SLIM's findings on the Machar dataset

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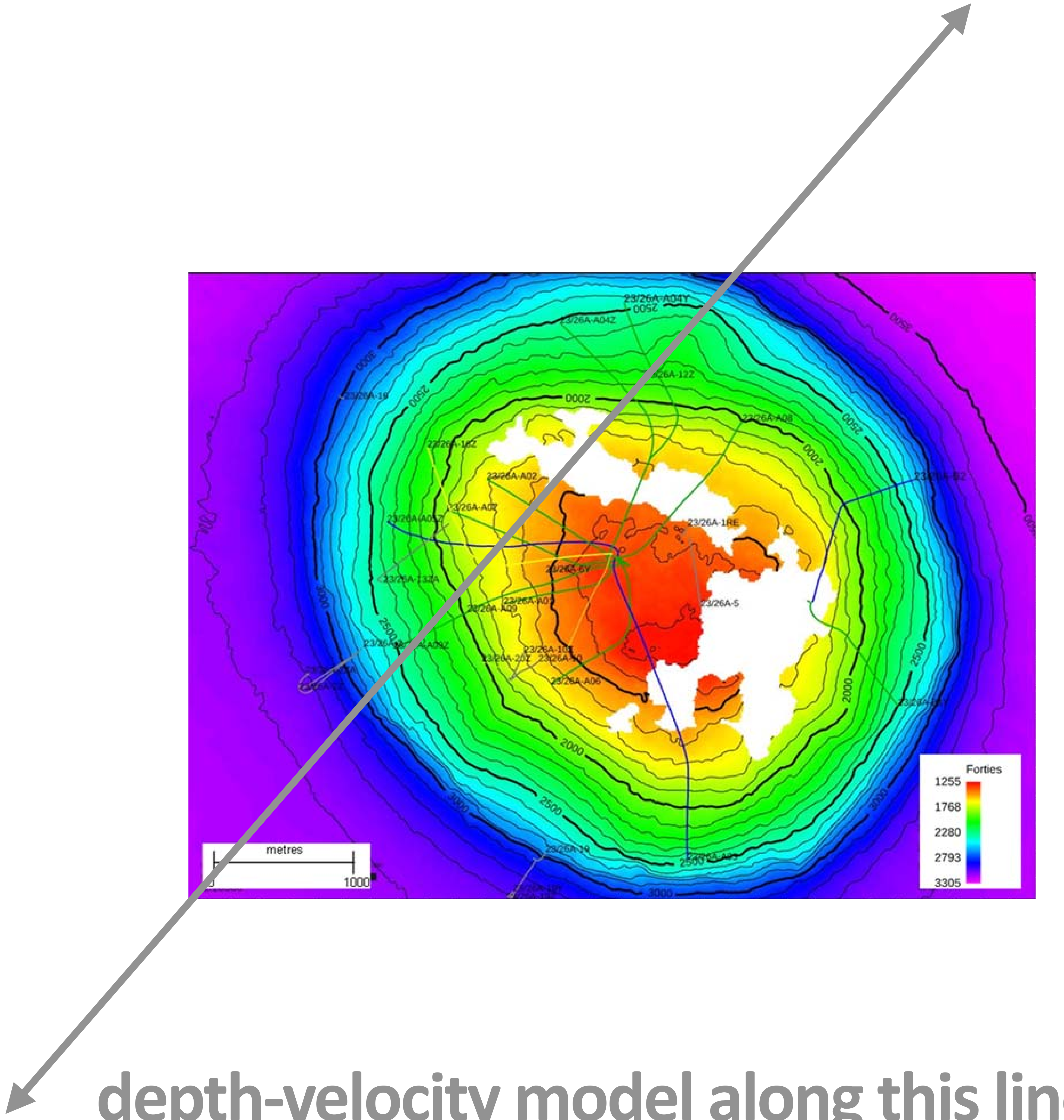
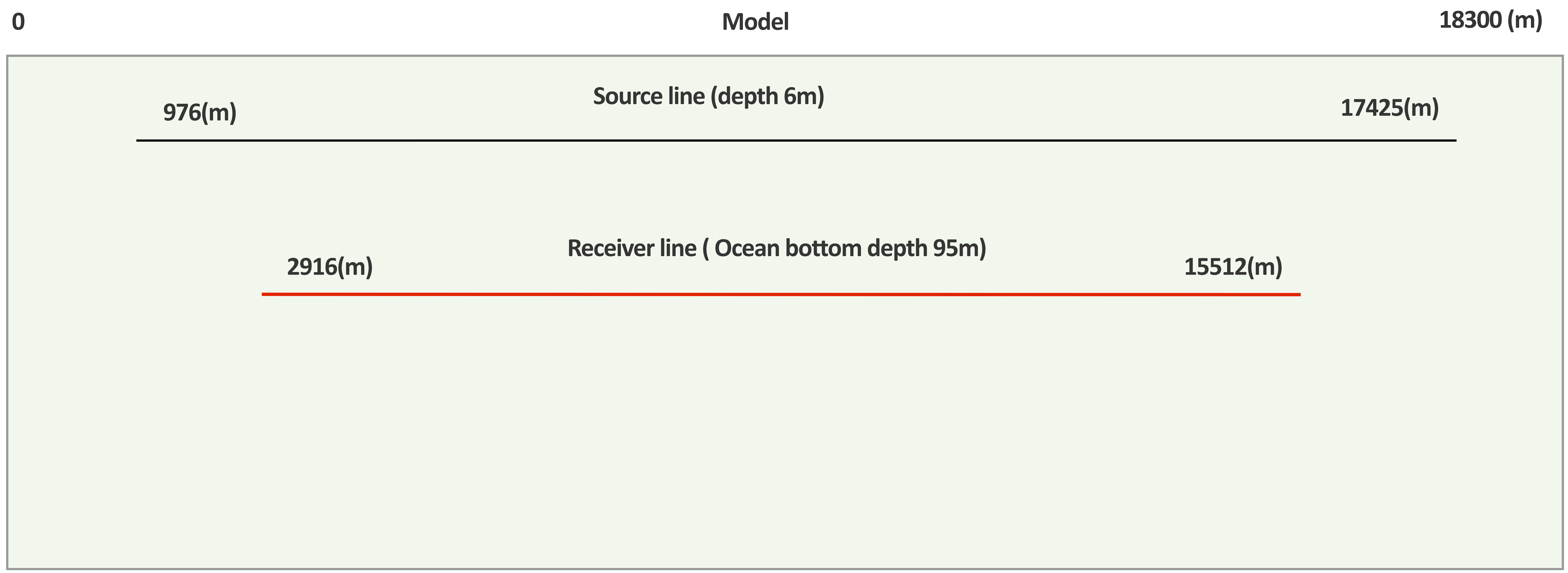
University of British Columbia

Imaging seismic structure



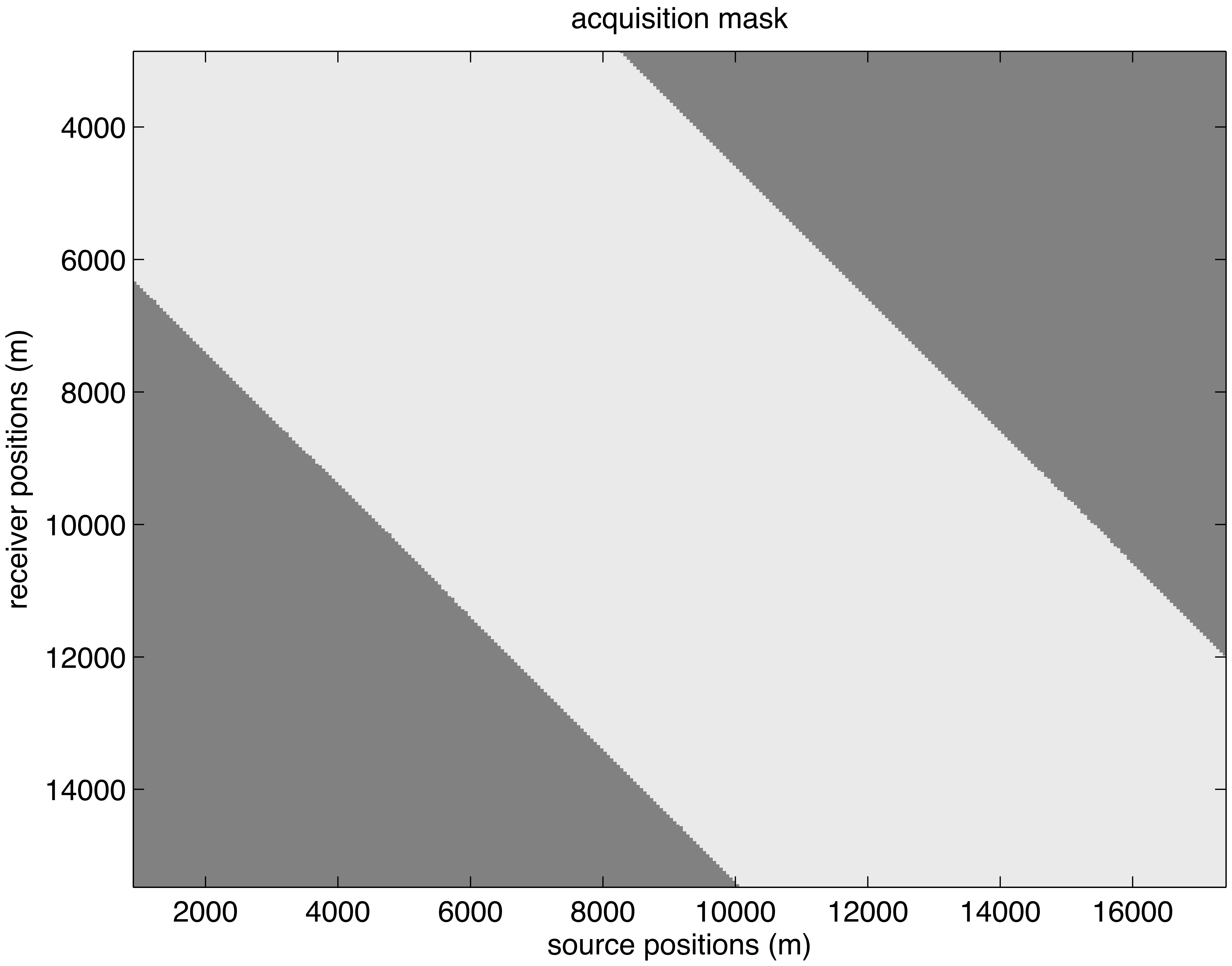
depth-velocity model along this line

Acquisition geometry



- Sources and receivers lies on irregular grid.
- # of source is 330 with an approximate spacing of 50 m
- # of receiver is 505 with an approximate spacing of 25 m

Source receiver mask
of processed data



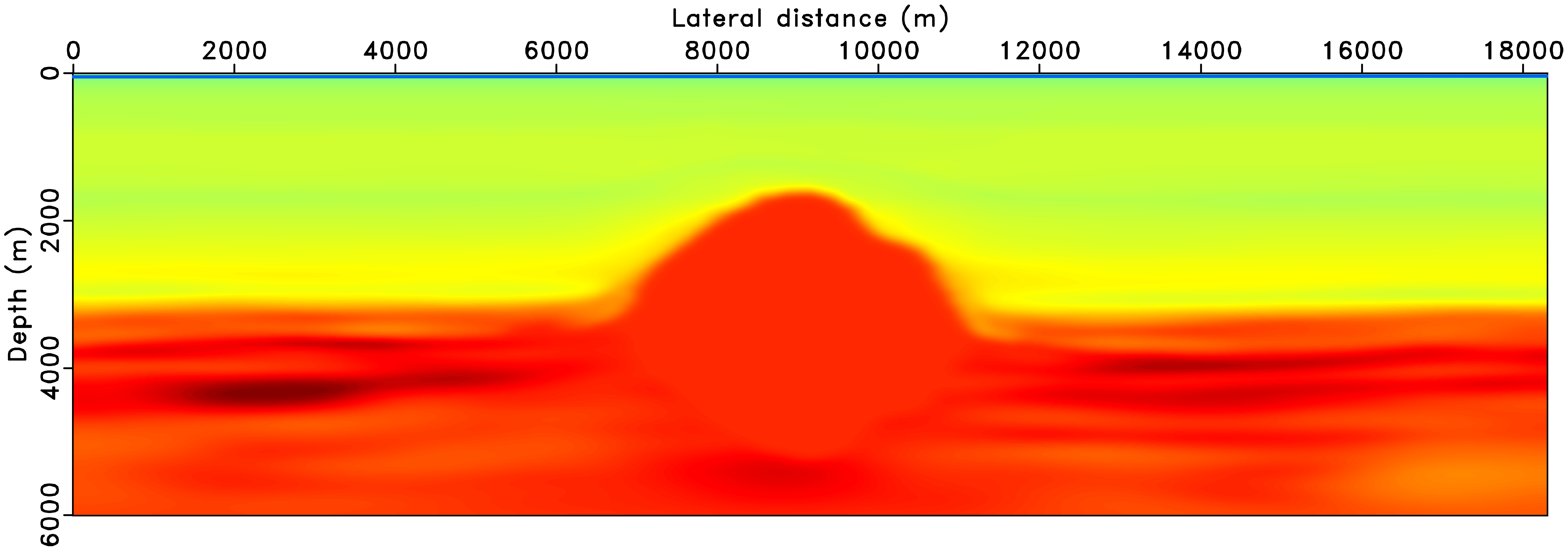
Wave velocity field

[provided by BP, with anisotropy correction, after interpolation and smoothing]

Water 0m–95m

Slow rock 95m–3000m

Salt & fast rock 3000m+



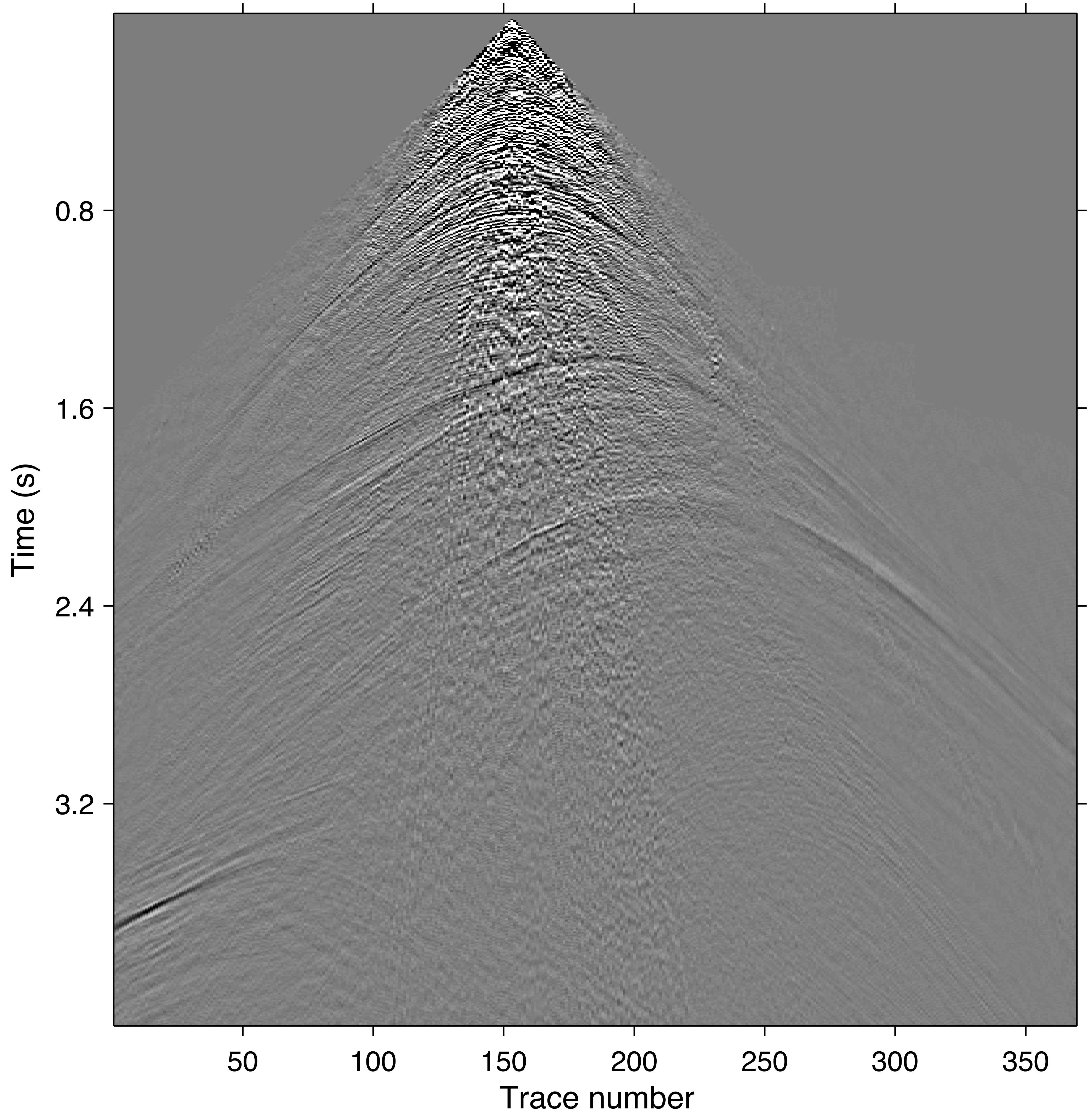
Imaging-RTM

Reverse time migration:

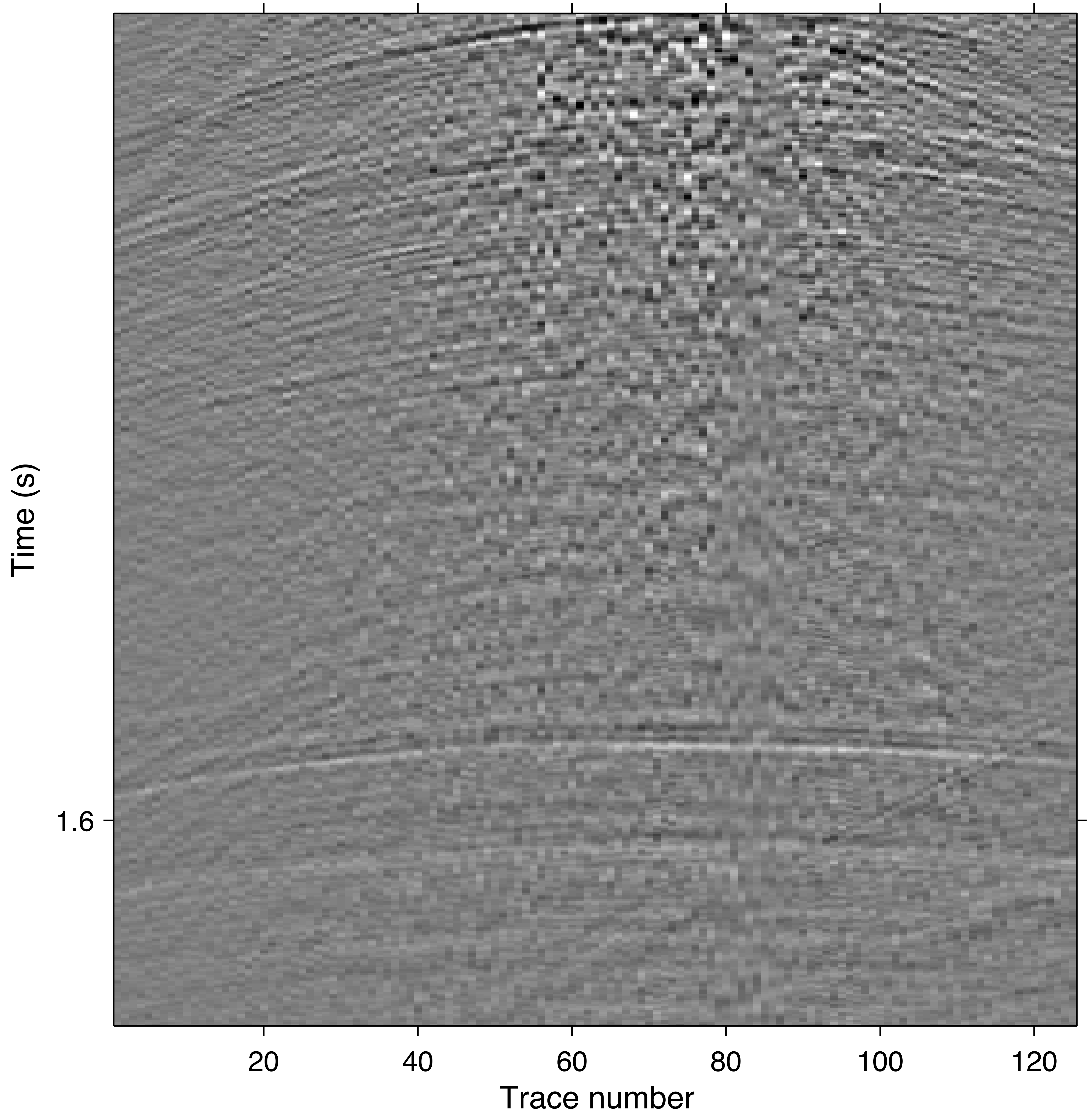
- all sources, all freq. up to 30Hz (higher freq. suffer from spacial aliasing), 10m grid spacing

Original seismic data

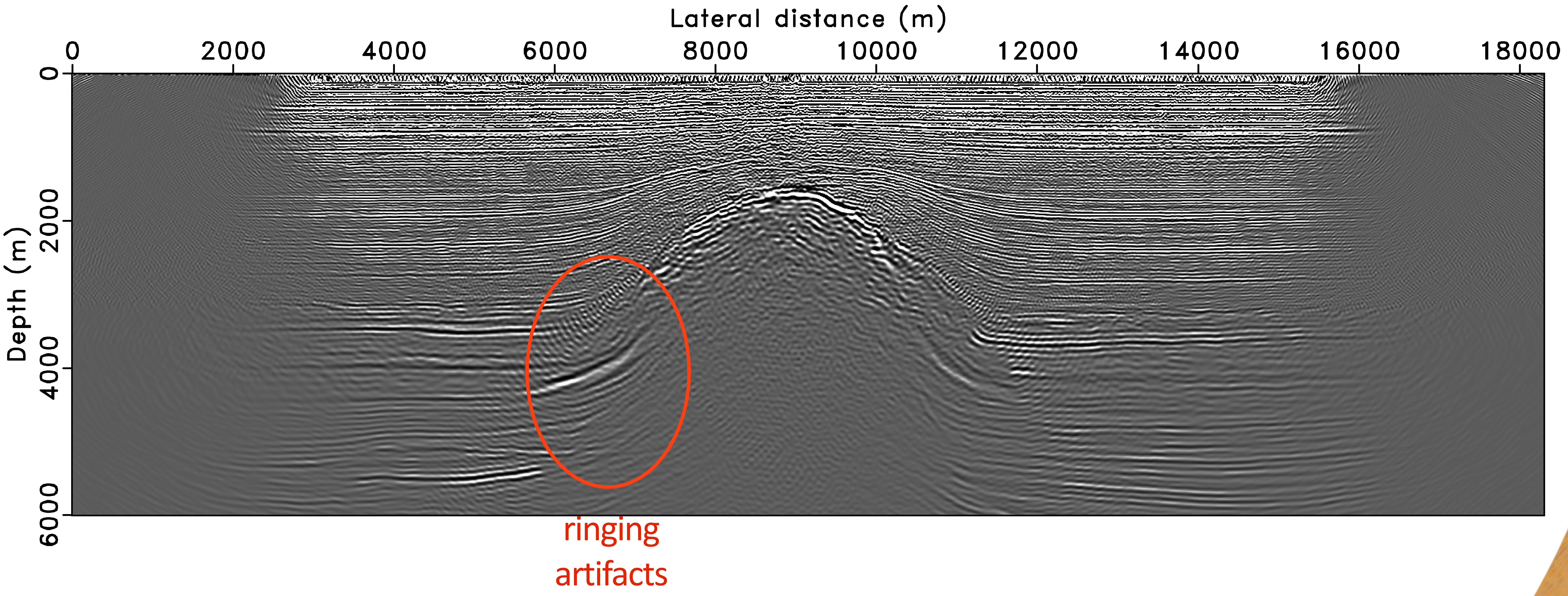
about 25m spatial sampling, 370 traces



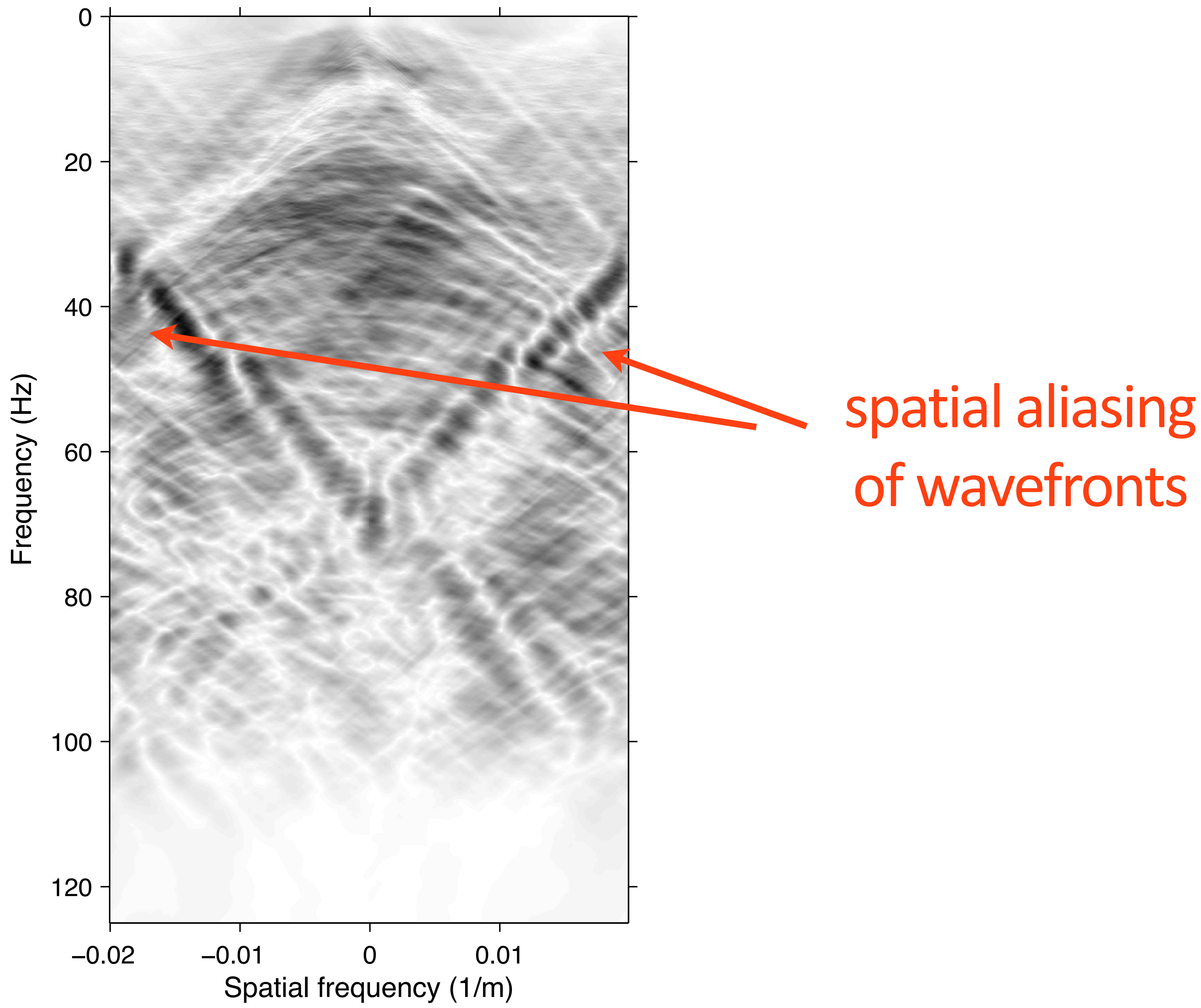
Zoomed in



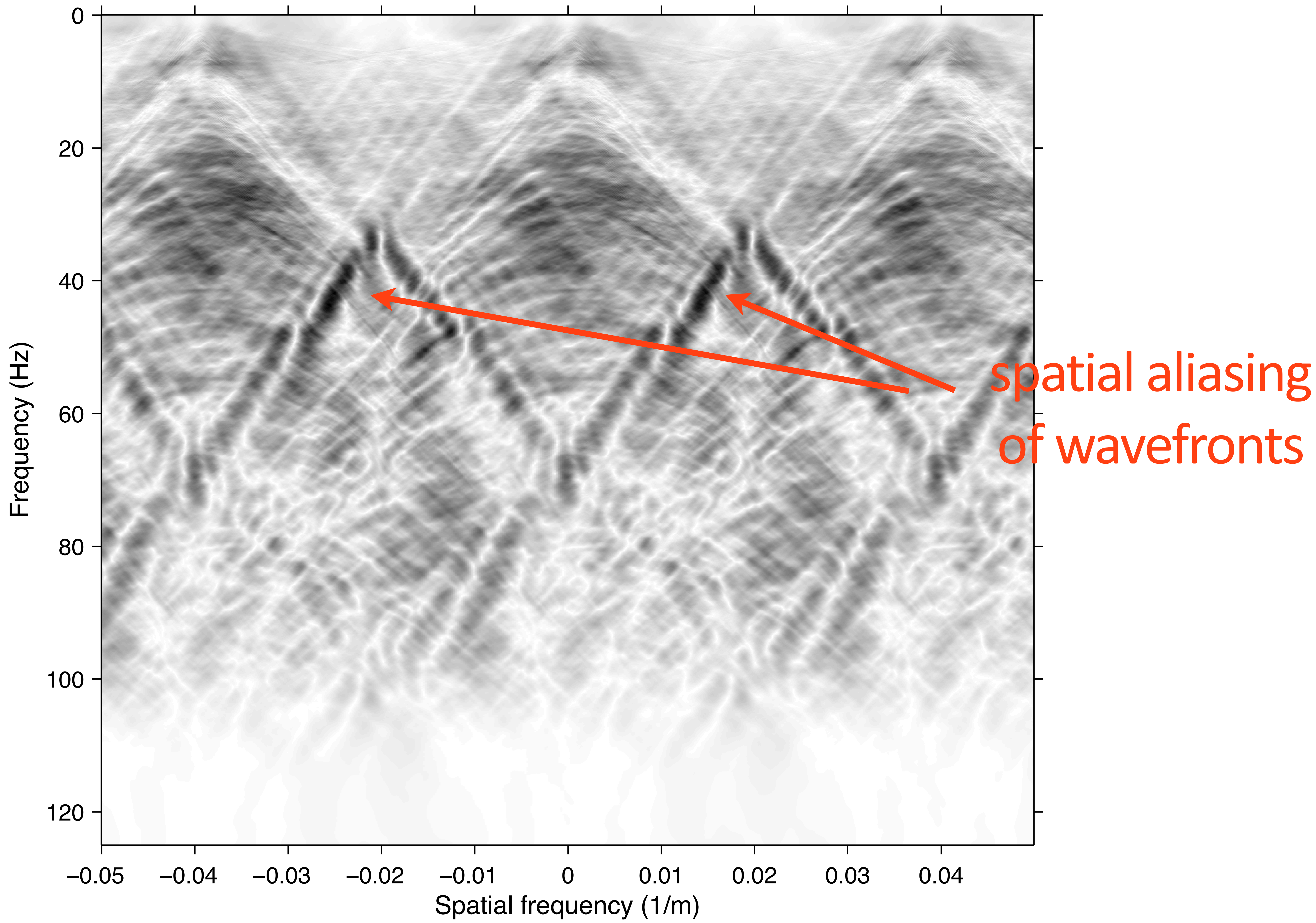
Reverse time migration



F-K (2D Fourier) spectrum



F-K nearest neighbor spectrum

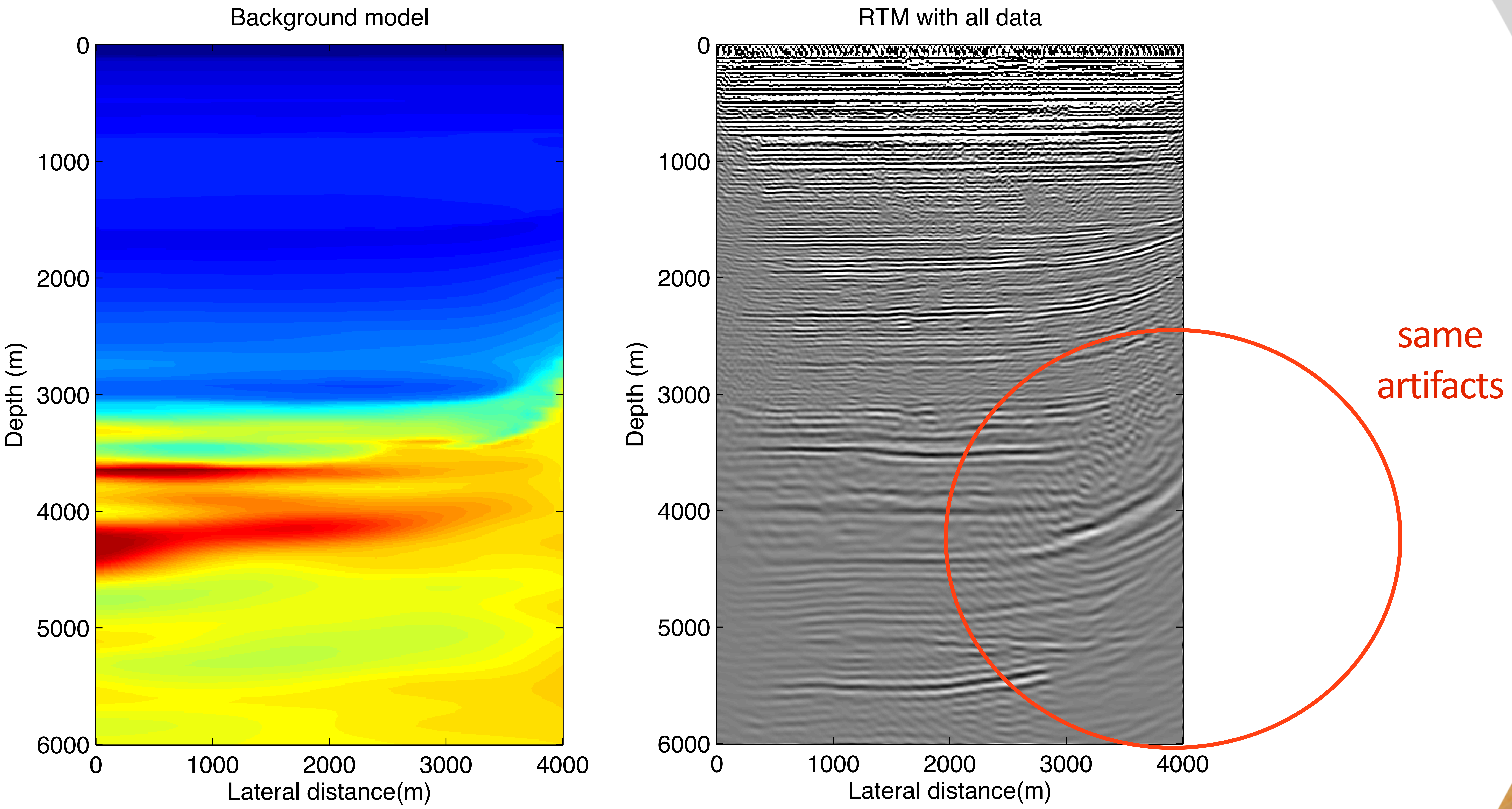


Remove imaging artifacts

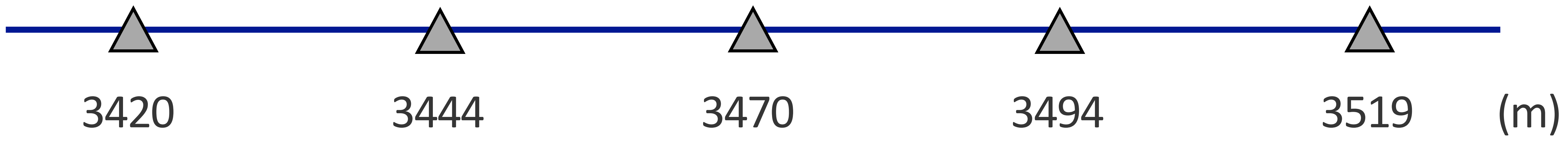
We use a cropped section of the model to reduce the turnaround time:

- first reproduce the artifacts
- then try to remove them by interpolating the data

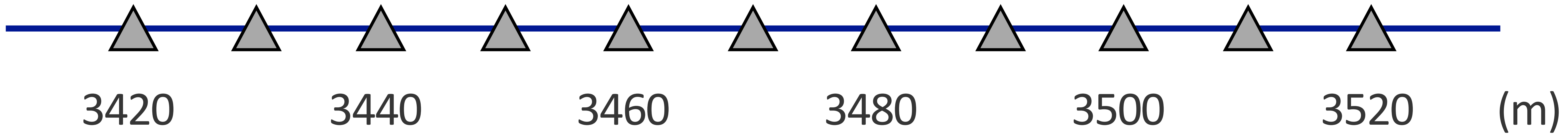
Artifacts reproduced with cropped model



Desired sampling

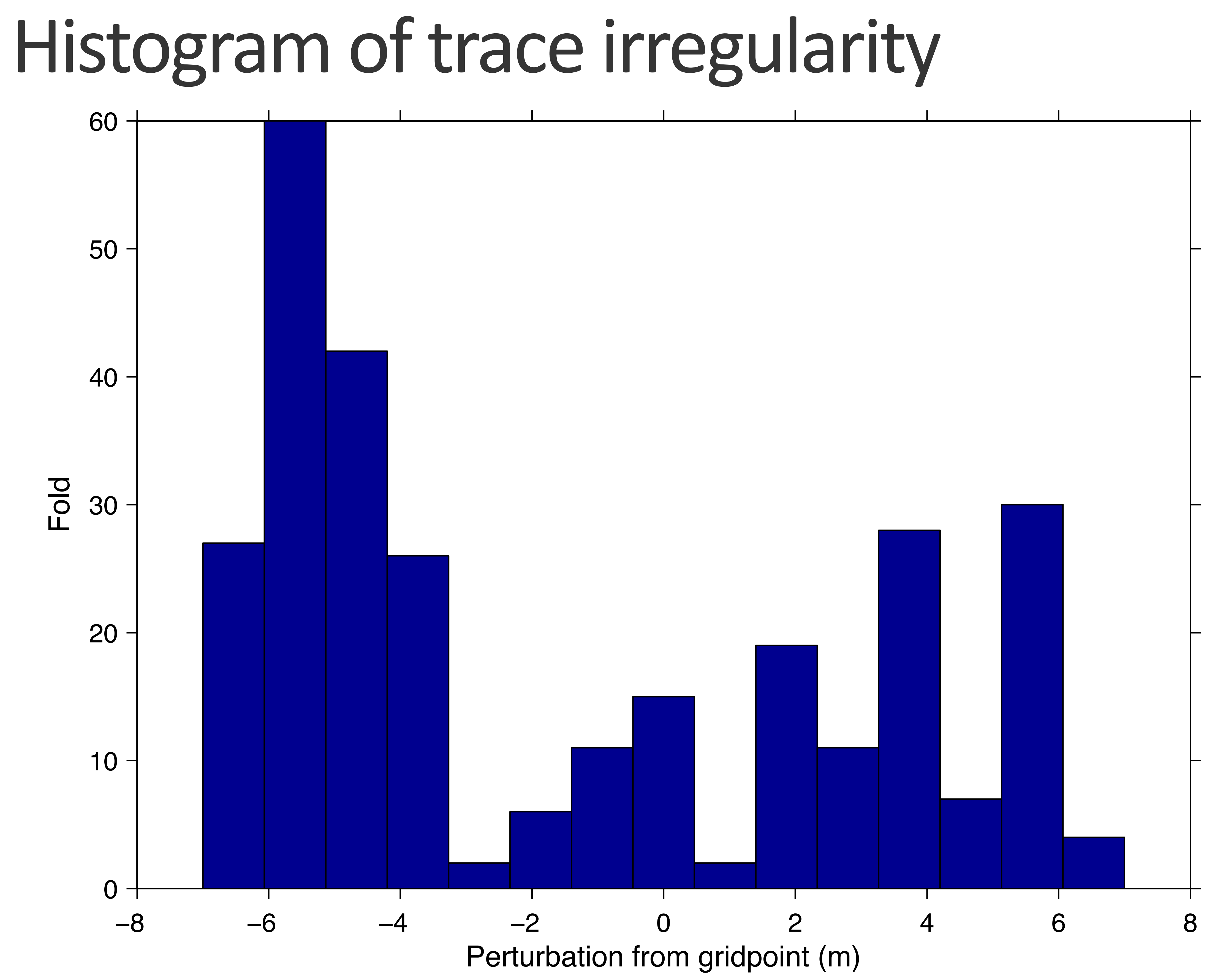


Original sampling (irregular), ~25m spacing



Desired sampling after interpolation, 10m spacing

Exploiting spatially irregular sampling



-8m

+8m

Trace interpolation via curevelet-domain basis pursuit

$\mathbf{x} = \mathbf{D}\mathbf{z}$ (assume **x** is not sparse, but **z** is)

$$\tilde{\mathbf{x}} = \mathbf{D} \cdot \underset{\mathbf{z}}{\operatorname{argmin}} \|\mathbf{z}\|_1 \text{ subject to } \mathbf{y} = \mathbf{A}\mathbf{D}\mathbf{z}$$

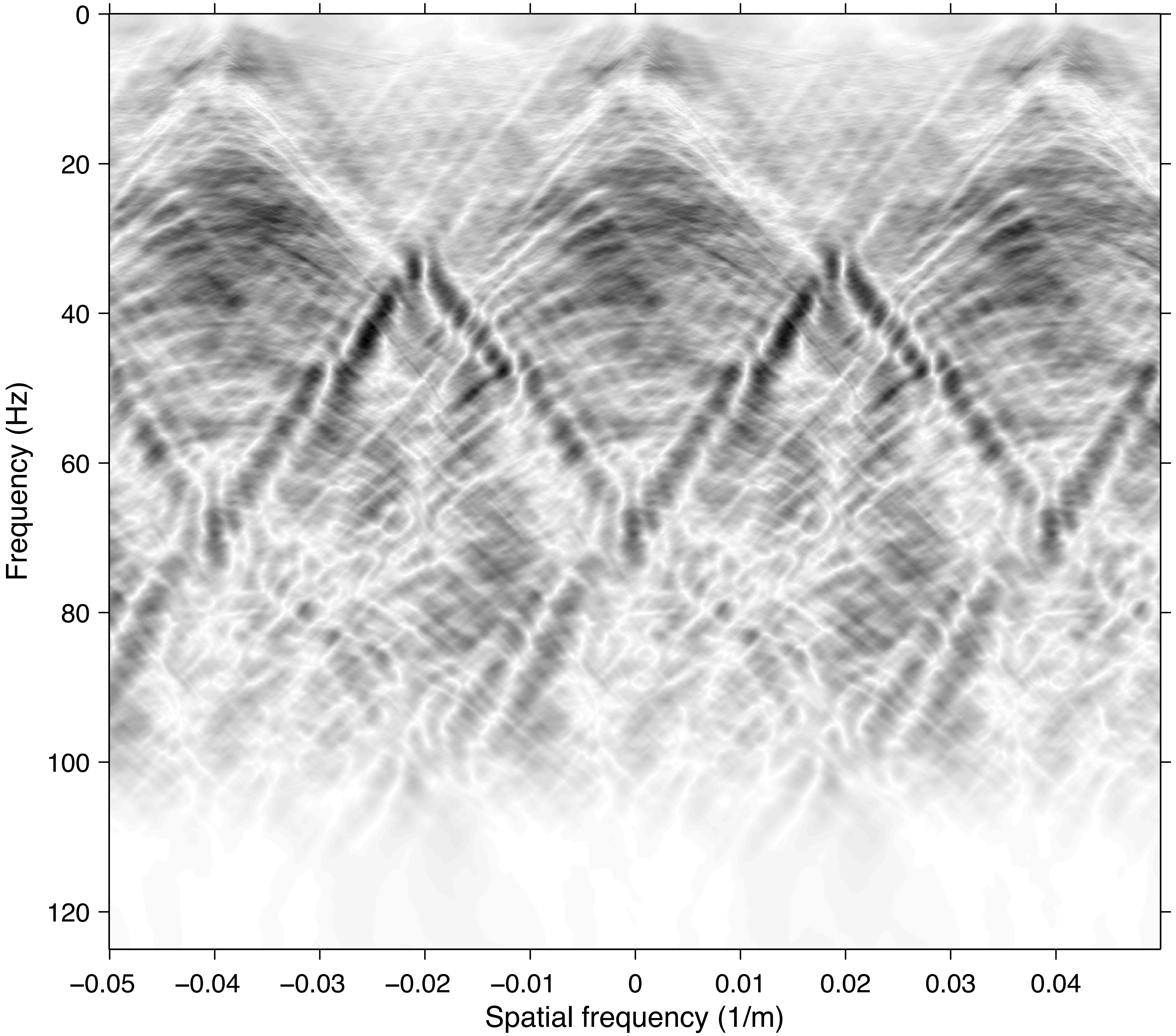
- ℓ_1-norm as convex measure of sparsity
- $\mathbf{y}$ is data with original spatial sampling
- $\mathbf{A}$ is trace restriction ('subsampling operator')
- $\mathbf{x}$ is a seismic wavefield with desired sampling
- $\mathbf{z}$ is *a* choice of curvelet coefficients that reconstructs $\mathbf{x}$
- $\mathbf{D}$ is curvelet synthesis operator

Regularization + Interpolation

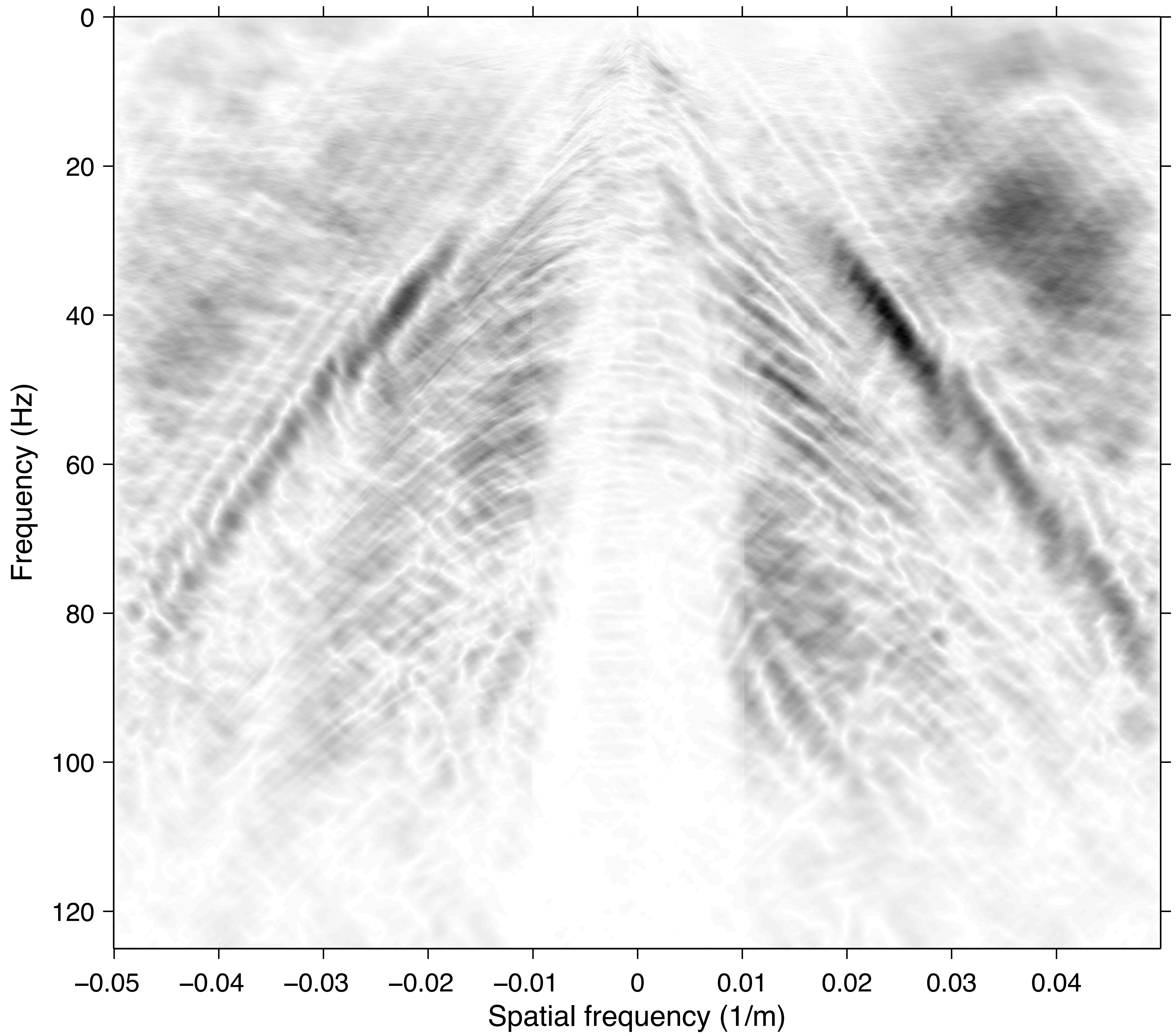
- Using non-uniform FFT as measurement operator $\mathbf{A}$ (maps coarse *non-uniform* spatial grid -> fine *uniform* grid 2D Fourier coefficients)

- Curvelet dictionary $\mathbf{D}$ constructed directly from uniform 2D Fourier coefficients

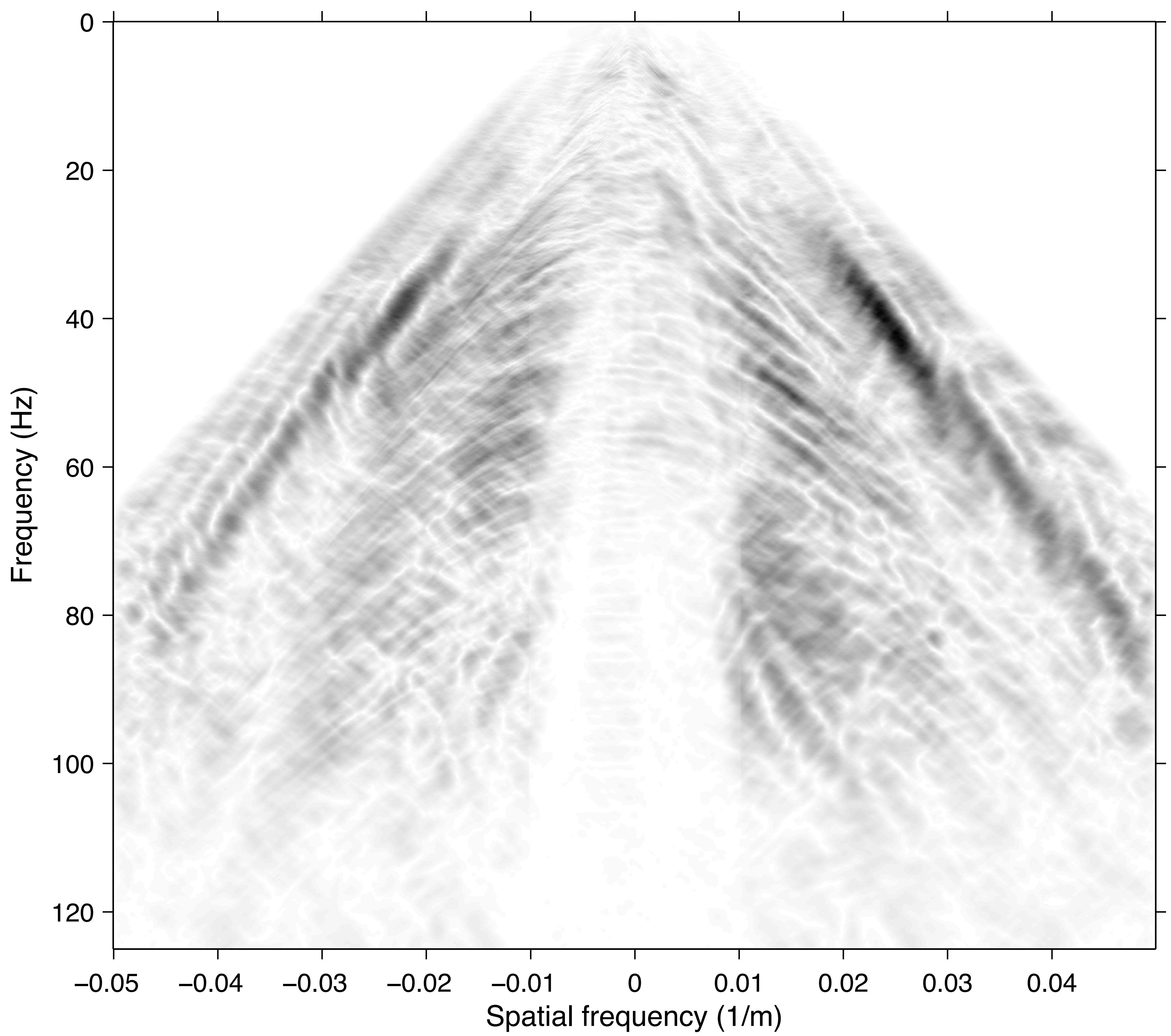
F-K spectrum before interpolation



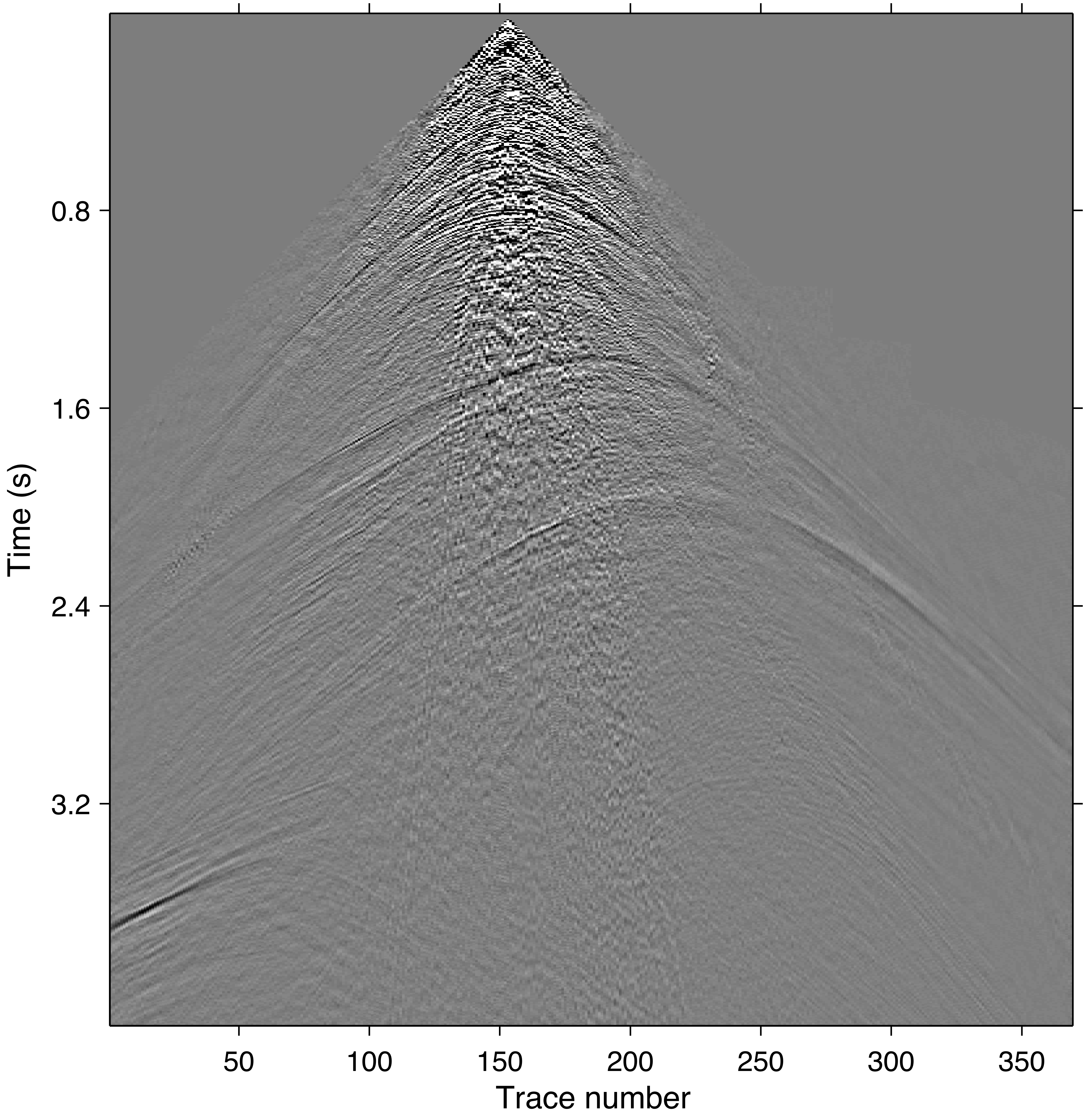
F-K spectrum after interpolation



F-K spectrum masking

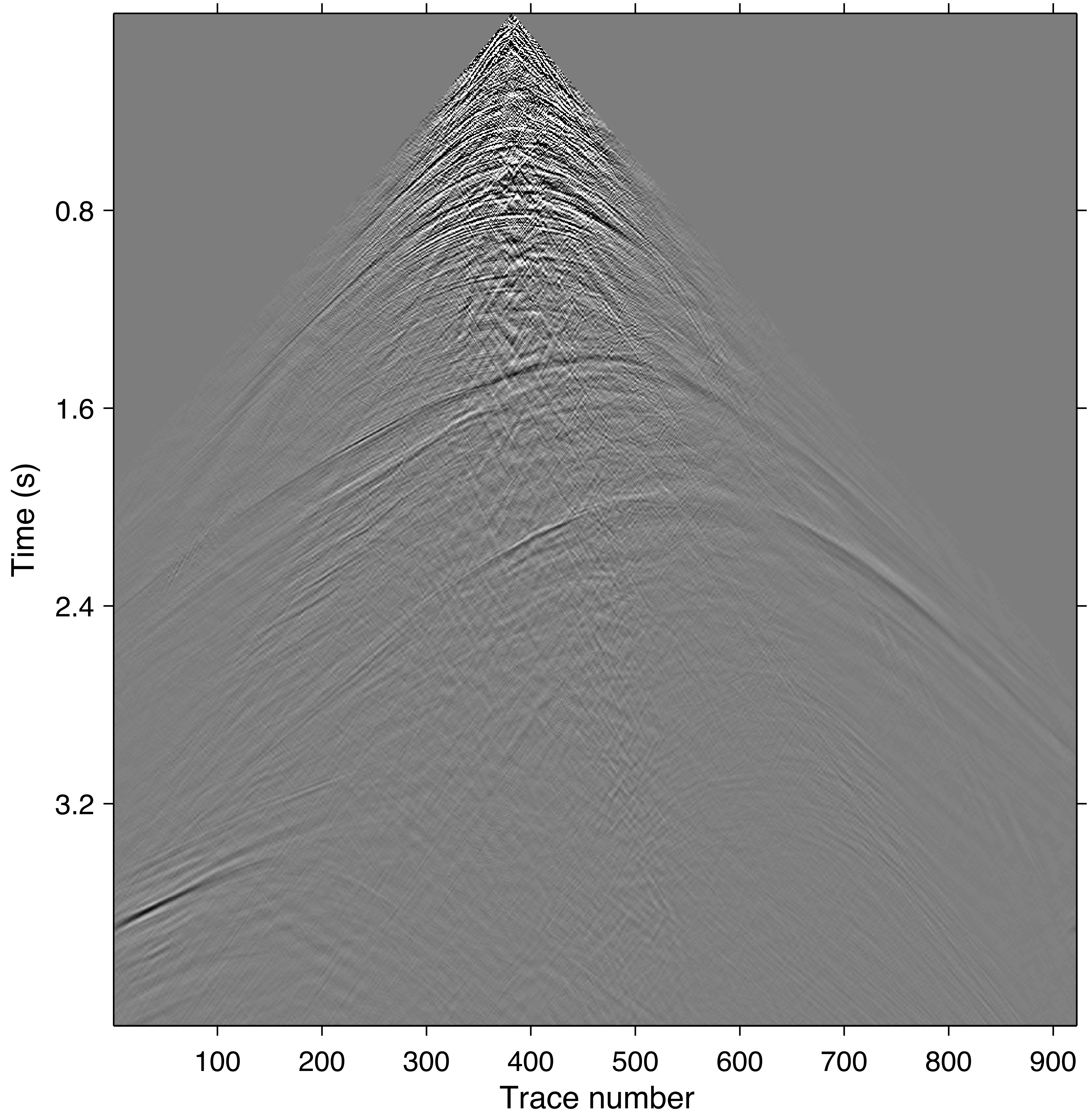


Original seismic data
about 25m spatial sampling, 370 traces

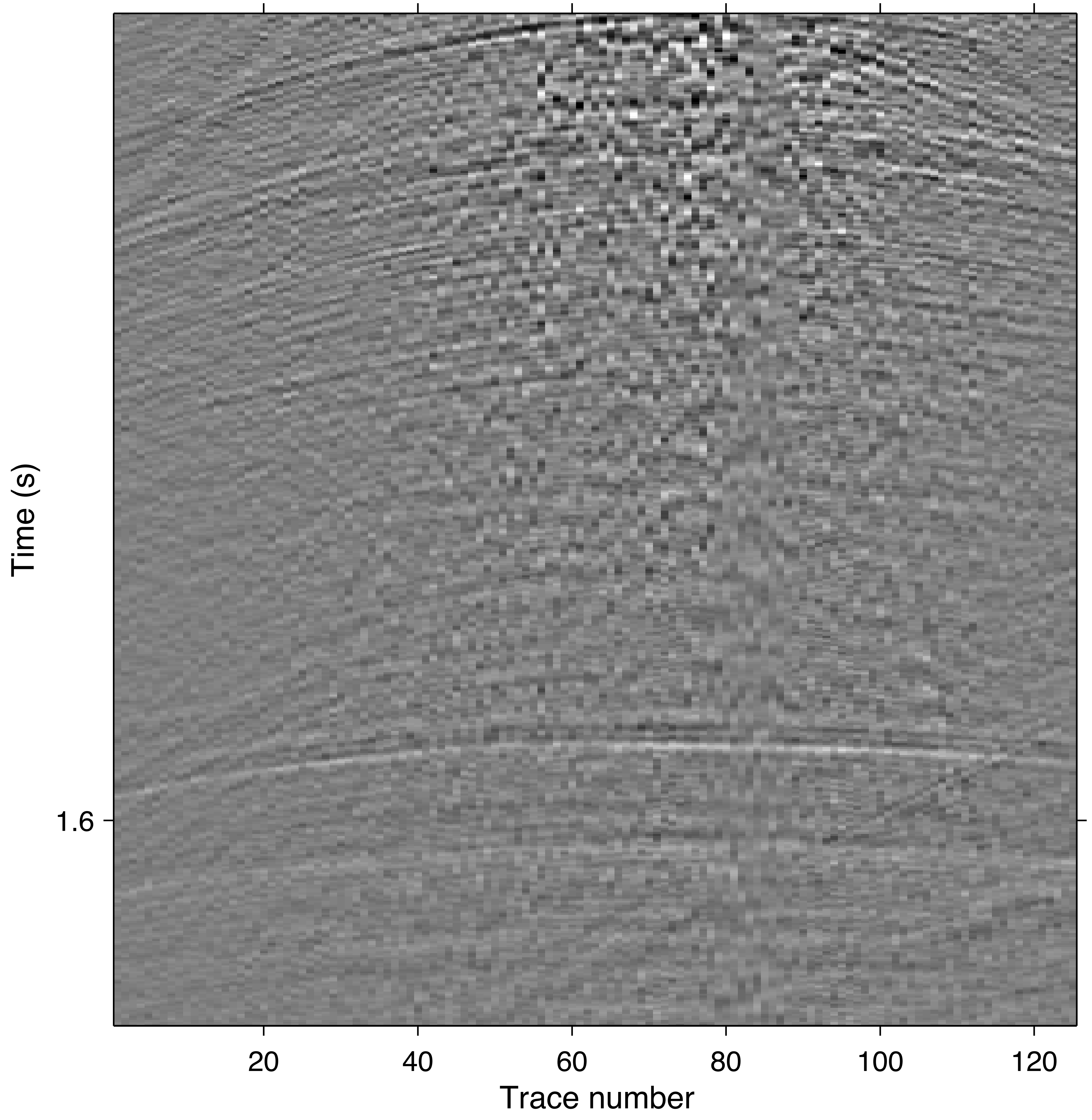


Final interpolated wavefield

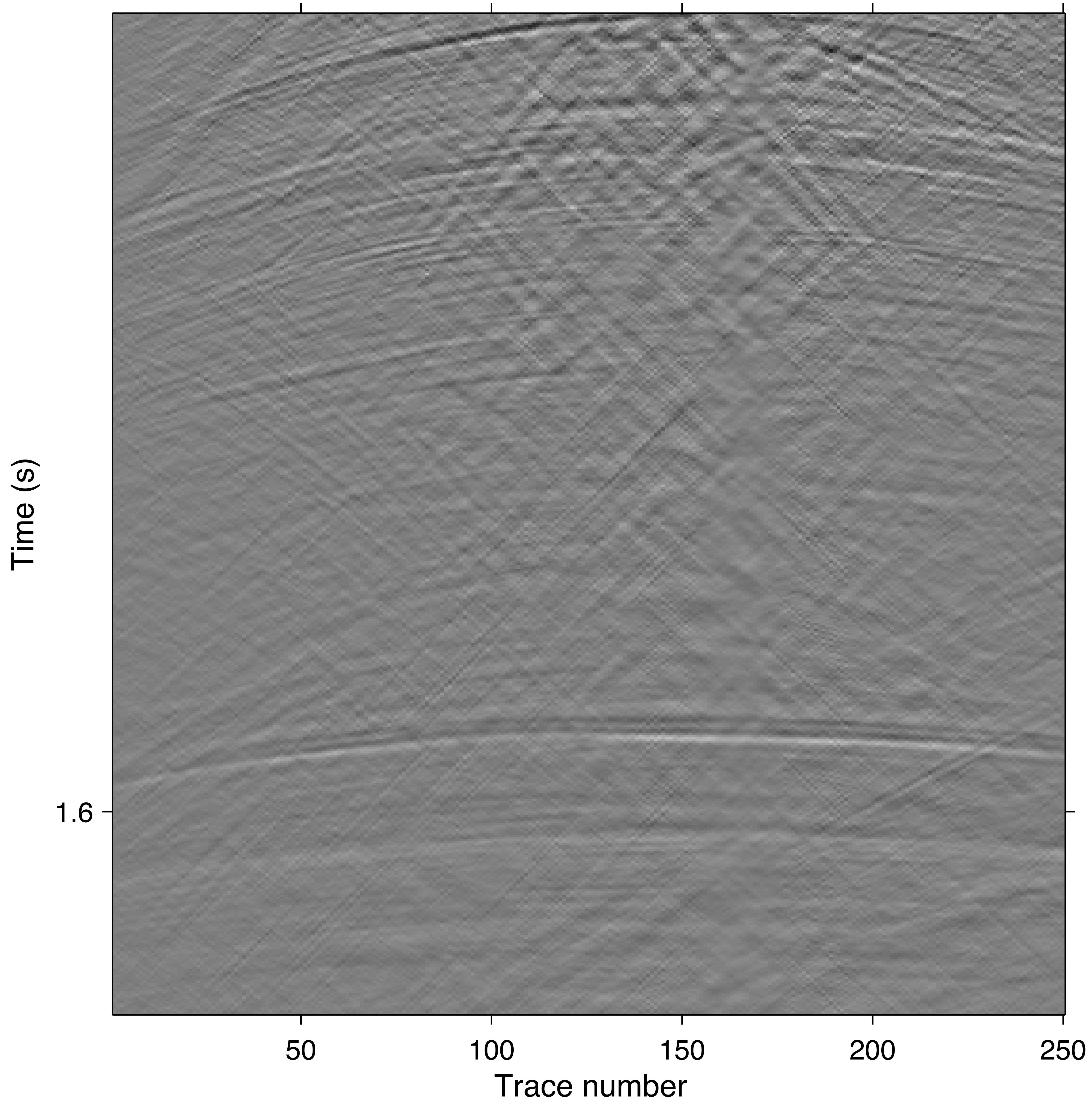
10m spatial sampling, 925 traces



Zoomed in

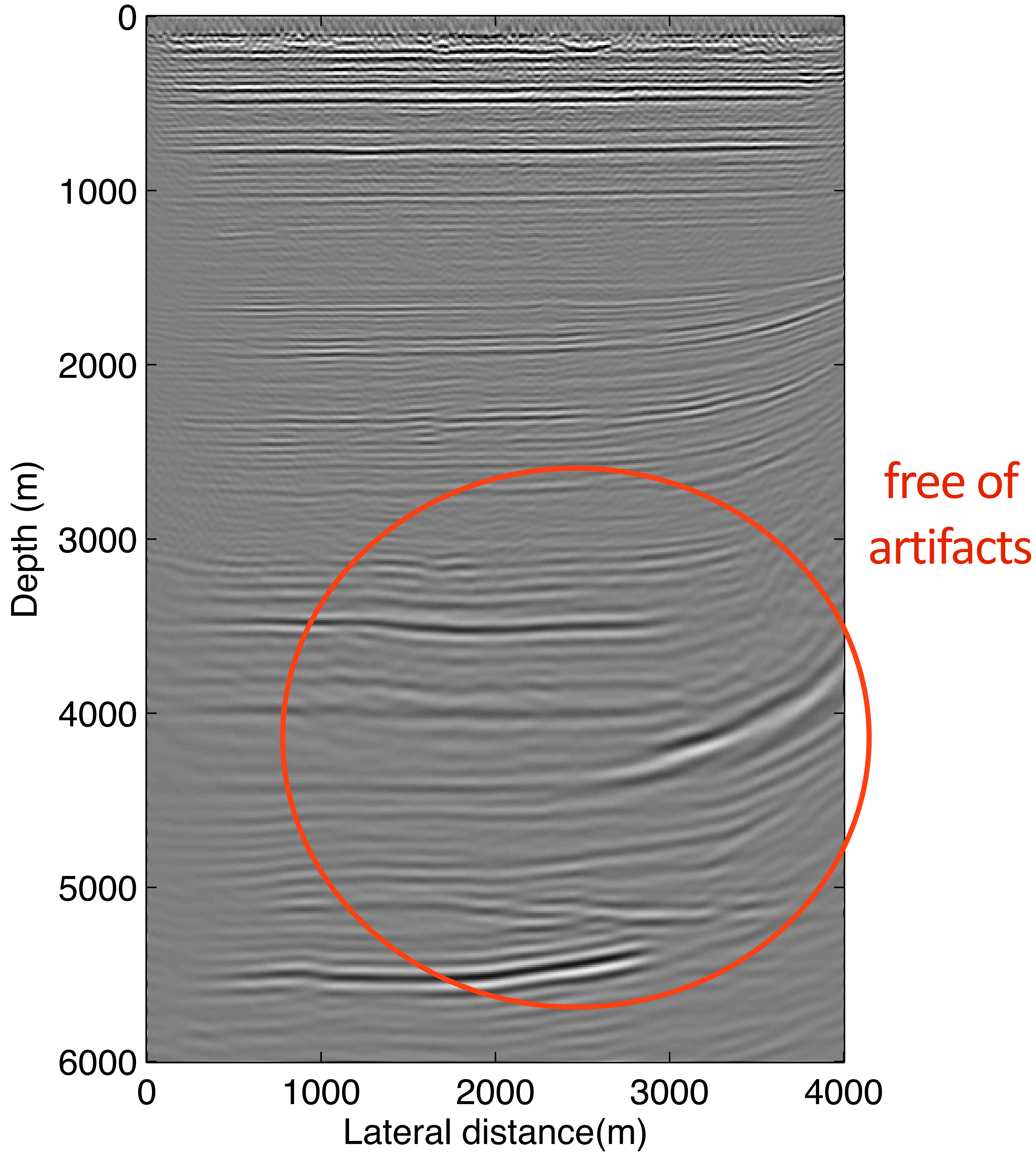


Zoomed in



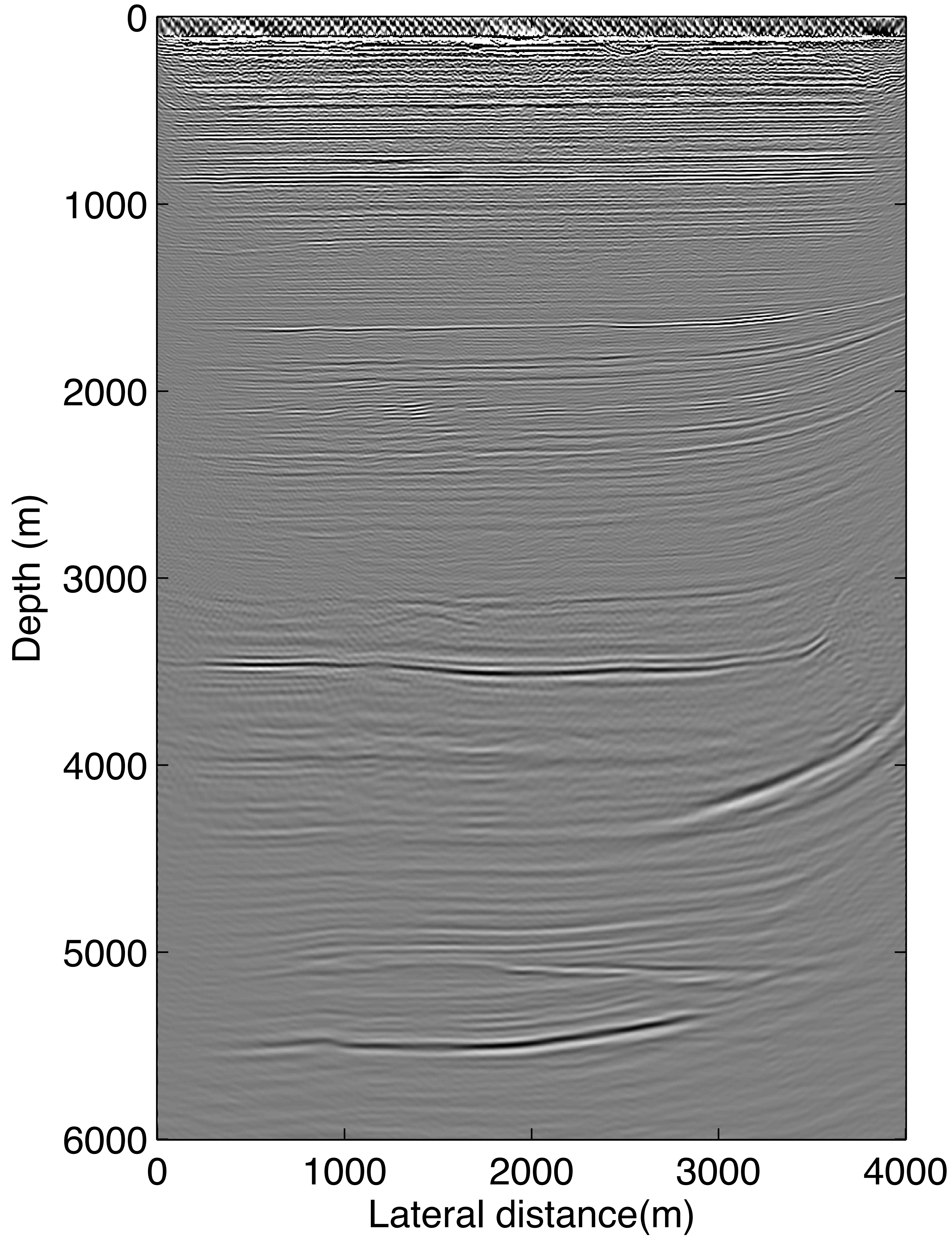
Reverse-time migrated image

[all freq. in 5-30Hz, all sources, 10m grid distance]



Reverse-time migrated image

[all freq. in 5-60Hz, all sources, 5m grid distance]



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Remarks

- The ringing artifacts in the high-velocity-contrast zone are caused by spacial aliasing in the data.
- We will extend the interpolation and imaging to the entire model (work in progress).

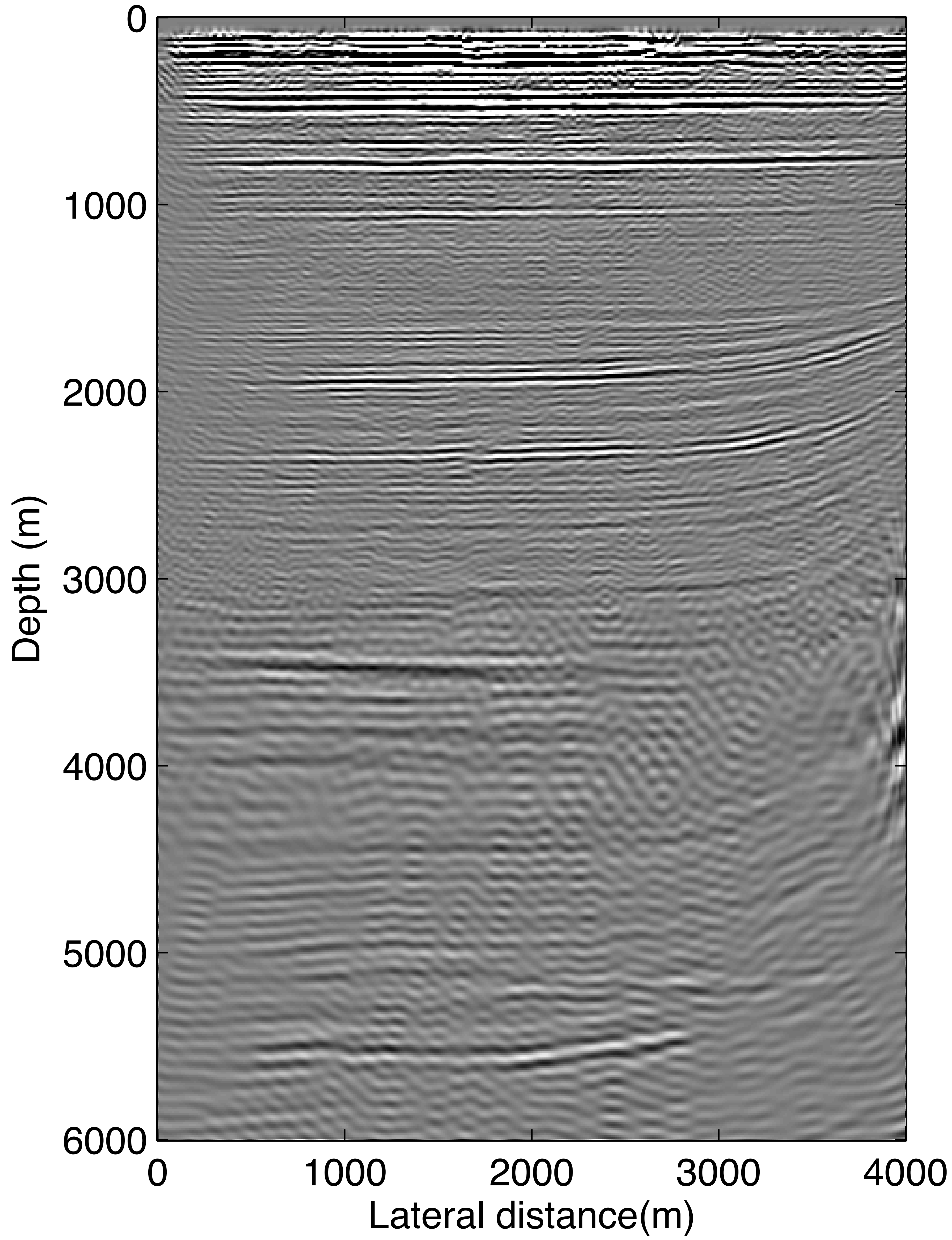
Imaging-L1 migration

- using dimensionality reduction to reduce computational cost
- source estimation on the fly

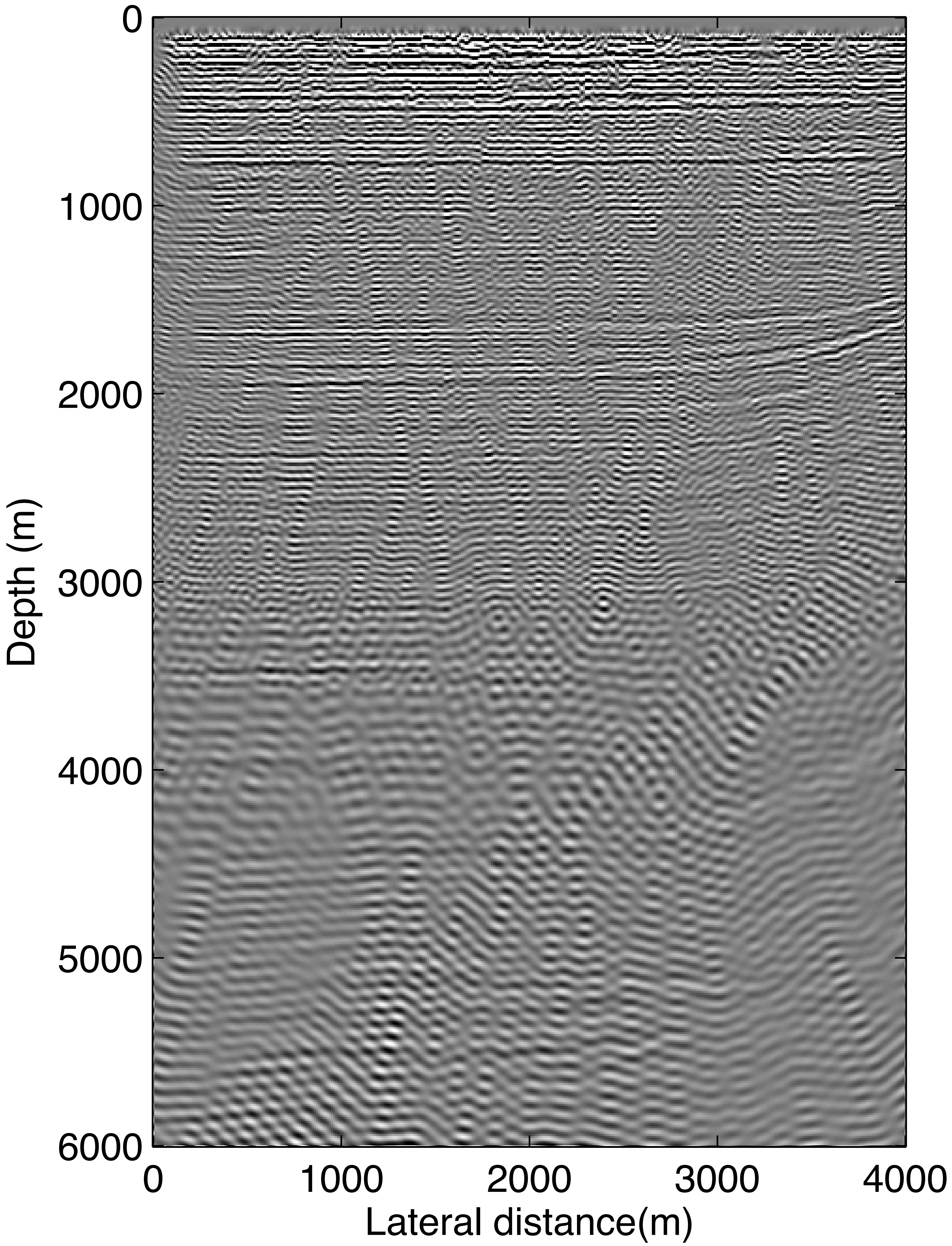
Setup

- use the cropped model to reduce the turnaround time
- no freq. subsampling, 50% source subsampling, 20 iterations

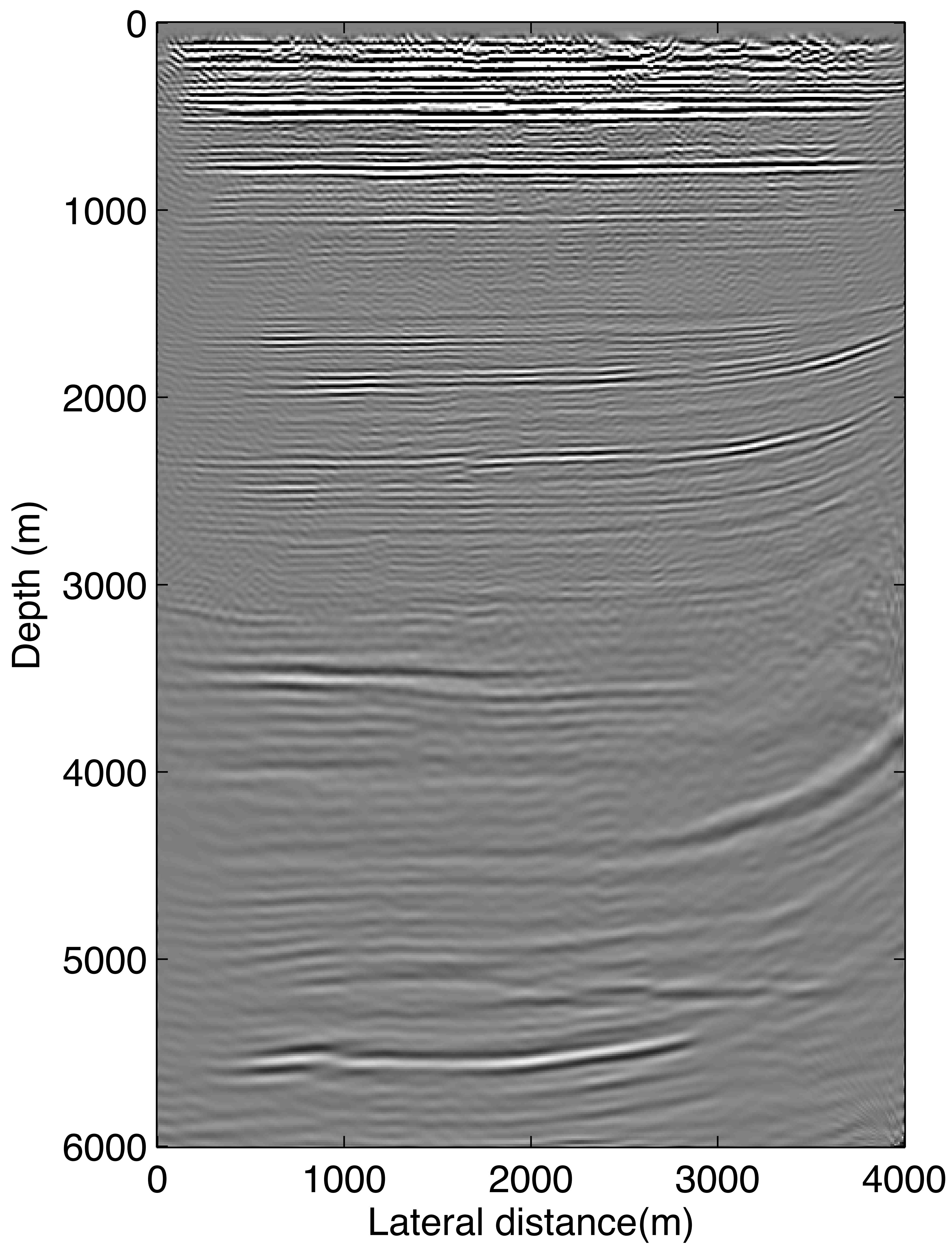
L1 migration w. source estimation, aliased data



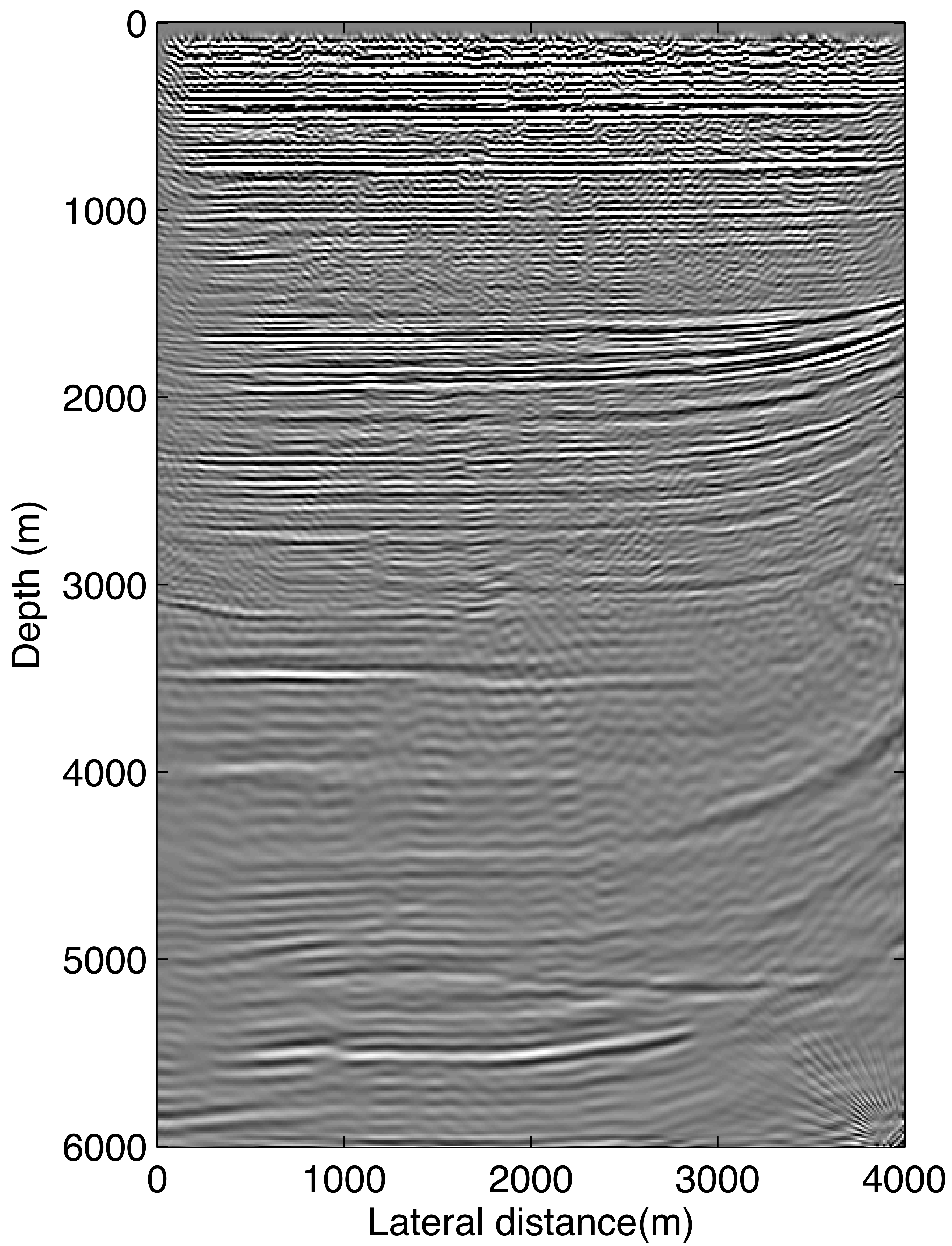
L1 migration w. impulsive source, aliased data



L1 migration w. source estimation, de-aliased data



L1 migration w. impulsive source, de-aliased data



Remarks

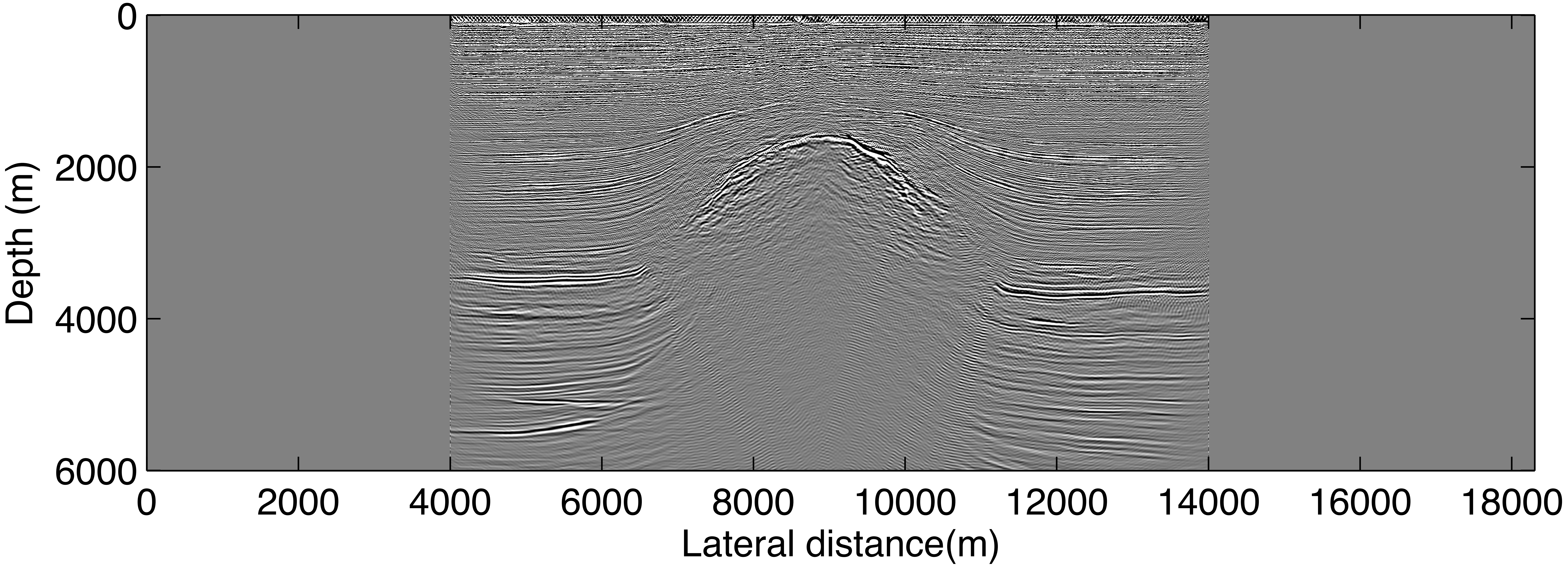
- Source wavelet is not important *per se*, but import for correctly inverting the image (a.k.a, nuisance parameter).
- On-the-fly source estimation greatly improves image quality.

Progress and future plan

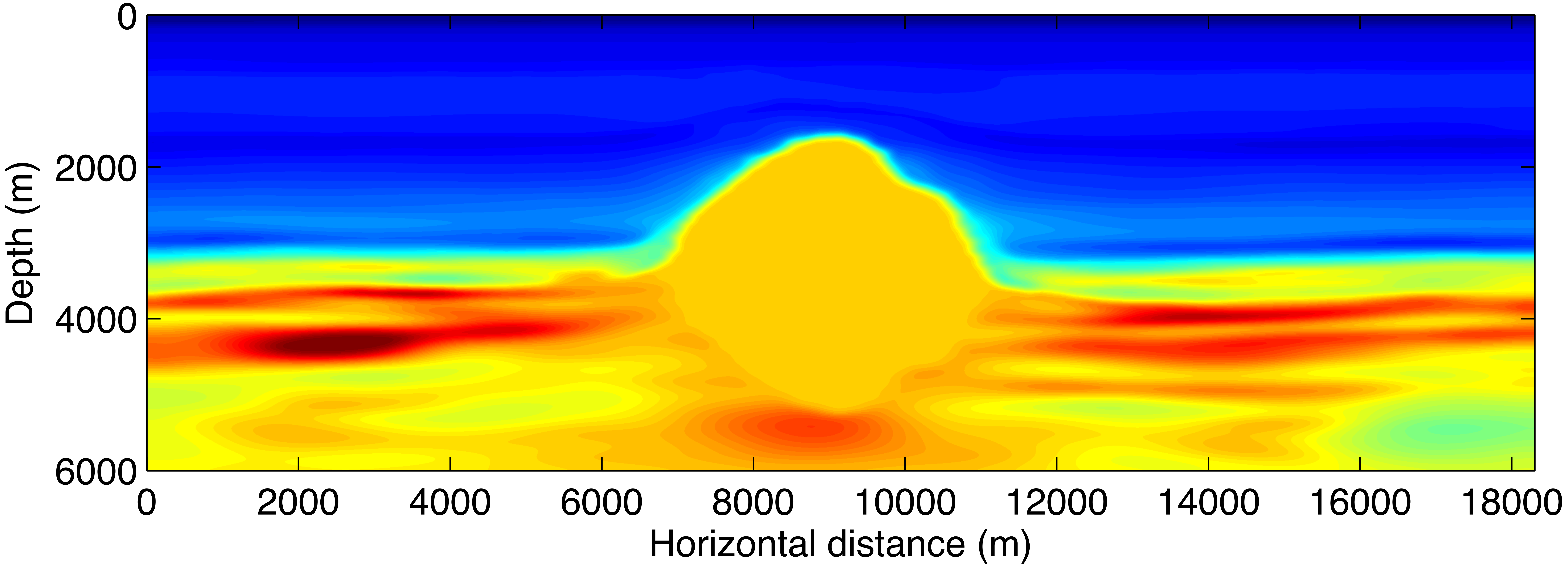
- RTM of the entire dataset using frequencies up to 60Hz. Currently in progress.
- Optimizing the subsampling strategy for more efficient sparsity-promoting migration.
- Working directly on the unprocessed pressure and particle velocity wavefield, with Robust EPSI and imaging-with-multiples implementations.

Frequency domain modelling

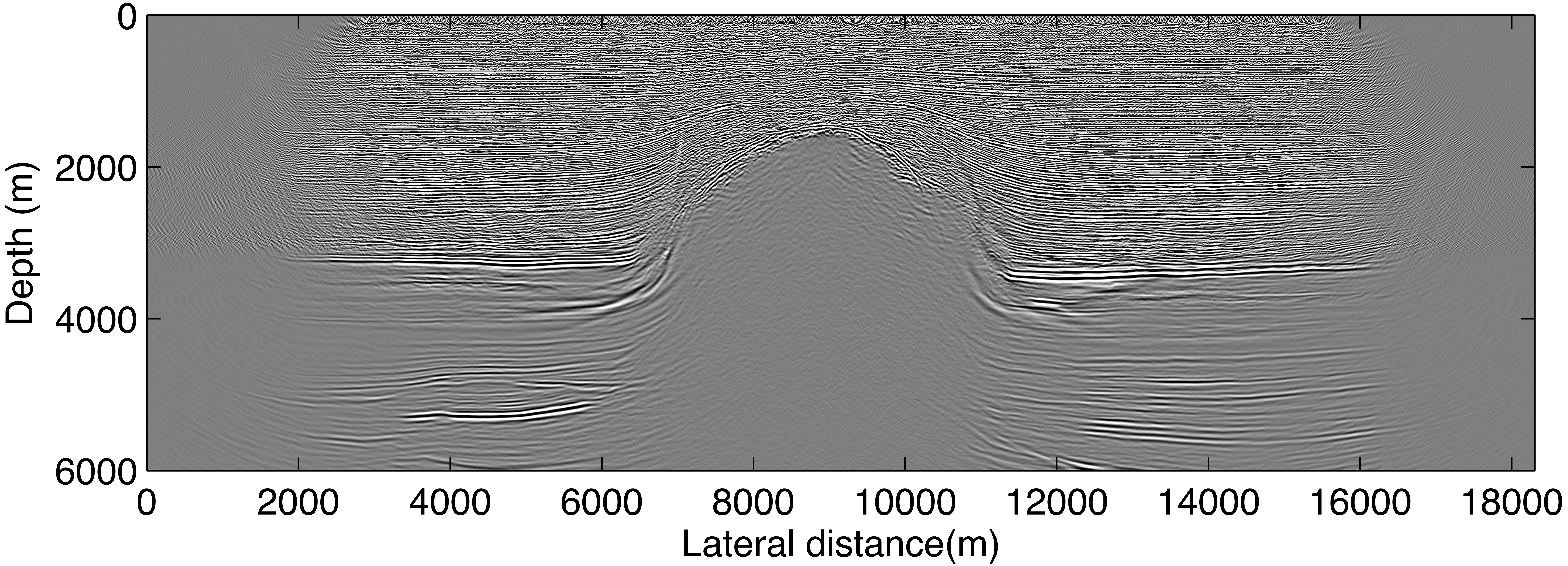
(can only image a part of the model due to computational constraints)



Background model



RTM of the entire model using iWave



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Acknowledgements

We would like to thank BP for sharing this Machar dataset with us and granting us the permission to show this work.

And thanks for your attention!

SINBAD

NSERC CRSNG

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