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A pitfall of muting and removing bad traces in surface-wave analysis

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ABSTRACT

Multi-channel analysis of surface/Love wave (MASW/MALW) has been widely used to construct the shallow shear (*S*)-wave velocity profile. The key step in surface-wave analysis is to generate accurate dispersion energy and pick the dispersive curves for inversion along the peaks of dispersion energy at different frequencies. In near-surface surface-wave acquisition, bad traces are very common and inevitable due to the imperfections in the recording instruments or others. The existence of bad traces will cause some artifacts in the dispersion energy image. To avoid the interference of bad traces on the surface-wave analysis, the bad traces should be alternatively muted (zeroed) or removed (deleted) from the raw surface-wave data before dispersion measurement. Most geophysicists and civil engineers, however, are not aware of the differences and implications between muting and removing of bad traces in surface-wave analysis. A synthetic test and a real-world example demonstrate the potential pitfalls of applying muting and removing on bad traces when using different dispersion-imaging methods. We implement muting and removing on bad traces respectively before dispersion measurement, and compare the influence of the two operations on three dispersion-imaging methods, high-resolution linear Radon transform (HRLRT), f-k transformation, and phase shift method. Results indicate that when using the HRLRT to generate the dispersive energy, muting bad traces will cause an even more complicated and discontinuous dispersive energy. When f-k transformation is utilized to conduct dispersive analysis, bad traces should be muted instead of removed to generate an accurate dispersion image to avoid the uneven sampling problem in the Fourier transform. As for the phase shift method, the difference between the two operations is slight, but we suggest that removal should be chosen because the integral for the phase-shift operator of the zeroed traces would bring in the sloped aliasing. This study provides a pre-process guidance for the real-world surface-wave data processing when the recorded shot gather contains inevitable bad traces.

1. Introduction

Multi-channel analysis of surface/Love wave (MASW/MALW) is a mature method which utilizes a multi-channel recording system to estimate near-surface shear (*S*)-wave velocity from high-frequency (≥2 Hz) surface (Rayleigh/Love) waves (e.g., Song et al., 1989; Park et al., 1999; Xia et al., 1999, 2009, 2012; Xia, 2014). Since the late 1990s, this technique has become the main seismic test method in determining S-wave velocities for applications of geotechnical and environmental engineering because they have the advantages of being non-destructive, non-invasive, low-cost, and relatively highly accurate (Lu and Lu and Wilson, 2017; Lin et al., 2017; Gaël et al., 2017; Yalcinkaya et al., 2016; Pamuk et al., 2017). There are three steps involved in the estimation of S-wave velocity: (1) acquisition of high-frequency broad-band surface (Rayleigh/Love) waves; (2) extraction of surface-wave dispersion curves from surface waves; (3) inversion of dispersion curves to obtain near-surface S-wave velocity profiles (Xia et al., 1999). The first two steps, acquisition of broad band surface waves and extraction of dispersion curves, are extremely critical to the third step of successfully inverting the dispersion curves to estimate the S-wave velocity.

Vibroseis and/or an impulsive source are commonly used for successfully producing, recording, and consistently analyzing broad-band surface waves. The advantages of the MASW/MALW method include the identification of higher-mode surface waves and isolation of noise (body waves, scattered and non-source generated surface waves) by using the multi-channel recording system (Xia et al., 2012; Socco et al., 2010). After recording wide-bandwidth surface waves, the shot gather can be transformed from the time-space (t-x) domain into the frequency-velocity (f-v) domain to generate an image of dispersion energy of surface waves. There are five methods available for imaging dispersion energy at present: the τ-p transformation (McMechan and Yedlin, 1981), the f-k transformation (e.g., Yilmaz, 1987), the phase shift method (Park et al., 1998), the frequency decomposition and slant stacking method (Xia et al., 2007), and the high-resolution linear Radon transformation (Luo et al., 2008). Shen et al. (2015) has

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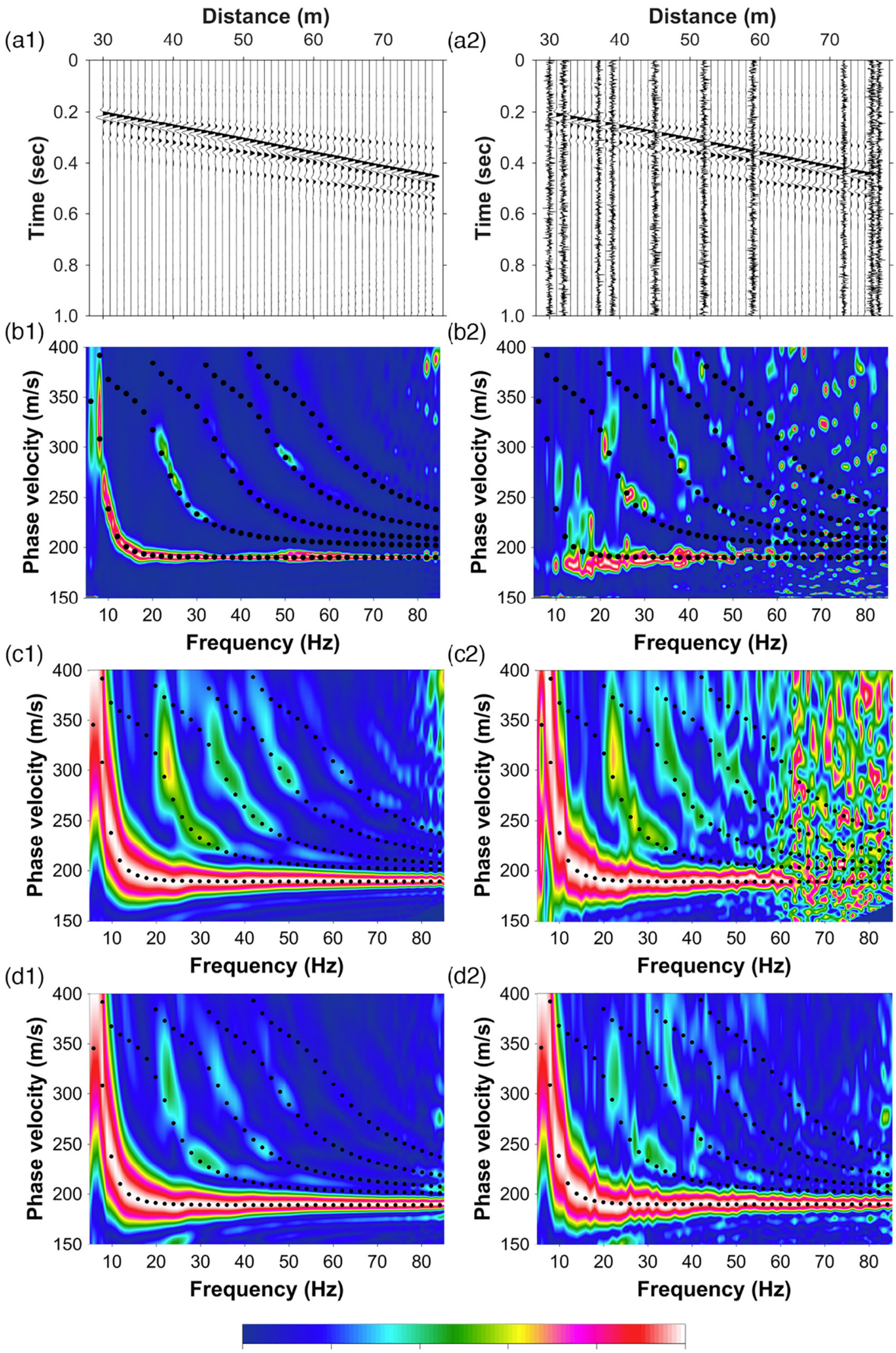

Fig. 1. (a1) A 48-channel synthetic data based on the two-layer model (Table 1). (a2) The new shot gather after ten selected traces (trace 1, 2, 3, 5, 6, 16, 19, 28, 32, 35, 37, 44, 45, 47, 48) are replaced with the Gaussian white noise traces. (b1, b2) The dispersion images of shot gather in Fig. 1-a1 and Fig. 1-a2 generated by HRLRT, respectively. (c1, c2) The dispersion images of the shot gather in Fig. 1-a1 and Fig. 1-a2 generated by f-k transformation, respectively. (d1, d2) The dispersion images of the shot gather in Fig. 1-a1 and Fig. 1-a2 generated by phase shift method, respectively. The black dots represent the theoretical phase velocities.