4D Consistent Sensor Reorientation and Horizontal Component Leakage Attenuation in Multi Component OBC Data

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Agenda

- Problem Setting
- Methodology
- Preliminary Results
- Next Steps

Problem Setting – Sensor Placement

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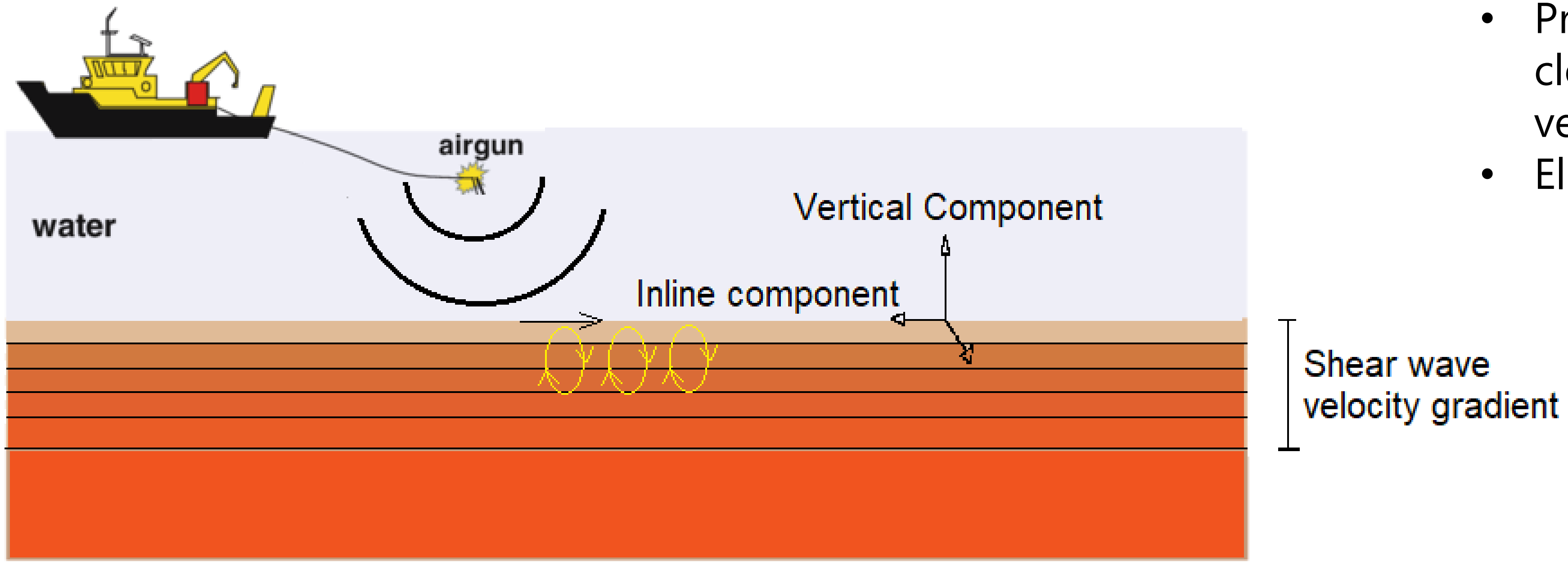
- Multi Component Acquisition: 3 Geophones (Accelerometers, 2 horizontal and one vertical) and 1 Hydrophone (Pressure Sensor)
- Sensor Movement must represent the particle motion caused by the passing wavefield – Coupling;
- Poor quality of OBC data can come from different signal responses from the two horizontal components
- Energy from different components can “leak” into others, specially the vertical component

Problem Setting – Sensor Placement

Sensors were placed at the water bottom without trenching

Problem Setting – Wave Propagation



- Evanescent waves in shallow layers (Scholte waves)
- Propagation velocity close to the shear wave velocity
- Elliptical Polarization

Problem Setting – Characteristics of Events

- Low frequency
- Low velocities (shear wave related)
- Moderate/high amplitude
- Varies from sensor to sensor
- Affected by type of sediment at water bottom
- Can be azimuthally dependent

Problem Setting: Data Examples

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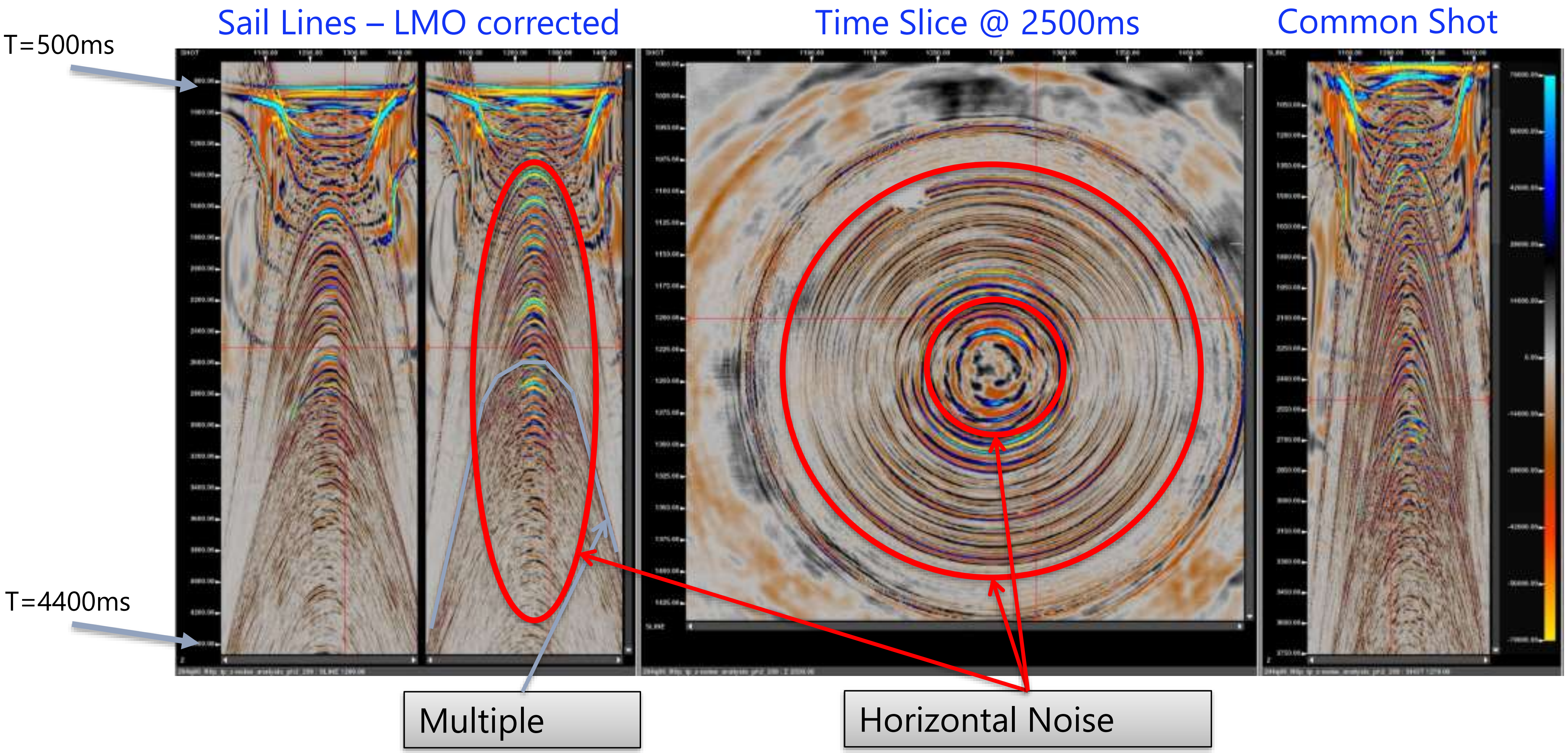
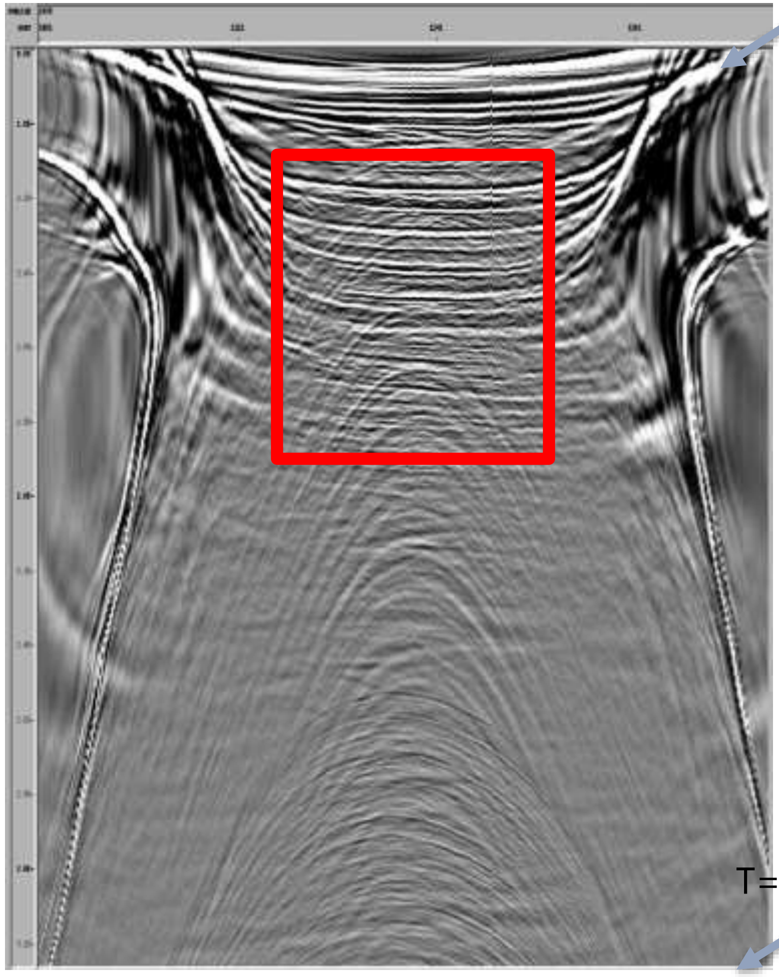
Vertical Component



Problem Setting: Data Examples

Vertical Component

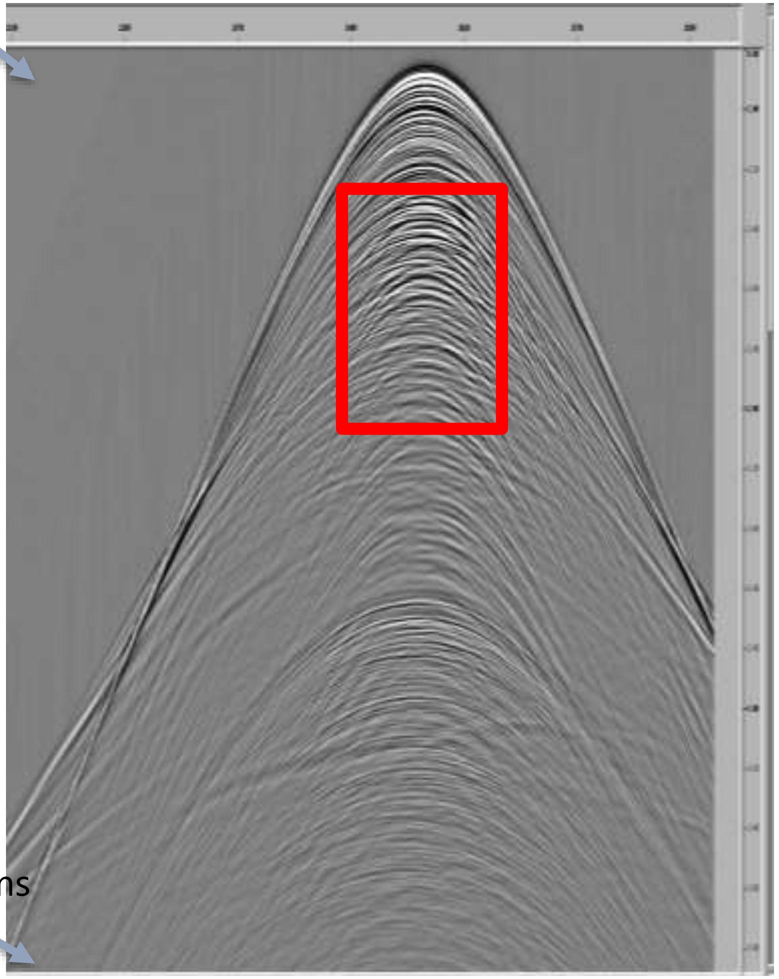
Receiver Gather



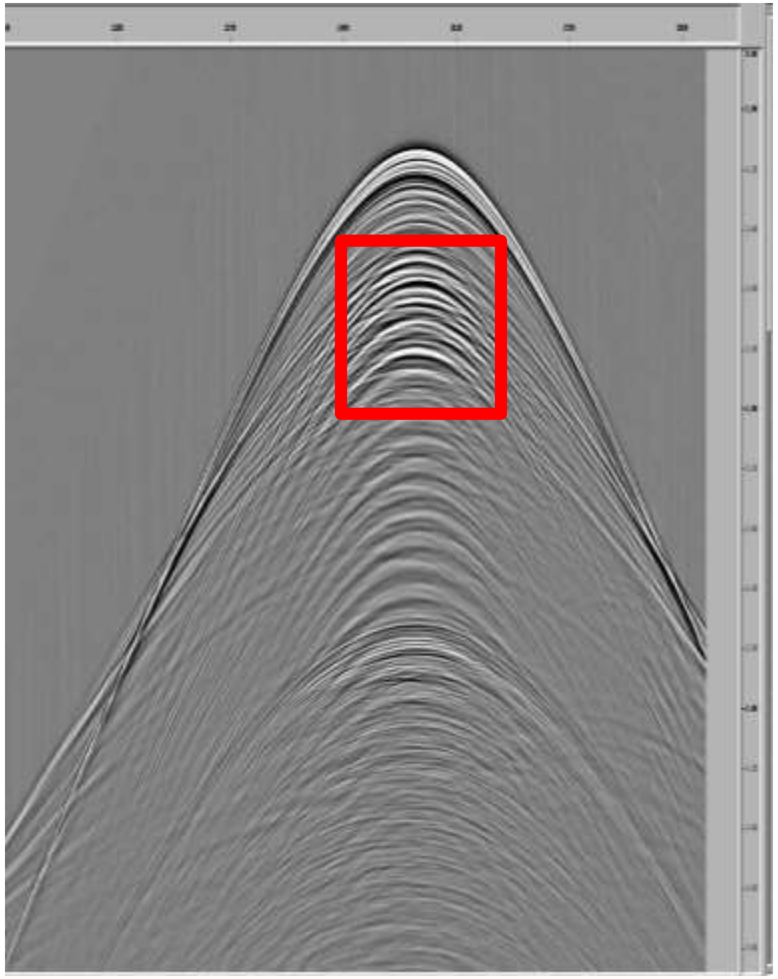
T=500ms

T=3500ms

Inline – Near Offset



Inline – Mid Offset



Problem Setting: Data Examples

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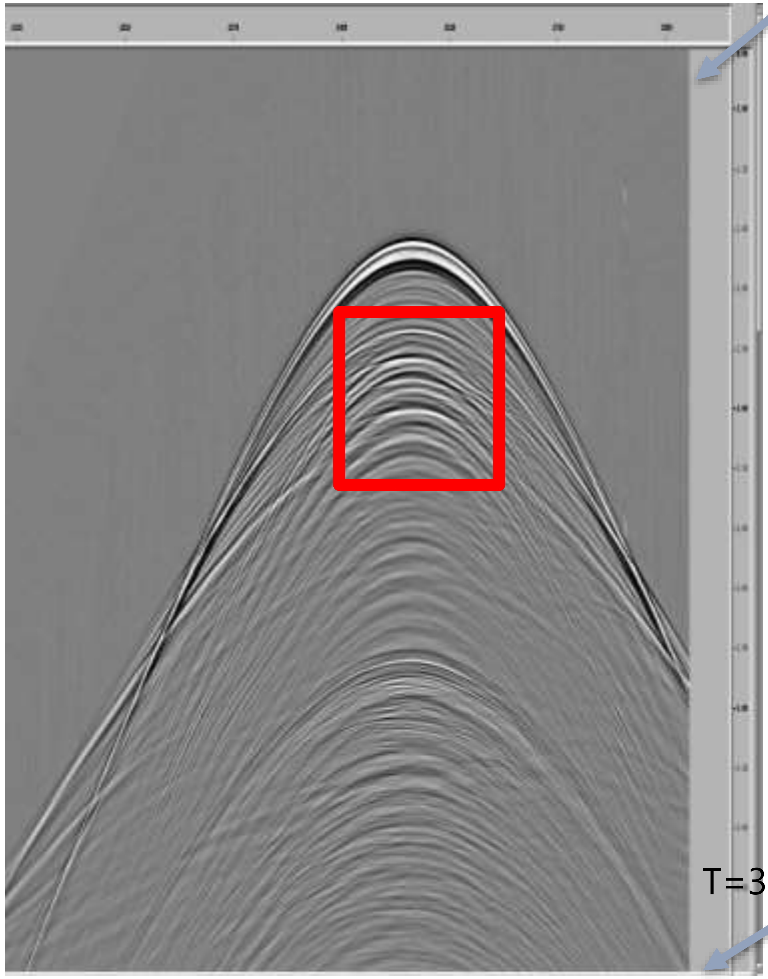
Vertical Component

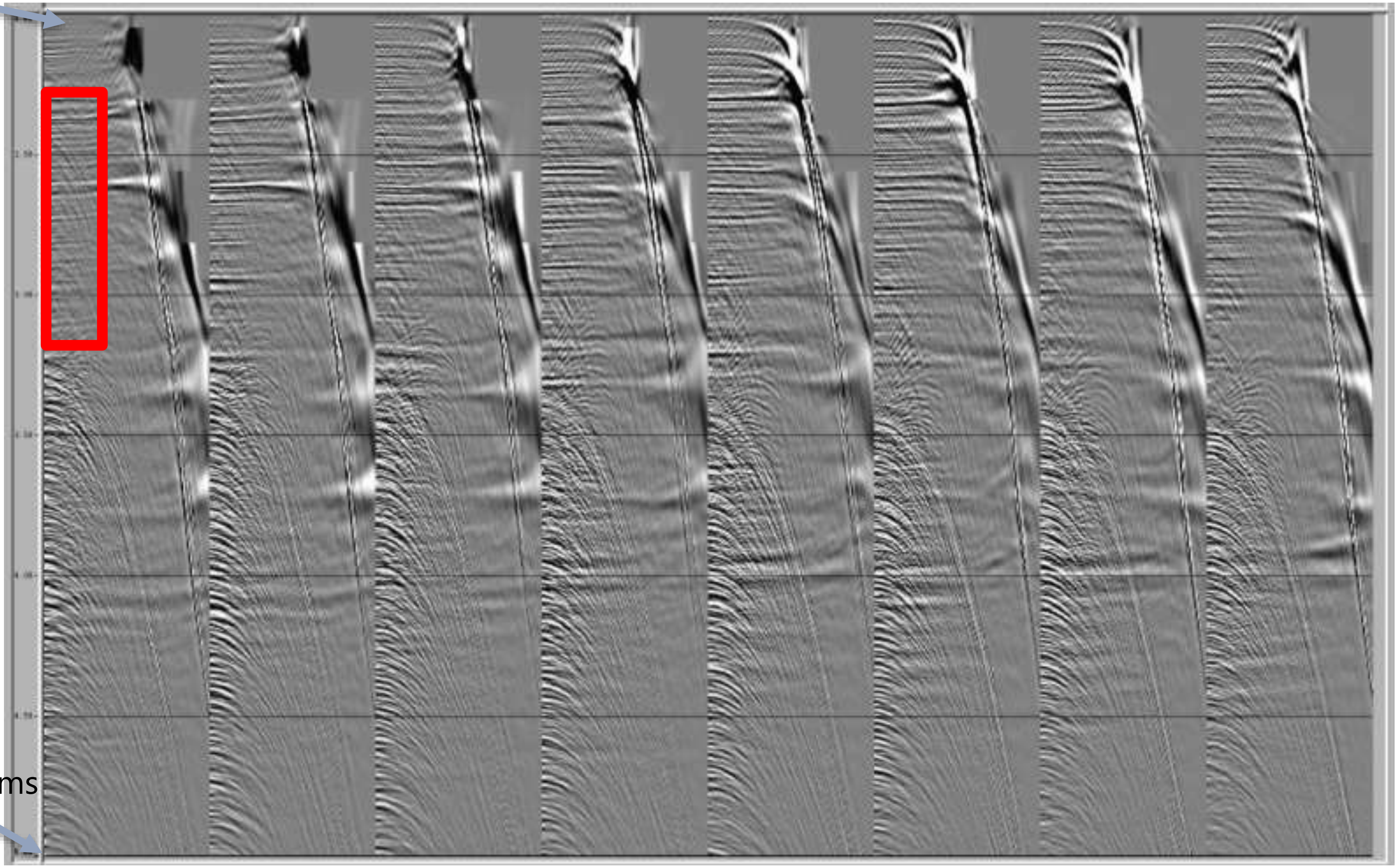
Inline – Far Offset



T=500ms

T=3500ms

Inline – Post Migration Gathers



Problem Setting: Effects on 4D Signal

- Time lapse seismic relies on subtle differences in the reservoir level
- Jubarte case: changes very weak (even with 4%NRMS)
- Every processing step has to be aimed at preserving the 4D signal
- The best 3D solution is not necessarily the best 4D result: residual noise and artifacts can contaminate the signal
- Proposal: a 4D consistent treatment horizontal waves leakage into the vertical component

Methodology: Current Landscape

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- Solutions exist for the 3D case, as seen in Landschulze (2019) and Gaiser (2007): Based on a model of detector coupling for OBC data (mass-spring-dashpot).
- Assumes Hydrophones are perfectly coupled to the fluid medium
- Assumes inline component has excellent coupling the sea floor.
- Uses a spectral balancing vector method to minimize transverse horizontal energy
- Physical Solutions: Improved sensor design can help mitigate sensor orientation problems (Byerley,2003)

Methodology: Governing Equations

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Recovery of Actual Ground Motion (Gaiser, 2007)

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \frac{1}{\det|\mathbf{G}|} \begin{pmatrix} C_y V_z - V_y C_z & 0 & 0 \\ 0 & IV_z & -IC_z \\ 0 & -IV_y & IC_y \end{pmatrix} \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

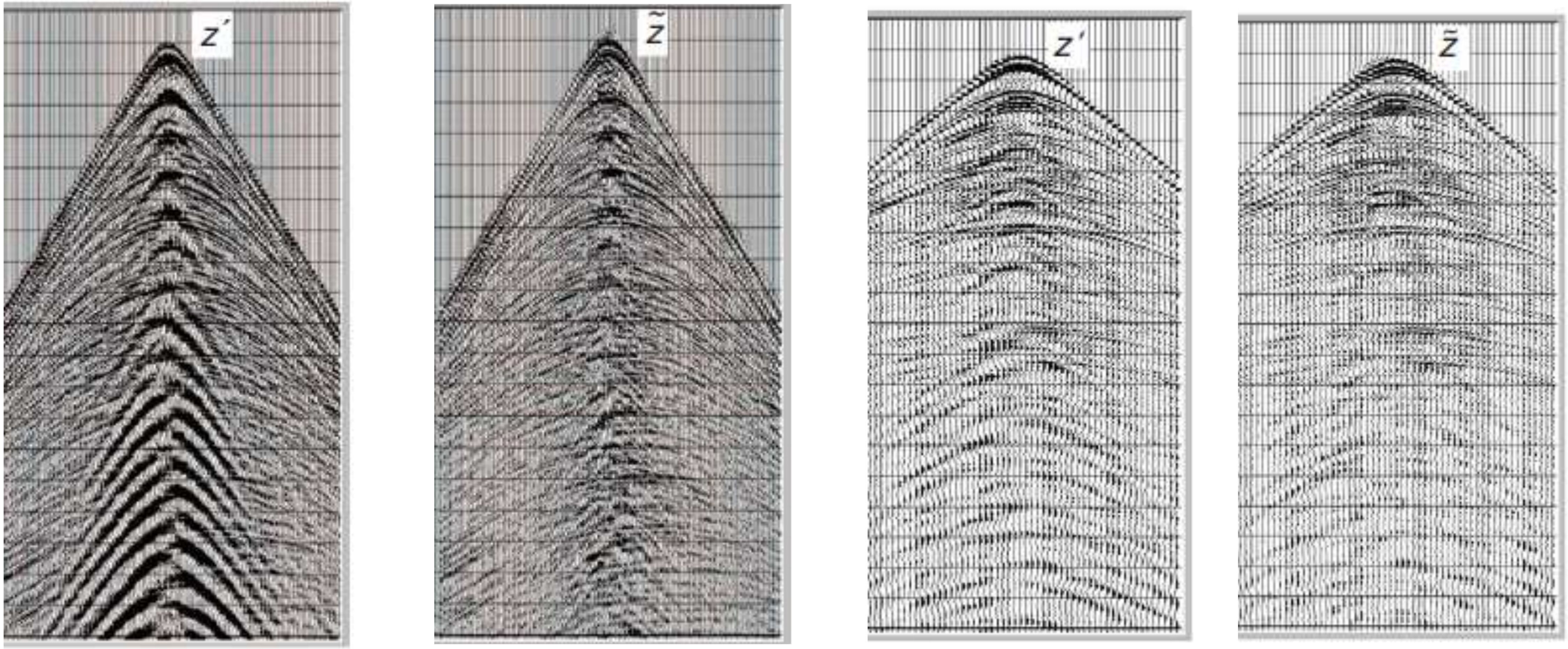
Horizontal energy attenuation in the Vertical component (Gaiser, 2007)

$$\sum_i |z_i'(\omega) - c_z'(\omega)\tilde{y}_i(\omega)|^2 = \min$$

Vertical component energy calibration using hydrophone as reference (Landschulze, 2019; Pfaffenholz and Barr, 1995)

$$\frac{p(\omega)}{1 + r_s e^{i\omega\tau}} - \frac{2}{1 - r_s^2 e^{i\omega 2\tau}} - \frac{z(\omega)}{1 - r_s e^{i\omega\tau}} = 0$$

Methodology: Literature Examples



Vertical component for a common receiver gather
before (left) and after (right) correction. (Gaiser, 2007).

Methodology: Proposed approach

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- The solutions found in the literature are focused on the 3D problem
- Adopting one of the datasets as reference (Base survey), the correction can be calculated in a 4D consistent fashion, seeking to minimize the presence of residual noise and artifacts in the final 4D signal
- Solution may not be the best 3D result, however it will reduce the 4D noise, leading to a more reliable dataset and smaller NRMS values.

Methodology: Proposed approach

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Processing Flow (Jubarte dataset)

Processing Flow (Synthetic dataset)

Methodology: Applying the correction

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- Step 1: Estimate rotation matrix coefficients by solving the linear system:

$$z_m(\omega) = Rz_b(\omega);$$

With z_m, z_b, recorded vertical component for monitor and base surveys, respectively.

- Step 2: Apply vector fidelity correction on the monitor dataset:

$$z_m^c = z_m - c_z(\omega)\tilde{y}(\omega)$$

- Define the minimization operator:

$$L(z) = z_m^c - Rz_b,$$

for which the minimizing solution is

$$\widehat{z_b^c} = (R^T R)^{-1} R^T z_m^c$$

This is the solution that minimizes the difference between the corrected base and monitor surveys.

Preliminary Results: Velocity and Density Models

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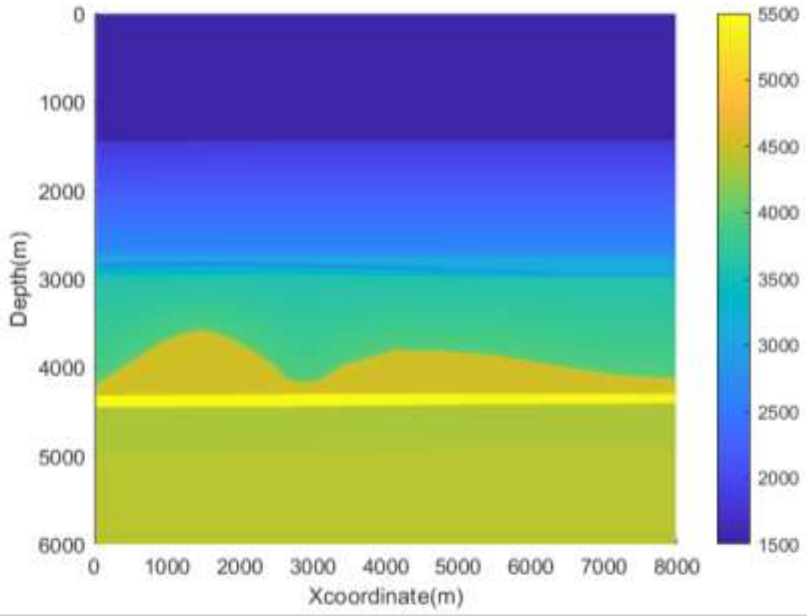
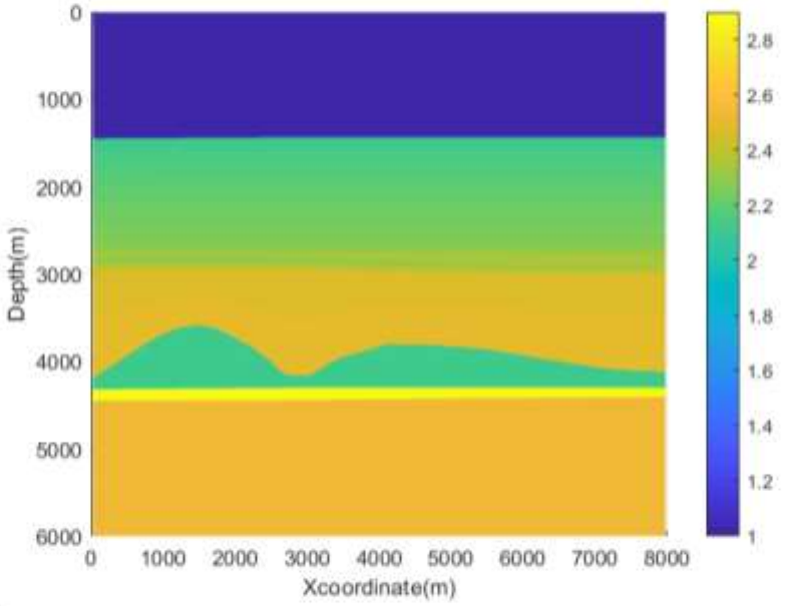
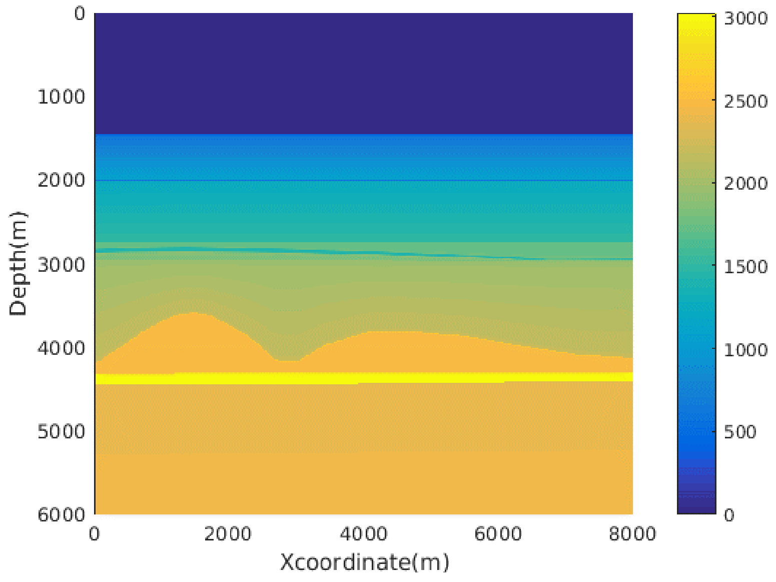


Velocity Model (P)

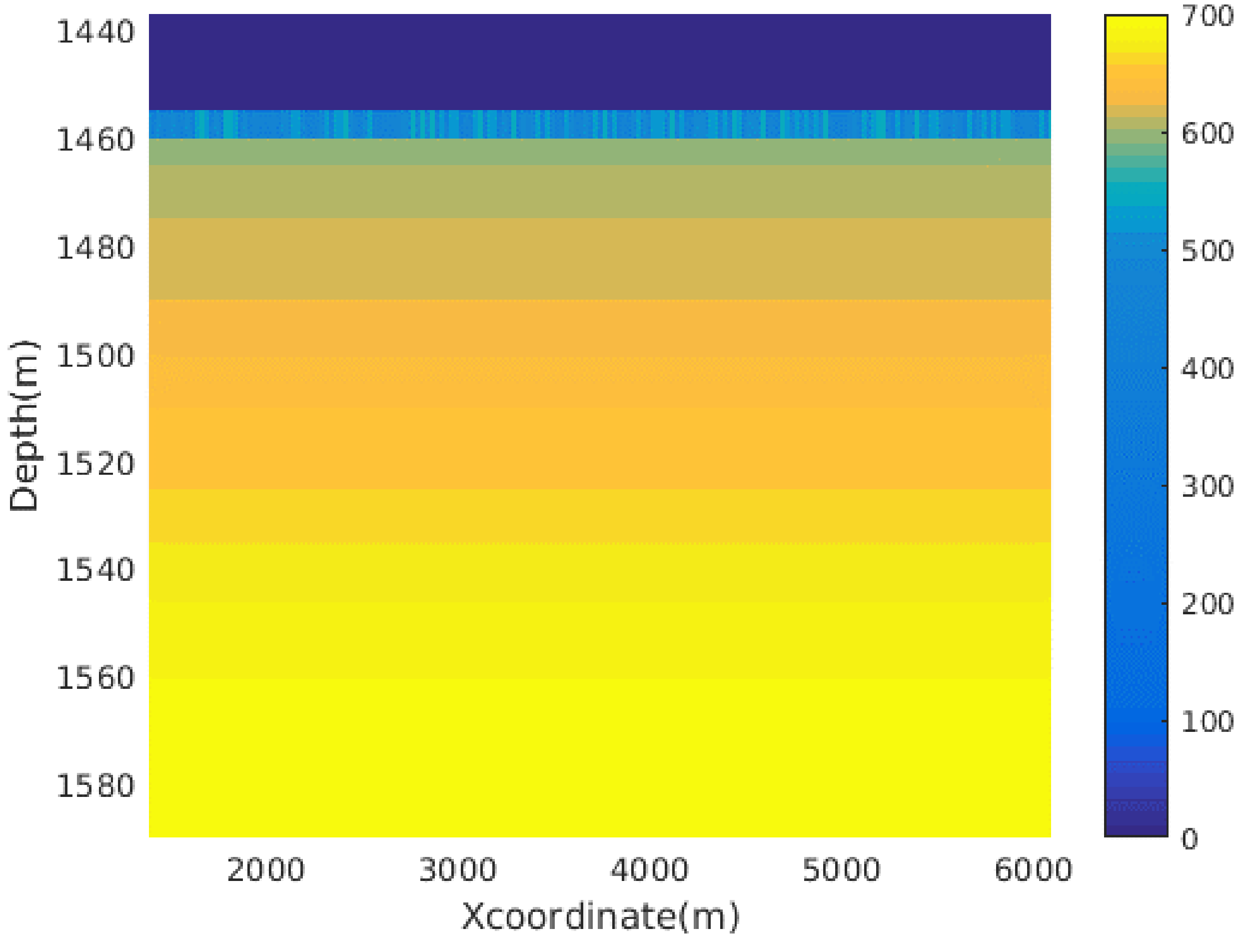


Density Model



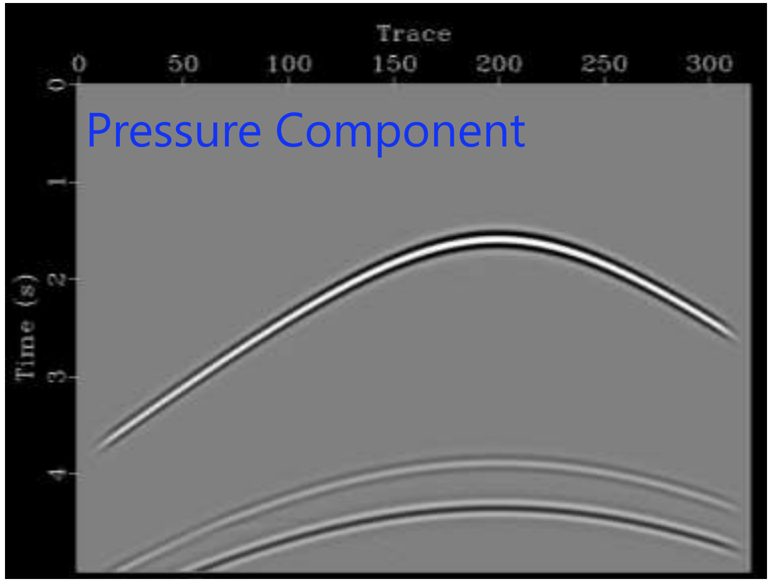
Velocity Model (S)

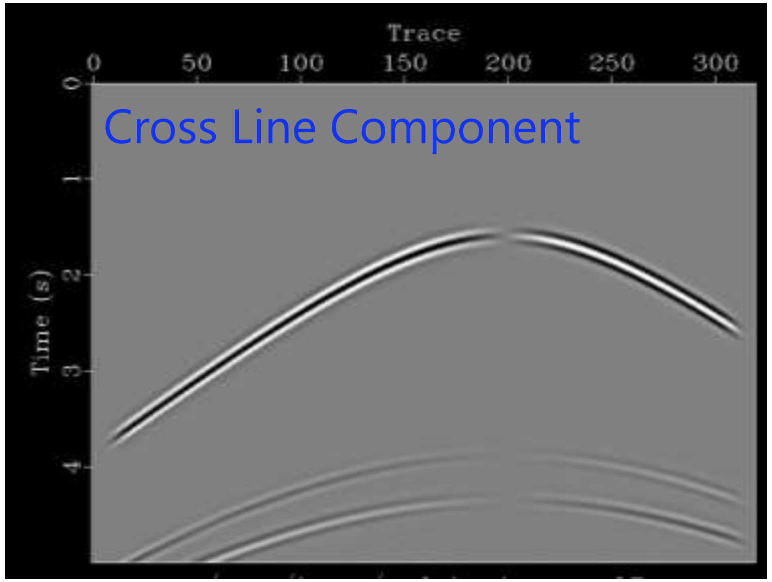
Preliminary Results: Perturbation on Vs Model

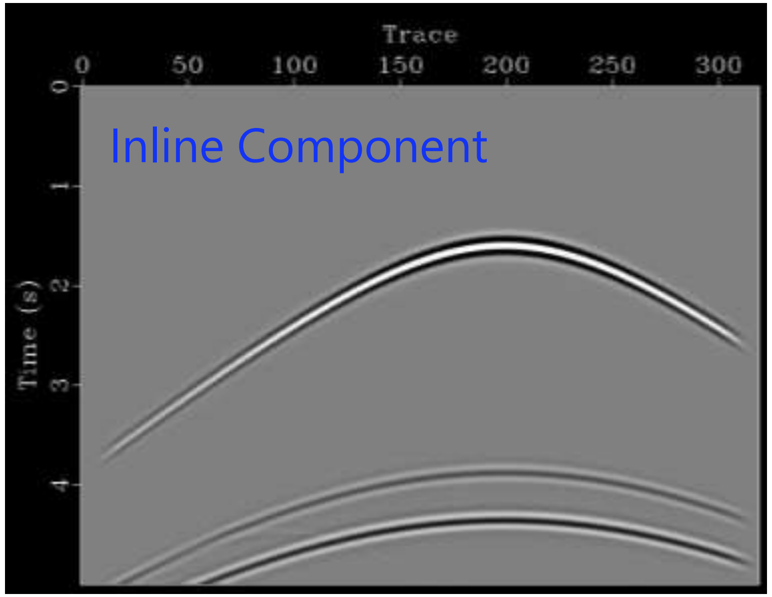


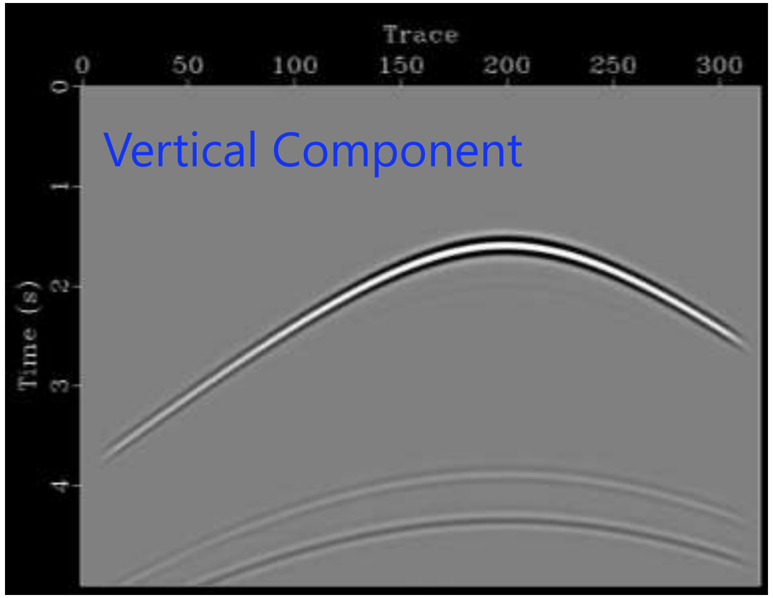
- Random modification of velocities in the water bottom (between 0 and 25%)
- Small gradient downwards

Preliminary Results: Synthetic data









Preliminary Results: Modified shear wave model

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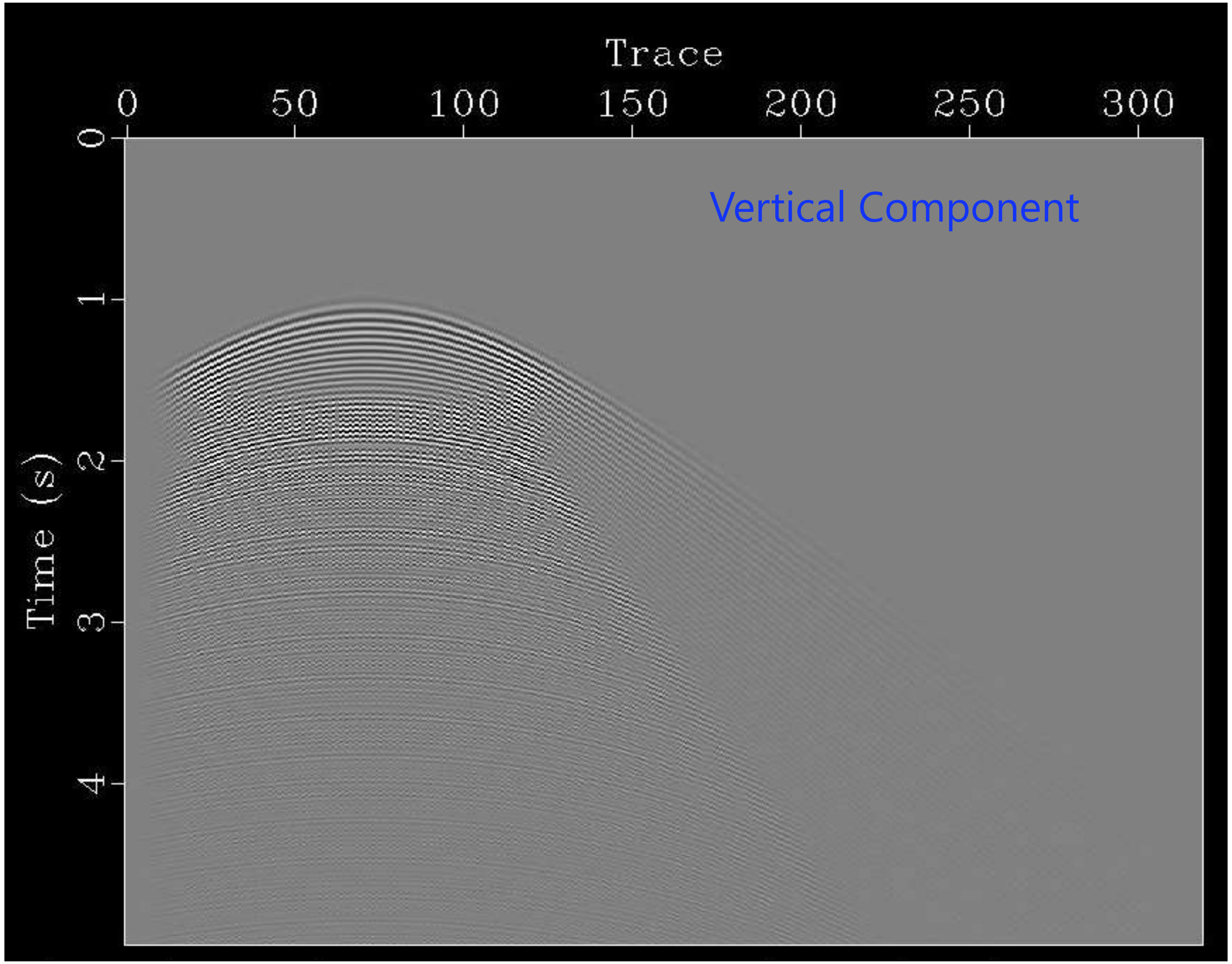

Next Steps

- Simulate horizontal energy leaking on vertical component
- Implement Solution for 3D datasets
- Implement 4D consistent algorithm
- Test on synthetic dataset (proof of concept)
- Apply correction to Jubarte dataset
- Evaluate new NRMS
- Introduce anisothropy

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Anadarko Petroleum Corporation

Apache

CGG

Chevron

CIMAREX

CNOOC

DAWSON Dawson Geophysical Company

devon

drillinginfo better, faster decisions

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ExxonMobil

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