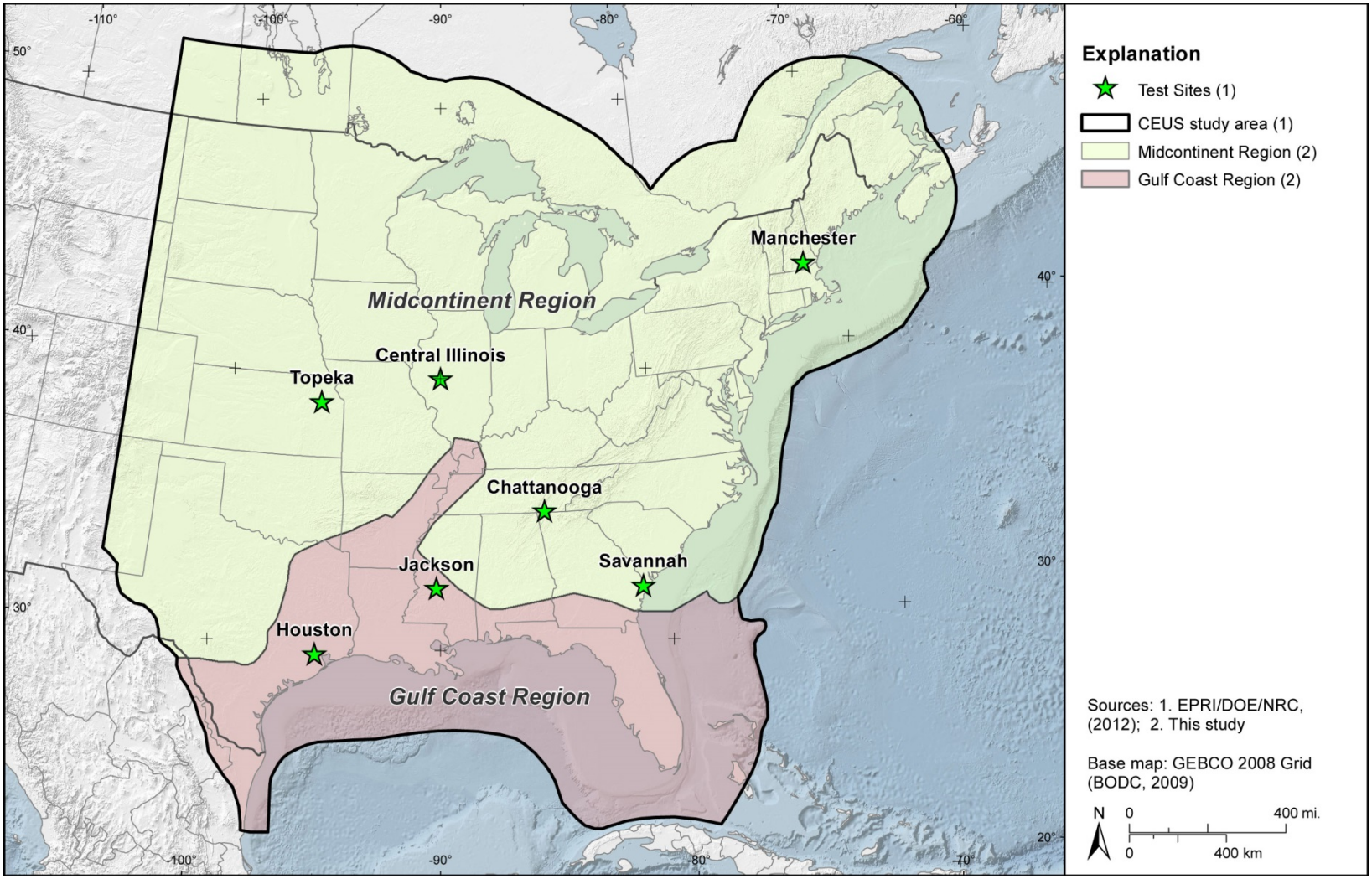
Updated EPRI (2004, 2006) GMM Clusters and Models

Cluster	Model Types and Cluster Weights (repeated large-magnitude earthquake sources/area earthquake sources)	Models
1	Single-Corner Brune Source (0.15/0.185)	Silva et al. (2002) – SC-CS-Sat[1] Silva et al. (2002) – SC-VS[1] Toro et al. (1997) Frankel et al. (1996)
2	Complex/Empirical Source $\sim R^{-1}$ Geometrical spreading (0.31/0.383)	Silva et al. (2002) – DC-Sat Atkinson (2008) with 2011 modifications (A08′)
3	Complex/Empirical Source $\sim R^{-1.3}$ Geometrical spreading (0.35/0.432)	Atkinson-Boore (2006) with 2011 modifications (AB06′) Pezeshk et al. (2011)
4	Finite-Source /Green's Function (0.19/0)	Somerville et al. (2001); slightly different models for rifted and nonrifted (not used for distributed seismicity sources with large contribution from **M** < 6)

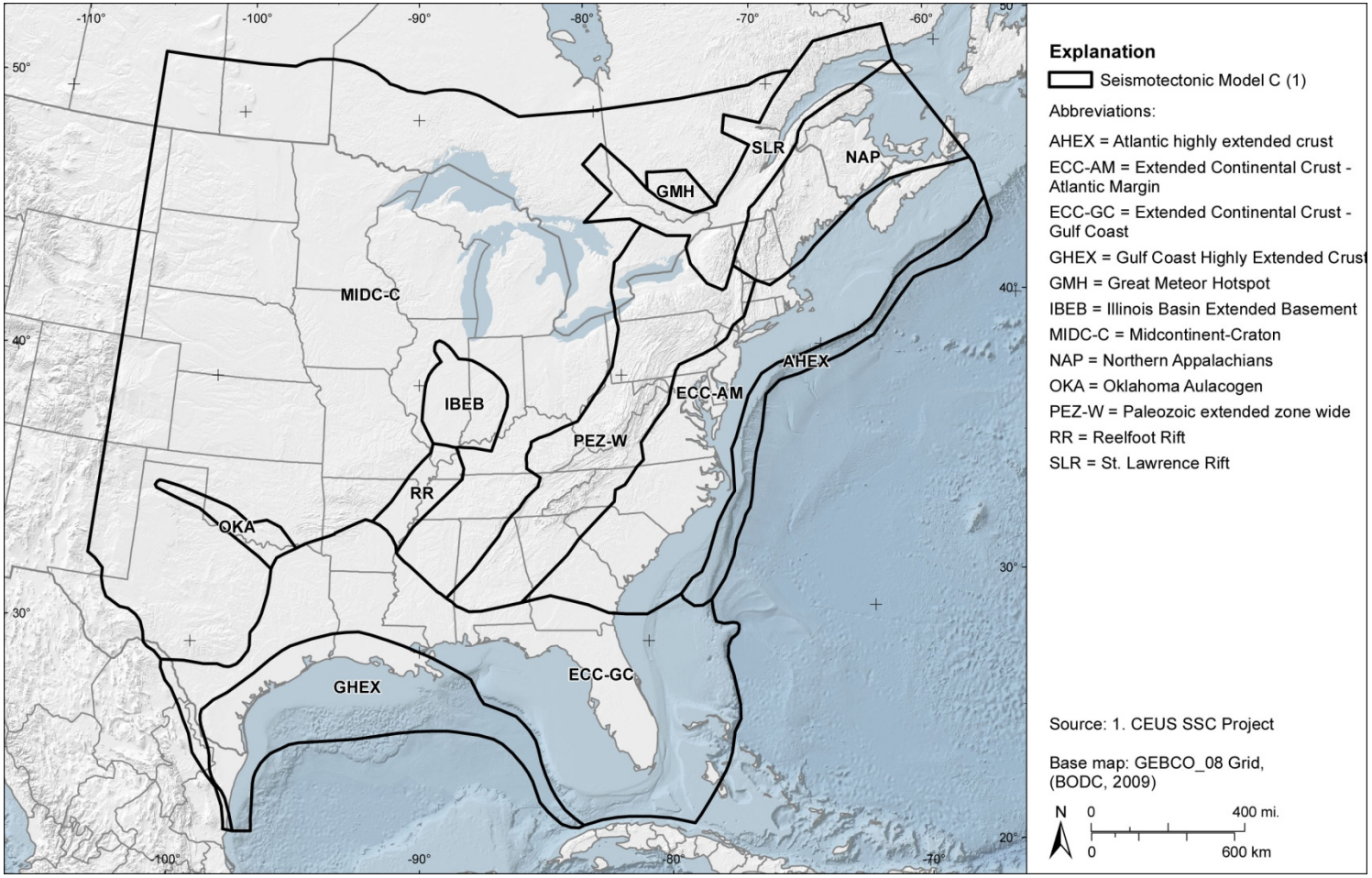
SC = single-corner; DC = double-corner; CS = constant stress; VS = variable stress; Sat = saturation.

[1] Treated as one model for calculation of weights.

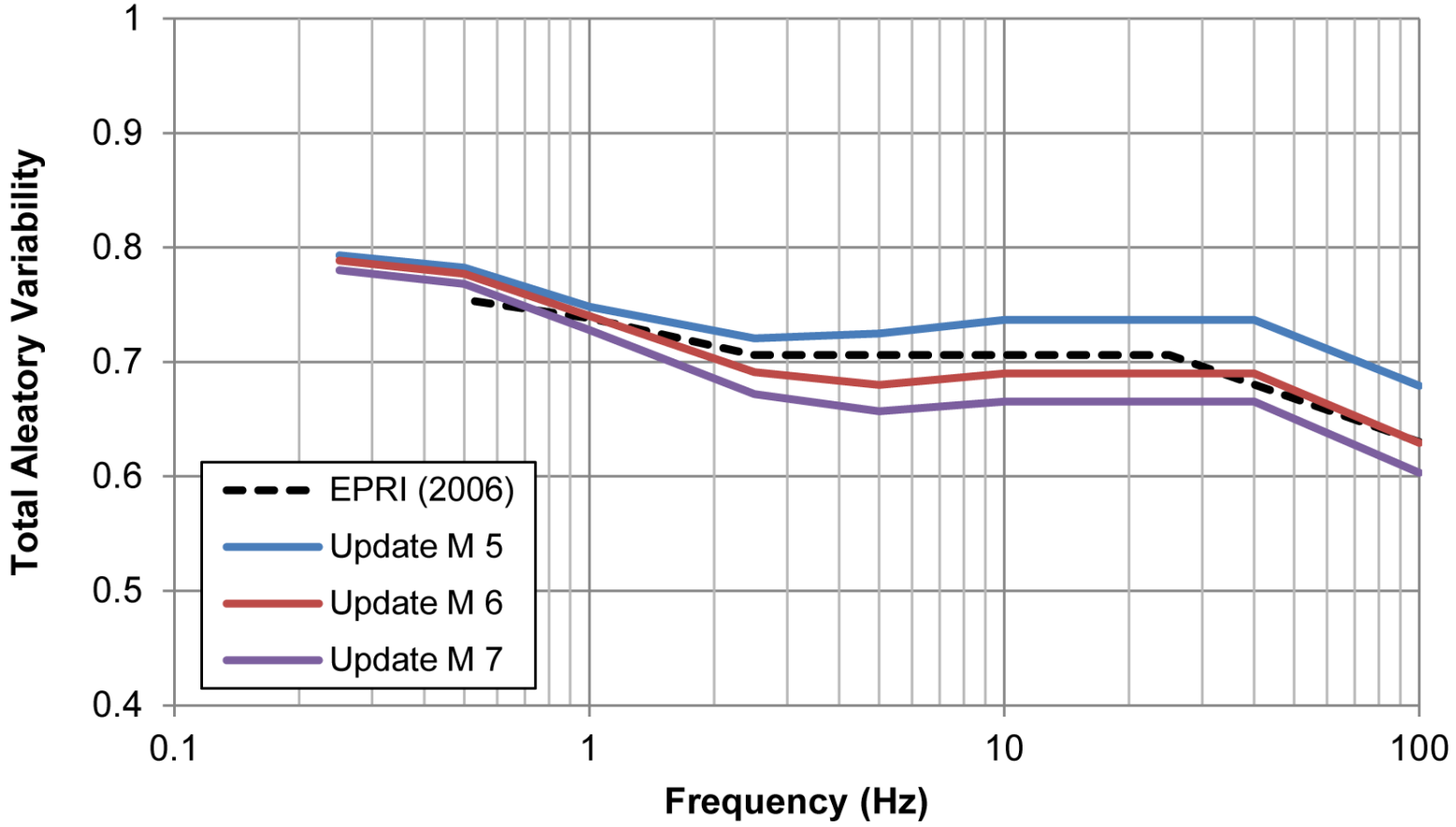
Study Area and Test Sites



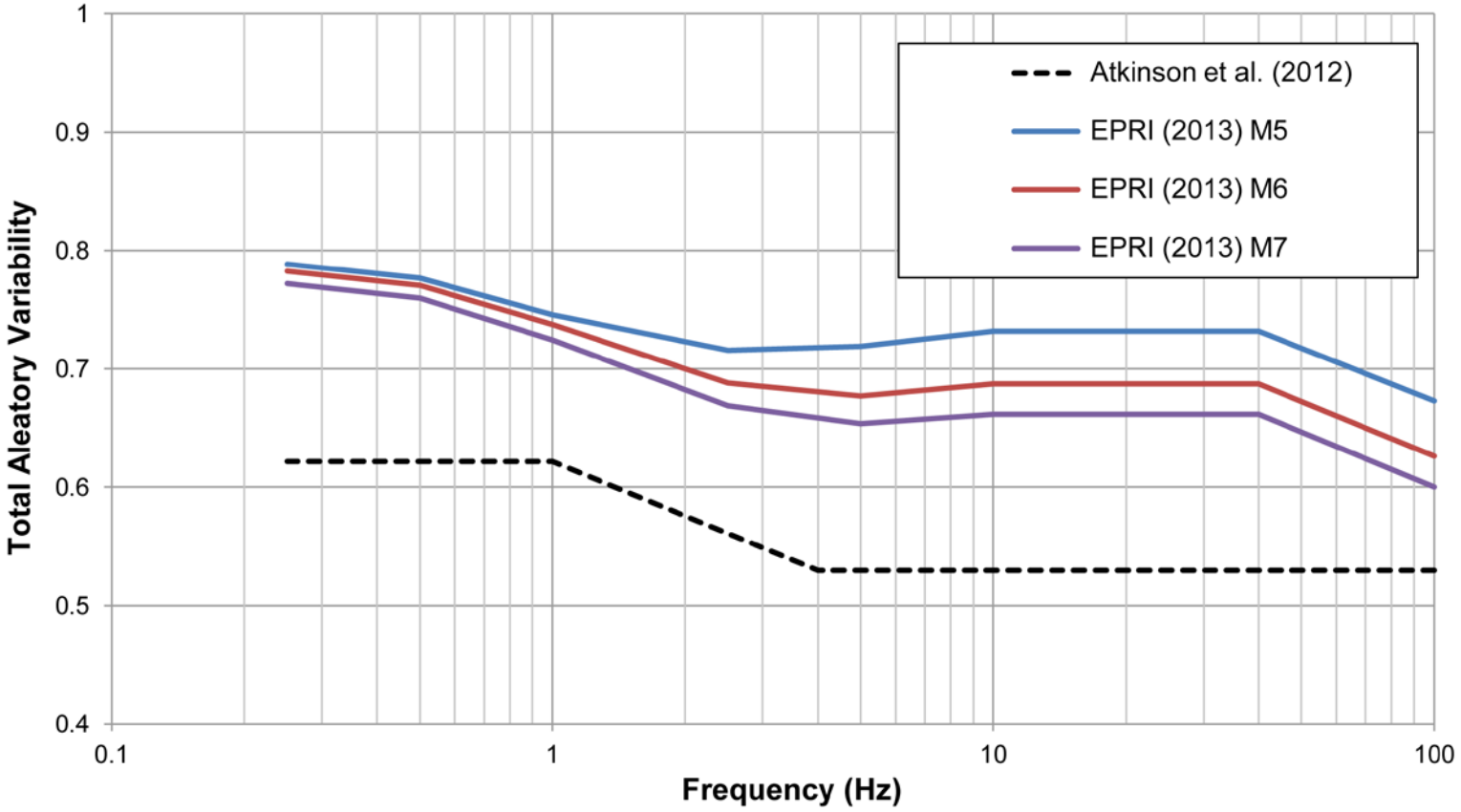
Seismotectonic Zones Developed in CEUS SSC Study



Total Aleatory Variability for EPRI (2006) GMM and Updated EPRI (2004, 2006) GMM



Comparison of Aleatory Variability Model Developed by Atkinson et al. (2012) with the model developed from this study



Stability of Aleatory Variability Models

- The aleatory variability models used in EPRI (2006) and in the update are based on statistical estimates. As such, they are subject to fluctuation as data sets change and associated models evolve

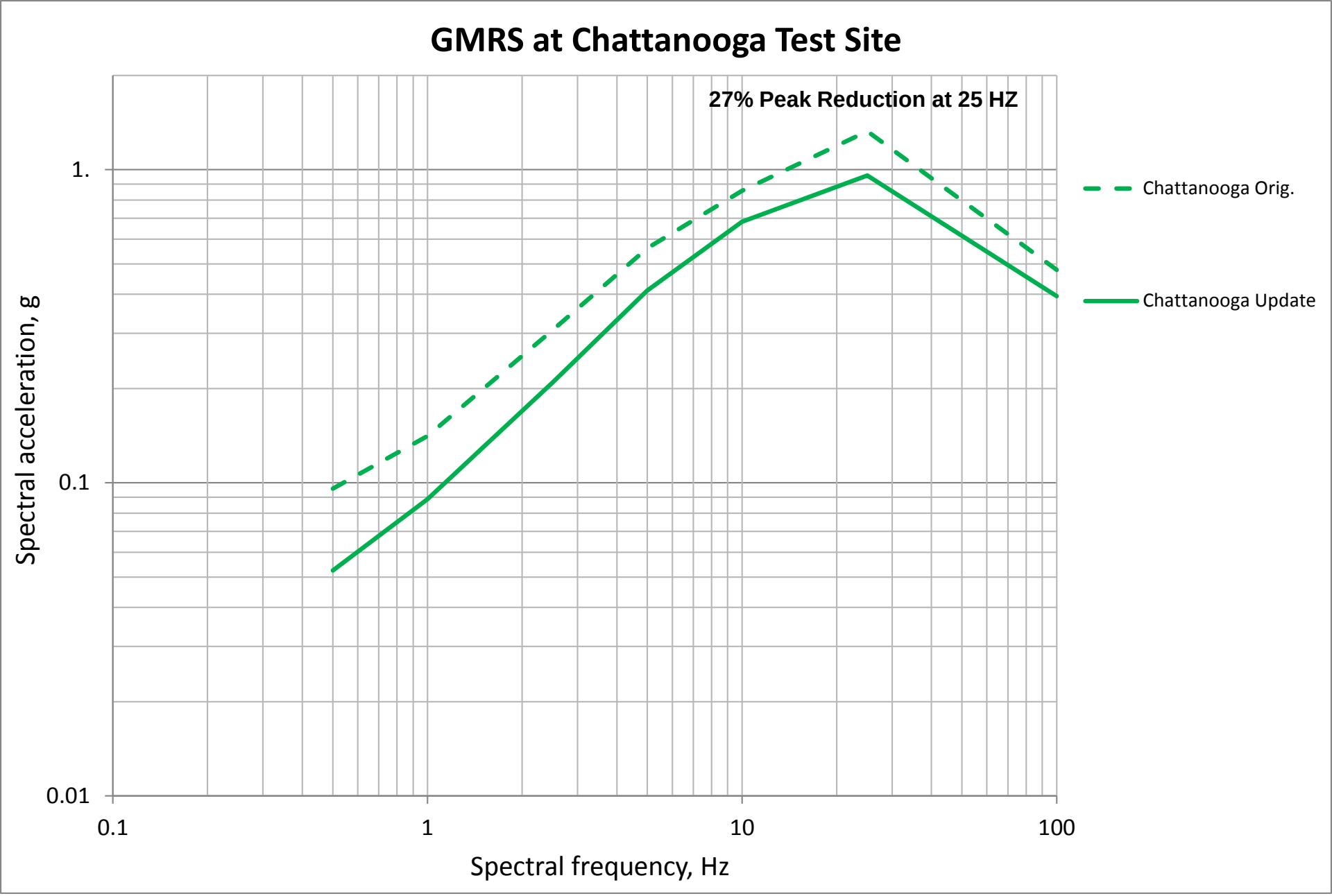
- Differences between preliminary and final aleatory estimates from NGA-West 2 are generally smaller than differences between preliminary and final aleatory estimates from NGA-West 1

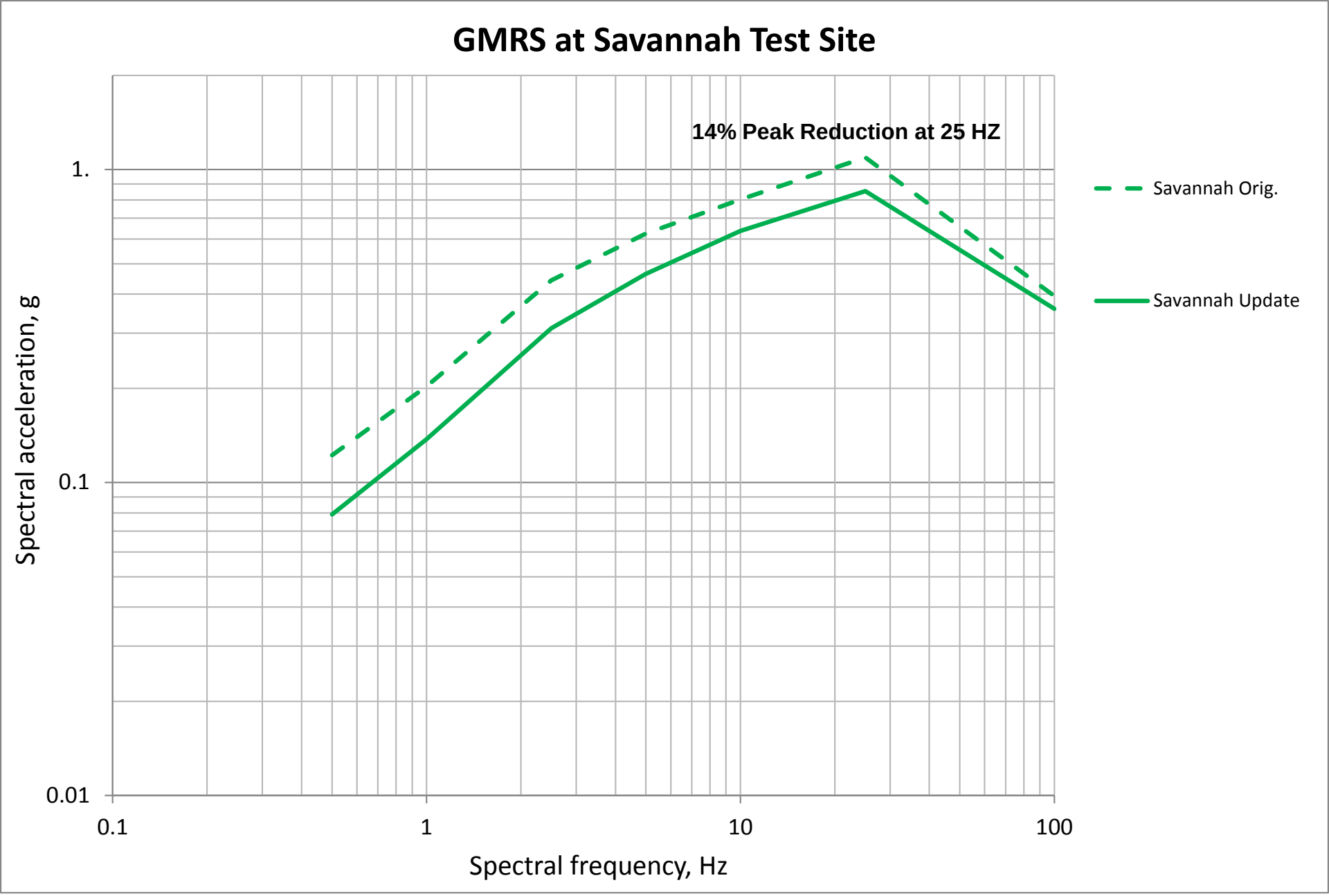
- Assessments based on preliminary NGA-West 2 estimates represent appropriate levels of aleatory variability
  - Differences between preliminary and final aleatory estimates from NGA-West 2 are within statistical uncertainty in estimates
  - The assessments are based on total observed aleatory variability; they are conservative when used in a ground motion estimation framework that incorporates additional site response uncertainty and variability

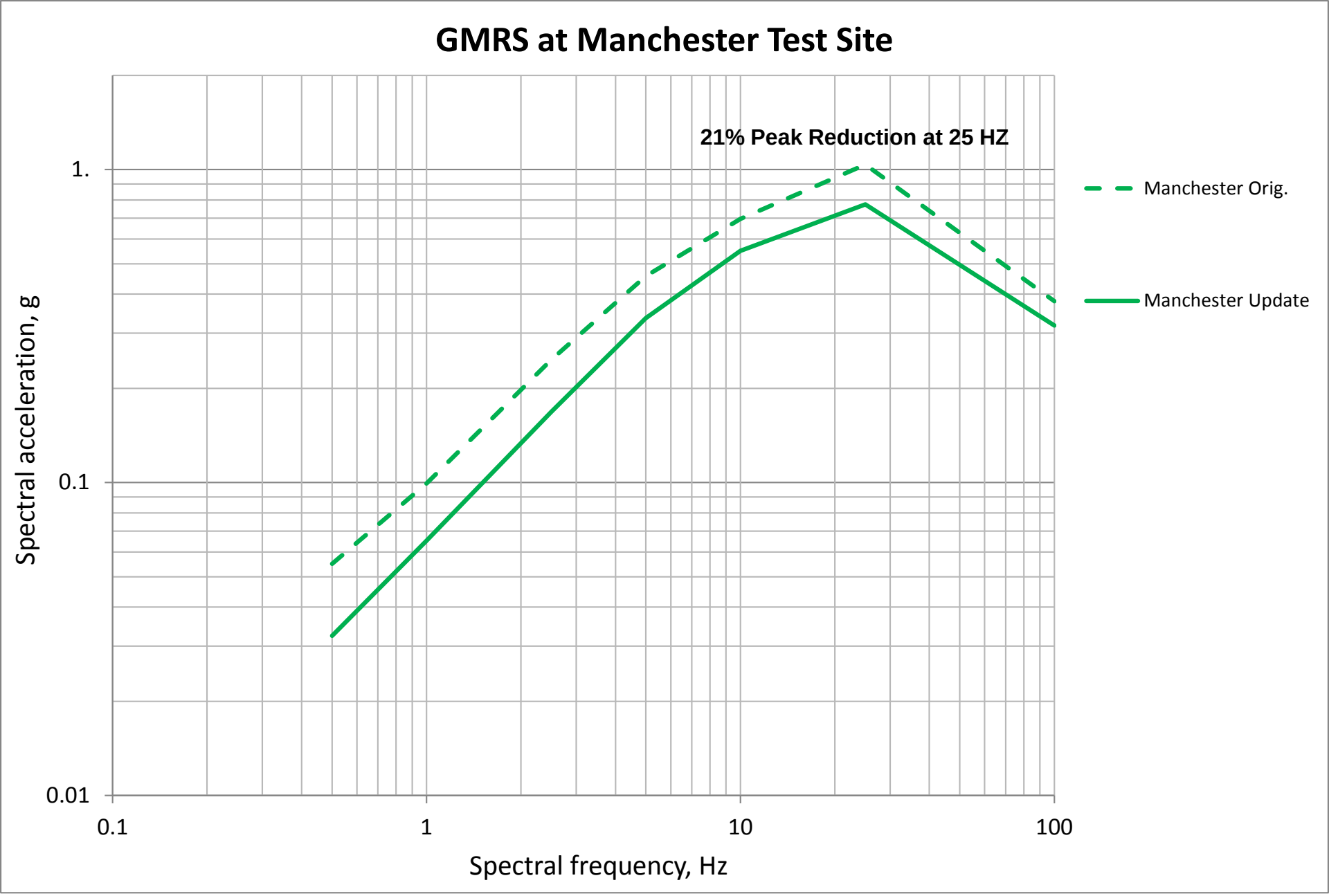
- Single-station sigma concept, in which the component of site-specific variability in site response is removed from aleatory variability, may prove to be a more stable approach for developing aleatory variability models for PSHA.

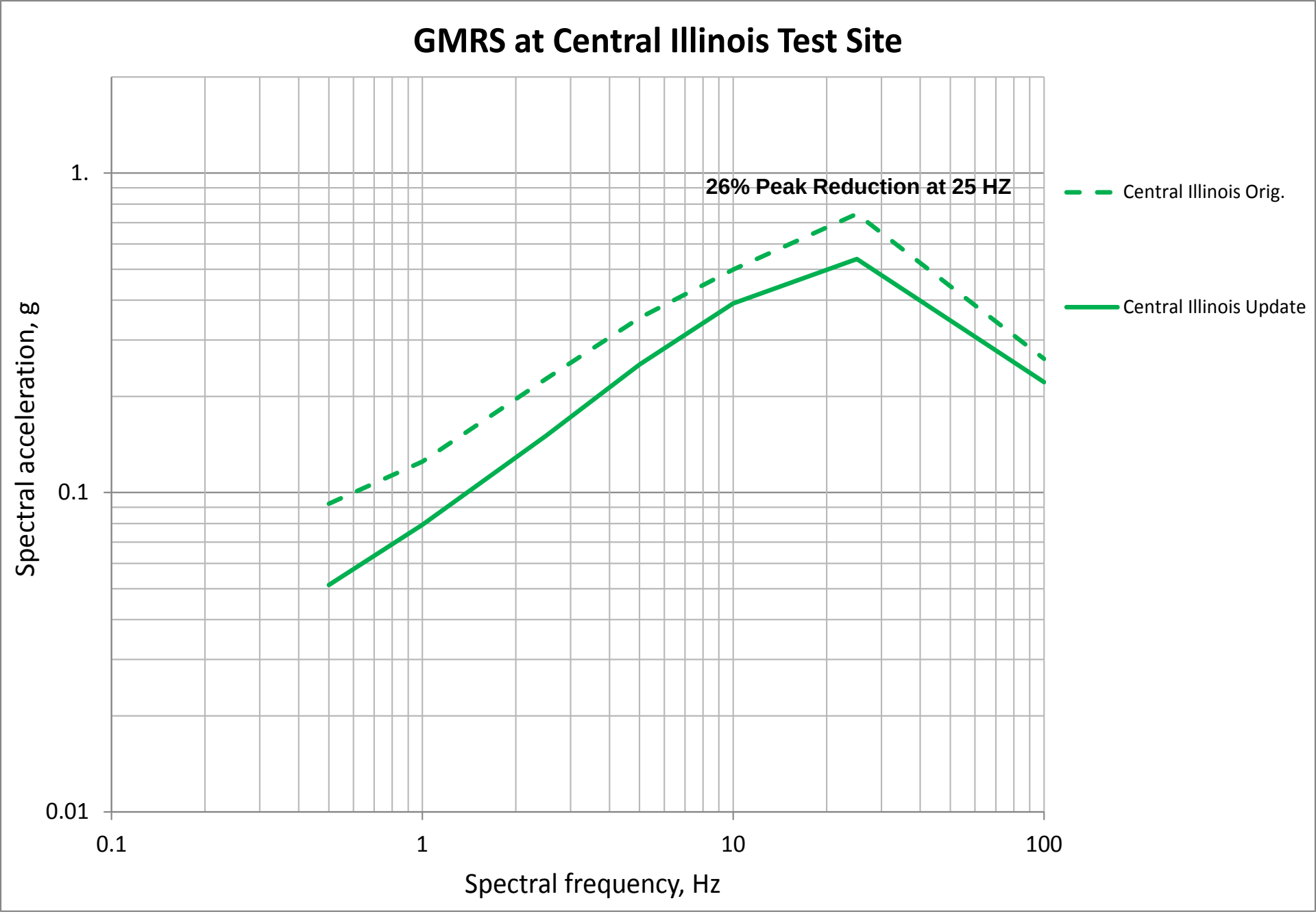
Rationale for Gulf Region Florida Boundary in Updated EPRI GMM

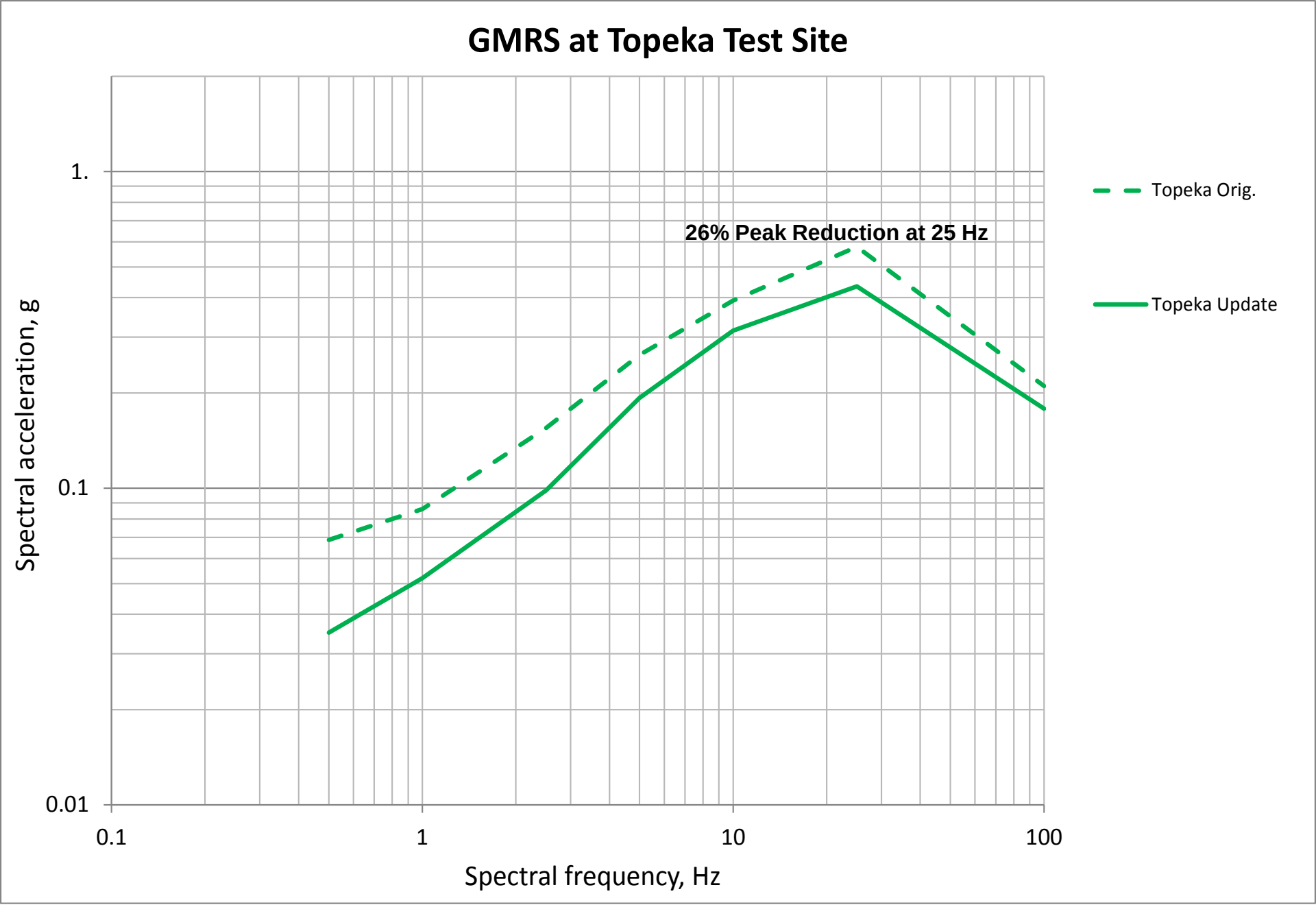
- Updated EPRI GMM based on structural framework of EPRI (2004, 2006) GMM
  - Mid-Continent Region
  - Gulf Region
- EPRI (2004) regionalization did not provide basis for Florida Gulf Region boundary
- There are two possible mechanisms for the observed low amplitudes of Lg in the Gulf region:
  - Lg phase blockage due to thinning/disruption of the crustal waveguide. It has been shown that structural boundaries that involve thinning of the crustal waveguide are particularly disruptive of Lg.
  - Anelastic attenuation caused by thick, low-velocity, low-Q sediments.
- The Gulf region defined in the CEUS SSC 2012 study delineates the region of the southern United States that has experienced crustal extension and thinning. This region closely corresponds to the northern and eastern margins of the Gulf of Mexico structural basin, which underwent extensional tectonics in the Mesozoic.

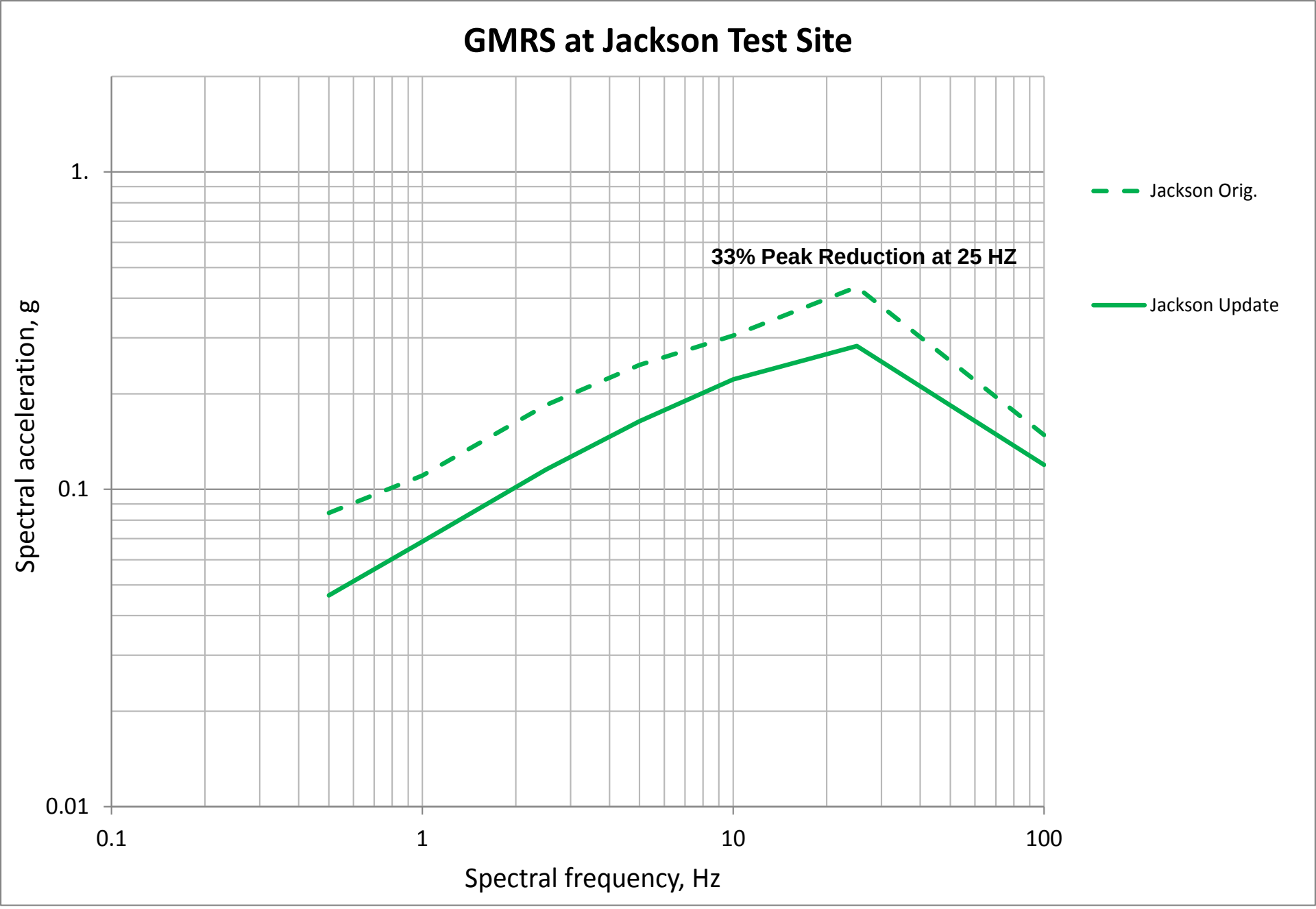

GMRS at Chattanooga Test Site
27% Peak Reduction at 25 HZ
Chattanooga Orig.
Chattanooga Update
Spectral acceleration, g
1.
0.1
0.01
0.1
1
10
100
Spectral frequency, Hz

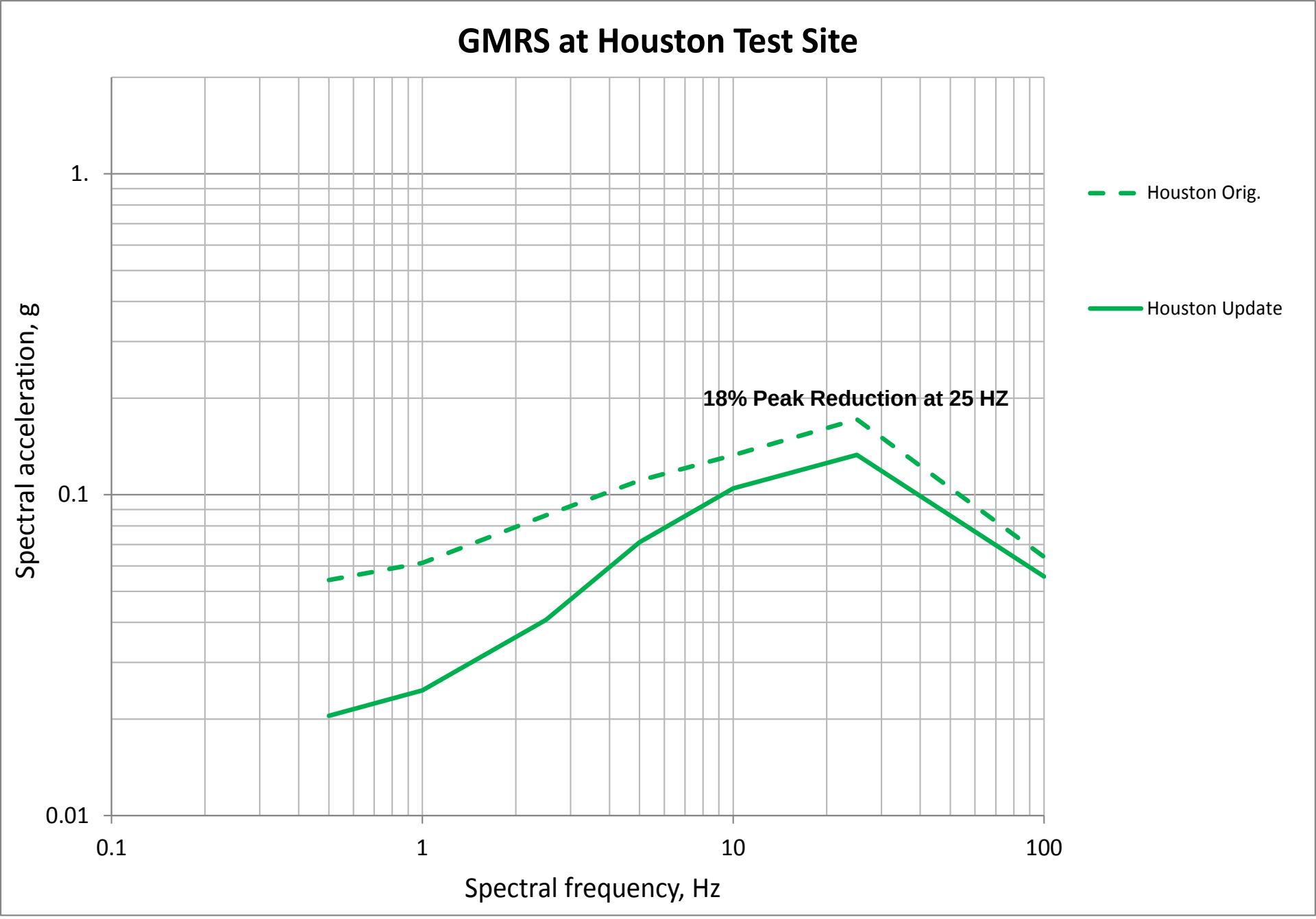

GMRS at Savannah Test Site
14% Peak Reduction at 25 HZ
Savannah Orig.
Savannah Update
Spectral acceleration, g
1.
0.1
0.01
0.1
1
10
100
Spectral frequency, Hz


GMRS at Manchester Test Site
21% Peak Reduction at 25 HZ
Manchester Orig.
Manchester Update
Spectral acceleration, g
1.
0.1
0.01
0.1
1
10
100
Spectral frequency, Hz

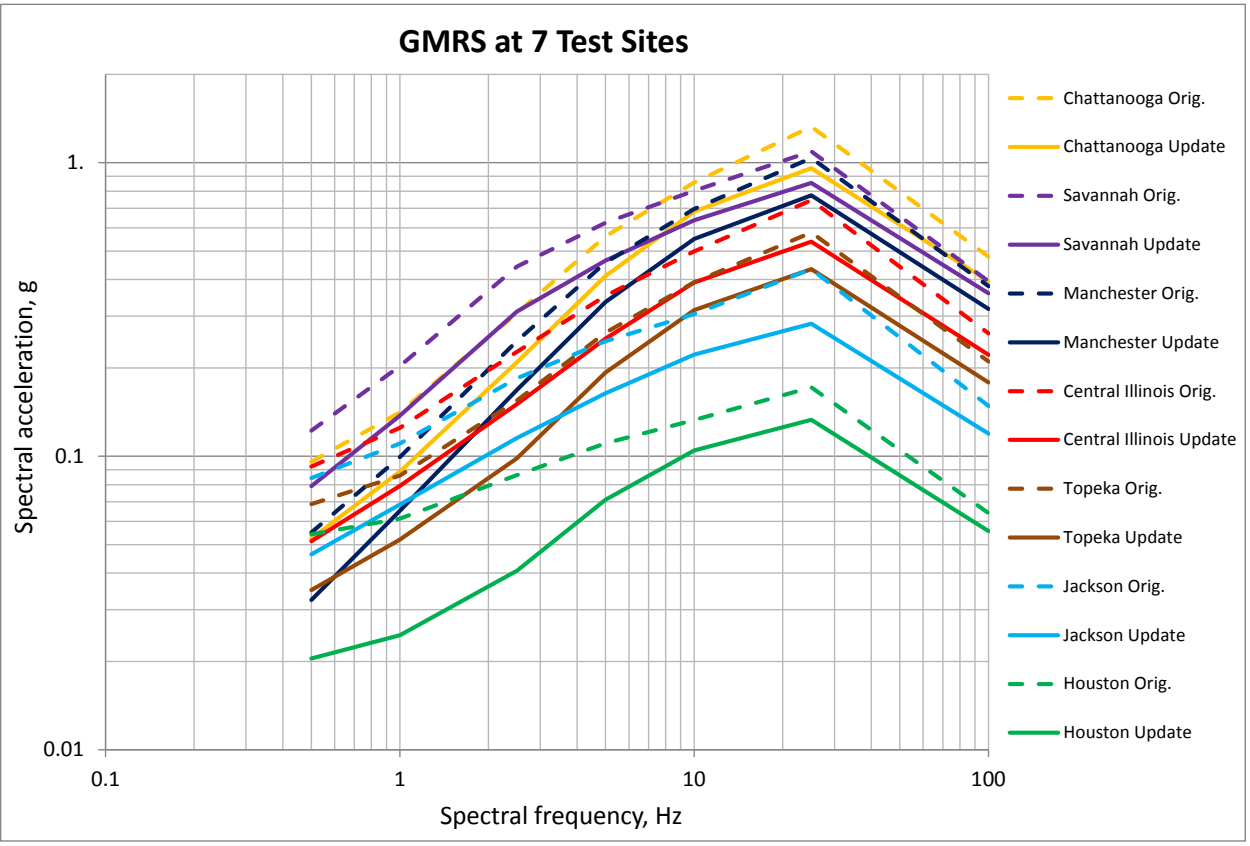

GMRS at Central Illinois Test Site
26% Peak Reduction at 25 HZ
Central Illinois Orig.
Central Illinois Update
Spectral acceleration, g
1.
0.1
0.01
0.1
1
10
100
Spectral frequency, Hz


GMRS at Topeka Test Site
1.
0.1
0.01
Spectral acceleration, g
0.1
1
10
100
Spectral frequency, Hz
26% Peak Reduction at 25 Hz
Topeka Orig.
Topeka Update


GMRS at Jackson Test Site
1.
0.1
0.01
Spectral acceleration, g
0.1
1
10
100
Spectral frequency, Hz
33% Peak Reduction at 25 HZ
Jackson Orig.
Jackson Update


GMRS at Houston Test Site
1.
0.1
0.01
Spectral acceleration, g
0.1
1
10
100
Spectral frequency, Hz
18% Peak Reduction at 25 HZ
Houston Orig.
Houston Update

Comparison of Ground-Motion Response Spectra



Concluding Remarks

- An updated EPRI GMM has been developed to calculate ground motion response spectra (GMRS) at sites of existing nuclear power plant sites
- The Updated EPRI (2004, 2006) GMM was developed using the same structural framework as EPRI (2004) but using current ground-motion prediction equations (GMPEs) and considering a new NGA-East ground-motion database, 80% of which was obtained after EPRI (2004)
- The center, body and range (CBR) of views of the larger technical community have been captured and represented in the Updated EPRI GMM
- There is an important decrease in ground motion at rock at all frequencies except peak ground acceleration (PGA) for the test sites in the Midcontinent Region and Gulf Region when the Updated EPRI GMM (2013) is used with the CEUS SSC Model (2012)
- PPRP (4/5/13) and NRC (8/30/13) of the Updated EPRI GMM have been obtained
- The value of the updated GMM has been enhanced through the participation of recognized seismologists and ground motion experts from industry, government and academia and productive cooperation from the Pacific Earthquake Engineering Research Center (PEER), members of the NGA-East Project and the United States Geological Survey (USGS)
- NGA-East Project PPRP requested that the NGA-East GMM results be compared to the EPRI (2004, 2006) GMM and the EPRI (2013) GMM results using the CEUS SSC source model in its report for the July 14-16, 2014 Workshop.