Plane-wave Least-squares Reverse Time Migration

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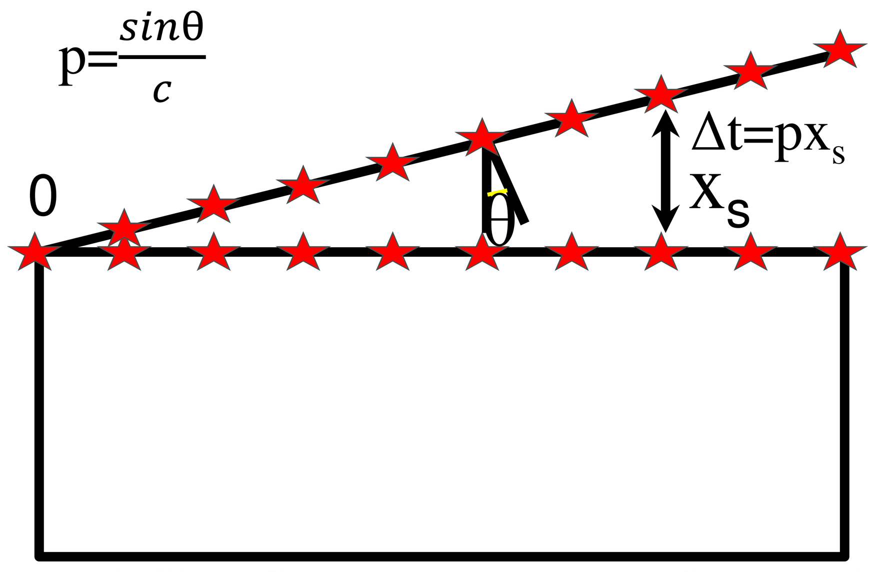
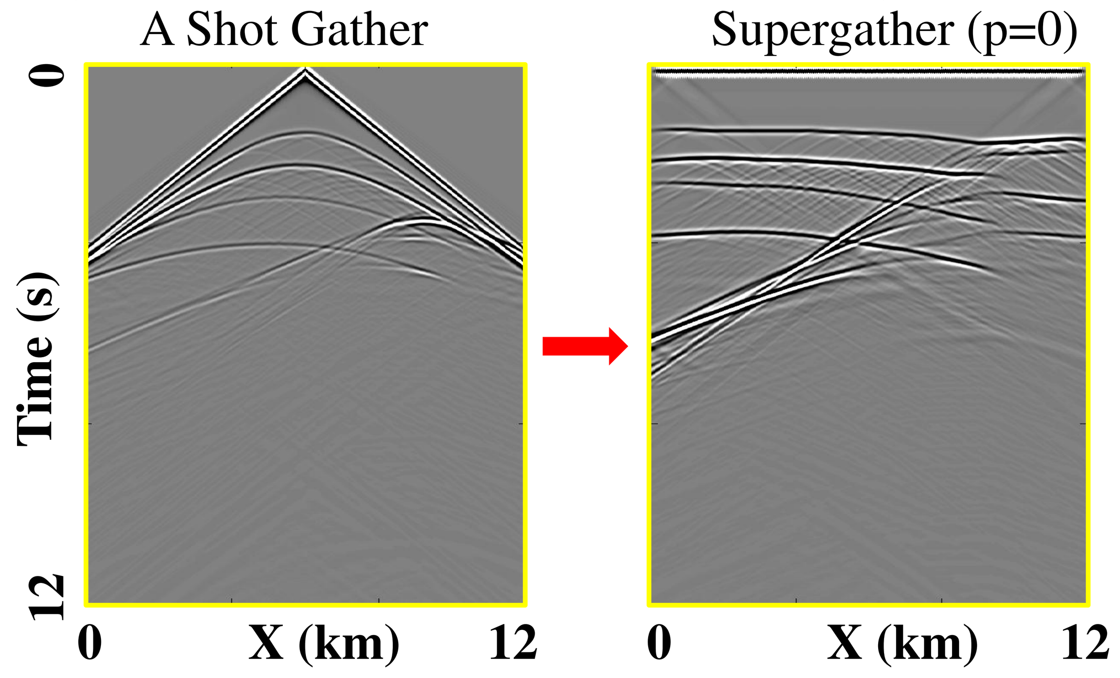
A plane-wave least-squares reverse time migration (LSRTM) is formulated with a new parameterization, where the migration image of each shot gather is updated separately and an ensemble of prestack images is produced along with common image gathers. The merits of plane-wave LSRTM are the following: (1) plane-wave prestack LSRTM can sometimes offer stable convergence even when the migration velocity has bulk errors of up to 5%; (2) to significantly reduce computation cost, linear phase-shift encoding is applied to hundreds of shot gathers to produce dozens of plane waves. Unlike phase-shift encoding with random time shifts applied to each shot gather, plane-wave encoding can be effectively applied to data with a marine streamer geometry; (3) plane-wave prestack LSRTM can provide higher quality images than standard RTM. Numerical tests on the Marmousi2 model and a marine field dataset are performed to illustrate the benefits of plane-wave least-squares reverse time migration. Empirical results show that LSRTM in the plane-wave domain, compared to standard reverse time migration, produces images efficiently with fewer artifacts and better spatial resolution. Moreover, the prestack image ensemble accommodates more unknowns to makes it more robust than conventional least-squares migration in the presence of migration velocity errors.

Plane Wave Encoding

$$d(p,g,t)=\sum_s d(s,gt)*\delta(t-px_s)$$

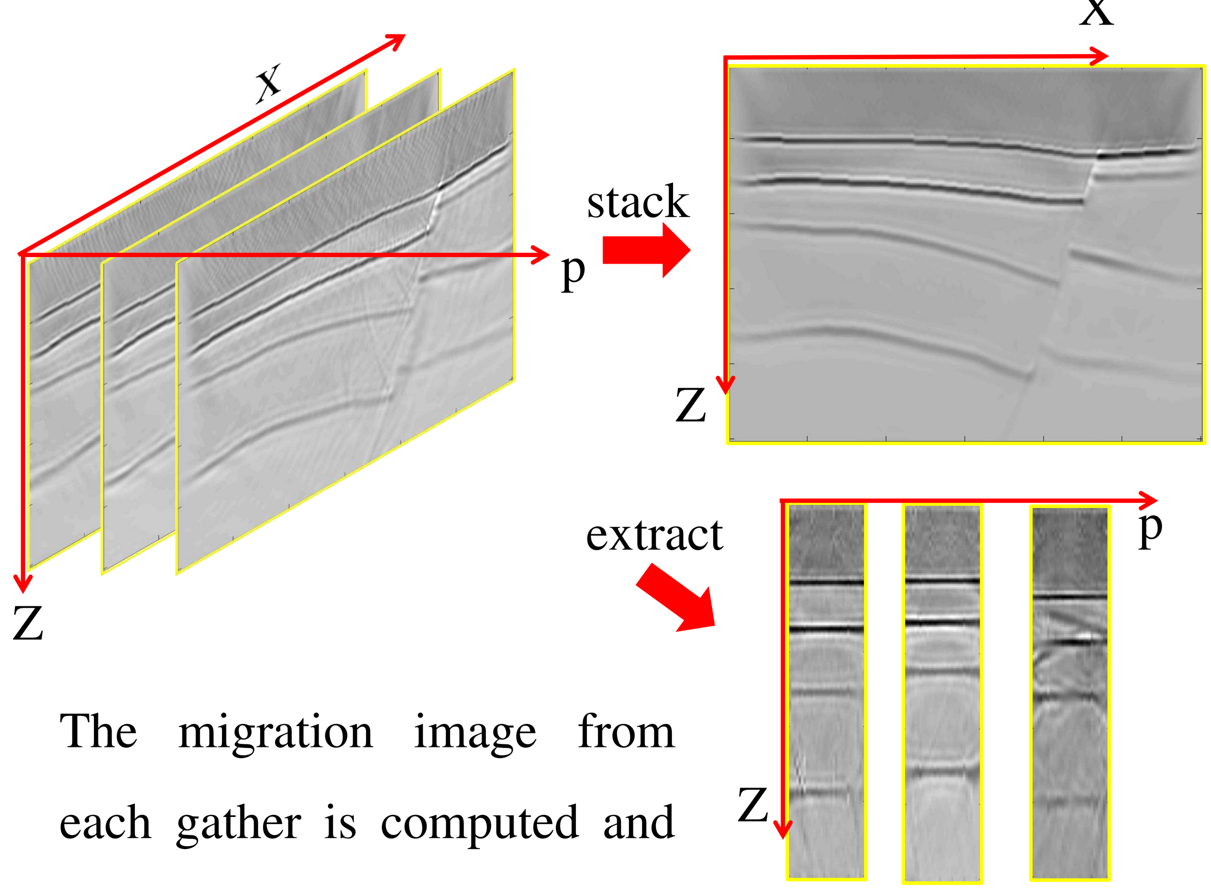
$$p=\frac{\sin\theta}{c}$$





Prestack Image

Prestack image: $m = m(x,p)$



The migration image from each gather is computed and updated through the iterations of least-squares reverse time migration.

Least-squares Migration

Misfit:

$$f(m)=\frac{1}{2}\|Lm-d\|^2+\frac{\lambda}{2}\left\|\frac{\partial m}{\partial p}\right\|^2$$

Penalty on image difference of nearby angles.

Numerical Scheme:

$$g^{(k+1)}=L^T(Lm^{(k)}\text{-d})\text{-}\lambda\frac{\partial^2 m^{(k)}}{\partial p^2}$$

$$m^{(k+1)}=m^{(k)}\text{-}\alpha g^{(k+1)}$$

Results: Marmousi2 Model

Geometry:

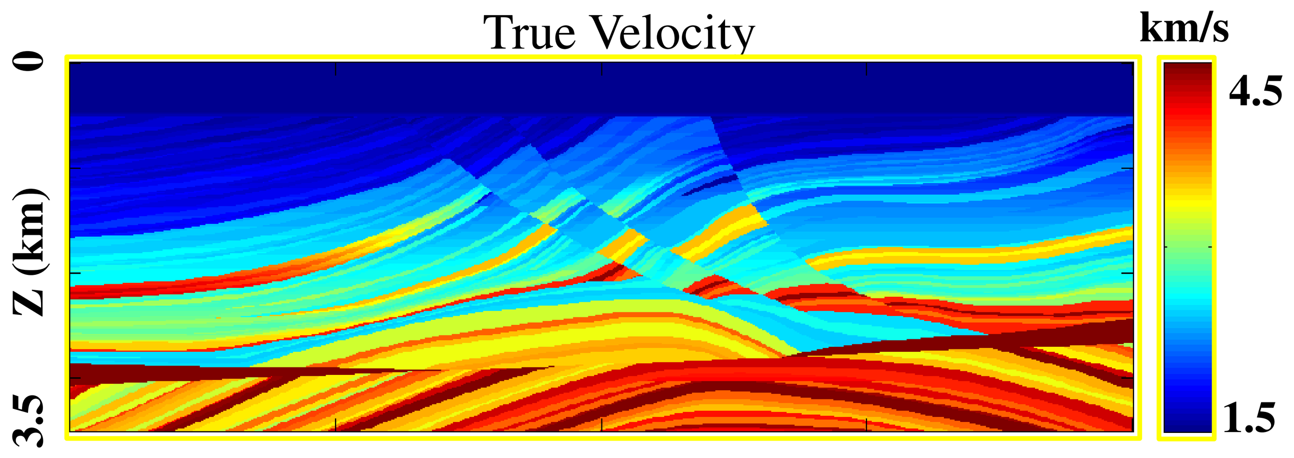
Model size: 801 x 351 Grid interval: 10 m

Shots: 801 Wavelet: Ricker

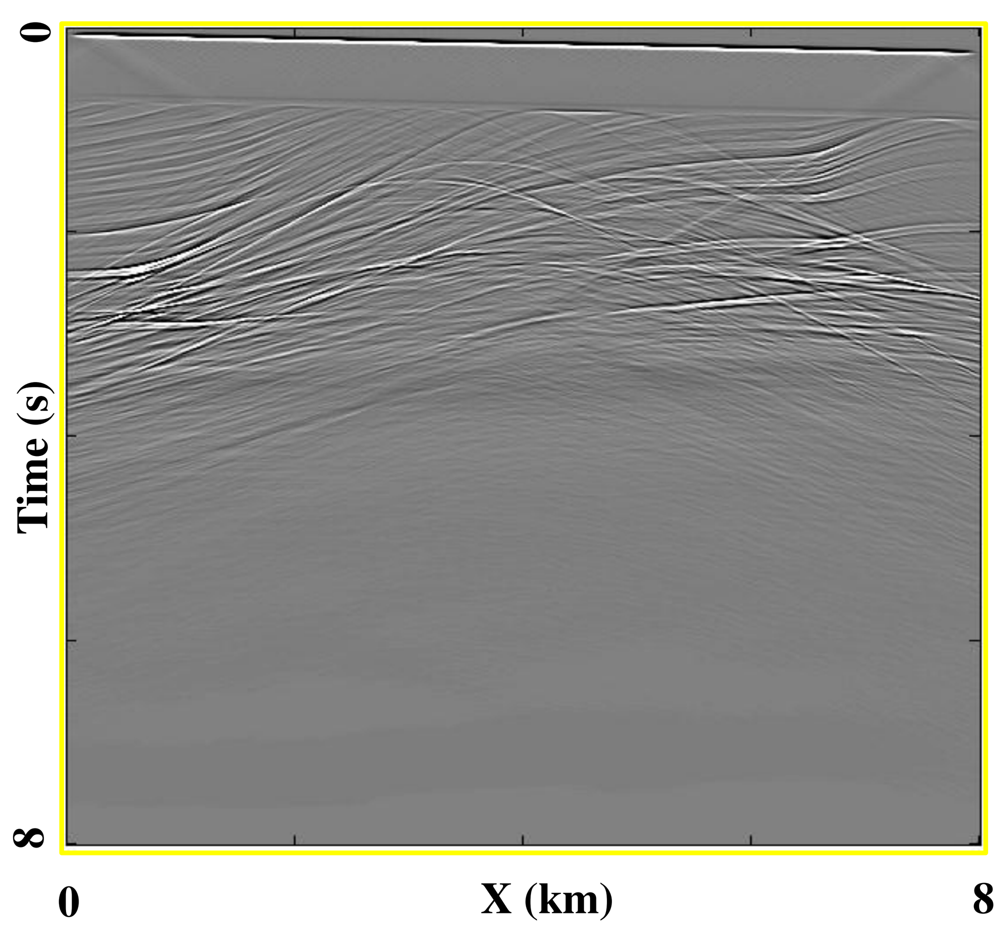
Receivers: 801 Freq: 20 Hz

Plane waves: 31 (-30 <= θ <= 30)

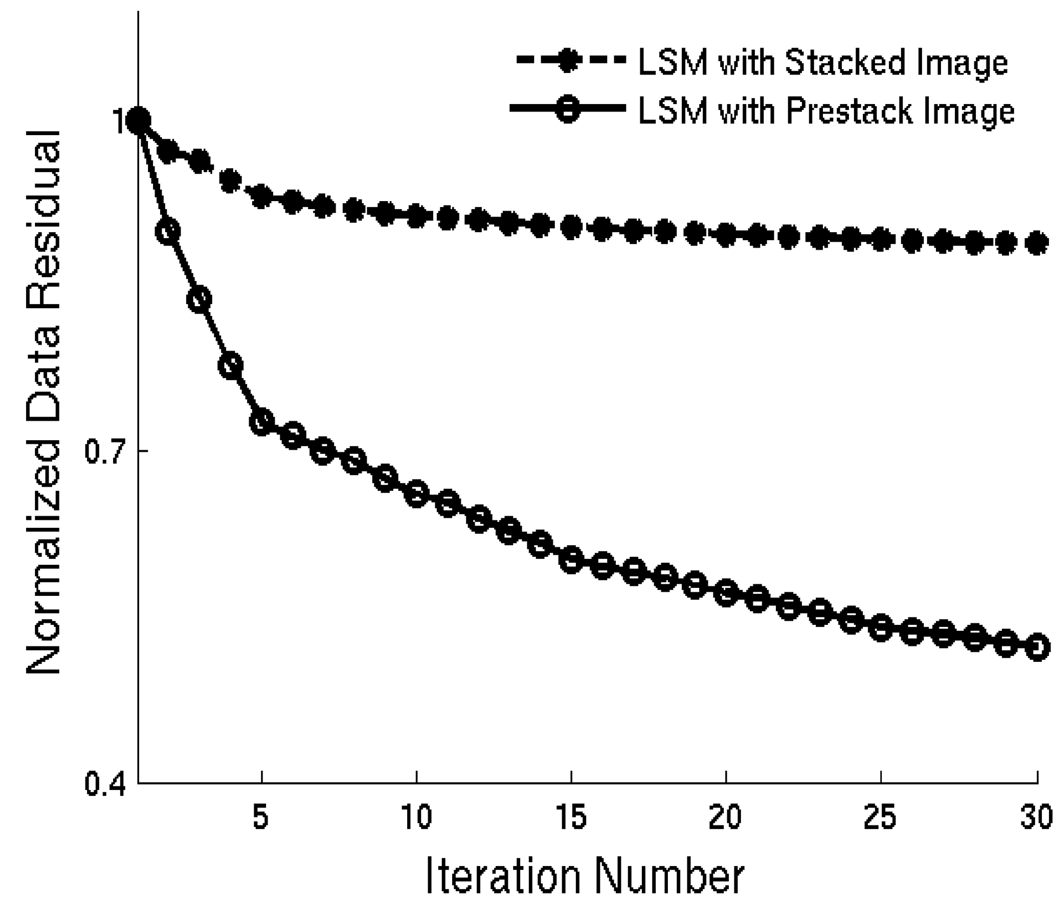
True Velocity



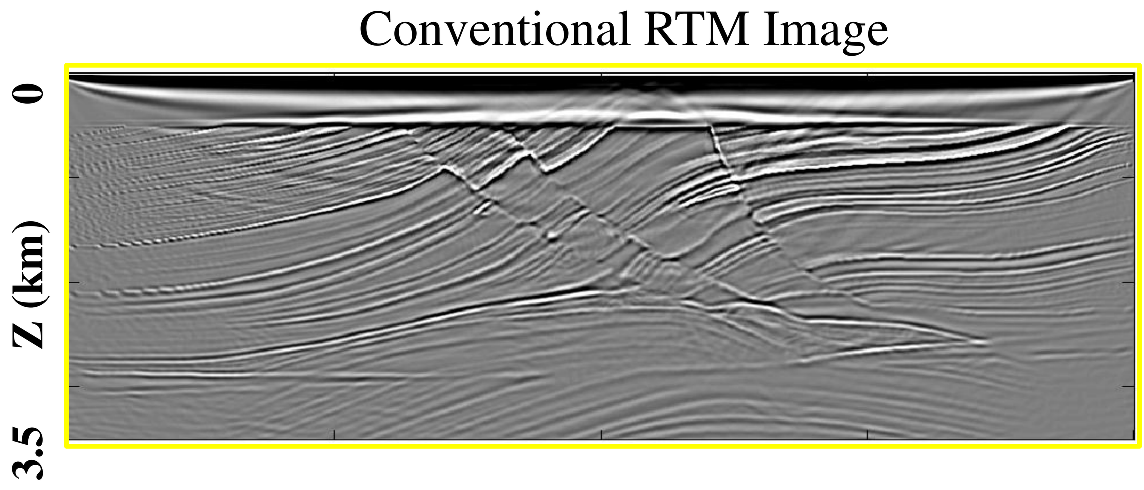
A Plane-wave Gather (p= 22.2μs/m)



Convergence Curves /w 5% Velocity Error



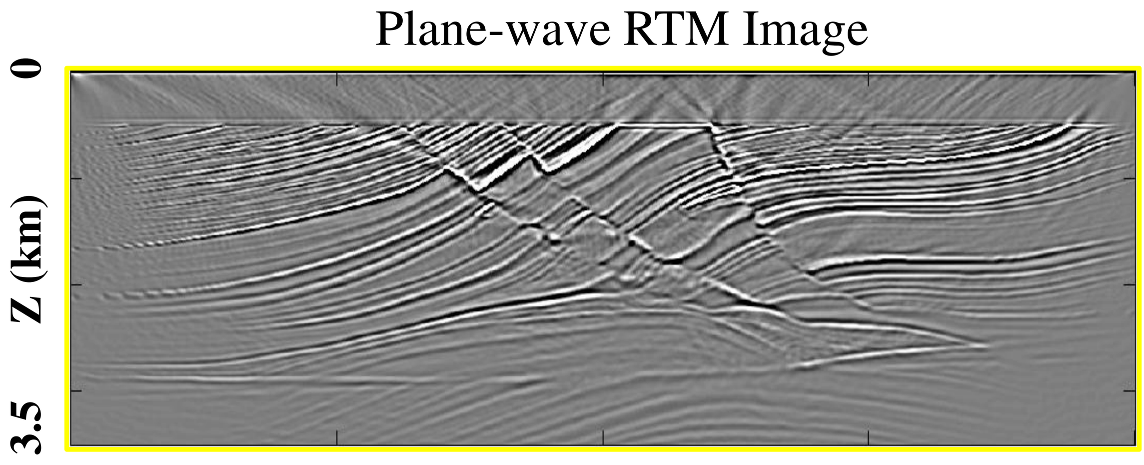
Conventional RTM Image



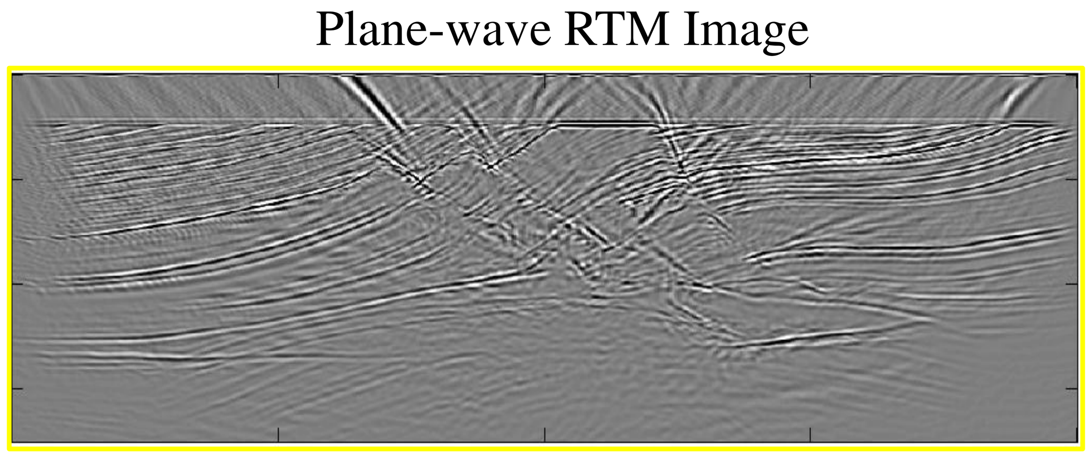
Results: Velocity with 5% error

Common Image Gathers

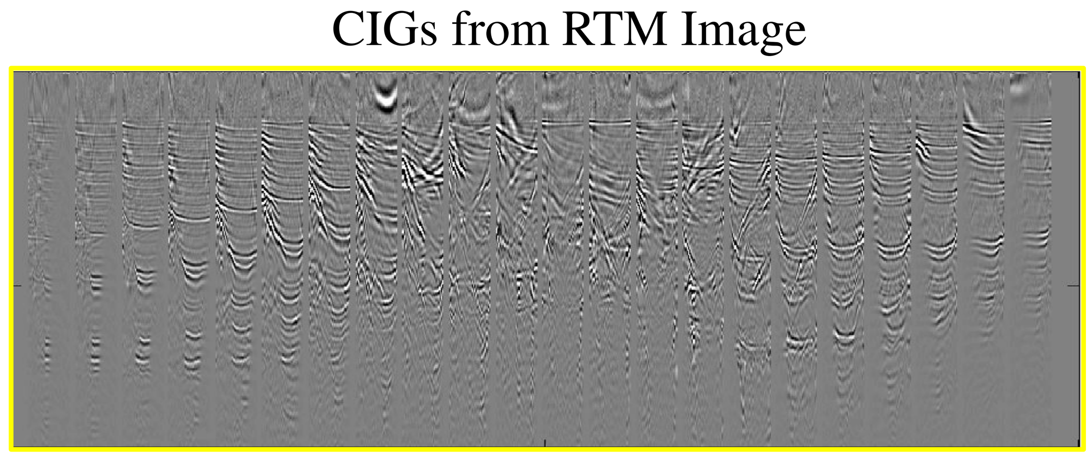
Plane-wave RTM Image



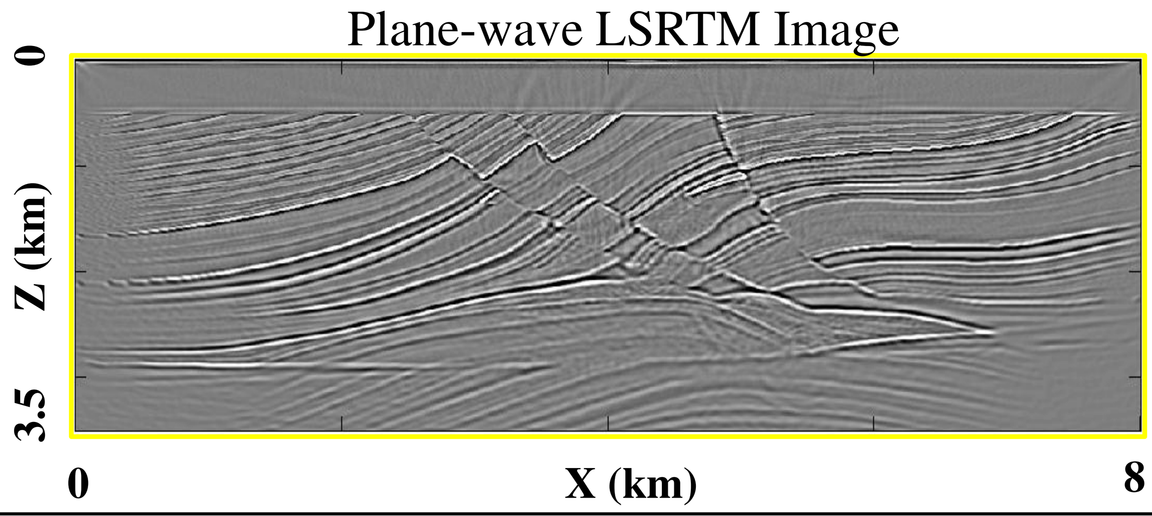
Plane-wave RTM Image



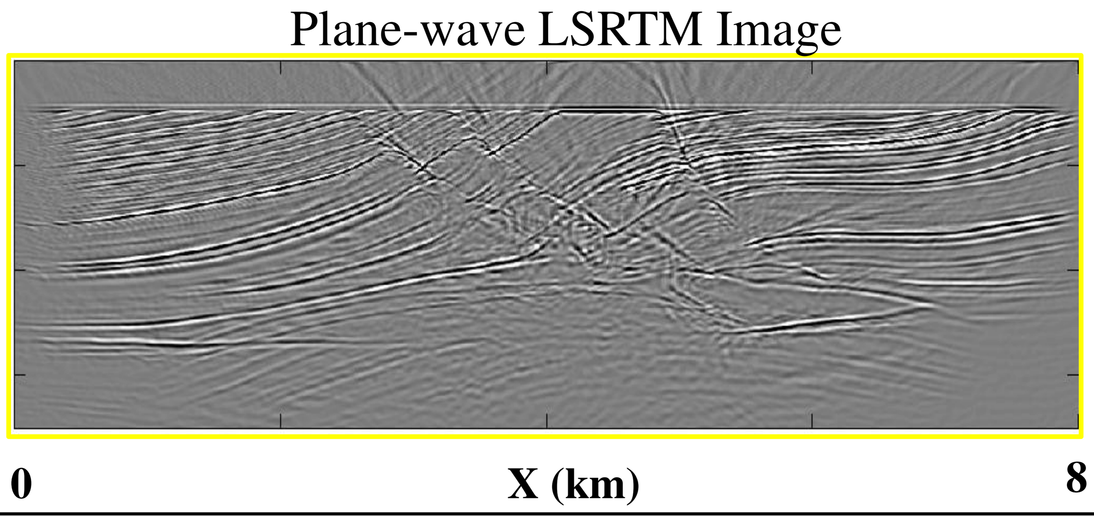
CIGs from RTM Image



Plane-wave LSRTM Image



Plane-wave LSRTM Image



CIGs from LSRTM Image