

# Seismic Modelling in 3D for Migration Testing

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# Outline

- Exhaustive datasets
- Modelling methods
- Theoretical discussion
- Example
- Migrations
- Conclusions

# Exhaustive Dataset

- A 2D or 3D seismic dataset with no significant spatial aliasing in either source or receiver gathers.

$$\text{Requires } \Delta x \leq \frac{v}{2f_{\max}}$$

where  $\Delta x$  is source or receiver spacing in any dimension.

$$\text{Number of traces (3D)} \quad n_{tr} = \left( \frac{L}{\Delta x} \right)^4 = \left( \frac{2f_{\max} L}{v} \right)^4$$

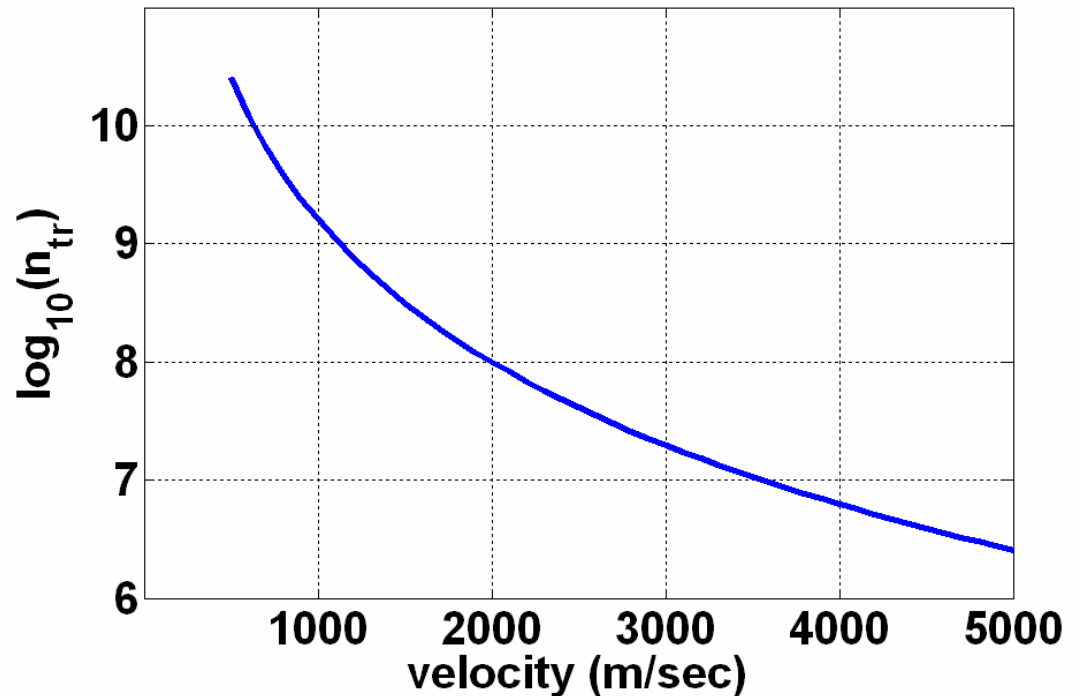
where an  $L \times L$  survey patch is assumed.

# Exhaustive dataset

$\Delta x \downarrow L \rightarrow$	1000	500	250
40	0.39	0.024	0.0015
10	100	6.25	0.39
2.5	2560	1600	100

Number of traces in possible exhaustive survey in millions.

For a maximum frequency of 100Hz and an aperture of 1km, the number of traces required for an exhaustive dataset is shown versus velocity.



# 3D Modelling Methods

Finite difference: too slow

Ray tracing: no diffractions

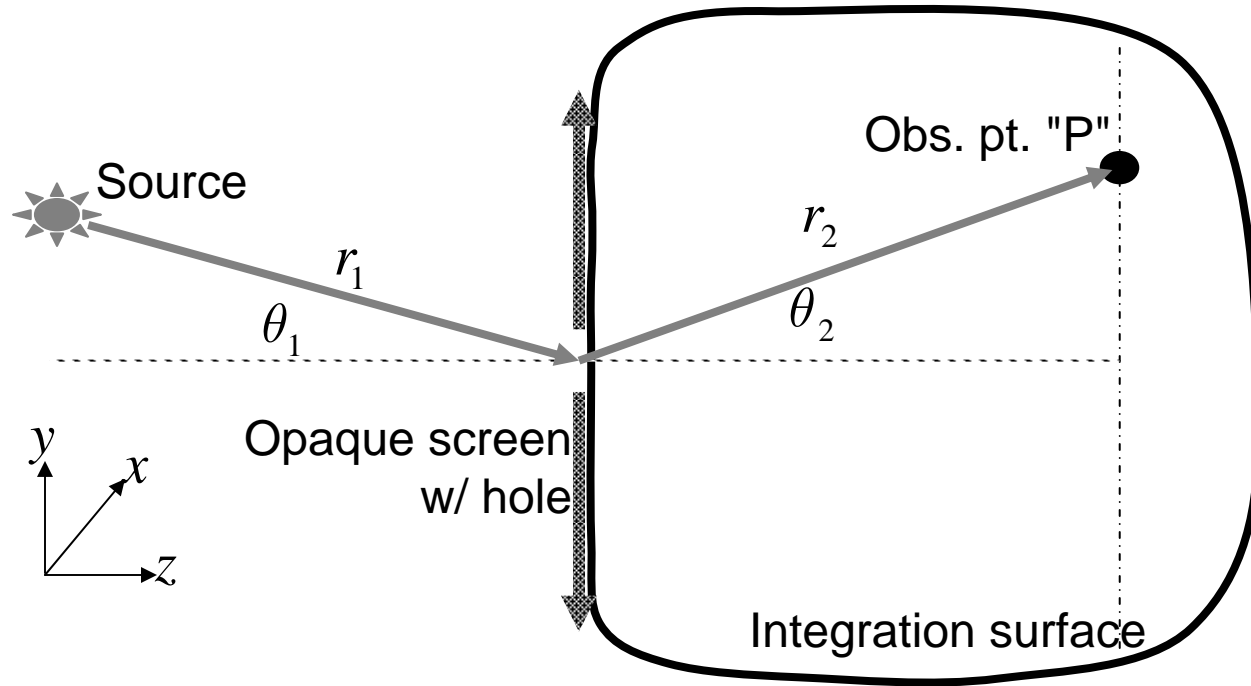
Kirchhoff: still too slow

Gaussian beams: maybe but complicated

Migration backwards: Ahhhhh

(Rayleigh-Sommerfeld)

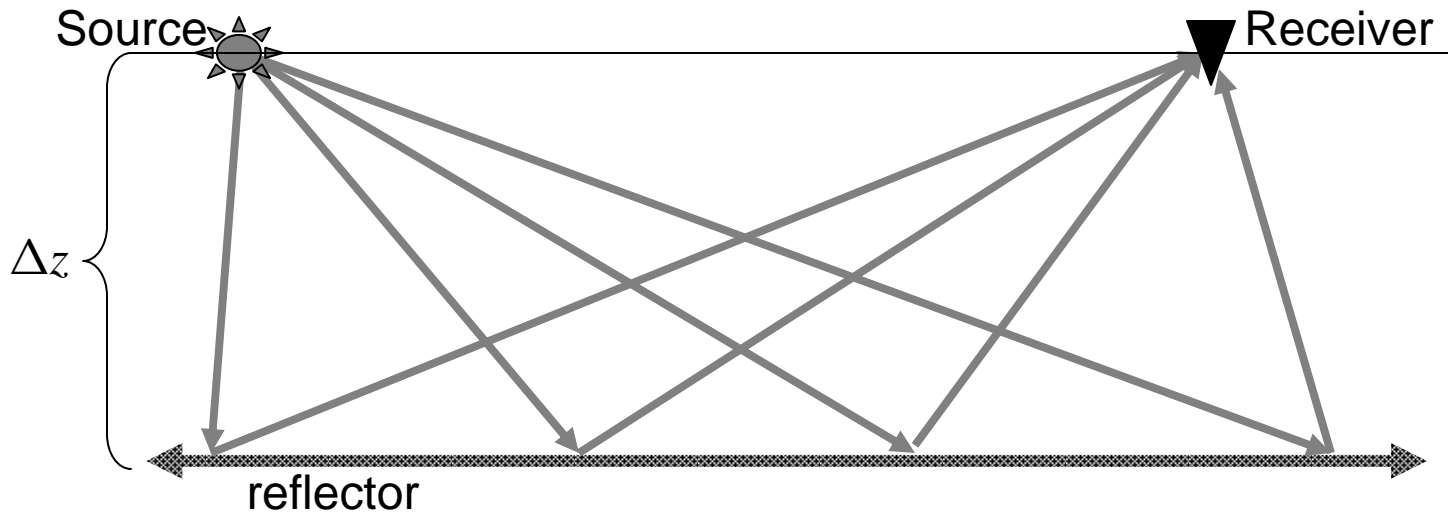
# Kirchhoff Diffraction Theory



$$\psi_P = \int_{\text{screen}} \underbrace{\frac{e^{ik(r_1+r_2)}}{r_1 r_2}}_{\text{propagation}} \left( \underbrace{\frac{\cos \theta_1 + \cos \theta_2}{2}}_{\text{obliquity}} \right) \underbrace{\rho_{\text{screen}}}_{\text{reflectivity}} d\mu$$

$$\rho_{\text{screen}} = \begin{cases} 1 \dots \text{in hole} \\ 0 \dots \text{otherwise} \end{cases}$$

# Ravleigh-Sommerfeld Diffraction Theory



$$\psi_{inc} = \underbrace{\mathbf{F}_{2D}^{-1} e^{ik_z \Delta z} \mathbf{F}_{2D}}_{\text{extrapolate to reflector}} \psi_{source}$$

$$\psi_P = \underbrace{\mathbf{F}_{2D}^{-1} e^{ik_z \Delta z} \mathbf{F}_{2D}}_{\text{extrapolate to P}} \underbrace{\rho_{refl}}_{\text{reflectivity}} \psi_{inc}$$

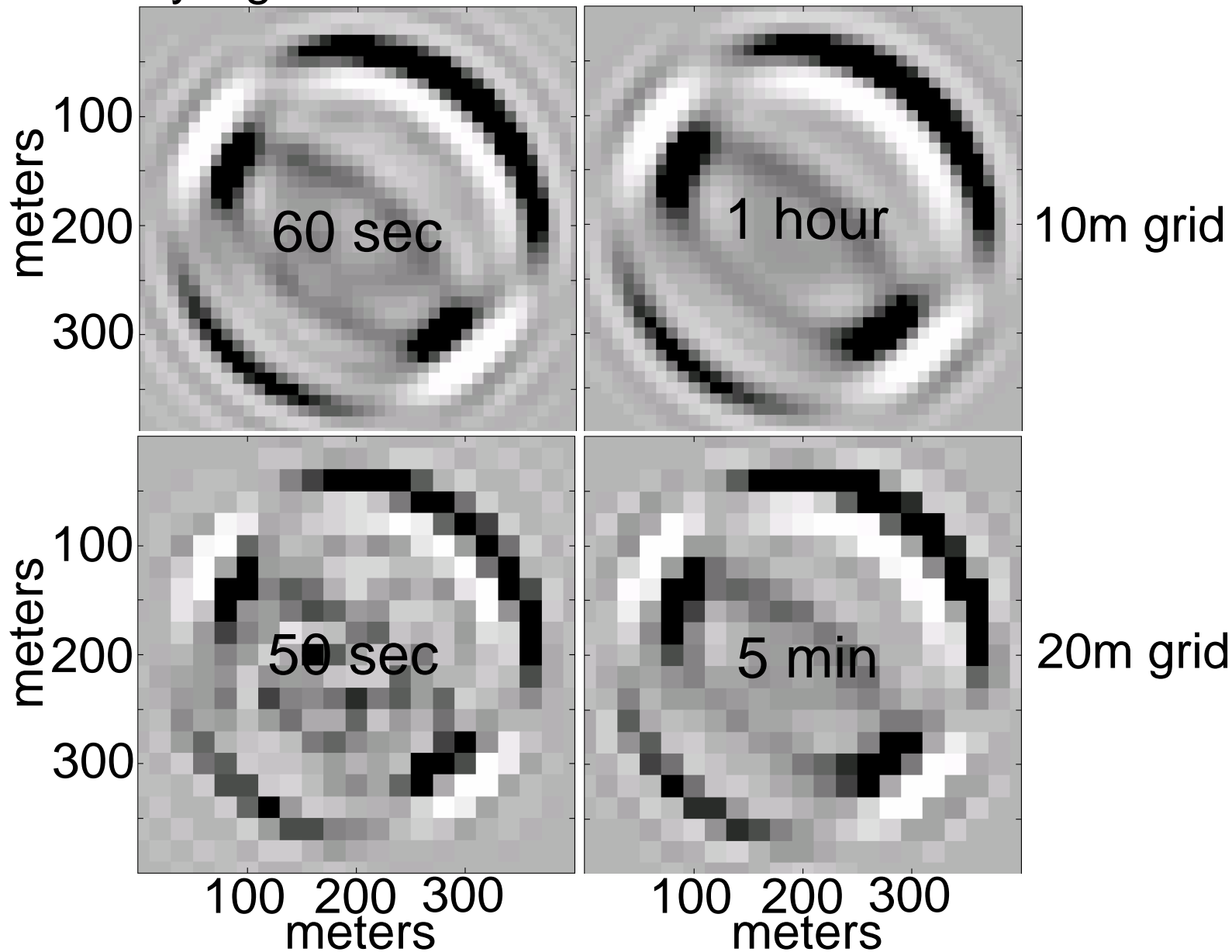
Matlab codes:

shot\_model3D  
stack\_model3D

# Algorithm Comparison

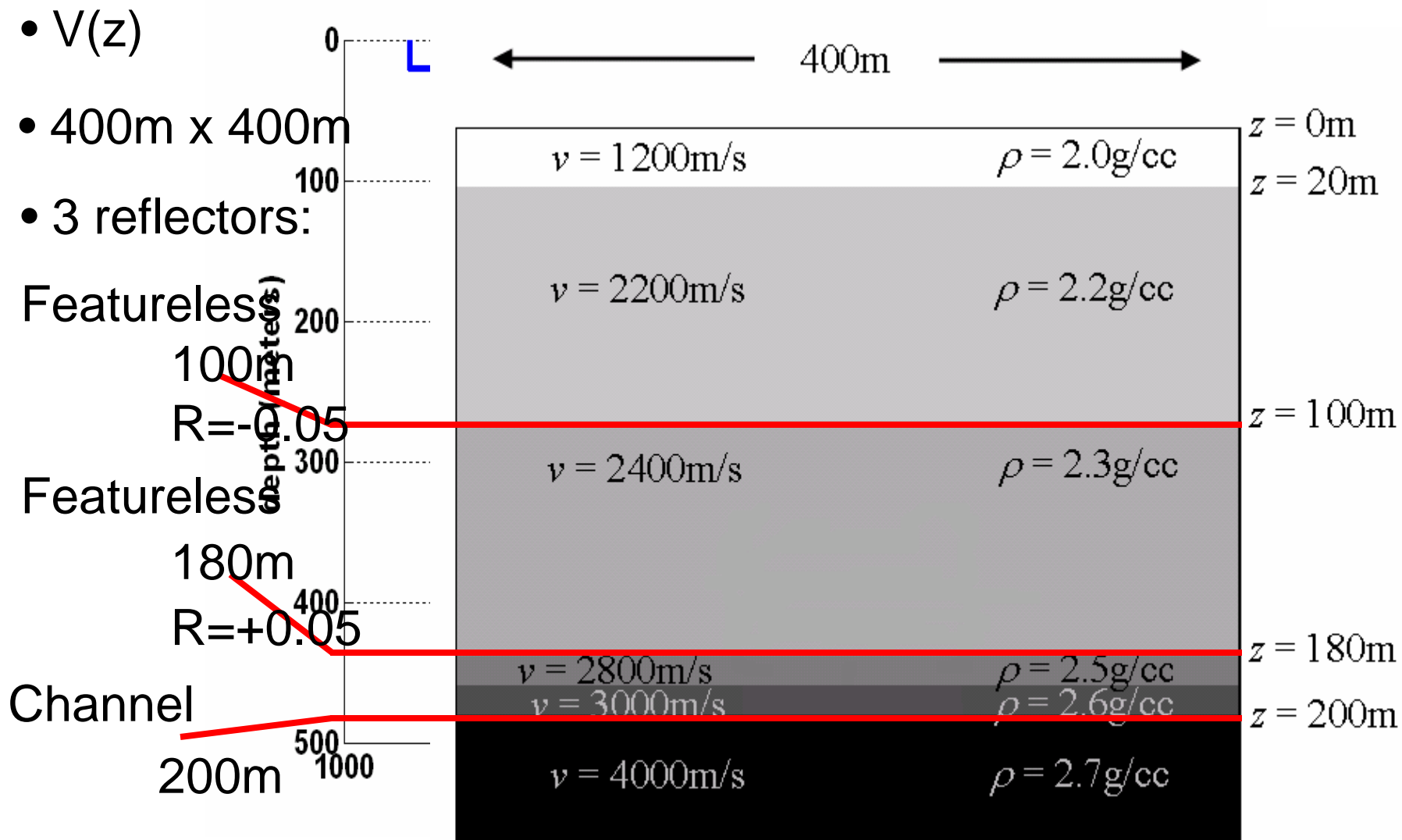
Rayleigh-Sommerfeld

Kirchhoff

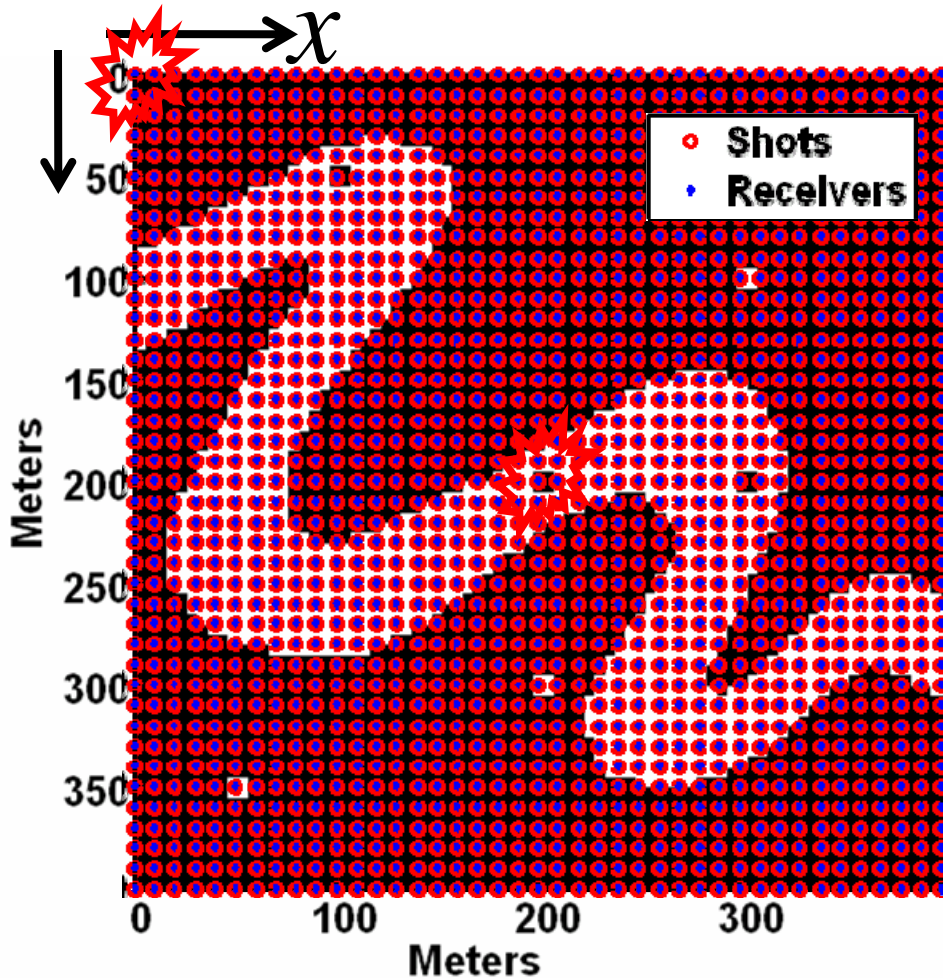




# Geological Model



# Channel Horizon



$$\Delta x_s = \Delta y_s = 10\text{m}$$

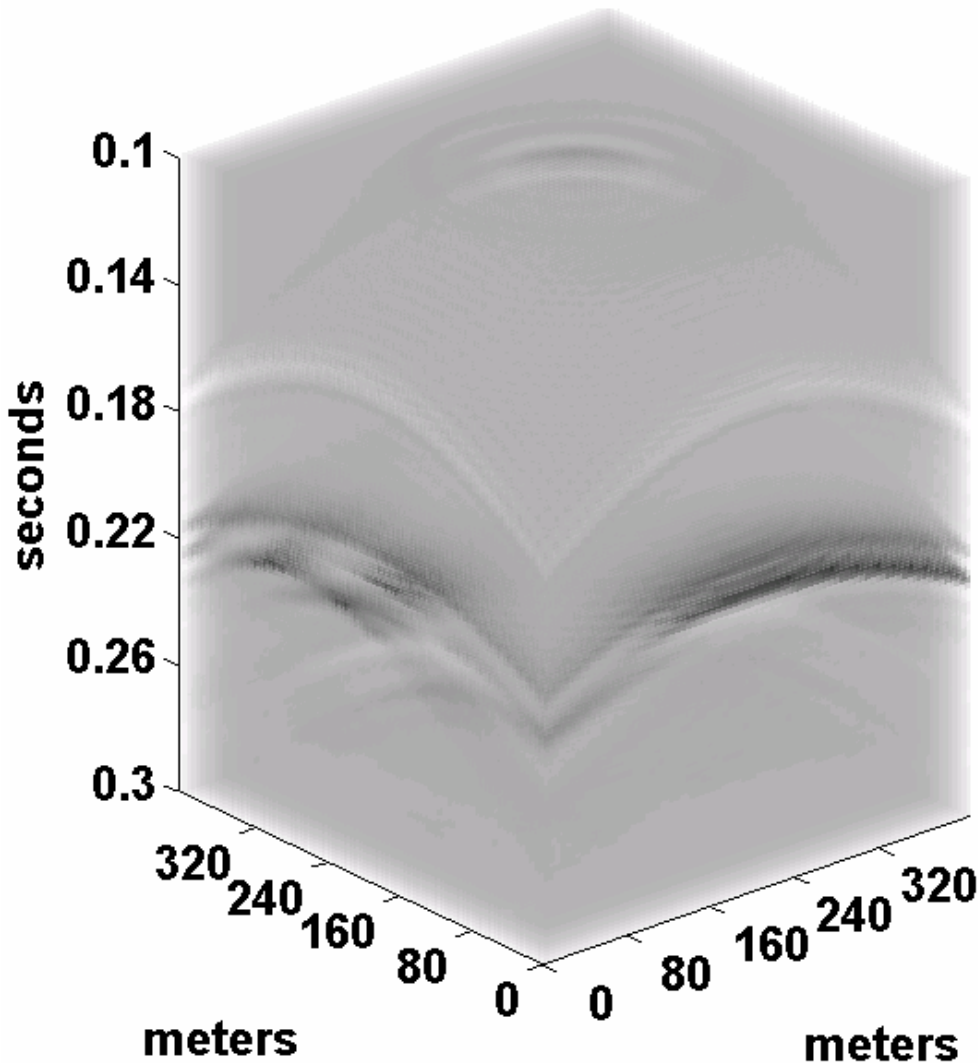
$$\Delta x_r = \Delta y_r = 10\text{m}$$

41 source lines

41 receiver lines

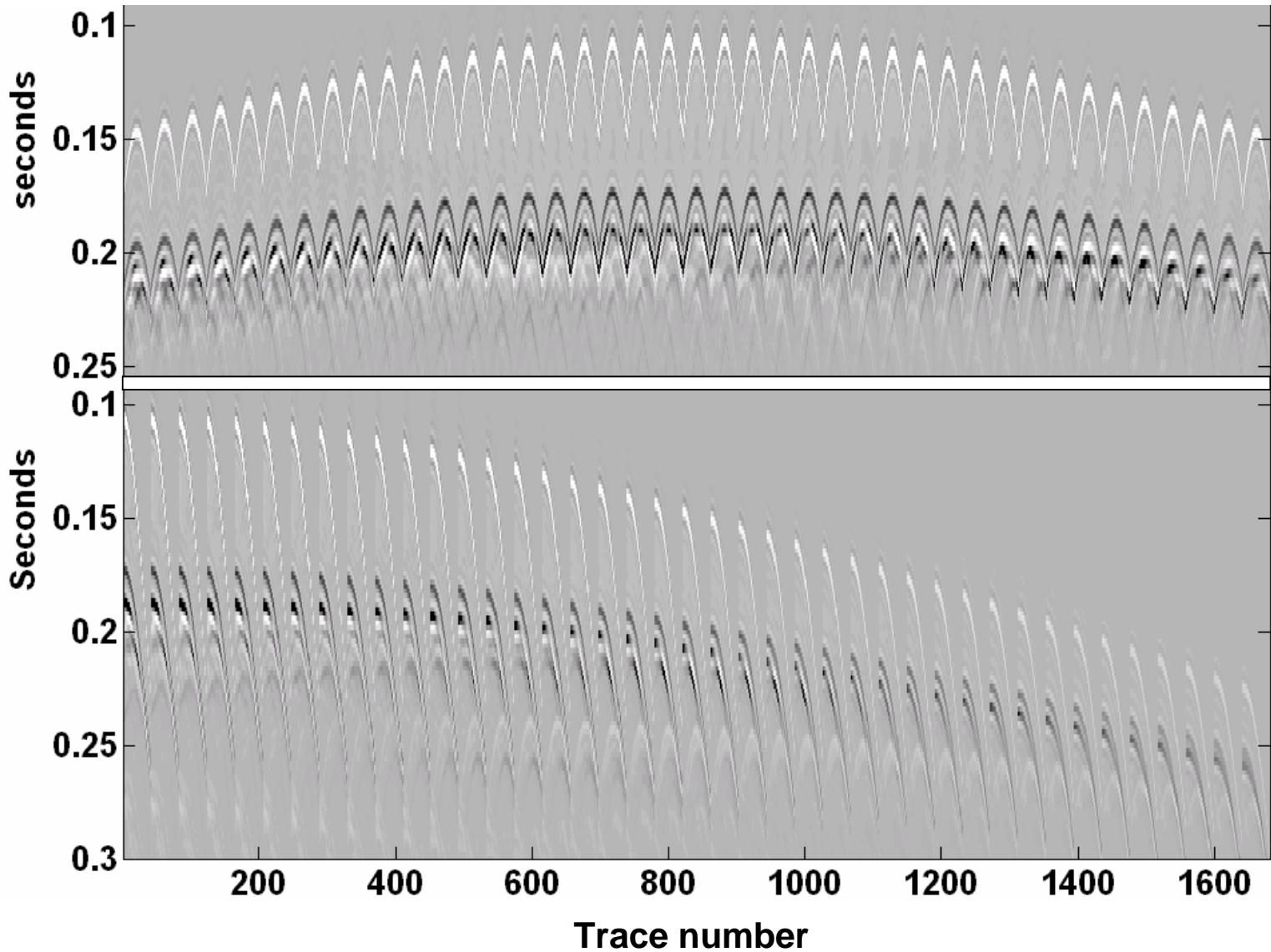
1681 Shots, 1681 Receivers, 2825761 Traces

# 3D Source Records

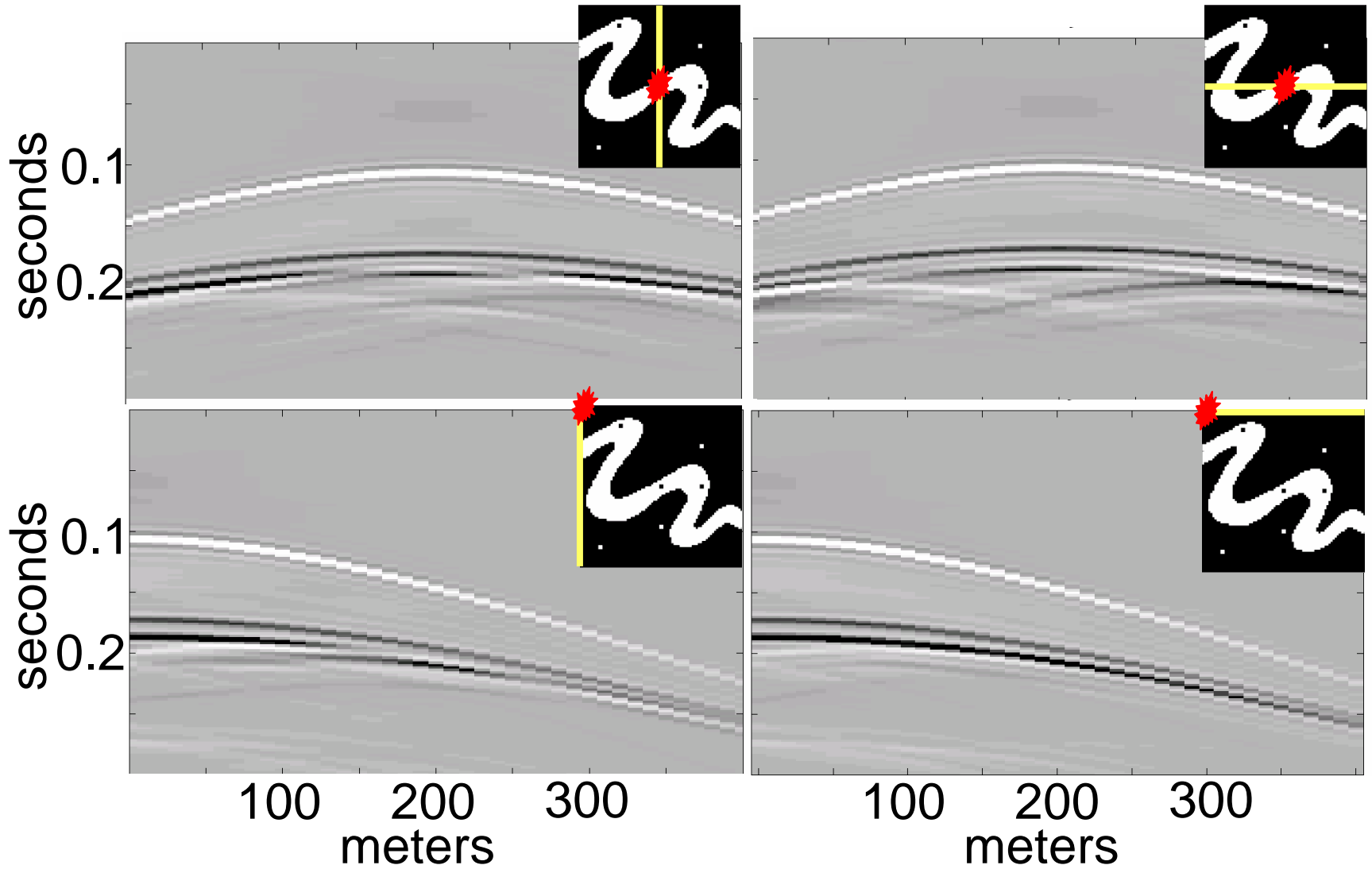


Source spectrum:  
[0 0 110 180] Hz  
Zero phase

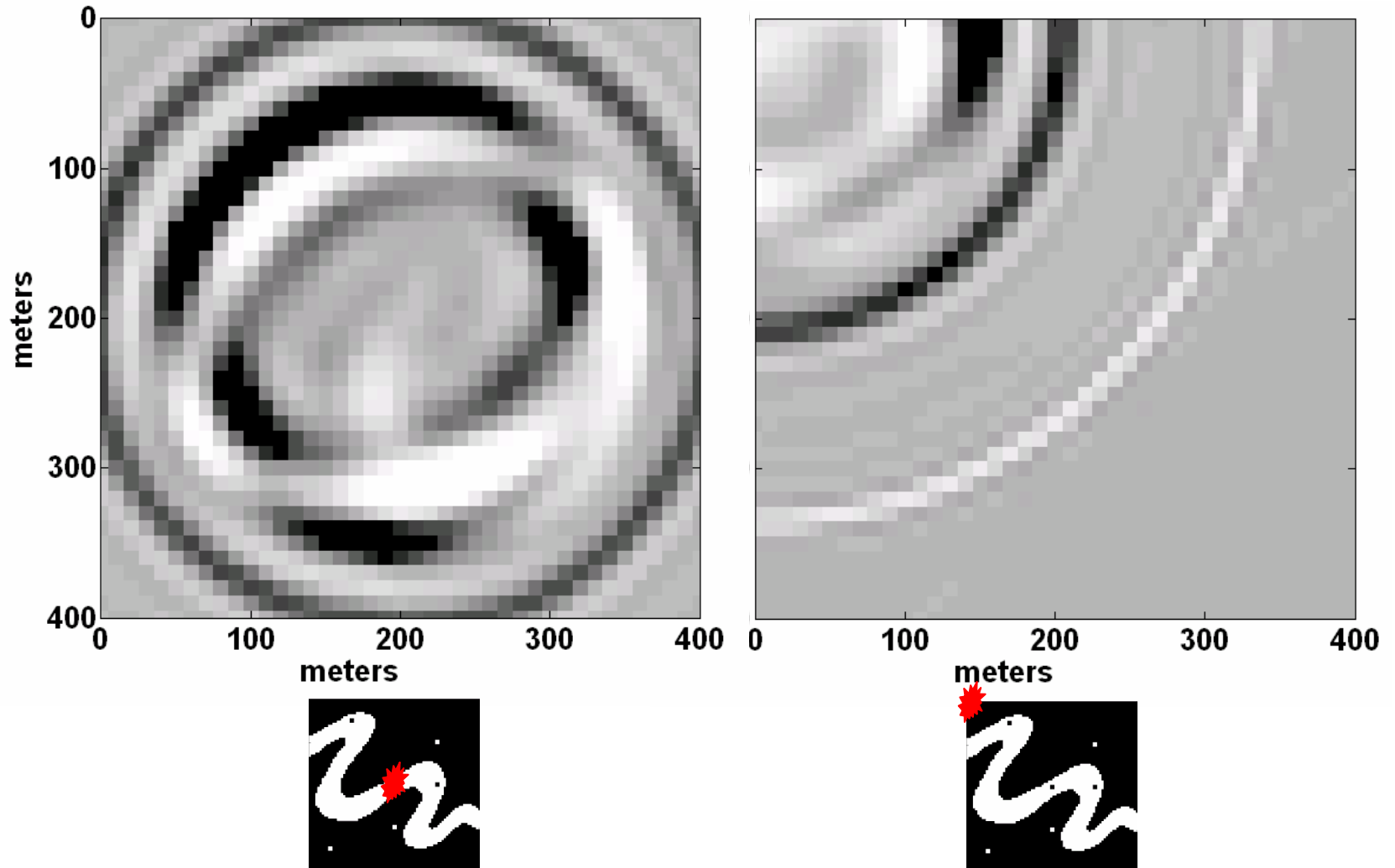
# 3D Source Records



# 2D Receiver Lines



# Time Slices at 200ms

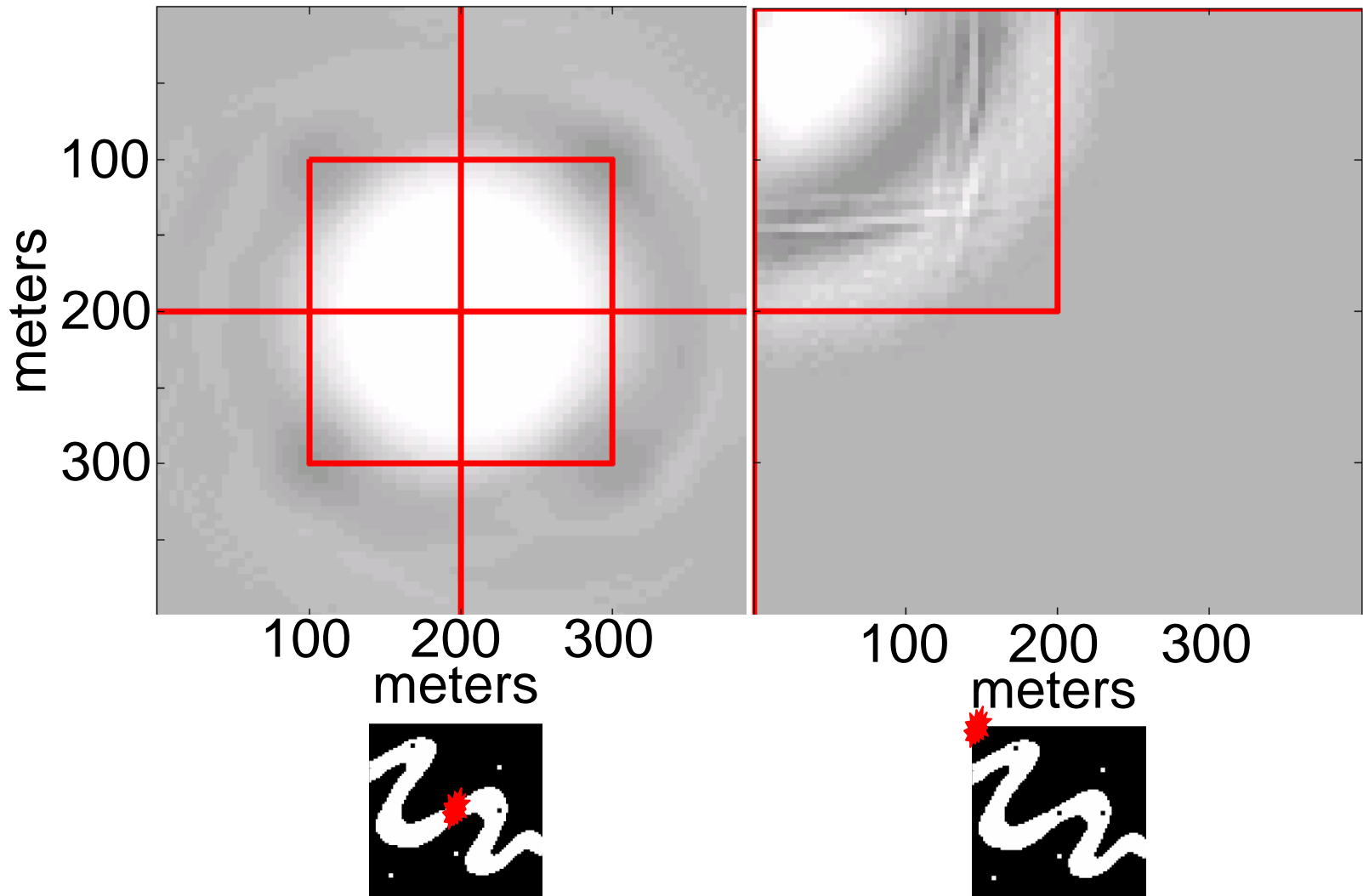


# 3D Migrations

Pre and post stack 3D Kirchhoff ( $v(z)$ ) migrations

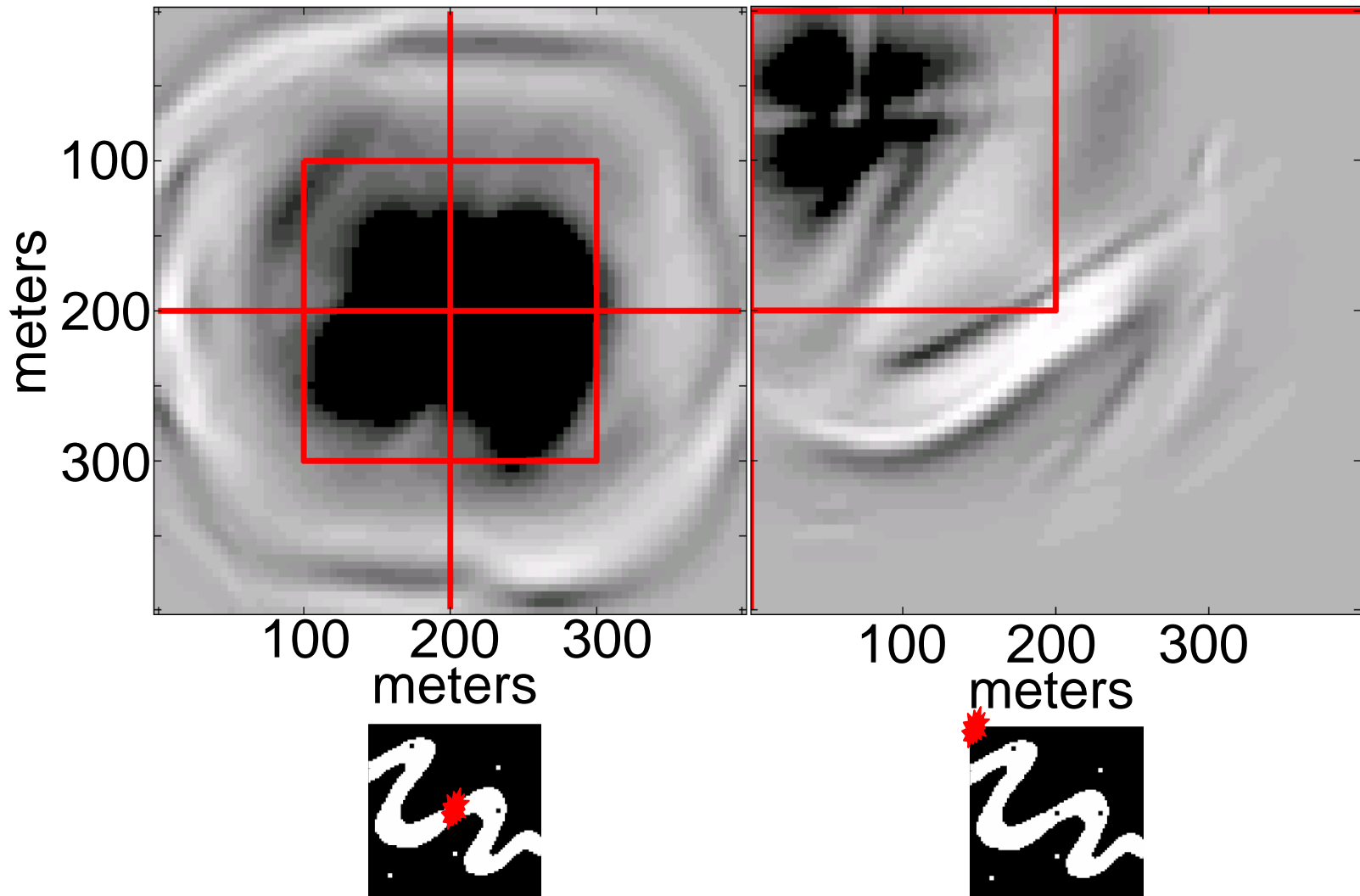
Matlab codes: `kirk_shot3D` and `kirk_stack3D`

# Migrated 100m reflector

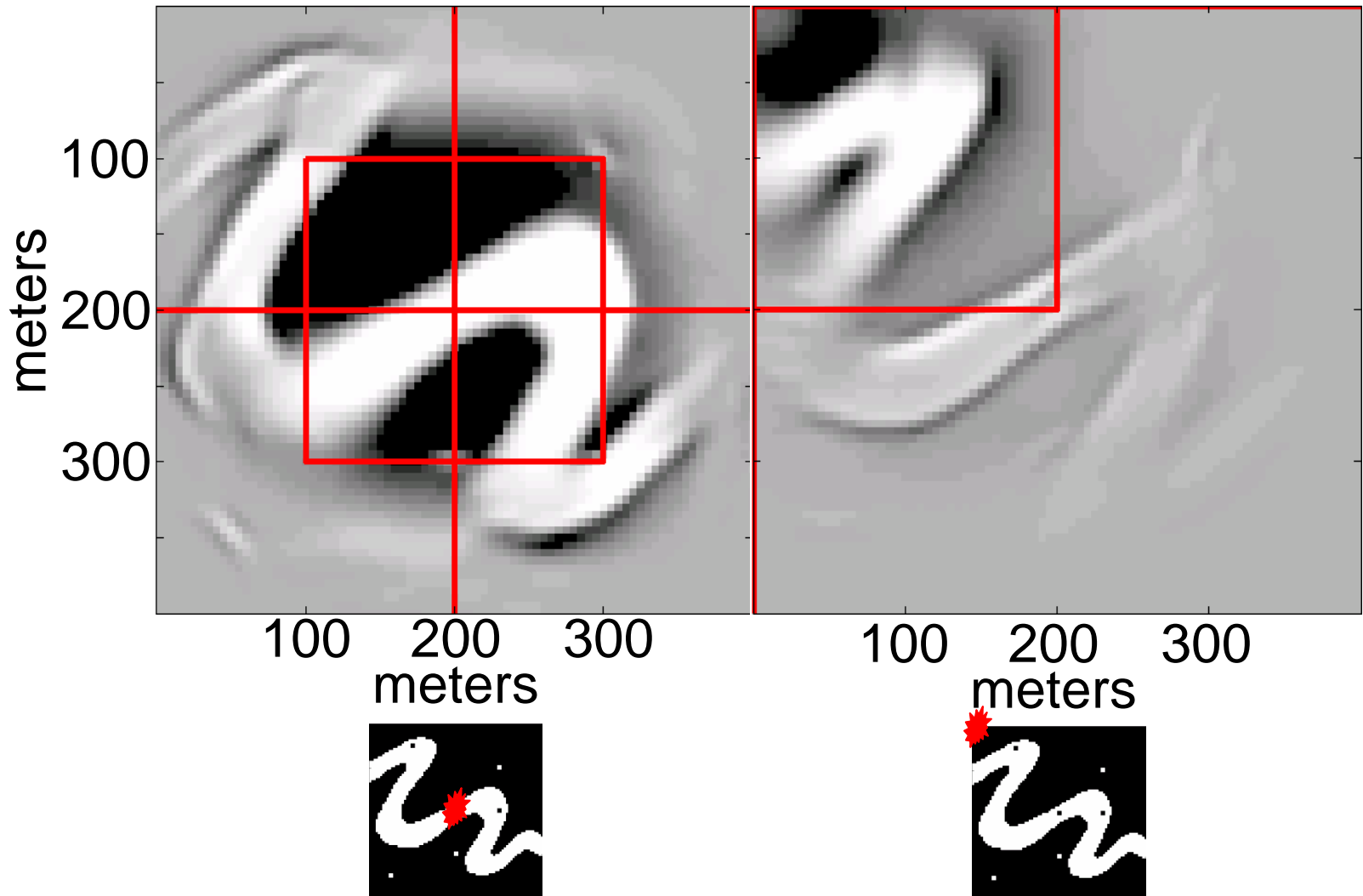




# Migrated 180m reflector



# Migrated 200m reflector



# Conclusions

- Exhaustive datasets, with no spatial aliasing, are possible with appropriate modelling.
- Rayleigh-Sommerfeld modelling is comparable in accuracy to Kirchhoff but much faster
- An exhaustive 3D dataset has been created and is available to sponsors
- 3D modelling and migration codes released to sponsors
- 3D migrations illustrate illumination, resolution, and footprint issues



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