

# Multicomponent deblending of marine data using a pattern-based approach

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and Shuki Ronen

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# Outline

1. Multicomponent blended data
2. Pattern-based deblending
3. Multicomponent pattern-based deblending
4. Results

# Outline

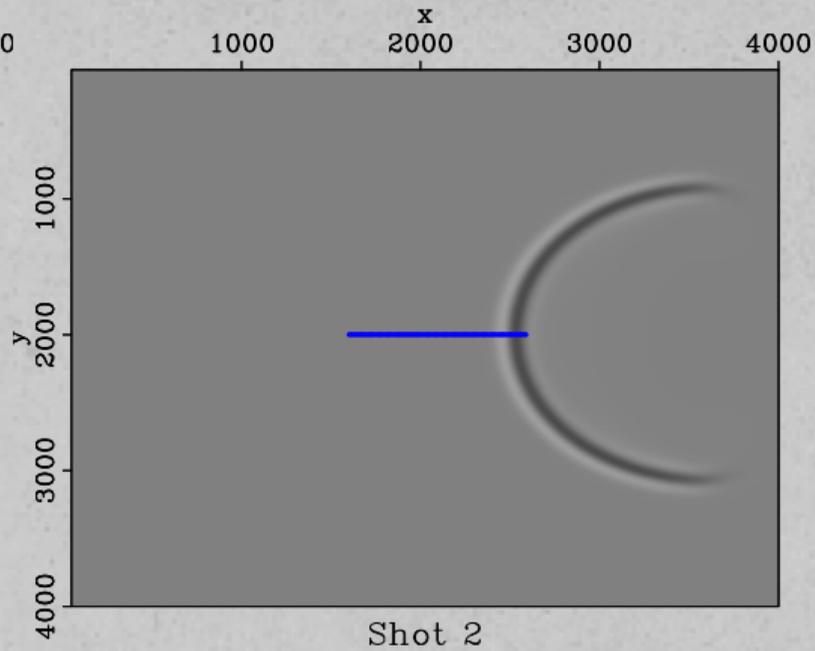
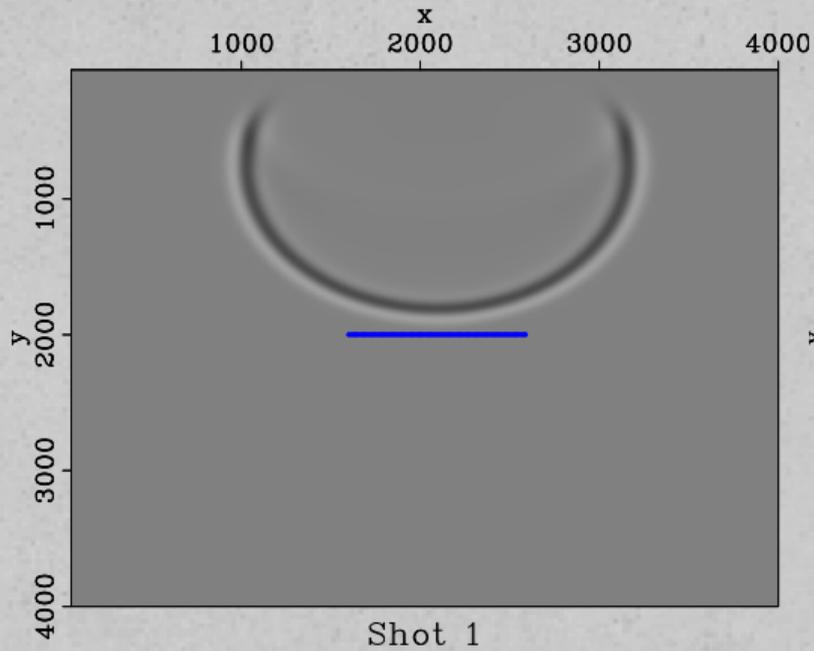
**1.** Multicomponent blended data

2.

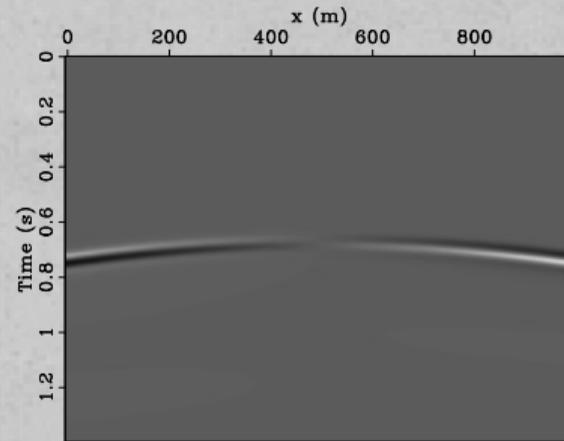
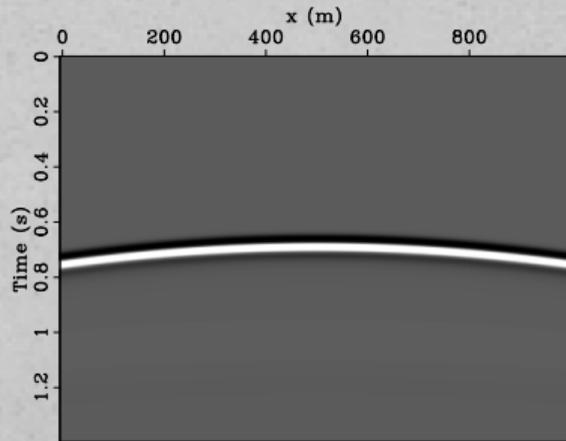
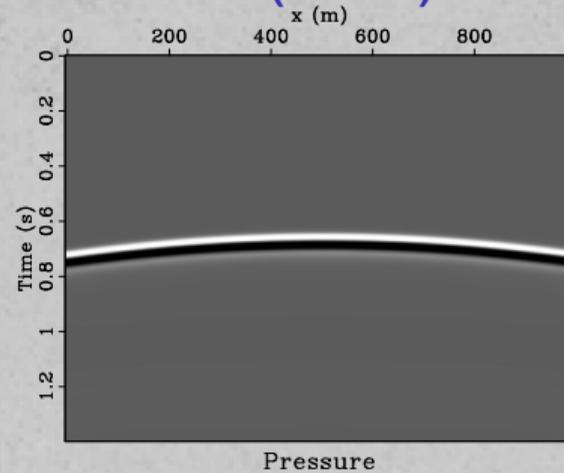
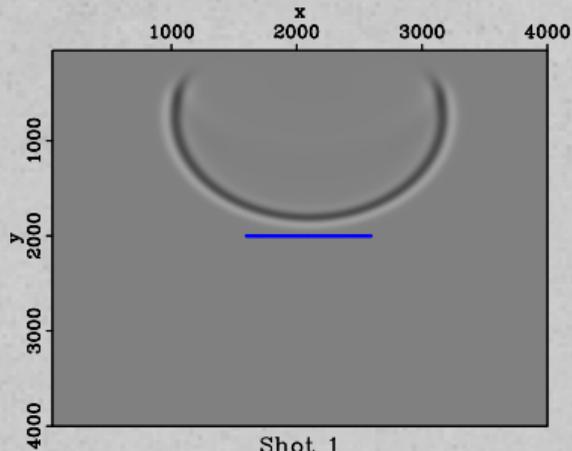
3.

4.

# Two shots - different azimuths



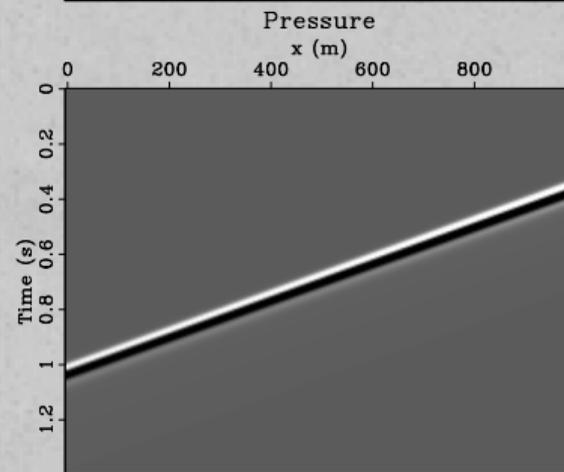
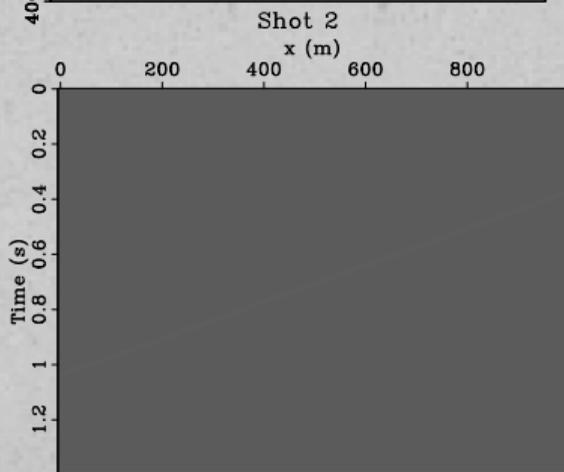
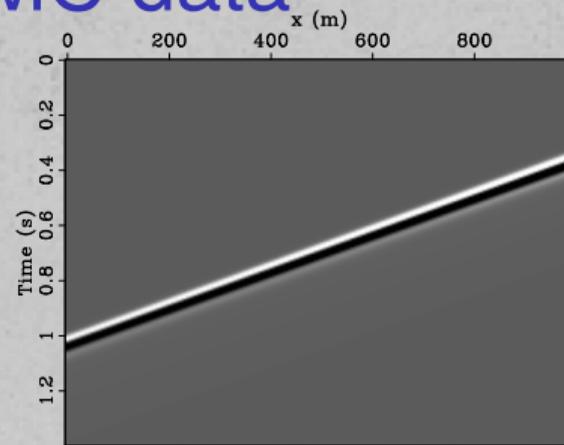
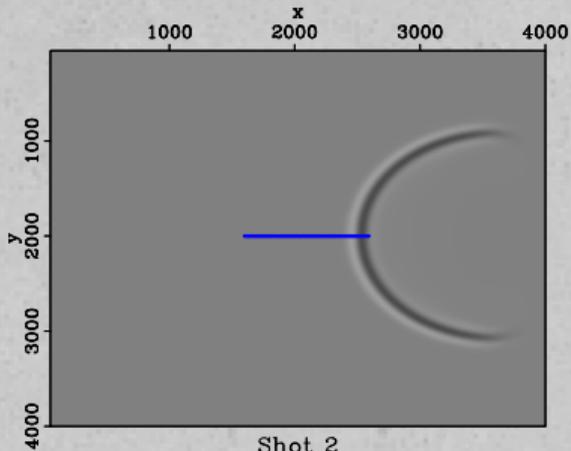
# Shot one - multicomponent (MC) data



Y component

X component

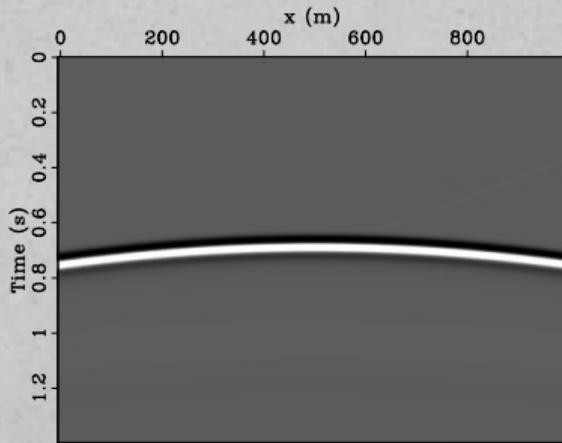
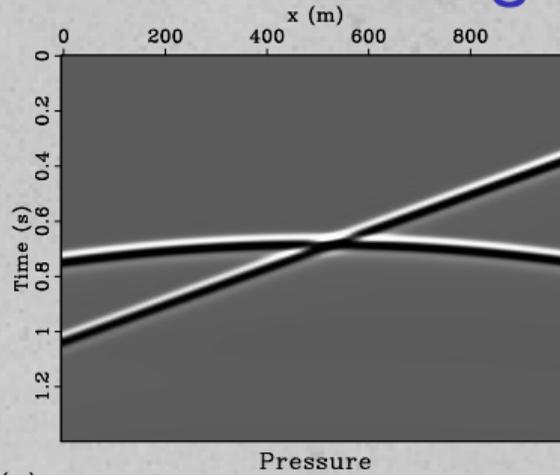
# Shot two - MC data



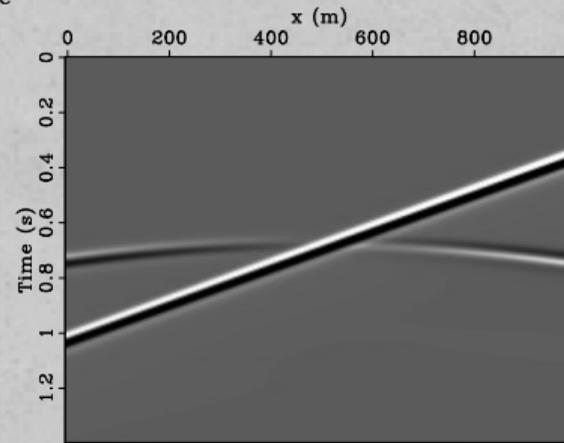
Y component

X component

# Blended MC shot gathers



Y component



X component

**Can we use the geophone data to improve the  
deblending on the hydrophone?**

# Outline

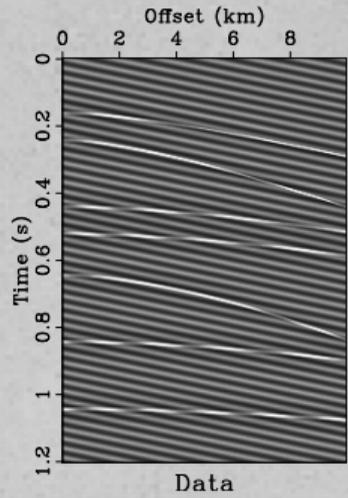
1.

**2. Pattern-based deblending**

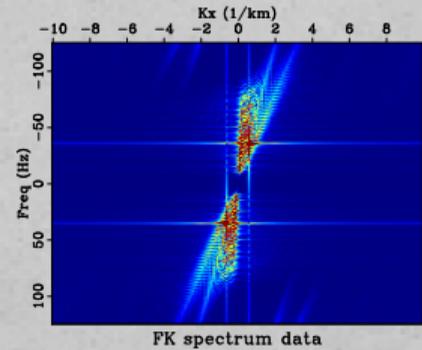
3.

4.

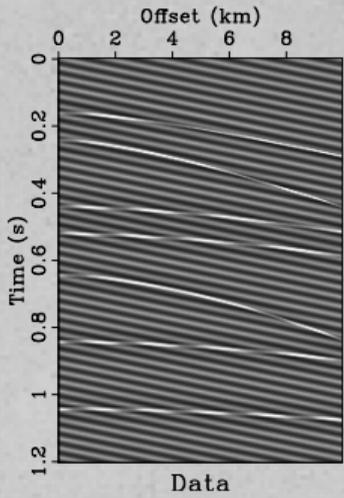
# Additive signal and noise ( $d = s + n$ )



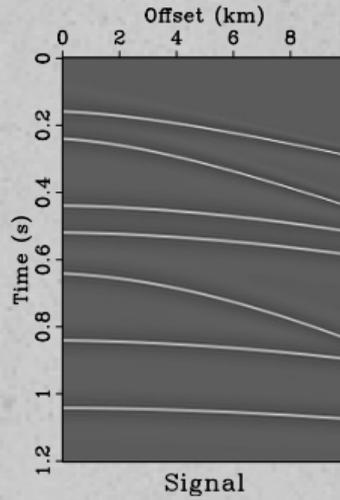
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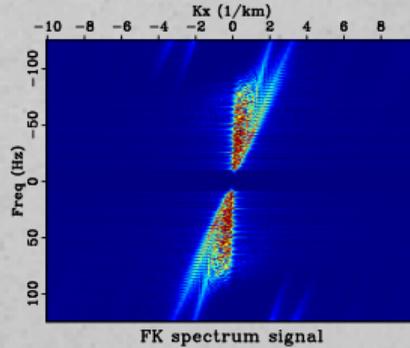
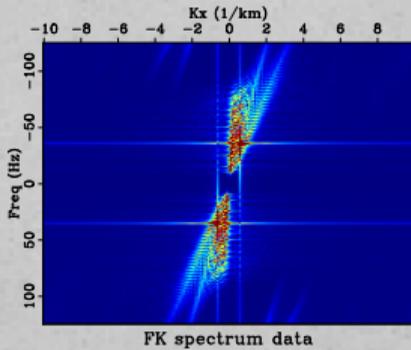
# Additive signal and noise ( $d = s + n$ )



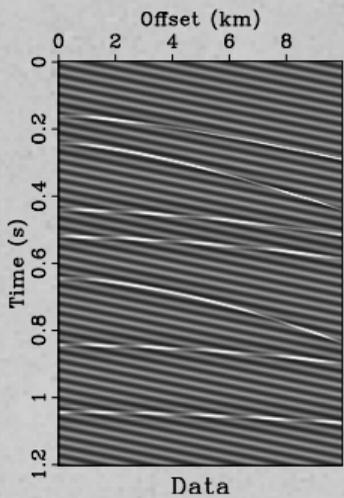
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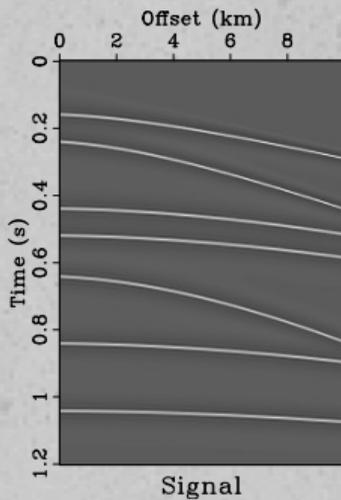
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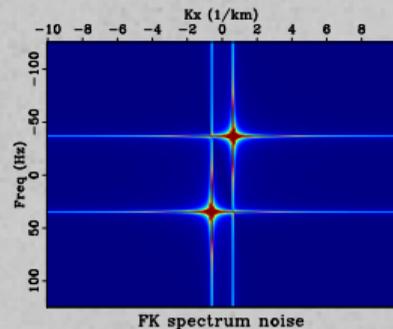
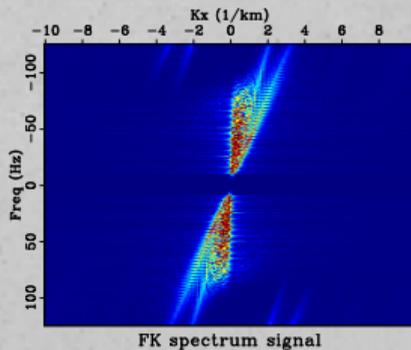
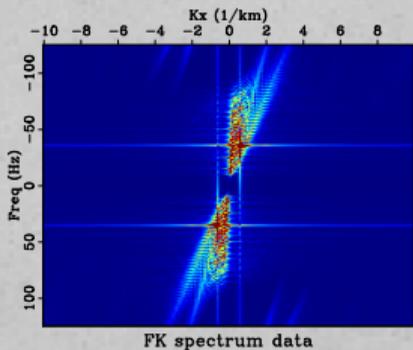
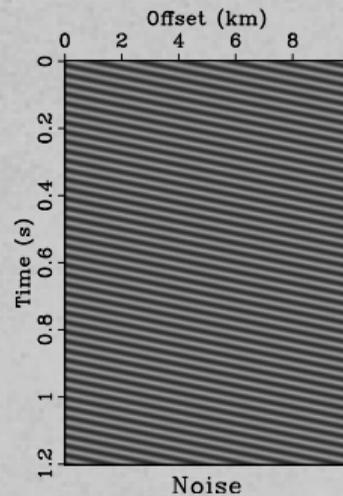
# Additive signal and noise ( $d = s + n$ )



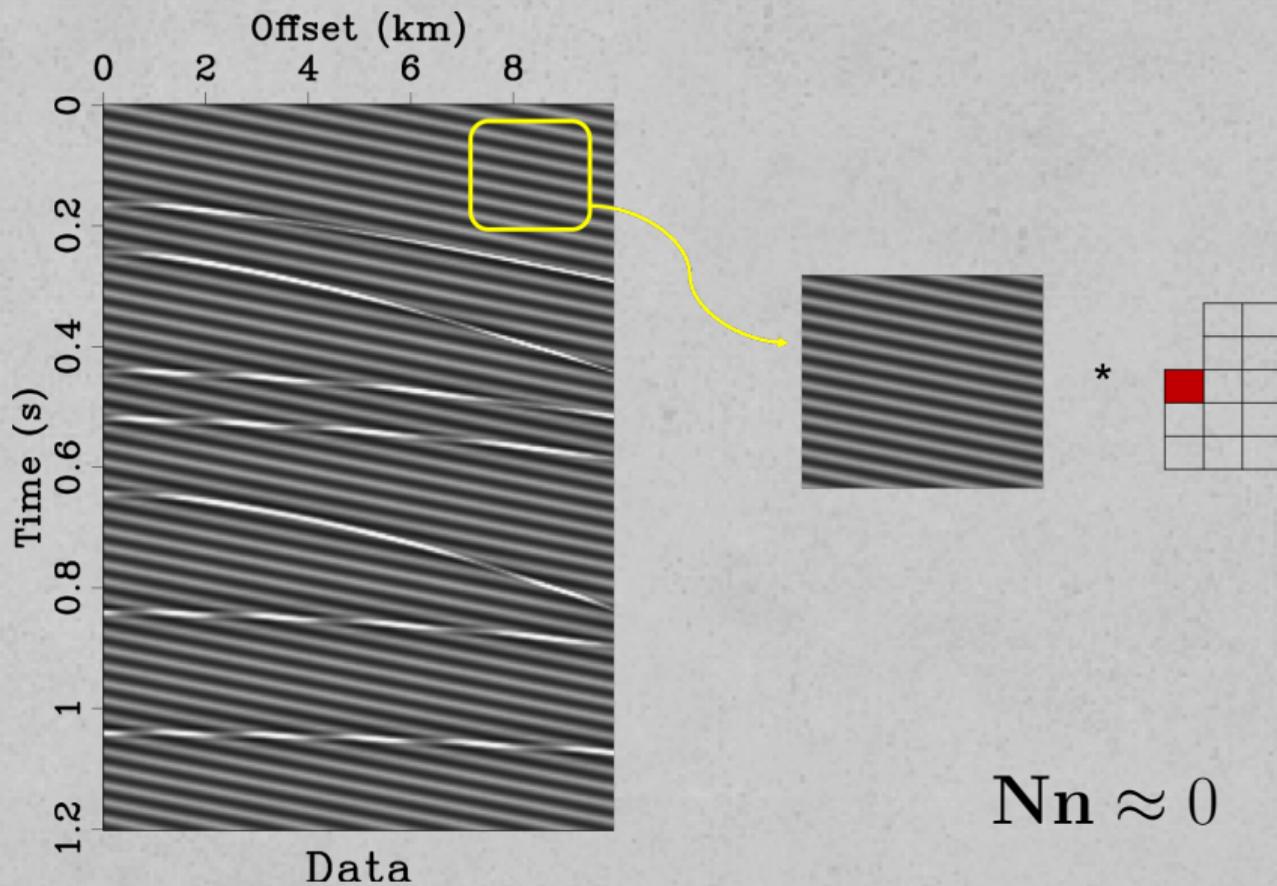
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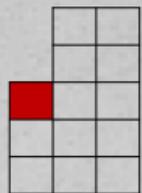
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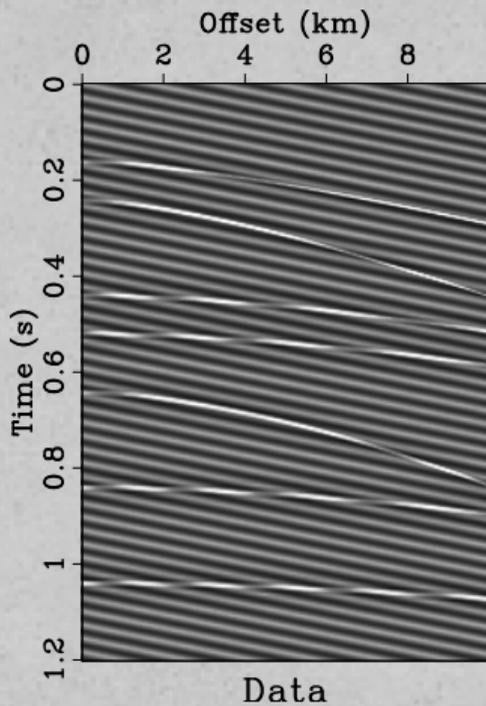
# Estimate prediction-error filter (PEF)



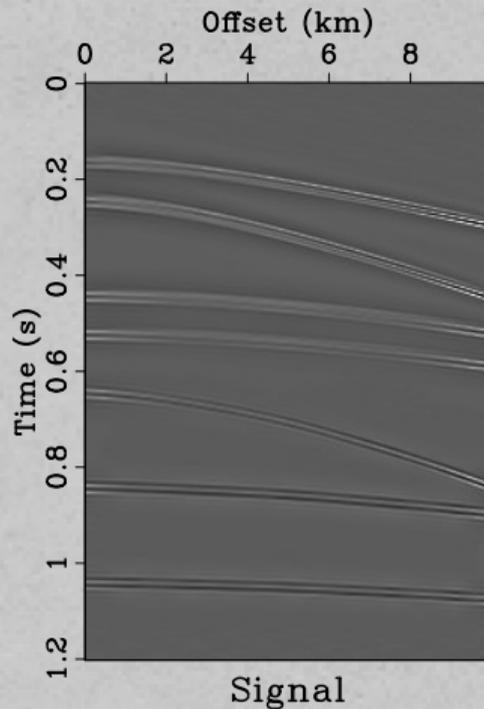
# Apply noise PEF to data



\*

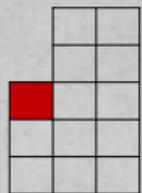


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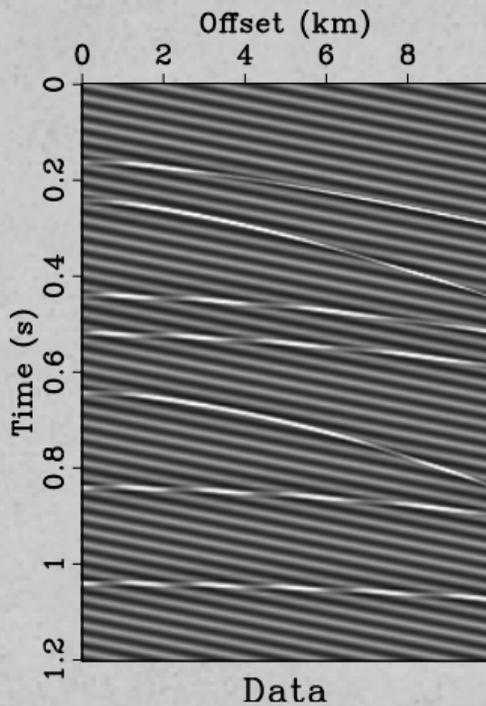


$$\mathbf{N}d = \mathbf{N}(s + \mathbf{n}) \approx s,$$

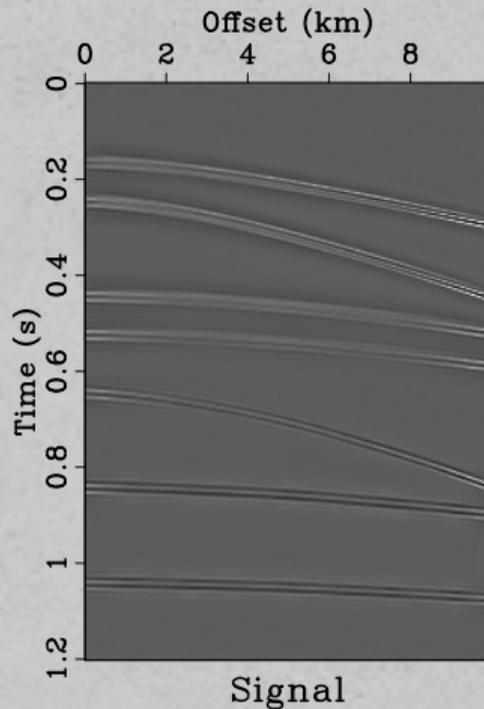
# Apply noise PEF to data



\*



=



$$\mathbf{N}d = \mathbf{N}(s + \mathbf{n}) \approx s,$$

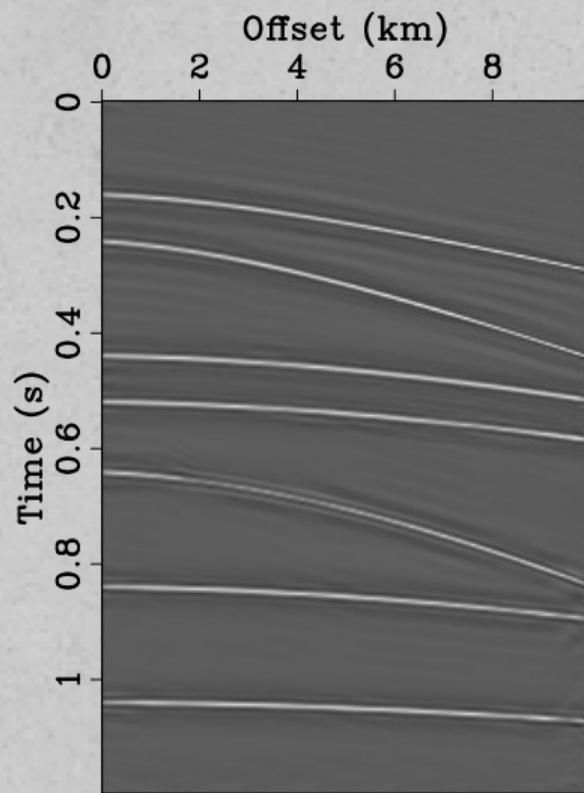
$$\mathbf{S}s \approx 0$$

# Signal and noise separation inversion

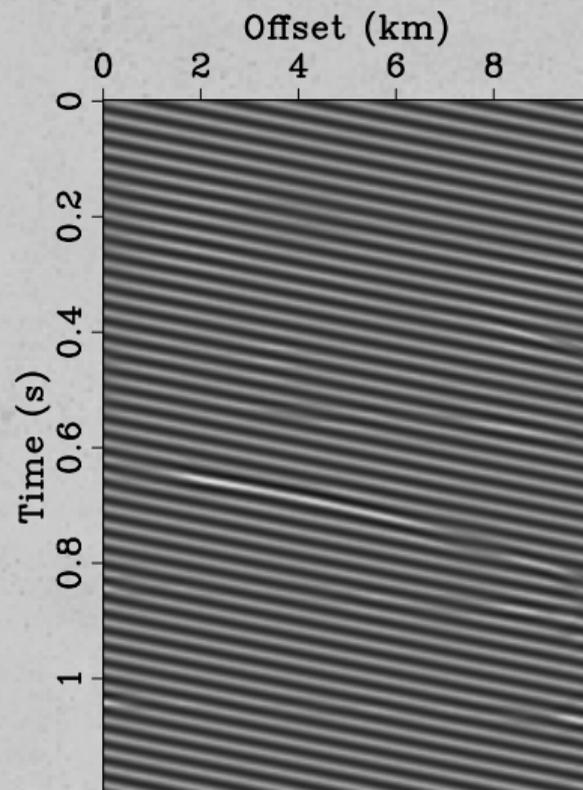
$$\mathbf{s}^*, \mathbf{n}^* = \underset{\mathbf{s}, \mathbf{n}}{\operatorname{argmin}} \frac{1}{2} \|\mathbf{s} + \mathbf{n} - \mathbf{d}\|_2^2 + \frac{\epsilon^2}{2} \|\mathbf{S}\mathbf{s}\|_2^2 + \frac{\epsilon^2}{2} \|\mathbf{N}\mathbf{n}\|_2^2$$

- $\mathbf{d}$ : data
- $\mathbf{s}^*$ : estimated signal
- $\mathbf{n}^*$ : estimated noise
- $\mathbf{S}$ : PEF estimated on signal pattern (proxy)
- $\mathbf{N}$ : PEF estimated on noise pattern (proxy)

# Estimated signal and noise



Estimated signal



Estimated noise

# MC data and the pattern-based method

- Multicomponent data provide directional patterns
- **How can we use PEFs to capture these patterns?**

# Outline

1.

2.

**3. Multicomponent pattern-based deblending**

4.

# Relationship between pressure and velocity

- Euler's linearized conservation of momentum (acoustic medium):

$$\rho \frac{\partial \mathbf{v}(\mathbf{x}, t)}{\partial t} = -\nabla p(\mathbf{x}, t)$$

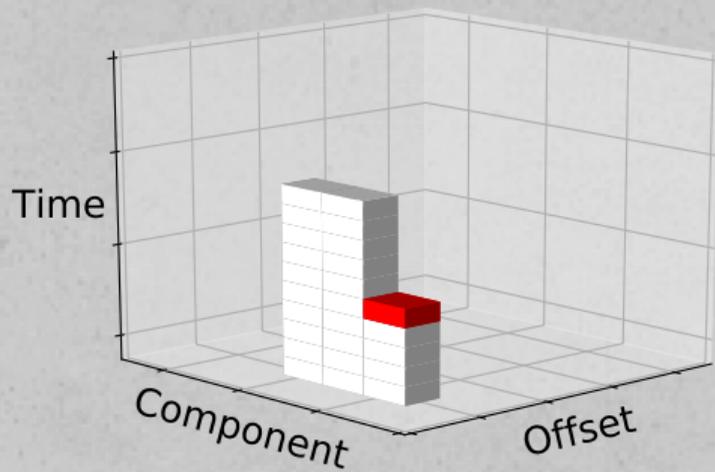
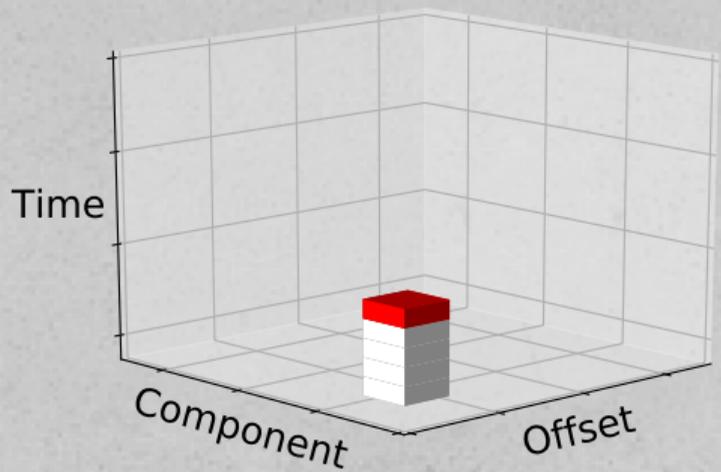
- ▶  $\mathbf{v}(\mathbf{x}, t)$ : acoustic particle velocity
- ▶  $p(\mathbf{x}, t)$ : pressure
- ▶  $\rho$ : density

# Relationship between pressure and velocity

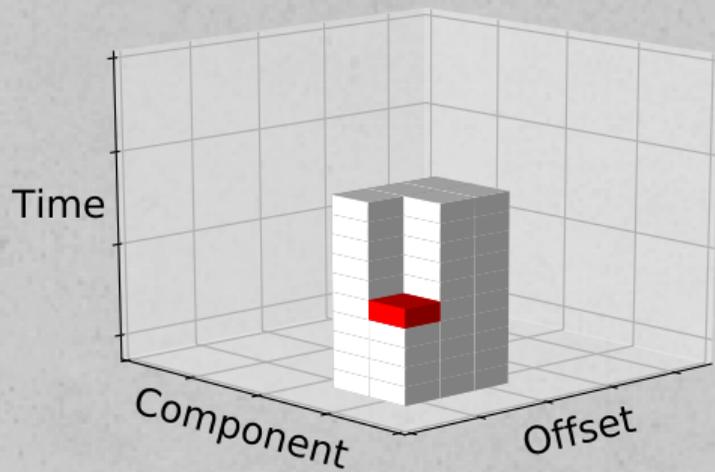
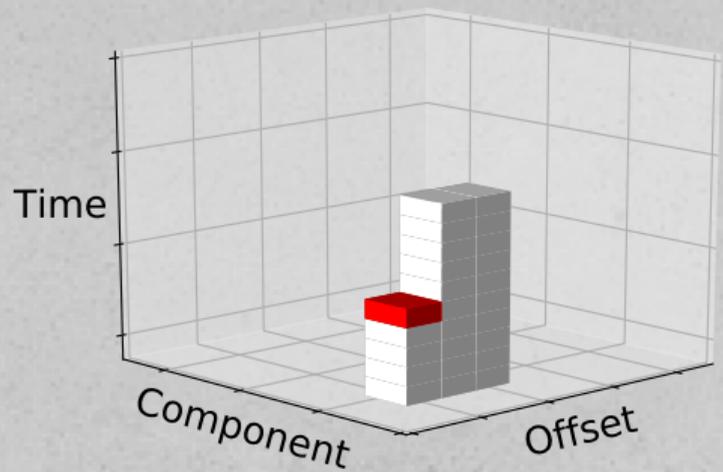
$$\Rightarrow \mathbf{v}(\mathbf{x}, t) = -\frac{1}{\rho} \int_0^T \nabla p(\mathbf{x}, t) dt$$

- They are linearly related
- We can use a PEF to find this relationship

# PEF stencils in 1D



# PEF stencils in 2D



# Different units between $p$ and $\mathbf{v}$

- Pressure data: [Pa]
- Particle velocity: [m/s]
- PEFs are dimensionless  $\Rightarrow$  scale by acoustic impedance
- PZ summation:  $p + \rho c \mathbf{v}$

# Outline

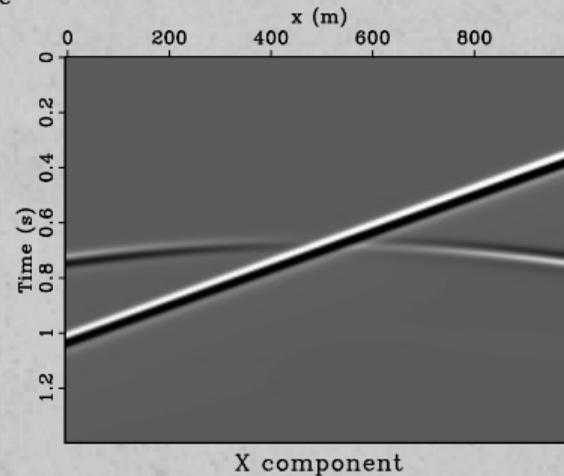
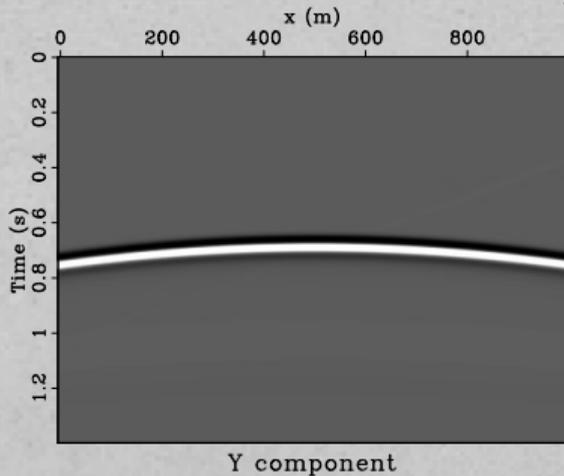
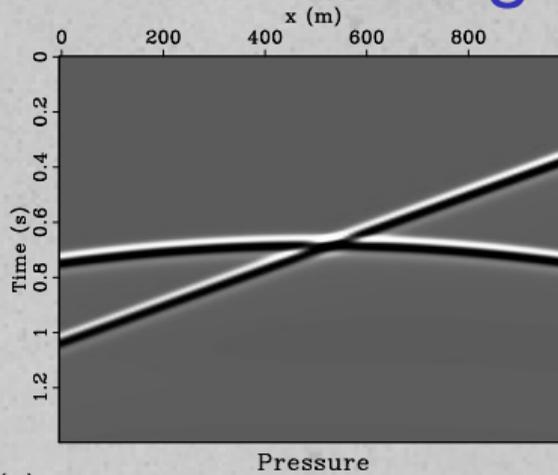
1.

2.

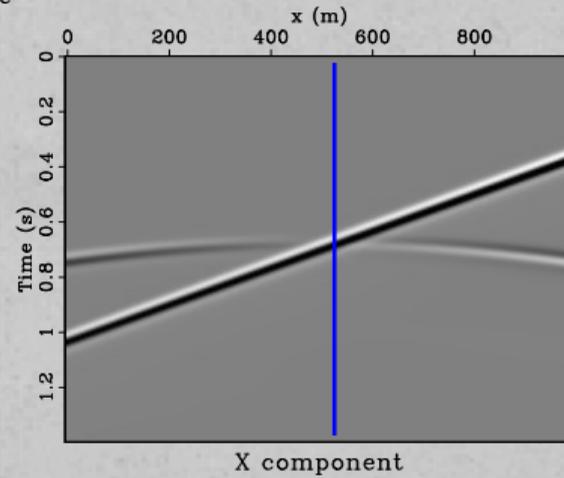
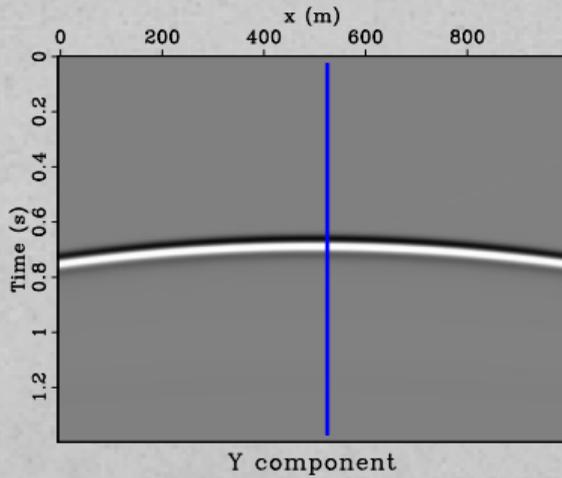
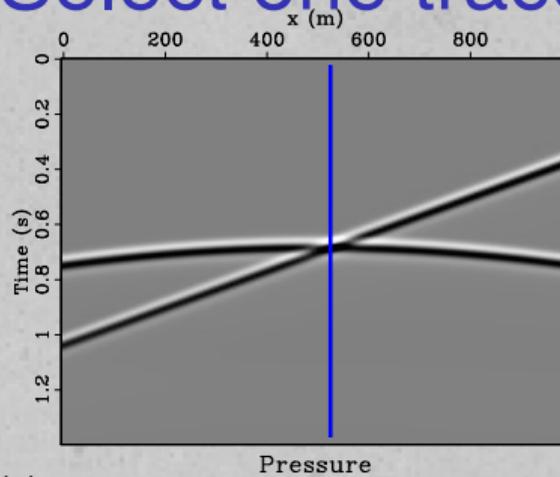
3.

**4. Results**

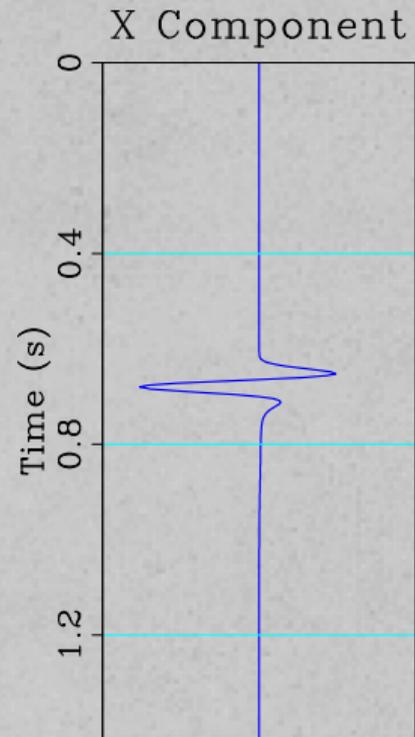
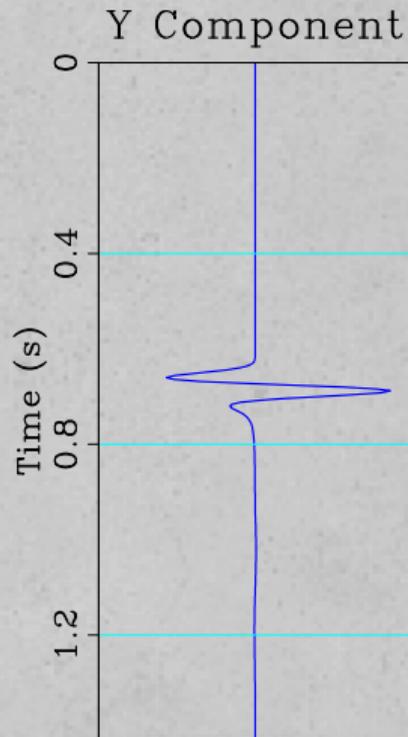
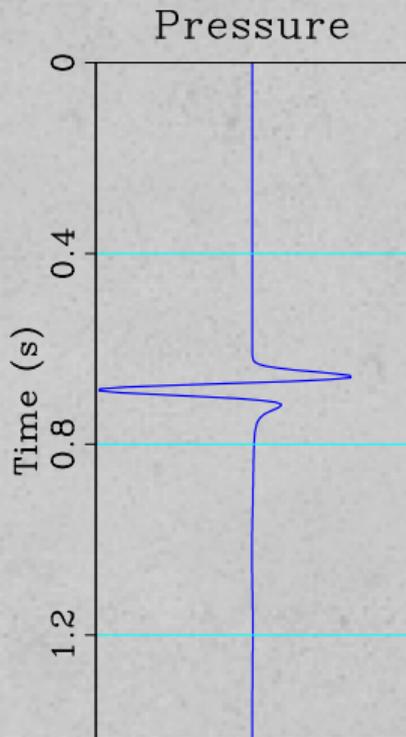
# Blended MC shot gathers



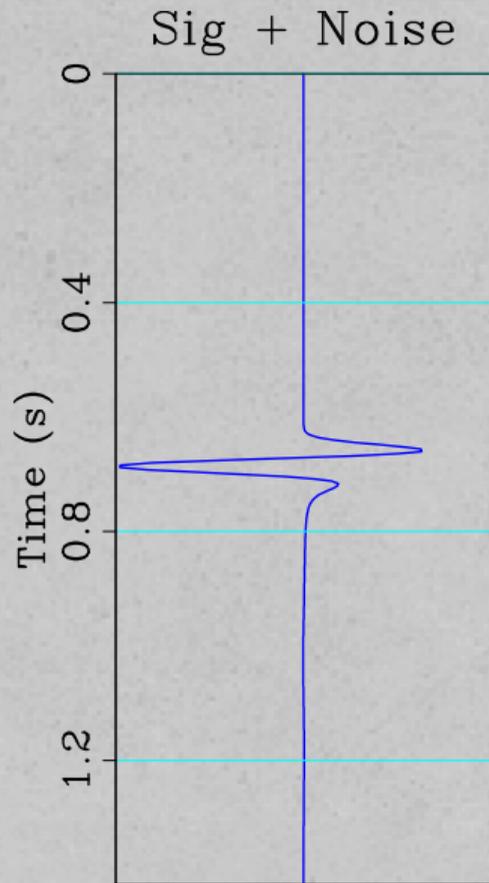
# Select one trace



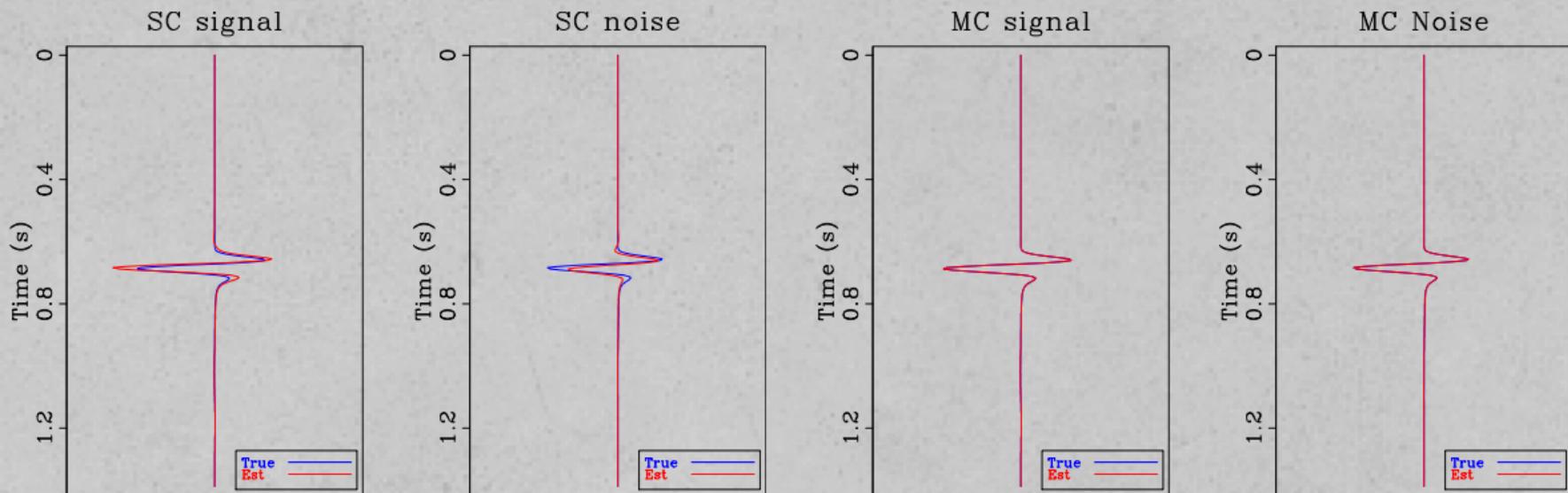
# Single trace of blended MC data



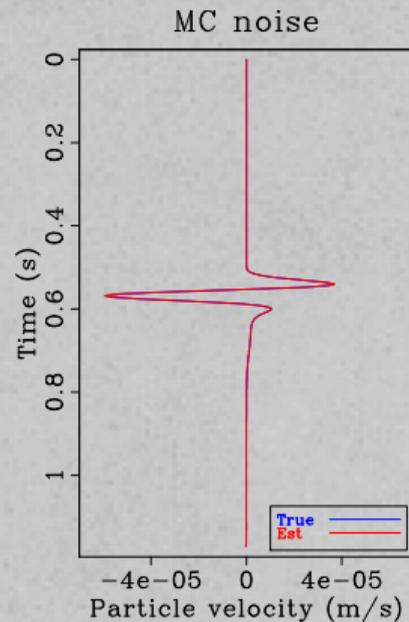
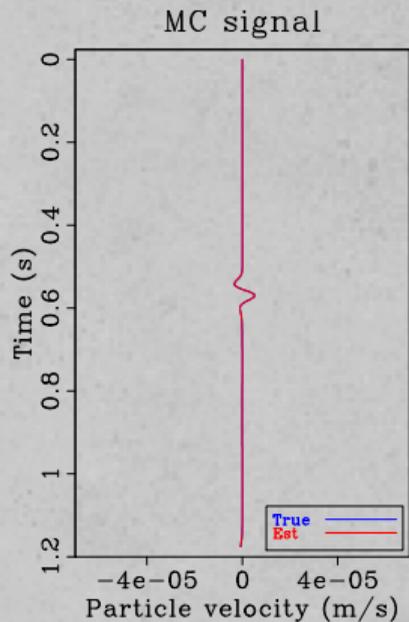
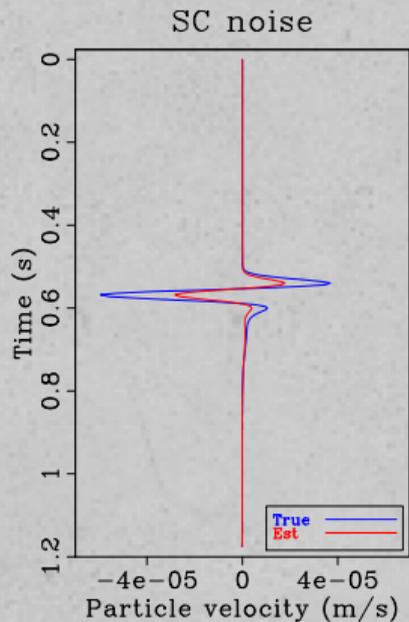
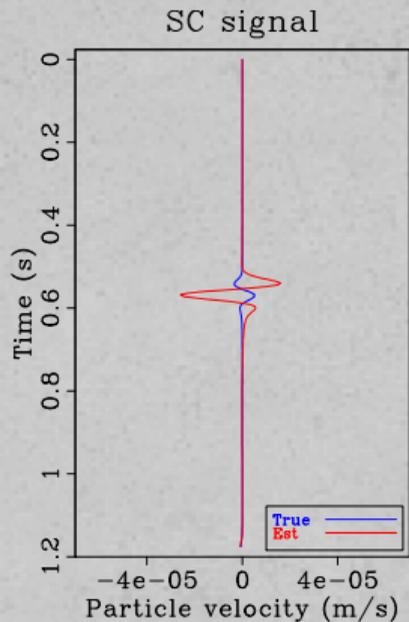
# Complete overlap



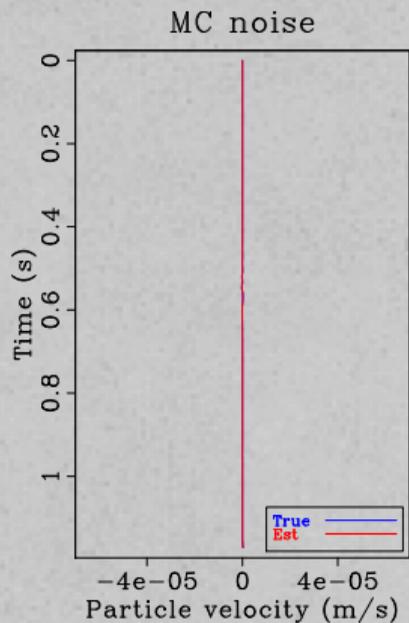
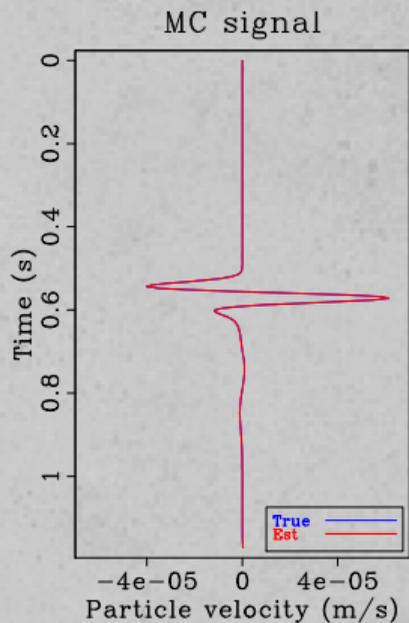
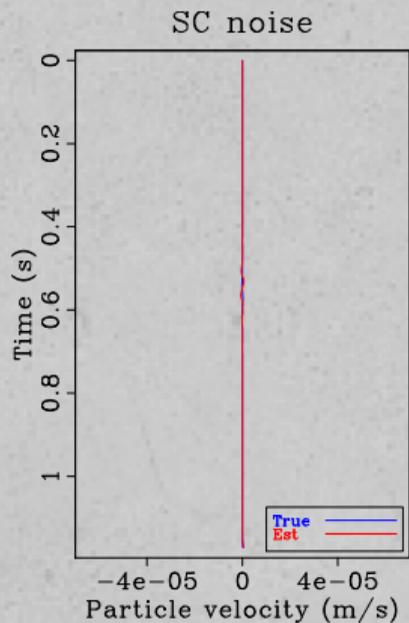
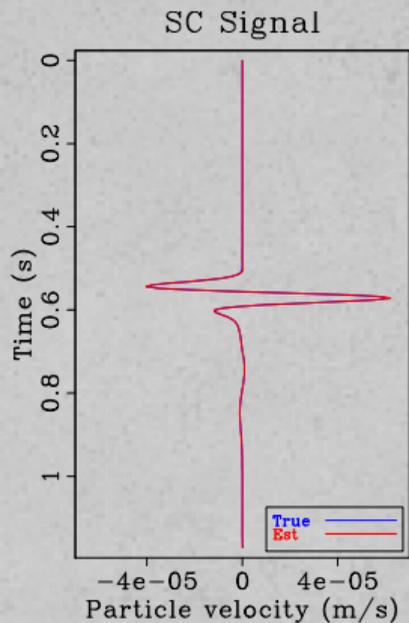
# Hydrophone - recovered signal and noise



# X component - recovered signal and noise

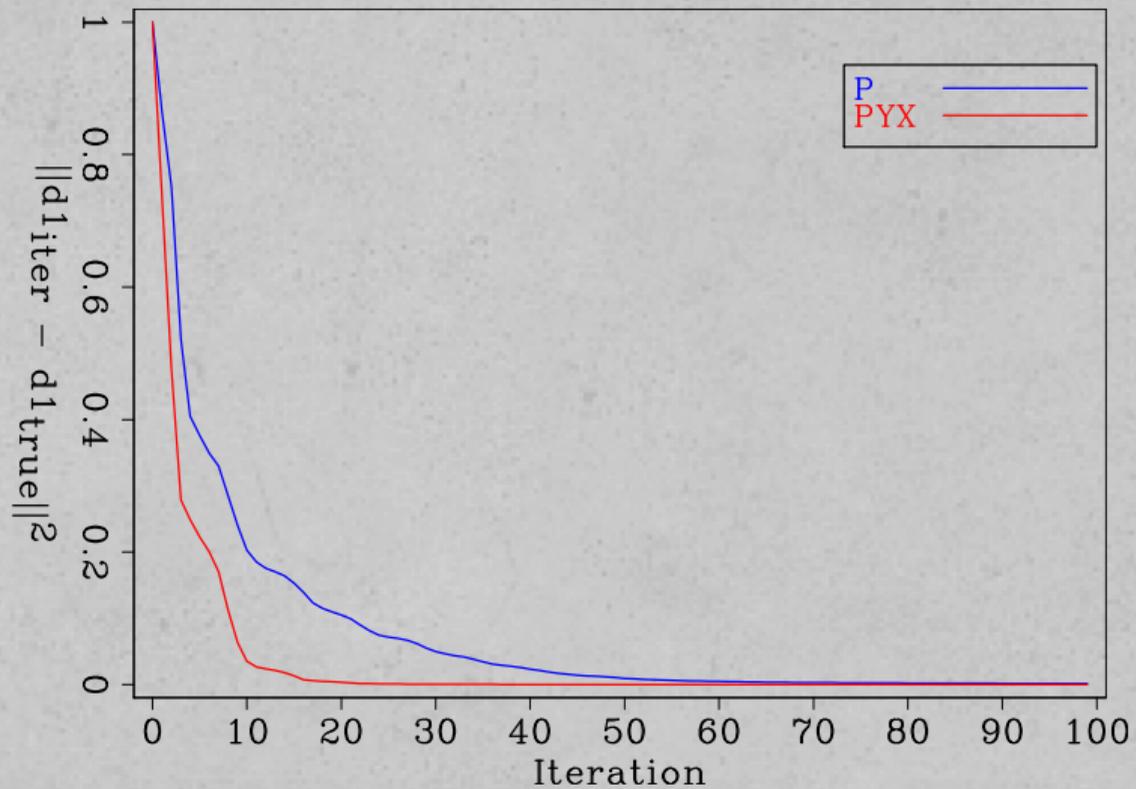


# Y component - recovered signal and noise



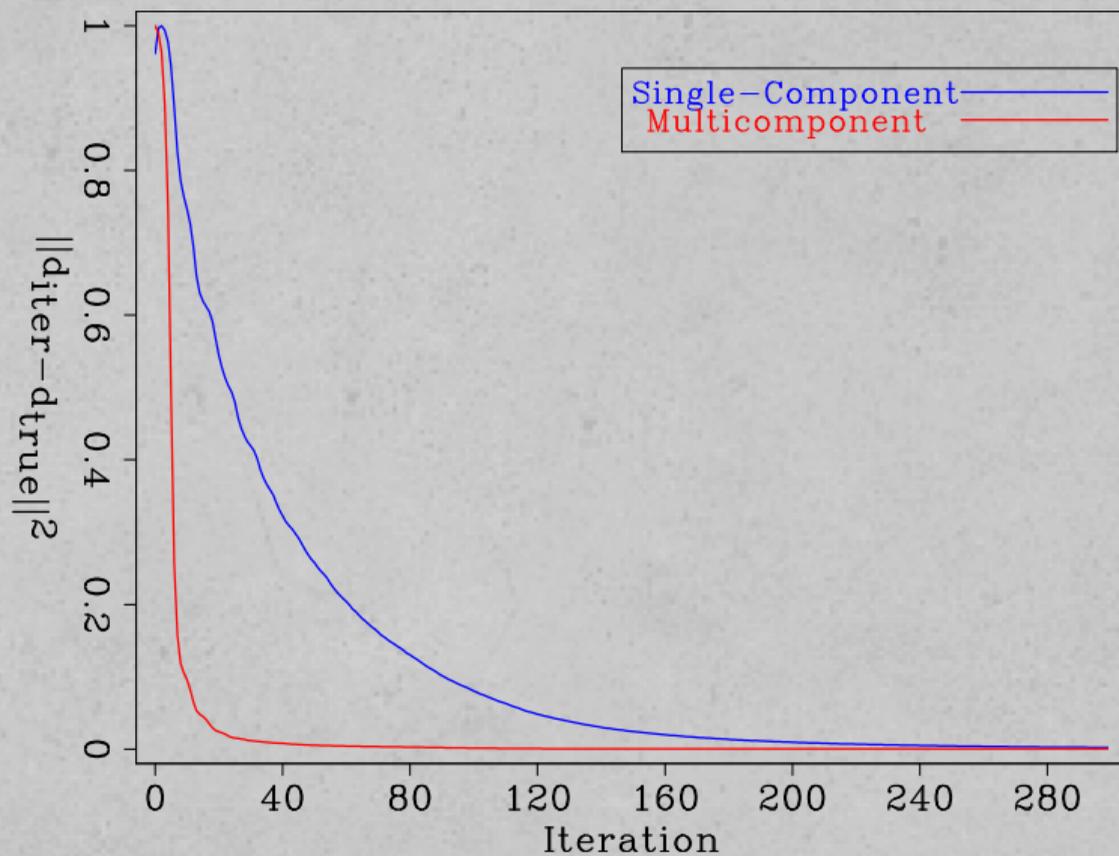
# Hydrophone deblending comparison

# Hydrophone model residual

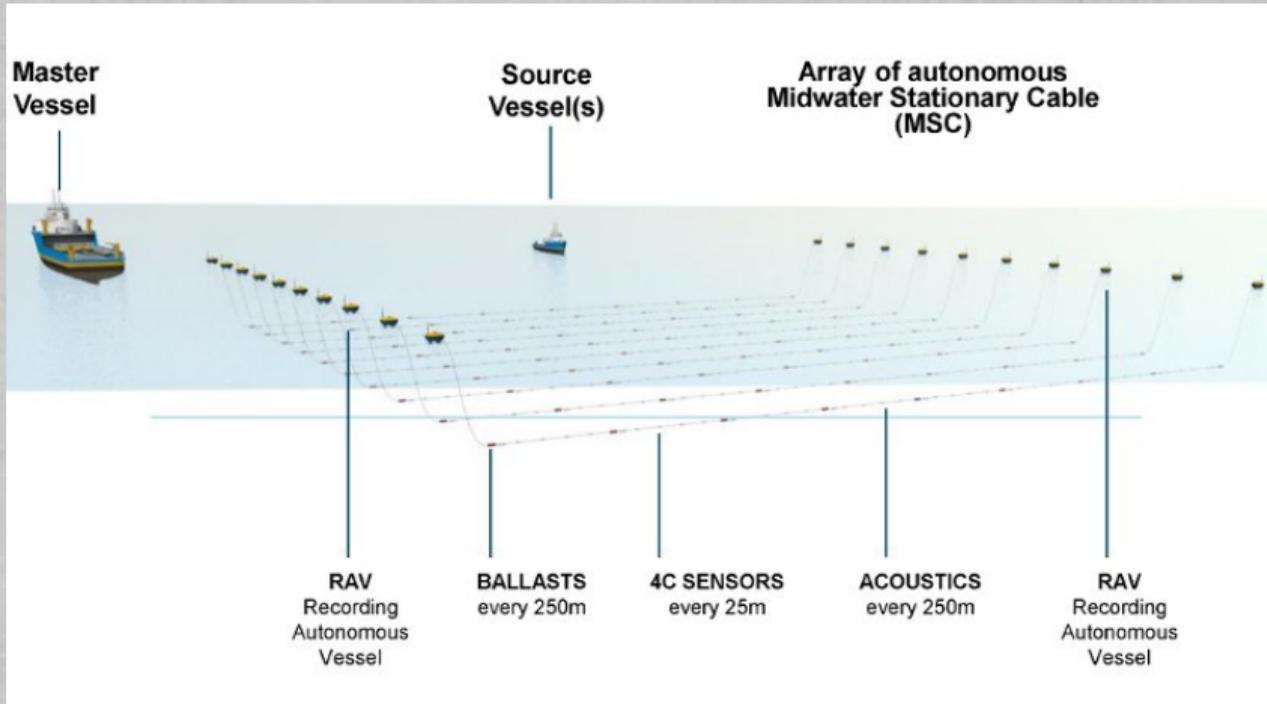


# X component deblending comparison

# X component model residual



# Free cable™ data



**source:** <https://geoexpro.com/articles/2017/03/the-future-of-marine-seismic-acquisition>

# Areal view



**source:** Kietta, 2016

# Side view

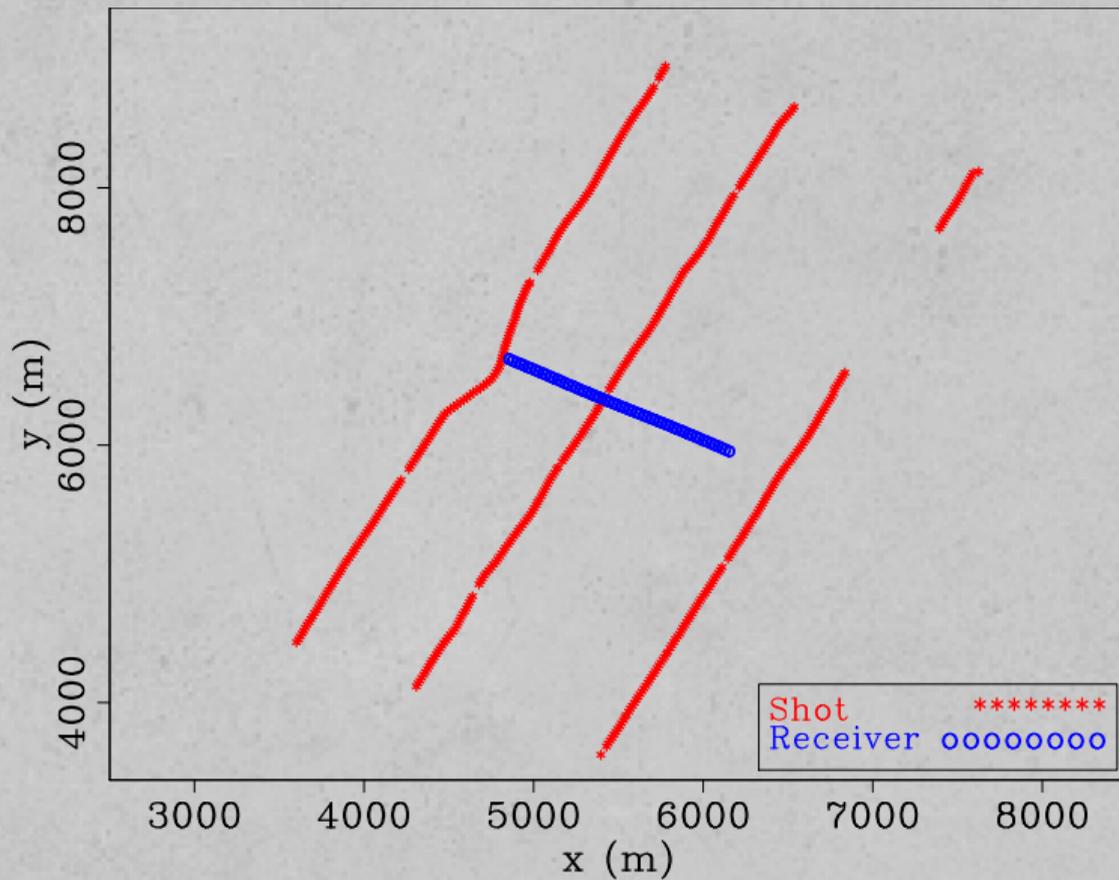


**source:** <https://geoexpo.com/articles/2017/03/the-future-of-marine-seismic-acquisition>

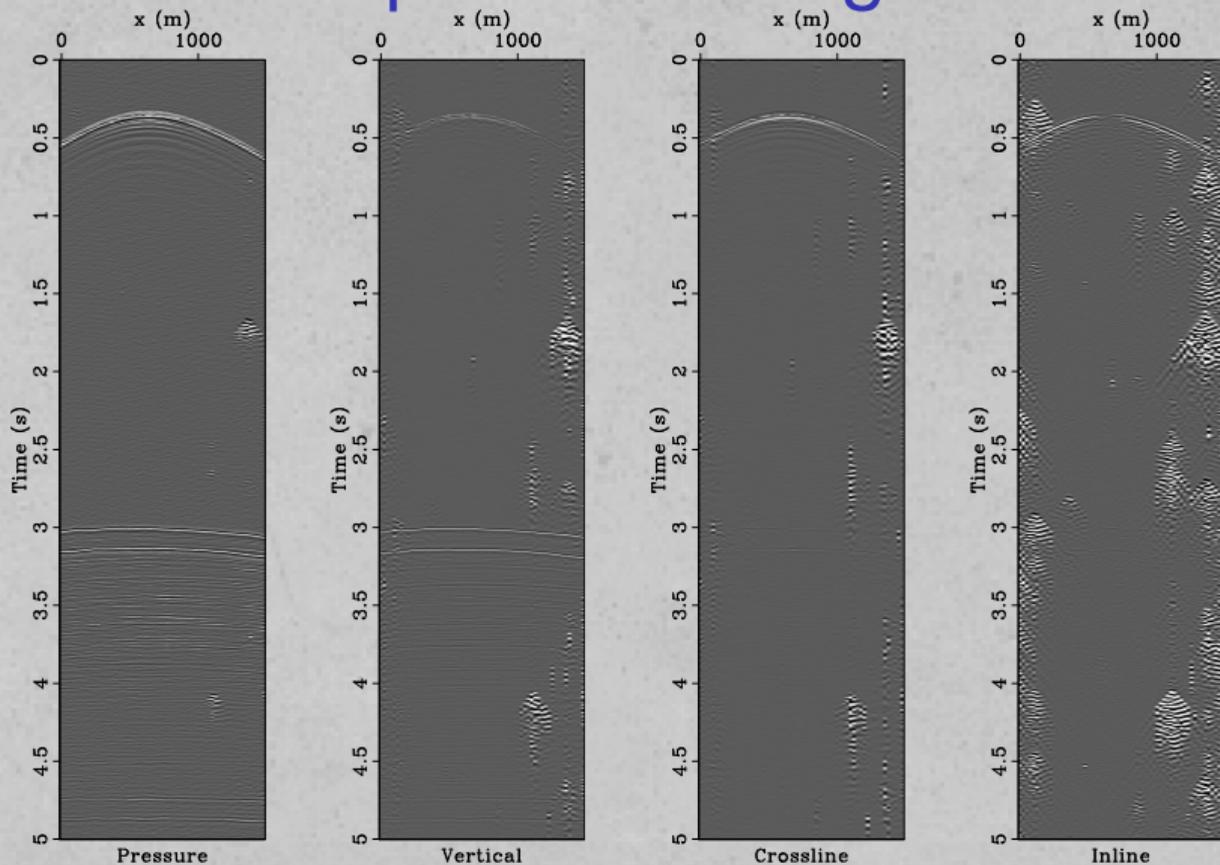
# Kietta survey



# Acquisition geometry

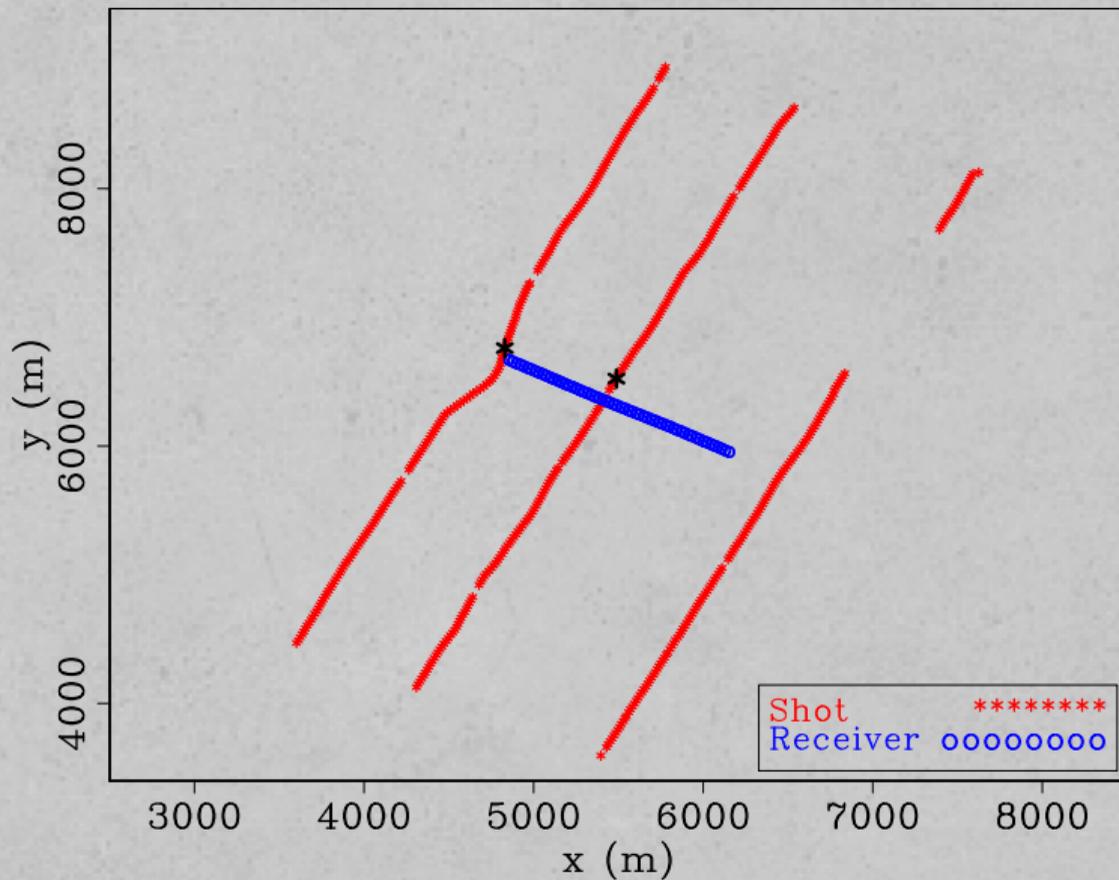


# Multicomponent shot gathers

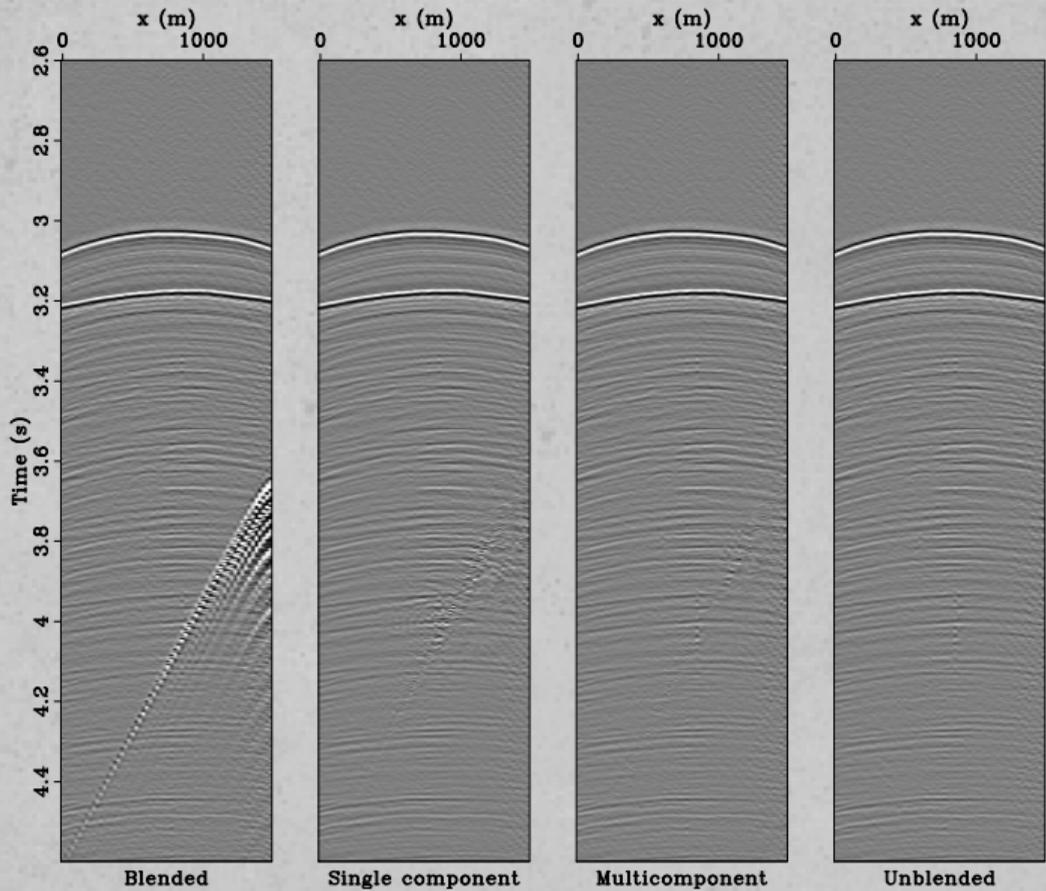


Please note: data from early system. Noise problem has been fixed.

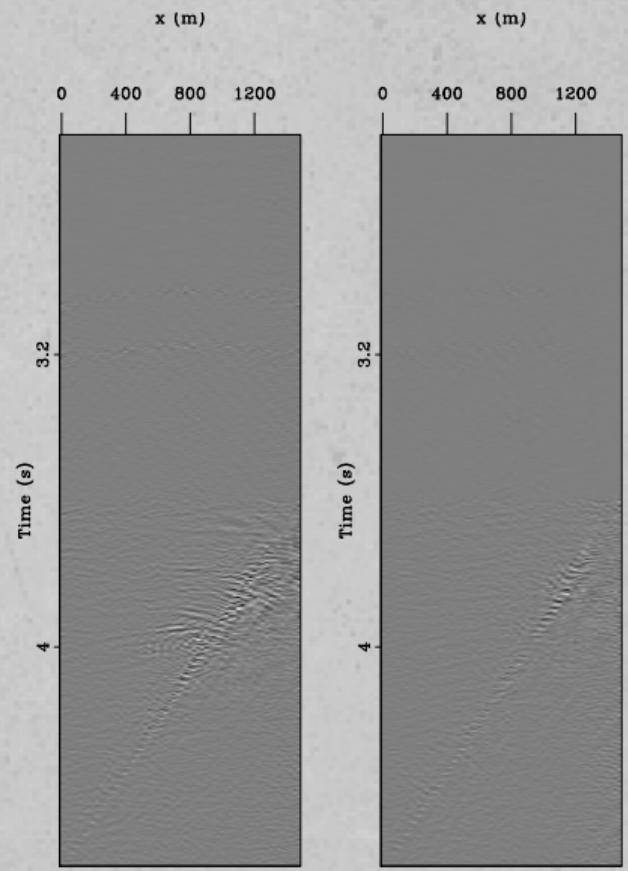
# Inline crossline shots



# Deblended hydrophone



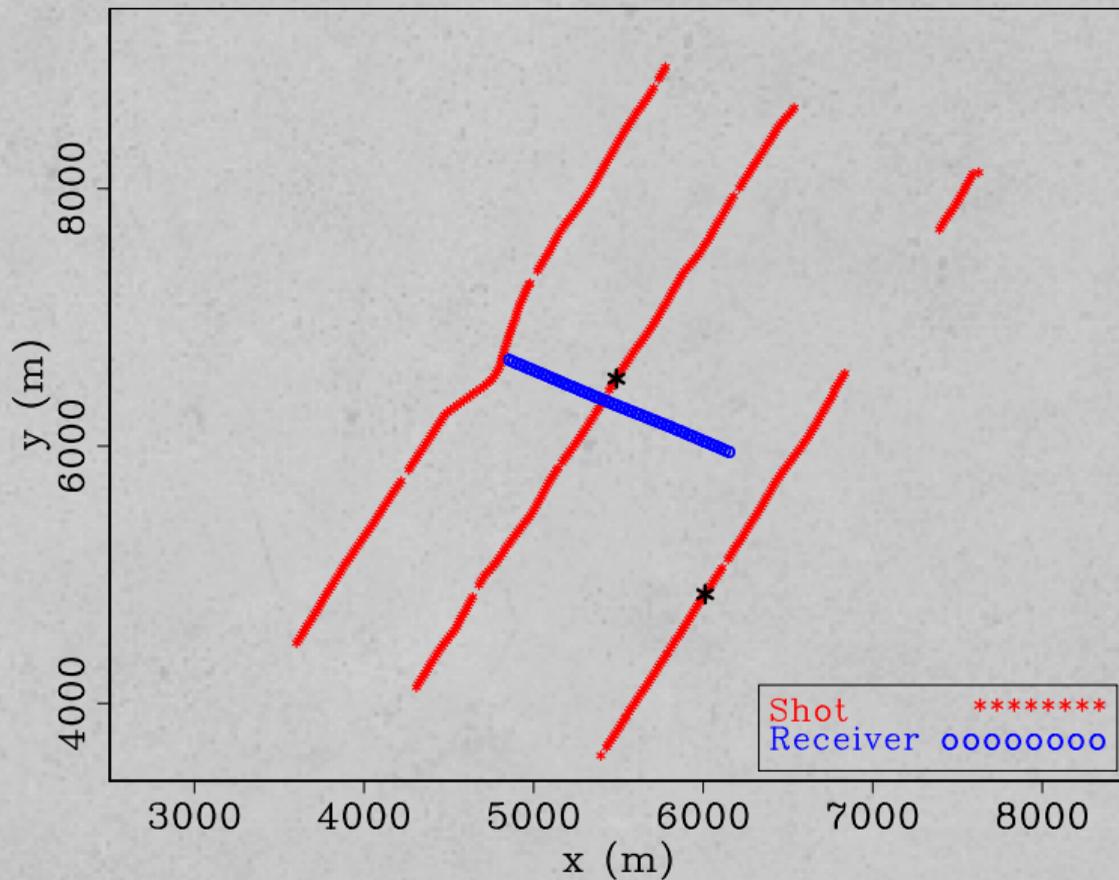
# Deblended residual



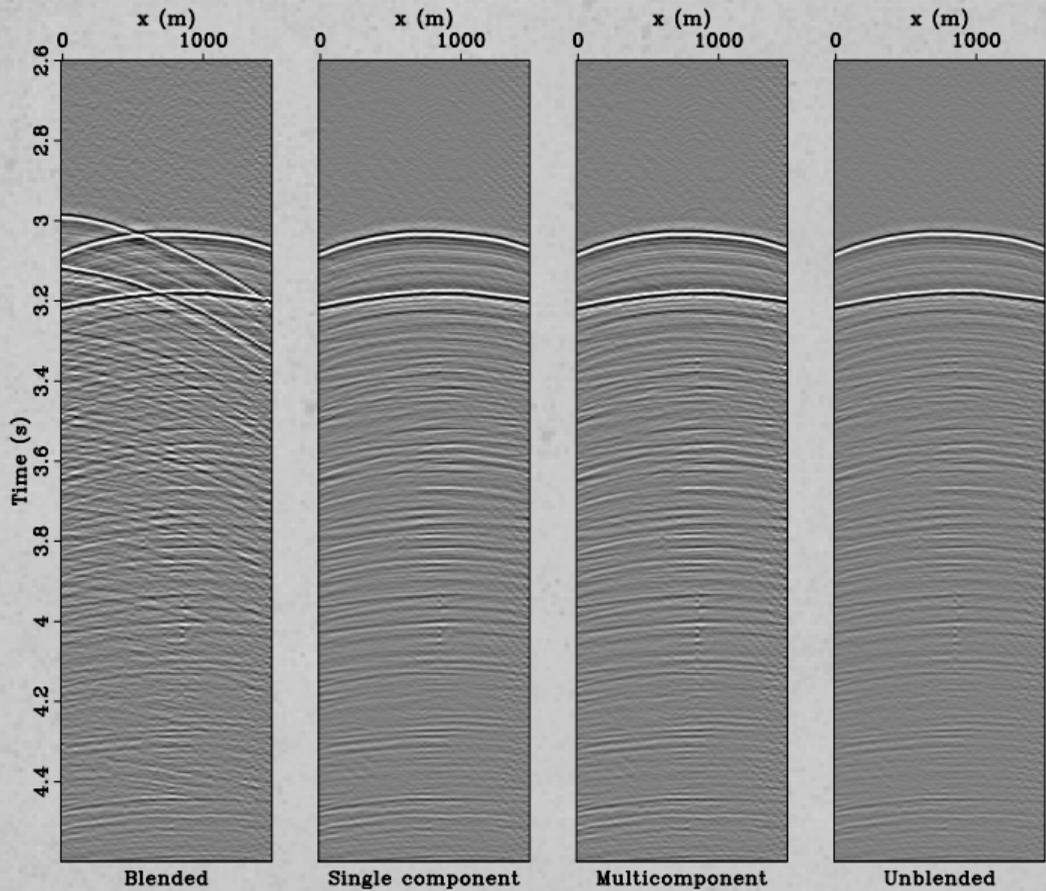
Single component

Multicomponent

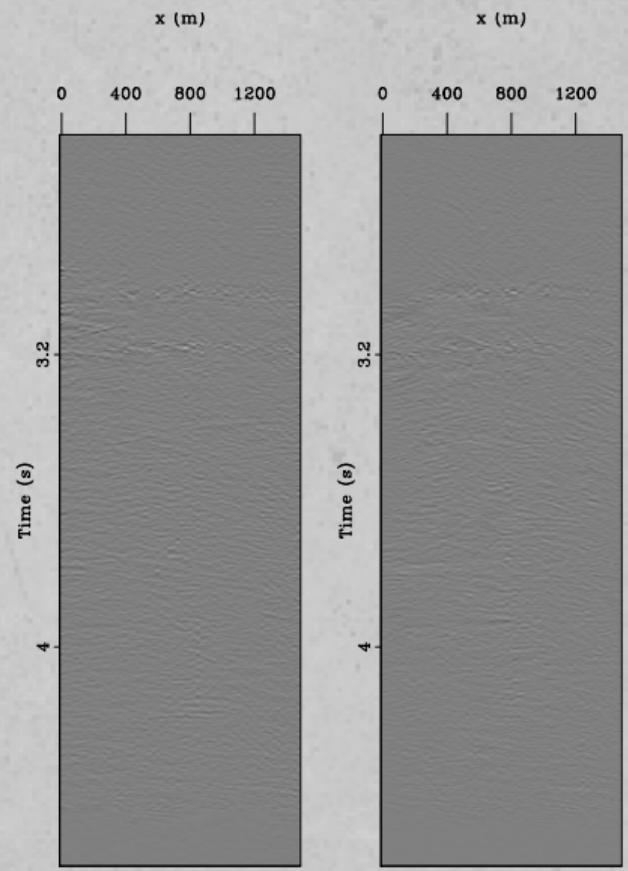
# Inline crossline shots



# Deblended hydrophone



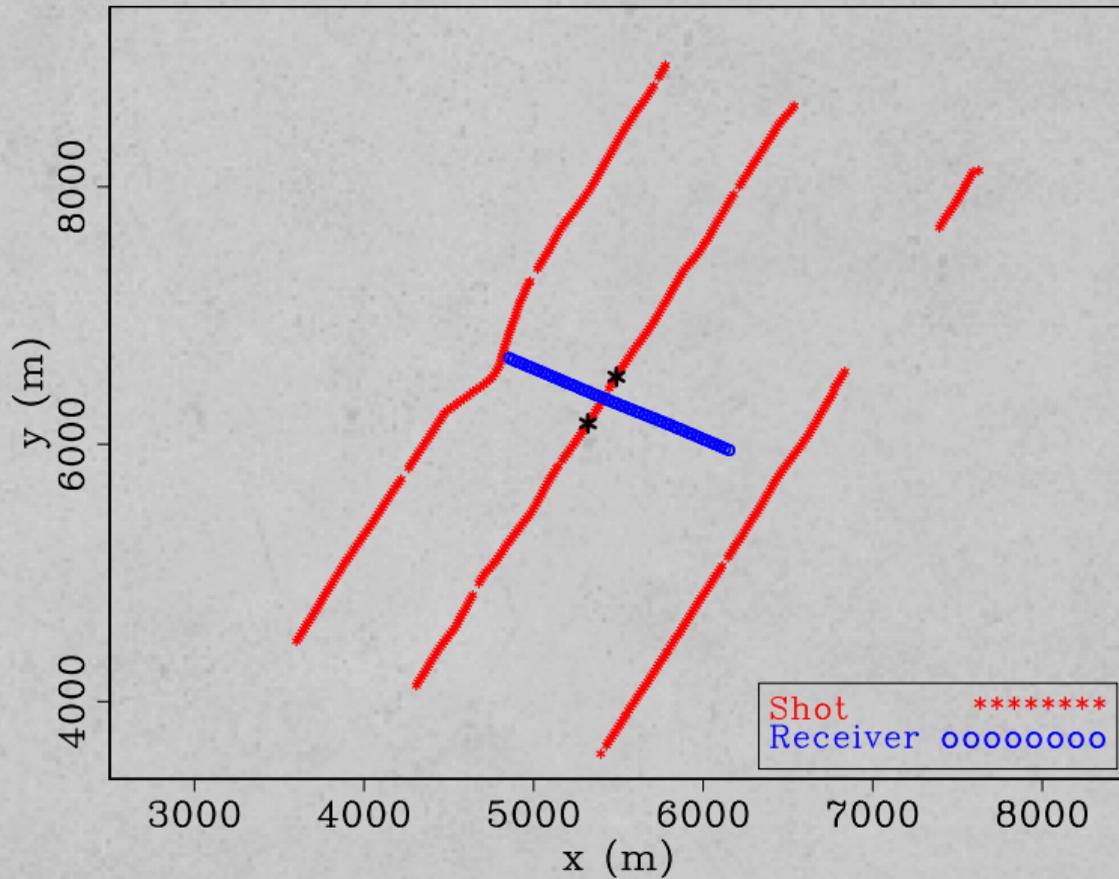
# Deblended residual



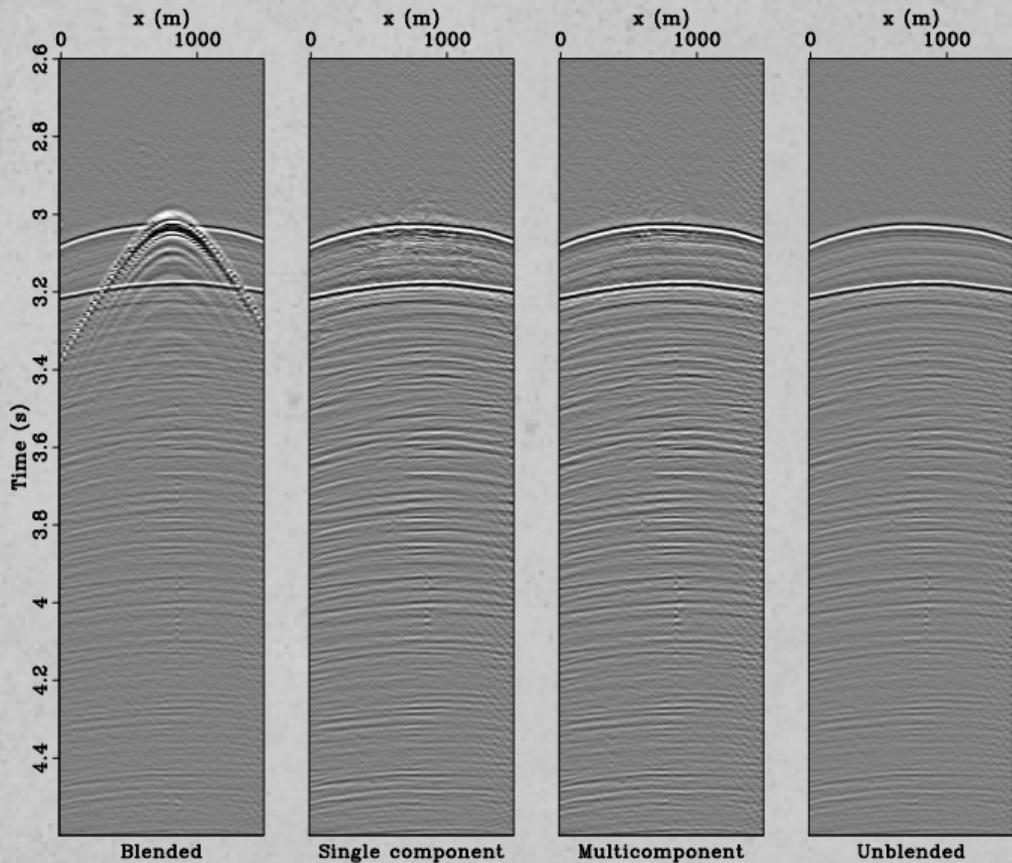
Single component

Multicomponent

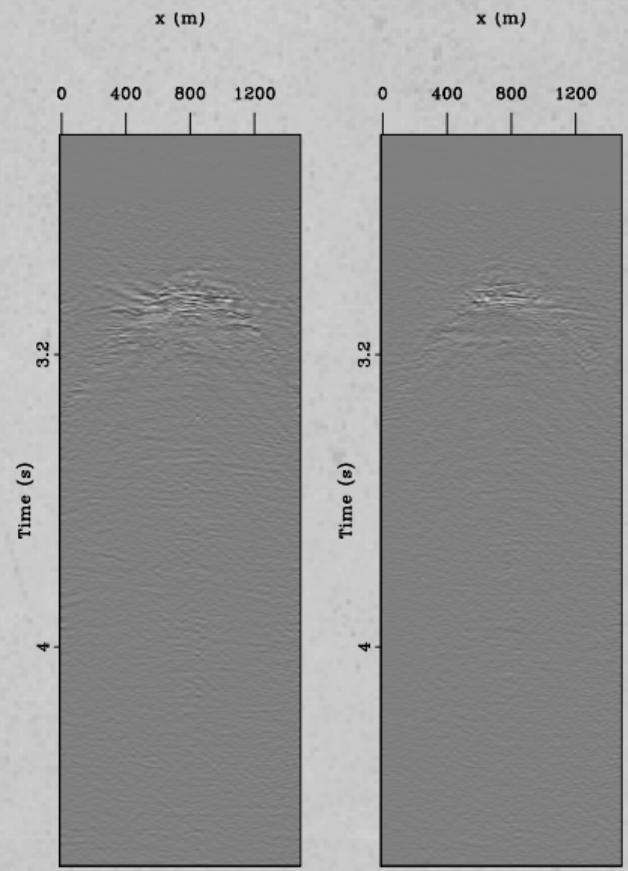
# Crossline shots



# Deblended hydrophone



# Deblended residual



Single component

Multicomponent

# Conclusions/future work

1. Pattern-based method works for multicomponent data
2. Provides an increase in SNR (3X)
3. Still developing the theory
4. Apply to ocean-bottom node data

# Acknowledgements

1. Thanks to Kietta for providing and allowing us to show the data
2. Thanks to Dr. Stewart A. Levin for his help in rotating and preprocessing the data

# Questions?

