Joint inversion of reflectivity and background subsurface components

Thesis defense

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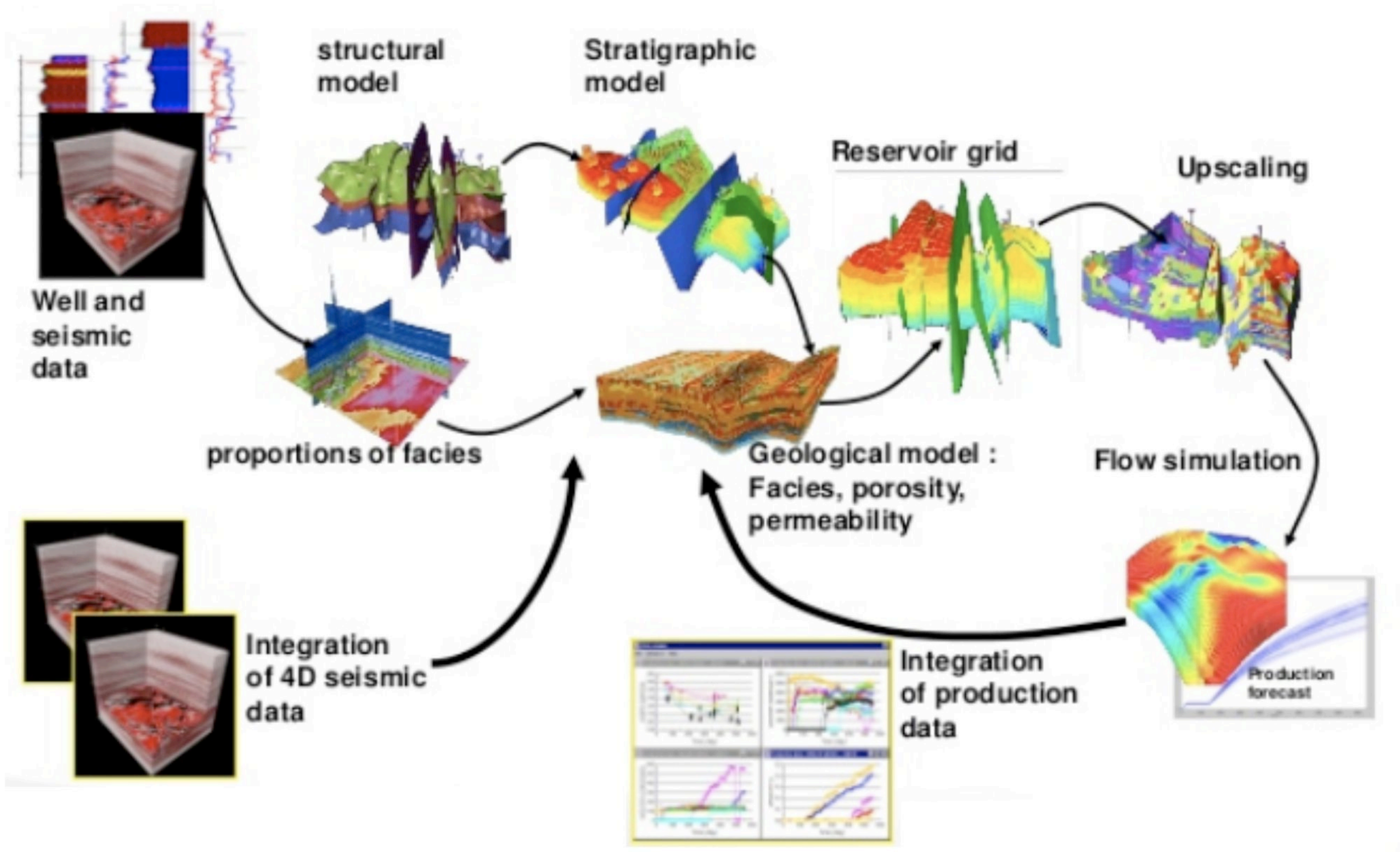
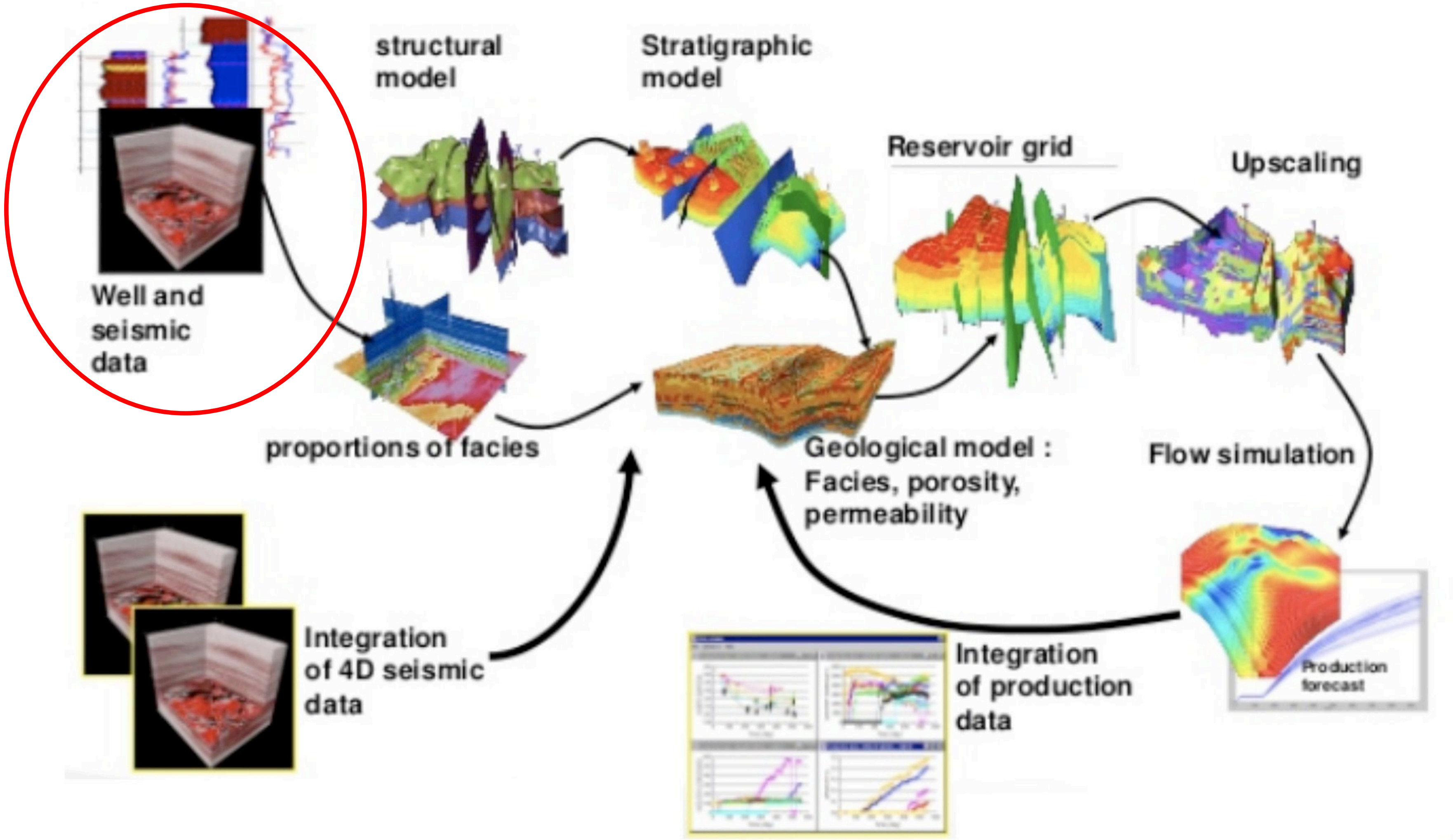
August 14, 2020

INTRODUCTION



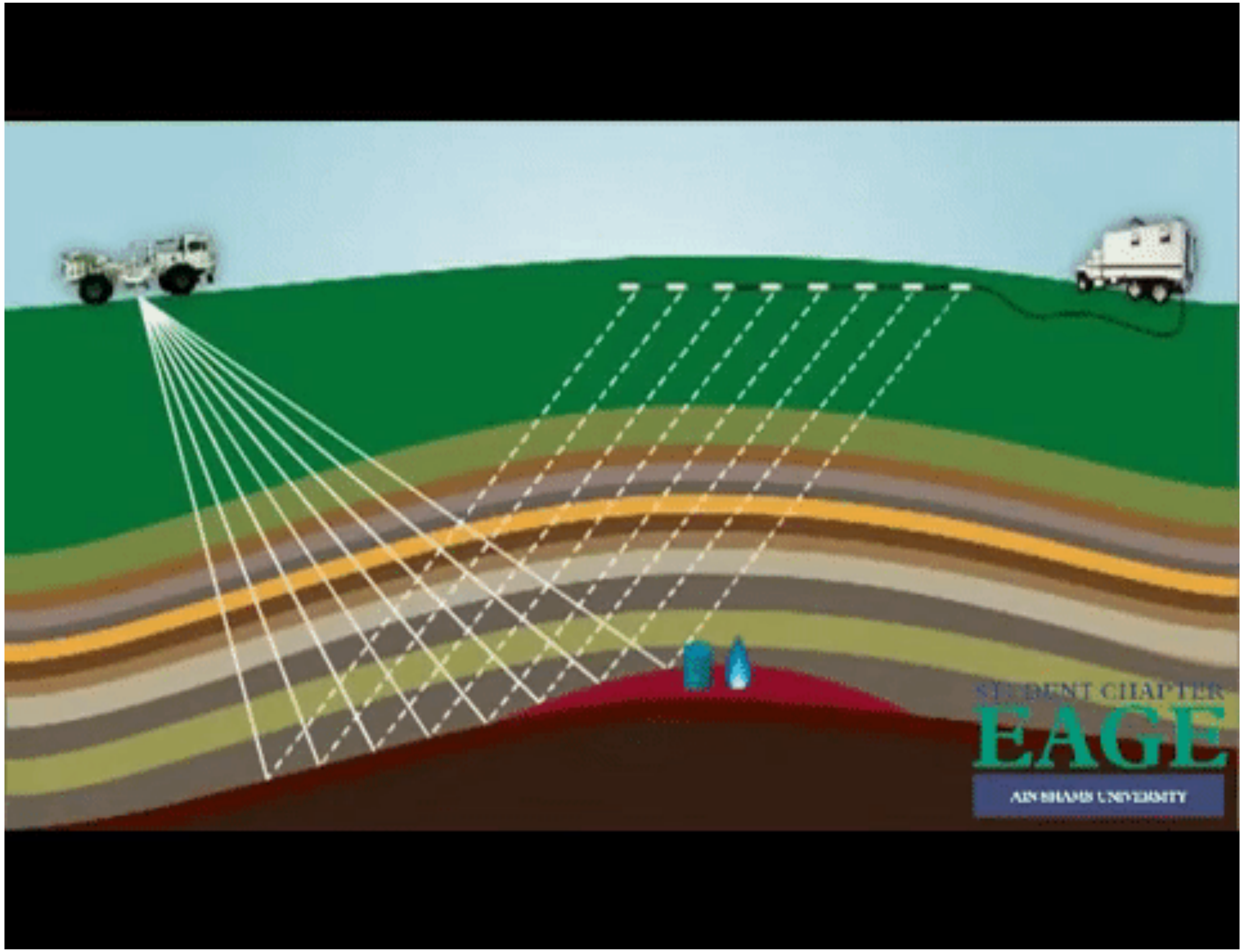
INTRODUCTION



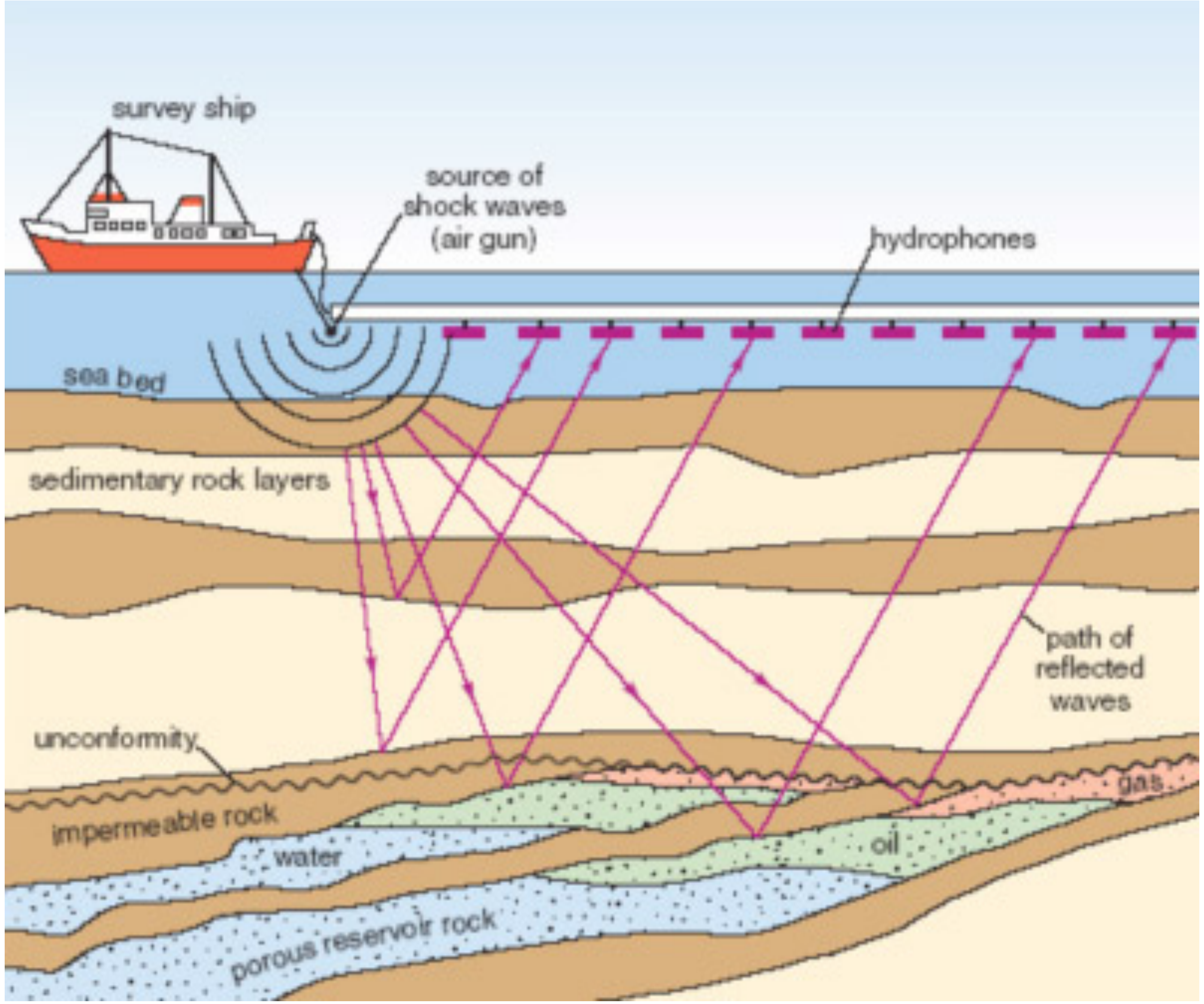
Main task in seismic imaging:

Estimate acoustic/elastic subsurface parameters!

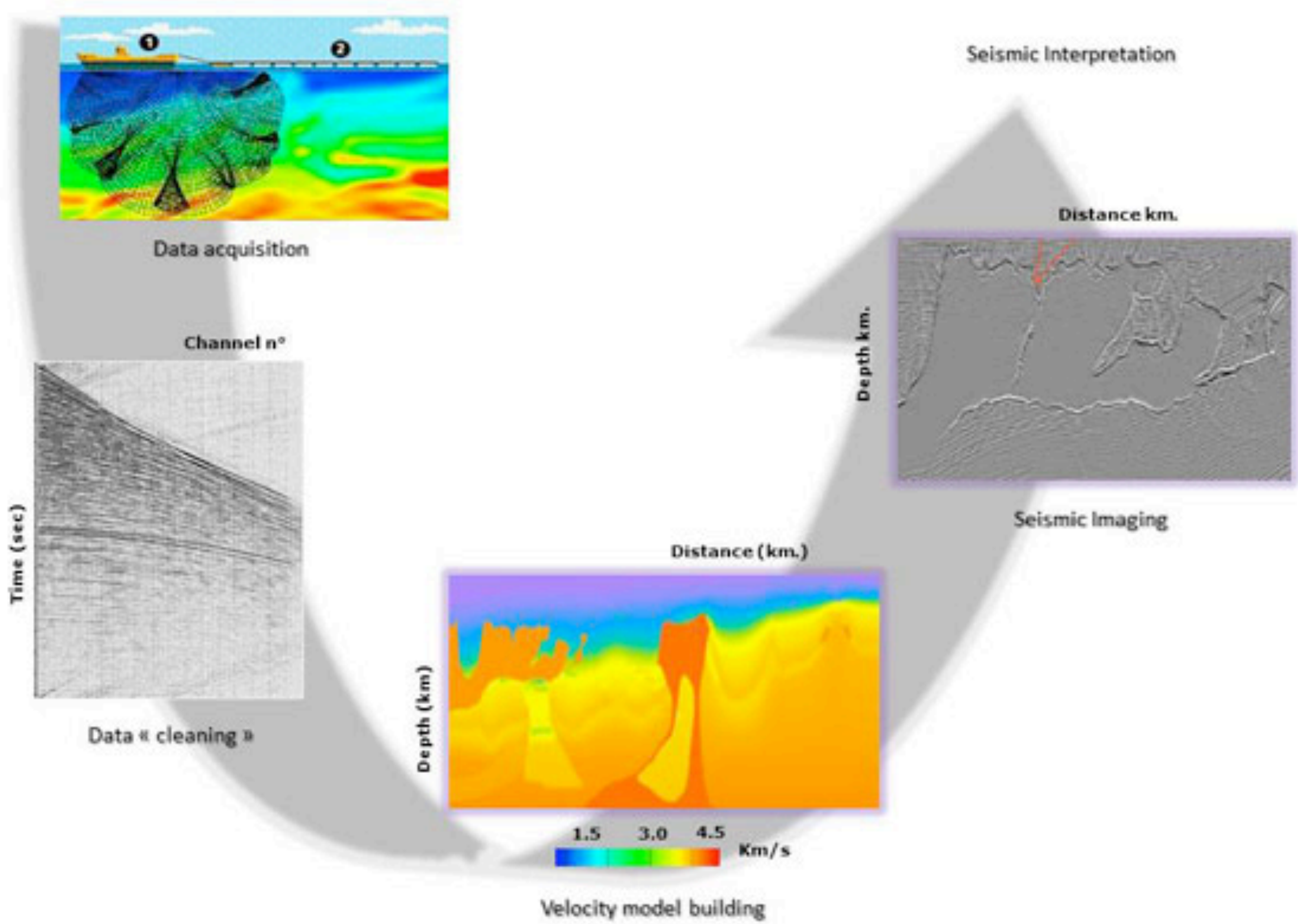
First, we need to acquire seismic data, onshore…



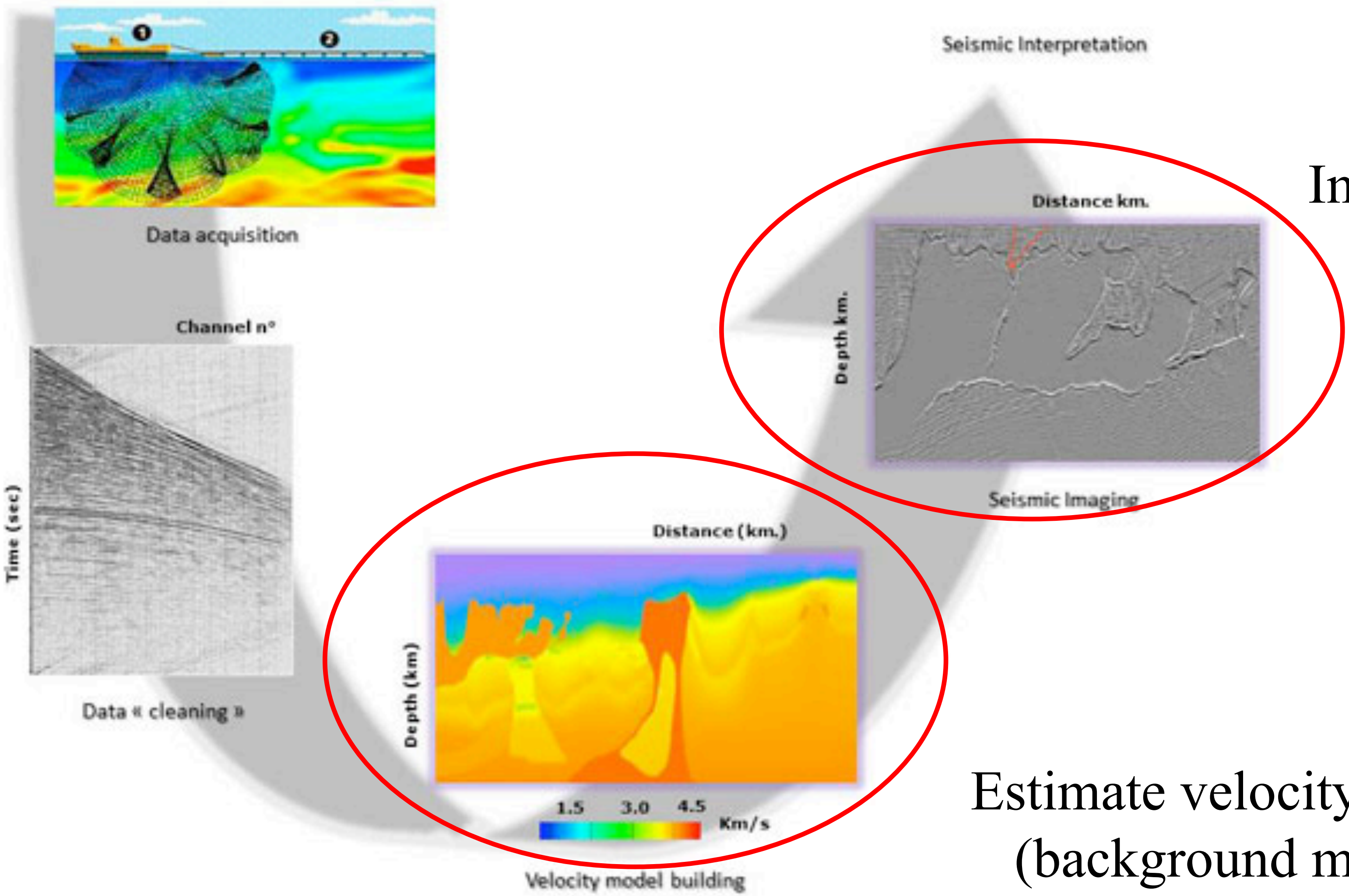
… or offshore!


survey ship
source of
shock waves
(air gun)
hydrophones
sea bed
sedimentary rock layers
path of
reflected
waves
unconformity
gas
impermeable rock
water
oil
porous reservoir rock

Next, we need to process the seismic data!



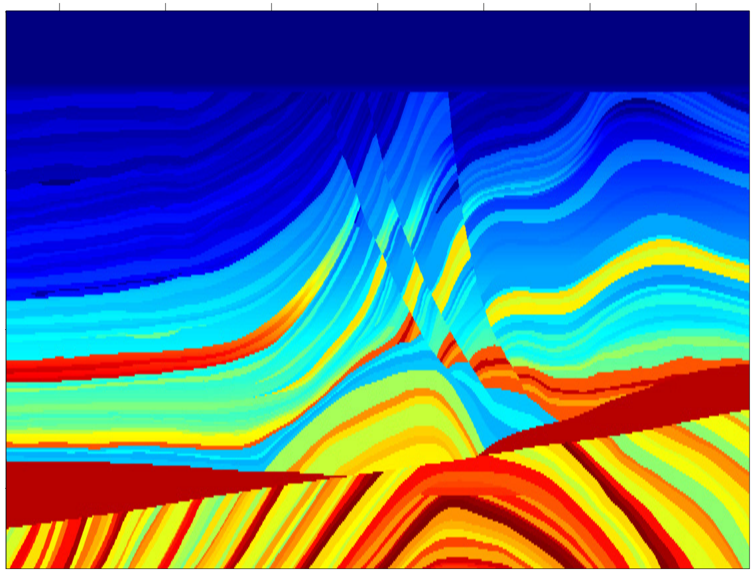
Next, we need to process the seismic data!



Imaging

Estimate velocity model (background model)

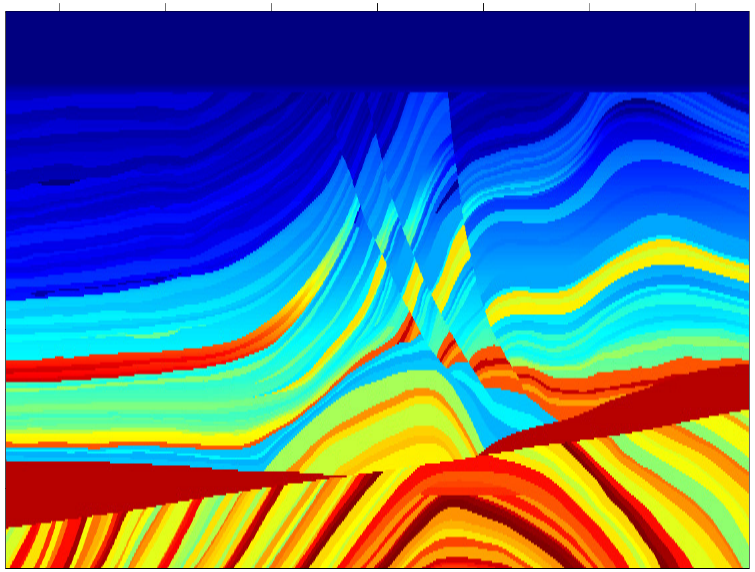
Different scales of the subsurface parameters

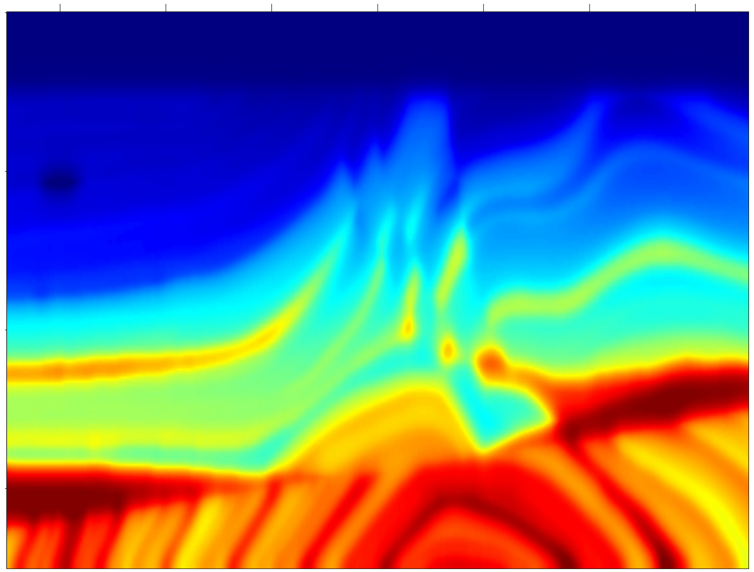


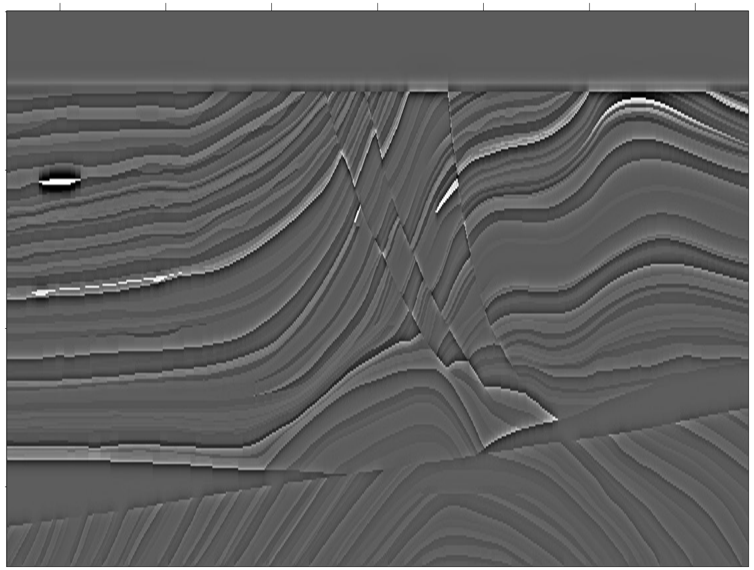
m

Subsurface model

Different scales of the subsurface parameters







m = **b** + **r**

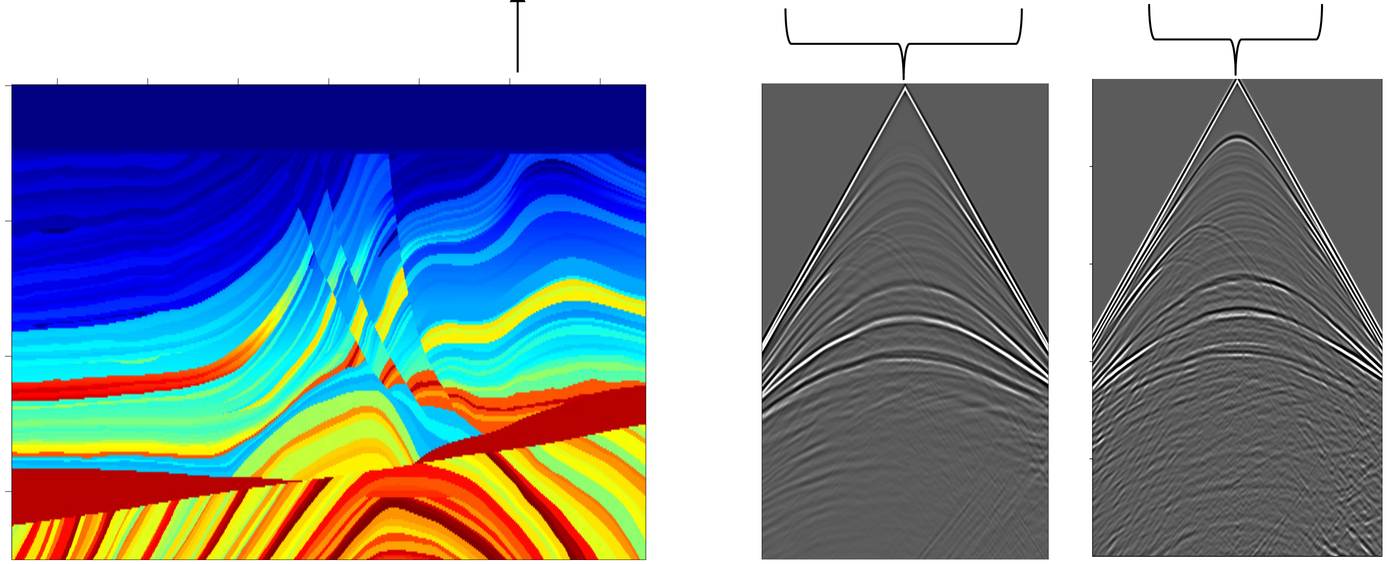
Subsurface model

Background component of subsurface model (low-wavenumber component)

Reflectivity component of subsurface model (high-wavenumber component)

Full waveform inversion (FWI)

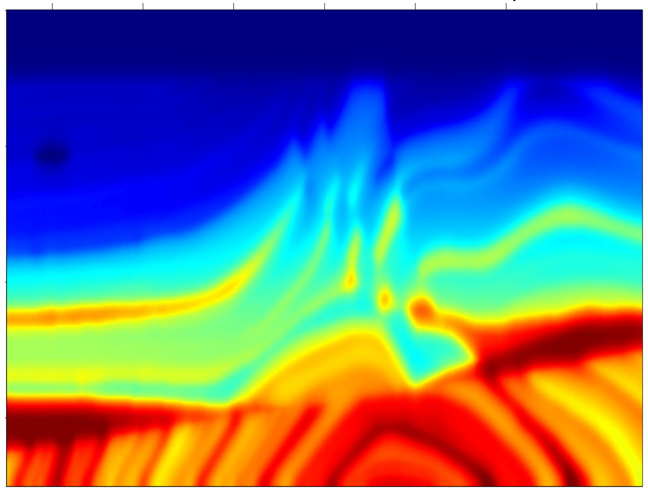
$$\Phi(\mathbf{m}) = \|\mathcal{L}(\mathbf{m}) - \mathbf{d}_{\text{obs}}\|_2^2$$

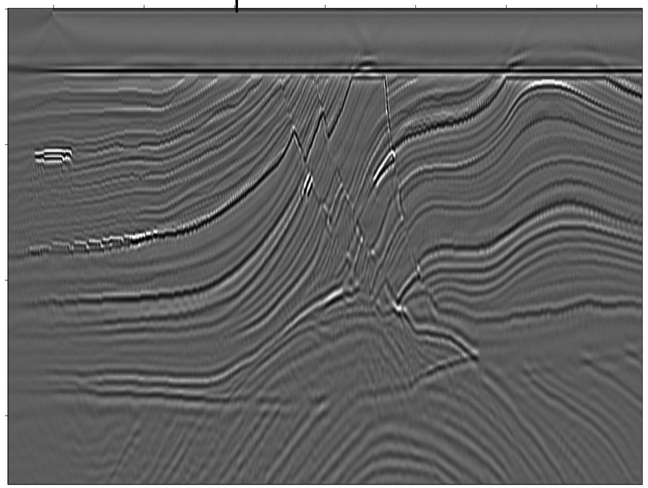


- Predict data with the acoustic/elastic wave equation
- Nonlinear; presence of local minima
- We obtain a high-wavenumber version of **b**!

Wave-equation migration velocity analysis (WEMVA)

$$\Phi(\mathbf{b}) = -\|\mathbf{I}(\mathbf{b})\|_2^2$$



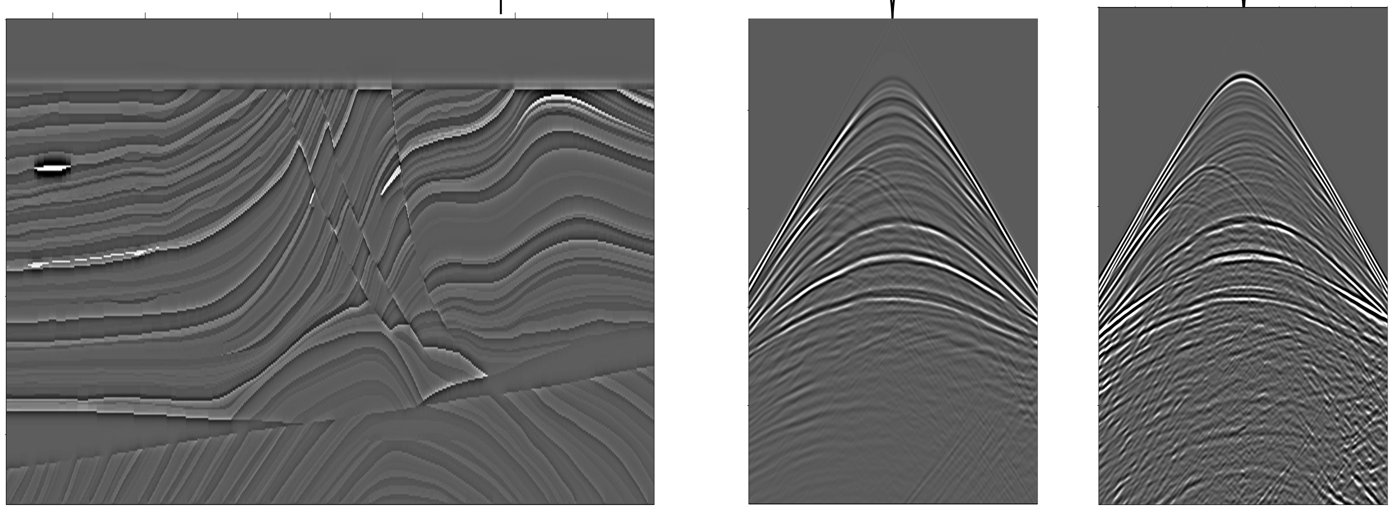


- Generally good for imaging purposes!
- FWI should be better, but it’d more prone to fall into local minima
- A good idea could be used WEMVA model as input for FWI!

INTRODUCTION

Linearized waveform inversion (*data space*)

$$\Phi(\mathbf{r}) = \|\mathbf{L}(\mathbf{b})\mathbf{r} - \mathbf{\Delta d}\|_2^2$$



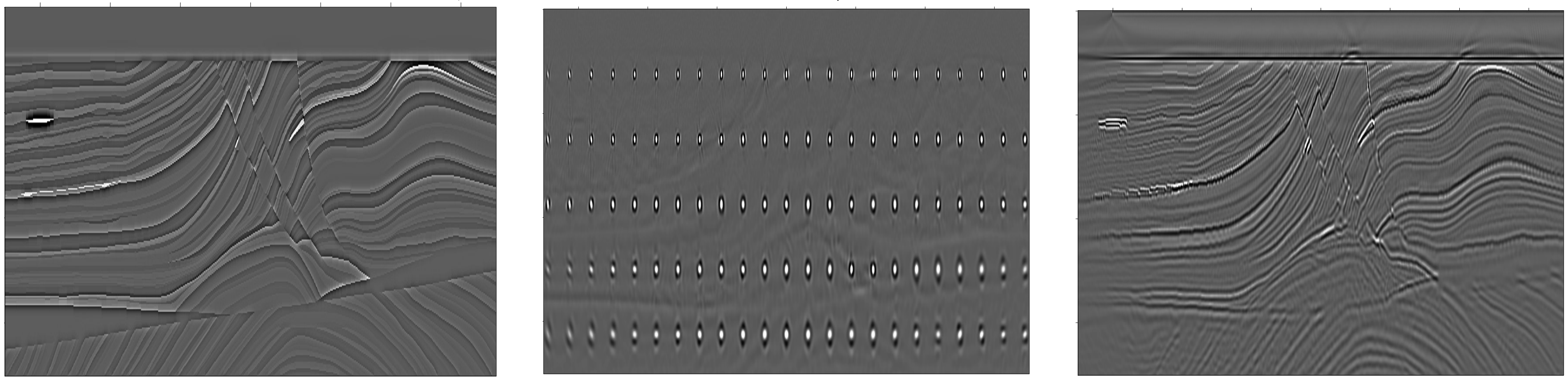
Conventional migration!

$$\mathbf{I}(\mathbf{b}) = \mathbf{L}(\mathbf{b})^T\mathbf{\Delta d}$$

- Also known as “Least-squares migration”
- Assumes accurate background subsurface model
- Effective, but requires lots of computations: 1 iteration costs ~ 2 migrations

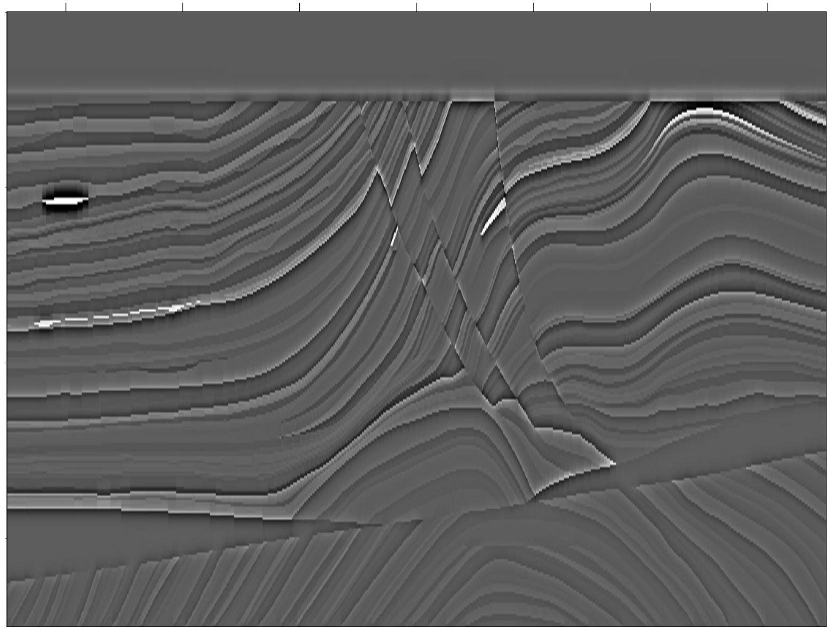
Linearized waveform inversion (*image space*)

$$\Phi(\mathbf{r}) = \|\mathbf{H}(\mathbf{b})\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2$$

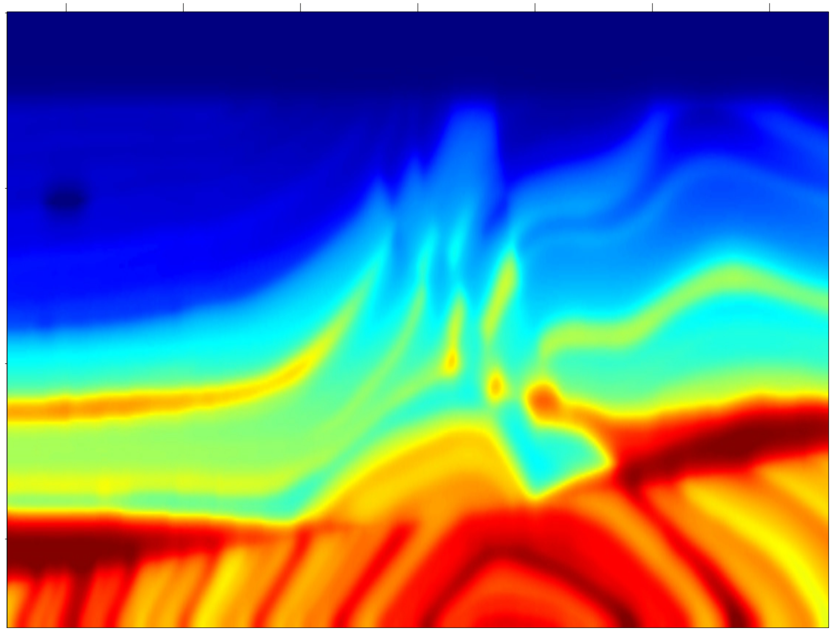


- The FWI's Gauss-Newton Hessian is defined as: $\mathbf{H} = \mathbf{L}^\mathrm{T}\mathbf{L}$
- It can be less precise than data-space LWI
- Once the Hessian is estimated, the inversion is fast (matrix-like multiplications)

<u>Thesis proposal</u>: Inverting for the reflectivity and background model simultaneously!

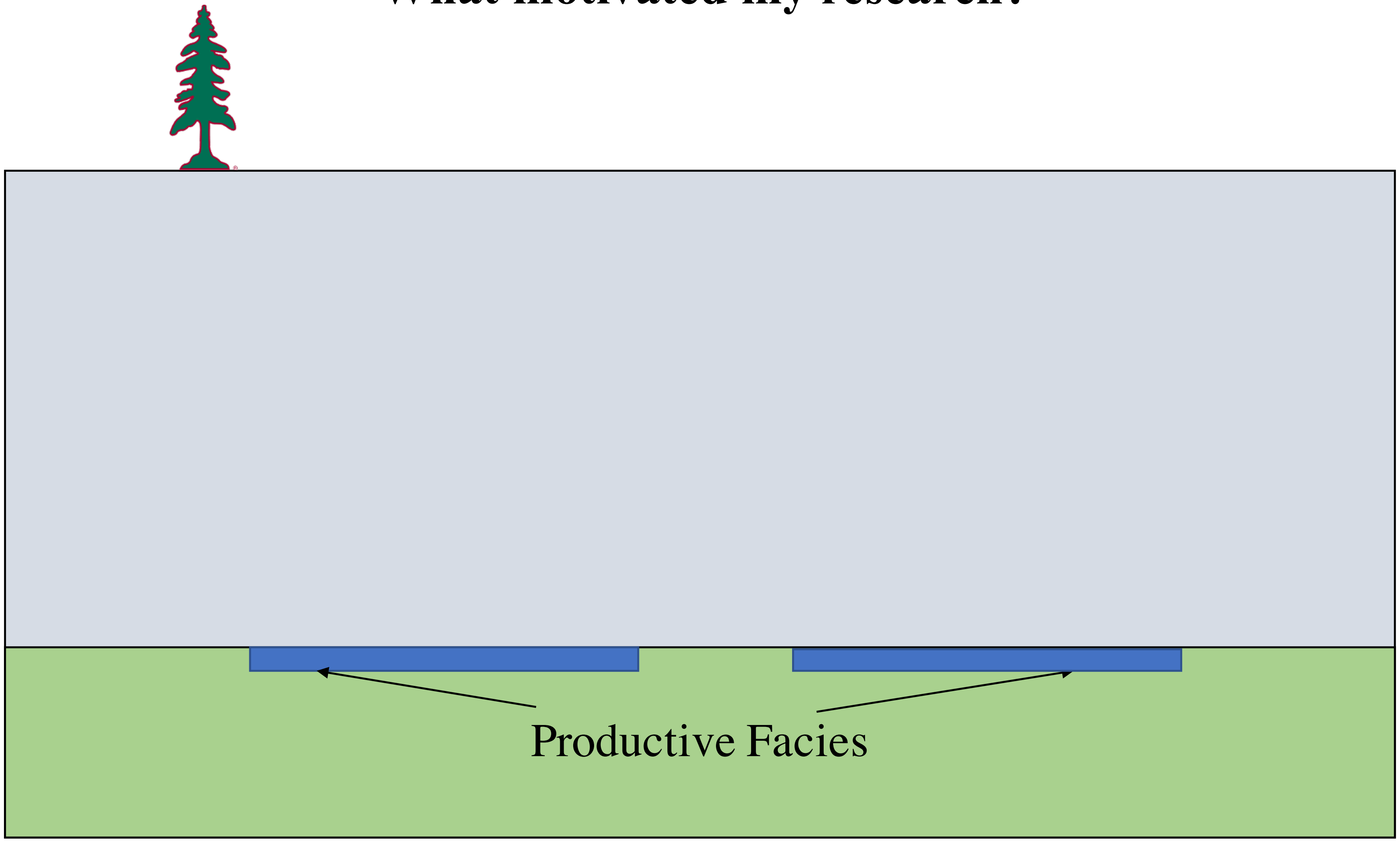


Reflectivity component of subsurface model



Background component of subsurface model

What motivated my research?



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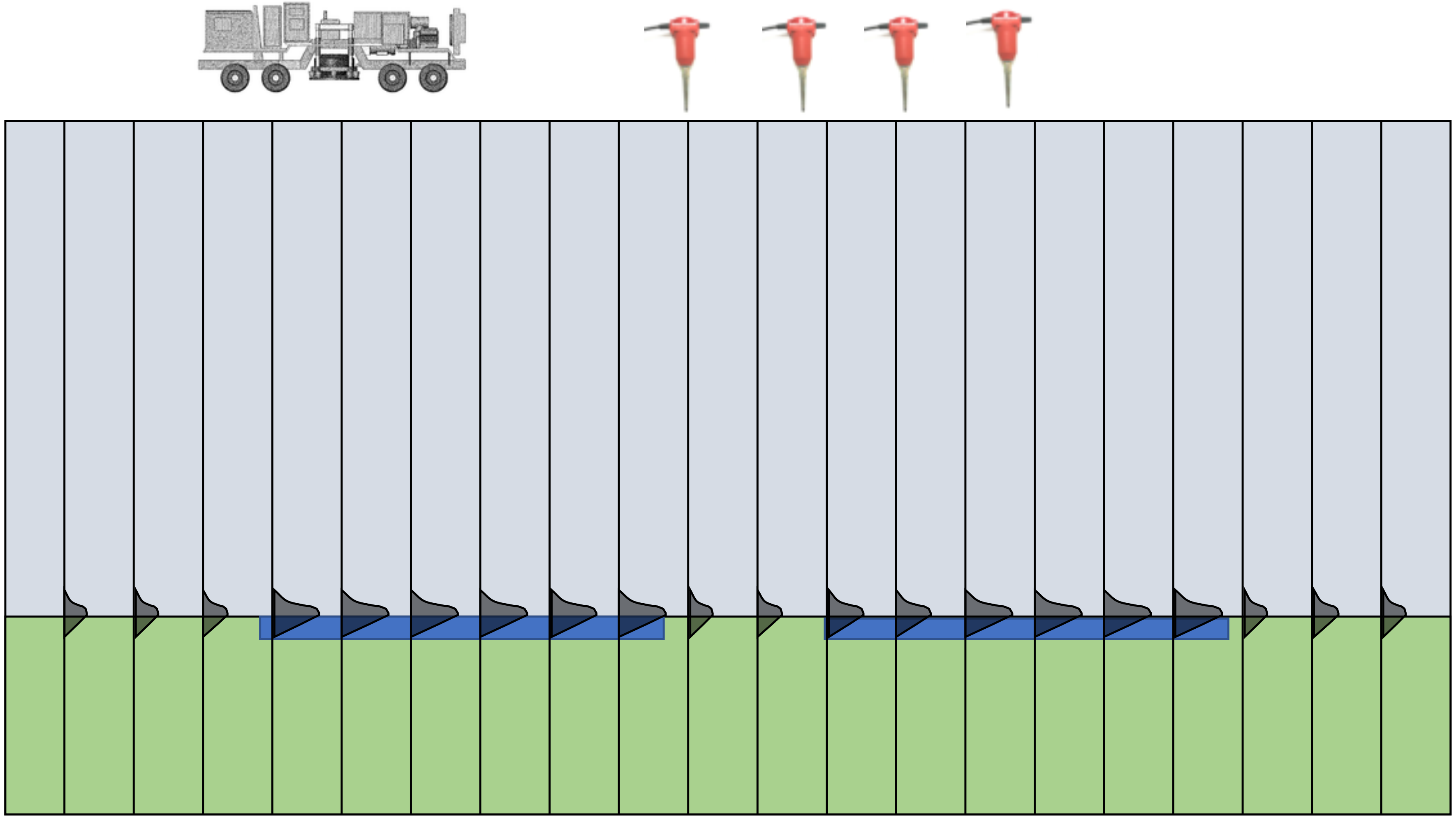

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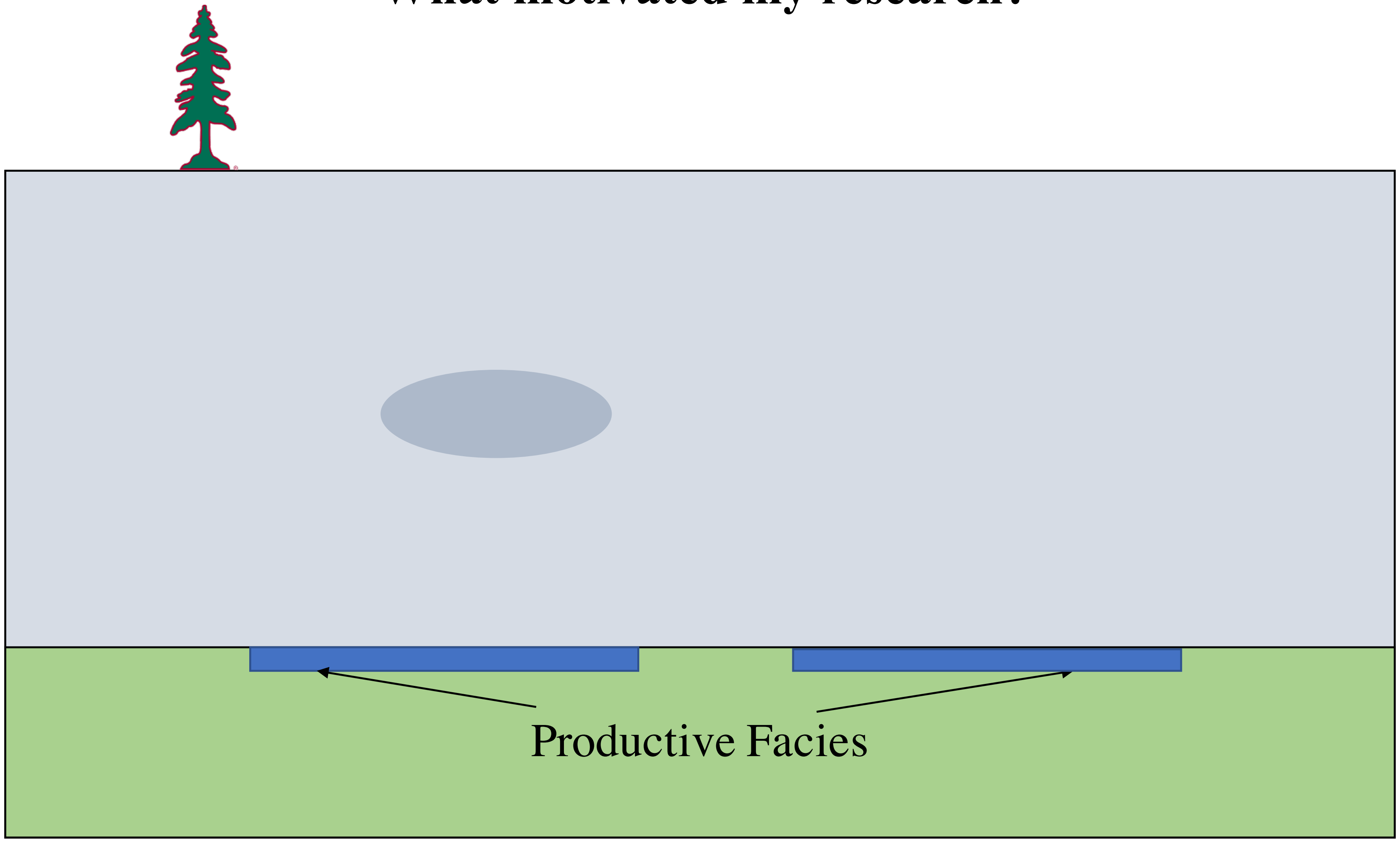

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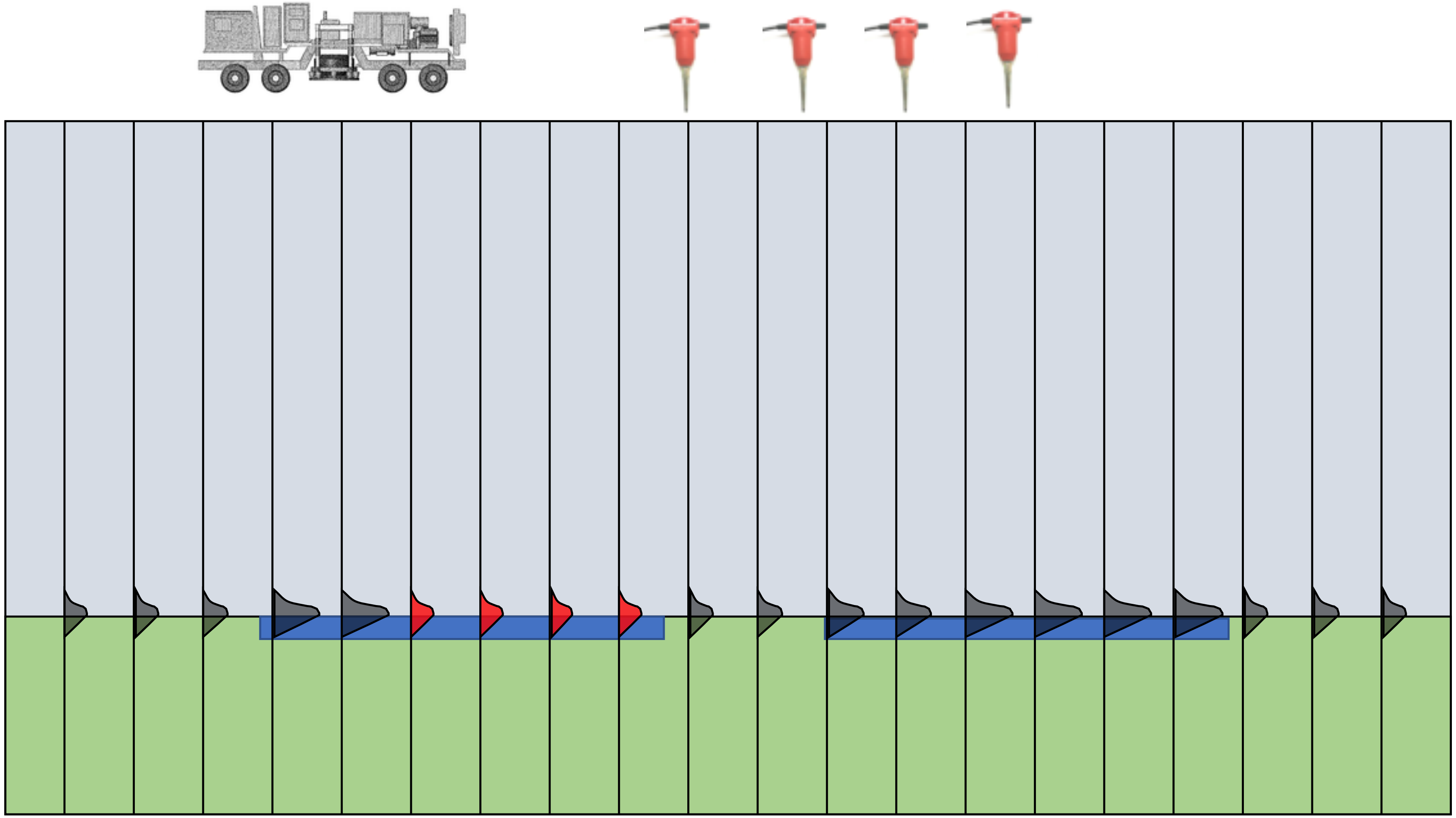

Joint Inversion of Reflectivity and Background Components (JIRB)

- Chapter 1: Introduction
- Chapter 2: Theory
- Chapter 3: Random boundary condition
- Chapter 4: Application to synthetic 2D data
- Chapter 5: Application to 3D marine data

Joint Inversion of Reflectivity and Background Components (JIRB)

- Chapter 1: Introduction
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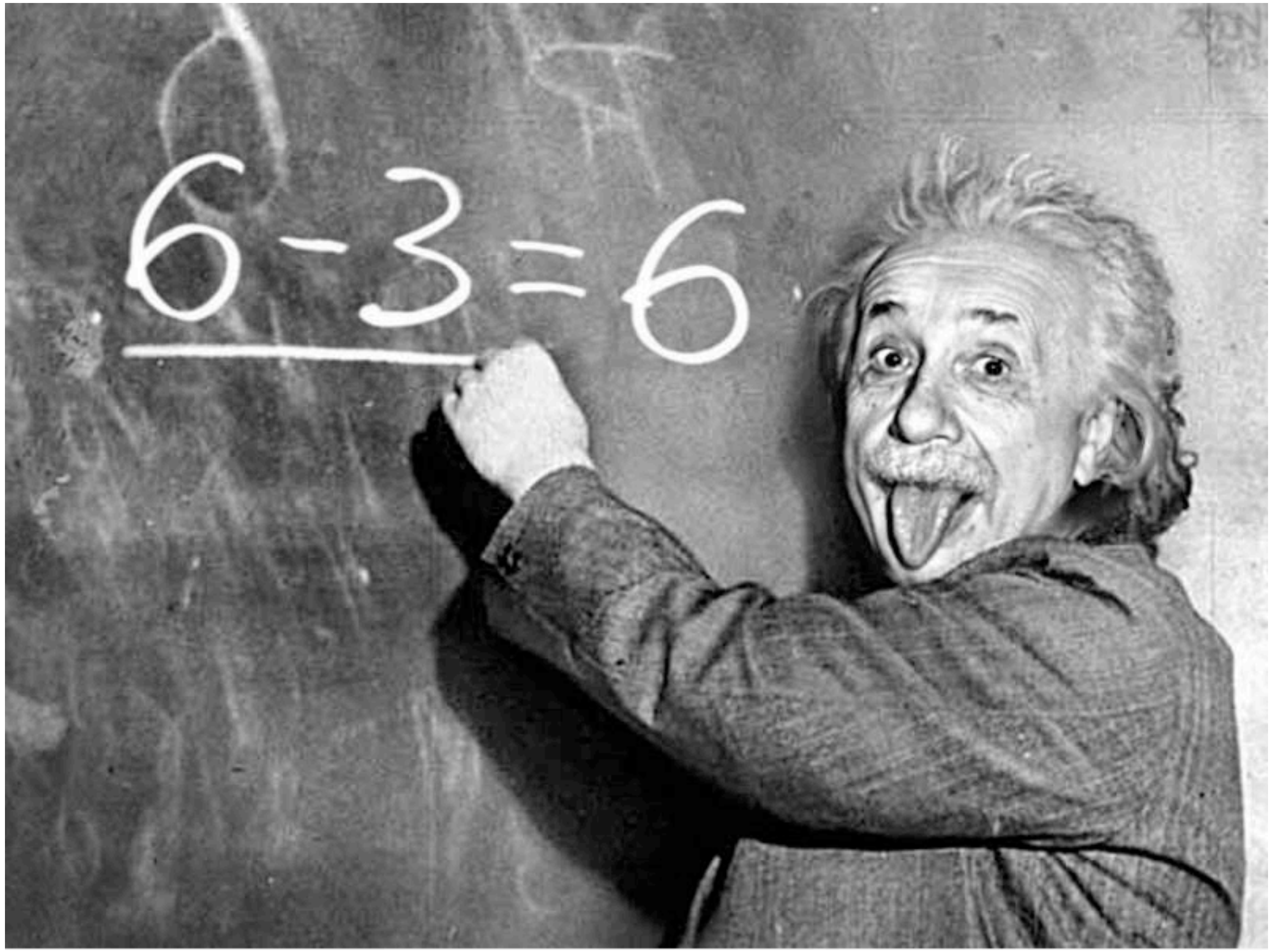
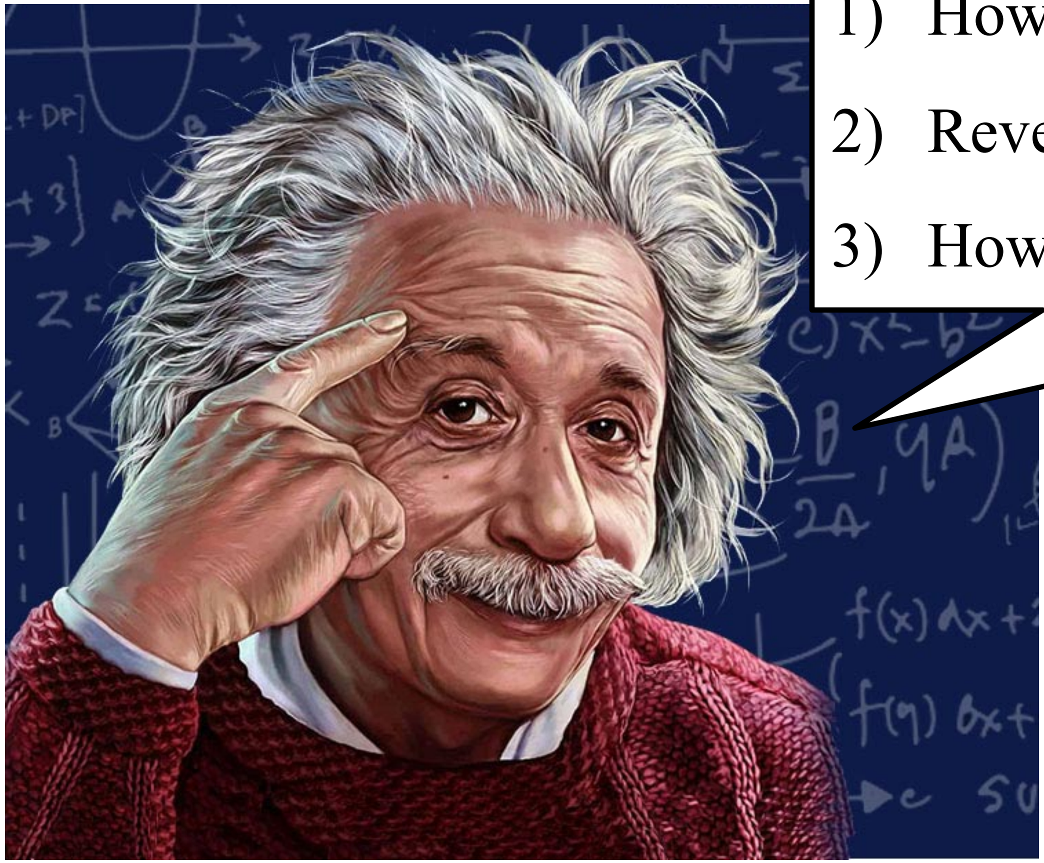
- Chapter 5: Application to 3D marine data

Some bits of theory

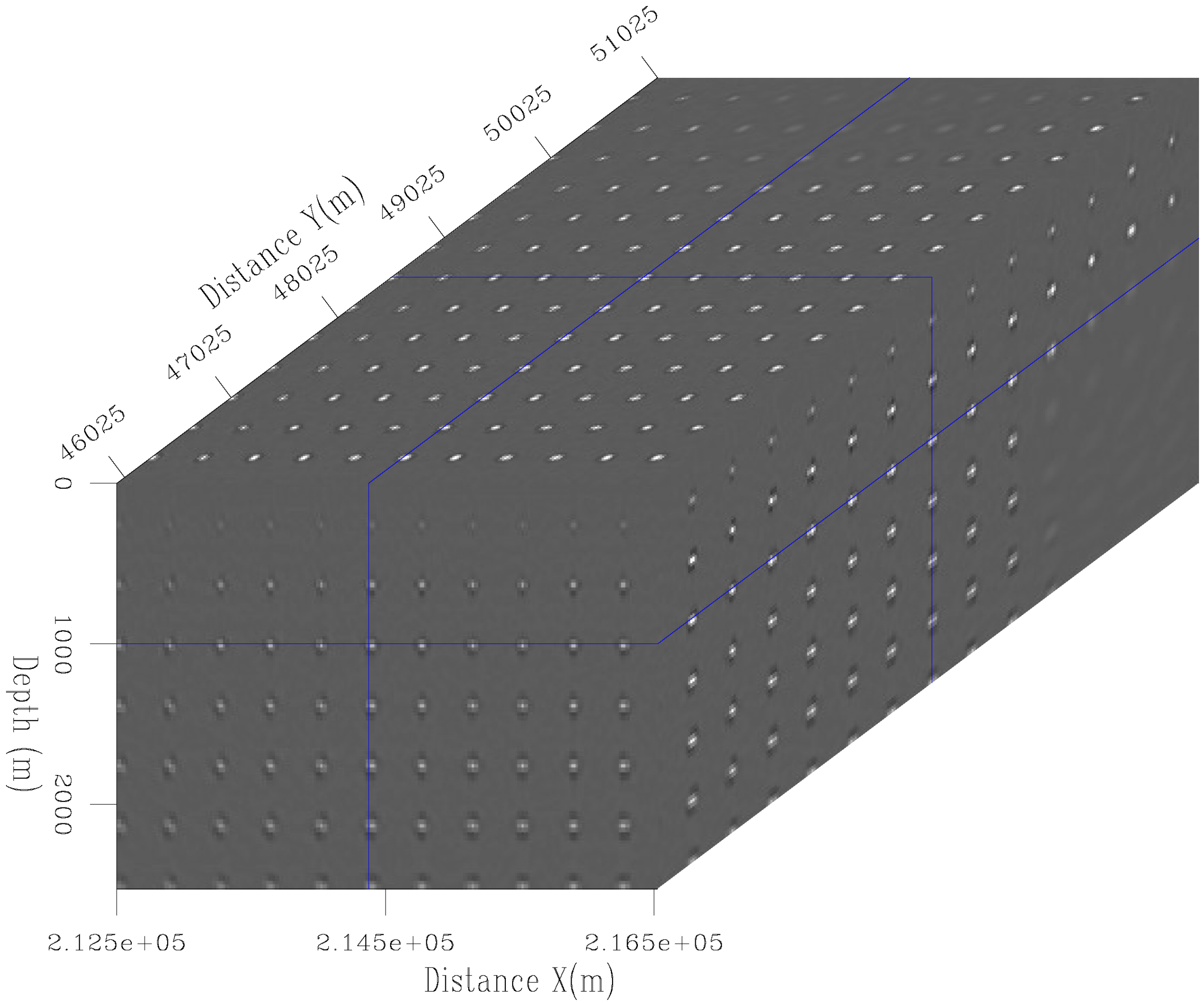


What you need to know to understand JIRB:

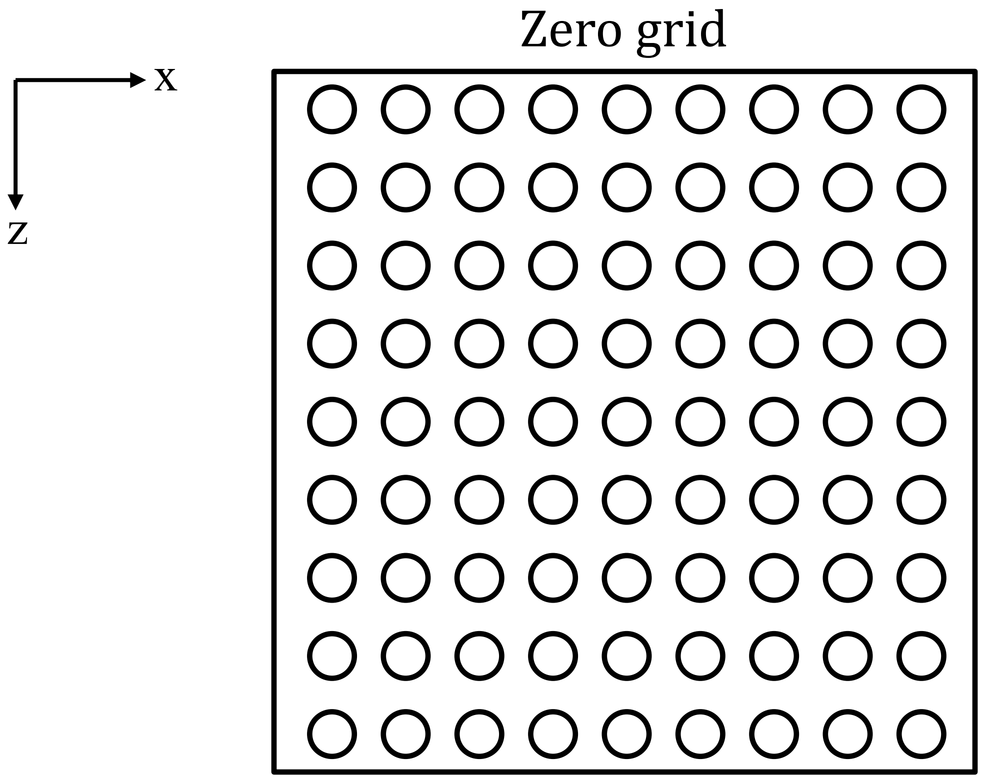


1) How to precompute the Hessian for LWI
2) Reverse-time migration (RTM)
3) How the WEMVA operator works

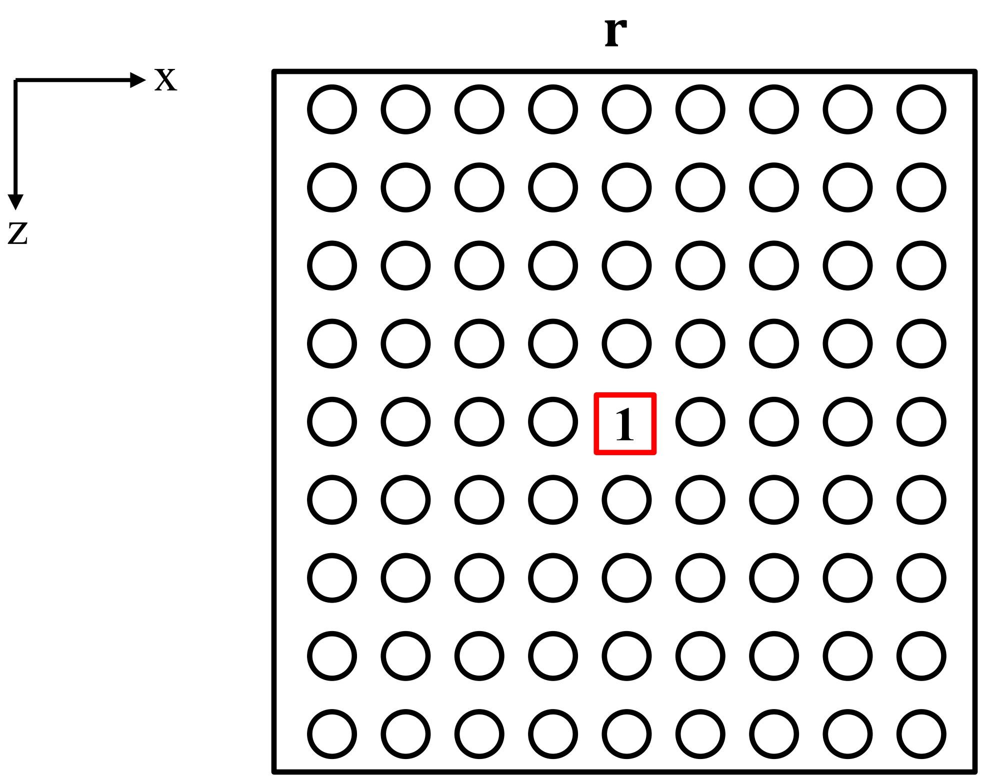
Gauss Newton Hessian: Point-spread functions



Gauss Newton Hessian: Point-spread functions

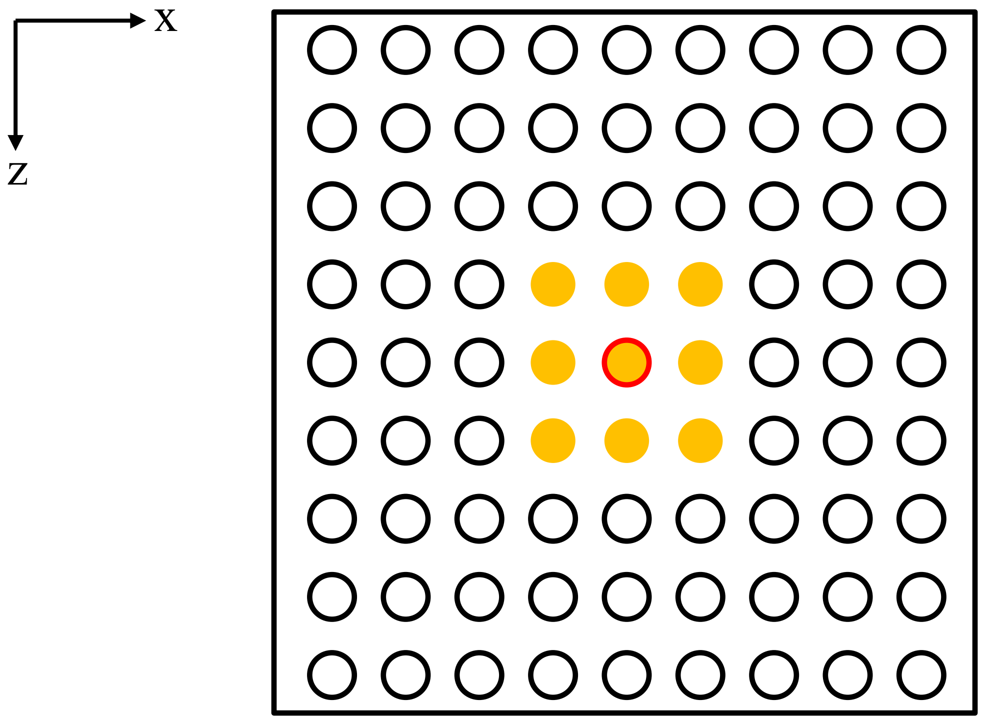


Gauss Newton Hessian: Point-spread functions

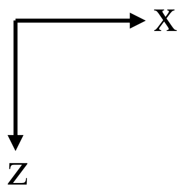


Gauss Newton Hessian: Point-spread functions

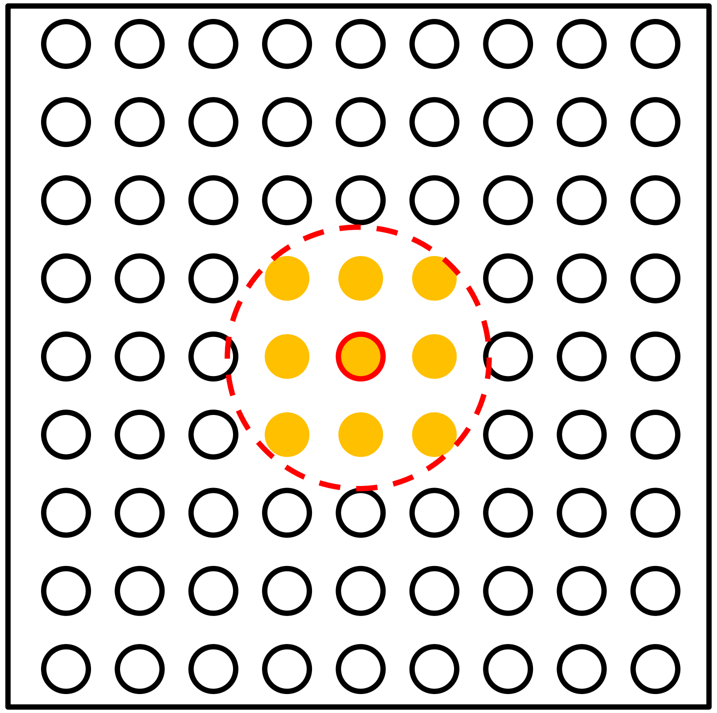
$$\mathbf{I} = \mathbf{Hr} = \mathbf{L^T L r}$$



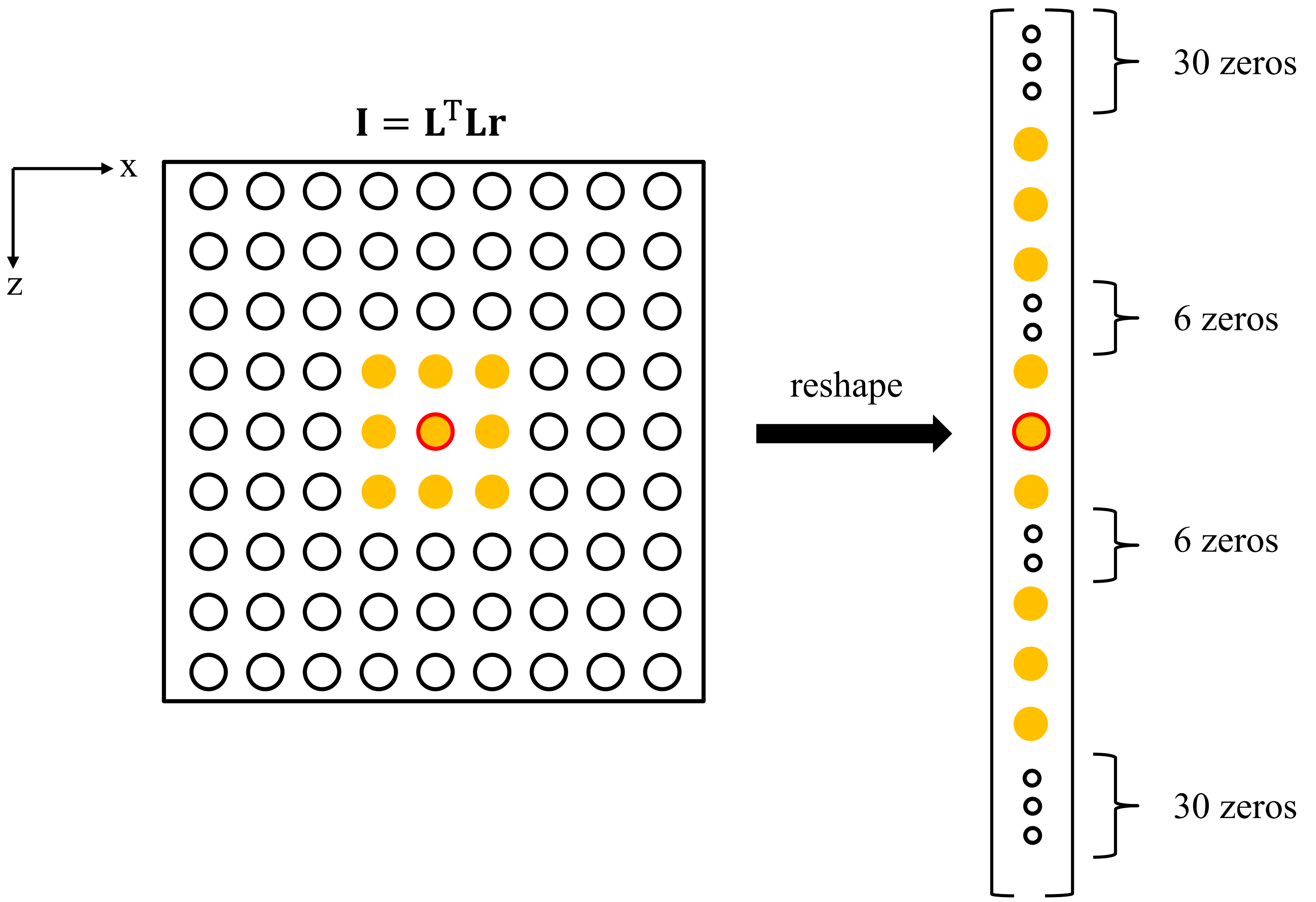
Gauss Newton Hessian: Point-spread functions

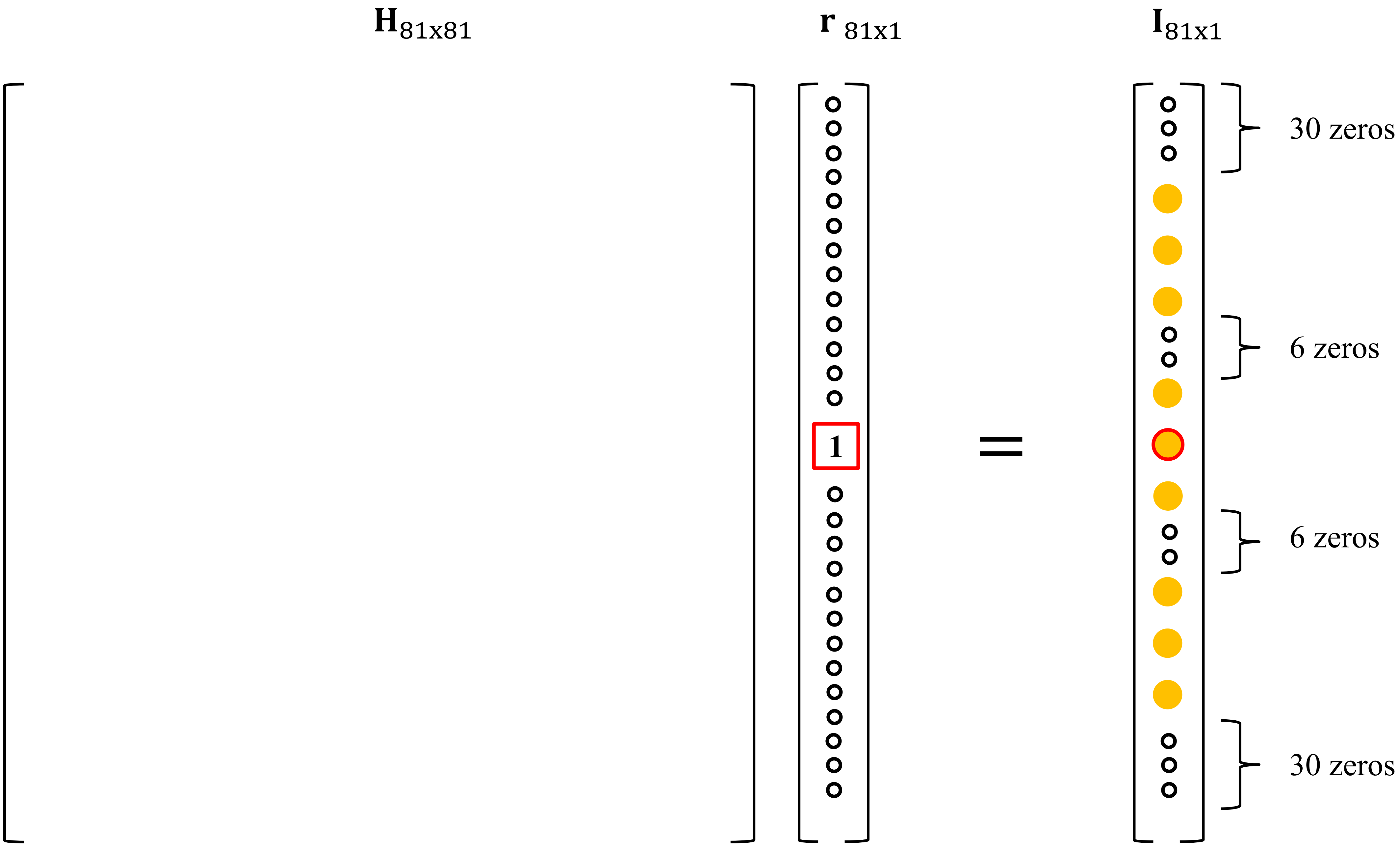


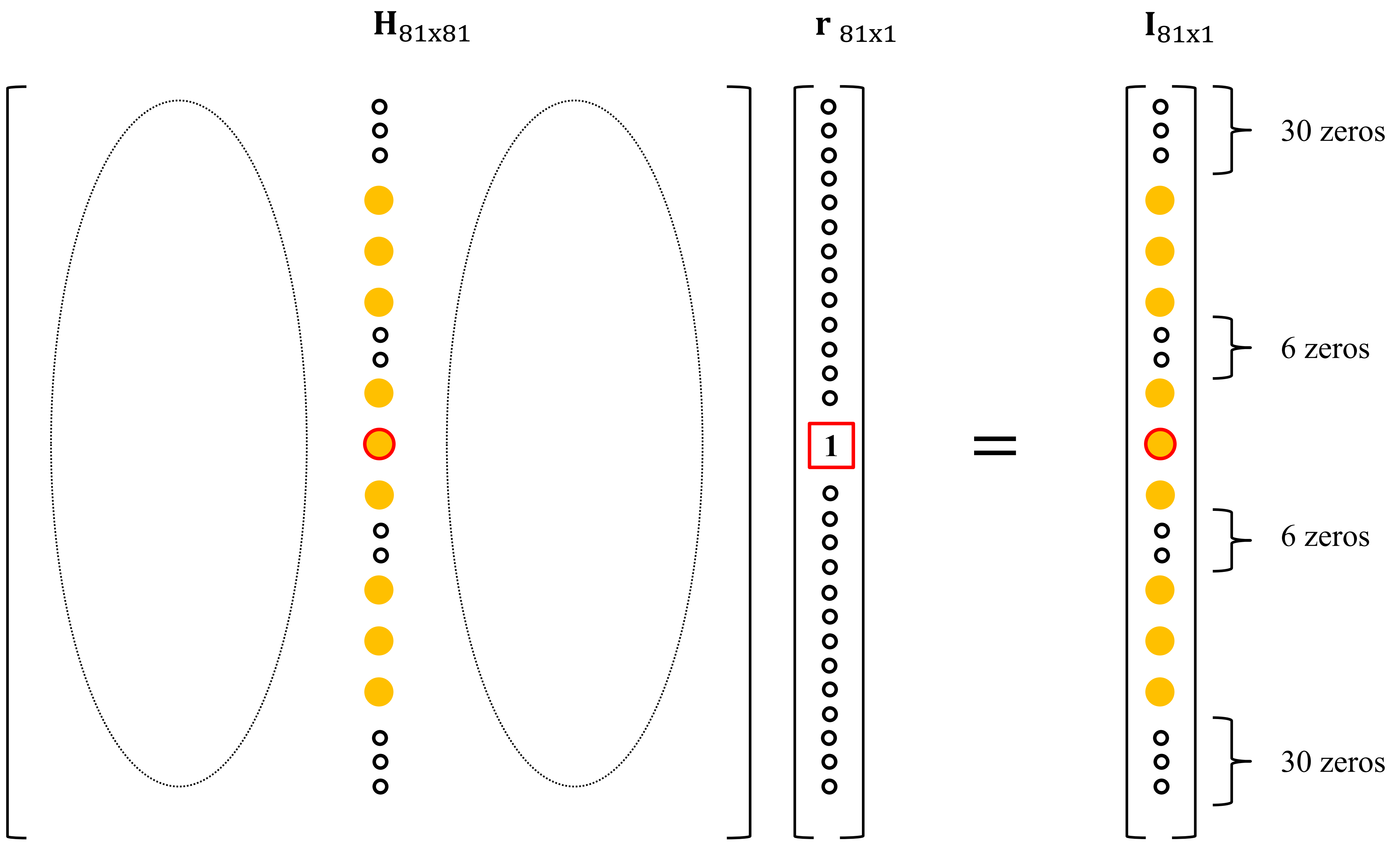
$$\mathbf{I} = \mathbf{H}\mathbf{r} = \mathbf{L}^T\mathbf{L}\mathbf{r}$$



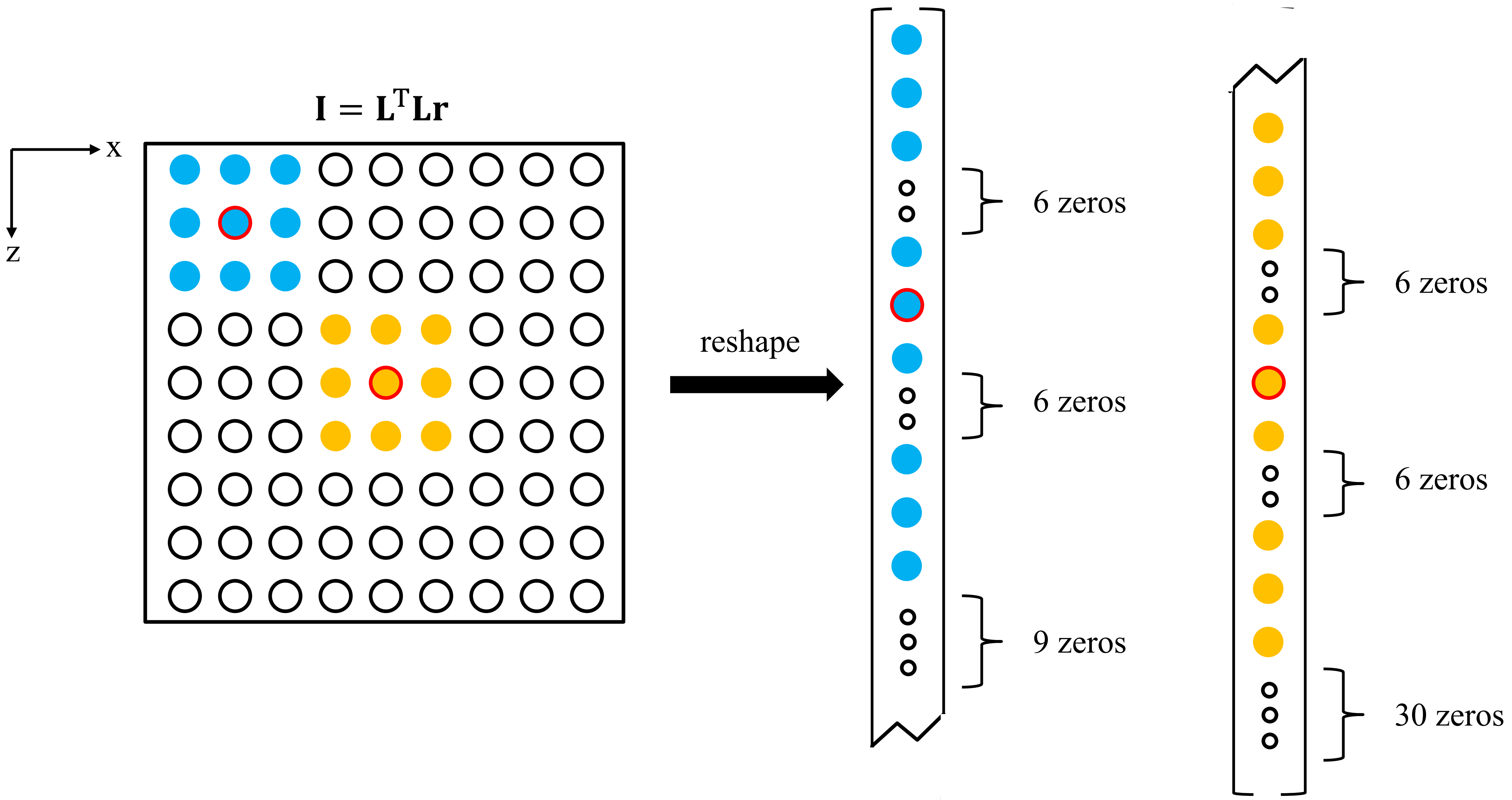
$$\mathbf{I} = \mathbf{L}^T\mathbf{L}\mathbf{r}$$



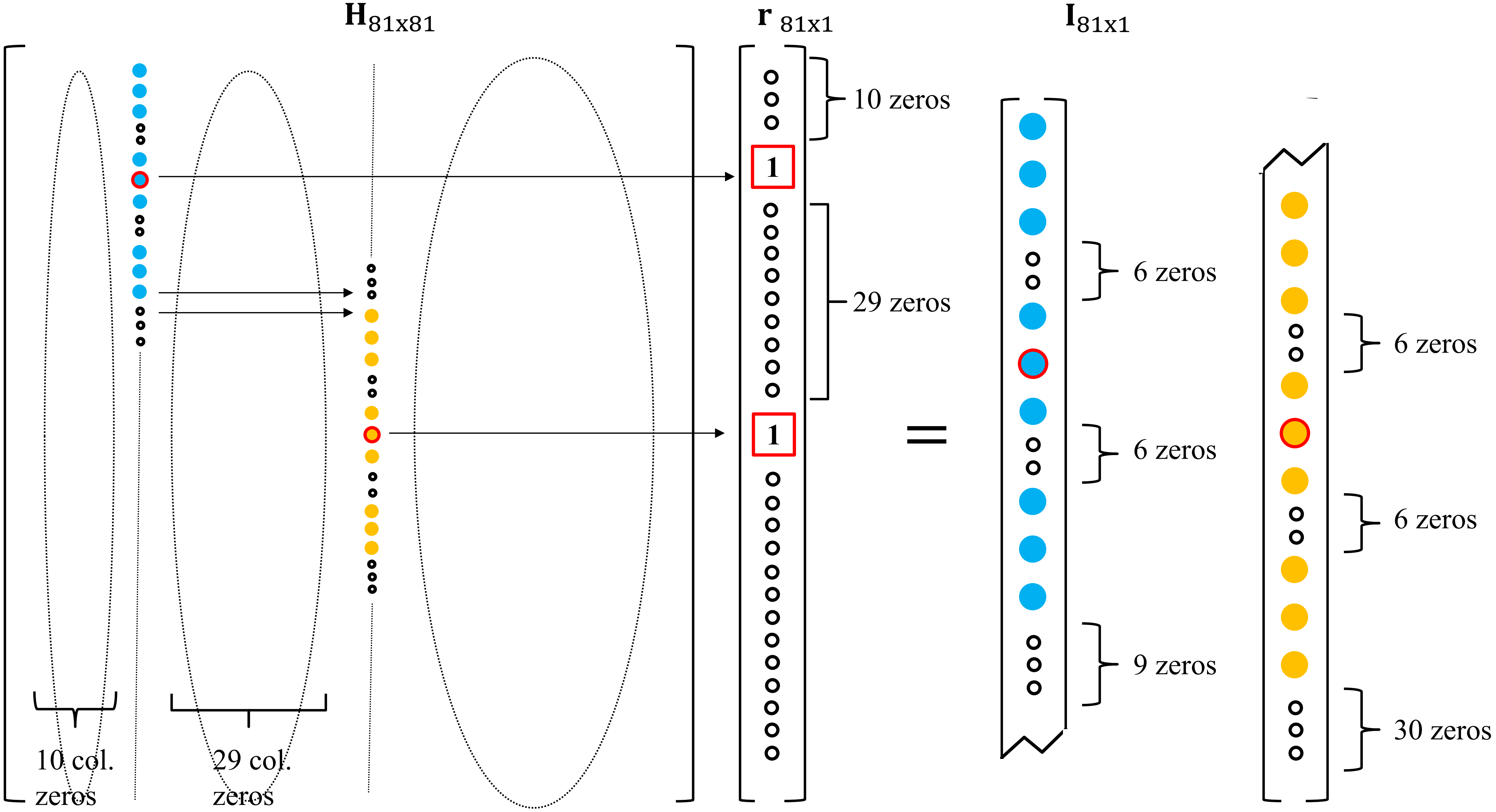

H_{81x81}
r_{81x1}
I_{81x1}
1
=
30 zeros
6 zeros
6 zeros
30 zeros



H_{81x81}
r_{81x1}
I_{81x1}
1
=
30 zeros
6 zeros
6 zeros
30 zeros

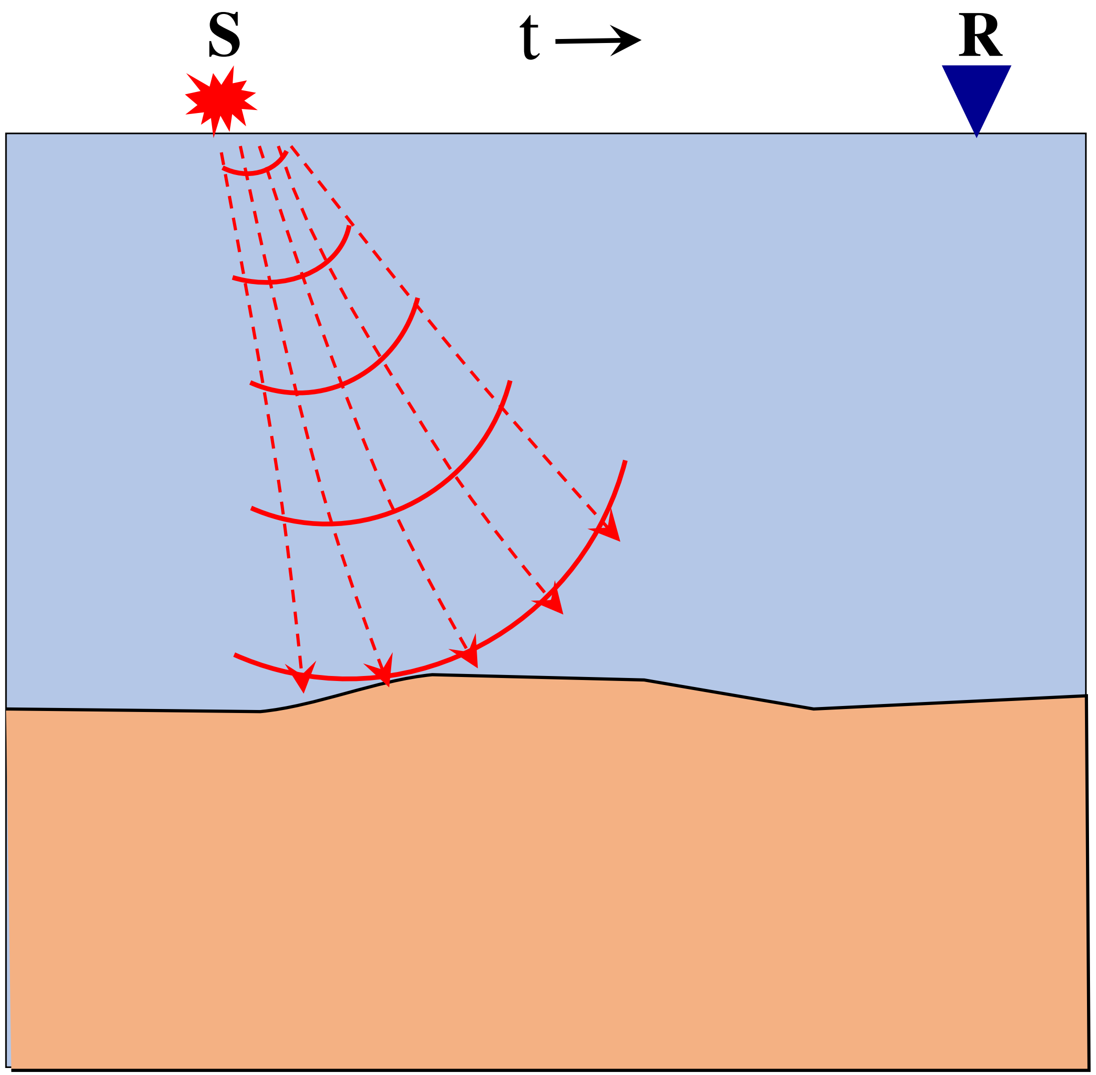


I = L^T Lr
x
z
reshape
6 zeros
6 zeros
9 zeros
6 zeros
6 zeros
30 zeros



H_{81x81}
r_{81x1}
I_{81x1}
10 zeros
1
29 zeros
1
=
6 zeros
6 zeros
9 zeros
6 zeros
6 zeros
30 zeros
10 col. zeros
29 col. zeros

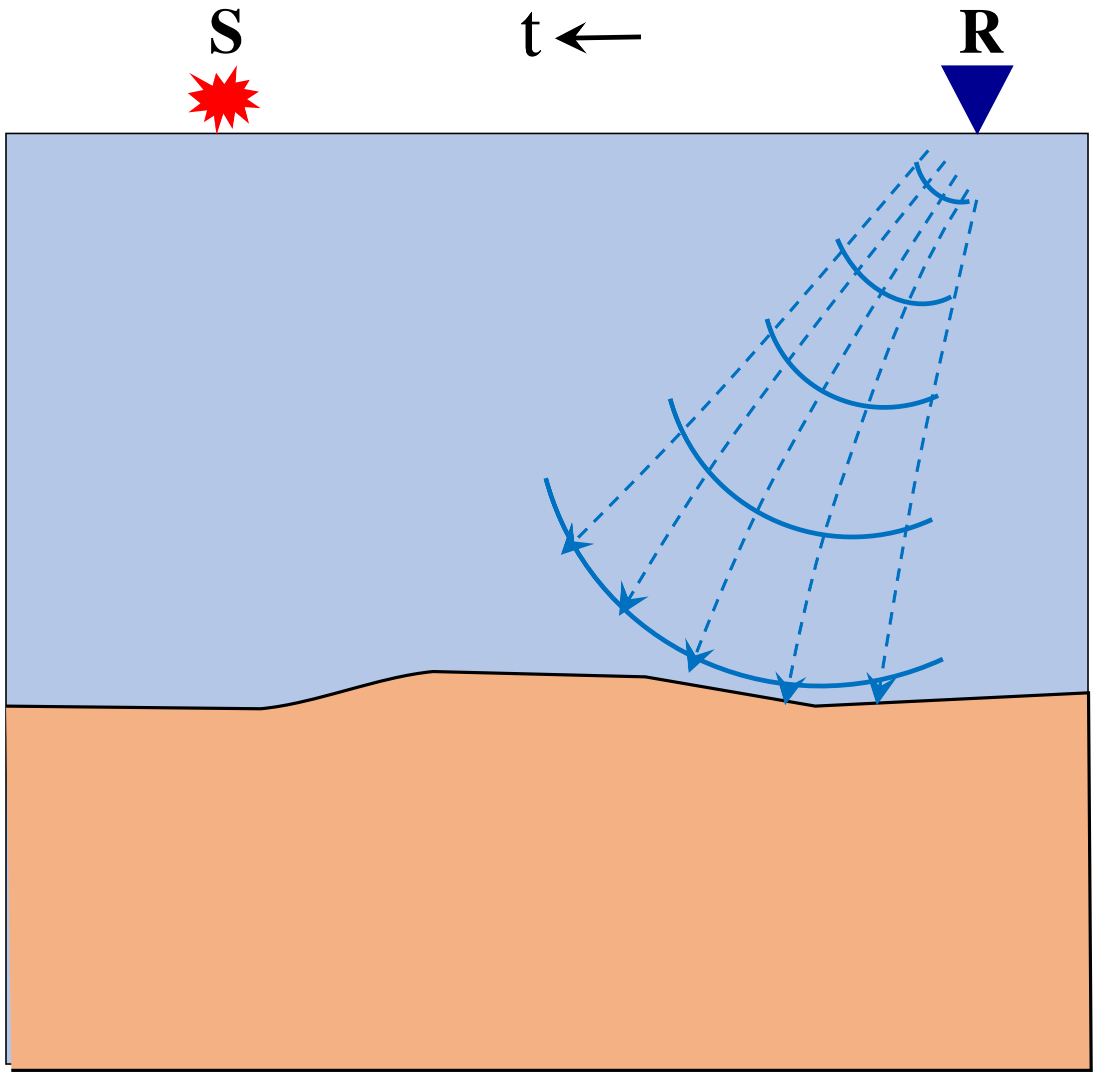
RTM: $\mathbf{I}(\mathbf{b}) = \mathbf{L}(\mathbf{b})^T \Delta\mathbf{d}$



Conventional reverse-time migration (RTM):

1) Propagate the source wavefield (Fwd in time)

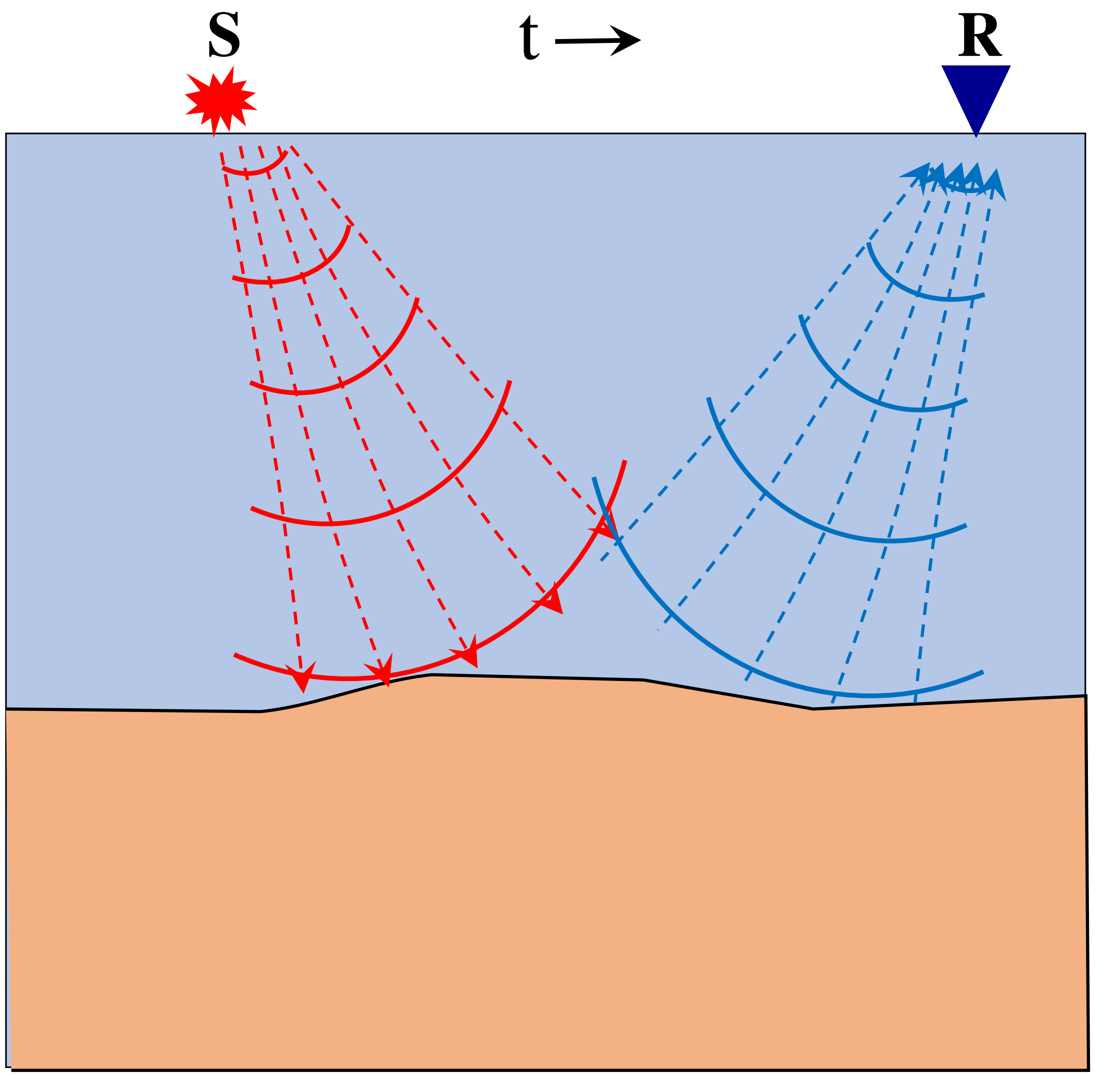
$$\text{RTM: } \mathbf{I}(\mathbf{b}) = \mathbf{L}(\mathbf{b})^{T} \Delta \mathbf{d}$$



Conventional reverse-time migration (RTM):

1) Propagate the source wavefield (Fwd in time)
2) Propagate the receiver wavefield (Bwd in time)

RTM: $\mathbf{I}(\mathbf{b}) = \mathbf{L}(\mathbf{b})^T \Delta\mathbf{d}$

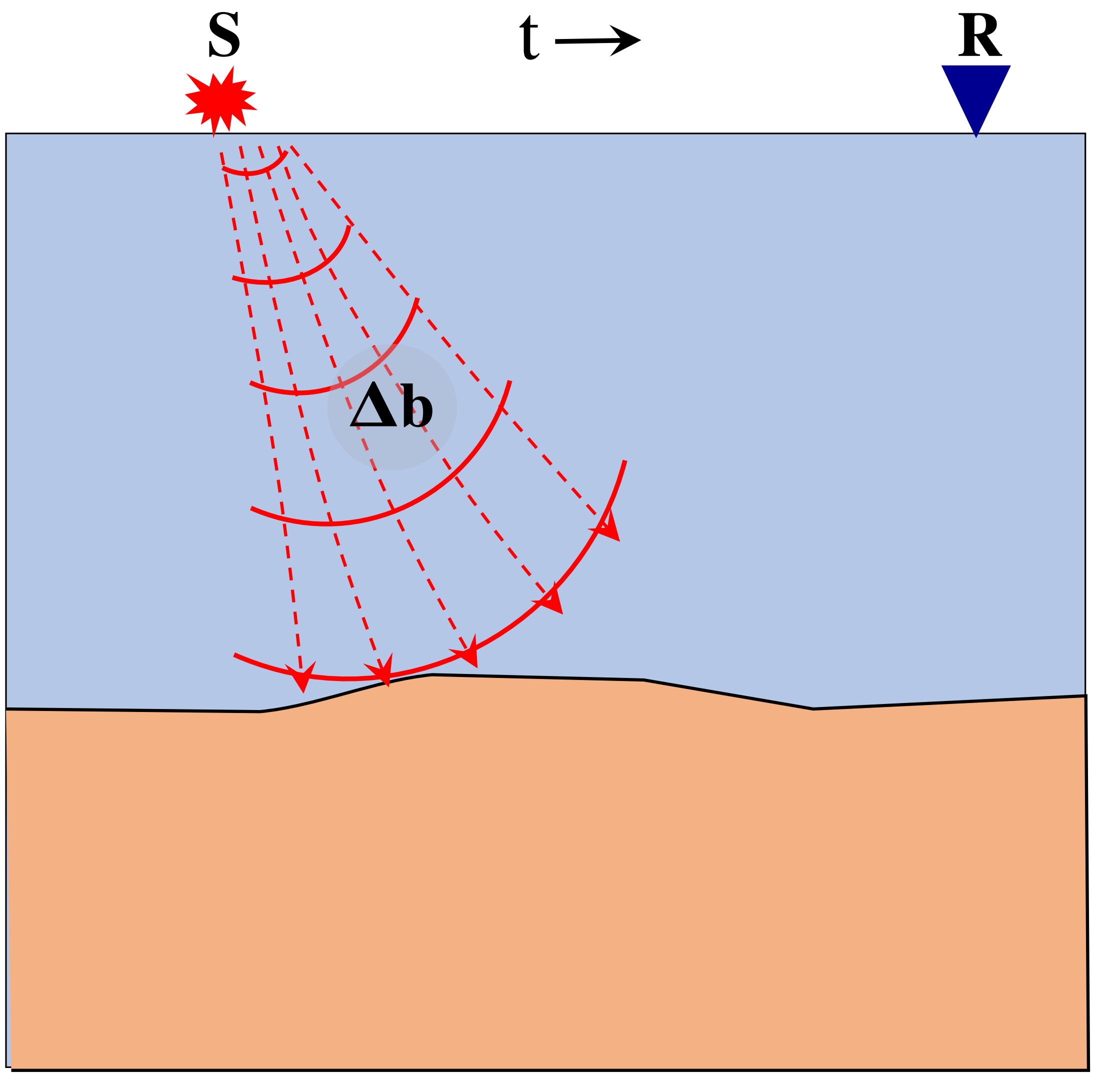


Conventional reverse-time migration (RTM):

1) Propagate the source wavefield (Fwd in time)
2) Propagate the receiver wavefield (Bwd in time)
3) Perform zero-lag crosscorrelation in time

$$\mathbf{I}(\mathbf{x}) = \sum_t \mathbf{S}(\mathbf{x}, t)\mathbf{R}(\mathbf{x}, t)$$

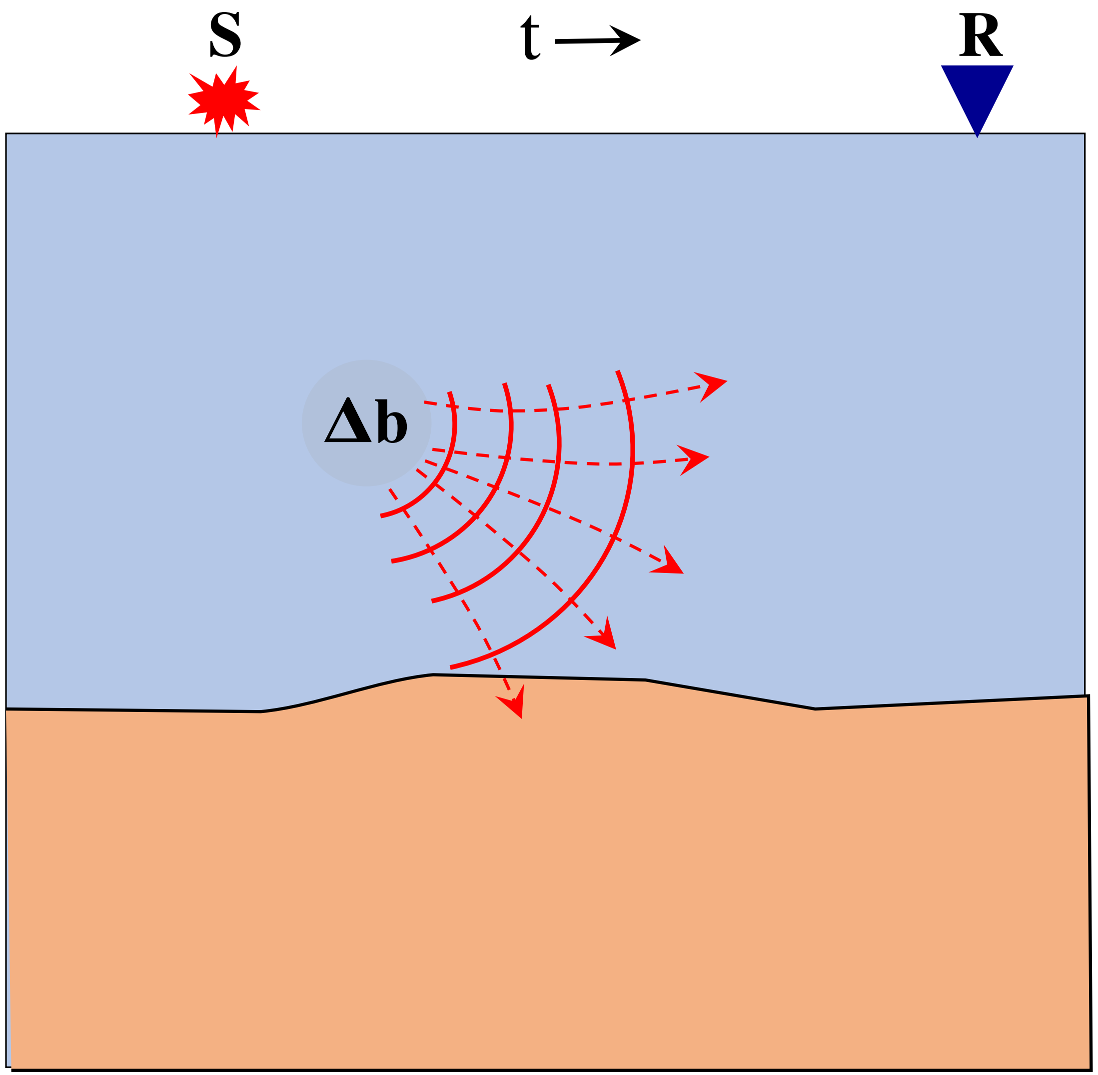
$$\text{WEMVA: } \Delta \mathbf{I} = \mathbf{W}(\mathbf{b}_0)\Delta \mathbf{b}$$



WEMVA:

1) Propagate the source wavefield (Fwd in time)

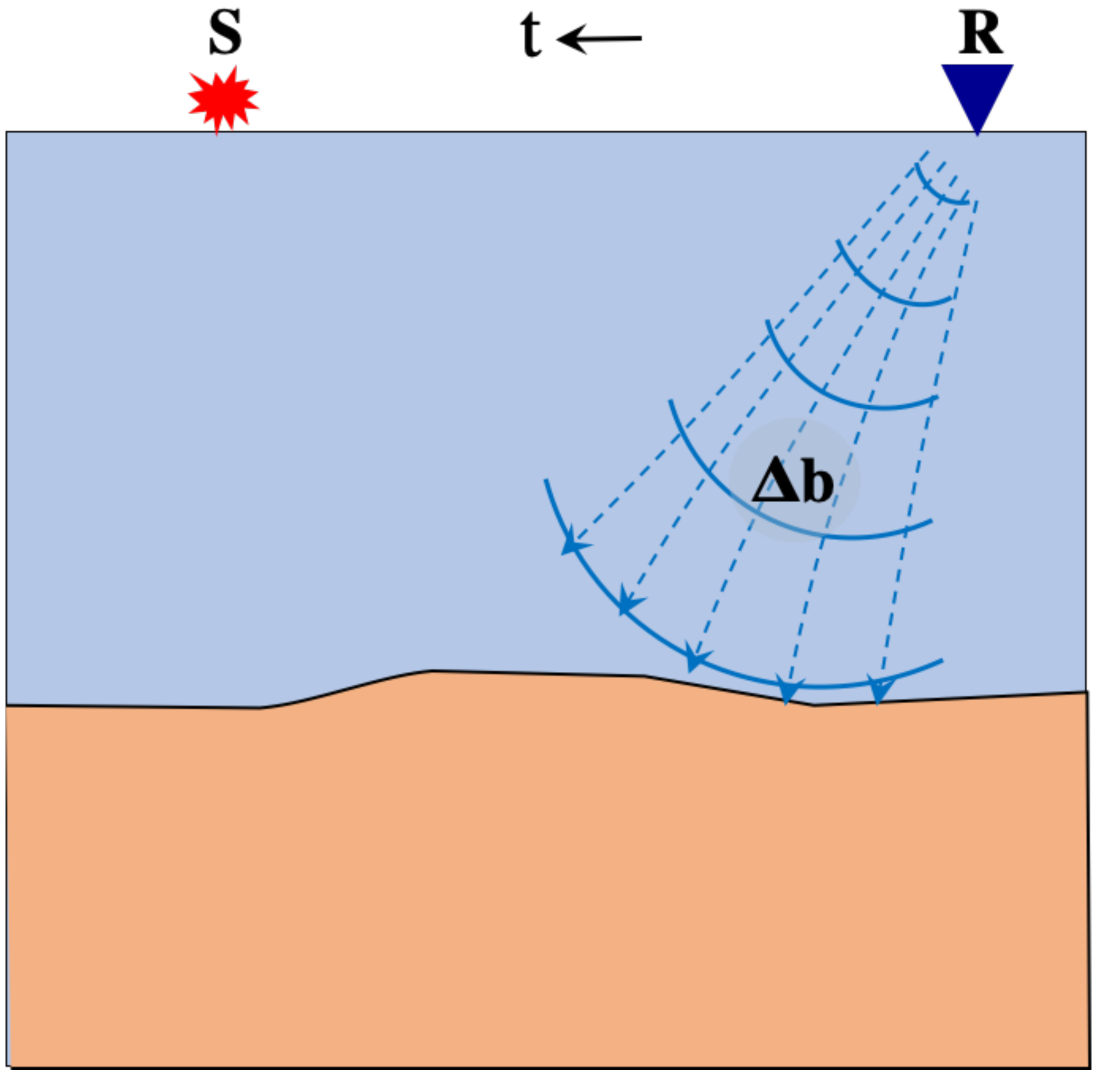
WEMVA: $\Delta\mathbf{I} = \mathbf{W}(\mathbf{b}_0)\Delta\mathbf{b}$



WEMVA:

1) Propagate the source wavefield (Fwd in time)
2) Scatter the source wavefield

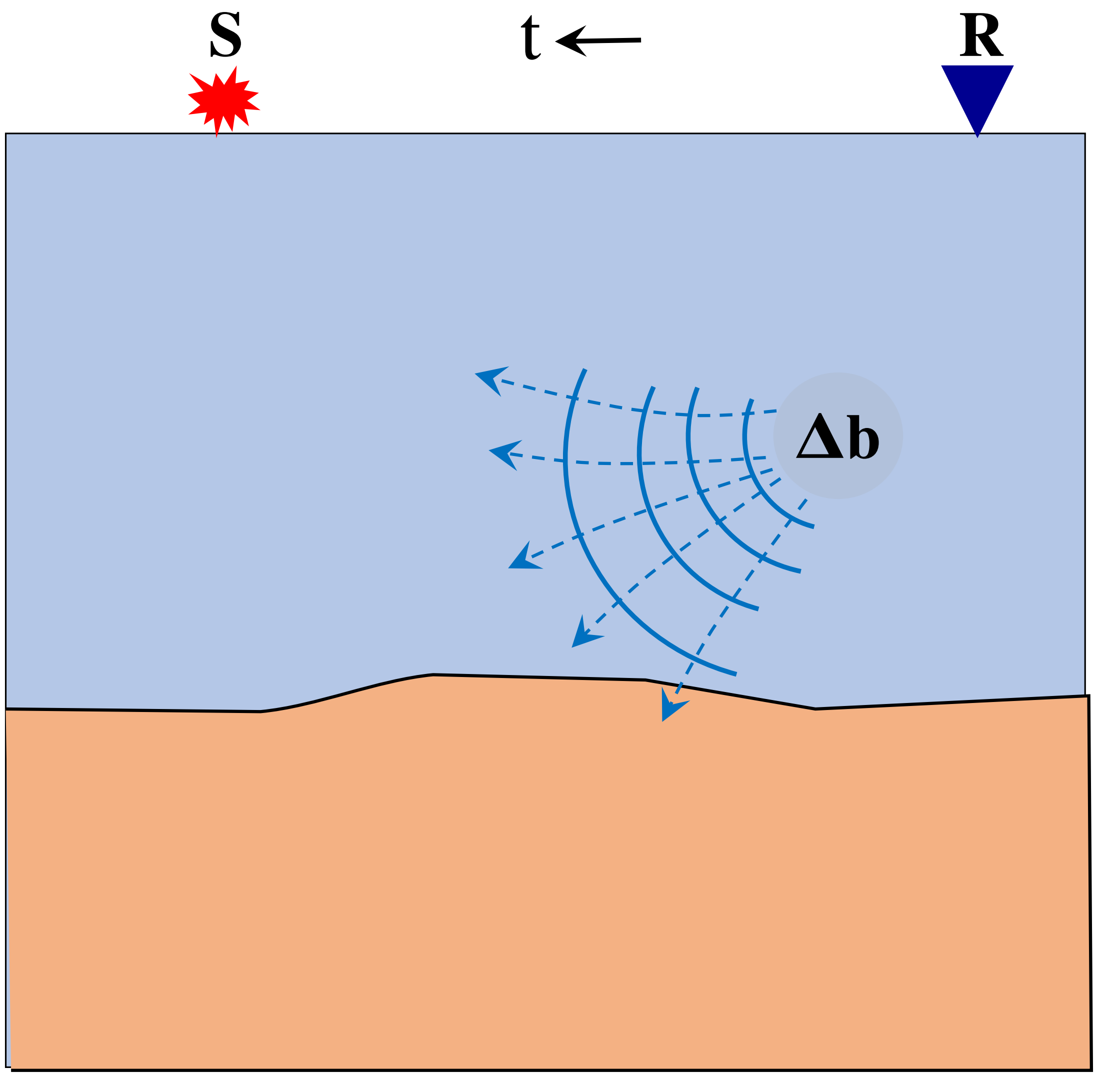
WEMVA: $\Delta\mathbf{I} = \mathbf{W}(\mathbf{b}_0)\Delta\mathbf{b}$



WEMVA:

1) Propagate the source wavefield (Fwd in time)
2) Scatter the source wavefield
3) Propagate the receiver wavefield (Bwd in time)

WEMVA: $\Delta\mathbf{I} = \mathbf{W}(\mathbf{b}_0)\Delta\mathbf{b}$

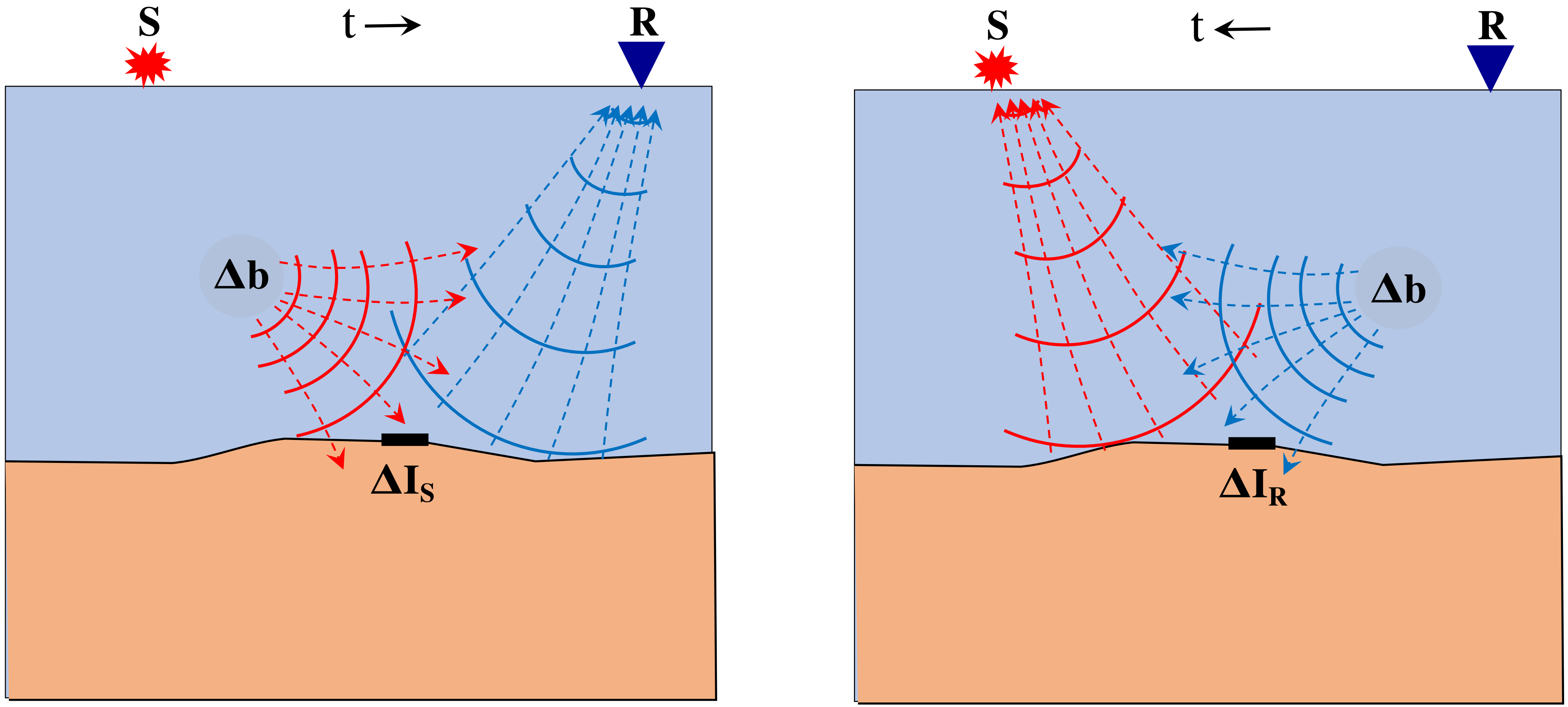


WEMVA:

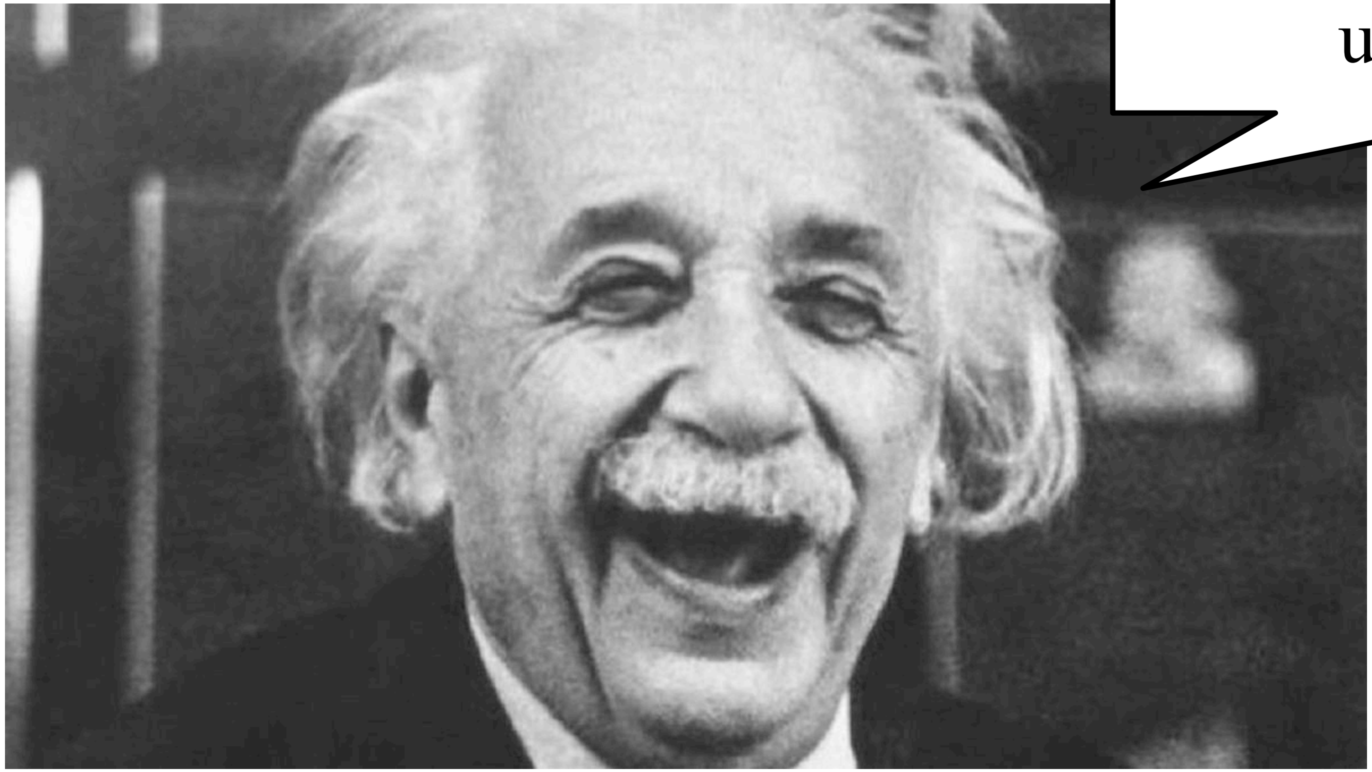
1) Propagate the source wavefield (Fwd in time)
2) Scatter the source wavefield
3) Propagate the receiver wavefield (Bwd in time)
4) Scatter the receiver wavefield

WEMVA: $\Delta\mathbf{I} = \mathbf{W}(\mathbf{b}_0)\Delta\mathbf{b}$

5) Perform crosscorrelations:



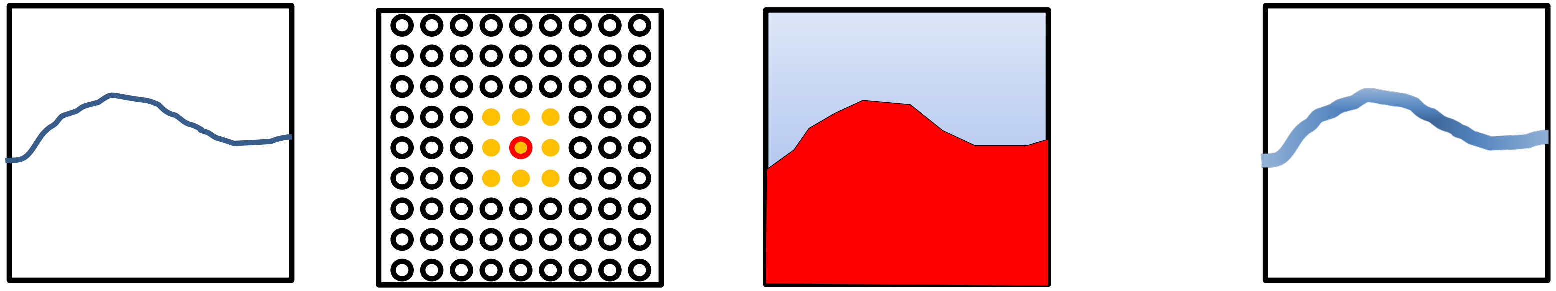
$$\boldsymbol{\Delta}\mathbf{I}(\mathbf{x}) = \sum_t \left[\delta\mathbf{S}(\mathbf{x},t)\mathbf{R}(\mathbf{x},t) + \mathbf{S}(\mathbf{x},t)\delta\mathbf{R}(\mathbf{x},t)\right] = \boldsymbol{\Delta}\mathbf{I}_{\mathrm{S}}(\mathbf{x}) + \boldsymbol{\Delta}\mathbf{I}_{\mathrm{R}}(\mathbf{x})$$


Good! Now you're prepared to understand JIRB!

Joint inversion of reflectivity and background components

Start with conventional LWI (image space):

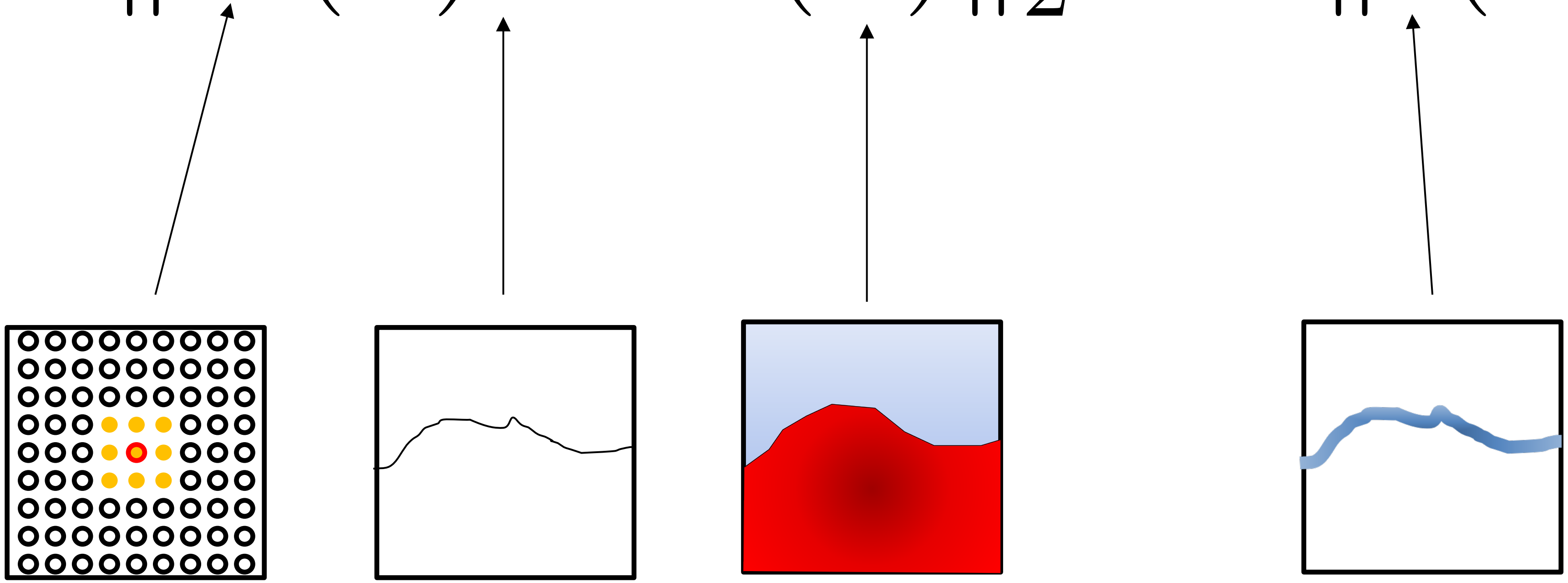
$$\Phi(\mathbf{r}) = \|\mathbf{H}(\mathbf{b}_0)\mathbf{r} - \mathbf{I}(\mathbf{b}_0)\|_2^2$$



Joint inversion of reflectivity and background components

Make of **b** another model parameter:

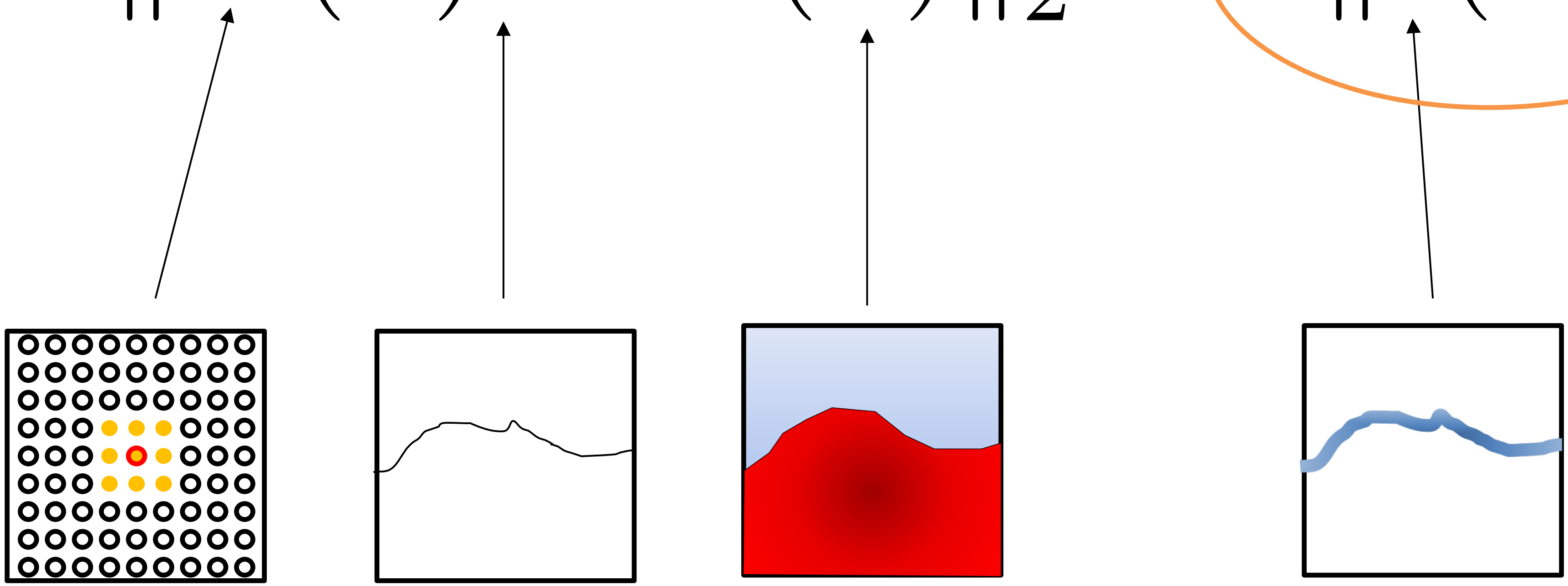
$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}(\mathbf{b})\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$



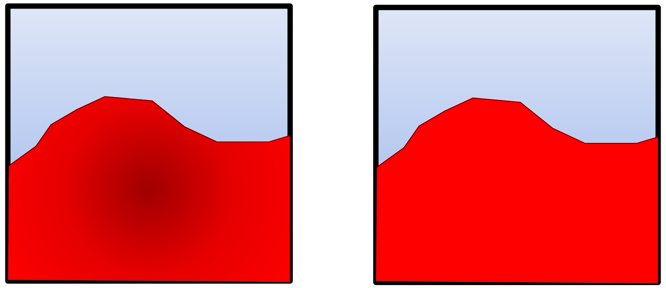
Joint inversion of reflectivity and background components

Make of **b** another model parameter:

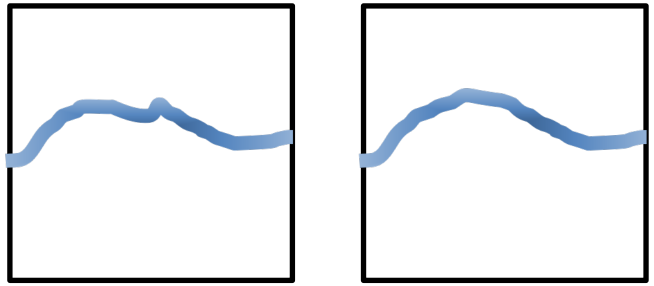
$$\Phi(\mathbf{r},\mathbf{b}) = \|\mathbf{H}(\mathbf{b})\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

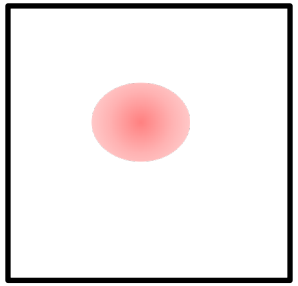


Original idea: Linearizing



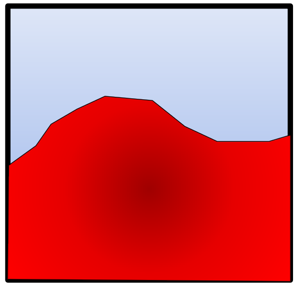
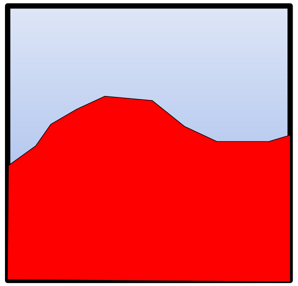
$$\mathbf{I}(\mathbf{b}) \approx \mathbf{I}(\mathbf{b}_0) + \left[\frac{\partial \mathbf{I}(\mathbf{b}_0)}{\partial \mathbf{b}}\right] \boldsymbol{\Delta}\mathbf{b}$$



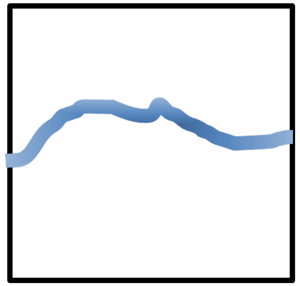
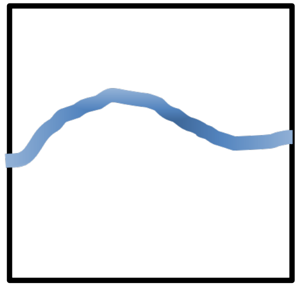
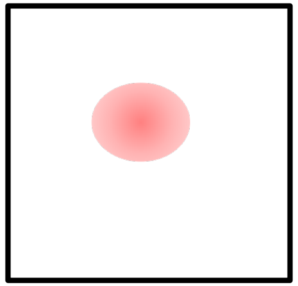
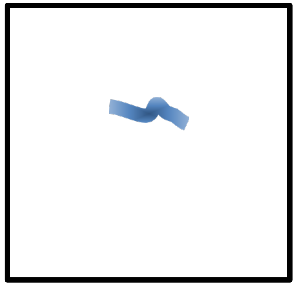


THEORY

Original idea: Linearizing

$$\mathbf{I}(\mathbf{b}) \approx \mathbf{I}(\mathbf{b}_0) + \left[\frac{\partial \mathbf{I}(\mathbf{b}_0)}{\partial \mathbf{b}}\right]\boldsymbol{\Delta}\mathbf{b} = \mathbf{I}(\mathbf{b}_0) + \underbrace{\mathbf{W}(\mathbf{b}_0)\boldsymbol{\Delta}\mathbf{b}}$$

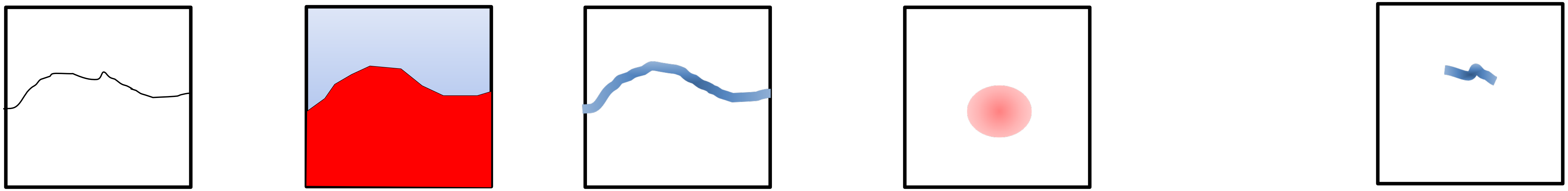
   

Original idea: Linearizing

Substitute expanded image into objective function:

0

$$\Phi(\mathbf{r},\boldsymbol{\Delta}\mathbf{b}) = \|\mathbf{H}(\mathbf{b}_0+\boldsymbol{\Delta}\mathbf{b})\mathbf{r} - \mathbf{I}(\mathbf{b}_0) - \mathbf{W}(\mathbf{b}_0)\boldsymbol{\Delta}\mathbf{b}\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b}_0) + \mathbf{W}(\mathbf{b}_0)\boldsymbol{\Delta}\mathbf{b}\|_2^2$$

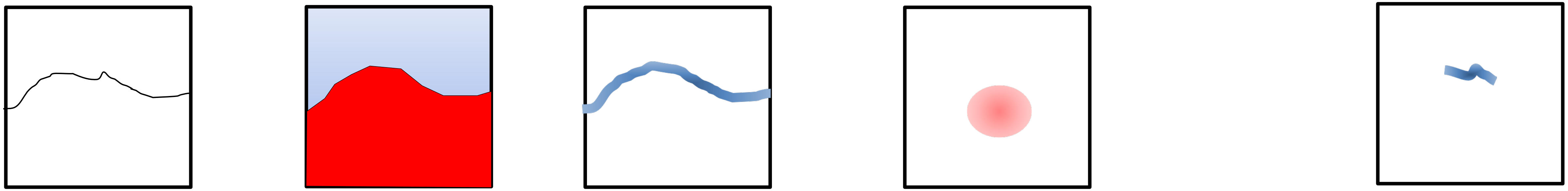


Original idea: Linearizing

Substitute expanded image into objective function:

0

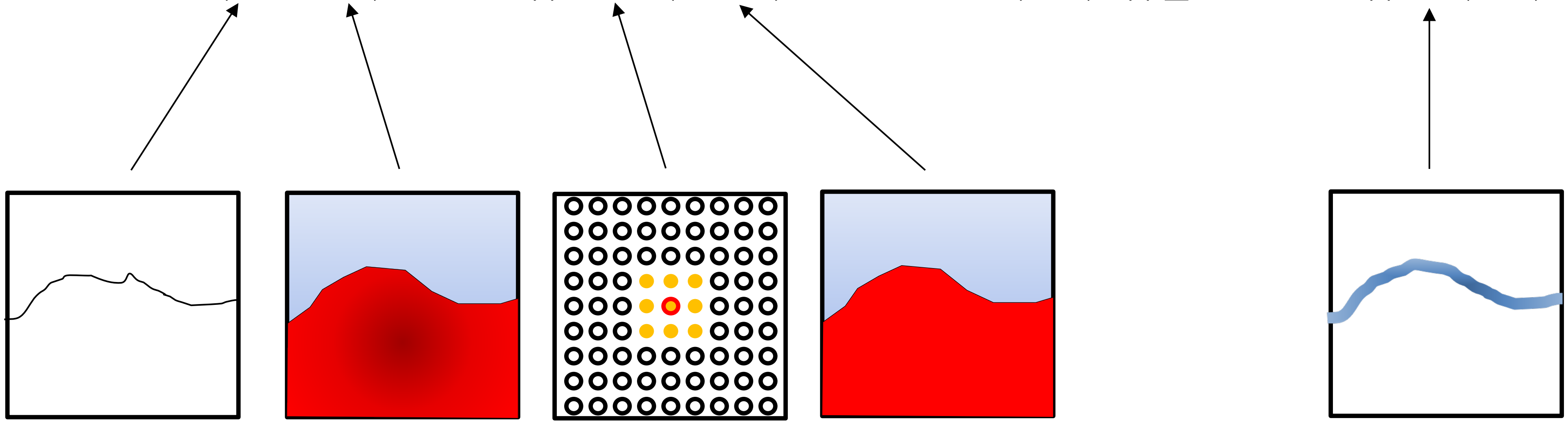
$$\Phi(\mathbf{r},\boldsymbol{\Delta}\mathbf{b}) = \|\mathbf{H}(\mathbf{b}_0+\boldsymbol{\Delta}\mathbf{b})\mathbf{r} - \mathbf{I}(\mathbf{b}_0) - \mathbf{W}(\mathbf{b}_0)\boldsymbol{\Delta}\mathbf{b}\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b}_0)+\mathbf{W}(\mathbf{b}_0)\boldsymbol{\Delta}\mathbf{b}\|_2^2$$



This linearization scheme didn't work!!!

Solution: Set JIRB as a nonlinear problem

$$\Phi(\mathbf{r},\mathbf{b}) = \|\mathbf{H}(\mathbf{b}_0)\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

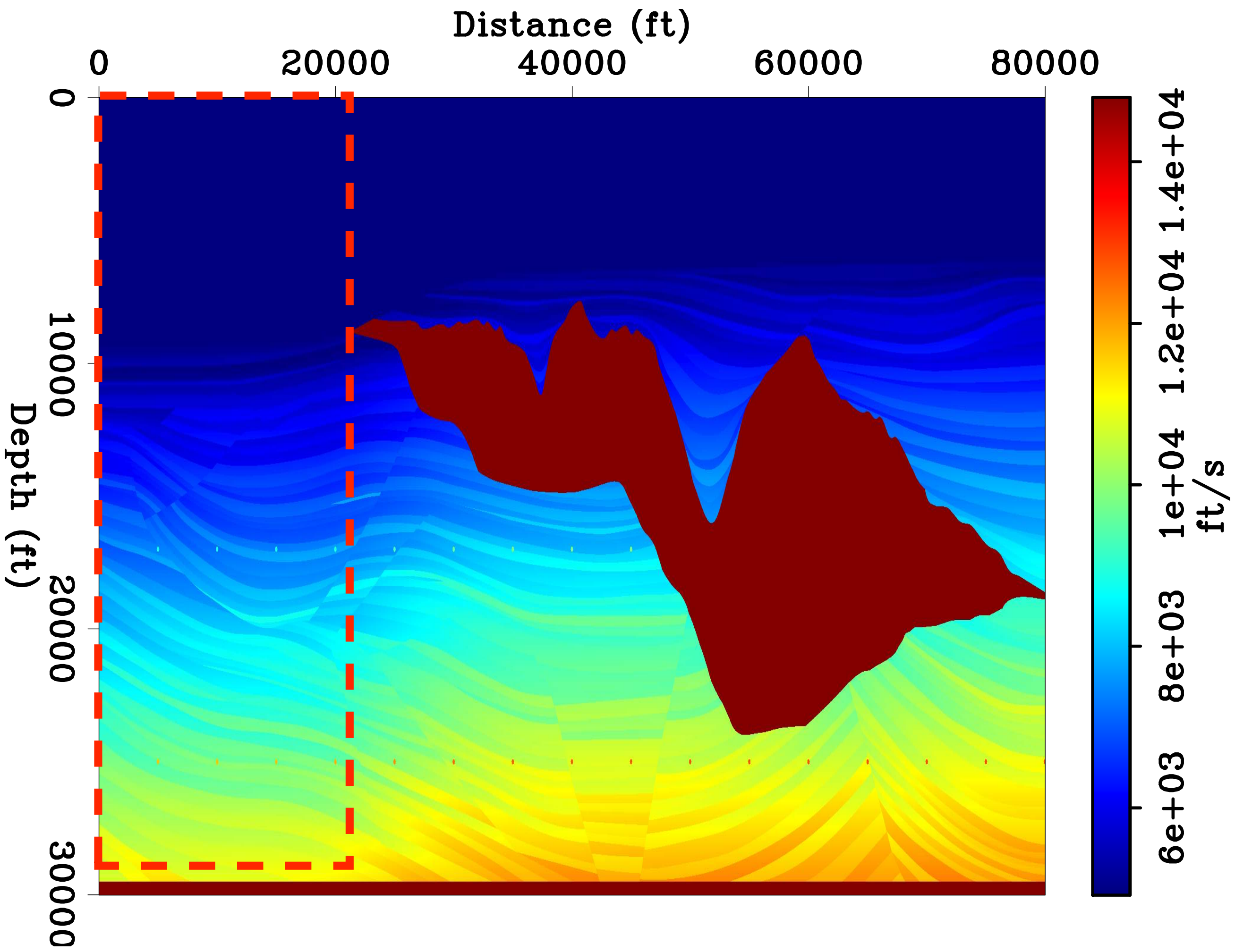


$$\mathbf{H}(\mathbf{b})\mathbf{r} \approx \mathbf{H}(\mathbf{b}_0)\mathbf{r}$$

Numerical Results

2D NUMERICAL TESTS

2D synthetic test: Preliminaries



Velocity model (sed. Section Sigsbee):

- Horizontal: 20,000 ft (6096 m)
- Vertical: 27,000 ft (8230 m)
- Spacing: 75 ft (22.86)

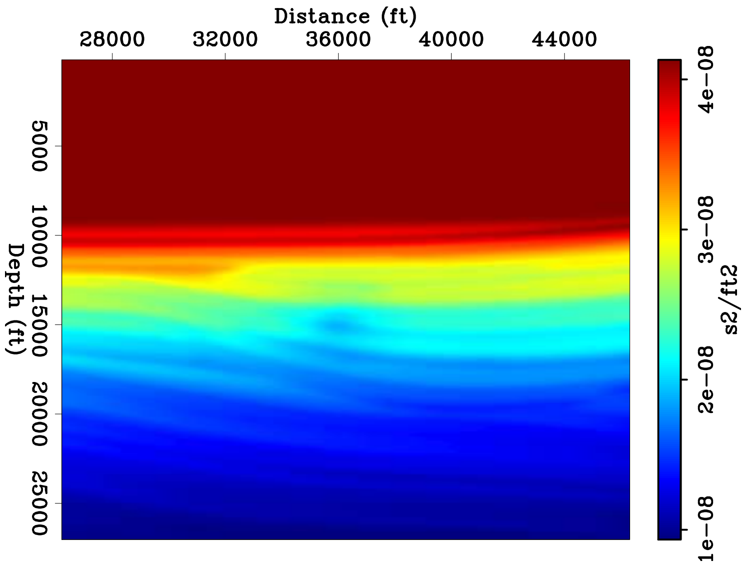
Acquisition geometry:

- 54 split-spread shots
- 651 receivers per shot
- Shot spacing: 500 ft (152.4 m)
- Receiver spacing: 75 ft (22.86)

Imaging:

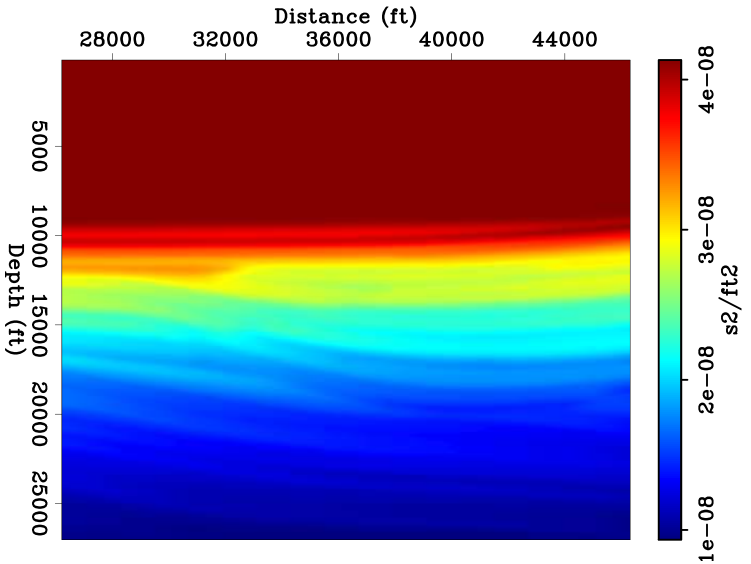
- Inversions ran until line search failed

2D synthetic test: Preliminaries



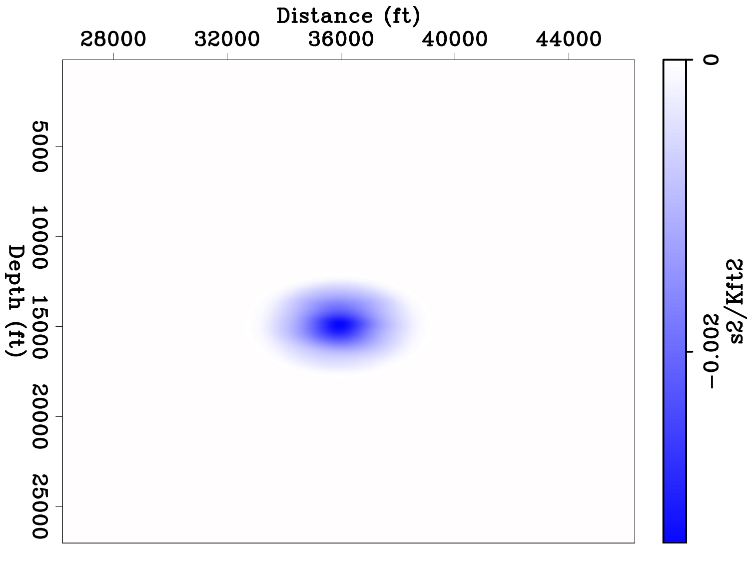
$\mathbf{b}$

=



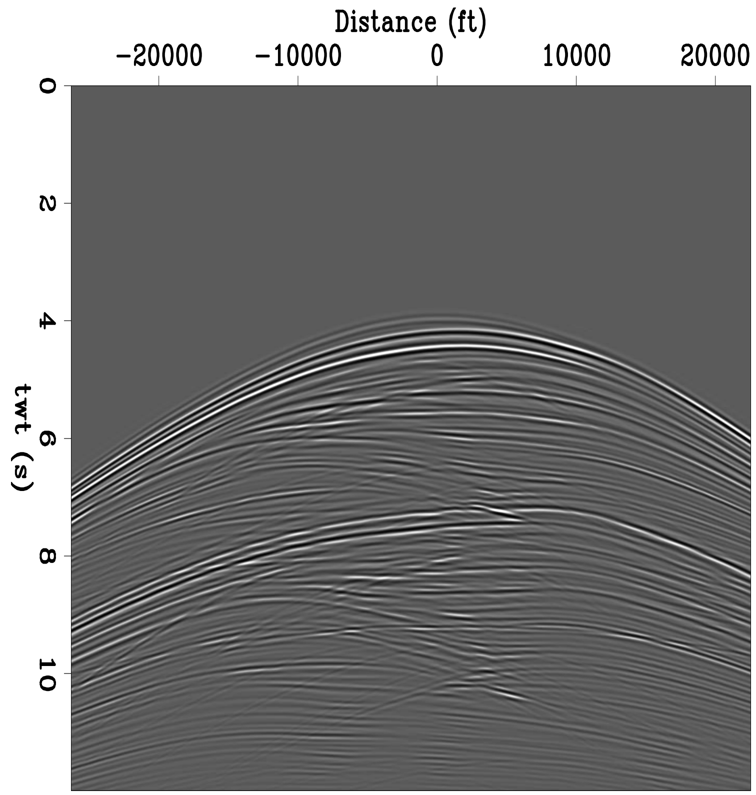
$\mathbf{b}_0$

+

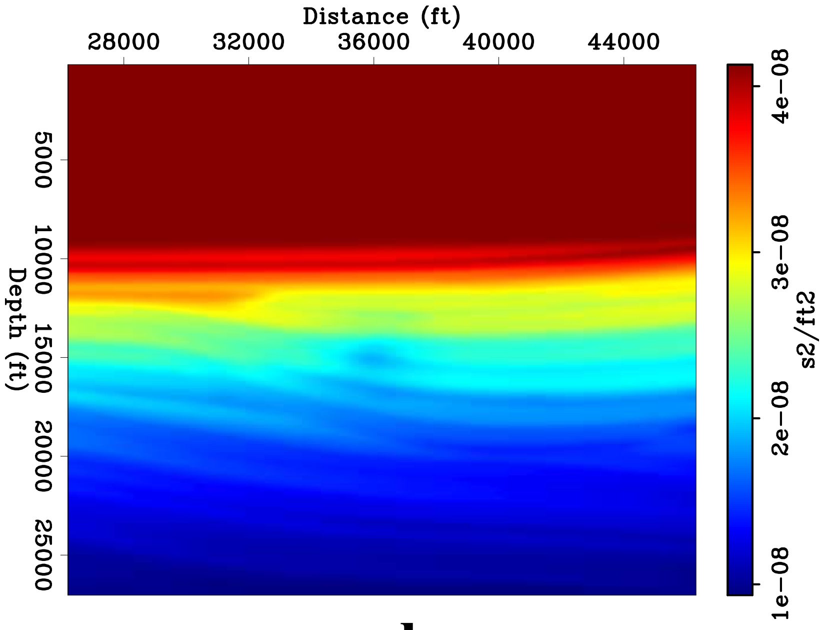


$\Delta\mathbf{b}$

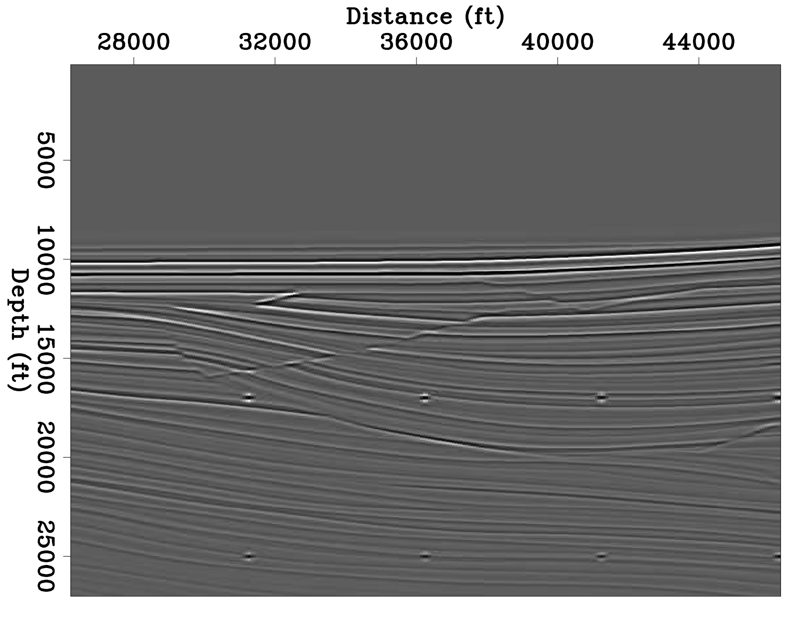
2D synthetic test: Preliminaries



$\mathbf{d}_{obs}$



b

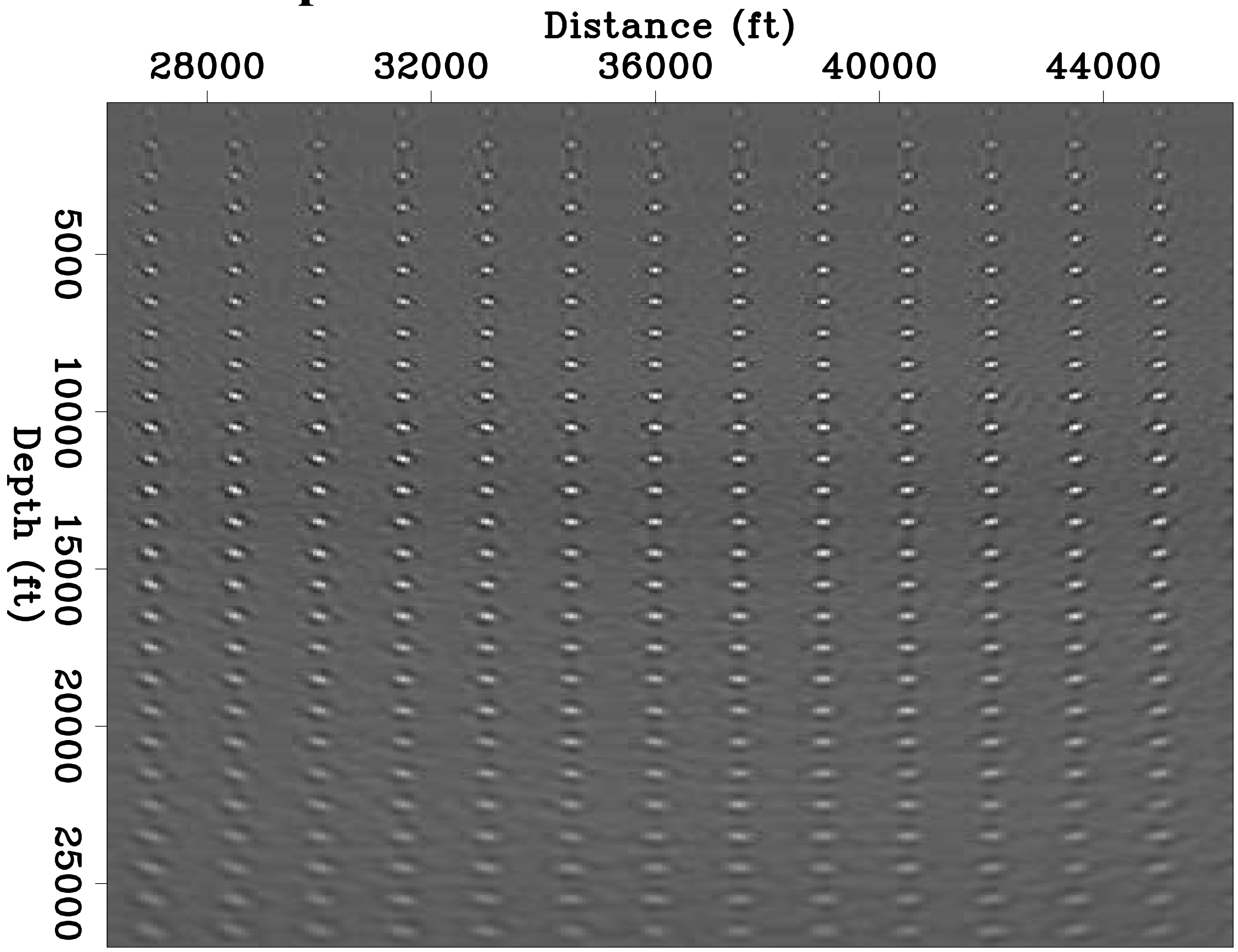


r

Born modeled data:

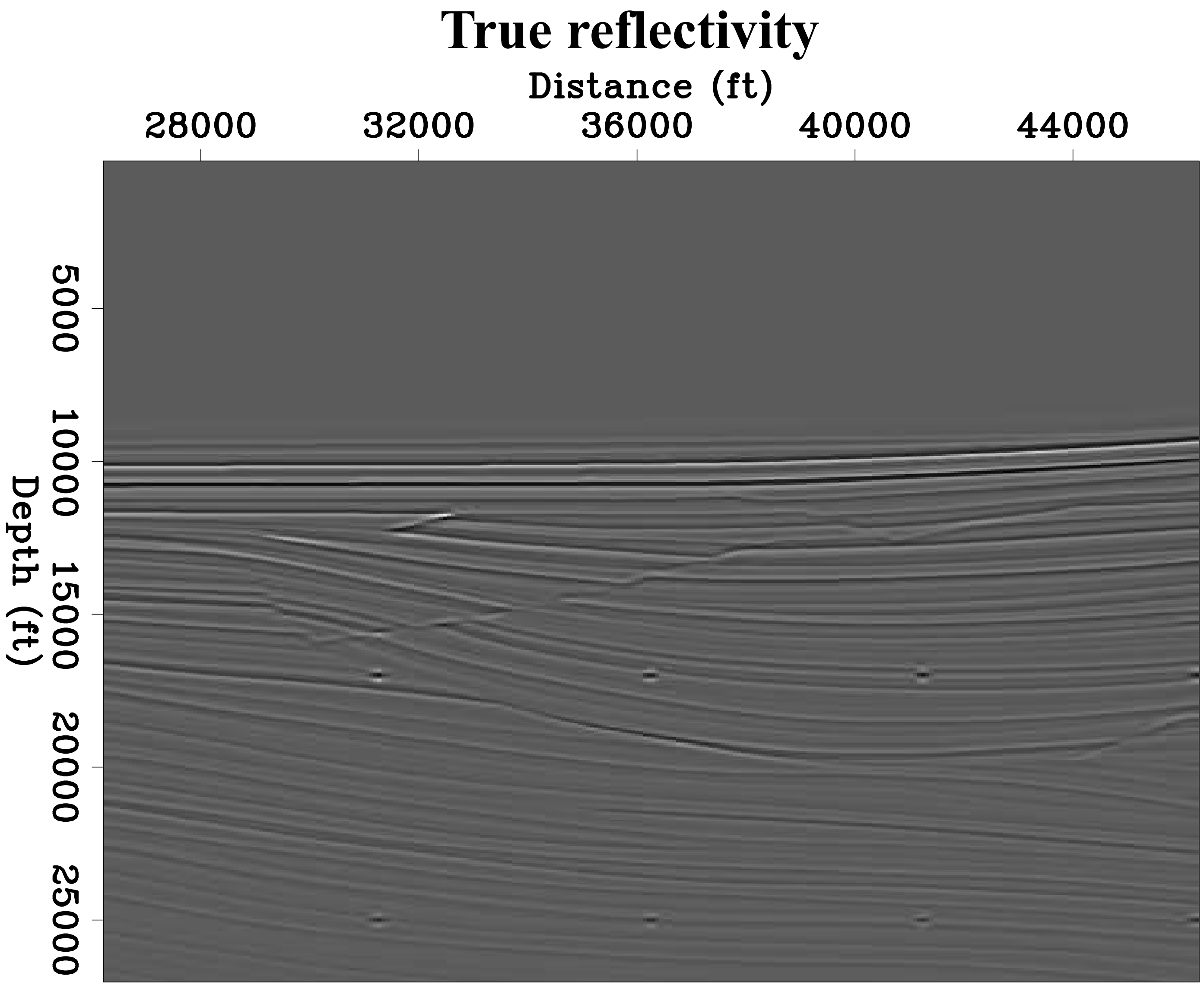
$\mathbf{d}_{obs}=\mathbf{L}(\mathbf{b})\mathbf{r}$

Point-spread functions: Hessian estimation

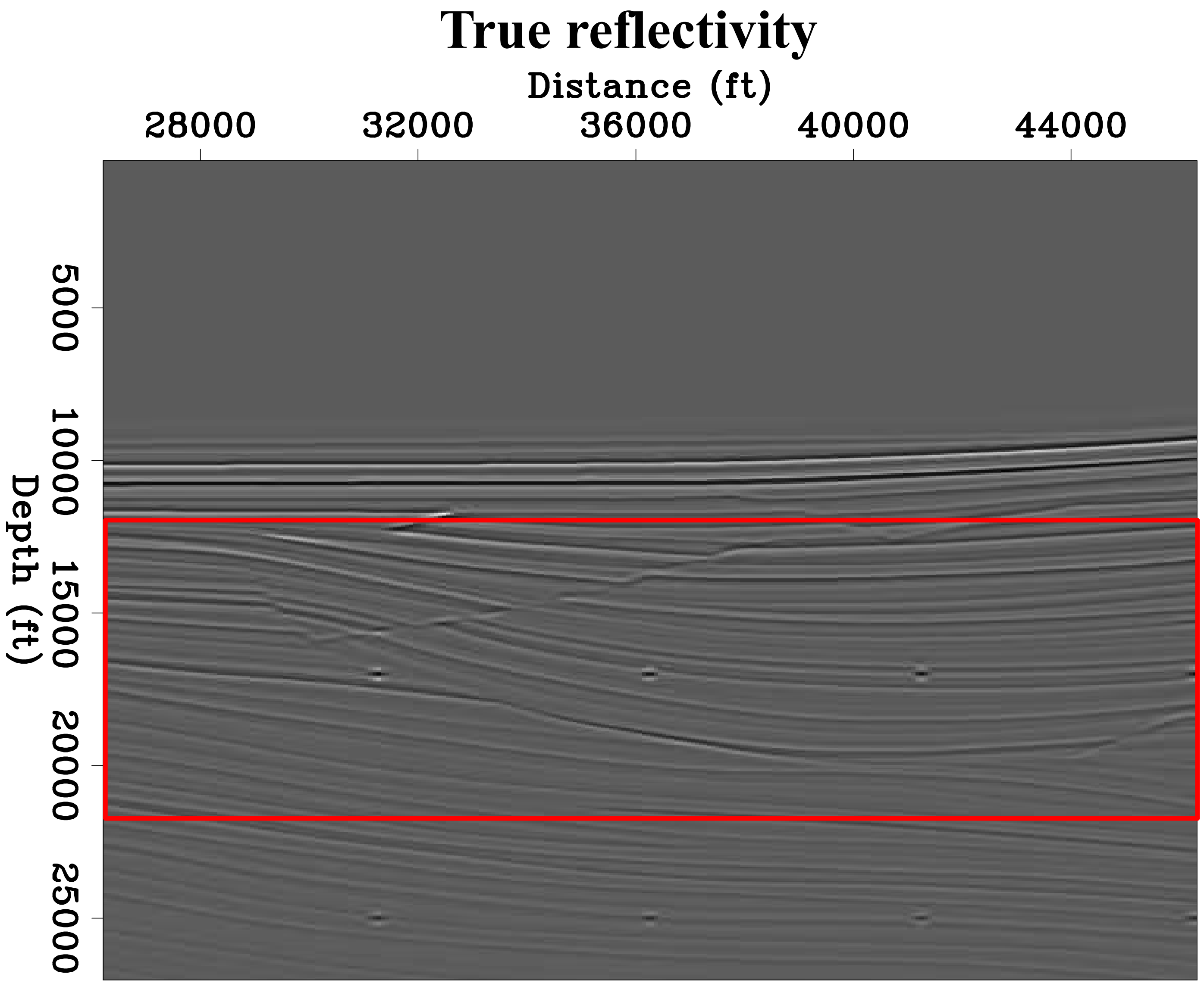


Reflectivity model:

True reflectivity vs. LWI

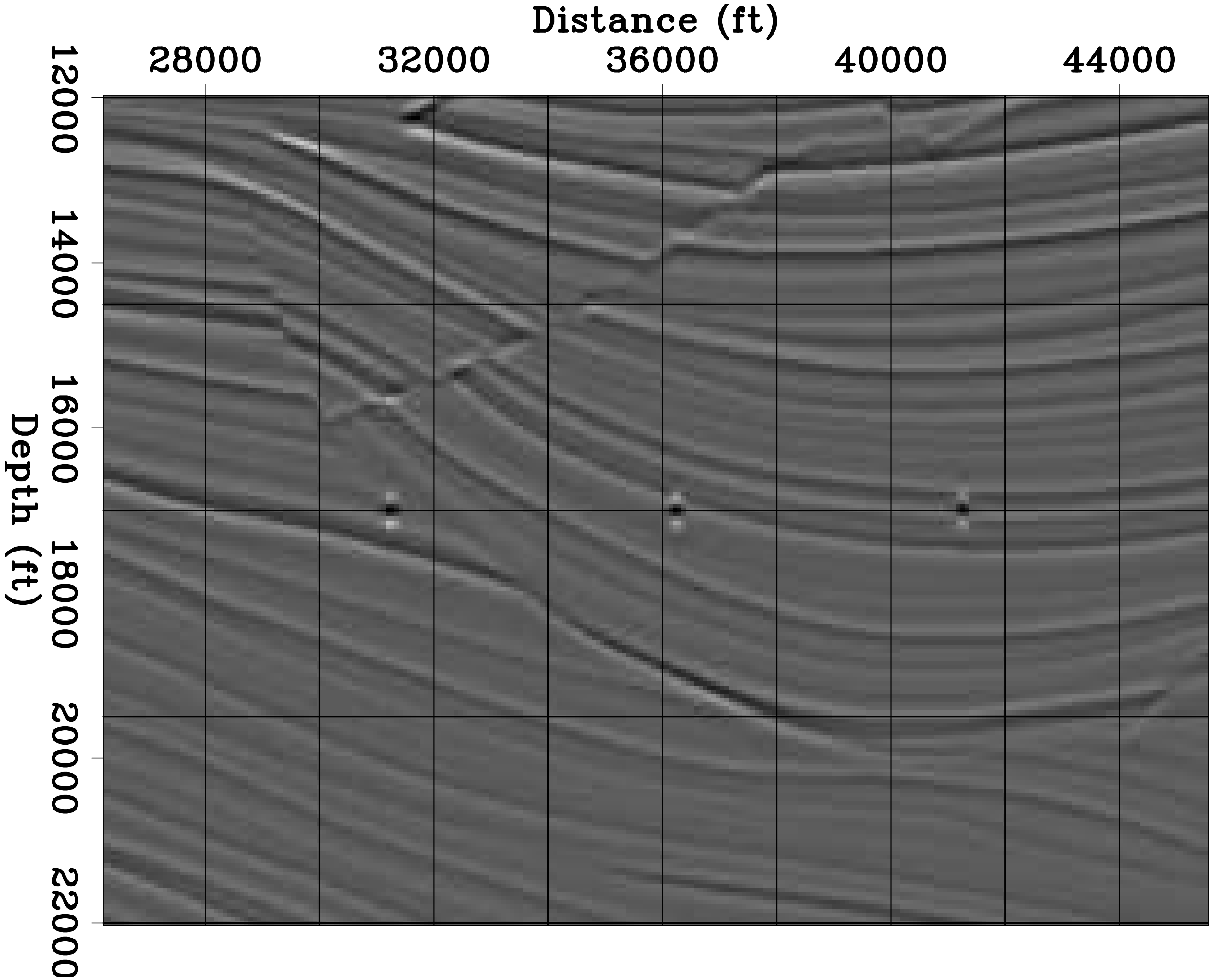

True reflectivity
Distance (ft)
28000
32000
36000
40000
44000
Depth (ft)
5000
10000
15000
20000
25000

2D NUMERICAL RESULTS

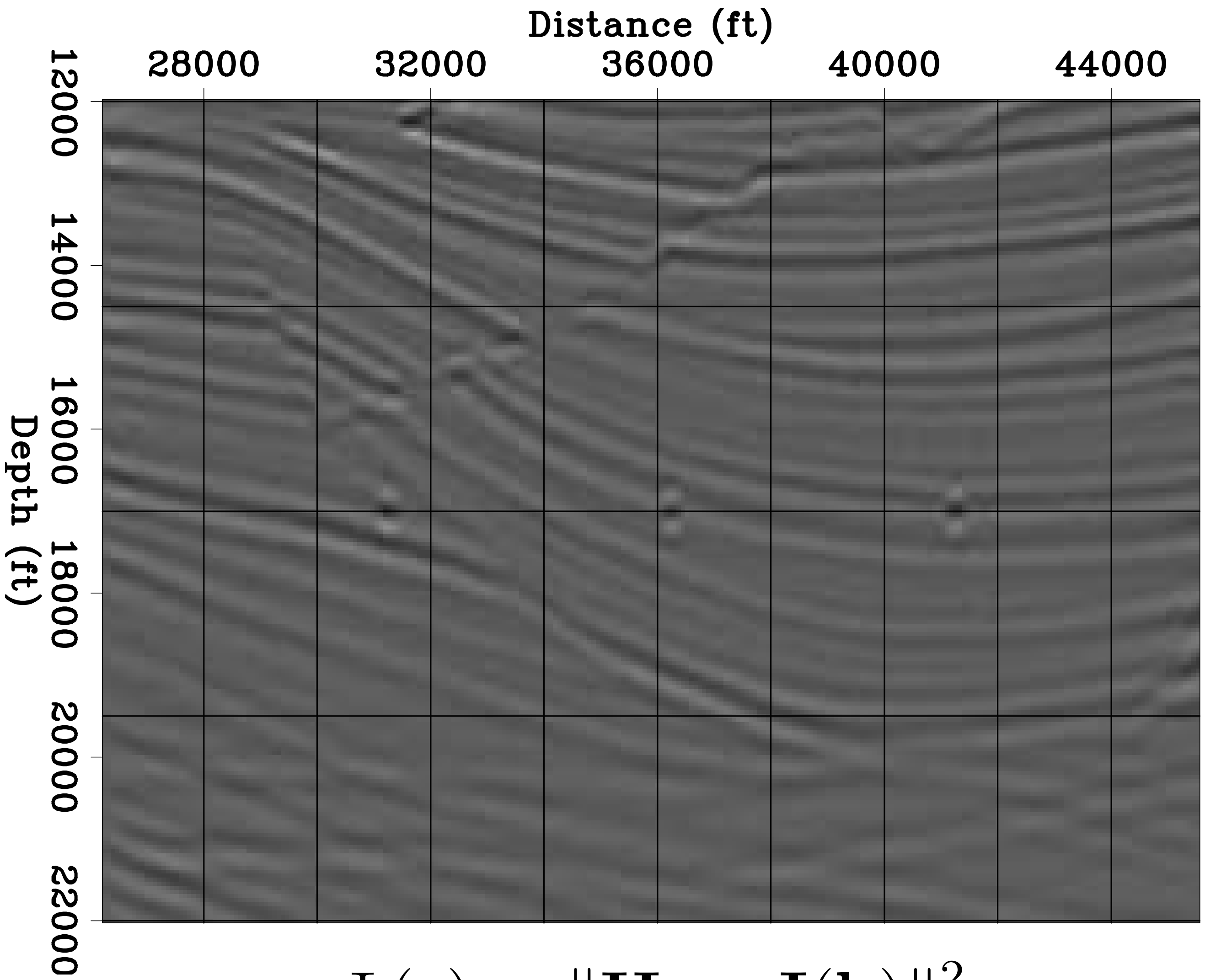


2D NUMERICAL RESULTS

True reflectivity

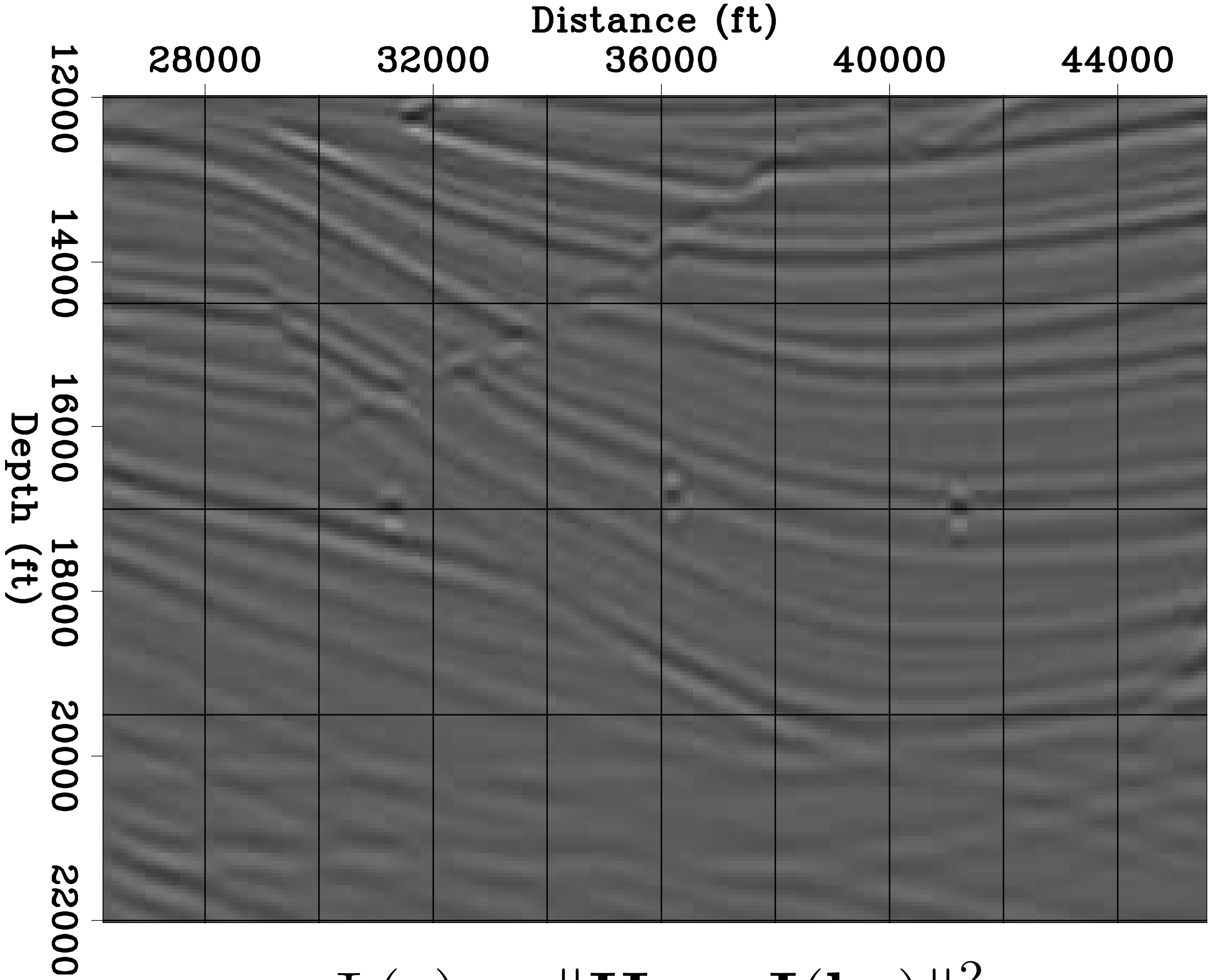


LWI: True background model (b)



$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2$$

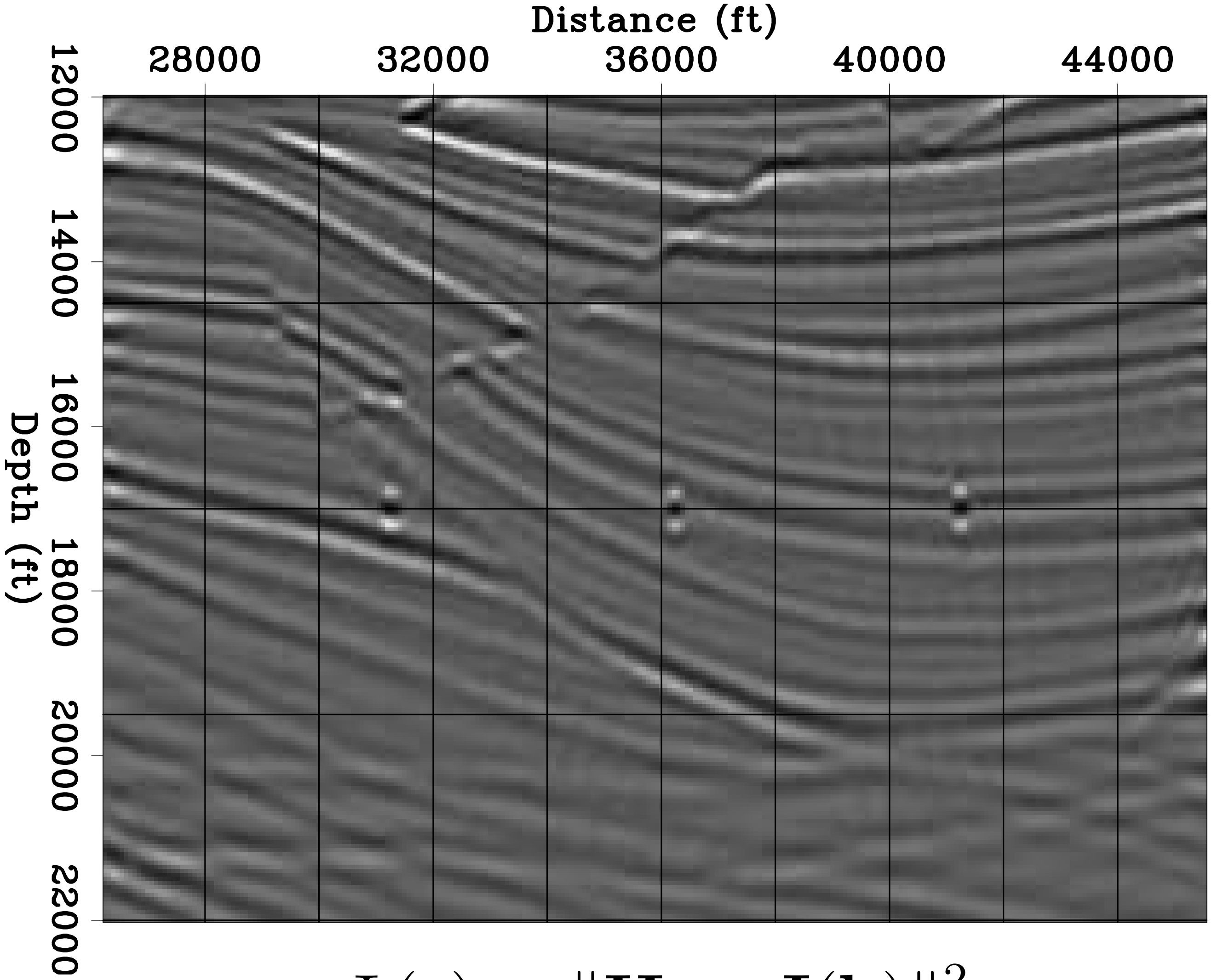
LWI: Wrong background model (b_0)



$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b}_0)\|_2^2$$

Reflectivity model:
LWI vs. JIRB

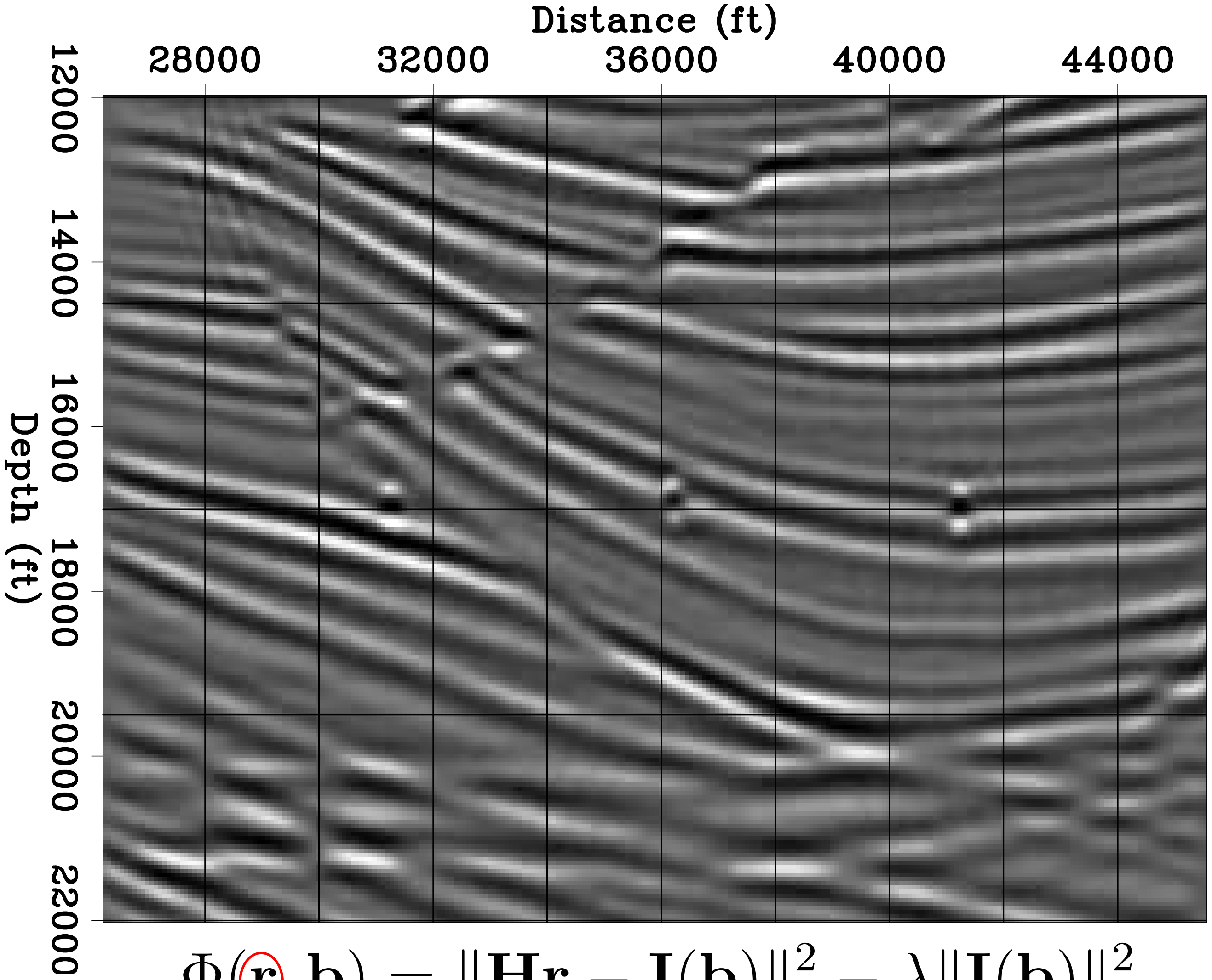
LWI: True background model (b)



$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2$$

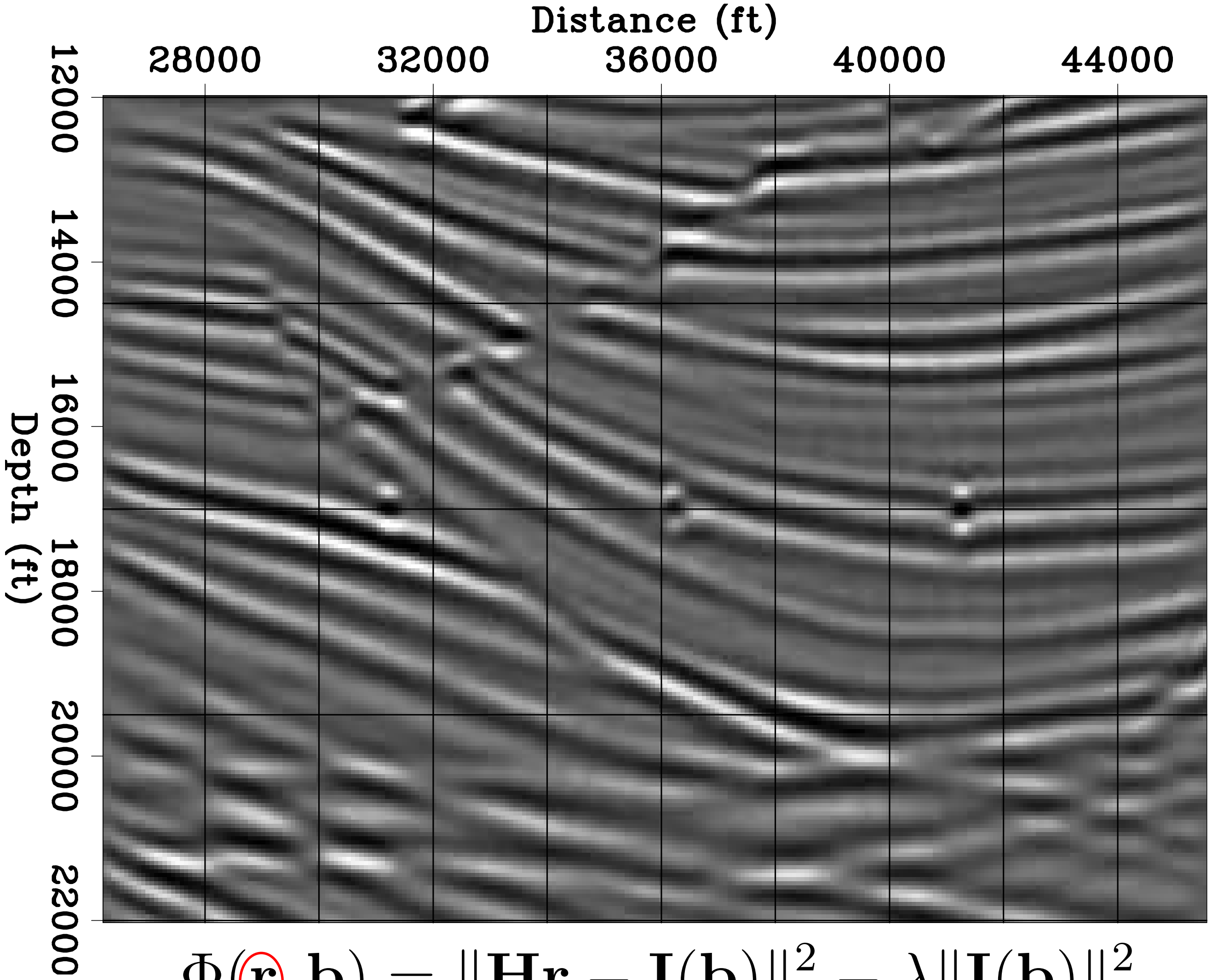
2D NUMERICAL RESULTS

JIRB: λ = 5 (40 iterations*)



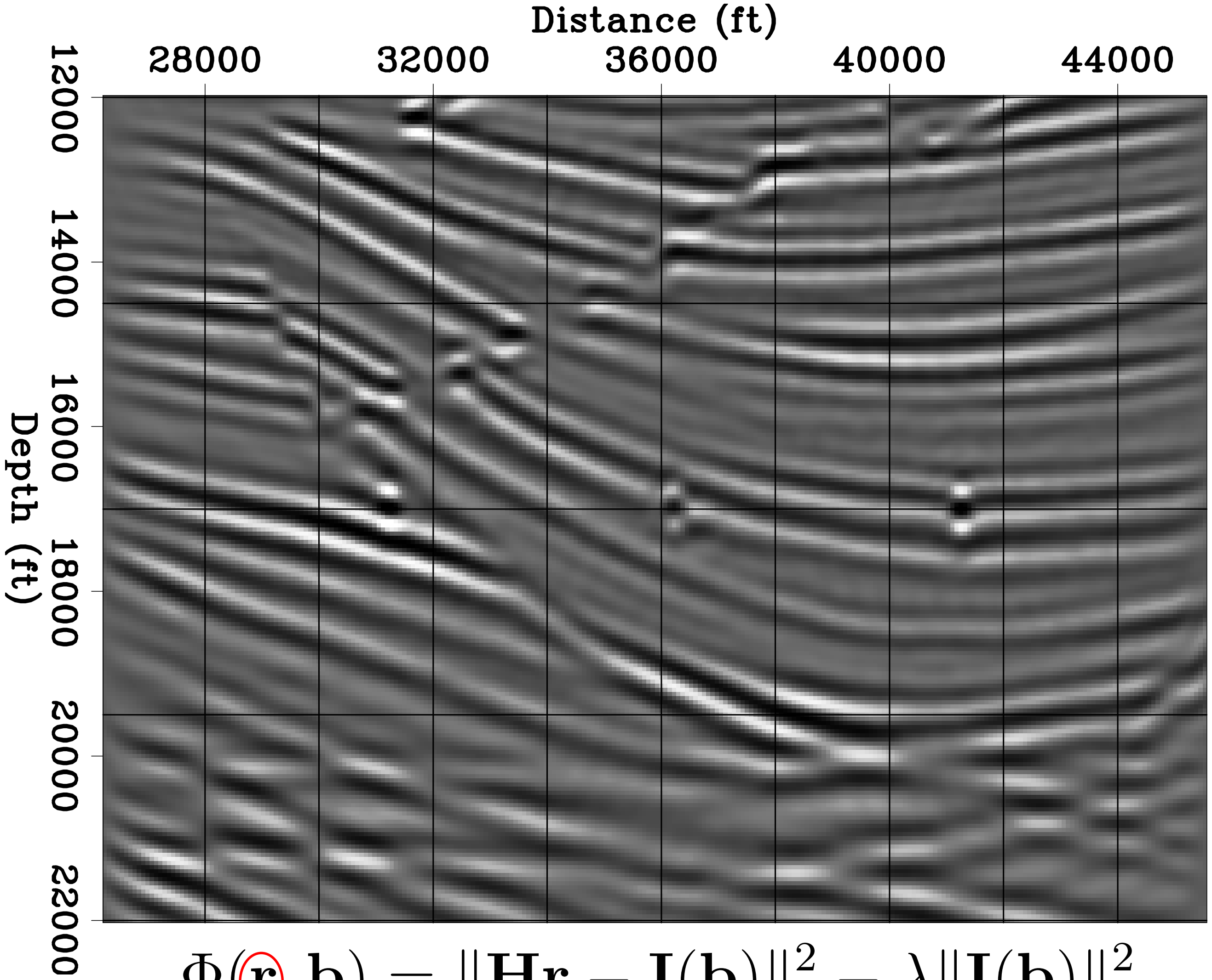
$$\Phi(\mathbf{r}, \mathrm{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathrm{b})\|_2^2 - \lambda\|\mathbf{I}(\mathrm{b})\|_2^2$$

JIRB: $\lambda = 10$ (30 iterations)



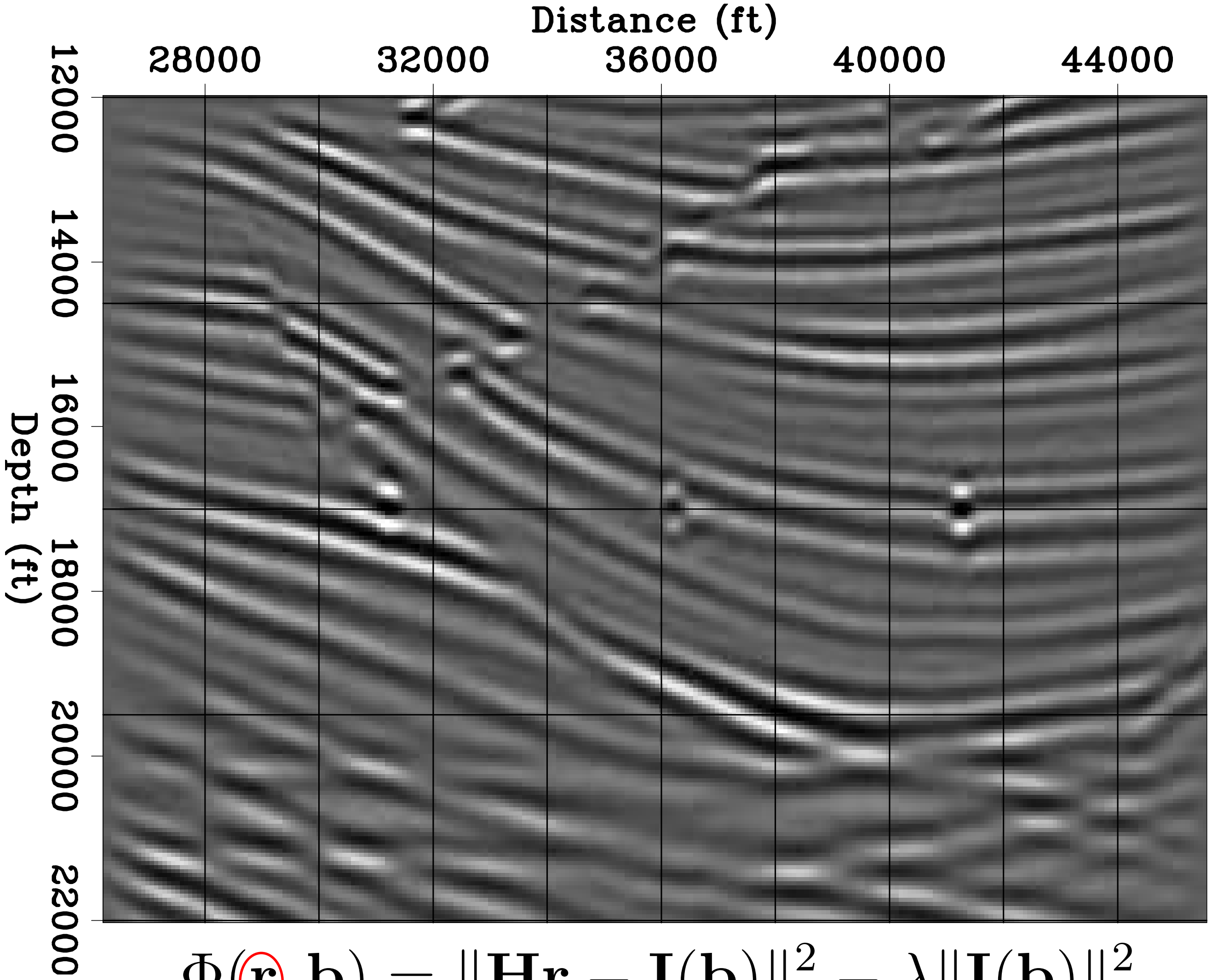
$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

JIRB: $\lambda = 15$ (10 iterations)



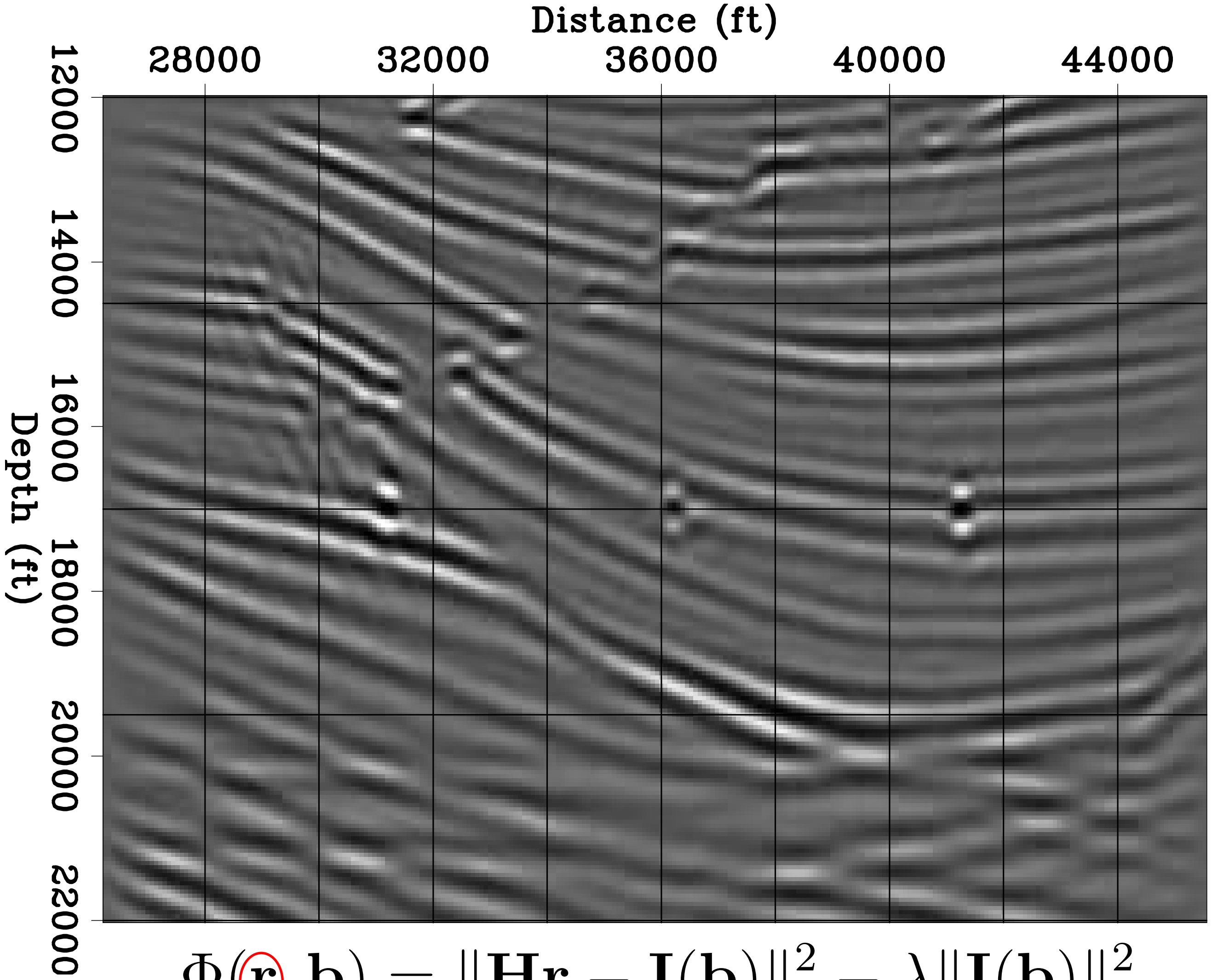
$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

JIRB: $\lambda = 20$ (4 iterations)



$$\Phi(\mathbf{r}, \mathrm{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathrm{b})\|_2^2 - \lambda\|\mathbf{I}(\mathrm{b})\|_2^2$$

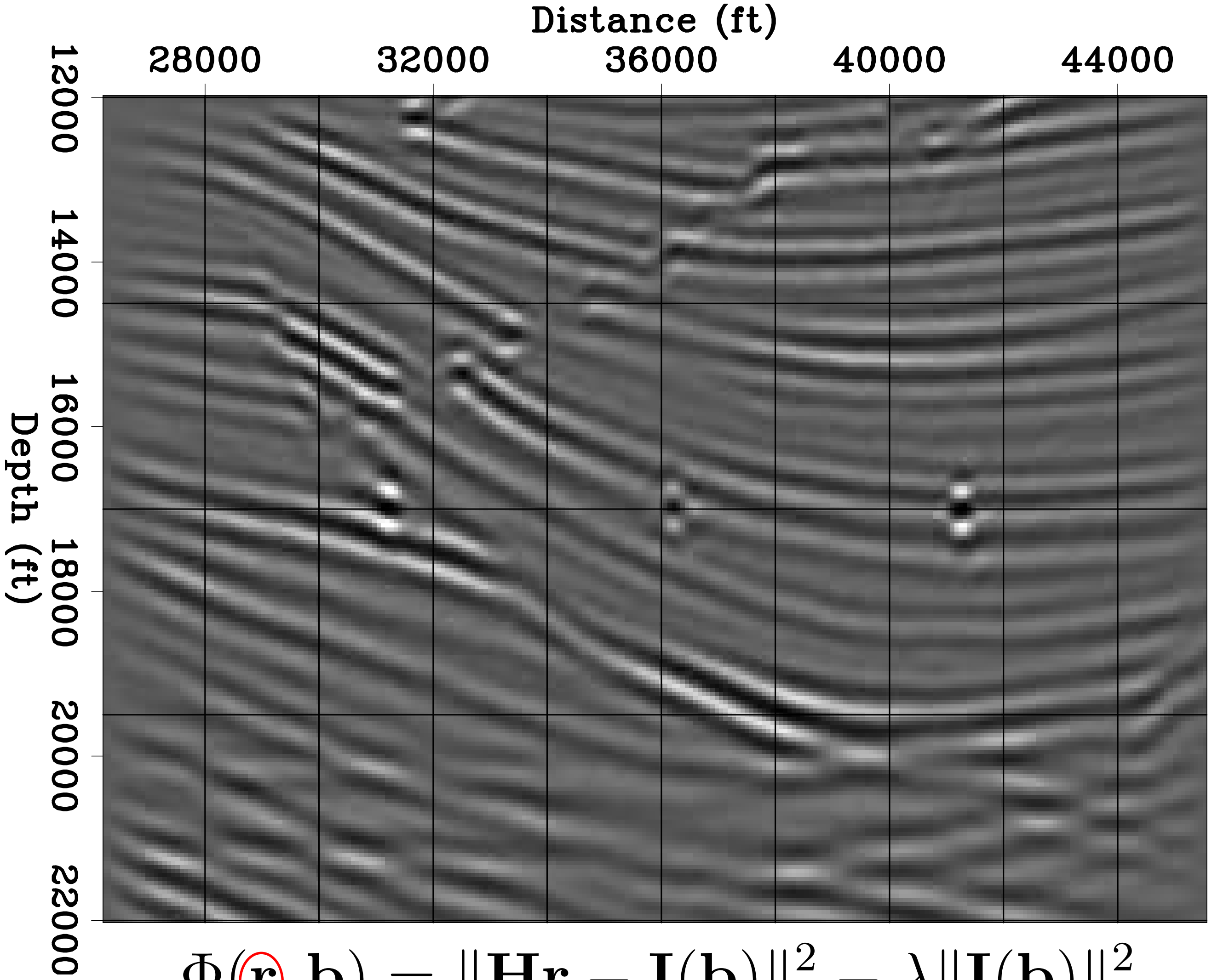
JIRB: $\lambda = 25$ (3 iterations)



$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda \|\mathbf{I}(\mathbf{b})\|_2^2$$

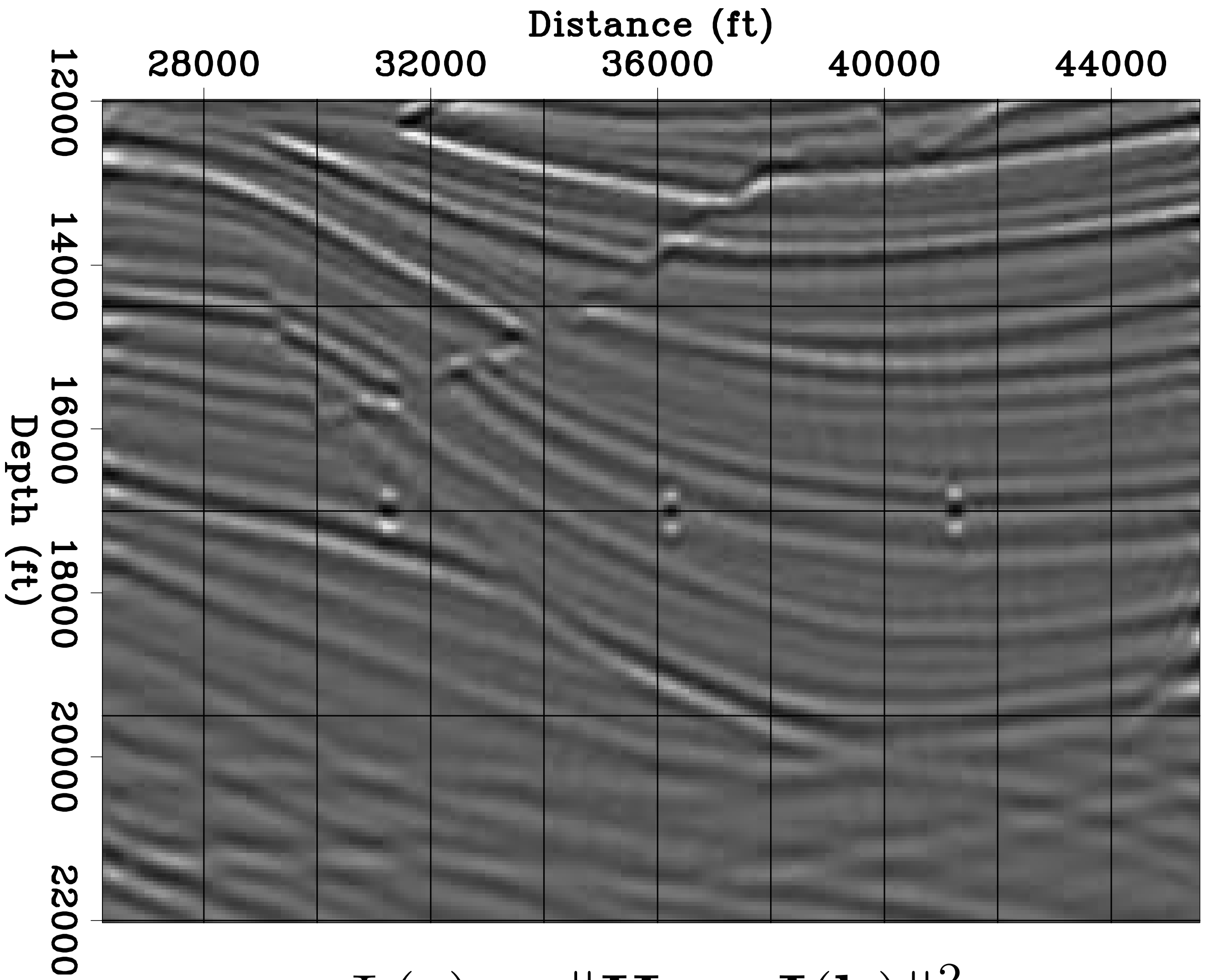
2D NUMERICAL RESULTS

JIRB: $\lambda = 30$ (3 iterations)



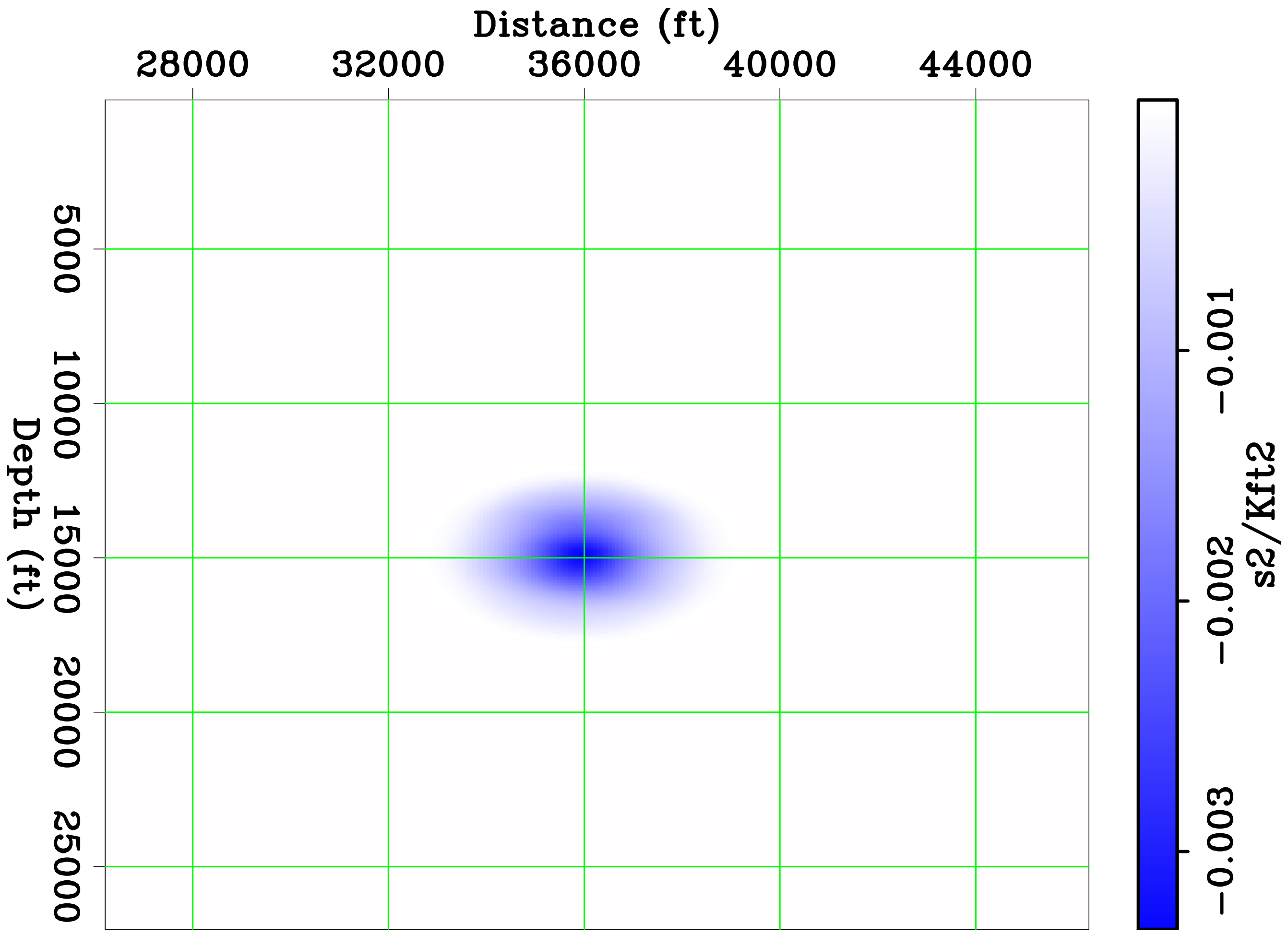
$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda \|\mathbf{I}(\mathbf{b})\|_2^2$$

LWI: True background model (b)

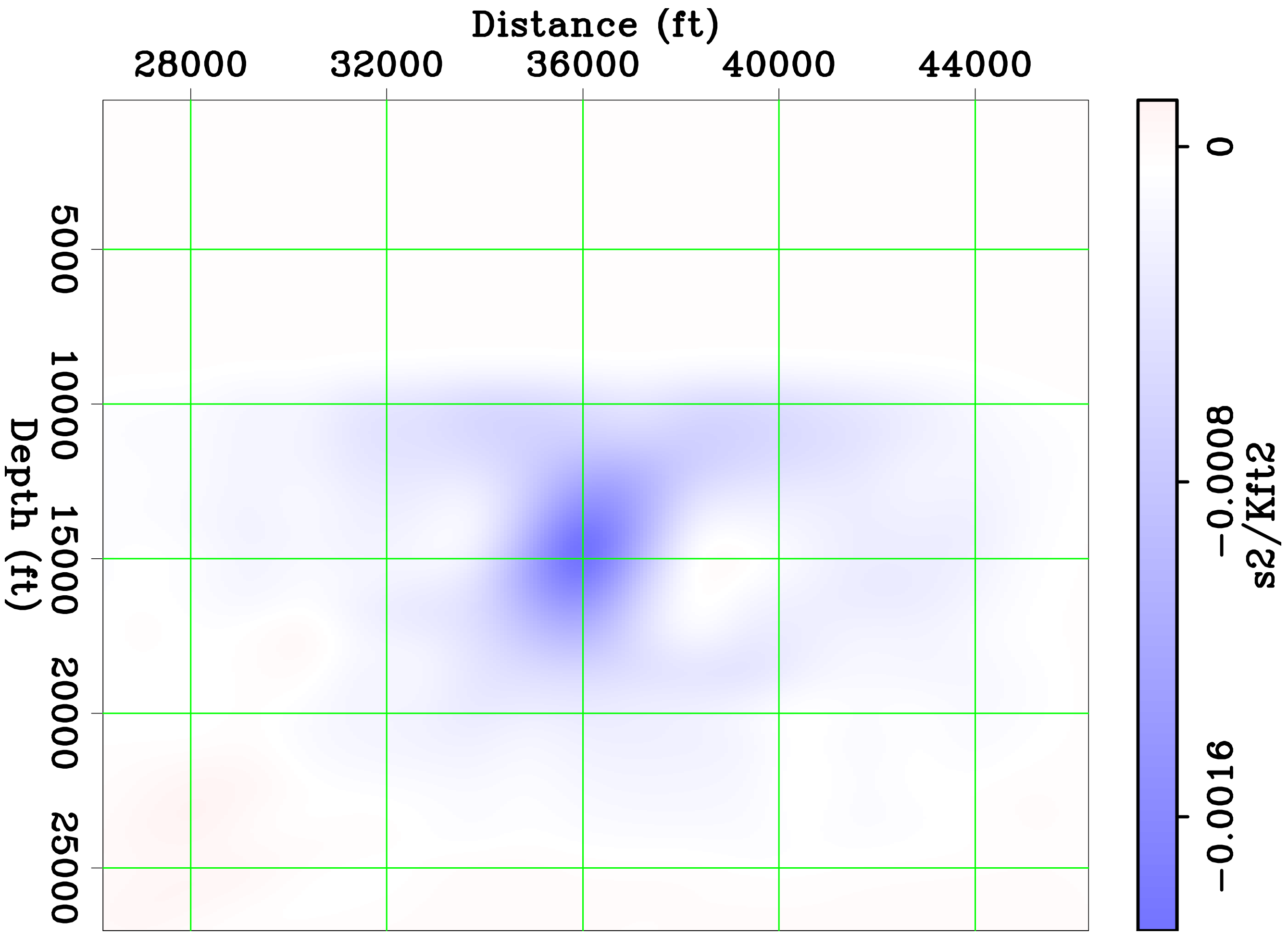


$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2$$

True perturbation in the background



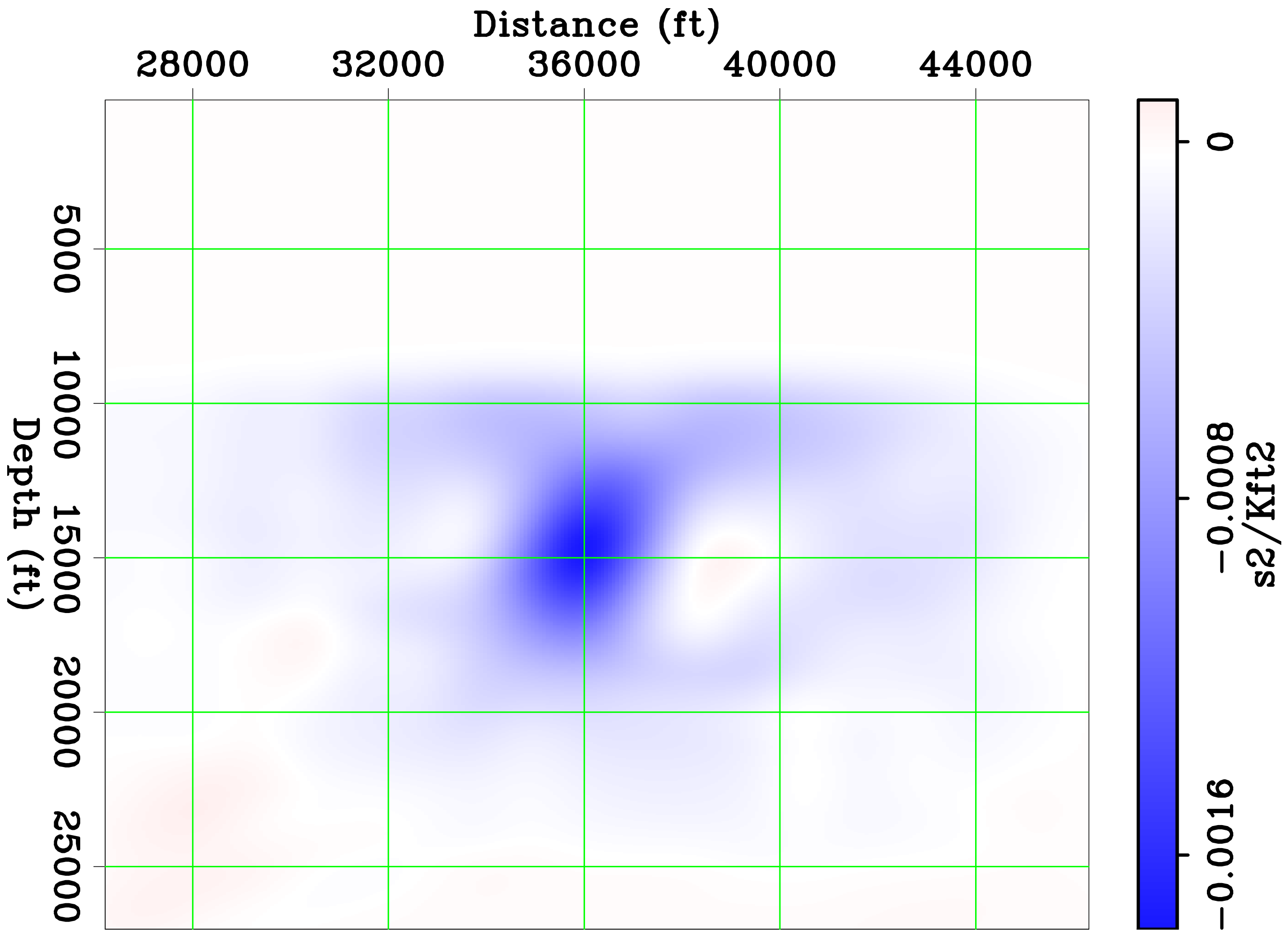
JIRB perturbation in the background ($\lambda = 25$)



$$\Phi(\mathbf{r}, \mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

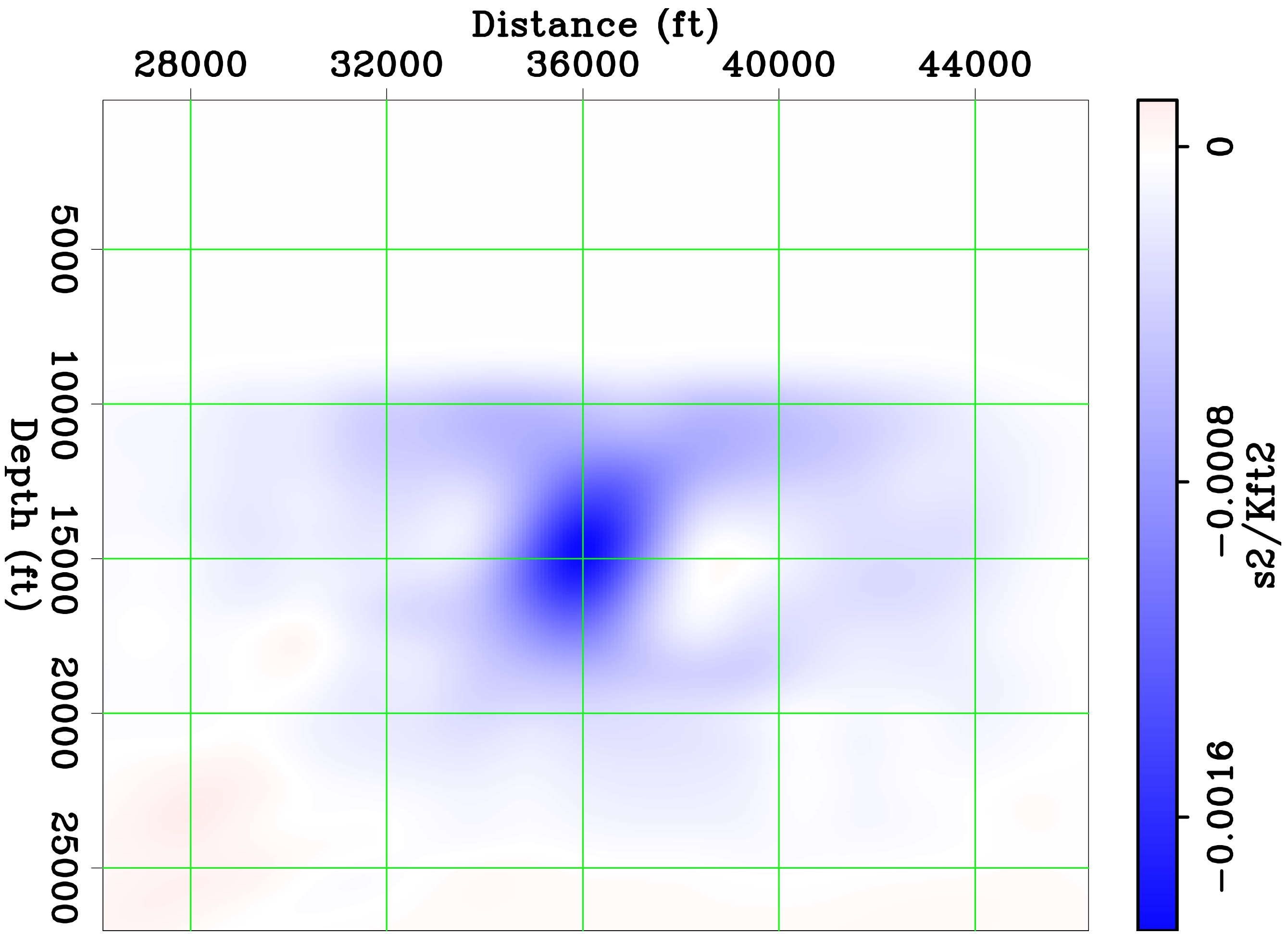
Background model:
WEMVA vs. JIRB

WEMVA perturbation in the background



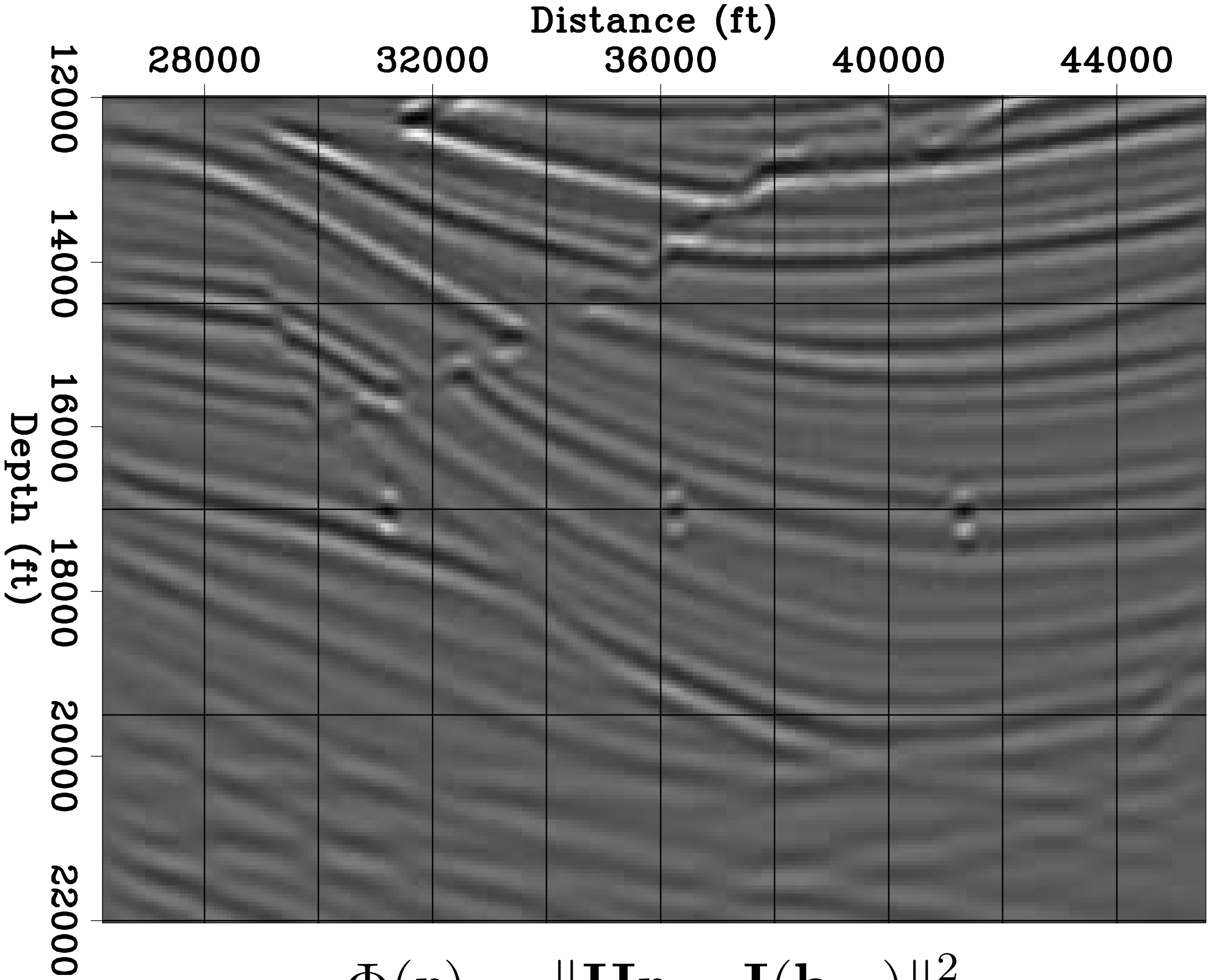
$$\Phi(\mathbf{b}) = -\|\mathbf{I}(\mathbf{b})\|_2^2 \quad \Delta\mathbf{b} = \mathbf{b} - \mathbf{b}_0$$

JIRB perturbation in the background ($\lambda = 25$)



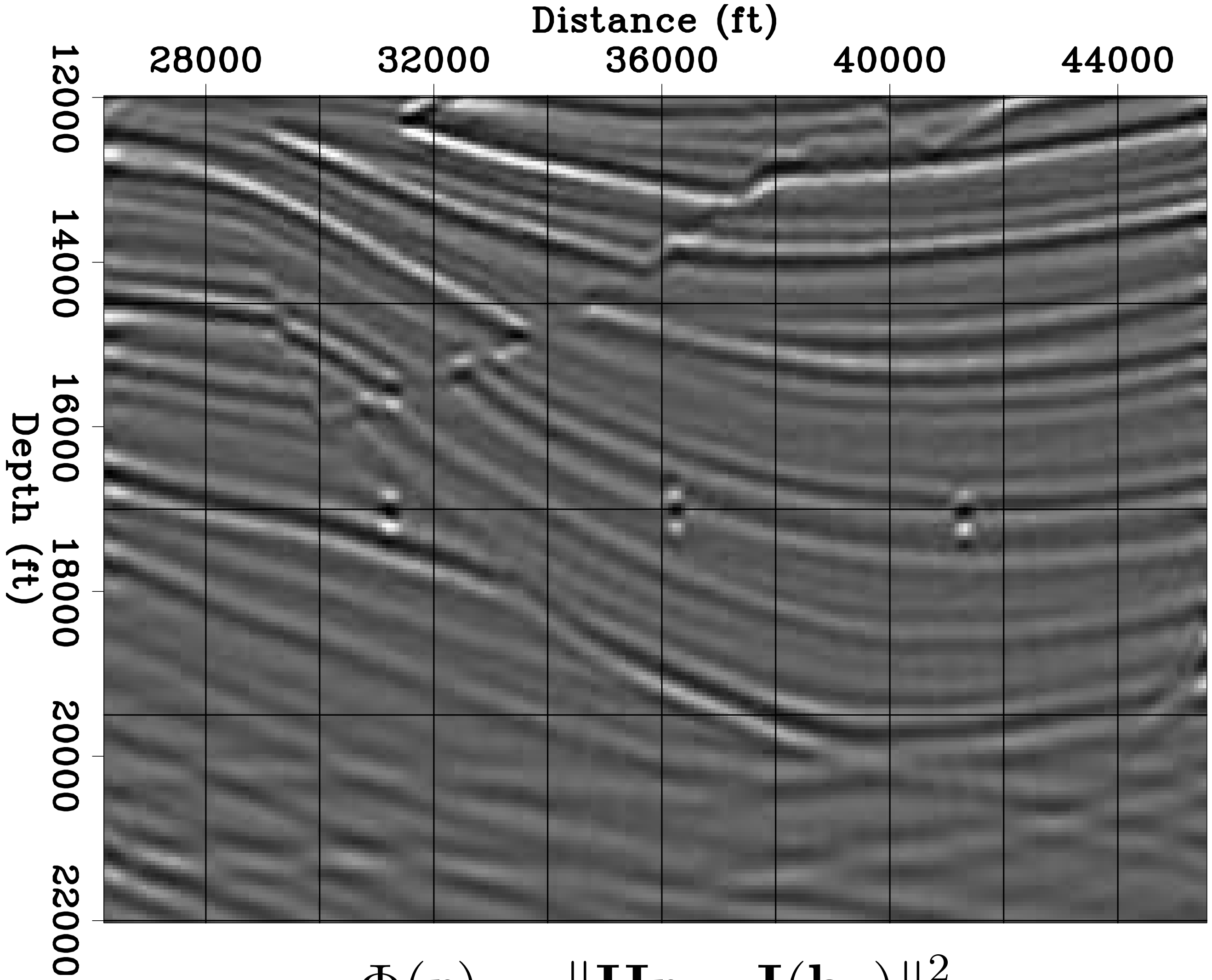
$$\Phi(\mathbf{r},\mathbf{b}) = \|\mathbf{Hr} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2 \quad \Delta\mathbf{b} = \mathbf{b} - \mathbf{b}_0$$

LWI with WEMVA background model



$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b}_W)\|_2^2$$

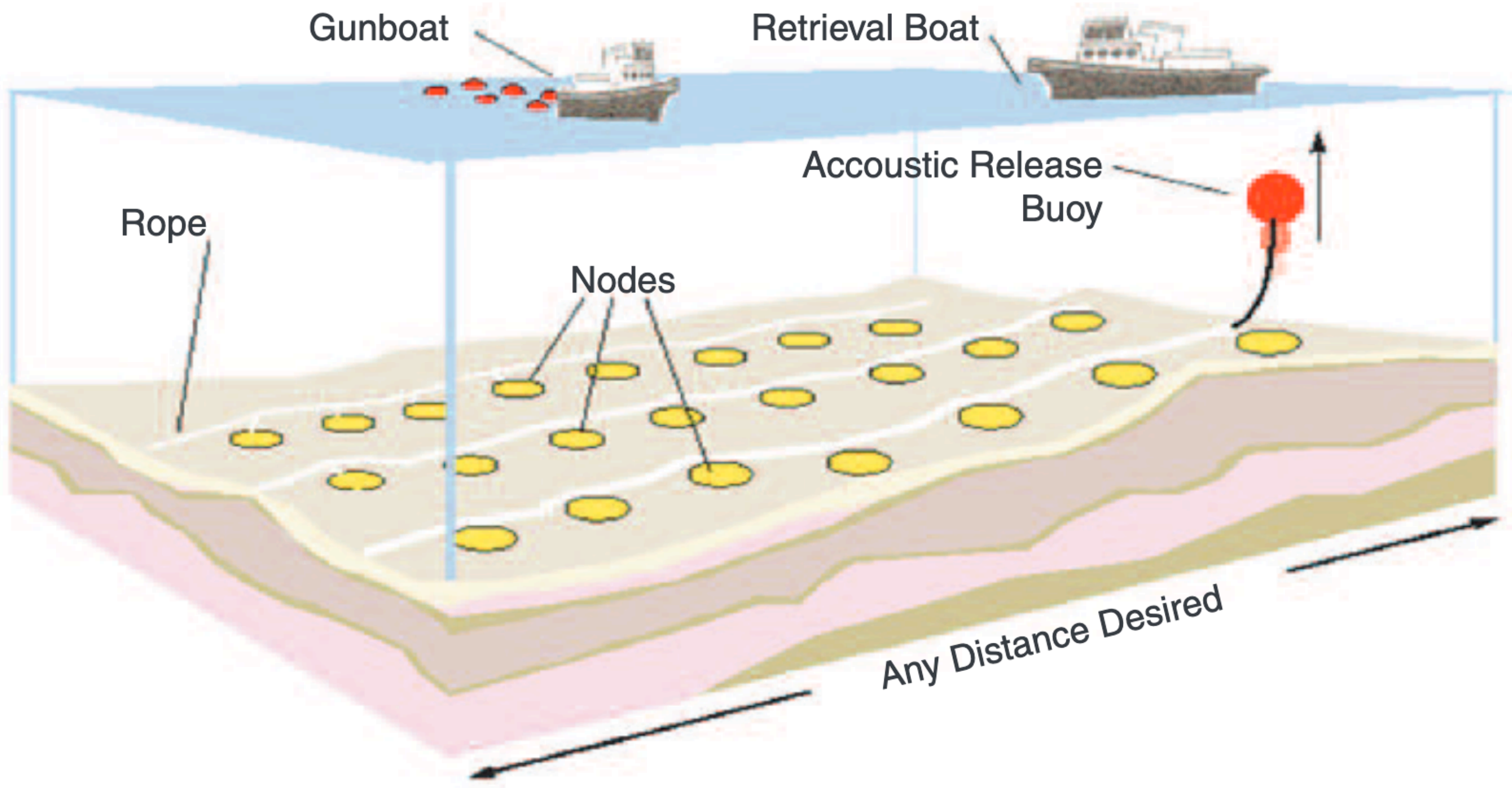
LWI with JIRB background model



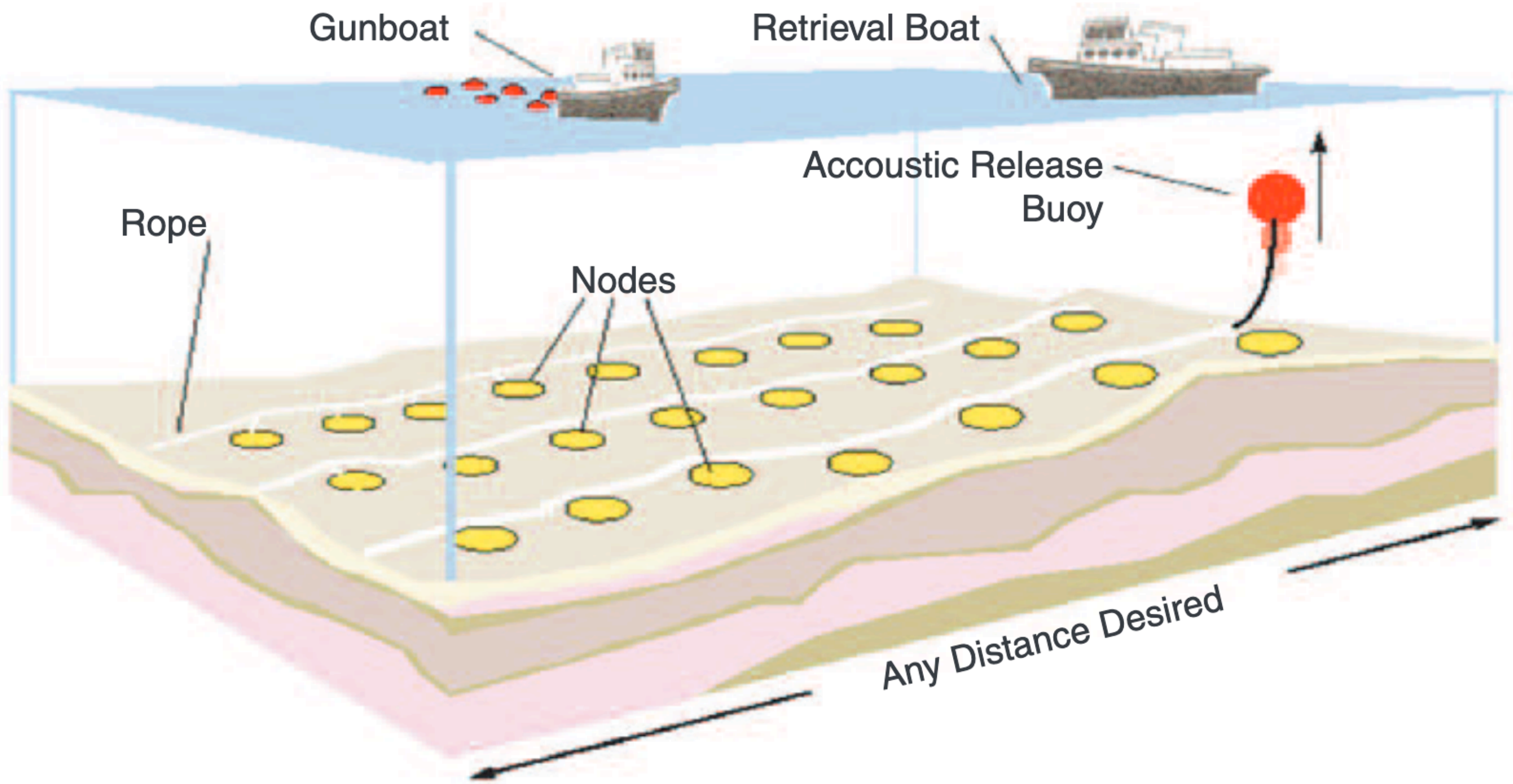
$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b}_{\mathrm{J}})\|_2^2$$

3D NUMERICAL TESTS

3D real data test: Ocean Bottom Node (OBN)

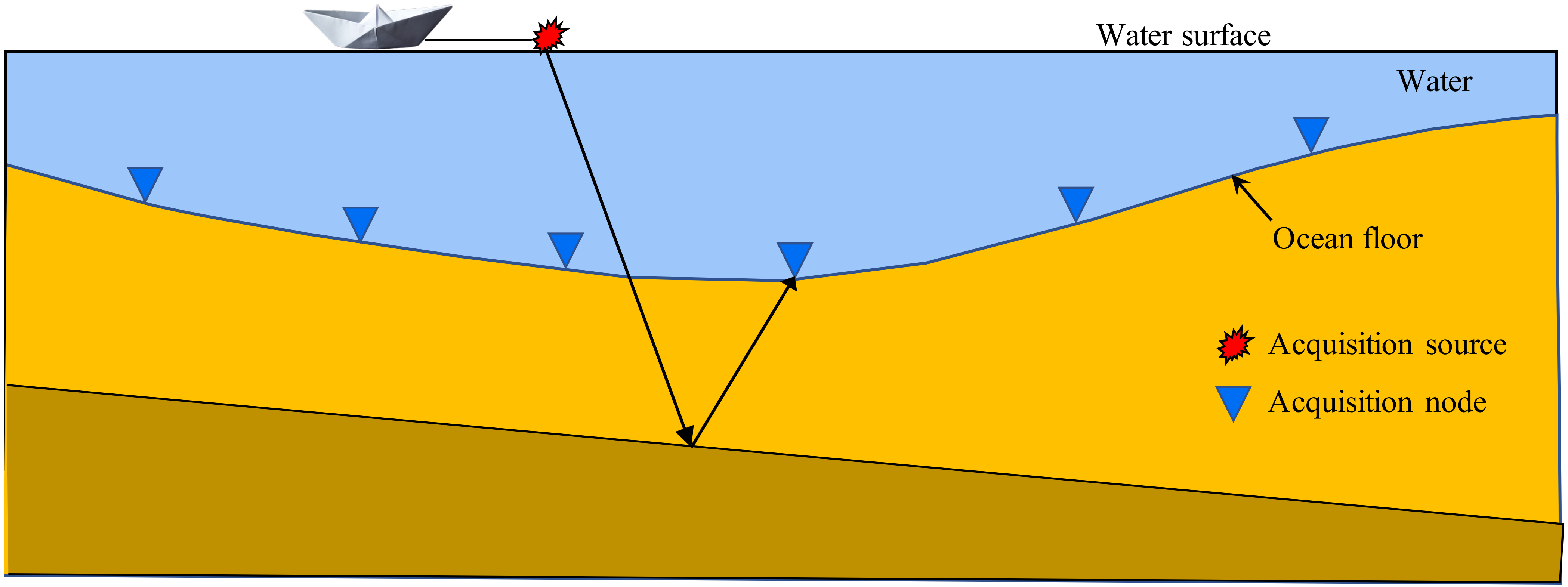


3D real data test: Ocean Bottom Node (OBN)

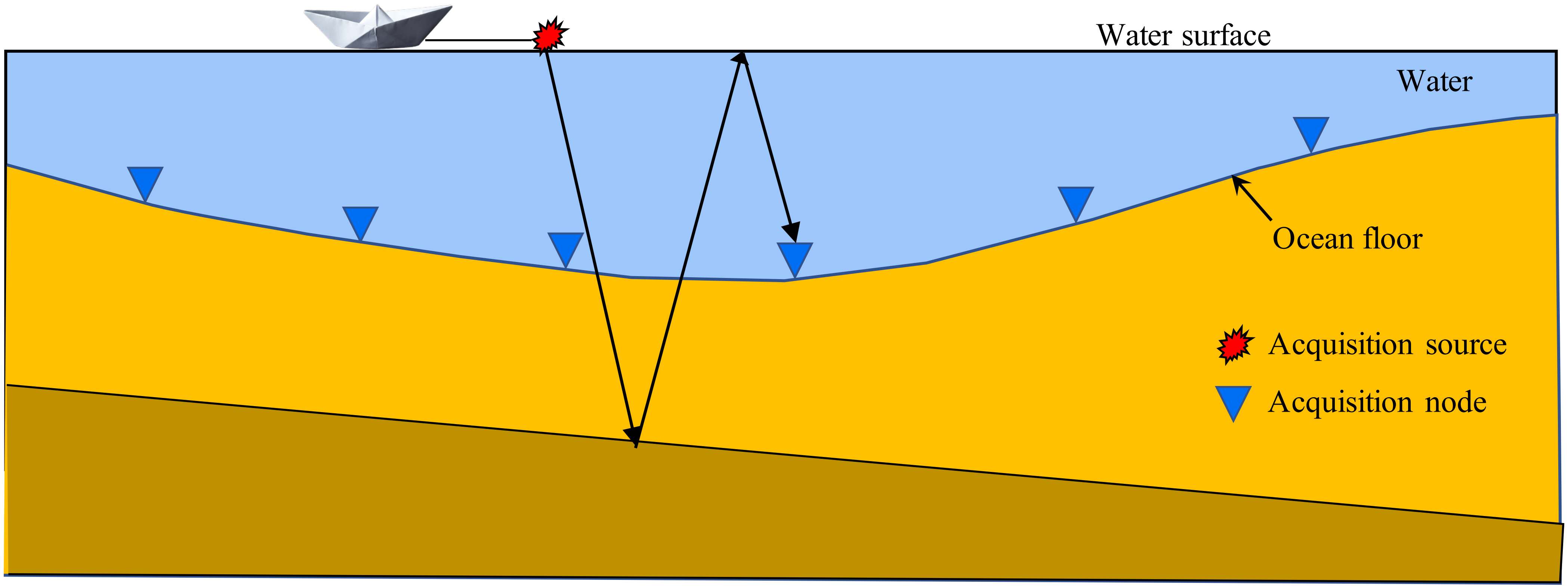


- Hydrophone: Measures pressure => Scalar
- Geophone: Measures Displacement => Vector

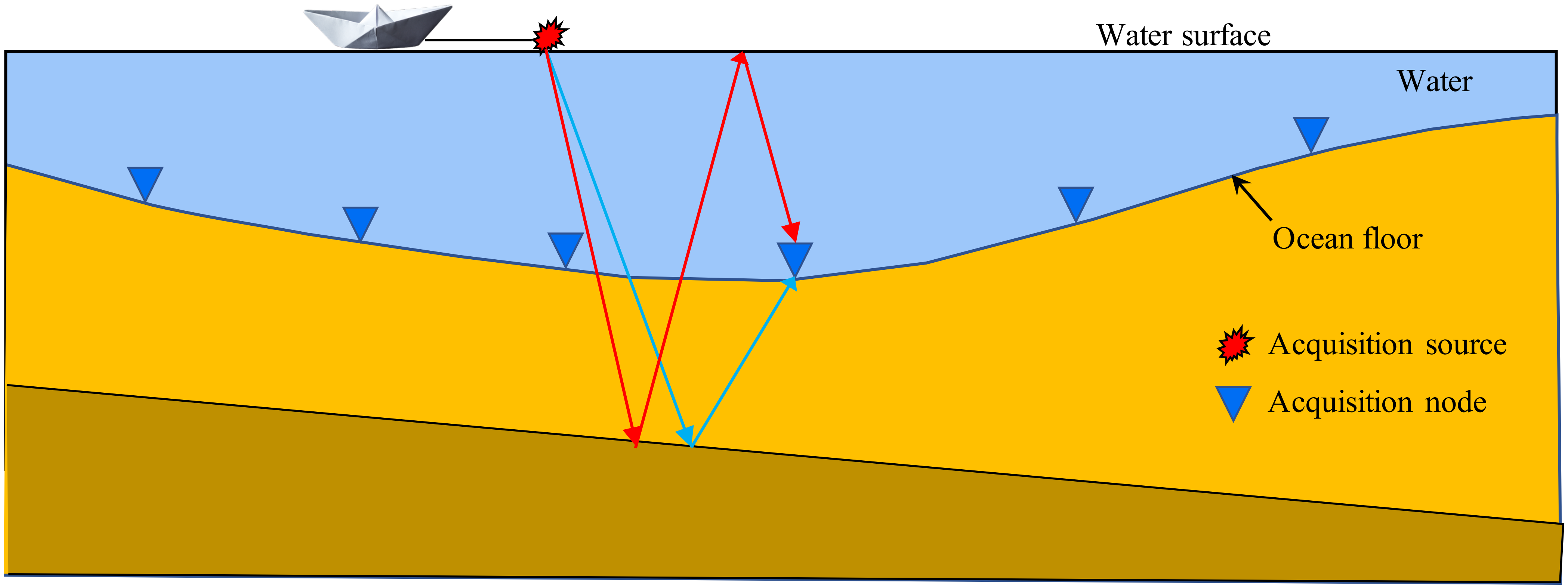
Upgoing component



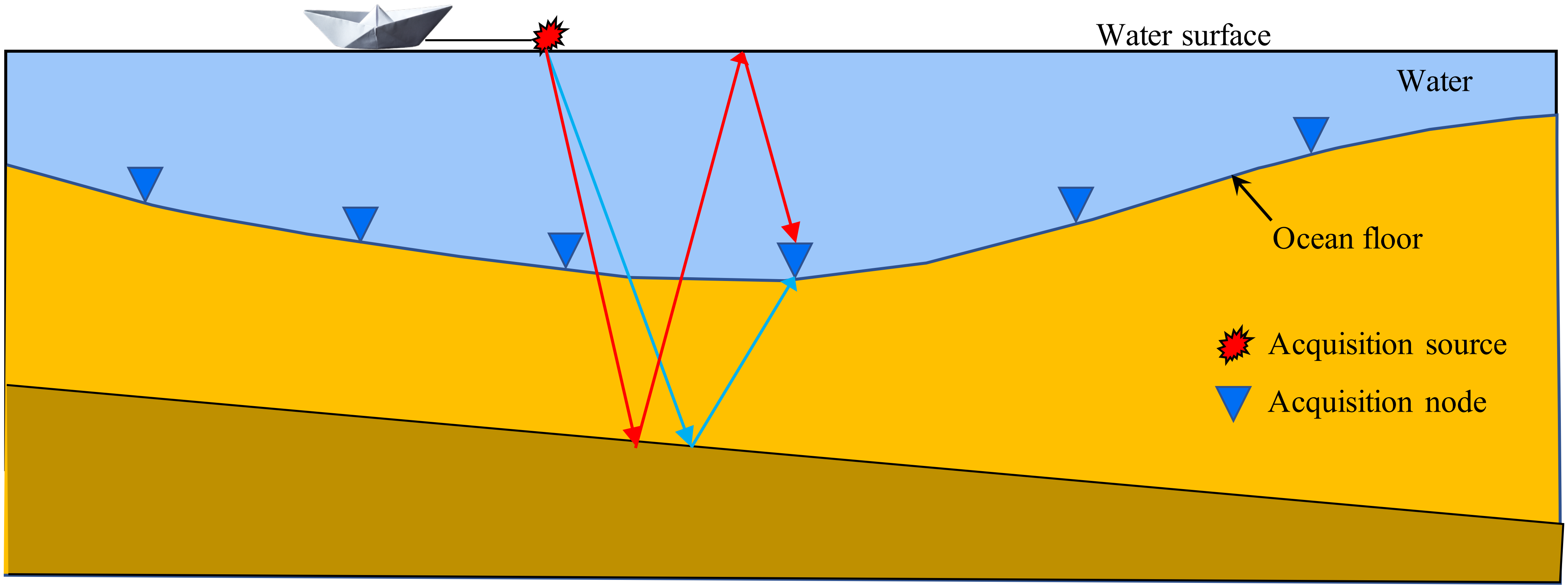
Downgoing component



Upgoing and downgoing components

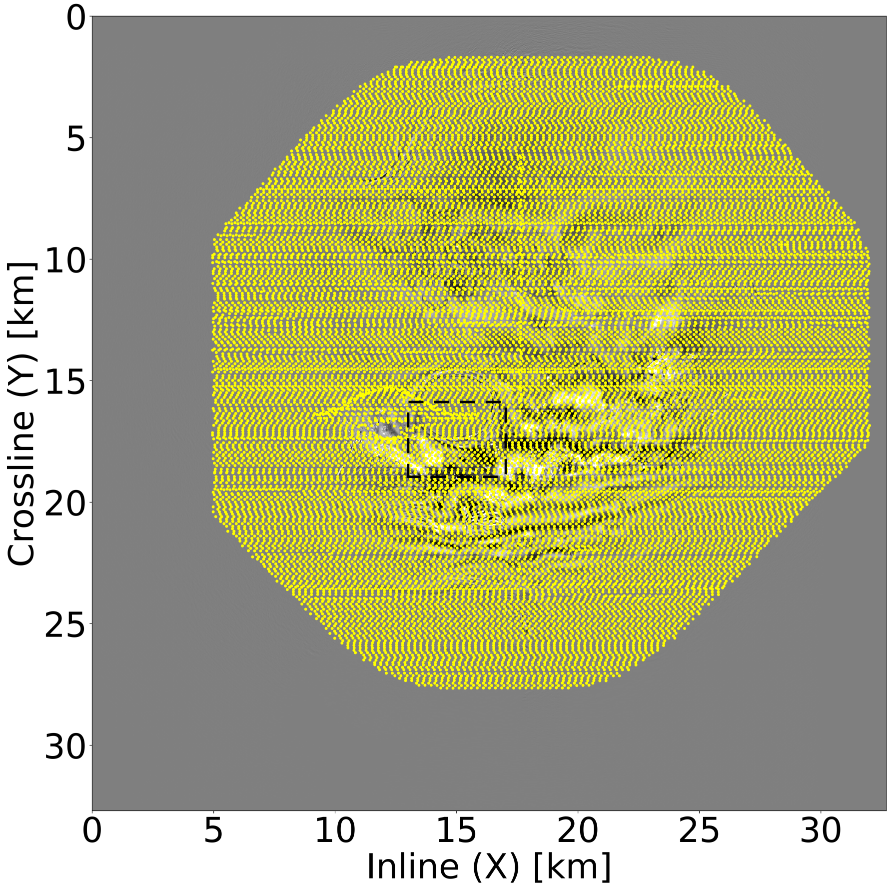


Upgoing and downgoing components

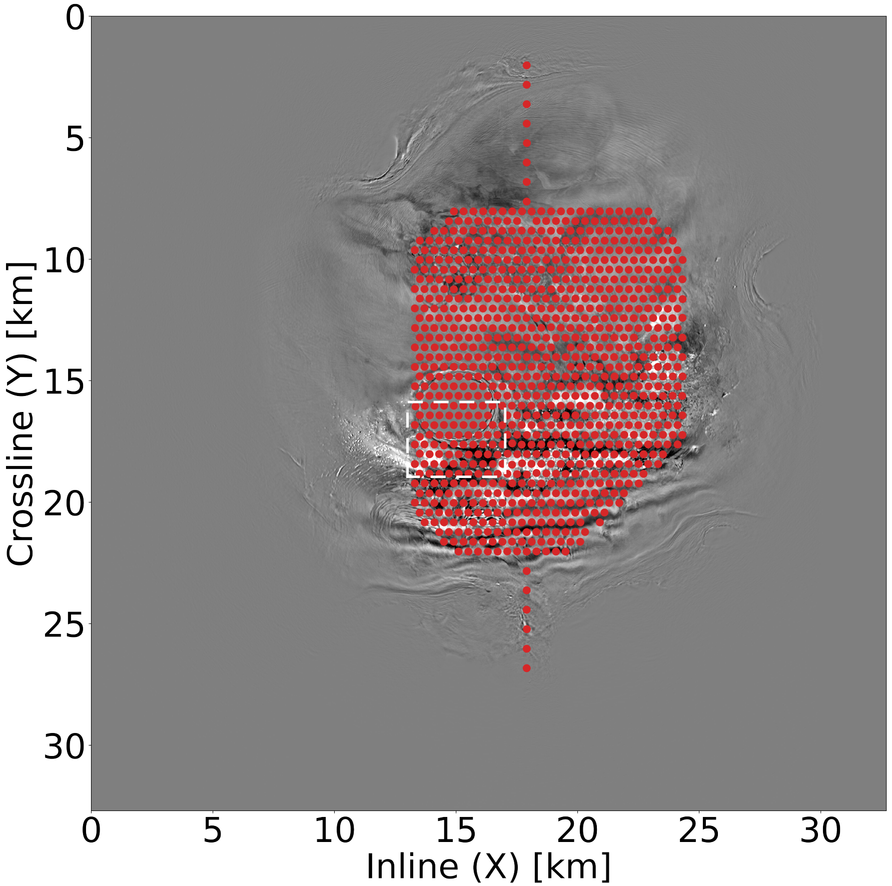


We separate components using PZ-summation!

Shell 3D dataset (Gulf of Mexico)

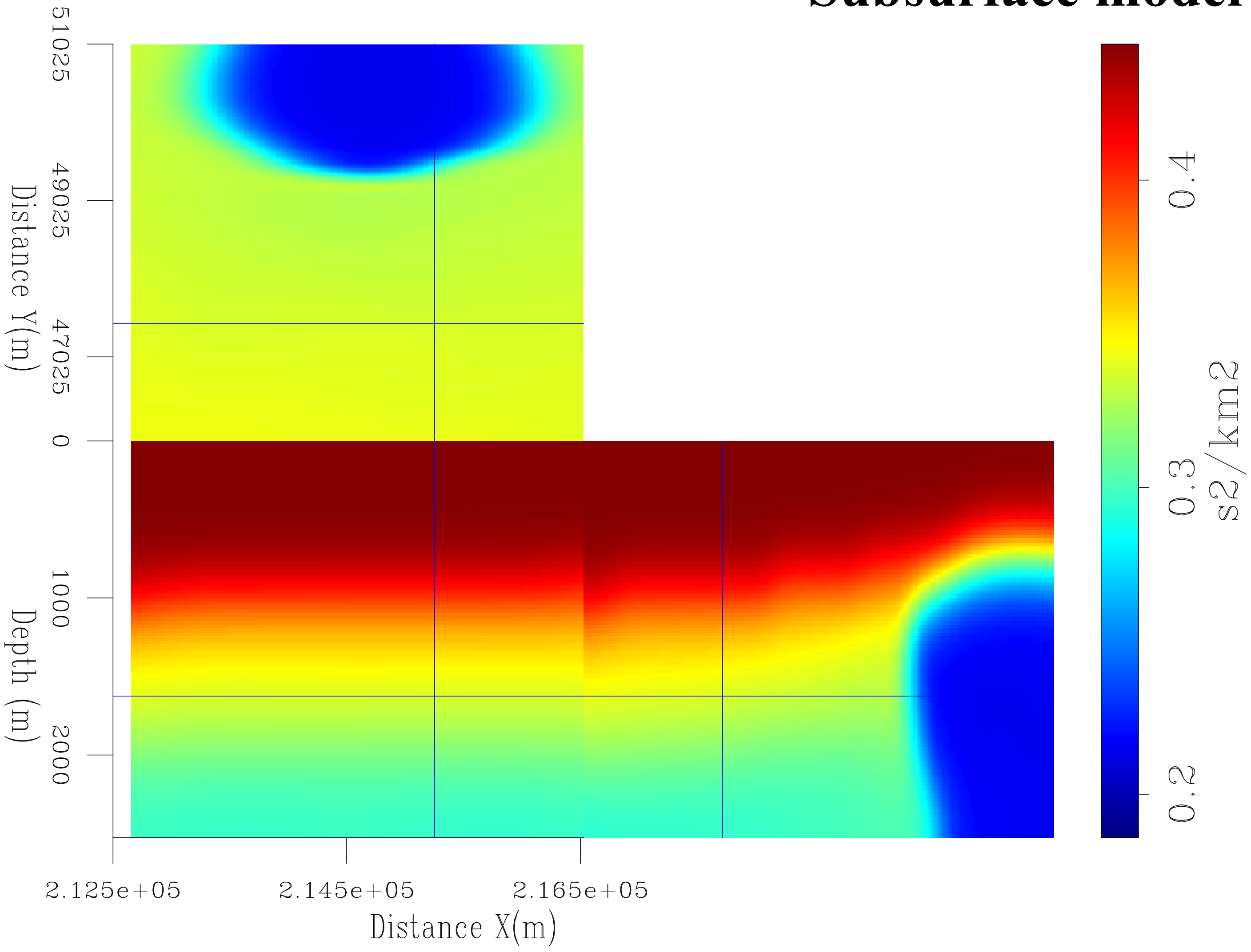


Sources



Nodes

Subsurface model and data



Subsurface model (slowness squared):

- Inline: 4000 m
- Crossline: 5050 m
- Vertical: 2500 m
- Spacing: 25 m
- Imaging aperture: 50 samples

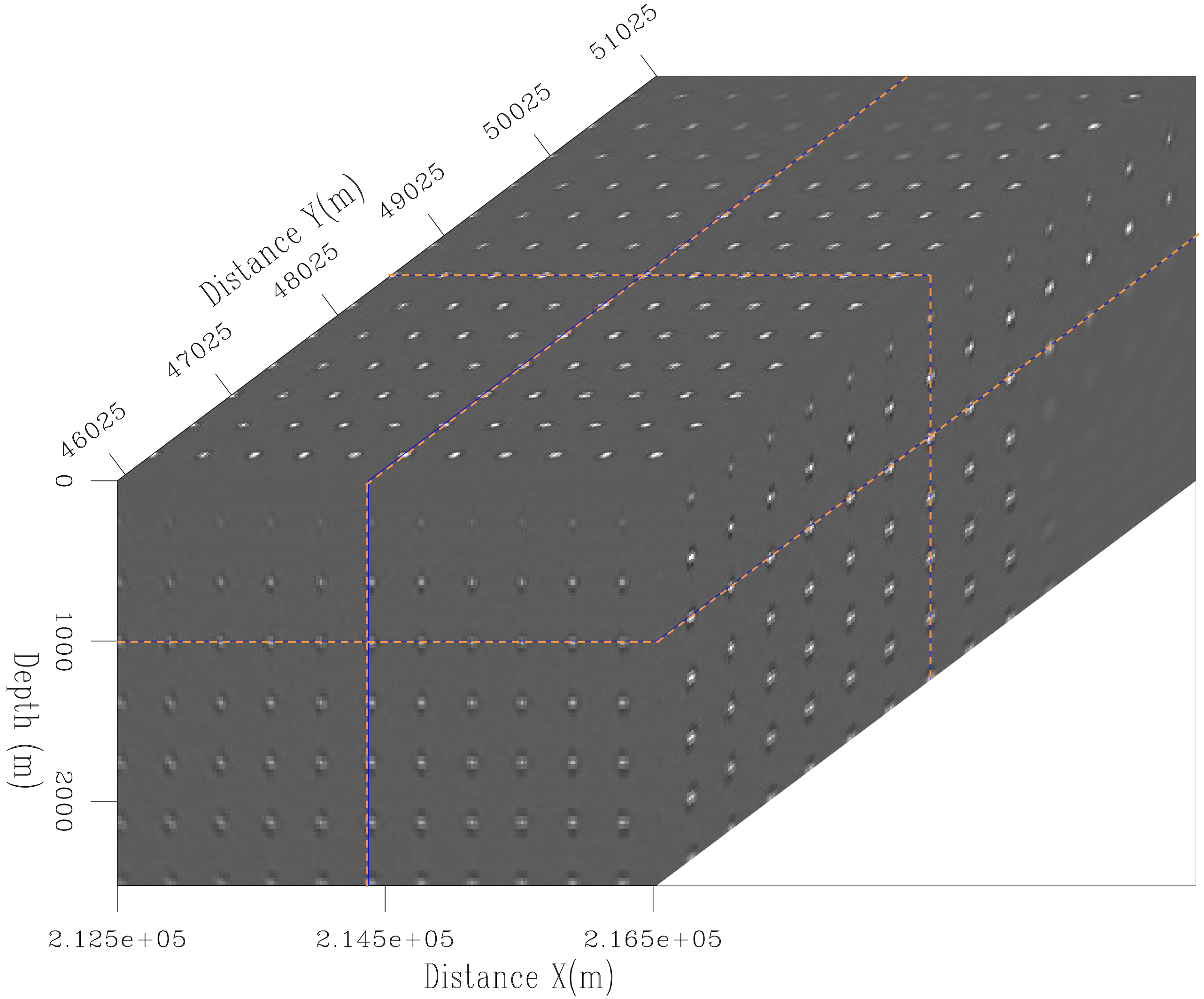
Data:

- 226 nodes in the computational area
- Sorted in common-receiver gathers
- Binned to 25x25 m grid
- 539x441=237699 traces (include aperture)
- CRGs span the computational area
- Ricker wavelet, ~10.5 Hz dom. Frequency

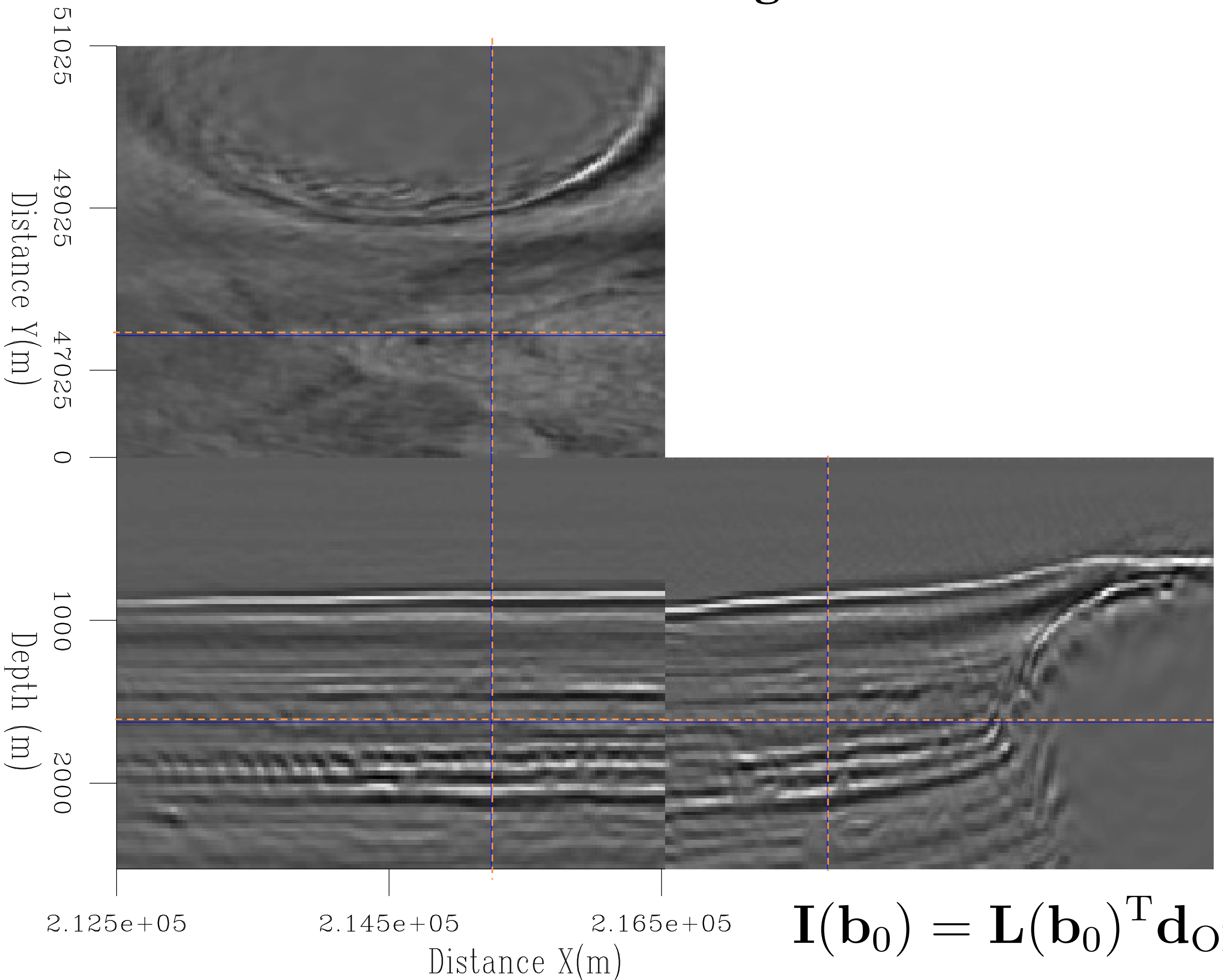
Imaging:

- Mirror imaging, using the downgoing component
- Inversions ran for 10 iterations (9 WEMVA)

Point-spread functions: Seeded every 15 gridpoints

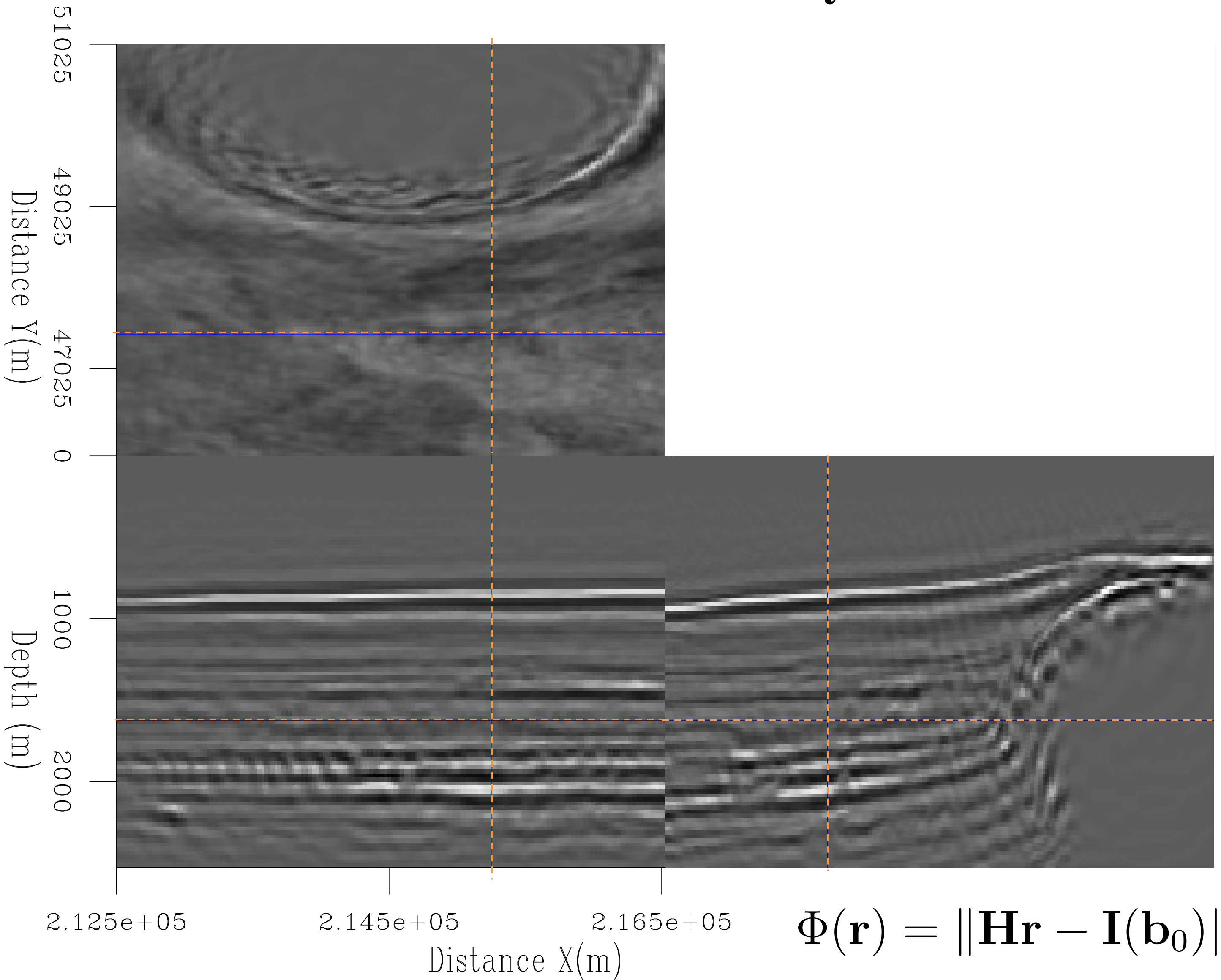


RTM image



$$\mathbf{I}(\mathbf{b}_0) = \mathbf{L}(\mathbf{b}_0)^T \mathbf{d}_{\mathrm{OBN}}$$

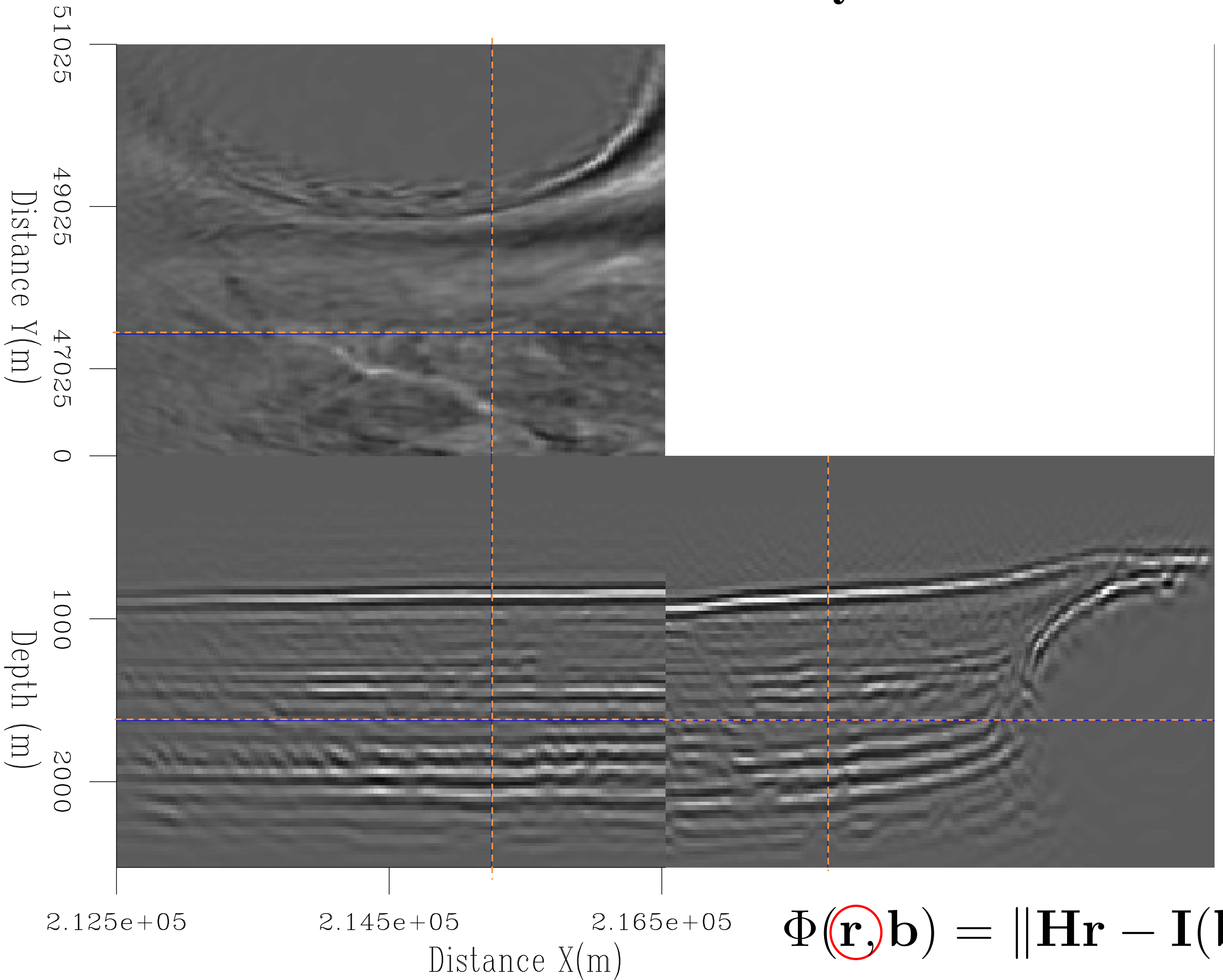
LWI reflectivity



$$\Phi(\mathbf{r}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b}_0)\|_2^2$$

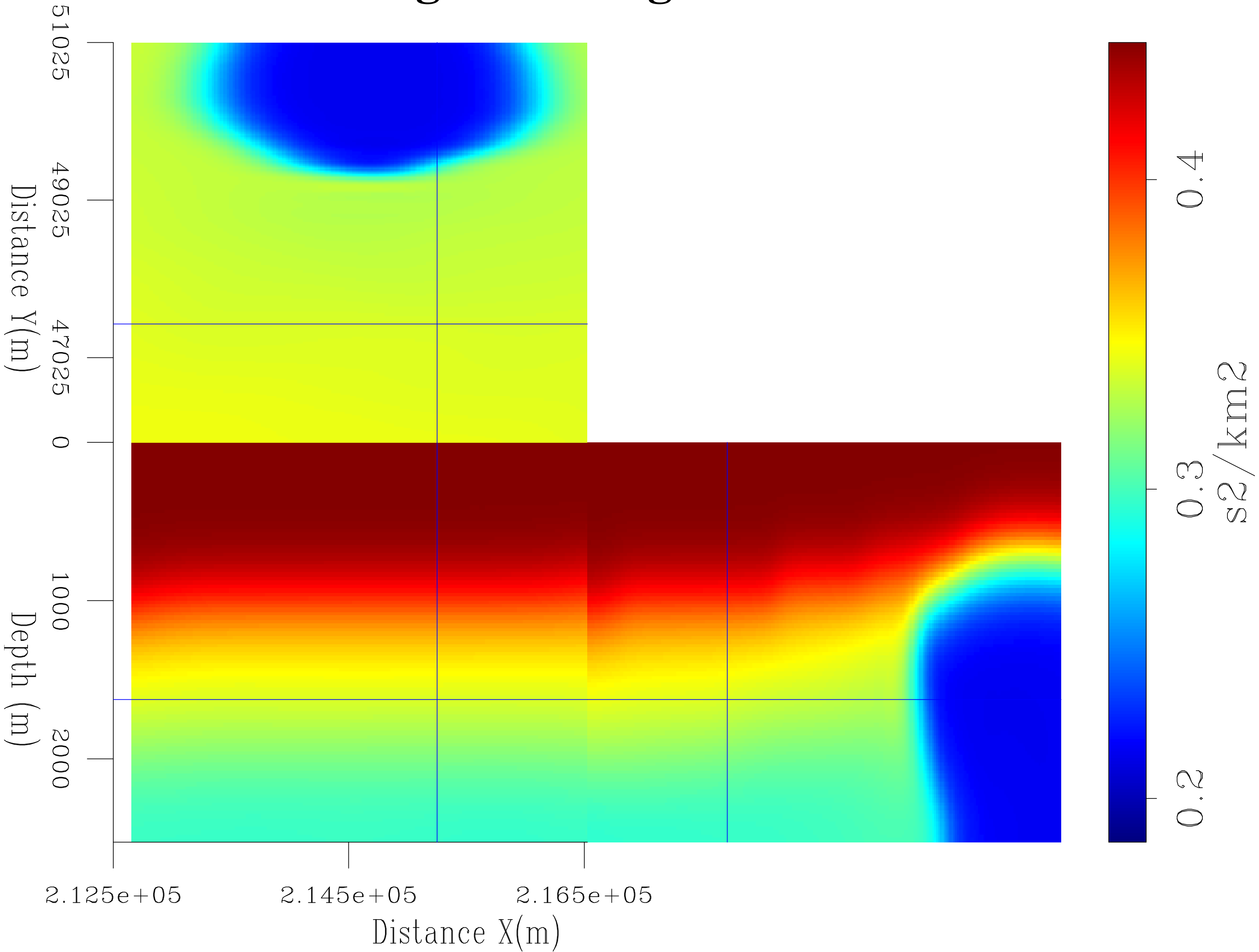
3D NUMERICAL RESULTS

JIRB reflectivity

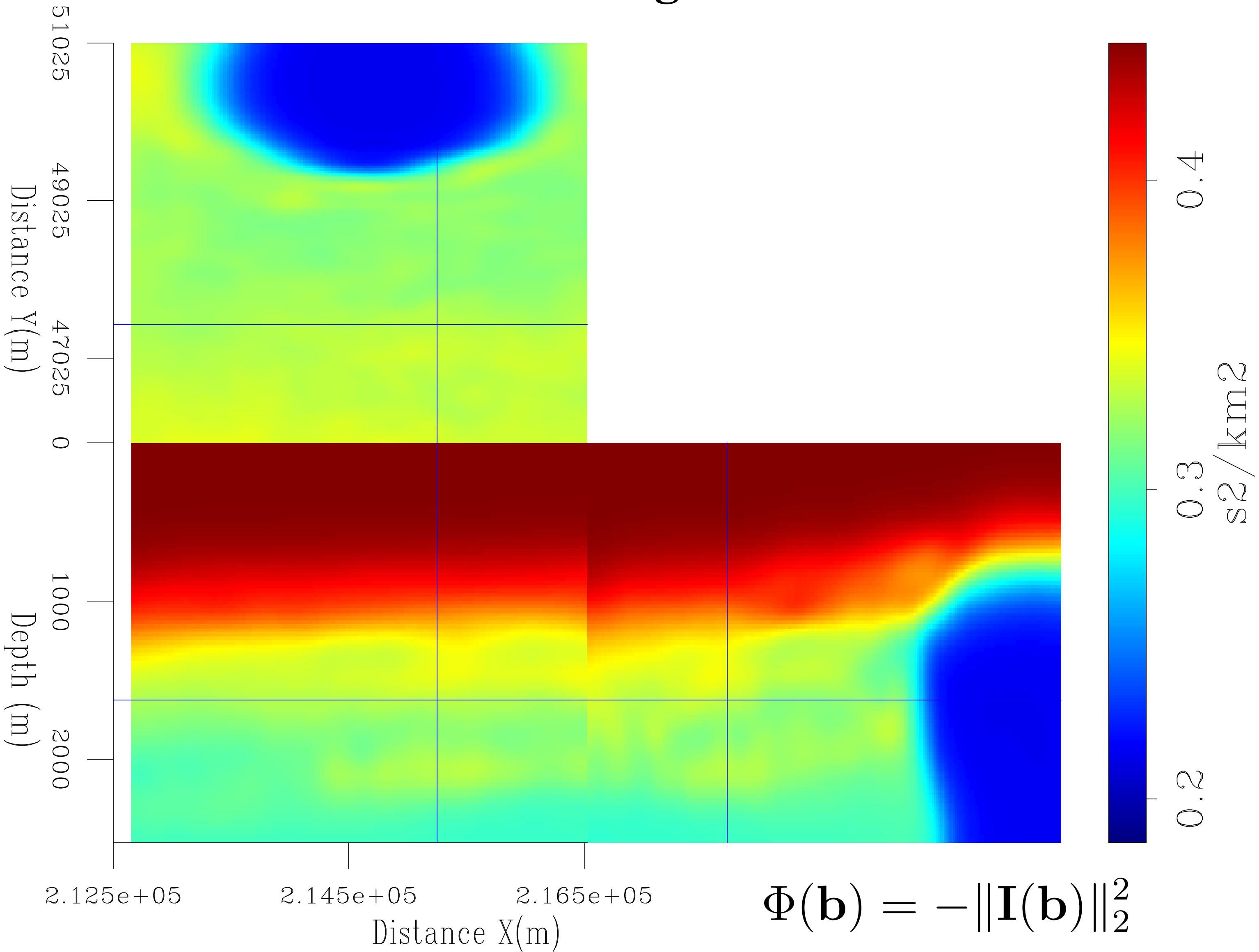


$$\Phi(\mathbf{r},\mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

Original background model

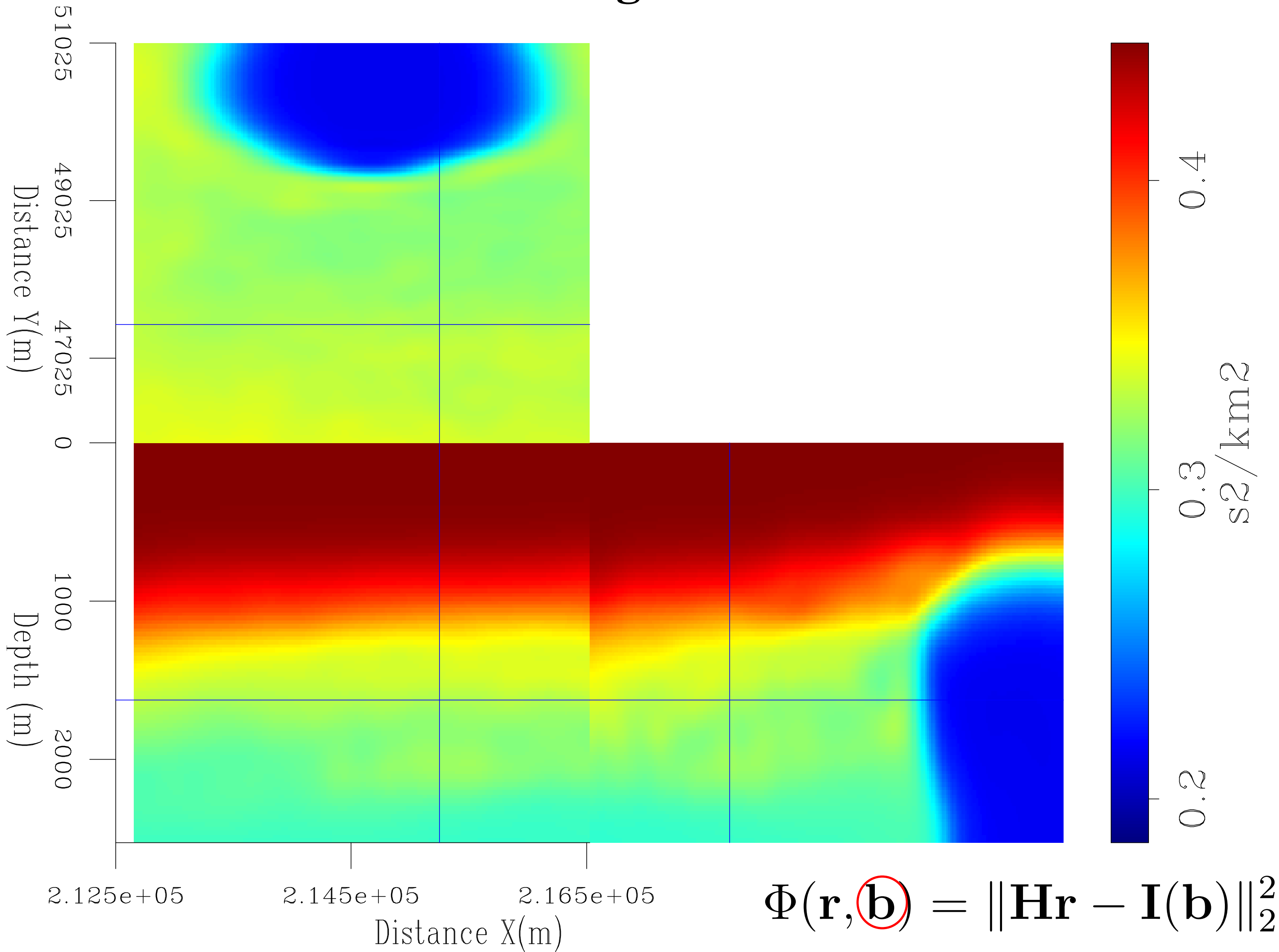


WEMVA background model



$$\Phi(\mathbf{b}) = -\|\mathbf{I}(\mathbf{b})\|_2^2$$

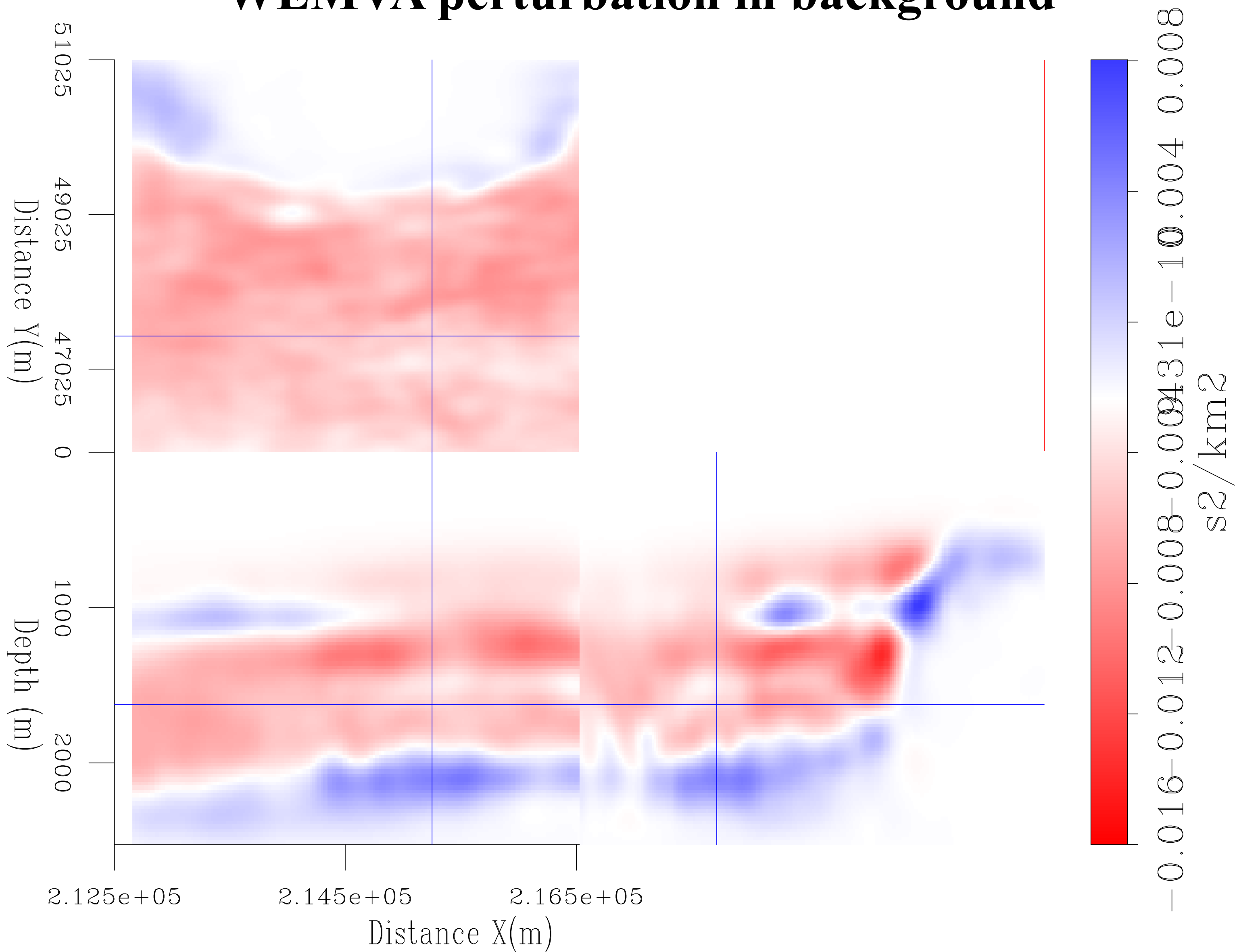
JIRB background model



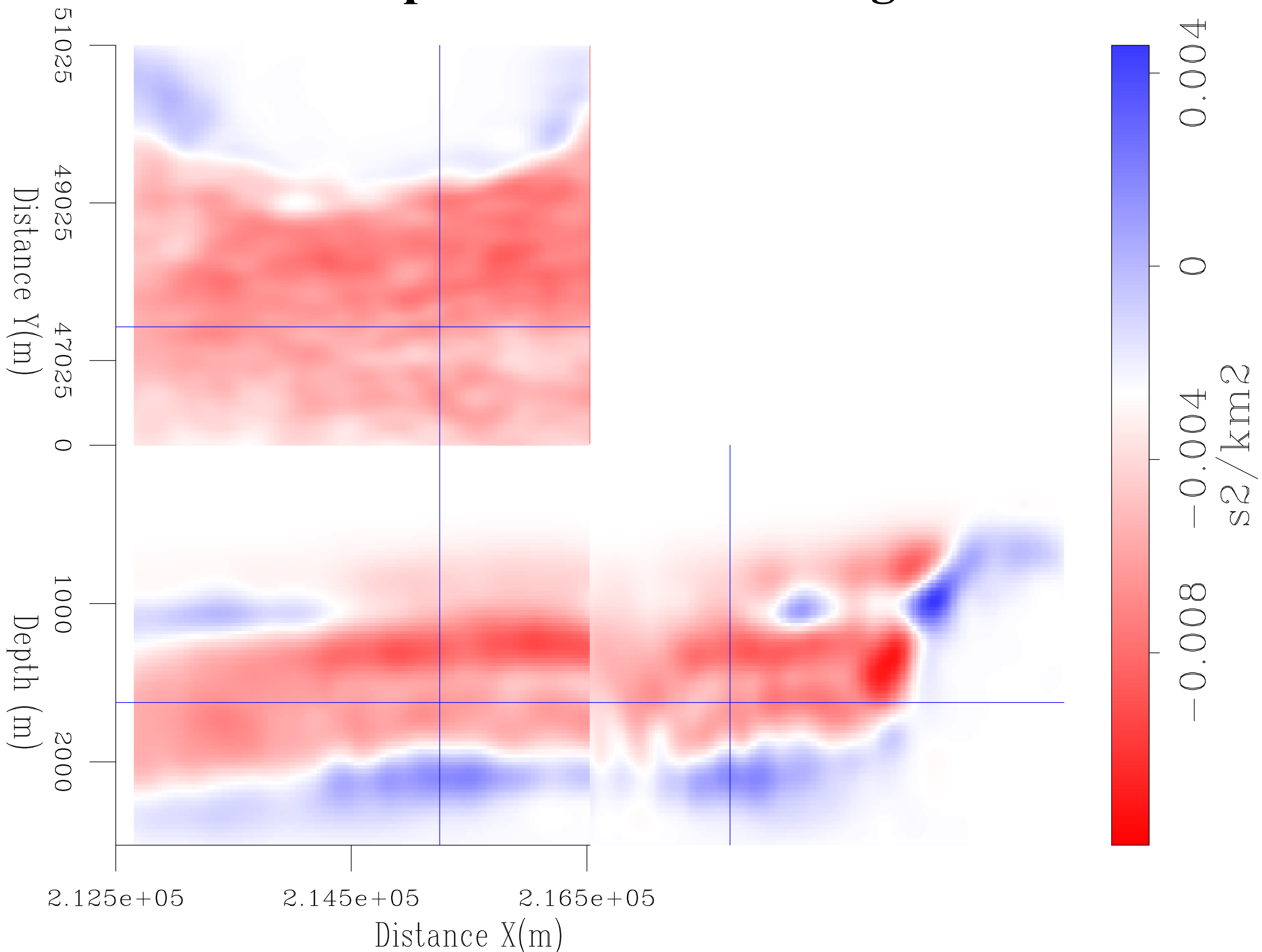
$$\Phi(\mathbf{r},\mathbf{b}) = \|\mathbf{H}\mathbf{r} - \mathbf{I}(\mathbf{b})\|_2^2 - \lambda\|\mathbf{I}(\mathbf{b})\|_2^2$$

3D NUMERICAL RESULTS

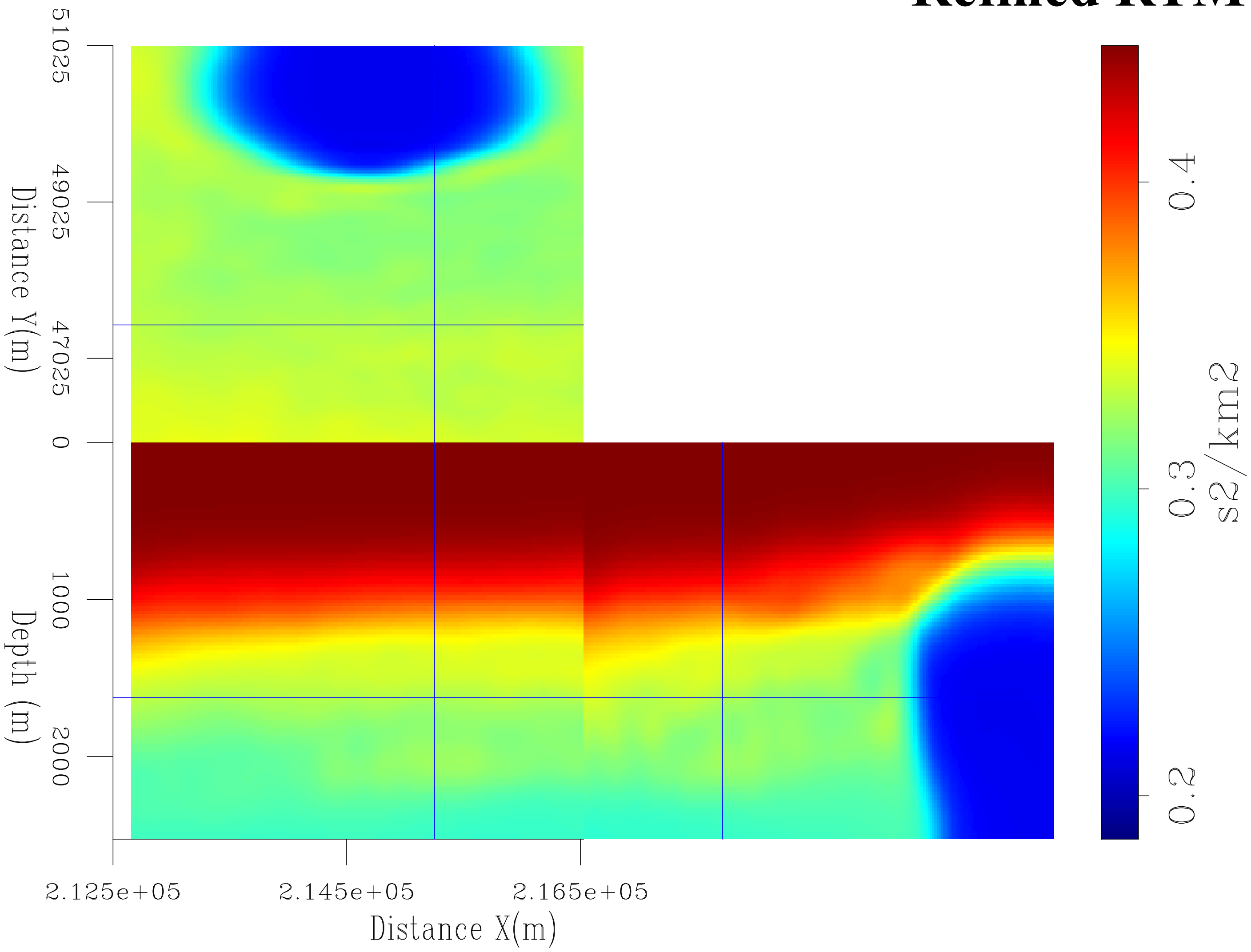
WEMVA perturbation in background



JIRB perturbation in background



Refined RTM tests

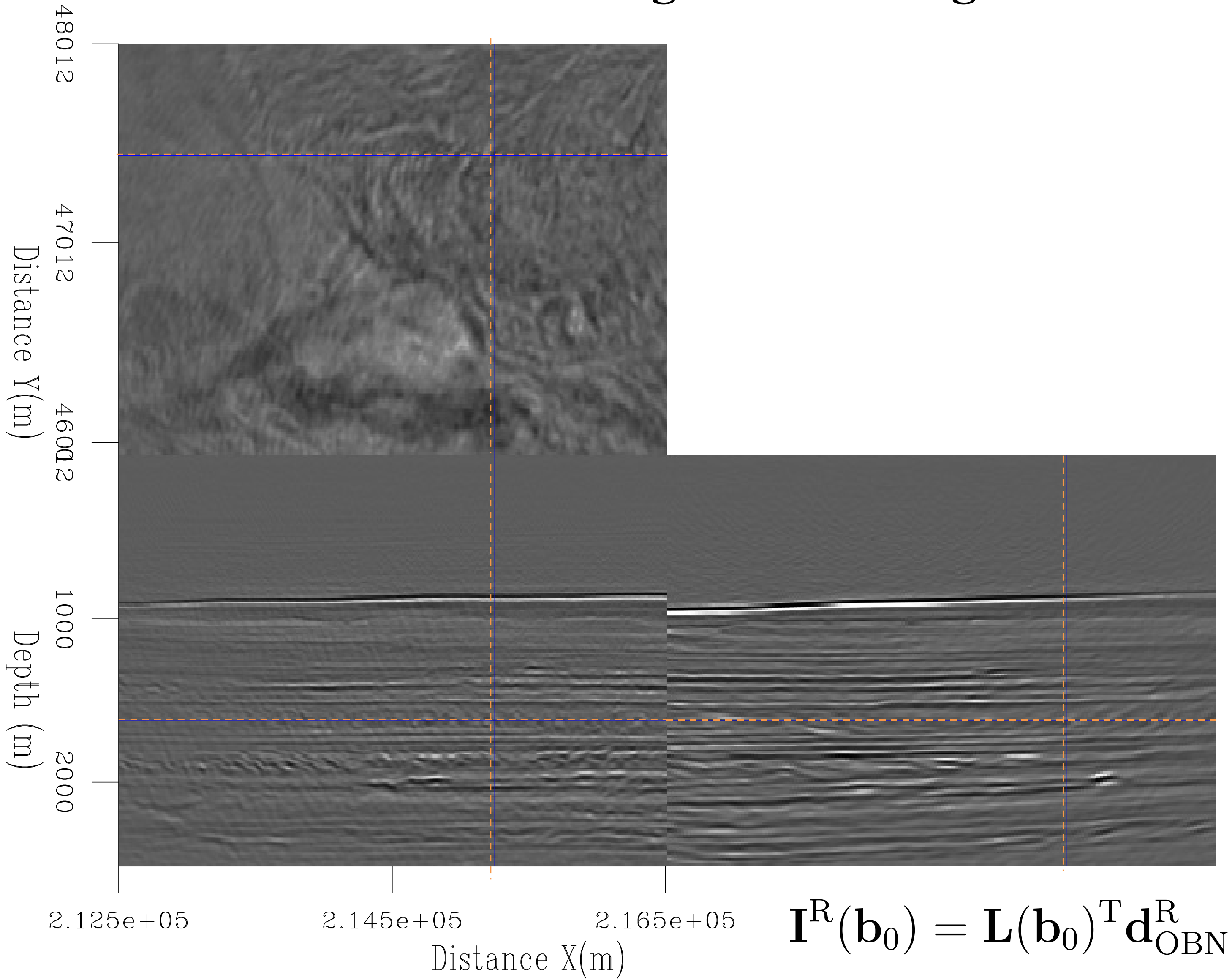


Objective: Improve stratigraphic features

- Refine model to 12.5x12.5x12.5 m
- Re-bin data to 12.5x12.5 m grid
- 877x681=597237 traces
- Imaging aperture: 50 samples
- Duplicate dom. frequency (~19 Hz)
- Run refined RTM tests for initial background model, WEMVA, and JIRB background models

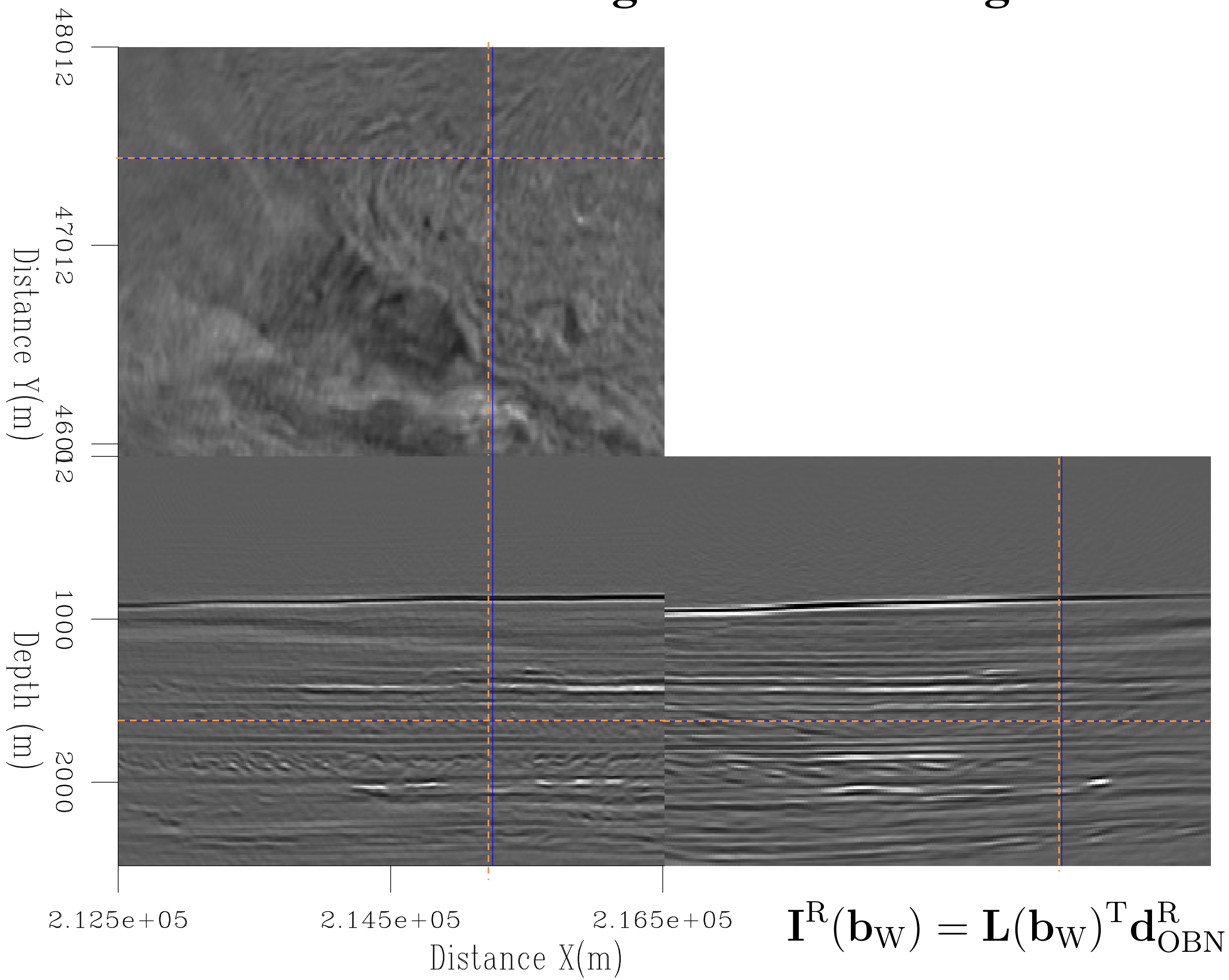
Compare refined RTM images run with initial model vs. WEMVA model

Refined RTM using initial background



$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_0) = \mathbf{L}(\mathbf{b}_0)^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

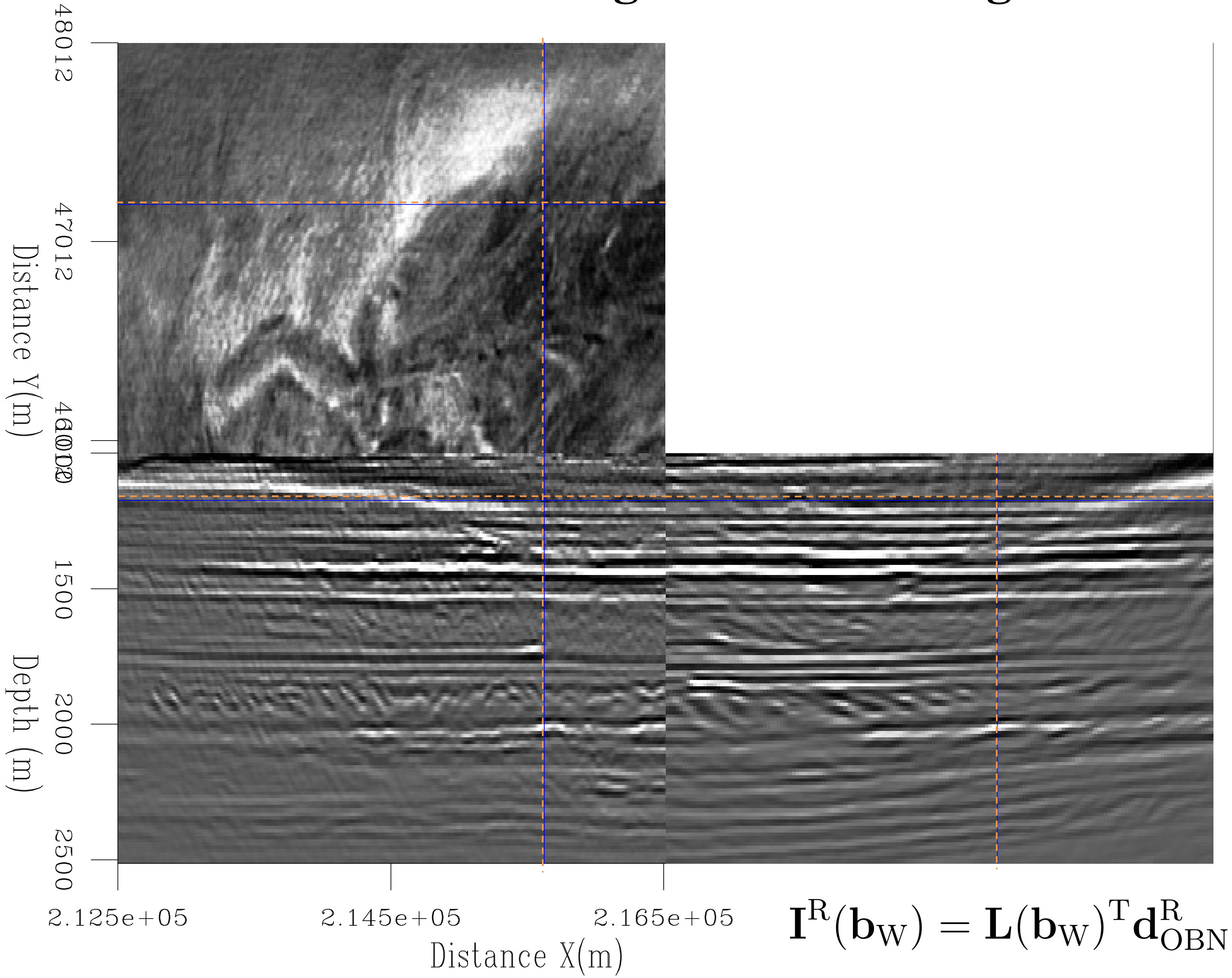
Refined RTM using WEMVA background



$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{W}}) = \mathbf{L}(\mathbf{b}_{\mathrm{W}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

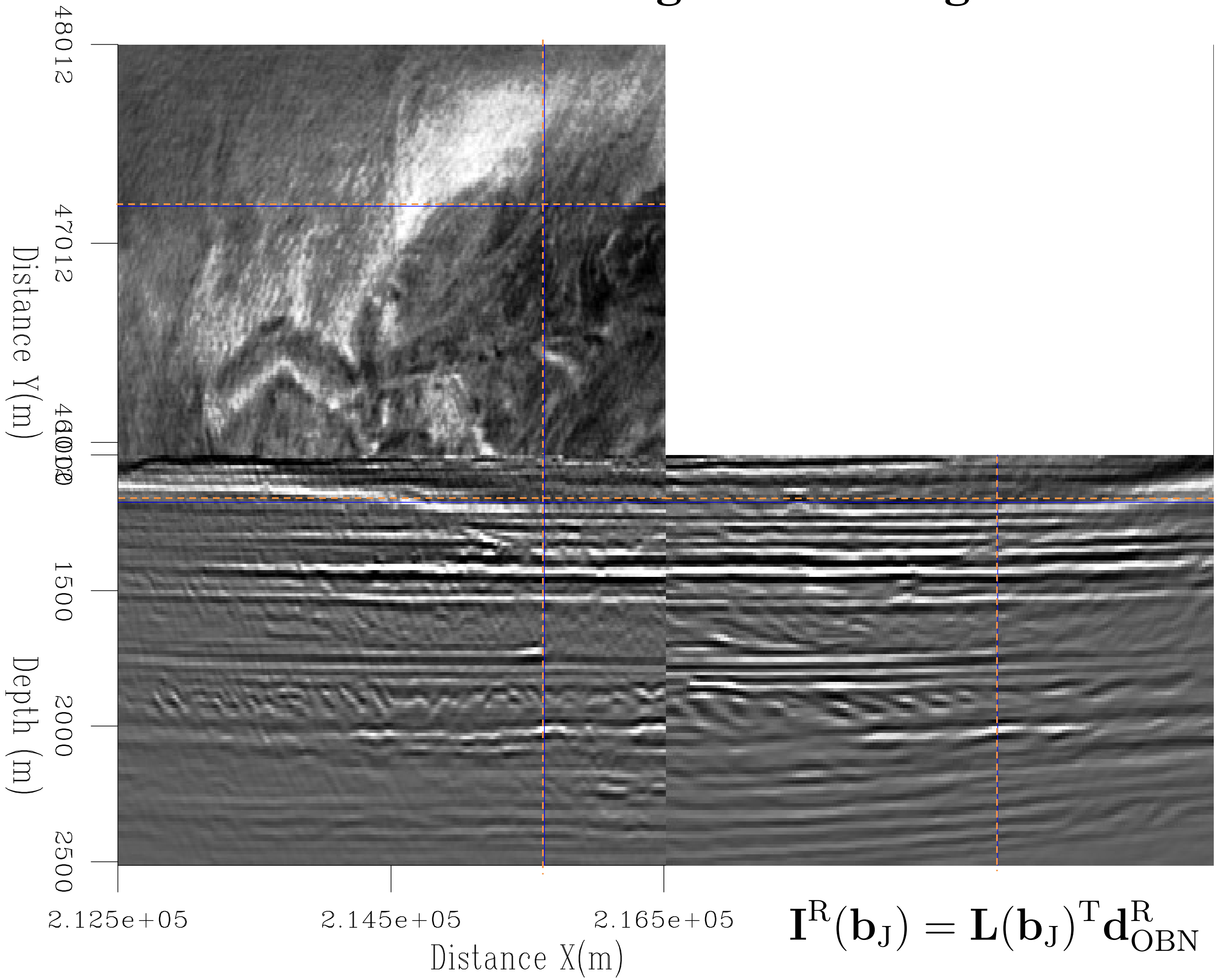
Compare refined RTM images run with WEMVA model vs. JIRB model

Refined RTM using WEMVA background



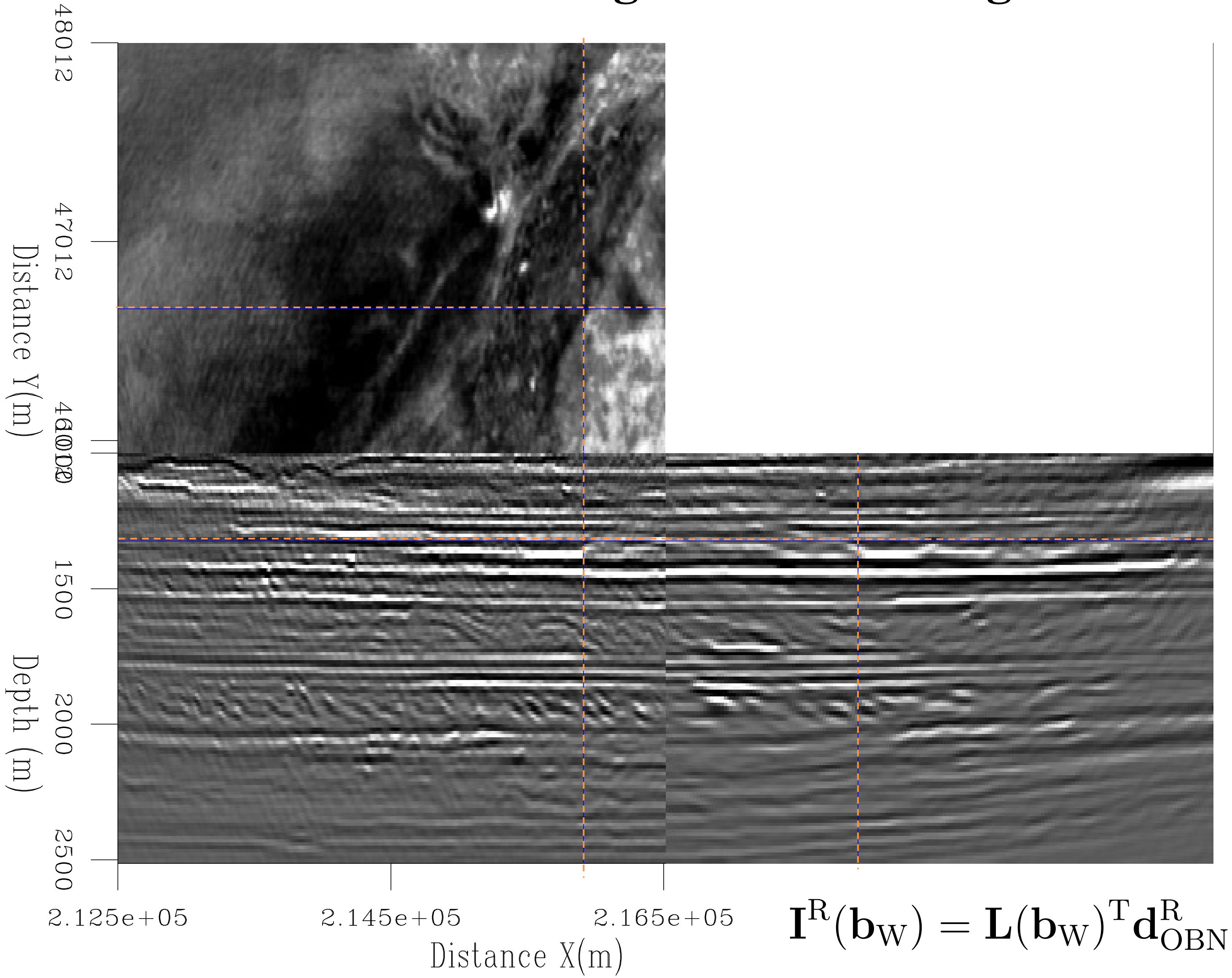
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{W}}) = \mathbf{L}(\mathbf{b}_{\mathrm{W}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using JIRB background



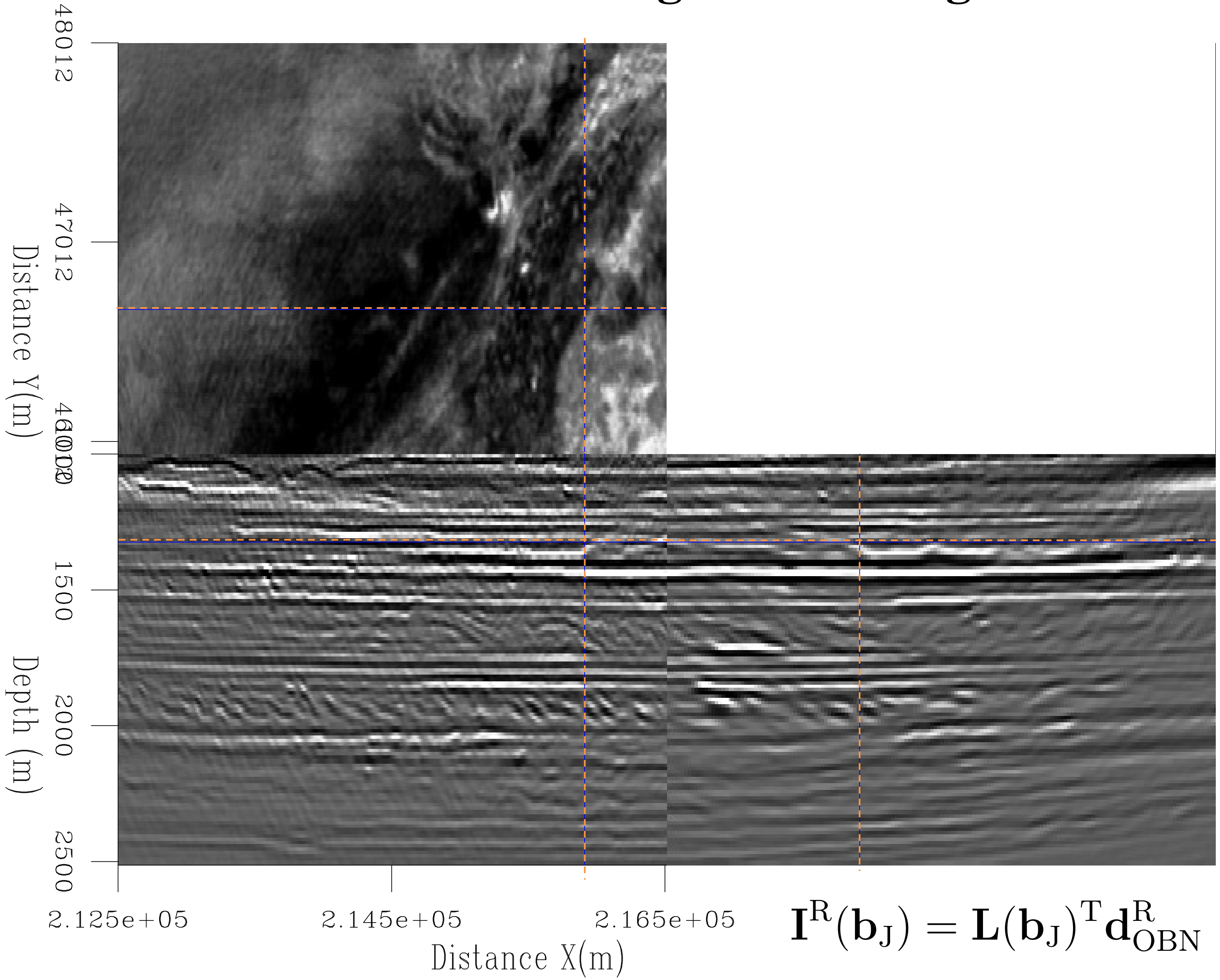
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{J}}) = \mathbf{L}(\mathbf{b}_{\mathrm{J}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using WEMVA background



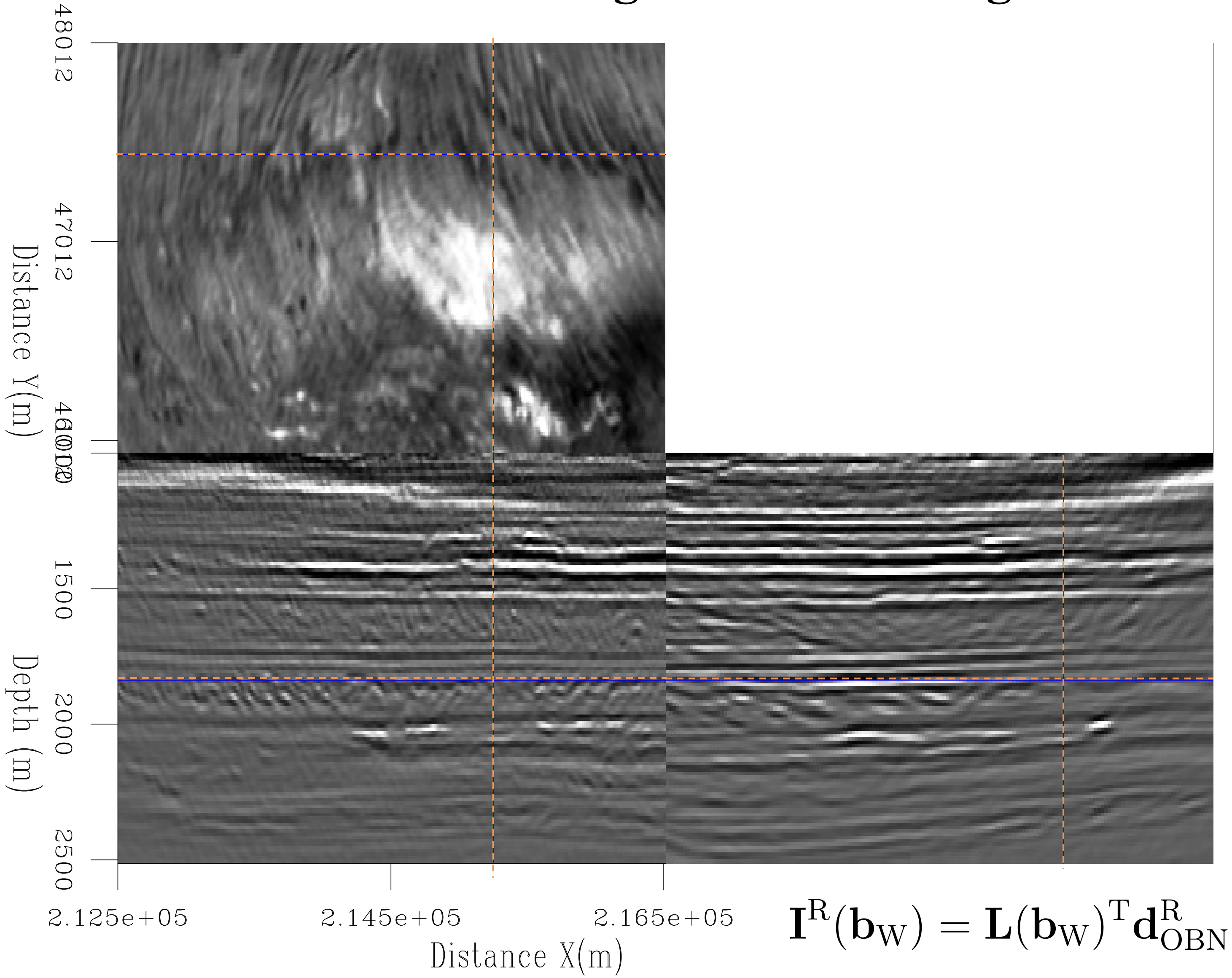
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{W}}) = \mathbf{L}(\mathbf{b}_{\mathrm{W}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using JIRB background



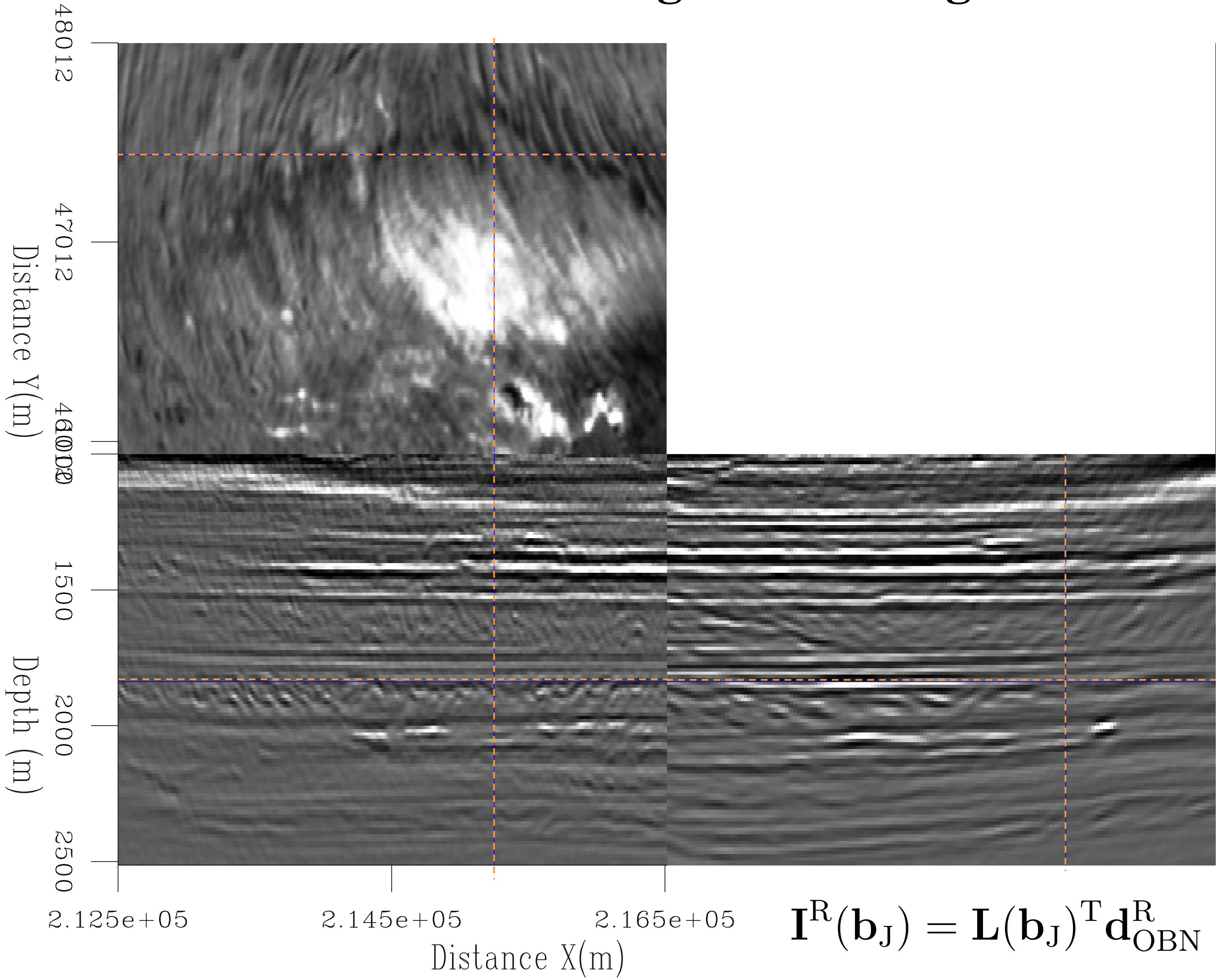
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{J}}) = \mathbf{L}(\mathbf{b}_{\mathrm{J}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using WEMVA background



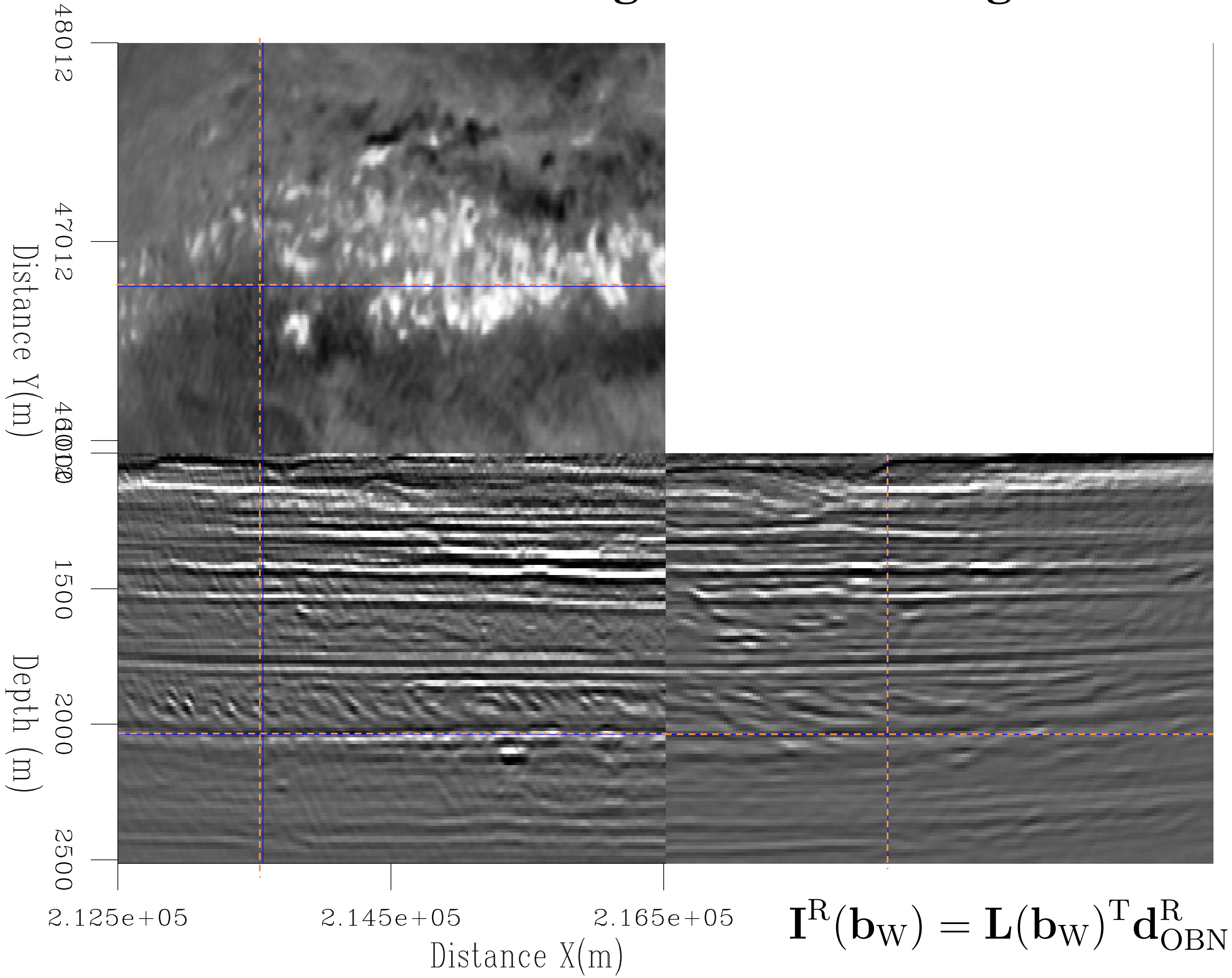
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{W}}) = \mathbf{L}(\mathbf{b}_{\mathrm{W}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using JIRB background



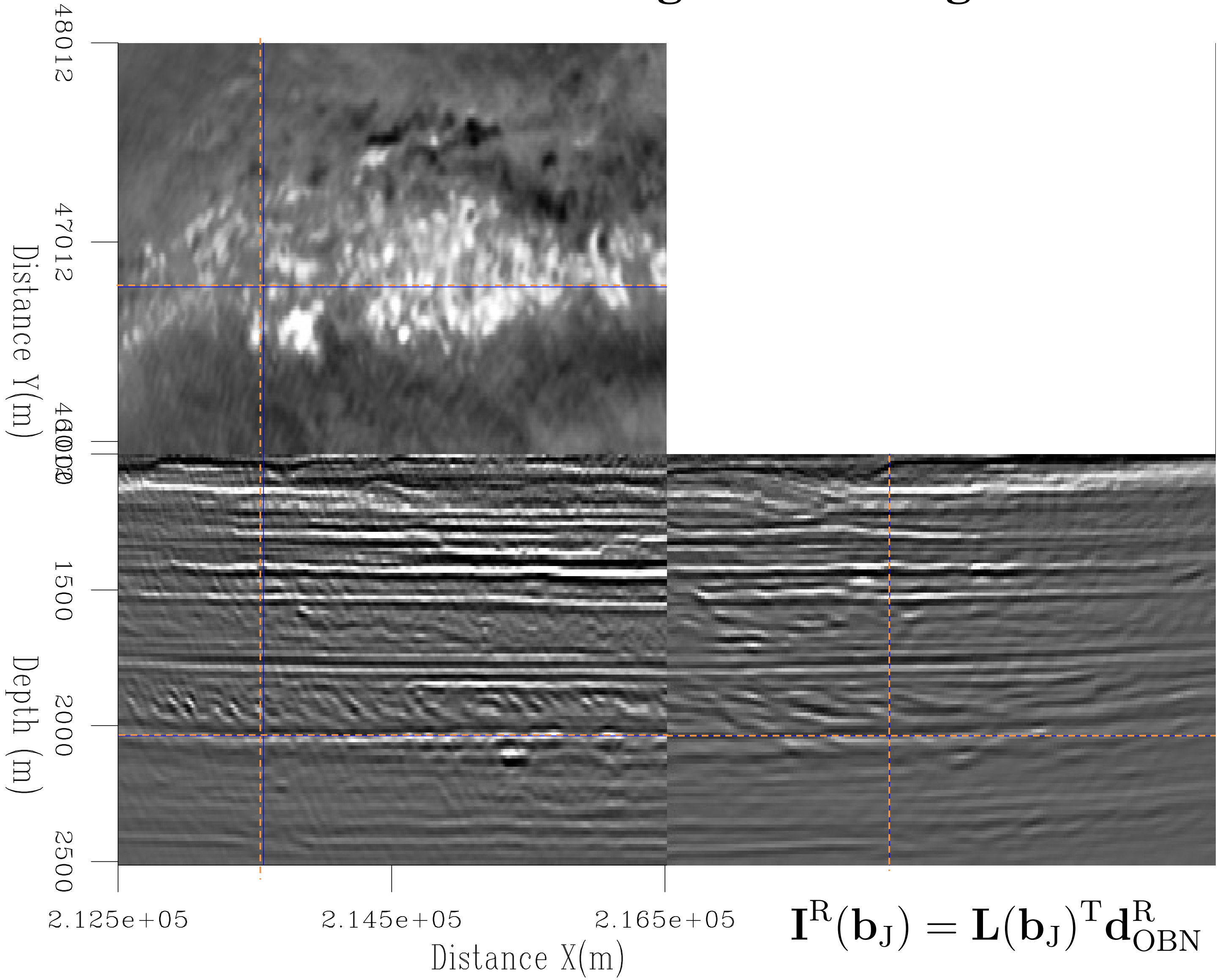
$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{J}}) = \mathbf{L}(\mathbf{b}_{\mathrm{J}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using WEMVA background



$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{W}}) = \mathbf{L}(\mathbf{b}_{\mathrm{W}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

Refined RTM using JIRB background



$$\mathbf{I}^{\mathrm{R}}(\mathbf{b}_{\mathrm{J}}) = \mathbf{L}(\mathbf{b}_{\mathrm{J}})^{\mathrm{T}}\mathbf{d}^{\mathrm{R}}_{\mathrm{OBN}}$$

To conclude…

CONCLUSIONS

- The JIRB method can correct remaining inaccuracies in the background model, yielding more focused seismic events in the reflectivity image
- The JIRB method can also obtain a better background model for RTM or LWI
- The method could not be implemented in a linear fashion. A nonlinear scheme was the solution
- Synthetic and field data tests show improvement in seismic events’ focusing. In particular, the 3D field data exhibited improvements in deep-water stratigraphic features

Acknowledgements

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Biondo

Bob

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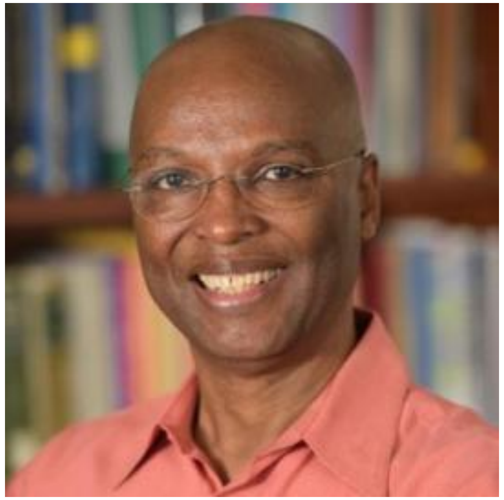
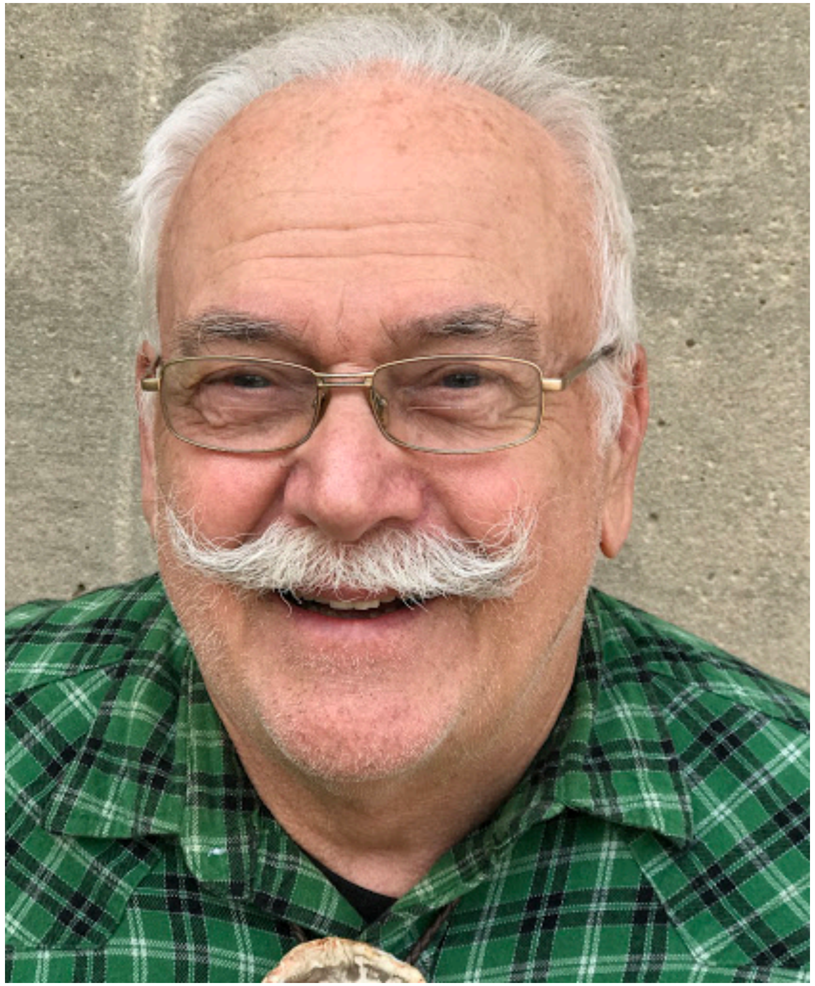
Jenny



Jerry

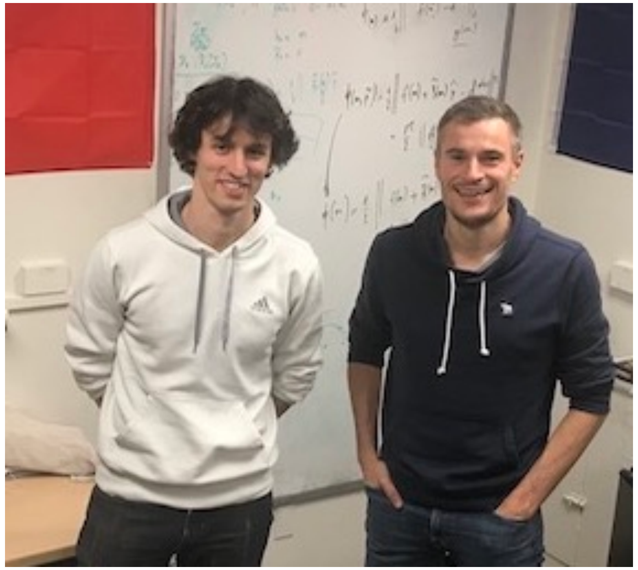
Gary



Jon

Stew

Shuki



Ettore & Guillaume

Fantine

Yinbin

Rahul

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Taylor

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Milad

Rachael

Jared

Claudia

Liliane


PLAZA SÉSAMO
ELMO


Odio la NAVIDAD

Pemex's crew:

- The bosses: Humberto Salazar, Carlos Caraveo, Alfredo Vázquez, Leonardo Aguilera,…
- Current colleagues: Karen, Alejandra, Ernesto, Sergio, Silvino, Madai, Juan, Jorge,…
- Friends: Javier Sánchez, Humberto Arévalo, Sergio Chávez, Moisés Hernández,…

THANKS FOR YOUR ATTENTION!