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Mixed-phase wavelet estimation for designature in marine seismic data processing

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Summary

De-signature is a key step in marine seismic data processing, aimed at removing the source signature to enhance temporal resolution. This study compares two de-signature approaches that differ in how the source wavelet is obtained. The first approach is deterministic and uses a modeled far-field source wavelet derived from the air-gun array configuration. The second approach is data-driven and extracts a mixed-phase source wavelet from the data using higher-order statistics.
The performance of both methods is evaluated on a deep-water dataset. The comparison focuses on their ability to achieve zero-phase alignment across all the frequency band up to 250 Hz. Results indicate that the data-driven approach provides better bubble attenuation and achieves improved zero-phasing up to approximately 64 Hz. At higher frequencies, both methods perform comparably

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Introduction

A typical wavelet-processing sequence in marine seismic data begins with system delay correction, low-frequency noise attenuation, source and receiver deghosting, and finally de-signature. All these steps are applied at the acquisition sampling rate (typically 2 msec) to ensure a truly broadband outcome.

When the air-gun array configuration is fully known, the far-field signature can be accurately modeled. Its amplitude spectrum is smoothed around the bubble frequency, and it is used to derive a zero-phase equivalent wavelet, referred to as the *target wavelet*. The de-signature filter is a Wiener filter that matches the source wavelet (far field) to this target wavelet (Yilmaz, 2001).

However, in some cases, residual bubble energy may remain after de-signature. This is caused by variation of the conditions of the sources while in operation such as sea temperature and array movement due to sea-state. To address this issue, the source wavelet is extracted from the data and used instead of the modeled far-field signature. This extraction is performed without any phase assumption using a novel method based on higher-order statistics (Bekara, 2020). For efficiency, the process of wavelet estimation uses pre-stack seismic data restricted to a maximum offset of about 800 m. The portion of data for estimation is defined within a 2000 msec gate starting at the water-bottom reflection. Compared with the conventional extraction method where the water bottom reflections are fattened and stacked, this approach results in a much less geology leakage and therefore a more reliable source wavelet estimation.

In this paper we will compare the designature output using the deterministic approach where the far field signature is used to model the target wavelet and a data-driven approach where the target wavelet is extracted from the data.

Data example

Figure 1 shows the autocorrelation of a near-offset channel (inner cable) before and after de-signature using both methods. When the far-field modeled de-signature operator is applied, residual bubbles are still visible (Figure 1b). These are significantly reduced when the extracted wavelet is used to derive the de-signature filter (Figure 1c). This improvement occurs because extraction captures the actual bubble characteristics, such as peak frequency, which may differ from the modeled one due to factors like water temperature changes and variations in the source during operation.

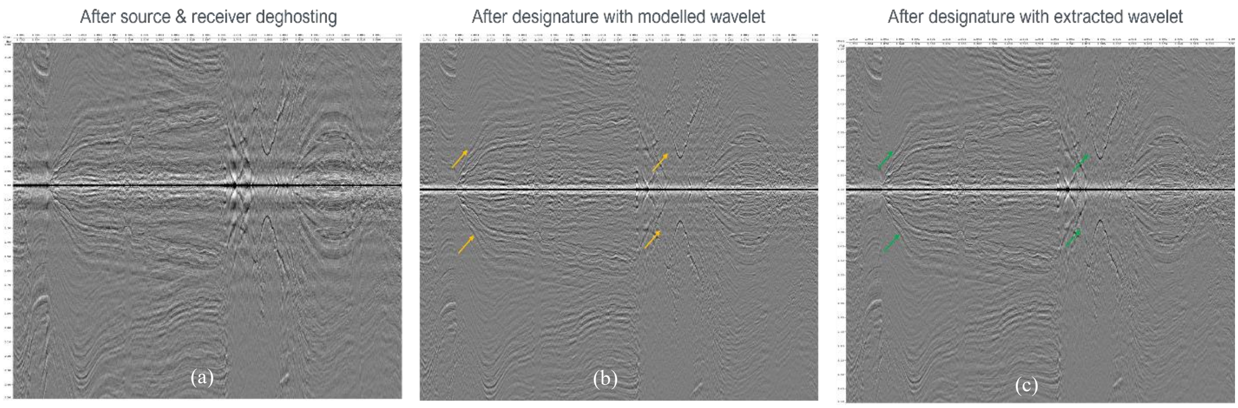

Figure 1. *Autocorrelation of the near offset channel before designature (a) and after designature using the far field modelled signature (b), using signature extracted from the data (c)*

Figure 2 presents a portion of a 2D stack before and after de-signature using both methods. Besides eliminating residual bubbles more effectively when using the extracted wavelet, zero-phasing around the water bottom also shows slight improvement.

Conclusion

Wavelet extraction for de-signature should be considered when the conventional modeled approach does not achieve the desired quality. Even in this deep-water survey, extracting the wavelet by simple stacking along the water-bottom reflection was insufficient. A more sophisticated method using higher-order statistics was required to extract the desired wavelet and achieve improved results.

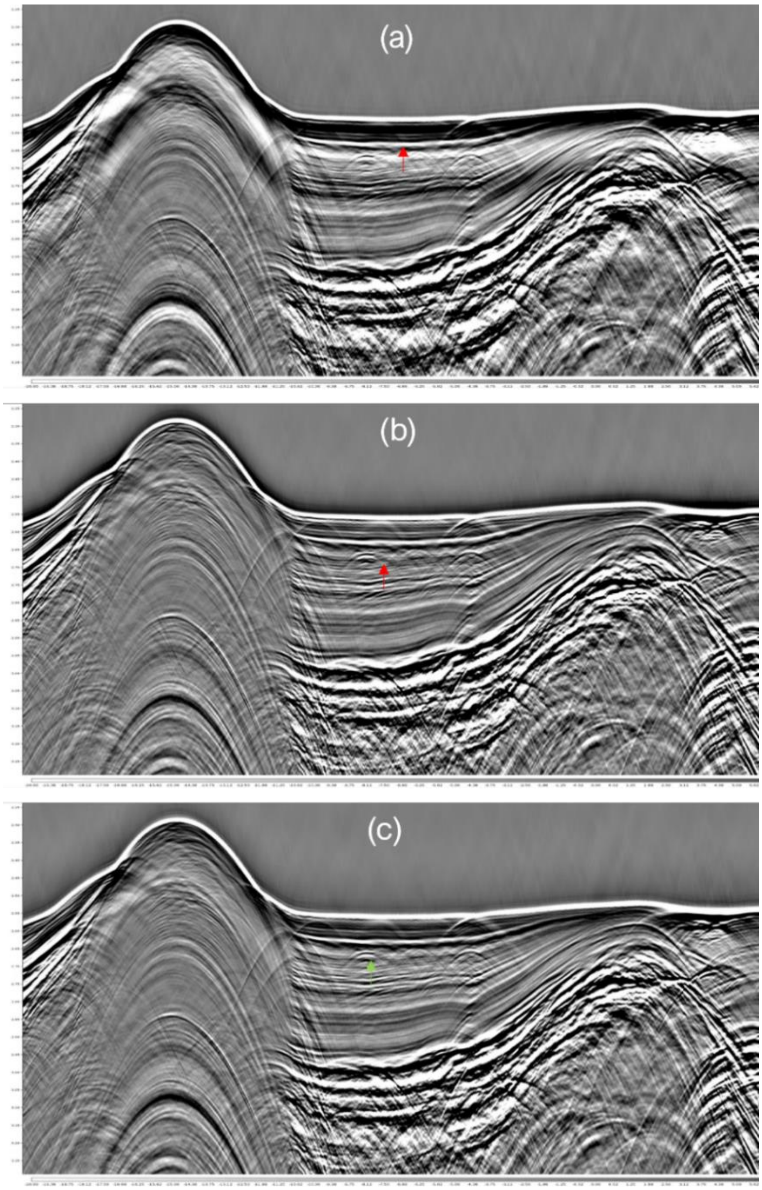

Figure 2. *2D offset stack before designature (a) and after designature using the far field modelled signature (b), using signature extracted from the data (c)*

Acknowledgement
The authors would like to thank TGS Multi-client for the permission to show the data and TGS Cairo Imaging for their support.

References

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