

Randomized marine acquisition for ocean-bottom surveys

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The data deluge

How to handle it?



Motivation

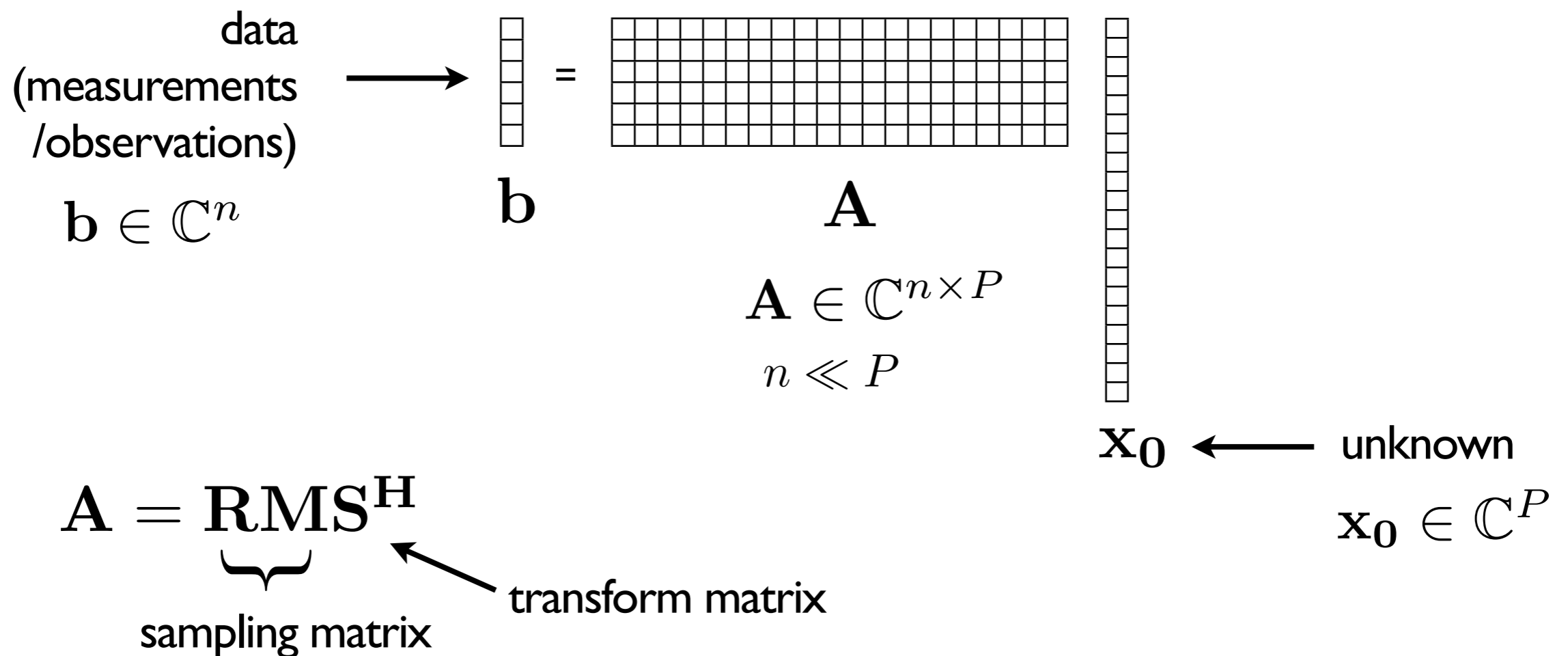
- ▶ Is there a way to circumvent the Nyquist-related acquisition/processing costs?
- ▶ Rethink seismic acquisition design
- ▶ Marine acquisition (with ocean-bottom nodes)

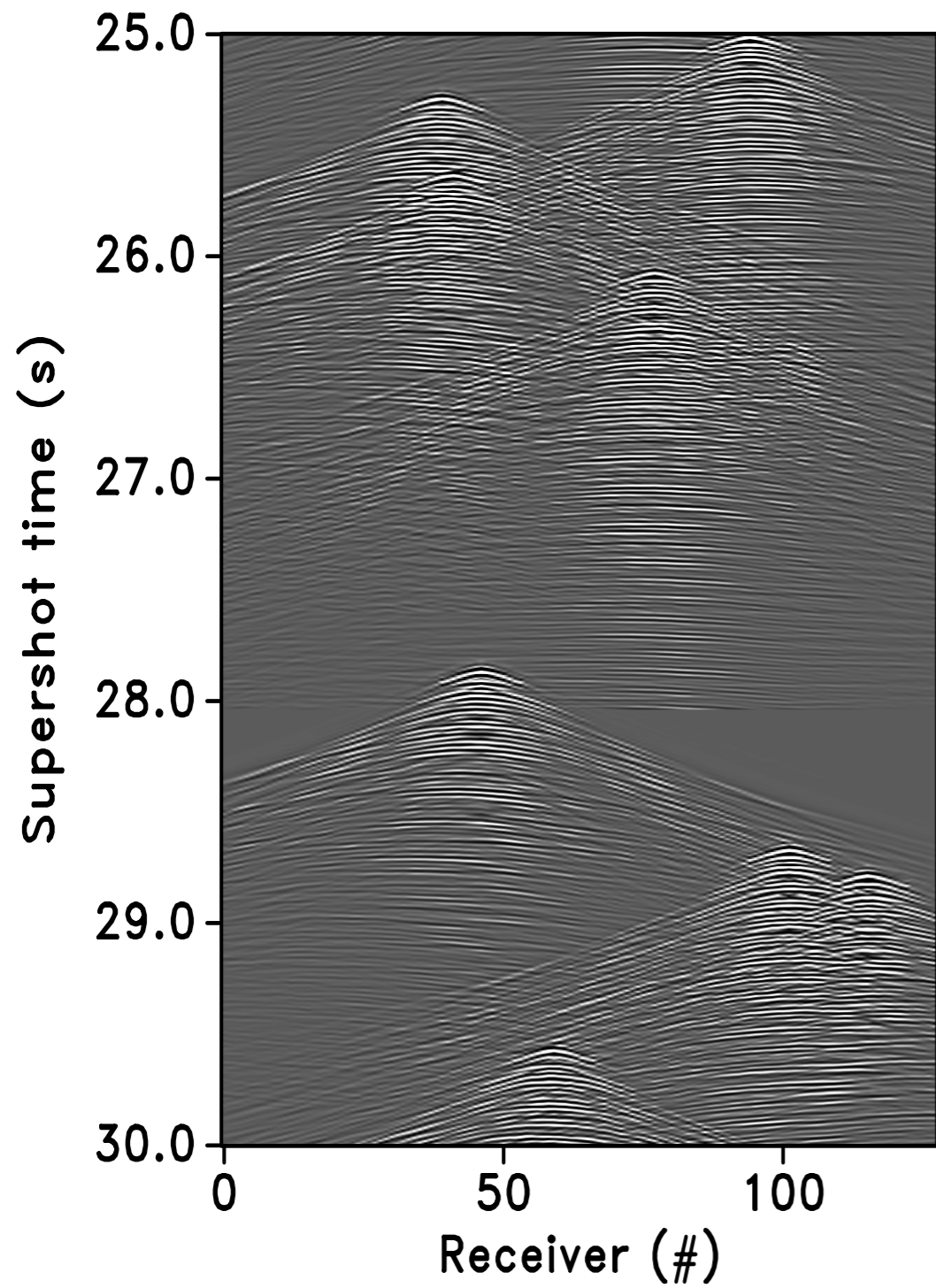
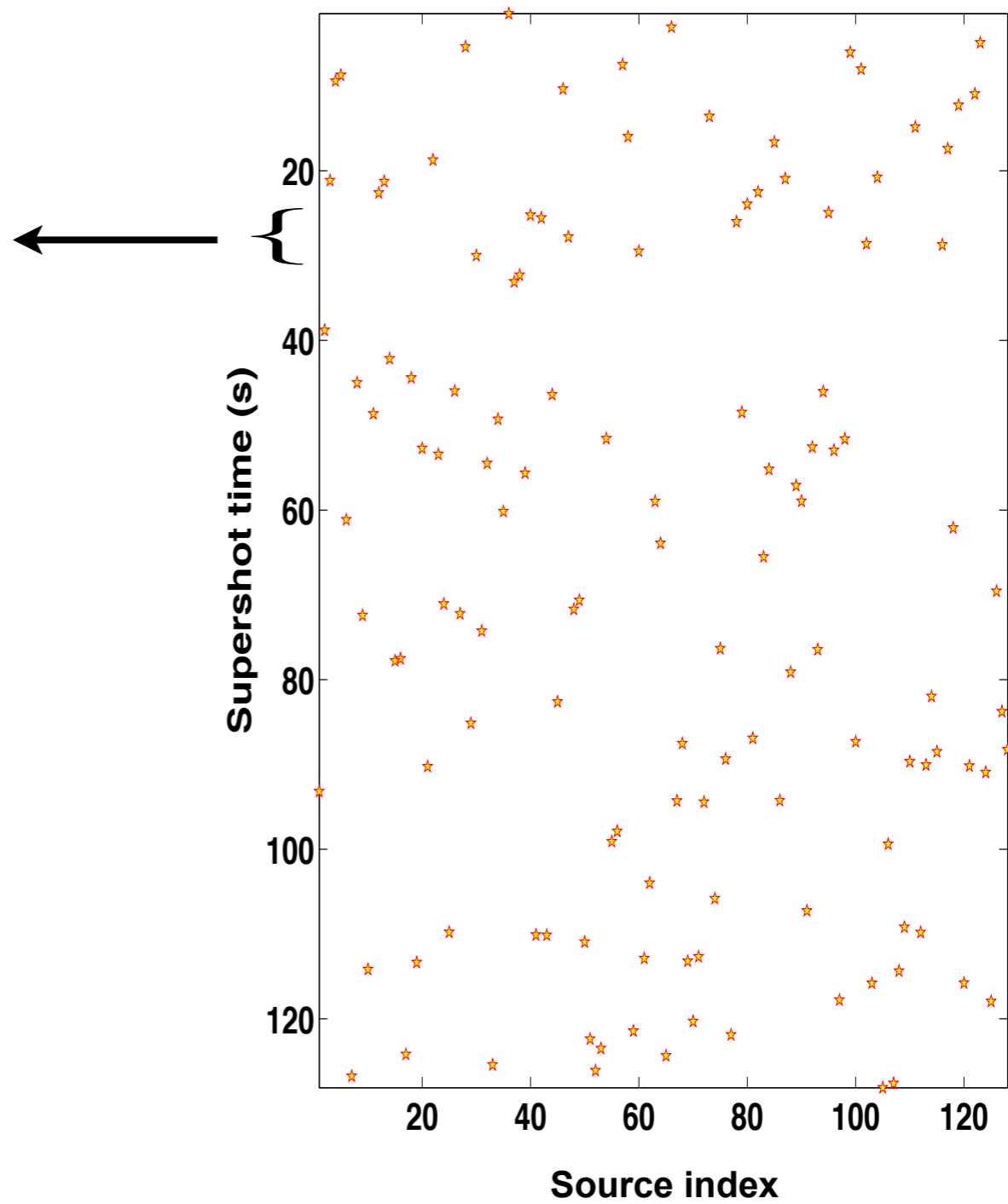
Outline

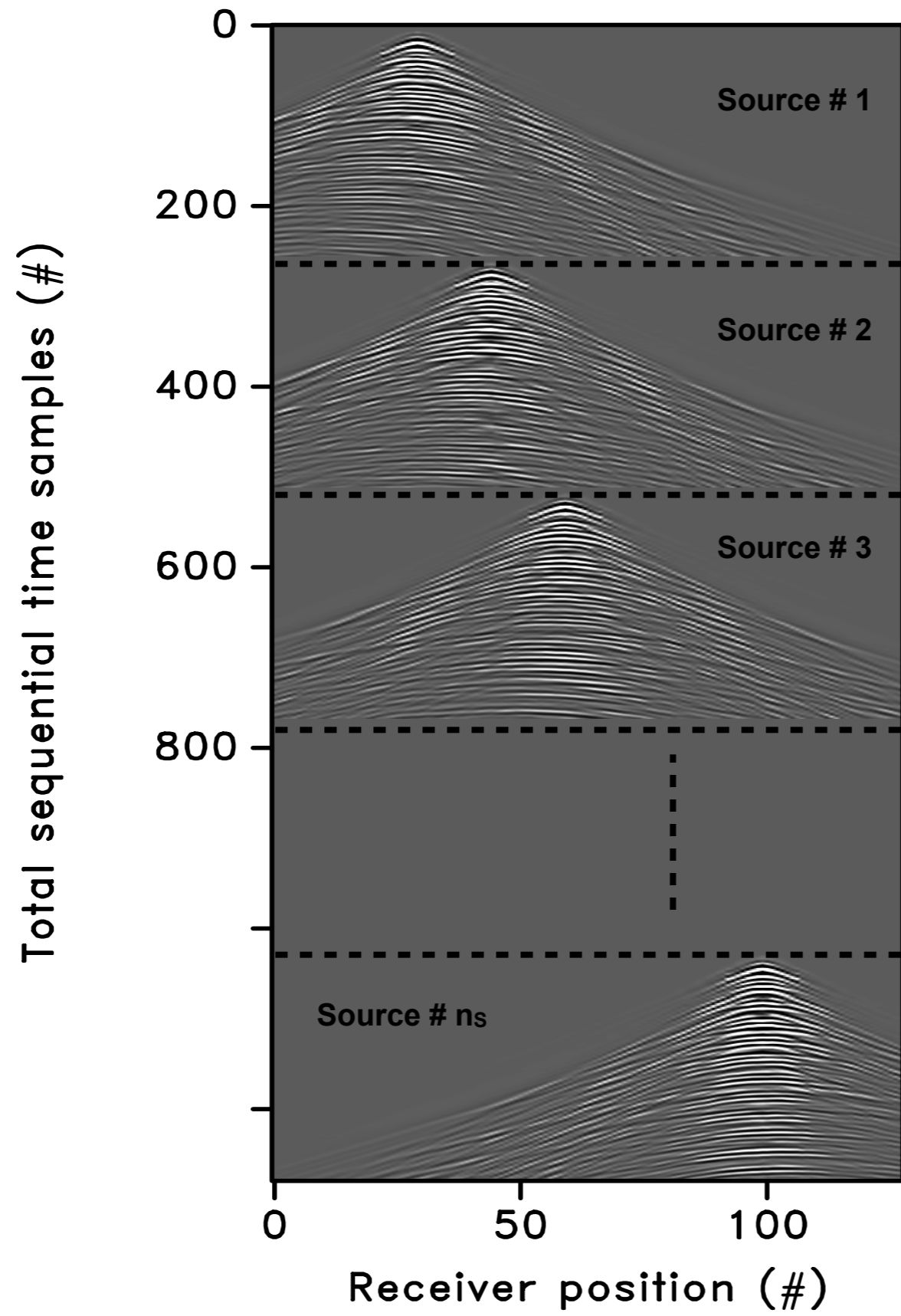
- ▶ Problem statement
 - recovery
- ▶ *Design of efficient* marine acquisition
- ▶ Experimental results of *sparsity*-promoting processing

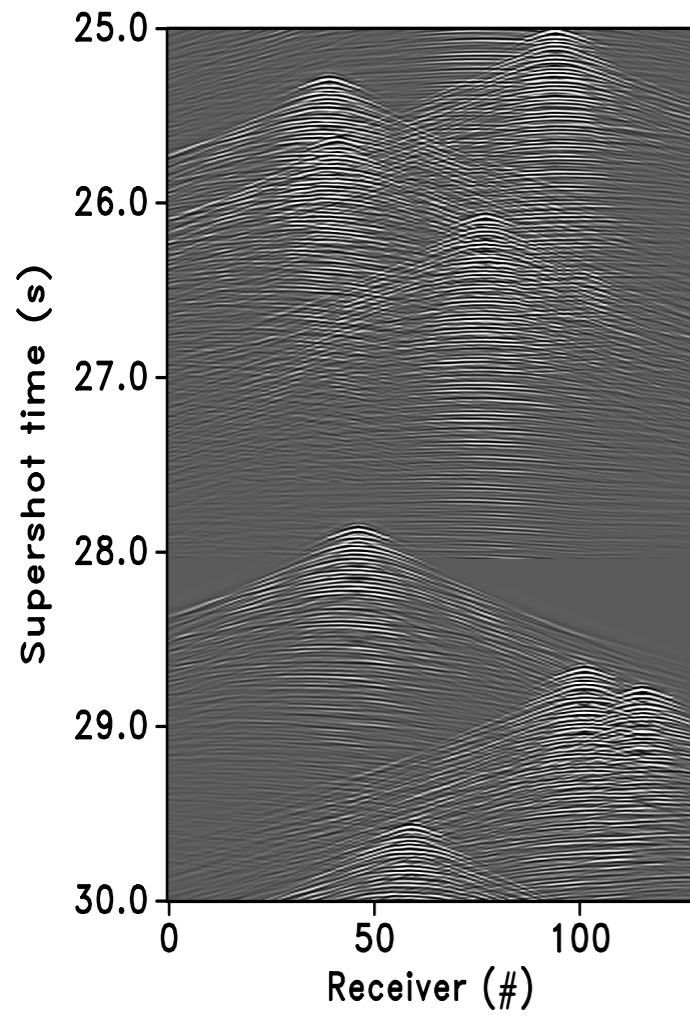
Problem statement

Solve an *underdetermined* system of *linear* equations:

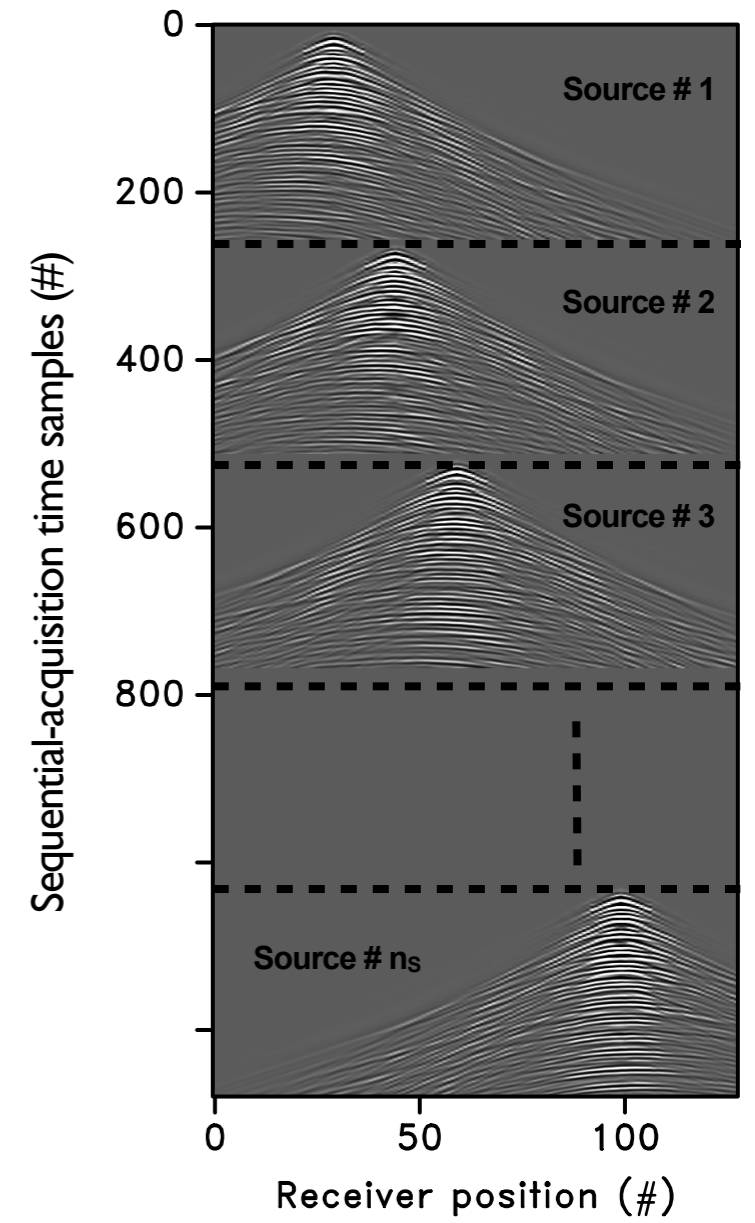


b**SIMULTANEOUS ACQUISITION**

**d**

b

=

RM**d**

Sparse recovery

Solve the convex optimization problem
(one-norm minimization):

$$\tilde{\mathbf{x}} = \arg \min_{\mathbf{x}} \|\mathbf{x}\|_1 \quad \text{subject to} \quad \underbrace{\mathbf{Ax} = \mathbf{b}}_{\text{data-consistent amplitude recovery}}$$

Sparsity-promoting solver: SPG_{ℓ_1} [van den Berg and Friedlander, 2008]

Recover single-source prestack data volume: $\tilde{\mathbf{d}} = \mathbf{S}^H \tilde{\mathbf{x}}$

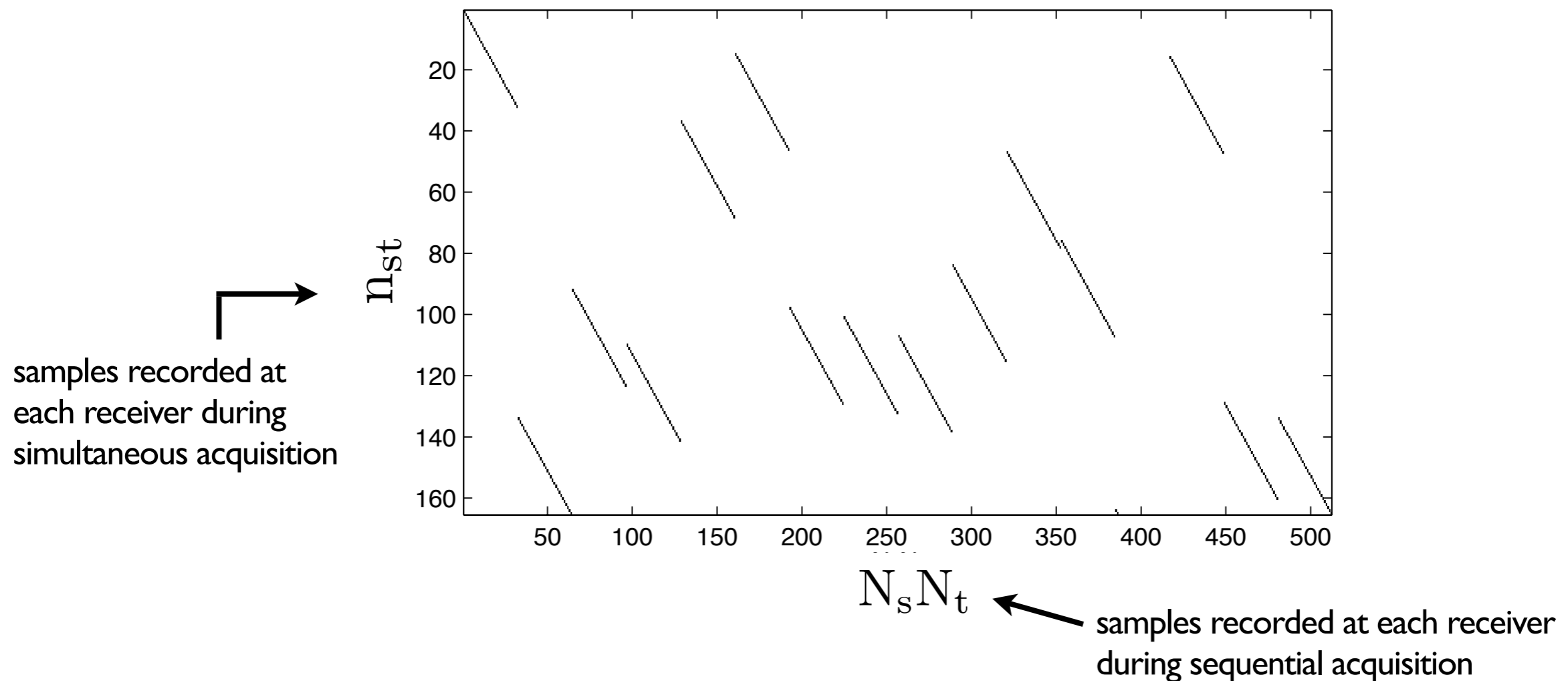
Outline

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- ▶ ***Design of efficient* marine acquisition**
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“Ideal” simultaneous acquisition matrix

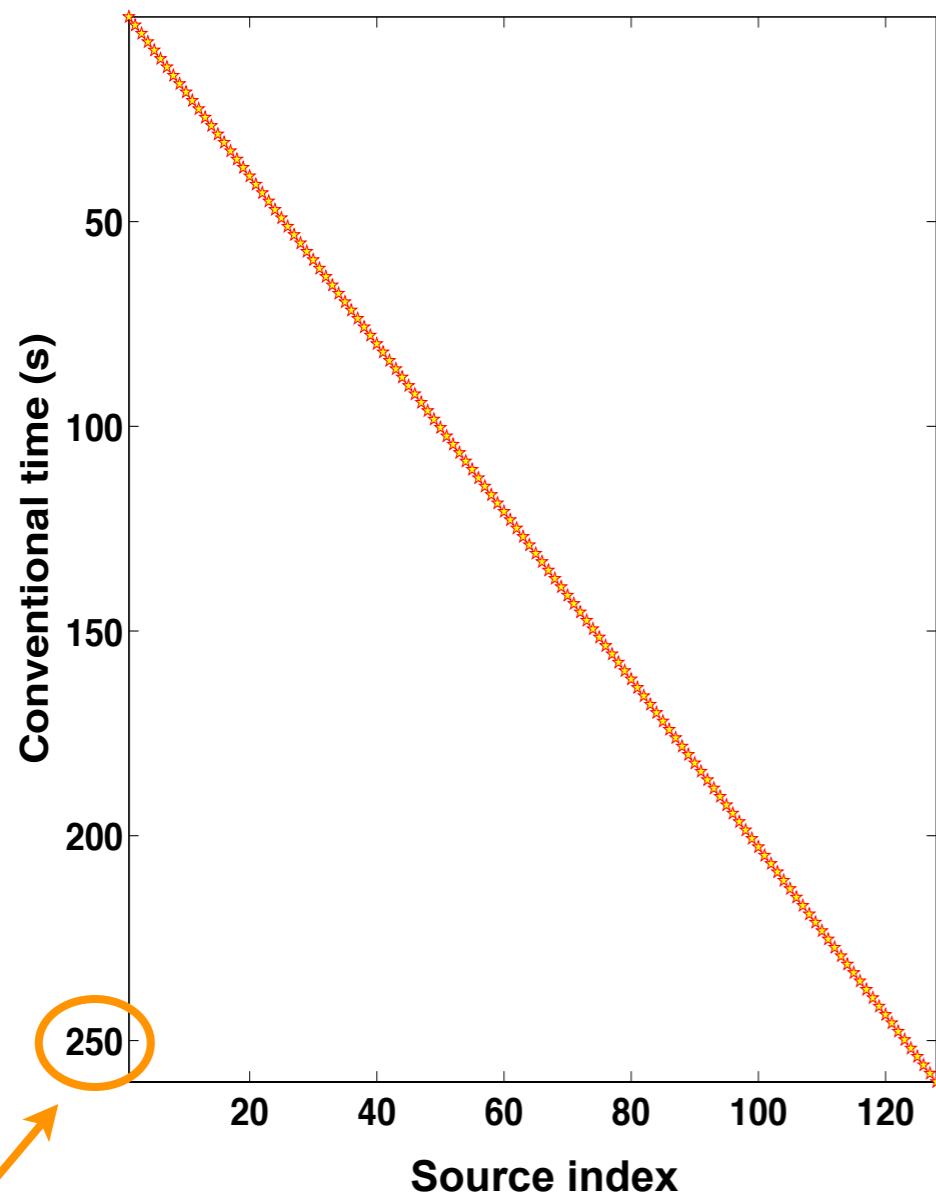
For a seismic line with N_s sources, N_r receivers, and N_t time samples, the sampling matrix is

RM



Sequential vs. simultaneous sources

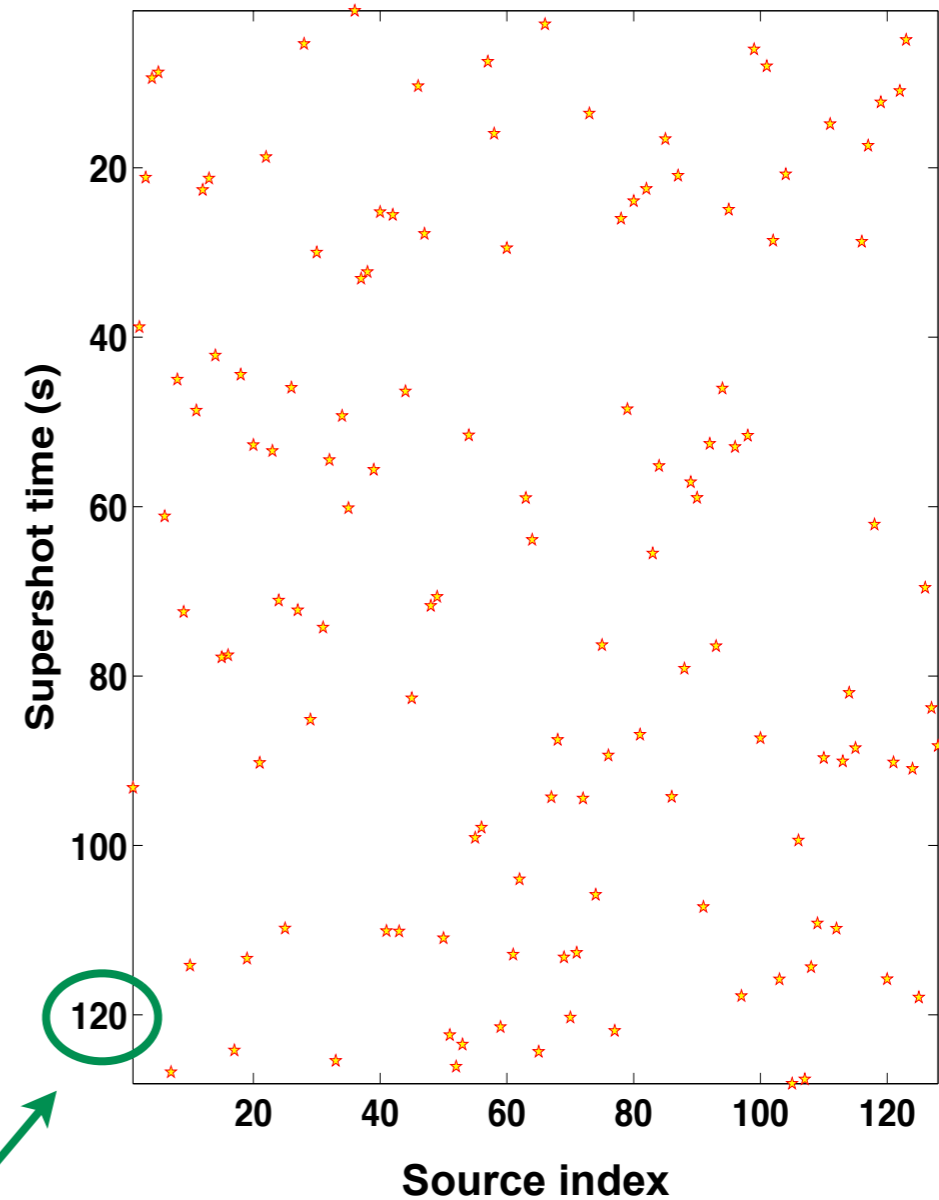
CONVENTIONAL SEQUENTIAL ACQUISITION



Conventional survey time:

$$t = N_s \times N_t$$

“IDEAL” SIMULTANEOUS ACQUISITION

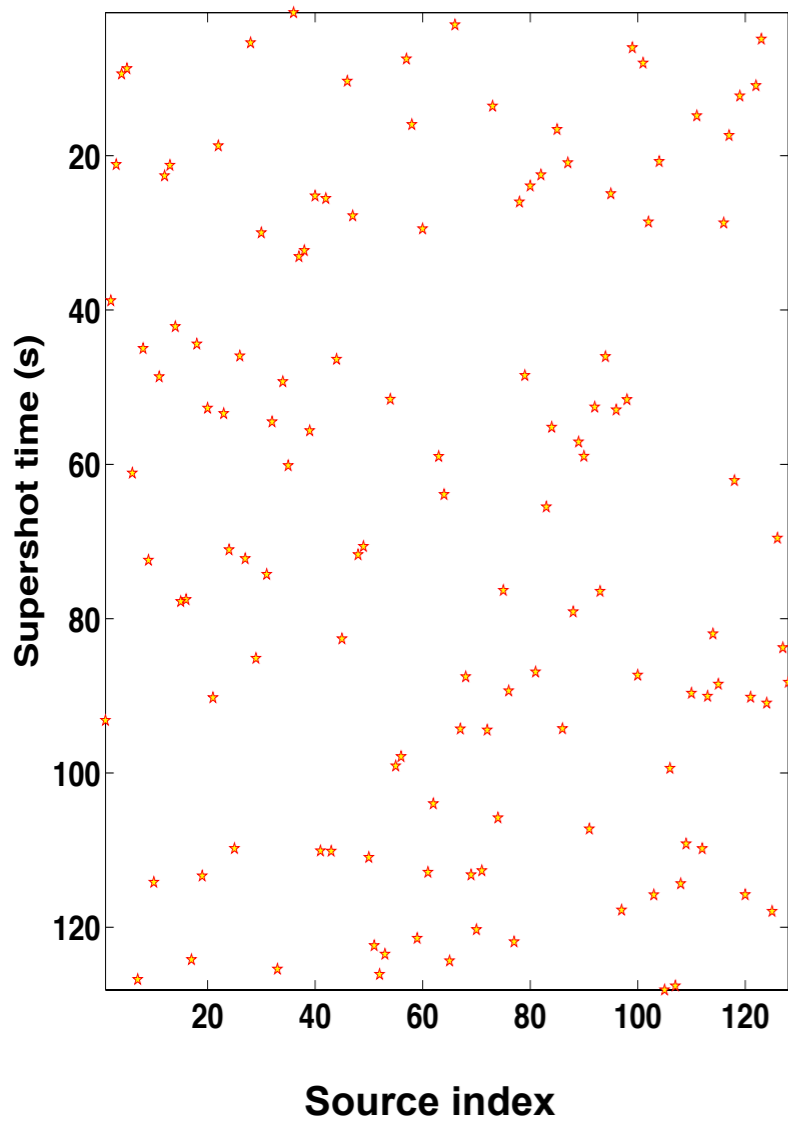


Theoretical survey time:

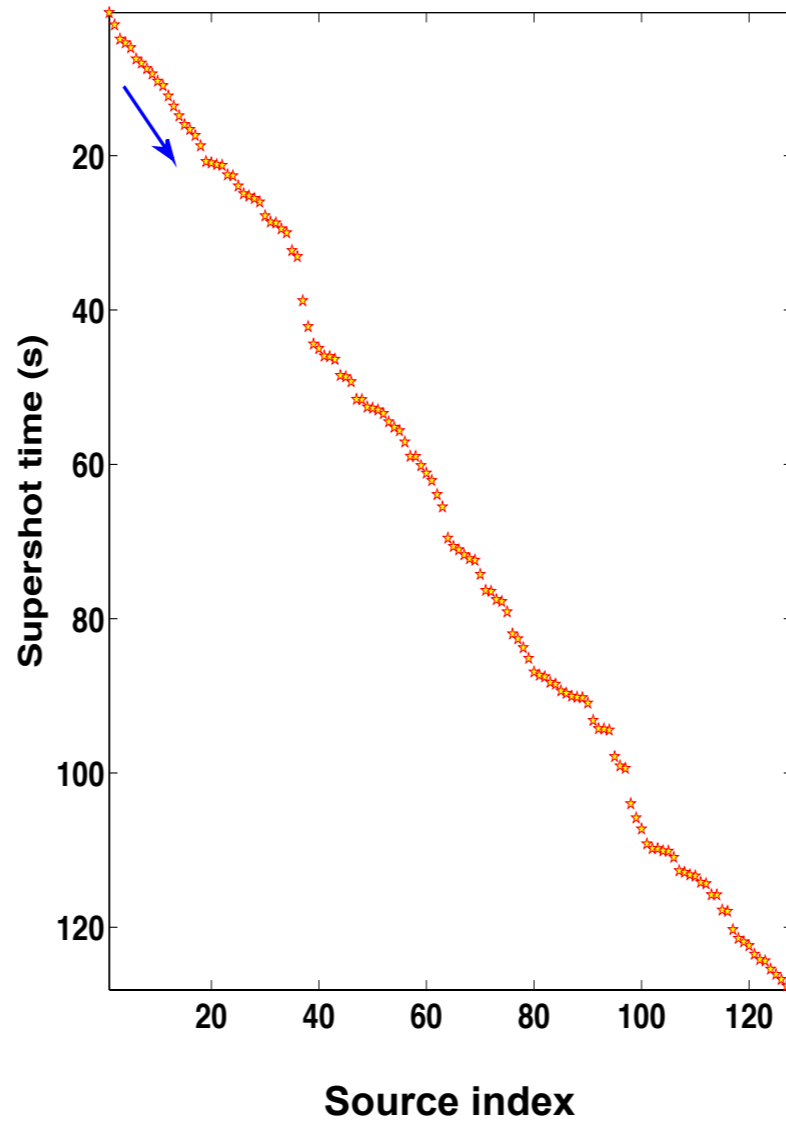
$$t = n_{st} \ll n_s \times N_t$$

Sampling schemes

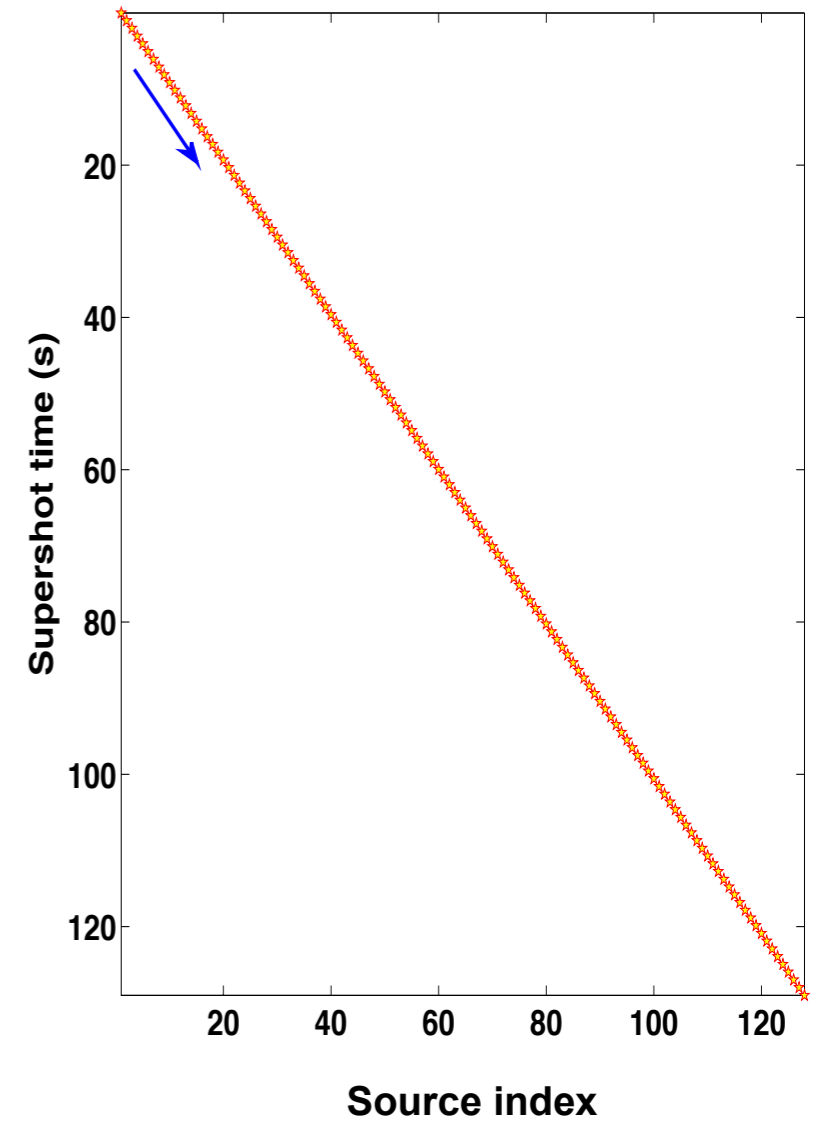
**“IDEAL” SIMULTANEOUS
ACQUISITION**



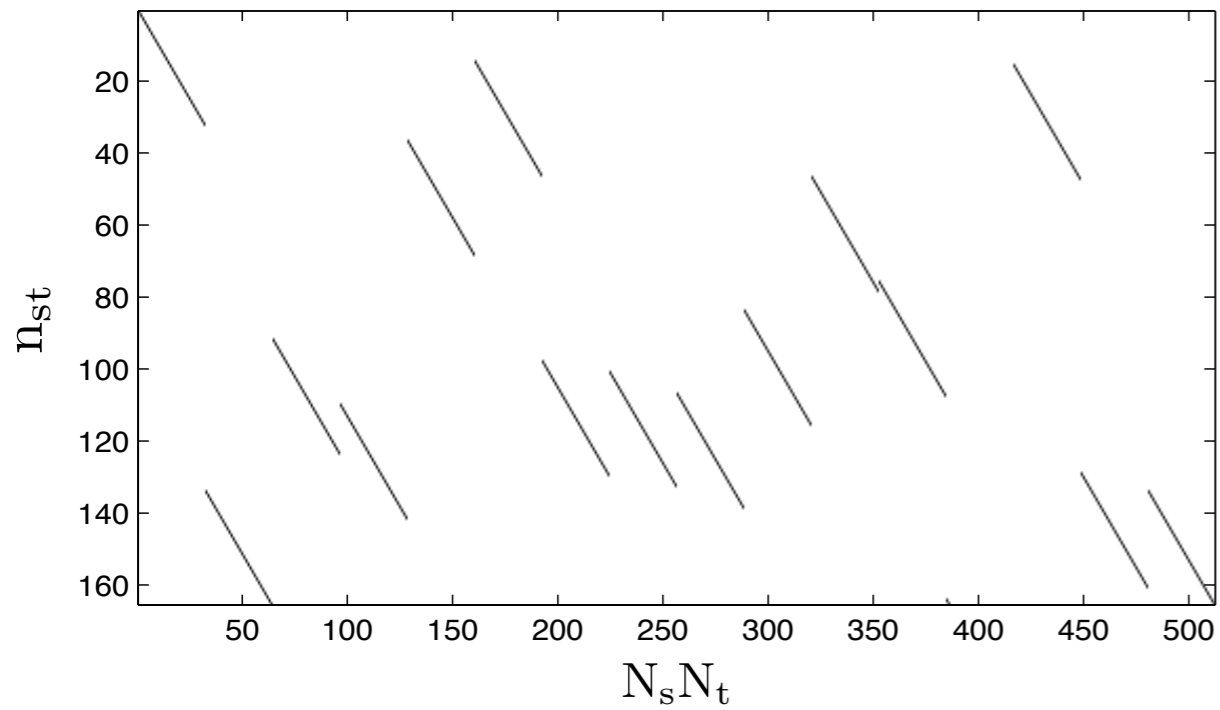
**RANDOM
TIME-DITHERING**



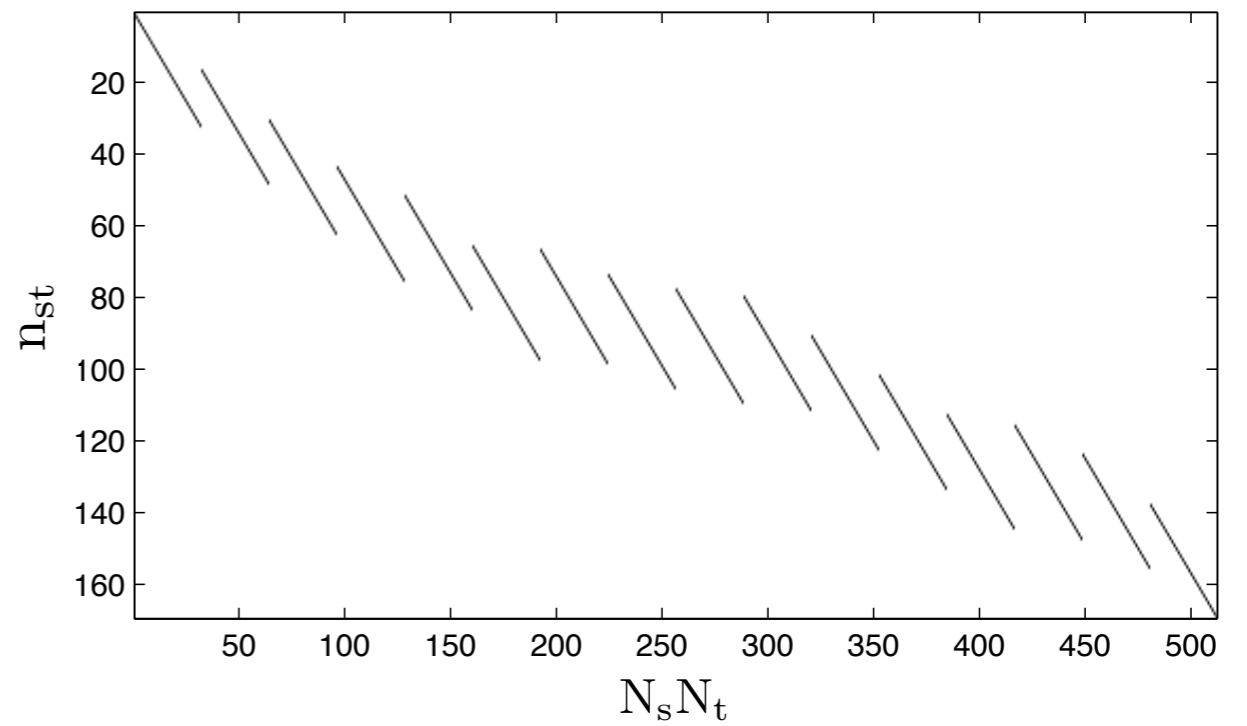
**PERIODIC
TIME-DITHERING**



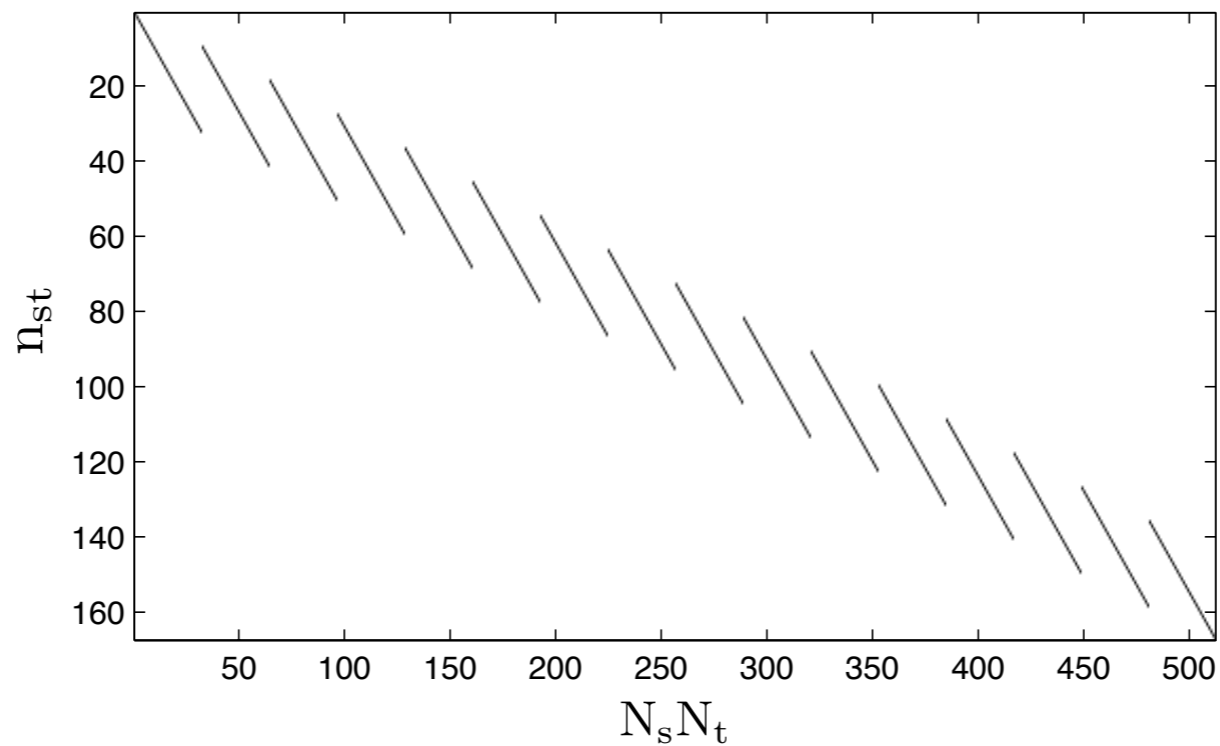
Sampling matrix (RM)



**"IDEAL" SIMULTANEOUS
ACQUISITION**



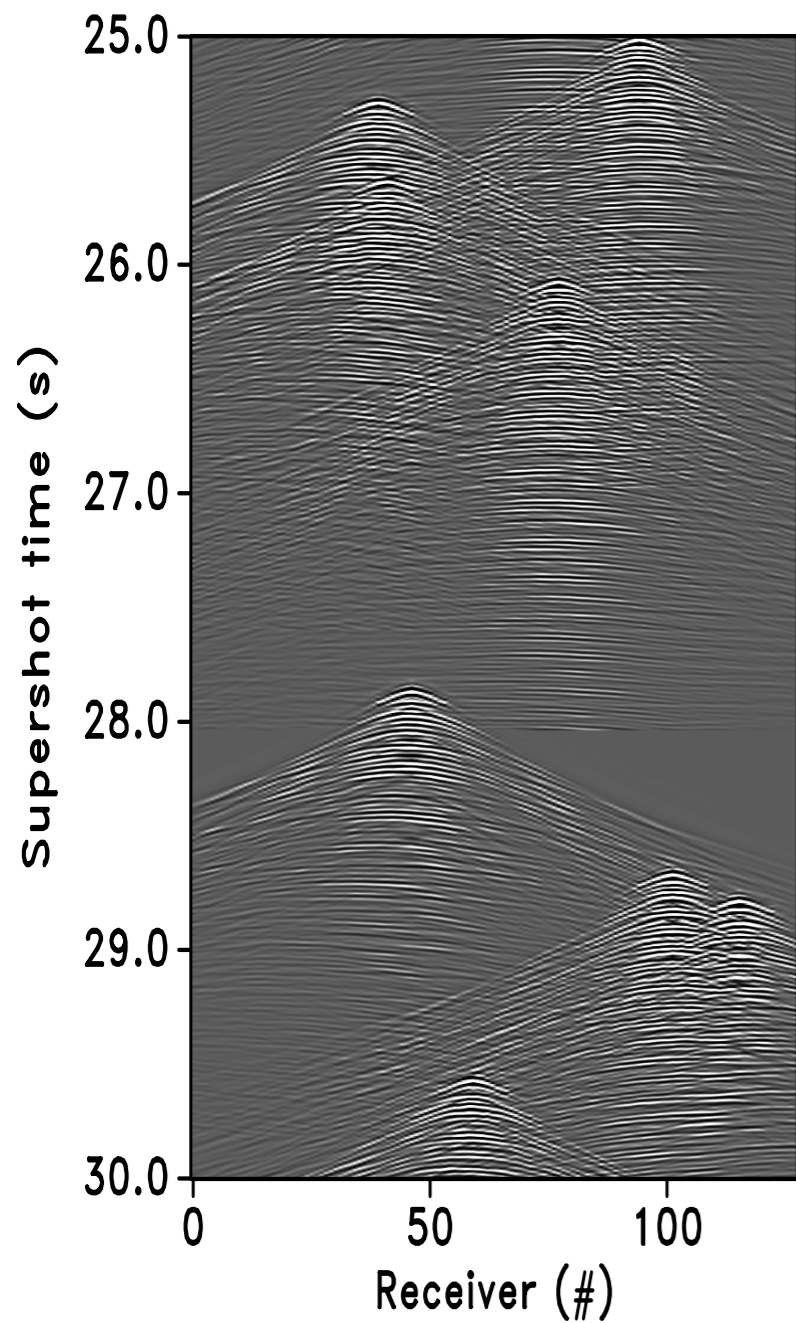
**RANDOM
TIME-DITHERING**



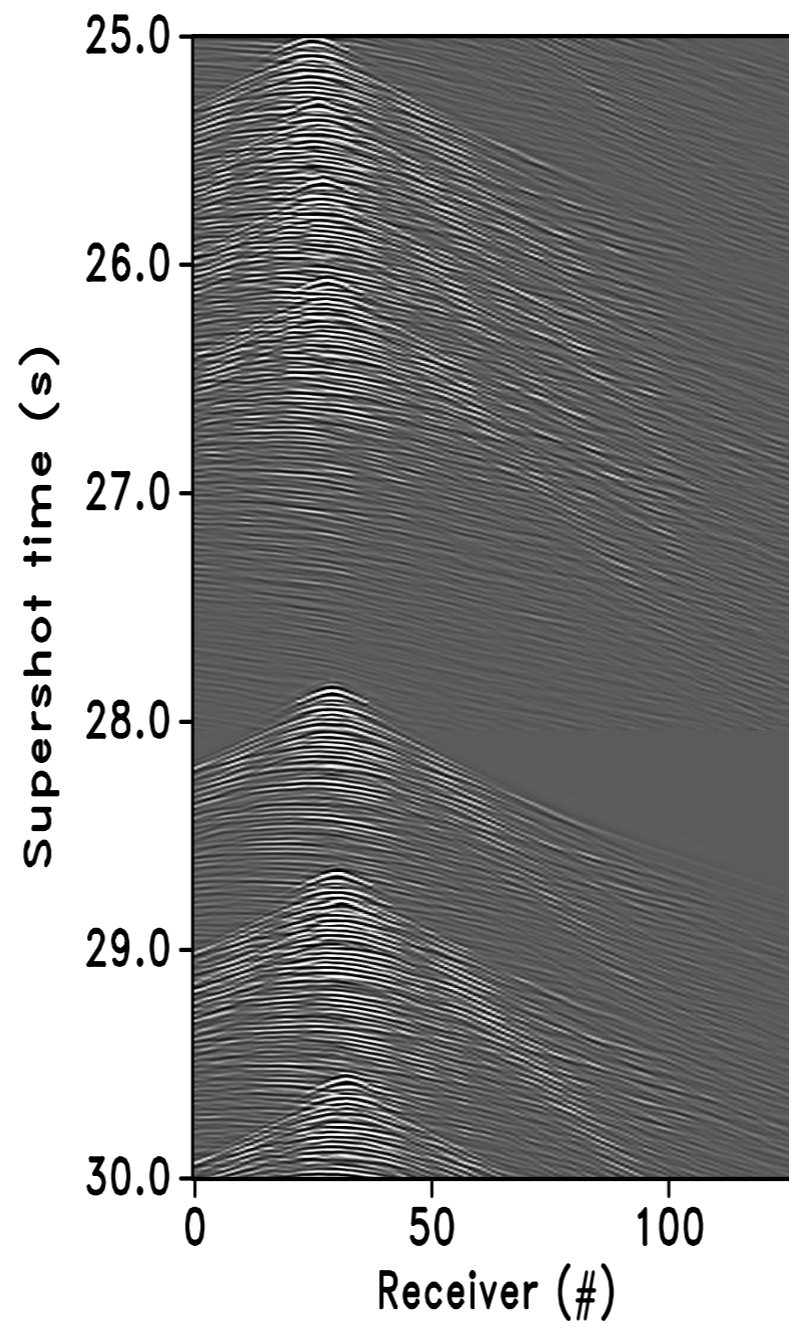
**PERIODIC
TIME-DITHERING**

Measurements (b)

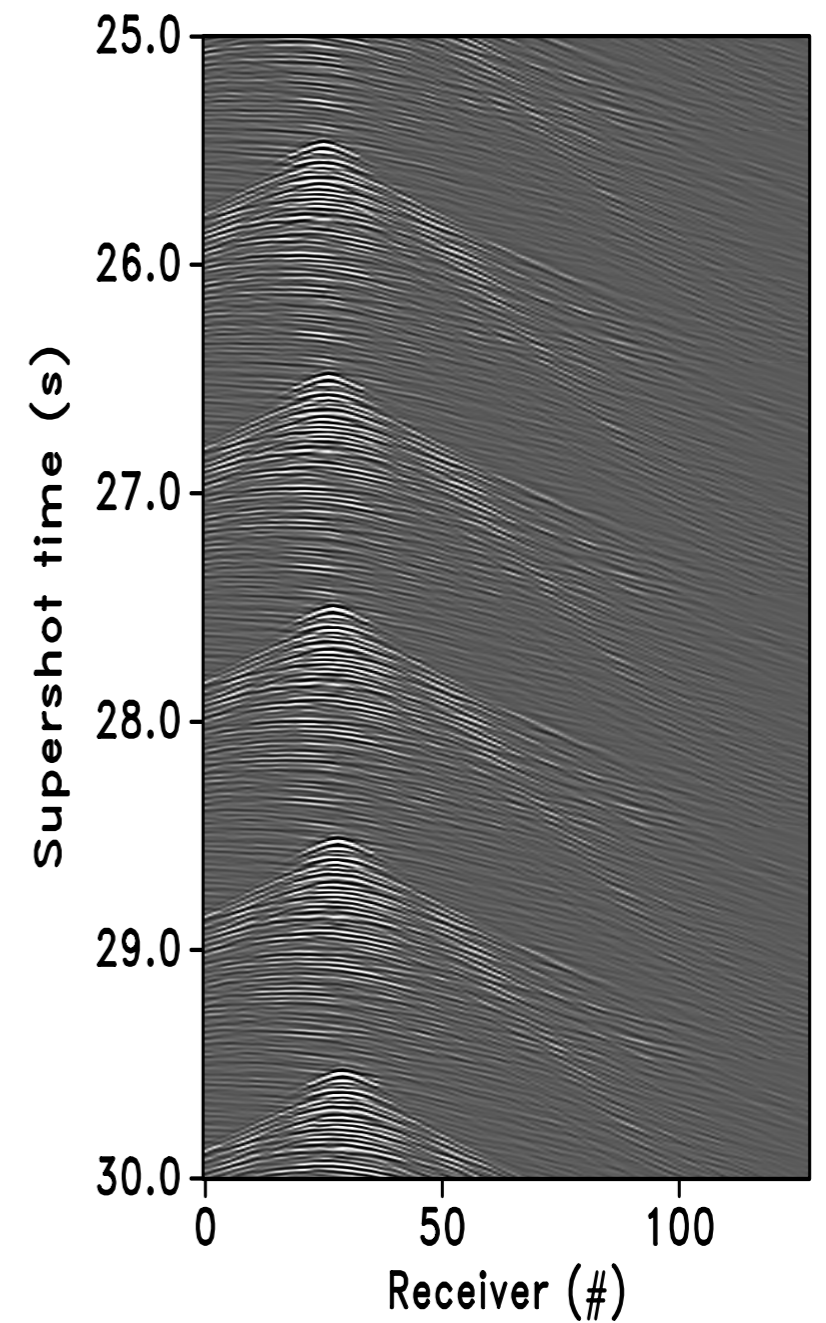
“IDEAL” SIMULTANEOUS
ACQUISITION



RANDOM
TIME-DITHERING



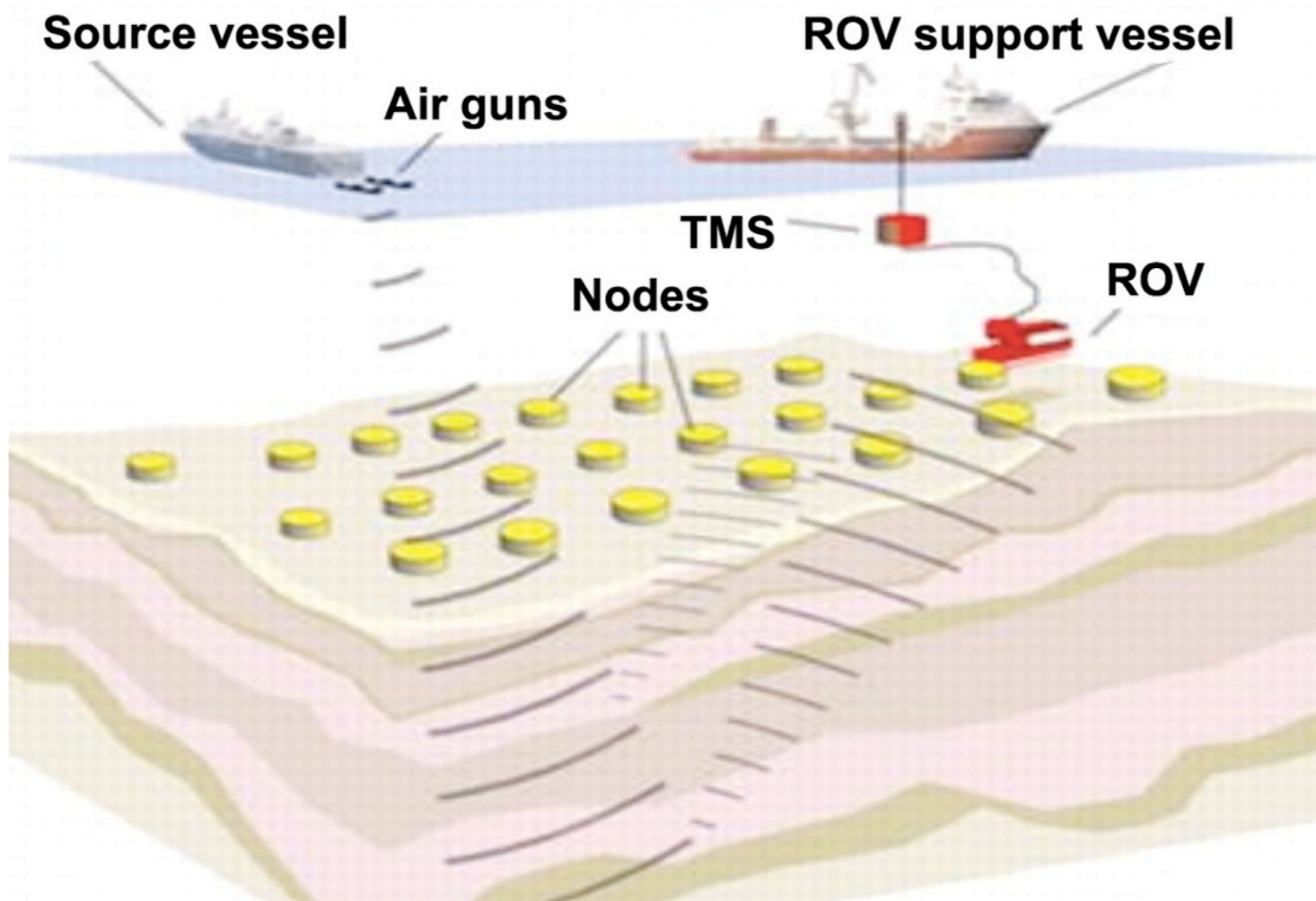
PERIODIC
TIME-DITHERING



Outline

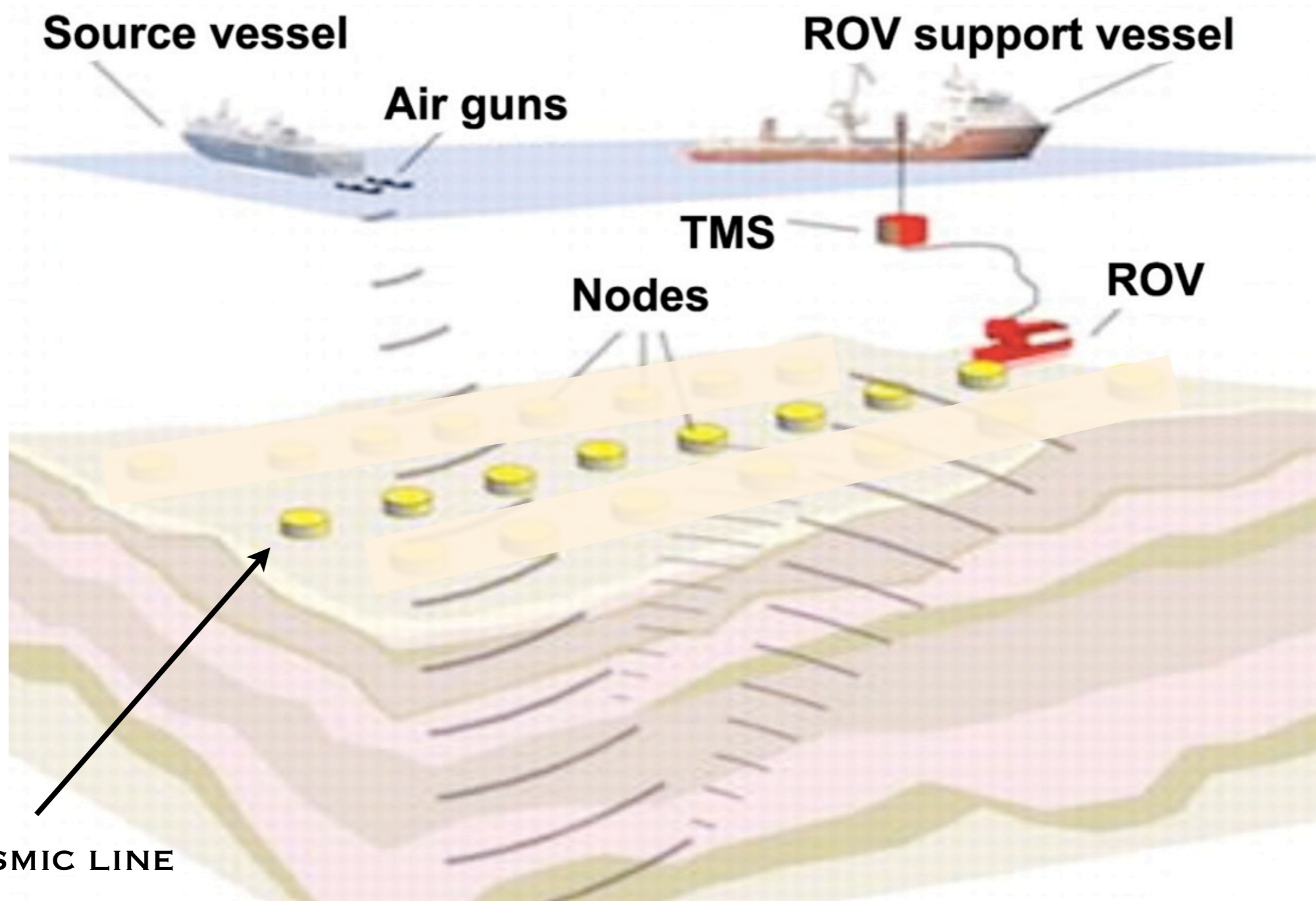
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- ▶ **Experimental results of *sparsity*-promoting processing**

Ocean-bottom node acquisition

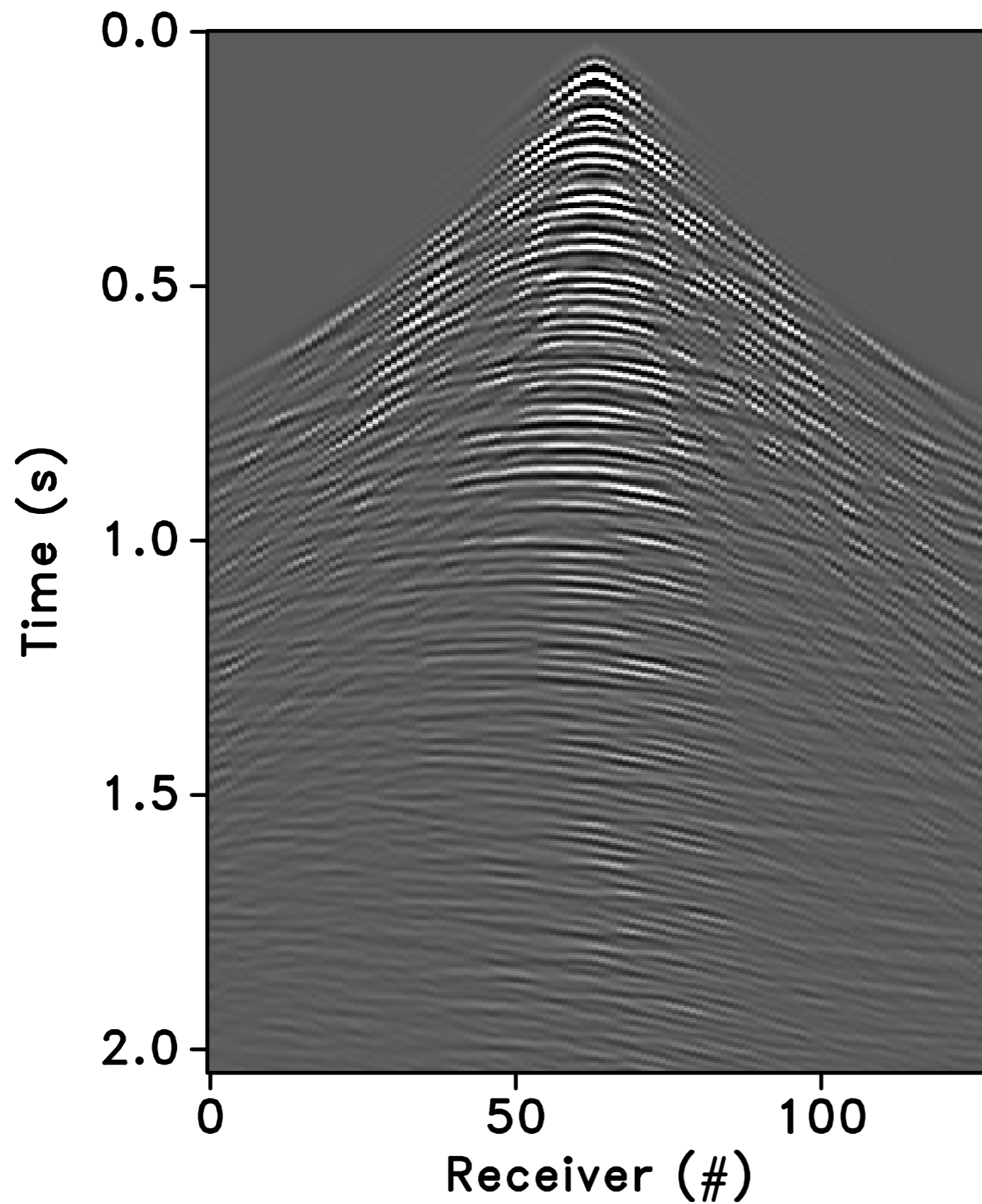


However...

...you will see



ONE SEISMIC LINE

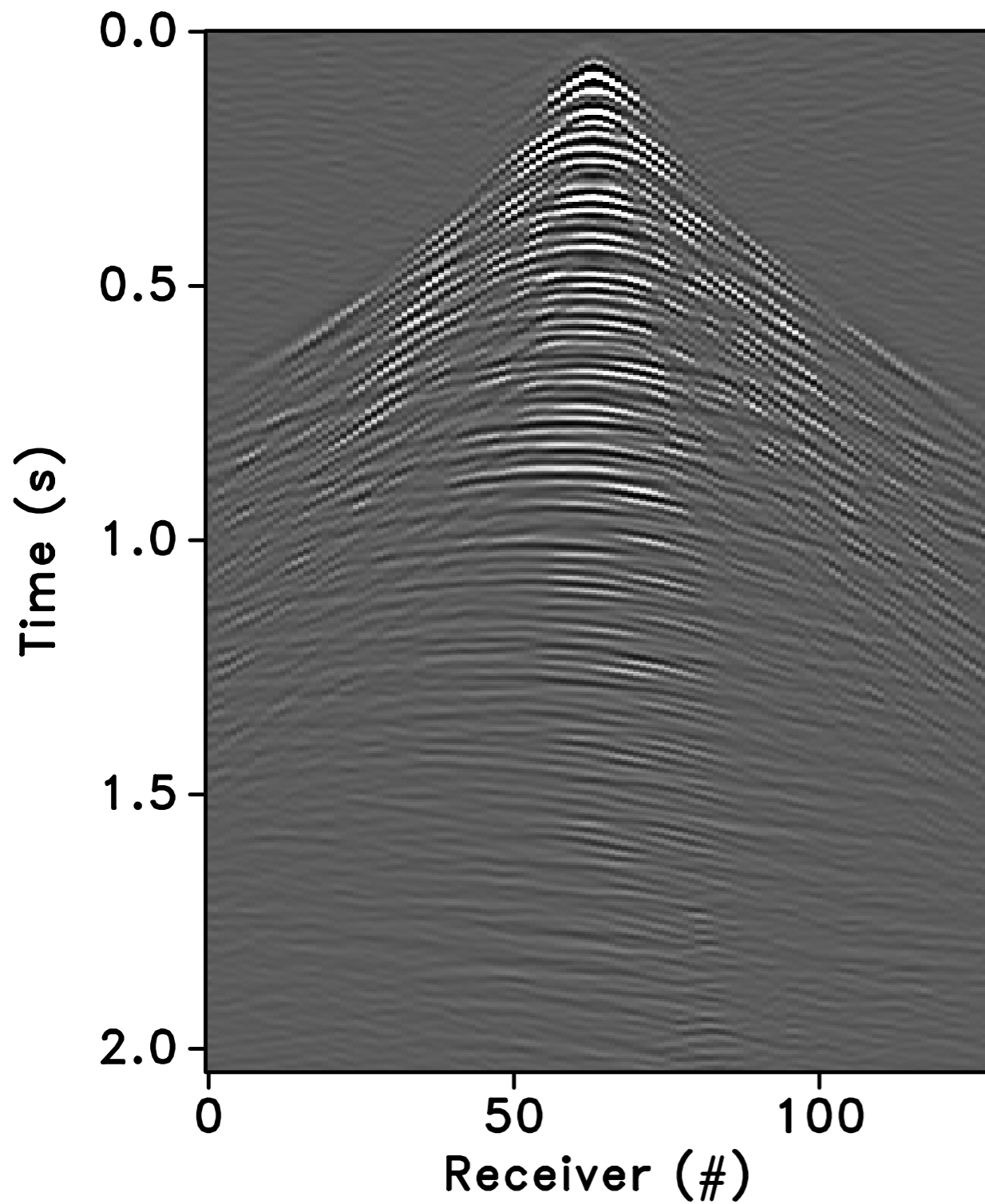


Gulf of Suez
(shot gather)

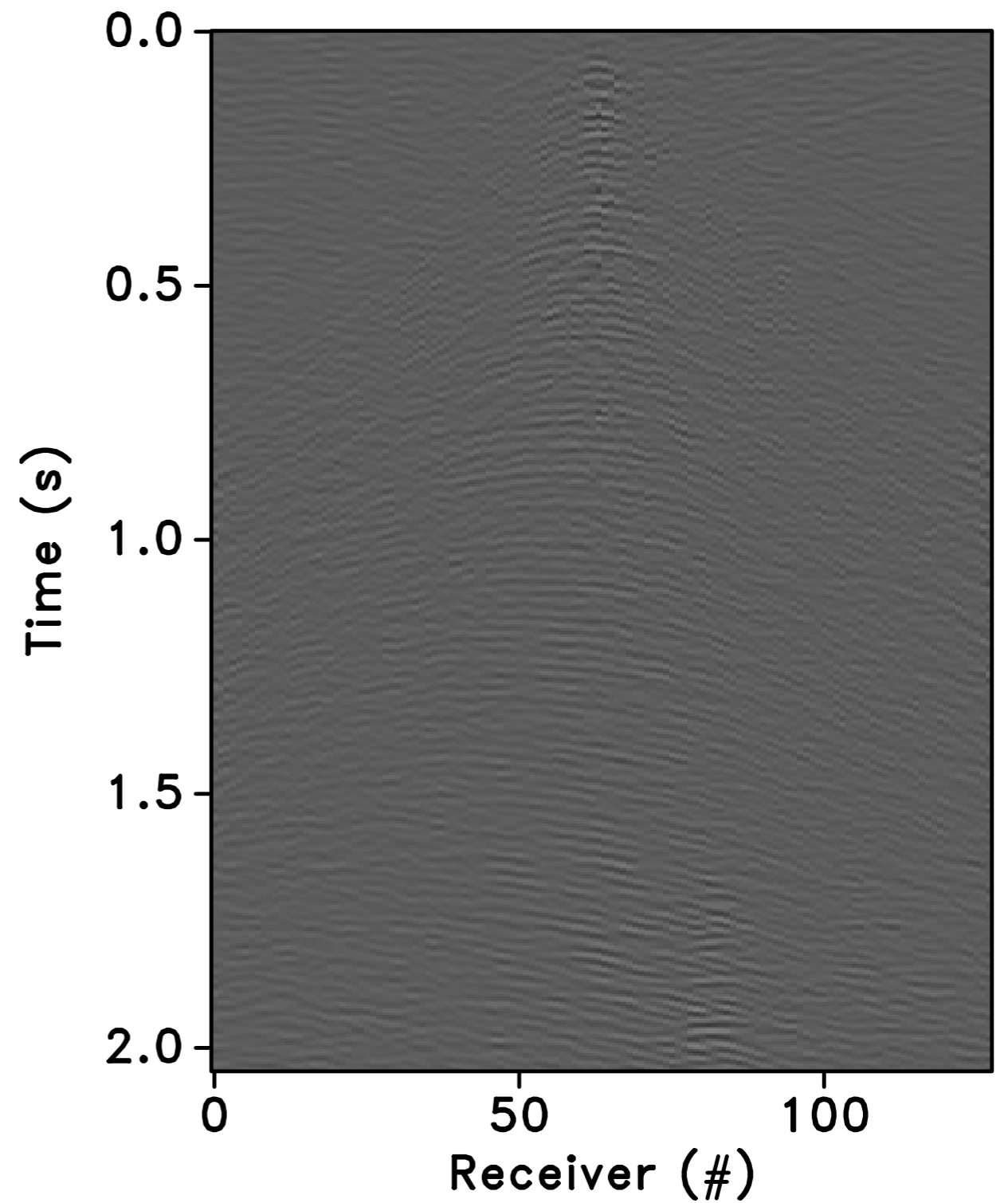
512 time samples
128 receivers
128 sources

“Ideal” simultaneous acquisition Sparsity-promoting recovery : 10.5 dB

RECOVERED



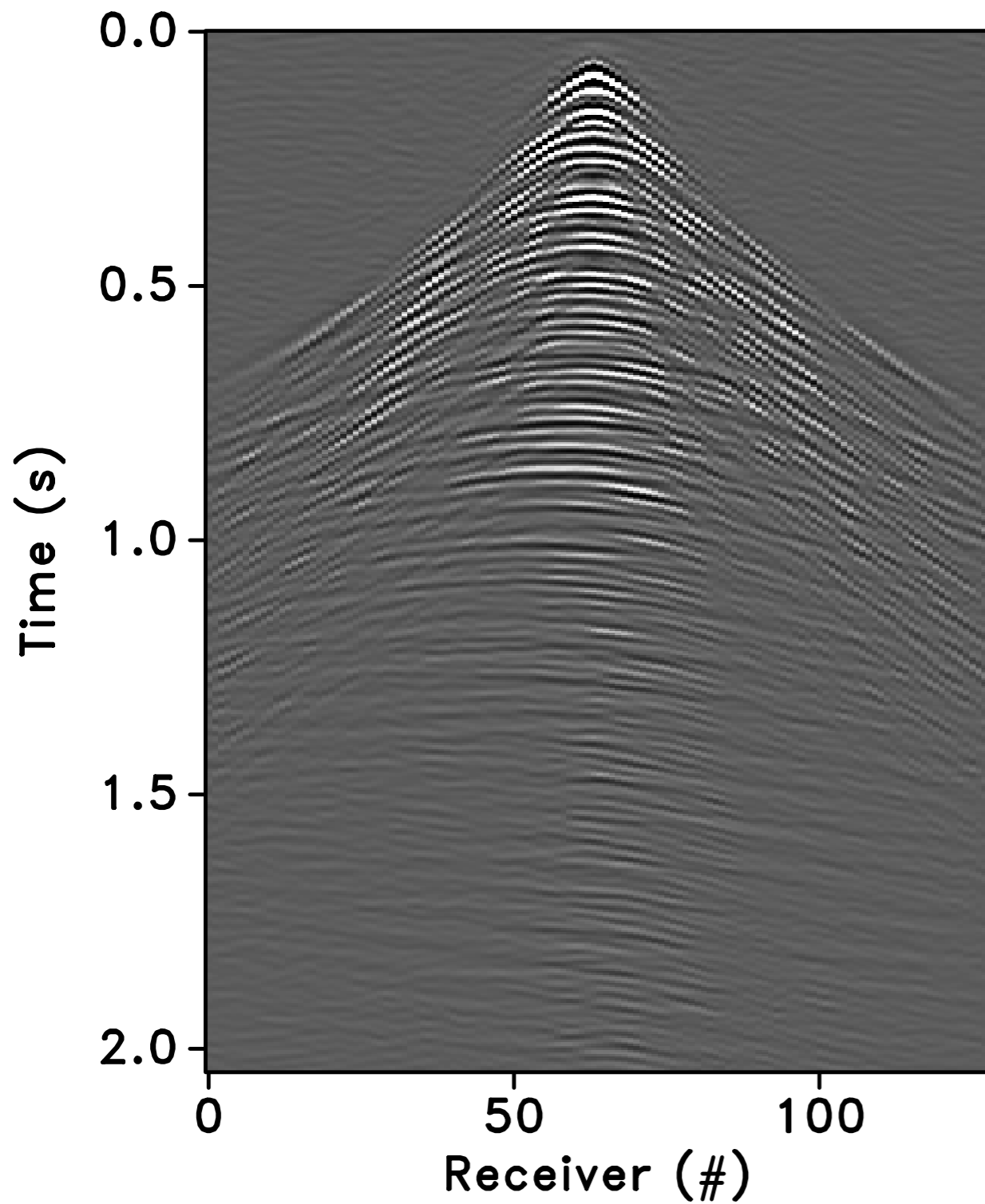
RESIDUAL



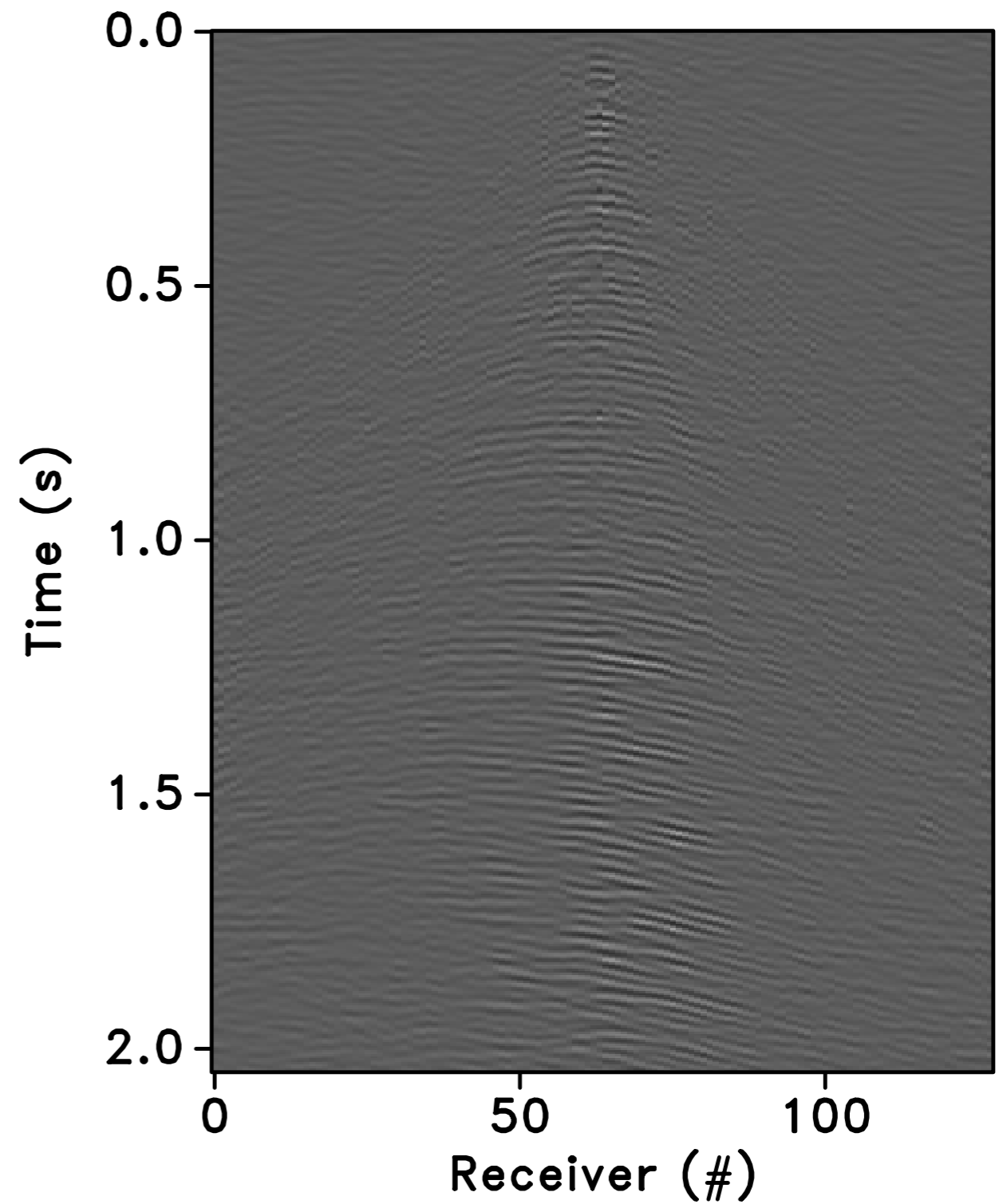
Random time-dithering

Sparsity-promoting recovery : 8.06 dB

RECOVERED



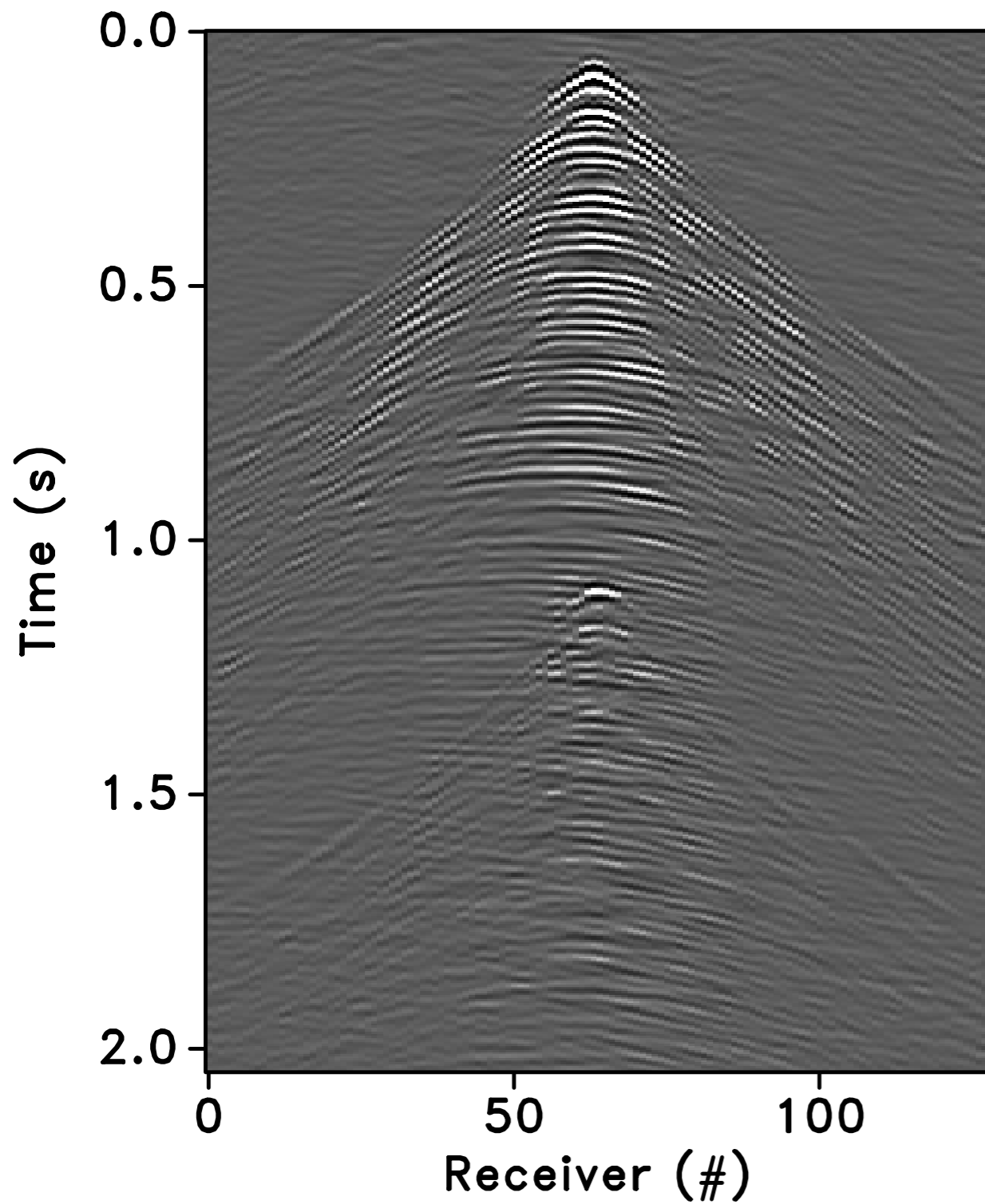
RESIDUAL



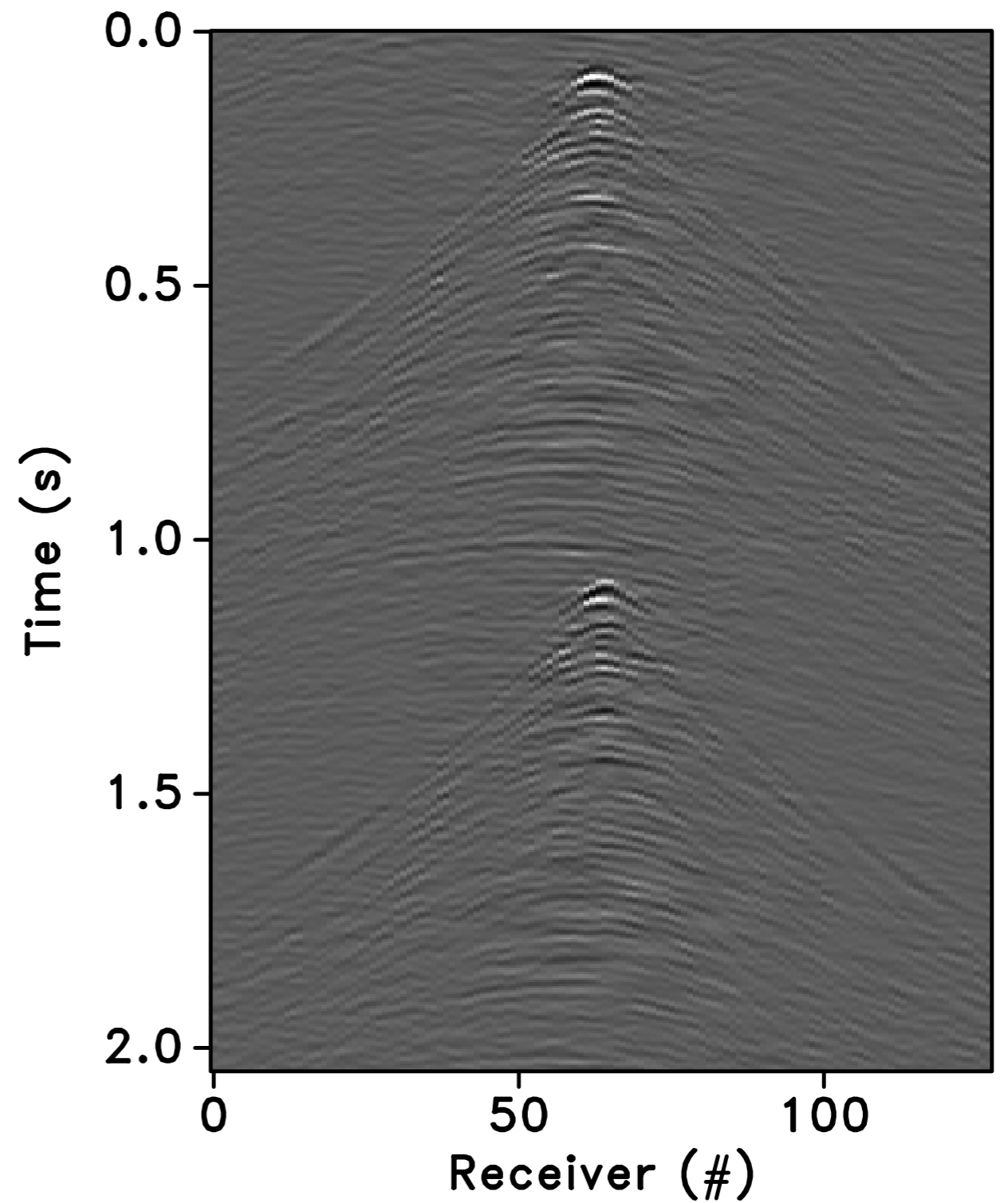
Periodic time-dithering

Sparsity-promoting recovery : 4.80 dB

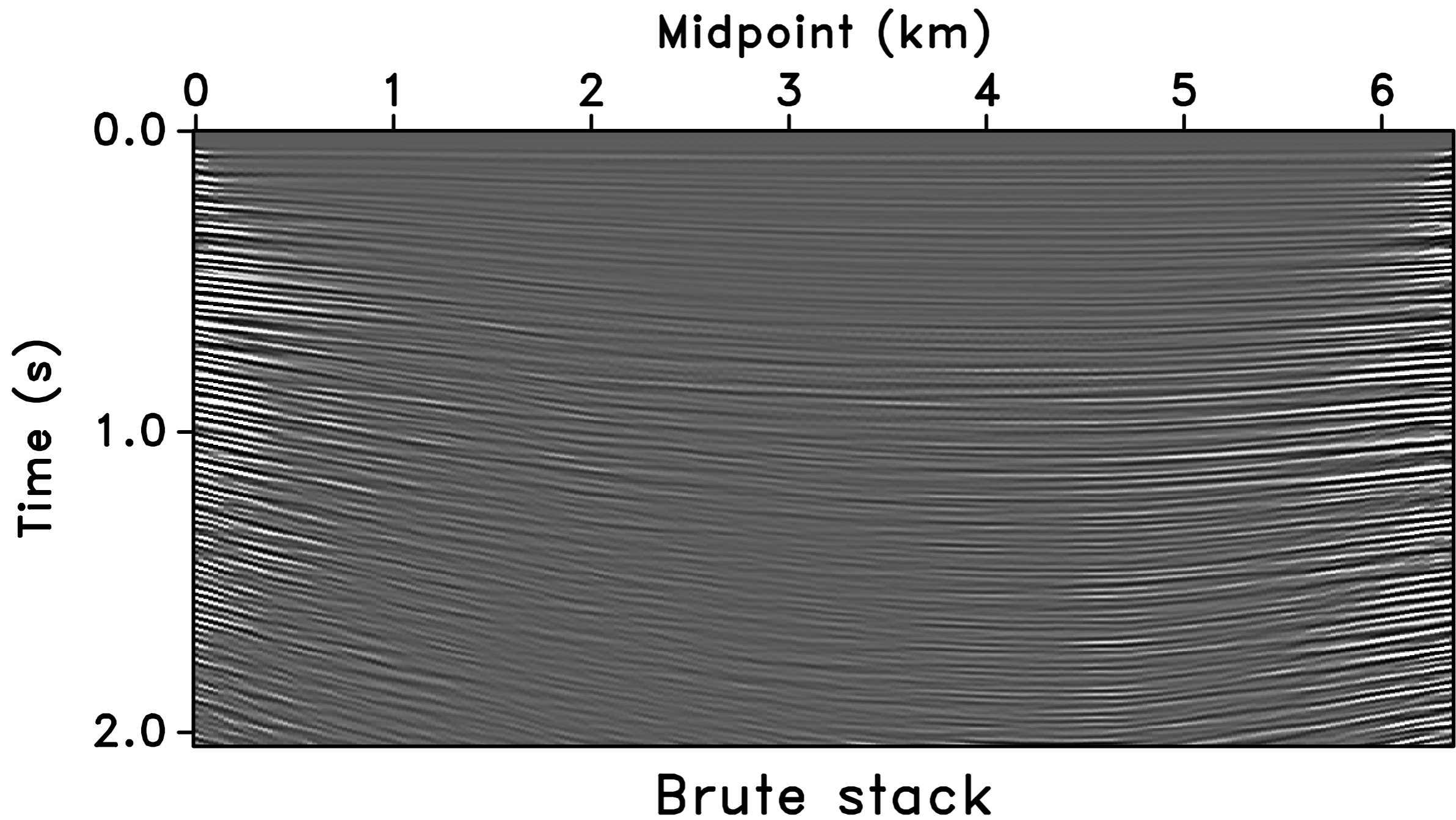
RECOVERED



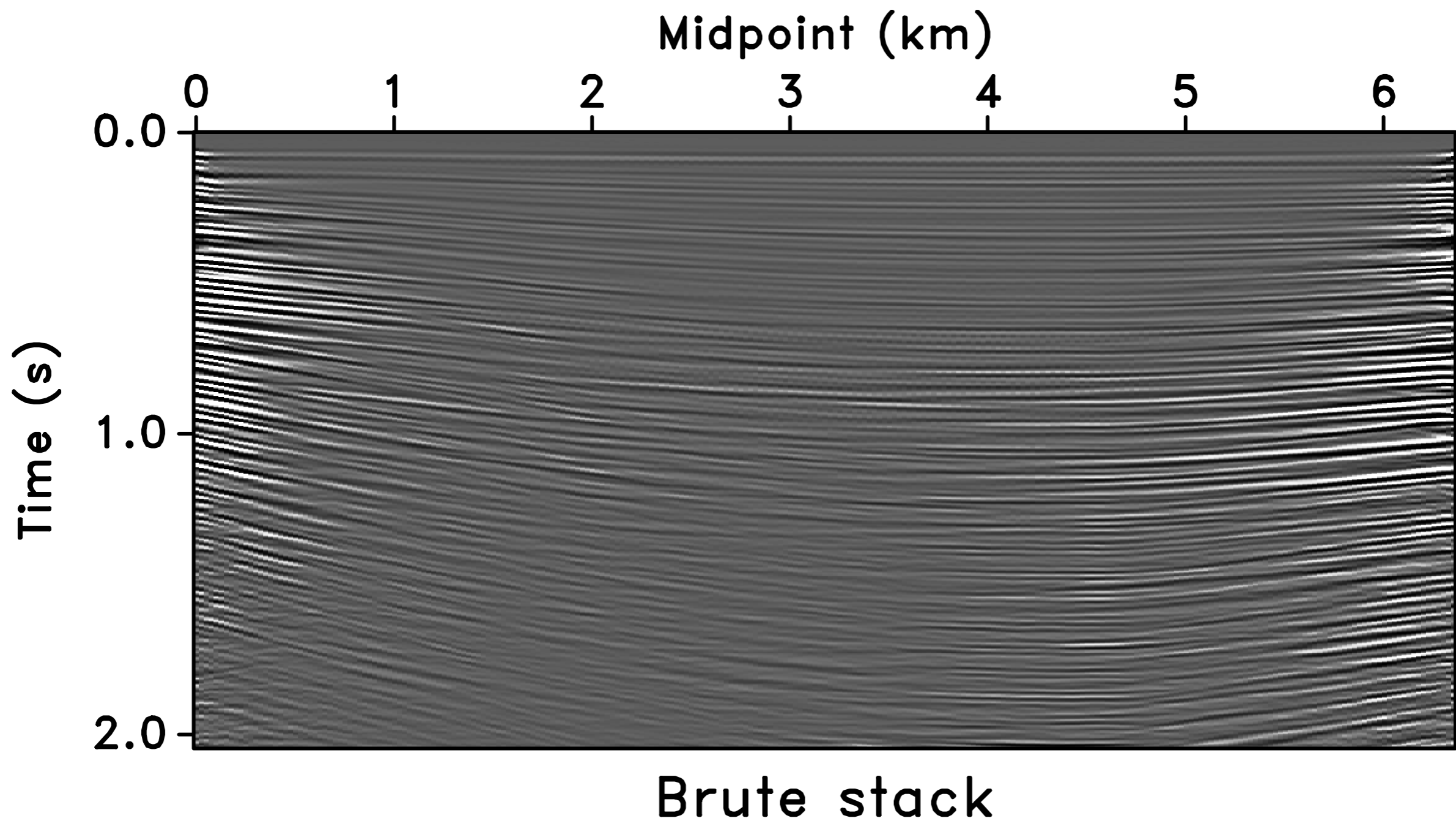
RESIDUAL



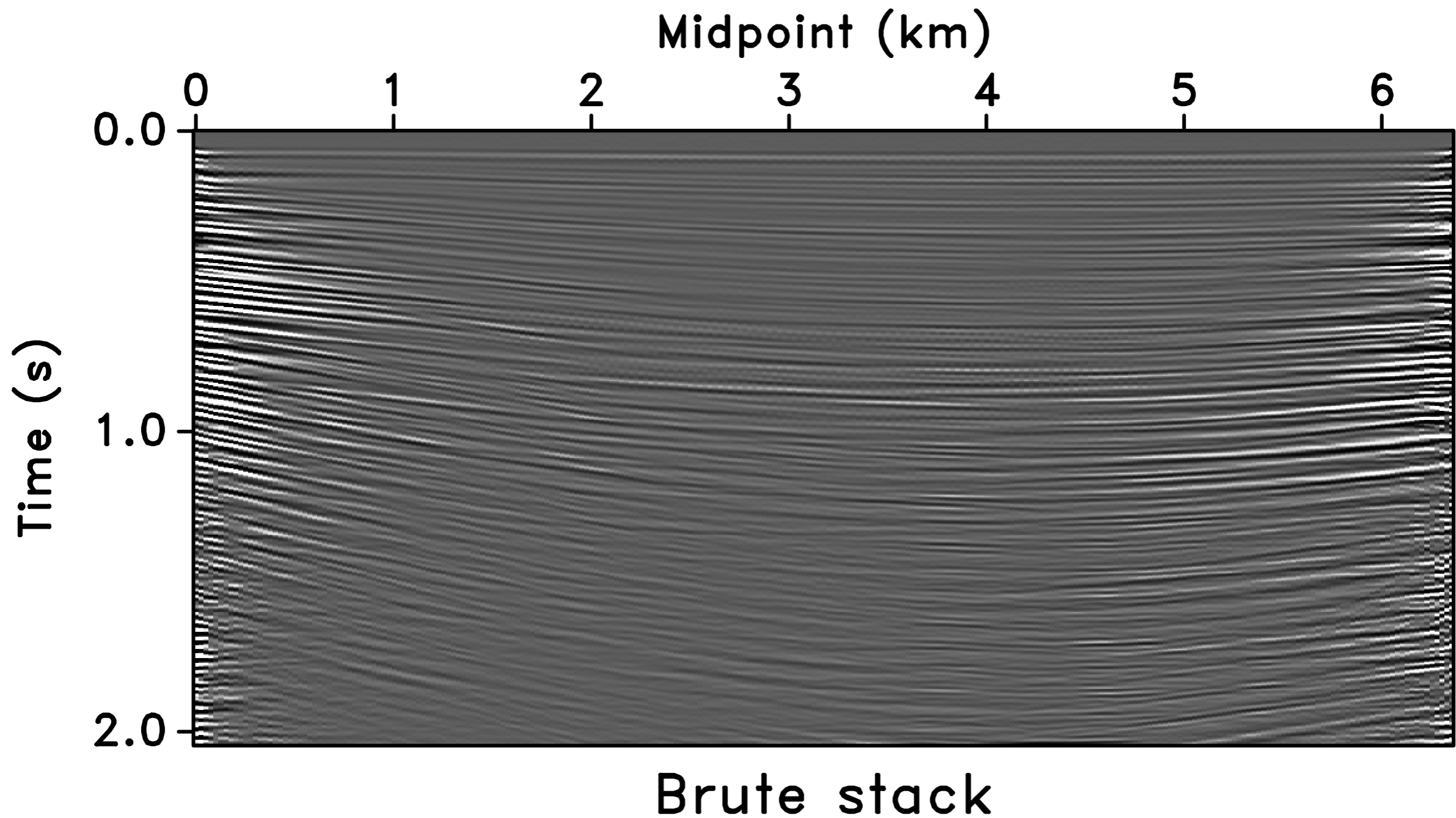
True data



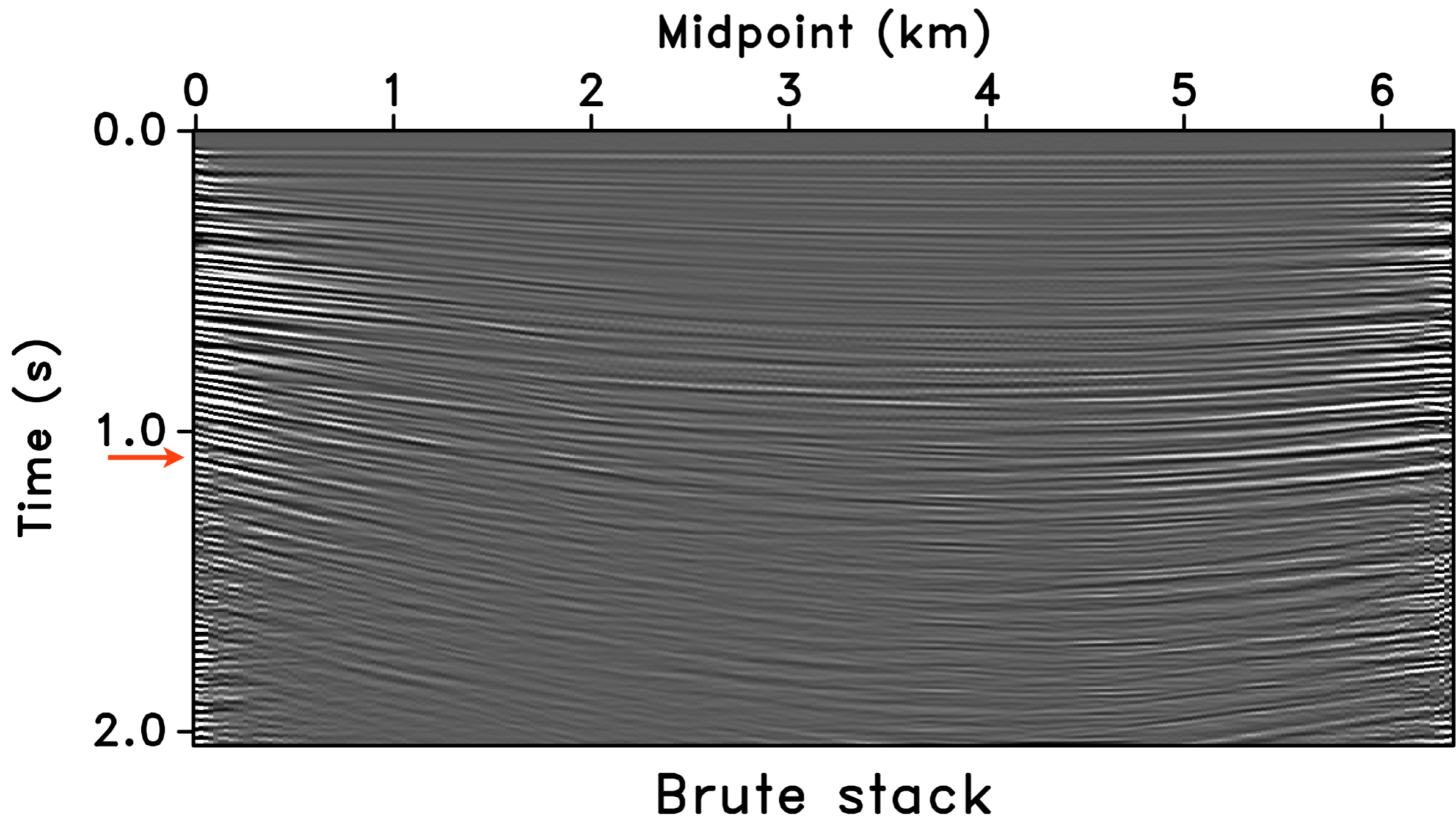
“Ideal” simultaneous acquisition



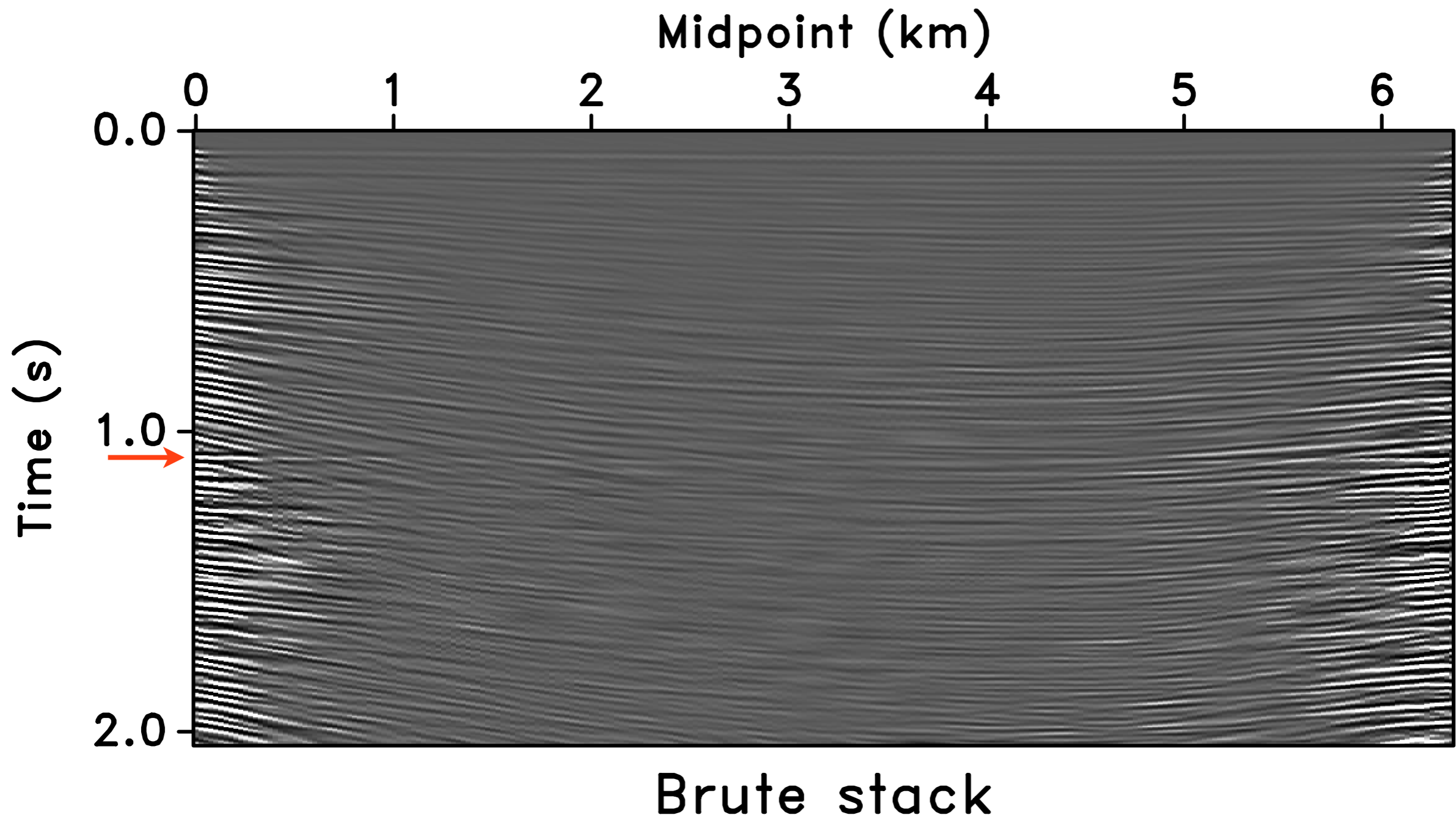
Random time-dithering



Random time-dithering



Periodic time-dithering

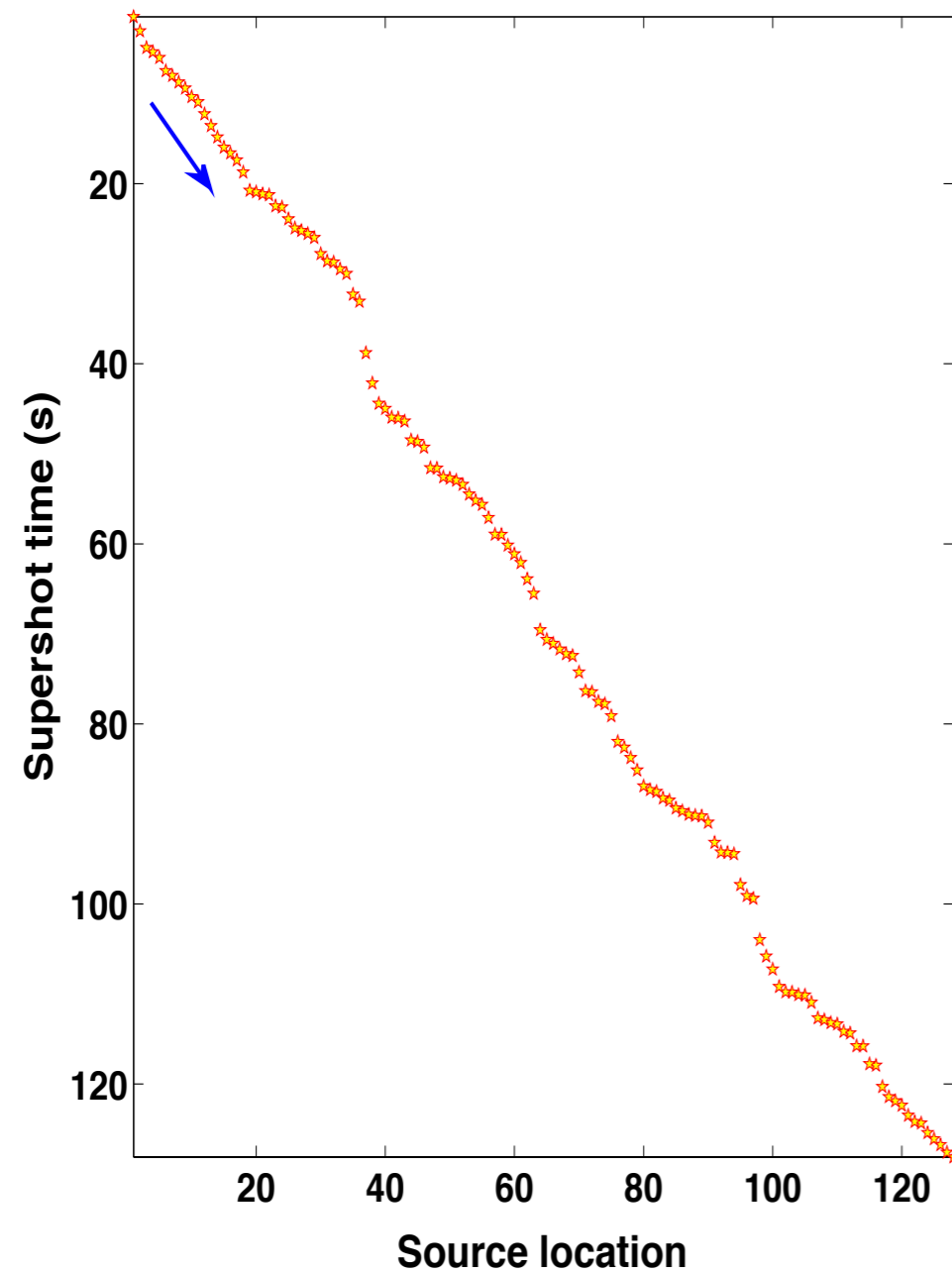


SNR (dB)

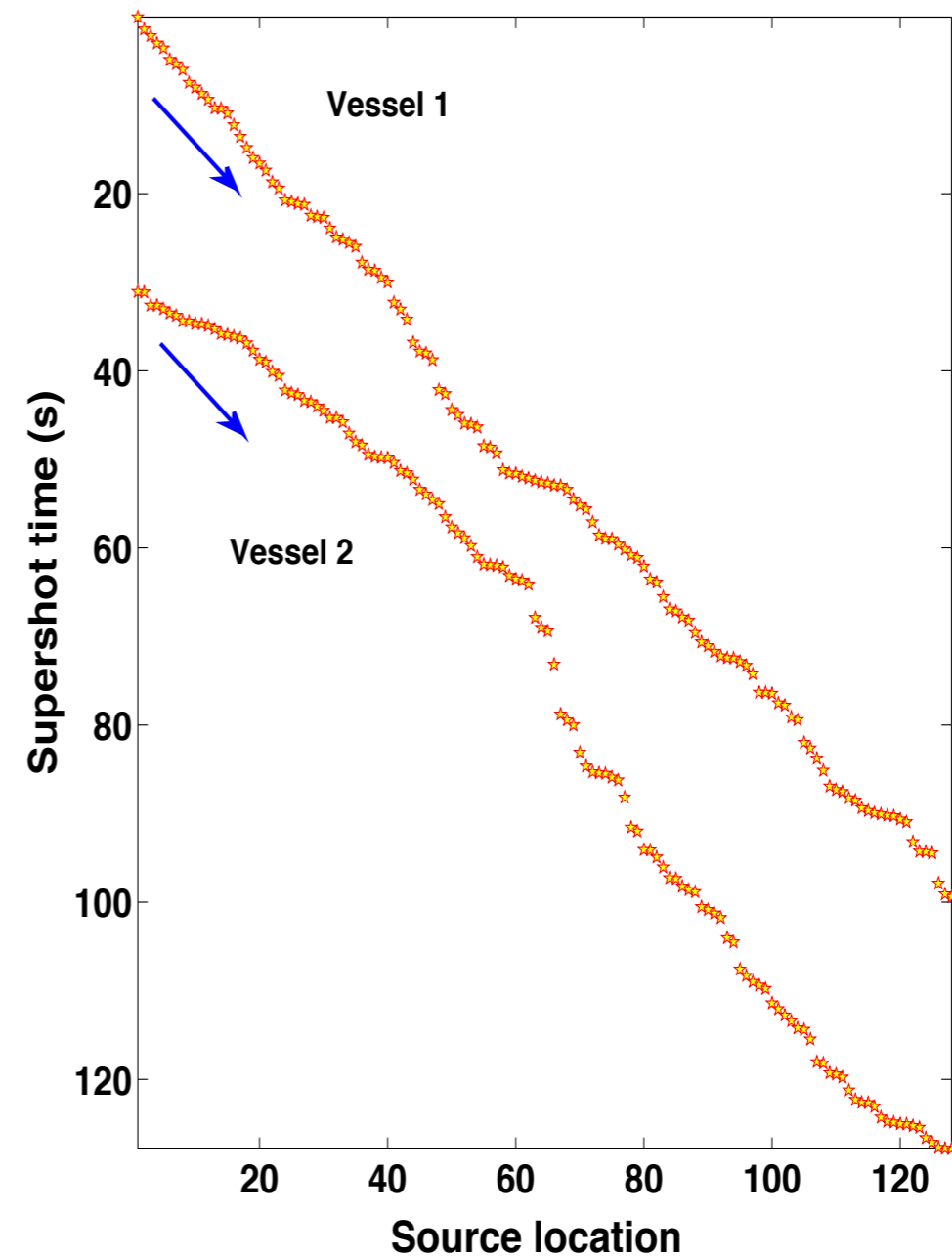
SUBSAMPLING RATIO	SIMULTANEOUS ACQUISITION	RANDOM TIME-DITHERING	PERIODIC TIME-DITHERING
0.75	13.0	11.2	6.93
0.50	10.5	8.06	4.80
0.33	8.31	5.33	*7.32
0.25	6.55	4.35	2.85
0.10	2.82	1.14	1.60

Random time-dithering

1 SOURCE VESSEL



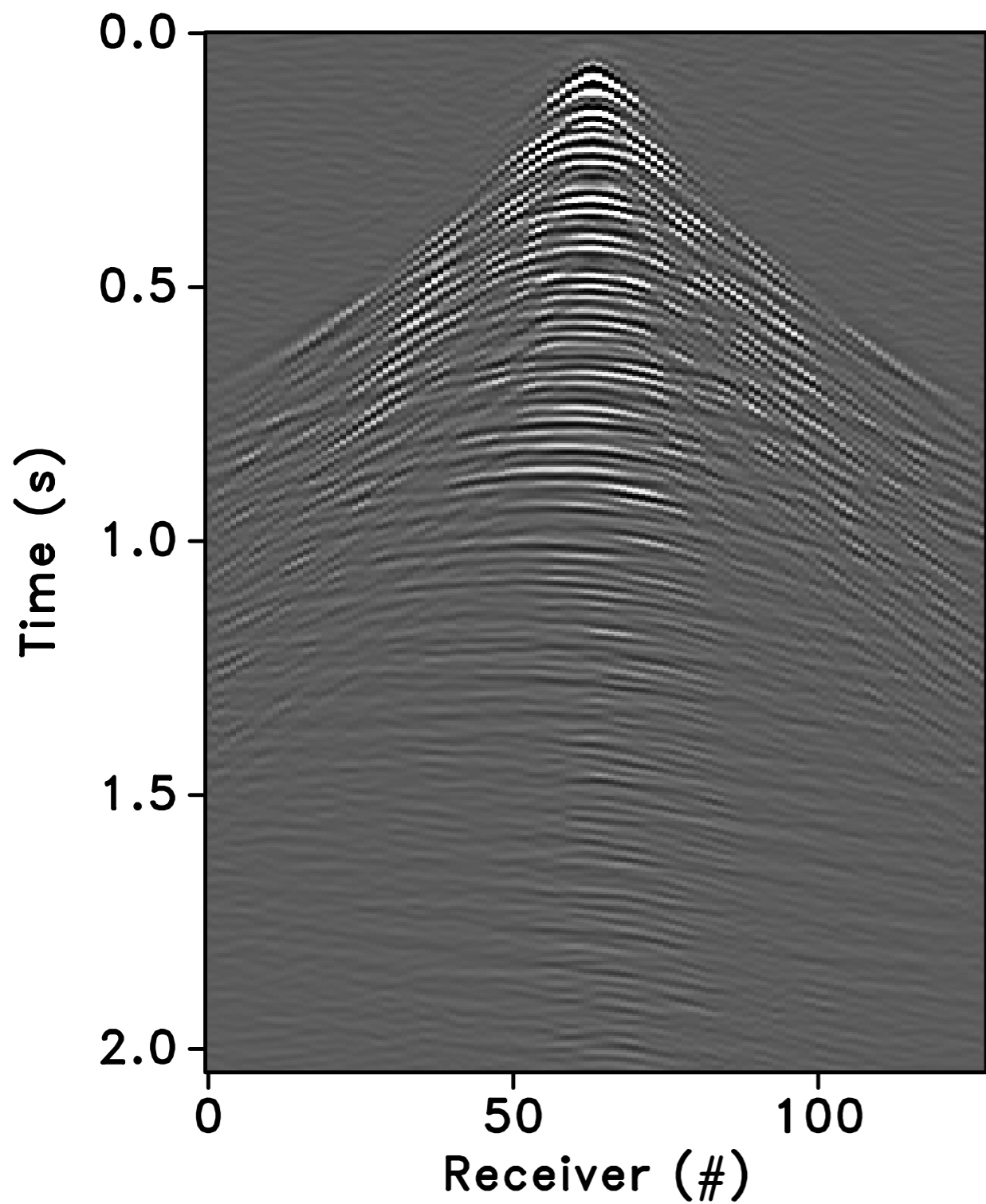
2 SOURCE VESSELS



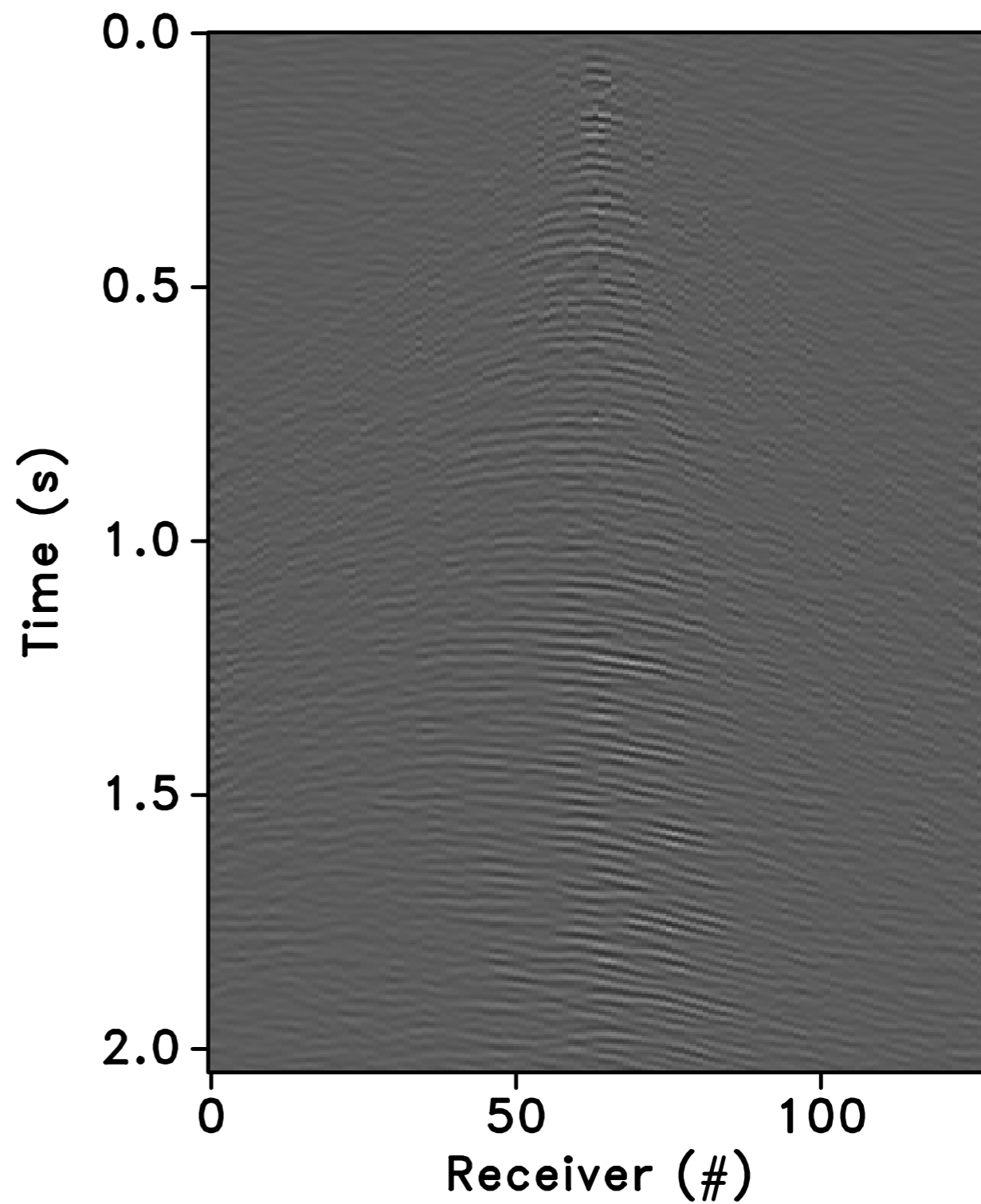
Random time-dithering with 1 source vessel

Recovery : 8.06 dB

RECOVERED



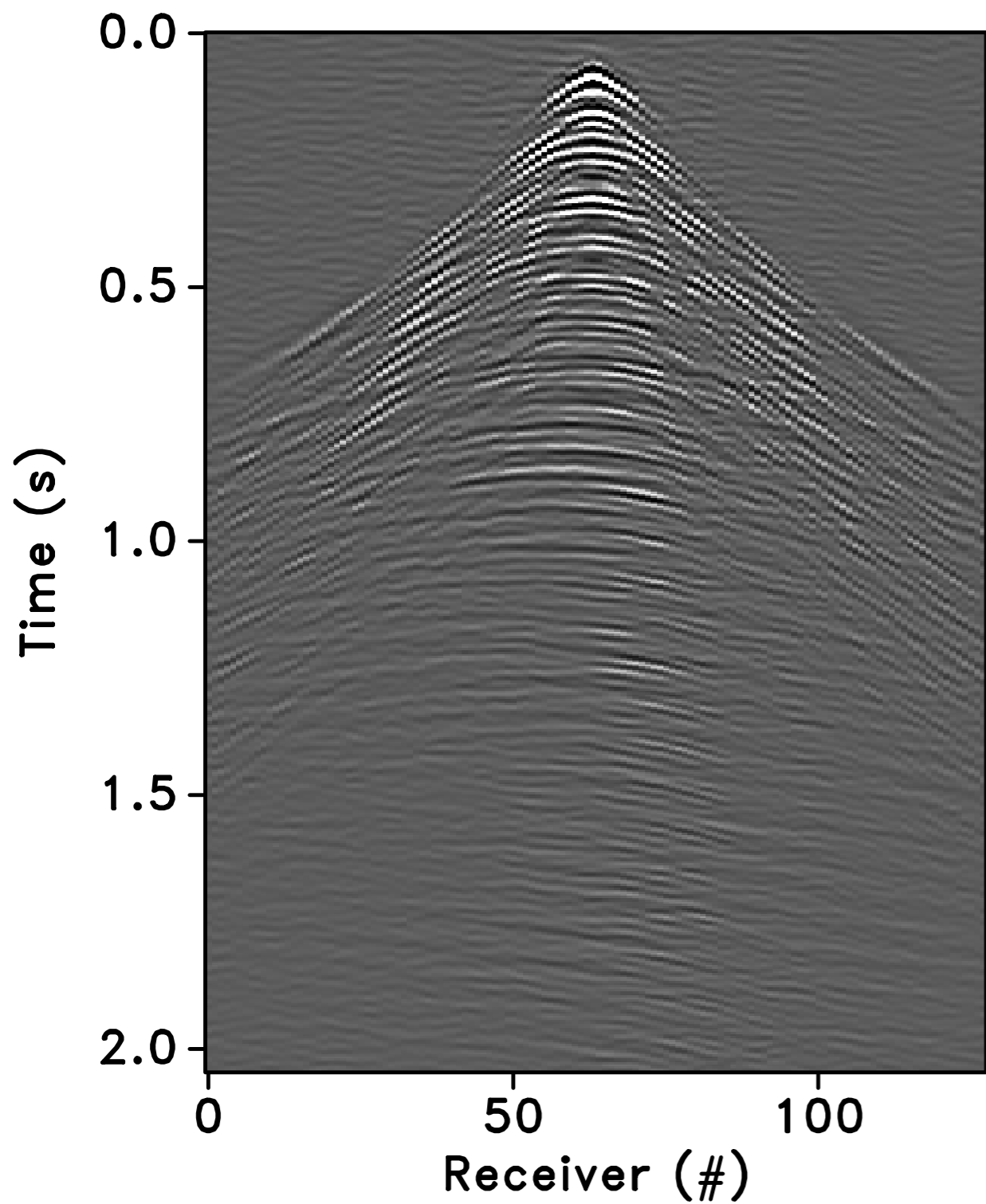
RESIDUAL



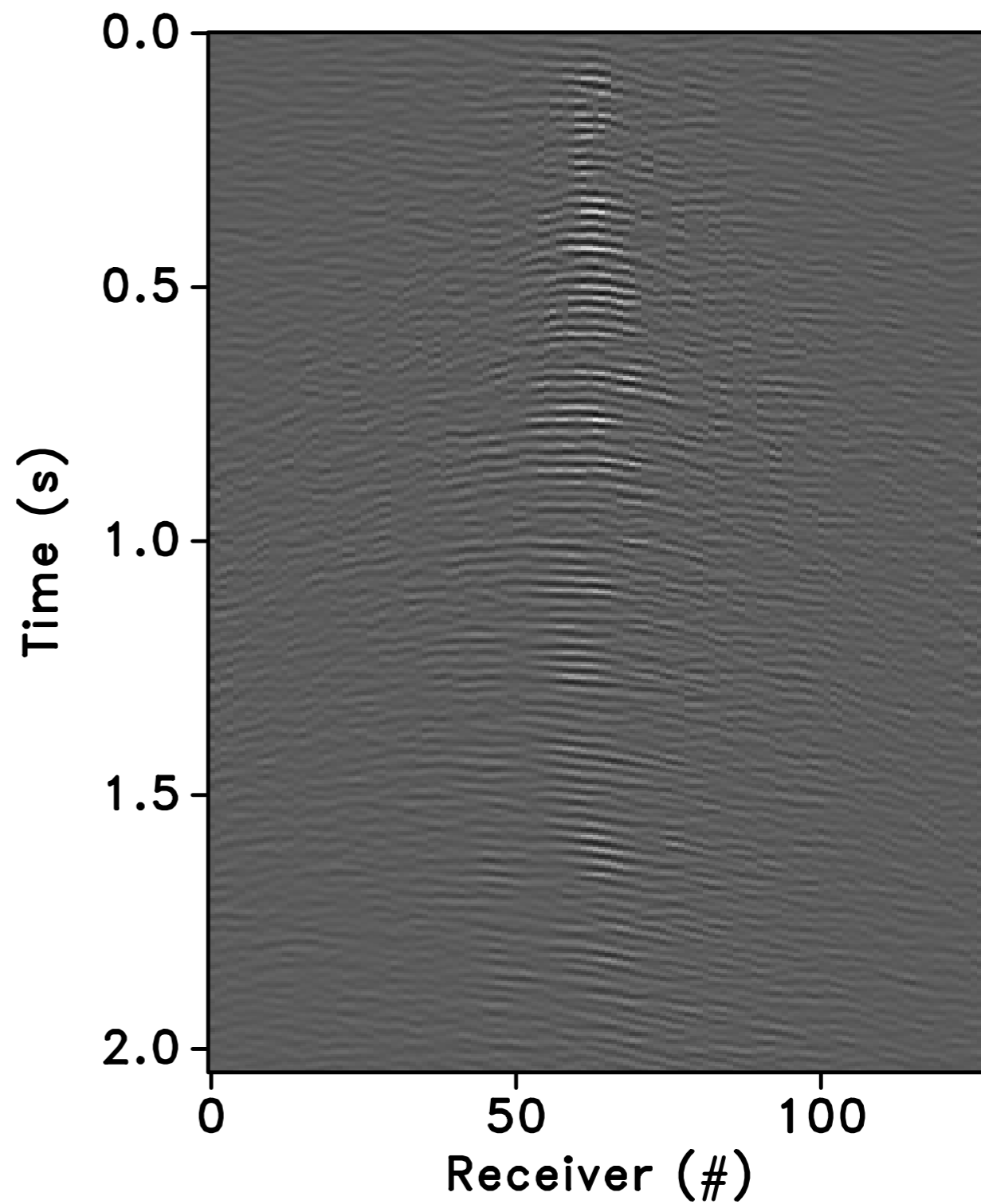
Random time-dithering with 2 source vessels

Recovery : 10.3 dB

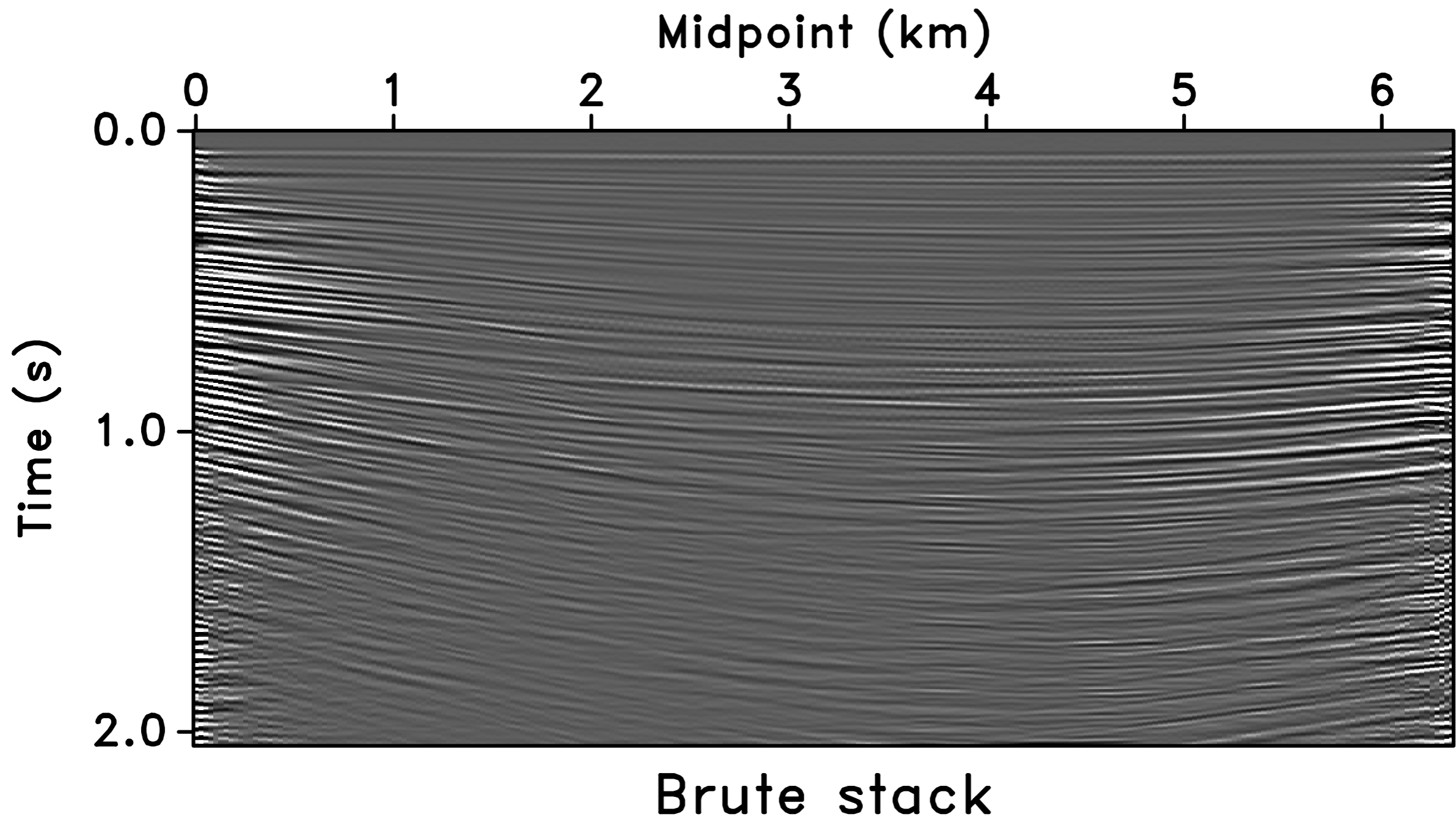
RECOVERED



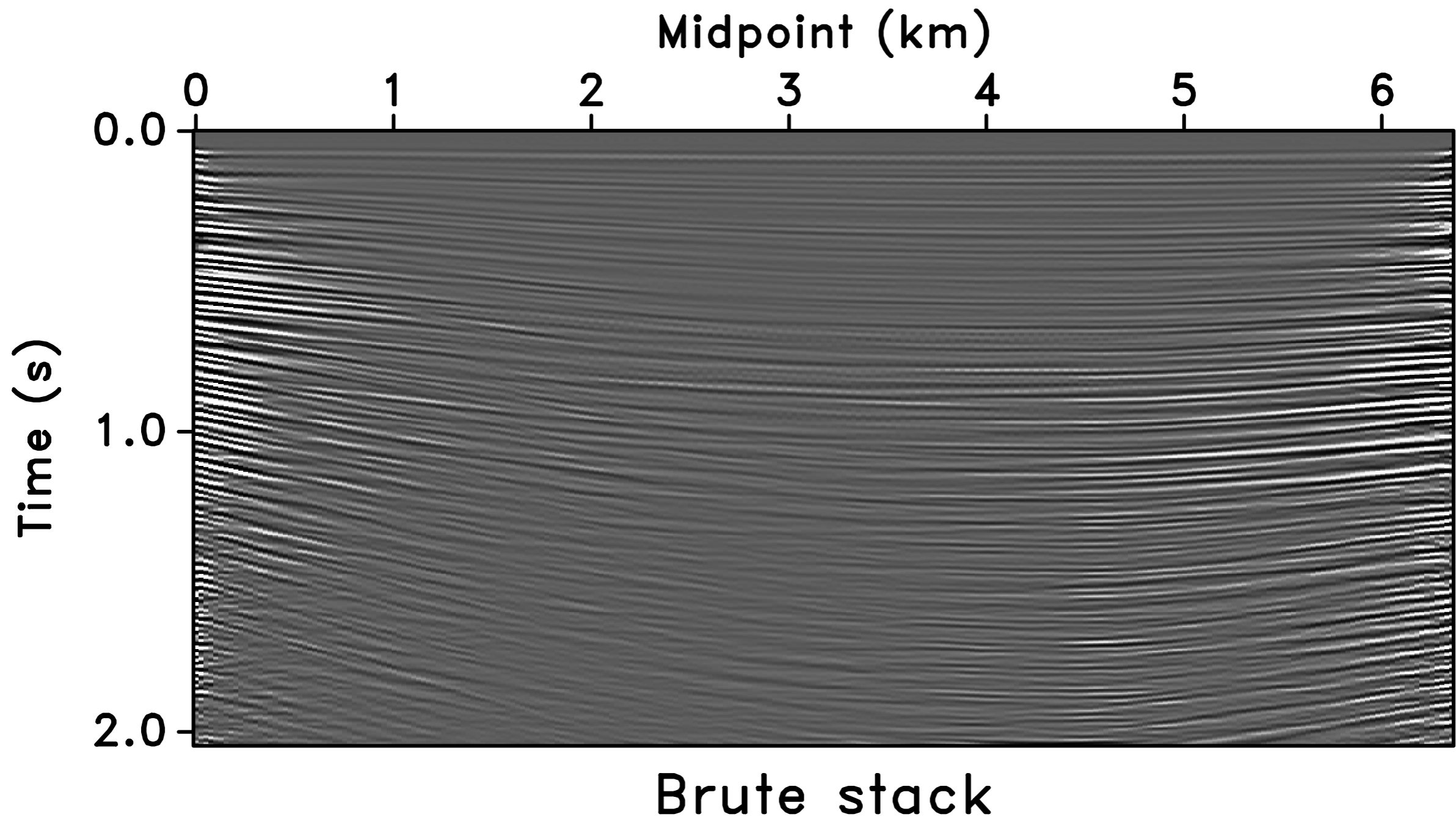
RESIDUAL



Random time-dithering with *1* source vessel



Random time-dithering with 2 source vessels



Conclusions

Randomized (simultaneous) marine acquisition is a *linear subsampling system*

Underlying interaction between *acquisition design* and *reconstruction fidelity*

Only dither: efficient marine acquisition - improves with simultaneous sources

Future work

Design *physically realizable* acquisition schemes

References

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SINBAD



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