The Relation between m_{bLg} and M_w and between $m_{Lg}(f)$ and M_w Using Recent US Earthquakes and Random Vibration Theory

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Background

- The *Lg* phase is a superposition of higher-mode surface waves with a group velocity between 3.2 and 3.6 s and with a period between 0.7 and 1.3 s.
- Nuttli (1973) developed the m_{bLg} magnitude scale to quantify the size of an earthquake from 1-second-period *Lg* waves on WWSSN short-period vertical seismograms
- Nuttli (1986) reformulated the original m_{bLg} formula in terms of ground motion at 10 km and accounted for different coefficients of anelastic attenuation
- Herrmann and Kijko (1983) modified the m_{bLg} scale to account for the frequency of the observed *Lg* waves
- In this study, 2 methods are employed for each calculation of m_{bLg} and $m_{Lg}(f)$. The poster presents only the SLU Method, the method that attempts to replicate the USGS procedure for calculating m_{bLg}.

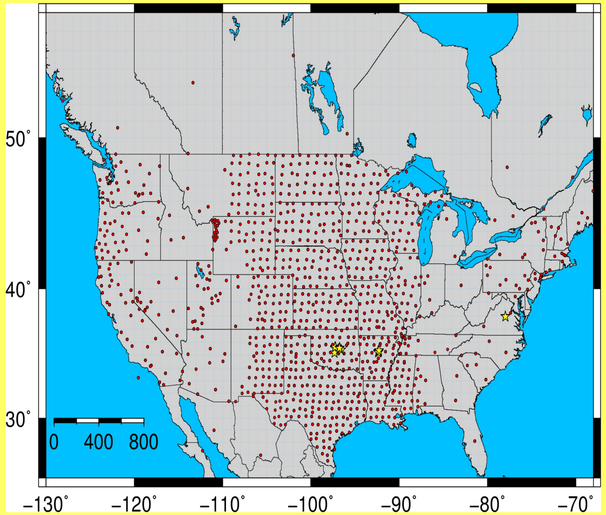
Objectives

- Derive relationship between m_{bLg} and M_w from earthquake data and RVT
- Derive relationship between $m_{Lg}(f)$ and M_w from earthquake data and RVT
- Address whether a single γ is appropriate for the central and eastern United States

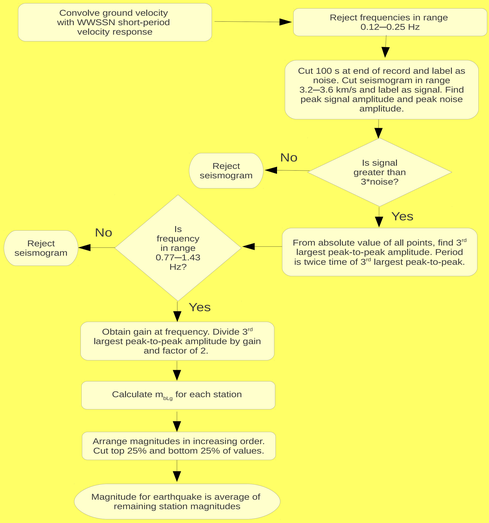
Conclusions

- The regression analysis and modeling support a linear relationship between m_{bLg} and M_w and between $m_{Lg}(f)$ and M_w for $3.0 < M_w < 4.2$.
  - The lack of data for larger events prevents confident predictions for larger m_{bLg} or $m_{Lg}(f)$.
  - We have confidence in using m_{bLg} and $m_{Lg}(f)$ to estimate M_w for smaller events.
- A single γ is probably not appropriate for the central and eastern United States.
  - The 10 earthquakes with the most observations have γ ranging from 0.00007 to 0.00061.

Map of epicenters for 38 earthquakes (yellow stars) and all stations that recorded ground motion (red dots)

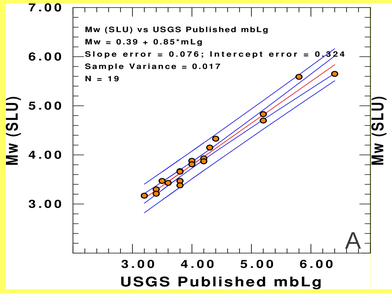


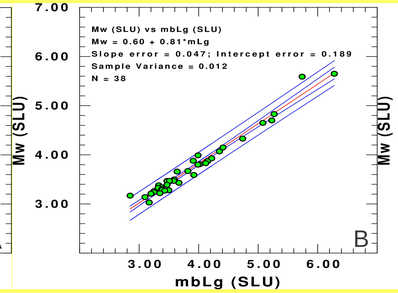
Processing procedure for SLU computation of m_{bLg}

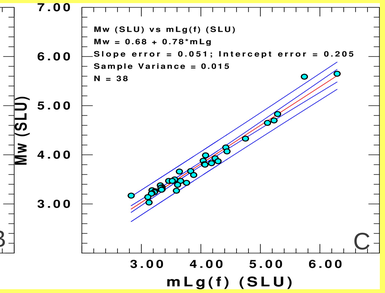


Regression Analysis

- The regression analysis uses linear least-squares regression for Figures A–C
- Figure A depicts the relationship between the published NEIC m_{bLg} magnitudes and the SLU M_w magnitudes
- Figure B depicts the relationship between the SLU m_{bLg} magnitudes and the SLU M_w magnitudes.
- Figure C depicts the relationship between the SLU $m_{Lg}(f)$ magnitudes and the SLU M_w magnitudes
- Figures A–C: the red line is the regression line, the inner blue lines are the 95% confidence bands on the regression line, and the outer blue lines are the 95% confidence bands on the data

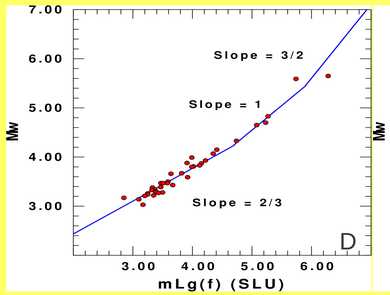


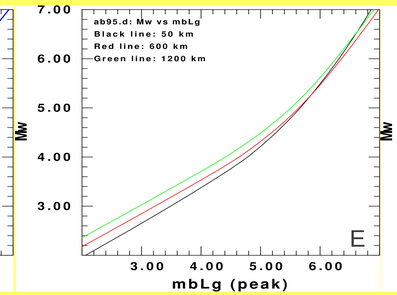


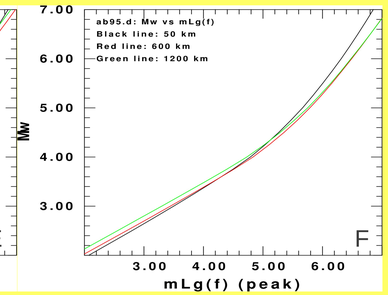


Modeling

- The model input for the random vibration theory simulations is from Atkinson and Boore (1995)
- Because random vibration theory predicts peak motions, peak ground displacement is used in the calculation of the m_{bLg} and $m_{Lg}(f)$ magnitudes. The use of peak motions lead to overestimates of m_{bLg} and $m_{Lg}(f)$ compared to the use of 3rd largest peak-to-peak motion, as Figure D uses.
- Figure D shows a possible tripartite relationship between $m_{Lg}(f)$ and M_w based on simple spectral scaling for smaller magnitudes and on simulations for larger magnitudes.
- Figures E and F show the relationships between the *Lg* magnitudes and M_w for simulations at 3 distances.
- Figure F highlights the effect of a frequency-dependent γ.







Magnitude Formula: m_{bLg}

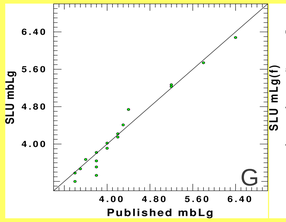
- $m_{bLg} = 2.96 + .8333\log(r/10) + .4343\gamma r + \log(A_0)$
  - Epicentral distance r (km)
  - Coefficient of anelastic attentuation γ (km^{-1})
  - Third-largest instrument-corrected amplitude A_0 (μm)
  - Nuttli (1973) computed γ = .07 deg^{-1}= .00063 km^{-1} for North America east of the Rocky Mountains

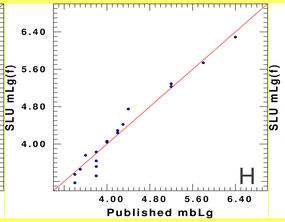
Magnitude Formula: $m_{Lg}(f)$

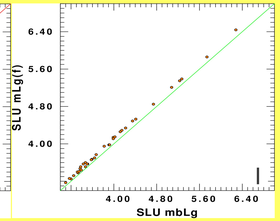
- $m_{Lg}(f) = 2.94 + .8333\log(r/10) + .4343\gamma r + \log(A_0)$
  - Epicentral distance r (km)
  - Coefficient of anelastic attentuation γ (km^{-1})
  - Third-largest instrument-corrected amplitude A (μm)
  - Herrmann and Kijko (1983) used γ = .001$f^{0.7}$

Note: Processing procedure for $m_{Lg}(f)$ is the same as above except that γ = .001$f^{0.7}$ instead of γ = .00063 km^{-1}

Figures G–I show the *Lg* magnitudes plotted against each other



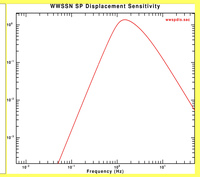




Instrument Information

CONSTANT 532.1425
ZEROS 2
0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00
POLES 5
-3.72500000E+00 6.22000000E+00
-3.72500000E+00 -6.22000000E+00
-5.61200000E+00 0.00000000E+00
-1.32400000E+01 0.00000000E+00
-2.10800000E+01 0.00000000E+00

- The above information gives a displacement sensitivity of 1 at 1 Hz
- We divided the original constant from HYDRA (3.34355005e+03) by 2π



Gamma Calculation

- The model for amplitude as a function of distance was $A(r)=Cr^{-n}e^{-\gamma r}$
  - Constant C (dimensionless)
  - Geometric speading n (dimensionless)
  - Coefficient of anelastic attenuation γ (km^{-1})
  - Epicentral distance r (km)
- We linearized the model:
  $\ln(A) + n*\ln(r) = -\gamma r + \ln(C)$
- We assumed n = .8333, an assumption consistent with an Airy phase
- Only distances between 50 and 1200 km are used in the regression

Date	Mw	γ (km-1)
15 January 2010	3.81	0.00061
27 February 2010	4.15	0.00023
13 October 2010	4.33	0.00026
20 November 2010	3.87	0.00030
24 November 2010	3.93	0.00020
18 February 2011	4.07	0.00016
28 February 2011	4.65	0.00010
5 November 2011	4.70	0.00007
6 November 2011	5.59	0.00031
8 November 2011	4.83	0.00042

References

Herrmann, R. B. and A. Kijko (1983). Short-Period *Lg* Magnitudes: Instrument, Attenuation, and Source Effects, *Bull. Seism. Soc. Am.*, **73**, 1835-1850.

Nuttli, O.W. (1986). *Lg* magnitudes of selected east Kazakhstan underground explosions, *Bull. Seismol. Soc. Amer.*, **76**, 1241-1251

Nuttli, O.W. (1973). Seismic wave attenuation and magnitude relations for eastern North America, *J. Geophys. Res.*, **78**, 876-885.