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Dave Boore's notes concerning low-cut filter values contained in the PEER NGA spreadsheet

On May 07, 2004 I sent an email to all developers and a few other interested parties pointing out that the low-cut (high-pass) filter corners in the PEER NGA spreadsheet for some of the analog recordings for the 1978 Tabas earthquake are suspiciously low (see Figure 1). I hypothesized that the records had had long-period noise removed via polynomial corrections, and thus the filter corners should not be used as a guide to the useable bandwidth of the response spectrum. The only reply I received was from Vladimir Graizer. As the recent version of the PEER NGA spreadsheet (Flatfile V2 (June-09-04).xls) still contains the low filter corners for the Tabas records, I thought I should process the data myself to get a better understanding of what is going on.

Figure 1 contains a modified version of the plot I sent in May. In this note I look in detail at horizontral component records from two stations: Tabas and Bajestan (the latter having the lowest corner of all of the Tabas recordings, although it is 120 km from the fault). I obtained the unprocessed data from the European Strong-Motion Database web site. The Bajestan recording has obvious problems: an offset at 8.3 s on the x component and spikes on the y component (Figure 2). Correcting for the spikes was easy— I just replaced them with the average of the two adjacent values. Dealing with the offset was more difficult. I show in Figures 3 and 4 the results of filtering at the PEER NGA value of 0.02 Hz, as well as 0.1 and 0.2 Hz. Figure 2 contains the results of filtering with no corrections for the offset on the x component. But it is clear that without removing the offset, the waveforms and peak motions are not believable for the 0.02 Hz filter. The waveforms and peaks motions are more reasonable for the higher frequency filters, but the offset in acceleration leads to erroneous motions in the velocity and displacements with amplitudes that are close to the peak motions. I tried removing the offsets by fitting simultaneously two quadratics to the motions on either side of the offset, constraining the linear and quadratic terms to be the same for both functions. The difference in constant terms was used as a correction. The results were not that much better. After some trial and error, I finally subtracted from the acceleration second and fourth order polynomials fit to the motions before and after the offset. Filtering these baseline-corrected records gave the results shown in Figure 4. The results look better than before, but still the records filtered using the 0.02 Hz filter corner are dominated by unrealistically long-period motions. The filtered y-component record is shown in Figure 5, after despiking. Again the motions obtained using a 0.02 Hz filter corner are not realistic. The results in Figure 3, 4, and 5 convince me that the filter corner given in PEER NGA spreadsheet is not correct, at least for Bajestan (and probably not for most other records, the exception being the large-motion recording at Tabas).

The processed records for Tabas are shown in Figures 6 and 7 for the two horizontal components. The PEER NGA value of 0.05 Hz for the low-cut filter corner seems reasonable.

Figure 8 compares the geometric mean of the motions at Bajestan and Tabas obtained by my processing and contained in the PEER NGA spreadsheet (previous version). The PEER PGV value for Bajestan is similar to that obtained for a filter around 0.1 Hz, whereas the PGD value implies a lower frequency corner (but not as low as 0.02 Hz). The Tabas values indicate that the filter corner of 0.05 Hz (the PEER NGA value) may be OK. There is relative stability in the PGV, although as often happens, the value of PGD is sensitive to the low-cut filter corner (and this is the prime reason that I will not be providing ground-motion prediction equations for PGD).

The pseudo-acceleration spectra for the Bajestan and Tabas recordings are shown in Figures 9 and 10. The high value at short periods for the European Strong-Motion Database results are due to the presence of a large amplitude spike on the Bajestan y-component (Figure 2) that was not removed during data processing. Otherwise the agreement is good over the period range 0.2–2 s. Note that the PEER NGA PGA value, and thus the short-period response spectrum, at Tabas is lower than the others (but recall that I used the European uncorrected data, so agreement should be expected between the non-PEER values at short periods, which are not as sensitive to filtering). (European Strong-Motion Database processed data on the web site, as opposed to the recently released CD, uses a low-frequency filter of 0.25 Hz for all records.)

Another potential problem: Kashmar is an S triggered record (Figure 11).

Conclusions: 1) the low-cut filter corners of all but the Tabas recording of the 1978 Tabas earthquake are probably too small; 2) the PGD is sensitive to the filter corner; 3) the PEER NGA PGA for Tabas is about 15 percent lower than the value from the European Strong-Motion Database web site; 4) Kashmar is an S-triggered record.

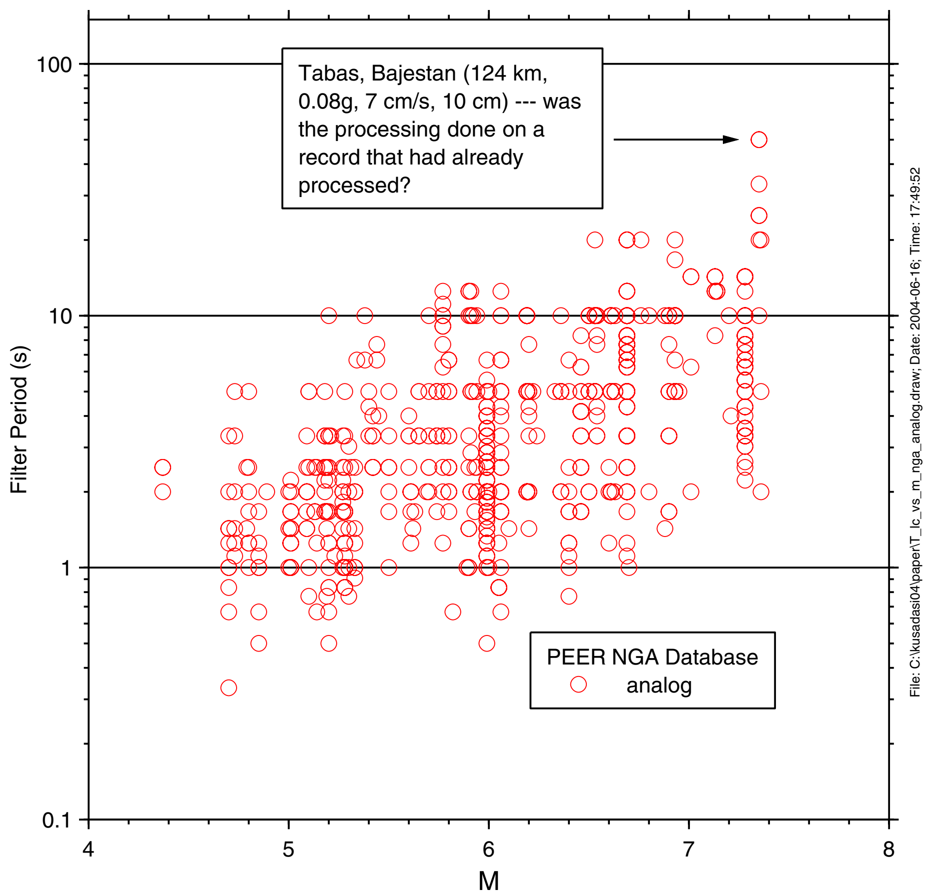

Figure 1. Low-cut filter corners, expressed as periods, vs. M for data in the previous version of the PEER NGA spreadsheet, for analog instruments. Many values for the digitally-recorded Tabas earthquake seem too large.

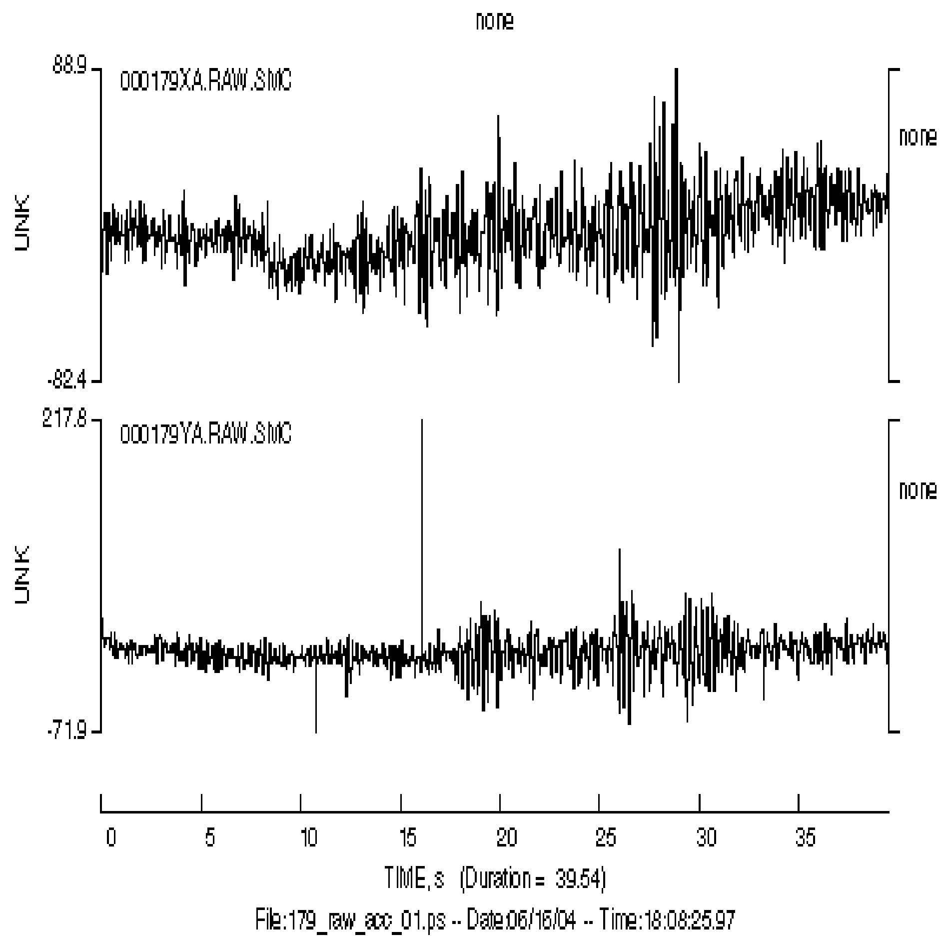

Figure 2. Uncorrected traces from the Bajestan recording of the 1978 Tabas earthquake, obtained from the European Strong-Motion database web site. Note the step offset on the x component at about 8.3 sec, and the large spikes on the y component.

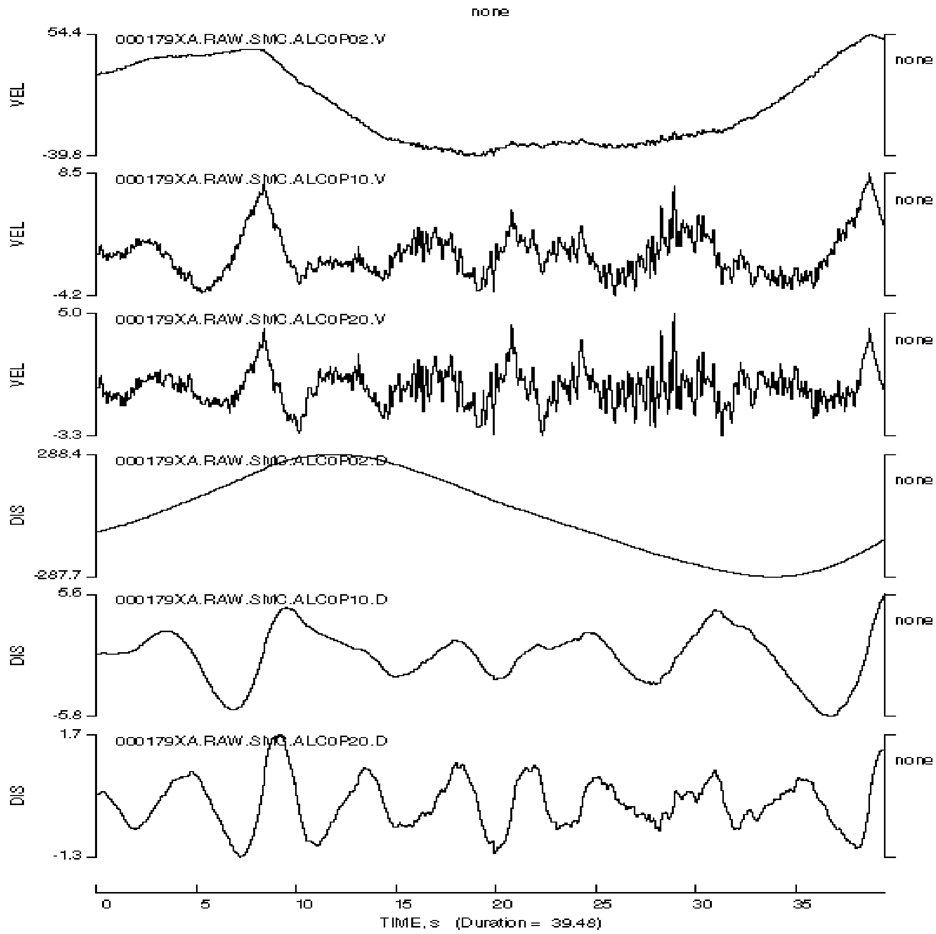

Figure 3. x-component velocity and displacement traces for the Bajestan recording of the 1978 Tabas earthquake, obtained by filtering the unprocessed acceleration with acausal Butterworth filters with corner frequencies of 0.02, 0.10, and 0.20 Hz. At low-frequencies the filter decays as $1/f^8$. No correction was made for the step offset on the x component at about 8.3 sec. Only the original portion of the processed time series are shown (the pre- and post-filter transients are not shown).

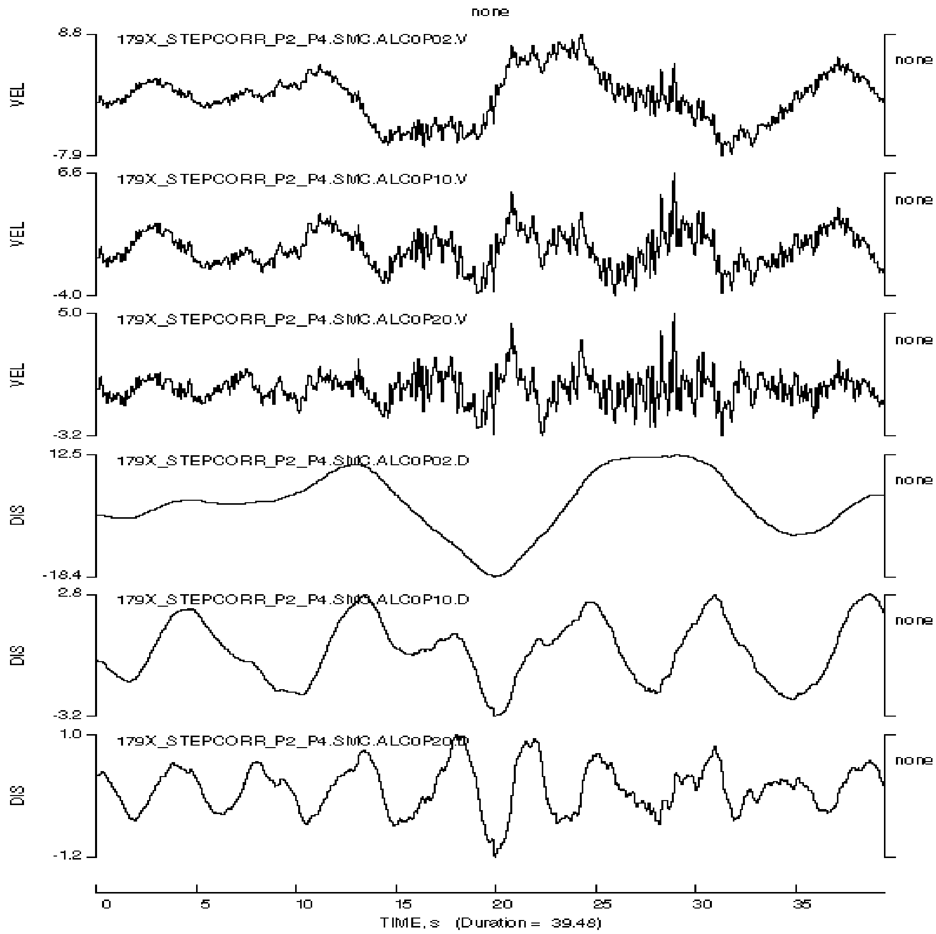

Figure 4. x-component velocity and displacement traces for the Bajestan recording of the 1978 Tabas earthquake, obtained by filtering the unprocessed, step-corrected acceleration with acausal Butterworth filters with corner frequencies of 0.02, 0.10, and 0.20 Hz. At low-frequencies the filter decays as $1/f^8$. The correction for the step offset on the x component at about 8.3 sec was made by subtracting from the unprocessed record second and fourth order polynomials fit to the unprocessed accelerations on either side of the offset. Only the original portion of the processed time series are shown (the pre- and post-filter transients are not shown).

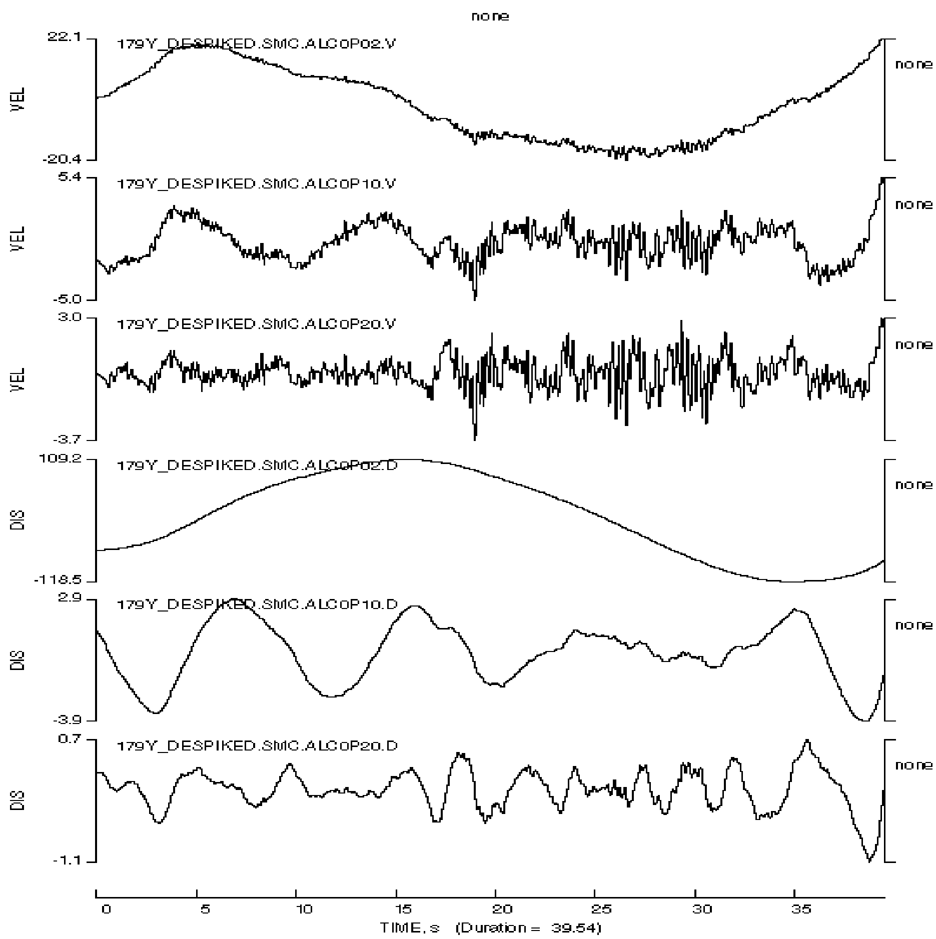

Figure 5. y-component velocity and displacement traces for the Bajestan recording of the 1978 Tabas earthquake, obtained by filtering the unprocessed, step-corrected acceleration with acausal Butterworth filters with corner frequencies of 0.02, 0.10, and 0.20 Hz, after replacing the spikes at 10.74,12.26, 16.04, 25.98, and 33.2 sec with averages of the values on either side of the spike. At low-frequencies the filter decays as $1/f^8$. Only the original portion of the processed time series are shown (the pre- and post-filter transients are not shown).

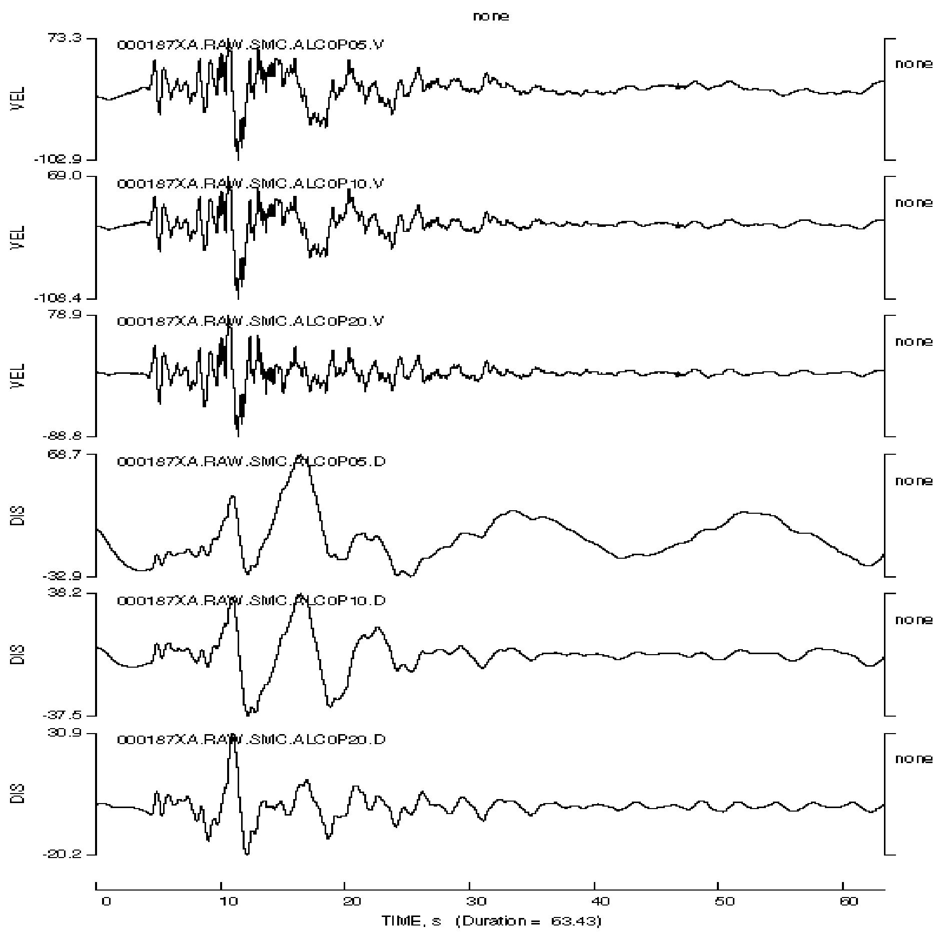

Figure 6. x-component velocity and displacement traces for the Tabas recording of the 1978 Tabas earthquake, obtained by filtering the unprocessed acceleration with acausal Butterworth filters with corner frequencies of 0.05, 0.10, and 0.20 Hz.

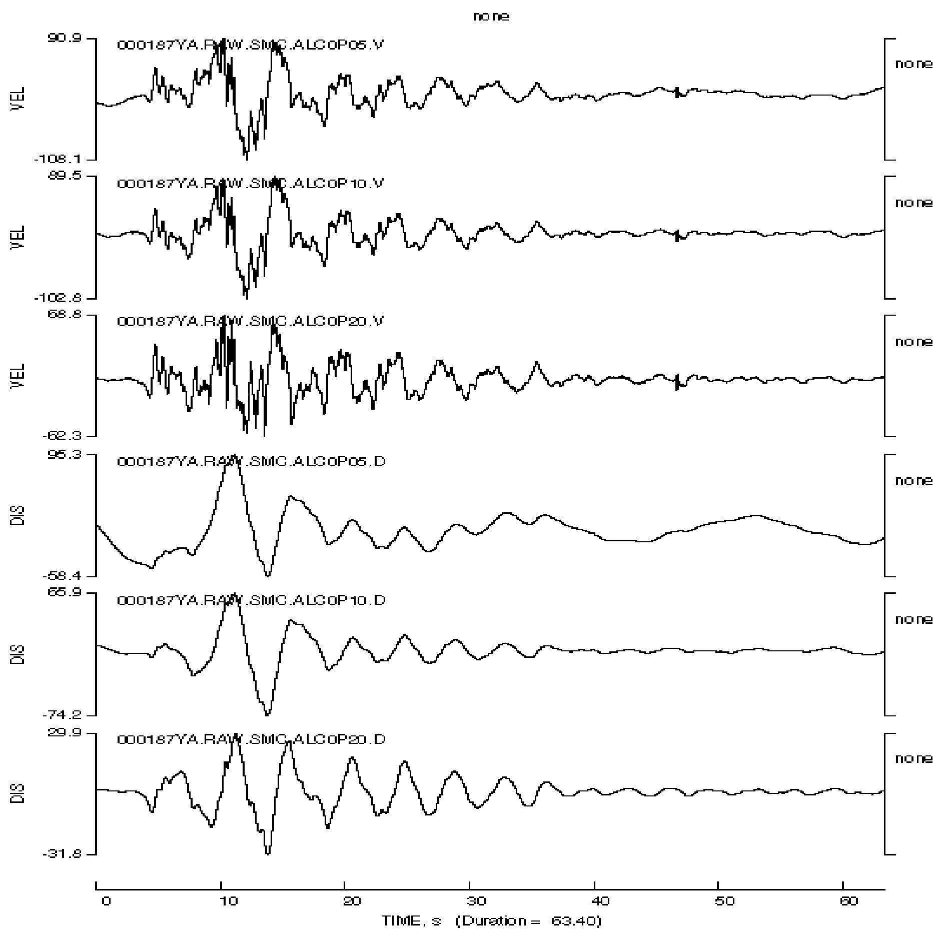

Figure 7. y-component velocity and displacement traces for the Tabas recording of the 1978 Tabas earthquake, obtained by filtering the unprocessed acceleration with acausal Butterworth filters with corner frequencies of 0.05, 0.10, and 0.20 Hz.

Tabas, Iran 1978 0916

station: Bajestan

data source	f_hp (Hz)	pga(cm/s/s)	pgv (cm/s)	pgd(cm)
PEER NGA:	0.02	77.89	6.60	10.39
Filter only	0.02	74.64	34.52	183.46
Filter only	0.1	76.02	6.84	5.02
Filter only	0.2	76.48	4.30	1.37
Constant step correction	0.02	74.77	37.76	194.87
Constant step correction	0.1	75.98	7.42	5.29
Constant step correction	0.2	76.48	4.30	1.28
Polynomial step correction	0.02	76.27	13.88	46.34
Polynomial step correction	0.1	76.15	6.02	3.58
Polynomial step correction	0.2	76.48	4.30	1.15

station: Tabas

data source	f_hp (Hz)	pga(cm/s/s)	pgv (cm/s)	pgd(cm)
PEER NGA:	0.05	827.96	109.00	59.09
Filter only	0.05	949.84	105.47	80.91
Filter only	0.1	952.11	105.56	53.24
Filter only	0.2	980.82	78.16	31.35

Figure 8. Geometric-mean peak ground motions for the Bajestan and Tabas recordings of the 1978 Tabas earthquake from records processed by PEER NGA and by D. Boore, showing the influence of filter corner.

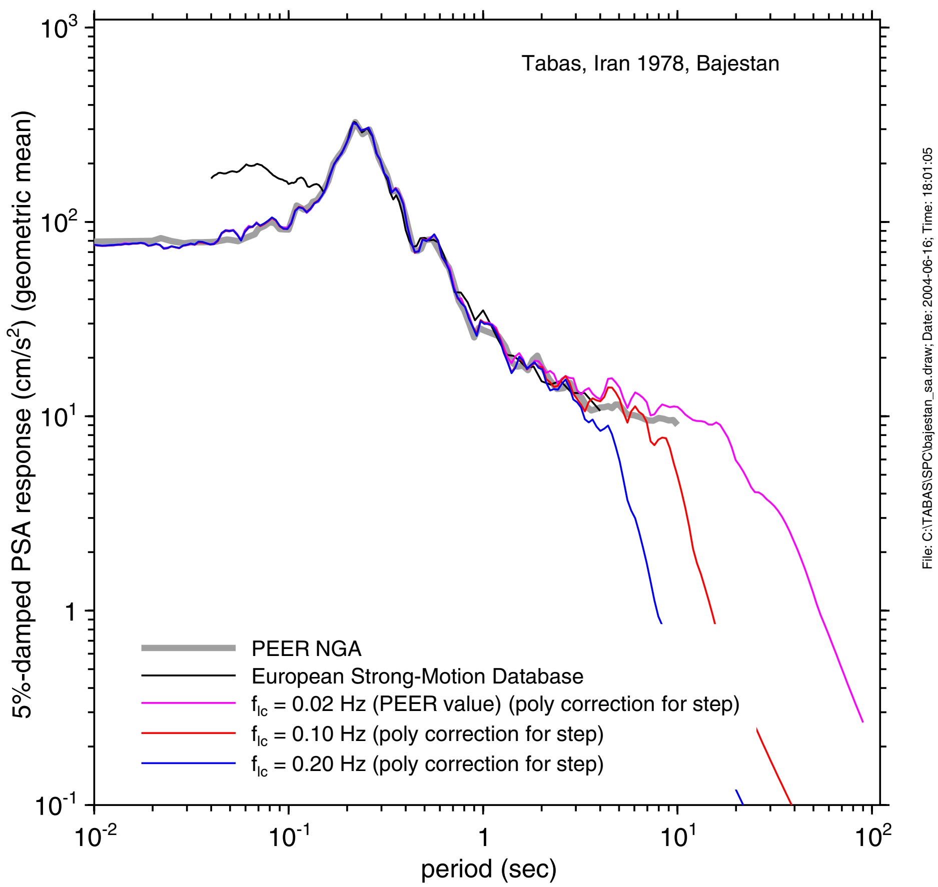

Figure 9. Geometric-mean SA for Bajestan record of the Tabas earthquake, processed by different groups and using different filter corners. Note that D. Boore's processing included a polynomial step correction for one component and despiking of the other component (not done for the processing of records available from the European Strong-Motion Database web site, which explains the divergence at short periods).

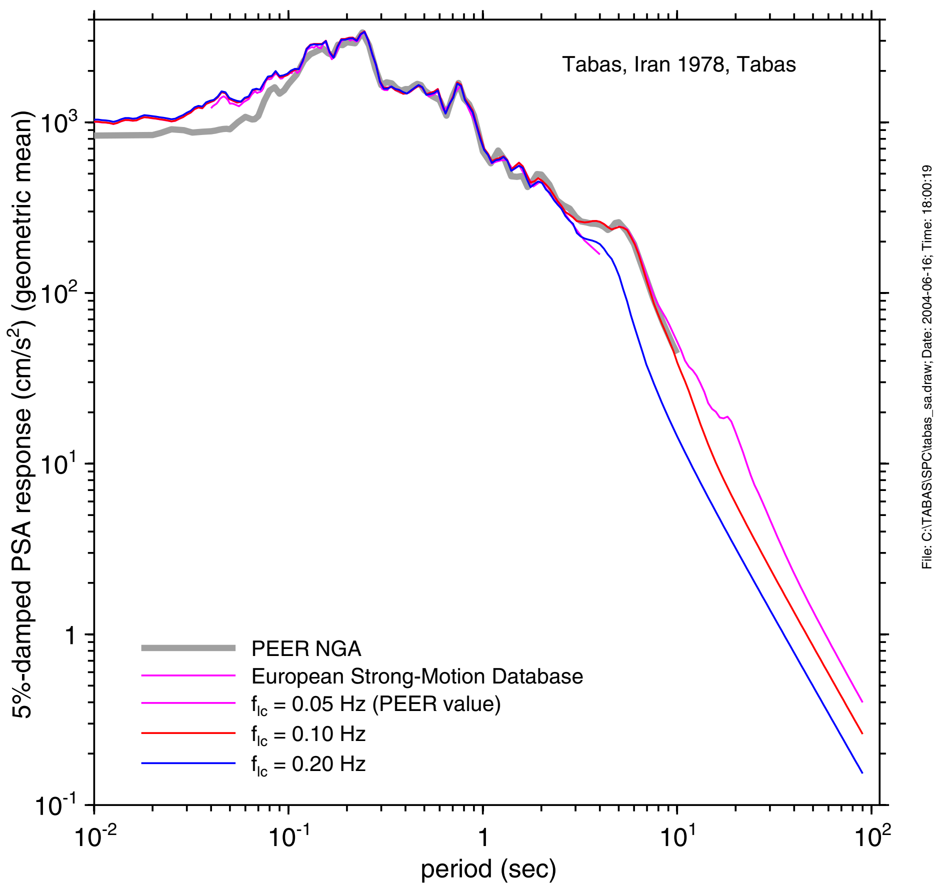

Figure 10. Geometric-mean SA for Tabas record of the Tabas earthquake, processed by different groups and using different filter corners. Note the difference between the PEER NGA and the other values at short periods.

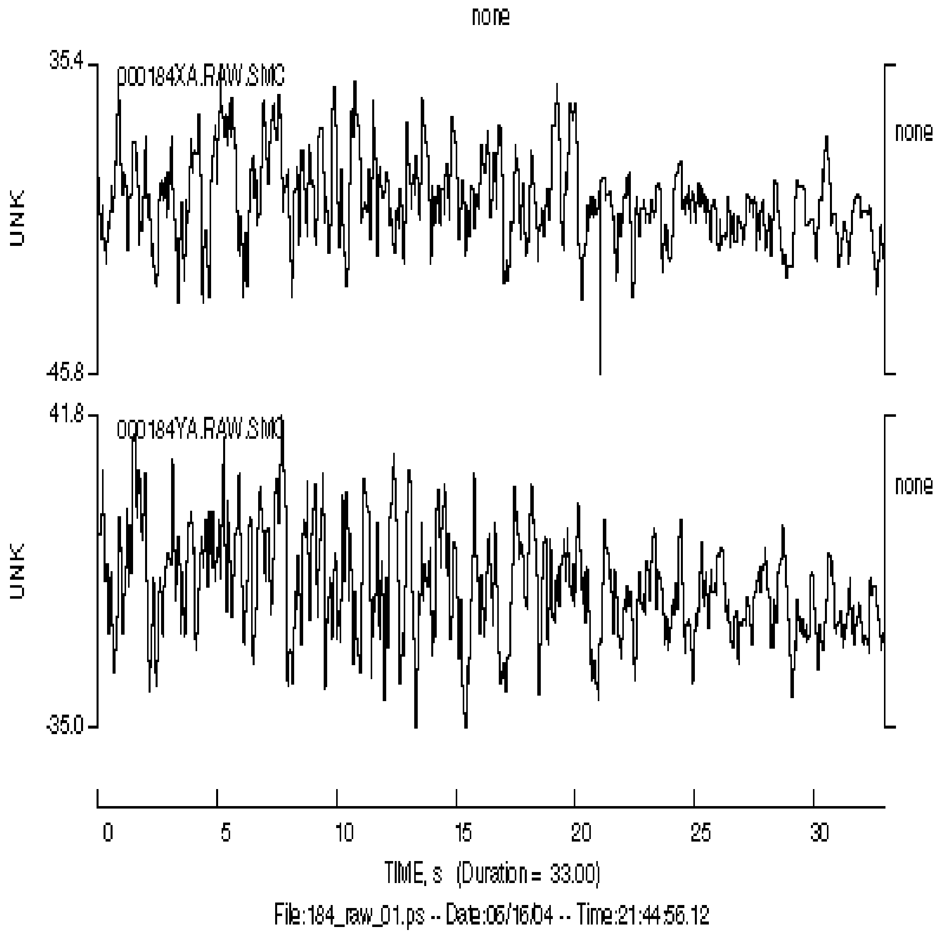

Figure 11. Unprocessed x- and y-component accelerations for Kashmar recording of the 1978 Tabas earthquake, showing that it is an S-triggered record.