Comments on constraining attenuation and source parameters

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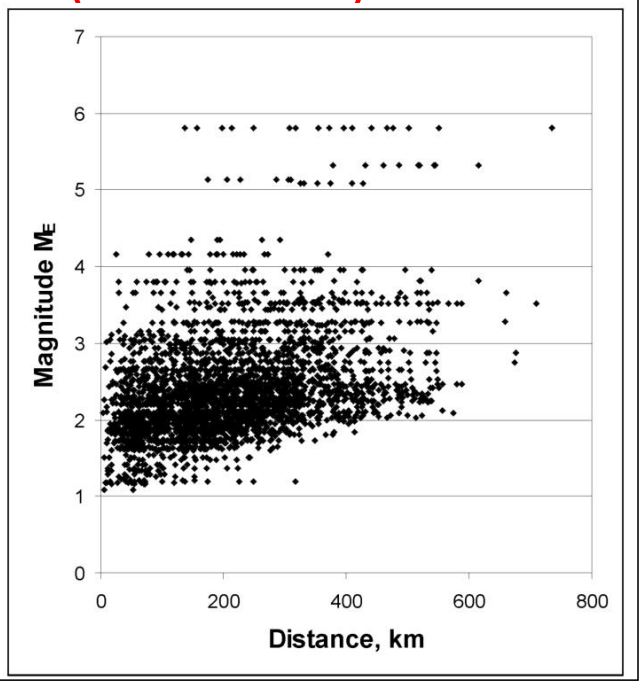
Some new results on attenuation (Q) and source (SE Canada)

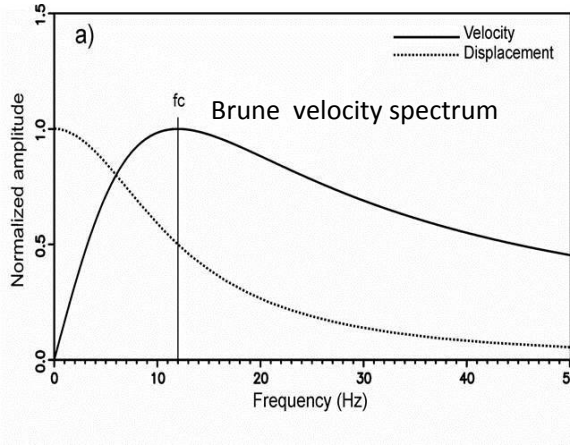
- there is a family of equivalent Q relations of the form $Q=Q_o f^n$
- Q might depend on amplitude level
- Small-to-moderate events are not self-similar

(Dineva, Mereu and Atkinson, submitted)



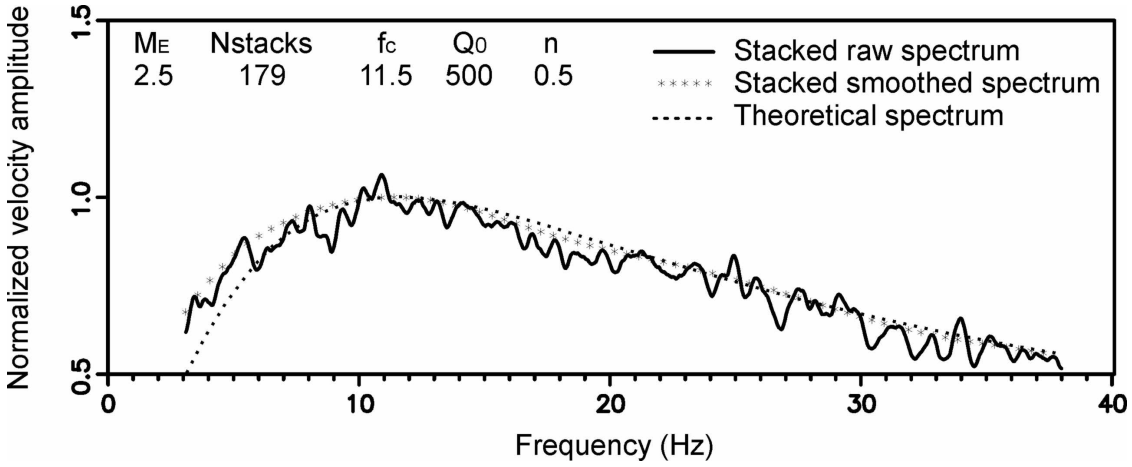
Estimation of Q in SE Canada based on spectral shape (eliminating need to assume geometric spreading)

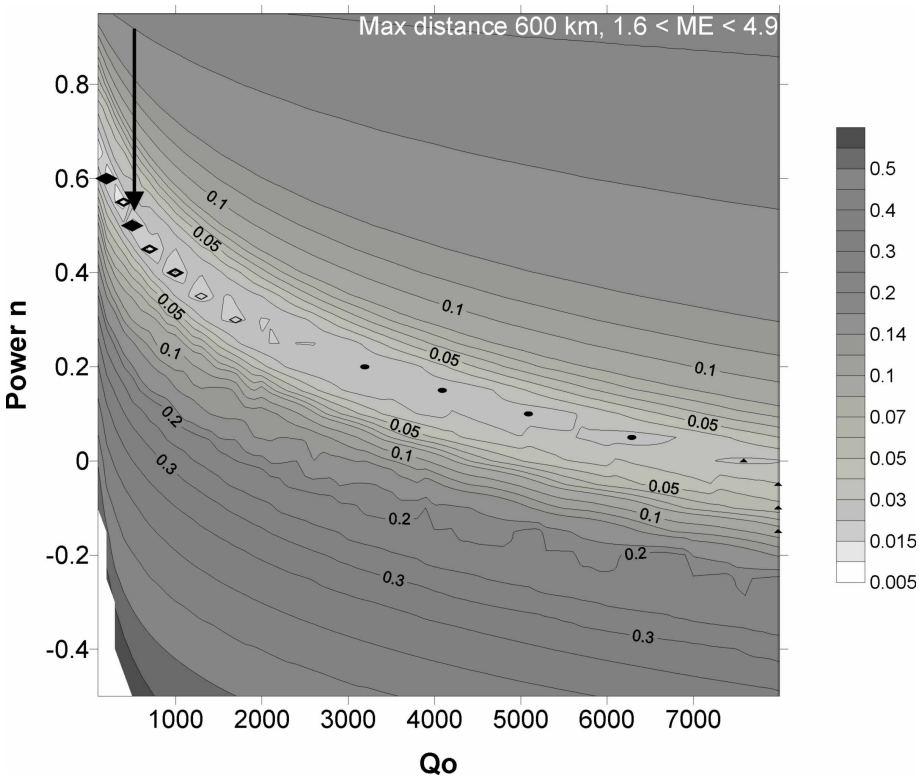
- Based on stacking velocity spectra in 0.1 M unit bins, each spectrum normalized to amplitude at the peak (works because velocity spectra peak at the corner frequency)
- Compare normalized spectra to Brune shape to determine required Q correction



(Dineva, Mereu and Atkinson, submitted)

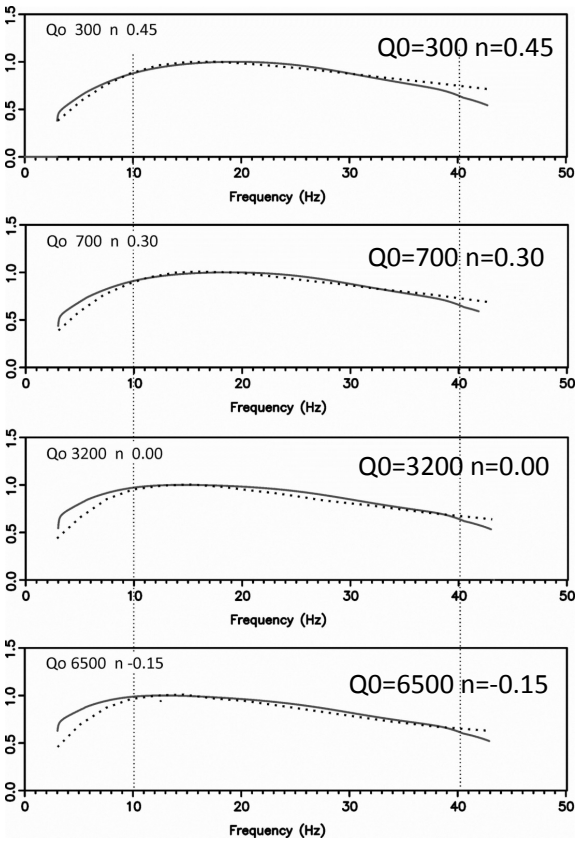
Example of stacked spectrum fit with Brune spectrum (M_E 2.5). All individual spectra are corrected with Q_0 = 500 and n = 0.5.





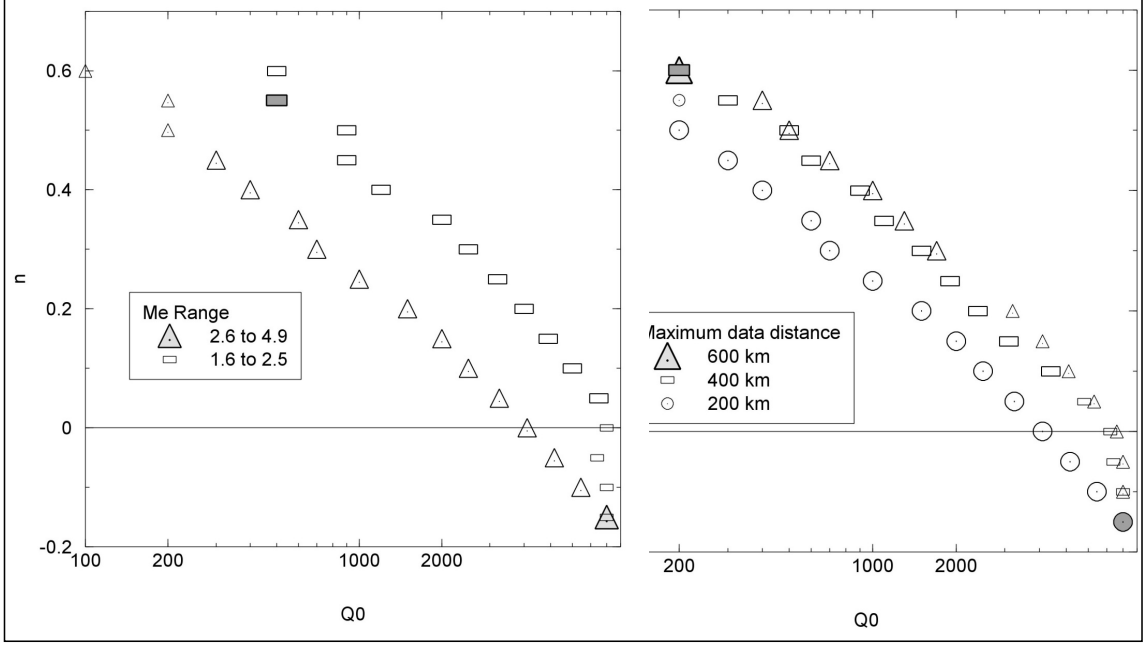
Best-fit Q (assuming Brune shape) that minimizes error lies along a trade-off line between Qo and n

$Q=Qof^n$

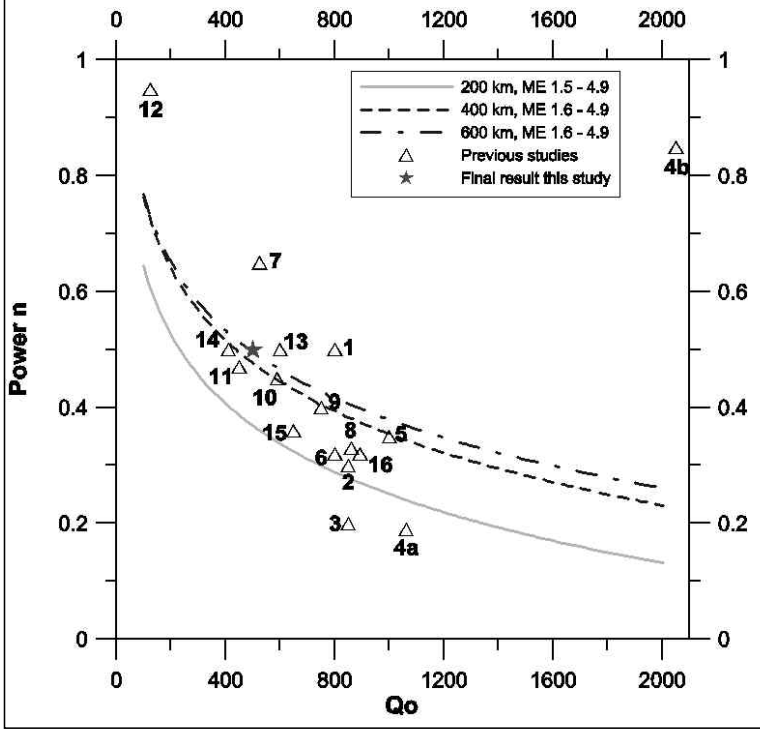


Different Qo-n combinations have same effect on spectral shape

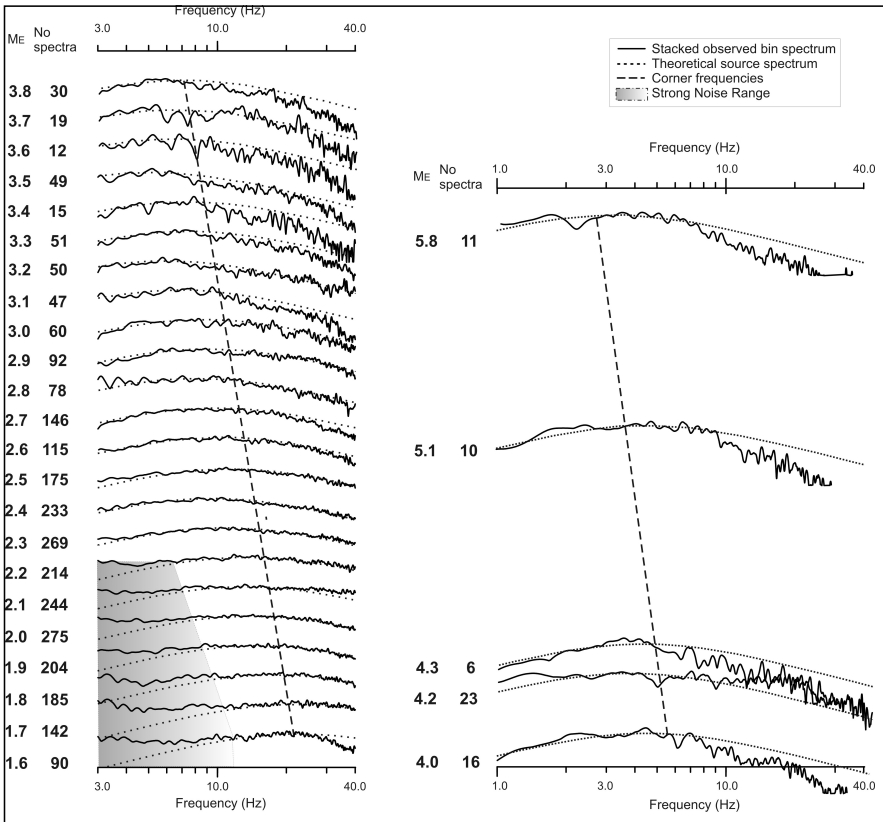
Qo-n pairs show dependence on magnitude and distance (amplitude?)



Other Q studies all plot along the Qo-n trade-off line….



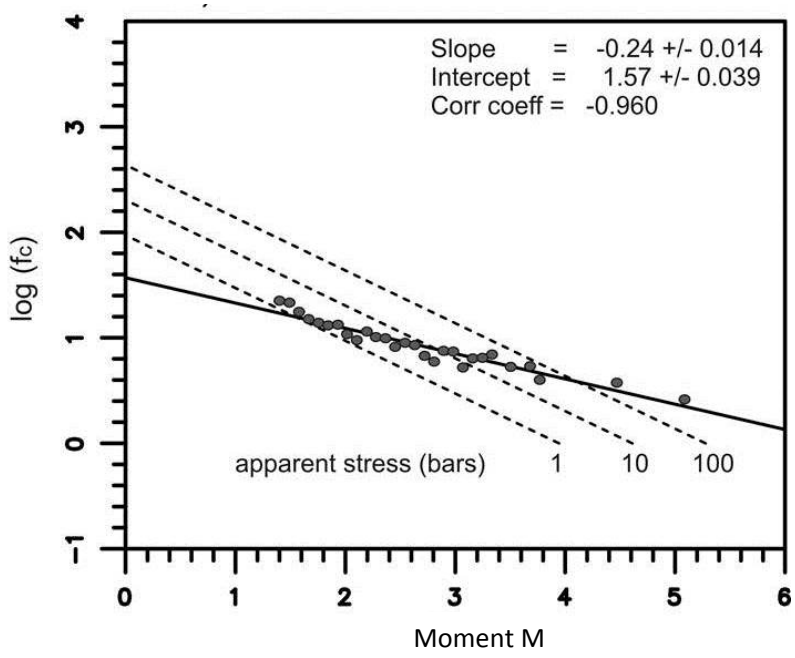
1 – Nuttli, 1981; 2 – Herrmann and Kijko, 1983; 3 – Hasegawa, 1985; 4 – Chun et al., 1987; 5 - Goncz&Dean, 1986; 6 – Gupta and McLaughlin, 1987; 7 – Shin and Herrmann, 1987; 8–11 – Woodgold, 1990, 12 – Eastern Canada; 13 – Atkinson&Boore, 1995; 14 – Boatwright and Seekins, 2011; 15 - Erikson et al., 2004; 16 – Atkinson, 2004



Source parameters from Q-corrected spectra: Picking corner frequency from peak of stacked velocity spectra

(Dineva, Mereu and Atkinson, submitted)

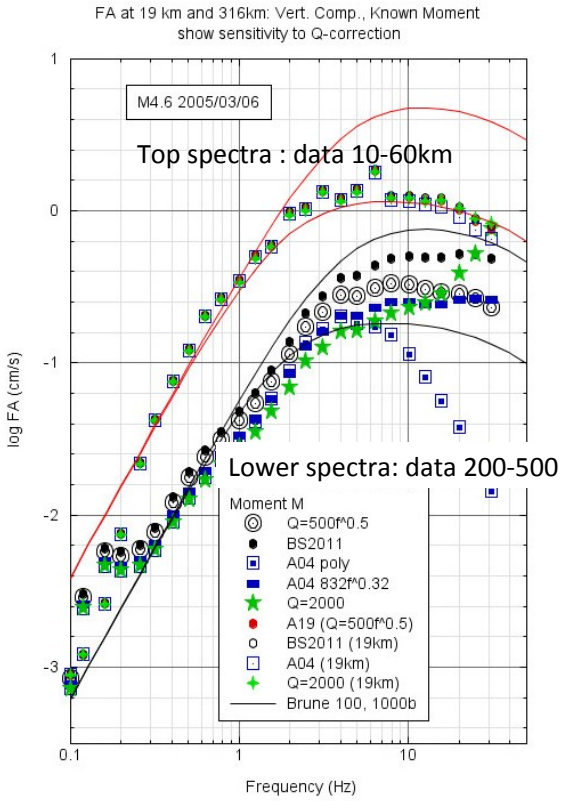
Relationship between the corner frequency and moment magnitude: clearly not self-similar, at least for small-to-moderate events



Dineva, Mereu and Atkinson, submitted

Attenuation and source parameters in ground-motion modeling

- attenuation and source parameters are closely connected in ground motion model (trade-off)
- It is not meaningful to talk about source parameters and attenuation parameters for a ground-motion simulation model independently, if matching model to observations
- I illustrate this with source spectra inferred from regional observations (200 to 500 km), by correcting the spectra just for Q effects (on shape), then shifting the spectra to match known seismic moment
- This eliminates the need to know geometric spreading, so simplifies the attenuation problem (assuming gsprd is frequency-independent)
- Use M4.7 Riviere du Loup, Quebec earthquake, due to rich ground motion records at both near and far distances



Sensitivity of inferred source spectra to Q:
compare to Brune model with 100, 1000 bars
Assumed Q=500f^0.5
Alternatives:
BS11 Q=400f^0.5
A04 Q = 893f^0.32 and polynomial form
Constant Q=2000

Note A04 polynomial not a good idea! It improved Q at low freq but blows up at f>10Hz, where it matters more.
A04 Q= 893 f^0.32 much better behaved for shape corrections at regional dist.
BS11 Q=400f^0.5 works very well – suggests higher stress than A04.

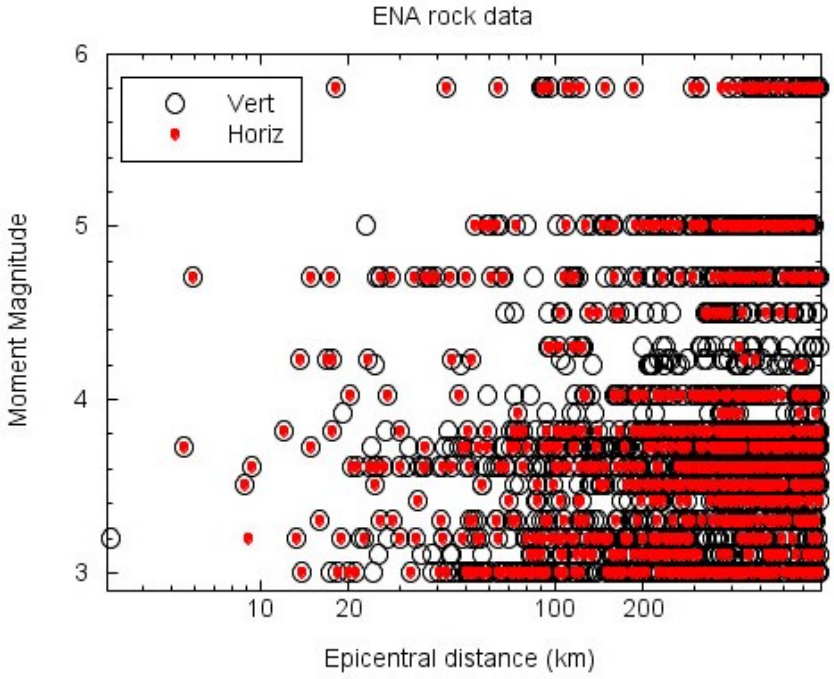
Some thoughts

- Stress drop and attenuation are just trading model parameters in the context of ground motion simulations
- Talking about "stress drop" is meaningless – we are interested in ground motion; the same ground motion is produced by high stress-high attenuation or low stress – low attenuation, and we really can't distinguish clearly between the two (not enough near-source data)
- Most useful thing NGA-E could do would be to advocate free-field ground-motion instruments in the east so that we could gain more insight from the next significant eastern earthquake (we've already wasted the last one).

Data-based comments on ENA attenuation

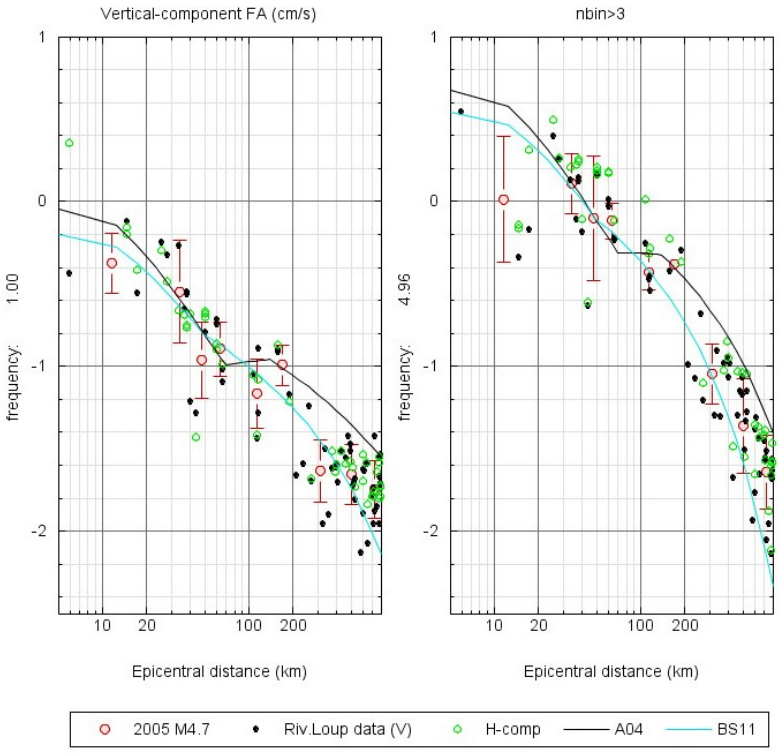
- Based on ENA Fourier amplitude data (www.seismotoolbox.ca) **M** 3 to 5.8, to 800km
- Vertical and geomean horizontal component
- Vertical data are more plentiful and show same trends as horizontal
- Use just rock data (Vs30>1000 km/s, mostly >2000 km/s) so that site can be neglected

Database distribution



Overall observations on attenuation

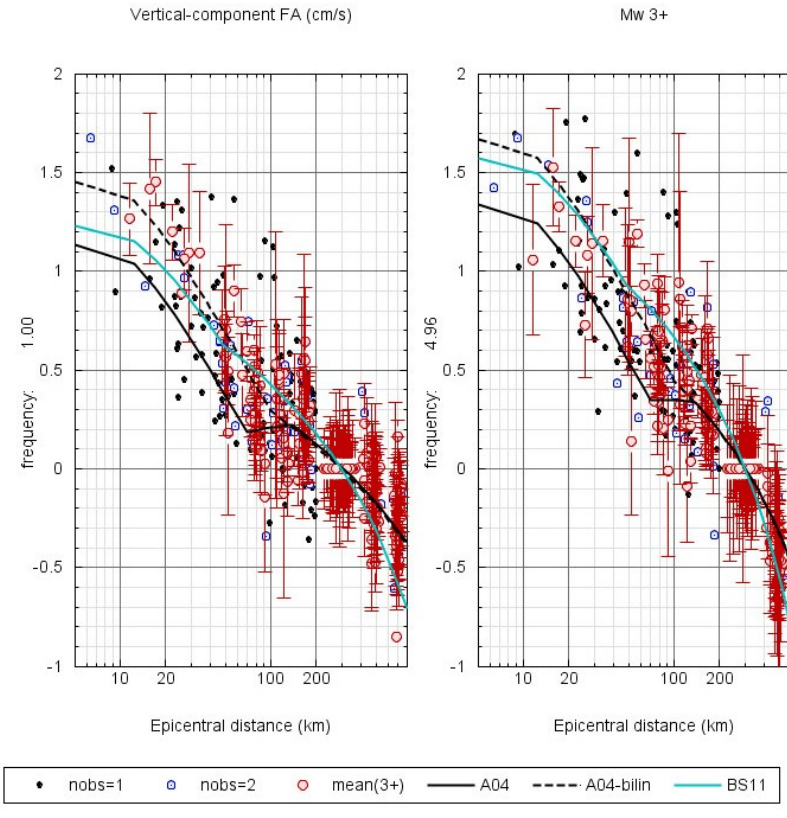
- We can look at overall attenuation behaviour by obtaining average log amplitudes in distance bins (logA in logD bins) for each event
- This gives us an event-specific attenuation shape, for well-recorded events (e.g. 2005 M4.7 Riviere du Loup)



Example of binned data: Riv.Loup Vert. mean and std.dev. (red with error bars) (note both vert. and horiz. data are shown in background)

This is by far the richest event for dist. coverage.

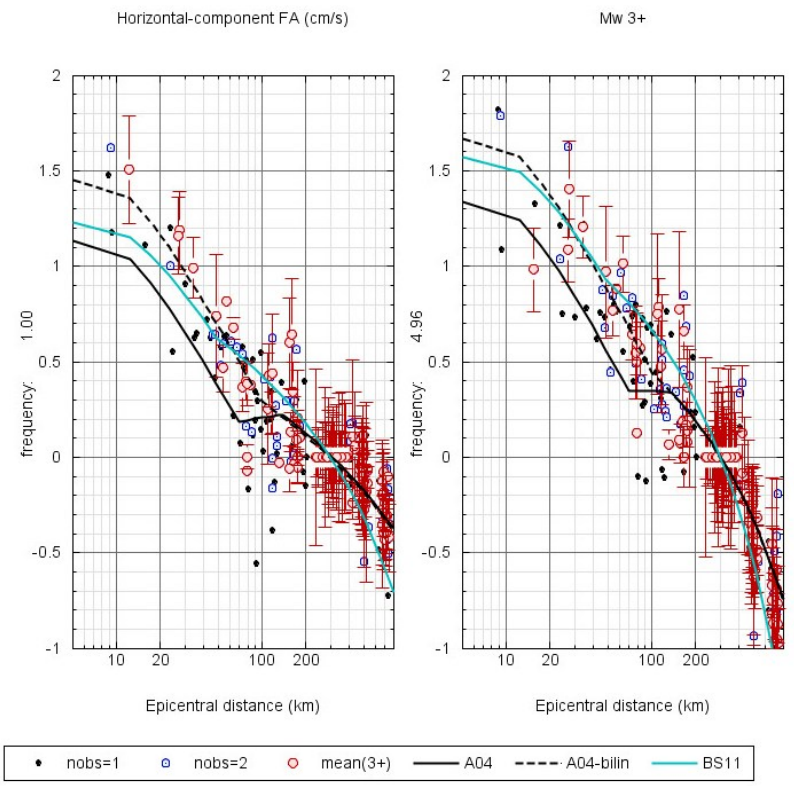
Need to stack multiple events to see overall shape



Vertical-comp FA data in distance bins for **M**>3

All events normalized to give **A=1 in the 200-400km dist bin** (plotted at mean dist within bin for each event)

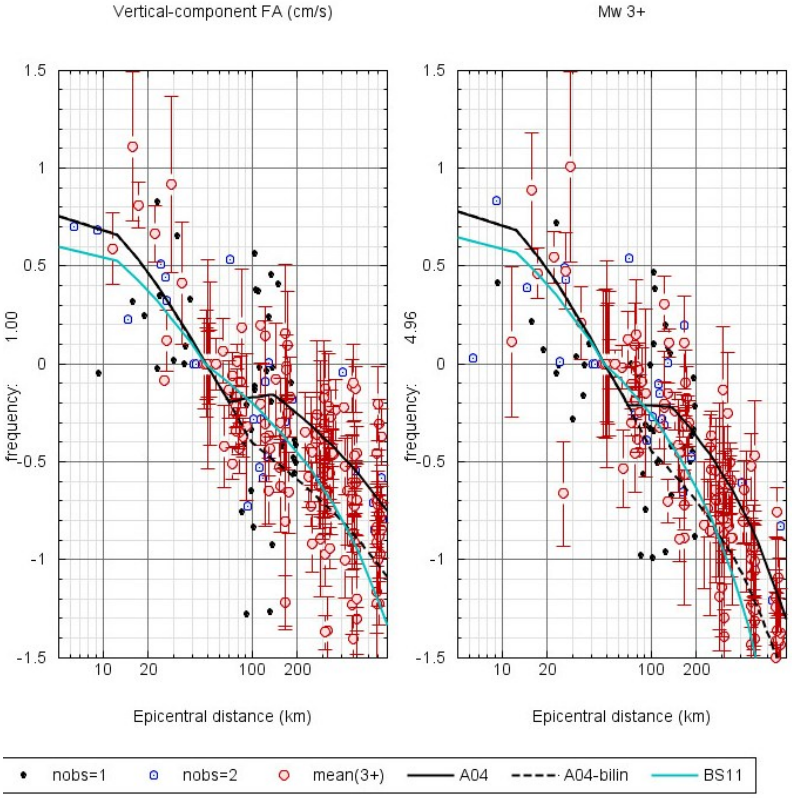
This shows variability in attenuation, starting from regional dist and going back to near-source



Horizontal-comp FA data in distance bins for **M**>3

All events normalized to give **A=1 in the 200-400km dist bin** (plotted at mean dist within bin for each event)

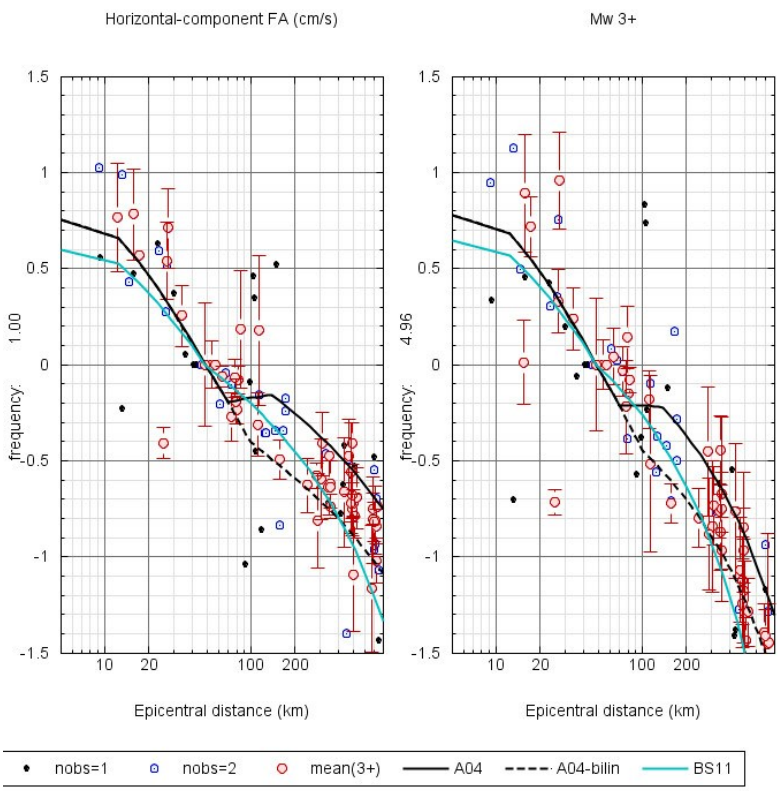
This shows variability in attenuation, starting from regional dist and going back to near-source



Vert-comp FA data in distance bins for **M**>3

All events normalized to give **A=1 in the 40-60 km dist bin** (plotted at mean dist within bin for each event)

This shows variability in attenuation, starting from near-source dist and out to regional dist



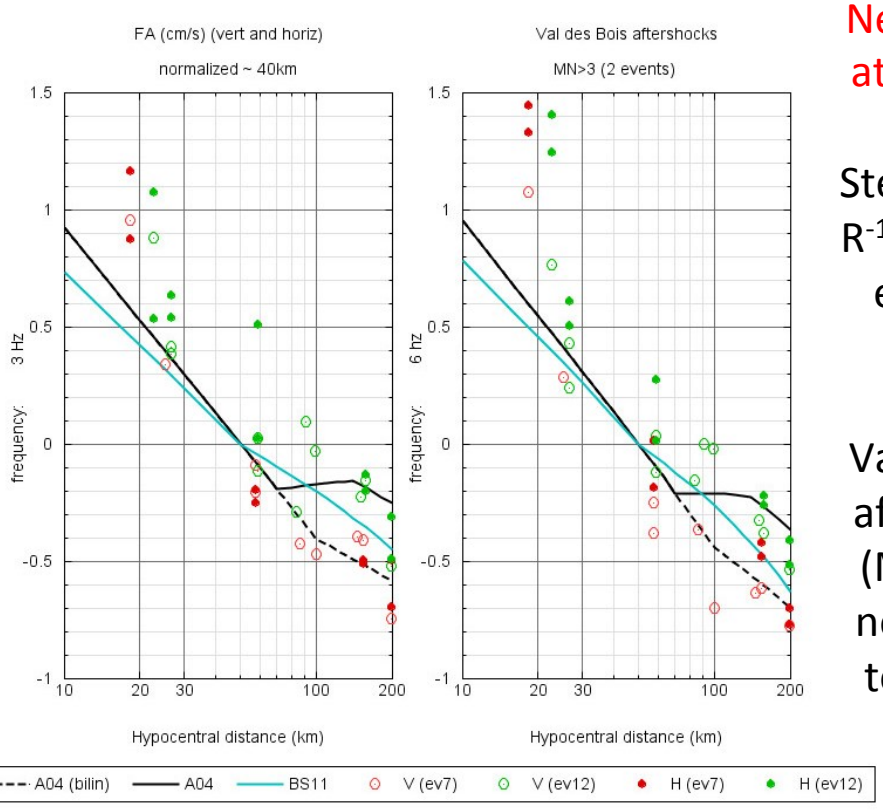
Horiz-comp FA data in distance bins for **M**>3

All events normalized to give **A=1 in the 40-60 km dist bin** (plotted at mean dist within bin for each event)

This shows variability in attenuation, starting from near-source dist and out to regional dist

Summary on attenuation shapes

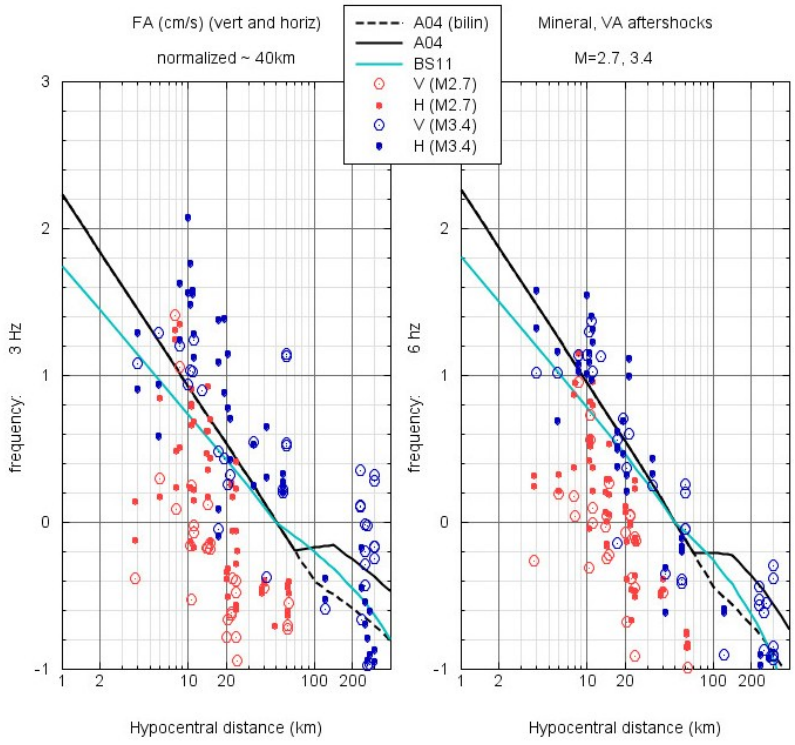
- Normalized ground motion data can be used to place constraints on geometric spreading and Q combinations that are consistent with the data and their variability
- Could be applied to evaluating uncertainty in attenuation rates from source to regional distances
- Could be applied to evaluating uncertainty on source parameters derived from regional data via an attenuation model
- Data suggest slope steeper than $R^{-1.3}$



Near-source attenuation

Steeper than $R^{-1.3}$? Or site effects at VDBQ?

Val des Bois aftershocks (MN3, 3.3) normalized to ~1 near 40km



Mineral, VA aftershocks

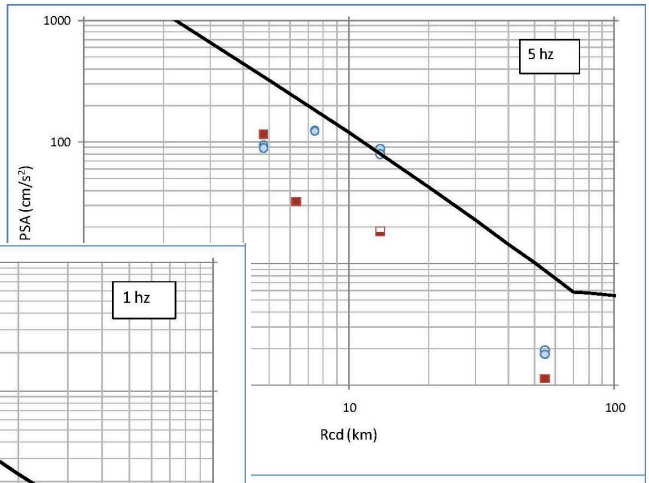
Attenuation slightly steeper than $R^{-1.3}$

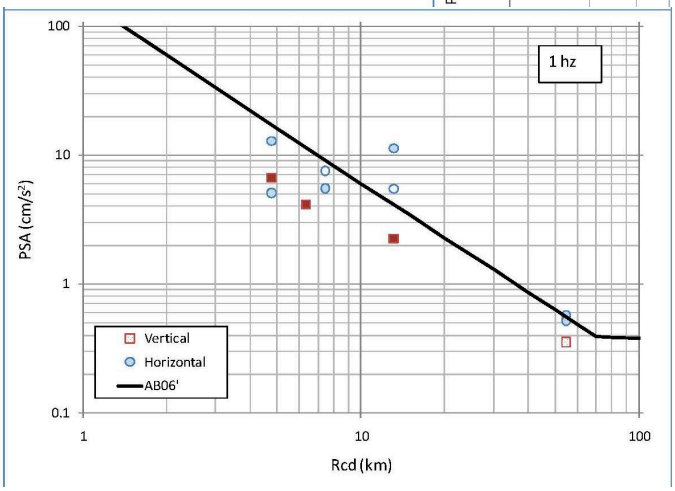
Other evidence of steep near-source attenuation

- Atkinson and Kraeva (2010 BSSA)
- Study of attenuation of shallow Sudbury events (mining-induced)
- Found $R^{-1.3}$ in first 25 to 30 km for H-comp
- $R^{-1.1}$ for V-comp

Event-specific near-source attenuation

Arkansas earthquake, **M**=4.7 (from Shahram Pezeshk)





Compared to AB06' with assumed $R^{-1.3}$

Questions on ground-motion regionalization of attenuation

- Do ground-motion data from different ENA regions (eg. SE U.S., New Madrid) have different attenuation?
- Are attenuation differences well-enough documented, and sufficiently important, to justify different attenuation models for different regions?
- Data-based studies of these questions need to be conducted (overlaying data for a common magnitude metric)