Investigation of the m_{bLg} Magnitude Using Recent USArray Transportable Array Waveforms

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Background

- The *Lg* phase comprises a superposition of higher-mode surface waves with a group velocity of about 3.5 km/s
- Nuttli (1973) developed the m_{bLg} magnitude scale to quantify the size of an earthquake from 1-second-period *Lg* waves
- Nuttli (1986) calibrated the original m_{bLg} formula at 10 km and accounted for different coefficients of anelastic attenuation
- The NEIC and this study use an approximation of Nuttli's 1986 formula

Objectives

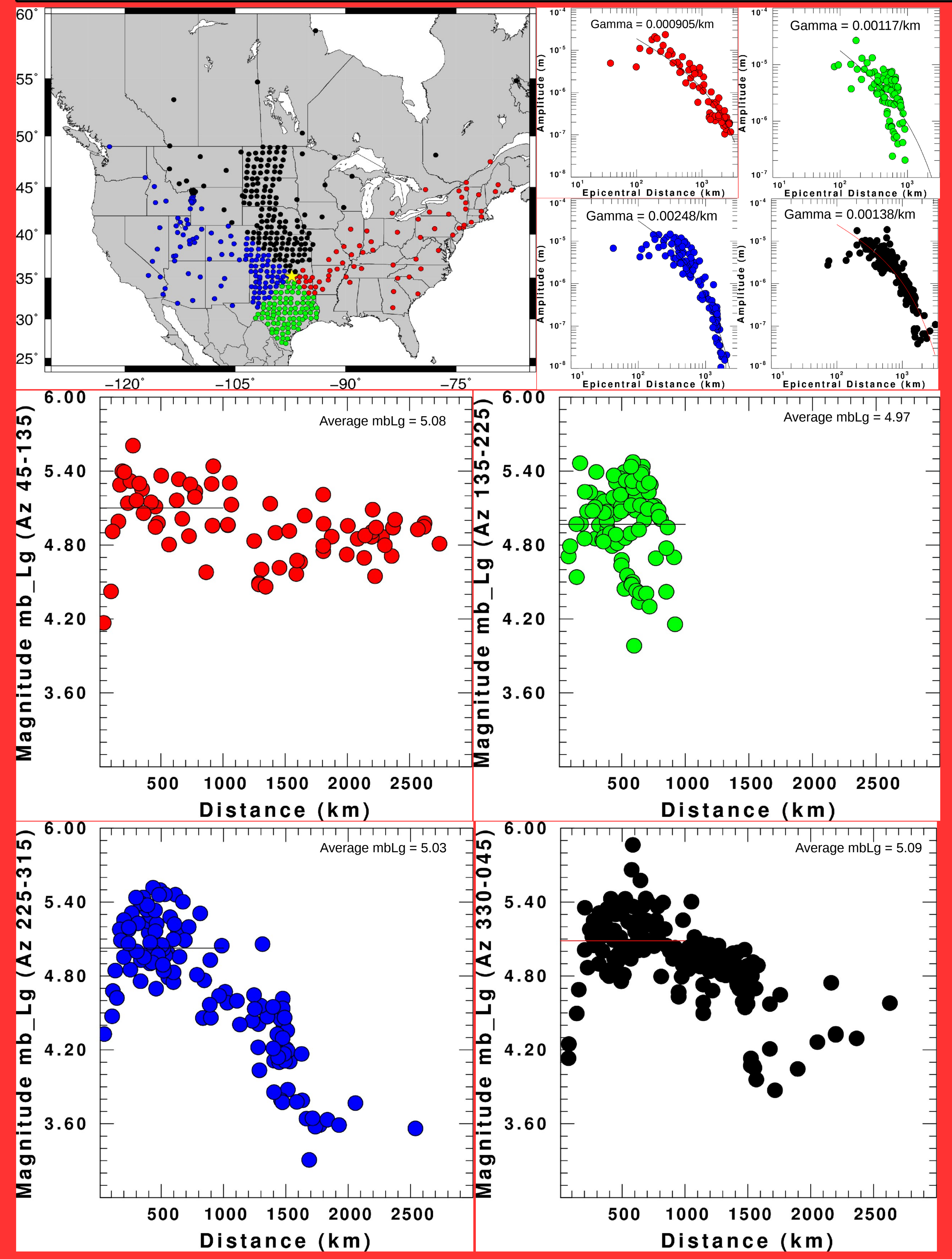
- Determine whether the m_{bLg} scale is consistent across epicentral distances
- Determine whether a constant coefficient of anelastic attenuation is appropriate for all paths east of the Rocky Mountains
- Determine whether the m_{bLg} scale and the M_w scale have a discernible relationship so that an m_{bLg} magntiude could be a proxy for an M_w magnitude

Conclusions

- The average m_{bLg}, whether computed using only stations under 1000 km or those both above and below 1000 km, are similar.
  - However, a conspicuous drop in magnitude after 1000 km occurs for wave propagation paths to the west and to the north.
- A constant coefficient of elastic attenuation is not justified for all paths east of the Rocky Mountains.
  - For example, those through the Great Plains to the north may have coefficients 50% to 100% greater than Nuttli's value
- A linear formula between m_{bLg} and M_w over the M_w range of 3 to 4.5 may be a sufficient approximation
  - Outside of this range, though, a linear relationship may not hold

Oklahoma, October 13, 2010

M_w = 4.33 m_{blg}1000 = 5.07 m_{bLg}all = 4.94



Gamma Calculation

- Although for the magnitude computations γ = .00063 km^{-1} was used, we computed different gamma values for each azimuthal sector
- 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 assumed n = .8333, an assumption consistent with an Airy phase
- We linearized the model with the following result
  $\ln(A) + n*\ln(r) = -\gamma r + \ln(C)$
- We performed linear least-squares regression with $Y = \ln(A) + n*\ln(r)$, $B = \ln(C)$, and $M = -\gamma$

Magnitude Formula

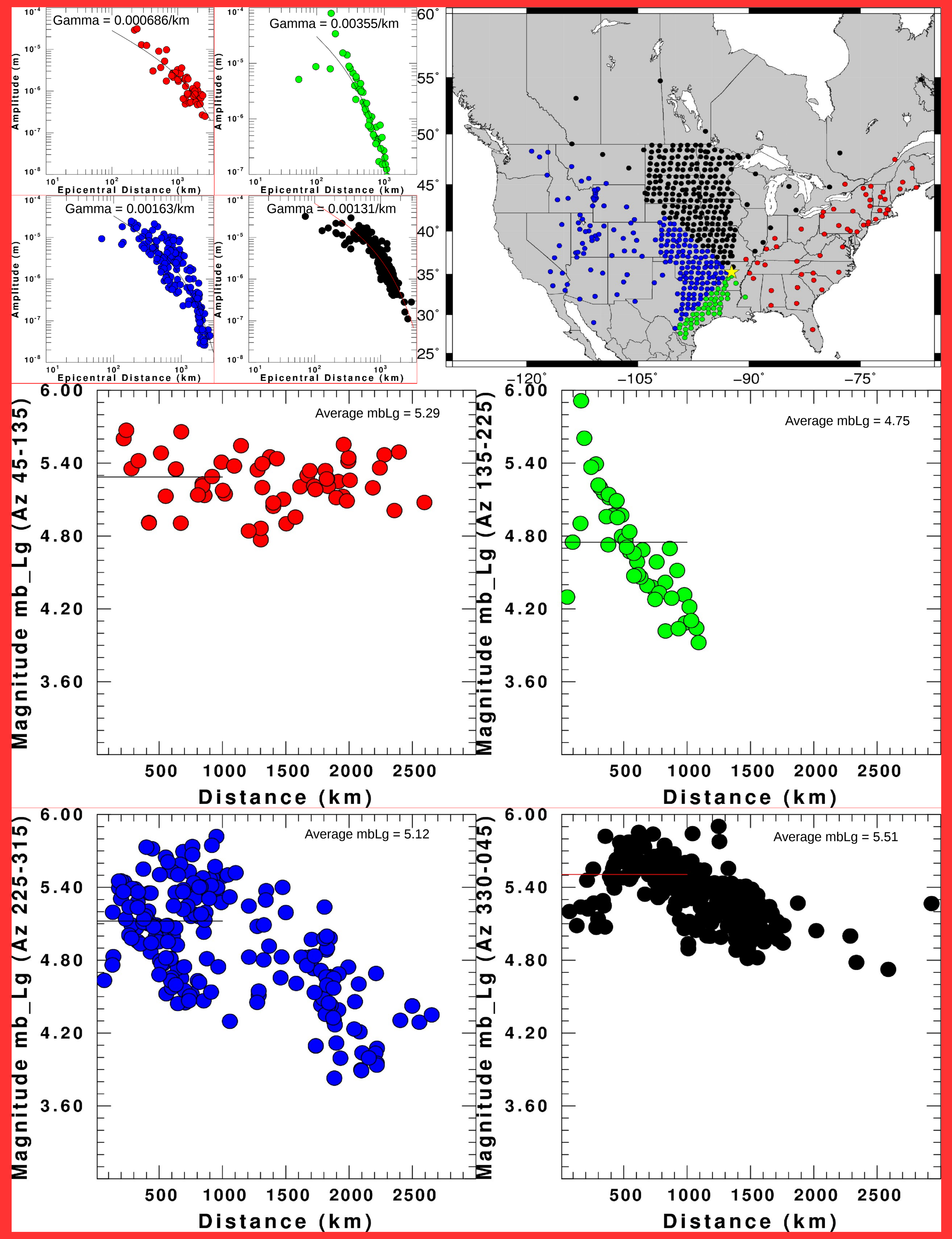
- m_{bLg} = 2.96 + .8333log(r/10) + .4343γr + log(A_0)
  - Epicentral distance r (km)
  - Coefficient of anelastic attentuation γ (km^{-1})
  - Instrument-corrected amplitude A_0 (μm)
  - Nuttli (1973) computed γ = .07 deg^{-1}= .00063 km^{-1} for North America east of the Rocky Mountains

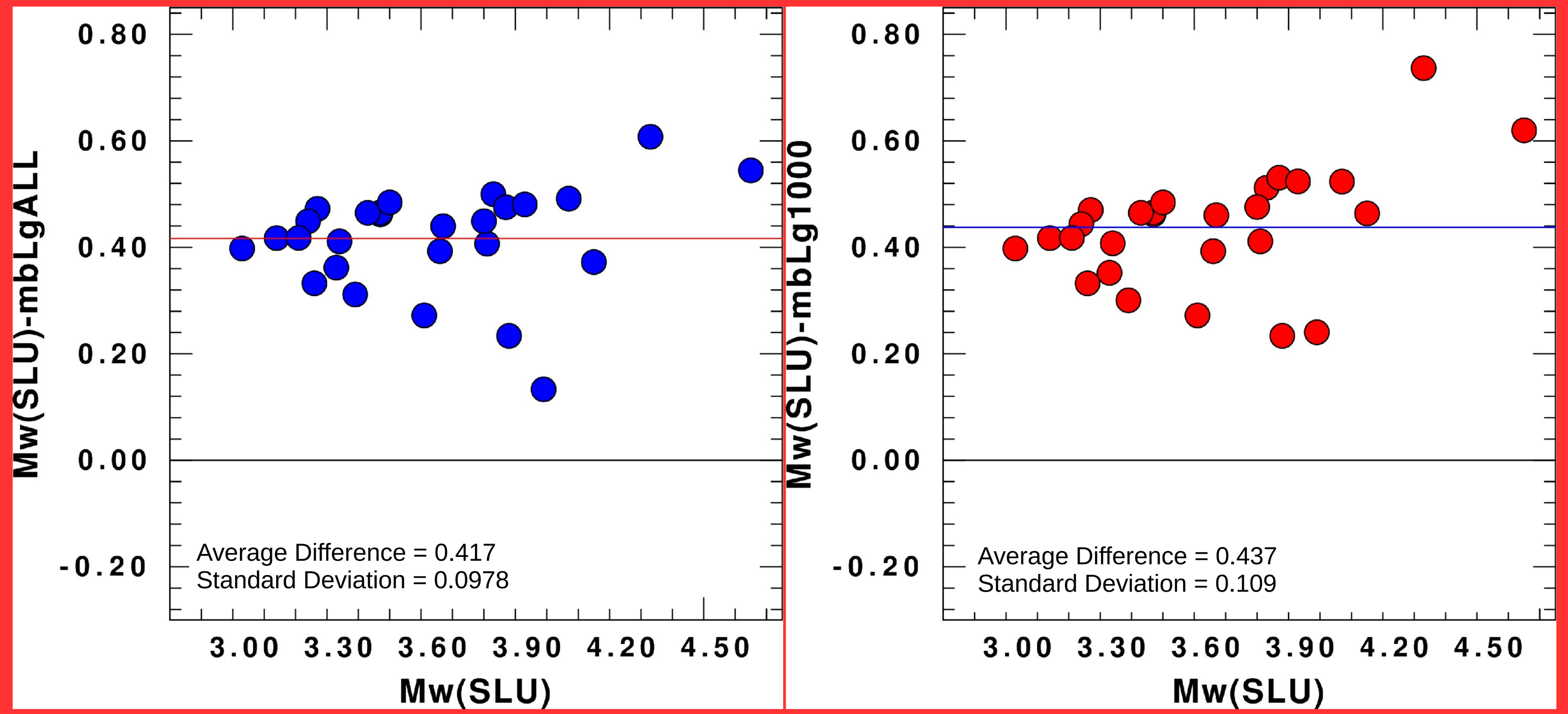
Magnitude Computation

- The epicentral distance for each station came directly from the sac file
- To compute A_0, we used the following formula:
  A_0 = (|Maximum Peak| + |Lowest Trough|)/2
- We divided the event region into 4 sectors by azimuth and calculated an average for each sector for the epicentral distances 0 to 1000 km
- For the m_{bLg} of the entire event, we calculated 2 trimmed averages:
  - A trimmed 25% mean for all stations within 1000 km
  - A trimmed 25% mean for all stations

Arkansas, February 28, 2011

M_w = 4.65 m_{bLg}1000 = 5.27 m_{bLg}all = 5.19

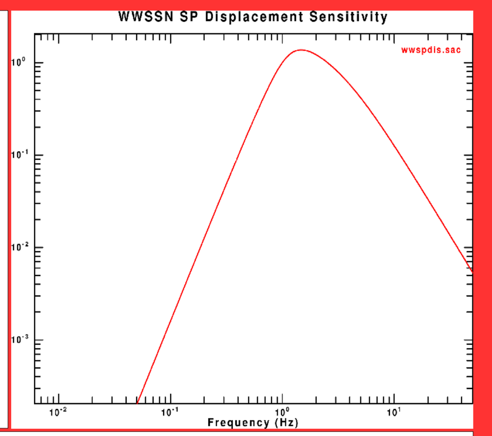




Instrument Information

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



Processing Procedure

- Deconvolve waveforms in order to obtain ground motion velocity in m/s
- Remove trend
- Convolve ground motion velocity with WWSSN short-period instrument response in order to obtain seismograms
- Limit velocity window from 3.2 km/s to 3.6 km/s
- Using only vertical component, cut 100 seconds at the end of seismogram and label noise
- Find maximum peak
- Keep seismograms with maximum positive peak at least 3 times the noise
- Reject frequencies between .1 and .25 Hz

Mw vs mbLg-Mw

- The m_{bLg} trimmed mean averages minus the M_w values are plotted against M_w
- The statistics for both plots suggest that the differences between all stations and those under 1000 km is slight
- Over the magnitude interval of the studied events, the m_{bLg} is about .3 to .5 units above the M_w, possibly implying a simple formula:
  $M_w \approx m_{bLg} + .4$
- We also ran computer simulations using stochastic processes and scaling, giving similar results in the magnitude range of the actual events
- However, the computer simulations showed that, outside of the studied magnitude interval, a simple formula may not hold

References
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.