PSS~Geo

Geophysical services to the oil industry

All Seismic Processing Deghosting techniques

Introduction

Over the last 50 years, the process of seismic ghost elimination have been approached by many scientists. The theoretical understanding and solution of the problem were found, but its practical implementation was not successful. As a results, the engineers were needed to step forward and design steamers which help to eliminate the ghost during acquisition, and extend the bandwidth. The process strongly uplifted the quality of the acquired data. The extended low and high frequency parts of the seismic spectrum made tremendous improvement in seismic interpretation, even allowing to separate different impedance layers. As to reacquire seismic data again is very expensive, another question faced geoscientists: what should we do with the already acquired by conventional method data? Many thousand kilometers of seismic covering the Globe must not be wasted.

A new wave of mathematical ghost removal became popular in 2009-2011. The approach was considered very unstable mainly because of errors and sensitivity in ghost-timing-depth estimates. Today we have several companies and universities who suggest diverse approaches for a ghost elimination. Testing these codes on the real data show very big limitations: ghost is still presented, ghost is partly removed in the shallow part (but not straight after water bottom), no proper restoration of the spectrum removed (e.g. no low frequencies and spectrum still shows that "two wavelets" present; no high frequencies restored). The most harmful approach for the industry is a "black box technology" followed "cleaning process" . It often leads to the wrong impendence layers interpretation, dry wells, and results in interpreter's reduced confidence. Such a processes often contain spectral whitening and smoothing.

Ghost operator

In 1993, Amundsen L. described ghost function for horizontal streamer. Wave-equation of the ghost function in the frequency-horizontal wavenumber domain for the reviser side is

$$G(k_x,k_y,z) = 1 + r_0 exp(2ik_z z),$$

where $k_z=(k^2-k_x^2-k_y^2)^{1/2}$ is the vertical wavenumber, $k=\omega/c_0$ is the wavenumber, ω is the circular frequency, z is the recording depth, c_0 is the propagation velocity, and r_0 is the reflection coefficient at the sea surface. $r_0 = -1$ for the vacuum-fluid interface. Then, the deghosted function defined as inverse of the ghost function

$$D(k_x,k_y,)= 1/(G(k_x,k_y,z)) = 1/(1 + r_0 exp(2ik_z z)).$$

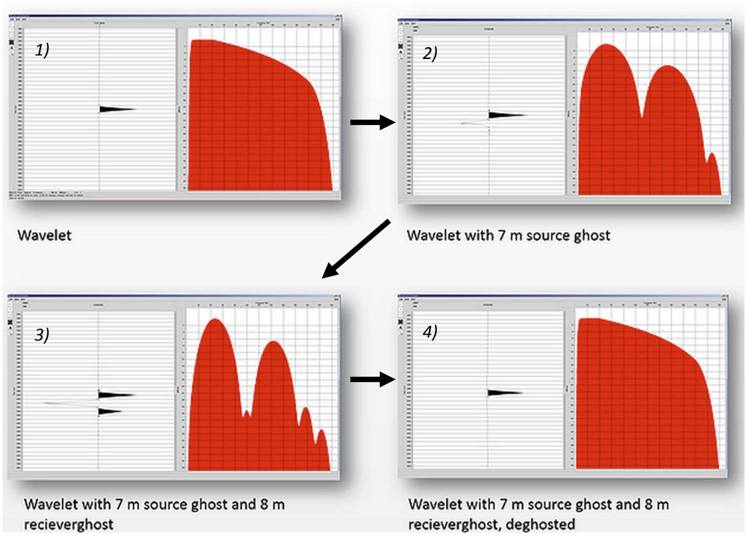
Amundsen L. et al. 2013, expand deghosting function as a Taylor series

$$D(k_x,k_y,)= \sum_{n=0}^{\infty}(-r_0)^n exp(2ik_z z).$$

Reflection coefficient can be counted if the sea surface is not a perfect surface.

Application to the real data

The main idea of the deghosting techniques is the application of a proper deghosting operator to the seismic data, which must remove both



Theoretical explanation of low and high frequencies recovery during deghosting process. 1) Wavelet with wide range. 2)-3) Wavelet with source and receiver ghosts, and its frequency range with losses (in red). 4) Application of deghosting operator to the wavelet gives full reconstruction of the original wavelet spectrum.

source and receiver ghosts.

Depending of different survey/streamer configurations and geological settings the deghosting solution can be derived from the data in different domains. This could be both FK, Tau-P and XT-domains or, for very variable streamer depth, a special algorithm working in local Dip-Xt domains can be used .

To achieve a stable solution for the full seismic section the estimation of ghost delay and reflection coefficient should be performed in a sliding window. For compensation inaccurate and unstable estimations, estimations both of a deghosted data and a "pure" ghost signal should be performed. The estimation is combined in a least square inversion scheme to calculate an optimal deghosting, and to use of estimated receiver delay times for static corrections.

The deghosting process can be done in any stage in the processing, but preferably after noise reduction. For data with tiny variations in receiver depths, we have also successfully produced deghosted data after migration. In such cases the results are often comparable with a proper prestack or premigation deghosting.

Alternative methods

There are two more alternative methods for *visual* ghost elimination. One is based on a blind deconvolution approach, where the average wavelet is derived in sliding windows and a wavelet shaping/deghosting operator is derived and applied to the data. Another one is based on pure wavelet shaping filters.

The actual methods for deghosting will vary from project to project, depending on survey configuration, noise level in the data and the stage at which the process is preformed.

Normally PSS-Geo prefers to do proper prestack deghosting after some level of denoise.

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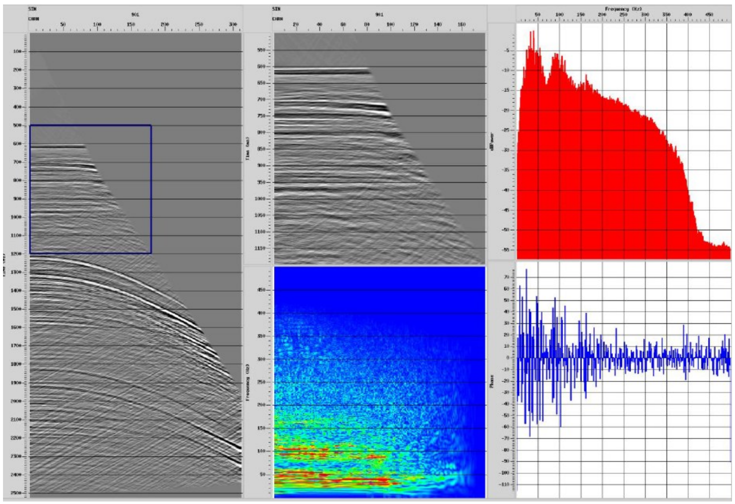
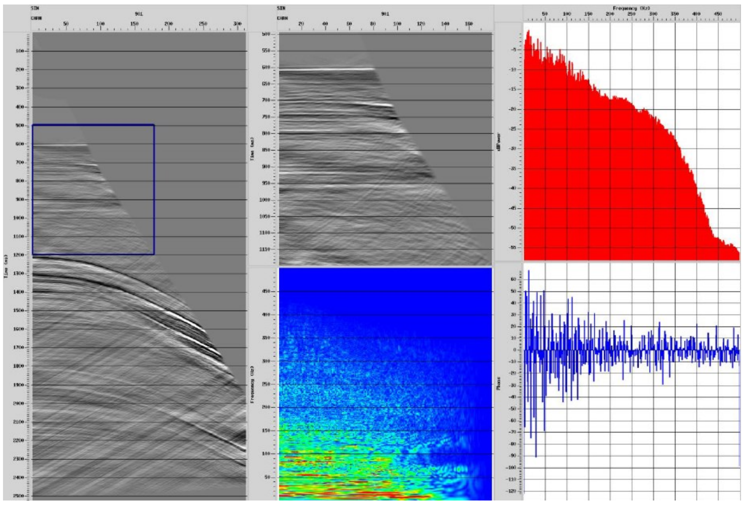
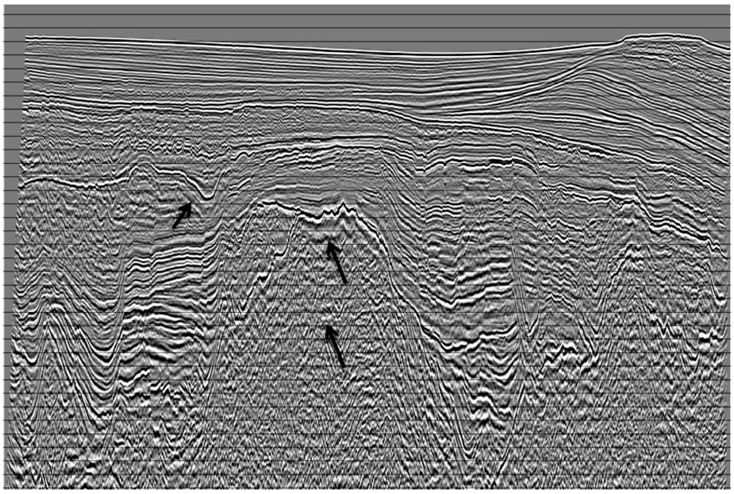
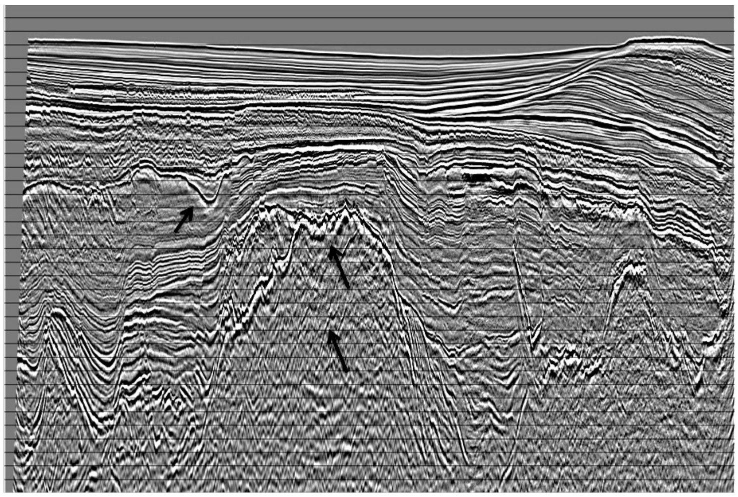
Original

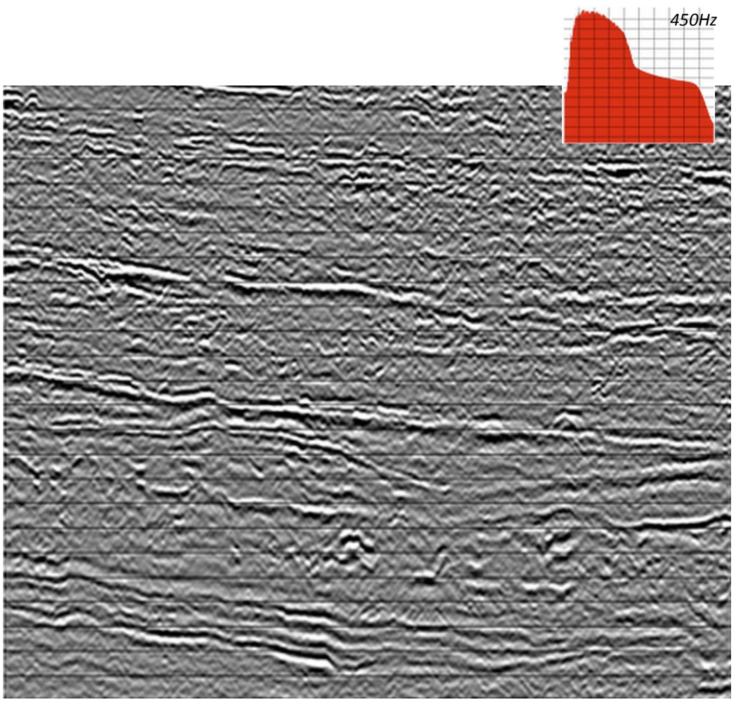
Deghosted

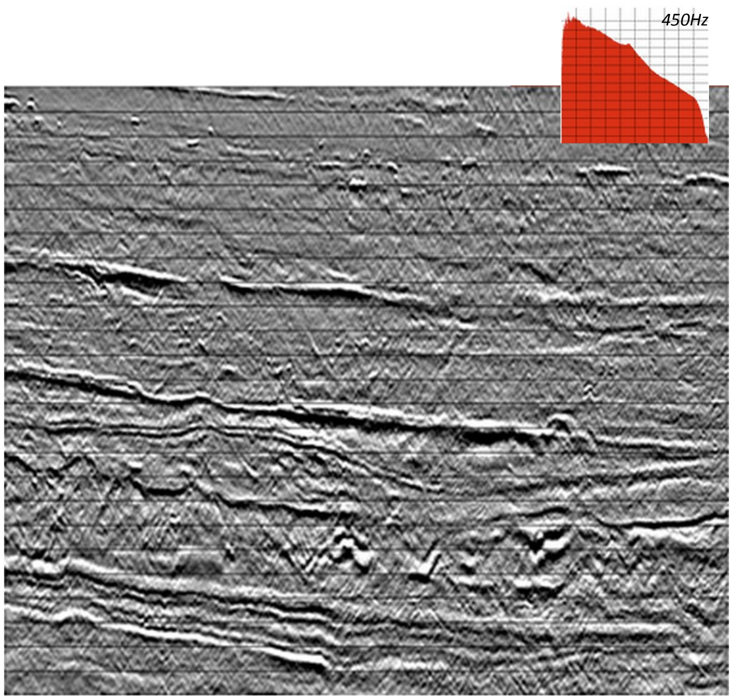












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