Analysis of Surface Wave Benchmarking Data

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Outline

- Dispersion Analysis Methods
- Dispersion Curves
- Inversion
- Conclusion

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Dispersion Analysis Methods – Active (SASW)

SASW (Spectral Analysis of Surface Waves)

- Calculate the phase difference between two signals received at two geophones.

- Sensitive to noise, such as body waves and higher-mode surface waves.

Dispersion Analysis Methods – Active (MASW)

MASW (Multi-Channel Analysis of Surface Waves)

- 2D wave field transform can be implemented via FK transform, phase shift, or tau-p transform.
- Not sensitive to noise as waves with different apparent velocities are naturally separated after transform.

Dispersion Analysis Methods – Passive

There are two methods to determine dispersion curves:

1. SPAC / ESPAC

   Fitting the spatial autocorrelation coefficient

2. Beamforming (FK)
   - Determining wave vector velocity in FK, FV, or FP domain.
   - Implementation techniques: FK, phase shift, Tau-P.

Applied to the same data, the SPAC method usually yields a higher resolution, especially at low frequencies

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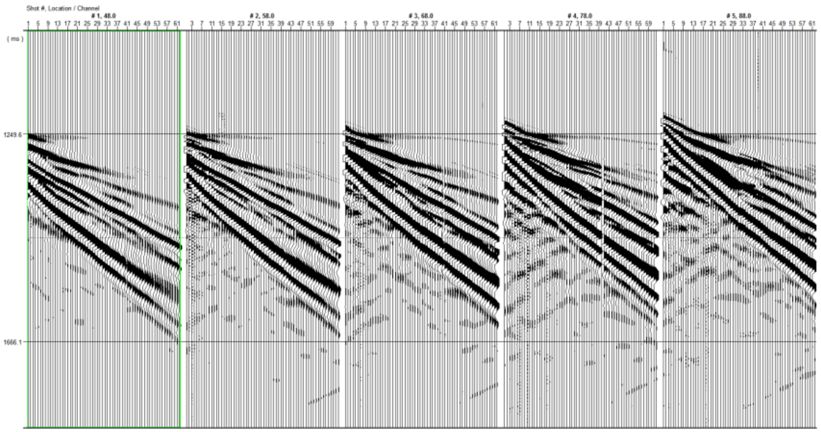
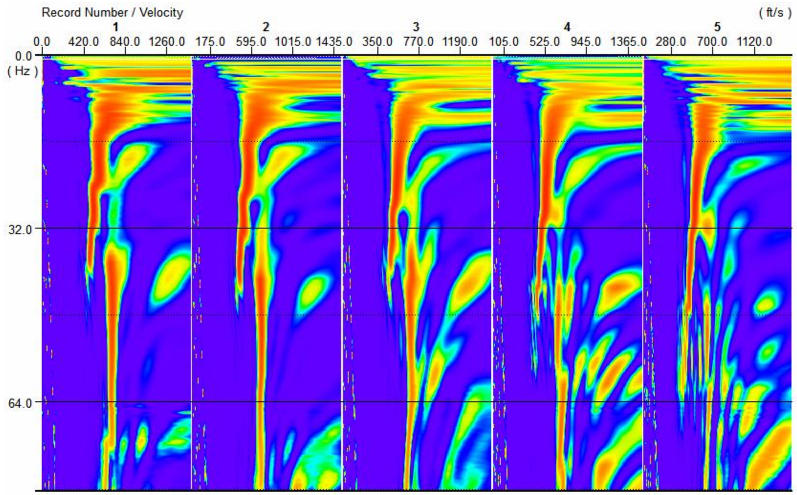
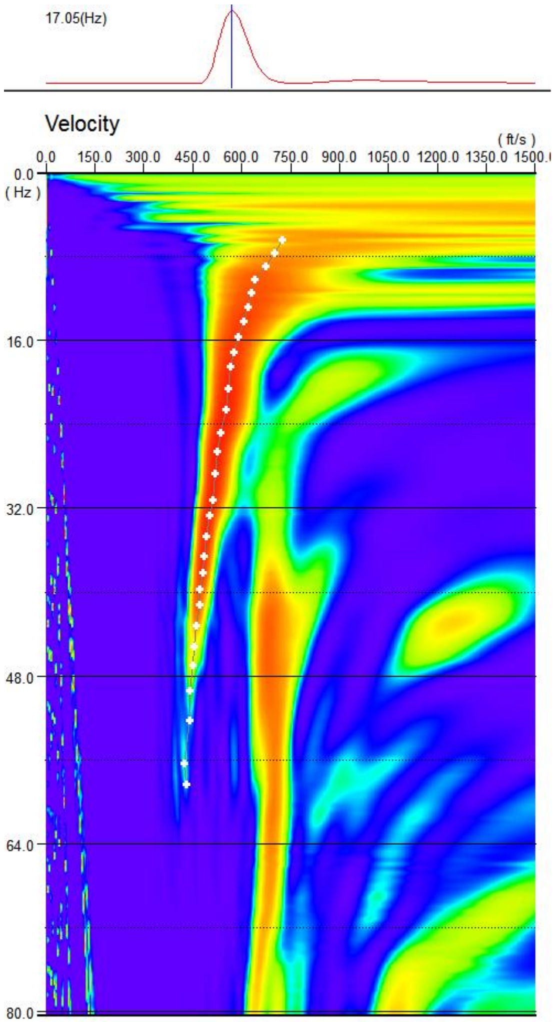
Dispersion Curves – Active 98~220







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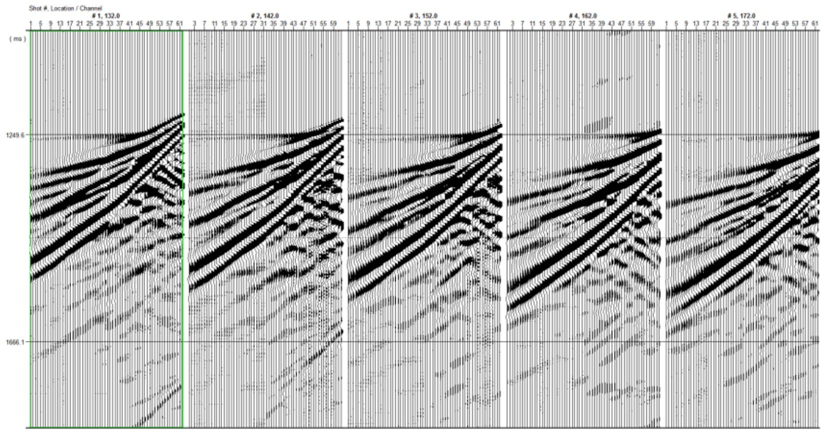
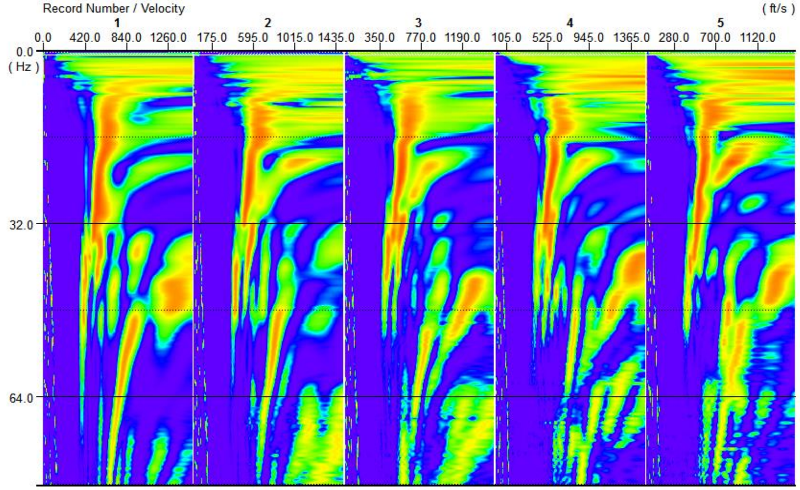
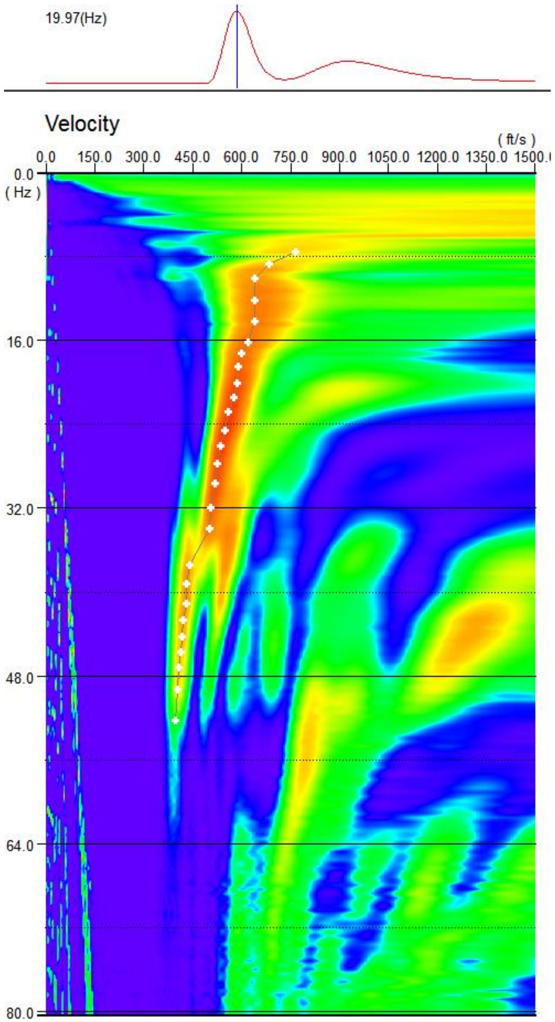
Dispersion Curves – Active 122~0







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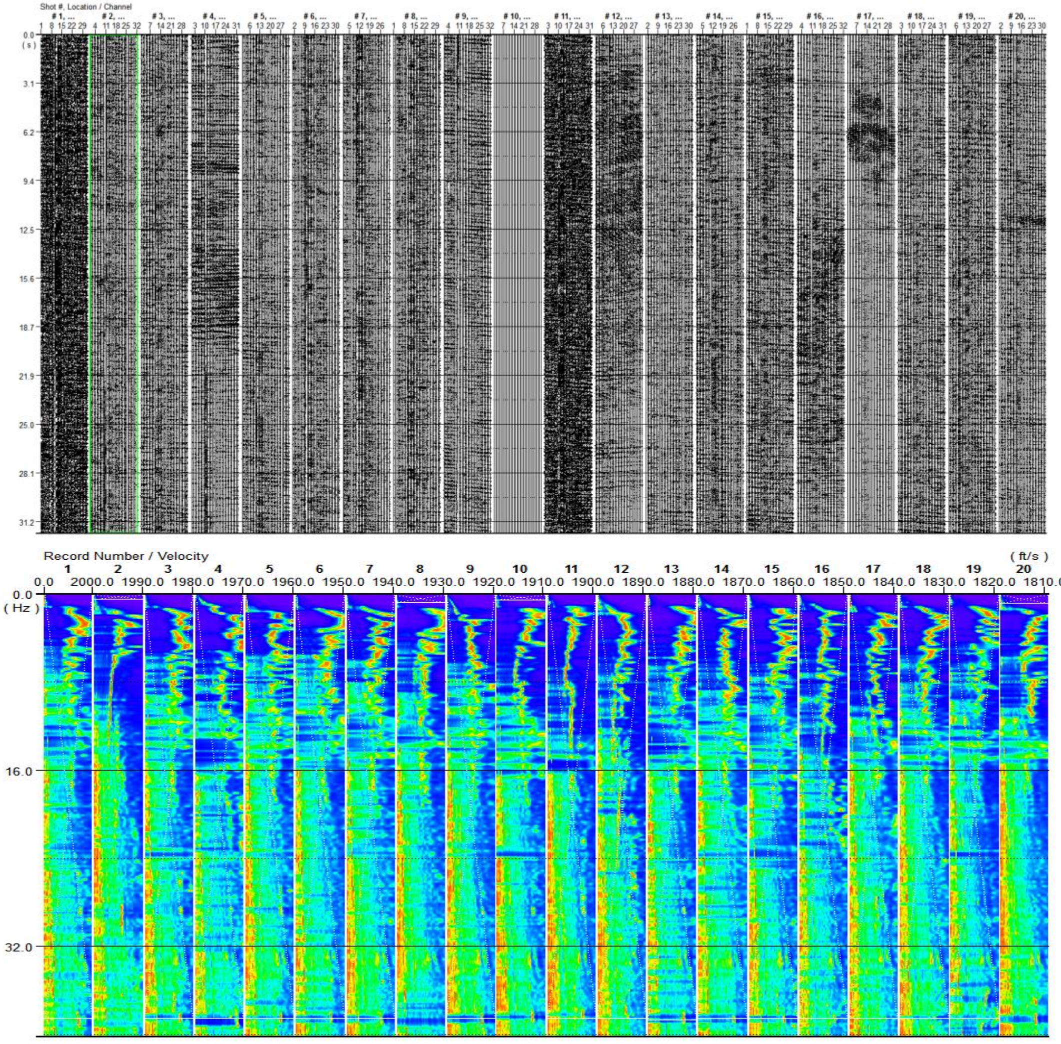
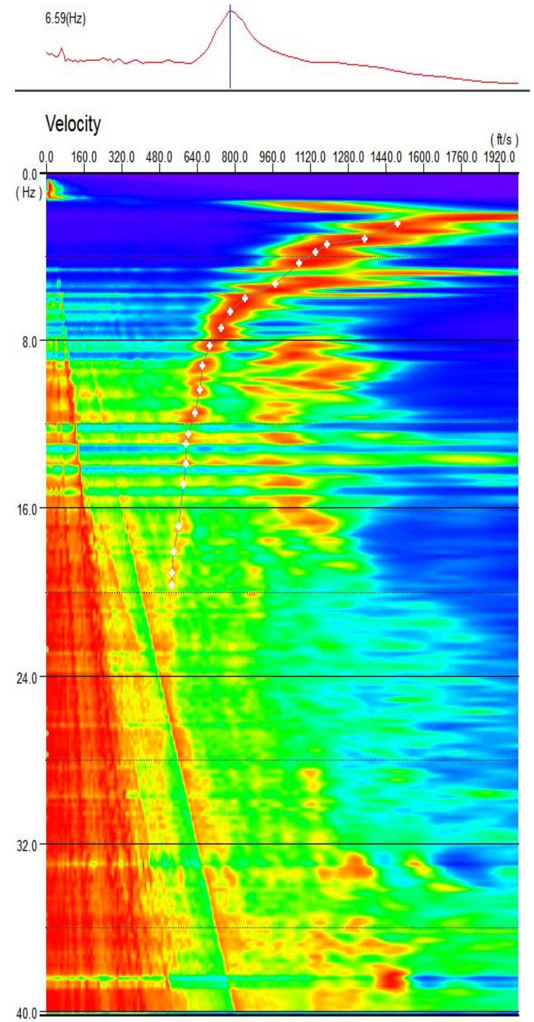
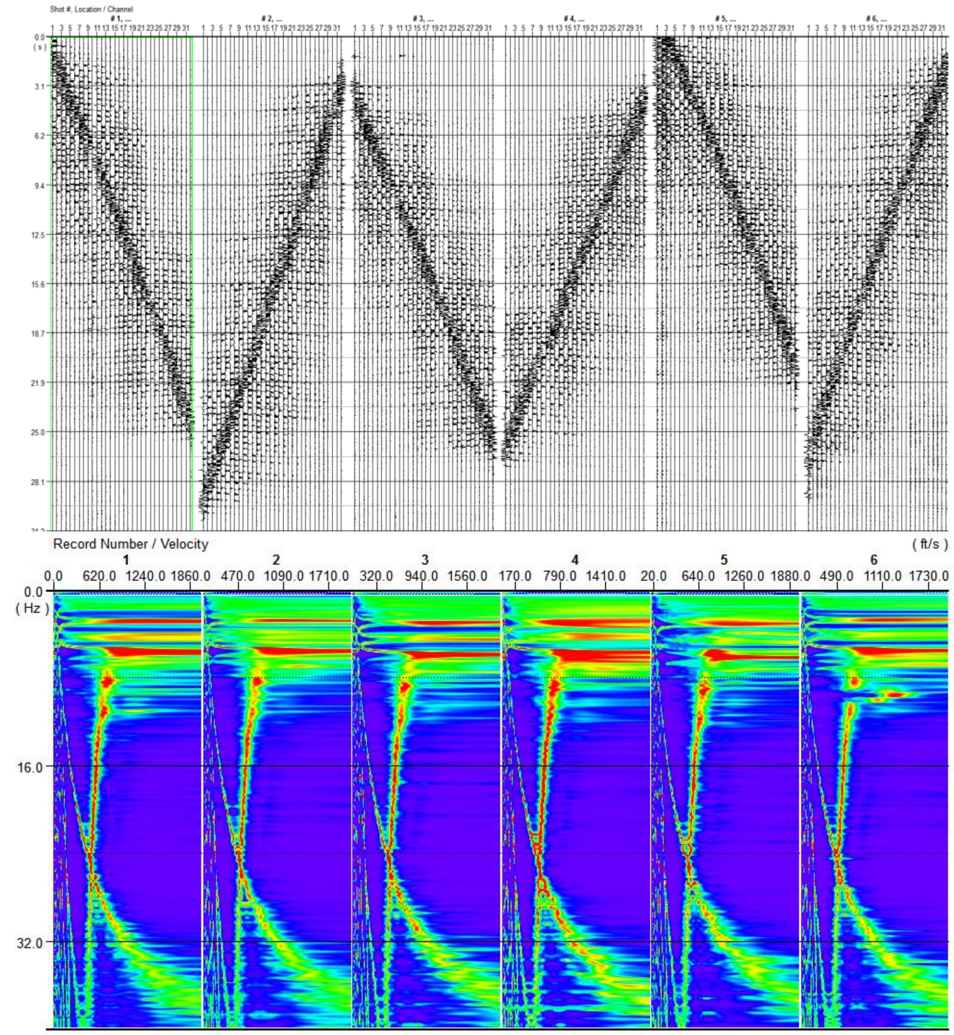
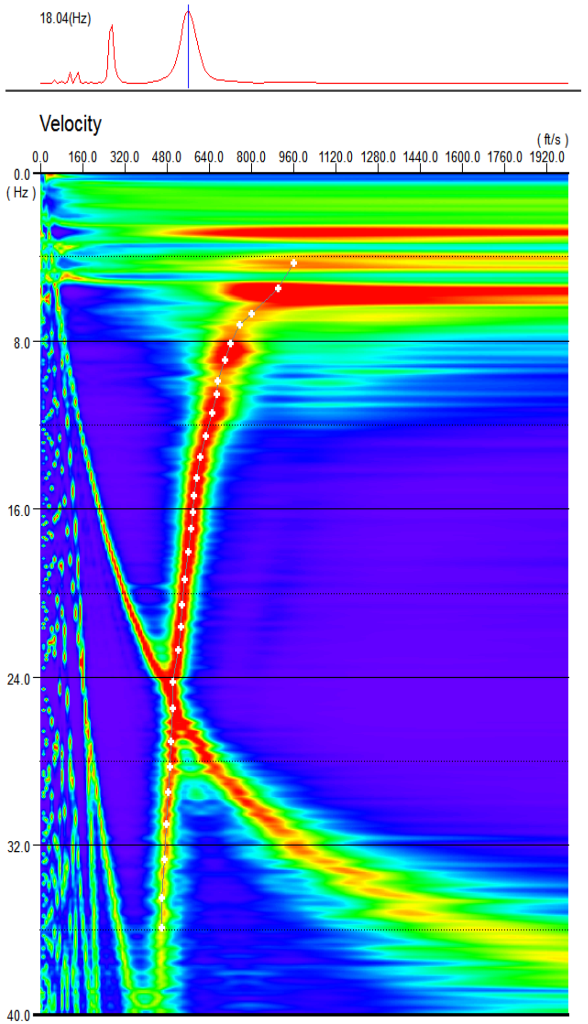
Dispersion Curves – Passive





Dispersion Curves – Passive + Jogging





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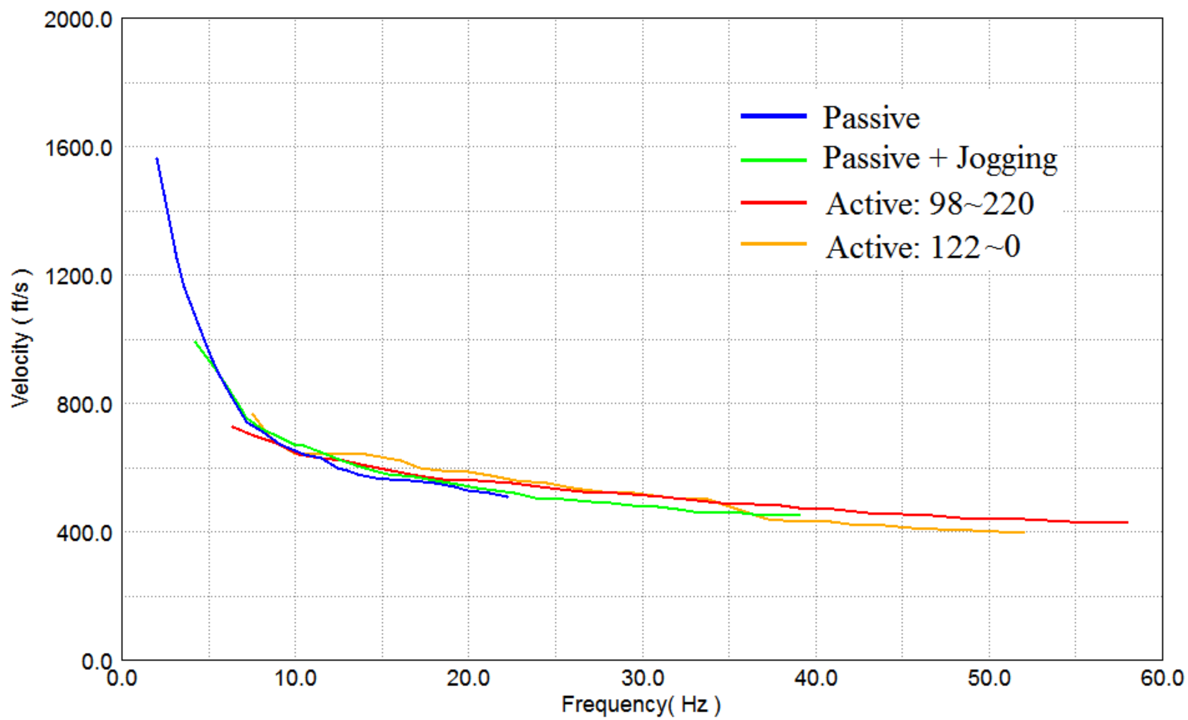
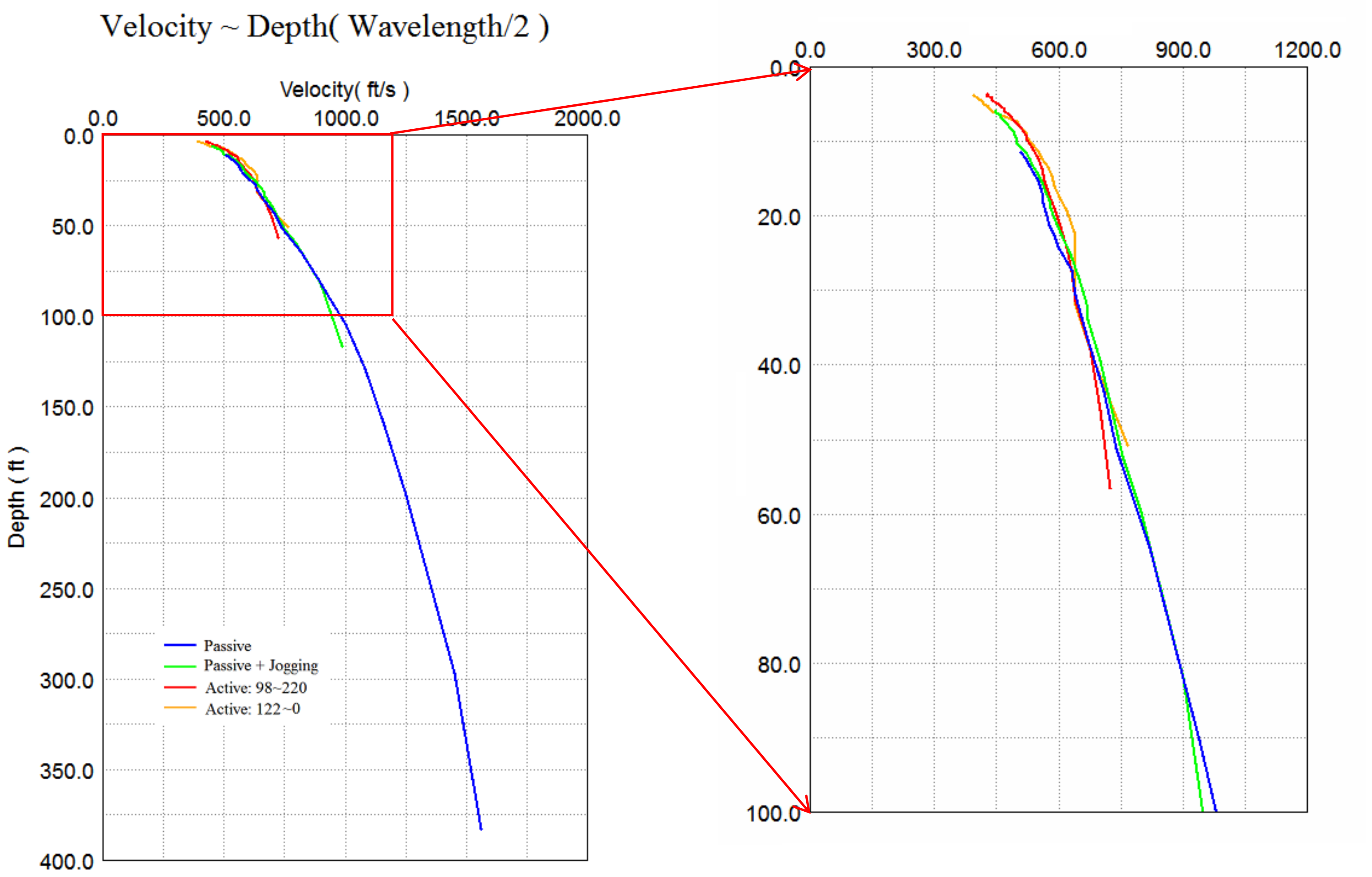
Comparison of Dispersion Curves



Comparison of Dispersion Curves (V~D)



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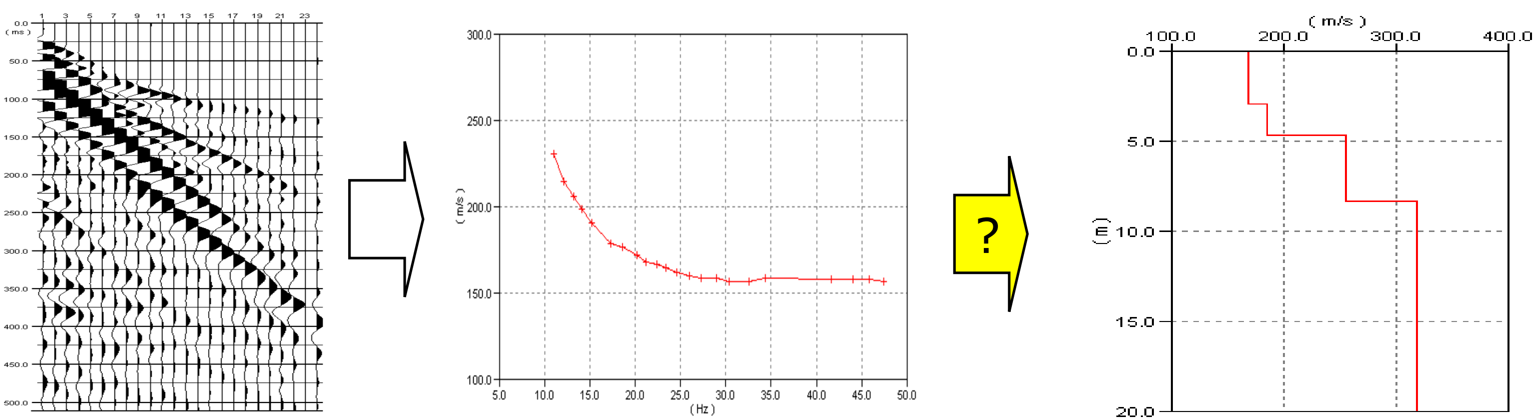
Inversion – Overview

Derive the shear wave velocity and thickness from the dispersion curve

Surface Wave

Dispersion Curve

Velocity / Thickness



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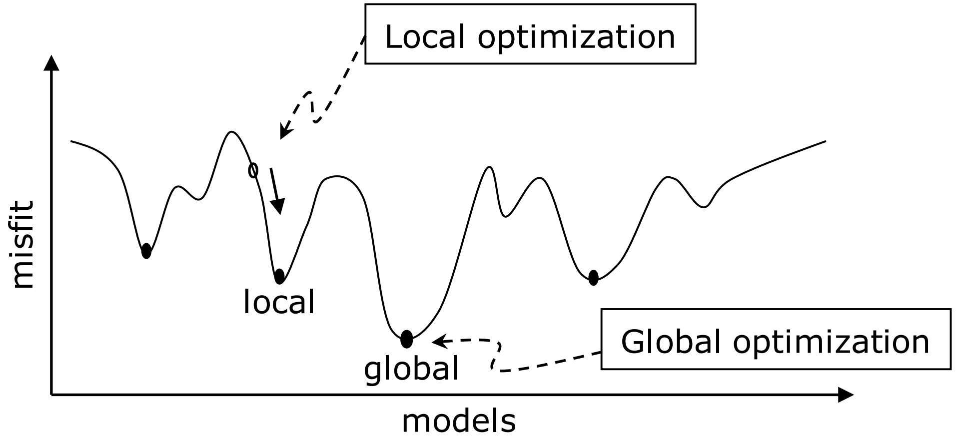
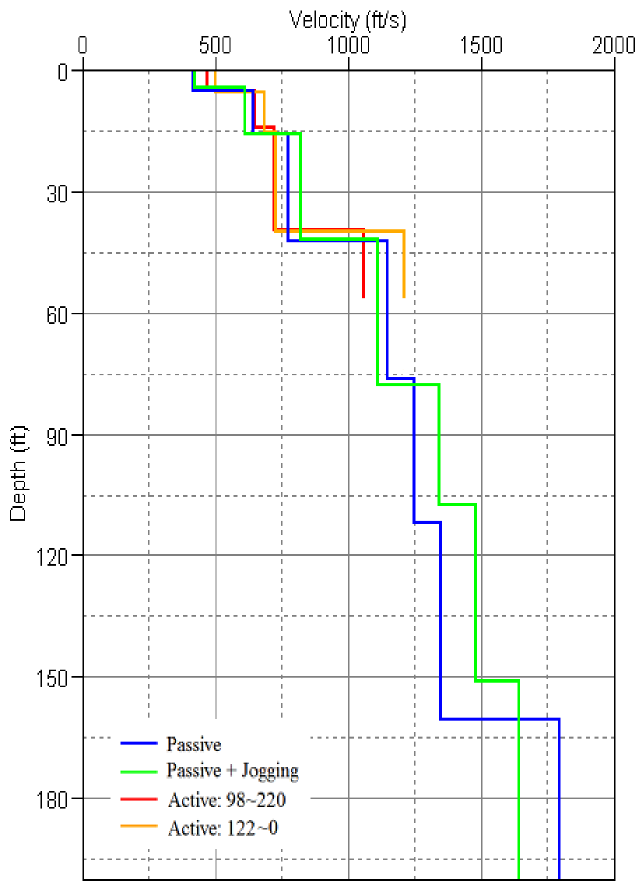
Inversion – Genetic Algorithm

- The inversion of a surface wave dispersion curve is a nonlinear optimization problem, i.e., the objective function exhibits multiple minima and maxima.
- The classical solutions based on linearization are local optimization techniques, and may fail if the starting model is not close to the true model.
- Genetic algorithm (GA) is a global optimization approach, and is more likely to converge toward a global minimum.

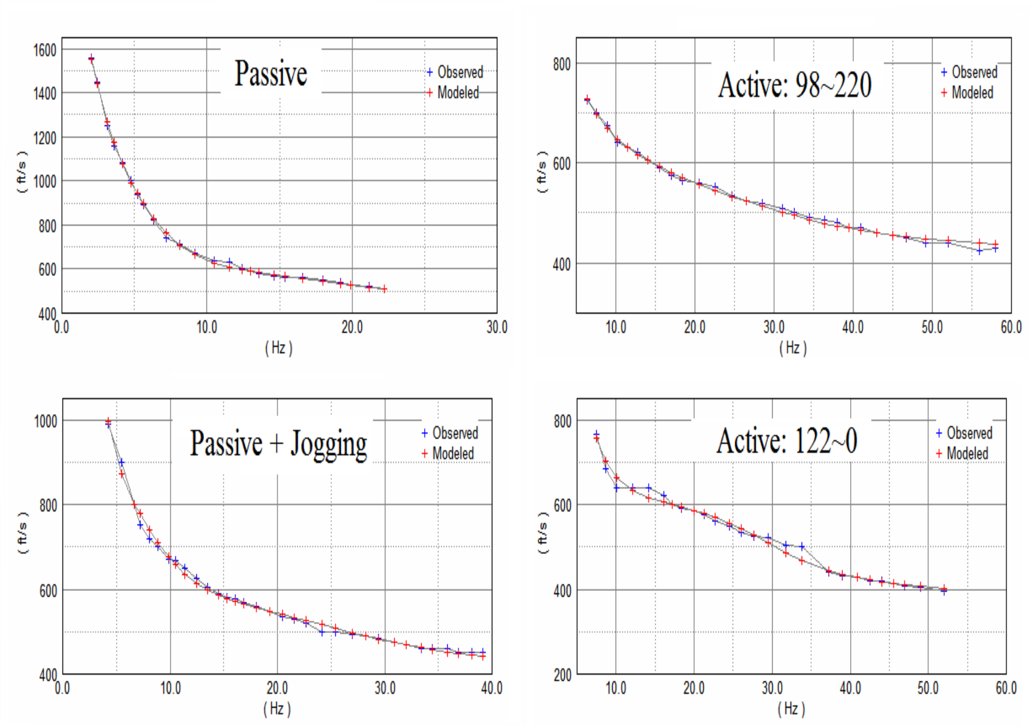


Inversion – Models

Models



Observed and Modeled Dispersion Curves



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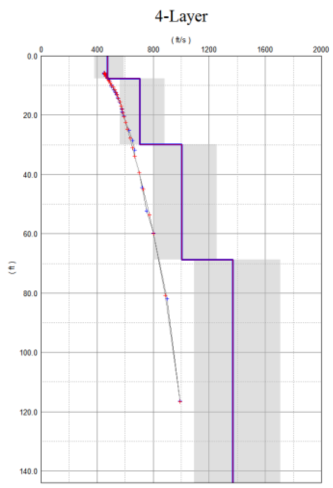
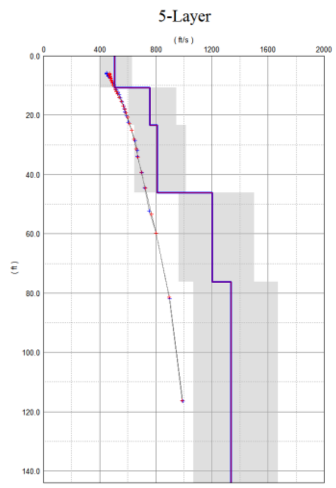
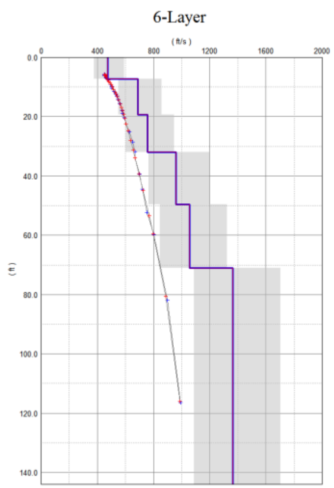
Inversion – Non-uniqueness (uncertainties)

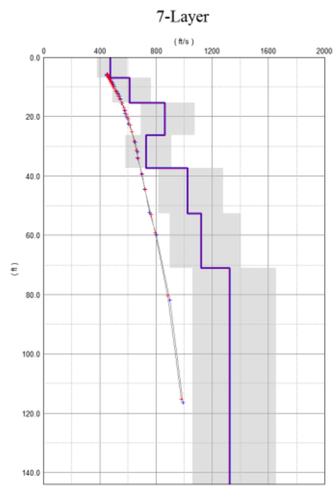
- Non-uniqueness is a common phenomenon in all inverse problems.
- One dispersion curve can yield different velocity models, and vice versa.
- Dispersion is a kind of average response of the elastic properties of subsurface.

Inversion – Non-uniqueness and Average Velocity









# of Layers	Misfit(%)	Vs100 (ft/s)
4	0.80	915.7
5	0.92	918.8
6	0.69	912.6
7	0.68	916.3

$$Misfit = \sqrt{\frac{\sum_{i=1}^{n}(x_{oi} - x_{ci})^2}{\sum_{i=1}^{n} {x_{oi}}^2}} \qquad V_{s100} = \frac{\sum_{i=1}^{N} H_i}{\sum_{i=1}^{N} \frac{H_i}{V_{Si}}}$$

The value of Vs100 is quite stable even though the number of layers changes from 4 to 7.

Conclusion

- There are a variety of methods available for dispersion curve analysis.
- Dispersion curves of active and passive surface wave benchmarking data present good agreement over the overlapping frequency ranges.
- Active surface wave generates reliable dispersion curves at higher frequencies, while passive wave yields higher resolutions at lower frequencies.
- Models derived from all dispersion curves with GA inversion are quite comparable.
- Non-uniqueness exists, but dispersion inversion can provide reliable average shear-wave velocity.