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Broadband Processing of Slant Streamer Data from Offshore Tunisia

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SUMMARY

Marine seismic data acquired by a flat streamer presents notch diversity introduced by instability of source and receiver depths. Slant streamer data may benefit from further notch diversity introduced by towing receivers in a range of linearly increasing depths. The horizontal slowness shift introduced by the angle of streamer can be used to redatum the acquired wavefields. Receiver side deghosting is facilitated by the uniform angular distinction between the signal and the ghost in the τ-θ domain. We demonstrate the effectiveness of our τ-θ deghosting technique by applying it to a 3D survey acquired in Kaboudia, offshore Tunisia.

Introduction

Advantages of marine seismic data acquired by a slant streamer over flat streamer data are first noticed by Bearnth and Moore (1989). Due to the interference from a down-going wavefield reflected at the sea surface, flat streamer data often contains weaker signal around the notch frequencies associated with the receiver depths. Figure 1 shows the amplitude and phase spectra of a selection of traces demonstrating the inconsistency of the notch frequency along the streamer length. It can be observed that the notch frequency is not uniform along the streamer length. This 'natural' notch diversity is due to the fact that in practice neither the water surface nor the streamer is truly flat.

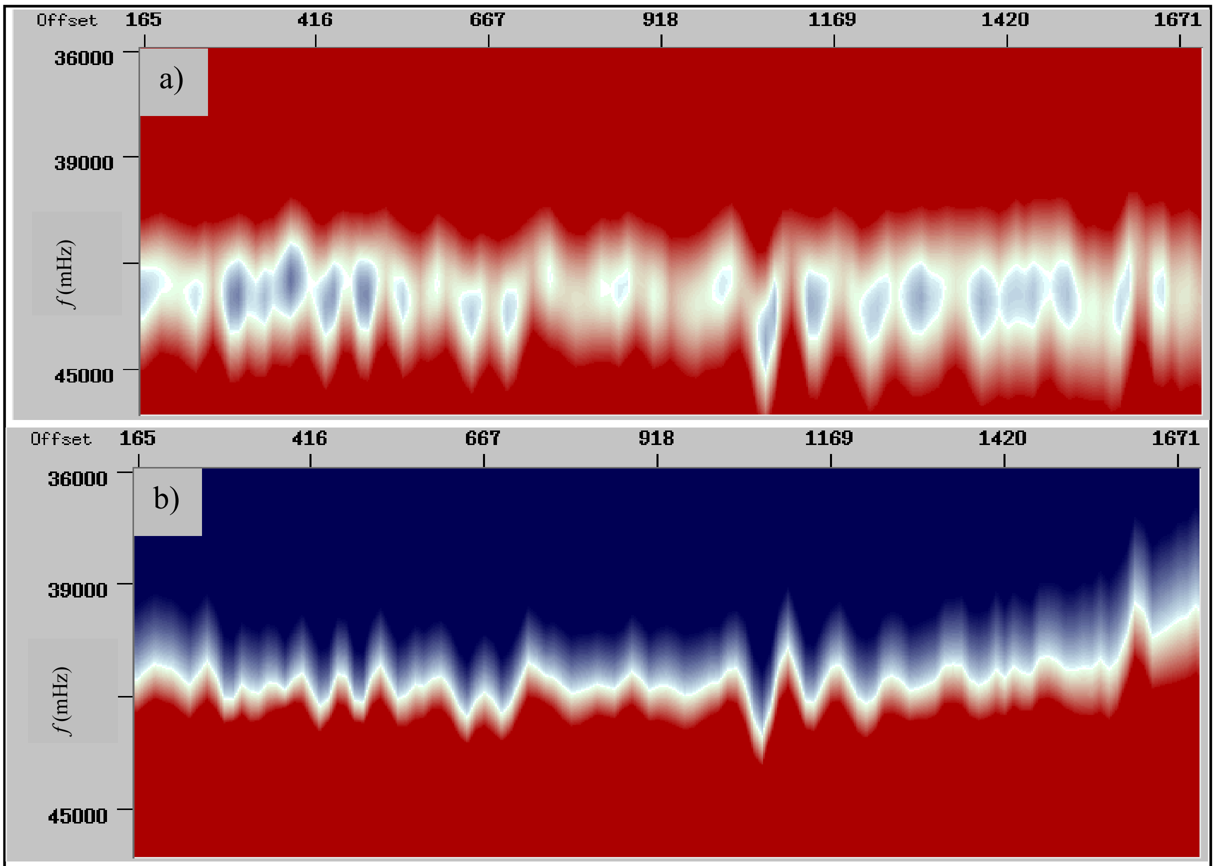

Figure 1 a) Amplitude spectra, and b) phase spectra of a number of traces representing a shot gather acquired at a nominal depth of about 18 m. These spectra are obtained after the water-bottom event is approximately isolated and NMO corrected. It can be seen that the notch frequency is inconsistent along the streamer length, due to the instability of the sea surface and the streamer shape.

This nearly random diversity means that although some valid signals are received in the vicinity of the nominal notch frequency, these signals may not stack constructively. The rapid change of phase around the notch frequencies means that the weak signal, which survives the ghost interference can be destroyed further by the stacking process. As a result, even after a successful pre-stack deghosting, there is a chance that the stacking process could re-introduce a secondary notch at the centre of a frequency range in which the phase discrepancy occurs. This secondary loss of signal can be observed more often on the shallow events where primary and ghosts are almost parallel after the NMO correction. This effect may no longer be observable when a slant streamer is used, because the phase discrepancy is diversified along a wider range of frequencies.

Systematic notch diversity may be introduced by towing the streamer over a range of receiver depths. Although in practice a flat streamer may not be achievable, the term variable-depth is often used to refer to a case in which the streamer is deliberately towed in a desired non-flat shape. The streamer can be simply slanted linearly (Bearnth and Moore, 1989; Dragoset, 1991), or can be given a desired non-linear shape (Soubaras and Dowle, 2010). It is possible to use processing techniques to redatum the recorded data, or effectively de-shape the streamer, and attenuate the receiver side ghost, to estimate the wavefield which could have been recorded by a flat streamer at the mean sea level. Masoomzadeh *et al.* (2013) introduced a method of processing slant-streamer data in the τ-θ domain. In this paper we report the successful application of that method to real data.

Deghosting slant streamer data in the τ-θ domain

The real data example presented in this section is from a 3D survey acquired in Kaboudia permit, offshore Tunisia. Source depth was about 6 m and the nearest and farthest receivers were towed at depths of about 5 and 25 m respectively. Figure 2 demonstrates a shot gather from this survey before and after deghosting process in both *t-x* and τ-θ domain. In the latter domain an angle-variant temporal separation between primary and ghosts can be observed. For slant streamer data, the receiver side ghost shows both temporal and angular separations. However, an appropriate offset shift can eliminate the temporal component, leaving a merely angular distinction. A virtual source may be assumed at the intercept offset, at which an extension of the slant streamer could have crossed the sea surface.

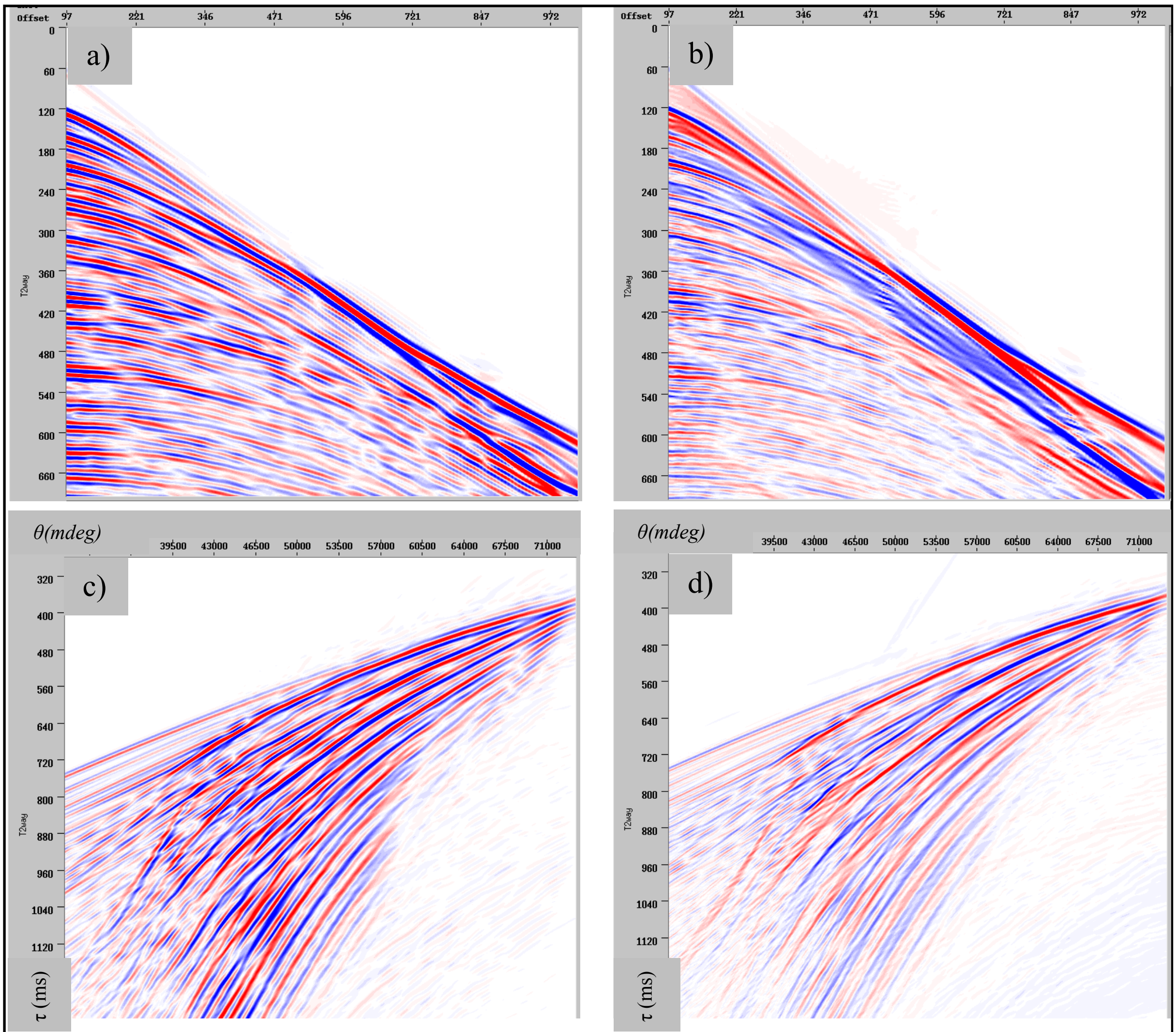

Figure 2 *a) A shot gather acquired by a linearly slanted streamer before deghosting. b) As a) after source and receiver side deghosting. c) A zoomed view of the data transformed into the τ-θ domain showing a lateral separation between primary and receiver side ghost. d) As c) after source and receiver side deghosting.*

Figure 3 demonstrates the receiver side deghosting process in the *f*-*κ* domain, which is the 2D Fourier transformation of the data in the *τ*-*θ* domain. Diagonal notches in the *f*-*κ* domain represent a combination of temporal and angular separations between primary and ghosted wavefields, whereas vertical notches represent a purely angular separation.

Figure 4 shows a comparison of stack sections before and after full deghosting process followed by statistical deconvolution applied to attenuate bubble effect and residual ghosts. Figure 5 shows a similar comparison for a time slice view.

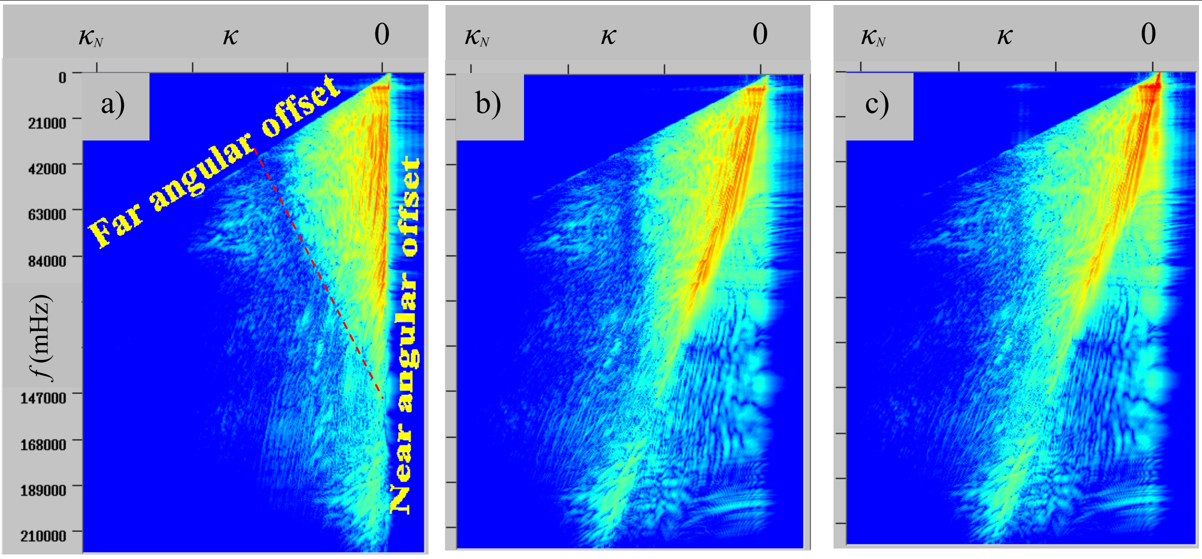

Figure 3 *Logarithmic amplitude spectrum of a shot gather in the f-κ domain. a) A diagonal notch pattern, highlighted by a red dotted line extended from about 30 to 150 Hz, corresponding to the receiver depths of about 25 to 5m. b) A vertical notch pattern is observed when a coordinate shift to the intercept offset is applied prior to the τ-θ transformation. c) After the receiver side deghosting operation.*

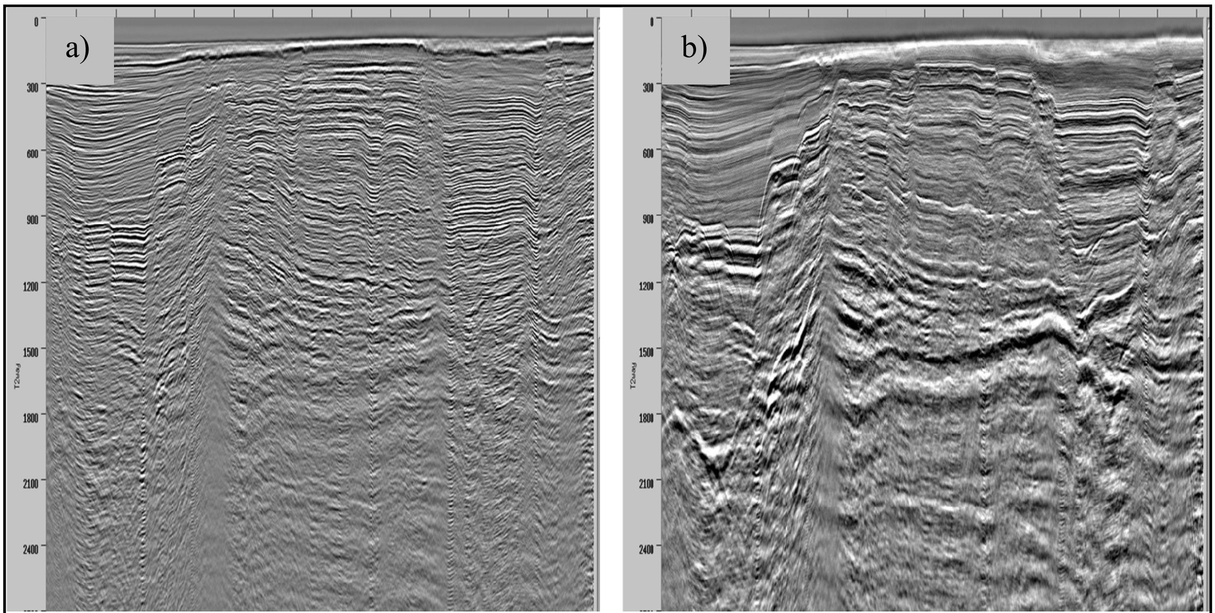

Figure 4 *a stacked section of slant streamer data, a) before deghosting, b) after deghosting for both source and receiver sides. It can be seen that the temporal resolution is improved and the low frequency content is enhanced.*

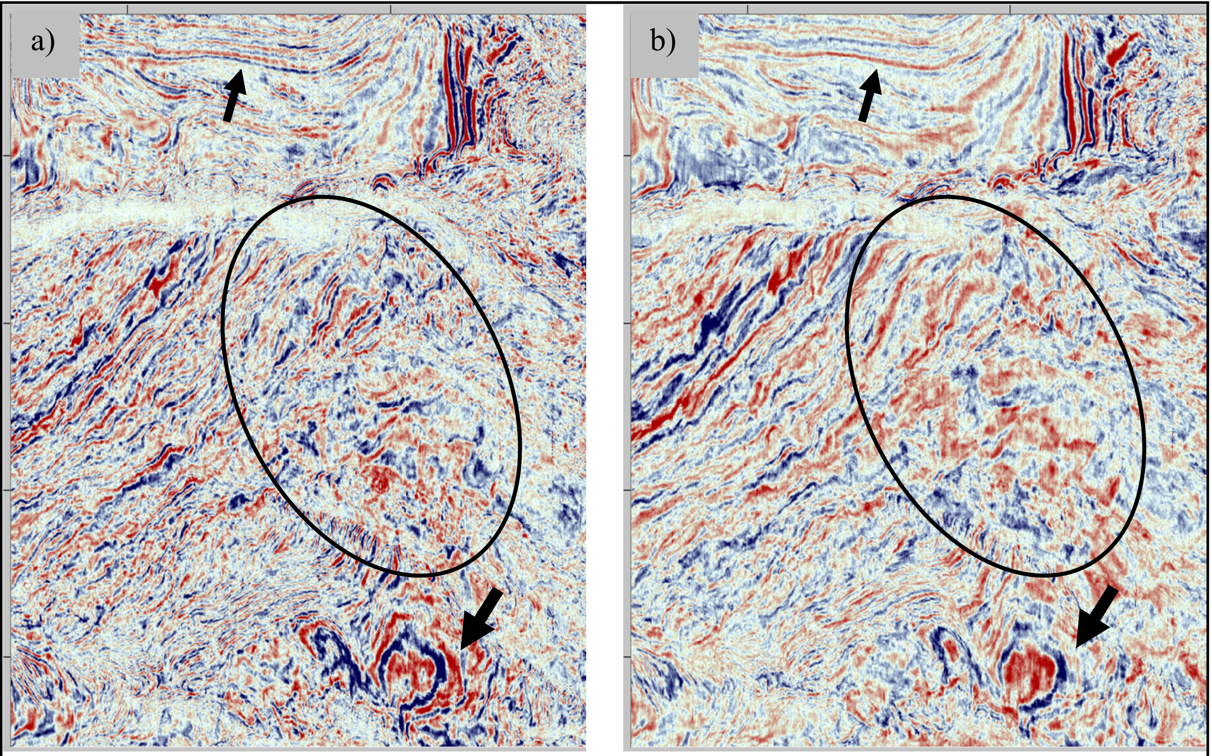

Figure 5 *A time slice from slant streamer data, a) before deghosting, b) after deghosting for both source and receiver sides. It can be seen that the spatial resolution is improved, the low frequency content is enhanced and the misleading ghosted events are attenuated.*

Conclusions

Marine seismic data acquired by slant streamer offers advantages over data from conventional flat streamer. Wavefields recorded by linearly slanted streamer can be deghosted and redatumed in the τ-θ domain. This process can be performed in an early processing stage so that conventional velocity analysis and demultiple processes designed for flat streamer data remain applicable. We successfully applied our redatuming and deghosting technique to a 3D survey acquired by slanted streamers. The results show impressive temporal and spatial resolution enhancement in both stacked section and time slice views.

Acknowledgements

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