Regionalization and its Effects on Ground Motions, Gulf Coast Issues, and Geometric-Spreading from Virginia Aftershocks

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USGS National Seismic Hazard Map Workshop on Ground Motion Predication Equations for the 2014 Update

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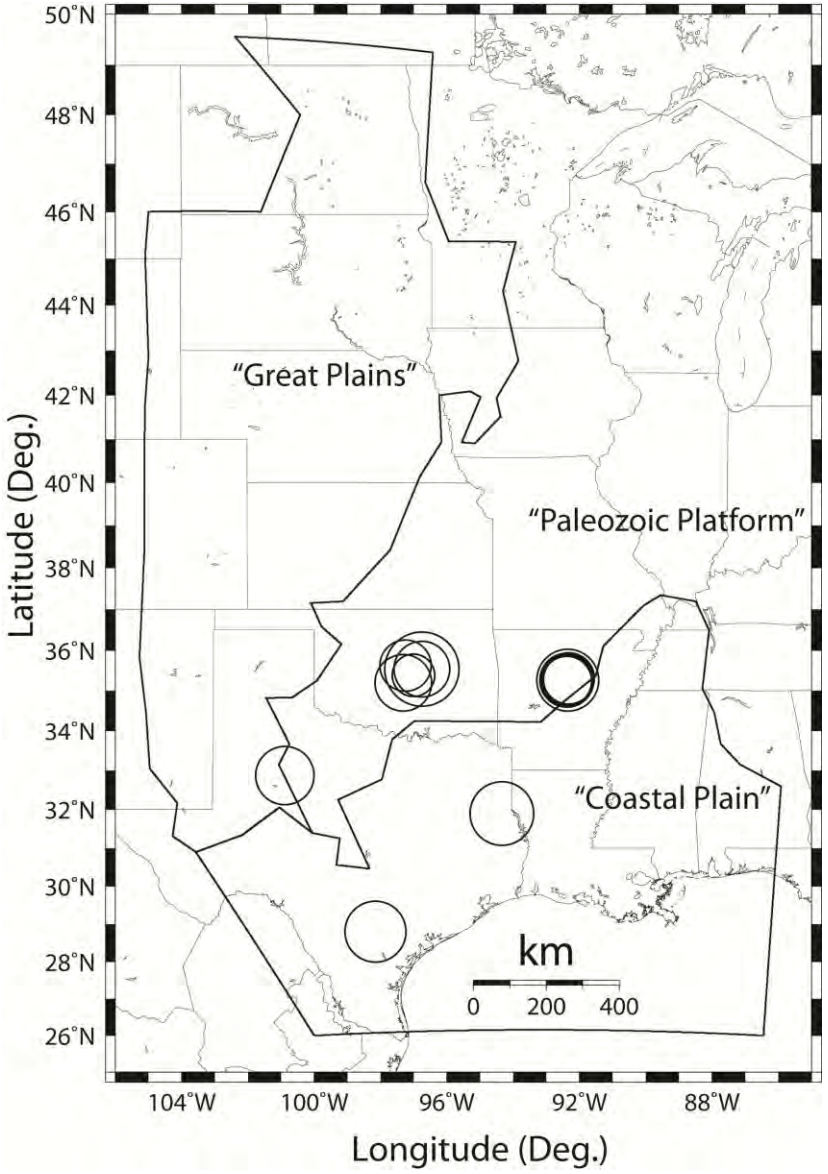
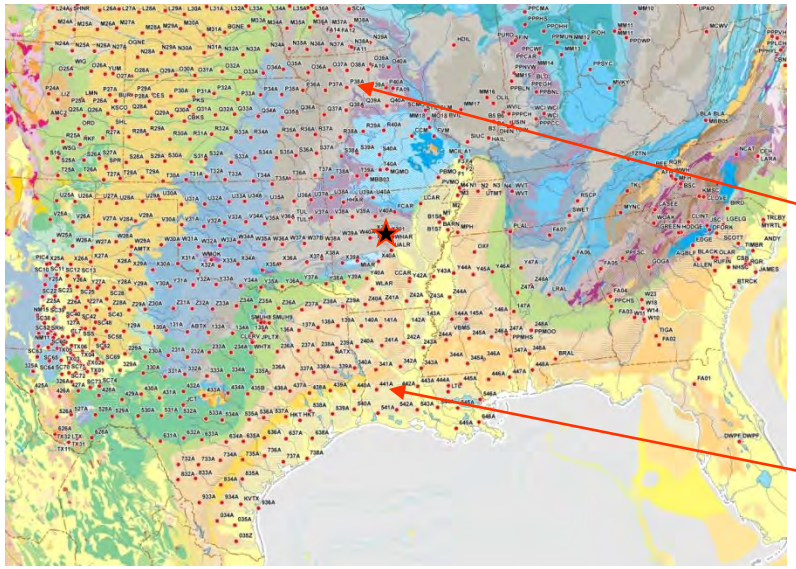


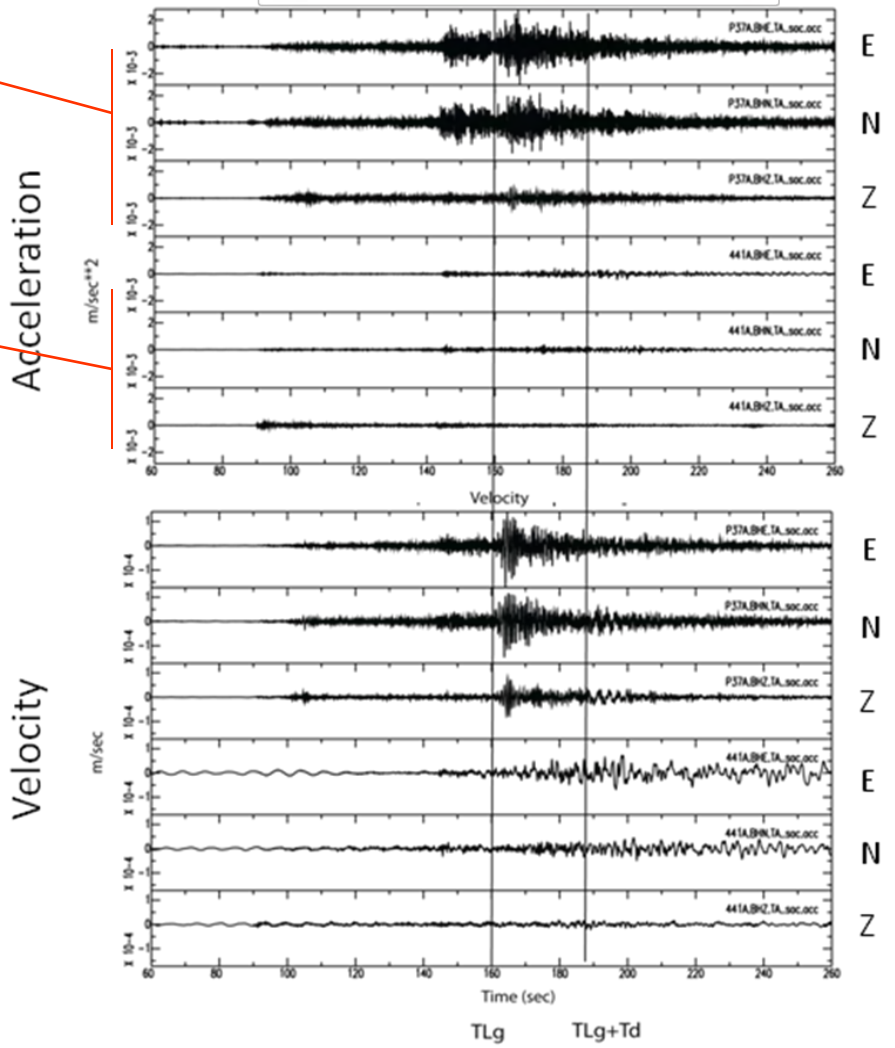
Table 1

No.	State	Date	Lat.	Long.	Moment Magnitude
1	OK	10-13-2010	35.202	-97.309	4.33
2	AR	10-15-2010	35.276	-92.322	3.80
3	AR	11-20-2010	35.316	-92.317	3.90
4	OK	11-24-2010	35.627	-97.246	3.90
5	OK	12-27-2010	35.540	-96.750	4.15
6	OK	12-12-2010	35.392	-96.995	3.20
7	AR	02-17-2011	35.276	-92.361	3.80
8	AR	02-18-2011	35.257	-92.370	3.90
9	AR	02-18-2011	35.271	-92.377	4.10
10	AR	02-28-2011	35.265	-93.340	4.65
11	AR	04-07-2011	35.350	-92.373	3.73
12	AR	04-08-2011	35.261	-92.362	3.90
13	OK	11-06-2011	35.537	-96.747	5.60
14	TX	09-11-2011	32.874	-100.876	4.40
15	TX	10-20-2011	28.806	-98.147	4.60
16	TX	05-17-2012	31.902	-94.332	4.83

Circles show epicenters of 16 earthquakes listed in Table 1. Lines define three regions defined on the basis of surface geology.



Upper: Acceleration recordings at station P37A (Missouri) and 441A (Louisiana). Lower: Velocity. Three component motions E-W, N-S, Vertical are indicated



Definition of signal duration

$$\int_{t_0}^{t_0+t_d} a^2\,dt = 0.7 \int_{t_0}^{t_0+150} a^2\,dt$$

$$t_d = 8.71 + 0.026\Delta$$

TLg = origin time + r / 3.53

Td = 8.71 + 0.026 r

If the amplitude variations described above are due to propagation effects resulting from crustal structure relatively near the sites, a potentially useful regression model to parameterize the effect would be the following:

Fourier Amplitude, earthquake i, receiver j.

d = 1/Qβ

$$Ln\left[\frac{A_{ij}(\omega)}{g(r_{ij})}\right] = \sum_{p=1}^{neq} c_p \ln S_p(\omega) + \sum_{q=1}^{nsta-1} b_q \ln T_q(\omega) - d\frac{\omega r_{ij}}{2}$$

Source Term

Receiver Term

Geometrical Spreading

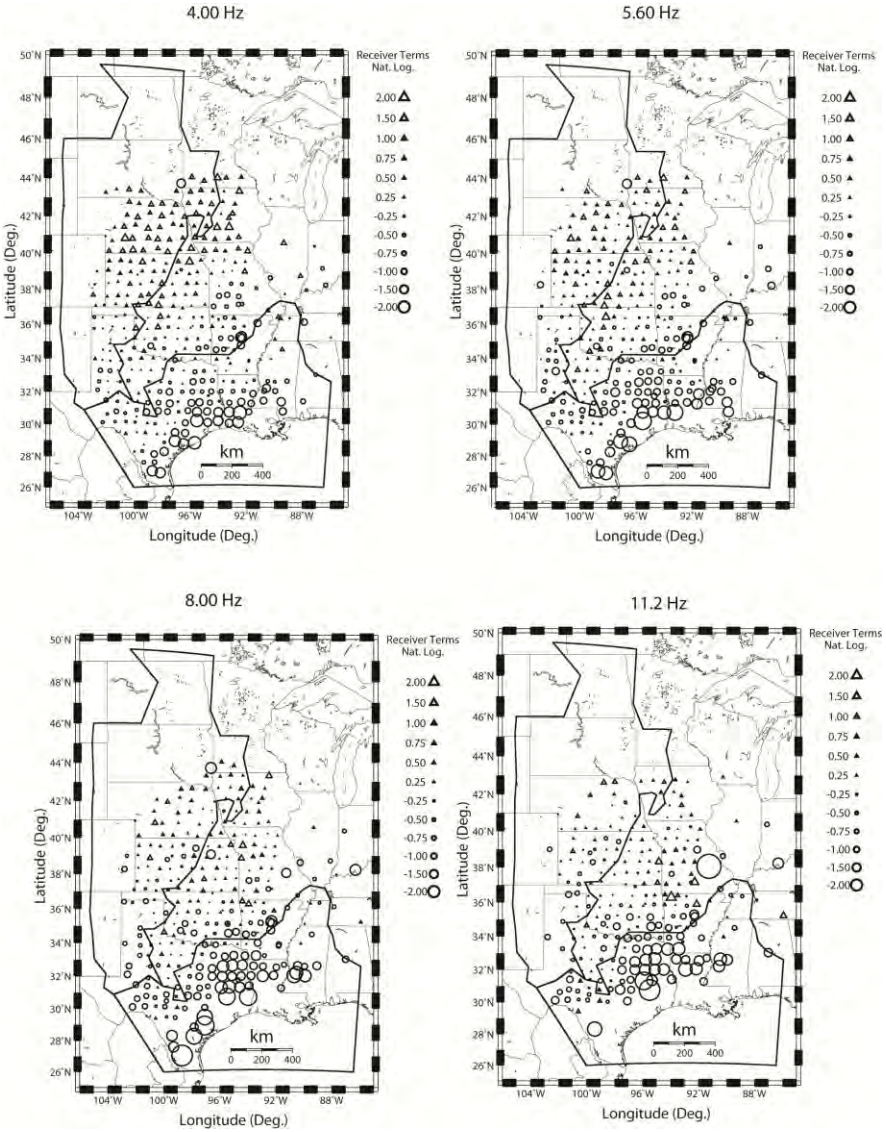
$c_p = 1$ if $p=i$, $c_p = 0$ otherwise

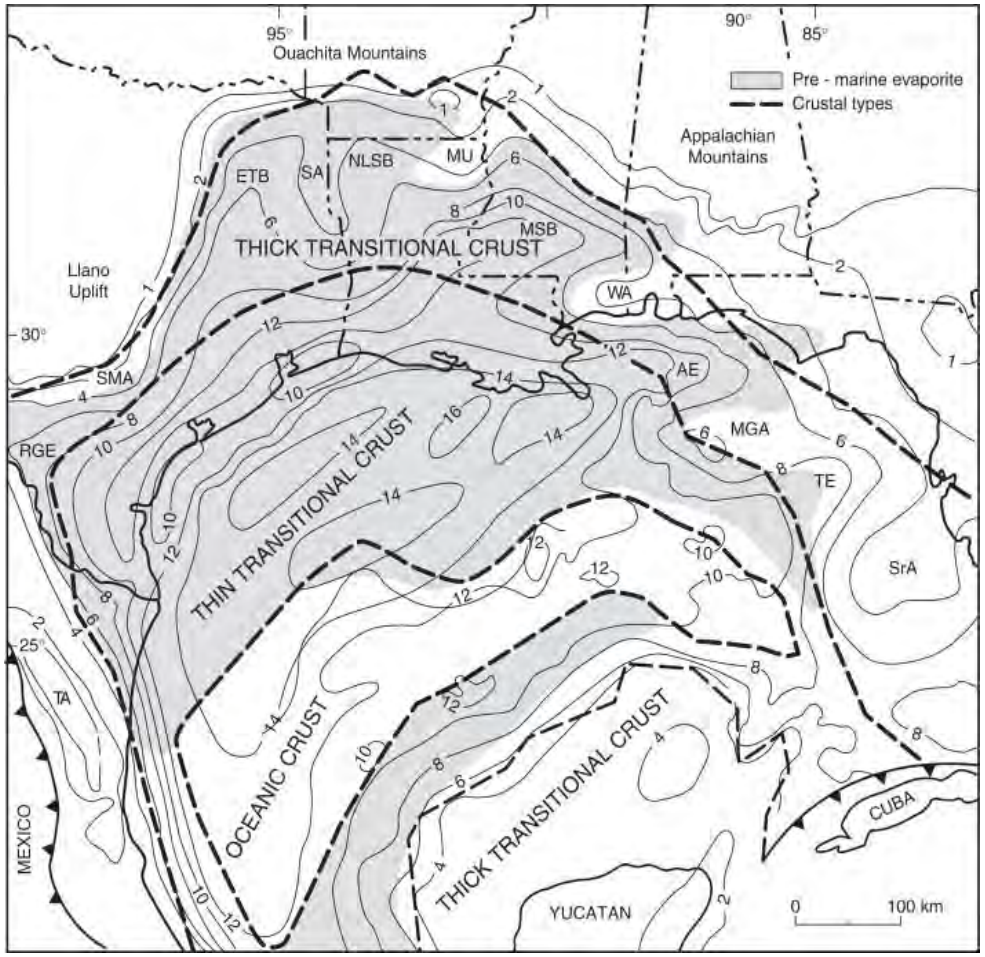
$b_q = 1$ if $q=j$, $b_q = 0$ otherwise

Unknowns to be determined: neq source terms, nsta-1 receiver terms, and d

Note: an arbitrary constant can be added to all receiver terms and subtracted from all source terms.

Receiver Terms





Crustal types, depth to basement (km), and original distribution of Jurassic Louann pre-marine evaporite beneath the Gulf of Mexico basin. *From Galloway,W.E. (2008) Depositional Evolution of the Gulf of Mexico Sedimentary Basin, in Sedimentary Basins of the United States and Canada, Vol. 5, pp 505-548, Elsevier*.

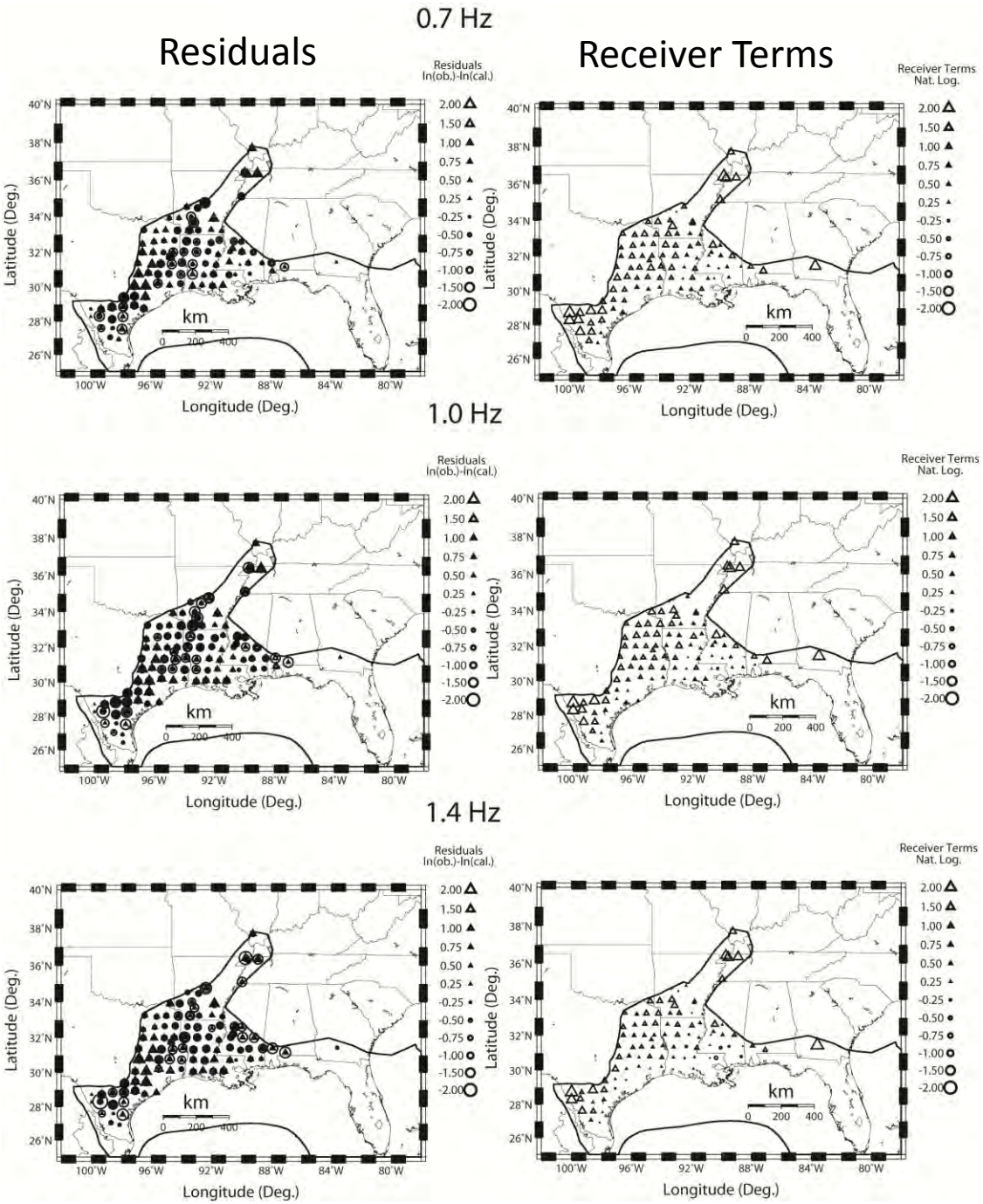
$$Ln\left[\frac{A_{ij}(f)}{S_i(f)G_{ij}(r)}\right] = R_j(f) - \frac{\pi r_{ij} f}{QV}$$

$A_{ij}(f)$ = Fourier acceleration amplitude (geometric mean of the two horizontal components),
$S_i(f)$ = Earthquake source amplitude spectrum,
$G_{ij}(r)$= Geometrical spreading (independent of frequency f),
$R_j(f)$ = Site amplitude term,
r_{ij} = hypocentral distance, from ith earthquake to the jth station.

$$G(r) = r^{-1.3}, \qquad r \leq 60\ km$$

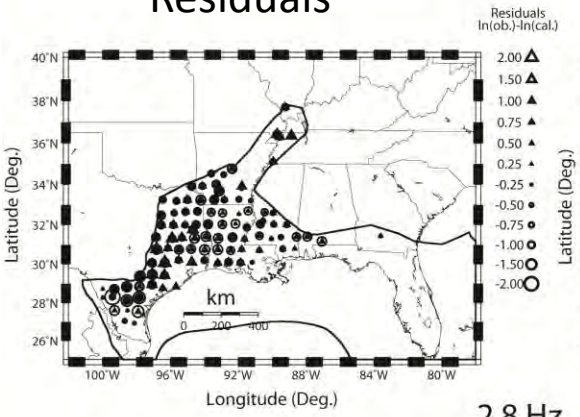
$$G(r) = 60^{-1.3}, 60 \leq r \leq 120\ km$$

$$G(r) = 60^{-1.3}\left(\frac{r}{120}\right)^{-0.5}, r > 120\ km$$

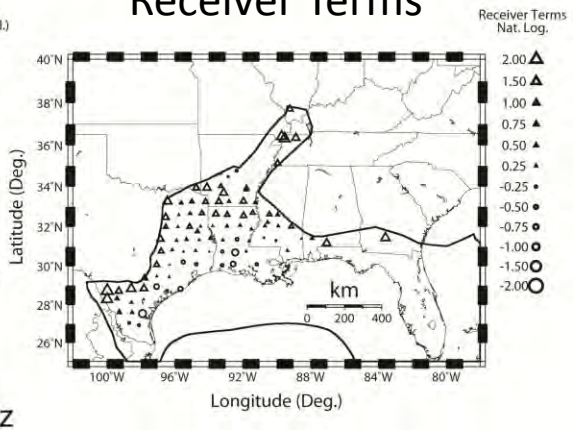

0.7 Hz
Residuals
Receiver Terms
1.0 Hz
1.4 Hz
Residuals
ln(ob.)-ln(cal.)
Receiver Terms
Nat. Log.
2.00
1.50
1.00
0.75
0.50
0.25
-0.25
-0.50
-0.75
-1.00
-1.50
-2.00
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
Latitude (Deg.)
100°W
96°W
92°W
88°W
84°W
80°W
Longitude (Deg.)
km
0
200
400

2.0 Hz

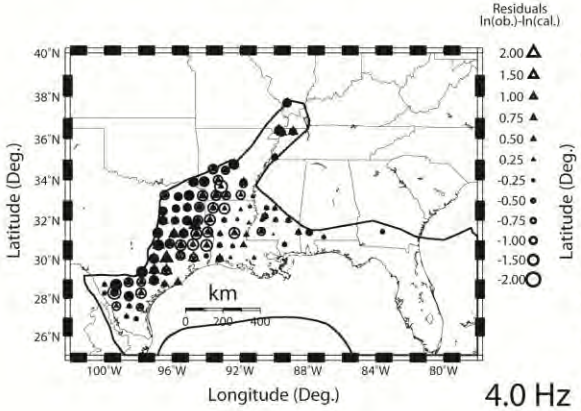
Residuals

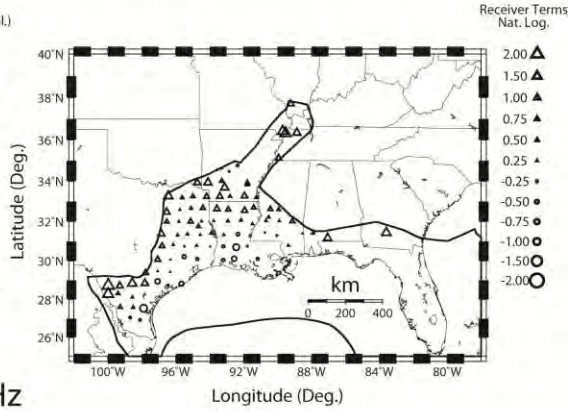


Receiver Terms

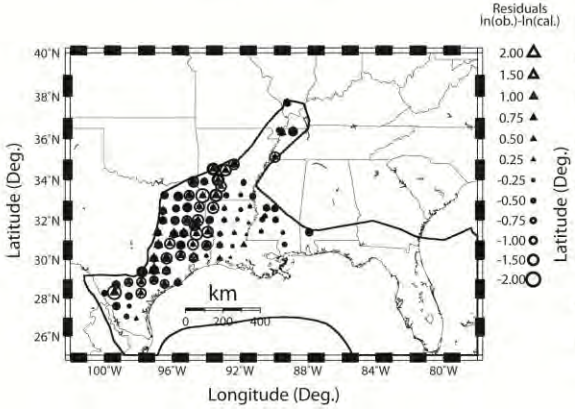


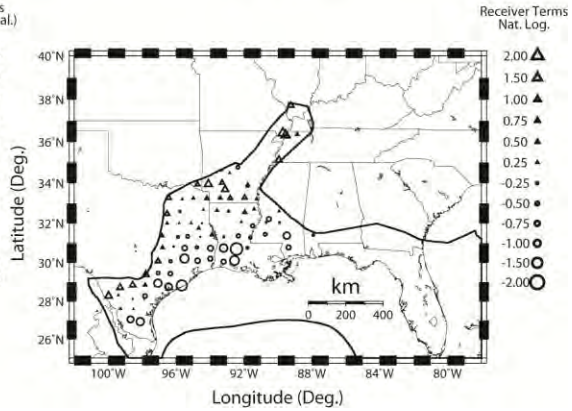
2.8 Hz

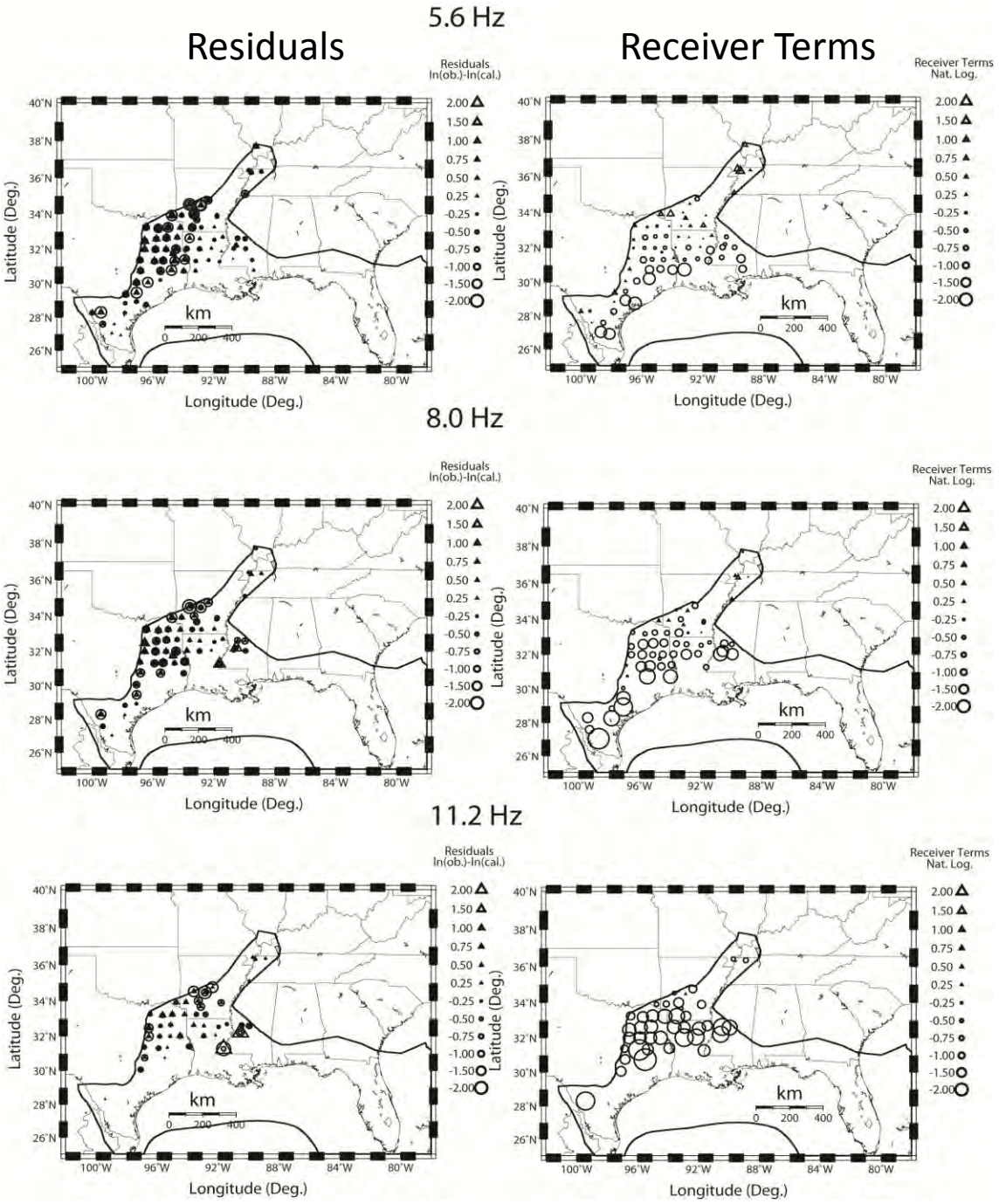


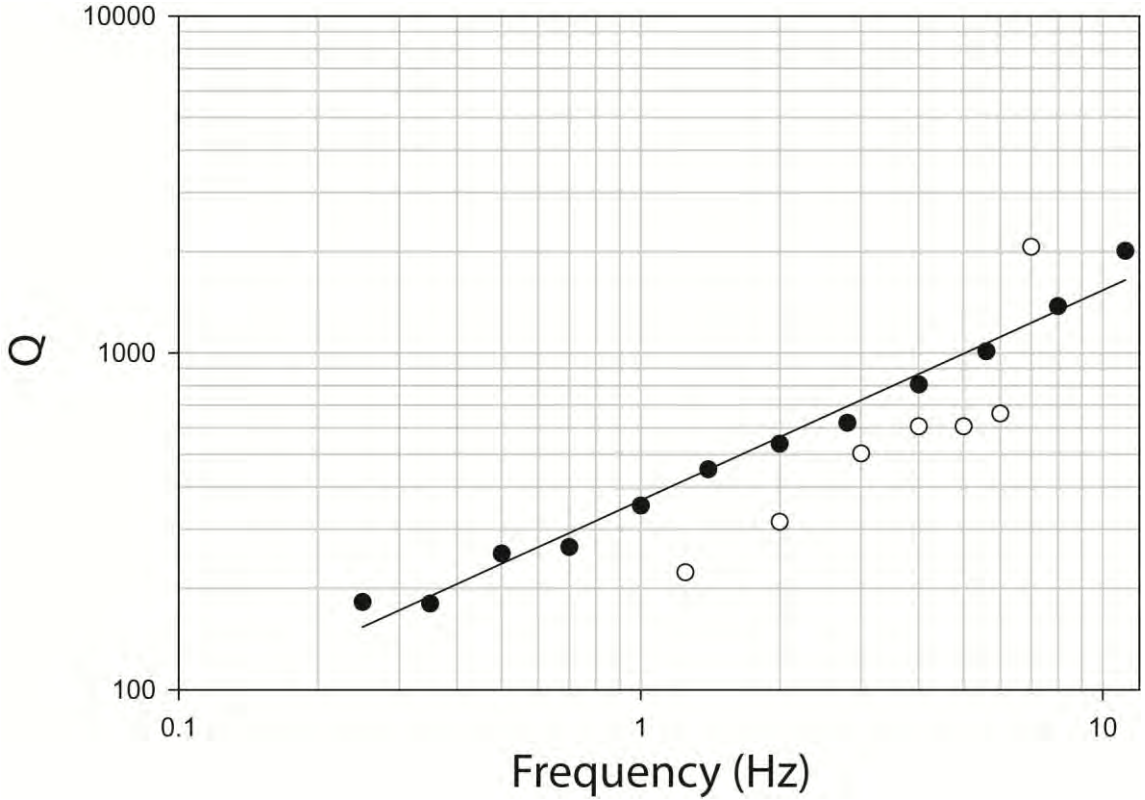


4.0 Hz






5.6 Hz
Residuals
Receiver Terms
8.0 Hz
11.2 Hz
Residuals
ln(ob.)-ln(cal.)
Receiver Terms
Nat. Log.
Latitude (Deg.)
Longitude (Deg.)
km
0 200 400
2.00
1.50
1.00
0.75
0.50
0.25
-0.25
-0.50
-0.75
-1.00
-1.50
-2.00
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
100°W
96°W
92°W
88°W
84°W
80°W

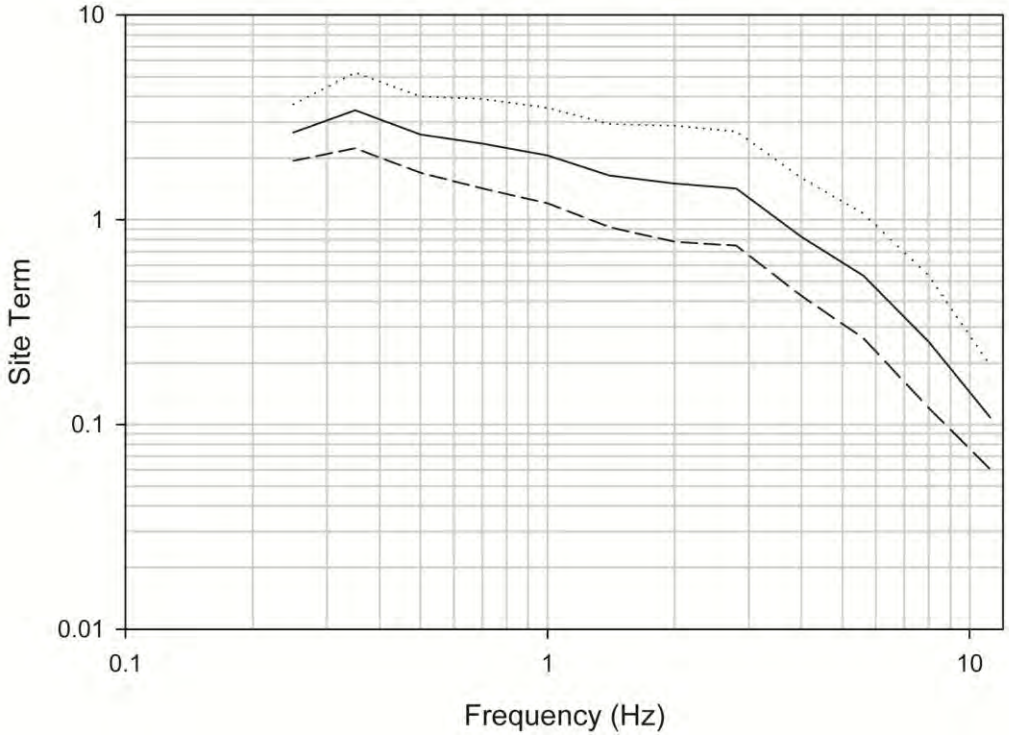


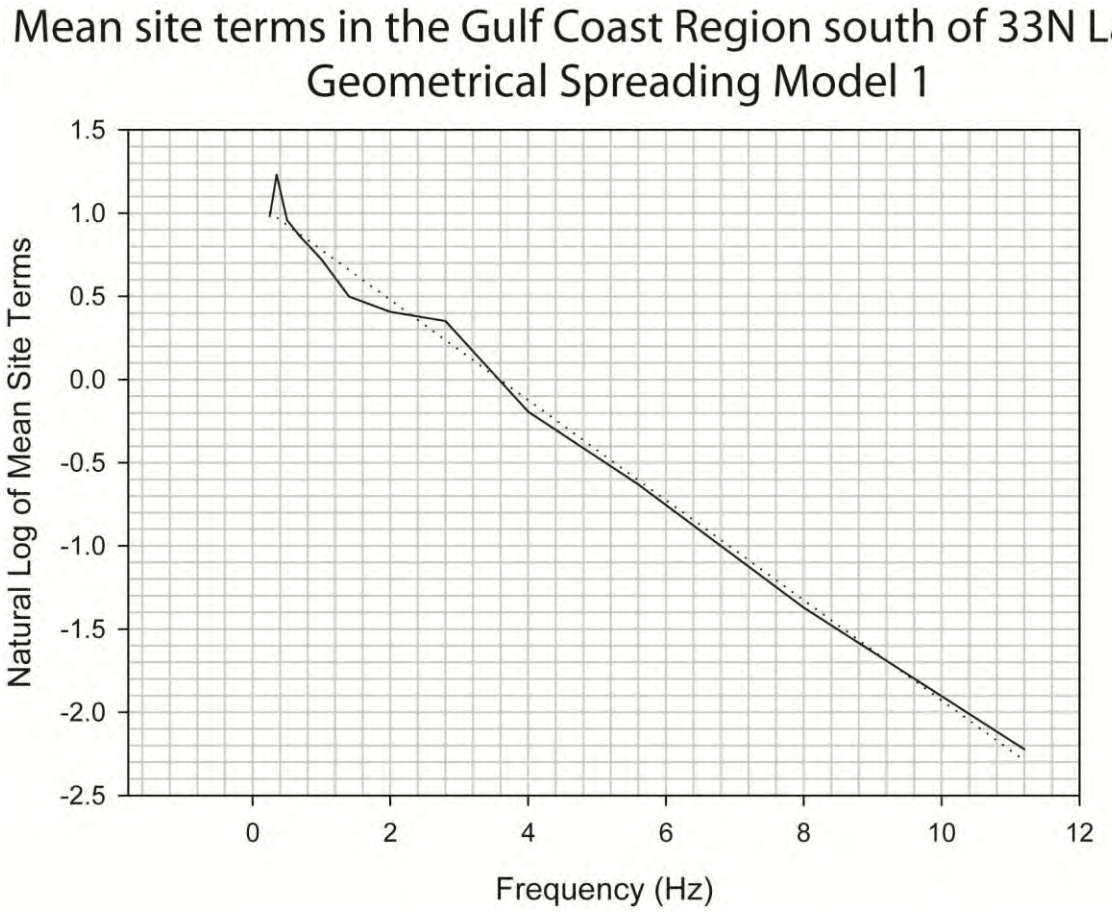
$$\log Q = (2.562 \pm 0.014) + (0.624 \pm 0.025) \log f$$

or

$$Q = 365 f^{0.624}$$

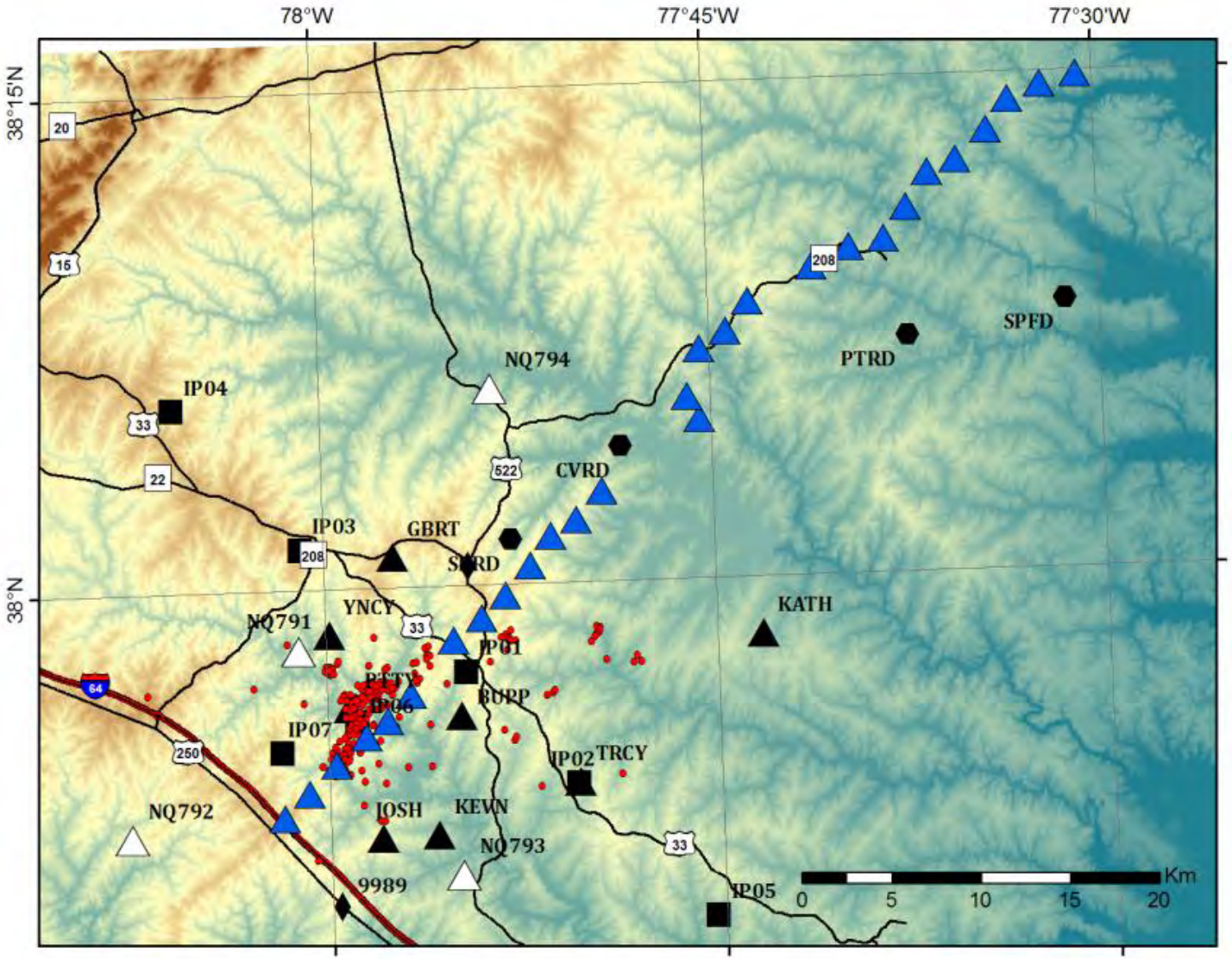
Site terms for stations in the Gulf Coast Region south of 33N Latitude
Geometrical Spreading Model 1



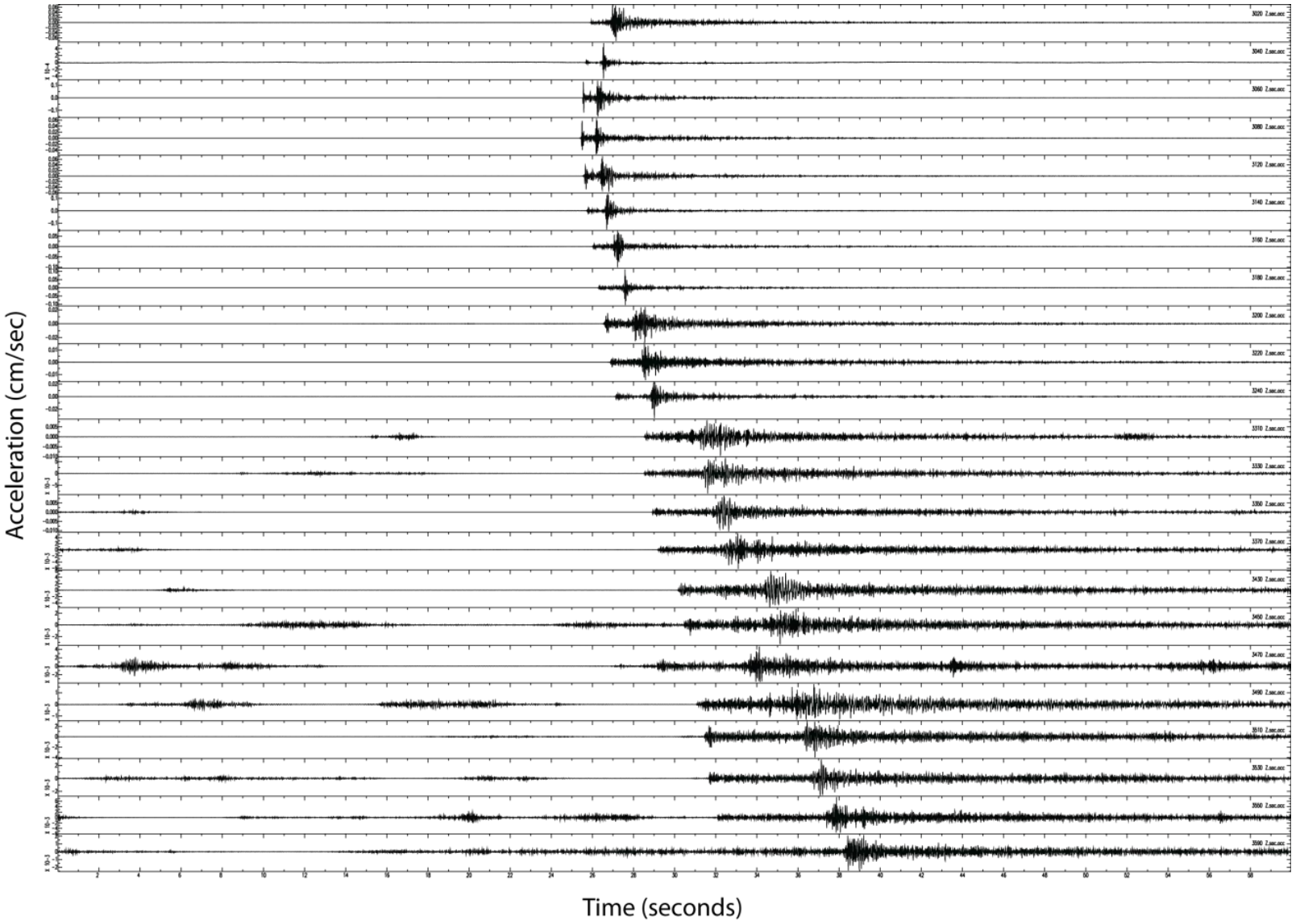


The dotted line shows a linear regression fit to the natural logarithm of the site terms, implying a K_o value of 0.096 +/- 0.010

Preliminary Results Concerning High-Frequency Ground Motion From the 2011 Virginia Earthquake Aftershock Sequence

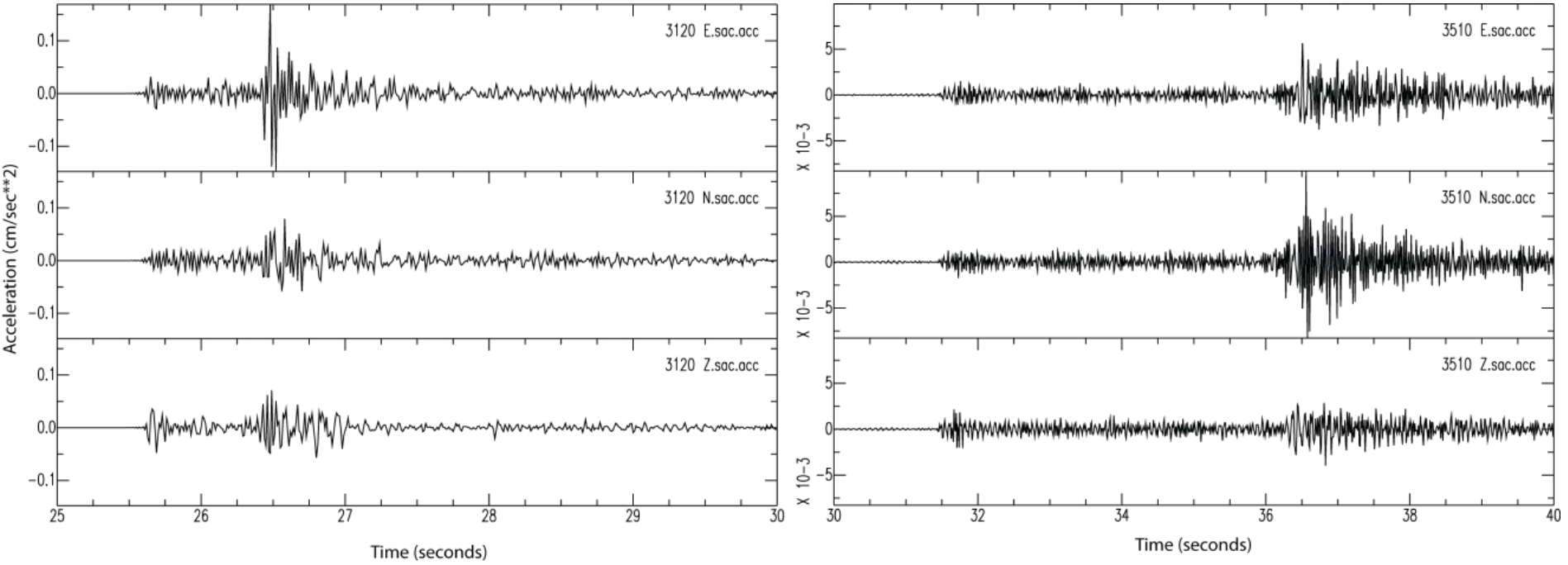


Vertical component (acceleration) recordings of the 16:54, Sept. 5, 2011 UTC aftershock recorded by the AIDA profile stations

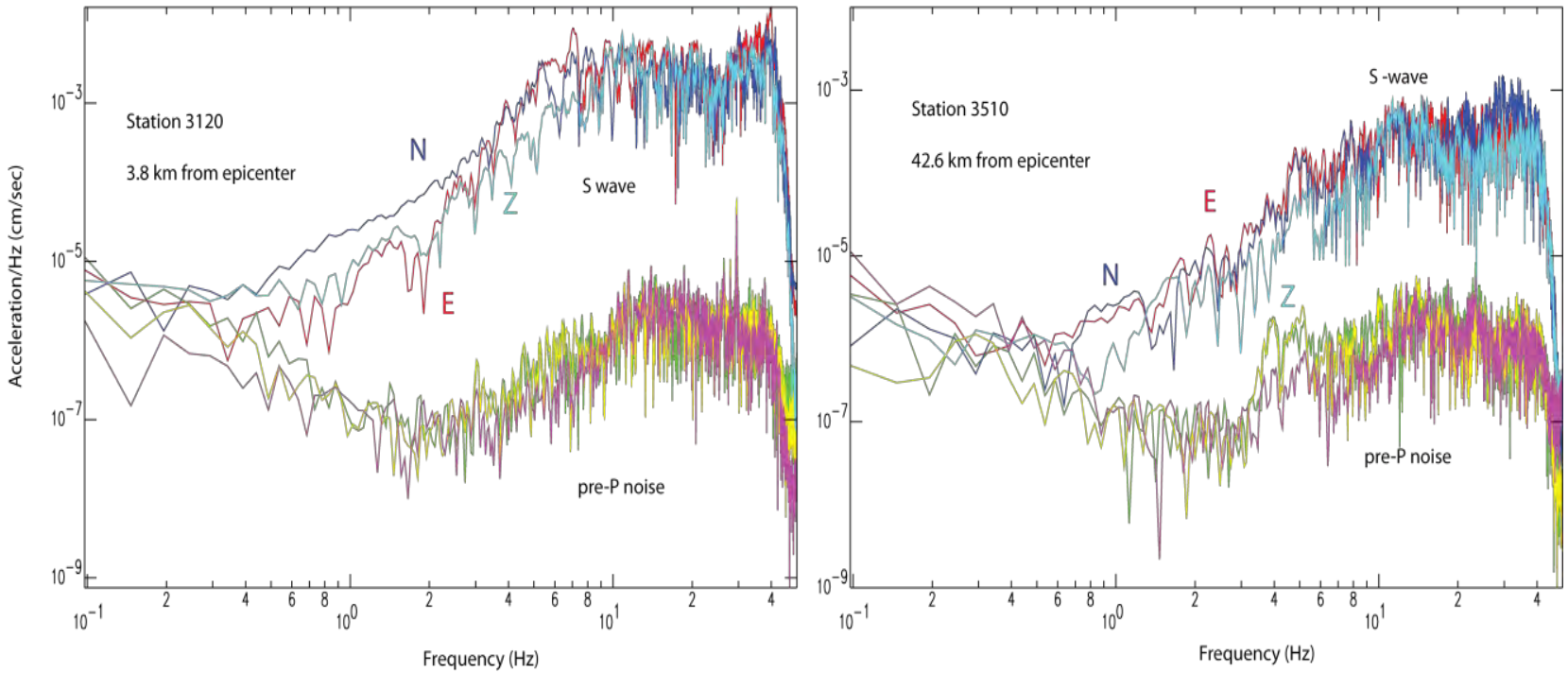


3.8 km

42.6 km



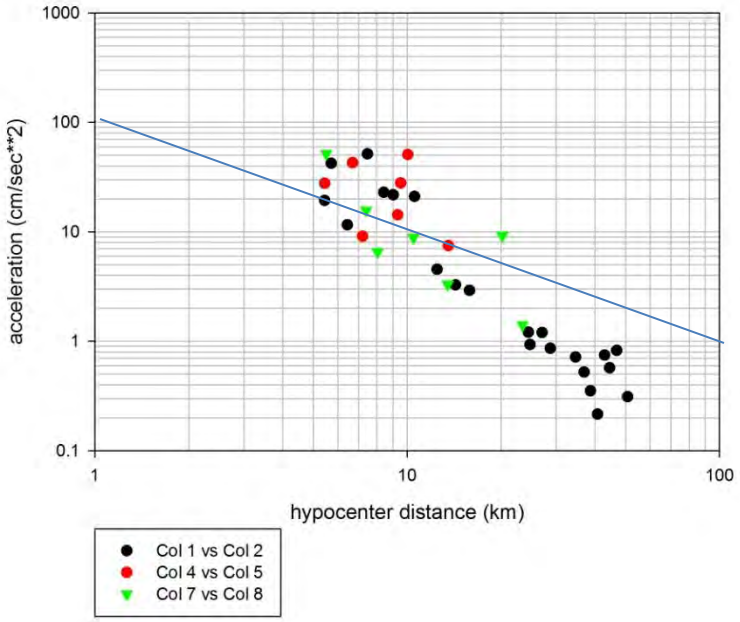
(Left) Acceleration recorded at AIDA profile station 3120 at 3.8 km from the epicenter of the 16:54, Sept. 5, 2011 UTC aftershock. (Right) Acceleration recorded at station 3510, 42.6 km from the epicenter.



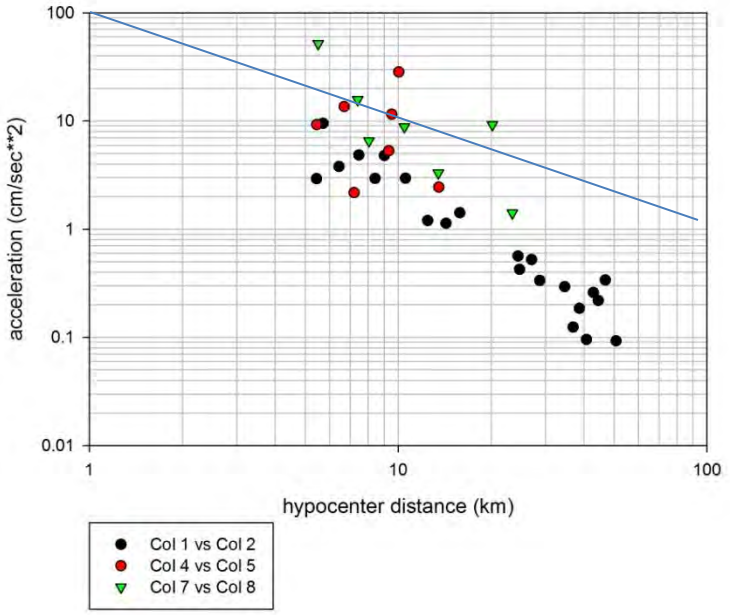
(Left) Fourier amplitude spectra of the S wave and pre-P wave noise at AIDA profile station 3120. (Right) station 3510.

Band-Pass Filtered Max. Amplitudes of the 16:54, Sept. 5, 2011 UTC aftershock

PGA, geometric mean
of the horizontal comp.



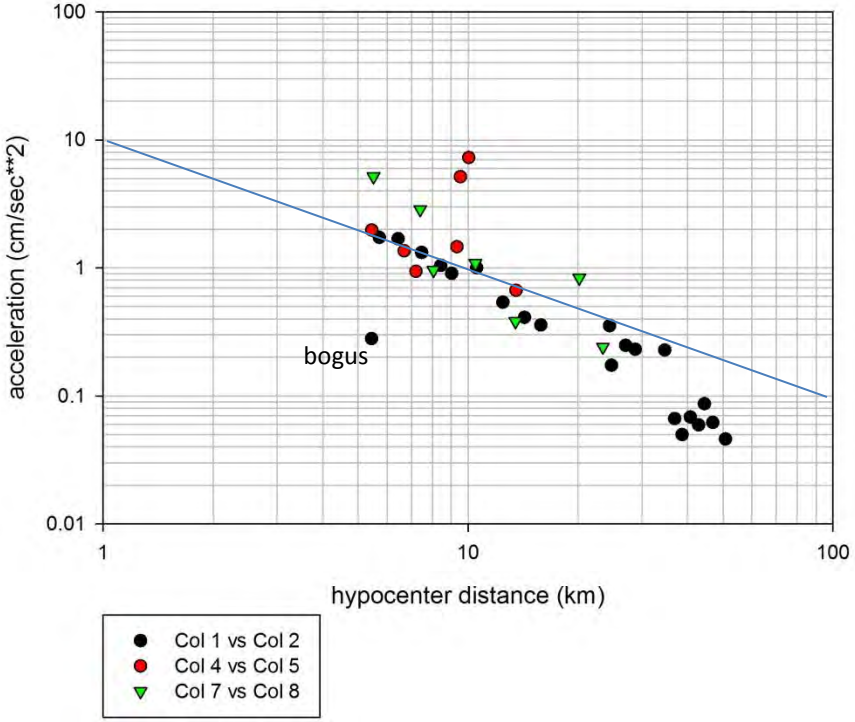
8 -16 Hz pass-band,
Geometric mean horizonal



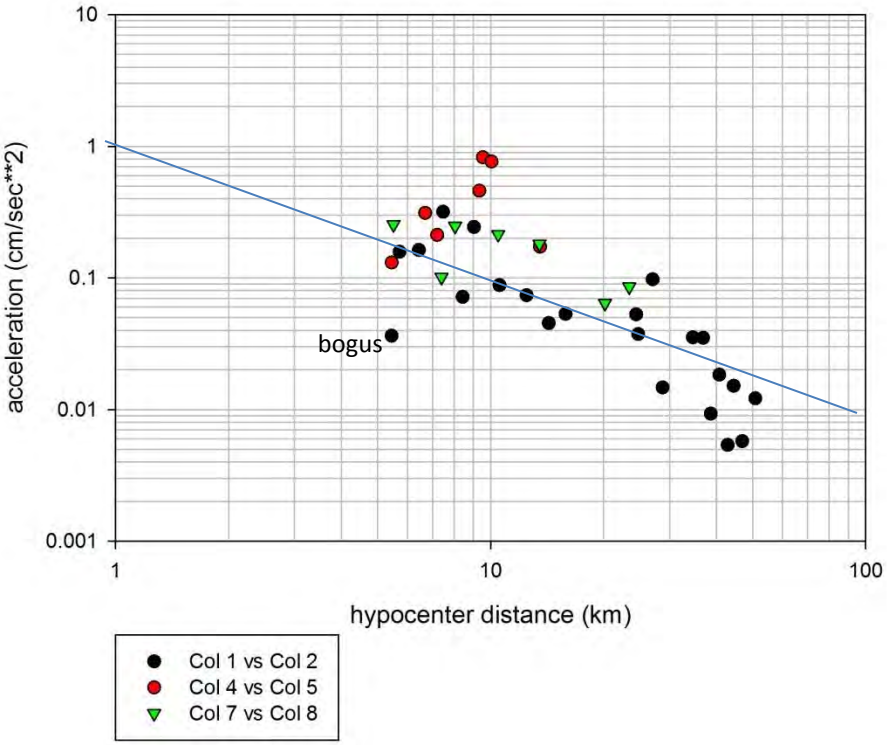
AIDA Profile: Black
YC network: Green
XY network: Red

Band-Pass Filtered Max. Amplitudes recordings of the 16:54, Sept. 5, 2011 UTC aftershock

4 - 8 Hz pass-band,
Geometric mean horizontal



2 - 4 Hz pass-band,
Geometric mean horizontal



AIDA Profile: Black
YC network: Green
XY network: Red

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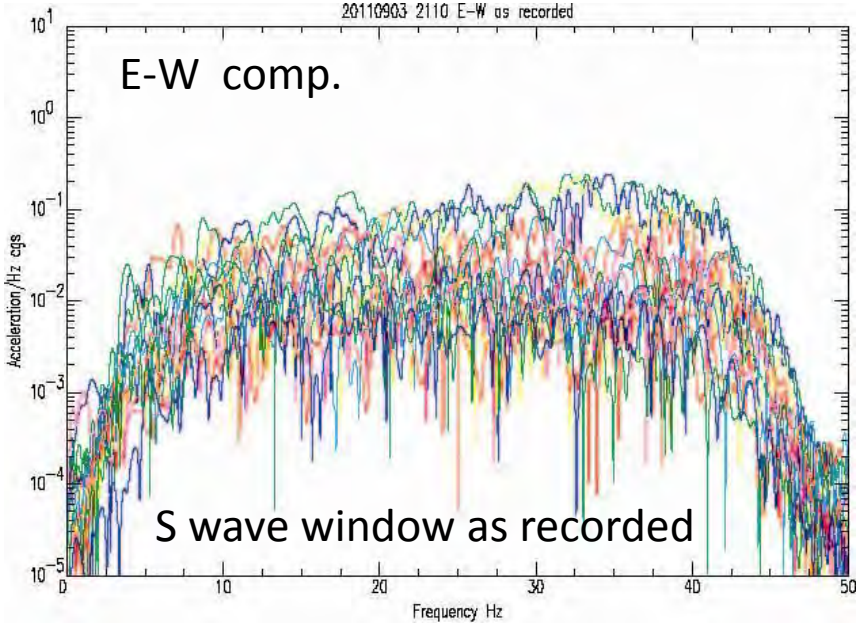

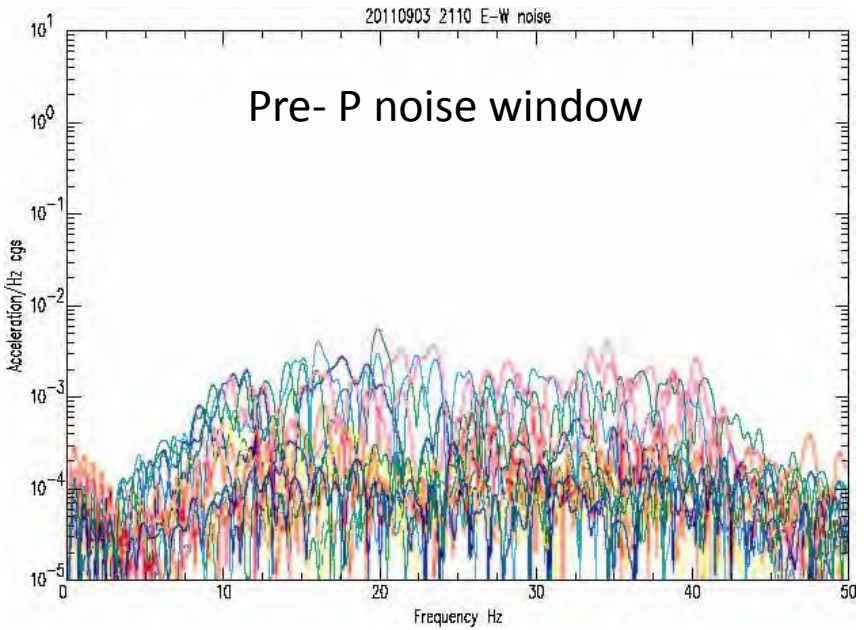

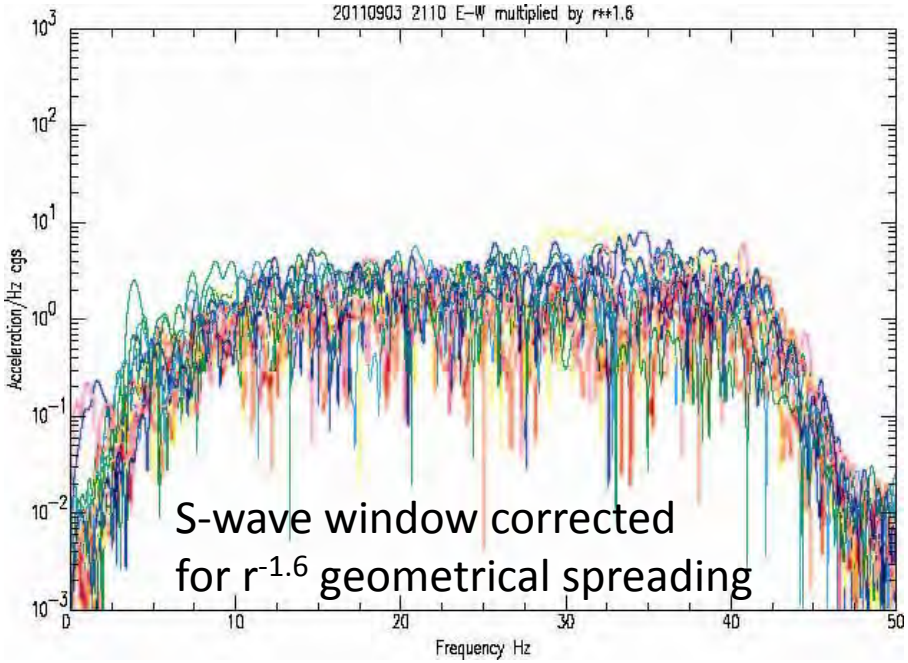

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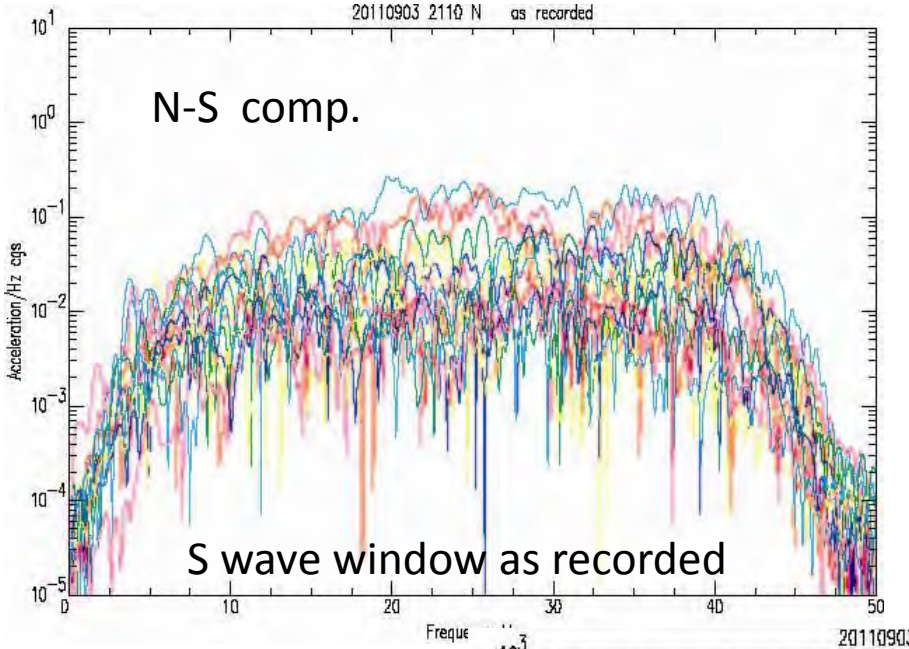

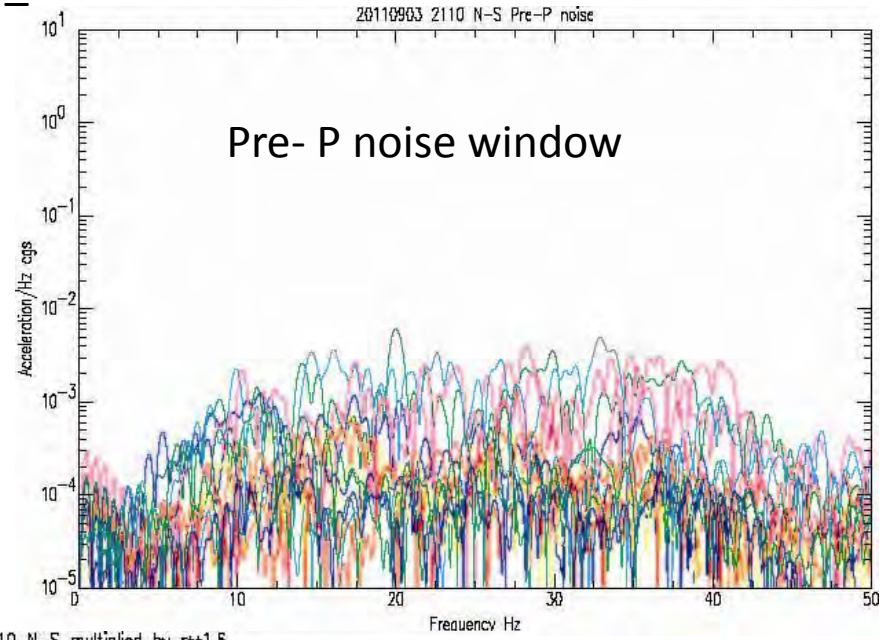

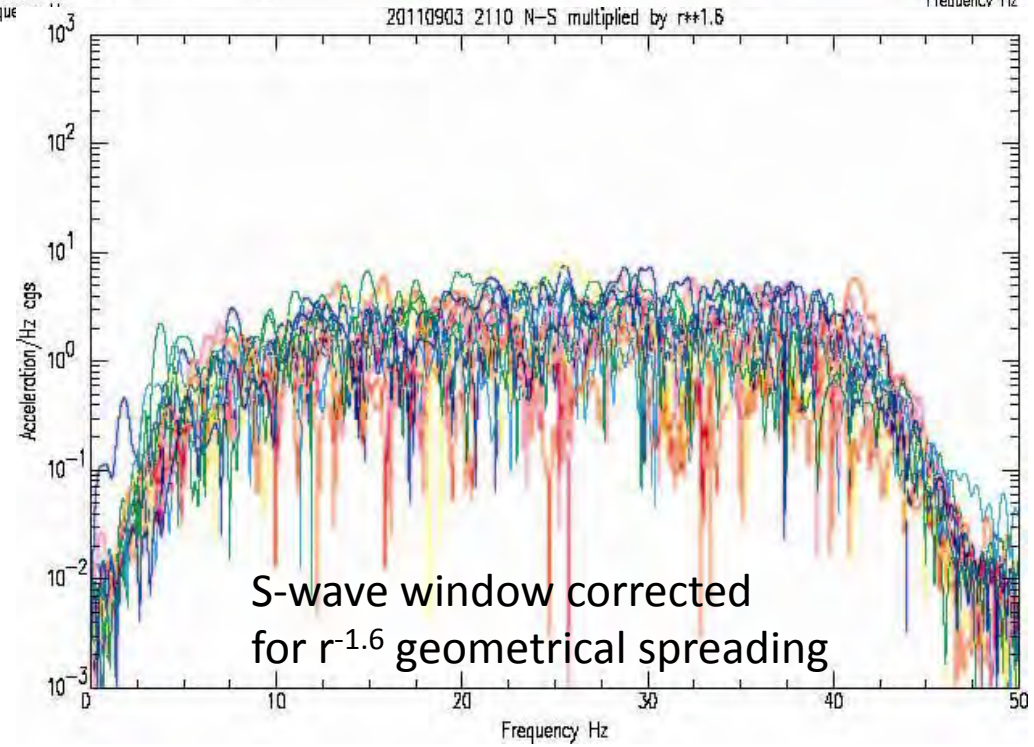

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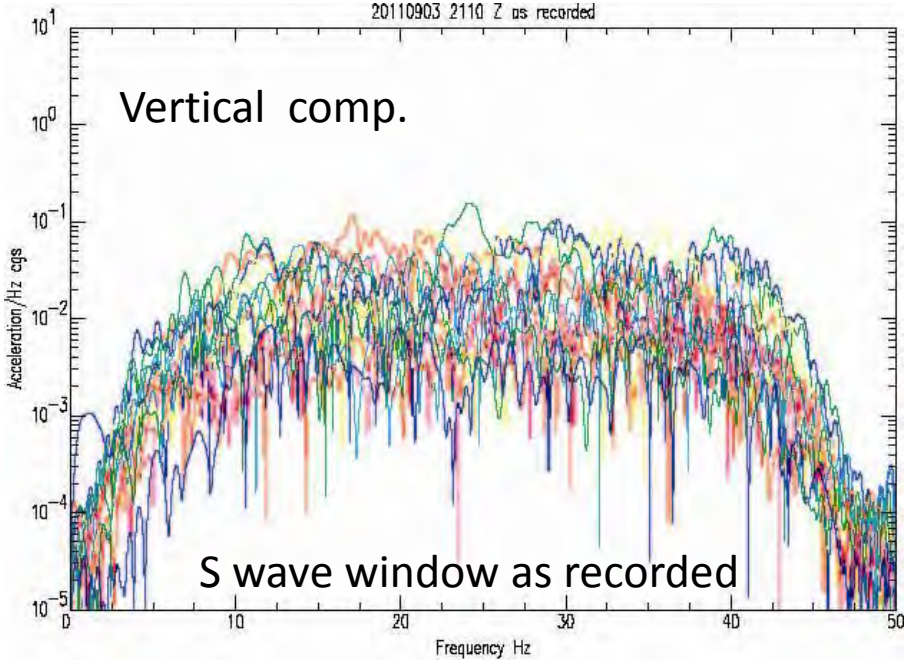

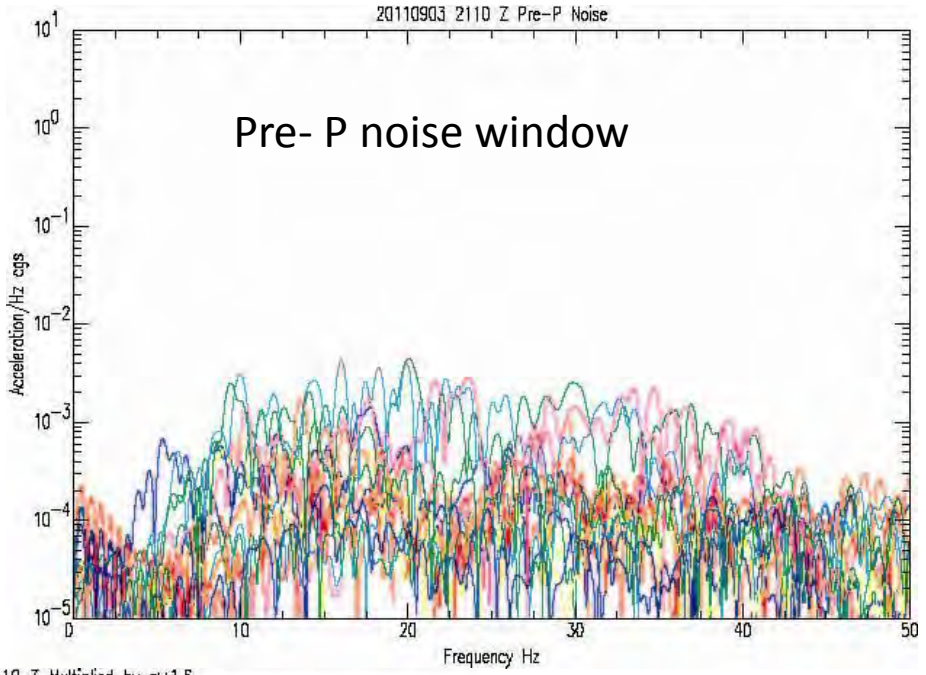

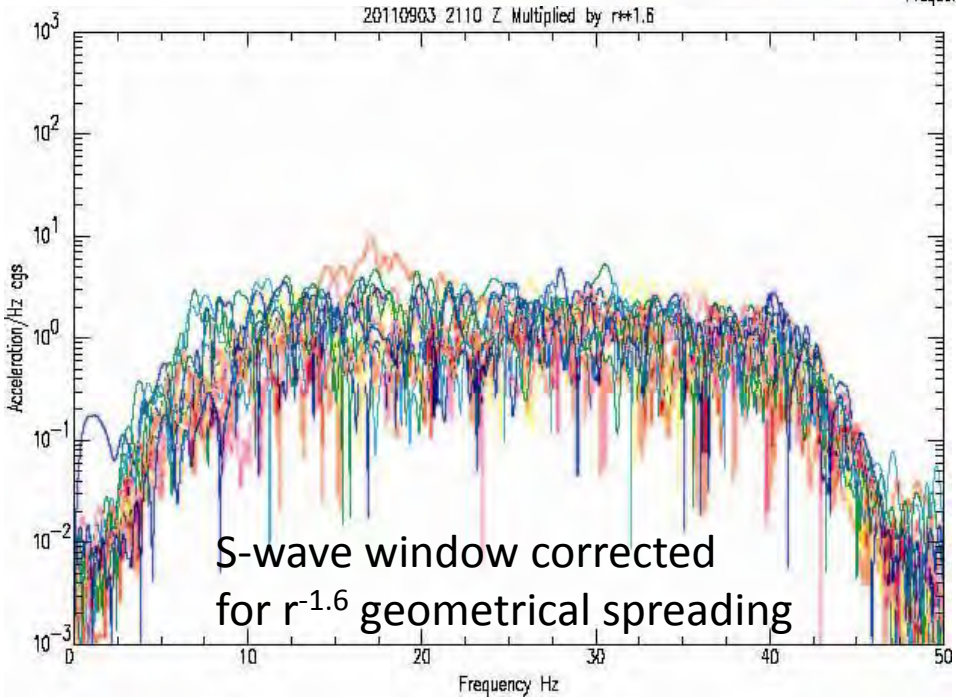

Preliminary analysis suggests:

1) Geometrical spreading from shallow (e.g., 5-6 km) focal depth aftershocks appears to be frequency dependent:

$r^{-1.0}$ for < 4 Hz,

$r^{-1.6}$ for > 4 Hz

2) The high-frequency acceleration spectra appear flat to 40Hz. Apparent Kappa is very small, Q is apparently very high*

*These results are preliminary and conditional on spectral ratio analysis for confirmation.