

# RadExPro seismic software for high resolution marine seismic processing



## RadExPro – complete solution for High-Resolution marine seismic processing

Various types of marine seismic surveys:

Single channel

2D Multichannel (variable spacing groups, slanted streamers)

3D acquisitions

OBN surveys



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Various types of marine seismic surveys:

All types of HR/UHR sources:

Single channel

Sparker

2D Multichannel (variable spacing groups, slanted streamers)

Boomer

Airgun

3D acquisitions

OBN surveys



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Single channel

2D Multichannel (variable spacing groups, slanted streamers)

3D acquisitions

OBN surveys

All types of HR/UHR sources:

Sparker

Boomer Airgun Applications:

Geohazard assessment for tophole drilling

Renewable energy developments

Pipeline routes and offshore installations

Geological studies for nearsurface processses

Other applications (dredging, boulder detections, etc.)



# Acquisition and frequency content problems

High frequency content - additional requirements in terms of processing algorithms, they need to be adjusted for URH data:

- Shallow towing and noisier ships result in increased noise level
- Sea swelling affect correlation of high frequencies problem of marine statics
- Less control over the towing depth, so standard deghosting approaches cannot be used

- ...



Shallow tow of the spread results in increased level of noise

Small vessels do not provide same low noise level comparing to large-scale seismic vessels

Towing techniques during acquisition may result in increased noise level

#### **Available solutions:**

Filtering (bandpass, Butterworth, TVBF)

TFD Noise attenuation

FK, Radon filtering

2D/3D Sparse FK, Sparse Radon filtering

2D/3D FXY predictive filtering

Other techniques can be implemented with available algorithms



#### **Noise attenuation**





# **Static corrections**

High frequencies, presented in the data result in very short wavelengths

Even small swell motion during acquisition results in high static disturbance

Statics reduces image resolution due to incoherent stacking

#### **Available solutions:**

Swell filtering

Trim statics

COSA\*

Custom

\* "3D pre-processing techniques for marine VHR seismic data"N. Wardell, P. Diviacco, R. Sinceri - First break volume 20.7, July 2002



#### Swell Effect on Multichannel Sparker Data – Channel #10





#### Swell Effect on Multichannel Sparker Data – Brute Stack



Data acquired by GEO MARINE 3D UHR system



## HR static corrections

#### Swell Effect on Multichannel Sparker Data – after Hi-Res Statics application



Data acquired by GEO MARINE 3D UHR system



deconvolution

deconvolution

algorithms

factorization





1250

# **Designature by predictive deconvolution**

Multichannel HR data – stack before designature





# **Designature by predictive deconvolution**

Multichannel HR data – stack after designature





#### Single channel seismic section before designature





#### Single channel seismic section after designature





#### Single channel seismic section after designature





#### Single channel seismic section after designature





Statistical Deconvolution of sparker wavelet. Stacked section: before





Statistical Deconvolution of sparker wavelet. Stacked section: after





# SharpSeis - dedicated algorithm for ghosts removal



Principle scheme of marine towed acquisition

Ghost time delay:  $\tau = 2d\cos\theta/V$ 

- V water velocity
- d streamer depth
- $\theta$  angle of incidence



Solution: Adaptive Recursive Filtering \*

- 1. Recursive filtering
- 2. Filtering in the reverse time
- Nonlinear combination of forward and reverse filters
- 4. Regularization of the solution
- Adaptive selection of filter parameters
   (time delay and q)



\* Vakulenko S.A., Buryak S.V., Gofman P.A. and Finikov D.B., 2014, Deghosting of High Resolution Marine Seismic Data by Adaptive Filtering Algorithm, Near Surface Geoscience 2014 - 20th European Meeting of Environmental and Engineering Geophysics pp 1



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Deep towed streamer, small volume airgun, before deghosting

Primaries

Ghosts



Data courtesy of The University of Tromsø and UiT Centre of Excellence, Acquired with P-Cable 3D System



Deep towed streamer, small volume airgun, after deghosting



Data courtesy of The University of Tromsø and UiT Centre of Excellence, Acquired with P-Cable 3D System



Deep towed streamer, small volume airgun, after deghosting, spectra comparison



Data courtesy of The University of Tromsø and UiT Centre of Excellence, Acquired with P-Cable 3D System



#### Seismic section before deghosting



Survey parameters

Source – G-Boomer Streamer – 1 channel Water Depth – 20-30 m



## Seismic section before deghosting, zoomed





#### Seismic section before deghosting



Survey parameters

Source – G-Boomer Streamer – 1 channel Water Depth – 20-30 m



#### Seismic section after deghosting



Survey parameters

Source – G-Boomer Streamer – 1 channel Water Depth – 20-30 m



#### Seismic section before debubbling



Survey parameters

Source – G-Boomer Streamer – 1 channel Water Depth – 20-30 m



## Oil and gas industry typical solutions:

- 1. Gundalf source modelling
- 2. Estimation from NFH (Ziolkowski, A., 1982)

#### Available solutions for HR data:

- 1. Wavelet extraction and inverse filter application
- 2. Bubble prediction filter
- 3. Modification of KSF (J. Claerbout and A. Guitton (2015)) \*

\* Claerbout, J., Guitton, A., 2015, Ricker-Compliant Deconvolution: Geophysical Prospecting, Volume 63, Issue 3, pages 615-625

Vakulenko S.A., Poluboyarinov M.A. and Buryak S.V., 2016, Implementation and Application of Debbubling Algorithm, Based on Kolmogorov Spectral Factorization, Near Surface Geoscience 2016 - Second Applied Shallow Marine Geophysics Conference pp 1



#### Seismic section before debubbling



Survey parameters

Source – G-Boomer Streamer - HRStreamer, single channel Water Depth – 20-30 m



#### Seismic section after debubbling



Survey parameters

Source – G-Boomer Streamer - HRStreamer, single channel Water Depth – 20-30 m

Data acquired by Geodevice

<sup>1</sup> f (Hz)

7000



#### Seismic section before debubbling







#### Seismic section after debubbling





0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 f (Hz)



# **Designature outline**

- Modern HR marine seismic acquisitions use various sources for signal generation. Depending on the source type and its parameters, source signature may significantly vary.
- Resulting complicated wavelet, when convolved with the reflectivity series, significantly reduces resolution of the final image and needs to be eliminated.
- RadExPro provides various algorithms for designature of HR seismic data to achieve high resolution of the resulting image.



# **Multiple elimination**

Multiple reflections is well-known problem for marine seismic data

High frequencies, presented in the data result in large static differences between modelled multiple and multiple itself

Adaptive subtraction and adjusted static parameter provides good demultiple results

#### **Available solutions:**

Zero-offset demultiple (single channel, post-stack)

SRME (multichannel pre-stack, subtraction adapted for HR)

Tau-pi deconvolution

Radon demultiple

Custom algorithms (modelling and adaptive subtraction)



# **Pre-stack demultiple: SRME**

#### Stacked seismic section – **before** multiple elimination





# **Pre-stack demultiple: SRME**

#### Stacked seismic section – after multiple elimination





## Zero-offset demultiple

## Single channel boomer data – **before** multiple elimination





## Zero-offset demultiple

## Single channel boomer data – after multiple elimination





# Post-stack demultiple

Stacked data (16 channels) – before multiple elimination





# Post-stack demultiple

Stacked data (16 channels) – after multiple elimination





# **3D Regularization**

Sea and ocean currents as well as other obstacles (GPS positioning) often result in gaps in CDP coverage

Non-equal offset distribution results in footprints on time slices

#### **Available solutions:**

3D Regularization



# **3D Regularization**

Time slices **before** regularization



3D survey, flip-flop airguns + slanted streamers



Common parameters... Zoom Tools

# **3D Regularization**

Time slices after regularization



3D survey, flip-flop airguns + slanted streamers



# **Footprints attenuation**

Time slices (100 ms) – before FPA



#### Large scale seismic for shallow imaging purposes

16000



**Footprints attenuation** 

Time slices (100 ms) – after FPA



Large scale seismic for shallow imaging purposes



# User-friendly interface, replica tables and queues

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## **3D visualization**





# Some other examples



## Stacked seismic section after denoising





## Stacked seismic section – after SRME+deghosting+PSTKM





# Geohazard assessment – shallow gas zones





#### Geohazard assessment – paleo channels in the Kara Sea





Ladoga Lake – sea trials



Data acquired by Geodevice with FWS-125 Sparker and 4-channel streamer, processed in RadExPro Seismic software



#### Ladoga Lake – boulders detection



Data acquired by Geodevice with FWS-125 Sparker, processed in RadExPro Seismic software





#### Post-glacier boulders detection with less than 0.5 m size

Lots of diffraction hyperbolas can be seen on non-migrated image. Some of them are marked by arrows. Diffractions are caused by post-glacier boulders.



## Some of our clients:

