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APPENDIX D COMMENT RESPONSE TABLES AND OTHER PPRP AND OBSERVER FEEDBACK

D.1 Introduction

Documentation is an essential part of any SSHAC Level assessment process. Feedback from the PPRP and Observers (NRC and DNFSB) was important for the EPRI (2004, 2006) GMM Review Project to evaluate the full range of views of the larger technical community. Appendix D provides the documentation of that feedback below in an unedited form. Slides presented at the PPRP Closure Briefing but not included in handout are provided after PPRP Comment Response Table. Slides from the TI Lead's presentation from the PPRP Closure Briefing are also included in this appendix if they were referred to in the comment response tables.

- **PPRP** – Comments and recommendations received from the PPRP are documented, in part, in Section D.2 and also in Appendix H. The PPRP Comment Response Table in Section D.2 documents review comments, together with TI Team responses, associated with the draft updated GMM presented at the PPRP Closure Briefing on February 13, 2013. These include PPRP suggestions made prior to that meeting on how the TI Team could amplify its presentations to make the meeting more productive. The PPRP also provided appended comments to reach closure with respect to the Updated EPRI (2004, 2006) GMM when the activities described in Section 3.4.6 were occurring. Those appended comments, along with the TI Team's and Project Manager's responses, are included in Section D.2. Appendix H includes the PPRP's formal feedback to the project in PPRP Reports #1 through #6.
- **Observers (NRC and DNFSB)** – One of the goals of the EPRI (2004, 2006) GMM Project was to have full engagement and transparency between the project and Observers (e.g., the NRC and DNFSB). Section D.2 includes NRC and DNFSB Comment Response Tables. These consist of responses by the TI Team to the NRC and DNFSB comments to the Intermediate Document, which was provided on January 18, 2013 to facilitate discussion at the PPRP Closure Briefing on February 13, 2013. The Intermediate Document described the draft updated EPRI (2004, 2006) GMM with accompanying text. The PPRP and NRC provided input on what information the TI Team should include in the Intermediate Document.
- **NRC Staff** – The NRC Staff provided more detailed comments at a public meeting on February 28, 2013. These comments, along with the TI Team's and Project Manager's responses, are in tabular form in the Project Manager's presentation to the NRC on

March 26, 2013, which is provided in Section D.3. The responses in the Project Manager's presentation are divided into three groups, as follows:

- Comments requiring clarifications/discussions
- Comments addressed
- Comments requiring additional work

The NRC Staff made a presentation on April 11, 2013, to the Advisory Committee on Reactor Safeguards (ACRS) full committee regarding the EPRI (2004, 2006) GMM Review Project. The NRC Staff presentation to the ACRS is included in Section D.3. At the ACRS full-committee briefing, the NRC Staff stated, "The Updated model appears to address issues raised by the peer reviewers and Staff."

D.2 Comment Response Tables

- PPRP comment responses and PPRP appended comments
- NRC comment responses
- DNFSB comment responses (Jeffrey Kimball)

D.3 Slide Presentations

- Selected slides from Toro presentation at PPRP closure briefing on February 13, 2013
- Salomone presentation at NRC public meeting on March 26, 2013
- NRC Staff presentation to ACRS full committee on April 11, 2013

PPRP Comment Response Table

COMMENT	RESPONSE
Chapters 6 and 8 are well written and the information on methodology, computational procedures, and outcomes are quite adequate.	Comment noted and appreciated
1. Empirical site adjustment factors are covered in the interim report, but not the analytical adjustment factors. I understand that it takes time to write Section 8.3.1, but a few plots comparing adjustment factors from these two approaches would go a long way in helping us review the importance of site adjustment in determining weights.	Plots of Analytical Amplification factor versus frequency for recording stations GS.OK001 (Vs30 = 610 m/s), ET.SWET (Vs30=940 m/s) and PN.PPBLN (Vs30 = 1916 m/s) were provided in the PPRP Closure Briefing on February 13, 2013. See Slides 35, 31 and 33, respectively[1]. These plots show analytical factors for a range of values of Vs30. A comparison of analytical vs. empirical amplification factors for 10 Hz and 1 Hz are shown on Slide 45 and Slide 48, respectively. Note analytical adjustment is station and record-specific (depends on Fourier Amplification factor of site and on frequency content of motion) and the empirical adjustment depends on Vs30 (category specific) and depends slightly on GMPE.
2. It is not clear what are the definition and the method for computing sigma_data_constraint (page 8-10)? Since it's used in defining the epistemic uncertainty (Eq.8.2.4-4), elaborations are needed.	The approach is described in slides 95 and 96, and will be described in the final report.
3. GMPEs are always plotted as a function of distance (e.g., Figures 8.4, 8.5, and 8.10). The same information plotted against **M** (say, at R=10, 30, 70 km, and a few other larger distances) will provide additional insights on how amplitude scales with **M** and how it varies between GMPEs.	Plots of cluster medians versus **M** were presented in the PPRP Closure Briefing on February 13, 2013 and are provided in the Appendix to this document.
4. In Figure 8.4, add curves for **M** 3 and **M** 4 to cover the magnitude range where the majority of data are.	Curves for **M** 4 added.

[1] All slides referenced in these responses are provided following the response tables.

5. Some examples of response spectra from both the updated GMM and the 2004-2006 EPRI GMM	Some examples of response spectra from both the updated GMM and the 2004-2006 EPRI GMM were presented in the PPRP Closure Briefing on February 13, 2013. See Slides 204, 205, 206 and 207.
6. Provide a more in-depth discussion of the decision to consider the OK-AR earthquake ground motion data as possibly "anomalous" and the impact of that decision on the results. Information provided might include: • Review of the reasons for considering those data are not typical • Why there is some weight given to the interpretation that those data are not part of the suite of ground motions the updated GMM is intended to predict. • What portion of the overall data set the earthquakes comprise. • Has the database been examined to determine if any other of the earthquakes or regions are anomalous in a sense similar to that for the OK-AR events (depth, stress parameter, kappa)? • Review the impact on the interim and final results • Review the technical basis for the weights given to inclusion or exclusion of those data.	An expanded discussion of the effect of always using OK-AR Data for frequencies of 0.5 Hz, 2.5 Hz, 5 Hz, 10 Hz, 25 Hz and PGA was presented in the PPRP Closure Briefing on February 13, 2013. See Slides 148-154. The effect of always using OK-AR Data on cluster weights is shown on Slide 147. As part of completion of the model, the effect of the OK-AR data will be examined using all candidate models. We will also check SE Canada versus the rest of the US (excluding OK-AR).
<u>PPRP Closure Briefing Report (Draft) dated February 22, 2013</u>	
<u>Pg.6: Checking Exercise:</u>In view of the potential for inadvertent errors in the TI Team's analyses included in the Intermediate Document, the PPRP recommends that a checking exercise be undertaken immediately to verify the key analyses supporting the updated GMM	We have undertaken an effort to check all aspects of the calculations, based on the feedback received by the PPRP and observers. The strong motion database has been updated to the August version of the NGA East flat file. This incorporates corrections to some of the data made by the NGA East project. The database has been further reviewed to consolidate multiple recordings at a site into a single set of

	values using the widest band width recording, or the union of multiple recordings where they individually cover different band widths. Implementation of the candidate GMPEs in R has been rechecked by separate implementation in Excel and the Excel implementation is undergoing independent verification. The procedure to extend the measured profiles to greater depths has been corrected so that it follows the Silva's templates (from EPRI SPID document) more closely. The analytical-adjustment approach is being re-checked to confirm that it is performing as expected. This process includes repeating the comparison to the empirically derived adjustments.
Pg. 7: Analytical Adjustment for Recording-Site Conditions: For immediate attention, in light of observer comments made during the Closure Briefing, we recommend that the TI Team re-examine how it implements the analytical adjustment for recording site condition to ensure that the procedure used is technically correct.	As part of the checking effort described above, we are examining our implementation of the analytical approach, including the extension of profiles to greater depths (see above).
Pg. 8: Weighting-decisions and the CBR of TDI: The PPRP recommends that the TI Team carefully re-examine the within-cluster weights, the cluster weights, and the confidence weights underpinning the updated GMM, considering : (1) the results of the sensitivity analyses, (2) the small number of new GMPEs since completion of the EPRI (2004, 2006) GMM, and (3) the appropriateness of the large weights of Cluster 2 and 3 on predicted ground motions in the updated GMM, particularly	The TI Team is planning to modify the GMM to address these issues. In particular, the following changes are being implemented: (1) adopt the approach where within-cluster weights are capped at 2/3; (2) calculate cluster weights giving 25% weight to consistency with the data and 75% weight to confidence; and (3) introduce magnitude scaling in the calculation of within-cluster epistemic uncertainty using the approach described in the response to the next question.

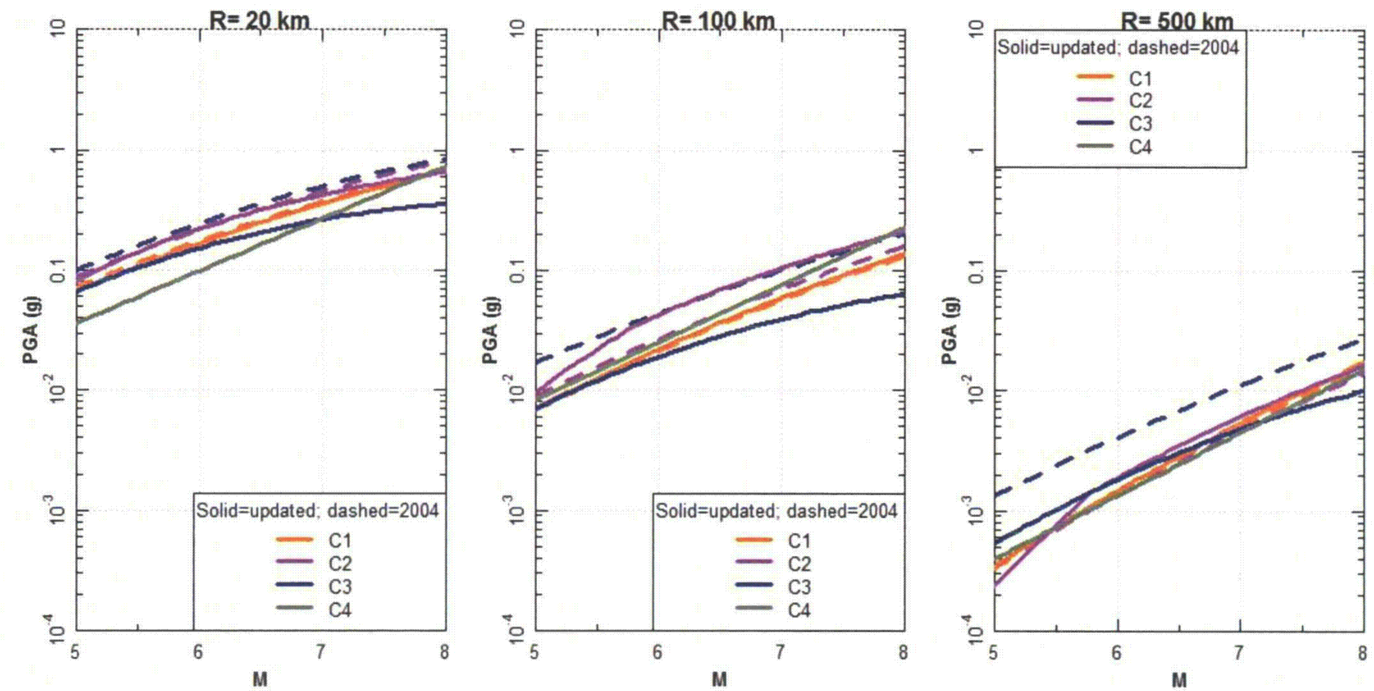
in the large-magnitude range (do small-magnitude data have diagnostic power on large-magnitude ground motion?). The TI Team should also assess whether epistemic uncertainty is adequately characterized. We further recommend that the TI Team provide to the PPRP the outcome of this exercise, including justification for the final weights it decides to adopt.	
Pg. 10: Magnitude scaling: In order to bolster the TI Team's ability to defend the point that the updated GMM appropriately represents the CBR of TDI of the larger technical community, the PPRP recommends that the TI Team make an effort to confirm their position by posing the question directly to CEUS ground-motion experts.	The TI Team is considering an approach to introduce magnitude-scaling uncertainty as part of the within-cluster epistemic uncertainty. In this approach, all GMPEs in all clusters are considered, with equal weights. The differences in scaling are quantified by calculating the standard deviation (as a function of magnitude and distance) of the ratio ln[Sa(M,R)/Sa(5,R)]. This standard deviation is then combined with the data-constraints-sigma and used to calculate the within-cluster epistemic uncertainty. This approach will broaden the epistemic-uncertainty bands at greater distances.
Pg. 12: Does the Preliminary Updated GMM Better Represent the CBR of TDI than the Existing GMM?: The PPRP recommends that the TI Team consider whether additional epistemic uncertainty may be appropriate to reflect the limited ability to test the GMPEs against data in poorly sampled magnitude and distance ranges.	This issue is addressed in the response to the above two questions. The TI Team feels that the modifications to the data-consistency weights and the introduction of magnitude-scaling uncertainty will provide a more adequate representation of the CBR of TDI.
Pg. 14: PPRP's Position Regarding the Use of the Updated GMM for Industry Response to the NRC RFI of March 12, 2012: We recommend that every feasible effort be undertaken by the TI Team at this time to critically check the updated GMM, besides re-examining the weights underpinning the updated GMM (see recommendation in an earlier section).	The TI Team is in the process of performing this check, as described in the responses above.

References

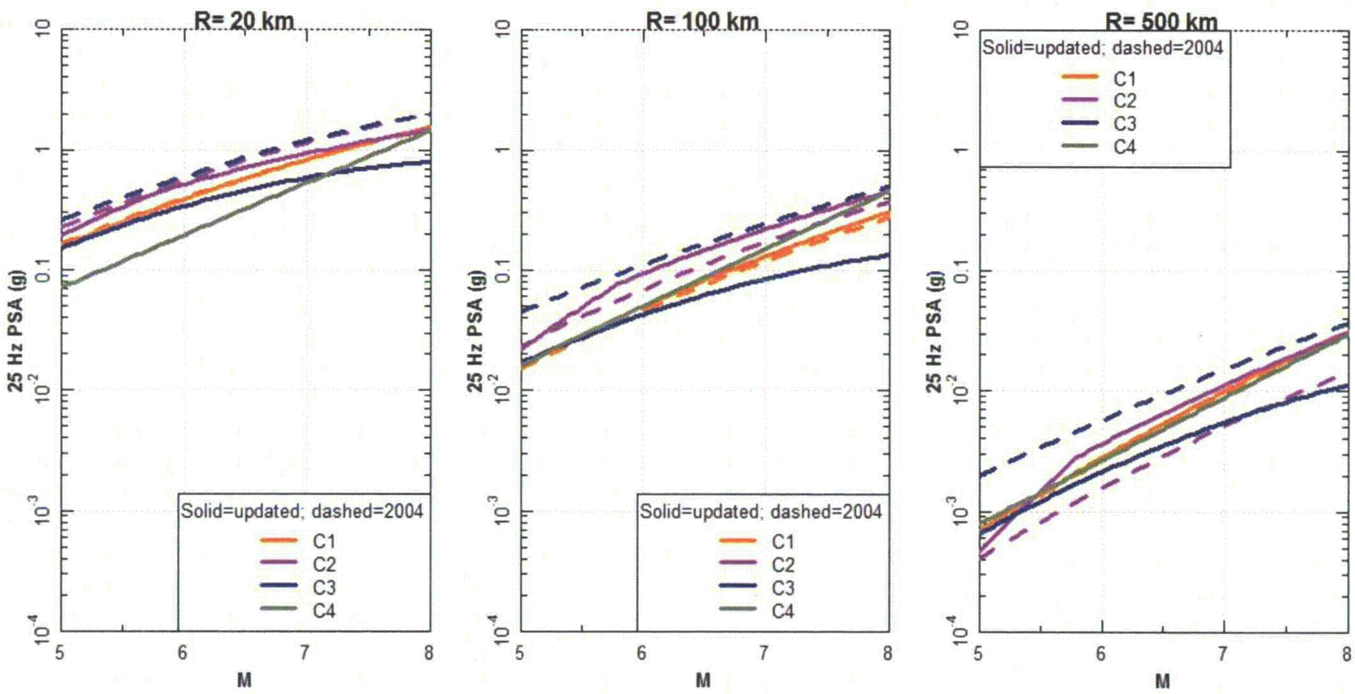
1. PPRP Closure Briefing Presentation dated 2/13/13 (Handout)

Appendix: Slides Presented at PPRP Closure Briefing on 2/13/13 but not included in Reference 1

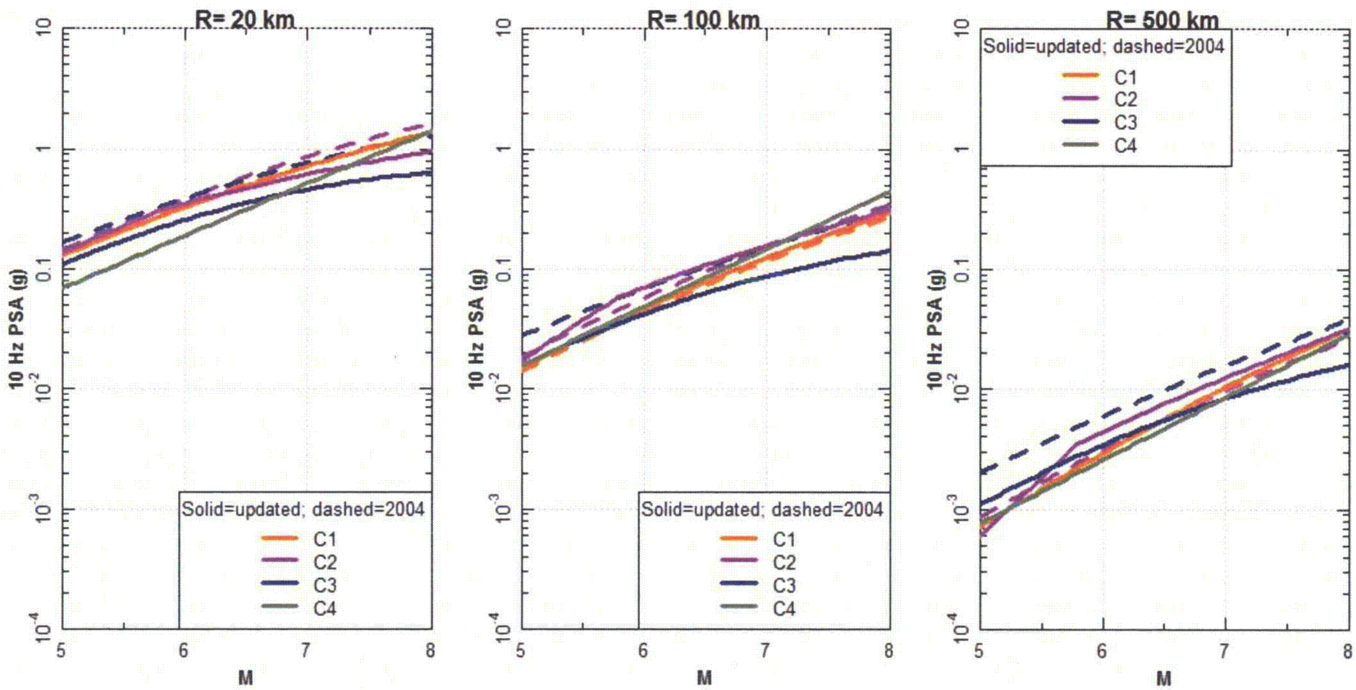
Magnitude Scaling by Cluster: PGA



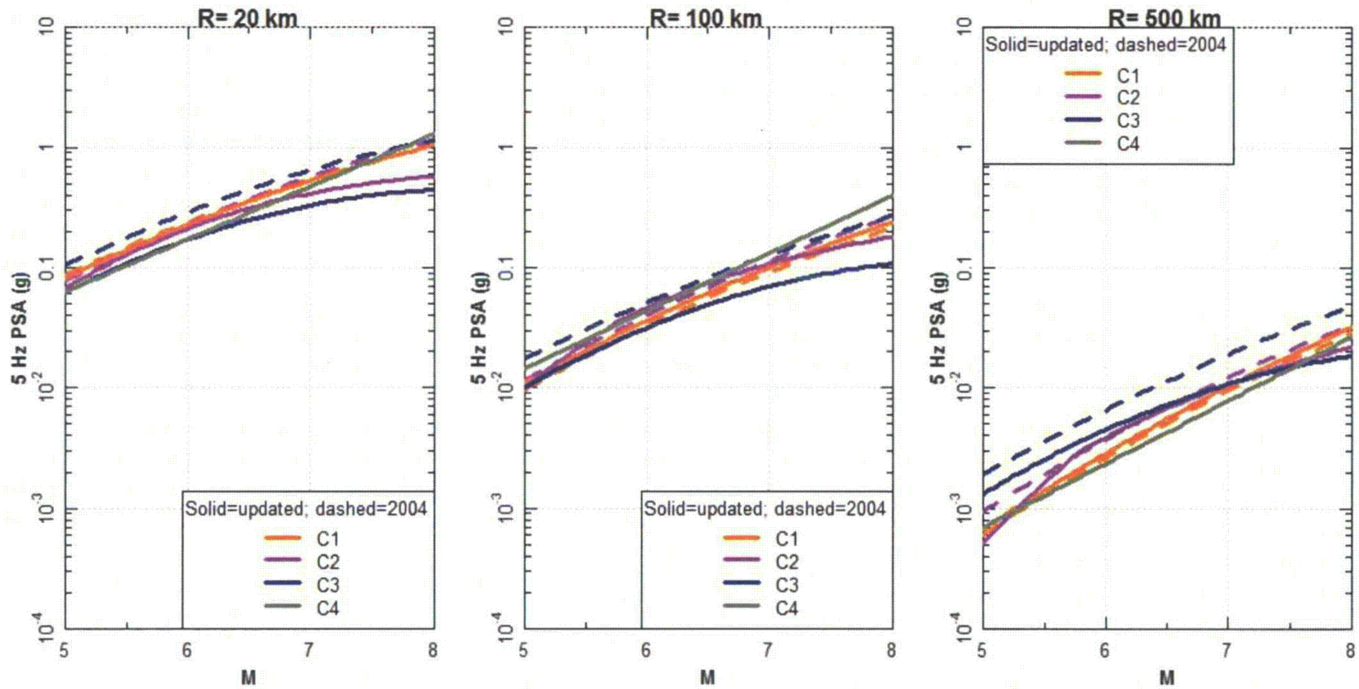
Magnitude Scaling by Cluster: 25 Hz



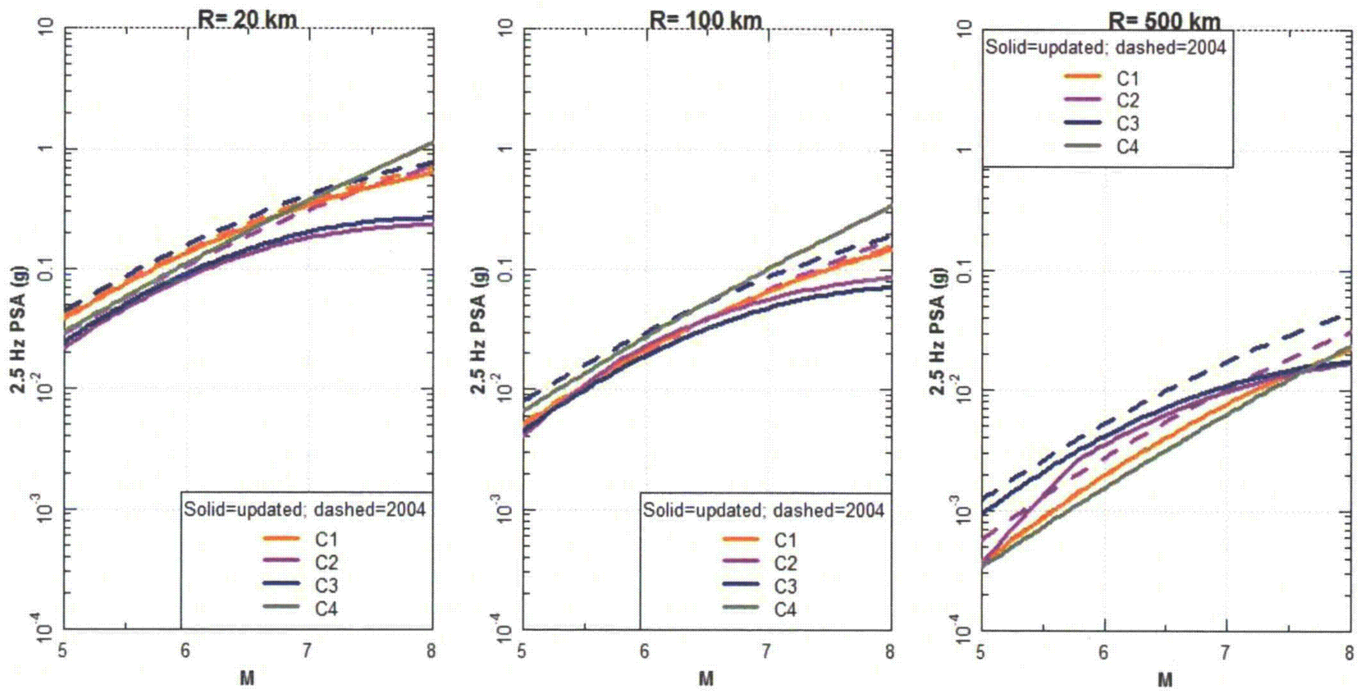
Magnitude Scaling by Cluster: 10 Hz



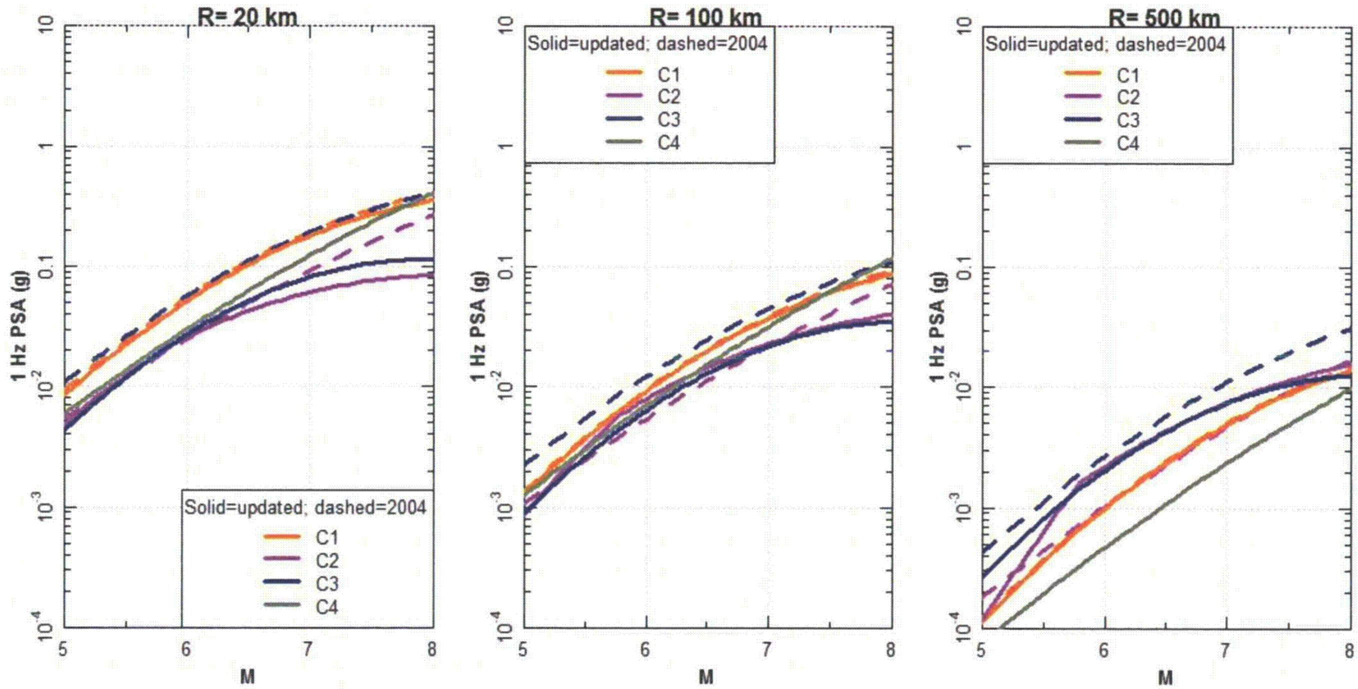
Magnitude Scaling by Cluster: 5 Hz



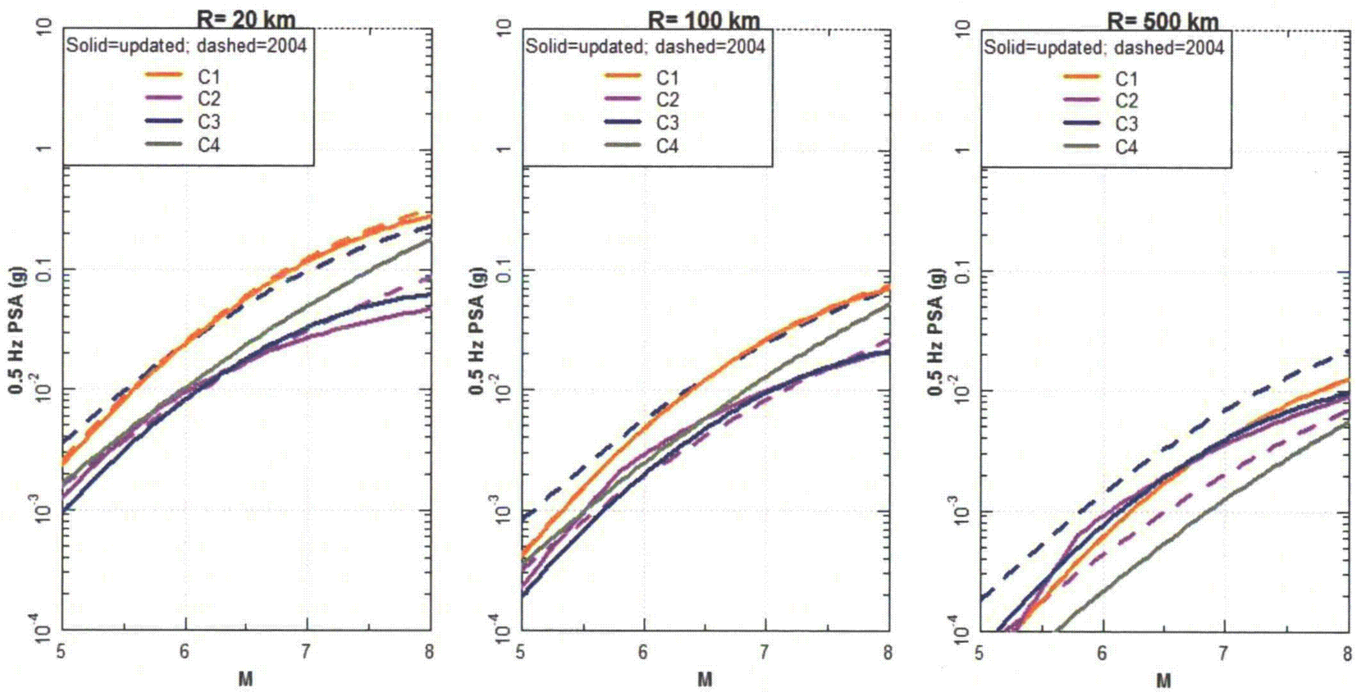
Magnitude Scaling by Cluster: 2.5 Hz



Magnitude Scaling by Cluster: 1 Hz



Magnitude Scaling by Cluster: 0.5 Hz



REQUEST FOR INFORMATION FROM THE TI TEAM TO ENABLE PPRP REPORT #5

Before the PPRP writes and submits its PPRP Report #5, we ask you and the TI Team to provide the following information:

1. A copy of the Hazard Input Document (HID)for the updated GMM. This will give us a clear understanding of the version of the updated GMM that we are approving.

The HID for the Mid-Continent Region was sent in a separate email dated 3/23/13. Preparation of HID for Gulf Region which requires more computer will be sent when it is available.

2. Response to the request stated in the last sentence of Appended Comment (I).1.

3. Response to the request stated in the last sentence of Appended Comment (I).2.

4. Response to the questions posed in Appended Comments (III).1. and (III).2.

5. Response to the request stated in Appended Comment (IV).

As an aside, as pointed out during our March 15 conference call:
* The title slide (Slide 1) of the revised PowerPoint summary should be corrected to read "PPRP Letter of 2/22/2013 (rev. 3/6/2013)" *Slide 1[1] changed to read, "PPRP Letter of 2/22/2013 (rev.3/6/2013)" as shown in Rev. 2 of the PowerPoint Summary.*
* The TI Team may wish to re-examine the potentially misleading use of "corrected" on Slide 2

In terms of the implementation of the candidate GMPEs in R, the implementation of the adjustment from B/C to hard rock for A08' was changed from strict use of Table 2 of Atkinson and Boore (2011) to a simple model based on the hard rock/BC ratio obtained using Atkinson and Boore (2006). This modification (as indicated by the PPRP, it is not a correction), implements the intent of Table 2 of Atkinson and Boore (2011) to provide a simple representation of the adjustment. It can be period independent for frequencies of 10 Hz and less, but should include distance dependence for PGA and 25 Hz.

Use of the word, "corrected" was changed on Slide 2 for Items 3, 5 and 6 as shown on Rev.2 of the PowerPoint Summary.

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[1] All slides referenced in this request for information are provided immediately following the text.

Use of the word, "corrected" was changed on Slide 4 for Item 5 as shown on Rev.2 of the PowerPoint Summary.

* The wording on Slide 3 does not correspond with that in the final version of PPRP Report #4

Wording on Slide 3 changed to correspond to the final version of PPRP Report #4.

Please contact me if you have any questions.

For the PPRP,

Walter Arabasz, Chairman
801-581-7410 (office)
801-554-1845 (cell)

--------------Begin Appended Comments--------------------------------

(I). Two revisions are not part of the March-15 conference call discussions,

1. The '0.3 at M8' issue:
   a. TI team revised their estimate to 0.36 at M8 (first bullet of slide 32).
   b. A new element to 'reduce double counting' of variability (slide 17): They used 1/2 the variance of total magnitude scaling, which leads to 0.25 at M8 (2nd bullet of slide 32).

   We should ask TI team to provide more explanation on this element and justify their choice of '1/2 the variance of total magnitude scaling'.

*The TI team's review of the value for total magnitude scaling uncertainty involved computing the approximate linear fit to the values for all of the candidate models at distances from 1 to 500 km. As shown on slide 27 of the revised presentation sent on March 16, the simple linear model with a value of 0.36 at **M** 8 reasonably approximates the computed values at distances from 20 to 70 km. (The values shown on slide 27 were computed using the confidence weights assigned to the 4 clusters of 0.2, 0.3, 0.3, and 0.2 for clusters 1, 2, 3, and 4, respectively, applied to the models in each of the clusters. However, use of equal weights applied to all of the models produces similar values.) Outside of this distance range, the magnitude scaling variability increases. This increase is attributed to interplay between basic magnitude scaling and the interaction with modeling of geometric spreading and attenuation with distance. It is thought that these aspects of variability in magnitude scaling would be captured by the variability among the four cluster median models as they exhibit differences. Slide 30 shows the sigma in magnitude scaling computed from the 4 new cluster median models. The values are comparable to those shown on slide 27. Table 1 compares the magnitude scaling sigma values across all models (column 2) to the magnitude scaling sigma across the four cluster medians (column 3). Column 4 lists residual sigma computed by subtracting the variance across the 4 cluster medians from the total magnitude scaling variance. The residual standard deviation is the amount that should be captured by within-cluster magnitude scaling. As indicated the values are relatively small. The fifth column shows the ratio of the residual intra-cluster sigma values to the total sigma values.*

Table 1 Magnitude Scaling Sigma for Models Applied to Large Magnitude Earthquakes

Distance	Sigma in Magnitude Scaling at **M** 8			
	Total Across All Models	Across Cluster 1-4 Medians	Residual Intra-cluster	Ratio Residual Intra-cluster over Total
1	0.59	0.58	0.11	0.18
5	0.48	0.45	0.17	0.35
10	0.43	0.41	0.13	0.30
20	0.38	0.39	0.00	0.00
30	0.36	0.37	0.00	0.00
50	0.34	0.35	0.00	0.00
70	0.36	0.34	0.12	0.33
100	0.41	0.38	0.15	0.38
140	0.48	0.44	0.19	0.40
200	0.53	0.46	0.26	0.50
300	0.60	0.50	0.33	0.55
500	0.70	0.57	0.41	0.58

The above comparison was repeated using the GMPE set that would apply to distributed seismic sources. The values are listed in Table 2. For this case, the residual intra-cluster is a larger fraction of the total sigma.

Table 2 Magnitude Scaling Sigma for Models Applied to Distributed Seismicity Sources

Distance	Sigma in Magnitude Scaling at **M** 8			
	Total Across All Models in Clusters 1-3	Across Cluster 1-3 Medians	Residual Intra-cluster	Ratio Residual Intra-cluster over Total
1	0.56	0.47	0.30	0.54
5	0.42	0.28	0.31	0.75
10	0.36	0.21	0.29	0.81
20	0.31	0.22	0.22	0.70
30	0.29	0.22	0.19	0.65
50	0.29	0.23	0.18	0.61
70	0.32	0.24	0.21	0.66
100	0.39	0.31	0.24	0.61
140	0.47	0.39	0.26	0.56
200	0.53	0.44	0.30	0.56
300	0.61	0.50	0.35	0.57
500	0.72	0.59	0.41	0.57

For the development of the total intra-cluster sigma it was assumed that the intra-cluster magnitude scaling variance is equal to half of the total magnitude scaling variance, that is the intra-cluster magnitude scaling sigma = $\sqrt{1/2}$ *times the total magnitude scaling variance. Comparing this value to those listed in column 5 of Tables 1 and 2 shows that the assumed value of 0.707 is conservative, but not unreasonably conservative. As discussed above, a value of 0.36 is used to represent the total magnitude scaling sigma at **M** 8. Using the value of ½ of the variance, the intra-cluster magnitude scaling sigma at **M** 8 was set at 0.25.*

2. On slide 33, the M5 curve for intra-cluster epistemic uncertainty is lower than what it used to be (compared to slide 28 of 'EPRI Actions in Response to PPRP _Complete_Final 031513'). This reduction was not discussed in our conference call and I can't find explanation in the revised PPT file. We should ask TI team for explanation and justification for this reduction.

*The data-based intra-cluster epistemic uncertainty at **M** 5 was originally computed using only the data from the sites for which analytical site adjustments were made. For the analysis presented in the revised slides, the data from the empirical sites was also used to assess the data-based uncertainty at **M** 5. These two estimates were combined by computing the average of the variances computed for the analytical and empirical site adjustments.*

(II). Checking of plots

Slides 45-47: For M 5, mean curve is above the 85% curve. Also, this

disagrees with the fractiles shown in slides 48-50.
Slides 51-53: same observation as above.

(III). Questions to TI team

1. Slides 48 and 49: The 15%-85% range is narrower for Rjb=20 than for Rjb=50km. What is the explanation for this behavior? Intuitively, shouldn't it be the other way around? Rjb=20km is not as well sampled and thus not as well constrained as Rjb=50km.

I would expect that this is a result of the models crossing it 20 km and diverging at 50, reflecting differences in distance scaling. This can be seen by looking at the envelope intra-cluster sigma plots for clusters 1 and 2 (slides 35 and 37). The model-to-model variability is increasing with distance for these clusters.

2. Which site adjustment factor was used in the computation of data-constraint sigma? Is it sensitive to the type of adjustment?

See response to I.2 above

(IV). Additional material
1. Comparison of analytical site adjustment factors with factors computed by others (Silva?). Robin volunteered to do some comparisons.

Please provide clarification as per Larry Salomone email to Walter Arabasz dated 3/23/13.

Overview of EPRI (2004, 2006) GMM Review Project

Technical Integration Team:
Gabriel Toro - Lead (LCI)
Martin Chapman (VT)
Robin McGuire (LCI)
Bob Youngs (AMEC E&I)
Larry Salomone – Project Manager

Closure Briefing

February 13, 2013

Topics

- Summary of strong-motion data
- Adjustments to reference site conditions
- Updated GMPE clusters
- Development of Updated GMM
- Sensitivity analyses
- Graphical exploration of updated GMM & comparisons to EPRI (2004)
- Epistemic uncertainty
- Comparison to NGA-West
- Model for the Gulf Crustal region

Summary of Strong Motion Data

Data Used

- PEER NGA East database of strong motion recordings.
- Classified sites based on geology and measured/inferred V_{S30}
  - Soft rock (younger rocks and/or $500 \leq V_{S30} < 1000$ m/s
  - Intermediate rock (older rocks and/or $1000 \leq V_{S30} < 1890$ m/s
  - $V_{S30} \geq 1980$ m/s

NRC (Observer) Comment Response Table

COMMENT	RESPONSE
1) Lack of epistemic uncertainty – concerns about whether the final GMM with the weighting captures the CBR of the TDI.	Slides 197 to 205 presented in the PPRP Closure Briefing on February 13, 2013 show the epistemic uncertainty. Slides 210 and 211 show a comparison with uncertainty bands from Atkinson (2013) for low frequency and high frequency respectively. Additional work was also performed to examine the alternative to add additional epistemic uncertainty at the higher magnitudes and lower frequencies. There is sufficient epistemic uncertainty in the Updated EPRI (2004, 2006) GMM.
2) Documentation – assigned Sections (6.1, 6.2, 6.3, 8 and 10) do not adequately describe and evaluate the results nor do they provide justification that the final updated GMM meets the CBR of the TDI.	PPRP feedback stated that Chapters 6 and 8 are well written and the information on methodology, computational procedures and outcomes are quite adequate. PPRP Closure Briefing Report documents that the updated EPRI (2004, 2006) GMM represents the CBR of TDIs given currently available data, the range of technically defensible GMPEs, and present day advances in GMM modeling. Report text provided to support the Closure Briefing will be revised with additional documentation of the evaluation and integration process in response to feedback received during the Closure Briefing.
3) Over-reliance on limited dataset- Half of the data is from the SE Canada/NE US resulting in heavy weights for GMPEs developed using that limited dataset.	Disagree. Dataset used provided spatial coverage representative of the CEUS as shown on Slide 5, Table: Summary of Number of Recordings used for empirical and analytical scaling of ground motions and visually on Slides 6-9 provided in PPRP Closure Briefing on February 13, 2013. Data from a wide region were used, a majority of which was outside SE Canada and NE US.

COMMENT	RESPONSE
4) Replacement vs. Update – With elimination of several previous models and introduction of only three new models, this appears to no longer be an update.	This issue was discussed at length in the working meetings and resolved. Incorporated J. Ake's feedback in WM #3, EPRI (2004, 2006) needs to be re-assessed. Revision (Update) would retain the EPRI (2004, 2006) GMM structure and update it based on evaluation and integration to represent new data, models and methods using a SSHAC Level 2 process. This approach was followed to develop the Updated EPRI (2004, 2006) GMM.
5) Site Correction- NRC unable to replicate analytical approach for the one example station.	Analytical Approach incorporating site corrections was reviewed and adjustments were made to resolve the issues identified in PPRP Closure Briefing of February 13, 2013. The extension of profiles to greater depths will be fully described in the project report.
6) Aleatory variability model – NGA W2 model adopted without any justification.	1) Followed EPRI (2006) assessment that CENA and WNA aleatory variability should be similar. 2) Used average of preliminary NGA W2 aleatory models augmented by published NGA 2008 GMPEs to update EPRI (2004, 2006) aleatory model. 3) Included small increase in event-to-event variability to account for slightly larger variability noted in data, as per EPRI (2006). 4) For simplicity, dropped alternative option for lower within-earthquake variability to represent more uniformity in CENA hard rock sites as impact on mean hazard is small. 5) Note: Atkinson suggests that aleatory variability is lower in CENA than in WNA.
7) Resulting GMM is similar to WUS GMPEs- does this make sense for the CEUS.	Disagree. A comparison with WNA (NGA, 2008) was provided in the PPRP Closure Briefing on February 15, 2013 on Slide 215.

Jeffrey Kimball (Observer) Comment Response Table

COMMENT	RESPONSE
The context for the observations and feedback is that of an observer who has been following the efforts of EPRI as supported by the GMM Project Manager, TI Team, and PPRP, to complete the update of the EPRI 2004/2006) ground motion models. The GMM update is intended to follow the same general methodology as that of EPRI 2004. As outlined in the project plan, this update is based on following SSHAC Level II guidelines. In the context of NRC NUREG-2117, the project is not being executed as a "replacement" of EPRI 2004/2006.	Noted
While there are aspects of the EPRI GMM update that improve on the previous work of EPRI 2004/2006, there are several places where documentation could be improved to support decisions made.	Noted and additional documentation included in presentations for PPRP Closure Briefing on February 13, 2013.
1a) Information for all of the sites assessed should be included in the final documentation including a data file of the modeled velocity profiles, kappa estimates, and a complete set of amplification factors for the 54 sites modeled.	Will consider adding to Project FTP site at the completion of the study for future use.
1b) Provide additional data and information to explain how the extended shear-wave velocity profile was developed.	Information will be provided in the form of profiles and amplification factors for additional sites.
1c) Plot kappa amplification contribution versus frequency for a range of kappa site assumptions. Provide kappa values for ET.SWET discussing why this site amplifies Fourier amplitudes for frequencies above about 20 Hz, and how Equation 6.2.1.2-5 is being used.	Calculated kappa values will be provided for all profiles, as well as plots illustrating the sensitivity of Fourier spectra (and, more importantly, response spectra).
1d) Execute equivalent linear analysis of site response as part of determining if use of the QWL approach introduces any undesired approximates at certain sites for specific frequencies	Agree that this task is longer term, and it should be performed to support the NGA-East Project

2) Prepare similar figures (Figure 6.3.2-1 through 6.3.2-12) for the range of new median cluster GMPEs to see if the updated models have improved the situation in Section 6.3.2.	We will prepare and examine these figures and consider including them in the final report.
3) Prepare similar figures (Figures 6.3.1-1 through 6.3.1-12) for the new EPRI cluster median models to determine how the new models fit the data.	We will prepare and examine these figures and consider including them in the final report.
4) It is not clear that the documentation fully support the conclusion that the exclusion of data for Arkansas and Oklahoma should be given 50% weight for all frequencies Is this issue based on one seismologist or represents a broader view.	Performed sensitivity analysis to show the effect with and without the AR-OK data. This issue was raised by C. Cramer, who assembled the NGA-East database and served as a Resource Expert for this project.
5) Explain why the boundaries for the bins (Section 8.2.3 (page 8-7) are appropriate and how the importance factors were derived. Improve documentation by adding a table to display how much data falls within each of the bins to gain perspective on the results that are subsequently provided for GMPE weights in each cluster. Did the importance factors consider the amount of available data in each bin?	Table: Summary of Number of Recordings used for empirical and analytical scaling of ground motions added to presentation provided in PPRP Closure Briefing on February 13, 2013. See Slide 5. Expanded explanations of these issues will be provided in the report.
6) Provide an explanation of why combining high and low frequencies is appropriate.	Spectral shapes are improved and seismic hazard calculations are simplified.
7) Add additional Tables similar to 8.3.3-1 through 8.3.3-4 for all frequencies and clusters (1 to3).	We will consider including these tables in the final report or in an appendix.
8) Perform a sensitivity assessment to see if individual frequencies had been used would the cluster median models change significantly.	An additional sensitivity analysis was performed and the results were presented in the PPRP Closure Briefing on February 13, 2013. Change was not significant. (See Slide 165).

9) Explain why the approach to derive overall epistemic uncertainty for each cluster discussed in Section 8.5 will not result in an underestimate of epistemic uncertainty.	Slides 197 to 205 presented in the PPRP Closure Briefing on February 13, 2013 show the epistemic uncertainty. Slides 210 and 211 show a comparison with uncertainty bands from Atkinson (2013) for low frequency and high frequency respectively. Additional work was also performed to examine the alternative to add additional epistemic uncertainty at the higher magnitudes and lower frequencies. There is sufficient epistemic uncertainty in the Updated EPRI (2004, 2006) GMM. The approach followed is similar to the approach in EPRI (2004), except for the non-inclusion of parametric uncertainties (which are known to be problematic)
10) Section 8.7 refers to Tables 8.7-1 and 8.7-4 that show examples of cluster weights for each of the 6 data bins used. Add tables for each cluster for all frequencies. Perform sensitivity analysis using only Magnitude greater than 4.75 data.	 Completed sensitivity analysis and the results were presented in the PPRP Closure Briefing on February 13, 2013 (See Slide 130)
11) Plot cluster medians against the ground motion data and the epistemic range of cluster models to determine if the updated models improve the situation as noted with the EPRI 2004 models (see #2).	See response to 2 above.
12) Add a figure which provides an example of the benefit of combining both high and low frequencies avoids the possibility of UHS with unrealistic spectral shape discontinuities between 2.5 and 5 Hz.	We will prepare and examine the figure suggested and consider including it in the final report.

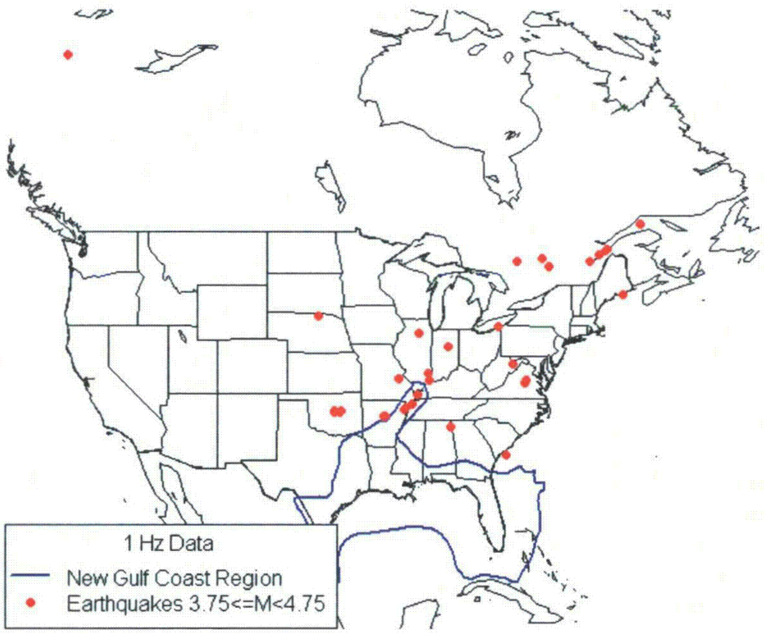
13) Elaborate on how the confidence weights were assigned. Information provided suggests that Clusters 2 and 3 better represent recent ground motion models reflecting the differences in geometric spreading. The question becomes whether this general preference is reflected in the close confidence weights for Clusters 1 and 4 as compared to Clusters 2 and 3. Documentation could be improved by discussing these issues in more detail as supporting final weights for the confidence judgments or the weights between the data driven approach versus the confidence approach. Explain why alternative approaches to developing the confidence weights were not used.	The rationale for confidence weights were provided on Slide 117 in the PPRP Closure Briefing on February 13, 2013: 1) Data are more abundant than in 2004 (thus, data weight was raised from 25% to 50%); 2) Data are still limited, especially in the magnitude – distance range of interest; 3) Clusters 2 and 3 (30% each) include new GMPEs, which have had the benefit of updated CEUS data and advances in GMPE development in CENA and other regions; 4) Clusters 1 and 4 (20% each) approaches still carry weight within the technical community and; 5) **<u>Overall effect:</u>** combined data and confidence weights generate a more robust GMM. An alternative approach was used and the results were presented in the PPRP Closure Briefing on February 13, 2013 (See Slides 173 to 191)
14) Documentation could be improved by including figures within Section 8 comparing cluster median models for several magnitudes and several frequencies or by providing response spectra comparisons for a small set of magnitude and distances.	We will prepare and examine these figures and consider including them in the final report.
15) Documentation could be improved by comparing the cluster medians with WUS ground motion models as a check to ensure that the anticipated CEUS versus WUS ground motion differences are reflected in this update.	A comparison with NGA (2008) for Active Tectonic Regions was presented in the PPRP Closure Briefing on February 13, 2013 (See Slide 215).
13) Three recent opinion papers published in Earthquake Spectra discuss the use of logic trees in PSHAs.	Noted

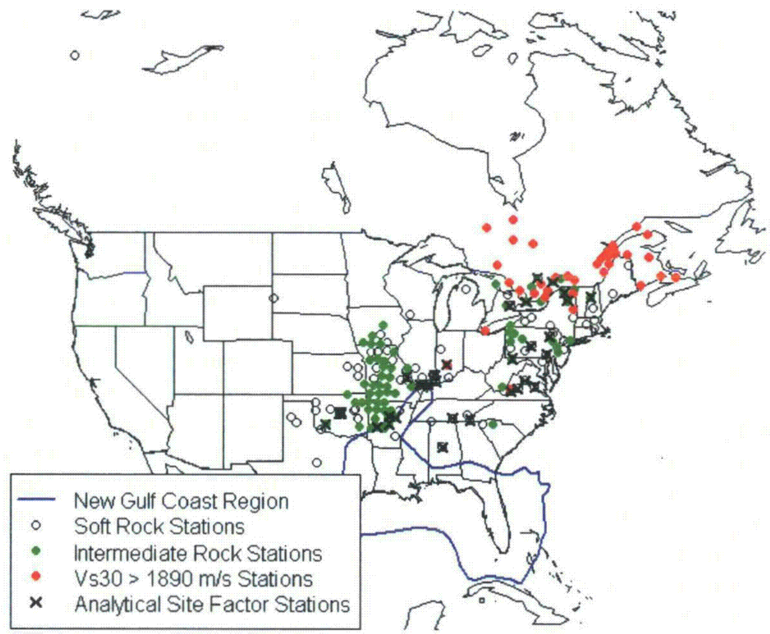
Selected slides from Toro presentation at PPRP closure briefing on February 13, 2013

Summary of Number of Recordings

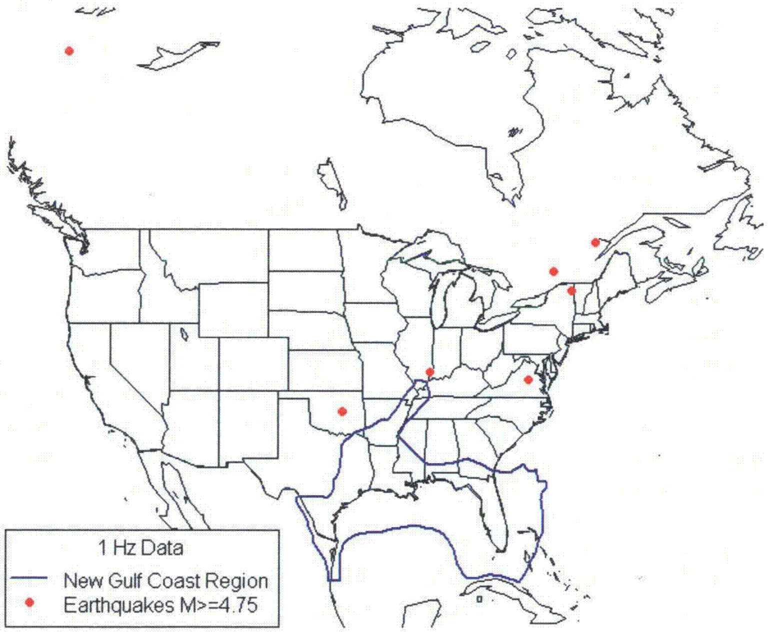
	Empirical Scaling of Ground Motions		Analytical Scaling of Ground Motions	
Magnitude Range	3.75 ≤ **M** <4.75	**M** ≥ 4.75	3.75 ≤ **M** < 4.75	**M** ≥ 4.75
Number of Earthquakes	36	8	34	6
Number of Records R ≤ 70 km	79	21	30	7
Number of Records 70 < R ≤ 150 km	53	17	21	4
Number of Records 150 < R ≤ 500 km	428	141	118	18

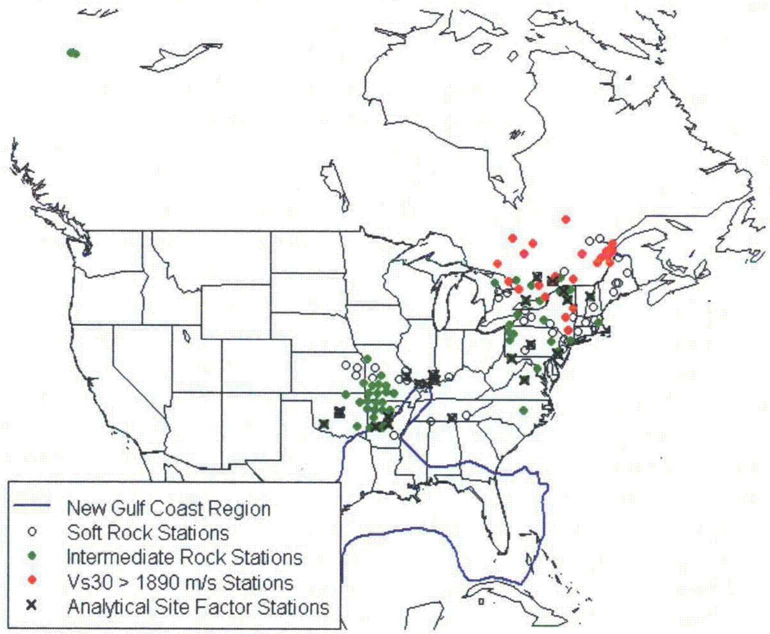
1 Hz Data, 3.75 ≤ **M** < 4.75



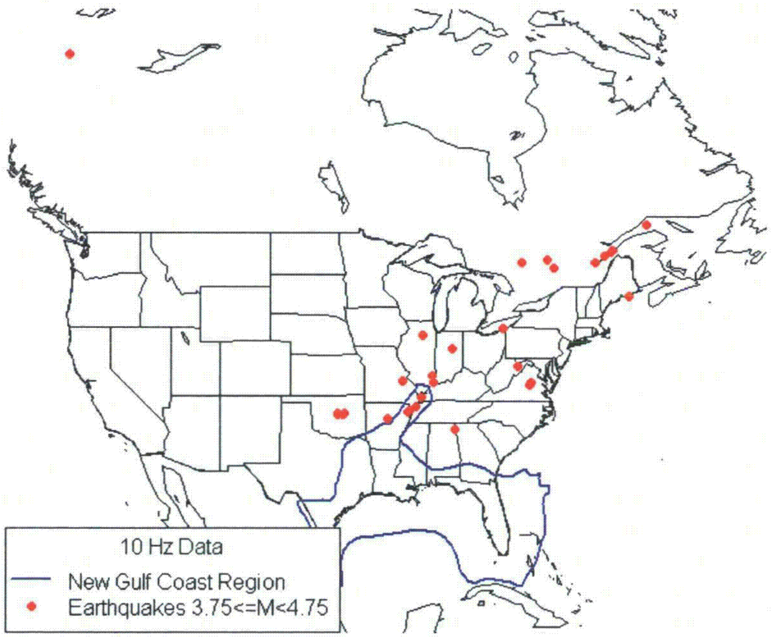


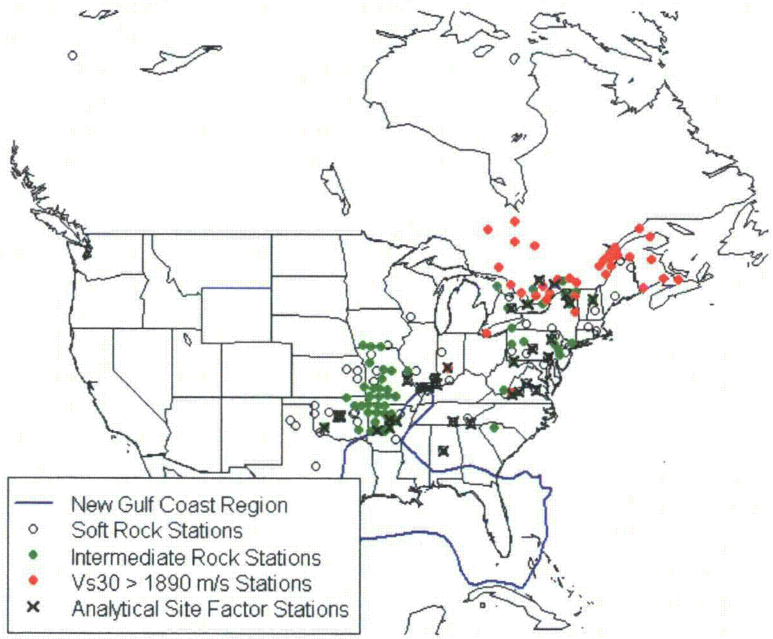
1 Hz Data, **M** ≥ 4.75



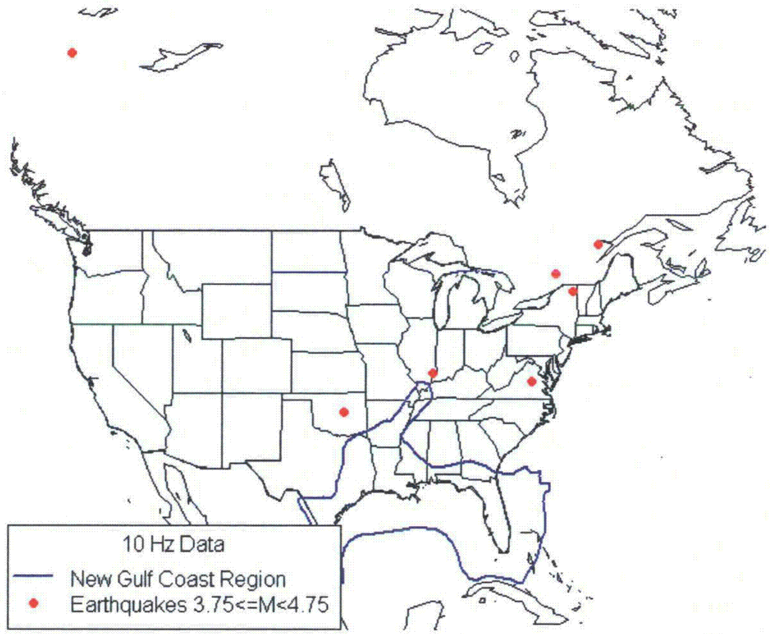


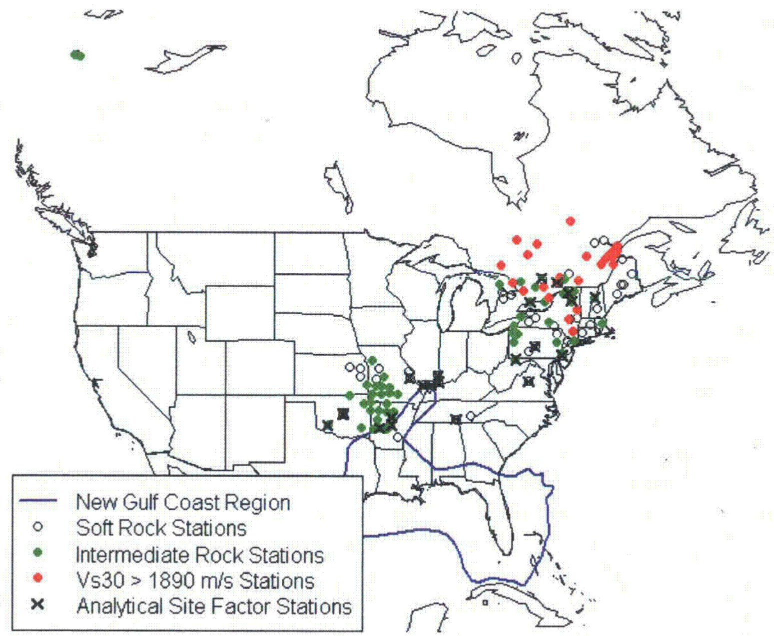
10 Hz Data, 3.75 ≤ **M** < 4.75



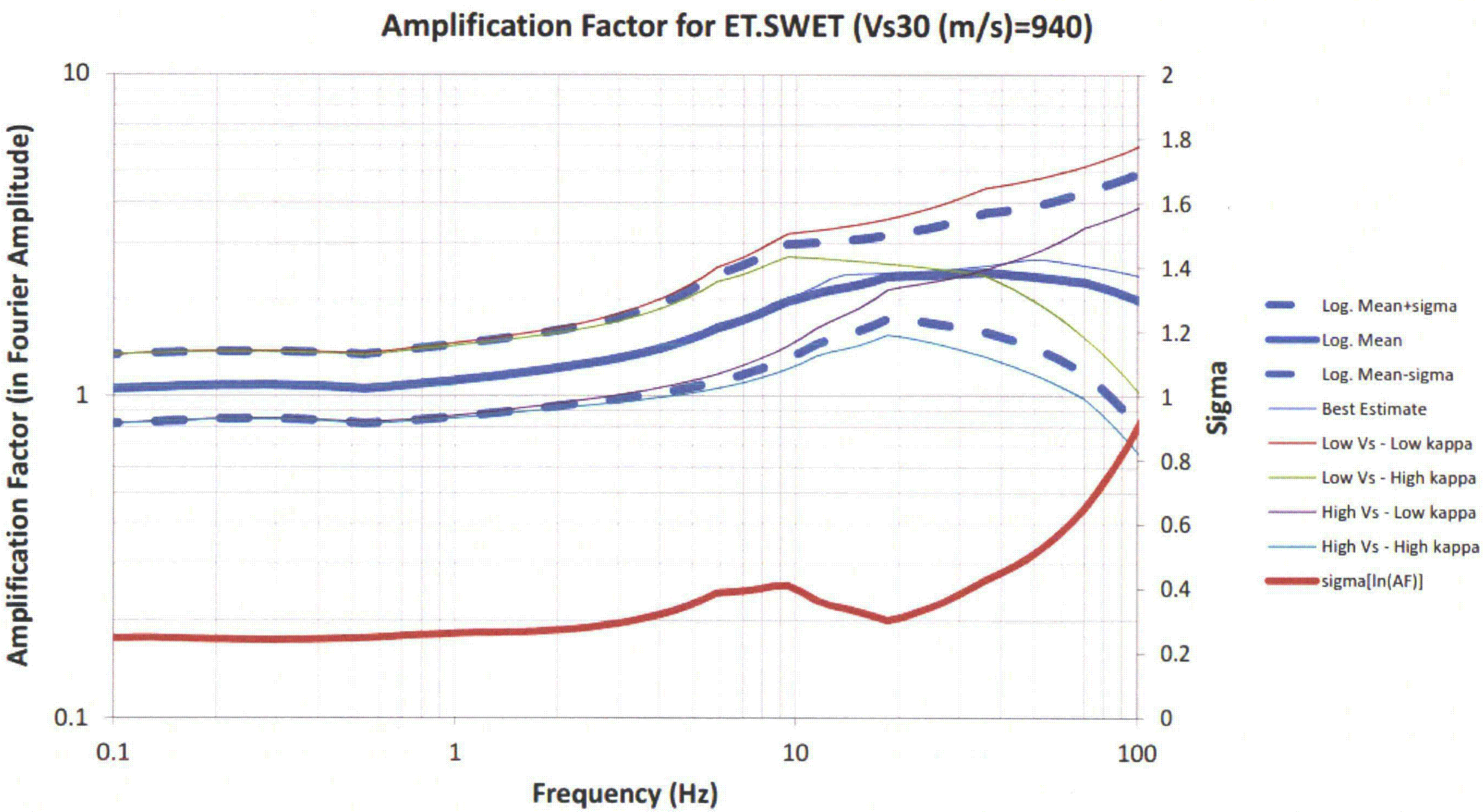


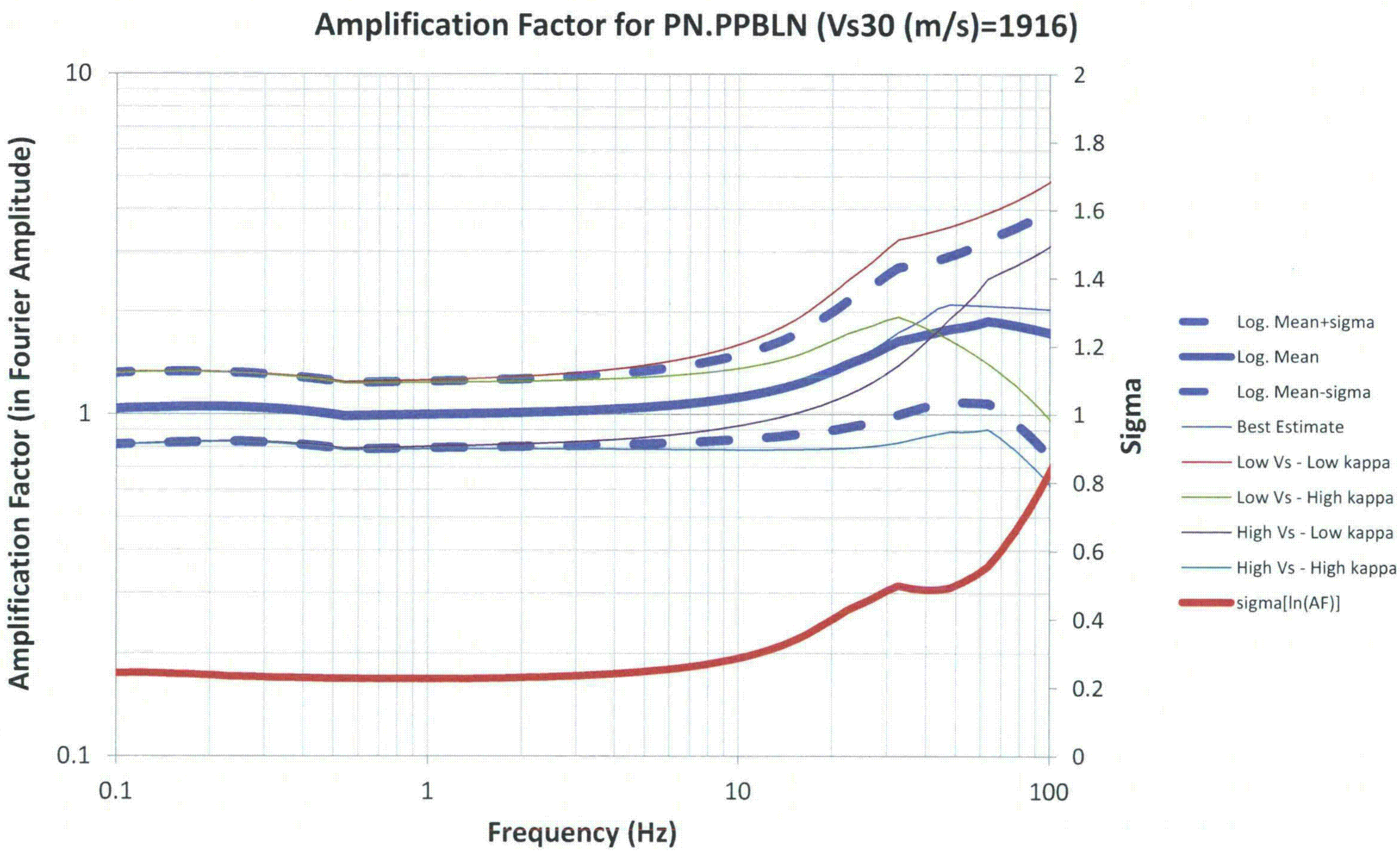
10 Hz Data, **M** ≥ 4.75

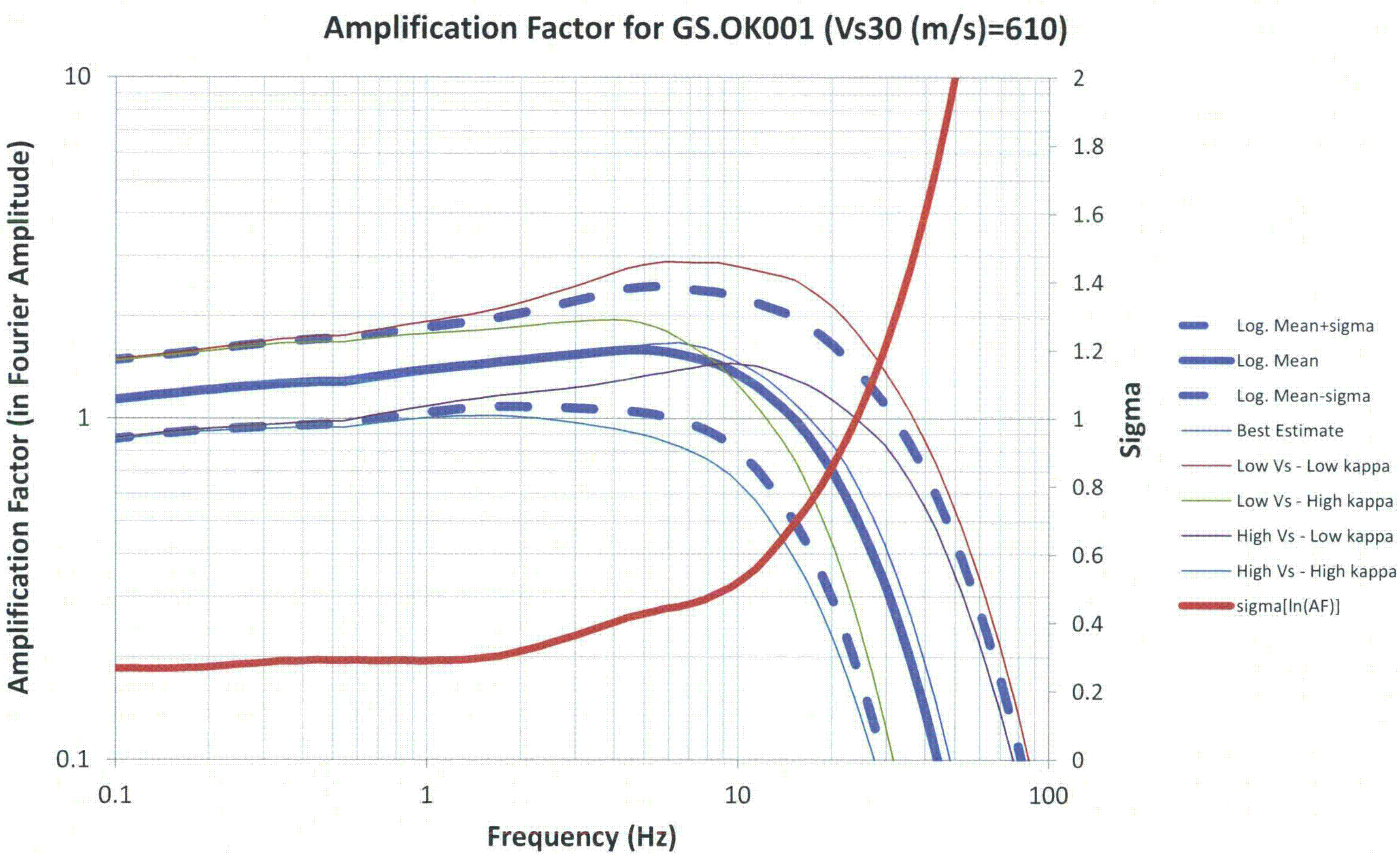




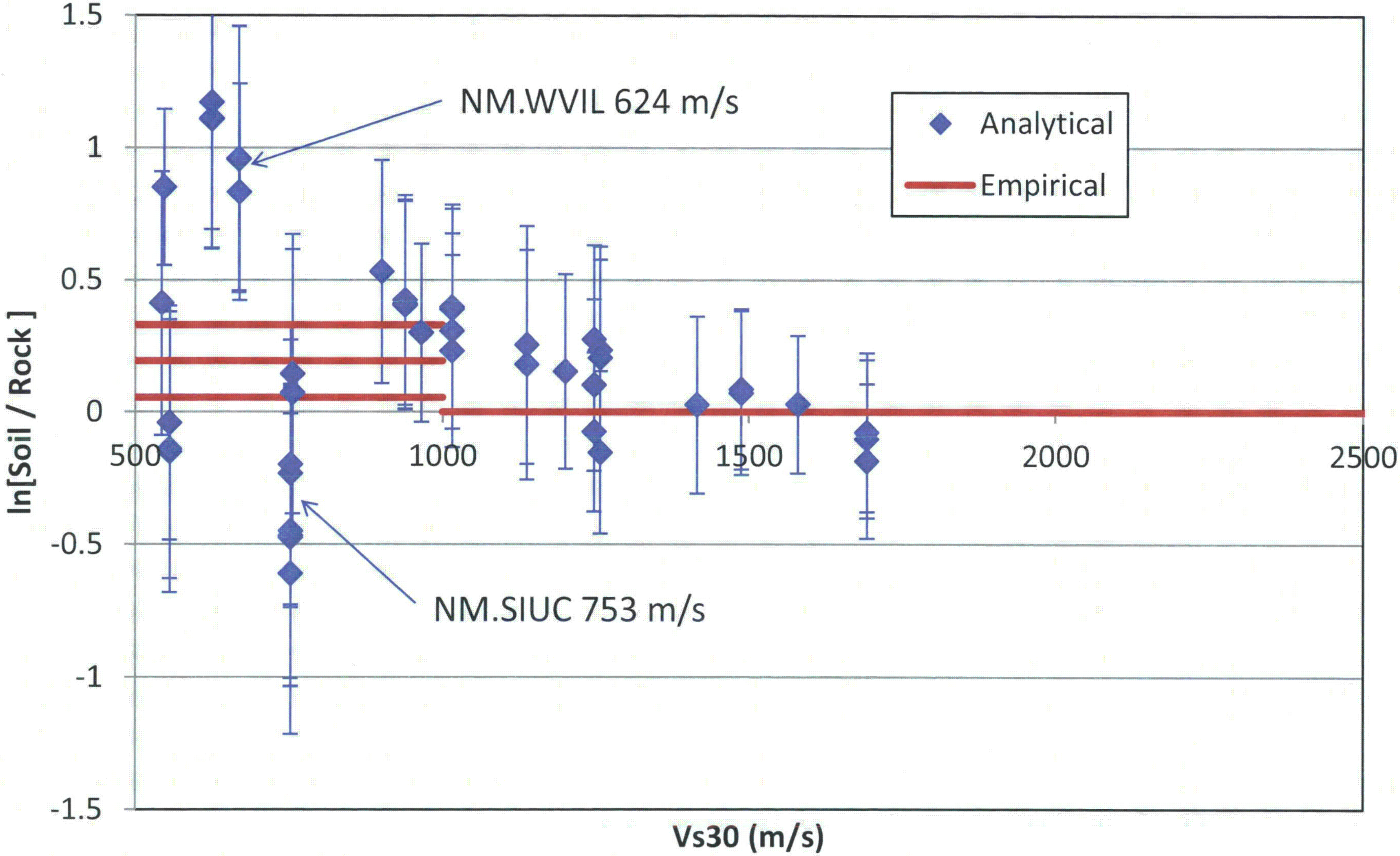
Typical Result




Amplification Factor for PN.PPBLN (Vs30 (m/s)=1916)
Amplification Factor (in Fourier Amplitude)
10
1
0.1
0.1
1
10
100
Frequency (Hz)
Sigma
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Log. Mean+sigma
Log. Mean
Log. Mean-sigma
Best Estimate
Low Vs - Low kappa
Low Vs - High kappa
High Vs - Low kappa
High Vs - High kappa
sigma[ln(AF)]

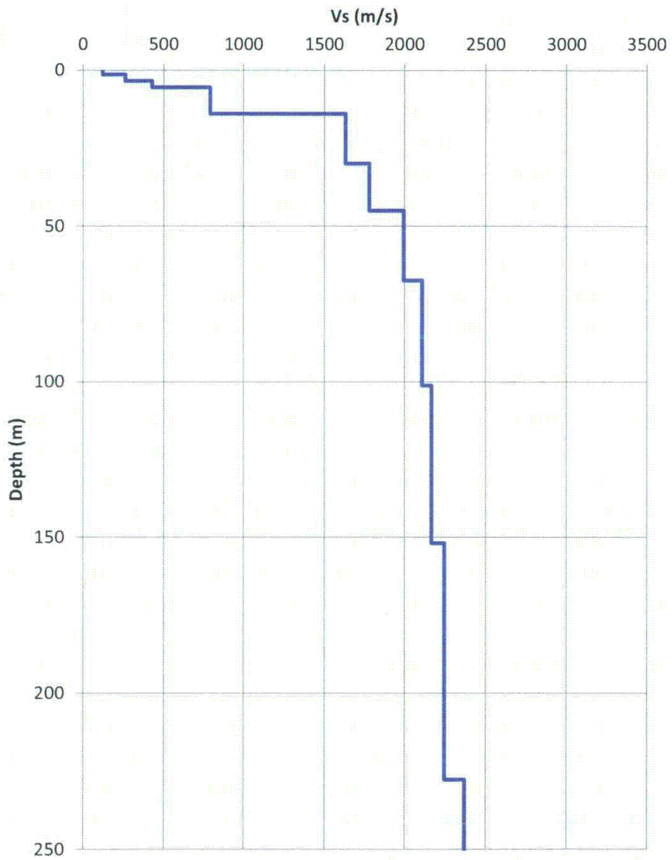

Amplification Factor for GS.OK001 (Vs30 (m/s)=610)
Amplification Factor (in Fourier Amplitude)
Sigma
Frequency (Hz)
10
1
0.1
0.1
1
10
100
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Log. Mean+sigma
Log. Mean
Log. Mean-sigma
Best Estimate
Low Vs - Low kappa
Low Vs - High kappa
High Vs - Low kappa
High Vs - High kappa
sigma[ln(AF)]

Analytical vs. Empirical Amplification Factors (10 Hz)

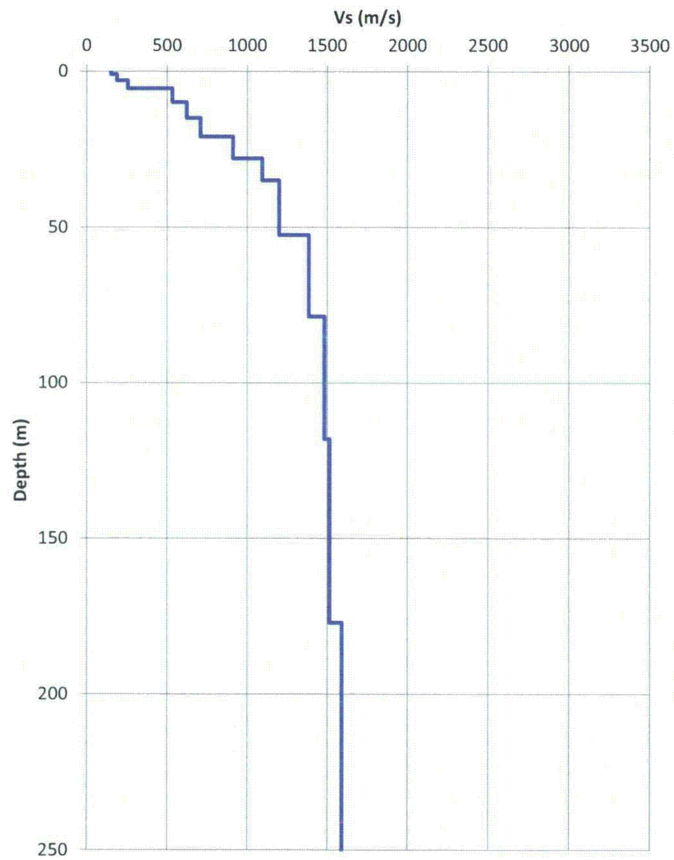


Compare Profiles

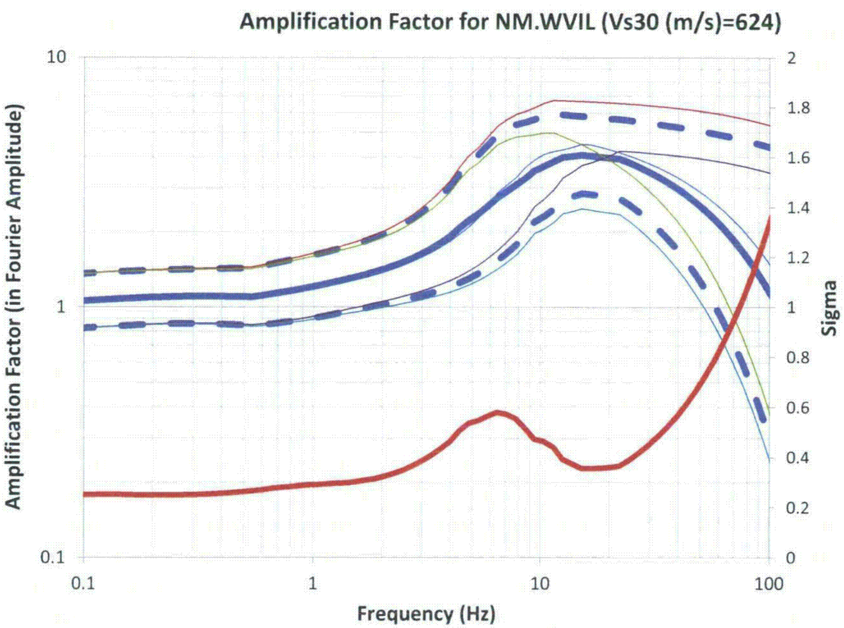
NM.WVIL

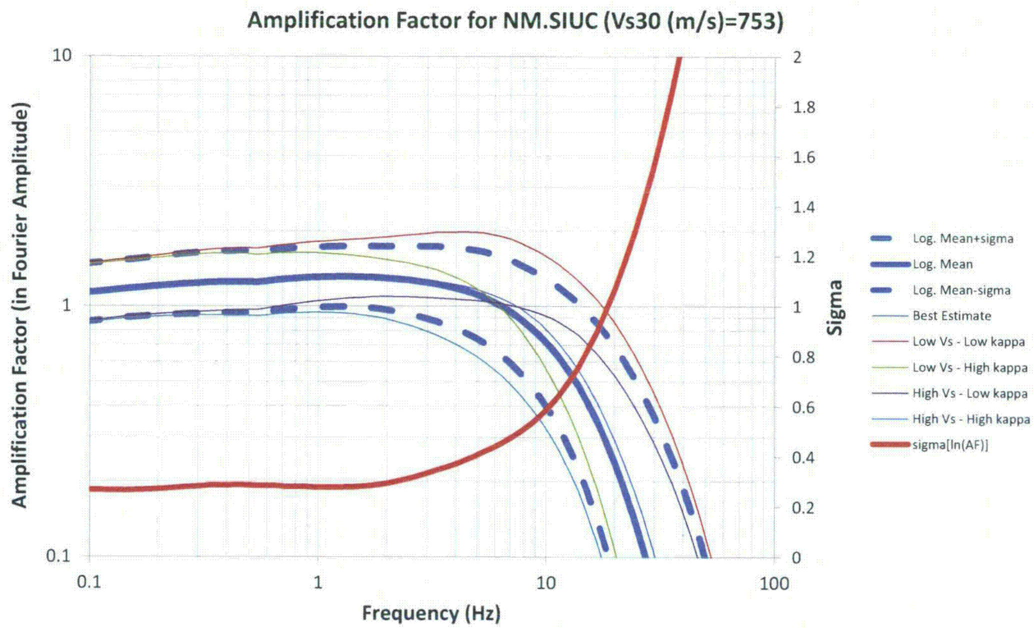


NM.SIUC

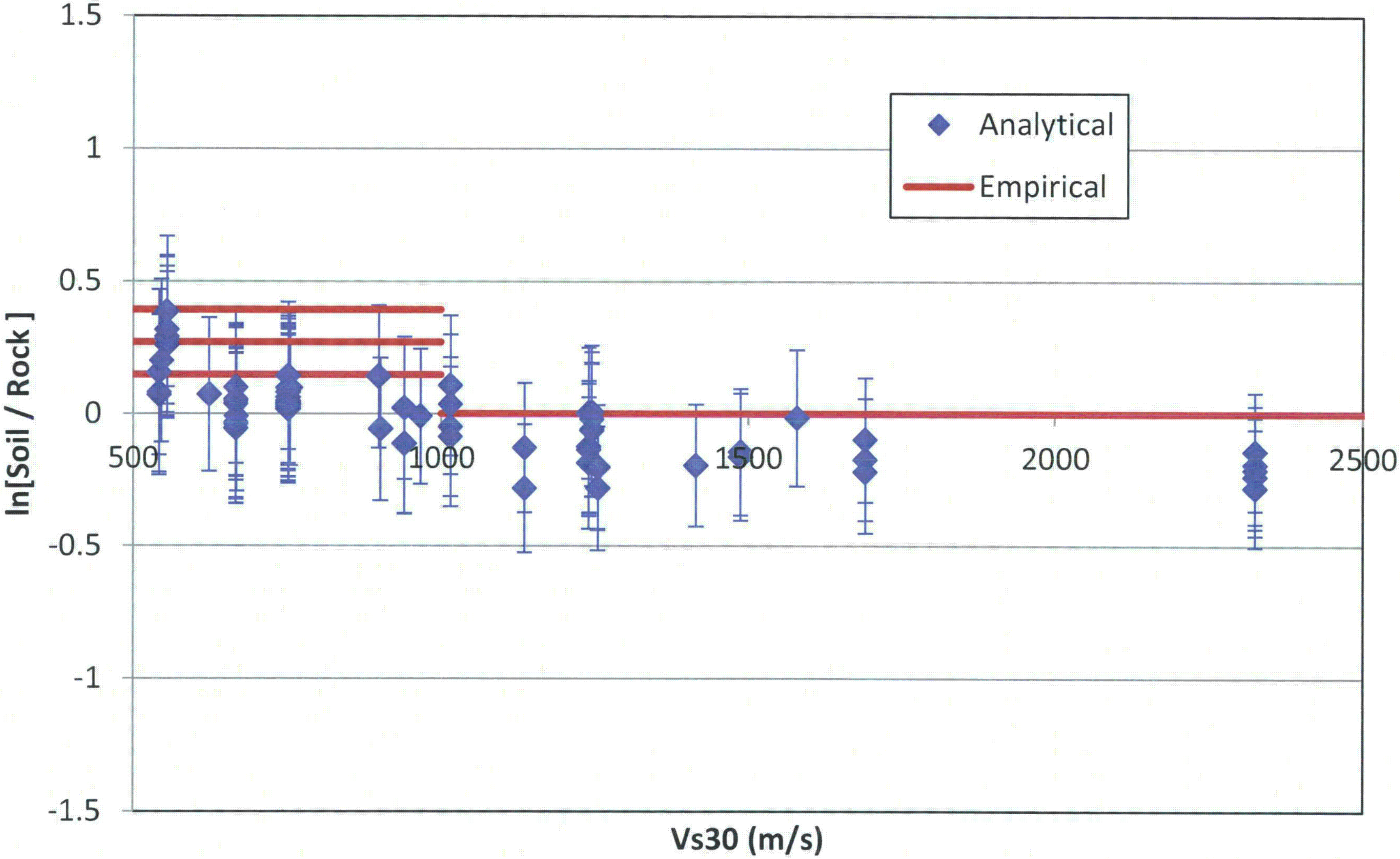


Compare FA Amplification Factors





Analytical vs. Empirical Amplification Factors (1 Hz)

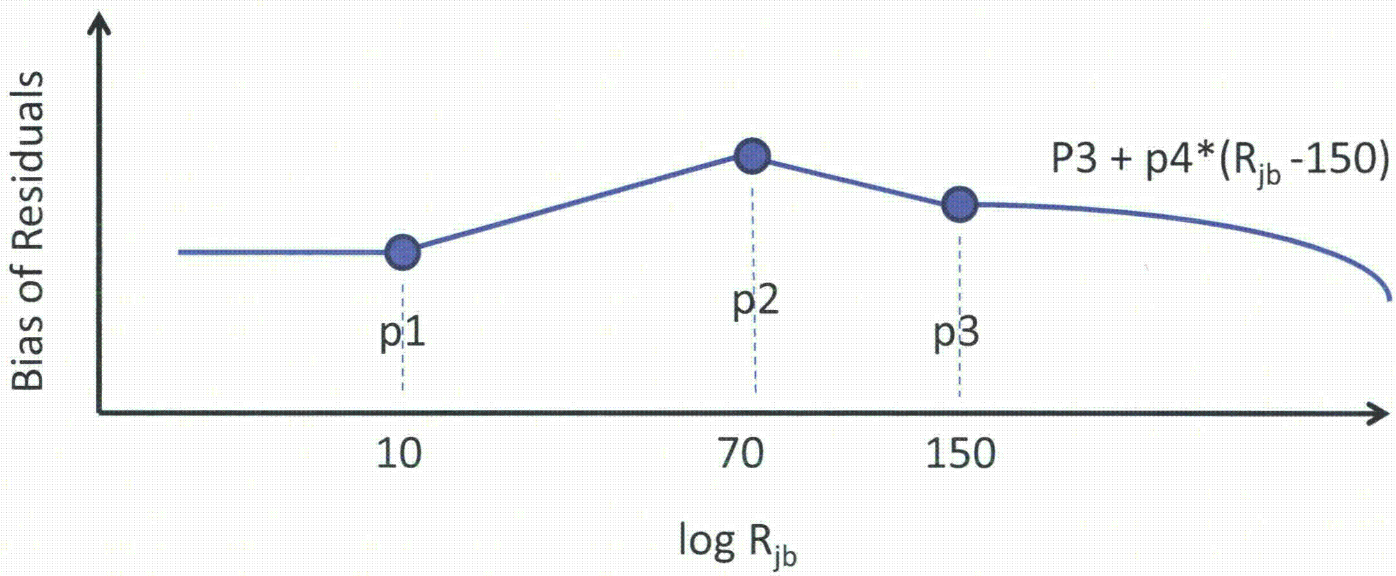


Updated Model (3 of 4)

$\sigma(m,r,f)_{\text{dataconstrain}}$

- Greatly expanded database provides for use of data-constrained estimate of median uncertainty
  - Standard error of mean of analytical adjusted residuals accounting for correlation matrix
  - Represent by piece-wise linear function of $\ln(R_{JB})$

Model for Mean Residual



- Model is fit to residuals from analytical approach, considering correlations
- Standard errors of estimation of p1...p4 → data-constrained estimates of statistical uncertainty

Rationale for Confidence Weights

- Data are more abundant than in 2004 (thus, data weight was raised from 25% to 50%)
- Data are still limited, especially in the magnitude-distance range of interest
- Clusters 2 and 3 (30% each) include recent GMPEs, which have had the benefit of more CEUS data and more technical insights from work on GMs in CENA and other regions
- Clusters 1 and 4 (20% each) approaches still carry weight within the technical community
- Overall effect: combined data & confidence weights generate a more robust GMM

Effect of Excluding M<4.75 Data - Cluster Weights

- Base-Case Cluster Weights (includes M3.75-4.75 with ¼ weight)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.02	0.24	0.68	0.07
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.11	0.27	0.49	0.13

- Weights after removing M3.75-4.75 data

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.04	0.47	0.38	0.11
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.12	0.39	0.34	0.16

Effect of Always Using OK-AR Data – Cluster Weights

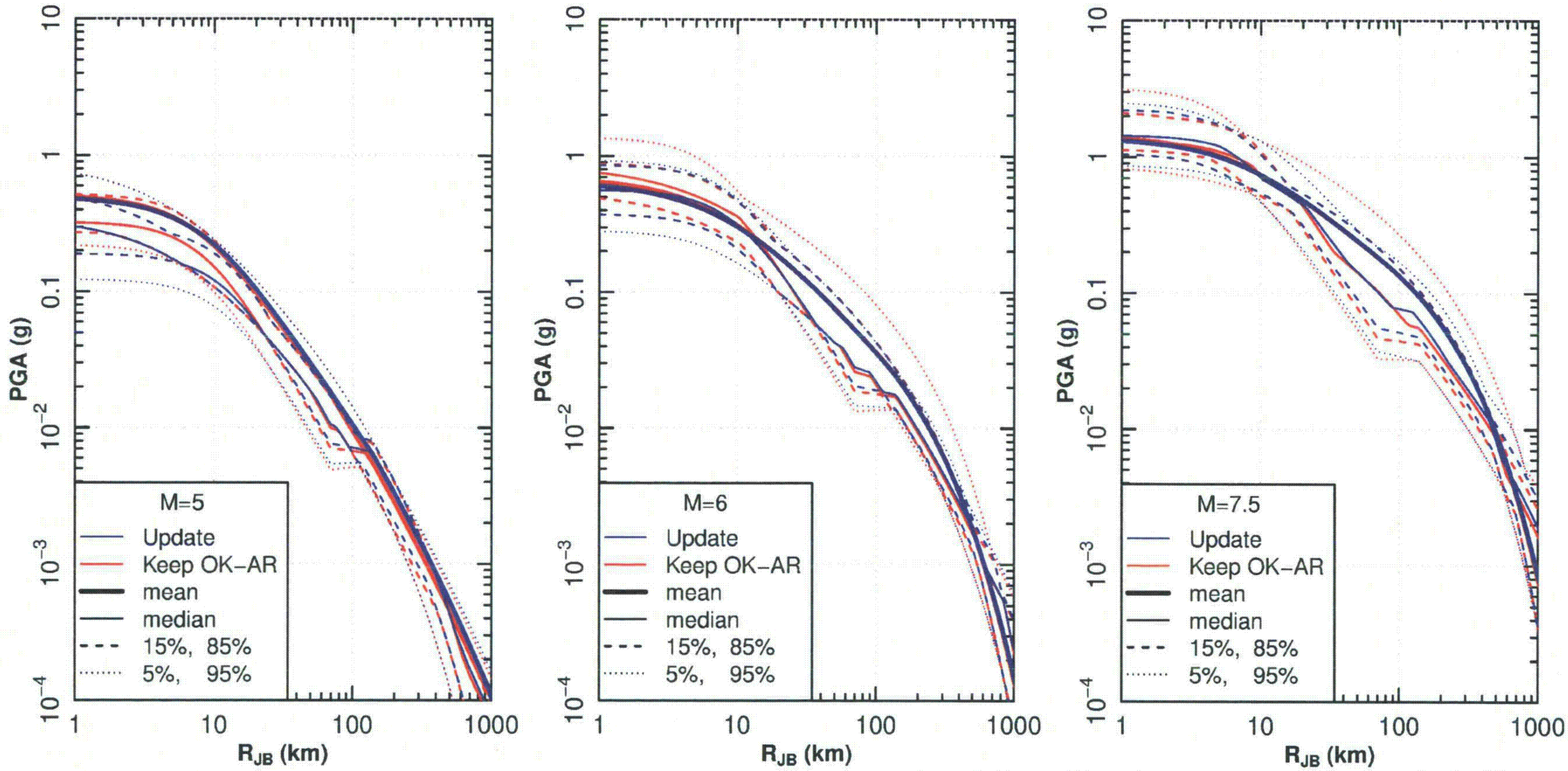
- Base-Case Cluster Weights

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.02	0.24	0.68	0.07
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.11	0.27	0.49	0.13

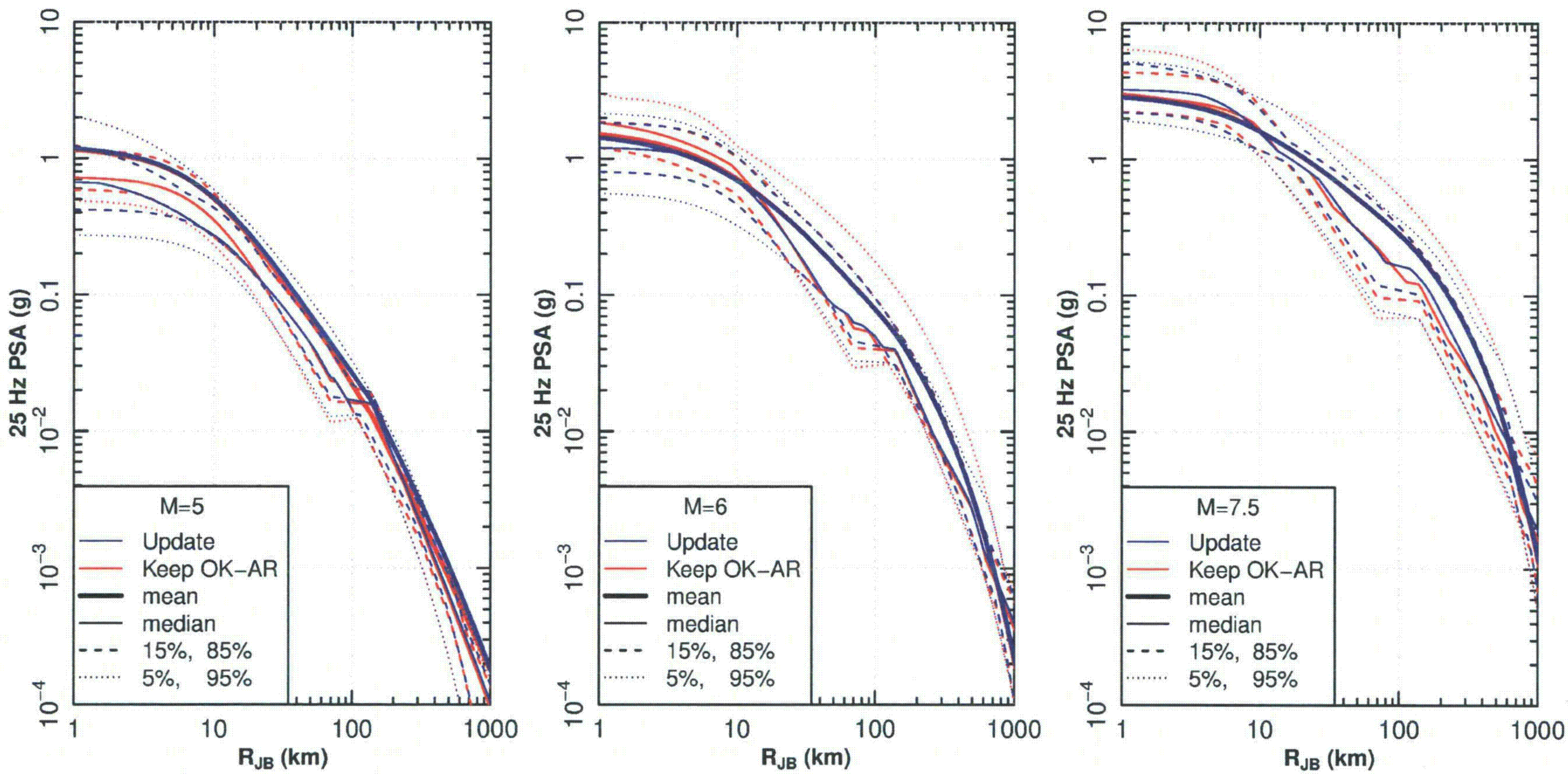
- Weights if Always Using OK-AR Data

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.01	0.26	0.69	0.05
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.10	0.28	0.49	0.13

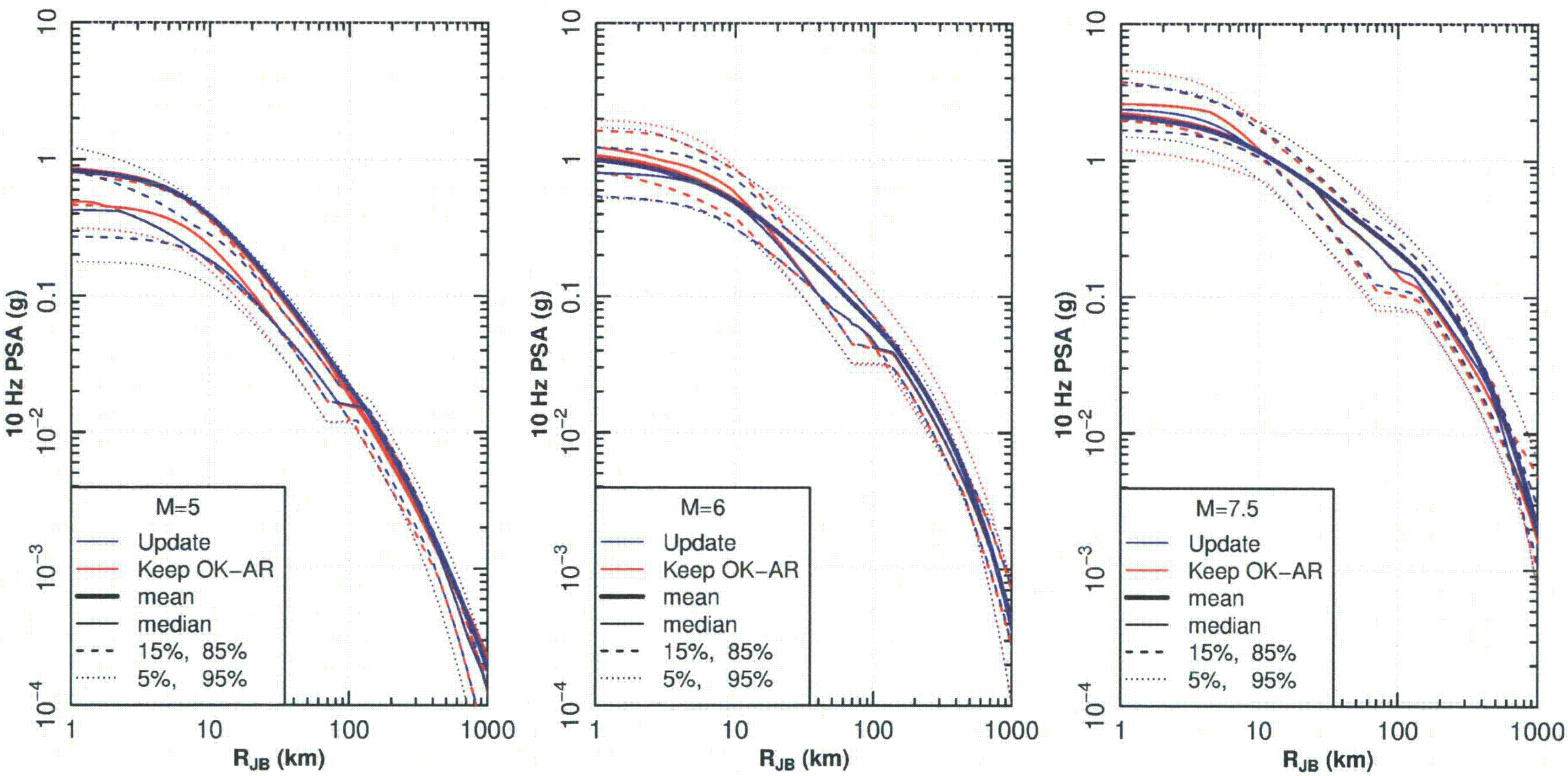
Effect of Always Using OK-AR Data – PGA



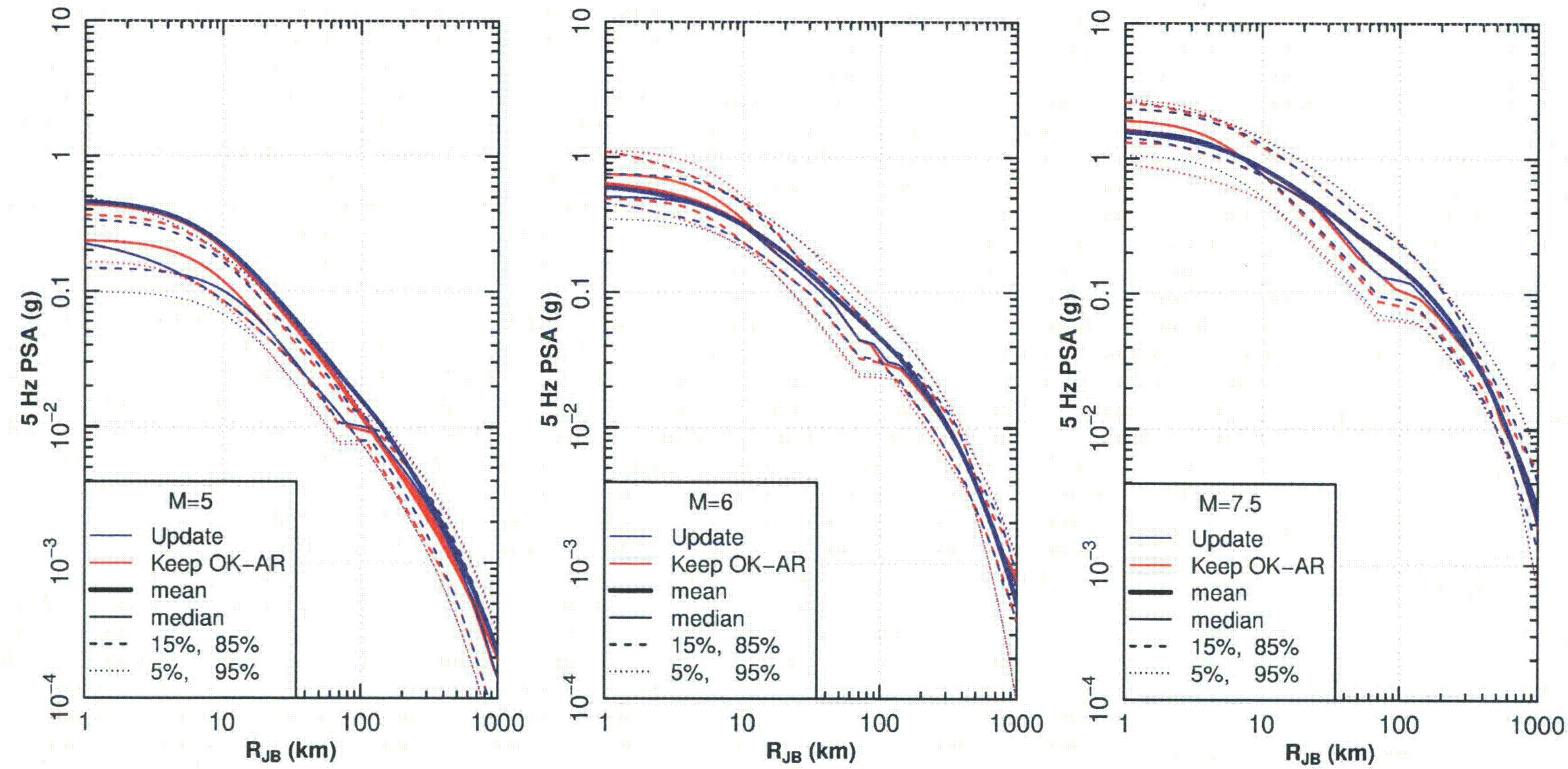
Effect of Always Using OK-AR Data – 25 Hz



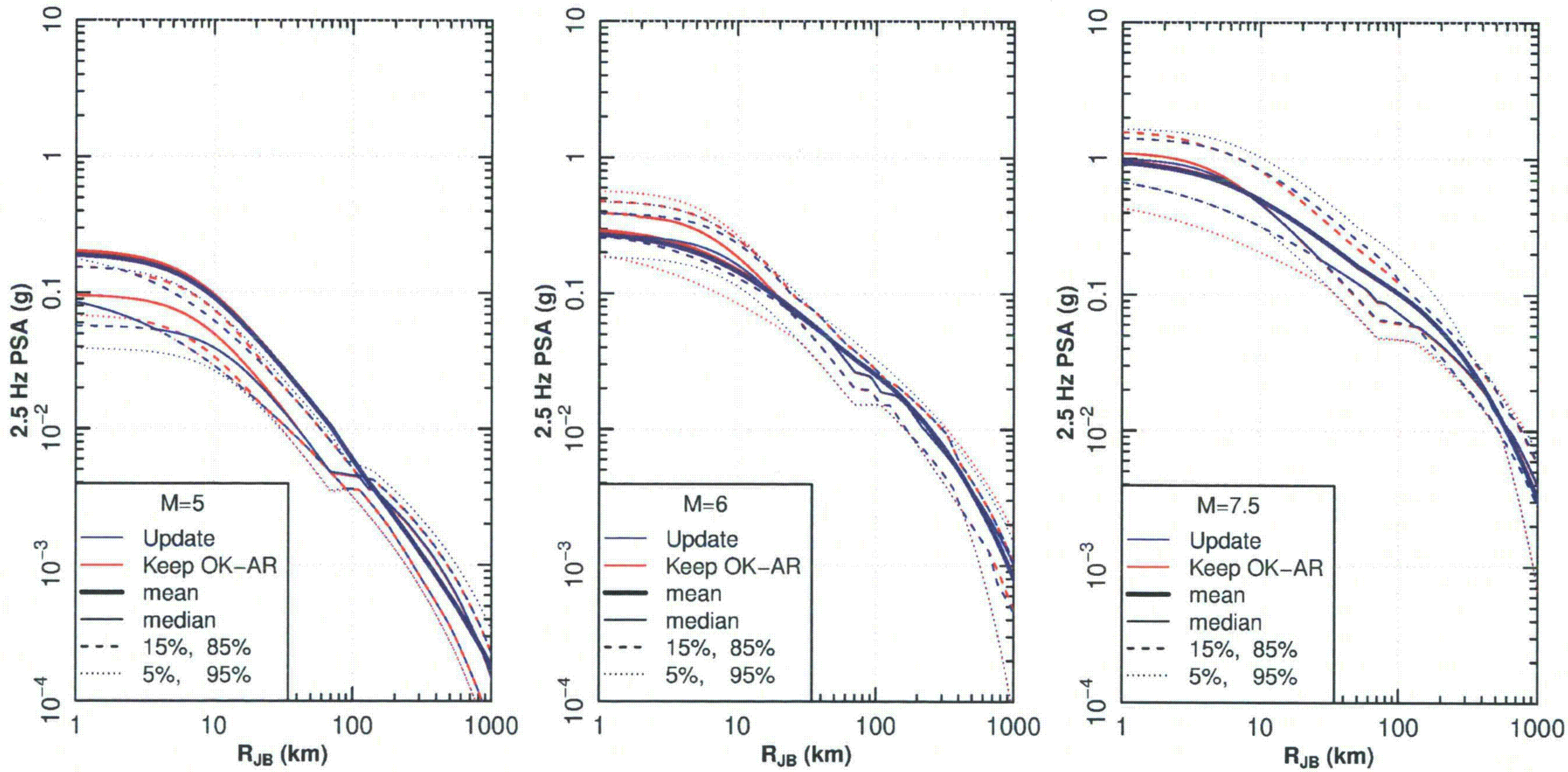
Effect of Always Using OK-AR Data – 10 Hz



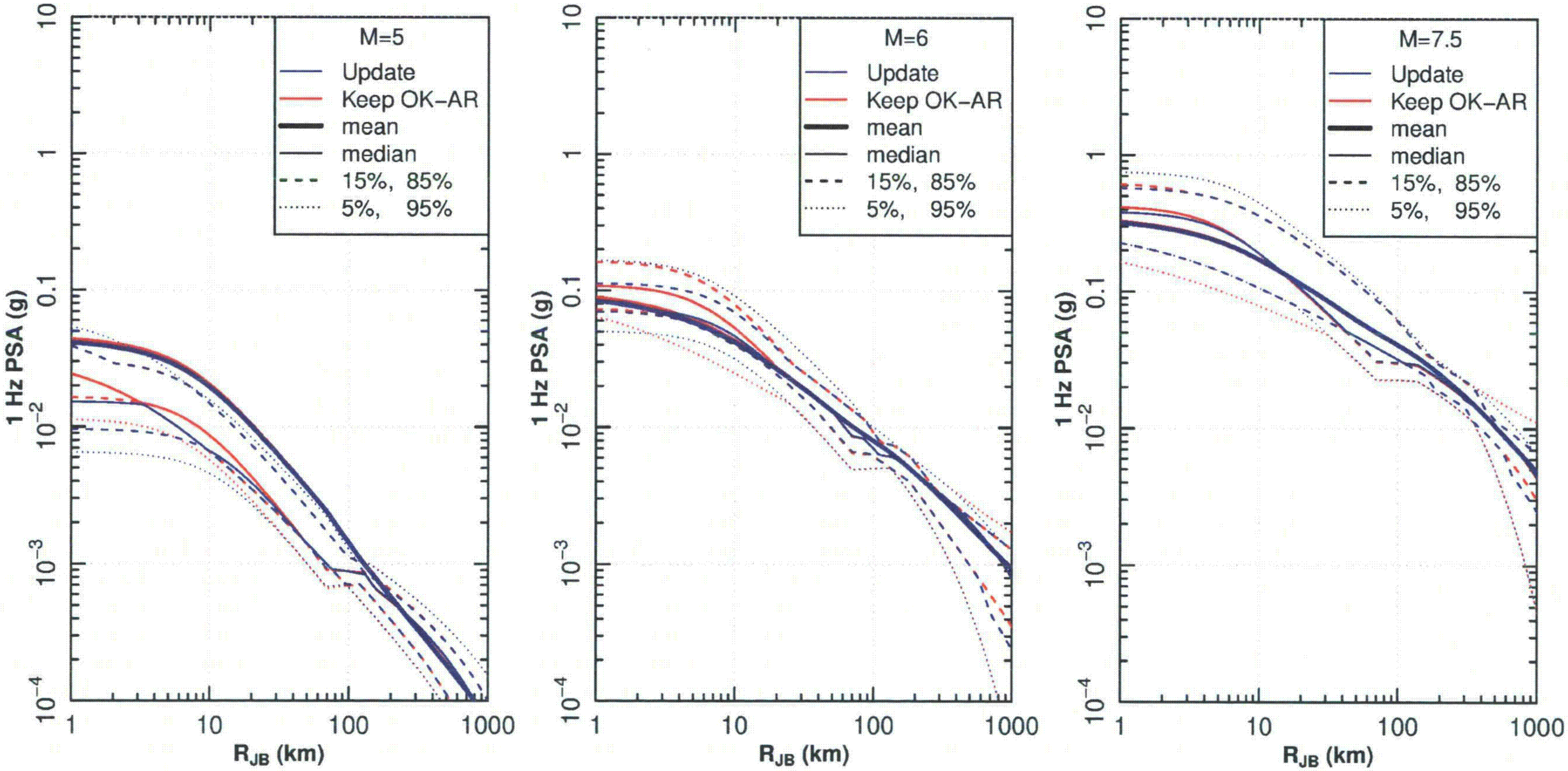
Effect of Always Using OK-AR Data – 5 Hz



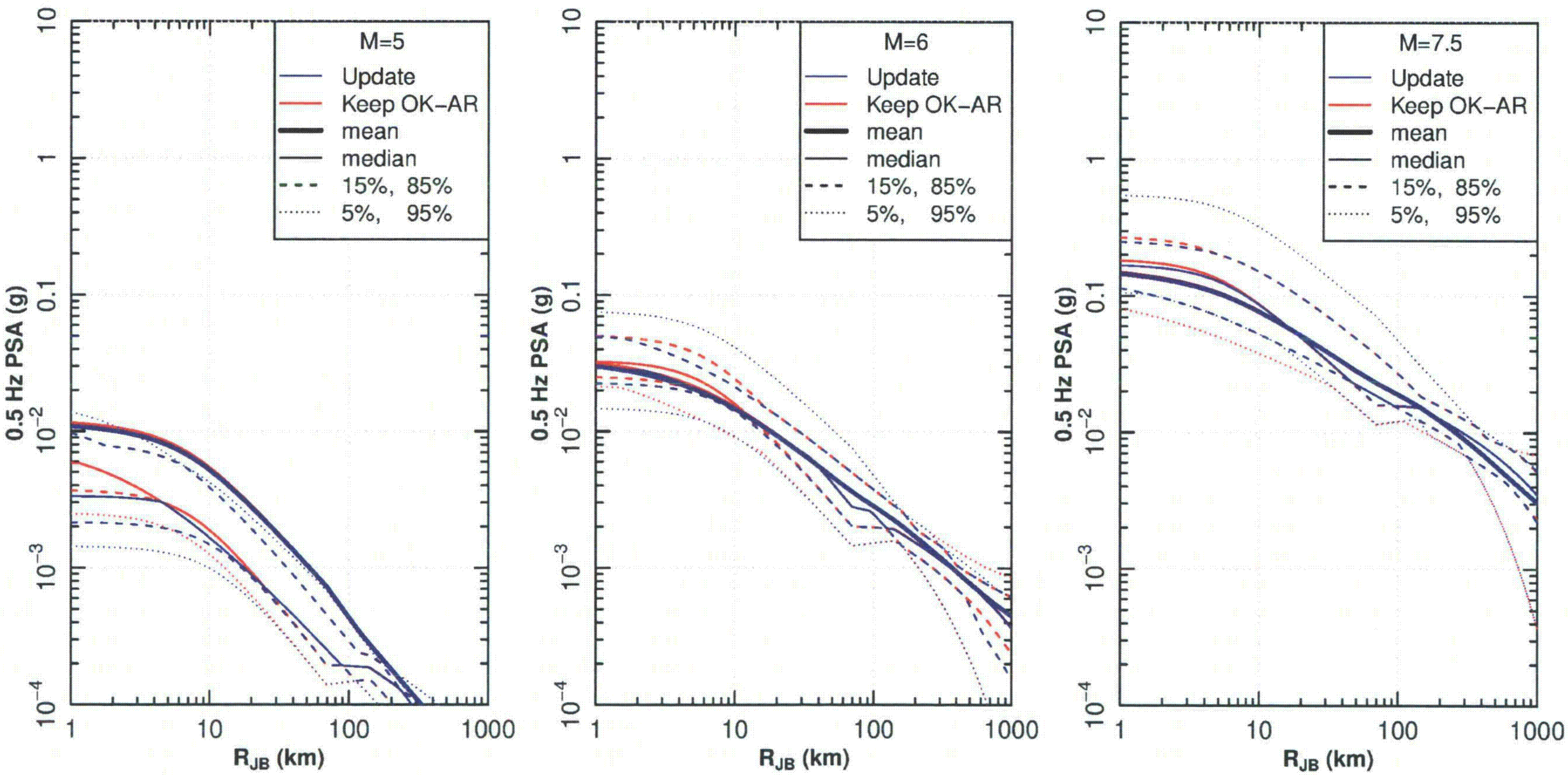
Effect of Always Using OK-AR Data – 2.5 Hz



Effect of Always Using OK-AR Data – 1 Hz



Effect of Always Using OK-AR Data – 0.5 Hz



Effect of Considering 1 and 10 Hz only for Within-Cluster Weights - Cluster Weights

- Base-Case Cluster Weights

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.02	0.24	0.68	0.07
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.11	0.27	0.49	0.13

- Weights with 1 and 10-Hz-based medians

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.06	0.29	0.59	0.06
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.13	0.29	0.45	0.13

Alternative Approach for Calculation of Within-Cluster Weights (SWW)

- Approach: put a 2/3 cap on the highest within-cluster weight and re-distribute remaining weights
- Rationale:
  - Data are more abundant than before, but still limited (same arguments used for confidence weights)
  - May increase epistemic uncertainty by giving more weight to alternative M-scaling assumptions

Effect on Within-Cluster Weights

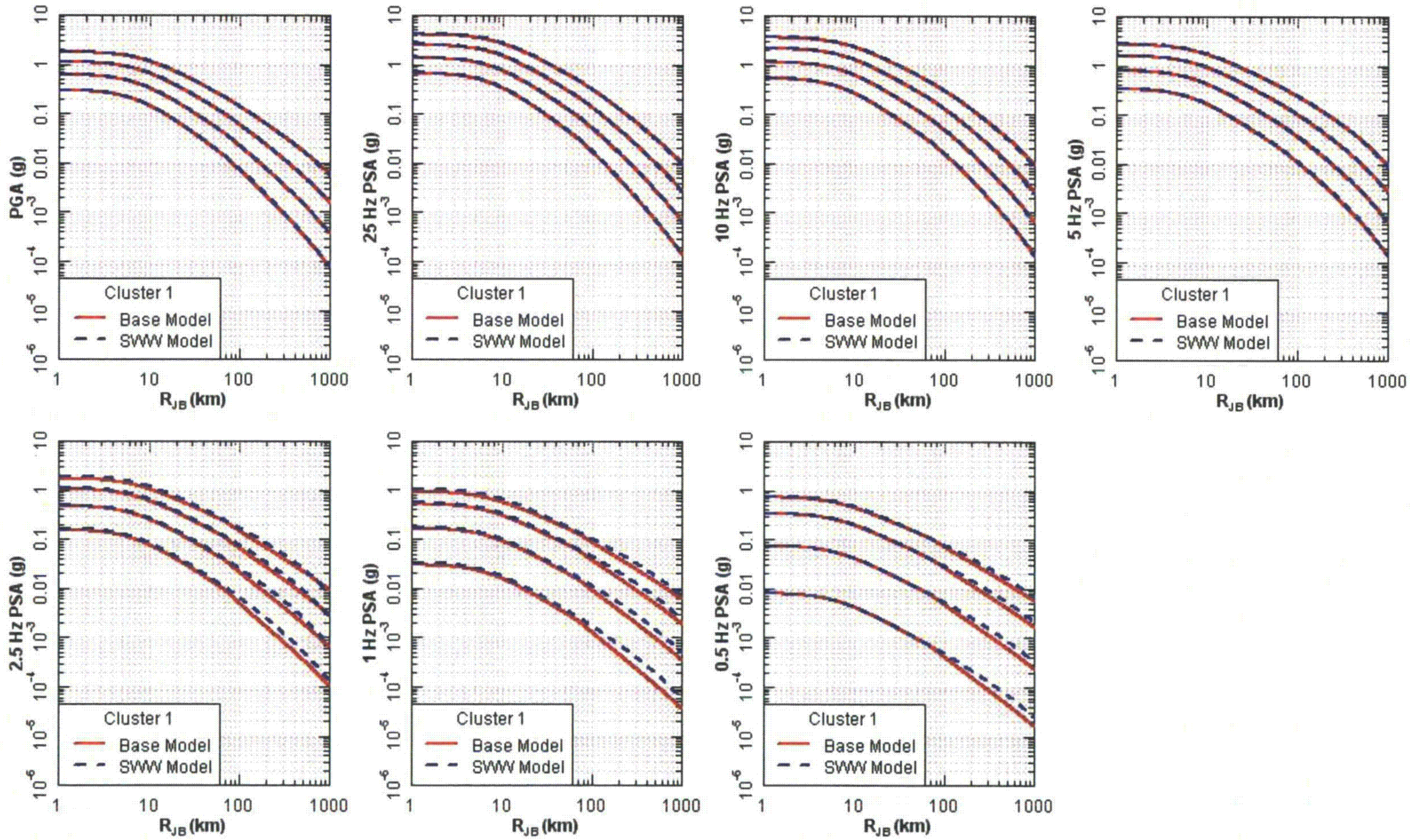
- Base Case

Cluster	1				2		3	
GMPE	**SSCCSS**	**SSCVS**	**TEL**	**FEL**	**A08'**	**SDCS**	**AB06p**	**PZT**
HF Weight	0.45	0.28	0.11	0.17	0.59	0.41	0.63	0.37
LF Weight	0.24	0.76	0.00	0.00	0.99	0.01	0.75	0.25

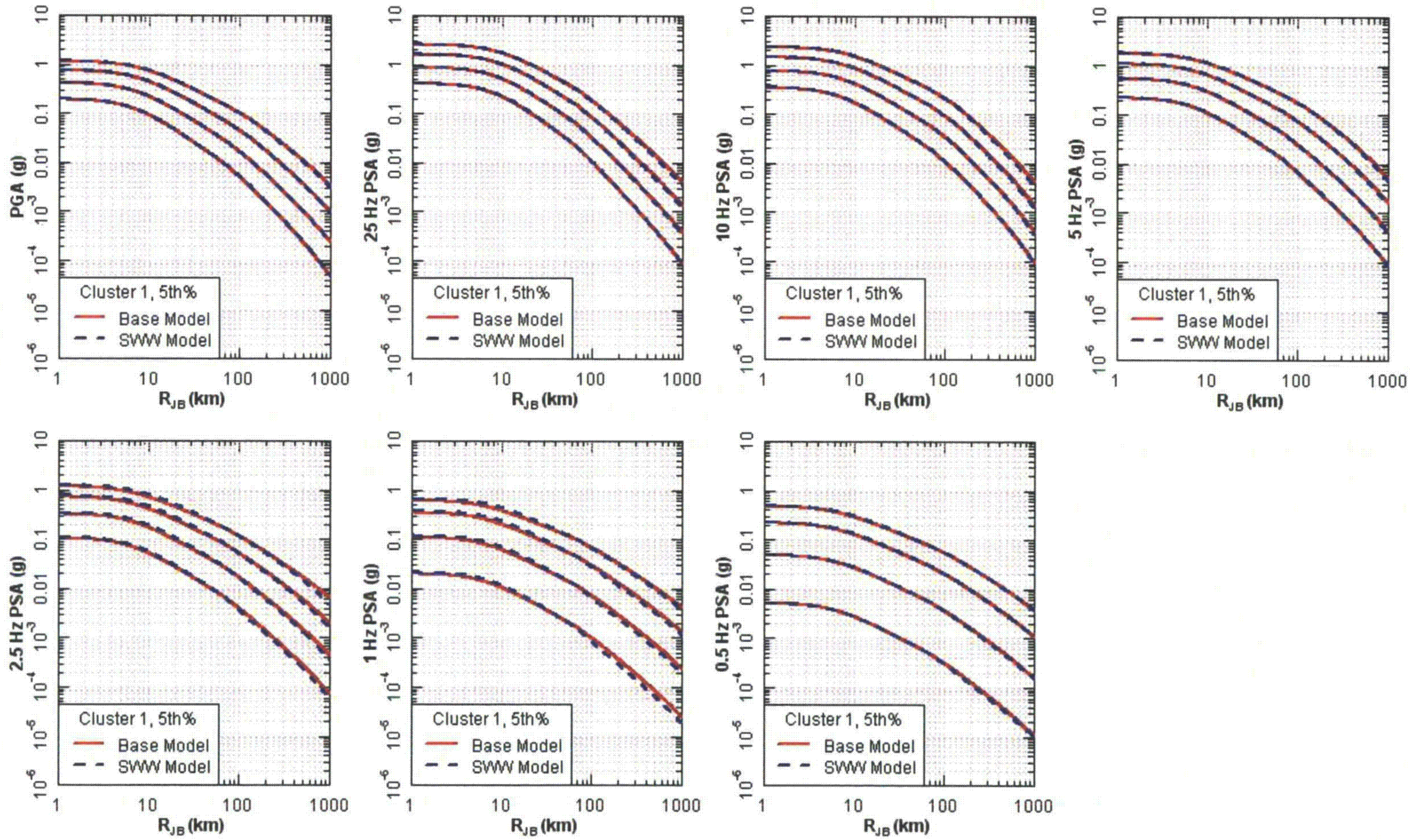
- Weights based on capping weights at 2/3

Cluster	1				2		3	
GMPE	**SSCCSS**	**SSCVS**	**TEL**	**FEL**	**A08'**	**SDCS**	**AB06p**	**PZT**
HF Weight	0.410	0.257	0.129	0.205	0.593	0.407	0.634	0.366
LF Weight	0.161	0.506	0.102	0.231	0.667	0.333	0.667	0.333

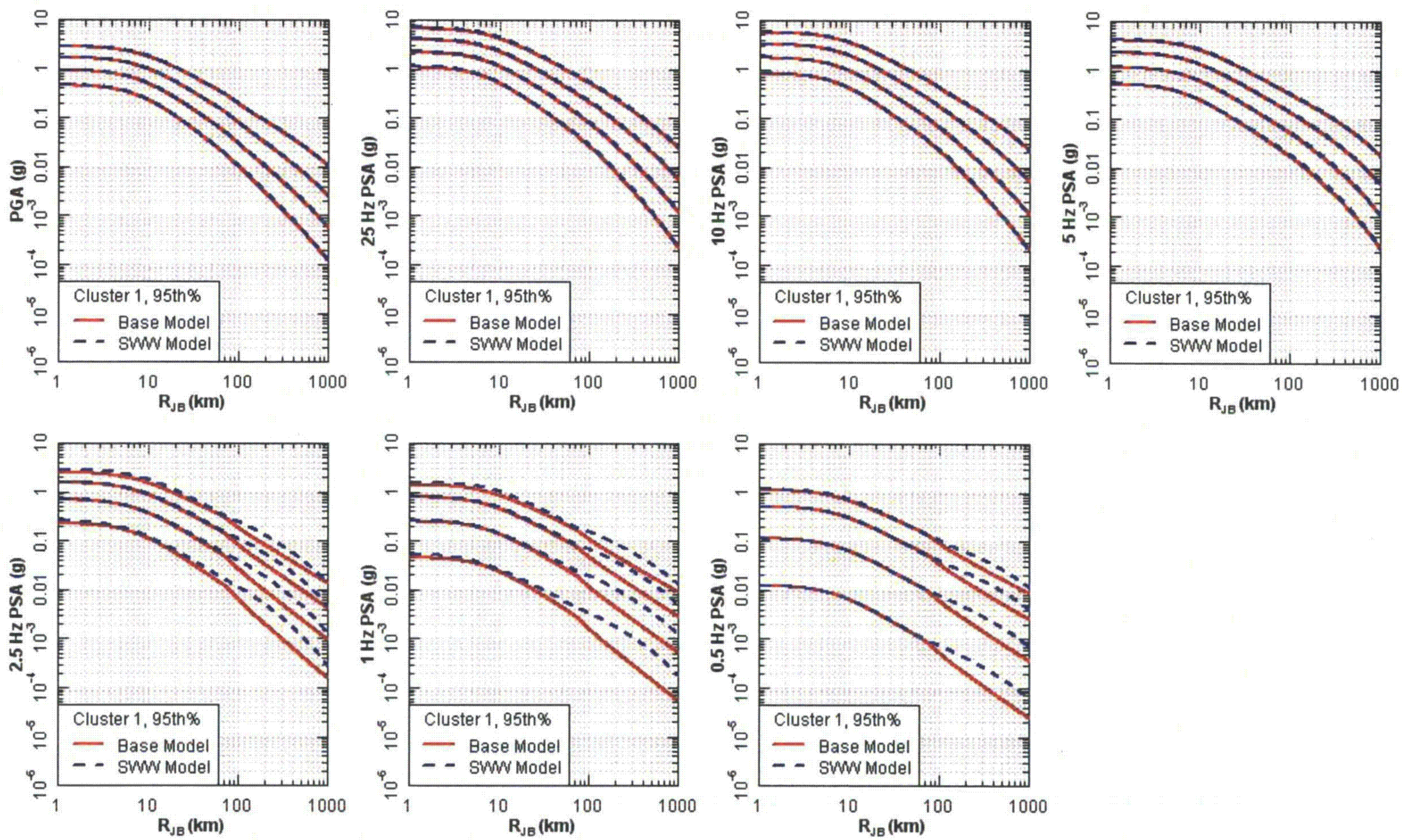
Cluster 1 Median



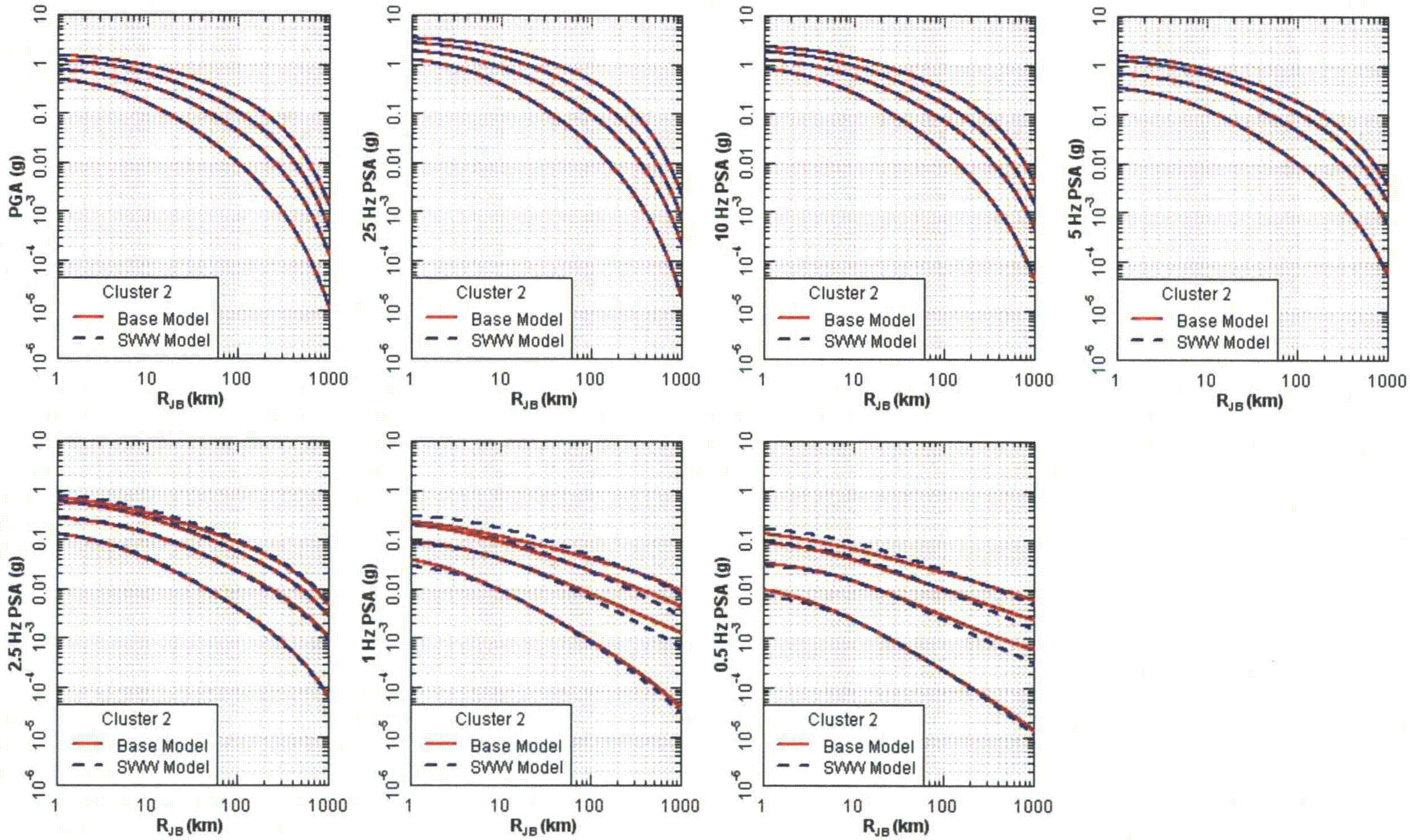
Cluster 1 5th%



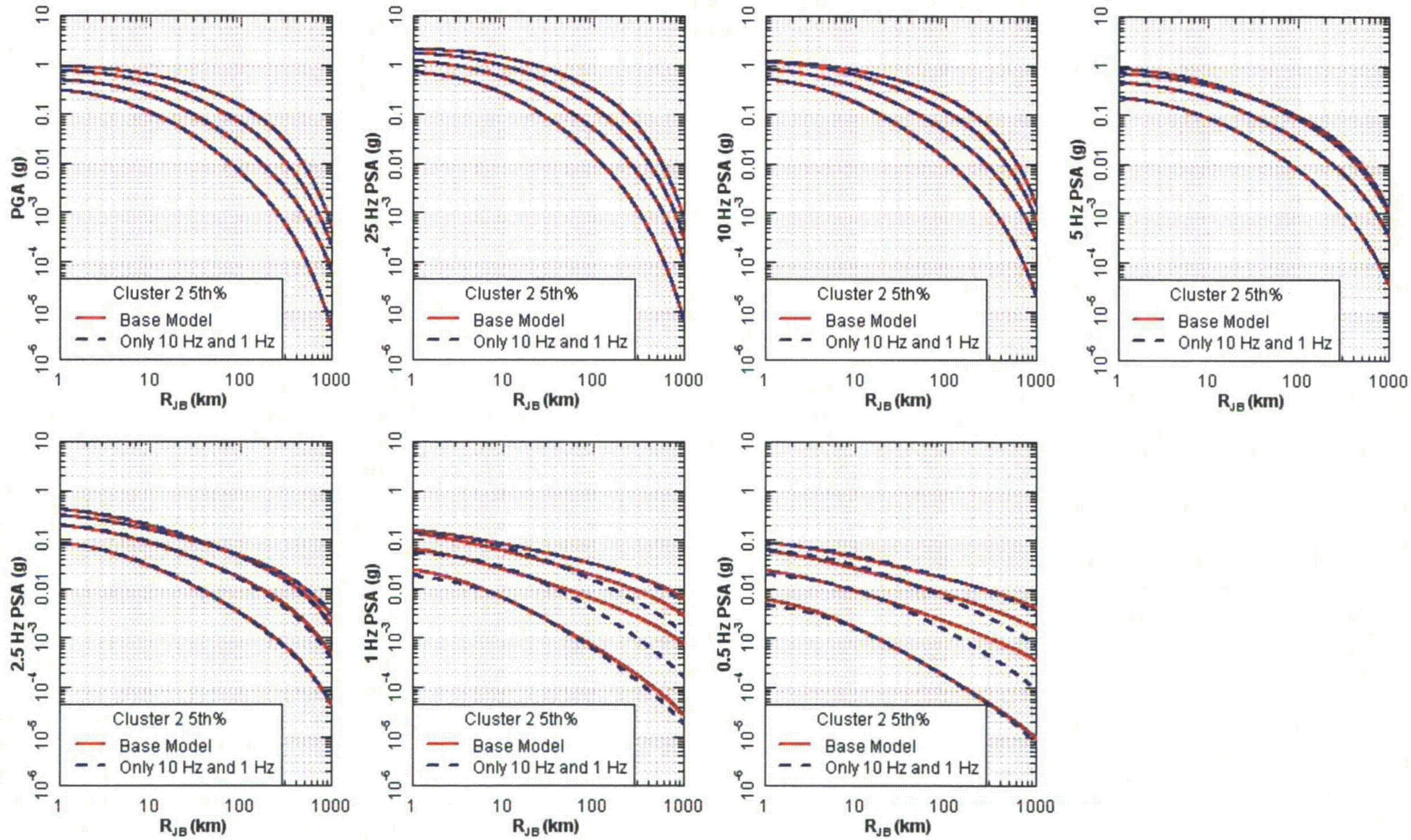
Cluster 1 95th%



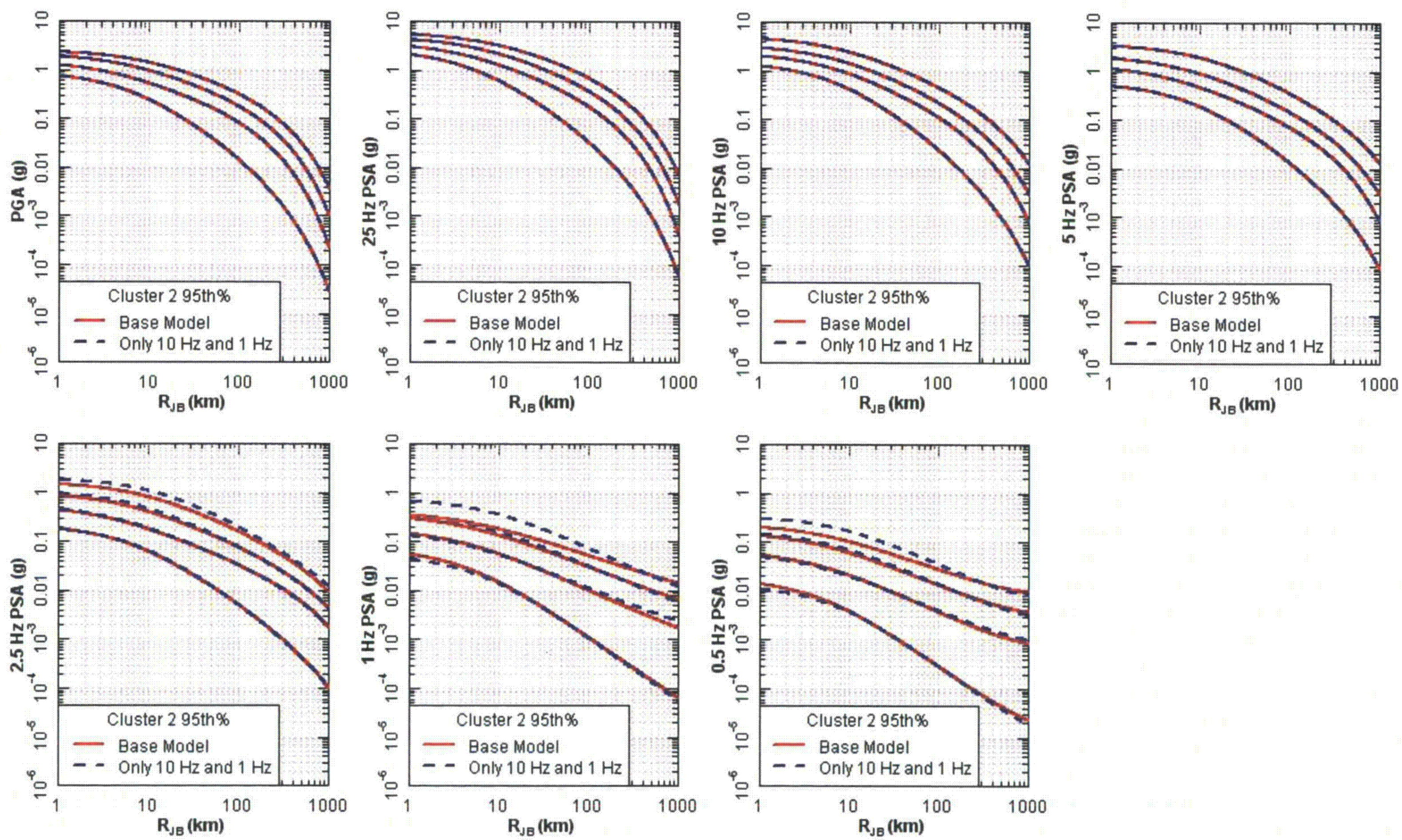
Cluster 2 Median



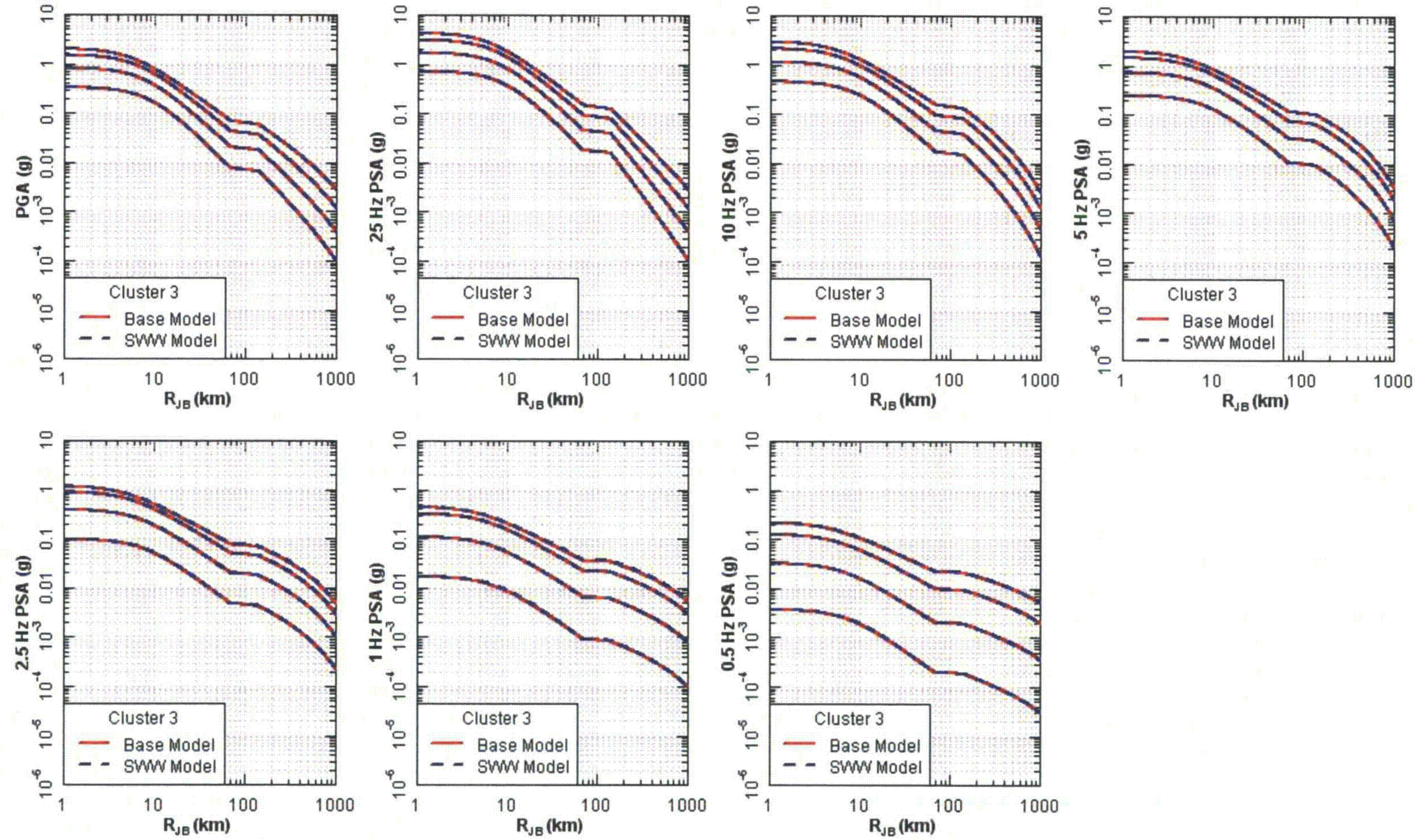
Cluster 2 5th%



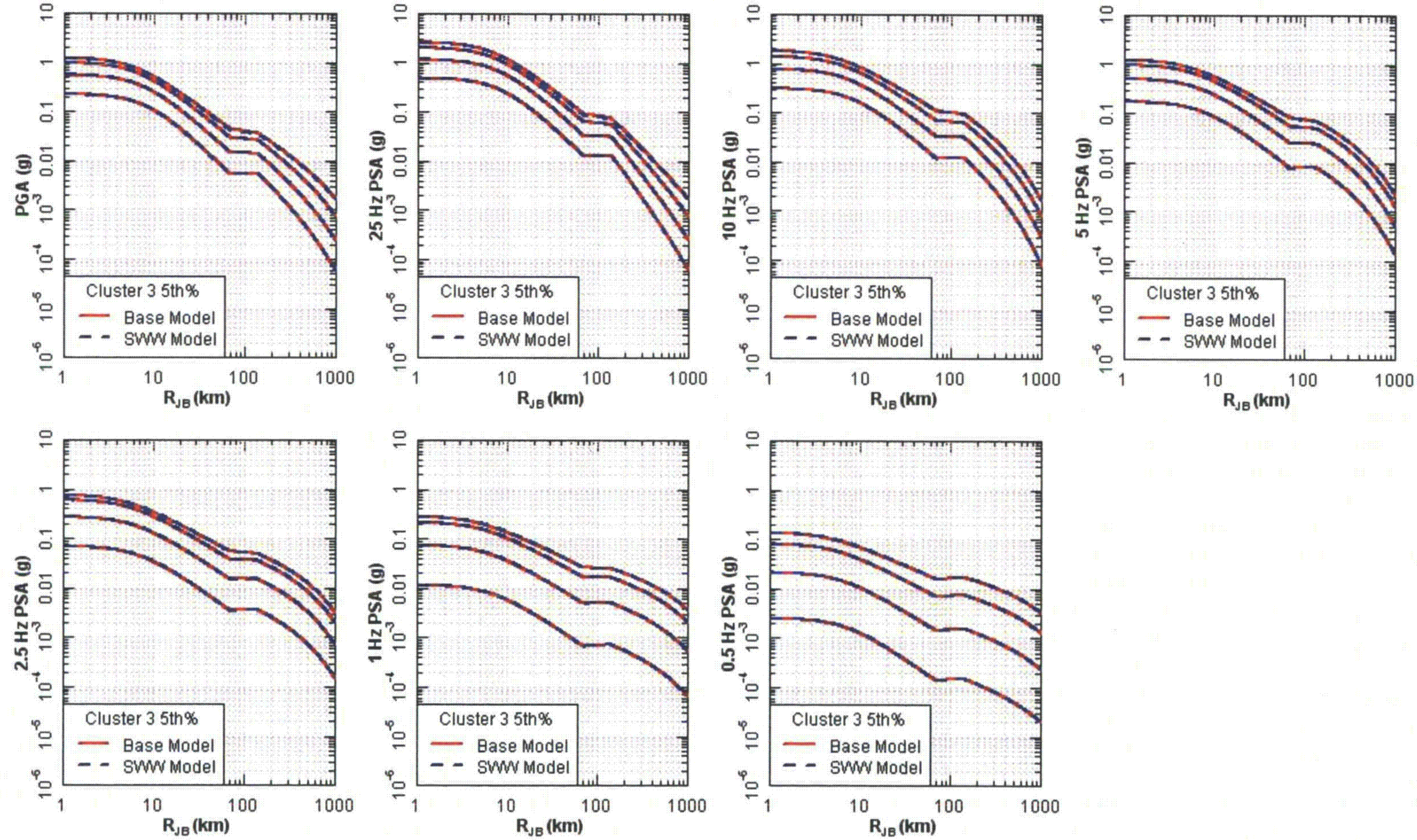
Cluster 2 95th%



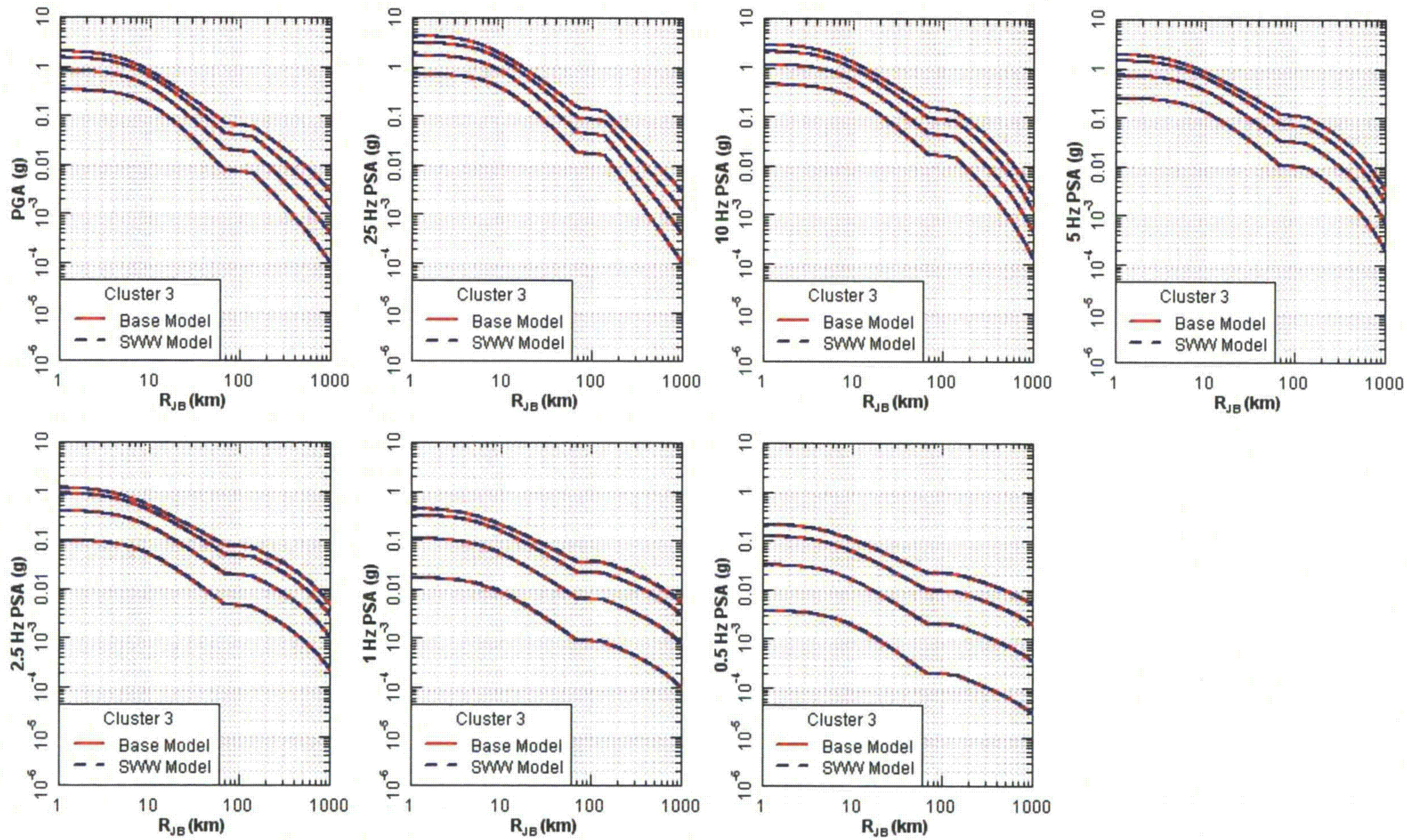
Cluster 3 Median



Cluster 3 5^{th}%



Cluster 3 95th%



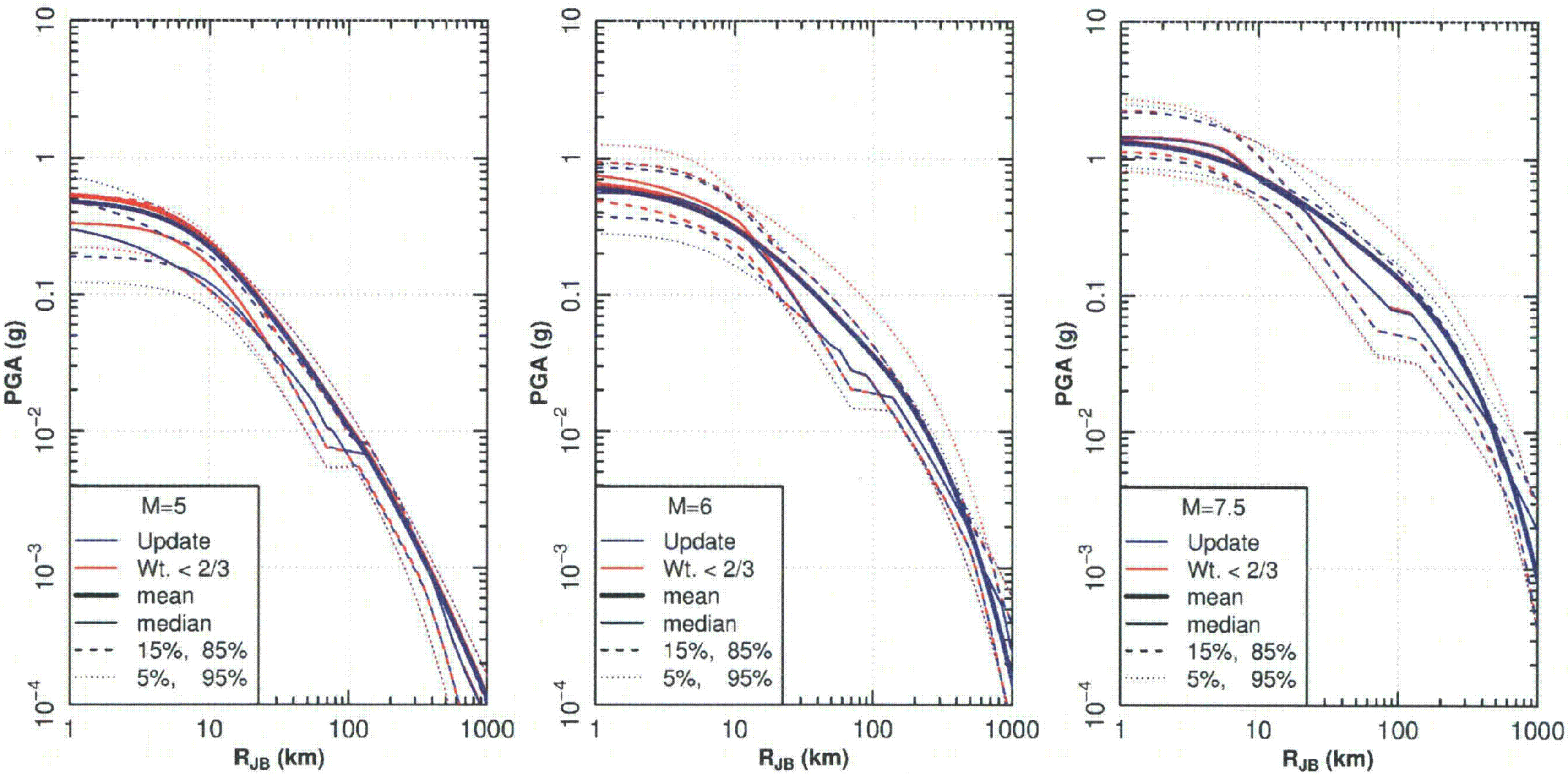
Effect of alternative approach for Within-Cluster Weights - Cluster Weights

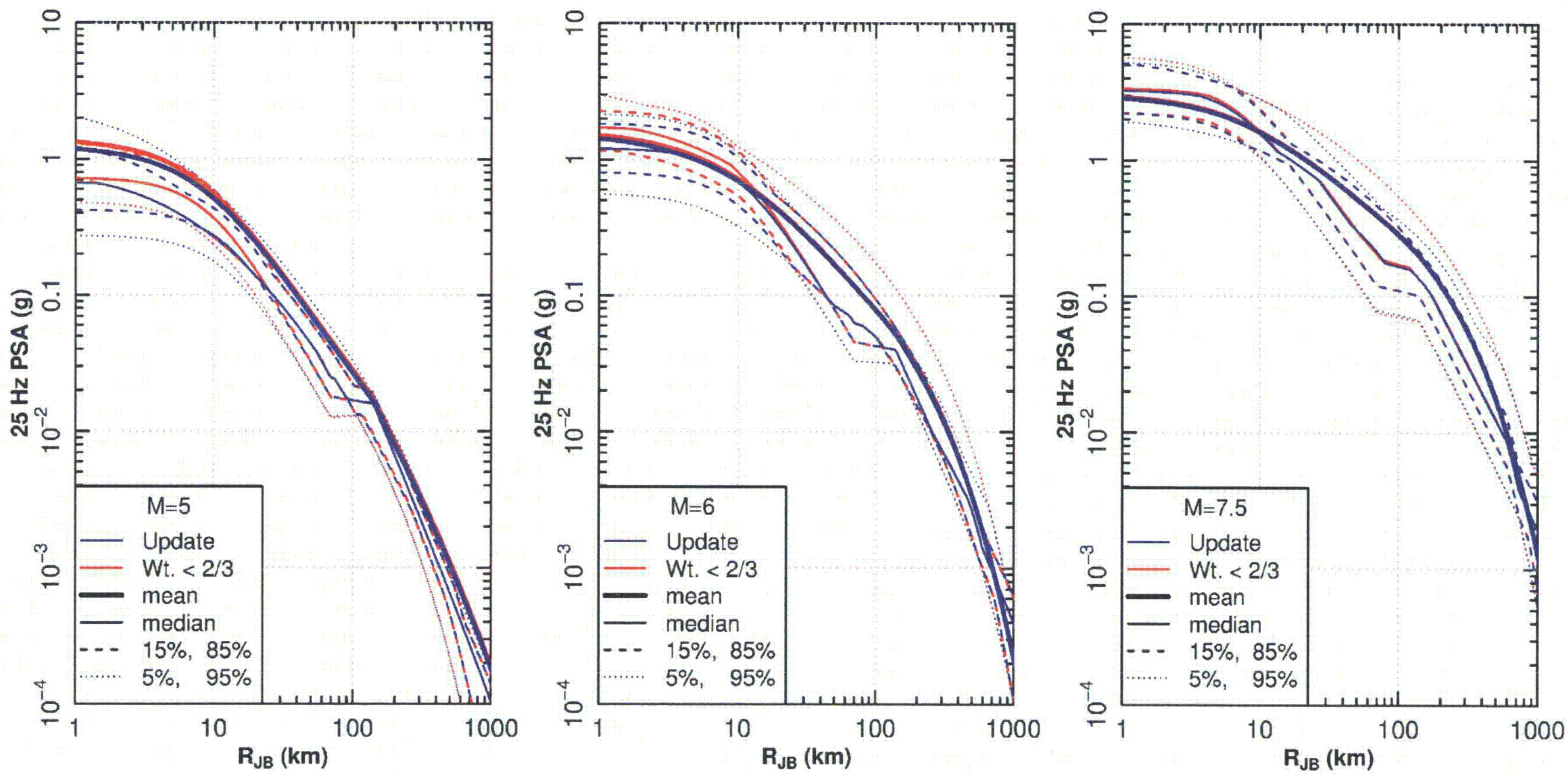
- Base-Case Cluster Weights

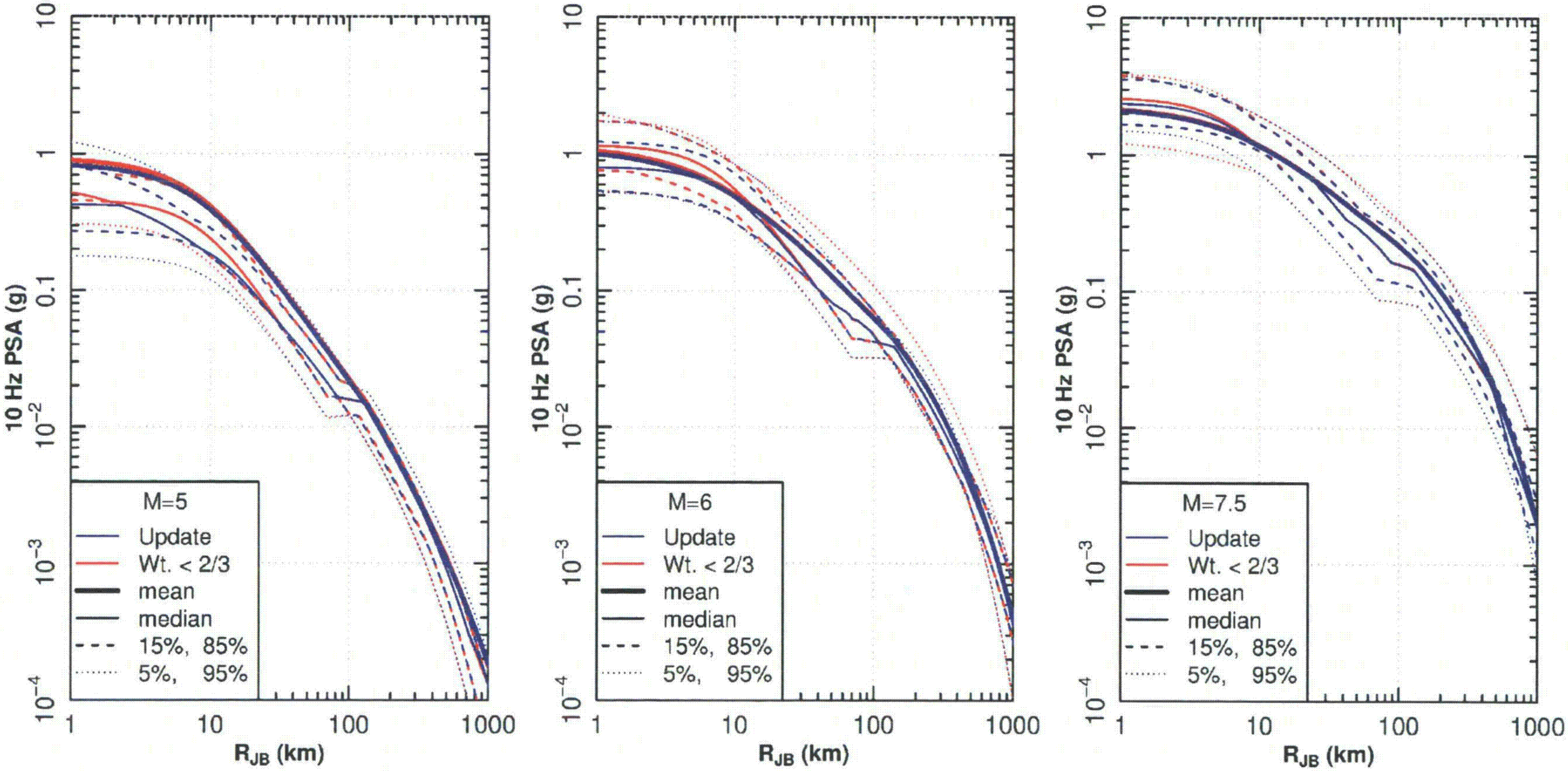
	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.02	0.24	0.68	0.07
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.11	0.27	0.49	0.13

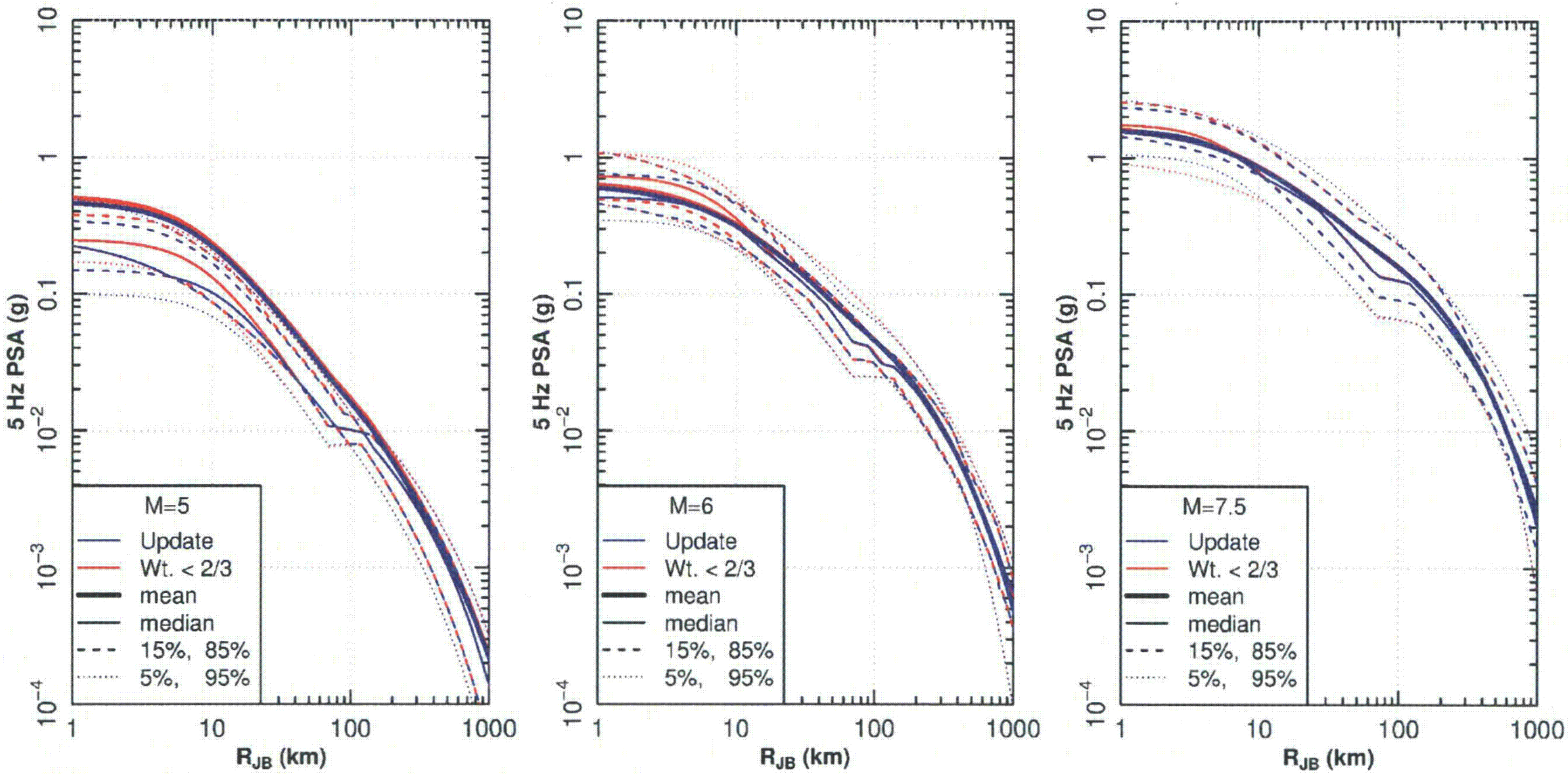
- Using alternative within-cluster weights

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
Weight Based on Consistency with Data (avg. HF and LF) 50%	0.02	0.25	0.68	0.06
Weight Based on Confidence in GMPEs 50%	0.20	0.30	0.30	0.20
Combined Weight	0.11	0.28	0.49	0.13

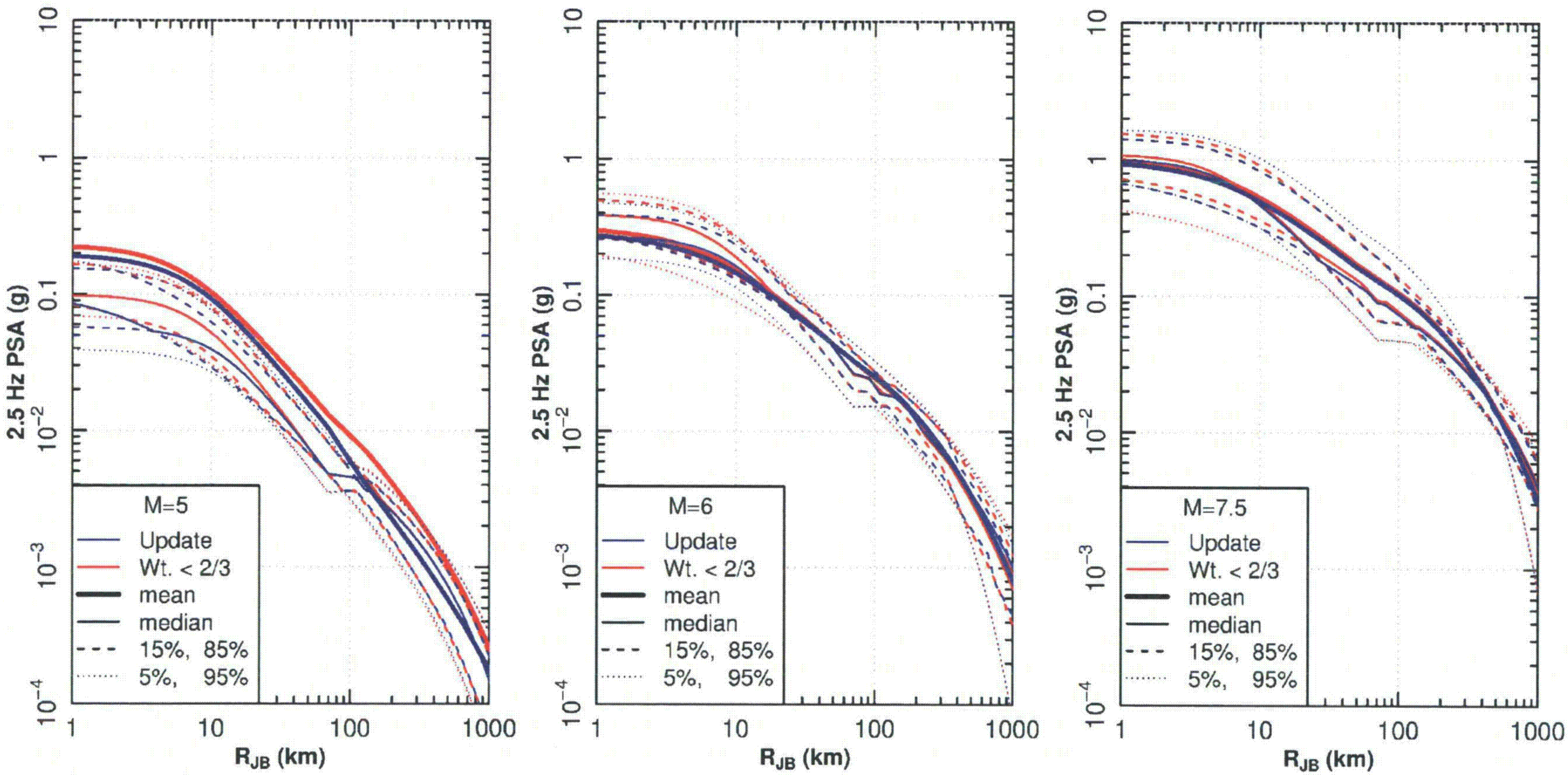

M=5
M=6
M=7.5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%
PGA (g)
R_JB (km)
10
1
0.1
10^-2
10^-3
10^-4
1
10
100
1000

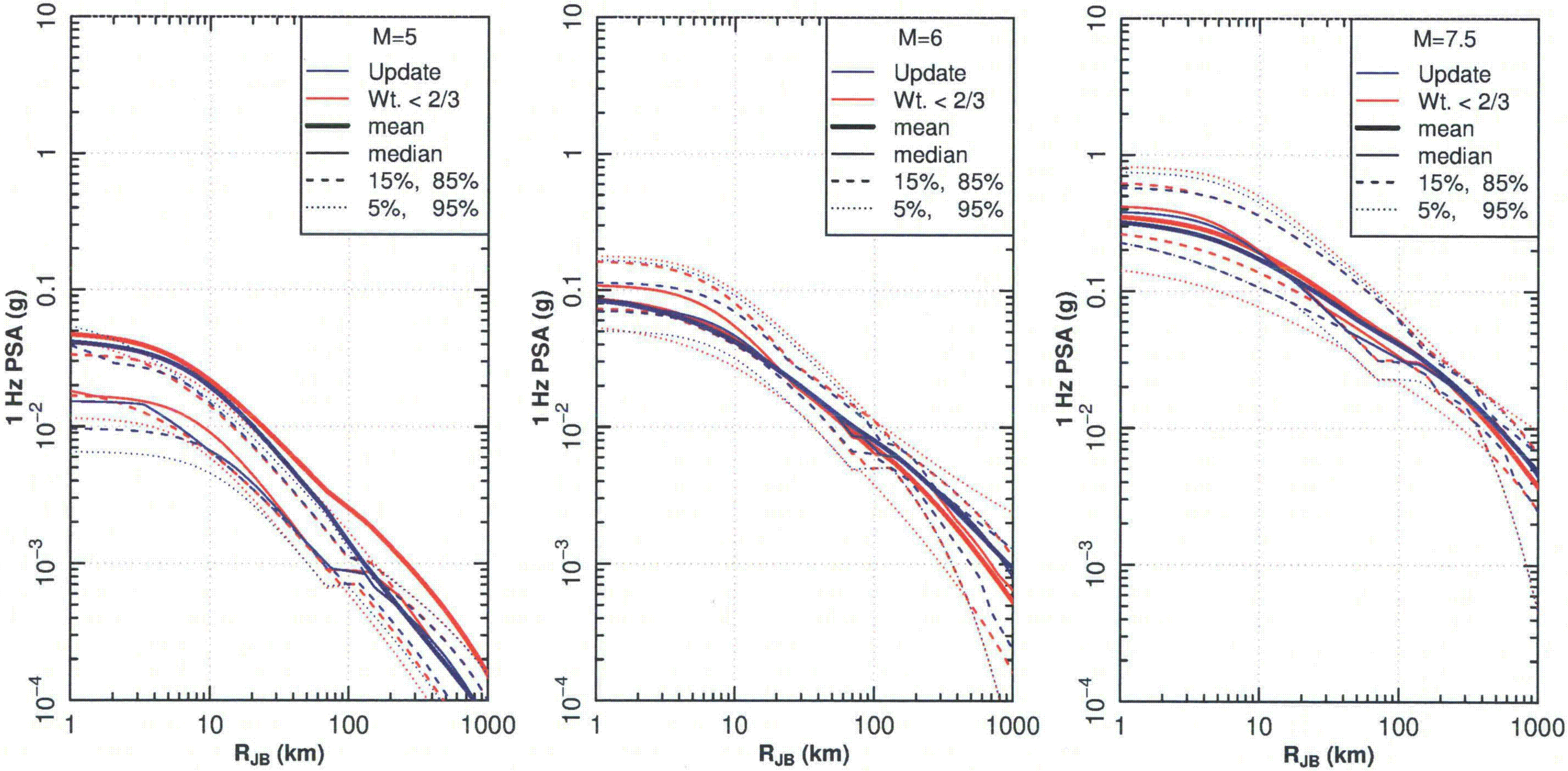

25 Hz PSA (g)
R_JB (km)
M=5
M=6
M=7.5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%

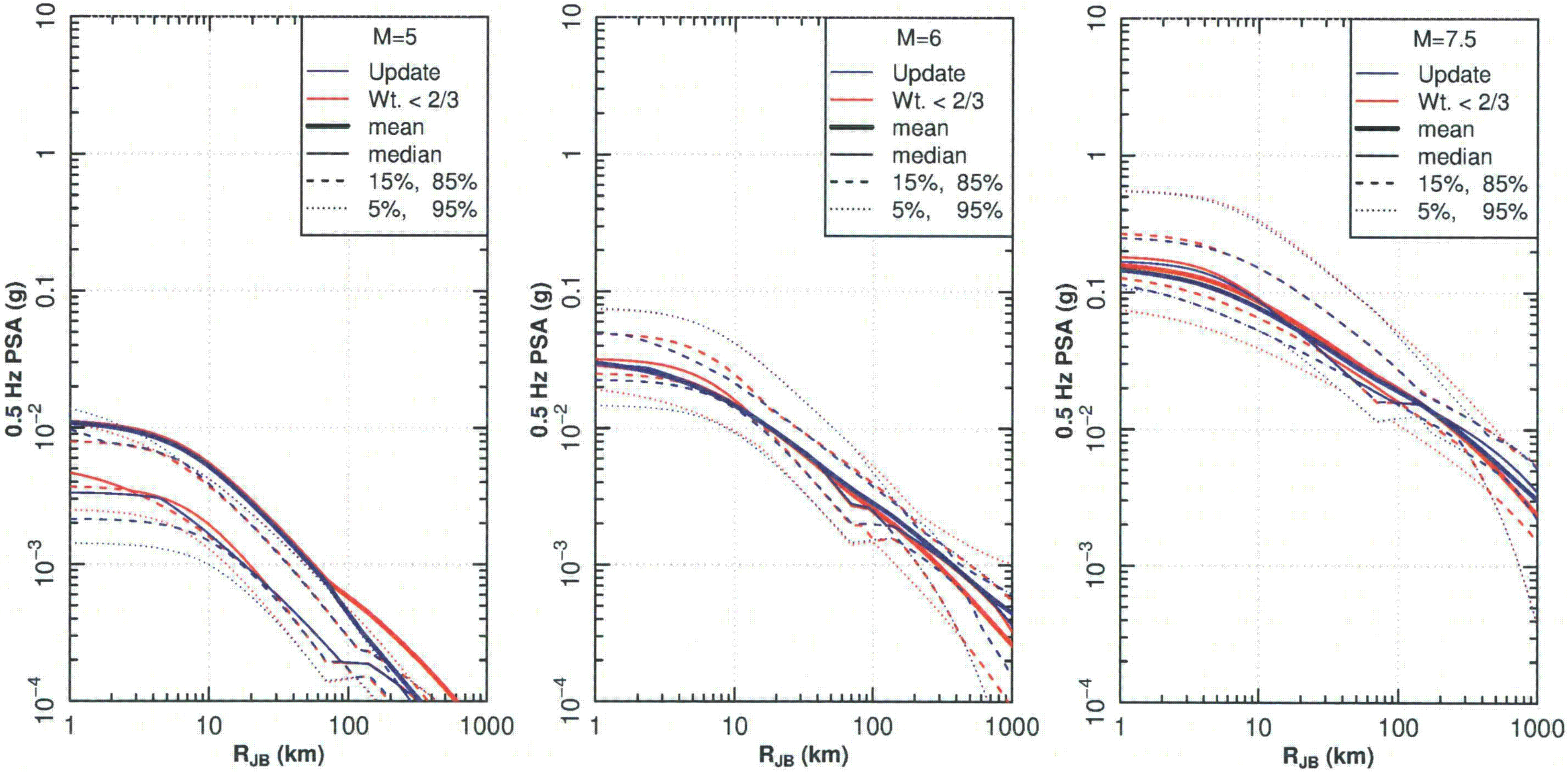

10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10 Hz PSA (g)
1
10
100
1000
R_{JB} (km)
M=5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%
M=6
M=7.5



5 Hz PSA (g)
R_JB (km)
M=5
M=6
M=7.5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%


10
1
0.1
10^{-2}
10^{-3}
10^{-4}
2.5 Hz PSA (g)
1
10
100
1000
R_{JB} (km)
M=5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%
M=6
M=7.5

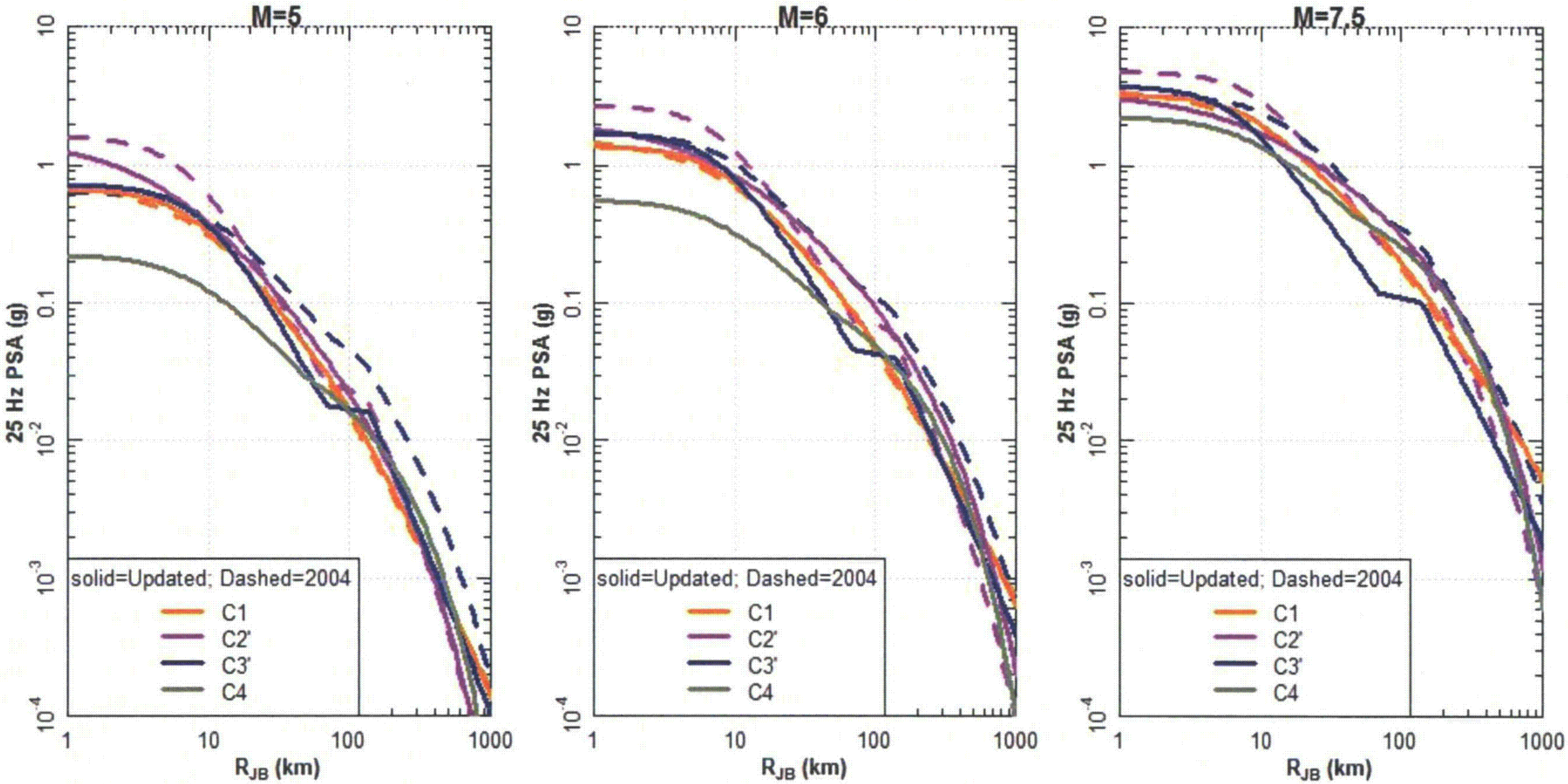

M=5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%
M=6
M=7.5
1 Hz PSA (g)
R_JB (km)
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
1
10
100
1000


M=5
M=6
M=7.5
Update
Wt. < 2/3
mean
median
15%, 85%
5%, 95%
0.5 Hz PSA (g)
R_{JB} (km)
1
10
100
1000
10^{-4}
10^{-3}
10^{-2}
0.1
1
10

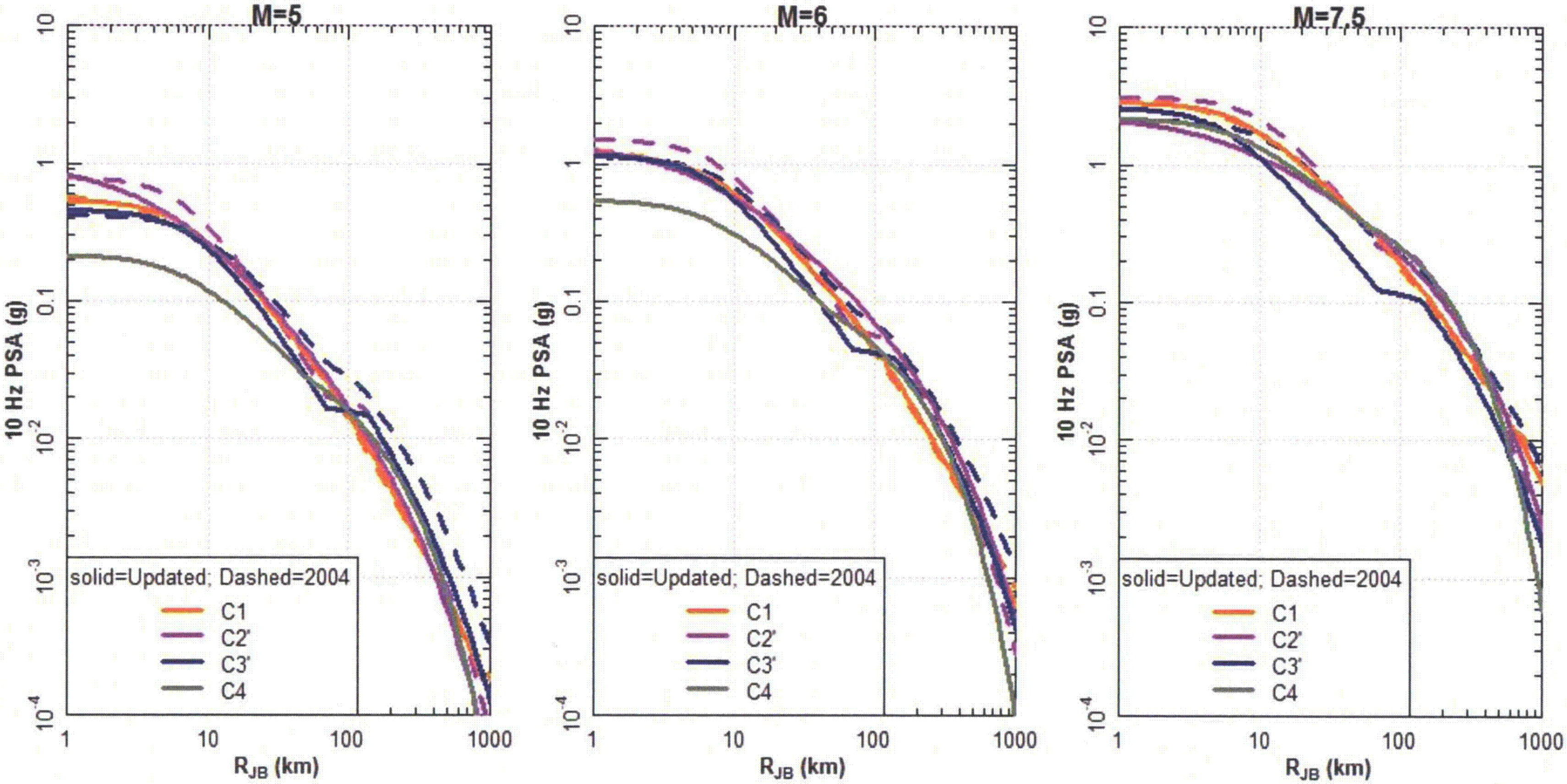
Graphical Exploration of Updated GMM and Comparisons to EPRI (2004)

Gabriel Toro

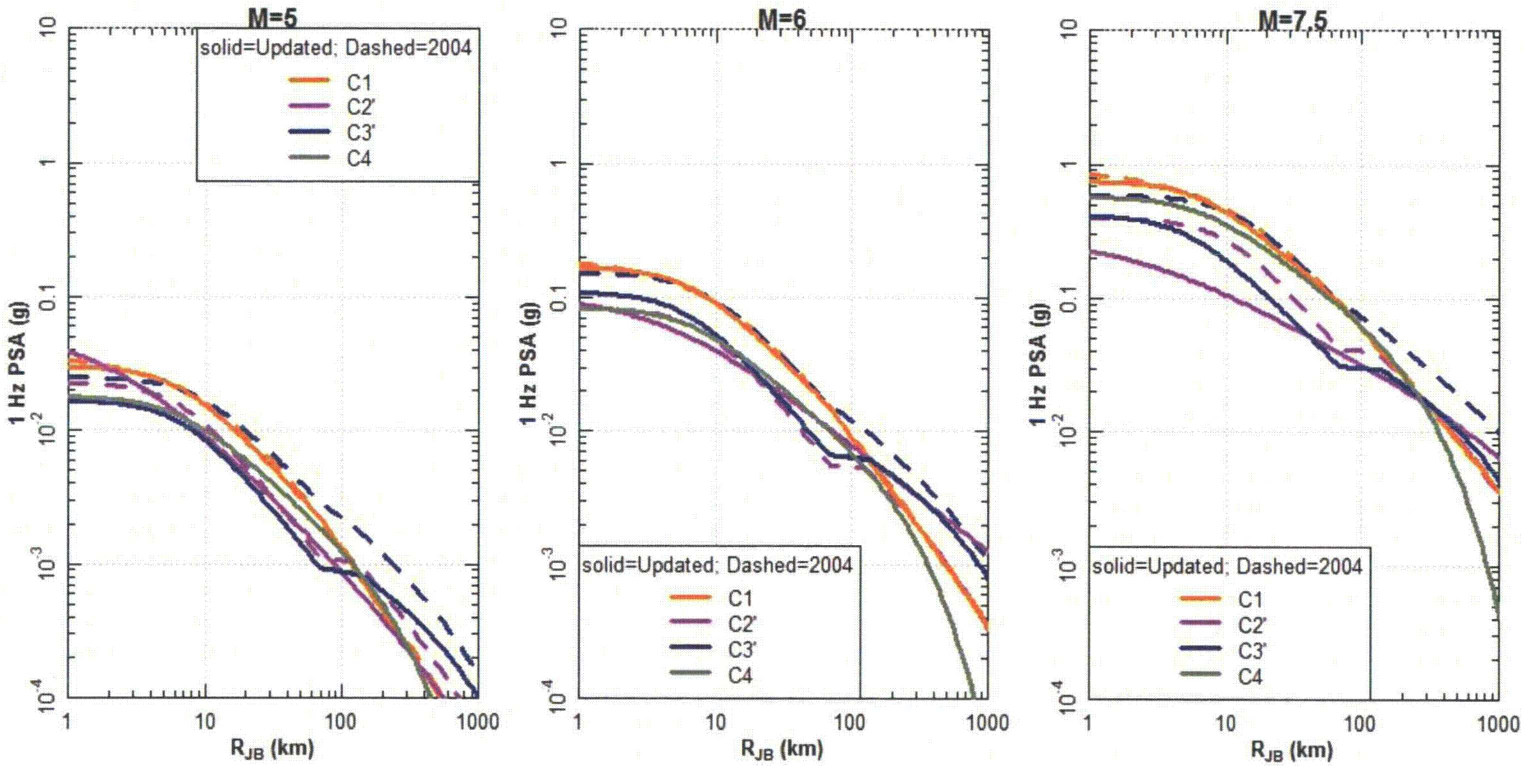
Comparisons by Cluster (25 Hz)



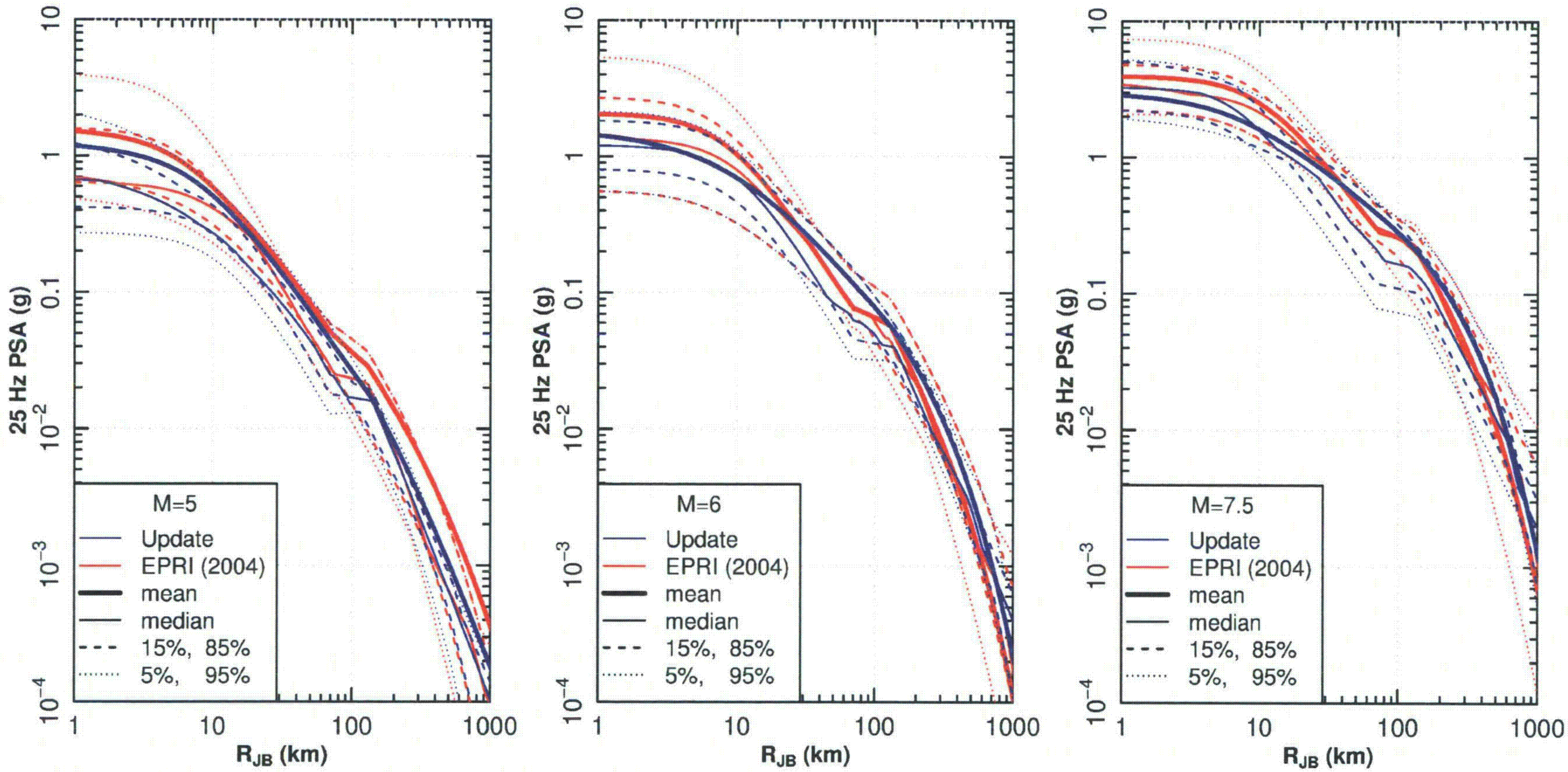
Comparisons by Cluster (10 Hz)



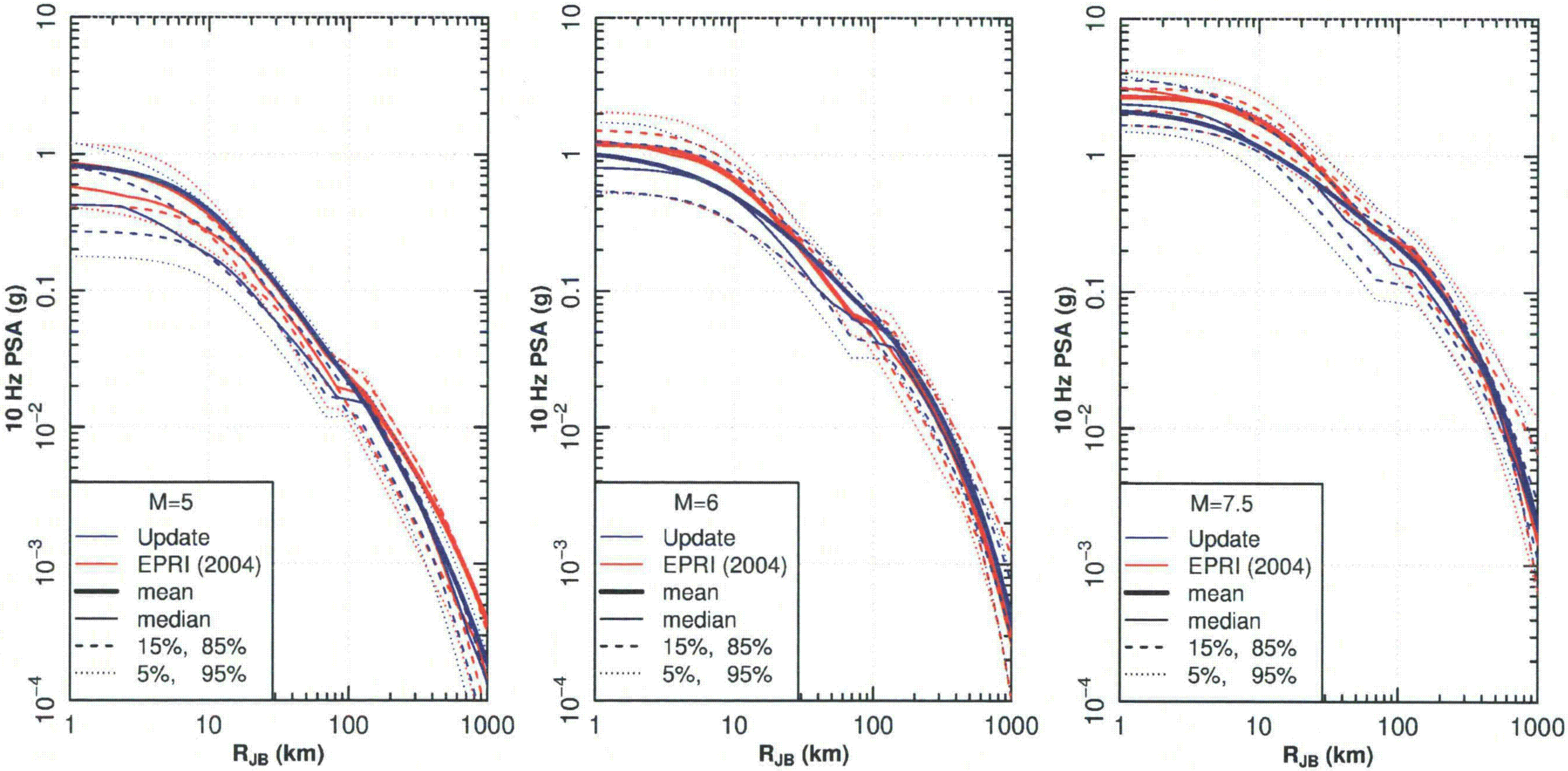
Comparisons by Cluster (1 Hz)



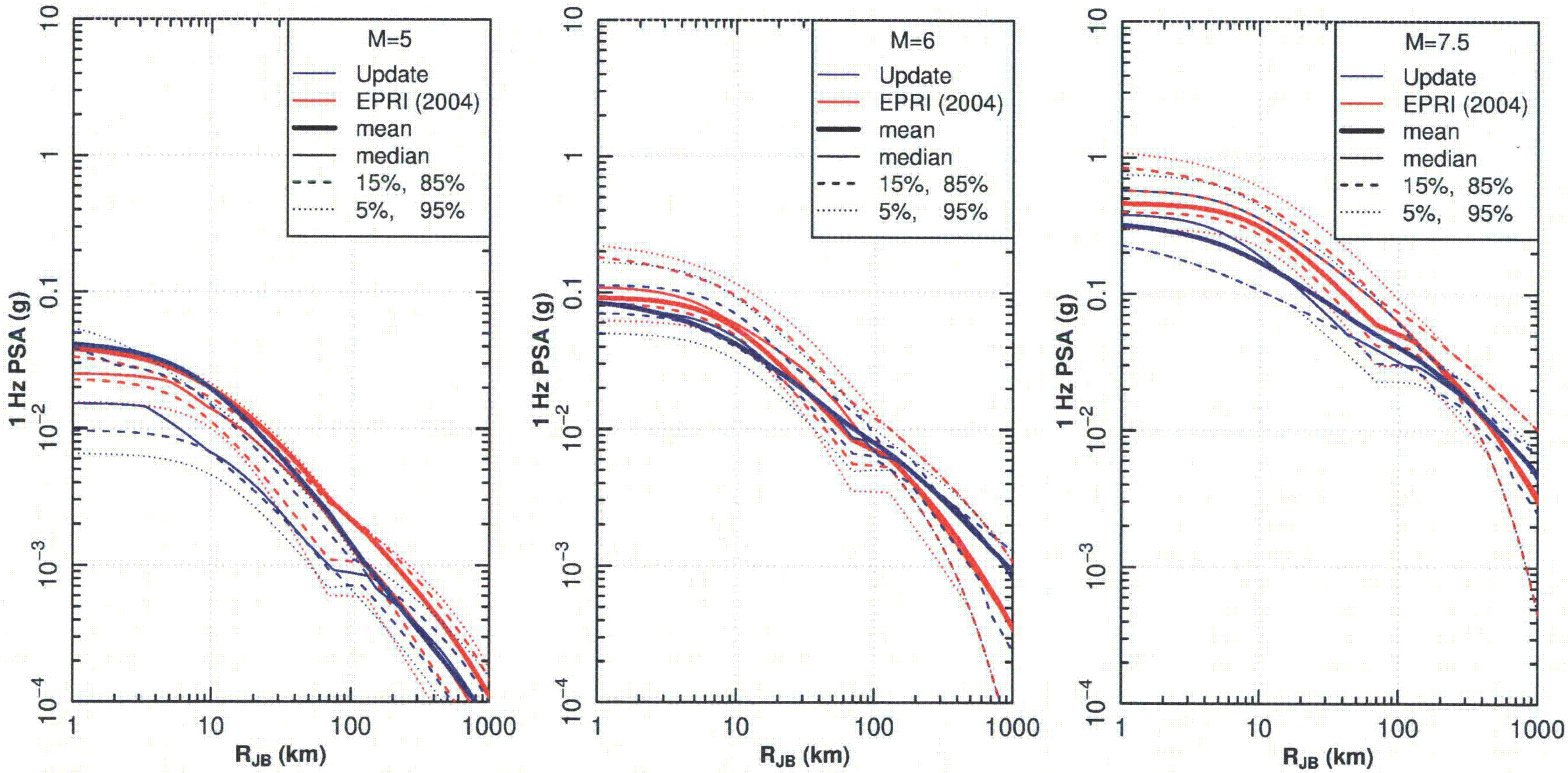
Comparisons by Fractiles (25 Hz)



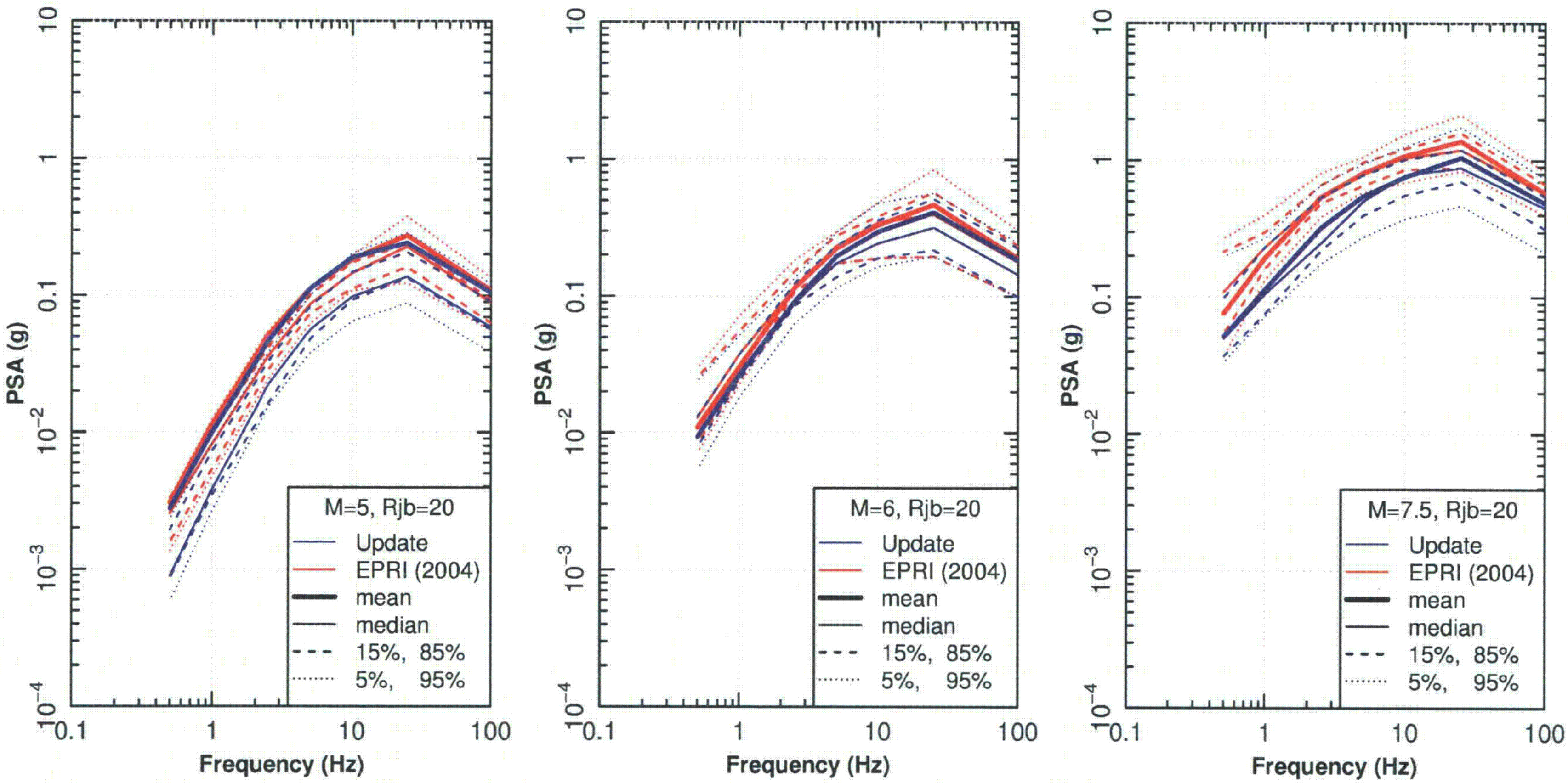
Comparisons by Fractiles (10 Hz)



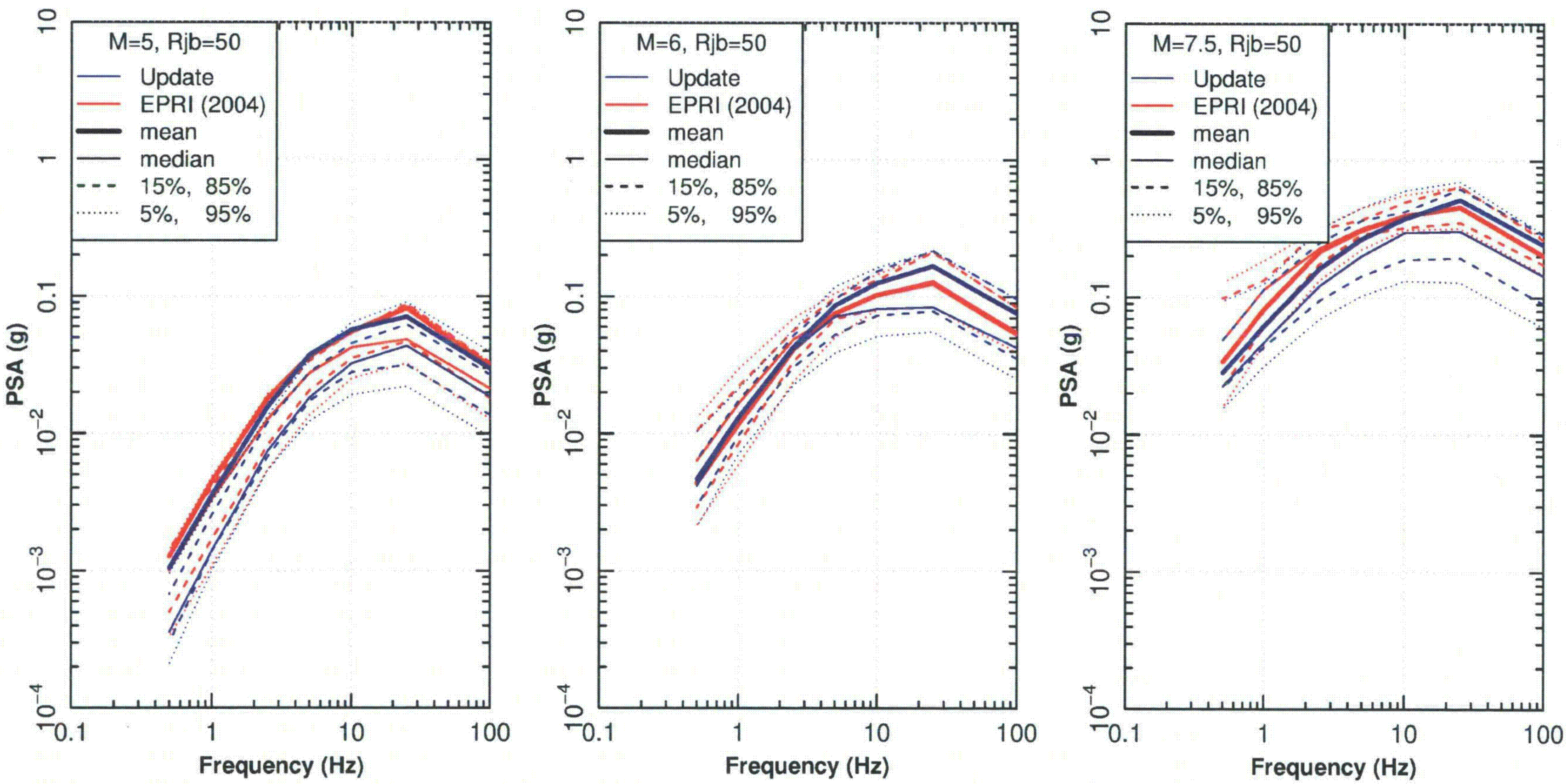
Comparisons by Fractiles (1 Hz)



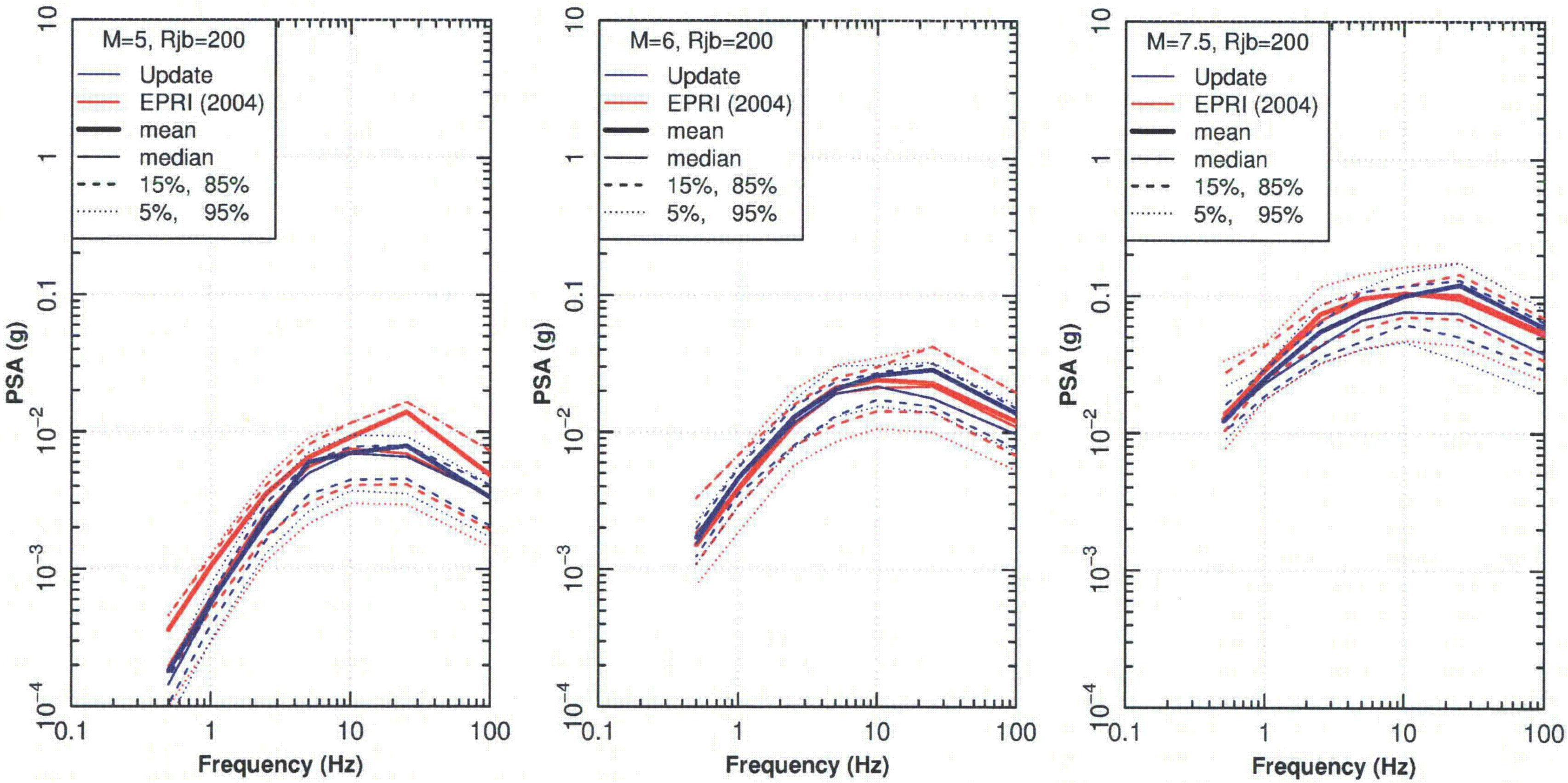
Comparisons by Fractiles (Spectra at 20 km)



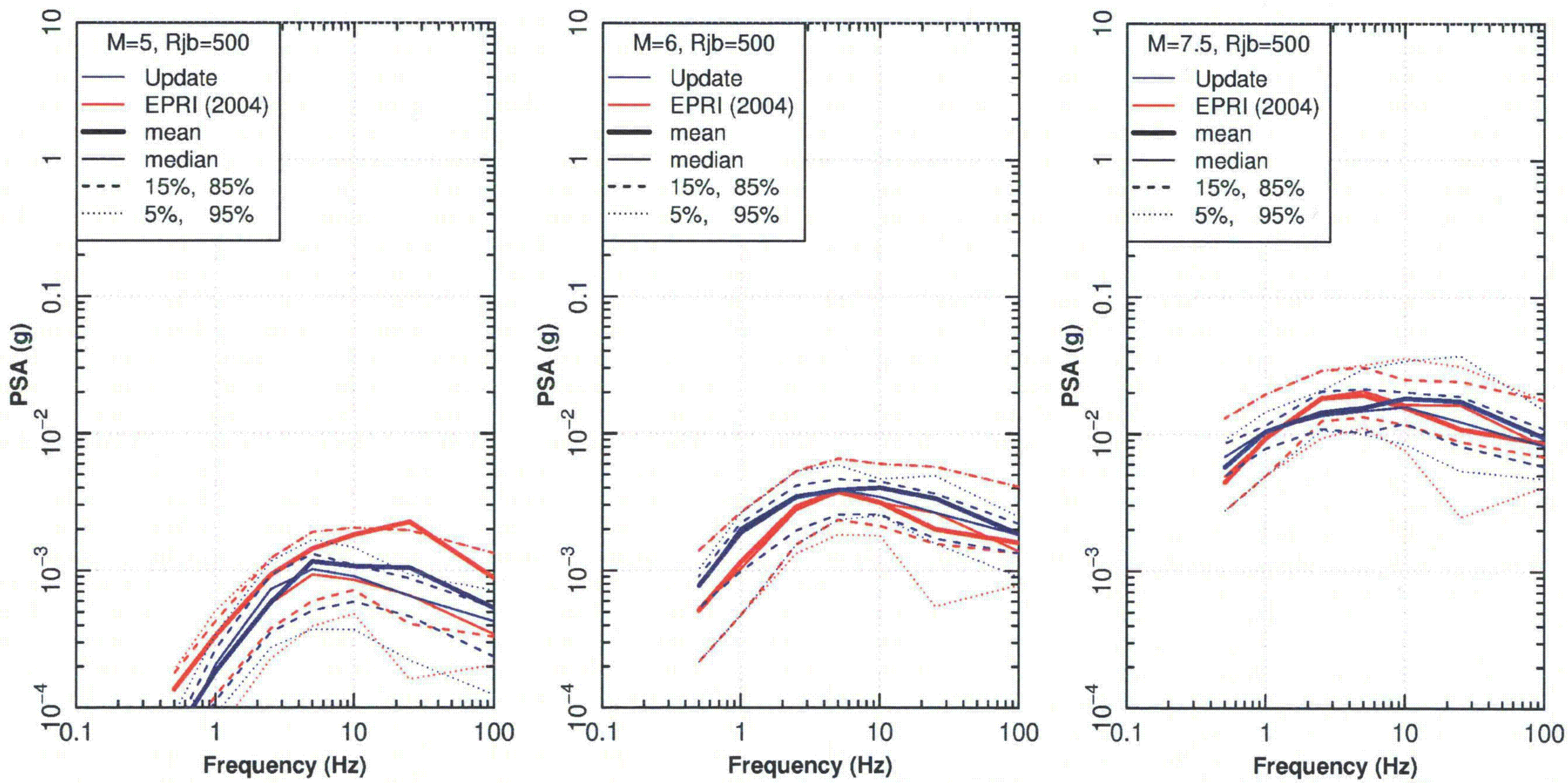
Comparisons by Fractiles (Spectra at 50 km)



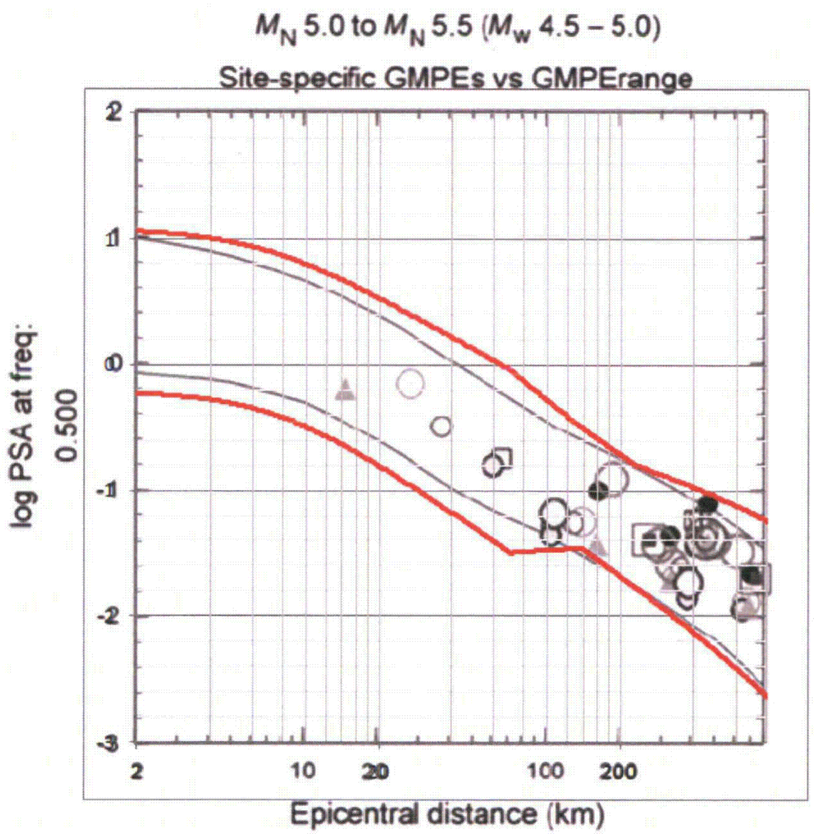
Comparisons by Fractiles (Spectra at 200 km)

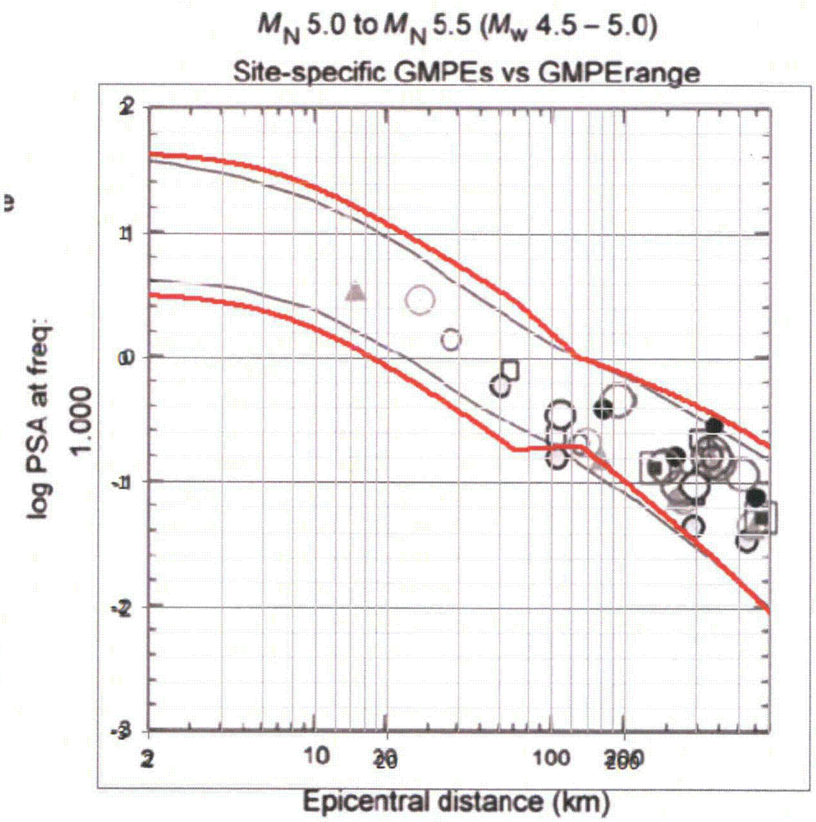


Comparisons by Fractiles (Spectra at 500 km)

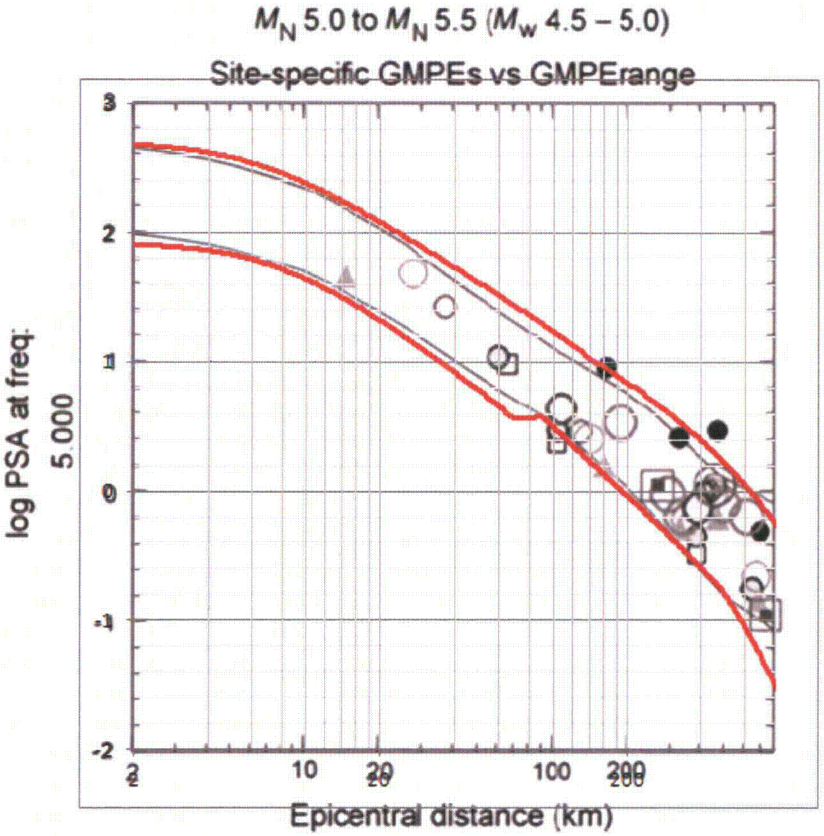


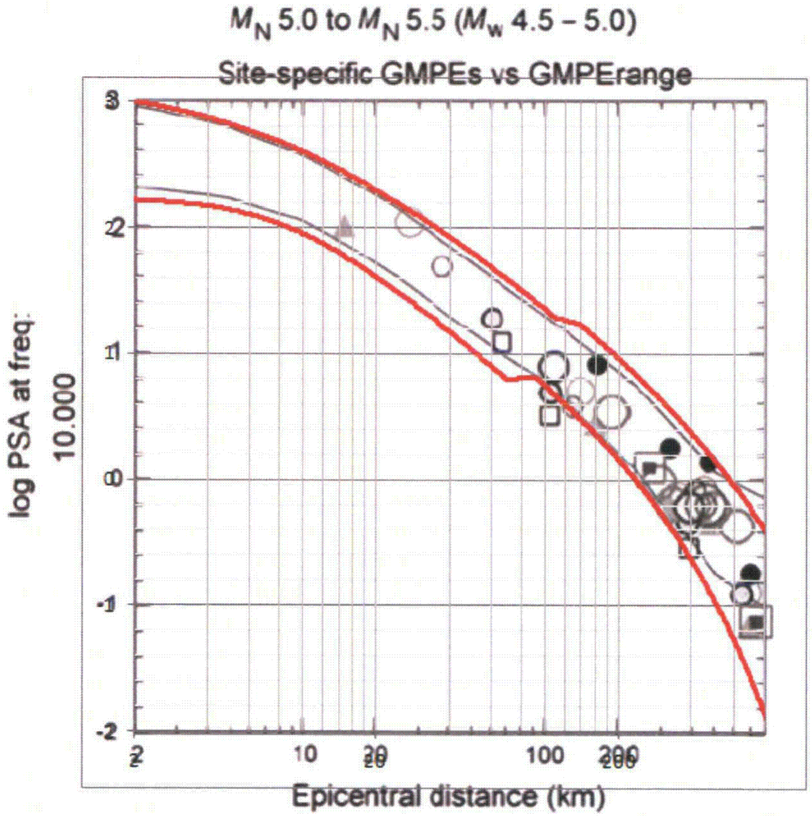
Low Frequency Comparisons



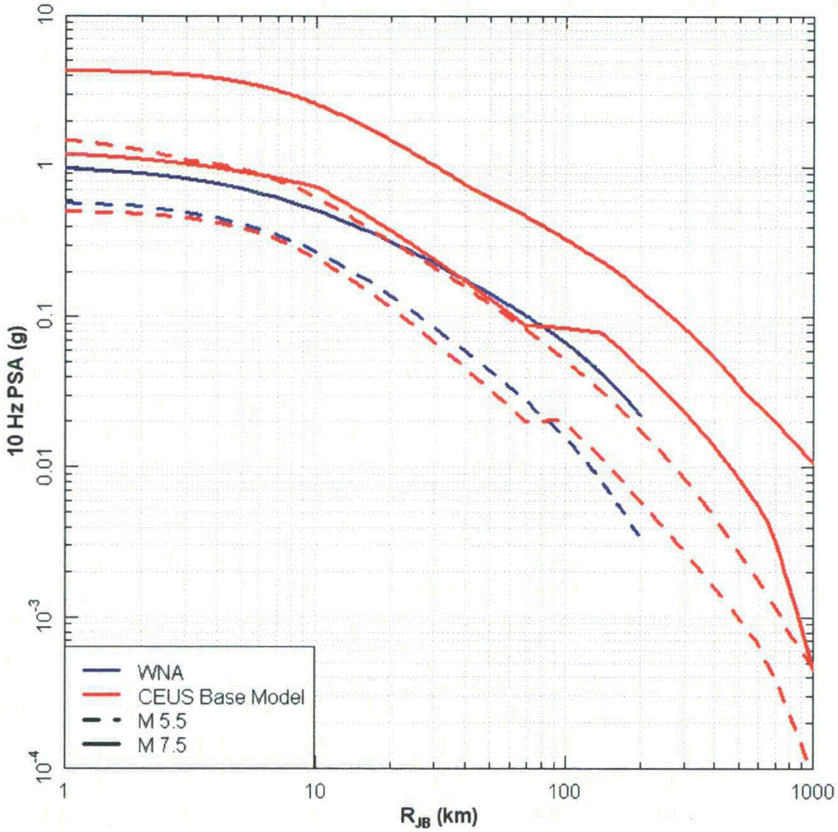


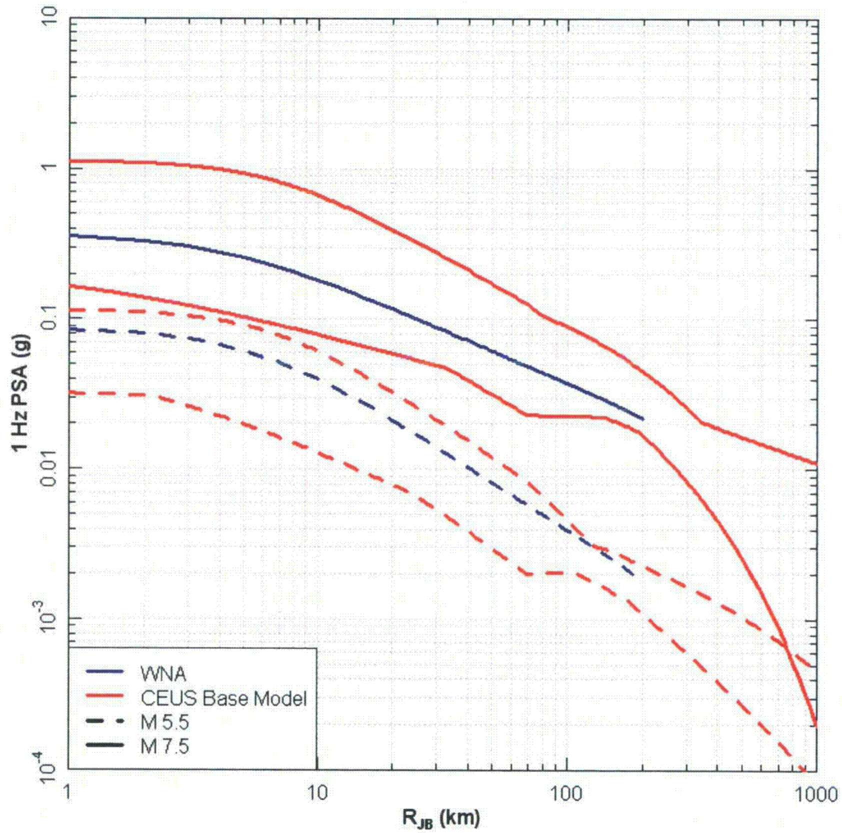
High Frequency Comparisons

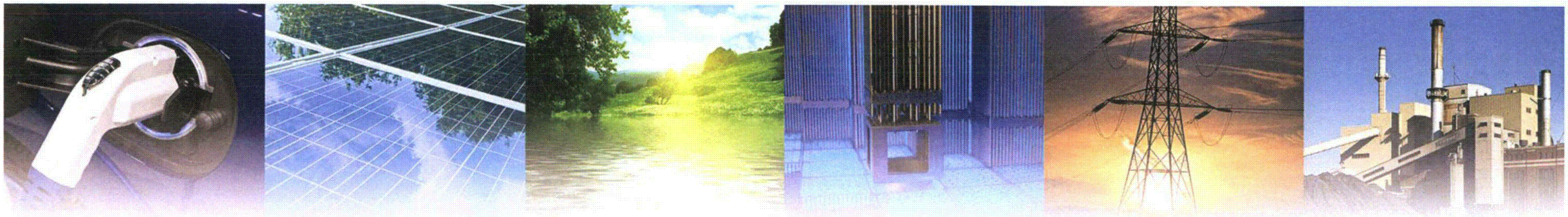




Comparison with NGA (2008) for Active Tectonic Regions







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EPRI (2004,2006) Ground Motion Model (GMM) Review Project

Lawrence Salomone

Project Manager

Nuclear Regulatory Commission

Public Meeting

March 26, 2012

Objectives

- Review and Discuss NRC Feedback Regarding Updated EPRI (2004, 2006) GMM
- Complete NRC Action List for TI Team
- Present Proposed Path Forward for Review and Discussion
- Present Proposed Schedule for Review and Discussion

NRC Feedback – Clarifications / Discussion

Comment	Response
Lack of epistemic uncertainty. Only 3 new GMPE equations were brought in while 7 GMPEs were eliminated.	Three (3) new GMPEs actually represent 2011 versions of earlier GMMs; Seven (7) GMPEs eliminated based on Resource Expert and Proponent Interviews; Discuss alternate approach; Including models that are no longer supported by their proponents is inconsistent with goal to capture CBR of the TDI.
Inter-cluster weights, frequencies (lows, highs, etc.) were grouped together, resulting in some GMPEs with nearly zero weight – Consider frequency-by-frequency basis	EPRI (2004, 2006) GMM considered all frequencies; Updated EPRI (2004, 2006) GMM considered high and low frequencies separately; Considering frequency-by-frequency requires breaking GMMs up, may produce choppy spectral shapes, and complicates the hazard calculations substantially; Results using 1 Hz and 10 Hz provided in PPRP Closure Briefing on 2/13/13. They show only small differences relative to base case.

NRC Feedback – Clarifications / Discussion

Comment	Response
Are there any other interpretations that could be presented (that are not represented by GMPEs), such as simple seismological models (representing stress drop, etc.) to establish ranges of interpretation?	Beyond the scope of a SSHAC Level 2 study focused on updating rather than replacing the EPRI (2004, 2006) GMM
Sensitivity on distance bins may be over-emphasized, probably shrinking the last bin (25-500 km)	Clarification required to explain that upper distance bins were already down-weighted
Much of the data is within 200 km, and primarily from SE Canada, primarily with Vertical component data, which has been converted to Horizontal as error free. Should the uncertainty of this process be captured?	Clarification required to explain how the spatial coverage of the data is adequate and that vertical data were not used; only horizontal component data were used

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NRC Feedback – Comments Addressed

Comment	Response
Several new ideas were presented at PPRP Closure Briefing on February 13, 2013 were not part of the draft report	Additional new ideas have been incorporated into the Updated GMM since the PPRP Closure Briefing
Weighting scheme is fully dependent on limited data, thus some models get low weight - Subjective cap on individual GMPEs	Added subjective cap on weights to individual GMPEs in each cluster and reduced importance of data-consistency weights in calculating cluster weights
Are implied seismological parameters sufficiently broad to capture the CBR	Incorporated uncertainty in Magnitude scaling into Updated EPRI (2004, 2006) GMM
Data set (limited for weighting) does not adequately represent CEUS	Dataset used provided spatial coverage representative of the CEUS, obtained and checked updated Ground-Motion Database From NGA-East Project

NRC Feedback – Additional Work

Comment	Response
Placed too much emphasis on just a few models which is counter to CBR of TDI	Re-calculating weights to provide more even distribution, recognizing the limitations of data
Draft sections were not complete (holes), did not address aspects of the model, nor conclusions on how the CBR for TDI was captured	Provide final report for review – Add Section in final report that explains how CBR of TDI was captured
Test sites hazard curves are significantly lower. Need sensitivity study to see why this occurs	Add Section in final report that explains why seismic hazard curves are lower; Provide sensitivity study to show why EPRI (2004, 2006) GMM overestimates seismic hazard

NRC Feedback – Additional Work

Comment	Response
Limited pool of data and equations, many models were eliminated, thus need to demonstrate that the CBR of TDI is actually captured	Add section in final report that explains how CBR of TDI was captured; Discuss alternate approach to eliminating EPRI (2004) GMPEs recommended for replacement by developers
Need to see some sensitivities. Compare evolution of EPRI 04/06 to the current update via GMPE updates. Compare 1 Hz RLME results at specific frequencies. Rerun 04/06 eliminating Cluster 3, Model 3	Add Section in final report that discusses evolution of GMMs from EPRI (2004, 2006) GMM to new GMMs to Updated EPRI (2004, 2006) GMM; Discuss dissecting median model of clusters; Include sensitivity results or add plots and discussion, if necessary
Need to work with NRC to address NRC concerns to reach closure	Provide final report and follow proposed path forward determined in March 26, 2013 meeting

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Representation of CBR of TDI

TI Team Response: The updated model properly captures the CBR of current TDIs for the following reasons:

Process: A SSHAC Level 2 process has been followed, with a number of Level-3 enhancements, while keeping the same overall framework and approach as EPRI (2004).

- **Ground-Motion Data.** Update is based on a significantly larger database of recordings than was available in the EPRI (2004) GMM development, including data from important earthquakes such as Mineral, Val-de-Bois, Mt. Carmel, etc.

- **Station Data.** Station data have been collected and used to adjust recorded motions to reference site conditions using two alternative approaches.

- **Engagement of Resource and Proponent Experts**. The Update Assessment engaged current CEUS GMM developers and current GMPE developers beyond the normal SSHAC Level 2 guidance, including a feedback workshop. These interactions assure that the Profession's knowledge of data, models, and methods gained during the nearly 10 years that have elapsed since the EPRI (2004) work has been evaluated and properly represented in the updated GMM.

Representation of CBR of TDI (cont'd)

TI Team Response (cont'd):

•**Candidate GMPEs.** The TI Team's reviews of the literature and engagement of Resource and Proponent Experts identified that seven GMPEs that were evaluated and represented in the EPRI (2004) GMM have been superseded by Proponents' subsequent GMPEs and introduced three new GMPEs. The three new GMPEs are in their second generation of development, based on more currently available data. The PZT GMPE is consistent with Campbell's 2009 NEHRP model and with his recent work. These activities identified the GMPEs that represent the range of current TDIs.

•**Comparisons with Other Studies.** The epistemic uncertainty in the updated model is comparable to the range proposed by Atkinson and Adams for the Canadian seismic hazard maps.

•**PPRP and Observer Feedback.** The TI Team's assessment has incorporated extensive feedback from PPRP Members and Observers. As a particular example, considering the limitations of currently available relevant data additional uncertainty in magnitude scaling was added to ensure the goal of representing the CBR of the TDI was met.

Proposed Path Forward

Activity	Date
Complete NRC Action List for TI Team and PM	March 26
Obtain Closure with PPRP & Complete SSHAC Level 2 Report:	
• Update seismic hazard calculations for 7 test sites	April 5
• Draft report to PPRP for review	April 24
• Receive comments from PPRP	May 13
• Receive Final PPRP Closure Report	May 28
• Complete SSHAC Level 2 final report	May 31
Provide Complete Report to NRC for Review	June 3
NRC Provide Comments and Any Outstanding Action Items	July 1
TI Team Respond to NRC Comments Action List, Update GMM, if necessary, and Provide Documentation to NRC	July 31
NRC Acceptance of Updated Ground-Motion Model (GMM)	August 30

Summary of Proposed Interactions

Activity	Date
Work with NRC Project Observers to Ensure Understanding of NRC Feedback	As Required
NRC Briefing (Tentative)	June 5
NRC Comments on Updated GMM	July 1
TI Team Respond to NRC Comments Action List; Revise Updated GMM, if necessary; Provide Documentation to NRC	July 31
NRC Briefing (Tentative)	August 6
NRC Acceptance of Updated Ground-Motion Model (GMM)	August 30

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Protecting People and the Environment

Presentation on Seismic Ground Motion Model Update for the CEUS

April 11, 2013

Clifford Munson, Senior Advisor, DSEA, NRO
Jon Ake, Senior Seismologist, DE, RES
Vladimir Graizer, Seismologist, DSEA, NRO
Yong Li, Seismologist, DE, NRR

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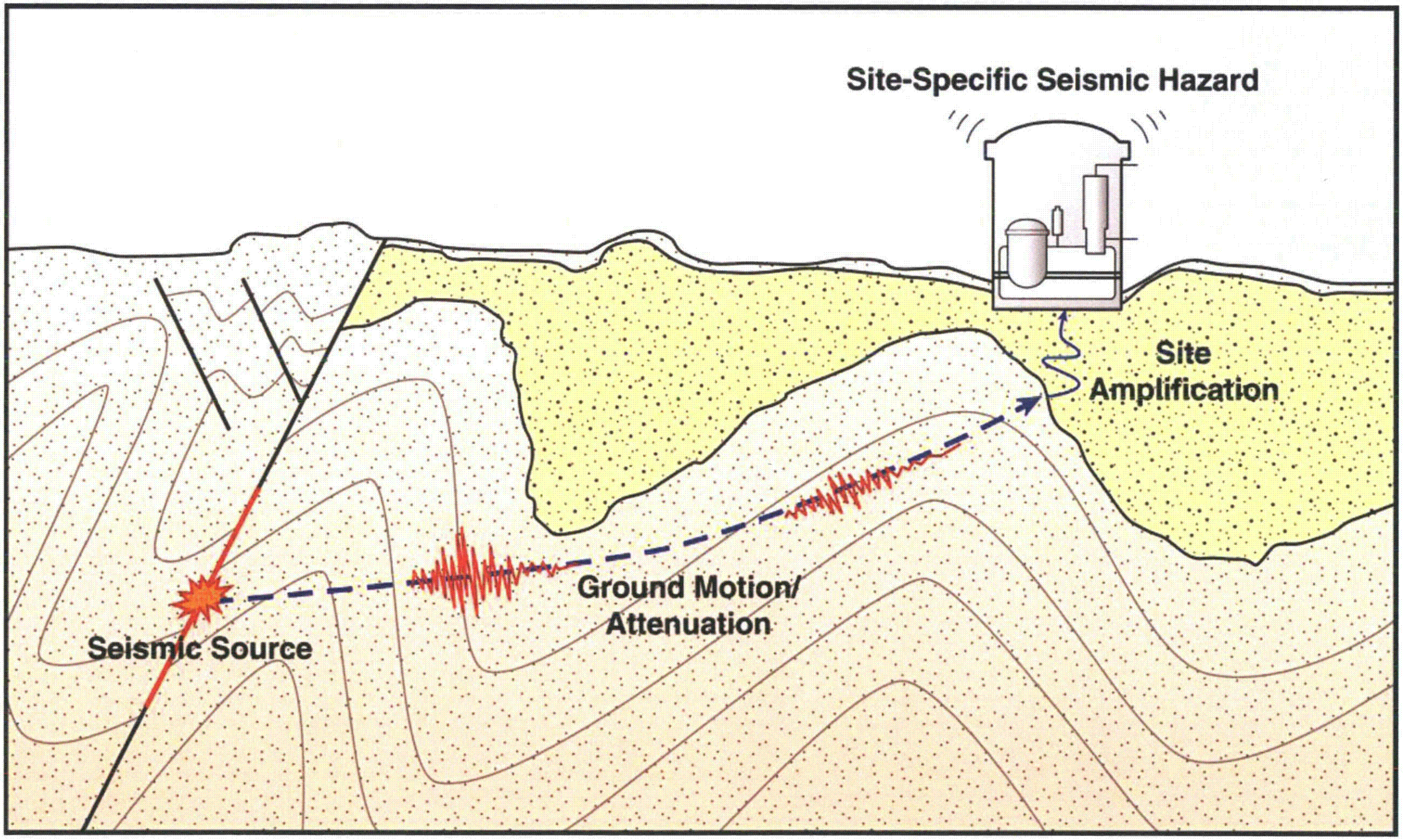
Outline of Presentation

- Background
- EPRI (2004, 2006) Ground Motion Model
- Update of Model
- Path Forward

Site-Specific Seismic Hazard Development



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Ground Motion Models for Stable Continental Regions

- Ground motion parameters (peak ground acceleration, spectral acceleration) estimated using prediction equations
  - Earthquake magnitude
  - Source-to-site distance
  - Local site conditions
- Ground motion data sparse in magnitude-distance range of engineering interest
- Stochastic approaches used rather than empirical methods

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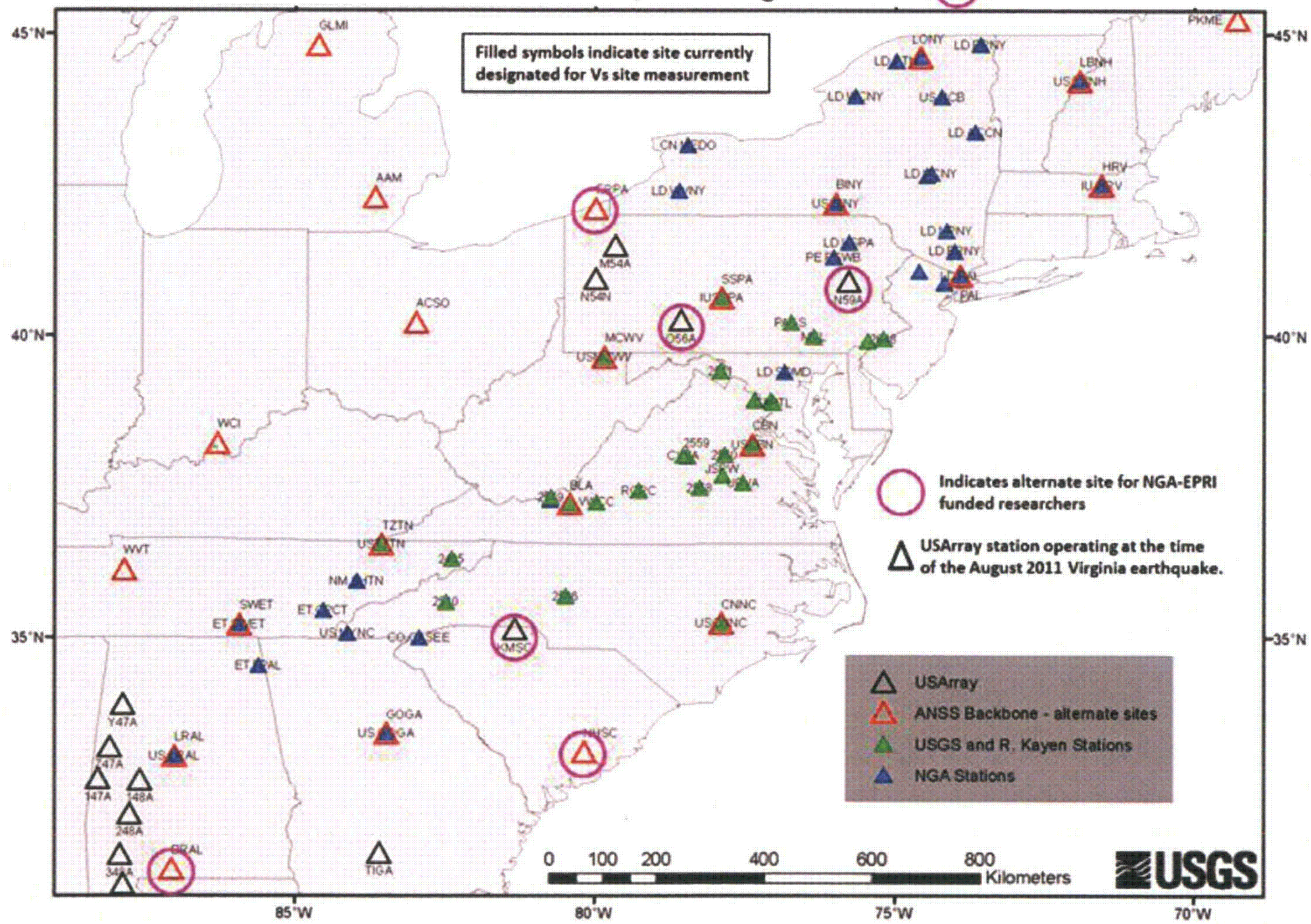
2012 Vs Site Characterization – Eastern US; showing alternates



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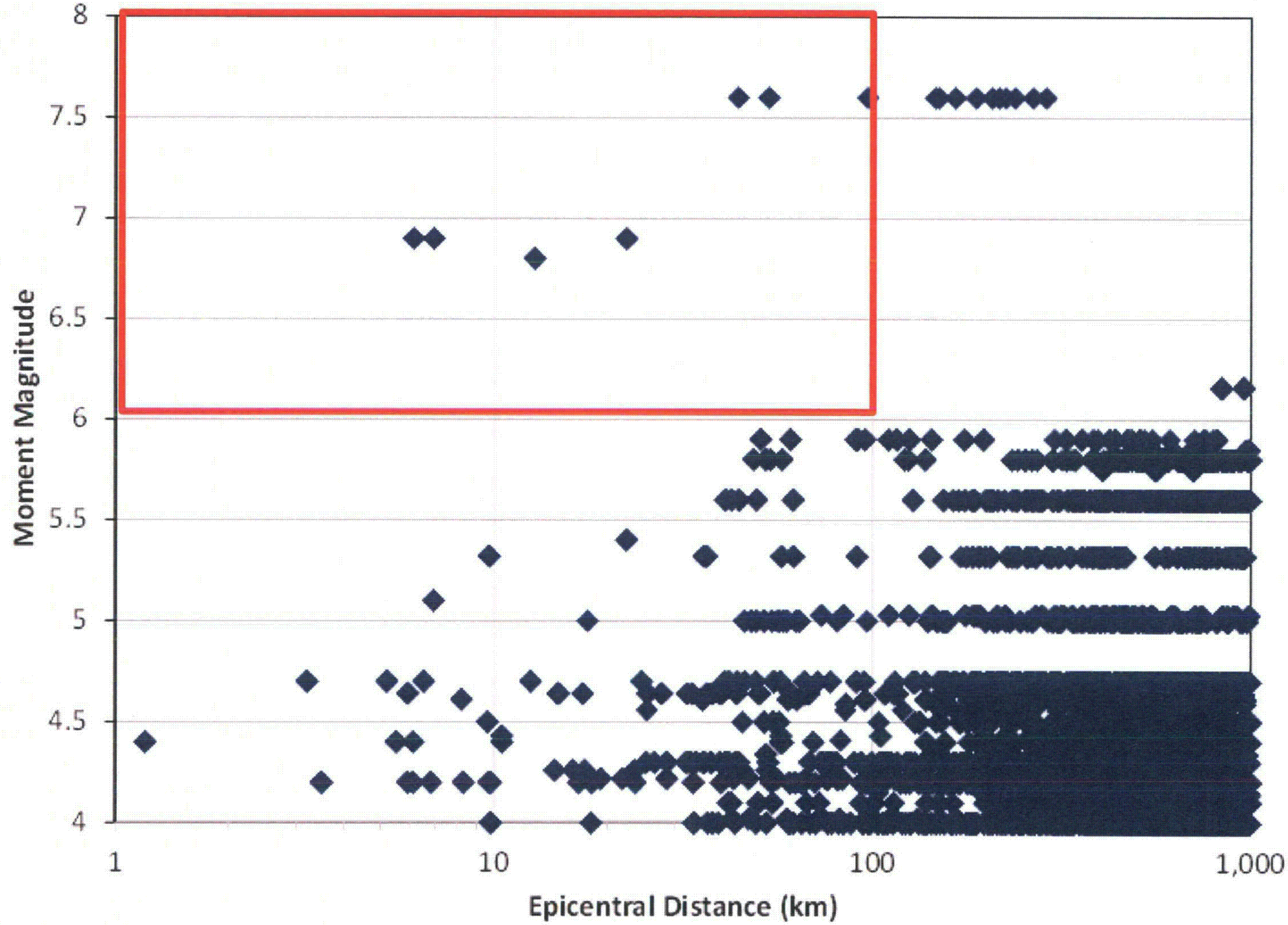
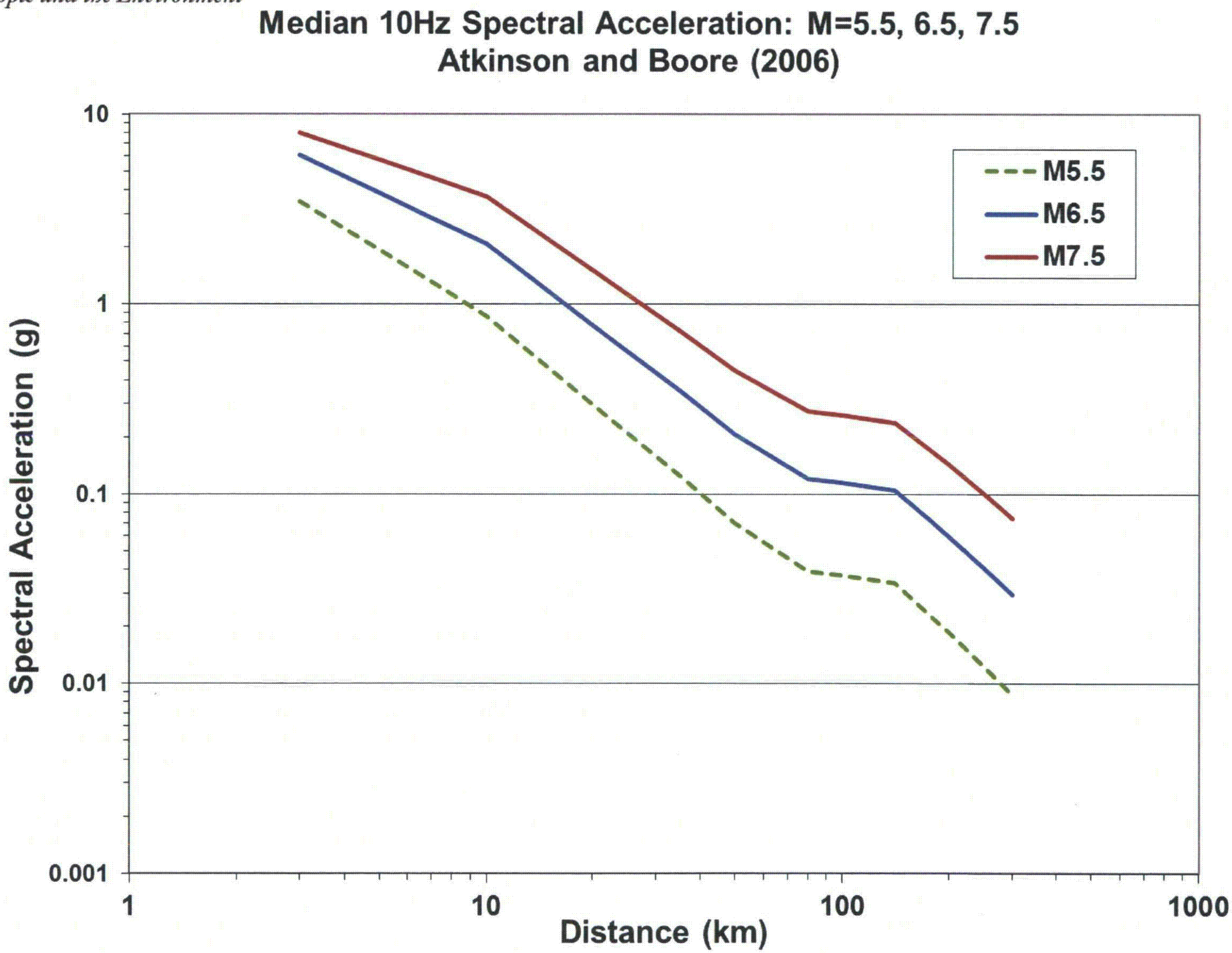
MAGNITUDE-DISTANCE PLOT



Example Ground Motion Model



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EPRI CEUS GMM (2004, 2006)

Cluster	Model Type	Models
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 & Silva (2002) Atkinson (2001) & Sadigh et al. (1997) Campbell (2003)
4	Finite Source /Greens Function	Somerville et al. (2001)

CEUS Ground Motion Models

- EPRI (2004, 2006) used by ESP & COL applicants
- NRC, DOE, and industry initiated NGA-East in 2009
  - Multi-year SSHAC Level 3 project
  - Scheduled to finish in 2015
- EPRI (2004, 2006) specified in 50.54(f) letter
- EPRI decided to update (2004, 2006) model for use in NTTF R2.1 hazard reevaluations

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Rationale for Update

- Significant amount of new data
  - 80% of records from earthquakes since 2002
  - Notable earthquakes
    - 2008 M5.3 Mt. Carmel, IL
    - 2010 M5.0 Val des Bois, Quebec
    - 2011 M5.8 Mineral, VA
    - 2011 M5.6 Sparks, OK
- Measurements at recording stations
- Some older models superseded by newer models

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EPRI CEUS GMM Update

Cluster	Model Type	Models
1	Single Corner Brune Source	Silva et al (2002) - SC-CS-Sat Silva et al (2002) - SC-VS Toro et al (1997) Frankel et al (1996)
2	Complex/Empirical $\sim R^{-1}$ Geometrical spreading	Silva et al (2002) DC – Sat Atkinson (2008')
3	Complex/Empirical $\sim R^{-1.3}$ Geometrical spreading	Atkinson & Boore (2006') Pezeshk et al (2011)
4	Finite Source /Green's Function	Somerville et al. (2001)

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Updated EPRI Ground Motion Model

- EPRI produced draft model and documentation in Feb 2013
- Staff unable to endorse
  - Treatment of uncertainty
  - Documentation of model
- EPRI presented updated GMM at public meeting on March 26
- Updated model appears to address issues raised by peer reviewers and staff

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Updated EPRI Ground Motion Model

- Added treatment of uncertainty for scaling ground motions for increased earthquake magnitudes
- Places a cap on weights for individual models within each cluster
- EPRI working on enhancing documentation
  - Details of database
  - Meeting objectives of SSHAC guidance

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CEUS EPRI Ground Motion Model (GMM)

Path Forward

- Industry requested 6 month delay for CEUS hazard submittals (Sept 2013 to March 2014)
  - Documentation of model complete by June 2013
  - Staff review and interactions complete by Aug 2013
  - If endorsed, updated model to be used by licensees for hazard reevaluations