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（Summary）

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（要　旨）

Near surface characterization start to gain huge importance from exploration geophysicists and many methods are being proposed to retrieve the 2D structures of shallow soils. Since most of these methods are based on the modal inversion of the surface-waves, they can only be applicable to laterally homogeneous or smoothly heterogeneous soil models. We are proposing a time domain waveform inversion for 2D near-surface exploration, which can offer an alternative approach to the existing surface-wave techniques for layered soils. Our method directly fits the input Rayleigh waveforms to retrieve the 2D soil structure without the need of any modal identification, allowing the reconstruction of soil models that can be challenging with the modal inversion based approaches.

The inversion is based on numerical modeling of the 2D soil structure using a 2.5D staggered finite difference scheme to simulate the P-SV wavefield. The numerical soil model is materialized by several blocks with specific physical parameters; the inversion strategy consists of finding the most optimal numerical model with the appropriate block velocities and layer interface among a population of solutions.

The search engine for the solution is based on a hybrid heuristic method combining the Genetic Algorithms and the Simulated Annealing. The difference between the synthetic and the observed waveforms is minimized in time domain using a misfit function. The deconvolution is a post processing operation that we applied to both observed and calculated waveforms in order to achieve an inversion without the source signature.

Three numerical examples of inversions representing different soil configurations allowed to assess the ability of our method to properly determine complex 2D soil profiles which can be more or less challenging to retrieve using the conventional near surface exploration methods: A two-layered soil model with an irregular interface, another soil model with strong lateral velocity, as well as a soil model with a blind layer were successfully reconstructed in noisy environments, using a single station and relatively small number of receivers.
We also conducted a parametric study, and assessed the effect of the different parameters on our inversion.

After proving the feasibility of our method on numerical experiments, we applied it to real data and attempted to retrieve a 2D soil structure from field data acquired on field. We conducted a seismic survey inside our university campus, where the availability of borehole data allowed confirming the validity of our soil model. We inverted two shots at both ends of the survey line simultaneously, and succeeded to obtain the 2D soil structure of the shallow layers.
Comparison of our 2D inverted soil model, with the 1D soil profile provided by the borehole shows a good correlation, except for the shallow layer where improvements were carried for construction purpose after the borehole measurements.

Finally, we applied our inversion method to solve real geotechnical problem as a case study. We succeeded to provide the 2D soil structure using waveform inversion of seismic data acquired near the K-NET strong motion station MYG004 of Tsukidate (Miyagi prefecture), where abnormal amplifications were reported during the 2011 earthquake off the Pacific coast of Tohoku. The inverted 2D soil model underlined a clear lateral S-wave velocity variation at the surface layer, we also examined the effect of this velocity inhomogeneity on the soil response, and found that it could play an important role in amplifying the content on the high frequencies.

We concluded our thesis by discussing the advantages and disadvantages of our method with respect to other near-surface methods, its time implementation, and the further developments and perspectives that will allow inversion of more complex soil models.