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Localized Wave-field Processing and Inversion for Critical Zone Tectonic Velocity Structure Investigation – A Prerequisite Step before the Full Waveform Inversion

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The main weakness in regional tomography study is that shallow velocity model is not well-defined as near-surface effects create complicate non-linear wave propagation phenomena. Full-waveform inversion could be seriously hampered by field operation, source/receiver layout, geometry thus create insufficient spatial sampling. We proposed an updated wave-field array processing and inversion to define velocity structure through local slant-stack transformation (LSST). Localized velocity filter (LSSF) is useful for extracting weak yet coherent signals while removing interfering seismic phases as well as random noise.

The main advantages of utilizing localized slant-stack processing among others are: (1) Trace interval regularization and trace interpolation, (2) Optimum velocity filtering, (3) Remove interfered signals and random noises thus enhance weak yet coherent signals. Such regularization process also become an important step before full-waveform inversion. For inversion, the recorded data is "imaged" at each depth based on the assumed velocity through downward continuation. The observed data is decomposed into many wavelets follow by a phase shift operator and coherency stacking procedure within the image domain. The optimal velocity function is determined iteratively and automatically by scanning through all possible velocity values and determined its energy coherency. Travel-time picking is not needed. For wide-angle reflection/refraction (WARR) seismic data, refracted head wave arrivals and post-critical reflections form a well-defined monotonic trajectory after wave-field processing. For inversion, the desired slowness-depth solution can be obtained within (τ, p, z) space follow by applying the imaging condition$(\tau = 0)$. For quality control, seismic ray tracing can be performed for travel-time prediction and to match the first and later arrivals. Furthermore, such approach can be also performed through step-wise multi-frequency manner to improve its resolution.

The proposed processing and inversion of seismic data is developed, test and implemented for both synthetic and long-offset TAIGER data. Synthetic tests show that the inversion is stable and typically require high frequency contributions for better convergence within the shallow region. For field data application, the WARR data collected in SW Taiwan provide a unique test case. Results show that we can achieve much better resolution than the conventional travel-time tomography by comparing other three different velocity models obtained from the same dataset. Localized seismic wave-field processing and inversion can be incorporated as a step before the full waveform inversion (FWI).