Comparing path durations from the Mineral mainshock and best-recorded aftershock with the BT15 model

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The path duration model in Boore and Thompson (2015) (BT15) are based on the programs and methods discussed in Boore and Thompson (2014). In retrospect, I see that BT15 should have included more detail about the derivation of the model. For example, the path durations are the record duration minus the source duration, assuming a single-corner frequency model with 400 bars stress parameter, and the record durations are the geometric means of 2 times the difference in the times to the 0.8 and 0.2 fractions of the normalized Husid plot. In addition, the Mineral mainshock data were not included in deriving the BT15 path duration model, I think because their values at distances beyond about 100 km seemed abnormally low compare to the more abundant smaller magnitude data (which guided the path duration model).

I obtained time series records of the mainshock at distances within 130 km from Tadahiro Kishida so that I could compare with the durations in a 2014-06-10 flatfile provided as part of the NGA-East project. I also computed durations from data sent by Martin Chapman for a well-recorded mbLg=3.12 aftershock. Here is a figure comparing various durations:

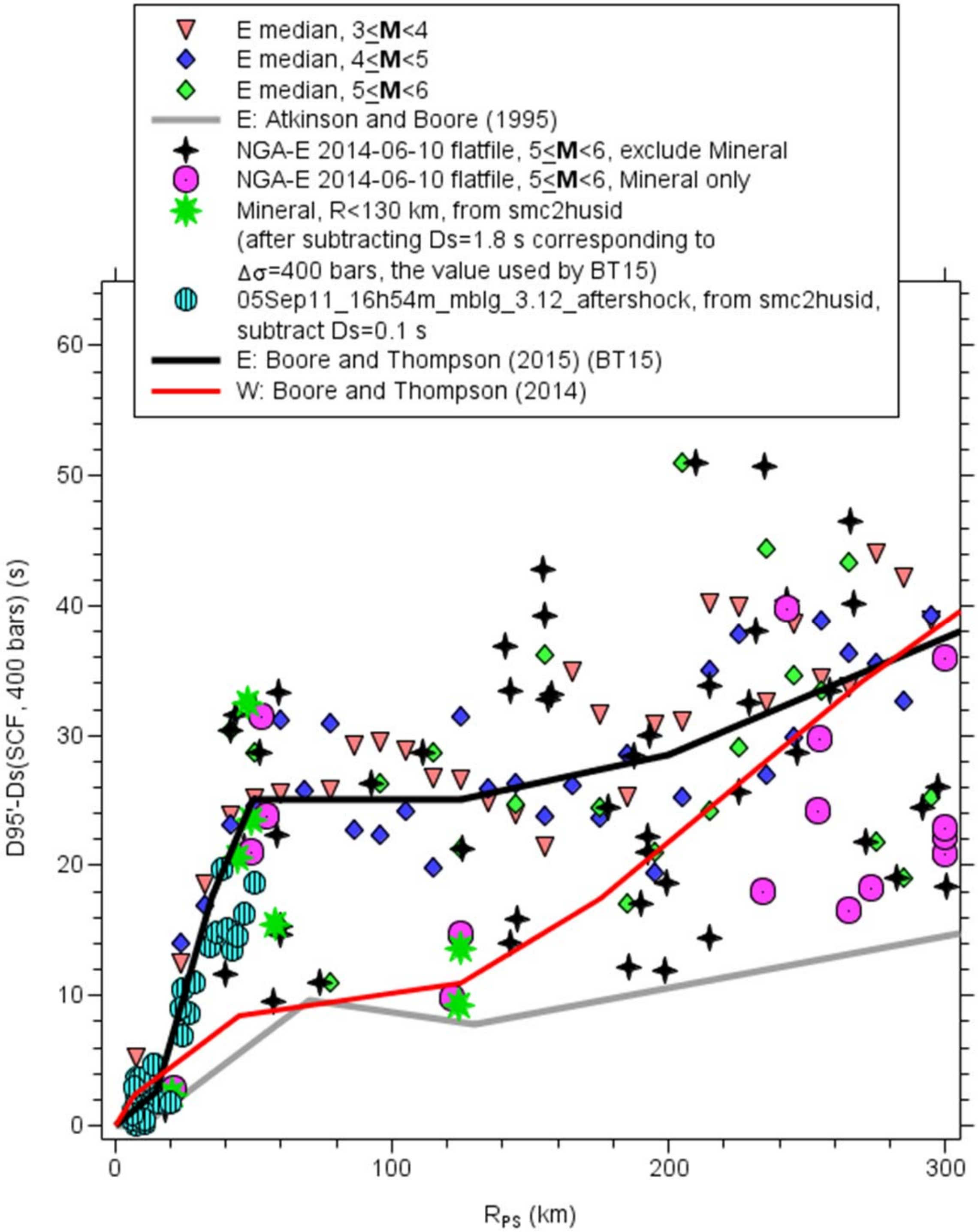

E median, 3≤M<4
E median, 4≤M<5
E median, 5≤M<6
E: Atkinson and Boore (1995)
NGA-E 2014-06-10 flatfile, 5≤M<6, exclude Mineral
NGA-E 2014-06-10 flatfile, 5≤M<6, Mineral only
Mineral, R<130 km, from smc2husid
(after subtracting Ds=1.8 s corresponding to
Δσ=400 bars, the value used by BT15)
05Sep11_16h54m_mblg_3.12_aftershock, from smc2husid,
subtract Ds=0.1 s
E: Boore and Thompson (2015) (BT15)
W: Boore and Thompson (2014)
D95'-Ds(SCF, 400 bars) (s)
R_PS (km)
0
10
20
30
40
50
60
0
100
200
300

Figure 1.

My computations of durations for the mainshock (green starbursts) are similar to those in the NGA-East flatfile (magenta-filled circles) (there are slight differences in the distances). The records providing the value at 58 km were not in the 2014-06-10 NGA-East flatfile.

Although there is little overlap in distances, the mainshock and aftershock durations (available to distances less than 51 km) seem consistent with one another and also seem to be in general agreement with the BT15 model within 50 km.

Having said that, there are some nagging questions regarding the assumed model of the envelope function used in my SMSIM calculations. BT14 made an effort to compare the observed shapes of the Husid plots with those from the standard window used in SMSIM, but BT15 did not make a similar study for ENA records. Here are some comparisons of the acceleration time series and Husid plots for the mainshock, arrange by distance. This will be followed by two of the aftershocks:

MAINSHOCK

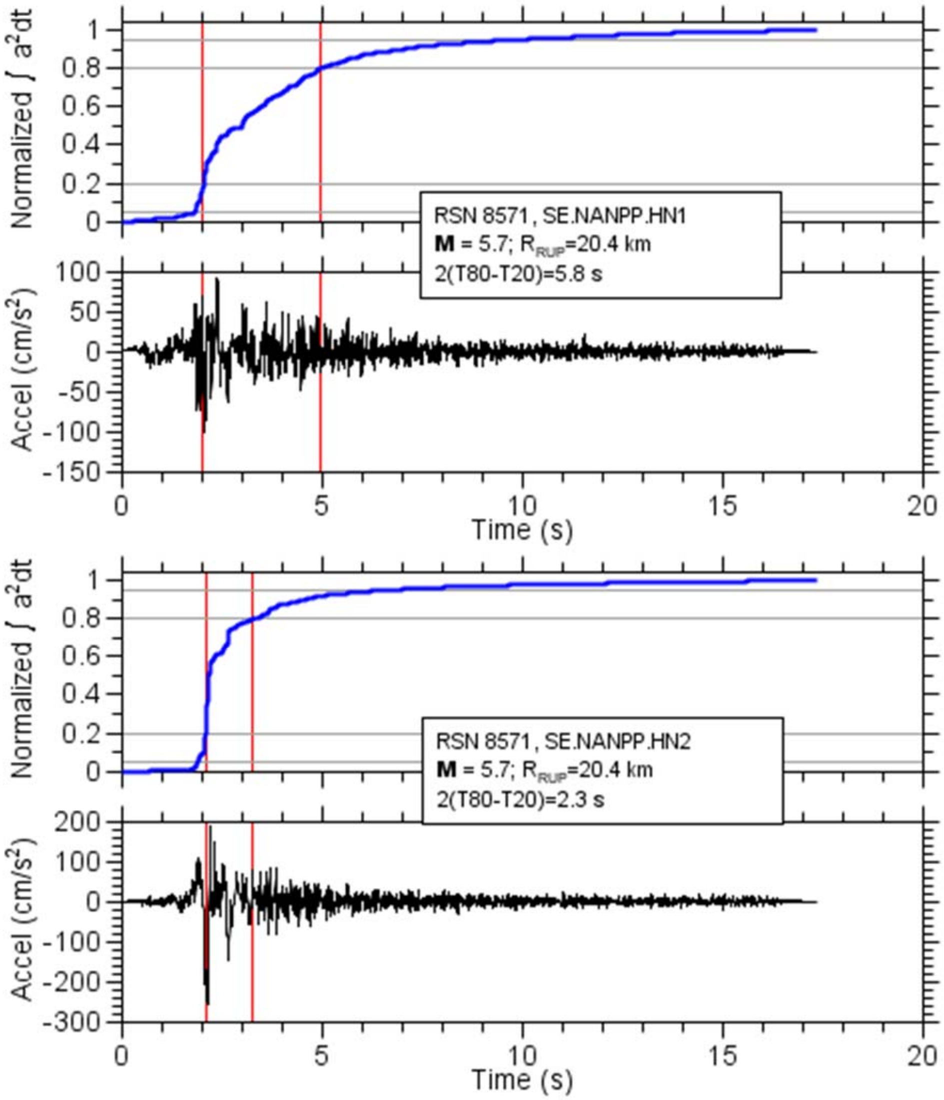


Figure 2.

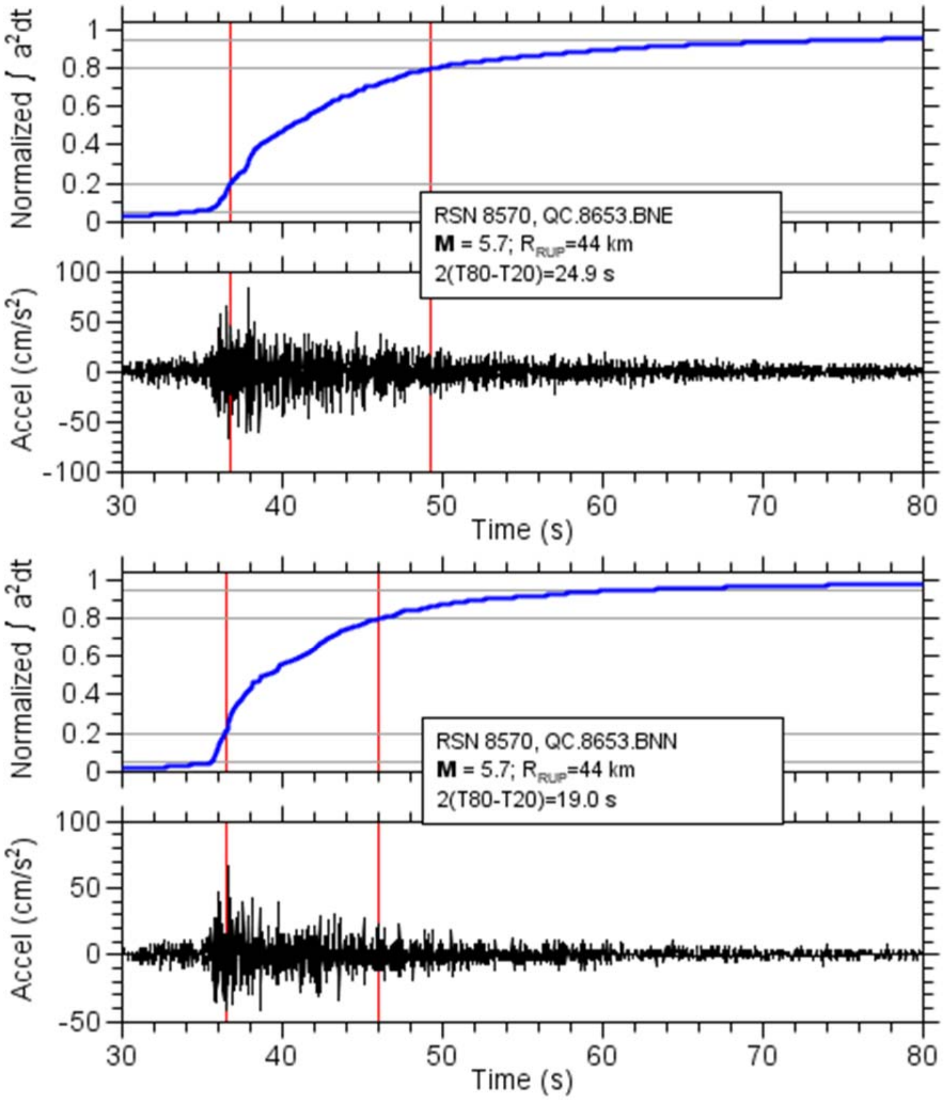

RSN 8570, QC.8653.BNE
M = 5.7; R_RUP=44 km
2(T80-T20)=24.9 s
Normalized ∫ a²dt
Accel (cm/s²)
Time (s)
RSN 8570, QC.8653.BNN
M = 5.7; R_RUP=44 km
2(T80-T20)=19.0 s
Normalized ∫ a²dt
Accel (cm/s²)
Time (s)

Figure 3.

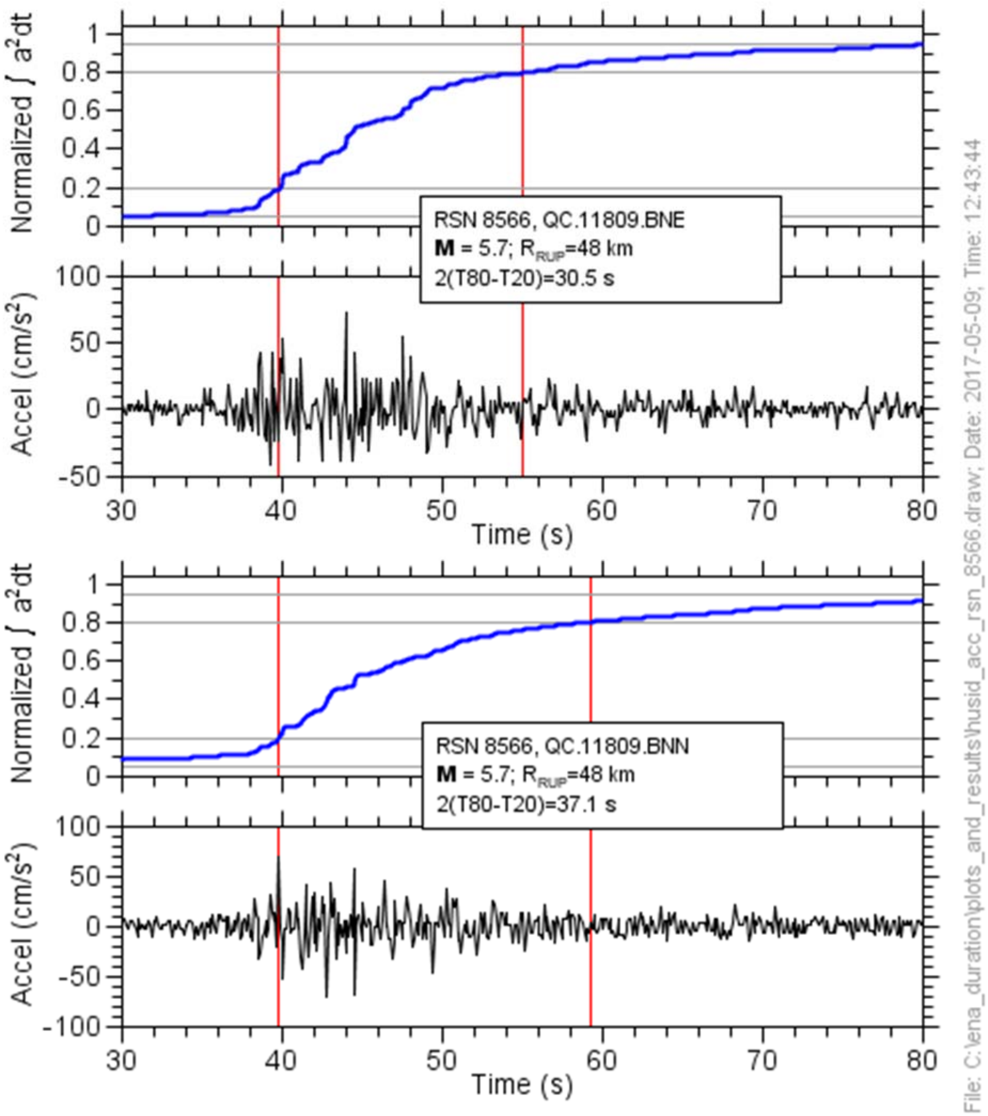
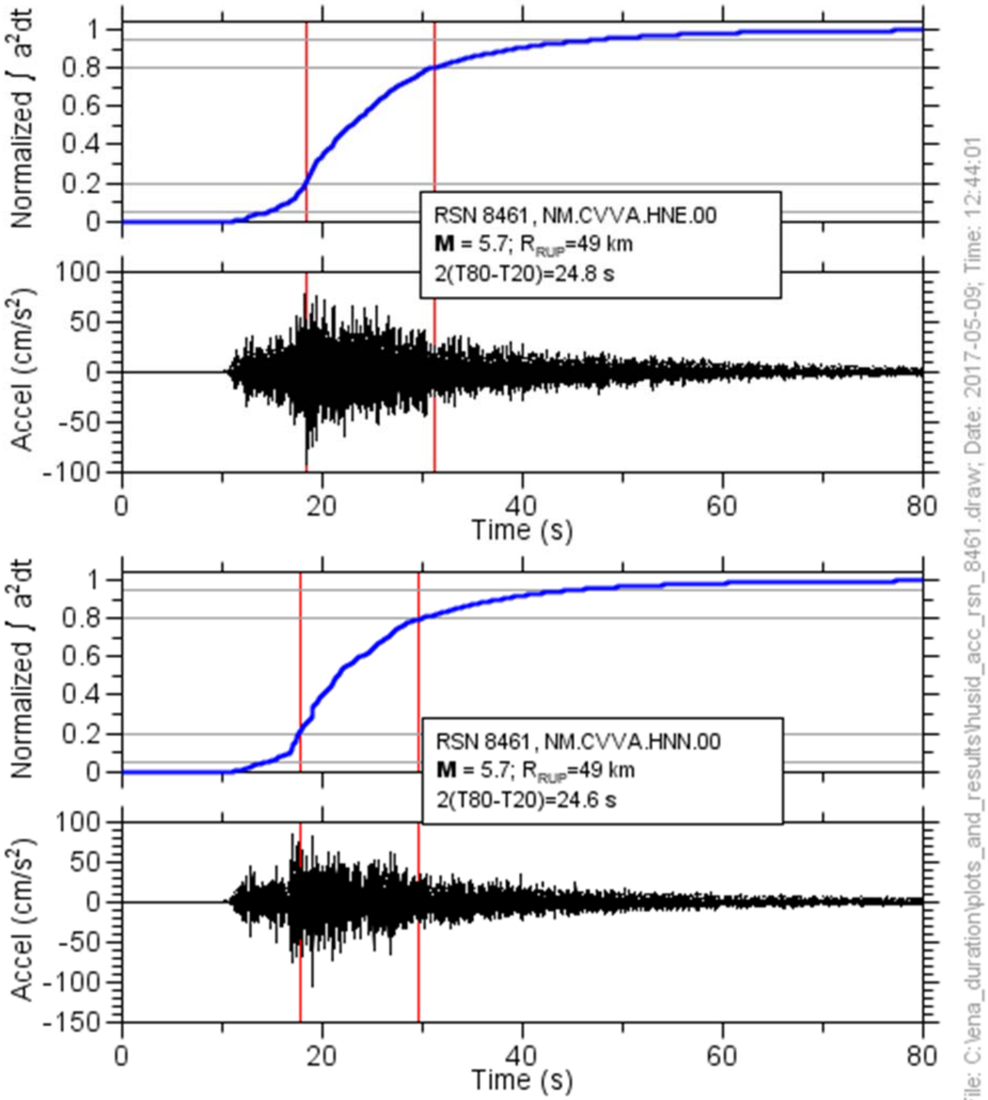

Normalized ∫ a²dt
RSN 8566, QC.11809.BNE
M = 5.7; R_RUP=48 km
2(T80-T20)=30.5 s
Accel (cm/s²)
Time (s)
RSN 8566, QC.11809.BNN
M = 5.7; R_RUP=48 km
2(T80-T20)=37.1 s
File: C:\ena_duration\plots_and_results\husid_acc_rsn_8566.draw; Date: 2017-05-09; Time: 12:43:44

Figure 4.



Normalized ∫ a²dt
RSN 8461, NM.CVVA.HNE.00
M = 5.7; R_RUP=49 km
2(T80-T20)=24.8 s
Accel (cm/s²)
Time (s)
RSN 8461, NM.CVVA.HNN.00
M = 5.7; R_RUP=49 km
2(T80-T20)=24.6 s
File: C:\ena_duration\plots_and_results\husid_acc_rsn_8461.draw; Date: 2017-05-09; Time: 12:44:01

Figure 5.

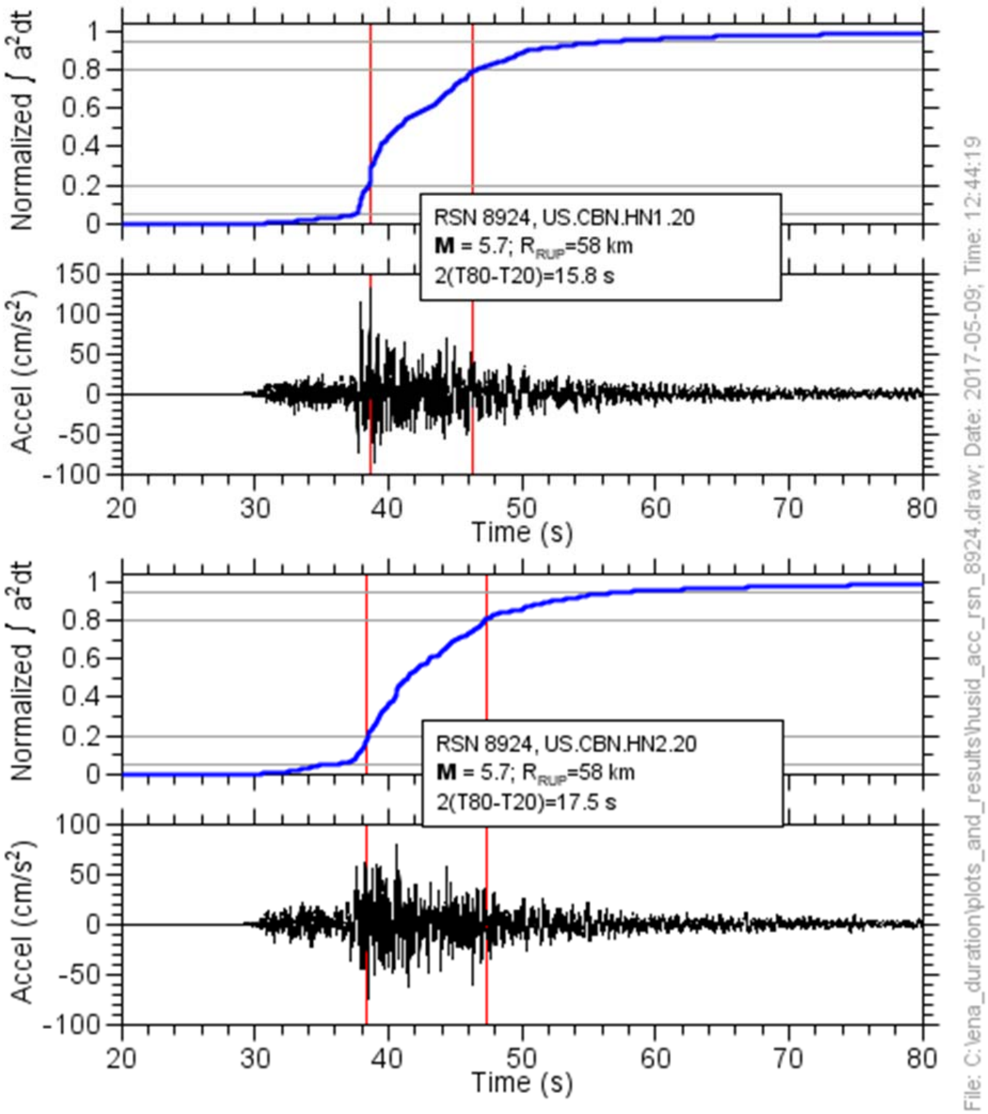
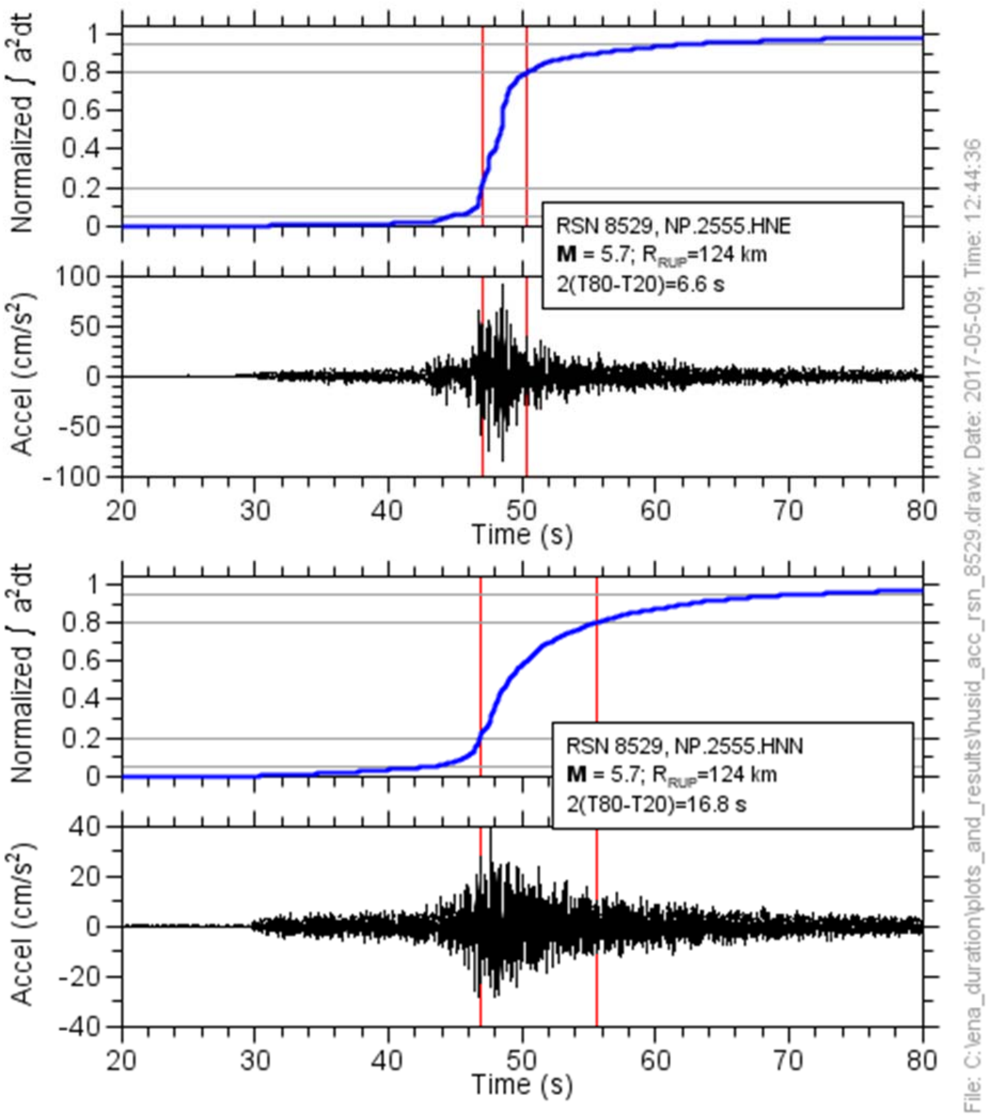

Normalized ∫ a²dt
1
0.8
0.6
0.4
0.2
0
RSN 8924, US.CBN.HN1.20
M = 5.7; R_RUP=58 km
2(T80-T20)=15.8 s
Accel (cm/s²)
150
100
50
0
-50
-100
20
30
40
50
60
70
80
Time (s)
Normalized ∫ a²dt
RSN 8924, US.CBN.HN2.20
M = 5.7; R_RUP=58 km
2(T80-T20)=17.5 s
Accel (cm/s²)
File: C:\ena_duration\plots_and_results\husid_acc_rsn_8924.draw; Date: 2017-05-09; Time: 12:44:19

Figure 6.



Normalized ∫ a²dt
RSN 8529, NP.2555.HNE
M = 5.7; R_RUP=124 km
2(T80-T20)=6.6 s
Accel (cm/s²)
Time (s)
RSN 8529, NP.2555.HNN
M = 5.7; R_RUP=124 km
2(T80-T20)=16.8 s
File: C:\ena_duration\plots_and_results\husid_acc_rsn_8529.draw; Date: 2017-05-09; Time: 12:44:36

Figure 8.

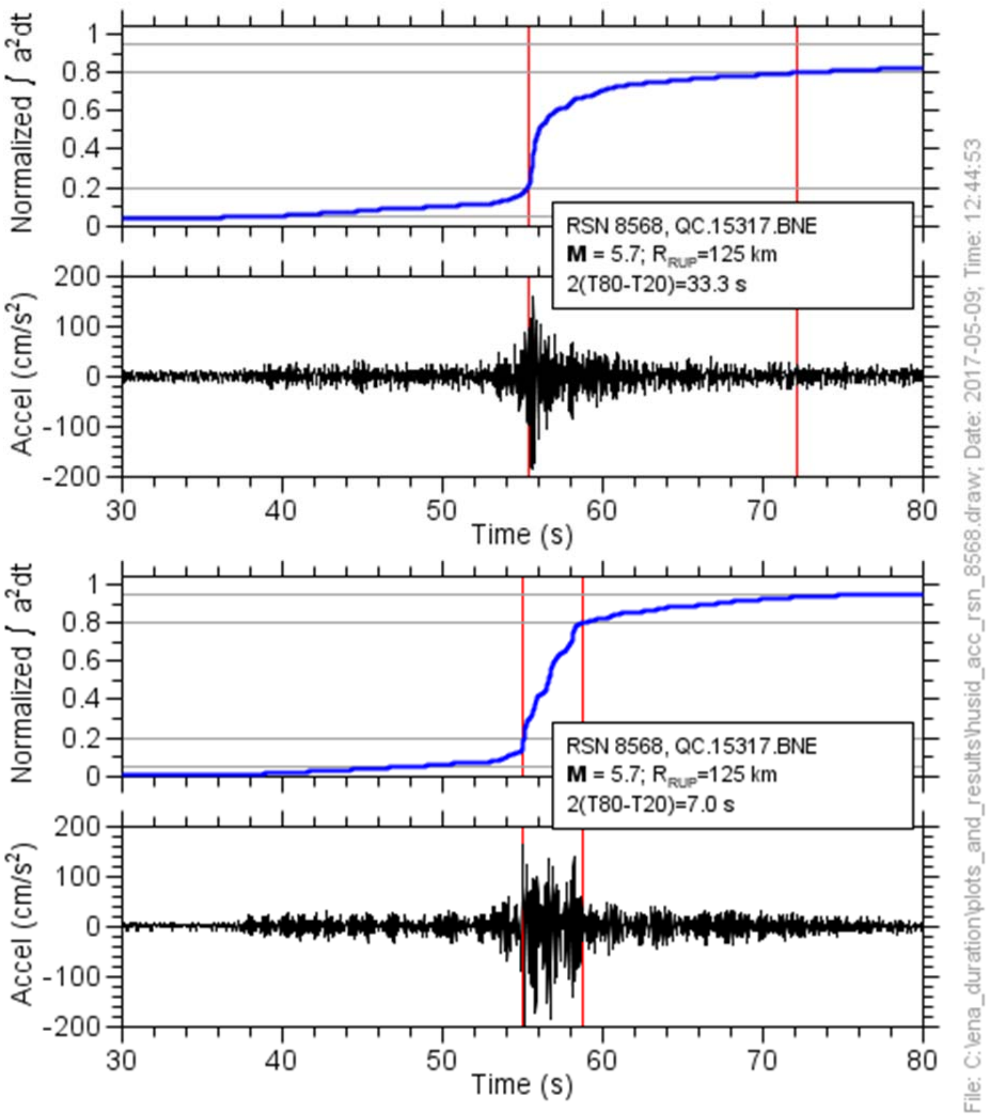

Normalized ∫ a²dt
Accel (cm/s²)
RSN 8568, QC.15317.BNE
M = 5.7; R_RUP=125 km
2(T80-T20)=33.3 s
Time (s)
RSN 8568, QC.15317.BNE
M = 5.7; R_RUP=125 km
2(T80-T20)=7.0 s
File: C:\ena_duration\plots_and_results\husid_acc_rsn_8568.draw; Date: 2017-05-09; Time: 12:44:53

Figure 9.

AFTERSHOCK

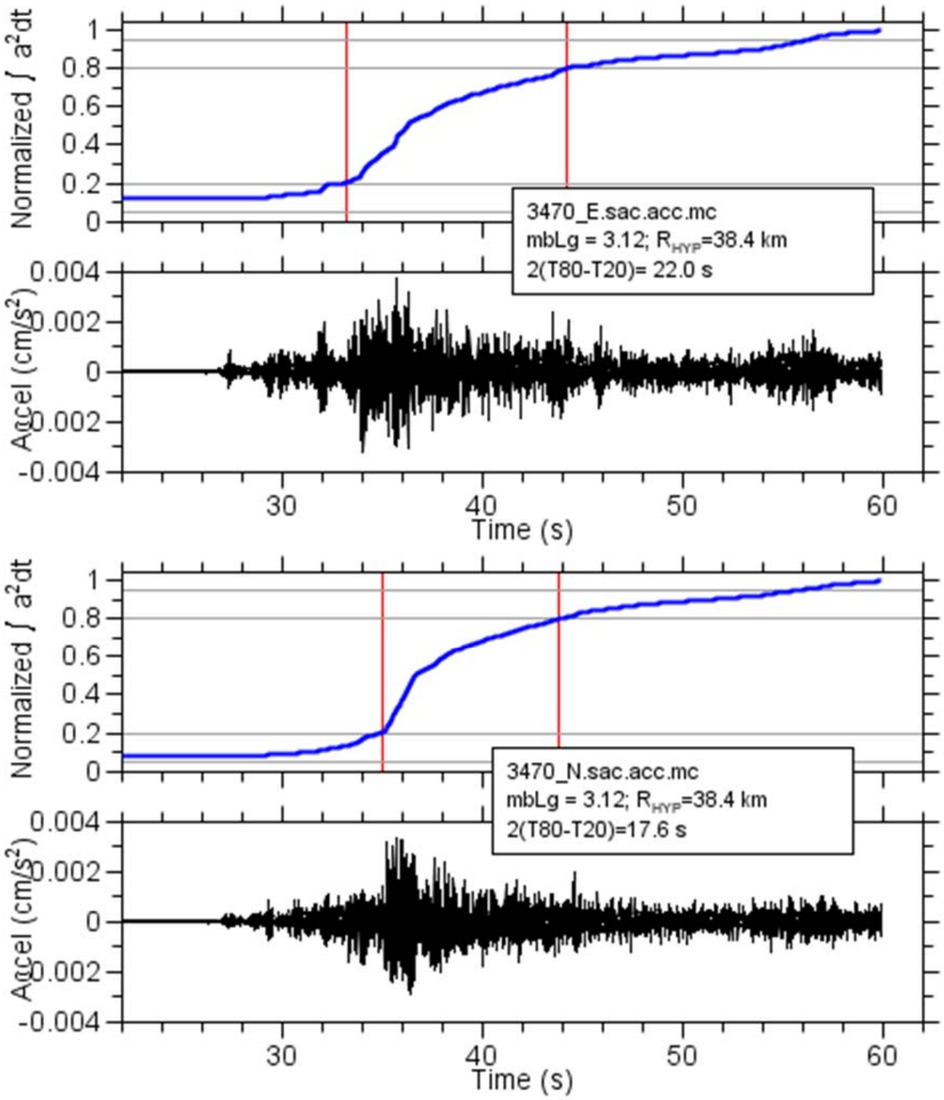


Figure 10.

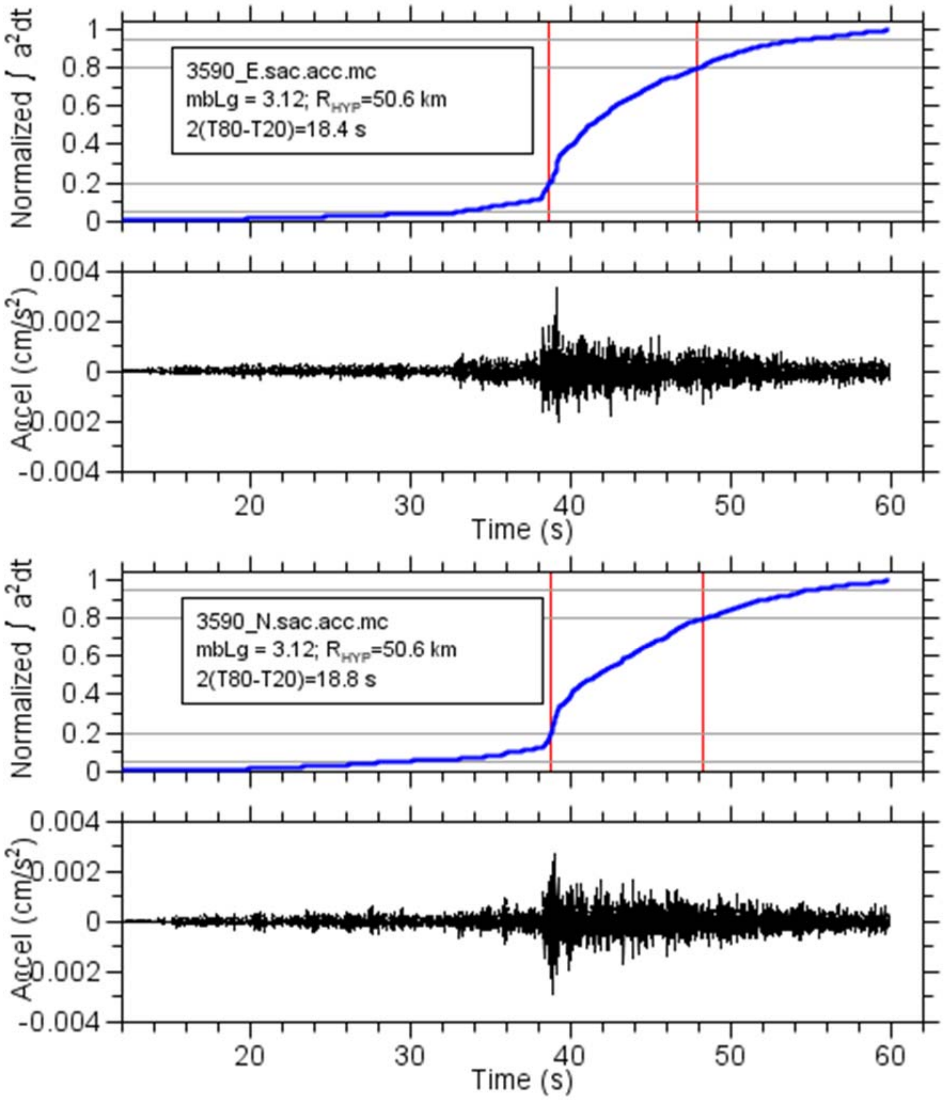


Figure 11.

Note that T20 (the time at which the normalized Husid plot reaches a value of 0.2) often is somewhat later than the S arrival, (T20 is used to avoid including P-waves, as discussed in BT14) but this won't have much effect on the durations used in simulations.

Sometimes the Husid plot shows a rapid increase of short duration, followed by a slower decay. This feature is not included in the default window parameters used in my SMSIM calculations, although the window function could be changed to include it. But what is causing the longer durations after the rapid rise? Presumably this is scattered energy that appears in ENA because of a colder crust than in WNA. Is it proper to apply the stochastic model to this energy? The model assumes that the FAS radiated by the source is distributed over a duration that is the addition of the source duration and a path duration. Bob Herrmann was the first to use the path duration, based on his simulations of wave propagation in a plane layered earth (no scattering). Tom Hanks and Annemarie Baltay have questioned the use of the path duration in the stochastic model, thinking about energy leaving different parts of the focal sphere. I thought a lot about this and aside from giving me a headache, I came to no conclusions other than to ignore their concerns. The whole question of path duration for ENA as it is to be used in the stochastic model would be a good topic for a graduate student.

Another thing: I now realize that the 400 bar stress parameter used by BT15 for determining the source duration may have been too high, leading to a shorter source duration that a smaller stress parameter. For example, my inversion of ENA response spectra using a simple 1/R model gives 162 bars. For the Mineral mainshock (M=5.7) this gives a source duration of 1.6 s, whereas the source duration for 400 bars is 1.2 s. This is not a large difference, and for consistency with the figure from BT15 (the modified version of which is Figure 1 in these notes), I kept the 400 bars when determining the path durations shown in Figure 1. I may modify my SMSIM programs to adjust the path duration for the stress parameter of the model used in a particular run.

Bottom line: the path durations for the Mineral mainshock and best recorded aftershock are generally consistent with the BT15 path duration model to about 50 km, but it would be good to look into the nature of the waveforms in the context of doing stochastic model simulations.

References

Boore, D.M. and E.M. Thompson (2014). Path durations for use in the stochastic-method simulation of ground motions, *Bull. Seismol. Soc. Am.* **104**, 2541–2552.

Boore, D.M. and E.M. Thompson (2015). Revisions to some parameters used in stochastic-method simulations of ground motion, *Bull. Seismol. Soc. Am.* **105**, 1029–1041.