Comparison of FV, FP and FK for Dispersion Analysis of Surface Waves

Don Zhao
Geogiga Technology Corp.
Outline

- Surface Wave Methods
- Comparison in Different Domains
- Uncertainty of Velocity
- Conclusion
Surface Wave Methods

- MASW (Multi-channel Analysis of Surface Waves)
  - linear and 2d array, active and passive surface waves
- ReMi (Refraction Microtremor)
  - linear array, passive surface waves

All methods must conduct wave field transform in FV, FP or FK domain. From a mathematical point of view, all these domains are equivalent since $v$, $p$, and $k$ are related to one another.

However because this relationship is nonlinear, i.e., $v = 1/p$ and $k = f/v$, the dispersion images in these domains illustrate different patterns, which could affect the picking of dispersion curves.
Surface Wave Methods - Wave Field Transform

All methods perform wave field transform explicitly or implicitly to determine the phase velocity of surface waves.
Comparison - Synthetic Data

24 Channels
Spacing: 5m
At low frequencies, the FV image shows the lowest resolution.
Comparison - Field Data (Active)
Comparison - Field Data (Passive)

F-K

F-P

F-V

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Comparison - Explanation

The dispersion images in FP and FK domain appear to have sharp changes at low frequencies, and the resolution seems to be higher than that in FV domain.

This is not true because of the non-linear relationship between v, p, and k.
As $p$ approaches 0 (high velocity), small changes of $p$ yield big changes of $V$, and vice versa.

$$v = \frac{1}{p} \quad \Rightarrow \quad dv = -\frac{1}{p^2} dp$$

$$v = \frac{f}{k} \quad \Rightarrow \quad dv = -\frac{f}{k^2} dk$$
For a given frequency, regular changes of $P$ yield irregular changes of $v$
Uncertainty of Velocity

No matter what method is used, the foundation to determine the phase velocity of surface waves is the phase difference:

$$\Delta \phi(f) = \frac{2\pi \cdot \Delta x}{\lambda(f)}$$
Uncertainty of Velocity - Spacing

For a given number of channels, the longer spread (larger spacing) measures the phase velocity more accurately.
For a given spacing, the longer spread (more channels) measures the phase velocity more accurately.
Uncertainty of Velocity - Explanation

- For the dispersion analysis of surface waves, the velocity tends to have large uncertainties at low frequencies. This phenomenon becomes more serious for the passive surface waves because the dominant frequency of passive surface waves is lower than that of active surface waves.

- This fact can be directly revealed from the FV domain where the energy usually dramatically spreads out at low frequencies, while the FP and FK domain conceal this fact to some degree.
Conclusion

- For all multi-channel based methods, the dispersion images can be generated in FK, FP, or FV domain.
- The dispersion image in FV domain directly and intuitively reveals the fact of uncertainty of velocity at low frequencies.
- Picking dispersion curve in FV domain is easier, while more caution should be taken when picking in FP or FK domain.