Interpolation of diffracted multiples

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SEP - 124
Pages 225-234

Motivation

- Diffracted multiples are problematic, especially in the cross-line direction
- 3D SRME is one way to attack them, but
- 3D SRME needs dense and regular sampling

Interpolation of diffracted multiples

- Interpolating with prediction-error filters (PEFs)
- Description of dataset
- Flip-flop interpolation results
- Receiver cable interpolation results

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PEF-based interpolation

Interpolation can be done in two steps:

1. Gather some information about what data you have (estimate a PEF)
2. Use that knowledge to fill the holes

Estimating a PEF

$$\mathbf{0} \quad \approx \quad \mathbf{r} = \begin{bmatrix} d_2 & d_1 & d_0 \\ d_3 & d_2 & d_1 \\ d_4 & d_3 & d_2 \\ d_5 & d_4 & d_3 \\ d_6 & d_5 & d_4 \end{bmatrix} \begin{bmatrix} 0 & \cdot & \cdot \\ \cdot & 1 & \cdot \\ \cdot & \cdot & 1 \end{bmatrix} \begin{bmatrix} 1 \\ f_1 \\ f_2 \end{bmatrix} + \begin{bmatrix} d_2 \\ d_3 \\ d_4 \\ d_5 \\ d_6 \end{bmatrix}$$

Convolve data (d_i) with an unknown filter (f_i)
Force the first coefficient to be 1

Estimating a PEF

$$\min_{\mathbf{f}} \|\mathbf{W}(\mathbf{D}\mathbf{f})\|^2$$

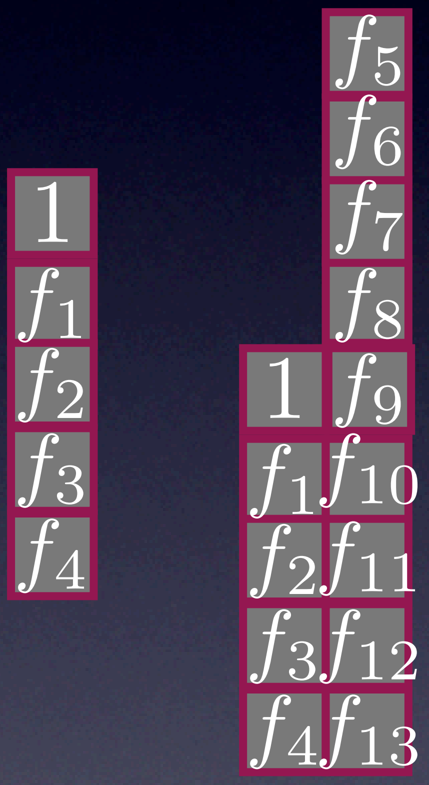
$\mathbf{W}$ is a diagonal weight for missing data

$\mathbf{D}$ is convolution with the data

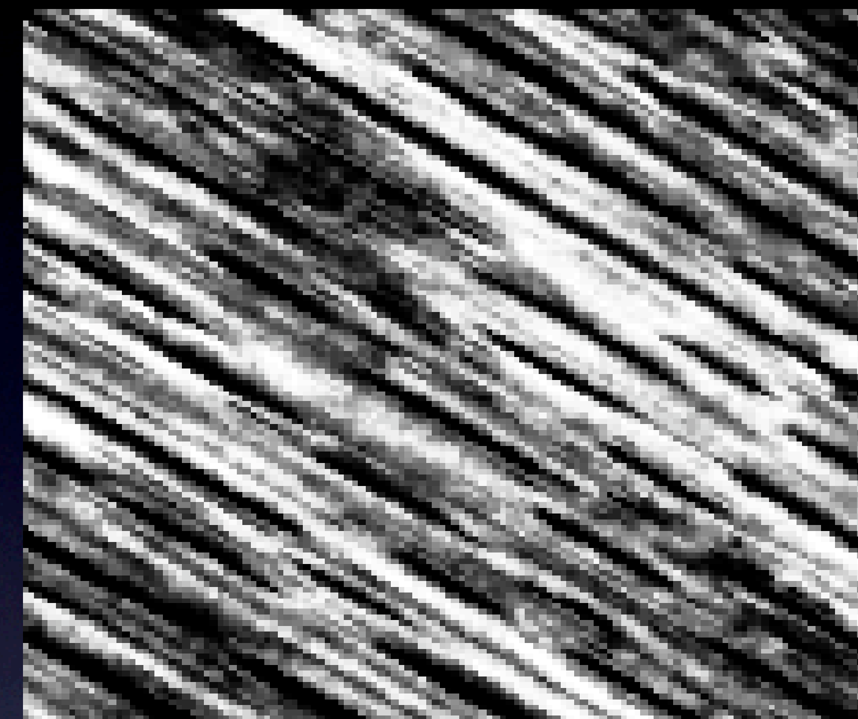
$\mathbf{f}$ is the unknown filter

Multi-dimensional PEFs

- A PEF can be n-dimensional
- Implementation is straightforward with the helical coordinate



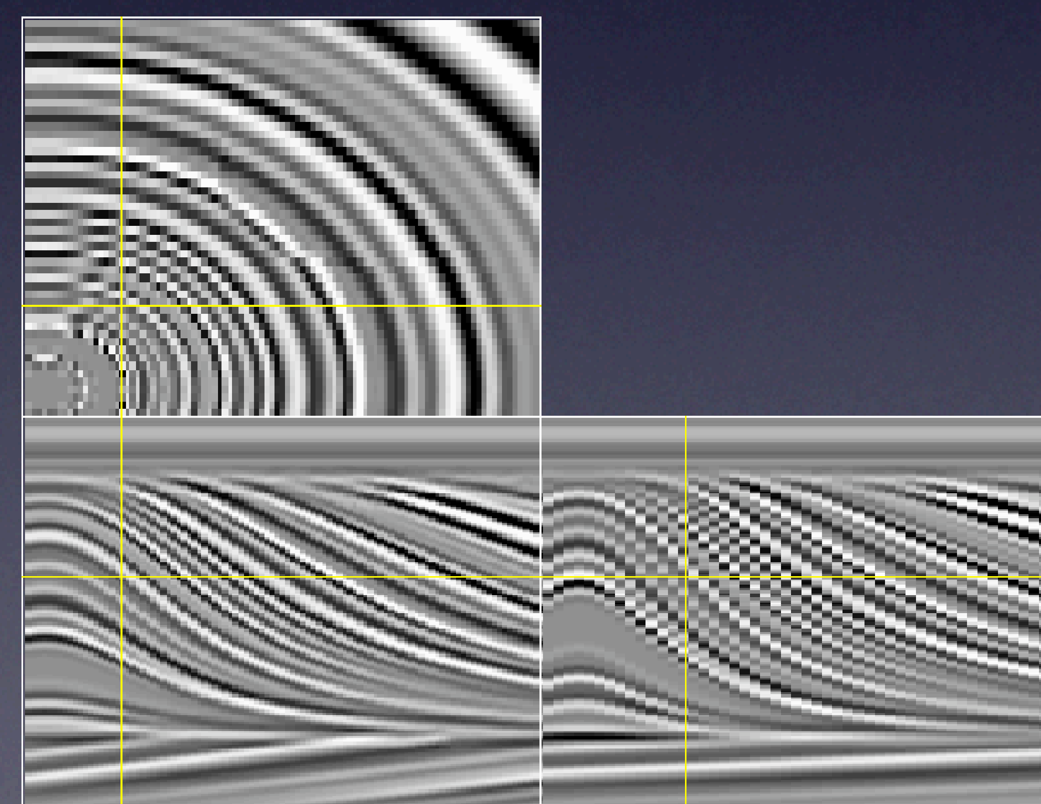
Non-stationary PEFs



- The statistics of our data often change with position
- Options:
  - break the problem up into stationary regions

  OR

  - deal with everything at once with non-stationary filters



Estimating a non-stationary PEF

$$\min_{\mathbf{f}} \|\mathbf{W}(\mathbf{Df})\|^2 + \epsilon^2 \|\mathbf{Af}\|^2$$

$\mathbf{W}$ is a diagonal weight for missing data

$\mathbf{D}$ is convolution with the data

$\mathbf{A}$ is a regularization operator

$\mathbf{f}$ is the unknown filter

ϵ is a tradeoff parameter

Filling in missing data

- Estimate the PEF, then use it in a second least-squares problem

$$\min_{\mathbf{m}} \parallel \mathbf{m} - \mathbf{d} \parallel^2 + \epsilon^2 \parallel \mathbf{F}\mathbf{m} \parallel^2$$

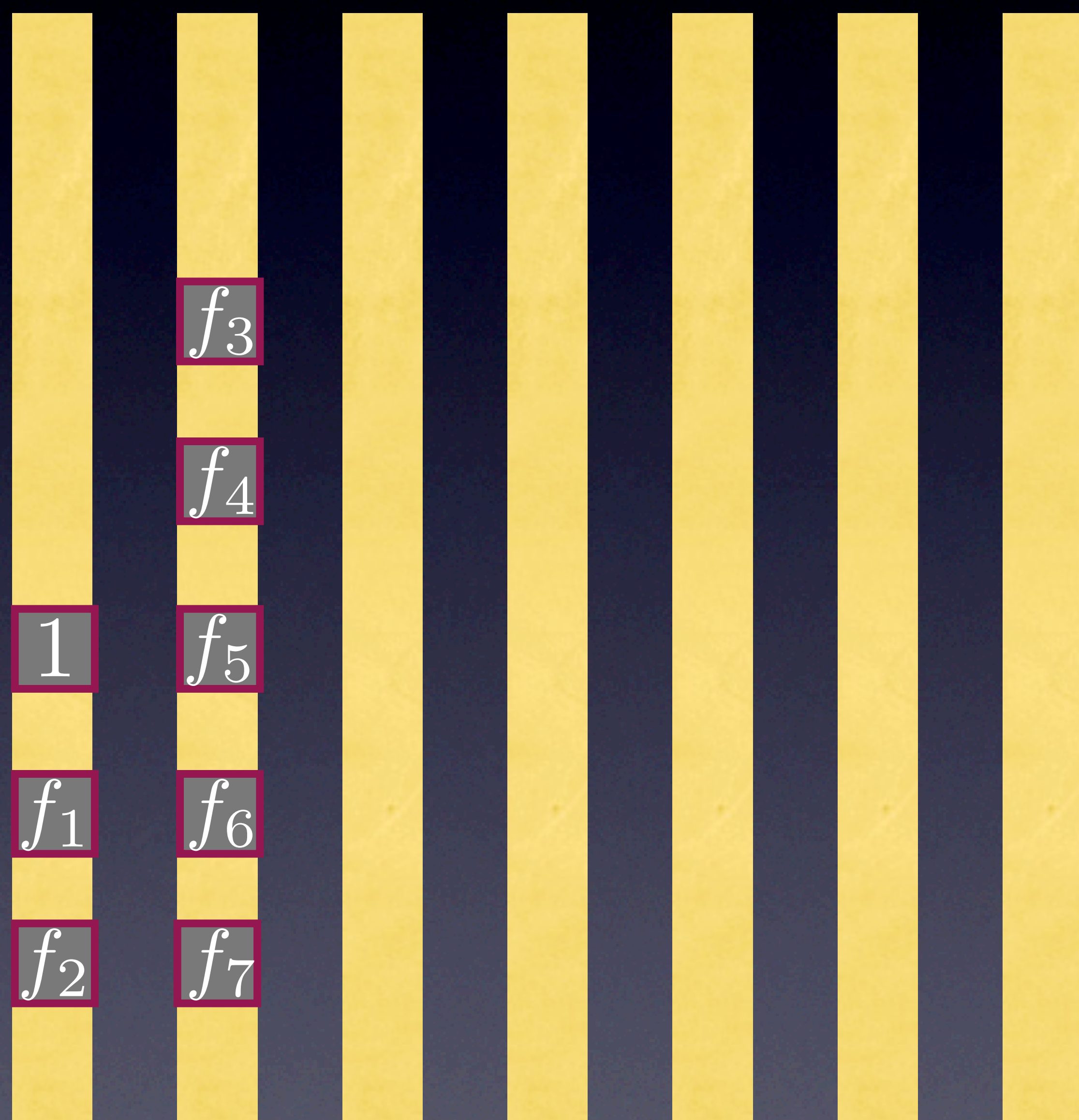
- Minimize convolution of the PEF with the model and honor the original data

Interpolating by a factor of 2

- If any part of the PEF falls on unknown data, $W_i = 0$
- If $W = 0$ everywhere, we cannot estimate a PEF

$$W_i = 0$$

Interpolating by a factor of 2



- By spreading the filter out, we can avoid $W_i = 0$
- If $W = 0$ everywhere, we cannot estimate a PEF

$$W_i = 1$$

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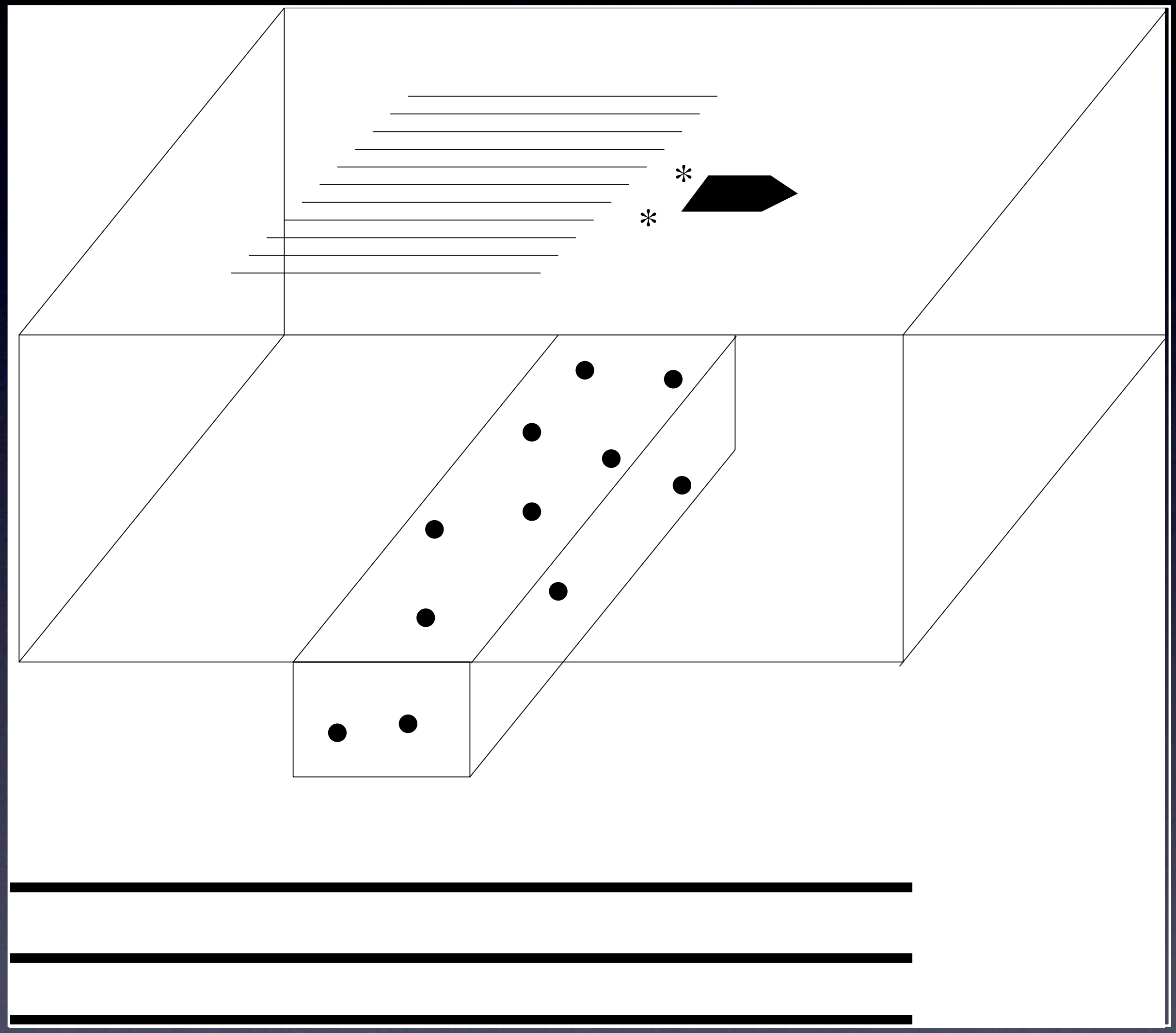
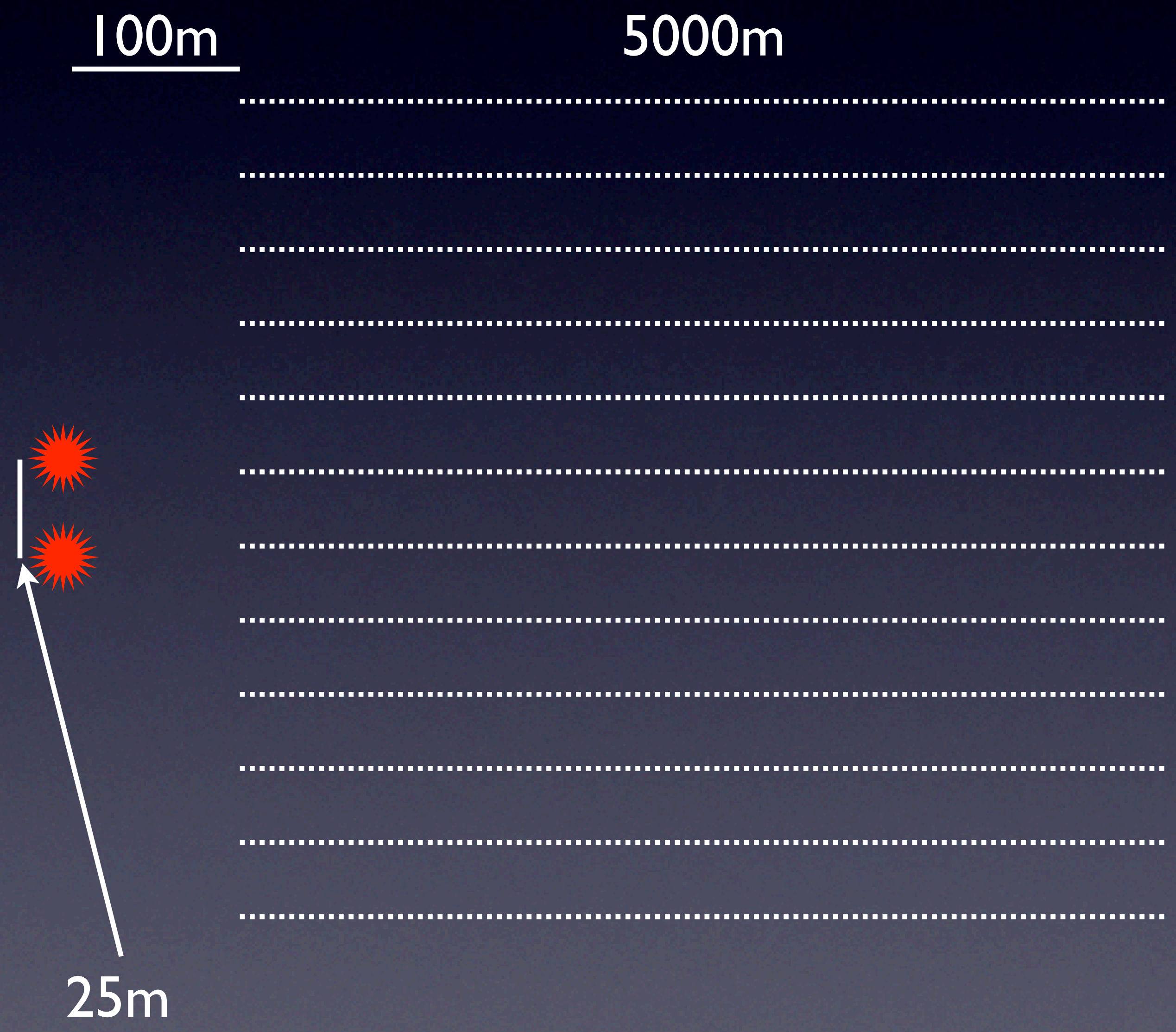
Lots of diffractors

- constant-velocity
- 500 point diffractors
- reflections interfere with diffracted multiples



Acquisition Geometry

	sampling (m)	interpolation desired
receivers (inline)	12.5m	0x
shots (inline)	37.5m (flops)	3x
receiver cables (crossline)	50m	4x
sail lines (crossline)	200m	16x 8x (w/flops)



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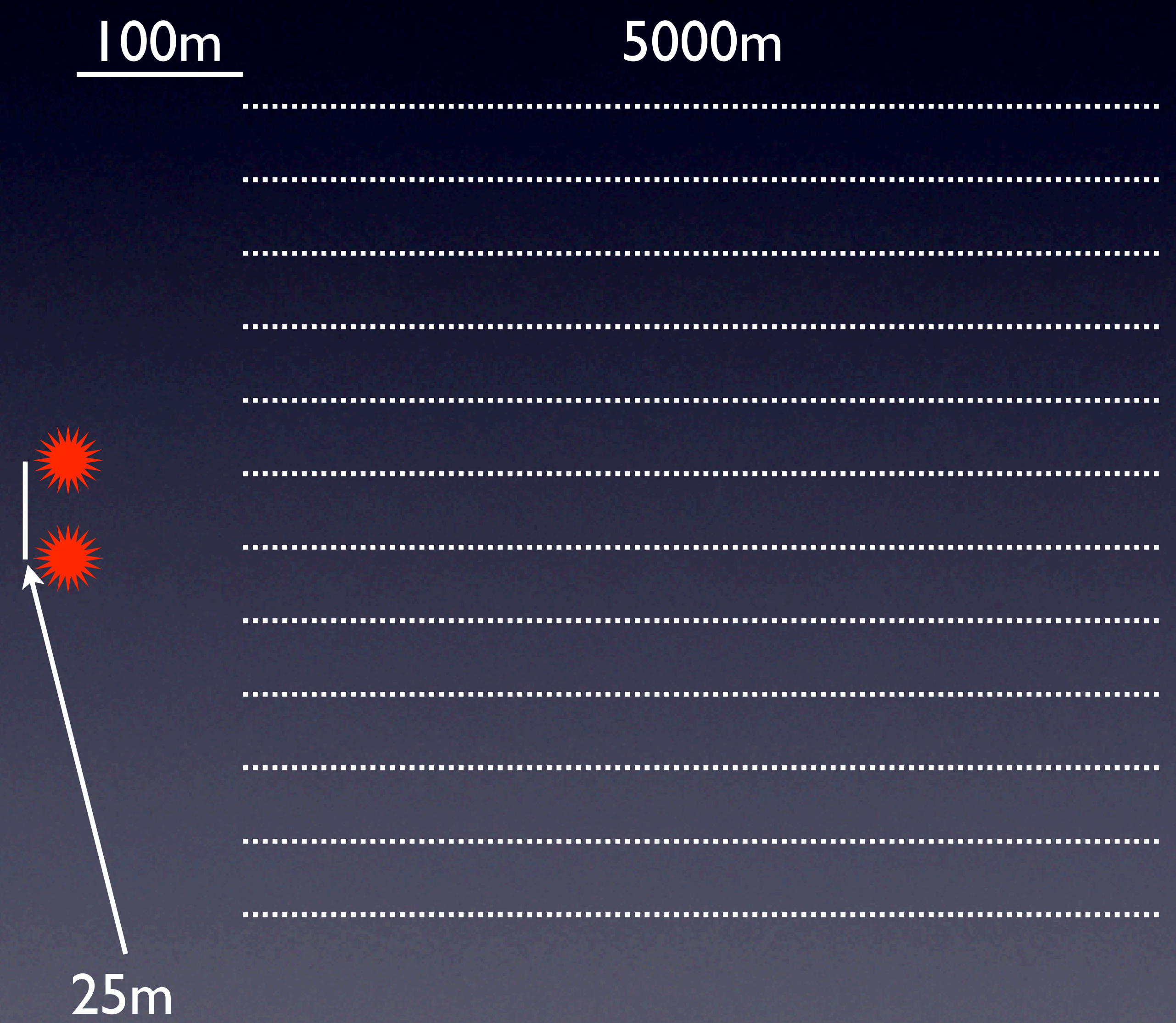

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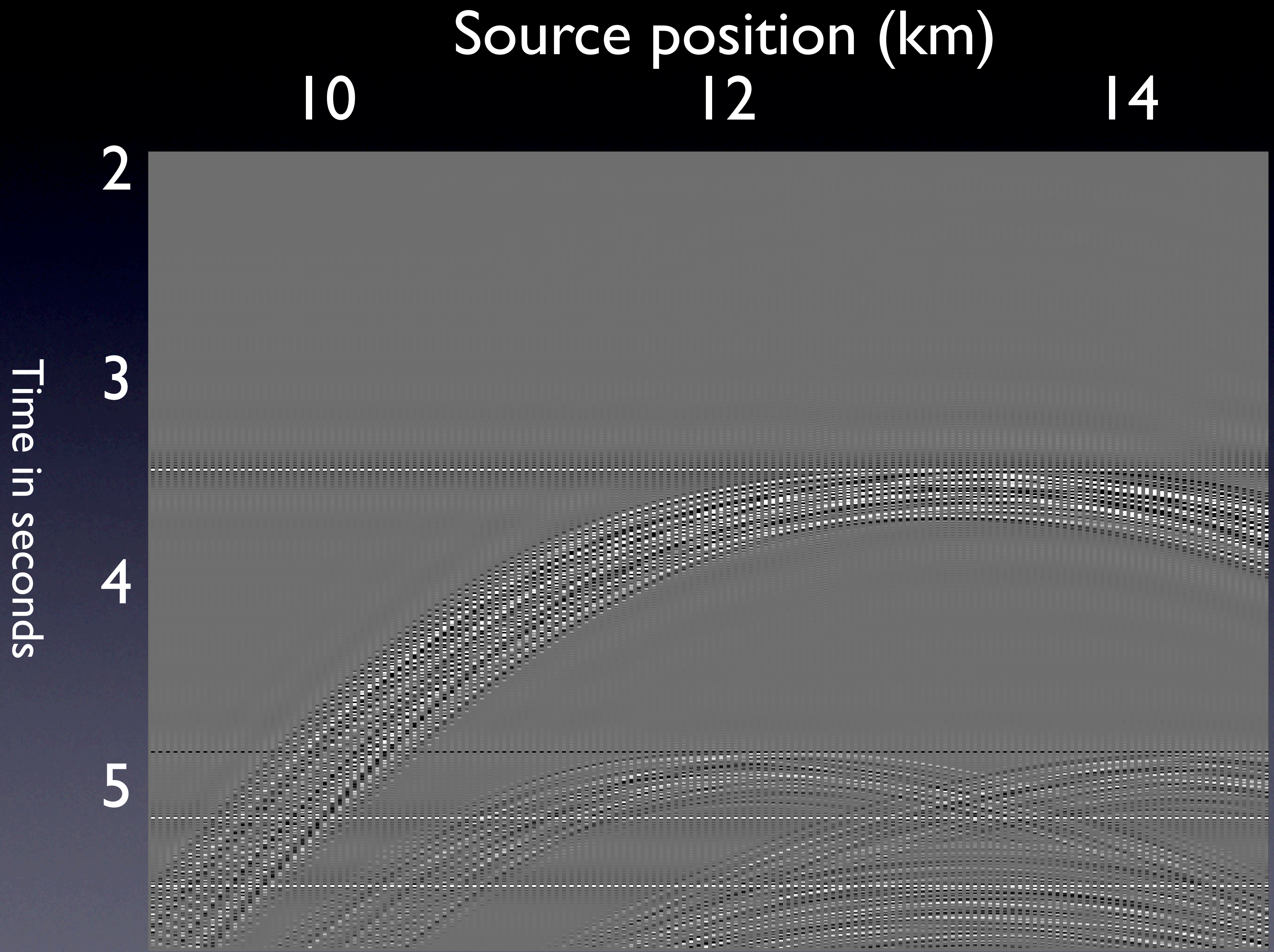
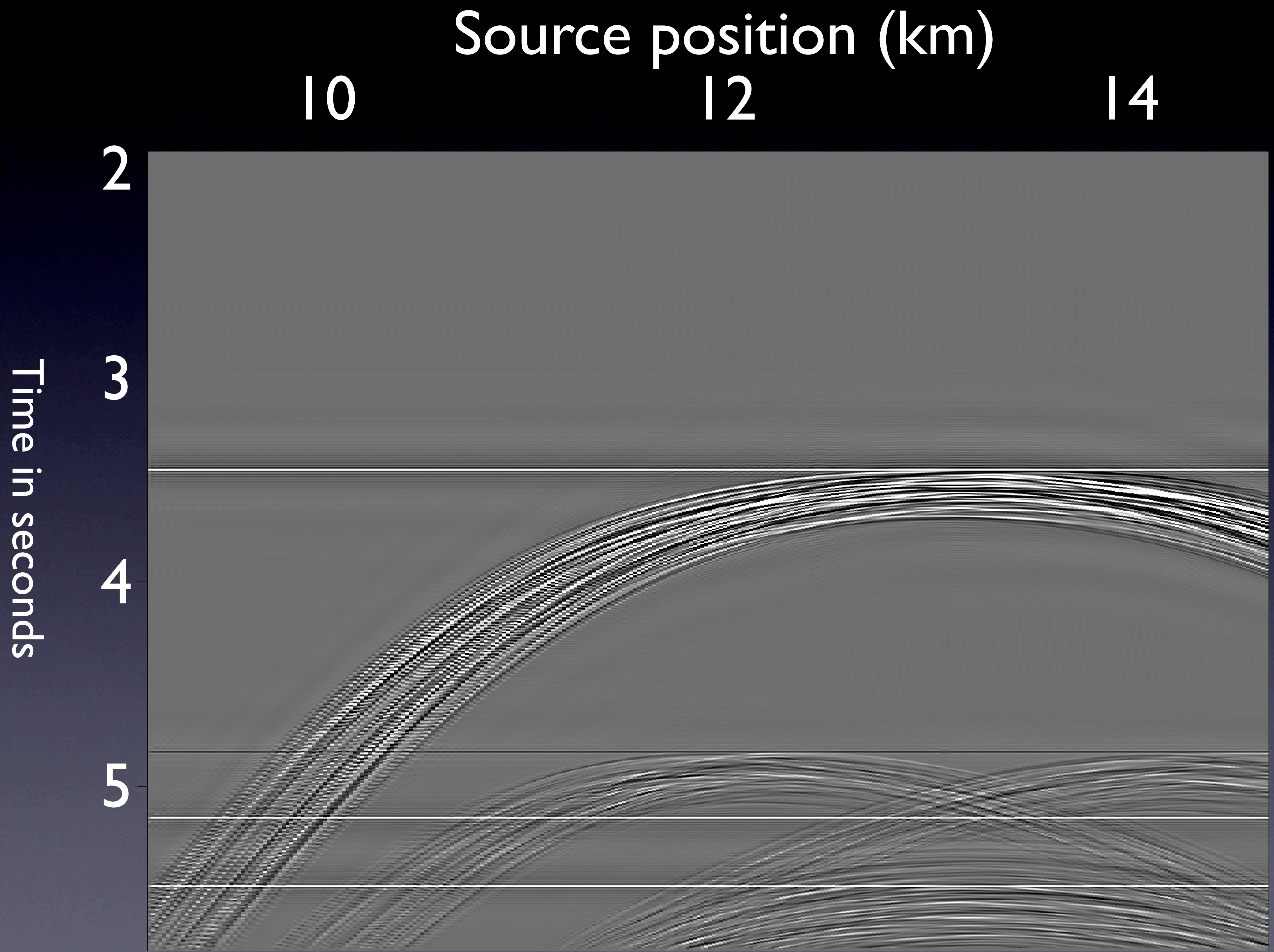
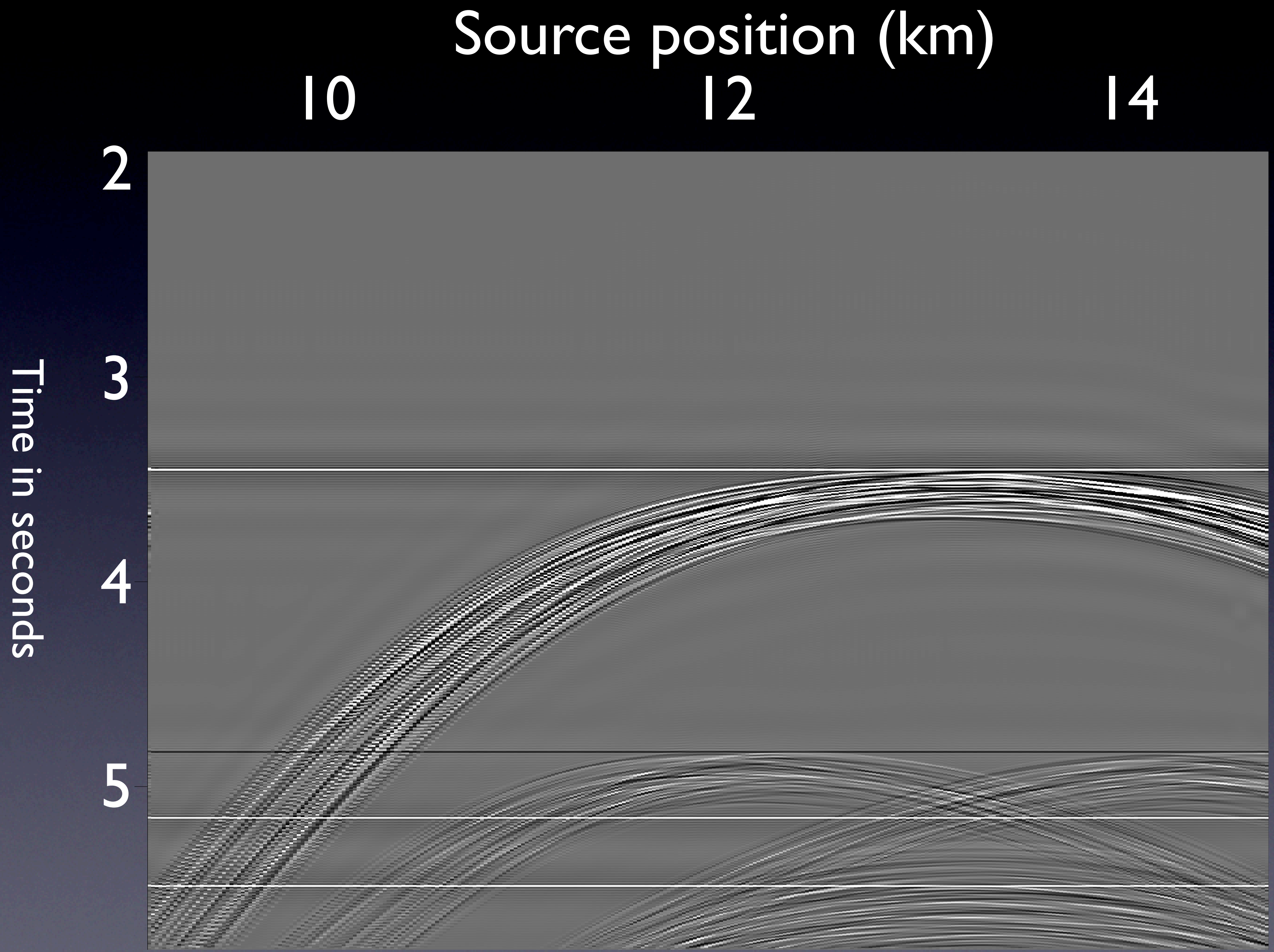
Common-Receiver Gather



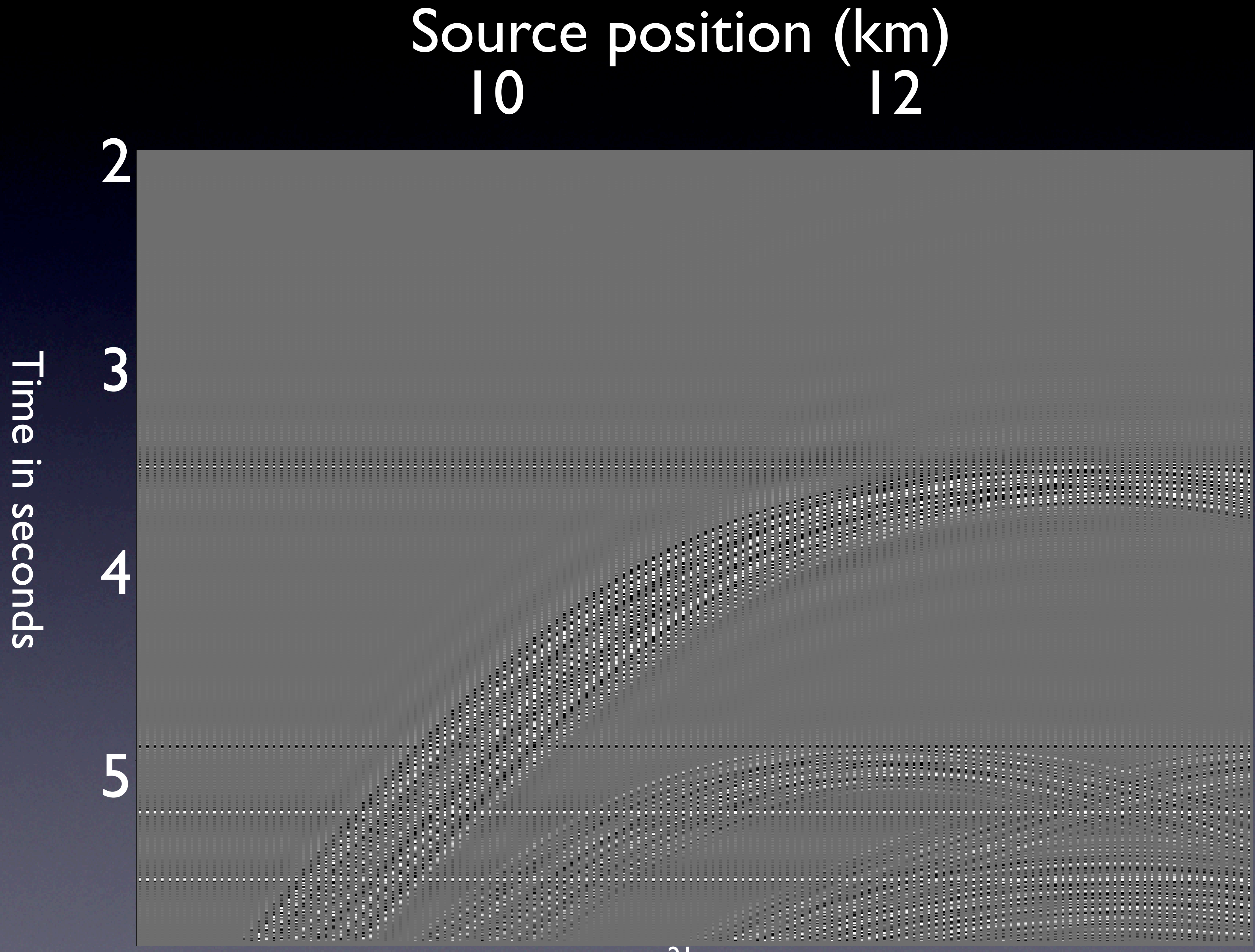
2D PEF Interpolation



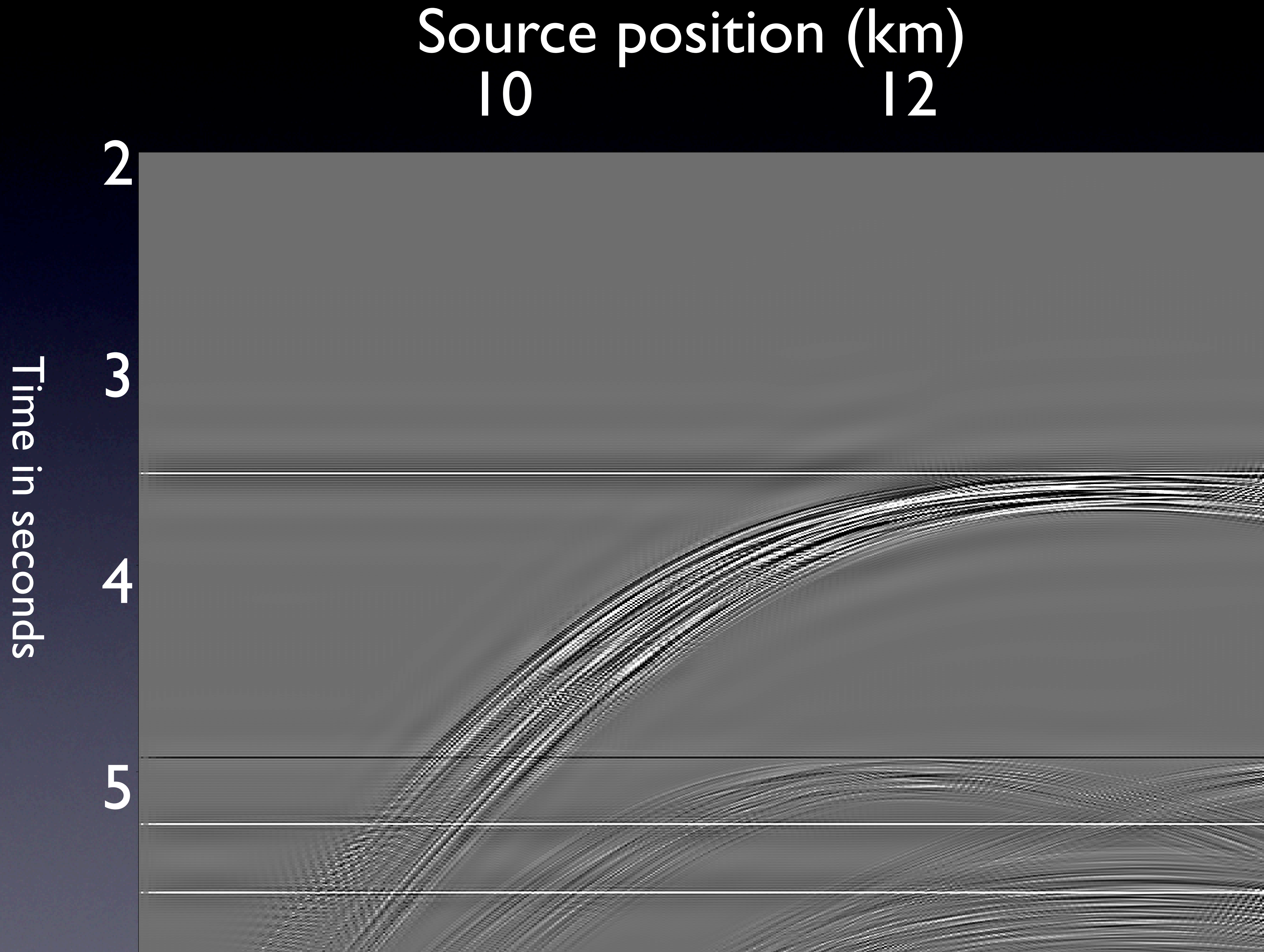
3D PEF Interpolation



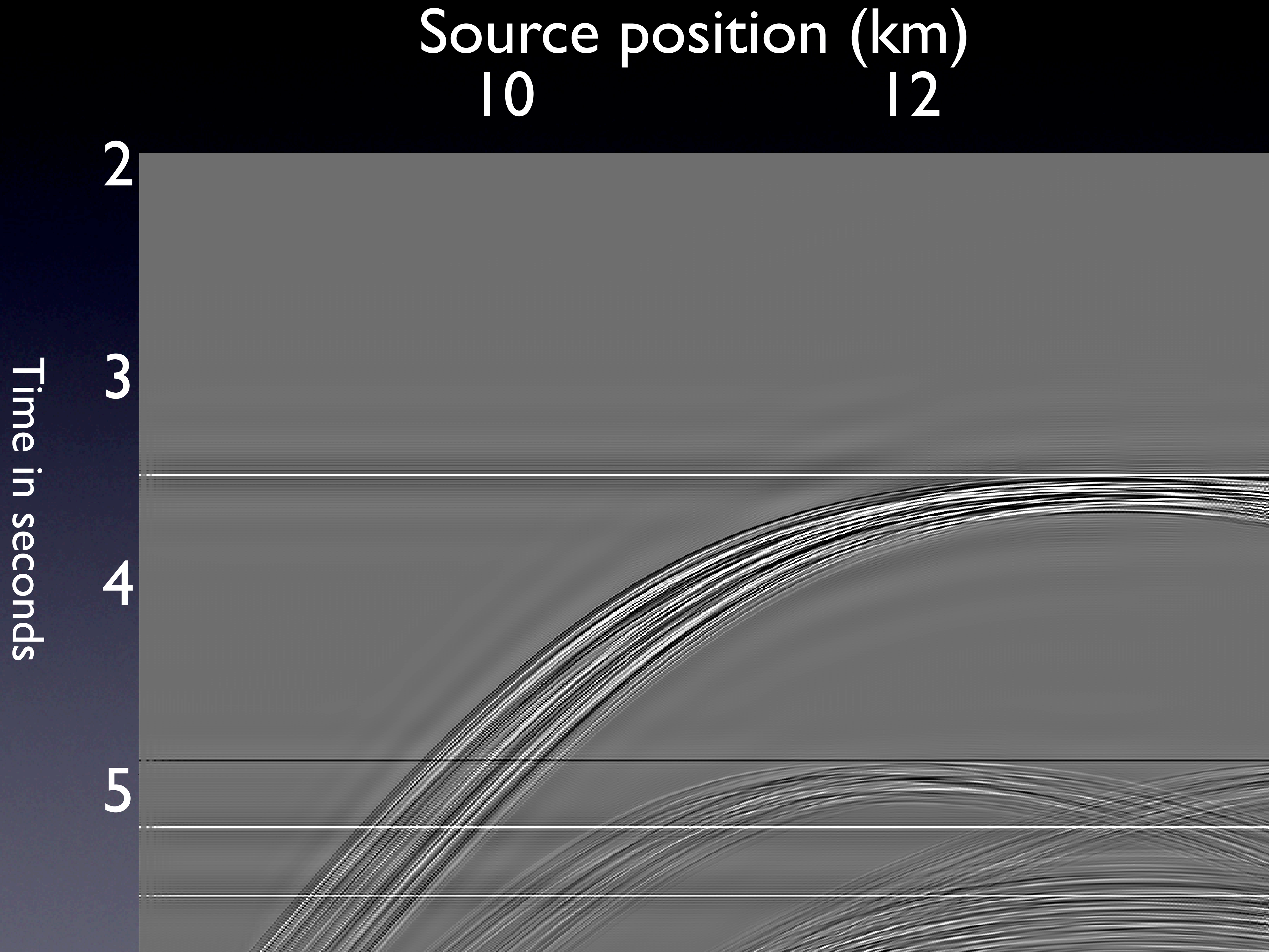
Factor of 3 Interpolation



Factor of 3 Interpolation



Factor of 4 Interpolation



Flip-flop interpolation

- Dimensionality of filters doesn't have much impact
- Interpolation by a factor of 4 (by doubling the sampling twice) works much better than interpolating by a factor of 3

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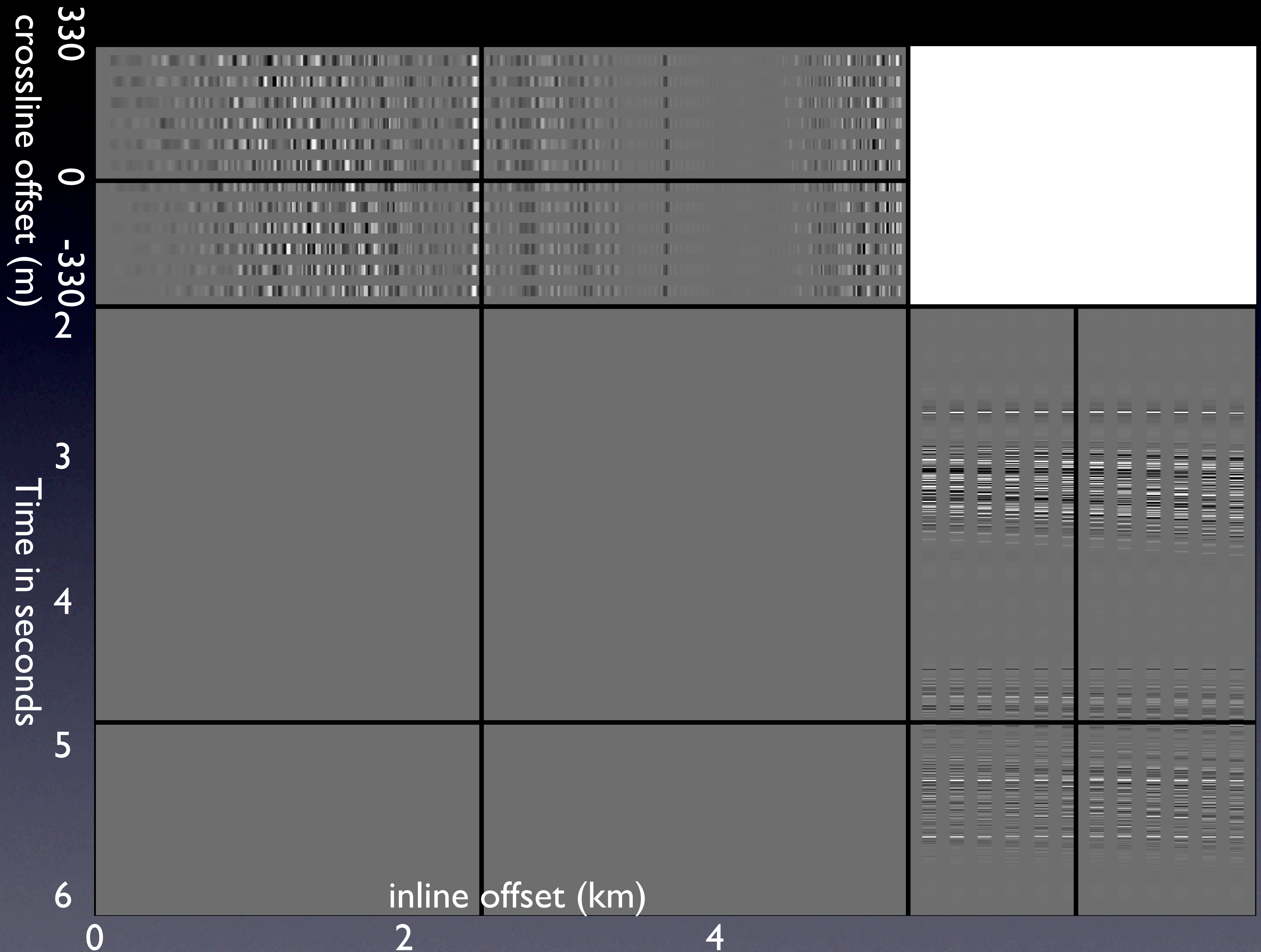
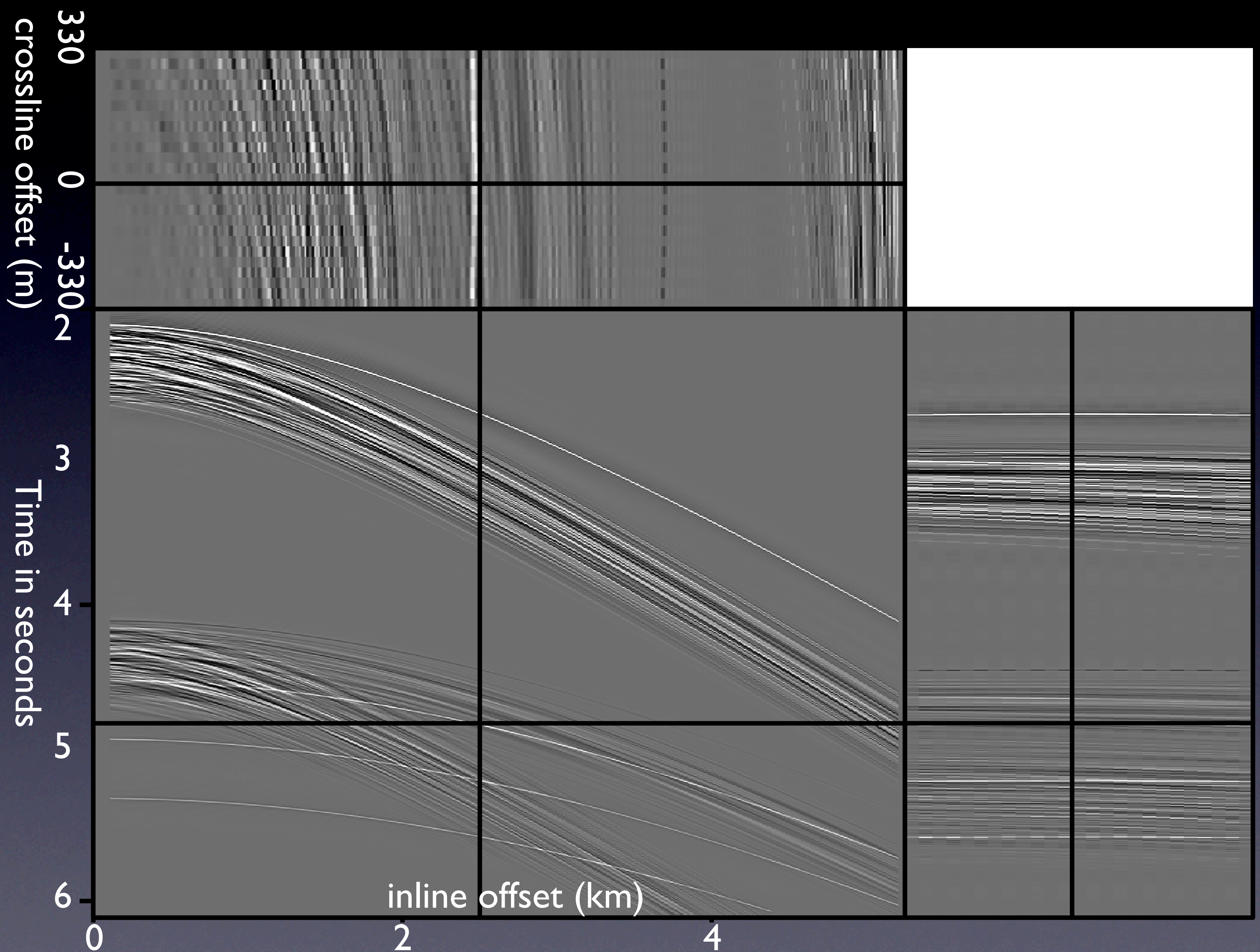
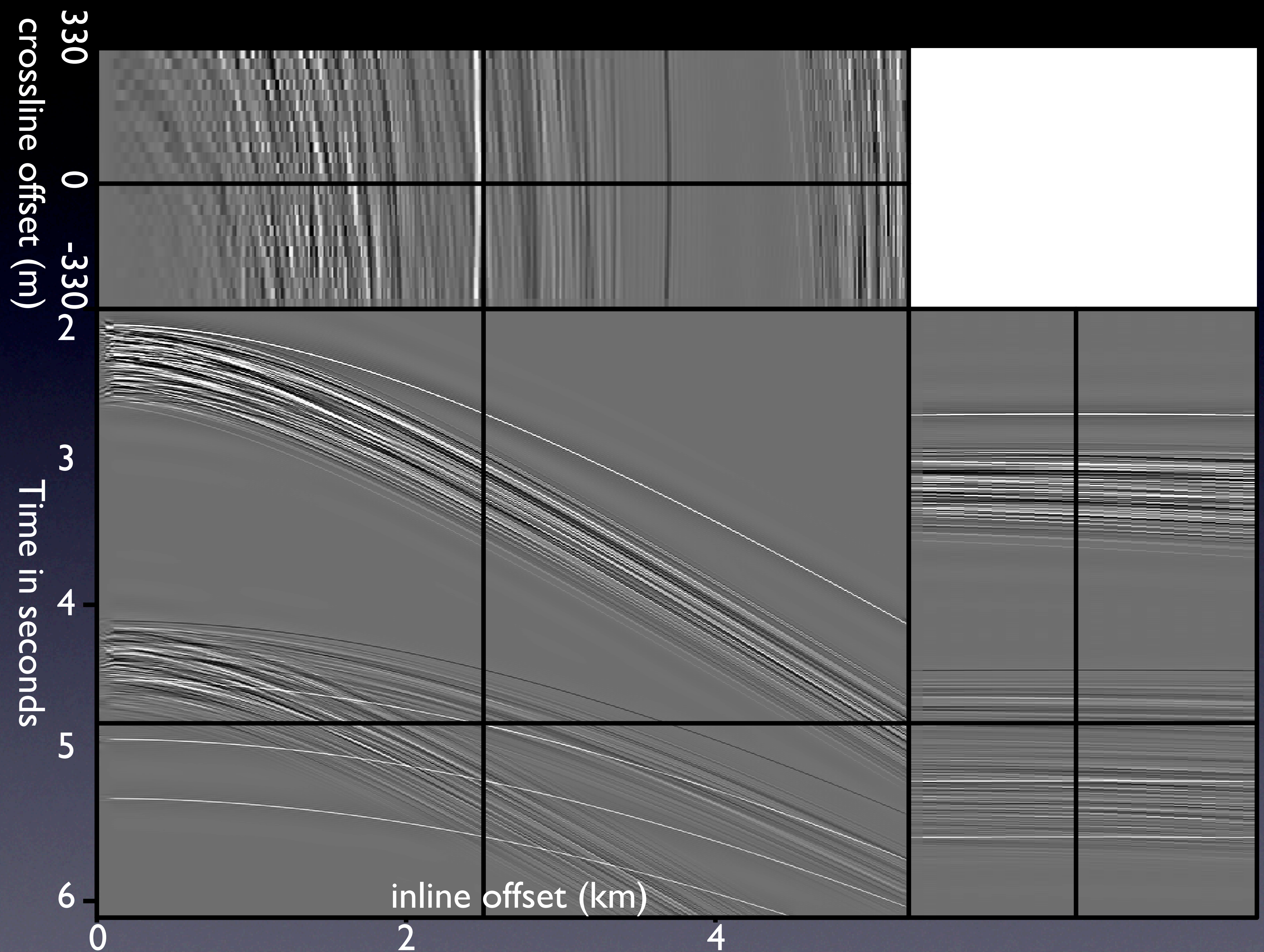
A single shot



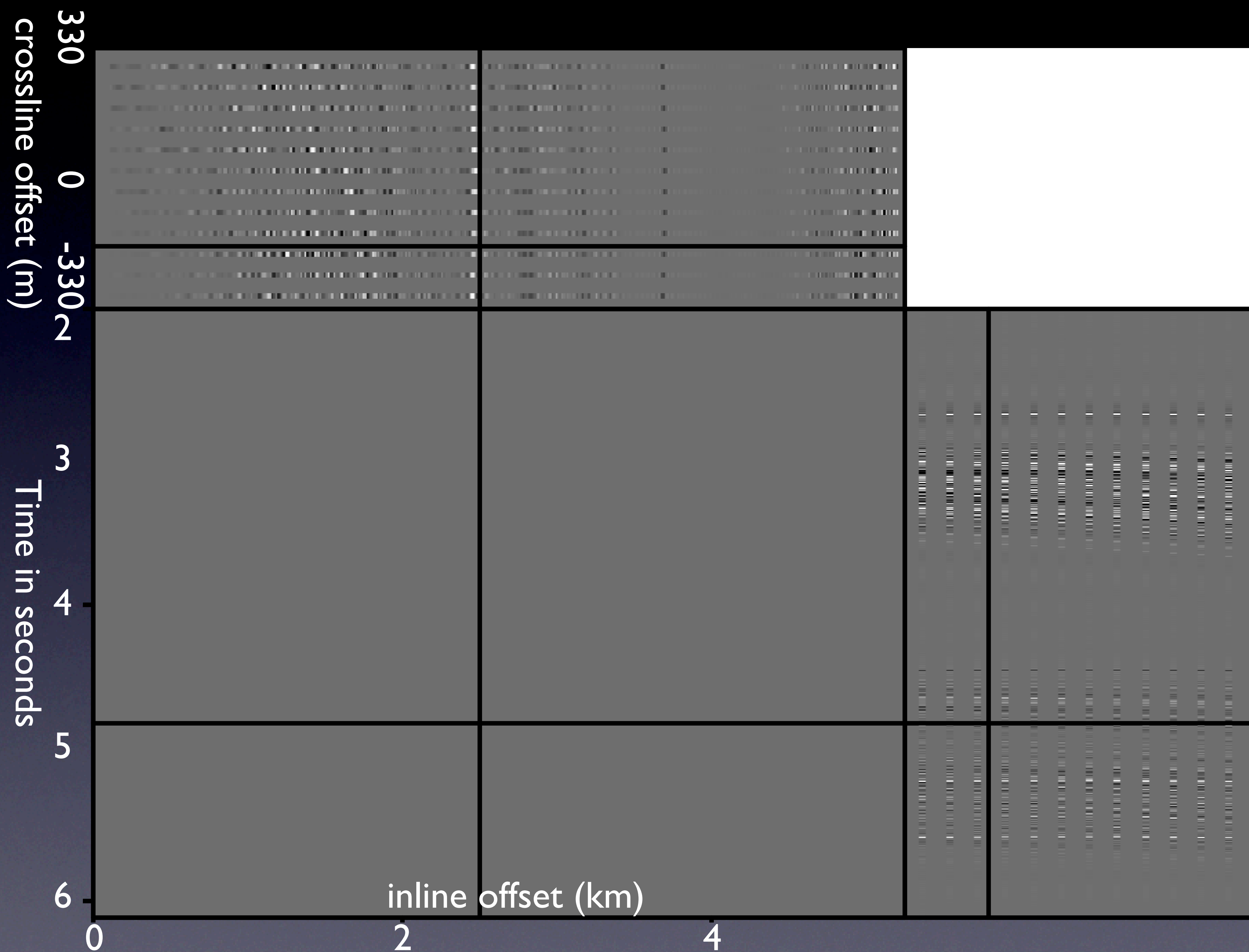
2D Interpolation



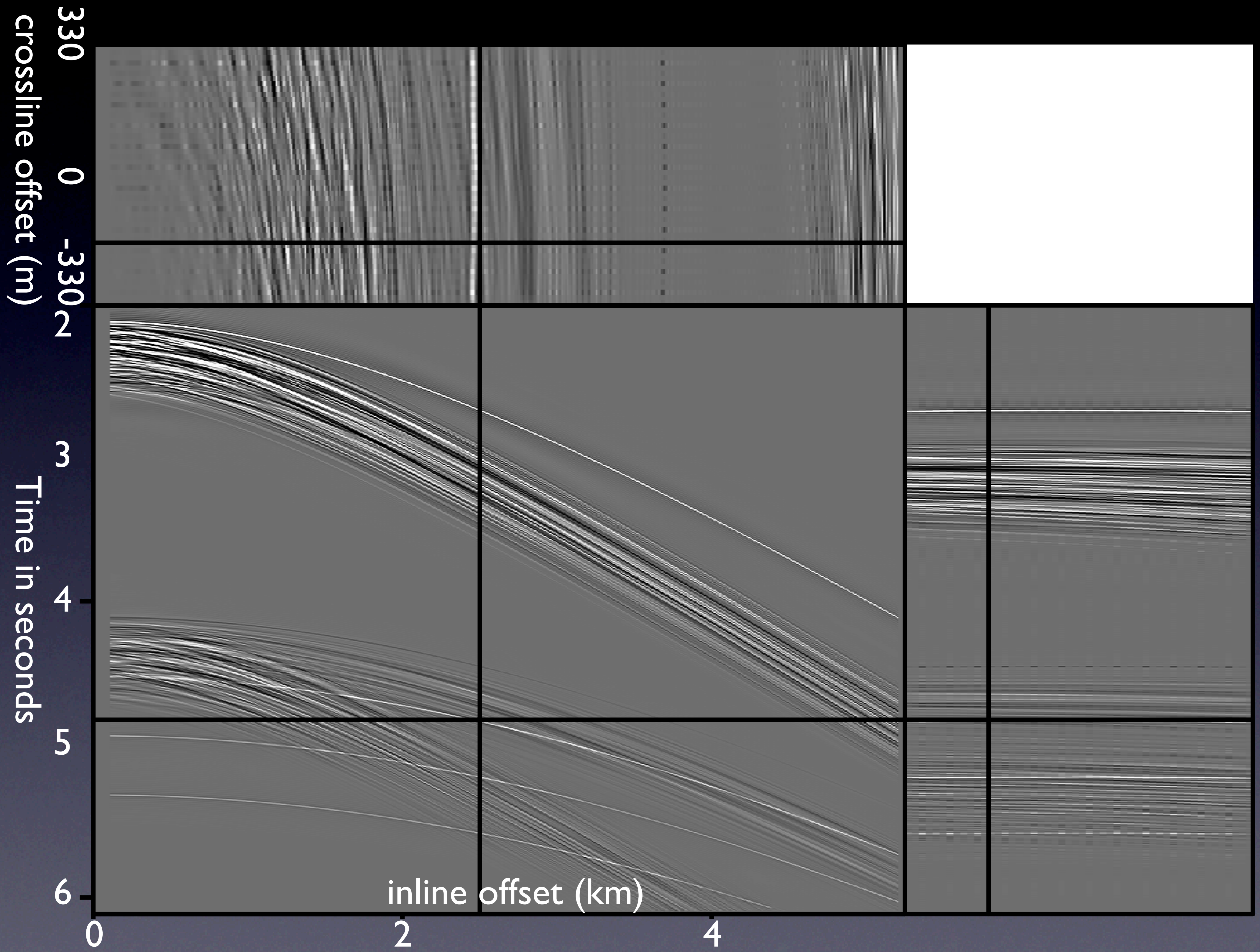
3D Interpolation



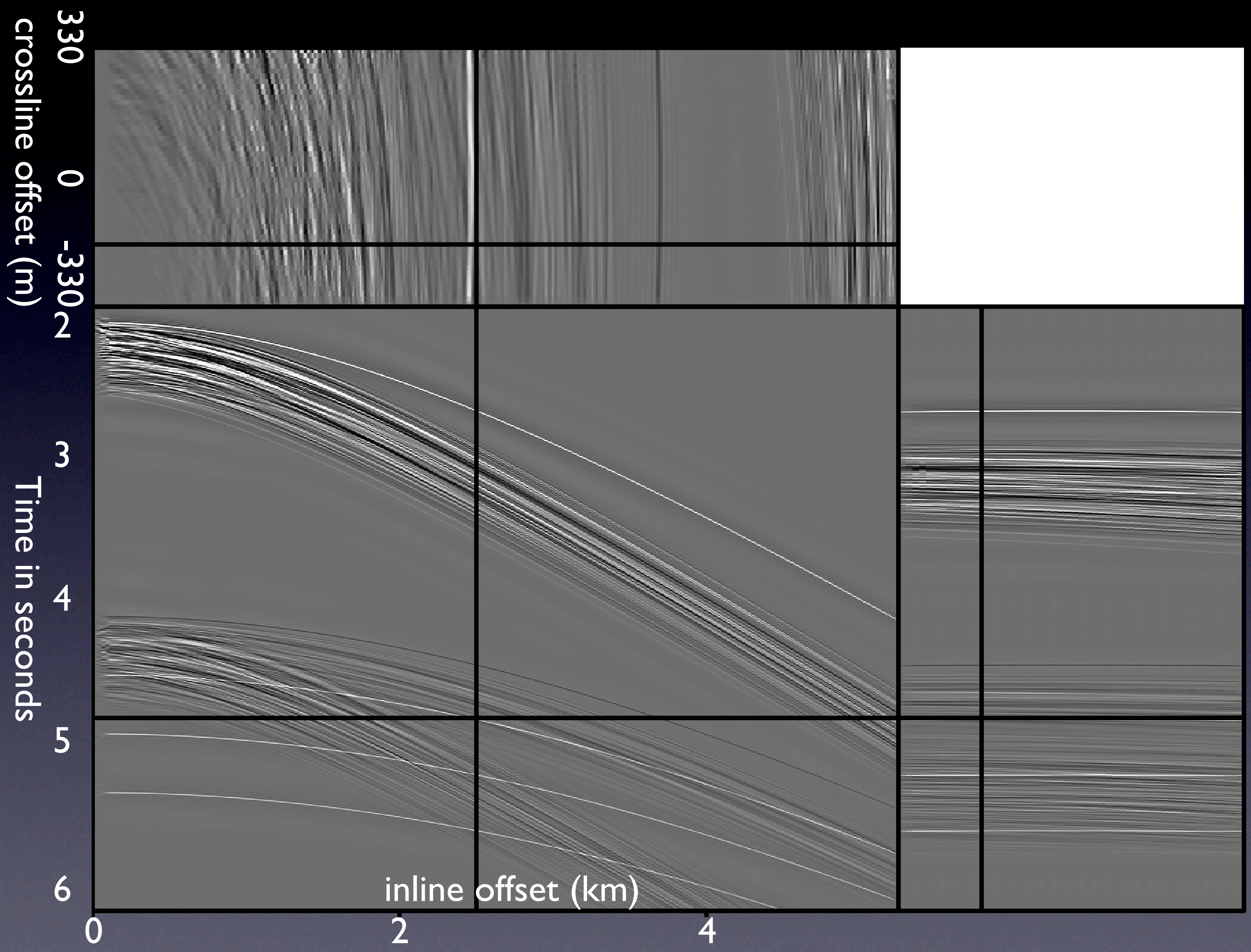
Interpolating by a factor of 4



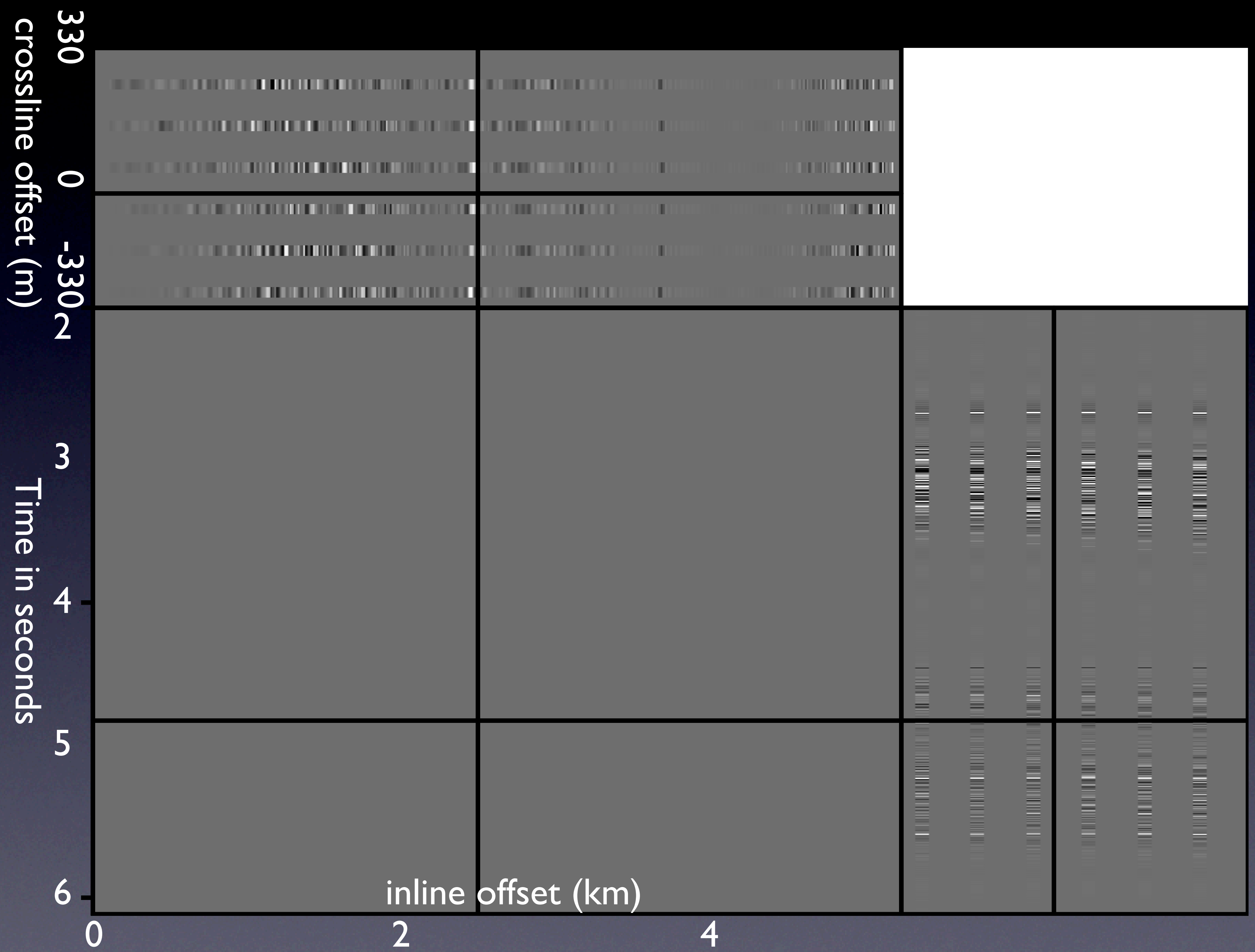
2D PEFs, factor of 4



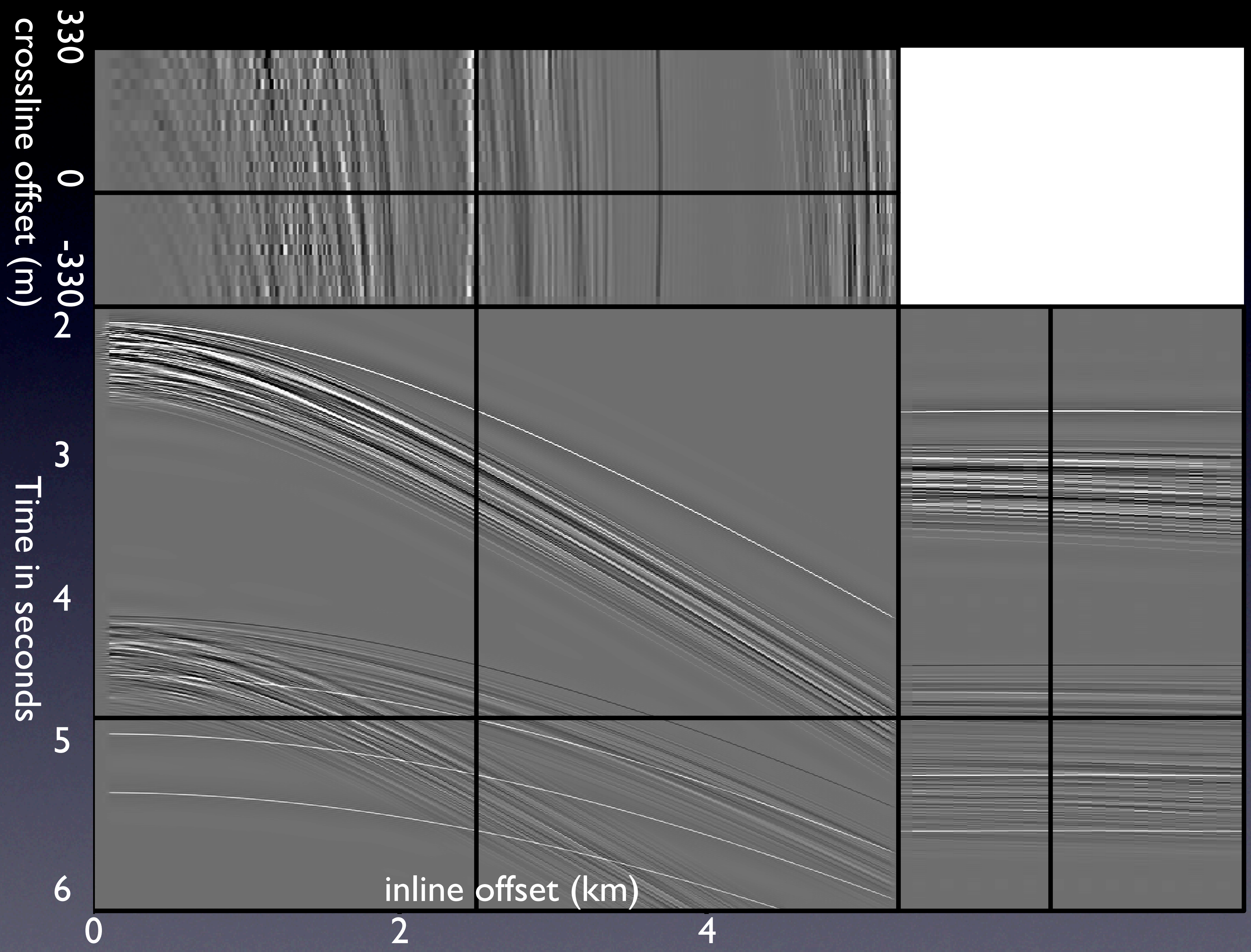
3D PEFs, factor of 4



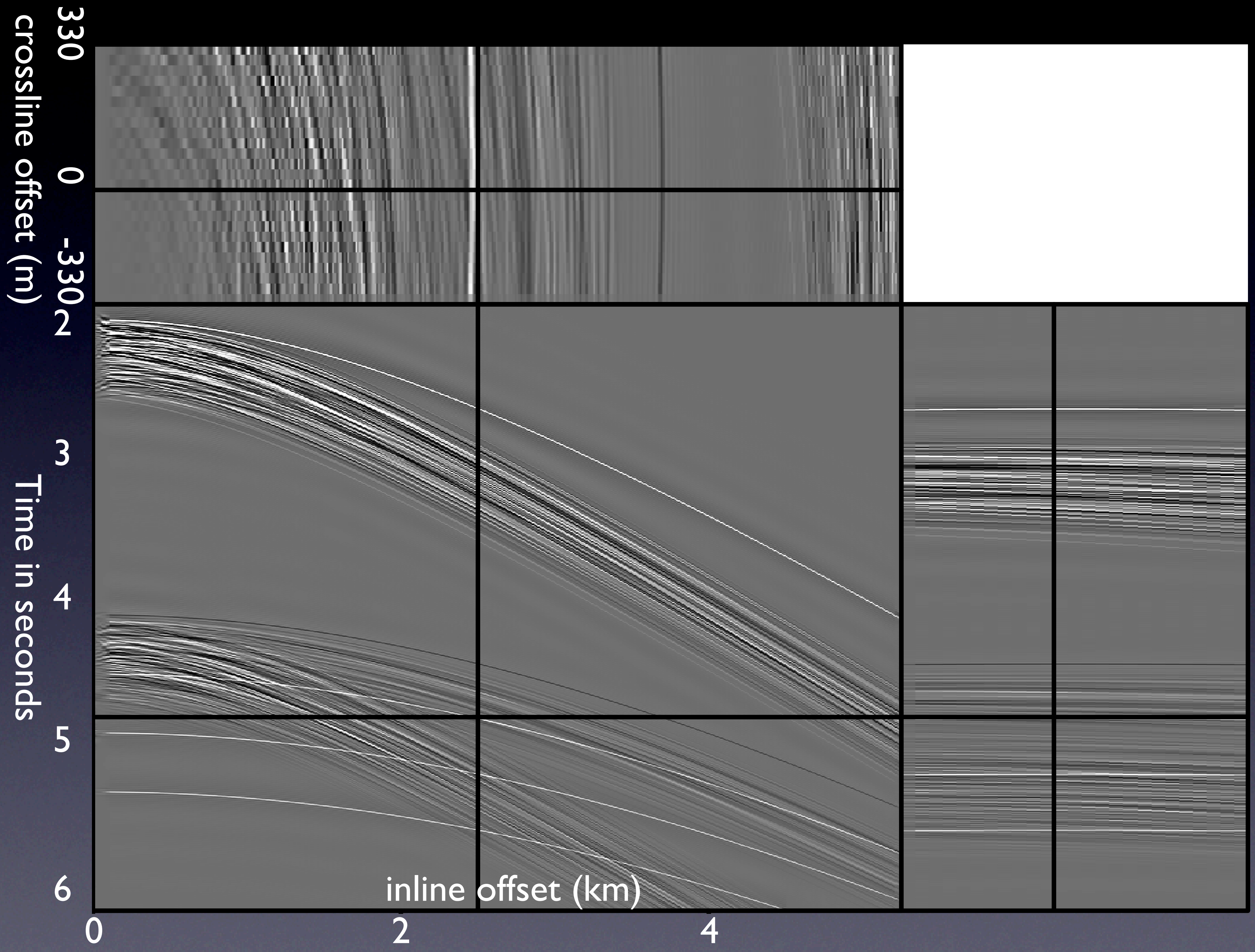
6 cables, factor of 4



6 cables, factor of 4



12 cables, factor of 2



Conclusions

- Inline interpolation is relatively insensitive to the quality of the interpolation
- A factor of 4 is much easier to get than a factor of 3
- Receiver cable interpolation is substantially improved with higher-dimension filters
- Additional receiver cables are very valuable

Future Work

- Going to 4D filters could improve results
  - Much more expensive
  - edge effects increase substantially
- Work with real geometry and sail lines
- The quality of the interpolation should be judged by the output of 3D SRME

Acknowledgments

- Anatoly Baumstein and David Hinkley at ExxonMobil for the data