Near-surface seismic characterization from sparsely sampled data sets

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OVERVIEW

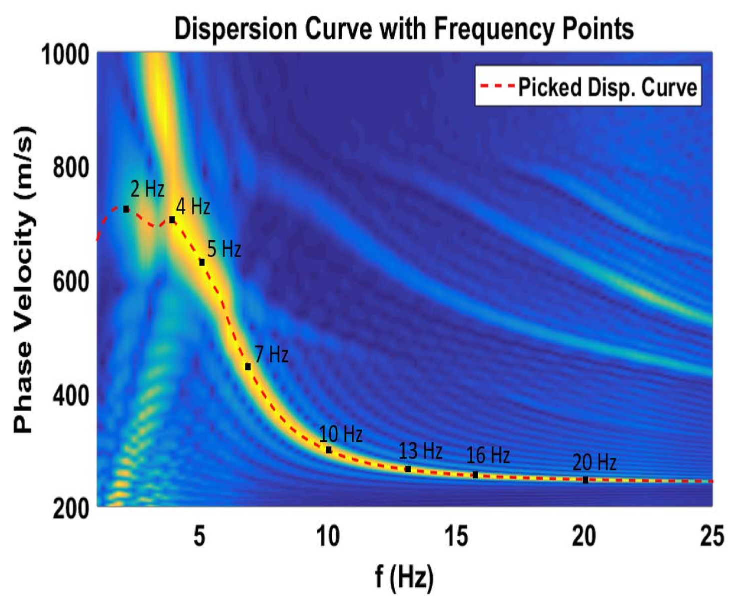
- Recorded ground roll in seismic data contains information about the difficult to characterize-near-surface layer(s).
- Exploration or commercial scale seismic data is inappropriate, in its raw form, for near-surface characterization.
- Data with non-ideal sampling is processed, improving resolution of dispersion curves necessary for velocity inversion.
- Velocity inversion is performed on processed data, producing a 2D shear-wave velocity profile over the survey line.

GOALS

- Apply multi-channel analysis of surface waves (MASW) techniques to data acquired for other purposes.
- Improve resolution of dispersion curves enough for accurate picking of curve.
- Formulate a stable velocity inversion algorithm to apply to these curves.
- Produce representative, reasonable velocity profiles using non-ideal, sparsely sampled data.

INVERSION OF DISPERSION CURVES

- Linear least-squares inversion implementation.
- Initial velocity model estimated from observed dispersion curve (FIG.1).



$$Vs_1 = \frac{V_r(high)}{0.88} \quad \text{(first layer)}$$

$$Vs_n = \frac{V_r(low)}{0.88} \quad \text{(half-space)}$$

$$Vs_i = \frac{V_r(f_i)}{0.88} \quad (i = 2, 3, \ldots, n-1)$$

$$z_n = 0.63\,\lambda \quad \text{Depth of layers}$$
$$= 0.63\,\frac{Vs_n}{f_n}$$

FIG. 1. Dispersion curve, with picked frequency, velocity points; points for initial estimation of shear velocity (equations at right). (Xia et al., 1999).

- Marquardt-Levenberg regularization, and velocity variation regularization added to Normal Equations (eq.1).
- $\boldsymbol{\delta_R} = ((\mathbf{J^TJ} + \lambda(\frac{\partial^2 \mathbf{R}}{\partial \mathbf{Vs_{n1}} \partial \mathbf{Vs_{n2}}}) + \beta\mathbf{I})^{-1} (\mathbf{J^Tg} - \lambda \frac{\partial \mathbf{R}}{\partial \mathbf{Vs_n}})$ (eq.1)
- $\boldsymbol{\delta_R}$ is added to the initial velocity estimation at every iteration. Repeated until error is minimized (step 5, FIG.2).

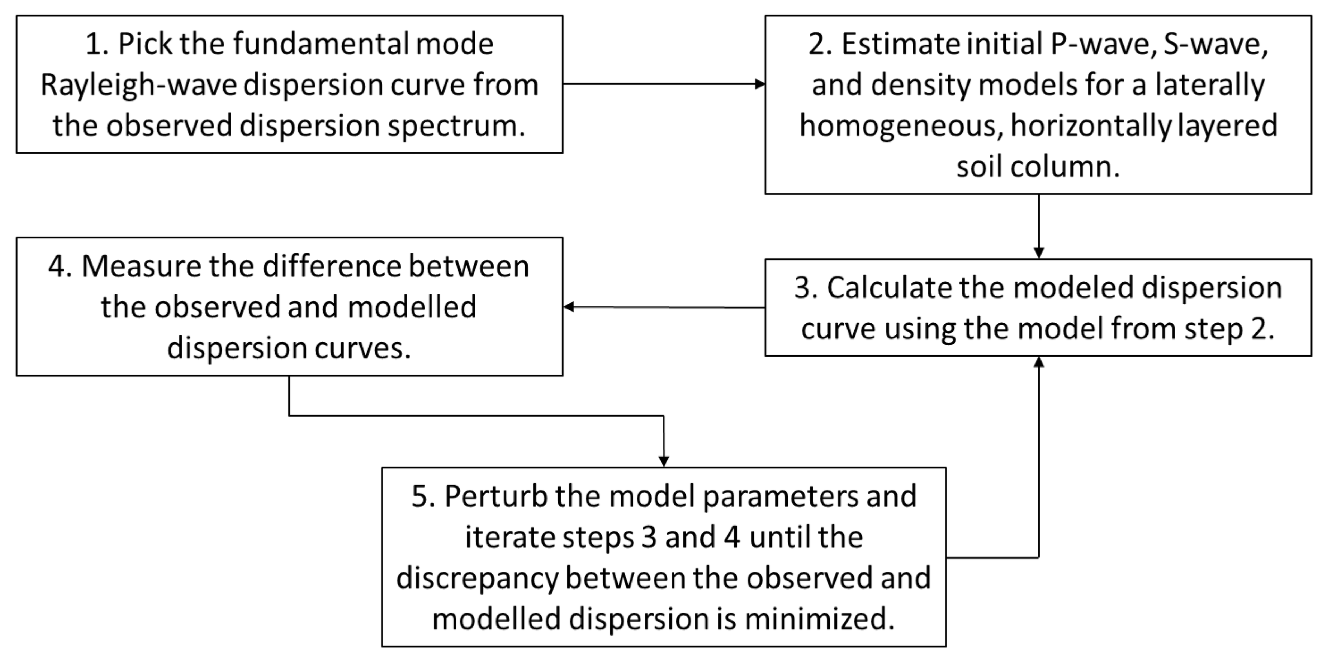


FIG. 2. Iterative inversion workflow. Adapted from Yilmaz, 2015.

PRIDDIS THUMPER EXPERIMENT

- 200m long survey line
- 5m receiver spacing. 10Hz geophones
- Vertical impulse thumper source (FIG.3)

FIG. 3. Left: Field location map. Source points marked with X. Right: CREWES thumper source, in shear wave generating orientation (±45º).

DATA AND RESULTS

- Data are processed as follows: Stack collocated shot records, LNMO correction, interpolation to 1.25m trace spacing, reverse LNMO, FK filter.
- Only source points with ≥100m of offset data are used. (102 North, 111N, 121N, 121 South, 131S, and 139S).

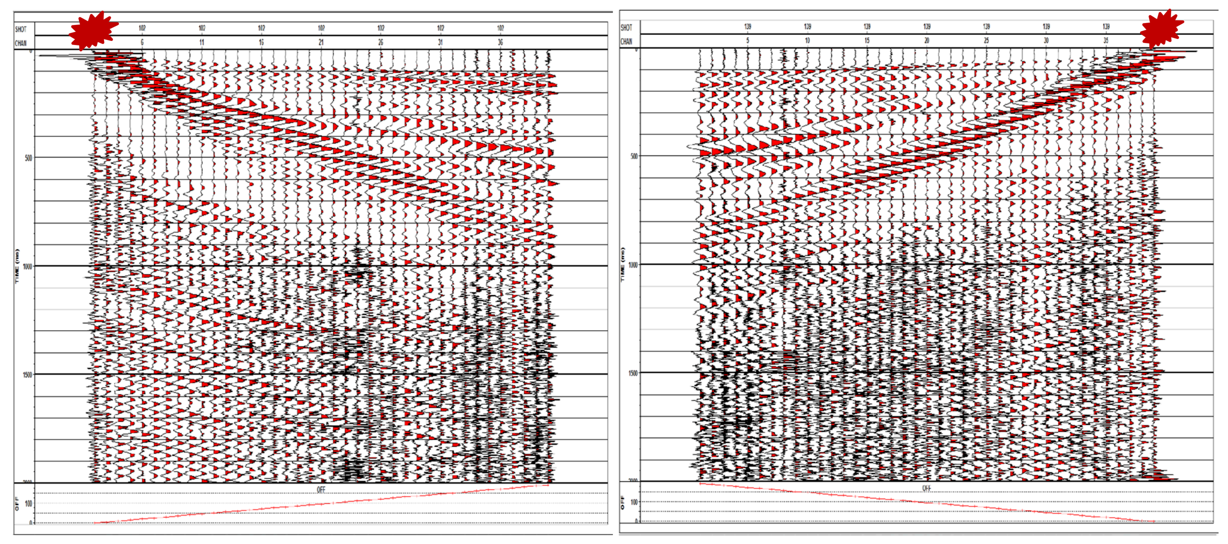


FIG. 4. Raw shot records showing ground roll, and asymmetry of arrivals. Left: Source point 102. Right: Source point 139. AGC applied to both.

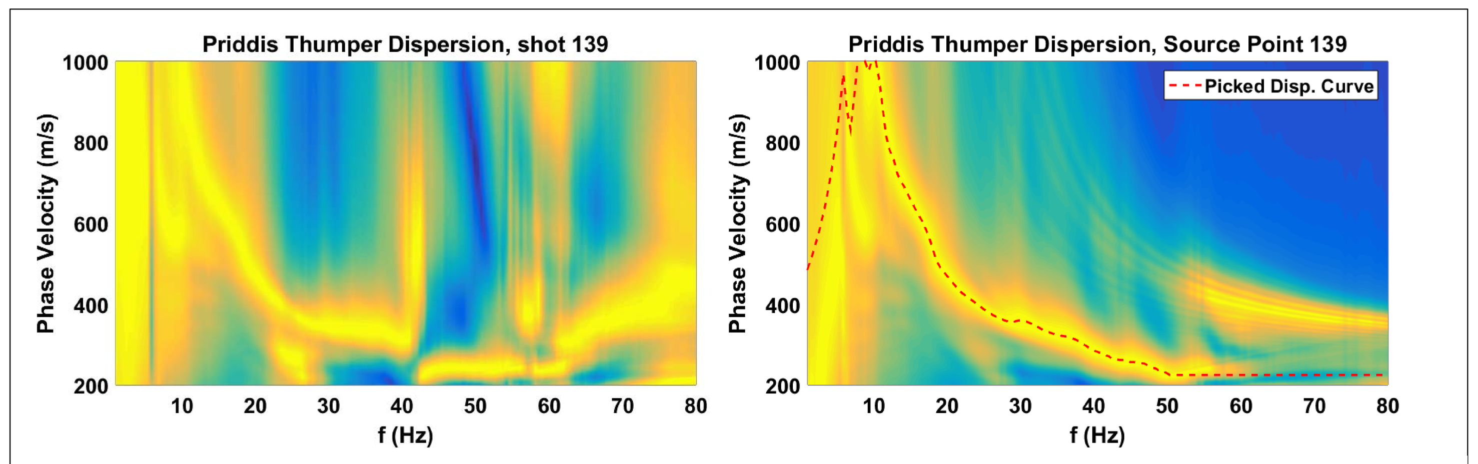


FIG. 5. Left: Dispersion spectra generated from raw shot record. Right: Dispersion spectra from processed data.

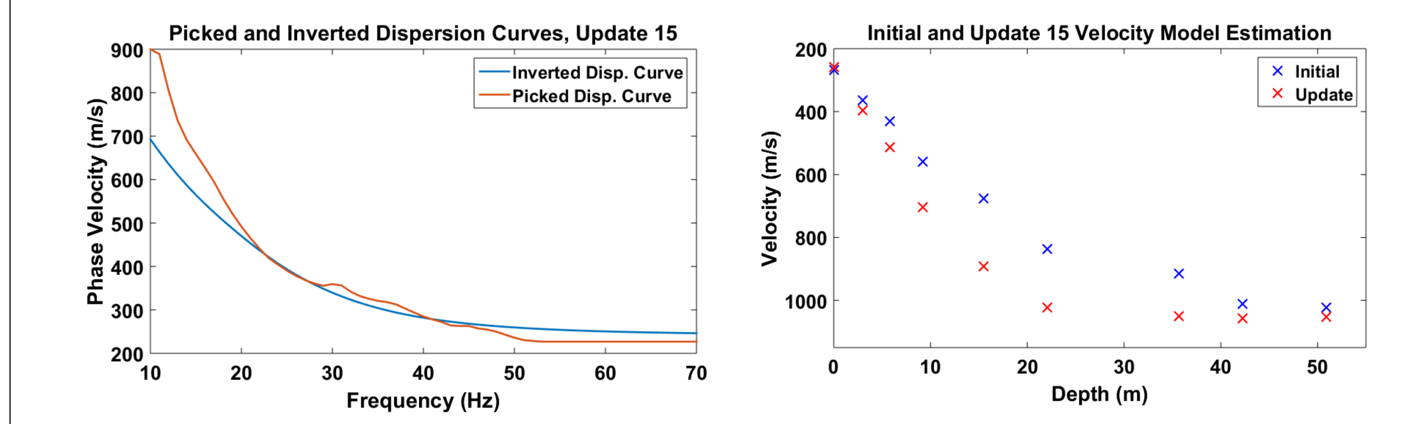


FIG. 6. Left: Observed and inverted dispersion curves. Regularization limits high V_R predictions, allowing low frequency separation. Right: Initial estimate and inverted V_s profiles.

- 1D V_s profiles are generated for each shot record.
- Profiles are placed adjacent to the source point from which they originated.
- Bilinear interpolation is performed, producing a 2D V_s profile over the survey line.

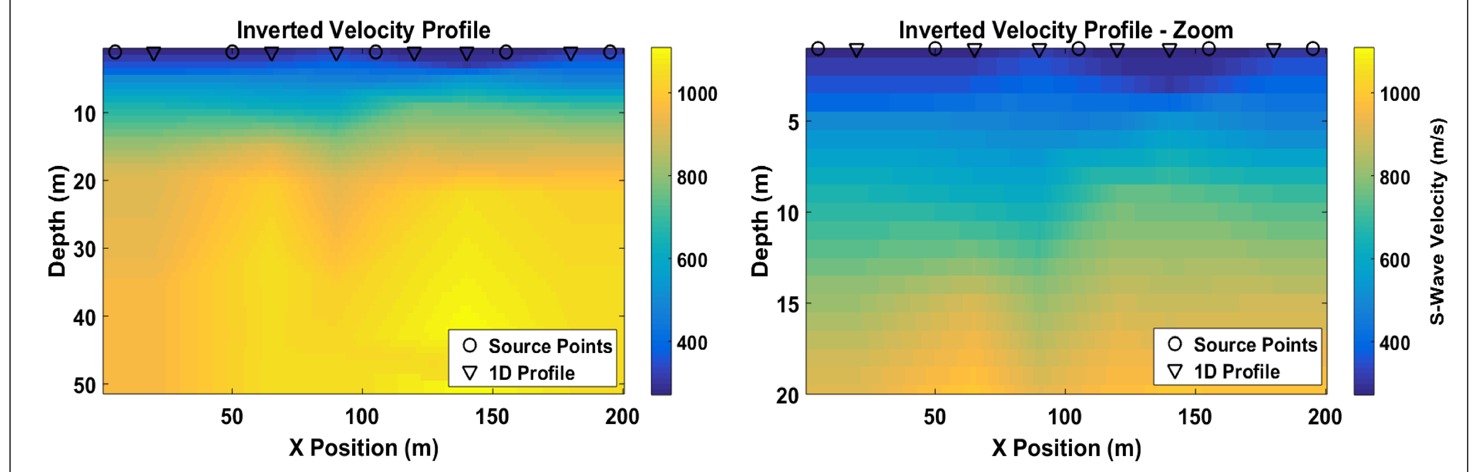


FIG. 7. Left: Inverted 2D velocity profile. Right: Near-surface zoom. North to the right.

SUMMARY

- Processing sot records increases resolution of dispersion curves
- Near-surface V_s model is estimated from sparsely sampled seismic data.
- Estimated velocity profile consistent with shallow well drill cuttings.
- Methods can be applied to more sparsely sampled data.
  - Has been successfully applied to Hussar low frequency data, sampled at 20m receiver interval.

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