Extended imaging, deconvolution, and two-way wavefields

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Surface data

Source wavelet

Velocity

$u_r$

$u_s$

Extended correlation

[Diagram of a layered model with depth and horizontal scale, showing data flow through $u_r$ and $u_s$.]
Surface data

Source wavelet

Velocity

$u_r$

$u_s$

Extended correlation
Surface data → Marchenko Equations

Marchenko Equations → Extended correlation

Velocity

$u_s, u_r$
Surface data → Marchenko Equations → Extended correlation

Velocity

Marchenko Equations:

\[ u_s \quad u_r \]
slow  correct  fast
\[ l(\mathbf{x}) = \sum_{\mathbf{x}_s, t} u_s(\mathbf{x}_s, \mathbf{x}, t) u_r(\mathbf{x}_s, \mathbf{x}, t) \]

*\( u_s \): source wavefield

*\( u_r \): receiver wavefield
RTM

\[ L(v)u_s = s \]

\[ L^\top(v)u_r = d \]
RTM

\[ L(v)u_s = s \]

\[ L^\top(v)u_r = d \]

Marchenko

\[ u_s = P_1(f_1^+, f_1^-, d) \]

\[ u_r = P_2(f_1^+, f_1^-, d) \]
extended imaging

\[ l(\mathbf{x}, \lambda, \tau) = \sum_{\mathbf{x}_s, t} u_s(\mathbf{x}_s, \mathbf{x} - \lambda, t - \tau) u_r(\mathbf{x}_s, \mathbf{x} + \lambda, t + \tau) \]

\(u_s\): source wavefield
\(u_r\): receiver wavefield
$I = U_s^\top u_r$

$U_s^\top$: extended imaging
$u_r$: receiver wavefield
Deconvolution extended imaging

\[ U_s l \approx u_r \]

\( U_s \): adjoint of extended imaging

\( u_r \): receiver wavefield
deconvolution extended imaging

\[
\left( U_s^\top U_s + \epsilon^2 I \right) I = U_s^\top u_r
\]

\( I \): extended deconvolution image
errors in the background model
extended correlation

RTM

slow

correct

fast
extended correlation

slow

Marchenko

correct

fast
extended deconvolution

slow

fast

Marchenko
extended correlation $\lambda \rightarrow \theta$

RTM

Slow

Correct

Fast
extended correlation $\lambda \rightarrow \theta$  Marchenko

slow

correct

fast
extended deconvolution $\lambda \rightarrow \theta$

slow

correct

fast

Marchenko
extended correlation $\lambda \rightarrow \theta$

slow

correct

fast
extended deconvolution $\lambda \rightarrow \theta$

slow

correct

fast

Marchenko
slow model
correct model
fast model
extended images, slow model
extended images, correct model
extended images, fast model
angle gathers, slow model
angle gathers, correct model
angle gathers, fast model
angle gathers, correct model deconvolution
angle gathers, correct model correlation
angle gathers, correct model deconvolution
angle gathers, correct model correlation
conclusions

eliminate bias
conclusions

eliminate bias

sensitive to velocity errors
conclusions

eliminate bias

sensitive to velocity errors

improved resolution and illumination
acknowledgements

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