Land Full Waveform Inversion

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Abstract

Objectives/Scope: Seismic velocities are crucial for data processing, imaging and interpretation. However, land seismic surveys often show low data quality due to near surface conditions such as cavities, unconsolidated soil, complex topography etc, making velocity estimation challenging. Using full waveform inversion (FWI), we aim to build a detailed P-wave velocity model for better subsurface imaging.

Methods, Procedures, Process: The preprocessing steps applied on the recorded seismic data include filtering the shot gathers in the f-k domain to remove the surface waves and back-scattered waves. We also normalize the recorded traces to compensate for amplitude loss and/or weak geophone-ground coupling. After that, the slopes of the direct and head waves are picked to build an initial velocity model. When inverting the low frequencies, the FWI gradient shows singularities at the source-receiver points, leading to unreasonably high velocities. Hence, we mute these singularities and use short offsets first to stabilize the inversion, then add the far offset traces. On the other hand, inverting higher frequencies does not require such strategies.

Results, Observations, Conclusions: Using short offsets, FWI recovers shallow sedimentary layers above 100 m, and a low velocity zone at 200 m depth which might represent a fault zone. Increasing the offset range leads to the reconstruction of two other low-velocity zones (LVZs) at 100 m depth. These LVZs are confirmed by a first-arrival traveltime tomogram from our previous study, but the FWI models show higher resolution and higher velocities than the first arrivals traveltime tomogram, probably due to more data constraint. In addition, a LVZ deeper than 250 m depth is shown on the FWI models. Such depth is beyond the maximum penetration of the first arrivals and thus is not shown in that tomogram. Inverting high frequencies sharpens the FWI velocity model to some extent. Migration with the final FWI model further shows structures inside the LVZs. We conclude that land FWI requires dedicated data preprocessing steps, such as f-k filtering, and proper gradient conditioning, such as muting the source-receiver singularities especially with low frequencies. One of our perspectives is to include seismic attenuation in the inversion to better fit short and far offsets simultaneously.

Novel/Additive Information: We showcase that acoustic FWI can produce a reasonable P-wave velocity model from land data, if the elastic effects in the data are minimized and the velocity gradient is conditioned. The final FWI model confirms the existence of a fault zone in the studied area, and reveals a deeper LVZ that is not yet reported in the literature, the truth of which needs further investigation.