Numerical characteristics of surface waves on 3D6C records

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Surface waves propagate along the shallow part of a medium and are widely used to estimate the S-wave velocity structure in seismology (Yao et al., 2011). Recently, multi-component acquisition of surface waves is of great interest, because joint analysis of multi-component surface waves helps to obtain an accurate estimation of near-surface S-wave velocities (Xia et al., 2003). However, the existing studies on multi-component surface waves mainly focus on three translational components. Rotational components have different information from the translational components (Lee et al. 2007; Sun et al. 2018). To study rotational characteristics of surface waves, we simulate six-component (6C) seismic waves by the 3-dimensional (3D) staggered-grid finite-difference method.

The geological model is a homogeneous layered model given in Table 1. We simulate the wavefields with the time step size of 0.1 ms and the spatial cell size of 0.1 m*0.1 m. The time order of accuracy is 2 and the spatial order of accuracy is 12. The first example uses a vertical point source at the free surface. The six-component seismic data with the 6-m nearest offset on inline direction is shown in Fig.1. Strong waves can be seen on the X component, Z component, and Ry component, while few waves are on other components. So only these three components are useful under the condition of a vertical point source. Through analysis of their frequency-velocity (f-v) spectra calculated by the high-resolution linear Radon transform (Qiu et al. 2019), shown in Fig.2, we find that, (1) the distribution of dispersive energy on the Ry component is similar to the Z component but is different from the X component; (2) the relative maxima of dispersive energy on all these three components generally consist with the theoretical dispersion curves of Rayleigh waves. And so, we can determine that these waves are mainly of Rayleigh waves.

The second example uses a transverse point source, along the crossline direction, at the free surface. The seismic data on inline direction is shown in Fig.3, where the Y component, Rx component, and Rz component record obvious energy. The f-v spectra of these components are shown in Fig.4. Similarly, the relative maxima of dispersive energy on the Y component and Rz component coincide well with the theoretical dispersion curves of Love waves, although the Rz-component dispersive energy are clearer than that of the Y component. However, the dispersive energy on the Rx component has strong distortion and its maxima deviates from the theoretical dispersion curves of Love waves. Maybe, the Rx component contains other non-ignorable waves, besides Love waves.

As believed, this work will help to learn the wavefields of rotational components in the active-source near-surface model. It can be concluded that the main waves are Rayleigh waves on the X component, Z component, and Ry component when excited by a vertical point source, while Love waves are dominant on the other three components when excited by a transverse point source. In addition, we find that the rotational components have different dispersion characteristics from the translational components which will be beneficial to estimate the near-surface S-wave velocities.

Table 1. The parameters of our model

Thickness (m)	Vp (m/s)	Vs (m/s)	Density (kg/m^3)

10	800	200	2000
-	1200	600	2000

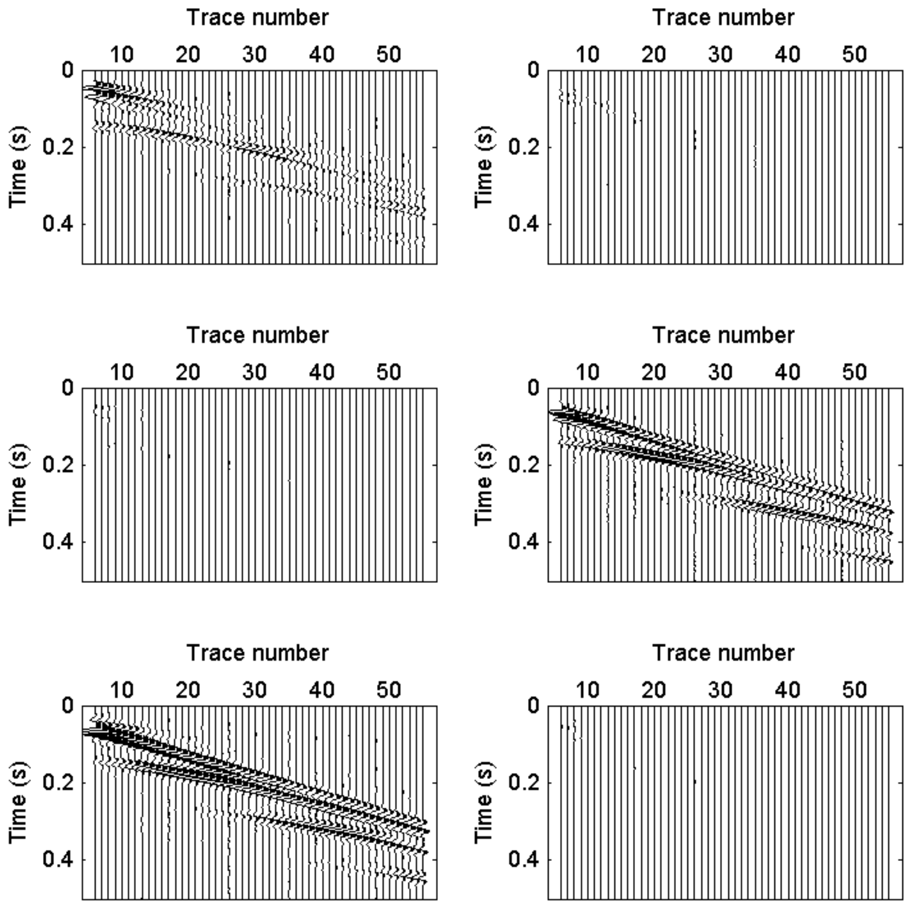
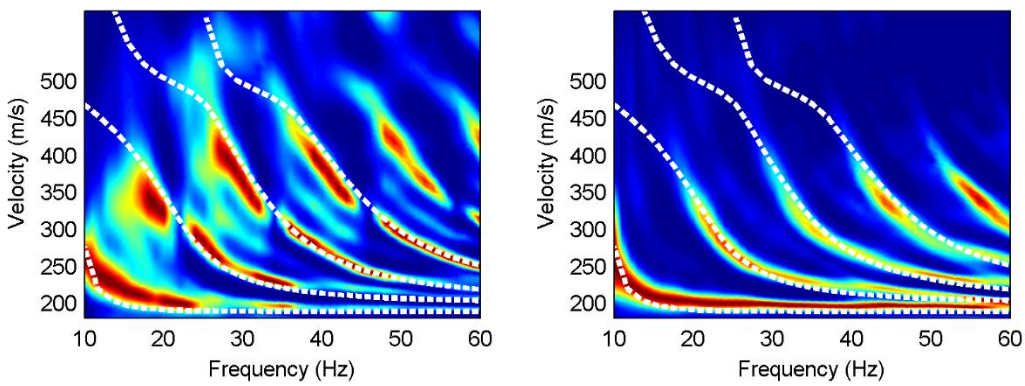


Fig.1. Synthetic six-component seismic data by a vertical point source. The data of the first column are the translational-components: X component, Y component, and Z component. The data of the second column are the rotational-components: Rx component, Ry component, and Rz component.



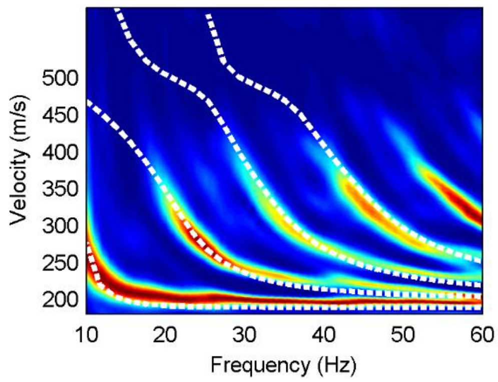


Fig.2. Frequency-velocity spectra of (a) X component, (b) Z component, and (c) Ry component, where the white dotted lines represent the theoretical dispersion curves of Rayleigh waves.

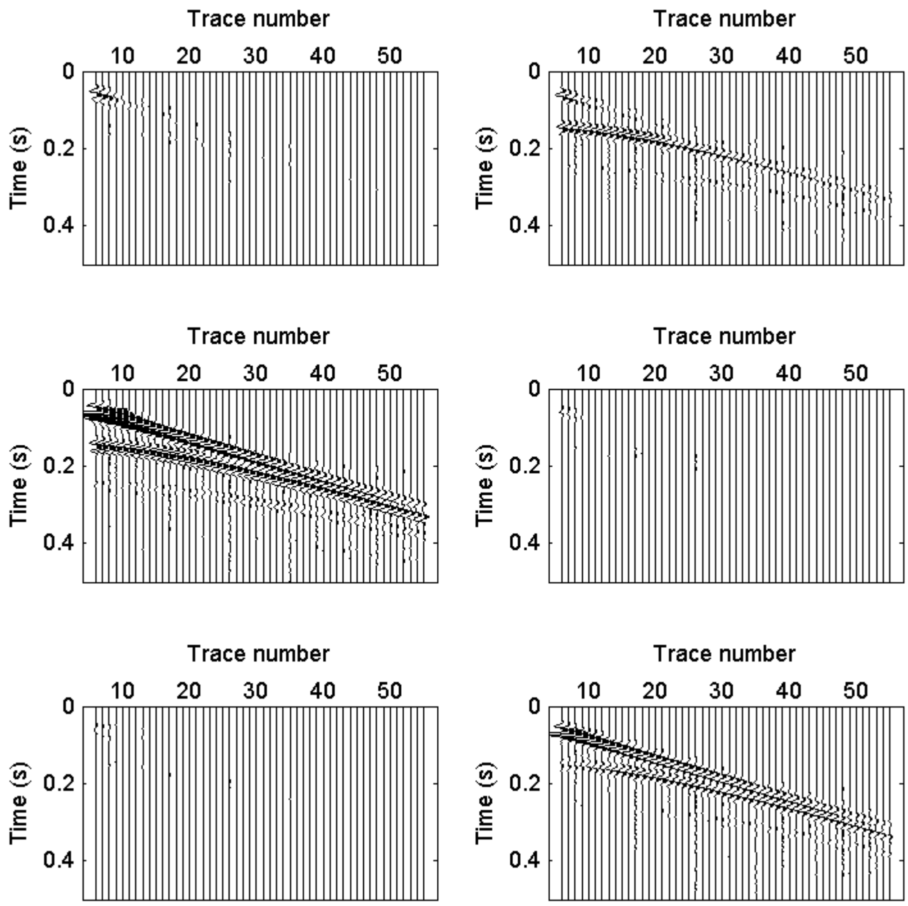


Fig.3. Synthetic six-component seismic data by a transverse point source. The data of the first column are the translational-components: X component, Y component, and Z component. The data of the second column are the rotational-components: Rx component, Ry component, and Rz component.

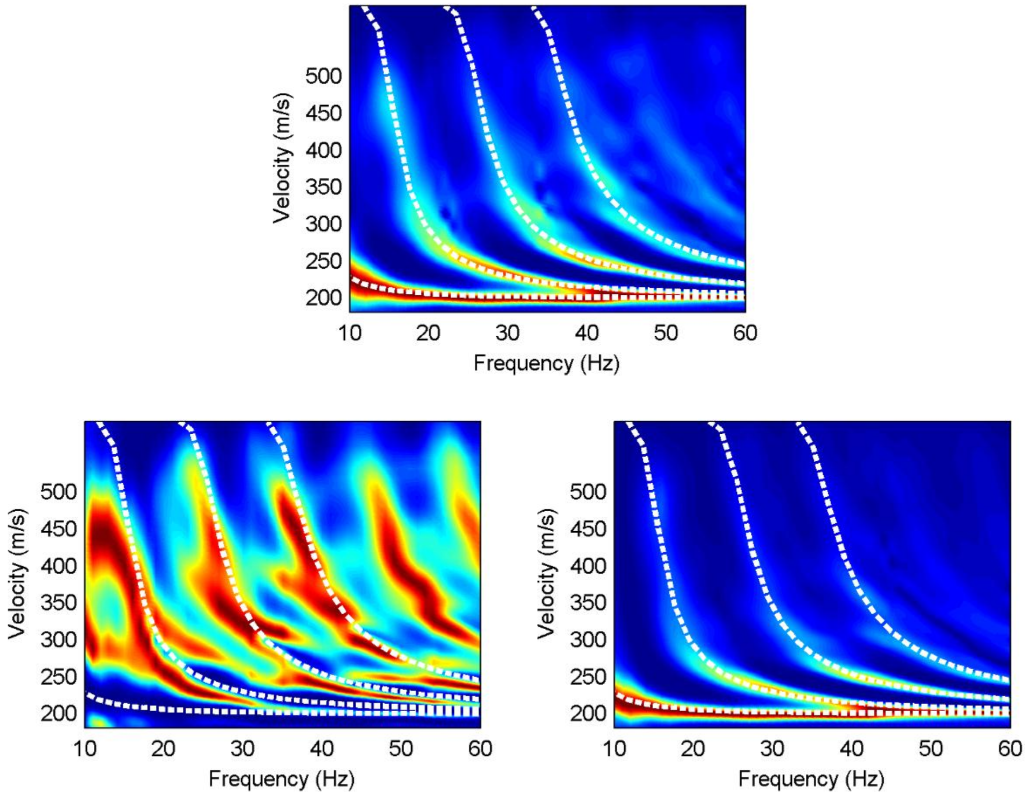


Fig.4. Frequency-velocity spectra of (a) Y component, (b) Rx component, and (c) Rz component, where the white dotted lines represent the theoretical dispersion curves of Love waves.

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References

Lee W., Celebi M., Todorovska M. and Diggles M. 2007. Rotational seismology and engineering applications: Proceedings for the first international workshop, menlo park, california, USA—september 18 to 19, 2007. US Geol. Surv. Open File Rep **1144**.

Qiu X., Wang C., Lu J. and Wang Y. 2019. Surface-wave extraction based on morphological diversity of seismic events. Applied Sciences **9**, 17.

Sun L., Zhang Z. and Wang Y. 2018. Six-component elastic-wave simulation and analysis, EGU General Assembly Conference Abstracts, p. 14930.

Xia J., Miller R. D., Park C. B. and Tian G. 2003. Inversion of high frequency surface waves with fundamental and higher modes. Journal of Applied Geophysics 52, 45-57.

Yao H., Gouedard P., Collins J. A., McGuire J. J. and van der Hilst R. D. 2011. Structure of young east pacific rise lithosphere from ambient noise correlation analysis of fundamental-and higher-mode scholte-Rayleigh waves. Comptes Rendus Geoscience 343, 571-583.