Enhancements to the FOCI algorithm using a WLS approach and CICA for migration velocity analysis

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Motivation

- To use weighted least squares (WLS) in designing wavefield extrapolators.

"Using a transition band in the weighted least squares design of wavefield extrapolators"

- To use this WLS to enhance FOCI (forward operator and conjugate inverse) to design short operators.

"Enhancing the FOCI extrapolation method by using a weighted least-squares approach"

- To carry out migration velocity analysis using common image cube analysis (CICA).

"Migration velocity analysis using the common image cube analysis (CICA)"

Outline

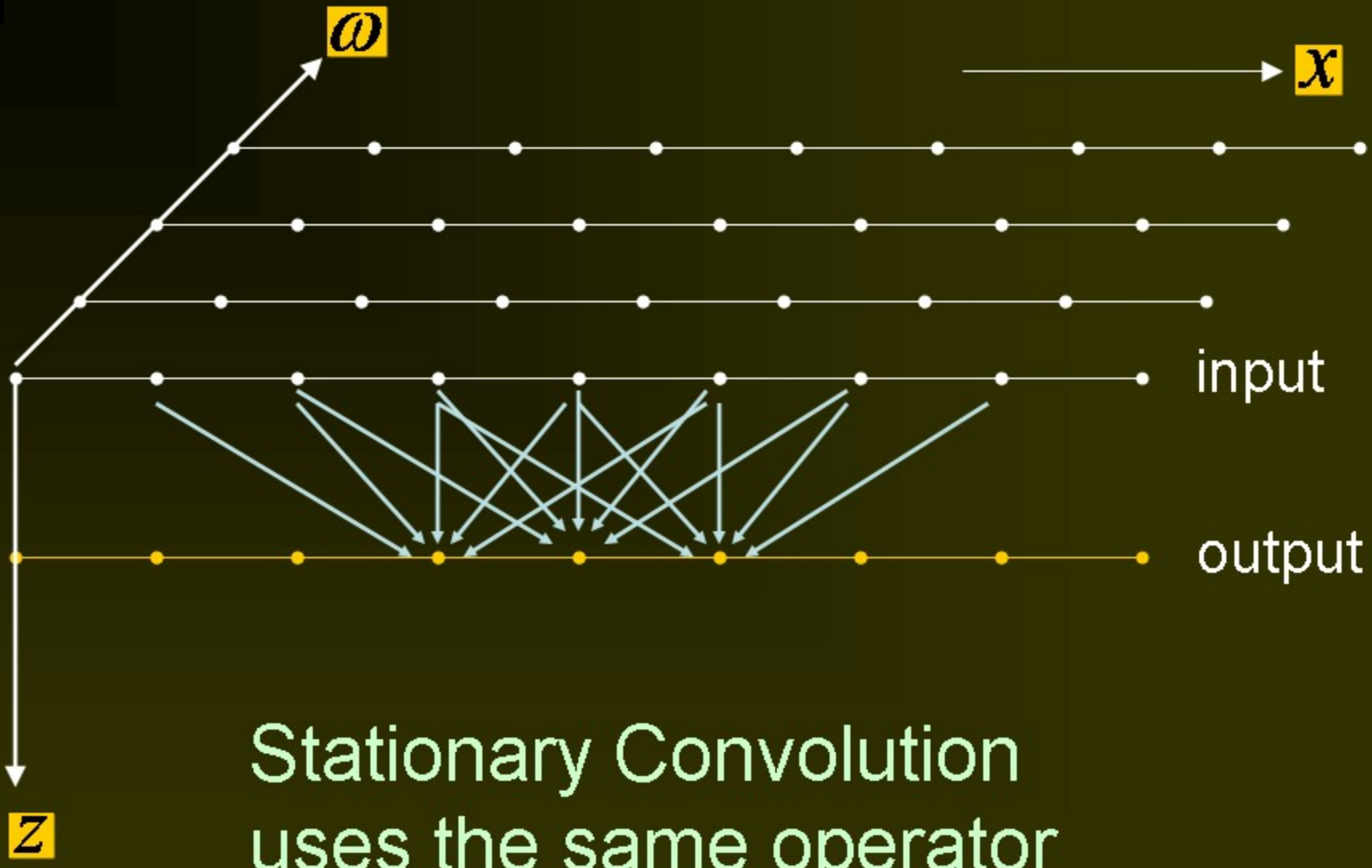
- Theory of wavefield extrapolation methods.
- Least squares methods for designing wavefield extrapolators.
- Using the WLS approach to enhance the FOCI algorithm.
- Review of migration velocity analysis methods.
- Using CICA for migration velocity analysis.
- Conclusions.

Explicit wavefield extrapolation methods

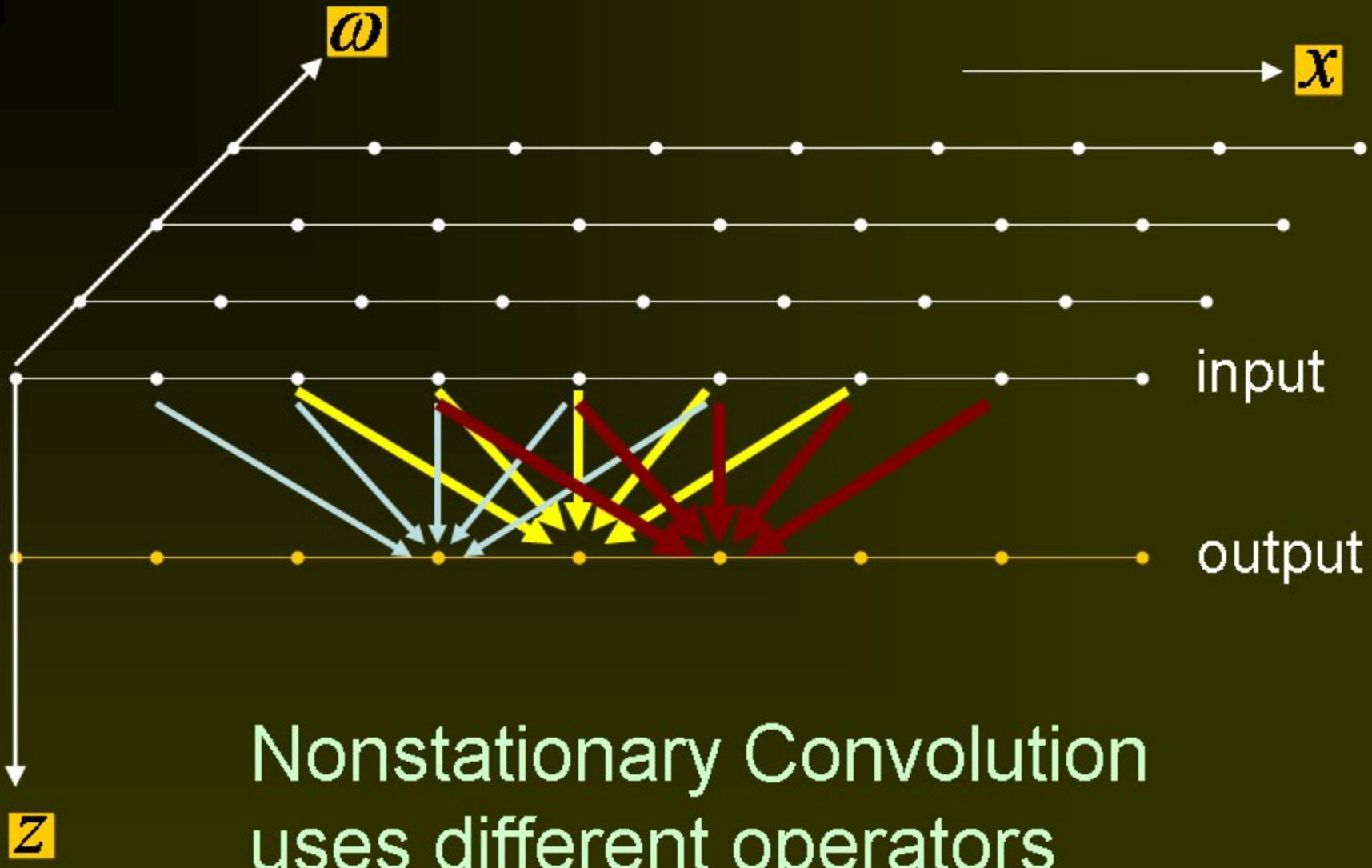
$$\psi(x, z+\Delta z, \omega) = \frac{1}{2\pi}\int_{\mathbb{R}} \psi(x', z, \omega) W(x-x', x, \Delta z, \omega)\, dx'$$

$$W(x-x', x, \Delta z, \omega) = \frac{1}{2\pi}\int_{\mathbb{R}} \hat{W}(k_x, x, \Delta z, \omega) e^{-ik_x(x-x')}\, dk_x$$

$$\hat{W}(k_x, x, \Delta z, \omega) = \exp\left(i\Delta z \sqrt{\frac{\omega^2}{v^2(x)} - k_x^2} \right)$$



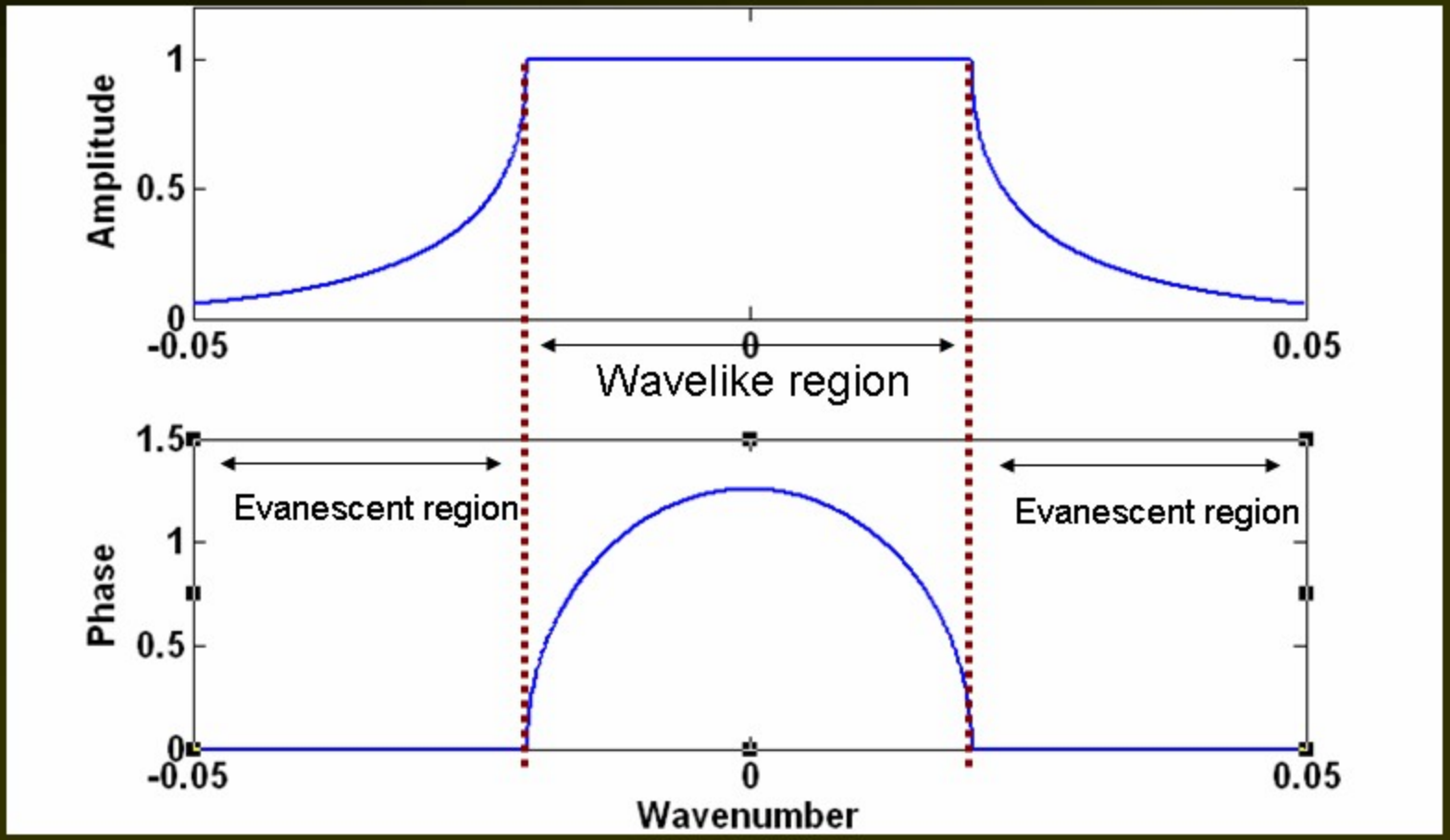
Stationary Convolution
uses the same operator



Nonstationary Convolution
uses different operators

Amplitude and phase spectra of the phase shift operator

V=2000 m/s dx=dz=10 m f=40 Hz



Least squares methods for designing wavefield extrapolators:

- Weighted least squares using a transition function.
- Weighted least squares using a transition band.

Weighted Least squares (WLS)

$$\hat{W}(m\Delta k_x) = \Delta x \sum_{n=-N}^{n=N} \exp(im\Delta k_x n\Delta x) W(n\Delta x)$$

$$\underline{\hat{w}} = \underline{\Gamma}\,\underline{w}$$

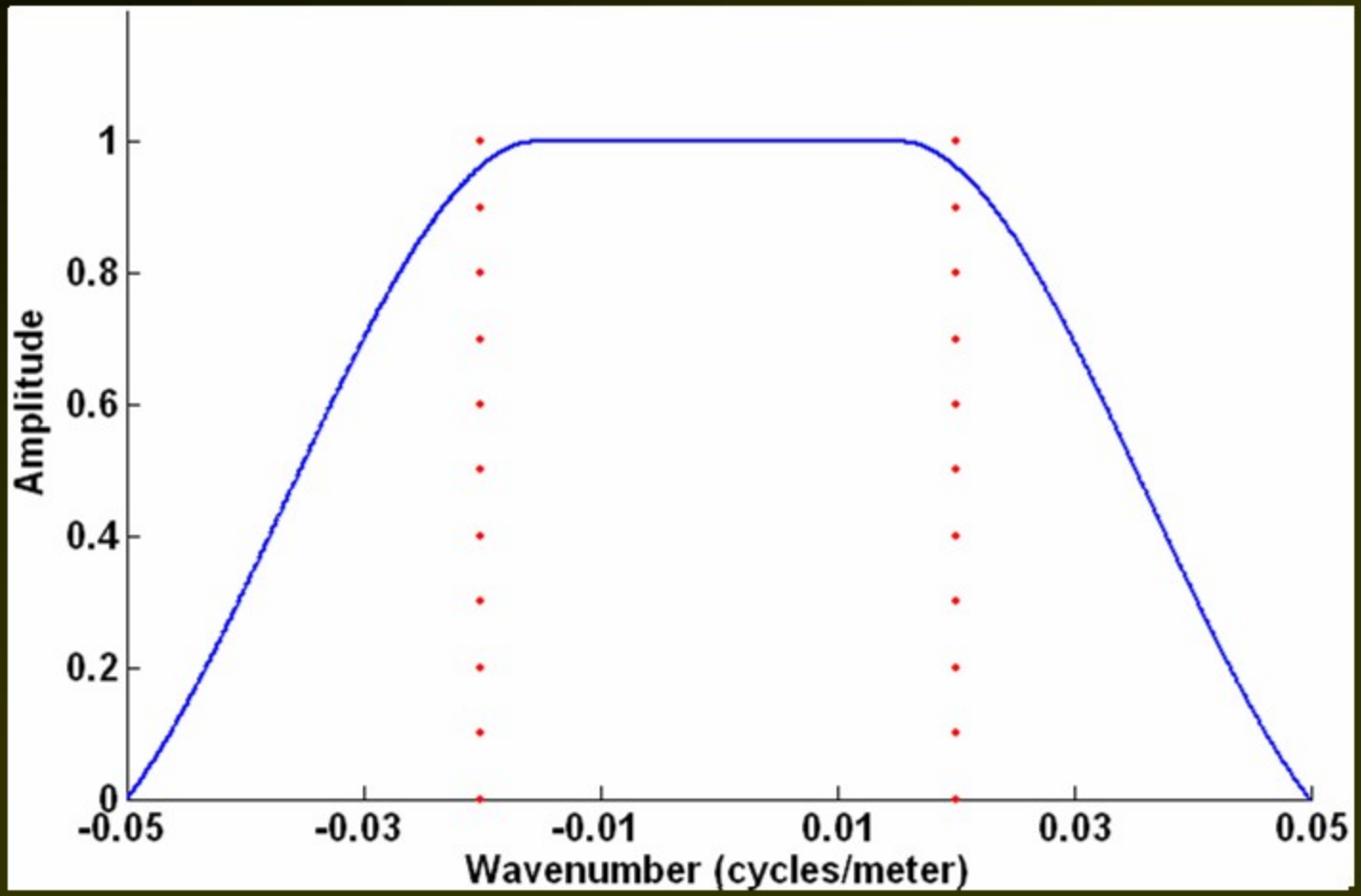
$$\langle \underline{w} \rangle = \left[\underline{\Gamma}^H \underline{\tilde{\Lambda}} \underline{\Gamma} \right]^{-1} \underline{\Gamma}^H \underline{\tilde{\Lambda}} \underline{\hat{w}}$$

where,

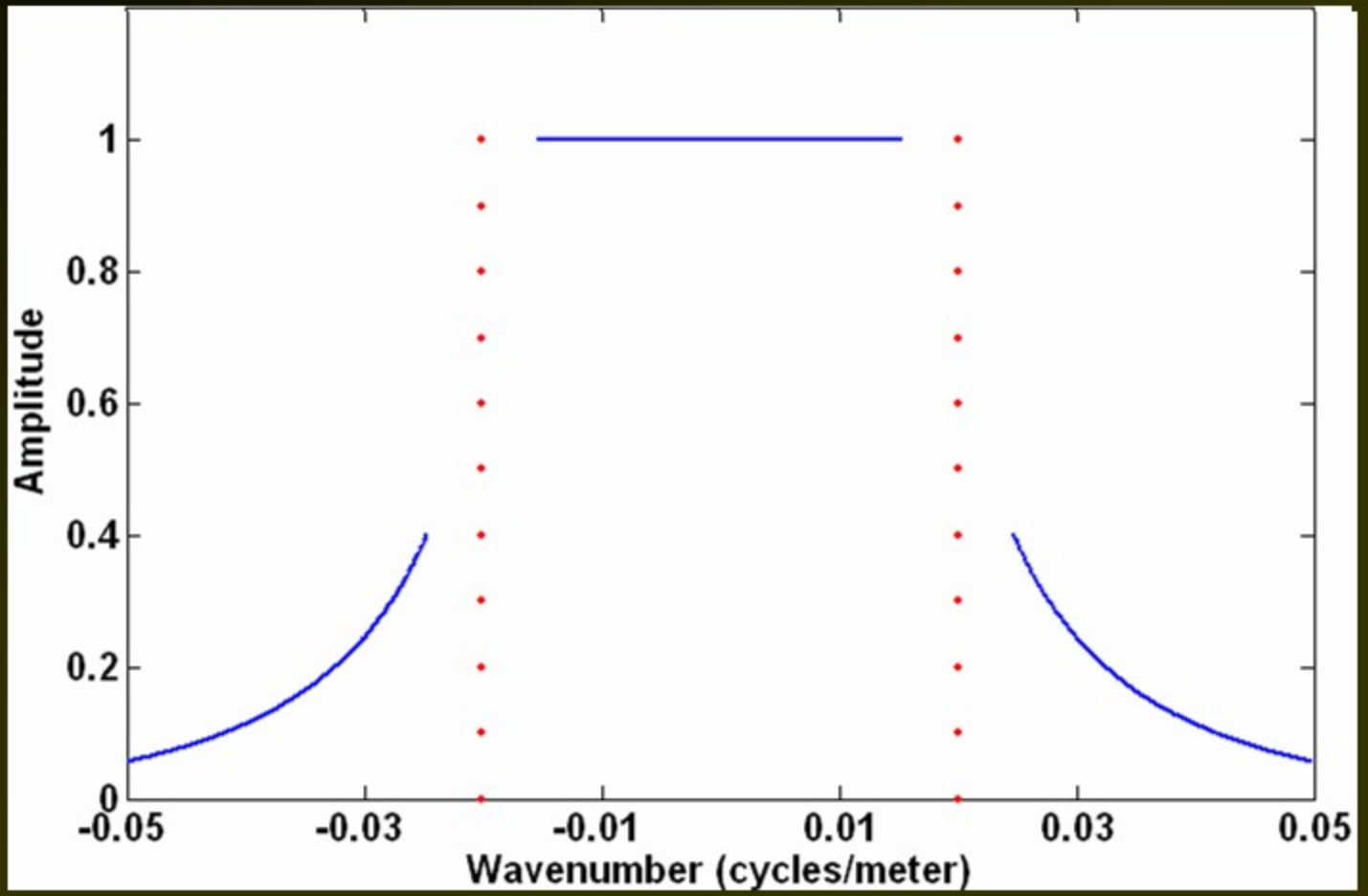
$\tilde{\Lambda}$ = **weight function**

Using a transition function in WLS

(Thorbecke et al., 2004)

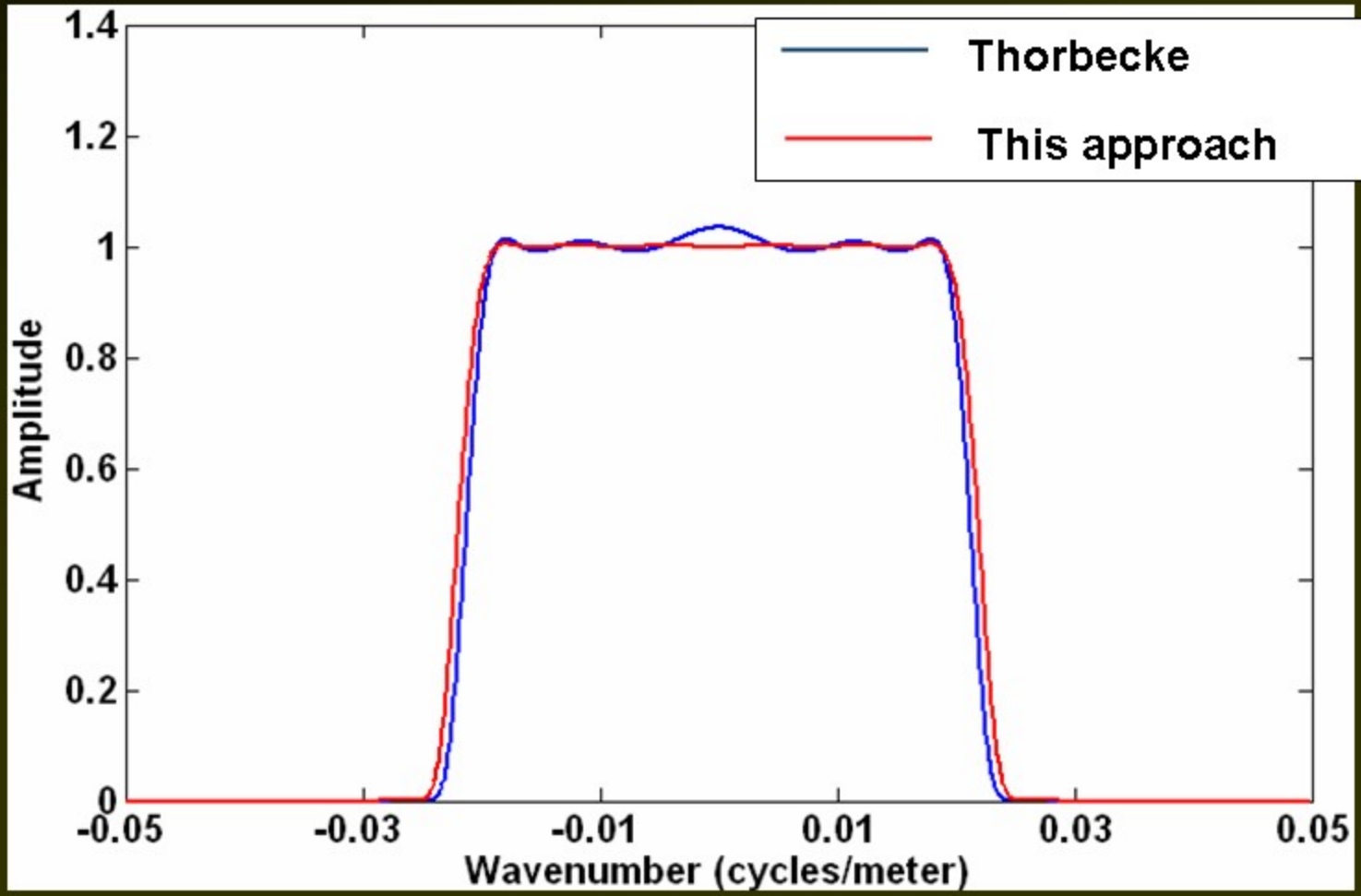


Using a transition band in WLS



A comparison between transition function and band in WLS

N=15 dz=2 m dx=10 m v=2000 m/s f=50 Hz



The FOCI method (Margrave et al. 2005)

$$\tilde{W}_{for}\left(\Delta z/2\right)=H\left(n_{for}\right)W\left(\Delta z/2\right)$$

$$\tilde{W}_{I}\bullet\tilde{W}_{for}\left(\Delta z/2\right)=F^{-1}\left[\left|\hat{W}\left(\Delta z/2\right)\right|^{\eta}\right]$$

$$W_{F}\left(\Delta z\right)=\tilde{W}_{I}^{*}\bullet\tilde{W}_{for}\left(\Delta z/2\right)$$

$$W_{P}\left(\Delta z\right)=H(n_{win})W_{F}\left(\Delta z\right)$$

η Controls the degree of evanescent filtering.

The FOCI method (Margrave et al. 2005)

$$\tilde{W}_{for}\left(\Delta z/2\right)=WLS\left(W\left(\Delta z/2\right)\right)$$

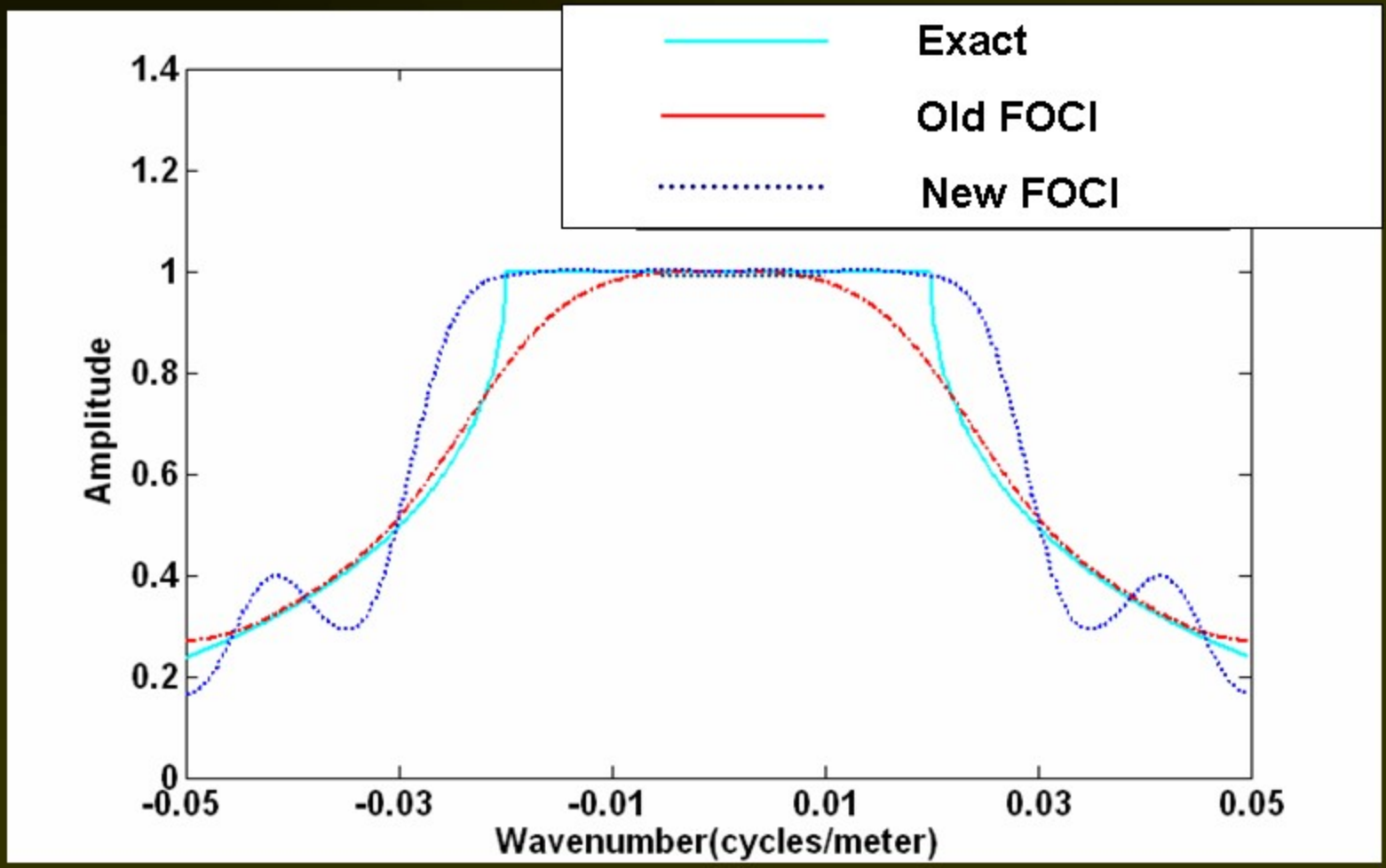
$$\tilde{W}_{I}\bullet\tilde{W}_{for}\left(\Delta z/2\right)=F^{-1}\left[\left|\hat{W}\left(\Delta z/2\right)\right|^{\eta}\right]$$

$$W_{F}\left(\Delta z\right)=\tilde{W}_{I}^{*}\bullet\tilde{W}_{for}\left(\Delta z/2\right)$$

$$W_{P}\left(\Delta z\right)=WLS\left(W_{F}\left(\Delta z\right)\right)$$

η Controls the degree of evanescent filtering.

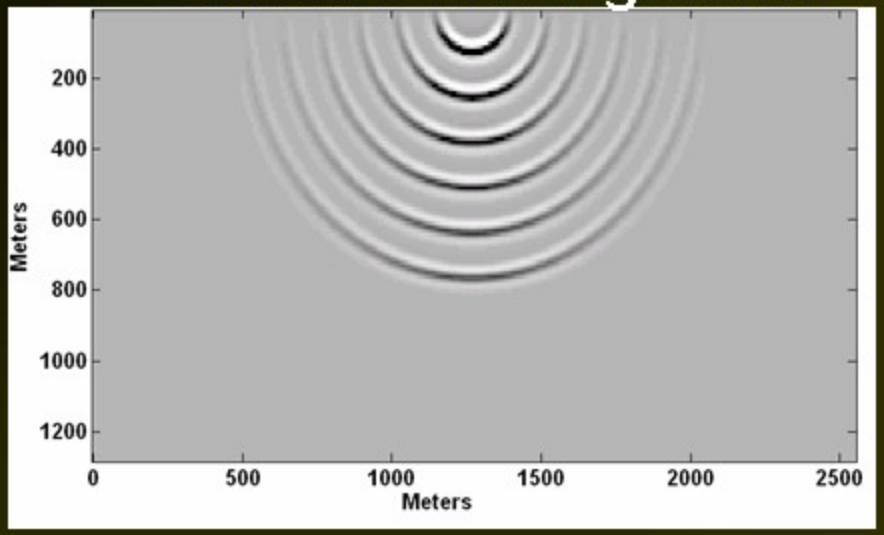
Amplitude spectra of 15 point operators



15 point operator

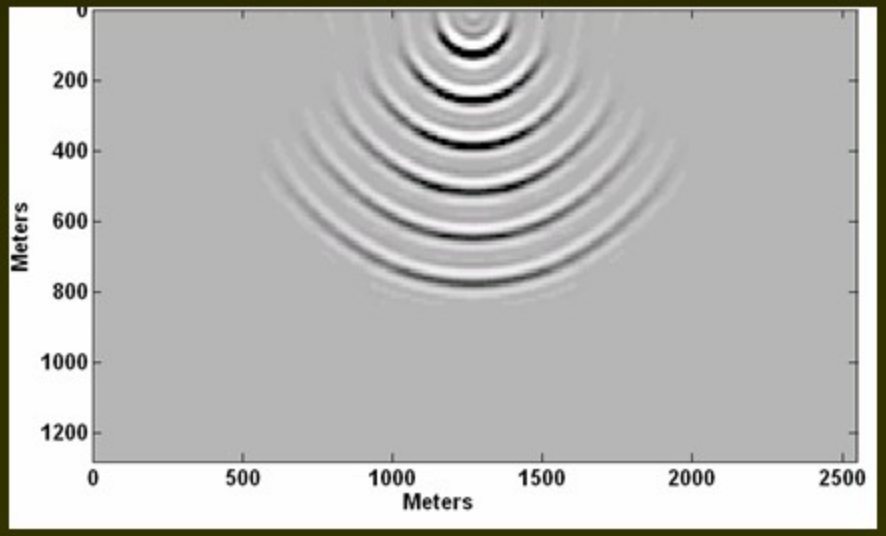
(a)

Phase shift migration

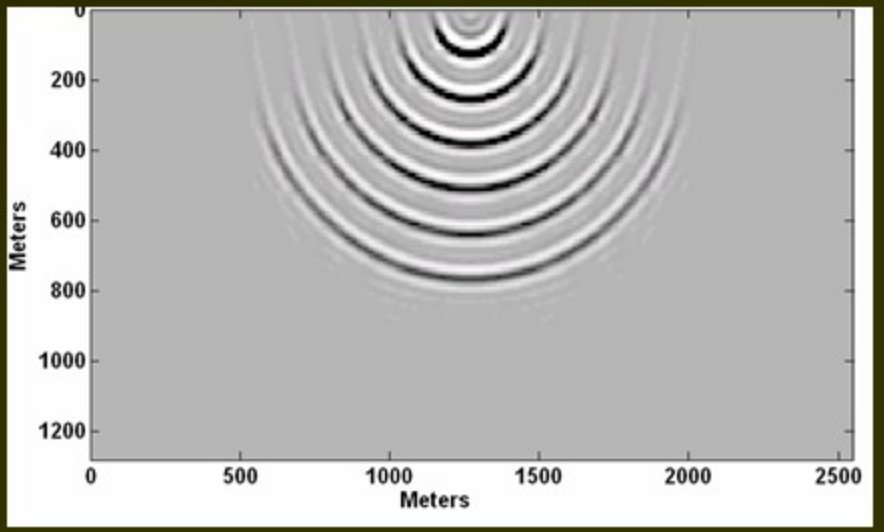


(b)

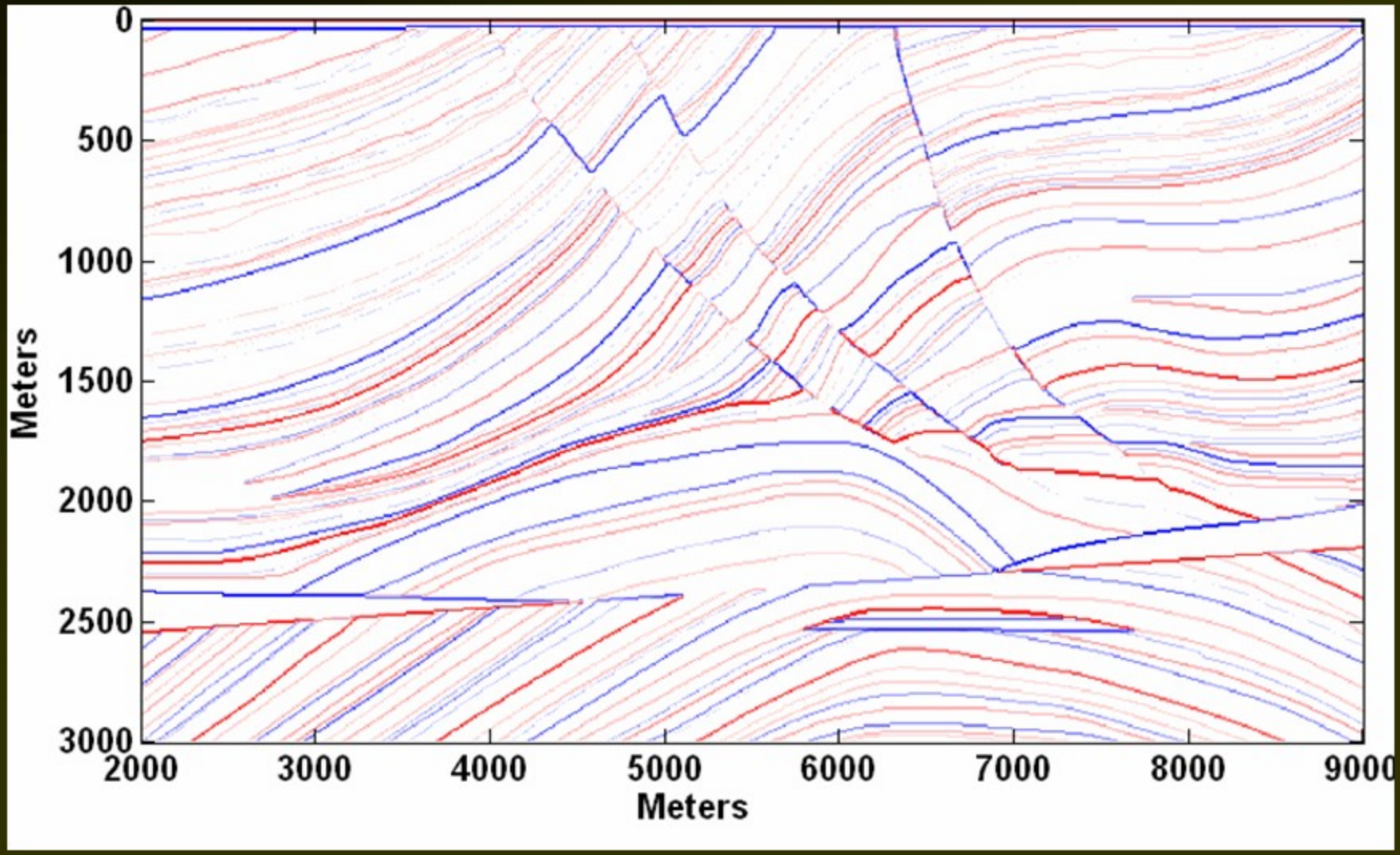
Old FOCI



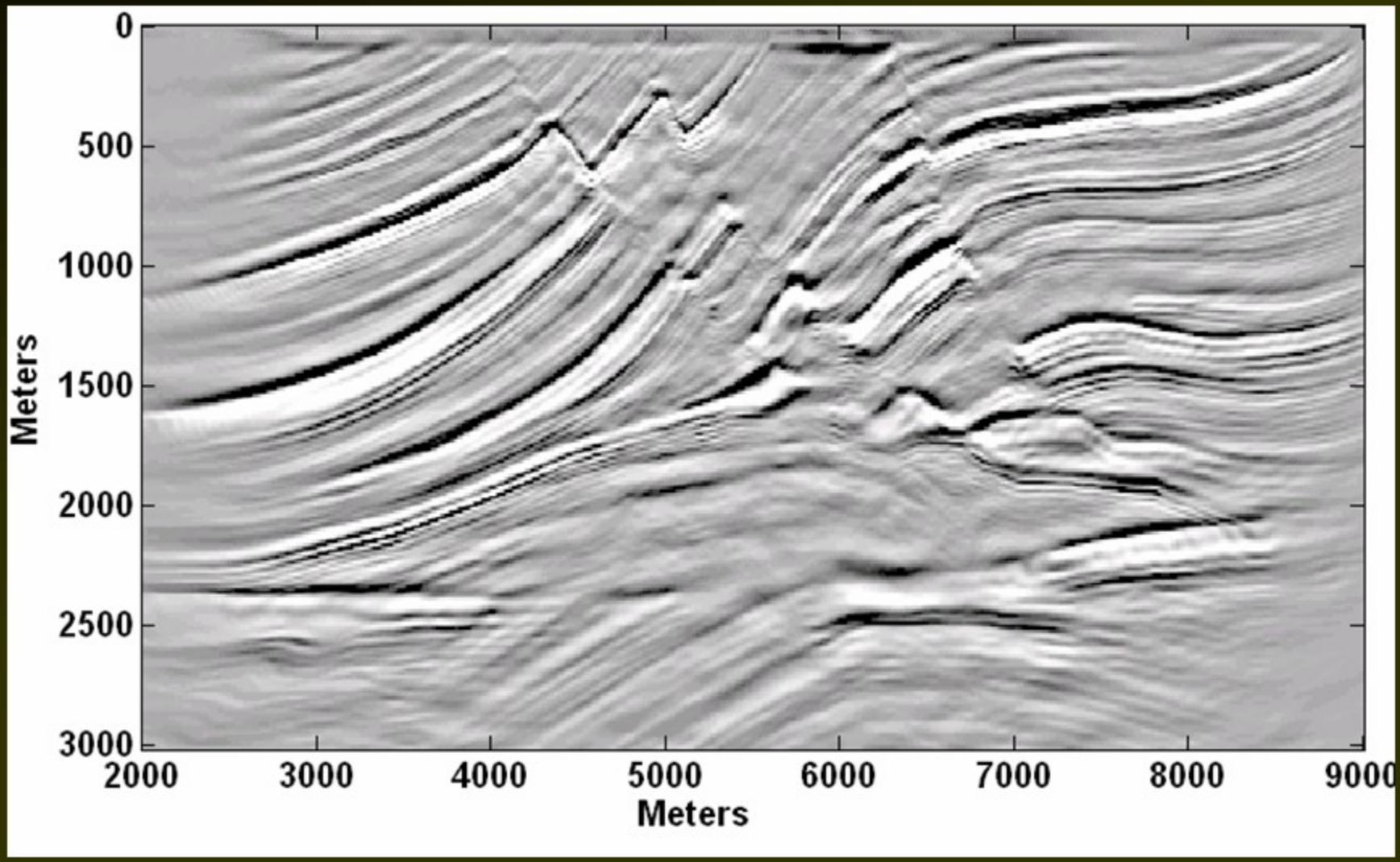
New FOCI



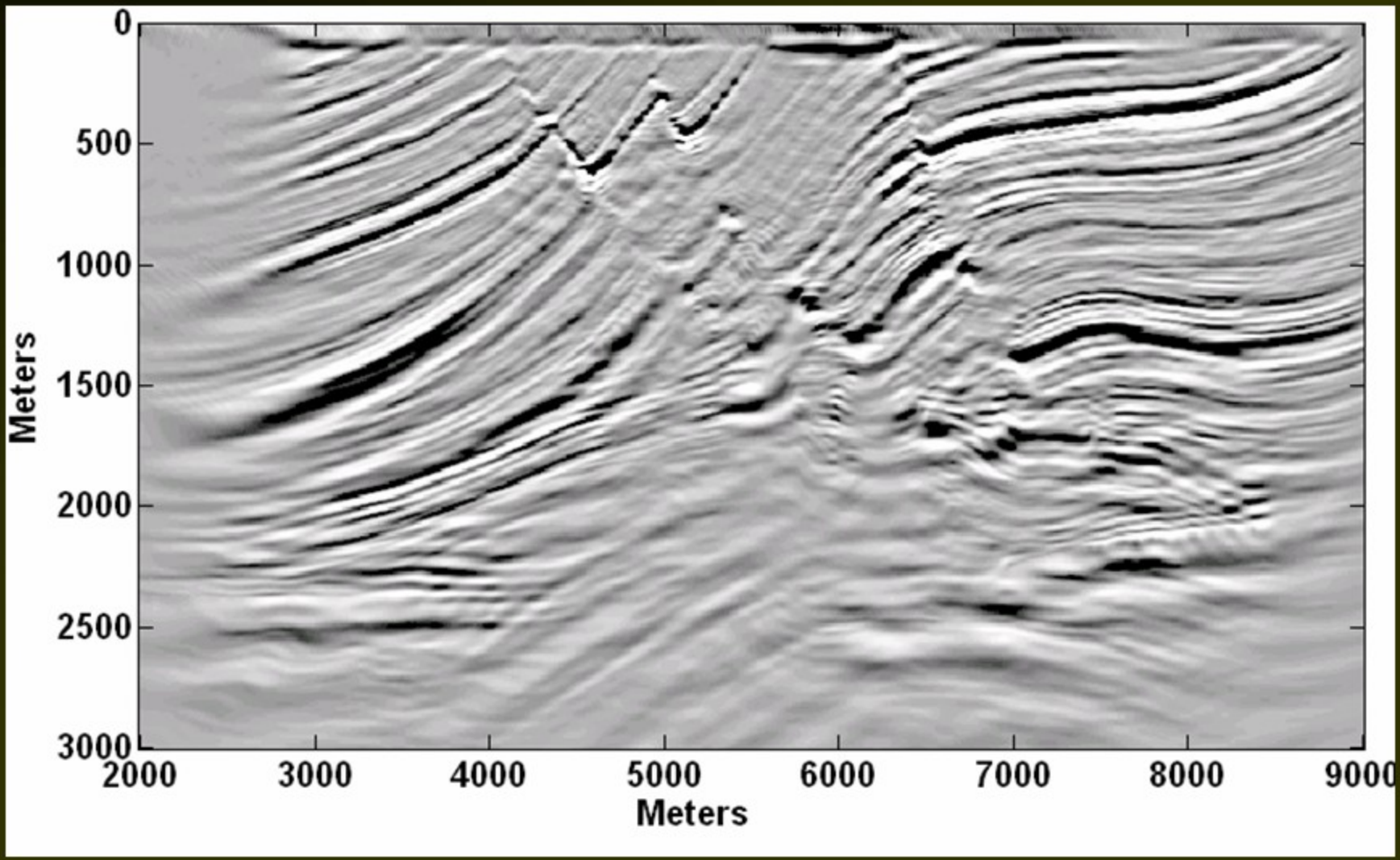
Reflectivity of Marmousi



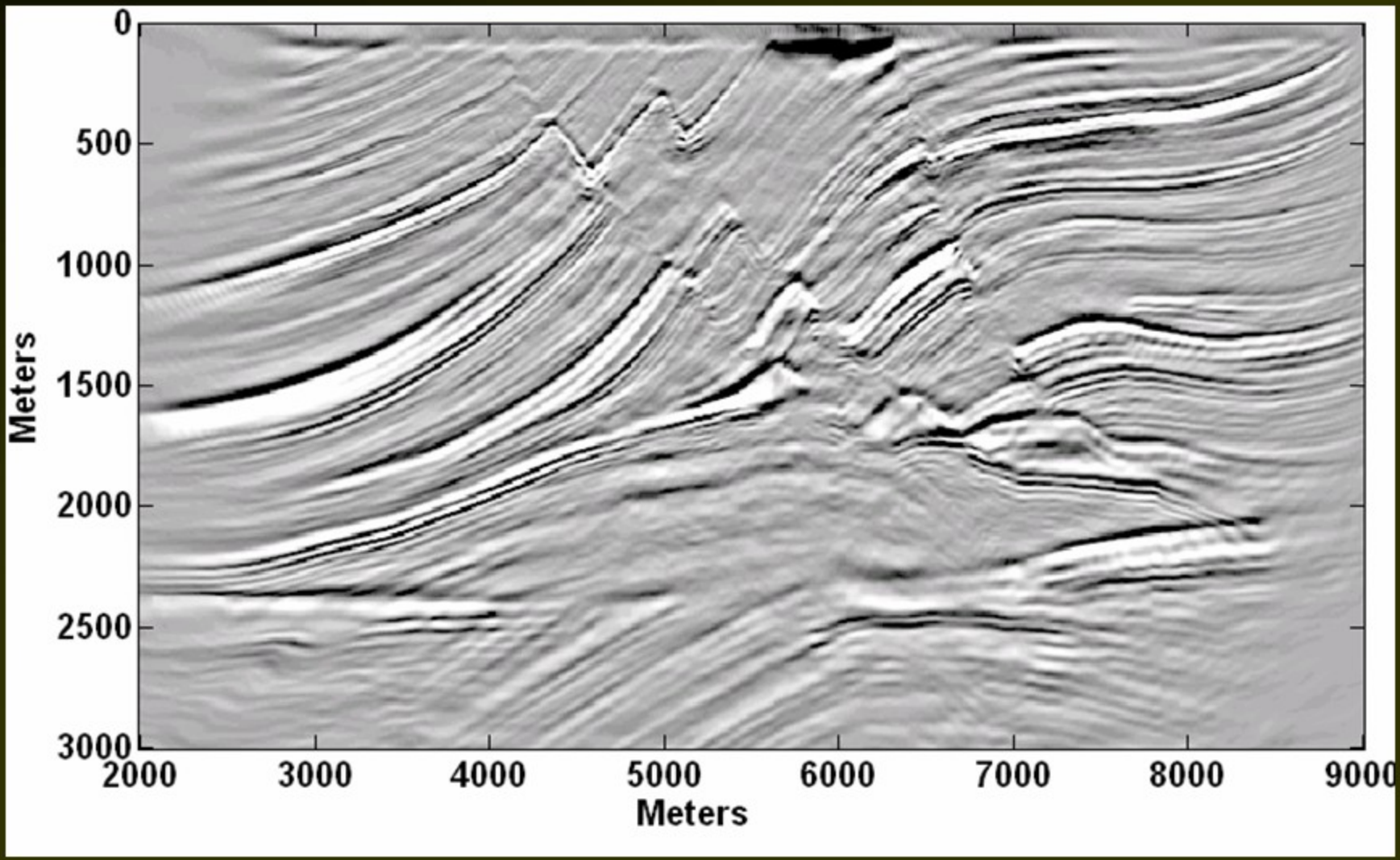
Old FOCI
operator = 51 points



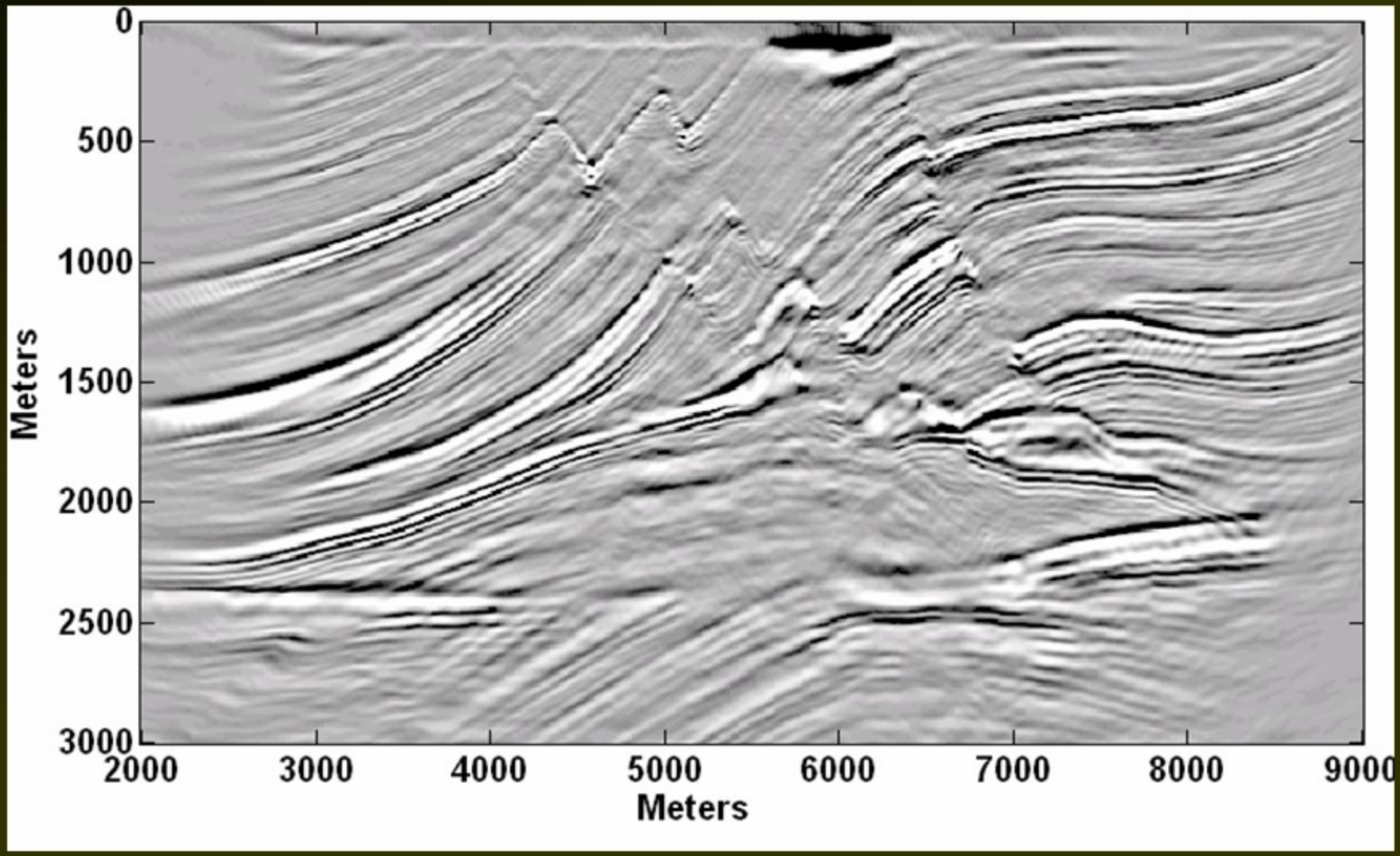
Old FOCI
operator = 15 points



New FOCI operator = 15 points

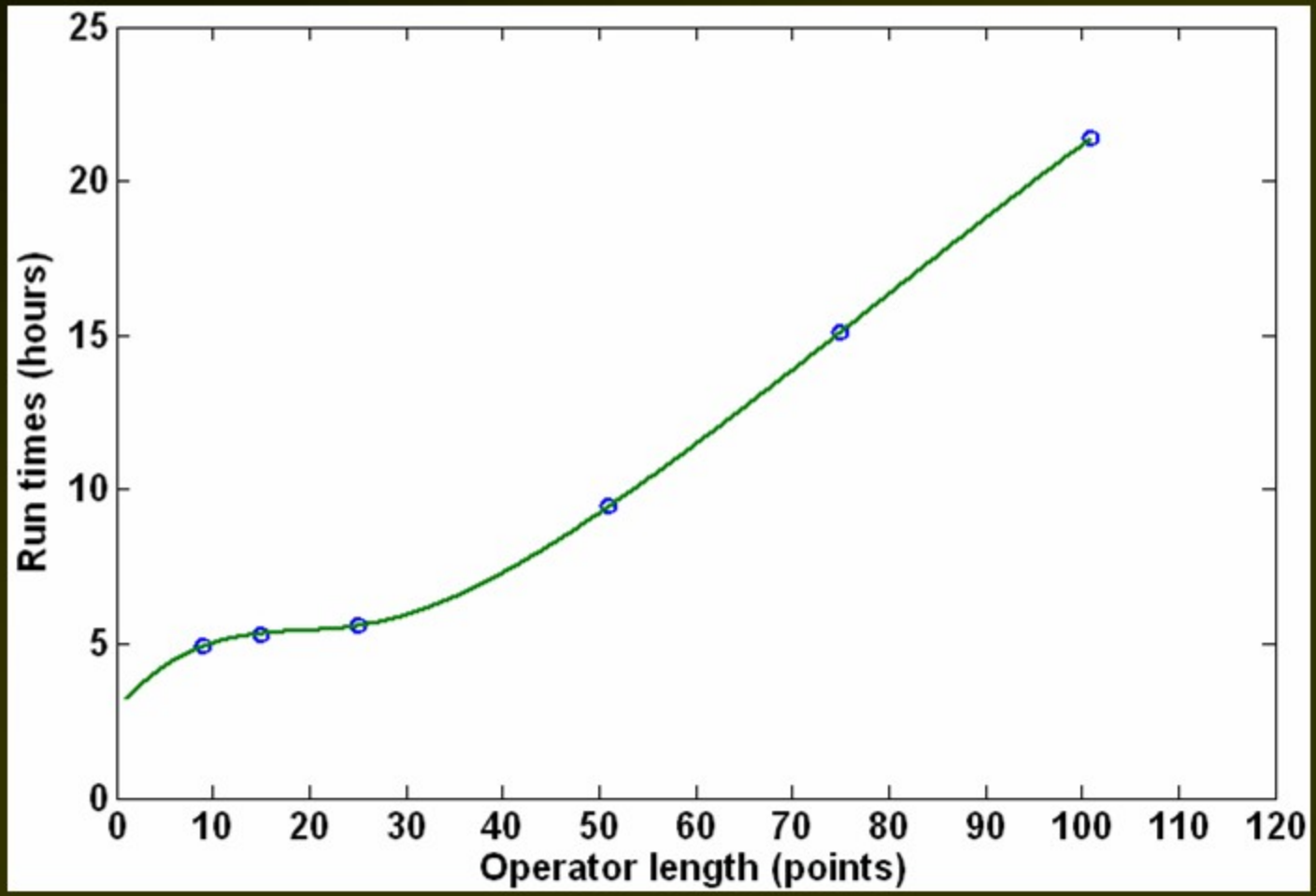


FOCI with WLS operator = 9 points



Operator length vs. run times

dx=12.5 m dz=12.5 m



Migration velocity analysis (MVA)

"…every velocity model is wrong, the question is how wrong you are…"

Conventional velocity analysis

- Domain: Common midpoint (CMP) gathers.

- Type of velocity: Root mean square (RMS).

Deregowski loop

DTS panels

ODCIG gathers

CIG gathers

ADCIG gathers

DFA panels

CFP gathers

HDCIG gathers

Time shifting panels

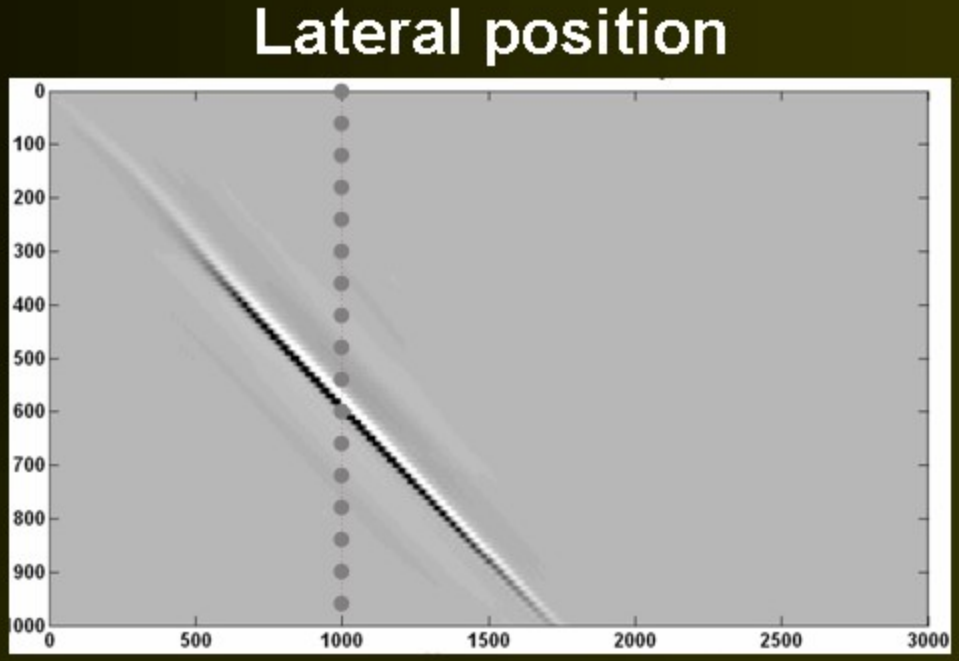
RMS velocity

Average velocity

Interval velocity

Tomography

Global Tomography


Lateral position
Depth
0
100
200
300
400
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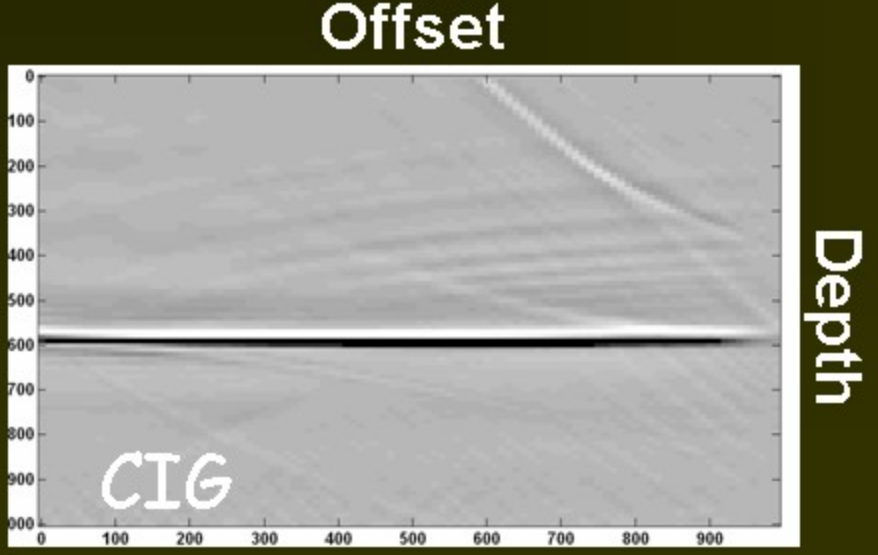
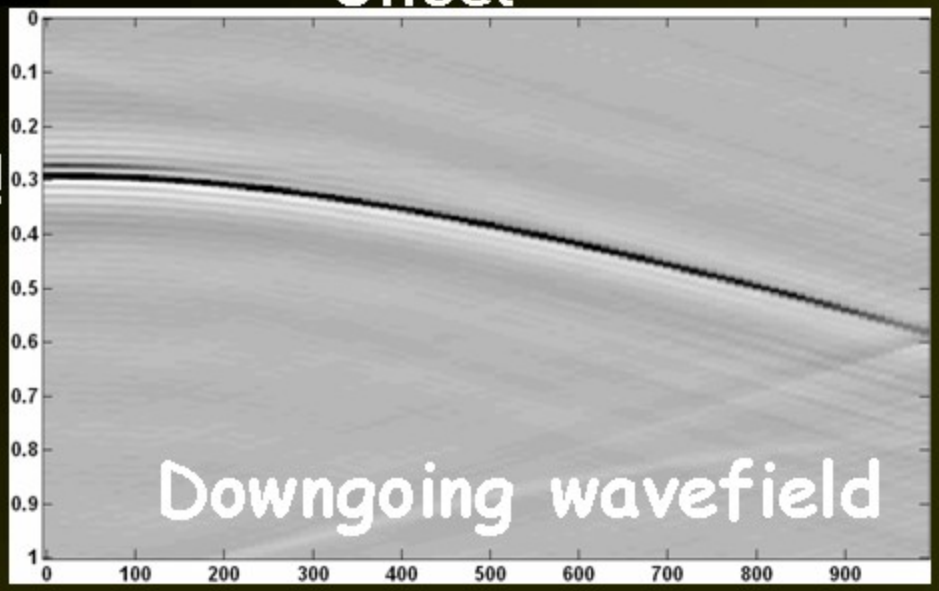
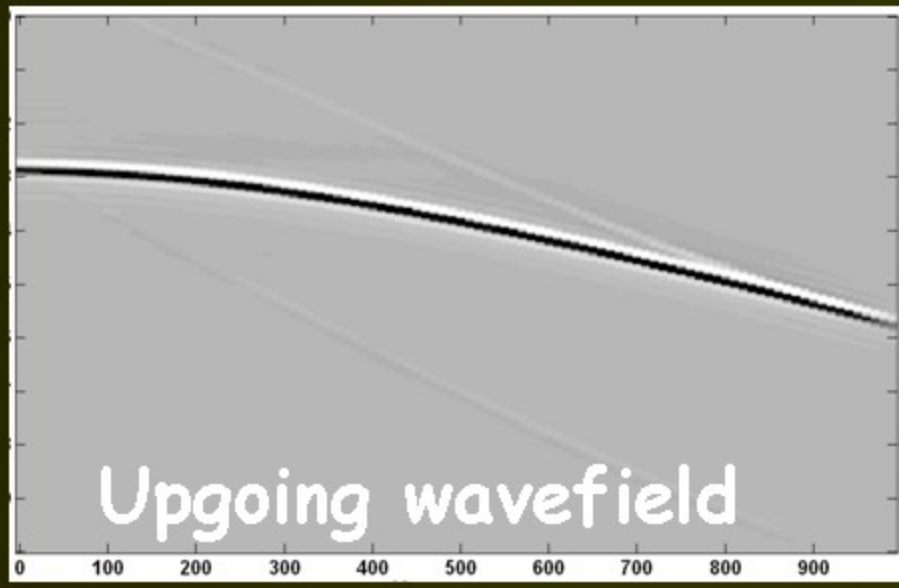
600
700
800
900
1000
0
500
1000
1500
2000
2500
3000

$$\sum_{offset}$$


Offset
Depth
CIG
0
100
200
300
400
500
600
700
800
900
1000

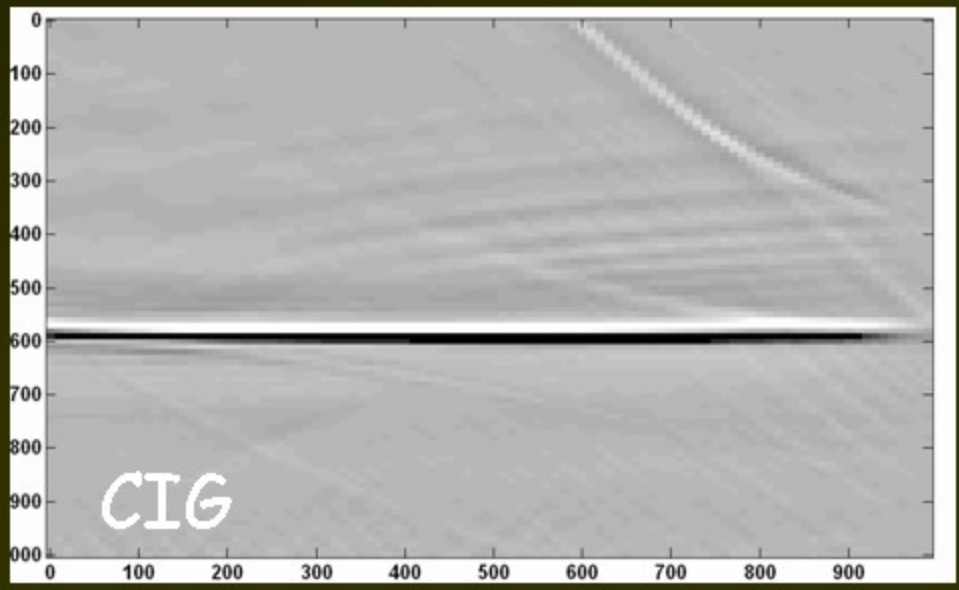


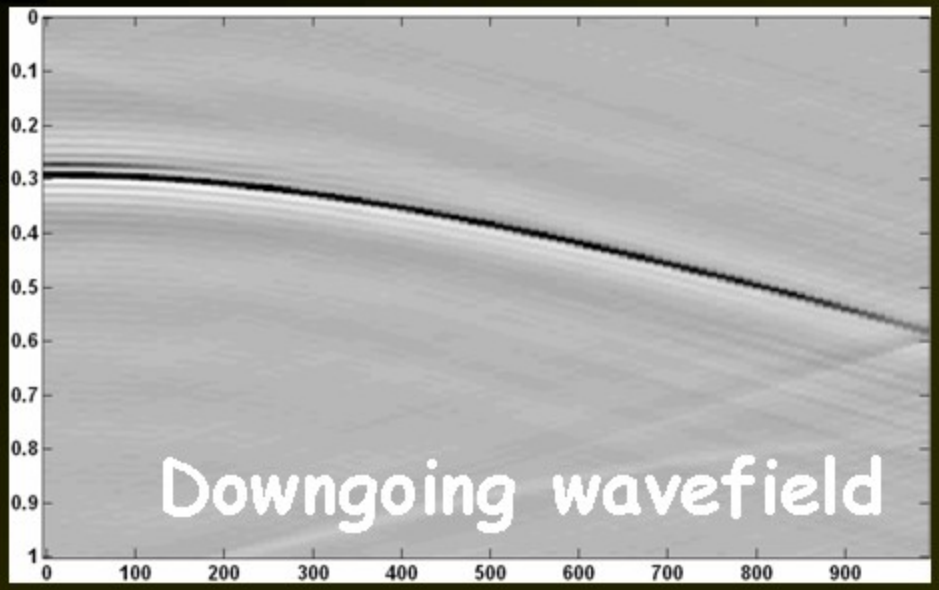


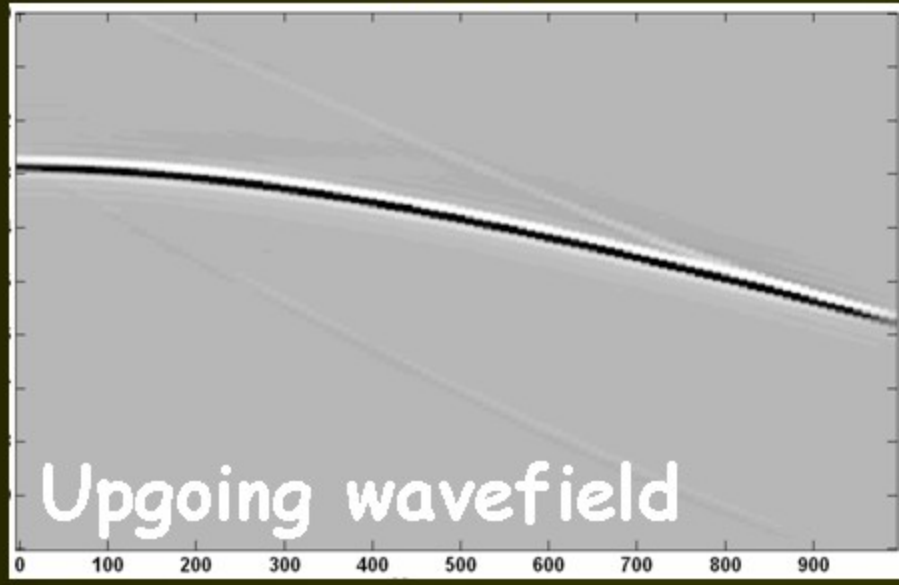
Residual curvature analysis

(RCA)

(Al-Yahya, 1989)



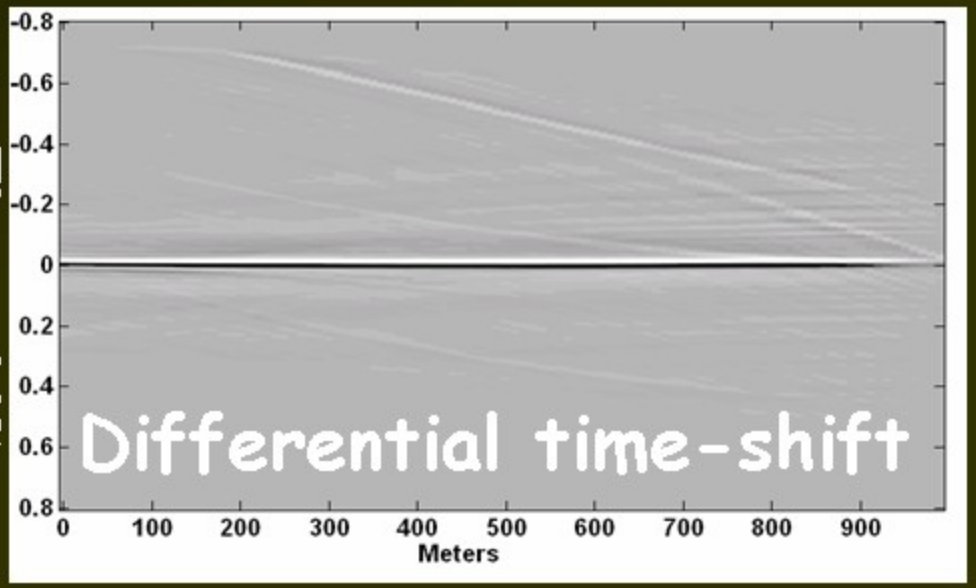




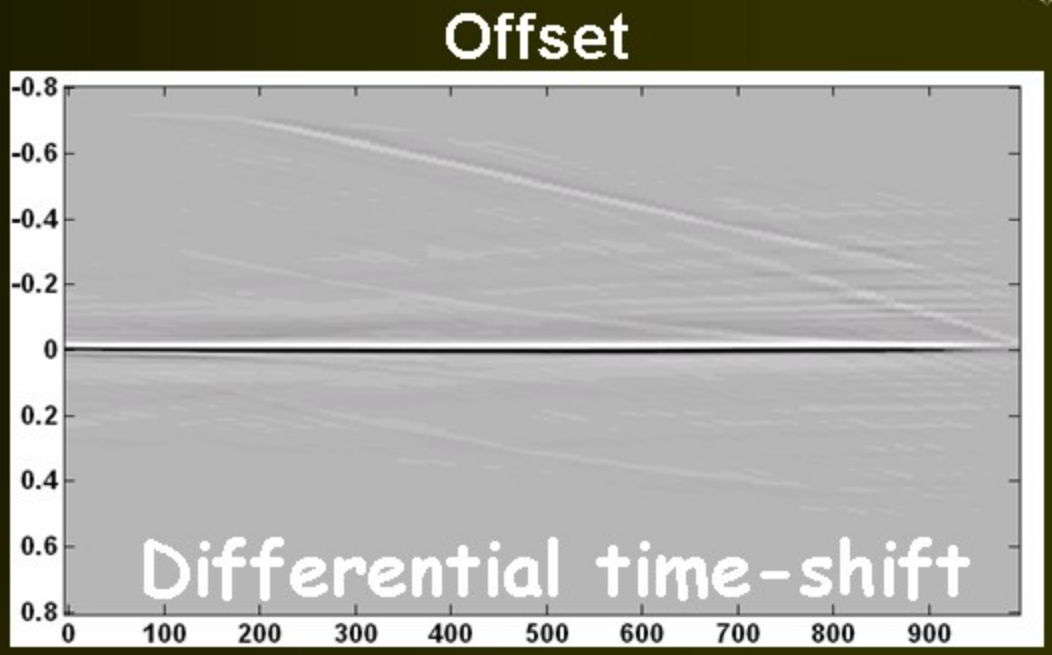
Common focus point

(CFP) analysis

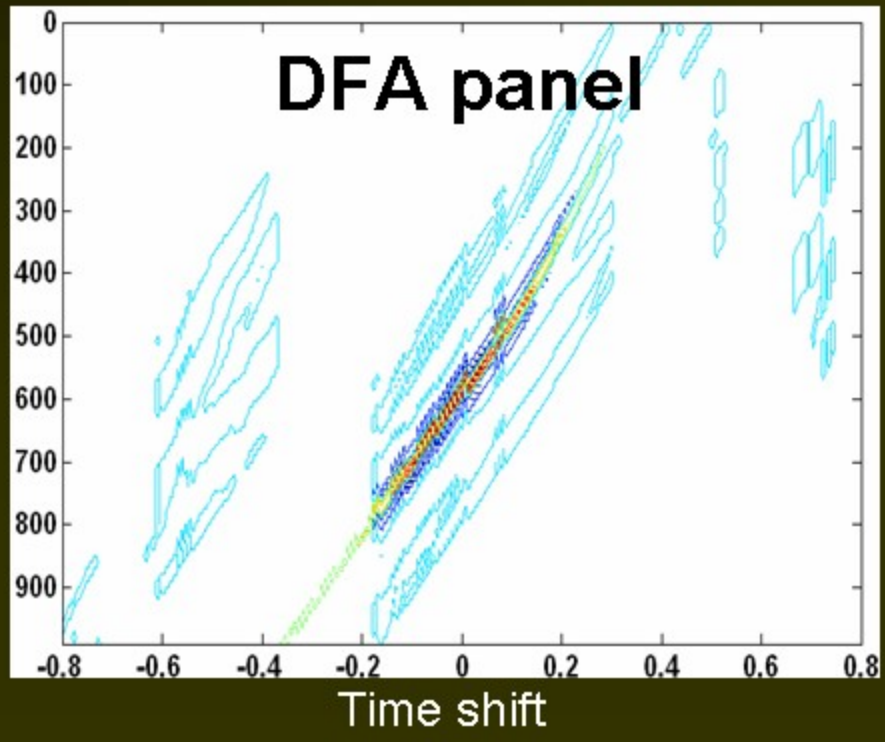
(Berkhout, 1997)



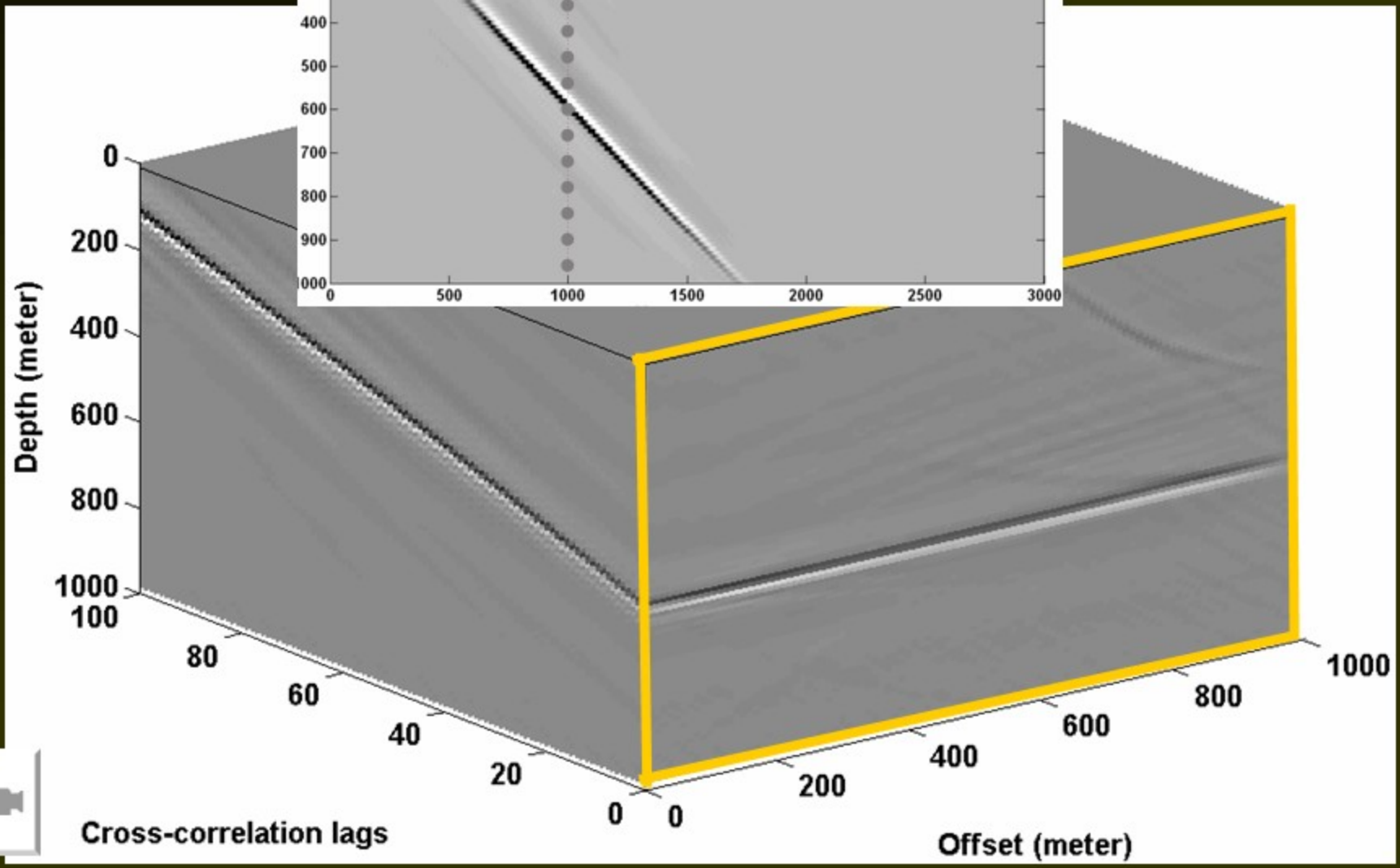
$$\sum_{offset}$$

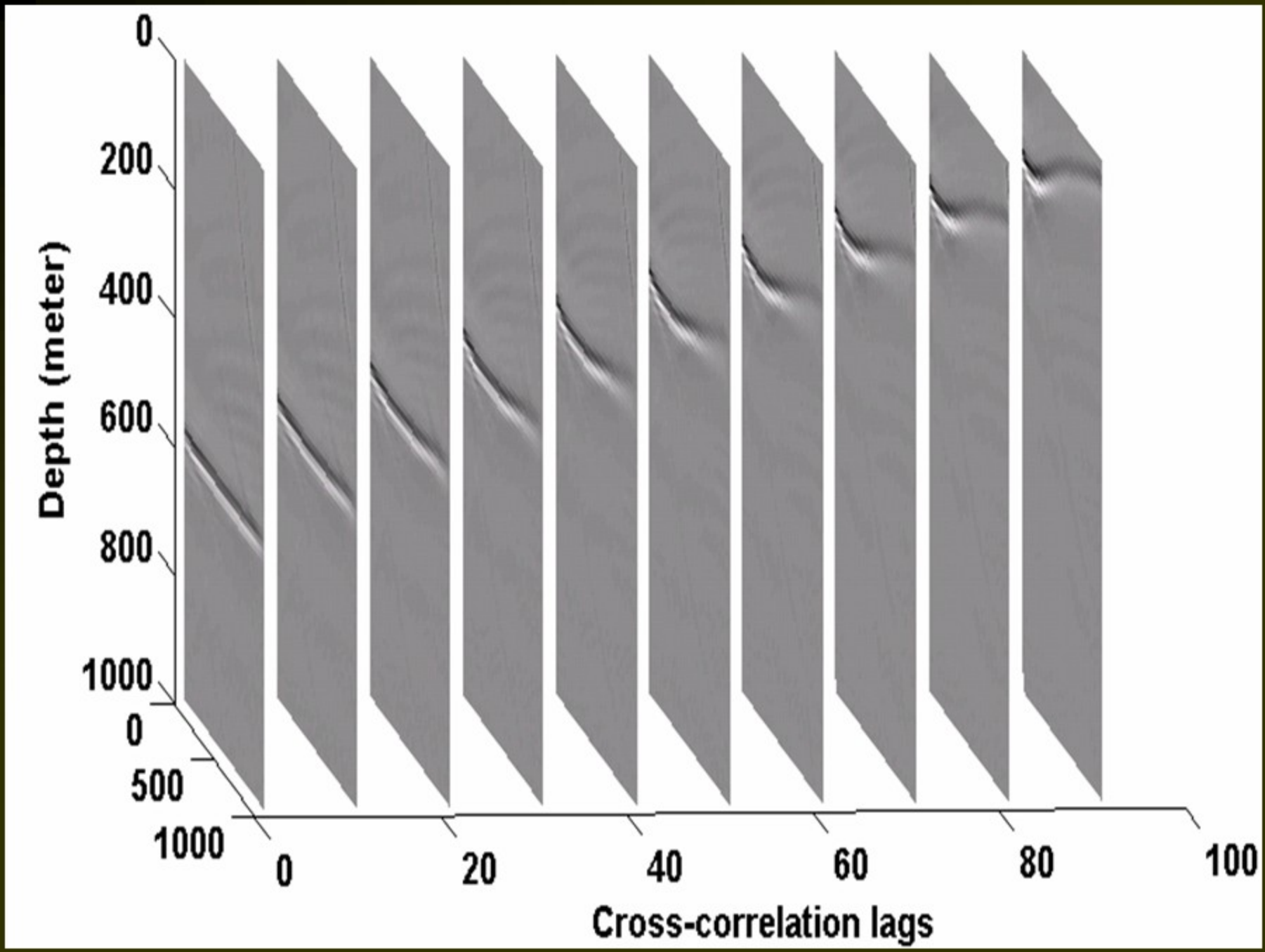


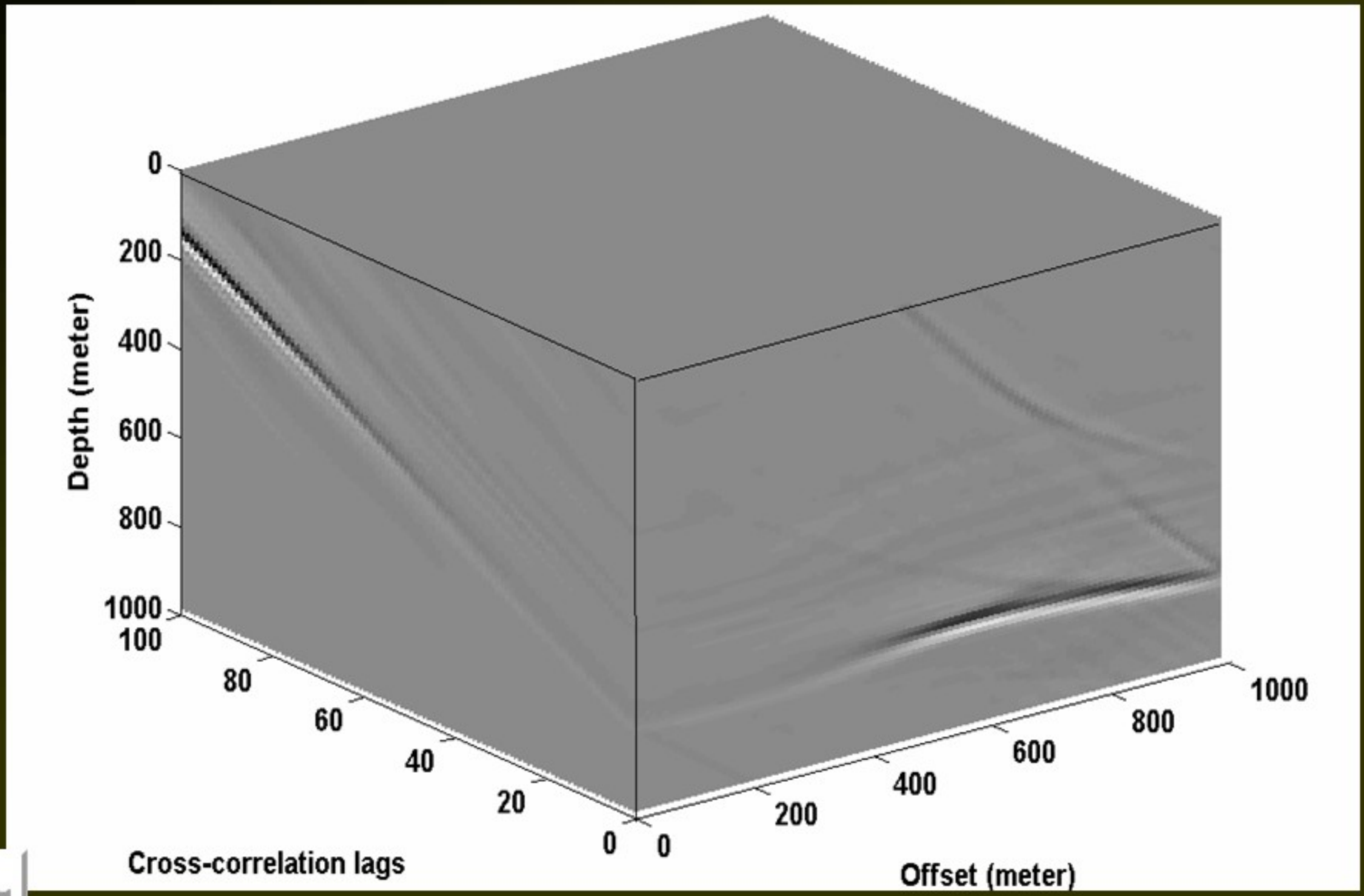
Depth focusing analysis (DFA) (Faye and Jeannot, 1986)

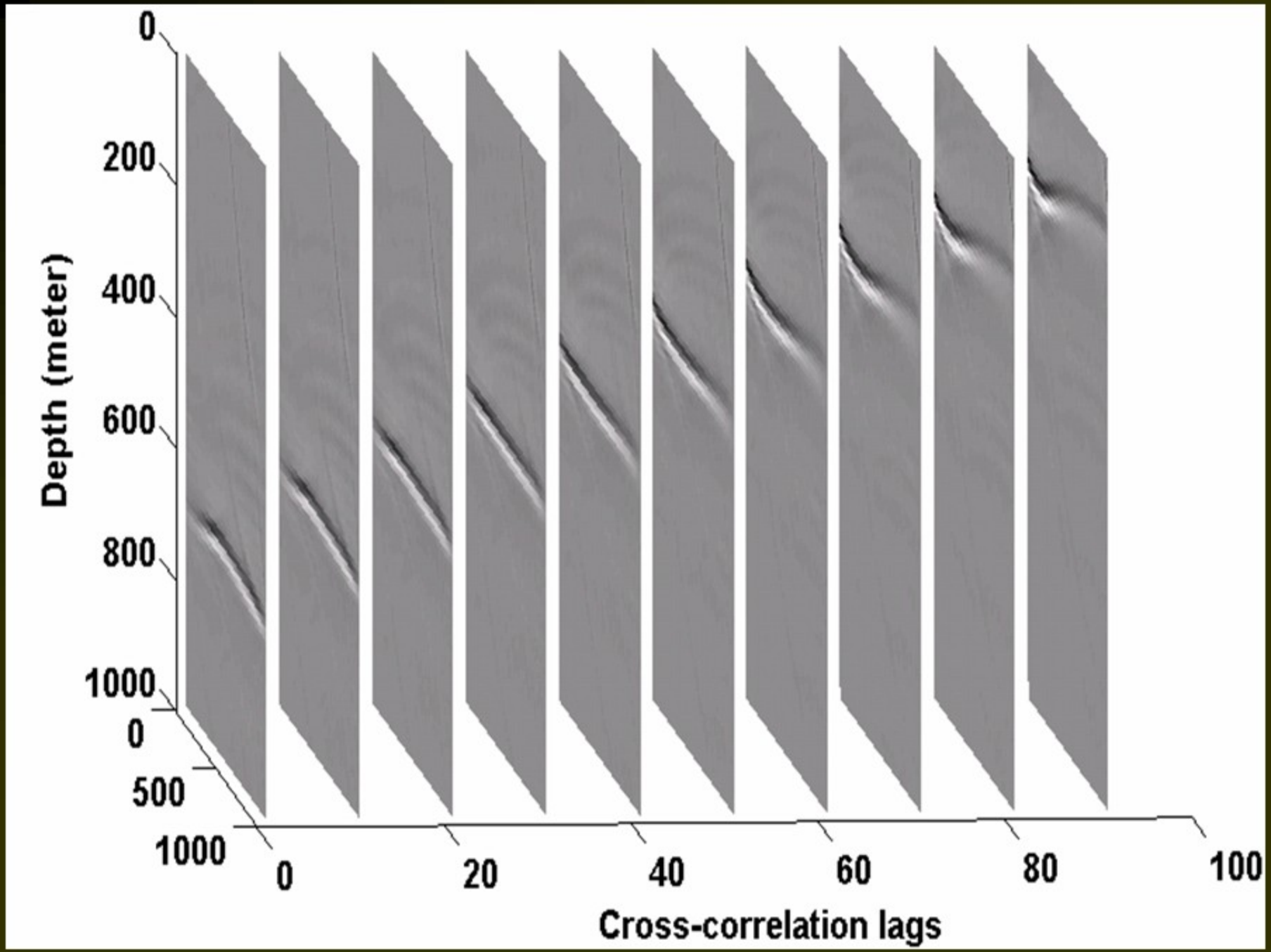


The common image cube analysis




Depth (meter)
0
200
400
600
800
1000
0
500
1000
0
20
40
60
80
100
Cross-correlation lags


0
200
400
600
800
1000
Depth (meter)
100
80
60
40
20
0
Cross-correlation lags
0
200
400
600
800
1000
Offset (meter)


Depth (meter)
0
200
400
600
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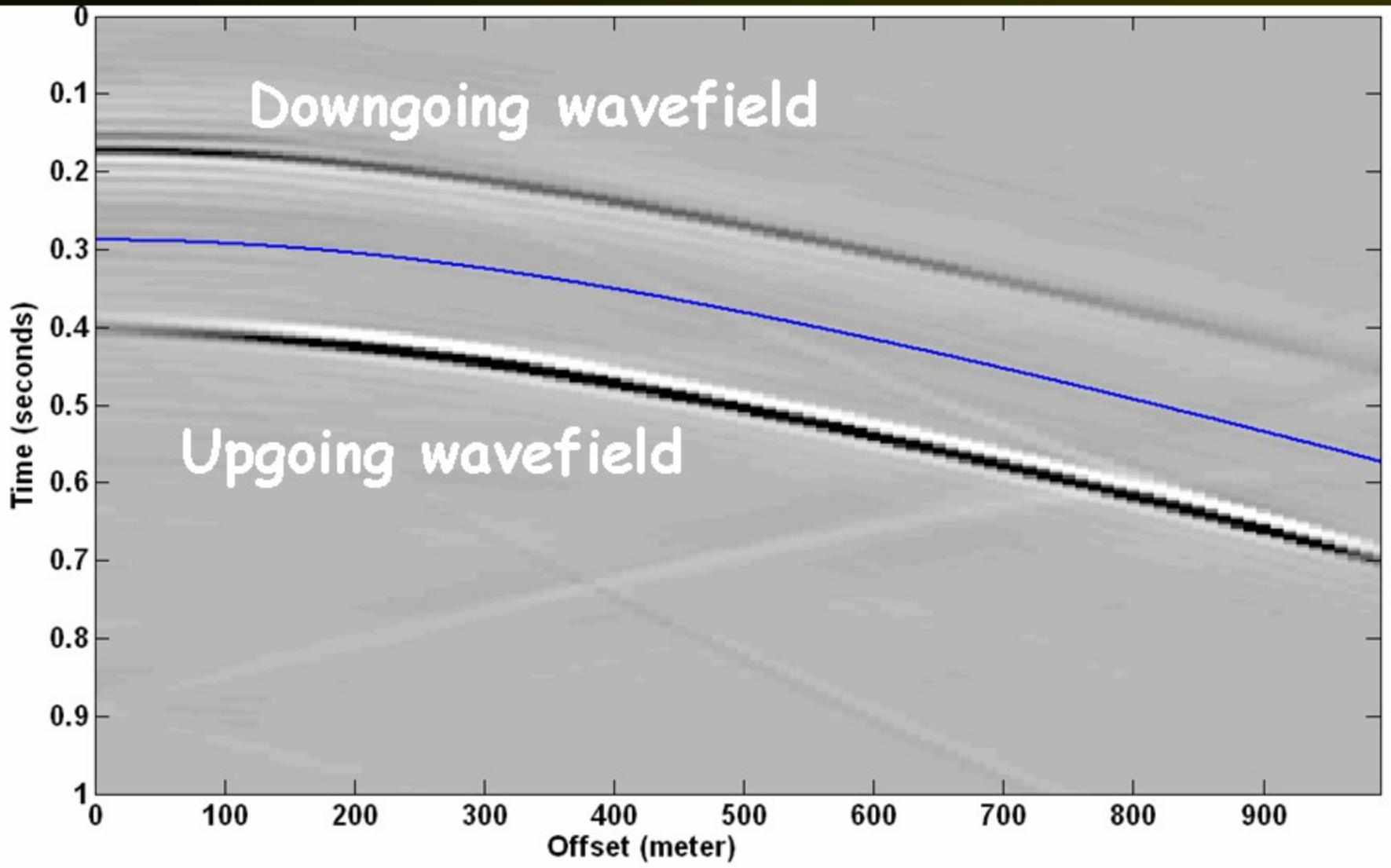
500
1000
0
20
40
60
80
100
Cross-correlation lags

Wavefields at the focusing depth



Conclusions

- Weighted least squares using a transition band can be used to design wavefield extrapolators.
- The enhanced FOCI algorithm with WLS can now be used to design very short operators and be more efficient.
- The different MVA's may seem different but they are all related.
- CICA offers more prestack information than the DFA, RCA, and CFP approaches.

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