Joint Inversion of up- and down-going signal for ocean bottom data

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SEP140 p.83-94

Mandy Wong
Biondo Biondi
Shuki Ronen

Overview

- **Introduction**

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- Introduction
- The inverse problem

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- Numerical Example
  - Marmousi with regular sampling
  - Marmousi with coarse sampling

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Introduction

- **Why Ocean bottom seismic acquisition?**
  - **Wide azimuth illumination**
  - **Shear wave recording**

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  - **Shear wave recording**
  - **Quiet recording environment**
  - **Improved repeatability**

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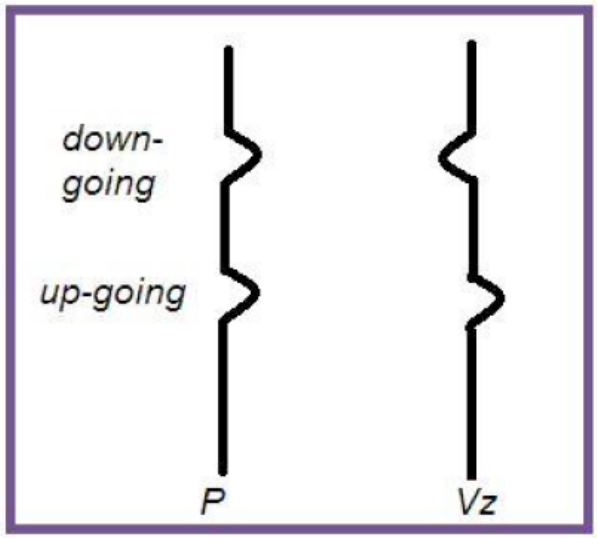
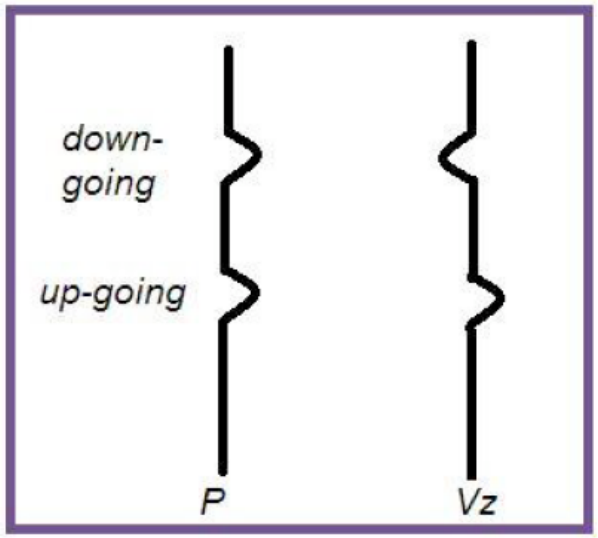
  - **Wide azimuth illumination**
  - **Shear wave recording**
  - **Quiet recording environment**
  - **Improved repeatability**
  - **PZ combination**

PZ combination



PZ combination



$$U(t,x) = \frac{1}{2}\left(P(t,x) + \text{scale}(x)Z(t,x)\right),$$

$$D(t,x) = \frac{1}{2}\left(P(t,x) - \text{scale}(x)Z(t,x)\right),$$

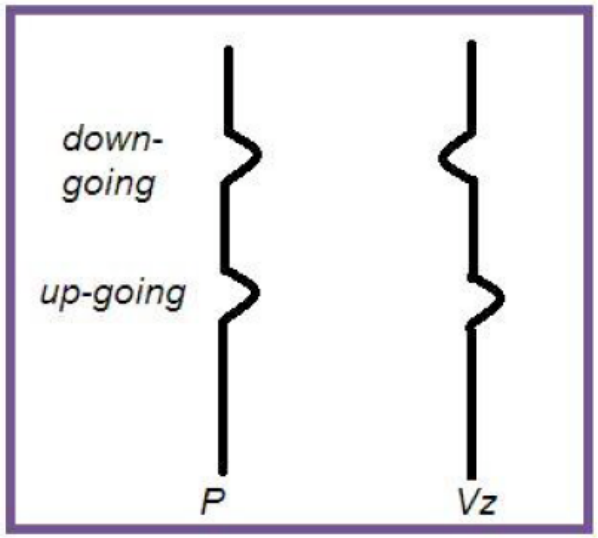
$U(t,x)$ is the up-going wavefield

$D(t,x)$ is the down-going wavefield

$P(t,x)$ is the pressure

$Z(t,x)$ is the vertical particle velocity

PZ combination



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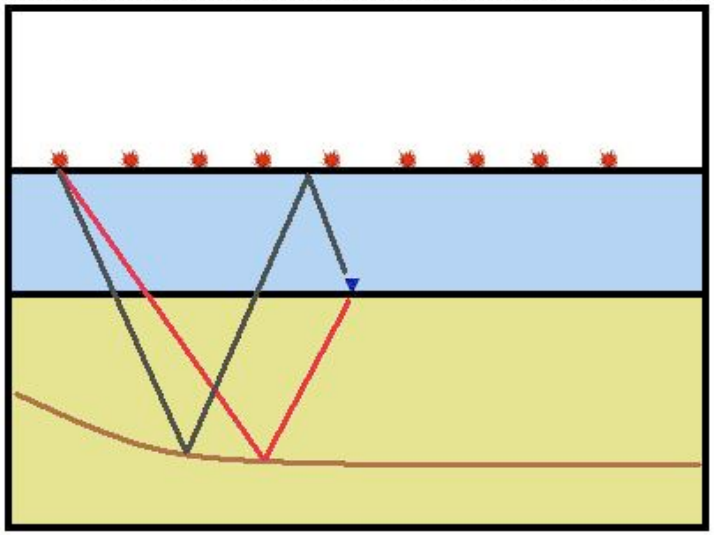
(White, 1964; Barr and Sander, 1989; Soubaras, 1996; Schalkwijk et al. 1999; Amundsen 1999)

P-wave processing for OBS data

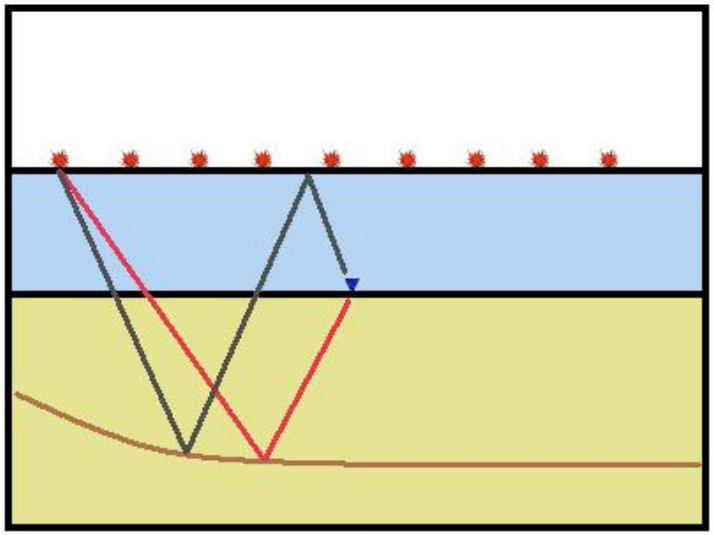
- **Migration of Primary**
  - **Remove free surface multiples**



Primary
Receiver Ghost

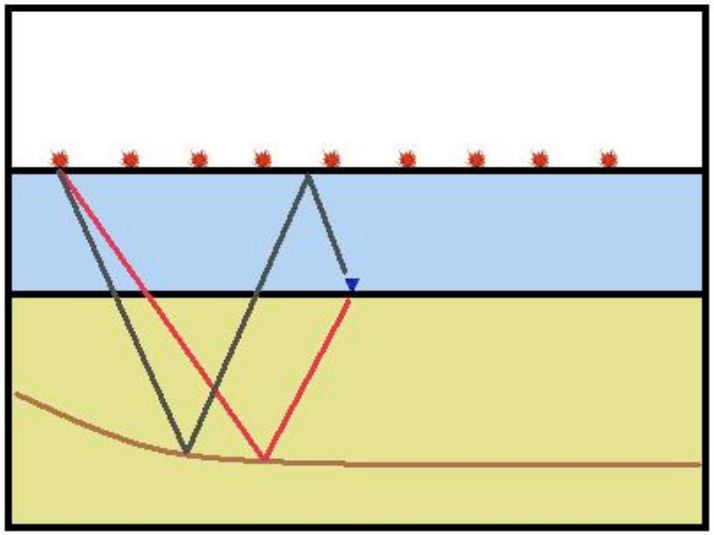
P-wave processing for OBS data

- **Migration of Primary**
  - **Remove free surface multiples**
    - **PZ summation**
    - **Up-down deconvolution (Amundsen , 2001)**

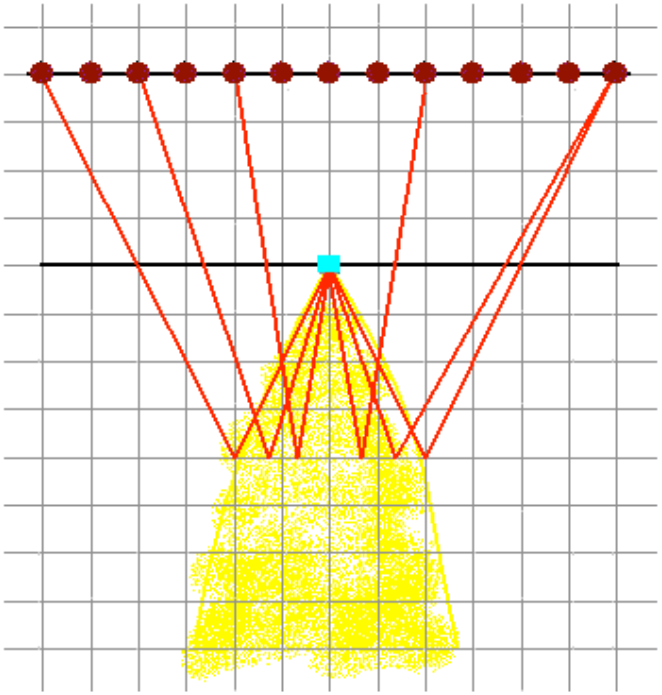


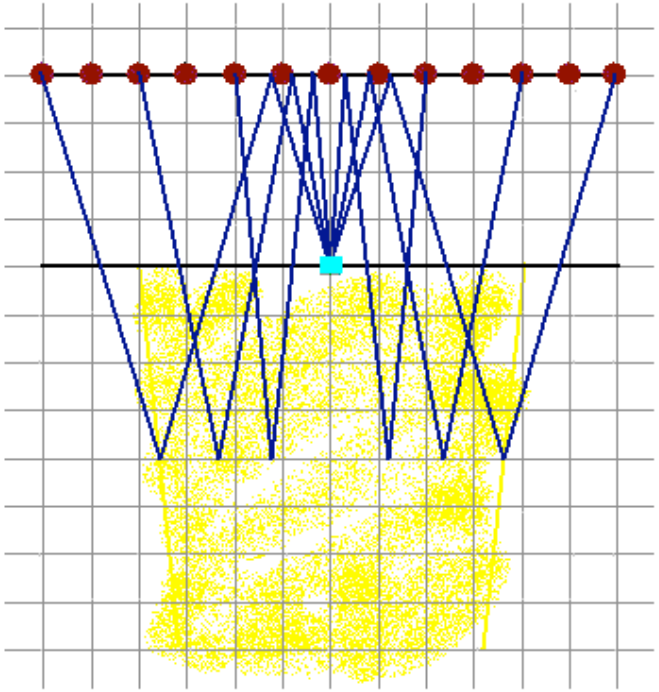
P-wave processing for OBS data

- **Migration of Receiver ghost**
  - **Mirror Imaging**
  - **Godfrey et al., 1998; Ronen et al., 2005; Grion et al., 2007; Dash et al., 2009**



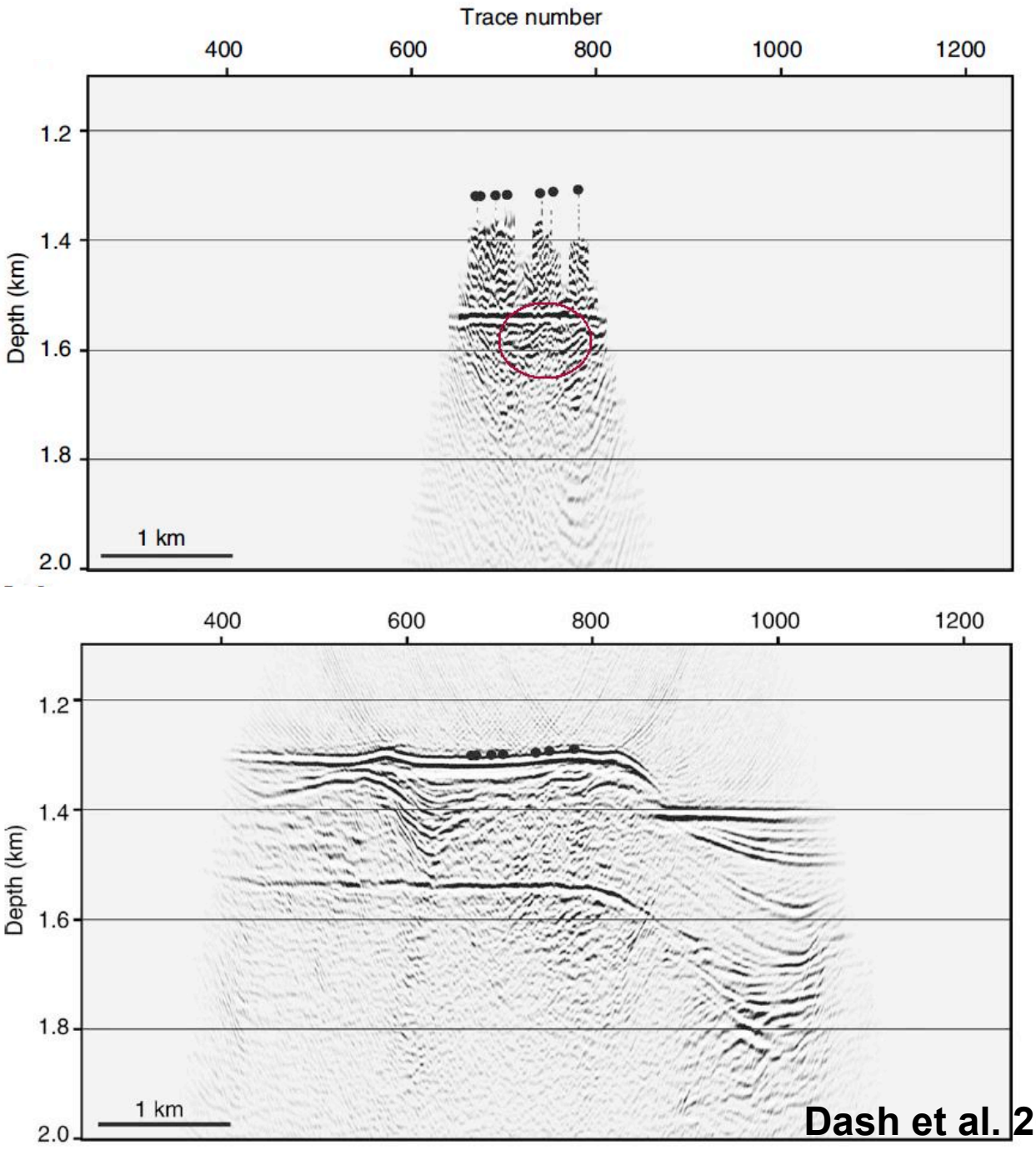
Comparison of illuminations





Primary

Receiver Ghost / Mirror



Dash et al. 2009

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The Inverse Problem

Joint fitting of up- and down-going data.

$$min\left(\|\mathbf{L}_{\uparrow}\mathbf{m}-\mathbf{d}_{\uparrow}\|^2+\|\mathbf{L}_{\downarrow}\mathbf{m}-\mathbf{d}_{\downarrow}\|^2\right)$$

m is the model that describe the image

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$\mathbf{m}$ is the model that describe the image

$\mathbf{d}_{\uparrow}$ is the up-going wavefield at the receiver

$\mathbf{d}_{\downarrow}$ is the down-going wavefield at the receiver

The Inverse Problem

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$$min\left(\|\mathbf{L}_{\uparrow}\mathbf{m}-\mathbf{d}_{\uparrow}\|^2+\|\mathbf{L}_{\downarrow}\mathbf{m}-\mathbf{d}_{\downarrow}\|^2\right)$$

$\mathbf{m}$ is the model that describe the image

$\mathbf{d}_{\uparrow}$ is the up-going wavefield at the receiver

$\mathbf{d}_{\downarrow}$ is the down-going wavefield at the receiver

$\mathbf{L}_{\uparrow}$ is an operator that models up-going wavefield at the receiver

$\mathbf{L}_{\downarrow}$ is an operator that models down-going wavefield at the receiver

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Joint fitting of up- and down-going data.

$$0 \approx \begin{bmatrix} \mathbf{L}_{\uparrow} \\ \mathbf{L}_{\downarrow} \end{bmatrix} \mathbf{m} - \begin{bmatrix} \mathbf{d}_{\uparrow} \\ \mathbf{d}_{\downarrow} \end{bmatrix}$$

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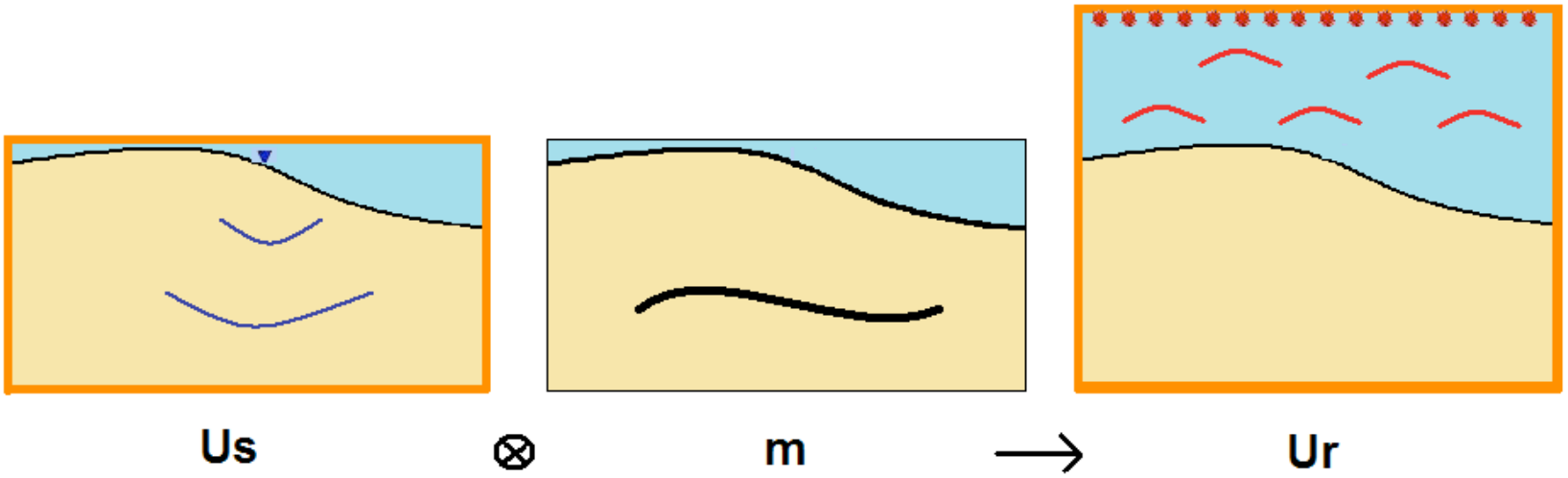
The Inverse Problem

Joint fitting of PRIMARY and MIRROR signal

$$0 \approx \begin{bmatrix} \mathbf{L}_{\uparrow} \\ \mathbf{L}_{\downarrow} \end{bmatrix} \mathbf{m} - \begin{bmatrix} \mathbf{d}_{\uparrow} \\ \mathbf{d}_{\downarrow} \end{bmatrix}$$

$$0 \approx \begin{bmatrix} \mathbf{L}_p \\ \mathbf{L}_g \end{bmatrix} \mathbf{m} - \begin{bmatrix} \mathbf{d}_p \\ \mathbf{d}_g \end{bmatrix}$$

The Forward Primary Operators



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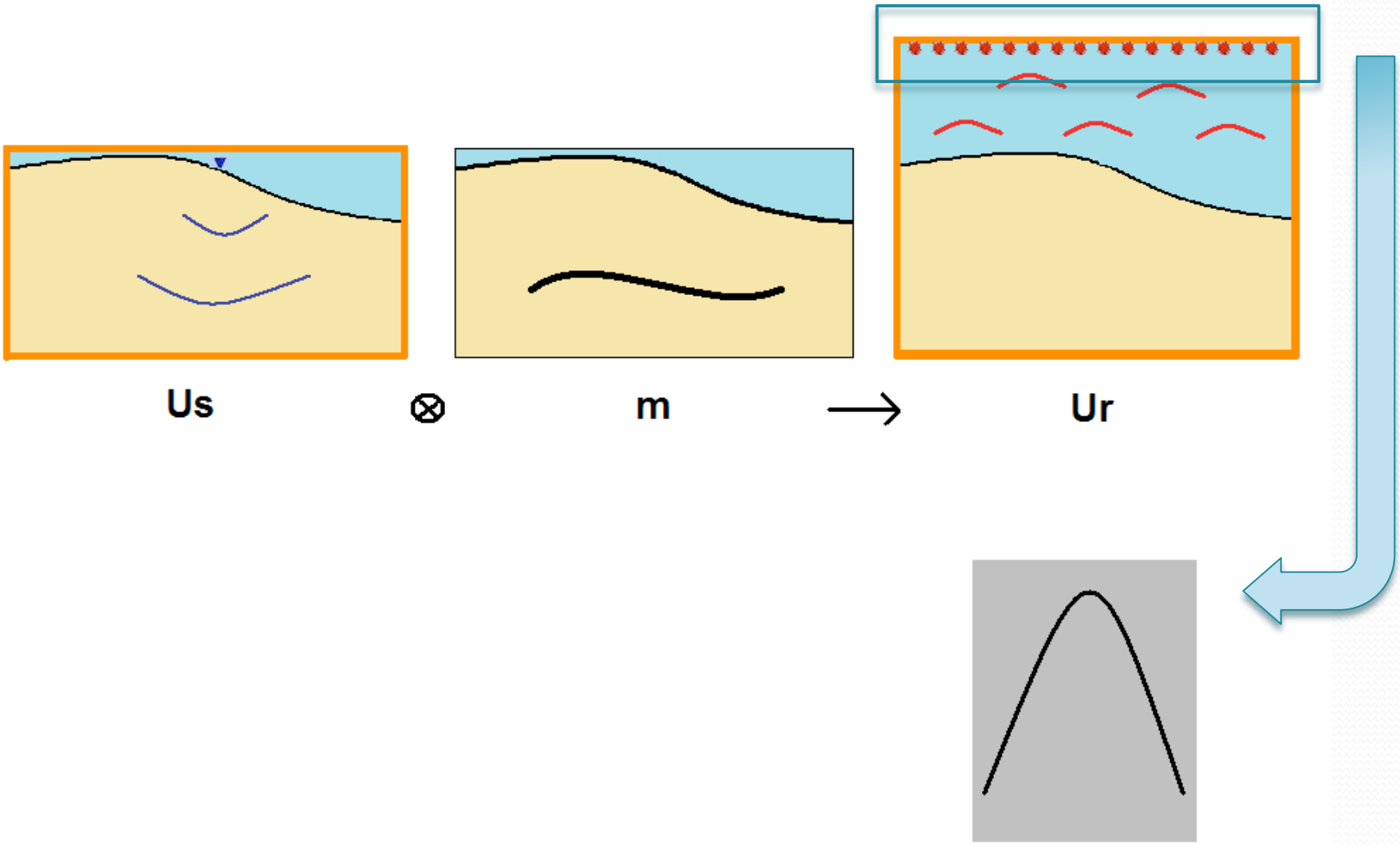

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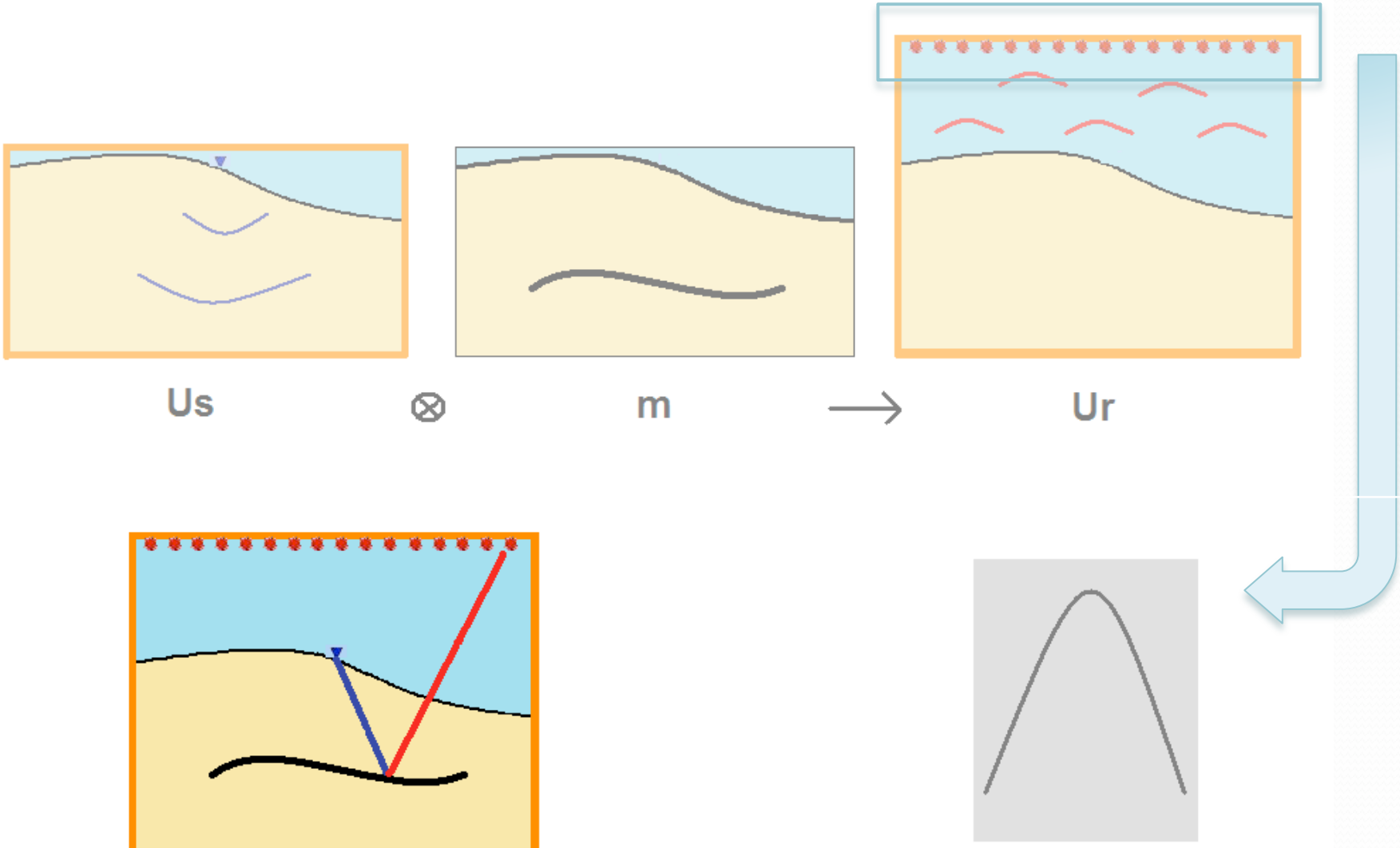
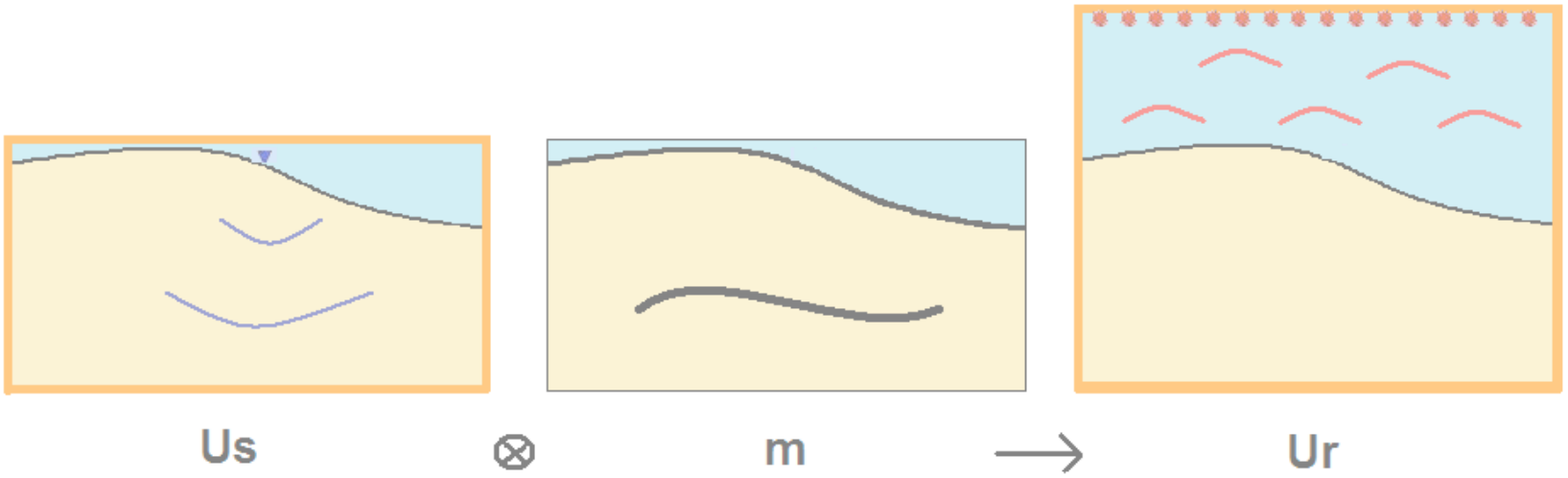
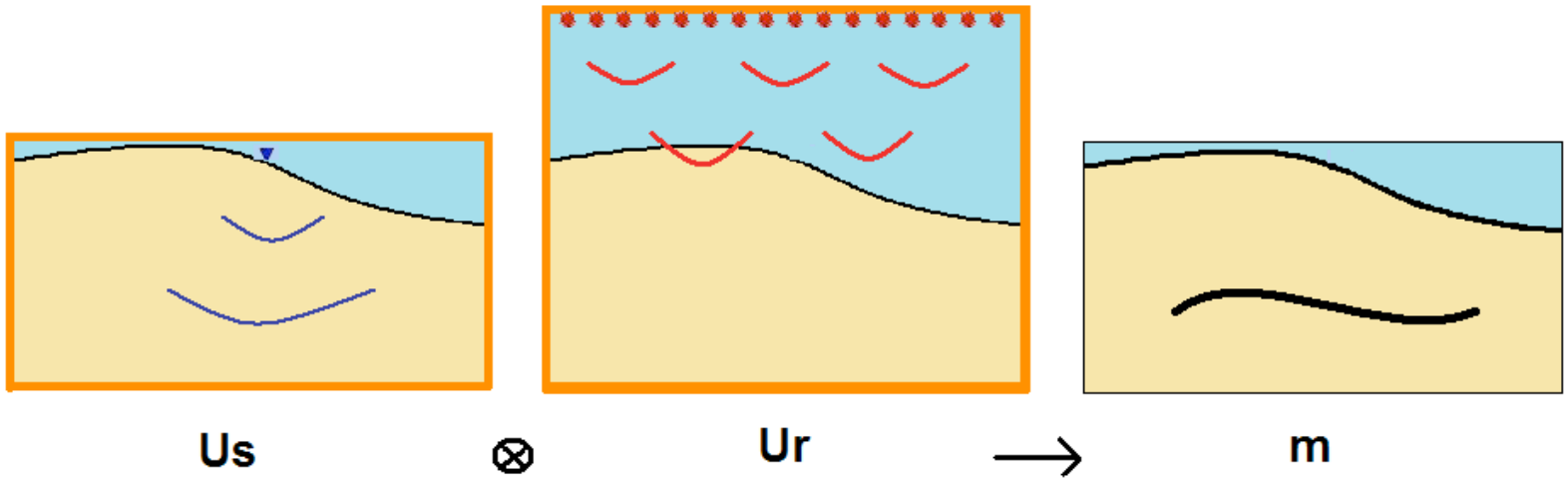
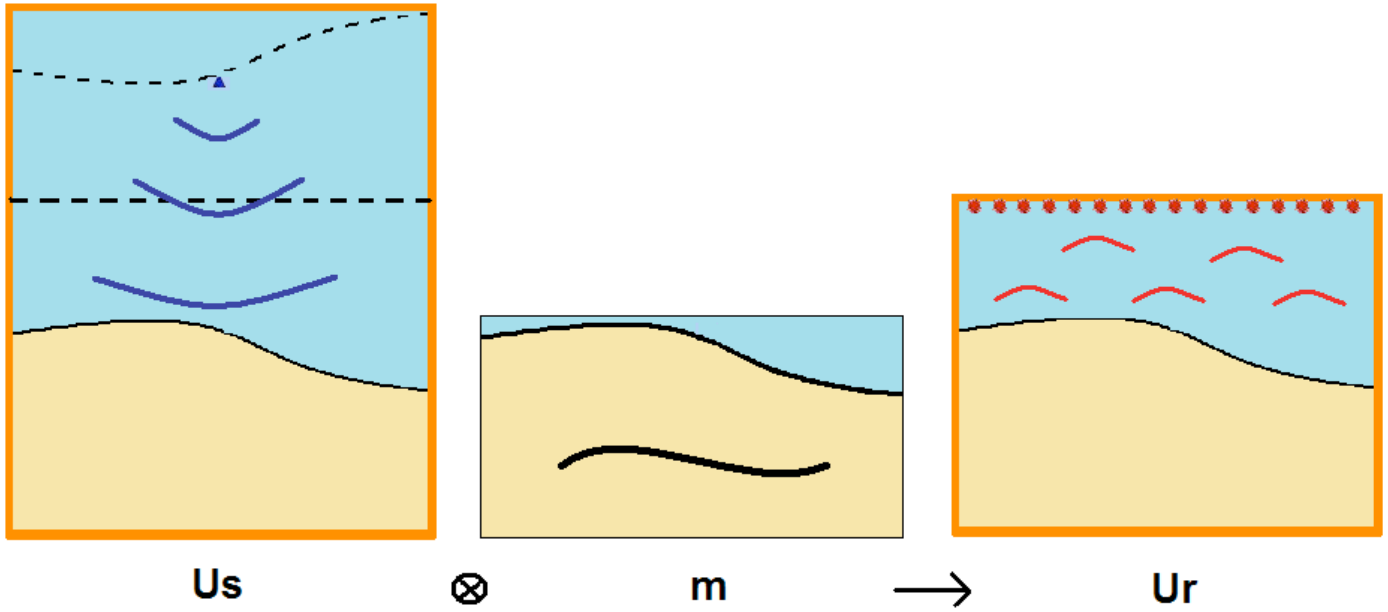


The Reverse Primary Operators





The Forward Mirror Operators



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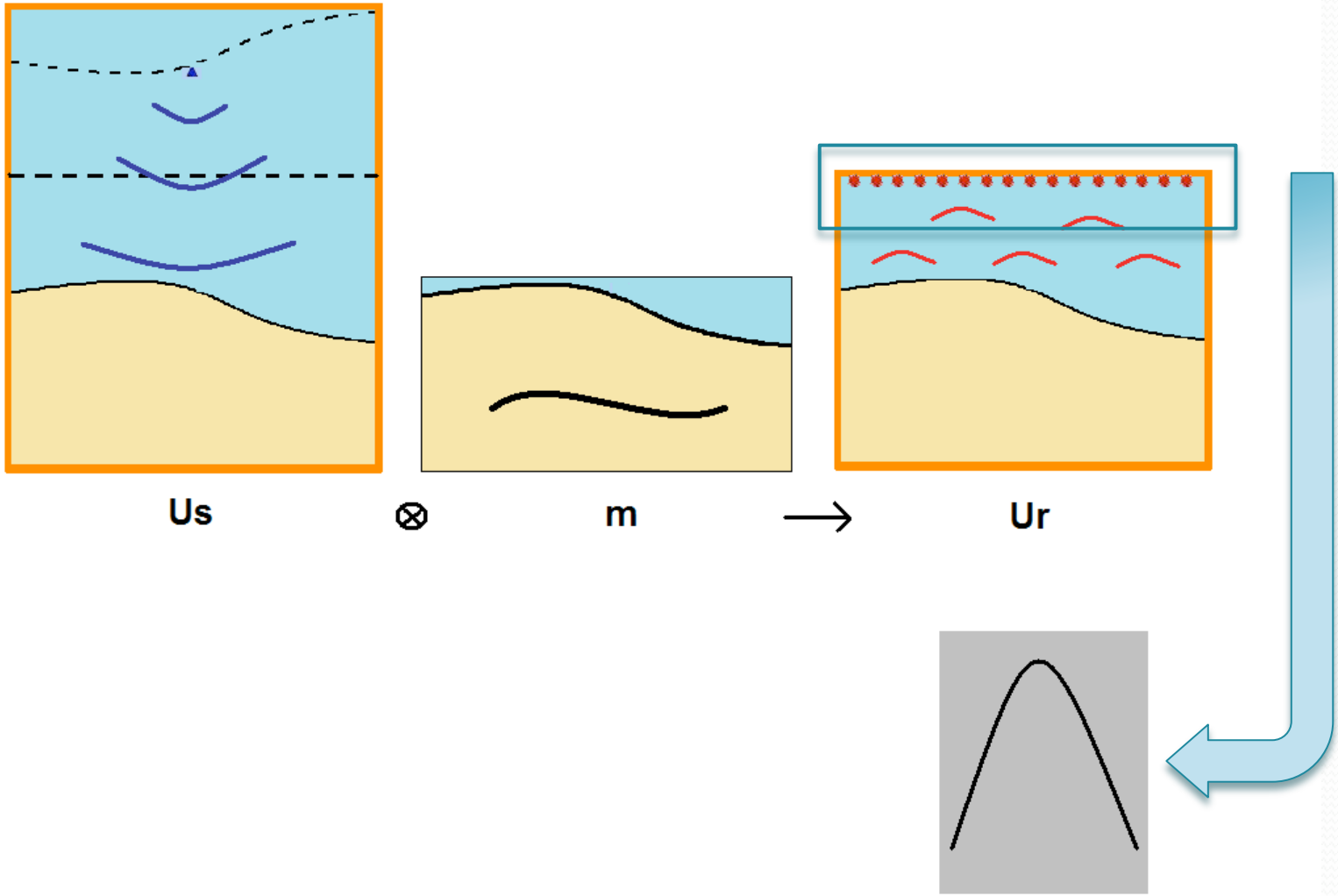

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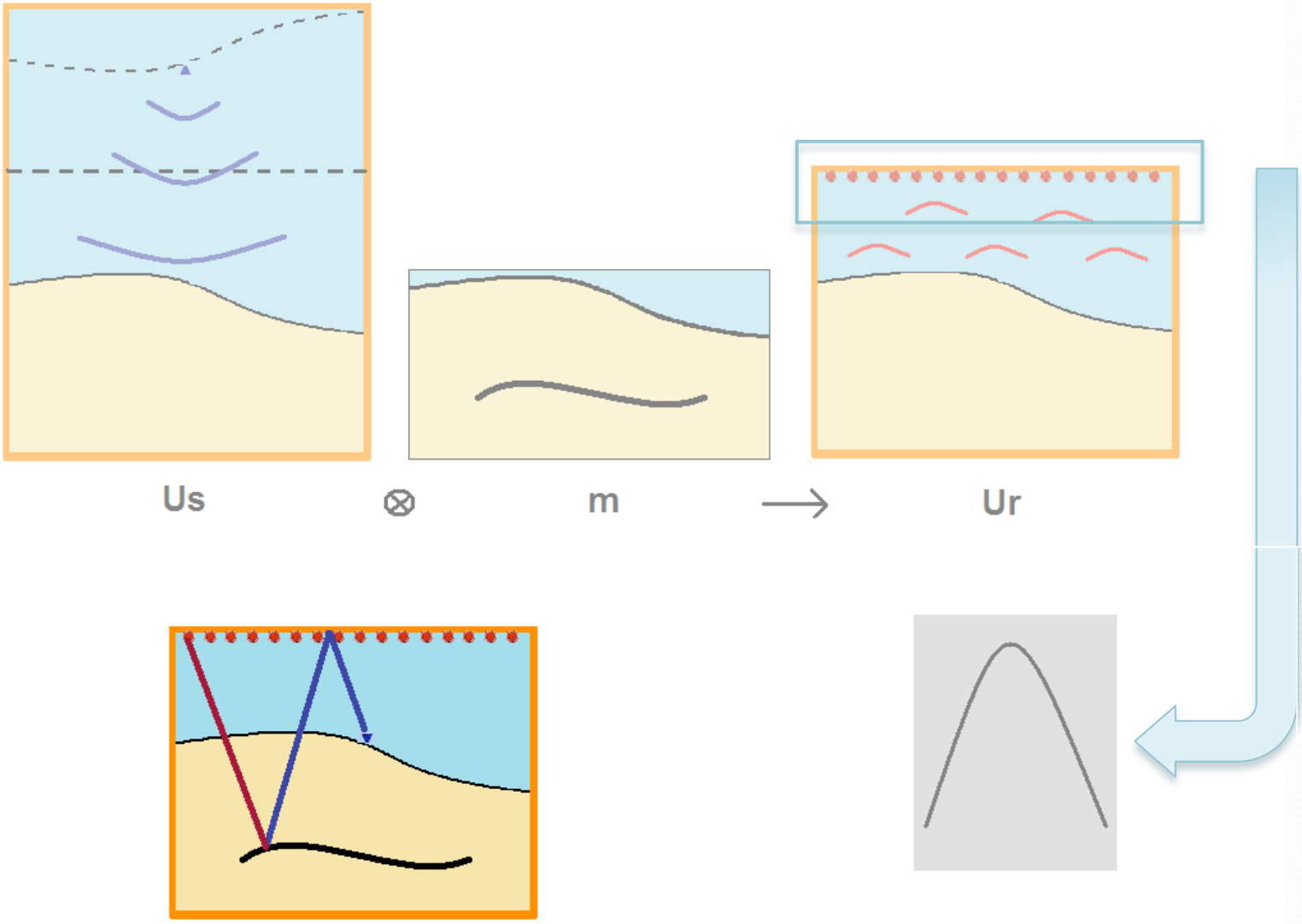

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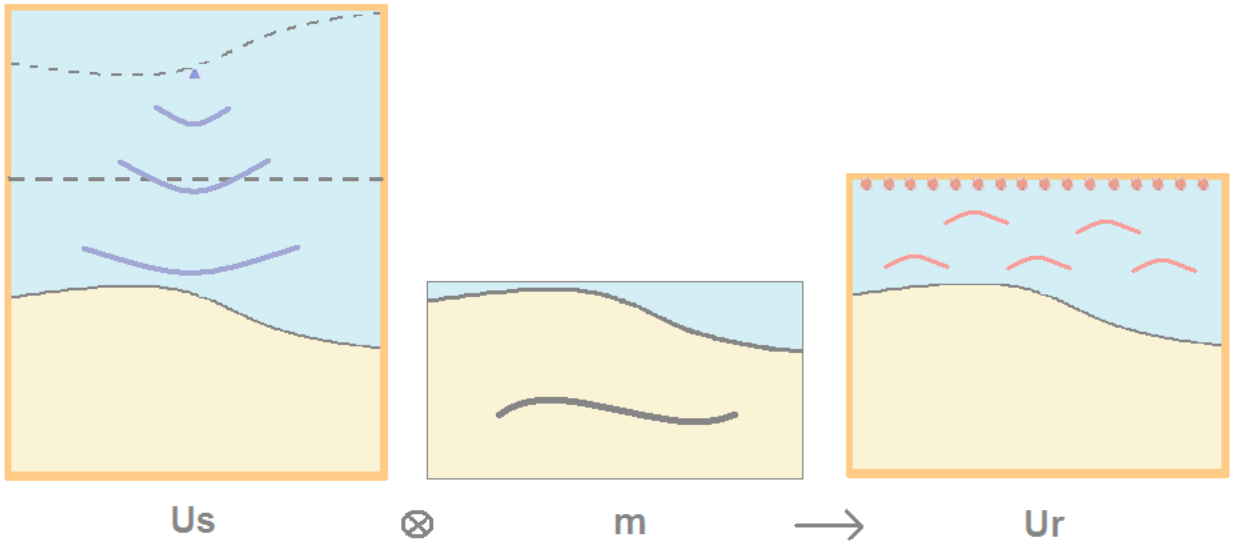

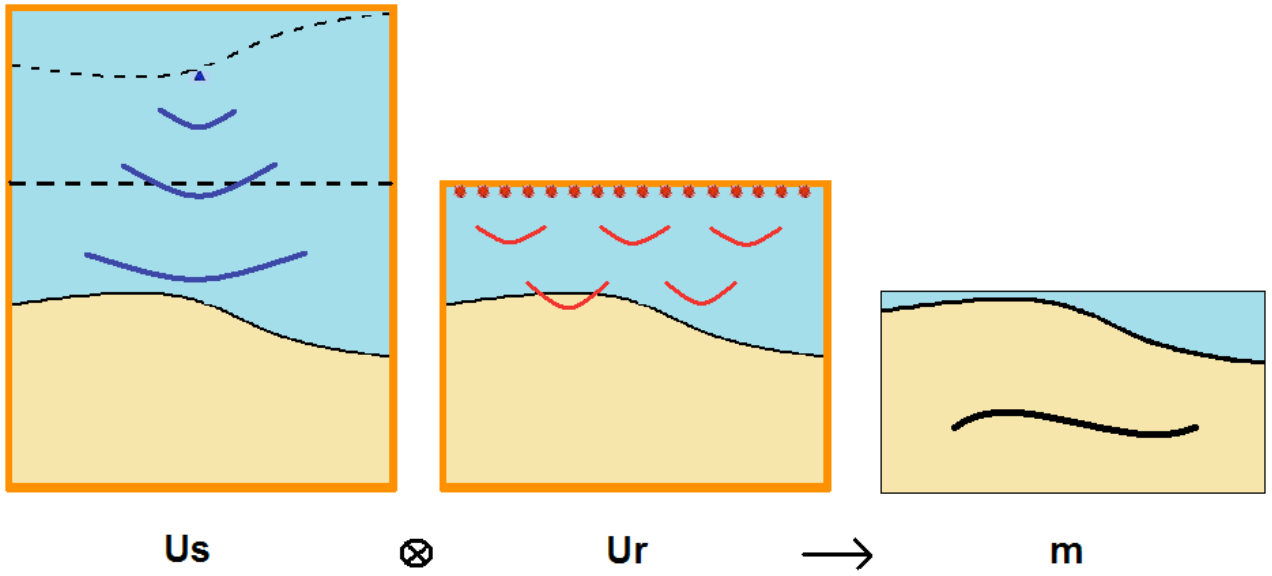

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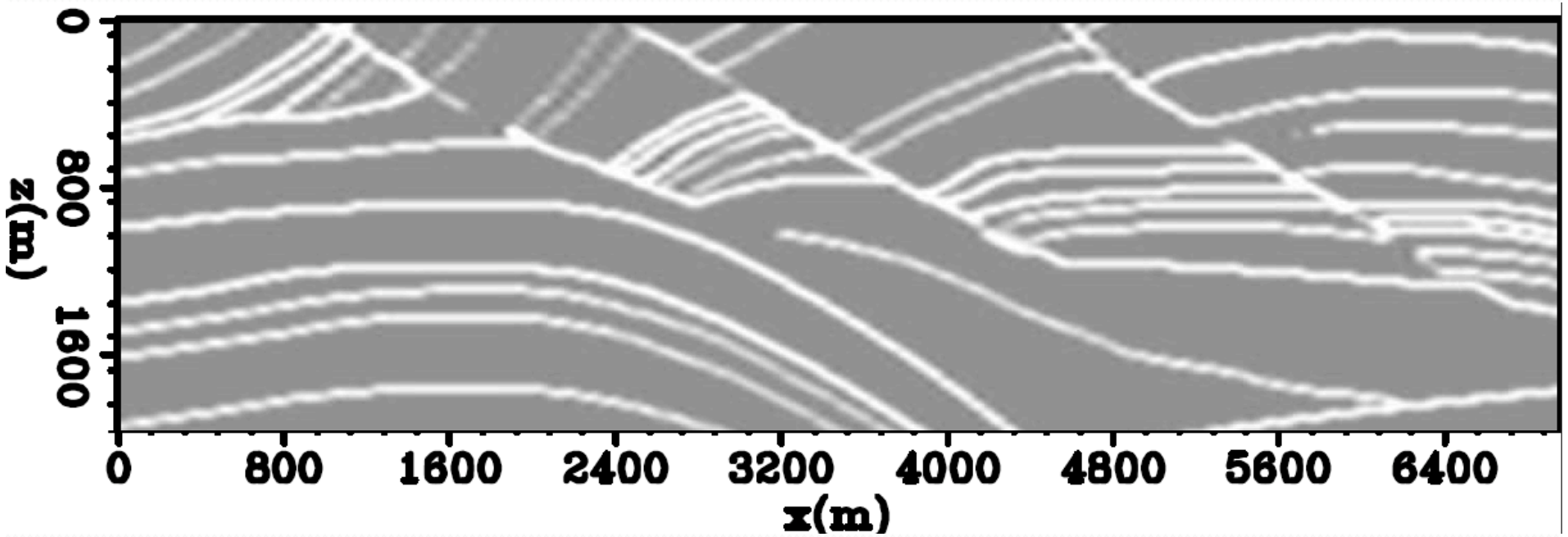
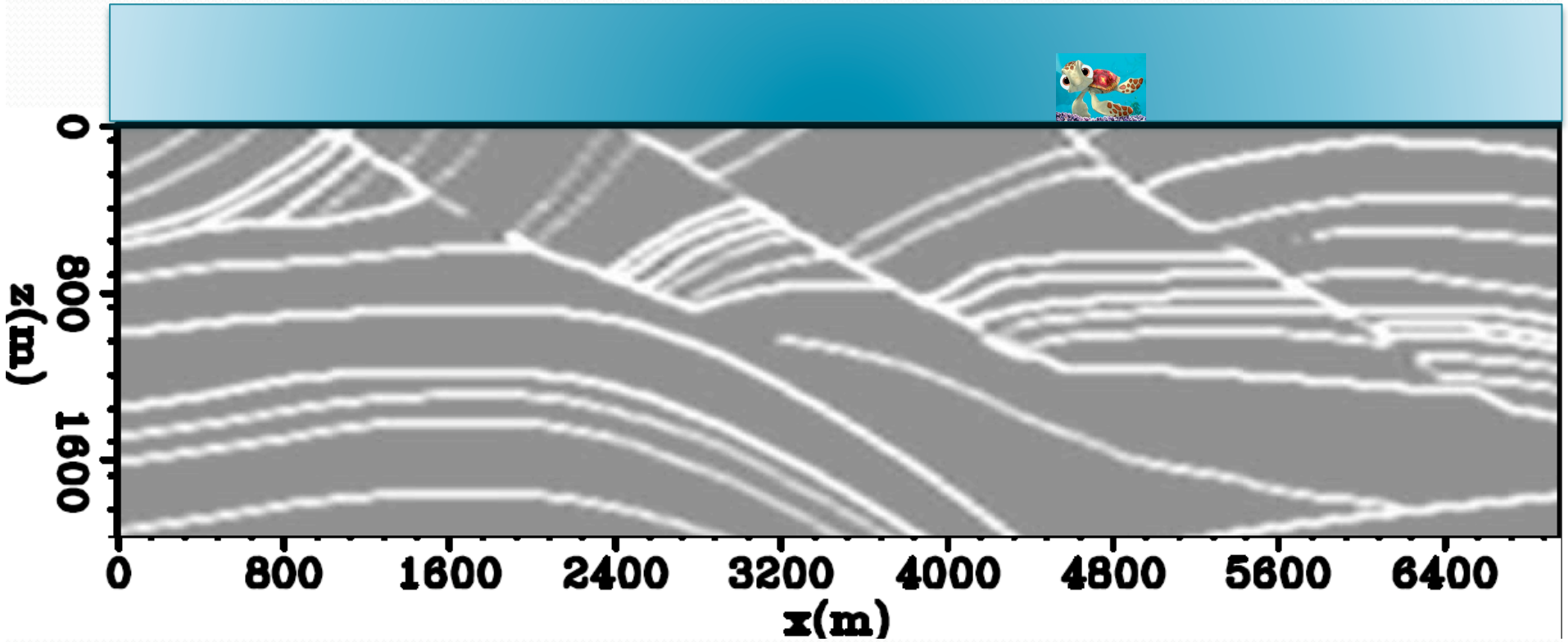
Marmousi Example 1



Numerical Example

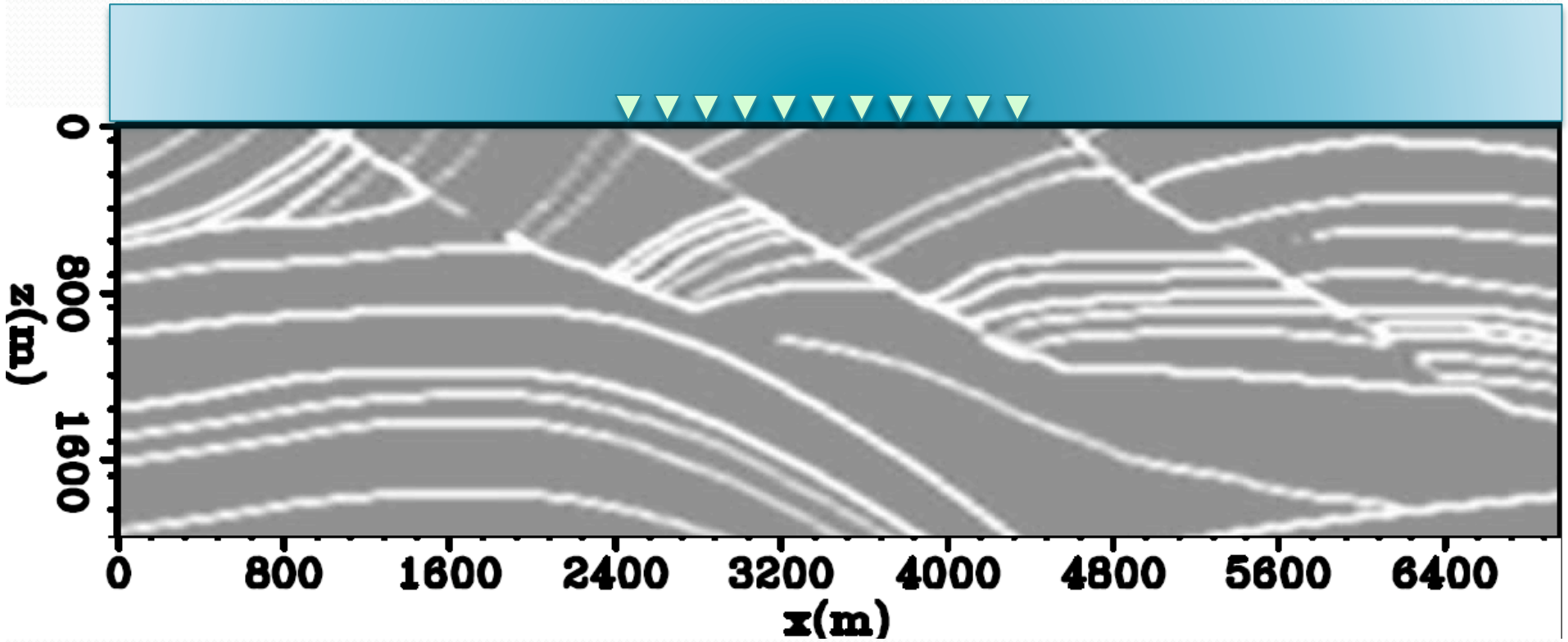
Water depth of 500m



Numerical Example

20 receivers
100m spacing

Water depth
of 500m

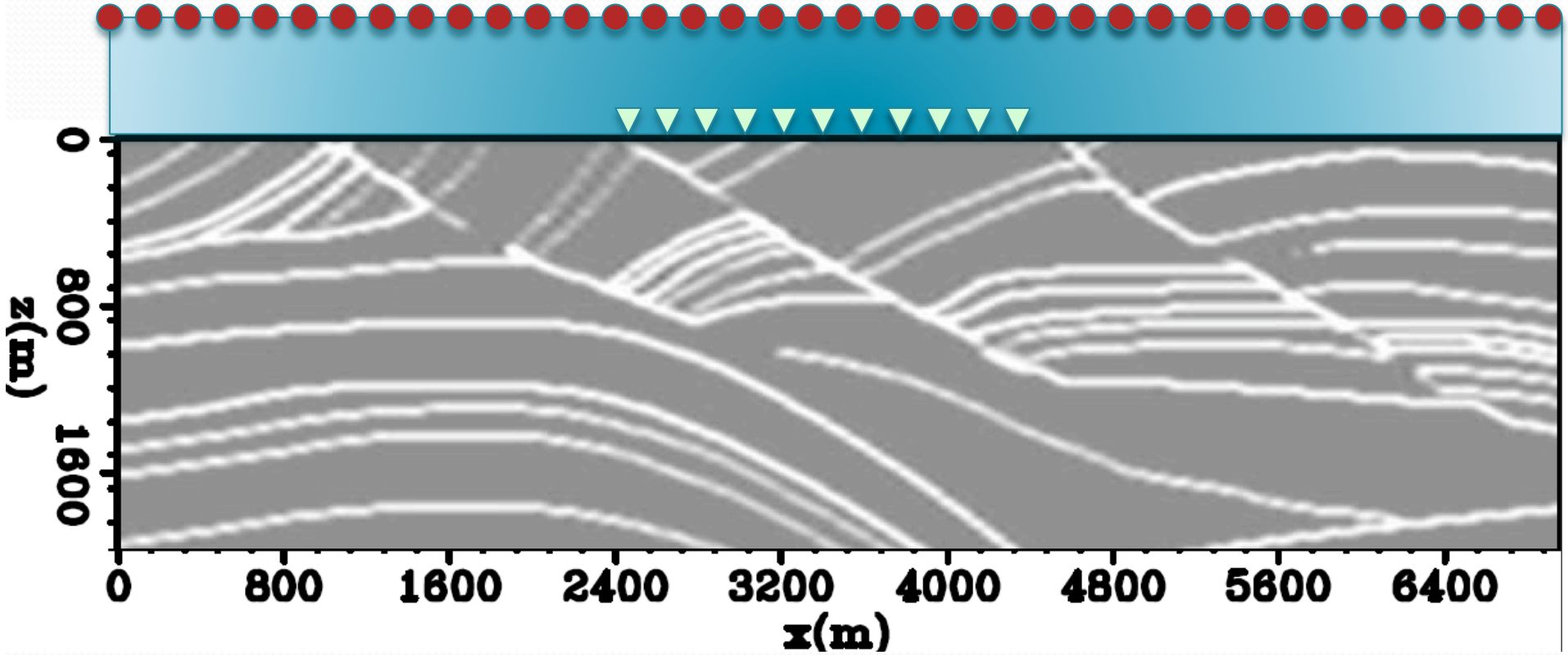


Numerical Example

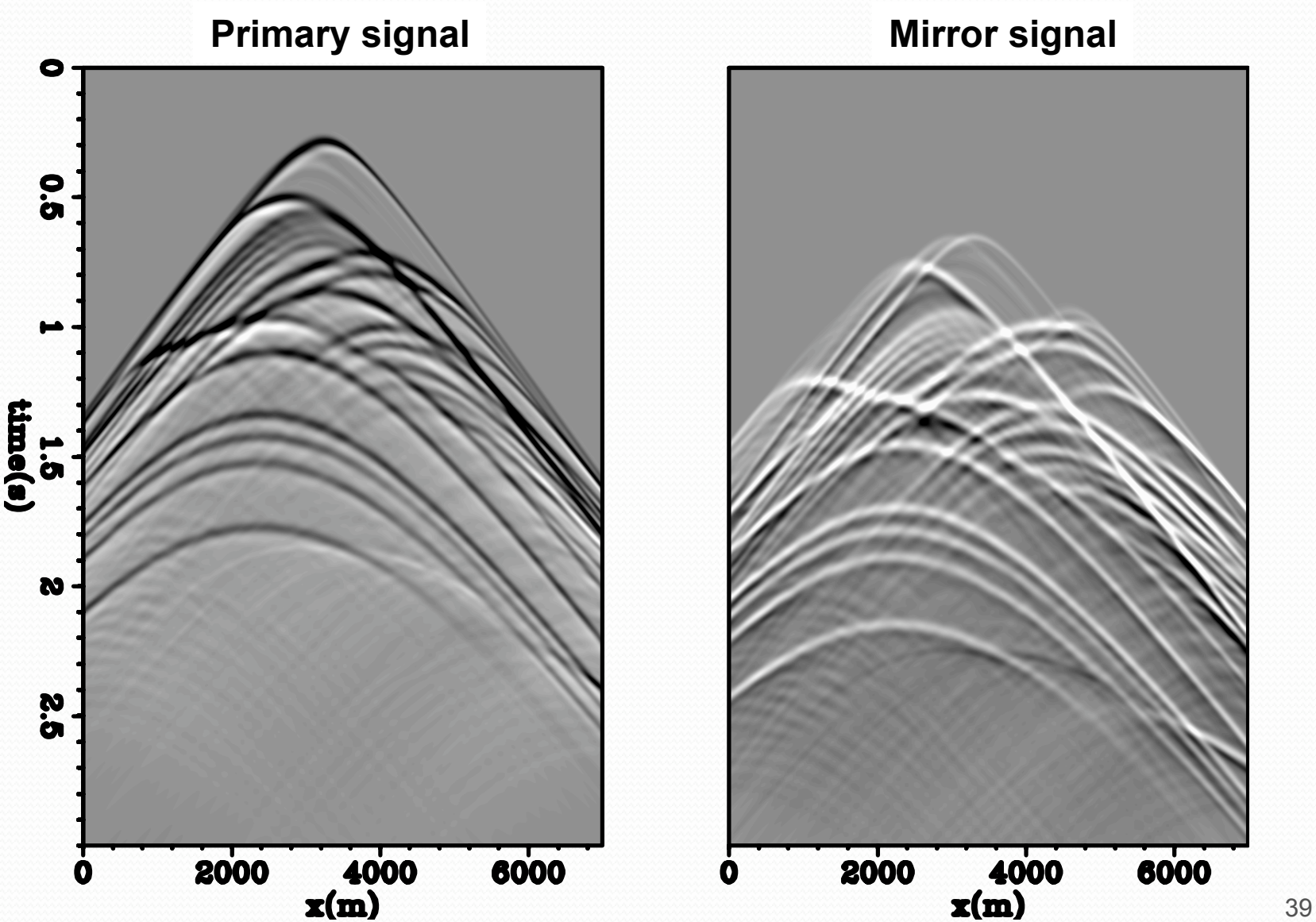
20 receivers
100m spacing

1000 shots
10m spacing

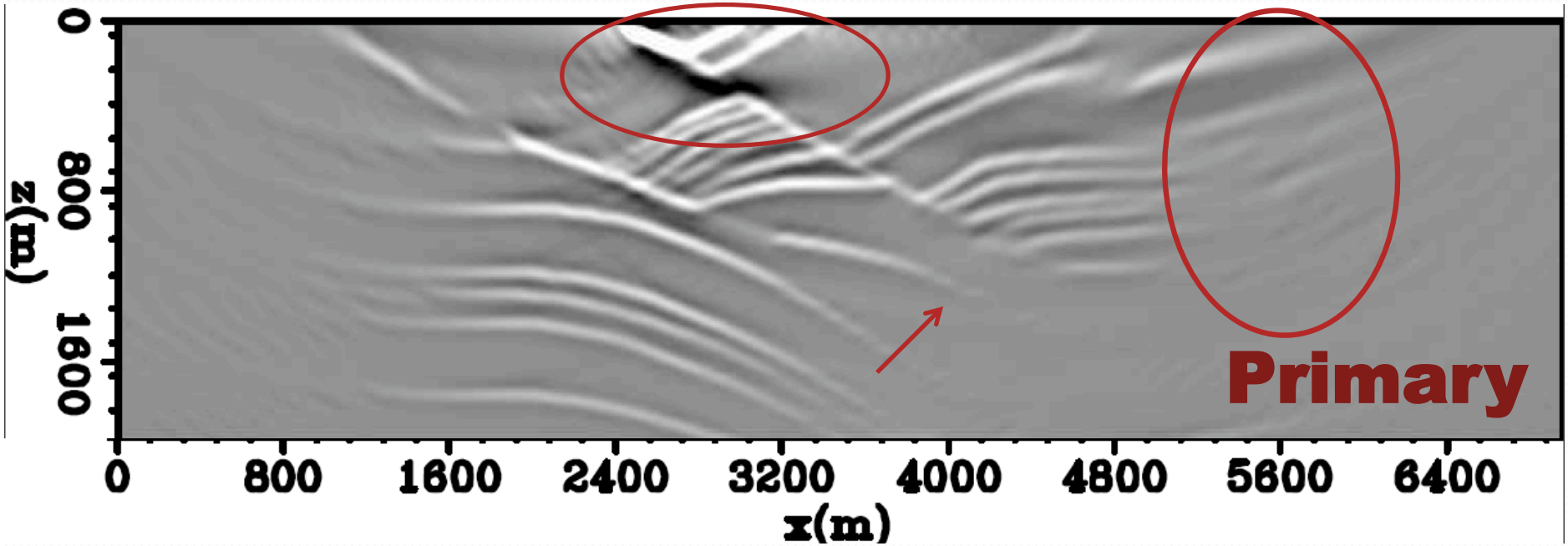
Water depth
of 500m



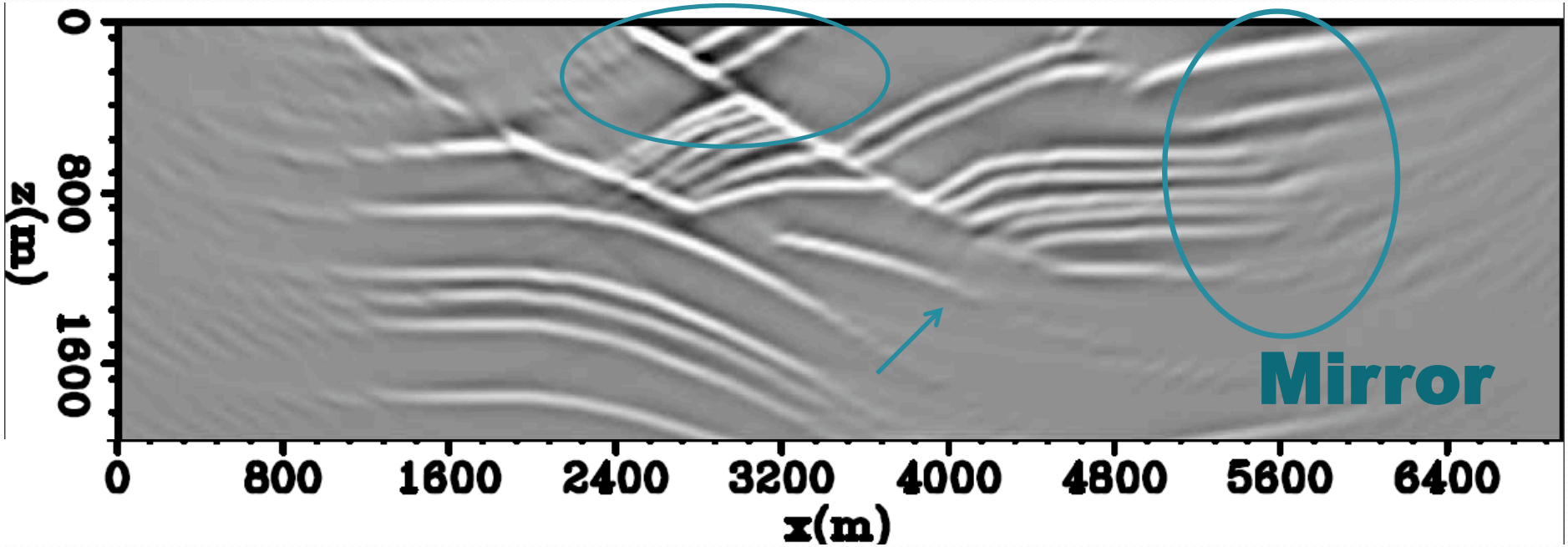
Synthetic Data



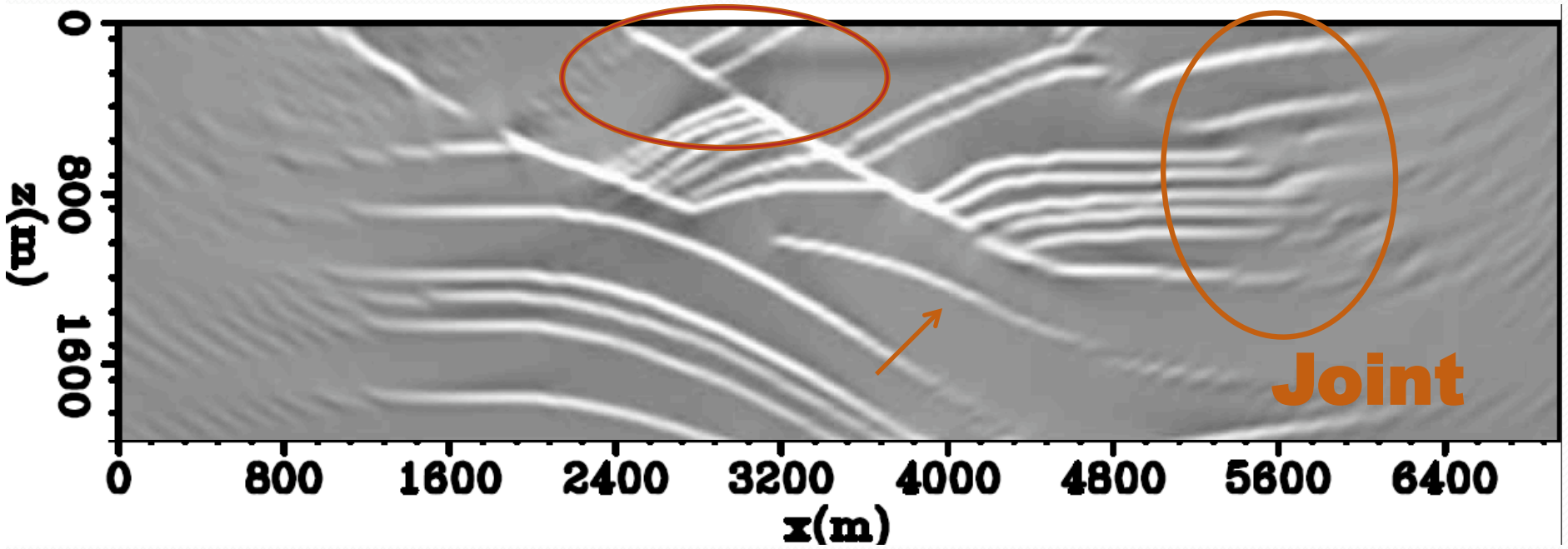
Migration with primary



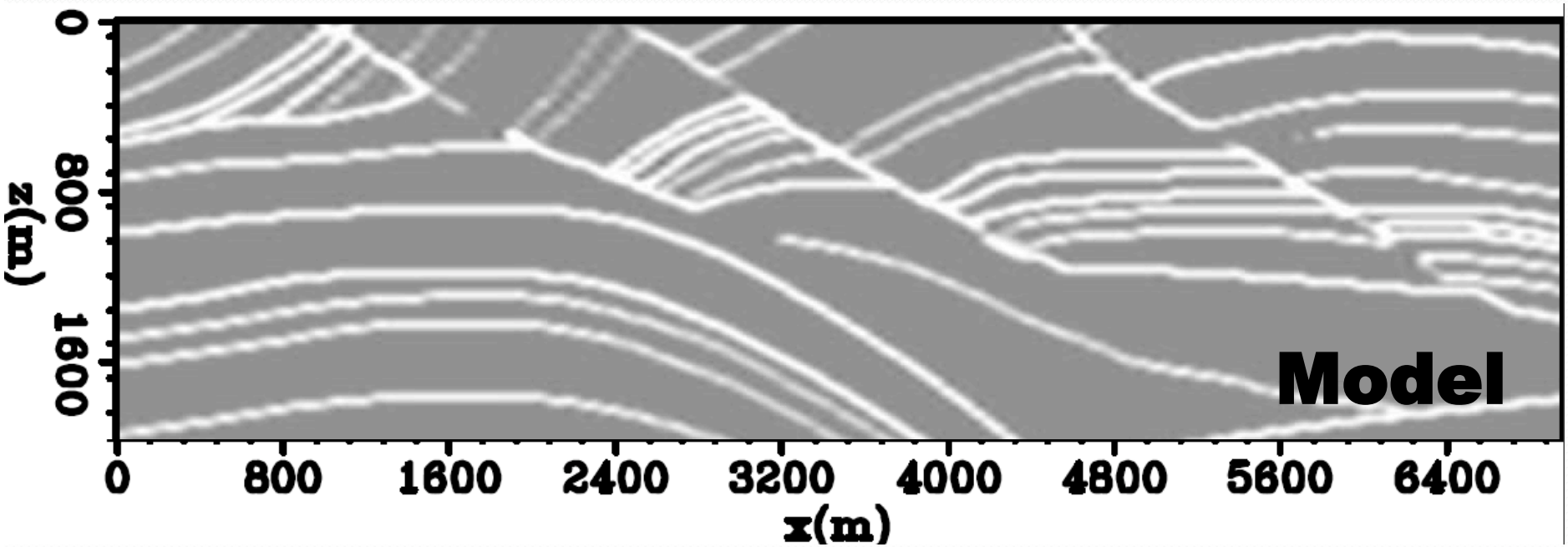
Migration with mirror signal



Joint Inversion result



Original Reflectivity model



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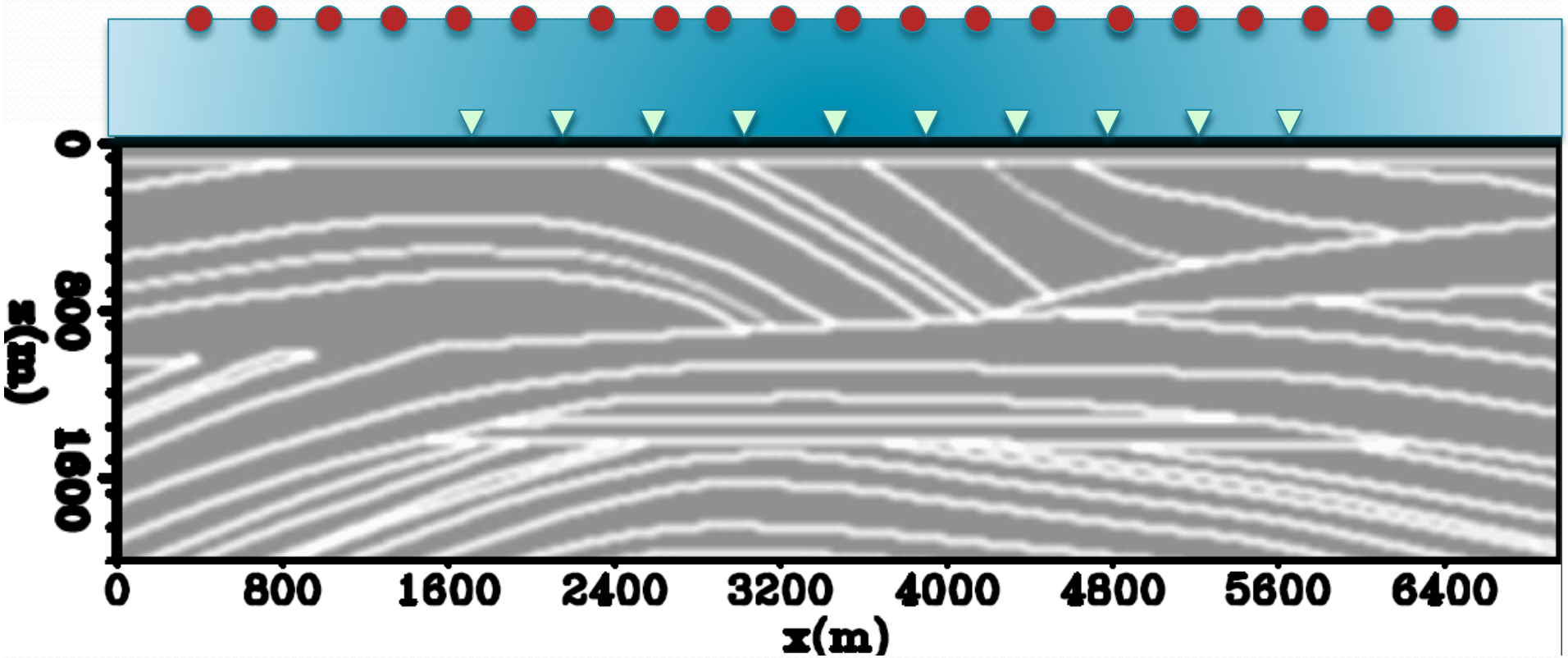
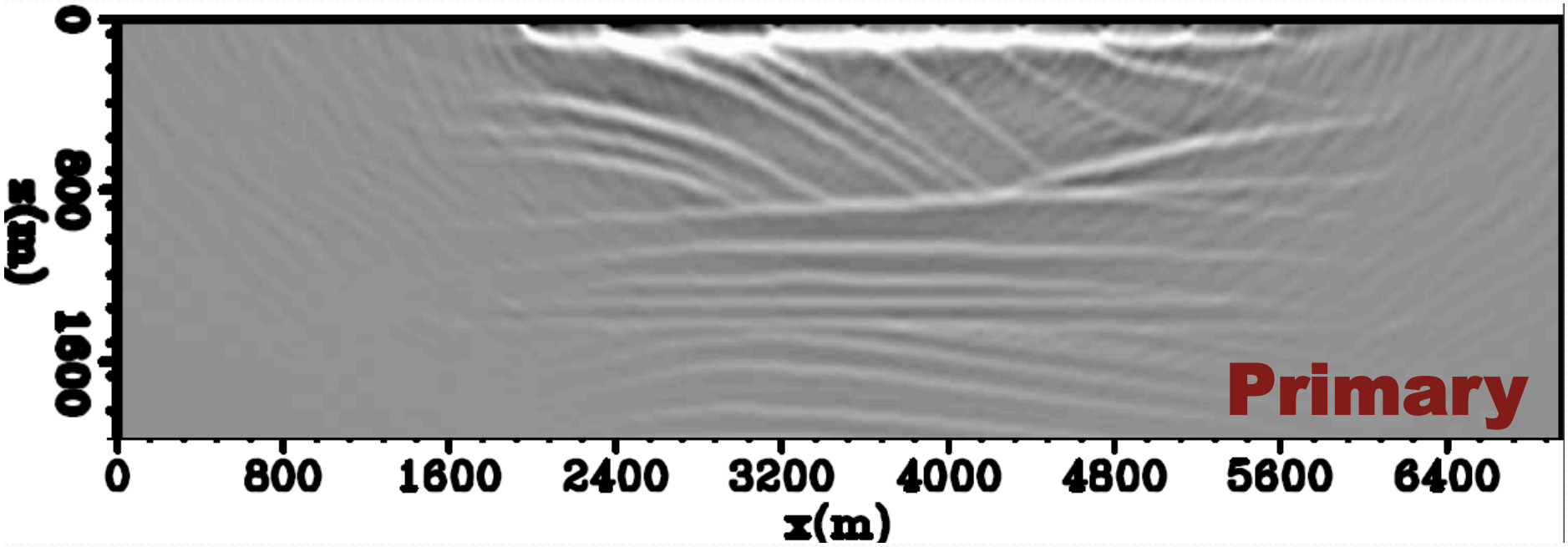
Marmousi example 2: Sparse sampling

10 receivers
400m spacing

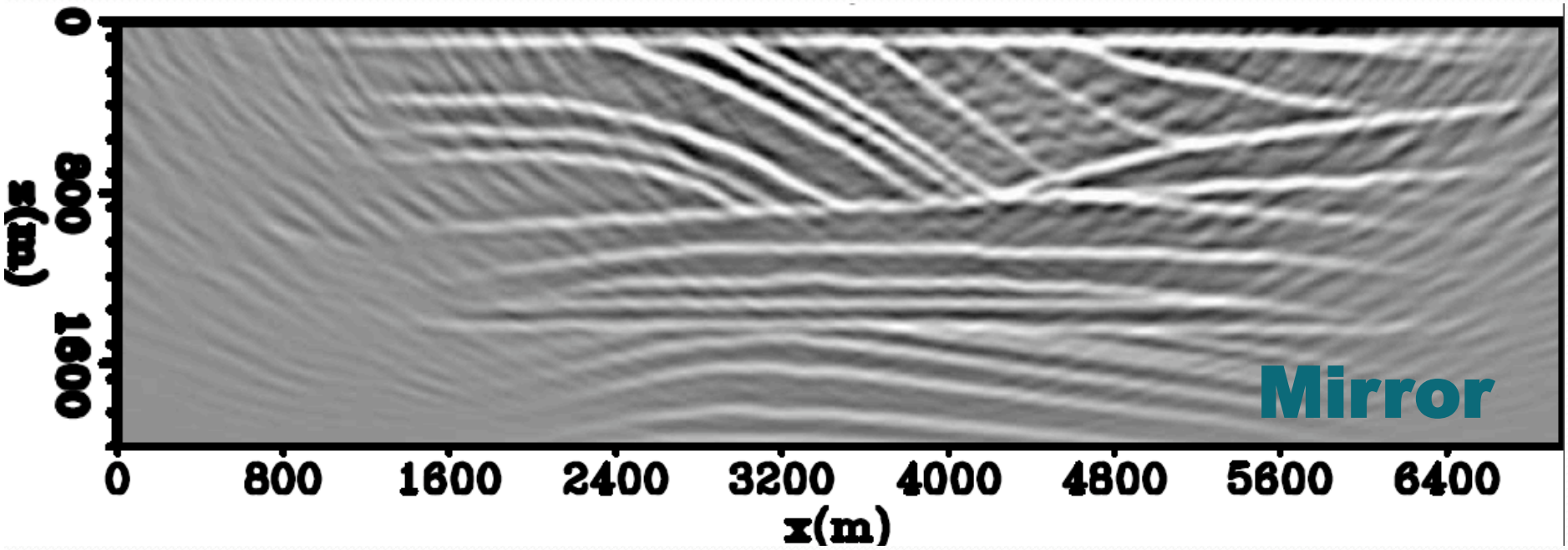
22 shots
300m spacing



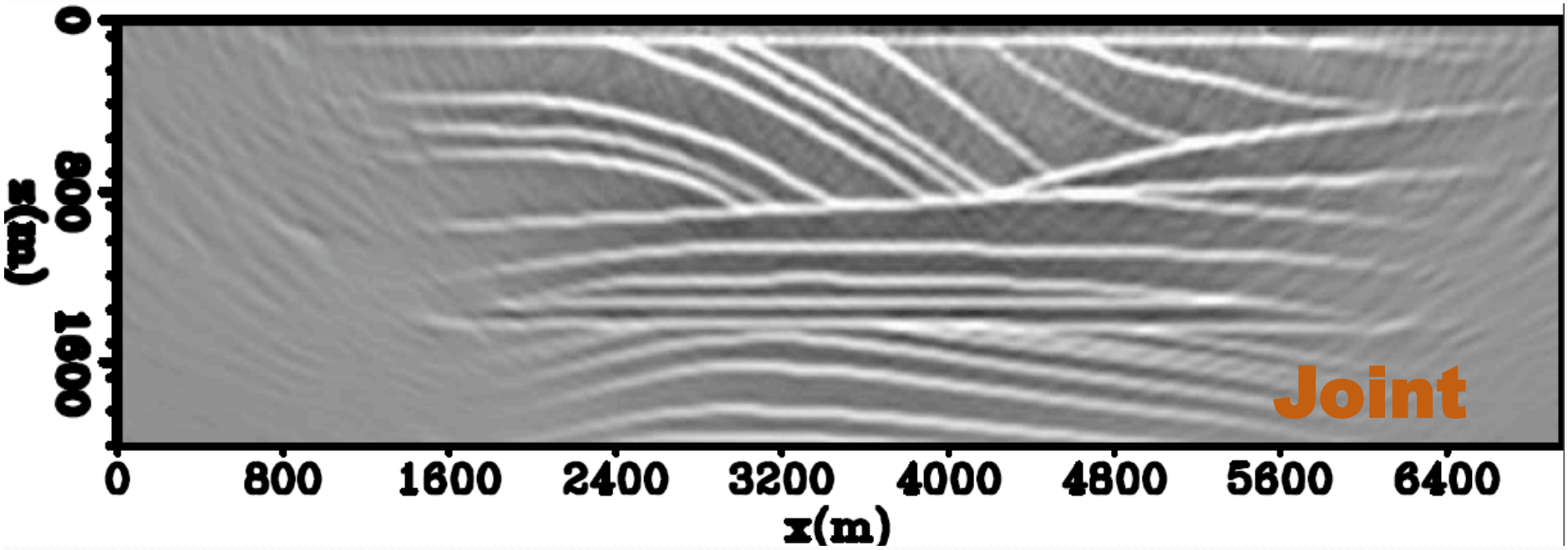
Migration with primary



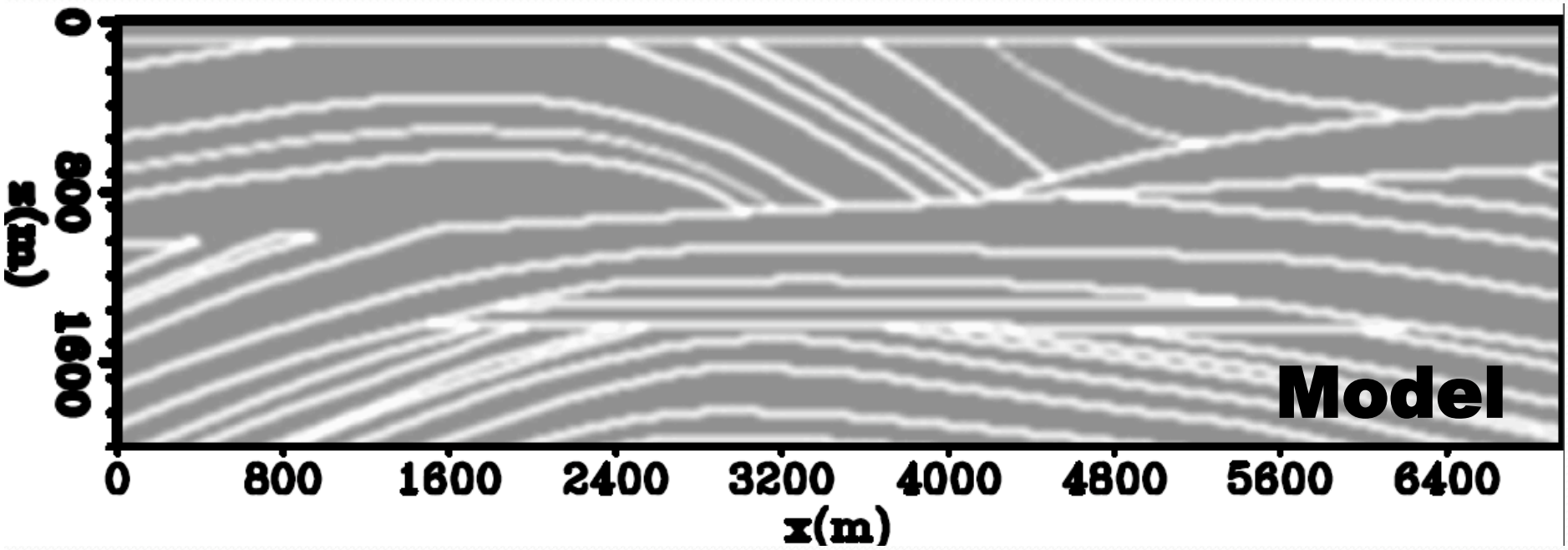
Migration with mirror signal



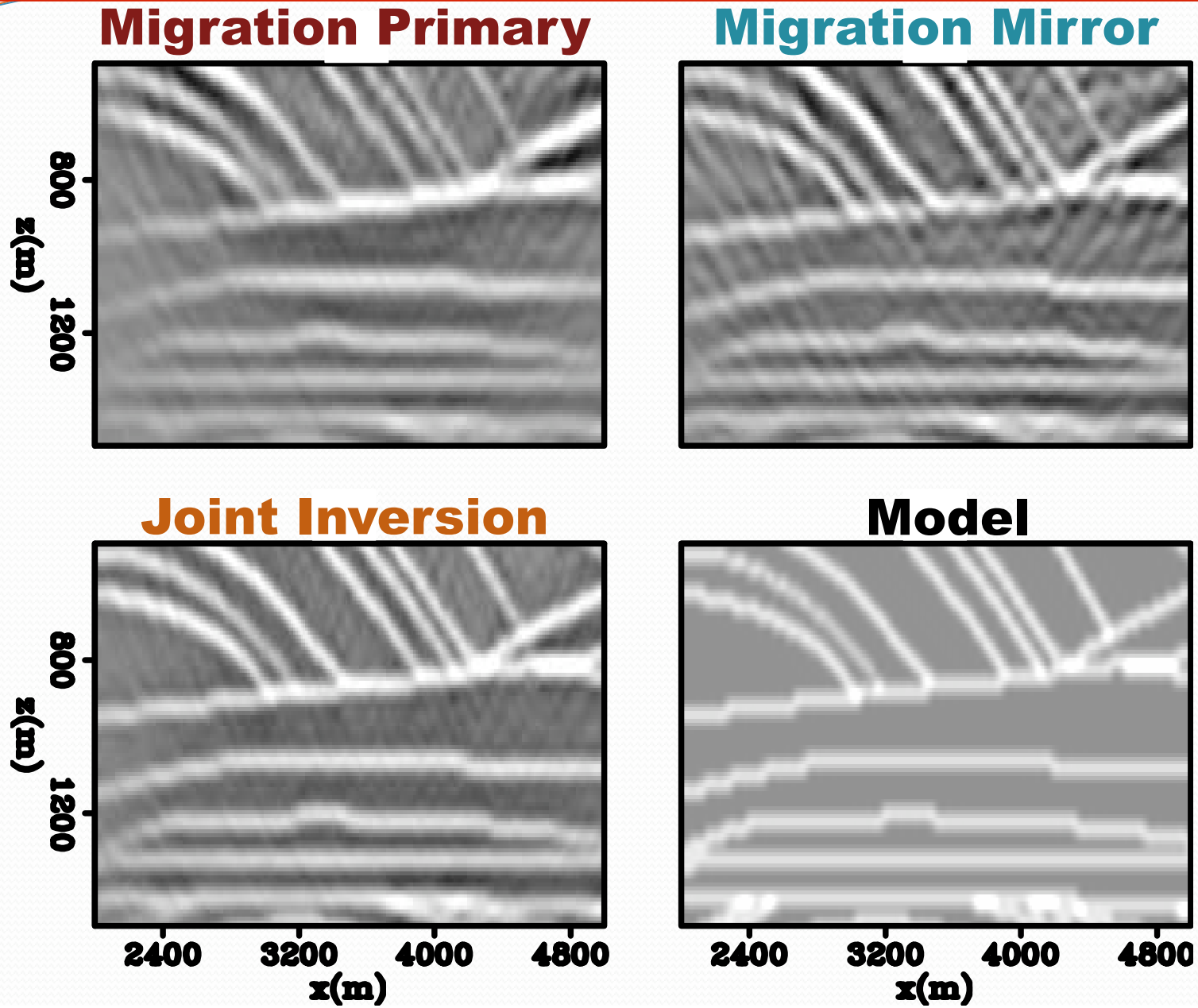
Joint Inversion result



Original reflectivity model



Comparison of Migration and Inversion



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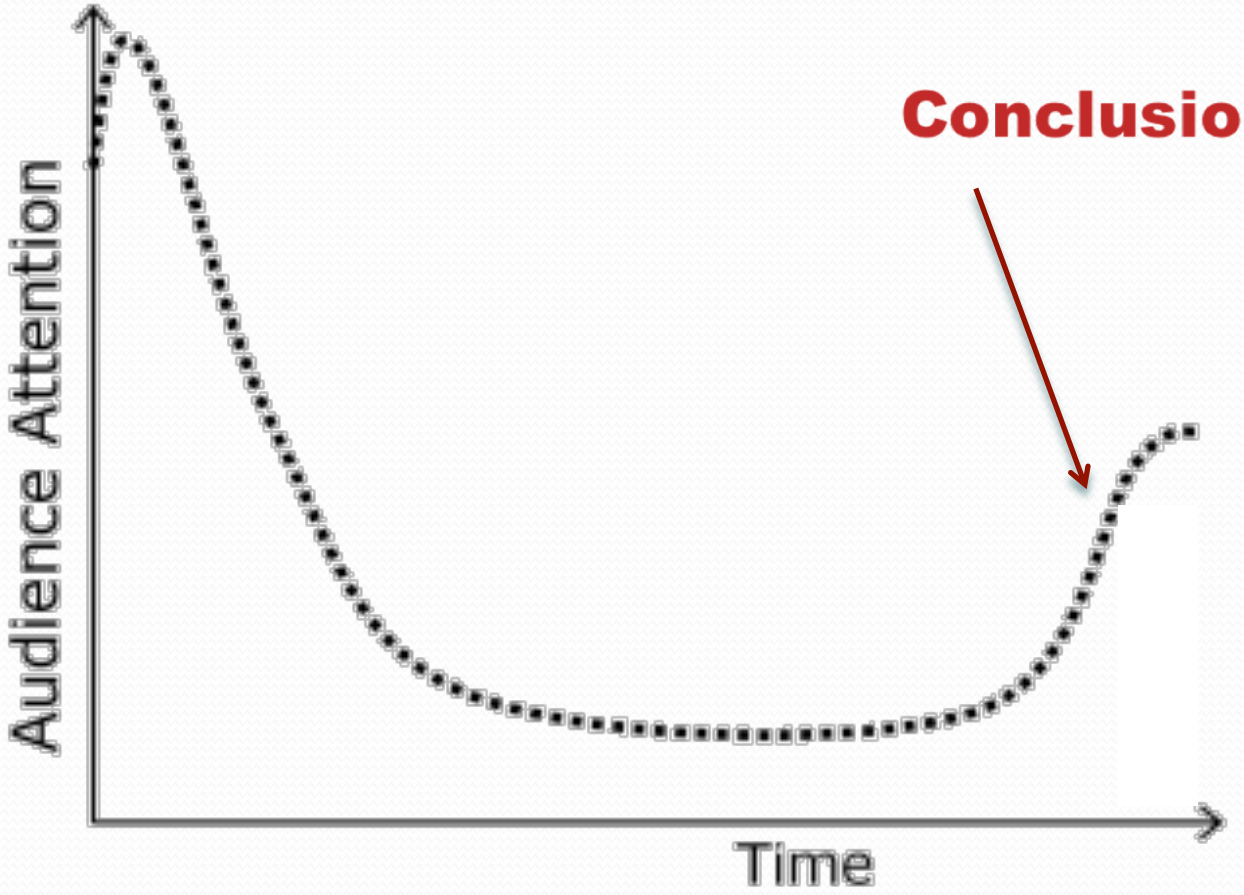

Conclusion

- **Free-surface multiples can be used as signal**

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- Developed a procedure to jointly image primary and mirror signals

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Conclusion

- Free-surface multiples can be used as signal
- Developed a procedure to jointly image primary and mirror signals
- Joint inversion combines the benefit from the two type of signals to form a coherent image
  - Higher illumination fold by the primary
  - Wider illumination by the mirror signal (for OBN geometry)

Future Work

- **Extend the procedure to image all free-surface multiples**

Future Work

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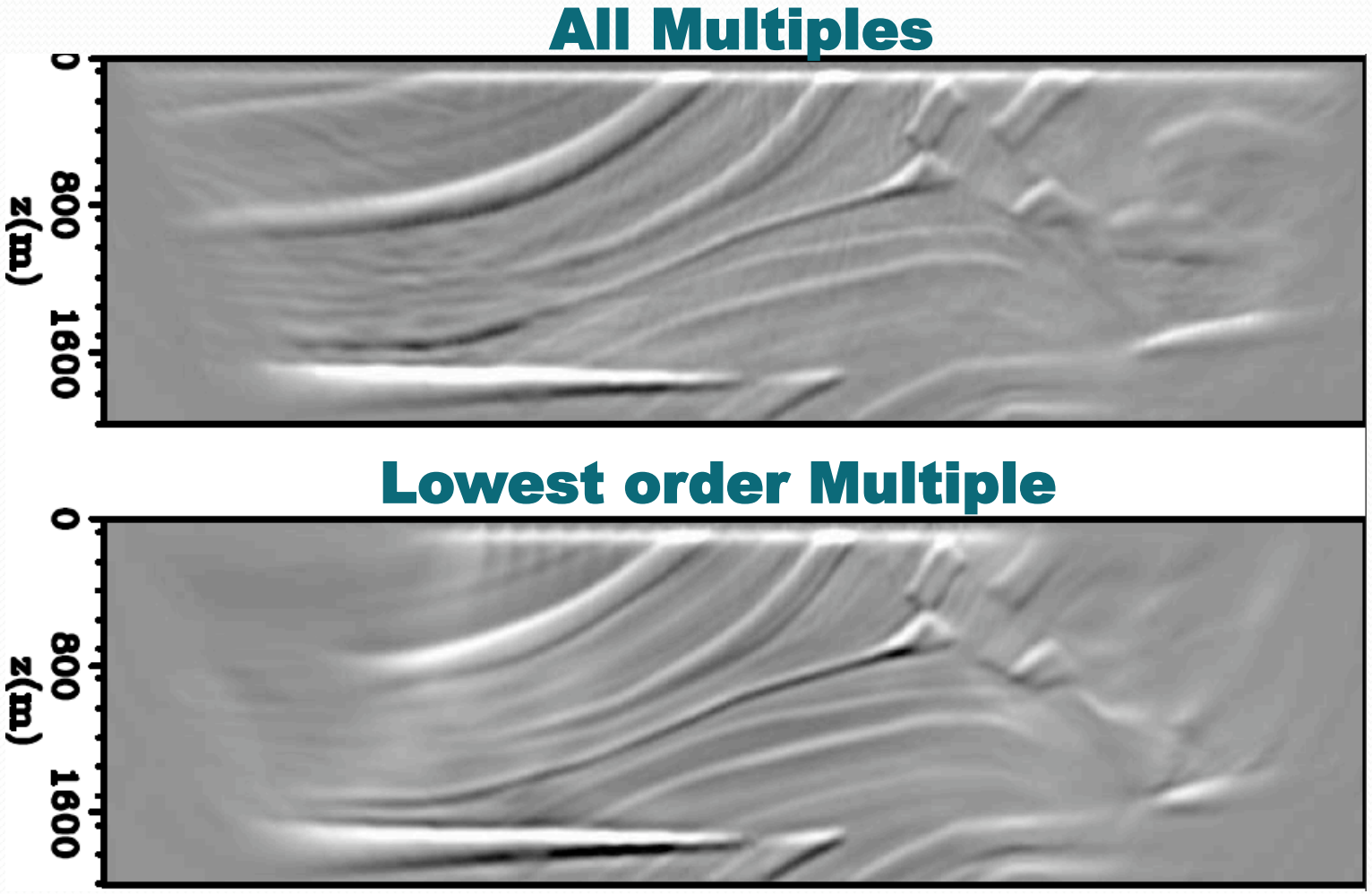

Future Work

- Extend the procedure to image all free-surface multiples
- Investigate on the optimal regularization and weighting for the inverse problem

mandyman@sep.stanford.edu