SIGNAL
ANALYSIS &
IMAGING GROUP

3D deblending and reconstruction with interpolated MSSA for arbitrary irregular-grid compressive simultaneous-source data

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OUTLINE

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   - Interpolated-MSSA (I-MSSA) method
3. **Synthetic example**
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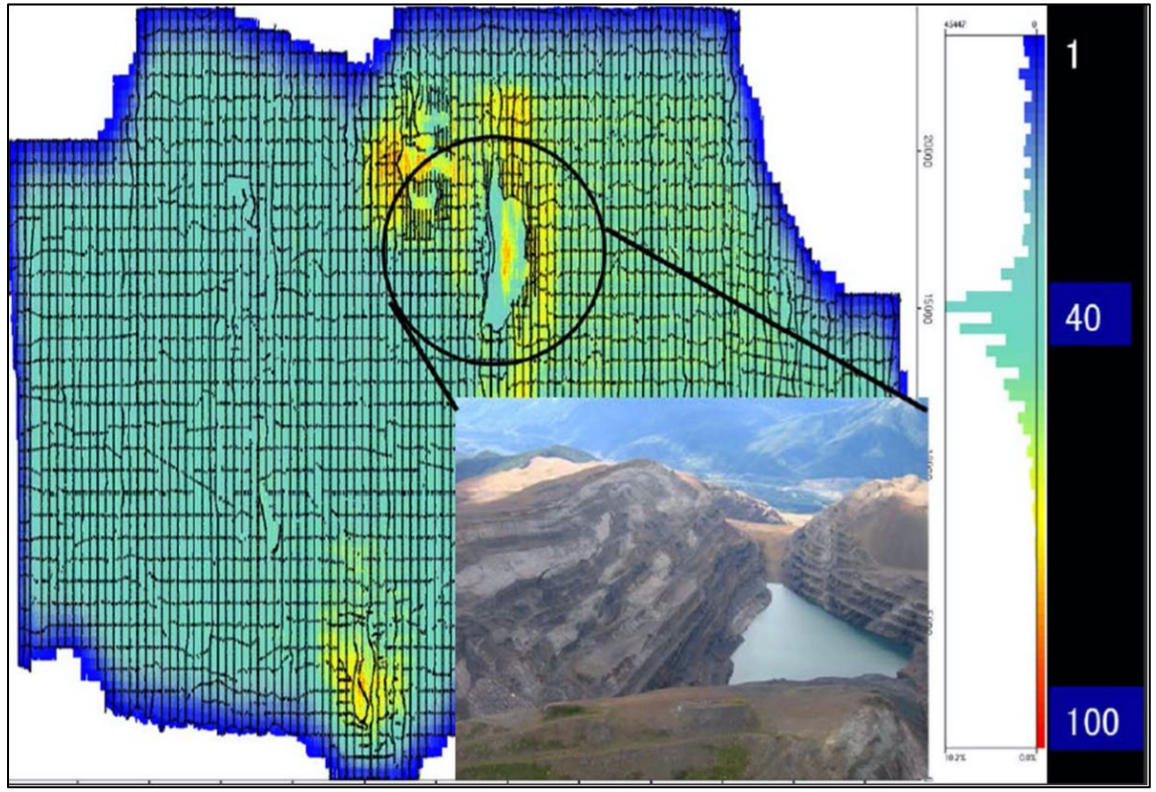
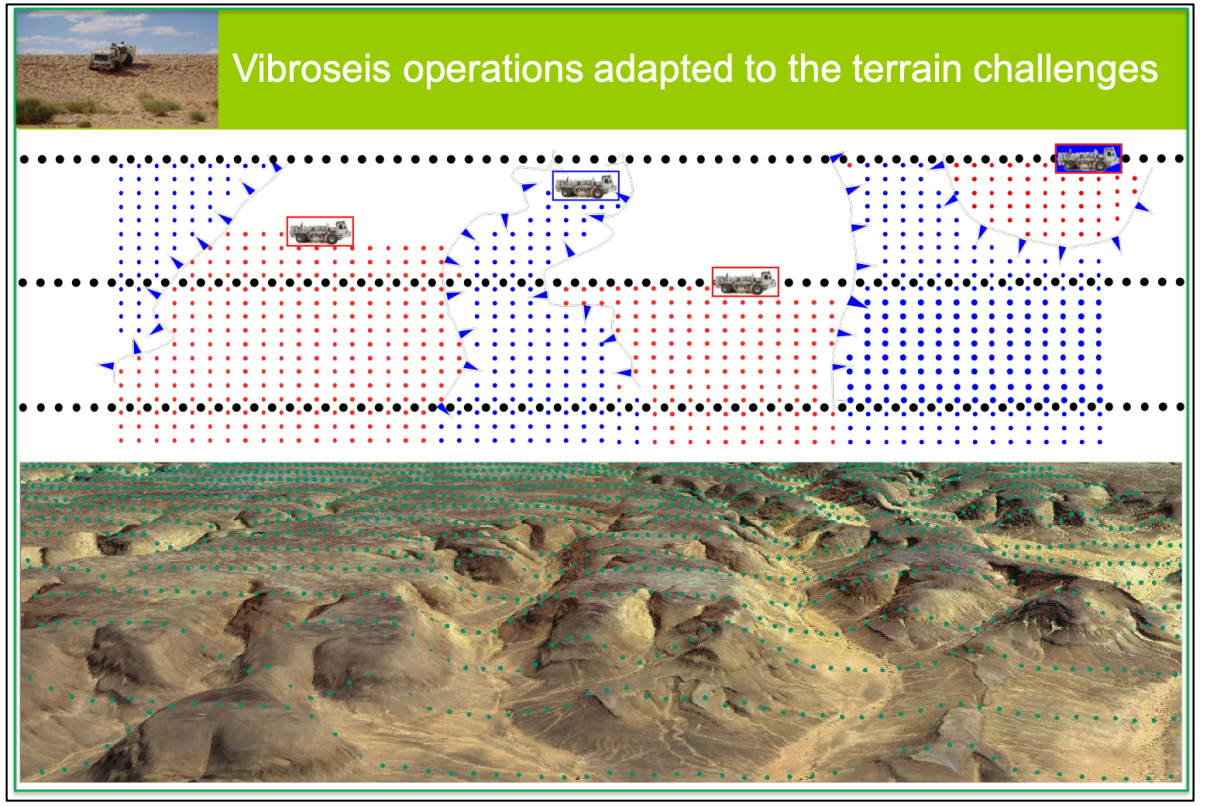
   - With random noise
4. **Real data example**
5. **Conclusion**
6. **Acknowledgement**

Introduction



(Trad,2008)



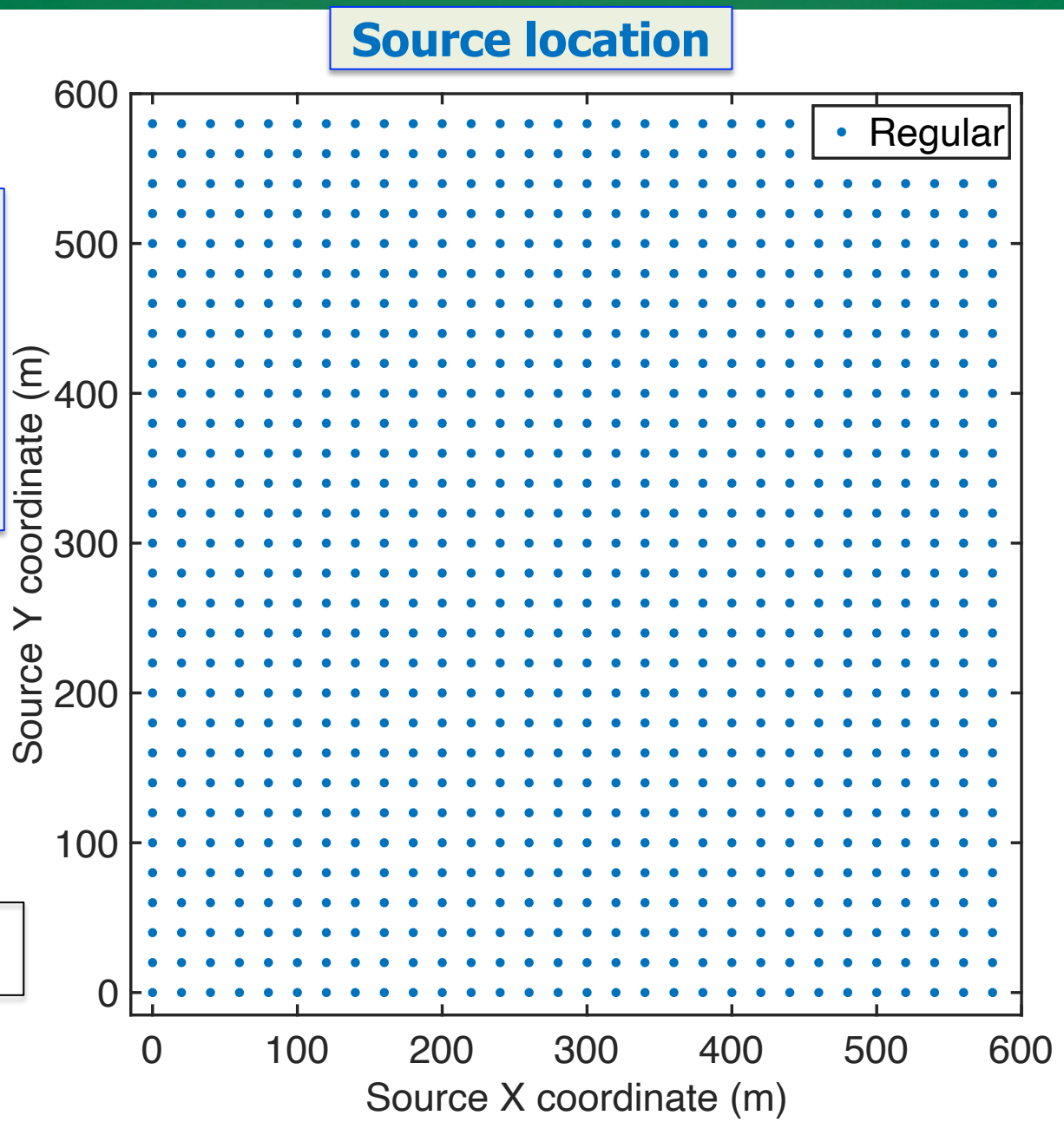
(Ray Abma, 2010)

- Toy example

3D seismic acquisition = 5D seismic data (t,sx,sy,rx,ry)

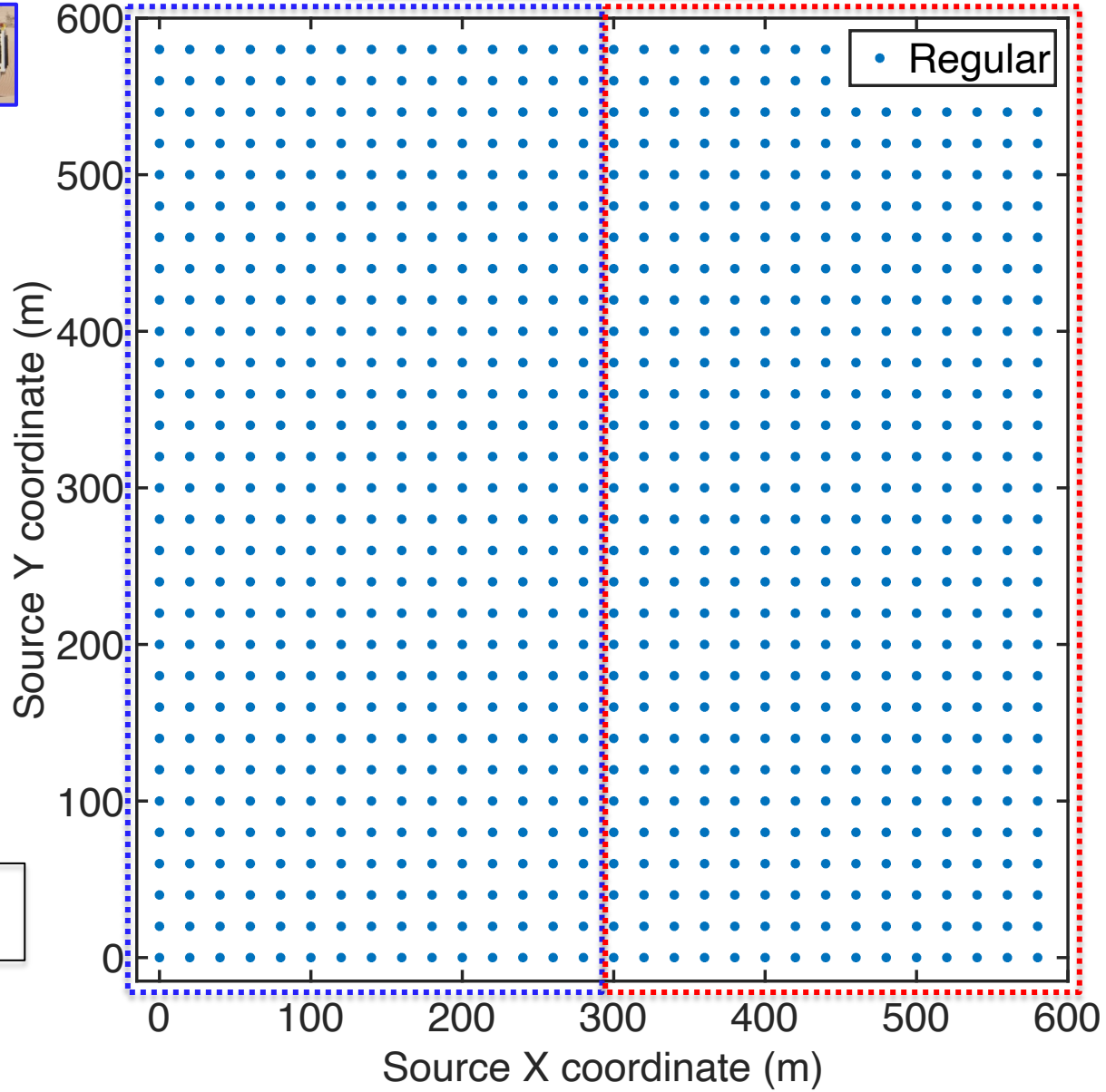
1 CRG is a 3D cube

- Regular source location



Source 1

Source location



Source 2

3D Simultaneous-source acquisition (BF=2)

= 5D seismic data (t,sx,sy,rx,ry)

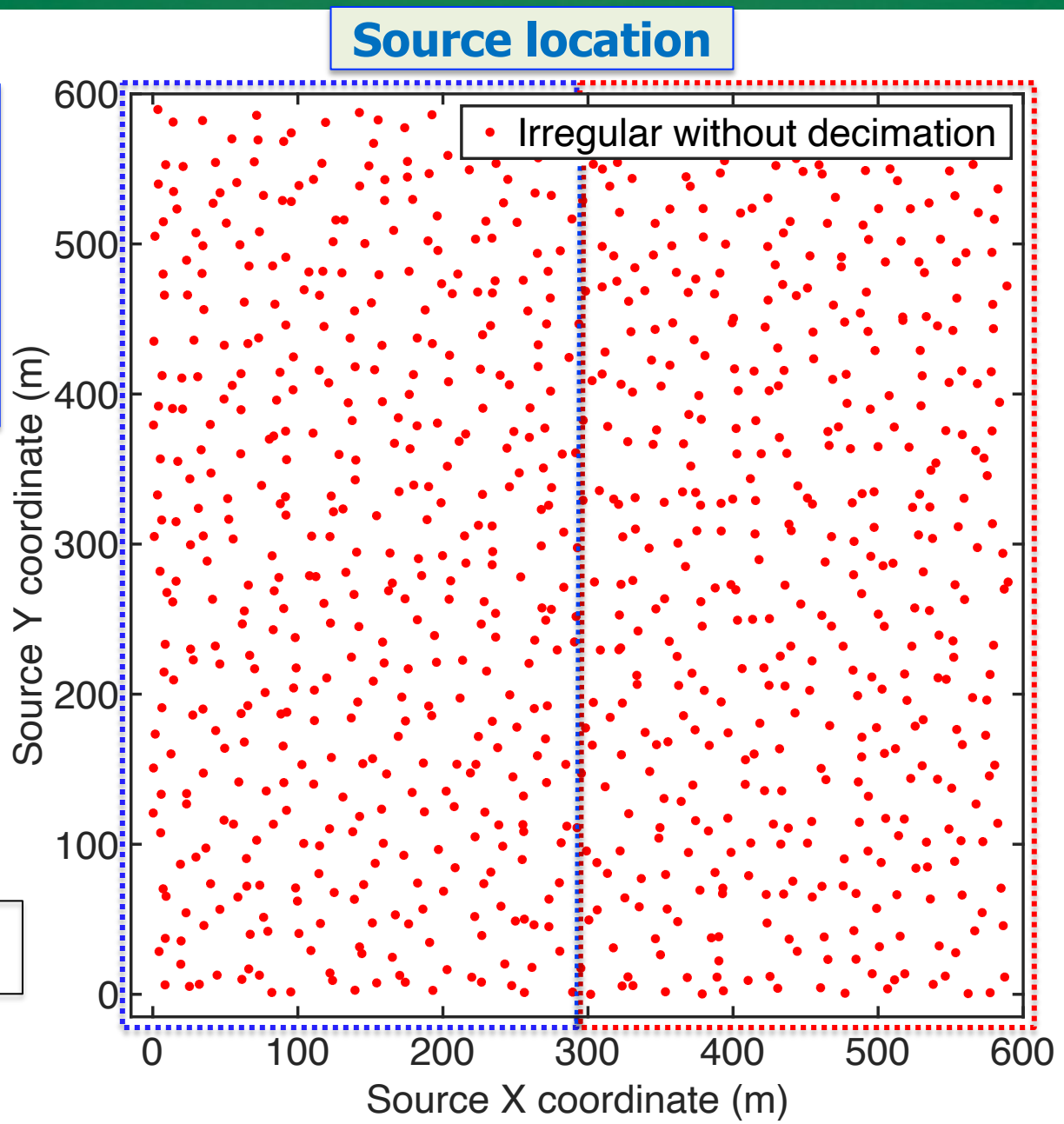
1 CRG is a 3D cube

- Regular source location

- *Conventional acquisition: 10 days*
- *Blending acquisition (BF=2): ≈ 5 days*

3D seismic acquisition = 5D seismic data (t,sx,sy,rx,ry)

1 CRG is a 3D cube

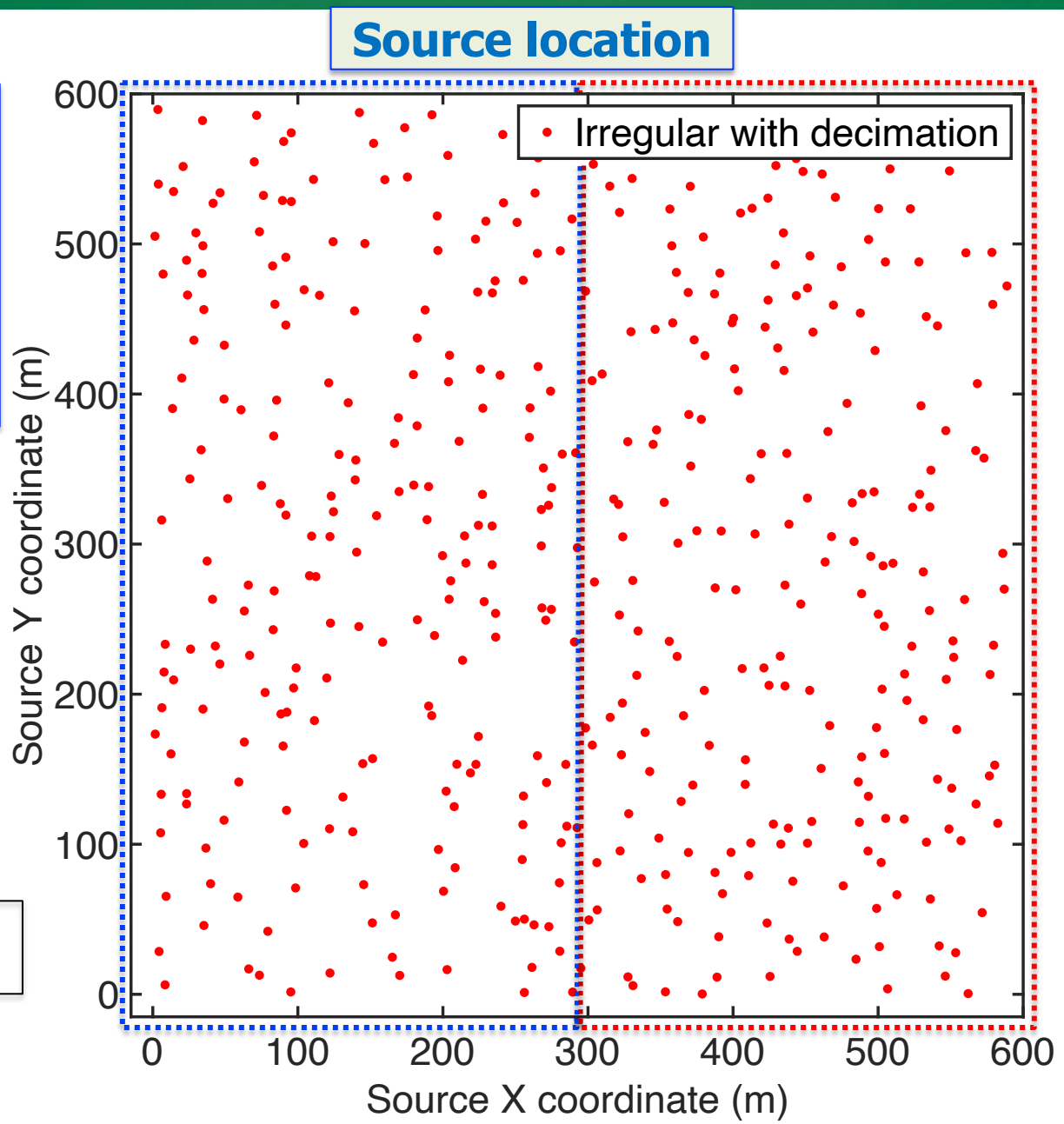


- Irregular source location

- *Conventional acquisition: 10 days*
- *Blending acquisition (BF=2): ≈ 5 days*

3D seismic acquisition = 5D seismic data (t,sx,sy,rx,ry)

1 CRG is a 3D cube



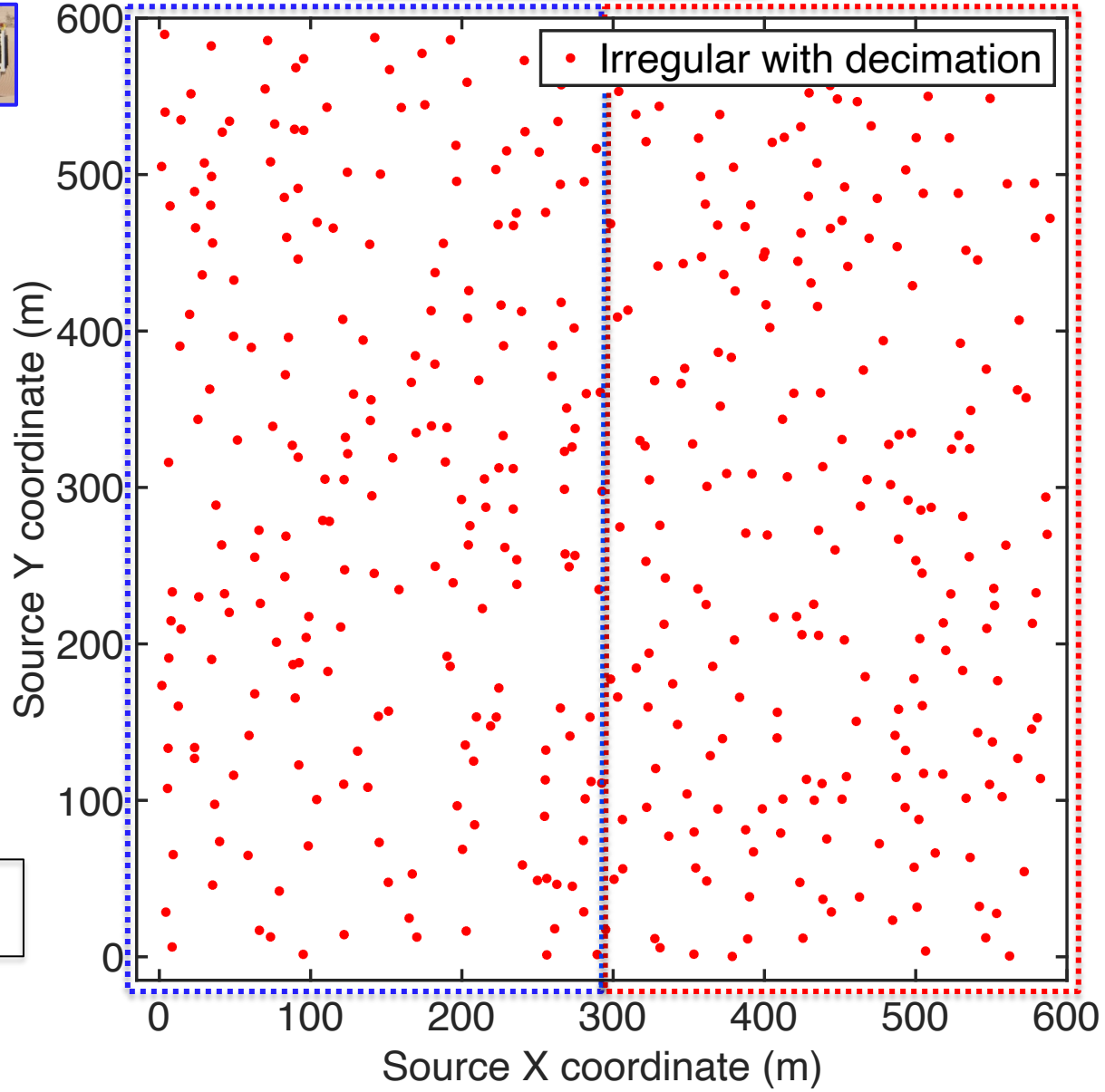
Dec = 50% decimation

• Irregular source location

Source 1

Source location

Source 2



3D Simultaneous-source acquisition (BF=2)

+ 50% shot number decimation

= 5D seismic data (t,sx,sy,rx,ry)

• Irregular source location

1 CRG is a 3D cube

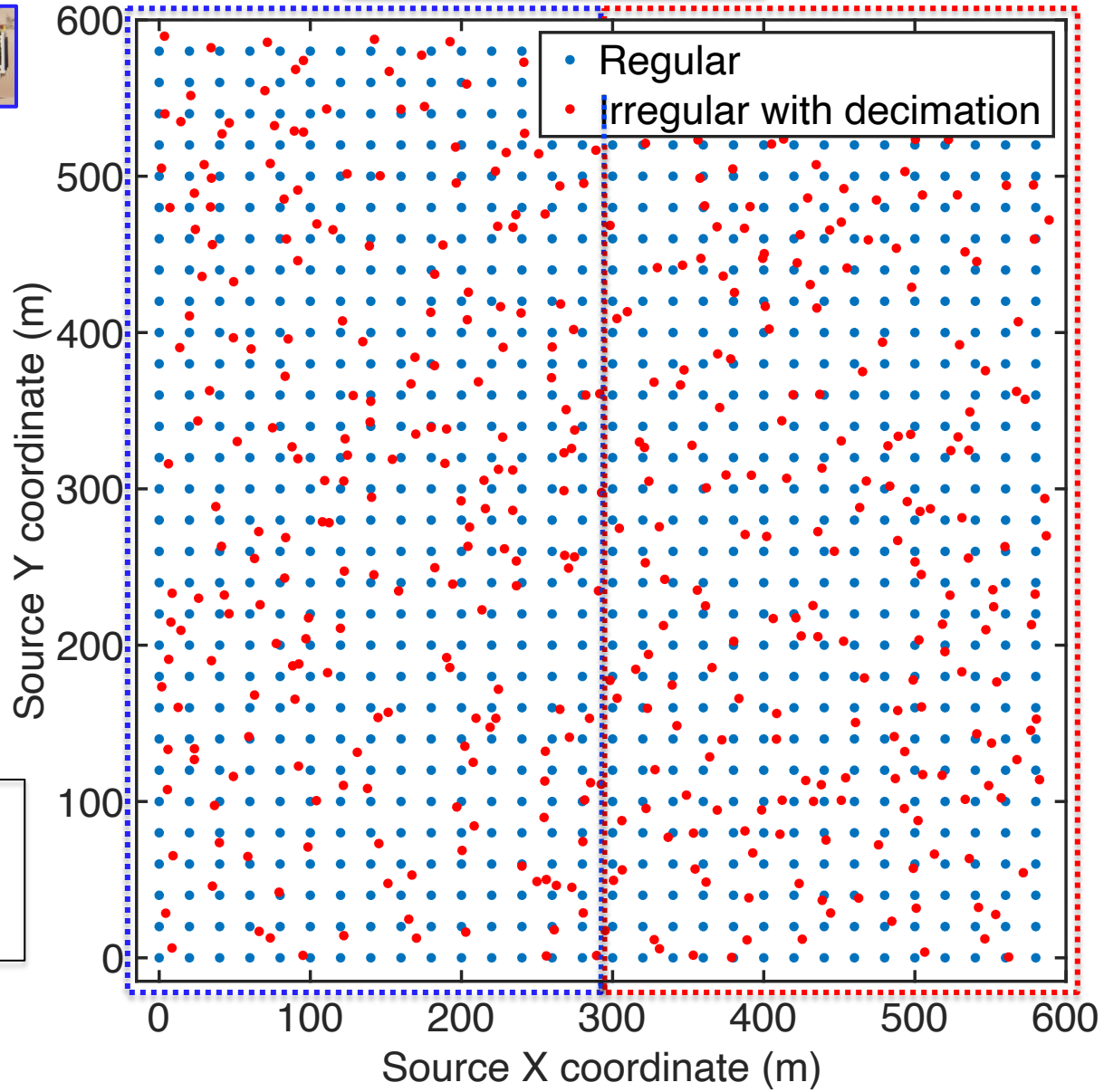
Dec = 50% decimation

$$T\_obs = \frac{T\_conv}{BF} * (1\text{-}Dec)$$

- *Conventional acquisition: 10 days*
- *Blending acquisition (BF=2): ≈ 5 days (Time compression)*
- *Compressive blending acquisition (dec=50%): ≈ 2.5 days (Spatial compression)*

Source 1

Source location



Source 2

3D Simultaneous-source acquisition (BF=2)

+ 50% shot number decimation

= 5D seismic data (t,sx,sy,rx,ry)

- Regular source location
- Irregular source location

1 CRG is a 3D cube

Dec = 50% decimation

$$T\_obs = \frac{T\_conv}{BF} * (1\text{-}Dec)$$

- *Conventional acquisition: 10 days*
- *Blending acquisition (BF=2): ≈ 5 days (Time compression)*
- *Compressive blending acquisition (dec=50%): ≈ 2.5 days (Spatial compression)*

Deblending + Irregular Reconstruction

Projected Gradient Descent Method

- MSSA with binning

$$J = \|\mathbf{b} - \mathcal{B}\mathcal{T}\mathbf{D}\|_2^2 \quad s.t. \quad rank(\mathbf{D}) \leq k$$

$$\mathcal{T}_{ij} = \begin{cases} 1 & \text{if one trace is assigned to grid point } (i,j) \\ 0 & \text{if grid point } (i,j) \text{ is empty} \end{cases}$$

- I-MSSA

$$J = \|\mathbf{b} - \mathcal{B}\mathcal{W}\mathbf{D}\|_2^2 \quad s.t. \quad rank(\mathbf{D}) \leq k$$

$$\mathcal{W}: \quad regular \rightarrow irregular$$

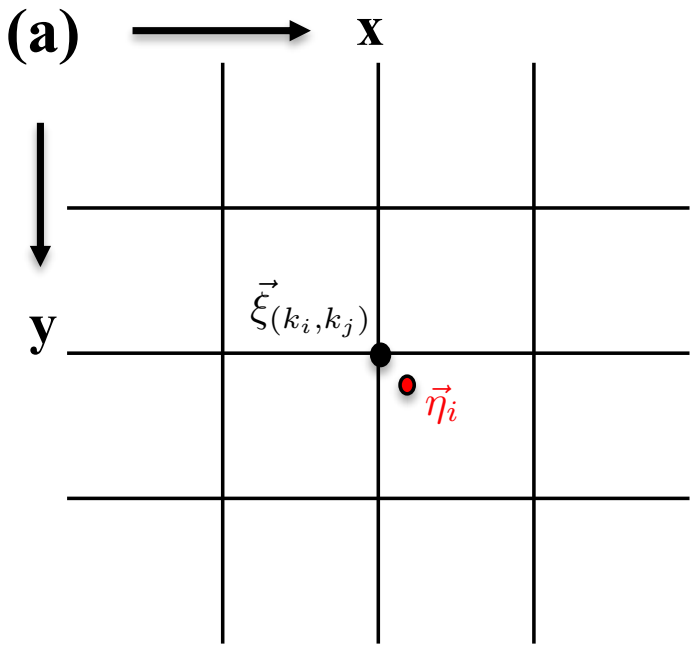
$$\mathcal{W}^*: \quad irregular \rightarrow regular$$

- ***Sinc-Kaiser interpolator*** $\mathcal{W}_k(t) = \text{sinc}(\pi t)\dfrac{I_0\left(a\sqrt{1-(t/(N+1))^2}\right)}{I_0(a)}$

Projected Gradient Descent Method

- MSSA with binning

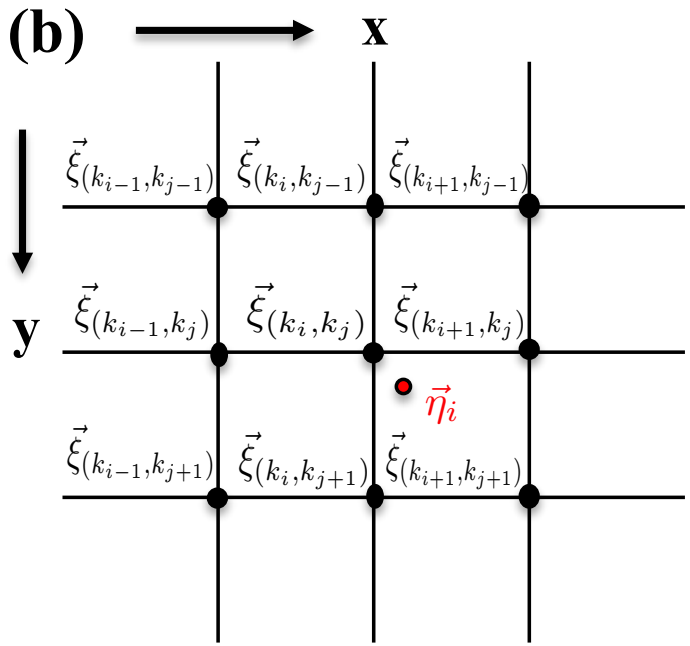
Sampling operator



$$\mathbf{D}^{\nu} = \mathscr{P}[\mathbf{D}^{\nu-1} - \lambda \mathscr{T}^* \mathcal{B}^* (\mathcal{B}\mathscr{T}\mathbf{D}^{\nu-1} - \mathbf{b})]$$

- I-MSSA

Sinc-Kaiser interpolator



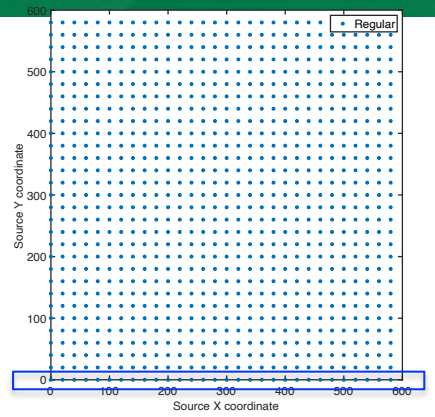
$$\mathbf{D}^{\nu} = \mathscr{P}[\mathbf{D}^{\nu-1} - \lambda \mathcal{W}^* \mathcal{B}^* (\mathcal{B}\mathcal{W}\mathbf{D}^{\nu-1} - \mathbf{b})]$$

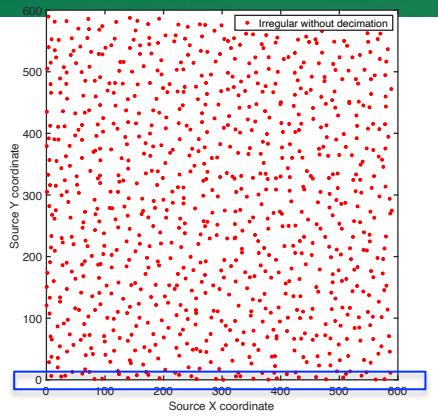
Projection operator = ***M**ultichannel **S**ingular **S**pectrum **A**nalysis* (MSSA)

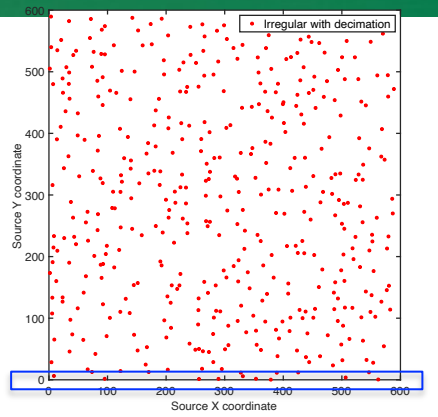
Blending noise only

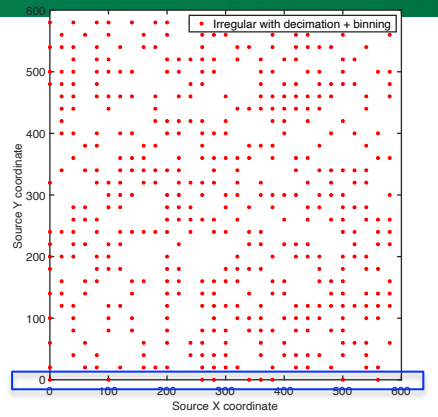
Blending noise (BF=2) + 50% decimation

Preliminary setting

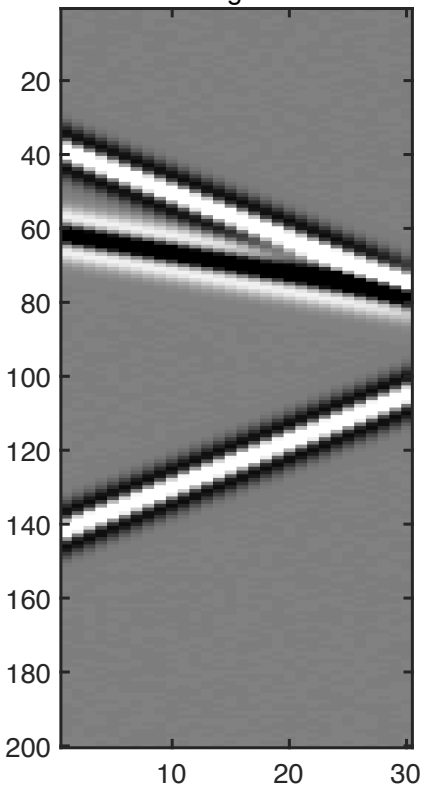




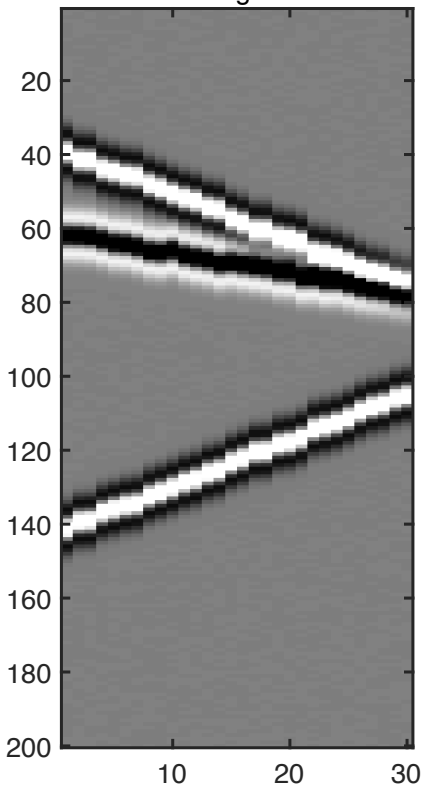




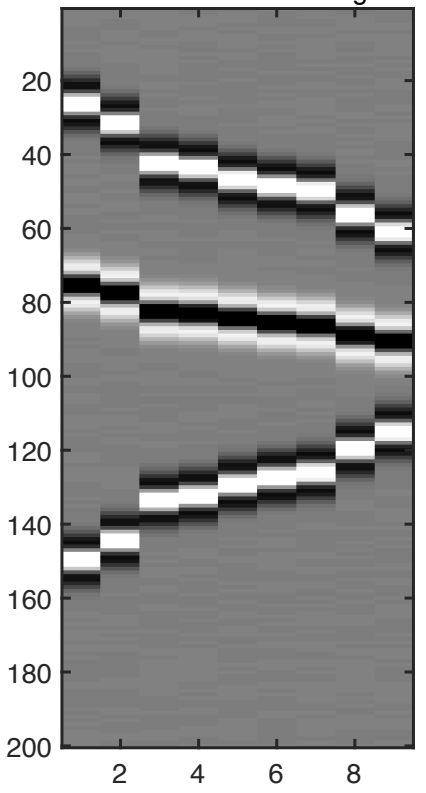
Clean regular data



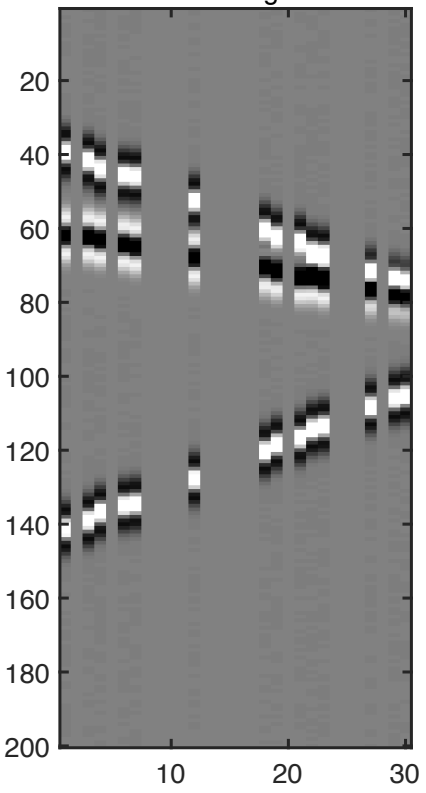
Clean irregular data



Observed real clean irregular

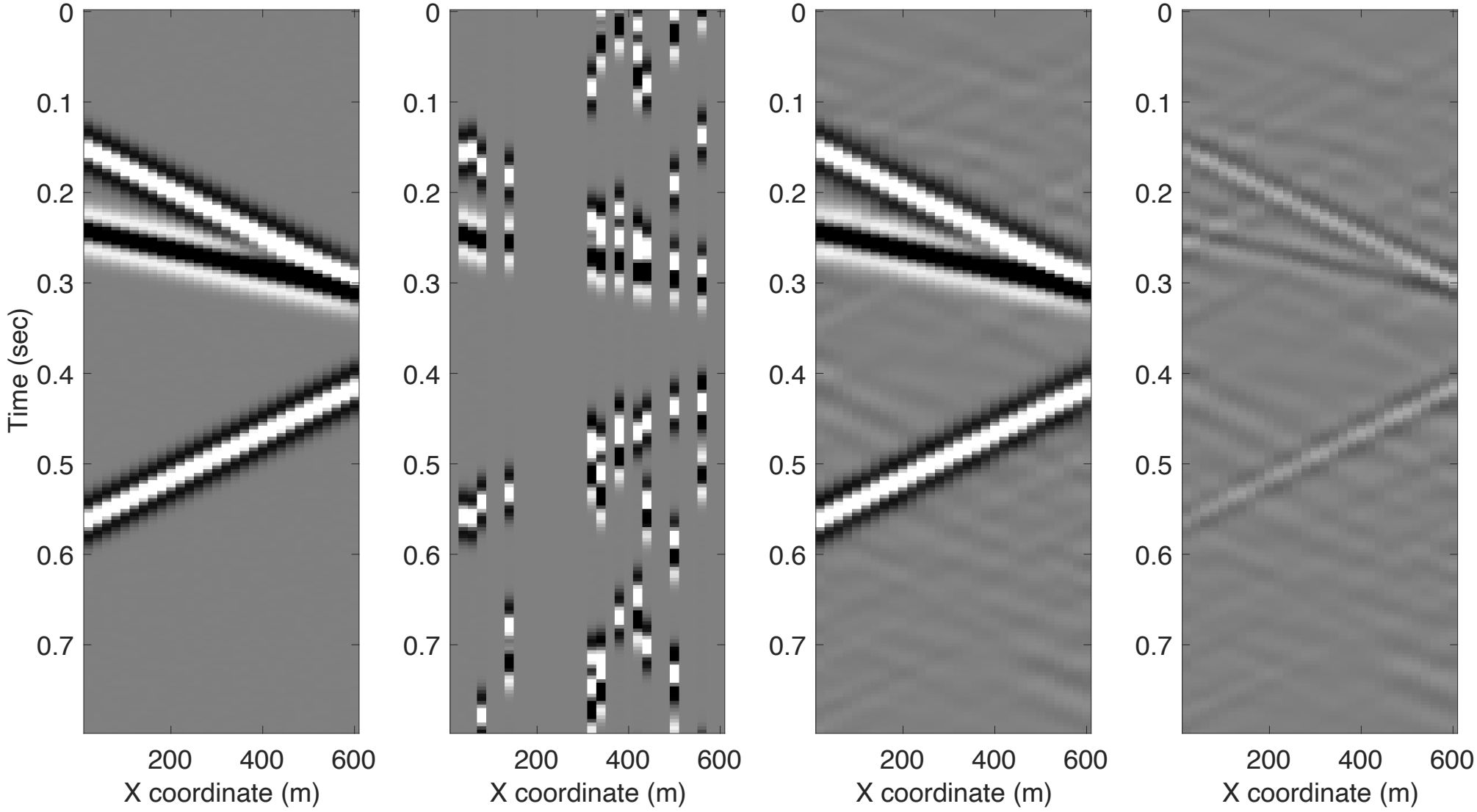


Observed clean irregular + binning



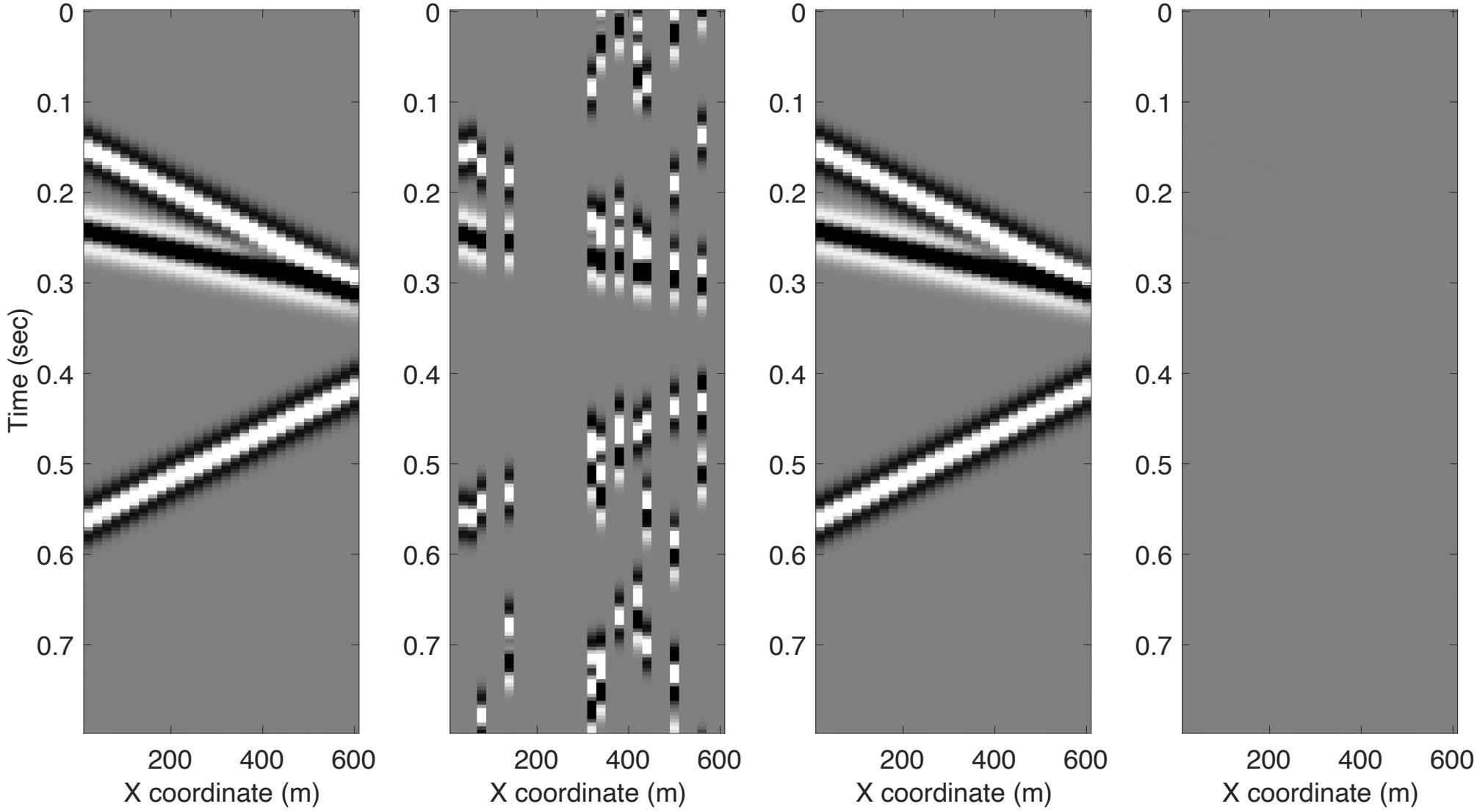
Blending noise (BF=2) + 50% decimation

MSSA + Binning

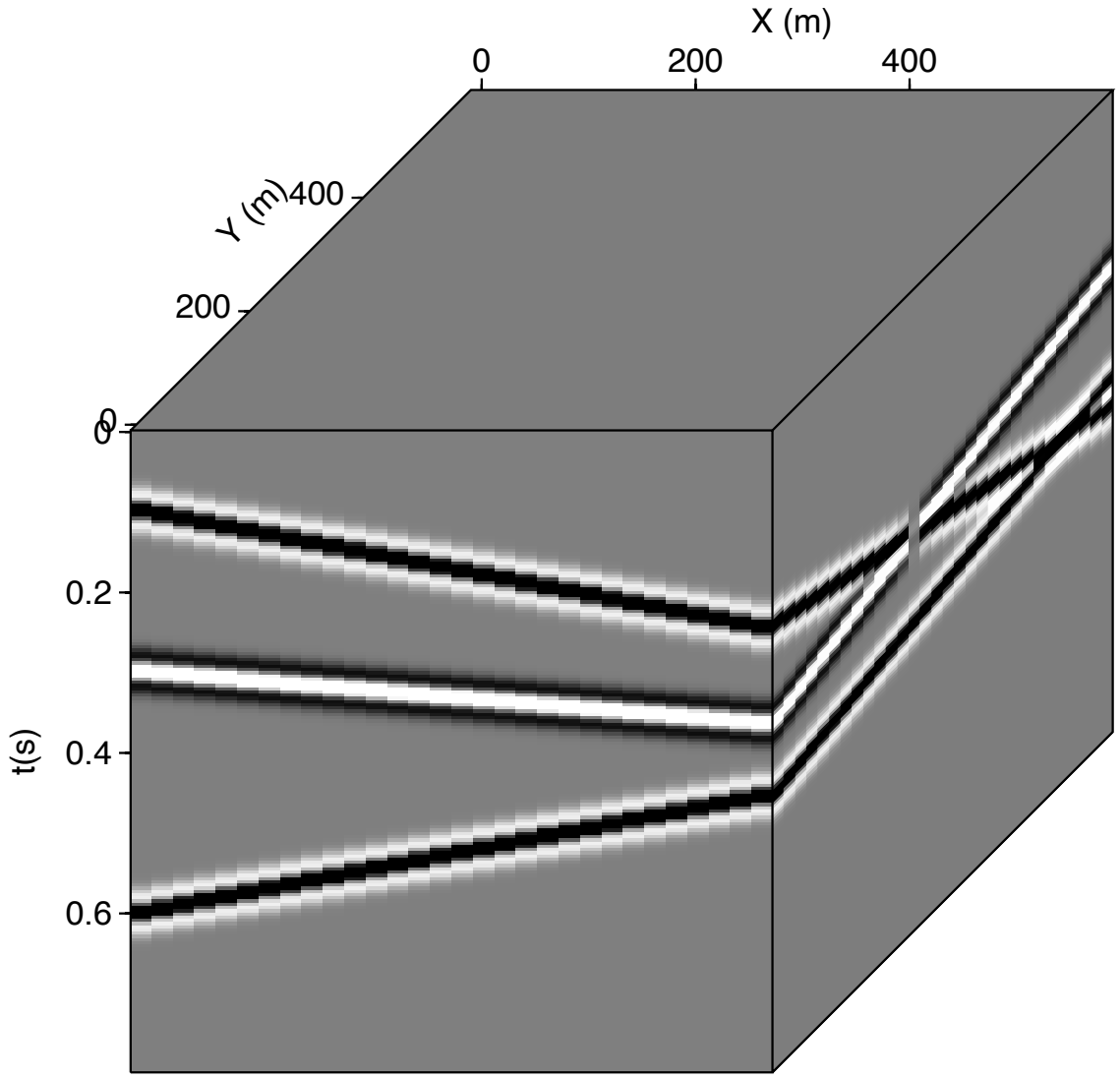


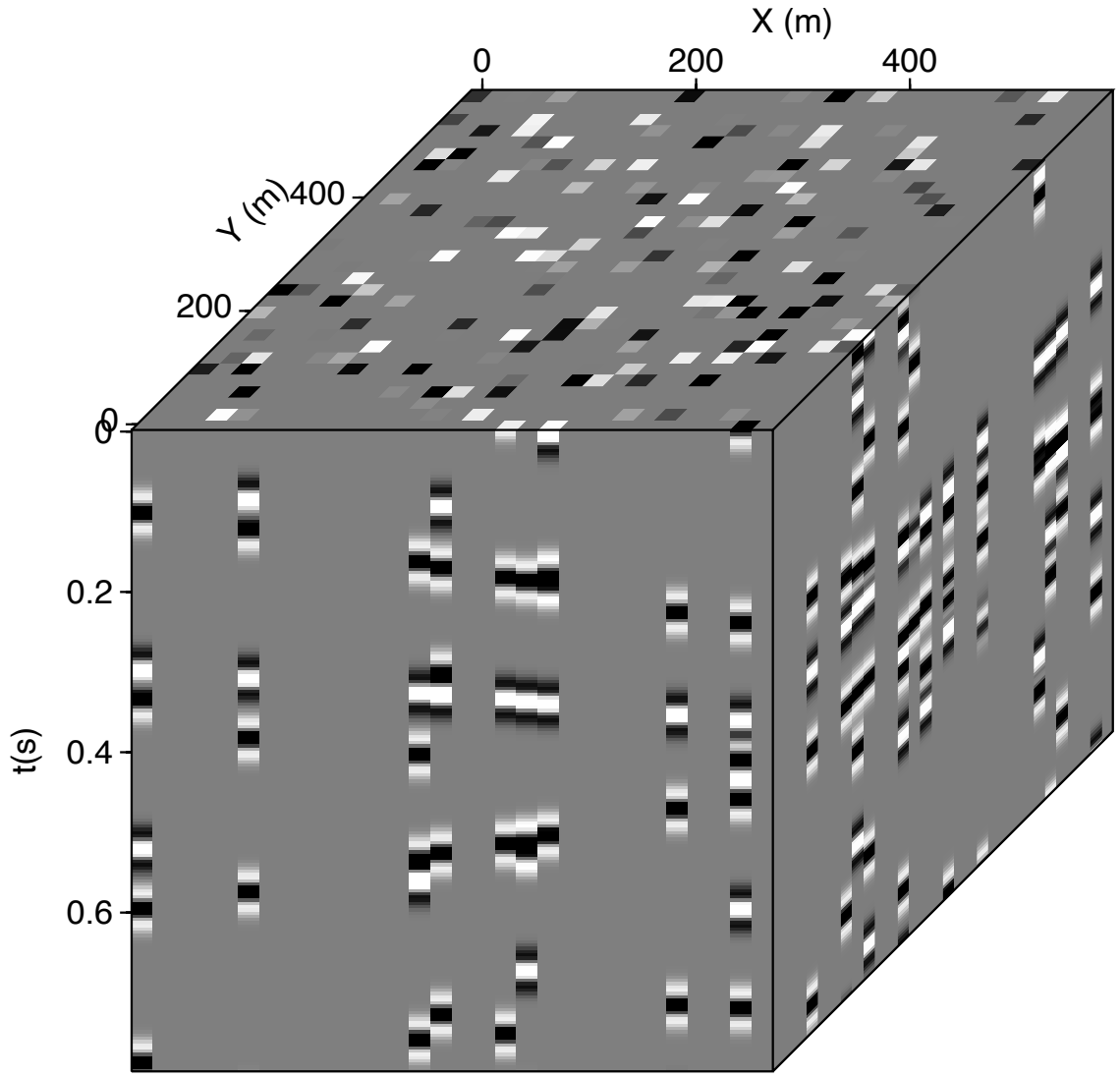
Blending noise (BF=2) + 50% decimation

I-MSSA

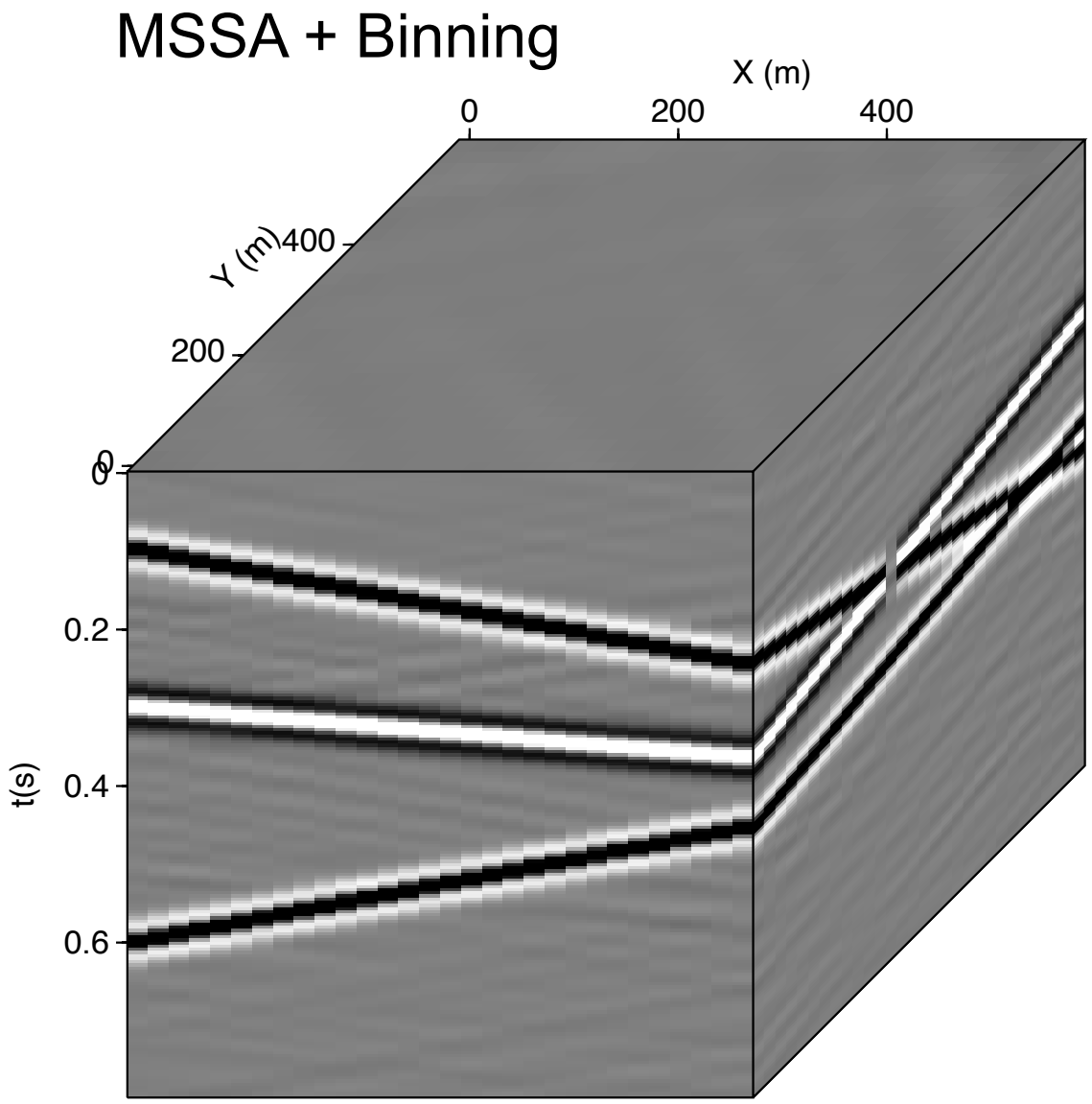


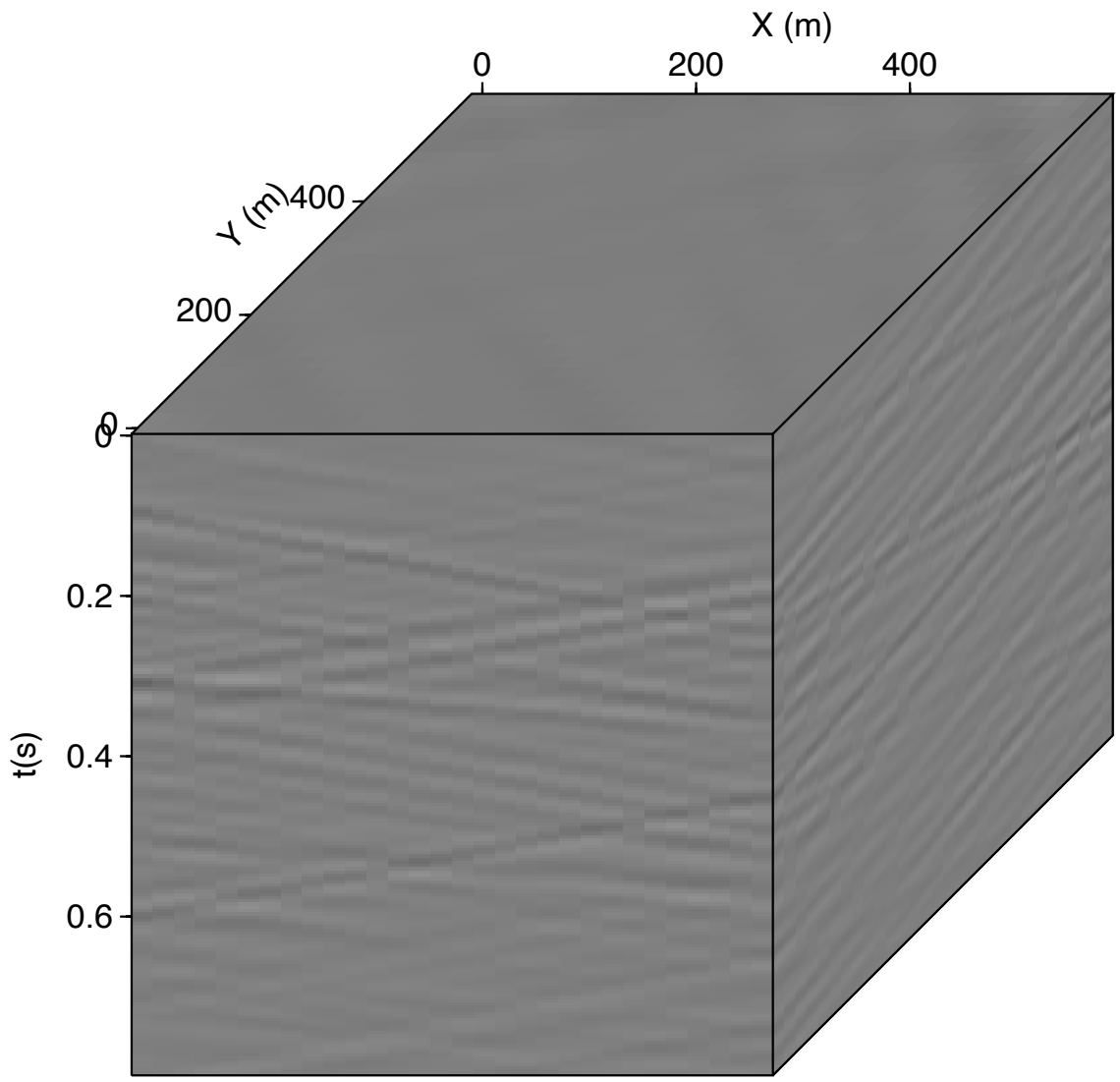
Blending noise (BF=2) + 50% decimation





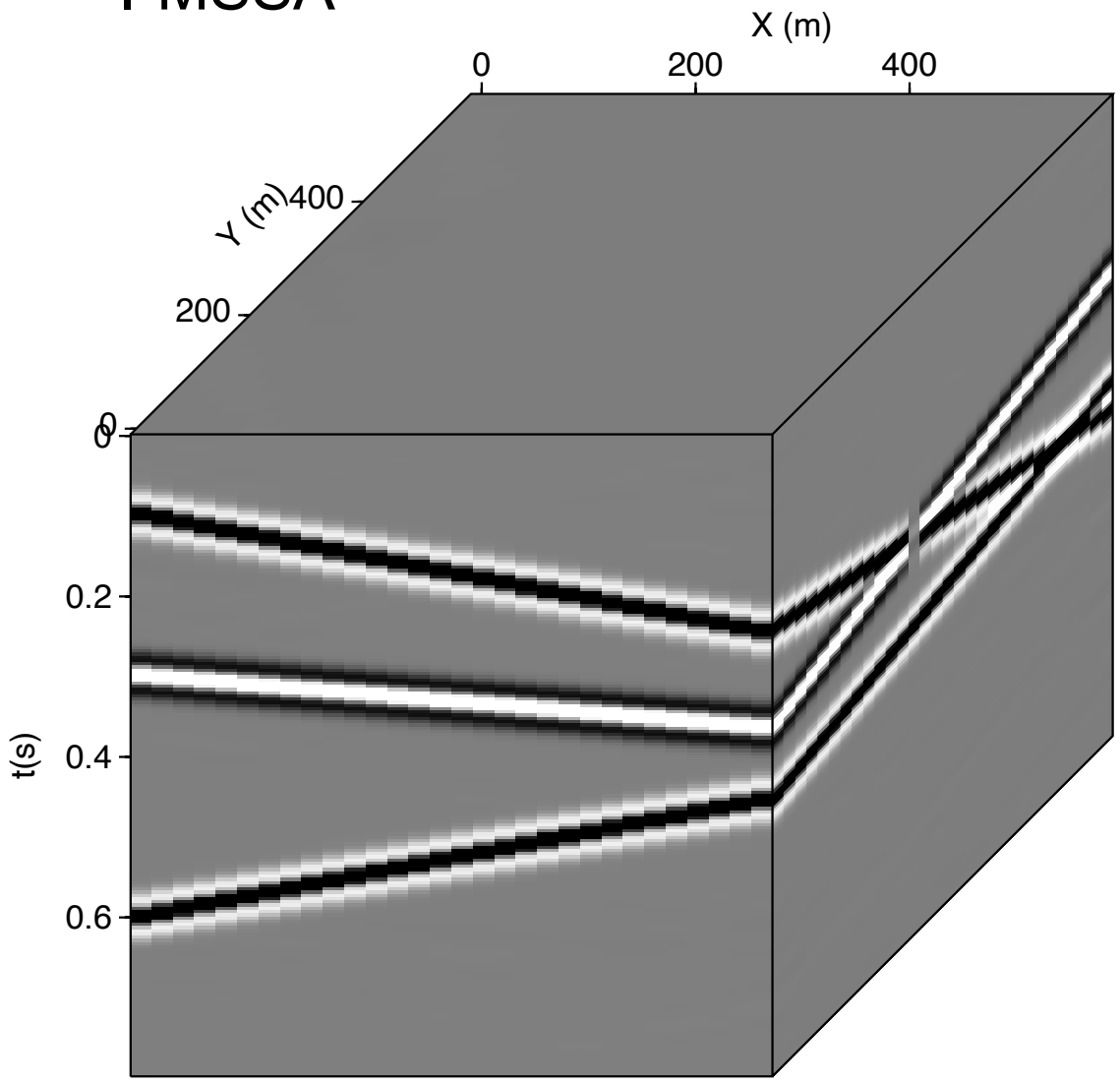
Blending noise (BF=2) + 50% decimation

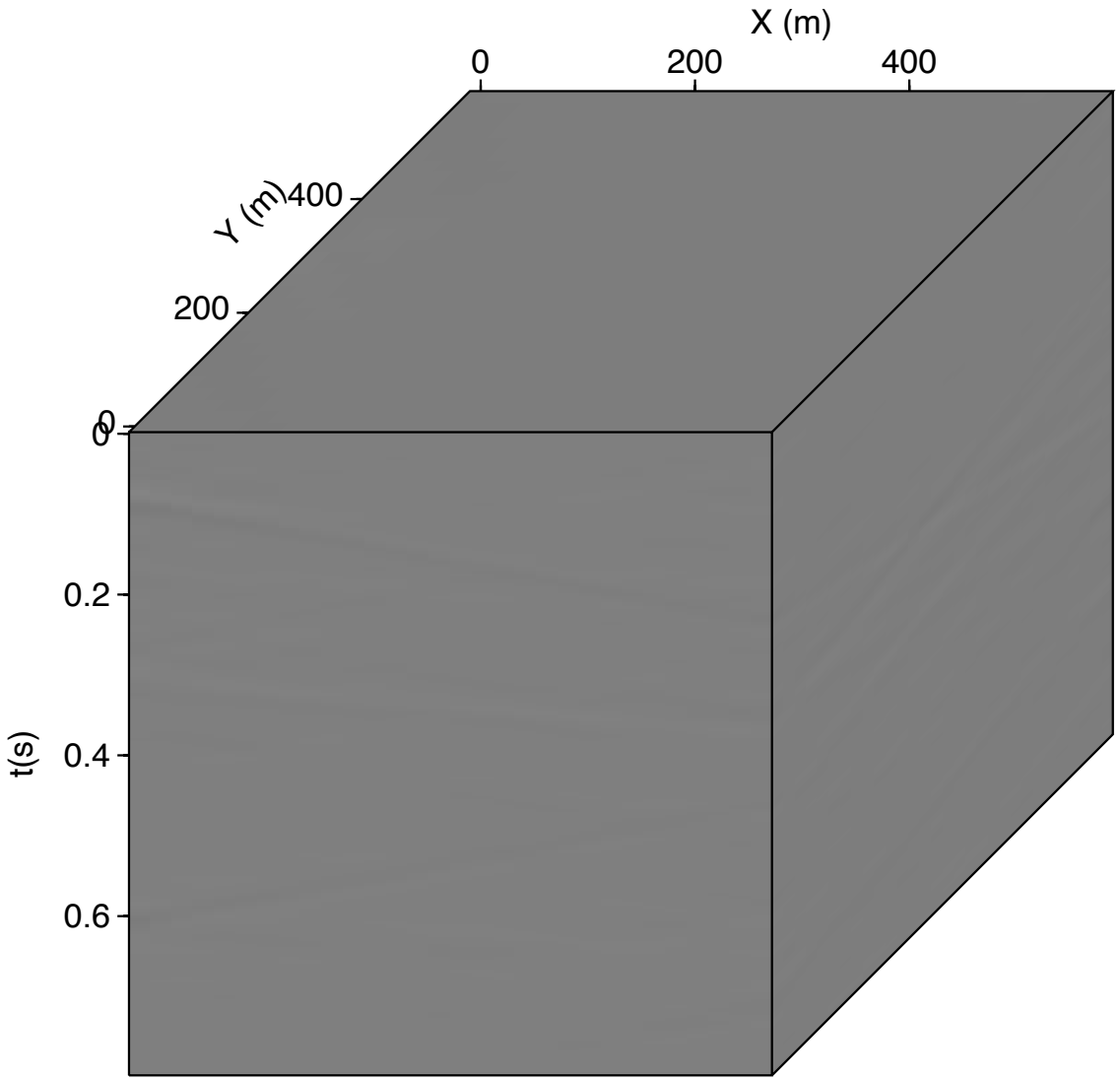




Blending noise (BF=2) + 50% decimation

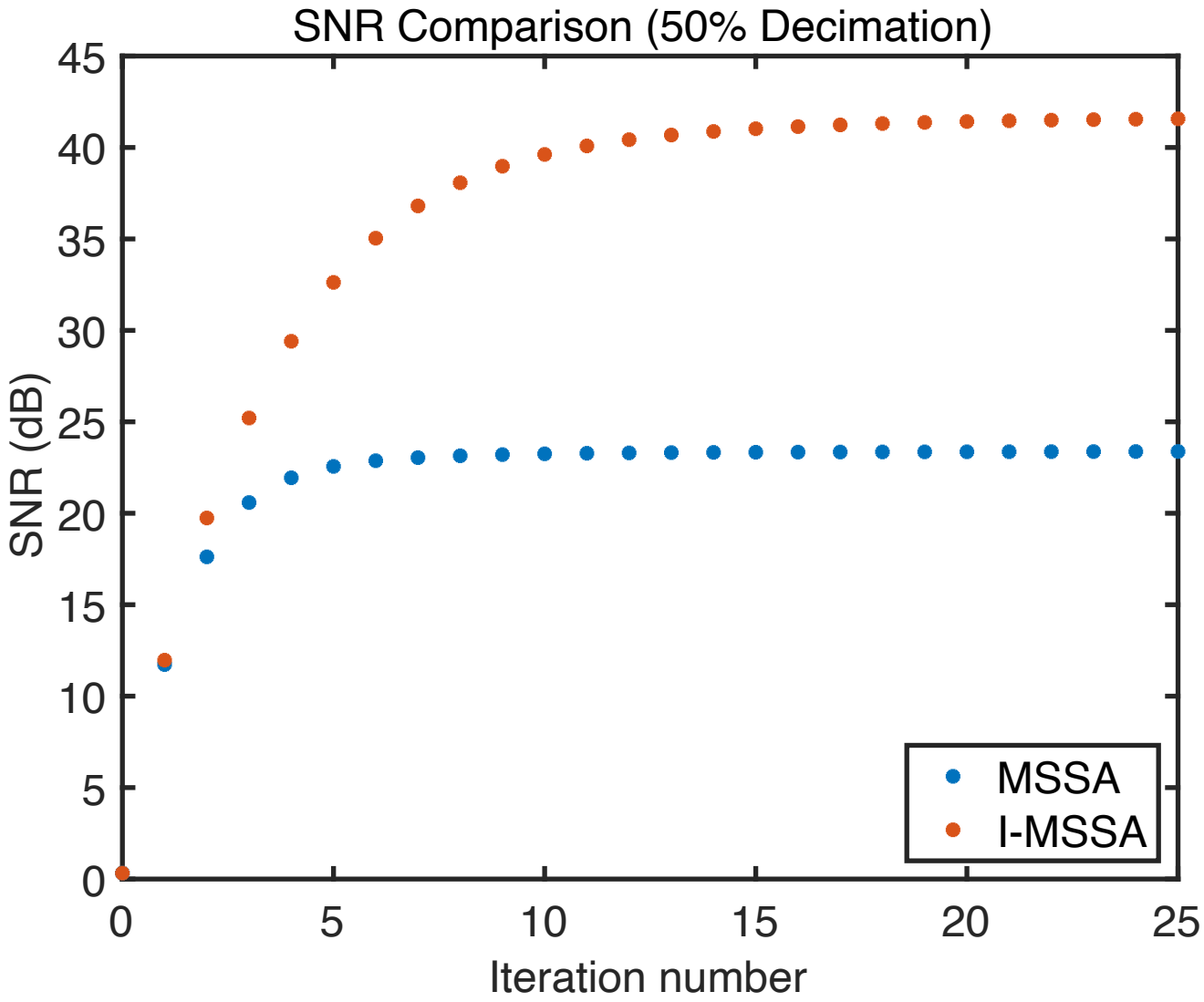
I-MSSA





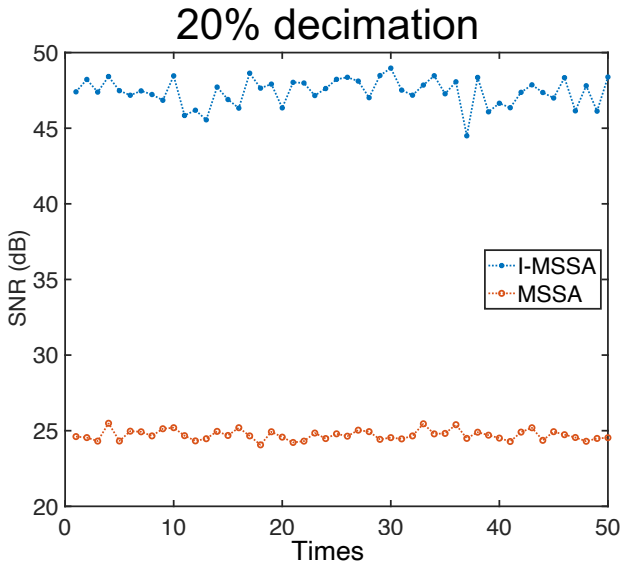
Blending noise (BF=2) + 50% decimation

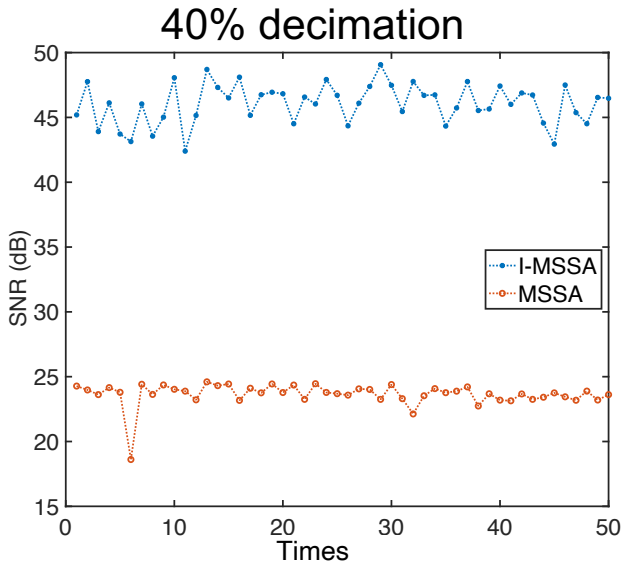
50% decimation

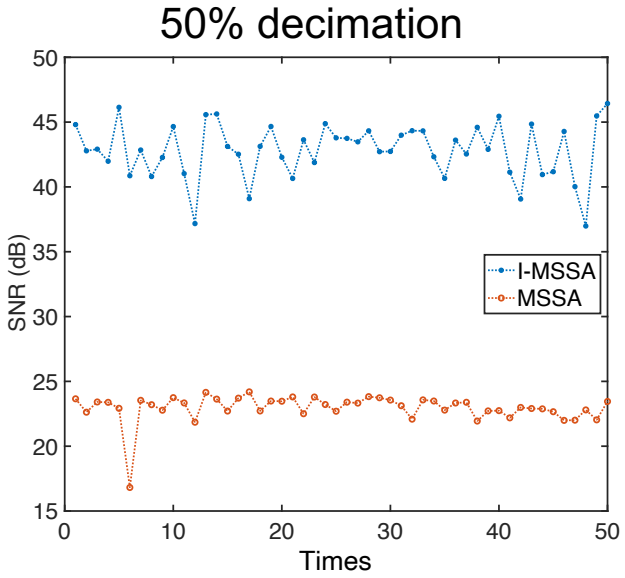


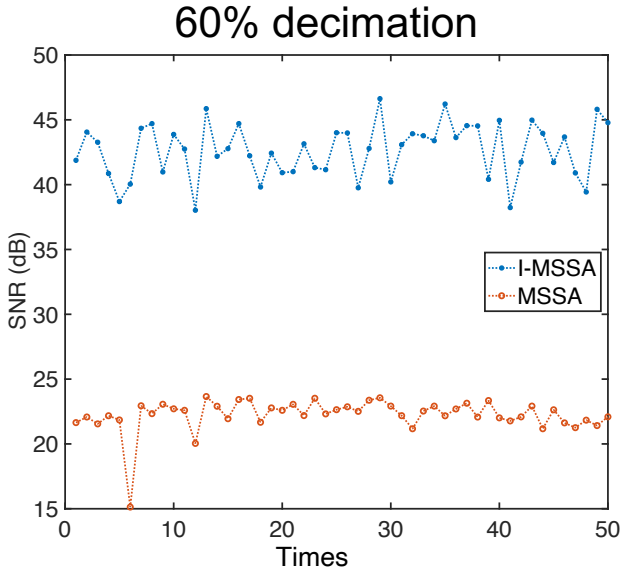
Blending noise (BF=2)

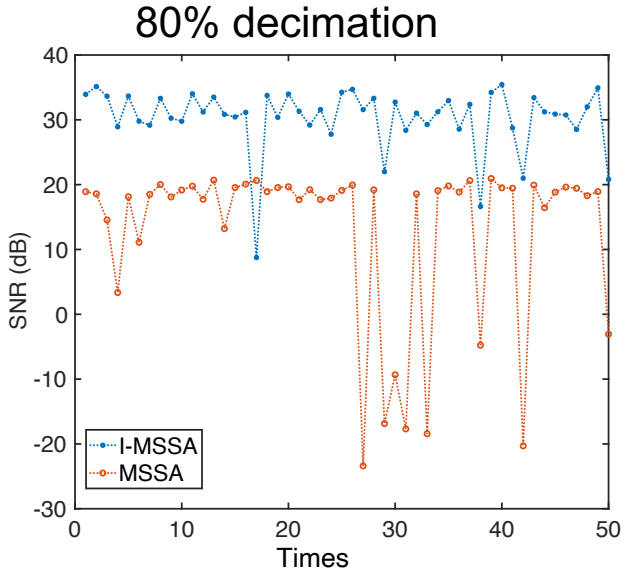
50 times random schemes







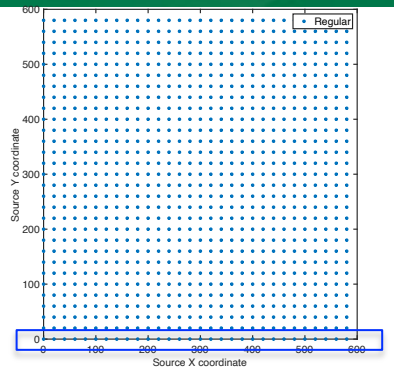


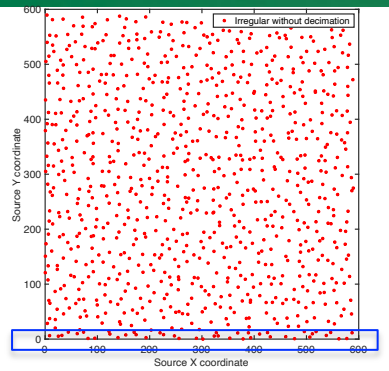


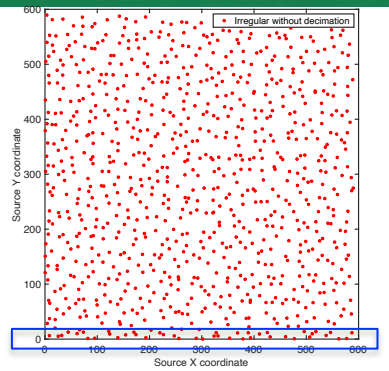
Gaussian Noise + Blending noise

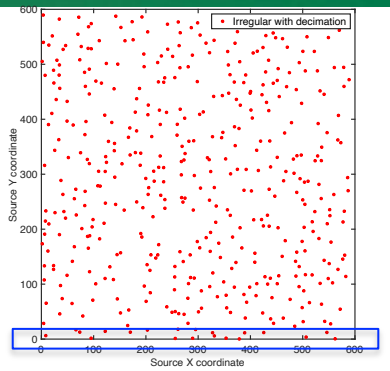
Gaussian Noise (SNR=1) + Blending noise (BF=2) + 50% decimation

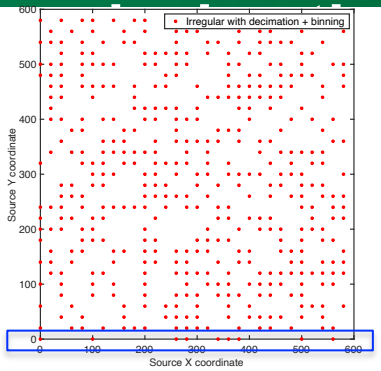
Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%



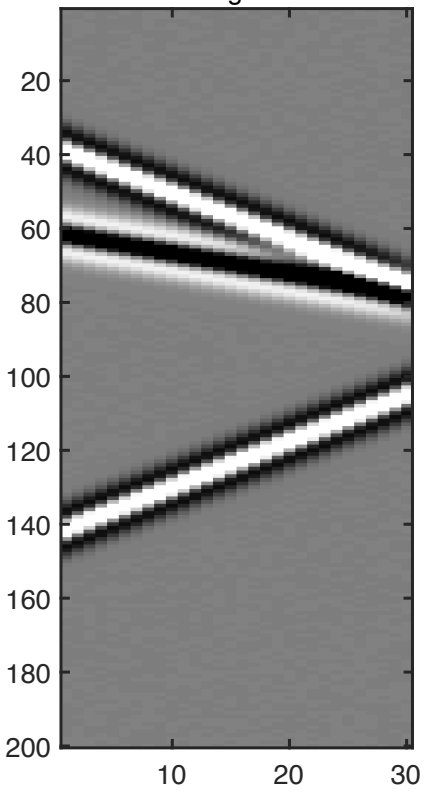




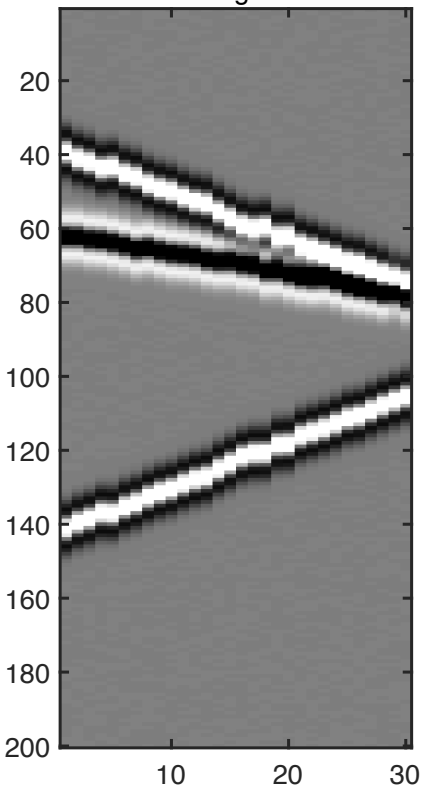




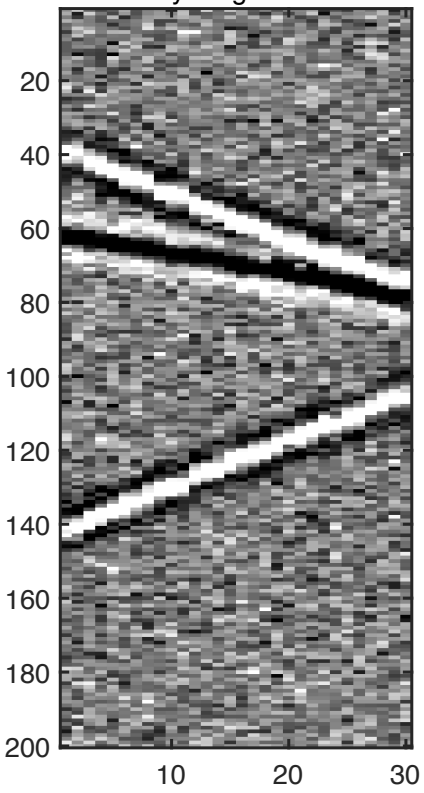
Clean regular data



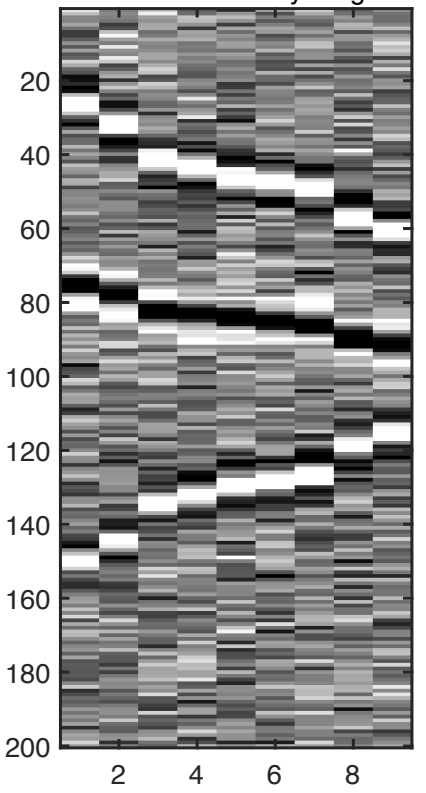
Clean irregular data



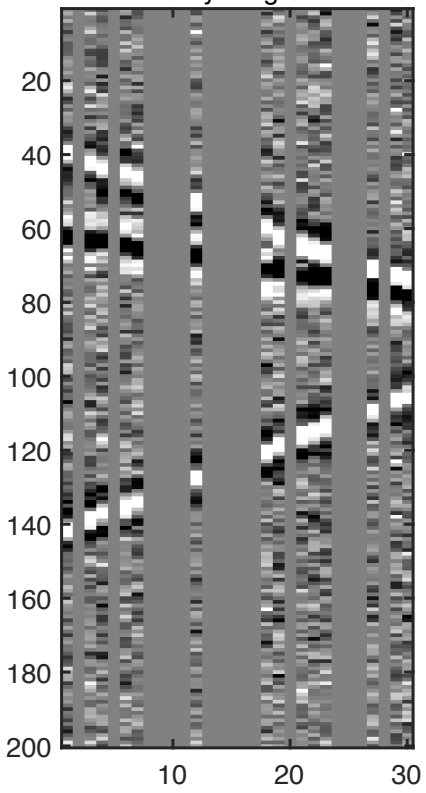
Noisy irregular data



Observed real noisy irregular

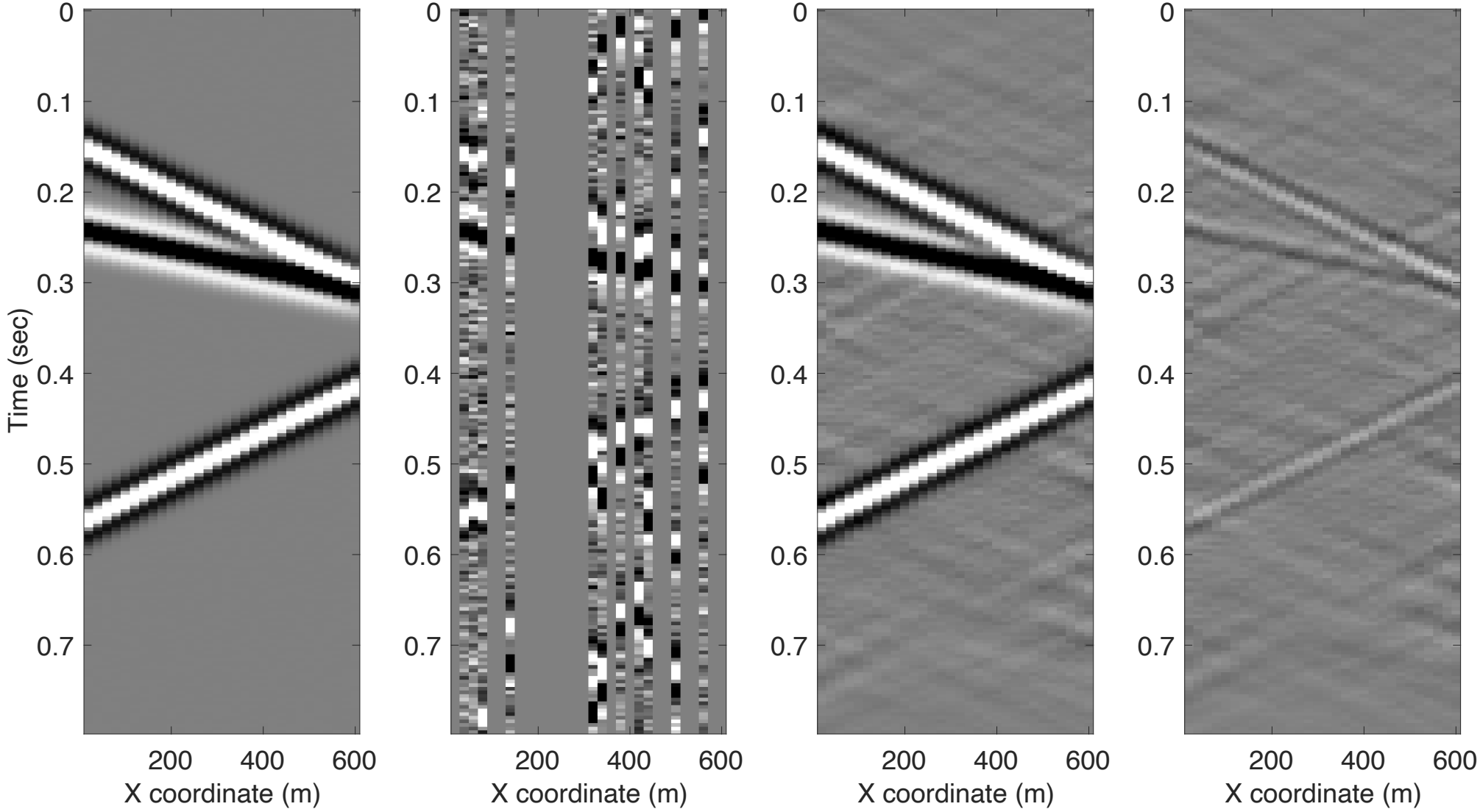


Observed noisy irregular + binning



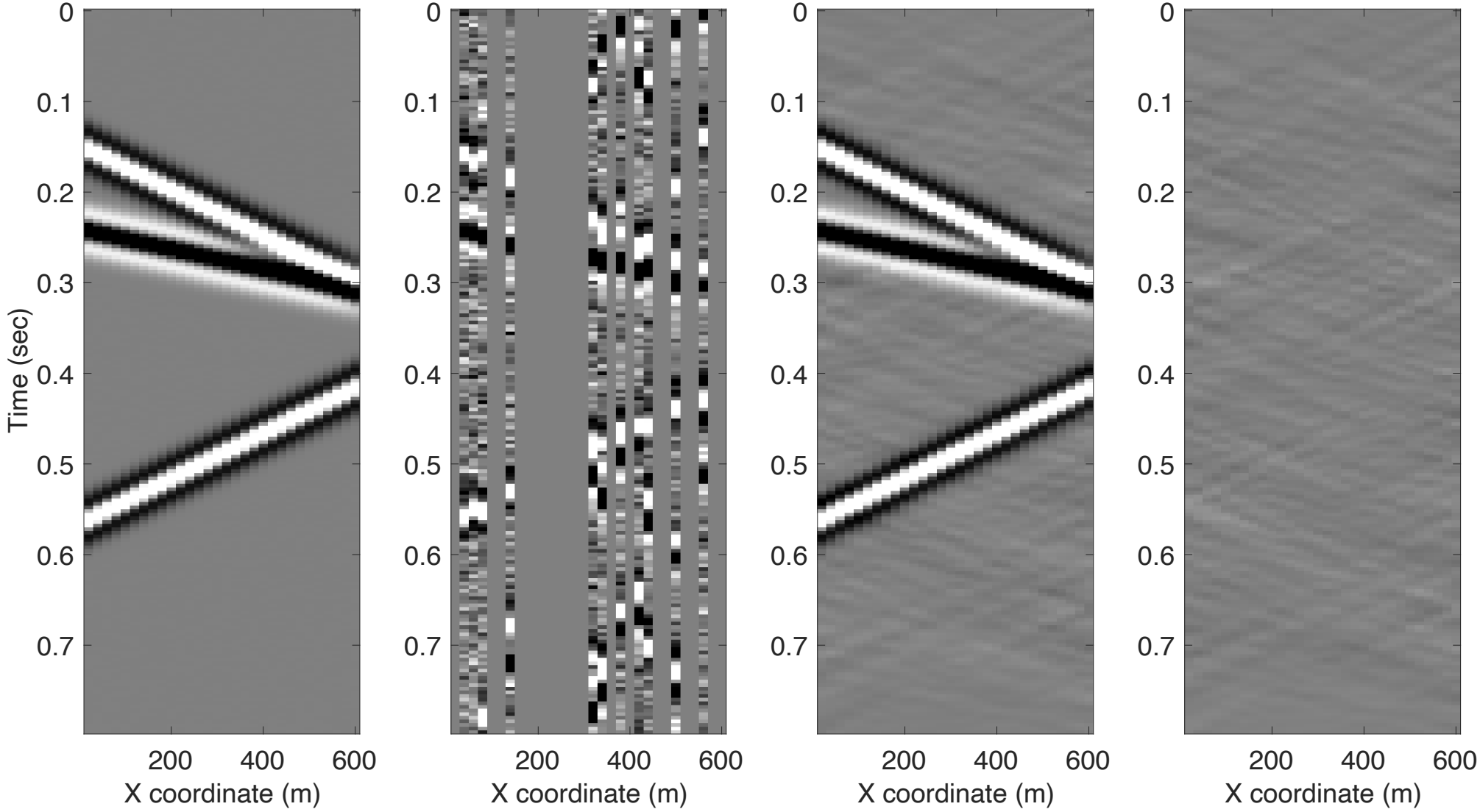
Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%

Synthetic example (Deblending + MSSA reconstruction)

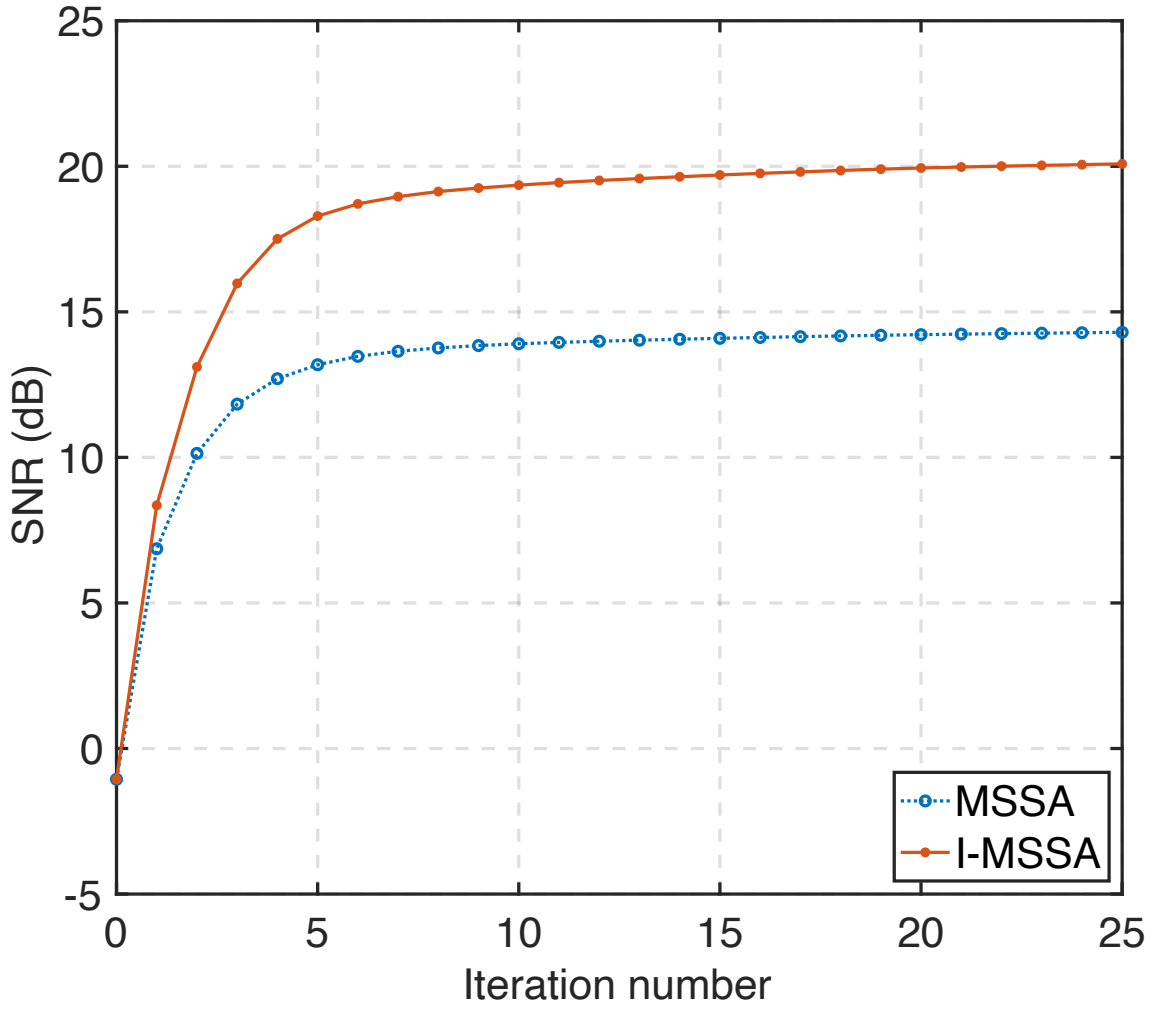


Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50% decimation

Synthetic example (Deblending + I-MSSA reconstruction)

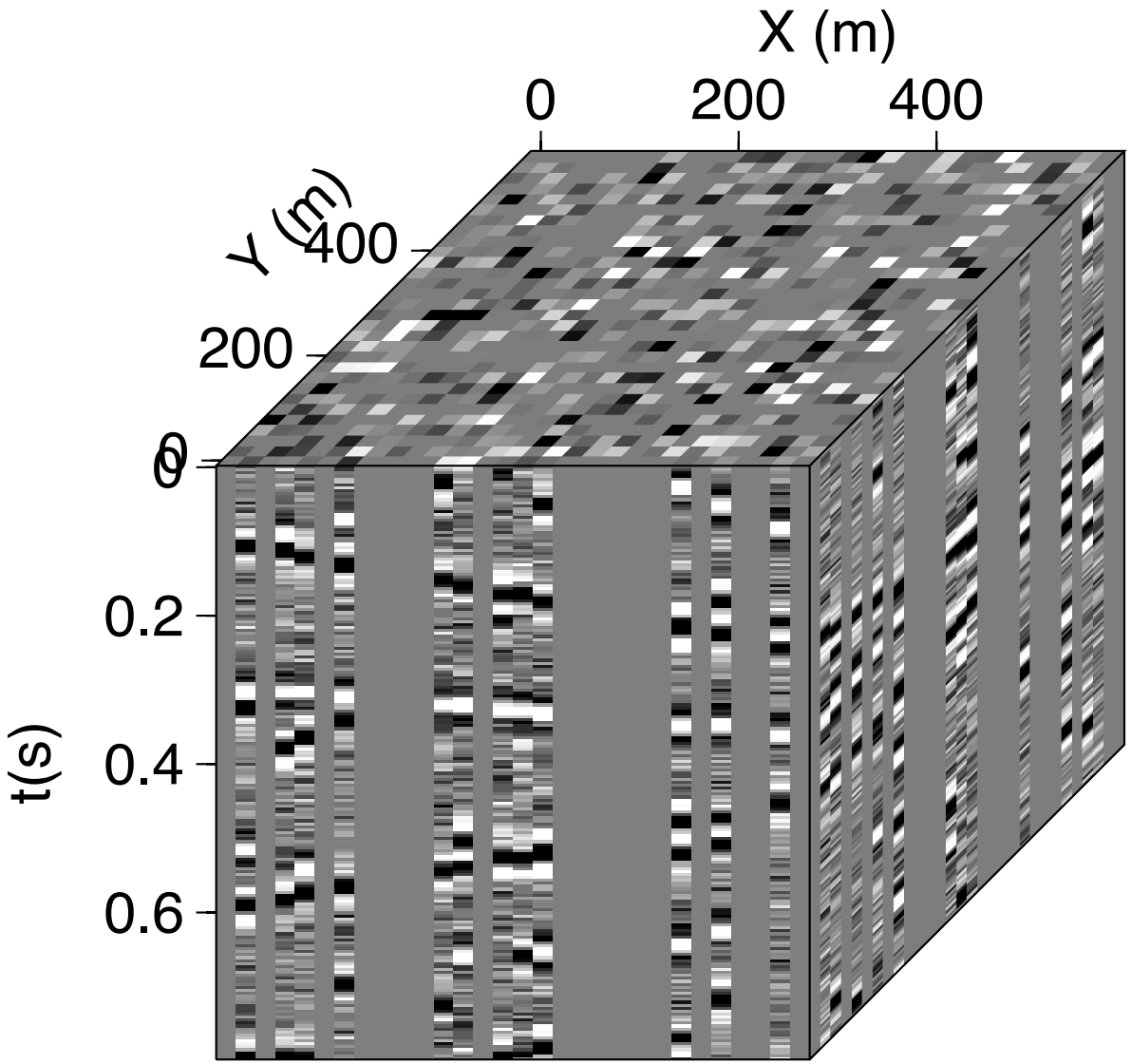


Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%



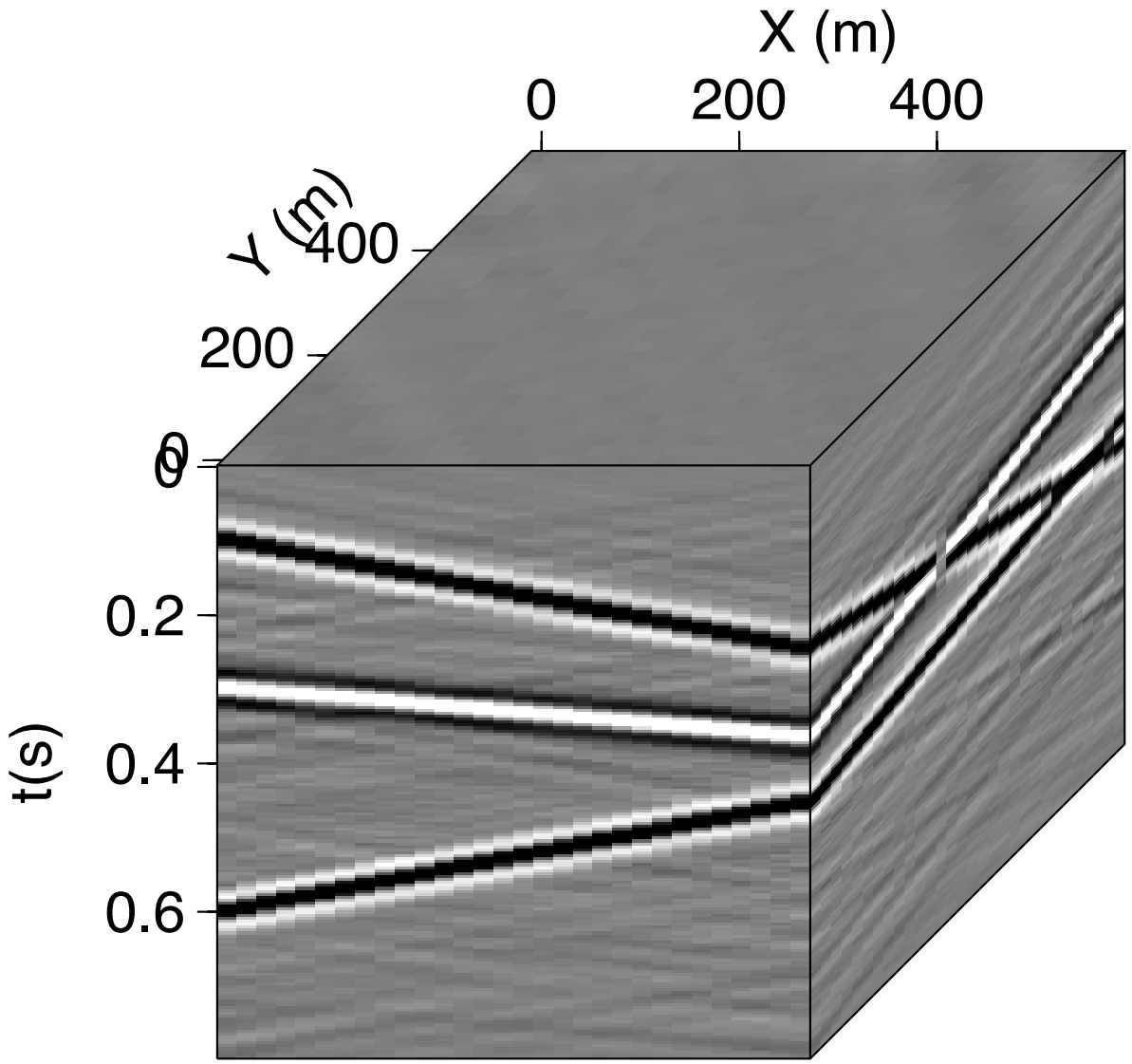
Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%

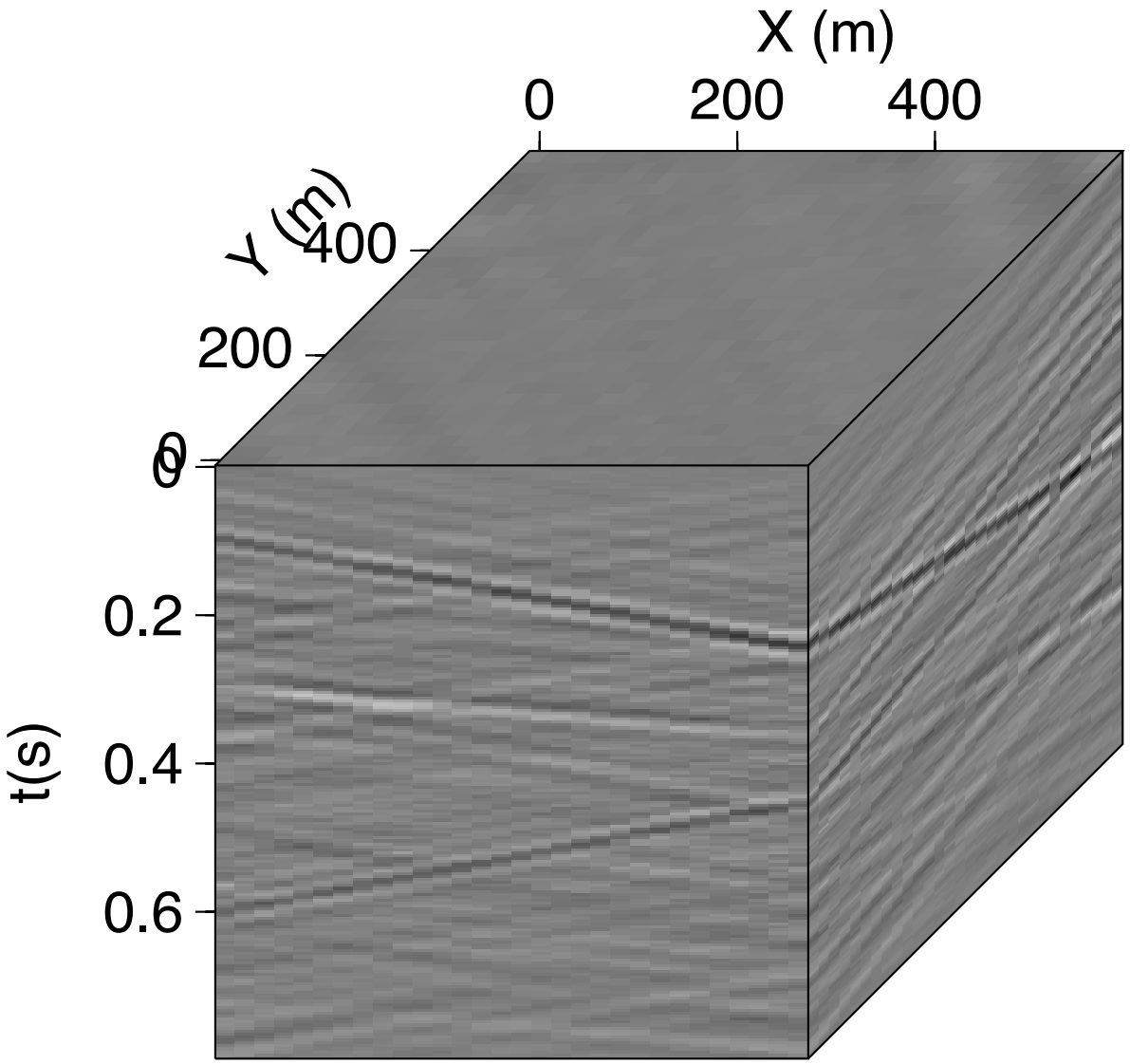
Synthetic example (Deblending + I-MSSA reconstruction)



Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%

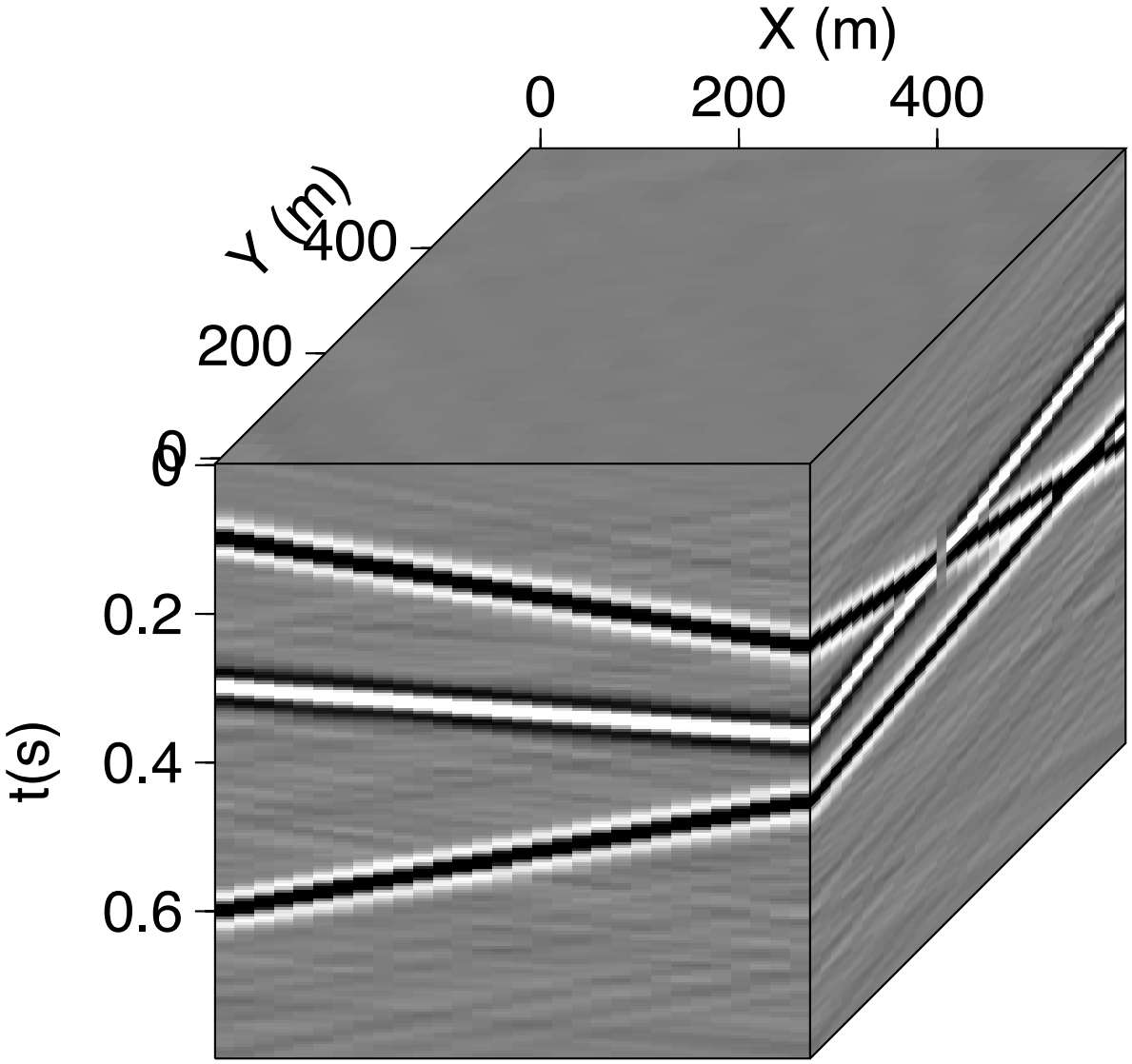
Synthetic example (Deblending + MSSA reconstruction)

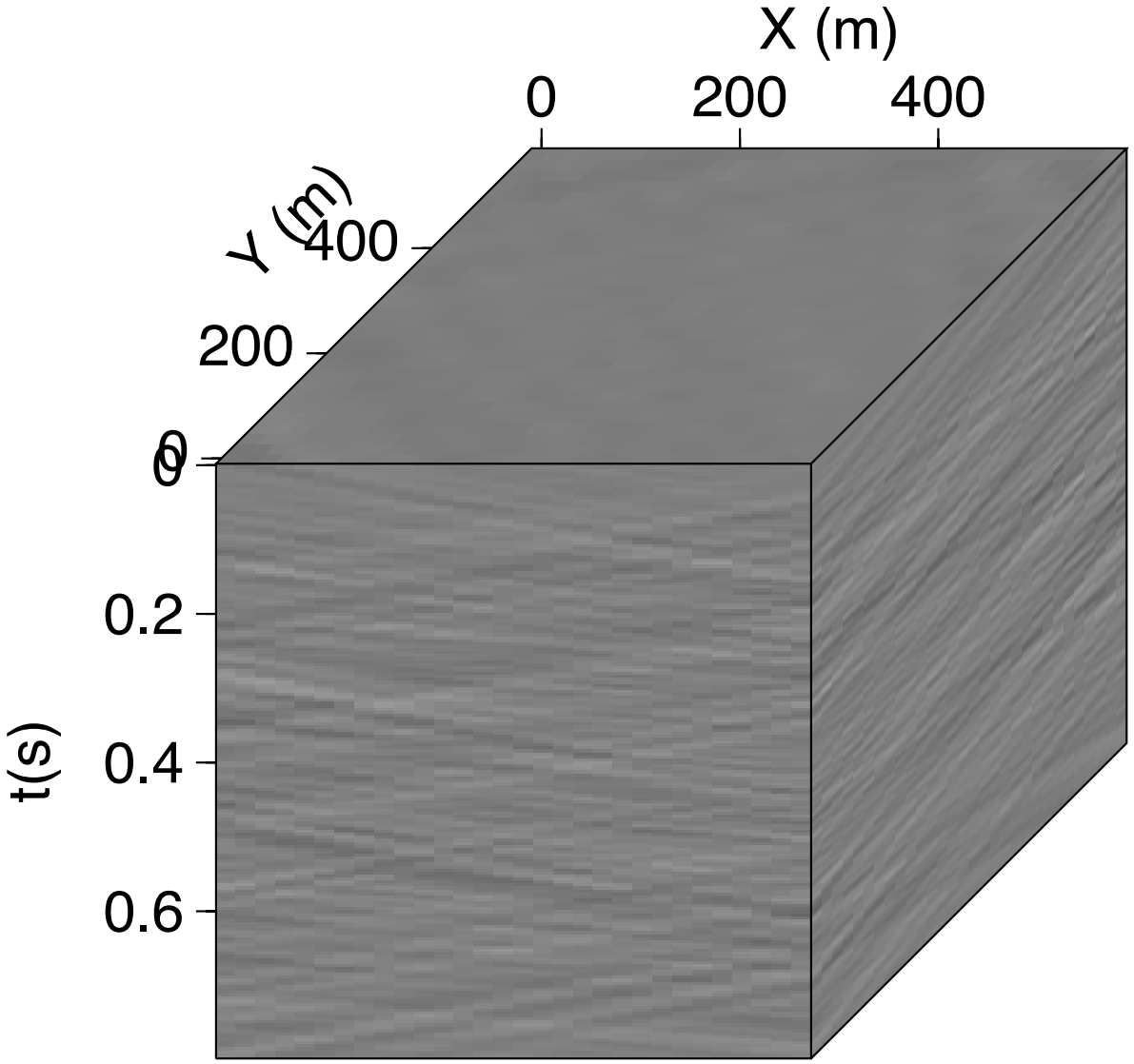




Gaussian Noise (SNR=2) + Blending noise (BF=2) + 50%

Synthetic example (Deblending + I-MSSA reconstruction)



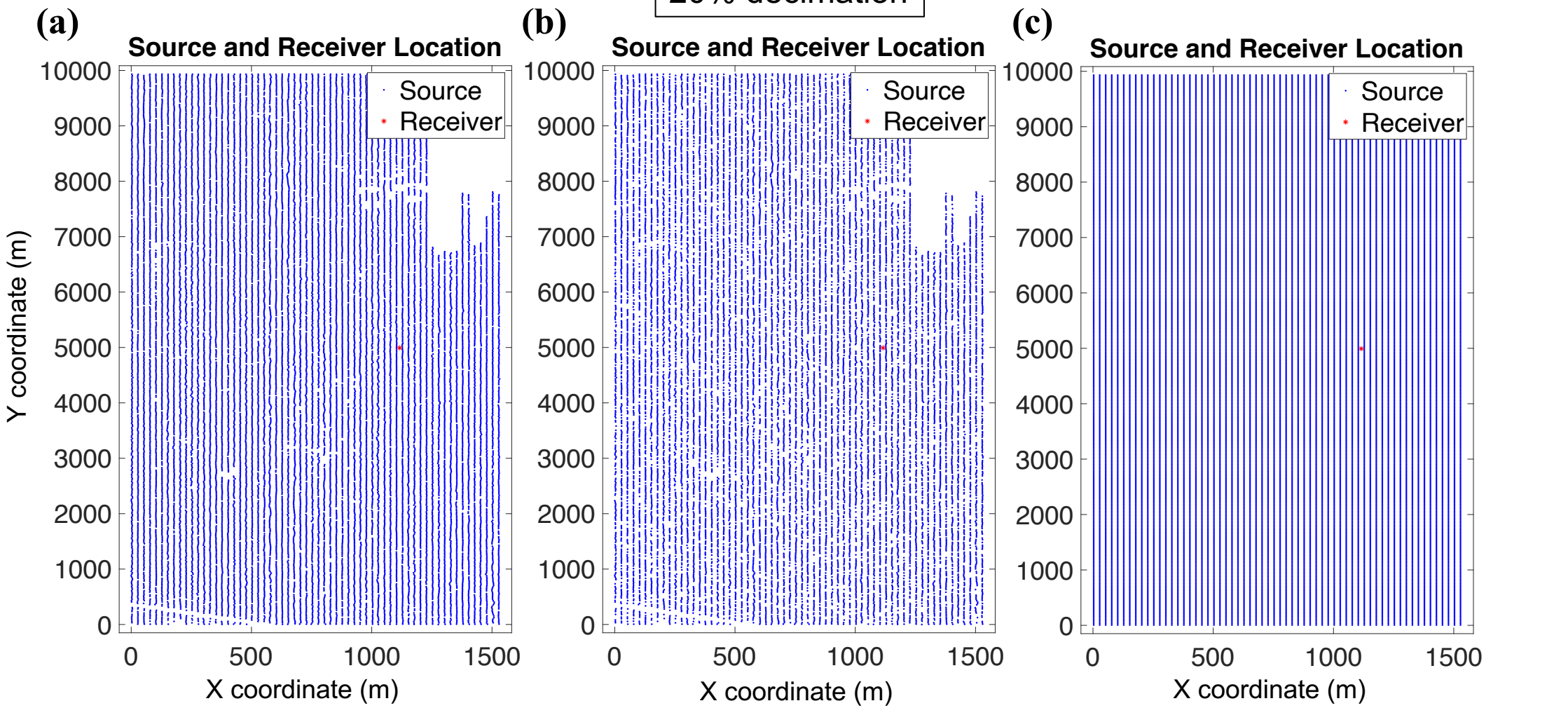


Real Example (Deblending + Irregular Reconstruction)

Real Example (Deblending + Irregular Reconstruction)

- Coordinate distribution

20% decimation



22480 source points

17927 source points

398*62=24676 source points

Projected Gradient Descent Method

$$J = \|\mathbf{b} - \mathcal{B}\mathcal{W}\mathbf{D}\|_2^2 \quad s.t. \quad rank(\mathbf{D}) \leq k$$

$$J = \|\mathbf{b} - \mathcal{B}\mathcal{W}\mathcal{L}\mathbf{D}\|_2^2 \quad s.t. \quad rank(\mathbf{D}) \leq k$$

$\mathcal{L}$: *Unpatch operator*

$\mathcal{L}^*$: *Patch operator*

$\mathcal{W}$: $regular \rightarrow irregular$

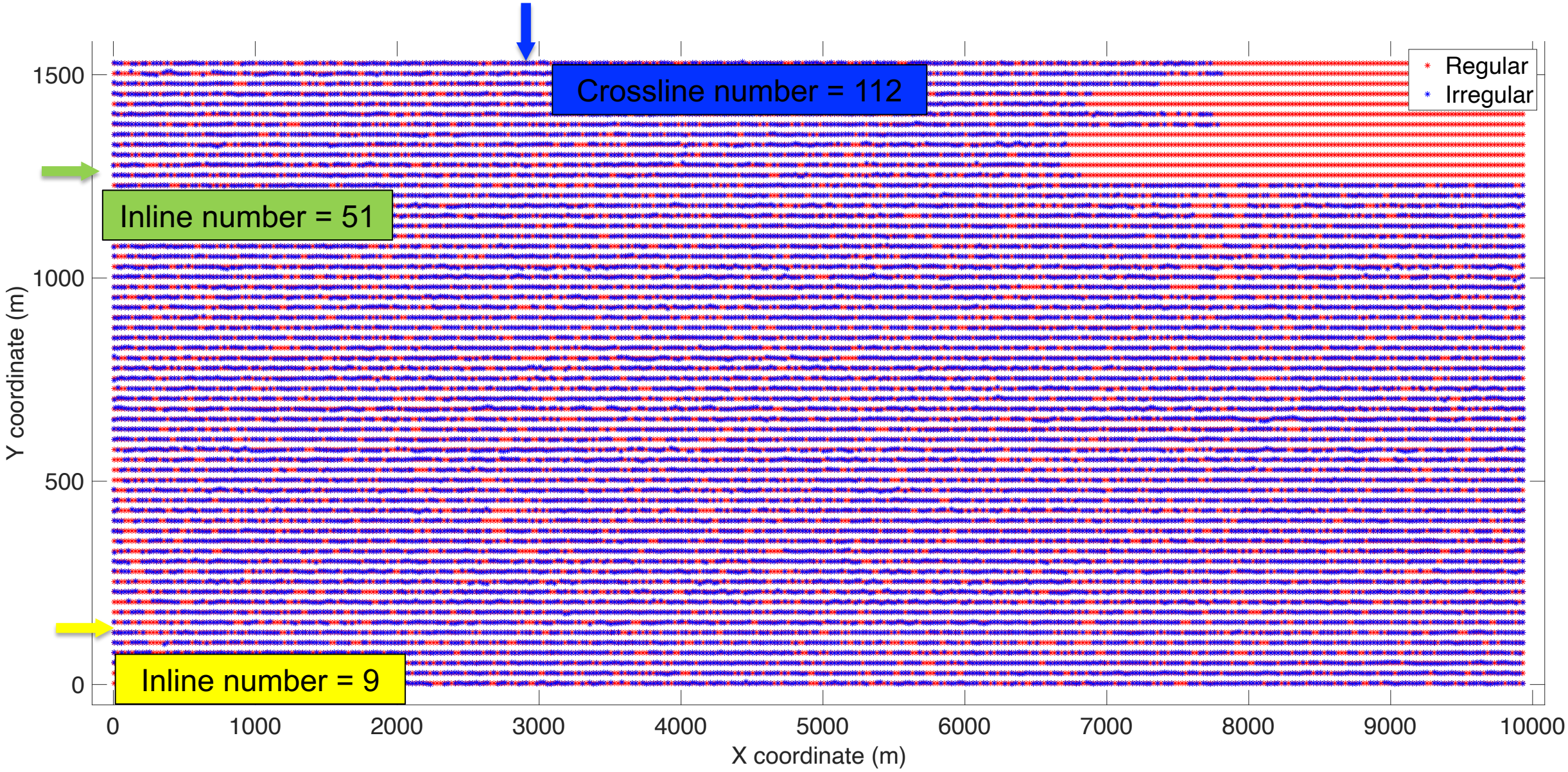
$\mathcal{W}^*$: $irregular \rightarrow regular$

- ***Sinc-Kaiser interpolator***

$$\mathbf{D}^{\nu} = \mathcal{L}\mathscr{P}\mathcal{L}^*[\mathbf{D}^{\nu-1} - \lambda\mathcal{W}^*\mathcal{B}^*(\mathcal{B}\mathcal{W}\mathbf{D}^{\nu-1} - \mathbf{b})]$$

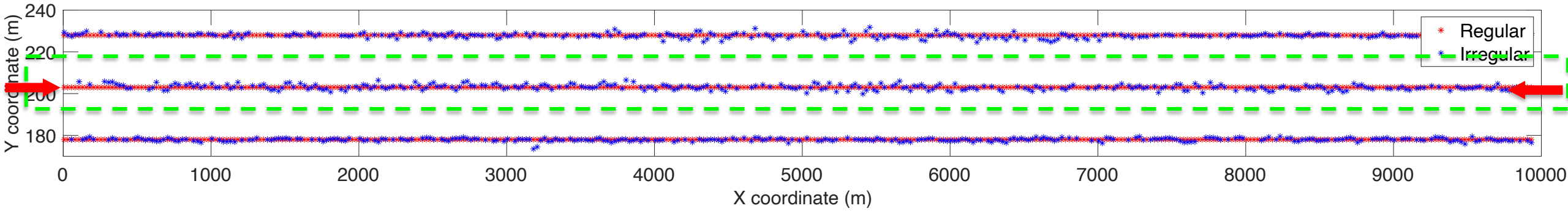
Projection operator = MSSA

Result Display



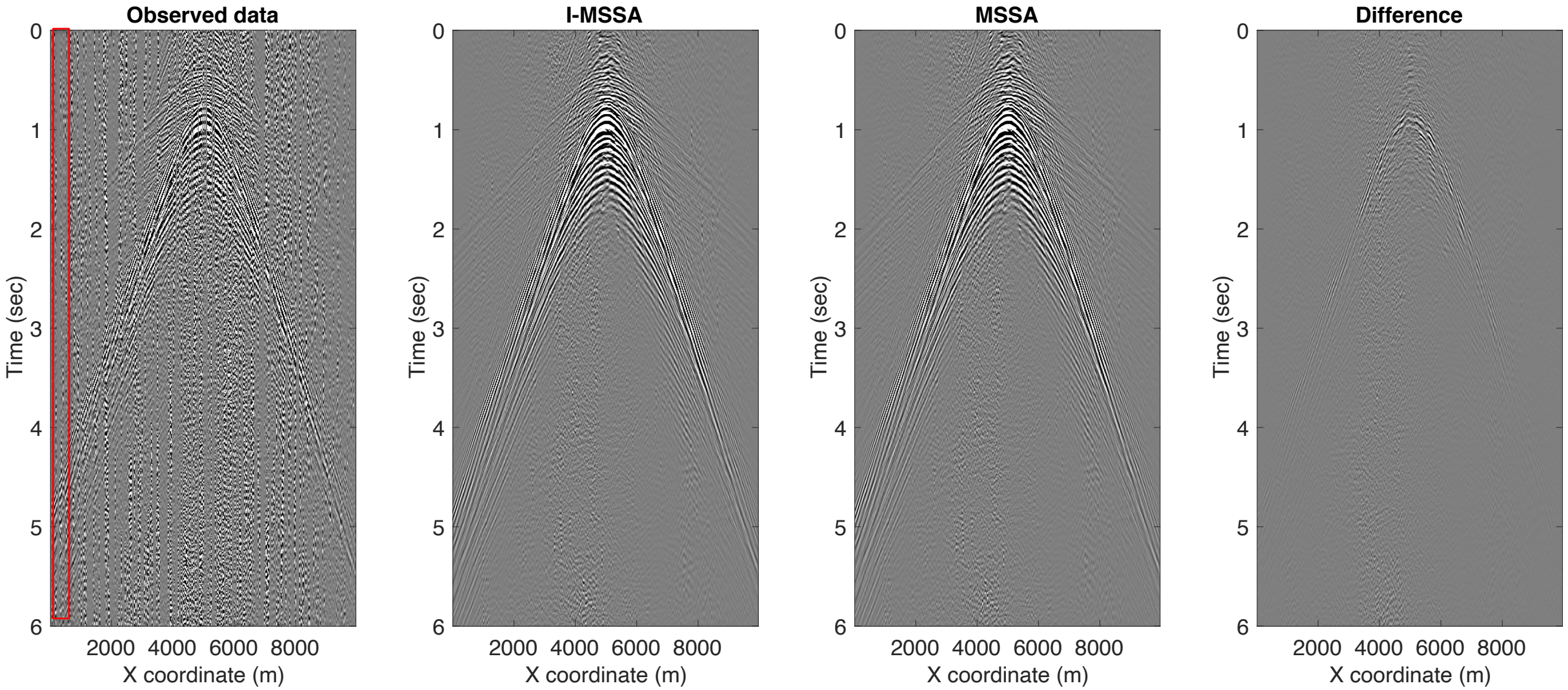
Result display

Inline number = 9



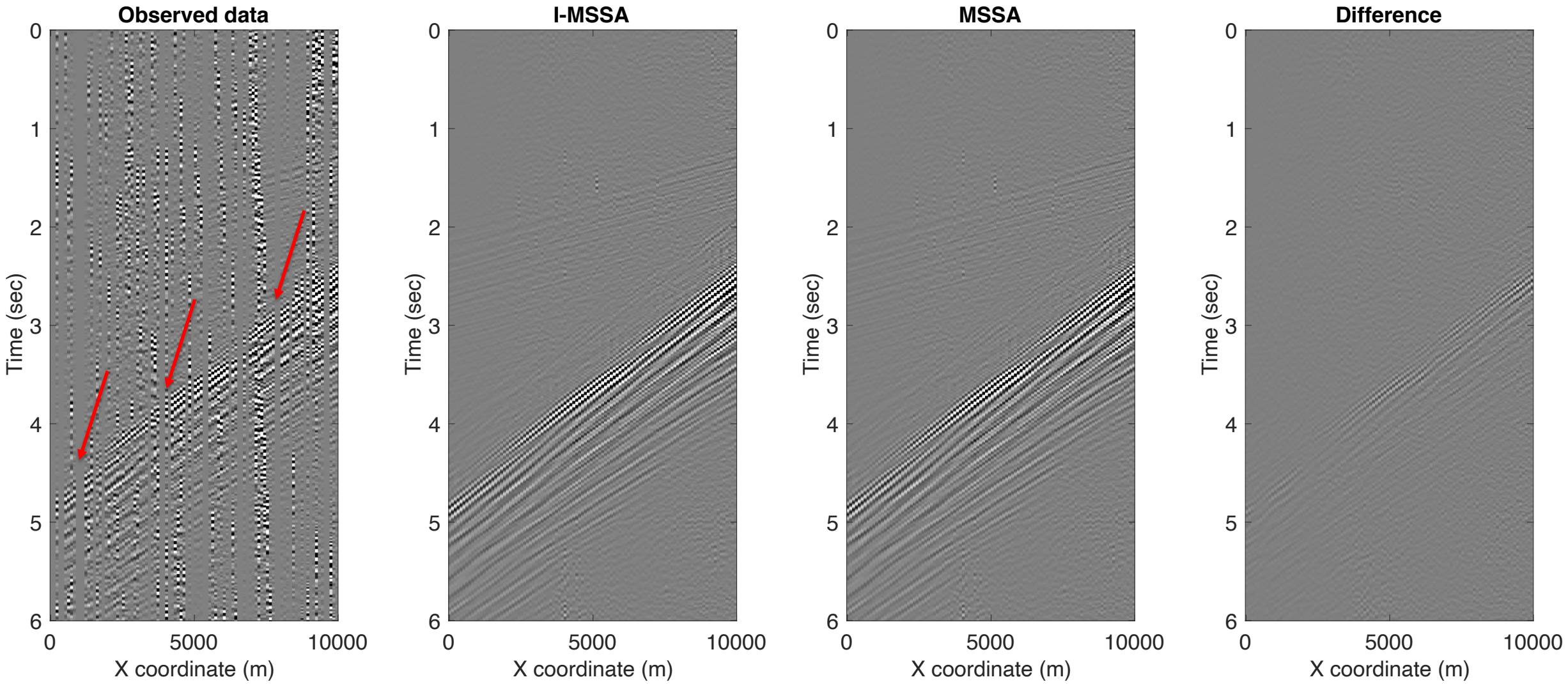
Real Example (Deblending + Irregular Reconstruction)

- Inline number = 9



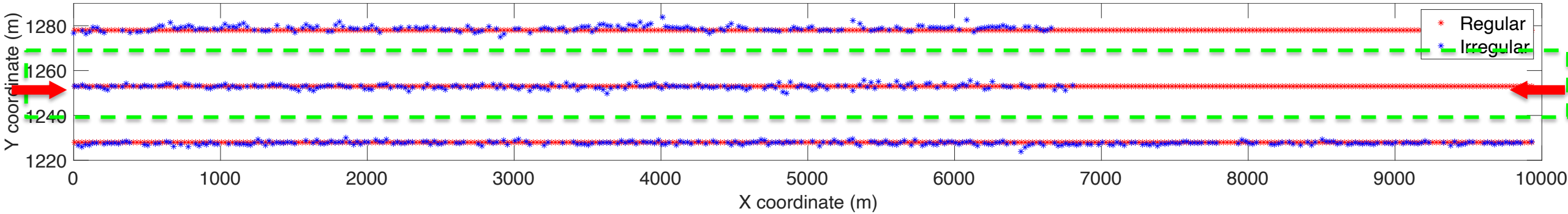
Real Example (Deblending + Irregular Reconstruction)

- Inline number = 9



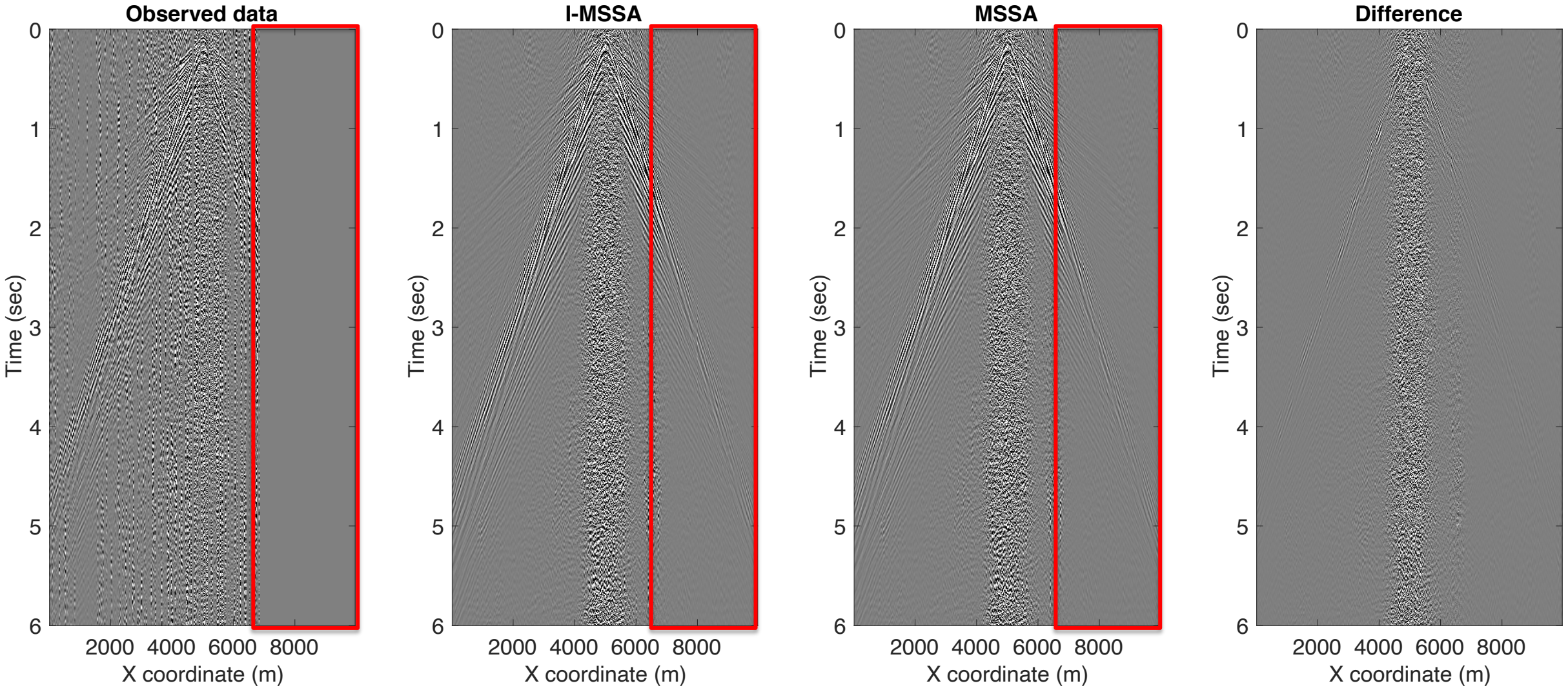
Result display

Inline number = 51



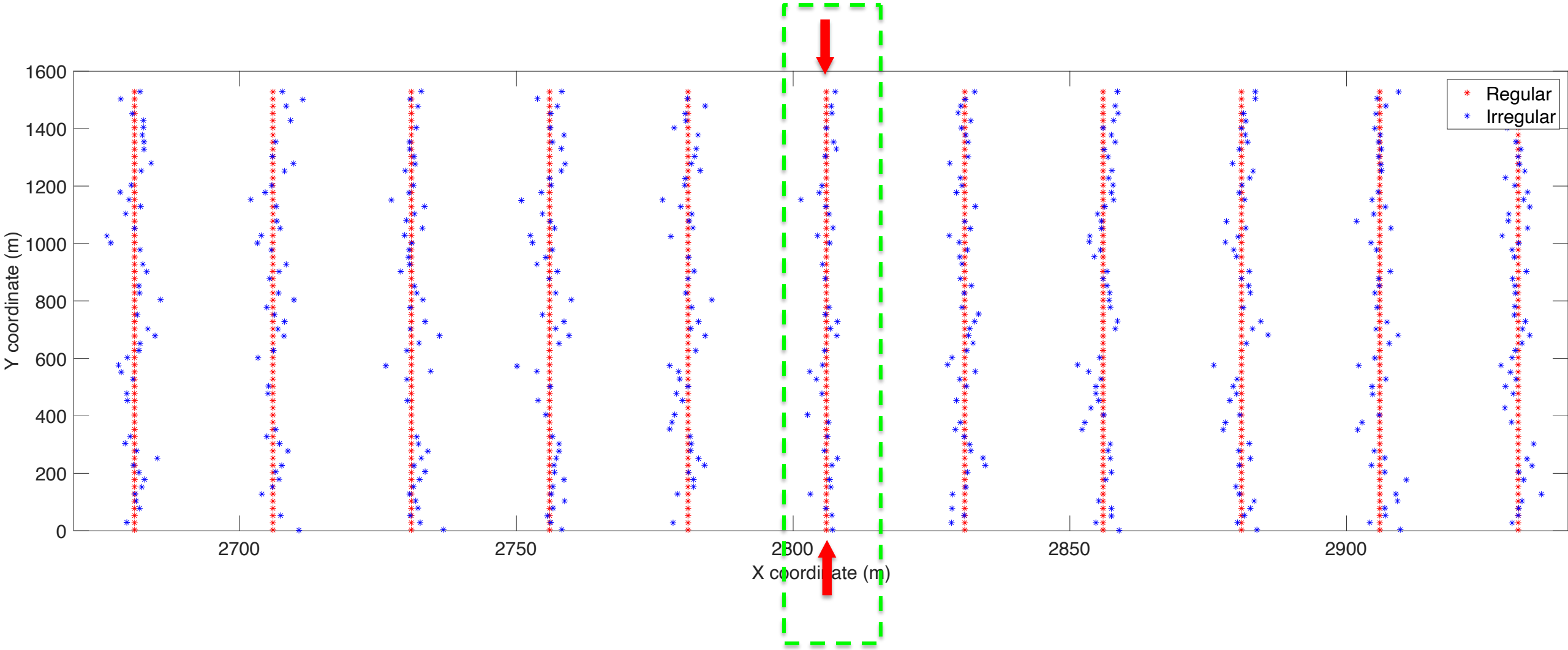
Real Example (Deblending + Irregular Reconstruction)

- Inline number = 51



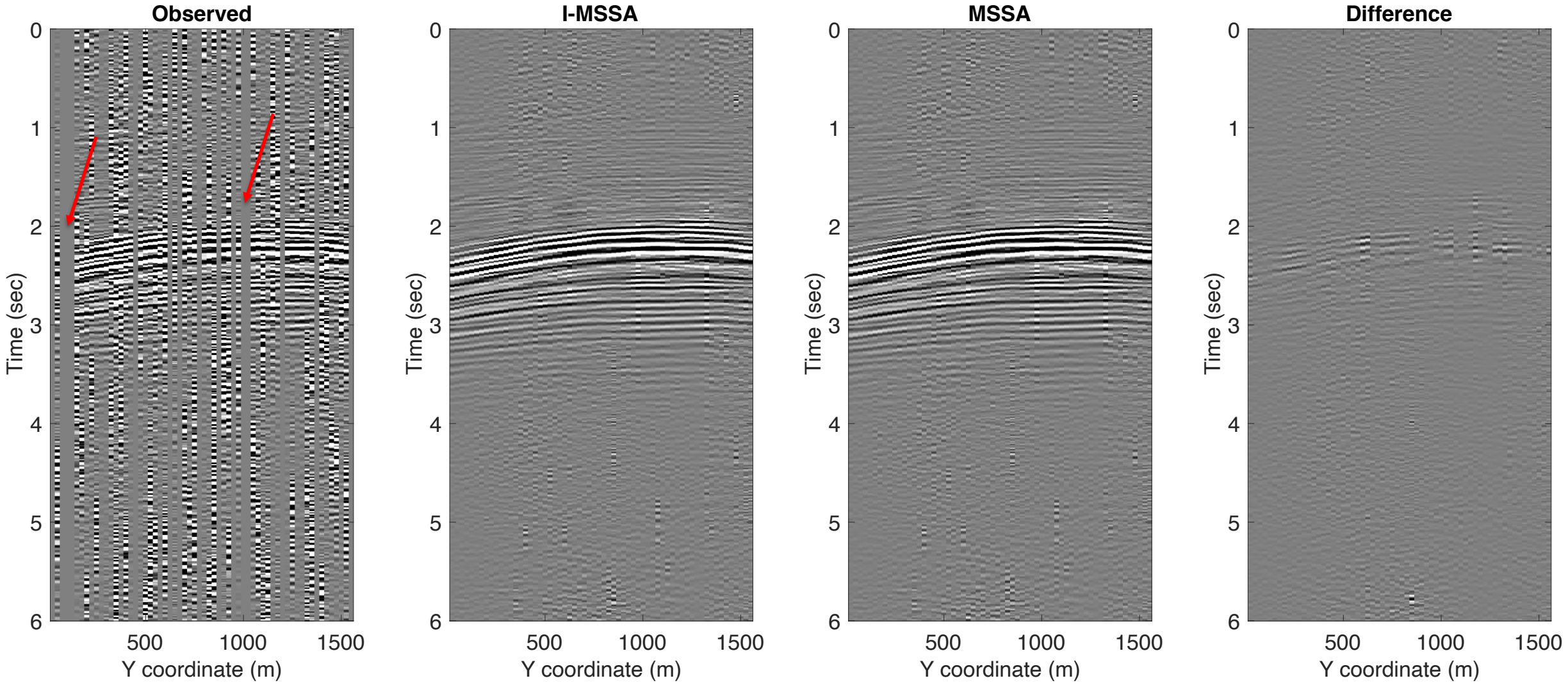
Result display

- Crossline number = 112



Real Example (Deblending + Irregular Reconstruction)

- Crossline number = 112



Conclusion and Summary

- The I-MSSA method is a useful tool for **irregular grid seismic data reconstruction.**
- The I-MSSA in conjunction with the **Projected Gradient Descent** Method was used to deblending and shots reconstruction simultaneously.
- We do not have a **ground truth solution** for our real data test. Hence, we cannot evaluate precisely and QC the deblending and reconstruction results. However, we believe that experiments with synthetics show that it is important to avoid binning errors. Therefore, **IMSSA should be preferentially used rather than MSSA in combination of source position binning**.
- More real datasets for tests would benefit this research, so if you can provide data, it will be appreciated.

Acknowledgement

- The sponsors of the Signal Analysis and Imaging Group (SAIG) at the University of Alberta.