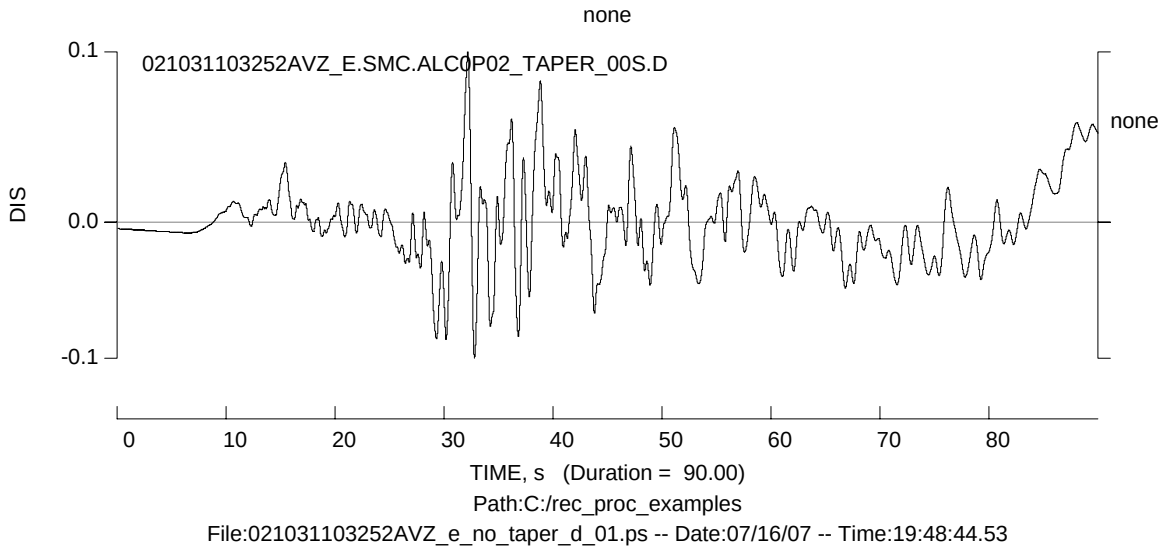
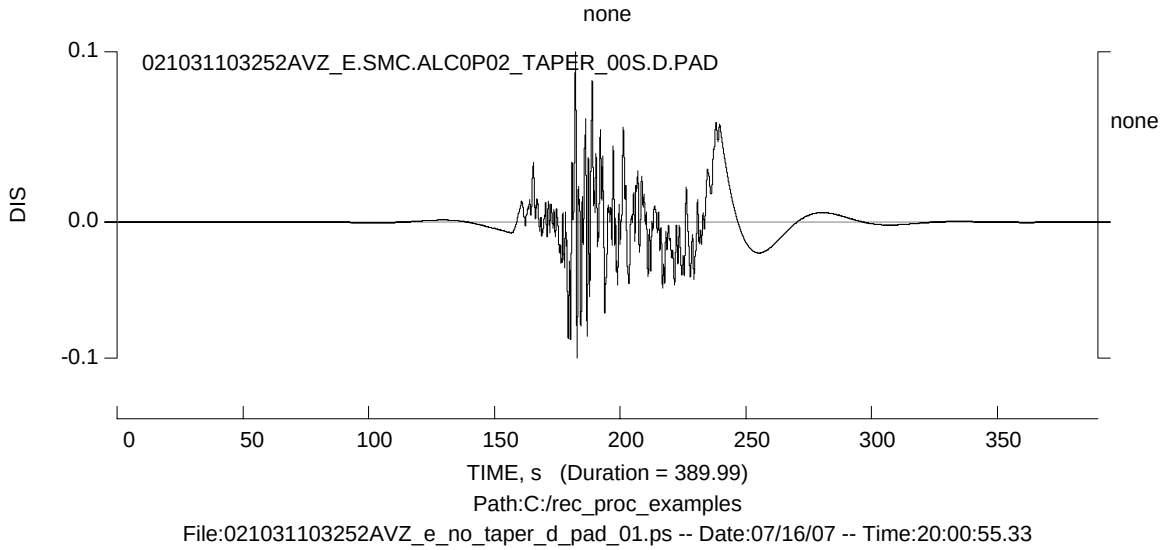
Using tapers at the beginning and end of the time series to which pads will be added before filtering

Notes by David M. Boore

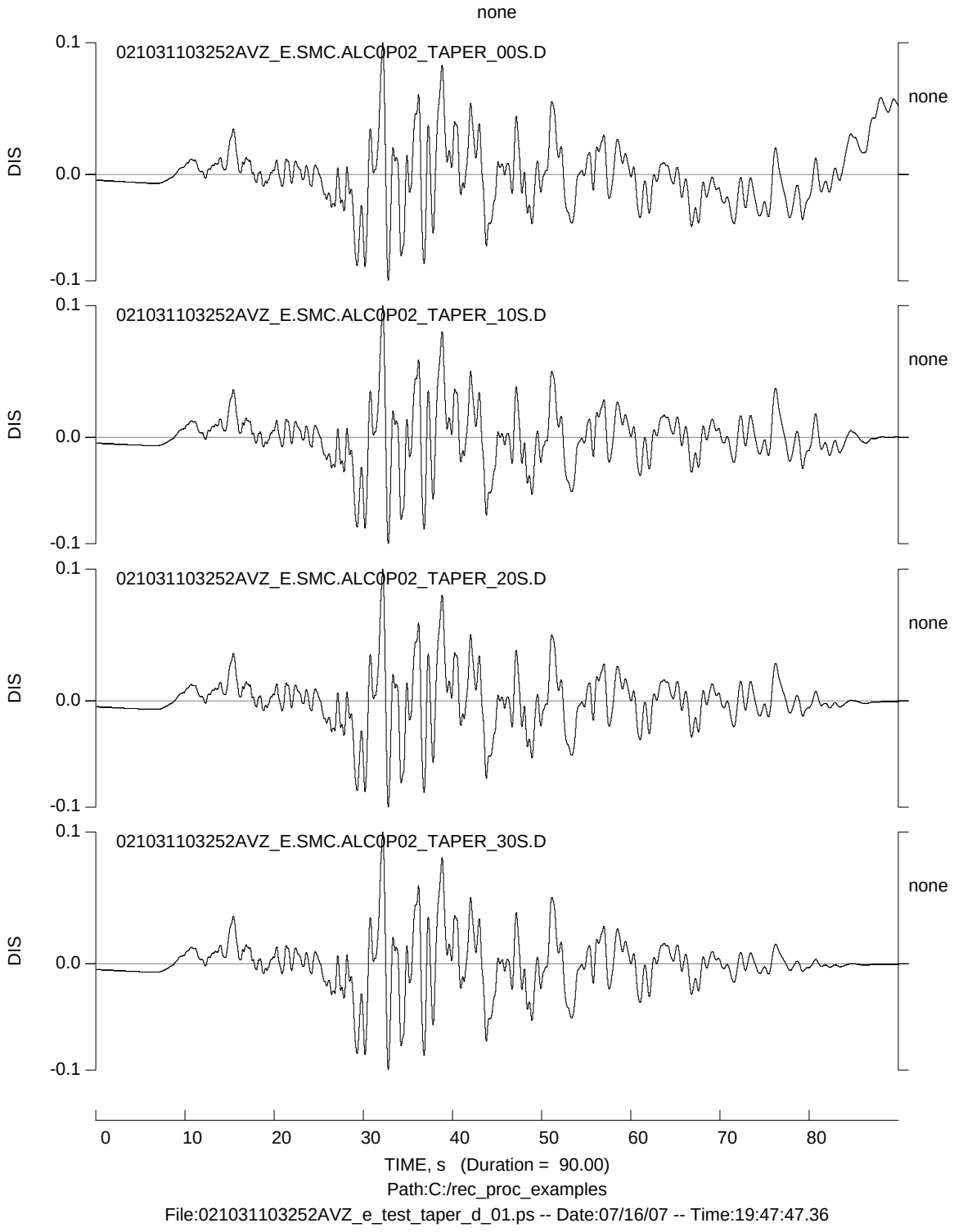
I have sometimes observed that a transient occurs near the end (or less often the front) of the pad-stripped displacements obtained from filtered accelerations (where the pads start from the first zero crossing at the front and back of the original time series---this corresponds to zcross = T in my program `blpadflt`). Here is an example:



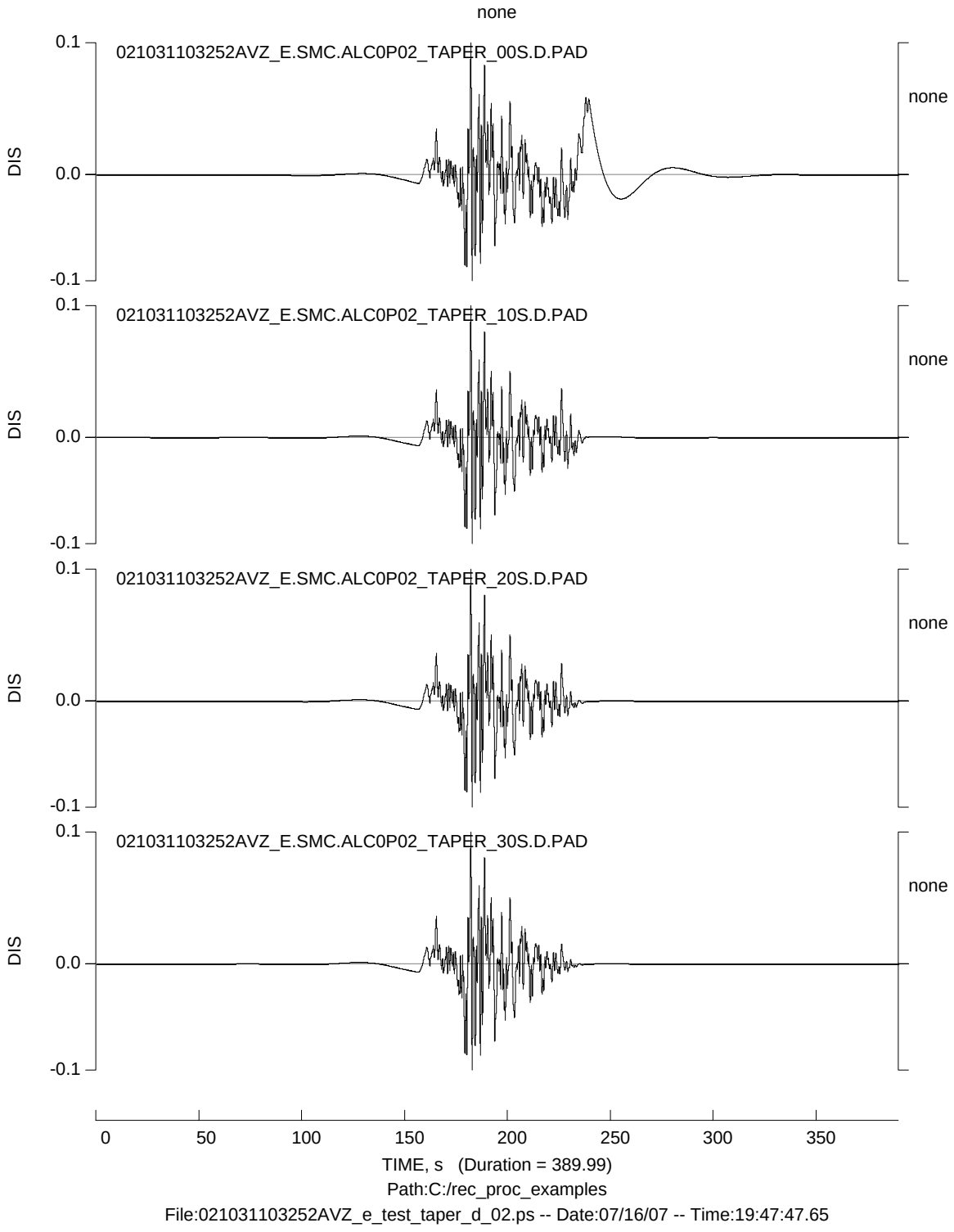
and with the pads:



(The time series was low-cut filtered with an acausal filter having a corner frequency of 0.02 Hz and an asymptotic trend of f^8 at low frequencies.) The transient at the end is probably due to a localized drift in the acceleration trace near the end of the record. While not aesthetically pleasing, the transient does not affect the peak displacement, and often does not affect the long-period response spectrum (as will be shown for this several other examples). One way of dealing with this transient is simply to snip off the offending portion of the trace, but then there may be an incompatibility between the new displacement trace and the response spectrum (for reasons given in Boore, 2005). A better procedure is to apply short tapers to the ends of the time series to which the zero pads will be added (this time series may be shorter than the original time series if the zcross = T option is chosen). Here is a figure showing the pad-stripped results of adding tapers of 10, 20, and 30 s to the time series shown above:

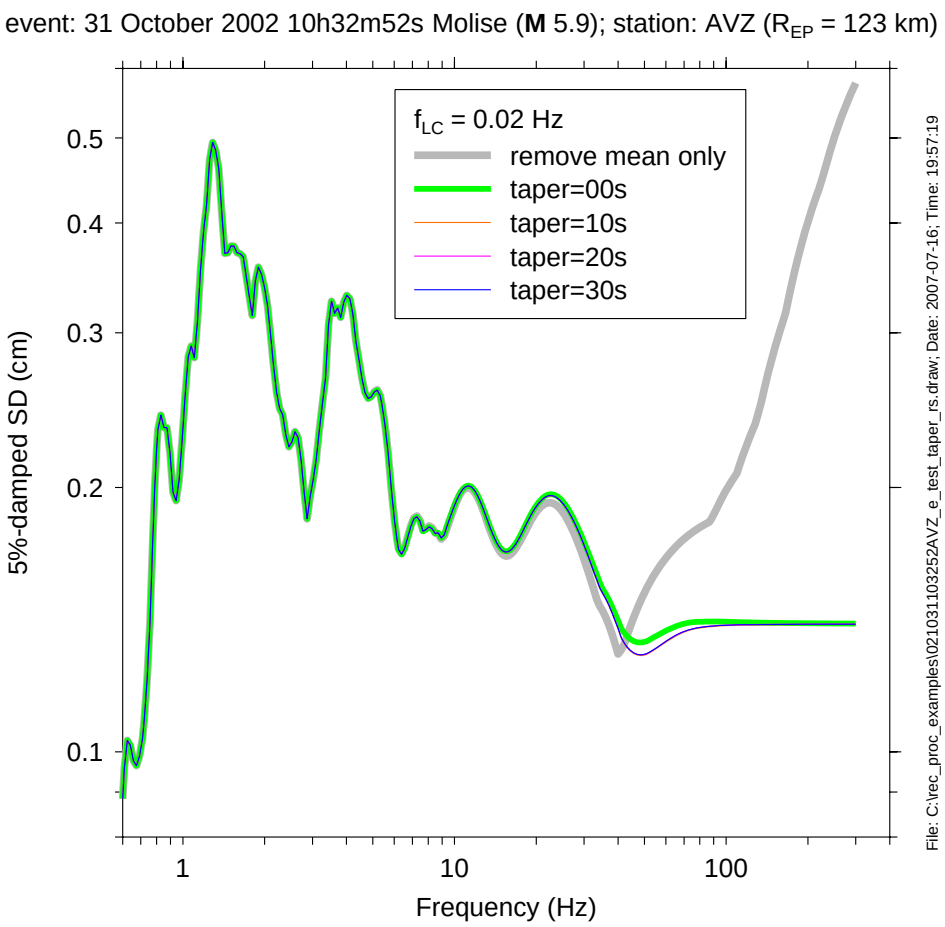


and here is the same figure without stripping off the padded portions:



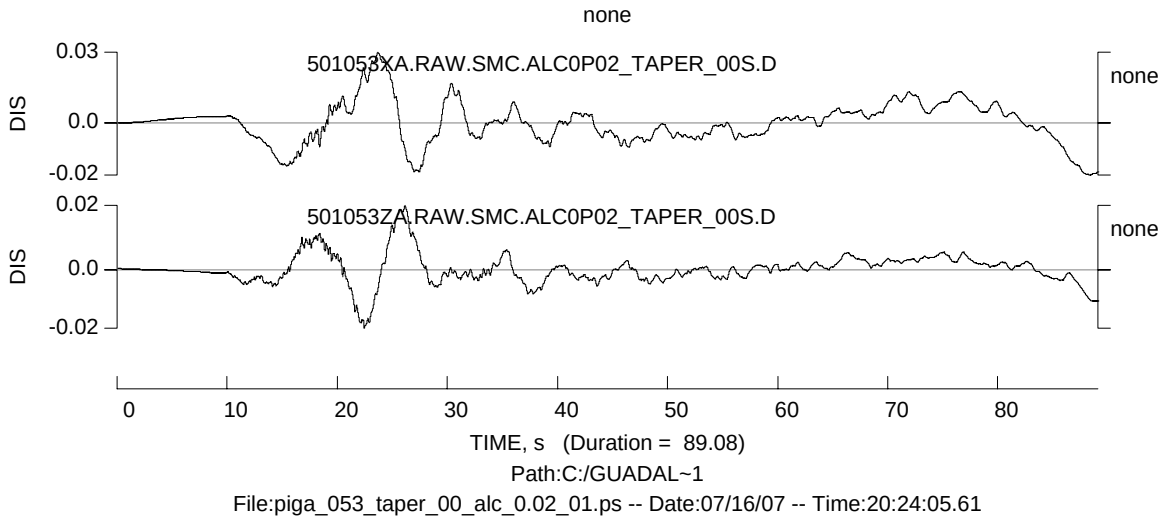
Clearly the tapers have removed the transient.

The displacement response spectrum for the unfiltered, filtered and untapered, and filtered and tapered time series is shown here:

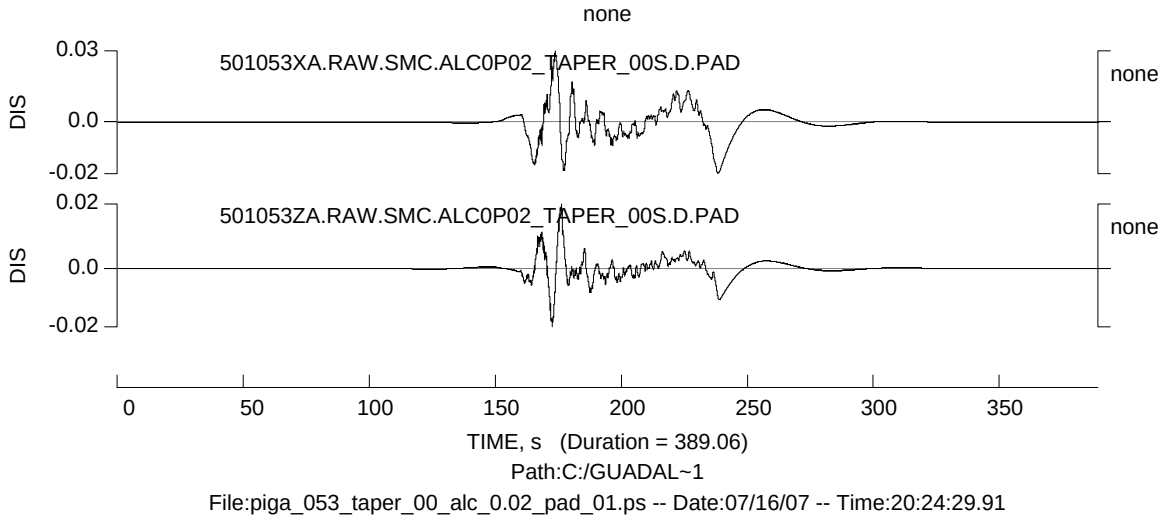


Surprisingly, in this example the very noticeable transient had little effect on the response spectrum. It is also clear that the taper lengths of 10, 20, and 30 s gave the same response spectrum.

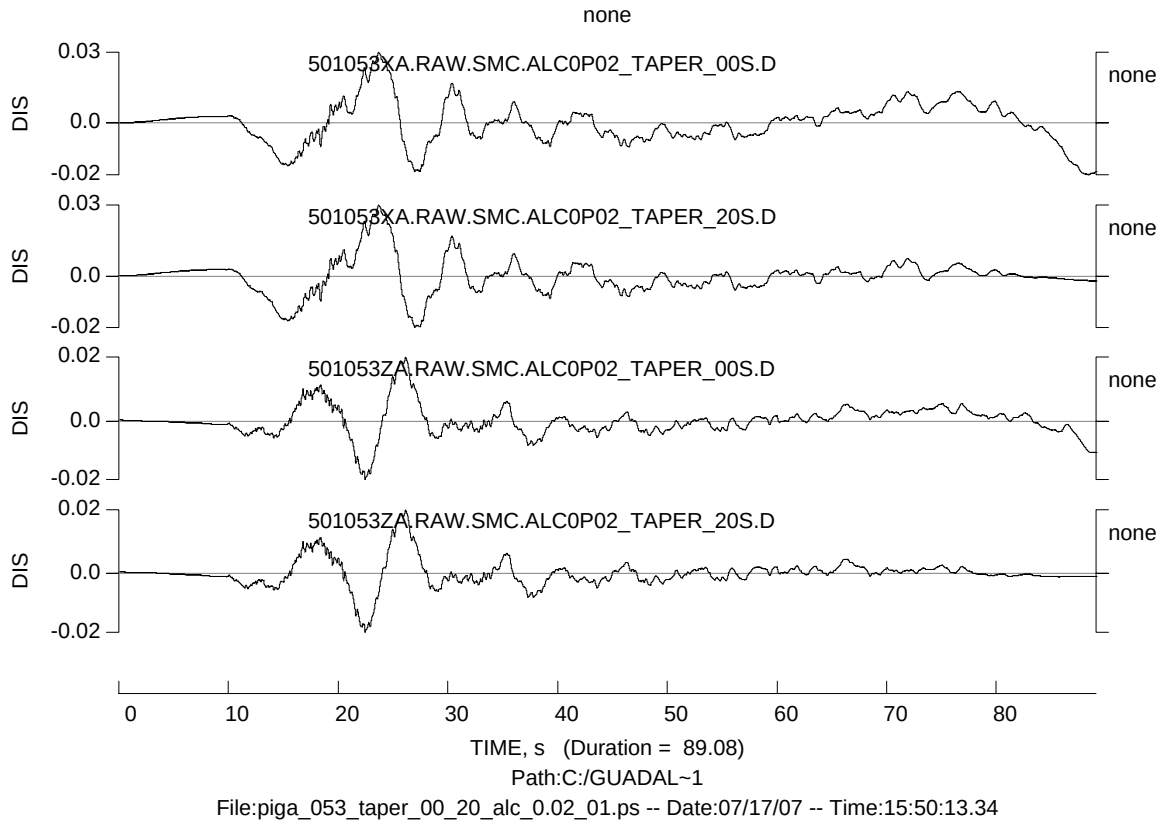
In some cases, the transient can affect the response spectrum. Consider these two components, low-cut filtered as before, at 0.02 Hz (with no tapering):



and without the pads stripped off:



Here are plots of the displacements with and without tapering before filtering: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TIME, s (Duration = 89.08)
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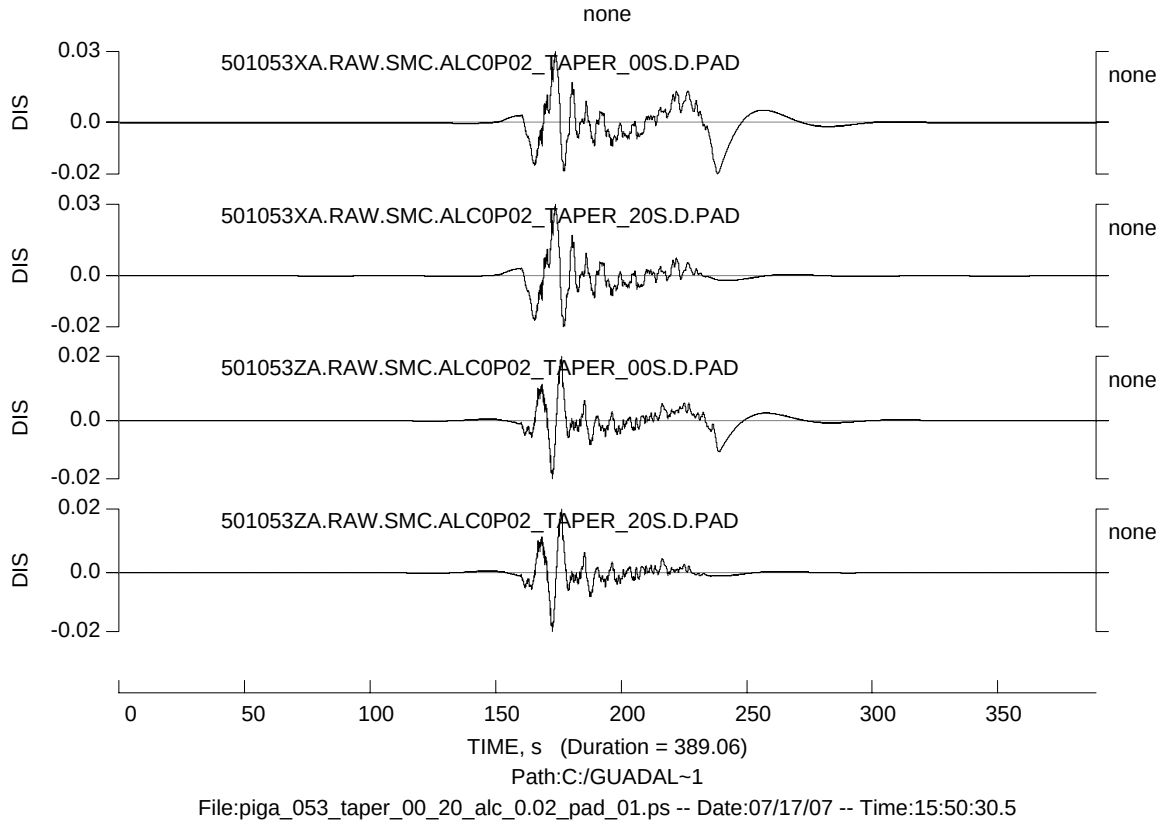
File:piga_053_taper_00_20_alc_0.02_01.ps -- Date:07/17/07 -- Time:15:50:13.34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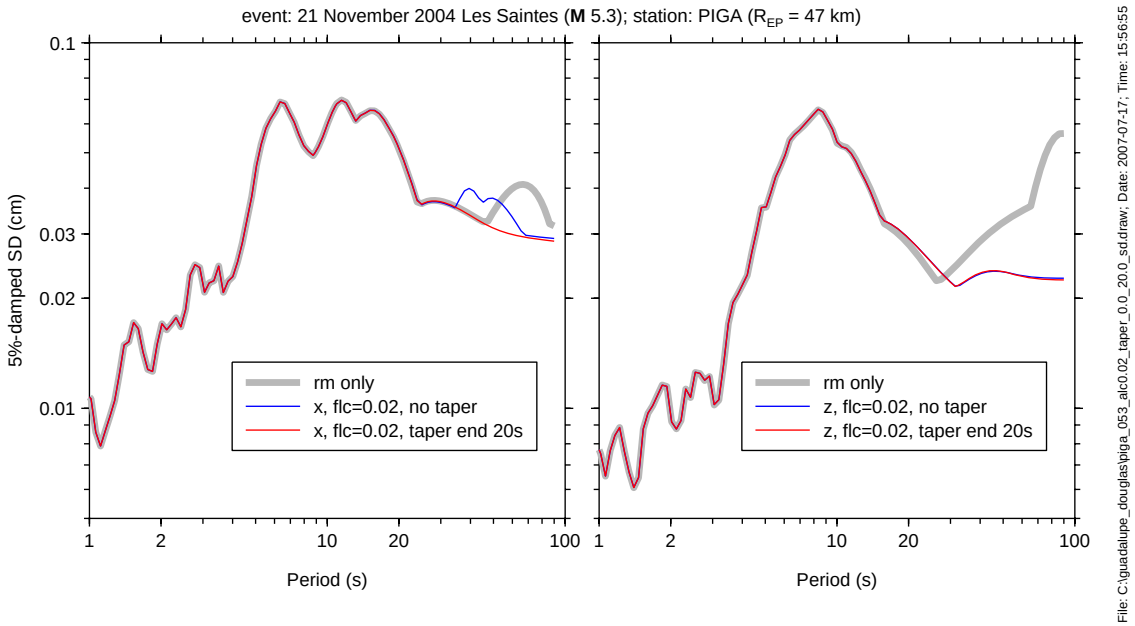
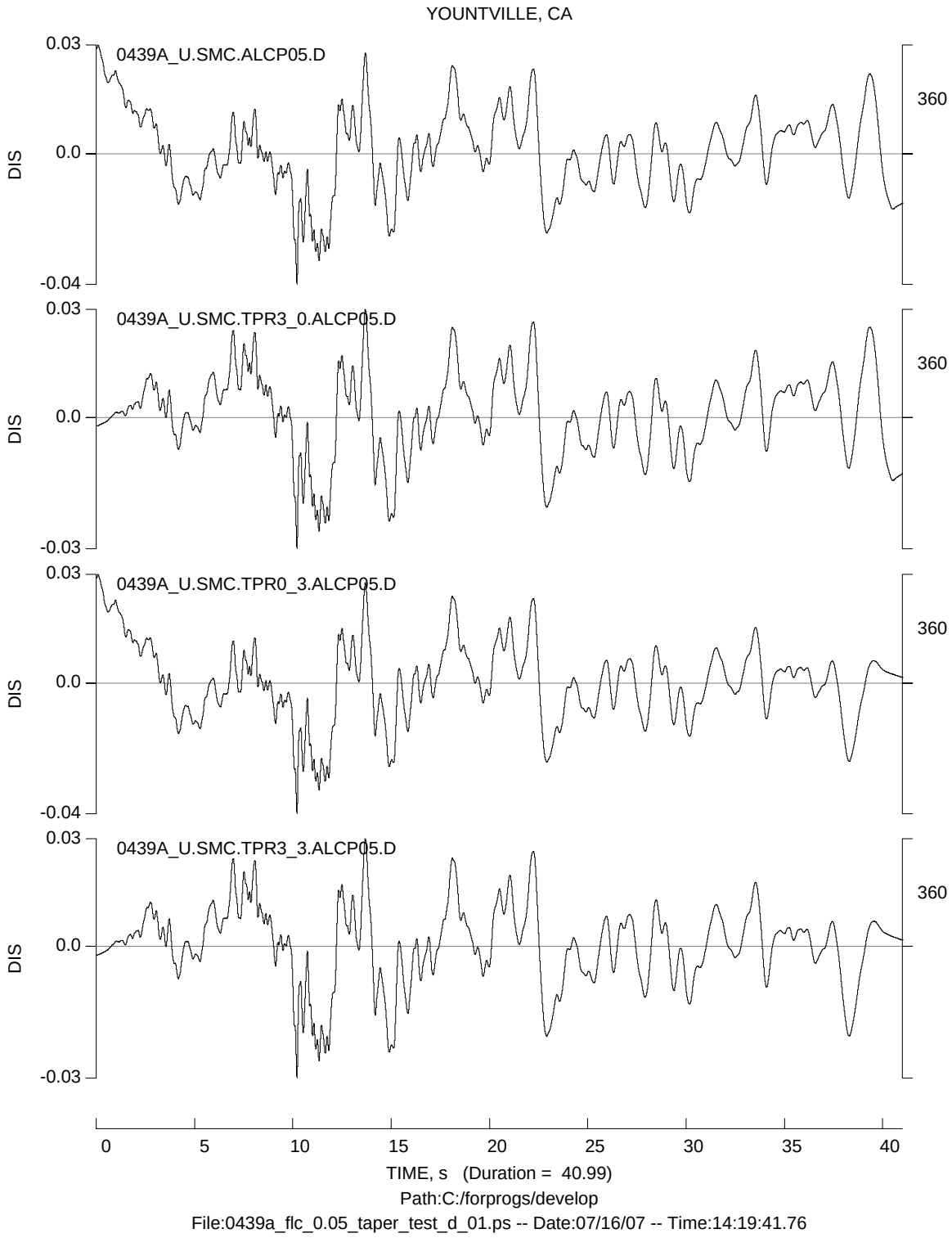
Path:C:/GUADAL~1
File:piga_053_taper_00_20_alc_0.02_pad_01.ps -- Date:07/17/07 -- Time:15:50:30.5

In this case the tapers reduced the transients, but they did not remove them as they did in the previous example. But the transients have been reduced sufficiently that they have little affect on the response spectrum, as shown here:



It is interesting to note that only on the x component was the transient in the untapered record large enough to affect the response spectrum (compare untapered, component x (left graph) and untapered, component z (right graph)).

As a final example, I show a very instructive case involving transients at the beginning and the end of the filtered original time series. Here are the displacements for a low-cut filter of 0.05 Hz, with and without tapering ("TPR3_0", "TPR0_3", and "TPR3_3" are the results of a 3 s taper at the beginning, a 3 s taper at the end, and 3 s tapers at the beginning and end, respectively):


YOUNTVILLE, CA
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0439A_U.SMC.TPR3_0.ALCP05.D
0439A_U.SMC.TPR0_3.ALCP05.D
0439A_U.SMC.TPR3_3.ALCP05.D
DIS
0.03
0.0
-0.04
-0.03
360
0
5
10
15
20
25
30
35
40
TIME, s (Duration = 40.99)
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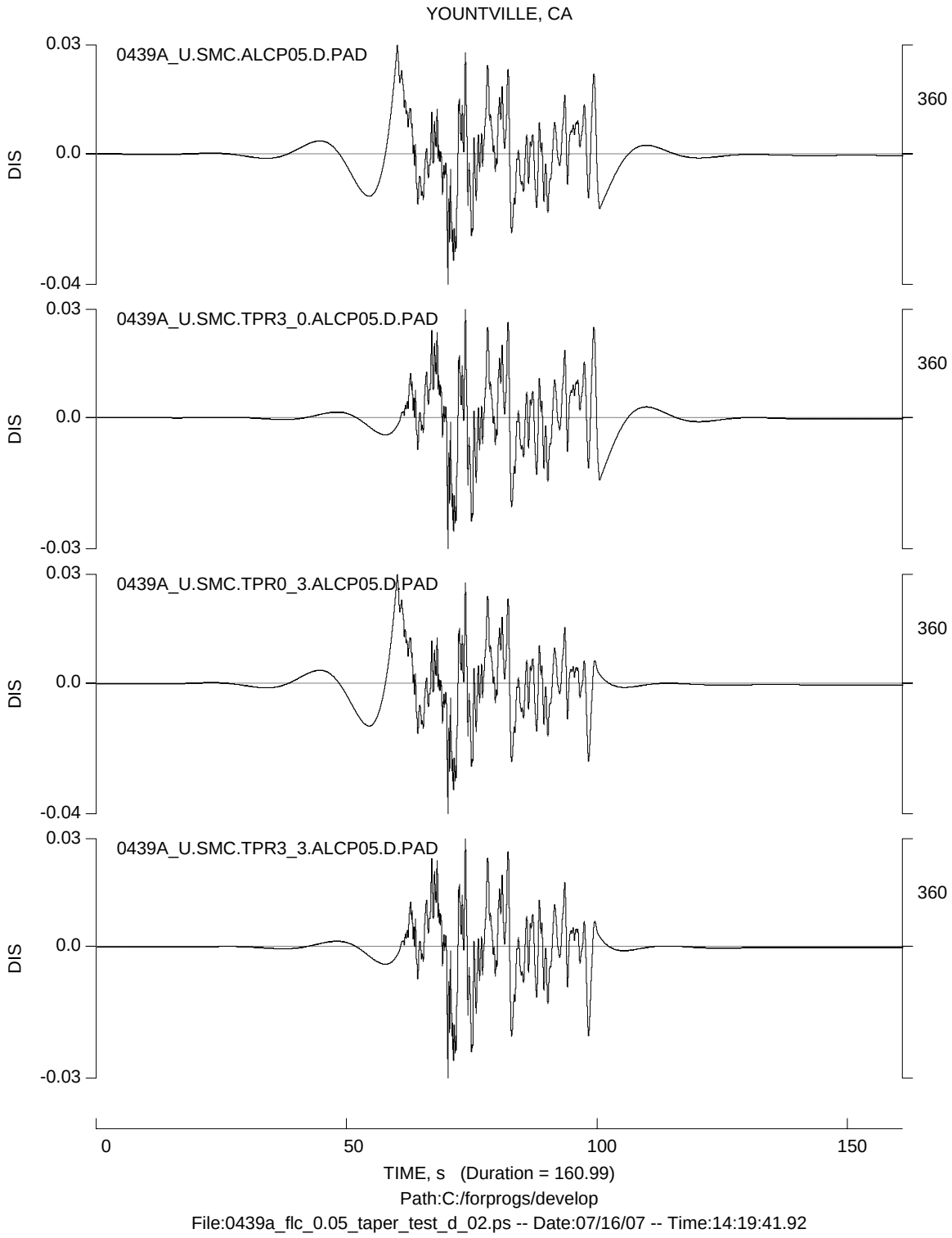
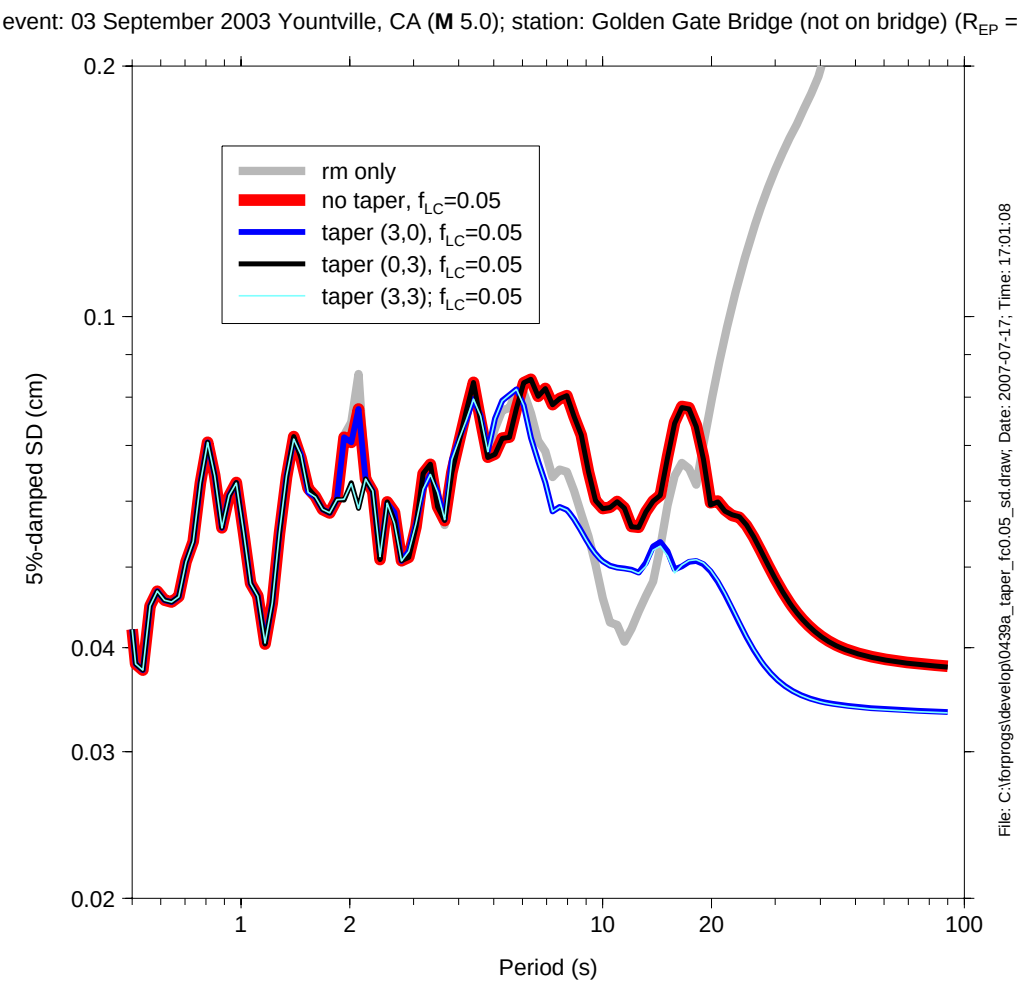


And here is the displacement spectrum for these cases:



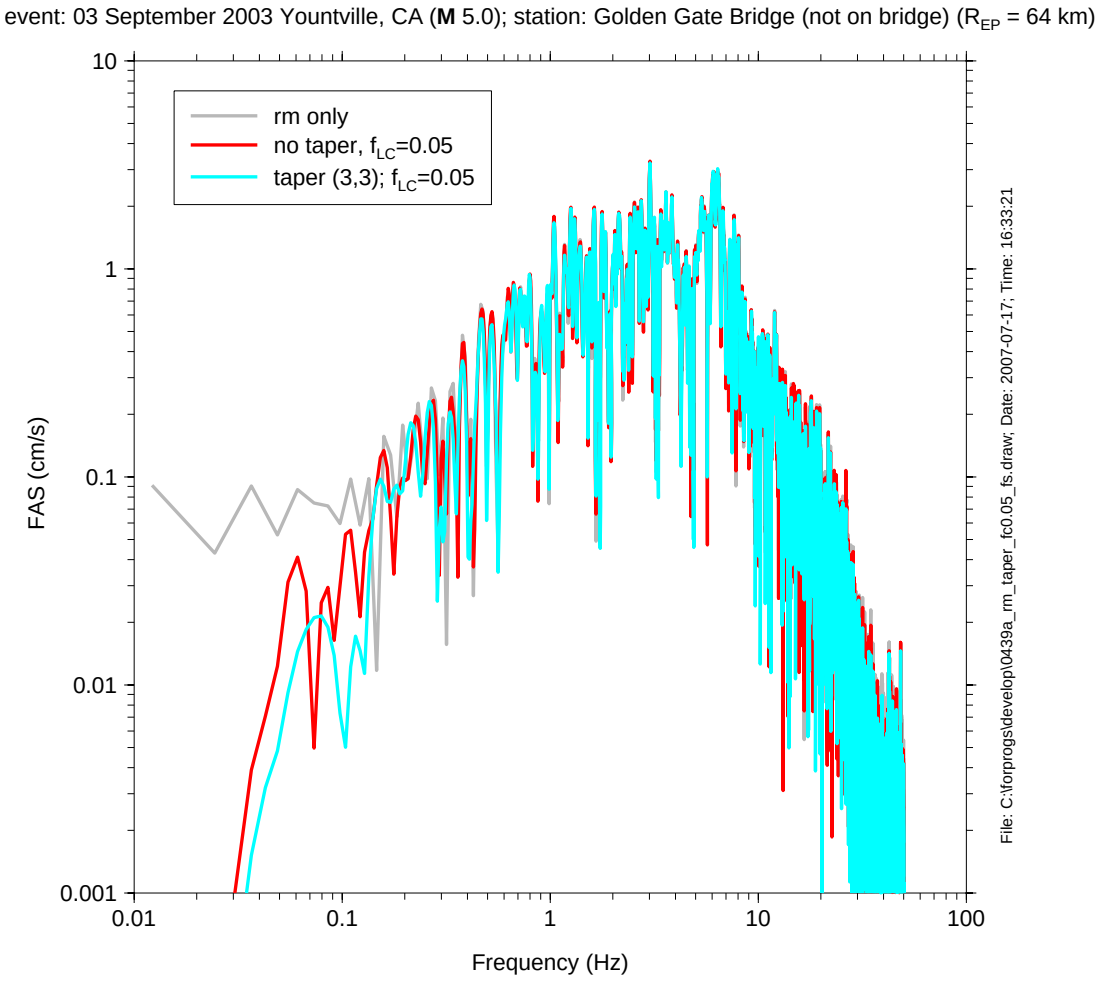
Comparing the response spectra and the plots of displacements, the following points can be made:

1. The narrow peak at T = 2 s is related to the transient at the end of non-padded time series; it is removed by tapering the end. The beginning transient does not affect the response spectrum near 2 s (tapering the time series at the beginning only [blue curve] does not eliminate the peak in SD). Note that this record has significant motions with periods greater than 1 s late in the record, and this contributes to the sensitivity of the response spectrum to the later part of the time series (by the nature of response spectra as the maximum of the oscillator time series, the response specrum is usually controlled by the motions during the strong motion portion of the shaking).

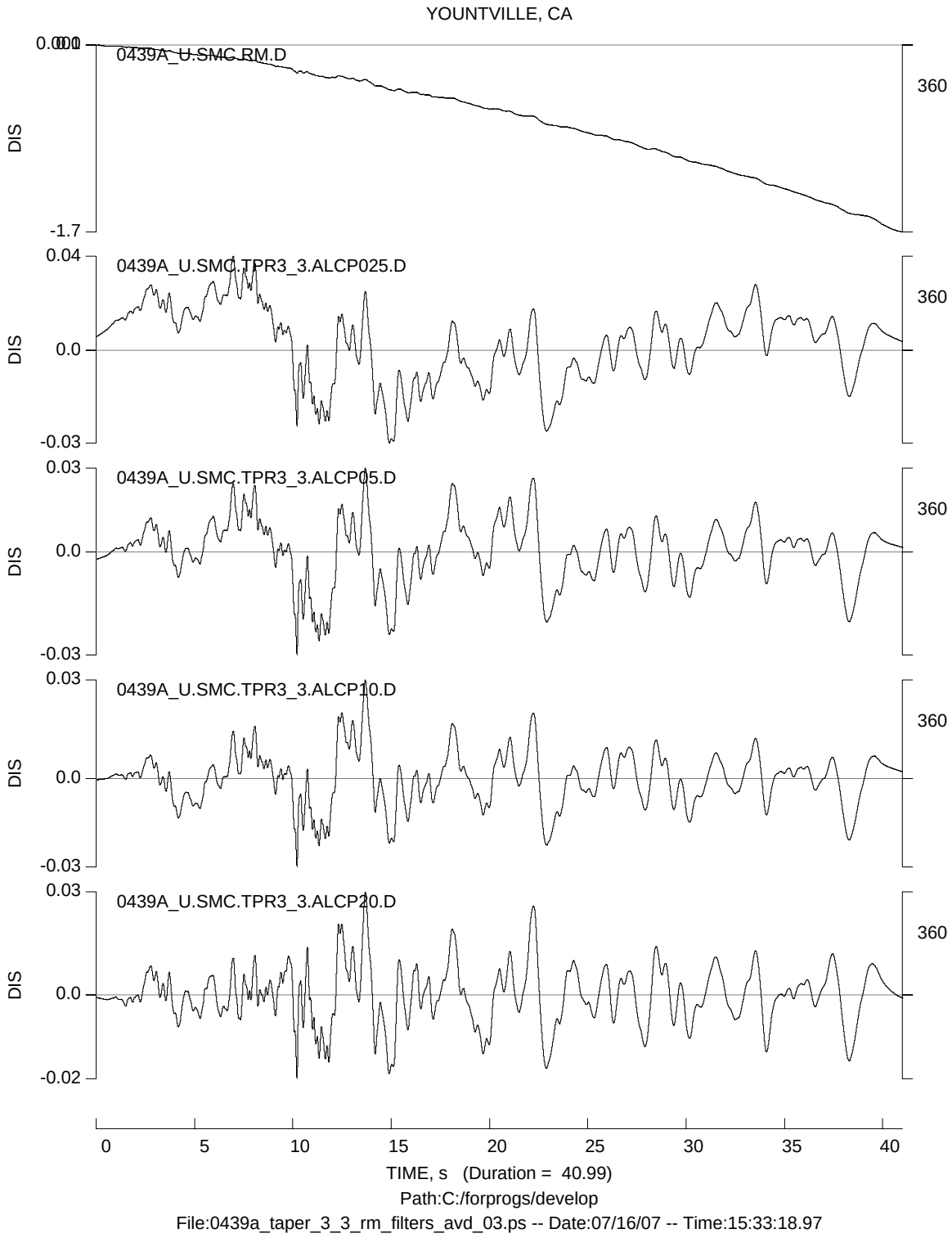
2. The spectrum for periods beyond about 6 s are significantly influenced by the transient at the beginning of the record. The taper reduces this transient significantly, and the response spectra is much

smaller at long periods as a result. The ending transient does not affect the response spectrum at long periods (tapering the time series at the end only [black curve] yields the same SD as for no tapers at long periods).

For completeness, here is a plot of the Fourier acceleration spectrum for three cases: 1) zeroth-order correction (remove mean determined from the pre-event portion of the record from the whole record, with no filtering), 2) filtered, but tapers; 3) filtered, with 3 s tapers fore and aft.



Having established the usefulness of tapering at the front and back, I now show the results of a series of low-cut filters (0.025, 0.5, 0.10, and 0.20 Hz). Here are the pad-stripped and padded displacements for the suite of filters: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DIS
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0.0
-0.03
0439A_U.SMC.TPR3_3.ALCP05.D
0.03
0.0
-0.03
0439A_U.SMC.TPR3_3.ALCP10.D
0.03
0.0
-0.03
0439A_U.SMC.TPR3_3.ALCP20.D
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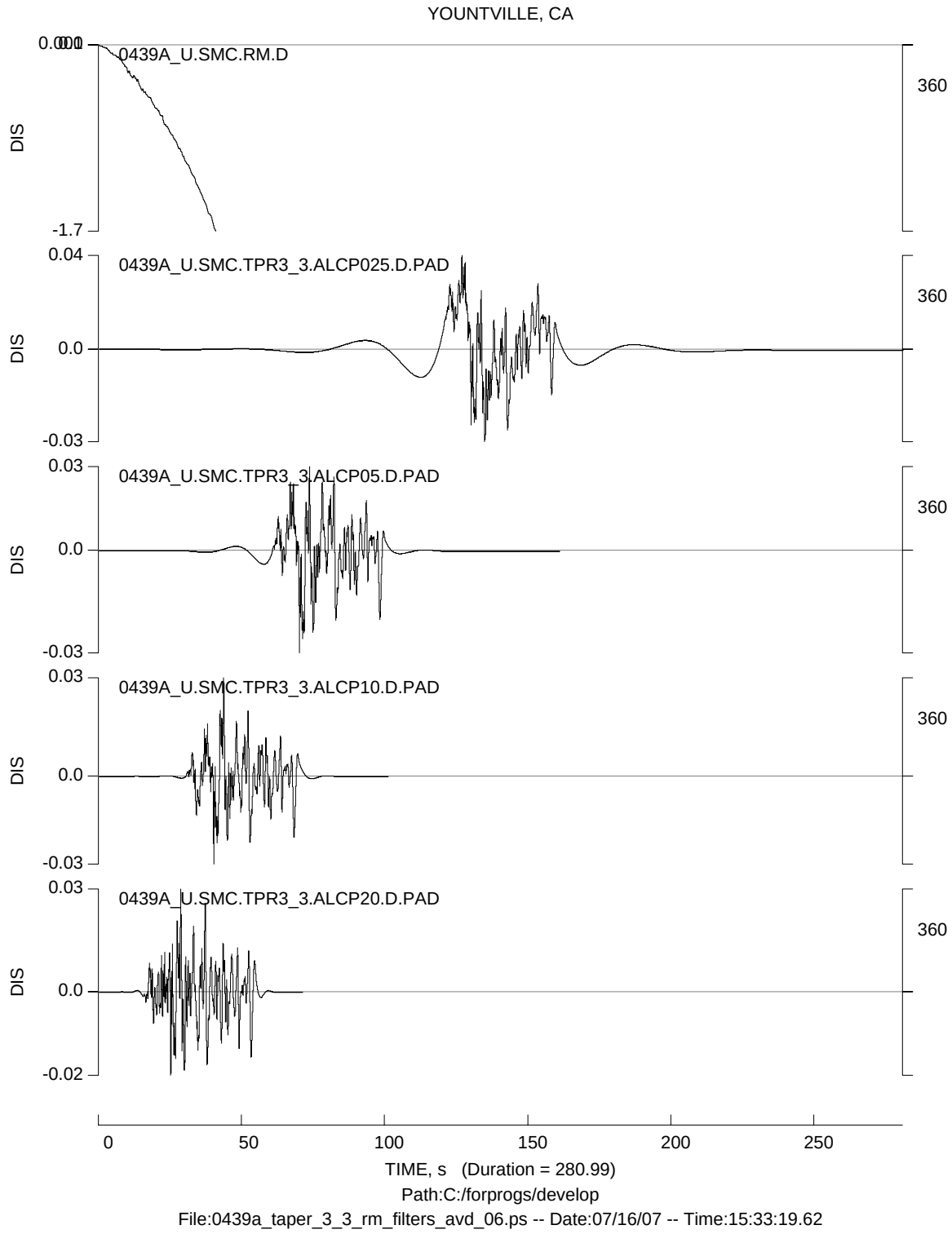
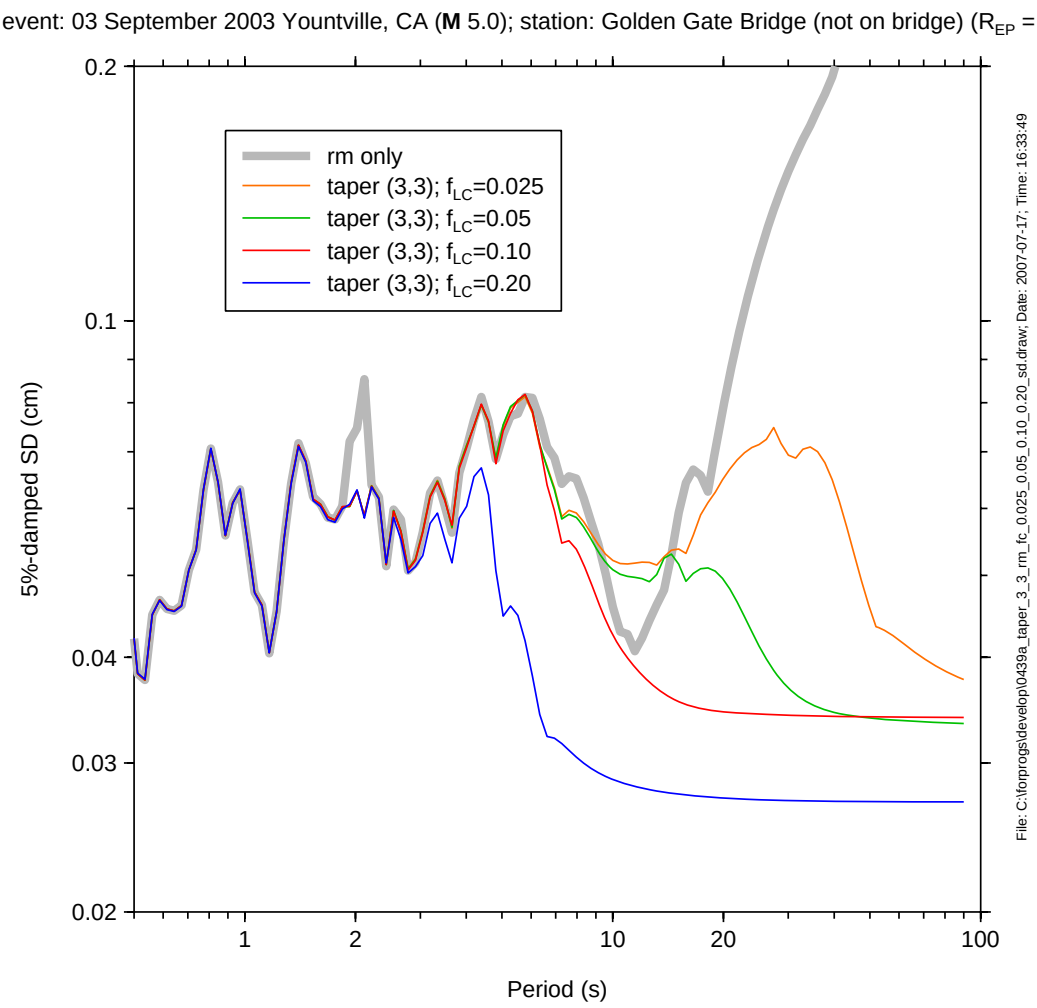


And here are the response spectra:



Note the difference in SD between the 0.1 Hz and the 0.2 Hz filters, indicating that the record contains a significant amount of motion at periods greater than about 3 s. This is seen in the displacement time series as long period oscillation riding on the shorter period motions. So what filter is appropriate? A conservative choice would be 0.2 Hz, although a case can be made for a value smaller than this. In fact, the only clearly inappropriate choice would be 0.025 Hz.

Note also that the SD from the zeroth-order correction is smaller than the SD from some of the filtered traces at some periods---I'm not quite sure why this is the case, but the relation between response spectra and Fourier spectra can be difficult to predict for oscillator periods outside the bandwidth of the ground motion. Another possibility that I should check is that the transients and the tapering have added energy at periods for which the zeroth-order correction is below the SD from the filtered time series. This would best be done

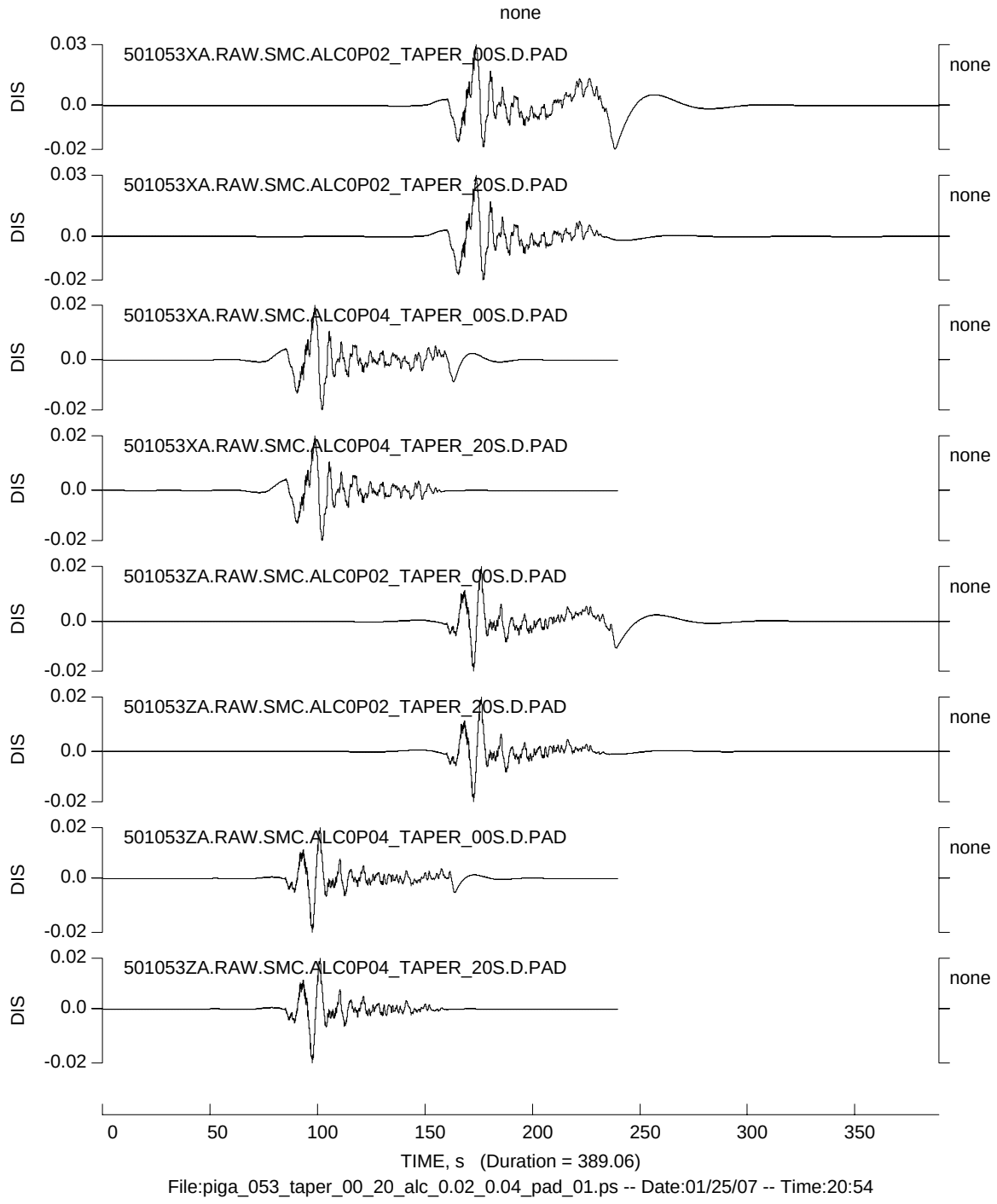
by adding noise to a signal with known SD. Perhaps I will do that in the future. Another useful exercise would be to use pads of different durations (but the results shown earlier suggest that pad length is not important).

A matter of procedure: it is useful to do the filtering without tapers and to plot the resulting displacements to see if transients exist at the front or the back of the unpadded time series; if no large transients are present, then tapering is not needed.

One important point: transients are expected as the natural consequence of filtering; tapers are used only to reduce the size of the transients due to mismatches at the ends of the record between the original accelerations and the zero pads. It is not realistic or desireable to remove completely the transients.

References

Boore, D. M. (2005). On pads and filters: Processing strong-motion data, ***Bull. Seism. Soc. Am.*** **95**, 745—750.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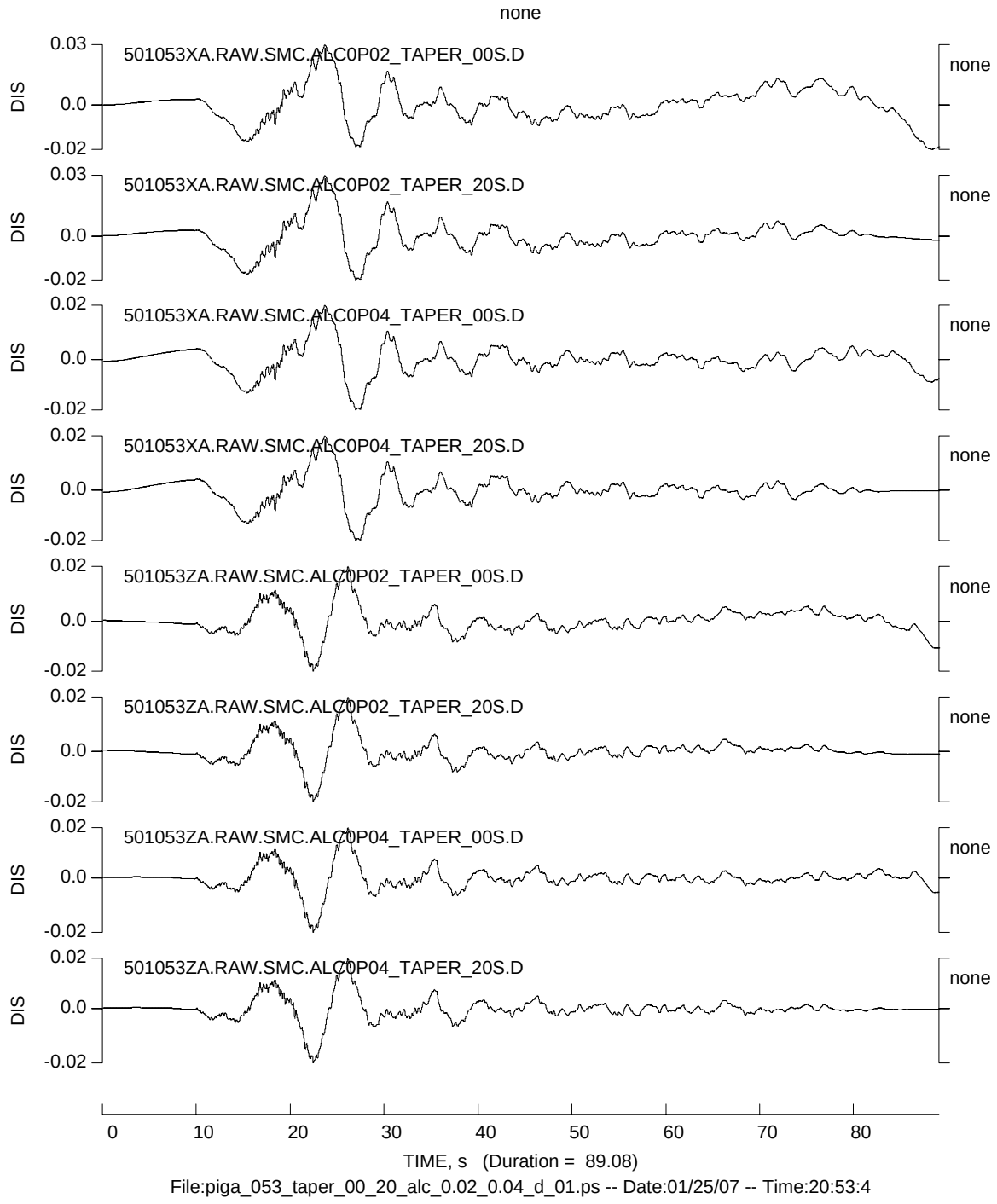
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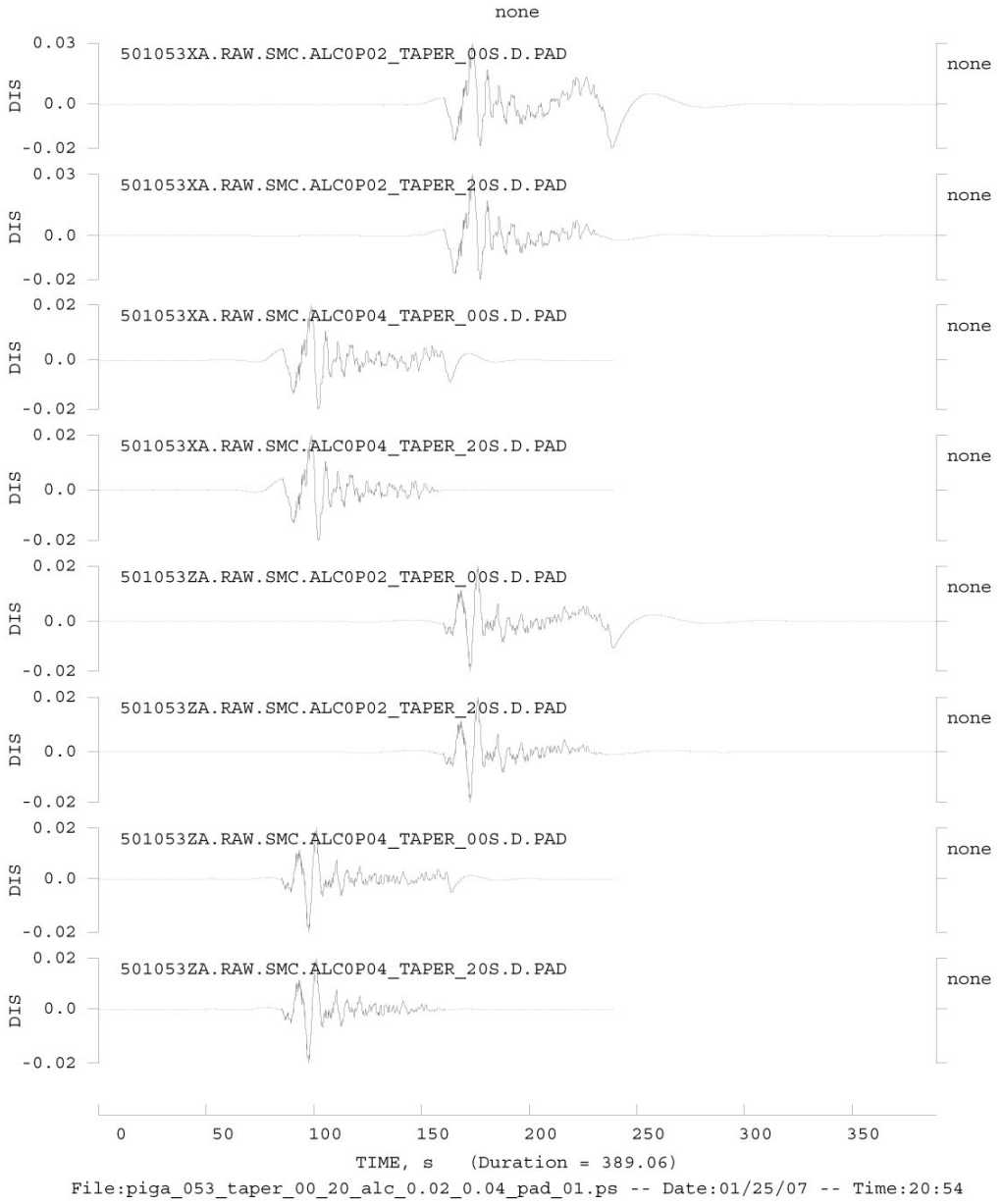
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