Investigating isolated velocity changes with coda waves and the dynamic warping method

Dylan Mikesell and Alison Malcolm, Massachusetts Institute of Technology, Cambridge, MA, USA

Preferred session: Ambient seismic noise, diffuse fields and interferometry

Preferred session type: Oral or Poster

Seismologists have suggested many ways to analyze and interpret complex coda wave signals. The doublet and coda wave interferometry methods are two approaches that quantify material changes using coda waves. Both methods are based on the assumption that the velocity change influences the arrivals in the coda. We have known for many years that only parts of coda change when the velocity change is not homogeneous, and researchers have continued developing methods to locate isolated changes using coda waves (e.g., LOCADIFF).

Many of the common methods to analyze coda waves use crosscorrelation techniques to measure time shifts between two seismic traces. Using these time shifts (Δt), it can be shown that

$$\frac{\Delta V}{V} = \frac{-\Delta t}{t}, \tag{1}$$

when we assume a homogeneous velocity change ΔV. In the work presented here, we look at an approach to more accurately quantify the magnitude of the time shifts using Dynamic Warping (DW). This is a non-linear approach to measure time shifts between coda arrivals before and after a velocity change has occurred in the subsurface.

We compare and contrast the DW approach with the more traditional linear approaches to estimating Δt (e.g., windowed crosscorrelation and stretching). We use multiple scattering numerical models to show the benefits of the DW method. For instance, Figure 1(a) shows two seismic traces before and after an isolated velocity change is introduced. The two traces diverge after ~ 3 s, when waves that have sampled the velocity change arrive at this receiver. Figure 1(b) shows the same two traces after realigning the red trace based on the time shifts shown in Figure 1(c).

Dynamic warping optimizes the misfit between each sample in the two traces. Therefore, if only a few arrivals in the coda have sampled the velocity change, the estimated time shifts are not linear with time (e.g., Figure 1(c)). Using this approach time-shift estimation is less sensitive to cycle skipping, and we have the ability to determine where in time the shift occurs. Dynamic warping does not smear the Δt estimate throughout time; therefore, the magnitude of the estimated velocity change from dynamic warping is closer to the true velocity change in the medium.

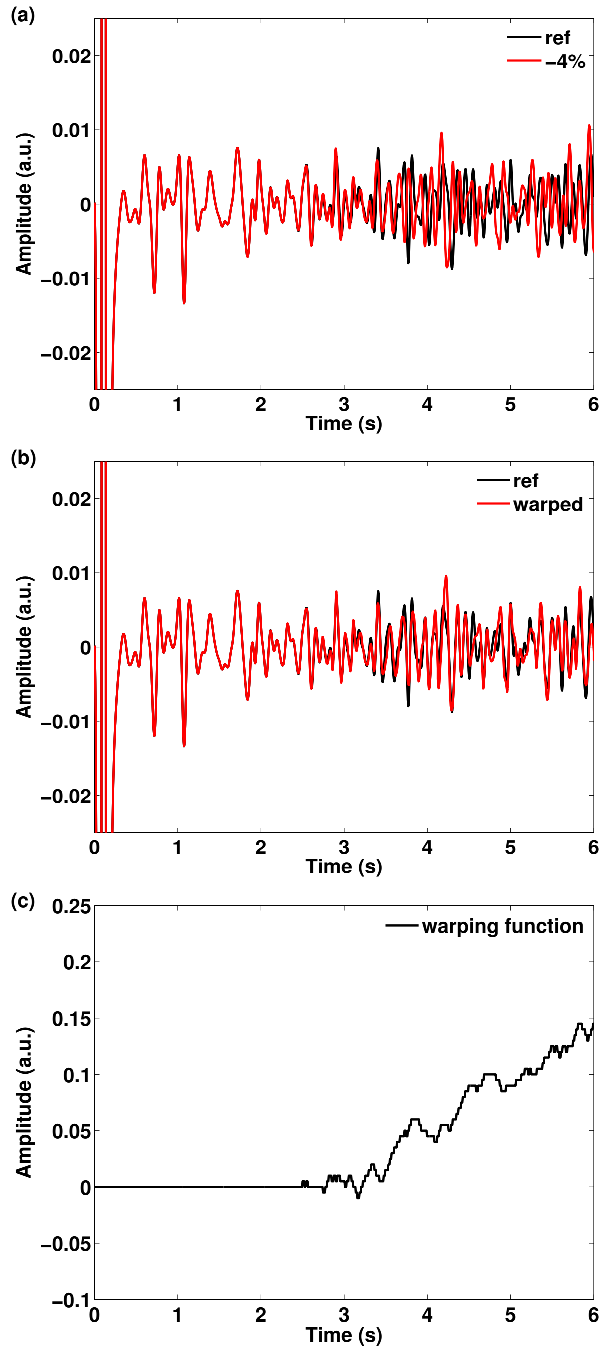

Figure 1: (a) Two seismic traces. The black trace is the reference trace in a random 2D media. The red trace shows the wavefield after decreasing the background velocity by 4% in an isolated part of the model. The two traces are identical up to ~ 3 s, when the velocity change starts to influence the wavefield. (b) Comparison of the same two traces after applying dynamic warping. (c) The non-linear warping function.