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Processing Ground Roll for the Study of Near-Surface Rayleigh Wave Dispersion

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Summary

In investigations of the generation of dispersion curves from shot records, it was noted that as receiver spacing increased, aliasing noise and other artefacts in the tau-p domain increased. This resulted in shear wave velocity dispersion curve “noise”, which masked the true dispersion curve. The purpose of this study is to test whether interpolation of ground roll in synthetic shot records can reduce the tau-p aliasing from sparsely sampled shot records, and as a result improve the resolution of generated dispersion curves. Two processing flows are tested, and the generated dispersion curves are compared to those from raw more densely sampled data, to select the best method. It is found that interpolation of raw records followed by filtering acheives a result similar to original more densely sampled data.

Introduction

In Mills et al. (2016), initial modelling of surface wave dispersion was conducted, which produces clear dispersion curves with good resolution to high frequencies (80Hz). The above paper outlines methods of near surface characterization, specifically multichannel analysis of surface waves (MASW). A 2m receiver spacing is used for all models in that study, as a dense receiver spacing is typically used in MASW surveys, as small as 1m in Long and Donahue (2007) and Park et al., (2002). However, in exploration seismic surveys, it is uneconomical and unnecessary to sample so frequently, so greater receiver spacings are used. At receiver spacing equal to those seen in the 2011 experimental low frequency Hussar survey of 20m (Margrave et al., 2011), the aliasing noise is severe enough to mask the dispersion trend at any frequency. In the Hussar data, dispersion curve generation efforts are fruitless, and result in dispersion spectra consisting almost entirely of noise.

This report will explore the possibility of improving the resolution of dispersion spectra through interpolation of reflection survey scale seismic data, to a denser receiver spacing. Synthetic shot records will be used to study dispersion curve generation, and processing methods to improve these spectra. Shot records, and their associated dispersion spectra, will be compared for receiver spacings of 20m and 10m. LNMO correction followed by 2D interpolation is used to resample the shot records, but other filtering methods are tested on the shot records to improve the resulting dispersion spectra.

Theory and Method

Shear wave dispersion spectra (the *f-v* spectrum) are generated for each shot record through use of the tau-*p* method (Turner (1990), Yilmaz (2015)). This involves tau-*p* transforming the data over a range of slowness values, producing tau-p data with twice as many *p* traces as there were x traces. This data is then Fourier transformed over the time variable τ, producing $d(p, \omega)$. The phase velocities are then extracted by mapping slowness p to velocity, trace-by-trace. Computing the amplitude spectrum of the tau data yields the values of the frequencies (ω) (Yilmaz, 2015). Modelled dispersion spectra for the data are finally generated by plotting phase velocity vs frequency ω. The dispersion spectra are used to QC the processing methods tested.

The interpolation used for this study is a 2D trace interpolation, 2DIntr in GEDCO Vista, which operates in the frequency-wave number (FK) domain (GEDCO, 2013). This interpolation requires the events being interpolated to be horizontal, so a linear normal moveout (LNMO) correction is applied to the data, using an average or the ground roll velocity. The LNMO corrected shot records are input into the interpolation algorithm, which runs over the entire dataset. Within this data, the events of interest, ground roll, are mostly sub-horizontal and parallel, so will be interpolated correctly, but other events (reflections, direct arrivals) will not be. The data is interpolated to 10m receiver spacing, and inverse LNMO corrected.

Examples

Initially synthetic shot records are created through finite difference forward modelling, with 20m and 10m receiver spacing, over the same geological model (FIG. 1), and dispersion spectra are generated for these. An explosive point source is used to generate all shot records, centered in the model (x=2500m, on the near surface discontinuity) at 5m depth. The 10m spacing shot record and spectra will be the standard that we attempt to recreate from the more sparsely sampled 20m shot record.

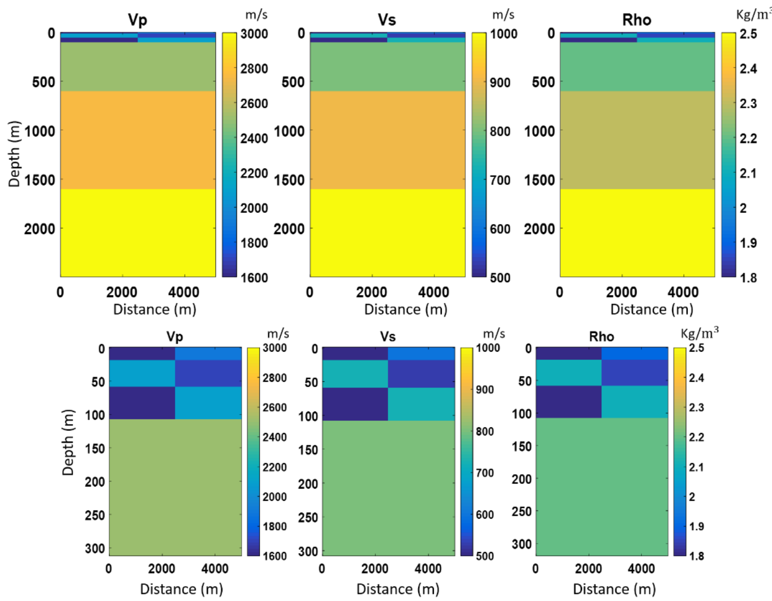

FIG. 1. Geologic models used for synthetic modelling. Top: Full model. Bottom: Near surface zoom.

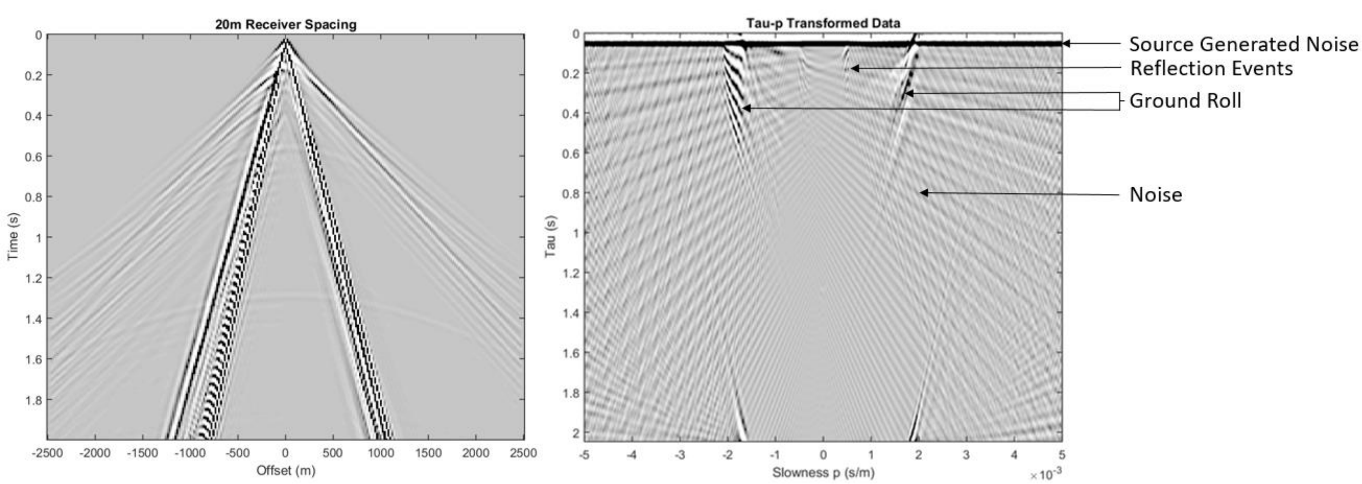

FIG. 2. Left: Shot record with 20m receiver spacing. Right: Tau-p transformed shot record, with events labelled.

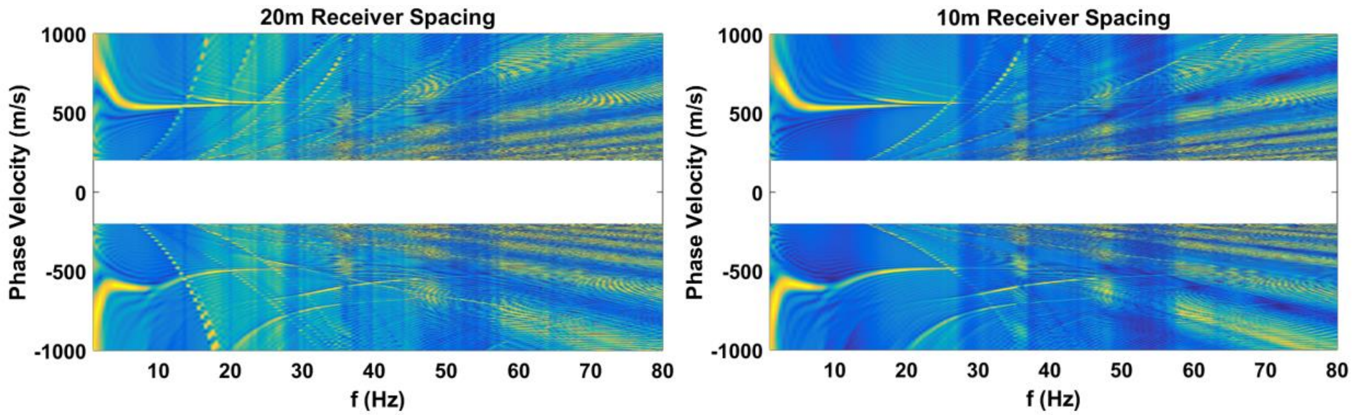

FIG. 3. Shear wave dispersion spectra from the 20m (Left) and 10m (Right) receiver spacing shot records. The thick yellow curve is the fundamental mode of the dispersion. Top: positive offset dispersion. Bottom: Negative offset dispersion.

The 20m receiver shot record and its tau-p transform are shown in FIG. 2. The aliasing noise is clearly visible in the tau-p domain. The generated dispersion spectra for both the 20m and 10m data are shown in FIG. 3. Comparing these, we can see that the closer receiver spacing results in better resolution of the dispersion curve, with fewer noise artefacts obscuring the curve.

Method 1: Filtering followed by interploation

First we will attempt to isolate the ground roll through FK filtering, to remove reflections, and muting refractions and direct arrivals. The dispersion curves after FK filtering are less resolvable than the unfiltered result, including a high amplitude energy band from 20-35Hz that obsures the dispersion curve. This is likely caused by the removal of aliased ground roll energy in this frequency range during the FK filtering. Direct and refracted arrivals are then muted, resulting in minimal improvements to the dispersion spectra. The resulting shot record is shown in FIG. 4 (Left), with it's dispersion spectra in FIG. 4 (Right). The dispersion curve is now more clearly visible at frequencies below 20Hz, however the high amplitude energy band is obscures the curve at higher frequencies. This result indicates that interpolating before FK filtering is necessary to preserve the surface wave energy.

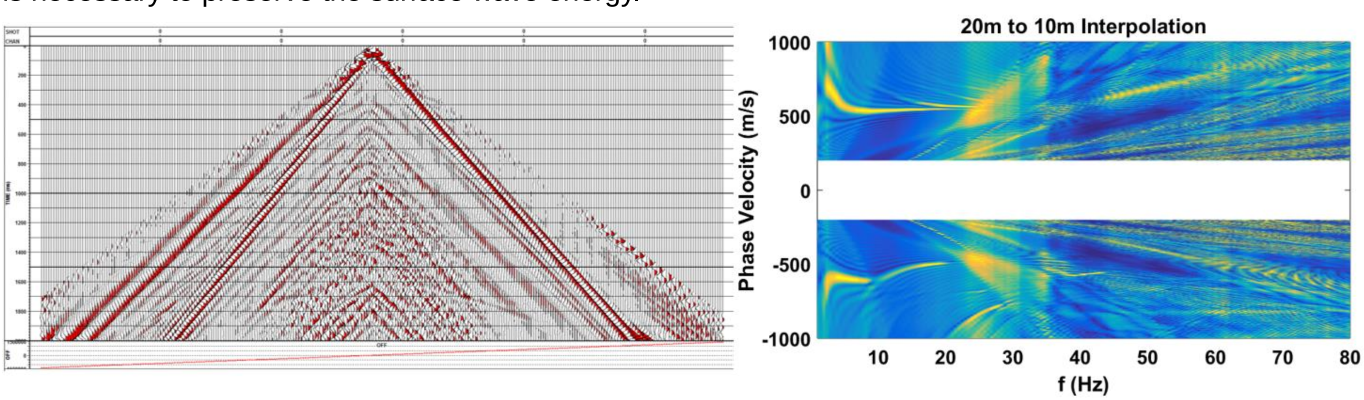

FIG. 4. Left: Shot record after method 1 processing. Right: Dispersion spectra generated from this shot record.

Method 2: Interpolation before filtering

In the next method, we perform the same steps in the reverse order, with interpolation followed by filtering and muting. The interpolation alone has a significant impact on the dispersion curve resolution. FK filtering and muting give slight further improvements to this. The final processed shot record is shown in FIG. 5 (Left), with it's dispersion spectra in FIG. 5 (Right). Below 35 Hz, the dispersion curve (Yellow) is clear, unobstructed, and uncrossed by other events. The curves are continuous and traceable to 35 Hz, and are higher amplitude from 30-35 Hz than in the 10m data.

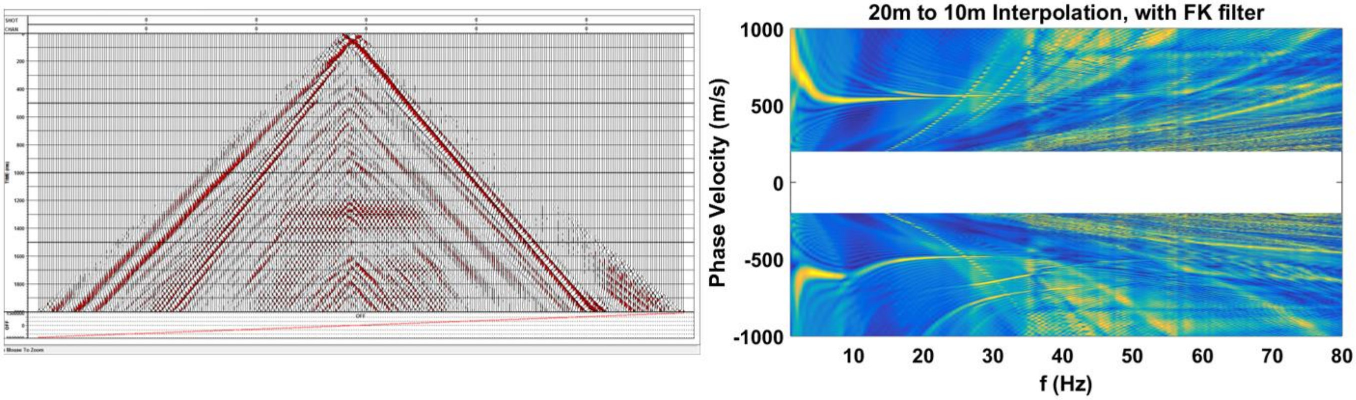

FIG. 5. Left: Shot record after method 2 processing. Right: Dispersion spectra generated from this shot record.

Conclusions

MASW surveys are conducted using very dense receiver spacing (1-2m), while this is uneconomic for larger scale exploration surveys which use receiver spacings in the 15-25m range. Through interpolation, FK filtering, and muting, we attempted to improve the resolution of dispersion curves from sparsely sampled data, to match those produced from denser sample spacings.

Two processing methods were tested to improve dispersion curve resolution, and it was found that method 2, interpolation followed by processing, produced the best result with dispersion curves resolvable up to 35 Hz. Method 1 was somewhat effective, however filtering before interpolation resulted in removal of aliased data, leading to loss of interpolatable ground roll data, and data loss in the final dispersion spectra. In method 2, resolution of the curves was improved over the original 10m spectra between 30-35 Hz. When method 2 is followed, more sparsely sampled data can be interpolated and processed, to match the quality of data acquired with closer receiver spacing. This demonstrates that sparser receiver spacings can be used in the initial survey to reduce costs, and processed to a higher sample rate as needed to acquire dispersion data.

Acknowledgements

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